28800/ R1 Rev3

Technical Report

Bulby's Wood Public Toilet Refurbishment

Water Supply Assessment

Newcastle City Council

23rd January 2015

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Executive Summary

A planning application has been submitted to the Northumbria National Park Authority (NNPA) for refurbishment of the public toilet block in Bulby's Wood Car Park. In addition to internal reorganisation of the building, it is proposed to provide a new water supply from a new borehole installation.

Given the proximity of the borehole to the River Breamish, which has statutory conservation designations as a SSSI and SAC sites, an assessment has been undertaken to determine the potential effects of the borehole abstraction on the flow regime in the river and thereby the status of aquatic habitats and support species.

The study comprised a site visit and desk study to collate data and information to allow development of a baseline characterisation of the local geology, hydrology, and hydrogeology against which the potential effects of borehole abstraction could be assessed. This work was also combined with consultations with a borehole contractor with local installation experience and the provision of water usage information from NNPA. The new shallow borehole will need to be excavated into superficial alluvial deposits to provide a reliable water supply of good quality. The groundwater in these alluvial deposits are assumed to be hydraulic connectivity with the river and provide a moderate proportion of the base flow.

Given the low water usage requirement of the toilet block in relation to river discharge, the hydrological characteristics of the river and the abstraction and return of treated wastewater via a soakaway to the same superficial geology it was concluded that there would be no significant effect on the fluvial flow regime. It was therefore also concluded that operation of the proposed borehole would also have no negative significant impact upon the quality and integrity of aquatic habitats and support species within the River Breamish.

Further recommendations were also provided based on observations made during the site visit.

1 Introduction

1.1 Background

Atmos Consulting ('Atmos') were commissioned to undertake an assessment of the potential effects from provision of a new water supply to a public toilet block located in a car park in the Northumberland National Park at Bulby's Wood near Ingram, Northumbria (NGR NU00810 16376). A planning application has been submitted for refurbishment of the toilet block including the provision of a new borehole water supply.

The toilet block is located adjacent to the River Breamish, which forms part of the Tweed catchment. The reach of river that flows west to east immediately to the north of the toilet block forms part of the River Tweed Special Area of Conservation (SAC) and River Till SSSI.

Historically water was supplied to the toilet block through a direct surface abstraction from a hydraulic ram pump which was lost during a previous flood event. Since the loss of the pump, the toilet block header tank has been periodically manually filled by buckets of water taken from the river. Given the close vicinity of the new proposed borehole to the River Breamish, there is a need to assess whether abstractions will potentially impact upon groundwater resource, that contribute to supporting base flow in the river, and thereby the quality or integrity of the SAC and SSSI aquatic habitats and supported species.

This report will be submitted to the National Park Planning Authority as supporting information to the planning application proposals for the toilet block refurbishment works.

1.2 Study Objectives

The key objectives of the study are:

1) To undertake a site visit for familiarisation of the toilet block location, the adjacent reach of the River Breamish, the historical abstraction and wastewater disposal systems (the latter being retained in their current configuration following refurbishment works);
2) Undertake consultations with a borehole contractor to obtain background information on previous borehole construction and constraints in the locality;
3) To collate and examine available relevant baseline data on geology, hydrogeology and hydrology for the locality of the toilet block and the River Breamish;
4) Assess the potential effects of the new borehole on the flow regime in the River Breamish and status and integrity of habitats and support species within the River Till (The Tweed Catchment in England) SSSI and River Tweed SAC.

2 Assessment Methodology

2.1 Site Visit

A site visit was undertaken on 10th December 2014 by Matthew Hopkins of Atmos for the purpose of visual inspection of the toilet block, the former surface water abstraction system and wastewater drainage system. Matthew met with Richard Barnes of Newcastle City Council during the visit to obtain background information on the history of the toilet block operation and the proposals for refurbishment. A visual inspection was undertaken of the existing toilet block infrastructure and aquatic habitat present in the adjacent River Breamish. A series of photographs and observational notes were recorded during the site visit.

2.2 Consultations

A telephone consultation was undertaken with Richard Harrison of Hydroserve, who has previous experience of borehole installations in the area. Richard confirmed that a borehole was installed at Ingram in 1994. The borehole was excavated to a shallow depth of around 26m into the alluvium drift deposits to provide an artesian supply of potentially high yield. To his knowledge this borehole has continued to operate since installation without any supply or quality issue. Richard confirmed that the abstraction yield from solid geology in the area was low and unreliable and the limited groundwater resource was mainly associated with localised fracturing of the underlying volcanic deposits. It was also has indicated that attempted abstractions from the deeper geological strata deposits have been characterised by high concentrations of iron that discolour the water orange. Richard indicated that construction of a borehole at the toilet block location would require excavation of a shallow well into the alluvium deposits associated with the River Breamish corridor to provide a reliable supply yield and quality to the Bulby's Wood toilet block.

2.3 Baseline Data Collation

Baseline data collation was undertaken through a number of sources. The collation of data was made more complex by the fact the River Breamish form part of the River Till/ Tweed catchment which straddles the England and Scotland border. Review of the interactive Water Framework Directive (WFD) mapping on the SEPA website indicated that the River Breamish is defined as a WFD waterbody (GB102021073040) as part of the Solway Tweed River Basin District. Therefore a due diligence request for a range of data was initially submitted to the Scottish Environmental Protection Agency (SEPA) who subsequently informed Atmos that they held no information for the Bulby's Wood site and recommended a data request was submitted to the Environment Agency (EA) in England. A request was submitted to the EA to supply a range of data within a 1.5km radial search area of the site although the response indicated there were no data available that would like be relevant to the study.

As part of this study it was considered critical for the assessment to obtain flow characterisation data for the River Breamish against which the potential magnitude of effect for any new borehole abstraction could be assessed. Therefore a site specific River Flow Estimate report based on the LowFlows software was commissioned from Wallingford Hydrosolutions Ltd.

A range of other information sources were accessed to characterise the baseline conditions. These included:

- The British Geological Survey (BGS) and GIS datasets and Interactive mapping on their datasets to examine soils, drift and solid geology, together with hydrogeological characteristic for the site area;
- The Flood Estimation Handbook (FEH) CD-ROM;
- The Magic Website to examine local conservation designations;
- Natural England Website to view citations on the River Till SSSI;
- JNCC website for the River Tweed SAC citation; and
- Environment Agency (2013) Till Abstraction Licencing Strategy.
- River Till Restoration Strategy (March 2013)
- Environment Agency 'Whats in my Backyard' Interactive mapping tool
- SEPA Interactive mapping tool.

3 Baseline Description

3.1 Site Description

The Bulby's Wood public toilet block is located on the north east corner of a public car park sited in an area of woodland and bounded to the north by the River Breamish. The building is a stone block and pebble dash clad structure with a slate tiled roof (see Photograph 1).

Photograph 1: The Bulby's Wood Toilet Block

The existing layout of the toilet provides separate female, male and disabled toilet facilities. Currently the building provides a total of 7 toilets, a trough urinal and 3 wash basins. The refurbishment of the toilet block will reduce the number of toilets available due to the inclusion of a ranger's office within the building. The new internal configuration will provide 4 toilets, 2 small urinals and 5 washbasins. The refurbishment works will also include the installation of a borehole water supply located to the south of the toilet block.

