NORTH WEST
cambridge

Washpit Brook Flood Reduction Scheme

Condition 28

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URS

North West Cambridge - Washpit Brook Flood Reduction Scheme

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TABLE OF CONTENTS

1. INTRODUCTION

This document presents the Washpit Brook Flood Reduction Scheme which has been prepared in response to Condition 28 for the planning consent for the North West Cambridge development (reference 11/1114/OUT and S/1886/11) ("the development"). This document develops the information presented in the Flood Risk Assessment ("FRA") and the Addendum to the Flood Risk Assessment ("the Addendum") which were prepared as supporting documents to the Outline Planning Applications for the development.

1.1 Planning Condition

The following Planning Condition has been considered in the preparation of the Washpit Brook Flood Reduction Scheme.

1.2 Flood Risk and Sustainable Drainage Systems

Condition 28

No development shall commence until such time as a full flood reduction scheme is submitted to reduce flood risk downstream in accordance with the Addendum to Level 3 FRA dated September 2011 and addendum March 2012 and Design, Access and Landscape Statement dated March 2012, and must be accordance with NPPF 2012 guidance. The final model and flood alleviation measures offered by possible Washpit Brook modifications must be submitted to and approved in writing by the Local Planning Authority prior to commencement of development. The final channel modifications and associated works must be constructed in accordance with the satisfactory flood reduction scheme. The model and associated works shall ensure the following 6 points:

a) The minimum percentage reduction in peak flow downstream of the site shall be at least 25% and 10% for events with a return period of 1 in 20 and 1 in 100 years (including an allowance for climate change) respectively.

b) The flow control structure shall be designed ensuring that the peak flood level at the M11 culverts does not exceed 12.54mAOD and 12.76mAOD for events with a return period of 1 in 20 and 1 in 100 years (including an allowance for climate change) respectively.

c) Floodwater shall be stored within landscaped areas of the area designated as Primarily Open Land 5 as shown on Drawing No NWC/OPA/PAR/03/A dated February 2012 on Parameter Plan 03 and shall not encroach upon structures within the development including any surface water attenuation features. The Landscape Management Plan shall complement this and shall recognise floodwater areas that must be able to naturally drain back into the Washpit Brook and those which shall be promoted as wetted areas.

d) The new (proposed) fluvial flood extent including Flood Zones 2 and 3 shall not result in any encroachment into the built development except that shown within Figure E of the Addendum to the Level 3 FRA dated March 2012. This encroachment area will be fully mitigated against flooding.

e) Cleaned modelled outlines and levels are produced in order to consider these within the context of the EA flood maps.

f) The final model will contain manning's n values that satisfactorily represent the roughness values for the Primarily Open Land 5.

The flood reduction scheme shall include precise specification and detail of the works/measures required and an assessment of the downstream and upstream impacts of the proposed works once completed.

The works/measures shall be carried out in accordance with an agreed phasing plan, and the approved details.

REASON To ensure that the development does not result in any increased flooding within the Washpit Brook catchment and offers an amount of reduced flood risk downstream. North West Cambridge Area Action Plan Policies NW25, NW26 and NW27.

1.3 Planning Policy

Planning Policy requirements can be found in **Appendix A**.

1.4 Flood Risk Assessment

The flood alleviation scheme outlined within the Level 3 FRA retained the existing watercourse geometry and involved the installation of an online flow control structure to promote floodwater storage within the Western Edge and thereby reduce the downstream peak flow. A two stage channel was to be constructed by reducing the level of the area of floodplain that is situated beyond the gas main easement to increase the volume of floodwater storage available. A minimum depth of 0.5m from bed to bank of the Washpit Brook was to be retained on its existing alignment to form a low flow channel. This approach satisfied the flood risk reduction objectives; it also introduced a requirement for existing vegetation to be removed, where it was situated directly adjacent to the existing watercourse.

1.5 Addendum to Flood Risk Assessment

Following the post application consultation with the planning authorities and Environment Agency, the parameters for the Western Edge were developed by layering together a series of practical parameters that combined to enable a multi-functional piece of green infrastructure. The resulting solution preserved existing vegetation, created new and improved ecological habitats, provided improved maintenance access and reduced flood risk downstream.

The solution presented in the Addendum was subsequently adjusted after a further round of consultation with the parties listed above to maintain the alignment of the Washpit Brook. The process of this evolution is outlined in the parameter-compliant indicative plans and sections that are presented within **Appendix B** together with indicative design drawings that indicate one way that the required geometry and flood containment can be achieved in a parameter-compliant manner, via a proposed low flow channel and two stage channel.

The refined flood alleviation scheme has been designed to provide compatibility with the following constraints, which were identified within the Level 3 FRA:-

1. Effect upon peak flows and the flood hydrograph downstream of the site;
2. Effect upstream of the site, via the M11 culverts and,
3. Effect upon flood extent within the site.

Girton and other settlements downstream of the development are vulnerable to flooding resulting from a range of flood return periods. The flood alleviation scheme has been designed to reduce the peak flow discharged from the site towards Girton generally, including flood events with a return period of 1 in 20, 1 in 100 and 1 in 1000 years, rather than focusing purely on the most extreme events.

Two culverts pass below the M11 and allow the passage of water into the site from land to the west. These culverts discharge directly into the Washpit Brook within the site. The refined

flood alleviation scheme has been designed to ensure that water levels will not be increased in the vicinity of the M11 culverts.

The storage of floodwater within the site will cause water levels to be elevated downstream of the M11 culverts. Earthwork landforms are proposed on the western edge of the development to balance cut and fill across the site, complement the landscape design, and provide sheltered areas of open land that may be less affected by noise from the M11. These landforms have been designed geometrically to assist in the storage of floodwater and thus to manage flood risk.

2. CONSTRAINTS AND OPPORTUNITIES

2.1 Constraints

From the Environment Agency's on line flood maps, the site is located within Flood Zone 1 (low flooding probability) as defined in the Technical Note to the National Planning Policy Framework ("the NPPF") on flood risk. However, a hydraulic modelling study undertaken on the Washpit Brook as part of the site's Flood Risk Assessment has identified areas of the site adjoining the watercourse that appear to be in Flood Zones 2 and 3. These flood risk zones are associated with the predicted flooding extent from the Washpit Brook during a flooding event with a return period of 1 in 100 years (Flood Zone 3) and a flooding event with a return period of 1 in 1000 years (Flood Zone 2). There is a known flood risk to existing development at Girton and further downstream and it is therefore important that this risk is not increased as a result of the development.

The Environment Agency Flood Map identifies the potential for significant flooding within Girton at the confluence of the Washpit Brook and Beck Brook, which is situated approximately 2km downstream of the site, and nine properties on Dodford Lane were believed to have flooded on 21 October 2001.

A medium pressure gas main runs parallel to the M11, close to the Washpit Brook. The gas main has an easement of 20m and no excavation or fill can take place within the extent of the easement.

2.2 Opportunities

Earthwork landforms are proposed on the western edge of the development to balance cut and fill across the site, complement the landscape design, and provide sheltered areas of open land that may be less affected by noise from the M11.

These landforms will be designed geometrically to assist in the storage of floodwater and manage flood risk.

Surface water drainage will run down the green fingers of the development and will be captured behind the landforms before discharging into the Washpit Brook. The creation of areas of flood storage adjacent to the Washpit Brook will create opportunities to enhance the landscape character of the watercourse.

The parameters for the Western Edge have been developed to create new and improved ecological habitats, delivering benefits for biodiversity, whilst retaining the most valuable existing features.

3. LANDSCAPE

The development will be partially shielded from the M11 through the creation of a modified landform utilising the arisings from on site construction activity. The existing alignment of the Washpit Brook will create a breach in the landform which will be overlapped for acoustic and visual containment purposes. The landform will be further refined into a series of scalloped profiles that connect to the green finger within the development. This also protects the development from flooding in stages before the Western Edge is complete.

The position of the easement for the high pressure gas main constrains the width of the two stage channel at the southern end of the Washpit Brook and creates a constraint between the proposed retention ponds that are situated on the eastern side of the proposed landforms and the Washpit Brook (as it will not be practical to reduce the ground level over the gas main).

To overcome this constraint, a new low flow channel will be provided along the western edge of the earthwork landforms to intercept the attenuated discharge from the retention ponds and to connect with the existing reach of the Washpit Brook located upstream. Flow will be conveyed downstream to the eastern side of the easement. A 1m diameter pipe culvert will allow the new low flow channel to discharge into the existing reach of the Washpit Brook, beneath the maintenance access track. The cross section of the new watercourse will incorporate a second stage channel that will be capable of storing floodwater in order to maximise the effectiveness of the flood alleviation scheme.

The central section of the Washpit Brook has been retained where it currently intercepts runoff from the culverts that pass below the M11 to allow conveyance of flow generated off site. This extends until it meets with the culvert beneath the maintenance access track.

The proposed online flow control structure will be positioned upstream (i.e. south) of some existing mature trees alongside the northern half of the Washpit Brook.

Downstream of the flow control structure no significant alterations to the Washpit Brook are proposed, except for the removal of an access culvert, which is no longer required, and the formalisation of the maintenance access.

Surface water drainage running down the green fingers will be captured behind the landforms before discharging into the Washpit Brook. The creation of areas of flood storage adjacent to the Washpit Brook will create opportunities to enhance the landscape character of the watercourse. The watercourse will be expanded to create two flood plains either side of the gas main, parallel to the M11.

It is proposed that the detailed landscape proposals for new banks of the watercourse will include marginal planting and steep sections to create water vole habitats, whilst areas of the channel will expand into meadows, ponds and wetland habitats. The final landform will be sculpted to create a landscape designed to manage views into and out of the site and to disaggregate the landform into a series of layered ridges.

Further details will be provided in the Reserved Matters Applications for landscaping details in accordance with Condition 11.

4. ECOLOGY

4.1 Existing ecology

The Washpit Brook flows adjacent to the M11 on the western boundary of the site and through the centre of the north-western corner. The Biodiversity Strategy prepared in response to Condition 34 describes the ecology supported by the Washpit Brook.

4.2 Proposed works

The watercourse will be retained on its current alignment, with modifications to bank profile in places to allow the creation of a second stage channel to provide flood storage. The banks of the central section of the Brook (which provides the most valuable habitat for water voles) will be retained intact (as shown in cross-sections WSH-1961 and WSH-1998 (drawings D127313-SK-065 to 069)). In the unlikely event that water voles are present on affected sections of the channel at the time of the modifications they would be 'displaced' into this retained section. Further details are provided in the Biodiversity Strategy.

Existing trees on the banks of the Brook will be retained as far as possible, although a small number of trees may need to be removed to construct the flow control structure. Further details will be provided in the Reserved Matters Applications for landscaping details in accordance with Condition 12.

The new drainage and attenuation features associated with the Washpit Brook will be designed to provide valuable habitat for water voles in particular. Linear habitat ponds will be created as part of new 'low flow channels', which will receive water from retention ponds and will be over-deepened to ensure that they hold water over as prolonged a period as possible. The new sections of channel and habitat ponds will have a steep (1:1 slope) earth bank on one side (at and immediately above water level), sown with a wildflower grass mix, and with a planting ledge below water level. Where bank re-enforcement is required this will be achieved through the use of coir fibre matting. Wetland vegetation will be planted at, and immediately below, water level.

There will be an overall increase in the availability of wetland habitat (by more than 50%) as new backwaters and linear ponds are created as low flow channels. Downstream of the flow control structure no significant alterations to the Washpit Brook are proposed, except for the removal of an access culvert, which is no longer required, and the formalisation of the maintenance access.

4.3 Protection measures

Appropriate pollution control measures will be implemented to avoid pollution or increased turbidity in the Washpit Brook during construction of the flow control structure and the bank modification works, to protect adjacent and downstream habitats.

It is considered likely that water voles are absent from the Brook within the site boundaries, although it is difficult to confirm absence of the species. Given that it has been recorded on site in the past, a precautionary approach to the works will be adopted in areas of suitable habitat, as described in the Biodiversity Strategy.

The culvert located within 10-15m of Sett K will be removed. This will be undertaken under licence to Natural England and will be carefully supervised by the licence holder to ensure that the sett is not damaged. Dependent on the extent of the works it may be considered appropriate to temporarily exclude badgers from the sett until the works have been completed.

It is considered unlikely that other aspects of the development would directly affect the Washpit Brook. Nevertheless, the Brook will be protected within a buffer zone throughout the remaining construction phases of the development. The buffer zone will be fenced off using

netlon-type fencing to prevent accidental damage, and to restrict access during the works. Appropriate pollution control measures will be implemented to avoid pollution or increased turbidity in the Washpit Brook.

4.4 Enhancement measures

The modifications to the banks of the Washpit Brook have been designed to provide enhanced habitat for water voles and a range of other species. Further details on the designs of these features and the triggers for construction are provided in the Biodiversity Strategy. Further details will be provided in the Reserved Matters Applications for ecology in accordance with Condition 35.

5. DESIGN CRITERIA

The final channel modifications and associated works must be constructed in accordance with the satisfactory flood reduction scheme. The model and associated works shall ensure the following 6 points:

a) The minimum percentage reduction in peak flow downstream of the site shall be at least 25% and 10% for events with a return period of 1 in 20 and 1 in 100 years (including an allowance for climate change) respectively.

b) The flow control structure shall be designed ensuring that the peak flood level at the M11 culverts does not exceed 12.54mAOD and 12.76mAOD for events with a return period of 1 in 20 and 1 in 100 years (including an allowance for climate change) respectively.

c) Floodwater shall be stored within landscaped areas of the area designated as Primarily Open Land 5 as shown on Drawing No NWC/OPA/PAR/03/A dated February 2012 on Parameter Plan 03 and shall not encroach upon structures within the development including any surface water attenuation features. The Landscape Management Plan shall complement this and shall recognise floodwater areas that must be able to naturally drain back into the Washpit Brook and those which shall be promoted as wetted areas.

d) The new (proposed) fluvial flood extent including Flood Zones 2 and 3 shall not result in any encroachment into the built development except that shown within Figure E of the Addendum to the Level 3 FRA dated March 2012. This encroachment area will be fully mitigated against flooding.

e) Cleaned modelled outlines and levels are produced in order to consider these within the context of the EA flood maps.

f) The final model will contain manning's n values that satisfactorily represent the roughness values for the Primarily Open Land 5.

The flood reduction scheme shall include precise specification and detail of the works/measures required and an assessment of the downstream and upstream impacts of the proposed works once completed.

The works/measures shall be carried out in accordance with an agreed phasing plan, and the approved details.

6. PROPOSED FLOW CONTROL AND STORAGE

6.1 Proposed scheme

The proposed flood alleviation scheme includes open water storage with a flow control structure. Open water storage has been selected in preference to alternative options such as underground tanks or cellular storage as this provides ecological, landscape, water quality and landscape benefits and can be more readily accessed for maintenance.

A weir and pipe have been selected for the flow control structure in preference to a hydrobrake as this combination presents the lowest maintenance risk with no moving parts.

6.2 Flow control structure

The flow control structure, will comprise a 1.3m diameter low flow pipe with a crest level set at 12.90m AOD and will be positioned at the location shown on drawing D127313-SK-P1-180, in **Appendix C**. Further details on the form of the structure will be provided in the Reserved Matters Applications for landscaping details in accordance with Condition 11.

6.3 Flood storage area

The flood storage area will be constructed upstream of the flow control structure through the excavation of material adjacent to the existing brook to form a two stage channel and the construction of additional low flow channels to form a two stage channel.

A 20m wide easement for a high pressure gas main dissects the southern half of the flood storage area. A maintenance access track will be positioned within the easement zone. Ground levels will be retained within the easement zone and under extreme conditions floodwater may spill across it from one channel to another.

The proposed earthworks bunds have been design geometrically to function in combination with the two stage channel in order to contain floodwater and ensure that flood risk to the development will not be increased by the flood alleviation measures.

A 3d ground model of the Washpit Brook has been constructed in Civils 3D based on the 1d cross-sections from the fluvial model. The 3d ground model has been built to confirm and demonstrate that the flood alleviation scheme can be accommodated within the existing and proposed landscape whilst accommodating the constraints of the gas easement and ecology.

A fall towards the low flow channel has been incorporated into the 3d ground model and 1d fluvial model to facilitate drainage of any floodwater back to the low flow channel. **Appendix C** contains updated plans and cross-sections through the Washpit Brook.

Preliminary geotechnical analysis has been undertaken on the proposed slopes of the channels. The analysis demonstrates that the natural ground can stand at slopes of 1:3. The ecological enhancement slopes, which are to stand at slopes of 1:1, will require an ‘engineered’ solution. The slope stability analysis has confirmed that the provision of a 2m offset between the top of the slope of the Washpit Brook channel and the earthworks on the Western Edge is adequate.

An existing culvert, which is located at the coordinates 542,030mE, 260,731mN, will be removed as part of the scheme. The culvert removal provides opportunities for the bed of the Washpit Brook to be locally re-profiled to form a more uniform gradient and thereby enable the storage volume to be maximised. The downstream half of the Washpit Brook will be reprofiled only, as the reach upstream of this was more constrained due to the presence of the culverts located beneath the M11. Further details on the bed of the Washpit Brook will be provided in the Reserved Matters Applications for landscaping and ecology details in accordance with Condition 11 and 35.

7. FLUVIAL MODELLING OF FLOOD ALLEVIATION SCHEME

7.1 Model Construction

The baseline hydraulic model has been amended to include the features contained within the updated flood alleviation scheme. The changes made to the model are summarised below:

- Landscape landforms have been included between node WSH-2437 and WSH-1400.
- Inclusion of additional channels (NEW-2432 to NEW-1901) to the east of Washpit Brook and (New-1901 to NEW-1660) to the west of Washpit Brook
- The flow control structure, which comprises a culvert and raised spill level, has been included at WSH-1660 to locally restrict the hydraulic capacity of the watercourse and promote the storage of floodwater upstream;
- A 1m diameter pipe culvert has been included at WSH-1901 to allow passage of the new channel beneath the maintenance access track;
- The Washpit Brook channel has been re-profiled upstream of WSH-1660 to maximise the storage volume;
- Ground levels on the banks of Washpit Brook and the newly created channels have been lowered to increase storage volume between nodes WSH-2437 and WSH-1660;
- The level of the right (i.e. east) bank has been raised to 13.15m AOD between node WSH-1901 and WSH-1660 to ensure the floodwater does not encroach upon built areas within the Proposed Development.

A model summary sheet is included with **Appendix D**.

7.2 Hydrology

The hydrology from the baseline modelling has been retained for the proposed flood modelling. This applied the ReFH method, rather than the statistical method and was considered a conservative approach. However, the manner in which it has been applied to the hydraulic model has been altered slightly in the refined flood alleviation scheme. Due to the redistribution of the two stage channel, connectivity to the upstream catchment has been altered, which has resulted in the slight modification to the hydrological input. Catchment 1 (as defined within the Level 3 FRA) has been split into two sub-catchments and applied to the refined flood alleviation hydraulic model based upon the upstream contributing area of the catchment.

A sensitivity test has been undertaken with respect to the hydrological flows used within the refined flood alleviation model and is discussed within section 7.5.

7.3 Model Results

Model simulations have been undertaken for the baseline scenario and the proposed flood alleviation scheme for the 1 in 20 year, 1 in 100 year, 1 in 100 year with 20% increase in flow for climate change and 1 in 1000 year events. The model simulations were used to determine the effect of the proposed scheme on the flows and levels in Washpit Brook, and to produce the maximum flood extents for mapping (see Section 7.4).

In addition flow hydrographs were developed for the 1 in 2 year and 1in 5 year events to check how the proposed flood alleviation scheme would operate for smaller flood events.

Reduction in Downstream Peak Flows

Table 7-1 provides a comparison of the peak flows downstream of the development by considering the existing baseline and proposed (i.e. refined flood alleviation scheme) scenario. It also defines the approximate percentage reduction in peak flow discharged from the site that may be obtained through its implementation.

Table 7-1: Effect upon Peak Flows Downstream of the site

DOWNSTREAM EFFECT ON PEAK FLOW (m^3/s)			
1 IN 2 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (% reduction)
WSH-0939	0.99	0.7	0.29
1 IN 5 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (% reduction)
WSH-0939	1.36	0.86	0.37
1 IN 20 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (% reduction)
WSH-0939	1.85	1.37	26
1 IN 100 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (% reduction)
WSH-0939	2.57	2.23	13
1 IN 100 YEAR + CC			
NODE	BASELINE	PROPOSED REV 3	EFFECT (% reduction)
WSH-0939	3.00	2.71	10
1 IN 1000 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (% reduction)
WSH-0939	4.22	4.10	3

Table 7-1 indicates that the refined flood alleviation scheme would provide a significant reduction in peak flows downstream for a range of flood return periods, which will reduce flood risk for Girton when compared to the existing baseline situation. For example, under the 1 in 20 year event a reduction in flow of 26% is observed. The percentage reduction in peak flow is reduced as the flow return period increases because the positive effect of the scheme is diluted by the higher flows. Under the 1 in 1000 year event, the peak flow is still reduced by 3%.

Figure 7-1 is provided to graphically illustrate the effect that the refined flood alleviation scheme would have on the downstream hydrograph. This figure indicates that these measures would permit the peak flows to be reduced from 3.0 to 2.7 m^3/s for a 1 in 100 year event including a 20% allowance for climate change. The volume of floodwater discharged would be the same; however, it would be discharged over a longer period of time.

For the smaller events the effect of the flood alleviation scheme is larger with a reduction in peak flows downstream of 29% and 37% for the 2 year and 5 year events respectively. The attenuation of the flood hydrograph is more marked as shown in Figure 7-2 for the 5 year event.

