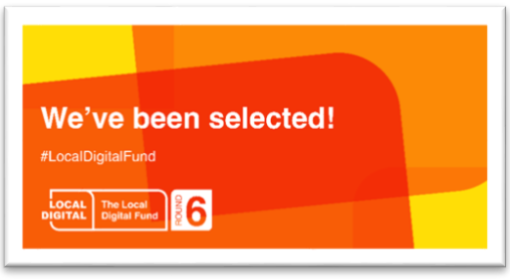
DIGITAL SMART FLOOD WARNING SYSTEMS

BUSINESS CASE



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Contents

OVERVIEW OF PROJECT CONTACTS

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KEY ABBREVIATIONS

Abbreviation	Definition
BAU	Business as usual
DLUHC	Department for Levelling Up, Housing and Communities
EA	Environment Agency
iCASP	Integrated Catchment Solutions Programme
IoT	Internet of Things
KC	Kirklees Council
LA	Local Authority
LCC	Leeds City Council
LLFA	Lead Local Flood Authorities
LoRaWAN	Long Range Wide Area Network
LPWAN	Low Power Wider Area Network
SMART (target)	Specific, Measurable, Achievable, Realistic, Timely
WMDC	Wakefield Metropolitan District Council

KEY DEFINITIONS

Item	Definition
Hotspot	A location where it has been identified that it is at risk of regular flooding
Analogous Cost Estimate	Comparative estimate based on a similar project.

SCHEME DESCRIPTION

The project sought to explore the use of 'smart' technologies to deliver a solution to address the need for a real time surface water flood warning system.

A discovery 'scoping' phase has been completed. Presented below is a business case for Alpha-stage funding to develop a pilot scheme testing a Long-Range Wide Area Network for surface water monitoring, infrastructure maintenance and improved flood response.

BACKGROUND AND SITUATION

SURFACE WATER FLOODING

'*Surface water flooding – also referred to as pluvial or flash flooding – happens when there is so much rain that it cannot drain away quickly enough, either because drainage networks reach capacity and overflow, or because they are not operating at full capacity due to blockages in pipes and sewers, or in above ground drainage like gullies. Instead of draining away, the rainwater collects at low levels and causes flooding. Surface water flooding can occur in rural and urban settings*.' (National Infrastructure Commission, 2022, p. 14)

Surface water flooding is driven by factors including rainfall volume and intensity; land cover permeability and soil moisture status; drainage system presence and type; flood infrastructure maintenance; and topography.

THE KEY ISSUES

Floods account for an estimated 44% of disasters worldwide (CRED & UNDRR, 2020). Individual events can be catastrophic and, in the UK, the winter storms of 2015-16 cost approximately £1.6 billion (Environment Agency, 2018). Currently, 325,000 properties in the UK are at risk from surface water (pluvial) flooding; these properties have a >60% chance of flooding in the next 30 years and this figure will increase with urbanisation and climate change (National Infrastructure Commission, 2022). The negative impacts are high and include human health, livelihoods and wellbeing. However, surface water flooding is poorly understood both regionally and nationally; risks are localised, modelling is weak, and therefore the specific location, extent and magnitude of flooding is challenging to predict.

At a national level there is a need for the Environment Agency to provide strategic leadership and work with local authorities to protect people, the economy, environment, and property from surface water flooding. However, there is no comprehensive record of surface water flooding incidents across England nor any comprehensive assessment of the underlying causes (National Infrastructure Commission, 2022). Local investigations are inconsistent in quality and not centrally collected, reducing the opportunities for learning.

At a local level, surface water is a growing problem across West Yorkshire and the current local flood response is reactive rather than proactive. In contrast to fluvial flooding, there is no comprehensive real-time monitoring system, early warning system or system of data collection and analysis outside of local authority incident reports. This reduces the opportunity to identify the level of risk to specific areas and properties that support decision making and long-term strategic flood risk investment. A recent report from the National Infrastructure Commission recommended that local authorities are required to develop: '*costed, long term, joint plans to manage surface water flooding, including local targets for risk reduction, assured by the Environment Agency with input from Ofwat*.' (National Infrastructure Commission, 2022, p. 5).

LORAWAN DESCRIPTION

LoRaWAN (**Long Range Wide Area Network**) technology has emerged as a promising solution. LoRaWAN is a low-power, wide-area network (**LPWAN**) designed to enable long-range communication between low-power devices using radio frequencies via the AM network. In brief, data is collected from sensors at predetermined intervals, or in response to a stimulus, and sent in a small (32-64 bits), encrypted data package to a gateway. The gateway receives the information and securely transmits it to the organisations' dashboard which processes the data and displays it. The dashboard can be customised to show the data in graphical, map or tabular form, and send alerts, if required, to the appropriate response team. Sensors are available for many different applications including surface water levels and rain gauges. Using this information, decisions can be made regarding flood infrastructure maintenance, flood mitigation or incident response.

LoRaWAN technology is ideal for applications where data is transmitted over long distances and battery life is critical; data can be transmitted over 25-35km but can travel >80 km if signal is good, and sensor batteries are expected to last 1-2 years with a 15-minutes reading frequency. Alternative power sources including mains electricity and solar power can be used. LoRaWAN therefore offers low power consumption, long-range connectivity, and secure data transmission.

