SRN50 Resilience - Infiltration
Enhancement Business Case

2nd October 2023
Version 1.0

Contents

List of Tables and Figures

Executive Summary

Sewerage systems in parts of our region are especially vulnerable to ground water due to the following feature of our collection systems and our geology.

1. A higher proportion of our sewer assets were designed as foul sewers, compared to other WaSCs. Typically, these have a lower capacity than their combined sewer counterparts, this is significant as these sewers will be overloaded at lower rates of infiltration than sewers of a larger diameter.
2. We have a relatively large number of catchments which experience high groundwater events when compared to other WaSCs.
3. We have a high number of infiltration reduction plans (IRP) (see Appendix 1 Infiltration reduction plan Actions (southernwater.co.uk) when compared to other WaSCs. IRP's are a requirement of the Environment Agency in response to the EA Regulatory Position Statement (see Appendix 2) and detail the actions to be taken to minimise the impact of groundwater events

Groundwater events impact directly on the level of service to our customers when they occur operational measures such as continuous tankering are deployed to maintain service. Unlike Dry Weather Flow infiltration these events inundate (flood) our collection systems. To protect service to our customers we have shown, in a full-scale trial at Pan Parish, Andover that it is possible to provide enhanced resilience but this does need to be delivered at scale. Since 2013 we have been addressing groundwater ingress to sewers in a piecemeal approach i.e. we survey sections of sewer, line those found to be leaking and then return to repeat the process if the problem re-occurs. None of the 18 systems covered by Infiltration Reduction Plans are yet watertight to the degree that we do not need to over pump. The history in the IRP documents evidences this. The piecemeal approach has been proven to not work and we need now to change our approach to a larger full system approach.

Our investment plan includes for 736km of sewer watertightness enhancement measures between AMP8 and AMP9. During AMP8 we will deliver 222km of enhanced sewers in nine collection systems with the greatest impacted catchments. 30,000 homes will benefit from this investment.

This enhancement case links strongly to the Planning Objectives in the Drainage and Wastewater Management plan associated with reducing sewer flooding, reducing storm overflows and achieving compliance at wastewater treatment works. It also allows us to deliver the agreed actions in the published infiltration reduction plans which reduce the need for dry weather discharges to manage the flow derived from high groundwater.

This case does not duplicate and is separate to the investment required to address spill frequency from storm overflows. This addresses discharges resulting from over pumping activity within sewer networks prone to Groundwater Infiltration where there are no overflow ancillaries.

Summary of Enhancement Case	
Name of Enhancement Case	PR24 EC – Infiltration Enhancement Case
Summary of Case	Our plan for Infiltration management will reduce Groundwater Infiltration (GI) into wastewater collection systems to acceptable rates[1]. To achieve this, we will enhance the 'watertightness' properties of the collection systems, to above industry standard design, in high groundwater infiltration areas which have a formal Infiltration reduction plan as agreed with the Environment Agency. We will approach this using a large-scale deployment of interventions both on public and private sewers and a long-term enhanced monitoring approach to ensure the optimum level of activity is undertaken to allow us to address infiltration reduction.
Expected Benefits (catchments)	Infiltration Reduction plans will be reduced from 18 to 15 with full measures being installed at 3 sites. 117km of watertight measures to be deployed at: • LAVANT • PAN PARISH • ST MARYBOURNE A further 105 km of watertight measures to be deployed at the six systems below. We are planning for 20% of each system to be made watertight with the remainder to follow as appropriate in future AMPs: • LOWER NAILBOURNE • GOODWORTH CLAITFORD • SIDLESHAM • BARNHAM • WINCHELSEA BEACH • UPPER NAILBOURNE Indirect benefits will include: reduction in pollution incidents, flooding, restricted toilet use, disruptive tanker movements, "dry day" discharges
Associated Price Control	Wastewater Network +
Enhancement TOTEX	£38,898,574.71
Enhancement OPEX	£0
Enhancement CAPEX	£38,898,575
Is this enhancement proposed for a direct procurement for customer (DPC)?	No - DPC has not been proposed for this enhancement case as the Capex investment is less than £200m, so it does not pass the materiality threshold for DPC.

[1] Sewers for Adoption 6th Edition (WRc, 2006), which is based upon BS EN 1610 "Construction and testing of drains and sewers". This is shown in the following equation:

Acceptable infiltration (l/d) = 24 x D x L

D = Internal diameter of pipe (m)

L = Length of section under test (m)

1. Introduction and Background

Sewerage systems are designed to convey domestic foul flow to wastewater treatment works for treatment prior to the discharge of treated effluent to the environment, normally rivers and coastal waters. Strict limits on the volume and bio-chemical content of discharges are set by the Environment Agency. In all foul systems a proportion of the total flow is groundwater and traditional hydraulic design assumes that infiltration flow is 40% of the foul flow, this equates to 28% of average daily flow. It is therefore recognised that sewerage systems are not designed to be watertight. The industry standard and regulator approved document on sewer design: the Sewers for Adoption manual (see Appendix 3) includes for an allowance of infiltration in sewer capacity design of 0.5l/s per metre of pipe which confirms that sewers are not designed to be watertight. How vulnerable a sewerage system is to groundwater varies depending on geology, groundwater levels, three-dimensional location of the sewerage system relative to groundwater, age of system, type of construction and system design.

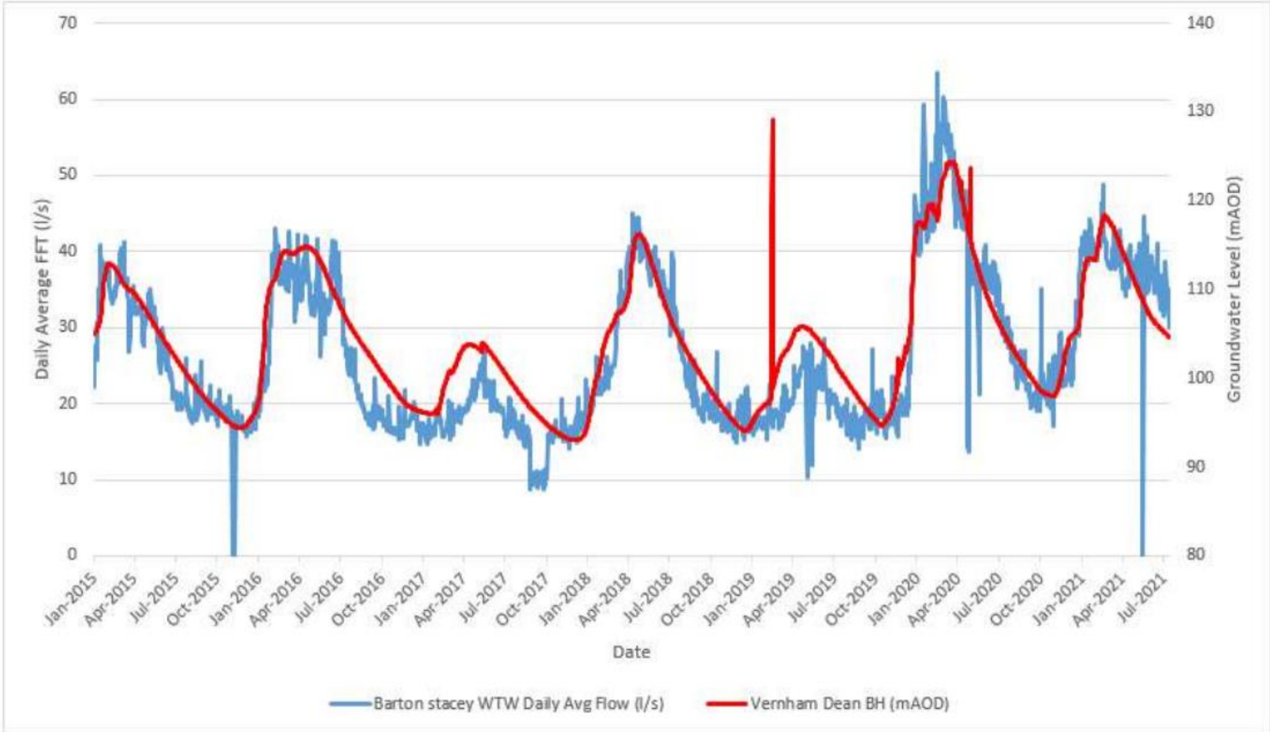
In parts of our region, the above factors combine resulting in locations which are particularly vulnerable to high groundwater. The consequence of these high groundwater events is that systems become overwhelmed by the infiltration flow, which rises to many times the design estimate resulting in loss of foul drainage conveyance, restricted toilet use, escape of flow from the system resulting in flooding and pollution incidents, high operational cost to manage flows and mitigate the impact and disruption to communities affected by long periods of HGV vehicle movements to respond to the situation.

Typically, capital maintenance investment is centred around maintaining the health of the system and is monitored by the number of sewer collapses per unit length of sewer against set targets. To achieve the targets with respect to sewer collapse, we undertake a risk-based approach and target investment to those assets of poor structural condition which have the greatest risk of collapse and prioritise investment to those poor condition sewers where the consequence of failure is greatest. The base investment mechanism does not assess or address water-tightness, our work on managing infiltration shows that high infiltration rates can be seen in sewers in good structural condition and not at risk of structural failure.

Addressing the impact of groundwater infiltration cannot typically be solved through capital maintenance. Capital maintenance activity addresses sewers where the structural condition is grade 4 or 5 meaning that the asset requires rehabilitation or replacement. We find most infiltration occurs in good condition sewers at poor pipe joints (see section 2.1). Our current level of capital maintenance investment in sewer rehabilitation results in approximately 11 km per year of refurbishment/repairs (average 2017 to 2021). Our Annual Performance Report data (see Appendix 7) performance in respect of collapse rates is 7 per year per 1,000km of sewer over the same period. This ranks us as mid table against other operators. This demonstrates that our systems are generally structurally sound but because of the infiltration issue good structural integrity does not deliver watertight sewers, infiltration is a separate issue that needs to be addressed outside capital maintenance. Capital maintenance investment is focused on rehabilitating structurally impaired sewers (grades 4- 5 (condition grades)) and generally not improving watertightness of collection systems. An opportunistic approach to seal sewers whilst attending a sewer repair is not applicable for this work due to the sheer scale of sewer sealing required. The opportunistic element would work in reverse here in that when lining sewers to deliver water tightness we would also address structural defects as we found them during the course of the lining work.

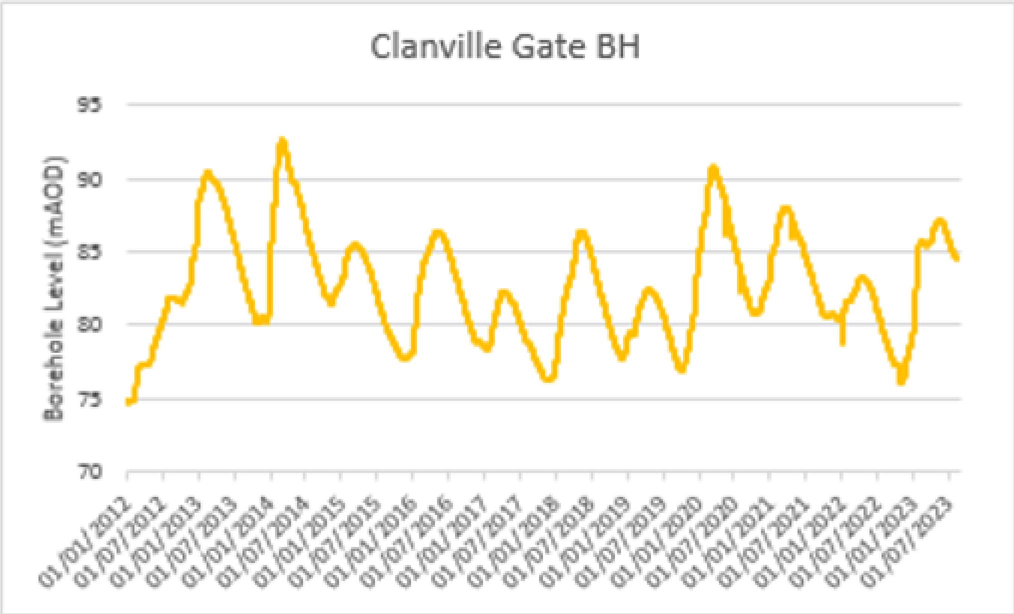
In collection systems impacted by groundwater events we see a direct correlation between the groundwater levels and the flow arriving at the treatment works. Figure 1 shows the strong correlation between Vernham Dean borehole (groundwater level monitor), and flows arriving at our Barton Stacey wastewater treatment works. However, the greatest impact is not in dry weather flow compliance, the impact is more within the collection system where we need to manage the excess flow by tankering and overpumping.

Figure 1: Groundwater levels from 2015 to 2021, compared to Barton Stacey WTW flow data



Groundwater events overwhelm the collection system to such a point that without additional operational interventions the collection system will fail in its principal duty to collect and treat the wastewater. Collection systems which were designed for wastewater only have little capacity to drain and dispose groundwater event flows. As groundwater events rarely cause surface flooding but restrict the ability for the collection system to effectually drain, the total impact of these events requires broader improvements to the system to be resolved. The impact on service is evident in storm overflow spills performance and in an uplift in operational costs to convey and treat the water. Unlike surface water flooding events (which typically flood for hours) groundwater events typically continue for months at a time. Collection systems have a nominal structural design life of 100 years, though they are not designed to be watertight. Over time, a collection systems water tightness will deteriorate. However, groundwater event infiltration is only evident when groundwater reaches a level sufficient to infiltrate the collection system (typically when the levels are within 600mm of ground level). Normal solutions such as installing repair patches into the collection system provide little benefit as water will readily find another entry point. Groundwater events do not occur every year, 2022 for example, had minimal impact however, the frequency of events appears to be more frequent. See Figure 2 below as an example of annual variability from a borehole in Andover, Hants.

Figure 2: Groundwater levels from 2012 to 2023, showing annual variability



We show in this document that industry standard serviceable sewers (Grade 1, 2 and 3) and sewers built and tested to the Code for Adoptions (see Appendix 3) are not resistant to GI[2]. Dealing only with defective sewers covered under base activity, is not sufficient to provide resilience against groundwater events in collection systems that are subject to infiltration reduction plans. These are a requirement of the Regulatory Position Statement (see Appendix 2) published by Environment Agency and detail the actions to be taken to minimise the impact of groundwater events.

In the Southern Water region, we see a greater problem of groundwater events than other companies because of two factors.

1. Water Company comparison data published by OFWAT in APR reports (see Appendix 7) show we have the industry second highest foul only collection systems with 84% of public collection system being foul only.
2. A review of other Water Companies published infiltration reduction plans show we have the highest number of infiltration reduction plans which have a provision for directly over-pumping to a receiving water body, when the system is inundated[3].

---

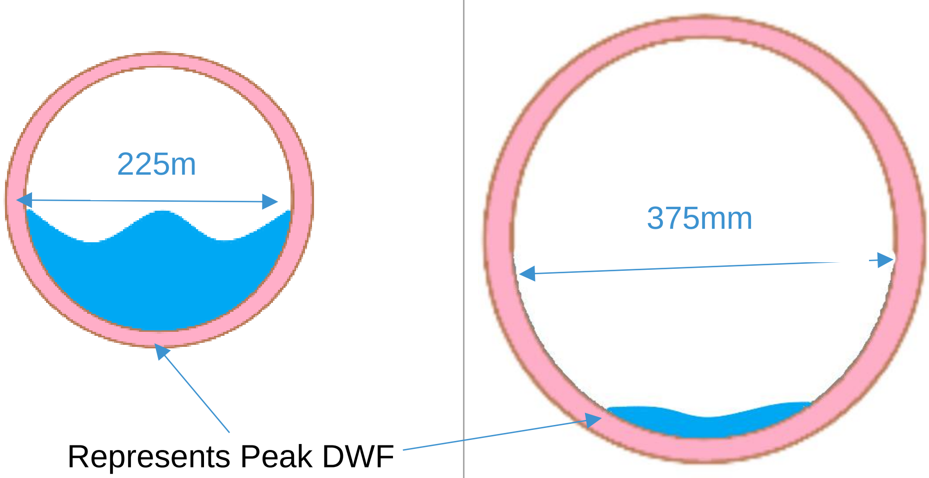
[2] Sewer Rehabilitation Manual, 4th Edition, Volume I, Appendix A, Page A/8. – https://srm.wrcplc.co.uk/Secure/Login.aspx?returnurl=%2fDefault.aspx

[3] In extreme groundwater events the under the terms of an IRP the Environment Agency will agree to the installation of temporary pumps within the network. These pumps lift flows form the collection system and discharge directly to a stream or river. Before discharge, primary and UV treatment is provided. The use of this procedure protects customer but can operate for weeks at a time.

In respect of the first point foul only collection systems are inherently less resilient to non-foul flows than a combined collection system. Figure 1.3 and **Error! Reference source not found.**.1 illustrates the provision o f capacity for non-urban wastewater flows.

Figure 3: Comparison between foul and combined sewer capacity

Separate foul sewer Peak Flow Design Separate collection systems are designed with a capacity of 4,000 l/house/day. The design assumes a maximum peak flow of 6 x Domestic Flow[4] + an allowance of 10% for infiltration.	**Combined sewer Peak Flow Design** 3 x Dry Weather Flow[5] + Rainfall response[6] with 10% allowance for infiltration.



The Table 1 below shows that separate foul sewer collection systems have inherently less capacity and hence less resilience than a combined sewer collection system. Put simply combined sewer collection systems are designed larger and typically have an overflow mechanism whereas a separate foul sewer collection system is designed as a "treat all flows" system. The historic industry standard documents in which these definitions and formulas can be found is the Ministry of Housing and Local Government (1970) Technical Committee on Storm Overflows and the Disposal of Storm Sewage, Final Report, HMSO, London. The conclusions from this report are included in Appendix 4.

[4] Domestic flow $P_{Dwelling}$ x G G = per capita domestic flow (l/hd/d) - assumed to be 200 l/h/d. $P_{Dwelling}$ Assumed occupancy rate per dwelling – assumed to be 3 population per dwelling. Domestic flow is subject to daily (diurnal) variation. Typically a maximum observed variation in domestic flow is between 2 and 3 x average domestic flow.

[5] Dry Weather Flow = PG + IDWF + E Where: DWF = total dry weather flow (l/d), P = catchment population (number), G = per capita domestic flow (l/hd/d), I_{DWF} = dry weather infiltration (l/d) and E = trade effluent flow (l/d). PG (domestic flow) is subject to daily (diurnal) variation. DWF may vary seasonally due to changing levels of sewer infiltration and population numbers.

[6] The flow in a combined sewerage system will increase when it rains.

Table 1: Comparison between foul and combined sewer capacity

Design scenario for 700 houses	Foul System	Combined system
Peak dry weather base flow (3 DWF)	16 l/s	16 l/s
Peak design flow	32 l/s	125 l/s
Pipe design capacity	32 l/s	125 l/s
Available headroom at 3DWF	16 l/s	109 l/s
Groundwater flow = 3DWF	16 l/s	16 l/s
Remaining capacity at high groundwater	0 l/s	93 l/s

In relation to the second point, we have a total of 18 Infiltration Reduction Plans[7] (IRP's) (see Appendix 1 Infiltration reduction plan Actions (southernwater.co.uk)) in place. These are in response to the EA Regulatory Position Statement with respect to managing flows by overpumping. We are committed to deliver against the action plans contained within the IRPs. The IRPs were first produced in 2013 and we have for the last 10 years been surveying and sealing sewers in these catchments. Although some successes can be identified, for example in some areas groundwater levels now need to be much higher before infiltration to sewers is triggered, the issues have not been eradicated in any system and the IRP remains a live document. A measure of success of this proposal would be the retirement of the IRP for systems where the entire system impacted by groundwater is watertight and there is no longer a need to manage excess flow. Figure.4 maps the location of the IRP collection system the bedrock and the location of chalk streams. Although chalk aquifers are a principal link to groundwater infiltration, it is the underlying downland fluvial (river) drainage which causes groundwater events. Chalk aquifers are especially affected as fluvial drainage is less well developed. The purpose of the Infiltration Reduction Plan is to ensure Compliance with the EA Regulatory Position Statement (see Appendix 2) with an action plan to over time reduce infiltration into sewers and cease discharges to the environment. If the plan is actioned then the EA are mindful to collate all discharges to watercourses by seasonal overpumping arrangements to one category 3 incident per groundwater season as long as the action plan is followed and that no incidents are causing environmental harm greater than a category 3 incident. Failure to act could results in all overpumping activity to be counted by the 12,24,24 method of incident classification which would result in hundreds of Category 3 pollution incidents per high groundwater season which would also adversely impact our storm overflow reporting both in terms of overall spills and dry day spills.

