Bosham (West Sussex) Pathfinder
Technical Report

June 2023

from Southern Water

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Document History

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Executive Summary

The Bosham catchment, located in West Sussex, was specifically chosen as a Pathfinder study due to the performance of the storm overflows within the catchment.

The original Bosham sewer network was built to perform as a foul only system, however over time it appears that the system now operates similarly to a combined system with wastewater flows and some surface water runoff connecting into the sewerage network. Over time, the village has developed, and with more people working from home and the increase in use of holiday homes in the area, the dry weather flow in the catchment has increased. The system now also experiences significant excess water in the network from other sources, resulting in numerous storm overflow discharges and some property and highway flooding. This catchment was selected so that, by using a holistic catchment approach to managing flows, we can identify options to reduce storm overflow spills and pollution incidents affecting Chichester Harbour.

The catchment is relatively small, with an estimated population of approximately 4,000 but it includes two storm overflows within the sewerage system; one located within the catchment network and one at the wastewater treatment works. These storm overflows, previously called combined sewer overflows (CSOs), act like a relief valve during periods of heavy rain. They release flows into the environment to reduce sewage flooding in the catchment.

Having groundwater or surface water runoff from rainfall mix with the sewage creates several issues including: an increased risk of flooding, contamination of rainwater that could be fed straight back into the environment and increased costs of pumping and treating diluted sewage, as well as the impact of overflow spills into the environment.

Managing surface water is a complex, shared problem, as it means making sure that water drains effectively from homes and gardens, roads, fields, businesses, and public spaces. It requires a holistic, multi stakeholder approach to manage these flows successfully.

Southern Water has set up a Task Force with several aims, the key one being to significantly reduce the use of storm overflows by 2030. To investigate how this can be achieved, several pathfinder projects have been set up and the Bosham catchment is one of those. These pathfinders have a staged approach as follows:

Stage 0 – Study and surveys
Stage 1 – No regret interventions and trials
Stage 2 – More complex interventions and large-scale pilots
Stage 3 – Larger scale investments to deliver the outcome

The interventions identified are likely to be a mix of types of innovative and traditional solutions such as:

- Upstream source control (removing and slowing the flow of rainwater)
- System optimisation (making better use of the existing infrastructure)
- Infrastructure enhancements (build new or larger infrastructure)

The mechanism that these interventions will be delivered by is also likely to be innovative, with Southern Water working in partnership with West Sussex County Council, local council projects and community groups to provide solutions that provide multiple benefits.

Within Bosham we believe the key opportunities will be focused on source control, groundwater infiltration reduction measures and reducing the volume of non-domestic flows entering the sewerage network. The reduction in the volume of flow passing through the system would lower the risk of the system being overwhelmed, leading to a reduction in flooding risk and a reduction in the operation of overflows in the catchment.

To better manage the non-domestic flows entering the network, we will look at options to install sustainable urban drainage systems where appropriate. For all these interventions, further survey work and modelling will be required, to confirm if the potential interventions will provide the benefit required. We will continue to identify and, where appropriate, enact these interventions whilst we collate the results of the rest of the surveys.

This report is only the start of the journey towards a more sustainable drainage system in Bosham. We will work as partners, alongside other stakeholders, to investigate and better understand the existing drainage systems, to identify and deliver opportunities for improvement, and plan and implement solutions together for the sustainable growth of the village of Bosham.

What we ask of our partners and the community is to continue to support that journey, with photos and data, ideas, and enthusiasm. So that together we can agree how decisions can be made, now and in the future, for our mutual benefit.

1.0 The Catchment

1.1 Location and Local Government Services

Bosham is a coastal village and civil parish in the Chichester District of West Sussex, approximately two miles to the west of Chichester. Bosham Parish Council is responsible for local amenities such as recreation grounds, bus shelters and public events. Chichester District Council and West Sussex County Council are responsible for the more strategic services; with West Sussex having responsibility for education, social care and transport, roads and parking and Chichester District Council having responsibility for council tax, planning and building control, housing and climate change services.

1.2 Geography & Topography

The Bosham catchment lies in West Sussex between Chichester and Havant. It includes the principal settlements of Bosham, West Ashling and Funtington, with the smaller settlement of Bosham Hoe located at the southern end of the catchment. Both Bosham and Bosham Hoe are located within the Chichester Harbour Area of Outstanding Natural Beauty (AONB) whilst West Ashling and Funtington are located within the boundary of the South Downs National Park.

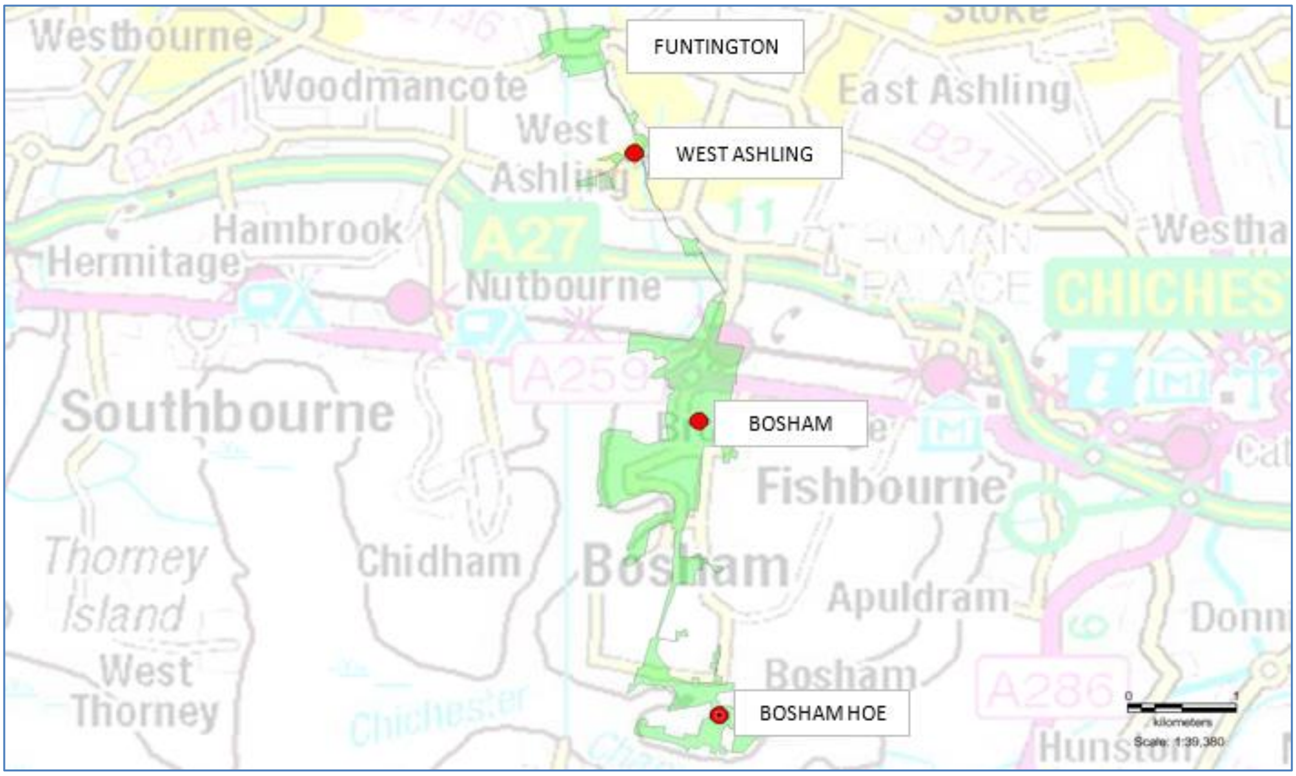

Figure 1 – Location of Bosham Catchment[1]

The A259 runs east to west through the northern part of Bosham, approximately parallel to the main rail line linking Fishbourne/Chichester in the east to Havant in the west. The main A27 also runs east-west slightly further north of this main rail line.

[1] Southern Water Drainage Area Plan 2019

The main watercourses in the catchment are Bosham Stream and Colner Creek, which run from the north through the catchment and discharge into Bosham Quay, which then feeds into the Chichester Channel. Further information on the watercourses is detailed section 1.11.

The ground levels fall from the north of the drainage catchment to the south, with elevation levels of 36mAOD in Funtington to 3mAOD in the southern end towards Chichester Harbour. The main Bosham village area lies on the shoreline of a relatively flat coastal plain which marks the boundary between the South Downs and the English Channel.

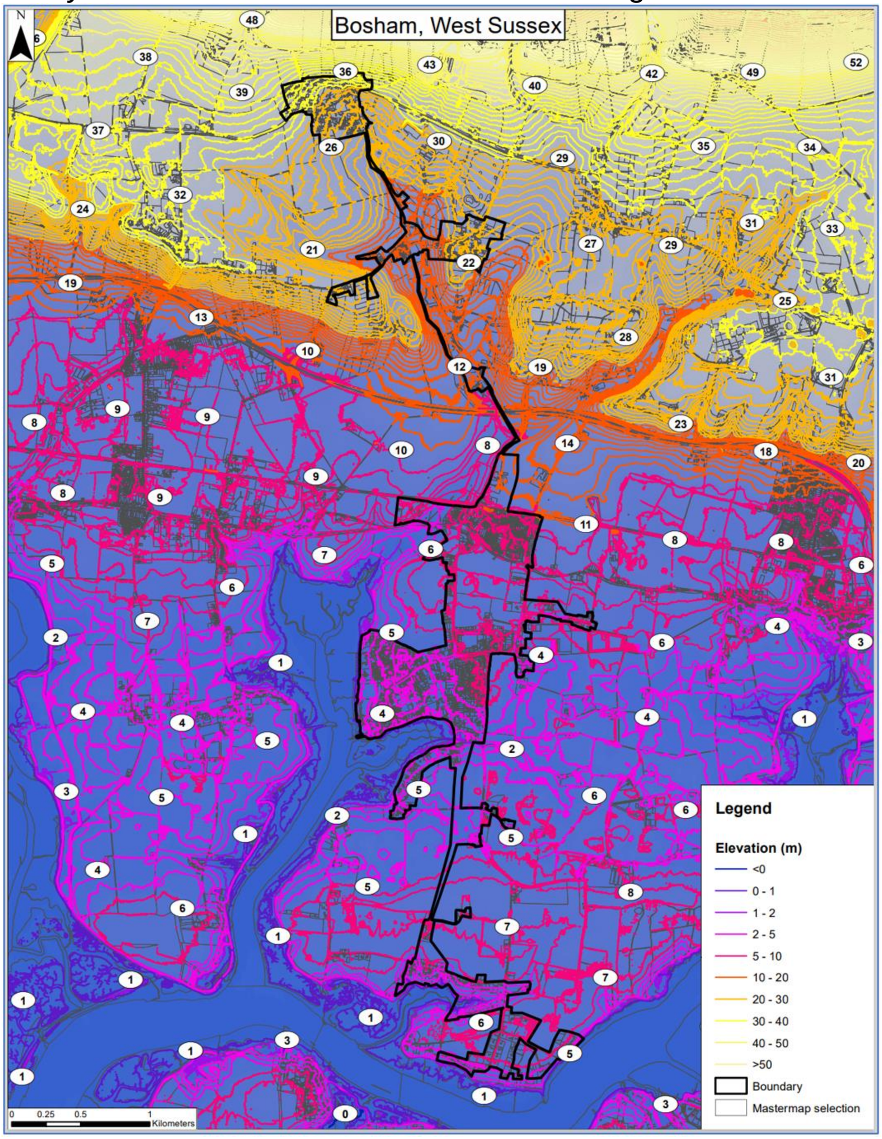

Figure 2 – Bosham Catchment Topography EA LiDAR[2]

1.3 Geology

Bosham village is underlain by a solid geology of Chalk – Lewes Nodular Chalk, Seaford Chalk, Newhaven Chalk, Culver Chalk and Portsdown Chalk Formation. North of the catchment in the Broadbridge area and south of Bosham in the Bosham Hoe area, the

[2] Southern Water Asset Miner OS copyright

bedrock geology is made up of the Lambeth Group - clay, silt and sand. Chichester and Fishbourne are both underlain by London Clay Formation - clay, silt and sand.

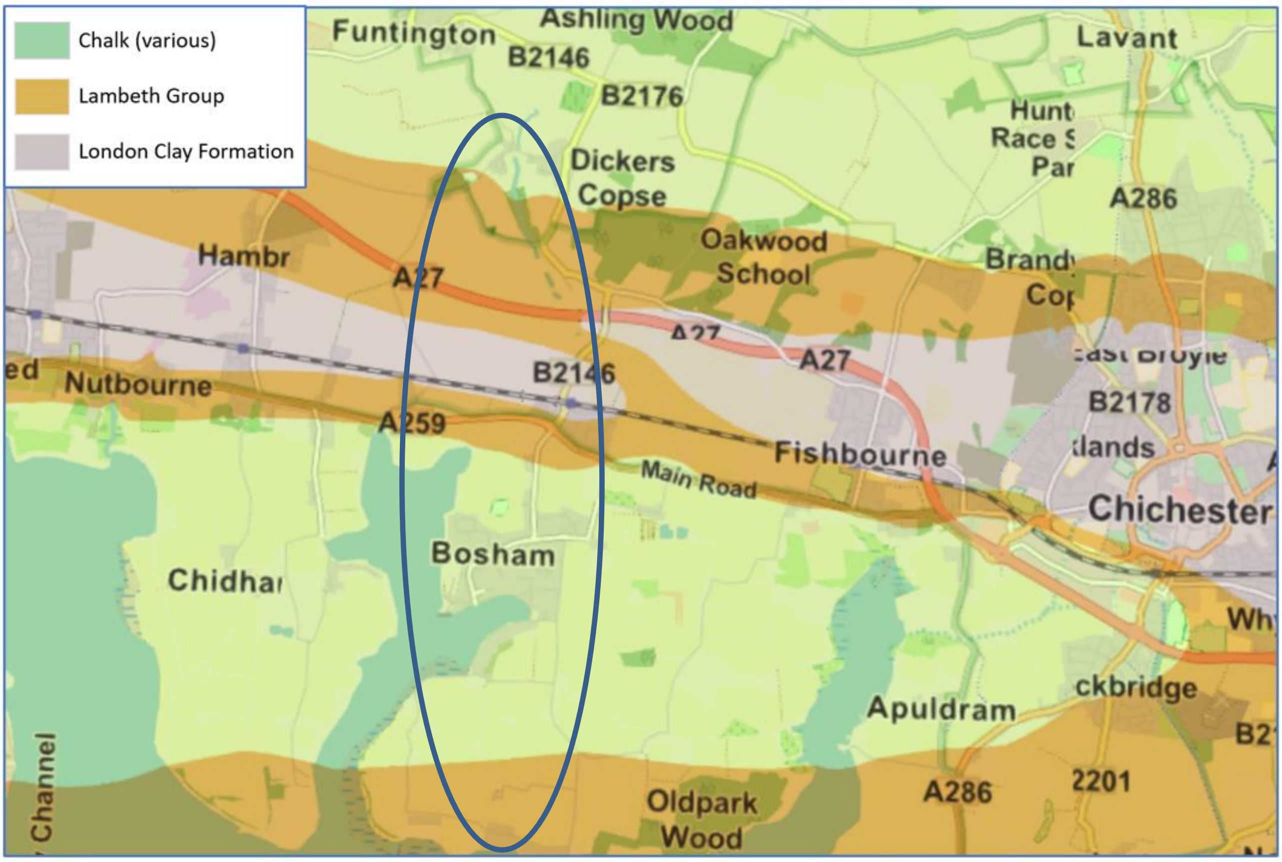

Figure 3 – Bedrock Geology of Bosham[3]

The Bosham catchment has several different superficial deposits across the catchment lying on top of the bedrock geology.

Superficial Deposit	Description	Location
Beach and Tidal Flat Deposits	There are beach deposits consisting of shingle, sand, silt and clay, which may be in the form of dunes, sheets or banks. Tidal Flat Deposits usually consist of silt and clay with sand and gravel layers, also with potential peat layers from the tidal zone. Where clays are present, permeability would be expected to be low.	These deposits are present nearest to the coast, for example on the eastern edge of the Bosham Channel.
River Terrace Deposits	These deposits consist mainly of sand and gravel, locally with lenses of silt, clay or peat.	These deposits are present throughout most of the catchment, for example in Bosham village and in land, north of Bosham Hoe.

[3] www.bgs.ac.uk

Superficial Deposit	Description	Location
Raised Marine Deposits	Raised marine and coastal zone deposits are isostatically uplifted marine and coastal zone deposits which crop out in part above the high-water mark. Variable lithology. Gravel (shingle), sand, silt and clay; commonly charged with organic debris (plant and shell).	These deposits are present to the west of Bosham village along the banks of the Bosham channel
Head Deposits	These deposits comprise mainly of clay, silt, sand and gravel this area is expected to be derived from the Chalk Formations. Head deposits often have a high clay content so would be expected to have indifferent permeability.	These deposits occur as a narrow transverse band of deposit aligned south of Bosham village, following Shore Road. It also occurs north of Bosham in the Broadbridge area.
Alluvial Fan Deposits	These deposits comprise mainly of clay, silt, sand and gravel. Alluvial fan deposits are low, outspread, relatively flat to gently sloping masses of loose rock material, shaped like a fan or segment of a cone. They are deposited by streams at the mouths of tributary valleys onto a plain or broad valley.	These deposits occur mainly towards the north of the catchment, for example in the Broadbridge area near the Colner Creek watercourse.

Table 1: Bosham Geology – Superficial Deposits

Borehole Data

West Sussex County Council and the Environment Agency have been contacted regarding whether there are any boreholes, either current or historical, that have monitored ground water within the catchment. West Sussex County Council have confirmed that they do not have any groundwater monitoring boreholes in the area. Chichester District Council have confirmed there is one known borehole, located at the reservoirs in Chequer Lane, where Langmeads Farm have a license from DEFRA.

The Environment Agency have one observational borehole detailed in their records near to the Bosham catchment. The borehole is located along Newells Lane and a request for groundwater level data has been submitted.

Recent proposed developments in the area have carried out groundwater monitoring as part of the planning applications. Searches of the Chichester District Council planning portal have confirmed locations where groundwater monitoring has taken place as part of development applications in the catchment. Groundwater monitoring was completed between October 2016 and March 2017 for the Highgrove Farm development site; this site area is detailed as an area of groundwater emergence in the West Sussex County Council Strategic Flood Risk Assessment. The monitoring recorded groundwater levels across the site to vary between 1.61m and 0.23m below ground level.

1.4 Southern Water Drainage System

Drainage systems can be made up of single pipe systems, (combined), and two pipe systems, (foul and surface water). The drainage system within Bosham, consists of foul sewers, with a small number of Southern Water owned surface water sewers. Appendix B provides some background information on how drainage systems have developed and the contribution that legacy housing, (houses where the roof drainage and sewage drainage combine), makes to the surface water management.

1.5 The Foul Sewerage System

The Bosham catchment consists of foul sewers, ranging in diameter from 175mm to 375mm. A small number of surface water sewers are indicated in the Southern Water Graphical information system (GIS) in the Bosham part of the catchment, ranging in diameter from 100mm to 375mm.

There are nine wastewater pumping stations within Bosham: Stanbury Close WPS, Main Road WPS, Windmill Nursery WPS, 4 Spindrift Mews WPS, Shore Road WPS, Critchfield Lane WPS, Southwood Farm WPS, Taylors Lane WPS and Smugglers Lane WPS (Figure 16). All the wastewater pumping stations, except Taylors Lane WPS and Smugglers Lane WPS, are catchment stations and they lift the flows a short distance into the next section of gravity sewers. Taylors Lane WPS is a terminal pumping station into the treatment works, serving most of the Bosham catchment and receiving flows from all the catchment pumping stations. Smugglers Lane WPS is a terminal pumping station, that includes sewage pumps and vacuum pumps serving the southern area of Bosham Hoe.

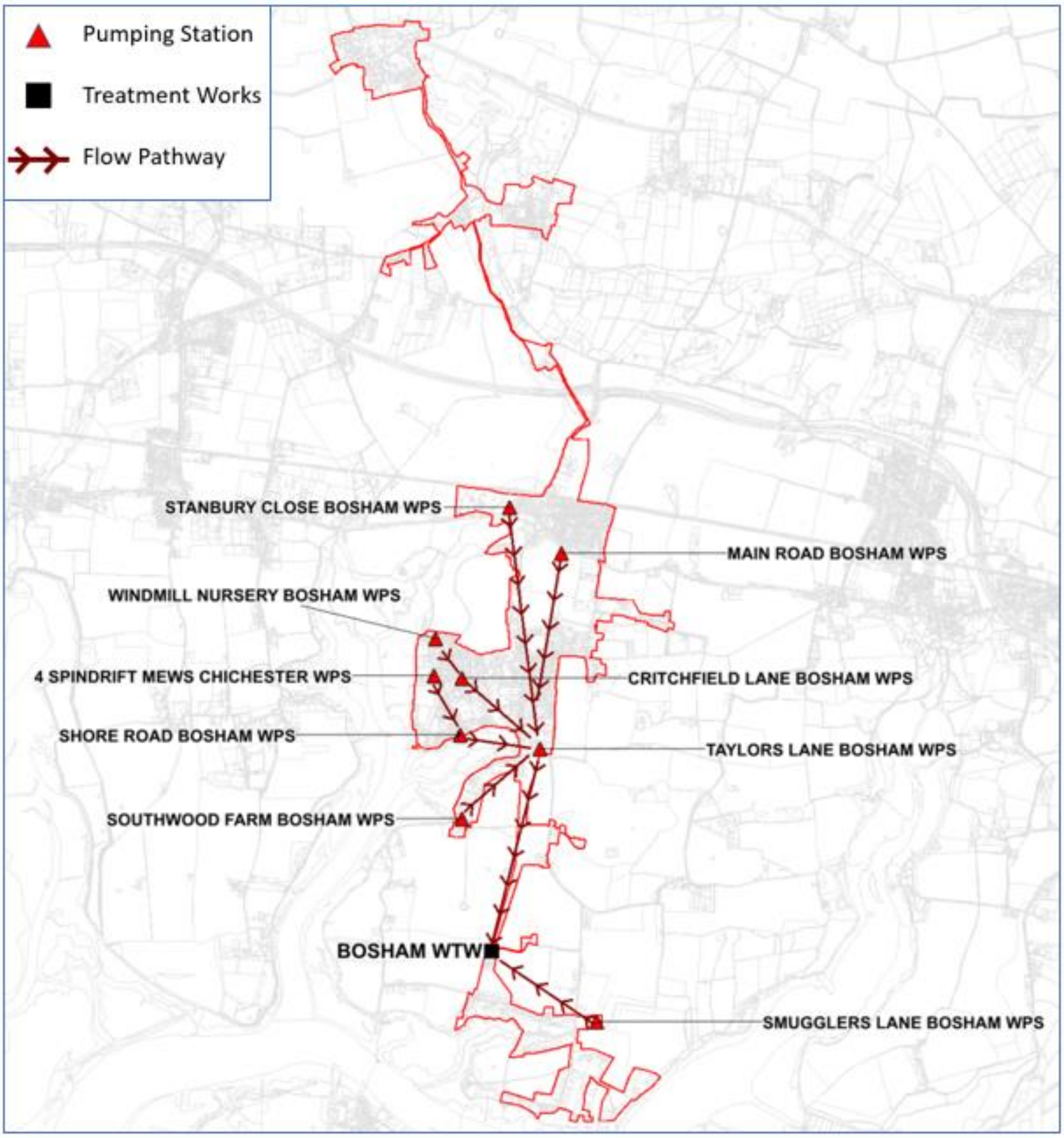

Figure 4 - Bosham WTW and Pumping Stations within the catchment

The northern part of the catchment, Funtington and West Ashling, drains under gravity via 175mm and 225mm diameter sewers towards Bosham. Areas to the east of the catchment are pumped into the main sewer line via small pumping stations, including Main Road WPS.

