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CMA Water Redeterminations

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Dear Panel Members,

Following the CMA panel's interest on the factors influencing water leakage from pipes, I believe it may be of assistance to you if I provide a view of some of the environmental impacts on buried infrastructure.

As a way of introduction, I am an academic environmental data scientist who has spent much of the last two decades developing infrastructure-focused environmental hazard models for the whole of the UK. My specific expertise lies in modelling the interactions between soil, weather and infrastructure failures.

Over my career in the university environment, and now as an independent academic and a director of two geohazard companies, I have helped most major UK water companies, as well as other infrastructure companies, insurance companies and mortgage lenders to understand the impact of the environment on their assets and investments. I hope now to convey some of these impacts to you, in a concise manner.

I attach to this letter as summary document, in which I explain how certain soil and weather conditions impact on buried infrastructure, and how East Anglia compares with other parts of the UK. I will only touch on each of these points briefly, but I include links to publicly available papers and presentations which describe these interactions and infrastructure impacts in more detail.

In this letter I include a number of maps, figures and findings from peer-reviewed scientific literature, datasets, publicly available reports and public conference presentations. These publications describe the impact of the environment on pipes, and many demonstrate that pipes in East Anglia are particularly susceptible to a number of soil and weather related geohazards.

As demonstrated by the maps I include, the combination of soils, climate and the composition of the water infrastructure in this region of the UK creates a very challenging environment in which to achieve low burst numbers and low levels of leakage. Furthermore, it should be noted that the risks to infrastructure posed by many of these geohazards are continuing to increase with our changing climate.

On a personal note, I do feel strongly that the impact of climate change on the UK's water infrastructure has been underestimated by the regulator in this case. It is my personal view that more investment should be made now to ensure that our water distribution systems are fit to efficiently serve our growing communities (and children) both now and into the future. We should equip our infrastructure to operate well in the emerging climate.

I do hope that this very brief overview of the interactions of buried pipes with the soil and weather conditions provides you with some useful context for your deliberations.

Should you require clarification on any point, please do let me know, as I feel this is an important topic to understand.

Wishing you all the very best,

[redacted]

Dr. Timothy S. Farewell

MapleSky Ltd

The impact of the environment on buried pipes in the Anglian Water Region

Pipes fail more in unstable, changing, and extreme environments

Pipes are particularly susceptible to both rapid changes, and extremes, in their physical and operating environments. Where vulnerable pipes lie in aggressive soils, and are acted upon by extreme and changing weather patterns, more leakage and bursts can be expected (Figure 1). Higher leakage and burst rates are associated with hot and cold temperature extremes, large fluctuations in soil moisture content, highly shrinkable or corrosive soils and rapid changes in water temperature or pressure (Barton et al, 2019). East Anglia is prone to all these conditions.

Figure 2 demonstrates how fluctuations in moisture content in clay-rich soils can lead to increased leakage and bursts, especially from Asbestos Cement, Iron and PVC pipes, which are prevalent in the Anglian Water region.

For an in-depth review of the many interrelated factors which lead to pipe failures, you may wish to read our 2019 paper: *Improving pipe failure predictions: Factors affecting pipe failure in drinking water networks.*

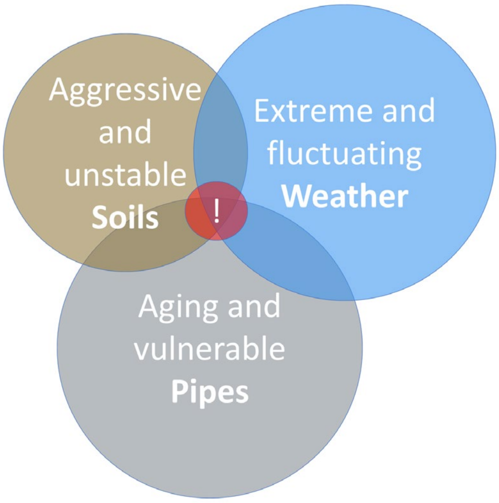


Figure 1 - leakage and bursts are more likely to occur where aging and vulnerable pipes are buried in hazardous soil and acted on by extreme and changing weather patterns

Environmental geohazards and leakage in East Anglia

There are 3 components, which when combined make large parts of Anglian Water's network particularly susceptible to leakage issues, compared to the national average conditions.

