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PORTSMOUTH WATER

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FLOOD RISK ASSESSMENT AND DRAINAGE STRATEGY

REPORT REF – 191925-R01

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DOCUMENT CONTROL SHEET

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1. INTRODUCTION

Preface

1.1 Ardent Consulting Engineers (hereafter referred to as 'Ardent'), has been appointed by Portsmouth Water, to prepare a Flood Risk Assessment (FRA) to support a development at the land owned by Portsmouth Water to the rear of the Portsmouth Water headquarters at West Street, Havant, PO9 1LG.

1.2 This FRA has been prepared with specific reference to the requirements of National Planning Policy Framework (NPPF, July 2021) and the Planning Practice Guidance (PPG, March 2014).

Existing Site

1.3 The Site is approximately 1.365 ha and is centred at Ordnance Survey grid reference SU 71106 06165 on Solent Road, Havant with the nearest post code being PO9 1LG The Site is located within Portsmouth Water owned land to the rear of the Portsmouth Water Headquarters at West Street, Havant, PO9 1LG. The Brockhampton Stream (an EA 'main river') flows through the centre of the Portsmouth Water owned land and marks the boundary along the northern edge of the site. Refer to Figure 1-1 below for a site Location Plan.

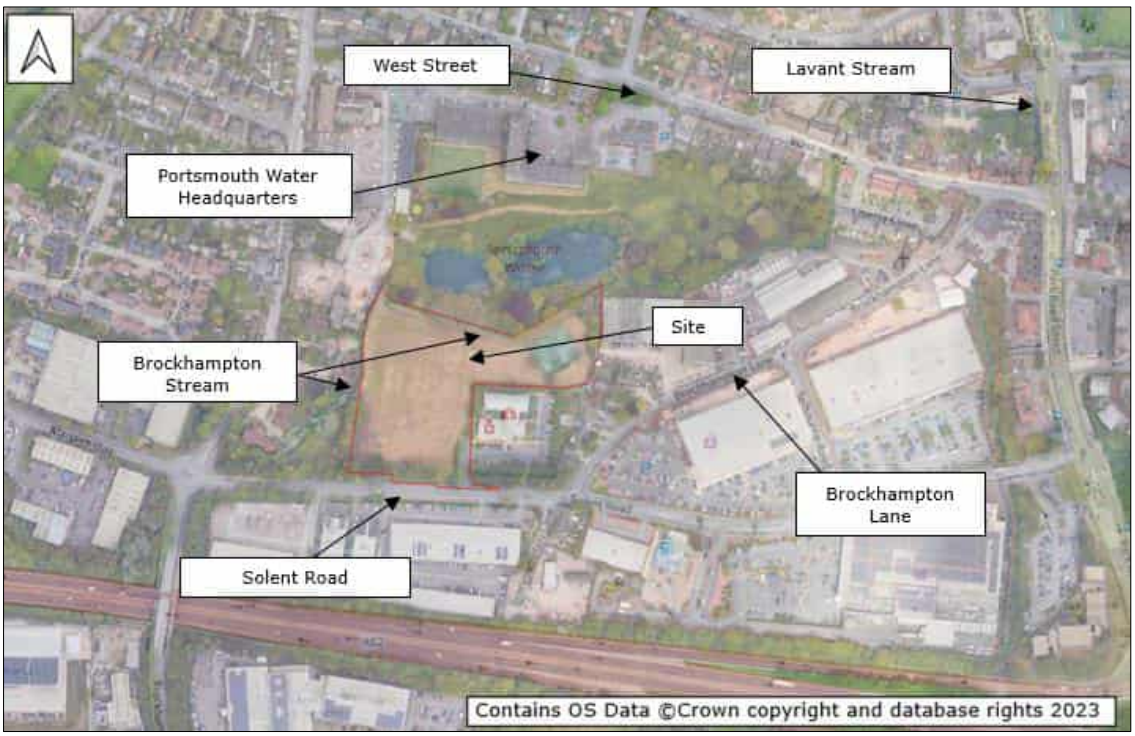

Figure 1-1: Site Location

Development Proposals

1.4 The existing site is currently formed of undeveloped greenfield land with the exception of a disused former tennis court in the western part of the Site.

1.5 The scheme proposals comprise of the construction of a building for use as office space and associated parking areas. The proposed development layout plan can be found in Appendix A and is shown in Figure 1-2.

1.6 The development is classified as having an overall 'Less Vulnerable' classification within the NPPF.

Figure 1-2: Proposed Ground Floor Development

2. BASELINE PARAMETERS

Topography

2.1 Ardent have obtained 1 metre resolution LiDAR ground elevation data of the study area, from the Environment Agency. The LiDAR data shows that elevations on the site fall from approximately 5.9 m AOD in the northeast corner down to 4.8 m AOD in the southwestern corner (refer to Figure 2 3 below).

Figure 2-1: 1m resolution LiDAR data

2.2 The topographical survey (Appendix B) indicates similarly - site levels fall from east to west. Spot levels taken from the topographical survey are as follows: 5.75m AOD on the east to 5.00m AOD on the west falling a gradient of approximately 1:240.

Hydrology

2.3 There are several waterbodies within the vicinity of the site (refer to Figure 2-2). The Brockhampton Stream flows from east to west along the northern boundary of the Site and southwards along the western boundary. The Lavant Stream flows east of the site and is classified as a 'main river'. The upper catchment of the Lavant Stream is situated on chalk bedrock before flowing through the urban area of Havant through multiple culverted sections. The channel is artificially

diverged approximately 400 m upstream of the Site for the creation of a flood bypass channel which flows southwards through the urban area.

2.4 The Site lies adjacent to a boundary between permeable chalk bedrock and impermeable London Clay Formation to the north. Consequently, several springs are present in the area including the Brockhampton Springs on the Portsmouth Water site which give rise to the two ponds to the north of the site. Also adjacent to the south of the development site are two open ditches and a culverted section which are understood to be fed by the urban drainage network to the east and north. These are understood to discharge into the Lavant Stream south of the site.

2.5 Approximately 350 m to the northwest of the Site, the Hermitage Stream flows from north to south. A flood relief culvert is present on the Lavant Stream approximately 1.5 km upstream of the Site which is designed to transfer flows from the Lavant Stream catchment into the Hermitage Stream during extreme rainfall events. Both the Hermitage Stream and the Lavant Stream discharge to the estuary approximately 1.0 km to the south of the Site.

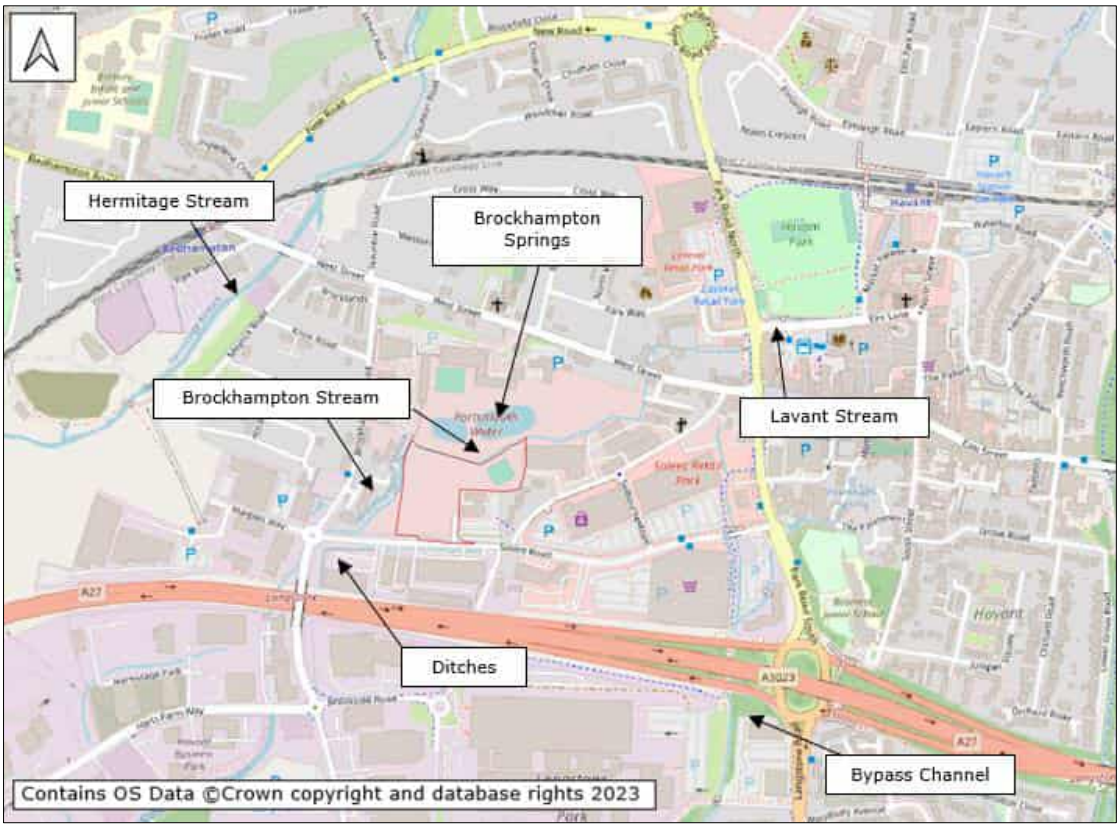

Figure 2-2: Location of Waterbodies

Ground Conditions

2.6 As mentioned above, the geology of the local area is quite complex. British Geological Survey data (refer to Figure 2-3) shows that the Site is located on permeable chalk geology with impermeable London Clay Formation bedrock to the north. This change in permeability results in the emergence of several springs in the vicinity of the Site.

Figure 2-3: British Geological Survey data

Existing Sewer Infrastructure

2.7 A utilities survey of the site and surrounding area shows the existing surface water and foul sewers. See Figure 2-4 and refer to Appendix B.

2.8 A 375mm storm water pipe runs through the northern side of the site from east to west, before changing direction and running south across the western border of the site. After about 10 m, the pipe changes direction to the west, most likely draining the water to the Brockhampton Stream.

2.9 Along Solent Road to the south, there is a system of drains running west, draining into the storm water pipe which runs north and connects to a pipe that drains into the Brockhampton Stream.

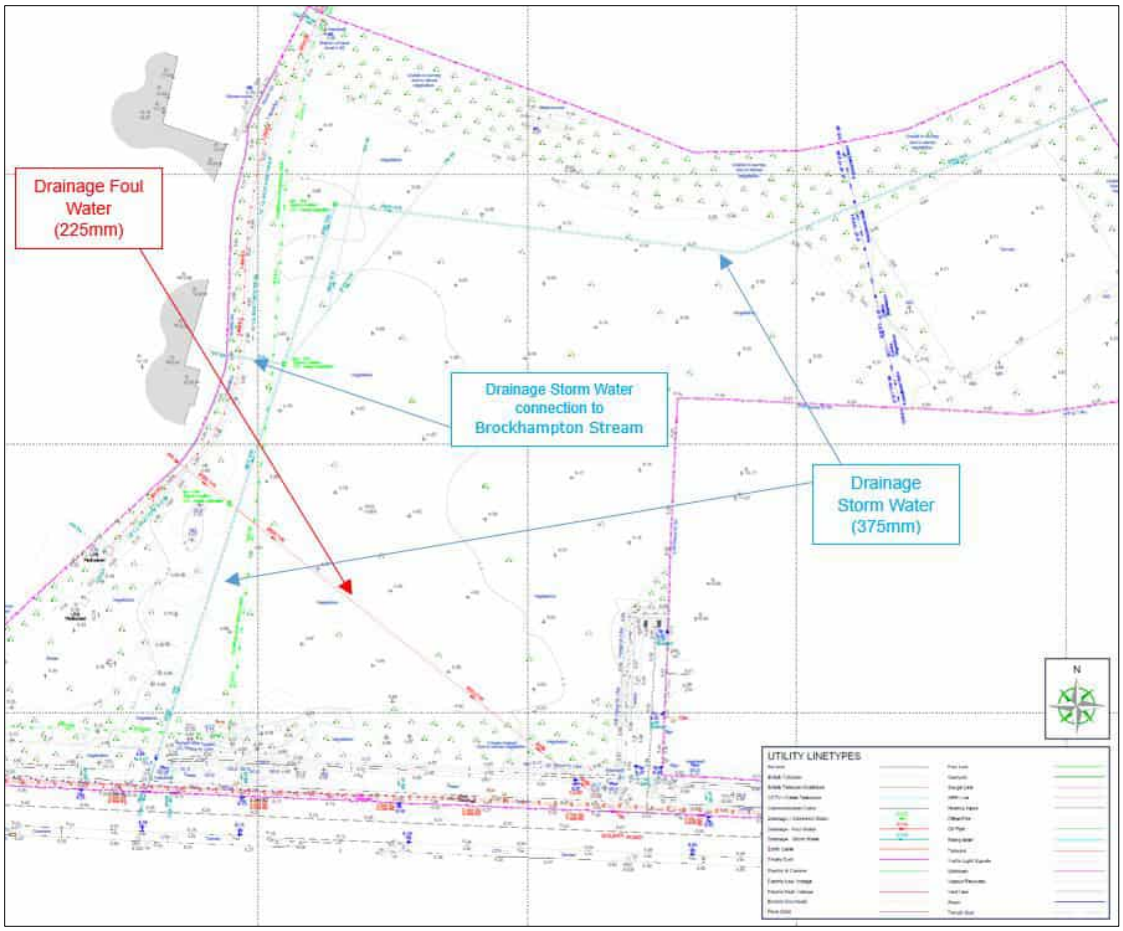

Figure 2-4: Utility Asset location

2.10 A 225mm foul water pipe runs across the site from northwest to southeast. The pipe is connected to wider Southern Water sewer network at Brockhampton Lane (Appendix B).

3. POLICY CONTEXT

National Planning Policy Framework

3.1 The National Planning Policy Framework (NPPF) was revised in September 2023; where paragraphs 159 to 169 inclusive establish the Planning Policy relating to flood risk management. The Technical Guide to the NPPF was superseded by the Planning Practice Guidance (PPG) in March 2014. The Flood risk and coastal change guidance was updated in August 2022.

3.2 The PPG states that when planning or decision making in terms of flood risk, the process followed should be to avoid, control, mitigate and manage residual risk.

3.3 'Avoiding' risk relates to the application of the sequential and exception tests, as discussed in detail for the site in Section 6 and summarised below:

- In plan-making, a sequential approach should be employed. This involves applying the 'Sequential Test' and, if needed, the 'Exception Test'.
- In decision-making, where necessary, planning authorities also apply the Sequential Test and, if needed, the Exception Test, to ensure that flood risk is minimised and appropriately addressed.
- Where the sequential and the exception tests have been applied as necessary and not met, development should not be allowed.
- Substitute lower vulnerability uses for higher vulnerability uses.
- Within sites, using site layout to locate the most vulnerable aspects of development in areas of lowest flood risk, unless there are overriding reasons to prefer a different location. In addition, measures to avoid flood risk vertically can then be taken, by locating the most vulnerable uses on upper storeys, and by raising finished floor and/or ground levels, where appropriate and that such techniques are suitably designed. Such measures should also account for residual flood risks from flood risk management infrastructure.

3.4 The PPG provides the methodology required to undertake the Sequential and Exception Tests and this should be applied to all sources of flooding.

3.5 'Controlling' the risk relates to measures that will control the risk of flooding

affecting the site. Early discussions with relevant flood risk management authorities, reference to Strategic Flood Risk Assessments and any programme of flood and coastal erosion risk management schemes will help to identify such opportunities.

3.6 'Mitigating' the risk relates to the use of flood resistance and resilience measures to address any residual risks after the use of avoidance and control measures.

3.7 'Managing' the risk relates to considering further management measures to deal with any residual risk remaining after avoidance, control and mitigation have been utilized such as providing safe access and escape routes and considering whether adequate flood warning would be available to people using the development. Residual risks will need to be safely managed to ensure people are not exposed to hazardous flooding.

Flood and Water Management Act (2010)

3.8 The Flood and Water Management Act places a duty on all flood risk management authorities to co-operate with each other. The act also provides lead local flood authorities and the Environment Agency with a power to request information required in connection with their flood risk management functions.

3.9 The Lead Local Flood Authority (LLFA) for the proposed development is Hampshire County Council.

Sustainable Drainage Systems - Non-statutory technical standards for sustainable drainage systems (March 2015)

3.10 The Non-statutory technical standards for sustainable drainage systems were published in March 2015. They should be used in conjunction with the Planning Practice Guidance. In addition, the Best Practice Guidance for the Non-statutory technical standards were published in July 2015 by LASOO.

3.11 The Local Planning Authority (LPA) may set local requirements for planning permission that have the effect of more stringent requirements than these non-statutory technical standards.

3.12 In addition, SuDS should be designed in accordance with CIRIA 753 SuDS Manual, which represents current best practice.

Havant Borough Council Core Strategy (2011)

3.13 The Havant Borough Core Strategy is the principal document setting out the broad detail and direction of development in the borough up to 2026.

3.14 Policy CS15 relates to managing flood risk and coastal erosion risk in new developments. It states development in areas at risk of flooding now and in the future will only be permitted where:

a) It meets the sequential and exception test (where required) in relation to PPS25;

b) The site is located in a low hazard area as defined in the Strategic Flood Risk Assessment;

c) A site-specific flood risk assessment demonstrates that the development will be safe, including the access, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall;

d) The scheme incorporates flood protection, flood resilience and resistance measures appropriate to the character and biodiversity of the area and the specific requirements of the site;

e) Appropriate flood warning and evacuation plans are in place; and

f) New site drainage systems are designed taking account of events which exceed the normal design standard.

Partnership for Urban South Hampshire Strategic Flood Risk Assessment (Updated 2016)

3.15 The Partnership for Urban South Hampshire Strategic Flood Risk Assessment (PUSH SFRA) was produced by Atkins in 2016 and is an update to the original Strategic Flood Risk Assessment Produced in 2007.

3.16 PUSH is a partnership of Hampshire County Council, Isle of Wight, Portsmouth and Southampton and the district authorities of Eastleigh, East Hampshire, Fareham, Gosport, Havant, New Forest, Test Valley and Winchester.

3.17 The PUSH SFRA includes mapping of flood risk within the area.

Hampshire County Council Local Flood and Water Management Strategy (2019)

3.18 As part of its duties as the designated LLFA under the Flood and Water Management Act 2010, Hampshire County Council is required to develop, maintain, implement, and monitor a Local Flood Risk Management Strategy (LFRMS).

3.19 The Local Strategy is a document which sets out how Hampshire County Council is responding to identified local flood risk. The key policies of the LFRMS are:

a) Effective Partnership Working Policy – To ensure collaboration and successful flood risk management Hampshire County Council will undertake effective partnership working.

b) Catchment Approach Policy – To better understand the risks associated with the movement of water Hampshire County Council will develop a catchment approach to flood and water management.

c) Priorities and Risk Management Policy – To help protect communities that are most vulnerable to flooding, Hampshire County Council will continue to identify risks and develop clear priorities.

d) Sustainable and Resilient Development Policy – To ensure successful and sustainable growth Hampshire County Council will support the planning process by encouraging resilient development.

e) Recording, Prioritising and Investigating Flood Events Policy – To increase knowledge and understanding of flood events Hampshire County Council will record, prioritise and investigate instances of flooding.

f) Working with Multi-Agency Groups Policy – To reduce flood risk in vulnerable areas Hampshire County Council will work with Multi-Agency Groups to develop Flood Alleviation Schemes.

g) Supporting Community Resilience Policy – To improve adaptation to and recovery from flood events Hampshire County Council will encourage and support community resilience.

Climate Change Allowances

3.20 The Planning Practice Guidance states that to allow for the predicted impacts of

climate change on surface water runoff within the East Hampshire Management Catchment, the following increases detailed in Table 3-1 below should be allowed for peak rainfall intensity. For development with a lifetime up to or beyond 2100, the upper end allowances should be used.

East Hampshire Management Catchment	Central	Upper
3.3% annual exceedance rainfall event		
2050s	20%	35%
2070s	25%	40%
1% annual exceedance rainfall event		
2050s	20%	40%
2070s	25%	45%

Table 3-1: East Hampshire Management Catchment Peak Rainfall Allowances

3.21 Therefore, under the NPPF an allowance of 45% for the effects of climate change for the 1% annual exceedance rainfall event would achieve the policy requirements in designing the drainage elements the proposed residential redevelopment.

4. SEQUENTIAL AND EXCEPTION TESTS

Sequential Test Requirements

4.1 The objective of the Sequential Test is to steer new developments toward areas with the lowest probability of flooding. Where there are no reasonably available sites in lower flood risk areas, local planning authorities in their decision making should take into account the flood risk vulnerability of land uses and consider reasonably available sites in higher flood risk areas.

4.2 As the Site is shown to be located within Flood Zone 3 on the Environment Agency and SFRA mapping, it would be necessary for the Site to undergo the Sequential Test. However, it is acknowledged that the site was allocated in the previous Local Plan for a new Portsmouth Water HQ. The sequential test at that time was passed on the basis that the HQ had to be in this location for operational reasons, being close to a water source.

4.3 The Local Planning Authority should confirm that the Site passes the Sequential Test.

Exception Test Requirements

4.4 Table 2 of the PPG, replicated below in Figure 4-1, confirms the Exception Test is not required to be undertaken for 'less vulnerable' uses in Flood Zone 3.

Flood Zones	Flood Risk Vulnerability Classification				
	Essential infrastructure	Highly vulnerable	More vulnerable	Less vulnerable	Water compatible
Zone 1	✔	✔	✔	✔	✔
Zone 2	✔	Exception Test required	✔	✔	✔
Zone 3a †	Exception Test required †	X	Exception Test required	✔	✔
Zone 3b *	Exception Test required *	X	X	X	✔ *

Key:

✔ Exception test is not required

X Development should not be permitted

Figure 4-1: Table 2 of the Planning Practice Guidance

5. SOURCES OF FLOODING

5.1 The NPPF requires flood risk from the following sources to be assessed, each of which are assessed separately:

- Fluvial sources (river flooding);
- Tidal sources (flooding from the sea);
- Pluvial sources (flooding resulting from overland flows);
- Groundwater sources;
- Sewer Flooding;
- Artificial sources, canals, reservoirs etc.; and,
- It also requires the risk from increases in surface water discharge to be assessed (surface water management).

Fluvial/Tidal Flooding

5.2 Flood Zones refer to the probability of river and sea flooding, ignoring the presence of defences. The NPPF Planning Practice Guidance defines Flood Zones as follows:

- **Flood Zone 1**: **Low Probability**. Land having a less than 0.1% annual probability of river or sea flooding. (Shown as 'clear' on the Flood Map for Planning – all land outside Zones 2, 3a and 3b)
- **Flood Zone 2**: **Medium Probability**. Land having between a 1% and 0.1% annual probability of river flooding; or land having between a 0.5% and 0.1% annual probability of sea flooding. (Land shown in light blue on the Flood Map)
- **Flood Zone 3a**: **High Probability**. Land having a 1% or greater annual probability of river flooding; or Land having a 0.5% or greater annual probability of sea. (Land shown in dark blue on the Flood Map)
- **Flood Zone 3b: The Functional Floodplain**. This zone comprises land where water from rivers or the sea has to flow or be stored in times of flood. The identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. Functional floodplain will normally comprise:
    - land having a 3.3% or greater annual probability of flooding, with any existing flood risk management infrastructure operating

effectively; or

- land that is designed to flood (such as a flood attenuation scheme), even if it would only flood in more extreme events (such as 0.1% annual probability of flooding).

5.3 The Flood Zones are shown on the EA Flood Map for Planning (Rivers and Sea). The Planning Practice Guidance states that the Zones shown on the EA Flood Map do not take account of flood defences or the possible impacts of climate change and consequent changes in the future probability of flooding.

5.4 According to the EA Flood Map for Planning (Figure 5-1) the south and southeast part of the site is located in land designated as Flood Zone 3 (high probability of fluvial flooding) and is shown as undefended.

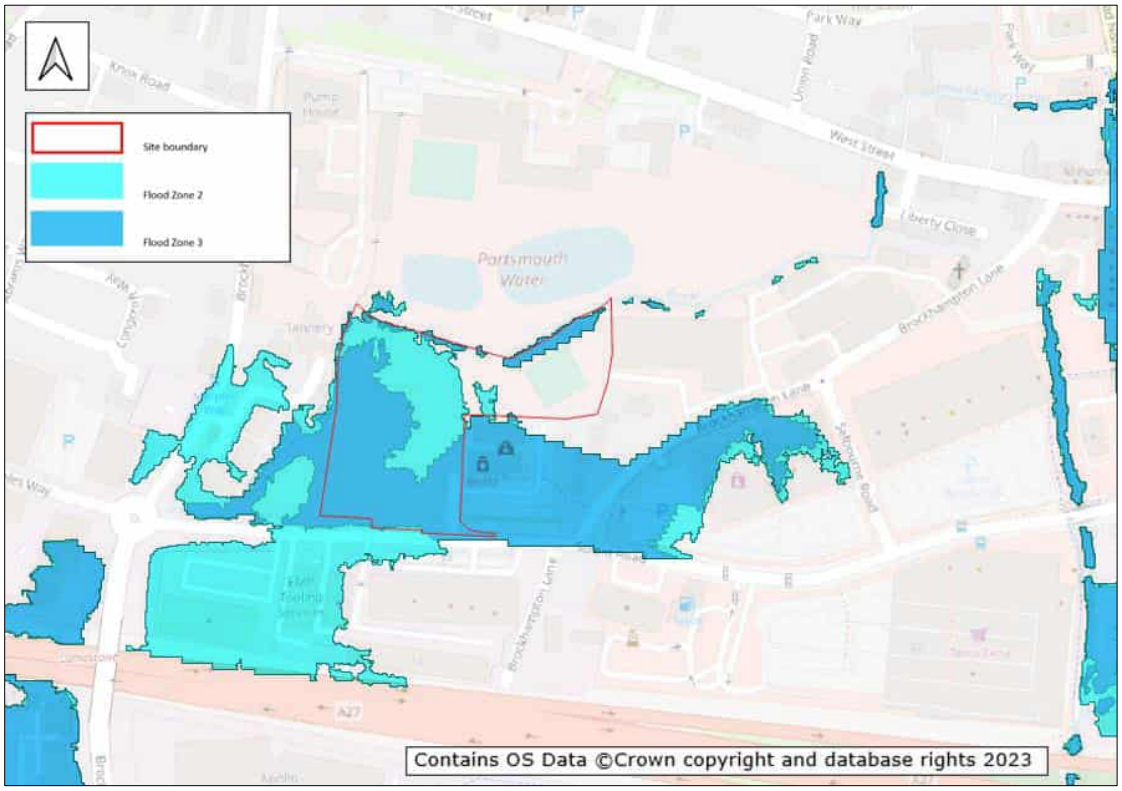

Figure 5-1: EA Flood Map for Planning (Rivers and Sea)

5.5 The northeastern corner is shown to be in Flood Zone 1 (low probability of flooding). However, the flood zone outlines have been derived from a hydraulic model constructed in 2008 using hydraulic modelling software InfoWorks CS and RS.

Updated Hydraulic Modelling

5.6 In July 2020 Ardent constructed a dynamically linked 1D-2D hydraulic model of the Brockhampton Stream and floodplain using Flood Modeller Pro (1D) and Tuflow (2D) software packages based on new cross sectional channel survey data as well as utilising data, river sections and sewer sections taken from the original Infoworks models where appropriate. The model options included the removal of the culvert on the Brockhampton Stream, south of Brockhampton Springs.

5.7 Through consultation with the Environment Agency (EA) it became apparent that the hydrology associated with the model was outdated and would need revising and that also, several structures within the model were not accurately represented or were not included. Therefore, confidence in the modelling outputs and flood outlines was reduced but this represented the best available information. As part of the assessment of flood risk to the Site it was therefore decided to update the hydrology and make an assessment based on the latest climate change guidance and update the hydraulic model with new survey data.

5.8 Details of the July 2020 hydraulic model are provided in Appendix C.

5.9 In January 2021, Ardent on behalf of Portsmouth Water submitted a Flood Risk Activity Permit to the Environment Agency (Environmental Permit licence number EPR/PB3294JJ) for mitigation works including the removal of the 2.5m long 450mm diameter cast iron culvert approximately 120m south of the Portsmouth Water Ltd. Headquarters, and associated groundworks on the Brockhampton Stream.

5.10 The works are underway and when completed, the site will remain flood free during the 1 in 100 year plus climate change scenario. See Figure 5-2 for hydraulic modelling results.

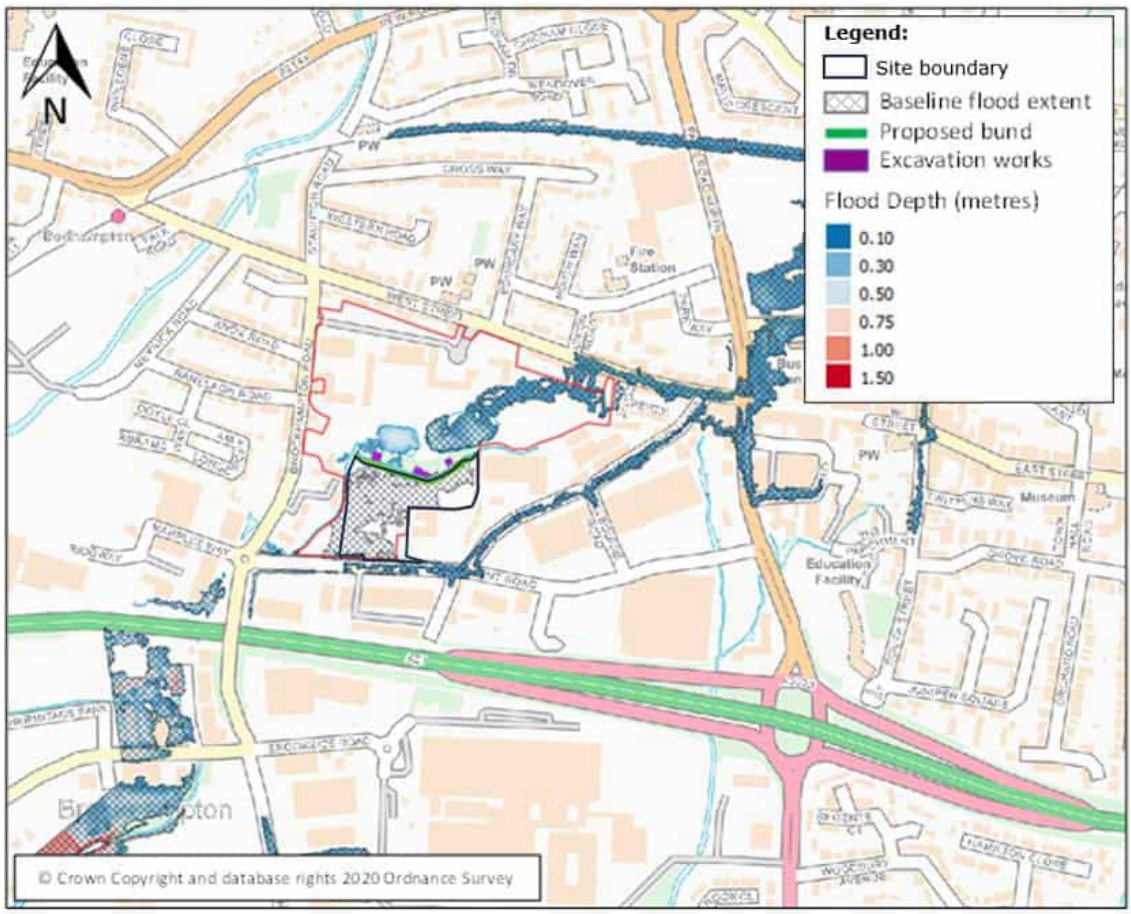

Figure 5-2: 1 in 100 year plus 45% climate change, mitigation scenario maximum flood depths, July 2020

5.11 Tidal flooding is not considered a risk to the site due to the inland location of the development.

Pluvial Flooding

5.12 The risk of flooding from surface water is presented in the GOV.UK online map at a strategic scale. It can be seen from the surface water flood map in Figure 5-3 that the site is shown to have a low to high risk of flooding. The low flood risk covers the majority of the site with medium risk being in the central and western sides of the site. The high surface water risk is associated with the adjoining watercourse and drainage network in the area.

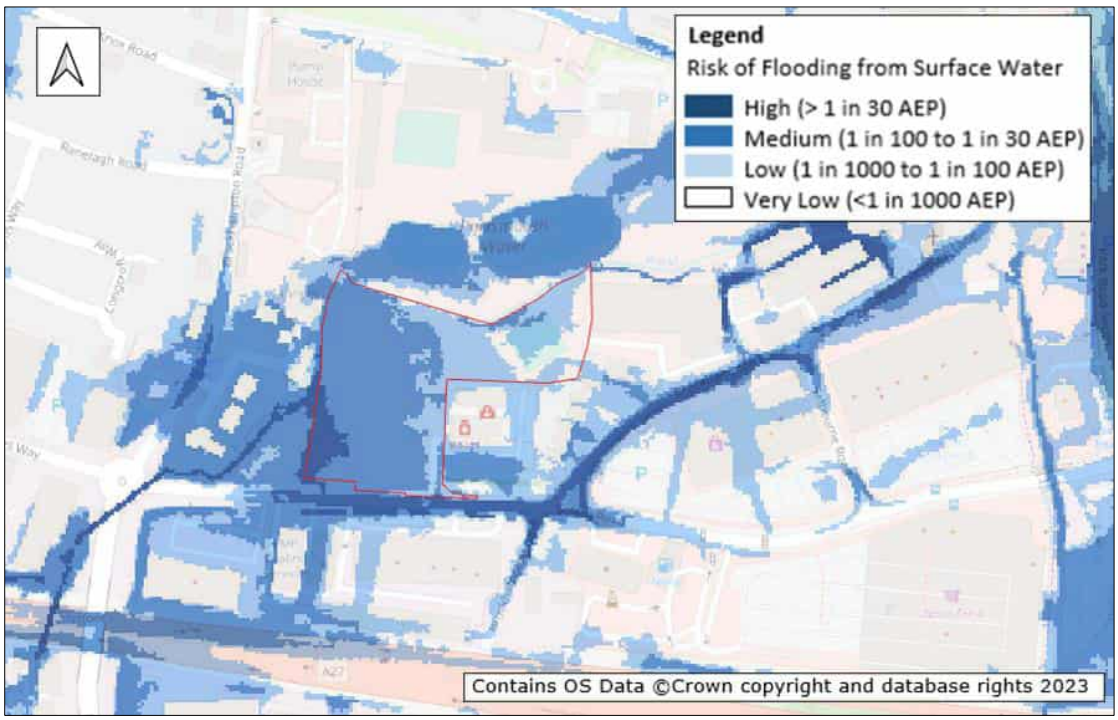

Figure 5-3: EA Flood Map for Surface Water

5.13 Given that surface water flood risk in this area is associated with the adjoining watercourse and drainage network, the flood alleviation works undertaken will provide a significant betterment to the site. Therefore, the fluvial hydraulic modelling is considered to be more representative of flood risk at the site. Based on the hydraulic model (refer to Figure 5-2 in the previous section), the risk from surface water flooding from the site will be low and unlikely to cause any risk to the site.

Groundwater Flooding

5.14 The site geology is expected to consist of a Made Ground, which is in turn underlain by superficial deposits comprising of Alluvium, Head Deposits and River Terrace Deposits, followed by Chalk bedrock. Shallow groundwater has been recorded at the Site therefore considered to be medium risk, however the proposed finished surface and finished floor levels will be raised from current ground levels and therefore the existing flood risk from groundwater to the development is considered to be low.

5.15 The impact of water level rises in the adjoining watercourse and subsequent groundwater levels rising would therefore have limited impact on the proposed development.

Sewer Flooding

5.16 As mentioned in section above, the site will have new surface and foul water connection points. The discharge from the site will be restricted to Greenfield runoff rates therefore not increasing flows from the site.

5.17 Therefore, the risk of sewer flooding to the site is considered low.

Artificial Sources

5.18 The EA Flood Risk from Reservoirs mapping indicates that the site is located outside of an area of potential risk from flooding. There has been no loss of life in the UK from reservoir flooding since 1925.

5.19 There are no canals in close proximity to the site. A review of the Environment Agency's online Risk of Flooding from Reservoirs Map shows that the Site is not in an 'at risk' area. As the Site is not in the vicinity of any canals or at risk of reservoir flooding, the Site is not considered to be at risk of flooding from artificial sources.

6. SUSTAINABLE DRAINAGE STRATEGY

6.1 DEFRA's Non-statutory technical guidance for Sustainable Drainage Systems and CIRIA Guidance C753 "The SuDS Manual" have been used to determine the appropriate SuDS Strategy, which considers the spatial and environmental constraints of the Site.

6.2 Under the NPPF an allowance of 45% for the effects of climate change will achieve the policy requirements for the proposed development.

Existing Surface Water Discharge

6.3 The planning redline boundary equates to 1.546ha of which based on the photos and topographical survey, the site approximately 93.6% is permeable based on the photos and topographical survey of the site.

6.4 The existing runoff rates from the Site were determined using the Wallingford Procedure Rational Method for an assumed critical 5-minute storm:

$$Q = 2.78 \times i \times A$$

Where:

Q = Peak Discharge (l/s)

i = Rainfall Intensity (mm/hr)

(50.8mm/hr for 1yr 5 min storm - TRRL Report 595)

A = Contributing Impermeable Areas (ha)

6.5 The surface water run-off generated from the Site during the 1 year, 30 year, and 100 year rainfall events are provided in Appendix D.

6.6 For comparison the equivalent Greenfield runoff rates from the Site have been determined using the ICP SuDS Mean Annual Flow Method (IoH 124).

6.7 A summary of both the existing Brownfield and equivalent Greenfield runoff rates are proposed in Table 6-1.

	Site Area (ha)	Impermeable Area (ha)	Surface Water Run-off (l/s)			
			1 year	2 year (Qbar)	30 year	100 year
Existing brownfield	1.546	0.099	13.98	-	31.11	39.60
Proposed developable area	0.669	Greenfield	2.0	2.3	5.3	7.5

Table 6-1: Greenfield and Existing Surface Water Run-Off Rates

Drainage Hierarchy

6.8 In accordance with the Planning Practice Guidance and Havant Level 1 Strategic Flood Risk Assessment, surface water run off not collected for use must be disposed of according to the following hierarchy:

- into the ground (infiltration);
- to a surface water body;
- to a surface water sewer, highway drain, or another drainage system;
- to a combined sewer.

Into the Ground (Infiltration)

6.9 The existing site geology consists of a variable thickness of topsoil and Made Ground, which is in turn underlain by superficial deposits comprising of Alluvium. A high groundwater levels has also been recorded. Infiltration will therefore not be possible at this site and the initial design provided as part of this report has therefore allowed for no infiltration. Lined permeable paving could be considered feasible as a methos of storage, discharging to the proposed drainage network.

To a Surface Water Body

6.10 As discussed in Section 2, the Brockhampton Stream flows from east to west along the northern boundary of the Site and southwards along the western boundary. The connection to the surface water body has been considered.

To a Surface Water Sewer

6.11 Based on the topographical survey data (Appendix B) it is understood that the existing private surface water sewer crosses the site. Although manholes are

shown on the map the details of levels are not provided. As there is a surface water body in the vicinity of the site, and this is higher up the hierarchy, discharge to a Surface Water network has not been considered.

To a Combined Sewer

6.12 There are no combined water sewers and drains within the vicinity of the Site. As this is further down the hierarchy than discharging to a surface water body this method of discharge has not been considered.

Proposed Sustainable Drainage Systems (SuDS)

6.13 The constraints and opportunities for the use of SuDS techniques are appraised using the Management Train approach outlined in CIRIA C753 'The SuDS Manual' in Table 6-2 below.

6.14 the Site is located on permeable chalk geology with impermeable London Clay Formation bedrock to the north. This change in permeability results in the emergence of several springs in the vicinity of the Site.

Type:	**Infiltration Devices (Source Control)**
Constraints:	High potential groundwater with nearby chalk within the Site make infiltration unfeasible.
Opportunities:	There are no opportunities for infiltration on the Site.
Type:	**Lined Permeable Paving (Source Control)**
Constraints:	Infiltrating permeable paving would not be possible but shared surfaces and parking areas can be utilised as lined permeable paving for treatment and attenuation.
Opportunities:	Permeable paving can be used in order to provide additional water attenuation and a storage of treatment before discharging into the nearby watercourse.
Type:	**Rainwater Harvesting (Source Control)**
Constraints:	The benefit of rainwater harvesting on a specific design storm event cannot be quantified due to the availability of storage within the structure.
Opportunities:	Opportunities in amenity areas to provide harvesting features such as raised planters and water butts exist. It would be difficult to quantify storage contribution, and therefore these features are not included within calculations as a part of this surface water management strategy.
Type:	**Swales, etc. (Permeable Conveyance)**

Constraints:	In order to provide practicable attenuation benefits 1:3 side slope swales tend to require a significant land requirement.
Opportunities:	There are no opportunities to incorporate swales into the development due to spatial constraints.
Type:	**Attenuation Basin / Ponds (end of pipe treatment)**
Constraints:	Significant land requirement.
Opportunities:	There are no opportunities to provide attenuation basin within the Site due to spatial constraints.
Type:	**Attenuation Tanks (end of pipe treatment)**
Constraints:	It is recommended that attenuation tanks are installed above the groundwater table, because groundwater pressure significantly increases lateral loads on the walls if the tank. Where a storage tank has to be installed either close to or below the groundwater table, the possibility of floating should be prevented.
Opportunities:	Geo-cellular storage attenuation is considered to help reduce flow rates from the Site by providing attenuation storage. A flow control structure (pump) will be required to constrain the rate of water discharged from the tank.
Type:	**Proprietary SuDS – Downstream Defender (end of pipe system.**
Constraints:	None.
Opportunities:	Could be used to improve the quality of surface water discharge offsite if required.

Table 6-2: C753 SuDS Management Train, Site Assessment

6.15 After consideration of the CIRIA C753 approach the most viable SuDS option for the development Site is considered to be a combination of lined permeable paving, shallow geo-cellular attenuation tanks and above ground pond features. This will provide the necessary storage and treatment for up to the 1 in 100-year storm event including an allowance of 45% for climate change.

Pre and Post Development Impermeable Area

6.16 The planning redline boundary equates to approximately 1.546ha of which 6.4% is considered existing hardstanding areas. The redevelopment proposals will increase the impermeable area across the Site through the introduction access roads and an office building.

6.17 Refer to the Table 6-3 for a comparison of pre and post development areas.

	Site Area [ha]		Percentage Impermeable Area
	Impermeable	Permeable	
Pre-Development	0.099	1.448	6.38%
Post-Development	0.576	0.971	37.18%

Table 6-3: Permeable and Impermeable Areas for Pre and Post Development

Proposed Discharge Rates

6.18 In line with the principles of integrated Construction Industry Research and Information Association (CIRIA) Sustainable Drainage System SuDS Manual (C753), it is desired to achieve Greenfield runoff rates from the site and ensure that surface water run-off is managed as close to its source as possible. It is proposed to discharge at a maximum rate of 5.4 l/s (equivalent to Qbar) for all storm events (up to and including the 100 year plus a 45% allowance for climate change). This provides betterment to all existing storm events and is also lower than the higher order Greenfield rates.

6.19 Table 6-4 below highlights the existing and proposed surface water runoff discharge rates for the site under various rainfall events. Refer to Appendix D for existing surface water runoff calculations.

Return Period	Existing Runoff Rates (l/s)	Proposed Runoff Rates (l/s)	% Runoff Reduction
1 in 1 year	13.98	2.3	-83.55
1 in 30 years	31.11	2.3	-92.61
1 in 100 year	39.60	2.3	-94.19
1 in 100 year + 45%	-	2.3	-

Table 6-4: Existing and Proposed Surface Water Runoff Rates

Proposed Attenuation Provisions

6.20 After consideration of the CIRIA C753 SuDS Management Train approach, the most viable SuDS options for this site is a solution of Permeable Paving and

Attenuation Tank.

6.21 The proposal includes one Permavoid Area West, one Permeable Paving area East (#1 and #2 respectively) of the proposed office building, and a Geo-cellular tank, with the Permavoid Area discharging into the Geo-Cellular attenuation tank.

6.22 The Brockhampton Stream bed level at the location of the outfall is at 4.506m AOD with right bank at 7.00m AOD. The site levels at the western side are at approximately 5.02m AOD. To accommodate the system of pipes on site and to discharge to the Brockhampton Stream, the surface water run-off will be restricted to 2.3l/s Greenfield Runoff rates by a pump before discharging via a rising main to the Brockhampton Stream.

6.23 The proposals have been modelled utilising Innovyze Micro Drainage Software to assess the capacity of the different SuDS features.

6.24 A summary of the attenuation requirements, with reference to the drawing 2205900-D01 provided in Appendix E, is provided in Table 6-5 below.

SuDS Reference	Structure Area	Dimension		Contributing area	Depth [m]	Porosity	Volume [m³]
	[m²]	Length [m]	Width [m]	[ha]			
Permavoid Paving #1[1]	1418.87	52.55	27.00	0.289	0.30	0.30	127.70
Permeable Paving #2[1]	1038.53	58.34	17.80	0.106	0.60	0.95	591.96
Road area (included within pipe network)				0.181			
Geo-Cellular Attenuation Tank	300.00	28.00	12.00	-	0.40	0.95	114.00
Total	2591.40	-		0.575		-	833.66

Table 6-5: Proposed Attenuation Provisions

6.25 The storage provisions equate to a total storage volume of 833.66 m^3 to restrict the discharge for all storm events (up to and including the 100 year plus a 45% allowance for climate change) to 2.3 l/s. Refer to the drawing 1919250-D01

provided in Appendix E.

6.26 In addition to the proposed SuDS, opportunities have been considered to include further SuDS features within the landscaped areas of the site. This could include rain gardens, tree pits and raised planters. The final design and incorporation of these features is subject to detailed design and a finalised landscape layout.

Surface Water Quality

6.27 The recommended stage of treatment in terms of water quality would be provided through the aforementioned permeable paving. In line with the SuDS Manual C753 Tables 26.2 and 26.3, the pollution hazard and mitigation indices associated with proposed development are mitigated by the provision of SuDS features.

