NW Bicester

An application for the exemplar phase of the
NW Bicester Eco Development proposals submitted by
P3Eco (Bicester) Limited **and the** A2Dominion Group

Flood Risk Assessment

Hyder

P3Eco Ltd a2dominion

Hyder Consulting (UK) Limited
2212959
29 Bressenden Place
London
SW1E 5DZ
United Kingdom
Tel: +44 (0)20 3014 9000
Fax: +44 (0)20 7828 1794
www.hyderconsulting.com

P3Eco (Bicester) Ltd and A2Dominion Group

NW Bicester Eco Development

Flood Risk Assessment - Exemplar Site

Author	Pete Harrison/Susan Borrer	
Checker	Leanne Roach	
Approver	Bob Sargent	
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SUMMARY

A Flood Risk Assessment (FRA) and drainage strategy has been undertaken to accompany the planning application for the proposed NW Bicester eco development. This report has been prepared by Hyder Consulting (UK) Limited on behalf of the A2Dominion Group and P3Eco (Bicester) Ltd in accordance with the guidelines set out in “Planning Policy Statement 25, Development and Flood Risk.”

The following table is an overview of the flood risk and drainage strategy for the proposed development of the site, based upon the currently available information.

Item	Response
Site Location	The site is 2 km from the centre of Bicester with an approximate grid reference of 457656 224697
Size and Current Land Use	The site is approximately 21.1 ha and is mainly open agricultural land.
Environment Agency Flood Zone	The majority of the site falls within Flood Zone 1: Low Probability. This zone comprises land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding in any year (<0.1%). There are areas of Flood Zone 2 and 3 adjacent to the watercourses, although no development is proposed for these areas.
Fluvial Flood Risk	**Low** risk of fluvial flooding
Tidal Flood Risk	**Low** risk of tidal flooding
Surface Water Flood Risk	**Low** risk of surface water flooding
Groundwater Flood Risk	**Low** risk of groundwater flooding with suitable mitigation
Artificial Flood Risk	**Low** risk of flooding from artificial sources
Historical Flooding	No record of historical flooding
Proposed Development	Approximately 393 residential units with associated services
PPS25 Flood Risk Vulnerability	More Vulnerable
Sequential & Exception Tests	The proposed development types are permitted within Flood Zone 1 and do not require the exception test.

Based on this assessment, it is concluded the site can be developed safely, without exposing the new development to an unacceptable degree of flood risk or increasing the flood risk to third parties.

1 INTRODUCTION

1.1 Terms of Reference

This report has been prepared by Hyder Consulting (UK) Limited (Hyder) on behalf of the A2Dominion Group and P3Eco (Bicester) Ltd for the proposed NW Bicester eco development.

The NW Bicester eco development will comprise approximately 5,000 homes, secondary school, a number of primary schools, retail and commercial space along with health care and other community facilities. Approximately 40% of the overall site will be green open space, including playing fields, semi private and public open space. The first phase of the eco development will be an Exemplar for future development, which will comprise 393 homes, land for a primary school, a nursery, and areas of commercial and retail property.

This report outlines a Level 3 Flood Risk Assessment (FRA) for the Exemplar Site development only. The remainder of the NW Bicester eco development site will be covered in a separate FRA.

The assessment in this report has been carried out in accordance with the guidelines set out in “Planning Policy Statement 25: Development and Flood Risk” (PPS25).

The aim of this FRA is to demonstrate that the site can be developed safely, without exposing the new development to an unacceptable degree of flood risk or increasing the flood risk to third parties. The objectives are to:

- Identify potential sources of flooding and assess the risk they pose to the site;
- Consider the effect of predicted climate change on future flood risk to the site;
- Determine the impact of the development on flood risk to third parties;
- Determine an appropriate surface water drainage strategy;
- Recommend appropriate flood risk mitigation measures.

This report has been compiled from a number of sources which Hyder believes to be trustworthy. Hyder is unable to guarantee the accuracy of information provided by others.

This report is based on information available at the time of preparation. Consequently, there is potential for further information to become available. These changes may lead to future alteration to the conclusions drawn in this report for which Hyder cannot be held responsible.

1.2 Site Description

The eco development site is situated across 416 ha of mainly greenfield land approximately 1.5 km to the north west of Bicester with a National Grid Reference (NGR) of 457656 224697. The site is located north of the A4095 which forms the current boundary of Bicester, west of the B4100, east of the B4030 and south of Bucknell, encompassing Crowmarsh Farm.

Although the eco development site is largely Greenfield, it includes a number of buildings and areas of hardstanding associated with them. These include Lovelynch House, Himley Farm, Gowell Farm, Aldershot Farm, the police depot, Lord’s Farm, Hawkwell Farm, Crowmarsh Farm and Home Farm. The site is bisected by both Bucknell Road and the railway.

The Exemplar Site is situated at the northeast end of the development and covers an area of approximately 21.1 ha of Grade 3 agricultural land.

Within the Exemplar site there are several water features, including the River Bure and its associated tributaries, and various field drains. The Bure flows in a southerly direction from Caversfield House to a culvert beneath the A4095. Downstream from this it flows in an open channel between Lucerine Avenue and Purslane Drive. There is a tributary flowing in an easterly direction from Bucknell which converges with the Bure downstream of Home Farm, and another tributary which flows in an easterly direction from Crowmarsh Farm and converges with the Bure at the A4095 culvert.

The extents of the Exemplar site are shown on Figure 1 below.