For further information and specifics on the LoRaWAN potential for flood management, read the *Digital Smart Flood Warning Systems User Research Report*.

LORAWAN PROS

1. **Wide Coverage**: LoRaWAN technology allows for long-range communication between sensors and gateways, enabling large areas to be monitored for surface water flooding.
2. **Low Power Consumption**: LoRaWAN sensors consume little power, which means that they can operate for prolonged periods of time on a single battery charge.
3. **High Accuracy**: LoRaWAN sensors can be calibrated to provide highly accurate data on water levels, enabling early detection of potential flooding.
4. **Cost-Effective**: LoRaWAN sensors and gateways are cost-effective compared to traditional monitoring solutions.
5. **Economies of Scale**: Other services may use the network to collect data, e.g., air quality, footfall, temperature & humidity.

LORAWAN CONS

1. Limited data transmission that is unsuitable for CCTV and pictures.
2. Reduced options for powering the gateways in remote locations.
3. Less reliable data transmission in certain topographic contexts.
4. Ongoing maintenance requirements may limit the density of the sensor network.

STRATEGIC CASE – CASE FOR CHANGE AND RATIONALE FOR INTERVENTION

- There is no location-specific surface water early warning system.
    - Forecasts tend to be at coarse, broad regional resolution and not suitable for LLFA application relevant to populations and properties at risk.
    - LLFA do not know extent or location of surface water flooding during an event, which causes inefficient resource allocation.
    - Surface water flooding is rapid and, in many instances, it is difficult to attend an incident before it drains.
    - There are practical problems associated with the lack of real time data for organising an effective and targeted response.
    - Surface water response is too dependent on information and reports from the public.
- No systematic data collection on the causes of each event – including heavy rain, poor maintenance, saturation levels.
    - Surface water mapping, and understand of surface water risk, is poor and relies on data such as that from LiDAR.
    - Risk mapping needs to be accurate to target resources efficiently to deliver the best protection.
    - Data would improve reliability of local risk mapping at street level considering local drainage systems such as dropped kerbs and local topography.
    - Data collected during a flooding event may indicate where bottlenecks exist in the surface water drainage network thereby identifying locations where investment to increase capacity or provide additional flood protection can be implemented.
- The public have a poor understanding of surface water flooding (BMG, August 2022)
- Urbanisation is increasing the number of properties at risk.
- Increasing impermeable surfaces increase the risk of surface water flooding.
- Climate change increases the risk of surface water flooding. Uncertainty is dependent on climate change scenarios.

BUSINESS AS USUAL

The costs and benefits of the proposal as compared with BAU are to be developed within the risk register and benefit management plan. This will inform a cost benefit ratio as the pilot progresses.

Current costs include:

- Property damage
- Damage to drainage infrastructure
- Health and wellbeing costs associated with surface water flood events.
- Clean-up costs
- Inefficient ongoing maintenance of debris screens
- Inefficient LLFA emergency response
- Transport travel times and re-routing costs

Benefits from the strategic investment include:

- High resolution monitoring to target rapid response interventions.
- Ongoing maintenance better targeted, reducing significant damage costs.
- Reduced property damage
- Better planning for transport, including emergency service re-routing.
- Better public engagement to minimise wellbeing costs and enhance health benefits.

IMPACT ON STRATEGIC PRIORITIES

The following is written using strategic priorities of Wakefield Metropolitical District Council. We recognise the need to be focused on what matters most to our residents and the future of our district and communities. Alignment helps us invest in areas with maximum benefit.

The following strategic objectives are based on resident feedback, intelligence data, and the long-term challenges and opportunities for our region.

Building a fairer future (wakefield.gov.uk)

WMDC Strategic Priorities	Impact	Rationale Outline
2a. Better Health & Lives: 1. Ensure that adults across the district feel safe, responsible, and empowered.	1. High Impact	The warning system will improve flood event response, data sharing and empower communities to take appropriate action.
2c. Places to be Proud of: 1. Ensure Wakefield residents, voluntary and community sector and businesses use their skills and assets to help themselves.	1. High Impact	Various voluntary community groups may use their skills to aid their communities. Flood wardens get the information they need and a network that they may add sensors to. Workshops allow them to advise on sensor requirements.
2f. A Modern Council that Delivers: 1. Utilising people, partnerships, assets, and technology to maximum effect for our communities 2. Genuine community and resident participation in everything we do	1. High Impact 2. Medium Impact	Creation of a digital smart warning system network would allow communities and other services to data share and expand the sensor array using the gateway network.

DISCOVERY PHASE STAKEHOLDER ENGAGEMENT AND SUPPORT

During the discovery phase, the following information was collected and disseminated to form this business case; further information on stakeholder engagement can be found in the DSFWS project User Research Report and Appendices, publicly available through the Local Digital Fund.