Water supply to the toilet block is currently arranged through manual filling of the header tank through periodic refilling with water taken by bucket from the River Breamish. Historically water was supplied by pump through a direct surface water abstraction from the adjacent River Breamish, although this system was lost during a previous flood event. Remnants remain of the previous water supply system that include two abstraction chambers and a 90mm diameter main surface abstraction feed pipe in an eroding area of river margin (see Photograph 2).

Photograph 2: A disused 90mm diameter main feed pipe of the former surface water abstraction

An estimate was provided by NNPA on the expected water usage for the toilet block. This was based on the following assumptions:

NNPA projected car parking usage (assuming 2.5 persons per car), equates to a total annual use of about 5,000 persons and assuming all persons use a WC (low volume cisterns of 10 litres) this equate to 5,000 flushes or 50,000 litres per annum. There would be peak usage during the summer and this would be at about 50-75% of this total usage (ie 3750 persons), over a summer period of 4 months (June-September) then this would still only equate to 475 litres per day or 0.475m^3 per day on a straight line average daily use. It is expected that usage over the weekends may create peaks within this period. However, the peak number of persons and water passing, in our NNPA opinion would still only be 750-1500 litres per day at weekends which would only raise this to a maximum daily volume of 1.5m^3.

For the purpose of the assessment a conservative approach will be adopted and the maximum daily volume requirements of 1500 litres will be used for any subsequent calculations.

Wastewater generated by the toilet block passes through a Klargester unit for treatment before discharging to a soak-away system on the south bank of the River Breamish (see Photograph 3). This wastewater disposal route will be retained following the proposed refurbishment works.

Photograph 3: Approximate location of soakaway for treated wastewater

The layout of the wastewater drainage system and proposed new borehole location are shown in drawing G5043-11 in the Figures section of this report.

The reach of the River Breamish located adjacent to the toilet block shows the typical characteristics of a fast flowing, relatively shallow reach of an upland river of moderate gradient. The river channel is approximately 12 metres in width with water depths of up to 60cms. The substrate of the river comprises a mixture of boulders, cobbles, and pebbles (see Photograph 4). Visually this stretch of river appears to provide good quality nursery habitat for non-migratory and migratory salmonid parr.

Photograph 4: River Breamish channel adjacent to the toilet block.

The right bank of the river has a low gradient riparian with an open aspect to the west and woodland to the east of the car parking area. An eroding riverbank was noted in directly to the north of the toilet block. (see Photograph 5).

Photograph 5: Eroding bank to the north of the toilet block

The left bank has been protected from erosion through consolidation by the roots of mature trees in the riparian zone and beyond has a relatively steep slope rising to the north.

3.2 Soils and Geology

3.2.1 Soils

The soil types at the proposed borehole location and surrounding area are presented in Figure 1. The proposed borehole's location is within a band of riverine clay, sand and gravel deposits that follow the alignment of the River Breamish. These alluvial deposits typically display high permeability characteristics, particularly where sand and gravels predominate. To the north of the borehole there is a small area of Andesite, formed by weathering of volcanic rocks, with extensive glacial till deposits to the west. These glacial tills are also present to the south of the alluvium corridor and the proposed borehole location. Till deposits are often high in clay content and typically show low levels of permeability with associated high rates of surface drainage run-off.

Extensive areas of Volcanic Breccia soils are present in the mosaic of soil types surrounding the proposed borehole location. These soil types are of variable permeability but can often be free draining where large particle size is a feature. Where free draining soils of high permeability are present these will form the primary routes in the locality for recharge of groundwater resources.

3.2.2 Drift Geology

The superficial or drift geology at the borehole location and surrounding area is presented in Figure 2. The drift deposits comprise a corridor of alluvium that follows the alignment of the River Breamish. The alluvium deposits are described as being soft to firm consolidated, compressible silty clay containing layers of silt, sand, peat and basal gravel. Such deposits display a variable permeability dependent on the proportional composition of clay. These alluvium deposits are predominantly surrounded by Devensian - Diamicton till where mapping data is available. Given the frequently impermeable nature of till then this pattern of drift deposits suggests that shallow depth ground water resource is likely to be mainly restricted to the areas of alluvium and that this groundwater is likely to be in hydraulic connectivity with the River Breamish. As such, a proportion of the base flow within the river will be derived from groundwater resource within the alluvial corridor.

3.2.3 Solid Geology

The underlying solid bedrock geology at the borehole location (see Figure 3) comprises Andesite of the Cheviot Volcanic Formation from the early Devonian Period. This formation is described as a thick pile of andesitic lava with associated pyroclastic and reworked volcanic rocks, subordinate biotite-phyric rhyolite and tuff. Such geology tends to provide limited groundwater resource which tends be restricted to areas of local fracturing.

3.3 Hydrogeology

Given the nature of the drift and solids geological deposits, the main reliable local groundwater resource is likely to be restricted to the alluvium corridor associated with the River Breamish. On the BGS website (accessed 09/01/2015) the area in the vicinity of the toilet block and proposed borehole location is classed as a low productivity aquifer where flow is virtually all through fractures and other discontinuities. This reflects the volcanic nature of the underlying solid geology.

Data presented on the Environment Agency Interactive mapping (accessed 15/01/2015)indicates that aquifers in the superficial geology are restricted to the alluvium deposits associated with the River Breamish corridor and are classified as Secondary A type aquifers. These are areas where permeable geological layers are capable of supporting water supplies at a local level rather than strategic scale, and in some cases form an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers. The solid geology in the area is classified as a Secondary B aquifer. These aquifers are predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.

These characteristics of the local hydrogeology accords with the experience of the local borehole contractor discussed during consultation i.e reliable local water supply are generally achieved through excavation of a shallow borehole into the alluvium deposits of the River Breamish corridor.

There are no groundwater source protection zones within the vicinity of the new borehole location. The closest is a Zone 3 catchment area around Wooler at a distance of approximately 11km to the north.

There are no licenced abstractions within the immediate vicinity of the proposed toilet block borehole location. The nearest licenced abstraction is at Thruton, approximately 9.2 kms to the south-east of the study site. This is a groundwater private water supply abstraction (licence no. 1/22/02/043) with a maximum allowance of 28.4 cubic metres per day. However, this does not necessarily indicate that other abstraction installations are not present locally as there is no requirement to licence abstractions of less than 20 cubic metres per day under the Water Act (2003).

The Environment Agency have published a licencing strategy document for the River Till catchment which includes the River Breamish (Till Abstraction Licencing Strategy (February 2013). This document sets out the restrictions on surface and groundwater abstraction licencing across the Tweed / Till catchment. The expected maximum daily water abstraction requirement for the refurbished toilet block is 1.5 m^3/ day (based on correspondence and estimate received from Colin Wilson of the Northumbria National Park Authority on the 10/12/14) which is significantly below the 20 m^3/ day threshold where licencing of the abstraction would be required.

3.4 Hydrology

The River Breamish drains part of the northern area of the Northumberland National Park around Comb Fell and Shill Moor. The river flows in an easterly direction until the A697 at Powburn before heading north and the northwest to form the River Till and subsequently the River Tweed.

The hydrological characteristics of the river have been obtained from two key data sources:

- Flood Estimation Handbook (FEH) CD-ROM 1999; and
- A site specific River Flow Estimate Report commissioned from Wallingford Hydrosolutions.

Output from the FEH CD-ROM was produced for the point where the River Breamish passes the Bulby's Wood toilet block at grid reference NU 00800 16400. The key catchment and hydrological data are summarised in Table 1 below.

