Data challenges of the July 2021 Flooding

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This paper summarises the work undertaken as part of Thames Water's Independent Flood Review, [1]carried out between November 2021 and July 2022. Its aim is to prompt wider discussion in the industry about improvements at pace to improve response to flooding and how we can use data and more joined-up approaches to protect communities at highest risk from flooding, now and in the future.

In summer 2021, on two occasions 2 months of rain fell in 2 hours resulting in surface water flood events which heavily impacted London. The floods affecting over 1,500 properties, as well as infrastructure such as hospitals and Underground stations. The immediate disruption was felt across London, with those most directly affected unable to return to their homes over a year later.

The London Flood Review (LFR) was commissioned by Thames Water in 2021 to better understand the extent and causes of these floods, to determine how the drainage systems performed and to recommend how risks of future flooding might be managed in the future. This paper, written by members contributing to the LFR, highlights some of the specific data challenges faced during the Review, the findings and recommendations and focuses on what we, as an industry, could be doing to make improvements for communities at risk of flooding.

There is widespread acknowledgement that things need to approve across flood risk management in the UK. Findings from the Pitt Review in 2007 and subsequent legislation (FWMA 2010) have highlighted needs for change but more frequent storms are likely to be present in future: the Met Office stated that "rain that does fall in summer will likely be more intense than what we currently experience. For example, rainfall from an event that typically occurs once every two years in summer is expected to increase by around 25 per cent. This will impact on the frequency and severity of surface-water flooding, particularly in urban areas."[2]

1. Introduction

1.1 Flooding History

What is surface water flooding?

Flooding occurs when flows from rainfall exceed the boundaries of the system that exists to convey normal flows: this could be sub-terranean drainage systems, aquifers, river systems. Whilst flooding and floodplains have existed as long as humans have, it is clear that we are at increasing threat from flooding, in particular surface water (or pluvial) flooding.

Pluvial flooding occurs when the volume of water falling cannot drain away through existing drainage systems or infiltrate through the soil. Urban areas are more susceptible because they have more concrete. Urban areas with high density housing are the most susceptible of all. Intensity of rainfall is also a big factor: when it comes down hard, it cannot infiltrate as effectively into the soil so more becomes runoff. With higher intensity events, urban growth and development and uncertainty over

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[1] London flooding response | About us | Thames Water

[2] UK and Global extreme events – Heavy rainfall and floods - Met Office Accessed Nov 2023

the economy and climate change, it is likely that these events will worsen and impact communities which are already facing deprivation and hardship.

What has happened in the past?

Flooding is not a new issue. Floods have occurred in the past, but human interactions with flood-prone areas are increasing.

London itself has seen several flooding events over time. Whilst significant investment has been placed in the Thames Barrier and measures to reduce the city from river flooding and tidal surges, the surface water flood risk has often taken a back seat.

In 1975, a localised thunderstorm happened in Hampstead, where three months of rainfall fell in just three hours. Mainline railway and underground stations were affected as the stations and tunnels were inundated and electrics failed.

In 2007, several areas of the UK were affected during heavy summer storms. London was one of those areas, with over 1400 properties being flooded from the sewer system and surface water flooding. West London was particularly affected with Heathrow Airport cancelling 141 flights on the 20th July 2007

In July 2021, two similar events occurred which have been investigated in more detail. In both cases, high intensity rainfall was predicted and the Met Office submitted yellow and amber warnings for surface water flooding.

What happened during these events?

12 July

Rainfall fell over north-west London, with the most intense rainfall hitting Bayswater. The rainfall intensities exceeded 100mm/hr, as shown in Figure 1, and detailed rainfall analysis indicates the event could be greater than a 1 in 400-year return period in some locations.

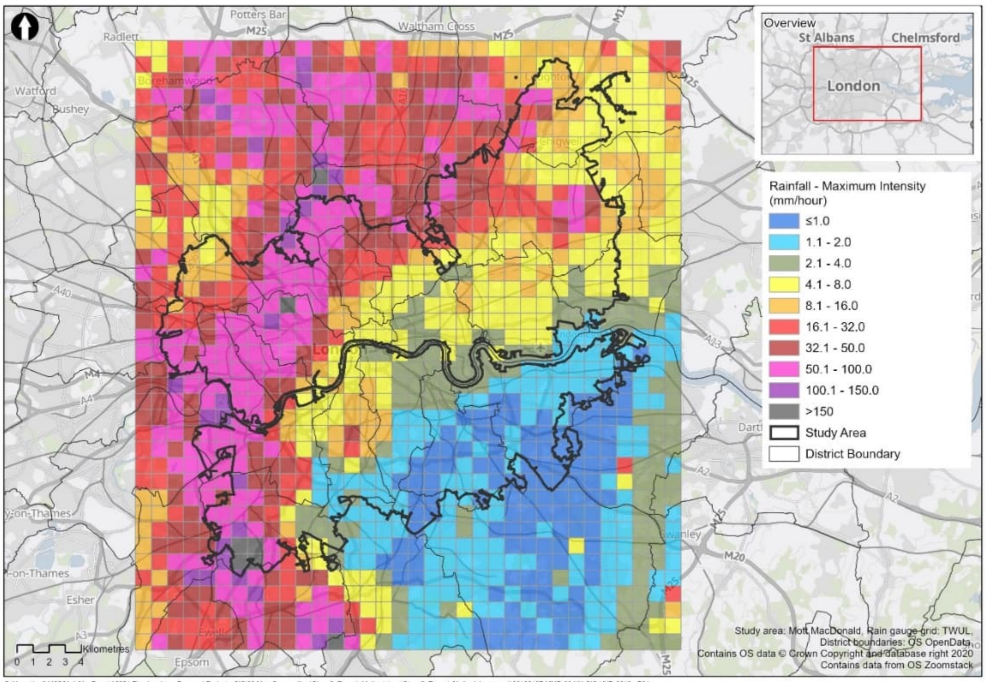

Figure 1- Rainfall intensity map for 12th July 2021

The peak intensity rainfall also occurred at the same time as the tidal peak, as shown in Figure 2. As a result, much of the sewer system was tide-locked and therefore could not spill via combined sewer overflows to the River Thames.