Downstream of the site the Washpit Brooks meets with Beck Brook. Appropriate checks have been undertaken which confirm that the flood alleviation scheme would also benefit flood risk downstream of this confluence.

Figure 7-1: 1 in 100 year event + 20% allowance for climate change peak flow at WSH-0939

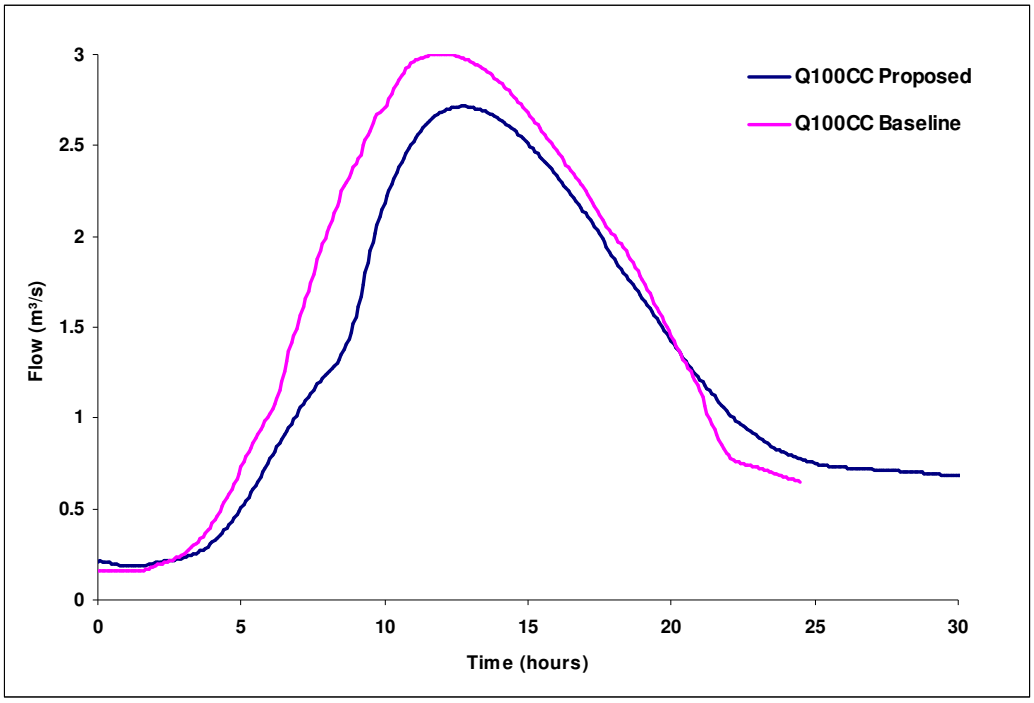
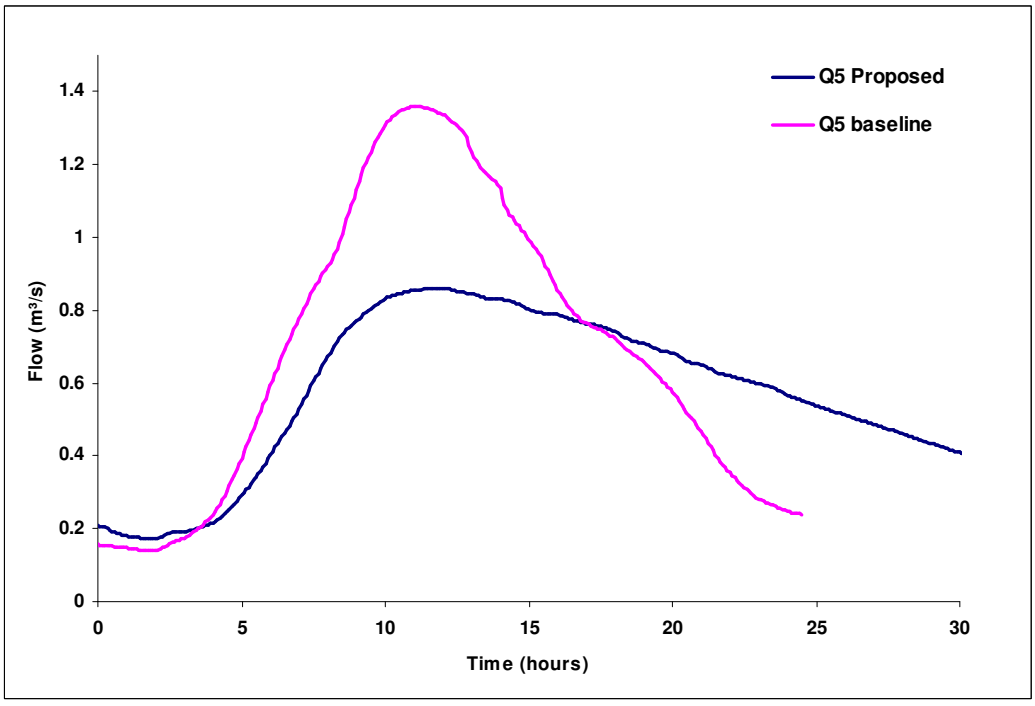


Figure 7-2: 1 in 5 year event peak flow at WSH-0939



Water Levels at face of the M11 Culverts

Table 7-2 shows the effect upon flood levels within the site, adjacent to the M11 culverts. The fourth column on the table reflects the reduction in peak flood level between the proposed scenario, compared to the baseline scenario.

Table 7-2: Effect upon Peak Flood Level at the M11 Culverts (all levels expressed as AOD)

UPSTREAM EFFECT ON STAGE (m AOD)			
1 IN 2 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (m) proposed - baseline
WSH-2060	12.33	12.01	-0.32
1 IN 5 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (m) proposed - baseline
WSH-2060	12.42	12.19	-0.23
1 IN 20 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (m) proposed - baseline
WSH-2060	12.54	12.37	-0.17
1 IN 100 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (m) proposed - baseline
WSH-2060	12.68	12.59	-0.09
1 IN 100 YEAR + CC			
NODE	BASELINE	PROPOSED REV 3	EFFECT (m) proposed - baseline
WSH-2060	12.76	12.71	-0.05
1 IN 1000 YEAR			
NODE	BASELINE	PROPOSED REV 3	EFFECT (m) proposed - baseline
WSH-2060	13.00	13.00	0.00

Table 7-2 indicates that the refined flood alleviation scheme would not cause the peak water level adjacent to the M11 culverts to be increased, as it allows the peak flood level at the culverts to be reduced by 0.17m for a flood event with a return period of 20 years. The reduction in peak water level is reduced as the flood return period increases because the positive effect of the scheme is diluted by the higher flows. Under the 1 in 1000 year event, no effect is observed.

For smaller events the effect of the flood alleviation scheme is more marked with a reduction in peak water level at the M11 culvert of 0.32m and 0.23m for the 2 year and 5 year events respectively.

7.4 Flood Maps

The hydraulic modelling of the refined flood alleviation scheme has resulted in the identification of revised flood zones within the site. Updated flood maps have been provided within **Appendix E** in order to define the extent of flooding that would occur within the site following the implementation of the revised flood alleviation scheme.

The revised flood maps indicate that the refined flood alleviation scheme result in a reduction in flood extent downstream. Consequently, no development blocks are affected up to and including the 1 in 100 year including 20% climate change event.

The refined flood maps also indicate that the entire built development will be located outside Flood Zone 1, with the exception of part of a single block in the northwest corner of the site, which is partially located in Flood Zone 2. The type of development is classified in general terms of Flood Vulnerability as 'More Vulnerable' under Table 2 of the Technical Guidance.to the National Planning Policy Framework. Table 3 of the Technical Guidance defines the relationship between Flood Vulnerability and Flood Zone Compatibility and states that all uses of land are appropriate in Flood Zone 1, and all but 'Highly Vulnerable' land use is appropriate in Flood Zone 2. As none of the development is classified as 'Highly Vulnerable', the development is considered to be in compliance with the requirement of NPPF and an Exception Test will not be required for the development proposals. More importantly, land use within each development block will be sequentially located to steer all 'More Vulnerable' and 'Less Vulnerable' development (i.e. buildings) into Flood Zone 1, to ensure that the site is safe.

This is the same conclusion as that outlined in the original level 3 FRA.

7.5 Sensitivity analysis

A sensitivity analysis is included within **Appendix F**, which considers the effect of blockage upon the flow control structure.

The sensitivity analysis also investigates the effect of the application of different peak flow estimates of the Washpit Brook, which were provided by the Environment Agency, prepared for the Cottenham Load Flood Alleviation Scheme modelling undertaken by Halcrow in 2003. The peak flows estimates prepared by Halcrow are based upon an out of date methodology, but were found to be larger compared to the hydrology discussed above.

The sensitivity test has not identified any issues or concerns and the benefits identified above remain with the inclusion of the Halcrow hydrology.

A full table of output results for some of the storm events discussed in this chapter is provided within **Appendix G**.

8. MANAGEMENT RESPONSIBILITY

All watercourses within the site must be maintained to an acceptable standard, which includes clearance of debris presenting a flood risk from the channel and at the upstream face of all culverts. No built development will be constructed within 5m of either the banks of the Washpit Brook or any connecting ditches to ensure that access is available for maintenance requirements.

The proposed scheme involves the construction of a two stage channel adjacent to the existing Washpit Brook in order to store excess flow generated by provision of online flow control structures that will facilitate a reduction in downstream peak flow. However, it is not intended that the development proposals will alter the maintenance responsibility of the Lead Local Flood Authority (LLFA), which will still include land located within a distance of 5m from the top of the bank of the existing watercourse. The remainder of the two stage channel will be maintained by the landowner, the University of Cambridge, as part of the wider landscape management strategy.

The Washpit Brook will be further enhanced through the implementation of appropriate management. The flood alleviation works will generally be maintained by the University of Cambridge as part of the open space. The LLFA will be responsible for maintaining the low flow channel, which follows the alignment of the original watercourse.

8.1 Maintain water flow within the Washpit Brook

It will be necessary to remove silt and dense in-channel vegetation at 5 to 10 year intervals. Silt and in-channel vegetation removal should be done on a rotational basis so that only 20% of the length of the brook is de-silted in any one year.

8.2 Maintain water quality within the Washpit Brook

Any spillages, litter or other pollutants within, or in the vicinity of, the Washpit Brook will need to be removed as soon as possible to prevent long-term effects on water quality. Educational material should be provided to local residents and other users of the development site to reduce the likelihood of such events occurring.

8.3 Maintain bankside and in-channel vegetation

Bankside and in-channel vegetation should be cut every two years on a rotational basis, so that vegetation is retained intact on one bank of the brook. Vegetation cutting should take place in October to minimise the effect on water voles and avoid the nesting bird period.

8.4 Riparian Zone

A 5m wide riparian zone is provided to enable the LLFA to perform maintenance works. Maintenance vehicles are required to travel along an informal grass track that is situated directly adjacent to the watercourse bank. This track has evidence of rutting that has occurred due to the ground softening when floodwater breaches the top of the bank of the watercourse.

The remodelling of the Western Edge enables floodwater to be contained within a two stage channel in order to reduce the frequency that the sections of the maintenance access will be submerged.

The alignment of the Washpit Brook cannot be changed without amending the award and a 5m wide maintenance access will need to be retained. The southern section of the maintenance access track has been repositioned within the easement of the high pressure gas main in order to ensure that it may be used to maintain the existing utility and the watercourse. Ramps will be provided outside the easement to enable maintenance access vehicles to gain access to the existing riparian zone from the maintenance access track.

9. CONCLUSIONS

This document presents the Washpit Brook Flood Reduction Scheme which has been prepared in response to Condition 28 for the planning consent for the North West Cambridge development (reference 11/1114/OUT and S/1886/11).

The baseline hydraulic model has been amended to include the features contained within the updated flood alleviation scheme, as described in Section 7 of this report.

A 3d ground model of the Washpit Brook has been constructed in Civils 3D based on the 1d cross-sections from the fluvial model. The 3d ground model has been built to confirm and demonstrate that the flood alleviation scheme can be accommodated within the existing and proposed landscape whilst accommodating the constraints of the gas easement and ecology.

The fluvial modelling has confirmed that the Washpit Brook Flood Reduction Scheme is capable of restricting the peak flow in accordance with the requirements of Condition 28 and that flood risk will not be increased upstream or to the development.

APPENDIX A – PLANNING POLICY

Legislative and policy context

There is a very wide range of legislation, policy and guidance pertaining to water resources and impact assessment; however, this section only refers to water resources related policy and legislation that is directly relevant to the development and its range of potential effects.

Legislation

Water Framework Directive

The Water Framework Directive (WFD) (Commission of the European Communities, 2000) establishes a framework for a European wide approach to action in the field of water policy. Its ultimate aim is to ensure all inland and near shore watercourses and waterbodies (including groundwater) are of 'Good' status or better, in terms of ecological, but also chemical, biological and physical parameters, by the year 2015. Therefore, any activities or developments that could cause detriment to a nearby water resource, or prevent the future ability of a water resource to reach its potential status, must be mitigated so as to reduce the potential for harm and allow the aims of the Directive to be realised.

A waterbody is assessed for Ecological Status and Chemical Status as part of the WFD, the methodology for determining status has been set out by the UK Technical Advisory Group on the WFD[1]. The Environment Agency is responsible for monitoring and ensuring that the targets are met. Waterbodies are classed as either: High, Good, Moderate, Poor or Bad.

The Ecological Status is based on biological quality which includes invertebrates, fish and macrophytes; physicochemical quality which includes temperature, dissolved oxygen, salinity, pH and nutrients; and hydromorphological quality which assesses the range of available habitats.

Chemical Status is assessed on the presence and concentration of Priority Substances for which standards have been established. A full list is located in the UKTAG advice for classification[1].

The elements that these criteria are based on are specific for the different waterbody type – Rivers, Lakes, Transitional Waters and Coastal Waters. The classification is assigned by comparing the feature in question with the reference values. The system works on a 'worst case' scenario, whereby if one classification is not met, then regardless of the quality of the others, the lowest value is reported[2]. The aim is to keep or restore waterbodies as close to a natural state as possible.

UKTAG[3] has proposed water quality, ecology, water abstraction and river flow standards to be adopted in order to ensure that waterbodies in the UK (including groundwater) meet the required status[4]. These are currently in draft form as published in the draft River Basin Management Plans (RBMPs) and will not be formalised until the final RBMPs are published in December 2009 (prior to EC sign off).

WFD Groundwater Daughter Directive

The existing Groundwater Directive is to be repealed by the Water Framework Directive in 2013. New or amended regulations are expected before then to enact both the Water Framework Directive and its Daughter Directive on the protection of groundwater. This new Groundwater Directive (2006/118/EC) is commonly referred to as the Groundwater Daughter Directive.

The Water Framework Directive and the new Groundwater Directive make changes to how groundwater can be protected. These changes will provide a new regulatory setting for the protection of groundwater. However, the new or amended Regulations will be no less protective than the existing Regulations. The

[1] UK Technical Advisory Group on the Water Framework Directive; 2007; Recommendations on Surface Water Classification Schemes for the Purposes of the Water Framework Directive; http://www.wfduk.org/UKCLASSPUB/LibraryPublicDocs/sw_status_classification
[2] In the Draft WRMP, where Fish or Phosphorus are considered to be poor, a compromise is made between the status of phosphorus and fish and the rest of the determinants. This will be confirmed within the final RBMPs.
[3] The UKTAG (UK Technical Advisory Group) is a working group of experts drawn from environment and conservation agencies. It was formed to provide technical advice to the UK's government administrations and its own member agencies. The UKTAG also includes representatives from the Republic of Ireland.
[4] UK Environmental Standards and Conditions (Phase I) Final Report, April 2008. UK Technical Advisory Group on the Water Framework Directive.

existing principle of preventing or limiting the inputs of List 1 or List 2 substances respectively into groundwater under the original Groundwater Regulations 1998 will remain, but will be expanded to encompass all pollutants (any substance liable to cause pollution). For example, nitrate will be included as a pollutant.

The Water Resources Act 1991

The Water Resources Act 1991 (HMSO, 1991), in particular Section 92(1)(a), stipulates that the Secretary of State (SoS) may make provisions to *"prohibit a person from having custody or control of poisonous, noxious or polluting matter unless prescribed works and precautions and other steps have been carried out or taken for the purpose of preventing or controlling the entry of the matter into any controlled waters"*. This has implications for the development, in that all potential pollution sources of controlled waters must be mitigated.

The Urban Wastewater Treatment Directive

The Urban Waste Water Treatment Directive (UWWTD) requires secondary treatment of urban waste-water to prevent the environment from being adversely affected by the disposal of insufficiently treated urban waste water.

The Groundwater Directive (80/68/EEC) and Groundwater Regulations 1998

The Groundwater Directive aims to protect groundwater from pollution by controlling discharges and disposals of certain dangerous substances to groundwater. In the UK, the directive is implemented through the Groundwater Regulations 1998. The Directive aims to protect groundwater under these Regulations by preventing or limiting the inputs of listed substances into groundwater. Substances controlled under these Regulations fall into two lists:

- **List 1** substances are the most toxic and must be prevented from entering groundwater. Substances in this list may be disposed of to the ground, under a permit, but must not reach groundwater. They include pesticides, sheep dip, solvents, hydrocarbons, mercury, cadmium and cyanide.
- **List 2** substances are less dangerous, and can be discharged to groundwater under a permit, but must not cause pollution. Examples include sewage, trade effluent and most wastes. Substances in this list include some heavy metals and ammonia (which is present in sewage effluent), phosphorus and its compounds

Flood and Water Management Act 2010

The Flood and Water Management Act which received Royal Assent in April 2010 aims to implement the recommendations of the Pitt Review, carried out following the 2007 summer floods. The Act and the Pitt Review itself, aim to respond to the pressures of climate change and increased population, which will increase water stress, drought risk, water quality issues and flood risk.

The key features of the Act are:

- To give the Environment Agency an overview of all flood and coastal erosion risk management and unitary and county councils the lead in managing the risk of all local floods.
- To introduce an improved risk based approach to reservoir safety.
- To encourage the uptake of sustainable drainage systems by removing the automatic right to connect to sewers and providing for unitary and county councils to adopt SuDS for new developments and redevelopments.
- To allow sewerage companies to adopt drains and sewers that are connected to the adopted sewer.

- To widen the list of uses of water that water companies can control during periods of water shortage, and enable Government to add to and remove uses from the list.

- To enable water and sewerage companies to operate concessionary schemes for community groups on surface water drainage charges.

- To reduce 'bad debt' in the water industry by amending the Water Industry Act 1991 to provide a named customer and clarify who is responsible for paying the water bill.

- To make it easier for water and sewerage companies to develop and implement social tariffs where companies consider there is a good cause to do so, and in light of guidance that will be issued by the SoS following a full public consultation.

The Act aims to:

- reduce the likelihood and impacts of flooding;
- improve authority ability to manage the risk of flooding;
- improve water quality;
- give water companies better powers to conserve water during drought;
- reduce red tape and other burdens on water and sewerage companies;
- improve the overall efficiency and management of the industry; and
- reduce pollution.

The Act will reduce flood risk by delivering surface water management plans and ending the automatic right to connect to sewers for surface water drainage, requiring developers to put SuDS in place in new developments, wherever practicable.

Commencement No 1 Order brings into force provisions of the Flood and Water Management Act 2010 to provide power for Ministers to make orders and regulations to give effect to the Act. Article 3 provides that sections 4 and 36 of the Act, and some definition sections, are brought into force from 1st September 2010, so far as to enable Ministers to make orders relating to flood risk management functions. The Schedule introduced by Article 4 specifies other provisions that came into force from 1st October 2010, which includes the power to make regulations relating to levies, adoption of drains or sewers by the sewerage undertaker, liability of occupiers of residential premises for water and sewerage charges, duties of a risk management authority and special administration. Article 5 contains transitional provisions.

The Code for Sustainable Homes

The Code for Sustainable Homes has been introduced to drive a step-change in sustainable home building practice. It is a standard for key elements of design and construction which affect the sustainability of a new home. The Code uses a sustainability rating system – indicated by 'stars', to communicate the overall sustainability performance of a home. The table below summarises the mandatory minimum standards which exist under the Code for each assessment level relating to indoor water consumption:

Level 1(★)	Maximum Internal potable water consumption measured in litres per person per day (l/p/d)	120 l/p/d
Level 2(★★)		120 l/p/d
Level 3(★★★)		105 l/p/d
Level 4(★★★★)		105 l/p/d
Level 5(★★★★★)		80 l/p/d
Level 6(★★★★★★)		80 l/p/d

Mandatory minimum performance standards are set for some issues irrespective of the code level rating that is sought. One of these is the management of surface water runoff from developments which in turn relates to:

- Peak rate of runoff into watercourses – to ensure that this is no greater for the developed site than it was for the pre-development site.

- The additional predicted volume of runoff generated by the development is reduced to zero wherever possible by means of infiltration to groundwater and/or by harvesting it for reuse within the buildings as a replacement for potable water in non-potable applications such as toilet flushing or washing machine operation.

Additional credits are available for using SuDS to improve water quality of the rainwater discharged or for protecting the quality of the receiving waters.

Future Water – The Government's Water Strategy for England

'Future Water' presents the Government's water strategy for England – its vision for sustainable delivery of secure water supplies and an improved and protected water environment.

The Government's water strategy for England aims to secure water supplies and improve the protection of the water environment. Increases in housing and climate change will make it vital to manage demand better and new reservoirs may be needed. Work to improve water quality must continue, flooding must to be managed better and metering of household use may become compulsory.