6.28 On a scale from 0 – 1, 'Commercial Yard & delivery areas' are deemed to have the following pollution hazard indices:

- Total suspended solids = 0.7
- Metals = 0.6
- Hydrocarbons = 0.7

6.29 The SuDS Manual confirms that in England and Wales, where the destination of runoff is to a watercourse then surface water indices should be used for the surface water discharge (Table 26.3 of The SuDS Manual).

6.30 The proposed surface water drainage strategy discharges via a new headwall into a watercourse. Therefore, the use of the surface water indices approach is deemed to be appropriate.

6.31 In terms of pollution control the car parking for the Portsmouth Water office building discharges via porous paving prior to connecting to the new drainage system. The industrial unit's commercial yard and delivery areas are to be protected by Class 1 bypass petrol interceptor. The pollution mitigation assessment is summarised in Table **6-6** below. The pollution removal characteristics of the pollution control features are based on data in CIRIA C753 and data provided by the product manufacturers.

Type of SuDS component	Total suspended solids (TSS)	Metals Hydrocarbons	Metals Hydrocarbons
Class 1 Bypass Petrol Interceptor (Kingspan or similar)	0.4*	0.6*	0.88*
Total	0.4	0.6	0.8
*subject to manufactures details			

Table 6-6: Pollution Mitigation Assessment for the site

6.32 The results in Table 6-7 show that there is a minor residual impact associated with the Total Suspended Solids. However, whilst Pollution Mitigation Index data is not provided in CIRIA C753 for gullies/catch pit manholes, it is anticipated that sumps at the base of the gullies and catch pits will provide a positive improvement that would mitigate the residual impact for the Total Suspended Solids.

Future Maintenance

6.33 Regular inspection and maintenance are required to ensure effective long-term operation of the system. A management company will be appointed to maintain communal areas, landscaping and shared SuDS throughout the development.

6.34 Typical maintenance activities for SuDS components are presented in Table 32.1 of "The SuDS Manual". Table 20.15 of 'The SuDS Manual' presents operation and maintenance requirements for pervious pavements and Table 21.3 presents operation and maintenance requirements for attenuation storage tanks.

6.35 The on-site drainage will be managed by the site management company who will be responsible to maintain any on-site services including drainage. The off-site private drainage is managed by a management company managing the business park.

6.36 See Table 6-7 for management and maintenance strategy.

Drainage Feature	Regular maintenance	Occasional/Remedial maintenance	Monitoring

Manholes and Inspection Chambers	Check for accumulation of debris and silt and clean as necessary. Covers and frames to be checked for damage. Exposed concrete and adjacent surfacing to be checked for cracking and general damage. Check condition of inlet and outlet pipes, flap valves, baffles etc.	Clean as necessary. All manhole and inspection chamber covers and frames to be replaced as necessary. Repair exposed concrete and surfacing as necessary. Repair/rehabilitation of inlets, outlet, overflows, and vents, as required.	Inspect every 6 months or after large storm.
Attenuation tank	Check for accumulation of debris and silt and clean as necessary. Check condition of inlet and outlet pipes and ventilation structures.	Clean as necessary. Repair/rehabilitation of inlets and outlet, as required.	Inspect every 6 months or after large storm.
Pumping Station	Check for accumulation of debris and silt and clean as necessary. Check condition of inlet and outlet pipes and ventilation structures.	Clean as necessary. Repair/rehabilitation of inlets and outlet, as required.	Inspect every 6 months or after large storm.
Permeable paving	Brushing and vacuuming Stabilise and mow contributing adjacent area.	Removal of weed or management using glyphospate applied directly into weeds by an applicator rather than spraying. Remediate any landscaping which has been raised to within 50mm of the level of the paving. Remedial work to any depressions, rutting	Monthly for three months after installation Monthly for three months, 48hrs after large storms in first 6 months

	and cracked or broken blocks considered detrimental to structural performance or a hazard to users.	

Table 6-7: Management and Maintenance Strategy

7. FOUL WATER DRAINAGE STRATEGY

Existing Foul Water Drainage Strategy

7.1 The site is currently undeveloped and such the existing peak foul water flow rates from the site is considered to be 0.0l/s.

Proposed Foul Water Drainage Strategy

7.2 The proposed development will provide office units with the total area of approximately 991.97 m^2.

7.3 Based on the Thames Water Foul Flow Rates Criteria, the peak Foul Flow discharged rate for the proposed development is calculated to be 1.137l/s from the Site. Refer to the Foul Loading Calculations provided in Appendix F.

7.4 It is proposed that foul flows from the development will discharge into the Southern Water foul network along the Solent Road to the existing manhole 1004. The connection will be via gravity subject to confirmation of the invert level of the existing Southern Water sewer; this will be confirmed at the detailed design stage. Refer to the drainage strategy drawing 191925-D01 provided in Appendix F.

7.5 As the proposals result in an increase in the foul water discharge rate, capacity will have to be confirmed with Southern Water through their capacity check process.

8. SUMMARY AND CONCLUSIONS

7.6 Ardent Consulting Engineers has been appointed by Portsmouth Water, to prepare a Flood Risk Assessment (FRA) to support a development at Portsmouth Water owned land to the rear of Portsmouth Water headquarters at West Street, Havant, PO9 1LG.

7.7 This FRA considers the current policy relating to flood risk, including the National Planning Policy Framework and local flood risk policy.

7.8 According to the EA Flood Map for Planning a south and southeast part of the site is located in land designated as Flood Zone 3 and Flood Zone 2 and is shown as undefended. The northeastern corner is shown to be in Flood Zone 1.

7.9 In July 2020, Ardent built a dynamically linked 1D-2D hydraulic model of the Brockhampton Stream and floodplain using FMP (1D) and Tuflow (2D) software based on new cross sectional channel survey data and existing Infoworks model where appropriate. The model options included the removal of the culvert on the Brockhampton Stream, south of Brockhampton Springs. In January 2021, Ardent on behalf of Portsmouth Water submitted a Flood Risk Activity Permit to the Environment Agency (Environmental Permit licence number EPR/PB3294JJ) for mitigation works including the removal of the 2.5m long 450mm diameter cast iron culvert approximately 120m south of the Portsmouth Water Ltd. Headquarters, and associated groundworks on the Brockhampton Stream.

7.10 The works are underway and when completed, the site will remain flood free during the 1 in 100 year plus climate change scenario.

7.11 The site is shown to have a low to high surface water risk of flooding. The low surface water flood risk covers the majority of the site with medium risk being in the central and western side of the site. The high surface water risk is associated with the adjoining watercourse and network of drainage in the area. Following the flood alleviation works mentioned above, the risk from surface water flooding from the site is assessed as low.

7.12 The proposed finished surface and finished floor levels will be raised from current ground levels and that the existing flood risk from groundwater to the development is considered to be low.

7.13 The risk of sewer flooding and flooding from artificial sources to the site is

considered low.

7.14 The sustainable drainage strategy proposes that the maximum surface water discharge rate for all storm events (up to and including the 100 year plus a 45% allowance for climate change) will be restricted to 2.3l/s Greenfield Runoff rates by a flow control (pump) before discharging to the Brockhampton Stream.

7.15 After consideration of the CIRIA C753 approach, the most viable SuDS options for this Site is the use of a lined permeable paving, permavoid and an attenuation tank, equating to a total attenuation volume of 833.66m^3.

7.16 The proposed surface water drainage network within the Site will be designed to contain the critical duration of 1 in 100 year return period storm duration with a 45% allowance for climate change without increasing the risk to the person or property both on and of site.

7.17 The maintenance of all SuDS components will be in accord with the best practices and the CIRIA Manual C753. A private management company will be set up to maintain the surface water drainage network. The name of the Management Company to be advised.

7.18 The peak Foul Flow discharge rate for the proposed development is calculated to be 1.13/s from the Site. Refer to the Foul Loading Calculations provided in Appendix F. As the peak foul rate is higher than existing, the capacity within existing Southern Water network has to be confirmed.

7.19 In conclusion, this FRA demonstrates that the proposals are consistent with the aims of the NPPF and the Planning Practice Guidance to the NPPF along with the aims of local flood risk policy. The Site will not be at significant risk of flooding or increase the flood risk to others.

Appendix A Site Layout and Development Proposals

NOTES

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Subject to Statutory Approvals.

Rev	Description	Chk	Date
P	Planting updated to suit landscape architect and ecologist design	RP	10/08/2023
N	Existing vegetation shown to Solent Road boundary	RP	10/07/2023
M	Minor tweaks to align with consultant information	RP	14/04/2023
L	Landscaping adjusted	RP	15/03/2023
K	Industrial units omitted & sheet title block updated	RP	28/02/2023
J	Pedestrian route markings highlighted in green for clarity-colour to clients choice	ED	18/02/2022
H	bird boxes omitted as more info is on other documents	ED	16/02/2022
G	Parking & white lining amended to highways comments	ED	02/02/2022
F	White lining reinstated	ED	25/11/2021
E	Landscaping between office and medical centre increased	ED	22/11/2021
D	Landscaping updated	ED	04/11/2021
C	White lining added	ED	18/10/2021
B	Eatern path extended	ED	21/09/2021
A	Eastern footpath extended to include crossing & tactile paving indicated to highways request	ED	21/09/2021

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RIBA Chartered Practice

cornisharchitects

Project Title.

SOLENT ROAD
HAVANT

Drawing Title.

SITE PLAN
AS PROPOSED

Drawing Status.

TOWN PLANNING

Scale. 0 5 metres 40

Drawn By.	Scale.	Date.	Chk'd By.
R P	1:500 @ A2	14/10/2020	E D

Drawing No. 23002 - TP - 003

Rev. P

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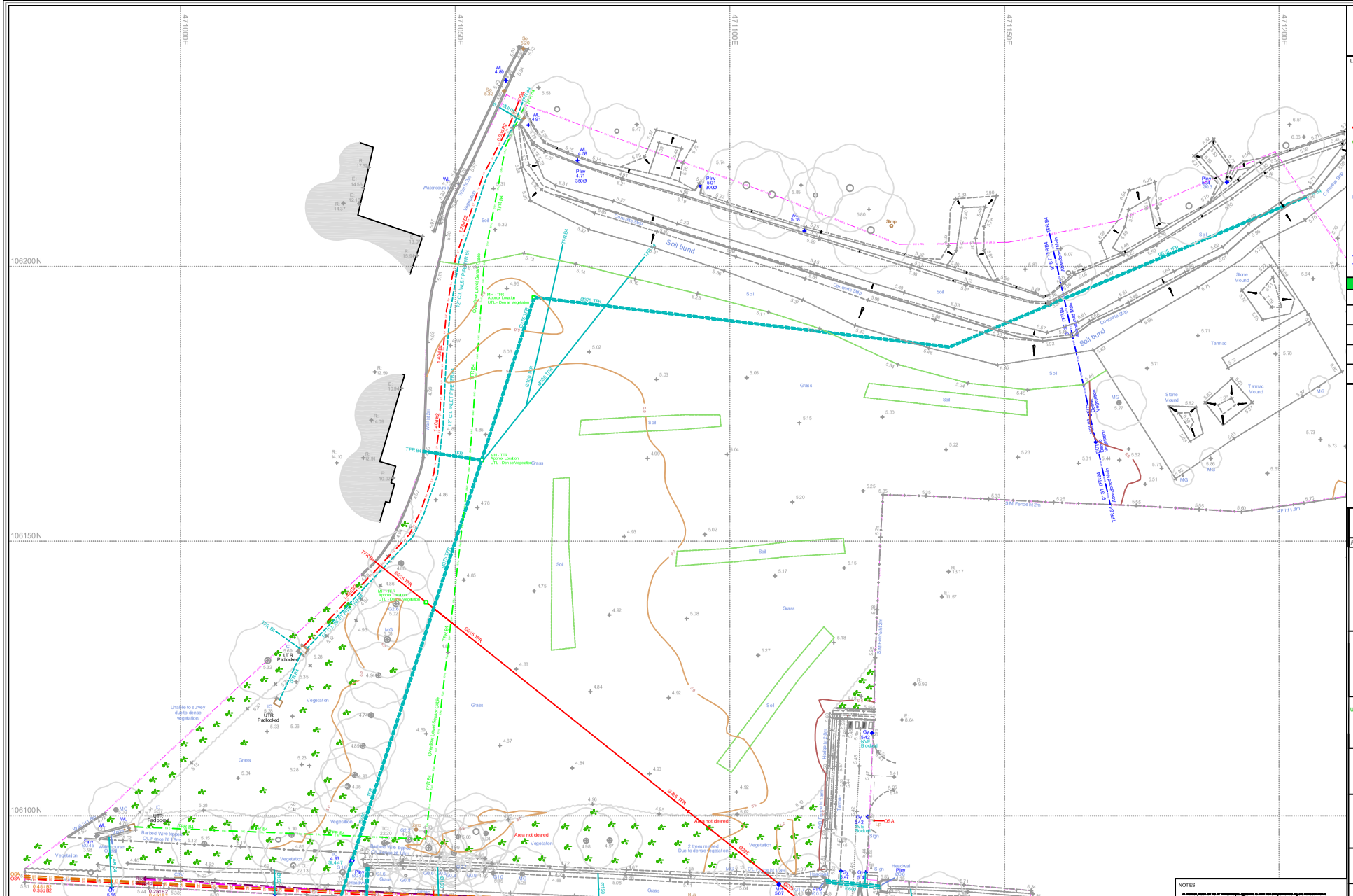
Appendix B Topographic Survey and Southern Water Asset Plan



LEGEND

Buildings
Walls
Kerb line
Edge / Footway
Drainage
Road / Carriageway
Top of Bank
Station and Name
Station Level
Tree / Bush / Sapling
Area of Undergrowth
Woodland
Ridge Level
Eaves Level
Flat Roof Level
Gate
Fence types:
Hedge
Intewoven
Iron Railings
Wire Mesh
Post & Rail
Post & Wire
Chain Link
Wooden Panels
Close Boarded
Steel Palisade

IC Inspect onchamber
Pipe Pipe invert
Gy Gully
Bg Back gully
Dp Down pipe
Pipe Pipe above ground
MH Manhole
WL Water level
Fl Flood light
Lp Lamp post
Tp Telegraph post
Ep Electricity pole
T Traffic light
Bus Bus stop
Sv Stop valve
St Stop tap
Er Earth rod
Wm Water meter
Gas Gas valve
Av Air valve
IC2 Unidentified inspection
Wo Wash out
Re Rodding eye
BB Beacon
CTV Cable tv
Mkr Marker post
Gmk Gas meter post
Sv Sluice
Fh Fire hydrant

Bo Bollard
Bb Bollard
Rb Rubbish bin
Vp Vent pipe
Gl Ground light
Llbx Letter box
Stump Tree Stump
Sty Stile
IFL Internal floor level
THL Threshold level
Sp Sign post
TH Trashcan
BH Barrier
ELC Electric
BT British Telecom
Cbox Control box
TT Textile
BP Brick paved
CPS Concrete paving slabs
CVR Cover
Rwall Retaining wall
TWL Top of Wall Level
TCL Tree canopy level
Gr Girth
MG Mast gate
IC Inspection chamber
CL Cover level
IL Invert level
UTL Unable to locate

PAS128 : 2014

SIX PAS 128 CATEGORY	QUALITY LEVEL	CRITERIA USED IN THE PRESENTATION OF DATA SET 1 (ROAD)
TYPE B - DETECTION	QL-B	A TOTAL OF THE SEVEN 1 MILE B LINE SUGGESTED TO CARRY OUT TYPE B DETECTION WERE SELECTED. THESE FOR A TOTAL OF 5.1 KM OF B LINE DETECTED ROUTE. (NOTE DETECTION PER MILE)
	QL-B	ATTENTION OF THE USER IS DIRECTED TO THE FACT THAT ONLY 1 MILE OF TYPE B DETECTION WAS CARRIED OUT. (ONLY 1 MILE OF B LINE DETECTION WAS CARRIED OUT IN THIS PROJECT. (NOTE DETECTION PER MILE)
	QL-B	A TOTAL OF 1 MILE OF TYPE B DETECTION WAS CARRIED OUT ON THE ROAD. (ONLY 1 MILE OF B LINE DETECTION WAS CARRIED OUT IN THIS PROJECT. (NOTE DETECTION PER MILE)
	QL-B	A TOTAL OF 1 MILE OF TYPE B DETECTION WAS CARRIED OUT ON THE ROAD. (ONLY 1 MILE OF B LINE DETECTION WAS CARRIED OUT IN THIS PROJECT. (NOTE DETECTION PER MILE)

DISCLAIMER

Whilst every effort has been taken in the preparation of this drawing, the original land marks/apparatus configuration may have been altered since the surveying was produced. The user shall make further enquiries and investigations to satisfy himself as to the accuracy of this drawing and position of the apparatus. The exact positions of the apparatus should be verified by the use of suitable detection devices and safe digging practices in accordance with HSG47, further advice on the location of apparatus should be recommended by the owner. No representation is made by Greenhatch Group, its agents or servants as to the accuracy, completeness, and sufficiency or otherwise of this drawing and the position of the apparatus.

All apparatus shall be treated as live unless proved otherwise by the owner. It is the users responsibility to ensure that the information on the location of apparatus is provided to all persons (either direct labour or contractors) working in proximity to the apparatus.

Rev	Date	Description	Drawn	G. Ref.

greenhatch group

- Topographical Surveys
- Site Engineering
- Utility / CCTV Surveys
- Measured Building Surveys
- 3D Laser Scanning
- Revit & BIM Models

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Regents Park
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CLIENT
Chancerygate Group Ltd

PROJECT
Solent Road, Havant, PO9 1DQ

TITLE
Utility Survey

SCALE	DATE
A2@ 1: 500	July 2019
DRAWN	QUALITY REF
RW	GH5411

Level datum	See note
Grid orientation	See note
Job number	34028
Drawing No.	34028_T_UG
Rev.	0

Comments
This plan should only be used for its original purpose. Greenhatch Group accepts no responsibility for this plan if supplied to any party other than the original client.
All dimensions should be checked on site prior to design and construction.
Drainage information (where applicable) has been visually inspected from the surface and therefore should be treated as approximate only.

Notes:

NOTES

In all cases please call the JFF first before you dig service to each and every premises any 6 weeks minimum 0800 777 4000
Always consult utility plans

1. Greenhatch Group cannot guarantee that every underground utility has been identified, although every effort has been made to accurately identify the utility plant underground detail. It is recommended that this information should be obtained from the relevant authority, this is not within our remit.
2. Greenhatch Group cannot be held responsible for any eligible connections between structures unless permission to do so has been given by the owner.
3. Greenhatch Group cannot guarantee that all utility plant has been identified, although every effort has been made to accurately identify the utility plant underground detail. It is recommended that this information should be obtained from the relevant authority. Water authorities have been added from Ordnance Survey MG. Telecoms information is approximate.

UTILITY LINE TYPES

Air Line		Fuel Line	
British Telecom		Gas Line	
British Telecom Overhead		Geophysics	
CATV / Cable Television		GPR Line	
Communications Cable		Heating Pipes	
Drainage - Combined Water		Lifeline Etc	
Drainage - Foul Water		Oil Pipe	
Drainage - Storm Water		Racing Mast	
Earth Cable		Telecom	
Empty Duct		Traffic Light Signals	
Electric AC Mains		Unknown	
Electric Low Voltage		Vapour Recovery	
Electric High Voltage		Water Line	
Electric Overhead		Water	
Non-ferrous		Trench Box	

UTILITY SURVEY INFORMATION

Combined Manhole		Unable to Survey	UTS
Depths Top of Service (m)	0.4 Bd	Unable to Make Level	UTB
End of Trial	EOT	Unable to Trace	UTT
Inferred Run	INR	Assumed Rate	AR
Invert Level	IRL	Assumed Connection	ACC
Taken From Records	TFR	Stand Connection	SC
Off Site Location	OSA	Not Visible Bd	NVB
Bore Hole	BD	Not Open Visible	NOV
Not Found	NF	Not Depth Indicated	NDI
Not Found and	NAD		
Unable to Survey		GPR - Anomaly	
Unable - Blocks		Multiple Connections	

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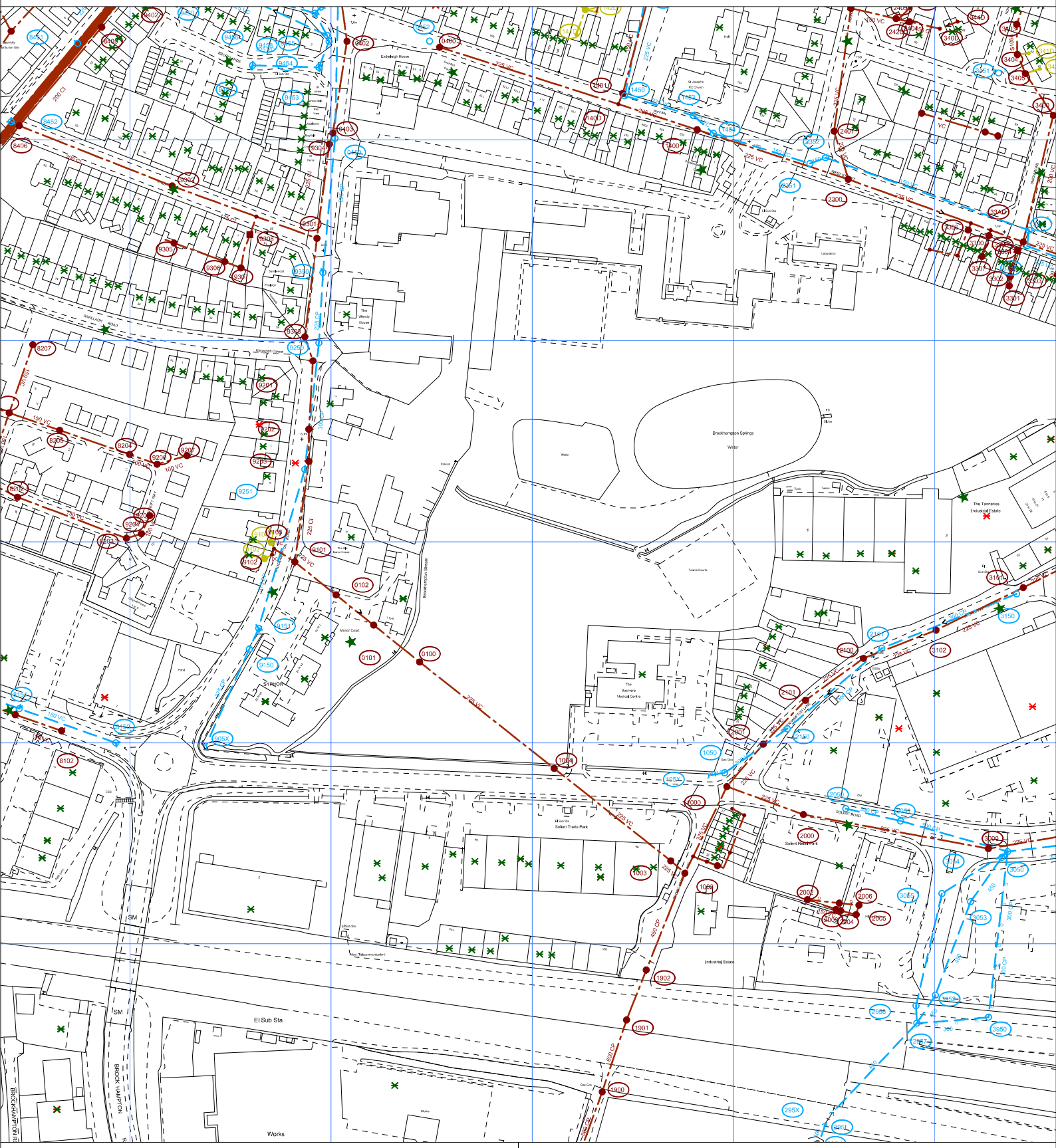
SOUTHERN WATER



The positions of pipes shown on this plan are believed to be correct, but Southern Water Services Ltd accept no responsibility in the event of inaccuracy. The actual positions should be determined on site.

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Southern Water

O.S. REF: SU7106SW	Scale: 1:2500	Printed By: ngravik	Date: 11-11-2021
Screen Print		Southern Water MapGuide Browser	
WARNING: BAC pipes are constructed of Bonded Asbestos Cement		Requested By:	
WARNING: Unknown (UNK) materials may include Bonded Asbestos Cement			

N

Appendix C Ardent hydraulic Model Report, January 2020, (ref: 191920-04) and Flood Risk Assessment – culvert removal (FRAP), July 2020 (ref: 191920 – 07)

HYDRAULIC MODELLING NOTE

Prepared on behalf of Portsmouth Water

ARDENT | CONSULTING ENGINEERS

Date : 13 January 2020

Project : Solent Road, Havant – Hydraulic Modelling Note

Project Ref : 191920

Report Ref : 191920-04

Report Title : Hydraulic Modelling Note

DOCUMENT CONTROL

REV	ISSUE PURPOSE	AUTHOR	CHECKED	APPROVED	DATE
-	For Approval	JE	JE	BC	13-01-20

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1.0 INTRODUCTION

Ardent Consulting Engineers (hereafter referred to as Ardent) has been commissioned by Portsmouth Water to undertake a hydraulic modelling exercise for a proposed commercial development Site on Solent Road Havant, centred at National Grid Reference SU 71091 06157. The nearest postcode to the Site is PO9 1DQ (refer to **Figure 1** below).

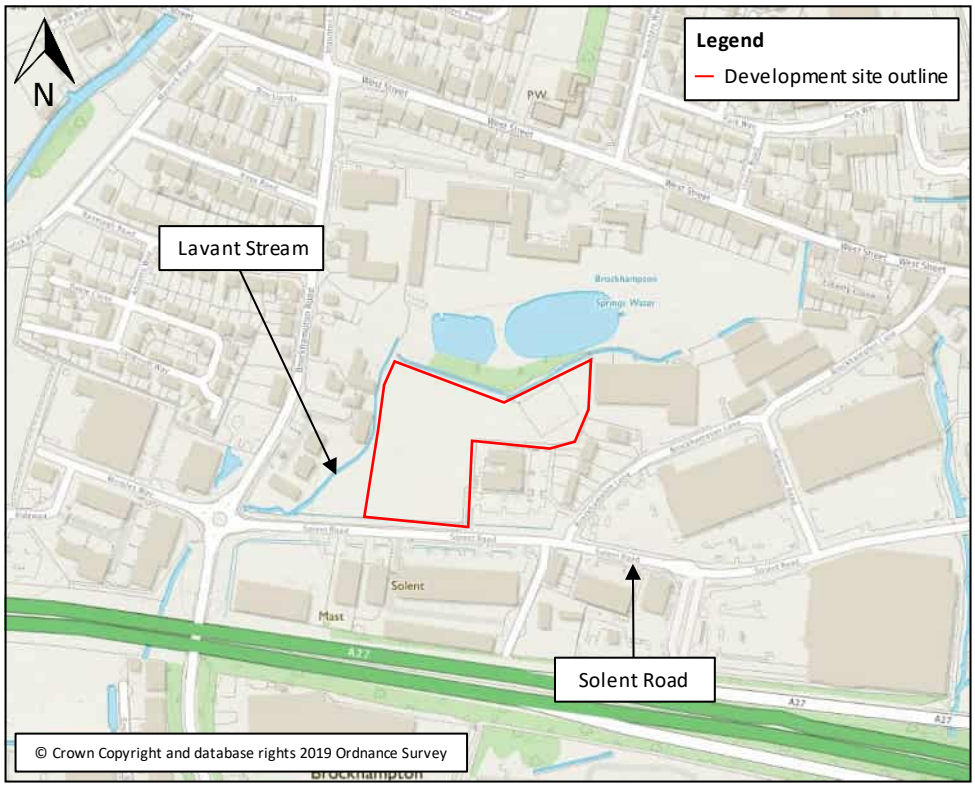

Figure 1: Site Location

The Environment Agency's online flood mapping indicate that the Site is located within Flood Zone 3 (refer to **Figure 2** below). However, the flood outlines have been derived from a hydraulic model constructed in 2008 using hydraulic modelling software InfoWorks CS and RS. Through consultation with the Environment Agency (EA) it became apparent that the hydrology associated with the model was outdated and would need revising and that also, several structures within the model were not accurately represented or were not included. Therefore, confidence in the modelling outputs and flood outlines was reduced but this represented the best available information. As part of the assessment of flood risk to the

Site it was therefore decided to update the hydrology and make an assessment based on the latest climate change guidance and update the hydraulic model with new survey data.

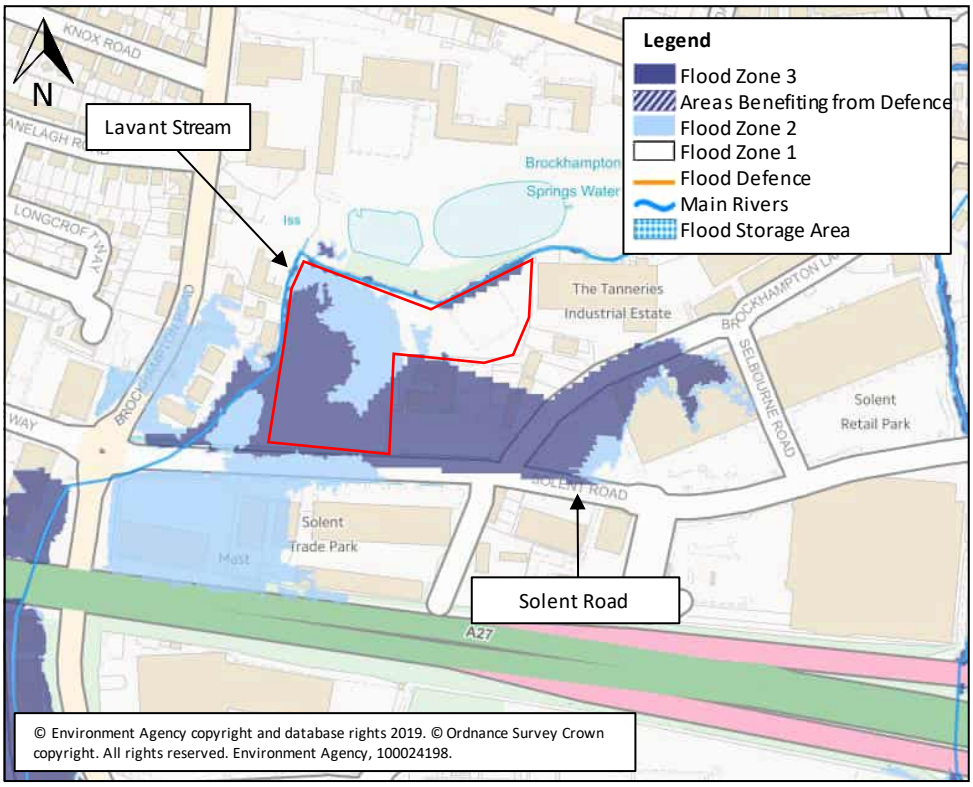

Figure 2: EA Flood Map for Planning

As stated above the original EA model was constructed in 2008 by Atkins using InfoWorks CS and RS which allows for combined modelling of both the sewer and river systems respectively. These software packages have now been superseded by an updated software package. It was considered that as part of this assessment it would not be necessary to model the sewer system in full and therefore the decision was made that a new model would be constructed in hydraulic modelling software Flood Modeller Pro (FMP) incorporating the data from the old InfoWorks models and the newly surveyed channel cross section data.

This report discusses the modelling methodology in further detail as well as presenting a discussion on the modelling outputs.

2.0 HYDRAULIC MODELLING

2.1 Background

The original EA hydraulic model of the Lavant Stream was constructed in 2008 by Atkins using Infoworks CS and RS as part of the Havant Flood Mapping Study.

InfoWorks CS allows for modelling of the urban drainage network or sewer system. InfoWorks RS allows the modelling of the river network. These are legacy software packages and are no longer supported.

For the purposes of this study it was decided to construct a dynamically linked 1D-2D model of the Lavant Stream and floodplain using FMP (1D) and Tuflow (2D) software packages utilising data, river sections and sewer sections taken from the original Infoworks models.

2.2 Hydrology

Fluvial Inflows

As part of this study, the EA advised that the hydrology of the model would likely need updating to include more recent data and would also require an assessment of the latest climate change scenarios.

A hydrology report was prepared by consultant hydrologist Dr Paul Garrad and is included in **Appendix A**. The report identifies that the catchment of the Lavant Stream is divided into the upper, rural, chalk dominated catchment and the lower, urban, clay catchment (approximately 56 km² and 1.5 km² respectively) and that these two distinct catchments influence the hydrology of the system significantly.

Flows for the larger, predominantly rural, chalk catchment were derived using the Flood Estimation Handbook statistical method. Flows for the smaller, urban, clay catchment were derived using the ReFH method. Peak flows are included within the hydrology report in **Appendix A**.

The hydrology of the Lavant Stream is complex within the urban area of Havant. As with most urban catchments, runoff is contributed to the stream at multiple points along its reach from the surrounding urban sewer system and surface water network. The Lavant Stream is also characterised by the presence of several long culverts as it flows through the town centre. In addition, the main channel divides into two separate watercourses upstream of the Site adjacent to Park Road North. The bypass channel, as it's known, flows south adjacent to Park Road South and towards the estuary. The other channel flows westwards and southwards in culverted section towards the Site where it is fed by a series of springs at a boundary between clay and chalk geology. At this location the Lavant Stream is sometimes referred to as "Brockhampton Springs".

Upstream of the urban area, a flood relief culvert known as the Lavant Link Pipe is present. This structure is designed to transfer flows from the Lavant Stream to the neighbouring Hermitage Stream during peak flows.

Due to the complex nature of the urban hydrology outlined above, it was considered that it would not be appropriate to apply the urban hydrology to the model as a single inflow at the upstream of the model reach. Instead, the urban hydrology has been divided and applied incrementally along the urban reach based on the urban subcatchments as defined in the original EA Infoworks CS model.

In accordance with the EA's latest guidance, an assessment of the impact of climate change has been taken into consideration by increasing fluvial and sewer flows as well as the tidal boundary levels. Suitable allowance for increased river flow due to climate change were considered based on the EA's February 2016 guidance.

For more vulnerable residential developments in Flood Zone 3 the 'higher central' allowance is used and for less vulnerable commercial developments the 'central' climate change allowance is required and this should be considered for the lifetime of the development.

The proposed development Site is located in the South East Region and is intended for commercial development. The central allowance is therefore appropriate in this instance, however as a conservative assessment the higher central allowance has been used in this study i.e. the 1 in 100 year plus 45% event.

Tidal Boundary

The Tidal boundary was updated based on the East Solent Tidal Model built by JBA in July 2018. The model domain covering the area of interest is that of the Hayling Island model and the closest node to the Site of interest is BNDRY_5. The remaining nodes are located further east and south away from the Site of interest.

The 1 in 2 year climate change tidal curve was used in the model. The 2 year present day tidal peak level, according to the East Solent Modelling study undertaken by JBA in July 2018, is 2.91m AOD. Guidance from the EA states[1] that the anticipated rise in sea level for the south east of England up to the year 2115 is expected to be 1.21 m. Therefore, this value was used for the Climate Change adjustment. Based on the above the 2 year climate change tidal peak level is 4.11m AOD.

2.3 Data Sources

1D Domain

The 1D model has been constructed using a mixture of different data sources.

The primary data source that has informed the 1D domain is channel survey cross sections collected by Terrain Geomatics in May 2019 of the Lavant Stream. The surveyed reach extends from Farringdon Road down to the estuary but did not include the Bypass Channel and also, due to access restrictions, did not include details of the Lavant Link Pipe.

The modelled reach was supplemented with data from the original EA InfoWorks RS model. Cross sectional data was extracted and incorporated to the FMP model extending the reach approximately 600 m upstream of Farringdon Road as well as at other selected locations

Cross sections for the Bypass Channel adjacent to Park Road North were also extracted from the RS Model and incorporated into the FMP model. Details of the Lavant Link Pipe were extracted from the CS model.

[1] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#future-flood-risk-management

Observations and measurements of additional structures and features were also made during a walkover of the Site and modelled reach.

Further details regarding the control structure immediately downstream of the inlet to the Lavant Link Pipe at Crossland Drive were obtained through consultation with the EA (refer to **Appendix B**). The consultation established that a penstock is present downstream of the inlet which restricts flows during peak events and elevates the upstream water level. This enables flow to enter the Lavant Link Pipe which is subsequently transferred to the Hermitage Stream catchment to the west.

Due to access restrictions, the surveyors were unable to collect data of this structure directly. Therefore, the details supplied by the EA represent the best available information of this structure. The penstock was represented in the model using two orifice units with assumptions made on the dimensions of the structure based on the photograph provided by the EA in **Figure 3** below.

Figure 3: Penstock control structure downstream of Lavant Link Pipe

<u>2D domain</u>

The floodplain has been represented within the 2D domain of the model using LiDAR data. 1m resolution LiDAR data of the study area was obtained from the EA and incorporated into the hydraulic model.

OS OpenMap Local shapefile data was obtained from Ordnance Survey. This was then used to inform the 'materials' file within Tuflow. The 'materials' file allows for a Manning's 'n'

roughness value to be applied to the floodplain.

Together, the LiDAR data and 'materials' file allow for an accurate representation of over land flow paths throughout the 2D model domain.

3.0 MODEL RESULTS

The Ardent FMP hydraulic model of the Lavant Stream was run for the 1 in 100 year and 1 in 100 year plus 45% climate change scenarios. These are presented in **Figure 4** and **Figure 5** below against the original EA outlines (note the EA climate change option has been run with a 20% uplift in flows rather than the 45% central allowance simulated by Ardent).

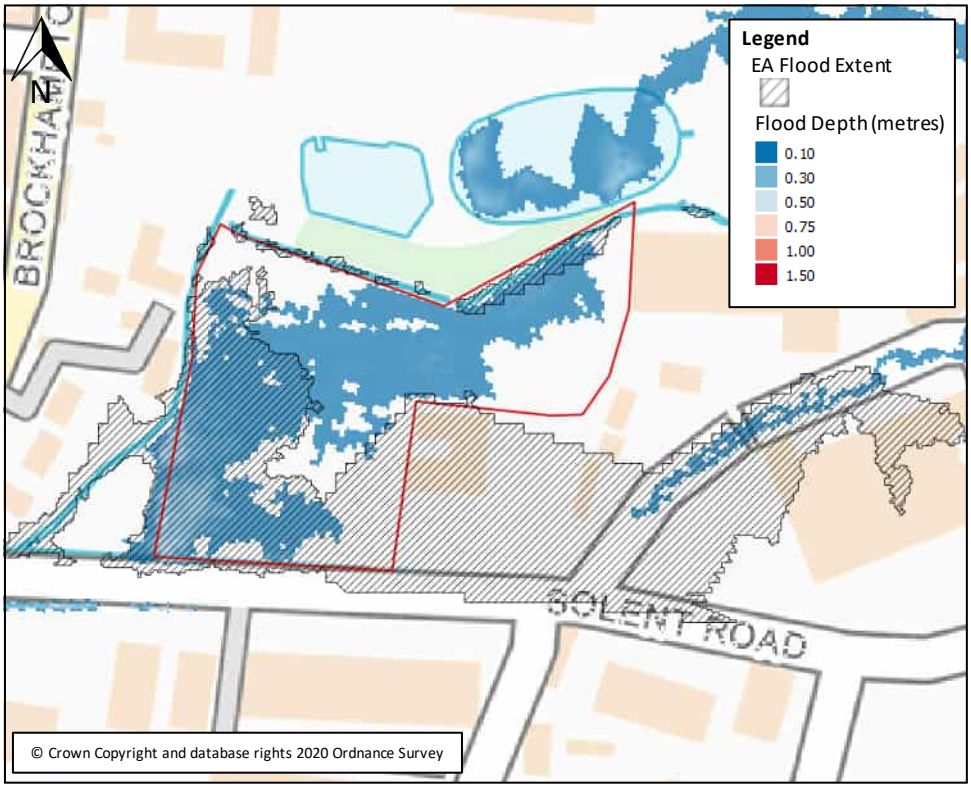

Figure 4: Comparison of the Ardent and EA baseline 1 in 100 year flood extents

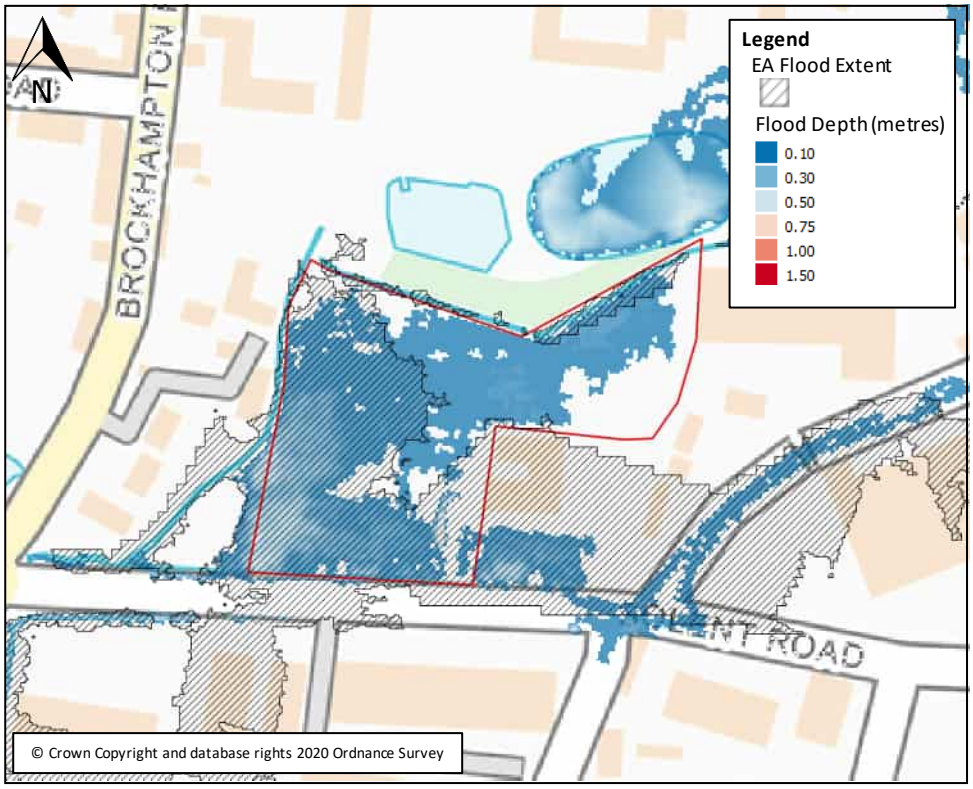

Figure 5: Comparison of the Ardent and EA baseline 1 in 100 year climate change flood extents

Figure 4 shows that the proposed Site becomes flooded during the 1 in 100 year event. The flood extent is larger than the original EA extent. The EA outline suggests that flood water is coming out of bank on the Lavant Stream on the western boundary of the Site as the watercourse flows southwards. However, analysis of aerial photography and site visits have confirmed that the presence of a 2.0 m high wall running the length of the channel at this location prohibits any water from coming out of bank. Further interrogation of the EA model indicates that this wall has not been included within the model. The EA outputs are therefore misrepresentative.

The EA were consulted regarding their modelled outputs who stated that the wall has not been included in their model as the Flood Map for Planning does not take into account the presence of flood defences (despite the wall not being a formal flood defence).

In the Ardent outputs, the 2.0 m wall is included which prevents any out of bank flow occurring at this location. The Site however becomes flooded as a result of the limiting capacity of a 600 mm diameter culvert on the northern boundary of the Site. This constriction

results in water levels becoming elevated upstream of the culvert and spilling over the left bank of the watercourse. This forms a shallow flow path across the Site (less than 100 mm depth) with water propagating westward. Water is unable to re-enter the watercourse in the Ardent model as the 2.0 m high wall is included. Instead, flood water flows south where a drainage ditch is present along the southern boundary of the Site adjacent to Solent Road. This ditch, and a series of culverts, serve to convey flood flows away from the Site and back into the Lavant Stream downstream of the Site.

Figure 5 also shows that the development Site becomes flooded during the 1 in 100 year plus 45% climate change scenario. The EA climate change outline also shows a large portion of the Site to be flooded but again this is a consequence of flows coming out of bank adjacent to the western boundary. As with the 1 in 100 year event, in the Ardent outputs, flows are coming out of bank along the northern boundary.

Ardent have undertaken additional hydraulic modelling runs in order to test potential mitigation options and remove the risk of flooding to the Site.

In the first instance, it was proposed to remove the limiting 600 mm diameter culvert on the northern boundary of the Site. In addition, it was proposed to lower elevations of the right bank adjacent to the culvert to provide additional attenuation and improve the conveyance capacity of the watercourse due to the increase in peak flows due to the removal of the culvert. The results of the proposed 1 in 100 year event are shown in **Figure 6** below. An illustration of the proposed bank works is provided in the cross section in **Figure 7** (not to scale).