[7] The Environment Agency's (EA) Regulatory Position Statement (RPS) requires Water and Sewerage Companies (WaSC), which are aware of sewerage systems in their area vulnerable to groundwater infiltration, to submit Infiltration Reduction Plans (IRPs) to the EA for approval.

Table 2: List of 18 sites with Infiltration Reduction Plans

Alkham Valley	Goodworth Claitford	Barnham
Hambledon	Lancing	Chilbolton
Lower Nailbourne	Hursley	Winchelsea Beach
Kings Somborne	Sidlesham	The Green Southwick
Lavant	St Marybourne	Appleshaw
Pan Parish	Longparish	Upper Nailbourne

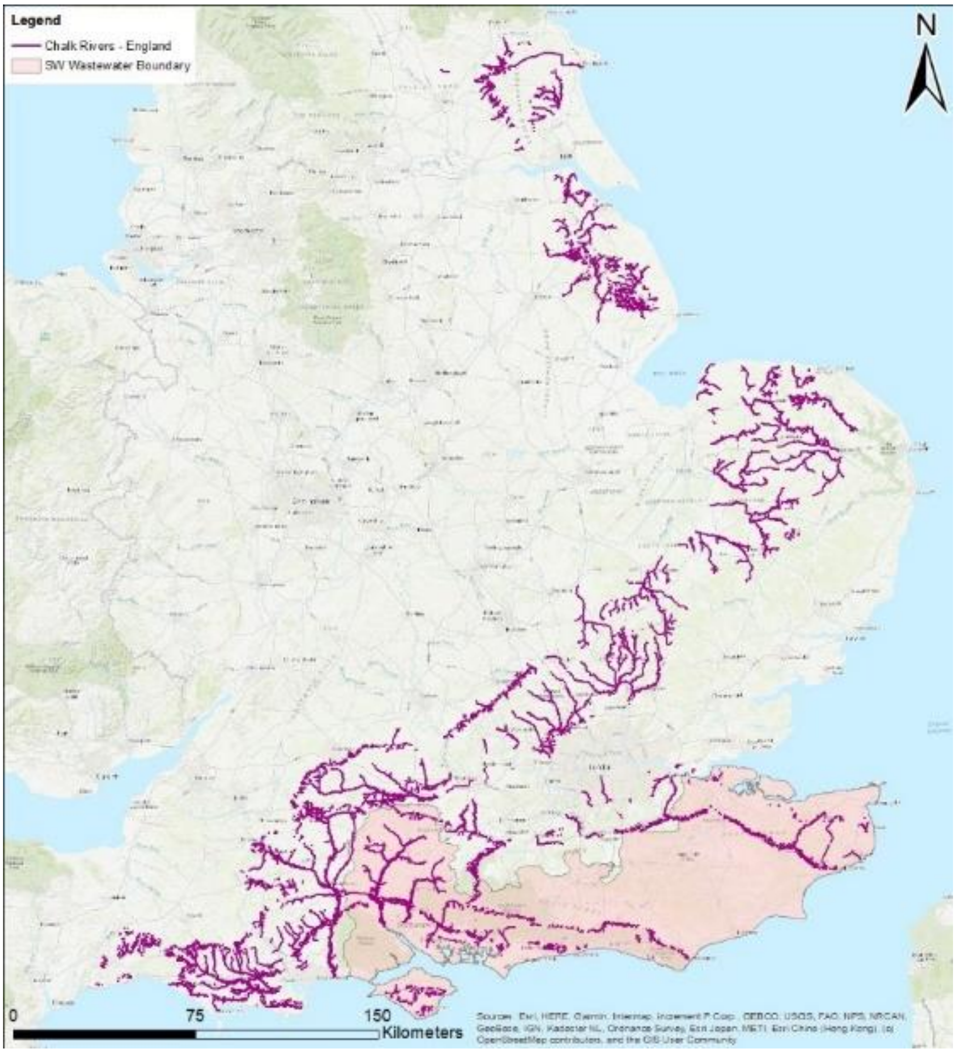


Figure 4: Location and geology of collection system subject to Infiltration Reduction Plans

To comply with the Regulatory Position Statement we need to make sewers more resilient to groundwater infiltration than they were ever designed / expected to be. Our case is focused on enhancing sewers that are already in reasonable structural condition and have a low likelihood of collapse to be more resilient to groundwater event infiltration. This will then reduce the risk of dry day spills and as seen in section 2.5 this approach is supported by our customers. Climate research UKCIP18 report (Appendix 5) predicts that winter rainfall will increase by up to 39% as the climate changes and it can be expected that groundwater levels would also increase as a result leading to greater infiltration to sewers should the proposed resilience measures not be implemented. The challenge of groundwater event infiltration is becoming more significant and more widespread due to climate change. Responding to the impacts of climate change requires systems to be made more resilient to uncertainty and to therefore provide an enhanced level of resilience compared with existing standards.

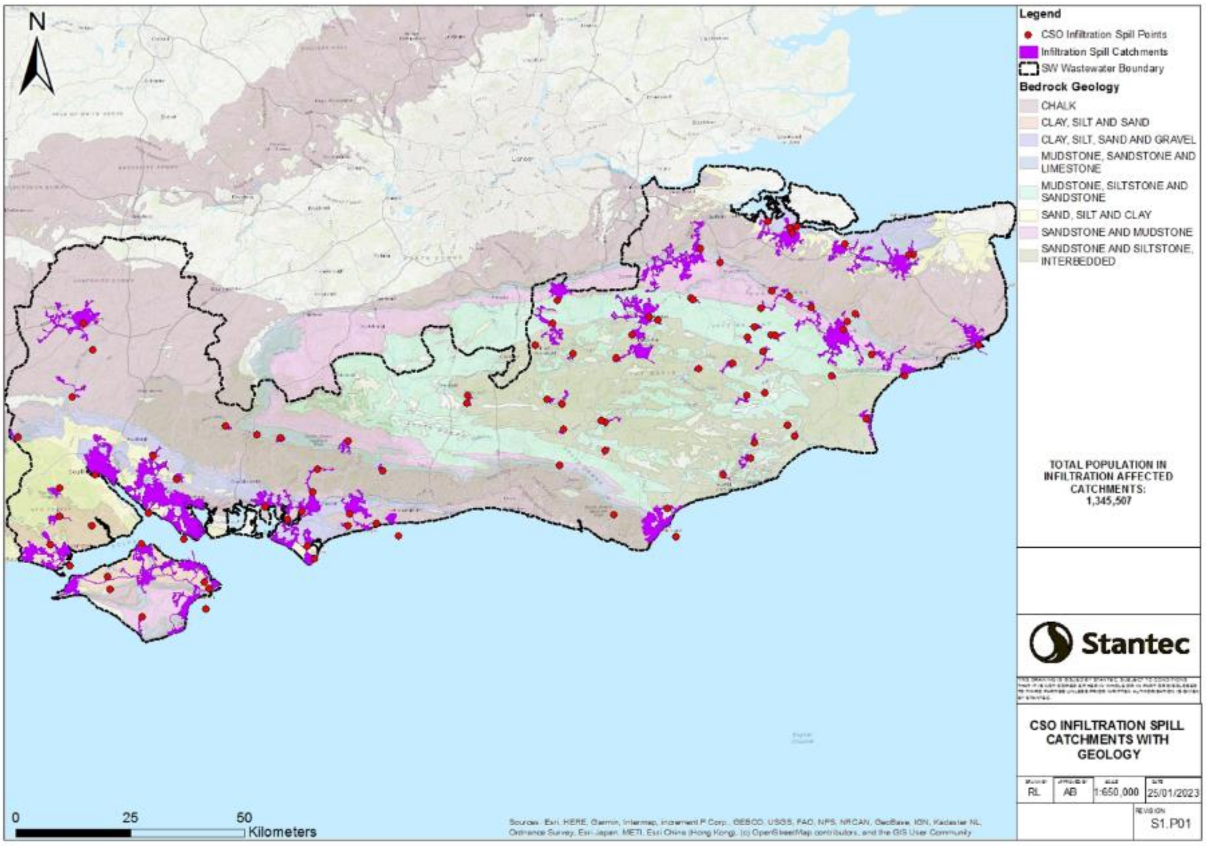


Figure 5: Southern Water wastewater systems impacted by infiltration

Our approach to creating a watertight system and address infiltration at source will be to :

- undertake comprehensive surveys of the public sewerage system prone to groundwater submersion
- line those sewers which show potential for infiltration at joints.
- repair any structural defects found
- seal joints in small diameter pipes and private systems and manholes by [redacted]
- monitor the effectiveness of the sealing on base flows
- in future consider the need for nature based interventions to treat the excess flow – this will be a future development and is not part of this enhancement case

We have embraced new techniques such as [redacted] which is a flood grouting system widely used in Germany; [redacted], which is a survey method to detect potential defects in pipe full conditions and long-term temperature monitoring[8]. These innovative methods of identifying and dealing with infiltration are industry leading and we are sharing outcomes with other Companies to allow the industry to move forward together with this challenge. The industry level trial at the Andover Pan parishes[9] (see Appendix 6 and Appendix 8) provides confidence that GI can be addressed using a targeted large-scale deployment of interventions for public, private sewers and long-term enhanced monitoring. Dealing with the GI at source (i.e. address the root cause) is the most effective way as it takes these 'unwanted flows' out of the foul system creating a resilient sewerage system to groundwater events / future climate change. This comprehensive approach is leading the way in adapting our collection systems to tackle excess consequences of ground water event infiltration. Working together with the Environment Agency (EA), Customers and sharing data with the wider industry will be an outcome of this investment. We demonstrate that this is the most sustainable, environmentally friendly and customer beneficial solution. Initial findings from Pan Parish suggest that 100% water tightness is uncertain. To further protect customers, we are and will continue to explore the use of Nature-based Solutions (NbS) (wetlands) to provide Secondary treatment in IRPs. This dual approach will ultimately provide a layered approach to resilience as we develop the most efficient techniques to provide long term operational resilience. The introduction of wetlands is not included in this proposal.

Our plan for AMP8 shows we will undertake 222km of sewer watertightness measures in the nine sewer collection systems of:

- Lavant
- Pan Parishes (Andover)
- St Marybourne
- Upper Nailbourne
- Lower Nailbourne
- Winchelsea Beach
- Sildlesham
- Barnham
- Goodworth Claitford

Our multi-AMP plan is part of a longer-term delivery strategy to fully address the challenges outlined in the 18 IRPs.

This multi-AMP investment approach will allow suppliers and contractors to scale up to meet demand without excessively inflating prices. It will also allow us to assess and refine our technique of source control and NbS to meet our community and customer needs.

We recognise that the work undertaken will also remedy structural defects that should be rehabilitated under base investment. To avoid double counting, we will undertake Industry standard inspections (CCTV) to

[8] Ground water is typically significant colder than domestic flows, in sewer temperature meters can detect when groundwater inflows to inform installation of watertight sealing measures.

[9] The Pan Parish Forum has been formed by seven parishes, all of which sit on the western edge of Andover, Hampshire, draining to the Fullerton treatment works and are covered by the Pan Parish IRP Microsoft Word - Pan Parish IRP v5.4 AA (southernwater.co.uk).

identify any pre-existing structural defects and will fund the cost of remedying these defects through base investment and not as part of this EC. This opportunistic approach will deliver greater value to customers as more benefit is delivered for no additional cost and also will reduce disruption by not having to re-visit site to undertake follow on remedial work.

Links to data table lines		
Enhancement	Table	Line
Resilience Enhancement – wastewater capex	CWW3	168

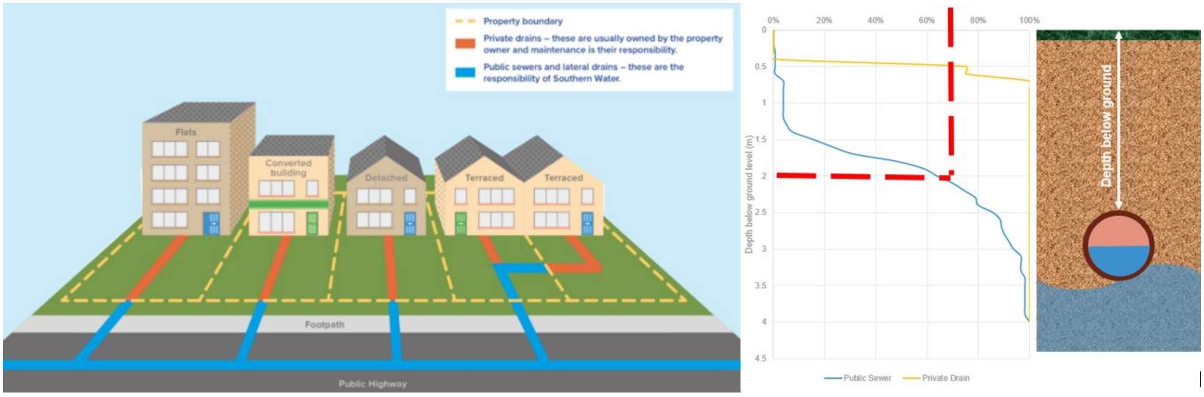
Links to common/bespoke performance commitments		
Performance commitment name	Unit of measurement of benefit from this investment	Observations
Number of pollution incidents category 3	Incidents per year	

2. Needs Case for Enhancement

2.1. Wastewater Collection system

Southern Water are responsible for the maintenance of the public sewers and the public drains within the sewerage systems. These systems are designed to transfer wastewater (foul and/or surface water) only and have not been sized to convey any land drainage or groundwater. The rest of the drainage network is owned by the private landowners. Typically, private drainage and much of the foul only sewage system is laid at nominal cover, less than 2m depth to invert. Figure 6 shows the ownership and proportional distribution of sewer length versus depth of both public and private sewerage in a typical system. The data indicates that 75% of the sewerage is constructed shallower than 2m in depth.

Figure 6: Sewerage Ownership and relative depth



Groundwater rises and falls throughout the year. When the groundwater is low the amount of the collection system which is 'exposed' to the influence of groundwater is low (less than 10%). When the groundwater is at average levels more of the collection system is exposed to the network, typically up to 25%. During a high groundwater event a far greater proportion of the collection system is exposed to the influence of groundwater, up to 90% in some systems. Groundwater events do not occur every year and can range from mild to extreme events which continue for many months at a time. The figures quoted were determined from our infiltration reduction pilot study in the Pan Parish area of Andover (see Appendix 6).

The infographic in Figure 7 shows how groundwater interacts with the collection system. The IRP catchments are more than 90% foul only collection system (see Table 1 for details) and, as such have an inherent resilience weakness in terms of its purpose.

Currently, when groundwater overloads the sewer system, service is maintained using a combination of tankering of flows directly from the sewer system and transporting them for disposal, and directly over-pumping flows from the collection system to a nearby receiving watercourse. These operations can continue for 24/7 for months at a time.

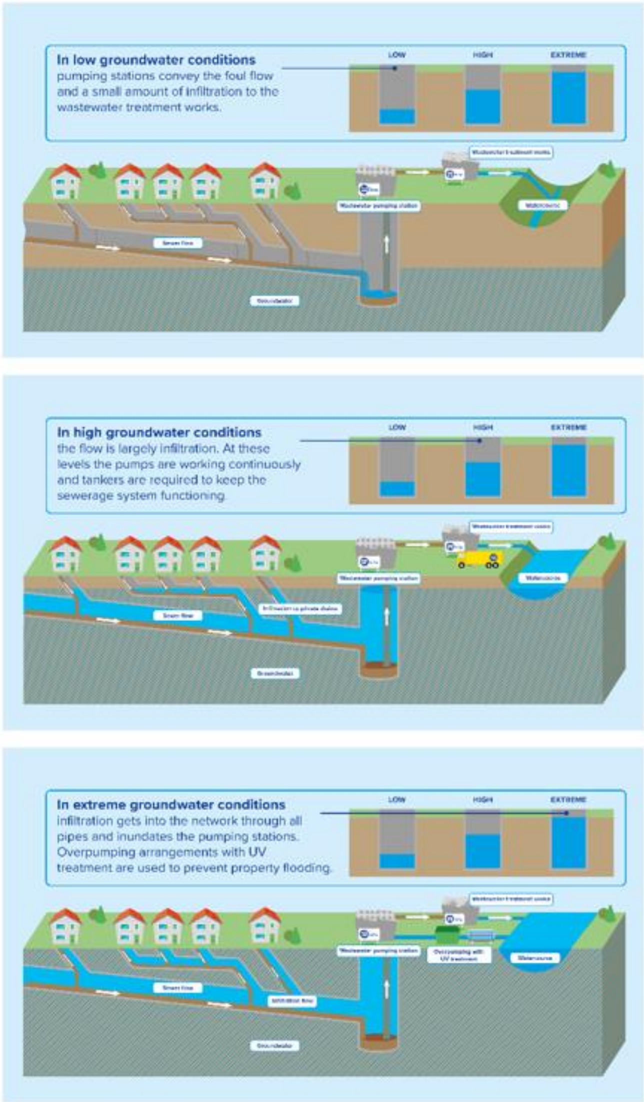


Figure 7: The interaction between the water table and collection system

Figure 8 illustrates the challenge of a perfectly structurally sound sewer which is evidently not watertight. Evidence of pre-lining CCTV will be a pre-requisite for lining conducted as part of this enhancement case.

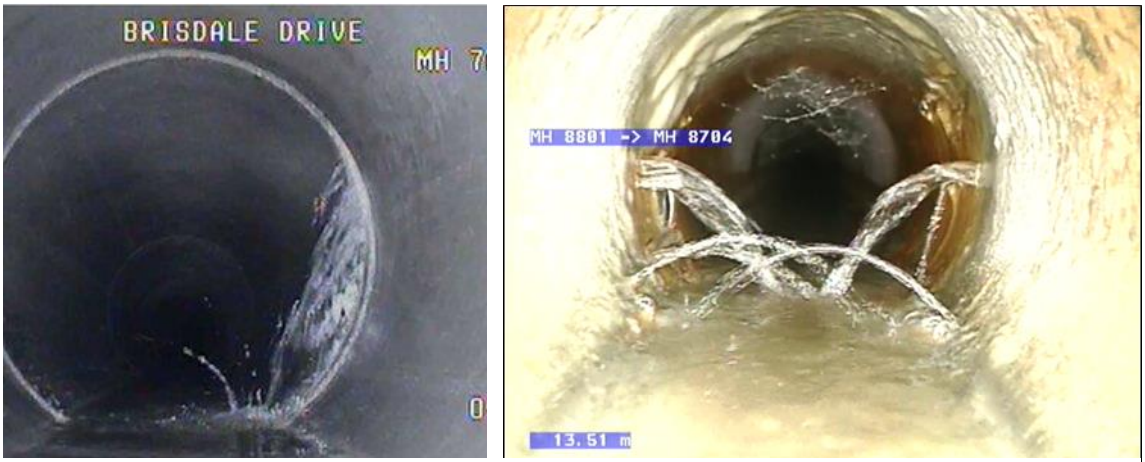


Figure 8: Two CCTV images showing observed inflow to a structural grade 1 sewer

2.2. Low Regret Assessment.

We have assessed this programme against the criteria for low regret investment identified in the LTDS guidance and Appendix 9 of the Final Methodology. The guidance identified that low regret investments meet the needs across a wide range of plausible scenarios, meet short-term requirements; or keep future options open, including cost minimisation.