Groundwater Protection: Policy and Practice (GP3)

The Environment Agency has set out a framework for the regulation and management of groundwater in a set of documents, collectively known as Groundwater Protection: Policy and Practice (GP3). The policies and guidance within GP3 replace the previous policy covered in the Environment Agency's 'Policy and Practice for the Protection of Groundwater'.

Part 4 of GP3 "Legislation and Policies" was issued for consultation in 2007 and published in July 2008. The policies for the protection and management of groundwater have been considered in this assessment, including the control of pollutants to groundwater, contaminated land, permitted activities with respect to Source Protection Zones, and groundwater resource management.

The Pitt Review

Sir Michael Pitt was asked by Ministers to conduct an independent review of the flooding emergency that took place in June and July 2007. The Review made the recommendations that the Government should:

- establish a Cabinet Committee dedicated to tackling the risk of flooding, bringing flooding in line with other major risks such as pandemic flu and terrorism;
- publish monthly summaries of progress during the recovery phase of major flooding events, including number of households still displaced;
- ensure proper resourcing of flood resilience measures, with above inflation increases every spending review;
- establish a National Resilience Forum to facilitate national level planning for flooding and other emergencies;
- have pre planned, rather than ad hoc, financial arrangements in place for responding to the financial burden of exceptional emergencies; and
- publish an action plan to implement the recommendations in this review, with regular progress updates.

The Government's response to the Pitt Review was published in December 2008 and supported the findings of the review, indicating that Local Authorities should take the lead in implementing its recommendations.

The National Flood and Coastal Erosion Risk Management Strategy for England

The Environment Agency and DEFRA jointly published this document in July 2011 in order to identify actions that can be taken to manage the risk of flood and coastal erosion in England in order to reduce the impact on Communities that could occur as a result of climate change and development in areas at risk.

The strategy builds on existing approaches to flood and coastal risk management and promotes the use of a wide range of measures to manage risk. It also indicates that risk should be managed in a co-ordinated way within catchments and along the coast balancing the needs of communities, the economy and the environment. This strategy will form the framework within which communities have a greater role in local risk management decisions and sets out the Environment Agency's strategic overview role in flood and coastal erosion risk management (FCERM).

This approach is aligned with the recommendations made by Sir Michael Pitt in his review of the summer 2007 floods. The strategy encourages more effective risk management by enabling people, communities, business, infrastructure operators and the public sector to work together to:

- ensure a clear understanding of the risks of flooding and coastal erosion, nationally and locally, so that investment in risk management can be prioritised more effectively;
- set out clear and consistent plans for risk management so that communities and businesses can make informed decisions about the management of the remaining risk;
- manage flood and coastal erosion risks in an appropriate way, taking account of the needs of communities and the environment;
- ensure that emergency plans and responses to flood incidents are effective and that communities are able to respond effectively to flood forecasts, warnings and advice;
- help communities to recover more quickly and effectively after incidents.

The National Planning Policy Framework (NPPF)

While the NPPF is to be read as a whole in the context of flood risk and drainage the NPPF states at paragraph 100 that when determining planning applications, local planning authorities should ensure flood risk is not increased elsewhere and only consider development in flood risk areas appropriate where informed by a site-specific flood risk assessment following the Sequential Test, and if required the Exception Test, it can be demonstrated that:

- within the site, the most vulnerable development is located in areas of lowest flood risk unless there are overriding reasons to prefer a different location; and
- development is appropriately flood resilient and resistant, including safe access and escape routes where required, and that any residual risk can be safely managed; and it gives priority to the use of sustainable drainage systems.

Paragraph 104 of the NPPF notes that for individual developments on sites allocated in development plans through the Sequential Test, applicants need not apply the sequential test.

Local Policy, Strategy & Guidance

The site lies astride the administrative boundaries of South Cambridgeshire District Council (SCDC) and Cambridge City Council (CCC). As a result, water related policies contained within both of the authorities' emerging Local development Frameworks are relevant to the development and have been referenced here.

North West Cambridge Area Action Plan

The principal Local development Document that has been produced jointly by SCDC and CCC and that relates specifically to the site is the North West Cambridge Area Action Plan which was adopted in October 2009. The Plan contains the following policies relevant to water resources:

- NW24: Climate Change & Sustainable Design and Construction
  1) 'development will be required to demonstrate that it has been designed to adapt to the predicted effects of climate change'
  2) 'Residential development will be required to demonstrate that:
  a) All dwellings approved on or before 31 March 2013 will meet Code for Sustainable Homes Level 4 or higher, up to a maximum of 50 dwellings across the site. All dwellings above 50 will meet Code for Sustainable Homes Level 5 or higher (these Levels include water conservation measures);
  b) All dwellings approved on or after 1 April 2013 will meet Code for Sustainable Homes Level 5 or higher;
  c) There is no adverse impact on the water environment and biodiversity as a result of the implementation and management of water conservation measures.'
  3) 'Non residential development and student housing will be required to demonstrate that:
  f) It will incorporate water conservation measures including water saving devices, greywater and/or rainwater recycling in all buildings to significantly reduce potable water consumption; and
  g) There is no adverse impact on the water environment and biodiversity as a result of the implementation and management of water conservation measures.'

  'The East of England has the lowest rainfall in the country and is described officially as semi-arid. A high proportion of the available water resource is already being exploited and as such, even allowing for the impacts of climate change, careful management of water resources will be crucial if the economic potential of the Cambridge Sub-Region is to continue to be realised. development at North West Cambridge provides an opportunity to design water conservation measures into the infrastructure and buildings in order to reduce per capita demand for water. This should be a fundamental approach of the development. It is important that water conservation measures are applied to each building to ensure that there is a comprehensive strategy to water use reduction across the site and measures are not applied to some buildings and not others. The CSH provides appropriate targets to improve water conservation over time, using the same dates and Code levels as for energy reduction and other sustainability requirements set out in the Code. For residential development, the 30% reduction required at Code Level 4 compared to 2006 levels equates to 105 litres/head/day, while the 47% reduction required by Code Level 5 equates to 80 litres/head/day.'

  'The principle of reuse and recycling of water is also an important part of an integrated approach to water management that will facilitate the use of water from drainage as a design feature of the development. Care must be taken to ensure that water reuse and recycling does not have an adverse effect on biodiversity, or the wider water environment, in accordance with the requirements of the Water Framework Directive.'

- Policy NW25: Surface Water Drainage
  '1. Surface water drainage for the site should be designed as far as possible as a sustainable drainage system (SuDS) to reduce overall run-off volumes leaving the site, control the rate of flow and improve water quality before it joins any water course or other receiving body;
  2. The surface water drainage system will seek to hold water on the site, ensuring that it is released to surrounding water courses at an equal, or slower, rate than was the case prior to development;
  3. Water storage areas should be designed and integrated into the development with drainage, recreation, biodiversity and amenity value; and
  4. Any surface water drainage scheme will need to be capable of reducing the downstream flood risk associated with storm events as well as normal rainfall events. All flood mitigation measures must make allowance for the forecast effects of climate change.'

  'The eastern and northern parts of the site lie above the surrounding land. The area then slopes down to the Washpit Brook and as such surface water at the site drains naturally in that

direction. Apart from the immediate area along the Washpit Brook, there is little evidence of flood risk to the site itself.

However, surface water run-off will increase as a result of development, which will create impermeable areas. As a result, full attenuation measures will be required to ensure that surface water runoff from the development does not increase the risk of flooding to the site itself and areas downstream of the development.

The principles of Sustainable Drainage Systems (SuDS) should be employed where possible on the site to deal with surface water drainage. SuDS are an alternative approach to drainage that replicate as closely as possible the natural drainage of the site before development. This reduces the risk of flood downstream of the development, helps replenish ground water and remove pollutants gathered during run-off, benefiting local wildlife, in line with the SuDS management train.

A Strategic Water and Drainage Strategy will be required to support a planning application. This will include a strategic scale flood risk assessment for the site and any impact on the wider catchment, and will identify the types of SuDS proposed and options for future adoption and maintenance arrangements.

- Policy NW26: Foul Drainage and Sewage Disposal
  development of any single phase will not result in harm in the form of untreated wastewater or increased flood risk from treated wastewater. Planning conditions (which may include 'Grampian' style conditions) will link the start and phased development of the site to the availability of wastewater treatment capacity and the capacity of receiving watercourses.

  The foul water produced at the site will be directed to Cambridge Sewage Treatment Works at Milton to take advantage of consolidating existing facilities. Anglian Water are currently undertaking an appraisal of sewerage provision for the whole catchment and the outcome of that appraisal will inform the approach to be followed for foul water arising from North West Cambridge.

  In accordance with the requirements of the WFD, the treatment of wastewater must not cause deterioration of the water environment. The options for the treatment of foul drainage and sewage disposal from the site will need to be agreed with the Environment Agency to ensure that development does not result in further pressure on the water environment and compromise WFD objectives.

- Policy NW27: Management and Maintenance of Surface Water Drainage Systems
  1. All water bodies, watercourses and sustainable drainage features required to serve the development will be maintained and managed by one or more publicly accountable bodies to ensure a comprehensive and integrated approach to surface water drainage with defined areas of responsibility;
  2. No development shall commence until the written agreement of the local planning authorities has been secured stating that organisations with sufficient powers, funding, resources, expertise and integrated management are legally committed to maintain and manage all surface water systems on the North West Cambridge site in perpetuity.

  North West Cambridge's surface water drainage systems will need to be managed in perpetuity, during and beyond the lifetime of construction. The options for this are for maintenance and management to be the responsibility of one or more of the following:

  a. The City and/or District Council;
  b. A water company such as Anglian Water;
  c. A publicly accountable trust.

It is important to ensure that the body or bodies made responsible have adequate expertise and are financially stable in perpetuity. It will be the responsibility of the developer to secure and fund a suitable management and maintenance body/bodies in agreement with the Authorities.

Phase 1 Water Cycle Strategy for Major Growth Areas in and around Cambridge (October 2008)

A Phase 1 Water Cycle Strategy (WCS) was completed by consultants for Cambridgeshire Horizons. It assesses the potential impacts and constraints associated with the proposed major development areas by considering flood risk, water resources and supply, foul sewerage, wastewater treatment, water quality and water related ecology. This study establishes the most effective foul drainage and water supply strategy for all development in the Cambridge catchment and contains the following conclusions and recommendations in relation to the development.

This strategic planning document considers how the water services infrastructure can be achieved to meet the target of 42,500 new homes in Cambridge and South Cambridgeshire by 2021. Cambridge is supplied by groundwater abstraction and is situated in an area of *Serious Water Stress* as classified by the EA. It is vital that practices are put into place to reduce water consumption significantly in the new developments and that wherever practical, rainwater is harvested and recycled within the house and on the garden. Greywater systems also need to be considered. Water neutrality i.e. no increase in water supplies for the area over the next 10 years, is potentially achievable through:

- Compulsory implementation of the Code for Sustainable Homes (aiming for Level 6)
- Compulsory metering
- Installing water smart measures in existing homes

The following conclusions were drawn from the study relating to the water resources of the proposed North West Cambridge development site:

- Flood Risk Management
  - most of the site appears to fall within the EA's Flood Zone 1
  - There is a known history of flooding on the Beck Brook/Cottenham Lode catchment downstream of the site therefore the surface water discharge from the development must be managed by means of flow attenuation and long term storage to prevent any increase in flood risk downstream and should seek where possible to reduce the present risk.
  - It is advised that developers on this catchment undertake an independent hydraulic modelling study to:
    - Assess the current standard of protection for Histon and Impington.
    - Demonstrate that the flood risk in the Cottenham Lode catchment will not increase as a result of the combined cumulative effect of developments in the catchment.
    - Assess the opportunity for strategic flood risk mitigations options in the catchment.
    - Assess the opportunity for enhancing the level of service to areas where there is a known flood risk and make a contribution towards the cost of a scheme to enhance the level of service.
  - A site specific FRA is required by PPS25

- Groundwater and SuDS
  - The site is on variable geology of limited permeability; hence site specific surveys would be required to prepare a suitable SuDS strategy.

- Foul Drainage, Sewage Treatment and Water Quality
  - Foul water from the site will be discharged to the Cambridge WwTW. The discharge consent at the Works will not require revision to accommodate the increased flows from the strategic development sites including the NW Cambridge site before 2016; however, improvements may be needed to the treatment works in order to maintain

the quality of the effluent discharged to the River Cam. Some of these improvements may be required before 2016 if the EA decide to tighten the discharge quality limits of the consent as the volume of discharge from the works increases with the increase in new development, in order to comply with the requirements of the Freshwater Fish Directive of the WFD. AWS will seek investment to facilitate these improvements through its regulatory periodic review process for implementation in AMP 5 (2010 - 2015) or AMP 6 (2015 - 2021).

- The large diameter sewer network can accommodate al of the flow from the strategic developments without upgrade. The NW Cambridge site will connect into the branches of the tunnel network on Madingley and Histon Road but downstream of the junction of Madingley Road and Wilberforce Road to avoid connections to existing sewers that have insufficient capacity.
- The strategic development sites around Cambridge will not be connected to the sewerage system upstream of the four combined sewer overflows (CSOs) (except that at Cambridge WwTW) and therefore the discharge volume from these CSOs is not expected to increase as a result of the strategic development sites including the North West Cambridge site.

- Water Supply
  - Currently provided by Cambridge Water Company which will also be responsible for strategic water resources for the North West development site.
  - No specific technical constraints have been identified which might prevent growth in the study area including the Application Ste which will require a new 3.2km long 450mm diameter extension to the existing ring main to provide the required capacity.

Phase 2 Water Cycle Strategy for Major Growth Areas in and around Cambridge (October 2010)

A Phase 2 report was completed by consultants for Cambridge Horizons and considered the recommendations made in the Phase 1 report which focused on identifying a strategy and providing the technical evidence base to show how new sustainable water services infrastructure for the Major sites in and around Cambridge (including the North West Cambridge University site) could be delivered to maximise three opportunities:

- aspiring to water neutrality;
- improving biodiversity by protecting environmental water quality and hydromorphology, and;
- protecting and enhancing communities through sustainable surface water management.

The findings and recommendations of the WCS have been incorporated into the development proposals. The following is a summary of the findings relevant to the development presented under the following water infrastructure headings used in the WCS report:

- Water Resources – *CSH Level 5/6 should be the target for all new homes built after 2016. To meet CSH level 5/6 will require progressive implementation of greywater recycling (GWR) and/or rainwater harvesting (RWH) systems at either a household or community scale, in addition to implementation of water efficient appliances and changes in consumers' behaviours/attitudes towards water consumption. GWR and RWH are not currently widely implemented in the UK. Challenges remain with widespread implementation of GWR and RWH, not least because of the issues surrounding adoption of GWR or RWH systems; no consistent model or legislation is currently in place to support consistent adoption and water companies are currently not permitted to charge for non-potable water.*

- Sustainable Surface Water Management – taken from Section 4.5 of the Phase 2 WCS

4.5.4 Achieving the vision for sustainable surface water management relies on the development and subsequent implementation of planning policies and vigilant management of development through the planning process.

Planning applications should:

- *demonstrate the ambition for achieving 100% above ground drainage through implementation of a range of SuDS measures from source control (e.g. green roofs) to large-scale attenuation storage;*
- *provide justification and evidence where achieving 100% above ground drainage will not be feasible due to proposed densities, topography, ground conditions, or the location of development; demonstrate that drainage proposals are aligned with the forthcoming National SuDS Standards and will be accepted by Cambridgeshire County Council (as the new SuDS Approval Body); demonstrate that proposed SuDS measures will be integrated into the built environment to provide amenity and contribute to a network of open space, and; demonstrate that proposed SuDS measures will be used to enhance the local environment and biodiversity.*

4.5.5 The planning authorities will be responsible for implementing the recommendations through the development of planning policies and determination of planning applications, although other technical stakeholders (e.g. the Environment Agency) will provide technical advice and scrutiny of planning applications to support the planning authorities.

4.5.6 development where vision for sustainable surface water management may not be achievable.

4.5.7 Overall, the evidence base supports a local policy approach which aims for 100% above ground drainage for future developments, and using SuDS to create or enhance amenity and biodiversity and contribute to the provision of green infrastructure. However, it is recognised that there are a number of site-by-site circumstances which may make it difficult to achieve the aspiration with regards to surface water management.

- *High water table – a high water table may preclude the use of above ground drainage, as was the case at the Orchard Park development. In such cases, the planning application must provide evidence that above ground drainage is not possible and provide a strategy which ensure surface water runoff to the receiving watercourse is greenfield equivalent (on greenfield sites) or at a reduced rate (on brownfield sites). In some locations with a high water table it may be possible to utilise SuDS at a shallow depth, although it must be noted that this could increase the potential land take required for drainage.*
- *Topography – where there is insufficient gradient to drain surface water and the potential to infiltrate surface water is poor, it may be necessary to utilise underground drainage to ensure surface water is effectively drained away from domestic and non-domestic dwellings.*

- <u>Environmental Water Quality – taken from Section 5.4 of the Phase 2 WCS</u>
  The Phase 2 WCS has also set out the evidence base (from the CIRIA SUS Manual) to ensure surface and ground waters are adequately protected from polluted surface water runoff, including;

  - *ensuring a sufficient number of treatment stages are provided depending on the source of surface water runoff:*
  - *roofs only – 1 treatment stage;*
    residential roads, parking areas, commercial zones – 2 treatment stages;
    refuse collection/industrial areas/loading bays/lorry parks/highways – 3 treatment stages;
  - *ensuring that typical pollutants which are generated in the urban environment are considered and treated through SuDS approaches.*

- Wastewater Infrastructure – the WCS has made an assessment of treatment capacity available for the proposed new development in the Cambridge area including the potential impacts on flood risk and river quality downstream of the Cambridge WwTW. No significant increase was predicted to flood risk as a result of increases in treated flows. There are two sources of potential pollution to receiving watercourses as a result of increases in discharges to treatment works. These are:

    - Increase in final treated discharge load
    - Increase in intermittent discharges from combined sewer overflows (CSOs), pumping stations and storm tanks at WwTW.

    In the foreseeable future, consent limits will be set with a view to meeting the requirements of the Water Framework Directive (WFD) whose aim is to ensure that good river quality standards are met throughout each waterbody. The intention will be to set the discharge consent limits based upon the quality and volume of the receiving watercourse and the volume of wastewater effluent at the point of discharge. To maintain water quality in the watercourses, the consent standards in the future on the effluent discharges from the Cambridge WwTW will need to be periodically reviewed by the EA. Improvements to the treatment works will be required as the new developments come on stream to maintain the current discharge consent standards. This has been accepted by Anglian Water and planned for in their future AMP6 programme.

- Ecological Assessment – taken from Section 7.6 of the Phase 2 WCS

    7.6.2 This assessment has followed DCLG guidance on HRA. Coarse screening has identified three European sites with the potential to be affected by hypothetical water management changes associated with proposed new developments around Cambridge. One of these (Wicken Fen Ramsar site) was discounted at the coarse screening stage since its hydrology cannot be affected by any of the developments. The others (Breckland SAC and SPA and Ouse Washes SAC and Ramsar site) were discounted at the more detailed screening stage as it has been determined that the proposals will not have any discernible effect on their hydrology or water quality.

    7.6.3 Thus, it can be concluded that No Significant Effect would result from implementing the proposals and projections that are identified in the Cambridge WCS, noting that this assessment has only considered water environment consequences.

Level 1 Strategic Flood Risk Assessment (Sept 2010)

A Level 1 Strategic Flood Risk Assessment (SFRA) of the district has been completed on behalf of South Cambridgeshire District Council and Cambridge City Council by consultants, and endorsed by the Environment Agency. The study assessed the flood risk from all types of flooding in the district, taking into account the existing climate and predicted changes in the climate. The principal aim of the study was to set out flood risk constraints to help inform the preparation of the Local development Framework (LDF) documents. The study area has been categorised into Flood Risk Zones in accordance with Planning Policy Statement 25: 'development and Flood Risk' (PPS25). The Study replaces the previous SFRA carried out in 2005.

The SFRA is essentially a planning tool. It is an assessment of flood risk from all sources intended to inform the spatial planning process and, therefore, the level of detail and accuracy should relate to this strategic objective. The SFRA will help to steer future land use in a sequential and holistic manner, taking into consideration sustainability and the requirements of PPS25 (development & Flood Risk).

The SFRA considers all potential sources of flood risk within the administrative area and indicates that no historical flooding has been identified at the site; this would indicate that the site would be expected almost entirely to be located within Flood Zone 1.

Catchment Abstraction Management Strategy

Catchment Abstraction Management Strategies (CAMS) are developed by the Environment Agency to manage water resources at a local level. Through consultation with stakeholders and data acquisition within a CAMS area the documents present the current status of groundwater and outline a future framework for water use. CAMS incorporate a resource assessment that identifies how much water is available, known as the 'resource availability status', and where it is located.

The site falls within the Cam and Ely Ouse Catchment Abstraction Management Strategy[5] area which has identified the Washpit Brook as within the Old West River and Old West Level Dependent Management Unit (LDMU). The area has a current water resource availability status of 'No Water Available'. The target status of the area for 2013 and indeed up to 2019 is 'No Water Available'.

Catchment Flood Management Plan

Catchment Flood Management Plans (CFMPs) are developed by the Environment Agency on river catchments in the UK. Their aim is to understand the factors that contribute to flood risk within a catchment and to develop sustainable policies on the best ways to manage flood risk within the catchment over the next 50 – 100 years.