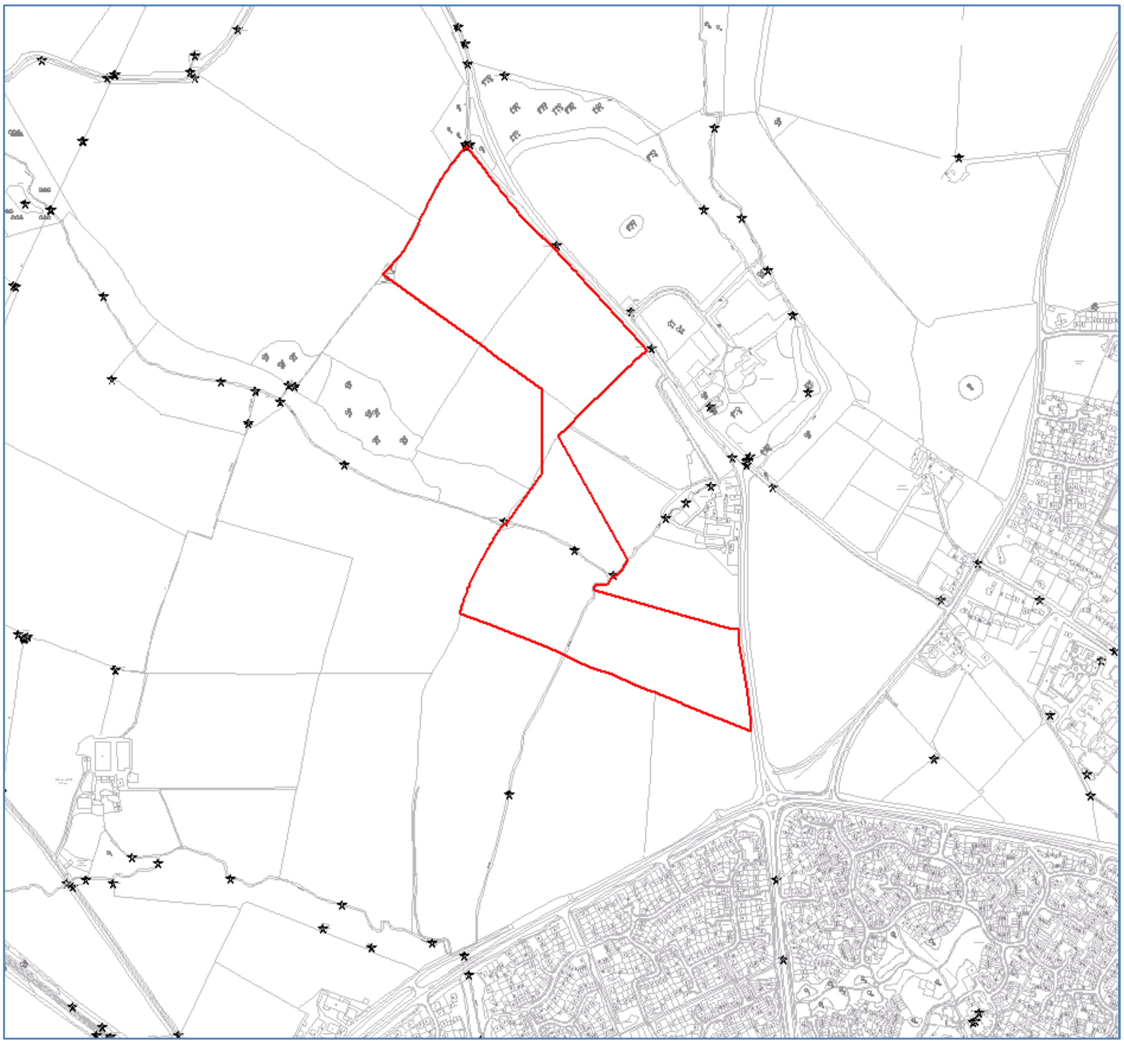

Figure 1 – Exemplar Site Location

1.3 Site Topography

A topographical survey has been completed for the Exemplar Site. Drawing 7013 in Appendix A shows contours and topological details of the Exemplar Site produced from the topographical survey.

The topography varies between extremes of 92.3 m AOD and 81.7 m AOD, with a general slope downwards from the north western boundary southeast towards Bicester. The watercourses (the River Bure and tributaries) are the lowest points on the site.

1.4 Geotechnical Conditions

Ground conditions have been assessed within a desk study (NW Bicester Eco Development - Phase 1 Desk Study, 2501-UA001881-UP33R-01, Hyder, July 2010) and a factual report summarising the findings of onsite ground investigation (NW Bicester Eco Development - Exemplar Site Factual Report 2504-UA001881-UP33R-01, Hyder, September 2010).

In summary, the investigations indicate that the site comprises stratum of sand and gravel overlying clay bands and limestone.

1.5 Development Proposal

The proposed site layout for the Exemplar site is shown in Appendix B. The development proposal includes approximately 393 residential properties (including flats), a business centre, land for a primary school with associated grounds, nursery, post office, energy centre and service yard, retail premises and associated roads and kerbing.

Residential properties are mostly based in the northwestern and southeastern corners of the site, with the remaining public buildings arranged around the centre of the site.

Two bridges will be constructed over the watercourses, with one over the River Bure and one over the northernmost of its two tributaries.

2 ASSESSMENT OF THE FLOOD RISK

2.1 Planning Policies

2.1.1 Planning Policy Statement 25

PPS25 sets out the Government's national policies for flood risk management in a land use planning context within England.

PPS25 states that developers and local authorities should try to relocate existing development to land in zones with the lowest probability of flooding and to:

> *"reduce the flood risk to and from new development through location, layout and design, incorporating sustainable drainage systems (SUDS)".*

A sequential risk based approach to determine the suitability of land from development in flood risk areas is central to PPS25 and should be applied at all levels within the planning process.

2.1.2 Ecotowns, A supplement to Planning Policy Statement 1

Policy ET 18 (Flood Risk Management) states:

> *"There is a strong expectation that all of the built-up areas of an eco-town (including housing, other public buildings and infrastructure) will be fully within Flood Zone 1 – the lowest risk. Flood Zone 2 (medium risk) should, as far as possible, be used for open spaces and informal recreational areas that can serve as multi-functional spaces, for example, those used for flood storage. There should be no built up development in Flood Zone 3 with the exception of water-compatible development and where absolutely necessary, essential infrastructure."*

2.2 Flood Risk Vulnerability

As the eco development is a mixed use development there will be a variety of flood risk vulnerability classes (as defined in table D.2 of PPS25). These include:

- Residential – Highly vulnerable
- Nursery – More vulnerable
- Shops & offices – Less vulnerable
- Public open space and nature areas – Water compatible

The sequential and exception tests will not be required as in accordance with the precautionary principal (advocated by PPS25) and Ecotowns: A supplement to Planning Policy Statement 1, the development will be located within Flood Zone 1 (areas of low risk).

2.3 Historical Flooding

There are no historical records of flooding within or around the site from either the EA or the SFRA.

2.4 Sources of Flood Risk

2.4.1 Fluvial Flooding

The EA flood maps that cover the site are based upon a coarse DTM and JFLOW modelling and as such do not take account of the impacts of climate change and are therefore not suitable for use within a FRA to determine the extents of flood zones in relation to building location and associated finished floor levels. Therefore, detailed hydraulic modelling has been undertaken as part of this FRA. This modelling is discussed in Section 3.

2.4.2 Tidal Flooding

As the eco development is located significantly inland it is considered to be at **low** risk of Tidal Flooding.

