# Smarter Suffolk Project

# Gully Sensors

## Final Report

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# Contents

# 1 Executive Summary

Gullies are an essential part of highways drainage and highways maintenance management, with historic construction covering over 200 years of road construction, hence a wide range of physical structures. Functions include preventing flooding and managing surface water, supporting road surface longevity and maintenance, supporting road safety and reducing consequent damage to drainage systems and adjacent properties. Suffolk Highways for Suffolk County Council (SCC) manage approximately 144,000 highways gullies across the county. Gullies comprise a gully pot with a sump to collect sedimentation, and an outflow pipe to remove water. Accumulated sedimentation in gully pots is removed as required. Onward water management is into highways drains to surface water, soakaways or sewage systems. Drainage management has moved from cyclical to risk-based to direct resources as needed.

This project explored whether sensors can be fitted into the gullies to assist with determining gully operation and cleansing requirements. Gully sensors proposed by a range of companies measured different parameters from: depth to surface level (water if present); approximate fill level of silt in the gully (in 25% increments); if there is water present or absent at a specific height (flood / no flood); light levels in the gully head.

These Internet-of-Things sensors communicated using different communications technologies. Provision of LoRaWAN gateways (whether by the project or by the supplier) enabled re-transmission of signals from multiple devices (but presented challenges); other devices connected via mobile services from the device.

Sensors trialled in this project were provided by two suppliers:

- KaarbonTech provided the Farsite Liquinet Sensor measuring depth to water / other surface level. This is battery-powered and communicates via mobile data from the in-gully device.
- InTouch provided a sensor measuring approximate depth of silt, with a flood sensor and light level sensor included in the device head near the top of the gully pot. The in-gully device was battery powered, but required a nearby column-mounted data concentrator for onward data transmission which required a power source.

The differences in the parameters measured by these sensors, and the communications and data provision, meant that these devices and services were operationally significantly different.
Some other sensors available, that were not trialled, are also described in this report.

Data access from these sensors for analysis and use also differed:

- Data from KaarbonTech sensors was available from the sensor-specific dashboard from the device developer, which provided clear and adaptable visualisations and from which data files could be downloaded for analysis. KaarbonTech also integrated data as visualisations within their asset management platform used by SCC.
- Data from InTouch sensors was not made available as csv or similar files for analysis. Visualisations were presented on a dashboard, which was not found to be as usable.

Sensors were installed across Suffolk, for operation on a 6 or 9 month time frame. Installations were in locations selected to be of interest to the drainage experts, and were rural, urban and coastal.

Sensor reliability was assessed as continuity of data; where data was not available last dates of operation were reviewed. Sensors from KaarbonTech were found to be continuously operational, with only four (8%) ceasing operation prior to the end of the trial, one of which had been removed during construction and one is considered likely to have failed due to prolonged flooding. Continuity of data could not be assessed for InTouch, as data files could not be accessed. Some sensors from InTouch had never managed to connect, and others failed during the trial, potentially due to data concentrator failure. Sensors also appeared disturbed following gully cleansing.

Data from KaarbonTech sensors were found to be variable on a datapoint-to-datapoint basis, with significant quantization potentially indicating operational levels within the gully pot. Daily medians indicated seasonal changes and the function of the topologically lower gully as an indicator of increasing liquid levels which propagate up to the next gullies in the network. It is noted that liquid levels may be easier to use if presented as depth to liquid (rather than % full) and presented in the context of depth to outflow. Measured depth to fill level in these sensors was found approximately to correlate to reported depth to fill level. Installations above a road under a rail bridge did not reveal any floods during the period of operation, but sensor readings were confounded by passing cars. Visits to non-operational sensors revealed loss due to persistent water, due to gully replacement and for reasons that could not be discerned.

Data was not provided for sensors from InTouch (has been promised but not received). Analyses based on their dashboard visualisations has been limited. Installation was constrained by requiring nearby powered locations for the data concentrator, which limits device locations. Five of twenty installed sensors were operational at the end of the trial period, indicating 75% ceased to be operational or were never operational. It is inferred that communication connection issues were a significant cause of this. Silt fill level sensors were found to be highly variable, which suggests that they do not consistently represent the conditions in the gully pot. InTouch are not currently in a position to provide a commercially mature service.

The business case for use of sensors in gullies has been examined. At present, costs of sensors are significantly (orders of magnitude) higher than provision of an in-person inspection service, meaning that installation of sensors in all gullies is not a cost-effective proposition. Future changes in technology pricing and reliability may change this in future. At present, gully sensors may be a suitable provision in gullies that are indicator gullies providing evidence of operation of a connected network or similar gullies; or in locations that are hard to inspect in-person. Silt sensing technology has not yet proved commercially mature or reliable, and flood binary sensing provides little information, potentially too late. Depth to surface sensing appears most appropriate for useful and usable information.

It is concluded that sensors in specific selected gullies may be beneficial, and that depth-to-surface sensors that communicate directly are most suitable.

# 2 Introduction

## 2.1 Introduction

This report discusses the potential for sensors to be incorporated into the management of highways gullies. The first section comprises the Executive Summary of the report.

This second section of report describes highway drainage management, including both the physical infrastructure and also the asset management software used to plan and record maintenance of that infrastructure.

The third section describes and reviews four commercially available remote sensors that can be used for gully monitoring with the intention of informing gully management decisions. These are offered by different companies, using Internet-of-Things communication technologies to report gully condition in real-time. This report examines the function of these sensors, and their potential for incorporation into asset-management decision models. Two of these sensors were selected for wider installation and assessment in gullies across Suffolk.

The fourth section details the acquisition of data from these installed sensors, and analyses the data acquired. It explores the information that can be gained from using sensors such as these, and its potential use to the local authority.

The fifth section assesses the financial, social and business case inputs for the potential use of gully sensors across Suffolk.

The sixth section provides overall conclusions and recommendations.

## 2.2 Highway drainage

The highway drainage system is constructed to capture and manage surface water on the highway to prevent or minimise flooding, thus improving road safety, usability and infrastructure longevity. Highway drainage functions include:

- Preventing flooding, ponding and seepage, keeping the vehicle and pedestrian highway free of standing water;
- Directing surface water falling on the highway to the drainage system or surface watercourse quickly;
- Keeping the road structure as dry as possible, to help retain it in good condition;
- Supporting road safety, reducing injury and damage from the hazards caused by surface water;
- Preventing highway surface water from flooding adjacent property;
- Preventing blockages in highway drainage systems.

Highway drainage includes three main infrastructure components introduced in this subsection: gullies, larger infrastructure, and water management.

### 2.2.1 Gullies

A highways gully comprises a ‘gully pot’ (also referred to as a ‘trap’ or ‘drainage pit’) covered by a metal grate, located on the edge of a road. The gully pot separates solid matter from liquids by sedimentation, preventing it from causing blockages in the water drainage pipework; this solid material will include leaves, silt, cigarette butts, dropped litter, and other detritus, some of which is seasonal. The gully pots need to be emptied of this accumulated solid matter to enable them to continue to operate, and to prevent blockages of the drainage system. Emptying gullies when needed prevents blockages in pipework that would require further remedial work (such as jetting). Costs of such remedial work to the infrastructure can be high.

### 2.2.2 Larger structures

The highways drainage network in Suffolk also includes larger structures including soakaways and pumping stations. Soakaways are large, underground, porous structures that enable water to drain into the surrounding ground. They are usually around two to three metres deep and can have plan areas up to 30m by 60m in the larger structures. Approximately a quarter of gullies in Suffolk are understood to empty into soakaways. Soakaways are installed in appropriate geological and hydrogeological settings, to manage water drainage where the gully pot itself cannot buffer and discharge the surface water. Soakaways are not on a regular emptying cycle, and their porous structure will, through time, become less porous with silt deposition, reducing their lifespan. Installation of soakaways is a high fixed cost, quoted at around £250,000 for one recent installation.

Suffolk County Council run between six and ten pumping stations (including three in Bury St Edmunds and two in Kesgrave). A pumping station can cost around £200,000 to construct, and maintenance costs include replacing and repairing pumps. Some systems have telemetry for remote communication of operational issues.

### 2.2.3 Water management

Water drained from the highway and accumulating in the gully pot is directed into the outflow or highway drain, which is the pipe connecting the gully to the receiving water body. This could be the sewage system, soakaway (an underground drainage pit, enabling water to soak into the ground as described above) or surface water body.

## 2.3 Drainage management

### 2.3.1 Purpose of drainage management

Drainage asset and operational management enables the accurate recording of asset locations and structure, of interventions such as cleaning, maintenance and remedial action, and developing a record of observations. This enables a move from cyclical cleansing, where all gullies are emptied on the same regular cycle, to risk-based gully management, where gullies are emptied at different frequencies based on need.

Frequencies for gully emptying can be based on a range of factors, including road type and use, speed and strategic importance in the network, experience of flooding or gully blockage, previous observation of silt filling rate, access, weather, land elevation and other inputs.

### 2.3.2 Management software

There are a number of asset management suppliers, offering software and hardware tools to improve management of the process of gully cleansing. Gully management software can support the move to increase efficiency by changing from cyclical gully cleansing to using a risk-based cleansing approach, inspecting and cleansing gullies at different frequencies depending on need. The various parameters (as described in the previous section) can be applied within management software to produce an optimised cleansing program.

### 2.3.3 Suffolk County Council

Suffolk County Council has approximately 144,000 gullies on highways across the county. This gully network has evolved for more than a century, with some infrastructure in Suffolk dating back to medieval times. The network is not comprehensively mapped, though increased use of new asset management software has enabled systematic accumulation of knowledge about the network.

Suffolk County Council's annual gully maintenance programme includes costs associated with regular maintenance. Water from the gully network drains into surface water where possible, accessing rivers, ditches, into soakaways, or into the Anglian Water network. The solid matter from most gully pots in Suffolk is emptied every one or two years, depending on need. Where appropriate, less frequent emptying is being applied, and in other locations more frequent emptying may be applied.

Suffolk County Council currently use asset management tools from KaarbonTech, and are satisfied with the tools available. These tools include GIS location of gullies, and records of observations made by operatives when cleansing the gullies. These observations include silt levels, by visual inspection, and reported as quarter full, half full, three-quarters full or completely full. Creating this knowledge base enables the identification of gullies that cause problems, or that need emptying more frequently. The KaarbonTech software is used to build up a map and understanding of the network infrastructure and how it operates. This enables a risk-based cleansing strategy to be developed, and priority planning of work, which can reduce need for remedial work.

### 2.3.4 Other Local Authorities

Gully cleaning management processes in different counties are not consistent. Some continue to clean gullies on a standard cycle. Some apply inspections before cleansing to enable maintenance and reduce abortive cleansing visits. Different local authorities have different contract agreements and fees with the contractors undertaking their gully cleansing, maintenance and inspections. Management of these processes is a balance of costs and savings.

### 2.3.5 Management Challenges

Highways drainage management presents a range of challenges. These include:

- Efficiently maintaining records of gully locations, visits, observations and maintenance;
- Efficiently emptying gullies at appropriate frequencies, with sufficient visits to gullies that fill more quickly, and no wasted visits to gullies more frequently than needed;
- Preventing disruption caused by floods and minimising disruption and expense of traffic management. Required frequency varies significantly;
- Traffic management requirements for gully emptying at some locations adds to cost, complexity and scheduling requirements;
- With gullies on a slope (say a group of ten to fifteen on a slope), the most downhill gully will typically be the one to flood.

## 2.4 Sensors

### 2.4.1 Purpose of gully sensors

Gully sensors have been proposed due to their ability to provide an additional source of information, and therefore potentially improve gully cleansing programmes.

This information could be for specific gullies with identified challenges, or for gullies that are considered representative of a larger geographical area with multiple gullies that do not have sensors.

Possibilities for effective use of sensors in gullies:

- Gullies that are in locations requiring more complex traffic management and that have a significant impact on the road network were they to flood, enabling emptying visits to be minimised without being too late to prevent flooding;
- Gullies that are known to be liable to flooding;
- Gullies where a very infrequent emptying could be considered, to enable remote monitoring of conditions.

### 2.4.2 Parameters sensed

The gully sensors considered within this report do not all monitor the same parameters. They monitor a selection of the following parameters, though no sensors monitored all of these:

- Depth to water (or other surface if no water) in the gully;
- Approximate fill level of silt in the gully, at 25%, 50%, 75% and full;
- If the gully is in flood (at the level of a single sensor above the outlet);
- Light level in the gully, indicating if the grate is covered.

Discussions with drainage management indicated that it is not clear which of these parameters would be most useful for operational management decisions.

### 2.4.3 Communications networks

The sensors communicate with online dashboards via Internet-of-Things type technologies. The sensors assessed in this section use different communications technologies, which include:

- 3GPP mobile services, enabling access where mobile network coverage is available;
- LoRaWAN technology, requiring deployment of accessible LoRaWAN gateways;
- Short-range radio or LoRa protocol signals from the gully sensor to a separate communication hub (referred to as ‘data concentrators’ by the supplier), which uses 3GPP mobile for onward communication, this required power.

The accessibility of a communication network is integral to the appropriate selection of gully sensor hardware.

For installation by the project, sensors were selected that use 3GPP mobile services direct from the sensor, and that use LoRa signals from the sensor to a dedicated communications hub (‘data concentrator’), with 3GPP mobile onward communication.

# 3 Specific sensors

## 3.1 Introduction

This section of the report details four available gully sensors. These sensors are provided by different companies and operate in different ways, as a comparison of the range of products available in the market. This includes discussion of how the sensors function, how the suppliers provide information, and how they operate.

## 3.2 KaarbonTech

### 3.2.1 Introduction

KaarbonTech are the current supplier of drainage asset management to Suffolk County Council. Suffolk Highways (within Suffolk County Council) have been building their asset knowledge through the system and are using the risk strategy to inform planning. KaarbonTech have very recently added sensors to their offering, and Suffolk County Council were pleased to trial these sensors. As part of the project, KaarbonTech integrated these sensors with their asset management platform, as well as providing separate dashboard access to the sensor data (Section 4.2.2)

### 3.2.2 Sensor hardware

The sensor provided by KaarbonTech is the Farsite Liquinet (understood to be identical to the Farsite Netbin nPod sensor) which measures depth to water level (or other surface) in the gully.  Vendor documentation is included in a digital archive for this report. The sensor is pictured in Figure 1. Its dimensions are approximately 140mm x 122mm x 46mm, and it has a rotatable sensor housing.


*Figure 1: Farsite liquinet, image from [https://iot.farsite.com/products/liquinet-flood-sensors/](https://iot.farsite.com/products/liquinet-flood-sensors/) 02/04/2020*

The sensor measures depth to a surface (in the case of a gully, depth to water), using twin 40KHz ultrasonic sensors, with a reported depth range of 0.03m to 4.0m, and accuracy of ±0.02m. The sensor does not measure flood, light levels or silt depth.