- Climate: Extreme temperatures and droughts are common in the Anglian Water region
- Soils: The soils are particularly aggressive to pipes in the Anglian Water region
- Infrastructure vulnerability and leak detection: The pipe materials used are particularly susceptible to ground hazards in the Anglian Water region. At the same time, due to the nature of the network and soils, leaks can take longer to find.

While all these components interact with each other, we will look at each of these in turn. We will then briefly discuss the expected impacts from our changing climate.

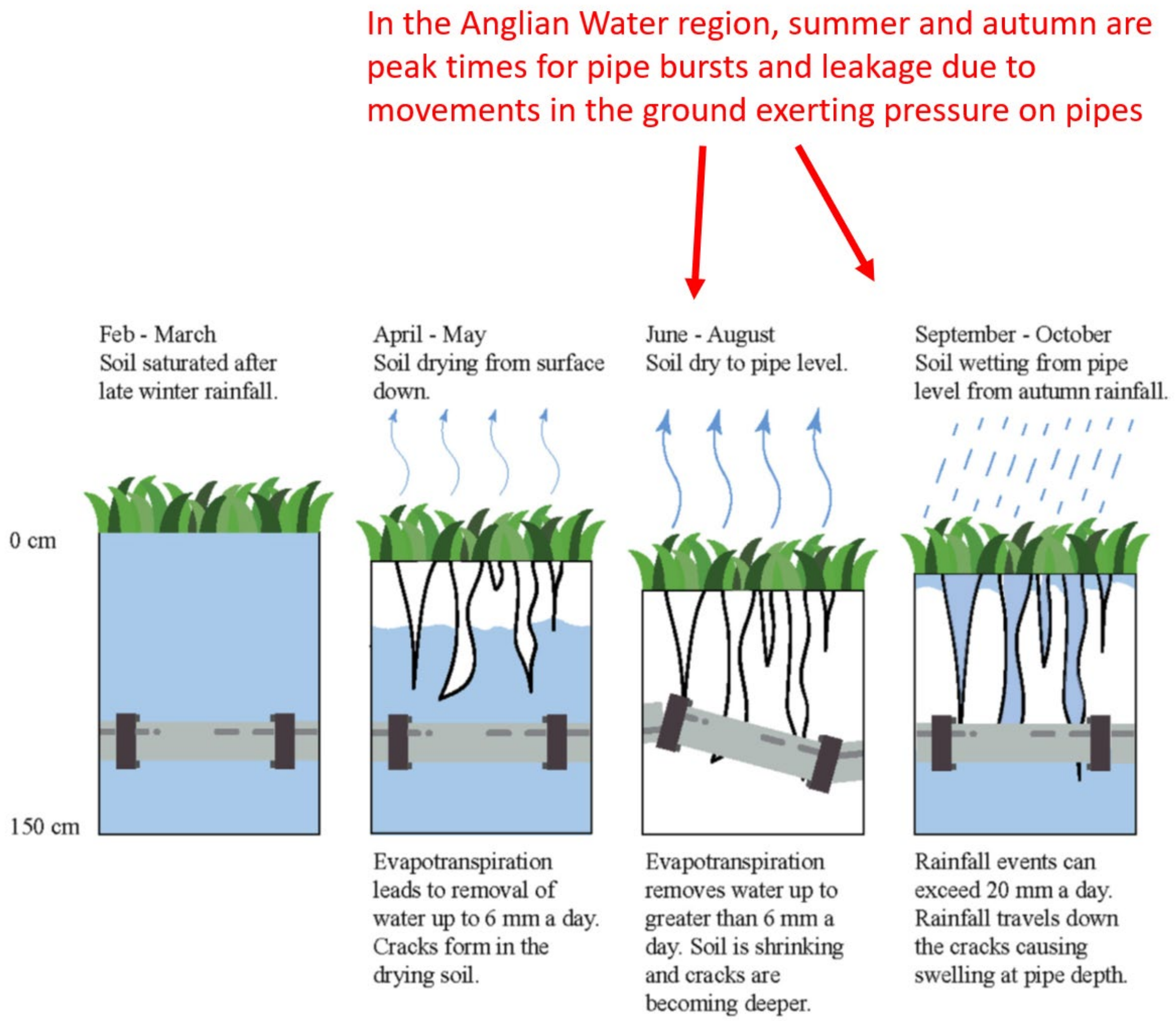


Figure 2 The impact on pipes of seasonal shrink-swell clay rich soils (adapted from Barton et al, 2019 & Farewell et. al, 2012;)