2.4.3 Groundwater Flooding

The Ground Investigation (Hyder, 2010) indicates that with the exception of the Forest Marble Formation cropping out in the floors and sides of the valleys, the whole of the site area is underlain by the Cornbrash Formation. This is a local aquifer and water strikes have been recorded in shallow, site-investigation boreholes drilled within the site area. The rest water levels are generally slightly higher than the strike levels; both are generally between about 0.5 and 4.0 m below ground level (bgl).

The Forest Marble Formation, may hold small quantities of water in any limestone bands present, but the upper part generally acts as an aquiclude between the Cornbrash Formation and the underlying White Limestone Formation. There are no boreholes drilled through the Forest Marble Formation in the site area that record water strikes within it.

The White Limestone Formation constitutes a major aquifer in the area, which provides some sources of public supply. There are several boreholes in the wider area, some within the site area, that penetrate this formation:

The Environment Agency (EA) Groundwater Vulnerability Map on the EA website has been reviewed to determine the vulnerability of the groundwater underlying the Site with the following conclusions:

> *The superficial deposits are not classified as an aquifer. The underlying Cornbrash Formation is classified as a Secondary A Aquifer, which comprises "permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers."*

Additional boreholes and trial pits were drilled across the site during August 2010, the location of these are shown in Appendix C. Due to the drilling process, it was not possible to carry out groundwater monitoring of the boreholes during the ground investigation. Five of the six trial pits excavated were found to be dry, with TP1 striking water at a depth of 2.9 m bgl.

Groundwater monitoring results following completion of the ground investigation are ongoing. Initial results from a monitoring visit on 13 August 2010 showed standing water levels between 3.1 m bgl and 6.3 m bgl, which suggest that excavation for foundations will not encounter groundwater as the excavation required for the proposed development will typically be less than 2 m bgl.

However, excavations undertaken during the ground investigation within the surrounding area were carried out after heavy rain and encountered shallower groundwater levels above the limestone. Therefore, where foundations are based at shallow level on top of the limestone, some groundwater flooding may be expected following heavy rain.

It is therefore expected that parts of the site would be considered at **high** risk of groundwater flooding. Potential mitigation measures to protect the site from groundwater flooding would include:

- The provision of preferential flow paths away from the buildings to the surface water drainage system;
- Locating buildings outside the areas of highest risk;
- The provision of damp proof courses and tanking if required.

With the incorporation of mitigation measures such as those outlined the site can be considered to be at **low** risk of groundwater flooding.

2.4.4 Surface Water Flooding

The site is located on a slope which drains to a number of local watercourses (the River Bure and its tributaries). As the site is currently farmland, it is likely that there are farm drains that outlet to these watercourses. These provide the main means of drainage on the site presently.

If the capacity of these drains is exceeded then there is potential for localised flooding through the site, although this would drain quickly to the local watercourses due to the slope of the site.

The proposed development will incorporate surface water management measures to ensure that the runoff rates across the site are maintained at the existing Greenfield rates. This will ensure that the flood risk from surface water runoff to the site and surrounding land is maintained at the baseline level.

Details on surface water management are summarised in Section 3 of this report with further detail presented in the Exemplar Site Drainage Strategy report (7501-UA001881-UP21R-01). As with any development, if appropriate SUDS design measures are not incorporated within the proposals, surface water flooding issues may potentially develop where impermeable areas are increased.

Based on the existing surface water runoff regime and providing that, as described above, appropriate SUDS measures are incorporated within the proposed development, it is considered that the site is at **low** risk of surface water flooding.

2.4.5 Flooding from artificial sources

The site is located within a small catchment, in which no artificial sources (which include but are not limited to canals/reservoirs/sewers) have been identified. Once the site is developed there remains the risk of sewer flooding, however, with suitable design this risk can be minimised. It is therefore considered that the site is at **low** risk of flooding from artificial sources.

3 FLUVIAL FLOOD RISK ASSESSMENT

3.1 Methodology

3.1.1 Site walkover

A site walkover of the site was undertaken in June 2010 when the watercourse channels and structures along the reach of interest were inspected and key flood water flow paths were identified.

3.1.2 Hydrological Assessment

Flood flow estimates for the River Bure and its tributaries were derived by applying the FEH Statistical with a permeable adjustment and the IOH 124 methods which represent current best practice methodologies for UK flood flow estimation. Consideration was given to the use of the Revitalised Flood Hydrograph (ReFH) method but due to the low SPRHOST values this method is not suitable.

The model was initially run with this hydrology, but the hydrology used in the model was later updated using information from the Environment Agency's River Bure model.

Details of the hydrological assessment and subsequent adjustments are provided in Section 3.2.

3.1.3 Hydraulic Assessment

The assessment of fluvial flood risk was made using an ISIS model (Halcrow, version 3.3) of the appropriate section of the River Bure and its tributaries, which is described in more detail in Section 3.3. The model was run to simulate the flowing return periods

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

An unsteady state modelling approach with variable hydrographs was adopted to gain the best accuracy possible at this site.

3.2 Hydrological Assessment

Design flood flows for the River Bure and its tributaries were estimated using Flood Estimation Handbook Statistical method, including the permeable catchment adjustment procedure, due to the nature of the catchment. The Revitalised Rainfall Runoff Method (ReFH) and the Institute of Hydrology 124 (IoH 124) methods were considered for use but were deemed unsuitable. The ReFH method was deemed inappropriate as its application in permeable catchments is not recommended and the EA Flood Estimation Guidelines "advise users to avoid IoH124 for flood estimation on most small catchments."

Prior to undertaking the flow estimation, FEH catchment descriptors were checked against available information. The catchments of the tributaries are too small to enable separate flow estimates to be undertaken. Therefore, for consistency the flow estimates were undertaken for the River Bure catchment at the downstream point of interest and these flows were proportioned by catchment area to obtain the estimates at the other required locations.

3.2.1 The FEH Statistical Method

The FEH Statistical method bases the estimation of future flood events on trends in historical flood flow data (AMAX) from a single gauged site or a group of gauged catchments (a pooling group analysis). The generation of peak flow estimates is a two-stage process.

Estimation of the Index Flood (QMED)

QMED, the median annual flood flow (the index flood event) is estimated where possible using gauged AMAX data recorded on the subject watercourse at the location of interest. In ungauged catchments an empirical equation that includes a number of 'catchment descriptors', such as area and soil type, is used and ideally, an adjustment is made based on flow data from a local, hydrologically similar 'donor' catchment.

Catchment descriptors for the River Bure catchment to the downstream extents of the model, the A4095, were exported from the FEH CD-ROM v3 and are presented in Table 3-1.