The sensor attaches to the gully grate using two M6 security bolts into the grate metal. The maneuverable sensor housing indicates that it could potentially be mounted on the gully wall, and the sensors angled through 90° to direct them onto the water surface.

The sensor is IP67 rated, indicating that it is dust-tight, with temporary protection against immersion (tested for 30 minutes at 1m water depth).

The sensor uses a Lithium Thionyl Chloride battery, and claims a ten year life based on two updates per day.

#### 3.2.3 Sensor communication

The Farsite Liquinet sensor communicates using 3GPP mobile standards, supporting GPRS(2G), 3G, LTE Cat-M1 and NB-IoT (NB1). These technologies could be anticipated to cover most of Suffolk, with some not-spots (see Section 3.7.3).

The sensor does not support any other network technologies.

#### 3.2.4 Approvals, standards and compliance

The Farsite Liquinet sensor cites the following approvals and compliance by initials in its datasheet. Abbreviations have been extended and explained for this report:

- CE: European Economic Area certification for products conforming with relevant health, safety and environmental protection standards. This would be expected to include electrical safety, radio safety, radio emissions and accepted interference, safe use and operation.
- FCC: United States Federal Communications Commission Declaration of Conformity. This certifies that electromagnetic interference from the device is within approved limits.
- RoHS2: European Union Restriction of Hazardous Substances directive 2. This restricts the use of specified substances, restricting the material content of new electronic equipment sold in the European Union, including proscribing the use of lead-based solders.
- REACH: European Union Registration, Evaluation, Authorisation and Restriction of Chemicals. This regulates the production and use of chemical substances.
- WEEE: European Union Waste Electrical and Electronic Equipment Directive sets collection, recycling and recovery targets for electrical goods.

#### 3.2.5 Sensor dashboard and data

Farsite and KaarbonTech have developed an online hub management platform for the Liquinet sensors, which provides current and historic water levels and enables configuration of sensors and alerts.

KaarbonTech also offer their “Gully Smart” gully management software, currently used by Suffolk County Council. Each gully asset is given risk and vulnerability scores, based on the user’s system data and questions, with parameters weighted by the user. This can be done for individual gullies, or gullies grouped geographically by road section. Scoring is provided for vulnerability (likelihood of failure) and importance (importance of location in highways network), which can be viewed separately and combined. Sensor outputs are not currently integrated as an input parameter within the management software. These can be compared with the whole asset collection. Changes in these scores can be tracked. Incomplete data can be estimated. Cleaning cycle lengths can be applied based on risk, and used to calculate number of cleans per annum, and budget. Cycle lengths can be set and adjusted based on the risk matrix.

### 3.3 Danalto

#### 3.3.1 Introduction

Lucy Zodion proposed the Danalto Gully Spy sensor to the Smarter Suffolk project, as part of their Ki Smart City offering. The sensor has an independent dashboard, but, unlike the other sensors discussed in this report, is not associated with a gully or drainage asset management package. Danalto are a Dublin-based Internet of Things company. The Danalto Gully Spy sensor was installed at Adastral Park, but data was not available from this sensor during the project.

### 3.3.2 Sensor hardware

The Danalto Gully Spy is a small (92x63x48mm) overflow sensor, using a capacitive sensor to identify flood conditions. Vendor documentation is included in a digital archive for this report. It is shown in Figure 2.

*Figure 2: Danalto Gully Spy fitted to a gully at Adastral Park. Photo H Steventon*

The sensor monitors for flood incidents (presence or absence of submersion of the capacitive sensor). The sensor does not measure water level, light levels or silt depth.

The sensor is quickly attached to the gully grate by two metal ball-lock cable-ties (recommended are HellermanTyton MBT14HS ties) to the gully grate. The sensor should be attached in the centre of the grate.

The sensor body is IP67 rated, indicating that it is dust-tight, with temporary protection against immersion (tested for 30 minutes at 1m water depth).

A lifespan of up to 8 years, subject to configuration, is claimed.

### 3.3.3 Sensor communication

The Danalto Gully Spy sensor communicates using LoRaWAN v.1.0.2 using Over The Air Authentication.  This would require coverage from a LoRa network to communicate with the device.

### 3.3.4 Approvals, standards and compliance

The Danalto Gully Spy sensor claims to conform to the following standards in its datasheet. Abbreviations have been extended and explained for this report.

- EN300-220: European Standard on electromagnetic compatibility and radio spectrum matters

- EN301-489: European Standard on electromagnetic compatibility for radio equipment and services
- EN60950: Information Technology Equipment – Safety.

### 3.3.5 Sensor dashboard and data

The Danalto Gully Spy is not currently integrated into wider gully management software. It has a configurable alert and notification service, enabling a range of messaging services (including SMS, email and other platforms) for emergency flood alerts and remote monitoring. It is not supported by predictive or modelling software: reports of floods represent incidents in progress.

## 3.4 InTouch SmartWater

### 3.4.1 Introduction

InTouch describe themselves as “an innovation catalyst”, who have developed SmartWater gully cleansing and drainage information gathering with Transport Systems (now Connected Places) Catapult funding. The SmartWater model takes input from a number of sources, including their sensor data, traffic count, topography and weather predictions. Like other providers, they are not clear on how to best locate and integrate sensors. The InTouch SmartWater Smart Gully Probe is being assessed within this project.

### 3.4.2 Sensor hardware

The InTouch SmartWater Smart Gully probe measures silt levels and light levels and incorporates a flood sensor. The probe comprises a sensor body joined to the transmitter head by a short cable. The transmitter head transmits to a repeater and data concentrator unit, discussed in Section 3.4.3. Vendor documentation is included in a digital archive for this report. The sensors are shown in Figure 3; sensors can be provided in a range of lengths from 250mm to 1000mm. The silt sensor is in the probe, and the light and flood sensors in the transmitter head.

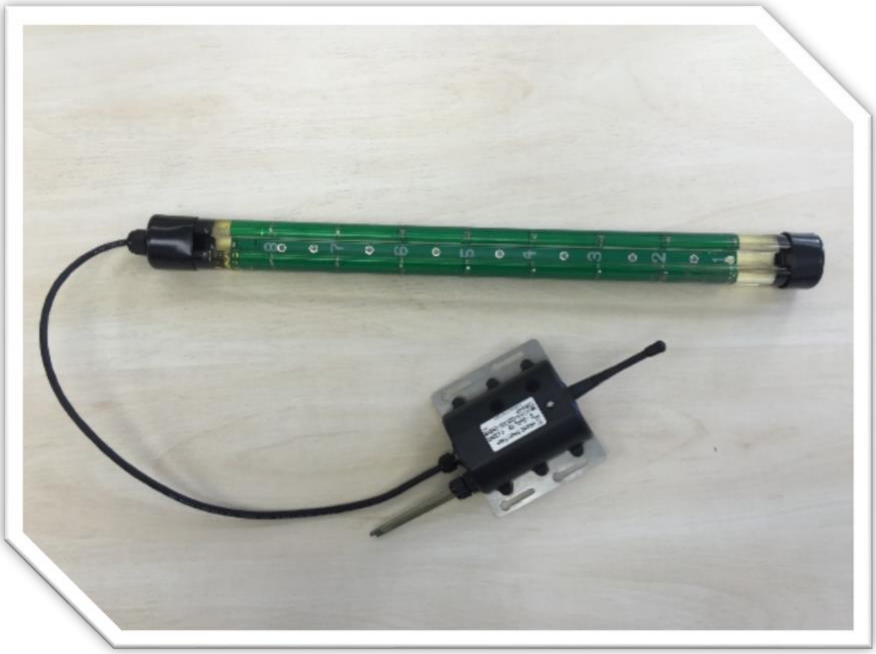


*Figure 3: InTouch SmartWater Gully Smart sensor*

The sensor measures depth of silt using LEDs and light dependent resistors as sensors along its length: increasing turbidity from rising silt levels will block the light from the LED from being received by the sensors and thus indicate the depth of silt in the gully. It claims 70% accuracy.

The sensor does not measure depth to or height of water in the gully.

The sensor attaches to the gully wall using screws, or to a metal bar secured under the grate, or an expanding tension bar across the gully.

The sensor is IP68 rated, indicating that it is dust-tight, and suitable for continuous immersion in water.

The separate data concentrator is designed to be mounted on street furniture, from which it needs to be powered. It is IP66 rated, indicating that it is dust-tight and resistant to jets of water. It can be attached using stainless steel banding straps.

#### 3.4.3 Sensor communication

The InTouch SmartWater sensor has two-part hardware, with in-gully sensors communicating to a local, powered data concentrator via licence-free UHF (868-870MHz) radio transmission. The data concentrator could be up to 2.5m from the transmitter head.

The data concentrator receives signals from the transmitter head of the probe. It transmits using GPRS or LAN, and has an optional USB interface. It contains an 8GB microSD card as internal memory.

#### 3.4.4 Approvals, standards and compliance

The InTouch SmartWater Gully Smart sensor does not list any standards or compliance on its documentation. An approach to the manufacturer is being made to ascertain if it is certified to any specific standards.

#### 3.4.5 Sensor dashboard and data

The InTouch SmartWater drainage management service includes asset inventory management, forecasting of condition using a combination of inputs including inspection, modelling, weather, topography, silt-level, and live input from sensors. This should support a risk-based approach to gully management, targeting resources, based on a machine-learning, predictive model.

The current InTouch dashboard is not currently end-user friendly.

### 3.5 Map16

#### 3.5.1 Introduction

Map16 are a supplier of risk-based drainage asset management. They offer two different gully sensors. They claim that their sensors were designed to be as low cost as possible to enable larger deployments.

#### 3.5.2 Sensor hardware

They refer to their two sensors as their “gully sensor” and “ultra sonic sewer sensor”. These are discussed below. Vendor documentation is included in a digital archive for this report.

Map16 Gully Sensor detects water levels in the gully pot using a number (usually three) of float switches positioned to detect water at 25% full, 50% full and outfall level. It is described as measuring “empty, low, blocked at connection, and high”. Map16 claim that modelling within their software can calculate silt level based on the water level, using previous observations, weather data and local knowledge. This sensor is pictured in Figure 4; it is approximately 122mm x 122mm x 114mm in size with attached probe with float switches. The sensor does not measure above outfall flood, light levels or precise depth to water in the gully. It is described as requiring no calibration or adjustments, as the sensor depths are determined at installation.

*Figure 4: Map16 gully sensor, image from data sheet*

The Map16 ultra sonic sewer sensor measures depth to water in the sewer. The sensor is pictured in Figure 5, it is approximately 122mm x 122mm x 114mm in size, with a protruding conical cover for the sensor housing. The sensor does not measure flood, light levels or silt levels.

*Figure 5: Map16 sewer sensors, image from data sheet*

The gully sensor attaches to the gully wall using screws into the gully wall. Installation is described as 'quick and easy' in less than 15 minutes, using 'high grade 216 stainless steel mounting hardware'. The ultrasonic sewer sensor is mounted to the sewer cover, using industrial grade neodymium rare earth magnets.

The gully sensor and the sewer sensor are both IP68 rated, indicating that they are dust-tight, and suitable for continuous immersion in water.

A lifespan of over 5 years is claimed, using 3xAA Energizer Ultimate Lithium Batteries in the gully sensor and lithium-thionyl chloride battery in the sewer sensor. These are not designed to be user serviceable.

#### 3.5.3 Sensor communication

The Map16 gully sensor communicates on LoRaWAN 868MHz (European frequency), using OTAA (Over The Air Authentication) or ABP (activation by personalisation); they state that they apply ADR (adaptive data rate). It communicates on a 10 minute interval. Map16 usually install their own LoRa gateways to provide the network, using 3G or 4G backhaul.

The ultrasonic depth sensor communicates using 4G /3G data.

#### 3.5.4 Approvals, standards and compliance

The Map16 LoRa gully sensor claims the following communication certification for the radio module.

- European RED Certified Radio Module: The European Radio Equipment Directive sets requirements for health and safety, electromagnetic compatibility, efficient use of the radio spectrum, and interoperability, and provides a basis for governing privacy, data, and fraud.

#### 3.5.5 Sensor dashboard and data

Map16 provides asset management with mobile collection, web dashboards of asset and sensor outputs, and a risk-based drainage management solution. They can integrate a range of risk data, including Environment Agency flood data, silt levels, elevation models and insurance claims. Existing clients have commented on Map16's ability to incorporate additional data, such as topography or historical, disorganised gully monitoring records.

### 3.6 Comparison of Sensors

Details from the preceding section are summarised in Table 1, including parameters measured, size of the hardware, its IP rating, network requirements and data representation.

| | KaarbonTech | Danalto | InTouch | Map16 gully | Map16 sewer |
|---|---|---|---|---|---|
| Parameters | Depth to surface | Flood or not flood | Silt depth Light level | Water at 3 levels | Depth to water |
| Size (mm) | 140x122x46 | 92x63x48 | tbc | 122x122x114 plus detector | |
| IP rating | IP67 | IP67 | IP68 | IP68 | IP68 |
| Network | 3GPP: GPRS(2G), 3G, LTE Cat-M1 NB-IoT (NB1) | LoRaWAN | UHF to second-part data concentrator, then GPRS | LoRaWAN | 4G or 3G data |
| Dashboard | Online platform from Farsite | Online dashboard | Dashboard under development | Online dashboard | Online dashboard |
| Battery type | Lithium Thionyl Chloride | tbc | tbc | 3xAA Energizer Ultimate Lithium | lithium-thionyl chloride |
| Cited lifespan | 10 yrs | 8 years | tbc | > 5 years | > 5 years |

*Table 1 Comparative Summary of gully sensor hardware*

## 3.7 Initial evaluation

### 3.7.1 Ingress Protection Ratings

Two of the sensors have an IP67 rating, which is a lower liquid ingress protection rating than the other gully sensors discussed in this report. IP67 would be considered to make these sensors vulnerable to failure in a gully flood. Drainage experts consider that for in-gully installation, IP68 rating would be more appropriate. This potential concern is applicable to sensors from KaarbonTech / Farsite, and from Danalto, and is assessed in Section 4.2.3, where it was not found to have been problematic during the course of this project.

### 3.7.2 Size and physical structure

Larger sensors, and those with a protruding aerial, might be considered to be more vulnerable to damage during the gully cleansing process. This potential concern is applicable to sensors from InTouch and Map16.
Some people have commented on seeing these products that their physical structure (including the cables and antennae) appear more vulnerable to physical damage from the harsh gully environment and from cleansing operatives.
This potential concern has been assessed during the project, with sensors appearing disturbed in location though operational on visits following gully cleansing.