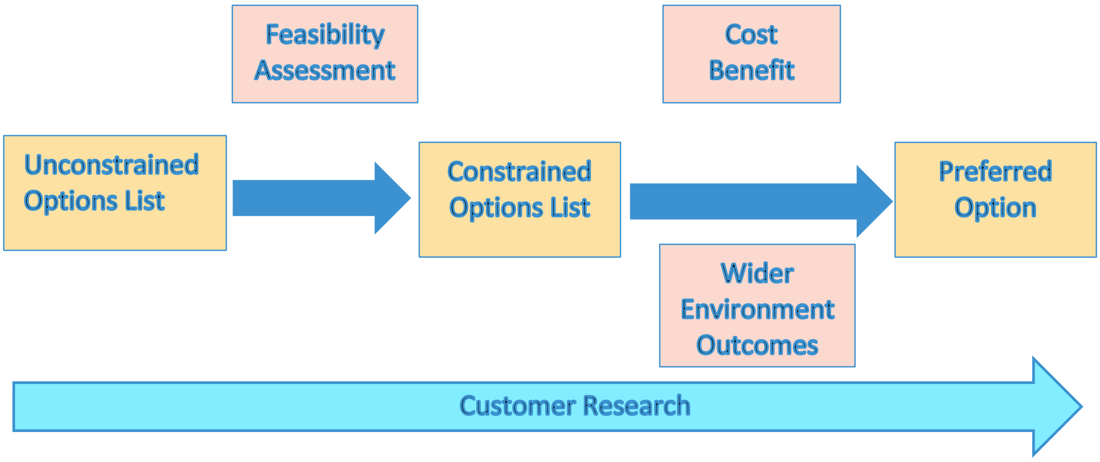
We consider that the investment proposed in this enhancement case is a low regret investment for the following reasons:

- Needs – Groundwater Event Infiltration causes pollution and flooding issues and results in high customer and environmentally impacting operational mitigation and water management activity. The instance of high groundwater events is increasing due to climate change.
- Timing – The research shows that customers are willing to pay +£2 on bills per year to support infiltration reduction (see section 2.5).
- Optioneering – We explored a wide range of options to address this GI challenge, we researched good practice and emerging R&D technologies to identify an ‘unconstrained’ long list of potential solution, regardless of the effectiveness, feasibility of cost-benefit. From this we assessed feasibility to understand the technical suitability to produce a list of constrained options, which has then been tested for cost benefit against our value framework to understand the solution which provides the ‘best value’ for the customer. Customer research has also fed into the solution selection process.
- Future scenarios – Our investment plan includes for 736km of sewer watertightness enhancement measures between AMP8 and AMP9. During AMP8 we will deliver 222km of enhanced sewers in 9 collection systems with the greatest impacted catchments. 30,000 homes will benefit from this investment.

3. Best Option for Customers

We explored a wide range of options to address this GI challenge, we researched good practice and emerging R&D technologies to identify an 'unconstrained' long list of potential solution, regardless of the effectiveness, feasibility of cost-benefit. Form this we assessed feasibility to understand the technical suitability to produce a list of constrained options, which has then been tested for cost benefit against our public value framework to understand the solution which provides the 'best value' for the customer. Customer research has also fed into the solution selection process.

Figure 9: Solution development and assessment process



Options Considered

We explored a wide range of options to address this GI challenge, we researched good practice and emerging R&D technologies to identify a 'unconstrained' long list of potential solution, regardless of the effectiveness, feasibility of cost-benefit. From this we assessed feasibility to understand the technical suitability. We then discuss the effectiveness, feasibility, and value of these options. A common element to all options will be recording of flows in the system at times of high groundwater to understand and determine the effectiveness of the intervention in reducing inflow. Table 3 lists the options considered.

Table 3: Unconstrained to constrained list

Option considered (Unconstrained)	Unconstrained to Constrained	Rationale
Tactical system relining	Yes	Preferred option – adaptive solution. Effective, relatively low cost and low carbon
Reduce other inflows	Yes	May be partially effective due to being site specific. Potentially low cost. Would need to be used in conjunction with relining option to address all mechanisms.
Natural Flood Management (NFM)	Yes	Possible solution for the 25-year plan. Would need to be used in conjunction with sewer sealing options to address all mechanisms and will be site specific.
End of pipe solutions (in catchment or at STW)	Yes	Not currently permitted by the EA for 'Excessive Infiltration' systems. Possible future technology may enable this as a more feasible solution
Flood grout sealing	Yes	Unproven technique in UK conditions, but possible to investigate as an alternative to CIPP in option P3.
Whole System Relining	No	Prohibitively expensive, high carbon, not good value and disruptive
Combined sewer separation.	No	Convert existing combined sewers to surface water only and construct new foul water sewers. Prohibitively expensive
Infiltration reduction - Reduce groundwater levels	No	Prohibitively expensive / limited benefit and would need to be sustainable (in line with drought plans)
Do nothing/Maintain Status Quo	Yes	Taken forward for comparative purposes. Includes Tankering
Find and Fix relining	No	10 years of using this approach with no retired IRPs
Storage tanks	No	Not feasible as storage of any size will eventually fill and not be able to drain. The root cause does not lend itself to this solution type.
Tankering	No	Included in Maintain Status Quo option
New Combined Sewer Overflow	Not feasible	Not feasible as the EA discount this as an option in para 1.4 of their Regulatory Position Statement on Discharges made from groundwater surcharged sewers.(Appendix 2 PR24 - supporting data - All Documents (sharepoint.com)

WATER for LIFE from Southern Water

3.1. Constrained List

3.1.1. Tactical System Lining ([redacted] / CIPP) Approach)

CIPP Lining comprises a resin saturated lining tube that is installed in a pipeline to create what has become known as a close fit 'pipe-within-a-pipe' either as a structural or non-structural solution to pipeline deterioration. [redacted] "flood grouting process" comprises the flushing of the wastewater or sewage system to be remedied with two liquid components in sequence which together harden to form a watertight seal preventing infiltration at joints and fine cracks in pipes which are not themselves structural defects.

This approach is based on the Andover Pan Parish pathfinder pilot scheme which has been operational for more than 6 months. The pilot focused on seven parishes[10], all of which sit on the western edge of the town of Andover, Hampshire, draining to our Fullerton wastewater treatment works. In these systems we are sealing the sewers and manholes at high risk of infiltration, and we have installed long term depth monitors in these systems to monitor the benefit of the work being undertaken.

This approach is iterative, and its aim is to identify the optimum economic level of infiltration remediation to be achieved through a combination of large-scale deployment of interventions both public and private and long-term enhanced monitoring. It is through the installed monitors we will be able to monitor the benefit of the work completed. Results of this approach show a reduction in the need for mitigating action such as tankering and overpumping during 2022/23 despite the high groundwater table.

3.1.2. Reduce other inflows

Groundwater infiltration is not the only source of 'unwanted flow' in a separate sewerage system, surface, land and fluvial flows can – and do – enter a collection system not via the fabric of the infrastructure but via inlet structures such as gullies. The 'overland' inflow will mimic a groundwater inflow directly to the collection and have a similar affect. Providing an alternative pathway for these flows can involve improvement to land or surface drainage to provide effectual drainage. It is an important step in the range of measures required to fully return a collection system to a foul only as designed status. However, there is downside to this approach in that if other flows in the system are reduced then the infiltration element may increase to a point where the system is filled. Infiltration into a sewer will cease when the internal pressure in the pipe is equal or greater than the external water pressure. Reducing the pressure within the pipe may draw in more flow, this makes addressing the root cause of infiltration i.e. leaking joints, the primary requirement.

3.1.3. Natural Flood Management

Natural Flood Management provides an alternative pathway for surface/ land/ fluvial waters. Ensuring that water is safely managed in nature where it can provide benefit. This involves improving land drainage ditches to ensure effective drainage of surface water which can otherwise exacerbate localised groundwater levels and increase the likelihood of groundwater infiltration. This option is relevant only in certain localities and trials to date have showed limited benefit of this approach in terms of impacting groundwater levels. This option would not in itself address the issue around watertightness of the sewerage system and resilience to high groundwater.

[10] Parishes include Kimpton, Fyfield, Thruxton, Monxton, Amport, Quarley, Abbots Ann, Upper Claitford

However, the maintenance of the land drainage systems will provide additional sustainability to resilience options and is something we will continue to promote with local and district authorities. As described earlier it is possible that Nature Based interventions such as wetlands would be beneficial as a second phase to manage flow in systems in the most excessive groundwater events, these are not included in this enhancement case.

3.1.4. End of pipe solutions (in catchment or at WTW)

Upgrade the receiving WTW to be able to treat additional GI flows. This does not treat the source of the problem and will incur increased treatment costs however may be the only cost beneficial option in larger systems. As climate change impacts groundwater and makes GI more of a risk additional upgrade may be required over time to keep up with flows.

Seasonal treatment plants/wetland treatment of discharges in the network or at the WTW. This is a potential viable solution for some systems where land is available, however would require EA approval to be a viable solution.

This solution is relatively new to the UK water industry and would need to be discussed in detail with the Environment Agency with respect to the permitting of seasonal treatment, it has only been tested at one other location within the UK. It is likely that this approach would take longer to become effective before fully treating sewage whilst plants are established. If the risk of GI increases with climate change wetlands might need to expand over time to keep up with flows.

3.1.5. Flood grout sealing

This is a technique for sealing sewers and laterals that has a long track record in Europe and with some mixed results in the UK. It uses a two-part grout to seal areas around the pipe where there are leaks / voids. The sewer section (which can include laterals and property drains) is “flooded” with the first grout solution. This seeps out through leaks and saturates the soil around the defects. It is then pumped out of the pipe and replaced with the second solution. This also seeps out and reacts with the first solution to form a solid silicate grout. Experience in the industry is that because the grout in this process provides a non-flexible seal, natural pipe and ground movement can cause the grout to fracture and for the watertightness properties to be lost. Our proposal to use the [redacted] method reduces this risk as it creates a flexible seal.

3.1.6. Do nothing/Maintain Status Quo

An approach of only carrying out base investment to address structural defects and managing the network impacts of infiltration by tankering and over-pumping does not comply with the requirements of the EA Regulatory Position Statement. Taking account of climate change predictions on winter rainfall further deterioration in performance is likely to occur if nothing is done to address the issue.

Capital maintenance investment will continue but unfortunately it doesn’t significantly reduce groundwater event inundation of a collection system as this only addresses structural condition of sewers and does not address watertightness of sewers in sound structural condition.

3.2. Rejected unconstrained options

3.2.1. Whole System Relining

One way to overcome the lack of effectiveness of a find and fix approach is to line every sewer, lateral and drain in the system to ensure that the system is made fully watertight. This is a very expensive option and is an ineffective use of customers' money as some of the work would be on pipes that were not suffering significant infiltration or at risk from it in the future.

3.2.2. Combined sewer separation.

This option would be the radical one of replacing the existing sewers with ones constructed using different techniques that could guarantee a watertight system. There are major drawbacks:

- It would be incredibly expensive and disruptive requiring the wholescale replacement of sewers and of property laterals and drains.
- Manholes might also need to be replaced as these can be a source of infiltration.
- At present, there is no readily available construction or testing method that would guarantee a watertight system although using techniques currently used for watermains might offer the basis of a way forward.

We will research construction techniques for use in new sewerage systems to avoid creating more problems in the future, but we do not see this as being feasible or cost effective for solving existing problems.

3.2.3. Infiltration reduction - Reduce groundwater levels

This would involve abstracting groundwater and discharging it to a watercourse to lower groundwater levels below the critical level for sewer infiltration. We are not aware of this technique ever being tried in the UK. The technique would have several major drawbacks.

- The volumes to be abstracted could be very large requiring major investment.
- The discharged flows would affect the natural flow regime of the river with damage to the environment and habitats.
- Dewatering options may affect water sources, which in drought situations is not aligned with Water Resource strategies.
- The increased flows could increase the risk of winter flooding downstream of the discharge.
- There would be large operating costs, energy use and carbon footprint.
- The groundwater pumped out would be as treated as wastewater and hence could need to be put into the foul sewerage systems as a trade waste, eliminating any benefit achieved.

We therefore do not intend to progress this option further.

3.2.4. Find and Fix relining

The industry has historically targeted infiltration reduction using 'find-and-fix' sewer lining and manhole sealing. This involves lifting manholes to identify locations of higher-than-expected flow that may also exhibit signs of excess clear water (infiltration) flows and then using CCTV inspection to identify the source of inflow and carrying out lining or sealing to reduce the inflow at ad-hoc locations.

Southern Water's approach to date has been centred on a 'find and fix' basis which has involved monitoring and investigating the networks in periods of high groundwater to identify sources of ingress and fix as we find them. This approach is constrained because investigations are typically limited to periods of high groundwater and when high groundwater occurs there are limited windows of time in which investigations can be successfully undertaken before flows either subside or the system is fully surcharged meaning CCTV surveys are not possible.

On occasions it is possible to over-pump between manholes to isolate sections of sewer to survey, this is not always feasible when the flows involved are simply too great to over-pump or the location prohibits this approach.) Once sections of sewers have been lined, we wait until high groundwater levels reoccur which may be several years later, to assess if the work has been effective.

The techniques employed have improved over recent AMPs including the development of low shrinkage lining and improvements in the adherence of the liner to the pipe material creating improved watertightness[11].

3.2.5. Storage tanks

The provision of detention storage is a common solution to overflow spills that are driven by direct rainfall runoff. These storm overflows are generally of short duration, and it is feasible and cost effective to store the excess flow and then release it back to the sewerage system for treatment.

This approach is not feasible or effective for groundwater induced storm overflows where the spill duration is weeks or months, and the excess flow volumes are enormous. This type of solution may delay the onset of an escape of wastewater from the system but would not reduce the overall duration or impact of spills.

3.2.6. New Combined Sewer Overflow

Storm overflows are designed to act as relief valves when the sewerage system is at risk of being overwhelmed, such as during heavy downpours when a lot of rainwater runs into drains and the sewerage system in a short space of time. If the system does get overwhelmed it can have dreadful impacts for customers, causing flooding or even backing up into people's homes in the worst-case scenario.
To prevent that happening water companies sometimes use storm overflows to release extra rainwater and wastewater into rivers or seas. This option is not a long term viable solution as the root cause of the infiltration is not being addressed. It is clear from the Environment Agency Regulatory Position Statement [9] that new storm overflows will not be considered as an acceptable method of reducing the impacts of infiltration on sewerage systems performance.

[11] https://standards-board.water.org.uk/document/wis-4-34-06-issue-3-specification-for-localised-sewer-repairs-using-cured-in-place-systems-with-or-without-re-rounding/

3.3. Scope of work

Our Infiltration Reduction Plans along with our annual mitigating actions show that since 2012 there are nine systems which suffer from groundwater infiltration more frequently than others. Our find and fix iterative approach in these systems has shown that even after 10 years we are still needing to implement disruptive mitigating activity to manage the sewerage systems including dry day discharges when the wastewater system is overwhelmed by groundwater. Our pilot study in Pan Parish demonstrates that delivering water tightness at scale using innovative techniques is successful in reducing infiltration to sewers.

From work undertaken to date on infiltration reduction a combination of sealing by flood grouting using [redacted] and cured in place sewer lining is required to achieve effective water tightness at least cost. We have assumed that 80% of sewers will be addressed by [redacted] and 20% by lining. The [redacted] technique is around 60% of the cost of lining and both techniques are much lower cost than alternative options to relay the system or to dig repair. Our tankering costs to manage high flows in the sewer can be up to £5m per year, the sewer sealing proposal is therefore cost beneficial on cost alone over the whole asset life, without taking account of the social and environmental impacts which would tip the balance even more in favour of addressing this issue.

Having identified the preferred generic option and unit cost, we then developed the appropriate scope of the investment, considering deliverability, and affordability.

Based on the work undertaken in the Pan Parish area of Andover we have found that a combination of traditional sewer lining and joint sealing using [redacted] is the preferred technique to create a watertight network. It is assumed that 80% of the 222km of sewer proposed to be sealed will be addressed by [redacted] and 20% by traditional lining technique. Our cost curves for cured in place lining show the current lowest rate this can be delivered at is [redacted] (Appendix 9). Section 4.1.3 of the Pan Parish report shows that the overall cost of deploying [redacted] is 53% of the traditional lining cost. However, because a proportion of the [redacted] work will be small diameter private sewers we have assumed we can deliver these at a lower unit rate of [redacted] which is less than half the unit rate for lining. This innovation is so new there is nothing that we can compare this rate with but we anticipate a large efficiency saving compared with more traditional techniques.

Table 4 below compares the four constrained options of sewer lining, [redacted] hybrid approach and continuing to mitigate the issue. The table also comments on the benefit delivered by each option. The option to relay a new sewerage system to address water tightness is not included in the table as the unit rate for new sewers will be higher than repairing existing and would not therefore be cost efficient compared with other options. Although sealing all sewers by the [redacted] technique is lowest cost this is not a technically achievable solution as [redacted] would not be an appropriate technique for large diameter assets on the public systems, it is proposed that these would be lined. An 80:20 spilt is proposed the majority being the least cost [redacted] activity. The costs include overhead and risk which have been evenly applied to unit rates.

Table 4: Proposed options with preferred highlighted

Option	Length	Unit cost £/m	30 year cost	Comments re benefit
1 - Lining	[redacted]	[redacted]	£65.8m	Compliance with RPS and IRP ; no dry day spills in systems addressed; 12 Category 3 pollution incidents avoided per year; Operational cost avoided
2 - [redacted]	[redacted]	[redacted]	£32.2m	Non-delivery of required benefit as large diameter sewers are not appropriate for [redacted] use
3 – Line 20%, [redacted] 80%	[redacted]	[redacted]	£38.9m	Compliance with RPS and IRP ; no dry day spills in systems addressed; 12 Category 3 pollution incidents per year; Operational cost avoided
4 - Mitigate	Tankering and overpumping	£3m p.a.	£90m (30 years)	Non-compliant with RPS and IRP. Pollutions will continue as current

Table 5 below shows the 9 sewerage systems we will address in this enhancement case, the length of sewer to be made water tight and the proportions of lining and [redacted] sealing. The average overall cost per metre of this work is circa [redacted].

Table 5: Scope of work and cost

IRP_Catchment	CatchmentPublic Sewer Pipe Length (km)	CatchmentPrivate Drain Length (km)	AMP8 %	AMP8 Investment (£)	AMP8 watertight collection system length Public (km)	AMP8 watertight collection system length Private (km)
Lower Nailbourne	66.01	22.21	20%	3,095,800	17.64	0
Lavant	24.71	10.36	100%	6,153,350	24.71	10.36
Pan Parish	35.40	24.39	100%	10,490,698	35.40	24.39
Goodworth Clatford	3.64	3.25	20%	241,783	1.38	0
Sidlesham	100.68	118.72	20%	7,699,144	43.88	0
St Marybourne	14.11	7.48	100%	3,788,161	14.11	7.48
Barnham	76.55	82.75	20%	5,590,126	31.86	0
Winchelsea Beach	4.27	6.02	20%	361,095	2.06	0
Upper Nailbourne	23.33	18.80	20%	1,478,418	8.42	0
Total	348.7	293.98		38,898,575	179.46	42.23

3.4. Customer Support

Sewer infiltration sounds serious and unacceptable to customers. It's a worrying situation that customers feel will only get worse in the long run due to climate change if it is not addressed. Although only in small number of areas, there is a preference for getting this work underway in AMP8. In different phases of our research[12], there is more support for a programme that replaces 40% of the sewers in the 18 areas in AMP8.

In acceptability testing of the business plan we saw customers also support this option. They also reference the offset of cost and environmental impact of the use of tankering to mitigate these issues. Those who do advocate doing nothing for now tend to focus on the fact that it is only occurring in 18 areas across the region, though they also want to know more about how many customers this actually affects.

"I think it's easy for us to say, oh no, we're not in those 18 areas. It's like, you know, not in my backyard. But there are people that are there that suffer and you can't help Mother Nature…So something needs to happen. Because, yeah, you know it's not acceptable in this day and age."

