Hydro-Logic Services

Sam Harrison
Ian Pick Associates Ltd
Station Farm Offices
Wansford Road
Nafferton
Driffield
East Yorkshire
YO25 8NJ

Ref: K0776/PR

8th December 2016

Dear Sam,

**FLOOD RISK ASSESSMENT AND SURFACE WATER MANAGEMENT PLAN, COMMERCIAL / AGRICULTURAL DEVELOPMENT, BARR FARM, DEEPING ST NICHOLAS, SPALDING, LINCOLNSHIRE PE11 3BW**

Thank you for instructing Hydro-Logic Services (International) Ltd to undertake a flood risk assessment and surface water management plan for the above site. Our findings are summarised below.

1) The site includes existing commercial / agricultural buildings and areas of currently undeveloped agricultural land. The proposed development includes six new poultry rearing units, a new area of hardstanding (concrete apron) to be used for waste washing and vehicular access, generator, fresh water tank, feed bins, control room(s), and an area for an attenuation basin.
2) The proposed development site is in Flood Zone 3 and at risk of flooding from fluvial/tidal sources. However, the site is on land benefitting from defences, which will protect against the combined 1 in 100 year fluvial and 1 in 200 year tidal flood. The proposed development is classed as *Less Vulnerable* and is be appropriate in the flood zone.
3) The Sequential Test may be deemed satisfied by virtue of the proposed development being at an existing site, and that no change of use is proposed. The Exception Test is not required.
4) There is generally a *Very Low* risk of surface water flooding on-site, with small isolated areas of *Low* risk.
5) The published soil characteristics indicate that surface permeability is limited and surface water runoff cannot be managed using infiltration. Accordingly, an attenuation design has been prepared that will reduce runoff rates from the proposed impermeable surfaces at the site to no greater than current, Greenfield rates, for a range of return period storms.
6) An outline attenuation design is presented in Appendix A. The Appendix shows that an attenuation basin of basal area 1,800 $m^2$, top area 2,180 $m^2$ and depth 0.9 m, with a compound outlet structure comprising a 75 mm diameter orifice at invert 0 m and a 100 mm diameter orifice at invert 0.45 m is suitable for the design.

7) Allowance is made for climate change by increasing the design rainfall by 20%, the NPPF and Environment Agency recommended central allowance for the potential change in peak rainfall between 2060 and 2115.

8) A survey of the site is recommended to ensure that the elevation of the basin is appropriate to enable adequate conveyance from impermeable surfaces to basin, and basin to outlet at the drain adjacent to the northern boundary of the site.

9) Residual risks include a rainstorm significantly above the 1:100 year plus climate change design value, and possible blockage of the control orifice, leading to the potential overtopping of the basin, and the possibility that overflow could cut through a natural earth embankment. A 2 m wide weir should therefore be constructed at the outflow, at an invert of 0.85 m above the base of the basin, which would act as a spillway to convey exceedance flows. The spill should route outflow to a concrete channel and towards the receptor drain at the northern boundary of the site.

10) It is recommended that the attenuation system should be checked for damage or blockage on a monthly basis and after heavy rains; all such costs should be borne by the site owner.

In summary, flood risks at the site are low or very low for all sources and if the measures recommended within this report are implemented, runoff from the site would be managed to comply with the flood risk provisions of the NPPF.

Yours sincerely,



Paul Roberts
**Hydrologist, Modeller, Analyst**
Tel. 01189 480150 (direct)

## Limitation of liability and use

The work described in this report was undertaken for the party or parties stated; for the purpose or purposes stated; to the time and budget constraints stated. No liability is accepted for use by other parties or for other purposes, or unreasonably beyond the terms and parameters of its commission and its delivery to normal professional standards.



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# Flood Risk Assessment Template based on the NPPF Practice Guide[1]

## 1 Development description and location

1a. What type of development is proposed and where will it be located?

- A location plan at an appropriate scale should be provided with the FRA, or cross referenced to the main application when it is submitted.