Bosham itself drains through a mix of gravity and pumped sewers to Taylors Lane WPS, where flows are pumped to Bosham WTW, located in fields to the north of Smugglers Lane.

The small settlement of Bosham Hoe in the south of the catchment drains via a vacuum system to Bosham WTW approximately 850m to the northwest. The system consists of 108 vacuum pods, each one serving an individual property, which combine flows at a vacuum station to the north of the area. The flows from the vacuum station are pumped via Smugglers Lane WPS to Bosham WTW. It is understood the vacuum system was installed in the Bosham Hoe area due to the high-level water table in the area and to eliminate the need for pumping stations to convey the flows across the area.

Southern Water have been carrying out the installation of sewer level monitors across the whole of their region. There are currently twenty-five sewer level monitors listed within the Bosham catchment, with a further fourteen locations scheduled for the catchment. These monitors will provide more 'real-time' data of water levels in the sewers to facilitate pro-active management of the network.

1.7 Bosham WTW

The Bosham drainage catchment is served by the Bosham Wastewater Treatment Works (WTW). The WTW is located towards the southern part of the catchment, just to the north of Smugglers Lane WPS, approximately 850m northwest of Bosham Hoe, on the River Itchen.

Figure 5 – Bosham WTW Location

Sewage is delivered to the treatment works via the rising main from Taylors Lane WPS and the rising main from Smugglers Lane WPS, including the flows from the Bosham Hoe vacuum system. Flow into the works is periodic and the largest inflow is provided by Taylors Lane Bosham WPS, which has duty/standby pumps with a capacity of between 68 and 73 l/s. Additional flows are received from Smugglers Lane WPS, which has a pumping capacity of approximately 40l/s. There is no control interaction between the smaller catchment pumping stations, therefore all pumping stations can discharge at full pumping capacity at the same time to the terminal pumping stations. Similarly, the terminal pumping stations do not have any controlled interaction between them and can pump at their full pumping capacity into the WTW.

Bosham WTW has a preliminary stage of screens and grit removal on the inlet to the WTW and then a three-phase treatment process. The key elements of the process stream are:

- Primary treatment consisting of two circular primary settlement tanks
- Secondary treatment (1st stage) consisting of four trickling filters.
- Secondary treatment (2nd stage) consisting of two conical bottom humus tanks.
- Tertiary Treatment Plant consisting of denitrification filters.

Treated sewage effluent is discharged into Chichester Harbour. The WTW currently has a Flow to Full Treatment flow rate of 42l/s.

The Dry Weather Flow, (DWF), capacity at Bosham WTW is close to being fully utilised, with only spare capacity for approximately another three hundred homes. There has been a significant increase in DWF flows in the catchment in 2021 due to increased tourism, a change in residents' working patterns and more water usage across the catchment.

At present, the WTW struggles to perform during storm conditions, especially during the winter months when groundwater infiltration in the catchment is high.

1.8 Bosham Storm Overflows

Storm overflows are a relief valve for the sewerage system to prevent the devastating impact of sewer flooding. For more information see the Southern Water Storm Overflows web page.

There are two sewer overflows within the Bosham catchment and the contributing areas to each overflow have been identified (Figure 7).

Most of the catchment, including the areas of Funtington, West Ashling and Bosham are upstream of the Taylors Lane storm overflow. The flows from Taylors Lane WPS are pumped to the WTW, where they merge with the flows from the Bosham Hoe area and any flow that cannot be treated or stored at the WTW will overflow at this location.

Sewer Overflow	Overflow Type	Releases in 2021[4]	Releases in 2020
Bosham (WTW) CSO	Storm Tank Overflow	38	82
Taylors Lane Bosham CEO	Combined Sewer Overflow	8	8

Table 2: List of Storm Overflows within the Bosham WTW catchment

The Bosham WTW overflow discharges to Furzefield Creek and Taylors Lane overflow discharges into Chichester Harbour.

[4] Southern Water Flow and Spill Reporting

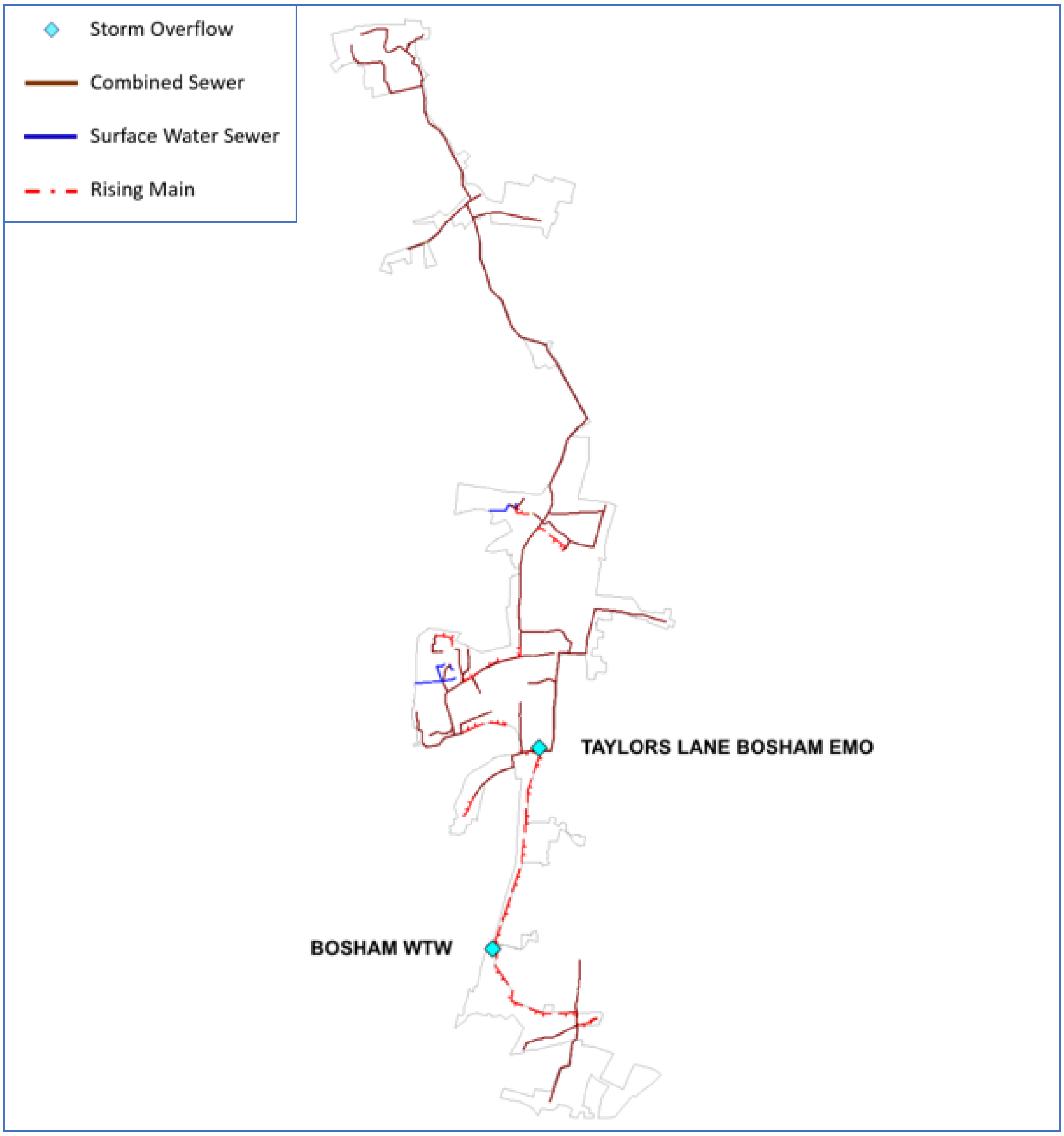

Figure 6 – Location of Overflows in the Bosham Catchment

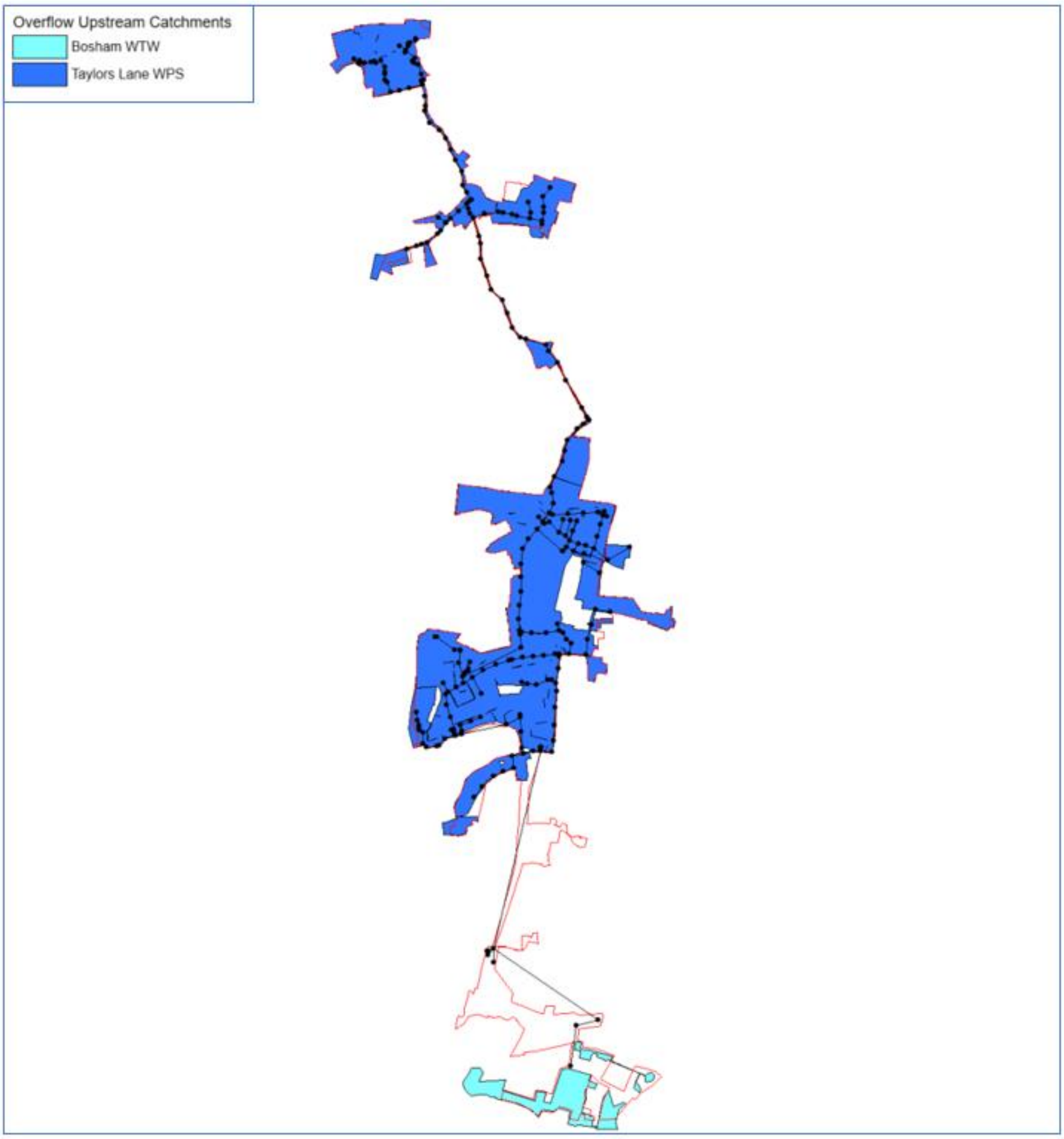

Figure 7 – Bosham Storm Overflows – Drainage Catchments[5]

1.9 The Surface Water System

A small number of surface water sewers are indicated in Southern Water GIS system within the Bosham area of the catchment. There is a small area of surface water network serving Stream Close and Moreton Road to the west of Bosham, discharging into Bosham Stream. There is another surface water sewer network serving The Holdens and Windward Road that discharges via a culverted watercourse to the Bosham Channel. There is an area of surface water network serving Stanbury Close to the north of Bosham that discharges to a tributary of Colner Creek. There is no information available confirming existence of soakaways but there are highway drainage systems in the catchment, which are operated and maintained by the local highway authority, West Sussex County Council.

[5] Southern Water Asset Miner System

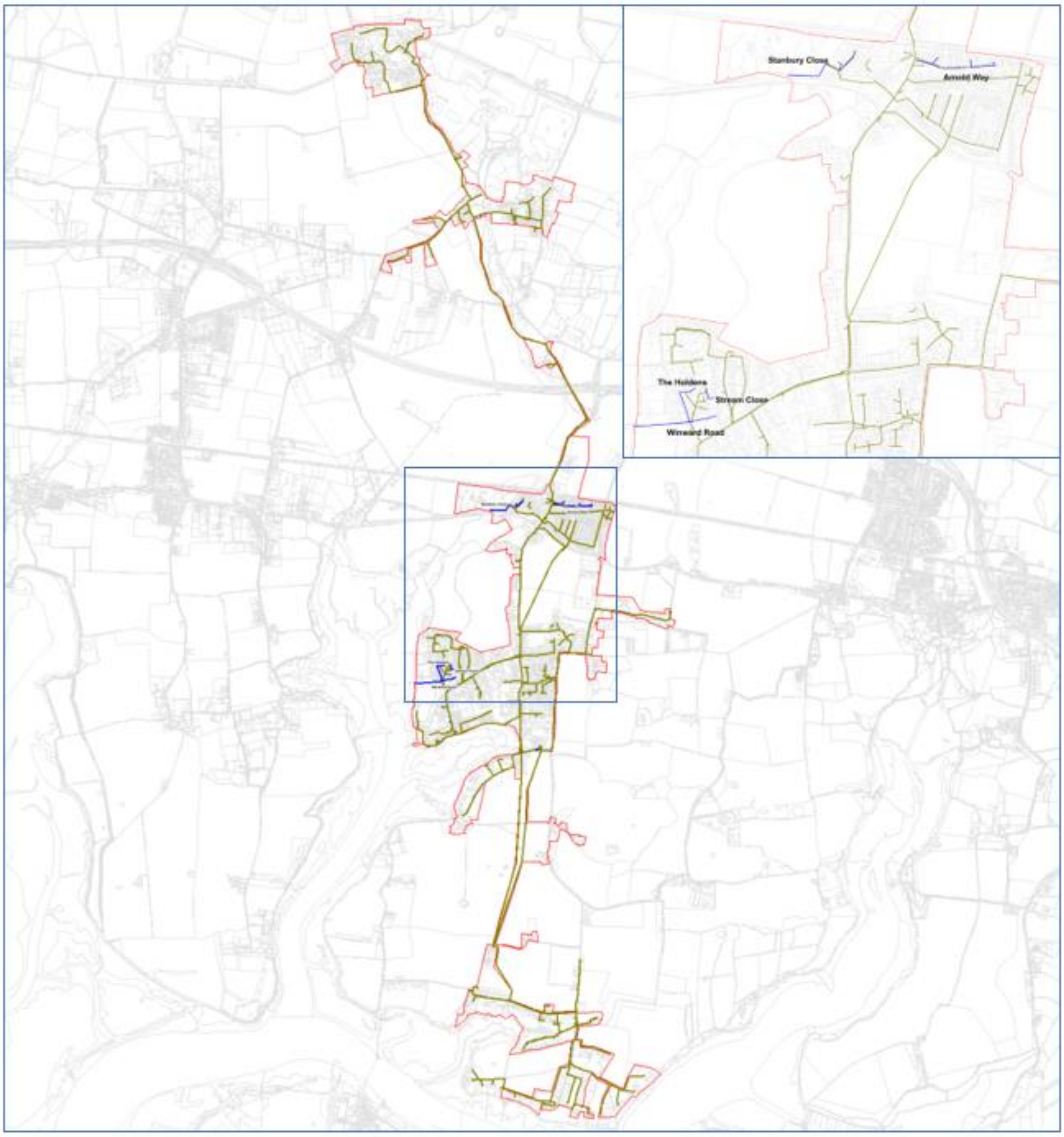

Figure 8 – Bosham Surface Water Sewers

1.10 The Highway Drainage System

West Sussex County Council have provided details of the confirmed locations of highway gullies. They do not hold details of the underground assets but have commented that most of the highway drainage within the catchment is a separate highway drainage system with outfalls to adjacent ditches and streams and does not contribute to the Southern Water sewer system.

The Southern Water GIS database holds details of a small area of highway drainage to the east of Bosham, serving Arnold Way; the information available does not confirm where this highway drainage discharges to.

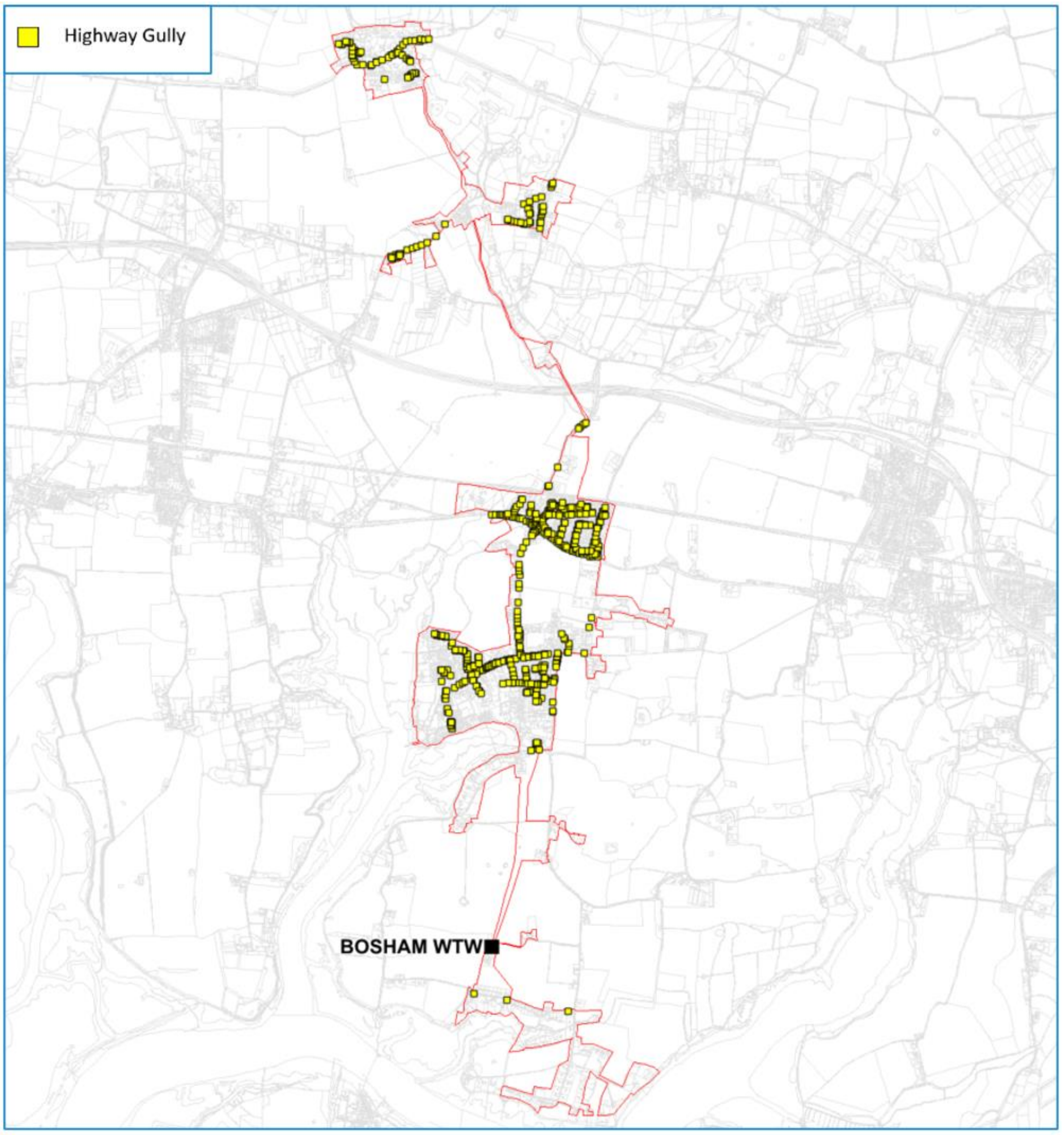

Figure 9 – Highway Gullies [6]