Low income customer

"I just had something like this recently in the river yard down here, where in middle of night, they were getting lots of lorries in to remove the sewerage. They were bringing lorries over from the mainland. So you think about all that extra cost? If this isn't done, whenever these incidents happen, then maybe we might pay more if we don't do it."

Household customer

[12] See Customer Engagement Chapter for more information on the research programmes

In our environmental ambition research you can see the trade-off results below:[13]

Figure 10: Summary of environmental ambition customer research

PLAN OPTIONS | Qualitative response adds a vital informed customer perspective to the trade-off selections made by a less informed base

	Base plan	Possible plan integrating qual insights		Overlaying the INFORMED narrative from the qual engagement
Storm overflows	[redacted] for nature based solutions for 155 overflows AND to build more concrete storage tanks	[redacted] for nature based solutions for 155 overflows AND to build some concrete storage tanks AND reduce frequency of top 30 spills	←	Customers want Southern Water to go further than government minimum requirements on storm overflows by tackling the top 30 spillers, and also raise some questions about whether more tank storage too quickly is best use of investment and environmentally sound.
Sewer infiltration	No extra investment before 2030	[redacted] to make 40% of the sewers in the 17 high risk locations more watertight	→	The more they find out about sewer infiltration, the more customers want to see Southern Water start to address it asap, though 50% in AMP8 may not be necessary.
Nutrient removal	[redacted] to treat all areas, including those with marginal benefits and those with a low environmental benefit	[redacted] to treat environmentally sensitive areas of interest and where there are high environmental benefits	←	Clear and consistent story from all parts of this research that customers are not prioritising AMP8 nutrient removal where environmental and cost benefits are anything but high – this is about affordability AND value.
River quality monitoring	[redacted] for Southern Water to manage river quality monitoring in the future	[redacted] for Environment Agency to manage river quality monitoring in the future	←	Customers believe that the EA is better placed and more credible to monitor river quality than Southern Water – clearcut finding from across the qual with an informed base.
Resilience	No extra investment before 2030	[redacted] to improve resilience of power supplies AND reduce risks caused by coastal erosion	→	Much debate on whether customers or SW should fund resilience, but most in qual agree that resilience work needs to happen in AMP8.
Carbon and net zero	[redacted] to focus on tests to reduce carbon emissions	[redacted] to focus on tests to reduce carbon emissions	[redacted]	Customers want carbon reduction, but they also want to do it the right way, and are often unconvinced by whether accelerated electric vehicle/low energy building programmes achieve more than target box ticking.
Share of preference	7.2%	92.8%		

[13] See Customer Engagement Chapter for details on Environmental Ambition Research

4. Cost Efficiency

This chapter provides detail on how we have developed our options and the associated costs for our AMP 8 Groundwater Infiltration Resilience schemes by applying our standard Cost Estimation and Optioneering approaches to ensure they are based on robust cost-evidence and represent efficient delivery for our customers.

Whilst developing different schemes to increase the resilience of our key sites to groundwater infiltration events we have applied our organisational optioneering process, which is governed by our Decision-Making Framework. This framework allows for a granular level of detailed optioneering and is aligned to our Risk and Value (R&V) process, which manages the full lifecycle delivery of a project. Information on how we've applied this Decision-Making Framework as part of our optioneering for our groundwater infiltration measures is provided in the following section.

More information on the general approach to cost estimation and optioneering, which all the associated definitions is provided in the 'SRN15 Cost and Option Methodology Technical Annex'.[14]

As set out in the Technical Annex, we separate our capital expenditure into the following four categories:

- Direct Costs (or Net Direct Works)
- Indirect Costs
- Risk
- Corporate Overheads

Our organisational process builds up the full cost stack by applying cost multipliers for Indirect, Risk and Corporate Overhead cost categories onto the Direct Costs for each scheme. More information on the definitions and rationale for the criteria is provided in SRN15 Cost and Option Methodology Technical Annex.

What cost multipliers have been applied for our Groundwater Infiltration Resilience Schemes?

Table 7 shows the overall Cost Multiplier for our Groundwater Infiltration Resilience solutions we propose to deliver in AMP 8.

Table 6: Groundwater Infiltration Resilience Enhancement Scheme Cost Multiplier Breakdown

Scheme	Overall Cost Multiplier
Groundwater Infiltration	1.57

More information on how the overall cost multiplier and associated costs for our Groundwater Infiltration resilience scheme is provided below.

[14] SRN15 Cost and Option Methodology Technical Annex

Table 8 shows the breakdown of costs and Cost Category Multipliers for our Groundwater Infiltration Resilience Schemes solutions we propose to deliver in AMP 8.

Table 7: Groundwater Infiltration Resilience Enhancement Scheme Cost Multiplier Breakdown and Total Cost Contribution

Scheme	Direct Cost	Indirect Cost	Risk	Corporate Overhead	
Costs	£25.8m	£8.6m	£0.4m	£4.1m	£38.9m
Multiplier (%)	100.0%	33.1%	1.3%	11.7%	1.57

The Groundwater Infiltration resilience scheme's cost multipliers are based on the following criteria:

- The scheme involves delivery of **Infrastructure** Projects
- The scheme is to be **'Traditionally Funded'**
- We have **High degrees of confidence in design maturity and scheme complexity** for the activity to be delivered at each site.

Table 8: Groundwater Infiltration Resilience Schemes Risk Cost Multiplier

Design Maturity	Complexity	Risk (%)
High	High	1.3%

How we have applied our optioneering approach to develop our Groundwater Infiltration Scheme Solution

- Need for investment identified following ongoing operational issues caused by groundwater infiltration causing flooding and pollution events across our region.
- Developed un unconstrained list of solutions that could reduce the impacts of groundwater infiltration on our sewerage network. These potential solutions were assessed for their feasibility and costs by ETS
- Level 1 direct costs for each site calculated by CIT using Southern Water Cost Models (More information on these cost models is available in SRN15 Cost and Option Methodology Technical Annex**)**, based on information provided from ETS on the enhancement work that is required.
- Constrained list of solutions were developed, the preferred option proposed. Project Related Cost (PRC) multipliers were then applied to understand the total scheme cost
- ETS reviewed designs and CIT applied updated PRC multipliers that considered confidence weightings on the Maturity of Design and Scheme Complexity.
- Providing an output of Level 2 capital costs for our proposed groundwater infiltration enhancement activity for the scheme.

More information on our Optioneering process can be found in in SRN15 Cost and Option Methodology Technical Annex.

As seen in Section 2.4 our proposal to deliver 80% of sewer sealing by the innovative [redacted] technique delivers a 41% efficiency saving compared with a more traditional sewer lining approach.

4.1.1. Adaptive pathway and continuous improvement.

The scale of investment in each system has been scoped based upon a modelled view of groundwater versus asset risk. The approach to the implementation of the scope is iterative as outlined in Section 2.0 to ensure that we fully address the agreed infiltration reduction plans.

To continue to ensure cost efficiency, we will collaborate with academics, industry forums and global utilities (including active engagement in the Ofwat Innovation fund and Green Recovery initiatives) to find innovative solutions that will drive down costs. We believe our combination of new sealing techniques, long term enhanced monitoring and use of nature-based solutions will fully address the need of IRPs. We are keen to work with other operators to solve this challenge for the industry.

At each stage, we will review, and actively support where appropriate, innovative methods being developed by the industry and its supply chain. This will include improvements to sewer lining techniques (particularly for laterals and drains), improvements in monitoring long term sewer flows, the potential use nature-based solutions. This will allow us to continually adapt the scope of work and scale of investment needed to deliver the improvements to the level of service supported by our customers at least cost.

In parallel with encouraging innovation in sewerage rehabilitation to reduce groundwater infiltration we will also encourage innovation in building watertight new sewerage systems to avoid creating future problems for both new and existing customers.

5. Customer Protection

The principal benefit of the investment case is the reduction and elimination of the need to over-pump directly to receiving waters within 18 catchments and thereby potentially increasing the risk of water quality issues along with disruption to the residents and customers.

- We have already shown that infiltration is driven by groundwater level and can vary significantly from year to year with some years requiring more response than other. However, extreme groundwater events are increasing in frequency due to climate change. The full benefit therefore needs to be seen in terms of the resilience it provides in the most challenging winters.
- Our approach is designed to achieve the maximum benefit for customers for the least cost i.e., not undertaking more sealing than is necessary to achieve the desired outcome.
- We have taken a 'system based, approach to resilience, accounting for the system interactions and interdependencies. Overlaps between other enhancement cases and with base investment have been considered as part of this enhancement case. Given the uncertainty (lack of evidence of successful reference sites) in this endeavour to address sewer infiltration we have taken a balanced investment view. To refine and develop our approach, to work with customers and communities to provide a layered resilient service.
- We have undertaken an industry level trial to develop a structured method/process for resilience management. Learning form this trial will inform our approach as we roll out comprehensive approach.
- In preparation of this case we have built our case on an industry trial reference site two years ahead planned investment. The interventions will be carefully monitored 'mitigate risks and maximise opportunities to improve efficiency. Use of [redacted] "flood grouting process" offers an opportunity to halve the costs of installing watertight measures against traditional CIPP measures. Although promising 'flooding process' don't work efficiently everywhere and we believe a combination of measures will be required.
- Integral to this case we be enhanced asset health monitoring and analyse. Potential benefits to the long term resilience and extension of hydraulic capacity asset life will be shared and reported. We will work with the industry to develop appropriate lagging and leading measures to monitor performance and establish a better view of risk in all our collection system.
- We will update and publish our data as a minimum in regular updates of the Infiltration Reduction Plans. We will be open and transparent with tour data, and use it to build trust and show accountability to customers and communities. Partnership such as the Pan parish is a fundamentally part of our approach

As part of our case, we have set out the mechanism whereby we undertake the sewer sealing work incrementally, allowing for checking of effectiveness at each stage before proceeding further.

This investment does not pass the materiality threshold for a Price Control Deliverable. However, we have an ambitious and stretching target to reduce pollution incidents, this investment when considered in the round with our investments in Storm overflows will enable us deliver on our target by reducing the risk of "dry day" discharges which lead to pollution incidents due to groundwater infiltration .. Sewer infiltration is directly linked to prolonged wet weather conditions which cause a prolonged rise in groundwater levels. These events are variable in level and duration and are difficult to predict, though data shows they are becoming more frequent. It is difficult therefore to state with accuracy the absolute benefit to be delivered by a sewer sealing programme in terms of impacts such as pollution or flooding incidents prevented.

However, from our experience it is anticipated that there will be improvement in the following areas. We will monitor the performance of the sewerage systems on completion of this work to fully quantify the benefits delivered and would expect to see the infiltration plans “retired” as the need for active control is no longer required:

- Category 3 pollution incidents
- External sewer flooding
- Customer complaints associated with the tankering, overpumping and restricted toilet use
- Reactive Operational costs associated with the management of groundwater in sewers including pumping and treatment costs.

In terms of our performance against pollution and flooding incidents, this investment is part of a suite of interventions associated with reducing the risk and incidence of such events. The other interventions being addressed by risk-based capital maintenance of sewers, rising mains and pumping stations and wastewater treatment works. Non-delivery of this enhancement spend will likely impact to some degree these performance commitments and therefore will contribute to penalty payments if we do not deliver as our forecasts are on the assumption we deliver this program. Therefore, given the materiality of this case and the impact on other performance commitments we are not proposing a price control deliverable.

We propose that the annual return of sewer length data is expanded to include the length of sewer made watertight by this sewer and manhole sealing programme, in addition to the current reports of sewers rehabilitated and replaced.

In addition, to ensure that we are not using enhancement funding to rectify existing structural issues, which should be undertaken as part of our existing capital maintenance budgets, we will utilise CCTV at all public sewers in the system risk zones prior to lining. Any structural defects identified (i.e., structural grade 4 and 5) will be rectified and funded by Base Investment and not through this EC.

6. Conclusion

Section	Key Commentary	Page
Introduction & Background	The infiltration of groundwater into sewerage systems does occur where sewers are laid in areas where the geology results in a fluctuating near surface groundwater table. This has the greatest impact in sewer systems which are predominantly foul by design. Under normal conditions, sewer design and service measures do not require watertight sewerage systems. The need is aligned with the DWMP planning objectives associated with flooding, storm overflows and WTW compliance. The actions are consistent with those stated in the 18 Infiltration Reductions plans written in response to the EA Regulatory Position Statement. To ensure effectual drainage in dry weather the inflow from infiltrating groundwater must be minimised.	5
Need for Enhancement Investment	Infiltration causes pollution and flooding issues and results in high customer and environmentally impacting operational mitigation and water management activity. The instance of high groundwater events is increasing due to climate change. To achieve this our systems must be watertight which is above and beyond the design standard for sewerage systems.	14
Best Option for Customers	A range of interventions is recommended to address the infiltrating sewer issue with priority being to return the system to a foul only watertight system.	17
Cost Efficiency	This chapter provides detail on how we have developed our options and the associated costs for our AMP 8 Groundwater Infiltration Resilience schemes by applying our standard Cost Estimation and Optioneering approaches to ensure they are based on robust cost-evidence and represent efficient delivery for our customers.	27
Customer Protection	Due to the annual variability of groundwater it is recommended that the delivery of the enhancement case is reported as additional lines in the annual OCF report on sewer lengths. A PCD is not required as the case is below the materiality threshold. However, where groundwater in sewers impacts system performance in relation to flooding and pollution ODI's, penalty payments will be applied.	30

References

[1] Sewers for Adoption 6th Edition (WRc, 2006), which is based upon BS EN 1610 “Construction and testing of drains and sewers”. This is shown in the following equation:
Acceptable infiltration (l/d) = 24 x D x L
D = Internal diameter of pipe (m)
L = Length of section under test (m)

[2] Sewer Rehabilitation Manual, 4th Edition, Volume I, Appendix A, Page A/8. – https://srm.wrcplc.co.uk/Secure/Login.aspx?returnurl=%2fDefault.aspx

[3] In extreme groundwater events the under the terms of an IRP the Environment Agency will agree to the installation of temporary pumps within the network. These pumps lift flows form the collection system and discharge directly to a stream or river. Before discharge, primary and UV treatment is provided. The use of this procedure protects customer but can operate for weeks at a time.

[4] Domestic flow PDwelling x G G = per capita domestic flow (l/hd/d) - assumed to be 200 l/h/d. PDwelling Assumed occupancy rate per dwelling – assumed to be 3 population per dwelling. Domestic flow is subject to daily (diurnal) variation. Typically a maximum observed variation in domestic flow is between 2 and 3 x average domestic flow.

[5] Dry Weather Flow = PG + IDWF + E Where: DWF = total dry weather flow (l/d), P = catchment population (number), G = per capita domestic flow (l/hd/d), IDWF = dry weather infiltration (l/d) and E = trade effluent flow (l/d). PG (domestic flow) is subject to daily (diurnal) variation. DWF may vary seasonally due to changing levels of sewer infiltration and population numbers.

[6] The flow in a combined sewerage system will increase when it rains.

[7] The Environment Agency’s (EA) Regulatory Position Statement (RPS) requires Water and Sewerage Companies (WaSC), which are aware of sewerage systems in their area vulnerable to groundwater infiltration, to submit Infiltration Reduction Plans (IRPs) to the EA for approval.

[8] Ground water is typically significant colder than domestic flows, in sewer temperature meters can detect when groundwater inflows to inform installation of watertight sealing measures.

[9] The Pan Parish Forum has been formed by seven parishes, all of which sit on the western edge of Andover, Hampshire, draining to the Fullerton treatment works and are covered by the Pan Parish IRP Microsoft Word - Pan Parish IRP v5.4 AA (southernwater.co.uk).

[10] Parishes include Kimpton, Fyfield, Thruxton, Monxton, Amport, Quarley, Abbots Ann, Upper Clatford

[11] https://standards-board.water.org.uk/document/wis-4-34-06-issue-3-specification-for-localised-sewer-repairs-using-cured-in-place-systems-with-or-without-re-rounding/

[12] See SRN03 Customer Acceptability Chapter for more information on the research programmes

[13] See SRN03 Customer Acceptability Chapter for details on Environmental Ambition Research

[14] SRN15 Cost and Option Methodology Technical Annex

Appendices

Majority of the appendices have been embedded within the document. For appendix 1, there is a direct link to the document and Appendix 2 has also been inserted in subsequent pages.

1	Link to Published Infiltration Reductions Plans (Infiltration reduction plan Actions (southernwater.co.uk)
2	EA Regulatory Position Statement
3	Sewers for Adoption
4	Storm Overflow Committee Report
5	UKCIP 2018 report
6	Pan Parish Pilot infiltration scheme
7	Link to Water Co. Annual Performance Reports
8	Pan Parish sewer sealing assessment
9	Rates for sewer lining

Appendix 1 – Link to Published Infiltration Reductions Plans

(Infiltration reduction plan Actions (southernwater.co.uk)

Appendix 2 – EA Regulatory Position Statement

Environment Agency

Regulatory Position Statement

Discharges made from Groundwater Surcharged Sewers

If you comply with the requirements below the Environment Agency will take no further enforcement action where groundwater induced infiltration leads to unavoidable discharges being made in accordance with the approved Infiltration Reduction Plan.

Background

1.1 On occasions temporary discharges have been used by Water and Sewerage Companies (WaSCs) to relieve pressure on sewers and ensure the continued efficiency and operation of household drainage facilities. These occasions are when sewerage systems become inundated by groundwater entering sewers (infiltration). While such occasions may be infrequent at a national scale it is recognised there are localities where groundwater levels (resulting from the nature of the underlying geology (e.g. chalk areas) or connectivity to fluvial flooding) means temporary discharges have been more frequently used.

1.2 Groundwater infiltration into drains and sewers generally occurs through cracks and faults in the pipe fabric. (In this RPS we will refer to sewers and drains generically as "sewers") These may develop as sewers deteriorate over time. Whilst sewers are generally designed with sufficient capacity to deal with moderate quantities of infiltration as well as sewage, in catchments where the water table rises above the level of the sewer, any cracks can admit substantial quantities of groundwater. The result can be loss of service to customers and in extreme cases sewers can overflow flooding land or property and impact on watercourses.

1.3 In the past we have generally acknowledged the need for such temporary discharges to watercourses in the short to medium term while the problems are investigated and resolved. We had recognised these temporary discharges using regulatory controls such as temporary consents. However, under the Environmental Permitting (England and Wales) Regulations 2010 (EPR) it is an offence to discharge sewage effluent to surface waters without a permit. Water and Sewerage Companies have therefore sought to permit these activities.

1.4 We consider it inappropriate to permit discharges necessitated by groundwater infiltration due to the requirements of Annex 1A of the Urban Waste Water Treatment Directive (91/271/EEC) (UWWTD). This requires leaks in the collecting system to be prevented using "best technical knowledge not entailing excessive cost". (BTKNEEC). We consider that where leakage is sufficient to cause flooding, or cause storm overflows to operate, it has not been prevented using BTKNEEC.

1.5 This regulatory position statement therefore outlines our position on issues related to groundwater infiltration and sets out how we will regulate discharges to relieve pressures on sewers following groundwater infiltration. Using this approach we will seek to minimise groundwater infiltration so that both sewer flooding (resulting from groundwater infiltration to sewer) and the need for pumping out of sewers to watercourses is removed. We are not seeking the complete elimination of groundwater infiltration.

The Environment Agency's Position

2.1 We will not support any acceptance of continued, long-term, groundwater infiltration into sewers where the infiltration may result in the need for pumping out of sewers into watercourses. We believe that:

- Chronically leaking sewers do not comply with the UWWTD Annex 1A requirement to prevent leaks in the collecting system using BTKNEEC.
- Where cracks in sewers permit groundwater infiltration these cracks may also, in dry conditions, enable sewage to leak from the sewer and pollute groundwater. This constitutes an un-permitted "groundwater activity" under EPR which is an offence.

We seek to minimise groundwater infiltration, rather than complete elimination, so that the need for pumping out of sewers to watercourses is removed.

2.2 Where WaSCs are aware of sewerage systems within their area that are vulnerable to groundwater infiltration and:

i. have a history of overflows being used to relieve pressure on sewers, or

ii. where the WaSC believes there is a risk of an overflow being required to relieve pressure on sewers the WaSC will notify the Environment Agency of these risks as soon as reasonably practicable and submit to the Environment Agency for approval an appropriate "Infiltration Reduction Plan" within 6 months of the first notification of risks.

