Hemlington, Middlesbrough

Flood Risk Assessment and Drainage Strategy (Final)

August 2018

www.jbaconsulting.com

Middlesbrough Council

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Revision history

Revision Ref/Date	Amendments	Issued to
2/08/2018	Final Report	Grant Alexander

Contract

This report describes work commissioned by Grant Alexander, on behalf of Middlesbrough Council, by an email dated 15 June 2018. Middlesbrough Council's representative for the contract was Grant Alexander of Middlesbrough Council. Alex Woodger and Mark McMillan of JBA Consulting carried out this work.

Prepared by ..... Alex Woodger BEng
Technical Assistant

Reviewed by ..... Iain Ferguson BEng MSc CEng MICE
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Approved by ..... Rene Dobson BEng CEng MICE
Associate Director

Purpose

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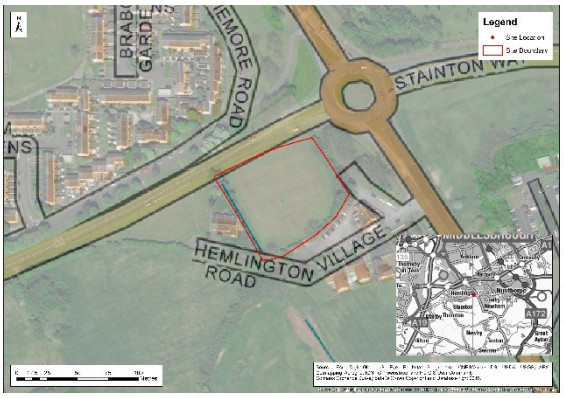
Executive summary

Item	Description
1.	**DESCRIPTION OF PROPOSED DEVELOPMENT** The site is a greenfield site off of Hemlington Village Road, Hemlington, Middlesbrough (E450100 N514300). The site is an irregular polygon in shape covering an area of approximately 0.67Ha as shown below. The LiDAR indicates the site falls from south to north from approximately 52m AOD to 50m AOD. The closest open watercourse to the site is an unnamed watercourse that flows south to north along the western site boundary. It is proposed to develop the site to provide 42 residential units. The development will be accessed from Hemlington Village Road. There is no detailed design at this stage, a number of assumptions have been made to facilitate the assessment. The drainage strategy for the development is thus based on an estimated initial percentage impermeable area of 40% equating to 0.27Ha.
2.	**PLANS AND MAPS**
	 **Redline boundary plan**
	 **Long Term Flood Risk Plan**
	EXISTING SITE DESCRIPTION **Total Area** 0.67 Ha **Greenfield** ✓ **Brownfield** x **Mixed Green & Brownfield** x **Existing runoff destinations** Open watercourse flowing through site **Ground conditions** Clay soils dominate **Ground Contamination** Unknown **Ground infiltration potential** Low
	FLOOD RISK ASSESSMENT/STATEMENT **Coastal** Flood Zone 1 **Fluvial** Flood Zone 1 **Pluvial** Areas of high, medium and low risk within site. **Groundwater** Low **Other Sources** N/A
	DEVELOPMENT DRAINAGE STRATEGY **Runoff Destinations** **Ground** x **Sea or Estuary** x **Surface water body** ✓ **Surface water drain** x **Combined sewer** x **Method of peak flow control** **Restrict flows to QBAR runoff rates** ✓ **Restrict flows to previously developed rates** x **Proposed development peak discharge rate** 5 litres / second (Equivalent to 7.46 litres / second / hectare)

Item	Description
	METHOD OF VOLUME CONTROL **Match greenfield runoff volume** x **Runoff volume discharged at QBAR runoff rate** ✓ **Match previously developed volume** x **Estimated total development attenuation volume** 159 - 252 m^3 (This volume includes an allowance of 10% for development creep and 40% for climate change) **Flood Risk Within Development** The drainage system will be designed not to flood any part of the site for a 30Y rainfall event. Exceedance flows will be managed in planned flow routes that minimise the risk to people and property.
B	**DESIGN & MAINTENANCE** Outline SUDs Statement describing its character and visual appearance, and any amenity and ecological enhancements. A new foul water pipe network shall be installed to convey the flows to the combined sewer within Stainton Way. The surface water flows up to and including the 100-year event will be attenuated to the QBAR rate and discharge to the watercourse that flows through the site. Storage for flows up to the 30-year event will be within a formal above ground storage system. Storage for flows up to the 100-year event will be within more informal storage within public green space. Outline details of maintenance responsibilities It is planned to vest the foul drainage network and the formal surface water drainage network (up to 30-year return period) with Northumbrian Water. A management company will maintain the surface water drainage not vested with Northumbrian Water. Outline public health and safety considerations, if appropriate The development is suitable for above ground SuDS techniques. The designers risk assessment shall take cognisance of the residential setting when designing SuDS and also assess the hazards and risks to people arising from planned overland flow paths. Outline details of Ecology and Water Quality implications The proposed development presents a low risk to the water environment. There are no known water sensitive receptors downstream of the development. A Simple Index Approach has been completed and indicates that a SuDS management train consisting of two stages such as a pond and a swale are sufficient for removal of suspended solids, hydrocarbons and metals from surface water runoff from residential roofing, residential parking and low traffic roads.
C	**EVIDENCE OF THIRD PARTY AGREEMENT FOR DISCHARGE TO THEIR SYSTEM (IN PRINCIPLE/CONSENT TO DISCHARGE)** Northumbrian Water has consented to the estimated foul flow of 1.9 l/sec discharging to the combined sewer network at manhole 6103 without restriction. No surface water flows are permitted to be discharged into the Northumbrian Water combined sewer network.

Contents

List of Figures

List of Tables

Abbreviations

Abb	Abbreviation
EA	Environment Agency
FRA	Flood Risk Assessment
FFL	Finished Floor Level
LLFA	Lead Local Flood Authority
NPPF	National Planning Policy Framework
PPG	Planning Practice Guidance
MC	Middlesbrough Council
SFA	Sewers for Adoption

1 Introduction

1.1 Background

Middlesbrough Council commissioned JBA to prepare a Flood Risk Assessment (FRA) and Drainage Strategy to assess the flood risk associated with the proposed residential development on land off Hemlington Village Road, Hemlington, Middlesbrough.

The report will be undertaken in accordance with Environment Agency, Middlesbrough Council and Northumbrian Water development control policies and will focus on:

- Site use and Current Drainage Regime
- Flooding History
- Ground Conditions and use of SuDS
- Impact of development and proposed drainage strategy
- Consideration of sources of flood risk

1.2 Reporting Guidelines

This Flood Risk Assessment is consistent with the reporting requirements detailed within the National Planning Policy Framework (NPPF) and Planning Practice Guidance (PPG).

As the development is not within 20 metres of a main river and is located within Flood Zone 1, consultation is not required with the Environment Agency (EA).

The UK Government Flood Map for Planning identifies 3 zones to aid flood risk planning for coastal and river flooding:

Flood Zone 1: This zone has a chance of flooding of less than 0.1%.

Flood Zone 2: This zone has a chance of flooding of between 0.1% and 1%.

Flood Zone 3: This zone has a chance of flooding of between 1% and 3.3%.

These zones take into account the effect of any flood defences in the area. These defences reduce but do not completely stop the chance of flooding as they can be overtopped, or fail.

The UK Government has also published long term flood risk information maps which identifies the likelihood of flooding from river, sea, surface water, and reservoirs in England. These are used to assist development master planning and manage overland flow routes.

The development site is shown to lie within Flood Zone 1 on the Flood Map for Planning. There are some localised areas of low to high surface water flood risk within the development boundary, but these could be effectively managed within the proposed development.

The PPG to the NPPF refers to vulnerability classifications, which are based on the sensitivity of different forms of development. The residential nature of this development results in a 'more vulnerable' classification.

Table 3 in the NPPF technical guidance (copied below) provides information in relation to the appropriate vulnerability classes within each of the flood risk zones.

Table 1-1 Flood Risk Vulnerability and Flood Zone Compatibility

Flood risk vulnerability classification		Essential infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone	**Zone 1**	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test required	✓	✓
	Zone 3a	Exception Test required	✓	×	Exception Test required	✓
	Zone 3b functional floodplain	Exception Test required	✓	×	×	×

Based on the above table the intended use of the development is consistent with NPPF guidance. Therefore, a sequential and exception test is not required.

To facilitate adoption of the drainage infrastructure by Northumbrian Water, the development drainage will comply with the 6th Edition of 'Sewers For Adoption' (SFA). A 'pre-development' Point of Connection enquiry has been made to Northumbrian Water to ensure that the drainage strategy is acceptable in principle prior to a planning application being made. Northumbrian Water's response is included in Appendix B.

