the international water association

AI-empowered Asset Management

the international water association

WEBINAR

20 April 2021 | 15:00 CEST

iwa-network.org/webinars

inspiring change

IWA SPECIALIST GROUP ON STRATEGIC ASSET MANAGEMENT

IWA the international water association — STRATEGIC ASSET MANAGEMENT


Rita Salgado Brito – LNEC, Portugal
Chair


Oliver Nachevski – GIZ, North Macedonia
Vice-chair


Bénédicte Rulleau – INRAE, France
Secretary and Treasurer


Helena Alegre – LNEC, Portugal
Member


Rita Amaral – Lis-Water, Portugal
YWP Member


Cristiano Gonçalves Nascimento Gouveia – Caesb, Brazil


Eric Montes – Maynilad Water, Philippines


Nicolas Caradot – KWB, Germany
YWP Member


Elvira Estruch Juan – ITA, Spain
YWP Member


Boudewijn Neijens – Copperleaf Technologies, Canada
Member


Takayuki Sawai – NJS Co. Ltd, Japan
Member


Sandra Cecilia Muhirirwe – NWSC, Uganda
YWP Member


Andres Torres – Pontificia Universidad Javeriana, Colombia
Member

Management Committee of IWA SAM SG

- Join over **1,300 water professionals:** https://iwa-connect.org/group/strategic-asset-management/timeline
- The platform for collaboration and knowledge sharing on Asset Management
- Organising the 2022 LESAM conference in Bordeaux

the international water association

Alexander Ringe
Berliner Wasser-betriebe
Germany

Aisha Mamade
Baseform
Portugal

Pascale Rouault
KWB
Germany

Youen Pericault
Luleå University of Technology
Sweden

Srinath Kumar
SewerAI
USA

Dulcy Abraham
Purdue University
USA

Nico Caradot
KWB
Germany

Elvira Estruch
Universitat Politècnica de València
Spain

inspiring change

AGENDA

the international water association

- **Introduction**
  Nico Caradot | *Elvira Estruch*

1. **Improving rehabilitation strategies by using simulation models**
   Alexander Ringe
2. **AI Tools for Asset Management Planning**
   Aisha Mamade

- **Q&A Panel Discussion 1**

3. **Uncertainties in sewer deterioration models: How much can we trust?**
   Pascale Rouault
4. **Data-enabled coordination of urban infrastructures rehabilitation**
   Youen Pericault
5. **AI-Enabled Sewer Defect Coding for Greater Speed and Consistency**
   Srinath Kumar | *Dulcy Abraham*

- **Q&A Panel Discussion 2**

Improving rehabilitation strategies by using simulation models

ALEXANDER RINGE
BERLINER WASSERBETRIEBE,
GERMANY

Berliner Wasserbetriebe

SEMA BERLIN

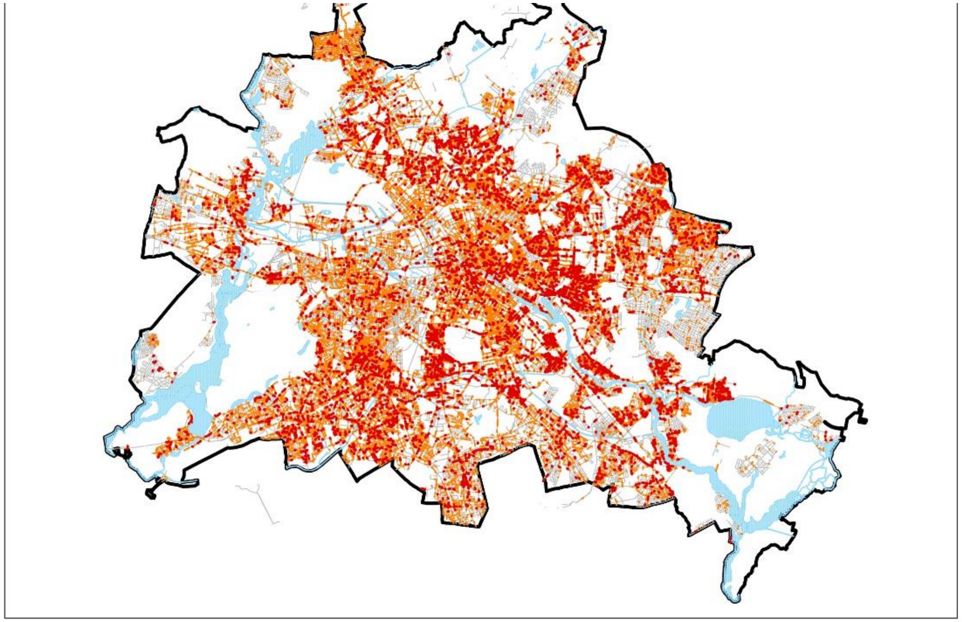
IWA the international water association

inspiring change

CHALLENGE SEWER NETWORK BERLIN

the international water association

Symbolic visualisation - no real rehab need in map!



- ~ 10.000 km of sewers
- ~ 750 km/a of CCTV
- € for rehabilitation limited (sewage fee etc.)
- construction constraints in the city
- prevent further deterioration

map legend:

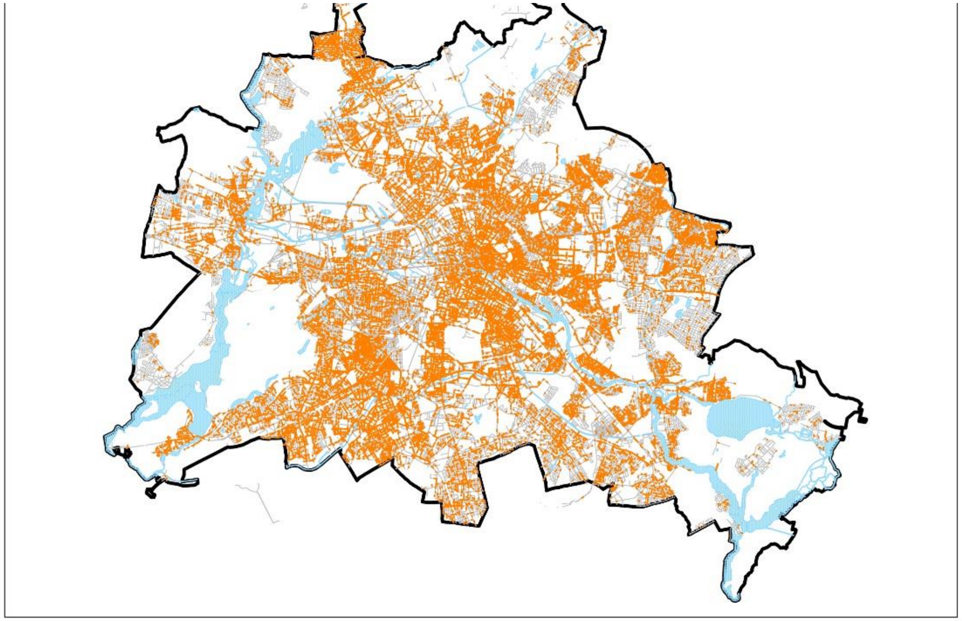
sewer network Berlin

symbolic sewer lines with short-term need for rehabilitation

symbolic sewer lines with mid-term need for rehabilitation

GOAL OF INVESTMENT STRATEGY

Symbolic visualisation - no real rehab need in map!



- reduce risk of collapse!
- optimise € for rehabilitation!
- **continuously improve network condition!**

map legend:

sewer network Berlin

symbolic sewer lines with short-term need for rehabilitation

symbolic sewer lines with mid-term need for rehabilitation

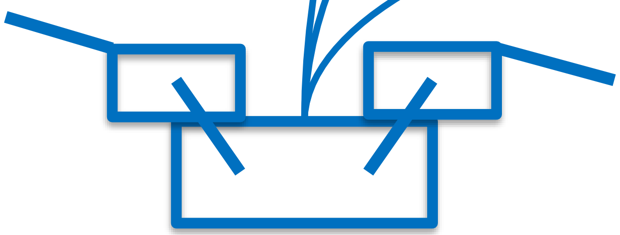
STRATEGY IMPLEMENTATION TOOLS

the international water association

SEMA BERLIN — strategy simulator (network level)

SEMA BERLIN — pipe simulator (pipe level)

AUZUKA — AI-based defect detection (trial in 2021)



Berliner Wasserbetriebe - Toolbox

pipe simulator

- Allocation of pipes with short-term rehabilition need
- Supports inspection strategy (hotspot - search)

Probability of pipe for short-term rehab need:

- 31 - 35 %
- 26 - 30 %
- 21 - 25 %
- 16 - 20 %
- 11 - 15 %
- 0 - 10 %

AI-based defect detection

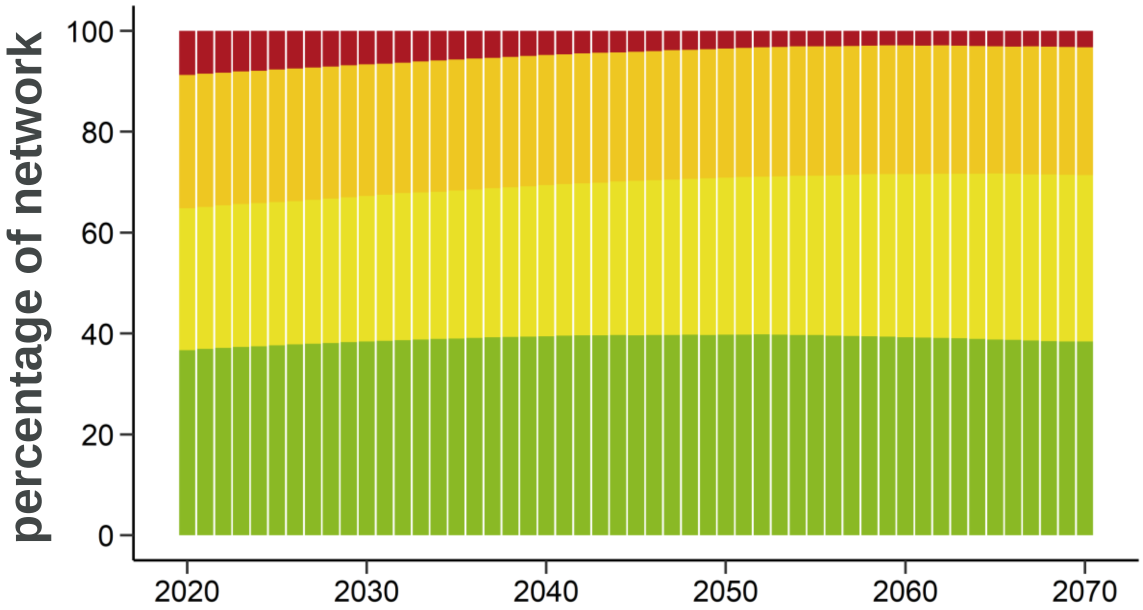
- Trial in 2021
- Improvement of CCTV evaluation quality (input data of strategy simulator)

Cutout of AI- Viewer:

Automatic crack detection

Automatic corrosion detection

Sewer network development



- Simulation of cost effective rehabilitation strategy (renewal & lining & repair)
- Simulation of network development incl. €

Need of rehab:

short-term

long-term

mid-term

none

FINDINGS OF Berliner Wasserbetriebe

- Use of simulation models is essential for a cost effective rehabilitation strategy of the sewer network
- Quality of input data determines quality of simulation results - focus on quality of input data!
- The quality of sewer network development modelling also depends strongly on the extent to which it takes into account actual rehabilitation practice and success of inspection strategy!

Thank you very much for your attention!