Table 1: Key catchment characteristics for the River Breamish upstream of the Bulby's Wood Toilet Block.

River Breamish at NU 00800 16400	
Area of catchment upstream	55.45 km^2
Average Altitude (ALTBAR)	379m
Mean slope along drainage paths (DPSBAR)	171.1 m/km
Baseflow Index (BFIHOST)	0.403
Proportion of time soils are wet (PROPWET)	0.45
Standard period Annual Average Rainfall (SAAR)	1039mm
Standard percentage run-off using the Hydrology of Soil Types Classifications (SPRHOST)	50.9

These data indicate the River Breamish has a moderately high bed gradient, that groundwater contributes a moderate proportion of the base flow and surface run-off is relatively high due to impermeable nature of the catchment and wet soil conditions. Rivers with these characteristics tend to be relatively flashy in flow characteristics in response to surface run-off associated with rainfall events within the catchment.

A River Flow Estimate Report was commissioned through Wallingford Hydrosolutions to provide specific flow estimates derived from LowFlows software for the reach of the River Breamish adjacent to the toilet block. This report is presented in Appendix A. For the purpose of assessment of potential impacts upon flow in the River Breamish the lowest estimated Q95 monthly discharge value (September at $0.143m^3/s$) has been used for the purpose of calculation. Q95 is considered to represent the low flow conditions in rivers and is commonly used as a hands off threshold for directed abstractions from river systems.

3.5 Water Framework Directive Status

The River Breamish forms part of the River Tweed catchment and therefore is included within the Solway-Tweed River Basin District under the Water Framework Directive (WFD. Therefore in terms of WFD classification the River Breamish falls under the WFD remit of SEPA.

SEPA has introduced water monitoring and classification systems that will provide the data to support the aim of the Water Framework Directive (2000/60/EC) (WFD): "that all water bodies are of good ecological status, or similar objective, by 2015".

The classification system covers all rivers, lochs, transitional, coastal and groundwater bodies, and is based on a new ecological classification system with five quality classes (High, Good, Moderate, Poor and Bad). The classification system has been devised following EU and UK guidance and is underpinned by a range of biological quality elements, supported by measurements of chemistry, hydrology (changes to levels and flows) and morphology (changes to the shape and function of water bodies). SEPA's interactive River Basin Management Plan (RBMP) Interactive Map was consulted to identify the status of the River Breamish.

This study section of river is encompassed by Till from Linhope Burn to Glen waterbody (i.d GB102021073040). In 2008, this waterbody was classified as having an overall status of Good with overall ecological status of Good. Future predictions of its status within the next rounds of River Basin Management Planning (RBMP) cycles were 'Good' up until 2027. No identified pressures were identified for this waterbody. All waterbody descriptors of chemical, biological and morphological status were found to be of Good or High status with the exception of hydrology that was classified as moderate.

3.6 Ecological Designations

The reach of the River Breamish adjacent to the site forms part of the Tweed catchment rivers - England: Till catchment SSSI and River Tweed SAC.

The River Breamish forms one of the seven units of the SSSI designation which is currently assigned a recovering unfavourable condition in relation to its SSSI objectives. The reasons for unfavourable condition are:

- Inappropriate weirs, dams and other structures;
- Water abstraction; and
- Water pollution from agricultural run-off.

The primary reasons for the SSSI citation are that the Till Catchment Rivers are clean rivers of high ecological value. Particularly notable are the supported beds of the aquatic plant *Ranunclus*, which are of international importance and the presence of the diatom *Didymosphenia* in the headwaters which is unique in England. The fish fauna of the river is particularly significant with large populations of Atlantic salmon, and three British species of lampreys (river, brook, and sea. The Till also provides an important habitat for otters.

The River Breamish forms part of the River Tweed SAC. This is a large SAC that incorporates the Tweed and a number of its tributaries. The primary reasons for SAC designation are the Annexe I habitat of watercourses of plain to montane levels with Ranunculion fluitantis and Callitricho-Batrachion vegetation and the presence of Annexe II species (Atlantic salmon and otter). Other Annex II species that are present as a qualifying feature, but not a primary reason for site selection are river, brook and sea lamprey species.

The supported fish populations are an important component of the statutory designations applied to the River Breamish. Flow conditions are a key component of the life history strategies and habitat requirements of these fish species. Therefore the restoration and maintenance of a natural flow regime is important for sustaining the future populations of these fish species within the Tweed / Till.

The River Till Restoration Strategy that was jointly produced by the Environment Agency, Natural England and the Tweed Forum was published in March 2013. This document sets out the phased future approach for restoration of the river and returning the watercourse to favourable condition in relation to its ecological designations.

The river is classified by the Environment Agency as a protected area under the Freshwater Fish Directive (2006/44/EC) for salmonids (Identifier code EA1109).

4 Discussion

4.1 Assessment of the potential effects of borehole abstraction on flow within the River Breamish

The refurbishment of the Bulby's Wood toilet block, including provision of a new borehole water supply is considered to be an improvement on the existing and historic system. The improvement works will reduce the numbers of toilets and combined with the use of modern more efficient fittings it is expected that water supply requirements will be reduced. The abstraction of water from a borehole rather than directly from the river will further provide additional benefits for example preventing the pumped entrainment of juvenile fish and invertebrates.

It is proposed that a shallow borehole will be excavated into the alluvial deposits associated with the River Breamish corridor. The borehole will be connected into the existing pipework system for the toilet block with a maximum estimated daily water volume usage of 1.5 cubic metres (1500 litres). The alluvial deposits are expected to be in direct hydraulic connectivity with the River Breamish and given the proximity of the borehole to the river channel, the abstraction will be drawing on groundwater resource that will contribute to base flow in the river.

Hydrological data derived from the FEH CD-ROM indicate that groundwater only provides a moderate contribution to flow in the river with an estimate base flow index of 0.403. Therefore surface drainage run-off is an important component to flow within the river and the run-off rate in the catchment is relatively high leading to rapid flood response within the river.

Data supplied in the River flow Estimate Report (see Appendix A) indicated the lowest Q95 flow discharge in the River Breamish at the study site occurs during September at 0.143m^3/s. The expected daily maximum abstraction from the borehole of 1.5m^3 may be compared against value in two ways, as a direct abstraction from the river or as a proportion of the flow resulting from groundwater baseflow (assuming Base Flow Index of 0.4). The latter provides a more realistic estimate given that the new water supply will be sourced from a borehole excavated into drift geology that is expected to be in hydraulically connected to the river channel.