Name	Information Acquired (discovery phase)	Format	Date of last communication
Partner Council Flood Risk Managers	Key flooding issues, existing solutions, hotspots, flood response, data required and digital cross-over.	Interviews	October 2023
Partner Council Digital Team Leads	LoRaWan requirements, specific area requirements, management of the network, data processing methods and platform	Interviews	October 2023
EA	Key flooding issues, existing solutions, current EA data, validation, responsibilities – warnings, flood advisory service, how might fluvial warning sit with pluvial and suggestions for the product.	Interviews	12th Oct 2023
Flood Wardens	Key challenges and opportunities for	Workshop	12th October 2023

	implementation of a LoRaWAN in West Yorkshire		
Service Providers	Key challenges and opportunities for implementation of a LoRaWAN in West Yorkshire	Workshop	25th Sept 2023
Norfolk County Council	Understand the pros and cons of an existing LoRaWan network	Consultation Meeting	29th Sept 2023
West Yorkshire Fire and Rescue	Key challenges and opportunities for implementation of a LoRaWAN in West Yorkshire – emergency services perspective	Consultation meeting	23rd November 2023
Alliot, Probado and Andel – LoRaWAN companies		Consultation meeting	23rd November 2023
West Yorkshire Resilience Forum Severe Weather Group		Consultation meeting	

HIGH-LEVEL BENEFITS OF A LORAWAN FOR FLOOD MITIGATION AND RESPONSE

An overview of benefits a LoRaWAN surface water network might realise.

Improved understanding of flood risk	i. Adequately monitor surface water through a region-wide network of precipitation, water level, soil saturation, watercourse, and other sensors e.g., Pinpoint heavy rainfall, flooding, and maintenance needs precisely ii. Limited maintenance and setup costs iii. Accurate and reliable real-time surface water data iv. Automated surface water flood alerts/warnings v. Data analysis and management software to support user needs (iteratively develop) vi. Integration into existing data sources and model a potential national data standard (opportunity for sharing see NIC 2022 report).
Improved flood response and recovery	i. Improved flood response and protect public safety. ii. Efficient and effective response and allocation of resources iii. A clear communication plan to ensure that alerts and notifications are received by partners and stakeholders. iv. Social and economic benefits from an improved early warning for residents and businesses.
Reduced impact of flooding on a Priority basis	i. Capture data from flood incidents to guide future priority flood risk management activities, flood forecasting, hydraulic modelling, and capital flood reduction schemes. ii. Improved understanding to inform appropriate planning development management
Inform targeted maintenance	i. Inform targeted hotspot watercourse, flood storage and grille maintenance on a priority basis rather than scheduled maintenance. ii. Inform landowners of maintenance and flood issues

NEXT STEPS: SYSTEM REQUIREMENTS

PILOT: PROOF OF CONCEPT (ALPHA PHASE)

A pilot is necessary to determine if a realistic and credible system can be created, managed, and maintained, testing system viability and requirements for the organisations involved. The following table outlines tasks to be completed during a pilot (Alpha stage) project.

RAG rated requirements are to be developed through an iterative process that will inform costs, benefits, and risks. This will inform workstreams and management delivery plans.

Alpha stage Requirement	**Notes**

Test dashboard creation within LA (minimum viable product)	• Inhouse build (workshop/training).
	  ○ E.g., Azure and Power Bi as at Leeds City Council.
	  ○ Explore external support e.g. Science and Technology Facilities Council or Resilience Direct GIS Mapping
	• Collaborate between partner councils – led by Leeds City Council (SC).
	• Team members learn how to create a dashboard – inclusion of relevant teams within each LA.
	• LA owns the dashboard capable of displaying real-time data, and historical data for post-event analysis.
	• LA's establish admin and maintenance procedure for dashboard.
	• LA develops capability to maintain (and develop) the dashboard.
	• Iterative approach taken to develop specific functionality.
	• This option enables LAs to decide whether to own and manage a dashboard themselves, or whether to procure externally

Test proof of concept – sensor to dashboard	• Visit proposed hotspot locations and map current gateway signal strength – assess requirements for improvement of robust gateway network.
	• Within a collaborative workshop, test set-up of a gateway and sensor network.
	  ○ Each LA to test one gateway and sensor.
	  ○ Test functionality.
	  ○ Test link to dashboard.
	• Highlight set-up/test functionality as part of a field-test at one hotspot location.
	• Team members learn, in practice, how the gateway and sensor connect – at least one person per LA.
	• **Agile approach to iteratively inform the requirement management process,** risk register and benefit management process.

Establish and test method of network installation	• Inclusion of all relevant departments to raise awareness of the system possibilities, including for cross-service applications. Establish interest in set-up of a LoRaWAN across Yorkshire.
	• Identify practical installation methods. For example, which teams would install sensors? What permissions are required? Who are the most appropriate external/in-house teams for maintenance and installation of the network.
	  ○ The Environment Agency have extensive experience with sensor installation. Consult EA on challenges associated with site permissions, safety requirements and sensor installation.
	  ○ University of Leeds and Leeds City Council have sensor installation expertise, often trialling innovative new devices. Establish their input on the flexible and adaptive nature of test phases.
	• Investigate contractual implications & specialist support required.
	• Investigate maintenance regime and long-term requirements for training, network updates, data assurance and security.
	• Investigate data sharing options, requirements, and preferences

Full rollout of the network to surface water flooding hotspots across West Yorkshire is intended for Beta stage.