Table 3-1 River Bure catchment descriptors

Descriptor		Value
AREA	Catchment Area (km^2)	10.48
FARL	Index of the influence of reservoirs and lakes	0.974
PROPWET	Index of the proportion of time that soils are wet	0.32
BFIHOST	Base flow index	0.857
SPRHOST	Soil index of the percentage runoff	13.1
DPLBAR	Index describing catchment size and drainage path configuration (km)	2.8
DPSBAR	Index of catchment steepness (m/km)	16.8
SAAR	Standard Average Annual Rainfall (mm)	647
URBEXT2000	Index of catchment urbanisation	0.0078

Local gauges were assessed for their suitability for use in the adjustment of QMED, however none were deemed suitable donors due to the low SPRHOST values observed at the site. In the absence of suitable recorded data on the River Bure and neighbouring catchments QMED was estimated to equal **0.33 m^3/s**, using the catchment descriptor equation with an adjustment for urbanisation.

Determination of Flood Growth Curve

The second stage of the method involves the determination of a flood growth curve, a statistical relationship between the relative magnitudes of high return period flood events and QMED.

The WINFAP-FEH v3.0.003 software package with HIFLOWS v3.02 data was used to determine the flood growth curve. The software enables the 'pooling' and analysis of data from hydrologically similar catchments to produce a flood growth curve based on a weighted average of the individual growth curves from the AMAX records at each of the pooled gauging stations.

A pooling group was compiled at the site, with a target return period of 100 years. The pooled growth curve was fitted using a Generalised Logistic distribution, and was considered statistically "strongly heterogeneous". A review of the pooling group was undertaken and sites 203046, 32029, 25011, 22003, 27010 were removed from the group due to hydrological dissimilarities between the catchments draining to these gauges and the subject site. Stations

50009 and 36009 were also investigated as they are outliers on the L-moment graphs but no reason was established to justify their removal. In order to retain the required number of station years within the pooling group two stations 27073 and 48004, were added, The resultant growth factors and peak flow estimates are presented in Table 3-2 below.

Table 3-2 Peak flow estimates for design flood events at site

Return Period (Annual Occurrence Probability)	Growth Factors	Peak flows for design events (m^3/s)
1 in 2 year (50%)	1	0.33
1 in 20 year (5%)	1.96	0.65
1 in 50 year (2%)	2.58	0.85
1 in 100 year (1%)	3.22	1.06
1 in 100 year plus climate change	-	1.27
1 in 1000 year (0.1%)	7.04	2.32

A 20% allowance for climate change was added to the 1 in 100 year flow estimate, in accordance with the PPS25 and the standard design life estimates for residential property.

As hydraulic modelling required full flow hydrographs, rather than peak flow estimates, hydrographs were developed using the ReFH modelling software and the peaks of the hydrographs were scaled to the FEH Statistical flows presented in Table 3-2.

3.2.2 Adjustments to Hydrology

As part of the hydraulic model build, information was requested from the Environment Agency's River Bure model to inform the downstream boundary condition for the Bicester eco development model. The Environment Agency supplied stage and flow hydrographs for nodes at the A4095 road bridge, and peak stage and flow values for the node located closest to the chosen downstream boundary point of the Bicester eco development model.

When this information was received, it was noted that the peak flows in the EA's River Bure model were significantly higher than those calculated in the hydrological assessment in Section 3.2.1 above. A comparison of the EA's River Bure flows at the downstream boundary with the hydrology calculated in Section 3.2.1 is shown in Table 3-3 below, for a range of events.

Table 3-3 Comparison of calculated flows with EA River Bure model flows

Return Period	Hydrological Assessment	EA River Bure model Node BU.3056	Percentage increase
20-year	0.65	2.45	377%
50-year	0.85	2.75	324%
100-year	1.06	3.03	286%
100-year plus climate change	1.27	3.43	271%
1000-year	2.32	4.41	190%

It was determined that the EA had conducted significant temporary gauging in the catchment and used this data in calculating the hydrology for the River Bure model. The gauging data and River Bure hydrology report could not be provided in the timescale available for the NW Bicester eco development modelling, and therefore it was not possible to use the gauged information to inform the hydrological assessment.

For this reason, it was decided to use the peak flows supplied from the River Bure model in the Bicester eco development model, as the additional gauging undertaken means that the River Bure model flows are likely to be more accurate. This is particularly important given that the assessed hydrology was significantly lower than the River Bure model flows, which could lead to underestimation of the flood risk to the site.

The shapes of the hydrographs used in the modelling were calculated by using the same ReFH hydrograph used for the hydrological assessment and scaling it to the new peak flows. The final hydrographs are shown in Figure 2 below.

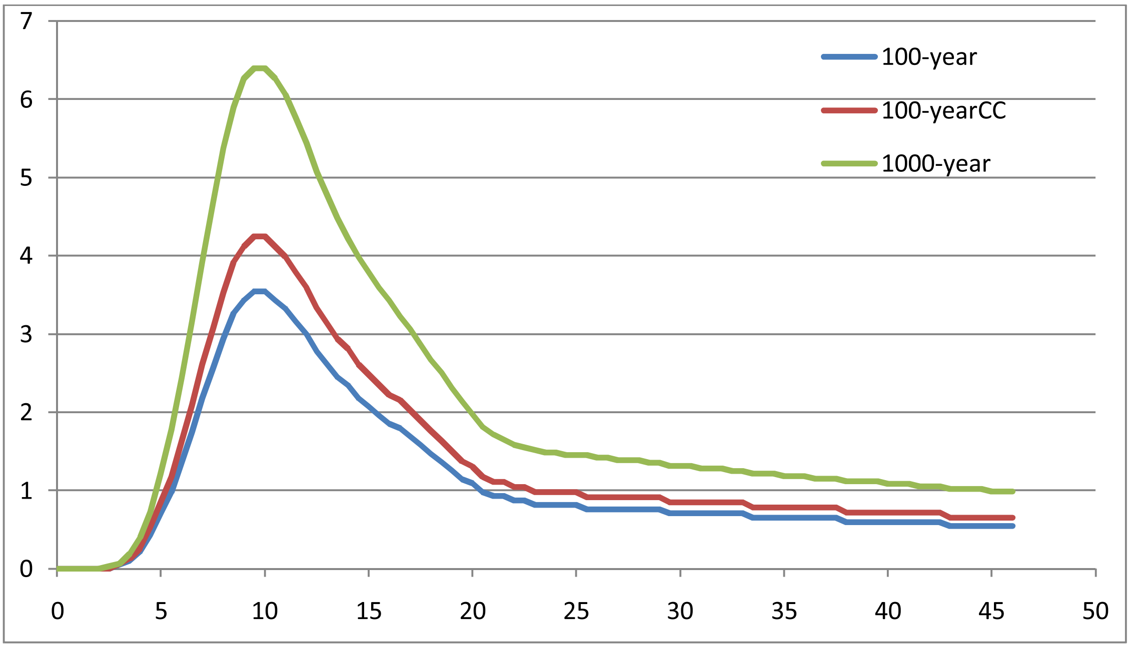

Figure 2 – Final total hydrographs

The hydrographs were then scaled by the same factors used in the hydrological assessment to divide the single flow for the River Bure into three flows for the Bure and its two tributaries. Baseflows of 0.15 cumecs were used for each tributary. The final 100-year flows for each tributary are shown in Figure 3 overleaf.