### 3.7.3 Communications

Sensors accessing mobile data services (ie GPRS/3G/4G or NB-IoT) would need to be installed in a location with adequate mobile coverage, but this would not be expected to provide a significant geographical constraint in most areas. The location of the gully sensor underground beneath a heavy iron grate may be problematic in rural areas in which coverage is marginal.
Sensors requiring LoRaWAN are dependent on the provision and maintenance of the LoRa gateways and network, which may be provided by local authority, sensor provider or a third party.

The InTouch sensor has a two-part installation which could give rise to concerns. Putting the radio above ground level helps with wireless WAN coverage, but also doubles the number of components to install/maintain/manage. An above-ground location will be more vulnerable to vandalism. A limited distance from the in-gully transmitter head suggests this can't be mounted very high up a lighting column unless the column is immediately adjacent to the gully, and limits potential sensor locations to those within a small radius of a powered source for the data concentrator.

A separate, non-thematic report has been provided to discuss infrastructure communications options in more detail (Steventon, 2021).

### 3.8 Measurements

It is remarked that these sensors do not measure the same parameters or provide the same information. Highways drainage domain experts within Suffolk County Council, and with suppliers, need to consider which parameters are likely to be of most use to the local authorities.

# 4 Assessment of Data

## 4.1 Data Sources and Acquisition

Data from the installed sensors have been analysed, and are discussed in this section.

Data used in the analysis were obtained from the following sources:

- KaarbonTech data was downloaded as CSV files from the sensor-specific KaarbonTech branded dashboard, developed by Farsite. This data was not available on the BT Data Exchange.
- InTouch visualisations from their dashboard have been assessed in this report; they have stated that further data will be provided as emailed csv files, but it was not received in time for inclusion in this report.

Data from KaarbonTech sensors were assessed using the Python programming language in interface Jupyter Notebooks, using two key libraries: pandas to structure dataframes and matplotlib for graphical presentations. Data were assessed for continuity of operation, which is presented in Section 4.2.3 and 4.2.6. Data were also assessed for information gathered for use in highways drainage management, as presented in Section 4.2.4 and 4.2.5

## 4.2 KaarbonTech sensor data

### 4.2.1 Installation and data access

Installation locations were selected by Suffolk County Council Highways Drainage experts in collaboration with asset management supplier KaarbonTech. Forty-eight sensors were installed across three sub-locations:

- Bury St Edmunds, 25 sensors in gullies installed on 23 June to 7 July 2021
- Needham Market, 7 sensors in gullies, 2 under a bridge, installed on 16 June 2021
- Stanton, 14 sensors in gullies installed on 23 June 2021

All data for all sensors was examined visually on the KaarbonTech branded dashboard, developed by Farsite, on 20/12/2021. This dashboard provides "at a glance" visualisation of each sub-location as a map and a list, further data for each sensor, and more detailed data available for download via their "Export Data" function.

Data was acquired for this analysis by downloading as csv files. Data from these sensors was not available on the Smarter Suffolk BT Data Exchange. The following data was selected for download and further analysis:

- Needham Market sub-location, including Needham Market High Street (Section 4.2.4) and Coddenham Road Bridge (Section 4.2.5).
- Four sensors that were identified as non-operational (Section 4.2.6).

The acquired csv files were imported into and assessed using programming software Python in Integrated Development Environment Jupyter Notebooks, Anaconda Distribution. Two key libraries used for the data analysis were pandas, to structure and manipulate data, and matplotlib for graphical presentations.

### 4.2.2 Dashboard

As described in Section 4.2.1, KaarbonTech provide a sensor-specific branded dashboard, developed by Farsite. This dashboard provides "at a glance" visualisation of each sub-location as a map and a list, further data for each sensor, and more detailed data available for download via their "Export Data" function. They also include fill level data for each sensor for the latest period (72 hours, 7 days, 14 days or 90 days), and rainfall data sourced from the Environment Agency's closest rainfall gauge, as visualisations in KaarbonTech's drainage Asset Management software, used by Suffolk County Council and widely used by other local authorities.

Screenshots for the same sensor for each of these is included in Figure 6 and Figure 7 below.

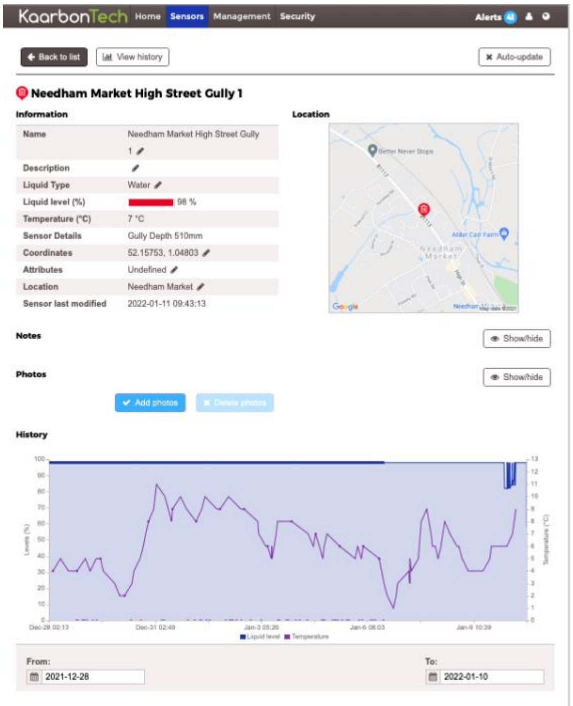



*Figure 6: Screenshot from KaarbonTech's sensor-specific dashboard*

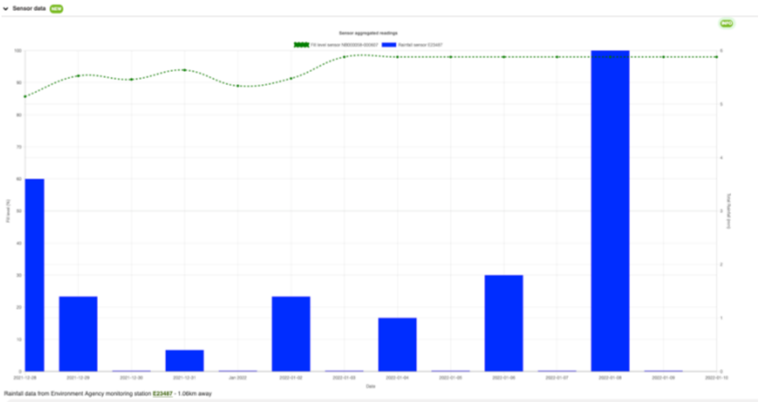


*Figure 7: Screenshot of sensor data from KaarbonTech's Asset Management Platform*

### 4.2.3 Reliability

Analysis of length of gap (greater than 120 minutes) during the operational period has been undertaken, which indicates the following:

| Location | No of data points | No of gaps > 2 hrs | Longest gap in data |
|---|---|---|---|
| Coddenham Bridge 1 | 18378 | 8 | 5hr 15 min |
| Coddenham Bridge 2 | 18807 | 0 | - |
| Needham Market High Street Gully 1 | 18918 | 0 | - |
| Needham Market High Street Gully 2 | 18965 | 0 | - |
| Needham Market High Street Gully 3 | 19359 | 1 | 2hr 15min |
| Needham Market High Street Gully 4 | 19047 | 1 | 2hr 45min |
| Needham Market High Street Gully 5 | 18881 | 1 | 2hr 15min |
| Needham Market High Street Gully 6 | 18869 | 0 | - |
| Needham Market High Street Gully 7 | 18959 | 0 | - |

*Table 2: Gaps in data during the 6 months analysed, KaarbonTech gully sensors, Needham Market*

Only six months of data have been analysed in this gaps analysis, which is the period of data available to date (from installation to data extraction). Given that caveat, the sensor communication is considered robust, with many sensors without any significant gaps, and those that have gaps in data regaining coverage quickly. In the context of other sensors assessed through the Smarter Suffolk project from other themes, the continuity of data can be considered comparatively reliable. For the use case of gully monitoring, very occasional gaps of only a few hours would not be generally considered problematic.

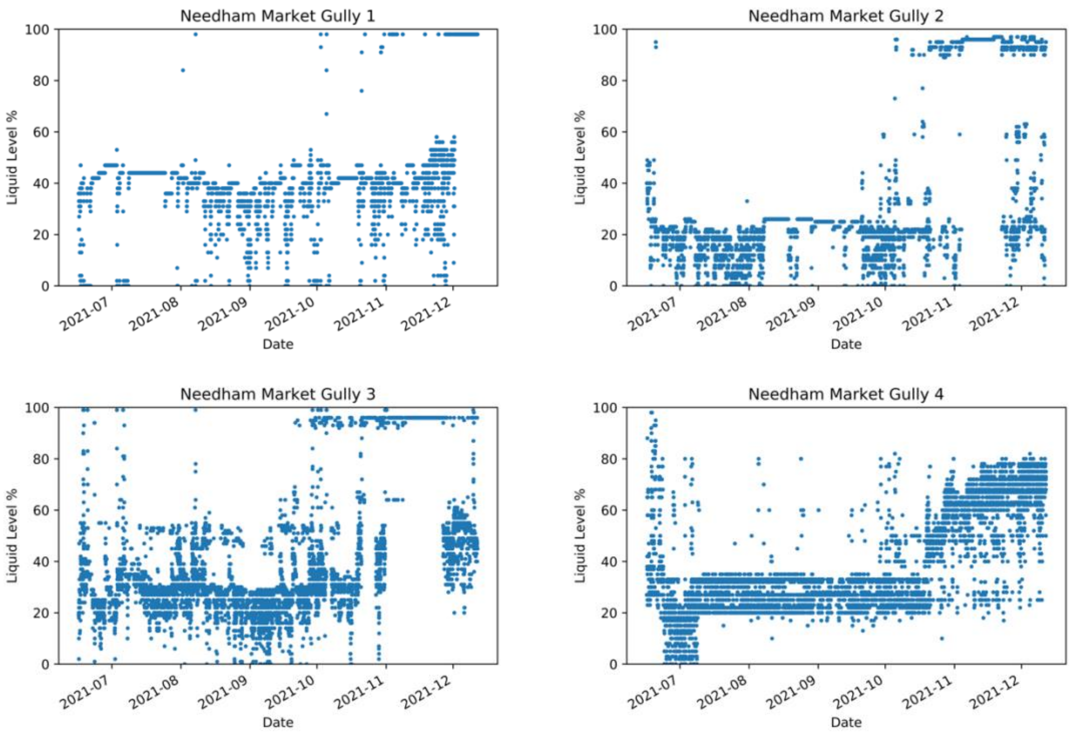
Outside the Needham Market sub-location, four of the 48 sensors installed have ceased operating during the six months of analysis. These are discussed further in Section 4.2.6.

### 4.2.4 Needham Market High Street

Seven sensors were installed on High Street, Needham Market, at locations selected by SCC drainage team. These locations are shown in Figure 8, using data from KaarbonTech Asset Management System to resolve discrepancies in the two dashboards.


*Figure 8: Locations of KaarbonTech Gully Sensors, Needham Market. Gully locations indicated with red circles and numbers (Base image from KaarbonTech Asset Management software, annotated by H Steventon based on data from KaarbonTech Asset Management System and KaarbonTech Liquismart dashboard). Photo: Open drain receiving water from this drainage network (photo: H Steventon)*

Data from these sensors was extracted and analysed for potential to indicate water on the road. Data is reported as a percentage that the gully is “full”.
A set of timeseries plots of this data for the period under analysis has been created, and is included in Figure 9. These are presented as scatterplots due to the complexity of including a line.



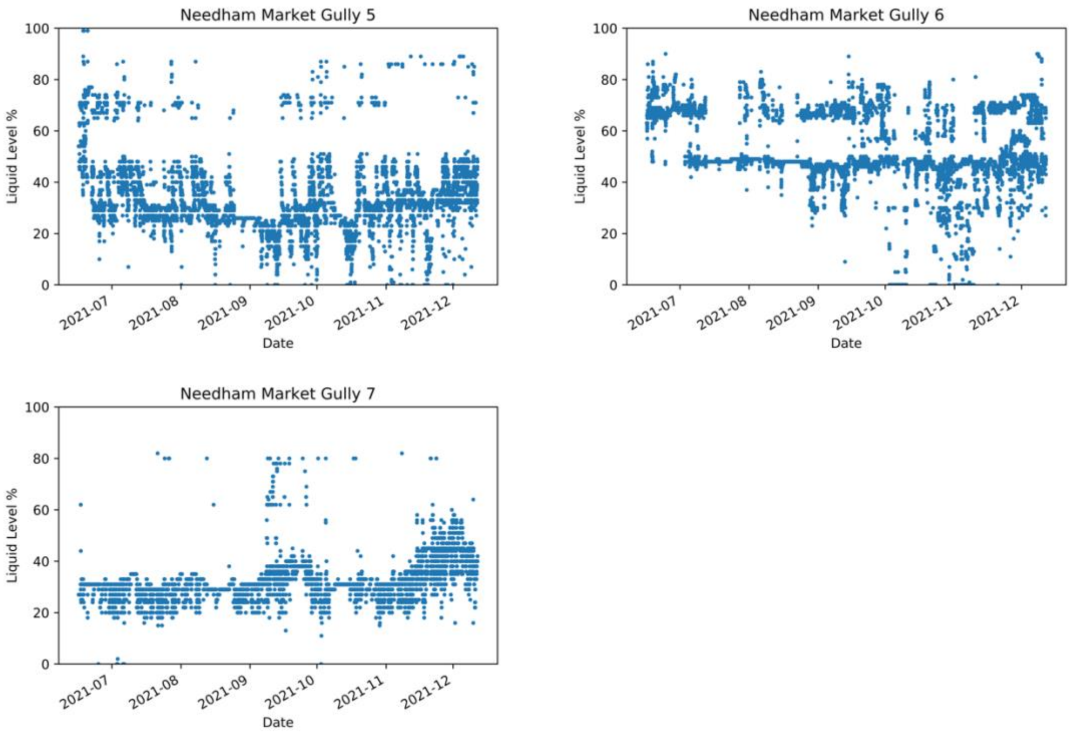



*Figure 9: Timeseries plots of fill level in gullies in Needham Market*

Observations from these plots include quantisation of the data, indicating the various operational levels of the gully pot, including the bottom and top of the outflow pipe, and sensor level at close to ground level when 100% full. It is also considered that some values (especially those below the outflow pipe, which are unlikely to occur, except in long periods of hot dry weather with little input and potential for evaporation) may represent echoes of the ultrasonic measuring beam rather than true depths of surface.

The sensors report fill level every 15 minutes, producing some variation during the day, with input and outflow patterns, and occasional errant reading, from ultrasonic echo or from debris entering the gully chamber. An example of this daily variability is from Gully 6 on the 02/10/21, as shown in Figure 10 below.