HIGH LEVEL REQUIREMENTS – DISCOVERY TO BETA PHASES

These will be further informed and refined as understanding improves.

MUST HAVE **Only reduced as a last resort.**	**SHOULD HAVE**	**COULD HAVE**	**WON'T HAVE**
Proof of Concept – gateway to sensor to dashboard	Service level agreements (data sharing)	Thunderstorms tracking. Live data from rain gauges	Live CCTV or pictures
Dashboard (minimum viable product).	Real time data	Soil saturation levels	The adopted system should not be reliant on a single supplier's equipment
Establish method of network installation	Hotspot focus	Create appropriate LoRaWAN coverage	
The LA retains network and data ownership.	Inter–operability.	Integration with existing EA water level monitors on main rivers	
Early Warning System	Non-proprietary and usable to inform new research for public good	Upstream monitoring	

	Appropriate alerts (e.g. emails) when critical levels reached sent to Flood management Team for improved infrastructure maintenance or flood response	Shareable with other LAs	
	Permit other non-flood related sensors to be trialled at the same time	Actively encourage other non-flood related uses of the gateways during the Alpha phase	
	Mapped the whole of each district for best overall coverage of LoRaWAN gateways, rather than simply specific to this project	Partitioned off a public facing access to the LoRaWAN during the trial	
	Positive comms about the project, the technology (IoT, Smart Tech)		

The elements listed above are part of an ongoing process to create clear, unambiguous, and simple requirements that are **SMART**. These requirements will be input into solution development and delivery of work against an acceptance criterion.

- **Requirements**: The stakeholders wants and needs – need to clearly define them with acceptance criteria.
- **Acceptance criteria**: The requirements and essential conditions that must be achieved before a deliverable is accepted.

OPTIONS APPRAISAL

We have identified three approaches to the development of a digital smart flood warning system in West Yorkshire, presented below in order of preference.

OPTION 1: A HOTSPOTS APPROACH USING LORAWAN

This option presents the pilot proof of concept (page 7) in further detail.

To systematically build a resilient digital system, we recommend a step-by-step approach is adopted, first undertaking an alpha stage pilot study to establish a small-scale network using known hotspot flood locations in West Yorkshire. If successful, further funding may be applied for to enable region-wide rollout.

GOVERNANCE ARRANGEMENTS

Wakefield will continue as project lead council, partnering with Leeds City Council, Kirklees Council, Environment Agency and iCASP. Governance arrangements for the digital discovery phase are outlined below; these arrangements have been successful and will continue into the alpha phase. The core project team will meet fortnightly, with responsibility split between members grouped into digital, flood and facilitation teams. The project lead council, WMDC, will report to the DLUHC Digital Team and West Yorkshire Flood Innovation Programme (WYFLIP) for feedback and support.

The Digital Discovery phase identified key partners as part of stakeholder engagement (see *Key Organisations, page 18*); Bradford and Calderdale councils, West Yorkshire Fire and Rescue, West Yorkshire Resilience Forum and the Flood Warden network have expressed interest into continuing to support the project closely.

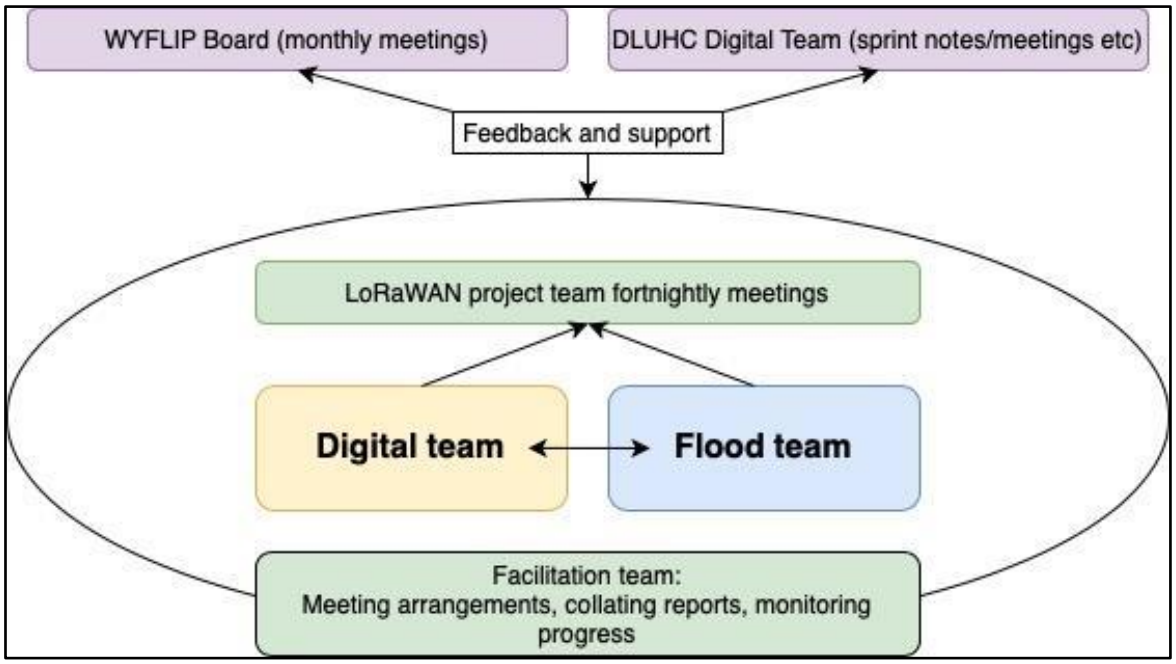

Figure 0.1: Governance structure

GANTT CHART

The table below outlines the timescale required to conduct activities described in *Pilot: Proof of Concept (page 7).*

Following items to be completed following confirmation of funding success.