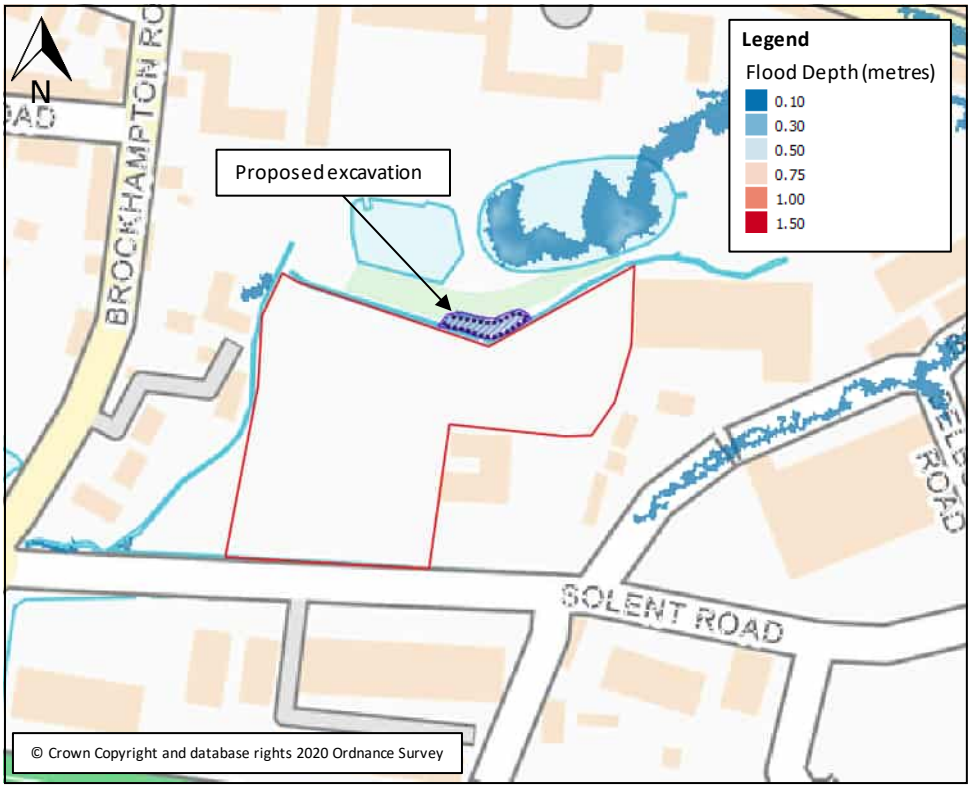

Figure 6: Ardent 1 in 100 year flood extent with proposed mitigation

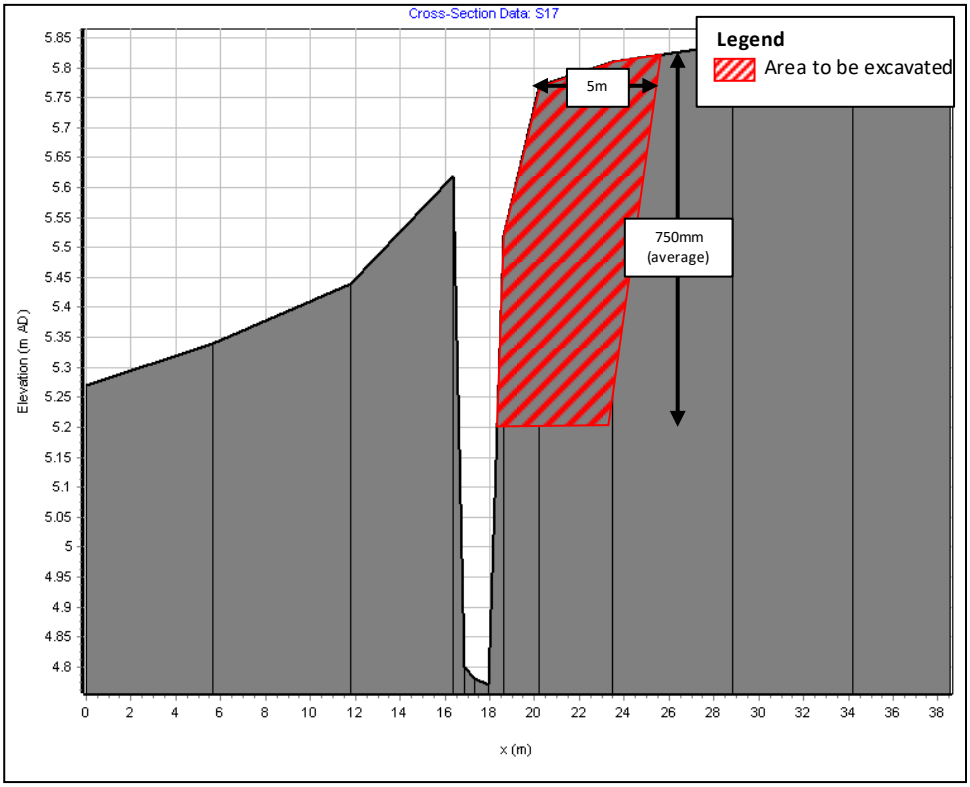

Figure 7: Cross section at culvert location showing proposed ground works (not to scale)

As can be seen in **Figure 6**, the proposed mitigation measures of removing the culvert and lowering the right bank have served to remove the 1 in 100 year flood extent from the development Site. The proposed mitigation measures would therefore remove the Site from fluvial Flood Zone 3.

The right bank has been lowered to an elevation of 5.2 m AOD along an approximately 40 m reach extending 5 m from the original top of bank mark. On average, approximately 750 mm depth of material would be excavated along this reach although actual depths would vary from approximately 500 mm to 900 mm. The estimated volume of material that would need to be excavated is 150 m³.

The model was also run for the 1 in 100 year plus 45% climate change scenario adopting the measures described above. However, the model results continue to show the Site becoming flooded in this scenario due to the increased volume of water in the system. In order to improve this, Ardent increased the length of right bank to be lowered to 5.2 m AOD.

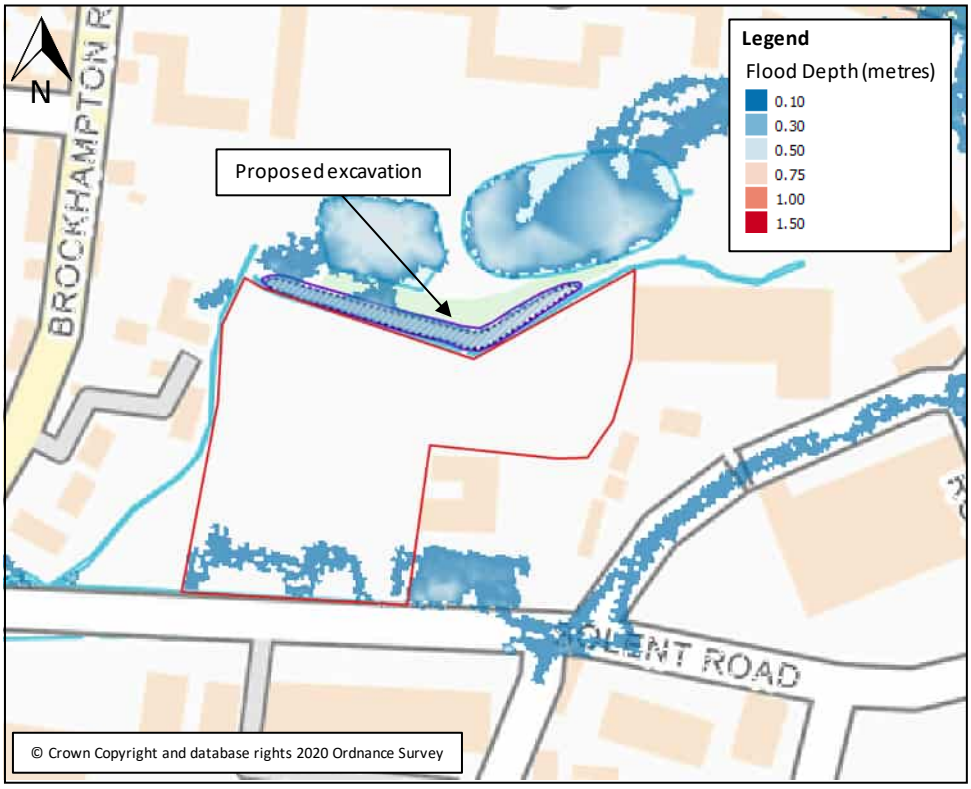

Figure 8: Ardent 1 in 100 year plus 45% climate change flood extent with proposed mitigation

Figure 8 above shows that by increasing the length of right bank to be lowered to 145m, this provides sufficient additionally channel capacity to prevent any out of bank flows occurring on Site.

Note that the flooding to the south of the Site is as a result of a flow path arising offsite. Depths are shallow, typically less than 100 mm. A series of ditches and culverts are present at this location and it is expected that in reality these would convey this flow path. The flood extent shown here is as a result of a poor representation of the ditch within the model which can be refined at a later date. It is considered that any remaining flooding associated with this flow path can be readily mitigated as part of any planning submission.

The volume of material needed to be excavated along the northern bank of the Lavant Stream to mitigate against the 1 in 100 year plus 45% climate change scenario is estimated to be approximately 525 m^3. Again, this is based on an average 750 mm depth of material being taken 5 m from the existing top of bank.

The combination of culvert removal with extended bank elevation is therefore capable of mitigating flooding from the Lavant Stream in the 1 in 100 year plus climate change event. Despite the provision of attenuation through lowering the right bank, removal of the culvert results in a slight increase in flows downstream of 0.25 m^3/s. As a result of this additional flow, there is a slight increase in flood risk downstream which this results in a minimal volume of flood water coming out of bank upstream and downstream of the culvert under Brockhampton Way. However, this flood water does not directly impact any property or functional areas. It should be noted that every effort was made to try and minimise this slight increase in flood extent however the resultant extents are considered to be acceptable.

4.0 CONCLUSIONS AND RECOMENDATIONS

Ardent Consulting Engineers has been commissioned by Portsmouth Water to undertake a hydraulic modelling exercise for a proposed commercial development Site on Solent Road, Havant.

The purpose of this modelling task was to provide an accurate and up to date assessment of flood risk to the proposed development site compared to the original EA model prepared in 2008.

The dynamically linked 1D-2D model has been prepared utilising new channel survey cross section data combined with data from the original EA model. This work picked up new structures and structures not represented within the original models.

A new hydrological assessment has been carried out utilising the latest data and methods.

The model has been simulated for the 1 in 100 year and 1 in 100 year plus 45% climate change (higher central allowance).

The updated modelling shows that the development Site beomces flooded during the 1 in 100 year event with a shallow flow path forming across the Site due to the limiting capacity of a 600 mm diameter culvert on the watercourse adjacent to the northern boundary of the Site. This is also true of the 1 in 100 year plus climate change event.

These outputs make an improvement on the EA modelling which also showed large parts of the Site as flooded during the 1 in 100 year event. However, these extents were misrepresentative due to the absence of a 2.0 m high wall in the EA model which prohibits out of bank flows at this location. The EA's Flood Zone 3 is consequently misrepresentative of flood risk at the Site.

Ardent have proposed mitigation measures aimed at removing flood risk from the Site for the two modelled storm events. The proposed mitigation involved removing the 600 mm diameter culvert and carrying out ground works to lower the right bank of the watercourse and thereby attenuate the increase in flows and minimise any potential increase in flood risk downstream.

It is estimate that in order to mitigate the risk of flooding in the 1 in 100 year event

approximately 150 m³ would need to be excavated from a 40 m length of the northern bank adjacent to the culvert. In order to mitigate the risk of flooding during the climate change scenario, approximately 525m³ of material would need to be excavated along a 140m reach of the watercourse.

Appendix A
Hydrological Assessment

Flood Hydrology

Lavant Stream,
Solent Road, Havant, Hampshire

May 2019

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Flood Hydrology
Lavant Stream at Solent Road, Havant, Hampshire

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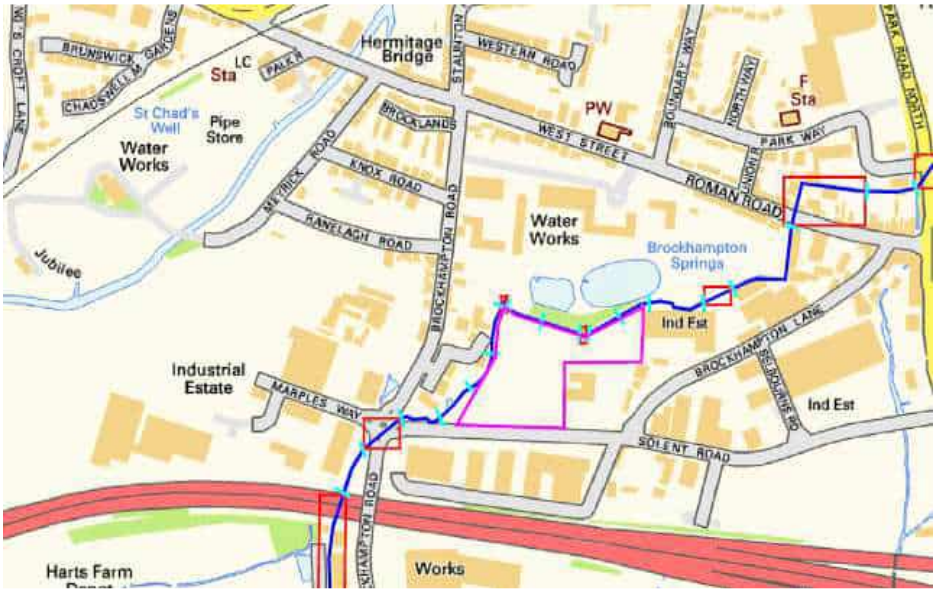
1 INTRODUCTION

1.1 Site Location

As part of a Flood Study for a site on Solent Road in Havant (Figure 1.1) flood levels are required for the Lavant Stream using a hydraulic river model. The EAs existing model of this watercourse dates from 2008 and the EA has suggested that the flood hydrology should be updated to include more recent events and updated methods. The revised and updated flood hydrology is therefore considered in this report.

Figure 1.1 Proposed Development Site and Flow Estimate Location



The Lavant Stream drains a 55km² mainly rural Chalk catchment upstream of Havant but the lower area lies on impermeable clay and drains urban areas of the town which discharge into the watercourse at numerous outfalls. The 2008 flood study suggested the interaction between flows from the upstream rural catchment and the urban drainage system is the prime cause of local flooding and any flood study should consider the interaction of these two components.

For this complex catchment the hydrological response will therefore be a function of:

- The baseflow dominated upper Chalk catchment with a winter high and summer low baseflow and a slow or muted response to rainfall due to the low percentage runoff. However very high peak flows can occur when the catchment is saturated and the percentage runoff may then be higher than the geology would suggest. This can occur after prolonged rainfall events such as occurred in October/November 2000.

- The quick response of the lower Lavant Stream catchment which is predominantly clay and heavily urbanised giving a rapid response to rainfall and with a high percentage and the runoff from these urban drainage systems then discharge into the stream network.

The EAs 2008 report states it is unlikely that a storm event on these two sources individually would result in flooding within Havant but it is when the two types of storm combine that flooding is more likely. This will occur due to high intensity short duration rainfall over the urban catchment following months of heavy rainfall with high river levels due to elevated baseflow on the larger rural catchment.

Flows in this report are therefore considered at two points, at the upstream end of the proposed model at the EAs Leigh Park flow gauge near Crossland Drive which represents the Chalk rural upstream catchment and the downstream of the urban area of Havant, which is in the London Clay, at the flow diversion near Park Way and Solent Way. There is a small difference in the catchment area between these points (Table 1.1) of 1.55km^2 and flows from this lower urban area are considered separately.

Table 1.1 Flow Estimate Locations

ID	Location	Easting	Northing	Area (km2)
Gauge	EA gauge at Crossland Drive	472103	107200	55.96
DS	Flow diversion at Park Way	471550	106250	57.51
Urban	Havant between gauge and Park Way			1.55

The hydrology of this watercourse is also complicated by a flood relief culvert, the Lavant Link Pipe, which diverts flows from the Lavant Stream to the Hermitage Stream when flows are above 0.28m^3/s. The inlet is located downstream of Crossland Drive road bridge and discharges into the Hermitage Stream 850m to the east upstream of Barncroft Way. The Lavant Stream also divides into two channels between Roman Road and Park Way upstream of Solent Road. These issues are considered in the hydraulic modelling element of this study.

1.2 Methodology

Flood flows are provided for a range of return periods, including the 2 year, 20 year, 100 year and 1000 year events using methods detailed in the Flood Estimation Handbook (FEH)[1] and the EA's FEH Guidelines[2]. Flow estimates for extreme events may be quite uncertain hence the approach is to use and compare

- the FEH Revised Statistical Pooling Group approach,
- the Revitalised Flood Hydrograph Method (ReFH) for the full catchment and for the urban area, and
- the single site method if appropriate.

These methods are considered in Section 2 of this report with extension to the 1000 year return period event, a comparison of flood estimates and the addition of an appropriate allowance for climate change are considered in Section 3. Flow from the urban area considered in Section 4.

[1] The *Flood Estimation Handbook,* Centre for Ecology & Hydrology, 1999.
[2] Environment Agency's *Flood Estimation Guidelines*, Technical guidance 197_08, January 2015

2 FLOOD FLOWS - RURAL CATCHMENT

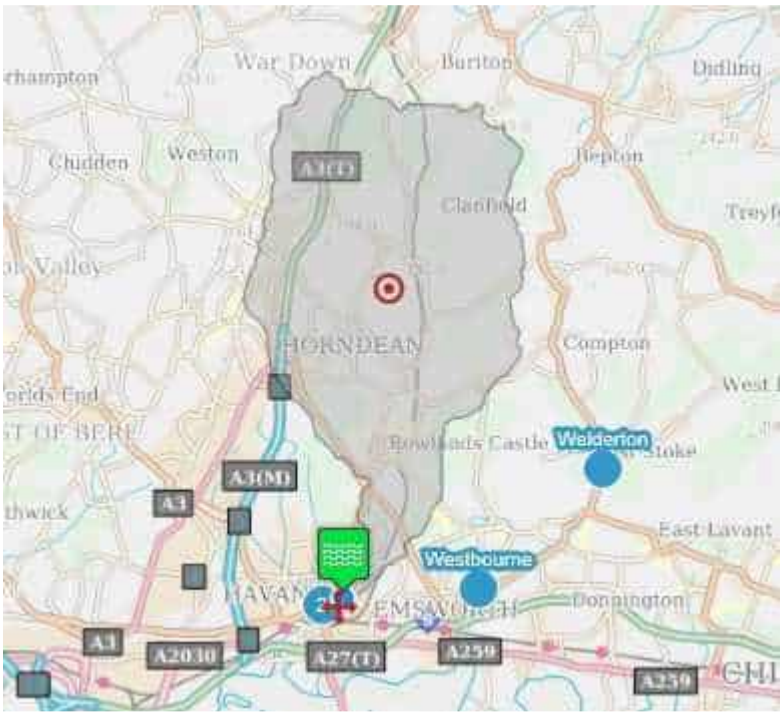
2.1 FEH Statistical Method

As a first approach it is convenient and appropriate to use the FEH Statistical method which is based on FEH Catchment Descriptors (CDs).

2.1.1 Catchment Descriptors

The FEH on-line has been used to provide the catchment delineation at the Leigh Park flow gauge (Figure 2.1) which confirms that the catchment has a simple structure with no lakes, reservoirs or major sub-catchments and a simple flood hydrograph response may be expected. As the catchment is rural FEH methods are considered suitable and can be used to derive flood flows at the required location. The catchment delineation was checked against OS maps and appears reasonable hence a manual adjustment of the FEH catchment area was not undertaken although in Chalk catchments the groundwater catchment may not always coincide with the topographical catchment.

Figure 2.1 Lavant Stream FEH Catchment Delineation at EA Flow Gauge



The FEH catchment descriptors (Table 2.1) show this drainage area is large (55.96km^2) and rural (URBEXT1990 = 0.021), with no lakes or ponds (FARL = 0.999) and with a low percentage runoff (SPRHOST 10.1%) which suggests no obvious reasons for not using the FEH methods for flood estimation. A full definition of these FEH parameters is given in FEH Volume 5. The previous 2008 flood study also noted the low permeability and required a permeable adjustment to the Stas method but this is no longer required with the Revised Stats method and the updated WINFAP 3/4.

Table 2.1 FEH Catchment Descriptors

Parameter	Gauge	DS
AREA	55.96	57.51
FARL	0.999	0.999
PROPWET	0.34	0.34
BFIHOST	0.886	0.872
DPLBAR	10.27	11.3
DPSBAR	89.1	87.5
SAAR	905	900
SPRHOST	10.1	10.99
URBEXT1990	0.0210	0.0293
URBEXT2000	0.0231	0.0521

2.1.2 FEH Index Flood (QMED)

The FEH catchment descriptors defined above are used to derive QMED, the median annual flood (Table 2.2), using the Revised Stats Method QMED equation[3]. The URBEXT2000 is updated to 2019 and the urban adjustment factor (UAF) uses both the original Bayliss method based on SPRHOST and also Kjedsen's updated method with UAF based on BFIHOST (Table 2.2). The EA's FEH guidelines recommend the Kjedsens urban adjusted QMED is used which gives a QMED of 3.461m^3/s at the EA gauging station.

Table 2.2 QMED from Catchment Descriptors

Site	Method	URBEXT 1990	URBEXT 2000	URBEXT 2019	UAF	QMED RURAL(m^3/s)	QMED URBAN(m^3/s)
Gauge	Bayliss	0.0210	0.0231	0.0240	1.084	2.862	3.101
Gauge	Kjedsen	0.0210	0.0231	0.0240	1.210	2.862	3.461
DS	Kjedsen	0.0293	0.0521	0.0541	1.440	3.123	4.498

The QMED-CD at an ungauged site is then adjusted using the ratio between QMED-CD and QMED-Flow data at a nearby local donor gauging station. The EA operate two gauges in the local area at Leigh Park on the Lavant Stream and on the adjacent Hermitage Stream at New Road (Table 2.3).

Table 2.3 EA Gauging Stations near Havant , Hampshire

CEH Ref	Watercourse	Location	Start Date	End Date	No Years	QMED ?	Pooling ?
42025	Lavant Stream	Leigh Park	1981	2002	22	No	No
42017	Hermitage Strm	New Road	10 Feb 1954	30 Sept 2017	51	Yes	No

The National River Flow Archive and HiFlows database (version 7) indicates:

- 42025, Lavant Stream at Leigh Park. A velocity-area station in a trapezoidal section. The rating is poorly defined at low flows and the station is bypassed by flood flows above

[3] *Improving the FEH statistical procedures for flood frequency estimation. CEH Science Report SC050050, July 2008*

3m^3/s. The topographical catchment greatly exceeds the groundwater catchment. The flow records are not suitable for QMED or pooling hence this station is not included in FEH or the HiFlows database. The gauge became ineffective in 2002 due to the insertion of a grill immediately downstream of the open channel site and flow records stopped at this time.

- 42017, Hermitage Stream at Havant. A Velocity area station in a concrete trapezoidal section in a formalised reach with grass berms. The structure is designed to measure up to 14m^3/s and all but exceptional flows are contained with the structure which has only been exceeded a few times since installed in 1954. The bridge downstream may cause some backing up. The theoretical rating is supported by numerous current meter gaugings. The flow records are suitable for QMED as it is gauged above this flow but the rating cannot be validated for higher flows above QMED hence the flow records are not suitable for pooling.

The timescale of this study does not allow for a detailed analysis of the high flow ratings at these two gauging stations but the flow data is considered suitable for QMED at only one of these stations and these flow data are used in the flood estimation process described below.

In selecting a suitable donor gauging station FEH also provides hydrological similarity criteria as follows;

- AREA – a factor of 4 or 5
- FARL – a difference of 0.05.
- BFIHOST – a difference of 0.18
- SAAR – a factor of 1.25
- SPRHOST – difference of 15

A comparison of the catchment descriptors at the potential donor station and at the site of interest (Table 2.4) suggests 42017 is outside the bounds of hydrological similarity in terms of BFIHOST and SPRHOST being located mainly on Clay strata rather than the Chalk hence the Hermitage Stream gauge is not suitable as a donor.

Table 2.4 Catchment Descriptors at Flow Estimate Site and Donor Gauging Stations

Site ID	AREA	FARL	BFIHOST	SAAR	SPRHOST	URBEXT90
42025	55.96	0.999	0.886	905	10.1	0.0210
42017	17.33	0.991	0.245	785	46.0	0.1675

Despite the reservations given above, in terms of flow data accuracy, in the absence of any other stations the Leigh Park gauge is considered as a donor principally as a check. This is based on the flow data provided in the EAs 2008 flood mapping study and as this station closed in 2002 there is no further or additional data to extend this record. A comparison suggests QMED from CDs overestimates that from flow data and that a factor of 0.517 should be applied to the CD estimates (Table 2.5) to match the data at the flow gauge.

Table 2.5 QMED at Donor Gauging Stations (m^3/s)

Ref	QMED-Urban CDs	QMED-AMAX	Ratio
Gauge at Leigh Park	3.461	1.790	0.517

The Revised Stats method requires this donor ratio is further adjusted based on the distance between the catchment centroids but as the flow estimation point is at this flow gauge this adjustment is not required. The adopted QMED at the gauge is therefore 1.79m^3/s (Table 2.6) the same as the recorded flow data.

Table 2.6 Adopted QMED

Site	QMED Rural CDs	QMED-urban	QMED Factor	Adopted QMED
Gauge	2.862	3.461	0.517	1.790
DS	3.123	4.498	0.517	2.326

2.1.3 Flood Frequency Curve

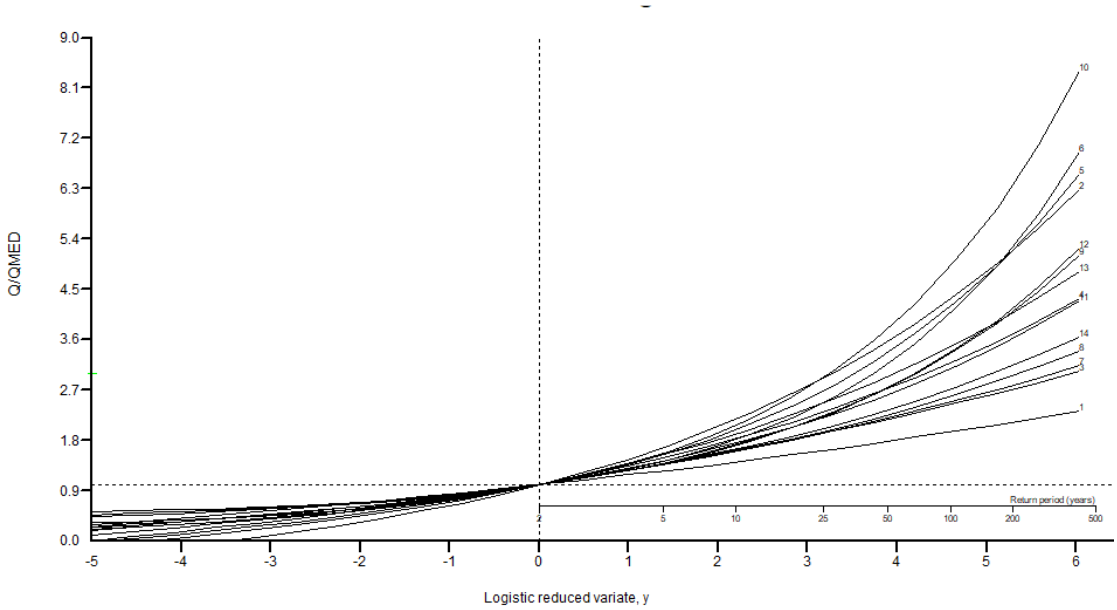
The calculation of a flood frequency curve and peak flows for a range of return periods requires the construction of a pooling group and the fitting of an extreme value distribution to the annual maximum flow data from hydrologically similar sites (pooling group) using WINFAP4.

The initial pooling group contains 14 stations with 513 station years of record and no stations were removed for having less than the required 8 years of data. Examination of the pooling group indicates it is possibly heterogeneous and a review considered optional (H2 = 1.583) but a review of the pooling group suggests no obvious or valid reason to remove any of the component stations. This discordancy arises as several of the component stations (Table 2.7) have relatively steep growth curve (Figure 2.2) with known major flood events (e.g. Doniford at Swill Bridge) and some stations have very flat growth curves but there was no justification for removing any sites from the group.

Table 2.7 Component Stations of Pooling Group – Lavant Stream

Station	Dist	Yrs data	QMED AMAX	L-CV	L-SKEW	Discord
42011 (Hamble @ Frogmill)	0.173	45	8.159	0.170	0.076	1.592
43806 (Wylye @ Brixton Deverill)	0.287	26	1.995	0.387	0.223	2.004
53017 (Boyd @ Bitton)	0.337	44	13.845	0.244	0.094	0.620
41022 (Lod @ Halfway Bridge)	0.362	47	15.900	0.295	0.179	0.581
27095 (Pickering Beck @ Pickering)	0.365	17	8.261	0.311	0.312	0.464
42008 (Cheriton Stream @ Sewards Bridge)	0.380	46	1.350	0.255	0.408	1.291
44011 (Asker @ East Bridge Bridport)	0.380	22	16.200	0.234	0.121	0.879
44003 (Asker @ Bridport)	0.380	14	12.354	0.224	0.170	1.468
76019 (Roe Beck @ Stockdalewath)	0.385	18	41.711	0.236	0.318	1.589
51001 (Doniford Stream @ Swill Bridge)	0.391	51	11.710	0.322	0.387	1.290
42006 (Meon @ Mislingford)	0.408	58	2.947	0.260	0.216	0.418
27059 (Laver @ Ripon Laver Weir)	0.452	40	22.024	0.231	0.334	1.055
20007 (Gifford Water @ Lennoxlove)	0.468	44	16.895	0.321	0.191	0.559
53023 (Sherston Avon @ Fosseway)	0.493	41	7.280	0.229	0.193	0.191

Figure 2.2 WINFAP Component Stations – Lavant Stream



WINFAP4 is often found to provide discordant pooling groups and this arises because it uses the FEH parameters FARL and FPEXT to generate a pooling group, which are measures of flood storage and attenuation, whereas the original WINFAP was based on the soil or geology as reflected in BFIHOST. WINFAP4 will often provide a more discordant pooling group as the shape of the growth curves of the component stations is more likely to be a function of the geology. However, the EA FEH Guidelines require the use of WINFAP4 and this is method is therefore adopted in this report.

Two extreme value distributions are often used on the pooled group data (i) the Generalised Logistic (GL), and (ii) the General Extreme Value (GEV) distribution both fitted to the annual maximum data by the method of L-Moments. WINFAP indicates that in this case the GL distribution provides the best fit to extreme value flood series and this is used to provide the estimated flood flows (Table 2.8). This give a 100 year flood flow at the flow gauge site of 4.85m^3/s. The same growth curves is applied to give flood flows at the downstream location.

Table 2.8 Estimated Flood Flows – Stats Method

Site	Return Period (Years)					
	2	**5**	**10**	**20**	**50**	**100**
Gauge	1.79	2.41	2.87	3.37	4.15	4.85
DS	2.33	2.96	3.44	3.96	4.76	5.48

2.2 Single Site Analysis

The flow data at the Lavant Stream gauging station is not suitable for QMED or pooling as the flow records are inaccurate and hence a single site analysis was not carried out. The 22-year Lavant record is also insufficient to provide confidence for estimated flows at return periods above half the length of record which is to the 11 year return period. The adjacent Hermitage Stream is a mainly clay catchment where the runoff response may be quite different to the

Chalk Lavant Stream catchment and hence these flow records cannot be used as the flood response may be quite different. It is therefore not possible to support the pooling group flood flow estimates with a single site growth curve from a local station with any confidence

2.3 Revitalised Flood Hydrograph Method (ReFH)

An alternative approach to flood estimation is to use flood hydrograph methods. The original FSR/FEH rainfall runoff method (RR) underwent significant modification in 2006 taking advantage of new data and more advanced hydrological modelling techniques since the original method was developed. The improved or Revitalised Flood Hydrograph method (ReFH) retains the overall structure of the earlier FSR/FEH RR approach but with various improvements and hence ReFH is now preferred to RR. ReFH is therefore used to derive peak flows for the specified design events based on the time to peak (Tp) and critical storm duration (Table 2.9), adjusted to be an odd multiple of the selected time step.

Table 2.9 ReFH Time to Peak and Critical Storm Duration

Site	Tp	Cmax	BL	BR	Duration (hrs)	Time Step (hrs)	Critical Dur (hrs)
Gauge	5.41	689.1	65.3	2.232	10.30	0.25	10.25

The derived flows at the Lavant gauge (Table 2.10) show that the ReFH QMED is lower that the Stats Method at 0.70m^3/s whilst the 100 year flow is higher at 5.50m^3/s.

Table 2.10 ReFH Flood Estimates (m^3/s)

Location	Return Period (Years)					
	2	5	10	20	50	100
Gauge	0.70	1.22	1.75	2.49	3.92	5.50

However, the EA's FEH Guidelines advise that ReFH does not perform well on urban or highly permeable catchments (BFIHOST>0.65) and ReFH can give unrealistically large values of Cmax to reproduce the losses and hence often provides unrealistic flows. This is partly because the flood event archive used to develop ReFH was deficient in events on permeable catchments. ReFH can therefore significantly underestimate QMED and overestimate more extreme floods, as shown above. The EA advise ReFH should not be used on permeable catchments and that the statistical method is normally preferred as it is based on fewer assumptions.

2.4 ReFH2

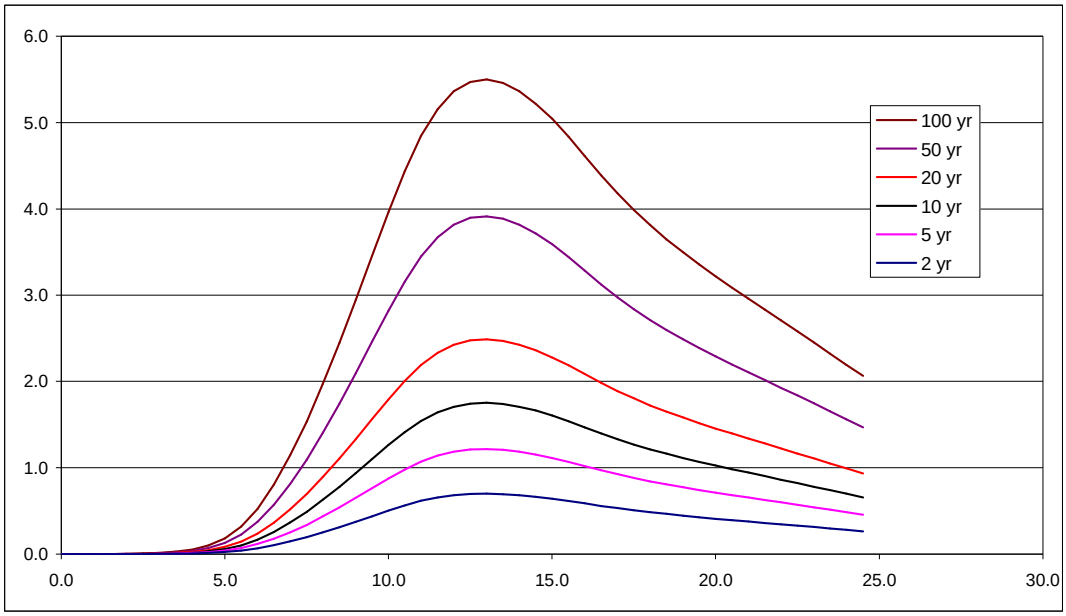
The ReFH method has been updated and ReFH2 includes updated equations, parameters and urban extent values and can use the updated FEH-2013 rainfall. The EAs guidelines recommend that both ReFH and ReFH2 are used until the implications of the ReFH2 changes are understood, which implies the peak flows from ReFH2 should not be used and that these flows are not yet accepted. The assessment of flood flows using this new method may be appropriate for large scale catchment and EA flood risk mapping studies but for a small scale flood studies and FRAs the limited budget and timescales suggest the appraisal of various methods is not appropriate or suitable and this is confirmed by the indicative timescales given in Table 2 of the EAs FEH Guidelines, where a more rapid assessment is required.

In addition the ReFH2 Technical Guidance Document shows the Stats method provides better estimates of peak flows than ReFH1 and ReFH2 when compared to measured QMED flows in terms of standard error and bias and hence the Stats method is always preferred. So even if ReFH2 is tested the estimated peak flows from the Stats method are more robust and would be adopted - the only advantage of ReFH is to provide the hydrograph shape for flood routing if using the hybrid method.

2.5 Hydrograph Shape

The ReFH hydrographs (Figure 2.3) and are typically asymmetrical as they are based on a kinked unit hydrograph. However the Lavant Stream may not provide a typical ReFH shaped response largely due to the mixture of land surface types, urban and rural, and the catchment geology of Chalk and Clay and due to the seasonal baseflow response and variable percentage runoff.

Figure 2.3 ReFH Hydrographs at Leigh Park Flow Gauge



The EAs 2008 report used the Probability Distributed Model (PDM) to provide flood hydrograph shape for the rural areas but due the variability of runoff response it was found that the PDM calibration parameters were not consistent and rather than take the average values from selected flood events the largest November 2000 flood was used to define the PDF parameters. The peak flows from the PDM hydrographs were forced to fit the Stats method, referred to as the hybrid approach, using a scaling factor of 0.491 for the 100 year and 0.471 for the 1000 year.

The shape of the ReFH hydrographs may not be as representative as PDM but as the peak flows are forced to match the Stats method the peak flows and flood levels should be similar. Alternatively, a PDM hydrograph could be exported from the EAs ISIS model so the same shaped hydrograph can be used

3 DISCUSSION

3.1 Extension to the 1000 year

The Statistical method was originally recommended for return periods up to 200 year event and ReFH is not calibrated beyond 150 years and technically these two methods are not suitable for extrapolating to the 1000 year event. The Environment Agency's Flood Estimation Guidelines[2] provide suggestions for calculating extreme floods up to the 1000 year event:

- Using a larger 200 year pooling group in the Statistical method as an intermediate between the more usual 100 year group and the potentially less homogeneous 1000 year although more recently a simple extension of the 100 year has been proposed.
- Use of ReFH although this relies on extending the method beyond the data set and as detailed above this is thought to overestimate flood flows on urban areas.
- Using the ReFH growth factors for the 200 and 1000 year event against the ReFH 100 year which are then applied to the Stats method 100 year peak flow but the same issue of using over estimated flood flows derived for urban areas will apply.

These three methods of extension provide dissimilar results (Table 3.1) due to the steepness of the ReFH growth curve but the simple extension of the Stats method is often preferred and this gives a 1000 year peak flow of 8.08m^3/s.

Table 3.1 Extension of Flood Flows at Leigh Park Flow Gauge

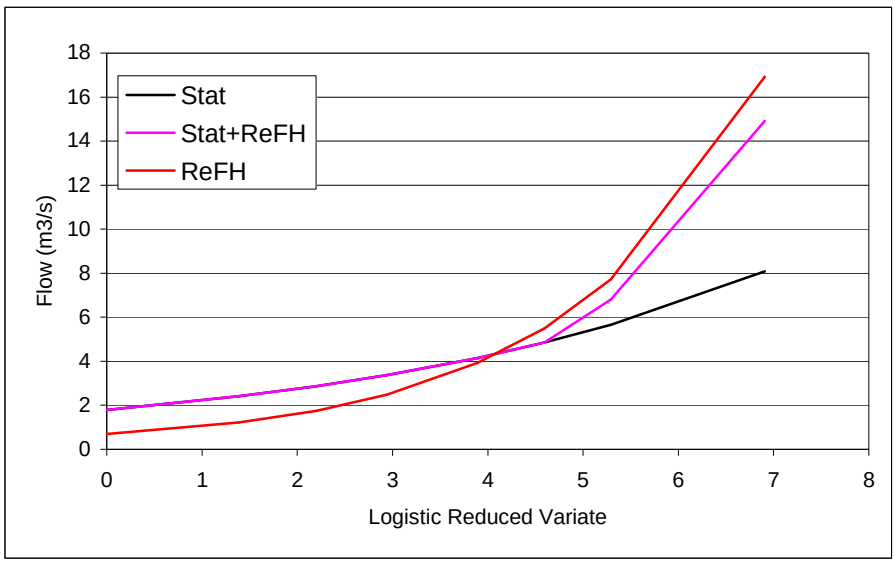
Method	Return Period (Years)							
	2	5	10	20	50	100	200	1000
Stat	1.79	2.41	2.87	3.37	4.15	4.85	5.65	8.08
ReFH	0.70	1.22	1.75	2.49	3.92	5.50	7.72	16.92
Stat+ReFH	1.79	2.41	2.87	3.37	4.15	4.85	6.81	14.92

3.2 Comparison of Flood Estimates

As detailed above QMED is lower and the more extreme flood flows from ReFH are higher than the Stats method (Table 3.1) but there is no justification for choosing either method. The extreme ReFH flows are far higher than the Stats method (Figure 3.1) but without any measured flood or flow data the choice of method is subjective.

The ReFH + Stats method of extension is also far steeper than the pooled growth Stats method curve. As ReFH is not suitable on permeable catchments both this and the ReFH + Stats methods are discounted and the Stats method is preferred.

Figure 3.1 Comparison of Flood Flow Estimates



These flood estimates are compared to the EAs 2008 report which provided a permeable adjusted pooling group and a single site analyses based on the available flow data at the Leigh Park flow gauge (Table 3.2). As the single site was based on just 22 years of flow records, and extension beyond half the length of record is uncertain, the permeable adjusted pooled flood frequency curve was adopted in this 2008 study. The Stats method estimates derived in this updated report have the same QMED value (as the same flow data was used) and a slightly steeper growth curve but essentially the flows are of the same magnitude.

Table 3.2 EA 2008 and Updated Flood Estimates at Leigh Park Flow Gauge

Method	Return Period (Years)							
	2	5	10	20	50	100	200	1000
2008 Pooled	1.79	2.40	2.85		4.09	4.76	5.53	7.80
2008 Single Site	1.79	2.1	2.3		2.8	3.0	3.2	3.7
2019 Stat	1.79	2.41	2.87	3.37	4.15	4.85	5.65	8.08

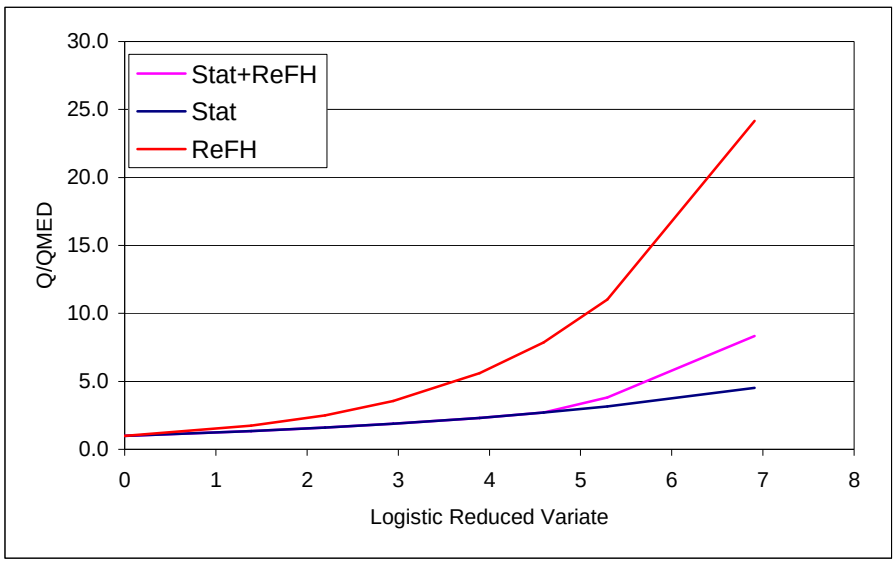
3.3 Comparison of Flood Growth Curve

A comparison of flood growth curves (Table 3.3) confirms that ReFH has a far steeper growth curve than the Stats method at extreme flood flows (Figure 3.2) but these are similar at lower return period. For permeable catchments ReFH and ReFH+Stat are usually discounted.

Table 3.3 Comparison of Flood Growth Curves at Leigh Park Flow Gauge

Method	2	5	10	20	50	100	200	1000
2019 Stat	1.00	1.35	1.60	1.88	2.32	2.71	3.16	4.51
2019 ReFH	1.00	1.74	2.50	3.56	5.60	7.86	11.03	24.17
Stat+ReFH	1.00	1.35	1.60	1.88	2.32	2.71	3.80	8.34
2008 Stat	1.00	1.34	1.59	1.86	2.28	2.66	3.09	4.36

Figure 3.2 Comparison of Flood Growth Curves



The EA's FEH Guidelines emphasise that historical flood data can be particularly valuable to confirm which of the flood flow estimation methods is the more realistic but apart from flow records at the gauge, which are of dubious quality, no such data are available on this catchment. The statistical method estimates of QMED are normally preferred as this is based on measured flow data with QMED confirmed or adjusted using local flow data and as the pooling group is based on recorded flow data this method is preferred.

3.4 Hybrid Method

The generation of flood hydrographs can be achieved in ISIS or Flood Mapper using the ReFH boundary unit and importing the FEH catchment descriptors CSV file. The peak flood flow of the ReFH hydrograph can be forced to fit the peak flow from the Stats method, referred to as the hybrid approach.

3.5 Climate Change

A suitable allowance for increased river flow due to climate change should then be considered based on the EA's February 2016 guidance (Table 3.4). The adopted allowance should depend on the type of development proposed and the flood zone which defines the allowance category. For more vulnerable residential developments in flood zone 3 the 'higher central' allowance is used and for less vulnerable commercial developments the 'central' climate change allowance is required and this should consider the lifetime of the development.

Table 3.4 Peak River Flow Allowances for South East Region

Allowance category	The '2020s' (2015 to 2039)	The '2050s' (2040 to 2069)	The '2080s' (2070 to 2115)
Upper end	25%	50%	105%
Higher central	15%	39%	45%
Central	10%	20%	35%

4 FLOOD FLOWS - URBAN AREA

4.1 Hydrological Response

Sections 2 and 3 of this report provide details of the estimated peak flows and the hydrological response from the upstream Chalk rural catchment based on standard FEH methods. There are reservations about the hydrological response as this catchment may exhibit a winter high and summer low baseflow and with a slow or muted response to rainfall due to the low percentage runoff. However very high peak flows can occur when the catchment is saturated and the percentage runoff may then be higher than the geology would suggest. This can occur after prolonged rainfall events such as October/November 2000 and the inconsistent PDM parameters noted in the EAs 2008 report may be due to variable percentage runoff from the selected events and hence the worst case Oct 2000 event was used.

The lower part of the Lavant Stream catchment is predominantly clay and is heavily urbanised giving a rapid response to rainfall and a high percentage runoff from the urban drainage systems that discharge into the stream network hence this area is considered separately. The ReFH hybrid approach defined above can be used for the rural catchment, possibly using the PDM ordinates from the ISIS model, and forced to match the Stats method flood estimates. Flows for the lower urban area are considered below using the revised ReFH method.