1. Climate: Extreme temperatures and droughts are common in the Anglian Water region

Hot and dry summers increase pipe failures and leakage (Figure 2). In addition, the periods of fluctuating very cold (above/below zero) temperatures have a dramatic impact on the rate of failures and leakage in winter months. The impact of these temperature extremes can be see in the summer and winter peaks in burst rates in Figure 4.

Anglian Water suffers from some of the hottest driest summers in the UK (Figure 3). Combined with the prevalence of shrinkable soils, this leads to some of the most aggressive ground movements in the UK. Such ground movements increase pipe failures and leakage (Barton et al, 2019, and AC, PVC, and Iron lines in Figure 4).

It should be recognised that our changing climate will impact on the number, location and severity of bursts and leaks (Pritchard et al, 2015). Already we are seeing the impact of climate change across the UK, and I believe strongly that water companies have a duty to understand, plan for and make investments now to mitigate the increasing impacts of more severe, extreme climates on their networks.

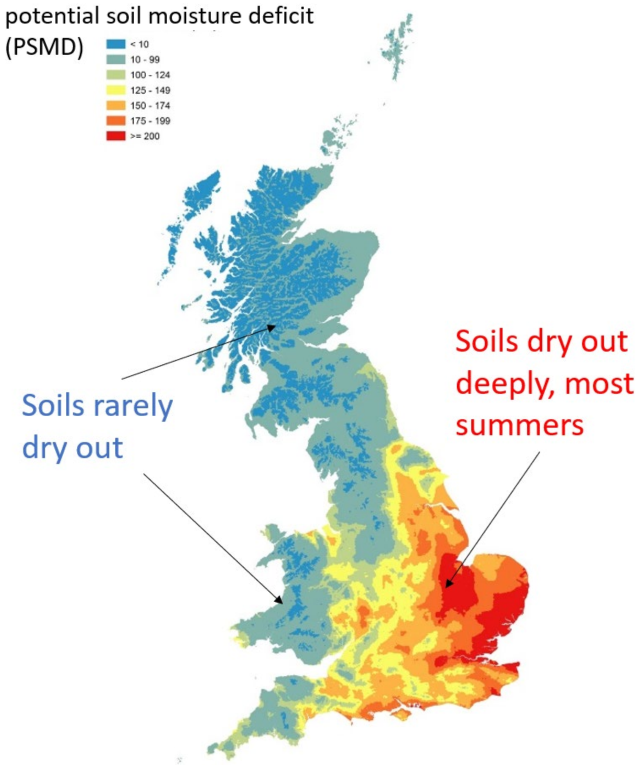


Figure 3 - average potential soil moisture deficit (PSMD) across the UK. (From Farewell; 2019 and an input to the Natural Perils Directory, Cranfield University (2019).

