24th ANNUAL LEAKAGE CONFERENCE

4 – 5 DECEMBER 2023
BIRMINGHAM & LIVESTREAM

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THE WATER REPORT
POLICY | REGULATION | COMPETITION

Meet up with our exhibitors and other delegates

aqualogic water conservation

BERMAD

GUTERMANN

HWM

MUELLER

OVARRO CONNECTING TECHNOLOGIES

SME WATER

suez

TECCURA SOFTWARE

TECHNOLOG

THE WATER REPORT POLICY | REGULATION | COMPETITION

Housekeeping

- Turn **phones/devices** to silent or off please
- **Q&As -** Raise your questions through:
  - **In the room - Roving microphones**
  - **Livestream – via Slido**
- We will also be **seeking your views through SliDo polls**
  - **Get the Slido app – use the handle #2749424**
- **Feedback forms: online form was emailed to you on Monday …here's the link** https://www.leakageconference.co.uk/feedback-form

plus, you have a hard copy within your Event Guide

Conference welcome

Peter Simpson

Chief Executive

Anglian Water

Research and innovation forum

UKWIR: Overview of research projects and Leakage Innovation Heatmap update

Jeremy Heath

Innovation Manager

SES Water

UKWIR: Overview of research projects and Leakage Innovation Heatmap update

Jez Heath – SES Water Innovation Manager
UKWIR Programme Lead on Leakage

The current UKWIR Leakage Programme.

Outcomes

Key Benefits

Prevent
We can prevent new leaks from forming and minimise the effect of existing ones

We understand how leaks form and develop and can minimise their growth

We can effectively justify and target mains replacement programmes to reduce leakage

- 28 – Optimising the selection of pipes for renewal to reduce leakage
- 29 – Calculating whole life costings and total value of mains renewal methodologies
- 25 – Assessing the levels of leakage on new polyethylene networks.
- 27 – A review of the success of previous mains renewal methods and an overview of new techniques
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- 17/WM/08/64 – Laying Leak Free New Networks
- 19/WM/08/71 – Incidence And Causes Of Repeat Bursts At Old Repairs

Aware
We can correctly measure and quantify the various components and areas that leakage occurs in and prioritise interventions

We understand the various components that make up leakage and can accurately quantify them

We can monitor the changes in leakage in components and geographical areas in order to effectively target resources

- 31 – Understanding what factors contribute to and affect overall DMA leakage
- 32 – Defining a consistent approach to calculating MAL and MAbL
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- 17/WM/08/65 – Water Accounting And Quantification Methods
- 17/WM/08/62 – Leakage Detection and Location - Non Acoustic Methods

Locate
We can accurately locate leakage on all materials and under all surface conditions

We understand the use and limitations of current leakage location methods

We can assist with the development and trials of new leak location methods

- 33 – Use of models to determine the size and most likely location of CSL
- 34 – Contract management to incentivise efficient leak location and repair
- WM/08/A/217 – Optical fibre sensing for acoustic leak detection
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- 17/WM/08/61 – Leakage Detection By Acoustic Methods
- WM/08/S/210 – Hydrant dynamics for acoustic leakage detection

Mend
We can repair leaks quickly and economically with minimum disruption

We can reduce the run time of leaks due to more effective repairs

We can assist in the development of new repair technologies

- 36 – Assisting the development and adoption of in pipe repair methods
- 37 – Development of testing methodologies for mains repair techniques
- 22/WM/12/01 – Transferring minimal excavation methods into the water industry
- 35 – Temporary flow reduction and repair technologies
- 17/WM/08/63 – Leak Repair Techniques
- 20/WM/08/73 – Impact of customer-side leakage approaches

Notes

Project Status

- Idea
- Planned
- Live
- Completed

Project Priority

- # High
- # Medium
- # Low
- # Not prioritised

For Information

Report reference *(on Completed projects)*

21/DW/13/10 – 1 – Project title

Version 14
Last Updated
22/02/2022

The future UKWIR Leakage Programme.

Choosing suitable future projects for the UKWIR Programme

- We are concerned that, as a result of the more strategic direction that the Big Questions are taking us, we are losing input and direction from the industry.
- We are now actively seeking the views of the Water UK leakage managers group on the programme priorities.
- This is accomplished by presenting them with a short list (8 No.) of projects that we feel are the current priorities. This may include projects that we feel are imperative.
- The short list is firstly prioritised by the Programme leads.
- The leakage managers group then vote on the sort list in order to provide an additional prioritisation.
- Taking into account both prioritisation exercises allows us to present projects for voting that we know have support from the industry.

The future UKWIR Leakage Programme. (PALM)

Use of models to determine the size and most likely location of CSL

- **Justification:** Currently failure models concentrate on mains failures. However, there would be considerable benefit to these solutions being extended to the prediction of supply and communication pipe failures.

- **Aiming to achieve:** Review the current solutions which predict mains failures and investigate the issues, potential costs and benefits of extending these solutions to communication and supply pipe failures. Data on supply pipe and communication pipe failures would be used to populate a simple model as proof of concept.

- **Anticipated benefits:** Validated models that proved successful at predicting failures would not only reduce location and leak run times but additionally allow more targeted replacement polices.

The future UKWIR Leakage Programme. (PALM)

Optimising the selection of pipes to renew for leakage

- **Justification:** With the current focus on reducing leakage levels, leakage has become a major driver for mains renewal, if not the principal driver. However leakage is not normally measured at the level of individual pipes, but only at DMA level.

- **Aiming to achieve:** Devise an effective method for the optimum selection of mains for renewal at sub-DMA level, where the principal driver for investment is reduction of leakage.

- **Anticipated benefits:** This will allow limited financial resources to be invested in renewal of specific pipes which will deliver the maximum possible benefit per pound invested.

The future UKWIR Leakage Programme. (PALM)

A review of the success of previous mains renewal methods and an overview of new techniques

- **Justification:** The UK water industry is aware that mains replacement programmes are not at the volume needed to create a healthy distribution network for future generations. In building Mains Rehab business cases the industry must be able to make good decisions as to the engineering techniques employed.
- **Aiming to achieve:** This first step seeks to analyse the impact of previous renewal programmes, primarily the S19 quality mains renewals of the 1990s, for their impact on leakage in the subsequent 2 decades and compare the findings against quoted and appraised performance of current and novel techniques. Generate a clear and evidenced appraisal of any measurable improvement in leakage performance from rehabbed DMAs to inform future project #28 - Calculating whole life costings and total value of mains renewal methodologies
- **Anticipated benefits:** Generate a simple, coherent measure of the impact of renewal eg; NRR, background leakage, burst rates, leaks per km, leaks per property

Company leakage research and innovation projects

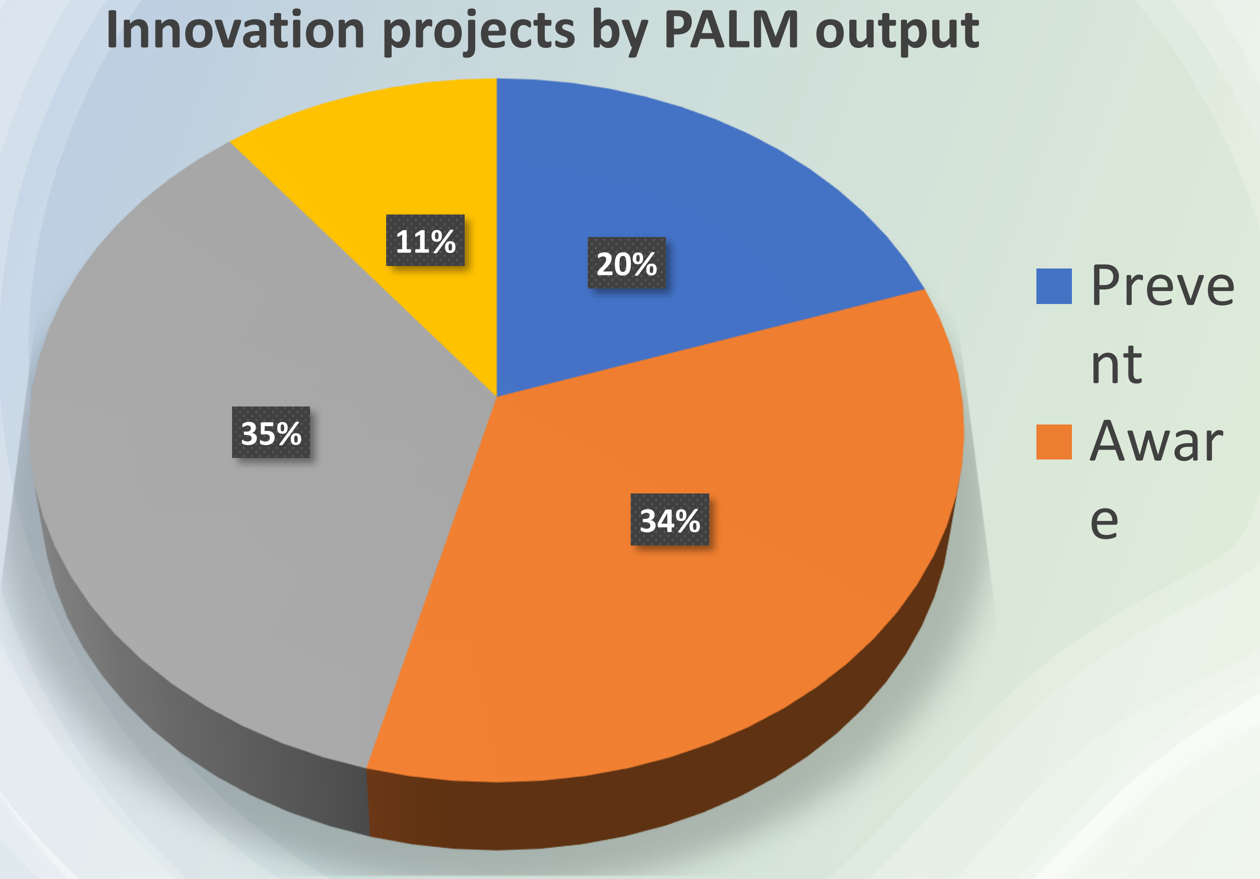
Company leakage research and innovation projects

Leakage Innovation Heatmap

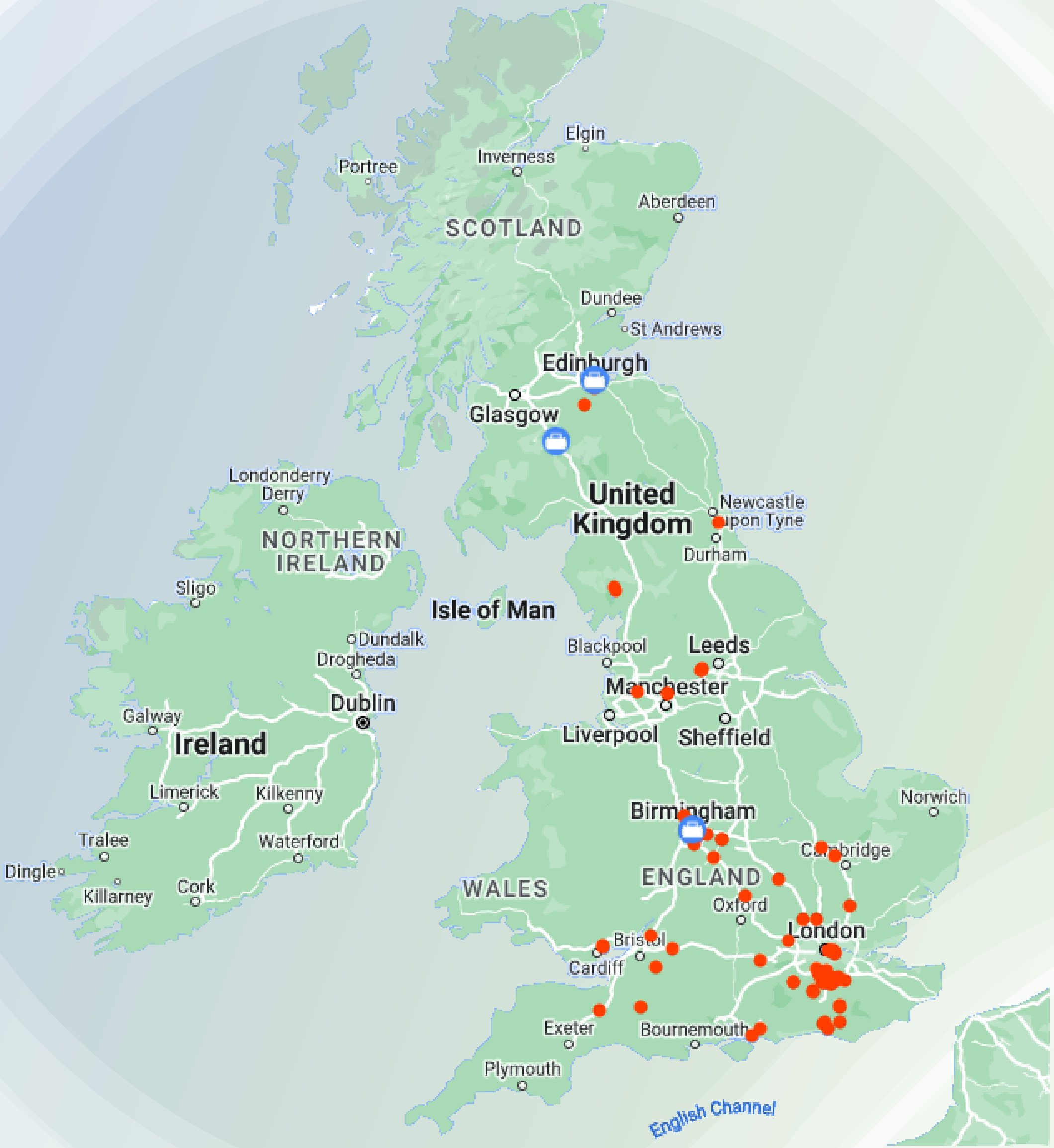
- Generated by the water companies in 2019, together with a road trip.
- 329 leakage projects shared across 17 water companies.
- Allowed us for the first time to map out where collaborative projects are possible and where innovation gaps exist.
- Projects scored individually on the financial value, completeness & willingness to share
- Results available on the UKWIR website
  https://ukwir.org/How-will-we-achieve-zero-leakage-in-a-sustainable-way-by-2050

Company leakage research and innovation projects

Leakage Innovation Heatmap



Portsmouth Water
Southern Water
Affinity Water
Thames Water
South East Water
Severn Trent Water
South Staffordshire Water & Cambridge Water Company
Yorkshire Water
United Utilities
Northern Ireland Water
Scottish Water
Anglian Water
South West Water & Bournemouth Water & Bristol Water
Wessex Water
Dŵr Cymru
SESWater
Northumbrian Water & Essex and Suffolk Water
Irish Water



Company leakage research and innovation projects

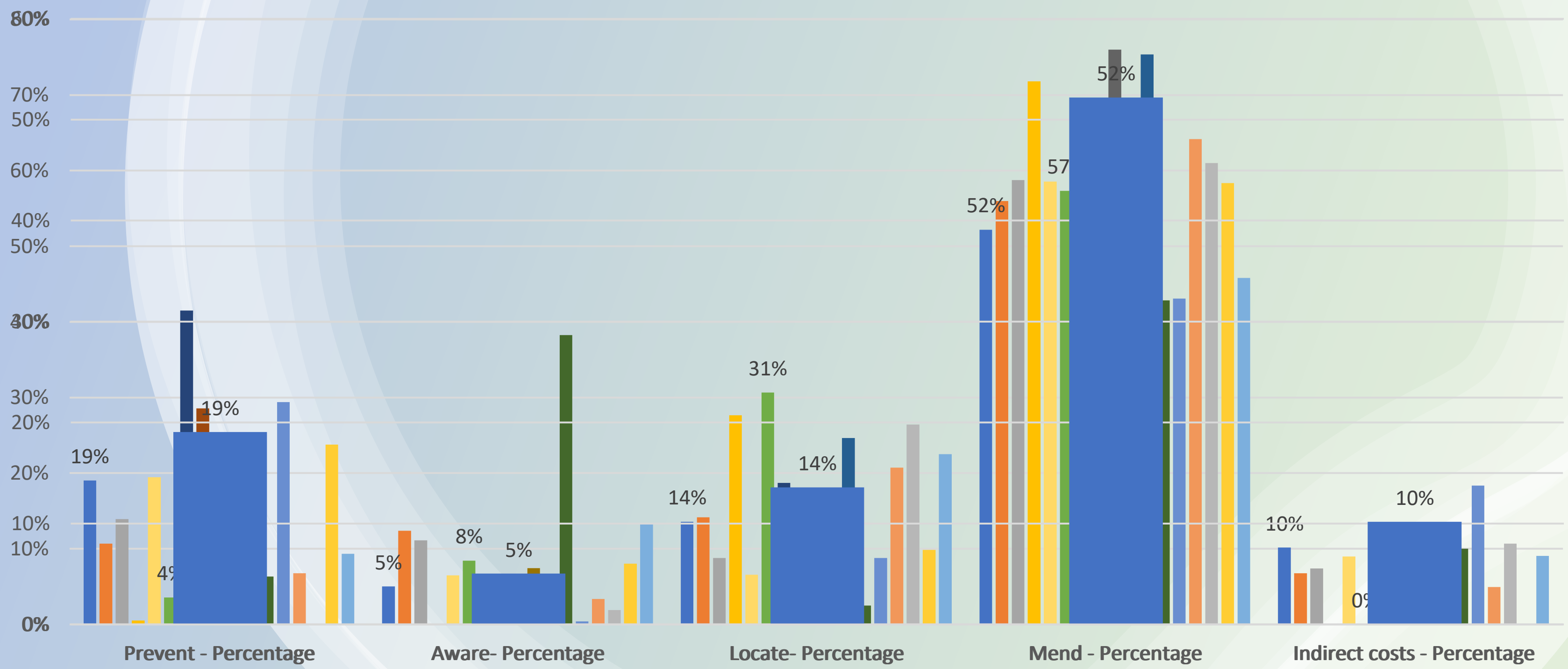
Leakage Innovation Heatmap Update

- All water companies are submitting their updated project list by the end of December.
- The updated heatmap will then be published in January 24.
- The heatmap will also show the shared innovation fund projects regarding leakage and a list of the UKWIR BQ2 projects.
- This will provide a single spreadsheet with all of the current and recently research and innovation projects on leakage.
- Completed leakage projects will be published on Spring knowledge share.
- I'm interested in discussions with supply chain on how to include their areas of innovation interest into this spreadsheet.