4.2 Revised ReFH Method

The EAs FEH guidelines states that ReFH in its original form should not be used for heavily or very heavily urbanised catchments (where URBEXT1990 is 0.125 to 0.5) and this relates to the lower part the catchment around Havant. However recent research (Kjeldsen, 2009) has led to a modified version of ReFH that accounts for increased runoff and this can be used on urban catchments. The EAs FEH Guidelines shows this revised method gives sensible results on several urban catchments. This modified ReFH approach does not use aspects of ReFH that are inappropriate or poorly calibrated for urban catchments, such as:

- The regression equation for CMAX, which does not represent the increase in runoff volume with urban extent.
- The initial soil moisture (Cini) which is calculated for design events based on an equation calibrated from only 7 catchments and which gives a physically unrealistic increase in Cmax as PROPWET decreases and
- The ‘a’ factor used to scale Cini to ensure that the resulting flood frequency curve is consistent with the results of the FEH statistical method and which was derived from an analysis of only 7 catchments.

However in this revised approach ReFH is used for rural green portion of urban areas (gardens, parks etc.) and also for the proportion of urban areas covered by hard surfaces with the percentage runoff set to a fixed value of 70% rather than using the ReFH losses model. The revised version of ReFH has therefore been used for the urbanised lower catchment of the Lavant Stream. Whilst a more accurate picture of sewer flows and pathways could be obtained from hydraulic modelling of the urban drainage network or from maps of the sewer network

but this requires a far more detailed study and the revised ReFH method is considered appropriate in this case.

4.3 Approach

The catchment is divided into two categories based on OS and FEH maps:

- The upstream mainly rural sub-catchment with flows defined in Section 2 above;
- The lower urban sub-catchment assuming runoff drain to local storm sewers following the ground topography and which drains to the watercourse assuming there is no import or export of flows to or from the FEH defined catchment.

Flows for the rural element are estimated using the standard ReFH model applied to 60% of the urban sub-catchment area assuming these urban areas are unpaved and rain water would infiltrate as it would on the rural catchments (Table 4.1). URBEXT1990 values are set to 0.0 resulting in the longer time to peak. Kjeldsen (2009) suggested 70% of these urban areas are unpaved but 60% was thought to be more appropriate as this part of the Lavant catchment is quite heavily urbanised.

The remaining 40% of the catchment is assumed to be paved with the percentage runoff (PR) set to 70% as suggested by Kjeldsen (2009). This is achieved by reducing the Cmax parameter by trial and error until the PR of 70% is achieved. URBEXT1990 was set to 0.5 to represent the faster routing of flood water through the urban catchment resulting in a shorter time to peak than on the rural part of the catchment. The catchment descriptors AREA and DPLBAR are also altered for each sub-catchment.

Table 4.1 Rural and Urban Areas in the Revised ReFH Model

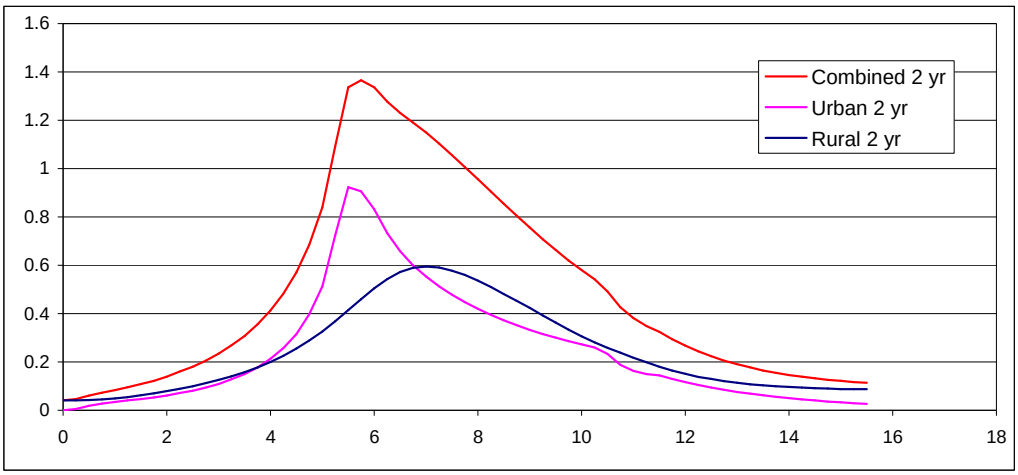
Site	AREA	FARL	BFIHOST	DPLBAR	DPSBAR	SAAR	SPR HOST	URBEXT 1990	URBEXT 2000
Leigh Park	55.96	0.999	0.886	10.27	89.1	905	10.10	0.0210	0.0231
DS	57.51	0.999	0.872	11.30	87.5	900	10.99	0.0293	0.0521
DS Gauge	1.55	1.0	0.367	1.27	90.0	720	43.07	0.3285	0.5
60% Rural	0.93	1.0	0.367	0.961	90.0	720	43.07	0.0	0.0
40% Urban	0.62	1.0	0.367	0.770	90.0	720	70.0	0.5	0.5

4.4 Flow Estimates

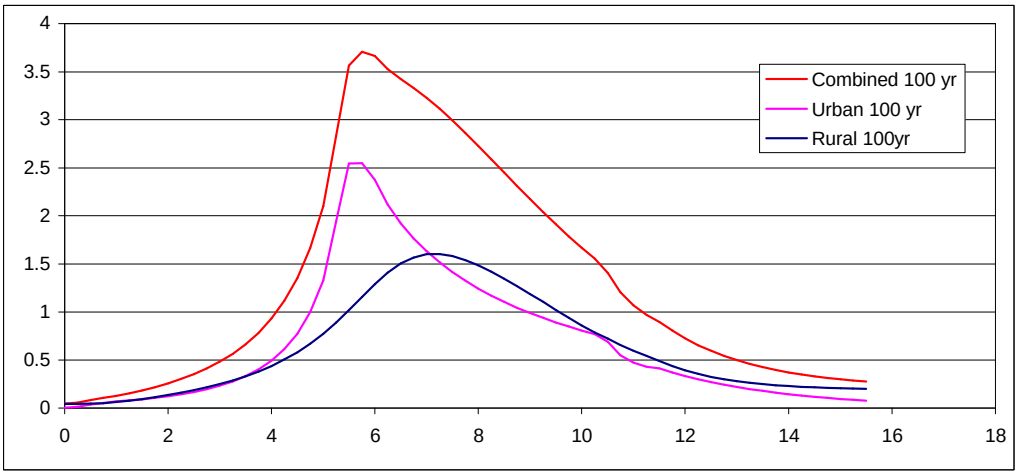
These steps then provide two hydrographs; one for the rural part of this urban area and one for the urban sub-catchment and these hydrographs are then added together to give the combined response (Figure 4.1) based on the different routing times and percentage runoff for the two parts of the sub-catchment. This is based on the same storm duration of 10.25 hours as used for the ReFH in the upper catchment on the basis that the same storm would affect both parts of this catchment. A range of storm durations could be investigated as part of the hydraulic modelling to identify the critical storm duration at the key point of interest.

Figure 4.1 Combined ReFH Hydrographs

2 year



100 year



The derived flows (Table 4.2) show that the Revised ReFH method for this lower urban area provides a QMED of 1.37 m^3/s and with a 100 year peak flow of 3.71 m^3/s.

Table 4.2 Revised ReFH Flood Estimates (m^3/s) for the Lower Urban Area

Location	Return Period (Years)						
	2	**10**	**20**	**50**	**100**	**200**	**1000**
Rural	0.60	0.95	1.11	1.37	1.60	1.91	2.96
Urban	0.92	1.45	1.73	2.16	2.55	3.05	4.54
Combined	1.37	2.15	2.55	3.15	3.71	4.40	6.52

The Revised ReFH flood hydrographs for each return period are given in Appendix A.

Appendix A Revised ReFH Method Flood Hydrographs for Urban Area of Havant

Time	Rural								Urban								Combined						
hrs	2 yr	10 yr	20 yr	50 yr	100yr	200 yr	1000 yr		2 yr	10 yr	20 yr	50 yr	100 yr	200 yr	1000 yr		2 yr	10 yr	20 yr	50 yr	100 yr	200 yr	1000 yr
0.0	0.041	0.041	0.041	0.041	0.041	0.041	0.041		0.000	0.001	0.001	0.002	0.003	0.003	0.006		0.041	0.042	0.042	0.043	0.044	0.044	0.047
0.25	0.041	0.041	0.042	0.042	0.042	0.042	0.042		0.006	0.009	0.010	0.012	0.013	0.014	0.018		0.047	0.050	0.052	0.054	0.055	0.056	0.060
0.5	0.042	0.044	0.044	0.045	0.045	0.046	0.048		0.019	0.029	0.031	0.034	0.036	0.038	0.044		0.061	0.073	0.075	0.079	0.081	0.084	0.092
0.75	0.045	0.048	0.049	0.050	0.052	0.053	0.057		0.028	0.043	0.046	0.049	0.053	0.056	0.065		0.073	0.091	0.095	0.099	0.105	0.109	0.122
1.0	0.049	0.054	0.056	0.059	0.061	0.064	0.072		0.035	0.054	0.057	0.062	0.067	0.070	0.082		0.084	0.108	0.113	0.121	0.128	0.134	0.154
1.25	0.054	0.063	0.066	0.071	0.075	0.079	0.092		0.041	0.062	0.067	0.072	0.078	0.082	0.097		0.095	0.125	0.133	0.143	0.153	0.161	0.189
1.5	0.062	0.075	0.080	0.087	0.093	0.100	0.119		0.047	0.071	0.076	0.083	0.090	0.096	0.114		0.109	0.146	0.156	0.170	0.183	0.196	0.233
1.75	0.07	0.088	0.095	0.105	0.113	0.123	0.150		0.053	0.082	0.088	0.096	0.104	0.112	0.134		0.123	0.17	0.183	0.201	0.217	0.235	0.284
2.0	0.079	0.102	0.111	0.124	0.135	0.148	0.184		0.061	0.094	0.101	0.112	0.121	0.131	0.159		0.140	0.196	0.212	0.236	0.256	0.279	0.343
2.25	0.089	0.118	0.129	0.146	0.159	0.175	0.221		0.071	0.108	0.117	0.130	0.142	0.153	0.189		0.160	0.226	0.246	0.276	0.301	0.328	0.410
2.5	0.100	0.135	0.149	0.170	0.186	0.206	0.262		0.081	0.124	0.136	0.152	0.166	0.181	0.226		0.181	0.259	0.285	0.322	0.352	0.387	0.488
2.75	0.112	0.154	0.171	0.196	0.215	0.240	0.309		0.094	0.144	0.158	0.178	0.196	0.215	0.272		0.206	0.298	0.329	0.374	0.411	0.455	0.581
3.0	0.126	0.176	0.196	0.225	0.249	0.278	0.361		0.109	0.168	0.185	0.209	0.232	0.256	0.329		0.235	0.344	0.381	0.434	0.481	0.534	0.690
3.25	0.141	0.200	0.224	0.259	0.287	0.321	0.422		0.128	0.197	0.218	0.248	0.277	0.308	0.401		0.269	0.397	0.442	0.507	0.564	0.629	0.823
3.5	0.158	0.227	0.256	0.297	0.330	0.372	0.493		0.150	0.231	0.258	0.297	0.332	0.372	0.492		0.308	0.458	0.514	0.594	0.662	0.744	0.985
3.75	0.178	0.259	0.292	0.340	0.380	0.429	0.575		0.178	0.275	0.308	0.357	0.403	0.455	0.609		0.356	0.534	0.600	0.697	0.783	0.884	1.184
4.0	0.200	0.295	0.334	0.391	0.438	0.496	0.671		0.213	0.329	0.372	0.435	0.493	0.561	0.762		0.413	0.624	0.706	0.826	0.931	1.057	1.433
4.25	0.226	0.335	0.381	0.448	0.504	0.574	0.784		0.257	0.399	0.454	0.536	0.612	0.701	0.966		0.483	0.734	0.835	0.984	1.116	1.275	1.750
4.5	0.255	0.382	0.436	0.515	0.581	0.663	0.917		0.316	0.491	0.564	0.672	0.772	0.892	1.246		0.571	0.873	1.000	1.187	1.353	1.555	2.163
4.75	0.288	0.436	0.499	0.591	0.669	0.768	1.074		0.397	0.619	0.716	0.863	0.997	1.161	1.644		0.685	1.055	1.215	1.454	1.666	1.929	2.718
5.0	0.326	0.497	0.57	0.679	0.772	0.889	1.259		0.513	0.803	0.937	1.142	1.329	1.560	2.240		0.839	1.300	1.507	1.821	2.101	2.449	3.499
5.25	0.368	0.566	0.651	0.779	0.890	1.029	1.476		0.723	1.136	1.340	1.653	1.941	2.298	3.350		1.091	1.702	1.991	2.432	2.831	3.327	4.826
5.5	0.414	0.641	0.740	0.890	1.020	1.186	1.722		0.923	1.454	1.729	2.155	2.544	3.033	4.472		1.337	2.095	2.469	3.045	3.564	4.219	6.194
5.75	0.460	0.718	0.832	1.004	1.156	1.349	1.984		0.906	1.432	1.713	2.150	2.550	3.054	4.537		1.366	2.150	2.545	3.154	3.706	4.403	6.521
6.0	0.505	0.792	0.920	1.115	1.289	1.510	2.246		0.831	1.315	1.581	1.995	2.375	2.854	4.265		1.336	2.107	2.501	3.110	3.664	4.364	6.511
6.25	0.543	0.857	0.998	1.214	1.408	1.656	2.489		0.733	1.161	1.402	1.776	2.119	2.554	3.834		1.276	2.018	2.400	2.990	3.527	4.210	6.323
6.5	0.572	0.907	1.059	1.293	1.503	1.775	2.693		0.659	1.046	1.265	1.608	1.922	2.320	3.493		1.231	1.953	2.324	2.901	3.425	4.095	6.186
6.75	0.589	0.938	1.097	1.344	1.567	1.856	2.841		0.601	0.955	1.157	1.473	1.762	2.130	3.213		1.190	1.893	2.254	2.817	3.329	3.986	6.054
7.0	0.595	0.950	1.113	1.367	1.599	1.898	2.928		0.554	0.880	1.068	1.361	1.630	1.972	2.978		1.149	1.830	2.181	2.728	3.229	3.870	5.906
7.25	0.591	0.945	1.109	1.366	1.601	1.906	2.960		0.513	0.816	0.991	1.264	1.515	1.834	2.772		1.104	1.761	2.100	2.630	3.116	3.740	5.732

7.5	0.578	0.927	1.090	1.345	1.580	1.885	2.944		0.478	0.760	0.924	1.180	1.414	1.712	2.590		1.056	1.687	2.014	2.525	2.994	3.597	5.534
7.75	0.560	0.899	1.057	1.308	1.539	1.840	2.890		0.447	0.711	0.865	1.104	1.324	1.604	2.426		1.007	1.610	1.922	2.412	2.863	3.444	5.316
8.0	0.536	0.863	1.016	1.259	1.484	1.777	2.805		0.420	0.667	0.811	1.037	1.243	1.506	2.279		0.956	1.530	1.827	2.296	2.727	3.283	5.084
8.25	0.510	0.822	0.969	1.202	1.419	1.702	2.698		0.395	0.628	0.764	0.976	1.170	1.418	2.146		0.905	1.450	1.733	2.178	2.589	3.120	4.844
8.5	0.482	0.777	0.917	1.139	1.346	1.617	2.573		0.372	0.592	0.72	0.92	1.104	1.337	2.024		0.854	1.369	1.637	2.059	2.450	2.954	4.597
8.75	0.453	0.730	0.862	1.072	1.268	1.525	2.435		0.352	0.56	0.681	0.87	1.043	1.264	1.914		0.805	1.290	1.543	1.942	2.311	2.789	4.349
9.0	0.423	0.681	0.804	1.002	1.186	1.428	2.288		0.333	0.530	0.645	0.824	0.988	1.197	1.812		0.756	1.211	1.449	1.826	2.174	2.625	4.100
9.25	0.392	0.632	0.747	0.93	1.103	1.329	2.134		0.316	0.503	0.612	0.782	0.937	1.135	1.719		0.708	1.135	1.359	1.712	2.040	2.464	3.853
9.5	0.363	0.583	0.689	0.859	1.019	1.229	1.978		0.301	0.478	0.581	0.743	0.89	1.078	1.632		0.664	1.061	1.270	1.602	1.909	2.307	3.610
9.75	0.334	0.536	0.633	0.790	0.938	1.131	1.824		0.286	0.455	0.553	0.707	0.847	1.026	1.553		0.620	0.991	1.186	1.497	1.785	2.157	3.377
10.0	0.307	0.491	0.581	0.724	0.86	1.038	1.675		0.273	0.433	0.527	0.673	0.807	0.977	1.479		0.580	0.924	1.108	1.397	1.667	2.015	3.154
10.25	0.282	0.450	0.532	0.663	0.787	0.950	1.535		0.260	0.414	0.503	0.642	0.769	0.932	1.410		0.542	0.864	1.035	1.305	1.556	1.882	2.945
10.5	0.259	0.413	0.487	0.607	0.720	0.869	1.403		0.233	0.37	0.449	0.572	0.686	0.829	1.253		0.492	0.783	0.936	1.179	1.406	1.698	2.656
10.75	0.238	0.377	0.445	0.554	0.657	0.792	1.277		0.189	0.300	0.363	0.461	0.55	0.664	0.999		0.427	0.677	0.808	1.015	1.207	1.456	2.276
11.0	0.218	0.344	0.405	0.504	0.597	0.719	1.157		0.164	0.260	0.313	0.396	0.472	0.569	0.852		0.382	0.604	0.718	0.900	1.069	1.288	2.009
11.25	0.199	0.313	0.368	0.456	0.540	0.650	1.043		0.150	0.237	0.285	0.36	0.429	0.516	0.772		0.349	0.550	0.653	0.816	0.969	1.166	1.815
11.5	0.181	0.284	0.333	0.412	0.486	0.584	0.934		0.144	0.227	0.274	0.346	0.411	0.495	0.740		0.325	0.511	0.607	0.758	0.897	1.079	1.674
11.75	0.165	0.256	0.300	0.370	0.436	0.523	0.831		0.129	0.204	0.246	0.311	0.369	0.445	0.666		0.295	0.460	0.546	0.681	0.806	0.969	1.497
12.0	0.151	0.232	0.271	0.334	0.392	0.469	0.742		0.116	0.183	0.221	0.282	0.332	0.400	0.599		0.268	0.416	0.492	0.614	0.725	0.870	1.341
12.25	0.139	0.212	0.247	0.303	0.355	0.424	0.667		0.104	0.165	0.199	0.252	0.299	0.360	0.539		0.244	0.377	0.446	0.555	0.655	0.785	1.206
12.5	0.129	0.195	0.227	0.278	0.325	0.386	0.604		0.094	0.148	0.179	0.227	0.269	0.324	0.485		0.223	0.344	0.406	0.505	0.595	0.711	1.090
12.75	0.120	0.182	0.211	0.257	0.300	0.356	0.553		0.085	0.134	0.161	0.200	0.242	0.292	0.436		0.205	0.316	0.372	0.461	0.543	0.648	0.990
13.0	0.114	0.170	0.197	0.240	0.279	0.330	0.511		0.076	0.120	0.145	0.183	0.218	0.263	0.393		0.191	0.291	0.342	0.424	0.497	0.593	0.904
13.25	0.108	0.161	0.186	0.226	0.262	0.310	0.477		0.068	0.108	0.131	0.165	0.196	0.236	0.353		0.177	0.270	0.317	0.391	0.459	0.547	0.831
13.5	0.103	0.154	0.177	0.214	0.248	0.293	0.449		0.061	0.097	0.117	0.148	0.170	0.213	0.318		0.165	0.252	0.294	0.363	0.425	0.506	0.768
13.75	0.100	0.147	0.170	0.205	0.237	0.279	0.425		0.055	0.087	0.106	0.134	0.159	0.191	0.286		0.156	0.235	0.276	0.339	0.396	0.471	0.712
14.0	0.096	0.142	0.163	0.197	0.227	0.267	0.406		0.050	0.076	0.095	0.120	0.143	0.172	0.258		0.146	0.221	0.258	0.318	0.370	0.440	0.664
14.25	0.094	0.138	0.158	0.190	0.220	0.258	0.390		0.045	0.071	0.085	0.108	0.128	0.155	0.232		0.139	0.209	0.243	0.299	0.349	0.413	0.622
14.5	0.092	0.134	0.154	0.185	0.213	0.250	0.378		0.040	0.064	0.077	0.097	0.116	0.139	0.208		0.133	0.198	0.231	0.283	0.329	0.390	0.587
14.75	0.090	0.131	0.151	0.181	0.209	0.244	0.369		0.036	0.057	0.069	0.087	0.104	0.125	0.180		0.127	0.189	0.220	0.269	0.313	0.370	0.557
15.0	0.088	0.129	0.148	0.178	0.205	0.240	0.362		0.032	0.051	0.062	0.079	0.094	0.113	0.169		0.121	0.181	0.210	0.257	0.299	0.353	0.531
15.25	0.087	0.128	0.146	0.176	0.203	0.237	0.357		0.029	0.046	0.056	0.071	0.084	0.101	0.152		0.117	0.175	0.202	0.247	0.288	0.339	0.509
15.5	0.087	0.127	0.145	0.174	0.201	0.235	0.354		0.026	0.042	0.050	0.064	0.076	0.091	0.137		0.114	0.169	0.195	0.238	0.277	0.327	0.491
Max	0.595	0.950	1.113	1.367	1.601	1.906	2.960		0.923	1.454	1.729	2.155	2.550	3.054	4.537		1.366	2.150	2.545	3.154	3.706	4.403	6.521

Appendix B
EA Consultation Regarding Control Structure

Hollie Tristram

From: Lupton, Sarah <Sarah.Lupton@environment-agency.gov.uk>
Sent: 06 September 2019 15:06
To: John Easton
Cc: SSD Enquiries
Subject: RE: 190807 SSD137786 - Site at Solent Road, Havand
Attachments: Historical inforamtion_very important.pdf

Hi John

The penstock is always left in the same position, as per the image, the gap is to allow fish passage. The penstock is approx. 805mm wide and the diameter of the opening is 500mm. I couldn't find any information on the screen but it looks to match the penstock in width from the image.

In looking again in the folders I have found the attached which you may find of use.

Again, this information is supplied subject to the notice which can be viewed via the following link:
http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

Best regards
Sarah

From: John Easton [mailto:jeaston@ardent-ce.co.uk]
Sent: 06 September 2019 13:56
To: Lupton, Sarah <Sarah.Lupton@environment-agency.gov.uk>
Cc: SSD Enquiries <SSDEnquiries@environment-agency.gov.uk>
Subject: RE: 190807 SSD137786 - Site at Solent Road, Havand

Hi Sarah,

That's great – many thanks for that, it's very helpful!

No need to send through the video for the Link Pipe.

Any further details that you can provide with respect to the penstock however would be very useful. i.e. when is it operational (it looks to be raised slightly in the photo below)? What is the diameter of the opening? How wide is the screen? Etc

Any further information you are able to provide in this regard would be much appreciated!

Kind regards,

John

John Easton
Hydraulic Modeller BSc (Hons) MSc

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From: Lupton, Sarah <Sarah.Lupton@environment-agency.gov.uk>
Sent: 06 September 2019 11:40
To: John Easton <jeaston@ardent-ce.co.uk>
Cc: SSD Enquiries <SSDEnquiries@environment-agency.gov.uk>
Subject: FW: 190807 SSD137786 - Site at Solent Road, Havand

Dear John,

Thanks for your email, apologies on the delay in getting back to you.

I have checked our records and we do not have cross sectional survey data or topographic survey data locally for the area you mention below.

With regard to the pipelink, please find a link to the most recent culvert inspection report which was completed in 2015. I can also send the video footage of this survey if this would be of use, please let me know. The pipe links flows in a westerly direction from Crossland Drive to the Hermitage Stream at Stockheath Lane.

In 2015 a new Penstock was installed downstream of Crossland Drive. It has a hole in it which allows a fixed amount of water downstream to Eastern Road, forcing more water into the Hermitage pipelink. Up to 3 Cumecs can be transferred from the Lavant Stream to the Hermitage in times of flood. There is also a screen immediately upstream of this structure. I have attached the best image I could find of the control gate and screen (looking downstream).

I have attached a map showing the watercourses and where our assets are located. If you would like further information on any of these assets please let me know and I will see what I can find.

Best regards

Sarah Lupton EngTech MICE

FCRM Advisor (Asset Performance)
East Hampshire and Chichester

✉: sarah.lupton@environment-agency.gov.uk
☎: 020 84745257
: Romsey District Office, Canal Walk, Romsey, Hampshire, SO51 7LP

Please note my working days are Monday, Wednesday, Thursday and Friday

·_

From: John Easton [mailto:jeaston@ardent-ce.co.uk]
Sent: 01 August 2019 14:44
To: Rabone, Anna <Anna.Rabone@environment-agency.gov.uk>
Cc: Brown, Sophie <sophie.brown@environment-agency.gov.uk>
Subject: RE: Site at Solent Road, Havand

Good afternoon Anna,

Further to my colleague Georgia's e-mail below, we have since obtained the EA's model of the Lavant Stream and been working with this to inform our assessment of our client's site.

We have obtained additional survey data of the watercourse to supplement the information in the EA's model however we were hopeful we could acquire some additional information from the EA if possible.

There are several structures on the watercourse some of which are crucial to the hydrology of the study area. Could we please ask for any channel cross sectional survey data or topographic survey data that the EA may hold for the Lavant Stream? In particular we would like information relating to the Lavant Link Pipe immediately downstream of Crossland Drive.

From observations made with Google Street View it looks as if there may be a hydraulic control downstream of the Link Pipe which, we assume, serves to elevate the water level upstream and allow flow to enter the pipe. However, our surveyors were not able to gain access to this structure to validate this assumption.

If you could please send us any raw survey data you have for the watercourse that would be much appreciated.

Please don't hesitate to get in touch should you require any further information.

Kind regards,

John
John Easton
Hydraulic Modeller BSc (Hons) MSc

Date : 12th May 2020

Project : Solent Road, Havant

Project Ref : 191920

Report Ref : 191920-06

Report Title : Response to EA PSO Team

DOCUMENT CONTROL

REV	ISSUE PURPOSE	AUTHOR	CHECKED	APPROVED	DATE
-	For Information	JE	JE	BC	12-05-20

1. INTRODUCTION

Ardent have been commissioned by Portsmouth Water to undertake a hydraulic modelling study to investigate removal of an existing culvert located on the Lavant Stream. The Lavant Stream is an EA 'main river' which flows through Portsmouth Water owned land (hereafter referred to as 'the Site') to the rear of the Portsmouth Water headquarters at West Street, Havant, PO9 1LG (National Grid Reference SU 71154 06195).

Ardent have previously prepared a hydraulic modelling report (report ref **191920-03**) that demonstrates the benefits of removing the culvert. The culvert in its present condition acts as a hydraulic control, throttling flows in peak events resulting in out of bank flows occurring across the Site. The hydraulic modelling work carried out shows that by removing the culvert, the Site is flood free during the 1 in 100 year event although some flooding of the Site is still occurs expected to occur during this event with the application of climate change.

Comments were put forward by the Environment Agency Partnership and Strategic Overview (PSO) team on the 22 November to Portsmouth Water via email (when reviewing information supplied by Portsmouth Water to secure a Flood Risk Activity Permit (FRAP) to remove the culvert under application reference "EPR/PB3294JJ". Each of these comments are addressed individually below.

Ardent subsequently responded to the EA PSO Team comments in their report **191920-05** which is understood to have been submitted to the EA in April 2020.

Ardent have now received additional comments from the EA PSO Team (document ref EPR/PB3294JJ) in response to report 191920-05. This document aims to address these comments.

2. EA Comments

Environment Agency:

1. In regards to comments 9 and 10, the flood extents show some increase in flooding when compared to the baseline model. To help us assess this further we require some clarification on your response.
    a) In figure titles for a number of the modelled extents mention both "proposed" and "baseline" can you please clarify further what these two scenarios include and don't include.

Ardent:

The baseline scenario presents existing conditions on site i.e. with the culvert in place. This culvert acts as a hydraulic control and throttles flow at this location resulting in an elevated water level upstream which comes out of bank and forms a flood flow path

across the site. Therefore, in order to mitigate against this risk, the proposed scenario removes the culvert and also incorporates inclusion of ground excavation works on the northern bank of the Lavant Stream with a low level bund included on the southern bank of the watercourse.

Environment Agency:

2. Can you provide some extra clarification and assessment of the very downstream extent of the flooding (especially in relation to the modelled climate change (CC) extents where this is more promninent), this looks as if it could be a glass walling or box edge effect based on the extent of the 2D model domain.
    a) We therefore require further analysis / assessment of this to understand if this is the situation, or if there is a further underlying issue.
    b) As well as further justification for the increase in extents and flood depths here, and the reasoning as to why these are occurring?

Ardent:

The model is not glass walling. The hydraulic model incorporates an 'HT' (stage / time) boundary at this location to take into account tidal conditions. Ardent consulted with the EA at the early stages of the model build process to determine what tidal conditions should be incorporated at the downstream boundary of the model. The EA advised that a 1 in 2 year tidal curve would be appropriate. During the climate change scenarios, Ardent applied an additional 1.2 m to this tidal curve to take into account the anticipated level of sea level rise for this region. This explains the resultant increase flood extent at this location. Flood waters within the study area are able to pass out of the 2D model domain at this location when the tidal level drops below a certain level.

Environment Agency:

3. The baseline model vs our current EA model puts an area previously not in our flood map as in the flood zone.
    a) We require further assessment, justification and/or clarification on the reasoning as to why and how this occurs?
    b) As well as the differences between the two modelled extents? Indicating where this extra flood extent come from?

Ardent:

The original EA hydraulic model of the Lavant Stream was constructed in 2008 by Atkins using Infoworks CS and RS as part of the Havant Flood Mapping Study. InfoWorks CS allows for modelling of the urban drainage network or sewer system. InfoWorks RS allows the modelling of the river network. These are legacy software packages and are no longer supported.

Through consultation with the Environment Agency (EA) it became apparent that the hydrology associated with the model was outdated and would need revising and that also, several structures within the model were not accurately represented or were not included. Therefore, confidence in the modelling outputs and flood outlines was reduced but this represented the best available information.

For the purposes of this study it was decided to construct a dynamically linked 1D-2D model of the Lavant Stream and floodplain using FMP (1D) and Tuflow (2D) software packages utilising data, river sections and sewer sections taken from the original Infoworks models as well as incorporating new survey data of watercourses and structures. It was also decided that as part of the assessment of flood risk to the Site

the hydrological inputs should be updated and make an assessment based on the latest climate change guidance.

3. CONCLUSIONS

Ardent have been commissioned by Portsmouth Water (PW) to undertake a hydraulic modelling exercise in support of a Flood Risk Activity Permit (FRAP) application to de-culvert a short stretch of the Lavant Stream that flows through the centre of PW owned land. Also associated with the de-culverting works is the implementation of a low bund (approximately 500-750mm) along approximately 160 m of the left bank of the watercourse.

The hydraulic modelling work carried out demonstrates that the proposed works have a de minimis impact on flood risk up and downstream across all modelled events. Furthermore, sensitivity testing of the hydraulic model suggests that chosen parameters are appropriate and fit for purpose and that therefore, the modelling outputs are sound.

This document has been prepared in response to the Environment Agency's (EA) latest comments on Ardent report ref 191920-05 in support of the FRAP application. Ardent hope that this has now satisfactorily addressed any concerns the EA had and that the supporting materials are sufficient in order for the EA to grant the FRAP for the proposed works.

ARDENT | CONSULTING ENGINEERS

PORTSMOUTH WATER

SOLENT ROAD

FLOOD RISK ASSESSMENT – CULVERT REMOVAL
(Flood Risk Activities Permit Application)

Report Ref NO. 191920-07
Project No. 191920
JULY 2020

PORTSMOUTH WATER

SOLENT ROAD

FLOOD RISK ASSESSMENT – CULVERT REMOVAL
(Flood Risk Activities Permit Application)

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REPORT REF NO. 191920-07
PROJECT NO. 191920
JULY 2020

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DOCUMENT CONTROL SHEET

REV	ISSUE PURPOSE	AUTHOR	CHECKED	APPROVED	DATE
-	Final	JE	JE	BC	22-07-20

1. INTRODUCTION

1.1. Ardent Consulting Engineers (hereafter referred to as "Ardent") has been commissioned by Portsmouth Water to undertake Flood Risk Assessment (FRA) in support of a Flood Risk Activities Permit (FRAP) application to the Environment Agency (EA) in order to facilitate the removal of a small culvert on the Lavant Stream where it flows through the centre of a proposed development site located on Portsmouth Water owned land at Solent Road, Havant (hereafter referred to as 'the site').

1.2. Ardent have undertaken a hydraulic modelling study of the watercourse in order to assess the risk of flooding to the development site. The conclusion of the modelling study identified that the site is at risk of flooding during the 1 in 100 year event however this is due in large part due to the throttling effect of a 600 mm dia culvert on the Lavant Stream that acts as the main hydraulic control along this reach resulting in out of bank flows and a shallow flow path being formed across the site. Consequently, it has been proposed that by removing the culvert the risk of flooding to the site can be mitigated. Ardent have carried out modelling runs with the culvert removed to demonstrate this. An interim hydraulic modelling note (report ref **191920-03**) was submitted to the EA Partnership and Strategic Overview (PSO) team as part of a Flood Risk Activities Permit application to remove the culvert and demonstrate that the modelling methodology was sound and that removal of the culvert did not result in an increase in flood risk offsite.

1.3. As part of the FRAP review process the EA have provided several iterations of comments and Ardent have responded accordingly to answer these queries. The outcome of which is that on the 26th June 2020 the EA confirmed that the hydraulic model was fit for the purpose of the FRAP application (refer to **Appendix A**). However, the EA also requested that a Flood Risk Assessment (FFRA) was prepared to appraise the baseline flood risk and determine the risk of flooding both on and off site as a result of the culvert removal.

1.4. This FRA has been prepared to specifically address the EA's request and satisfy the requirements of the FRAP application. The scope is therefore limited and is not intended to support any proposed planning application.

2. SITE DESCRIPTION

Site Location

2.1. The Site is approximately 1.6 ha and is centred at Ordnance Survey grid reference SU 71106 06165 on Solent Road, Havant with the nearest post code being PO9 1LX. The Site is located within Portsmouth Water owned land to the rear of Portsmouth Water headquarters at West Street, Havant, PO9 1LG. The Lavant Stream (EA 'main river') flows through the centre of the Portsmouth Water owned land and marks the boundary along the northern edge of the site. Refer to **Figure 2-1** below for site Location Plan.

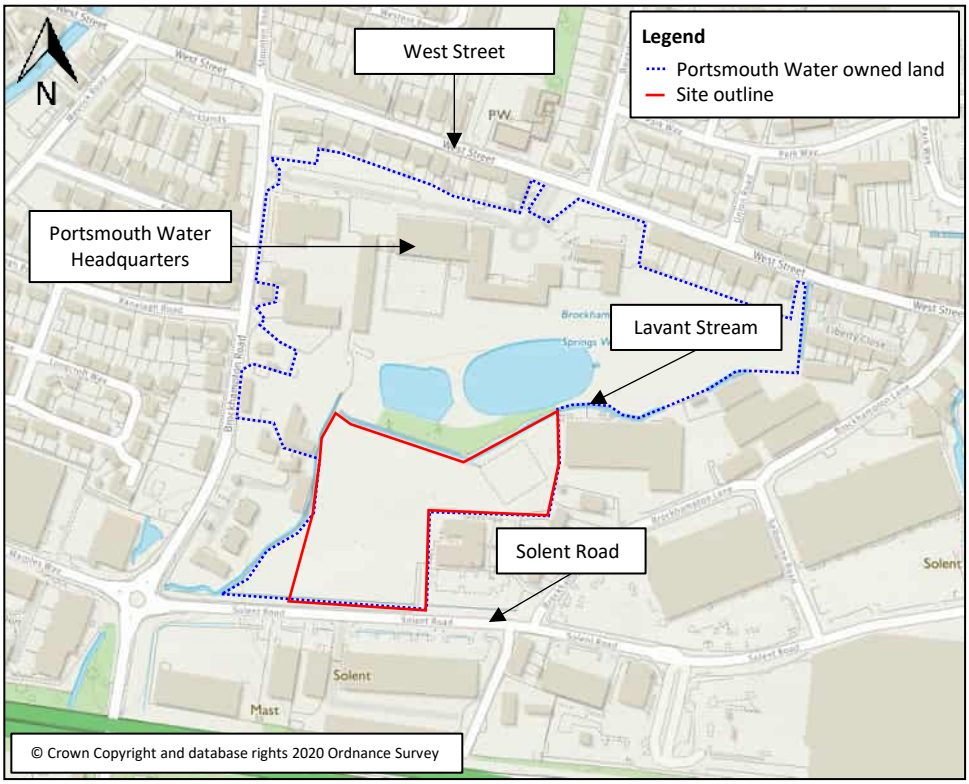

Figure 2-1: Site location plan

Waterbodies in the Vicinity of the Site

2.2. There are several waterbodies within the vicinity of the site (refer to **Figure 2-2**). The Lavant Stream flows from east to west along the northern boundary of the Site and southwards along the western boundary. The Lavant Stream is classified as 'main river'. The upper catchment of the Lavant Stream is situated on chalk bedrock before flowing through the urban area of Havant through multiple culverted sections. The channel is artificially diverged approximately 400 m

upstream of the Site for the creation of a flood bypass channel which flows southwards through the urban area.

2.3. The Site lies adjacent to a boundary between permeable chalk bedrock an impermeable London Clay Formation to the north. Consequently, several springs are present in the area including the Brockhampton Springs on the Portsmouth Water site which give rise to the two ponds to the north of the site. A spring is also present in the south west corner of the Portsmouth Water owned land which joins the Lavant Stream adjacent to Solent Road. Also adjacent to the south of the development site are two ditches in open and culverted section which are understood to be fed by the urban drainage network to the east and north. These are understood to discharge into the Lavant Stream south of the site.

2.4. Approximately 350 m to the north west of the Site, the Hermitage Stream flows from north to south. A flood relief culvert is present on the Lavant Stream approximately 1.5 km upstream of the Site which is designed to transfer flows from the Lavant Stream catchment into the Hermitage Stream during extreme rainfall events. Both the Hermitage Stream and the Lavant Stream discharge to the estuary approximately 1.0 km to the south of the Site.

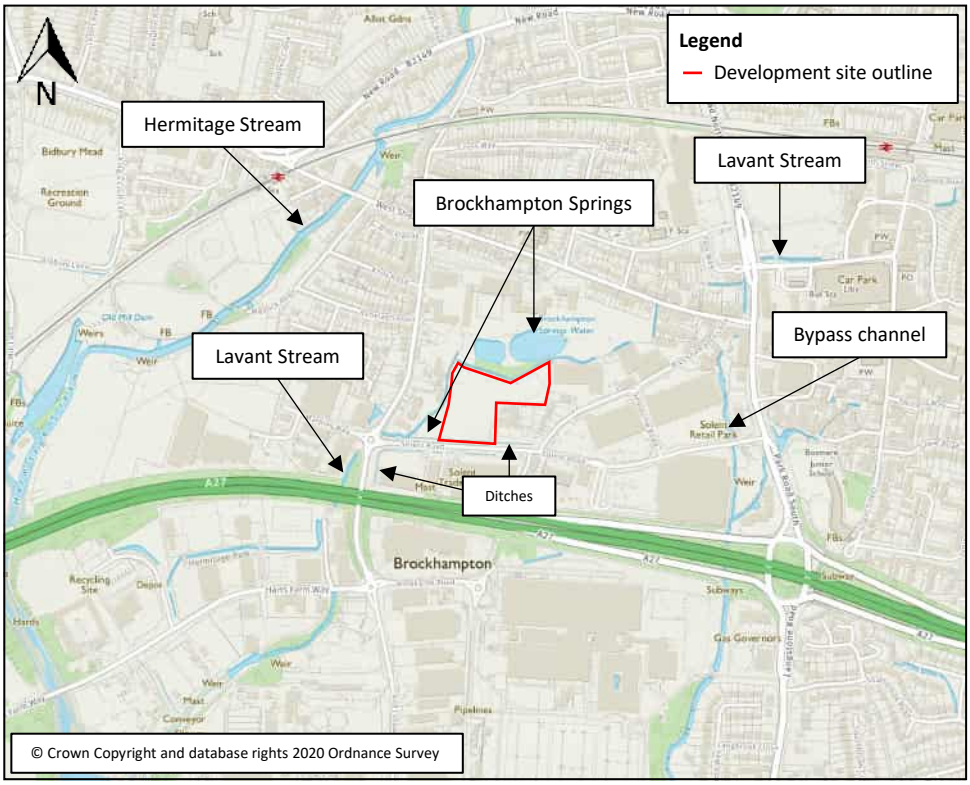

Figure 2-2: Waterbodies in the vicinity of the site

Existing Development

2.5. The existing site is currently formed of undeveloped Greenfield land with the exception of a disused former tennis court in the western part of the Site.

Topography

2.6. Ardent have obtained EA 1 metre resolution LiDAR data of the study area. The LiDAR data shows that elevations on the site fall from approximately 5.8 m AOD in the north west corner of the Site adjacent to the Lavant Stream down to 4.8 m AOD in the south western corner (refer to **Figure 2-3** below). This is a gradient of approximately 1:120.

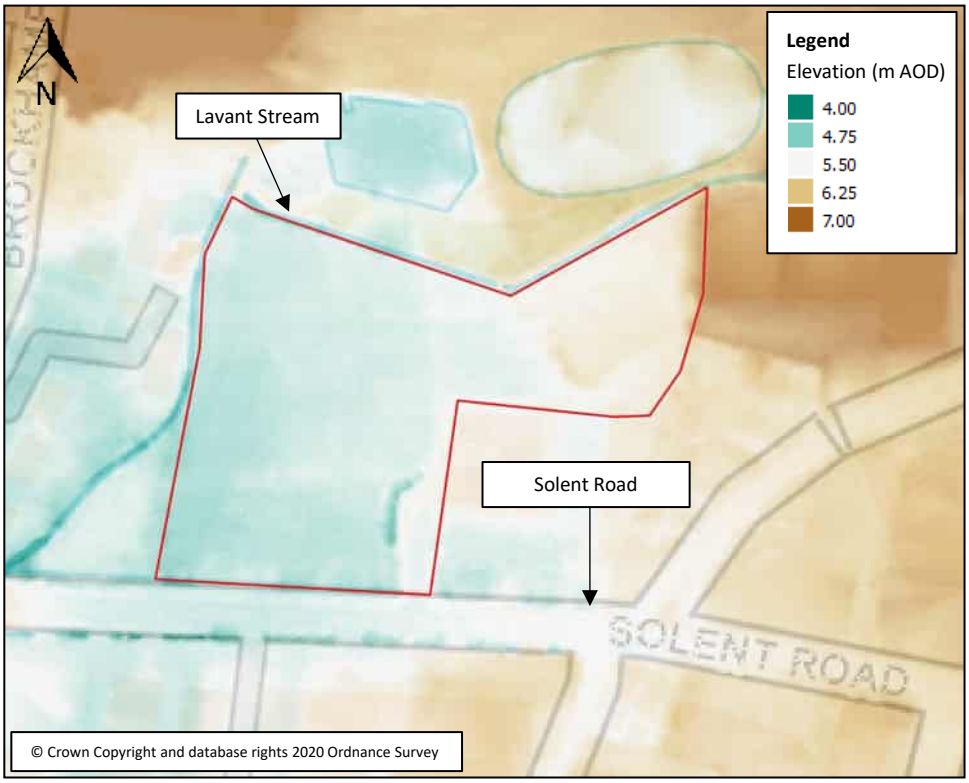

Figure 2-3: 1m resolution LiDAR data

Ground Conditions

2.7. As mentioned in **Section 2.2** above, the geology of the local area is quite complex. British Geological Survey data (refer to **Figure 2-4**) shows that the Site is located on permeable chalk geology with impermeable London Clay Formation bedrock to the north. This change in permeability results in the emergence of several springs in the vicinity of the Site.

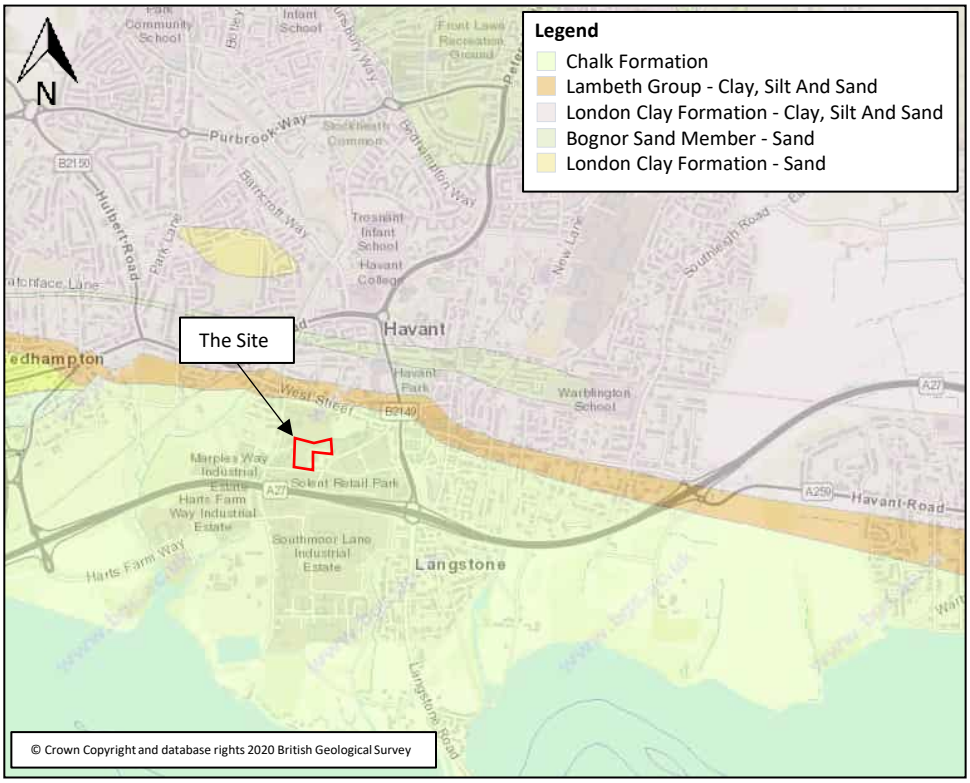

Figure 2-4: British Geological Survey data

3. BASELINE FLOOD RISK

Flood Zone Designation

3.1. Flood Zones refer to the probability of river and sea flooding, ignoring the presence of defences. The National Planning Policy Framework (NPPF) Planning Practice Guidance defines Flood Zones as follows:

- **Flood Zone 1: Low Probability**. Land having a less than 1 in 1,000 annual probability of river or sea flooding.
- **Flood Zone 2: Medium Probability**. Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding; or Land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding.
- **Flood Zone 3a: High Probability**. Land having a 1 in 100 or greater annual probability of river flooding; or Land having a 1 in 200 or greater annual probability of sea flooding.
- **Flood Zone 3b: The Functional Floodplain**. This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency.