*A commercial / agricultural development has been proposed on land at Barr Farm, Deeping St. Nicholas, Spalding, Lincolnshire PE11 3BW (the site). The site includes existing commercial / agricultural buildings and areas of currently undeveloped agricultural land.*

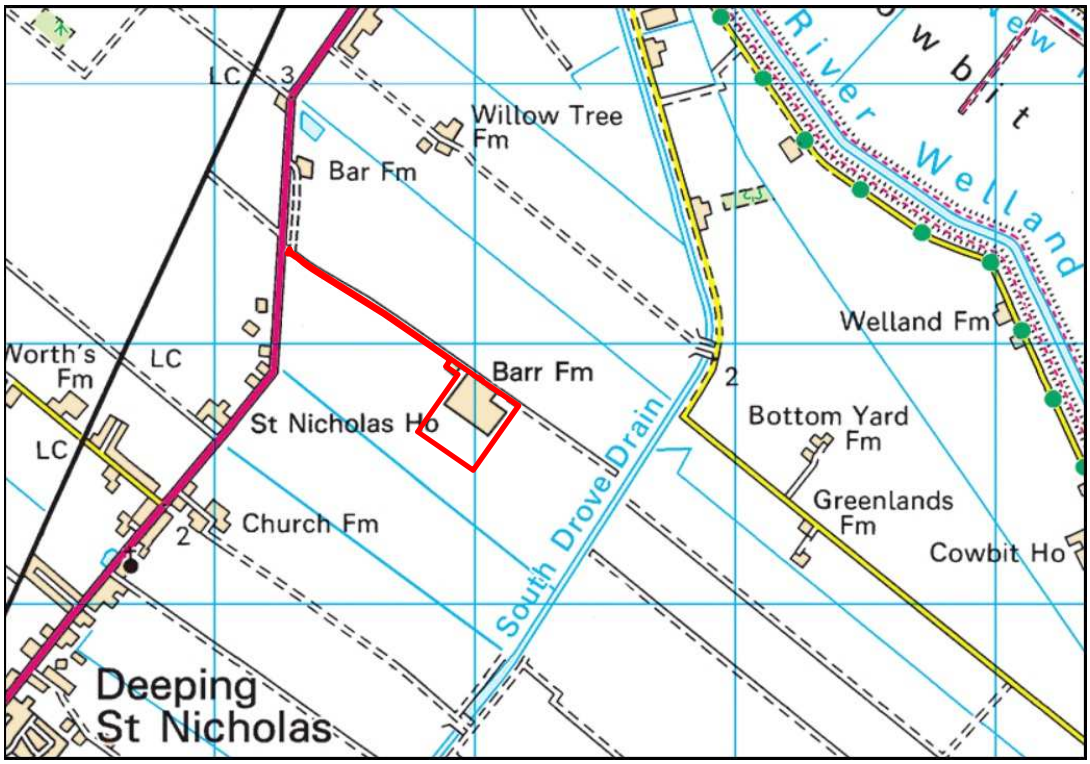
*The proposed development includes six new poultry rearing units, a new area of hardstanding (concrete apron) to be used for waste washing and vehicular access, generator, fresh water tank, feed bins, control room, and an area for an attenuation basin. Access to the site is by a private road running south-east from Littleworth Drove.*

*The coordinates of the approximate centre of the site are reproduced in Table 1. The location of the site is shown in Figure 1, and the location plan is shown in Figure 2. The total area of the site indicated by the red line boundary (excluding access road) is approximately 82,330 m$^2$.*

***Table 1 Approximate coordinates of the location of the site***

| | |
|---|---|
| *OS X (Eastings)* | *523000* |
| *OS Y (Northings)* | *316770* |
| *Nearest Post Code* | *PE11 3BW* |
| *Lat (WGS84)* | *N52:44:05 (52.734584)* |
| *Long (WGS84)* | *W0:10:47 (-0.179761)* |
| *Nat Grid* | *TF230167 / TF2300016770* |