Alexander Ringe
alexander.ringe@bwb.de

AI Tools for Asset Management Planning

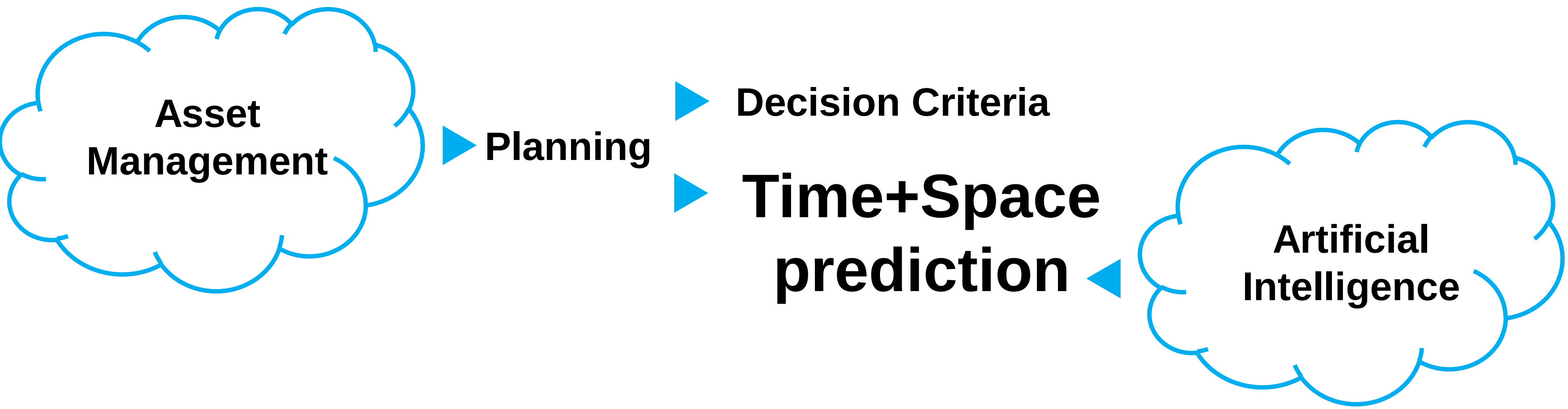
AISHA MAMADE
BASEFORM, PORTUGAL

baseform

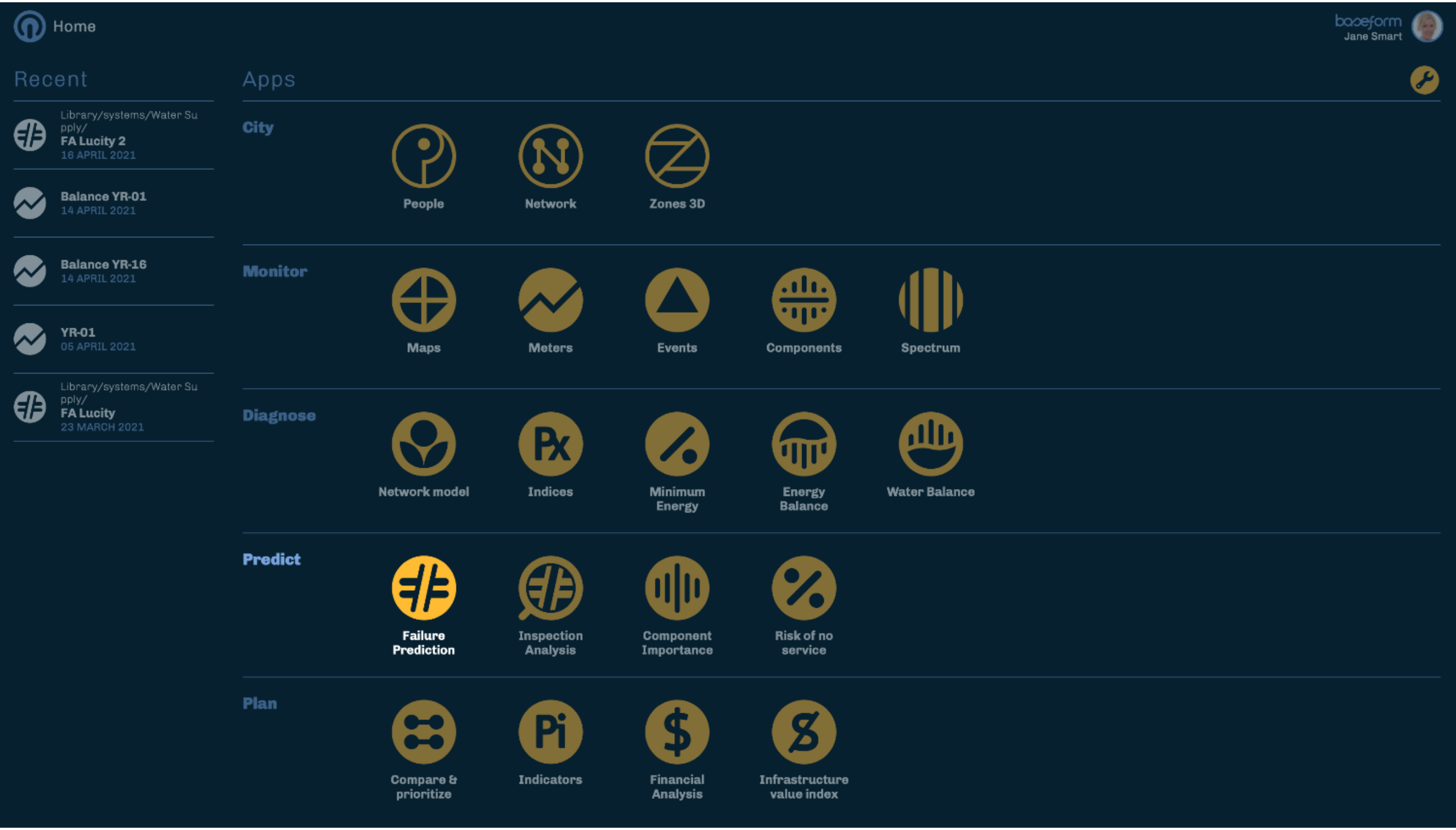
the international water association

inspiring change

SOME DEFINITIONS

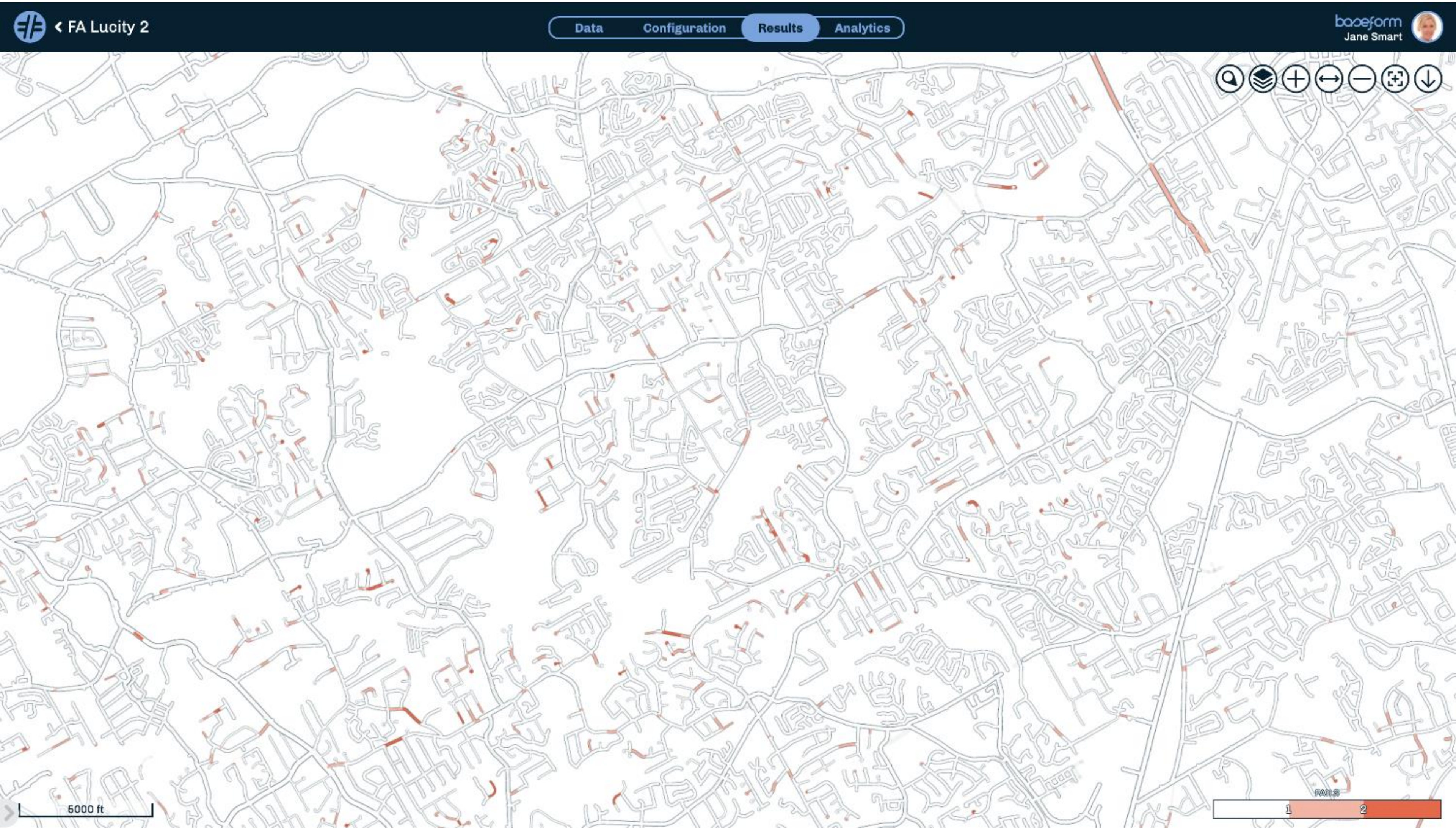


BASEFORM PREDICT APPS



OBSERVED PIPE BREAKS

the international water association



PREDICTED BREAK RATE

PREDICTED BREAK RATE

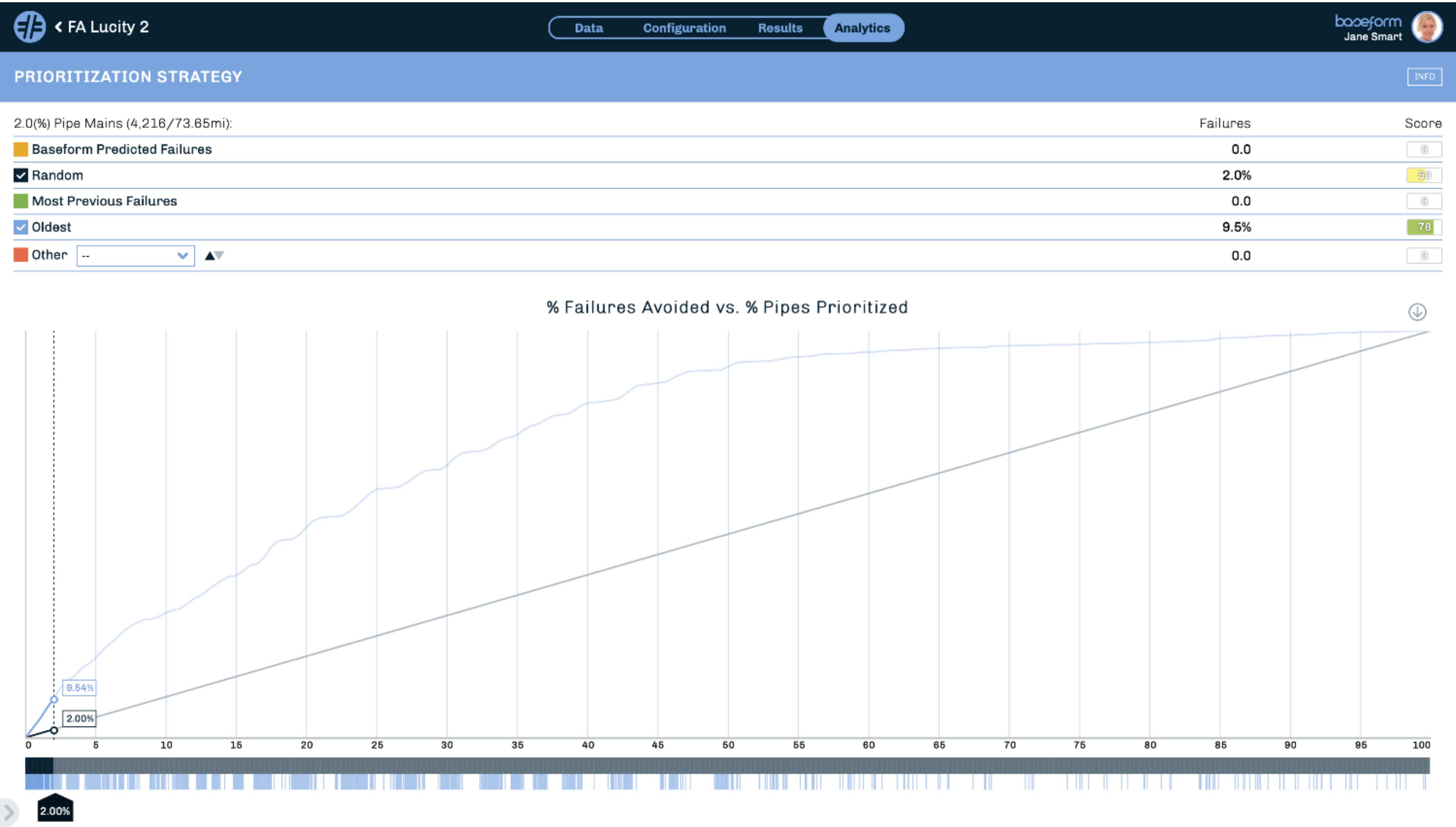
the international water association

PREDICTED BREAK RATE