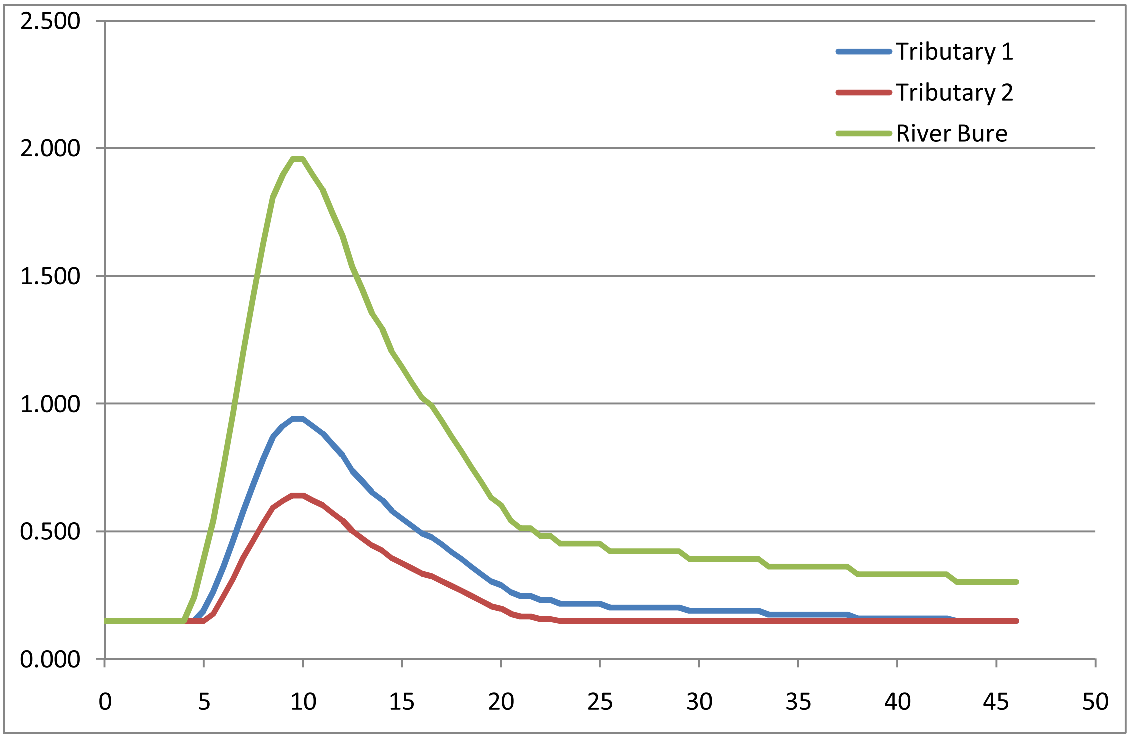

Figure 3 – 100-year flows for each watercourse

3.3 Hydraulic Assessment

3.3.1 Model Overview

An unsteady state ISIS model of the River Bure and associated tributaries and floodplains was constructed. The model contains three watercourses and a lake outflow as detailed in Table 3-4 and shown in Figure D1 in Appendix D.

Table 3-4 Watercourses contained in model

Watercourse	Name in model	Length of reach (m)	Upstream extent (NGR)	Downstream extent (NGR)
River Bure	Tributary 3 (T3) down to confluence with Tributary 2 (T2) down to confluence with Tributary 1 (T1) to downstream extent of model	1952	458174, 225414	457695, 223804
Tributary 1	Tributary 1 (T1)	2588 (to confluence with T2)	455409, 224548	457606, 224230
Tributary 2	Tributary 2 (T2)	1510 (to confluence with T3)	456707, 225662	457979, 224508
Lake outflow	Tributary 4 (T4)	260 (to culverted confluence with T3)	458207, 225342	458100, 225070

3.3.2 Cross Sections

The majority of the cross-section data in the model was generated from two cross-section surveys. The majority of the model was informed by Hyder's in-house surveyors, who also conducted a topographical survey of the Exemplar site and survey information necessary to model the connection between the River Bure and the lake at Caversfield House (discussed in Section 3.3.3 below). Additional survey was collected by Maltbys Land Surveyors to supplement the existing survey information. In particular extra information was gathered at the confluences of the watercourses and at the pond outflow (named as T4).

When the model was run, a number of sections were shown to be 'glass-walling', with modelled water levels higher than the highest ground level in the section. In some cases, the existing Hyder topographical survey was used to extend these sections across the floodplain. However, this information did not cover the full extent of the modelled watercourses. To extend the remaining sections, additional topographical information was required.

It was also identified after the initial runs that the lake at Caversfield House was connected to the River Bure at its upstream end, allowing flow along the lake to its culverted outlet. To model this flow path and the interaction between the lake and the River Bure, it was decided to model the lake using cross-sections. As survey data was not available for the lake, one LiDAR tile was purchased to aid in creating the lake sections and extending the River Bure sections in the area. The base level of the lake sections was taken from points on the survey of the River Bure that showed the left bank of the lake.

For any remaining glass-walling sections that weren't covered by either the site topographical survey or the LiDAR, a 5 m DTM was used to extend sections. As this was the least accurate of all the topographical information available, it was only used where other more accurate information could not be obtained.

3.3.3 Structures

The baseline model incorporates a number of structures that have been modelled using the survey data provided. The structures are listed in Table 3-5.