3.2. The Flood Zones are shown on the EA Flood Map for Planning (Rivers and Sea). The Planning Practice Guidance states that the Zones shown on the EA Flood Map do not take account of the possible impacts of climate change and consequent changes in the future probability of flooding.

Environment Agency Flood Map for Planning

3.3. According to the EA Flood Map for Planning (**Figure 4-1**) a large part of the site is located in land designated as Flood Zone 3 (high probability of fluvial flooding) and is shown as undefended. The north eastern corner is shown to be in Flood Zone 1 (low probability of flooding). However, the flood outlines have been derived from a hydraulic model constructed in 2008 using hydraulic modelling software InfoWorks CS and RS. Through consultation with the Environment Agency (EA) it became apparent that the hydrology associated with the model was outdated and would need revising and that also, several structures within the model were not accurately

represented or were not included. Therefore, confidence in the modelling outputs and flood outlines was reduced but this represented the best available information. As part of the assessment of flood risk to the Site it was therefore decided to update the hydrology and make an assessment based on the latest climate change guidance and update the hydraulic model with new survey data.

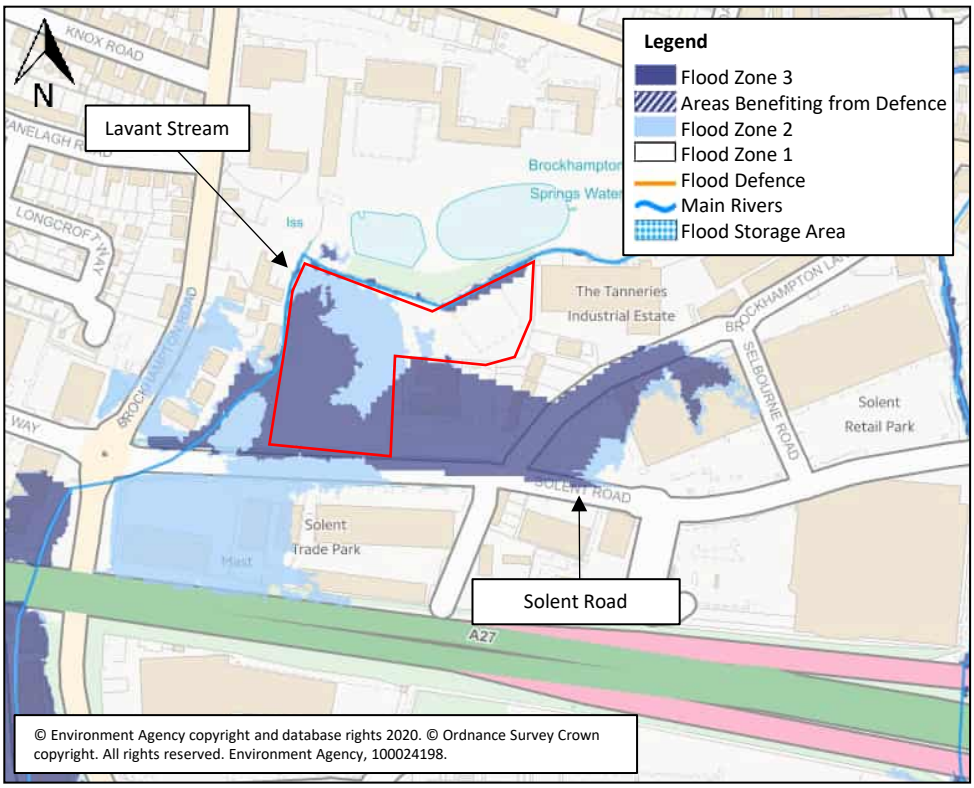

Figure 4-1: EA Flood Map for Planning (Rivers and Sea)

Hydraulic Model Build

3.4. The original EA hydraulic model of the Lavant Stream was constructed in 2008 by Atkins using Infoworks CS and RS as part of the Havant Flood Mapping Study.

3.5. InfoWorks CS allows for modelling of the urban drainage network or sewer system. InfoWorks RS allows the modelling of the river network. These are legacy software packages and are no longer supported.

3.6. Therefore in order to adequately appraise flood risk to the Site it was decided to construct a dynamically linked 1D-2D model of the Lavant

Stream and floodplain using FMP (1D) and Tuflow (2D) software packages based on new cross sectional channel survey data as well as utilising data, river sections and sewer sections taken from the original Infoworks models where appropriate.

Hydrology

Fluvial Inflows

3.7. As part of this study, the EA advised that the hydrology of the model would likely need updating to include more recent data and would also require an assessment of the latest climate change scenarios.

3.8. A hydrology report was prepared by consultant hydrologist Dr Paul Garrad and is included in **Appendix B**. The report identifies that the catchment of the Lavant Stream is divided into the upper, rural, chalk dominated catchment and the lower, urban, clay catchment (approximately 56 km² and 1.5 km² respectively) and that these two distinct catchments influence the hydrology of the system significantly.

3.9. Flows for the larger, predominantly rural, chalk catchment were derived using the Flood Estimation Handbook statistical method. Flows for the smaller, urban, clay catchment were derived using the ReFH method. Peak flows are included within the hydrology report in **Appendix B**.

3.10. The hydrology of the Lavant Stream is complex within the urban area of Havant. As with most urban catchments, runoff is contributed to the stream at multiple points along its reach from the surrounding urban sewer system and surface water network. The Lavant Stream is also characterised by the presence of several long culverts as it flows through the town centre. In addition, the main channel divides into two separate watercourses upstream of the Site adjacent to Park Road North. The bypass channel, as it's known, flows south adjacent to Park Road South and towards the estuary. The other channel flows westwards and southwards in culverted section towards the Site where it is fed by a series of springs at a boundary between clay and

chalk geology. At this location the Lavant Stream is sometimes referred to as "Brockhampton Springs".

3.11. Upstream of the urban area, a flood relief culvert known as the Lavant Link Pipe is present. This structure is designed to transfer flows from the Lavant Stream to the neighbouring Hermitage Stream during peak flows.

3.12. Due to the complex nature of the urban hydrology outlined above, it was considered that it would not be appropriate to apply the urban hydrology to the model as a single inflow at the upstream of the model reach. Instead, the urban hydrology has been divided and applied incrementally along the urban reach based on the urban subcatchments as defined in the original EA Infoworks CS model.

3.13. In accordance with the EA's latest guidance, an assessment of the impact of climate change has been taken into consideration by increasing fluvial and sewer flows as well as the tidal boundary levels. Suitable allowance for increased river flow due to climate change were considered based on the EA's February 2016 guidance.

3.14. The current Site is located in the South East Region and is allocated for commercial development. The central allowance is therefore appropriate in this instance, however as a conservative assessment the higher central allowance has been used in this study i.e. the 1 in 100 year plus 45% event.

<u>Tidal Boundary</u>

3.15. The Tidal boundary was updated based on the East Solent Tidal Model built by JBA in July 2018. The model domain covering the area of interest is that of the Hayling Island model and the closest node to the Site of interest is BNDRY_5. The remaining nodes are located further east and south away from the Site of interest.

3.16. The 1 in 2 year climate change tidal curve was used in the model. The 2 year present day tidal peak level, according to the East Solent Modelling study undertaken by JBA in July 2018, is 2.91 m AOD.

Guidance from the EA states[1] that the anticipated rise in sea level for the south east of England up to the year 2115 is expected to be 1.21 m. Therefore, this value was used for the Climate Change adjustment. Based on the above the 2 year climate change tidal peak level is 4.11m AOD.

Data sources

1D Domain

3.17. The 1D model has been constructed using a mixture of different data sources.

3.18. The primary data source that has informed the 1D domain is channel survey cross sections collected by Terrain Geomatics in May 2019 of the Lavant Stream. The surveyed reach extends from Farringdon Road down to the estuary but did not include the Bypass Channel and also, due to access restrictions, did not include details of the Lavant Link Pipe.

3.19. The modelled reach was supplemented with data from the original EA InfoWorks RS model. Cross sectional data was extracted and incorporated to the FMP model extending the reach approximately 600 m upstream of Farringdon Road as well as at other selected locations.

3.20. Cross sections for the Bypass Channel adjacent to Park Road North were also extracted from the RS Model and incorporated into the FMP model. Details of the Lavant Link Pipe were extracted from the CS model. The total 1D model extent therefore extends from north of Bartons Road approximately 3.0 km upstream of the Site down towards the estuary 700 m downstream of the Site where the tidal boundary is applied. These extents are considered appropriate for the scope of the study. Full 1D and 2D model extents are provided in **Appendix C**.

[1] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#future-flood-risk-management

3.21. Observations and measurements of additional structures and features were also made during a walkover of the Site and modelled reach.

3.22. Manning's 'n' values have been applied to the 1D domain based on Manning's 'n' for Channels from Chow, 1959 and a review of photographic data provided by the surveyor as well as observations made on Site. Where EA cross sections have been utilised the Manning's 'n' values have only been adjusted where information to the contrary is available. For in channel, Manning's 'n' values are typically in the range between 0.03-0.04 but are as low as 0.025 for some stretches of concrete lined channel and 0.015 for a short section of brick lined channel between nodes S31-S30. Manning's 'n' values of between 0.025-0.035 have been adopted for concrete structures and culverts throughout the 1D domain. The values for the 1D domain are within the range of typical Manning's 'n' values for in channel and are industry standard practice. They are therefore considered to be appropriate to the study.

3.23. Further details regarding the control structure immediately downstream of the inlet to the Lavant Link Pipe at Crossland Drive were obtained through consultation with the EA (refer to **Appendix D**). The consultation established that a penstock is present downstream of the inlet which restricts flows during peak events and elevates the upstream water level. This enables flow to enter the Lavant Link Pipe which is subsequently transferred to the Hermitage Stream catchment to the west.

3.24. Due to access restrictions, the surveyors were unable to collect data of this structure directly. Therefore, the details supplied by the EA represent the best available information of this structure. The penstock was represented in the model using two orifice units with assumptions made on the dimensions of the structure based on the photograph provided by the EA in **Figure 4-2** below.

Figure 4-2: Penstock control structure downstream of Lavant Link Pipe

2D domain

3.25. The floodplain has been represented within the 2D domain of the model using LiDAR data. 1m resolution LiDAR data of the study area was obtained from the EA and incorporated into the hydraulic model. The hydraulic model has been run with a 2m cell size to represent the 2D domain. This provides sufficient resolution to accurately model flood flow paths whilst also ensuring model run times are not excessive.

3.26. OS OpenMap Local shapefile data was obtained from Ordnance Survey. This was then used to inform the 'materials' file within Tuflow. The 'materials' file allows for a Manning's 'n' roughness value to be applied to the floodplain.

3.27. Together, the LiDAR data and 'materials' file allow for an accurate representation of over land flow paths throughout the 2D model domain.

3.28. Manning's 'n' values for the 2D domain are presented in **Table 4-1** below. These are within the range of typical Manning's 'n' values for floodplain and are industry standard practice. They are therefore considered to be appropriate to the study.

Table 4-1: Manning's 'n' values for 2D domain

Land use	Manning's 'n' value
Open Water	0.02
Roads/Tarmac	0.025
Default Grassed Areas / Car parks	0.035
Railway Tracks	0.04
Pasture / light vegetation	0.055
Urban areas/ Fenced Gardens	0.06
Dense vegetation / Wooded areas	0.08
Warehouse type Buildings	0.1
Masonry / Concrete Buildings	0.3
Stability Patch	0.9

Baseline Modelling Results

3.29. The Ardent baseline hydraulic model has been run for the following events:

- 1 in 100 year
- 1 in 100 year plus 45% climate change
- 1 in 1000 year
- 1 in 1000 year plus 45% climate change

3.30. The hydraulic model was run in the following software versions:

- Tuflow; 2018-03-AE-iDP-w64
- Flood Modeller Pro; 4.5.1

3.31. The model was run with a 1 second timestep for both the 1D and 2D domains. It is usual modelling practice to model the 1D domain with a timestep that is half that of the 2D domain if possible, however due to the inclusion of multiple structures in the urban reach a reduced 1D timestep was not possible due to instabilities.

3.32. Model plots for all baseline events are included in **Appendix E**. **Figure 4-3** below shows the maximum flood depths on Site during the 1 in 100 year plus 45% climate change baseline scenario overlain with the EA model flood extents for the 1 in 100 year plus 20% climate change scenario.

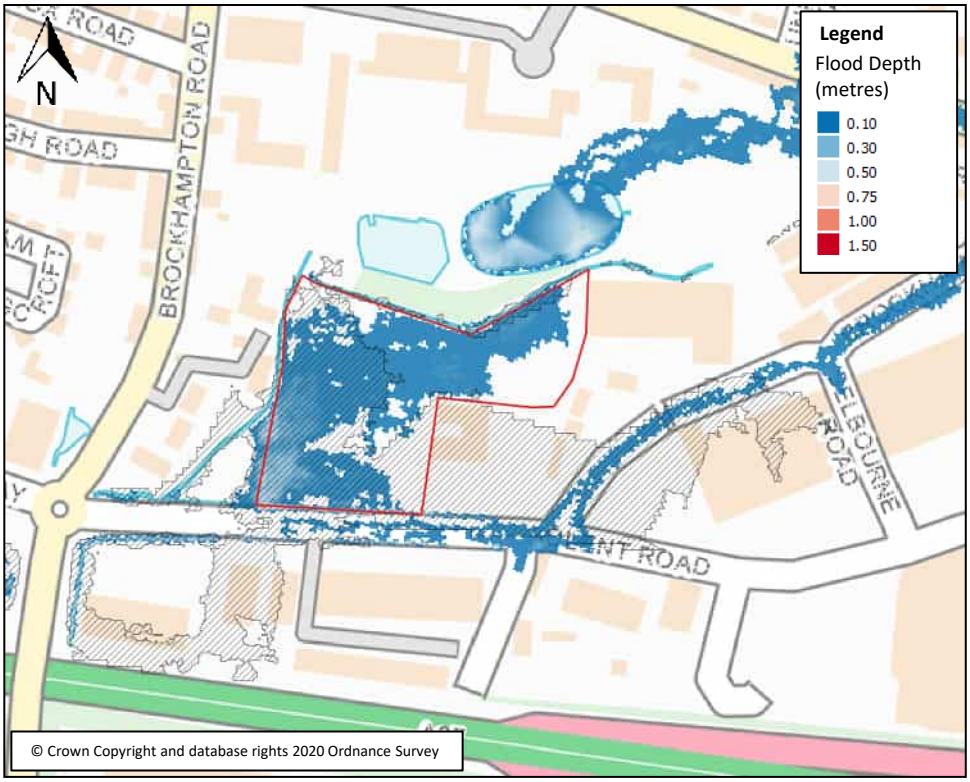

Figure 4-3: 1 in 100 year plus 45% climate change baseline scenario maximum flood depth

3.33. The EA flood outline covers the majority of the western and southern portions of the Site. However, the Ardent flood extent impacts the majority of the Site. The EA outline suggests that flood water is coming out of bank on the Lavant Stream on the western boundary of the Site as the watercourse flows southwards. However, analysis of aerial photography and site visits have confirmed that the presence of a 2.0 m high wall running the length of the channel at this location (**Figure 4-4**) prohibits any water from coming out of bank. Further interrogation of the EA model indicates that this wall has not been included within the model. The EA outputs are therefore misrepresentative.

3.34. The EA were consulted regarding their modelled outputs who stated that the wall has not been included in their model as the Flood Map for Planning does not take into account the presence of flood defences (despite the wall not being a formal flood defence).

Figure 4-4: 2.0 m high wall curtailing western boundary of the Site

3.35. In the Ardent outputs, the 2.0 m wall is included which prevents any out of bank flow occurring at this location. The Site however becomes flooded as a result of the limiting capacity of a 600 mm diameter culvert on the northern boundary of the Site. This constriction results in water levels becoming elevated upstream of the culvert and spilling over the left bank of the watercourse. This forms a shallow flow path across the Site (less than 100 mm depth) with water propagating westward. Water is unable to re-enter the watercourse in the Ardent model as the 2.0 m high wall is included. Instead, flood water flows south where a drainage ditch is present along the southern boundary of the Site adjacent to Solent Road. This ditch, and a series of

culverts, serve to convey flood flows away from the Site and back into the Lavant Stream downstream of the Site.

3.36. This flooding mechanism was also observed for the other modelled baseline events (refer to model plots in **Appendix E**).

3.37. In order to alleviate the flood risk to the Site, it was proposed to remove the 600 mm culvert in order to remove the hydraulic control. This is discussed in the following section.

Mitigation Modelling

3.38. In order to mitigate the risk of flooding to the Site, Ardent undertook an iterative process firstly be removing the 600 mm culvert on the Lavant Stream on the northern boundary of the Site from the 1D model domain. Elevations along the northern bank of the watercourse were also lowered in order to provide a degree of attenuation in order to reduce the potential risk in flooding downstream as a result of the increase in flows. In total a 145 m length of the northern bank was lowered to an elevation of 5.2 m AOD (average 750 mm depth of material). This served to alleviate the risk of flooding to the Site without impacting flood risk downstream. However, following an ecological assessment of the Site, it was confirmed that several trees had Tree Preservation Order (TPO) status and that it would not be possible to excavate the full 145 m reach. Therefore, targeted locations for excavation were established and it was proposed to also include a low level bund along the southern edge of the Lavant Stream.

3.39. The bund is to be set 5.0 m back from the watercourse with additional minor excavations carried out to provide additional attenuation. The bund is intended to tie in with brick arch culvert headwall at the north west corner of the Site. The bund has been designed to be typically 500 mm – 600 mm in height above adjacent ground levels. The proposed bund and excavation works are shown on drawing number **191920-001** in **Appendix F**.

3.40. In order to represent the bund and proposed excavation works within the 2D domain of the model, a series of 'z_shapes' were used that

allow the ground model utilised within Tuflow to be manipulated by either lowering or raising elevations. This in addition to the culvert removal from the 1D domain were the only changes made between the baseline and mitigation modelling scenarios.

Mitigation Model Results

3.41. **Figure 4-5** below shows the post development maximum flood depths for the 1 in 100 year plus 45% climate change mitigation scenario in comparison to the baseline flood extents. Model plots and comparison plots for all modelled events are included in **Appendix G**. It can be seen that the proposed mitigation measures of removing the culvert and the associated bund and excavation works have served to completely mitigate the risk of flooding to the Site. In addition, there is a de minimis impact on flood extents offsite as a result of the proposed works.

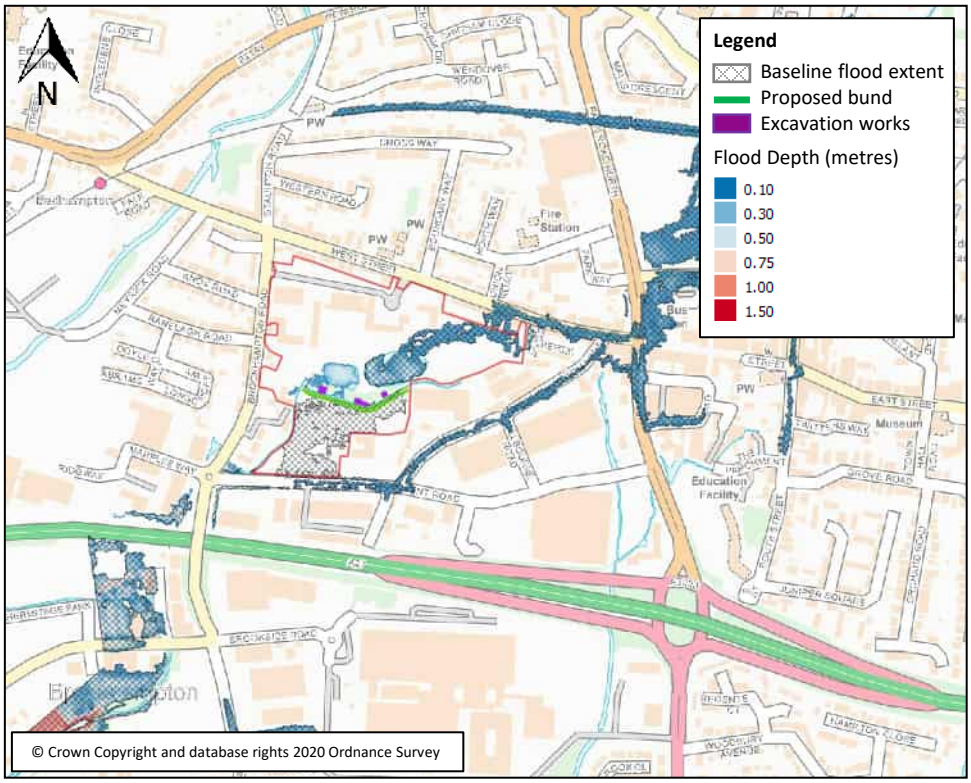

Figure 4-5: 1 in 100 year plus 45% climate change, mitigation scenario maximum flood depths

Sensitivity Testing

3.42. In order to test the accuracy of the model, it would be desirable to compare the modelled outputs against observed data and flood extents in order to calibrate and validate the model. However, there is currently no calibration data available which to test the model against. As a compromise, Ardent have modelled a range of return period events for both the baseline and proposed scenario as well as undertaken a series of sensitivity tests to determine the robustness and suitability of the model as well as to determine the impact of the proposed works offsite. This is considered to be wholly adequate given the scale of the proposed works and the nature of the FRAP application.

3.43. Standard modelling practice typically involves sensitivity testing of the following parameters:

- Boundary Conditions
  - Inflows
  - Downstream *boundary (+/- gradient 20%)*
- Manning's 'n' roughness (+/- 20%)

3.44. In testing the climate change scenario of the study area, the boundary conditions have been adjusted with an uplift in flows against the present day conditions but also at the downstream boundary. As discussed in **Section 3.16**, the study site is located within 1 km of the estuary and there is therefore a tidal influence at the downstream boundary. In the baseline scenario this has been accounted for by applying the 1 in 2 year maximum tidal curve taken from the JBA East Solent Tidal Model (2018). The 2 year present day tidal peak level, according to the East Solent Modelling study undertaken by JBA in July 2018, is 2.91m AOD. Guidance from the EA (December 2019) states that the anticipated rise in sea level for the south east of England (higher central allowance) up to the year 2115 is expected to be 1.21 m. Therefore, this value was used for the Climate Change adjustment. Based on the above the 2 year climate change tidal peak level is 4.11m AOD.

3.45. The results show that as expected with the uplift in inflows, there is an increase in maximum stage within the 1D results as well as an

increase in flood extents in the 2D where flood water is coming out of bank. With respect to the downstream boundary, the additional application of 1.21 m due to climate change elevates maximum water level downstream of the Site (see **Appendix H**). It is this which is the dominant hydraulic control influencing flood level at this location as opposed to the gradient of the bed level in this downstream reach. The results show that the Site, and the culvert are sufficiently elevated above this maximum tidal level so as not to be influenced by the impact of tide locking.

3.46. With regard to the Manning's 'n' roughness value sensitivity test, Ardent initially attempted to test this during the 1 in 100 year plus climate change event in the culvert removed scenario. However, due to the urbanised nature of the watercourse which flows through multiple culverts and structures, the 1D component of the model is quite sensitive when these structures become surcharged. During the climate change scenario, the steepness or 'flashy' nature of the urban hydrographs is amplified due to the significant uplift of 45% in peak flows (refer to example below) and exacerbates these instabilities. While testing Manning's 'n' in the 1 in 100 year plus climate change scenario, the 1D component of the model routinely crashed before the peak flood level was reached due to the factors mentioned above. Therefore, in order to ensure a complete test of Manning's 'n' could be assessed, the sensitivity test was carried out on the 1 in 100 year scenario without the application of climate change instead.

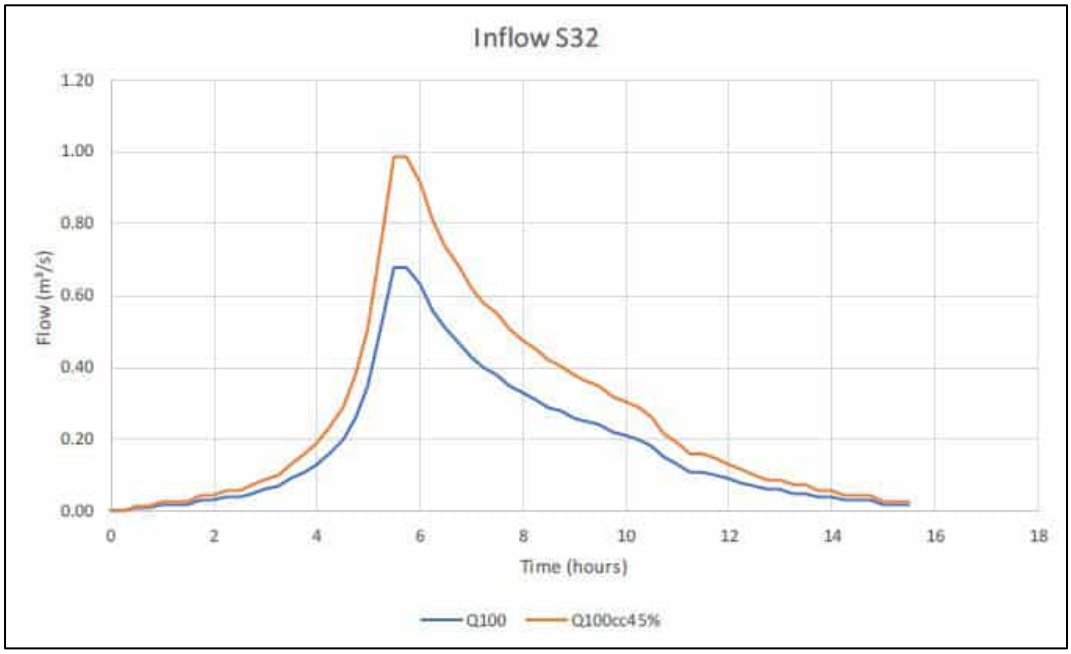

Figure 4-6: Comparison of baseline vs climate change hydrograph

3.47. The 1D, 1 in 100 year Manning's 'n' sensitivity results are presented in **Appendix H**. The results show that as expected, an increase in maximum stage within the 1D model associated with increase in Manning's 'n' and a decrease in maximum stage associated with a reduction in Manning's 'n'.

3.48. This is also broadly reflected in the 2D results (**Appendix H**) with an increase in flooding associated with an increase in Manning's 'n' and vice versa with a reduction. However, there are a couple of exceptions where the flood the +20% flood extent is less than the baseline scenario where flooding forms an overland flow path across roads and tarmacked areas. In the baseline scenario these areas have a Manning's 'n' value of 0.025. In the +20% scenario this increases to 0.030. This increase in resistance reduces velocities and prevents the flood flow path propagating further. In the –20% scenario, despite there being even less resistance in these areas, there is less volume coming out of bank to cause an increase in flood extent. The model is therefore considered to be robust to changes in Manning's 'n' with no significant changes as a result to changes in this parameter.

4. CONCLUSIONS

4.1. This FRA has been produced to support the Flood Risk Activities Permit (FRAP) application for the removal of a 600 mm diameter culvert on the Lavant Stream where it flows through Portsmouth Water owned land at Solent Road, Havant.

4.2. In constructing a new hydraulic model of the Lavant Stream based on new survey data and updated hydrological inputs, Ardent have been able to make a more robust, accurate and up to date assessment of baseline flood risk at the Site when compared to the EA outputs shown on the Flood Map for Planning. The Ardent baseline modelling outputs established that the Site was at risk of flooding due to the insufficient capacity of the 600 mm diameter culvert which acts as the main hydraulic control along this reach. The culvert has a throttling effect thereby elevating the upstream water level resulting in flows coming out of bank and propagating across the Site.

4.3. Ardent have undertaken proposed mitigation modelling scenarios to determine the potential impact of removing the culvert to alleviate flood risk at the Site. There was a risk that by removing the culvert flood risk downstream of the Site could be increased as a result of the additional flow volumes being conveyed within the channel. Consequently, earthworks were proposed along the north bank of the Lavant Stream to provide a degree of attenuation and reduce any potential offsite impacts. However, due to the presence of Tree Protection Orders, opportunities to excavate here would be limited. A 145 m bund was therefore also proposed on the left bank of the watercourse set back by a distance of 5 metres. This would allow for further attenuation whilst also ensuring the Site remains flood free during the 1 in 100 year plus climate change scenario.

4.4. The results of the mitigation modelling simulations showed that there was de minimis impact on flood risk offsite with the culvert removed when compared to the baseline modelling results. Sensitivity testing of key parameters has demonstrated that the model is fit for purpose.

4.5. In conclusion then this FRA has demonstrated that the FRAP application for removal of the culvert is acceptable in terms of not increasing flood risk offsite.

Appendix A

EA PSO Team Modelling Methodology Consultation

John Easton

From: Partnership and Strategic Overview team, HIOW <psohiow@environment-agency.gov.uk>
Sent: 26 June 2020 15:06
To: John Easton
Cc: Chris Hardyman; Jenna Dewhurst; 'Tony Chalkley'; Simon Deacon; Steve Cross; Brian Cafferkey; Georgia Athanasia
Subject: RE: EPR/PB3294JJ Ardent Flood Risk Report - Solent Road Havant [Filed 02 Jul 2020 11:28]
Attachments: EPR_PB3294JJ Schedule 5 Notice of request for more information.pdf

Hi John,

Thank you for your comments.

Our response is as follows:

Thank you for submitting the extra clarification and justification behind some of the modelling techniques. We can confirm that we deem that the model is fit for the purpose of this Flood Risk Activity Permit, we caveat this statement with the fact that if this was to come in as part of a planning application the model may be scrutinised further.

As part of the FRAP we ask that you now produce a flood risk assessment using the model and the scenarios you have produced to clearly conclude an assessment of flood risk both on site and off site. Any FRA should be clear on the methodology used and this justified where appropriate. If the FRA finds that flood risk is increased as part of the proposal, mitigation measures should be outlined to tackle this. We should note that this does not have to be a lengthy document, but needs to assess the baseline and proposed flood risk of the works and clearly conclude this alongside any potential mitigation measures.

Chris, as Agent for this FRAP I attach the Schedule 5 request for information. When we have seen the updated FRA this will likely satisfy schedule 1 regarding addressing the flood risk. We still await a response to schedule 2-9 regarding the environmental concerns.

Thank you for your patience in reviewing this Flood Risk Report.

I would like to stress that as per our policy on culverts, we hope to facilitate the removal of culverts where possible through our role as regulator.

As such we are more than keen to help these works proceed. If you have any questions please do let me know.

We look forward to receiving your FRA as per above.

Kindly,

Nathan Bayley

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Appendix B

Hydrology Report

Flood Hydrology

Lavant Stream,
Solent Road, Havant, Hampshire

May 2019

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Flood Hydrology
Lavant Stream at Solent Road, Havant, Hampshire

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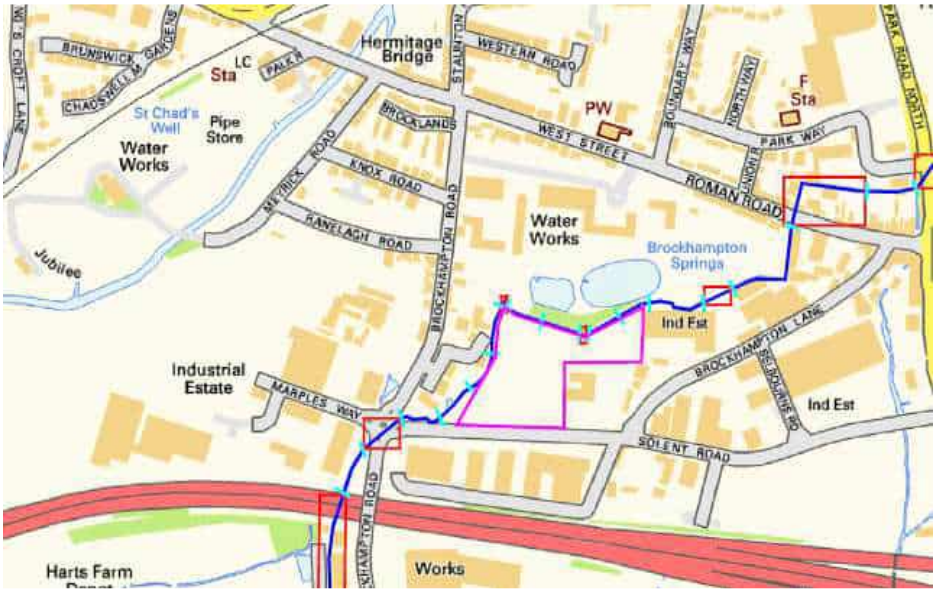
Appendix A Revised ReFH Method Flood Hydrographs for Urban Area of Havant

1 INTRODUCTION

1.1 Site Location

As part of a Flood Study for a site on Solent Road in Havant (Figure 1.1) flood levels are required for the Lavant Stream using a hydraulic river model. The EAs existing model of this watercourse dates from 2008 and the EA has suggested that the flood hydrology should be updated to include more recent events and updated methods. The revised and updated flood hydrology is therefore considered in this report.

Figure 1.1 Proposed Development Site and Flow Estimate Location



The Lavant Stream drains a 55km² mainly rural Chalk catchment upstream of Havant but the lower area lies on impermeable clay and drains urban areas of the town which discharge into the watercourse at numerous outfalls. The 2008 flood study suggested the interaction between flows from the upstream rural catchment and the urban drainage system is the prime cause of local flooding and any flood study should consider the interaction of these two components.

For this complex catchment the hydrological response will therefore be a function of:

- The baseflow dominated upper Chalk catchment with a winter high and summer low baseflow and a slow or muted response to rainfall due to the low percentage runoff. However very high peak flows can occur when the catchment is saturated and the percentage runoff may then be higher than the geology would suggest. This can occur after prolonged rainfall events such as occurred in October/November 2000.

- The quick response of the lower Lavant Stream catchment which is predominantly clay and heavily urbanised giving a rapid response to rainfall and with a high percentage and the runoff from these urban drainage systems then discharge into the stream network.

The EAs 2008 report states it is unlikely that a storm event on these two sources individually would result in flooding within Havant but it is when the two types of storm combine that flooding is more likely. This will occur due to high intensity short duration rainfall over the urban catchment following months of heavy rainfall with high river levels due to elevated baseflow on the larger rural catchment.

Flows in this report are therefore considered at two points, at the upstream end of the proposed model at the EAs Leigh Park flow gauge near Crossland Drive which represents the Chalk rural upstream catchment and the downstream of the urban area of Havant, which is in the London Clay, at the flow diversion near Park Way and Solent Way. There is a small difference in the catchment area between these points (Table 1.1) of 1.55km^2 and flows from this lower urban area are considered separately.

Table 1.1 Flow Estimate Locations

ID	Location	Easting	Northing	Area (km2)
Gauge	EA gauge at Crossland Drive	472103	107200	55.96
DS	Flow diversion at Park Way	471550	106250	57.51
Urban	Havant between gauge and Park Way			1.55

The hydrology of this watercourse is also complicated by a flood relief culvert, the Lavant Link Pipe, which diverts flows from the Lavant Stream to the Hermitage Stream when flows are above 0.28m^3/s. The inlet is located downstream of Crossland Drive road bridge and discharges into the Hermitage Stream 850m to the east upstream of Barncroft Way. The Lavant Stream also divides into two channels between Roman Road and Park Way upstream of Solent Road. These issues are considered in the hydraulic modelling element of this study.

1.2 Methodology

Flood flows are provided for a range of return periods, including the 2 year, 20 year, 100 year and 1000 year events using methods detailed in the Flood Estimation Handbook (FEH)[1] and the EA's FEH Guidelines[2]. Flow estimates for extreme events may be quite uncertain hence the approach is to use and compare

- the FEH Revised Statistical Pooling Group approach,
- the Revitalised Flood Hydrograph Method (ReFH) for the full catchment and for the urban area, and
- the single site method if appropriate.

These methods are considered in Section 2 of this report with extension to the 1000 year return period event, a comparison of flood estimates and the addition of an appropriate allowance for climate change are considered in Section 3. Flow from the urban area considered in Section 4.

[1] The *Flood Estimation Handbook,* Centre for Ecology & Hydrology, 1999.
[2] Environment Agency's *Flood Estimation Guidelines*, Technical guidance 197_08, January 2015

2 FLOOD FLOWS - RURAL CATCHMENT

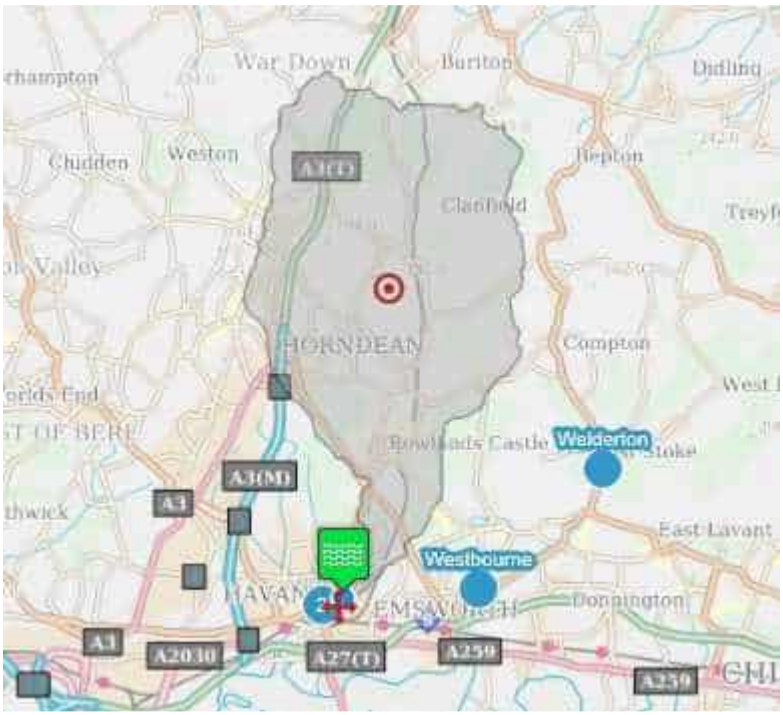
2.1 FEH Statistical Method

As a first approach it is convenient and appropriate to use the FEH Statistical method which is based on FEH Catchment Descriptors (CDs).

2.1.1 Catchment Descriptors

The FEH on-line has been used to provide the catchment delineation at the Leigh Park flow gauge (Figure 2.1) which confirms that the catchment has a simple structure with no lakes, reservoirs or major sub-catchments and a simple flood hydrograph response may be expected. As the catchment is rural FEH methods are considered suitable and can be used to derive flood flows at the required location. The catchment delineation was checked against OS maps and appears reasonable hence a manual adjustment of the FEH catchment area was not undertaken although in Chalk catchments the groundwater catchment may not always coincide with the topographical catchment.

Figure 2.1 Lavant Stream FEH Catchment Delineation at EA Flow Gauge



The FEH catchment descriptors (Table 2.1) show this drainage area is large (55.96km^2) and rural (URBEXT1990 = 0.021), with no lakes or ponds (FARL = 0.999) and with a low percentage runoff (SPRHOST 10.1%) which suggests no obvious reasons for not using the FEH methods for flood estimation. A full definition of these FEH parameters is given in FEH Volume 5. The previous 2008 flood study also noted the low permeability and required a permeable adjustment to the Stas method but this is no longer required with the Revised Stats method and the updated WINFAP 3/4.

Table 2.1 FEH Catchment Descriptors

Parameter	Gauge	DS
AREA	55.96	57.51
FARL	0.999	0.999
PROPWET	0.34	0.34
BFIHOST	0.886	0.872
DPLBAR	10.27	11.3
DPSBAR	89.1	87.5
SAAR	905	900
SPRHOST	10.1	10.99
URBEXT1990	0.0210	0.0293
URBEXT2000	0.0231	0.0521

2.1.2 FEH Index Flood (QMED)

The FEH catchment descriptors defined above are used to derive QMED, the median annual flood (Table 2.2), using the Revised Stats Method QMED equation[3]. The URBEXT2000 is updated to 2019 and the urban adjustment factor (UAF) uses both the original Bayliss method based on SPRHOST and also Kjedsen's updated method with UAF based on BFIHOST (Table 2.2). The EA's FEH guidelines recommend the Kjedsens urban adjusted QMED is used which gives a QMED of 3.461m^3/s at the EA gauging station.

Table 2.2 QMED from Catchment Descriptors

Site	Method	URBEXT 1990	URBEXT 2000	URBEXT 2019	UAF	QMED RURAL(m^3/s)	QMED URBAN(m^3/s)
Gauge	Bayliss	0.0210	0.0231	0.0240	1.084	2.862	3.101
Gauge	Kjedsen	0.0210	0.0231	0.0240	1.210	2.862	3.461
DS	Kjedsen	0.0293	0.0521	0.0541	1.440	3.123	4.498

The QMED-CD at an ungauged site is then adjusted using the ratio between QMED-CD and QMED-Flow data at a nearby local donor gauging station. The EA operate two gauges in the local area at Leigh Park on the Lavant Stream and on the adjacent Hermitage Stream at New Road (Table 2.3).

Table 2.3 EA Gauging Stations near Havant , Hampshire

CEH Ref	Watercourse	Location	Start Date	End Date	No Years	QMED ?	Pooling ?
42025	Lavant Stream	Leigh Park	1981	2002	22	No	No
42017	Hermitage Strm	New Road	10 Feb 1954	30 Sept 2017	51	Yes	No

The National River Flow Archive and HiFlows database (version 7) indicates:

- 42025, Lavant Stream at Leigh Park. A velocity-area station in a trapezoidal section. The rating is poorly defined at low flows and the station is bypassed by flood flows above

[3] *Improving the FEH statistical procedures for flood frequency estimation. CEH Science Report SC050050, July 2008*

3m^3/s. The topographical catchment greatly exceeds the groundwater catchment. The flow records are not suitable for QMED or pooling hence this station is not included in FEH or the HiFlows database. The gauge became ineffective in 2002 due to the insertion of a grill immediately downstream of the open channel site and flow records stopped at this time.

- 42017, Hermitage Stream at Havant. A Velocity area station in a concrete trapezoidal section in a formalised reach with grass berms. The structure is designed to measure up to 14m^3/s and all but exceptional flows are contained with the structure which has only been exceeded a few times since installed in 1954. The bridge downstream may cause some backing up. The theoretical rating is supported by numerous current meter gaugings. The flow records are suitable for QMED as it is gauged above this flow but the rating cannot be validated for higher flows above QMED hence the flow records are not suitable for pooling.

The timescale of this study does not allow for a detailed analysis of the high flow ratings at these two gauging stations but the flow data is considered suitable for QMED at only one of these stations and these flow data are used in the flood estimation process described below.

In selecting a suitable donor gauging station FEH also provides hydrological similarity criteria as follows;

- AREA – a factor of 4 or 5
- FARL – a difference of 0.05.
- BFIHOST – a difference of 0.18
- SAAR – a factor of 1.25
- SPRHOST – difference of 15

A comparison of the catchment descriptors at the potential donor station and at the site of interest (Table 2.4) suggests 42017 is outside the bounds of hydrological similarity in terms of BFIHOST and SPRHOST being located mainly on Clay strata rather than the Chalk hence the Hermitage Stream gauge is not suitable as a donor.

Table 2.4 Catchment Descriptors at Flow Estimate Site and Donor Gauging Stations

Site ID	AREA	FARL	BFIHOST	SAAR	SPRHOST	URBEXT90
42025	55.96	0.999	0.886	905	10.1	0.0210
42017	17.33	0.991	0.245	785	46.0	0.1675

Despite the reservations given above, in terms of flow data accuracy, in the absence of any other stations the Leigh Park gauge is considered as a donor principally as a check. This is based on the flow data provided in the EAs 2008 flood mapping study and as this station closed in 2002 there is no further or additional data to extend this record. A comparison suggests QMED from CDs overestimates that from flow data and that a factor of 0.517 should be applied to the CD estimates (Table 2.5) to match the data at the flow gauge.

Table 2.5 QMED at Donor Gauging Stations (m^3/s)

Ref	QMED-Urban CDs	QMED-AMAX	Ratio
Gauge at Leigh Park	3.461	1.790	0.517

The Revised Stats method requires this donor ratio is further adjusted based on the distance between the catchment centroids but as the flow estimation point is at this flow gauge this adjustment is not required. The adopted QMED at the gauge is therefore 1.79m^3/s (Table 2.6) the same as the recorded flow data.