***Figure 1 Location of the site (site boundary as red line)***



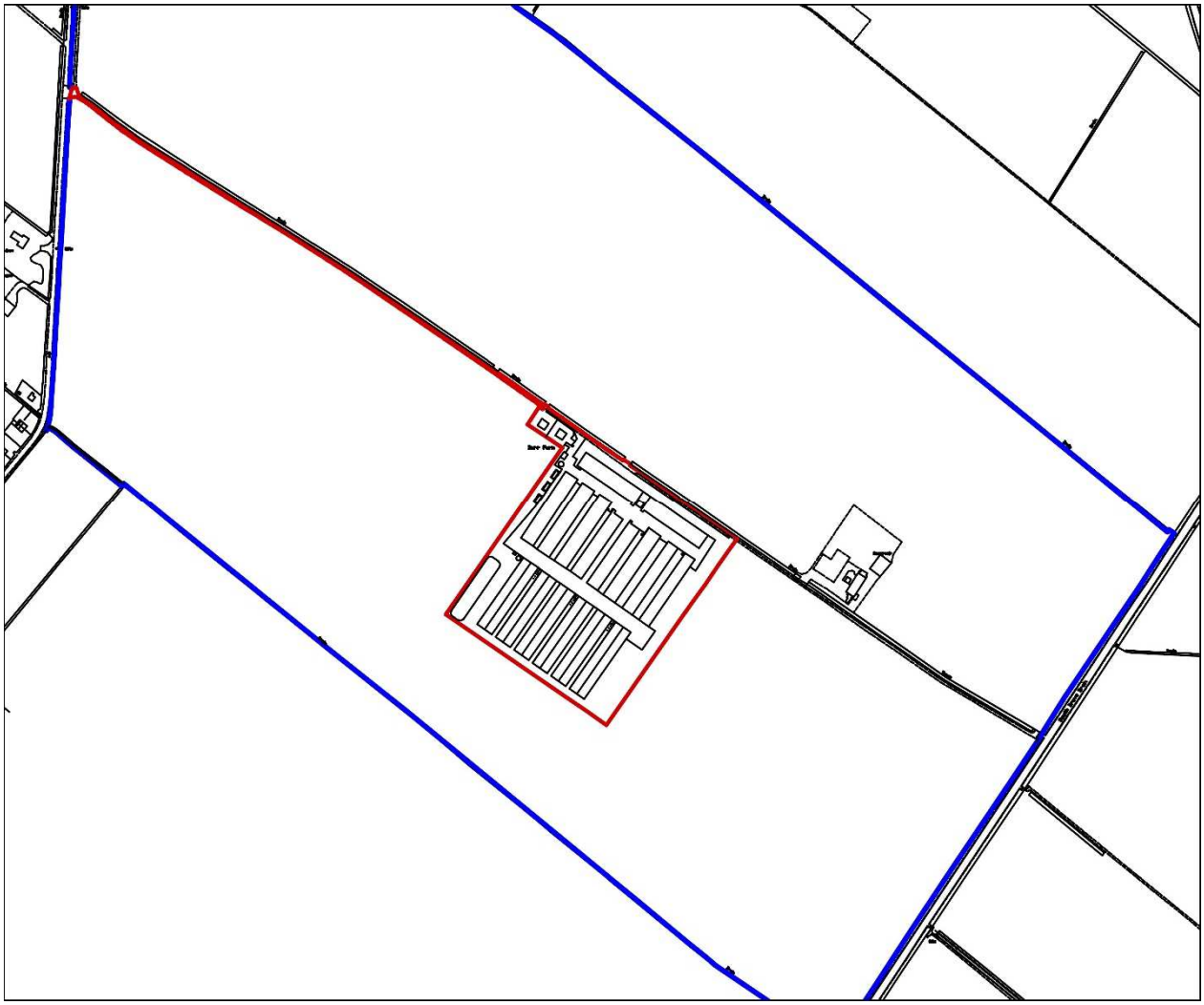

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[1] http://planningguidance.planningportal.gov.uk/blog/guidance/flood-risk-and-coastal-change/



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***Figure 2 Location plan of the site (site boundary as red line)***



*Source: Ian Pick Associates Ltd.*

1b. What is its vulnerability classification?

- Vulnerability classifications are provided in Table 2, NPPF Technical Guide

*The NPPF Technical Guide (DCLG, 2012b) provides a table describing flood risk classification by development type. This table confirms that the type of proposed development - land and buildings used for agriculture and forestry - is classified as Less Vulnerable (LV).*

1c. Is the proposed development consistent with the Local Development Documents?