Direct River Abstraction Calculation

Lowest monthly Q95 discharge value – 0.143m^3/s

Daily total volume based on Sept Q95 value – 12355m^3

Maximum volume of water abstracted for toilet block – 1.5m^3

Percentage of total daily Sept Q95 flow volume abstracted – **0.012%**

Baseflow Abstraction Calculation

Lowest monthly Q95 discharge value – 0.143m3/s

Proportion of discharge resulting from groundwater baseflow – 0.0572m^3/s

Daily total baseflow based on Q95 value and Baseflow index – 4942 m^3

Percentage of total daily Sept Q95 base flow volume abstracted – **0.03%**

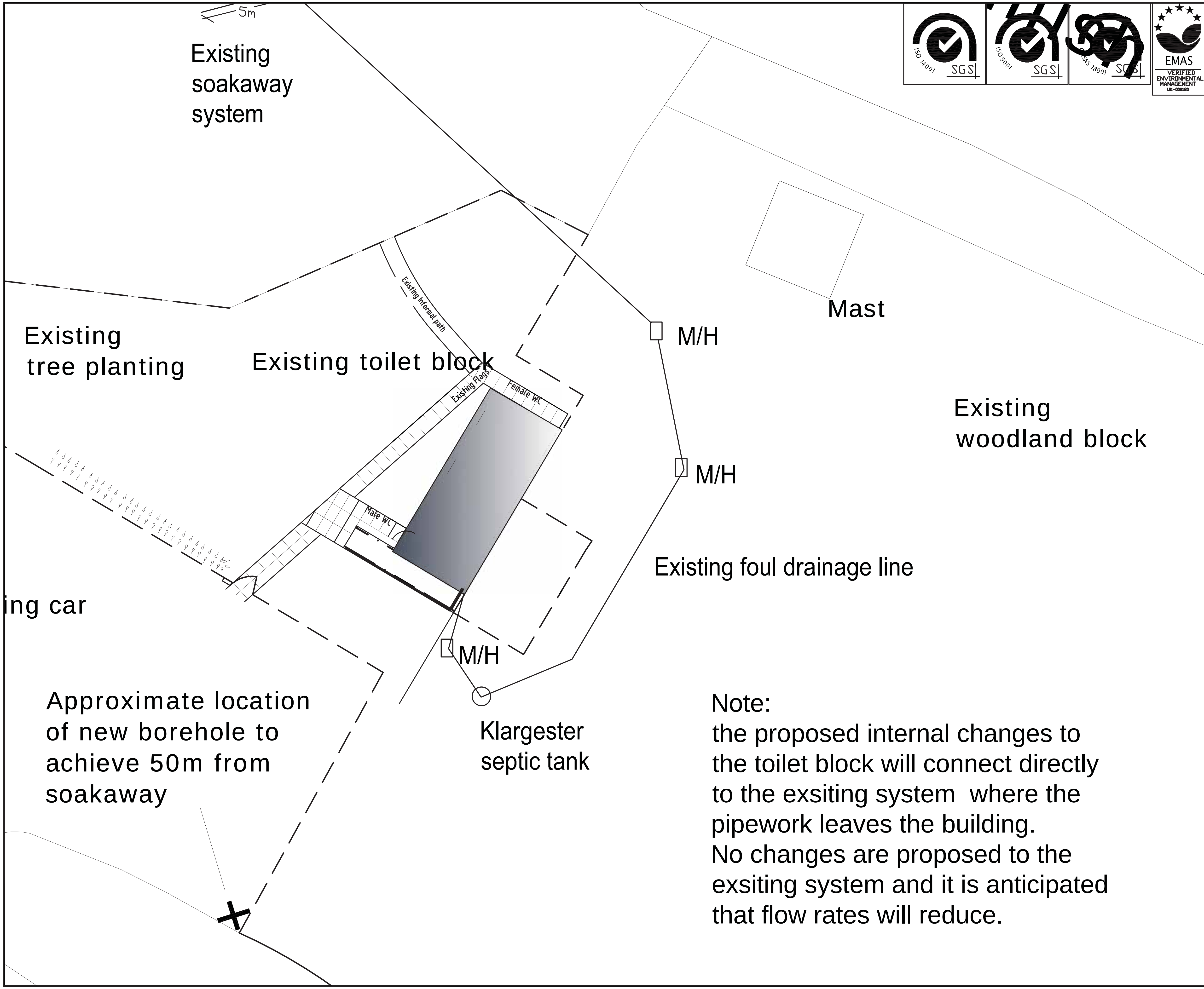
It can be seen that even adopting a conservation approach in the calculations above the proposed borehole abstraction is not expected to have a significant impact on the flow regime within the River Breamish. This is particularly the case as the actual water usage will be close to zero given that treated wastewater is effectively returned to the river and groundwater through the existing soak-away system.

Due to the low abstraction volume, the proposed borehole does not require a licencing. However, it is recommended that both Natural England and the Environment Agency are consulted as part of the installation process.

4.2 Potential effects on aquatic ecology and conservation designations

Given an absence of expected significant effect on flow regime in the River Breamish resulting from the proposed borehole operation, there is not predicted to be any effect on the integrity or condition status of habitats or support species within the river. Given the proximity to a sensitive river habitat, during refurbishment works good construction site practices and measures should be implemented to prevent potential pollution of the river from sources such as sediments, concrete and hydrocarbons.

Figures



Rev.	By	Date	Description

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Project
BULBY'S WOOD PUBLIC TOILET REFURBISHMENT

Drawing title
EXISTING FOUL DRAINAGE SYSTEM

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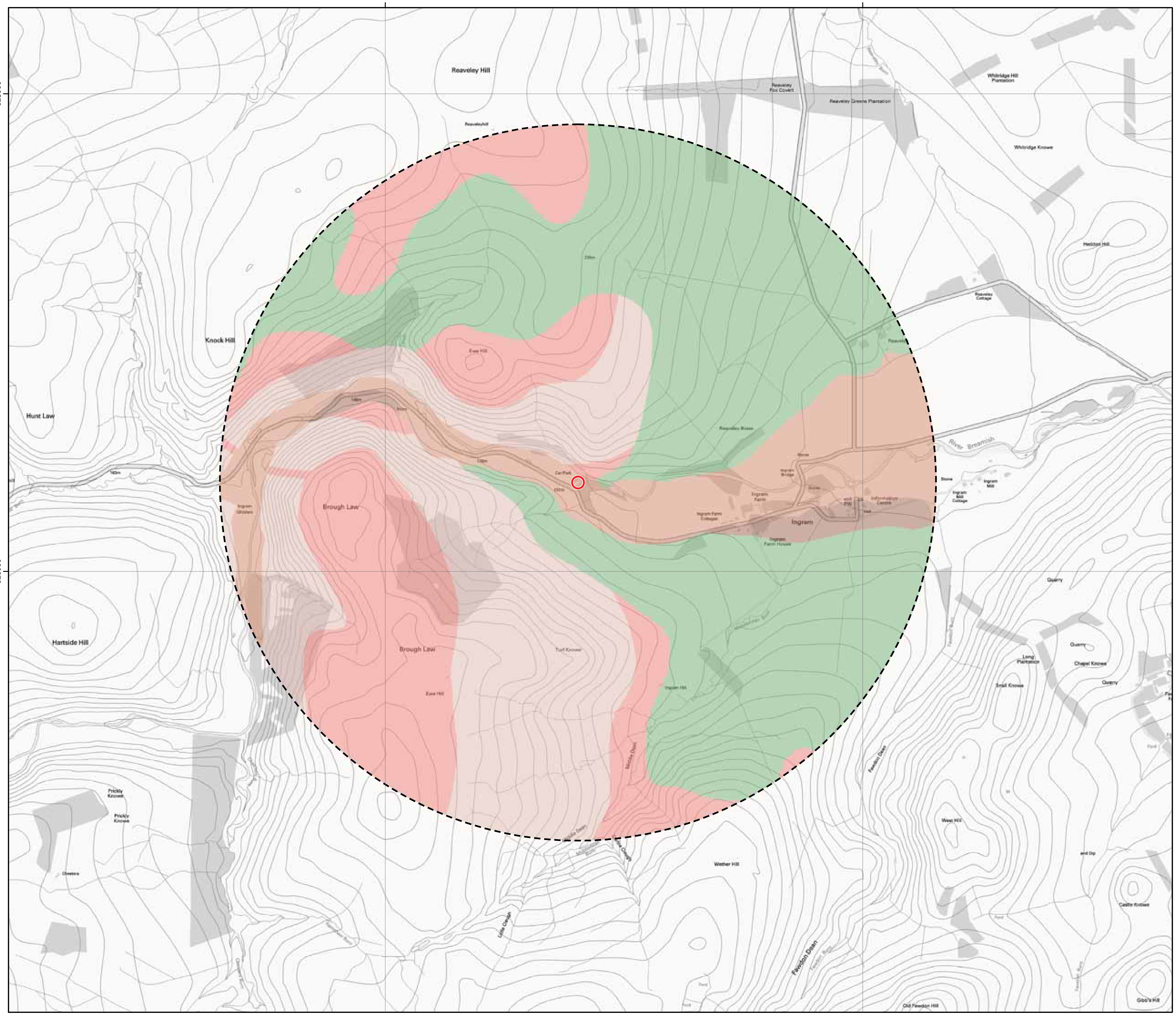