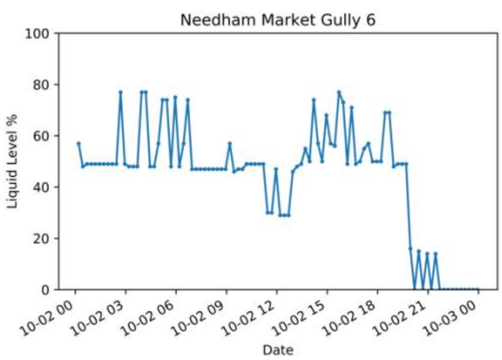



*Figure 10: Reported fill levels in Gully 6, 02/10/2021*

To smooth these daily variations, and examine the longer-term functioning of the gully during the autumn season, data for each gully was examined based on statistics for each day. For each day, the mean fill level, together with the interquartile range (25% - 75%) and 10%

to 90% range, has been calculated for the data. The results of this analysis are shown in Figure 11 to Figure 17 below.

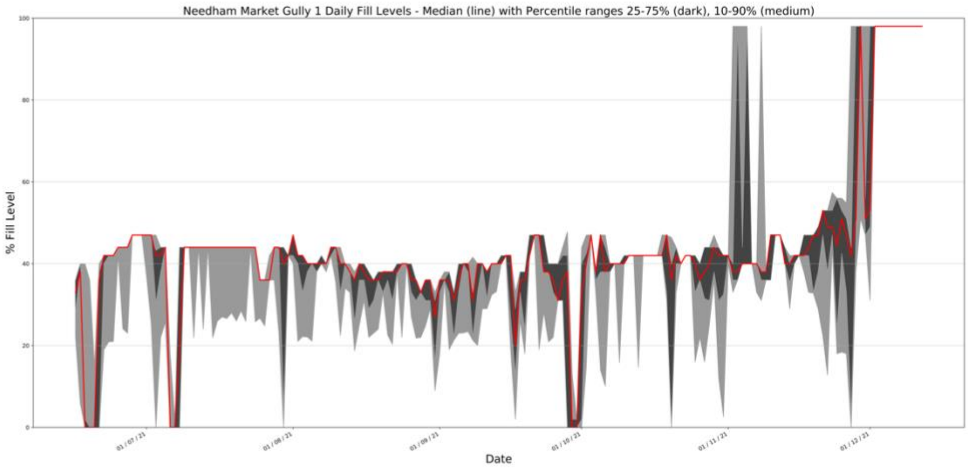



*Figure 11: Needham Market Gully 1 Daily Fill Levels - Median (line) with Percentile ranges 25-75% (dark), 10-90% (medium)*

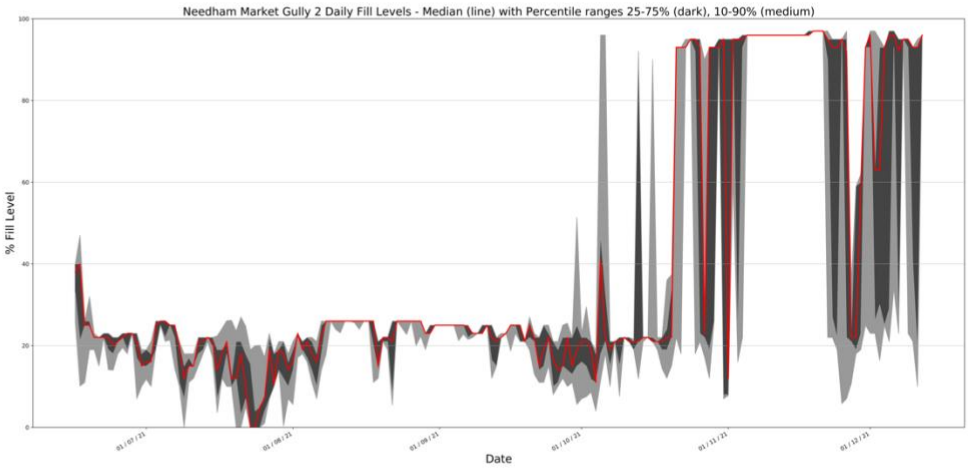



*Figure 12: Needham Market Gully 2 Daily Fill Levels - Median (line) with Percentile ranges 25-75% (dark), 10-90% (medium)*

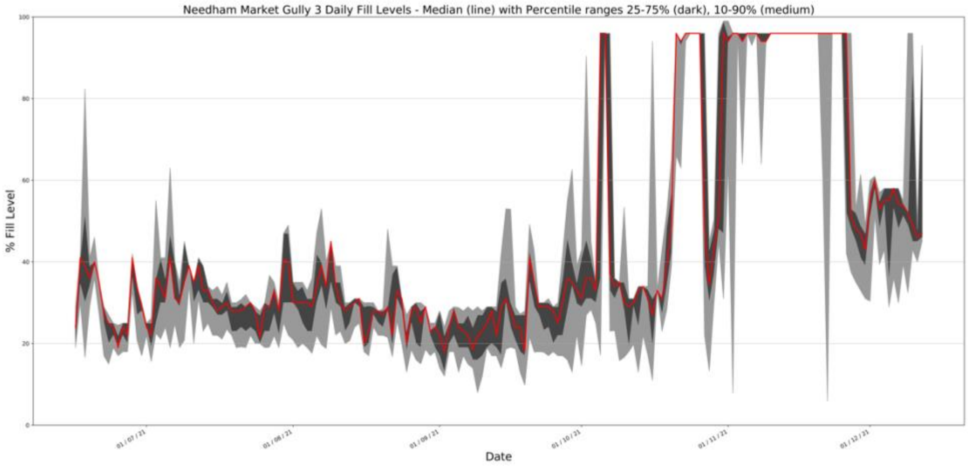



*Figure 13: Needham Market Gully 3 Daily Fill Levels - Median (line) with Percentile ranges 25-75% (dark), 10-90% (medium)*

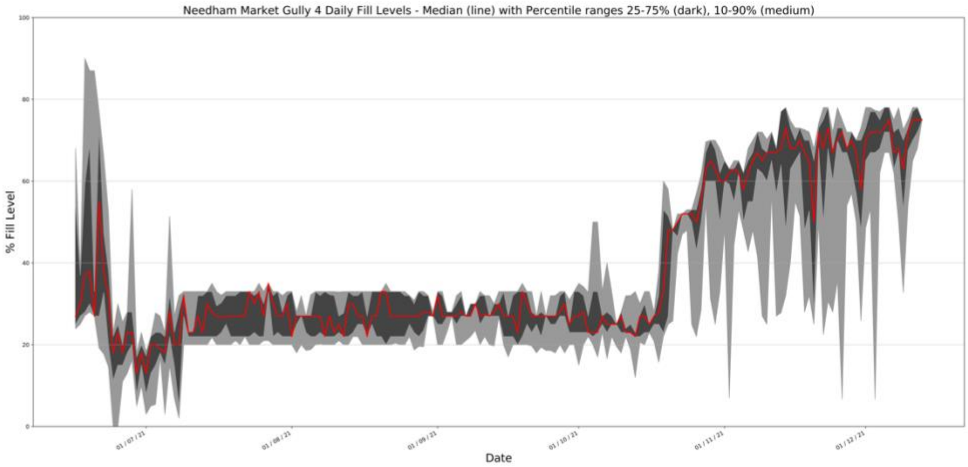



*Figure 14: Needham Market Gully 4 Daily Fill Levels - Median (line) with Percentile ranges 25-75% (dark), 10-90% (medium)*

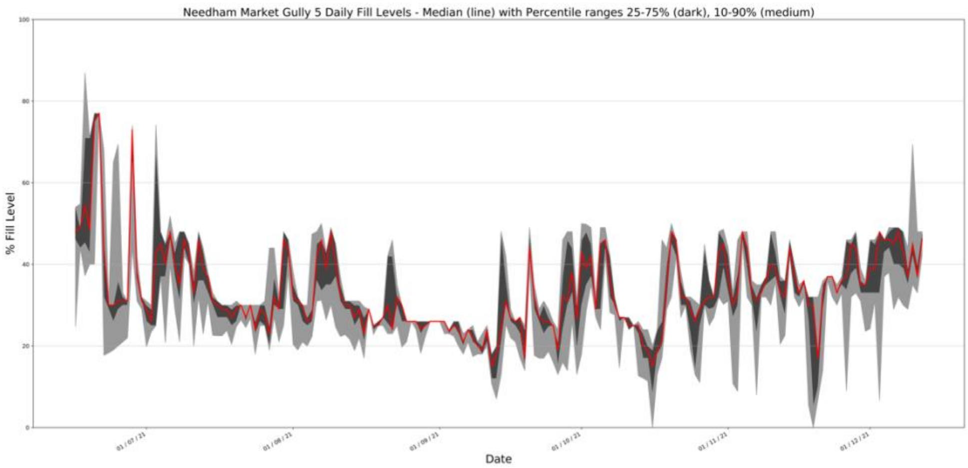



*Figure 15: Needham Market Gully 5 Daily Fill Levels - Median (line) with Percentile ranges 25-75% (dark), 10-90% (medium)*

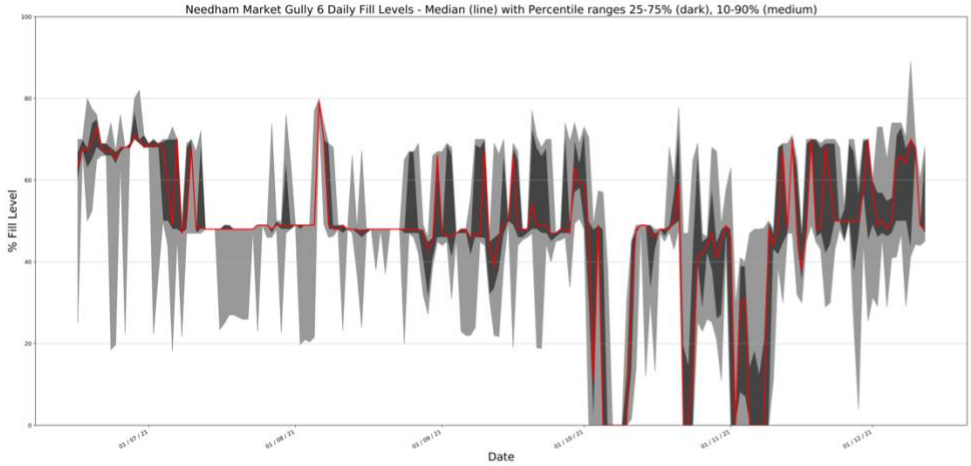



*Figure 16: Needham Market Gully 6 Daily Fill Levels - Median (line) with Percentile ranges 25-75% (dark), 10-90% (medium)*

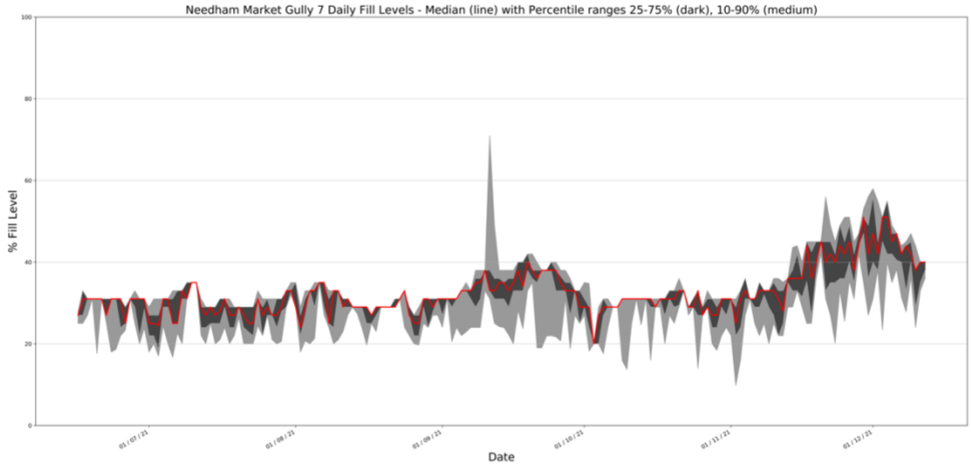



*Figure 17: Needham Market Gully 7 Daily Fill Levels - Median (line) with Percentile ranges 25-75% (dark), 10-90% (medium)*

Considering the flow direction from the gullies (as shown on Figure 8), drainage flows from Gully 7 and above, and Gully 6, partially into Gully 5; drainage from Gully 5 flows to Gully 4 to Gully 3 to Gully 2, from where it discharges into the open drain along Willow Walk (Figure 8). The mean fill depths in these gullies have been compared, and are shown in Figure 18 as both percentage fill and depth of fill.

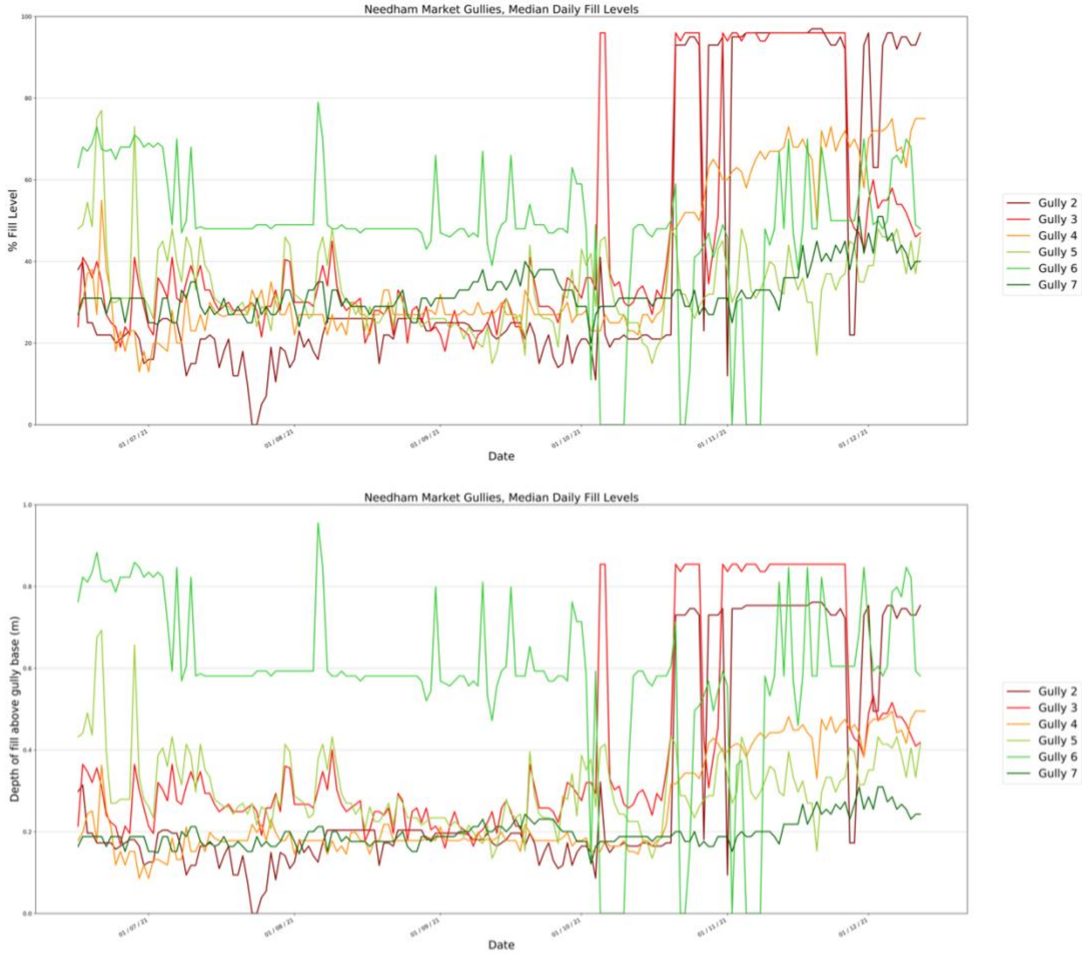



*Figure 18: Median fill levels from north-west gullies, as percentage fill and depth of fill*

From these plots, it can be seen that fill level in the gullies was generally within the gully pot during the summer period. Gully 3 first was shown as completely full during the period 5-7 October 2021, but levels fell again subsequently. During the later autumn period, fill levels in these gullies increased, with gullies 2 and 3 becoming completely full on 21/10/21. The impact of this can be seen in Gully 4, which has rising levels following this, though does not become full during the period of analysis. Increasing levels can also be seen in the other gullies upstream.