The site lies within the Great Ouse CFMP which is divided up into 25 different Policy Units. For each Policy unit the EA have defined a specific policy for managing flood risk. There are six Policy Options one of which is chosen for each Policy Unit. Policy Unit 20 (Cambridge) includes the area of the site. Policy 5, which is to '*take further action to reduce flood risk (now and/or in the future)*', was chosen by the EA for this Unit. This reflects the EA's concerns that there are high numbers of people and property in Cambridge at risk of flooding now and in the future with increased development and the impact of climate change. Policy 6 will allow present actions to control flood risk to be continued (channel maintenance and flood warning) and enhanced (the creation of new flood defences).

Cambridge and Milton Surface Water Management Plan

A SWMP outlines the preferred long-term strategy for the management of surface water flooding in high risk identified areas and is undertaken in consultation with local partners having responsibility for surface water management and drainage in that area. The goal of a surface water management plan is to establish a long-term action plan and to influence the future strategy of development for maintenance, investment and planning.

The Cambridge and Milton Surface Water Management Plan (SWMP) assesses the risk posed by surface water flooding within the study area by firstly identifying the areas with the highest risk of surface water flooding by comparing the modelling predictions with the historical database. This resulted in a list of eleven wetspots, which were then scored using a multi criteria analysis (MCA) method by which the impact of flooding on a wide range of receptors could be evaluated. MCA allows for the comparison of severity of flooding between geographical regions based on the perceived value of buildings. The eleven wetspots ranked in order of worst affected first after the MCA are:

1. King's Hedges and Arbury
2. Cherry Hinton (North and South)
3. North Chesterton
4. Bin Brook
5. South Chesterton
6. Milton
7. Castle School area
8. Cambridge Historic City Centre
9. Cherry Hinton Village
10. Vicar's Brook
11. Coldham's Common

[5] Cam & Ely Ouse Catchment Abstraction Management Strategy, Environment Agency (March 2007)

The top two wetspots identified were then subjected to further more detailed computer model development and engineering options were devised. Theoretical engineering measures to reduce the surface water flood risk were introduced into the models of each wetspot. Based on national guidance and best practice, open spaces within the existing urban environment were identified as potential areas where attenuation features could be utilised. These attenuation features could be basins, ponds, wetlands, swales etc. Measures such as permeable paving and rain gardens were also identified as potential ways of controlling the surface water and reducing flood risk.

The eastern portion of the site extends into the Bin Brook wetspot within which there are properties with a medium risk of flooding adjacent to the northern and eastern site boundary. However, the Bin Brook is not one of the top two wetspots identified; therefore the SWMP does not contain any prescriptive requirements for the management of surface water generated by the development.

APPENDIX B – PLANS AND SECTIONS FROM CONSULTATION

EXISTING HP GAS MAIN TO BE RETAINED

EXISTING TREES TO BE RETAINED

WSH-1395

WSH-1437

EXISTING CULVERT TO BE REMOVED

WSH-1548

WSH-1572

WSH-1606

WSH-1660

WSH-1744

WSH-1783

PROPOSED LOW FLOW CHANNEL TO ENABLE FLOODWATER TO DISSIPATE

EXTENT OF EXCAVATED GROUND TO FORM A WIDE SECOND STAGE CHANNEL CAPABLE OF STORING EXCESS FLOOD WATER GENERATED BY REDUCTION OF PEAK FLOW DOWNSTREAM

PROPOSED ONLINE FLOW CONTROL STRUCTURE INCORPORATING 1.3m Ø PIPE AND RAISED WEIR WITH A LEVEL OF 12.90mAOD. THE WEIR SHALL HAVE A LENGTH OF 7m TO EXTEND ACROSS THE FULL WIDTH OF THE EXISTING CHANNEL AND A WIDTH OF 5m TO FACILITATE ACCESS (REFER TO CROSS SECTION WSH1660)

PROPOSED BUND

WSH-1998

WSH-1961

EXISTING TREES TO BE RETAINED

PROPOSED 1mØ CULVERT BELOW MAINTENANCE ACCESS TRACK

EXISTING WATERCOURSE AND ASSOCIATED RIPARIAN ZONE TO BE RETAINED.

WSH-2060

WSH-2150

WSH-2195

EXISTING CULVERTS BELOW THE M11 TO BE RETAINED

WSH-2253

PROPOSED LOW FLOW CHANNEL TO CONVEY ATTENUATED DISCHARGE FROM RETENTION PONDS TO THE WASHPIT BROOK. THE CHANNEL WILL BE LOCALLY WIDENED AND DEEPENED IN VICINITY OF CULVERTS TO CREATE ONLINE HABITAT PONDS

EXISTING WATERCOURSE AND ASSOCIATED RIPARIAN ZONE TO BE RETAINED

WSH-2315

PROPOSED BUND

WSH-2437

EXTENT OF EXCAVATED GROUND TO FORM A WIDE SECOND STAGE CHANNEL CAPABLE OF STORING EXCESS FLOOD WATER GENERATED BY REDUCTION OF PEAK FLOW DOWNSTREAM. THE AREA TO THE WEST OF THE EASEMENT SHOULD BE TURFED TO FACILITATE MAINTENANCE ACCESS

PROPOSED CULVERT BELOW MAINTENANCE ACCESS TRACK

N

NOTES :

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS, SERVICES AND SPECIALIST DRAWINGS AND SPECIFICATION.
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4. DO NOT SCALE THIS DRAWING.
5. THIS DRAWING SHOWS ONE, BUT NOT THE ONLY, METHOD OF DELIVERING A PARAMETER COMPLIANT SOLUTION.
6. THE LOW FLOW CHANNEL SHOULD BE LOCALLY DEEPENED DOWNSTREAM OF PROPOSED OUTFALL AND EXISTING CULVERTS TO CREAT ONLINE PONDS

KEY :

- WASHPIT BROOK TO BE RETAINED
- PROPOSED LOW FLOW CHANNEL
- EXISTING OR PROPOSED POND
- PROPOSED SECOND STAGE CHANNEL TO STORE FLOODWATER
- PROPOSED BUND
- PROPOSED MAINTENANCE ACCESS TRACK
- EXISTING TREE
- HPG — EXISTING HIGH PRESSURE GAS MAIN AND 20m WIDE EASEMENT TO BE RETAINED

Client

UNIVERSITY OF CAMBRIDGE

Drawing Title

NORTH WEST CAMBRIDGE

ALTERNATIVE ILLUSTRATIVE PROPOSALS FOR THE WASHPIT BROOK

D127313-SK-065

Scale at A3 : 1:5,000		
Drw SH	App SES	Rev A
Chk JR	Date 24.11.11	Date 17.04.12

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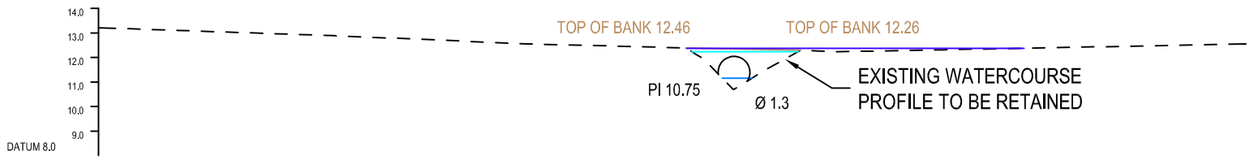
Plot Date :

AutoCAD File Name :

DB3



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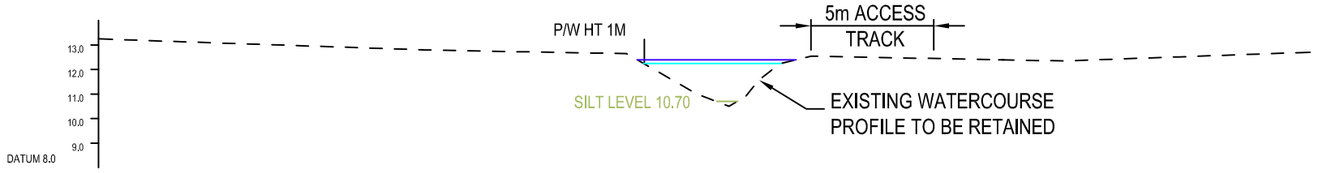

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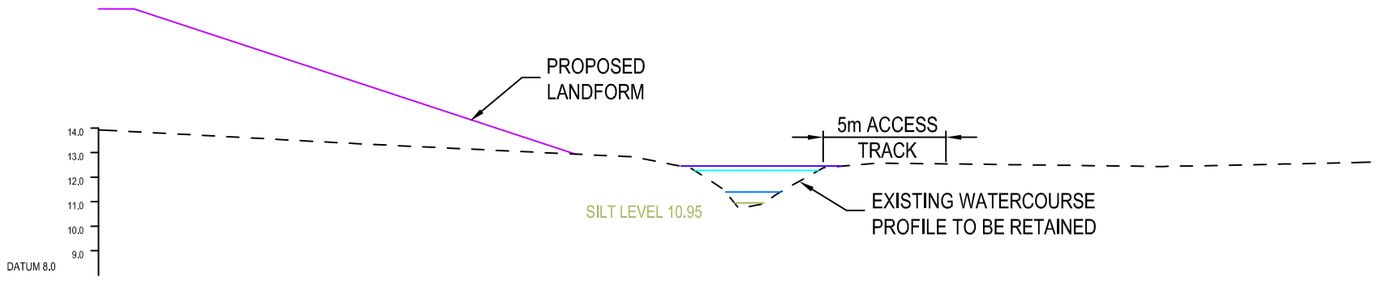

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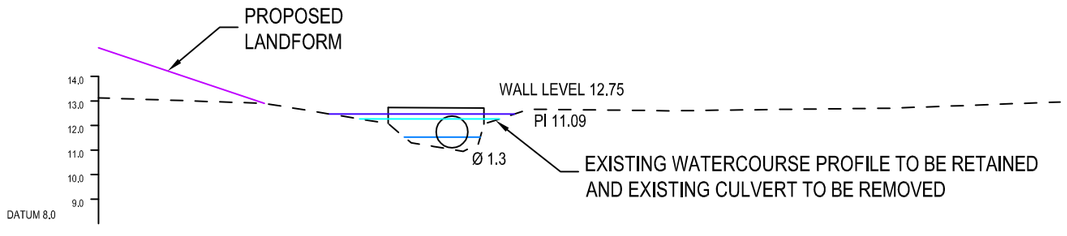

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NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS, SERVICES AND SPECIALIST DRAWINGS AND SPECIFICATION.
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3. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
4. DO NOT SCALE THIS DRAWING.
5. THIS DRAWING SHOWS ONE, BUT NOT THE ONLY, METHOD OF DELIVERING A PARAMETER COMPLIANT SOLUTION.
6. A 0.3m WIDE PLANTING SHELF SHALL BE PROVIDED IMMEDIATELY BELOW NORMAL WATER LEVEL ADJACENT TO 45° SLOPES

KEY

- EXISTING GROUND LEVEL
- PROPOSED GROUND LEVEL
- EXISTING WATER LEVEL
- 1:20 YEAR WATER LEVEL
- 1:100 YEAR WATER LEVEL

Plot Date :
File Name :

Client

UNIVERSITY OF CAMBRIDGE

Drawing Title

NORTH WEST CAMBRIDGE
ALTERNATIVE ILLUSTRATIVE PROPOSALS FOR WASHPIT BROOK
CROSS SECTIONS
(SHEET 1 OF 4)

D127313-SK-066

Scale at A3 : 1:250		
Drw SH	App BM	Rev
Chk JR	Date 30.04.12	Date

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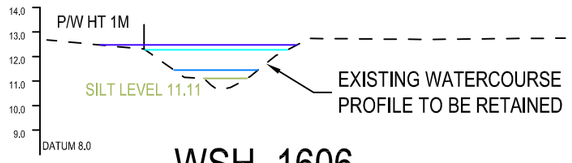
DB3



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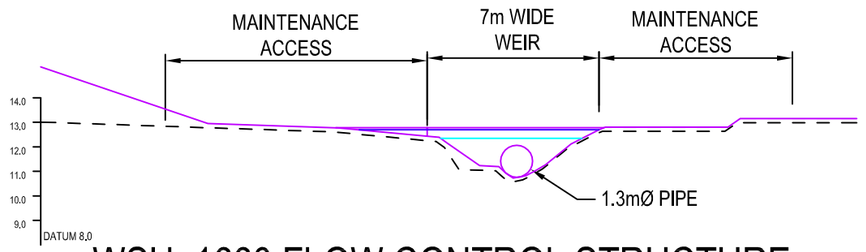
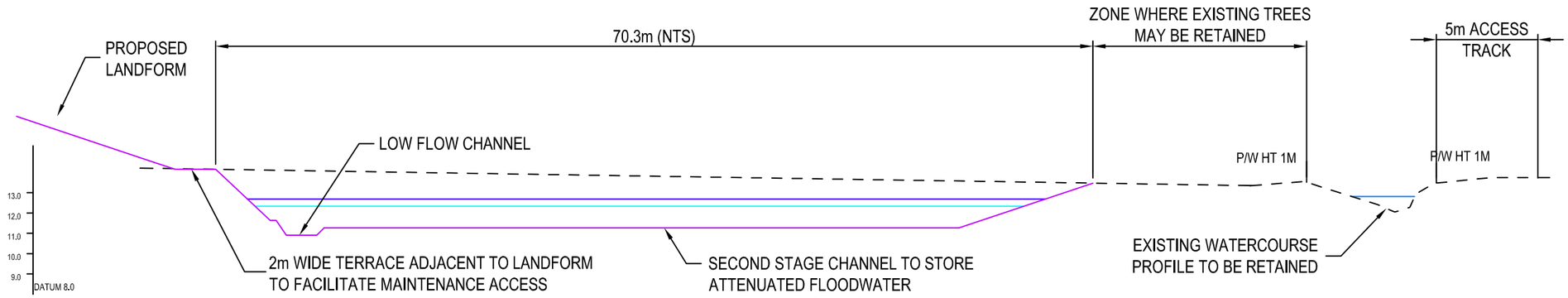


WSH_1660 FLOW CONTROL STRUCTURE



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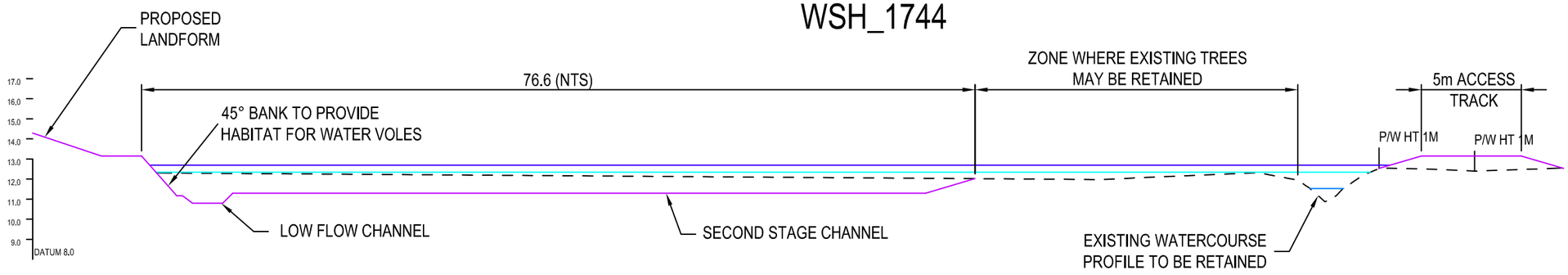

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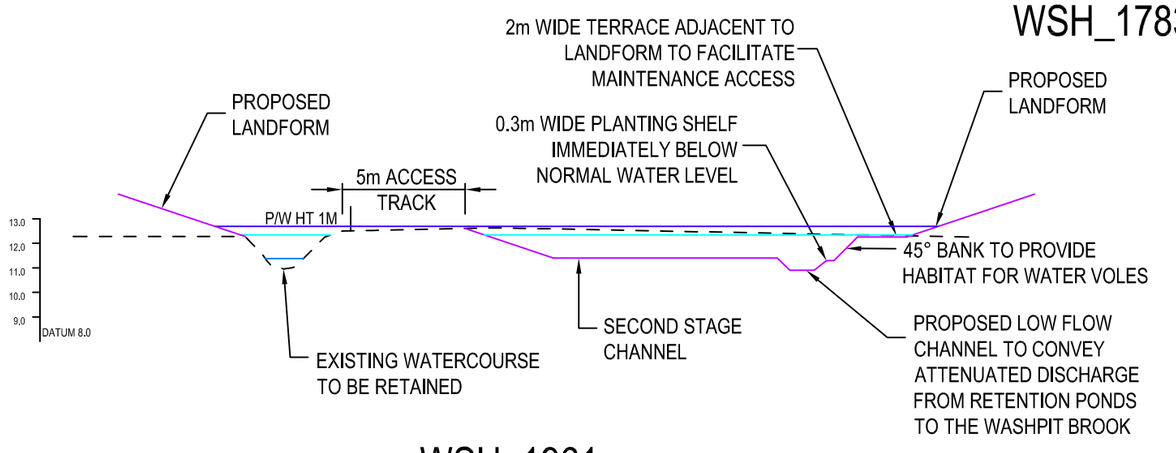

WSH_1961

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS, SERVICES AND SPECIALIST DRAWINGS AND SPECIFICATION.
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6. A 0.3m WIDE PLANTING SHELF SHALL BE PROVIDED IMMEDIATELY BELOW NORMAL WATER LEVEL ADJACENT TO 45° SLOPES

KEY

- EXISTING GROUND LEVEL
- PROPOSED GROUND LEVEL
- EXISTING WATER LEVEL
- 1:20 YEAR WATER LEVEL
- 1:100 YEAR WATER LEVEL

Plot Date :
File Name :

Client

UNIVERSITY OF CAMBRIDGE

Drawing Title

NORTH WEST CAMBRIDGE
ALTERNATIVE ILLUSTRATIVE PROPOSALS FOR WASHPIT BROOK
CROSS SECTIONS
(SHEET 2 OF 4)

D127313-SK-067

Scale at A3 : 1:250		
Drw SH	App BM	Rev
Chk JR	Date 30.04.12	Date

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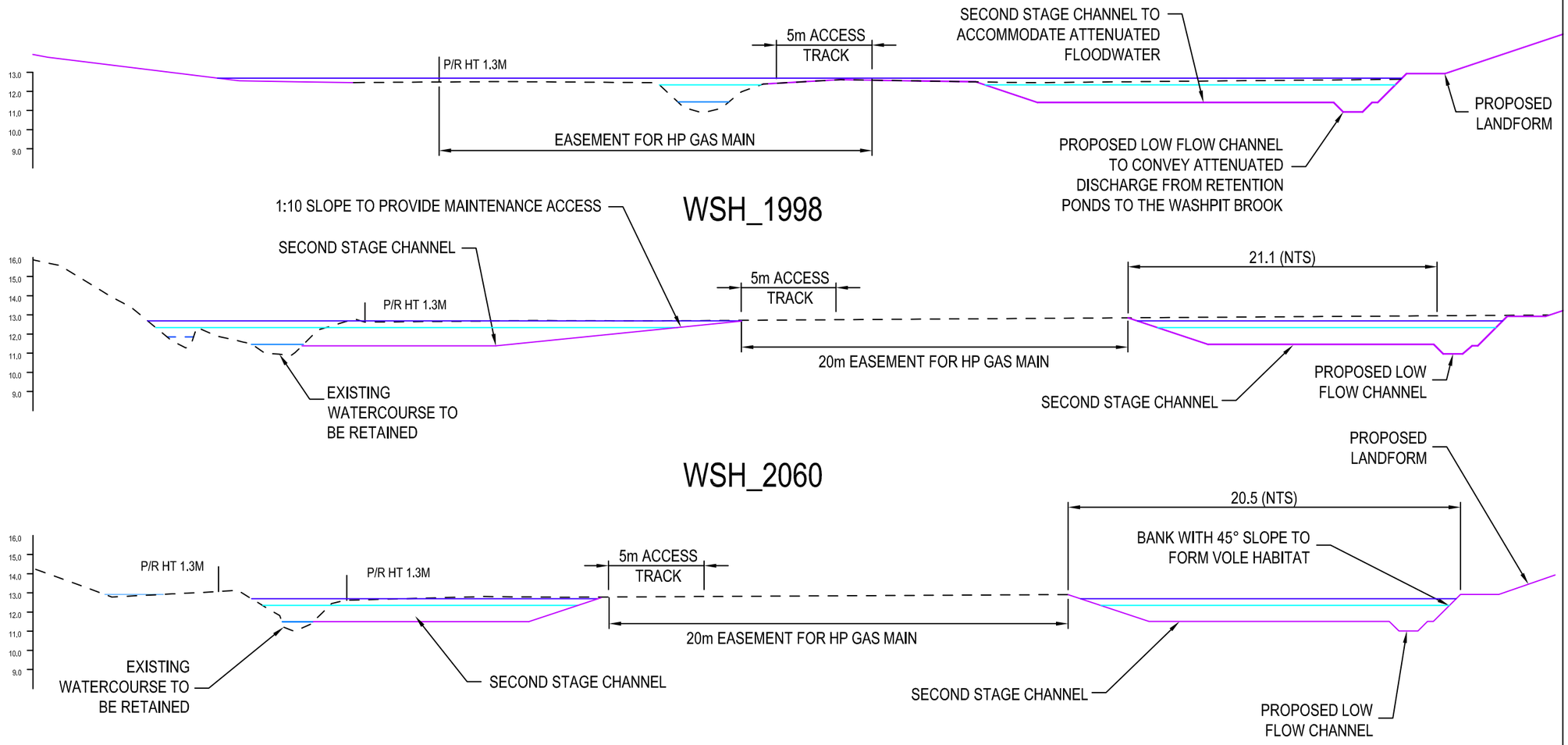
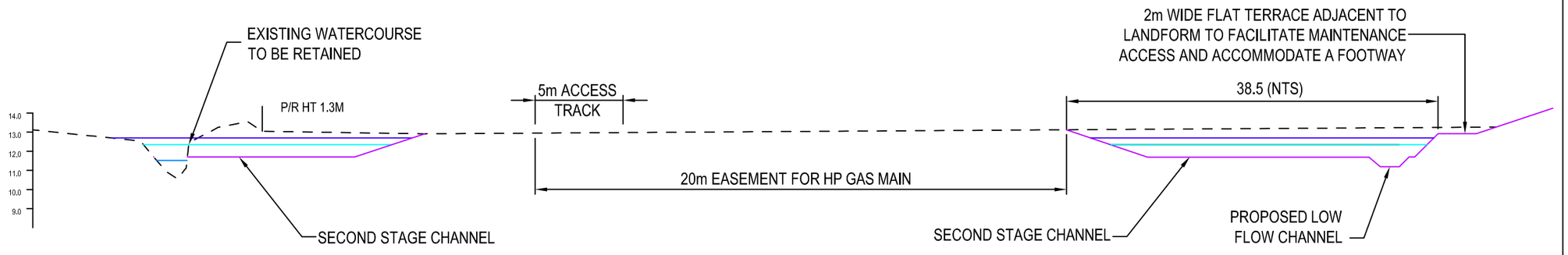
DB3