the international water association

HOW GOOD ARE THESE ESTIMATES?

the international water association



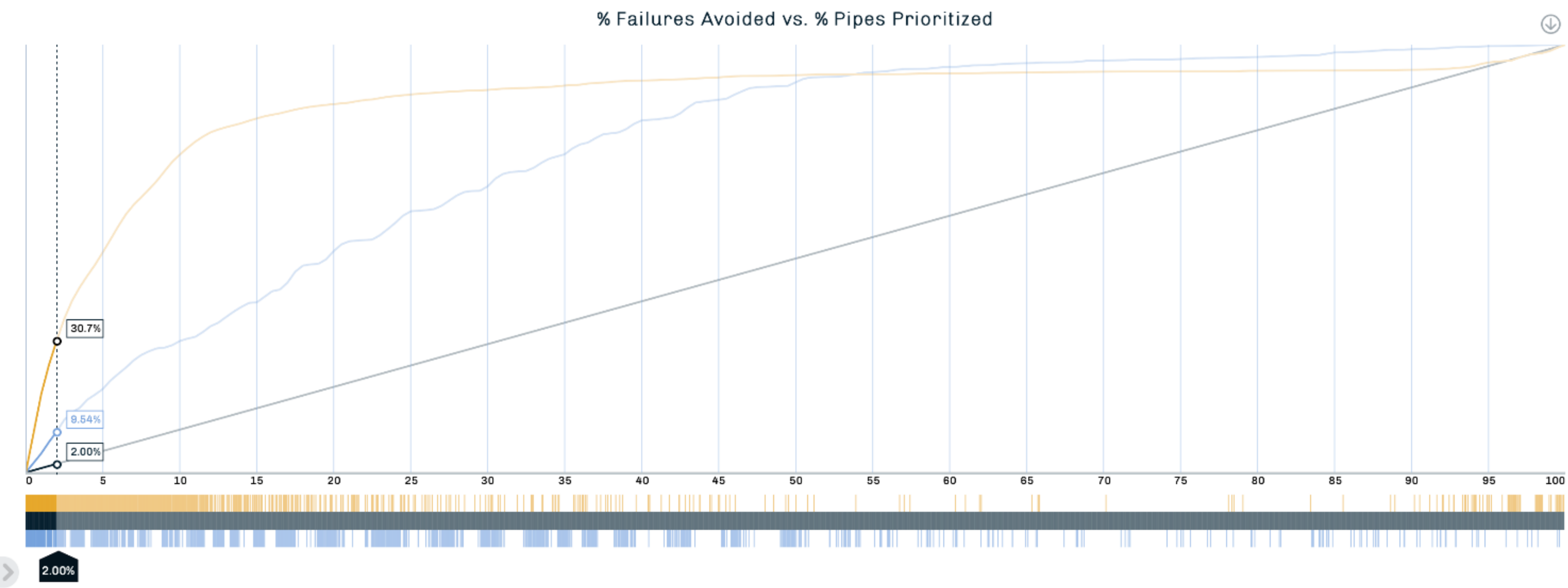
HOW GOOD ARE THESE ESTIMATES?

the international water association

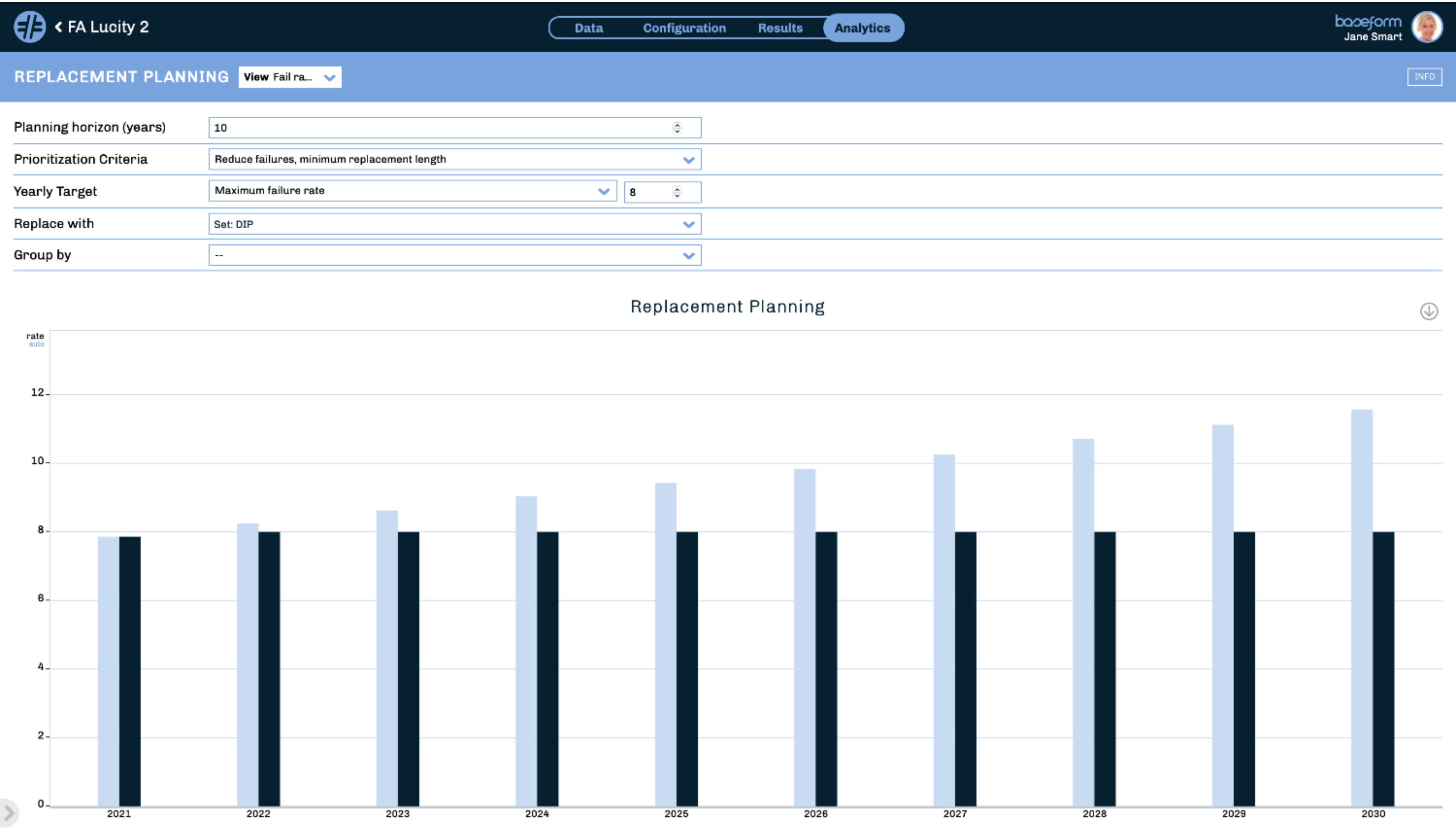
‹ FA Lucity 2 | Data | Configuration | Results | Analytics | baseform Jane Smart

PRIORITIZATION STRATEGY INFO

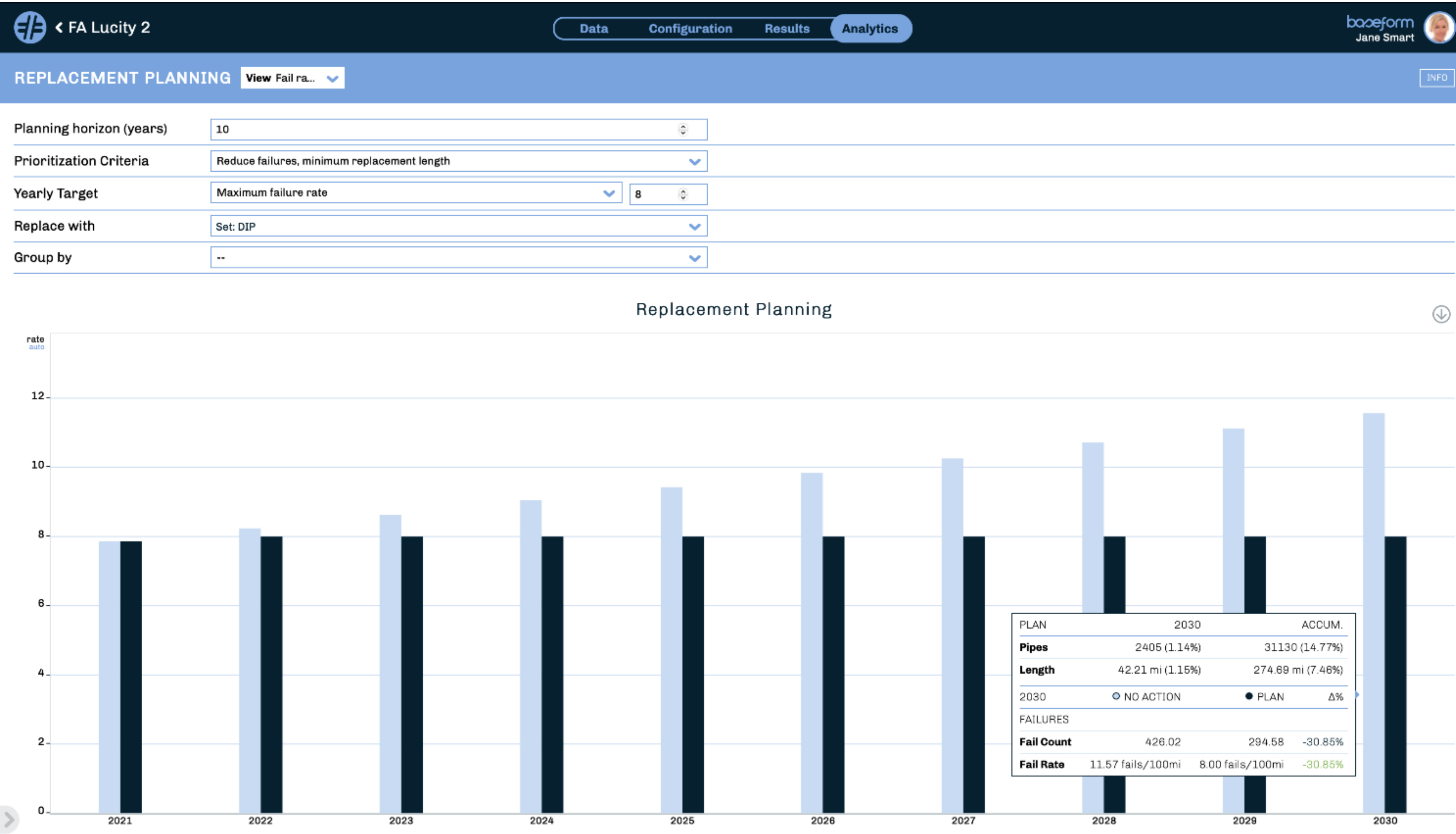
2.0(%) Pipe Mains (4,216/73.65mi):	Failures	Score
Baseform Predicted Failures	30.7%	87
Random	2.0%	50
Most Previous Failures	0.0	0
Oldest	9.5%	76
Other --	0.0	0