Learnings from the Leakage Roadtrip

The advantages of reading your PALM

- The PALM method has proved useful in understanding Companies strategies for leakage reduction. Data published on the CW19 spreadsheet shows the % breakdown in spend.



Learnings from the Leakage Roadtrip

The advantages of reading your PALM…

- The PALM method has proved useful in understanding Companies strategies for leakage reduction. Data published on the CW19 spreadsheet shows the % breakdown in spend.
- Whilst we are awaiting the heatmap results, it is clear from our discussions that priorities have changed within the water companies.
- In 2019, the priorities were definitely awareness and locate, with discussions mainly about smart networks and acoustic networks.
- At the end of each Roadtrip I asked the companies, based on the current research programme and their PR24 commitments, where should we focus our research.
- Almost every company wants more research on Mend solutions, to bring down the leak run times.

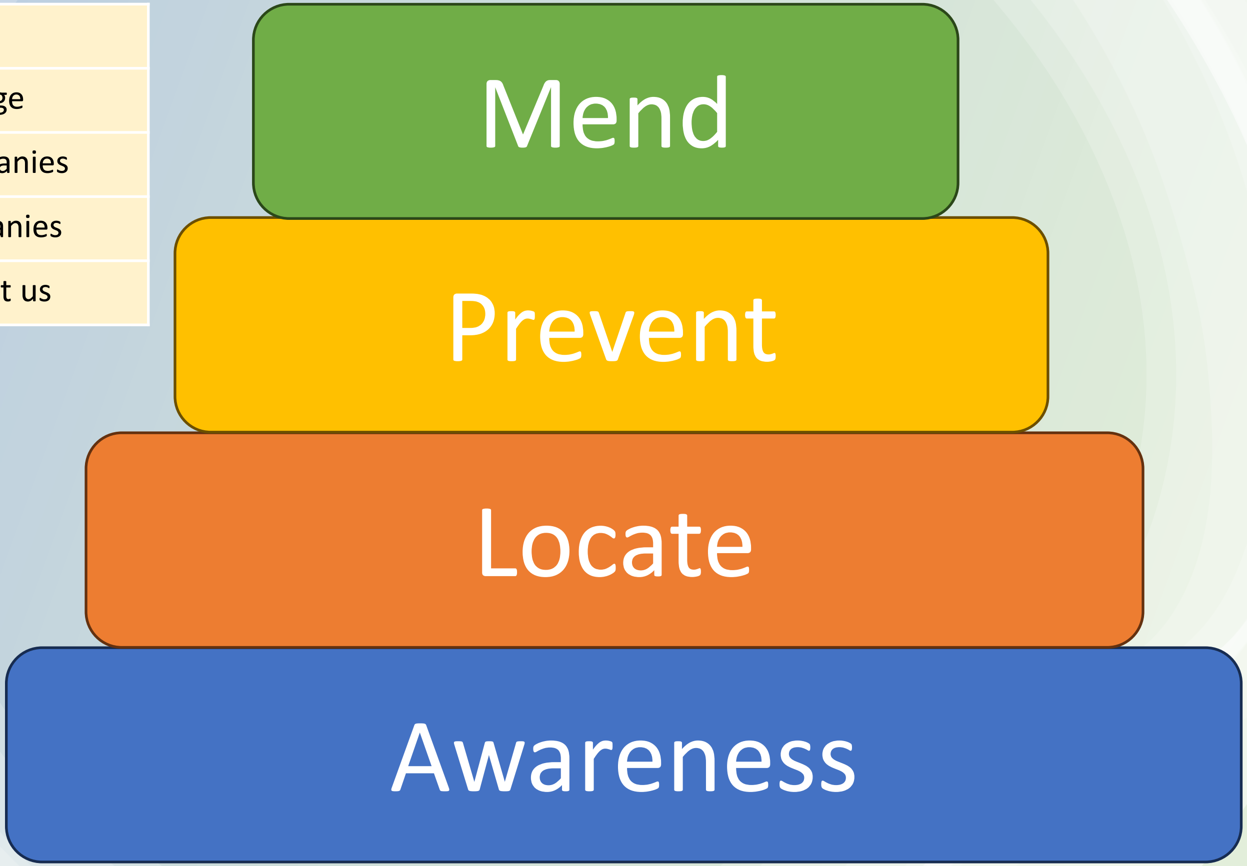
Learnings from the Leakage Roadtrip

Maslow's hierarchy of needs

Learnings from the Leakage Roadtrip

The Hierarchy of Leakage Innovation and Research (HoLIaR)

Research	Innovation
Benefits & Barriers	Bleeding edge
Horizon scanning	Some Companies
How to implement	Most Companies
Best practices	Everyone but us



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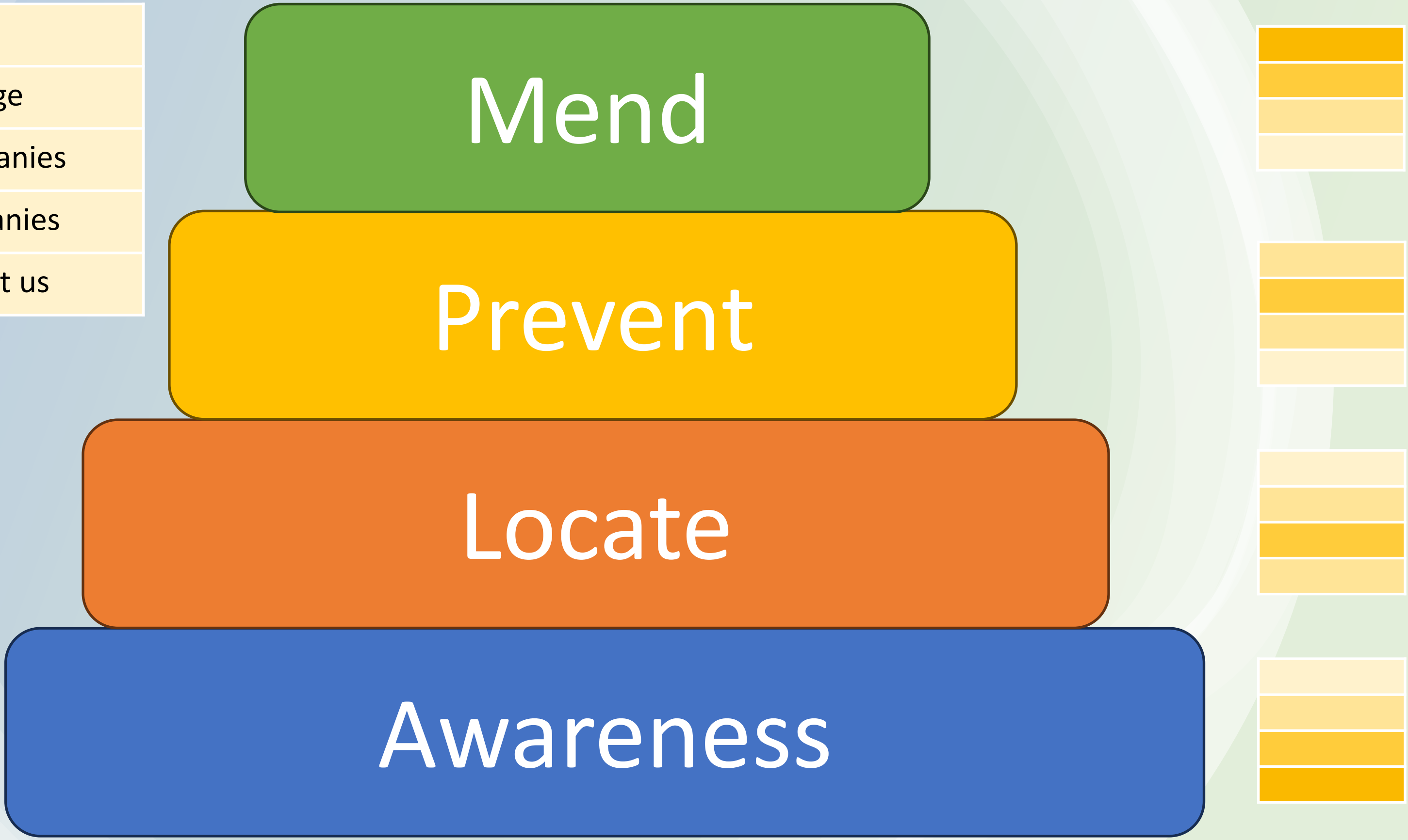

The current UKWIR Leakage Programme.

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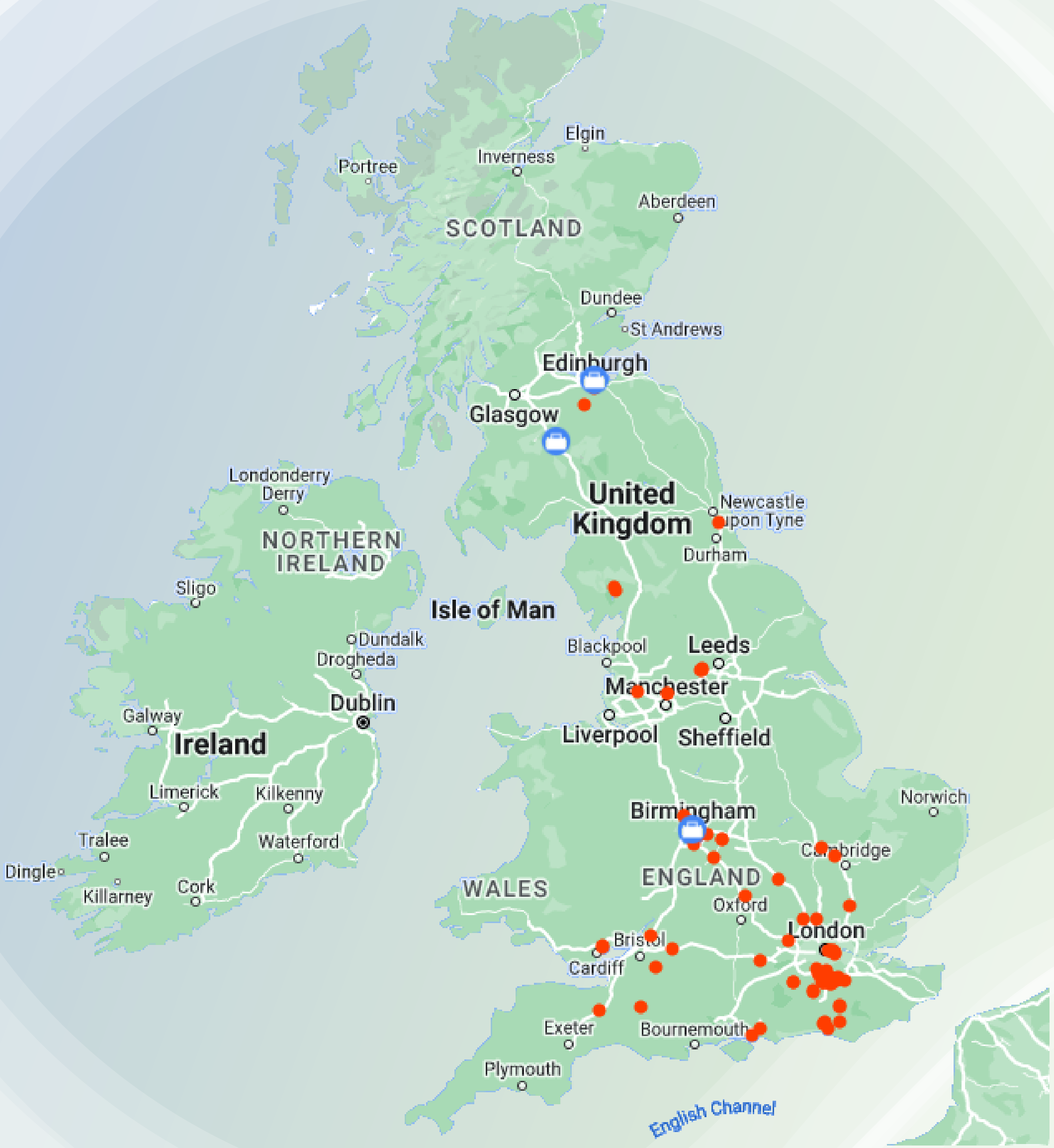
United Utilities
Northern Ireland Water
Scottish Water
Anglian Water
South West Water & Bournemouth Water & Bristol Water
Wessex Water
Dŵr Cymru
SESWater
Northumbrian Water & Essex and Suffolk Water
Irish Water



Questions?

Leakage research projects – industry and academia working together

Introduced & chaired by Jeremy Heath

Innovation Manager

SES Water

Updates: Acoustic research PhDs

Dr Jen Muggleton

Principal Research Fellow

University of Southampton

Zero Leakage/Zero Interruptions 2050

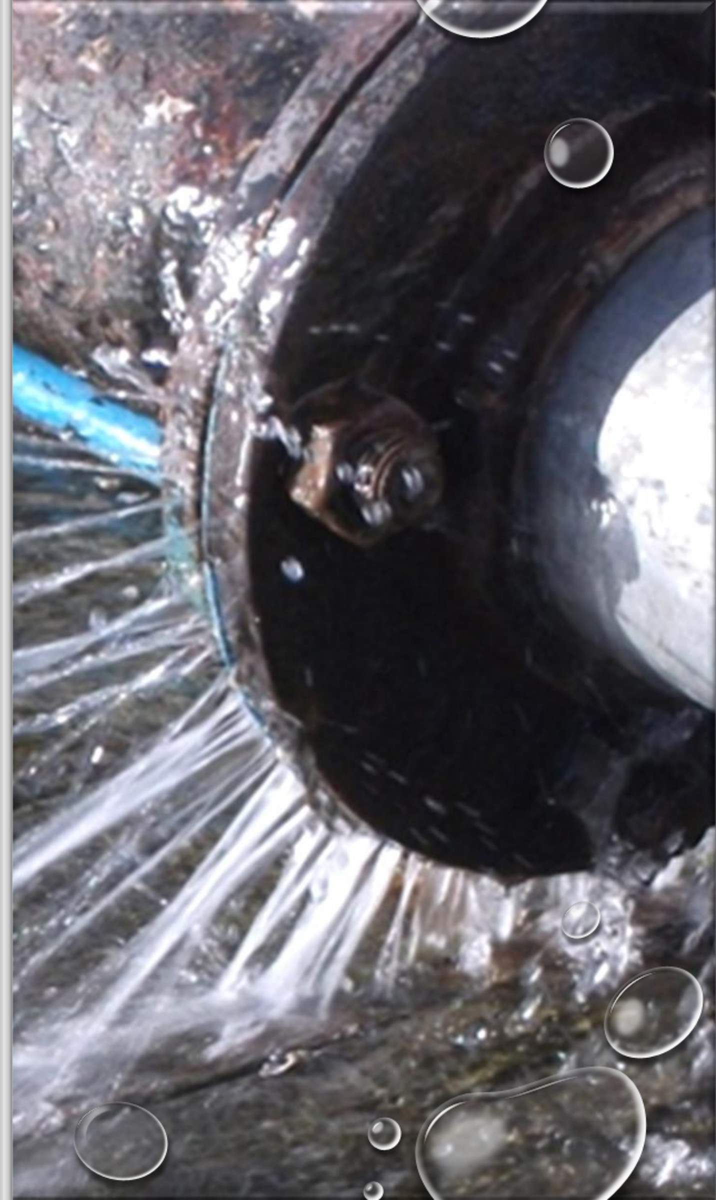
From Leak to Burst: Acoustic & Material considerations