Table 2.6 Adopted QMED

Site	QMED Rural CDs	QMED-urban	QMED Factor	Adopted QMED
Gauge	2.862	3.461	0.517	1.790
DS	3.123	4.498	0.517	2.326

2.1.3 Flood Frequency Curve

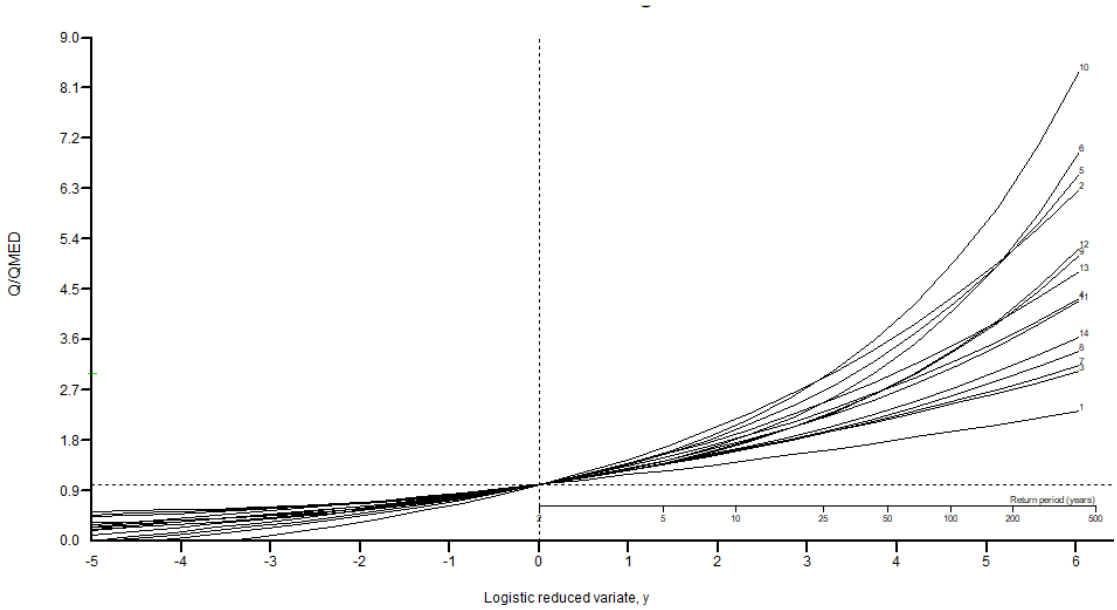
The calculation of a flood frequency curve and peak flows for a range of return periods requires the construction of a pooling group and the fitting of an extreme value distribution to the annual maximum flow data from hydrologically similar sites (pooling group) using WINFAP4.

The initial pooling group contains 14 stations with 513 station years of record and no stations were removed for having less than the required 8 years of data. Examination of the pooling group indicates it is possibly heterogeneous and a review considered optional (H2 = 1.583) but a review of the pooling group suggests no obvious or valid reason to remove any of the component stations. This discordancy arises as several of the component stations (Table 2.7) have relatively steep growth curve (Figure 2.2) with known major flood events (e.g. Doniford at Swill Bridge) and some stations have very flat growth curves but there was no justification for removing any sites from the group.

Table 2.7 Component Stations of Pooling Group – Lavant Stream

Station	Dist	Yrs data	QMED AMAX	L-CV	L-SKEW	Discord
42011 (Hamble @ Frogmill)	0.173	45	8.159	0.170	0.076	1.592
43806 (Wylye @ Brixton Deverill)	0.287	26	1.995	0.387	0.223	2.004
53017 (Boyd @ Bitton)	0.337	44	13.845	0.244	0.094	0.620
41022 (Lod @ Halfway Bridge)	0.362	47	15.900	0.295	0.179	0.581
27095 (Pickering Beck @ Pickering)	0.365	17	8.261	0.311	0.312	0.464
42008 (Cheriton Stream @ Sewards Bridge)	0.380	46	1.350	0.255	0.408	1.291
44011 (Asker @ East Bridge Bridport)	0.380	22	16.200	0.234	0.121	0.879
44003 (Asker @ Bridport)	0.380	14	12.354	0.224	0.170	1.468
76019 (Roe Beck @ Stockdalewath)	0.385	18	41.711	0.236	0.318	1.589
51001 (Doniford Stream @ Swill Bridge)	0.391	51	11.710	0.322	0.387	1.290
42006 (Meon @ Mislingford)	0.408	58	2.947	0.260	0.216	0.418
27059 (Laver @ Ripon Laver Weir)	0.452	40	22.024	0.231	0.334	1.055
20007 (Gifford Water @ Lennoxlove)	0.468	44	16.895	0.321	0.191	0.559
53023 (Sherston Avon @ Fosseway)	0.493	41	7.280	0.229	0.193	0.191

Figure 2.2 WINFAP Component Stations – Lavant Stream



WINFAP4 is often found to provide discordant pooling groups and this arises because it uses the FEH parameters FARL and FPEXT to generate a pooling group, which are measures of flood storage and attenuation, whereas the original WINFAP was based on the soil or geology as reflected in BFIHOST. WINFAP4 will often provide a more discordant pooling group as the shape of the growth curves of the component stations is more likely to be a function of the geology. However, the EA FEH Guidelines require the use of WINFAP4 and this is method is therefore adopted in this report.

Two extreme value distributions are often used on the pooled group data (i) the Generalised Logistic (GL), and (ii) the General Extreme Value (GEV) distribution both fitted to the annual maximum data by the method of L-Moments. WINFAP indicates that in this case the GL distribution provides the best fit to extreme value flood series and this is used to provide the estimated flood flows (Table 2.8). This give a 100 year flood flow at the flow gauge site of 4.85m^3/s. The same growth curves is applied to give flood flows at the downstream location.

Table 2.8 Estimated Flood Flows – Stats Method

Site	Return Period (Years)					
	2	**5**	**10**	**20**	**50**	**100**
Gauge	1.79	2.41	2.87	3.37	4.15	4.85
DS	2.33	2.96	3.44	3.96	4.76	5.48

2.2 Single Site Analysis

The flow data at the Lavant Stream gauging station is not suitable for QMED or pooling as the flow records are inaccurate and hence a single site analysis was not carried out. The 22-year Lavant record is also insufficient to provide confidence for estimated flows at return periods above half the length of record which is to the 11 year return period. The adjacent Hermitage Stream is a mainly clay catchment where the runoff response may be quite different to the

Chalk Lavant Stream catchment and hence these flow records cannot be used as the flood response may be quite different. It is therefore not possible to support the pooling group flood flow estimates with a single site growth curve from a local station with any confidence

2.3 Revitalised Flood Hydrograph Method (ReFH)

An alternative approach to flood estimation is to use flood hydrograph methods. The original FSR/FEH rainfall runoff method (RR) underwent significant modification in 2006 taking advantage of new data and more advanced hydrological modelling techniques since the original method was developed. The improved or Revitalised Flood Hydrograph method (ReFH) retains the overall structure of the earlier FSR/FEH RR approach but with various improvements and hence ReFH is now preferred to RR. ReFH is therefore used to derive peak flows for the specified design events based on the time to peak (Tp) and critical storm duration (Table 2.9), adjusted to be an odd multiple of the selected time step.

Table 2.9 ReFH Time to Peak and Critical Storm Duration

Site	Tp	Cmax	BL	BR	Duration (hrs)	Time Step (hrs)	Critical Dur (hrs)
Gauge	5.41	689.1	65.3	2.232	10.30	0.25	10.25

The derived flows at the Lavant gauge (Table 2.10) show that the ReFH QMED is lower that the Stats Method at 0.70m^3/s whilst the 100 year flow is higher at 5.50m^3/s.

Table 2.10 ReFH Flood Estimates (m^3/s)

Location	Return Period (Years)					
	2	5	10	20	50	100
Gauge	0.70	1.22	1.75	2.49	3.92	5.50

However, the EA's FEH Guidelines advise that ReFH does not perform well on urban or highly permeable catchments (BFIHOST>0.65) and ReFH can give unrealistically large values of Cmax to reproduce the losses and hence often provides unrealistic flows. This is partly because the flood event archive used to develop ReFH was deficient in events on permeable catchments. ReFH can therefore significantly underestimate QMED and overestimate more extreme floods, as shown above. The EA advise ReFH should not be used on permeable catchments and that the statistical method is normally preferred as it is based on fewer assumptions.

2.4 ReFH2

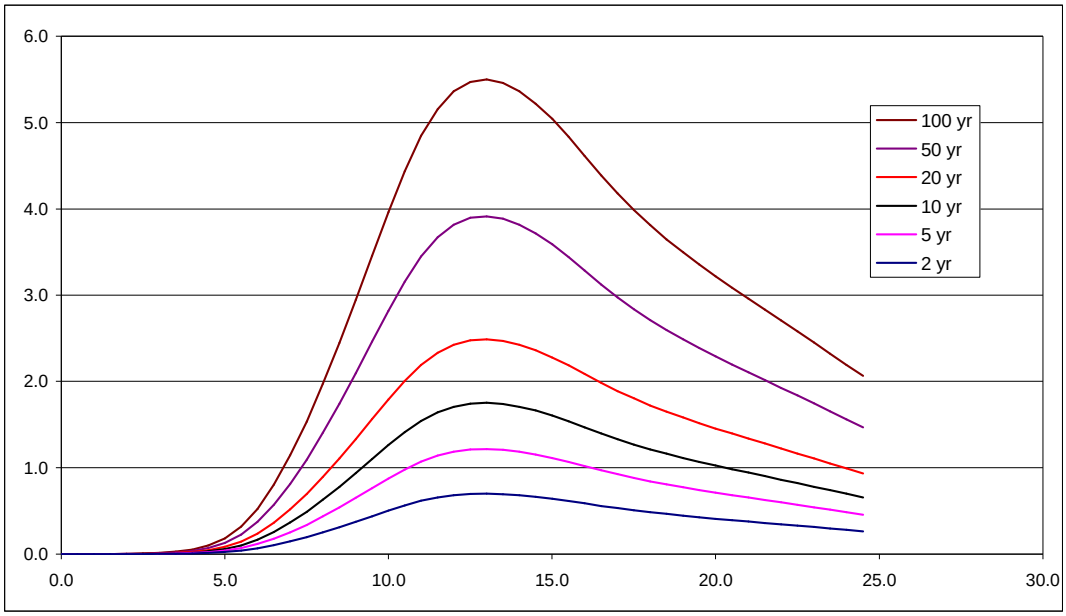
The ReFH method has been updated and ReFH2 includes updated equations, parameters and urban extent values and can use the updated FEH-2013 rainfall. The EAs guidelines recommend that both ReFH and ReFH2 are used until the implications of the ReFH2 changes are understood, which implies the peak flows from ReFH2 should not be used and that these flows are not yet accepted. The assessment of flood flows using this new method may be appropriate for large scale catchment and EA flood risk mapping studies but for a small scale flood studies and FRAs the limited budget and timescales suggest the appraisal of various methods is not appropriate or suitable and this is confirmed by the indicative timescales given in Table 2 of the EAs FEH Guidelines, where a more rapid assessment is required.

In addition the ReFH2 Technical Guidance Document shows the Stats method provides better estimates of peak flows than ReFH1 and ReFH2 when compared to measured QMED flows in terms of standard error and bias and hence the Stats method is always preferred. So even if ReFH2 is tested the estimated peak flows from the Stats method are more robust and would be adopted - the only advantage of ReFH is to provide the hydrograph shape for flood routing if using the hybrid method.

2.5 Hydrograph Shape

The ReFH hydrographs (Figure 2.3) and are typically asymmetrical as they are based on a kinked unit hydrograph. However the Lavant Stream may not provide a typical ReFH shaped response largely due to the mixture of land surface types, urban and rural, and the catchment geology of Chalk and Clay and due to the seasonal baseflow response and variable percentage runoff.

Figure 2.3 ReFH Hydrographs at Leigh Park Flow Gauge



The EAs 2008 report used the Probability Distributed Model (PDM) to provide flood hydrograph shape for the rural areas but due the variability of runoff response it was found that the PDM calibration parameters were not consistent and rather than take the average values from selected flood events the largest November 2000 flood was used to define the PDF parameters. The peak flows from the PDM hydrographs were forced to fit the Stats method, referred to as the hybrid approach, using a scaling factor of 0.491 for the 100 year and 0.471 for the 1000 year.

The shape of the ReFH hydrographs may not be as representative as PDM but as the peak flows are forced to match the Stats method the peak flows and flood levels should be similar. Alternatively, a PDM hydrograph could be exported from the EAs ISIS model so the same shaped hydrograph can be used

3 DISCUSSION

3.1 Extension to the 1000 year

The Statistical method was originally recommended for return periods up to 200 year event and ReFH is not calibrated beyond 150 years and technically these two methods are not suitable for extrapolating to the 1000 year event. The Environment Agency's Flood Estimation Guidelines[2] provide suggestions for calculating extreme floods up to the 1000 year event:

- Using a larger 200 year pooling group in the Statistical method as an intermediate between the more usual 100 year group and the potentially less homogeneous 1000 year although more recently a simple extension of the 100 year has been proposed.
- Use of ReFH although this relies on extending the method beyond the data set and as detailed above this is thought to overestimate flood flows on urban areas.
- Using the ReFH growth factors for the 200 and 1000 year event against the ReFH 100 year which are then applied to the Stats method 100 year peak flow but the same issue of using over estimated flood flows derived for urban areas will apply.

These three methods of extension provide dissimilar results (Table 3.1) due to the steepness of the ReFH growth curve but the simple extension of the Stats method is often preferred and this gives a 1000 year peak flow of 8.08m^3/s.

Table 3.1 Extension of Flood Flows at Leigh Park Flow Gauge

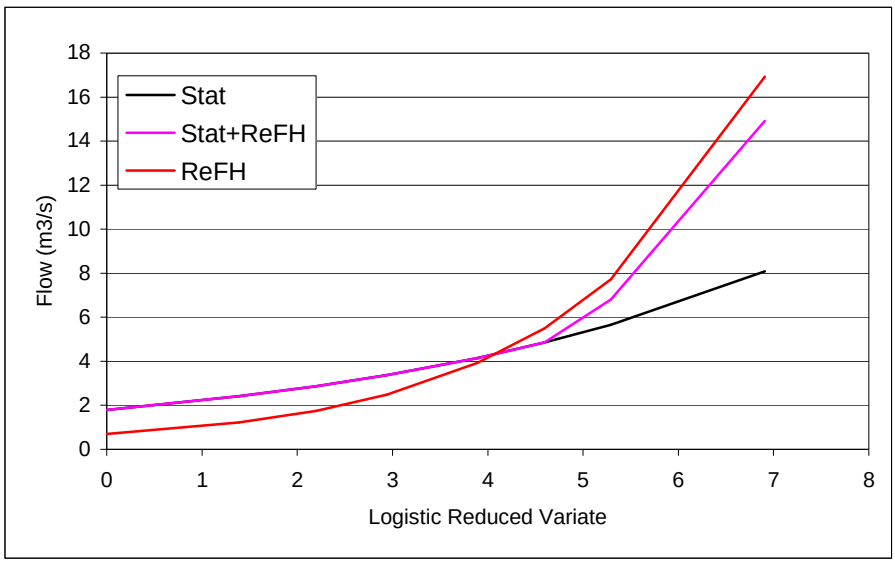
Method	Return Period (Years)							
	2	5	10	20	50	100	200	1000
Stat	1.79	2.41	2.87	3.37	4.15	4.85	5.65	8.08
ReFH	0.70	1.22	1.75	2.49	3.92	5.50	7.72	16.92
Stat+ReFH	1.79	2.41	2.87	3.37	4.15	4.85	6.81	14.92

3.2 Comparison of Flood Estimates

As detailed above QMED is lower and the more extreme flood flows from ReFH are higher than the Stats method (Table 3.1) but there is no justification for choosing either method. The extreme ReFH flows are far higher than the Stats method (Figure 3.1) but without any measured flood or flow data the choice of method is subjective.

The ReFH + Stats method of extension is also far steeper than the pooled growth Stats method curve. As ReFH is not suitable on permeable catchments both this and the ReFH + Stats methods are discounted and the Stats method is preferred.

Figure 3.1 Comparison of Flood Flow Estimates



These flood estimates are compared to the EAs 2008 report which provided a permeable adjusted pooling group and a single site analyses based on the available flow data at the Leigh Park flow gauge (Table 3.2). As the single site was based on just 22 years of flow records, and extension beyond half the length of record is uncertain, the permeable adjusted pooled flood frequency curve was adopted in this 2008 study. The Stats method estimates derived in this updated report have the same QMED value (as the same flow data was used) and a slightly steeper growth curve but essentially the flows are of the same magnitude.

Table 3.2 EA 2008 and Updated Flood Estimates at Leigh Park Flow Gauge

Method	Return Period (Years)							
	2	5	10	20	50	100	200	1000
2008 Pooled	1.79	2.40	2.85		4.09	4.76	5.53	7.80
2008 Single Site	1.79	2.1	2.3		2.8	3.0	3.2	3.7
2019 Stat	1.79	2.41	2.87	3.37	4.15	4.85	5.65	8.08

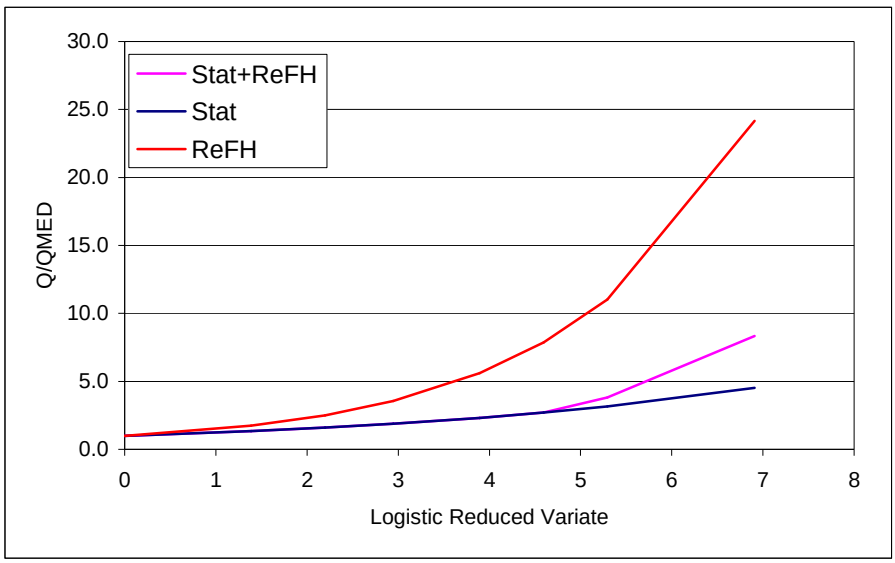
3.3 Comparison of Flood Growth Curve

A comparison of flood growth curves (Table 3.3) confirms that ReFH has a far steeper growth curve than the Stats method at extreme flood flows (Figure 3.2) but these are similar at lower return period. For permeable catchments ReFH and ReFH+Stat are usually discounted.

Table 3.3 Comparison of Flood Growth Curves at Leigh Park Flow Gauge

Method	2	5	10	20	50	100	200	1000
2019 Stat	1.00	1.35	1.60	1.88	2.32	2.71	3.16	4.51
2019 ReFH	1.00	1.74	2.50	3.56	5.60	7.86	11.03	24.17
Stat+ReFH	1.00	1.35	1.60	1.88	2.32	2.71	3.80	8.34
2008 Stat	1.00	1.34	1.59	1.86	2.28	2.66	3.09	4.36

Figure 3.2 Comparison of Flood Growth Curves



The EA's FEH Guidelines emphasise that historical flood data can be particularly valuable to confirm which of the flood flow estimation methods is the more realistic but apart from flow records at the gauge, which are of dubious quality, no such data are available on this catchment. The statistical method estimates of QMED are normally preferred as this is based on measured flow data with QMED confirmed or adjusted using local flow data and as the pooling group is based on recorded flow data this method is preferred.

3.4 Hybrid Method

The generation of flood hydrographs can be achieved in ISIS or Flood Mapper using the ReFH boundary unit and importing the FEH catchment descriptors CSV file. The peak flood flow of the ReFH hydrograph can be forced to fit the peak flow from the Stats method, referred to as the hybrid approach.

3.5 Climate Change

A suitable allowance for increased river flow due to climate change should then be considered based on the EA's February 2016 guidance (Table 3.4). The adopted allowance should depend on the type of development proposed and the flood zone which defines the allowance category. For more vulnerable residential developments in flood zone 3 the 'higher central' allowance is used and for less vulnerable commercial developments the 'central' climate change allowance is required and this should consider the lifetime of the development.

Table 3.4 Peak River Flow Allowances for South East Region

Allowance category	The '2020s' (2015 to 2039)	The '2050s' (2040 to 2069)	The '2080s' (2070 to 2115)
Upper end	25%	50%	105%
Higher central	15%	39%	45%
Central	10%	20%	35%

4 FLOOD FLOWS - URBAN AREA

4.1 Hydrological Response

Sections 2 and 3 of this report provide details of the estimated peak flows and the hydrological response from the upstream Chalk rural catchment based on standard FEH methods. There are reservations about the hydrological response as this catchment may exhibit a winter high and summer low baseflow and with a slow or muted response to rainfall due to the low percentage runoff. However very high peak flows can occur when the catchment is saturated and the percentage runoff may then be higher than the geology would suggest. This can occur after prolonged rainfall events such as October/November 2000 and the inconsistent PDM parameters noted in the EAs 2008 report may be due to variable percentage runoff from the selected events and hence the worst case Oct 2000 event was used.

The lower part of the Lavant Stream catchment is predominantly clay and is heavily urbanised giving a rapid response to rainfall and a high percentage runoff from the urban drainage systems that discharge into the stream network hence this area is considered separately. The ReFH hybrid approach defined above can be used for the rural catchment, possibly using the PDM ordinates from the ISIS model, and forced to match the Stats method flood estimates. Flows for the lower urban area are considered below using the revised ReFH method.

4.2 Revised ReFH Method

The EAs FEH guidelines states that ReFH in its original form should not be used for heavily or very heavily urbanised catchments (where URBEXT1990 is 0.125 to 0.5) and this relates to the lower part the catchment around Havant. However recent research (Kjeldsen, 2009) has led to a modified version of ReFH that accounts for increased runoff and this can be used on urban catchments. The EAs FEH Guidelines shows this revised method gives sensible results on several urban catchments. This modified ReFH approach does not use aspects of ReFH that are inappropriate or poorly calibrated for urban catchments, such as:

- The regression equation for CMAX, which does not represent the increase in runoff volume with urban extent.
- The initial soil moisture (Cini) which is calculated for design events based on an equation calibrated from only 7 catchments and which gives a physically unrealistic increase in Cmax as PROPWET decreases and
- The ‘a’ factor used to scale Cini to ensure that the resulting flood frequency curve is consistent with the results of the FEH statistical method and which was derived from an analysis of only 7 catchments.

However in this revised approach ReFH is used for rural green portion of urban areas (gardens, parks etc.) and also for the proportion of urban areas covered by hard surfaces with the percentage runoff set to a fixed value of 70% rather than using the ReFH losses model. The revised version of ReFH has therefore been used for the urbanised lower catchment of the Lavant Stream. Whilst a more accurate picture of sewer flows and pathways could be obtained from hydraulic modelling of the urban drainage network or from maps of the sewer network

but this requires a far more detailed study and the revised ReFH method is considered appropriate in this case.

4.3 Approach

The catchment is divided into two categories based on OS and FEH maps:

- The upstream mainly rural sub-catchment with flows defined in Section 2 above;
- The lower urban sub-catchment assuming runoff drain to local storm sewers following the ground topography and which drains to the watercourse assuming there is no import or export of flows to or from the FEH defined catchment.

Flows for the rural element are estimated using the standard ReFH model applied to 60% of the urban sub-catchment area assuming these urban areas are unpaved and rain water would infiltrate as it would on the rural catchments (Table 4.1). URBEXT1990 values are set to 0.0 resulting in the longer time to peak. Kjeldsen (2009) suggested 70% of these urban areas are unpaved but 60% was thought to be more appropriate as this part of the Lavant catchment is quite heavily urbanised.

The remaining 40% of the catchment is assumed to be paved with the percentage runoff (PR) set to 70% as suggested by Kjeldsen (2009). This is achieved by reducing the Cmax parameter by trial and error until the PR of 70% is achieved. URBEXT1990 was set to 0.5 to represent the faster routing of flood water through the urban catchment resulting in a shorter time to peak than on the rural part of the catchment. The catchment descriptors AREA and DPLBAR are also altered for each sub-catchment.

Table 4.1 Rural and Urban Areas in the Revised ReFH Model

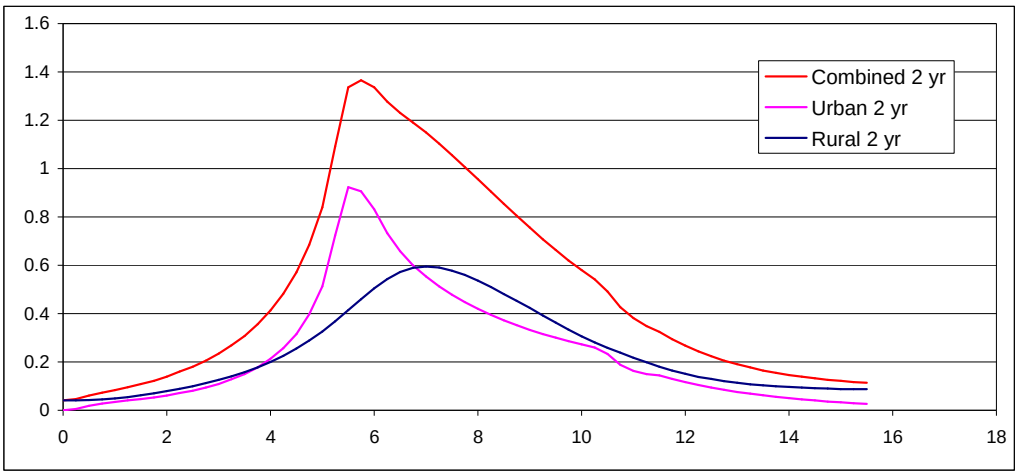
Site	AREA	FARL	BFIHOST	DPLBAR	DPSBAR	SAAR	SPR HOST	URBEXT 1990	URBEXT 2000
Leigh Park	55.96	0.999	0.886	10.27	89.1	905	10.10	0.0210	0.0231
DS	57.51	0.999	0.872	11.30	87.5	900	10.99	0.0293	0.0521
DS Gauge	1.55	1.0	0.367	1.27	90.0	720	43.07	0.3285	0.5
60% Rural	0.93	1.0	0.367	0.961	90.0	720	43.07	0.0	0.0
40% Urban	0.62	1.0	0.367	0.770	90.0	720	70.0	0.5	0.5

4.4 Flow Estimates

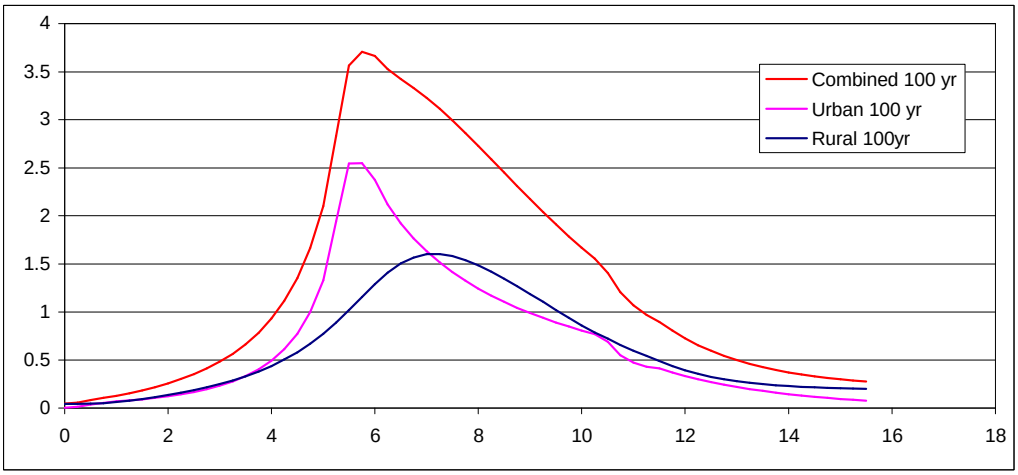
These steps then provide two hydrographs; one for the rural part of this urban area and one for the urban sub-catchment and these hydrographs are then added together to give the combined response (Figure 4.1) based on the different routing times and percentage runoff for the two parts of the sub-catchment. This is based on the same storm duration of 10.25 hours as used for the ReFH in the upper catchment on the basis that the same storm would affect both parts of this catchment. A range of storm durations could be investigated as part of the hydraulic modelling to identify the critical storm duration at the key point of interest.

Figure 4.1 Combined ReFH Hydrographs

2 year



100 year



The derived flows (Table 4.2) show that the Revised ReFH method for this lower urban area provides a QMED of 1.37 m^3/s and with a 100 year peak flow of 3.71 m^3/s.

Table 4.2 Revised ReFH Flood Estimates (m^3/s) for the Lower Urban Area

Location	Return Period (Years)						
	2	**10**	**20**	**50**	**100**	**200**	**1000**
Rural	0.60	0.95	1.11	1.37	1.60	1.91	2.96
Urban	0.92	1.45	1.73	2.16	2.55	3.05	4.54
Combined	1.37	2.15	2.55	3.15	3.71	4.40	6.52

The Revised ReFH flood hydrographs for each return period are given in Appendix A.

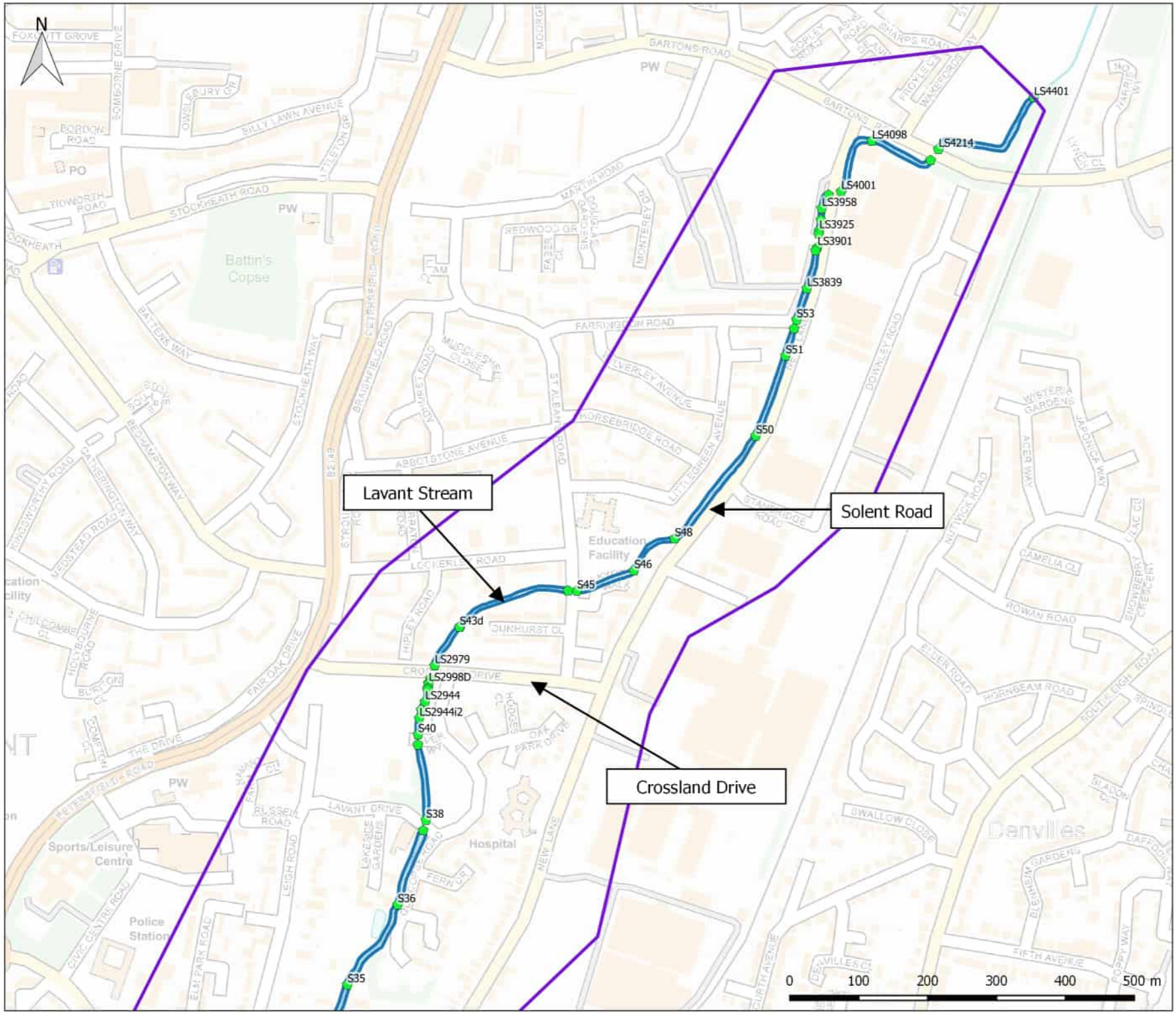
Appendix A Revised ReFH Method Flood Hydrographs for Urban Area of Havant

Time	Rural								Urban								Combined						
hrs	2 yr	10 yr	20 yr	50 yr	100yr	200 yr	1000 yr		2 yr	10 yr	20 yr	50 yr	100 yr	200 yr	1000 yr		2 yr	10 yr	20 yr	50 yr	100 yr	200 yr	1000 yr
0.0	0.041	0.041	0.041	0.041	0.041	0.041	0.041		0.000	0.001	0.001	0.002	0.003	0.003	0.006		0.041	0.042	0.042	0.043	0.044	0.044	0.047
0.25	0.041	0.041	0.042	0.042	0.042	0.042	0.042		0.006	0.009	0.010	0.012	0.013	0.014	0.018		0.047	0.050	0.052	0.054	0.055	0.056	0.060
0.5	0.042	0.044	0.044	0.045	0.045	0.046	0.048		0.019	0.029	0.031	0.034	0.036	0.038	0.044		0.061	0.073	0.075	0.079	0.081	0.084	0.092
0.75	0.045	0.048	0.049	0.050	0.052	0.053	0.057		0.028	0.043	0.046	0.049	0.053	0.056	0.065		0.073	0.091	0.095	0.099	0.105	0.109	0.122
1.0	0.049	0.054	0.056	0.059	0.061	0.064	0.072		0.035	0.054	0.057	0.062	0.067	0.070	0.082		0.084	0.108	0.113	0.121	0.128	0.134	0.154
1.25	0.054	0.063	0.066	0.071	0.075	0.079	0.092		0.041	0.062	0.067	0.072	0.078	0.082	0.097		0.095	0.125	0.133	0.143	0.153	0.161	0.189
1.5	0.062	0.075	0.080	0.087	0.093	0.100	0.119		0.047	0.071	0.076	0.083	0.090	0.096	0.114		0.109	0.146	0.156	0.170	0.183	0.196	0.233
1.75	0.07	0.088	0.095	0.105	0.113	0.123	0.150		0.053	0.082	0.088	0.096	0.104	0.112	0.134		0.123	0.17	0.183	0.201	0.217	0.235	0.284
2.0	0.079	0.102	0.111	0.124	0.135	0.148	0.184		0.061	0.094	0.101	0.112	0.121	0.131	0.159		0.140	0.196	0.212	0.236	0.256	0.279	0.343
2.25	0.089	0.118	0.129	0.146	0.159	0.175	0.221		0.071	0.108	0.117	0.130	0.142	0.153	0.189		0.160	0.226	0.246	0.276	0.301	0.328	0.410
2.5	0.100	0.135	0.149	0.170	0.186	0.206	0.262		0.081	0.124	0.136	0.152	0.166	0.181	0.226		0.181	0.259	0.285	0.322	0.352	0.387	0.488
2.75	0.112	0.154	0.171	0.196	0.215	0.240	0.309		0.094	0.144	0.158	0.178	0.196	0.215	0.272		0.206	0.298	0.329	0.374	0.411	0.455	0.581
3.0	0.126	0.176	0.196	0.225	0.249	0.278	0.361		0.109	0.168	0.185	0.209	0.232	0.256	0.329		0.235	0.344	0.381	0.434	0.481	0.534	0.690
3.25	0.141	0.200	0.224	0.259	0.287	0.321	0.422		0.128	0.197	0.218	0.248	0.277	0.308	0.401		0.269	0.397	0.442	0.507	0.564	0.629	0.823
3.5	0.158	0.227	0.256	0.297	0.330	0.372	0.493		0.150	0.231	0.258	0.297	0.332	0.372	0.492		0.308	0.458	0.514	0.594	0.662	0.744	0.985
3.75	0.178	0.259	0.292	0.340	0.380	0.429	0.575		0.178	0.275	0.308	0.357	0.403	0.455	0.609		0.356	0.534	0.600	0.697	0.783	0.884	1.184
4.0	0.200	0.295	0.334	0.391	0.438	0.496	0.671		0.213	0.329	0.372	0.435	0.493	0.561	0.762		0.413	0.624	0.706	0.826	0.931	1.057	1.433
4.25	0.226	0.335	0.381	0.448	0.504	0.574	0.784		0.257	0.399	0.454	0.536	0.612	0.701	0.966		0.483	0.734	0.835	0.984	1.116	1.275	1.750
4.5	0.255	0.382	0.436	0.515	0.581	0.663	0.917		0.316	0.491	0.564	0.672	0.772	0.892	1.246		0.571	0.873	1.000	1.187	1.353	1.555	2.163
4.75	0.288	0.436	0.499	0.591	0.669	0.768	1.074		0.397	0.619	0.716	0.863	0.997	1.161	1.644		0.685	1.055	1.215	1.454	1.666	1.929	2.718
5.0	0.326	0.497	0.57	0.679	0.772	0.889	1.259		0.513	0.803	0.937	1.142	1.329	1.560	2.240		0.839	1.300	1.507	1.821	2.101	2.449	3.499
5.25	0.368	0.566	0.651	0.779	0.890	1.029	1.476		0.723	1.136	1.340	1.653	1.941	2.298	3.350		1.091	1.702	1.991	2.432	2.831	3.327	4.826
5.5	0.414	0.641	0.740	0.890	1.020	1.186	1.722		0.923	1.454	1.729	2.155	2.544	3.033	4.472		1.337	2.095	2.469	3.045	3.564	4.219	6.194
5.75	0.460	0.718	0.832	1.004	1.156	1.349	1.984		0.906	1.432	1.713	2.150	2.550	3.054	4.537		1.366	2.150	2.545	3.154	3.706	4.403	6.521
6.0	0.505	0.792	0.920	1.115	1.289	1.510	2.246		0.831	1.315	1.581	1.995	2.375	2.854	4.265		1.336	2.107	2.501	3.110	3.664	4.364	6.511
6.25	0.543	0.857	0.998	1.214	1.408	1.656	2.489		0.733	1.161	1.402	1.776	2.119	2.554	3.834		1.276	2.018	2.400	2.990	3.527	4.210	6.323
6.5	0.572	0.907	1.059	1.293	1.503	1.775	2.693		0.659	1.046	1.265	1.608	1.922	2.320	3.493		1.231	1.953	2.324	2.901	3.425	4.095	6.186
6.75	0.589	0.938	1.097	1.344	1.567	1.856	2.841		0.601	0.955	1.157	1.473	1.762	2.130	3.213		1.190	1.893	2.254	2.817	3.329	3.986	6.054
7.0	0.595	0.950	1.113	1.367	1.599	1.898	2.928		0.554	0.880	1.068	1.361	1.630	1.972	2.978		1.149	1.830	2.181	2.728	3.229	3.870	5.906
7.25	0.591	0.945	1.109	1.366	1.601	1.906	2.960		0.513	0.816	0.991	1.264	1.515	1.834	2.772		1.104	1.761	2.100	2.630	3.116	3.740	5.732

7.5	0.578	0.927	1.090	1.345	1.580	1.885	2.944		0.478	0.760	0.924	1.180	1.414	1.712	2.590		1.056	1.687	2.014	2.525	2.994	3.597	5.534
7.75	0.560	0.899	1.057	1.308	1.539	1.840	2.890		0.447	0.711	0.865	1.104	1.324	1.604	2.426		1.007	1.610	1.922	2.412	2.863	3.444	5.316
8.0	0.536	0.863	1.016	1.259	1.484	1.777	2.805		0.420	0.667	0.811	1.037	1.243	1.506	2.279		0.956	1.530	1.827	2.296	2.727	3.283	5.084
8.25	0.510	0.822	0.969	1.202	1.419	1.702	2.698		0.395	0.628	0.764	0.976	1.170	1.418	2.146		0.905	1.450	1.733	2.178	2.589	3.120	4.844
8.5	0.482	0.777	0.917	1.139	1.346	1.617	2.573		0.372	0.592	0.72	0.92	1.104	1.337	2.024		0.854	1.369	1.637	2.059	2.450	2.954	4.597
8.75	0.453	0.730	0.862	1.072	1.268	1.525	2.435		0.352	0.56	0.681	0.87	1.043	1.264	1.914		0.805	1.290	1.543	1.942	2.311	2.789	4.349
9.0	0.423	0.681	0.804	1.002	1.186	1.428	2.288		0.333	0.530	0.645	0.824	0.988	1.197	1.812		0.756	1.211	1.449	1.826	2.174	2.625	4.100
9.25	0.392	0.632	0.747	0.93	1.103	1.329	2.134		0.316	0.503	0.612	0.782	0.937	1.135	1.719		0.708	1.135	1.359	1.712	2.040	2.464	3.853
9.5	0.363	0.583	0.689	0.859	1.019	1.229	1.978		0.301	0.478	0.581	0.743	0.89	1.078	1.632		0.664	1.061	1.270	1.602	1.909	2.307	3.610
9.75	0.334	0.536	0.633	0.790	0.938	1.131	1.824		0.286	0.455	0.553	0.707	0.847	1.026	1.553		0.620	0.991	1.186	1.497	1.785	2.157	3.377
10.0	0.307	0.491	0.581	0.724	0.86	1.038	1.675		0.273	0.433	0.527	0.673	0.807	0.977	1.479		0.580	0.924	1.108	1.397	1.667	2.015	3.154
10.25	0.282	0.450	0.532	0.663	0.787	0.950	1.535		0.260	0.414	0.503	0.642	0.769	0.932	1.410		0.542	0.864	1.035	1.305	1.556	1.882	2.945
10.5	0.259	0.413	0.487	0.607	0.720	0.869	1.403		0.233	0.37	0.449	0.572	0.686	0.829	1.253		0.492	0.783	0.936	1.179	1.406	1.698	2.656
10.75	0.238	0.377	0.445	0.554	0.657	0.792	1.277		0.189	0.300	0.363	0.461	0.55	0.664	0.999		0.427	0.677	0.808	1.015	1.207	1.456	2.276
11.0	0.218	0.344	0.405	0.504	0.597	0.719	1.157		0.164	0.260	0.313	0.396	0.472	0.569	0.852		0.382	0.604	0.718	0.900	1.069	1.288	2.009
11.25	0.199	0.313	0.368	0.456	0.540	0.650	1.043		0.150	0.237	0.285	0.36	0.429	0.516	0.772		0.349	0.550	0.653	0.816	0.969	1.166	1.815
11.5	0.181	0.284	0.333	0.412	0.486	0.584	0.934		0.144	0.227	0.274	0.346	0.411	0.495	0.740		0.325	0.511	0.607	0.758	0.897	1.079	1.674
11.75	0.165	0.256	0.300	0.370	0.436	0.523	0.831		0.129	0.204	0.246	0.311	0.369	0.445	0.666		0.295	0.460	0.546	0.681	0.806	0.969	1.497
12.0	0.151	0.232	0.271	0.334	0.392	0.469	0.742		0.116	0.183	0.221	0.282	0.332	0.400	0.599		0.268	0.416	0.492	0.614	0.725	0.870	1.341
12.25	0.139	0.212	0.247	0.303	0.355	0.424	0.667		0.104	0.165	0.199	0.252	0.299	0.360	0.539		0.244	0.377	0.446	0.555	0.655	0.785	1.206
12.5	0.129	0.195	0.227	0.278	0.325	0.386	0.604		0.094	0.148	0.179	0.227	0.269	0.324	0.485		0.223	0.344	0.406	0.505	0.595	0.711	1.090
12.75	0.120	0.182	0.211	0.257	0.300	0.356	0.553		0.085	0.134	0.161	0.200	0.242	0.292	0.436		0.205	0.316	0.372	0.461	0.543	0.648	0.990
13.0	0.114	0.170	0.197	0.240	0.279	0.330	0.511		0.076	0.120	0.145	0.183	0.218	0.263	0.393		0.191	0.291	0.342	0.424	0.497	0.593	0.904
13.25	0.108	0.161	0.186	0.226	0.262	0.310	0.477		0.068	0.108	0.131	0.165	0.196	0.236	0.353		0.177	0.270	0.317	0.391	0.459	0.547	0.831
13.5	0.103	0.154	0.177	0.214	0.248	0.293	0.449		0.061	0.097	0.117	0.148	0.170	0.213	0.318		0.165	0.252	0.294	0.363	0.425	0.506	0.768
13.75	0.100	0.147	0.170	0.205	0.237	0.279	0.425		0.055	0.087	0.106	0.134	0.159	0.191	0.286		0.156	0.235	0.276	0.339	0.396	0.471	0.712
14.0	0.096	0.142	0.163	0.197	0.227	0.267	0.406		0.050	0.076	0.095	0.120	0.143	0.172	0.258		0.146	0.221	0.258	0.318	0.370	0.440	0.664
14.25	0.094	0.138	0.158	0.190	0.220	0.258	0.390		0.045	0.071	0.085	0.108	0.128	0.155	0.232		0.139	0.209	0.243	0.299	0.349	0.413	0.622
14.5	0.092	0.134	0.154	0.185	0.213	0.250	0.378		0.040	0.064	0.077	0.097	0.116	0.139	0.208		0.133	0.198	0.231	0.283	0.329	0.390	0.587
14.75	0.090	0.131	0.151	0.181	0.209	0.244	0.369		0.036	0.057	0.069	0.087	0.104	0.125	0.180		0.127	0.189	0.220	0.269	0.313	0.370	0.557
15.0	0.088	0.129	0.148	0.178	0.205	0.240	0.362		0.032	0.051	0.062	0.079	0.094	0.113	0.169		0.121	0.181	0.210	0.257	0.299	0.353	0.531
15.25	0.087	0.128	0.146	0.176	0.203	0.237	0.357		0.029	0.046	0.056	0.071	0.084	0.101	0.152		0.117	0.175	0.202	0.247	0.288	0.339	0.509
15.5	0.087	0.127	0.145	0.174	0.201	0.235	0.354		0.026	0.042	0.050	0.064	0.076	0.091	0.137		0.114	0.169	0.195	0.238	0.277	0.327	0.491
Max	0.595	0.950	1.113	1.367	1.601	1.906	2.960		0.923	1.454	1.729	2.155	2.550	3.054	4.537		1.366	2.150	2.545	3.154	3.706	4.403	6.521

Appendix C

Hydraulic Model Extents



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Legend

- 1D Model Node
- 1D Model Domain
- 2D Model Domain

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EC3M 5JE

Tel: 020 7680 4088

Web: www.ardent-ce.co.uk
E-mail: enquiries@ardent-ce.co.uk

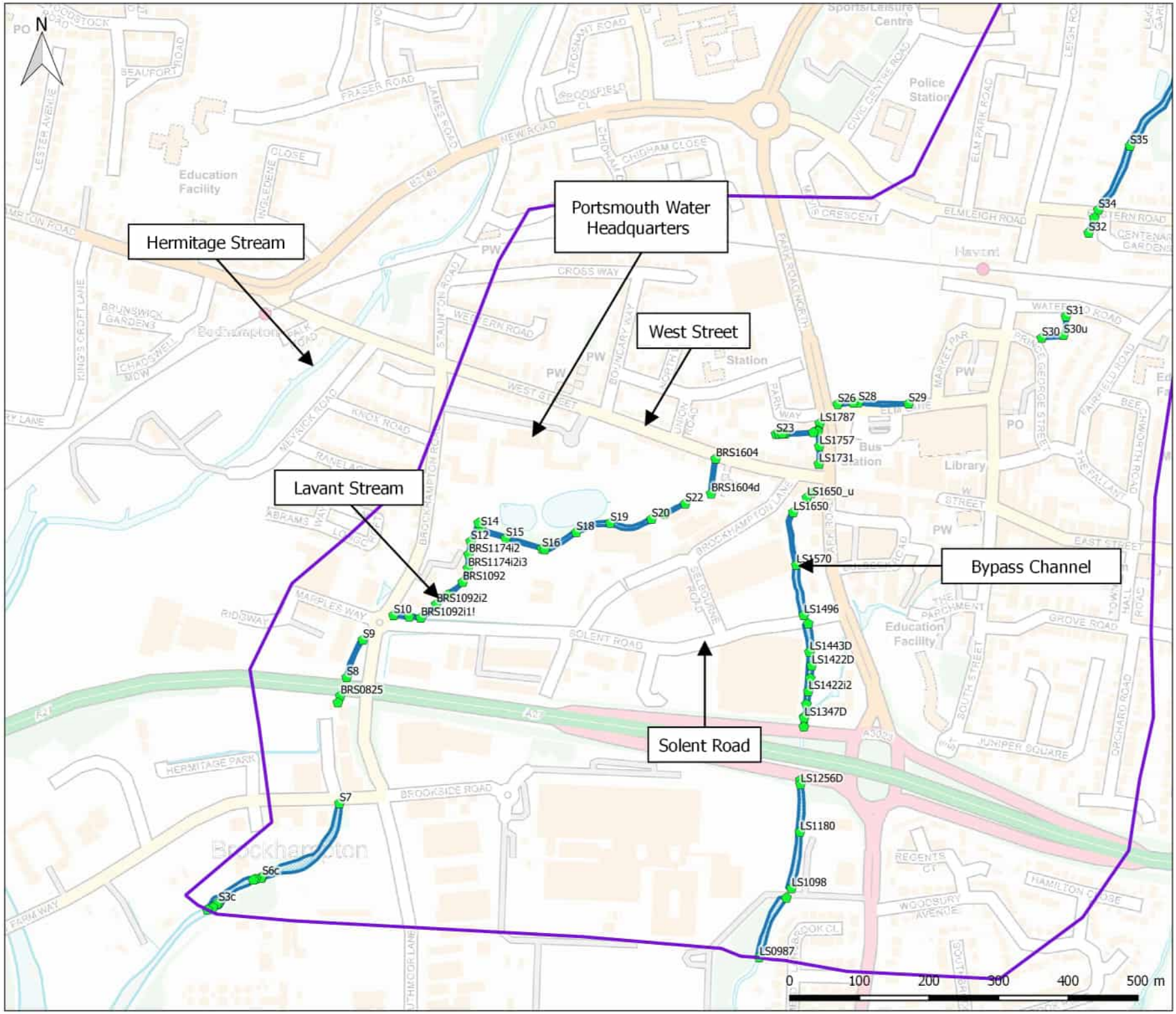
Client: Portsmouth Water

Project Title: 191920 - Solent Road, Havant

Drawing Title: Hydraulic Model Domains (North)

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref:	Date:
191920_SolentRoad_Model_Domains_North	05/02/2020



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Legend

- 1D Model Node
- 1D Model Domain
- 2D Model Domain

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EC3M 5JE

Tel: 020 7680 4088

Web: www.ardent-ce.co.uk
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Client: Portsmouth Water

Project Title: 191920 - Solent Road, Havant

Drawing Title: Hydraulic Model Domains (South)

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref: 191920_SolentRoad_Model_Domains_South

Date: 05/02/2020

Appendix D

EA Lavant Link Pipe Consultation

Hollie Tristram

From: Lupton, Sarah <Sarah.Lupton@environment-agency.gov.uk>
Sent: 06 September 2019 15:06
To: John Easton
Cc: SSD Enquiries
Subject: RE: 190807 SSD137786 - Site at Solent Road, Havand
Attachments: Historical inforamtion_very important.pdf

Hi John

The penstock is always left in the same position, as per the image, the gap is to allow fish passage. The penstock is approx. 805mm wide and the diameter of the opening is 500mm. I couldn't find any information on the screen but it looks to match the penstock in width from the image.