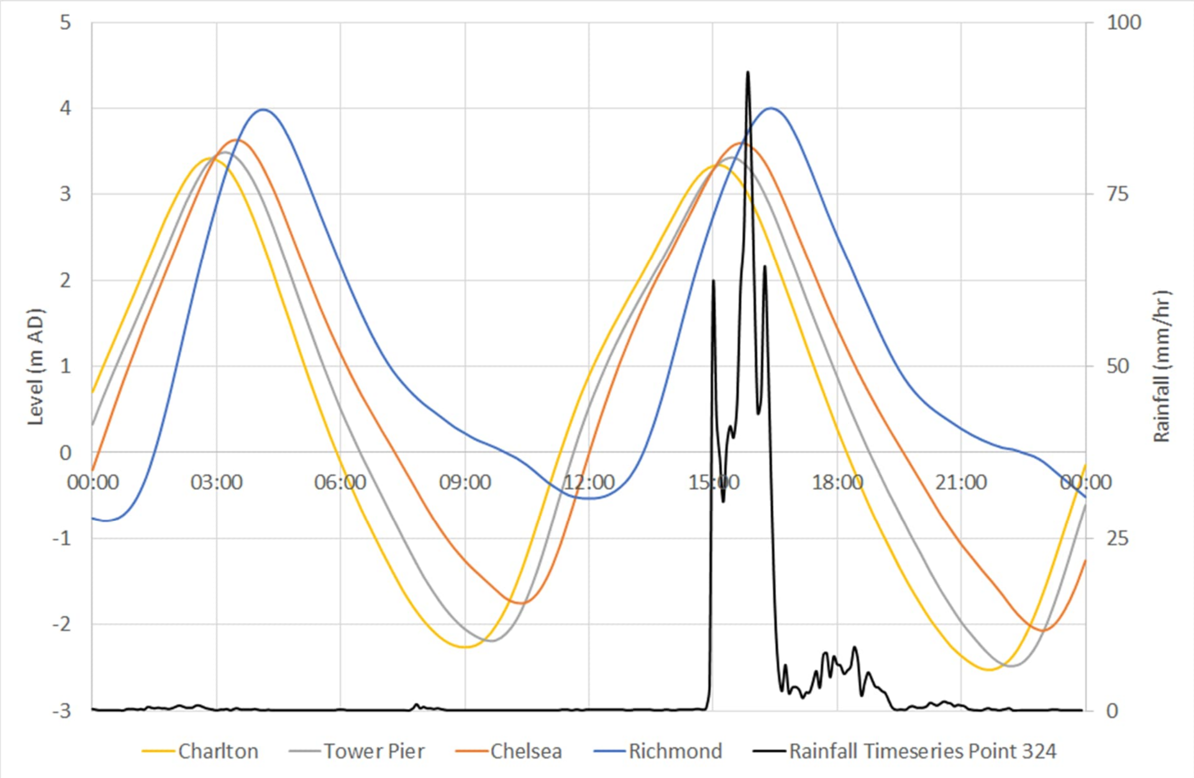

Figure 2 - Rainfall time series coinciding with observed tide level peaks

Flooding was widely reported in the London Boroughs of Camden, Hammersmith and Fulham, City of Westminster and Royal Borough of Kensington and Chelsea. Flood reports indicated a mix of both surface water and sewer flooding.

25 July

Rainfall fell over most of the city, with the most intense rainfall hitting Walthamstow. Both north and south of the river were affected and rainfall intensities peaked at around 50mm/hr: although lower than the 12th July 2021 event affected a much more widespread area. Again, the peak intensity rainfall occurred at the same time as high tide so many of the overflows were unable, or restricted by pump capacities.

Flooding was reported across the capital, with more, but smaller, pockets of flooding reports. For this event, however, major hospitals and infrastructure were also affected, and many tube stations were closed. Again there was a mixture of above ground and below ground flooding from multiple sources reported, as shown in Figure 3.