WSH_1998

WSH_2060

WSH_2150



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1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS, SERVICES AND SPECIALIST DRAWINGS AND SPECIFICATION.
2. ANY DISCREPANCIES IN DIMENSIONS OR DETAILS ON OR BETWEEN THESE DRAWINGS SHOULD BE DRAWN TO THE ATTENTION OF THE ARCHITECT AND / OR THE ENGINEER FOR CLARIFICATION.
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- EXISTING GROUND LEVEL
- PROPOSED GROUND LEVEL
- EXISTING WATER LEVEL
- 1:20 YEAR WATER LEVEL
- 1:100 YEAR WATER LEVEL

Plot Date :
File Name :

Client

UNIVERSITY OF CAMBRIDGE

Drawing Title

NORTH WEST CAMBRIDGE
ALTERNATIVE ILLUSTRATIVE PROPOSALS FOR WASHPIT BROOK
CROSS SECTIONS
(SHEET 3 OF 4)

D127313-SK-068

Scale at A3 : 1:250		
Drw SH	App BM	Rev
Chk JR	Date 30.04.12	Date

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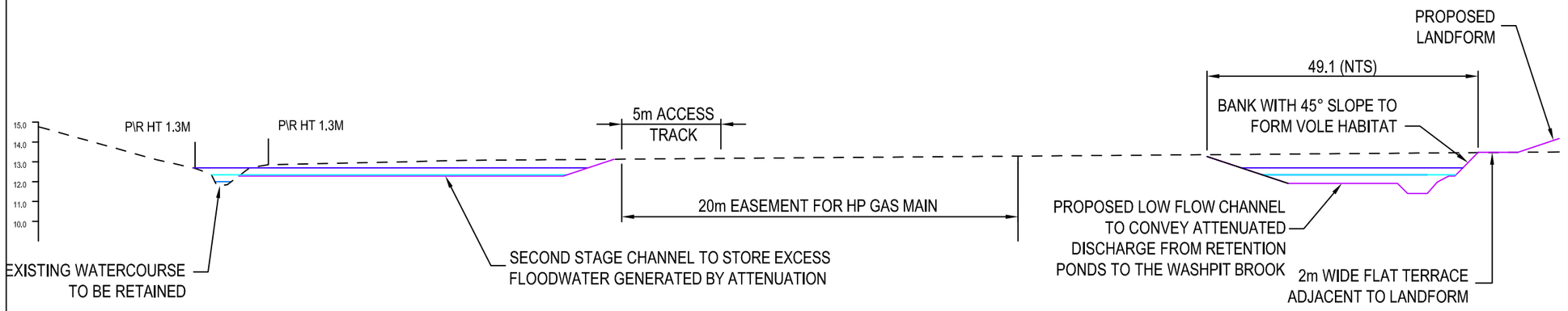
DB3



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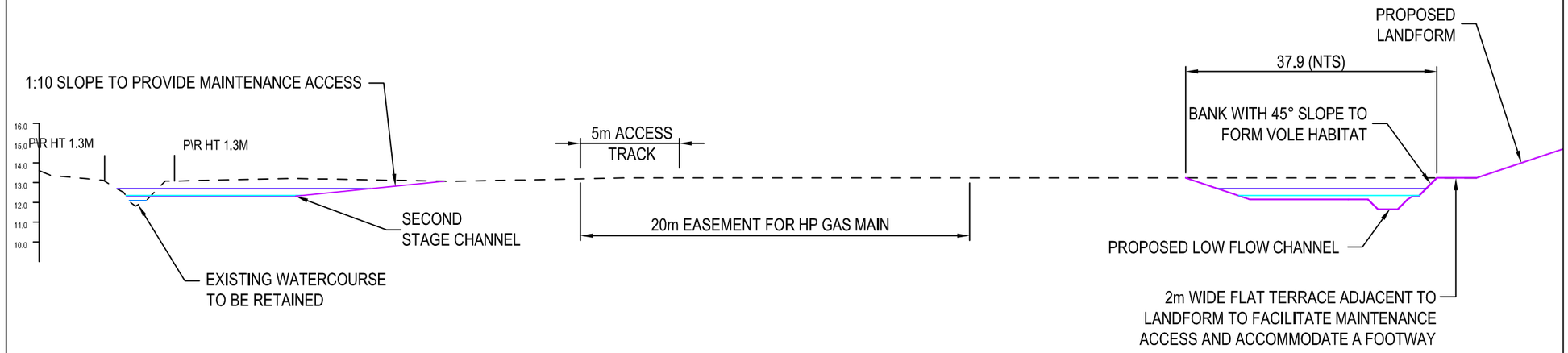

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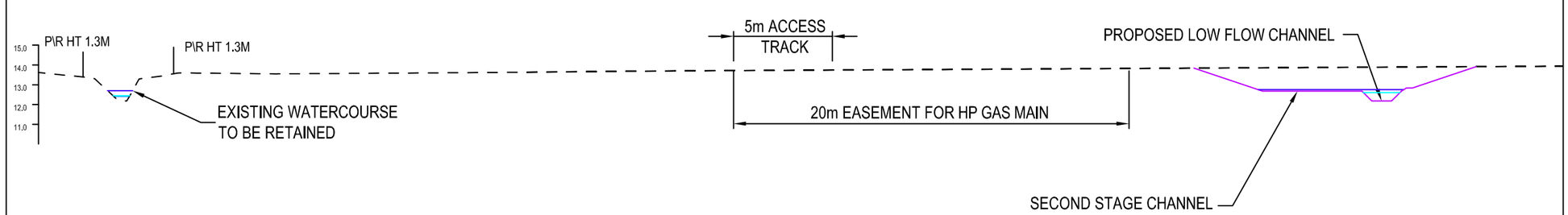

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1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS, SERVICES AND SPECIALIST DRAWINGS AND SPECIFICATION.
2. ANY DISCREPANCIES IN DIMENSIONS OR DETAILS ON OR BETWEEN THESE DRAWINGS SHOULD BE DRAWN TO THE ATTENTION OF THE ARCHITECT AND / OR THE ENGINEER FOR CLARIFICATION.
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KEY

- EXISTING GROUND LEVEL
- PROPOSED GROUND LEVEL
- EXISTING WATER LEVEL
- 1:20 YEAR WATER LEVEL
- 1:100 YEAR WATER LEVEL

Plot Date :
File Name :

Client

UNIVERSITY OF CAMBRIDGE

Drawing Title

NORTH WEST CAMBRIDGE
ALTERNATIVE ILLUSTRATIVE PROPOSALS FOR WASHPIT BROOK CROSS SECTIONS (SHEET 4 OF 4)

D127313-SK-069

Scale at A3 : 1:250		
Drw SH	App BM	Rev
Chk JR	Date 30.04.12	Date

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DB3

APPENDIX C – UPDATED PLANS AND SECTIONS

N

EXISTING HP GAS MAIN TO BE RETAINED

EXISTING CULVERT TO BE REMOVED

WSH-1395
WSH-1437
WSH-1548
WSH-1572
WSH-1606
WSH-1660
WSH-1744
WSH-1783
WSH-1908
WSH-1961
WSH-2060
WSH-2150
WSH-2195
WSH-2253
WSH-2315
WSH-2437

PROPOSED ONLINE FLOW CONTROL STRUCTURE INCORPORATING 1.3m Ø PIPE AND RAISED WEIR WITH A LEVEL OF 12.90mAOD. THE WEIR SHALL HAVE A LENGTH OF 7m TO EXTEND ACROSS THE FULL WIDTH OF THE EXISTING CHANNEL AND A WIDTH OF 5m TO FACILITATE ACCESS (REFER TO CROSS SECTION WSH1660)

PROPOSED 1mØ CULVERT BELOW MAINTENANCE ACCESS TRACK

EXISTING CULVERTS BELOW THE M11 TO BE RETAINED

PROPOSED CULVERT BELOW MAINTENANCE ACCESS TRACK

NOTES :

1. THIS DRAWING HAS BEEN CREATED FROM A 3D MODEL CREATED FROM THE CROSS SECTIONS USED WITHIN THE FLOOD MODEL. THE FINAL FORM OF THE CHANNEL WORKS WILL BE SUBJECT TO DETAILED DESIGN
2. FOR TYPICAL CROSS SECTIONS WSH-1395 TO WSH-1572 REFER TO DRAWING D127313-SK-066. FOR TYPICAL CROSS SECTIONS WSH-1660 TO WSH-2437 REFER TO DRAWING D127313-SK-P1-181
3. THE LOW FLOW CHANNEL SHOULD BE LOCALLY DEEPENED DOWNSTREAM OF PROPOSED OUTFALL AND EXISTING CULVERTS TO CREATE ONLINE PONDS

KEY :

- WASHPIT BROOK TO BE RETAINED
- PROPOSED LOW FLOW CHANNEL
- EXISTING OR PROPOSED POND - DETAILS TBC
- PROPOSED SECOND STAGE CHANNEL TO STORE FLOODWATER
- PROPOSED BUND
- PROPOSED MAINTENANCE ACCESS TRACK
- EXISTING TREE
- EXISTING HIGH PRESSURE GAS MAIN AND 20m WIDE EASEMENT TO BE RETAINED

This drawing is for preliminary purposes only and is subject to amendment during design development. UNDER NO CIRCUMSTANCES MUST THIS DRAWING BE USED FOR CONSTRUCTION PURPOSES

DRAFT FOR COMMENT

Revision Details	By / Check	Date	Suffix
TREE NOTES REMOVED	SG / SES	15.04.13	B
PROPOSE MAINTENANCE ACCESS ROUTE REVISED	JC / SES	29.01.13	A

NOTES

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

In addition to the hazard/risks normally associated with the types of work detailed on this drawing take note of above. It is assumed that all works on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

Purpose of Issue: INFORMATION

Client: UNIVERSITY OF CAMBRIDGE

Project Title: NORTH WEST CAMBRIDGE

Drawing Title: WASHPIT BROOK GENERAL ARRANGEMENT

Designed	Drawn	Checked	Approved	Date
IP	IP	SES	SES	21.12.12

URS Internal Project No.: D127313
Suitability:
Scale @ A1: 1:2500

URS Infrastructure & Environment UK Limited
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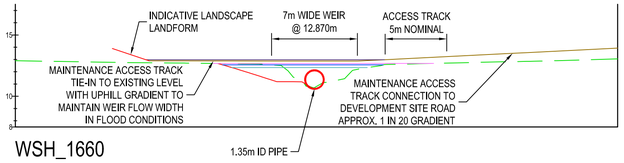
+44 (0)1256 310 201
www.ursglobal.com

Drawing Number: D127313-SK-P1-180
Rev: B

Plot Date : 15/04/2013 3:59:09 PM
File Name : K:\D127313 -NW CAMB\RDSDE\06A CAD\WORKING\SKETCHES\PHASE 1\D127313-SK-P1-180



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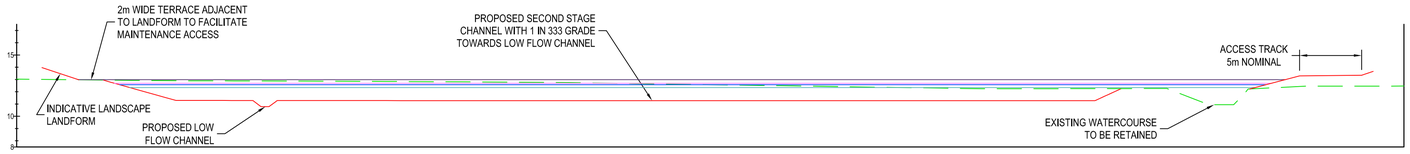

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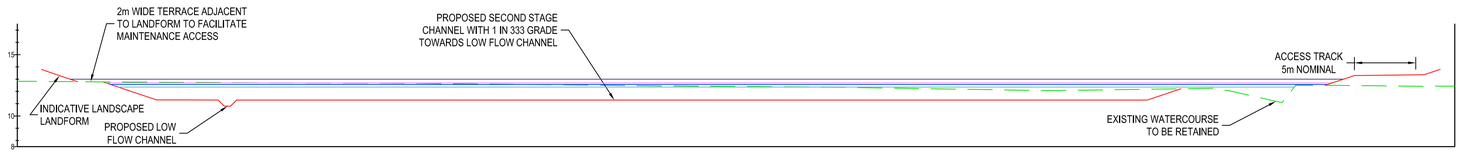

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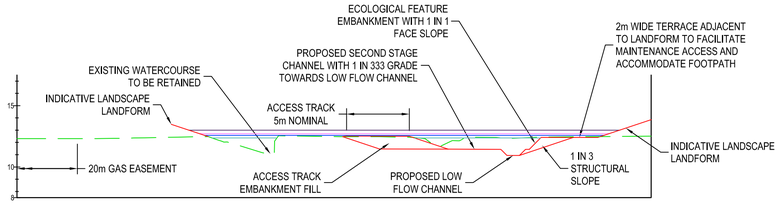

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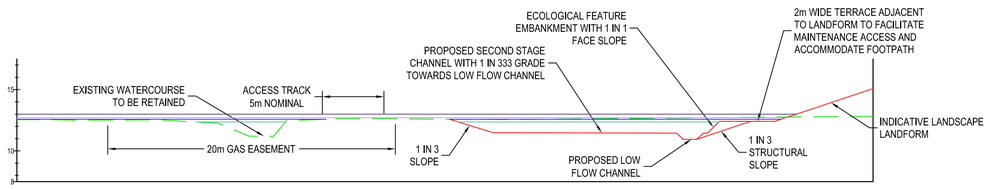

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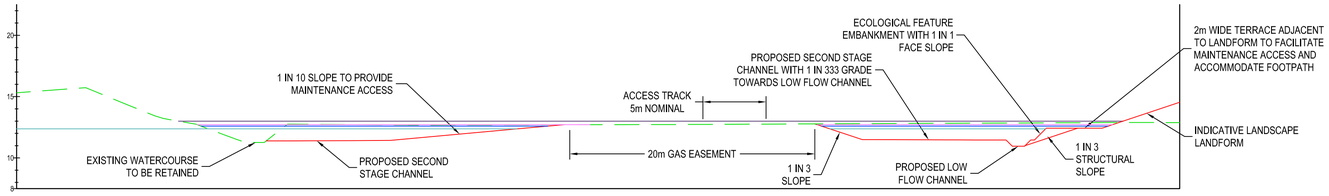

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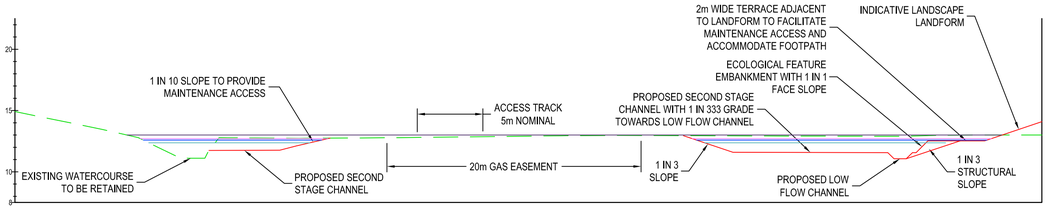

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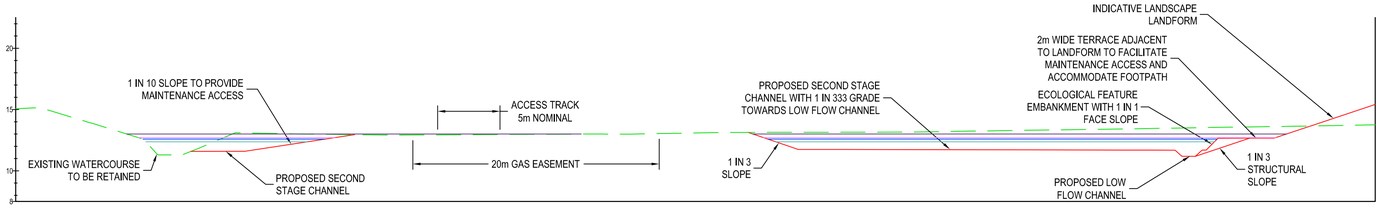

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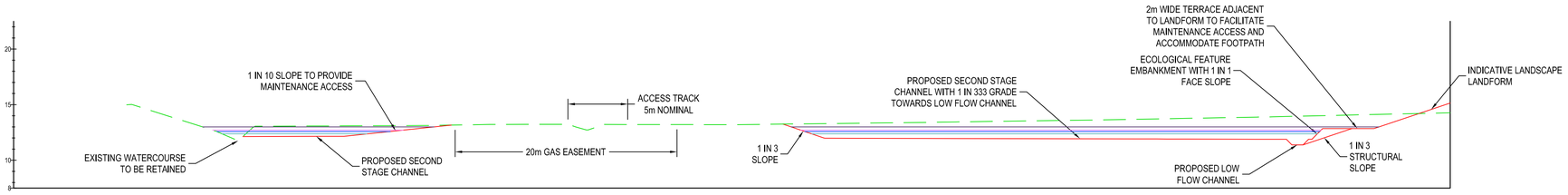
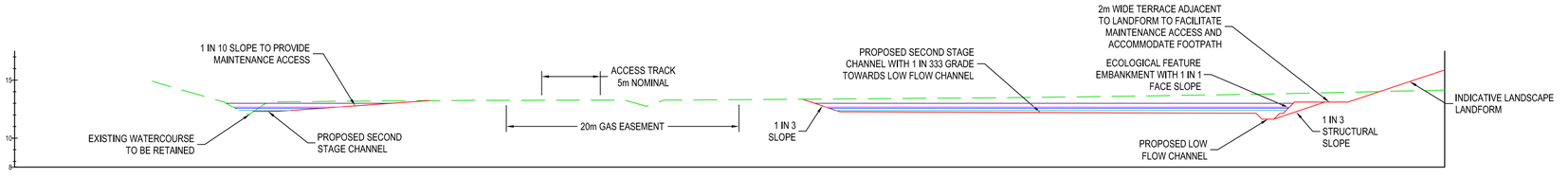


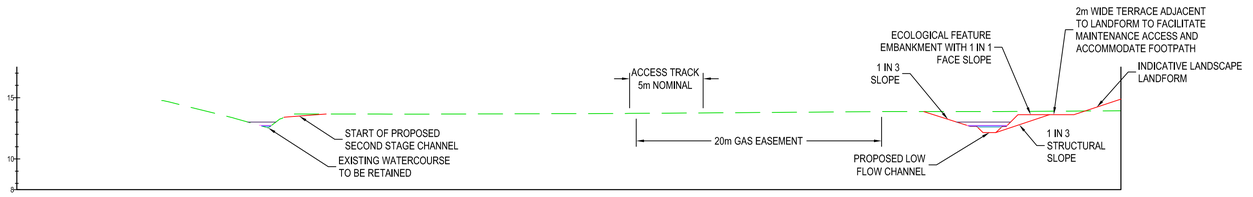
WSH_2253

KEY

- EXISTING GROUND
- PROPOSED GROUND
- FLOW CONTROL WEIR AND ACCESS LINK TO DEVELOPMENT
- 1 IN 20 YEAR FLOOD LEVEL
- 1 IN 100 YEAR FLOOD LEVEL
- 1 IN 100 YEAR PLUS CLIMATE CHANGE FLOOD LEVEL
- 1 IN 1000 YEAR FLOOD LEVEL



WSH_2315



WSH_2437

This drawing is for preliminary purposes only and is subject to amendment during design development. UNDER NO CIRCUMSTANCES MUST THIS DRAWING BE USED FOR CONSTRUCTION PURPOSES

Revision Details	By / Check	Date	Suffix

NOTES

1. THIS DRAWING HAS BEEN PRODUCED FROM A 3D MODEL CREATED FROM THE CROSS SECTIONS USED WITHIN THE FLOOD MODEL. THE FINAL FORM OF THE CHANNEL WORKS WILL BE SUBJECT TO DETAILED DESIGN
2. FOR SECTION LOCATIONS REFER TO DRAWING D127313-SK-P1-180

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

In addition to the hazard/risks normally associated with the types of work detailed on this drawing take note of above. It is assumed that all works on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