In looking again in the folders I have found the attached which you may find of use.

Again, this information is supplied subject to the notice which can be viewed via the following link:
http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

Best regards
Sarah

From: John Easton [mailto:jeaston@ardent-ce.co.uk]
Sent: 06 September 2019 13:56
To: Lupton, Sarah <Sarah.Lupton@environment-agency.gov.uk>
Cc: SSD Enquiries <SSDEnquiries@environment-agency.gov.uk>
Subject: RE: 190807 SSD137786 - Site at Solent Road, Havand

Hi Sarah,

That's great – many thanks for that, it's very helpful!

No need to send through the video for the Link Pipe.

Any further details that you can provide with respect to the penstock however would be very useful. i.e. when is it operational (it looks to be raised slightly in the photo below)? What is the diameter of the opening? How wide is the screen? Etc

Any further information you are able to provide in this regard would be much appreciated!

Kind regards,

John

John Easton
Hydraulic Modeller BSc (Hons) MSc

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T 020 7680 4088

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From: Lupton, Sarah <Sarah.Lupton@environment-agency.gov.uk>
Sent: 06 September 2019 11:40
To: John Easton <jeaston@ardent-ce.co.uk>
Cc: SSD Enquiries <SSDEnquiries@environment-agency.gov.uk>
Subject: FW: 190807 SSD137786 - Site at Solent Road, Havand

Dear John,

Thanks for your email, apologies on the delay in getting back to you.

I have checked our records and we do not have cross sectional survey data or topographic survey data locally for the area you mention below.

With regard to the pipelink, please find a link to the most recent culvert inspection report which was completed in 2015. I can also send the video footage of this survey if this would be of use, please let me know. The pipe links flows in a westerly direction from Crossland Drive to the Hermitage Stream at Stockheath Lane.

In 2015 a new Penstock was installed downstream of Crossland Drive. It has a hole in it which allows a fixed amount of water downstream to Eastern Road, forcing more water into the Hermitage pipelink. Up to 3 Cumecs can be transferred from the Lavant Stream to the Hermitage in times of flood. There is also a screen immediately upstream of this structure. I have attached the best image I could find of the control gate and screen (looking downstream).

I have attached a map showing the watercourses and where our assets are located. If you would like further information on any of these assets please let me know and I will see what I can find.

Best regards

Sarah Lupton EngTech MICE

FCRM Advisor (Asset Performance)
East Hampshire and Chichester

✉: sarah.lupton@environment-agency.gov.uk
☎: 020 847**45257**
: Romsey District Office, Canal Walk, Romsey, Hampshire, SO51 7LP

Please note my working days are Monday, Wednesday, Thursday and Friday

·–

From: John Easton [mailto:jeaston@ardent-ce.co.uk]
Sent: 01 August 2019 14:44
To: Rabone, Anna <Anna.Rabone@environment-agency.gov.uk>
Cc: Brown, Sophie <sophie.brown@environment-agency.gov.uk>
Subject: RE: Site at Solent Road, Havand

Good afternoon Anna,

Further to my colleague Georgia's e-mail below, we have since obtained the EA's model of the Lavant Stream and been working with this to inform our assessment of our client's site.

We have obtained additional survey data of the watercourse to supplement the information in the EA's model however we were hopeful we could acquire some additional information from the EA if possible.

There are several structures on the watercourse some of which are crucial to the hydrology of the study area. Could we please ask for any channel cross sectional survey data or topographic survey data that the EA may hold for the Lavant Stream? In particular we would like information relating to the Lavant Link Pipe immediately downstream of Crossland Drive.

From observations made with Google Street View it looks as if there may be a hydraulic control downstream of the Link Pipe which, we assume, serves to elevate the water level upstream and allow flow to enter the pipe. However, our surveyors were not able to gain access to this structure to validate this assumption.

If you could please send us any raw survey data you have for the watercourse that would be much appreciated.

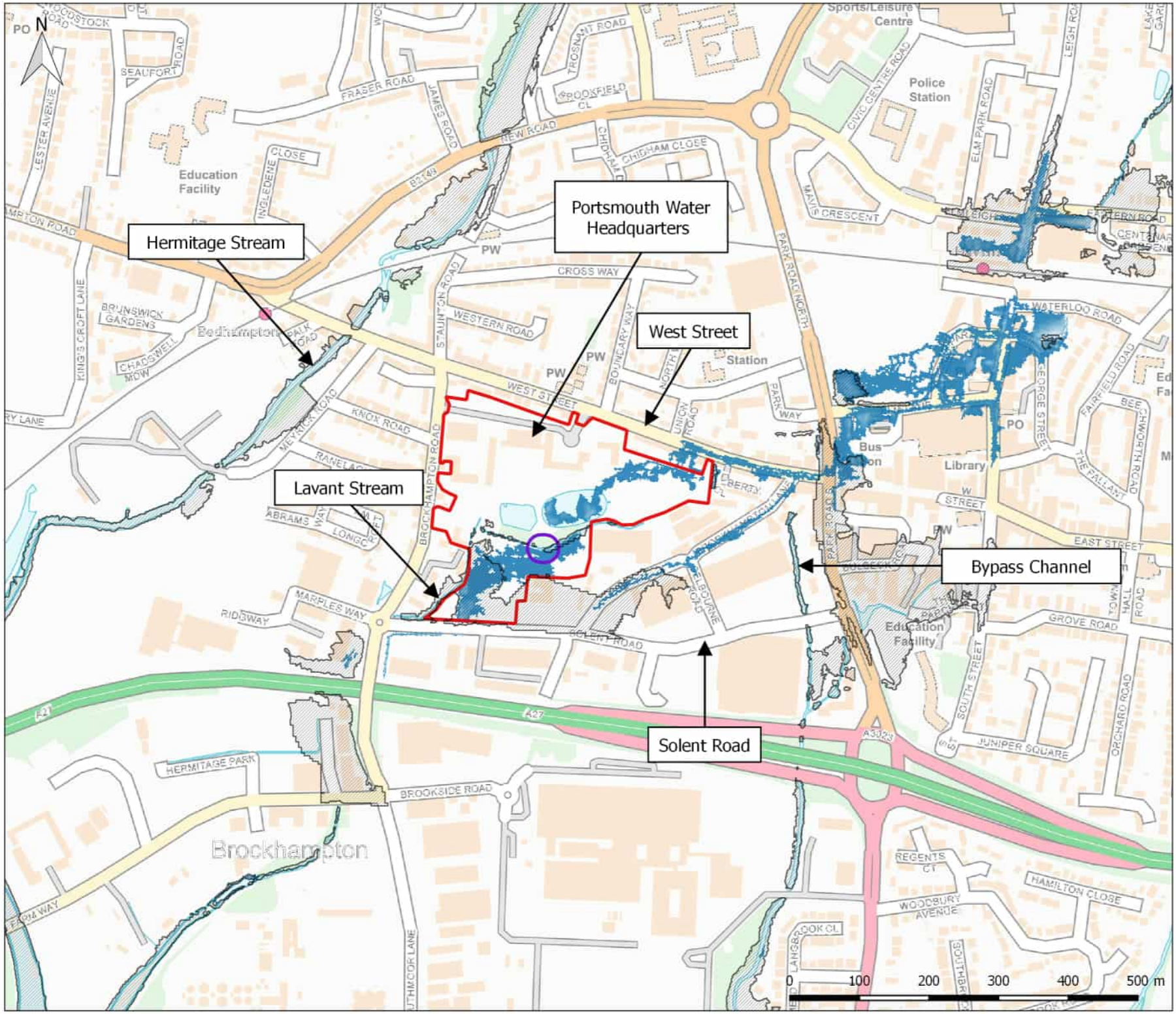
Please don't hesitate to get in touch should you require any further information.

Kind regards,

John
John Easton
Hydraulic Modeller BSc (Hons) MSc

Appendix E

Baseline Modelling Results



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Legend

- Portsmouth Water Site Boundary
- Culvert location
- EA 1 in 100 year flood outline

Ardent flood depth (metres)

- 0.10
- 0.30
- 0.50
- 0.75
- 1.00
- 1.50

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E-mail: enquiries@ardent-ce.co.uk

Client: Portsmouth Water

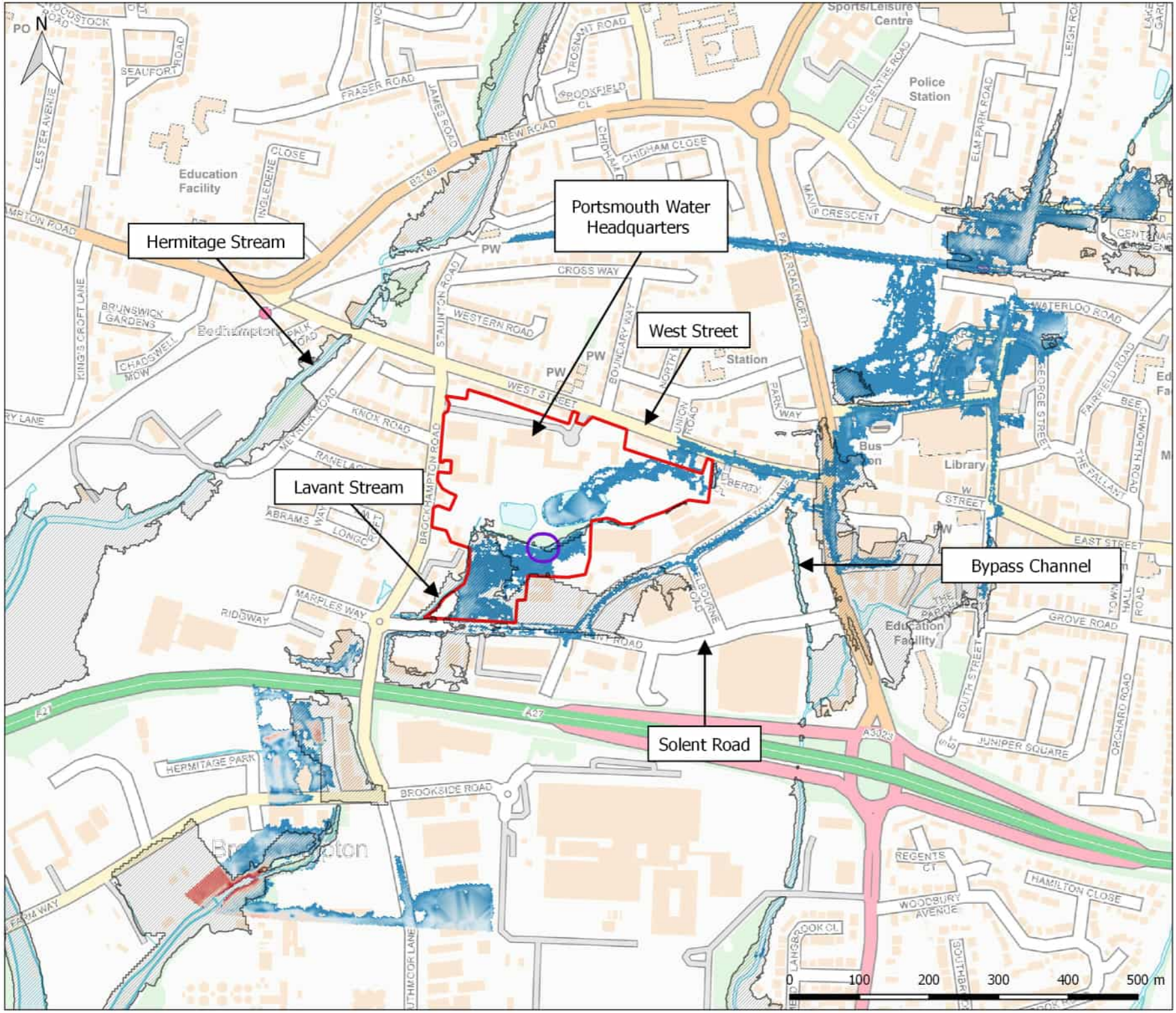
Project Title: 191920 - Solent Road, Havant

Drawing Title:

1 in 100 annual probability event
Maximum Flood Depth
Baseline Scenario - Culvert in Place

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref:	Date:
191920_SolentRoad_018_BSC_Q100_CLA_d_Ma	05/02/2020



Copyright:
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Legend

- Portsmouth Water Site Boundary
- Culvert location
- EA 1 in 100 year flood outline (+20% CC)

Ardent flood depth (metres)

- 0.10
- 0.30
- 0.50
- 0.75
- 1.00
- 1.50

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Web: www.ardent-ce.co.uk
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Client: Portsmouth Water

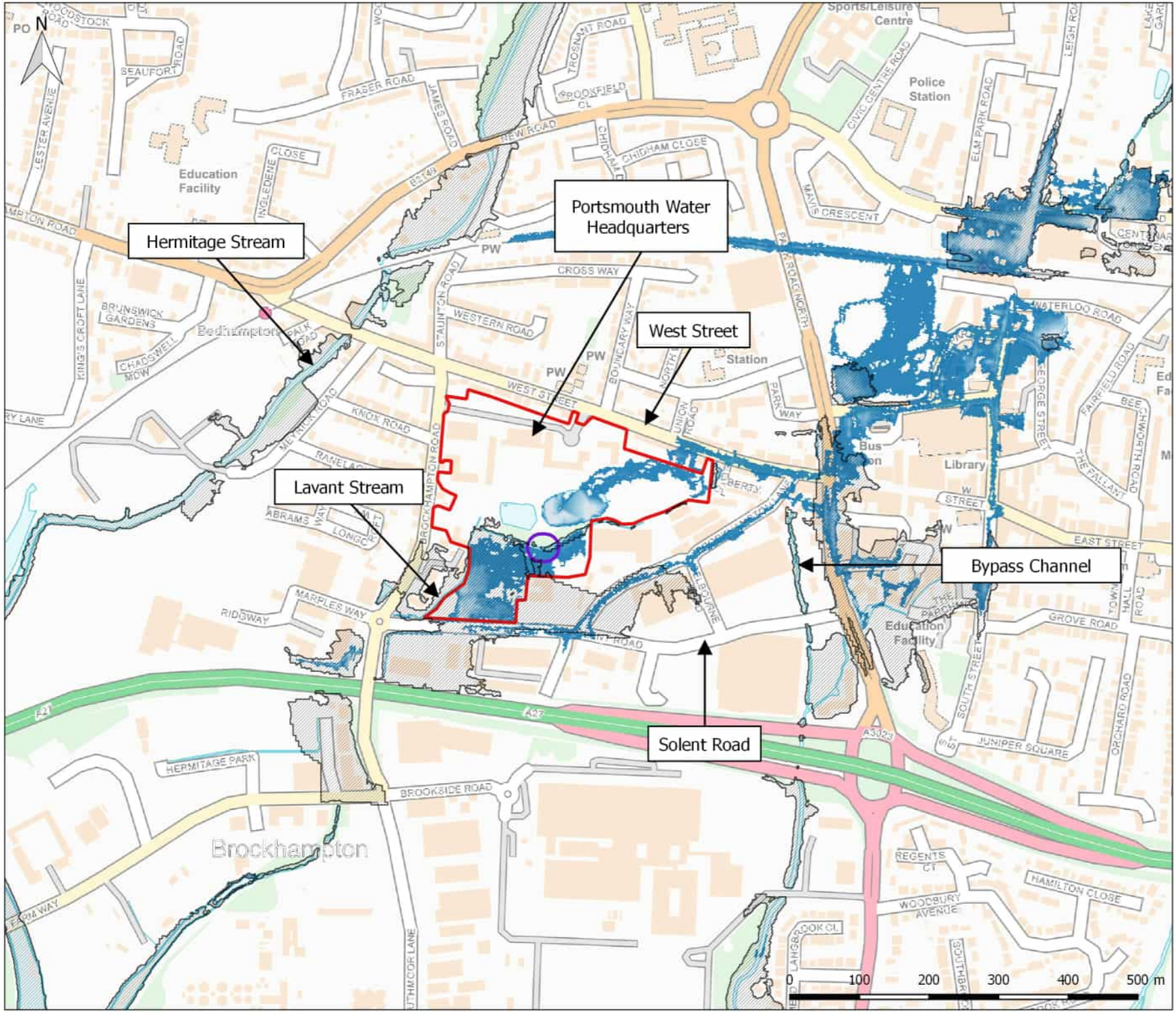
Project Title: 191920 - Solent Road, Havant

Drawing Title:

1 in 100 annual probability event
(plus 45% climate change)
Maximum Flood Depth
Baseline Scenario - Culvert in Place

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref:	Date:
191920_SolentRoad_01ll_BSC_Q100cc45_CLA_d_Mai	05/02/2020



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Legend

- Portsmouth Water Site Boundary
- Culvert location
- EA 1 in 1000 year flood outline

Ardent flood depth (metres)

- 0.10
- 0.30
- 0.50
- 0.75
- 1.00
- 1.50

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Client: Portsmouth Water

Project Title: 191920 - Solent Road, Havant

Drawing Title:

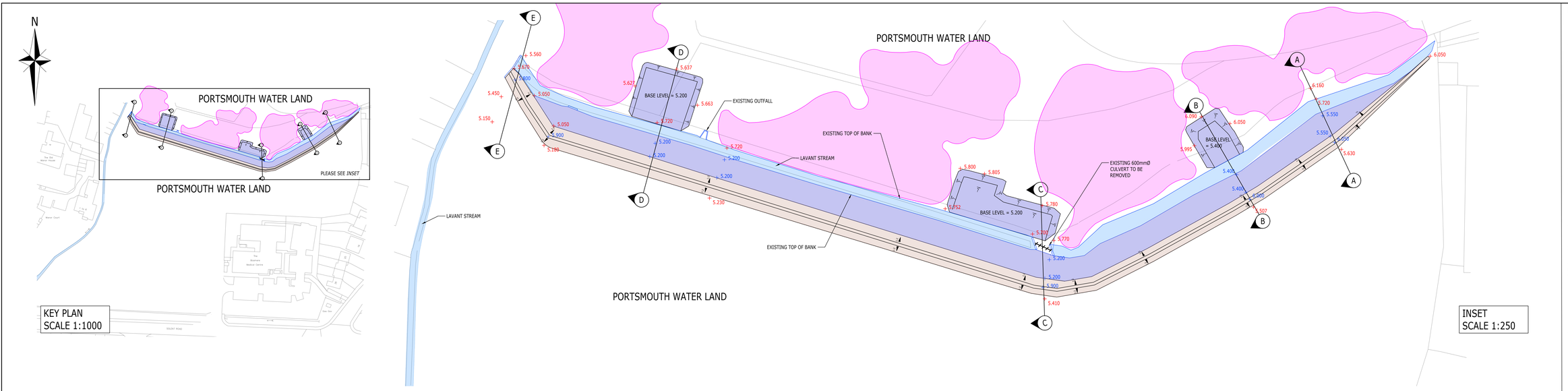
1 in 1000 annual probability event
Maximum Flood Depth
Baseline Scenario - Culvert in Place

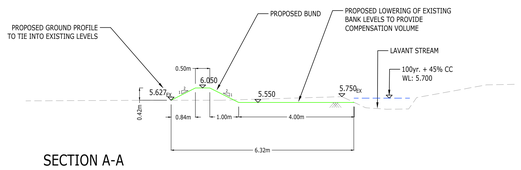
Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref:	Date:
191920_SolentRoad_018_BSC_Q1000_CLA_d_Map	05/02/2020

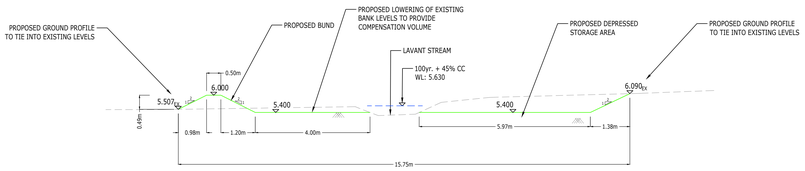
Appendix F

Proposed Mitigation Works





SECTION A-A
SCALE 1:75



SECTION B-B
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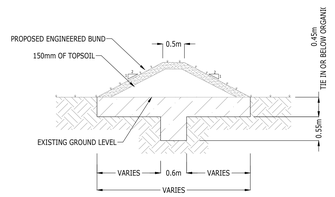
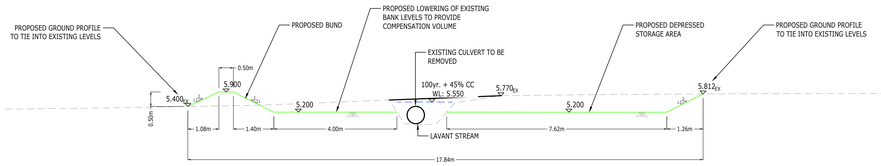
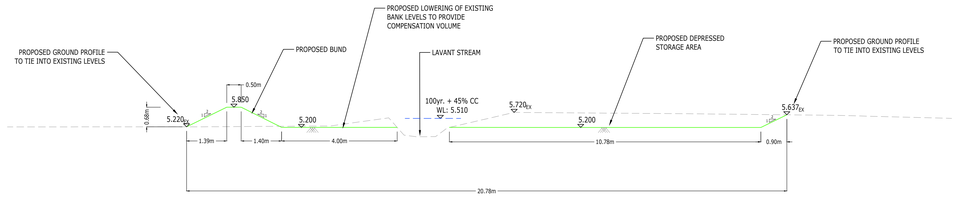


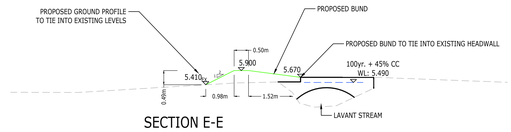
DETAIL 1
TYPICAL BUND SECTION AND KEY TRENCH WITH SIDE SLOPES AT 1:2
SCALE - 1:50



SECTION C-C
SCALE 1:75



SECTION D-D
SCALE 1:75



SECTION E-E
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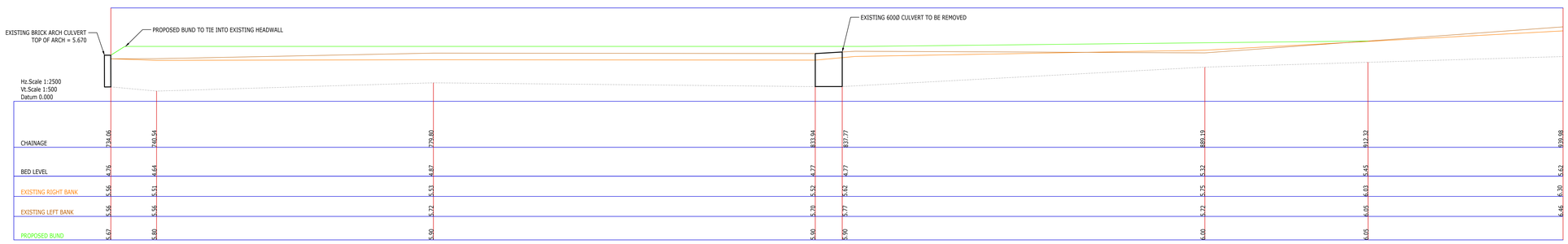

PROPOSED BUND LONGSECTION

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NOTES:

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE RELEVANT SPECIFICATION AND ALL OTHER RELATED DRAWINGS ISSUED BY THE ENGINEER.
2. ALL DIMENSIONS SHOWN ON THIS DRAWING ARE IN METRES UNLESS OTHERWISE STATED.
3. WORK FROM FIGURED DIMENSIONS ONLY.
4. ALL DIMENSIONS, LEVELS AND SURVEY GRID CO-ORDINATES ARE TO BE CHECKED ON SITE AND THE ENGINEER NOTIFIED IMMEDIATELY OF ANY DISCREPANCIES PRIOR TO THE COMMENCEMENT OF THE WORKS.
5. NO DEVIATION FROM THE DETAILS SHOWN ON THIS DRAWING IS PERMITTED WITHOUT PRIOR PERMISSION FROM THE ENGINEER.
6. ALL MATERIALS AND WORKMANSHIP SHALL COMPLY FULLY WITH THE MANUAL OF CONTRACT DOCUMENTS FOR HIGHWAY WORKS, VOLUME ONE, SPECIFICATION FOR HIGHWAY WORKS AND THE LOCAL AUTHORITY SPECIFICATION FOR ROAD CONSTRUCTION AND STANDARD DETAILS.
7. EXISTING TOPSOIL TO BE RETAINED ON SITE IN ACCORDANCE WITH BS 3882:07.
8. THE CONTRACTOR IS TO SATISFY HIMSELF THAT THE POSITION OF ALL UTILITIES IS CORRECT.
9. UNLESS STATED OTHERWISE, ALL EXCAVATED MATERIAL SHALL BE DISPOSED OF AT AN APPROVED TIP OFF-SITE.
10. THE PUBLIC HIGHWAY AND WORKS WILL BE KEPT CLEAN AND FREE OF DEBRIS BY USE OF WHEEL WASHING FACILITIES AND ROAD SWEEPERS TO THE COUNCIL'S SATISFACTION.
11. THIS DRAWING HAS BEEN BASED UPON CHANNEL SURVEY DATA UNDERTAKEN IN MAY 2019 BY TERRAIN GEOMATICS (REF. TGL/1164/1 TO TGL/1164/6). LEVELS TO BE CONFIRMED ON SITE.

CDM NOTES

THE ATTENTION OF THE CLIENT, PRINCIPAL DESIGNER, PRINCIPAL CONTRACTOR, DESIGNERS AND CONTRACTORS IS DRAWN TO THE FOLLOWING POTENTIAL RISKS IN CONJUNCTION WITH THE PROPOSED ON-SITE AND OFF-SITE WORKS AS DESIGNED FOR THIS PROJECT:

1. WORKS IN THE VICINITY OF LIVE SERVICES INCLUDING GAS, ELECTRICITY, BT AND TELECOMS WILL BE NECESSARY AND THE ADVICE OF ALL STATUTORY SERVICE COMPANIES MUST BE SOUGHT BEFORE ANY WORKS COMMENCE. PRIVATE SERVICES MAY BE PRESENT WITHIN THE LIMIT OF WORKS AND CARE SHOULD BE TAKEN TO LOCATE AND AVOID THESE DURING CONSTRUCTION.
2. WORKS WITHIN AND ABUTTING THE EXISTING HIGHWAY WILL ENTAIL TRAFFIC HAZARDS AND ALL APPROPRIATE SAFETY MEASURES INCLUDING BARRIERS, SIGNS AND LIGHTING MUST BE UNDERTAKEN TO THE APPROVAL OF THE LOCAL AUTHORITY, THE HIGHWAY AUTHORITY AND THE POLICE DEPARTMENT.
3. HAZARDOUS MATERIALS INCLUDING CEMENT AND BITUMINOUS MATERIALS ARE SPECIFIED AND THE MANUFACTURERS ADVICE ON SAFE HANDLING PROCEDURES MUST BE OBTAINED AND MADE CLEAR TO ALL OPERATIVES.
4. THE CONTRACTOR WILL BE RESPONSIBLE FOR LOCATING ALL EXISTING SERVICES WITHIN THE VICINITY OF THE WORKS (HAND DUG OR OTHER METHOD) AND ENSURE THESE ARE PROTECTED THROUGHOUT THE DURATION OF THE WORKS. ALL UTILITY PLANT SHOULD BE CLEARLY MARKED ON THE GROUND PRIOR TO COMMENCEMENT OF THE WORKS.
5. THE CONTRACTOR MUST ENSURE ALL WORKING AREAS ARE FULLY SECURE.
6. WORKS WITHIN DEEP WATERCOURSES ON SITE WILL BE NECESSARY. THE CONTRACTOR WILL BE RESPONSIBLE FOR ENSURING PERSONAL BUOYANCY EQUIPMENT IS AVAILABLE FOR ALL PERSONNEL AND RESCUE EQUIPMENT IS ALSO AVAILABLE. THE CONTRACTOR WILL ALSO ENSURE THAT THE CORRECT PROCEDURES ARE IN PLACE TO COPE ONCE A PROBLEM ARISES. THE CONTRACTOR WILL BE RESPONSIBLE FOR MONITORING WEATHER FORECAST DURING CONSTRUCTION PROGRAMME.

LEGEND - KEY PLAN

- EXISTING MAIN RIVER: LAVANT STREAM
- PROPOSED BUND
- PROPOSED COMPENSATION AREAS
- 5.995 EXISTING LEVELS
- 5.200 PROPOSED LEVELS
- PROPOSED SLOPE AND DIRECTION
- SECTION MARKER
- TREE PRESERVATION ORDER
- EXISTING 600mmØ CULVERT TO BE REMOVED

LEGEND - SECTIONS

- PROPOSED CREST OF BUND
- EXISTING GROUND / BED PROFILE
- EXISTING RIGHT BANK
- EXISTING LEFT BANK
- PROPOSED SLOPE AND DIRECTION
- 5.410 PROPOSED GROUND LEVELS
- 5.410 EXISTING GROUND LEVELS

NOT FOR CONSTRUCTION

FOR INFORMATION ONLY

DRAFT

Rev	Description	Drn	Chk	App	Date

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E-mail: enquiries@ardent-ce.co.uk

Client
PORTSMOUTH WATER

Project Title:
SOLENT ROAD, HAVANT

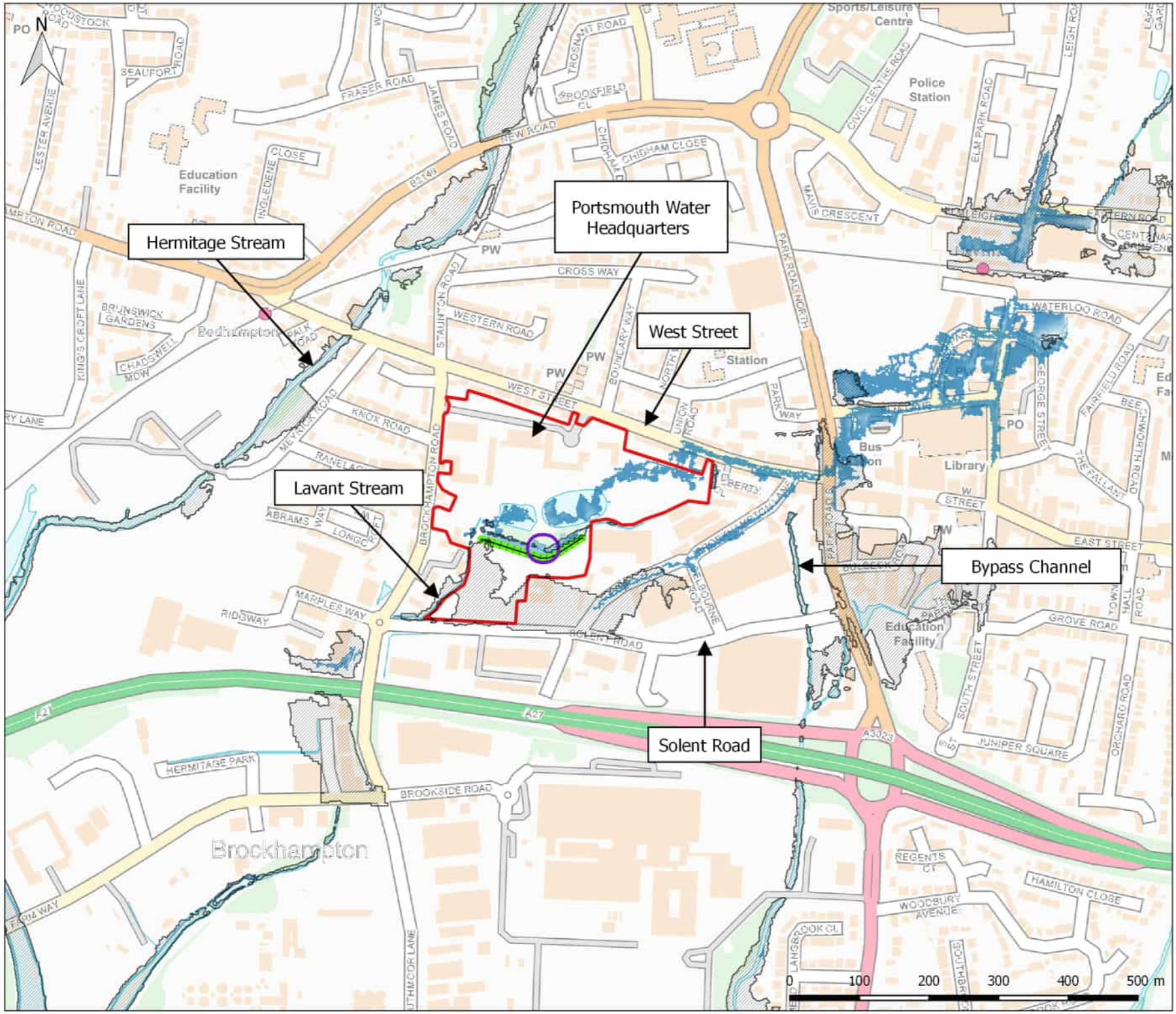
Drawing Title:
EPA - 600mmØ CULVERT REMOVAL
PROPOSED MITIGATION WORKS

AO Scale	Date	Designed by
AS SHOWN	January 2020	JE
Drawn by	Checked by	Approved by
LB	JE	BC

Drawing Number 191920-001 Rev -

Appendix G

Mitigation Modelling Results



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Legend

- Portsmouth Water site boundary
- Culvert location
- EA 1 in 100 year flood outline
- Proposed bund

Ardent flood depth (metres)

- 0.10
- 0.30
- 0.50
- 0.75
- 1.00
- 1.50

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E-mail: enquiries@ardent-ce.co.uk

Client: Portsmouth Water

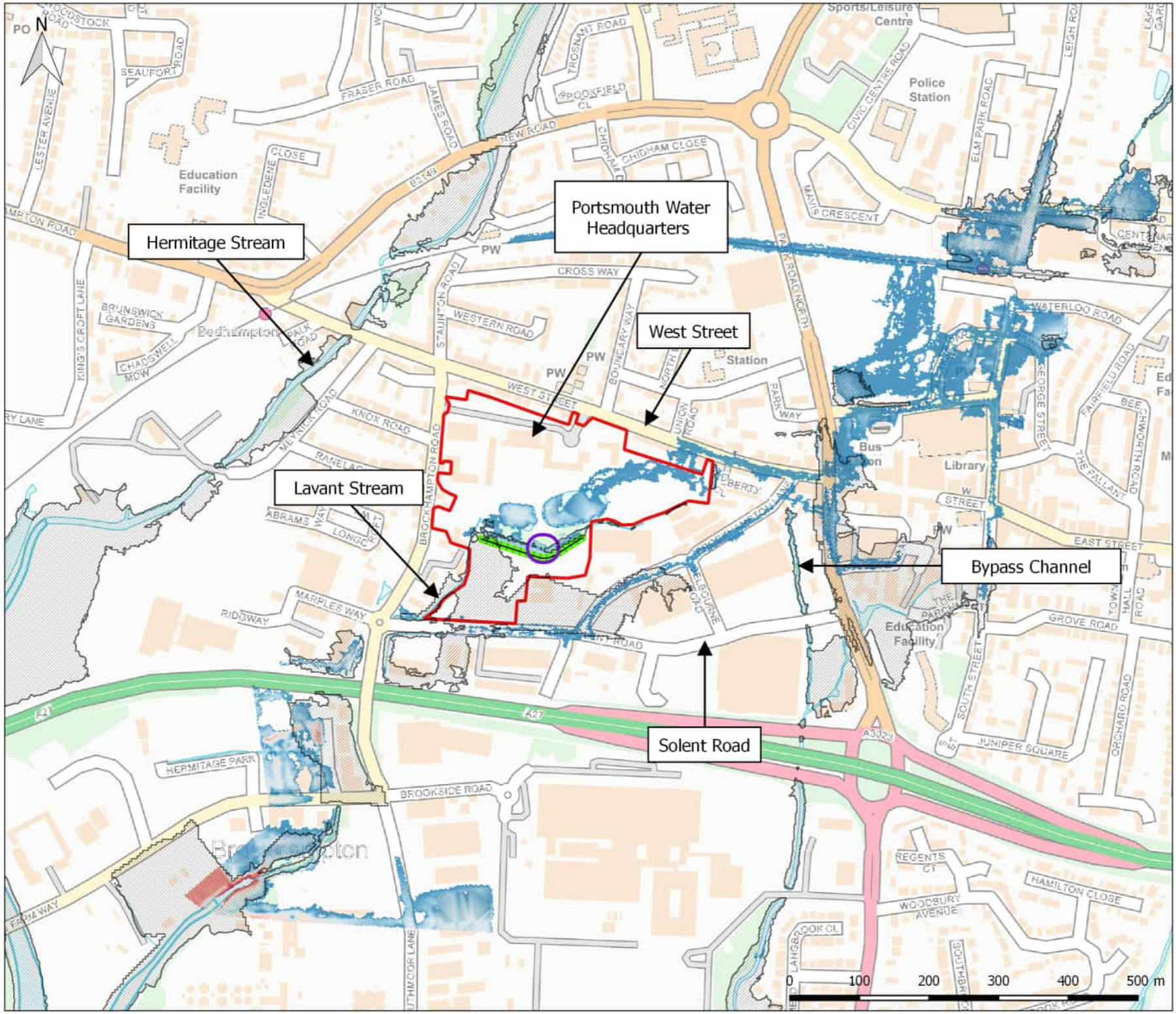
Project Title: 191920 - Solent Road, Havant

Drawing Title:

1 in 100 annual probability event
Maximum Flood Depth
Proposed Scenario - Culvert Removed

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref:	Date:
191920_SolentRoad_018_DEV_Q100_CLA_d_Max	05/02/2020



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Legend

- Portsmouth Water site boundary
- Culvert location
- EA 1 in 100 year flood outline (+20% CC)
- Proposed bund

Ardent flood depth (metres)

- 0.10
- 0.30
- 0.50
- 0.75
- 1.00
- 1.50

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Web: www.ardent-ce.co.uk
E-mail: enquiries@ardent-ce.co.uk

Client: Portsmouth Water

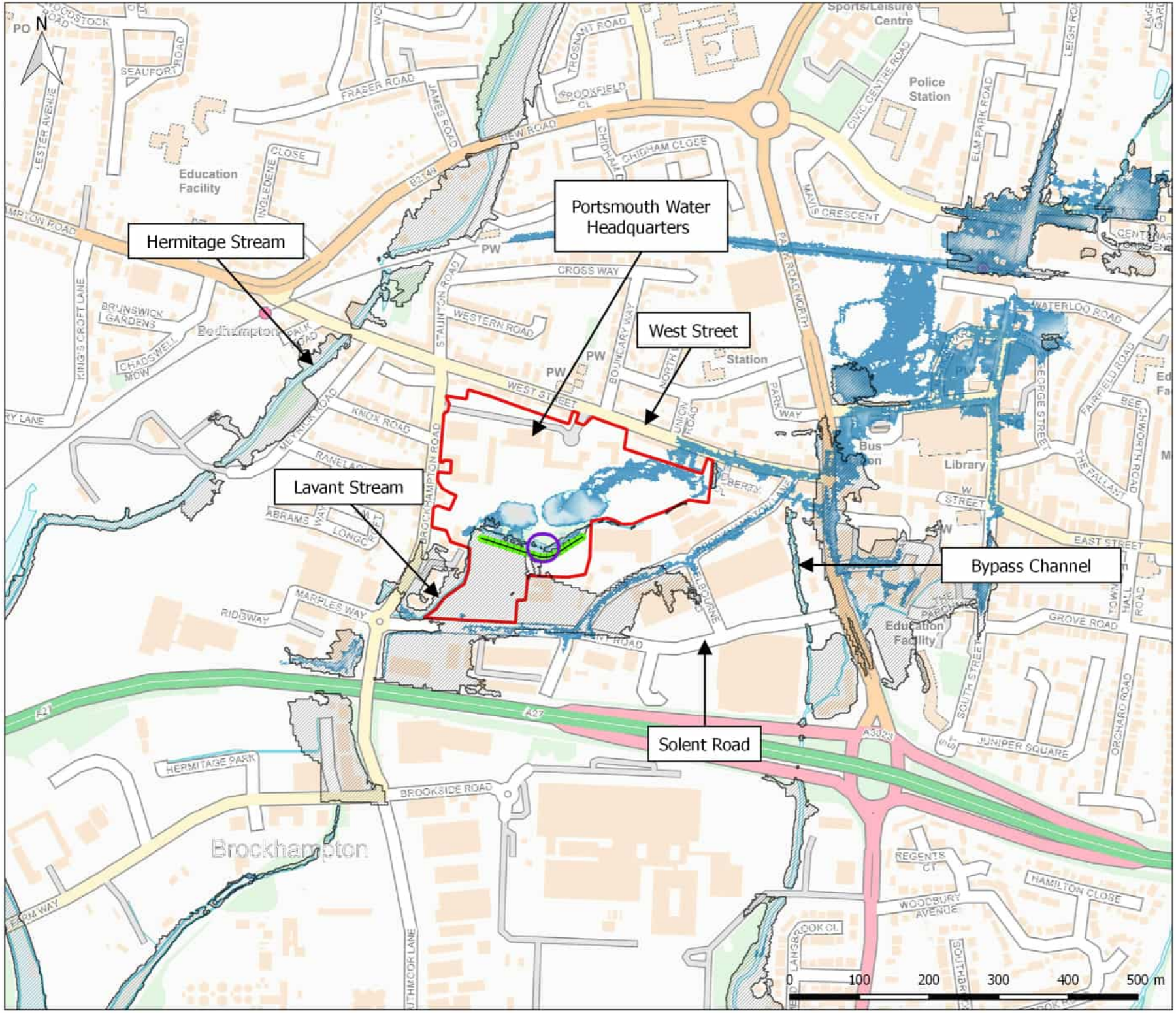
Project Title: 191920 - Solent Road, Havant