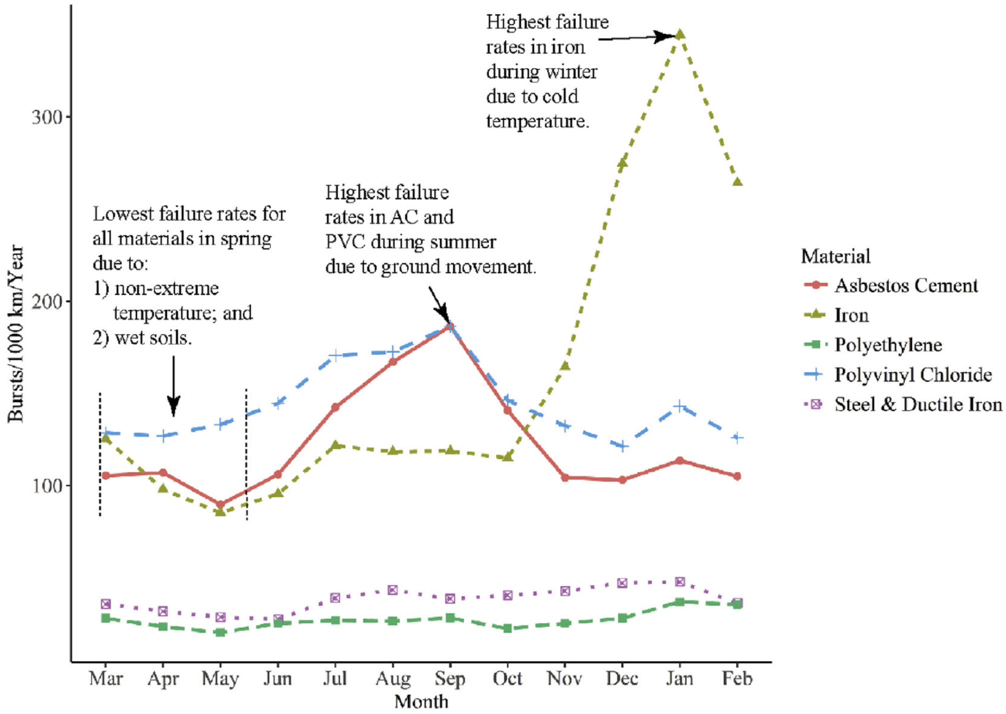


Figure 4 - summary of failure rates by month, to highlight the impact of both hot, and cold weather on Anglian Water's network. From Barton et al. (2019).

2. Soils: The soils are more aggressive to pipes in the Anglian Water region

Shrinkable and corrosive soils increase pipe failures and leakage (Barton et al, 2019). While there are many interactions between pipes and the soil environment, the three dominant soil impacts on infrastructure come from soils which are :

1) **clay rich** (so have a high ground movement potential)

2) **highly corrosive to iron** (so are susceptible to corrosion pitting, pipe degradation etc).

3) **extremely sandy** (so are prone to sand washout and cascading infrastructure failures, as well as hiding leaks)

Due to its geological past and human modifications (especially fen-draining) over recent centuries, **East Anglia is home to all such soils**, and many in higher amounts than the national average (Figure 5).

Shrinkable Clay Soils

Many soils in East Anglia are prone to extreme levels of ground movement due to the combination of hot, dry summers and shrinkable soils (Pritchard et al, 2015). As a result, the ground movement hazard is higher in Anglian Water’s region than many other water companies.

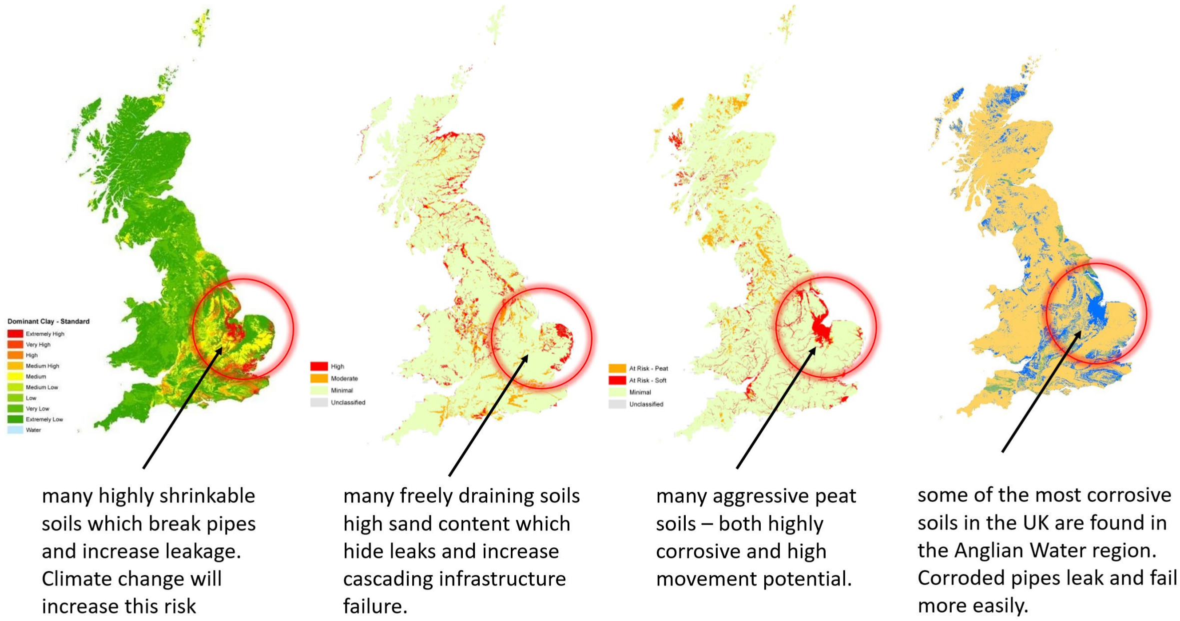


Figure 5 - The prevalence of soil related geohazards in the Anglian Water region. Adapted from NPD User Guide (Cranfield University, 2019) and BGS Civils Data (2020)