Similarly, Gully 1 drains into Gully 2, and the median fill levels in these two gullies can be compared (Figure 19). Again, increasing fill levels in Gully 2 (at the base of the drainage system) to full on 21/10/21, were followed by a rise in fill level in Gully 1, which became full on 11/12/21.

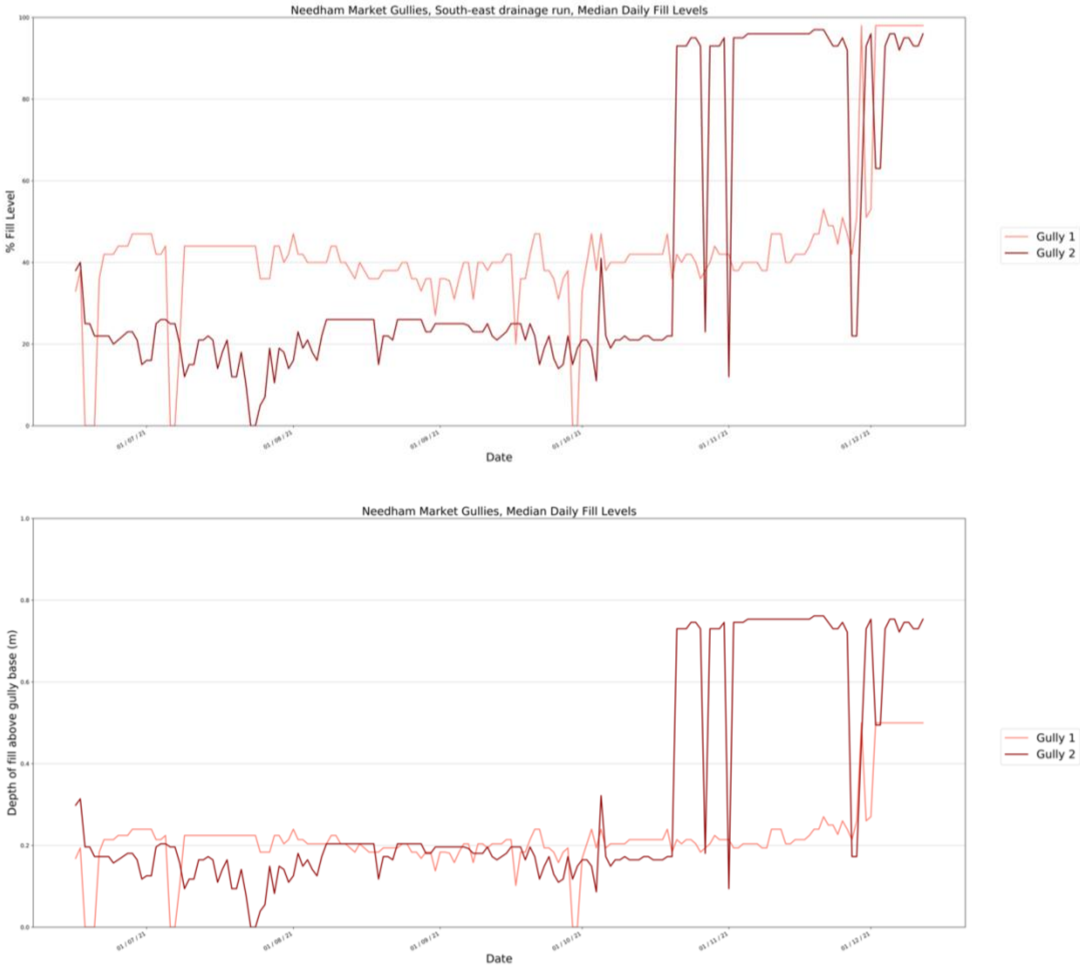



*Figure 19: Median fill levels from south-east gullies, as percentage fill and depth of fill*

As can be seen in Figure 20, the drainage from this system discharges a group of at least 17 gullies to the north-west of the drainage point, and at least 5 gullies to the south-east of the drainage point, as well as the four gullies at the drainage point. This suggests a total of at least 26 gullies draining through this part of the system. Analysis of fill levels from the sensors installed in gullies in this system indicates that fill levels at gullies in the base of the system can provide usable information for the drainage system, and early indication of growing issues. A suitably located single sensor could indicate operational status for the overall system in general, though not identifying single upstream gullies that have individual blockage issues. This would make the use of sensors in gully management more cost-effective.

*Figure 20: Drainage system drained to the north-west and south-east of the drainage point. Images from SCC's KaarbonTech Asset Management System*

Depth to water level was measured during a site visit (14/01/22). Using the depth to base reported on the KaarbonTech dashboard, this was converted into a measured percentage full, to compare with reported percentage full as reported on the dashboard for the same time. This is shown in Figure 21. This indicates that for these sensors, reported fill levels do appear to increase with measured fill levels, but indicate a higher reported % full than measured in two sensors. It is considered possible that these sensors are detecting the sides or debris in the gully pot. Other uses of these sensors have, on inspection, indicated greater variability between measured and reported data.

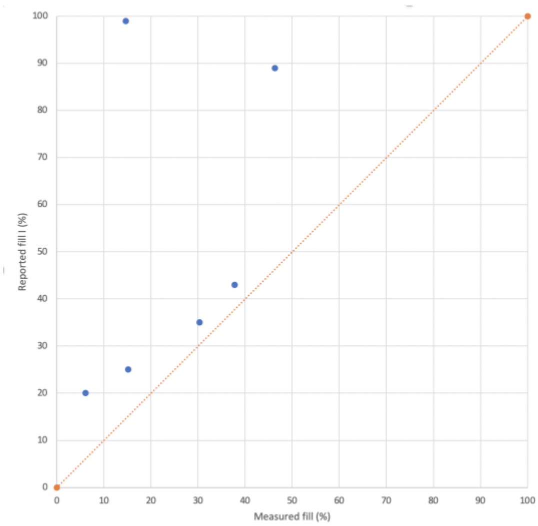


*Figure 21: Comparison of measured and reported depth of fill*

### 4.2.5 Coddenham Road Bridge

Two sensors were installed under Coddenham Bridge, which carries a railway above a road, and is a known location of occasional flooding relating to weather and drainage. These sensors were installed at a height of 194cm (reported in the online dashboard and downloaded data) as shown in photographs in Figure 22 and Figure 23.

*Figure 22: Sensors installed on Coddenham Road Bridge (photographs: H Steventon)*
*Image on the left shows CRB2 on the left, CRB1 on the right*
*Image on the right shows potential for car to trigger distance measurement*

Context for the road location through the bridge is included in Figure 23 to show the double bend on which this bridge is located.

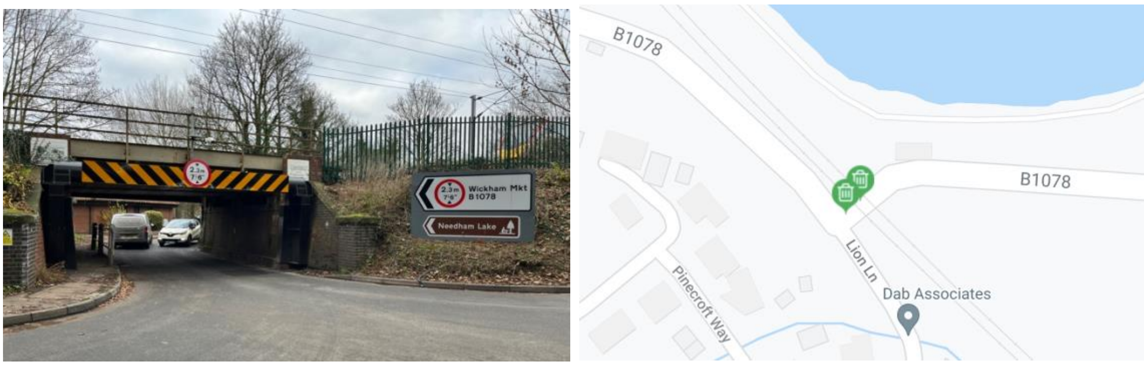



*Figure 23: Road location for sensors under Coddenham Road Bridge (photo: H Steventon, map from KaarbonTech dashboard)*

Data from these sensors was extracted and analysed for potential to indicate water on the road. Data is reported as a percentage "full", due to the primary use of these sensors (in bins and gullies). Assuming that the reported depth to base below sensor of 194cm is used as 100% full, the percentage full has been converted to height of surface above ground level.

Almost all (over 98%) datapoints were zero, indicating that there is nothing above the ground level at these times (Table 3).

| Sensor | Number of measurements | Number of non-zero measurements | Percent of non-zero measurements |
|---|---|---|---|
| CRB1 | 16811 | 315 | 1.87 |
| CRB2 | 17140 | 250 | 1.46 |

*Table 3: Number and proportion of non-zero measurements at Coddenham Road Bridge*

These non-zero values ranged between 1% and 70%, indicating a surface reflecting the ultrasonic beam at a height of between 0.02m and 1.36m above ground level (Table 4).

| Sensor | Minimum | | Mean | | Maximum | |
|---|---|---|---|---|---|---|
| | % | m | % | m | % | m |
| CRB1 | 1 | 0.02 | 24.3 | 0.47 | 70 | 1.36 |
| CRB2 | 1 | 0.02 | 26.0 | 0.50 | 67 | 1.30 |

*Table 4: Range of non-zero measurements at Coddenham Road Bridge*

The range of values and their times of measurement are shown in Figure 24 and indicate a relatively consistent range of values through the six month period of analysis.

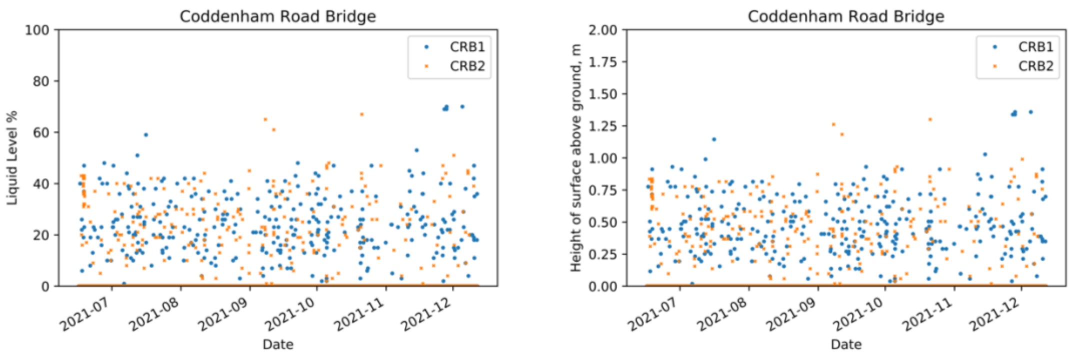



*Figure 24: Apparent fill level as given (% liquid level) and converted to height of surface above ground level (m)*

The majority of non-zero values are individual values, with values of zero before and after the non-zero value. Measurements are made at 15 minute intervals. It is considered likely that these individual non-zero values represent the ultrasonic signal for the measurement being reflected from a passing car or other item (such as wind-blown leaves or litter, or moving animals). There is no safe pedestrian access to this side of the bridge. Whilst the measurements made do not represent the height of car roofs (typically 1.4 m to 2.0m (Nationwide Vehicle Contracts, 2020)), it is considered likely that these represent the edge of the ultrasonic beam being reflected by the side of a passing car. The sensors were installed such that the beam is directed downwards alongside the bridge wall, but beam spread at distance from the sensor may encounter vehicles on the road.

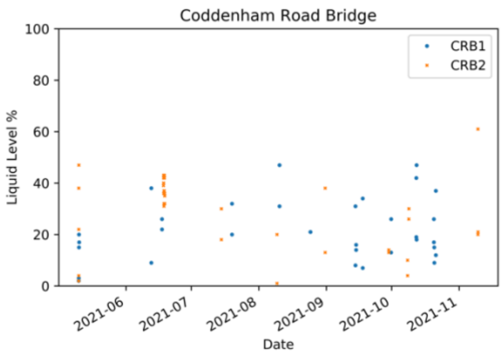
Therefore, consideration was given to occurrences where two or more consecutive non-zero values are encountered, as these may indicate an ongoing situation with a duration longer than 15 minutes. For this analysis, non-zero values that have a zero value immediately before and after were removed from the analysis. The remaining values were analysed as before: number of consecutive non-zero values is presented in Table 5 and range of measurements in Table 7. These consecutive non-zero values ranged between 1% and 61%, indicating surfaces reflecting the ultrasonic beam at a height of between 0.02m and 1.18m above ground level. It is considered that the surfaces identified in this analysis are due to separate passing cars, not a single flood event.

| Sensor | Number of measurements | Number of consecutive non-zero measurements | Percent of consecutive non-zero measurements |
|---|---|---|---|
| CRB1 | 16811 | 52 | 0.3 |
| CRB2 | 17140 | 37 | 0.2 |

*Table 5: Number and proportion of consecutive non-zero measurements at Coddenham Road Bridge*

| Sensor | Minimum | | Mean | | Maximum | |
|---|---|---|---|---|---|---|
| | % | m | % | m | % | m |
| CRB1 | 2 | 0.04 | 23 | 44 | 47 | 0.91 |
| CRB2 | 1 | 0.02 | 30 | 58 | 61 | 1.18 |

*Table 6: Range of non-zero measurements at Coddenham Road Bridge*



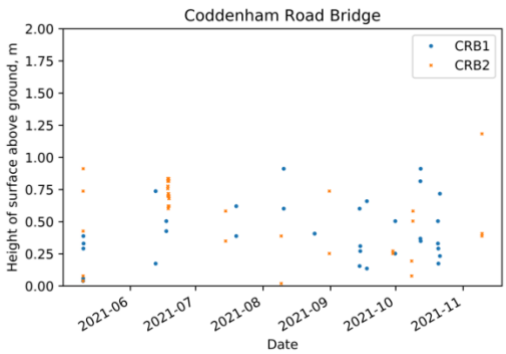




*Figure 25: Apparent fill level as given (% liquid level) and converted to height of surface above ground level (m) for consecutive non-zero values only*

Sensor CRB1 had only one occasion on which three consecutive values were non-zero. On all other occasions, only two consecutive values were non-zero. Sensor CRB2 had seven occasions on which more than two consecutive non-zero values, with up to nine consecutive non-zero values, indicating a fill level of 36% (0.7m) for a period of two hours (18/6/2021 between 15:49 and 15:49). During that period, values measured by sensor CRB1 were zero. Sensor CRB1 is on the "inside bend" for traffic driving on the left, and is therefore considered potentially more likely to be impacted by passing traffic.