Week	1	2	3	4	5	6	7	8
Decision on sensors/gateway type to be tested								
Procure sensors & gateways for pilot								

The above items must be complete before the following timetable begins.

Week	1	2	3	4	5	6	7	8
Visit proposed hotspot locations to establish gateway signal strength								
Investigate maintenance regime and long-term requirements for training.								
Cross-service engagement for system awareness & use								
Investigate data sharing options and requirements								
Training workshop for LoRaWAN set-up, including dashboard creation								
Assessment of required gateways & optimum gateway locations for Beta stage								
Identify practical installation methods								
Review of findings								

HOTSPOTS: GATEWAY AND SENSOR NETWORK

The table below outlines known hotspot locations in each local authority and describes the recurring issue at each hotspot as identified during the Digital Discovery phase. In the Alpha stage pilot, gateway signal strength will be mapped for each of these locations, and analysis undertaken to establish optimum gateway locations for future rollout. Using information obtained from gateway signal mapping, practicalities relating to network establishment will be considered including cost, permissions and requirements of sensor and gateway installation and maintenance. Cross-service and cross-organisation engagement will be used to ensure a full assessment is made.

For the pilot, one sensor and gateway per LA will be procured for testing, with workshops used to train organisations in in-house sensor/gateway set-up. Further procurement of sensors and gateways, and full rollout to hotspot locations, would occur in beta stage.

NB: Hotspot testing sites do include some main river locations, as they are affected surface water flooding. These locations facilitate calibration of new equipment against data collected by the Environment Agency.

Local Authority	Location	Description
Kirklees	Gynn Lane, Honley	Properties are at risk of flooding from Ludhill Dike. N: 414484, E: 412158
Kirklees	Manchester Road between Slaithwaite and Marsden	Main road between Huddersfield and Manchester is regularly flooded from Badger Gate Clough. N: 406572, E: 412872
Kirklees	Ravensthorpe	Allotments and public footpath are flooded to waist-deep levels from Canker Dike. N: 422286, E: 420862
Kirklees	Whitehall Road, near J26 of the M62	Motorway junction roundabout floods from Sugden Beck & Stubs Beck. N: 418168, E: 426611
Kirklees	Hagg Lane, Lower Hopton	Properties and road at risk of flooding from Liley Beck. N: 421159, E: 418914
Kirklees	Middlemost Pond, Birkby	Properties at risk of flooding from Grimescar Dike. N: 413863, E: 418496
Leeds	Barnsdale Road, Allerton Bywater	Regular flooding to the highway- road to be closed to avoid incidents. N:442616, E:427378
Leeds	Troydale Lane, Pudsey	Regular flooding to the highway. N423590, E:432647
Leeds	Mill Lane Collingham	low lying road that floods when beck levels rise- nowhere for water to go. N:438686, E:445904
Leeds	Farnley Lane, Otley	Blocked gullies causing flooding highway. N:420509, E:446318
Leeds	The Hollies, Pool in Wharfedale	Surface water run off flooding road and outbuildings. N:424661, E:444984
Leeds	Town Street, Guisely	Surface water runoff floods garage and limits residents' access to houses. N:419492, E: 442469
Wakefield	Reid Park Beck	Watercourse adjacent to pumping station. N:418154, E:428302
Wakefield	A638 Doncaster Road	Flooding under railway bridge. N:415861, E:444504
Wakefield	Minsthorpe Grille	Flooding from watercourse onto highway. N:410849, E:446516
Wakefield	River View, Castleford	Flooding from floodplain, River Calder. N:425979, E:441911
Wakefield	Agbrigg FAS	Agbrigg flood scheme watercourse levels. N:419260, E:434947
Wakefield	Bleakley Lane	Flooding of highway from open land. N:412404, E:435945

DASHBOARD OPTIONS TO BE INVESTIGATED

To monitor sensors appropriately, dashboards are required to view incoming data in each hotspot location. Dashboards will be created during a series of workshops by Leeds City Council to train each participating organisation in dashboard creation, development, and maintenance. Dashboards will be created specifically for use with the sensors procured. The type of sensors procured will depend on the recurring flood issue being investigated per hotspot (see *Hotspots: Gateway and sensor network*).

Two dashboard styles will be developed during the pilot, differing depending on audience needs. The following text outlines the idealistic end-product as identified in the Digital Discovery phase:

DASHBOARD 1: SERVICE PROVIDERS

For service providers, including the EA, emergency services, and local authority-based Highways and Flood Management Teams, access to data from across the whole region would enable a joined-up approach to flood response. Ideally, the dashboard would be accessible to all parties and show, in map form, the location of flooding and/or required infrastructure maintenance. Using this dashboard flood status across the region may be inferred, leading to advanced warning of river level rise, storm progression, emergency service provision and road access.