CAN I CREATE A RENEWAL PLAN WITH THESE RESULTS?



HOW MUCH BETTER IS THIS PLAN?



HOW MUCH BETTER IS THIS PLAN?

PLAN	2030	ACCUM.
Pipes	2405 (1.14%)	31130 (14.77%)
Length	42.21 mi (1.15%)	274.69 mi (7.46%)

2030	○ NO ACTION	● PLAN	Δ%
FAILURES			
Fail Count	426.02	294.58	-30.85%
Fail Rate	11.57 fails/100mi	8.00 fails/100mi	-30.85%

PREDICTING STRUCTURAL CONDITION

the international water association

City

People Network Zones 3D

baseform
Jane Smart

Yearly CCTV expenditure: $2M

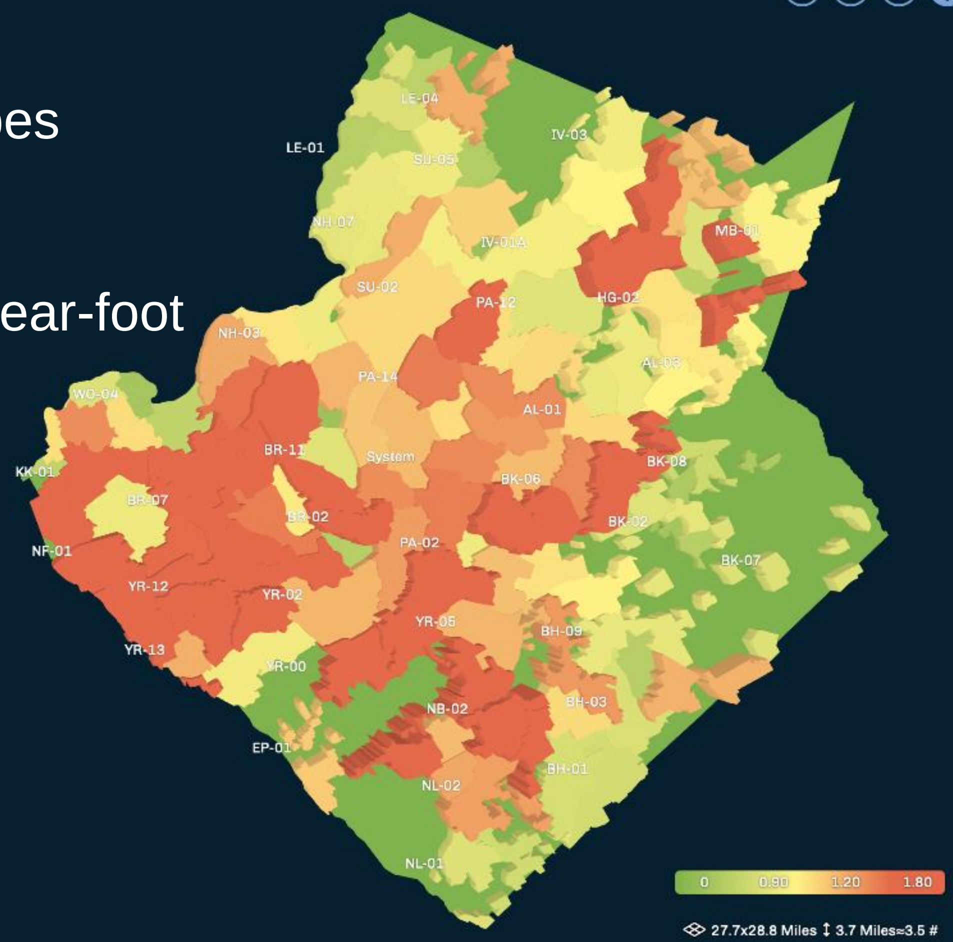
Success in finding failure-prone pipes

Previously: $40 per linear-foot

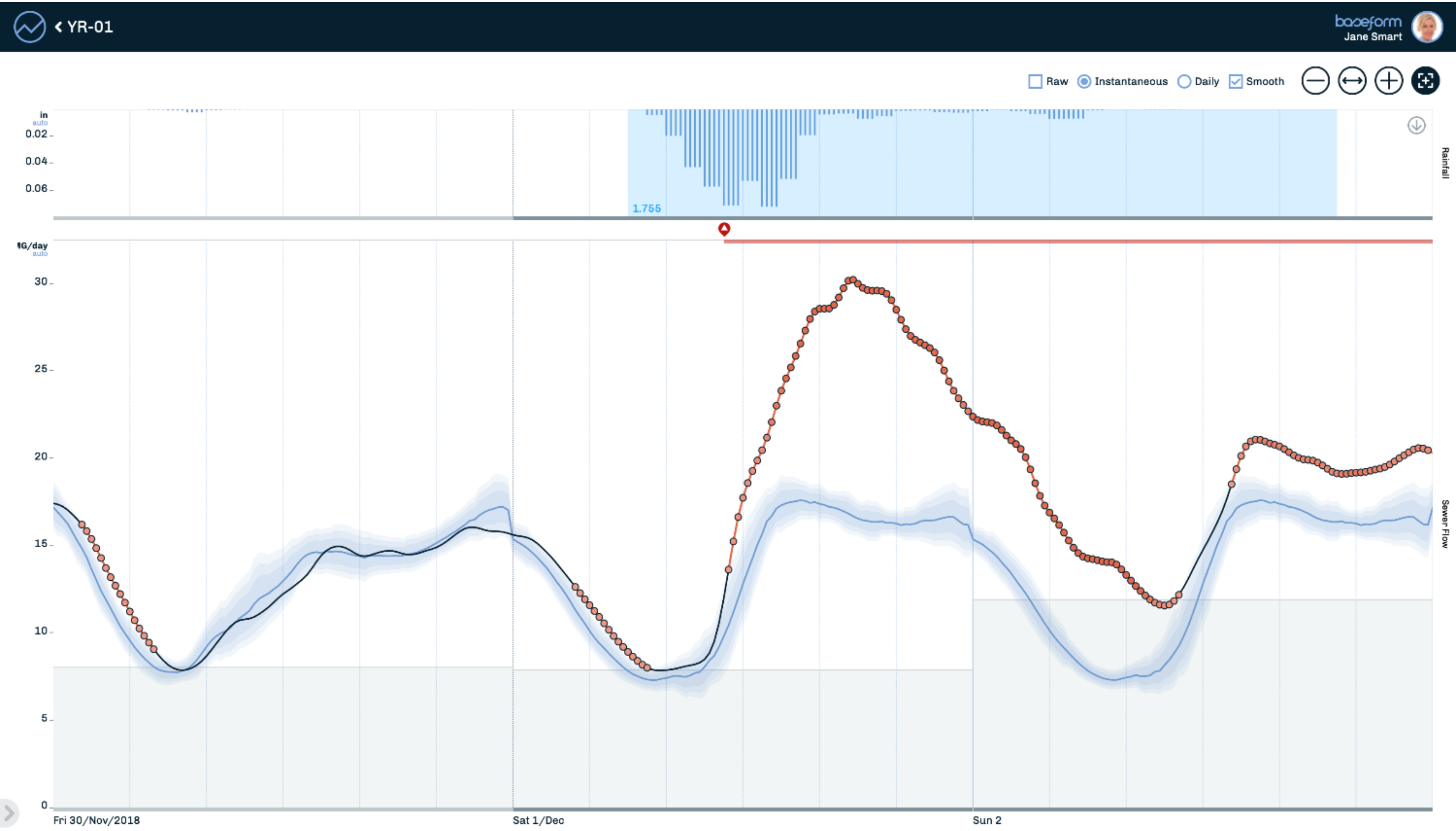
Guided by the software: $16 per linear-foot

A **59%** cost reduction;

or 3 times better



PREDICTING HUMAN CONSUMPTION



THANKS!

the fundamental purpose
of the water service has not changed

what is changing
is our ability to make
informed decisions.

aisha.mamade@baseform.com

the international water association

Q&A Discussion 1

ALEXANDER RINGE, AISHA MAMADE

(MODERATED BY NICO CARADOT & ELVIRA ESTRUCH)

inspiring change

POLL 1:
USE OF ARTIFICIAL INTELLIGENCE

the international water association

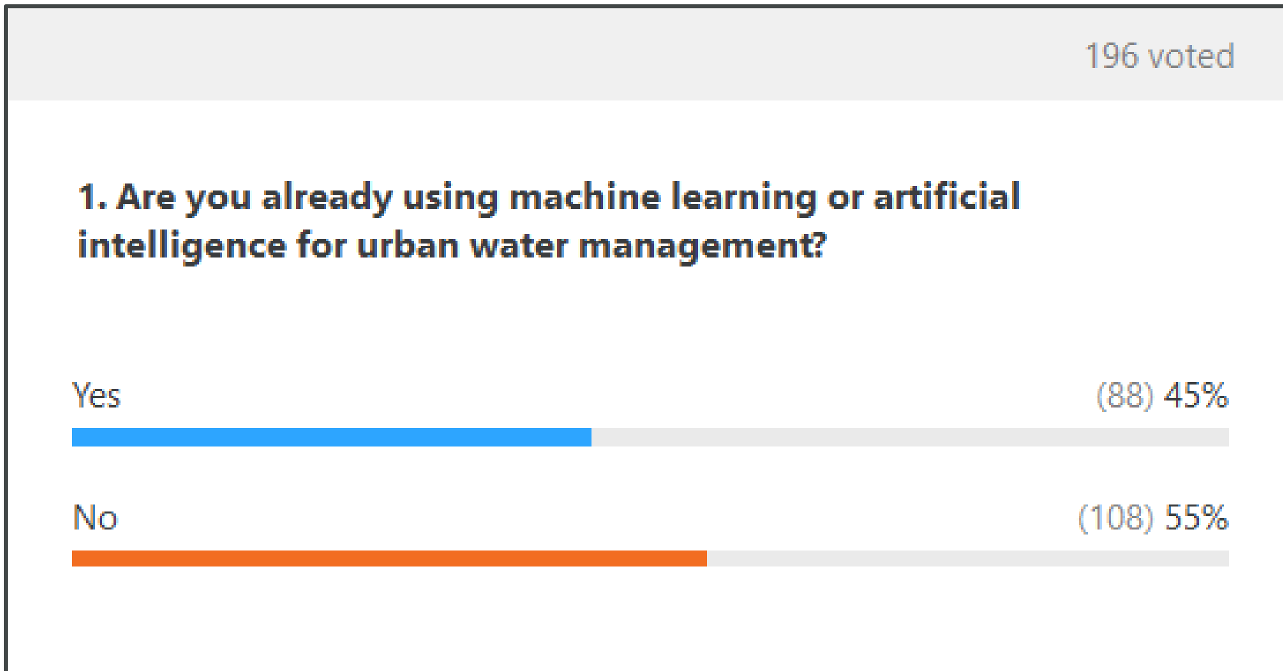
Single choice

1. **Are you already using machine learning or artificial intelligence for urban water management?**