Bulby Wood

Newcastle City Council

Figure 1
Soils

Key

- Borehole location
- 1.5 km buffer

Soils

- Glacial till
- Andesite
- Riverine clay and floodplain sands and gravel
- Volcanic breccia

atmos CONSULTING

0 125 250 500
Metres

Scale @ A3:
1:15,000

19/01/2015 28800/GY/003a

Drawn by: AA Checked by: TH Approved by: RS

Bulby Wood

Newcastle City Council

Figure 2
Superficial Geology

Key

- Borehole location
- Fault, inferred, displacement unknown
- Alluvium
- Glaciofluvial deposits
- River terrace deposits (undifferentiated)
- Till

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0 190 380 760
Metres

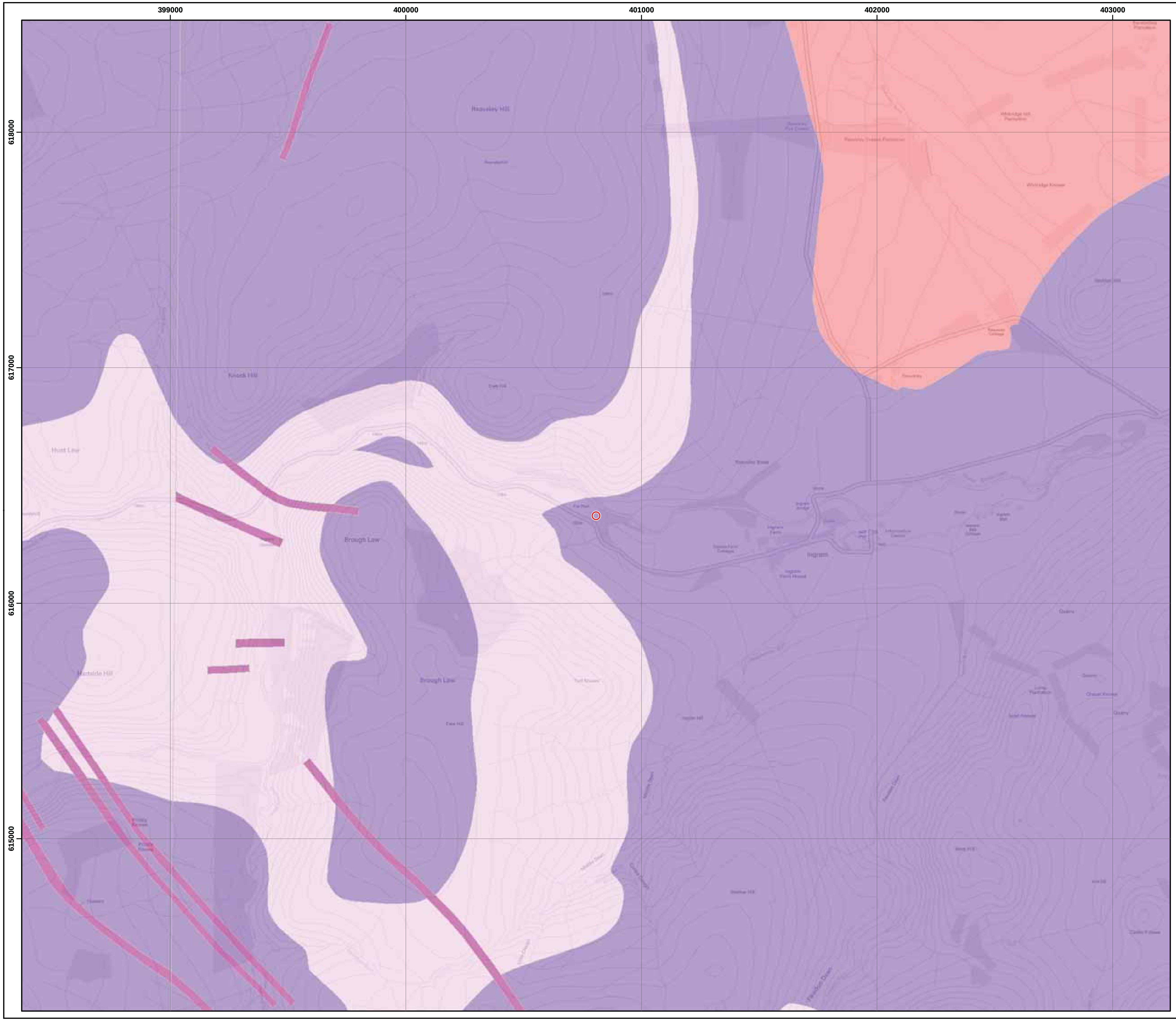
Scale @ A3:
1:15,000

19/01/2015 28800/GY/004a
Drawn by: AA Checked by: TH Approved by: RS

Bulby Wood

Newcastle City Council

Figure 3
Bedrock Geology



Key

- Borehole location

Bedrock geology

- Cheviot Dyke Swarm - Quartz-Feldspar-Porphyry
- Cheviot Volcanic Formation - Andesite
- Cheviot Volcanic Formation - Agglomerate
- Kinnesswood Formation - Conglomerate