Tees Valley have also issued SuDS design guidance outlining their requirements and ensure consistency and quality of design.

2 Flood Risk Assessment

2.1 Site Details and Location

The land where the development is proposed is a greenfield site off Hemlington Village Road, Hemlington, Middlesbrough (E450100 N514300). The site is an irregular polygon in shape covering an area of approximately 0.67Ha as shown below. The LiDAR indicates the site falls from south to north from approximately 52m AOD to 50m AOD. An open watercourse flows through the site. The ultimate discharge point of the watercourse is not determinable from mapping and aerial imagery.

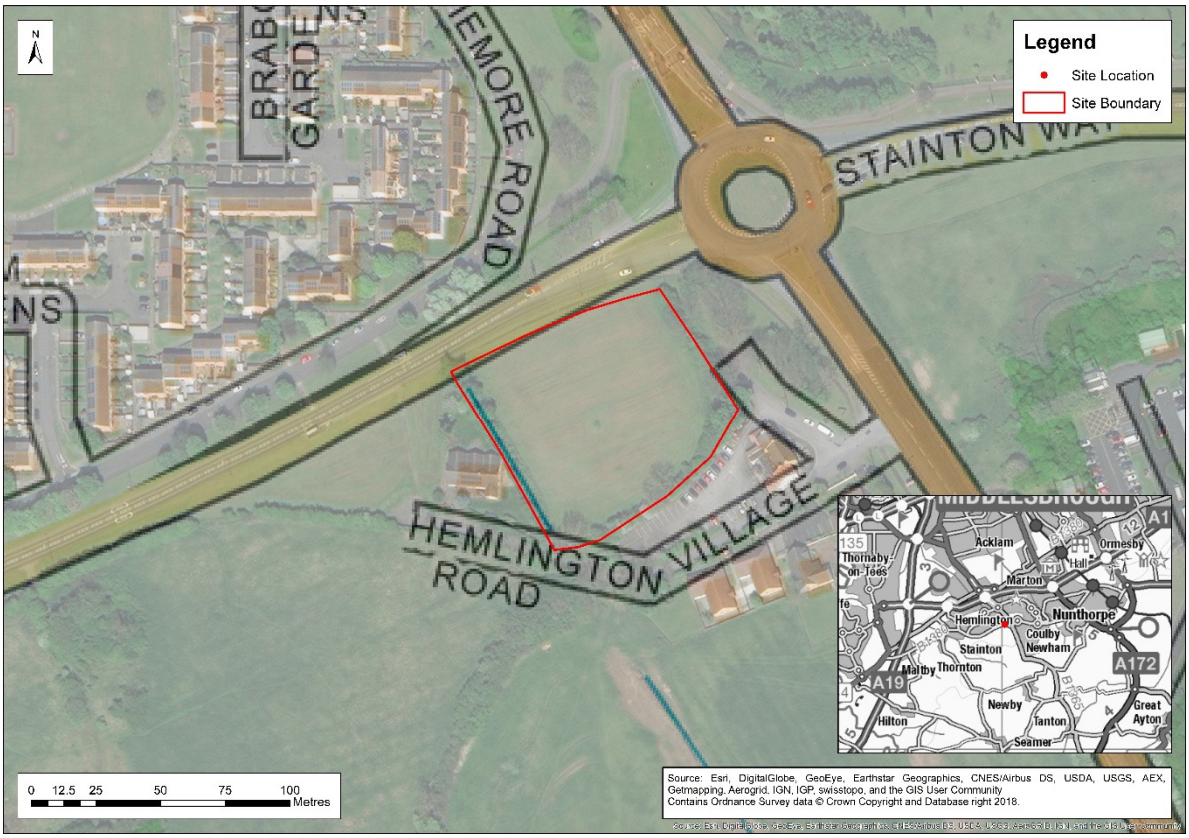


Figure 2-1 Site Location and Boundary

2.2 Existing and Proposed Development

The area proposed for development is open green space located between Stainton Way and Hemlington Village Road adjacent to The Gables Inn.

The proposed site will provide 42 residential dwellings. The development currently has access from Hemlington Village Road.

The existing drainage on the site can be seen in Appendix B.

2.3 Sources of Flood Risk

There are a number of potential sources of flooding that could impact any site, these are fluvial (originating from a watercourse), coastal, groundwater, surface water (pluvial), sewers and blocked culverts. The purpose of this report is to provide an assessment of flood risk to the site from those sources.

2.3.1 Coastal Flooding

The Environment Agency flood maps show the site is outwith the extents of coastal flooding, meaning that the site has a less than 0.1% chance of flooding from coastal sources. The EA flood map has been provided in Appendix C.

2.3.2 Fluvial Flooding

The Environment Agency flood maps show the site is outwith the extents of fluvial flooding, meaning that the site has a less than 0.1% chance of flooding from fluvial sources. The EA flood map has been provided in Appendix C.

2.3.3 Surface Water Flooding

The Environment Agency surface water flood maps show surface water flooding along the boundary of the site. Analysis of LiDAR and observations on site have confirmed that the surface water maps are a reasonable assessment of flood risk at the site. Surface water flooding is driven largely by a high risk of culvert blockage and downstream water levels. The ponding on Stainton Way is also confirmed as a local low point; if the culvert were to block, water would pond here before flood relief occurred further north of the site. The LiDAR indicates the site falls from south to north from approximately 52m AOD to 50m AOD.

Figure 2-2 Photo showing the open watercourse along western site boundary

2.3.4 Groundwater Flooding

This type of flooding is caused by water rising up from underlying rocks or flowing from springs. Groundwater is generally a contributing factor to flooding

rather than the primary source and would likely influence the duration and extent of flooding from other sources.

The recorded geology was accessed for the site from the British Geological Survey database, to help assess groundwater flooding risk. The superficial geology is recorded as being Devensian diamicton till.

It is considered that the risk of ground water flooding is very low.

2.3.5 Reservoir Flooding

The proposed site is located outwith the flood extents of reservoir flooding. The EA flood map has been provided in Appendix C.

2.3.6 Flood Defences

The Environment Agency mapping show the site does not lie in an area benefitting from any flood defences.

3 Existing Site Drainage

JBA Consulting has obtained a copy of the Northumbrian Water Sewerage Record plans for the area. A copy of the sewer record plan is included in Appendix B.

3.1 Pre-Development

An assessment of existing site runoff has been undertaken to ascertain baseline conditions and determine appropriate post development discharge rates. To estimate the pre-development runoff rates the Institute of Hydrology 124[1] methodology was used. This methodology is an extension of the Flood Studies Report (FSR) work aimed at providing a better estimate of peak runoff flow rates for small catchments (<25km^2) than had previously been developed. It is a correlation equation based on soil type, average rainfall and site area, all of which are easily measured. The site is characterised as a grassed undeveloped site. The proposed site area is approximately 0.67Ha and for the purposes of this assessment it has been conservatively assumed that it is 100% permeable (greenfield).

A summary of the peak pre-development discharge rates is included in Table 3-1 and the calculations are included in Appendix D.

Table 3-1 Pre-development runoff rates

Return Period (years)	IH124 Runoff (l/s)	IH124 runoff (l/s/ha)
QBAR	2.69	4.01
1	2.31	3.45
30	4.72	7.04
100	5.60	8.36

[1] Report No. 124, Flood estimation for small catchment, Institute of Hydrology, June 1994

4 Proposed Development

4.1 Surface Water Runoff Destination

The site is dominated by low-permeability clay soils, which is not suitable for disposal of surface water by infiltration.

Due to the proximity of open watercourse and the topography, the surface water network will discharge to the open watercourse that flows through the site.

It is proposed to maintain this flow path by mimicking it in the drainage network to reduce the impact from the development of the site.

4.2 Surface Water Peak Flow and volume control

Existing ground conditions do not permit the disposal of surface water runoff to ground and reducing the runoff to pre-development greenfield volumes will not be achievable. However, it is recognised that there is an opportunity to mitigate the impacts of development through the use of SuDS to reduce the post development runoff rates to the pre-development greenfield runoff rate.

It is proposed to manage surface water runoff within the development and attenuate runoff rates to the QBAR runoff rate of 4.01 l/s/ha. The total post development runoff rate will be 5.0 l/s up to the 100-year critical duration storm event plus allowance for climate change. A minimum discharge rate of 5 litres/second has been chosen as flow controls limited to discharge rates lower than 5.0 litres/second have a high risk of blockage.

4.3 Flood Risk Within and Outside the Development

The drainage system shall be designed to operate without flooding any part of the site up to the 1 in 30-year event and manage exceedance runoff up to the 1 in 100-year event plus allowance for climate change, refer to Section 4.4.1.