Purpose of issue: INFORMATION

Client: UNIVERSITY OF CAMBRIDGE

Project Title: NORTH WEST CAMBRIDGE

Drawing Title: WASHPIT BROOK TYPICAL CROSS SECTIONS

Designed	Drawn	Checked	Approved	Date
IP	IP	SES	SES	19.12.12

URS Internal Project No.: D127313

Suitability:

Scale @ A1: 1:250

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Drawing Number: D127313-SK-P1-181

Rev: -

Plot Date: 21/12/2012 9:55:05 PM
File Name: K:\D127313-NW CAMBRIDGE\CAD\WORKING\SKETCH\ESP\PHASE 1\D127313-SK-P1-181

APPENDIX D – MODEL SUMMARY SHEET

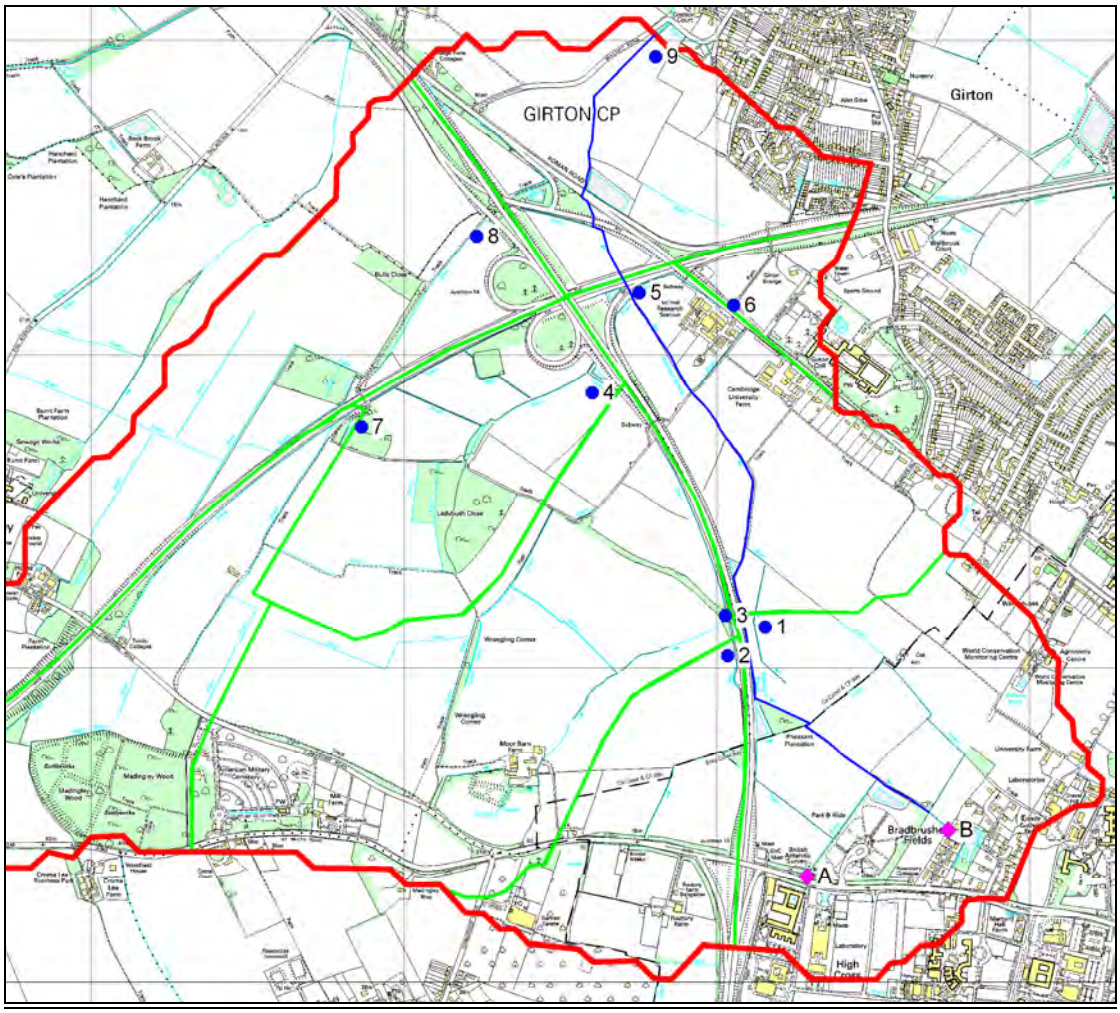
North West Cambridge ISIS Model Summary Sheet

URS has constructed a baseline and proposed model of the Washpit Brook, which flows through the NW Cambridge site. This document is intended to provide the key information for ease of review by the Environment Agency. Further information is included within the Level 3 Flood Risk Assessment.

Baseline Model

Hydrology

The Washpit Brook flows through the site, as shown on Figure 1 below (blue line). This blue line also defines the extent of the brook that has been included in the model. Figure 1 also shows the entire catchment (red outline) that contributes flow into the brook throughout the modelled reach. The sub-catchment area of each source of flow has been identified by green polygons. The extent of each sub-catchment was used to calculate the hydrological estimates for input into the hydraulic model



The hydrological estimates were entered into the model based upon the sub-catchments. Where appropriate, flows were entered using lateral flow nodes, to proportion inflow equally down the particular reach, such as catchment 1. Some catchments were found to flow into another, such as catchment 7 and 8 and therefore, the hydrographs were combined and entered as a point source because flow joins the Washpit Brook via a culvert.

Hydrographs were calculated using ReFH.

An ISIS model of the Washpit Brook was purchased from the Environment Agency, which overlapped with our model in the lower reaches (approximately 600m overlap). The EA model is approximately 10 years old and used the FEH rainfall-runoff method for the calculation of hydrographs. This method has been revised by the ReFH. Flows calculated in the EA model were larger i.e. 1 in 100 year event, EA flows approximately $7m^3/s$ and URS flows were $5m^3/s$. A sensitivity analysis was undertaken using the EA flows and no impact was observed in terms of the conclusions made using the URS hydrographs.

Naming convention
Cross sections were named based upon the chainage or distance from the model downstream extent.

Topographic survey
A topographic survey of the Washpit Brook was commissioned by URS following a site visit. The survey was undertaken by Greenhatch Group in August 2010.

URS undertook a site visit to identify specific cross section locations of the Washpit Brook and its tributaries. This included information at all key structures in the model reach.

Within the site, cross sections were extended through the floodplain where necessary using the site topographic survey. Beyond the site, cross sections were extended using 1m resolution LiDAR data (airborne topographic information).

Model construction
Interpolated nodes were used to improve model stability. A notional weir was also included at the upstream extent of the model for the same purpose. Structures were modelled using conduits, orifices or bridges.

A manning's 'n' value of 0.05 was applied to the entire model.

The model is geo-referenced, except where extended beyond the original watercourse survey extent.

Some cross sections were copied and levels adjusted accordingly, using interpolation, where new cross section (rather than interpolate) nodes were needed, such as at junctions.

The downstream boundary condition applied normal depth and a sensitivity test found that the model was extended sufficiently far downstream, so that any uncertainties associated with this would have no impact on flooding at the site.

Sensitivity analysis
A sensitivity analysis was undertaken on the manning's, flow (including ±20% and application of EA hydrographs), structure blockage and downstream boundary condition.

Proposed Model – Rev3 2012
The description below referred to the refined proposed model, which has been amended to reflect the revised proposals for the Washpit Brook. All components of the proposed model are the same as

the baseline model, except for the geometry of the watercourse, within a certain reach of the Washpit Brook through the site. The hydrological input has also been changed slightly.

The changes made to the proposed model have been summarised below:

- Included landscaping bunds between node WSH-2437[1] and WSH-1400, based upon 1 in 3 side slopes.
- The Washpit Brook has been realigned in various locations. This incorporates:
    - Repositioning the Washpit Brook along the edge of the two stage channel, adjacent to the maintenance access track and associated 20m High Pressure Gas Main Easement Zone. This connects to the M11 balancing pond and the ditch that flows around its perimeter.
    - A new low flow channel along the western toe of the earthwork landforms to intercept the attenuated discharge from the retention ponds and to connect with the existing reach of the Washpit Brook located upstream.
    - Retaining the central section of the Washpit Brook downstream of the culverts that pass below the M11, until the confluence with a new culvert beneath the maintenance access track (to allow passage of the new channel described above).
- Included new flow control structure (culvert and raised spill level) at WSH-1660 intended to promote storage of floodwater upstream. The proposed online flow control structure will be positioned upstream (i.e. south) of some existing mature trees alongside the northern half of the Washpit Brook
- Ground levels on banks of Washpit Brook and the newly created channels have been lowered to increase the storage volume between nodes WSH-2437 and WSH-1660;
- Ground levels within the 20m High Pressure Gas Main Easement Zone have been retained, but spill units have been included to allow water to flow over the 20m High Pressure Gas Main Easement Zone from one channel to another.
- Included a 1m diameter pipe culvert at WSH-1901 to allow passage of the new channel beneath the maintenance access track.
- Re-profiled Washpit Brook upstream of WSH-1660 to maximise the storage volume.
- Raised right bank level to 13.15m AOD from the flow control structure to the adjoining landscape bund upstream, to ensure the floodwater does not encroach upon built areas within the Proposed Development..

Hydrology

[1] Landscaping bunds extend a little further upstream but all scenarios are in bank at this location and the landscaping bunds are of no impact

The hydrology from the baseline modelling has been retained for the proposed flood modelling. However, the manner in which it has been applied to the hydraulic model has been altered slightly in the proposed model. Due to the realignment of the Washpit Brook, connectivity to the upstream catchment has been altered, which has resulted in the slight modification to the hydrological input. Catchment 1 (as defined within the Level 3 FRA) has been split into two sub-catchments, i.e. Catchment 1A and Catchment 1B. Catchment 1A accounted for approximately 91% of the original catchment area and the hydrographs were therefore reduced by 9%. The remainder of the hydrograph (i.e. approximately 9%) was applied to Catchment 1B. Catchment areas were estimated based upon topographic data.

Sensitivity analysis
A sensitivity analysis was undertaken on the application of EA hydrographs, to confirm if the use of larger flows made any difference to the conclusions i.e. does the proposed development result in any detrimental impact on the basis of these larger flows. No significant difference was observed.

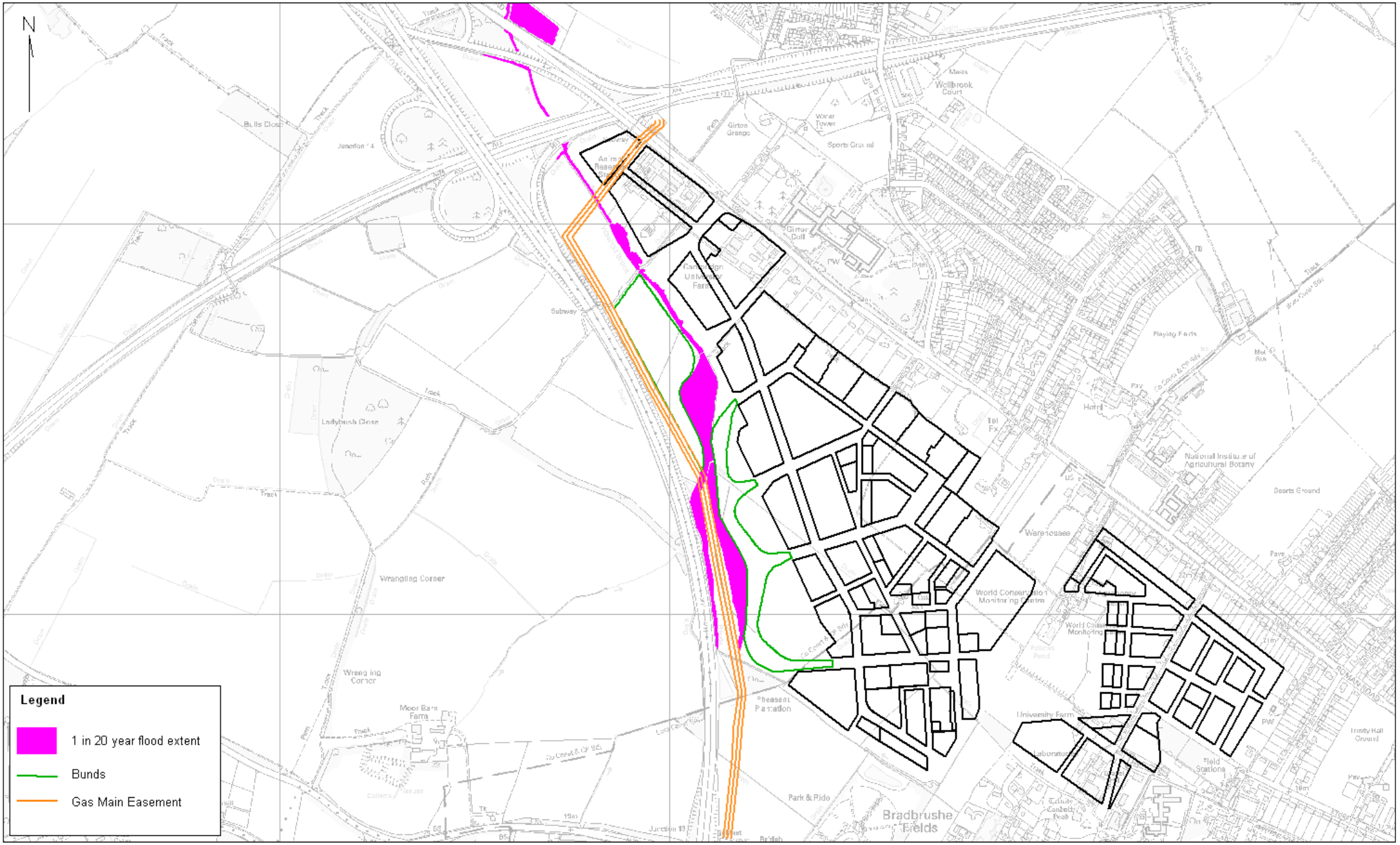
A second sensitivity analysis was undertaken to examine the impact of blockage on the proposed flow control structure.

Model Summary
A single .dat file was used for various scenarios, using .ied files to represent different design hydrographs.

Model	Event type	.dat file
Baseline 1 in 20 year event	Design	WASHPIT_BASELINE_FINAL
Baseline 1 in 100 year event	Design	WASHPIT_BASELINE_FINAL
Baseline 1 in 100+CC year event	Design	WASHPIT_BASELINE_FINAL
Baseline 1 in 1000 year event	Design	WASHPIT_BASELINE_FINAL
Baseline 1 in 20 year event Halcrow Flows	Sensitivity	WASHPIT_BASELINE_FINAL
Baseline 1 in 100 year event Halcrow Flows	Sensitivity	WASHPIT_BASELINE_FINAL
Baseline 1 in 100+cc year event Halcrow Flows	Sensitivity	WASHPIT_BASELINE_FINAL
Baseline 1 in 1000 year event Halcrow Flows	Sensitivity	WASHPIT_BASELINE_FINAL
Baseline 1 in 100 year event 50% Blockage (WSH-2657)	Sensitivity	WASHPIT_BASELINE_FINAL_BLOCKAGEB1-50%
Baseline 1 in 100 year event 50% Blockage (WSH-1579)	Sensitivity	WASHPIT_BASELINE_FINAL_BLOCKAGEB2-50%
Baseline 1 in 100 year event 50% Blockage (WSH-1395)	Sensitivity	WASHPIT_BASELINE_FINAL_BLOCKAGEB3-50%
Baseline 1 in 100 year event 50% Blockage (WSH-1255)	Sensitivity	WASHPIT_BASELINE_FINAL_BLOCKAGEB4-50%
Baseline 1 in 100 year event 50% Blockage (WSH-1014)	Sensitivity	WASHPIT_BASELINE_FINAL_BLOCKAGEB5-50%
Baseline 1 in 100 year event 95% Blockage (WSH-1014)	Sensitivity	WASHPIT_BASELINE_FINAL_BLOCKAGEB5-95%
Baseline 1 in 100 year event minus 20% Manning's n value	Sensitivity	WASHPIT_BASELINE_FINAL_MAN-20%
Baseline 1 in 100 year event plus 20% Manning's n value	Sensitivity	WASHPIT_BASELINE_FINAL_MAN+20%
Baseline 1 in 100 year event downstream boundary condition plus 0.5m	Sensitivity	WASHPIT_BASELINE_FINAL_DSBC+0.5m
Baseline 1 in 100 year event minus 20% flow	Sensitivity	WASHPIT_BASELINE_Q100_FINAL_FLOW-20%
Proposed 1 in 20 year event	Design	WASHPIT_PROP_REV3_1_FINAL.DAT
Proposed 1 in 100 year event	Design	WASHPIT_PROP_REV3_1_FINAL.DAT

Proposed 1 in 100+CC year event	Design	WASHPIT_PROP_REV3_1_FINAL.DAT
Proposed 1 in 1000 year event	Design	WASHPIT_PROP_REV3_1_FINAL.DAT
Proposed 1 in 20 year event Halcrow Flows	Sensitivity	WASHPIT_PROP_REV3_1_FINAL.DAT
Proposed 1 in 100 year event Halcrow Flows	Sensitivity	WASHPIT_PROP_REV3_1_FINAL.DAT
Proposed 1 in 100+cc year event Halcrow Flows	Sensitivity	WASHPIT_PROP_REV3_1_FINAL.DAT
Proposed 1 in 1000 year event Halcrow Flows	Sensitivity	WASHPIT_PROP_REV3_1_FINAL.DAT
Proposed 1 in 100 year event 50% blockage (WSH-1660)	Sensitivity	WASHPIT_PROP-REV3_1_ 50%BLOCK.DAT
Proposed 1 in 100 year event 50% blockage (WSH-1660)	Sensitivity	WASHPIT_PROP-REV3_1_ 75%BLOCK.DAT

APPENDIX E – FLOOD MAPS



Project: **North West Cambridge**

Title: **Proposed Fluvial Flood Extent of a 1 in 20 Year Event**

Figure A

Scale at A3: 1:9,000			
Drw DB	App NB	Rev 03	
Chk NB	Date 08/08/11	Date 16/11/12	

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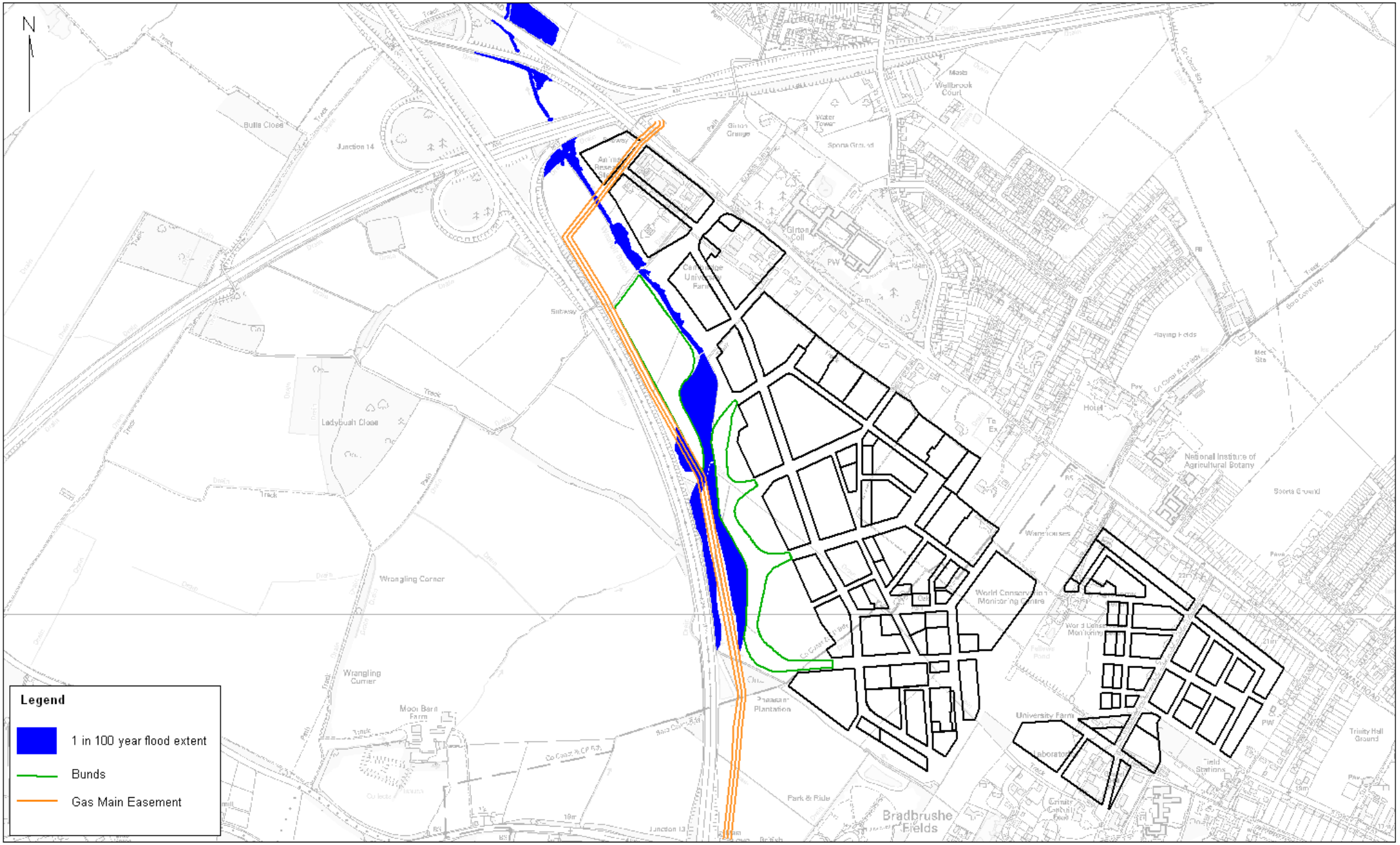