- Where the site is allocated in an existing LDD the allocation should be referred to. Your Local Planning Authority planning officer should be able to provide site-specific guidance on this issue.

*The location of the site is covered by South Holland District Council. The South Holland Local Plan (adopted July 2006) sets out the planning policies for the development and use of land in the District until the year 2021. The site is located outside the defined settlement limits of Deeping St. Nicholas and Spalding Town and is referred to as "open countryside" for Local Plan purposes.*

*Many of the policies originally set out in the 2006 Local Plan are no longer valid and have been superseded by national planning guidance set out in the National Planning Policy Framework (NPPF) and National Planning Policy Guidance (NPPG). One such policy was SG9 Development and Flood Risk. It may therefore be assumed NPPF/NPPG represents policy is this case.*



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*The 2006 South Holland Local Plan presents the following core strategic and general policies that are also relevant to, and appear to support, the proposed development.*

- *Policy SG1 – General Sustainable Development*
- *Policy SG4 – Development in the Countryside*
- *Policy SG11 - Sustainable Urban Drainage Systems (SUDS)*
- *Policy EC4 - Farm Diversification*

*The proposed development supports enterprise and the sustainability of the local community and appears to be consistent with the relevant core strategic and general policies within the 2006 South Holland Local Plan.*

1d. Please provide evidence that the Sequential Test or Exception Test has been applied in the selection of this site for this development type?

- Evidence is required that the Sequential Test has been used in allocating the land use proposed for the site and that reference has been made to the relevant Strategic Flood Risk Assessment (SFRA) in selecting development type and design (See paragraphs 100-104, NPPF and paragraphs 3-5, NPPF Technical Guide). Your Local Planning Authority planning officer should be able to provide site-specific guidance on this issue.
- Where use of the Exception Test is required, evidence should be provided that both elements of this test have been passed (see paragraphs 102, NPPF and paragraphs 4-5, NPPF Technical Guide). Your Local Planning Authority planning officer should be able to provide site-specific guidance on this issue.

*The NPPF Technical Guide (DCLG, 2012b) provides a table identifying flood risk vulnerability and flood zone compatibility, reproduced in Table 2 below. The table indicates that new developments classified as Less Vulnerable (LV) are considered appropriate in Flood Zone 3a, but are not permitted in Flood Zone 3b (functional floodplain, corresponding to the 1 in 20 year flood extent).*

*The South Holland District Council (SHDC) Strategic Flood Risk Assessment (SFRA) (Royal Haskoning, January 2010) is reviewed in sections 2b and 3b. The SFRA confirms that, within South Holland District, the functional floodplain comprises only the designated flood storage areas of the Cowbit and Crowland washes and at Surfleet reservoir, and therefore all other areas of Flood Zone 3 should be considered as Flood Zone 3a for the purposes of flood risk vulnerability and flood zone compatibility. Further, NPPF confirms that "areas which would naturally flood, but which are prevented from doing so by existing defences… will not normally be identified as functional floodplain". The site is therefore located in Flood Zone 3a, and the proposed development may be considered appropriate in the flood zone.*

*The Sequential Test may be deemed satisfied by virtue of the proposed development being at an existing agricultural site, and that no change of use is anticipated. There is no opportunity to apply a sequential approach to the allocation of land use within the site, since the site is uniformly level. As indicated in Table 2 the Exception Test is not required.*

***Table 2 Flood risk vulnerability and flood zone compatibility***

| Flood Zone | Definition | Essential Infrastructure | Water compatible | Highly Vulnerable | More Vulnerable | Less Vulnerable |
|---|---|---|---|---|---|---|
| 1 | $T>1,000$ | ✔ | ✔ | ✔ | ✔ | ✔ |
| 2 | $100<T_{fluv}<1,000$<br>$200<T_{tidal}<1,000$ | ✔ | ✔ | Exc | ✔ | ✔ |
| 3a | $T_{fluv}<100$<br>$T_{tidal}<200$ | Exc. | ✔ | ✘ | Exc | ✔ |
| 3b (functional floodplain) | $T_{fluv}<20$ | Exc | ✔ | ✘ | ✘ | ✘ |

*Table 3 from the NPPF Technical Guide (DCLG, 2012b)*

*Notes:*

| | | | |
|---|---|---|---|
| ✔ | development is appropriate | T | return period (fluv = fluvial) |
| ✘ | development should not be permitted | Exc | exception test should be applied |



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1e. *[Particularly relevant to minor developments (alterations & extensions) & changes of use]* Will your proposal increase overall the number of occupants and/or users of the building/land; or the nature or times of occupation or use, such that it may affect the degree of flood risk to these people?