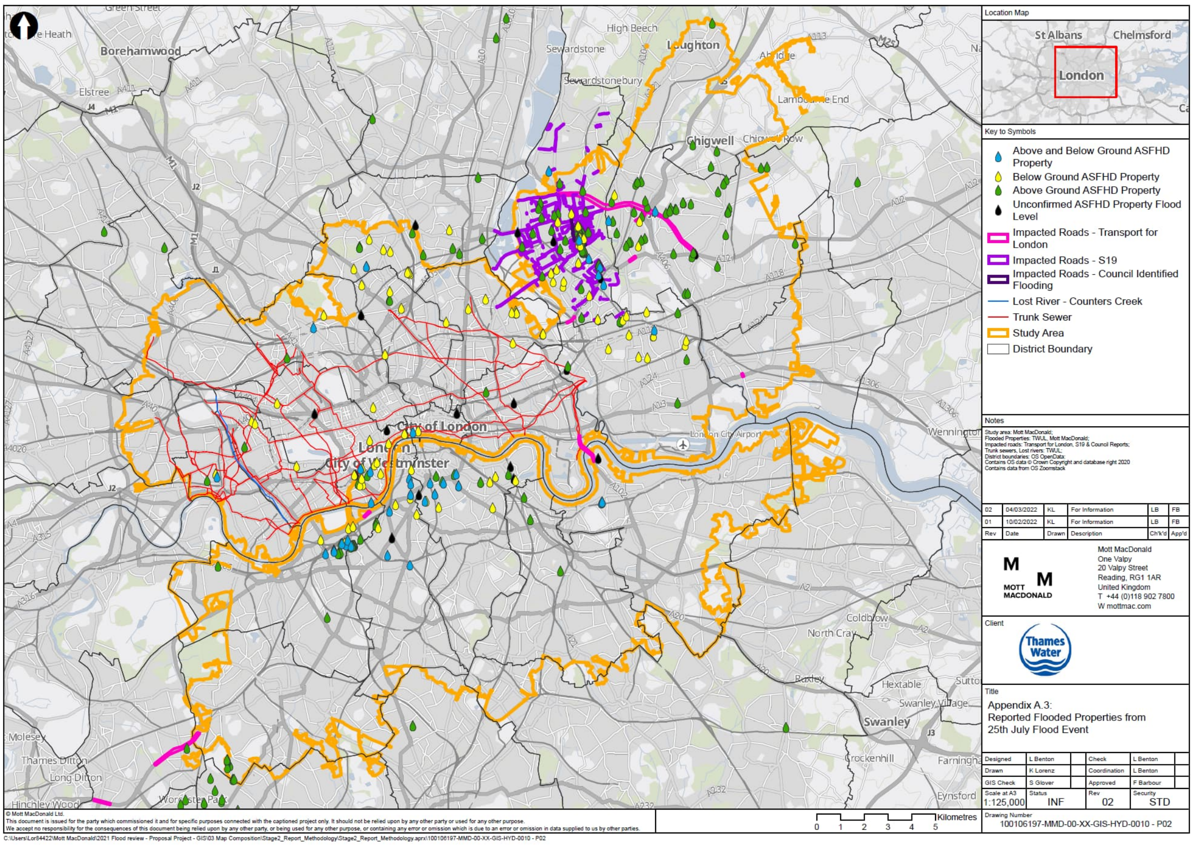

Figure 3 - Distribution of above and below ground flooding reports on 25th July 2021

Why is it so complicated?

People were affected across a huge area. For those experiencing flooding, levels rose by metres in a matter of minutes. The Met Office had submitted yellow warnings in advance of both events, indicating a range of predicted rainfall between 20-30mm. The area over which the warning was applicable was widespread, covering most of the south-east of England. Due to the nature of the convective rainfall events, the exact time, location and intensity of the event is very hard to predict. Thames Water and other responding organisations held pre-emptive meetings but decided that the impact would be low and therefore did not make ample preparations. For the 25th July event, the warning was upgraded on the day of the rainfall from yellow to amber, having learned from the 12th July event. However, flooding was experienced across large parts of London, despite mobilisation of response teams.

In addition, the rainfall crossed local authority and administrative boundaries, and surface water and sewer flooding occurred simultaneously, exacerbating the other. People reporting flooding were unclear of who was responsible, and people responding to flooding were limited by their duties under the Flood and Water Management Act 2010. In the end, people felt abandoned and unheard: something that should not have been allowed to happen. Things were made worse for those in social housing or rented properties, as the rebuild and refurbishment was made even more complex.

2. What lessons can be learnt?

2.1 Independent London Flood Review

The LFR has been led by an independent expert group (IEG) of external specialists to ensure objectivity and impartiality, chaired by water strategist Mike Woolgar and supported by flood modelling expert Professor Roger Falconer and city resilience expert Lykke Leonardsen from Copenhagen. To assist with the review, the IEG established a strategic stakeholder panel (SSP) which helped shape the objectives and provided input, guidance and feedback. This group comprised senior representatives from the Greater London Authority, Transport for London, London Councils, the London Drainage Engineers Group, the Environment Agency, the Consumer Council for Water, the Thames Regional Flood and Coastal Committee. Ofwat also joined the SSP to act as an observer throughout the process.

There were four stages of the review, which comprised:

- Stage 1: Data Discovery phase
  Gathering of data available during and after the flooding event, including modelling, rainfall data, monitoring and telemetry data, customer reports, areas at risk of flooding, emergency response and the potential limitations of that data in future phases of the study
- Stage 2: Detailed analysis of root causes of flooding
  Using hydraulic models, rainfall and scenario testing, the review set out the likely contributing factors of the event, including where rain fell, the impact of high tide on the sewer and surface water flooding, the performance of critical assets such as pumping stations and the influence of groundwater. Further evaluation was then given to the source and cause of flooding in specific areas, based on a combination of modelling and customer reports.
- Stage 3: Detailed analysis of the performance of assets related to flood risk
  Using hydraulic models, test scenarios were set up to determine the difference in water levels that might have been observed had specific schemes not been built. This included, predominantly, the sewer flood risk reduction schemes at Maida Vale, Westbourne Grove and Counters Creek. It also simulated the potential performance of the Counters Creek tunnel scheme which was not constructed. The review also considered the interaction of surface water and sewer flooding by analysing the performance at two areas where significant flooding was reported: Kilburn Park Road and Waltham Forest.
- Stage 4: Recommendations
  Using the findings of Stages 1-3, the review set out 5 core themes where recommendations were put forward.

2.2 Data challenges

As part of the Review, the core data upon which we built our analysis was essential to support our overall findings and produce a robust evidence base. Throughout the discovery phase, we repeatedly found challenges over finding and collating the data in such a way that it would be useful for the review. We discuss some of those challenges in the following section, which have been divided into challenges during the flooding incident, and challenges during the review after the event.

Data related to the event

During the events, flood waters were rising rapidly. Large parts of London were affected and emergency services were responding as quickly as they could. In contacting the London Fire Brigade, we were given hotspot maps to demonstrate where emergency calls related to flooding were originating. Through the review, we also met with local residents who had been flooded and became increasingly aware that people in the community were being told different things by the emergency services and local authorities which propagated confusion amidst those communities.