2.3 The Infiltration Reduction Plan should include as a minimum:

i. Description and quantification of the pressures and likely consequences (if no action is taken) of the effects of groundwater infiltration in the catchment. Details (e.g. sewer flooding, CSO discharges, inability to effectually drain) and locations of infiltration and of the likely impacts.

ii. Outline plans and timescales (milestones) to investigate source and severity of the infiltration problems.

iii. Details of anticipated unavoidable discharges (resulting from groundwater infiltration) indicating their location and the circumstances under which they will need to be made.

iv. Details of the proposed discharges such as screening that will be in place and maximum discharge rates etc.

v. Presentation of potential actions (options) that could be considered to resolve/minimise the infiltration and remove the need for discharges. Once the investigations into the infiltration are complete a confirmed plan of actions with milestones will need to be produced.

vi. A review date.

2.4 Discharges will generally include those made to avoid danger to health and those made to maintain sewerage services to customers. It may also include those made to protect critical infrastructure.

The Environment Agency expects that before controlled discharges are made, the WaSC should:

a) take all reasonable steps to prevent discharges and only make a controlled discharge if there are no reasonable alternatives (that is discharges are unavoidable).
b) if discharges can't be prevented, take all reasonable steps to minimise the volume and duration of discharges.
c) use screening and other mitigation measures to reduce impact.
d) inform the Environment Agency (by logging through the Agency's National Incident Communication Service and through informing a local

contact as detailed in the Infiltration Reduction Plan) and affected public when discharges are starting (through messages agreed and documented in the Infiltration Reduction Plan, such as signage and informing for example the Parish Council).

e) monitor the quality of the downstream watercourse in consultation with the Environment Agency as agreed in the Infiltration Reduction Plan (for example this could include; daily monitoring of upstream and downstream and of the discharge for ammonia, solids and bacterial quality, as determined by river amenity / use / quality).

The above points should be covered within the Infiltration Reduction Plan, agreed with the Environment Agency.

We would not expect the impact from the proposed discharges to exceed a category 3 incident to water, as determined by Environment Agency Officers in accordance with our Common Incident Classification System. Discharges that are anticipated or subsequently found to exceed this will either need appropriate treatment to prevent significant pollution or be excluded from being covered by this RPS. Following any unforeseen pollution incident the discharge/s will cease to be covered by this RPS. The Infiltration Reduction Plan (IRP) will need to be resubmitted and re-approved before it can apply again.

2.5 Infiltration Reduction Plans may be discharge location specific or cover a number of discharge locations within a single sewerage catchment.

2.6 The Infiltration Reduction Plan's objective will be to eliminate discharges to the environment resulting from groundwater infiltration. These plans may include direct action by the WaSC as well as liaison with the Local Authorities, members of the public, and others with a role to play in helping resolve the issues. The plans will detail the proposed actions and timescales.

2.7 We recognise investigations take time and responsibilities are complex. Solutions may be costly and technically challenging and may need to be collaborative. The effectiveness of solutions may be uncertain and solutions may therefore need to be iterative. We expect solutions to reduce the leakage and avoid the need for a discharge, may only succeed over the medium to longer term.

2.8 We will hold WaSCs responsible for the discharges they make even where the infiltration is due to inadequacies in drains or sewers not under their ownership. We expect them to use their powers and influence to affect a solution.

2.9 We will require agreement over the monitoring and reporting of any discharges and their impact on the environment. These will be specified in the approved plan.

2.10 We will not approve the Infiltration Reduction Plan if we believe it does not result in satisfactory progress towards the elimination of overflow discharges resulting from groundwater infiltration. Where we fail to approve the Infiltration Reduction Plans we expect WaSCs to submit an updated plan for approval within a month.

2.11 We require progress against the approved Infiltration Reduction Plan to be reported on a quarterly basis (or by other agreement with Environment Agency) by the WaSC.

Enforcement

3.1 We will take the following into consideration when considering enforcement action against WaSCs over these discharges:

i. that an Infiltration Reduction Plan has been approved,

ii. that the discharges are detailed within the Infiltration Reduction Plan,

iii. that the approved plan is being followed, including the meeting of agreed milestones, and

iv. that the activity has not caused pollution to the environment or harm to health.

Provided the criteria above are met we will not normally take enforcement action unless the discharge exceeds a category 3 incident (as categorised under the current version of the Environment Agency's Common Incident Classification system) to receiving waters. For a more detailed explanation of this enforcement position, please refer to our Enforcement and Sanctions Statement. This document can be found on Gov.UK website.

3.2 We acknowledge that progress against the plan's schedule of actions depends on the provision of funding. By clarifying our approach in this Regulatory Position Statement to WaSCs, Ofwat and Defra we hope this helps clarify funding routes for the necessary work.

3.3 Progress also depends on the collaboration of others. This Regulatory Position Statement is a signal to LLFAs (local authorities and others) that they have a responsibility to cooperate in resolving the groundwater infiltration problems.

This regulatory position will be reviewed after two years.

Version: 3

Issued: December 2016

Appendix 3 – WRC Sewers for Adoption

Appendix 4 – extract from 1970 SOC report

CHAPTER 9. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

324. We submitted our Interim Report in 1963 with considerable diffidence. Our investigations were incomplete, but we believed that, because practical decisions have continually to be made and cannot be easily altered for a number of years, it was better that they be made with inadequate guidance than with none at all.

325. Since the Interim Report was published, we have completed the special studies listed in Chapter 1 and this has enhanced our knowledge on some aspects of the problem. Nevertheless, these studies have shown that it will be a long time before some of the more important questions can be answered. The subject is a complex one and, although there is much evidence available on certain aspects, we are conscious of the fact that some of the advice we give is based on collective opinion rather than on established fact.

326. We do not think our final report is inconsistent with the Interim Report, but naturally it supersedes it.

327. It is appropriate at this point to review briefly the ground we have covered in the Report and to pick out some of the more important points that have emerged.

328. We began with a brief historical review of the events which led to the need for storm overflows and to the development of present-day practice, and we described how difficulties had arisen, leading to the appointment of the Committee.

329. In Chapter 2, we discussed the question of completely separating all surface water from existing combined and partially-separate sewerage systems, and from the information which we had been able to assemble, we concluded that, however desirable it might be, the complete separation of surface water from existing combined and partially-separate sewers would not be economically practicable. We suggested that the best that could be achieved would be separation of surface water as opportunities occurred, for example, when re-development schemes were carried out.

330. We went on to describe our survey of existing storm overflows which was an attempt to assess the magnitude of the problem as seen by the river boards, and this produced valuable information about the types of overflow in use and the extent to which they were, in the opinion of the river boards, satisfactory or otherwise. We felt that this information was particularly useful because, in the end, the river boards (now river authorities) have the duty to control storm-overflow discharges in their areas. This survey showed that there were special problems of closely-spaced overflows in some of the bigger towns but, apart from these, more than 80 per cent of storm overflows having the traditional setting of 6 DWF or higher were considered satisfactory. It was also evident that a worthwhile improvement would result if the discharge of gross solids were better controlled.

331. In Chapter 3, we described our field investigations on the flow and composition of storm sewage. The first part of the chapter was concerned with examination of flow variations in dry and wet weather at three sites, and showed how the duration and frequency of operation of an overflow, and the volume discharged, were related to overflow setting. Reasonably consistent results indicated the possibility of predicting the duration and volume of discharges from other overflows in comparable areas. Next, the factors which influence the strength of storm sewage were examined, and an assessment was made of the polluting load discharged and of how this might vary with overflow setting. Finally, we considered the provision of storage tanks at storm overflows, and showed how the benefit from this could be equivalent to that from a substantial increase in the setting.

332. Chapters 4 and 5 dealt with laboratory-scale and field-scale experiments on models of different types of storm overflow. Both series of experiments provided information which enabled us to compare the performance of some widely-used types. We found that, once the screenable material had been removed, there was little difference in the composition of the sewage flow passed to treatment and the storm-sewage flow, thus indicating that the impurities were not amenable to separation by hydraulic devices. The experiments suggested that the provision of storage at or downstream of the overflow was the most effective way of reducing total polluting load discharged as storm sewage, for any fixed setting.

333. Chapter 6 dealt with the setting of storm overflows, and we began by pointing out the shortcomings of the present practice of defining the setting in terms of a multiple of the dry-weather flow. We concluded that this practice would have to be changed. It seemed to us that the right way of expressing the setting would be in the form of the sum rather than the product of two terms. One of these terms would be the dry-weather flow and the other would be a term defining the amount of run-off to be retained in the sewer before overflowing started.

334. We then looked at our survey of existing overflows and the opinions of the river boards on these overflows, and we came to the conclusion that there was a case for a modest improvement on the traditional practice, but no justification, in the general case, for a radical improvement. This led to our suggesting that, taking account of likely increases in future water consumption, a desirable and modest improvement would be achieved by permitting a surface-water run-off equivalent to 300 g.h.d. to be retained in the sewer before discharge of storm sewage commenced, with an additional allowance to provide dilution for industrial effluent in the sewage.

335. The formula thus derived had the merit of simplicity, but we were conscious of the fact that

69

it was not scientifically derived and did not take account of many of the factors that influence storm-sewage discharge and its effects. We therefore turned to the experimental work described in Chapter 3. There were some formulae developed from that work which, we thought, might lead to better account being taken of the various relevant factors.

336. We discussed these formulae at great length and concluded that, at the present time, we could not justify their use in preference to the more simple formula based mainly upon the evidence of the survey. We thought, however, that the merits of the formulae developed in Chapter 3 ought to be tested by applying them to cases where the simpler formula was to be applied.

337. In Chapter 7, we discussed the design of overflows and gave our views on some of the more important considerations such as flow control and control of the discharge of gross solids. We also discussed the provision of storage based upon the evidence of the experimental work described in Chapter 3.

338. Chapter 8 dealt with storm tanks and we first described field investigations carried out on storm tanks at two sites. These studies, together with other evidence, led us to conclude that the capacity provided by the traditional design was generally adequate, and that there was no pressing need for improvements in overflow settings to be accompanied by increases in storm-tank capacity. We then went on to show that the traditional design basis, despite the adequate results it had provided in the past, was not, however compatible with our recommendation for overflow settings, and we therefore suggested a new design approach for use in the future.

Conclusions and recommendations

339. As a result of the investigations which have been made at our request, and the information we have gathered from various sources, we know a great deal more about storm overflows and their properties, behaviour and effects than we knew before. Even now, however, knowledge on some aspects of the subject is still scanty, for reasons which have been explained. Given the necessary facilities, staff and resources many of the gaps in our knowledge could eventually be filled, but it would take a long time to do so.

340. We would have liked the support of more established facts for most of our conclusions, and we realise that some of them depend more than they should on assumptions and opinions which, though they seem reasonable, could eventually be proved inaccurate to a greater or lesser extent. This is the reason why our recommendations are not as precise as many would wish them to be, and why we hope that research to obtain further information will in due course be carried out.

341. Storm overflows are only necessary when the sewerage system is combined or partially-separate. We estimate that, at the time of the I.S.P. survey (Table 1), there were some 36 million people in England and Wales (about 76 per cent of the total population) living in areas so sewered. (Paras. 30–32.)

342. In recent years there has been a marked tendency to adopt the separate system for new developments. We do not disapprove of this trend (whether or not it can be demonstrated that it is always worth the cost) and we think that it would be generally undesirable to adopt a policy which resulted in the construction of new sewerage systems with storm overflows. In pursuing a policy of separate-system sewerage, however, it should be borne in mind that there will be areas from which the flow of surface water is likely to be of a highly polluting character because of the activities (largely industrial) carried on in those areas. It would clearly be wise in those cases to discharge such surface water to the foul-sewerage system, and appropriate allowance should be made in the design of the system for the surface water to be taken into it. (Paras. 33–38.)

343. It would be unrealistic to contemplate eliminating, over the next few decades, all storm overflows, either by enlarging the sewer capacity or by providing separate sewers for the surface water. The cost of any such project would be prohibitive. However, the opportunity might be taken in re-development schemes to separate surface water in whole or in part. (Paras. 39–42.)

344. Our survey indicated that there are between 10 000 and 12 000 storm overflows in England and Wales and that some 37 per cent of these are unsatisfactory either in themselves or in association with others. Of those which were reported to be set at 6 DWF or higher and which could be assessed individually by their observable effect, only about 18 per cent were classed as unsatisfactory and this figure would have been reduced to about 14 per cent had efficient means of retaining gross solids been provided. Such figures do not establish a general need for any radical improvement in the normal overflow settings; in fact they indicate that much of the trouble arises from those overflows set lower than the hitherto traditional setting of 6 DWF. (Paras. 50–58.)

345. We think that there are generally too many storm overflows and that sewerage authorities could, with advantage, examine their systems with a view to using overflows and sewer capacity to the optimum extent. We believe that there should be close co-operation between sewerage authorities and river authorities in the study of this aspect and in the planning of remedial measures. (Paras. 58–60.)

346. We consider that the custom of expressing the setting as a multiple of the dry-weather flow is basically unsatisfactory. It is better to use the sum (rather than the product) of two terms, one being the dry-weather flow and the other the amount of surface water to be retained in the sewer before overflow commences. (Paras. 204–205.)

347. The results of the experimental work described in Chapter 3 make it possible, when combined with assumptions concerned with typicality, aims and some factors which have not been specifically studied, to derive formulae from which figures for the second of

70

the two terms can be calculated. We would like to see some experience in the use of these formulae with some comparative studies of the behaviour of overflows so set, in order to ascertain whether they adequately take into account the main factors affecting storm-sewage flows and their effect on receiving streams. Such studies would certainly take several years; meanwhile we cannot recommend such formulae for general adoption. (Paras. 223–245, 249–254; *Formulae B* and *C*.)

348. The formula we recommend for the normal case is an empirical one, but it is more readily comparable with the traditional one and is easily seen to be an improvement upon it in form. Where the existing dry-weather flow (sewage and infiltration) is high, the new formula may give results very little different from the old. Where the existing dry-weather flow is low, the new formula will mean an increase in the setting. On average, it corresponds with what we have called a modest improvement, and this is what we think the situation calls for. The formula we recommend is:

Setting $(Q) = DWF + 300P + 2E$ gallons per day, *Formula A*, where

DWF is the dry-weather flow in gallons per day (the average daily rate in dry weather including infiltration water and industrial effluents) of the "combined" and/or "partially-separate" areas draining to the point of overflow,

P is the population of these areas, and

E is the volume of industrial effluent, in gallons, discharged to the sewer from these areas in 24 hours.

Where areas drained on the separate system discharge sewage to the combined and/or partially-separate system upstream of an overflow, the quantity passed to treatment as defined by the above formula should be increased by an amount equal to 3 DWF from the "separate" areas. (Paras. 206–219, 248–254, *Formula A*.)

349. We consider the formula suitable unless there are special circumstances, such as overflows into very small (or very large) streams, which might justify an increase (or reduction) in the figure of 300, or where there may be abnormal discharges of industrial effluent, calling for a variation in the term "$2E$", or where there is reason to believe that a bare allowance of 3 DWF from any connected "separate" area would be inappropriate. Any such departure from the normal value would need to be justified on the merits of the case. We would point out that the figure of 300 g.h.d., though, in our view, reasonably based, is a rounded-off figure and so we do not think that it would be possible to justify variations in it of less than, say, 50 in magnitude. (Paras. 220 and 221.)

350. Our survey showed that a very high proportion of individual overflows set according to previous standards were satisfactory, and there is no obvious reason why these should be altered. However, as the overflows come up for reappraisal, we hope the settings will be made to conform with what we recommend. (Para. 255.)

351. Of the overflow structures studied, the high side-weir and stilling pond preferentially retain gross solids in the sewer but not to any really worthwhile extent, and performance depends very much on rate of flow. With downstream control, they give accurate control of flow to treatment, which is highly desirable. The choice between these two types would sometimes be determined by practical site considerations. (Paras. 171–173, 175, 179, 188–193, 195, 197–203.)

352. The particular vortex overflows we studied have no advantage over the high side-weir and stilling pond, but we recognise that the geometry of the model vortex overflows might have been improved. (Paras. 171–173, 176, 188–193, 196, 198–203.)

353. The low side-weir is inefficient, particularly in respect of flow control, and we have no evidence to support its continued use. It is so inefficient in providing proper separation of flows that we think an early opportunity should be taken of improving existing overflows of this type. Merely to build up the sills so that they become high side-weirs could, in many cases, cause difficulties lower down the system. However, if coupled with downstream control, conversion to high side-weirs would be relatively cheap and altogether desirable, provided that it did not cause unacceptable conditions of surcharge upstream. (Paras. 171–174, 188–191, 194, 197, 200–203, 257, 258.)

354. If the discharge from a storm overflow can be delayed by providing storage capacity downstream of it, much of the very strong first flush can be retained in the sewer for ultimate treatment, without increasing the capacity of the downstream sewers or the treatment plant. Such storage capacity could take the form of separate storage tanks or an over-sized (tank) sewer between the orifice (or similar control) and the overflow. When conditions permit, we recommend that consideration be given to some such installation. We also think that where storage is provided, there is justification for modifying the normal overflow setting and although, with our present knowledge, we cannot be precise, it would be reasonable to suggest, as a rough guide, that the provision of a storage tank (or equivalent) of about 2 hours' DWF capacity at the overflow would justify reducing the figure of 300 in the recommended formula to about 200. (Paras. 152–155, 171–173, 177, 179, 201, 202, 269–281.)

355. Storm overflows (with the possible exception of the low side-weir) can generally be expected to perform more efficiently when the upstream sewer is laid at a sub-critical gradient. (Paras. 171–179.)

356. We consider that, wherever practicable, some form of hydraulic control should be incorporated as a part of all storm-overflow installations. This could take the form of an orifice or a length of throttle pipe that would control with some degree of accuracy the maximum rate of flow passed forward. The orifice throttle should be of such a size as to be free from danger of blockage. (Paras. 263–266.)

357. Although gross solids constitute only a small proportion of the polluting load, they are aesthetically objectionable and the practice of introducing scum-

71

boards to retain them is, at best, only partially successful. Where amenity considerations are of particular importance, we recommend that consideration be given to the use of purpose-made mechanically-raked screens. If hand-raked screens are installed, frequent inspections and maintenance are of the utmost importance. (Paras. 267 and 268.)

358. Our studies have led us to conclude that the storm-tank capacity normally provided in association with the traditional 6–DWF overflow setting is adequate and perhaps more than adequate. (Paras. 305–308.)

359. The adoption of our recommended new "norm" for overflow settings is likely to result, in many cases, in higher peak flows reaching the sewage treatment works with, in consequence, higher flows being passed through existing storm tanks. This could require additional storm-tank capacity, but we do not think it should be assumed automatically that this will be so. A reasonable case should be made before it is demanded. (Paras. 309–312.)

360. It is our view that the quantity of sewage given full treatment should remain, as at present, three times dry-weather flow as defined in paragraph 303. This means that, where our recommended formula for overflow settings is adopted, the quantity separated for partial treatment in storm tanks will not be a multiple of dry-weather flow as before. It will be dependent on the domestic sewage flow and will actually tend to get smaller as the domestic sewage flow increases (see para. 310). It is therefore clear that the traditional method of designing storm-tank capacity on the basis of "hours' DWF" is not compatible with what we recommend. We think it should be defined in "gallons per head" in the same way as we have defined the amount of surface water that will be carried to treatment downstream of an overflow. (Para. 313.)

361. For new works and for existing works where an increase in storm-tank capacity has been proved necessary, we recommend that capacity be provided equal to 15 gallons per head of the population of the "combined" and/or "partially-separate" areas draining to the treatment works. (Paras. 314–317.)

Future investigations

362. The research and studies we have instigated have assisted us in reaching our conclusions but have at the same time made us conscious of the gaps in our present knowledge.