[6] West Sussex County Council Data, 2022

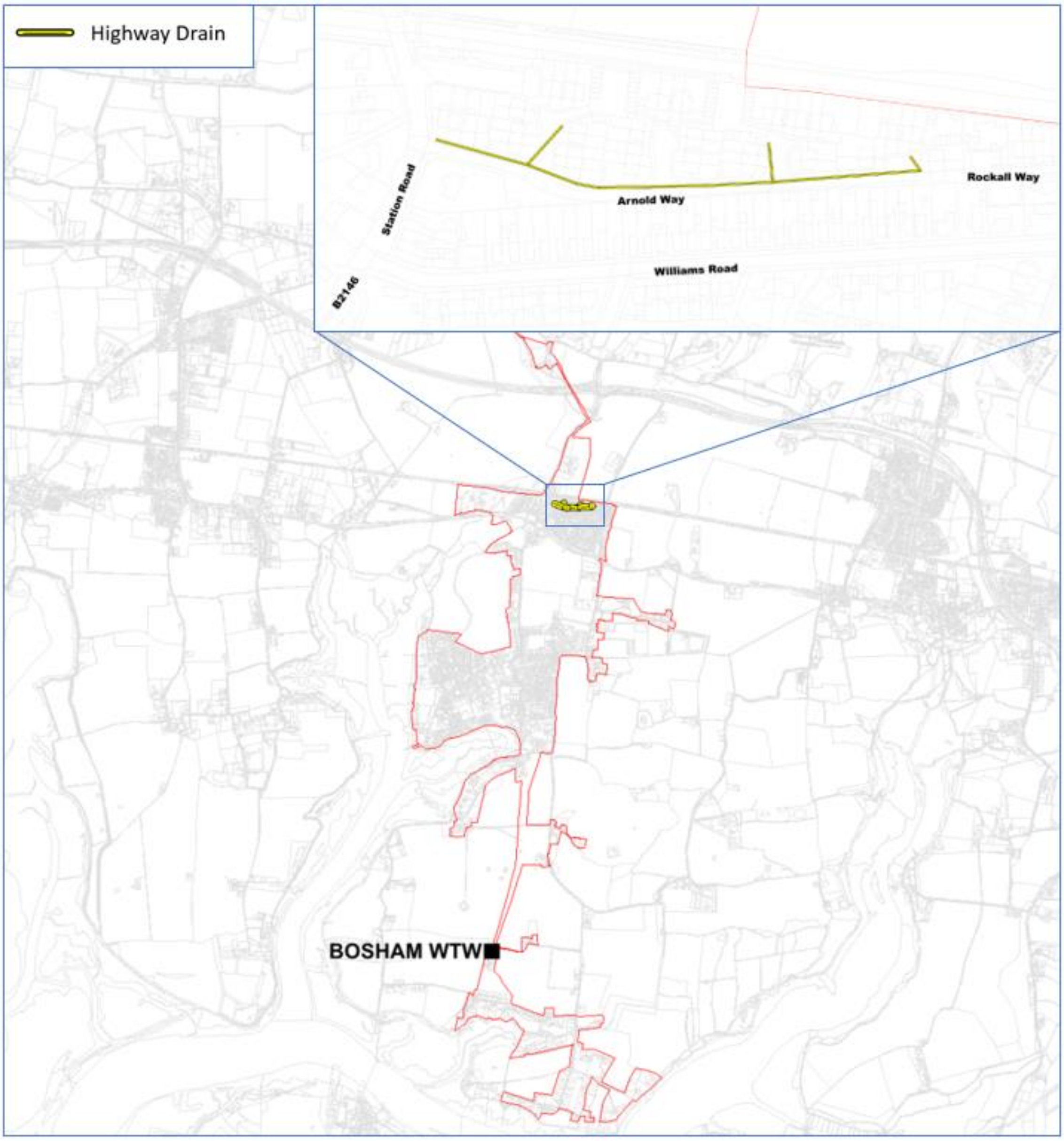

Figure 10 – Highway Drains[7]

1.11 River and Coastal System and Flooding

The main watercourses in the catchment are Bosham Stream and Colner Creek, which run from the north through the catchment and discharge into Bosham Quay, which feeds into the Chichester Channel. Furzefield Creek runs west through the northern side of Bosham Hoe, and several other smaller watercourses, drains and small bodies of water or ponds are located across the catchment. All these waterbodies ultimately drain into Chichester Harbour and are tidally influenced in their lower reaches. There is understood to be some interaction between the coastal waters and the sewerage system at Shore Road WPS where high tides enable seawater to reach the pumping station and local manholes.

[7] Southern Water Asset Minor Data, 2022

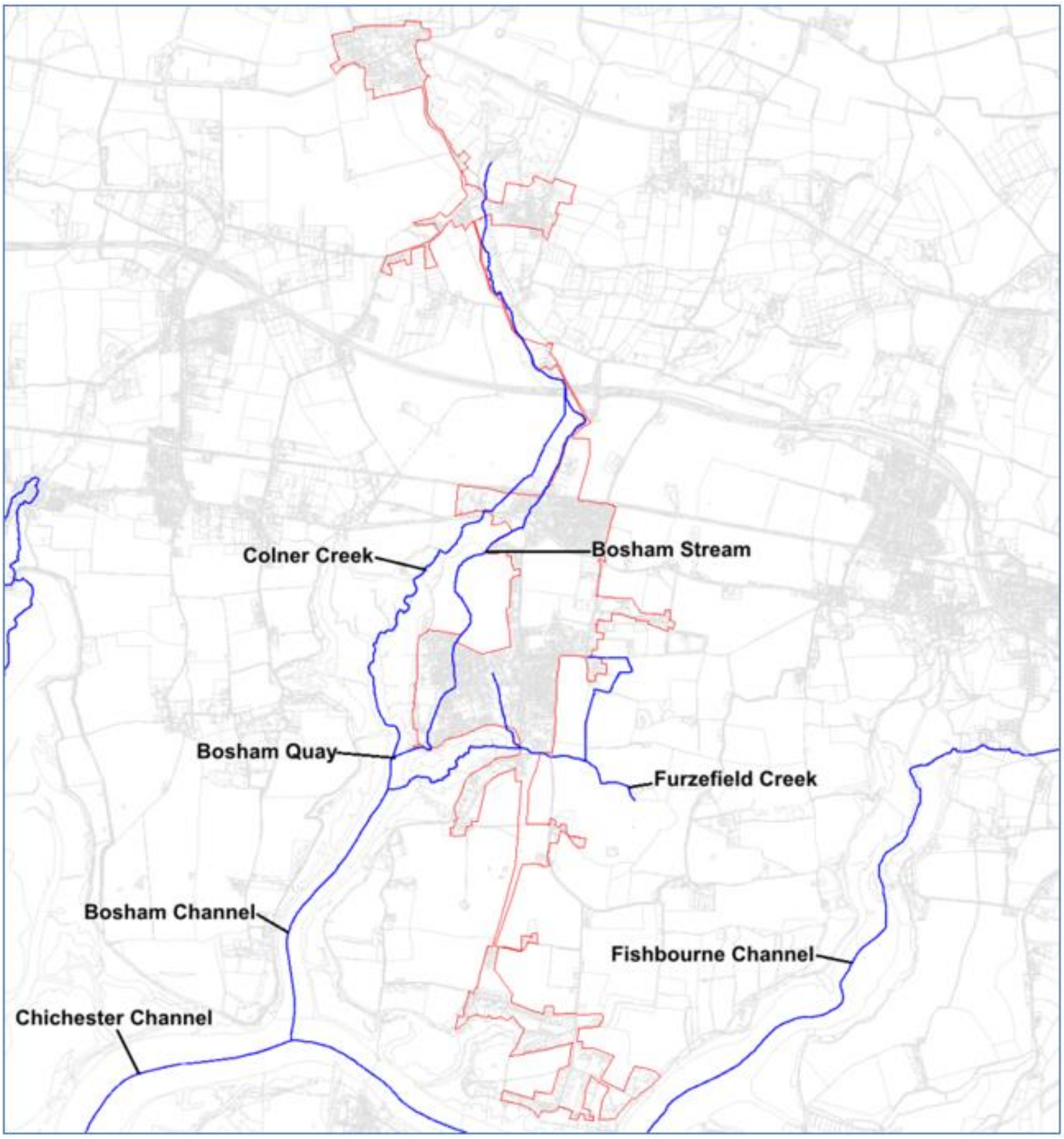

Figure 11 – Watercourses within the Bosham Drainage Catchment [8]

Figure 12 shows the risk of flooding caused by rivers or the sea. This assessment considers the effect of any flood defenses in the area. These defenses reduce but do not completely stop the chance of flooding as they can be overtopped or fail.

Parts of Bosham are located within Flood Zone 3, with a high probability of fluvial/tidal flooding. The high probability flood zones follow the rivers in the area and the coastline. The areas of the catchment located further inland and away from the watercourses have a low probability of flooding and are marked as Flood Zone 1 (Figure 12).

The areas of West Ashling and Funtington, located to the north of the Bosham drainage area, have a low probability of flooding and are marked as Flood Zone 1 (Figure 13).

[8] Southern Water Drainage Area Plan 2019

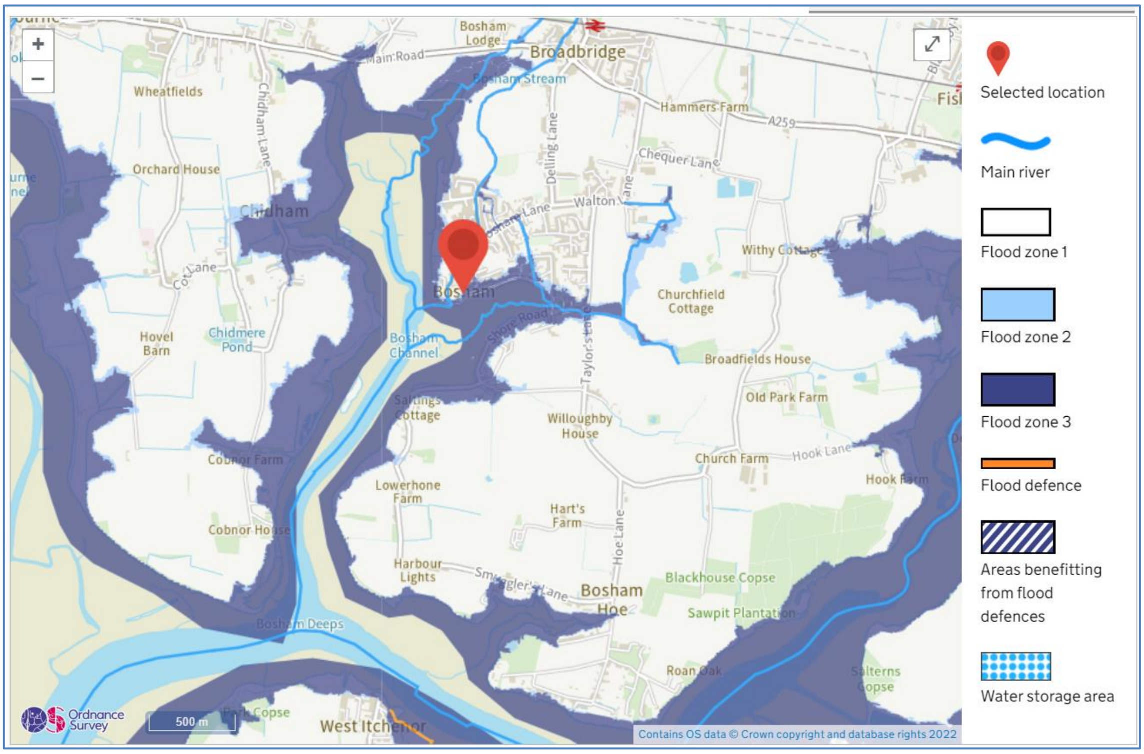

Figure 12 – Bosham - Environment Agency River and Coastal Flood Map[9]

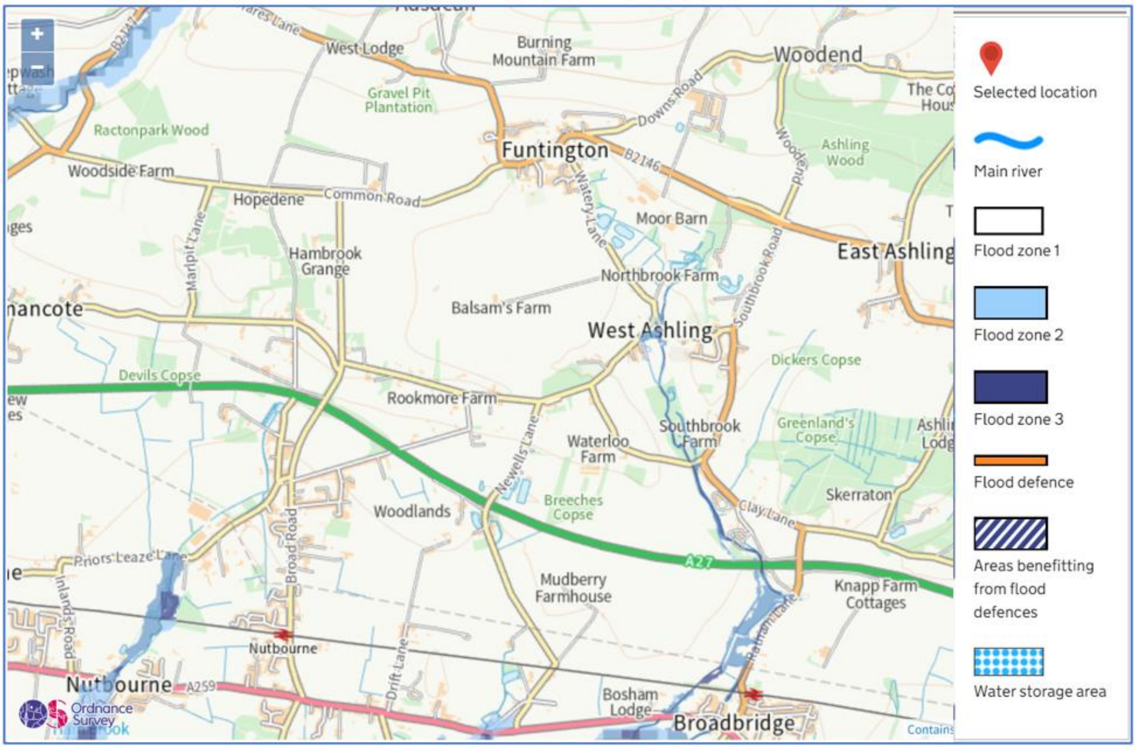

Figure 13 – West Ashling & Funtington - Environment Agency River and Coastal Flood Map[10]

9 Your long-term flood risk assessment - GOV.UK (check-long-term-flood-risk.service.gov.uk)
10 Your long-term flood risk assessment - GOV.UK (check-long-term-flood-risk.service.gov.uk)

1.12 Surface Water Flooding

Flooding from surface water is typically associated with natural overland flow paths and local depressions in topography where surface water runoff can accumulate during or following heavy rainfall events. The Environment Agency's map (Figure 15) shows the risk of flooding caused by surface water. Flooding from surface water is difficult to predict as rainfall location and volume are difficult to forecast. In addition, local features can greatly affect the chance and severity of flooding.

The map shows that there is a high risk of surface water flooding following the path of the Bosham Stream flowing south from Broadbridge and through Bosham village to Bosham Quay. A high risk of surface water flooding means that this area has a chance of flooding of greater than 3.3% each year. Other areas at high risk of surface water flooding are along the coast following Shore Road from Bosham to Bosham Hoe.

The majority of Bosham Village has a low risk of surface water flooding, with some medium to high risk areas in places such as Bosham Lane and Brook Avenue. Medium risk means that the area has a chance of flooding of between 1% and 3.3% each year, and low risk means that the area has a chance of flooding of between 0.1% and 1% each year.

The West Ashling village area and the highway areas of Funtington have a medium to high surface water risk (Figure 15).

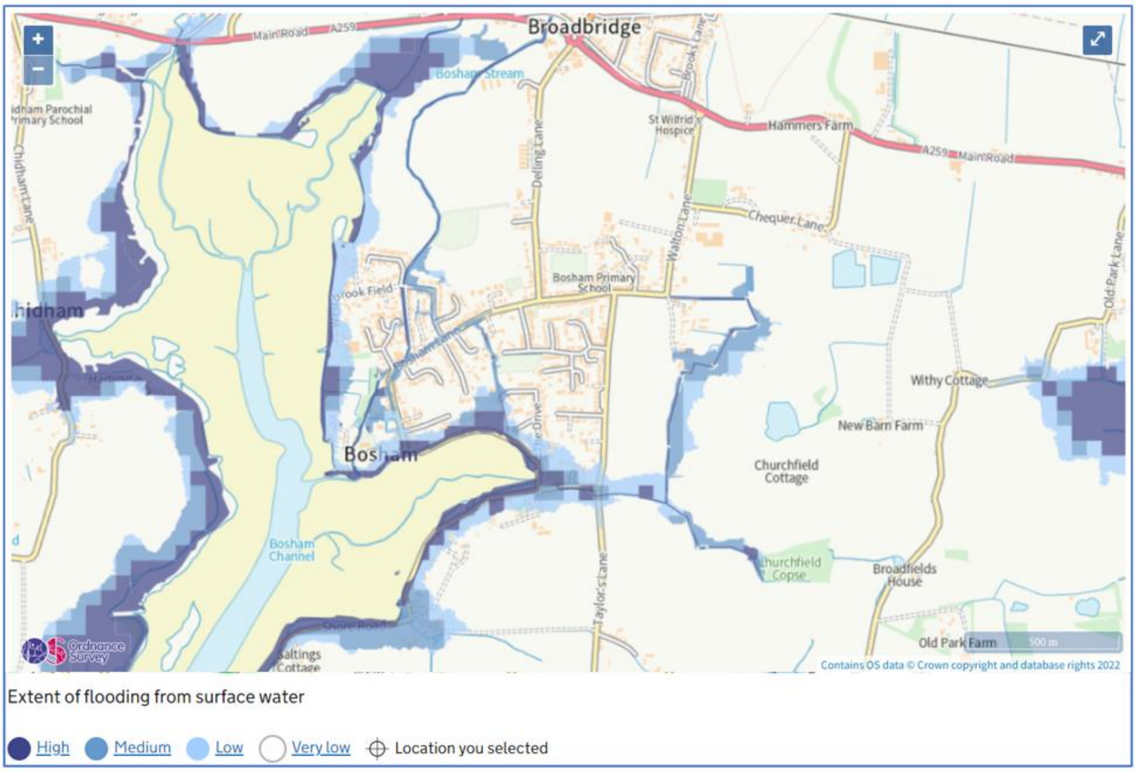

Figure 14 – Extract from the Environment Agency's Flood Risk from Surface Water map[11]

[11] Your long-term flood risk assessment - GOV.UK (check-long-term-flood-risk.service.gov.uk)

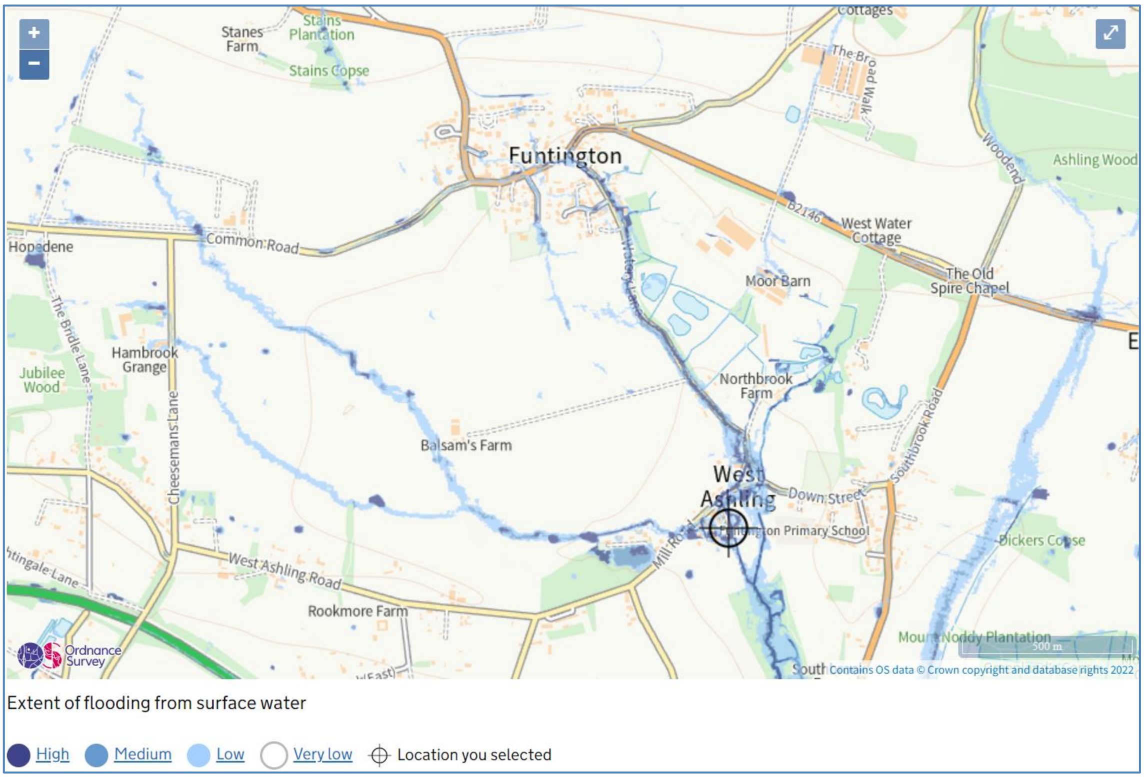

Figure 15 – Extract from the Environment Agency's Flood Risk from Surface Water map[12]

12 Your long-term flood risk assessment - GOV.UK (check-long-term-flood-risk.service.gov.uk)

1.13 Simplified Bosham Schematic Layout

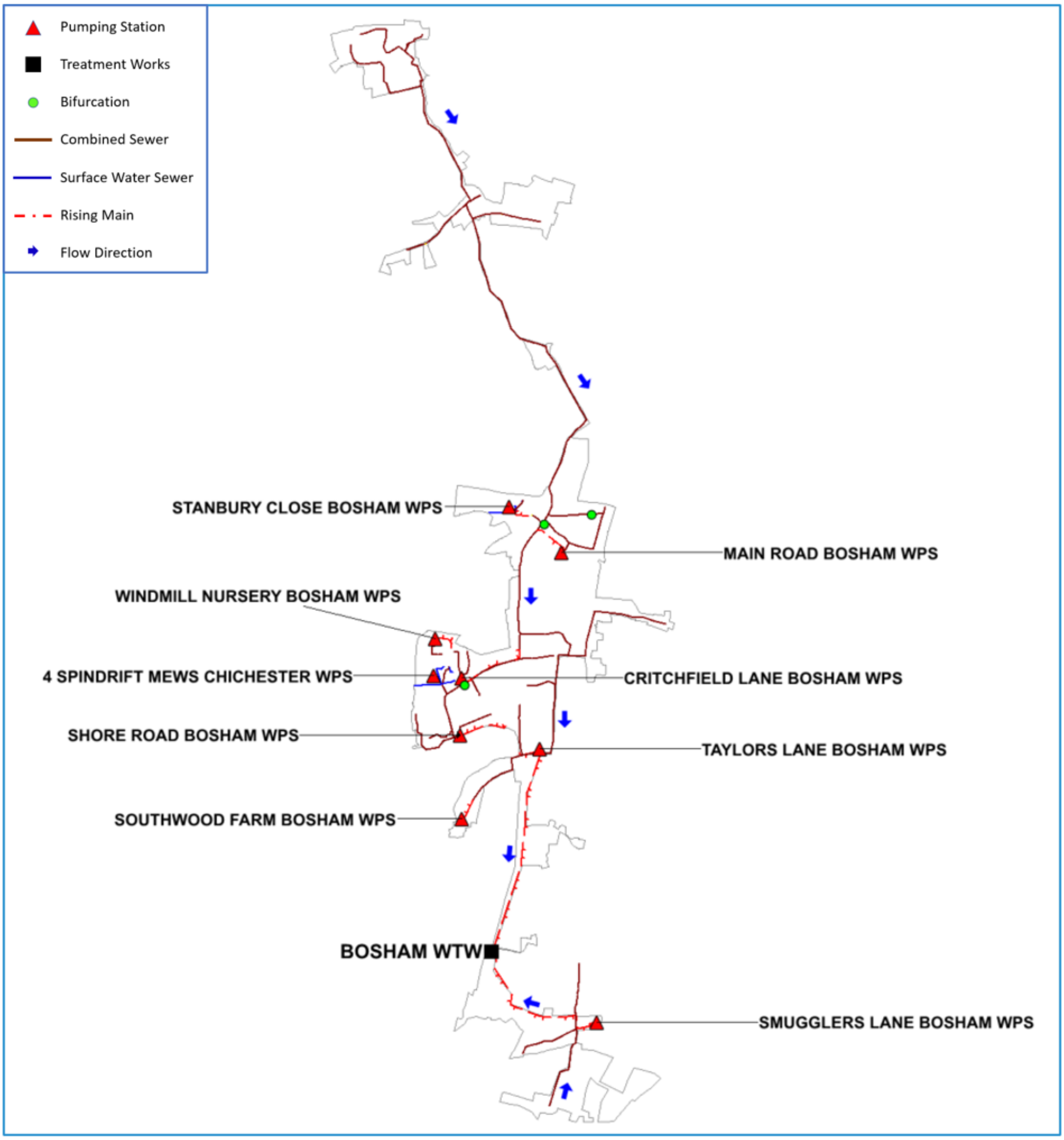

Figure 16 – Bosham Catchment Schematic

2.0 Why Change is Required

The Bosham catchment has been included in the Pathfinders programme due to the storm overflow performance experienced within the catchment. The catchment is understood to experience significant levels of groundwater infiltration during the winter months, which overwhelm the system and lead to the storm overflows spilling, with the overflow at the treatment works spilling for long durations. There are also some flooding locations within the catchment that may also benefit from work that could be completed as part of the Pathfinders programme.