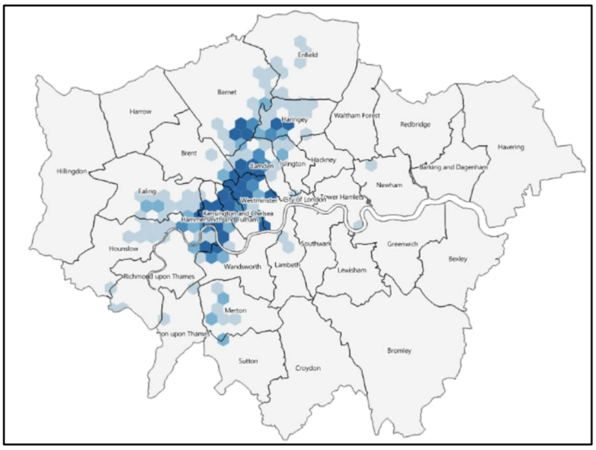

Figure 4- Distribution of calls received by London Fire Brigade on 12th July 2021

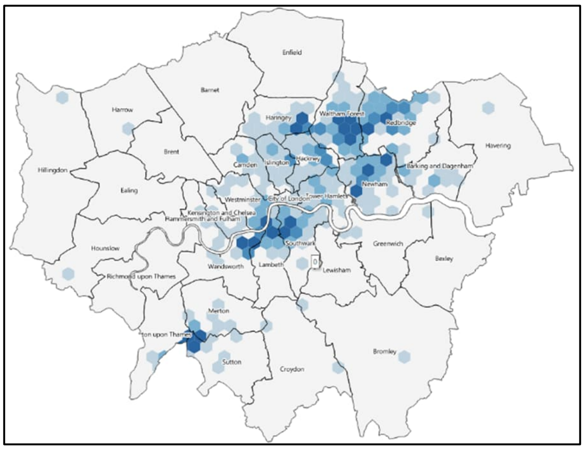

Figure 5- Distribution of calls received by London Fire Brigade on 25th July 2021

Some examples of information being shared with us range from responders to residents and demonstrate some of the mixed messages as part of our data collection. Some relate to the operation of drainage assets managed by Thames Water, some relate to the coordination of response from local authorities and emergency services, some relate to the hours spent trying to report flooding to the various authorities so that they could get help and some relate to the follow-up survey works carried out and different information being shared from operational teams on the ground to the communications from stakeholder management teams. Some examples of which are given to the right.

When reflecting on the reporting of flooding, members of the communities affected were unclear on who to report to. As the rain fell, both surface water and sewer flooding were widespread. Flows were backing up through toilets (clearly sewer flooding) but were also pouring through the airbricks and doorways (likely surface water flooding). The Flood and Water Management Act (FWMA) delineates who is responsible for what type of flooding, but it is clear that in these incidents this can lead to confusion on who to report to. Advice often aligns to the following which aligns with the duties listed in the FWMA:

Examples of feedback to the Review related to flooding

"Once the manhole cover was lifted, all the water drained away in seconds, it must have been blocked on the surface" Resident, Walthamstow

"The survey crew told us we would be fitted with…" Example of typical feedback related to discrepancy of official communications and individual survey/clean up crews

"Once the pumps were turned on at Lots Road, the flood water disappeared" Resident, Holland Park

"I was told I wouldn't flood again because I was fitted with a Flooding Local Improvement Project (FLIP) but I did" Resident, RBKC

- Report blocked drains, gullies and flooded roads to your local authority
- Report blocked rivers of flooding from the rivers or sea, contact the Environment Agency
- For sewer flooding, please call the local water company
- If you are in danger, ring 999.

In any emergency, it may be difficult to differentiate the source of flooding so people affected will make a call based on their judgement. In July 2021, this was further exacerbated by the number of calls which was more than Thames Water's customer call centre could manage, and was similarly reflected by the local authorities' response. Once customers were able to get through, the flooding incident was recorded depending on the source, and treated with accordingly. This resulted in a number of misreports and disparate information depending on who the customer could get through to and the perceived source of flooding.

Post-event analysis

One of the first exercises as part of the London Flood Review was to collate flooding history data, and other data we may need for the overall objectives for the project, from different sources as shown in Figure 6. Due to the challenges experienced in reporting, this information was stored very differently across organisations, depending on how the incident was reported and the presumed source of flooding. When the LFR first started, it was clear that new reports were continuing to arrive as part of data gathering undertaken by different organisations: at this point, this also included Members of Parliament's offices, housing associations as well as the more traditional organisations such as water companies, the Environment Agency and local authorities.

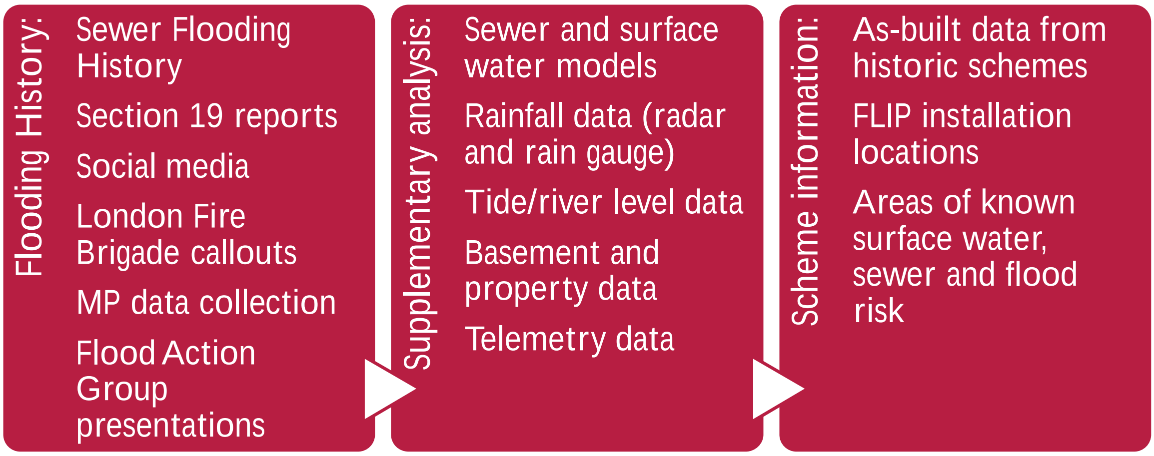

Figure 6 - Data sources for the Review

In the review we had to collate information from Thames Water, which complied with its flood reporting processes. In addition, we received data from the EA relating to reported flooding, several local authorities collated via the council and the MPs, information from TfL related to flooding infrastructure. We could not be sure that this information was complete, so we also conducted our own search of social media to identify potential unreported flooding. Whilst this method was fairly extensive, we still had no guarantee that it was complete and accurately reflected the mechanisms of the flooding event itself.