363. We consider that there is an urgent need for a study to be made of the effect of intermittent discharges of storm sewage on streams. This is clearly within the province of the Water Pollution Research Laboratory and we would have asked them to do it early in our investigations, had it not been for difficulties which we have already described. In view of the importance of the subject, we think renewed attempts should be made to overcome these difficulties. The first task would be to select a suitable site, and no doubt river authorities could be relied upon to make known to the Laboratory, locations which might prove useful.

364. We also believe that information could be collected and further knowledge acquired on the subjects of storage and the control of the discharge of gross solids by the study of actual overflows. This would require the introduction of additional facilities (for sampling, metering, etc.) at suitable existing overflows, or when new ones were constructed. We think that this work would be best done under the aegis of the Ministry of Housing and Local Government, who, with their knowledge of schemes involving construction of storm overflows, should be able, with the co-operation of local authorities, to select the most suitable sites, arrange for the necessary additional works, and co-ordinate the subsequent studies.

365. Similarly, the Ministry could, we think, take the initiative in arranging for information on storm-tank operation, which is obtained already by some authorities, to be collated in a form which would facilitate statistical analysis and direct comparison. This would in all probability bring to light generalisations on storm-sewage composition and storm-tank performance which could ultimately provide a sound basis for improved practice.

366. We do not recommend that special research be undertaken on the design of storm tanks. In so far as their purpose is storage, design details are irrelevant; in so far as their purpose is sedimentation, the design requirements are little different from those of ordinary sedimentation tanks and do not justify separate investigation.

367. It will be several years before the results of the above work are available and the practical effects of our recommendations can be observed on any reasonably large scale, and so we do not think that there would be any merit in reviewing the situation within, say, the next five or seven years. At some stage after that, however, it could well be that the situation would merit re-consideration by a representative committee.

Acknowledgments

368. In our work we have been privileged to receive most willing co-operation from many local authorities, from several river authorities (and their predecessors), from research laboratories and from individuals. Advice and assistance on a wide range of subjects has been readily given, and we wish to express our thanks for it. It is impossible to mention all of the above by name, but we are particularly grateful to the Corporations and officers of the County Boroughs or Boroughs of Bradford, Northampton, Brighouse, Luton, Stoke-on-Trent and Royal Tunbridge Wells, who co-operated to the full in the extended field studies described in Chapters 3, 5 and 8.

369. The field work at Northampton, Brighouse and Bradford was carried out for us by the Water Pollution Research Laboratory. Each investigation occupied more than two years and was fraught with difficulties

Appendix 5 – UKCP 2018 Report

UKCP 2018 Report

Appendix 6 – Pan Parish Pathfinder Report

Pan Parish Pathfinder
Infiltration Investigation

June 2022
Version 1.0

WATER for LIFE

from Southern Water

Pan Parish Pathfinder
Infiltration Investigation

Contents

Pan Parish Pathfinder
Infiltration Investigation

Document history

Revision	Purpose	Originated	Checked	Reviewed	Authorised
V1.0	Issue	Ally Potts	Penny Green	Rob McTaggart	

Pan Parish Pathfinder
Infiltration Investigation

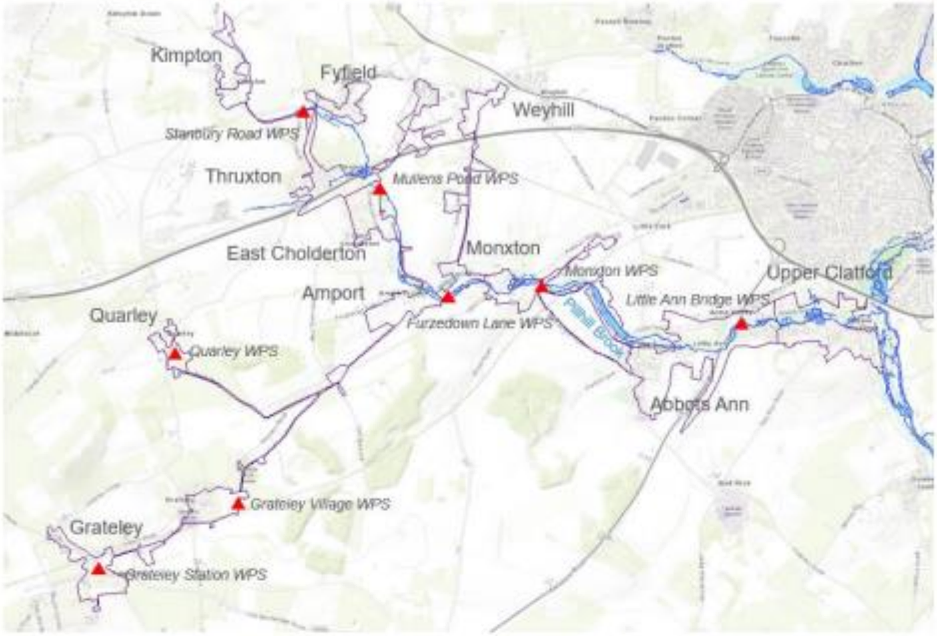
1. Introduction & Purpose

The Pan Parish Forum has been formed by seven parishes, all of which sit on the western edge of Andover, Hampshire, draining to the Fullerton wastewater treatment works. These are:

- Kimpton
- Fyfield
- Thruxton
- Monxton
- Amport
- Quarley
- Abbots Ann
- Upper Clatford

The sewer networks are linked by various pumping stations through the catchment. The area sits in a chalk aquifer region, so the sewer network regularly suffers from groundwater infiltration. In times of high groundwater, the pumping stations through the catchment cannot cope with the amount of infiltration, so Southern Water must send tankers to some of the pumping stations to take away the excess flow. In extreme conditions, it has been necessary to overpump to the nearby watercourse, the Pillhill Brook, to ensure that no flooding occurs.

Figure 1 Pan Parish area including pumping station locations



This report is an internal Southern Water Technical report that summarises: the investigations into why the infiltration may be occurring, the work Southern Water have been doing in the catchment, how effective it has been and sets out a potential plan to resolve the requirement for tankering and overpumping in the Pan Parish area.

2. State of the Drainage System

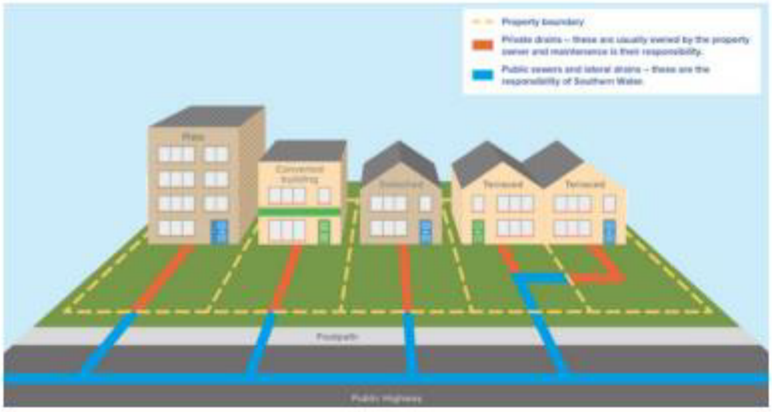
The Pan Parishes drainage system consists of a number of features. These are:

- Public sewers
- Public drains
- Private drains
- Land drains
- Highway drainage
- Pillhill Brook

All parts of the system are affected by groundwater levels at some stage of the groundwater cycle. The impacts of groundwater on the drainage system are depicted in the infographics in Appendix A.

Southern Water are responsible for the maintenance of the public sewers and the public drains within the catchment. This system is designed to transfer wastewater only and has not been sized to convey any land drainage or groundwater. The rest of the sewerage network is owned by the private landowners; the breakdown of ownership is detailed in Figure 2.

Figure 2 Sewerage Ownership



Southern Water have been actively managing their assets in this area, and prioritising and investigating pipes based on key risk factors, such as depth and proximity to the PillHill Brook. Historically, this investigation has been done using CCTV surveys. This has been the best method for identifying infiltration, but the timing of the surveys is key as it requires the groundwater to be high enough to start infiltrating into the sewer, but not so high that the pipe is inundated. Significant time and effort has gone into this, which has identified a large number of infiltration sources. Unfortunately, this type of survey cannot provide sufficient information to be confident that a pipe is not allowing infiltration into the network.

In total, almost 15km of sewers have been CCTV surveyed, some multiple times. This is 42% of the public sewer network, although in some parishes the coverage is more than 70%. This has led to 5.5km of pipe sealing.

More recently, [redacted] surveys have become an option to identifying structural defects in pipes. This is done by passing an electrode through the pipe and measuring the variation in electrical current through the wall of the pipe. Where the pipe is structurally sound, the electrical current that is received at ground level is low, but where there is a defect, a much higher current is recorded at ground level. The amount of current received at ground level gives an indication to the size of the defect identified. These have been done in the Parishes over the last two years and allow us to decide with more confidence whether any given pipe is watertight or requires intervention at the time of survey, independent of groundwater levels. Since using the electroscan technology, 9.2km of pipe have been surveyed in the Pan Parishes. This has been focussed in Kimpton, Fyfield, Thruxton, Monxton and Amport.

2.1. Watertightness

In the United States, research was done to devise a methodology for estimating the potential infiltration rate through a defect in a pipe. This research is used by the [redacted] contractors to allow them to estimate the potential for infiltration along each pipe that is scanned. The full details of the calculation methodology can be found in Appendix B. The calculation assumes that the groundwater is 308mm above the centreline of the pipe all the way along it, which is extremely unlikely, but in doing this it allows us to understand the potential for the system to suffer from infiltration. In a catchment like the Pan Parishes, where it is likely that the pipes are surrounded by groundwater regularly, it allows us to understand how many of the pipes are likely to be suffering from infiltration.

It is accepted in drainage design that some level of fresh water will make its way into the sewerage network, either through surface runoff, land drainage or infiltration, so modern systems are designed to allow for this ingress to be up to 40% of the foul flow. The network in the Pan Parishes will not have been designed to modern standards therefore, for the purposes of this study, we are basing an acceptable level of fresh water ingress as equivalent to the following: 40% of the total flow in the pipe, based on the number of houses connected to a pipe. Based on a common per capita consumption, or foul flow per head, rate of 150 litres/head/day, we are using 60 litres/head/day of infiltration as acceptable. If the infiltration rate quoted by the [redacted] results is less than this value, then the pipe can be classed as watertight and no work is required. The "40%" value of infiltration has been approximately converted into a flow rate per meter length of pipe, by comparing the length of public sewers in the Mullens Pond catchment to the population it serves. The "watertight" threshold has been plotted in Figure 3 along with the observed infiltration rates from the [redacted] surveys. This shows how most of the pipes do not meet the "watertight" threshold.

Figure 3 Comparison of observed [redacted] infiltrations vs theoretical watertight rate

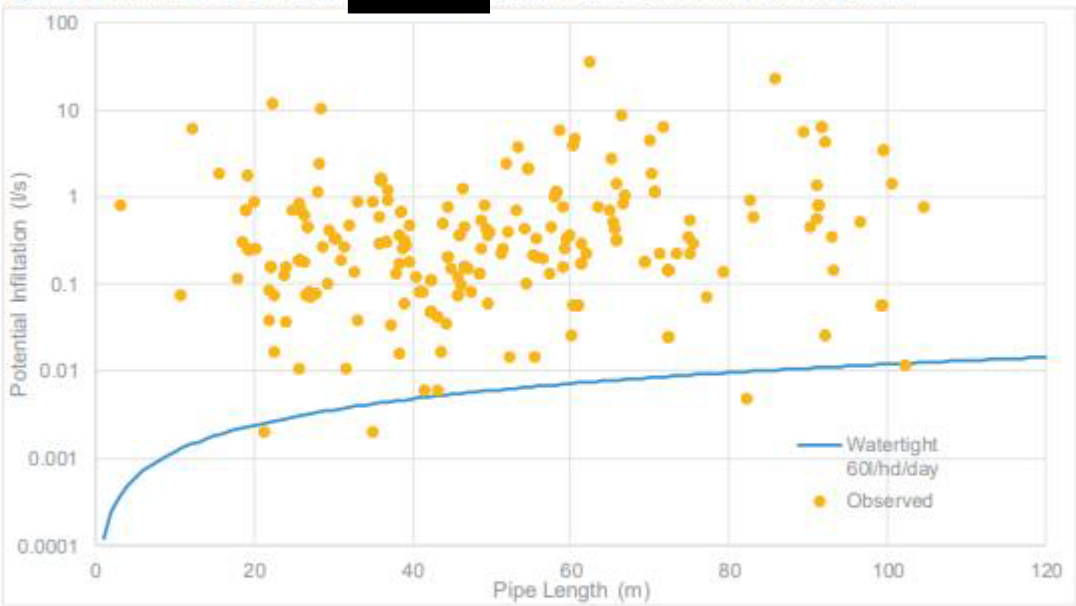


Figure 4 [redacted] survey results by area

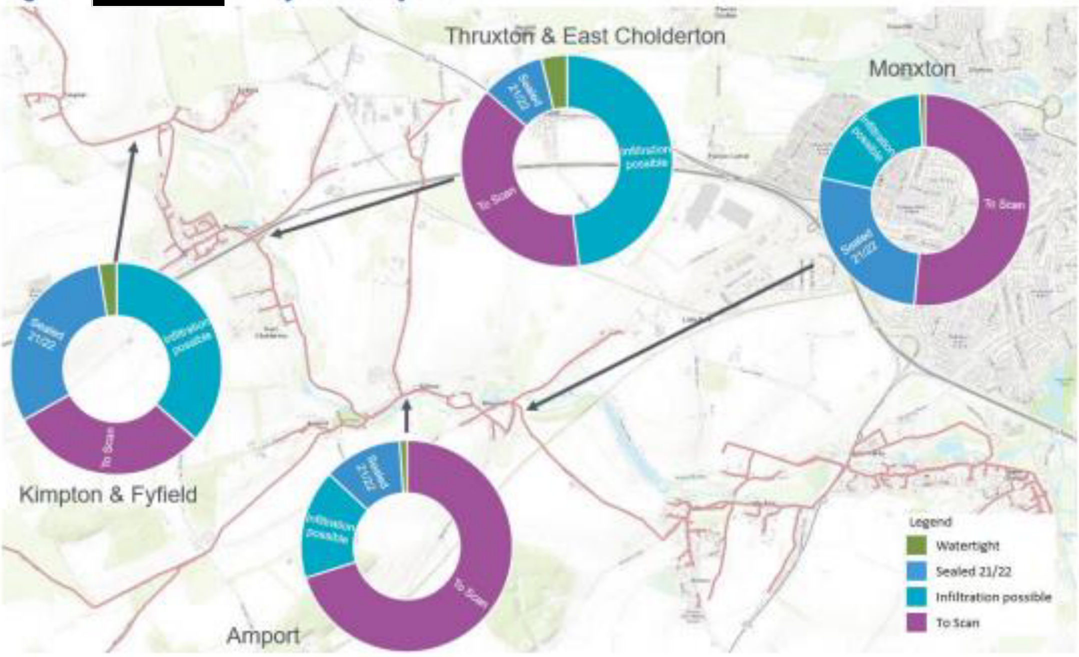


Figure 4 shows the proportion of the pipes in the different villages that have been scanned and then the findings of those scans. This shows that good progress has been made in the last two years, unfortunately only 15-25% of the scanned lengths have been found to be watertight. This indicates that more intensive scanning and sealing work would be required to ensure the public sewers are watertight.

Some of the [redacted] surveys were undertaken on pipes that had previously been sealed, to give a view on how well the sealing had worked and if any degradation could be identified. In total 1.35km of previously sealed pipes were scanned and unfortunately only 30% of these met the threshold for being "watertight". Some of the pipes had not had work done since 2008, so this degradation is understandable, but others had been sealed more recently, which implies the scans will need repeating regularly. Any future programme for rescanning and resealing may be needed to ensure the pipes remain watertight after their initial sealing.

2.2. Level

The potential for a pipe to suffer from infiltration, as quantified by the [redacted] is only one aspect that needs to be considered. There must also be groundwater surrounding the pipe for infiltration to occur. The deeper a pipe is below ground level, the more likely it is to be sitting within groundwater.

Figure 5 Relative pipe depths

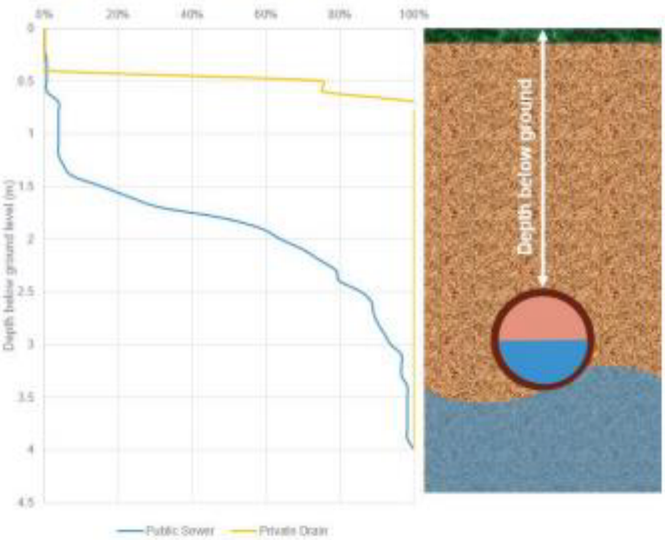


Figure 5 shows that the public assets tend to sit lower in the ground that the private assets. This demonstrates that the public assets are more likely to impacted by groundwater infiltration and that this will occur at lower groundwater levels. In extreme groundwater conditions, such as when tankering / over-pumping is required, the groundwater is likely to be up at the levels that it surrounds the private drains. This means the structural condition of these pipes is also important, although they are not being actively maintained or surveyed. At this time, surveys have not been carried out on the private drainage network as these are not within Southern Waters responsibility. Extrapolating the findings from the public sewer surveys, it is very likely that most of the private network will suffer from infiltration if the groundwater is sufficiently high; infiltration into private drains has been observed on site which reinforces this assumption.

3. Impact of Interventions

The current and future focus for the public sewers work in the area, is to be able to confirm their watertightness. As discussed in the previous section, there is still a significant amount of work to be done to ensure all public sewers are watertight, but it is important to understand how the historical interventions have impacted on the flow rates at points in the catchment. This has been done by analysing the pump run time data i.e. the number of minutes per day pumps are active, and the groundwater levels. The groundwater level data is taken from the Clanville Gate observation borehole, which is approximately 4.5km north east of the Pan Parishes. The groundwater levels are quoted in meters above ordinance datum, but due to the distance from the catchment, they are not directly comparable to the sewer levels in the Parishes. Therefore they can only be used as a guide to the groundwater levels in the catchment.