2.1 Sewer Overflow Performance

The Bosham catchment has two sewer overflows, one located at Taylors Lane pumping station, and one located at the Wastewater Treatment Works. The overflows discharge into Chichester Harbour and the event duration monitoring equipment documents that the storm overflows are triggering regularly in wet weather conditions. The overflow at Bosham WTW can discharge for long durations over several days during the winter months; this is understood to be related to the high levels of groundwater experienced in the catchment. The two storm overflows spilt a total of ninety times during 2020 and forty-six times during 2021, with most of the spills occurring at the treatment works overflow.

2.2 Flooding

The Southern Water flooding database details twenty-five locations currently at risk of external flooding; ten of the documented locations are properties and fifteen are listed as highways or other external areas. The flooding database details properties at risk in Down Street, Mill Road, Ratham Lane, Shore Road, Station Road and Watery Lane. The external and highway areas listed at risk are within Down Street, Ratham Lane, Shore Road, Station Road, Bosham Lane, High Street and Watery Lane.

Previous reports have provided information on three main areas that experience property flooding: the report details below focus on the areas of Stumps Lane, Watery Lane and the Harbour Cottages. Local network operations teams have been contacted for confirmation on these flooding mechanisms.

Stumps Lane is located upstream of Taylors Lane pumping station and properties experience flooding when the pumping station experiences operational issues leading to the system surcharging. Stumps Lane does not feature in the flooding database and instead is included in the customer action database as all entries are linked to the pumping station operation. It should be noted that these properties and the pumping station have experienced flooding from the nearby watercourse and a wall has been built to contain the flood water within the pumping station compound.

Two properties on Watery Lane experience flooding from manholes in their gardens. The lane is flanked by two ditches and during heavy rainfall the manholes spill, and the ditches break their banks. The flows from these two sources continue down Watery Lane towards the West Ashling Pond creating a pollution risk. Watery Lane does not have any pavements and therefore pedestrians must walk along the lane through the flood waters.

The Harbour Cottages, understood to be located along Shore Road, experience flooding via surcharging flows into the private laterals of the properties. During high tide seawater flows overland and can enter the sewer system, overwhelming the assets and causing surcharging within the system.

Bosham stakeholders and residents have described flooding from manholes at Bosham Lane, Street End (junction of Bosham Lane and High Street), Shore Road and Delling Lane.

3.0 Catchment Investigations

The desktop analysis of the Bosham catchment and the available data has analysed several key factors that could be impacting on the performance of the Bosham sewerage network, leading to the overflow discharges and flooding that have been experienced.

The following section describes those factors, how they can affect storm overflow spills and catchment flooding, the level of detail understood so far, for the Bosham catchment, and the potential next steps for the partners and stakeholders interested in the Bosham catchment. Section 4.0 provides more specific activities and actions that are recommended for the project and the catchment.

Interventions considered for the catchment include Southern Water operational interventions, above ground measures to remove or slow the flows, underground measures to remove or slow the flows, optimisation of the existing network and new infrastructure, including changes to the wastewater treatment works.

3.1 Sewer Maintenance

Sewer systems play an essential role in maintaining public health, protecting the environment, and managing surface water flood risk. If the condition of the sewerage networks is not monitored and maintained then it leads to blockages, collapses, sewer flooding and pollution discharges into waterbodies.

3.1.1 Risks

Issues located within sewers include cross sectional area losses from items such as deposits or root intrusions, infiltration into the sewer system and structural defects along the sewer lengths.

Deposition, such as fats, oils and greases or root intrusions, lead to a loss in cross sectional area of the sewer pipe. This cross-sectional loss reduces the flows that the sewer can pass forward, reducing the flow velocity and increasing the flow depth within the sewer. This flow condition change may only occur in a localised area of the system close to the deposition but where the cross-sectional area loss is significant, it can lead to that flow change being experienced much further upstream in the system.

Structural defects within the sewer network, such as cracks, fractures, displaced joints, and broken pipes can increase the chances of the sewer collapsing as the structural integrity of the pipework will be compromised. The collapse of a sewer can lead to flooding of properties, both internally and externally and pollution incidents; depending on where the collapse occurs in relation to local watercourses.

Infiltration increases the volume of water passing through the network. The sewer system may be unable to cope with the additional water, leading to surcharging in the system. When the sewer network becomes overwhelmed, it can lead to an increased risk of flooding and cause overflows to discharge to the watercourse to relieve the system.

3.1.2 Bosham Findings

The desktop exercise has confirmed there are areas of the Bosham sewer network that have regular maintenance tasks scheduled, such as CCTV and jetting, to manage sedimentation and root intrusions, and inspections of anti-flood devices and non-return valves on properties to ensure they are operating as expected. There are also assets that require one off maintenance to ensure they are performing as expected, such as manhole cover repairs and re-sealing of manhole covers.

The Bosham Association provided details on historical works and investigations completed on the sewer system. The commentary stated that the main clay pipes are not in poor condition but that the sewer joints connect with rubber seals which are allowing infiltration into the system. The design of the sewer system was not developed to stop ground water entering the sewers. The Funtington sewers had been tested and sealed but that there may be issues with the private laterals feeding into this area of the system; surveys completed in 2004 and 2007 showed the public sewers to be well sealed. The West Ashling sewers were relined in 2011 and investigations were planned for 2014/2015 for the West Ashling to Bosham sewers. It is unclear if these investigations were completed.

Data available from the Bosham Flow Action Plan confirms that CCTV works were completed, up to 2021, for several areas of the catchment as part of a Groundwater Infiltration Reduction Plan (Figure 18). The purpose of the plan was to investigate and reduce groundwater inundating the sewers which could have caused properties to be flooded. As a result of this CCTV some sealing of sewers and manholes was completed.

The sewer level monitors already active in Bosham are recording depths within the sewer system and understanding the typical response to dry and wet weather in these locations. This real-time monitoring has been recording the depths experienced and has detected a potential blockage in the catchment and triggered an alert.

The key catchment pumping stations have telemetry installed to provide ongoing data on the performance of the assets. The telemetry system alerts operational staff to any reduction in performance and maintenance can be completed as required.

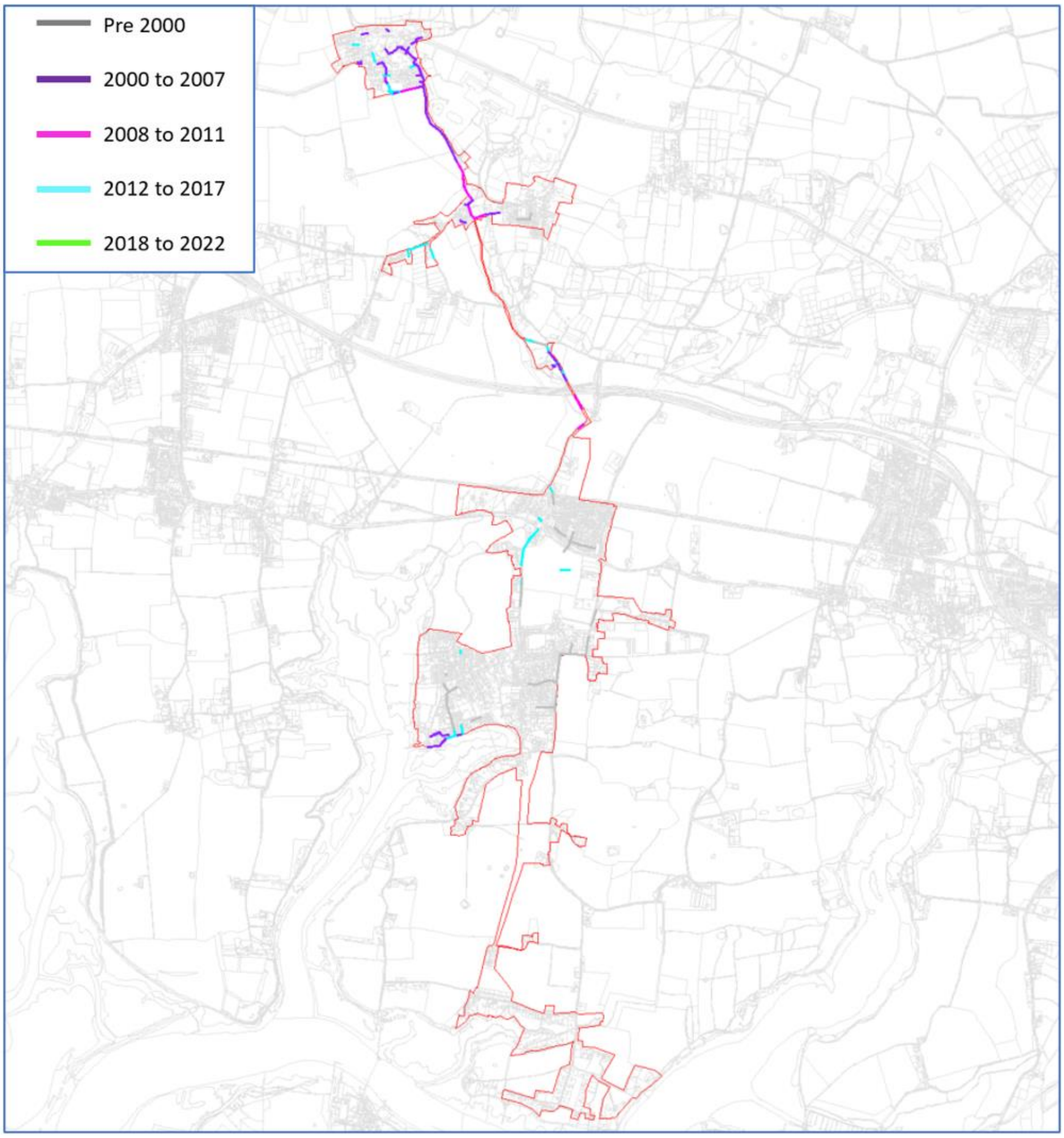

Figure 17 – Bosham CCTV Locations (up to 2017)

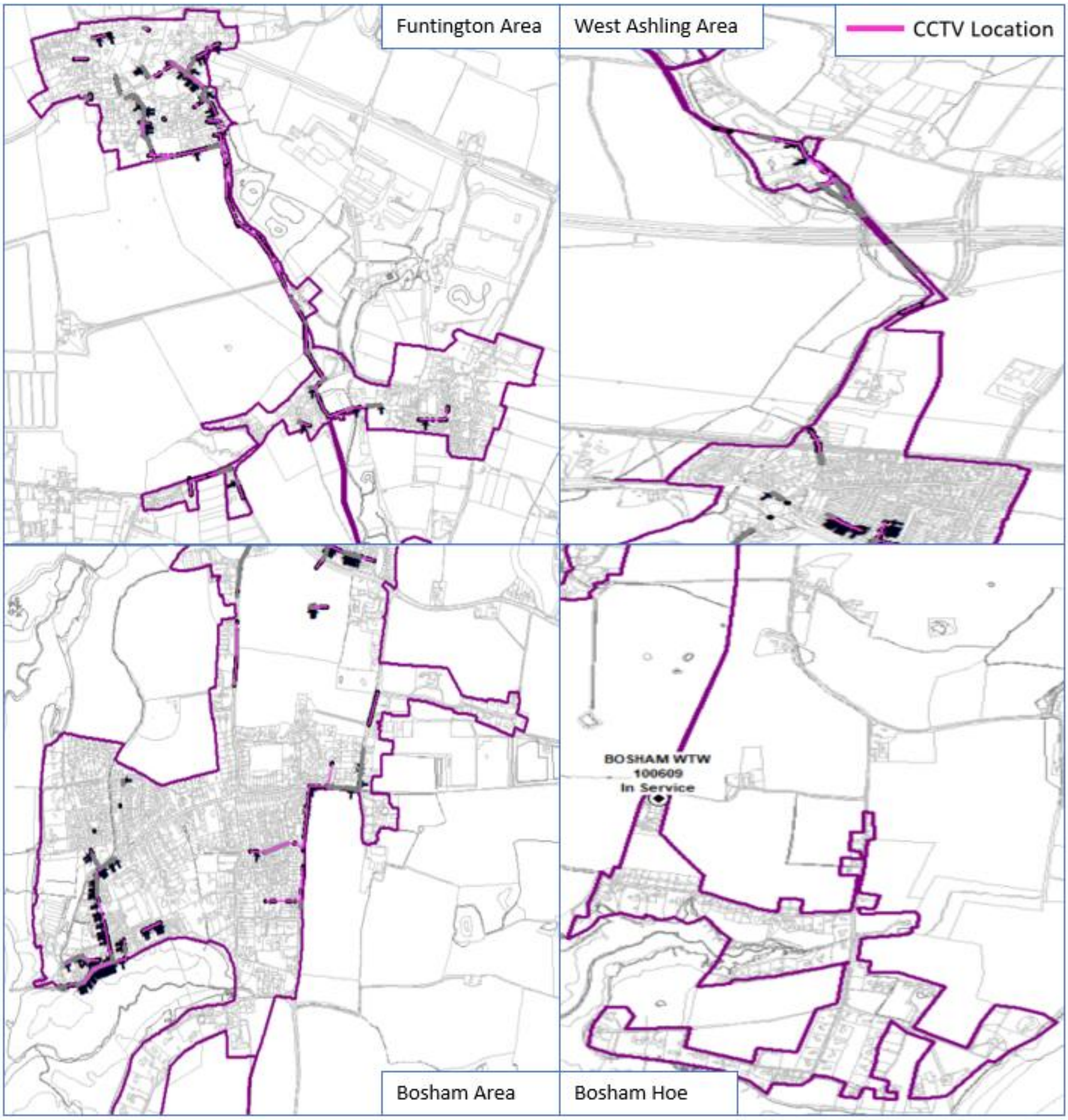

Figure 18 – Bosham CCTV Locations – Groundwater Infiltration Reduction Plan (up to 2021)[13]

3.1.3 Potential Actions and Investigations

A proposed action from this report is for Southern Water to undertake a review of the current Maintenance Service Tasks, (MST), for the catchment and review their scope and frequency. This MST could include CCTV to monitor the progress of any structural defects, deposition levels and root intrusions. Over time regular monitoring would provide trends in the siltation and depositions within the sewers; these trends would enable network operators to better understand the catchment and to implement pro-active maintenance of the network.

[13] Bosham WTW DWF Flow Action Plan 2021

Following on from previous CCTV completed as part of the Groundwater Infiltration Reduction Plan, there were further areas identified that could be a source of infiltration; additional investigations in these locations would confirm if sealing work was required. The traditional method for sealing sewers is to install leak tight liners into the public sewers, made either from an epoxy or a silicate-based resin. These liners have been tested against 5m head of water and have a design life of at least 50 years. Manholes can be sealed separately using a spray lining from the inside or stitch drilling and injecting a resin into the ground surrounding the manhole to make it watertight. These methodologies are well used and understood.

Southern Water have an ongoing Sewer Level Monitoring (SLM) programme, whereby 22,000 monitors will be in place across the Southern Water region by the end of 2022. The SLM programme will enable sewers to be continuously monitored and trends established to understand the typical levels at each SLM. Live monitoring of the SLMs will detect when measurements deviate from these typical levels, and network operatives will be alerted. The cause can be investigated, and action can be taken as necessary. There are several SLMs planned for the Bosham catchment, with a number of these monitors already installed and active within the catchment.

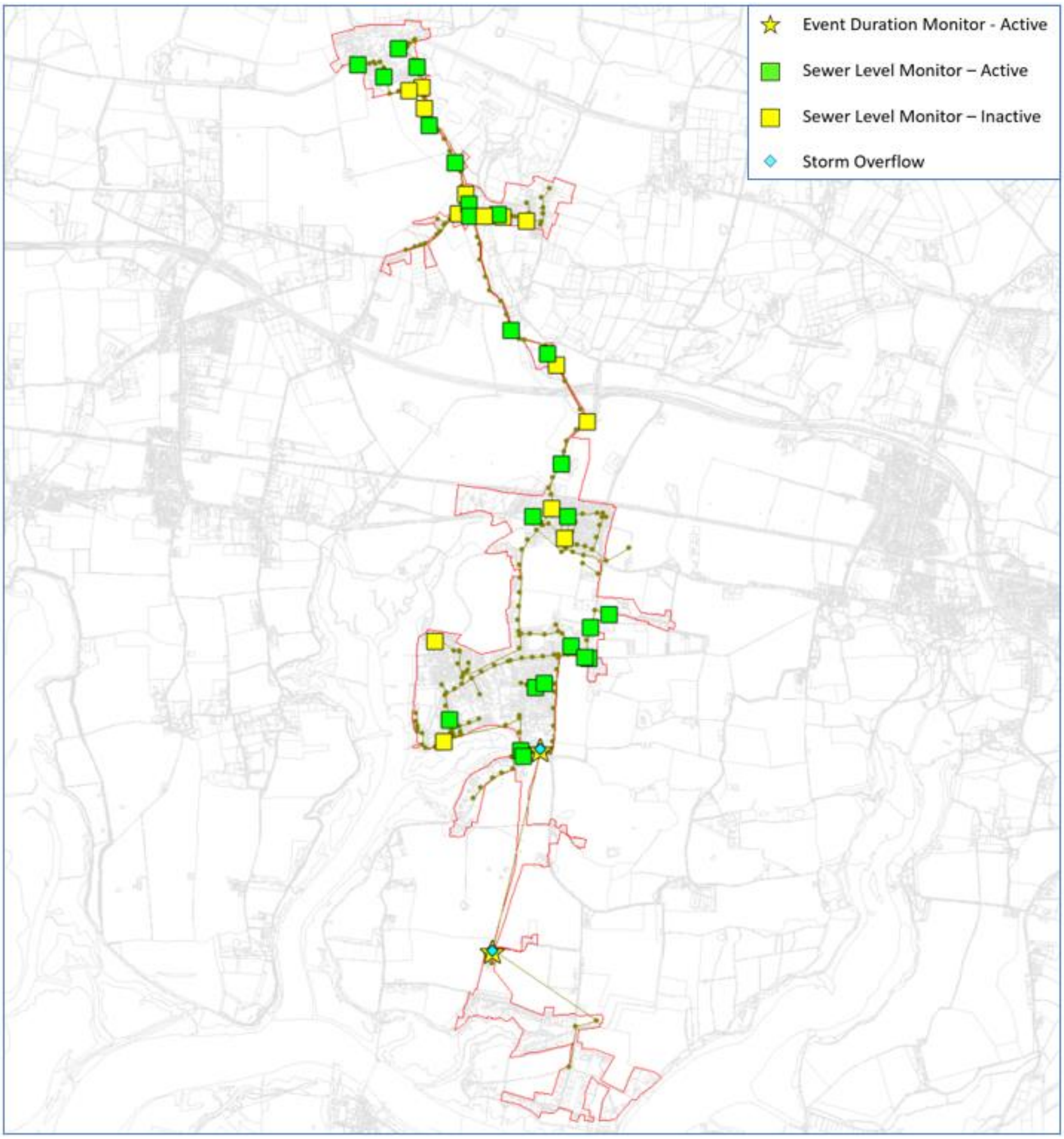

Figure 19 – Bosham Planned Monitoring Locations

Customers are a key element in maintaining the functionality of the sewer network. Customer behaviour can have a significant impact on the sewerage system through the disposal of unflushable items and fats, oils and grease, leading to blockages, flooding and pollution events. Educational campaigns, such as 'The Unflushables', can be promoted within the catchment to better inform customers and provide advice on the best way to dispose of these items, especially in areas where there are known maintenance issues.