Project: **North West Cambridge**

Title: **Proposed Fluvial Flood Extent of a 1 in 100 Year Event**

Figure B

Scale at A3: 1:9,000			
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Chk NB	Date 08/08/11	Date 16/11/12	

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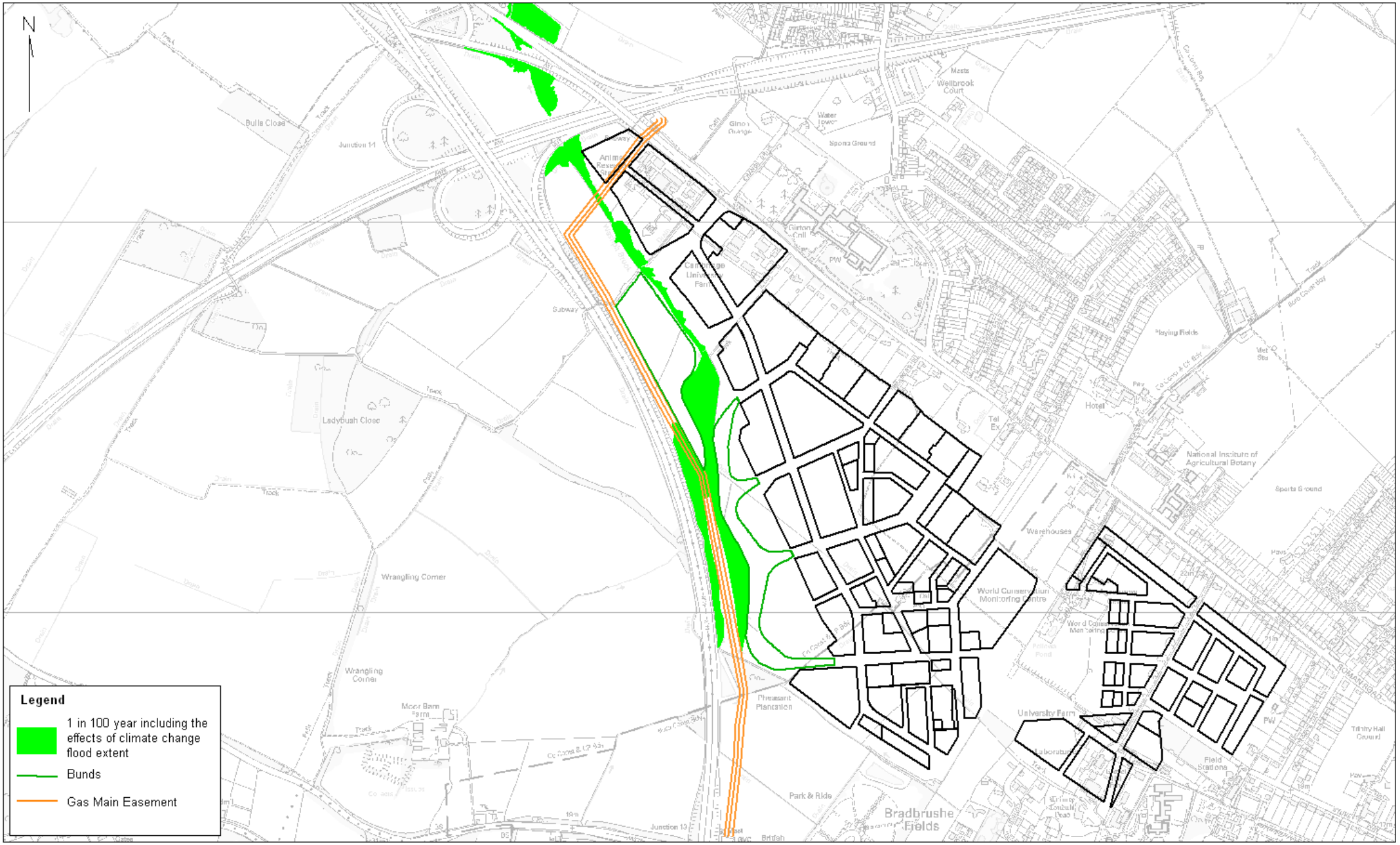

Project: **North West Cambridge**

Title: **Proposed Fluvial Flood Extent of a 1 in 100 Year Plus Climate Change Event**

Figure C

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Chk NB	Date 08/08/11	Date 16/11/12	

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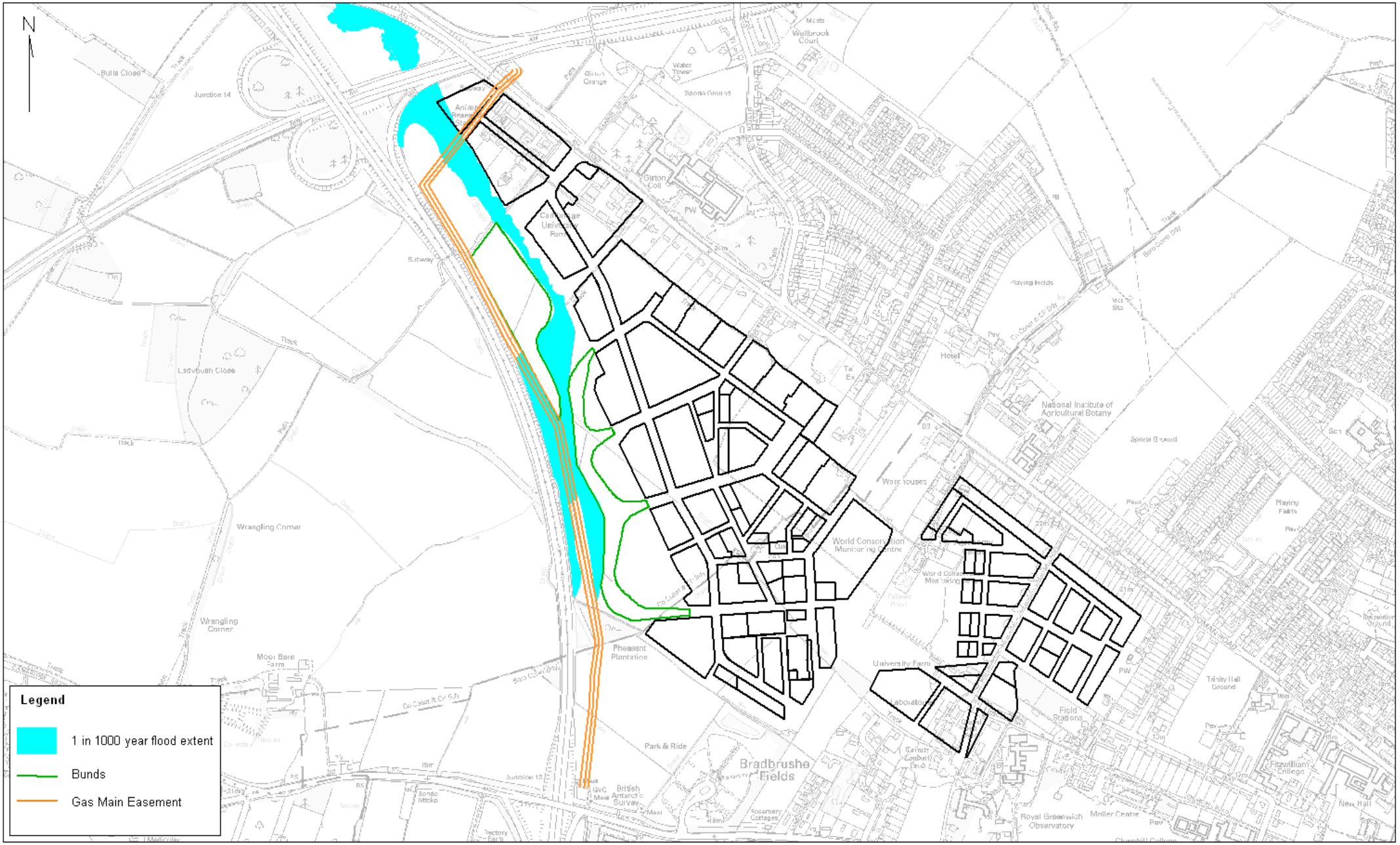

Project: **North West Cambridge**

Title: **Proposed Fluvial Flood Extent of a 1 in 1000 Year Event**

Figure D

Scale at A3: 1:9,000			
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Chk NB	Date 08/08/11	Date 16/11/12	

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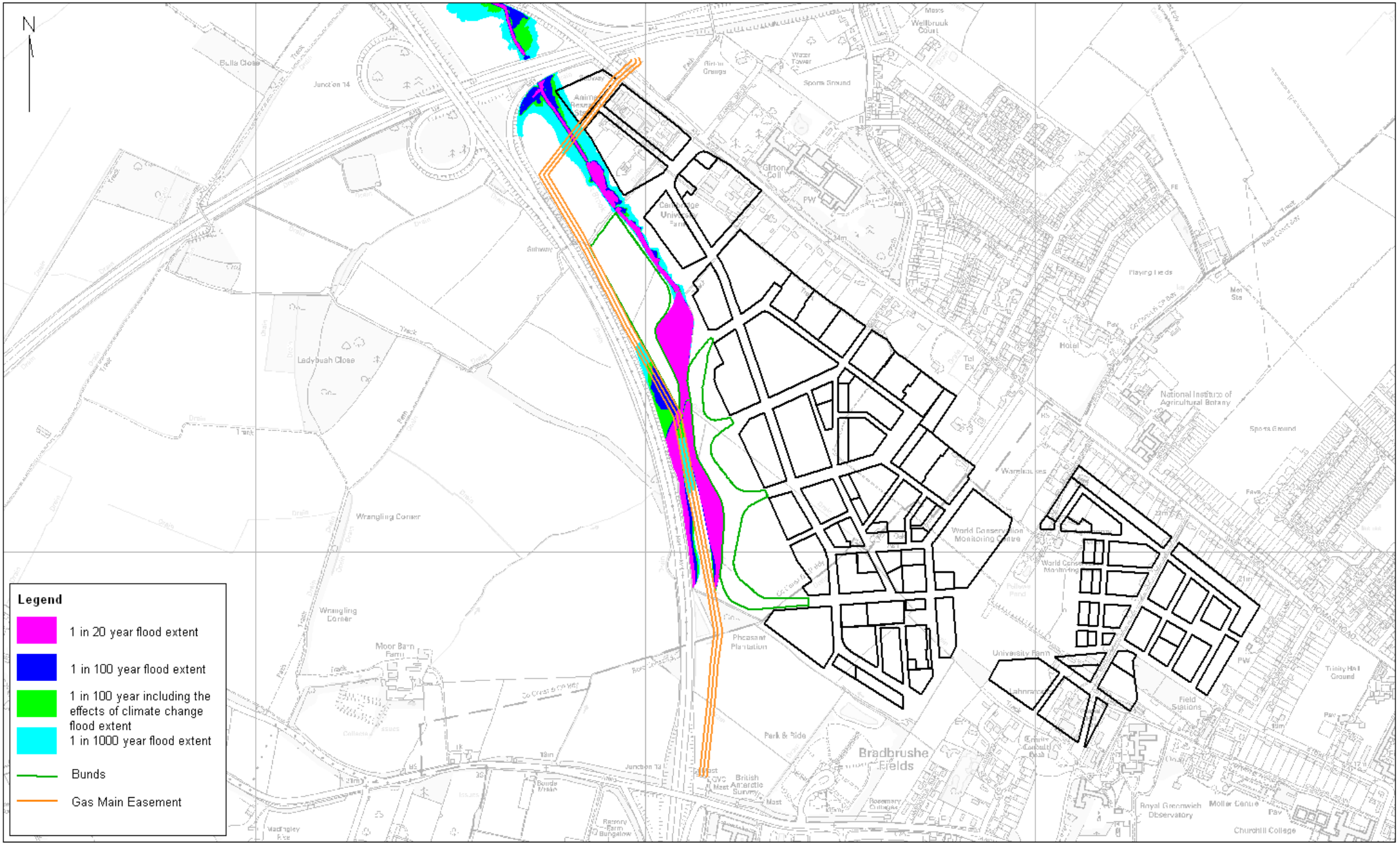

Project: **North West Cambridge**

Title: **Proposed Fluvial Flood Extent**

Figure E

Scale at A3: 1:9,000			
Drw DS	App NB	Rev 03	
Chk NB	Date 08/08/11	Date 16/11/12	

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APPENDIX F – SENSITIVITY ANALYSIS

Sensitivity Analysis – Refined Flood Alleviation Model

Sensitivity testing has been undertaken on the refined flood alleviation hydraulic model. This was to assess the impact of the hydrology calculated as part of the hydraulic modelling prepared by Halcrow in 2003 as part of the Cottenham Load Flood Alleviation Scheme pre-feasibility assessment. A blockage scenario of the proposed flow control structure has also been investigated to test the impact upon the likely flood extents.

Halcrow Hydrology

Hydrographs and peak flows were available for all of the events investigated within this study, except for the 1 in 1000 year return period, which was extrapolated. The Halcrow peak flows were larger than those calculated by URS, but applied the FEH rainfall runoff method, which has now been superseded by the ReFH method, as used by URS.

The hydrographs were entered into the model split based upon the proportion of sub-catchment area, as undertaken for baseline modelling (see Section 5.3.5). The impact observed both upstream and downstream of the site are illustrated in Table 1 and Table 2 below. The same format of table is used as presented within Section 7.3 of the main report, but the peak flows or stage illustrated below are based upon the Halcrow flows, for both baseline and proposed models.

The same conclusions can be drawn as that identified in Section 7.2. The sensitivity test shows that the proposed flood alleviation scheme still offers significant betterment upstream and downstream, using either the Halcrow flows or the URS flows. This is achieved under all of the scenarios investigated. The only difference is that the betterment offered is slightly reduced. For example, on the basis of the URS flows and under the 1 in 20 year event (i.e.Q20) a 28% reduction in flow downstream of the site is observed. However, based upon the results identified in Table , a reduction of 13% is observed using the Halcrow flows.

Table 1: Impact upon Peak Flows Downstream of the Site (Halcrow Flows)

Q20		
Node	BASELINE	PROPOSED
WSH-2060	2.52	2.18
Q100		
Node	BASELINE	PROPOSED
WSH-2060	3.5	3.26
Q100+CC		
Node	BASELINE	PROPOSED
WSH-2060	4.05	3.91
Q1000		
Node	BASELINE	PROPOSED
WSH-2060	4.52	4.40

Table 2: Impact upon Stage Upstream of the Site

Q20		
Node	BASELINE	PROPOSED
WSH-2060	12.67	12.57
Q100		
Node	BASELINE	PROPOSED
WSH-2060	12.86	12.85
Q100+CC		
Node	BASELINE	PROPOSED
WSH-2060	12.97	12.97
Q1000		
Node	BASELINE	PROPOSED
WSH-2060	13.06	13.05

Flow Control Blockage Scenario

Table able 3 illustrates the impact of a 50% and a 75% blockage scenario of the proposed flow control structure, on the basis of the 1 in 100 year event.

Table 3: Sensitivity testing of blockage of proposed structure

Node/Cross Section	Q100 Water Level (mAOD)	50% Blockage at WSH-1406	75% Blockage at WSH-1406
WSH-2947	14.99	14.99	14.99
WSH-2598	13.61	13.61	13.61
WSH-2150	12.59	12.74	12.94
WSH-1961	12.58	12.74	12.94
WSH-1606	12.42	12.37	12.35
WSH-1297	12.31	12.28	12.27
WSH-1014	11.85	11.74	11.59
WSH-0588	10.74	10.72	10.69
WSH-0124	10.46	10.44	10.43

Node WSH-2947 and WSH-2598 are located sufficiently far upstream not to experience any impact associated with blockage of the proposed flow control structure. Therefore, the cells are un-shaded. With distance downstream towards the flow control structure an increase in water level is observed, as would be expected.

Under the 75% blockage scenario a peak water level of 12.94m AOD is observed at the flow control structure. With the spill level set at 12.90m AOD, a limited rate of flow spills over the high level spill structure. This blockage scenario is not considered to introduce any additional flood risk to the proposed development, because the peak water levels observed are less than that under the 1 in 1000 year event, which the proposed development will be protected from.

Downstream of the flow control structure, peak water levels are significantly reduced. This is a result of the additional floodwater stored upstream due to the reduction in conveyance through the culvert. Therefore, the impact of structure blockage is considered to be beneficial for third parties downstream.

APPENDIX G – TABLE OF RESULTS

BASELINE MODEL RESULTS						
	Max Stage (mAOD)					
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-3132*	15.73	15.77	15.82	15.9	15.91	15.98
WSH-3075	15.66	15.70	15.74	15.81	15.82	15.9
WSH-3047	15.59	15.63	15.67	15.73	15.75	15.82
WSH-3018	15.51	15.54	15.59	15.65	15.66	15.74
WSH-2995	15.43	15.46	15.5	15.54	15.56	15.62
WSH-2984	15.40	15.43	15.47	15.5	15.51	15.56
WSH-2973	15.28	15.30	15.33	15.37	15.38	15.44
WSH-2973*-DS	14.91	14.97	15.04	15.15	15.19	15.34
WSH-2960	14.88	14.93	15	15.1	15.14	15.28
WSH-2947	14.82	14.86	14.92	15.01	15.05	15.2
WSH-2922	14.74	14.77	14.81	14.91	14.95	15.1
WSH-2922-CUS	14.74	14.77	14.81	14.91	14.95	15.1
WSH-2922-CDS	14.65	14.70	14.76	14.85	14.89	15.04
WSH-2922-SUS	14.74	14.77	14.81	14.91	14.95	15.1
WSH-2922-SDS	14.65	14.70	14.76	14.85	14.89	15.04
WSH-2914	14.65	14.70	14.76	14.85	14.89	15.04
WSH-2873	14.54	14.59	14.66	14.76	14.81	14.96
WSH-2832	14.45	14.50	14.56	14.65	14.69	14.83
WSH-2783	14.30	14.35	14.42	14.52	14.57	14.69
WSH-2763	14.23	14.29	14.37	14.49	14.54	14.67
WSH-2743	14.20	14.26	14.35	14.47	14.52	14.65
WSH-2723	14.19	14.25	14.34	14.46	14.52	14.64
WSH-2703	14.19	14.25	14.33	14.46	14.51	14.64
WSH-2657	14.08	14.14	14.23	14.37	14.42	14.49
WSH-2657-CUS	14.08	14.14	14.23	14.37	14.42	14.49
WSH-2657-CDS	13.99	14.03	14.08	14.14	14.18	14.28
WSH-2657-SUS	14.08	14.14	14.23	14.37	14.42	14.49
WSH-2657-SDS	13.99	14.03	14.08	14.14	14.18	14.28
WSH-2650	13.99	14.03	14.08	14.14	14.18	14.28
WSH-2641	13.59	13.64	13.71	13.82	13.87	14.04

PROPOSED (REVISION 3) MODEL RESULTS						
		Max Stage (mAOD)				
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-3132*	15.72	15.76	15.8	15.88	15.89	15.97
WSH-3075	15.65	15.68	15.73	15.8	15.81	15.88
WSH-3047	15.58	15.61	15.66	15.72	15.73	15.81
WSH-3018	15.50	15.53	15.57	15.64	15.65	15.72
WSH-2995	15.42	15.45	15.49	15.53	15.54	15.6
WSH-2984	15.39	15.42	15.46	15.49	15.5	15.55
WSH-2973	15.28	15.29	15.32	15.36	15.37	15.43
WSH-2973*-DS	14.89	14.95	15.01	15.12	15.15	15.3
WSH-2960	14.86	14.91	14.97	15.08	15.1	15.24
WSH-2947	14.81	14.85	14.9	14.99	15.02	15.15
WSH-2922	14.73	14.76	14.8	14.88	14.92	15.05
WSH-2922-CUS	14.73	14.76	14.8	14.88	14.92	15.05
WSH-2922-CDS	14.63	14.68	14.74	14.83	14.86	14.99
WSH-2922-SUS	14.73	14.76	14.8	14.88	14.92	15.05
WSH-2922-SDS	14.63	14.68	14.74	14.83	14.86	14.99
WSH-2914	14.63	14.68	14.74	14.83	14.86	14.99
WSH-2873	14.52	14.57	14.63	14.73	14.77	14.91
WSH-2832	14.43	14.48	14.53	14.62	14.66	14.78
WSH-2783	14.28	14.33	14.39	14.48	14.53	14.65
WSH-2763	14.21	14.27	14.34	14.45	14.5	14.62
WSH-2743	14.18	14.24	14.31	14.43	14.48	14.61
WSH-2723	14.17	14.23	14.3	14.42	14.48	14.6
WSH-2703	14.16	14.22	14.3	14.42	14.47	14.6
WSH-2657	14.06	14.12	14.19	14.33	14.39	14.46
WSH-2657-CUS	14.06	14.12	14.19	14.33	14.39	14.46
WSH-2657-CDS	13.98	14.02	14.06	14.12	14.15	14.24
WSH-2657-SUS	14.06	14.12	14.19	14.33	14.39	14.46
WSH-2657-SDS	13.98	14.02	14.06	14.12	14.15	14.24
WSH-2650	13.98	14.02	14.06	14.12	14.15	14.24
WSH-2641	13.57	13.62	13.68	13.77	13.82	13.96