The detailed design shall assess the practicalities of using the open spaces for storage taking account of potential constraints such as; services and ground conditions. All overland flow paths shall be assessed in accordance with DEFRA Guidance document 'Flood Risk to People' to avoid creating hazards to access and egress routes and all areas that are designed to accommodate temporary storage will be designed to be flood resilient.

4.4 Structural Integrity

It is planned to vest the foul drainage network and the formal surface water drainage network, required to contain up to the 30-year return period event, with Northumbrian Water. A management company may be engaged to maintain the surface water drainage not vested with Northumbrian Water. The drainage network shall be designed to the specification document Sewers for Adoption 6th Edition.

4.4.1 Climate Change

The NPPF provides guidance with respect to the implications of climate change and suggests appropriate additional allowance for drainage design with respect to uplifting rainfall intensities.

In terms of peak rainfall allowance for drainage design, the final drainage system shall be designed to include a 20% uplift in rainfall and a sensitivity analysis shall be carried out with a 40% uplift to show that the additional runoff is wholly contained within the site and there is no increase in the rate of runoff discharged

from the site. The design will also assess any implications to people from increased flood hazard (e.g. depths, velocities of surface water runoff).

4.5 Urban Creep

Urban creep is the conversion of permeable surfaces to impermeable over time e.g. impermeable surfacing of front gardens to provide additional parking spaces, extensions to existing buildings, creation of patio areas.

In accordance with Tees Valley Authorities Local Standards for Sustainable Drainage a 10% uplift in impermeable area has been applied.

4.6 Proposed Maintenance Regime

It is proposed to vest the development foul and surface water drainage network to Northumbrian Water via a Section 104 Agreement. The drainage network shall be designed to the specification document Sewers for Adoption 6th Edition.

The informal surface water storage to manage exceedance runoff arising from events greater than the 1 in 30-year event are unlikely to be vested to Northumbrian Water. A management company may be engaged to maintain the surface water drainage not vested with Northumbrian Water.

4.6.1 Estimated Surface Water Attenuation

The approximate storage volume required to attenuate total flows on site has been estimated using industry standard MicroDrainage software. As this development is at outline stage there are no detailed plans for impermeable areas an estimated impermeable area of 0.27Ha has been used assuming 40% impermeability. The results are included in the table below:

Table 4-1 Quick Storage Estimates

Return Period	Storage volume boundaries (m^3)	
	Lower	Upper
30 year +10% Urban Creep	65	111
100 year +10% Urban Creep	103	165
100 year +20%CC +10% Urban Creep	130	208
100 year +40%CC +10% Urban Creep	159	252

The estimated storage volumes take account of numerous variables, including the geometry of the storage structure, maximum head level and the efficiency of the flow control unit. An efficient flow control device, such as a vortex flow control unit would most likely result in the volume to be stored being closer to the lower estimate values. It should be noted that a combination of formal and informal surface water storage located around the site may provide the most efficient and cost-effective solution to surface water management.

4.7 Foul Water Drainage

Northumbrian water will permit a discharge of foul water flows from the site to the public sewer that is contained within Stainton Way at MH 6103, approximately 415m to the south-west of the site. The point of connection enquiry response from NWL can be found in Appendix B.

5 Conclusions and Summary

A detailed Flood Risk Assessment and outline drainage management plan has been prepared with respect to the planned development on land off of Hemlington Village Road, Hemlington, Middlesbrough.

The FRA has been undertaken in accordance with Environment Agency, Northumbrian Water and Middlesbrough Council development control guidance, and considers the setting of the development and likely impact on surrounding areas. A surface water and foul water drainage strategy has been outlined in the report.

It has been established that the site is located within Flood Zone 1, however; surface water is a significant flood risk at this site. To counter this, no development will take place within the surface water flood outlines and no land raising will be undertaken within these zones. The detailed design shall consider the flood relief level and provide a sufficient freeboard to the finished floor levels of each dwelling. The detailed design of the drainage network will consider the downstream boundary conditions and the potential for surcharge and the development layout will be developed ensuring safe access and egress during flood events.

The assessment has identified the current site drainage characteristics and also established the current level of risk from flooding. A summary of the risk and mitigation identified is presented below:

Table 5-1 Summary of Main Issues

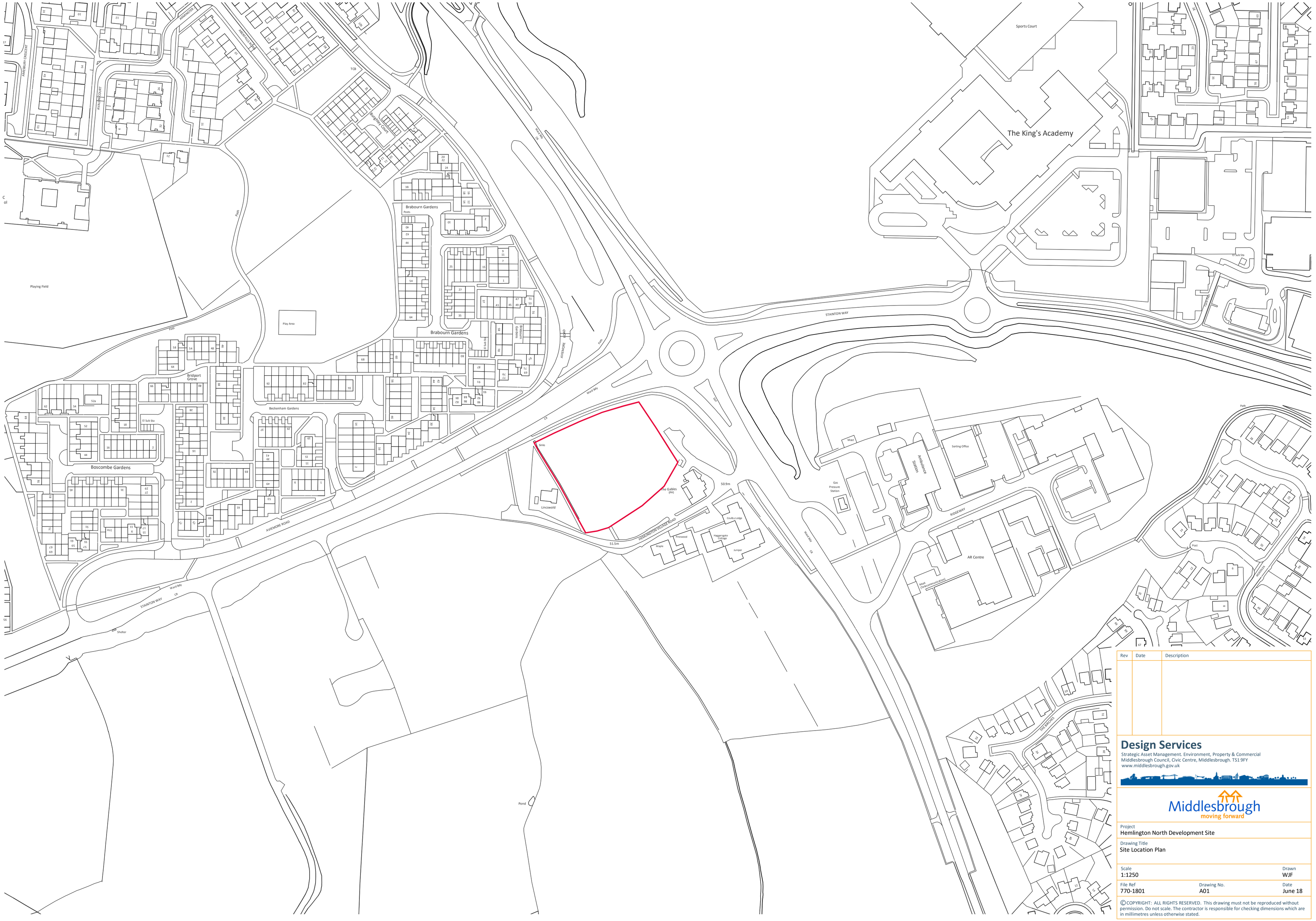
Issue	Summary	Residual Risk
Flood Zone	The development area of the site is located within Flood Zone 1. The proposed development is compatible to the flood setting.	Low
Fluvial flooding	The development is not located in an area at risk of fluvial flooding and there is no tidal flood risk due to the location of the site.	Low
Pluvial flooding	The Environment Agency surface water flood maps show surface water flooding along the boundary of the site. The development of the site needs to be carefully managed to ensure mitigation of this risk.	Low
Artificial sources	The site is not in an area at risk of reservoir flooding.	Low
Groundwater	The groundwater level will need to be assessed as part of a site investigation, however, it is not anticipated to be a risk to the development.	Low
Surface Water Management	The rate of surface water runoff discharged from the development will be restricted 5.0 litres/second which reflects a 24% reduction on the post development one-year return period runoff rate, 6.58 litres/second. Surface water flows in excess of this rate will be attenuated on the site.	Low

It is proposed to discharge surface water runoff to the watercourse flowing through the site. The discharge shall be restricted to the lowest practical rate of 5.0 litres per second. Any flows generated on site above this shall be attenuated up to the 100-year event, with a 40% climate change allowance and 10% allowance for urban creep. It is anticipated that flows attenuated up to the 30-year event, with a 10% allowance for urban creep shall be stored formally within

the Development using SuDS. With flows attenuated up to and including the 100-year event, with a 40% climate change allowance and 10% allowance for urban creep being stored in more informal storage, such as the green open space or car parking within the development.