Jen Muggleton

Institute of Sound and Vibration Research, University of Southampton

Portfolio of UKWIR Projects

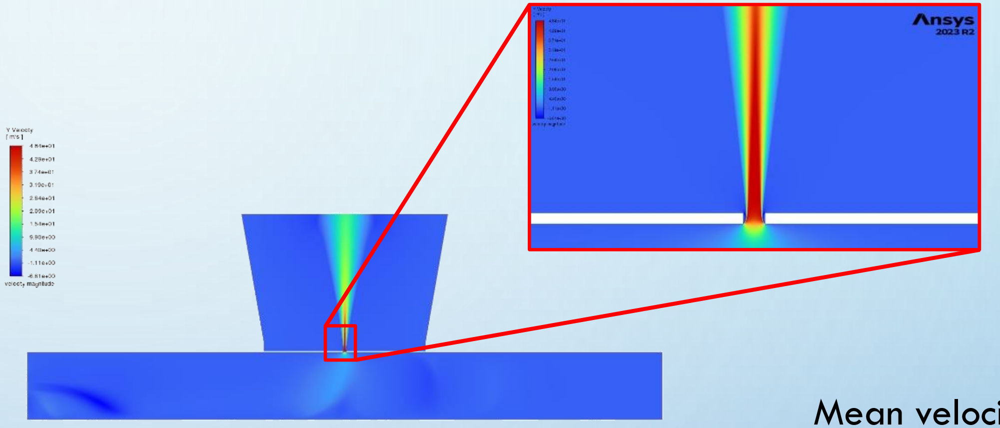
- Leak Noise Characterisation (2018-2023)
- Combining Transient and Steady State Signal Processing (2018-2023)
- Pipe Wave Modelling (2020-2024)
- Signal Processing for Distributed Acoustic Sensing (2021-2025)
- **Leak-2-Burst Leak Noise Characterisation (2022-2026)**
- **Evolution of critical defects under typical service conditions in cast iron pipe materials (2022-2026)**
- Optical Fibre Sensing for Pipeline Leak Detection (2023-2027)
- Hydrant Dynamics (2024-2027)
- Acoustic Rods for Closely-spaced Pipeline Sensing (2024-2027)



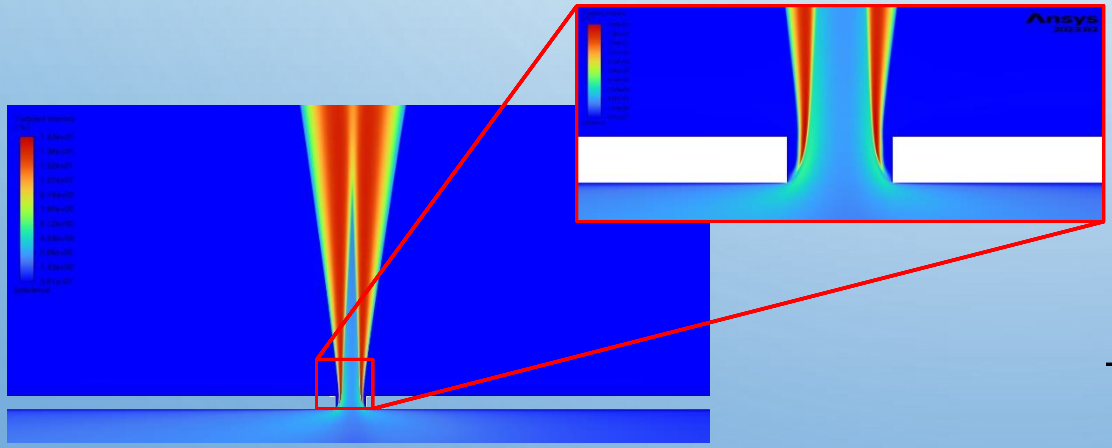
Leak-2-Burst Leak Noise Characterisation

- Investigating the leak noise generating mechanism
- Developing a model to characterise the leak noise based on empirical observations and theoretical considerations
- Determining the relation between the leak noise spectrum characteristics and leak discharge flow
- Investigating the evolution of leak noise by leakage geometry variation

Numerical Modelling Results



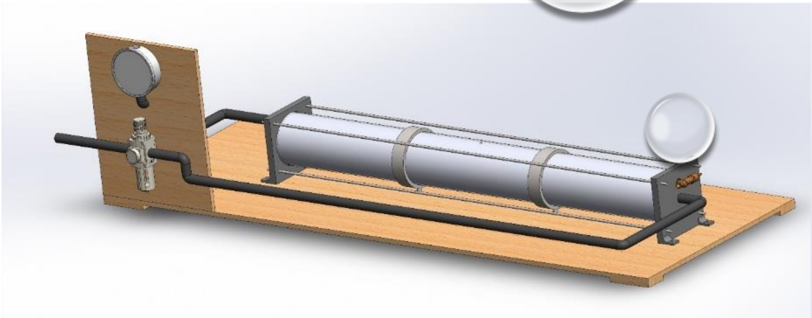
Mean velocity

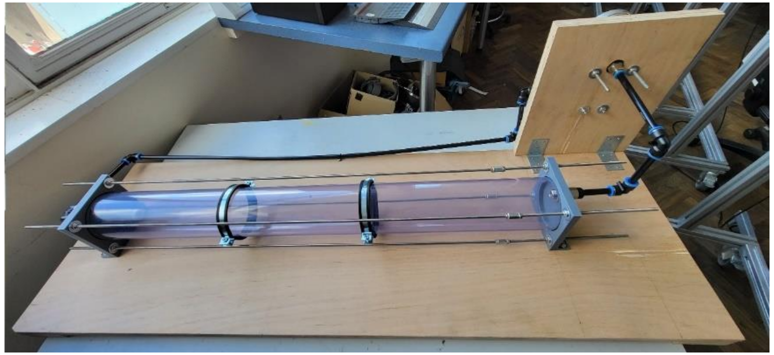


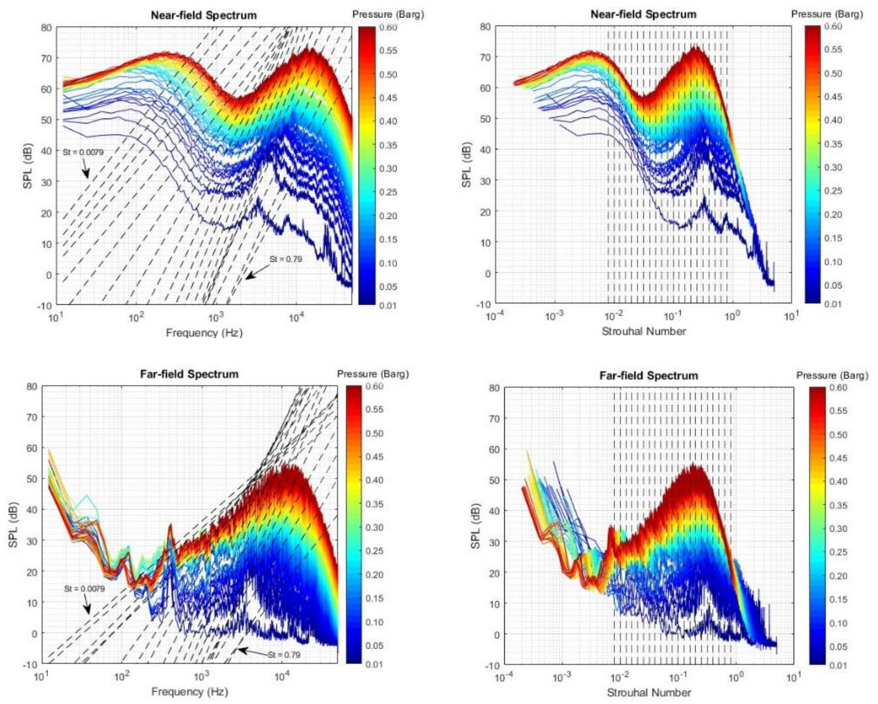
Turbulence intensity

Experimental Rig

- In-air pipe rig constructed
- Appropriate scaling applied to ensure representative of water-filled scenario
- Measurements made of
  - Mean flow @ exit
  - Turbulence (related to unsteady velocities)
  - Acoustic pressures outside pipe
  - Acoustic pressures inside pipe



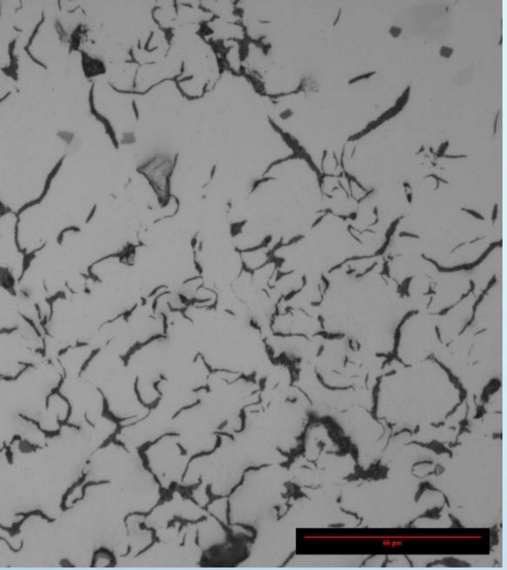


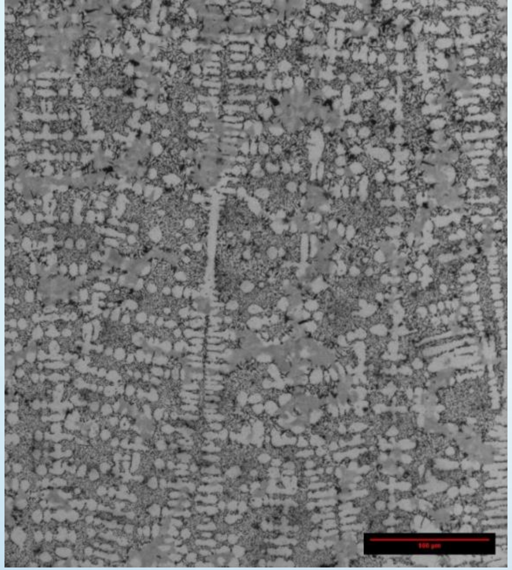


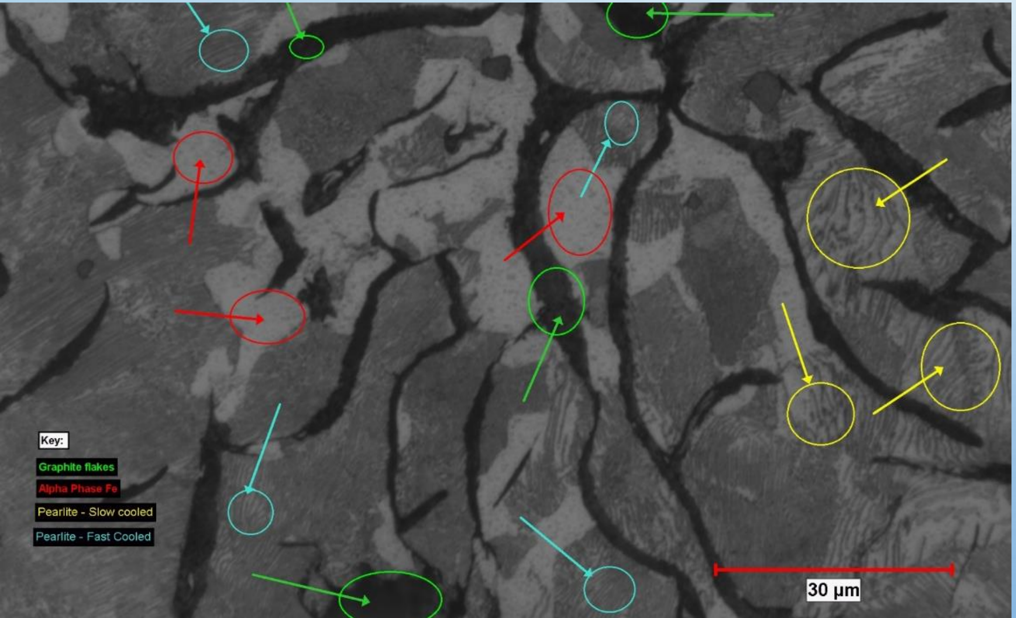
EXPERIMENTAL RESULTS

Future Work

- Noise measurement inside the pipe
- Repeating the measurements with different leak sizes and geometries
- Developing a CFD-based numerical model (unsteady turbulence simulation)
- Developing an analytical model based on experimental and numerical results
- Building a water pipe rig to test the model





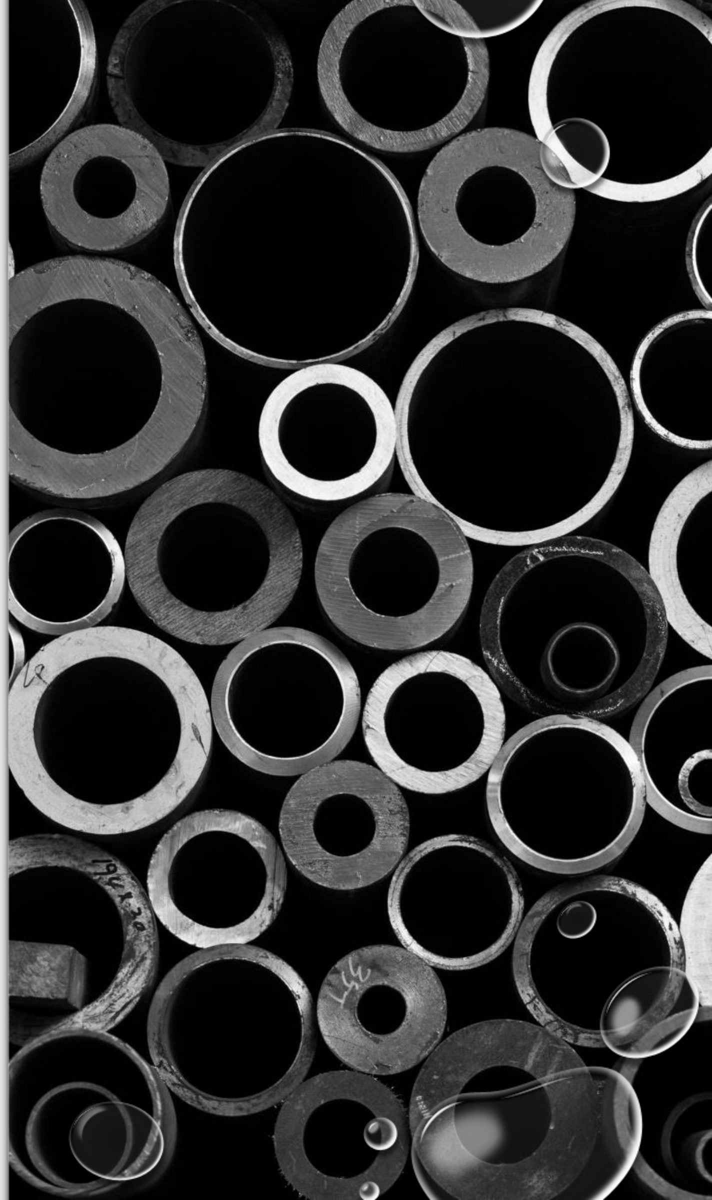


Evolution of critical defects under typical service conditions in cast iron pipe materials

- Project focusing on behaviour and performance of EN-GJL-250 flake graphite cast iron
- Leak-before-burst effect caused by fatigue cracks initiating from surface defects and growing through the pipe wall
- Grey cast irons have an inherently stochastic microstructure, influencing their mechanical and corrosion performance
- The impact of microstructural variation and electrochemical behaviour of these materials in soil environments is not well understood

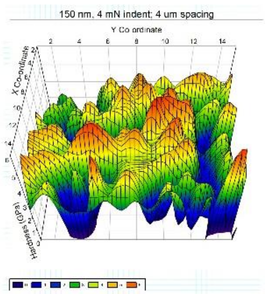
Aims and objectives

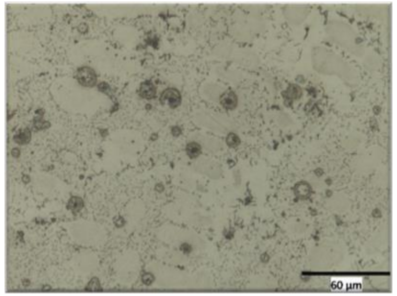
- Investigate and characterise the microstructure of grey cast iron
- Understand how corrosion pits form and propagate on external surface of cast iron pipe materials
- Understand how varying soil environments influence pit formation
- Explore the effect of external pitting on crack initiation and propagation

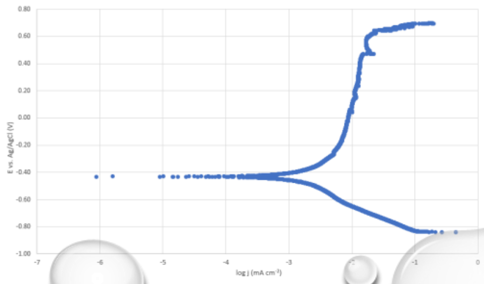


Ongoing work – corrosion / nano-hardness

- Initial testing to establish baseline corrosion performance in a low conductivity, slightly alkaline environment – simulating key parameters of clay soils known to be corrosive
- Nano-hardness testing to understand the properties of individual phases within a sample
- Pit initiation most prevalent at interface between ferrite and graphite phases as crevice corrosion around the graphite flakes