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0 190 380 760
Metres

Scale @ A3:
1:15,000

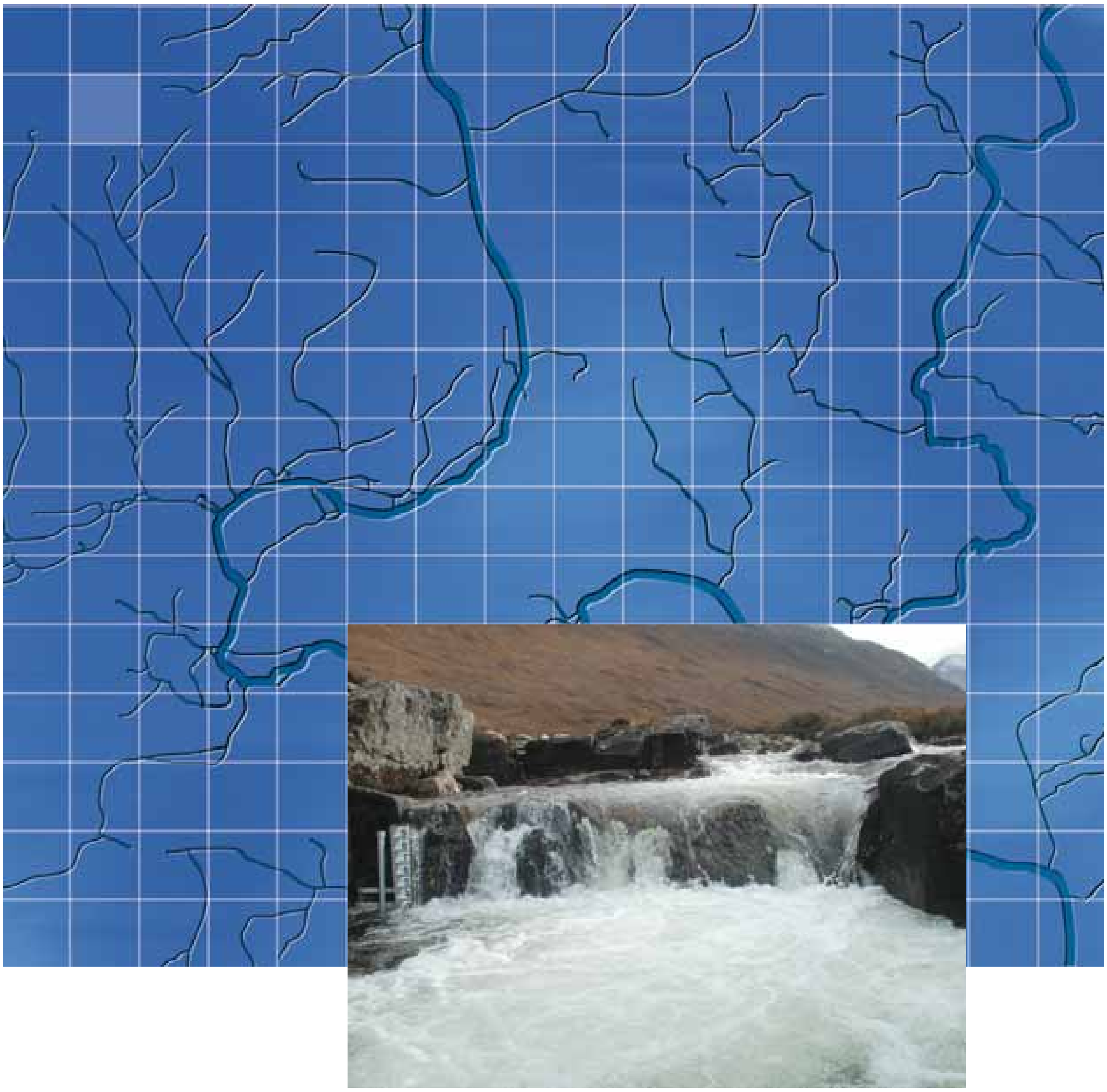
19/01/2015 28800/GY/005a
Drawn by: AA Checked by: TH Approved by: RS

Appendix A – River Flow Estimate Report

LowFlows Report 302/15

January 2015

Flow estimate for the River Breamish



Wallingford HydroSolutions Limited

For and on behalf of Wallingford HydroSolutions Ltd

Client	Atmos Consulting
Prepared by	Natalie Brisland
Approved by	Jude Jeans
Position	*Senior Consultant*
Invoice value	£175 (excl. VAT)

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Contents

1 Introduction

This report presents the annual and seasonal flow statistics for the site(s) requested using the LowFlows Enterprise model. The site location(s) have been confirmed using a digital map and copies of the correspondence are contained within Annex 1.

The LowFlows software system is the standard software system used by the Environment Agency, the Scottish Environment Protection Agency and the Northern Ireland Environment Agency for providing estimates of river flows within ungauged catchments. The software and underpinning science have been widely published in the scientific literature. The LowFlows software system is available for purchase as two versions; LowFlows 2 and LowFlows Enterprise. Wallingford HydroSolutions (WHS) is the sole appointed developer and distributor of the LowFlows software system.

Section 2 of the report provides an overview of our consultancy services; specifically our hydrometry services for supplementing the flow statistics presented within this report with at site measurements and flood event estimation services. We also provide a range of software products ranging from the Flood Estimation Handbook (FEH) software through to Hydra 2 to support hydropower design.

Section 3 presents the methods for the derivation of catchment characteristics and the annual and monthly flow estimates. Following the results for each site, Sections 5 and 6 present the assumptions and uncertainties within the flow estimates, followed by the consideration for use in section 7 and the warranty and liability in section 8.

2 WHS Consultancy Services

WHS is an independent company founded by the Centre for Ecology and Hydrology to deliver high quality consultancy services and environmental software systems to the water, energy and development sectors. WHS has a team of experienced technical staff including leading UK scientists located in three offices across the UK. We have a proven track record in provision of flood risk, water resources, environmental (including EIA) and field measurement consultancy services across the whole of the UK.

Our field measurement services, range from hydrometric (flow), topographic, ecological and geomorphological surveys through to aquatic habitat mapping.

We are currently operating flow measurement installations at over fifty sites in support of a wide range of activities including hydropower development, water supply, flood risk and research.

WHS is committed to continuously improving company performance and customer satisfaction. We are proud of our ISO 9001 certification for the provision of environmental consultancy services, development of hydrological software and associated training. For further information on all of our services and software, please visit our website www.hydrosolutions.co.uk.

3 Derivation of the LowFlows Results

Section 3.1 presents the methods used to define the catchment characteristics, and section 3.2 provides an overview of the long term annual and monthly flow statistics provided for the site(s). The flow statistic estimates contained in this report have been produced by LowFlows Enterprise[1] using models and relationships that relate these flow statistics to the climatic and hydrological characteristics of the catchment of interest. All flow statistics provided in this report are for natural flows, thus do not contain any artificial influences such as abstractions, discharges or impounding reservoirs.

3.1 Catchment Characteristics

The following catchment characteristics are provided in the results section of this report:

- **Catchment Area:** The catchment boundary may be derived using either a digital terrain model or an analogue river network based method. The digital method is the default option used in preference to the analogue method but may be misleading or not possible in some areas. The estimation method used to estimate the catchment boundary is identified within the results section for the site(s).
  - The digital method uses a Digital Terrain Model (DTM) to determine the topographic boundaries of the catchment.
  - The analogue method associates grid squares (200 m resolution) to the nearest stretch of river and defines the boundary by selecting grid squares which are assigned to river reaches upstream of the ungauged point.
- **Base-Flow Index (BFI):** The proportion of a hydrograph occurring as base flow, hence varying between zero and unity. BFI is indicative of catchment permeability with values approaching unity associated with highly permeable systems. BFI is estimated from a revised form of the HOSTBFI multivariate linear regression equation [2].

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[1] Young A. R., Grew R. and Holmes M.G.R. 2003. Low Flows 2000: A national water resources assessment and decision support. Water Science and Technology, 48 (10).
[2] Boorman, D.B., Hollis, J.M. and Lilly, A. 1994. Hydrology of Soil Types: a Hydrologically-based Classification of the Soils of the United Kingdom. IH Report 126.

3.2 Long Term Natural Flow Statistics

The following long term flow statistics are provided in the results section of this report.