Figure 6 Mullens Pond Pump Run Time and Groundwater Level percentile curves

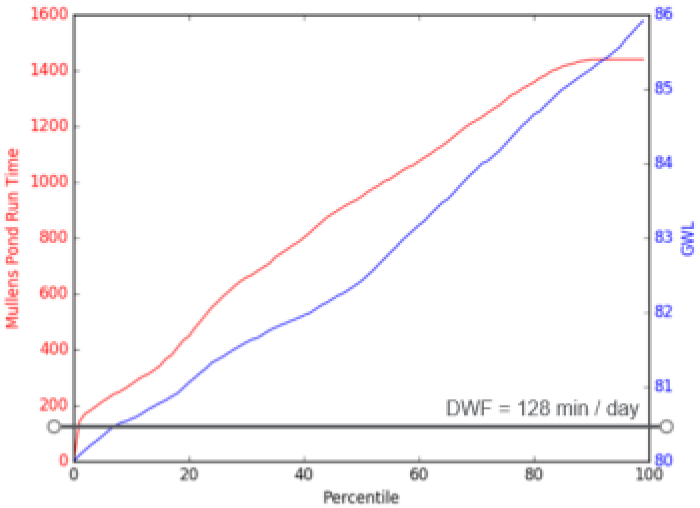
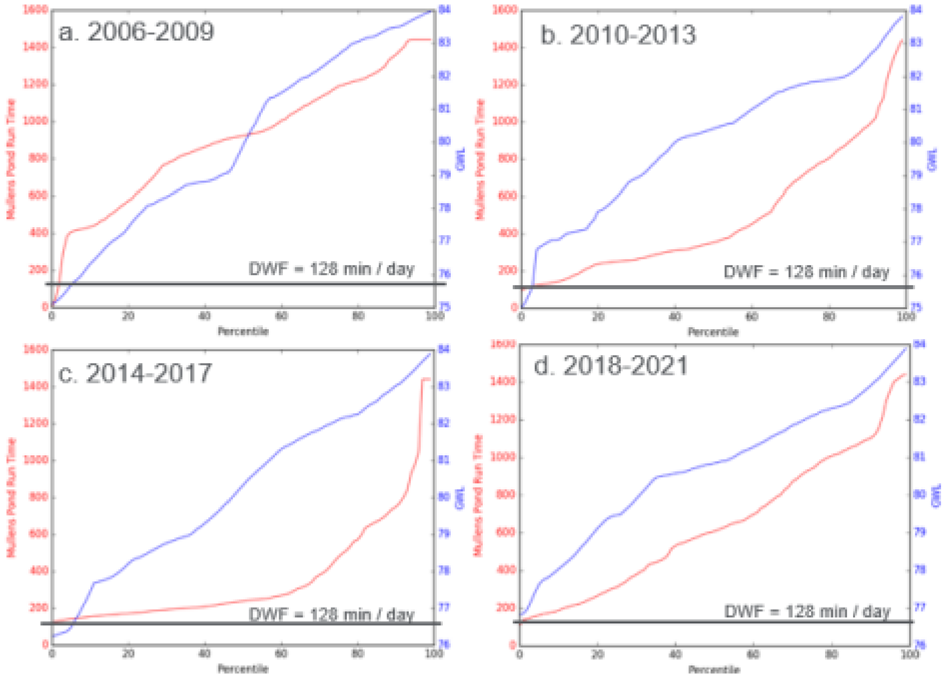


Figure 6 compares the exceedance percentiles i.e the percentage of the time a value is exceeded, of the pump run times at Mullens Pond WPS and the groundwater levels at Clanville Gate. If there were no infiltration or surface water inflow, the red line would be horizontal along the black line, showing the pumping station runs a consistent length of time each day. As it is, there is a strong correlation between pump run time and groundwater level, which implies there is interaction between the sewer network and the groundwater at all levels. Based on Figure 6, the volume of infiltration being transferred by the Mullens Pond WPS in a typical year is approximately 6 times greater than the volume of foul flow being transferred. Typically, infiltration would be expected to be 40% of the DWF, not 600%.

The data has been broken down into four-year blocks, to investigate whether there has been a change in performance due to the sealing of the public sewers.

Pan Parish Pathfinder
Infiltration Investigation

Figures 7a, b, c & d Pump run time at Groundwater levels below 84mAOD for four blocks of time

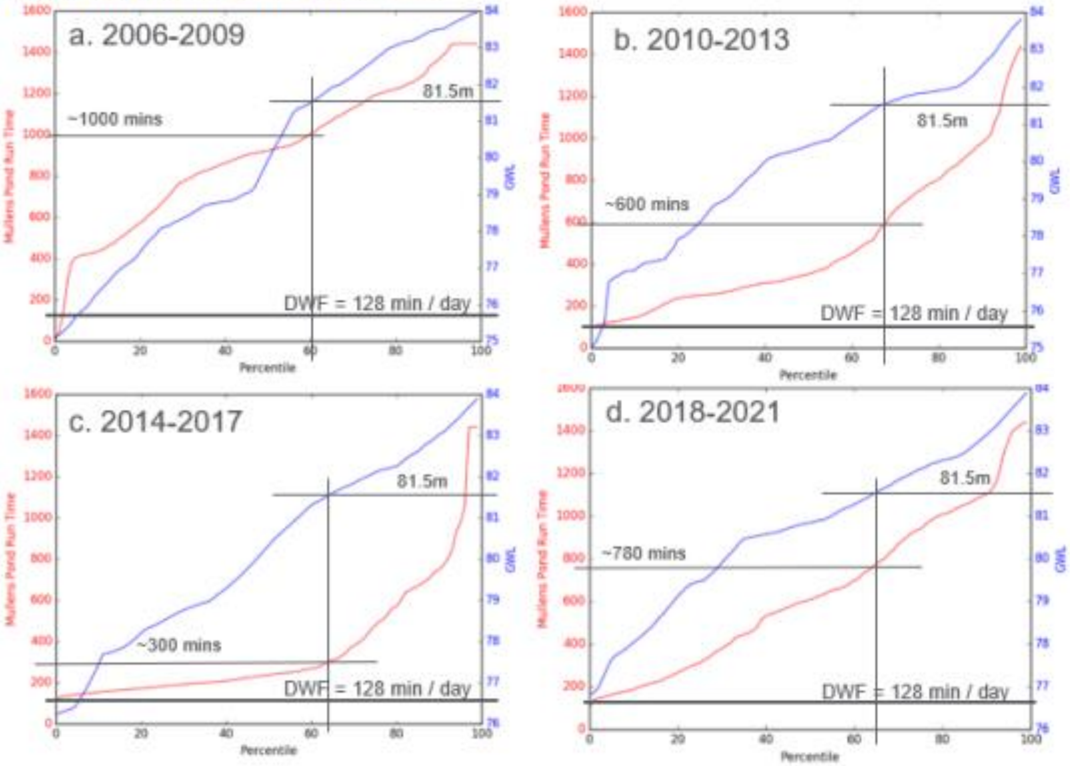


Figures 7a, b, c & d show how the sealing has impacted the pump run times at groundwater levels below 84mAOD i.e. where the public sewers sit. The red pump run time line stays much flatter at lower groundwater levels in the later time blocks. This indicates that the work done by Southern Water between 2006 and 2016 has reduced the infiltration at the regular groundwater levels, but when the groundwater moves into its more extreme states, the ingress is still significant. Unfortunately, Figures 7d shows an increase in inflow again at lower groundwater levels, although not back to the levels of 2006-2009. Most of the sealing work undertaken in the Mullens Pond WPS subcatchment was done between 2012 and 2014. This is reflected in the graphs, with the improvements showing in figure b, then to a greater extent in figure c. There was then very little sealing work between 2015 and 2020, so it suggests that regular work in the catchment is required to keep pipes watertight and the infiltration out, even at low groundwater levels.

The improvements can be quantified by estimating the reduction in pump run time at a given groundwater level. 8a-d are a repeat of Figures 7a-d, but this time showing the change of pump run times at 81.5mAOD.

Pan Parish Pathfinder
Infiltration Investigation

Figures 8a, b, c & d - Pump run time at Groundwater levels below 84mAOD for four blocks of time, highlighting pump run times at 81.5mAOD



These pump run time values can be converted into volumes transferred by the pumping station. Table 1 shows the changes in flows due to the sealing work undertaken in the catchment.

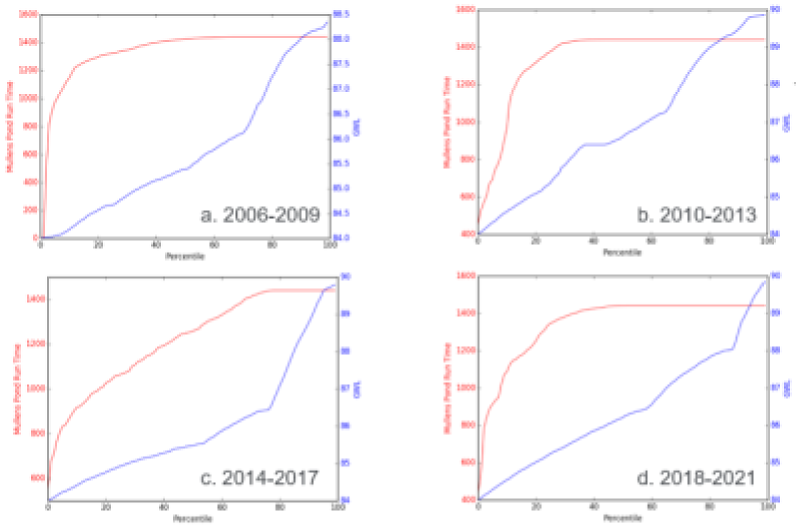
Table 1 Pump Run Times at Mullens Pond when GWL <84mAOD

	Pump Run Time @ 81.5mAOD (mins/day)	Volume (m³/day)	Infiltration as percentage of DWF	Sewage BOD concentration based on 60g/h/day (mg/l)
DWF	128	230.4	-	440
2006-2009	1000	1,800	681%	56
2010-2013	600	1,080	369%	94
2014-2017	300	540	134%	188
2018-2021	780	1,404	509%	72

Table 1 shows that the sealing work has had a marked improvement in the volume of flow being passed forward to treatment, although it should be noted that even at its lowest level, the infiltration flow was still higher than a typical catchment.

The increase in pump run times see in 2018-2021 indicates that some degradation in the network has occurred and not been resolved. Degradation is to be expected and if this pattern is to be avoided in the future, routine repeat electro scan work will be required to ensure any new defects can be sealed before they have a detrimental effect on performance.

Figures 9a, b, c & d Pump run times vs groundwater levels above 84mAOD



Looking at the higher groundwater levels, the graphs shown in Figures 9a-d show the pump run time (red) line is the opposite shape to those in Figures 8a-d. They are showing that generally 75% of the time when groundwater levels are above 84mAOD in Clanville Gate, the pumps at Mullens Pond are running continually, so tankering is likely. The concern is that where Figures 8b-d show a definite improvement due to the work done, Figures 9b-d are almost identical to a. Figures 9c does show a slight improvement as the initial gradient of the red line is flatter than the other three graphs, but this is not continued into the 2018-2021 graph, therefore not considered to be a trend.

The evidence in change of pump run time indicates that the work done by Southern Water has had a significant impact on the low level, everyday infiltration, reducing pump run times and carbon usage in pumping and treatment. Unfortunately, it has not had a noticeable impact on the service provided to customers during extreme groundwater conditions. The concern is that this may be due to the private drainage network, which becomes inundated during the high groundwater conditions.

The challenge in the catchment is that, while Southern Water are intending to make all their assets watertight, this may not be sufficient to resolve the problem and will require regular monitoring and intervention. It is likely the wider drainage network is accepting infiltration in extreme conditions, contributing to the contingency plan of tankering and emergency discharge that is impacting the local residents.

3.1. Conclusions of the analysis

The historical data analysis has provided further detail about the issues affecting the Parishes, these are:

- During the extreme groundwater conditions that cause tankering and / or overpumping from the pumping stations (GWL >84mAOD @ Clanville Gate), sealing the public sewer has little impact on the performance of the drainage network.

- The private drains suffer heavily from infiltration and contribute significantly to the tankering and overpumping
- Any sealing work undertaken needs to be reviewed / monitored regularly and repeated as appropriately.
- The Clanville Gate borehole is too remote to the catchment

4. Potential solutions & Costs

This section reviews the potential solutions to be considered for dealing with the groundwater infiltration in Pan Parish and the costs associated.

4.1. Option 1 - Sealing the System

4.1.1. Methodology

4.1.1.1. Traditional

The traditional methodology for sealing sewers is to install leak tight liners into the public sewers made either of epoxy or silicate-based resins. These are tested against 5m head of water and have a design life of at least 50 years. As a baseline, the proposed plan has been costed against this methodology as there is confidence in both the cost, the effectiveness and time requirements for installation. The manholes are sealed separately. This can be done by either spray lining the manhole from the inside, or stitch drilling and injecting a resin into the ground surrounding the manhole to make it watertight. These methodologies are well understood but are expensive.

The same methodology is also an option for the private drains. It will require the contractors to make just one visit to each property to identify, survey, seal and resurvey the assets. Care needs to be taken at the connection between the private drain and the public sewer, which is a weak point for watertightness. This part of the option cannot be costed with the same confidence as the work in the public sewers as the location and length of most of the private drains is unknown. An estimate of the pipe meterage per property has been made to allow an estimate in both time and programme to be made. Unfortunately, sealing every pipe is a time-consuming process. Every single length of pipe, both private and public will need to be sealed independently, meaning the man hours required to deliver this scope will be high.

This leak tight lining methodology would allow flexibility in programme as the private drains can be done at a separate time to the public sewer that it drains to. There are also numerous contractors comfortable in the technology and approach, therefore large numbers of crews could be deployed to deliver the scope quickly.

4.1.1.2. [redacted]

[redacted] technology is new to the UK, but it has been operating in Germany for the last 25 years. [redacted] consists of two silicate-based liquids that are installed by filling the network with each in turn, allowing the liquids to find and fill all the pipe defects, and once the second is pumped out, the pipe is sealed.

The benefits to this solution are that private drains can be sealed at the same time as the public sewer they drain to and that the joints at the connections are sealed as effectively as the rest of the pipe runs. An additional benefit as that, as the system is filled and monitored from the manholes at either end of the pipe run that is being sealed, the manholes are also sealed at minimal extra cost. This means that the length of time to seal the public and private network is likely to be much shorter, benefiting the programme and expected lower capital cost.

The downside to this approach is the lack of experience in the UK. Southern Water trialled this technology in three small pilot locations in 2021, but with the 21/22 winter being very dry, the pipes have not been challenged by high groundwater levels. These pipes have been scoped for an [redacted] survey to see if, after one year, there is any noticeable degradation. The limited experience means costing the scheme is difficult. While similar assumptions can be made on length of pipe per property, the exact layout of the private drainage system is much more critical, so additional survey work to identify and assess the condition of the private drainage is required before the exact details of how the tubogel can be implemented is understood.

4.1.2. Scope

The scale of the problem and the minimal benefit provided by the traditional targeted approach to infiltration, indicates that blanket sealing work, across both the public and private networks, is required to provide the best hope to reducing the current tankering and overpumping activities during future groundwater seasons. Across all the Pan Parishes, there are 4.8km of public sewers known to be susceptible to infiltration that have not yet been sealed and almost 25km of sewers that have not been surveyed. There are also more than 2,500 properties, most of which connect to the public sewerage network that are likely to be susceptible to infiltration. It is not realistic to be able to achieve all of this work before the next groundwater season, therefore different approaches will be taken in the different villages, given the perceived impact. Figure 10 and Figure 11 on the following pages explain the proposed plan of work. Note the numbers in the "Seal Everything" region depict the order in which the work will be done.

4.1.3. Costs

A baseline solution has been costed, based on traditional sealing methodologies, as per section **Error! Reference source not found.**.1. This has been used to then compare different methodologies and potential opportunities. **Error! Reference source not found.** breaks down the costs by village.

Table 2 Cost of option using traditional methodologies

	Kimpton	Fyfield	Thruxton	Weyhill	East Cholderton	Amport	Monxton	Quarley	Grateley	Abbotts Ann & Little Ann	Anna Valley & Upper Clatford	Total
Population	270.05	366.71	644.99	587.21	251.97	521.19	316.94	163.90	786.96	1,562.36	1,430.32	6,902.58
Sewer electroscan surveys	£ 2,623	£ 6,960	£ 4,351	£ 36,475	£ 5,242	£ 21,171	£ 10,880	£ -	£ -	£ 67,448	£ -	£ 155,150
Public sewer sealing	£ 163,921	£ 158,860	£ 459,985	£ -	£ 116,160	£ 177,343	£ 114,203	£ -	£ -	£ -	£ -	£ 1,190,472
Manhole sealing	£ 164,000	£ 104,000	£ 256,000	£ -	£ 44,000	£ 156,000	£ 104,000	£ -	£ -	£ -	£ -	£ 828,000
Drain sealing	£ 504,773	£ 721,778	£ 1,118,048	£ 4,718	£ 287,768	£ -	£ -	£ -	£ -	£ -	£ -	£ 2,637,083
Cost	£ 835,317	£ 991,598	£ 1,838,384	£ 41,192	£ 453,169	£ 354,513	£ 229,083	£ -	£ -	£ 67,448	£ -	£ 4,810,685
£/PE	£ 3,093.42	£ 2,704.04	£ 2,850.25	£ 70.15	£ 1,798.51	£ 680.20	£ 722.75	£ -	£ -	£ 43.17	£ -	£ 696.94

Costing of the [redacted] approach is still in process as providing an indicative cost is difficult without understanding the layout of the private drainage. At this stage, the only cost guideline is a statement from the

T

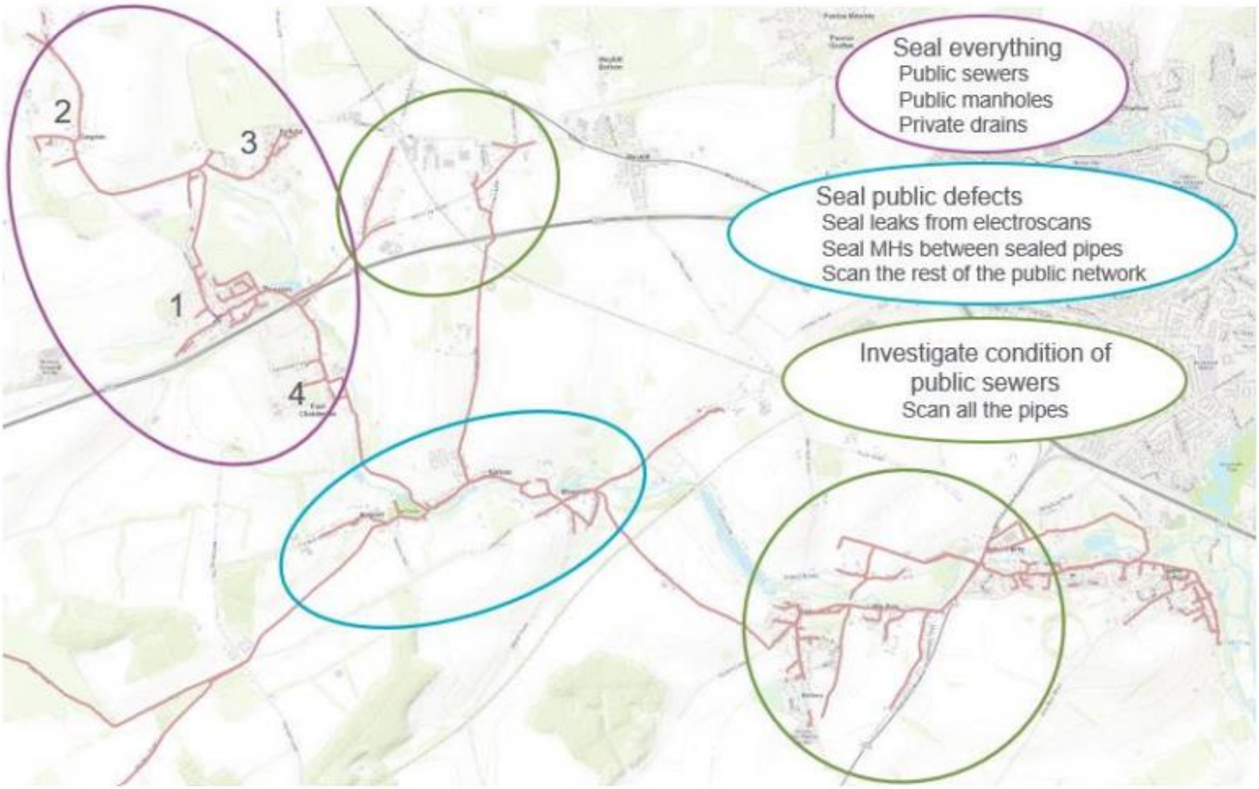
	Kimpton	Fyfield	Thruxton	Weyhill	East Cholderton	Amport	Monxton	Quarley	Grateley	Abbotts Ann & Little Ann	Anna Valley & Upper Clatford	Total
Population	270.03	366.71	644.99	587.21	251.97	521.19	316.94	163.90	786.96	1,562.36	1,430.32	6,902.58
Connectivity surveys	£ 14,063	£ 20,109	£ 31,149	£ 131	£ 8,017	£ -	£ -	£ -	£ -	£ -	£ -	£ 73,469
Sewer electroscan surveys	£ -	£ 2,357	£ 434	£ 36,475	£ 4,956	£ 21,171	£ 10,880	£ -	£ -	£ 67,448	£ -	£ 143,701
Public sewer lining	£ 25,367	£ 31,131	£ 80,199	£ -	£ 86,619	£ 177,343	£ 114,203	£ -	£ -	£ -	£ -	£ 514,862
Public sewer tubogel sealing	£ 165,757	£ 119,973	£ 254,018	£ -	£ 17,635	£ -	£ -	£ -	£ -	£ -	£ -	£ 557,384
Traditional manhole sealing	£ 52,000	£ 36,000	£ 48,000	£ -	£ 48,000	£ 156,000	£ 104,000	£ -	£ -	£ -	£ -	£ 444,000
Drain tubogel sealing	£ 160,500	£ 229,500	£ 355,500	£ 1,500	£ 91,500	£ -	£ -	£ -	£ -	£ -	£ -	£ 838,500
Cost	£ 417,688	£ 439,070	£ 769,300	£ 38,106	£ 256,727	£ 354,513	£ 229,063	£ -	£ -	£ 67,448	£ -	£ 2,571,917
£/PE	£ 1,546.82	£ 1,197.32	£ 1,192.73	£ 64.89	£ 1,018.88	£ 680.20	£ 722.73	£ -	£ -	£ 43.17	£ -	£ 372.60

[redacted] distributor who stated it would cost [redacted] This has therefore been taken to mean [redacted] meter of sewer, no cost has yet been allocated for the manholes that get sealed in the process. Based on this assumption, Table 3 gives an estimate of the [redacted] option.