Appendices

A Drawings



Rev	Date	Description

Design Services

Strategic Asset Management. Environment, Property & Commercial

Appendices

B NWL Correspondence

NORTHUMBRIAN WATER living water

T: 0345 609 4639
F: 0191 419 6510
nwl.co.uk

Northumbrian Water
New Development
Leat House
Pattinson Road
Washington
NE38 8LB

Ext: 36646
Direct Line: 0191 419 6646
Email: developmentenquiries@nwl.co.uk
Our Ref: 18NO551206

09 July 2018

Claire Bell
Middlesbrough Council
1st Floor Civic Centre
Middlesbrough
TS1 9FY

Dear Ms Bell,

Re: Point of Connection – Hemlington/Coulby Newham/Stainton Way/B1365

Further to the Point of Connection Application for the above site, received on 19 June 2018, we are now able to provide the following response.

We have based our response on the information in your application and accompanying correspondence. Therefore, should any of the information now be different, then you must ensure that you inform us of any changes as further Network Modelling may be required and our response may also change, leading to this response being invalid.

Northumbrian Water assesses the impact of the proposed development on our assets and assesses the capacity within our network's to accommodate and treat the anticipated flows arising from the development. We do not therefore offer comment on aspects of planning applications that are outside of our area of control.

Enclosed in this response is a scaled plan showing the **approximate** position of the water and sewerage networks within the vicinity of this site.

We have changed the way contractors and developers can access our assets.

Historically only our own staff and framework contractors could access our sewerage network. As of 1st January 2018, we are allowing third party contractors to access our sewer network on a site by site basis, subject to certain conditions.

Further information (including how to apply) is available from our web site - https://www.nwl.co.uk/developers/sewerage-services.aspx

Also enclosed is our extract showing locations within the approximate vicinity of this site that have, from our records, experienced flooding. This has been provided to demonstrate the known flood risks within the vicinity which have been considered as part of our assessment on this enquiry.

We have also carried out a review of your application and can confirm the following:

Sewerage and Sewage Treatment

Northumbrian Water would ask that you please separate the foul and surface water flows in

accordance with Part H of the Building Regulations prior to the final connection to the public sewer.

All new connections to the public sewerage system must first be approved through the Section 106 of the Water Industry Act 1991 process prior to construction.

Should you decide to proceed with this development, a fully completed Sewer Connection application form will be required. These are available to download from the following link:

https://www.nwl.co.uk/developers/new-connections.aspx

- Foul Water Discharge

The recommended discharge rate for this proposed development is 1.9 l/sec and can be accommodated at manhole 6103.

- Surface Water Discharge

No surface water flow from the proposed development will be allowed to connect into the existing public sewerage system unless it is proven that the alternative options which are listed within Part H of the Building Regulations 2003 are not available:

Rainwater from a system provided pursuant to sub-paragraphs (1) or (2) shall discharge to one of the following, listed in order of priority –

(a) an adequate soakaway or some other adequate infiltration system; or, where that is not reasonably practicable,

(b) a watercourse; or, where that is not reasonably practicable,

(c) a sewer.

In this instance we have identified that the surface water flow should discharge directly to the watercourse. We therefore suggest that you contact either the Environment Agency or Lead Local Flood Authority, as appropriate, to discuss this in further detail.

- Sewage Treatment Capacity

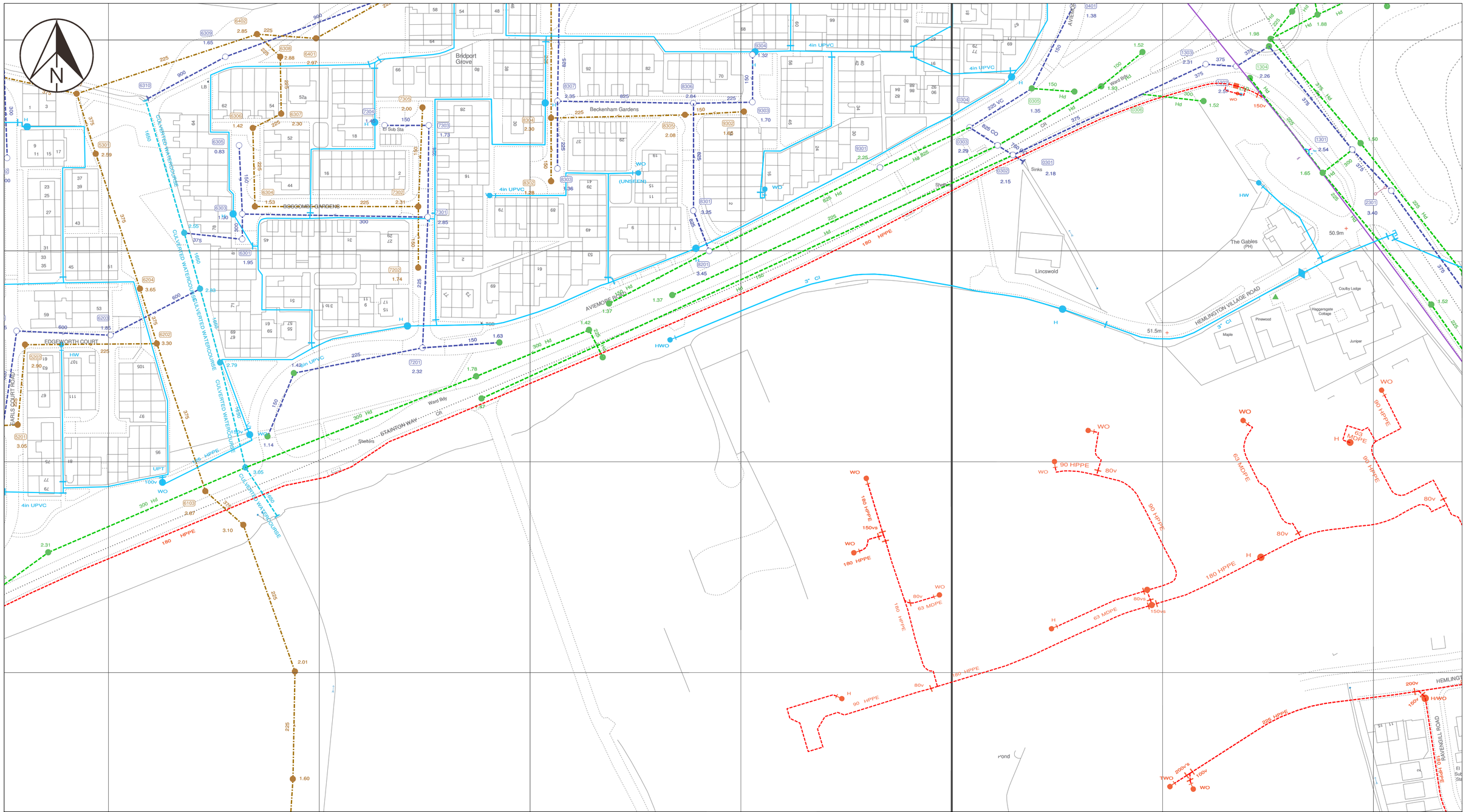
The Sewage Treatment Works to which this development finally discharges to is able to accept the additional flows.

Please note that this response is valid for 1 year only and you should resubmit your proposals should this period lapse prior to your development beginning.

Should you require any further assistance or information, then please do not hesitate to contact me at developmentenquiries@nwl.co.uk or alternatively on 0191 419 6646, please quote our reference number above in any future correspondence.