- Yes
- No

POLL 1:
USE OF ARTIFICIAL INTELLIGENCE

the international water association



POLL 2:
POTENTIAL FOR AI

Single choice

1. Where do you see the most potential for AI in urban water management?

- Water quality and quantity monitoring
- Condition assessment
- Operation and maintenance
- Investment and capital planning
- Treatment performance
- Water losses
- No potential

POLL 2: POTENTIAL FOR AI

208 voted

1. Where do you see the most potential for AI in urban water management?

Water quality and quantity monitoring	(18) 9%
Condition assessment	(51) 25%
Operation and maintenance	(62) 30%
Investment and capital planning	(32) 15%
Treatment performance	(12) 6%
Water losses	(32) 15%
No potential	(1) 0%

Uncertainties in sewer deterioration models: How much can we trust?

PASCALE ROUAULT
KWB, GERMANY

KOMPETENZZENTRUM Wasser Berlin

inspiring change

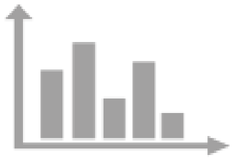
MODEL TOOLS ARE POWERFUL

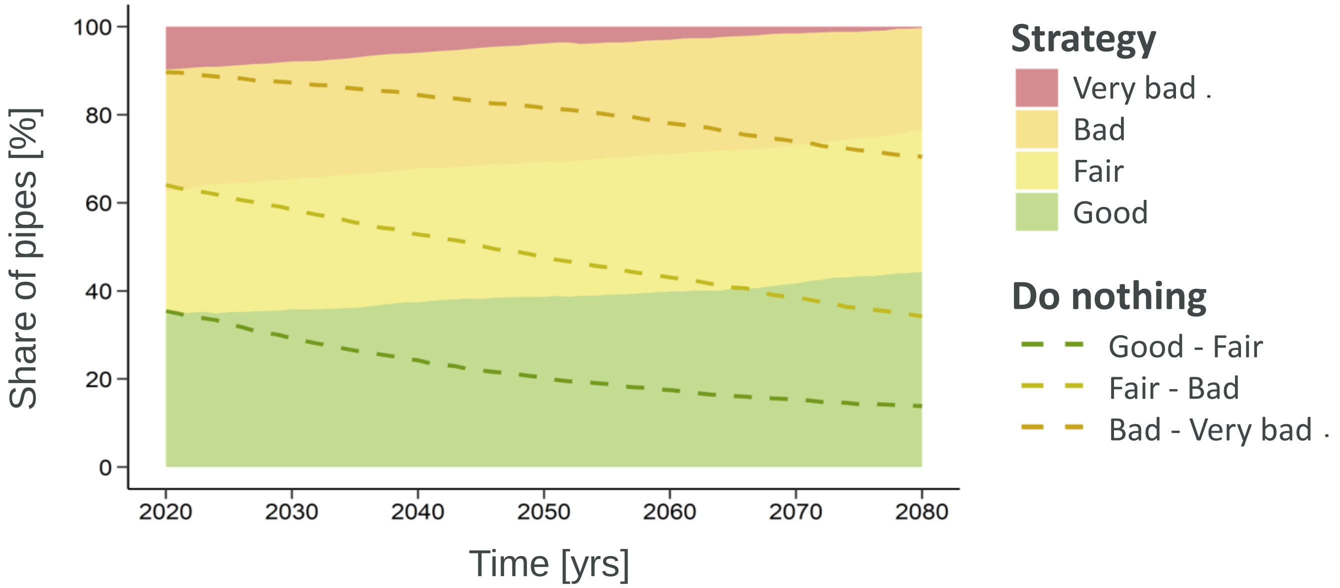
See Presentation Alexander Ringe (BWB) for the city of Berlin

Strategic network simulator

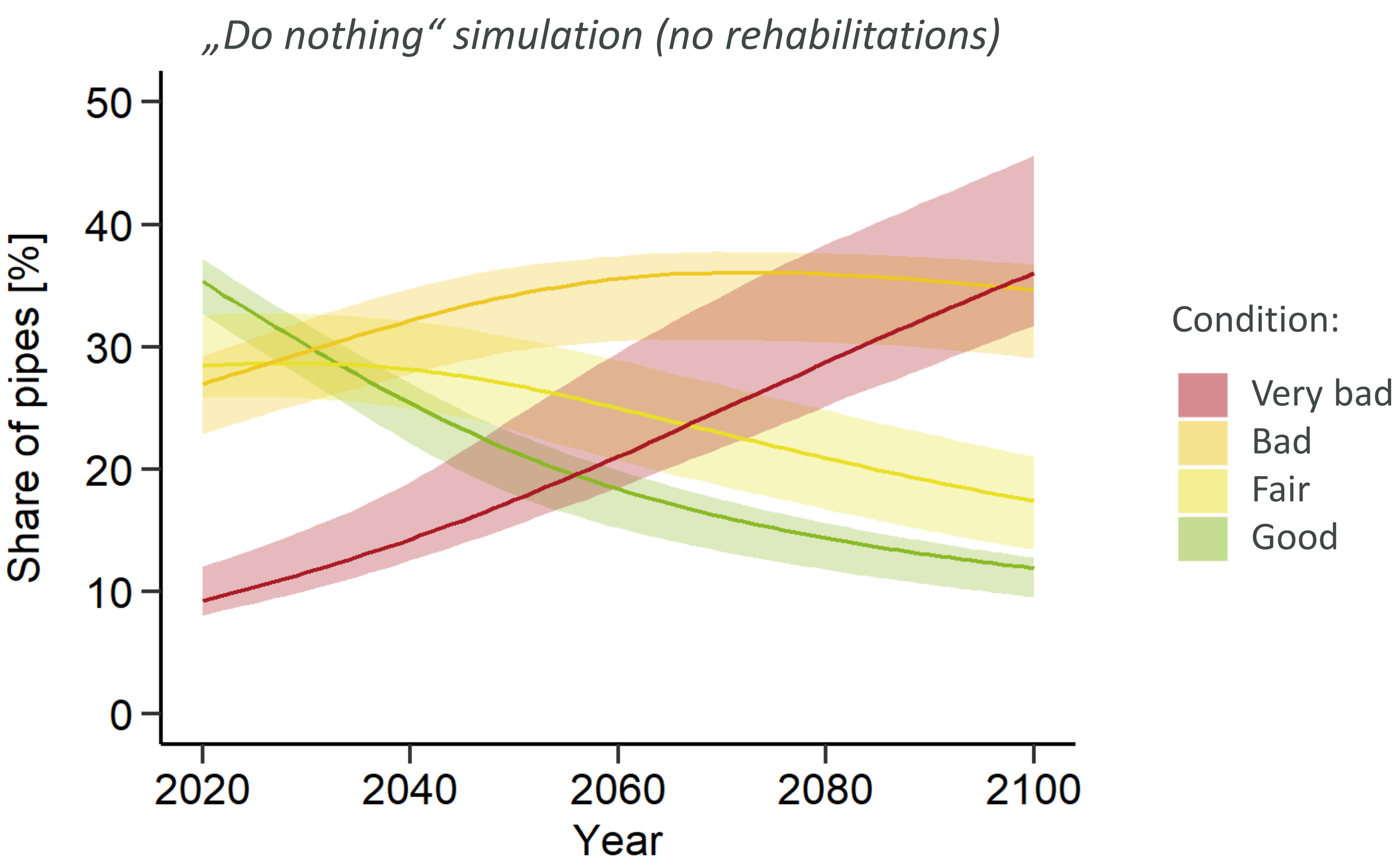
Long-term predictions on the sewer network condition under consideration of different investment strategies

Statistical model „GompitZ“





AS EVERY MODEL THEY ARE UNCERTAIN BUT HOW UNCERTAIN?

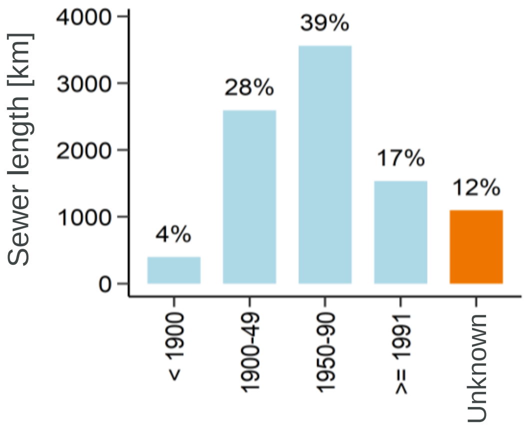


SOURCES OF UNCERTAINTIES

Group	Uncertainty source
Network data (input data uncertainties)	• Missing data (e.g. construction year)
CCTV data (calibration uncertainties)	• Subjectivity of condition assessment • Survival bias in condition data • Data availability (data quantity and representativity)
Deterioration + rehabilitation models (model structure uncertainties)	• Statistical representation of condition • Representation of repairs and linings

1. MISSING DATA

Construction years in Berlin:



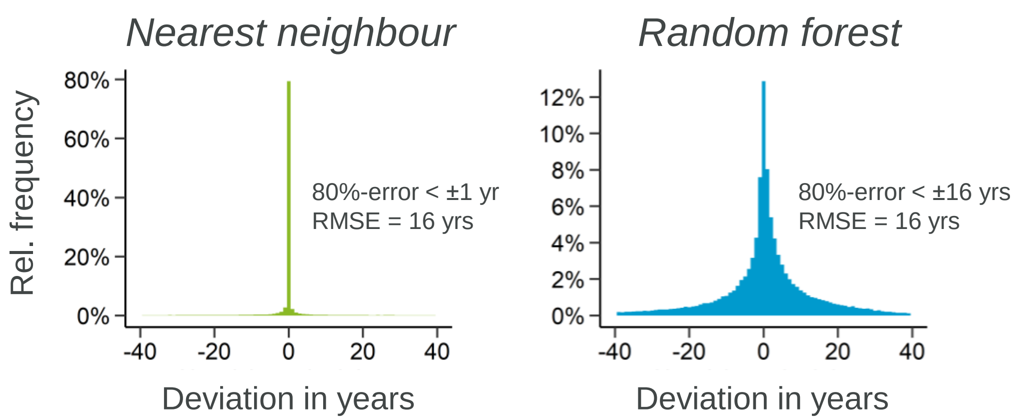
Two approaches tested for filling gaps:

- Nearest neighbour model based on construction year of neighbouring pipes
- Random Forest (input: sewerage type, shape, diameter, soil type, buildings, …)

Findings:

- All data gaps can be closed
- Accurate prediction for majority of pipes
- Symmetric error distribution
- Marginal effect on long-term sewer condition prediction