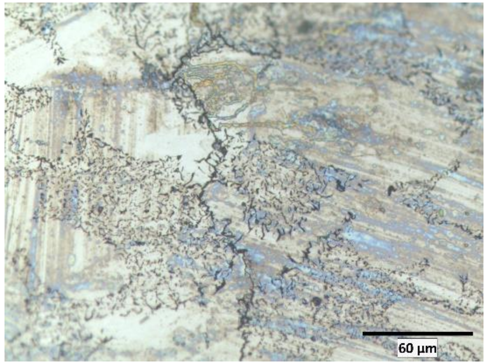


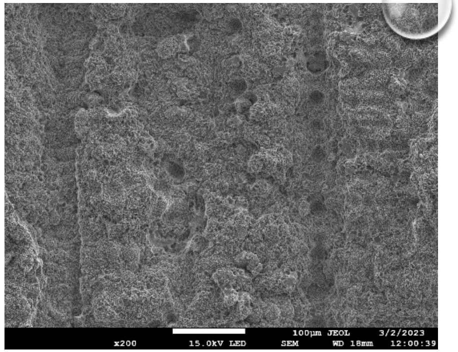


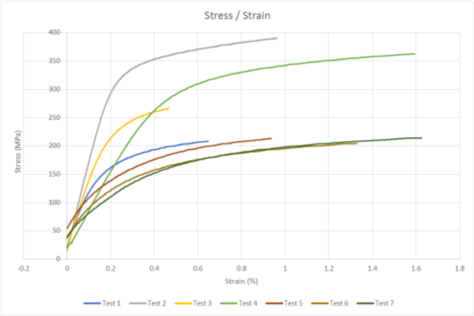


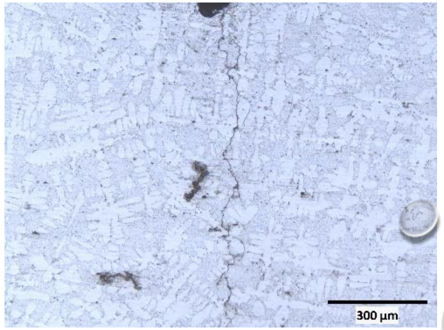
Ongoing work - mechanical

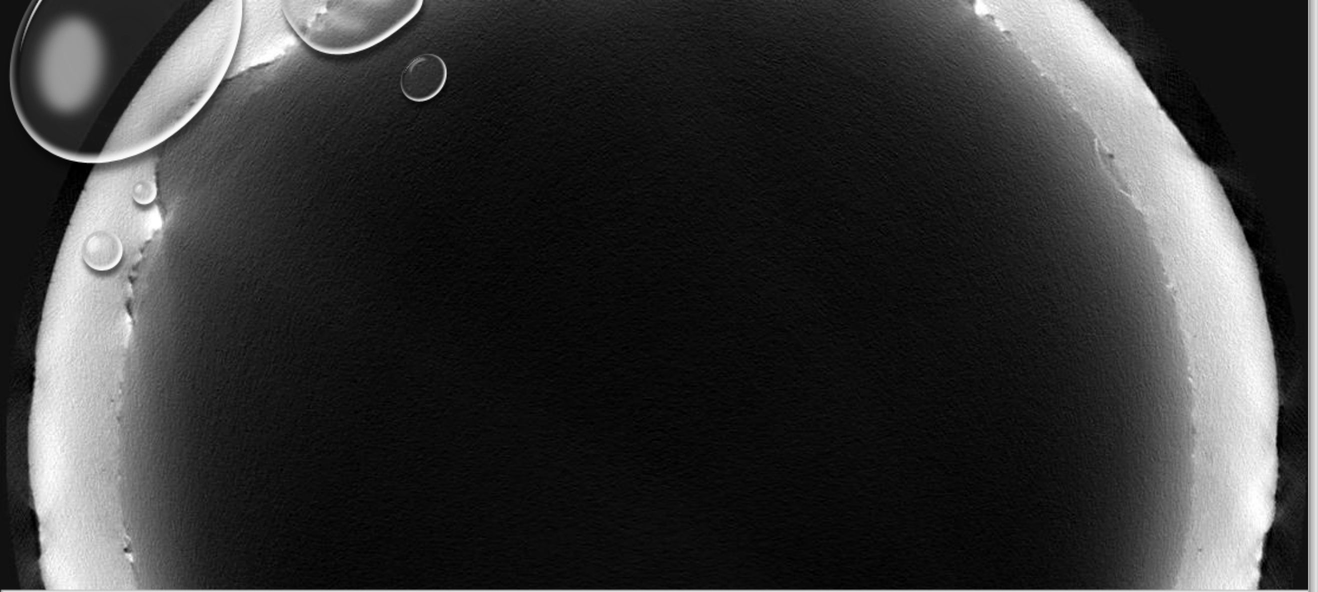
- Mechanical testing has focused on understanding paris law behaviour and crack growth mechanisms of grey cast irons
- Tensile testing carried out to ascertain material properties such as yield strength, UTS

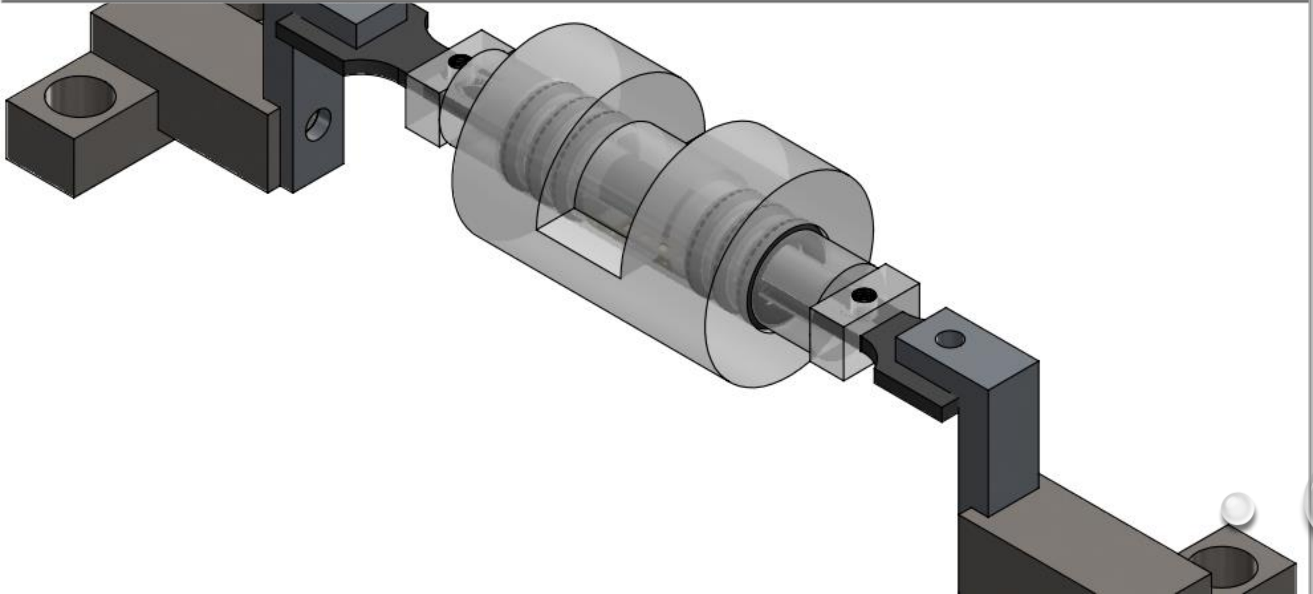












Future Work and Deliverables

- Mechanical testing of in-situ micro-tensile samples – x-ray CT scanning to observe live crack growth
- Modelling of pit propagation in varying soil environments
- Crack initiation from different pit geometries

Acknowledgements

Academics

- Professor Phillip Joseph
- Professor Philippa Reed
- Professor Julian Wharton

Students

- Mr Shahab Khodayari
- Mr Luke Ronayne

Funders

- UKWIR (Mr Jeremy Heath, Mr Dennis Dellow)
- EPSRC
- Faculty of Engineering & Physical Science, University of Southampton

Forthcoming Opportunities

PhD Projects

- We are open to student-proposed projects (funding potentially available)

Researchers & PhD Students

- Good undergraduate degree in Engineering, Mathematics or Physics
- Relevant experience may count in lieu
- 3.5 years full time or 7 years part time

Further Information

- Contact jmm@isvr.soton.ac.uk

And Finally…..

Thankyou for your Attention

Any Questions ?

Contact Details:
jmm@isvr.soton.ac.uk

Understanding cast iron pipes

Do grey cast iron pipes leak before they burst?

Edward John

PhD student

University of Sheffield

Do grey cast iron pipes leak before they burst?

Edward John[1]

5th December 2023

Supervisors: Luca Susmel[1], Joby Boxall[1], Richard Collins[1], Elisabeth Bowman[1], Dennis Dellow[2]

[1]*Civil and Structural Engineering, University of Sheffield, UK*

[2]*UK Water Industry Research, London, UK*

Presentation structure

Background

Why do we care about how leaks form?

Methods

How did we investigate the problem?

Results and summary

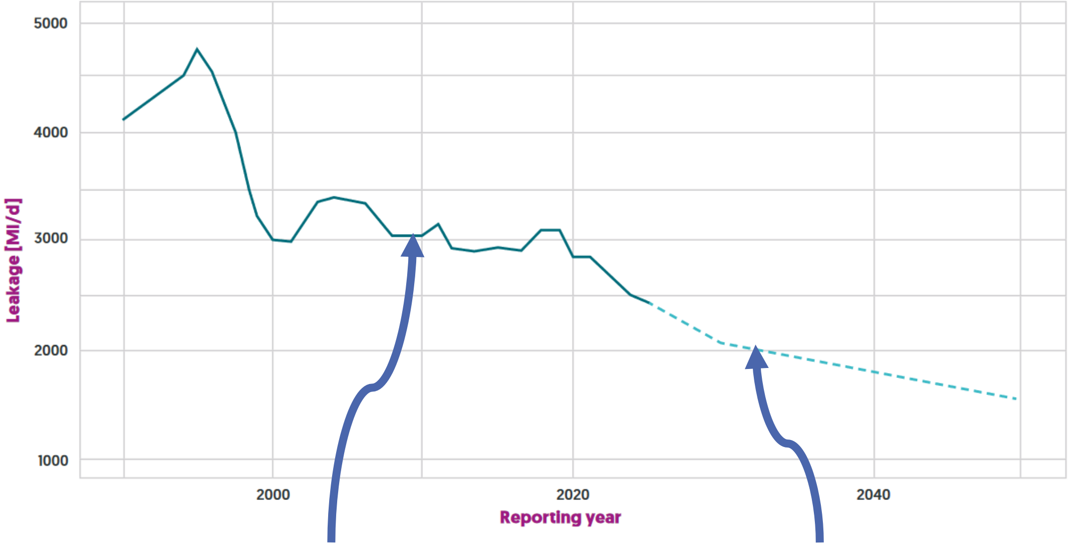
What did we find?

The University Of Sheffield.

UKWIR UK Water Industry Research

Background - Leakage

Leakage performance and commitments in England (Sanders et al, 2022)



Past performance   Future commitments

Can we find and fix leaks before they become bursts?

Can we replace pipes before they leak?

To do the above we need to understand **how leaks form and evolve**

Sanders, J., Marshallsay, D., Mountfort, G., Fox, G., & Butler, M. (2022). A leakage routemap to 2050. https://www.water.org.uk/news- item/milestone- leakageroutemap- to-revolutionise-the-reduction-of-leakage-from-pipes/

Background - Grey Cast Iron (GCI) pipes

- ✓ Used in new installations from the mid-1800s to the 1960s
- ✓ Have high failure rates
- ✓ GCI pipes are still very common - some networks are still 30 – 80 % GCI
- ✓ Vulnerable to corrosion and brittle

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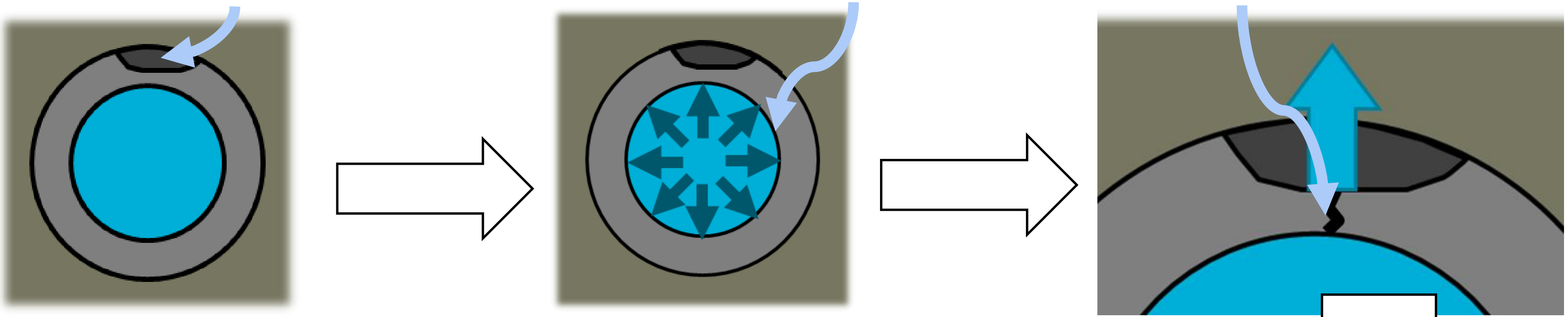
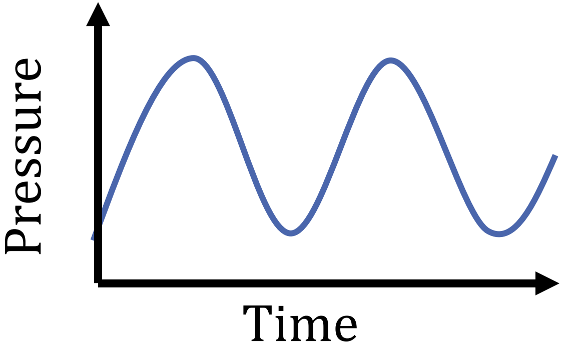
Barton, N. A., Farewell, T. S., Hallett, S. H., & Acland, T. F. (2019). Improving pipe failure predictions: Factors effecting pipe failure in drinking water networks. Water Research, 164, 114926. https://doi.org/10.1016/j.watres.2019.114926

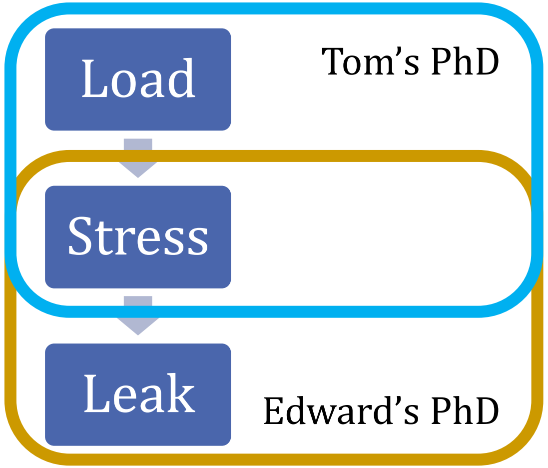
Rezaei, H., Ryan, B., & Stoianov, I. (2015). Pipe failure analysis and impact of dynamic hydraulic conditions in water supply networks. Procedia Engineering, 119, 253–262. https://doi.org/10.1016/j.proeng.2015.08.883

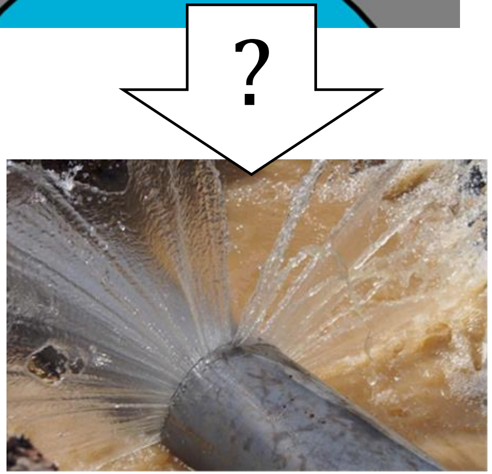
Background - How do leaks start in GCI pipes?

Corrosion pitting | Internal water pressure | Leaking crack









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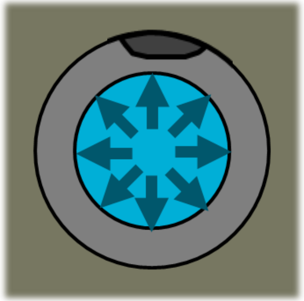
Research question

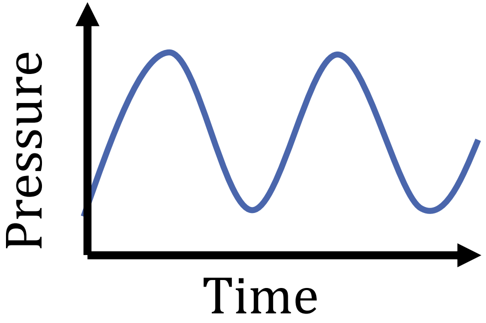
Do grey cast iron pipes leak before they burst?

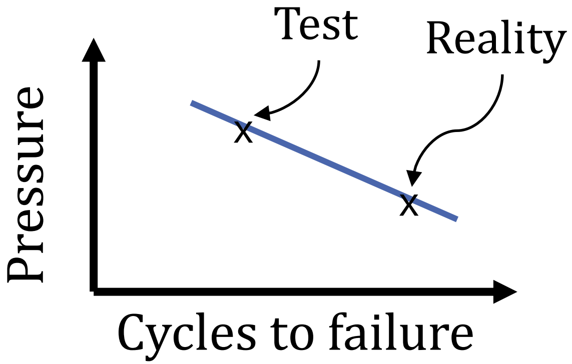
What are the characteristics of these leaks?