Yours sincerely,

Laura King
Developer Services



Waste Water - NWL Responsibility		Private/Non NWL		Proposed		Water Network - Network Types			
Combined		Combined		Combined		Distribution		AB Asbestos	
Foul		Foul		Foul		Treated			
Surface		Surface		Surface		Raw		Abandoned	
Treated Eff		Treated Eff				Fire			
Untreated Eff		Trade Eff				Supply		Out of Comm	
Overflow		Watercourse				Private			

NORTHUMBRIAN WATER *living water*

User : BOWMS

Title :

Date : 26/07/2018 10:22:25

Centre Point : 449896,514226

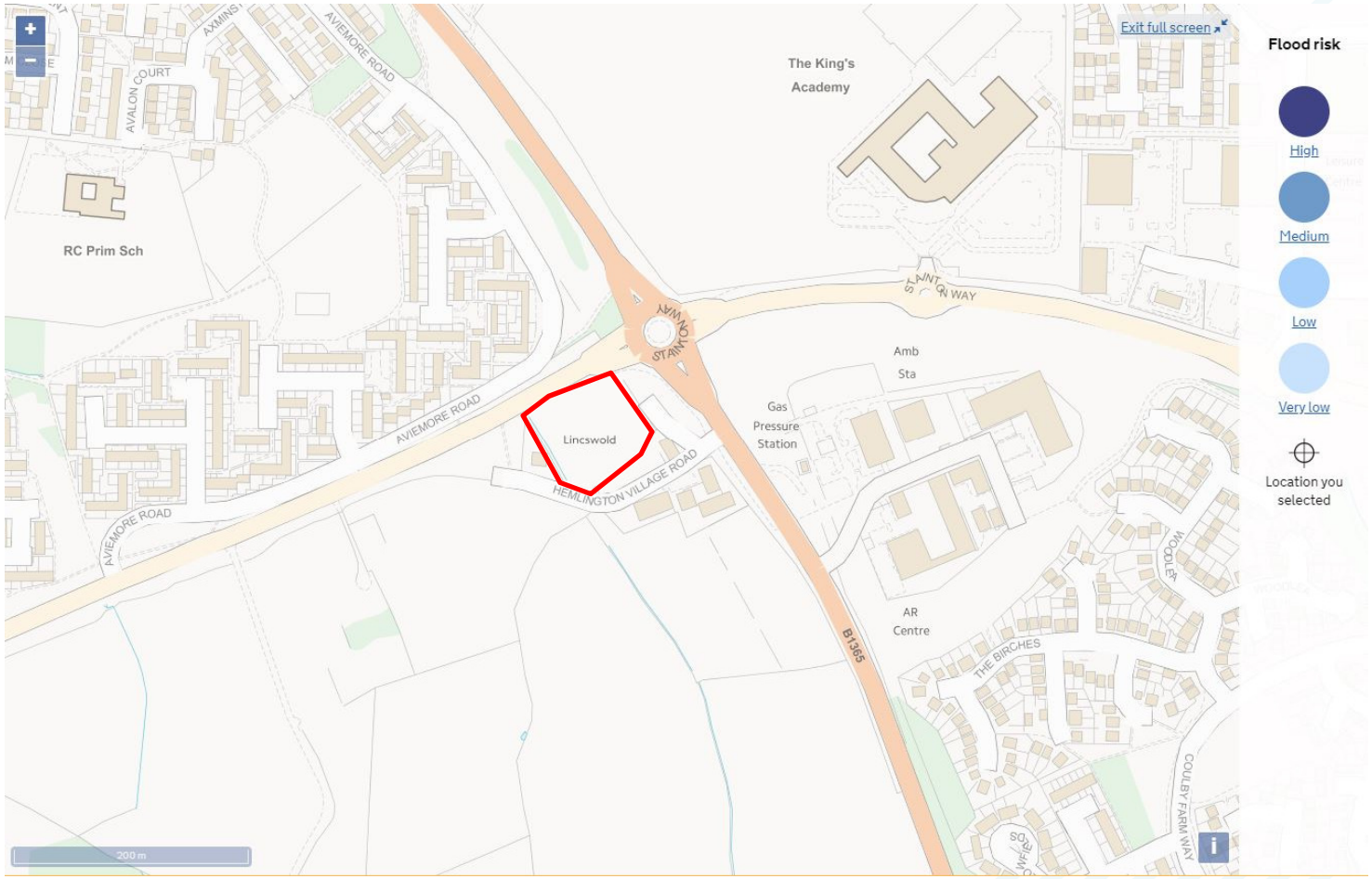
Map Sheet : NZ4914SE

Paper / Scale : A2@1:1249

10 m

C Environment Agency Flood Mapping

C.1 Fluvial and Tidal



C.2 Pluvial


Exit full screen
Flood risk
High
Medium
Low
Very low
Location you selected
The King's Academy
RC Prim Sch
Lincswold
Gas Pressure Station
AR Centre
AVIEMORE ROAD
HEMLINGTON VILLAGE ROAD
STAINTON WAY
B1365
BIRCHES
COULBY FARM WAY
200 m

C.3 Artificial Sources, i.e. Reservoirs

Appendices

D Runoff Rate Calculations

CALCULATION RECORD

Project Code:	2018s0786	**Page**	1	of	2		
Project Title:	Hemlington, Middlesbrough						
Subject:	**Pre-Development Runoff Rates**						

	Initials	Date
Designer:	AW	**26/07/2018**
Checker:	IF	**26/07/2018**
Approver:	MM	**26/07/2018**

Office: **Glasgow**

Catchment AREA (km^2)	From FEH CD-ROM	0.0067
$SAAR_{4170\ (mm)}$	From FEH CD-ROM	648
SOIL	From FSR WRAP maps	0.450

Enter fraction of catchment covered by each WRAP class:

1	2	3	4	5
			1	

$$Q_{BAR} = 0.00108\ x\ AREA^{0.89} x SAAR^{1.17} x SOIL^{2.17}$$

$QBAR_{rural\ \geq 50ha}$	0.003

Choose your region from the map. Enter a number, or I for Ireland or GB for Great Britain	3

Return period (years)	Design flow (m^3/s)	Specific runoff (l/s/ha)	Runoff (l/s)
1	0.002	3.45	2.31
5	0.003	5.00	3.35
10	0.004	5.81	3.89
30	0.005	7.04	4.72
50	0.005	7.60	5.09
75	0.005	8.04	5.39
100	0.006	8.36	5.60

MODIFIED RATIONAL METHOD

$$Q = 2.78\ x\ C\ x\ I\ x\ A\ x\ APF$$

Where

Q	=	Estimated Runoff Rate (l/s)
C	=	Dimensionless Runoff Coefficent
I	=	Rainfall Intensity (mm/hr)
A	=	Total Drainage Area (ha)
APF	=	Antecedent Percipition Factor

C =	0.70
A =	0
APF =	1

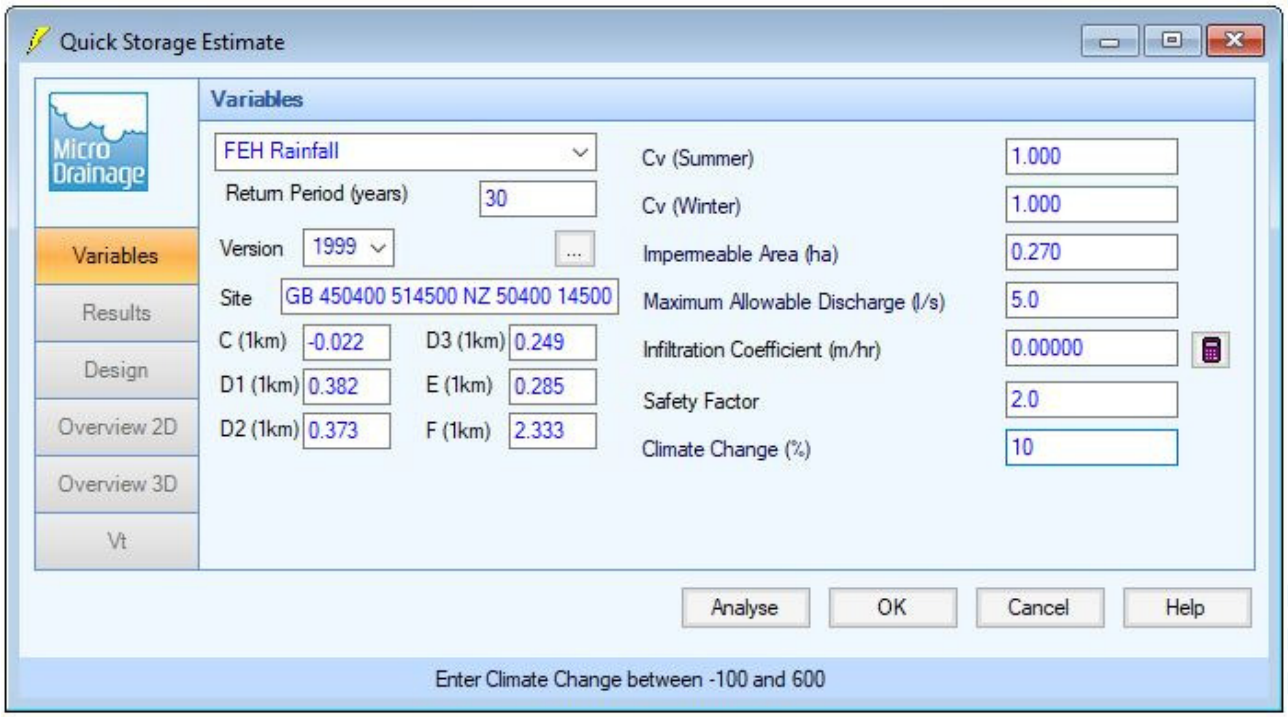
Return Period (years)	Rainfall Intensity (mm/hr)	Runoff (l/s)
1	10.0	0
5	15.3	0
10	19.0	0
30	26.3	0
75	34.2	0
100	37.2	0