The London sewer network models were critical in defining the scope of the study and understanding system response. The network of long-term monitors at critical assets and bifurcations within the network allowed us to have reasonable confidence in the sewer system response. However there were some limitations with the representation of flow controls: due to the age and manual operation of many of the assets, it was a challenge to represent these accurately within the time constraints of the Review. We used the sewer network model in further analysis to extensively test what-if scenarios and help to build a picture of performance of the drainage network. In some localised surface water flooding hotspots, we also added 2d elements to the model so that we could better understand the above and below ground systems. From that picture, we could then fully understand the causes of the flooding and make meaningful recommendations to improve for future similar events.

There were challenges related to the extents and connectivity of basements to the sewer network. Two of the most affected boroughs: Hammersmith and Fulham (LBHF) and Kensington and Chelsea (RBKC) have a high concentration of basements, many of which reported flooding during the 12th July event. In 2011, Thames Water undertook a large data collection exercise to try and understand where basements existed across these two boroughs: they compiled a large number of datasets and validated it using Google Streetview. Compiling this dataset in itself was a huge undertaking, but has not been kept up to date since. It is also impossible to keep it up to date: planning requirements related to basement development is not controlled in the same way; it is not known if basements are connected to the sewer system; it is not know if basements are habited; the depth and volume of basements are not known. The basement dataset consists of approximately 44,000 basements: of which 14,000 predict flooding based on the information available. This is out by a factor of ten (approximately 1400 reported flooding properties) when comparing against the number of reported flooding locations. Even though we had a good correlation of observed and predicted top water levels in the sewer network model, when compared with the long-term monitoring data, we could not reconcile the basement data. As such we focused our reporting on levels within the sewer system and were unable to provide exact numbers of flooding.

Each local authority, under their LLFA duties, should understand the risk in their borough. In 2010, Drain London was originally set up to better understand and manage surface water flood risk in London in a coordinated way. The initial programme was to deliver surface water flood risk mapping for all 32 boroughs and the City of London and develop more detailed studies for 28 areas at high risk of surface water flooding. When we approached local authorities for these models which informed flood risk across the capital, we were not able to obtain them within the timescales of the study. As a result, we commissioned bespoke surface water flooding maps for the events using the radar rainfall for those dates. We used this information, aligned with reported flooding data to assign a root cause of flooding related to surface water, sewer flooding or a combination of factors.

Asset Performance

A key limitation with the sewer network model was the representation of critical assets and their performance. In this particular instance, we are referring to sewer overflow pumping stations. The two examples we will discuss is Lots Road pumping station in Chelsea, and the Hammersmith pumping station. Both pumps are located on the northern bank of the River Thames. They operate during storm events by discharging flows from the sewer system to the river, to alleviate pressure on the network. At Hammersmith pumping station, the pumps can output a maximum flow of 25m^3/s; at Lots Road pumping station, the pumps discharge 6m^3/s from the Kensington inflow and 12m^3/s from the Walham Green/Fulham inflow.

During the 12 July 2021 event, one of the pumps at Hammersmith pumping station tripped out and reduced the total outflow capacity to 22m^3/s. This aligns with standard operation protocols for the pumping station, as there is often at least one pump out of operation for maintenance. This raised important questions about the operation of assets, such as the differentiation between assist and standby pumps. To public perception, a pump failed and this resulted in flooding. However, for quantification of risk and catchment performance during storm events, the pumping station was operating as expected, with a maximum of one pump out of action for the duration of the event. As a result, we used the hydraulic model to determine the difference in flood levels between all eight storm pumps operational, and seven pumps operational as was experienced during the event. The difference in levels at properties were reduced by less than 300mm across the catchment, which compared to flood depths of over 1.5m in some cases.

During the 12 July 2021 event, it was reported by members of the public that Lots Road pumping station was switched on later than it should have been. Furthermore, reports indicated that, as soon as the pumps were switched on, floodwater rapidly receded in the Holland Park area, approximately 2km north of the pumping station. The pumps at LRPS are manually operated, meaning that an operator has to go and physically switch on the pumps when levels in the sewer system are high. Using the records from the pumping station, we replicated what happened on the day to see if the timing of the manual switch-on affected the areas. In this case, we need to be considerate of how the pump operation is represented in the model: it cannot be represented as a manual control, but using trigger levels in real-time control we can evaluate the time at which the pumps would have turned on; and compare these with operational records. We can also use real-time control to set the time at which the pumps were recorded to turn on and compare these results to provide this evaluation. Again, across the whole catchment the difference in levels were less than 300mm which indicated that the flooding experienced would not have been significantly different.

2.3 Key recommendations

Several recommendations were identified throughout the review across five key themes: governance, funding, communications, evidence, and strategy. These themes aligned with other reviews taking place at a similar time, which are discussed further in Section 2.4.

- Governance - No single organisation is in overall charge of managing surface and sub-surface water flood risk in London. Furthermore, there is a lack of understanding of the overlaps and interactions between the differing responsibilities among a wide range of organisations;
- Funding - There is insufficient funding mobilised to manage the risk. There is a lack of knowledge about potential funding opportunities and a lack of understanding of what is needed to develop and submit proposals to secure the needed funds;
- Evidence - There is a lack of understanding of what flood assets are currently available, who owns and maintains them, and what condition they are in. In addition, there is also a lack of modelling that can help organisations understand where floods are likely to occur and what efforts should be undertaken to reduce the risk;
- Communication - There is a lack of understanding of the risks of surface water flooding and the responsibilities of the various stakeholders to lower such risks;
- Strategic plan – The absence of an overall strategic plan and vision, as well as a body tasked with its development and implementation, underpins all of these issues.