Table 3-5 Structures in the baseline model

ISIS node	Structure	ISIS unit
T1-2723	Small field ditch culvert	Symmetrical conduit
T1-2391	Inline pond outflow	Symmetrical conduit
T1-2064	Small field ditch culvert	Symmetrical conduit
T1-1564	Railway culvert	Symmetrical conduit
T1-1300	Road culvert	Arch bridge
T1-1051	Small field ditch culvert	Symmetrical conduit
T1-0452	Small footbridge	Orifice
T1-0427	Bridge under track	Arch bridge
T1-0416	Bridge under road	Symmetrical conduit
T2-1461	Small field ditch culvert	Symmetrical conduit
T2-0779	Small field ditch culvert	Orifice
T3-0741	Small footbridge	Orifice

T3-0637	Small culvert	Orifice
T3-0356	Permanent sluice board (see below)	Spill
T3-0355	Penstock (see below)	Vertical sluice
T3-0354	Road culvert	Symmetrical conduit
T3-0301	Road culvert	Symmetrical conduit
T3-0256	Small footbridge	USBPR bridge
T3-0176	Small bridge	USBPR bridge
T3-0157	Small bridge	USBPR bridge
T4-pondweir	Lake inflow from T3-0687	Orifice
T4-0025	Lake outflow culvert	Orifice
T4-0019	Small arched gap in wall over outflow channel	Arch bridge
T4-0015	Road culvert	Symmetrical conduit

In general the ISIS node used has matched the type of structure found in the study area. However, orifice units were used where model stability was compromised by using a bridge or culvert. This usually occurs when these units are surcharged as they do not handle the transition between normal and orifice flow very well and can cause model instability.

A number of culverts in the model use the symmetrical conduit unit with a thin 'hat' on the unit. This is because ISIS does not solve pressurised flow very well and therefore by using a small 'hat' the open channel equations are still used without a significant loss of accuracy in calculating water levels.

Flows into and out of these culverts are modelled using spill units rather than culvert inlet/outlets as these units are coming under increasing critique as was highlighted at the ISIS user group in November 2009. In Bicester most of the culverted sections are small and are part of the field ditch system. The culvert inlet/outlet units have been designed with larger culverts in mind and therefore using spill units is the methodology that has been followed here.

T3-356

The series of structures just upstream of the face of the B4100 road culvert is particularly complex. The model was informed by the survey information and from talking to the surveyors who undertook the work. Photographs from the surveys are shown in Figure 4.

Figure 4 – Photographs of the structures at T3-356

The first structure is a wooden board which has been placed in the channel and allows no water to pass under it, causing water to weir over the top of it to flow "through" the structure. After speaking with the surveyors they suggest the channel is likely to be ephemeral at this location. This structure was modelled as a spill with a coefficient of 1.2 in the ISIS model.

Water that flows over this structure enters a sump 1.37 m below the crest of the board. The water then flows through a penstock gate, which is open and then into another sump. Water then enters the road culvert, which is set 0.41 m above the base of the sump. This culvert extends for approximately 35 m before issuing at T3-314.

The first sump was modelled by repeating the section at the upstream face of the penstock, which was then linked to a vertical sluice unit with the weir information taken from the long section. The breadth of the weir was altered to ensure that the bore area was correct. The second sump was modelled using two river units with the geometry provided by the surveyors for the immediate downstream face of the penstock. However, the second section was raised to the bed level at the face of the road culvert as informed by the long section. The culvert was modelled using the spill and symmetrical conduit schematisation as described above.

A comparison of the long section at this location in ISIS and from the survey is shown in Figure 5.

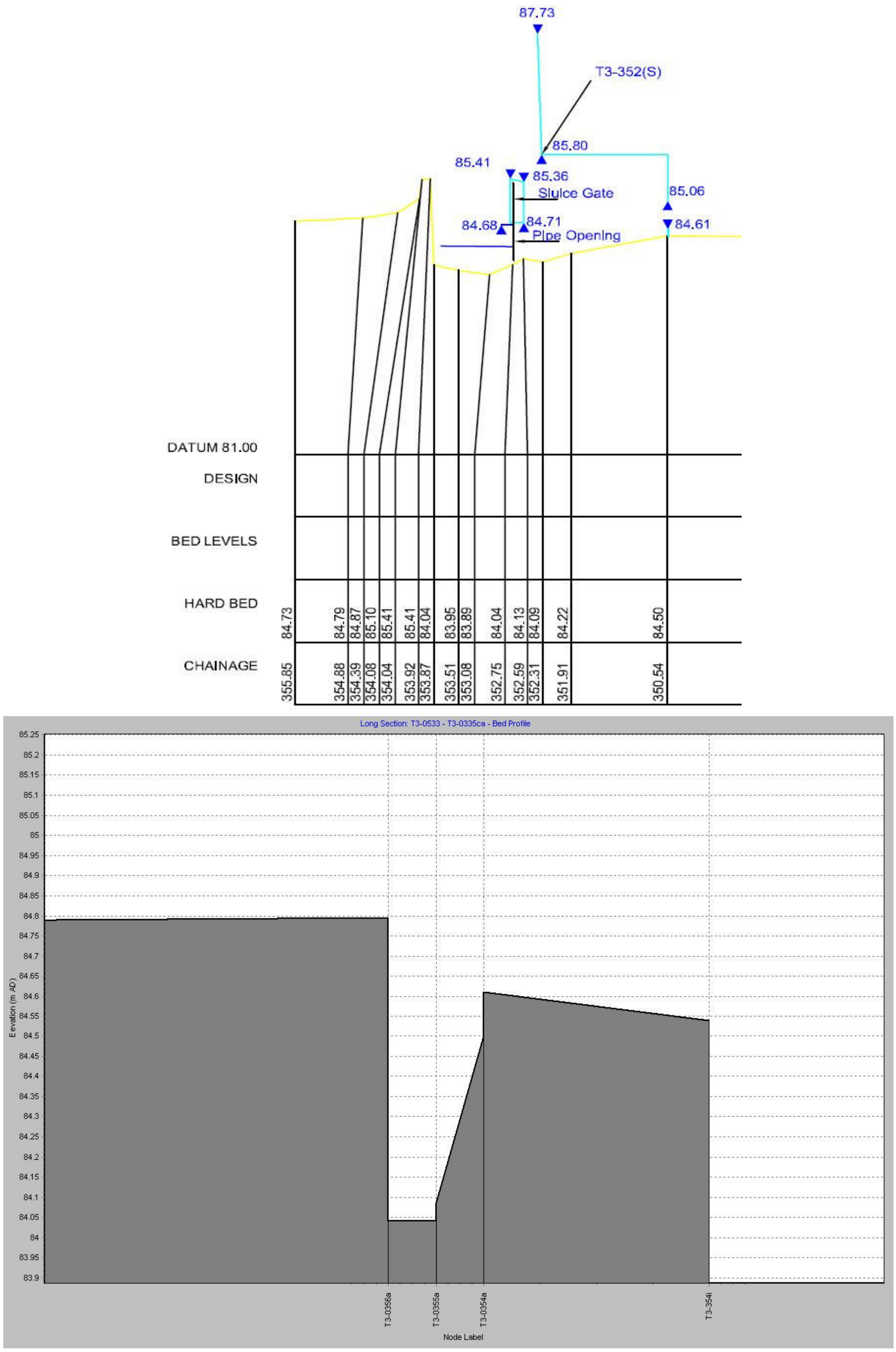

Figure 5 – The surveyed (top) and ISIS long sections at this location. Please note that the spill and vertical sluice gate information is not shown in the ISIS output.