- **Annual Mean Flow (MF):** The estimation of Mean Flow is based on a grid of long term average annual runoff developed by the Centre for Ecology and Hydrology (CEH). This was derived using the outputs from a deterministic water balance model using observed data from over 500 gauged catchments[3].
- **Mean Monthly Flows (MMF):** The MMF for each month are derived from the natural MF estimate by distributing the total average flow volume for the year between the months of this year. This distribution is based upon observed data from hydrologically similar gauged catchments.
- **Annual Flow Duration Curve (FDC) statistics:** The flow duration curve statistics are estimated using a procedure based on measured flow data from hydrologically similar gauged catchments[4]. This methodology was further updated by WHS in 2009. Flows are provided for the following exceedence percentiles: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99.
- **Mean Monthly Flow Duration Curves (MFDC):** The MFDC for each month is estimated using gauged MFDCs from hydrologically and climatologically similar catchments and the estimate of MMF for that month. The MFDC statistics are presented, by month for the following exceedence percentiles: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99.

If these long term natural flow statistics were calculated directly from a gauged flow record the annual statistics would be equivalent to those calculated using all of the daily flow data from all years of record and the monthly statistics for a month equivalent to those calculated from the gauged data for that month from all years.

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(3) Holmes, M.G.R., Young, A.R., Gustard, A.G. and Grew, R. 2002. A new approach to estimating Mean Flow in the United Kingdom. Hydrology and Earth System Sciences. 6(4) 709-720.

(4) Holmes, M.G.R., Young, A.R., Gustard, A.G. and Grew, R. 2002. A Region of Influence approach to predicting Flow Duration Curves within ungauged catchments. Hydrology and Earth System Sciences. 6(4) 721-731.

4 LowFlows Results for River Breamish (NU 00823 16402)

4.1 Catchment Characteristics

The catchment characteristics and map for this catchment are presented in the table and figure below. This catchment is comprised of granite and Cheviot Volcanic Formation overlain by till, alluvium, mineral soils and deep peat deposits.

Table 4.1 Catchment Characteristics

Basin Details	
Outlet grid reference	400819, 616415
Hydrometric area	21 (Northumbria)
Catchment definition method	Digital
Basin area (km²)	55.44
Base-Flow Index	0.40

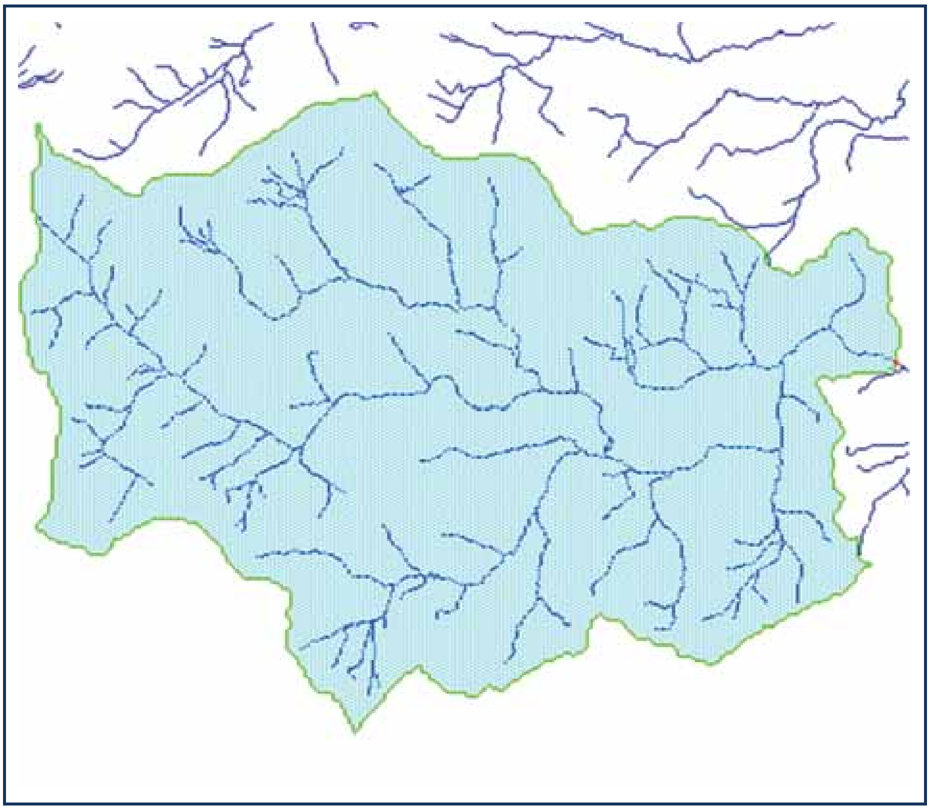

Figure 4.1 Catchment Boundary

4.2 Long Term Natural Flow Statistics

This section presents the long term natural flow statistics. The table below presents both the monthly mean flows and the annual flow duration statistics. The annual flow duration curve is also presented in the figure below, followed by a table displaying the monthly flow duration statistics.

Table 4.2 Mean Flows and Annual Flow Duration Curve Statistics

Mean Flows	Flow (m³/s)
Annual	**1.200**
January	1.916
February	1.673
March	1.785
April	1.332
May	0.799
June	0.534
July	0.520
August	0.654
September	0.785
October	1.166
November	1.588
December	1.672

Percentile	Flow (m³/s)
5	3.854
10	2.556
20	1.592
30	1.160
40	0.895
50	0.698
60	0.537
70	0.416
80	0.313
90	0.228
95	0.180
98	0.143
99	0.120