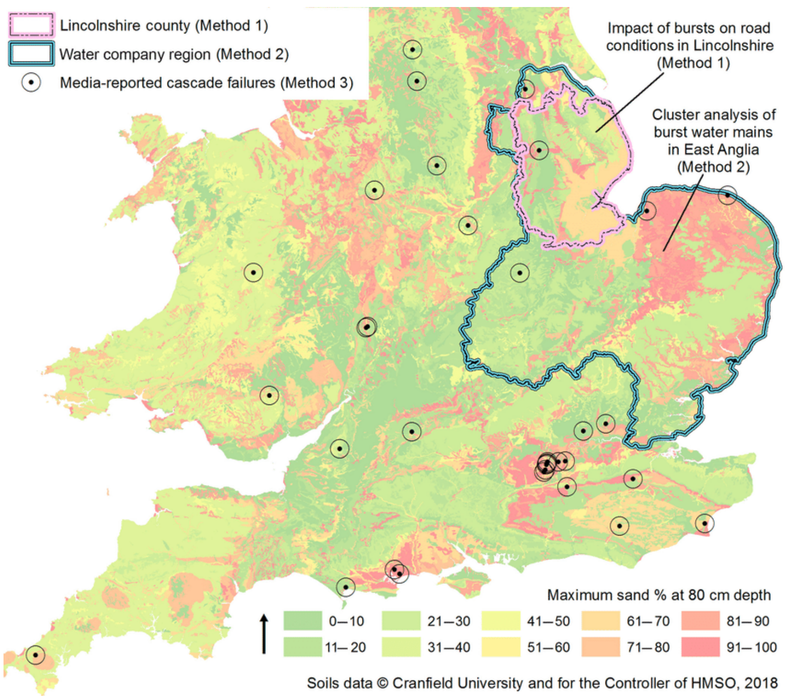


Figure 6 - Sand content at 80 cm depth (from Farewell et al, 2018) showing areas where leaks can remain undetected for extended periods of time.

Corrosive Soils

Some of the most corrosive soils in the UK are found in East Anglia (Cranfield University, 2020; BGS, 2020). Furthermore, unlike many of the other corrosive soils in the UK, these are not found at high altitudes where few people live. Instead, because towns and villages have developed on top of drained land, the infrastructure in these areas is exposed to the effect of aggressive low-land peats, which are both highly shrinkable and highly corrosive.

Sandy Soils

In the coastal regions, East Anglia has a large proportion of highly sandy soils at pipe depth. Such soils give rise to higher rates of cascading infrastructure failure (Farewell et al, 2018) but also, due to their freely draining nature, leaks in such soils can take longer to detect as the water drains away rather than rising to the surface, much like water through a sand castle (Figure 6).

3. Infrastructure vulnerability and leak detection:

The pipes are particularly susceptible to ground hazards in Anglian Water's region

Because it is the interaction between pipes the soils and the weather that leads to leakage and bursts, it is useful to consider the pipe materials in the network as part of this discussion. Over 60% of Anglian Water's network is made up of aging pipe materials which are particularly vulnerable to environmental geohazards. These include Asbestos Cement (AC), Cast Iron and PVC.