*The proposed development may increase the number of people working at the site and/or the nature and times of occupation and use of the site. However, the location of the site benefits from defences and therefore the risk of flooding should be considered a residual risk.*

**2. Definition of the flood hazard**

2a. What sources of flooding could affect the site? (see paragraph 2, NPPF Technical Guide).

- This may include hazards such as the sea, reservoirs or canals, which are remote from the site itself, but which have the potential to affect flood risk (see Section 1 of the NPPF Practice Guide).

*Table 3 shows the sources of flood risk at the site, with each risk discussed further in section 2b.*

***Table 3 Sources of flooding and possibility at site***

| ***Key sources of flooding*** | ***Possibility at Site*** |
|---|---|
| *Fluvial* | *The site is located in Flood Zone 3, inside the combined 1:100 year fluvial and 1:200 year tidal flood extent. However, the site is protected by defences, and the risk of flooding derives from the failure of those defences.* |
| *Tidal* | *As above.* |
| *Groundwater* | *The SHDC SFRA confirms that there are no reports of groundwater flooding occurring in the district.* |
| *Sewers* | *The site incorporates existing commercial / agricultural buildings, and there are both foul and surface water sewers close to the site. However, the SHDC SFRA confirms that flooding from sewers in the district is limited to minor isolated cases.* |
| *Surface water* | *The Environment Agency Flood Risk from Surface Water Map confirms the risk of surface water flooding is generally very low across the site, with small isolated areas of low risk.* |
| *Infrastructure failure* | *The Environment Agency Flood Risk from Reservoirs Map confirms the site is at risk of flooding due to defence failure.* |

*List taken from NPPF Practice Guide, Paragraph 2*[2]

2b. For each identified source, describe how flooding would occur, with reference to any historic records wherever these are available.

- An appraisal of each identified source, the mechanisms that could lead to a flood occurring and the pathways that flood water would take to, and across, the site.
- Inundation plans, and textural commentary, for historic flood events showing any information available on the mechanisms responsible for flooding, the depth to which the site was inundated, the velocity of the flood water, the routes taken by the flood water and the rate at which flooding occurred.

*The South Holland District Council (SHDC) Strategic Flood Risk Assessment (SFRA) (Royal Haskoning, January 2010) is referenced as a source of information throughout this section.*

*Flood risk at the location of the site derives from the interaction of fluvial flooding, flooding from*

[2] *http://planningguidance.planningportal.gov.uk/blog/guidance/flood-risk-and-coastal-change/planning-and-flood-risk/what-is-flood-risk/*