Assessing the non-zero data from the two sensors using an independent, two-tailed t-test gives a p-value of 0.11, indicating that the two sensors could be considered to measure data from the same population. However, assessing the consecutive non-zero data from the two sensors using an independent, two-tailed t-test gives a p-value of 0.01, indicating that these two sets of consecutive non-zero data from the two sensors mounted under the bridge are significantly different. This is considered to be due to the different positioning of cars driving under the bridge from each direction (Figure 23), and the impact that has on driving patterns.

### 4.2.6 Units that stopped operating

Four units stopped operating, as identified on the Farsite Dashboard by last data points. These were all in the Bury St Edmunds sub-location. As stated previously (Section 4.2.2) this is comparatively robust compared with other themes of the Smarter Suffolk project. Two of these (Mayfield Road Gully 1 and Nowton Road Gully 2) ceased operation at the same time, although investigation has not revealed an explanation for this apparent co-incidence. Last reported liquid levels are stated: none of these gullies appear to have been full at point of last operation.

| **Location** | **Time and date of last reported data** |
|---|---|
| Mayfield Road Gully 1 | 04:23 30 September 2021 at 63% |
| Nowton Road Gully 1 | 03:45 4 August 2021 at 7% |
| Nowton Road Gully 2 | 04:21 30 September 2021 at 66% |
| Sicklesmere Road Gully 3 | 02:45 9 July 2021 at 60% |

*Table 7: Time and date of last operation of KaarbonTech sensors that have ceased operating.*

The initial view on the dashboard does not indicate that these sensors are no longer operational, displaying the last reported liquid level even though this is some months previously. It is not obvious until the “History” timeseries chart is examined on the individual sensor page that these sensors are no longer returning data.


*Figure 26: Dashboard display of last reported liquid level, despite no data for many months*

In comparison with some other sensors across the Smarter Suffolk project, this is a relatively good resilience for continuity of sensors. However, cessation of 4 out of 48 sensors in 6 months of operation remains a consideration for further installation. Highways drainage gullies are a more challenging and inhospitable environment to install equipment in than above ground locations.

Potential reasons for these sensors stopping operating were explored by site visit and inspection, and are discussed in subsections below. These are summarised in Section 4.2.6.4.

#### 4.2.6.1 Nowton Road Gully 1

The latest highways inspection (16/08/2021) of this gully as recorded in KaarbonTech’s Asset Management software indicates that the gully was operational with cover described as “ok” and silt levels reported at 50%. On inspection for this report (21/12/2021), the cover was found to be heavily covered with leaves, and the water level very high (Figure 27) and in contact with the lower surface of the device.

*Figure 27: Nowton Road Gully 1, as initially located, and after minor leaf clearance to reveal sensor (Photo: H Steventon)*

All available data was extracted for the period of operation (07/07/21 to 04/08/21), which revealed sixteen measurements available: Battery life metadata, Signal level, Time since last device update, Average connection duration, Ultrasonic errors (over last day), Ultrasonic errors (over last 30 days), Liquid level, Temperature, Battery level, Coordinates, Liquid level (unprocessed), Ultrasonic errors, Position info, nPod Version (3.), Unlock authorisation accept counter, Unlock authorisation reject counter.

From an initial inspection of the contents of these sensor data, the following data were selected for further exploration:

- Signal level
- Liquid level
- Temperature
- Battery level
- Liquid level (unprocessed)

T-test statistics and inspection of plotted values revealed Liquid level and Liquid level (unprocessed) data to be identical, so the Liquid level (unprocessed) has not been considered further.

Inspection of the four remaining data sets indicates that temperature, signal level and battery level data is gathered beyond the date on which the fill level sensor ceased to operate (Figure 28).

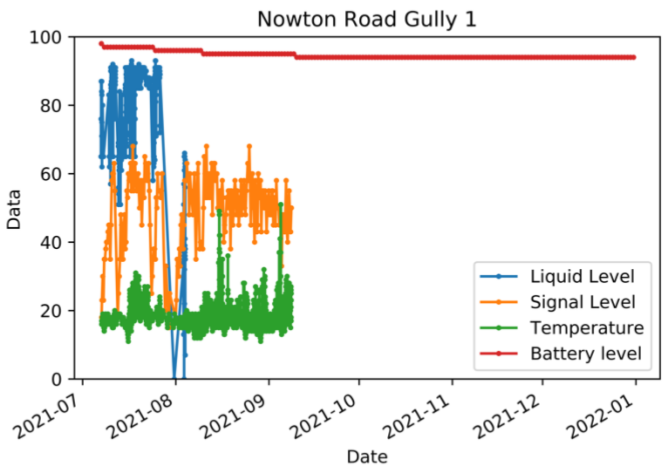



*Figure 28: Timeseries plots of data from sensor in Nowton Road Gully 1*

Liquid level data was reported until 04/08/21, and signal level and temperature until 08/09/21. Battery level continues to be reported, although the latest change corresponds with the latest data reported from the signal level and temperature: this may be due to continued filling of this data with the last reported value. The continuing reporting of temperature, with good signal and battery levels, indicates that the liquid level sensor failed before the whole device, but that about a month later the whole device failed. It can also be seen that signal level fell significantly at the point at which the liquid level measurements first failed.

Looking more closely at the liquid level during the period of operation (Figure 29), indicates a relatively stable gully operation, with a high level (typically reported as 91%, with some higher points) until 28/07/21, followed by a period of several days of absent data before some additional reported data during a period of a day, which appear unreliable compared with previous liquid levels.

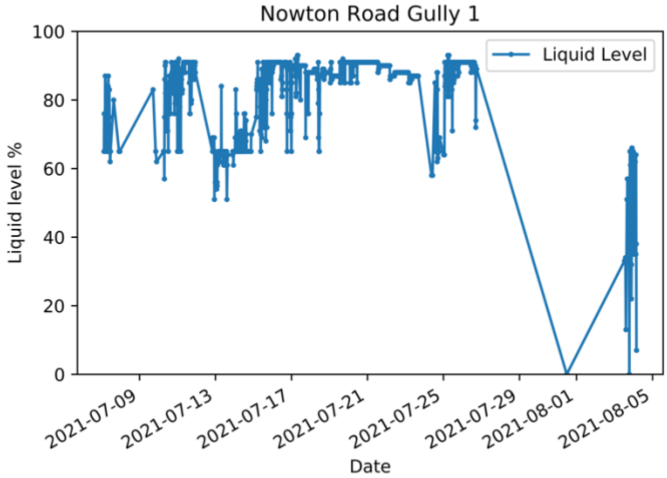



*Figure 29: Reported liquid levels from sensor in Nowton Road Gully 1*

Compared with other gullies in the trial, the water levels in this gully are much closer to the device (as observed during the site visit, and as reported during the period of operation in July 2021), and the device was observed to be in contact with water in the gully when visited. It is suggested that the device likely failed following repeated and / or prolonged periods of submersion, leading to water ingress into the device. It is noted that the devices are IP65 rated, and therefore not rated for prolonged immersion; the overall robustness of the devices installed in gullies in this trial is noted positively.

#### 4.2.6.2 Mayfield Road Gully 1

The latest highways inspection (02/09/2021) of this gully in recorded in KaarbonTech's Asset Management software indicates that the gully was operational with cover described as "ok" and reported as inaccessible. On inspection for this report (21/12/2021), the cover was found to be clear, and the device easily visible (Figure 30).

*Figure 30: Mayfield Road Gully 1 (photo: H Steventon, 21/12/21)*

As for the previously discussed device (Section 4.2.6.1), data for signal level, liquid level, battery level and temperature were extracted from the KaarbonTech / Farsite dashboard and inspected (Figure 31).

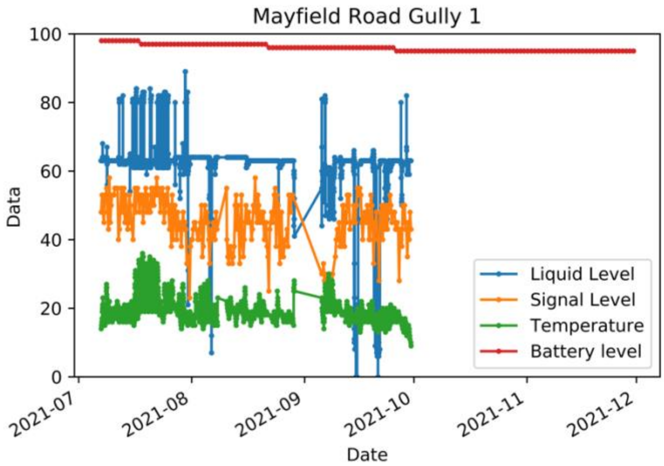



*Figure 31: Timeseries plots of data from sensor in Mayfield Road Gully 1*

These indicated that unlike for the sensor in Nowton Road Gully 1, all reported data (except battery life) ceased at the same time (30/09/21). Liquid level was not so high it is anticipated to be submerging the device, and the device was not in water at time of site visit. Signal level and batter level appear mainly continuous and reasonable. On examination of the data and device in-situ, no cause of cessation of operation is proposed.

#### 4.2.6.3 Nowton Road Gully 2 and Sicklesmere Road Gully 3

These two sensors are discussed together, as they have both been subject to gully replacement with new gully grate and surrounding road surface (as can be seen in photographs in Figure 32).

*Figure 32: Nowton Road Gully 2 (left) and Sicklesmere Road Gully 3 (right) (Photos: H Steventon 21/12/21)*

The sensor at Sicklesmere Road Gully 3 (Figure 32 left hand photograph) was not present at time of site visit. It is not known if the sensor was reinstalled when the gully grate was replaced, but has failed since and fallen into the gully, or was removed when the old grate was disposed of.
The sensor at Nowton Road Gully 2 was in place during the site visit having been reinstalled on the new grate; it is postulated that it ceased to operate during the construction removal and re-installation works.
As not all sensor locations have been inspected (just the non-operational ones, and those in the areas selected for further analysis) it is not known whether other sensors were re-installed following replacement, and have continued to operate successfully.

#### 4.2.6.4 Summary of units that stopped operating

A summary of the postulated reasons for these four sensors to cease operation is included in Table 8 below, as discussed in Sections 4.2.6.2 to 4.2.6.3 above.

| Location | Postulated reason for cessation of operation |
|---|---|
| Mayfield Road Gully 1 | Unknown |
| Nowton Road Gully 1 | Device failure due to lengthy and / or repeated submersion |
| Nowton Road Gully 2 | Re-installed but ceased to operate during gully replacement |
| Sicklesmere Road Gully 3 | Removed during gully replacement |

*Table 8: Possible reasons for four sensors to cease to operate*

## 4.3 In Touch Data

### 4.3.1 Installation

Installation locations were selected by Suffolk County Council Highways Drainage experts. Twenty sensors were installed across six sub-locations. Installation and connection start dates (where applicable) have been identified visually from the InTouch dashboard.

- Thorpeness, 3 sensors, never connected
- Aldringham, 4 sensors, connected on 30 and 31 March 2021
- Levington, 4 sensors, never connected
- East Felixstowe, 4 sensors, connected on 31 March 2021
- Needham Market, 3 sensors, connected on 31 March 2021
- Ipswich, 2 sensors, connected on 30 and 31 March 2021

At the time of analysis and reporting, data was not available from these sensors. Whilst sensors were listed on the BT Data Exchange, no data had been collected by the BT Data Exchange. The Grafana-based dashboard provided by InTouch was not consistently operational, and does not enable data download. InTouch have stated that they will provide data as emailed csv files for future data analysis, but data had not been received for inclusion in this report. Discussions regarding data for specific locations in Sections 4.3.4, 4.3.5 and 4.3.6 below are based on visual inspection of the InTouch dashboard.

InTouch have not appeared to provide as commercially-mature a service as the alternative trialled. Without easily available data, accessible to decision-makers in an appropriate format, the sensors are not easily used by the local authority.

### 4.3.2 Dashboard

As described in Section 4.3.1, InTouch provide a dashboard, based on a Grafana interface. This dashboard provides an overview visualisation, and a detailed asset view for each sensor. InTouch sensors report silt fill levels, but not depth to water: the sensor head reports flood or not-flood conditions at the height of the sensor head only.

Screenshots for the same sensor for each of these is included in Figure 33 and Figure 34 below.


*Figure 33: Screenshot of InTouch overview dashboard*


*Figure 34: Screenshot of InTouch asset view dashboard*

### 4.3.3 Reliability

Analysis of length of gap during the operational period could not be undertaken as data has not been made available for this analysis. Visual inspection of the dashboard indicates gaps of significant length (up to months) within the overall operational period in several sensors.

Sensors in two areas (Thorpeness and Levington) were never operational. It is understood that this is due to the challenge of positioning a data concentrator within reach of the installed sensors for onward transmission of data.