In addition to a region-wide overview, users should be able to access information relating specific locations within their region; this would enable a sensor-specific identification of maintenance required. Ideally, a traffic-light colour system would indicate severity of need; for example, water level on the road as 'clear,' 'passable with surface water present,' or 'impassable due to flood.'

Using information from the dashboard, service providers may respond to needs following actions as dictated by organisation-specific response procedures.

DASHBOARD 2: FLOOD WARDENS

For community groups, including residents and volunteer flood wardens: access to local data and specific sensors only. This is not a flood warning system. An app would be appropriate to house the data and control data access.

Ideally, the dashboard would be on an opt-in open access basis and provide real time information only, in map or data point form. The data would lead to improved monitoring of passing storms, improved lead times for flood alerts and enable local businesses and households to make better informed decisions regarding flood response. Inference based on upstream data together with existing forecasting will increase lead-in time and understanding for the more densely populated downstream areas. It was noted by workshop focus groups that false alarms are preferable to flooding without notice; this is especially true of local businesses that want to make stock safe. [1]

**A workshop (12/10/2023) worked intensively on priorities for a future dashboard and data access*

[1] LoRaWAN Residents Workshop Notes 12.10.2023.

DATA SHARING & DATA AGREEMENTS

The Digital Discovery phase identified that, to view hotspot sensor data from across the region, all organisations should ideally have access to one system to which data is uploaded and transmitted in real-time. A second system may be needed for flood wardens and community flood groups depending on the data sharing agreements made.

In the option 1 pilot, each local authority would have their own network of sensors, collecting data from that network and storing it internally in their own data repositories; sensor data would be owned by the local authority that sensor sits within. Three options have been identified to share data, depending on permissions granted within each organisation and the bodies involved:

1. **Service providers only:** A data sharing (open access) agreement for which all non-GDPR data is shared in real time. This may occur through a new sign-in only website, or through existing platforms such as A) Resilience Direct, which all organisations currently have access to, B) Data Mill North, currently used by Leeds City Council, or C) the Purple Air Network
2. **Public and/or Service providers:** Local authorities do not share raw data, but instead share an indication of flooding in a mapped traffic-light format. This data would be accessible via a website or app; management of the platform would requirement agreement of responsibility from all parties.
3. **Public:** Local authorities share unvalidated raw data for information-only to trusted flood wardens and/or community groups, with clear messaging to understand that the system is not currently for flood alerts or warning, but for informed decision-making. This data would be accessible ideally via an app.

For each of the above options, management of the data could occur either per local authority, or via a third-party to manage and maintain a shared system (website/app). A combination of data sharing options may be required depending on recipient of the data. Pilot option 1 will further investigate these options alongside digital and IT teams within partner organisations, using the dashboards created to test options.

Distinction should be made between data sharing and data publishing. Data should be shared in real time between service providers and flood warden networks on the understanding that this data is unvalidated; this data should be accessed via secure platforms requiring an account. Data may be published in an open-access forum, such as Data Mill North or the Purple Air Network, to be publicly available post-validation. Access to data after incidents would enable collaborative research, including citizen science, to occur towards innovative and sustainable catchment management. Long-term datasets may enable formulation of a true early flood warning system which send alerts based on historical precedence of flooding.

BUDGET: FINANCIAL DIMENSION

The following outlines an analogous cost estimate of developing a pilot whereby different solutions to the identified challenges will be tested. An iterative approach will be employed to test these solutions and inform the scope and requirements. Focus will be placed on the most challenging areas to test our riskiest assumptions: dashboard creation, sensor network connectivity and network installation and maintenance. This will include building working protypes that are as simple as possible but complex enough to test various solutions.

Alpha costs are primarily based are based on the experience of Leeds City Council and Kirklees Council.

ESTIMATED COSTS FOR INHOUSE LORAWAN

Alpha Stage Requirement	Task	Items	Notes	Time (hrs)	Time £60/hr	One Off Costs (£)
Dashboard Creation	Investigate inhouse dashboard build	Dashboard creation workshop	This will be led by Leeds City Council. It will include appropriate inhouse team representatives	0	£0.00	£3,500.00
Dashboard Creation	Investigate inhouse dashboard build	Dashboard creation workshop	Workshop preparation	10	£600.00	
Dashboard Creation	Investigate inhouse dashboard build	Explore external support	e.g. Science and Technology Facilities Council, Resilience Direct GIS Mapping. Consider external procurement options.	50	£3,000.00	
Dashboard Creation	Investigate inhouse dashboard build	Develop an iterative development strategy	Councils apply lessons to develop the dashboard	90	£5,400.00	
Dashboard Creation	Investigate external dashboard build	Establish options and costs	Compare with in-house build options	15	£900.00	
Dashboard Creation	Establish admin and maintenance procedures	Explore internal and external options	Develop an understanding on what is needed and links to other services	50	£3,000.00	
Test sensor to dashboard	Test link from sensors to dashboard (in lab	Test the data uploads to dashboard		30	£1,800.00	