BASELINE MODEL RESULTS						
	Max Stage (mAOD)					
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-2631	13.51	13.58	13.67	13.78	13.84	14.01
WSH-2598	13.41	13.47	13.56	13.67	13.73	13.9
WSH-2551	13.23	13.30	13.39	13.52	13.58	13.77
WSH-2505	13.12	13.19	13.28	13.4	13.46	13.66
WAS-2488	13.08	13.15	13.23	13.35	13.41	13.61
WSH-2471	12.97	13.04	13.14	13.27	13.34	13.56
WSH-2437	12.78	12.88	13	13.15	13.23	13.46
WSH-2376	12.64	12.74	12.86	13	13.08	13.27
WSH-2345	12.57	12.67	12.79	12.93	13	13.18
WSH-2315	12.51	12.61	12.73	12.88	12.95	13.12
WSH-2284	12.45	12.55	12.67	12.81	12.88	13.07

PROPOSED (REVISION 3) MODEL RESULTS						
		Max Stage (mAOD)				
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-2631	13.49	13.56	13.63	13.73	13.78	13.92
WSH-2598	13.39	13.45	13.51	13.61	13.66	13.8
WSH-2574	13.28	13.34	13.41	13.51	13.56	13.7
WSH-2551	13.19	13.25	13.31	13.41	13.46	13.6
WSH-2528	13.13	13.17	13.23	13.32	13.36	13.5
WSH-2505	12.85	12.90	12.95	13.04	13.07	13.2
NEW-2437	12.47	12.54	12.59	12.68	12.74	13.01
NEW-2376	12.22	12.27	12.39	12.59	12.7	13
NEW-2345	12.10	12.20	12.38	12.59	12.7	13
NEW-2315	12.04	12.19	12.38	12.59	12.7	13
NEW-2253	12.00	12.19	12.38	12.59	12.7	13
NEW-2195	12.00	12.19	12.38	12.59	12.7	13
NEW-2150	12.00	12.19	12.38	12.59	12.7	13
NEW-2060	12.00	12.19	12.38	12.59	12.7	13
NEW-1998	12.00	12.19	12.38	12.59	12.7	13
NEW-1961	12.00	12.19	12.38	12.59	12.7	13
NEW-1911	12.00	12.19	12.38	12.59	12.7	13
NEW-1911-US	12.00	12.19	12.38	12.59	12.7	13
NEW-1911-DS	11.99	12.18	12.36	12.57	12.69	13
NEW-1911-SUS	12.00	12.19	12.38	12.59	12.7	13
NEW-1911-SDS	11.99	12.18	12.36	12.57	12.69	13
NEW-1906	11.99	12.18	12.36	12.57	12.69	13
NEW-1901	11.99	12.18	12.36	12.57	12.69	13
WSH-2437	12.37	12.41	12.45	12.61	12.72	13.01
WSH-2376	12.21	12.25	12.38	12.59	12.71	13
WSH-2345	12.14	12.21	12.37	12.59	12.71	13
WSH-2315	12.09	12.20	12.37	12.59	12.71	13
WSH-2284	12.05	12.19	12.37	12.59	12.71	13

BASELINE MODEL RESULTS						
	Max Stage (mAOD)					
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-2268	12.41	12.52	12.63	12.78	12.85	13.05
WSH-2253	12.37	12.48	12.59	12.74	12.82	13.03
WSH-2224	12.34	12.45	12.56	12.72	12.8	13.02
WSH-2200*	12.34	12.44	12.56	12.71	12.79	13.02
WSH-2195	12.34	12.44	12.56	12.71	12.79	13.02
WSH-2150	12.33	12.43	12.55	12.69	12.78	13.01
WSH-2065*	12.33	12.43	12.54	12.68	12.76	13
WSH-2060	12.33	12.43	12.54	12.68	12.76	13
WSH-1998	12.32	12.42	12.53	12.67	12.76	13
WSH-1961	12.31	12.41	12.52	12.67	12.76	13
WSH-1901	12.30	12.40	12.51	12.67	12.76	13
WSH-1842	12.29	12.39	12.51	12.67	12.76	12.99
WSH-1783	12.28	12.38	12.51	12.67	12.75	12.99
WSH-1744	12.28	12.38	12.5	12.66	12.75	12.99
WSH-1698	12.27	12.37	12.5	12.66	12.75	12.99
WSH-1652	12.27	12.37	12.49	12.66	12.75	12.99

PROPOSED (REVISION 3) MODEL RESULTS						
		Max Stage (mAOD)				
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-2268	12.04	12.19	12.37	12.59	12.71	13
WSH-2253	12.03	12.19	12.37	12.59	12.71	13
WSH_2200*	12.01	12.19	12.37	12.59	12.71	13
WSH-2195	12.01	12.19	12.37	12.59	12.71	13
WB-2150	12.01	12.19	12.37	12.59	12.71	13
WB-2060*	12.01	12.19	12.37	12.59	12.71	13
WB-2060	12.01	12.19	12.37	12.59	12.71	13
WB-1198	12.01	12.19	12.37	12.58	12.7	13
WSH-1998	12.01	12.19	12.37	12.58	12.7	13
WSH-1961	12.00	12.19	12.36	12.58	12.7	13
WSH-1911	11.99	12.18	12.36	12.57	12.69	13
WSH-1901	11.99	12.18	12.36	12.57	12.69	13
WSH-1901-DS	11.99	12.18	12.36	12.57	12.69	13
WSH-1842	11.96	12.17	12.35	12.57	12.7	13
WSH-1783	11.91	12.15	12.35	12.57	12.69	13
WSH-1744	11.90	12.14	12.34	12.57	12.69	12.99
WSH-1698	11.89	12.14	12.34	12.56	12.68	12.98
WSH-1660	11.88	12.13	12.34	12.56	12.68	12.98
NEW-1901-DS	11.88	12.13	12.35	12.57	12.69	13
NEW-1783	11.88	12.13	12.35	12.57	12.69	13
NEW-1744	11.88	12.13	12.35	12.57	12.69	13
NEW-1660	11.88	12.13	12.34	12.56	12.68	12.98
WSH-1660-US	11.88	12.13	12.34	12.56	12.68	12.98
WSH-1660-DS	11.86	12.12	12.29	12.43	12.49	12.74
WSH-1660-SUS	11.88	12.13	12.34	12.56	12.68	12.98
WSH-1660-SDS	11.86	12.12	12.29	12.43	12.49	12.74
WSH-1655	11.86	12.12	12.29	12.43	12.49	12.74

BASELINE MODEL RESULTS						
	Max Stage (mAOD)					
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-1606	12.26	12.36	12.49	12.65	12.74	12.98
WSH-1592	12.26	12.36	12.48	12.64	12.73	12.98
WSH-1584	12.26	12.36	12.48	12.64	12.73	12.98
WSH-1579	12.26	12.36	12.48	12.64	12.73	12.98
WSH-1579-CUS	12.26	12.36	12.48	12.64	12.73	12.98
WSH-1579-CDS	12.21	12.28	12.36	12.46	12.51	12.74
WSH-1579-SUS	12.26	12.36	12.48	12.64	12.73	12.98
WSH-1579-SDS	12.21	12.28	12.36	12.46	12.51	12.74
WSH-1572	12.21	12.28	12.36	12.46	12.51	12.74
WSH-1566	12.21	12.28	12.36	12.45	12.5	12.74
WSH-1560	12.21	12.28	12.35	12.45	12.5	12.74
WSH-1548	12.21	12.27	12.35	12.44	12.49	12.73
WSH-1492	12.20	12.26	12.33	12.41	12.45	12.71
WSH-1437	12.19	12.25	12.32	12.39	12.43	12.69
WSH-1416	12.19	12.25	12.31	12.38	12.42	12.68
WSH-1410	12.19	12.25	12.31	12.38	12.41	12.68
WSH-1405	12.19	12.25	12.31	12.38	12.41	12.68
WSH-1400	12.19	12.24	12.31	12.37	12.41	12.67
WSH-1395	12.19	12.24	12.3	12.37	12.4	12.67
WSH-1395-C1	12.19	12.24	12.3	12.37	12.4	12.67
WSH-1395-C2	12.19	12.24	12.3	12.36	12.39	12.67
WSH-1395-SUS	12.19	12.24	12.3	12.37	12.4	12.67
WSH-1395-SDS	12.19	12.24	12.3	12.36	12.39	12.67
WSH-1386	12.19	12.24	12.3	12.36	12.39	12.67
WSH-1356	12.18	12.23	12.29	12.34	12.37	12.66
WSH-1326	12.18	12.23	12.28	12.34	12.37	12.66
WSH-1297	12.18	12.23	12.28	12.34	12.36	12.66
WSH-1255	12.17	12.22	12.27	12.32	12.34	12.65
WSH-1255-CUS	12.17	12.22	12.27	12.32	12.34	12.65
WSH-1255-CDS	11.37	11.55	11.8	12.06	12.18	12.65

PROPOSED (REVISION 3) MODEL RESULTS						
		Max Stage (mAOD)				
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-1606	11.85	12.11	12.28	12.42	12.48	12.72
WSH-1592	11.85	12.11	12.28	12.41	12.47	12.71
WSH-1584	11.85	12.11	12.28	12.41	12.47	12.7
WSH-1579	11.84	12.11	12.28	12.41	12.46	12.69
WSH-1572	11.84	12.11	12.28	12.4	12.46	12.69
WSH-1566	11.84	12.11	12.27	12.4	12.46	12.69
WSH-1560	11.84	12.11	12.27	12.4	12.45	12.69
WSH-1548	11.83	12.11	12.27	12.39	12.45	12.69
WSH-1492	11.82	12.10	12.26	12.37	12.42	12.66
WSH-1437	11.81	12.09	12.25	12.35	12.4	12.64
WSH-1416	11.81	12.09	12.25	12.35	12.39	12.64
WSH-1410	11.81	12.09	12.24	12.35	12.39	12.63
WSH-1405	11.80	12.09	12.24	12.34	12.38	12.63
WSH-1400	11.80	12.09	12.24	12.34	12.38	12.63
WSH-1395	11.80	12.09	12.24	12.34	12.38	12.63
WSH-1395-C1	11.80	12.09	12.24	12.34	12.38	12.63
WSH-1395-C2	11.80	12.09	12.24	12.33	12.36	12.62
WSH-1395-SUS	11.80	12.09	12.24	12.34	12.38	12.63
WSH-1395-SDS	11.80	12.09	12.24	12.33	12.36	12.62
WSH-1386	11.80	12.09	12.24	12.33	12.36	12.62
WSH-1356	11.79	12.08	12.23	12.32	12.35	12.62
WSH-1326	11.79	12.08	12.23	12.31	12.35	12.61
WSH-1297	11.78	12.08	12.23	12.31	12.35	12.61
WSH-1255	11.77	12.08	12.22	12.3	12.33	12.61
WSH-1255-CUS	11.77	12.08	12.22	12.3	12.33	12.61
WSH-1255-CDS	11.21	11.28	11.55	11.95	12.1	12.6

BASELINE MODEL RESULTS						
	Max Stage (mAOD)					
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-1255-SUS	12.17	12.22	12.27	12.32	12.34	12.65
WSH-1255-SDS	11.37	11.55	11.8	12.06	12.18	12.65
WSH-1249	11.37	11.55	11.8	12.06	12.18	12.65
WSH-1189	11.28	11.47	11.75	12.01	12.15	12.65
WSH-1131	11.18	11.41	11.72	12	12.13	12.64
WSH-1075	11.05	11.34	11.69	11.98	12.13	12.64
WSH-1049	11.02	11.32	11.69	11.98	12.13	12.64
WSH-1036	11.01	11.32	11.69	11.98	12.12	12.64
WSH-1014	11.01	11.31	11.69	11.98	12.12	12.64
WSH-1014-C1	11.01	11.31	11.69	11.98	12.12	12.64
WSH-1014-C2	11.00	11.30	11.66	11.93	12.06	12.51
WSH-1014-C3	10.99	11.29	11.64	11.89	12.01	12.41
WSH-1014-C4	10.99	11.28	11.62	11.85	11.95	12.31
WSH-1014-C5	10.98	11.27	11.6	11.82	11.9	12.2
WSH-1014-C6	10.98	11.26	11.58	11.78	11.85	12.1
WSH-1014-C7	10.97	11.24	11.56	11.74	11.79	12
WSH-1014-SUS	11.01	11.31	11.69	11.98	12.12	12.64
WSH-1014-SDS	10.97	11.24	11.56	11.74	11.79	12
WSH-0942	10.97	11.24	11.56	11.74	11.79	12
WSH-0939	10.96	11.24	11.55	11.73	11.78	12
WSH-0939-CUS	10.96	11.24	11.55	11.73	11.78	12
WSH-0939-CDS	10.83	11.00	11.17	11.4	11.55	11.99
WSH-0939-SUS	10.96	11.24	11.55	11.73	11.78	12
WSH-0939-SDS	10.83	11.00	11.17	11.4	11.55	11.99
WSH-0930	10.83	11.00	11.17	11.4	11.55	11.99
WSH-0891	10.80	10.96	11.13	11.38	11.53	11.98
WSH-0849	10.75	10.91	11.09	11.35	11.53	11.98
WSH-0828	10.71	10.87	11.06	11.34	11.52	11.98
WSH-0808	10.64	10.81	11.03	11.34	11.52	11.98
WSH-0798*	10.64	10.80	11.02	11.33	11.52	11.98

PROPOSED (REVISION 3) MODEL RESULTS						
		Max Stage (mAOD)				
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-1255-SUS	11.77	12.08	12.22	12.3	12.33	12.61
WSH-1255-SDS	11.21	11.28	11.55	11.95	12.1	12.6
WSH-1249	11.21	11.28	11.55	11.95	12.1	12.6
WSH-1189	11.11	11.19	11.48	11.9	12.06	12.6
WSH-1131	11.00	11.09	11.42	11.87	12.04	12.6
WSH-1075	10.85	10.97	11.35	11.86	12.03	12.59
WSH-1049	10.81	10.94	11.33	11.86	12.03	12.59
WSH-1036	10.80	10.94	11.33	11.85	12.03	12.59
WSH-1014	10.80	10.93	11.33	11.85	12.03	12.59
WSH-1014-C1	10.80	10.93	11.33	11.85	12.03	12.59
WSH-1014-C2	10.79	10.93	11.31	11.82	11.97	12.47
WSH-1014-C3	10.79	10.92	11.3	11.79	11.93	12.37
WSH-1014-C4	10.79	10.92	11.29	11.76	11.89	12.28
WSH-1014-C5	10.79	10.91	11.28	11.73	11.84	12.18
WSH-1014-C6	10.78	10.91	11.27	11.7	11.8	12.08
WSH-1014-C7	10.78	10.91	11.26	11.67	11.76	11.98
WSH-1014-SUS	10.80	10.93	11.33	11.85	12.03	12.59
WSH-1014-SDS	10.78	10.91	11.26	11.67	11.76	11.98
WSH-0942	10.78	10.91	11.26	11.67	11.76	11.98
WSH-0939	10.77	10.90	11.25	11.66	11.75	11.98
WSH-0939-CUS	10.77	10.90	11.25	11.66	11.75	11.98
WSH-0939-CDS	10.71	10.80	11.01	11.3	11.45	11.96
WSH-0939-SUS	10.77	10.90	11.25	11.66	11.75	11.98
WSH-0939-SDS	10.71	10.80	11.01	11.3	11.45	11.96
WSH-0930	10.71	10.80	11.01	11.3	11.45	11.96
WSH-0891	10.68	10.78	10.97	11.26	11.43	11.96
WSH-0849	10.65	10.74	10.93	11.23	11.41	11.96
WSH-0828	10.61	10.71	10.89	11.22	11.41	11.96
WSH-0808	10.56	10.66	10.84	11.21	11.4	11.96
WSH-0798*	10.55	10.66	10.83	11.2	11.4	11.96

BASELINE MODEL RESULTS						
	Max Stage (mAOD)					
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-0798-C1	10.64	10.80	11.02	11.33	11.52	11.98
WSH-0798-C2	10.63	10.79	11	11.29	11.47	11.89
WSH-0798-C3	10.63	10.78	10.98	11.26	11.42	11.79
WSH-0798-C4	10.62	10.77	10.96	11.22	11.37	11.7
WSH-0798-C5	10.62	10.76	10.94	11.18	11.32	11.61
WSH-0798*SUS	10.64	10.80	11.02	11.33	11.52	11.98
WSH-0798*SDS	10.62	10.76	10.94	11.18	11.32	11.61
WSH-0758*	10.62	10.76	10.94	11.18	11.32	11.61
WSH-0728	10.59	10.73	10.9	11.14	11.28	11.59
WSH-0699*	10.59	10.73	10.89	11.13	11.27	11.58
WSH-0699-SUS	10.59	10.73	10.89	11.13	11.27	11.58
WSH-0699-BUS	10.59	10.73	10.89	11.13	11.27	11.58
WSH-0699-BDS	10.56	10.68	10.81	10.95	11.01	11.08
WSH-0699-SDS	10.56	10.68	10.81	10.95	11.01	11.08
WSH-0654	10.56	10.68	10.81	10.95	11.01	11.08
WSH-0588	10.49	10.59	10.68	10.79	10.84	10.94
WSH-0530	10.43	10.52	10.6	10.68	10.72	10.81
WSH-0472	10.40	10.48	10.55	10.63	10.67	10.75
WSH-0416	10.38	10.45	10.52	10.6	10.63	10.71
WSH-0324	10.32	10.40	10.48	10.55	10.59	10.67
WSH-0274	10.29	10.37	10.46	10.53	10.56	10.65
WSH-0224	10.26	10.35	10.44	10.51	10.55	10.63
WSH-0174	10.24	10.33	10.43	10.5	10.53	10.62
WSH-0124	10.23	10.32	10.42	10.49	10.52	10.61
WSH-0067	10.20	10.30	10.4	10.47	10.51	10.59
WSH-0010	10.17	10.27	10.38	10.45	10.48	10.57
WSH-0010C1US	10.17	10.27	10.38	10.45	10.48	10.57
WSH-0010C1DS	10.12	10.20	10.31	10.41	10.46	10.56
WSH-0010C2US	10.17	10.27	10.38	10.45	10.48	10.57
WSH-0010C2DS	10.12	10.20	10.31	10.41	10.46	10.56

PROPOSED (REVISION 3) MODEL RESULTS						
		Max Stage (mAOD)				
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-0798-C1	10.55	10.66	10.83	11.2	11.4	11.96
WSH-0798-C2	10.54	10.65	10.82	11.17	11.36	11.87
WSH-0798-C3	10.54	10.65	10.8	11.14	11.31	11.78
WSH-0798-C4	10.54	10.64	10.79	11.11	11.27	11.69
WSH-0798-C5	10.54	10.64	10.78	11.08	11.23	11.59
WSH-0798*SUS	10.55	10.66	10.83	11.2	11.4	11.96
WSH-0798*SDS	10.54	10.64	10.78	11.08	11.23	11.59
WSH-0758*	10.54	10.64	10.78	11.08	11.23	11.59
WSH-0728	10.52	10.61	10.75	11.03	11.19	11.57
WSH-0699*	10.51	10.61	10.75	11.03	11.18	11.57
WSH-0699-BUS	10.51	10.61	10.75	11.03	11.18	11.57
WSH-0699-BDS	10.49	10.58	10.7	10.9	10.97	11.08
WSH-0699-SUS	10.51	10.61	10.75	11.03	11.18	11.57
WSH-0699-SDS	10.49	10.58	10.7	10.9	10.97	11.08
WSH-0654	10.49	10.58	10.7	10.9	10.97	11.08
WSH-0588	10.43	10.51	10.6	10.74	10.81	10.93
WSH-0530	10.38	10.45	10.53	10.65	10.69	10.8
WSH-0472	10.35	10.41	10.49	10.6	10.64	10.74
WSH-0416	10.33	10.39	10.46	10.57	10.61	10.7
WSH-0324	10.27	10.34	10.41	10.52	10.56	10.65
WSH-0274	10.24	10.31	10.39	10.5	10.54	10.63
WSH-0224	10.21	10.28	10.37	10.48	10.52	10.61
WSH-0174	10.18	10.26	10.35	10.47	10.51	10.6
WSH-0124	10.17	10.25	10.34	10.46	10.5	10.59
WSH-0067	10.14	10.23	10.32	10.44	10.48	10.57
WSH-0010	10.10	10.19	10.29	10.41	10.45	10.54
WSH-0010C1US	10.10	10.19	10.29	10.41	10.45	10.54
WSH-0010C1DS	10.07	10.14	10.22	10.36	10.41	10.53
WSH-0010C2US	10.10	10.19	10.29	10.41	10.45	10.54
WSH-0010C2DS	10.07	10.14	10.22	10.36	10.41	10.53

BASELINE MODEL RESULTS						
	Max Stage (mAOD)					
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-0010-SUS	10.17	10.27	10.38	10.45	10.48	10.57
WSH-0010-SDS	10.12	10.20	10.31	10.41	10.46	10.56
WSH-0000	10.12	10.20	10.31	10.41	10.46	10.56
WSH-0000-10	10.12	10.20	10.3	10.41	10.46	10.56

PROPOSED (REVISION 3) MODEL RESULTS						
		Max Stage (mAOD)				
	Q2	Q5	Q20	Q100	Q100CC	Q1000
WSH-0010-SUS	10.10	10.19	10.29	10.41	10.45	10.54
WSH-0010-SDS	10.07	10.14	10.22	10.36	10.41	10.53
WSH-0000	10.07	10.14	10.22	10.36	10.41	10.53
WSH-0000-10	10.07	10.14	10.21	10.35	10.41	10.53