See Section 4.0 for specific proposals for the next steps in the Bosham catchment.

3.2 Highway Drainage

The highway drainage system is utilised to remove rainwater from the highway and footpaths into the sewerage system. Highway gullies capture flows from the road edge and convey them into the highway drain. The highway drains then connect into the local watercourse, local drainage system, surface water sewer, foul or combined sewer system.

3.2.1 Risks

If highway drainage is connected into the sewerage network, then it will be increasing the flow volumes within the network, especially in times of heavy rainfall. These additional flows could overwhelm the system, raising top water levels, increasing the flood risk, and causing overflows to prematurely discharge into the watercourse. The additional flows would also put pressure on the wastewater treatment works, increasing the volume of flows that need to be treated.

3.2.2 Bosham Findings

The desktop exercise has confirmed there is highway drainage within the Bosham catchment (Figure 9 and Figure 10). West Sussex County Council have provided details of the confirmed locations of highway gullies. They do not hold details of the underground assets but have commented that most of the positive highway drainage within the catchment has a separate highway drainage system with outfalls to adjacent ditches and streams and does not contribute to the sewer system.

3.2.3 Potential Actions and Investigations

Most of the highway drainage within the Bosham catchment is understood to be drained separately and does not contribute to the sewer network. Surveys of the downstream connectivity of the highway drainage system would be beneficial to confirm discharge locations are to local ditches and watercourses and do not impact on the Southern Water sewer system.

If the highway drainage system is not regularly maintained and gullies kept clear, then the surface water runoff on the highway surfaces will be unable to enter the highway drainage system and may find routes into the sewer network via unsealed manhole covers.

Confirmation of any highway assets outside of the areas provided by West Sussex County Council would be useful, but the highway drainage network does not appear at this stage to be a significant contributor to the sewer system.

See Section 4.0 for specific proposals for the next steps in the Bosham catchment.

3.3 Roof Drainage

Historically, older parts of towns and cities have combined sewerage systems which take both the rainfall and wastewater to the sewage treatment works. Properties built later, from 1930s onwards, will have included a level of separation of the flows. The level of separation will vary from area to area depending on the existing sewerage system available and the ground conditions, with some areas using soakaways or a fully separate surface water system.

3.3.1 Risks

Surface water runoff from property roofs entering the sewerage system can significantly increase the volume of water passing through the network, especially during times of heavy rainfall. The sheer volume of flow can make it impossible for the sewer system to cope with the additional water leading to surcharging in the system. When the sewer network becomes overwhelmed, it can lead to an increased risk of flooding and cause overflows to discharge to the watercourse to relieve the system.

3.3.2 Bosham Findings

The desktop exercise has indicated that some of the roof drainage within Bosham connects into the main sewerage network. An Impermeable Area Survey, (IAS), completed in 2008 shows a proportion of large, detached properties in Funtington and West Ashling connect into the foul sewer system. There are several flooding locations in these areas of the catchment and therefore a reduction in the flows contributing to this section of the sewer network would be of benefit.

To the north of Bosham village, around Main Road, the IAS also indicates that there are properties in the North Road and Gifford Road areas to the eastern side that connect to the foul sewer system. The properties along Arnold Way and Stanbury Close have been surveyed as connecting to the surface water systems in those areas; confirmation of the downstream discharge point for the surface water system would be useful to understand.

The survey data for the central area of Bosham village indicates there are many properties connecting to the surface water system in the areas of Stream Close and Moreton Road to the west and the Leander Road area to the east. The IAS survey reports properties connecting to the foul system along Bosham Lane, High Street and Shore Road.

The surveyed areas of Bosham Hoe indicate the impermeable surfaces are all connected to soakaways and there is only one rooftop connecting into the foul system.

Figure 20 – Bosham Impermeable Area Survey 2008

3.3.3 Potential Actions and Investigations

Complete connectivity surveys in Funtington and West Ashling and at North Road, Gifford Road, Bosham Lane, High Street and Shore Road to confirm the properties that are contributing roof drainage to the sewerage network.

Removal or reduction of the property roof drainage entering the sewerage system by installing SuDS devices, such as leaky water butts or planters at each of the connected properties. Water butts enable the rainwater from the roofs to still be collected, but the rate at which the flows enter the sewerage network is controlled via an orifice within the device. Figure 21 indicates the theoretical impact of a water butt on the runoff experienced in the sewers; the water butt reduces the peak of the rainfall response and slows the flow of rainwater entering the sewer system. Southern Water 'leaky' water butts would provide the homeowner with a water source as the device would include a tap allowing the resident to make use of the collected water. SuDs planters are designed to capture rainwater run-off from roofs, rerouting the downpipe into the planter instead of directly into the sewerage system. The planter is made up of a series of layers, acting as both a sponge and a natural filter, attenuating flow and removing sediment as the water soaks through to the reservoir.

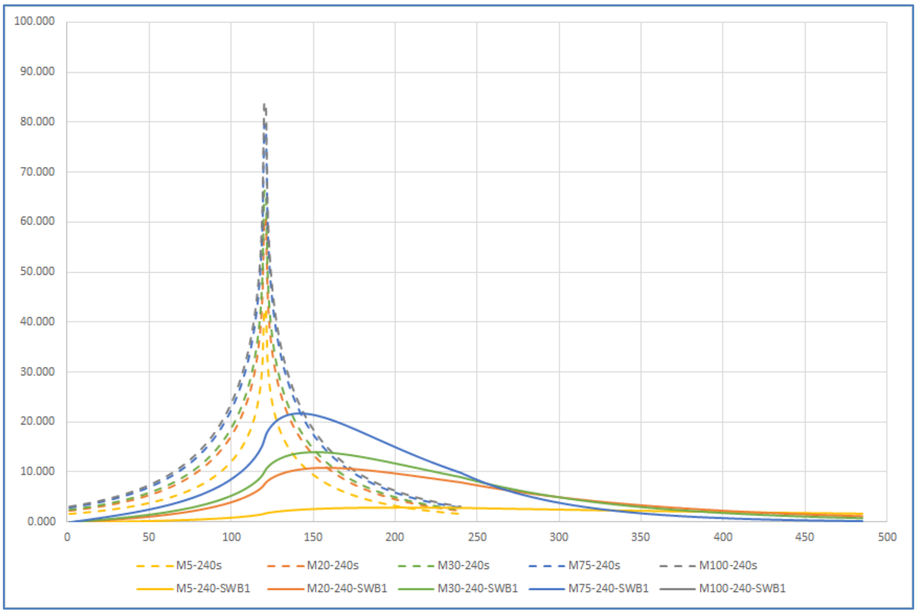

Figure 21 – Smart Water Butt Impact on Rainfall

Figure 22 – Water Butt and Planter Examples

Ideally the property roof drainage would be completely disconnected from the foul sewerage system and discharge to the ground or to the nearest surface water sewer or local watercourse. However, the proximity of the property to the nearest watercourse or surface water sewer and any impact on the watercourse would need to be considered to ensure the transfer of these flows did not cause any increase in risk.

See Section 4.0 for specific proposals for the next steps in the Bosham catchment.

3.4 Overland Flow

Overland flow is the flow of water over ground surfaces when excess rainwater can no longer infiltrate into the soil. Overland flow pathways are the natural routes for the rainwater to take to reach the nearest surface water body. The natural flow pathways may be interrupted via the development of towns, with highways or buildings constructed across the natural flow routes. Overland flows will pass across different surface types and may begin their journey on rural or manmade surfaces.

3.4.1 Risks

Significant flows can be experienced via overland flow pathways, especially during heavy rainfall events. These flows may continue to the nearest waterbody overland, or they may enter the sewer system via unsealed manhole covers, gullies or highway drainage.

The overland flows can cause flooding of highways or properties if the route to the waterbody passes through built up areas such as towns and villages, and the natural flow route is blocked or built upon.

The overland flows can cause pollution of the watercourses, depending on the types of land that the flows have passed over prior to discharging into the local waterbody; for example, agricultural land and industrial estates may include pollutants that could have a detrimental impact on the watercourses.

If the overland flows enter the sewer network, via gullies or other means, this will result in an increase in flow volumes experienced in the system. There may be a delay between the rainfall event and the overland flows reaching the sewer system if they have travelled a distance to reach an entry point into the network. The sewer system may be unable to cope with the additional water, leading to surcharging in the system. When the sewer network becomes overwhelmed, it can lead to an increased risk of flooding and cause overflows to discharge to the watercourse to relieve the system.

Overland flows can lead to erosion of land surfaces. The repeated occurrence of fast flowing water through the same flow pathway can erode soil and lead to changes to the landform. Overland flows can also have detrimental impacts on built environments, such as highways, kerb lines and buildings, when the flows consistently pass alongside or over the structures, leading to a failure of the materials.

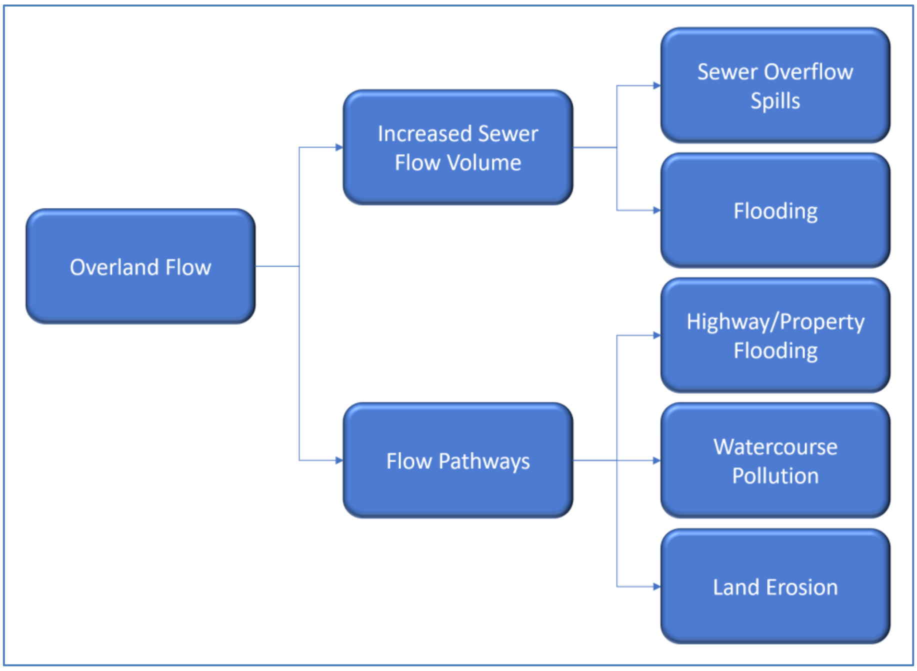

Figure 23 – Overland Flow Risks

3.4.2 Bosham Findings

The desktop exercise has investigated the topography of the Bosham catchment and the overland pathways that could be impacting on the sewerage system. The natural flow paths of the catchment drain flows from north to south, with the two lowest flow channels following the routes of Colner Creek and Bosham Stream, south towards Bosham Quay and the Bosham Channel. There is also a low-lying flow channel delivering flows east to west, that follows the path of the Furzefield Creek.

The Bosham Association have commented on flows draining from higher ground to the low-lying areas, filling and overwhelming the local ditches. Once the tidal level is high there is no more capacity for these additional flows in the ditches and they enter Taylor's Lane pumping station.

Local stakeholders have reported that Shore Road pumping station and surrounding area are submerged by high tides, and this has led to sea water entering the pumping station building. The manholes in this area have been sealed to reduce the volume of sea water entering the sewer network. There are also low-lying areas of the Bosham Hoe region that are submerged during high tides; this seawater could enter the sewer system at unsealed manhole locations.

The ditches and drains require regular maintenance to ensure they are at full capacity to convey the overland flows to the watercourses and south to the Harbour. A 2013 report stated that the Parish Council had been proactive in clearing ditches, sluices, and grills during wet weather. There was a summer education initiative sent out to inform riparian owners of their responsibilities to help keep ditches clear. The Parish Council worked with West Sussex County Council on clearing Delling Lane and completed further works on the ditches in Green Lane, Stumps End and Lower Hone. The Chichester District Council completed clearance work on the car park drains. It is unclear if this maintenance has continued with a regular schedule.

The Burhill Estate and the Sailing Club have responsibility for a sluice on the quay; in the 2013 report conclusion a replacement was required.

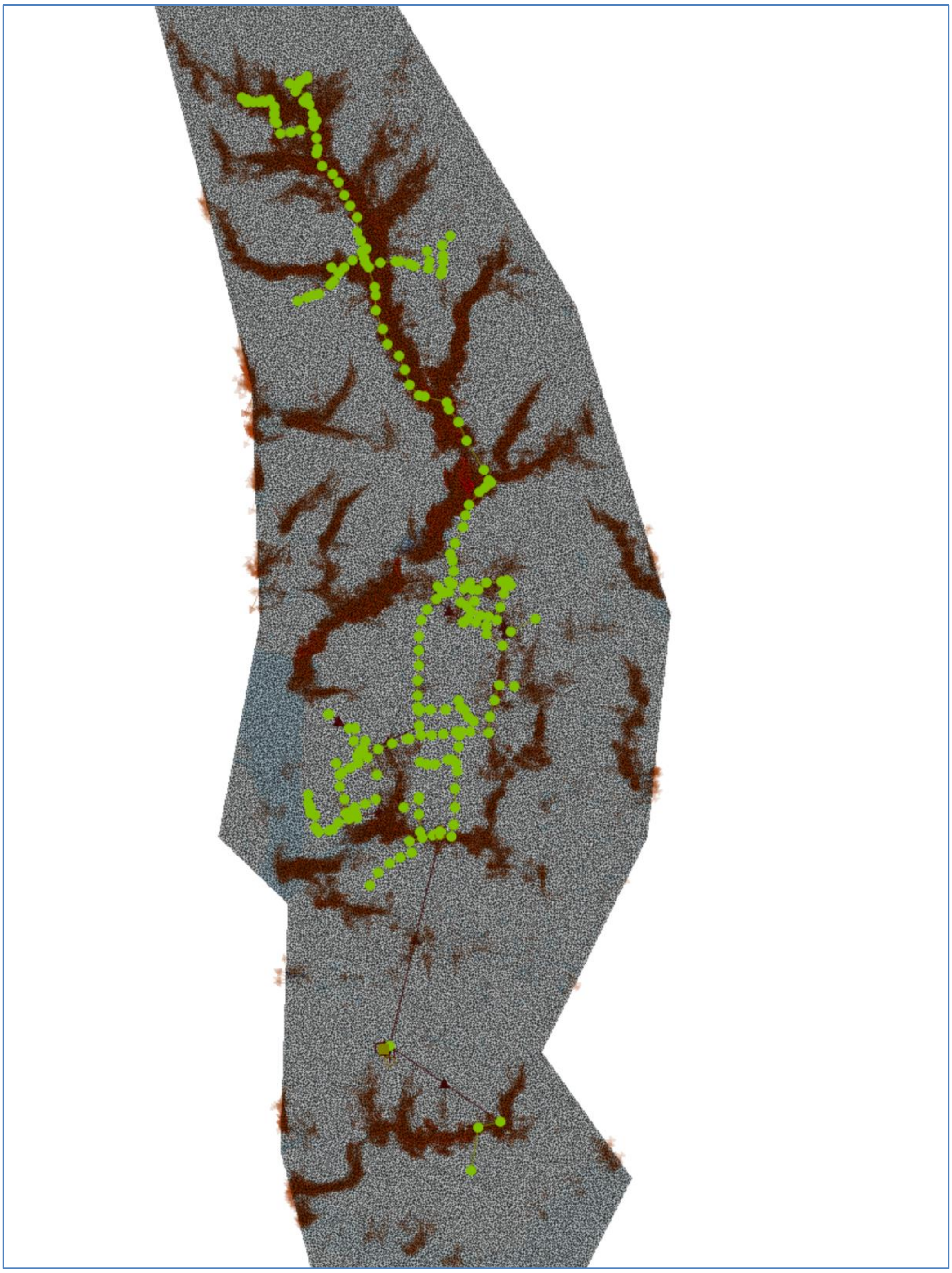

Figure 24 – Overland Flow Pathways

3.4.3 Potential Actions and Investigations

Rural runoff can be reduced and managed via Rural Sustainable Urban Drainage Systems, (RSuDS). RSuDs, including elements such as swales with or without barriers, retention ponds and basins, can be utilised to convey runoff whilst reducing volume and velocity.

Manholes located along the overland pathways where the sea level is higher than the highways, such as the Shore Road area, should be checked to ensure the seals are robust and stopping the sea water entering the sewer system via the manhole covers. Additional areas located along the low-lying flow pathways, such as Bosham Hoe, can be investigated to confirm whether sealing manhole covers would be beneficial.

Overland highway runoff can be controlled and managed via a highway drainage system; this system should include gullies and pipework to collect and convey the flows, discharging to the nearest watercourse. The information available from the Council shows there is highway drainage discharging to the local watercourses already in place in the catchment. Confirmation of the downstream connections could be useful but overland flows from the highways do not appear to be a significant issue in the Bosham catchment.

Regular maintenance of drainage ditches is vital to ensure the natural flow pathways have maximum capacity to convey flows. If the capacity of these natural elements is reduced, the water could overtop the banks and find another route, which could affect properties and highways. Formalisation of the drainage ditches, via culverts or manmade banks, could provide a more robust structure for the flows; these channels could also incorporate control measures such as orifices or drainage beds to reduce velocity and encourage infiltration into the soil.

See Section 4.0 for specific proposals.

3.5 Groundwater and Infiltration

Groundwater is the water found underground in the cracks and spaces between soil particles. The groundwater is derived from rainwater and snow melt percolating through the ground surfaces. Groundwater infiltration is the process by which groundwater finds its way into the underground sewerage network. Small leaks, openings, defective joints, and cracks are the main causes for infiltration.

3.5.1 Risks

The sewer systems have been designed to mainly convey wastewater flows, therefore any additional flows entering the system have the potential to overwhelm the network. The additional flows can result in surcharge of the network, raising the top water level leading to flooding of highways and properties. The increase in top water level can lead to overflows discharging to the watercourse. If the infiltration experienced in the system is significant, it could lead to overflow discharges during dry weather.

Infiltration flows could also result in the Wastewater Treatment Works being overwhelmed due to the increased flow volume reaching the site and going through the treatment process. The increase in flows could lead to the WTW spilling to the storm tanks prematurely and an increase in spills to the environment. The WTW becoming overwhelmed could lead to backing up in the main sewer network upstream of the WTW, surcharging the system and raising the top water level. An increase in top water level will increase the flooding and overflow risk for the catchment.

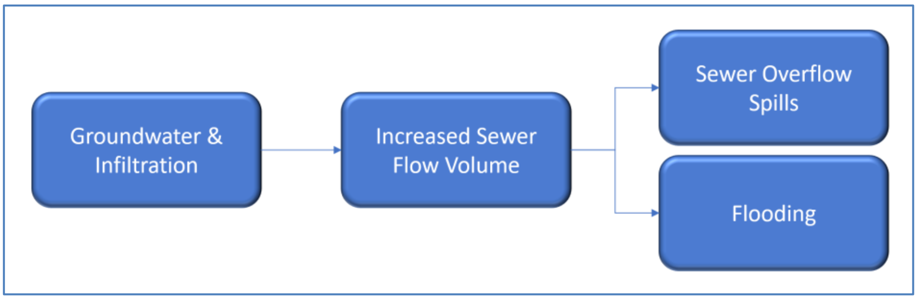

Figure 25 – Groundwater and Infiltration Risks

3.5.2 Bosham Findings

There is understood to be a groundwater infiltration issue within the Bosham catchment and there are several data sources confirming this statement.

Data from the Bosham Wastewater Treatment Works (WTW) shows a significant increase in flows to the works during the winter months. Discussions with the WTW team confirm the WTW can cope with the dry weather flows (DWF) reaching the site, but capacity issues are experienced when infiltration flows increase and the site becomes overwhelmed, leading to storm overflow discharges.

The Bosham WTW Flow Action Plan 2021 states that the daily flow trends were elevated from January 2021 to the end of May 2021 and again in December 2021. High base levels of total daily flow indicate groundwater infiltration is present in the catchment. The report states the catchment experiences above average infiltration from 2019 to 2021; the estimated infiltration value for 2021 was 982m³/day, approximately 200% of theoretical DWF when an infiltration value of 40% would be expected at the WTW. The infiltration values are calculated from the total recorded flows reaching the WTW minus the expected catchment flows from residents, businesses, and trade flows.

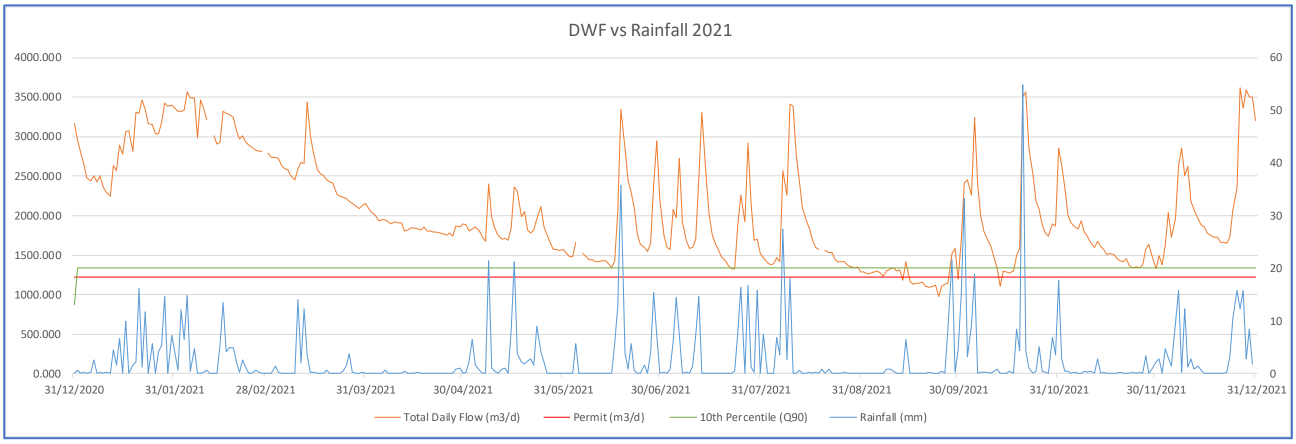

Figure 26 – Bosham WTW DWF Data 2021[14]

The Bosham WTW Flow Action Plan 2021 detailed areas where sewer and manhole sealing has already been implemented. The assessment also provided areas where future work should be completed and other assets where infiltration is thought to be an issue but has yet to be confirmed through survey work. Many sewers and manholes within the Funtington

[14] Bosham WTW DWF Flow Action Plan 2021

area have been sealed, along with further assets in and around Bosham Hoe and a small number of assets in the Shore Road area. Further assets that would benefit from sealing works have been identified in the Shore Road area and assets that require surveying with potential for sealing have been identified in West Ashling, Bosham Village and Bosham Hoe.