Sensors in the other four areas are indicated by visual inspection of the InTouch dashboard to have been operational as follows (Table 9):

| Location | Sensor reference | Date of last operation |
|---|---|---|
| Felixstowe | 60031002 | 11/12/21 |
| | 60031008 | 12/12/21 |
| | 60083920 | 12/12/21 |
| | 60083932 | 12/12/21 |
| Aldringham | 60068781 | 04/05/21<br>Operational 11/1/22 to present (15/1/22) |
| | 60068789 | 4/5/21 |
| | CNW148610 | 4/5/21 |
| | CNW148611 | 4/5/21<br>Operational 11/1/22 to present (15/1/22) |
| Needham Market | 60110775 | Operational on 15/1/22 |
| | 60110776 | Operational on 15/1/22 |
| | 60201755 | Operational on 15/1/22 |
| Ipswich | 60164291 | Operational on 15/1/22 |
| | 60197988 | Operational on 15/1/22 |

*Table 9: Time and date of last operation of InTouch sensors that have ceased operating*

This indicates that in two areas, sensors remained operational at the end of the period of analysis. The cessation of operation in the other two areas was on the same or consecutive days within the area, possibly indicating a failure of the data concentrator for onward communication rather than the specific devices. The data concentrator for Felixstowe was solar powered, and it is considered likely that it did not successfully operate during the reduced light of the winter months.

During the nine months of this trial, from the twenty sensors, seven were never operational, four worked for two months, and four for nearly nine months. Only seven continued to be operational at the point of inspection, of which two had been not operational for many months previously.

Sensors in Felixstowe (no longer operational), Needham Market (operational) and Levington (never operational) were inspected.

### 4.3.4 East Felixstowe

Four sensors were inspected in East Felixstowe, at locations indicated on Figure 35.


*Figure 35: Sensor locations, East Felixstowe, locations plotted from supplied information (left) and KaarbonTech Asset Management Platform (right)*

At the time of inspection, these sensors were no longer operational, so measured water and silt levels cannot be compared to reported levels. Sensors appeared to be installed and in position. Three sensors were beneath parked cars with limited access.

*Figure 36: InTouch sensors in East Felixstowe (sensor locations west to east, photos from left to right)*

### 4.3.5 Levington

Three sensors were inspected in Levington, at locations indicated on Figure 37.


*Figure 37: Sensor locations, Levington, locations plotted from supplied information (left) and KaarbonTech Asset Management Platform (right)*

These sensors have never been operational, so measured water and silt levels cannot be compared to reported levels. Sensors appeared to be installed and in position. Deep silt from adjacent domestic construction work was noted in the northern gully pot.

*Figure 38: InTouch sensors in Levington (sensor locations north to south, photos from left to right)*

### 4.3.6 Needham Market

Three sensors were inspected in Needham Market, at locations indicated on Figure 39.

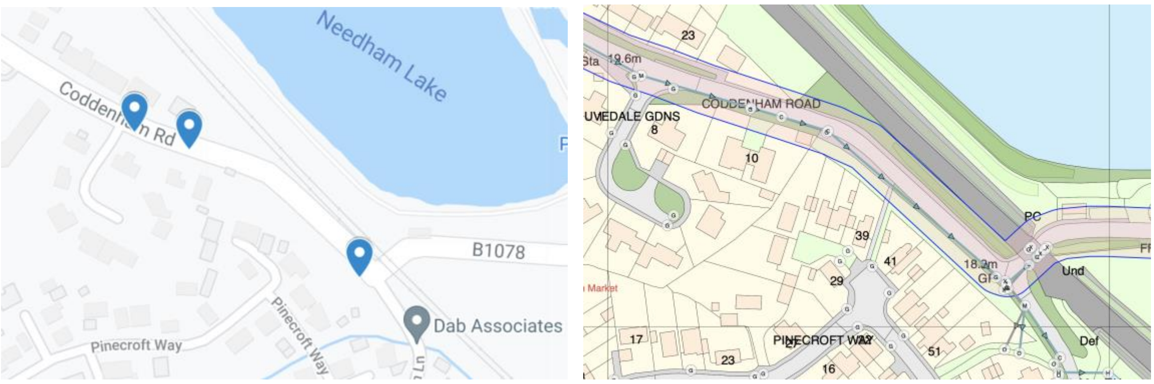



*Figure 39: Sensor locations, Needham Market, locations plotted from supplied information (left) and KaarbonTech Asset Management Platform (right)*

These sensors were operational at the time of inspection, so measured silt levels have been compared to reported levels. Sensors were observed: some silt sensors appeared not to be vertical, and some sensor head units appeared to have fallen from the installed positions. Cleansing had recently been completed and may have led to movement of the sensors.

*Figure 40: InTouch sensors in Needham Market (sensor locations west to east, photos from left to right)*

As cleansing had recently been undertaken, no silt was observed in the gully pots, and it could be ascertained whether sensors do continue to record silt levels following gully emptying. Screen shots from the InTouch dashboard for the 7 day period are included in the following figures. At the point of inspection and cleaning (12/01/2022) silt fill level was reported by the inspector at 75%, 75%, and 100% respectively. The change in silt fill level was observed in sensor 60201755, indicating successful cleansing and continued silt measuring (Figure 43) and no silt present in sensor 60110776 (Figure 41). Fill levels in the other sensor appears less reliable, failing to indicate emptying in sensor 60110775 (Figure 42) or fill level prior to emptying in sensor 60110776.

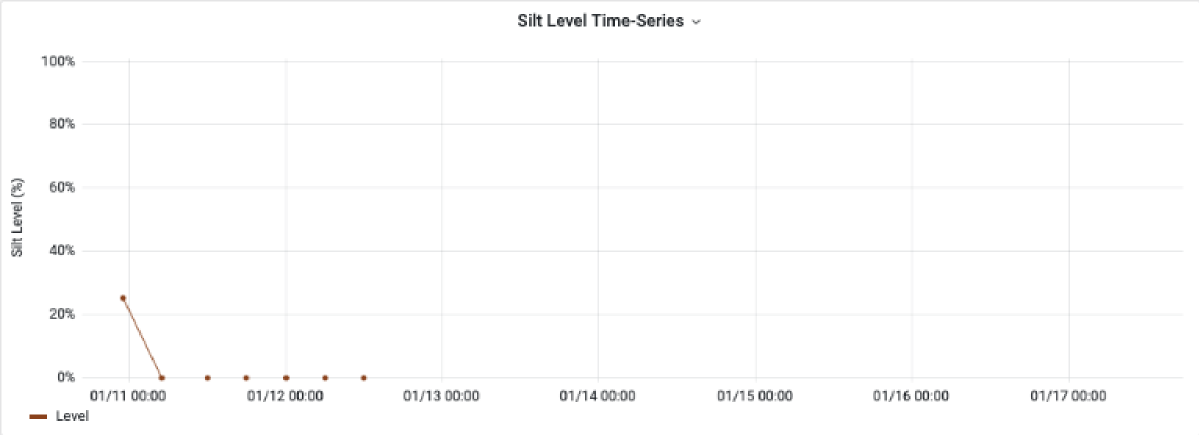



*Figure 41: Silt fill level in sensor 60110776*

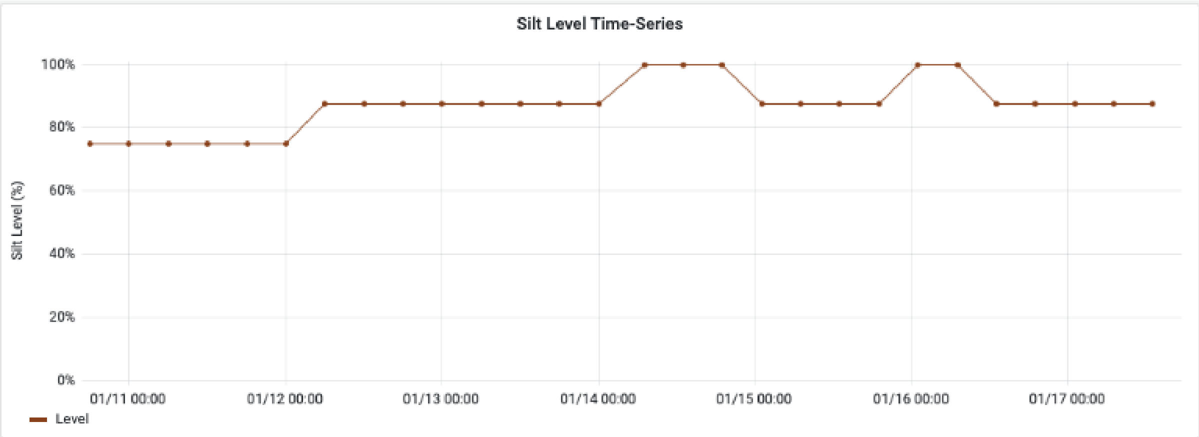



*Figure 42: Silt fill level in sensor 60110775*

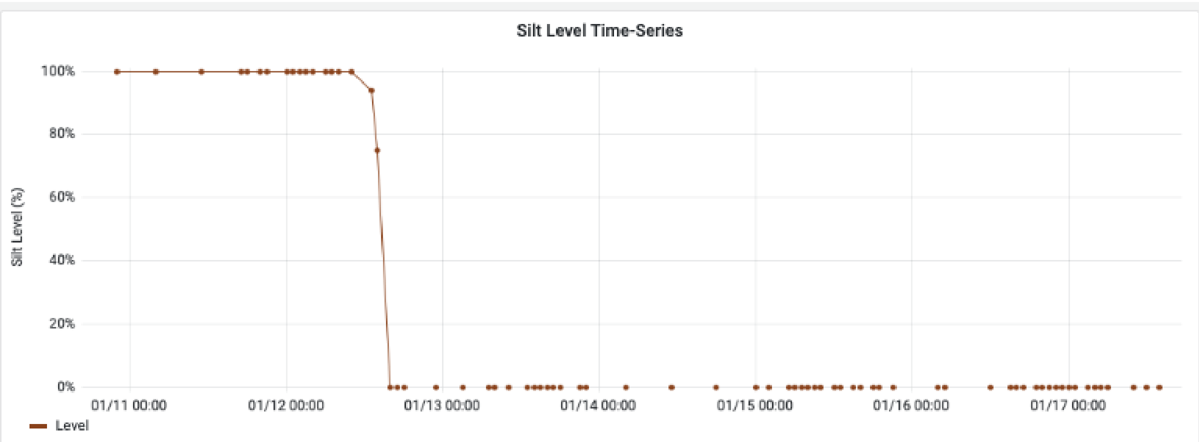



*Figure 43: Silt fill level in sensor 60201755*

For comparison, screenshots for the silt level indicated by these sensors for the period of operation is included in the following figures (Figure 44 to Figure 46). The quantization visible is due to the technology of silt fill level measurement, with discrete levels of detection. These indicate that variation in silt fill level is indicated by the sensors, but the fill levels observed prior to emptying were not accurately recorded in one of the three sensors.

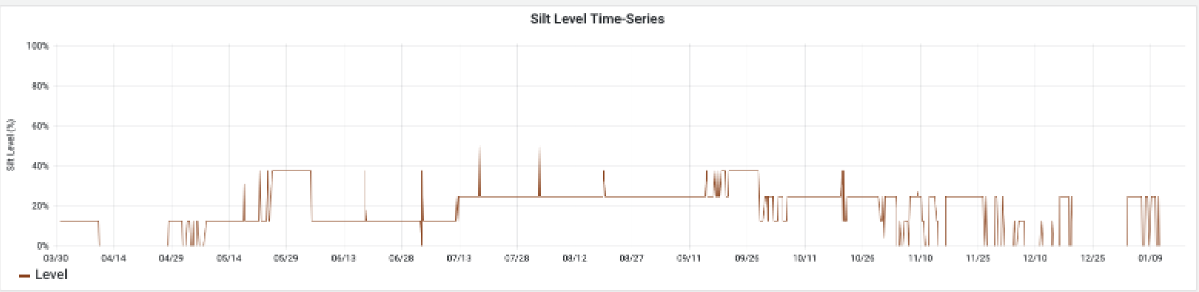



*Figure 44: Silt fill level in sensor 60110776*

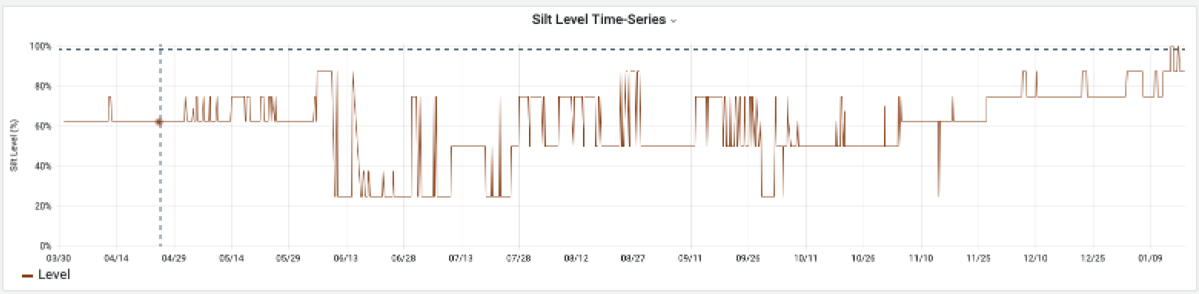



*Figure 45: Silt fill level in sensor 60110775*

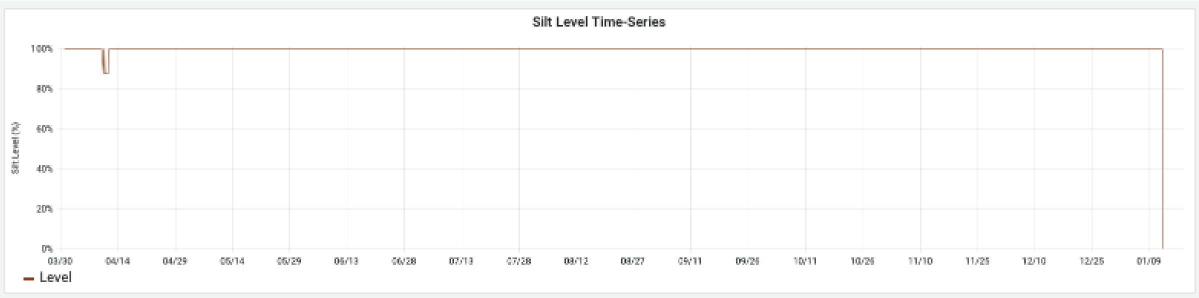



*Figure 46: Silt fill level in sensor 60201755*

## 4.4 Inspection of Installed Units

### 4.4.1 KaarbonTech

As detailed in Sections 4.2.4, 4.2.5 and 4.2.6, three groups of sensors were examined. Where visible, sensors appeared in relatively good physical condition (Figure 47).

*Figure 47: Coddenham Road Bridge sensor 2 (left) and 1 (right). Photos: H Steventon*

*Figure 48:Photos of KaarbonTech  sensors showing physical appearance after 6 months installation (photos: H Steventon)*

On some sensors, leaves and debris were caught on the surface of the grate; it is considered likely that the sensor placement could exacerbate the accumulation of debris on the grate, and thus cause obstruction to the operation of the gully.