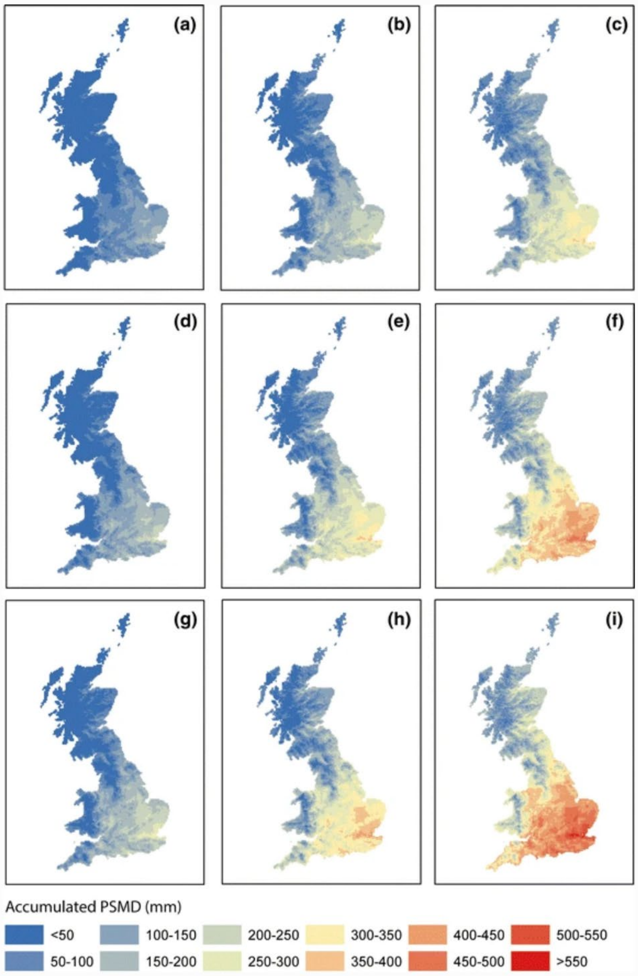
In fact, 18% of Anglian Water's network is made of Asbestos Cement, which is almost double average proportion of AC pipelines for UK water companies. AC pipes are highly vulnerable to soil-related ground movements (Figure 3). This material has joints every 5 m or so, and when the soil shrinks and swells, extra pressure is placed on these joints (Figure 2 & Barton et al, 2019)

The leaks can be harder to find in Anglian Water's region

Anglian Water has lower levels of metallic pipes than most other water companies. Cast Iron, Steel and Ductile Iron pipes only make up 23% of the Anglian Water network. This is important to note, as many established methods for leak detection work better on metallic pipes. As mentioned above, the sandier soils in this region can also increase the time taken to find small leaks as the water is less likely to rise to the surface in sandy soils. (Figure 6, Farewell et al, 2018).

4. The impact of climate change on expected bursts and leakage

It would be remiss not to highlight the very real increase in risk to the water network from our changing climate. We are already witnessing higher temperatures in the summer, and more extreme and variable weather events. As discussed above, the impact of extreme weather events on the network can be profound. A few years back we modelled the changing patterns of soil moisture deficit across the UK (Figure 7).



UKCP09-derived projections of accumulated annual PSMD for GB Baseline (1961–1990) **a** 10th, **b** 50th and **c** 90th percentiles; 2030 (2020–2049) **d** 10th, **e** 50th and **f** 90th percentiles; 2050 (2040–2069) **g** 10th, **h** 50th and **i** 90th percentiles

Figure 7- Increasingly hot and dry summers are expected moving from the baseline (1961-1990s) to our emerging climate (2020-2049) and then to the future (2040-2069) PSMD: Potential Soil Moisture Deficit. (From Pritchard et al, 2015).

It is apparent that the summers are set to become hotter, and drier. Not only will rainfall patterns make water scarcity more common in the summer months, but also the impact of this weather on even moderately shrinkable soils will increase the number of bursts and the overall level of leakage.

Some initial research I have undertaken has indicated that in the Anglian Region, which is already very dry, we can expect a large increase (20-30%) in the number of summer + autumn bursts from AC, Iron and PVC pipes (Figure 8). Other water companies further north will also see increases in soil shrink-swell related failures and leakage.