Drawing Title:

1 in 100 annual probability event
(plus 45% climate change)
Maximum Flood Depth
Proposed Scenario - Culvert Removed

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref:	Date:
191920_SolentRoad_01B_DEV_Q100cc45_CLA_d_Mai	05/02/2020



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Legend

- Portsmouth Water site boundary
- Culvert location
- EA 1 in 1000 year flood outline
- Proposed bund

Ardent flood depth (metres)

- 0.10
- 0.30
- 0.50
- 0.75
- 1.00
- 1.50

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52-56 Leadenhall Street
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Web: www.ardent-ce.co.uk
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Client: Portsmouth Water

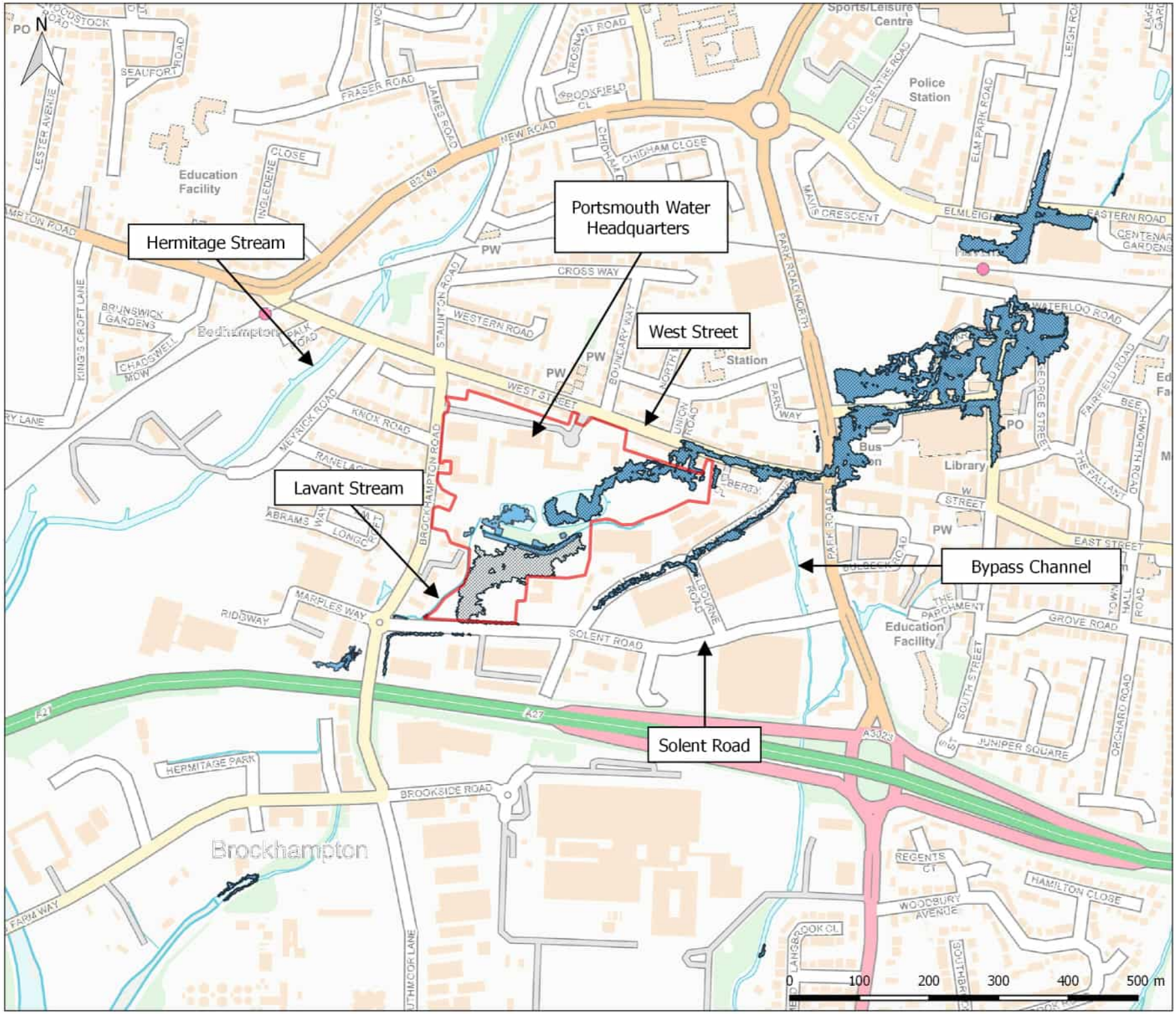
Project Title: 191920 - Solent Road, Havant

Drawing Title:

1 in 1000 annual probability event
Maximum Flood Depth
Proposed Scenario - Culvert Removed

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref:	Date:
191920_SolentRoad_018_DEV_Q1000_CLA_d_Map	05/02/2020



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Legend

- Portsmouth Water site boundary
- Baseline flood extent
- Proposed flood extent

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Client: Portsmouth Water

Project Title: 191920 - Solent Road, Havant

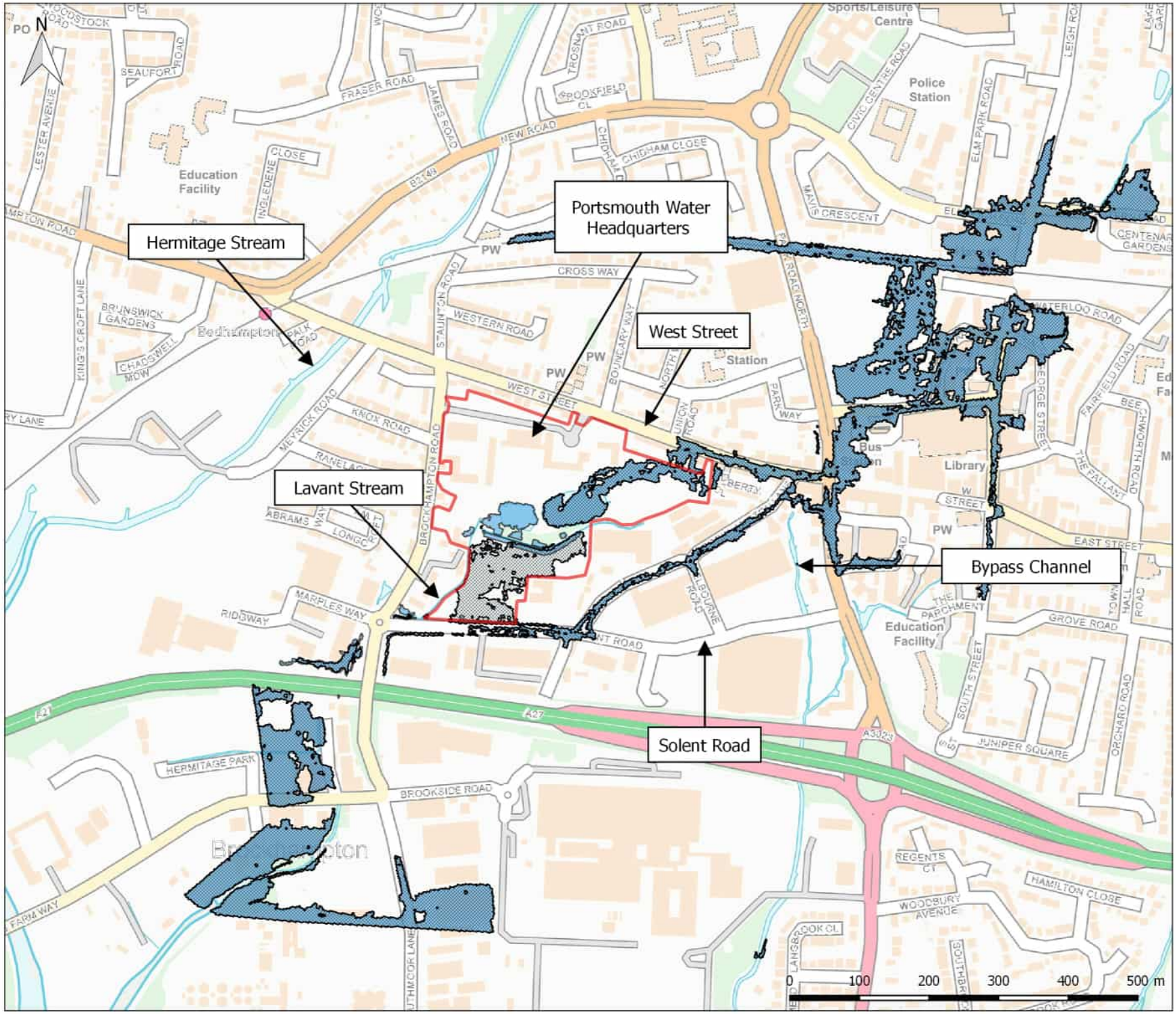
Drawing Title:

1 in 100 annual probability event
Flood extent comparison
Baseline and Proposed Scenario

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref: 191920_SolentRoad_018_Q100_Comparison

Date: 05/02/2020



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Legend

- Portsmouth Water site boundary
- Baseline flood extent
- Proposed flood extent

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Client: Portsmouth Water

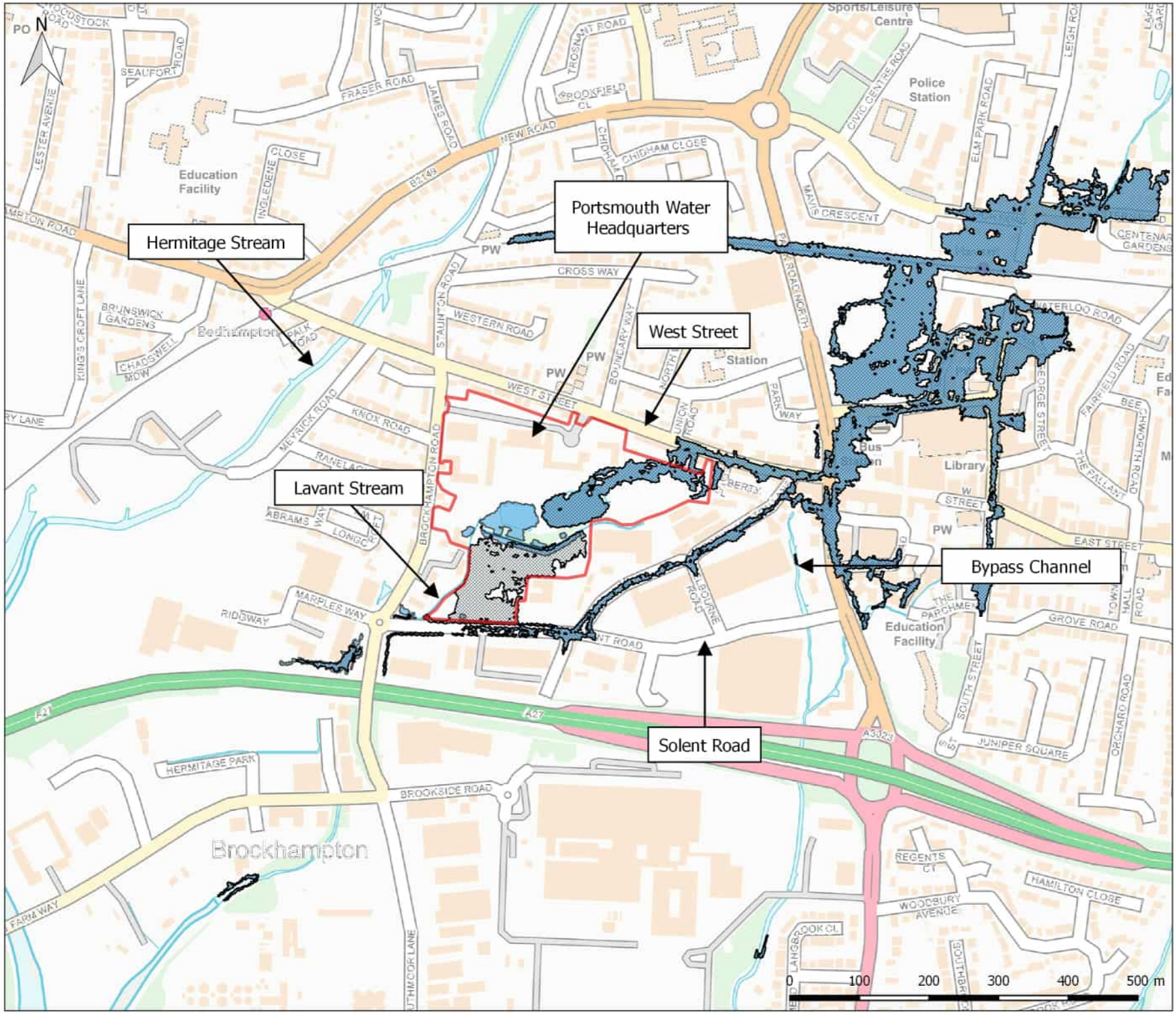
Project Title: 191920 - Solent Road, Havant

Drawing Title:
1 in 100 annual probability event
(plus 45% climate change)
Flood extent comparison
Baseline and Proposed Scenario

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref: 191920_SolentRoad_01B_Q100cc45_Comparison

Date: 05/02/2020



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Legend

- Portsmouth Water site boundary
- Baseline flood extent
- Proposed flood extent

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Client: Portsmouth Water

Project Title: 191920 - Solent Road, Havant

Drawing Title:

1 in 1000 annual probability event
Flood extent comparison
Baseline and Proposed Scenario

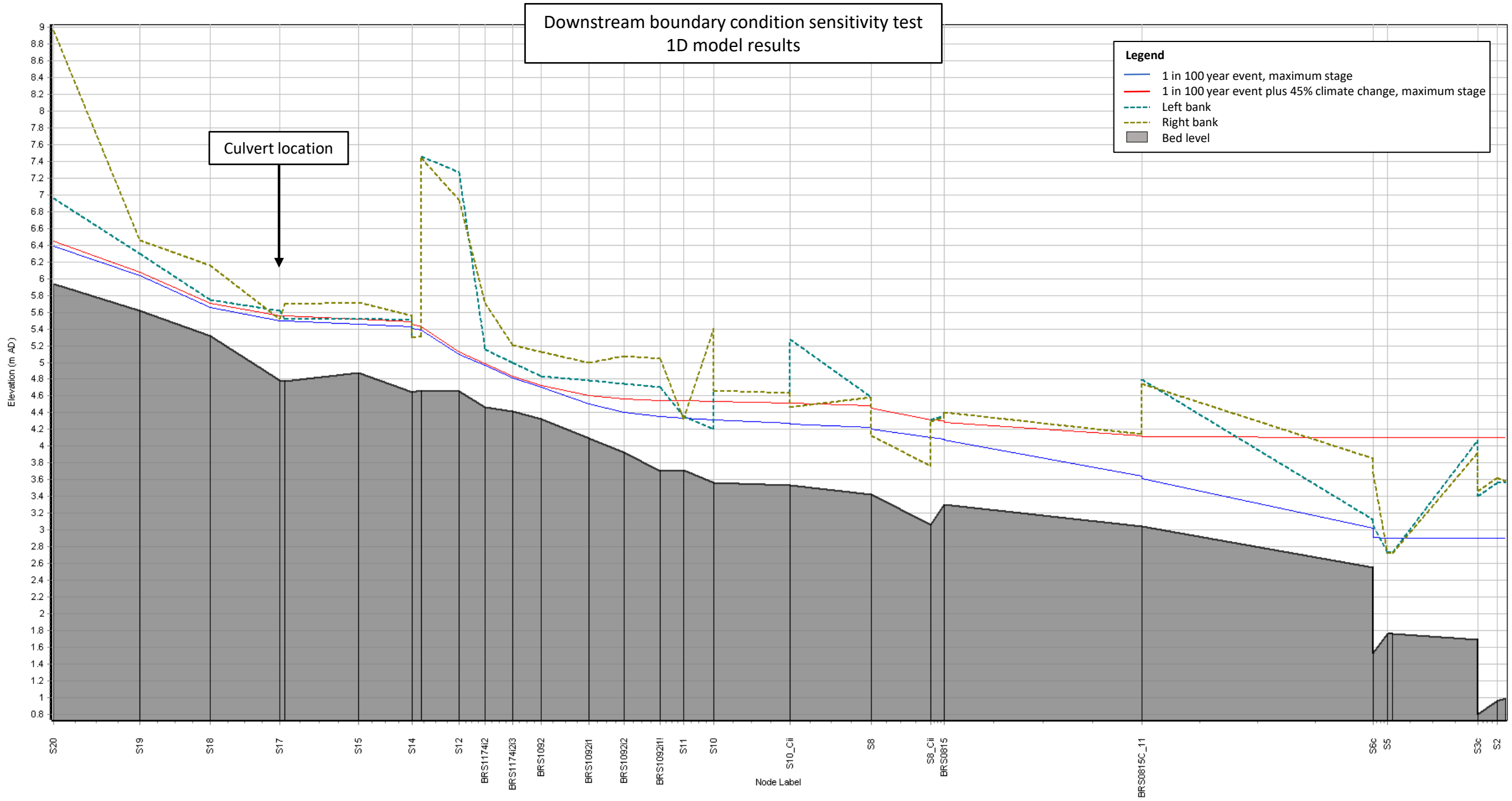
Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

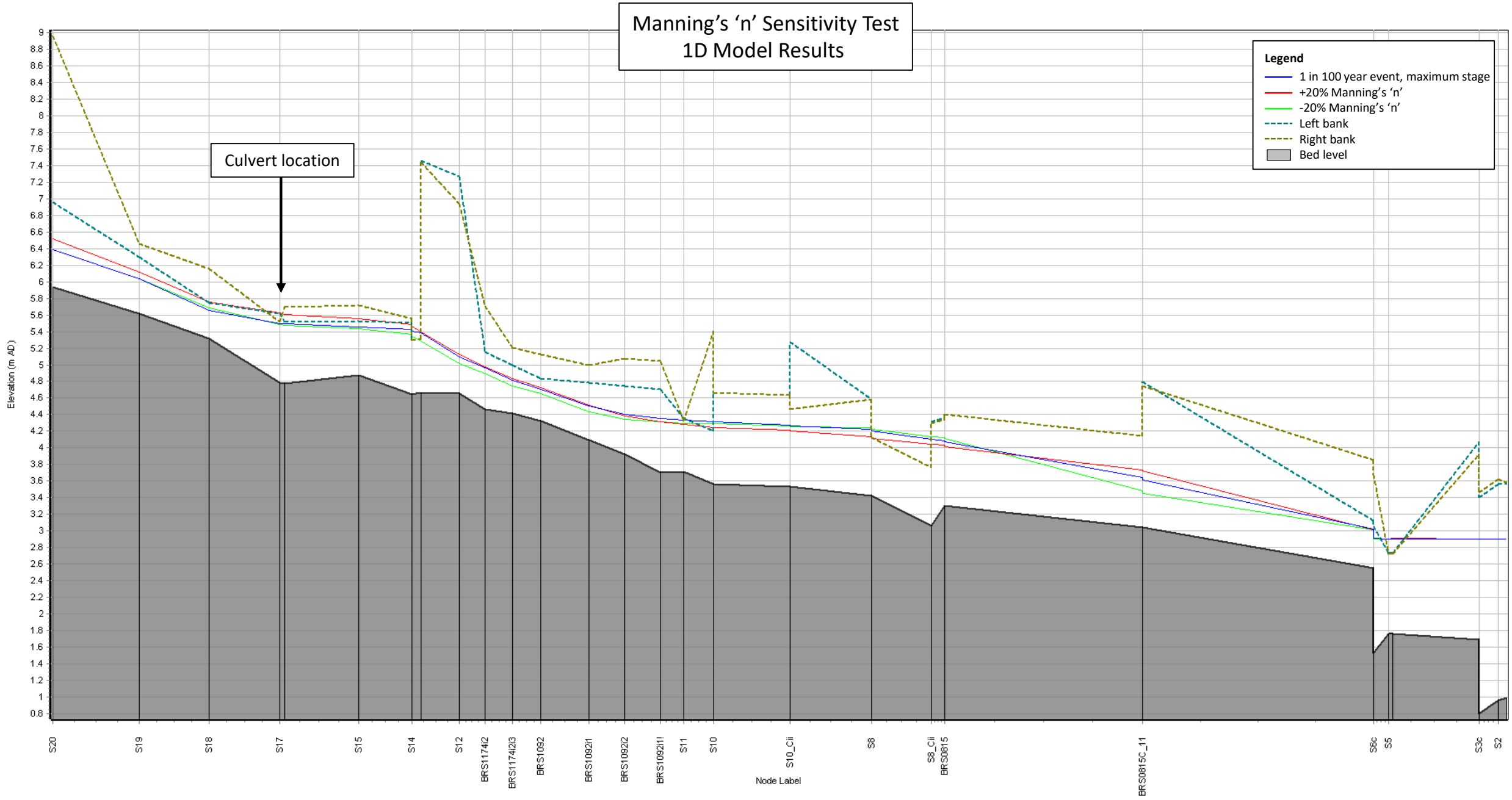
Drawing Ref: 191920_SolentRoad_018_Q1000_Comparison

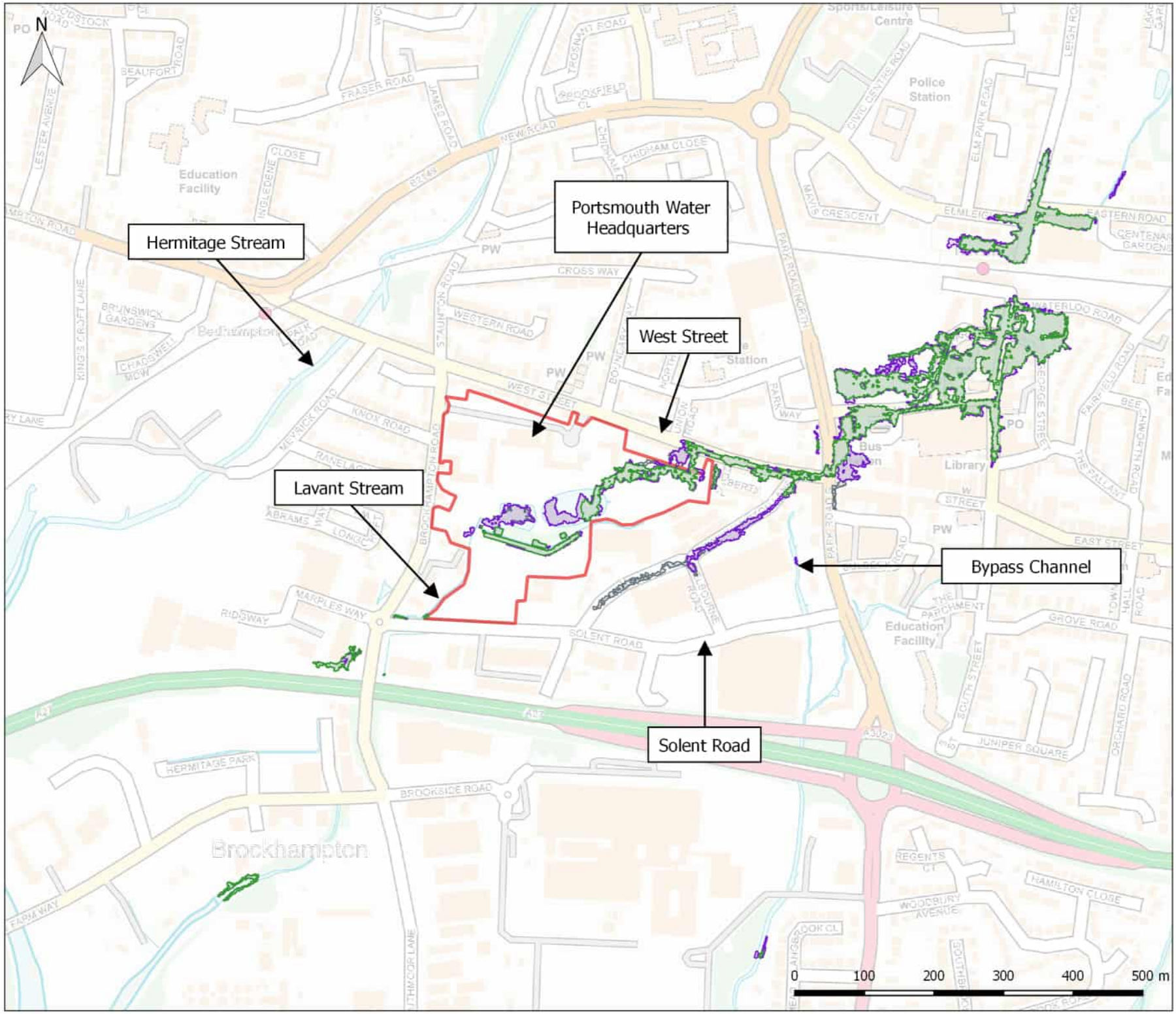
Date: 05/02/2020

Appendix H

Sensitivity Modelling Results


Downstream boundary condition sensitivity test
1D model results
Legend
1 in 100 year event, maximum stage
1 in 100 year event plus 45% climate change, maximum stage
Left bank
Right bank
Bed level
Culvert location
Elevation (m AD)
Node Label
S20
S19
S18
S17
S15
S14
S12
BRS1174i2
BRS1174i2i3
BRS1092
BRS1092i1
BRS1092i2
BRS1092i1i
S11
S10
S10_Cii
S8
S8_Cii
BRS0815
BRS0815C_11
S6c
S5
S3c
S2


Manning's 'n' Sensitivity Test
1D Model Results
Culvert location
Legend
1 in 100 year event, maximum stage
+20% Manning's 'n'
-20% Manning's 'n'
Left bank
Right bank
Bed level
Elevation (m AD)
Node Label
S20
S19
S18
S17
S15
S14
S12
BRS1174i2
BRS1174i2i3
BRS1092
BRS1092i1
BRS1092i2
BRS1092i1i
S11
S10
S10_Cii
S8
S8_Cii
BRS0815
BRS0815C_11
S6c
S5
S3c
S2



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Legend

- 1 in 100 year extent
- 20% decrease Manning's 'n'
- 20% increase Manning's 'n'

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Project Title: 191920 - Solent Road, Havant

Drawing Title:
Sensitivty Test
1 in 100 year proposed event
Baseline against +/- 20% Manning's 'n'
Maximum Flood Extents

Drawn:	Checked:	Approved:	Rev:
JE	CC	BC	-

Drawing Ref: 191920_SolentRoad_018_SEN_Q100_Mannings

Date: 18/06/2018

Appendix D Existing Surface Water Runoff Calculations

Greenfield Runoff Volume

FSR Data

Return Period (years)	100
Storm Duration (mins)	360
Region	England and Wales
M5-60 (mm)	19.500
Ratio R	0.350
Areal Reduction Factor	1.00
Area (ha)	0.669
SAAR (mm)	721
CWI	107.710
Urban	0.000
SPR	37.000

Results

Percentage Runoff (%)	36.89
Greenfield Runoff Volume (m^3)	159.063

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ICP SUDS Mean Annual Flood

Input

Return Period (years)	100	Soil	0.400
Area (ha)	0.669	Urban	0.000
SAAR (mm)	718	Region Number	Region 7

Results	**l/s**
QBAR Rural	2.3
QBAR Urban	2.3
Q100 years	7.5
Q1 year	2.0
Q30 years	5.3
Q100 years	7.5

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PRELIMINARY DRAINAGE CALCULATIONS

12/10/2023

EXISTING SURFACE WATER

Existing site information:

Site Boundary Area	15462	m2
Developable Area	0.669	ha
Impermeable Area	0.10	ha

Modified Rational Method Equation:

$$Q_n = 2.78\ CiA$$

where:

C	*Runoff Coeffic =*	1 (in this case 1 as using impermeable area)
i_n	*Rainfall Intensity for n return period (mm/hr)*	
A	*Impermeable Area (Ha)*	
Q_n	*Runoff for n return period (l/s)*	

The rainfall intensities for various return periods were extracted from Table 1(a) of the Transport and Road Research Laboratory Report - Estimated rainfall for drainage calculations in the United Kingdom (TRRL Report LR 595) by C. P. Young. For the 5 min duration.

i_1	50.8	mm/hr
i_{30}	113.02	mm/hr
i_{100}	143.9	mm/hr

Existing Surface Water Runoff:

Therefore:

			C		i_n		*A*		Q_n	
Q_1	2.78	x	1	x	50.8	x	0.10	=	**13.98**	**l/s**
Q_{30}	2.78	x	1	x	113.0	x	0.099	=	**31.11**	**l/s**
Q_{100}	2.78	x	1	x	143.9	x	0.099	=	**39.60**	**l/s**

Appendix E Drainage Strategy Calculations and Drainage Strategy Drawing 191925-D01

Existing Network Details for Storm

- Indicates pipe length does not match coordinates

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)	Section Type
1.000	18.570	0.078	238.0	0.046	4.00	0.0	0.600	o	300	Pipe/Conduit
1.001	19.900	0.084	238.0	0.030	0.00	0.0	0.600	o	300	Pipe/Conduit
1.002	20.006	0.084	238.0	0.029	0.00	0.0	0.600	o	300	Pipe/Conduit
1.003	8.814	0.114	77.3	0.019	0.00	0.0	0.600	o	300	Pipe/Conduit
2.000	5.000#	0.000	0.0	0.000	4.00	0.0	0.600	o	100	Pipe/Conduit
2.001	5.000#	0.033	150.0	0.000	0.00	0.0	0.060	o	100	Pipe/Conduit
2.002	21.329#	0.090	237.0	0.009	0.00	0.0	0.600	o	300	Pipe/Conduit
2.003	20.000#	0.084	238.0	0.015	0.00	0.0	0.600	o	300	Pipe/Conduit
1.004	15.670	0.080	195.9	0.017	0.00	0.0	0.600	o	300	Pipe/Conduit
3.000	5.000	0.000	0.0	0.000	4.00	0.0	0.600	o	100	Pipe/Conduit
3.001	5.000	0.033	150.0	0.000	0.00	0.0	0.060	o	100	Pipe/Conduit
3.002	7.310	0.031	238.0	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit
1.005	12.427	0.052	238.0	0.016	0.00	0.0	0.600	o	300	Pipe/Conduit
1.006	48.377	-0.932	-51.9	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit
1.007	8.000	0.200	40.0	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit

Network Results Table

PN	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Vel (m/s)	Cap (l/s)
1.000	4.260	0.046	0.0	1.01	71.7
1.001	4.182	0.076	0.0	1.01	71.7
1.002	4.098	0.105	0.0	1.01	71.7
1.003	4.014	0.124	0.0	1.79	126.5
2.000	4.870	0.000	0.0	0.00	0.0
2.001	4.870	0.000	0.0	0.78	6.1
2.002	4.637	0.009	0.0	1.02	71.9
2.003	4.547	0.024	0.0	1.01	71.7
1.004	3.900	0.165	0.0	1.12	79.2
3.000	4.320	0.000	0.0	0.00	0.0
3.001	4.320	0.000	0.0	0.78	6.1
3.002	4.087	0.000	0.0	1.01	71.7
1.005	3.820	0.181	0.0	1.01	71.7
1.006	3.768	0.181	0.0	0.00	0.0
1.007	4.700	0.181	0.0	2.49	176.2

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Free Flowing Outfall Details for Storm

Outfall Pipe Number	Outfall Name	C. Level (m)	I. Level (m)	Min I. Level (m)	D,L (mm)	W (mm)
1.007		5.000	4.500	0.000	0	0

Simulation Criteria for Storm

Volumetric Runoff Coeff	0.750	Additional Flow - % of Total Flow	0.000
Areal Reduction Factor	1.000	MADD Factor * 10m³/ha Storage	2.000
Hot Start (mins)	0	Inlet Coeffiecient	0.800
Hot Start Level (mm)	0	Flow per Person per Day (l/per/day)	0.000
Manhole Headloss Coeff (Global)	0.500	Run Time (mins)	60
Foul Sewage per hectare (l/s)	0.000	Output Interval (mins)	1

Number of Input Hydrographs	0	Number of Storage Structures	3
Number of Online Controls	3	Number of Time/Area Diagrams	2
Number of Offline Controls	1	Number of Real Time Controls	0

Synthetic Rainfall Details

Rainfall Model	FSR	Profile Type	Summer
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Storm Duration (mins)	30
Ratio R	0.350		

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Online Controls for Storm

Orifice Manhole: MH5c, DS/PN: 2.001, Volume (m³): 0.8

Diameter (m) 0.100 Discharge Coefficient 0.600 Invert Level (m) 4.870

Orifice Manhole: MH5b, DS/PN: 3.001, Volume (m³): 0.9

Diameter (m) 0.100 Discharge Coefficient 0.600 Invert Level (m) 4.320

Depth/Flow Relationship Manhole: MH8, DS/PN: 1.006, Volume (m³): 2.3

Invert Level (m) 3.768

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.200	0.0000	1.800	0.0000	3.400	0.0000	5.000	0.0000
0.400	0.0000	2.000	0.0000	3.600	0.0000	5.200	0.0000
0.600	0.0000	2.200	0.0000	3.800	0.0000	5.400	0.0000
0.800	0.0000	2.400	0.0000	4.000	0.0000	5.600	0.0000
1.000	0.0000	2.600	0.0000	4.200	0.0000	5.800	0.0000
1.200	0.0000	2.800	0.0000	4.400	0.0000	6.000	0.0000
1.400	0.0000	3.000	0.0000	4.600	0.0000		
1.600	0.0000	3.200	0.0000	4.800	0.0000		

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Offline Controls for Storm

Pump Manhole: MH8, DS/PN: 1.006, Loop to PN: 1.007

Invert Level (m) 3.768

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.200	2.3000	0.600	2.3000	1.000	2.3000
0.420	2.3000	0.800	2.3000	1.200	2.3000

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Storage Structures for Storm

Porous Car Park Manhole: MH5d, DS/PN: 2.000

Infiltration Coefficient Base (m/hr)	0.00000	Width (m)	27.0
Membrane Percolation (mm/hr)	1000	Length (m)	52.6
Max Percolation (l/s)	394.5	Slope (1:X)	600.0
Safety Factor	2.0	Depression Storage (mm)	5
Porosity	0.30	Evaporation (mm/day)	3
Invert Level (m)	5.020	Membrane Depth (mm)	200

Porous Car Park Manhole: MH6d, DS/PN: 3.000

Infiltration Coefficient Base (m/hr)	0.00000	Width (m)	17.8
Membrane Percolation (mm/hr)	1000	Length (m)	58.4
Max Percolation (l/s)	288.8	Slope (1:X)	600.0
Safety Factor	2.0	Depression Storage (mm)	5
Porosity	0.95	Evaporation (mm/day)	3
Invert Level (m)	4.320	Membrane Depth (mm)	200

Tank or Pond Manhole: MH6, DS/PN: 1.005

Invert Level (m) 3.820

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	300.0	0.400	300.0	0.401	0.0

Time Area Diagram at Pipe Number 2.000 for Storm

Total Area (ha) 0.289

Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)
0	4	0.097	4	8	0.096	8	12	0.096

Time Area Diagram at Pipe Number 3.000 for Storm

Total Area (ha) 0.106

Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)
0	4	0.036	4	8	0.035	8	12	0.035

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Summary of Critical Results by Maximum Level (Rank 2) for Storm

Simulation Criteria

Areal Reduction Factor 1.000 Additional Flow - % of Total Flow 0.000
Hot Start (mins) 0 MADD Factor * 10m³/ha Storage 2.000
Hot Start Level (mm) 0 Inlet Coeffiecient 0.800
Manhole Headloss Coeff (Global) 0.500 Flow per Person per Day (l/per/day) 0.000
Foul Sewage per hectare (l/s) 0.000

Number of Input Hydrographs 0 Number of Storage Structures 3
Number of Online Controls 3 Number of Time/Area Diagrams 2
Number of Offline Controls 1 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model FSR Ratio R 0.350
Region England and Wales Cv (Summer) 0.750
M5-60 (mm) 19.400 Cv (Winter) 0.840

Margin for Flood Risk Warning (mm) 300.0
Analysis Timestep 2.5 Second Increment (Extended)
DTS Status ON
DVD Status ON
Inertia Status ON

Profile(s) Summer and Winter
Duration(s) (mins) 15, 30, 60, 120, 240, 360, 480, 960, 1440
Return Period(s) (years) 1, 30, 100
Climate Change (%) 0, 0, 45

WARNING: Half Drain Time has not been calculated as the structure is too full.

PN	US/MH Name	Storm	Return Period	Climate Change	First (X) Surcharge	First (Y) Flood	First (Z) Overflow	Overflow Act.
1.000	MH1	360 Winter	100	+45%	30/360 Winter			
1.001	MH2	360 Winter	100	+45%	30/240 Winter			
1.002	MH3	360 Winter	100	+45%	30/240 Winter			
1.003	MH4	360 Winter	100	+45%	30/240 Summer			
2.000	MH5d	240 Winter	100	+45%	1/15 Summer			
2.001	MH5c	480 Winter	100	+45%	1/15 Summer			
2.002	MH5b	480 Winter	100	+45%	100/240 Winter			
2.003	MH5a	360 Winter	100	+45%	100/240 Summer			
1.004	MH5	360 Winter	100	+45%	30/240 Summer			
3.000	MH6d	960 Winter	100	+45%	30/480 Winter			
3.001	MH5b	1440 Winter	100	+45%	30/240 Winter			
3.002	MH6a	360 Winter	100	+45%	30/240 Winter			
1.005	MH6	360 Winter	100	+45%	30/120 Summer			
1.006	MH8	360 Winter	100	+45%	30/120 Summer		1/15 Summer	54
1.007	Out	120 Winter	100	+45%				

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Summary of Critical Results by Maximum Level (Rank 2) for Storm

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Half Drain Time (mins)	Pipe Flow (l/s)	Status
1.000	MH1	5.134	0.574	0.000	0.07			4.2	SURCHARGED
1.001	MH2	5.132	0.650	0.000	0.11			6.9	FLOOD RISK
1.002	MH3	5.129	0.731	0.000	0.15			9.3	FLOOD RISK
1.003	MH4	5.124	0.810	0.000	0.12			10.3	FLOOD RISK
2.000	MH5d	5.327	0.357	0.000	2.67		159	8.9	FLOOD RISK
2.001	MH5c	5.232	0.262	0.000	1.67			8.4	FLOOD RISK
2.002	MH5b	5.133	0.196	0.000	0.13			8.5	SURCHARGED
2.003	MH5a	5.127	0.280	0.000	0.16			9.9	FLOOD RISK
1.004	MH5	5.120	0.920	0.000	0.31			20.9	FLOOD RISK
3.000	MH6d	4.674	0.254	0.000	0.68			2.3	SURCHARGED
3.001	MH5b	4.718	0.298	0.000	0.45			2.3	SURCHARGED
3.002	MH6a	5.093	0.706	0.000	0.04			2.3	FLOOD RISK
1.005	MH6	5.108	0.988	0.000	0.14			8.3	FLOOD RISK
1.006	MH8	5.106	1.038	0.000	0.00	2.3		0.0	FLOOD RISK
1.007	Out	4.729	-0.271	0.000	0.02			2.3	FLOOD RISK

PN	US/MH Name	Level Exceeded
1.000	MH1	
1.001	MH2	
1.002	MH3	
1.003	MH4	
2.000	MH5d	
2.001	MH5c	
2.002	MH5b	
2.003	MH5a	
1.004	MH5	
3.000	MH6d	
3.001	MH5b	
3.002	MH6a	
1.005	MH6	
1.006	MH8	
1.007	Out	

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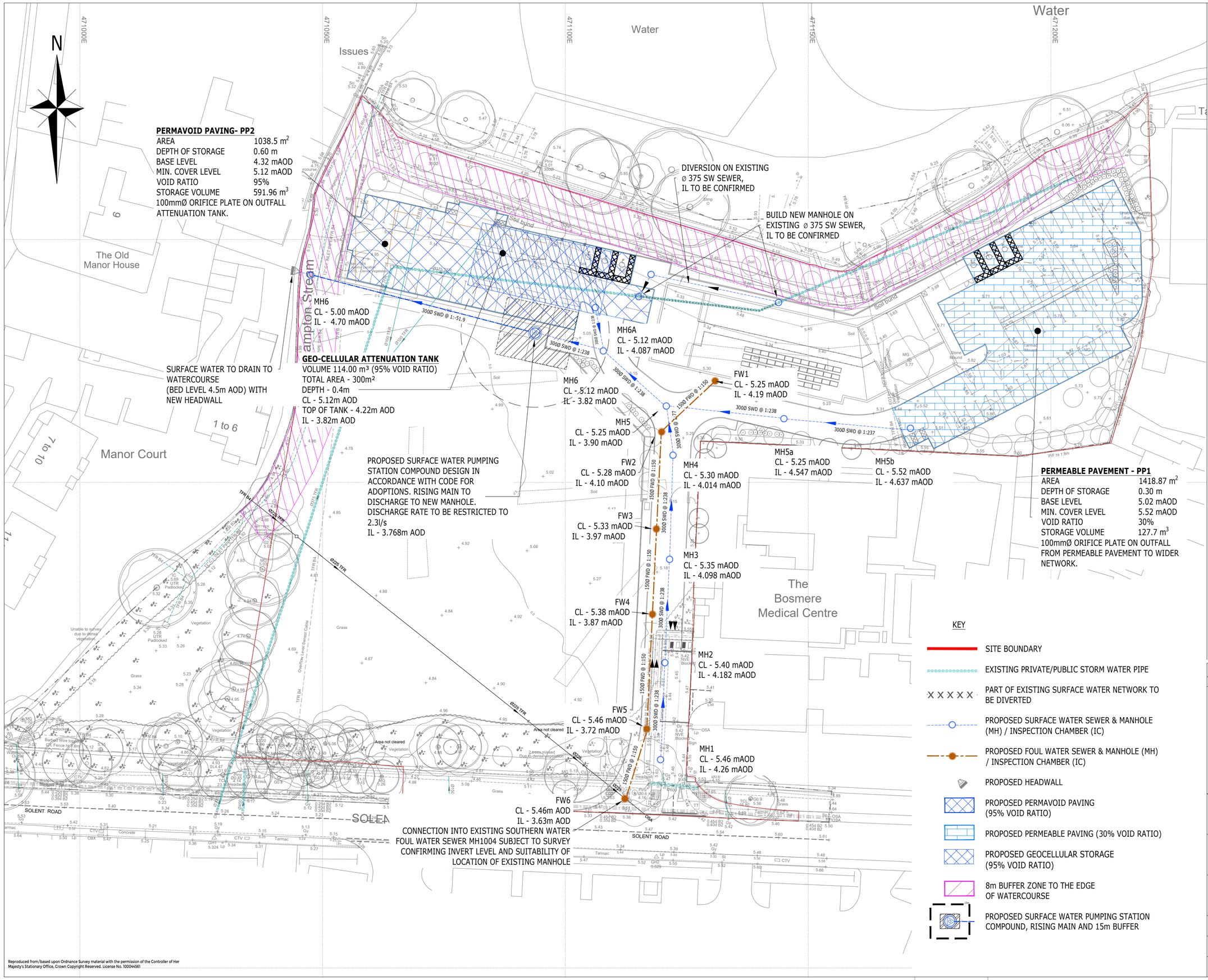

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NOTES:

1. DO NOT SCALE FROM THIS DRAWING.
2. ALL LEVELS ARE IN METRES ABOVE ORDNANCE DATUM AND ALL DIAMETERS IN MILLIMETRES UNLESS OTHERWISE STATED.
3. PROPOSED DRAINAGE IS SHOWN INDICATIVELY AND FOR INFORMATION ONLY.
4. LAYOUT BASED ON PROPOSED SITE PLAN PRODUCED BY CORNISHARCHITECTS IN OCTOBER 2020 (REF. 23002-TP-003)
5. THIS DRAWING HAS BEEN BASED UPON TOPOGRAPHIC SURVEY DATA PRODUCED BY GREENHATCH GROUP (REF. 34028_T ERV 3). LEVELS TO BE CONFIRMED ON SITE.
6. LOCATION OF EXISTING SEWERS HAVE BEEN TRANSCRIBED FROM SOUTHERN WATER ASSET PLAN.
7. EXISTING SEWERS DETAILS (INCLUDING SIZE, LEVELS, & CONDITION) SHOULD BE CONFIRMED BY A CCTV DRAINAGE SURVEY.
8. LOCATIONS OF OTHER UTILITIES SHOULD BE CONFIRMED ON SITE AND CHECKED FOR CLASHES WITH PROPOSED DRAINAGE STRATEGY.

NOT FOR CONSTRUCTION

FOR INFORMATION ONLY

Rev	Description	Drn	Chk	App	Date

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Client
PORTSMOUTH WATER

Project Title:
PORTSMOUTH WATER HQ

Drawing Title:
PROPOSED DRAINAGE STRATEGY

A2 Scale	Date	Designed by
1:500	OCTOBER 2023	MG
Drawn by	Checked by	Approved by
MG	VL	CC

Drawing Number 191925-D01 Rev -

Appendix F Foul Water Calculations

PRELIMINARY DRAINAGE CALCULATIONS

09/10/2023

ARDENT
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EXISTING FOUL WATER

Unit Type	Existing Area/Units		Hours (hrs)	Foul Water Flow Rate l/day			Peak Factor	Peaked Loading l/s			Loading (l/s)
The existing site is currently undeveloped	0	sqm	12	200	per	100 m sq	6.6	0.0003056	per	100 m sq	0.000
										TOTAL PROPOSED FOUL LOADING =	**0.000**

PROPOSED FOUL WATER

Unit Type	Proposed Area/Units		Hours (hrs)	Foul Water Flow Rate *l/day*		Peak Factor	Peaked Loading l/s		Loading (l/s)
Offices per 100m sq	991.97	sqm	12	7.5	sqm	6.6	0.001146	sqm	1.137
								TOTAL PROPOSED FOUL LOADING =	**1.137**