T1/T2 Confluence

The confluence between T1 and T2 is another unusual configuration. The two watercourses flow towards each other and then at the confluence, the combined watercourse flows at ninety degrees through a culvert (see Figure 6). The watercourse then reverts to open channel before entering a second culvert under the road.

At the actual confluence the bridge unit (T1-0427a) was informed from the survey. Then 1m back from this the same channel profile was used but with only the bed (25.714 LHB to 36.601 RHB) and not any of the banks. For each watercourse, the upstream section (T1-0450b and T2-0055) was copied to become the most downstream section before the confluence but the bed levels were dropped to the same level as at the points mentioned above (25.714 for T1 and 36.601 for T2) on the long section through the confluence provided by the surveyors. The sections were altered to include the wall on the relative bank. These channel profiles were copied into spill units and linked to the confluence section with the spill unit using a junction. This was because without a spill unrealistic water level profiles were obtained upstream of the confluence. The spill unit had a value of 1.5 to help model some of the energy losses that will occur at this location.

This schematisation was seen as the best that could be achieved given the information obtained. However, it is possible that the energy losses are not fully accounted for but there was no information available for an additional general loss unit to be used.

Figure 6 – The confluence between T1 and T2

3.3.4 Manning's Roughness Coefficients

The resistance to flow in a channel or over a floodplain is defined in a hydraulic model by the use of a roughness coefficient, Manning's number, otherwise known as Manning's '*n*'. The

Manning's '*n*' range of values used in the model, as outlined in Table 3-6, were based on site visit observations and published values (Chow, 1959).

Table 3-6Adopted Range of Manning's '*n*' coefficients

Location	Manning's '*n*'		Type of Channel / Floodplain and Description
Channel	Min	0.04	Clean, winding, some pools and shoals with some weeds and stones.
	Max	0.05	Winding, some pools and shoals, lower stages, more ineffective slopes and sections with weeds and stones.
Floodplain	Min	0.02	Concrete or tarmac.
	Max	0.07	Medium to dense brush in winter.

3.3.5 Boundary Conditions

Table 3-7 provides a summary of the different scenarios that were simulated in order to assess the existing and future flood risk on the proposed development site.

Flow hydrographs were obtained through the hydrological assessment and inputted as the upstream boundary condition.

The downstream boundary condition was taken from node BU.3056 of the Environment Agency hydraulic model developed for the River Bure through Bicester.

Table 3-7Modelled Scenarios

Scenario	Return period	Upstream boundary conditions	Downstream boundary condition
1:100	1 in 100 year	T1 – 0.942 m^3/s T2 – 0.641 m^3/s T3 – 1.958 m^3/s	77.21m
1:100+20%	1 in 100 year with climate change (20%)	T1 – 1.130 m^3/s T2 – 0.769 m^3/s T3 – 2.350 m^3/s	77.25m
1:1000	1 in 1000 year	T1 – 1.701 m^3/s T2 – 1.157 m^3/s T3 – 3.535 m^3/s	77.37m

3.3.6 Model Calibration

Unfortunately no recorded water level or flow data was available at the site and therefore model calibration was not possible. To gain further confidence in the model sensitivity analysis was undertaken as detailed in Section 3.5.

3.4 Baseline Flood Risk

The aim of the study is to gain an understanding of the degree of flood risk to the development site and confirm the potential flood mechanisms that could lead to its inundation.

The model predicts that floodwater is generally confined to the valleys in which the watercourses flow, with ponding occurring at confluences and upstream of constricting structures. The model does not predict any overland flow occurring.

Figure 7 and Figure 8 below show the modelled flood extent across the site for the 100-year and 1000-year events (i.e. Flood Zones 3 and 2 respectively). Figure 7 shows that the northern part of the development site has no flood risk whatsoever. Figure 8 shows that, in the southern part of the development site, flooding occurs predominantly on the flatter land around the confluence between the River Bure and the northernmost of the two tributaries. Away from the confluence, flooding is confined to the relatively narrow valley of the watercourse.

Figure 7 – Modelled flood extents for northern part of development site

Figure 8 – Modelled flood extents for southern part of development site

Figure 8 also shows that the flooding only impacts on green space within the development, and no buildings or roads are affected by flood water. The two bridges where roads cross the watercourses will be designed to cause no constriction to flow, and therefore will not increase the flood risk to the site. The development therefore has been placed entirely within Flood Zone 1, as is required for an Eco-Town under PPS1.

Table 3-8 below shows the modelled peak water levels through the development site for each return period. Cross-section locations are shown on Figure D2 in Appendix D.

Table 3-8Development Site Modelled Peak Water Levels

Node Label	100-year	100-year with climate change	1000-year
T2-0952	84.67	84.68	84.70
T2-0779a	83.34	83.38	83.49
T2-0777b	83.34	83.38	83.49
T2-0756a	83.34	83.38	83.49
T2-0756b	83.34	83.38	83.49
T2-0636	82.77	82.81	82.91

T3-0157a	83.54	83.59	83.71
T3-0152b	83.54	83.59	83.71
T3-0011	83.34	83.38	83.49

The model results have confirmed that the proposed development site is predominantly located within the Low Flood Risk Zone, with small areas of Medium and High risk around the watercourses. All proposed development has been located within the areas of Low risk, and therefore the development is considered to be at **low** risk of flooding from fluvial sources.

3.4.1 Flood Protection

Due to PPS1 restrictions on the siting of development in an Eco-Town, all of the buildings in the proposed development will be sited in Flood Zone 1. Therefore, no flood protection or mitigation measures will be necessary on the site.