How did we investigate this?

Pipes are hidden under the ground. To observe the process we used lab experiments.







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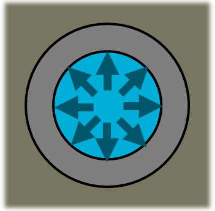
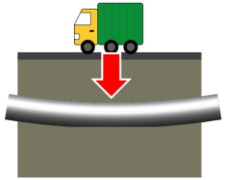
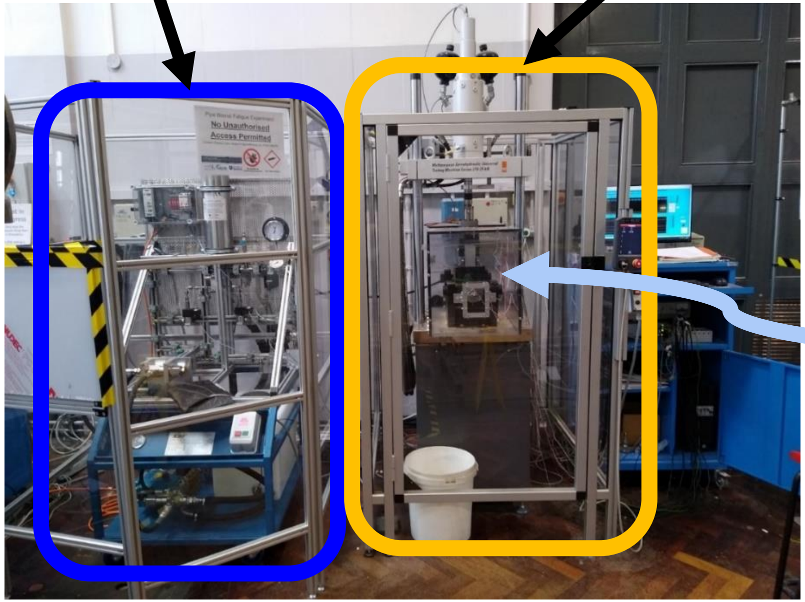
Experimental equipment

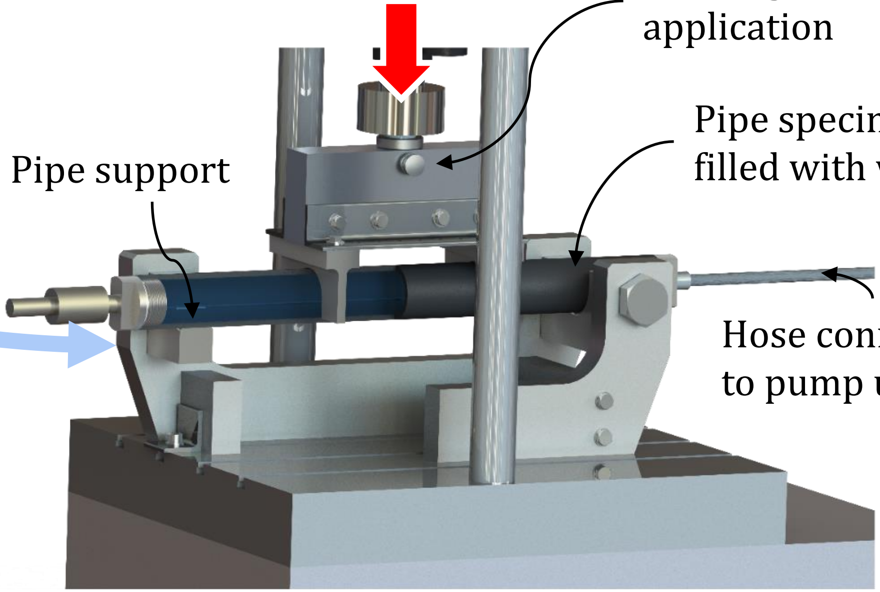
Pump unit:
Internal water pressure fatigue load



Fatigue machine:
Four-point bending fatigue load







Test Specimens

- Small diameter (~50 mm), new grey cast iron pipes
- Machined notches used to represent corrosion pitting

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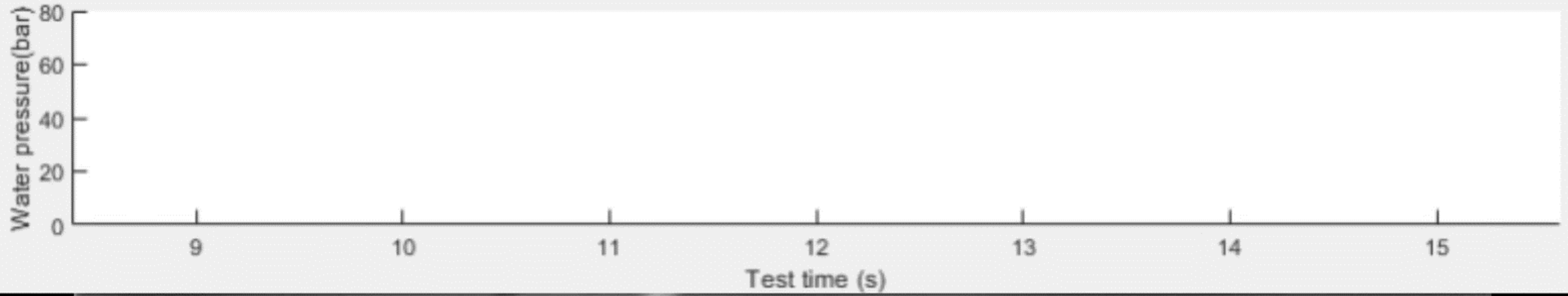
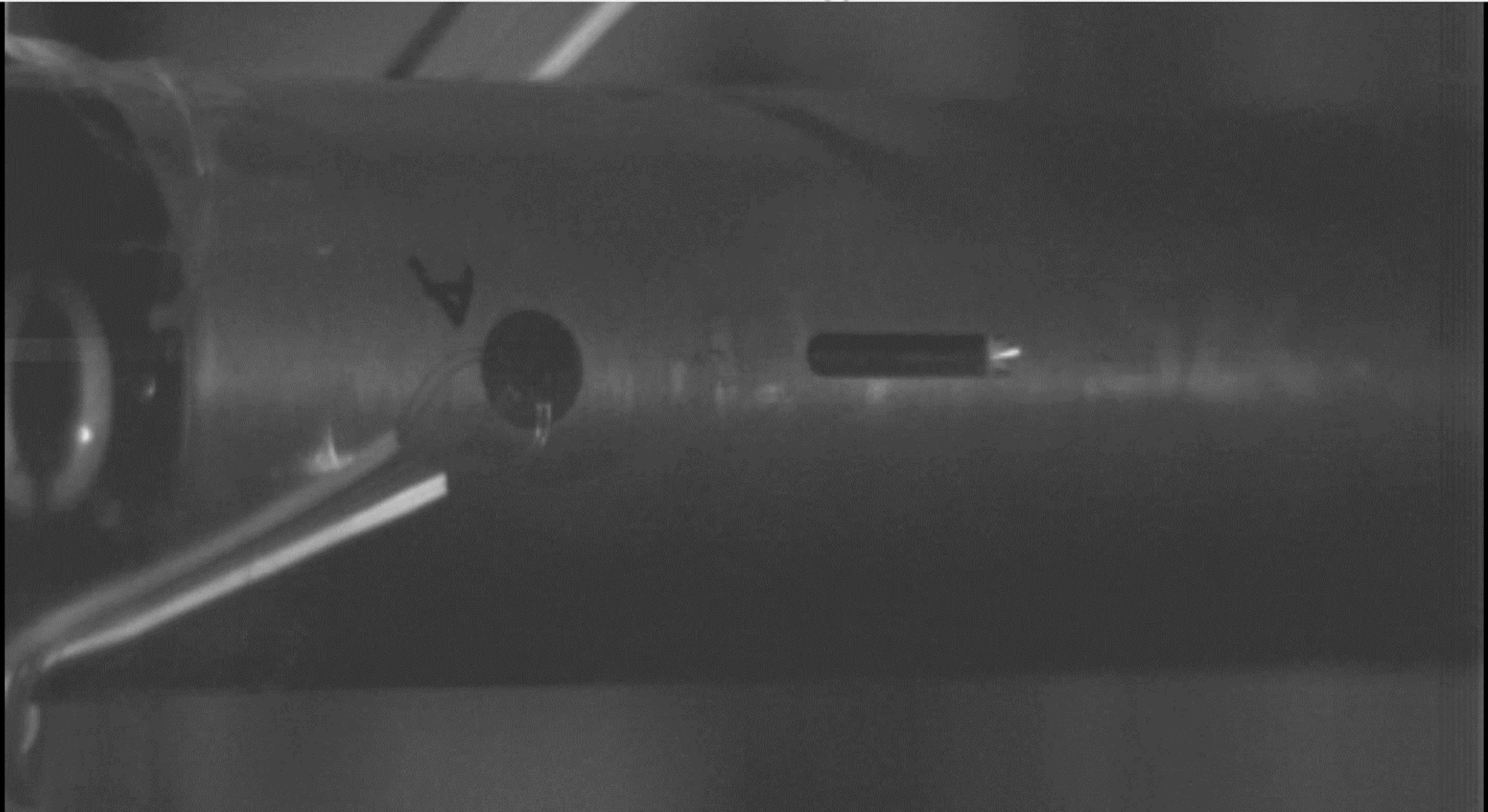
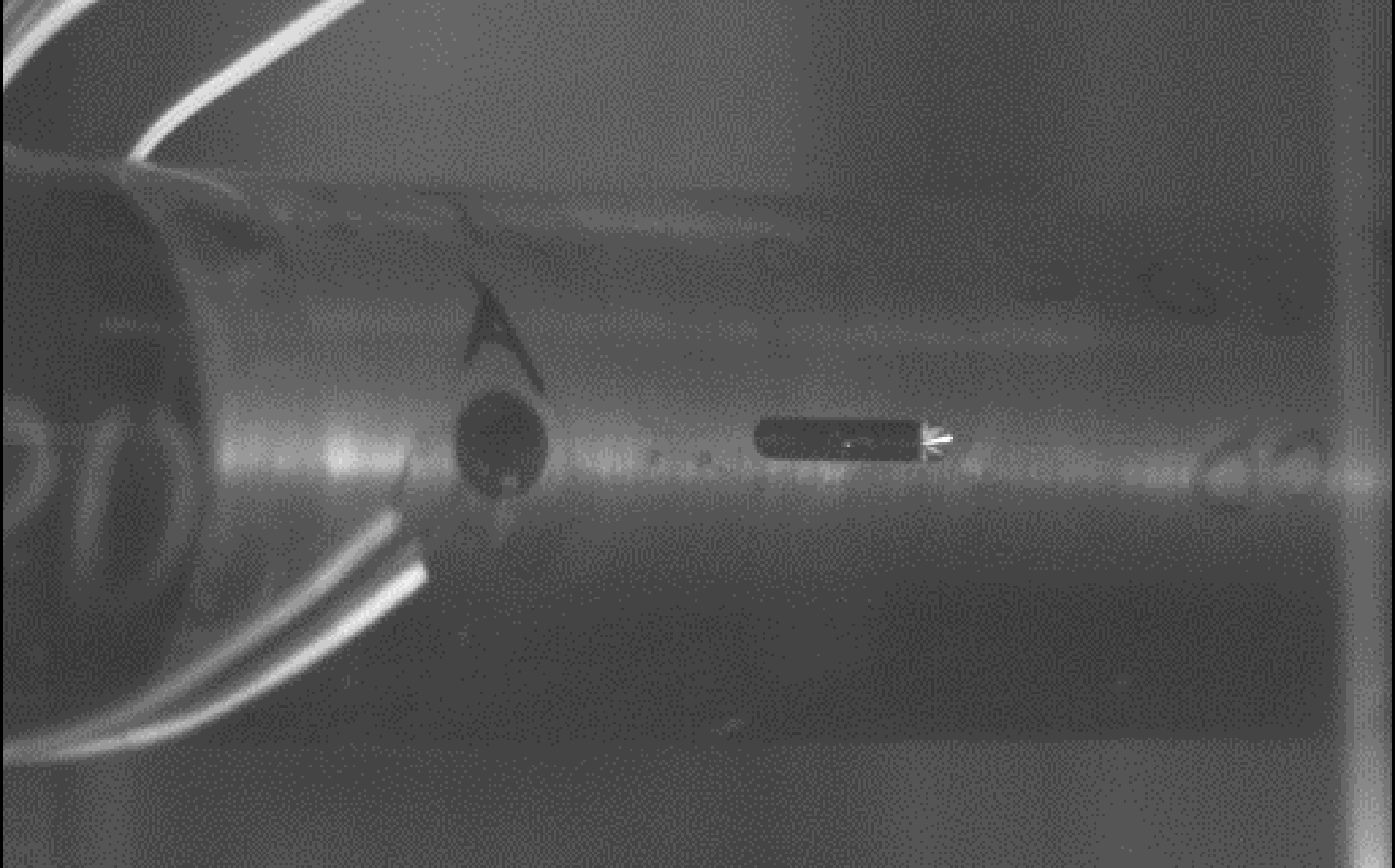
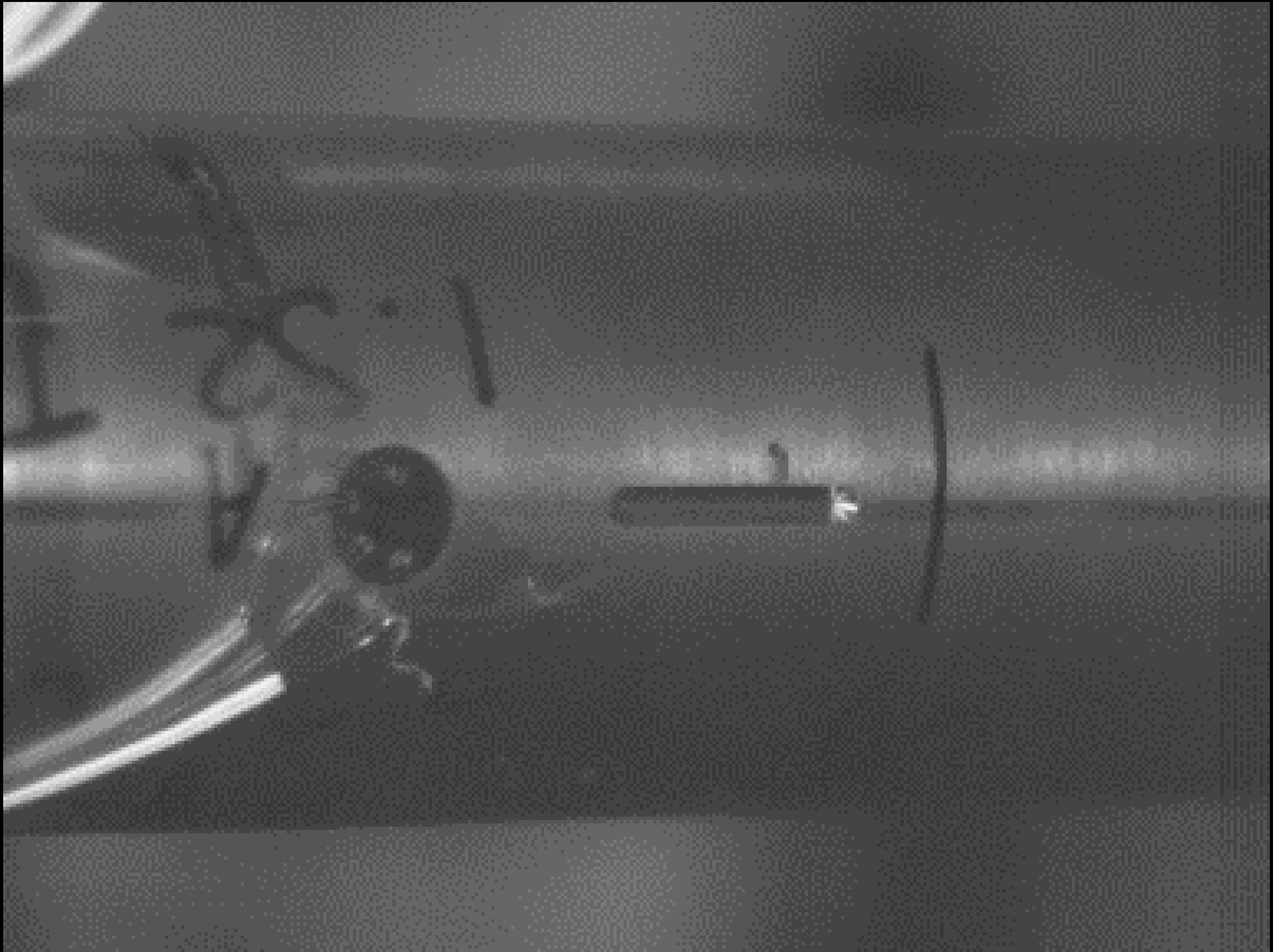
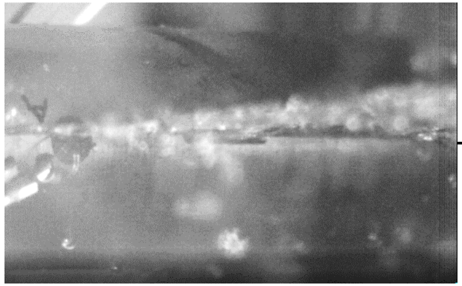