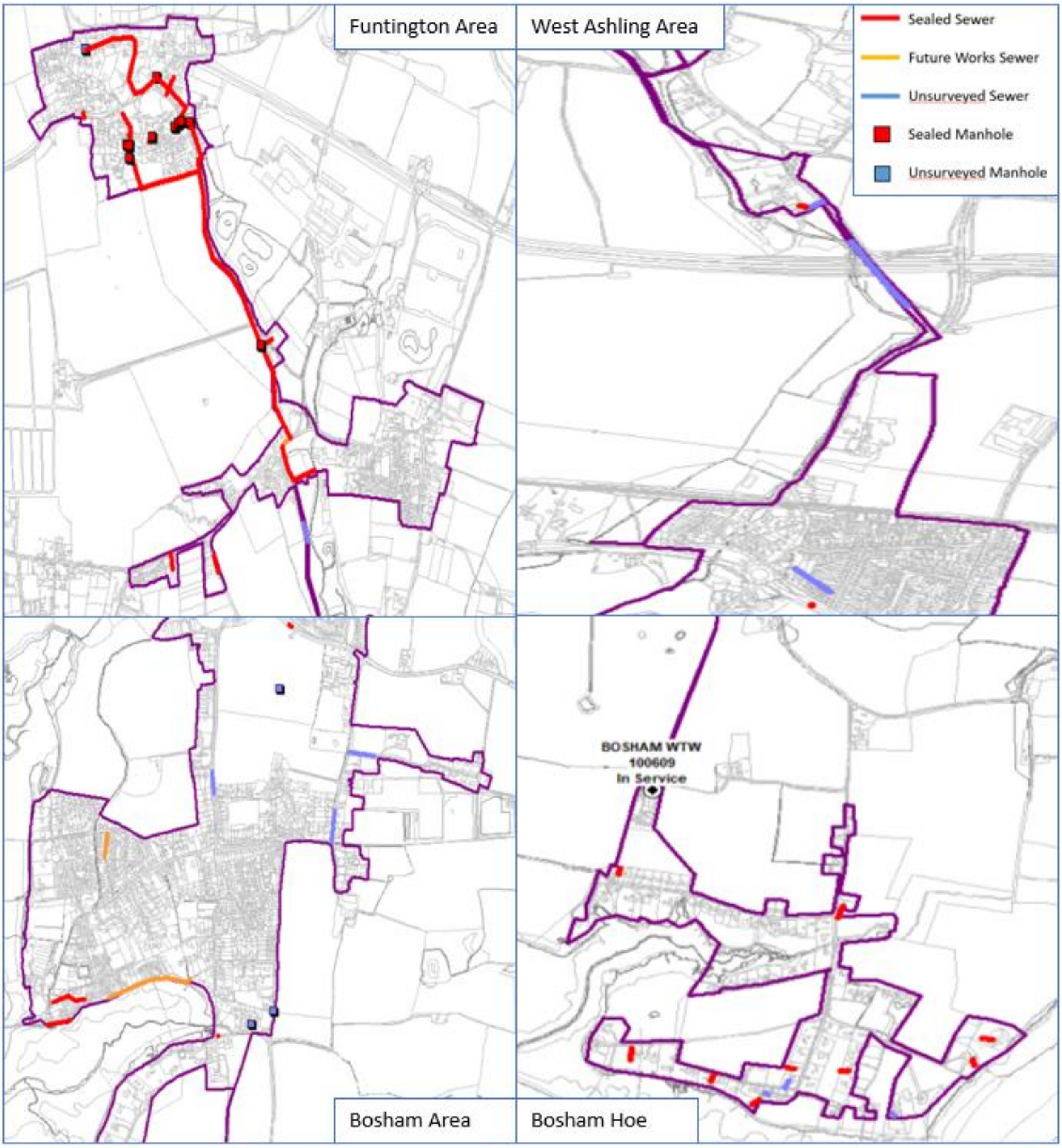

Figure 27 – Bosham Flow Action Plan Locations[15]

Assessments have been completed for the Bosham storm overflows to understand the drivers for the spills at each location and to confirm whether infiltration has an impact on the overflow performance. The assessment at the treatment works confirms that there is

[15] Bosham WTW DWF Flow Action Plan 2021

infiltration experienced in the system during the winter months and that there is a strong correlation between spills and an increase in river levels in the catchment. The assessment at Taylors Lane WPS does not indicate infiltration as the definitive single driver for spills at this overflow.

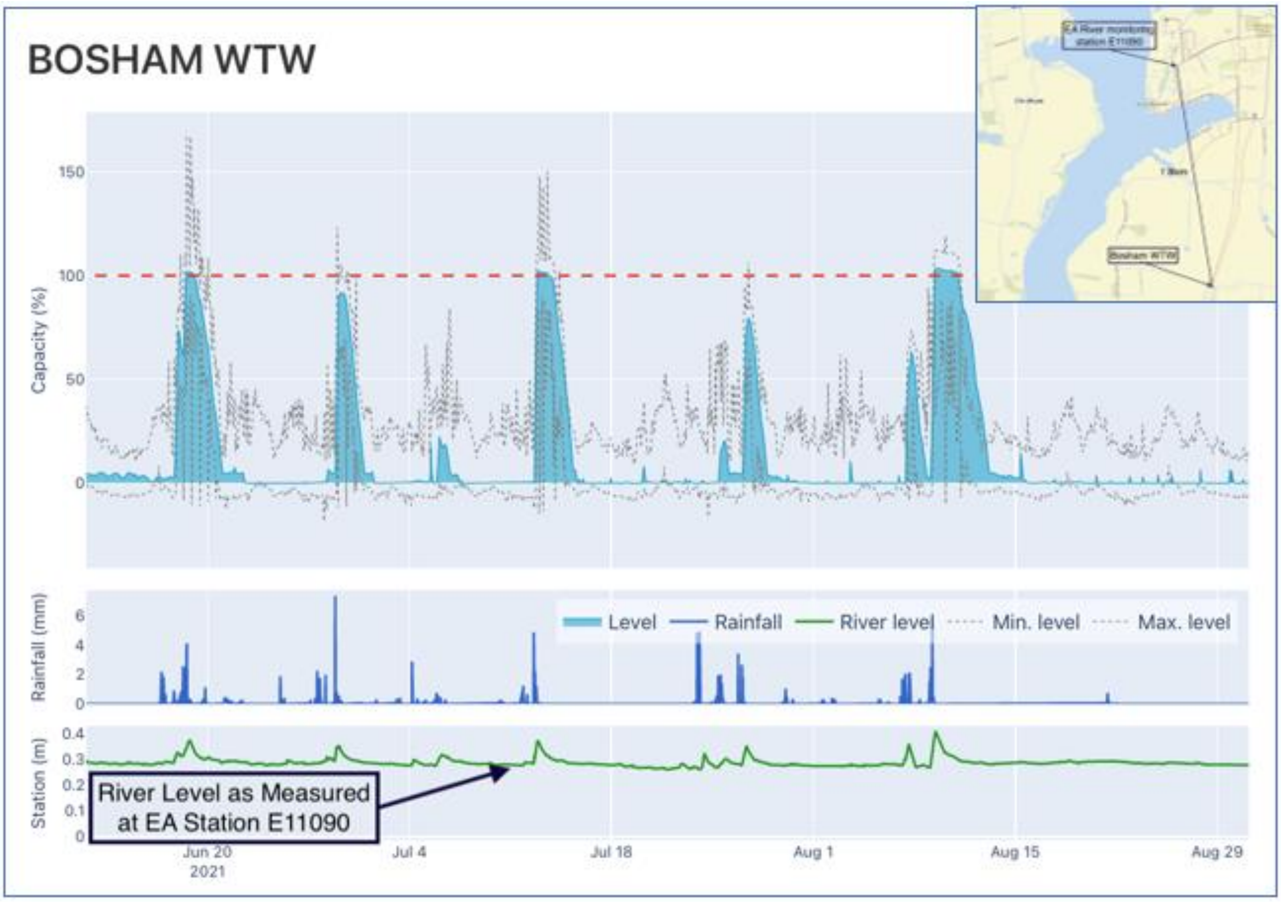

Figure 28 – Bosham WTW Data and River Level

There are no known pipe bridge crossings within the Bosham catchment but there are several locations where the sewers run parallel to or intersect a watercourse. Bosham Stream, and other smaller watercourses, run through the catchment crossing the sewer system in places. These streams discharge to the sea and therefore are tidally influenced in the lower reaches and there could be a risk of infiltration into the assets crossing the waterbodies.

Sewer level monitor data and telemetry data has been reviewed for the Bosham catchment including the WTW and Taylor's Lane WPS. The data shows:

- WTW telemetry shows an increase in base flows reaching the works during the winter months and long periods where the storm tank is fully utilised and spills at the overflow.
- Taylors Lane WPS telemetry for 2021 through to January 2023 shows a general trend of increasing flows reaching the site during the winter months and a decline in daily flows between May and October.
- Catchment SLMs show slow drain down after rainfall events in areas of the catchment including Watery Lane, Ratham Lane, Delling Lane, Walton Lane, Leander Road, Shore Road, High Street and Taylors Lane.

Further discussions with catchment stakeholders have identified the following:

- The ponds and streams in the West Ashling area are fed via groundwater emergence all year round, but this is elevated during the winter months.
- The sewer network in the Funtington area has been sealed as part of the Groundwater Infiltration Reduction Plan but there were issues noted with private connections.
- The main clay pipes within the catchment are generally in good condition but there are rubber seals at the connection joints that allow groundwater into the system.
- Ratham Lane, Watery Lane, Down Street and Shore Road experience extended surcharging when infiltration is high.
- The areas in the catchment affected greatest by infiltration are Shore Road, Ratham Lane and Mill Pond Lane.
- Shore Road WPS is inaccessible during high tides due to flooded roads; the WPS is protected from seawater ingress and manholes have been sealed.
- Maintenance has been completed on United Reformed Church and Millstream Hotel private laterals to reduce infiltration.

3.5.3 Potential Actions and Investigations

There are several ways that infiltration can be further investigated within the catchment; the investigations can utilise data already available alongside new surveys to confirm the assets most susceptible to additional flows infiltrating into the sewer system. A combination of the below methods may be the most appropriate approach for the catchment.

Additional surveys can be completed to investigate the locations already identified at risk from infiltration in the Flow Action Plan; these assets could be surveyed using either CCTV or Electroscan technology. These surveys can be rolled out across the catchment to locate any other areas at risk from infiltration.

CCTV surveys can locate any defects and points of infiltration within the network. CCTV surveys provide clear footage inside the sewer network, alongside detailed reporting that pinpoints all structural defects, depositions, root intrusions and large infiltration locations within the assets.

Electroscan surveys can identify structural defects in the pipework. An electrode is passed through the pipe measuring the variation in electrical current through the wall of the pipe. Where the pipe is structurally sound, the electrical current received at ground level is low but when there is a defect, a much higher current is recorded at ground level. The amount of current received at ground level provides an indication on the size of the defect. This technology has been used in other catchment areas and provides confidence into whether a pipe is structurally sound or defective and at risk of infiltration.

Desktop depth assessments can be completed to assess the likelihood of a pipe to suffer from infiltration. The depth of the pipe is a key factor in the likelihood of infiltration occurring as if the asset has groundwater surrounding it then it is more likely to experience infiltration than a sewer where groundwater is only surrounding half the asset. Public sewers tend to be deeper underground than private sewers and therefore public assets are more likely to be surrounded by groundwater. The sewers located at a lower depth are more susceptible to ground movement, leading to pipe defects, therefore the shallower public sewers and the private lateral connections are more likely to have pipe defects, which in turn could allow additional flows into the sewer system.

The public sewers within the Bosham catchment range between 0.64m and 4.4m depths, with approximately 59% of the sewers being at a depth of two metres or less and 41% being at a depth of greater than two metres.

Borehole data for the area has been requested from the Environment Agency, Chichester District Council and West Sussex County Council. The available data for the Highgrove Farm development site recorded the depth to groundwater was between 0.23 metres and 1.6 metres. Further boreholes could be installed in key locations across the catchment to assess the groundwater levels experienced in the Bosham catchment; this approach has been utilised in the nearby Chichester catchment. The borehole level data can be evaluated against the depths of the local sewer levels to confirm the areas where infiltration is more likely to occur and how regularly; this assessment would provide an indication of the areas at higher risk from regular infiltration and help to target the pipe condition survey locations.

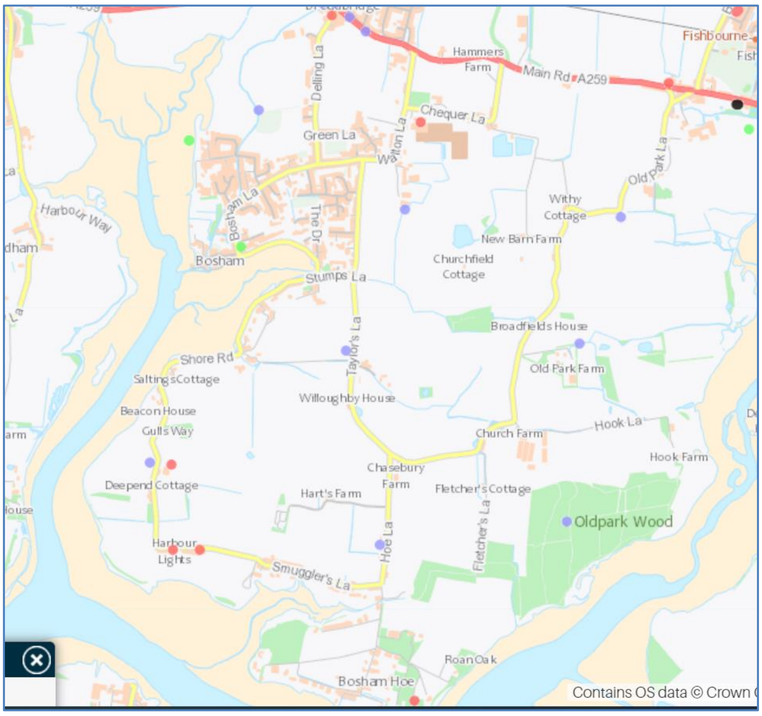

Figure 29 – Locations of Boreholes[16]

The areas upstream of Shore Road WPS are low-lying and known to suffer from seawater ingress, with highways becoming inaccessible during high tides. Some of the manholes have been sealed in this area to reduce the volume of seawater entering the system and overwhelming the pumping station, but further manholes and sewer assets may need sealing to prevent additional flows entering the sewer system.

Temperature sensors could be utilised to track temperature within the sewer network with values taken every six minutes. Foul flow tends to be warm, and infiltration is typically of a

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lower temperature of around 9 to 12 degrees Celsius, therefore an assessment can take place using the temperature sensor data to confirm infiltration in the network.

The temperature sensors should ideally be positioned across the catchment and be in situ between December and April to capture temperature changes due to infiltration. The temperature data should be analysed alongside rainfall data, river level data, address point data and traditional lift and look surveys to identify areas of the network that are experiencing infiltration.

Southern Water's Sewer Level Monitoring (SLM) programme could be used to locate areas of infiltration over time as the monitors would provide information on longer term trends within the sewer network. Summer levels could be compared to winter levels to confirm any locations where there is an increase in levels during the winter months, which is an indication that infiltration is occurring. The longer-term data would identify areas that are not suffering from infiltration at present but that develop an infiltration increase over time, indicating a change in groundwater levels or a decline in pipe condition. The data from the SLMs could be utilised alongside any borehole data to evaluate if the assets deemed to be below ground level are showing any signs of infiltration. If the asset is below water level for significant periods of the year and the SLM is not showing any signs of infiltration, then it can be assessed that the asset is in good condition and not allowing infiltration to occur. If the SLM data is showing signs of infiltration, then pipe condition surveys can be scheduled.

Once infiltration locations have been confirmed, these assets can be sealed to reinstate the structural integrity of the asset. The traditional method for sealing sewers is to install leak tight liners into the public sewers, made either from an epoxy or a silicate-based resin. These liners have been tested against 5m head of water and have a design life of at least 50 years. Manholes can be sealed separately using a spray lining from the inside or stitch drilling and injecting a resin into the ground surrounding the manhole to make it watertight.

Infiltration locations could also be sealed using Tubogel, a newer technology from Germany, that uses two silicate-based liquids. The liquids are installed by filling the network with each in turn, allowing the liquids to find and fill all the pipe defects. Once the second liquid is pumped out, the pipe is sealed. This type of sealant would allow for private and public assets to be repaired at the same time; this could be a suitable solution should the infiltration be located on both the public and private assets.

Overall there appears to be significant evidence that the catchment is at risk of infiltration entering the sewer system and that this is a key influence on the performance of the sewer system.

See Section 4.0 for specific proposals for the next steps in the Bosham catchment.

3.6 Private Drains and Pitch Fibre Pipes

Private drains are the connections from properties into the public sewer system and are the responsibility of the property owner. Private drains convey flows from the property into the lateral drains and then connect into the public sewer system; the lateral drains and public sewers are the responsibility of the water company.

Figure 30 –Drainage Responsibilities

In the UK, pitch fibre pipes were commonly installed from the 1950s through to the 1970s, connecting properties into the main sewerage system. The pipework was installed due to it being lighter and more cost effective than the alternative clay pipework. The pipe materials were a mixture of a wood cellulose and an inert coal tar pitch and were deemed a suitable drainage option for residential and commercial buildings.

3.6.1 Risks

Private drainage tends to be less than two metres below ground level because of connecting to the property pipework and needing to gravitate into the public sewer system. Due to the proximity of the assets to the ground surface, they are more susceptible to ground movement and in areas such as driveways they are more vulnerable to vehicular movements than the lower public assets. These private assets are therefore likely to suffer with pipe defects occurring. These pipe defects can take the form of cracks and fractures of the pipework or more serious joint deformations, which in turn may lead to blockages and infiltration into the public sewer system.

Pitch fibre pipework does not cope well with today's drainage needs. Current drainage systems process a significantly higher volume of water than they did decades ago. When vast quantities of hot water pass through pitch fibre pipes on a regular basis, it causes bubbles to form in the fibre itself. Furthermore, the presence of oils, fats and grease can have a significant destructive effect on the material compared to more modern drainage pipework. The lifespan of pitch fibre pipes is estimated at approximately 40 years; therefore, any remaining pitch fibre pipework is likely to be at risk of collapse or deformation.

When the private drains experience defects or the pitch fibre fails, it can lead to blockages on the sewer line, potentially leading to internal flooding of properties and restricted usage of bathrooms and internal domestic appliances. There is an increased risk that where the pipework has collapsed or deformed these areas could provide opportunities for infiltration into the system to occur. This infiltration would increase the flow volumes within the sewer system; this flow increase could add to the risk of flooding in the network and increased risk of the overflows in the catchment discharging to the watercourse.

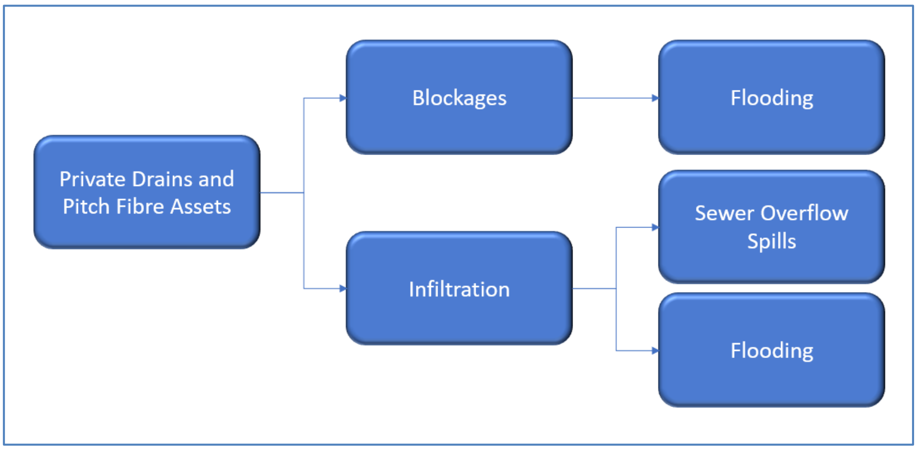

Figure 31 - Private Drainage and Pitch Fibre Risks

3.6.2 Bosham Findings

The desktop exercise has located entries within the Southern Water maintenance system that have confirmed pitch fibre pipework at properties within the Bosham catchment. These pitch fibre locations have been confirmed via visits by network operations teams due to blockage or flooding issues at the properties.

Pitch fibre assets have been located at Heather Close, Watery Lane, Fairfield Road, Fairfield Close, Crede Lane, Stream Lane and two locations at Moreton Road.

The Bosham Association commented that there were some issues with private laterals in the Funtington area of the catchment. Previous reports confirm schemes have been completed on the private laterals of the United Reformed Church and Millstream Hotel, both located on Bosham Lane, to reduce infiltration. It is unclear if the issues with these private laterals were related to pitch fibre materials.

A high-level desktop assessment of the catchment, based upon number of properties within the catchment and fifteen metres of private drains per property has estimated that there are approximately 32km of unmapped drains within Bosham.