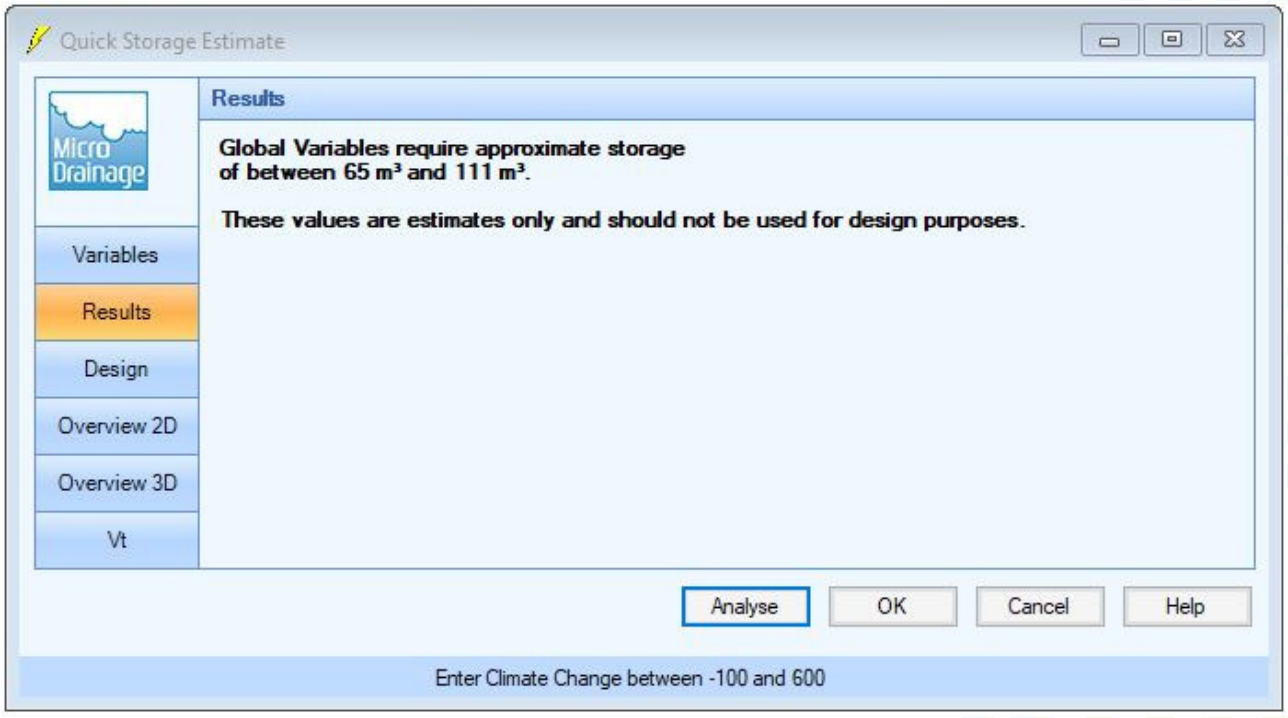
Return Period (years)	IH124 Runoff (l/s)	Modified Rational Runoff (l/s)	Total Runoff (l/s)
1	2.31	0.00	2.31
5	3.35	0.00	3.35
10	3.89	0.00	3.89
30	4.72	0.00	4.72
75	5.39	0.00	5.39
100	5.60	0.00	5.60