3.4.2 Third Party Flood Risk

All development will be sited within Flood Zone 1 and any roads crossing watercourses will have culverts adequately sized so that they cause no restrictions on flow. Therefore, there will be no loss of floodplain storage caused by the proposed development. Any increased surface water runoff caused by the development will also be attenuated to Greenfield rates (see Section 4). Therefore, there will be **no change** in third part flood risk as a result of the development.

3.4.3 Site Access and Egress

As stated in Section 3.4.4 above, all development will be sited within Flood Zone 1 and any roads crossing watercourses will be raised above flood levels and have culverts adequately sized so that they cause no restrictions on flow. Therefore, emergency access routes will not be affected by flooding.

3.5 Sensitivity Analysis

Model sensitivity tests are undertaken to determine the level of uncertainty in the predicted water levels associated with key model parameters. For consistency, all sensitivity tests have been carried out using the 1 in 100-year flow. A full discussion of the sensitivity analysis undertaken and the model results is presented in the Hydraulic Modelling Report in Appendix E. The following sensitivity tests were undertaken:

- Manning’s ‘n’ values increased by 20%
- Manning’s ‘n’ values decreased by 20%
- Downstream boundary increased by 0.5m
- Spill coefficients increased by 20%
- Spill coefficients decreased by 20%

Table 3-9 overleaf shows the changes in modelled water level through the development site caused by each sensitivity test.

Table 3-9 Sensitivity Test Changes in Modelled Water Level

Node Label	Increased Mannings	Decreased Mannings	Downstream Boundary	Spill Coefficients Increased	Spill Coefficients Decreased
T2-0952	0.00	-0.02	0.00	0.00	0.00
T2-0779a	0.03	-0.06	0.00	0.00	0.00
T2-0777b	0.03	-0.07	0.00	0.00	0.00
T2-0756a	0.03	-0.07	0.00	0.00	0.00
T2-0756b	0.03	-0.07	0.00	0.00	0.00
T2-0636	0.06	-0.03	0.00	-0.01	-0.01
T3-0157a	0.05	-0.07	0.00	0.00	0.00
T3-0152b	0.05	-0.07	0.00	0.00	0.00
T3-0011	0.03	-0.07	0.00	0.00	0.00
Maximum	0.06	-0.02	0.00	0.00	0.00
Minimum	0.00	-0.07	0.00	-0.01	-0.01
Average	0.03	-0.06	0.00	0.00	0.00

The results of the sensitivity test indicate that in the vicinity of the development site the model is not particularly sensitive to the adopted roughness coefficients, the downstream boundary conditions or the adopted spill coefficients. This provides confidence in the model results.

3.6 Assumptions and Limitations

3.6.1 General

The hydraulic model has been constructed using the best available data, and from a range of sources. Whilst some checks have been made to confirm the suitability of the data, Hyder Consulting cannot be held responsible for errors in third party works.

The model is considered to be a best representation of reality within the current constraints of modelling; accuracy is inherently related to the quality and extent of data available.

3.6.2 Hydrology

There is insufficient hydrometric data available to enable validation or calibration of the model. Therefore, there is a degree of uncertainty associated with the fluvial flow estimates used in this modelling study.

4 DRAINAGE STRATEGY

The surface water drainage strategy for the Exemplar development site is described in the Exemplar Site Drainage Strategy report (7501-UA001881-UP21R-01). The drainage strategy aims to demonstrate that the site will not increase flood risk within the site as well as at other locations as the post-development runoff rates are maintained at the Greenfield rates. The drainage strategy outlines the provision of a surface water drainage system which includes SUDS measures and attenuation storage within the site. This strategy will be used to inform the final detailed design of the drainage systems and surface water storage areas within the site.

4.1 Greenfield Runoff Rate

The Greenfield runoff rate was calculated for the site based on the Institute of Hydrology 124 method, as recommended by the Environment Agency/DEFRA guidance document: Preliminary Rainfall Runoff Management for Developments. The resultant runoff rates are outlined in Table 4-1 below.

Table 4-1 Greenfield Runoff Rate Estimation

Return Period	Greenfield Runoff	
	(l/s/ha)	(l/s)
Mean Annual Flood	2.29	40.1
1 in 30 year	5.12	89.6
1 in 100 year	7.29	127.6

4.2 Required Storage Volumes

The Exemplar development site has been divided into a number of catchments for the storage of runoff prior to discharge. The catchments are shown in Appendix F (taken from the drainage strategy report). A large proportion of the site would discharge via ground infiltration, and therefore an allowance has been made within each catchment for the proportion of properties which are likely to infiltrate and would not require storage within structures. A summary of storage volumes for each catchment is shown in Table 4-2.

Table 4-2 Storage Volumes

Catchment	Storage Volume (m^3)	Discharge (l/s)
1	105	6.1
2	80	2.5
3	215	12.7
4	95	8.7
5	65	5
6	90	5

4.3 Designing for exceedance

It is not economically viable or sustainable to build a drainage system that can accommodate the most extreme events. Consequently, the capacity of the drainage system may be exceeded on rare occasions, with excess water flowing above ground. The design of the site layout provides an opportunity to manage this exceedance flow and ensure that indiscriminate flooding of property does not occur.

5 CONCLUSIONS

5.1 Conclusions

The flood risk for the proposed development of NW Bicester eco development has been assessed in accordance with PPS25: Development and Flood Risk.

Hydraulic modelling has been undertaken to delineate the floodplain across the site and ensure that the development will not lead to an increase in flood risk elsewhere. The hydraulic modelling confirms that the areas where development is proposed within the eco development are located in areas of **low** risk of fluvial flooding.

The flood risk to the site is considered to be at **low** from fluvial, tidal, ground and surface water sources. The flood risk from artificial sources is also considered to be **low** as there are no sources within or upstream of the site.

The surface water drainage strategy has demonstrated that an appropriate drainage design can achieve the current Greenfield runoff rates or less.

Based on this assessment, it is therefore concluded that the proposed development can be undertaken in a sustainable manner without increasing the flood risk either at the site or to any other sites.

5.2 Recommendations

1 The recommendations outlined in the Drainage Strategy report should be adhered to.

2 Any changes in development layout will be subject to additional review.

3 All bridges over watercourses should be sized appropriately to ensure they do not cause any constriction to flow.

4 Design of landscaping and storage should be undertaken in such a way to avoid potential for inundation of buildings and evacuation routes, especially during exceedance events.

Appendix A

Topographical Survey

Appendix B

Site Layout

Appendix C

Geotechnical Investigation

Appendix D

Model Schematics

Appendix E

Hydraulic Modelling Report

Appendix F

Runoff Storage Catchments