*Figure 49: Photos of sensors showing accumulated debris on the sensor installation (photos: H Steventon)*

### 4.4.2 InTouch

As detailed in Sections 4.3.4, 4.3.5 and 4.3.6, three groups of sensors were examined. Sensor condition was variable (Figure 50), with some sensors appearing disturbed by cleansing operations. For long term use of these sensors, they need to be robust during gully emptying and cleansing, as well as during ongoing gully operation. Other sensors appeared in good condition. As the sensors are not mounted in the gully grates, build up of debris on the grate associated with the sensor position was not observed.

*Figure 50: Photos of InTouch sensors showing physical appearance after 9 months installation (photos: H Steventon)*

It was noted that some sensors were mounted with a bar diagonally across the gully Figure 51, which may provide a hindrance to gully cleansing and increase likelihood of damage to the sensor during cleansing and jetting processes.

*Figure 51: InTouch sensors installed with bar diagonally across gully anticipated to cause problems with gully cleansing.*

# 5 Financial Assessment / Business Case Inputs

## 5.1 Current Cost of Service

Existing drainage management is discussed in Section 2.3, and includes inspection and emptying. Historically, inspection has been on a regular cycle, but current management has moved to risk-based frequencies, determined for Suffolk County Council by relevant factors within KaarbonTech's Asset Management System. Frequencies based on risk could be as often as quarterly, or less than annually for gullies that operate without accumulating significant silt or other debris within the gully pot.

As a comparator, inspections for the seven gullies on Needham Market fitted with KaarbonTech sensors, and the three fitted with InTouch sensors has been identified from records in the asset management system. As multiple additional inspections have been undertaken associated with the installation of the sensors, inspection frequency prior to 2021 has been examined. This indicated that in general, one inspection per year has been undertaken, for these gullies. Some years specific gullies were not inspected, although surrounding gullies were inspected, likely due to access to those gullies being limited by parked cars or other obstacles. Inspections record condition of cover, gully operation, any cleaning required and undertaken during the inspection, and silt level. Examples are included in Figure 52.

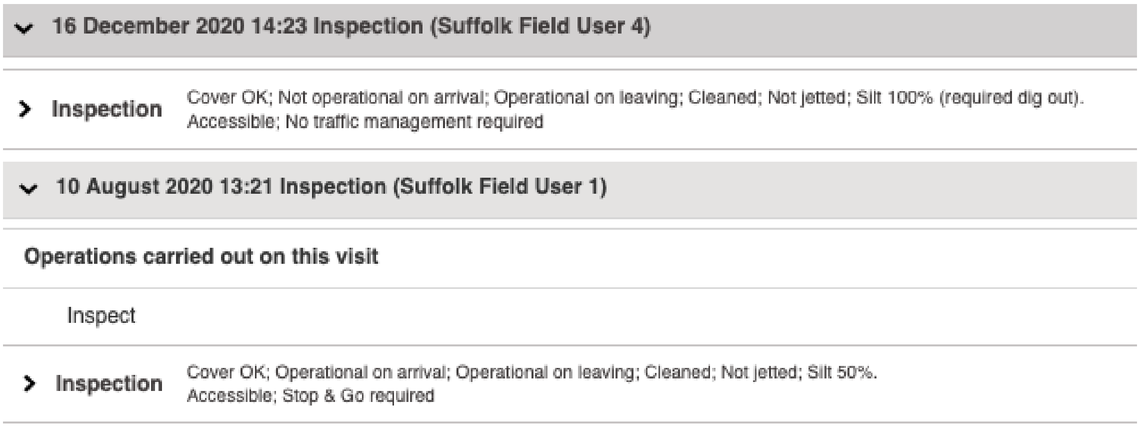



*Figure 52: Examples of existing inspection reports on SCC's KaarbonTech Asset Management platform*

These inspections are undertaken by contractors on a unit (per-inspection and / or per-clean) price. Whilst specific costs of existing contracts cannot be detailed in this report, for reasons of commercial confidentiality, indicative pricing has been provided by several local authority drainage managers. Example pricing is around £6 per inspection and clean when these are priced as a single item, with lower pricing for inspections and higher prices in local authorities where inspection and clean are undertaken separately.

Assuming this price is applied to all 144,000 gullies in Suffolk, and gullies are inspected and cleaned (if required) on average annually, this would indicate an approximate budget for this service of £864,000 per year.

Higher costs can apply for a number of reasons including:

- Where additional traffic management or road closures may be required to enable safe access for operatives;
- If additional work is required due to further in-pipe blockages.

In addition to contracted inspections, members of the public can report a blocked drain (amongst a wide range of other highways issues) on Suffolk County Council's map-based online reporting tool (Suffolk County Council, 2021, 2022). This provides a low-cost method of gathering additional information on visible drainage issues, and enabling public participation.

## 5.2 Indicative Costs of Sensor Provision

Sensors used in this trial have been provided by KaarbonTech and InTouch. Neither supplier have publicly available list pricing for these sensors and quotes for this project are commercially confidential. Indicative pricing discussed in this section is based on indicative pricing provided by KaarbonTech for inclusion in this report, and on approximate pricing within the Smarter Suffolk project.

KaarbonTech note that: *"we … quote each project uniquely due to the site investigations, interfaces and quantities of sensors. … [for] a quantity of 10 sensors, one-off costs would be around £16k with the annual costs at £3,500. This pricing includes site surveys, installation and integration with Gully SMART as well as the sim card costs for communication. … when the quantities of sensors increases, the unit price per sensor will decrease."*
Assuming an average lifetime of eight years, this would indicate an annualised cost of £550 per sensor. As stated, this per-sensor cost could reduce for a larger number of sensors. It is noted that the annual operational fees (including communications and platform integration) are larger than the annualised device cost.
Whilst cost of sensors to the two-year Smarter Suffolk project cannot be directly compared, this pricing is similar to that to the project.

InTouch also provided indicative pricing for this report. Using their pricing matrix provided, and assuming an installation of 20 sensors (ten of 500mm probe length and ten of 1000mm probe length) with 5 data concentrators (their recommended 1:4 ratio), indicated a capital total of approximately £14,130 and annual fee of £9000. Assuming an eight year operational lifetime would give a per-sensor cost of approximately £550 per sensor, comparable to the KaarbonTech pricing above. Costs to the Smarter Suffolk project was higher per sensor, as part of the trial.

It is noted that the sensors supplied by InTouch are significantly more complex devices than those supplied by KaarbonTech, measuring silt fill levels within the gully pots but not water fill levels (only flood / not flood at depth of the sensor head). However, the challenges in acquiring data, and the lack of consistency of the silt fill level data visualised, indicate that this system is not currently in a position to be useable in an operational setting.

## 5.3 Financial Comparison

To replace highways inspections, sensors would need to replace around 100 inspections per year to provide a comparable service, suggesting that sensors would need to be able to represent gully networks of interconnected or similar gullies that have significantly over 100 gullies. Further work will need to be done to identify how gullies can be associated to enable such correlations, and to identify the likely number of gullies that could be effectively represented by a single sensor.
It is noted, that gully visits for emptying will continue to be needed where appropriate, with associated costs.

Gully management companies are still developing their use of sensors to inform their asset management guidance. Sensors are not cost effective to be installed in every single gully, and uses could be in a number of ways:

- Sensors representing conditions in a number of gullies: this could be either as a single sensor indicating conditions in connected gullies (as discussed in Section 4.2.4) or as a sensor that indicates conditions in a selection of gullies that have been identified as responding in a similar way (with similar impacts from foliage and silt build up).
- Sensors in locations that are harder to inspect and clean cost-effectively, such as locations that require road closure or extensive traffic management.
- Sensors providing early information in locations known to create problematic impacts on significant roads, with impacts on public movement and consequent safety,

economic and social impacts. It is possible to link sensor information to automated displays, to enable “flood ahead” warning signs to activate on highways when required.
- Sensors could be installed to investigate and understand the operation of a set of gullies, such as is seen in Needham Market.

Connected sensors provide real-time continuous information on gully conditions, enabling alerts and action as required. This provides an additional service that can be used to minimise disruption on highways and prioritise gully cleansing.

## 5.4 Environmental and Social Analysis

Drainage management is essential for environmental and social reasons, controlling the precipitation flow from the highway in ways that enable both use of the highway, and effective and environmentally positive routing of the water in the hydrological and hydrogeological cycle (Suffolk Flood Risk Management Partnership, 2018). There is therefore environmental, social and economic benefits in effective and appropriately-designed highways drainage. Existing highways drainage networks are the result of many decades of construction, and can also be impacted by damage, blockage and change since construction. This report is specifically on the potential for sensors to inform gully maintenance in existing gullies, and does not reflect on construction of new drainage systems.

The use of sensors can provide environmental, economic and social benefits when decisions made based on data received enable a reduction in provision of unnecessary service, such as inspection visits to gullies that do not require cleansing. Not all the sensors in this project indicate silt fill levels. Most sensors indicate water fill levels: increase in water fill level above the level of the outflow is a strong indicator of silt accumulation or other blockage requiring emptying, jetting or cleansing. Thus provision of sensors for near-real-time data gathering can provide both a reduction in unnecessary service, and timely provision of additional emptying visits when required.

If sensors are used, locations are recommended based on need (Section 6). These would have the highest impact on community benefits, supporting targeted drainage maintenance of areas known to be challenging: whether due to access limitations or due to known frequency of floods or maintenance requirements. Early warning of road closures could have a benefit to road safety.

Provision of sensors in areas of access limitations can also have a benefit to the operatives undertaking the gully inspections and cleansing.

Conversely, the provision of Internet of Things and “Smart City” sensors in general also has some environmental disbenefits (Alsamhi *et al.*, 2019; Yang *et al.*, 2021) including: the manufacture, delivery and installation of the sensors; the energy required for their ongoing operation; energy for their data communication, management, storage and access; and end-of-life disposal.

## 5.5 Innovation Portfolio Builder

Proving Services have supplied an Innovation Portfolio Builder; gully fill level monitoring is not an identified option. Therefore, the potential impact for installing gully fill level sensors could not be assessed using this tool.

# 6 Conclusions and Recommendations

## 6.1 Conclusions

This report concludes that monitoring gully fills levels can be beneficial in specific circumstances, such as:

- Where traffic management is required, or inspector safety is challenging, such as on busy road junctions;
- At known key locations with frequent drainage issues;
- Covering a network of multiple gullies with a single "indicator" gully location;
- To automatically trigger signage on roads warning of floods ahead.

Business case evaluation comparing the cost of the sensors with the cost and frequency of inspection concludes that the sensors cannot become cost effective within their projected lifetime on a per-gully basis. As technology develops, and sensors become more reliable and less expensive, the potential provision of a sensor in more or all gullies may become cost-effective. At present, that is not the case.

Observational and data analysis research for this project indicated that the sensors trialled did not consistently provide a reliable record of water levels in the gullies at any single time. During data analysis, it was found that daily mean of the data provided an indication of seasonal variation within the gullies, although fill level (as a percentage) did not accurately match the measured fill level. Additional adjustments may result in more accurate measurements.

Discussions with service providers indicate that further consideration needs to be given to what is the most useful parameter to measure. Sensors explored by this project did not provide the same information, instead variously measuring:

- Depth to surface level (usually but not always water level), provided as a percentage;
- Depth of silt fill level (together with a single "flood" point, and lux levels);
- A single flood / not flood point.

Whilst depth of silt appears to be useful as it is the silt build up that requires emptying, the silt level sensors were not operationally effective in this trial (including communications and dashboard / data challenges). Additionally, water levels in the gullies were considered to be a strong indicator of gully operation, and of use to the drainage team to reveal when locations require attention. For this use, it would potentially be of more use to report the level of water in the gully pot, and the levels of the outflow pipe, rather than the "percentage full" for the entire gully pot. Gully pots do not have consistent geometries and operational water levels. Flood sensors (indicating flood / not flood) are not considered to be as useful as water level sensors, as they provide less information, and depending on depth of installation, the flood warning information is provided later during the incident.

Direct data connection from the device (using mobile data) has proved significantly easier to install, and more reliable.

A challenge in this project was the access to useable data. One provider provided a dashboard that was not consistently operational and less easy to use. The other had an easy-to-use dashboard with integration to their asset management system. For sensors to be of use to the drainage teams, data and alerts need to be easy to access and apply.

## 6.2 Recommendations

Within this project, the integration of sensors from the incumbent asset management company were most useful to the drainage team. Recommendations include:

- Presentation of the data provided from the sensors (as depth to water level in the context of the outflow levels);
- Use of sensors only when they can be economically justified, in indicator gullies covering a wider network or in selected locations;
- Further research to explore the longevity of sensors in gullies – these have operated for six months; further research will identify whether multiple years of operation is feasible. Gullies are a challenging environment for electronic and communications equipment.
- Consideration of installation arrangements in gullies: one set of sensors were installed on the gully grating, the other mounted in the gully (sometimes across the gully). Further research could indicate how installation in gullies impacts on longevity of the sensor.
- For use of depth to water sensors above ground, such as under Coddenham Bridge, mounting the sensors closer to the road surface would minimise reflections due to passing vehicles. It is recommended, were appropriate, to mount sensors within 1m of the road surface.
- Consideration of which of parameters are most useful for operational management decisions.
- It could be beneficial to mount the grate-mounted sensors on the gully walls to avoid debris collection at the grate.

## 6.3 Final Summary

The research within the Smarter Suffolk Live Labs project indicates that it is possible to fit sensors within drainage gullies. The sensors installed operate with multiple different technologies, and as such measure different parameters. It is considered that the depth to water level is of most use, but in a gully is interpreted in the context of the levels of the outflow pipes. The sensors are battery powered, and communicate via a range of different communications protocols. Sensors communicating via cellular data were most reliable. During use, individual sensor measurements varied significantly, but median measurements provided an indication of seasonal variation.

Current costs of sensor provision suggest that they are most likely to be beneficial in specific situations where the circumstances and numbers of gullies represented make them more effective. This research indicates than installation in large numbers of individual gullies is not currently financially worthwhile. As technology develops, and sensors become more reliable and less expensive, the potential provision of a sensor in more or all gullies may become cost-effective.

# 7 Discussions

Laurence Molloy, Data Visualisation
Amanda Mays, Suffolk County Council
John Rozier, Suffolk County Council
Joe Kinberley, Business Improvement Manager, Amey for Hampshire County Council

# 8 References

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# 9 Document History

| Date | Version | Author | Notes |
|---|---|---|---|
| 17/04/20 | Interim Draft | H Steventon | Reviewed with Prof N Caldwell |
| 21/04/20 | Interim Issue 1.0 | H Steventon | Issued to Suffolk County Council |
| Jan 2021 | Full Draft 1.0 | H Steventon | Reviewed with Prof N Caldwell |