	rathe, not field conditions).					
Test sensor to dashboard	Test link from sensors to dashboard (in lab rather, not field conditions).	Visit proposed hotspot locations: map LoRaWan signal strength, photograph and consider sensor location		30	£1,800.00	
Test sensor to dashboard	Dashboard to sensor workshop				£0.00	£3,500.00
Test sensor to dashboard	A field test at one hotspot location			30	£1,800.00	
Establish and test method of network installation	Inclusion of all relevant departments to raise awareness of the system possibilities, including for cross-service applications. Establish interest in set-up of a LoRaWAN.			20	£1,200.00	
Establish and test method of network installation	Identify practical installation method options			60	£3,600.00	
Establish and test method of network installation	Investigate contractual implications & specialist support required			30	£1,800.00	
Establish and test method of network installation	Investigate maintenance regime and long-term requirements for training, network updates and security.			60	£3,600.00	
Establish and test method of network installation	Workshop to explore network installation options				£0.00	£3,500.00
Project Management	iCASP/FLIP Support (SB)	Includes: facilitation, research management and report			£0.00	£50,000.00

		development, academic review				
Project Management	Project Management (HJH)			60	3600.00	
Project Management	**Weekly Meetings (1 hr)**	Team of 10 over 12 weeks		120	7200.00	
Project Management	**Time on project**			120	7200.00	
Hardware	Gateway *3				£0.00	£4,500.00
Hardware	Sensors *6				£0.00	£4,000.00
Unknown Variables			Uncertainty uplift of 20%		£0.00	£23,220.00
Total					£46,500.00	£92,220.00

BENEFITS IF IMPLEMENTED – ALPHA TO BETA PHASES

Benefit	Description
Road Closures	BAU requires operatives to visit road flooding events multiple times to manage road closures across the district. Sensors would reduce operative visits, travel costs, and improve most importantly increase the accuracy and efficiency of road closures: This improves public safety. Improved response and information availability will increase efficiency and therefore reduce travel disruption, this includes better planning for transport, including emergency service re-routing.
Infrastructure maintenance	Currently, infrastructure such as culverts, drains and debris screens are 'cleared' (debris removed) following reports of blockages or via regular maintenance visits to each location. Sensors would reduce operative visits, travel costs, and increase the accuracy and efficiency of infrastructure maintenance: this mitigates flood risk, improving public safety. In the long-term, the dataset will provide information on the frequency of maintenance visits required to each site.
Reputation enhancement	Collaboration with flood groups, businesses, and the wider community. Improved public engagement to minimise wellbeing costs, and enhance health benefits
BAU Grille clearance and maintenance	BAU: grilles clearance occurs to a scheduled; this is inefficient in that contractors visit sites that do not need attention and sites that do may not be cleared. Data targeted grille clearance will reduce costs and flood risk by targeting grilles when they need clearance.

Storm event grille clearance	BAU: Individual grille status during an event is unknown leading to poorly targeted resources within limited storm even lead-in time. Once a grilled is blocked and flooded it cannot be cleared due to health and safety restrictions. Case Study - Storm Babet 18th-21 October 2023 - Kingsley Timber Yard: The grille blocked and submerged before it could be cleared - the yard and associated buildings flooded.
Strategic Flood Information	Improvements in the future planning of flood responses as we will be able to make data driven decisions
Social and Mental Health	There is a wealth of research pertaining to the impact of flooding on human wellbeing. Any response to increase flood resilience will decrease the negative impact on our communities and any scheme that reduces the risk of flooding to homes and businesses will provide monetary benefits. Flooding and health: an overview - GOV.UK (www.gov.uk)
Flood Damage to Property and Infrastructure	These are national average, per property, annual damage estimates and have been developed for residential properties across flood events with different probabilities and levels of flood warning service. The estimates for an average house in 20/21 prices range from the following: • a property with no flood protection and no flood warning service – £5,444 per property, per annum • a property with existing protection against a "1 in 200" (0.5% annual probability) and a flood warning service of more than 8 hours – £42 per property, per annum. The Green Book (publishing.service.gov.uk) To be developed using local data. User Research: Flood Wardens, Garforth expressed a view that 10 minutes additional time can make an enormous difference in that local business can make safe their stock.
Connected Places Benefits	Wider benefits of establishing a LoRaWAN network for other council and external services through its contribution to Connected Places and IoT environment. Economies of scale. Contribute and utilise the Resilience Direct dashboard.