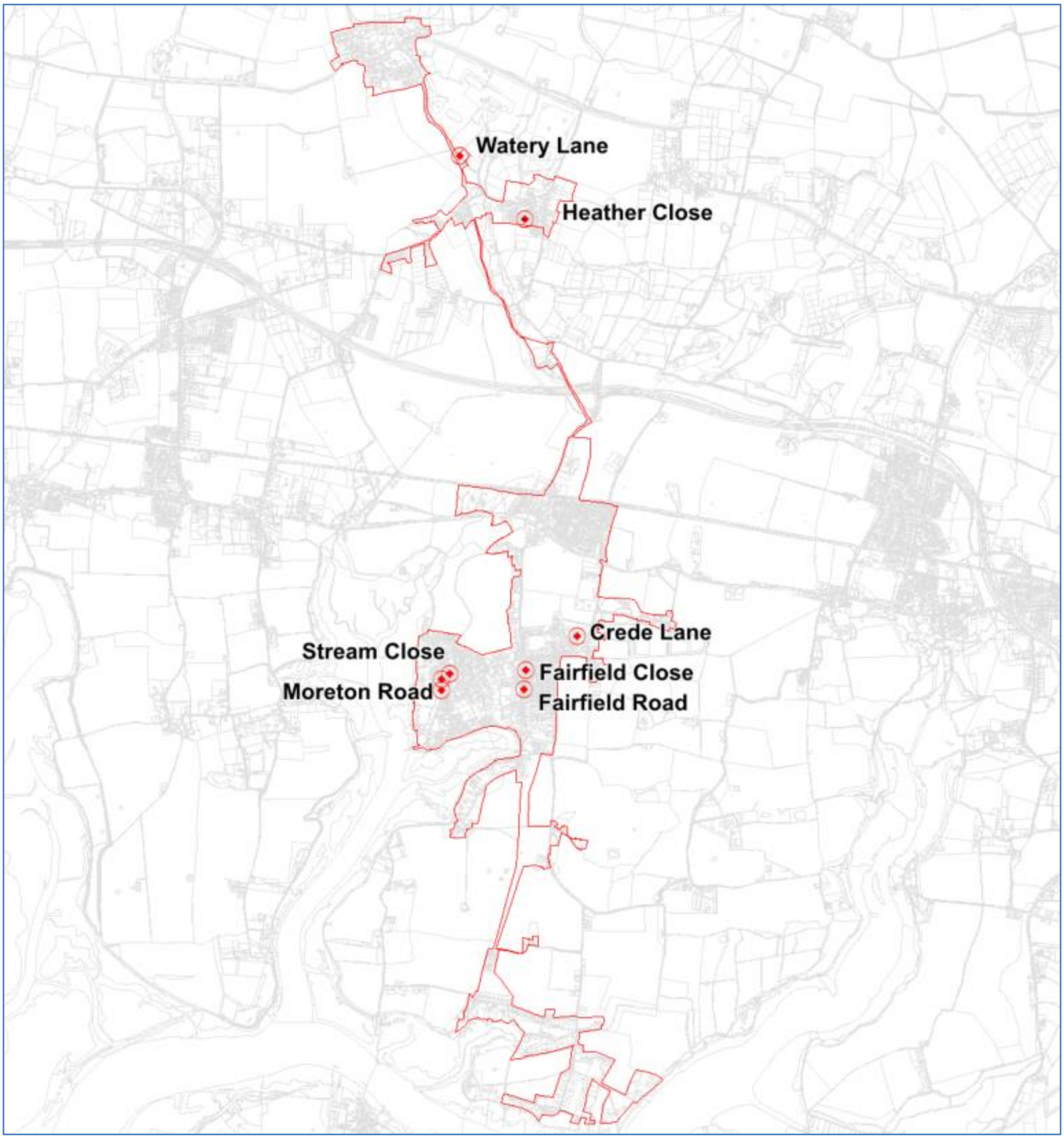

Figure 32 - Pitch Fibre Locations in the Catchment

3.6.3 Potential Actions and Investigations

Investigate the catchment in areas of high groundwater infiltration to confirm any additional pitch fibre locations and assess their existing condition to confirm the level of risk posed by these assets. These initial investigations would confirm the number of pitch fibre assets there are in Bosham, whether they are located on the private or public drainage systems and enable a repair schedule to be developed.

The initial areas to investigate would focus on the roads where pitch fibre pipework has been located previously, high water table areas, and areas of the catchment that were developed between 1950 and 1970. CCTV and manual inspections of property connections would be utilised to locate any further pitch fibre pipework and confirm their current condition and determine the associated risk to the drainage system. Private drains are owned by the property owner and the maintenance of these assets is the responsibility of the property owner. The maintenance of the public sewers, and lateral drains serving more than one property, is the responsibility of the water company.

Private drains can be investigated via CCTV to confirm any pipe defects that may be allowing infiltration to enter the sewer system. The areas to target can be identified using SLM data to confirm branches of the sewer system where infiltration is present; properties upstream of these locations can be investigated to confirm any defects. Groundwater level data can also be utilised to ascertain where the assets are likely to be below the groundwater table and at higher risk of infiltration.

Any damaged pipework would require repair to enable the flows to convey from the property to the sewer without issue. Liners can be added to the pipe to reform and reshape the pipe and to increase the strength of the asset. Once the liner has been installed and has set, the drainage will be reinforced and will no longer present the problems that a standard pitch fibre drainage system brings.

For significantly damaged pipework and collapses, replacement of the asset may be the appropriate solution which would involve excavation work and would be a more intrusive task than lining the asset.

Whilst the investigation to locate the pitch fibre pipework is implemented, the customers can help to reduce the risk of deterioration to these assets by reducing the fats, oils and greases disposed of into the sewer system. Customer information leaflets can be distributed across the catchment to provide advice on disposing of these items.

See Section 4.0 for specific proposals for the next steps in the Bosham catchment.

3.7 Connectivity

The desktop exercise has noted one connectivity query for the Bosham catchment. No other connectivity queries have been discovered.

The Bosham Annual Assembly Minutes 2013 detail a discussion regarding a disused pipe between Taylors Lane WPS and the outfall. It is a small diameter asset of approximately 100mm and was queried as to whether it was functional and if it could be utilised to help balance flows between the pumping station and the outfall. The pumping station has since been upgraded to a pumped outfall with an emergency gravity overflow and therefore it is unlikely that this asset could improve the performance of the pumping station.

The small area of highway drainage serving Arnold Way to the east of Bosham does not have a confirmed downstream discharge location. It would be useful to understand if this section of highway drainage was connected into and contributing flows to the foul sewer system.

3.8 Network Optimisation and Infrastructure Changes

There are two terminal pumping stations that feed into the WTW; Taylors Lane WPS, and Smugglers Lane WPS. These terminal pumping stations currently work independently of one another and there are no controls in place to collectively manage the flows. Investigations could be completed into the terminal pumping station capacities and pumping regimes, and whether real time control can be utilised to manage the flows and avoid concurrent pumping thereby reducing the peak flows reaching the WTW. This style of optimisation could also be investigated for the catchment pumping stations to understand if there are any locations where pumped flows could be controlled to manage the timing and peak flows as they are conveyed through the catchment.

The maximum pumping capacity of the terminal pumping stations is currently greater than the flow to full treatment capacity at the WTW. During dry weather the WTW copes with the incoming flows and treats all dry weather flows without issue. When storm events occur and the groundwater infiltration levels are higher, the flows coming into the works are greater than the FTFT capacity and additional flows are passed to the storm tank and returned to the treatment channel when there is FTFT capacity available. In larger storm events the storm tank becomes fully utilised and spills to the environment occur. The terminal pumping stations' operation could be investigated to reduce the peak pumping rate, hold back some of the flows or pump at different times to one another to understand if altering the timing of the peak flows reaching the WTW would have a beneficial impact on the utilisation of the storm tank and subsequent spills to the environment.

Infrastructure changes such as pipe upsizing or installing storage tanks would not reduce the number of spills experienced at the overflows. An intervention only consisting of increasing pipe diameters would provide more capacity for additional groundwater or seawater to enter the sewage system and the larger pipe diameters would then convey these flows more rapidly through the system, potentially overwhelming pumping stations and leading to more flooding or increasing storm overflow spills. Pipe upsizing would have to be implemented alongside an infiltration reduction intervention to have a positive impact on the storm overflows in the catchment. Likewise, an intervention to provide additional storage tanks would also need to be implemented alongside other intervention measures to ensure the additional volume provided by the storage tanks wasn't inundated by groundwater or seawater flows.

A further network optimisation investigation could locate any areas of the network that have spare capacity where flow could be held back via control gates and smart network controls during the peak of the rainfall events. The flows could be held back in upper branches of the system to enable the overwhelmed assets to convey the flows through to the downstream network; once the downstream network has available capacity, the control gates would release the upstream flows gradually through the system. Controlling the flows from the upstream areas of the network would help to control top water levels within the system, providing a reduction in flooding and overflow risks.

See Section 4.0 for specific proposals for the next steps in the Bosham catchment.

3.9 Bosham Wastewater Treatment Works Upgrade

Discussions with the network operations team have concluded that interventions focused solely on increasing the capacity of the WTW treatment process would not be the most beneficial intervention for the Bosham catchment to reduce the number of storm overflow spills experienced.

The WTW is currently working almost to capacity for dry weather flows and can manage these flows without issue. During the winter months when infiltration is high, the increased peak flows are too great for the flow to full treatment capacity and the additional flows pass to the storm tank and spill via the overflow.

There is some space to build assets within the WTW compound, but the location of this space would not be suitable for a new storm tank due to the configuration of the site. A new storm tank wouldn't be the most appropriate solution for the flows reaching the works as the additional capacity would likely be filled very quickly from the significant infiltration flows and the storm overflow would still spill.

The treatment process works to its' optimum capacity and therefore changes to the flow to full treatment flow rate could not be implemented without upgrades to all the assets on site. If the available space was used to build a new Primary Settlement Tank, then the site would also require additional Secondary Treatment assets of a new trickling filter and humus tank plus additional capacity added to the Tertiary Treatment Stage to ensure that none of the stages of the treatment process were overwhelmed by increases to the flows being treated.

One intervention that could be implemented at the WTW site would be to install an integrated constructed wetland area. An integrated constructed wetland is a manmade wetland area used to treat the effluent from the wastewater treatment works or in this case from the settled storm overflow point. The wetland area acts as a biofilter and can remove a range of pollutants, pathogens, and nutrients from the water prior to discharging to the local watercourse.

See Section 4.0 for specific proposals for the next steps in the Bosham catchment.

3.10 Bosham Schemes

There are several investigations and projects being completed or ongoing in and around the Bosham catchment that may provide further understanding of how the catchment operates. These schemes should provide additional positive changes to and wider understanding of the catchment as they are completed. Awareness of these schemes and collaboration between the different projects will enable a streamlined approach and knowledge sharing to be implemented for this area of the Southern Water region.

3.10.1 Colner Creek Optioneering

There is an ongoing Environment Improvement Project to provide a natural corridor and nutrient benefits to Colner Creek. The project involves liaison with several landowners covering all the farmland in the Bosham peninsula area; there may be the opportunity for data and knowledge sharing from this project.

3.10.2 Bosham WTW USA

A recently completed scheme at the wastewater treatment works investigated if the Flow to Full Treatment consented flow rate was being achieved. Works have been carried out at the site and there now follows a period of monitoring to confirm the changes at site are delivering the consented flow value.

3.10.3 Bosham Groundwater Infiltration Reduction Investigation and Sewer Surveys

The WTW Flow Action Plan details the findings and actions completed as part of a Bosham Groundwater Infiltration Plan. The work included CCTV and re-sealing of sewers and manholes within the catchment to reduce groundwater inundating the sewers that would have caused flooding to properties.

3.10.4 Bosham Hoe Infiltration Study

An infiltration investigation in the Bosham Hoe area was completed in 2011. The investigation included CCTV and connectivity surveys to identify and locate potential ground water infiltration and storm water connections to the existing foul drainage system within private properties in Bosham Hoe and Smugglers Lane. The investigation discovered several locations where infiltration was entering the foul sewer system and remediation works were completed at private properties and at Smugglers Lane WPS.

3.10.5 Harbours Strategy Project

Southern Water, working alongside other stakeholders, on an integrated catchment study investigating the whole water system that affects the harbours, including potable water, wastewater, storm overflows and catchment management. The project involves numerous stakeholders and data gathering and analysis; there may be the opportunity for data and knowledge sharing from this project.

3.11 Summary of Catchment Investigation

The desktop investigations have concluded there are high levels of groundwater infiltration and seawater ingress affecting the sewer system in Bosham; lining and sealing of key assets within the sewer system would help reduce the impact of these flows. There are areas where further surveys are required to confirm highway and roof runoff connectivity into the sewer system; if these areas are connecting into the network, then source control interventions would be necessary to reduce the impact on the sewer system. Real time control could be utilised to improve interaction and flow control between the catchment and terminal pumping stations. Further details on interventions recommended for the catchment are within Section 4.0.

4.0 Catchment Actions Overview

4.1 A Staged Approach

A staged approach is being undertaken to the pathfinder project which allows for some low-risk interventions and pilot schemes to be identified quickly, whilst further modelling and investigations take place, providing confidence and to ensure the catchment is fully understood and risks can be managed for larger interventions.

Learning from the Pathfinders will also feed into the Southern Water five yearly funding request process.

The staged approach is described below:

Stage	Description
Stage 0	Initial surveys and study with identification of early 'no regrets' low risk interventions and any additional surveys and modelling requirements
Stage 1	No regret interventions, further surveys and small trials (SWS and partner organisations)
Stage 2	More complex interventions and scaled pilots (SWS and partner organisations)
Stage 3	Larger scale investments to achieve pathfinder outcomes (SWS and partner organisations) • Model updates • Large Scale interventions

Table 3: Pathfinder Staged Approach

4.2 Interventions

The key to reducing these highlighted risk factors is either by reducing the volume of rainwater/groundwater getting into the sewer or increasing the sewer's ability to cope with it. To that end we have split this into four main types of intervention to reduce the risk of flooding and storm overflow use:

- Operational interventions
- Upstream source control (removing and slowing the flow of rainwater)
- System optimisation (making better use of the existing infrastructure)
- Infrastructure enhancements (build larger infrastructure)

Following the desktop investigation into Bosham, some key activities have been identified to further investigate and improve the performance of the network. In the short-term Stage 0 and Stage 1 activities can be completed to better understand the network. In the longer-term Stage 2 & 3 investigations, modelling and potential interventions have also been identified. These investigations and interventions are across the wastewater system. (as described in Section 3), and therefore require collaborative working from several partners and stakeholders. See Section 5.0 for further details on partnership and community working.

Stage	Contributing Factor	Intervention	Cost	Timescale	Risk	Value	Score
Stage 0	Sewer Maintenance	Review Maintenance Service Task (MST) schedule and amend as necessary	L	< 12 months	L	L	5
	Sewer Maintenance	Additional CCTV as suggested in the Groundwater Infiltration Reduction Plan information detailed in the Bosham Flow Action Plan	L	< 12 months	L	L	5
	Roof Drainage	Confirm roof connectivity in Funtington and West Ashling areas	L	< 12 months	L	M	6
	Highway Drainage	Regular Maintenance of highway gullies and assets	L	< 12 months	M	H	8
	Roof Drainage	Confirm roof connectivity in Bosham Lane, High Street, Shore Road, North Road, and Gifford Road	M	< 12 months	M	M	8
	Overland Flow	Regular ditch and watercourse maintenance to ensure rainfall and surface water can enter the waterbodies	M	< 12 months	M	M	8
	Groundwater and Infiltration	Installation and assessment of boreholes to understand water table levels for the catchment	M	Before 2025	M	M	8
Stage 1	Highway Drainage	Confirm downstream connectivity/discharge locations of the highway drainage system	L	< 12 months	L	L	5
	Roof Drainage	Confirm the downstream connectivity/discharge point for the surface water system serving Arnold Way and Stanbury Close	L	< 12 months	L	L	5
	Pipeline Crossings	CCTV the assets crossing the watercourses to confirm asset condition	L	Before 2025	L	L	5
	Groundwater and Infiltration	Depth assessments to understand which assets are at high risk of infiltration	L	< 12 months	L	L	5
	Sewer Maintenance	Sealing of sewers identified in Stage 0 CCTV surveys	M	Before 2025	L	M	7
	Sewer Maintenance	Continued review of SLM data	L	< 12 months	M	M	7
	Pitch Fibre and Private Drains	Support property owner to understand any repairs required on their private sewers	L	Before 2025	M	M	7
	Overland Flow	Seal manholes where the seawater is known to enter the sewer system around the Shore Road area.	M	Before 2025	M	M	8

Stage	Contributing Factor	Intervention	Cost	Timescale	Risk	Value	Score
	Pitch Fibre and Private Drains	Surveys in targeted areas to confirm any further public pitch fibre assets in high groundwater areas	M	< 12 months	L	H	8
	Roof Drainage	Install water butts at properties located in Funtington and West Ashling areas	M	Before 2025	M	H	9
	Roof Drainage	Install water butts at properties located in Bosham Lane, High Street, Shore Road, North Road, and Gifford Road	M	Before 2025	M	H	9
	Groundwater and Infiltration	CCTV and/or electroscan surveys to identify assets at risk of infiltration due to structural defects	M	< 12 months	M	H	9
Stage 2	Roof Drainage	If required, as a result of surveying the downstream connectivity/discharge point for the surface water system serving Arnold Way and Stanbury Close, connect the surface water system to the nearest watercourse with capacity.	L	Before 2025	M	L	6
	Pipeline Crossings	Sealing of sewers identified in pipeline crossing surveys	M	Before 2025	L	L	6
	Sewer Maintenance	Actions and repairs required as a result of the continued SLM data assessments	M	Before 2025	L	M	7
	Groundwater and Infiltration	SLM data assessments to understand long term infiltration levels in the catchment	L	Before 2025	M	M	7
	Highway Drainage	Remove any highway drainage located in highway surveys that is connecting into the sewer network	M	Before 2025	M	M	8
	Groundwater and Infiltration	Temperature sensor surveys to locate infiltration into the system	M	Before 2025	M	M	8
	Infrastructure Changes	Pumping station optimisation - real time control	M	Before 2025	H	L	8
	Pitch Fibre and Private Drains	Repair, if required, public pitch fibre assets.	M	Before 2025	M	H	9
Stage 3	Infrastructure Changes	Control gates within the catchment	M	2025+	M	L	8
	WTW Upgrades	Install wetlands within the works compound	H	2025+	L	M	9
	Groundwater and Infiltration	Repairing and or sealing assets identified in the groundwater survey investigations	H	2025+	L	H	10

Table 4: Bosham Actions and Investigation Plan

5.0 Partnership and Community Working – What can you do to Help?

"Water companies are not solely responsible for stormwater management; they are one of many organisations involved in ensuring communities stay protected. The change in the weather is testing all sectors of UK society, and we are all moving towards changes in population and in weather conditions that we have never before had to plan for"[17].

To achieve what is needed, utilities, councils and communities need to work together to achieve mutual benefits. Southern Water have committed to doing this by engaging with our partner organisations and the community to solve the problems.

So what can the community do?

5.1 Support Further Investigations for Bosham

We are interested in time and date stamped photos and videos to help us understand how the Bosham catchment reacts to rainfall. With time and date stamped evidence, and a clear location, we can match this information with other information to better understand how the whole system interacts. This includes:

- Photos and videos of overland flow.
- Photos and videos of flooded areas.
- Photos and videos of the level of the surface water ditches.
- Reporting blocked highway gullies to WSCC.

5.2 Protect the Pumping Stations, Foul and Combined Sewers

Fat, oil and grease[18]
Fat, oil and grease often ends up being washed down the kitchen sink. Over time, they harden to a concrete-like material and restrict the flow of wastewater in the pipes or even block them. These blockages can cause wastewater to back-up through toilets and sinks into homes and businesses, or escape through manholes into streets and rivers

Unflushables[19]
Items such as wipes, nappies and cotton buds are the scourge of our sewers - they create blockages, cause flooding in homes and damage the environment. Every year in England and Wales water companies deal with over 300,000 blockages – thousands of which see people's homes and belongings ruined by sewer flooding. Wastewater companies are still spending around £90 million each year clearing blockages nationwide, while damage to the environment by the plastics used in unflushable items has become a real focus.

Our sewers are only designed to take away the three Ps – pee, poo and paper.

[17] 21st Century Drainage Programme – the context, Water UK
[18] Fat, oil and grease (southernwater.co.uk)
[19] The Unflushables (southernwater.co.uk)

In the kitchen, follow our top tips to avoid fat, oil and grease building up in the sewer.

- Use containers – butter tubs, yoghurt pots or jam jars can all be used to collect cooled fat and oil – then just put them in the bin
- Clear your plates – scrape any leftover food or grease and fat residue from plates, pans or cooking utensils into the bin before washing up
- Bag it and bin it – put a bin in your bathroom for anything that isn't pee, poo or paper. Perhaps use scented nappy sacks or dog poo bags (degradable if you can) to throw away any nappies, sanitary items or condoms.
- Compost your food waste – collect uncooked fruit and vegetable peelings for use as compost in your garden.
- Strain the pain – a simple sink or drain strainer can stop food and hair getting down the pipes.

5.3 Protect Surface Water and Combined Sewer Capacity – Existing Developments

You can help release capacity in the existing sewer systems by using less water, removing surface water connections and slowing the flow

Households

- Install water butts and planters on your property that take the rainwater from your roof and either slow its connection to the sewers or ideally divert it to a soakaway.
- Could you convert your paved, impermeable driveways into permeable surfaces?
- Try to ensure that existing impermeable surfaces drain to a permeable surface rather than the road or the sewers.
- If possible, disconnect existing drainage from the combined and surface water sewerage systems.
- Report blocked highway gullies and drains asap to WSCC.
- Report blocked sewers to Southern Water.

Target 100[20]

Population growth, climate change, increased urbanisation and environmental protection mean we all need to change how we understand and value water. Target 100 is a commitment by Southern Water to its customers to support them to reduce personal consumption to an average of 100 litres each per day by 2040; while we reduce leakage by 15% by 2025 and 40% by 2040. As well as making sure there is enough water to go round, households could cut their bills, and less water used mean less water going into the foul and combined sewers, creating more capacity.

Community, businesses, developers & partnerships

Engage with SWS, WSCC, CDC and other partners to identify areas for surface water removal, ownership and maintenance. As described in Section 5.0 there are multiple benefits that can be achieved for the whole community.