These costings, although approximate, show that the use of [redacted] is likely to [redacted] As this study is a "pathfinder" to help identify an approach for Southern Water to take into other catchments with similar significant infiltration problems, as well as solving the issues in the catchment. It is suggested that it would be worth testing this approach and monitoring the effectiveness of the technology for the next 3 years, if not longer, to understand the longevity of the product. A regular [redacted] programme over the next 10 years will provide understanding of how effectively the [redacted] works and also give the local residents the peace of mind that, while they are in a catchment being used for innovation, they will not suffer as a consequence of this.

Pan Parish Pathfinder
Infiltration Investigation

Figure 10 Proposed option overview



Pan Parish Pathfinder
Infiltration Investigation

Figure 11 Details of proposed plan

Seal Everything

Thruxton, Kimpton, Fyfield & East Cholderton

Aim: no tankering from these villages

Scope:
Seal leaky public sewers – 4.5km
Seal public manholes – 134
Seal private drains – 559 properties (~8.4km)
Scan remaining public sewers – 1.9km

Aspiration: completion by Nov '22

Expectation: Seal Thruxton and Kimpton by Nov '22, follow with Fyfield & E Cholderton by Nov '23

Seal Public Defects

Amport & Monxton

Aim: no infiltration into the public network. Learn from "seal everything" villages and monitoring.

Scope:
Seal leaky public sewers – 1.4km
Seal public manholes – 65
Scan remaining public sewers – 3.2km
Monitor impact of upstream work
Plan future private drain sealing if required

Aspiration: sealing completed by Nov '22

Expectation: TBC

Investigate Everything

Weyhill, Abbotts Ann & Little Ann

Aim: understand how much infiltration can occur into the public network. Learn from monitoring and other villages.

Scope:
Scan public sewers – 10.4km

Aspiration: scans completed by Nov '22

Expectation: scans carried out between May '23 and Nov '23 (TBC)

Monitoring

All villages

Aim: Improve understanding local groundwater levels. Improve understanding on where infiltration is entering the network. Improve speed of reactive maintenance. Evidence suitability of sealing technique.

Scope: Observation boreholes and improved groundwater model
Temperature sensing
AMP cycle electro scan programme

Aspiration: Monitoring in place for Nov '22.

4.2. Whole Life Costs

The life cycle of the different sealing techniques varies. It is expected that a traditional leak tight liner should last 40 years, although some of the analysis done during this study suggests it is not uncommon to start seeing infiltration before this time. The [redacted] supplier claims that the product lasts for 25 years, it has not been used in the UK long enough for this to be validated, so an allowance must be made to re-seal areas more frequently. Table 4 outlines the likely ongoing capital expenditure required.

Table 4 Ongoing capital expenditure

	Traditional	[redacted]
Frequency (years)	10	[redacted]
[redacted] (km)	3.9	[redacted]
Public sewer sealing (km)	1.5	[redacted]
Private drain sealing (nr property)	140	[redacted]
Cost (£ absolute)	£995,671	£384,896
Annual Cost (£/yr)	£99,567	£76,979

The costs appear expensive, until they are compared with the ongoing costs of managing the infiltration in the network. The 10-year whole life costs of the two sealing techniques can be compared to the ongoing operational costs, assuming that there is a six year cycle that consists of four dry years then two wet years.

Table 5 10 year NPV Comparison

Option	Capital expenditure (inc monitoring)	Capital maintenance	Operational maintance (wet year)	Operational maintance (dry year)	10 year NPV
No additional intervention	-	-	£1,460,000	£800,000	£7,272,582
Traditional	£4,939,993	£995,671	-	-	£6,502,373
[redacted]	£2,701,225	£384,896	-	-	£3,211,624

Table 5 demonstrates that the current operational costs even in low groundwater years are still so high that the level of investment set out in the options is warranted.

4.3. Ongoing monitoring costs

For all options there needs to be a long-term monitoring and maintenance programme. This section explains the costs associated.

4.3.1.1. Ground Water monitoring

Observation boreholes are recommended to give an understanding of the groundwater level relative to the assets in the ground. There are two potential approaches to this monitoring, which depend on the availability of the Environment Agency groundwater model. These are outlined briefly in **Error! Reference source not found.**

Table 6 Groundwater monitoring options

With EA Model	Without EA model
5 x observation boreholes	10 x observation borehole
Model update / calibration Benefits wider groundwater level understanding	Simplistic local only model
£42,000 + EA model license fee	£55,000

Based on the wider benefit and lower cost, the intention is to install five boreholes and update the existing model, so long as the model is made available.

4.3.1.2. Infiltration monitoring

There is also a need to understand when and where infiltration is entering the sewer network if infiltration re-occurs once the system is sealed. One solution would be to routinely [redacted] areas within the network to check the "watertight" status of the network. A second option is to install temperature sensors into the invert of several pipes and monitor the data to flag any changes. Groundwater is colder than sewage so the data can be monitored drops in temperature, either sharp or gradual changes, and compare the findings to the groundwater level at the time to give an idea of the source of infiltration. This will allow timely remediation to keep the system "watertight". The intention is to install at least one temperature sensor in each village, with more in the upstream village. The intention is to install 26 monitors which may cost up to £75,000 for the first three years. There would be an ongoing cost for the lifetime of the sensors to maintain them and monitor the data, which is likely to be in the ballpark of £4,000 per annum.

4.4. Option 2 - Manage the Groundwater

An alternative approach to resolving the excessive infiltration at extreme groundwater levels could be to actively manage the groundwater level to ensure it does not get up to a level at which severe inundation occurs. This could be achieved by using the information captured by a network of observation boreholes to allow us to understand the groundwater levels in the different villages that trigger tankering / overpumping events, and therefore allow us to design a groundwater drainage system to keep the groundwater below these levels. This would require a network of underdrains and abstraction boreholes to drop the groundwater level. The water abstracted could be stored and used locally in a water reuse scheme. This style of strategy is well outside the traditional remit of Southern Water, but it would allow us to ensure that infiltration levels are carefully managed. This style of strategy could be scoped and costed to compare to the other options, once confidence in the local groundwater levels is available. This opportunity could only be realised in collaboration with the local residents, Parish Councils and the Environment Agency so potential buy in is needed before this opportunity is considered in any detail.

The impact of this strategy on the ecosystem needs to be carefully considered, any change in river flow outside of the flood conditions may have a negative impact on the sensitive chalk stream system. It is also likely that this strategy will have a high carbon cost as the volumes of groundwater needing to be pumped to reduce the levels sufficiently are likely to be large. It should be noted that this goes against the current strategic direction for Southern Water, of trying to reduce the abstraction rates from the Test and Itchen aquifers.

4.4.1. Costs

The option for groundwater management has not been explored in detail at this stage of the project. This is because more detailed groundwater level data and an improved groundwater model are needed to decide if this is viable, see section 4.3. Over the 2023 dry season, once this data has been collected, it will be reviewed and will be part of an ongoing discussion with stakeholders to assess the appetite for this type of solution.

4.5. Opportunity - Treatment of Excess Flow

There is a potential opportunity whereby instead of trying to prevent all infiltration during extreme groundwater levels, a sustainable methodology is developed to treat the escapes from the system. This would be by creating a wetland off the Pillhill Brook, next to the relief points, for example downstream of the Mullens Pond WPS where tankering first occurs. The wetlands would be able to treat the excess flow, which is already extremely dilute, to a quality comparable to the final effluent discharge from a fully functioning wastewater treatment works. Thereby minimising (negating?) and impact on the wildlife and ecosystem. The opportunity at Mullens Pond WPS is explored in more detail in Appendix C.

This opportunity is dependent on land being available in the critical locations, in sufficient large areas, to provide the required water quality improvements. It would also require buy in from the landowners, residents, Parish Councils and the Environment Agency.

The creation of a new wetland environments will have an ecological benefit and a carbon benefit. There may also be ways in which the wetlands could be used for other purposes outside of the groundwater season, such as flood storage of rainfall runoff during wet weather events. It would also provide the benefit to the residents of the Thruxton that their private drains would not need to be sealed, reducing any disruption to them.

If there is support for this opportunity, the impact of accepting infiltration, in times of high groundwater, into the sewers and away from the chalk stream ecosystem would need to be considered in more detail and discussed with partners and stakeholders.

5. Conclusions, Proposal and Next steps

Groundwater is overwhelming the drainage network in the Pan Parishes in high groundwater seasons. Despite extensive investigation and sealing within the public network, there has been little improvement when the groundwater levels are high. Continuing with the "targeted" sealing approach which has been implemented over the last 10 years is unlikely to resolve the problem, as this study has identified that this style of work is only sufficient to maintain the status quo. This also has a relatively high annual cost both in terms of CAPEX and OPEX as it is unlikely to reduce the requirement of tankering and overpumping due to the defects in the private network.

We intend to make every practicable effort to stop the infiltration in the Pan Parishes, which based on the findings of this study means we need to endeavour to undertake widespread sealing on both the public and private networks. This requires support from the local community to allow us access to the private network to seal it, otherwise the problem is very unlikely to be resolved. The cost of this work is expected to be in the order of £3.5million, with ongoing annual costs from AMP8 onwards of approximately £80,000 per annum. This is a significant investment based on the number of customers affected and unfortunately it will be disruptive over the 2022 and 2023 summers while the bulk of the work is carried out. This will also include ongoing monitoring and scheduled maintenance, so there will continue to be a Southern Water presence in the villages.

There is an opportunity to replace some of the invasive private drainage sealing with a wetland at Mullens Pond WPS would create a new amenity space and increase the diversity of the ecosystem in the area. This opportunity depends on agreement from the local community, the land owner and the Environment Agency.

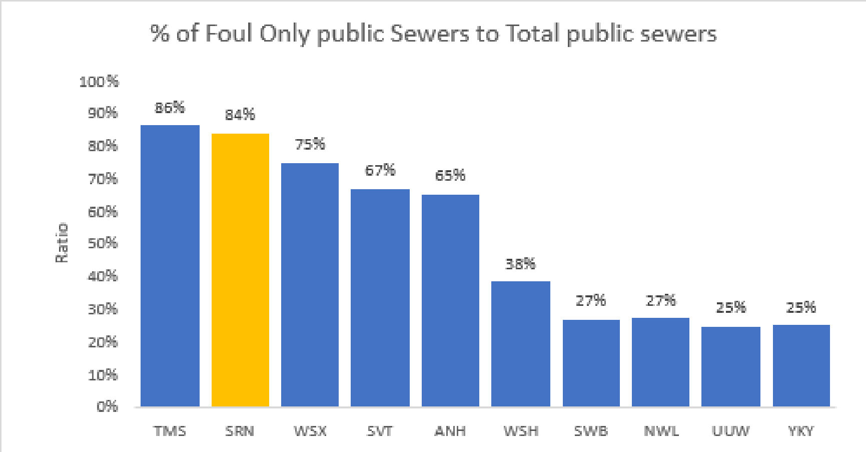
It is likely that, if this opportunity is agreed, it will not be implemented before the 22/23 winter and therefore one more winter of tankering / overpumping would need to be tolerated to support this more sustainable solution.

Proposal & next steps

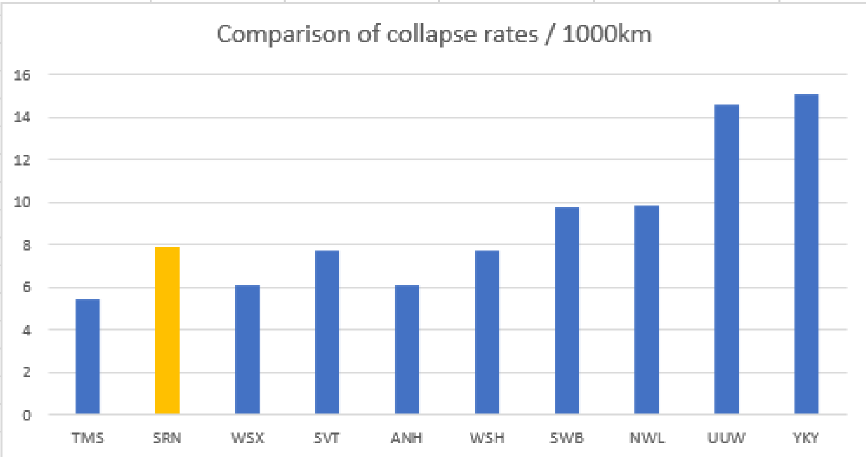
- Groundwater and infiltration monitoring – to provide data for further analysis
- Progress with scanning and sealing as per Option 1 - using tubogel as soon as possible.
- Discuss with residents and stakeholders to assess the appetite for the development of a a wetland solution

Appendix 7 – Comparison of Stated Co. APR data

Table 0



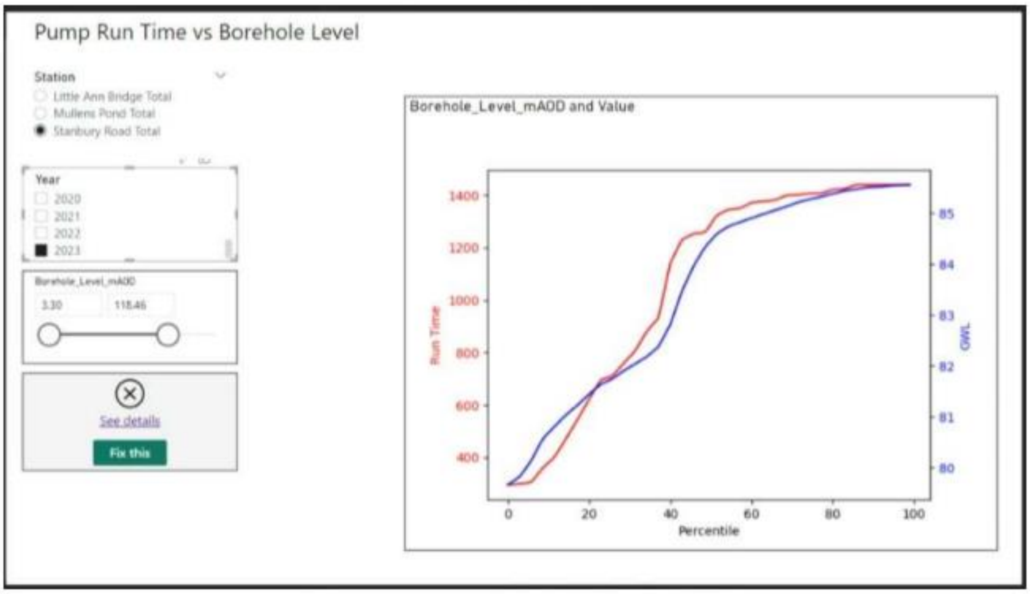
Company	Ratio
TMS	86%
SRN	84%
WSX	75%
SVT	67%
ANH	65%
WSH	38%
SWB	27%
NWL	27%
UUW	25%
YKY	25%



Company	
TMS	5.472215552
SRN	7.907618928
WSX	6.120280091
SVT	7.737844009
ANH	6.090592696
WSH	7.693980751
SWB	9.764292089
NWL	9.817578773
UUW	14.60942535
YKY	15.10031881

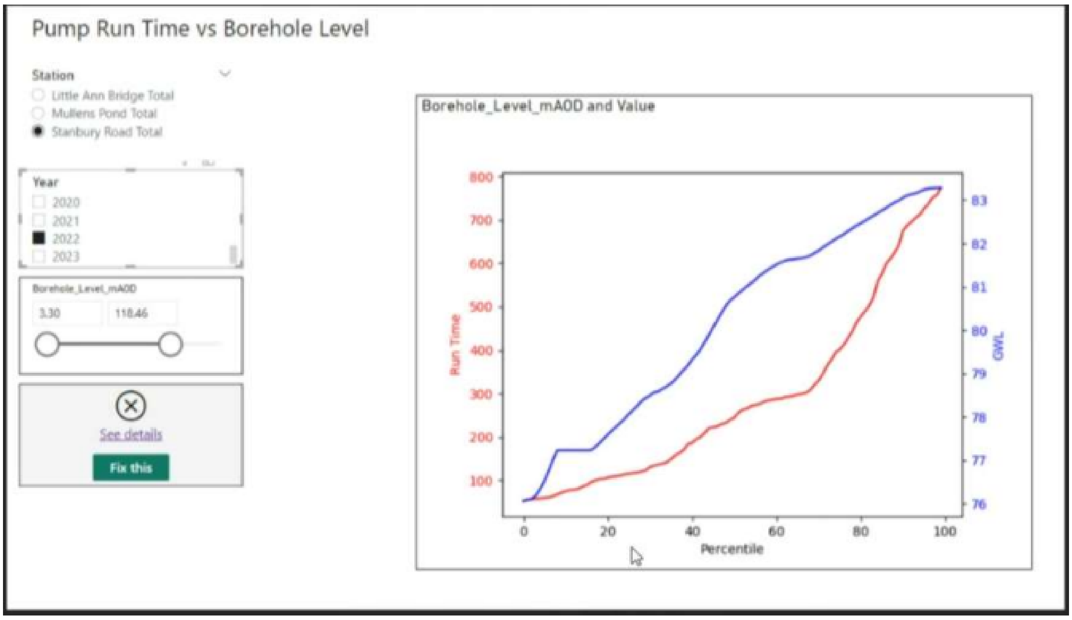
Appendix 8 – Conclusions from Pan Parish Pilot

Pump activity and groundwater level pre-sealing



1

Pump activity and groundwater level post sealing



2

Conclusion on sealing work

Comparison of the two graphs shows that post sealing the pump run time at Stanbury Road WPS reduced significantly after sealing work was completed.

There is a particularly marked difference when groundwater levels are less than 83 mAOD which demonstrates the effectiveness of sealing sewers closest to the water table.

This also demonstrates that as the water table rises infiltration increases as more sewers become submerged and therefore supports that infiltration reduction must be completed at scale to be fully successful.

3

Appendix 9 – CIPP lining costs

Sample of Cost Curve points for CIPP liners

Scope Area	Nett Direct Costs	Total Indirect	Total Cost £
CIPP 1m of 150mm dia Field / Verge	[redacted]		
CIPP 10m of 150mm dia Footpath			
CIPP 100m of 150mm dia Road			
CIPP 1m of 200mm dia Field / Verge			
CIPP 10m of 200mm dia Footpath			
CIPP 100m of 200mm dia Road			
CIPP 1m of 300mm dia Field / Verge			
CIPP 10m of 300mm dia Footpath			
CIPP 100m of 300mm dia Road			
CIPP 1m of 400mm dia Field / Verge			
CIPP 10m of 400mm dia Footpath			
CIPP 100m of 400mm dia Road			
CIPP 1m of 500mm in Road			
CIPP 1m of 600mm in Road			