Water pressure(bar)
80
60
40
20
0
9
10
11
12
13
14
15
Test time (s)




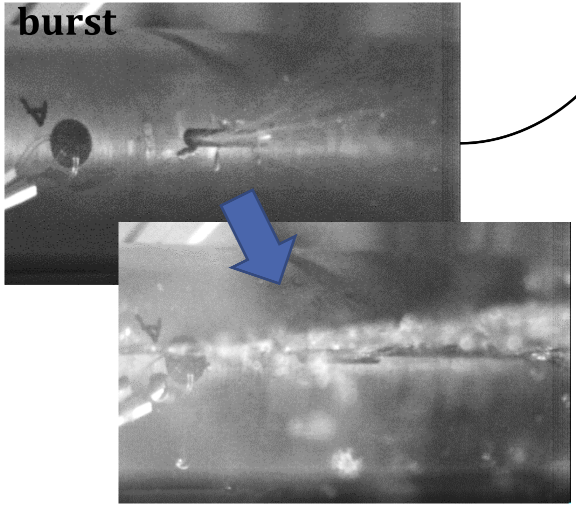


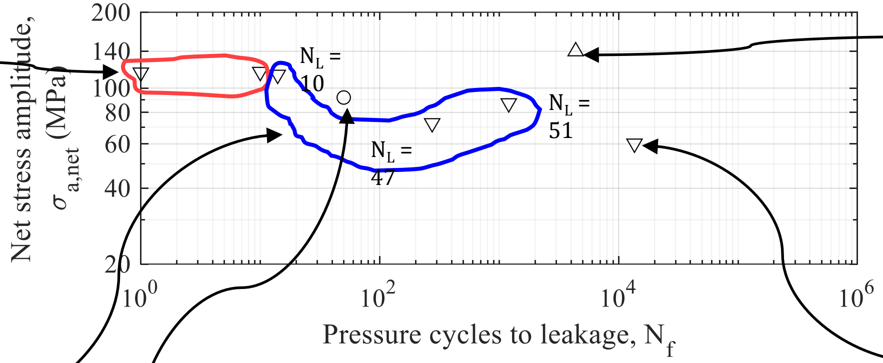
Leak type observations

Immediate burst

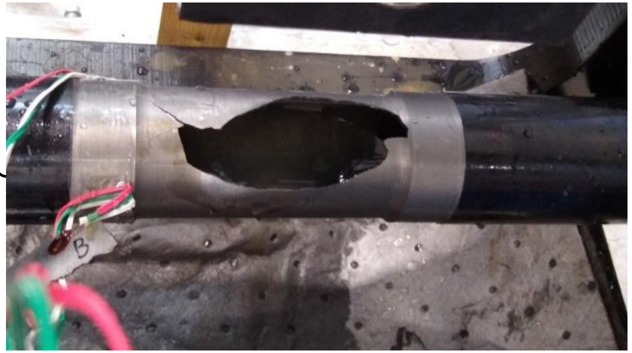


Leak then burst

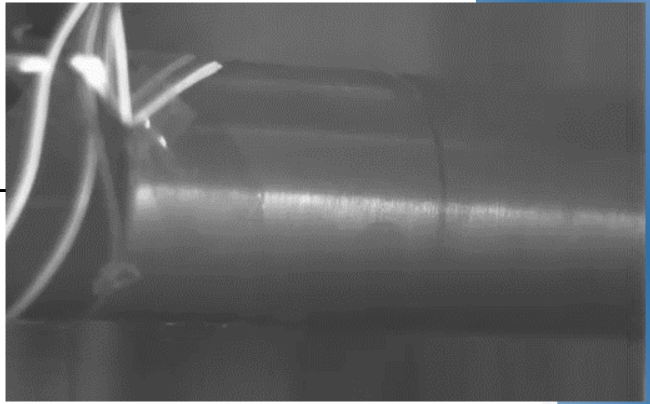




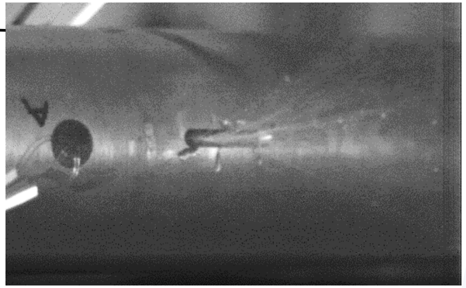
Blowout (no notch)



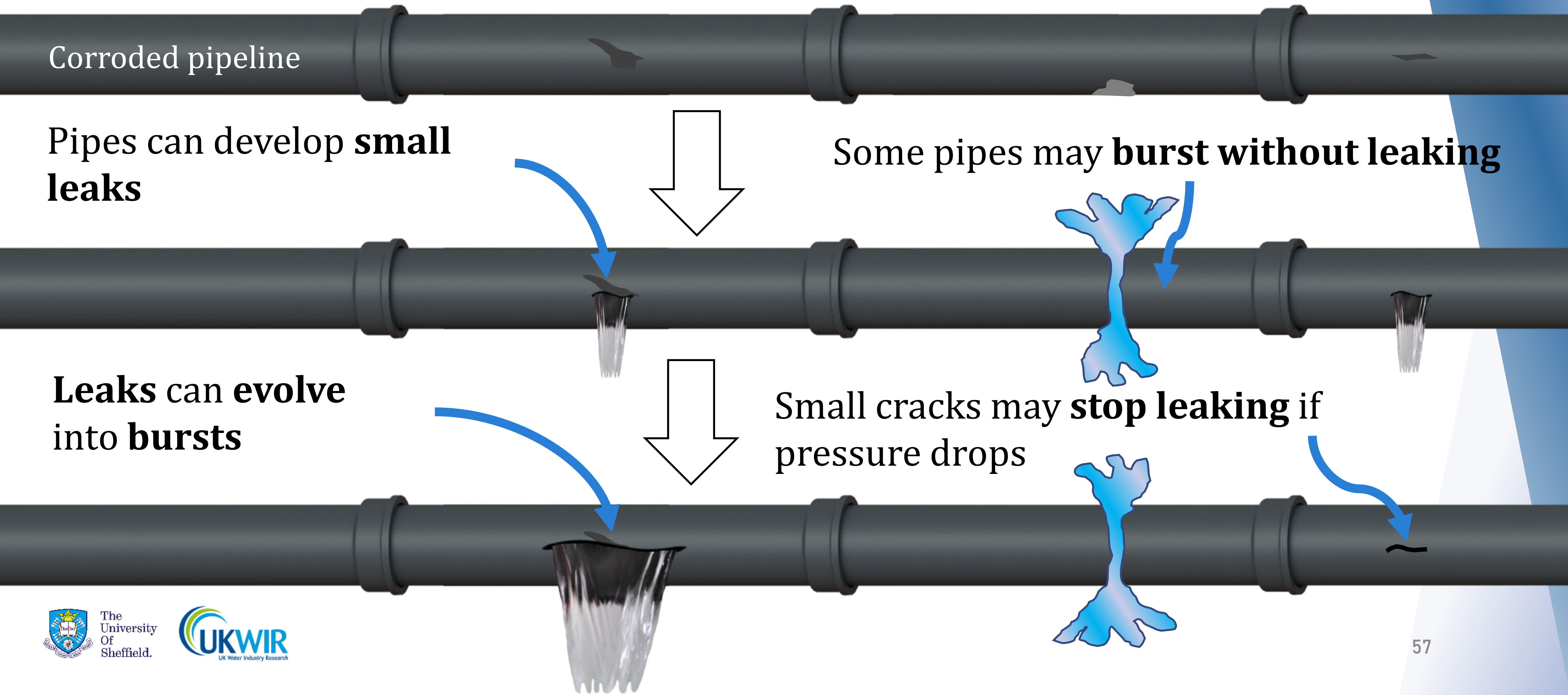
Circumferential burst



Leak 50 cycles with no burst



Do grey cast iron pipes leak before they burst?



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Understanding the degrading impact of pressure transients on cast iron pipe?

Thomas Langshaw

PhD student

University of Sheffield

Understanding the degrading impact of pressure transients on cast iron pipes

Thomas Langshaw[1], Richard Collins[1], Joby Boxall[1], Dennis Dellow[2]

[1]University of Sheffield, [2]UKWIR

The University Of Sheffield.

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Pressure transients

Bursts

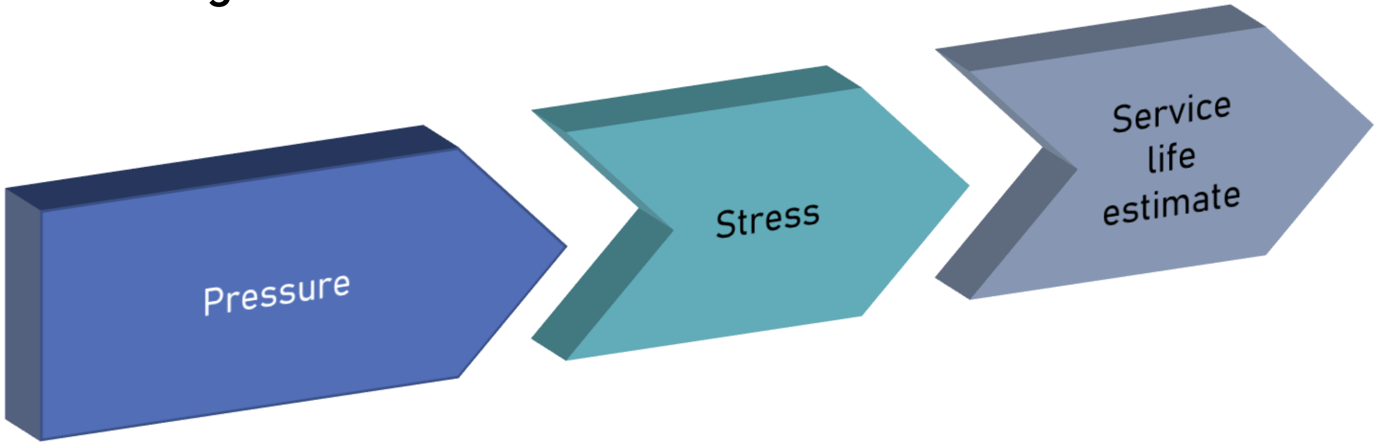
Mobilising sediment

Ingress

But what about fatigue from transients?

- Transients may also contribute to fatigue cracks, causing leakage
  - Such leaks may have a time window between hours and years prior to burst

- We cannot see our pipes without great effort, so we need to use a model to estimate fatigue.



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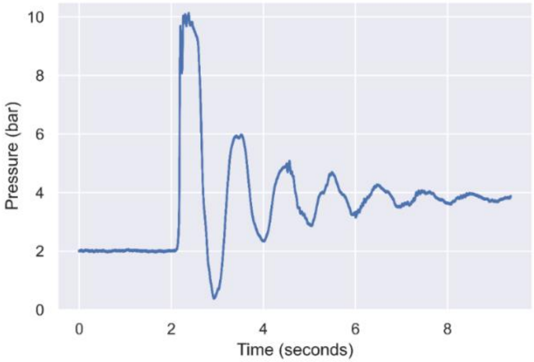
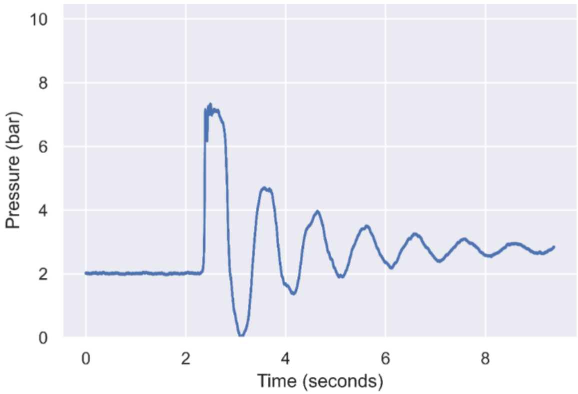
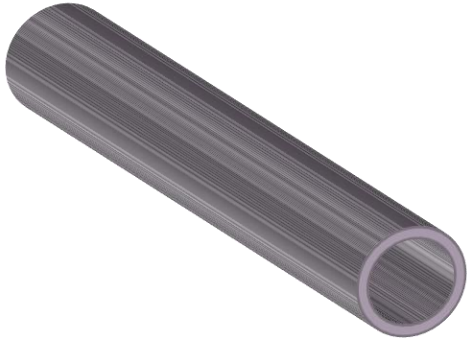
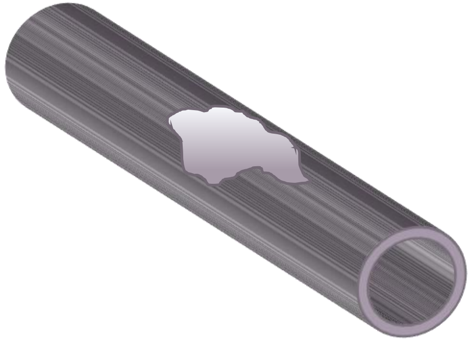
Optimising asset replacement









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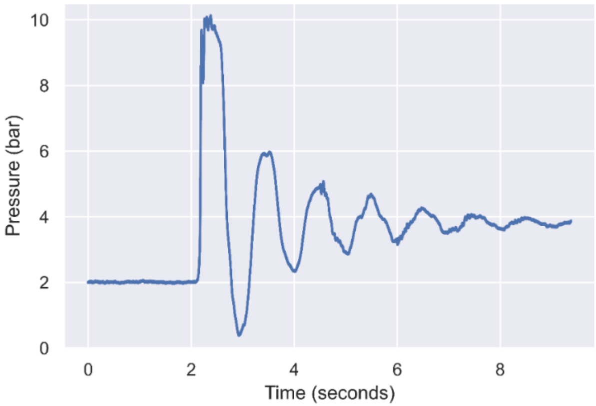
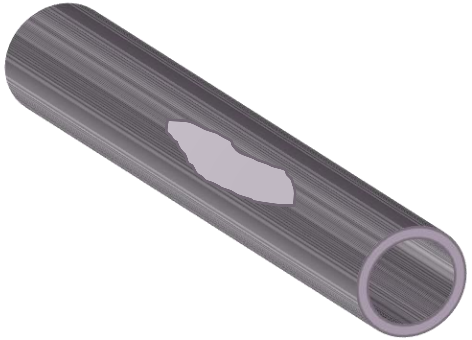
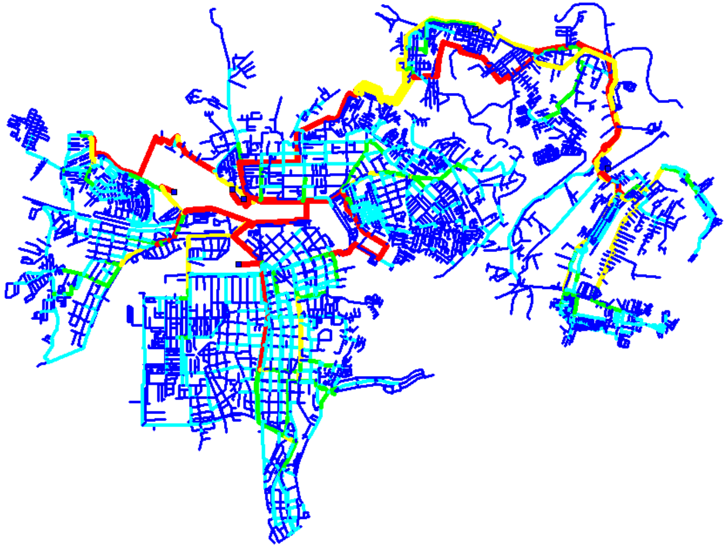
Understanding where fatigue occurs





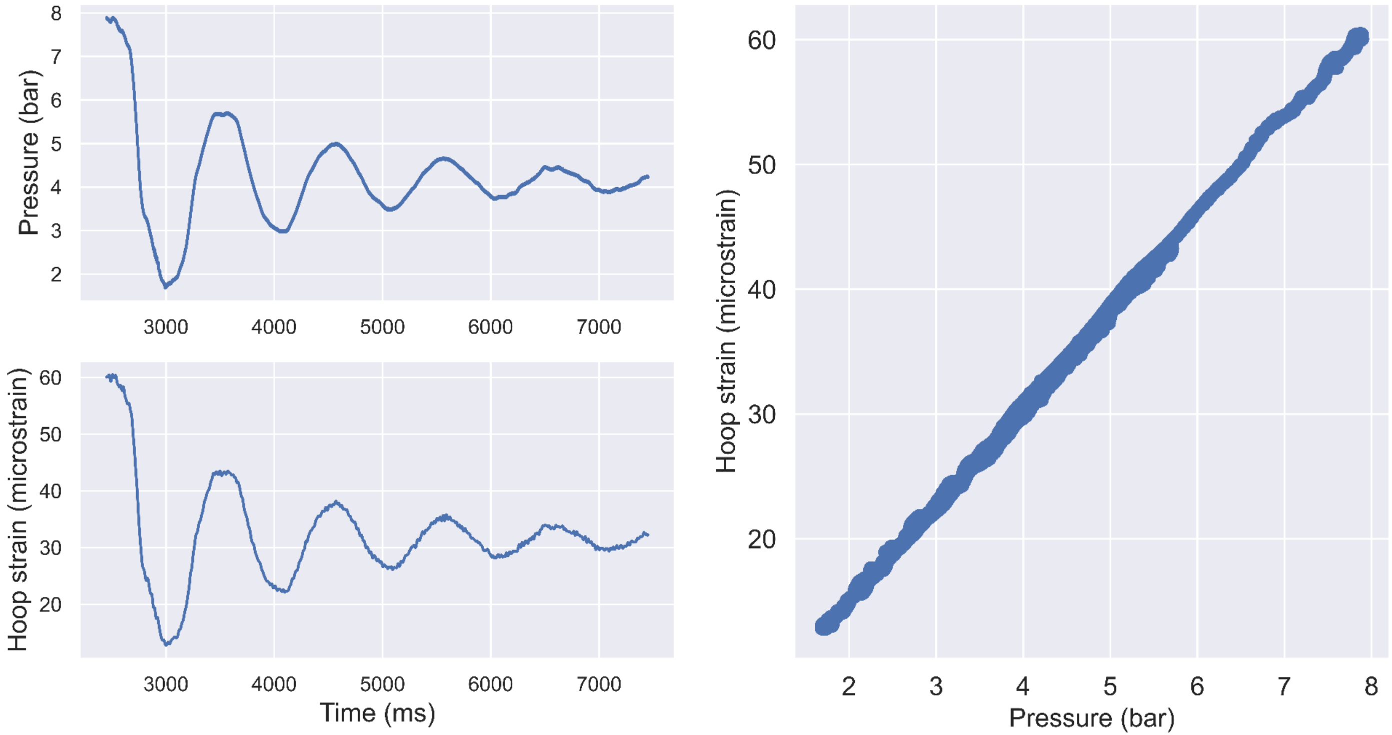


How are we achieving this?