Uncertainty range: ↕ 0.5%



2. SUBJECTIVE ASSESSMENT

Uncertainty matrix: Probabilities of being in real condition *i* when inspected in condition *j*

real

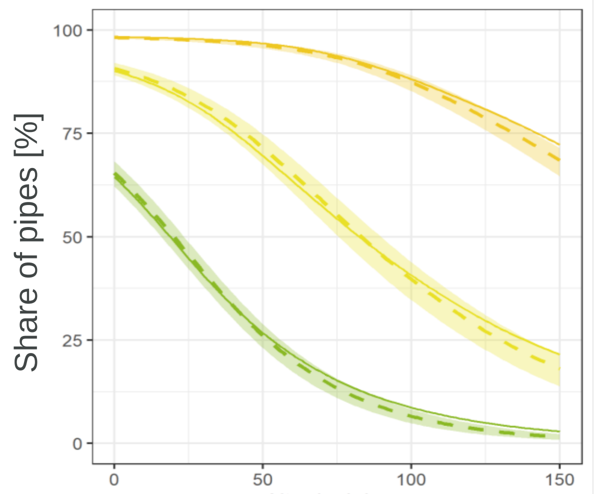
Inspected	1	2	3	4
1	82,2	7,7	4,3	3,5
2	13,5	72,2	16,4	6,4
3	3,6	18,2	72,9	18,0
4	0,7	1,9	6,4	72,1
Σ	100	100	100	100

Uncertainties originate from (i) subjective assessment and (ii) delayed documentation of rehabilitations → 70% for Berlin (assumption!)

quantified on basis of double inspections of the same pipe within max. 5 yrs without reported rehab (*n* = 4685)

Propagation of uncertainties from subjective assessment in survival curves (clay pipes)

(solid line = default survival curve)



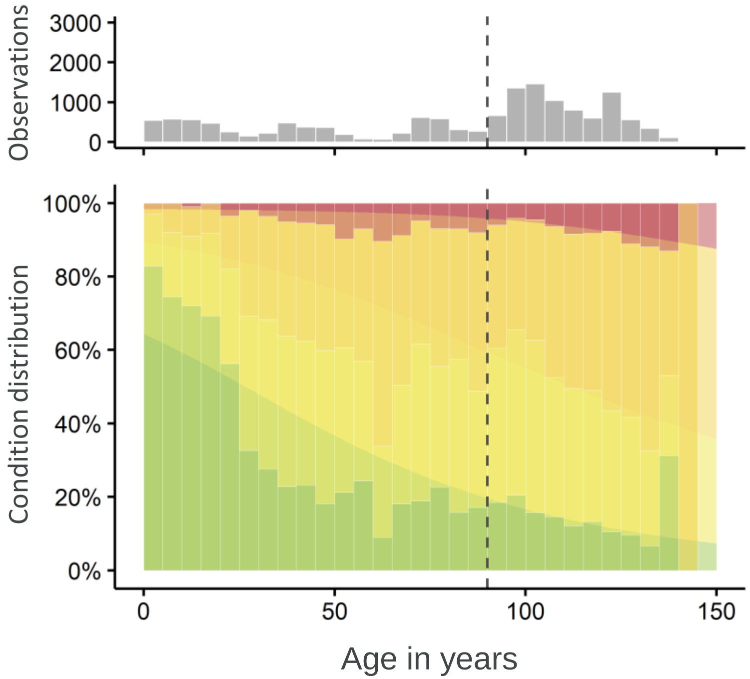
- Relevant uncertainties and systematic error in default survival curves
- Delayed documentation of rehabilitations is a major factor

Uncertainty range: 3.8%

3. SURVIVAL BIAS

Example: clay pipes (combined sewage)

Inspection data with survival bias



Calibration of survival curves with filtered inspection data

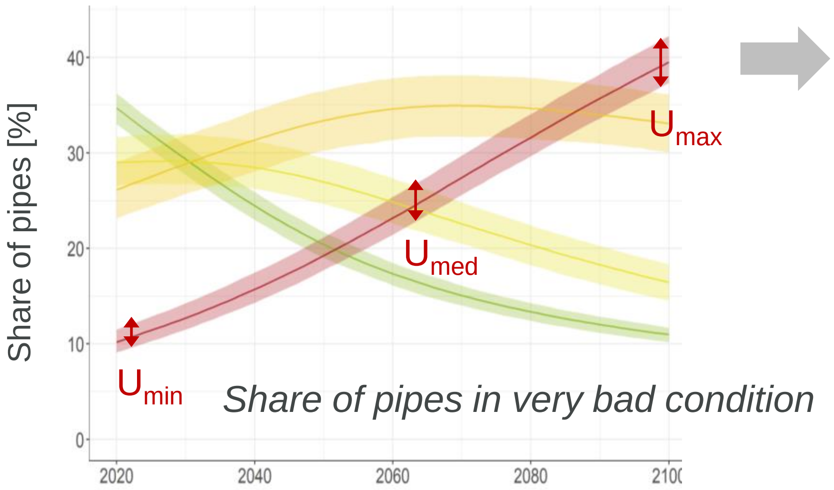
- Inspection data are biased: too few inspections of old pipes in very bad condition → too optimistic survival curves
- However, survival bias and ageing patterns are hard to distinguish

↕ Uncertainty range: 3.9%

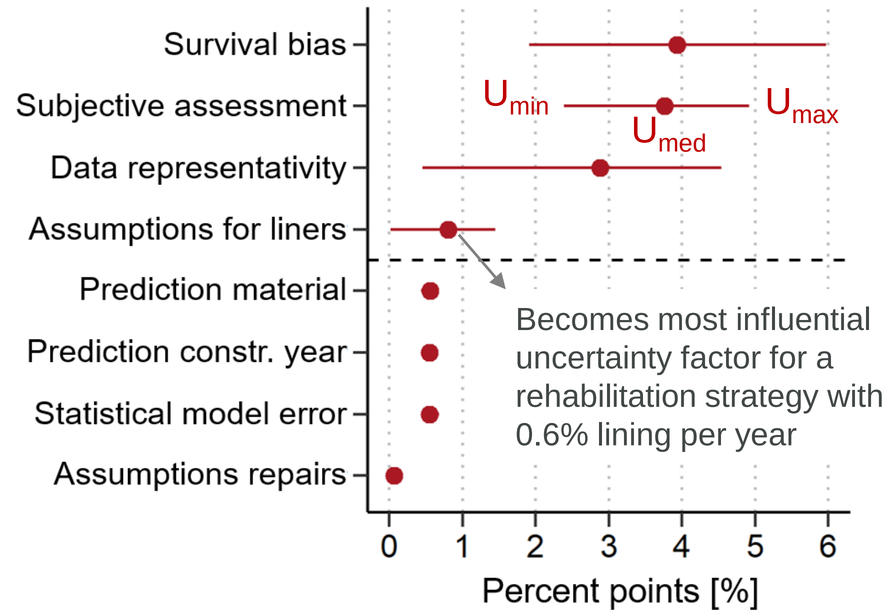
RANKING OF UNCERTAINTY FACTORS

Uncertainty propagation for do-nothing simulation

(Example: subjective assessment)



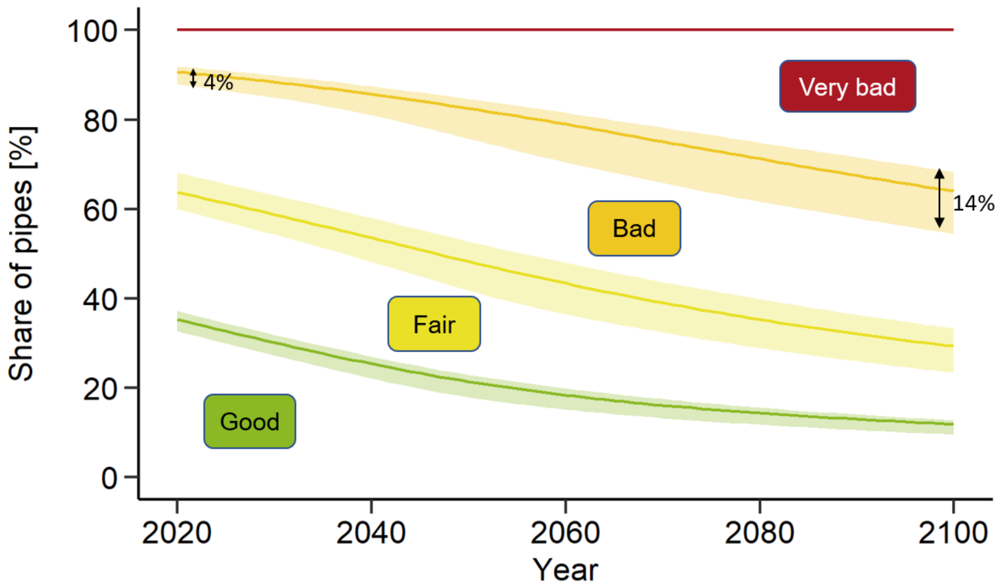
Ranking of uncertainty factors



- Four relevant uncertainty sources have been identified
- Assumptions for liners can become the most influential factors for rehab strategies with relevant lining shares, e.g. > 0.5% per year

OVERALL UNCERTAINTIES

Overall uncertainties (“Do-nothing” strategy)



- Predictions for the condition of the sewer network are subject to relevant uncertainties
- Overall uncertainties regarding the proportion of pipes in very bad condition for a 80-yrs forecast are 14 percentage points for a do-nothing-simulation
- For a selected rehabilitation strategy with a rehab rate of 1% per year * uncertainties increase to approx. 20 percentage points

* 20% renewal, 60% lining, 20% repair

PERSPECTIVES

the international water association

- The results can help utlities in...
  - Developing more reliable rehabilitation strategies
  - Reducing the identified uncertainties in the future

- Potential for reduction of uncertainties is seen in...
  - Support of condition assessment with AI-based image recognition
  - An improved and prompt documentation of rehabilitations and the condition of rehabilitated sewers
  - Experiments and long-term observations on the deterioration of liners, plastic pipes, reinforced concrete and other marginal material

Contact: pascale.rouault@kompetenz-wasser.de

the international water association

Data-enabled coordination of urban infrastructures rehabilitation

YOUEN PERICAULT
LULEÅ UNIVERSITY OF TECHNOLOGY
& LULEÅ MUNICIPALITY, SWEDEN

LULEÅ KOMMUN

inspiring change

COORDINATED REHABILITATION

- The fact of rehabilitating *adjacent* infrastructure assets (i.e. pipes, pavement) earlier or later than the end of their *functional lives* in order to perform the civil works in a single project.
- If done right, major opportunity to meet rehabilitation needs of multiple infrastructures at a lower economical, social and environmental cost.