For simplicity, the review aligned the recommendations to the same over-arching themes and made 28 recommendations were made in total[3].

The recommendations aligned more specifically to data fall within the evidence category and include:

- Investigate timescales and suitable application for multi-agency response to improve forecasting. Use forecasting to identify event risk zones and consider use of ICMLive models to develop computer learning models as a predictive tool to identify impact and operational response during an event.
- Develop existing modelling specifications, or create new ones, which provide clear guidance on the use of rainfall, boundary conditions and complex flow mechanisms. Ensure that a common model environment is used so that shared risks between LLFAs and TW are well understood.
- Review critical assets and identify ways of monitoring data and information, such as data sharing platforms, during an event to inform decision-making and prioritisation. This may draw on data from all organisations as well as freely available data. Consider whether a digital twin is of benefit to replicate the system and understand the impact of various operations on system performance.
- Review current data collection processes across all stakeholders and identify improvements. Establish a suitable data platform to host flooding history data and manage appropriately. Appoint a data manager to be responsible for data and how it is shared.
- Strategic Surface Water Management Group to assess criticality of strategic assets and assign required standard of protection. Review measures in place to ensure continuity of

[3] london-flood-review-stage-4-technical.pdf (thameswater.co.uk)

performance during flooding events. Review current Flood Asset Register compiled by LoDEG[4] and make recommendations to improve consistency and understanding of assets. Assess assets which are critical for flood risk management and the implications for other assets where they may fail. Communicate findings to all stakeholders.

- Establish a data sharing agreement between TW and other relevant stakeholders which sets out what and how data is shared. Enable LLFAs quick access to data.

2.4 Other findings

The recommendations share repeated themes with other reviews of the time. Since the Pitt Review, there has been recognition that a more coordinated response and better understanding of places likely to be affected by flooding would be important to learn for future flooding events. The Pitt Review identified the following themes as shown in Figure 6.

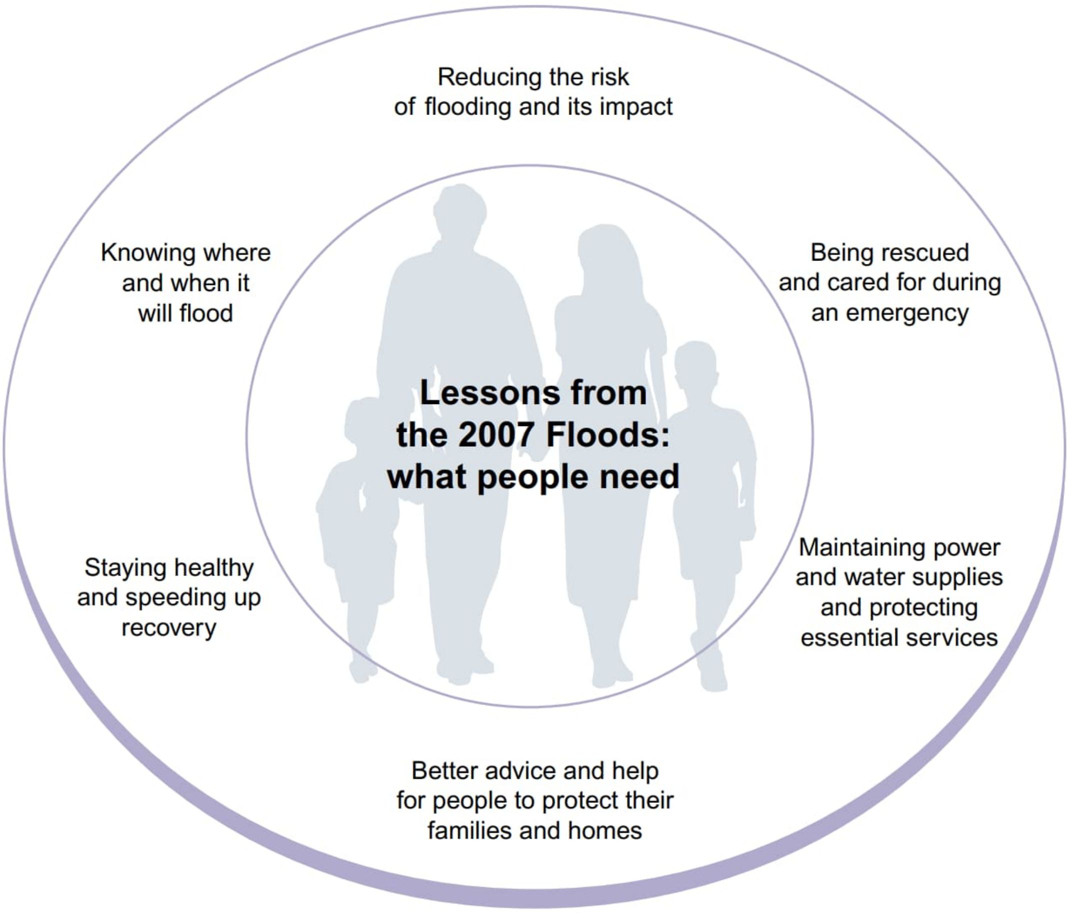

Figure 7- Lessons learned from the Pitt Review[5]

Key responses to the Pitt Review included the Flood and Water Management Act (2010) and the National Flood and Coastal Erosion Risk Management Strategy (2011) focusing on definition and management of flood risk and guidance on cooperation and data management. Yet, nearly 15 years later, we are still facing the same challenges and people are still affected in hugely by the impact of floods.

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[4] London Drainage Engineers Group (LoDEG | lotag)

[5] Pitt Review - final report (nationalarchives.gov.uk)

In response to the July 2021 floods, a Surface Water Task and Finish Group was established by the London Councils, in conjunction with other partners and produced the report, Surface Water Flood Risk Management in London[6]. There are ongoing round tables with the key stakeholders to ensure improvements continue to be made and progress is reported frequently. Thames Water also commissioned their own internal review into the flooding events, and improvements they could make to their internal processes. [7]

Subsequently the National Infrastructure Commission published their findings of a study on effective approaches to the management of surface water flooding in England[8]. This evidence-based study was not geographically constrained to London, but identified many of the similar challenges experienced during the London floods in 2021. It recognised the roles of both water and sewerage companies in managing and reducing surface water flood risk, along with local authorities and whilst it reinforced the need for joined-up strategic planning it did not specifically refer to data and challenges associated with sharing it.