- We are modelling the response of cast iron pipes during a range of transients
  - We are producing stress models capable of capturing the interaction of transient events with conditions of burial and local corrosion

  - These models shall provide increased confidence to existing and future fatigue analyses employed by water companies

Modelling an un-corroded pipe



Replicating reality

- The introduction of corrosion leads to far more complex stress states
  - This project is working to understand these stress states during transients

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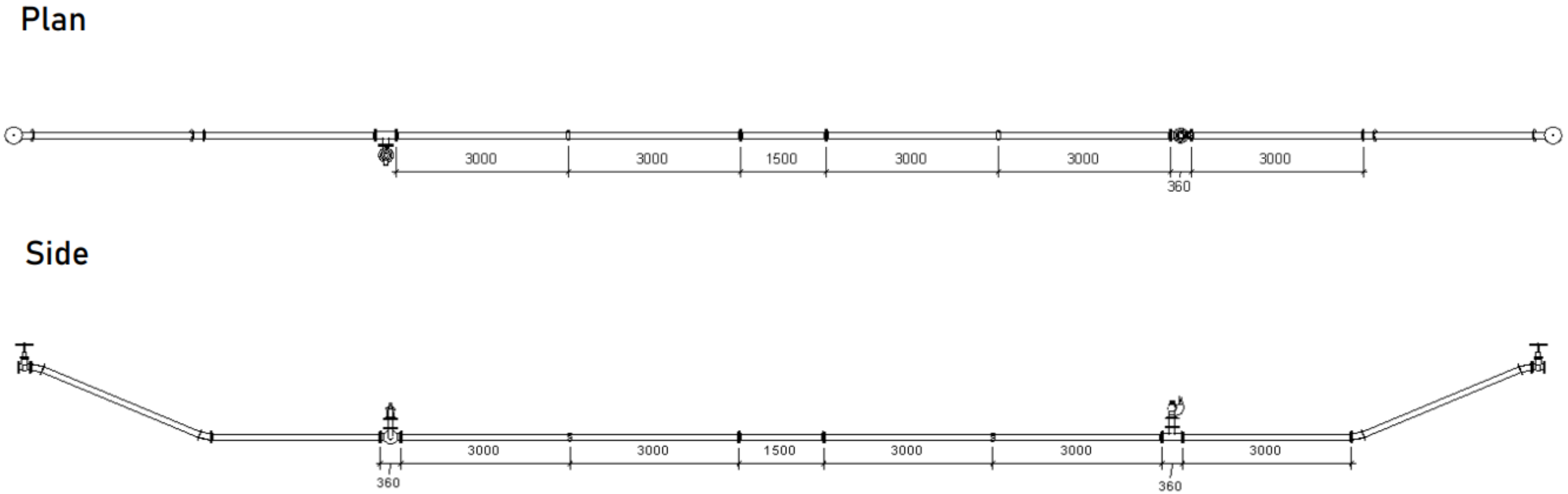
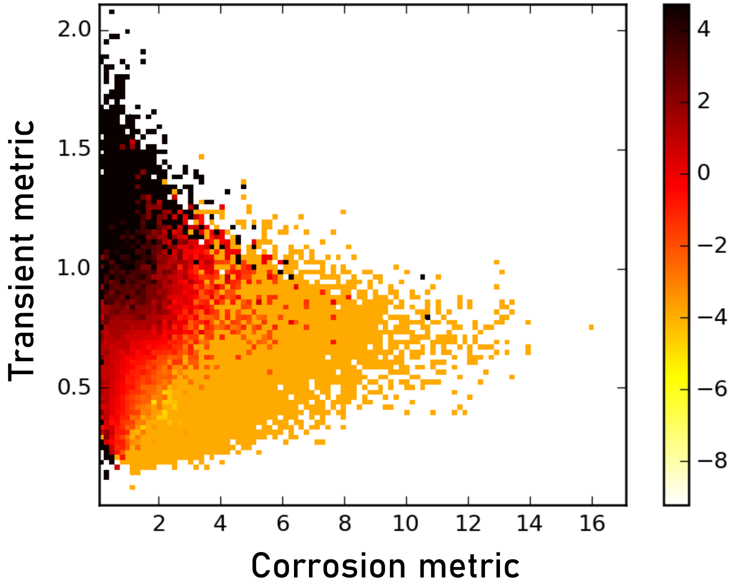
Experimental setup



Deepened understanding

- Using derived stress models, the relationship between a pipe's corrosion and transient regime can be investigated



Fatigue damage rate

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How can this information help?

- Adopting the results of this project shall contribute to a multi-pronged approach to asset management
  - Reduce transients causing the greatest damage to our network, and identify transients not of concern from a fatigue standpoint
  - Replace assets experiencing the greatest fatigue damage based on more than solely the magnitude and frequency of recorded transients

Questions for Edward and Thomas?

Transients: A force for good?

Dr Richard Collins

Senior Lecturer – Water Engineering

University of Sheffield

Transients:

A Force for Good?

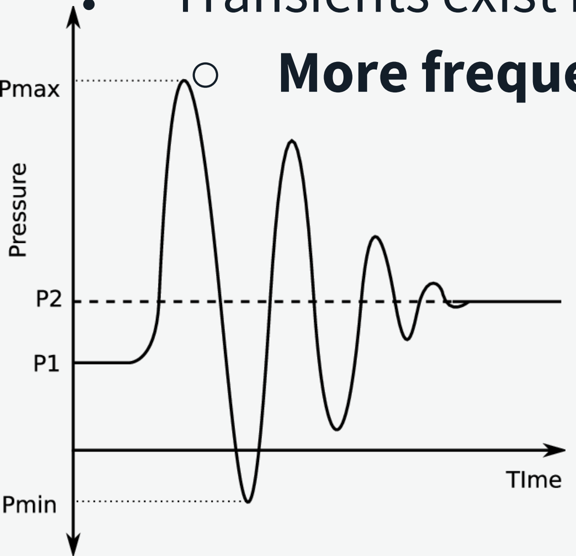
Dr Richard Collins

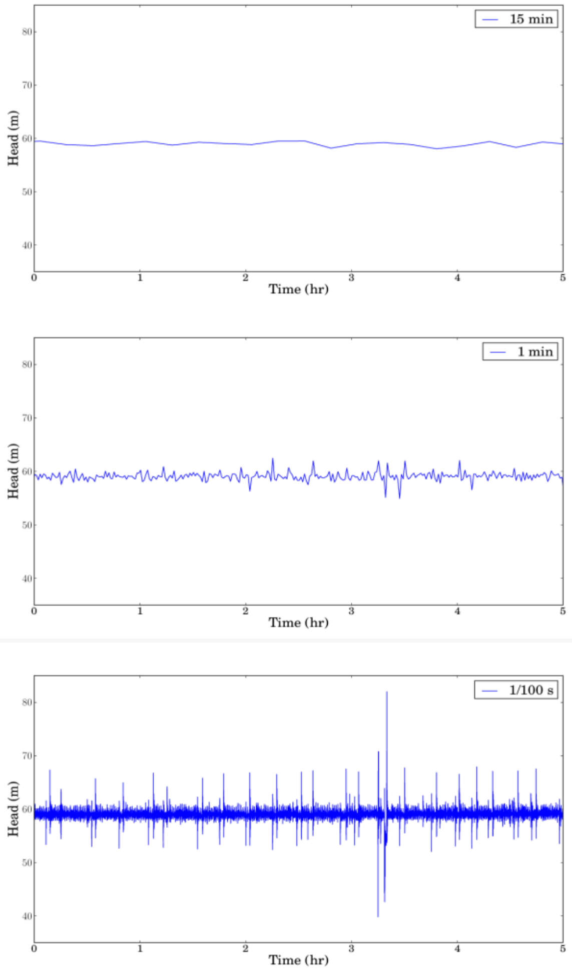
Annual Leakage Conference 2023

Hydraulic Transients in WDS

- Transients are waves of pressure and flow that propagate around WDS as a result of changes imposed on the system

- Transients exist in our systems
    - **More frequently than we used to believe**





Calm Networks

- Transients "stress" networks
  - **Increasing the numbers of leaks**
  - **Damaging infrastructure**

- Lots of evidence that 'calm networks' reduce bursts and water losses

But.....

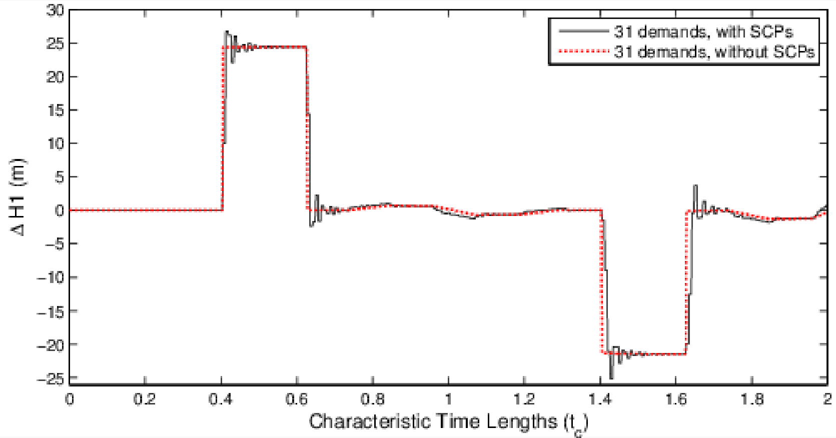
Transients Transmit Information

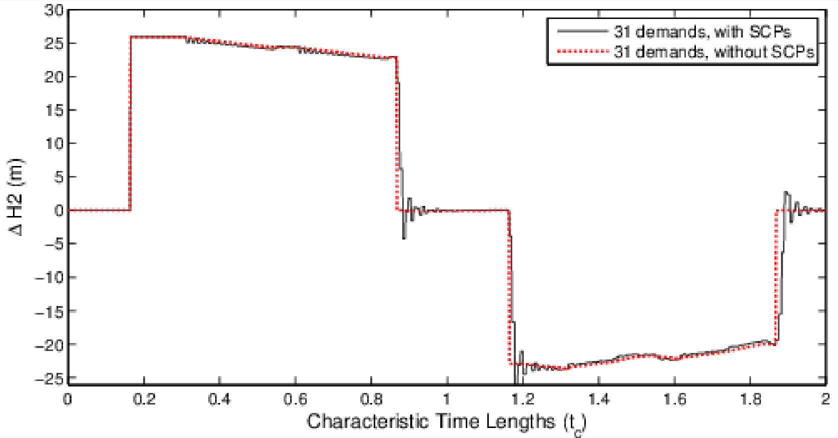
- As transients propagate through systems they are modified by all the features they pass:
    - **Leaks**
    - **Junctions**
    - **Blockages**
    - **Consumer connections / demands**

- Therefore can be pivotal in providing us critical information about the systems that is difficult to obtain by other means

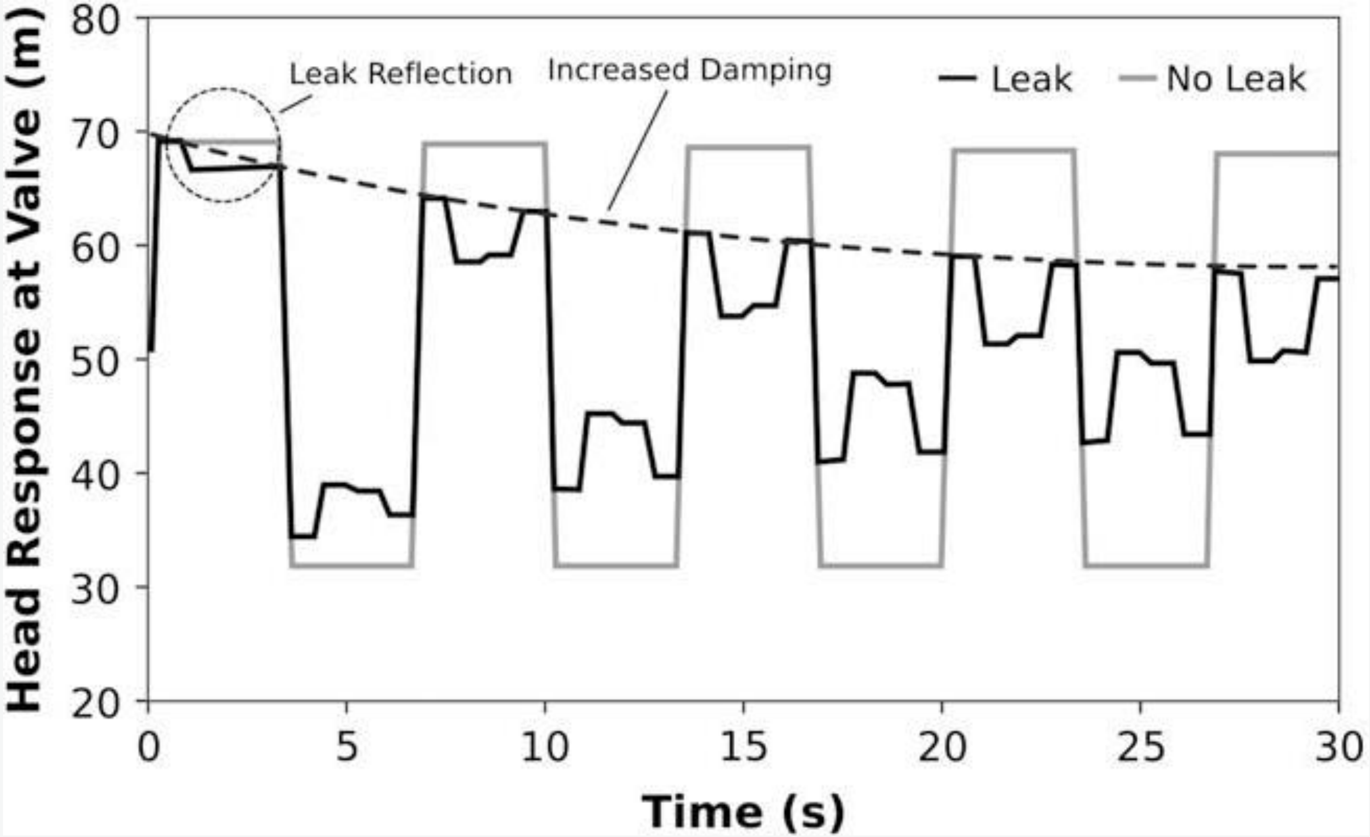
- The challenge is identifying and decoding the signals that are received

Edwards, Collins "The effect of demand uncertainty on transient propagation in water distribution systems. " 2013