RISKS IF IMPLEMENTED – ALPHA TO BETA PHASES

Risk category	Cause (Due to ...)	Risk (There is a risk that / of …)	Consequences (Which may result in ...)	Risk rating
Technological	LoRaWan and other networks connect wirelessly and will be placed in multiple environments that may inhibit the signal between the sensor and gateway, or cause sensors to malfunction.	The sensors will not communicate with the gateway at certain locations meaning some critical hotspots may not be included in the network. Increased time/costs required for sensor maintenance.	Reduce coverage, data availability, and increase costs as more gateways will be required. Unreliable sensor data readings	Medium
Regulatory / Legal	Each user and council have data sharing rules	Local Authorities and other agencies will not be able to share data between each other	The effectiveness of the early warning system is compromised. Lose the real-time benefit of upstream catchment passing data to lower stream catchments. Risk to property and people is not reduced as effectively as possible.	Medium
Financial	At concept stage there is a limited understanding of the specific method of requirement realisation.	The senor array necessary to capture the required data may not be feasible, for example, sensor network density needed to capture thunderstorm events in real-time or soil saturation, may be too high.	This will increase costs or limit the data that can be captured and in turn reduce the effectiveness of the early warning system and the data available to understand causes of specific flood events in specific localities.	Low
Environmental	Sensors are placed in challenging environments; For example, inside drainage gullies.	The sensors will fail or provide false readings	False flood alerts and high management costs	Low
Reputational	Alerts and warnings are provided	If alerts are not correct -timely, to the right people with the right message for action - we may not alert when we should, or we might over alert (‘cry wolf’).	**P**eople do not respond when there is a real risk.	Medium

FURTHER CONSIDERATIONS

Expansion to West Yorkshire: In addition to hotspots identified in Leeds, Kirklees and Wakefield, attendees to workshops held as part of the DSFWS Discovery phase identified key locations for testing a LoRaWAN in Calderdale and Bradford district areas.

OPTION 2: A HOTSPOTS APPROACH USING ALTERNATIVE (NON-LORAWAN) SENSORS

Description	Improve existing systems with the addition of SIM cards, matrix signs and CCTV and data sharing with partners such as Yorkshire Water. This includes researching what data is currently collected and if it can be made available to the council.
Net Costs	Minimal investment required in terms of development.
Advantages	Much data may already be collected, and it may be cost effective to develop a data sharing platform. Specific and known surface water flood risks may be mitigated through specific solutions such as using matrix road closure signs and SIM card data collection.
Disadvantages	The data would not be targeted at critical surface water flood risk hotspots as identified by local authorities. No region wide early warning system withal the accompanying economic and social costs. Bespoke maintenance of each system. No comprehensive real-time monitoring system, early warning system or system of data collection and analysis. This reduces the opportunity to identify the level of risk to specific areas and properties that support decision making and long-term strategic flood risk investment.
Conclusion	This would not meet many of areas outlined in the strategic case. Principally it would only achieve a limited early warning system and lack systematic data collection on the causes of each event – heavy rain, poor maintenance, saturation levels.

OPTION 3: MAINTAIN THE CURRENT SYSTEM

Description	BAU
Net Costs	No costs of developing a new service.
Advantages	If the Environment Agency take a strategic leadership role and develop a national plan that we may be consulted on, then in the future we can then develop our services within this strategy. This will increase the likelihood of developing a consistent central approach to surface water flood risk.
Disadvantages	All the issues outlined in the 'Key Issues' and 'Strategic Case' will remain. No comprehensive real-time monitoring system, early warning system or system of data collection and analysis. This reduces the opportunity to identify the level of risk to specific areas and properties that support decision making and long-term strategic flood risk investment. EA budget not sufficient. Workshop 2: Residents (12th Oct 2023) highlighted the difference early warning can make to businesses: ten minutes can make the difference between saving stock and assets and catastrophic flood damage costs.
Conclusion	This option does not meet the needs of residents, business, and other council services. The NIC has highlighted a national and local need to develop our understanding and management of surface water flood risk.

KEY ORGANISATIONS

Upper tier local authorities (unitary authorities or county councils) are the main organisations responsible for managing surface water flood risk. They are designated as Lead Local Flood Authorities and required to develop, maintain, apply, and monitor a strategy for local flood risk management in their area.

Highways authorities, which include local highway departments in unitary and county councils and National Highways and are responsible for draining highways or adjoining land.

District councils (including borough councils) in areas with no unitary authority, which are the local planning authority and are required to consider flood risks when developing local plans and assessing planning applications from developers.

Water and sewerage companies deliver and maintain clean water and sewerage services and have a duty to provide, improve and maintain a public sewer system to effectually drain their areas. They are distinct from 'water only' companies, who are only responsible for supplying water to properties and not for drainage.

Emergency services respond to flood incidents and require access to locations across the Yorkshire Area.

The West Yorkshire Flood Innovation Programme is a collaborative network, including the five local authorities in West Yorkshire, Yorkshire Water, Environment Agency, West Yorkshire Combined Authority and University of Leeds (using the iCASP team). The programme enables a partnership approach to catchment-based decision making.

Internal drainage boards are independent public authorities that manage water levels in low lying, mostly rural areas, to protect agriculture and the environment.

The Environment Agency is the non-departmental public body with strategic oversight of all flood sources and is responsible for managing flood risks from main rivers, the sea and reservoirs.

The Department for Environment, Food and Rural Affairs is the government department responsible for flood risk management policy in England.

Ofwat is the economic regulator for the water sector in England and in Wales. Ofwat scrutinises water companies' business plans and sets performance commitments for water companies to reduce sewer flooding.

Regional Flood and Coastal Committees provide a forum for local and regional authorities to coordinate regional activities. They approve Environment Agency requests to raise local levies or implement regional programmes of investment.

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