Appendices

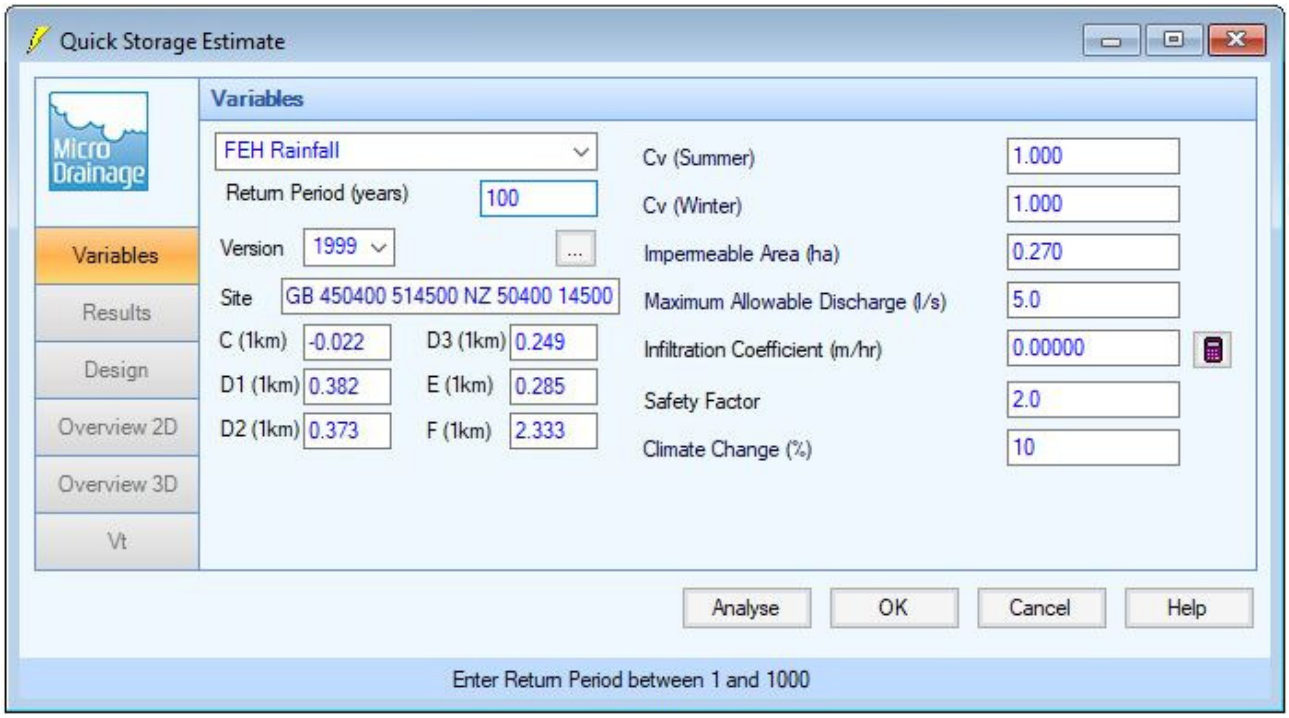
E Quick Storage Estimates

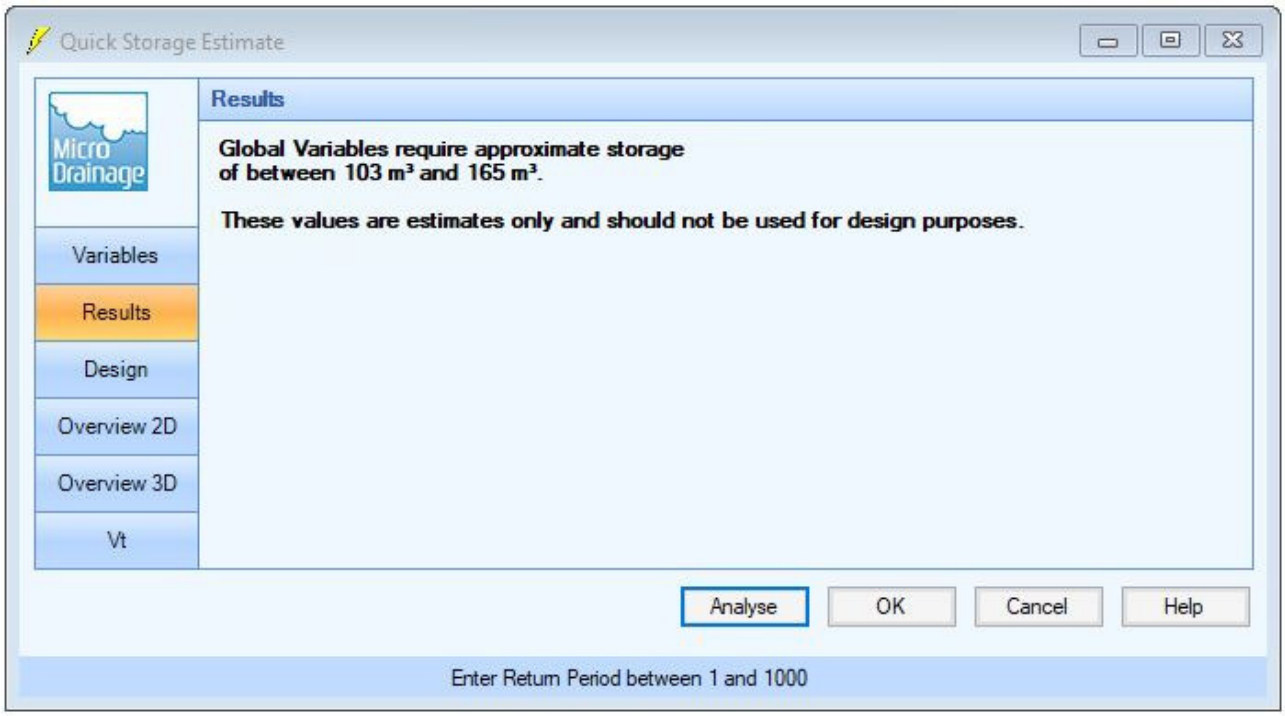
E.1 30 year +10% Urban Creep



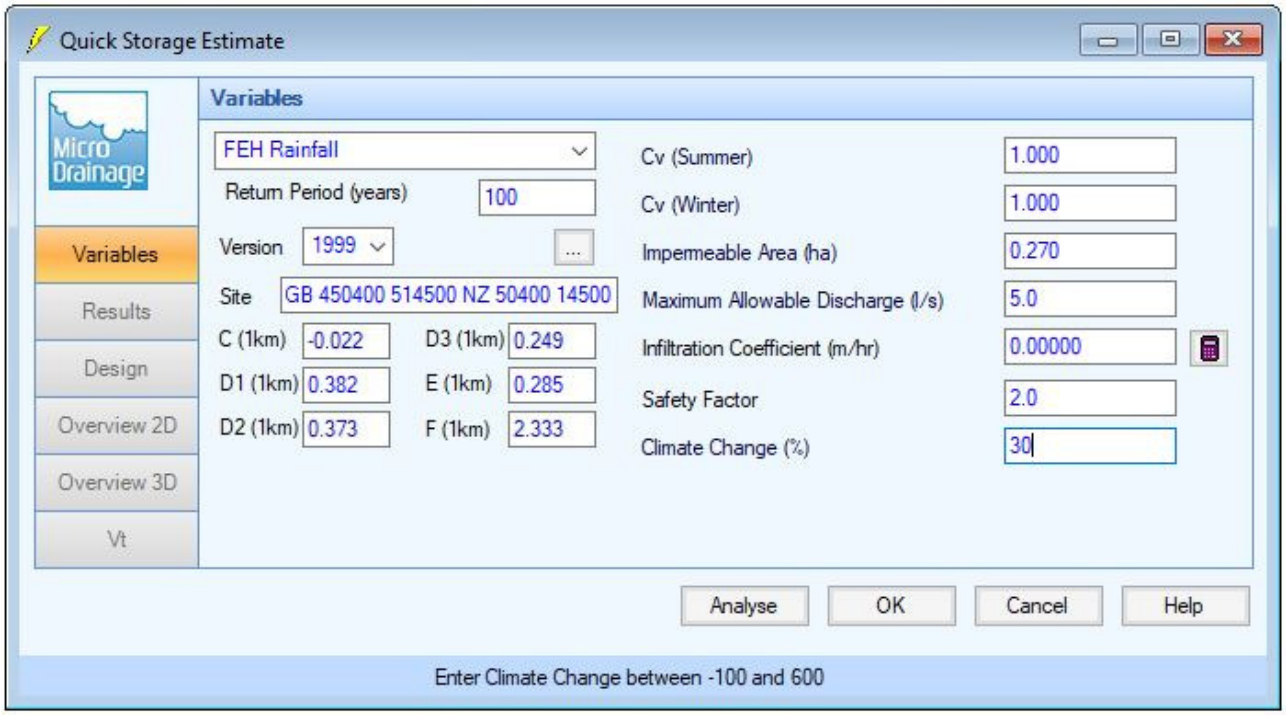


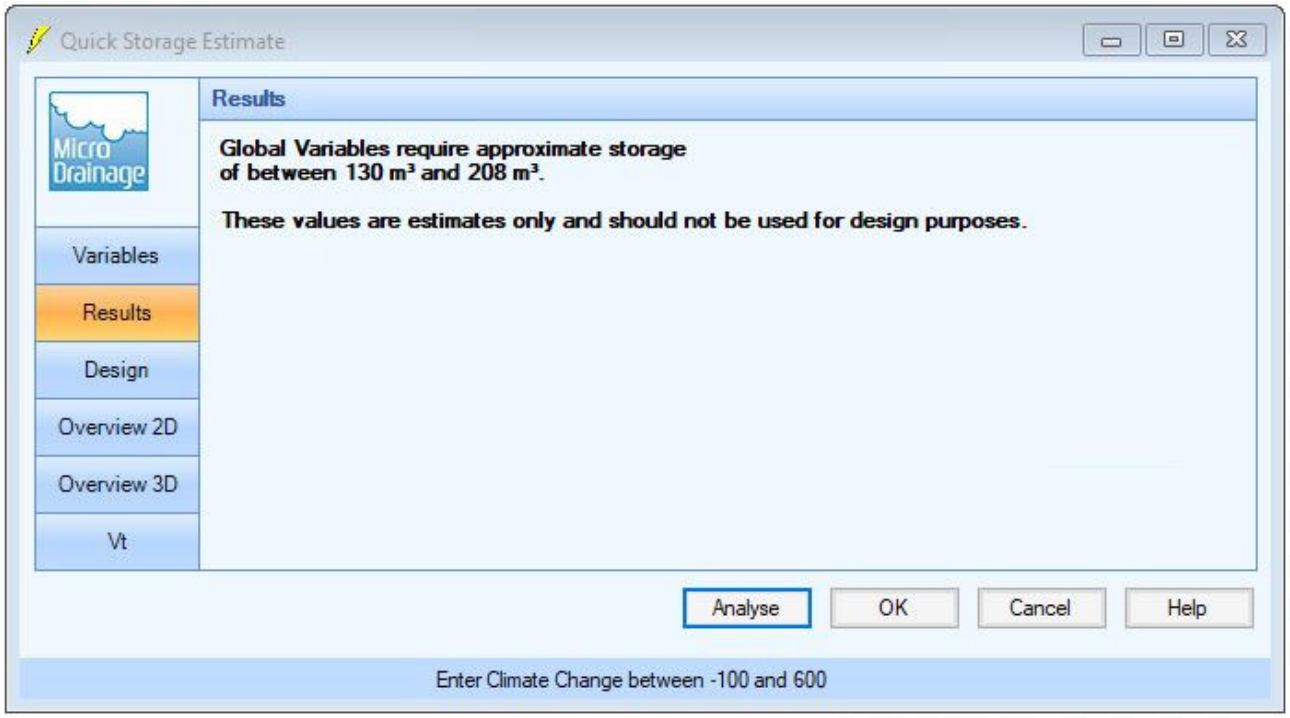
E.2 100 year +10% Urban Creep



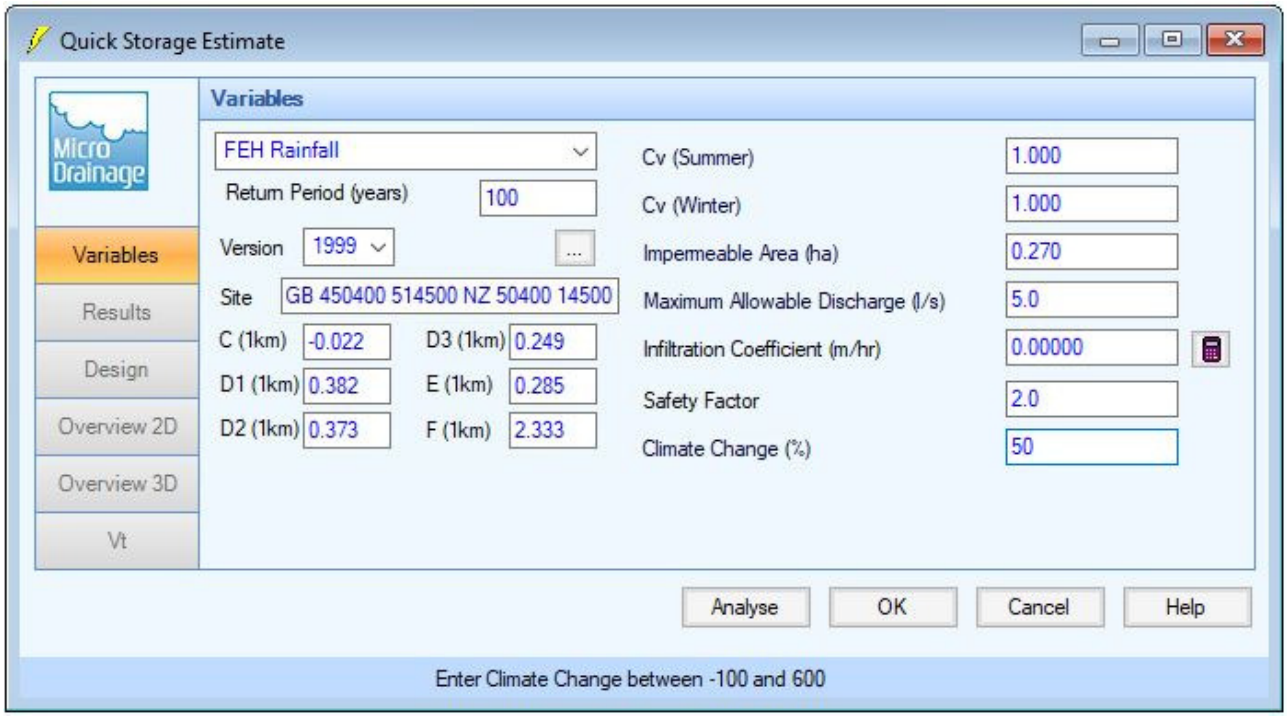