+	−
Probably lower linear costs per rehabilitated asset	Under-utilized functional life for assets replaced earlier
Lower risk of damaging adjacent infrastructures	Lower performance and higher risks for assets replaced late

COORDINATED REHABILITATION IN THE IAM PROCESS

the international water association

Strategical planning

- KPI targets
- Renewal rate
- Annual CAPEX budget
- Coordination policy

Tactical planning

- List of projects with different priorities, often risk-based

Operational planning

- Other factors including coordination influence which projects are actually implemented and when

Estimate of current level of coordination
Average linear cost for coordinated vs uncoordinated projects

INTERESTING QUESTIONS FOR A WATER UTILITY

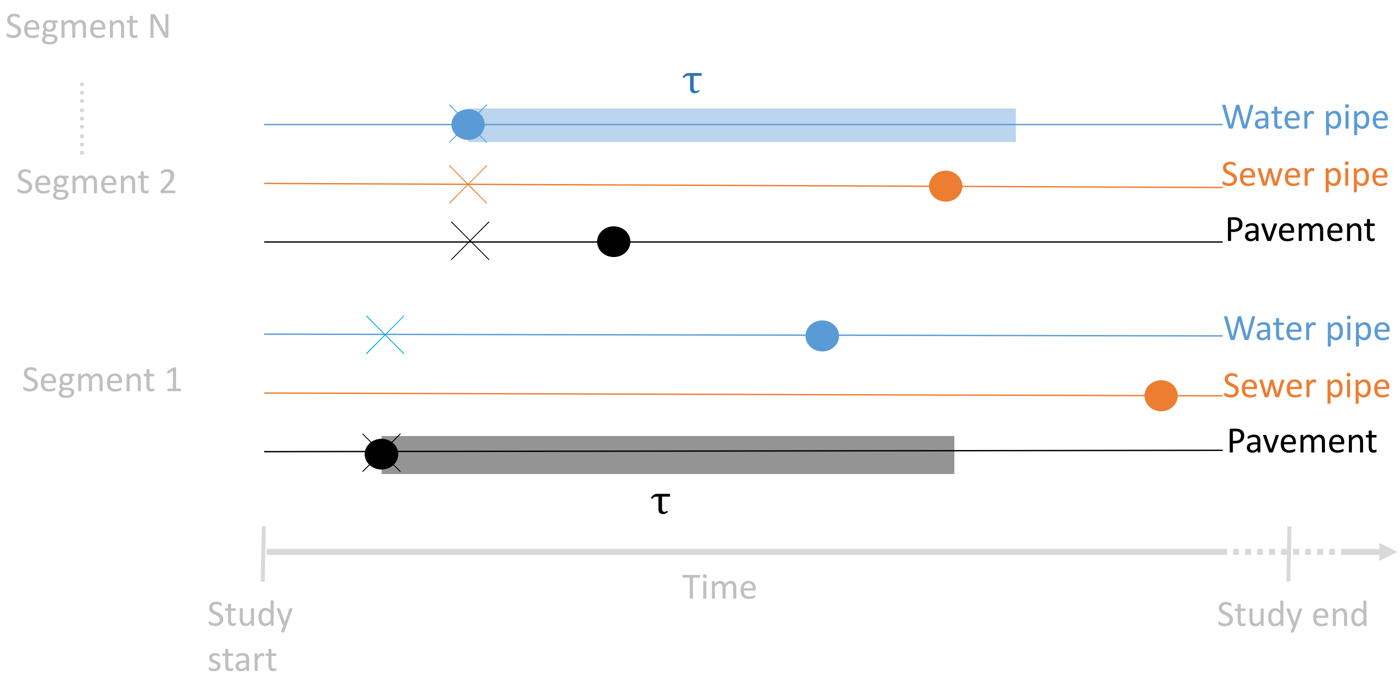
- How much coordinated rehabilitation do I perform today? Should I perform more? Less?
- Could I make a better use of coordination by steering its use from the strategical level?
- What are the long term consequences of coordination on my costs and level of risk/performances?

There is today a lack of method and modelling tools to address these questions at the strategical decision level.

Develop a better understanding of coordination at the strategical level allow for a more pro-active use of it to reach given goals.

QUANTIFYING COORDINATION

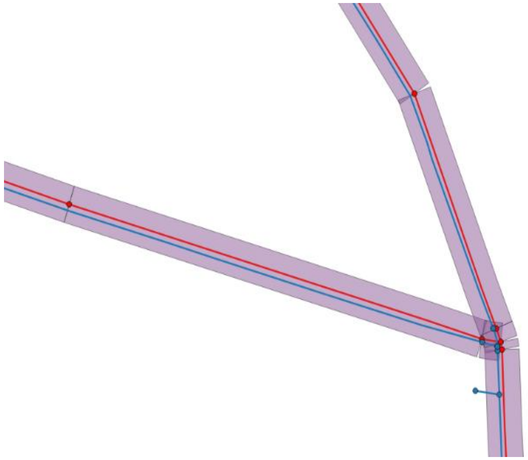
- Research at LTU: concept of coordination window
- Tau=0 ➔ opportunistic coordination; Tau=∞ ➔ systematic coordination
- Concept can be used to define coordination policies or to analyse previous coordination projects



MODELLING COORDINATION

- MURM prototype: compute long term rehab rate and costs for a given coordination policy (tau value)
- Main input data: linear costs of different rehab actions, cohort survival functions, **integrated asset inventory**:

	Cohort water	Cohort sewer	Inst. Year water	Inst. year sewer	Length (m)
Segment 1	Grey cast iron	Clay	1925	1925	45
Segment 2	Ductile cast iron	Concrete	1975	1990	32
……	……	……	……	……	……
Segment N	PE	PVC	2001	2001	52



- Functional lifetimes sampled according to survival functions, inter-infra correlation can be chosen.
- Simulation is repeated and average cost values computed (monte-carlo approach)

EXAMPLE OF RESULTS: RESIDENTIAL STREETS OF LULEÅ

Figure showing cumulated capital cost for the period 2020-2120 as a function of coordination window size (tau)

Contact panelist if you wish to receive a copy of the figure: youen.pericault@ltu.se

- 3500 segments, 176km
- Search for optimal levels
- Multi-criteria decision problem
- Total cost for rehab of water, sewer and road network.

EXAMPLE OF RESULTS: RESIDENTIAL STREETS OF LULEÅ

the international water association

Figure showing the evolution of yearly capital costs, global warming potential and renewal rates over the period 2020-2120 for a tau value of 0, 20 and 100 years.

Contact panelist if you wish to receive a copy of the figure: youen.pericault@ltu.se

- Visualisation of yearly economical and environmental costs
- Renewal rates to support each utility in securing adequate future budget to follow the agreed tau value.
- Good base to start discussing costs sharing principles.

THANK YOU FOR YOUR ATTENTION!

AI-Enabled Sewer Defect Coding for Greater Speed and Consistency

DULCY M. ABRAHAM
PURDUE UNIVERSITY, USA

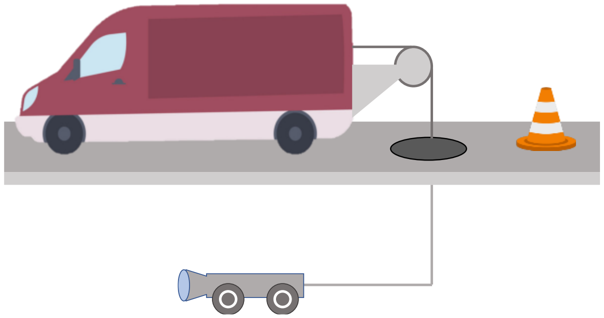
SRINATH SHIV KUMAR
SEWERAI, USA

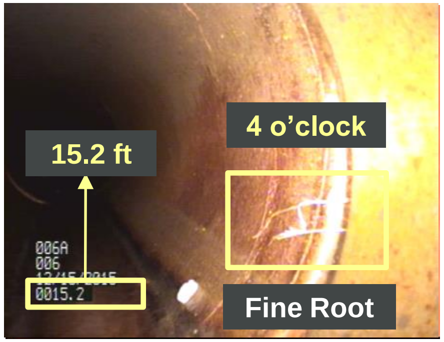
inspiring change

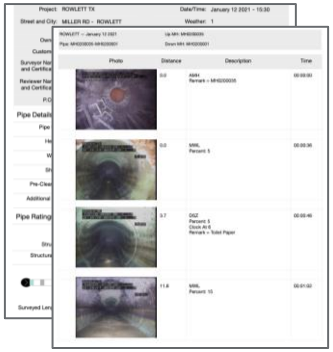
SEWER INSPECTION PROCESS

Water Research Foundation (WRF) # 4902

CCTV Inspections	*Manually Identify Defects*	*Inspection Report*







Costly and Slow

Prone to Human Error

Inconsistent Reports

How can AI Address these Issues?

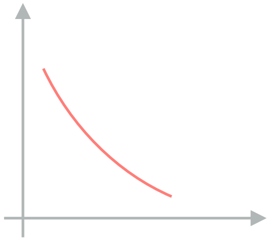
TERMINOLOGY

Artificial Intelligence

Deep Learning

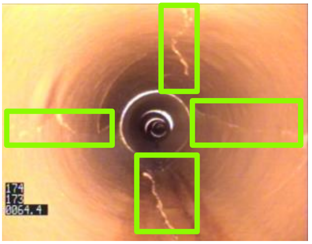
Numerical | *Audio* | *Vision*

Predicting Sewer Deterioration Rates

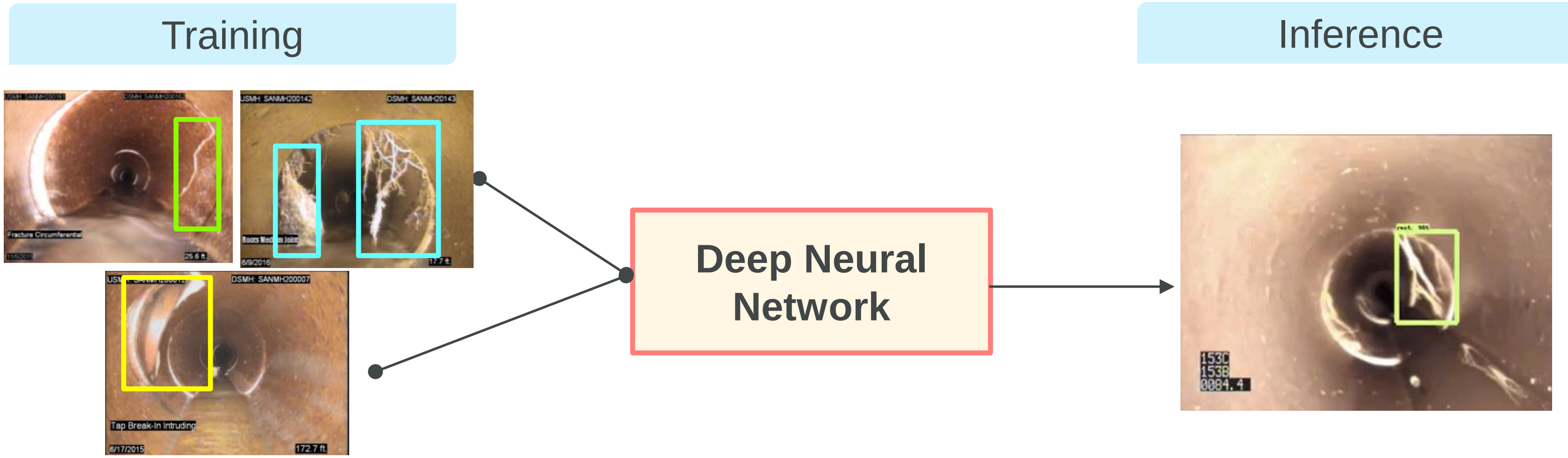


Acoustic Leak Detection

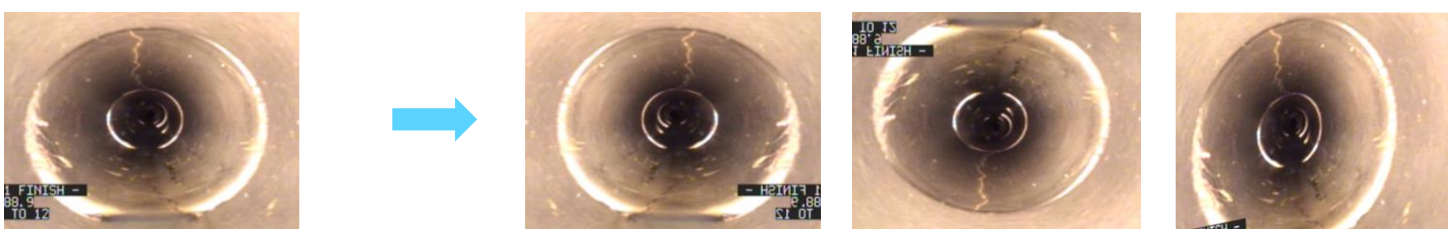
Automated Sewer Defect Detection



SEWER DEFECT DETECTION



12,000 original images each for training



500,000 images after augmentation

FINDINGS OF WRF4902 STUDY

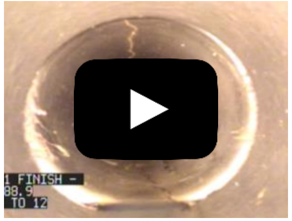
Better Recall than Humans

AI misses < 10% of defects, humans miss 25% of defects (Dirksen et al. 2013)