3. What has been done since the event?

It is easy to be critical of the response at the time. It is important that we, as industry professionals, learn from these events so that the impact of them reduces. There will always be a bigger event or more rainfall, especially with the impact of climate change on our weather patterns. Given the number of reviews and reflections into the London floods in 2021, this next section looks at what has been implemented since. There is general recognition that the problem cannot be tackled by one organisation alone, and therefore collaboration and coordination of efforts drive a lot of the improvements which have taken place since 2021.

The London Surface Water Strategic Group (LSWSG) was established following the events. The LSWSG is overseeing a programme of improvements to address this. It comprises senior-level representatives from London's Lead Local Flood Authorities and other organisations with a flood risk management or strategic governance role. Representatives of the LSWSG consist of London Boroughs, Greater London Authority, Environment Agency, Transport for London, Thames Water, London Fire Brigade, and the Thames Regional Flood and Coastal Committee. Their role is to set a strategy which manages surface water flooding and works to reduce flood risk from surface water across London, through collaboration and coordination. With high level support from the organisations represented, decisions are made effectively with commitment that they will be delivered. The LSWSG has met quarterly since being established in December 2022.

The LSWSG has consolidated the recommendations from the LFR, LAR, LSWTFG which cumulatively had 85 recommendations, and provided an update in the Annual Monitoring Report[9]. There are 12 'common' and 35 'review-specific recommendations which have been allocated into workstreams for governance, strategy, funding, evidence, communications and resilience. To date, 14 recommendations have been completed, 25 are in progress and 8 are yet to begin.

Actions related to data relate, again, most closely to the evidence category and include:

- Develop a centralised store of data to capture projects (both completed and prospective) and other key asset information across London, including Surface Water standard information, which may subsequently be utilised for prioritising *(In progress)*
- Review Surface Water flood opportunity mapping and modelling coverage, agree priorities and extend coverage through additional funding bid. *(In progress)*

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[6] Surface Water Flood Risk Management in London | London Councils
[7] july-flooding-internal-review.pdf (thameswater.co.uk)
[8] Surface water flooding - NIC
[9] Annual Monitoring Report (london.gov.uk)

- Establish a data sharing agreement between key organisations and other relevant stakeholders which sets out what and how data is shared before, during and after an incident. *(In progress)*
- Develop a partnership-wide approach to the fast-time collation of information about the location and extent of flooding impacts. Data based solutions (i.e. merging data held by different organisations) and publicly available / realtime information sharing solutions should be considered *(not started)*
- Develop existing modelling specifications, or create new ones, which provide clear guidance on the use of rainfall, boundary conditions and complex flow mechanisms. Ensure that a common model environment is used so that shared risks between LLFAs and TW are well understood *(in progress)*.

Thames Water have an ongoing programme to improve resilience of their customers. The scheme has been delivered in phases based on the vulnerability of residents and the risk to their property. Where customers are considered vulnerable, flooding local improvement projects (FLIPs) have been installed. Where surface water flooding is identified as a contributing factor the root cause of flooding, FLIPs are not appropriate as flows can enter the property via other means. In some cases, properties were known to have flooded as a result of extreme rainfall (e.g. greater than a 1 in 30-year return period events) and therefore an expensive scheme or property-level anti flood device would be considered poor value for money: in these cases, the properties were fitted with non-return valves. Where there were large clusters of flooding, consideration was given to a more holistic solution addressing multiple properties at once. It should be noted that the programme is still ongoing with the aim to improve resilience of properties which are at risk from sewer flooding.

Surface water flooding is to be considered through the refresh of surface water management plans, although these are still constrained to administrative boundaries. As recommended as part of the review, wider consideration should be given to the hydrological boundaries and to understand the influence and impact of surface water across administrative boundaries. Other recommendations reinforce the need for collaboration across risk management authorities and how they work together. Whilst not explicit to data, it is clear that creation of a common, single source of truth can play a pivotal role in reinforcing a collaborative environment.

One key finding of the reviews was that incidents of this severity are likely to become more frequent with the influence of climate change. Whilst we cannot prevent flooding, we can help those who are vulnerable or at risk from flooding to prepare; and we can equip organisations so that they are dealing with the flooding response in a proactive way, enhancing their readiness and preparations. When reviewing completed actions, these predominantly relate to communication and enhancement of multi-agency flood plans so that organisations are ready for such an event if it occurs again in the future. The recognition here is that strategies and development of solutions, whether they are hard-engineered or operational will take longer to implement with more formalised agreements. The initial focus has been on establishing the governance and endorsements for collaboration at a senior level and ensuring future emergency responses are suitable at dealing with future events.

4. What does the industry need to do?

As an industry, we have the knowledge and skills base to help , standardise and therefore share more easily the evidence to inform more holistic strategies, to understand and communicate the root causes of flood risk and to help risk management authorities and communities be better prepared. We don't need to patronise, but we need to ensure we communicate simply and effectively and data can help us to achieve this.

4.1 Connected strategies

The flooding experienced is not unique to London, other large cities face similar challenges and lessons can be learnt from local, regional and global initiatives. One important concept is the approach of systems thinking,

Systems thinking is a way of exploring and developing effective action by looking at connected wholes rather than separate parts.[10] In the water sector, we are well versed in thinking in separate parts, with water resources, wastewater planning and river quality and flood risk often managed by separate entities either within the same organisation (e.g. water companies and the Environment Agency) or across different organisations (e.g. risk management authorities for flood risk). However, we have proven that by considering the water cycle as a system we can develop more holistic strategies which can be more cost-effective for all parties involved. It can also help us to understand complex interactions between parts of the water cycle which are normally disparate. This is normally demonstrated through an integrated water management strategy, of which there are good examples for Manchester[11] and London (sub-regionally focused on the River Lea)[12].