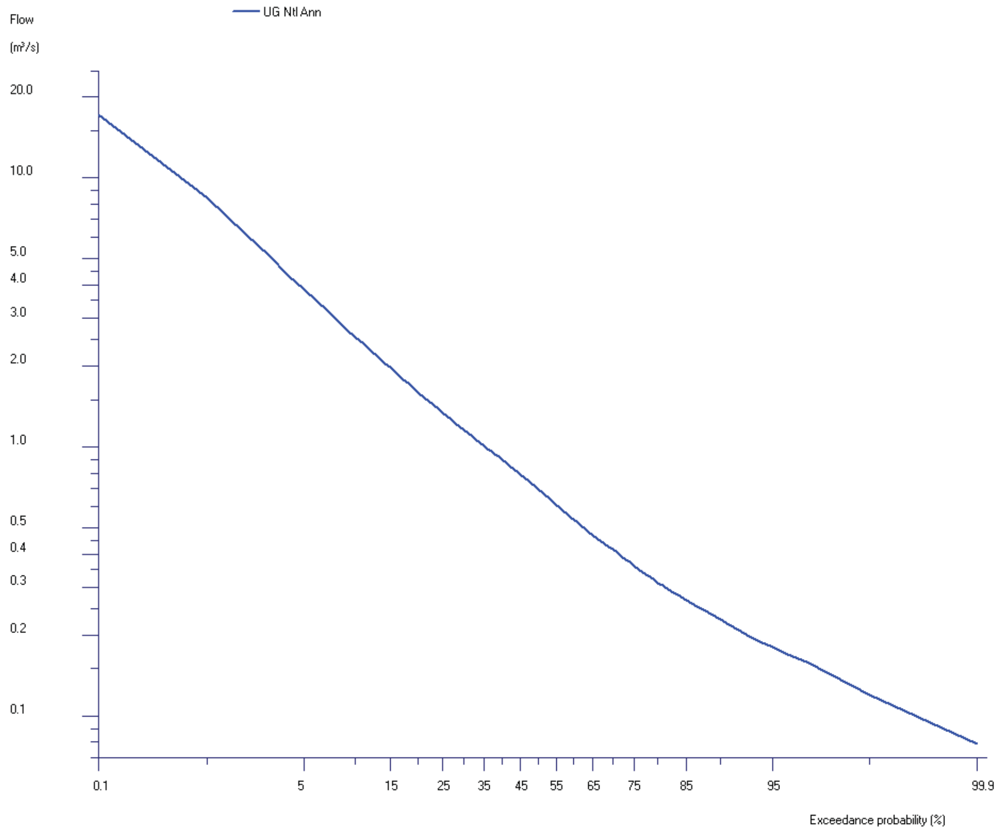

Figure 4.2 Annual Flow Duration Curve

Table 4.3 Monthly Flow Duration Curve Statistics

January		February		March		April	
Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)
5	4.995	5	4.851	5	4.922	5	3.451
10	3.775	10	3.531	10	3.330	10	2.524
20	2.513	20	2.090	20	2.107	20	1.770
30	1.920	30	1.435	30	1.620	30	1.346
40	1.519	40	1.168	40	1.329	40	1.072
50	1.233	50	0.974	50	1.111	50	0.890
60	1.033	60	0.826	60	0.941	60	0.752
70	0.892	70	0.701	70	0.784	70	0.637
80	0.748	80	0.571	80	0.634	80	0.523
90	0.600	90	0.458	90	0.475	90	0.416
95	0.469	95	0.406	95	0.354	95	0.346
99	0.301	99	0.337	99	0.261	99	0.268

May		June		July		August	
Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)
5	2.160	5	1.458	5	1.498	5	1.942
10	1.477	10	0.960	10	0.927	10	1.284
20	0.954	20	0.631	20	0.560	20	0.764
30	0.754	30	0.488	30	0.415	30	0.548
40	0.625	40	0.417	40	0.340	40	0.428
50	0.538	50	0.355	50	0.309	50	0.343
60	0.468	60	0.310	60	0.276	60	0.283
70	0.413	70	0.265	70	0.246	70	0.238
80	0.353	80	0.226	80	0.214	80	0.203
90	0.284	90	0.183	90	0.180	90	0.171
95	0.241	95	0.162	95	0.150	95	0.149
99	0.178	99	0.124	99	0.113	99	0.115

September		October		November		December	
Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)	Percentile	Q (m³/s)
5	2.548	5	3.842	5	4.471	5	4.180
10	1.610	10	2.658	10	3.040	10	3.151
20	1.028	20	1.575	20	2.049	20	2.259
30	0.656	30	1.091	30	1.590	30	1.693
40	0.484	40	0.769	40	1.271	40	1.381
50	0.383	50	0.567	50	1.043	50	1.162
60	0.316	60	0.457	60	0.838	60	0.982
70	0.271	70	0.368	70	0.673	70	0.821
80	0.230	80	0.255	80	0.464	80	0.661
90	0.172	90	0.181	90	0.324	90	0.497
95	0.143	95	0.153	95	0.253	95	0.419
99	0.110	99	0.092	99	0.167	99	0.281

5 Assumptions

Assumptions implicit in the estimated flow estimates are:

- Only natural flow statistics have been estimated and the impact of any artificial influences (for example abstractions, discharges or impounding reservoirs) is not included.
- The topographic catchment area identified is assumed to accurately reflect the true catchment area contributing to flows at the catchment outlet.
- The flow estimates are based on long term average records.

6 Model Uncertainty

The figures for factorial standard error of estimate for long term mean flow and Q95 are shown in Table 6.1. So, as an example the uncertainty in the estimate of mean flow in Scotland will generally be less than 11%. These standard errors are presented as a general guide only and should be considered in the context of the information presented within section 7. These errors are broadly comparable to the sampling errors that might be expected if mean flow was calculated from two to three years of error free gauged data and Q95 for in the order of five years error free gauged data.

If these estimates are to be used for high value decision making we would recommend that the estimates are corroborated through appropriate local flow measurement. For advice on flow measurement please contact us at info@hydrosolutions.co.uk.

Table 6.1 Model Factorial Standard Error (FSE)

Regions of the UK	FSE Mean Flow	FSE Q95
England and Wales	16	42
Scotland	11	35
Northern Ireland	11	30

7 Consideration for Use

The predictive performance of the Mean Flow and FDC Estimation Models may vary according to local conditions. The following is a list of significant, but not comprehensive, issues that need to be considered when estimating flows within ungauged catchments:

- Care needs to be taken when interpreting the results in smaller groundwater catchments in which river flows may be strongly influenced by point geological controls (such as spring lines and swallow holes).
- A catchment water balance is assumed within the LowFlows software; this assumption may be incorrect in smaller groundwater fed catchments where part of the regional groundwater flow bypasses the surface water catchment.
- The estimation of Mean Flow is based on a grid of long term average annual runoff developed by CEH. This was derived using the outputs from a deterministic water balance model using

observed data from over 500 gauged catchments. The predictive performance of the model may therefore be reduced in areas of low rainfall gauge density.

- Care needs to be taken when interpreting the result in very small catchments as the size of the catchment approached the spatial resolution of the underlying catchment characteristic datasets within LowFlows (1 km^2). For very small catchments it is recommended that the topographic contributing catchment is confirmed by a site walkover to identify any unmapped features that might modify the catchment area.
- Where available local measured flow data should be used to corroborate the LowFlows software estimates. This is good practice when using any generalised hydrological model.

8 Warranty and Liability

1. The assumptions and uncertainties associated with the flow estimation methods must be considered when making use of flow estimates produced by the system.
2. You are responsible for the interpretation of the Results presented within this report and training in the use of the estimation methods is strongly recommended.
3. Subject to 1 and 2 above, WHS do not seek to limit or exclude liability for personal injury or death arising from our negligence.
4. Except for 3 above our entire liability for any breach of our duties, whether or not attributable to our negligence, is limited to the fee that you have paid for this report.
5. Except for 3 and 4 above, in no event will WHS be liable to you for any damages, including lost profits, lost savings or other incidental or consequential damages arising on your use of the results even if we have been advised of the possibility of such damages.
6. Should any of these provisions be ruled invalid under any law or Act of Parliament, they shall be deemed modified or omitted only to the extent necessary to render them valid and the remainder of these provisions shall be upheld.

Annex 1: Copies of key correspondence with the client

From: Richard Steel [mailto:Richard.Steel@atmosconsulting.com]
Sent: 07 January 2015 09:54
To: lowflows@hydrosolutions.co.uk
Subject: RE: Message from the Wallingford HydroSolutions Ltd website

Good morning Natalie

Many thanks for getting back to me and providing the account information. I will set Wallingford up within our system as a supplier today. We have not requested a Flow Estimate Report from you previously and are happy to undertake advancement payment for the first report. If you could issue a pro-forma invoice then I will instruct our accounts to make the necessary payment.

The site we are looking for the report on is the River Breamish in North Northumbria at grid ref: NU 00823 16402 or Easting 400823 Northing 616402 (see attached figure for location - we are seeking a flow estimate on the river adjacent to the borehole location show).

Please could you indicate the standard turnaround time for production of the flow estimate report.

If you have any queries then please do not hesitate to contact me.

Regards

Richard