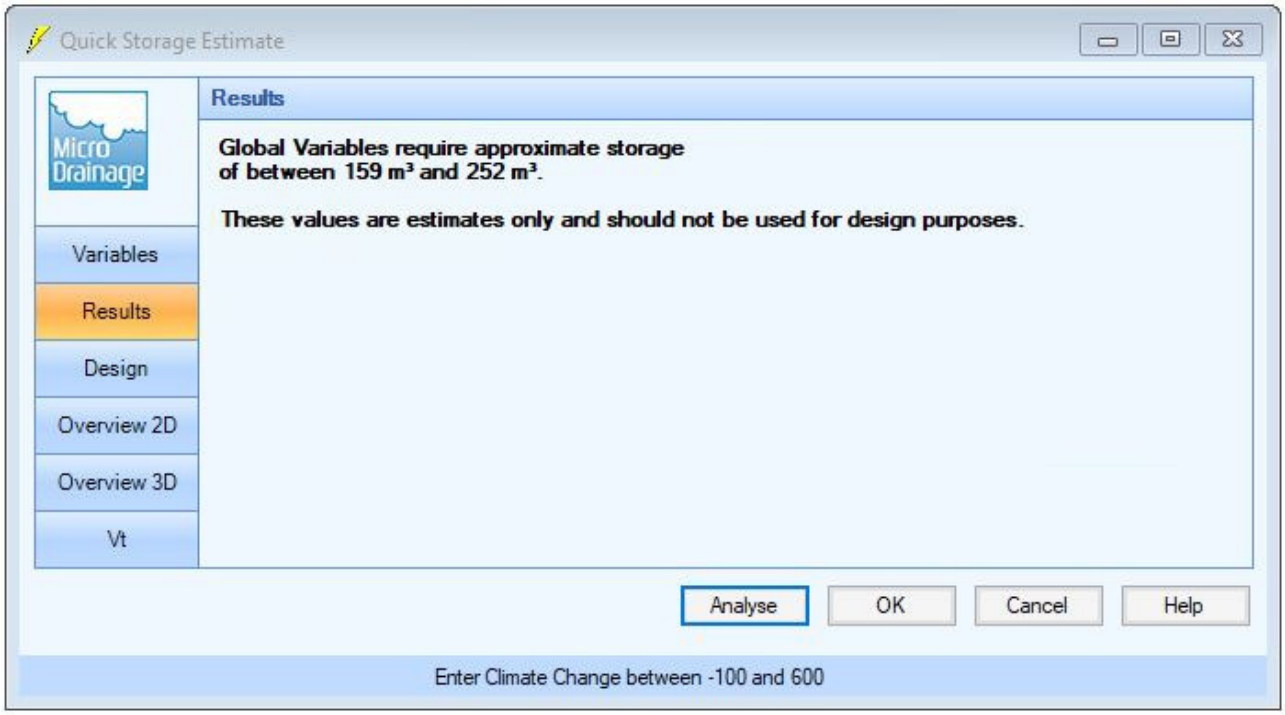
E.3 100 year+20% climate change +10% Urban Creep



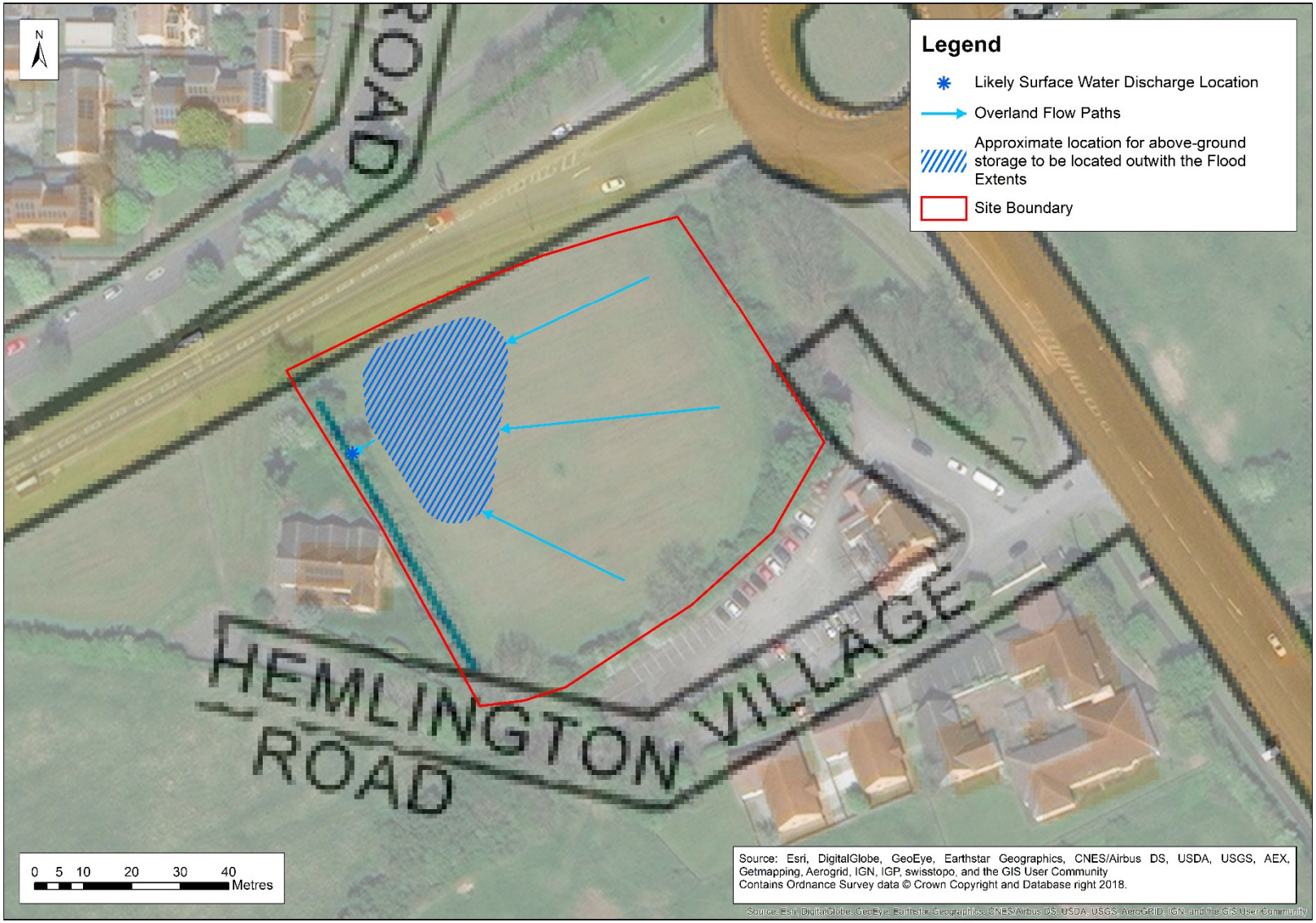


E.4 100 year+40% climate change +10% Urban Creep





F Drainage Layout Sketch



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