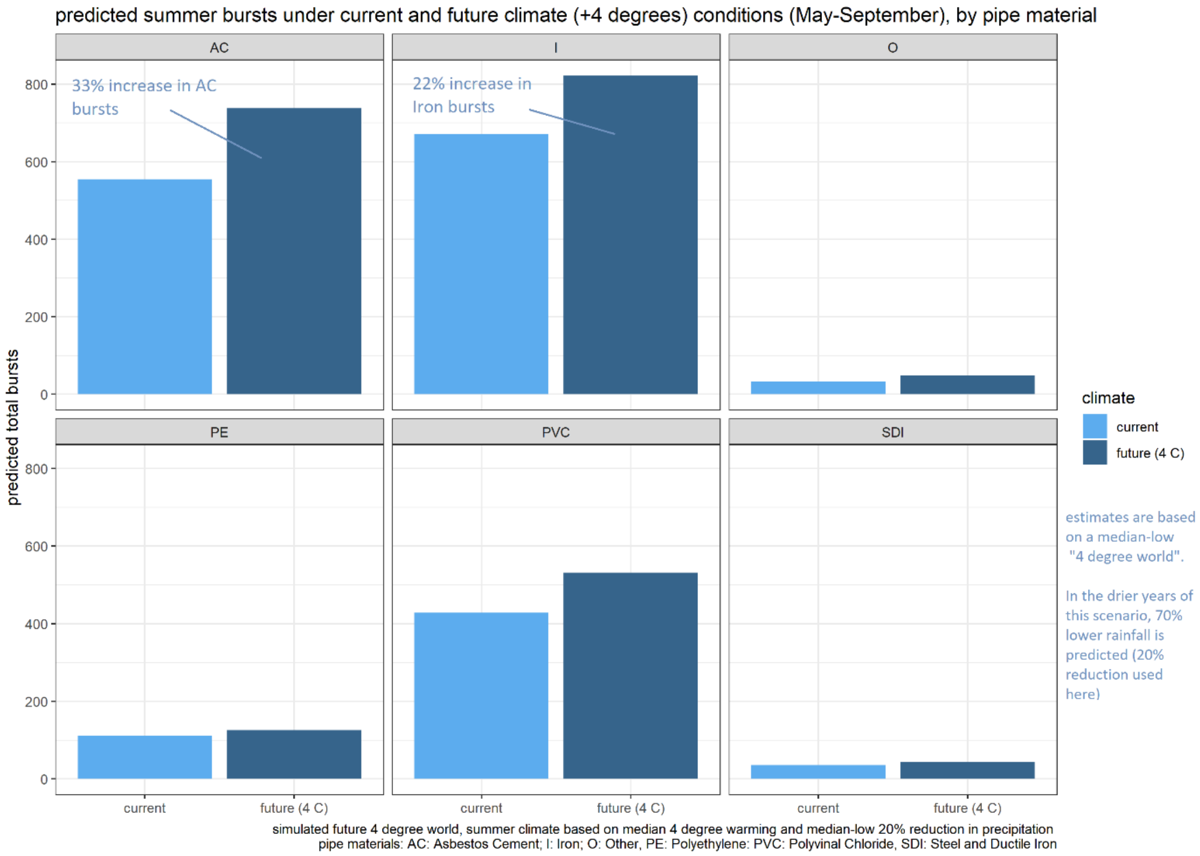


Figure 8 - initial model outputs showing the increase in expected bursts by pipe material under a mild 4 degree warming scenario.

Conclusions:

Pipes in East Anglia are particularly vulnerable to multiple soil and climatic geohazards: It is clear from the available maps and data that the aging and vulnerable pipes in Anglian Water's region are exposed to a number of geohazards arising from aggressive soils and extreme and fluctuating weather conditions (Figure 8). The very present geohazards make this region far from benign for pipe networks.

Climate change will increase leakage and bursts: It is also apparent that as the climate continues to change over the next 10 or 20 years, many of these hazards will increase in risk (Figure 7, Figure 8). The impact of climate change is not limited to the Anglian Water region, and an industry wide proactive approach to addressing these emerging risks is encouraged. Evidence is now available to help companies consider how and where climate change is likely to increase leakage and bursts, and such proactive planning is encouraged.

Selected References:

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

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BGS (2020) British Geological Survey website. Soil Corrosivity Data (Civils) https://www.bgs.ac.uk/products/groundConditions/corrosivity.html

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Farewell, T.S. (2019): The future of Subsidence. Climate Change and Perils Risk Management; 23rd July, 2019, London

Pritchard, O., Hallett, S.H. Farewell, T.S. (2015) Probabilistic soil moisture projections to assess Great Britain's future clay-related subsidence hazard. Climatic Change Volume 133, pages 635–650 https://link.springer.com/article/10.1007/s10584-015-1486-z