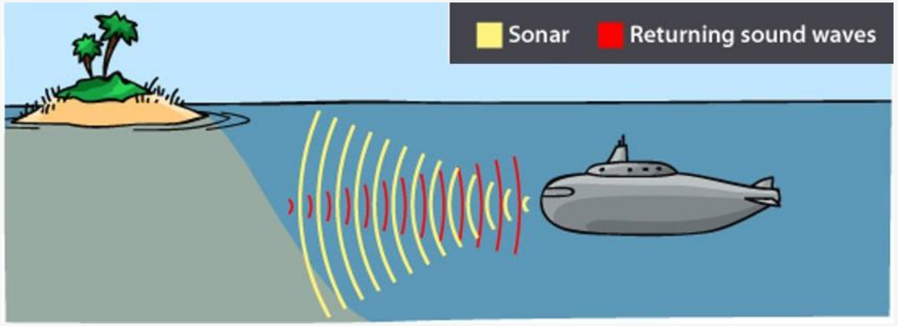


Transient Based Leak Detection

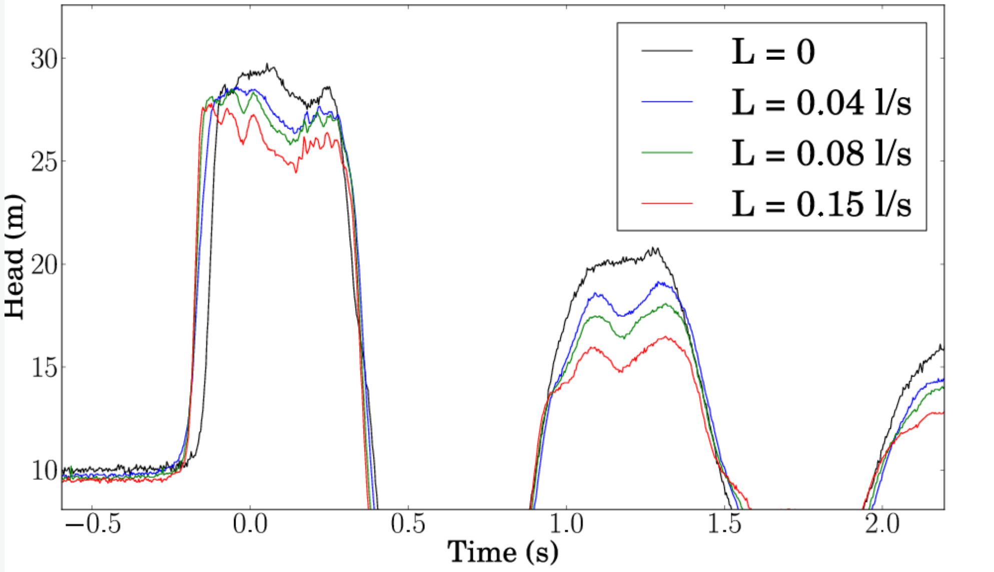


Impact of leak on transient propagation (Colombo et al. 2009)

Transients Reflectometry



- Simple in concept
    - **Like sonar in submarines**
    - **Waves are generated and reflections interpreted for information on leaks**



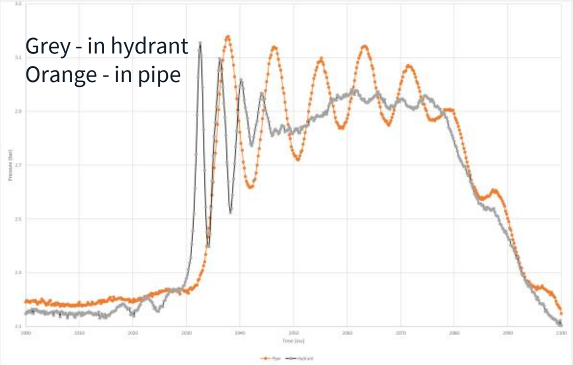
Determining size of leak from effect on reflection size (Collins et al.)

Transients Reflectometry: Challenges

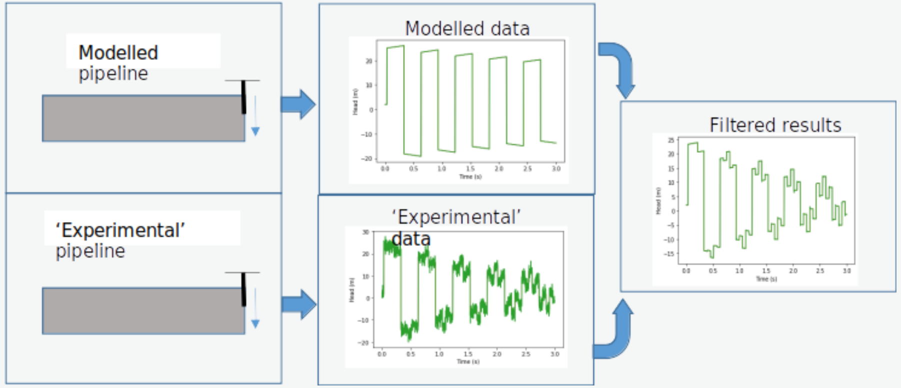
1. Acceptance it will require **generating** transients on your networks
   - **“Surgical transients”**

1. Getting a good signal into the system
   - **Hydrants are not a great injection method**

1. Interpreting the signal to identify leak response
   - **Matched Filters**



Impact of hydrant on transmitted signal

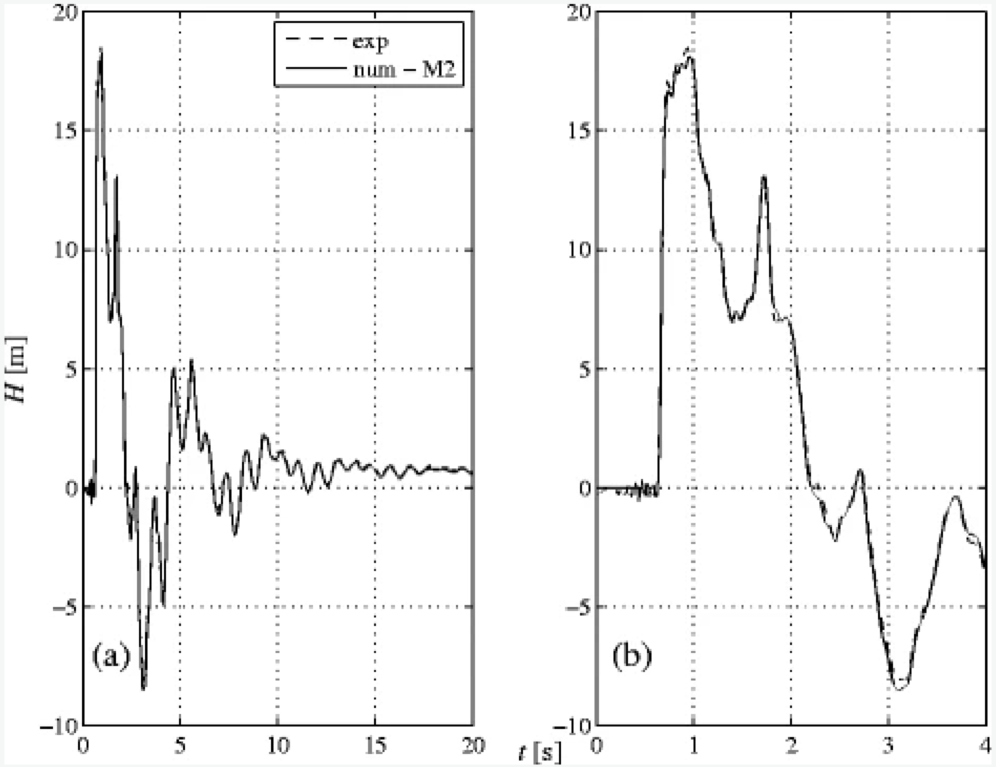


Charlie Whitelegg WIRe CDT Scottish Water

Inverse Transient Analysis

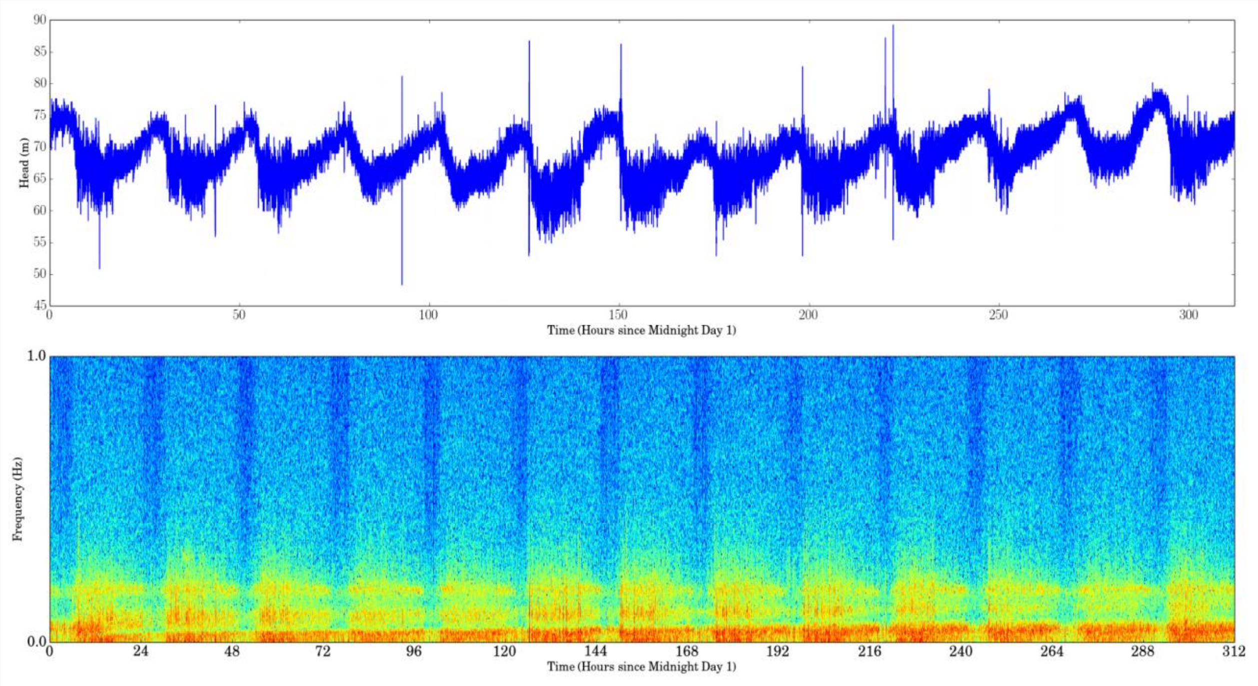
- Measure a transient event
- Build a numerical model of the system
- Optimise (calibrate) it such that you match the modelled and measured result

Challenges:
- Input space is huge
- Typically limited measured data to use



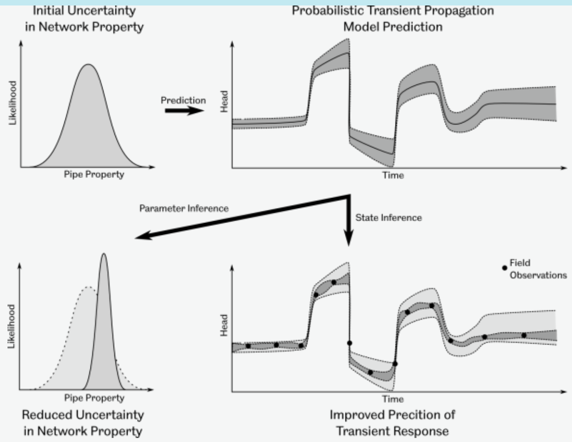
Long Term High Speed Pressure Monitoring

- Long term monitoring of transient pressures
- Capture “naturally occurring” events



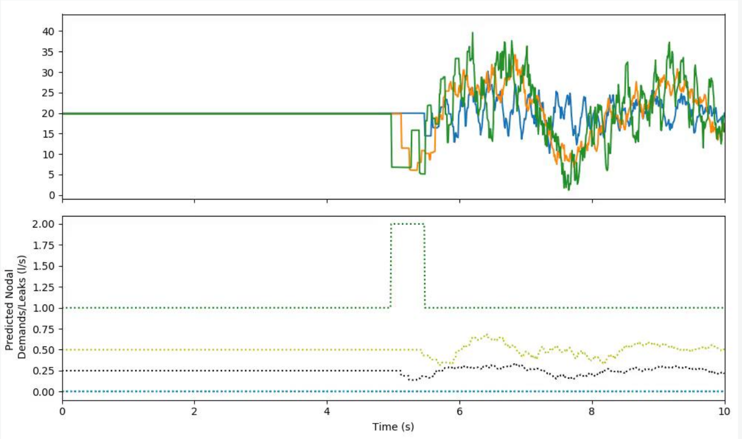
Artificial Intelligence / Machine Learning

- Probabilistic methods
- Artificial Neural Networks



Transient based state estimation (Collins et al.)

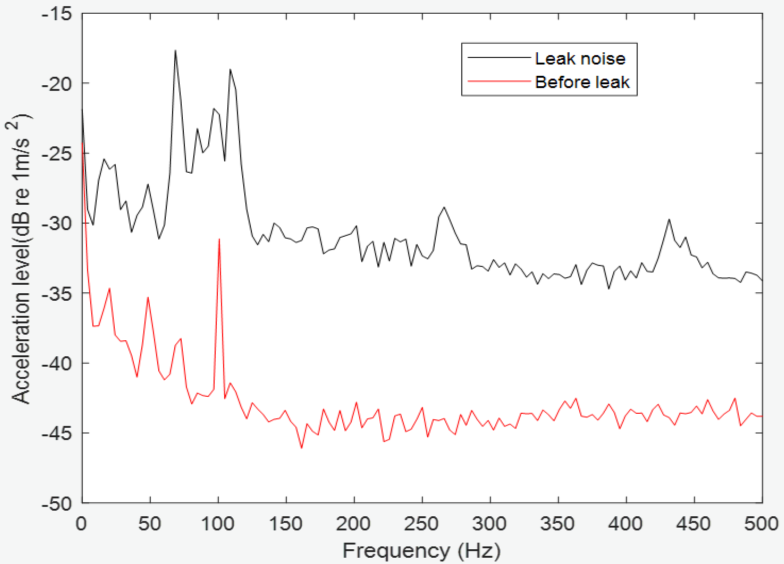
- Alert to changes
- Continuously updating understanding of state of the system

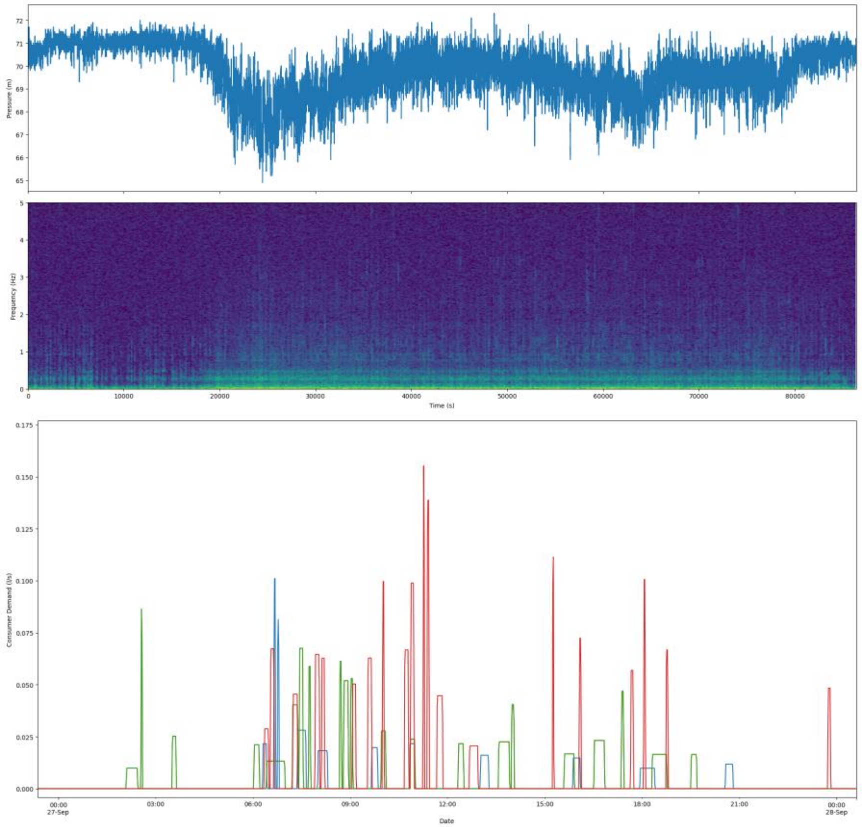


Exciting Advances

- Ye et al. Physics-informed neural networks for hydraulic transient analysis in pipeline systems (2022)
- Hajgato et al. Reconstructing Nodal Pressures in Water Distribution Systems with Graph Neural Networks (2021)

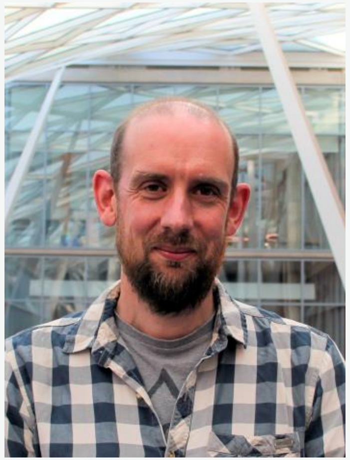
Managing Background Leakage





Conclusions

- WDS are dynamic systems
- Uncontrolled transients cause damage to WDS
- Transients provide information about systems
    - **Direct reflectometry**
    - **Inverse methods**
    - **Long term monitoring**
- Machine learning in conjunction with current deployment of high speed pressure sensors gives potential for identifying and locating leaks at a greater resolution than steady state approaches



Dr Richard Collins
Dept of Civil and Structural Engineering
University of Sheffield
r.p.collins@sheffield.ac.uk

Questions?

Networking refreshment break

Please add your post-it notes to the Thought Wall next door

Syrinix Logo Artwork.ai

Meet up with our exhibitors and other delegates

aqualogic water conservation

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GUTERMANN

HWM

MUELLER

OVARRO CONNECTING TECHNOLOGIES

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