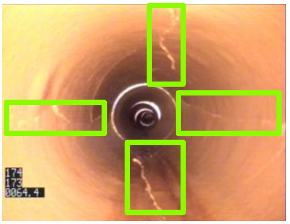
Worse Precision than Humans

AI creates 50% False Positives (humans < 5%)

Human experts are needed to review AI's outputs



AI Defect Detection

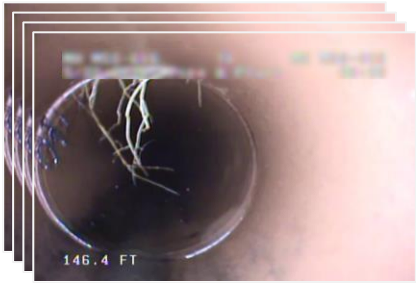


Human Review

- ***Add Images Into Training Set***
- ***Customer Deliverable***

SEWERAI PIONEER™ PLATFORM

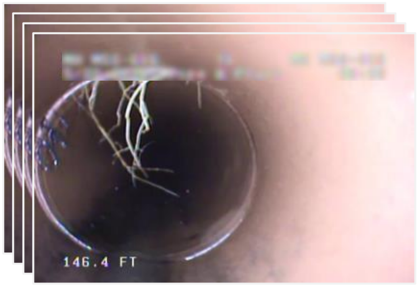
www.sewerai.com/pioneer



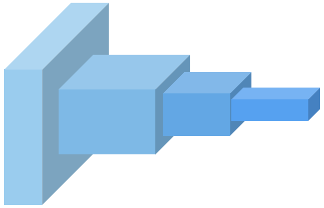
SEWERAI PIONEER™ PLATFORM

www.sewerai.com/pioneer

Under the Hood



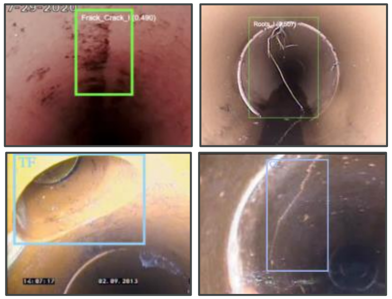
Deep Neural Networks Trained on 500,000 images



Post-Processing Algorithms

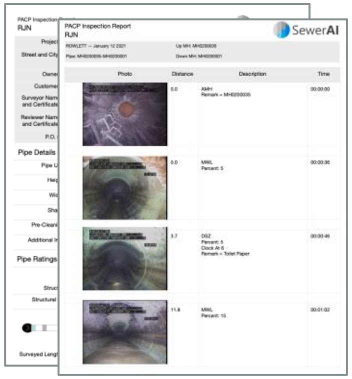
Proprietary Algorithms

Defects Identified by AI



Humans Review AI's Outputs

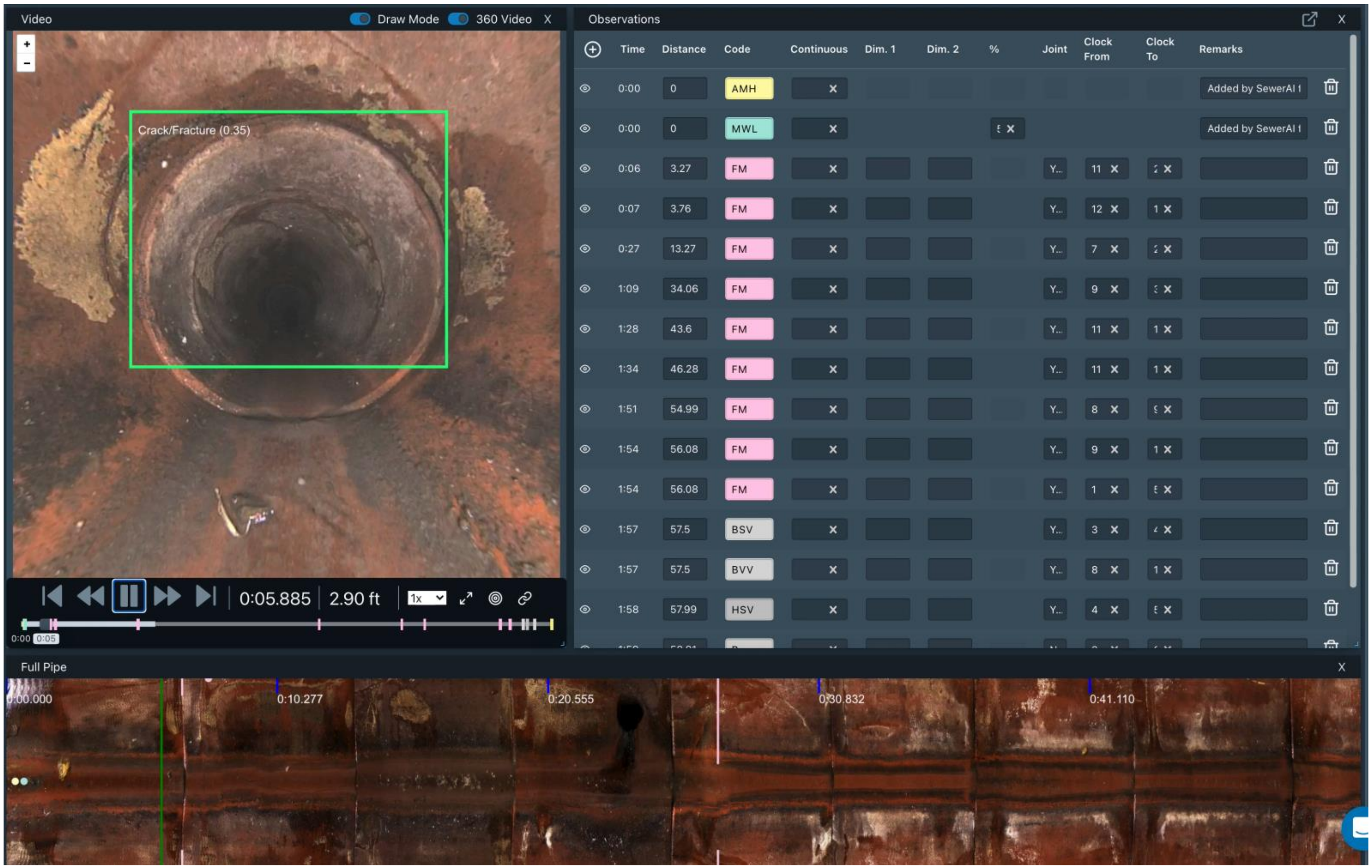
- Code Defects
- Correct AI Errors
- Re-Train AI



LARGE UTILITY IN CALIFORNIA: EAST BAY MUNICIPAL UTILITIES DISTRICT

the international water association

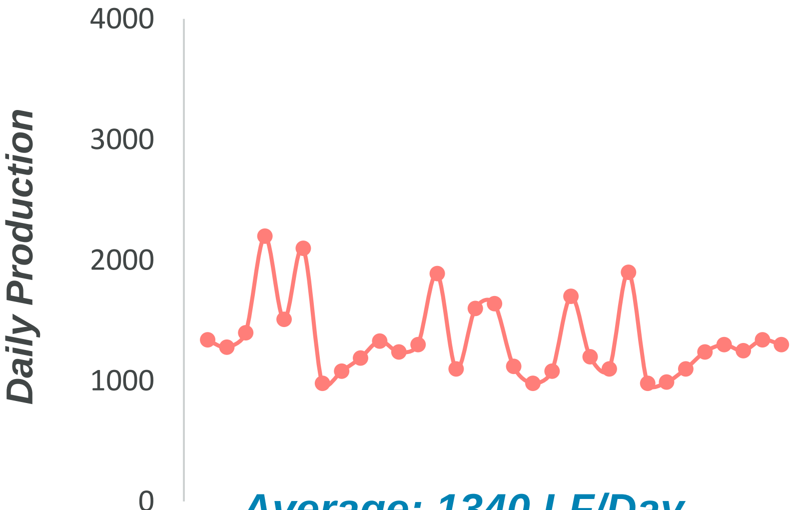
I&I Investigation → 65 miles of Digital Side Scan data in 18 days



CONTRACTOR IN US WEST COAST
PIPE AND PLANT SOLUTIONS INC.

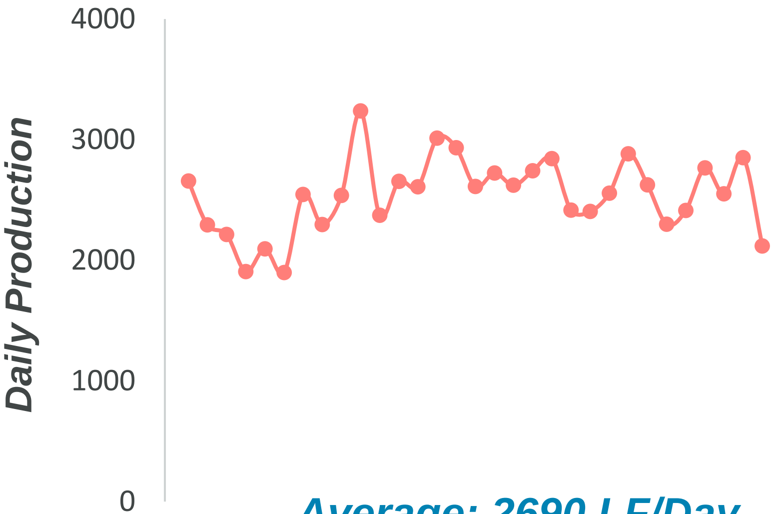
the international water association

Traditional Workflow



Average: 1340 LF/Day

AI-Enabled Workflow



Average: 2690 LF/Day

LESSONS LEARNED

AI can be more accurate and consistent than humans at identifying defects

Important to have human in-the-loop for reviewing AI outputs

AI-Enabled workflow → Significant improvement in productivity, accuracy, and consistency

Drone Inspections

Jetter Cameras

www.sewerai.com/pioneer

Q&A Discussion 2

PASCALE ROUAULT, YOUEN PERICAULT,
DULCY ABRAHAM, SRINATH KUMAR

(MODERATED BY NICO CARADOT & ELVIRA ESTRUCH)

EURO-SAM
SEWER ASSET MANAGEMENT WORKSHOP

- Held **online** on **16-17 June 2021**
- Free of charge
- 20 speakers
- Latest R&D outcomes on sewer asset management

- **Register now** at:
  - https://iwasamsg.wordpress.com/
  - https://udam.home.blog/

Join our network of water professionals!

the international water association

IWA brings professionals from many disciplines together to accelerate the science, innovation and practice that can make a difference in addressing water challenges.

Use code WEB21RECRUIT

for a **20% discount off** new membership.

Join before 31 December 2021 at:

www.iwa-connect.org

inspiring change

Register at: https://digital.worldwatercongress.org/