[20] Target 100, together let's hit target 100. (southernwater.co.uk)

5.4 Protect Surface Water and Combined Sewer Capacity – Future Developments

Households

- If you extend your house or create additional roof areas (urban creep) if possible, make sure these drain to a soakaway or surface water system or consider green roofs.
- If developing your drive or garden, could you install permeable paving rather than connect to the surface water system or drain to the highway system.
- Avoid misconnections - misconnections can happen during work to extend or improve a house, when a new house is built or simply when a new appliance is plumbed in. If any of your plumbing drains to a surface water sewer, the wastewater will pollute local watercourses. Similarly, if clean water drains are misconnected, they can overload the foul sewer and lead to flooding. It's the homeowner's responsibility to ensure there are no misconnections at their property. If you're unsure what to do, you can go to ConnectRight or contact Southern Water directly. Alternatively, for a list of plumbers in your area, visit the WaterSafe website.[21]

Community, businesses, developers & partnerships

- Ensure new developments are sustainable i.e. they are not connected to the combined sewer. Where possible, also avoid connection to the surface water system to allow rainwater to infiltrate to the water table, increasing the water availability for rivers and streams for biodiversity and for extraction for drinking water.

6.0 Future Sustainable Growth

Southern Water are looking to work with our drainage and surface water management partners, including Chichester District Council and West Sussex County Council, at how surface water management can be better considered and incorporated into the sustainable growth plans for Bosham. These conversations could include areas such as:

- More detailed consultation on specific proposals, including small scale developments
- Support to encourage more use of sustainable urban drainage schemes and nature-based solutions, including upstream ‘slowing the flow’ type measures.
- Ensuring that post construction, the installations comply with the requirements.
- Collaboration to make policies more aligned with sustainable drainage and climate change requirements.

[21] Bad plumbing and pollution (southernwater.co.uk)

7.0 Conclusions

The Bosham sewerage system was originally designed to convey the wastewater flows and roof drainage from a relatively small village area. Over time, the Bosham village has expanded, and the sewerage system is now conveying significantly greater flows than originally intended. The high groundwater levels and tidal influences in the catchment appear to also be contributing significant additional flows into the sewer system leading to sewer overflow discharges and property and highway flooding.

Groundwater infiltration reduction is an important element to lowering the number of storm overflow discharges occurring in the Bosham catchment. SLM data, additional surveys and depth assessments can be utilised to identify the areas most susceptible to groundwater infiltration. Mitigation measures, such as sewer relining, and manhole sealing can be implemented to reduce the volume of infiltration entering the sewer system.

The initial desktop investigations have discovered potential sources where surface water flows are also contributing to the sewerage network. These sources of additional flow can be further investigated to confirm connectivity and the impact they are having on the sewer system, storm overflow discharges and property and highway flooding. Slow the flow measures and surface water management techniques can be used to reduce the impact of these flows on the sewerage system. Opportunities to remove these flows from the network completely and discharge them to more suitable locations can also be considered and investigated.

Targeted connectivity surveys would verify the network layout in key areas and confirm any locations where there is roof drainage connected to the system. The runoff flows from these connected roof surfaces can be better controlled via slow the flow measures into the sewer network, or where possible removed from the sewer system.

In addition to reducing the number of storm overflow discharge, a sustainable wetland area could be installed at the wastewater treatment works to treat any remaining dilute storm discharges and improve the quality of the discharge reaching the local waterbody.

Sewer maintenance activities, such as CCTV and jetting programmes can be reviewed to ensure they are systematically scheduled in areas where sedimentation regularly occurs. The use of Sewer Level Monitoring is being used to pro-actively observe and analyse the network performance and drive the maintenance activities.

There may be other areas of opportunity within the catchment, and we will continue to work with our partners, and we look forward to engaging with the community, to identify opportunities that may also provide multiple benefits to the region, such as water resources, water quality, green space and biodiversity benefits.

Appendix A – Bosham Stakeholders

Southern Water have identified and liaised with several catchment stakeholders in the production of this report. Southern Water are keen to continue to work with these organisations and other location partners and stakeholders to discuss some of the opportunities to improve the performance of the storm overflows in the Bosham catchment.

- Kevin Macknay – Drainage and Flooding Lead, West Sussex County Council
- Penny Plant – Chichester District Council
- Nick Mills - Southern Water
- Rob McTaggart - Southern Water
- Penny Green - Southern Water
- Kevin Elms - Southern Water WTW Operations
- Paul Rooney – Southern Water WTW Operations
- Mark Ormand-Dobbin – Southern Water WPS Operations
- Bosham Association

Appendix B – How does Urban Drainage Work?

B.1 The Development of the Urban Drainage System

Victorian drainage – single pipe solution

The modern built sewerage network began to appear in the mid-19th century. Overcrowded cities had no means to control the disposal of wastewater. Rivers were overloaded and public health was under threat. Over the next 70 – 100 years, thousands of kilometres of sewers were laid. These combined sewers, as we know them today not only took wastewater from homes but also rainfall runoff from paved and roofed area.

Roofs and paved areas (urbanisation) and the provision of artificial drainage, or sewer systems, has a twofold effect on the natural drainage process. Firstly, it reduces infiltration thereby increasing the volume of run-off. Secondly, artificial surfaces, pipes and channels convey run-off more rapidly, making drainage areas more responsive to short duration/high intensity storms. This two-fold effect significantly changes the rates of run-off, by a factor of 10 or more when compared to a natural drainage system.

In addition to the intensification of peak flow, the single pipe system mixes untreated wastewater and surface water runoff. Conveyance capacity and disposal capacity at wastewater pumping stations and treatment works has traditionally been limited such that during heavy rainfall (to protect life and property) storm overflows operate to discharge a mixture of 'clean' surface runoff and screened untreated or partly treated wastewater (see Figure 33).

Early 20th Century drainage - two pipe solution

With the advent of modern sewers and cleaner streets, it became feasible to separately drain the two flows (wastewater and surface water). Between the first and second World Wars the building of new combined systems declined in favour of the new separate systems. The roofs and paved area were drained by a surface water system and the wastewater was drained by a foul water system. These foul water systems from new developments would typically connect to their older combined systems for conveyance and disposal at wastewater treatment works. Surface water systems would discharge direct to receiving waters (water courses, estuaries and coastal waters). Although separate systems removed the need to install new overflows, the rapid collection and conveyance of rainwater away from where it fell continues to cause problems, particularly in intense storms.

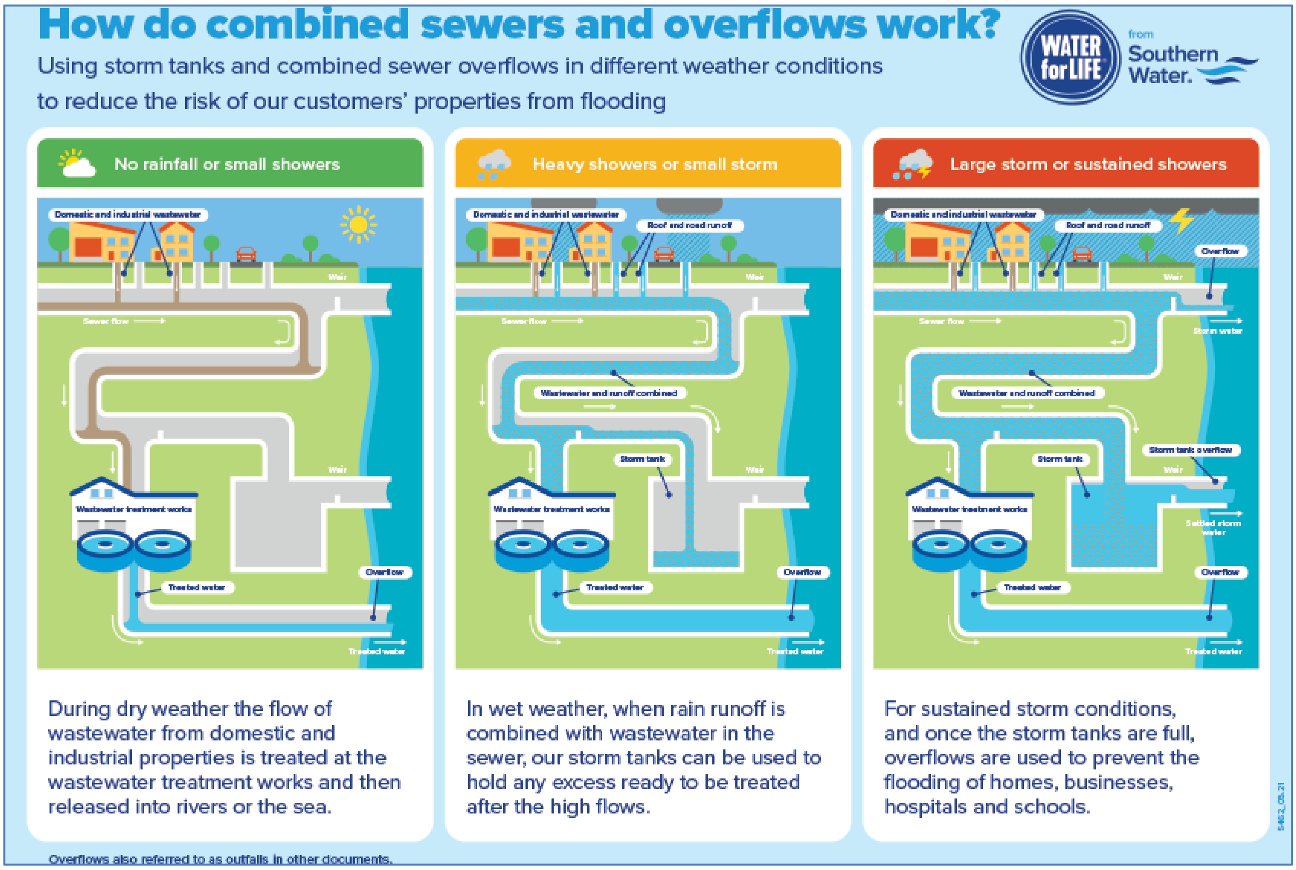

Figure 33 – How combined sewers and overflows work

Late 20th Century drainage – sustainable drainage

In the last 30 years, planning regulation has changed and there is now a requirement to reduce peak runoff rate from urbanized areas. Flows from new developments are restricted to 'greenfield' runoff i.e. a rate equivalent to that of a green field and are typically built with a Sustainable Urban Drainage System (SuDs). These systems closely mimic a natural drainage system.

Retrofitting sustainable drainage

Homes and paved areas drained by combined sewers can be retrofitted with a range of SuDS features which either 'slow the flow' or fully disconnect the surface water flow from the combined sewer system. Both methods reduce the intensity of the peak flows to a more consistent level and mimic natural drainage systems.

Sustainable drainage systems can also reduce flooding in the catchment, increase infiltration to replenish ground water systems and restore capacity in the network. They also reduce pressure on the downstream assets and therefore increase the asset life of existing infrastructure. This also results in storm overflows operating less often, with more flow being treated at wastewater treatment works before discharge to the environment.

B.2 The Contribution of Legacy Housing

Legacy housing is houses that are connected to the combined system. As you can see from Figure 34, only 13% of the water that falls on a home with sustainable drainage will drain to the sewer, therefore significantly reducing the contribution to, pressure on and risk to the downstream assets.

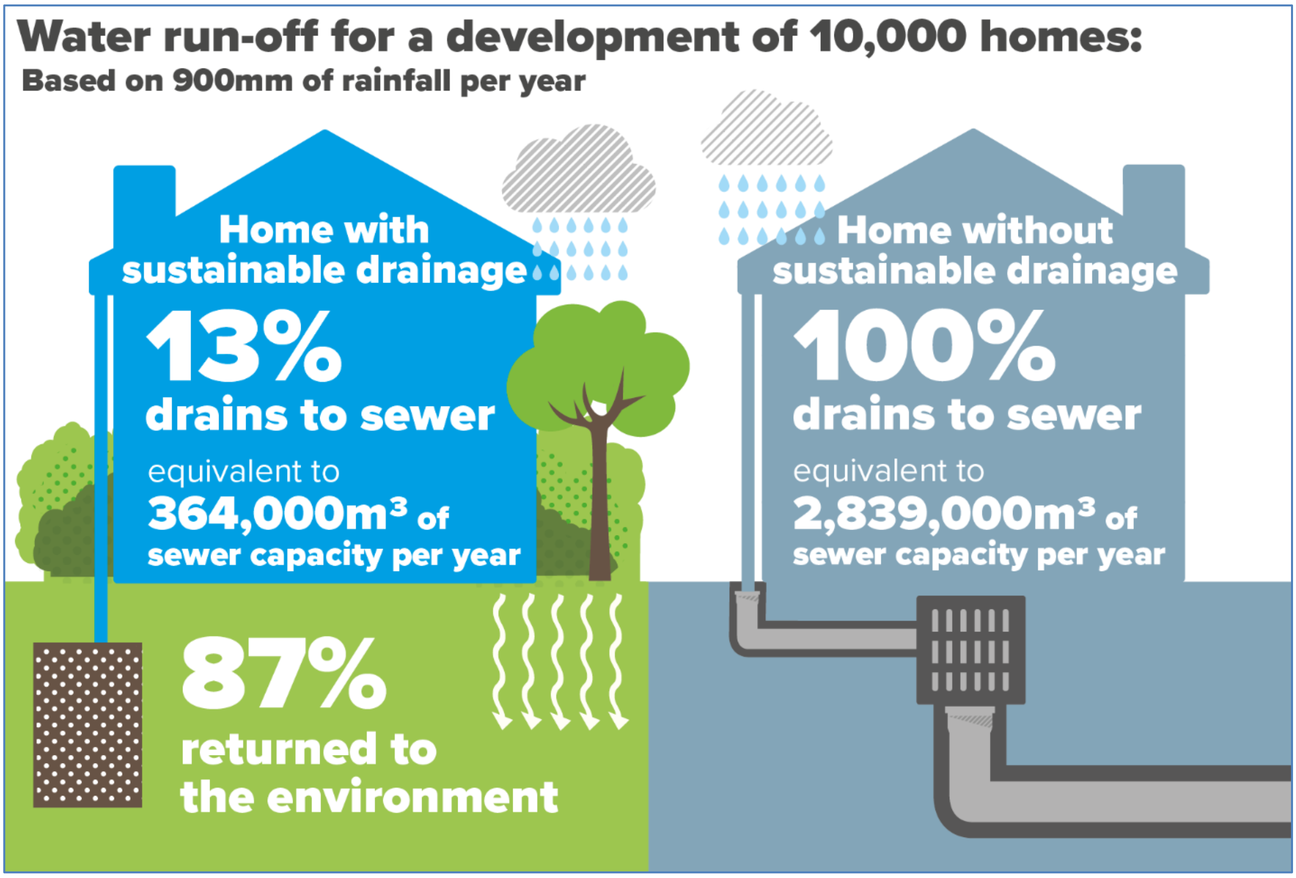

Figure 34 – The impact of legacy drainage systems

B.3 Highway Drainage System

Road or highway drainage i.e. road gullies, also connect to surface water systems. Often this is the same surface water system that takes roof drainage into the single pipe/combined system described in Appendix B.

When rain falls on the impermeable highway areas this can contribute to rapid increases in flow to the drainage system and overwhelm it. In particularly intense storms and/or if gullies are blocked, then overland flow can occur. This overland flow can cause flooding or allow rainwater to enter combined sewers which are not always designed for these extreme flows.

B.4 Internal Drainage Board

Across England there are a number of Internal Drainage Boards who work in partnership with local councils, the Environment Agency and other local partners to reduce the risk of flooding to agricultural, residential and industrial land, and are overseen by the Department for the Environment, Food and Rural Affairs. They carry out an annual programme of maintenance works to ensure water levels are kept at an appropriate and safe level.

Appendix C – Building a Holistic View of a Catchment for Storm Water Management

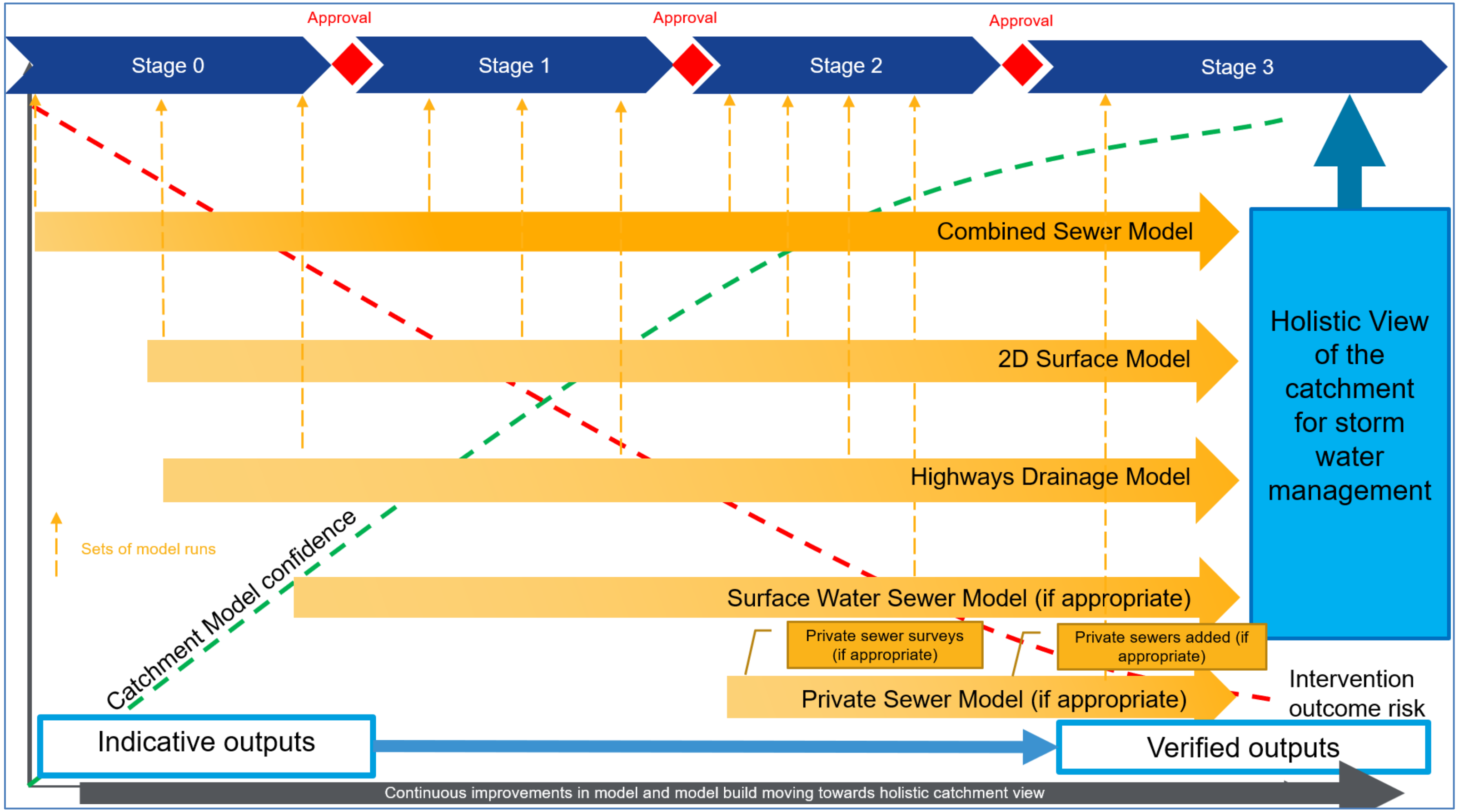

Figure 35 - Building a holistic view of a catchment

Glossary

Catchment	An area that is drained by a complex sewerage system comprising a network of pipes, wastewater pumping stations, and wastewater treatment works.
CCTV	Closed Circuit Television Video sewer inspection refers to the process of using a camera to see inside pipelines, sewer lines or drains.
CDC	Chichester District Council
Combined Sewers	A system that conveys both foul and surface water.
Storm Overflow	A traditional storm overflow which will have a condition for pass forward flow, an Event Duration Monitor (EDM), a screen and possibly storage volume.
DEFRA	Department for the Environment, Food and Rural Affairs
Dry weather flow	Dry weather flow is the flow of wastewater in a sewer system during dry weather that presents with minimal infiltration.
Dry weather flow pumps	These are pumps whose size is calculated to pump an agreed volume of flow forward to the WTW. This flow rate is agreed with the EA.
Emergency Overflow	Typically, on a pumping station or WTW and only used if the site has suffered a power or mechanical failure. For example, Diamond Road WPS has an emergency overflow.
EDM	Event Duration Monitor
FTFT	Flow to Full Treatment
FOG	Fat, oil and grease
Foul Sewer	A sewer that is expected to carry predominately foul sewage from toilets, sinks, baths and appliances from a domestic property. The foul sewer also carries wastewater industrial and commercial properties.
GIS	Geographic Information Systems (GIS) are most often associated with mapping and provides geographic information through maps or databases. GIS combines hardware, software and data to provide visual geographic information. Also known in Southern Water as the sewer record.
Hydro-Brake®	This is a device that controls the flow coming out of a tank. Under regular conditions, water passes through the Hydro-Brake® unrestricted and continues downstream at normal levels. At times of high flow e.g. during a rainstorm, the structure's internal geometry harnesses the natural energy of the flow. This holds back the water, releasing it at a controlled rate.
IDB	Internal Drainage Board
Intervention	An action or project being undertaken in order to provide a solution/benefit for the catchment issue e.g. flood risk or number of storm overflow discharges.

LSO	Long Sea Outfall
Main River	Main rivers are usually larger rivers and streams. The Environment Agency designates these and carries out maintenance, improvement or construction work on main rivers to manage flood risk.
MST	Maintenance Service Task Southern Water scheduled maintenance task
Natural capital	Southern Water defines natural capital as the element of nature that provides value to society.
Network model	A software model representing the piped drainage system through which different rainfall scenarios can be run to understand the impact on storage capacity, water levels and pumping station capacity.
No regret intervention	Where it has been agreed through Governance that intervention will provide a benefit with negligible risk of a negative outcome.
Ofwat	The Water Services Regulation Authority
Rainfall scenario	Different types of storms that can be used in a network model. These storms may vary in length or intensity.
Social capital	Social capital is defined as Southern Water's relationships and others' trust in the business.
SWS	Southern Water Services
SSO	Short Sea Outfall
Storm Overflow	Where a combined sewer discharges a diluted but untreated mix of wastewater and rainwater into a water body during rainfall. The term is synonymous, for the purposes of this document, with the terms, combined sewer overflow, intermittent discharge and storm tank overflow.
SuDs	Sustainable Urban Drainage Systems
Unflushables	Items which should be disposed of in the bin, not the toilet.
WPS	Wastewater pumping station
WSCC	West Sussex County Council
WTW	Wastewater treatment works