One of the challenges to overcome with the water sector is the variety of boundaries which come into play: the administrative boundaries, the drainage system boundaries, the water resource zones and transfers, and the hydrological boundaries of our river systems often intersect and overlap which means that it is hard to build a demonstrative evidence base and a strategy which satisfies all parties. This is important to consider as an initial step and requires effective engagement and a common understanding of the objectives and ambitions of the strategy. For example, for the River Lea there was recognition that the diversity of staff from water companies and the EA with quite a detailed understanding of the catchments they operate and their risks and local authority officers, some of which had a technical background in highways or flood risk, and some were more focused on planning and spatial strategy. The range of backgrounds and technical capability meant that part of the challenge was demonstrating the current risks and inter-relationships amongst members of the steering group.

4.2 Assets

As mentioned in Section 2.2, the range of knowledge relating to assets and risk can change significantly depending on resource, technical capability and, in some cases, length of service of employees. Whilst it is listed in the duties that there is a requirement to keep a register of assets which may have a significant impact on flood risk and share it within a reasonable timescale on request from other risk management authorities.

The definitions in the duties are vague: notably what counts as significant and what is a reasonable timescale. It is obvious that this might change depending on an incident: if it's related to strategy development, 20 days may be reasonable; conversely, in an event where flooding is happening in real time the availability of information is often not available to hand. Digital platforms can play a significant role in documenting assets and their purpose, as can be seen on the EA's Asset and Information Management Service (AIMS)[13]. As the uptake of SuDS and collaborative partnerships increase, further onus will be placed on the local authorities or asset operators to be able to provide this information and the design basis on which they were constructed. In addition, if models are used in the design of the asset, these models should also provide part of the design information and should be transferred

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[10] Systems thinking: an introduction - GOV.UK (www.gov.uk)

[11] Integrated Water Management Plan - Greater Manchester Combined Authority (greatermanchester-ca.gov.uk)

[12] london.gov.uk/sites/default/files/2023-07/Sub-regional integrated water management strategy East London - July 2023.pdf

[13] Asset Information and Maintenance Programme (data.gov.uk)

to the asset owner as part of the deliverables. Whilst this is best practice, it is still not practiced everywhere.

4.3 Common data environments and sharing

There is still resistance with sharing information, particularly related to flooding history, as this often includes personal data which may fall under the data protection regulations. However, there are increasing examples of common data environments, starting originally as part of the UK BIM Framework and the BS EN ISO 19650[14]. This was taken further as a conceptual digital twin for resilience planning as part of the climate resilience demonstration (CReDO)[15].

Sharing of data is becoming more widespread, examples can be found using the National Underground Asset Register[16], still in its pilot phase, but demonstrating how multiple organisations can share data on a large scale and the types of data agreements in place. We know that data can be cleaned and processed and displayed without sharing all the data, making it compliant with GDPR and other data protection regulations, but serving a purpose for its use in understanding risk.

When it comes to flood reporting, there are other examples where people can upload their own data and observations to a data input portal. There are risks with this approach: false information, non-standard information, misrepresentation of information and subsequent need for others to validate it. Also in a flooding event, it is unfair to expect people to prioritise reporting over trying to ensure that their families and property is safe. This also brings into question the role of insurance for flooding properties: as many homeowners are hesitant to report flooding as it will have an impact on their insurance premiums and the value of their property. This is not the focus of this paper, but is still a major concern and influences our ability to gain a full picture of flooding in severe flooding events.

5. Conclusions

Flooding will continue to happen; it will get worse and affect people more widely. Whilst we have used models in the past to understand flood risk, reducing the impact is heavily reliant on how we respond quickly and understand our assets. Data capture and data management can play a significant role in improving our response and permitting collaborative partnerships so solutions implemented can really meet the needs of the communities we serve.

The need for standardisation and sharing of flood event data was identified as a need from 2007 and more than 15 years later have we really moved forward? We are faced with the same disparate systems of spreadsheets filled in by different organisations that cannot be acceded by all responders. We have not moved forward with our event management data sharing.

Whilst some of the needs are much bigger than our drainage community, and will require lobbying and significant changes to how we regulate and allocate funding for flood risk management, there are some short-term actions we can undertake now. These include:

- Understanding risk across multiple water systems to implement integrated schemes which have multiple funding streams and benefits;
- Setting up digital co-creation spaces for people to upload and collaborate, promoting schemes which have much wider benefits;
- Using schemas and best practice examples of data management principles so that information can be shared proactively across multiple organisations.

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[14] Guidance-Part-C_Facilitating-the-common-data-environment-workflow-and-technical-solutions_Edition-1.pdf (ukbimframework.org)
[15] What is CReDo? - DT Hub Community (digitaltwinhub.co.uk)
[16] National Underground Asset Register (NUAR) - GOV.UK (www.gov.uk)

This is not enough, we should be thinking bigger and better. It is hard, it is complex but it needs to be fixed and we need to grasp the real potential from data. With permanent monitors in our sewers responders should be able to see how the wet wells are filling, and which properties are reporting flooding during the event. We should be thinking bigger.

This year, the Bangkok Decision Support System (DSS) won the ICE's Chris Binnie Award[17] for improvements in the water sector. The DSS is a real-time flood risk digital twin which accurately predicts where, when and how much rainfall and stormwater flooding will occur in real time. Many UK organisations, when consulted, have confirmed that they feel that such an equivalent system is a long way away, or the terms of reference are too difficult to define. We have our industry experts present here today, but how do we align our expertise with the needs of the communities which are affected by flooding. The computing capacity is there, the technology for rainfall and prediction is there, so what is holding us back?

[17] ICE Awards 2023 Winners Announced | Institution of Civil Engineers (ICE)