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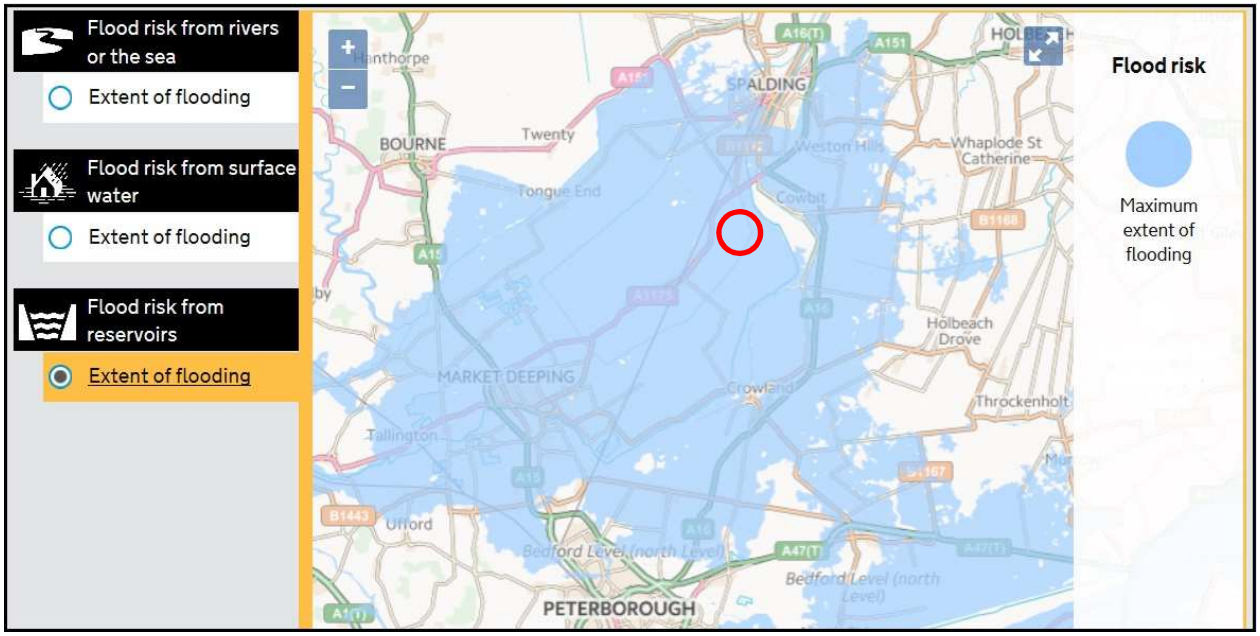
*the sea, defence failure, shortfall in capacity and/or failure of infrastructure in the internal drainage network.*

*As indicated in Table 3 and Figure 5, the site is located in Flood Zone 3, inside the combined 1:100 year fluvial and 1:200 year tidal flood extent. The fluvial component derives from the River Welland to the east of the site, and to a lesser extent, the River Glen to the west the site. The tidal component derives from The Wash, approximately 23 km to the north-east of the site.*

*The flood zone mapping ignores the effects of defences. Within the South Holland District, the River Welland and River Glen are embanked and so have no direct floodplain other than at designated flood storage areas. Examples of such flood storage areas are the Cowbit and Crowland Washes, to the east and south of the site respectively. These washlands are located to the east of the River Welland and are designed to receive and store flood water in order to protect Spalding further downstream.*

*Since the site is protected by defences, the risk of flooding derives mainly from the failure of those defences. The Environment Agency Flood Risk from Reservoirs (Infrastructure Failure) Map is shown in Figure 3. It may be seen that the risk of flooding from infrastructure failure is extensive throughout the South Holland District. Environment Agency on flooding from infrastructure failure is that this risk is generally considered to be very small.*

***Figure 3 Environment Agency Flood Risk from Reservoirs Map (site shown as red circle)***




*Source: Environment Agency*

*The location of the site is protected against flooding from the River Welland, approximately 1.8 km from the site at its closest, and from the River Glen, approximately 6.5 km from the site. The SFRA Appendix A Table 6L confirms the Welland defences have sufficient freeboard to protect against the 1:1000 year fluvial flood event. The SFRA Appendix A Table 7R confirms the Glen defences generally have sufficient freeboard to protect against the 1:1000 year fluvial flood event, although several locations distant from the site may not be secure at peak flood levels. The SFRA Figure 6 indicates the Welland and Glen defences are in fair to good condition.*

*The main effect of tidal flooding at the location of the site would be to compound the effects of fluvial flooding resulting from defence failure.*

*There is also the risk of flooding from the internal drainage network between the Rivers Welland and Glen. The drainage network at the location of the site is managed by the Welland and Deepings Internal Drainage Board (IDB). The surface water discharge and land drainage is managed through a network of drains, with water level controlled by pumping stations and*



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*sluices. The IDB aims to provide flood protection up to 1 m freeboard to land levels at the 5% (1 in 20) annual probability flood event. Allowing for the run-off storage capacity remaining within the 1 m freeboard, this standard effectively means that during the 1% annual probability event there may be shallow flooding over lower-lying areas, but flooding to roads and properties should only occur in isolated instances. Some shallow flooding may also occur in lower-lying areas in events more common than that of 1% annual probability. As well as overcapacity, flooding could also result from the failure of pumping and control systems within the IDB area.*

*The SFRA confirms the following information related to historical flooding.*

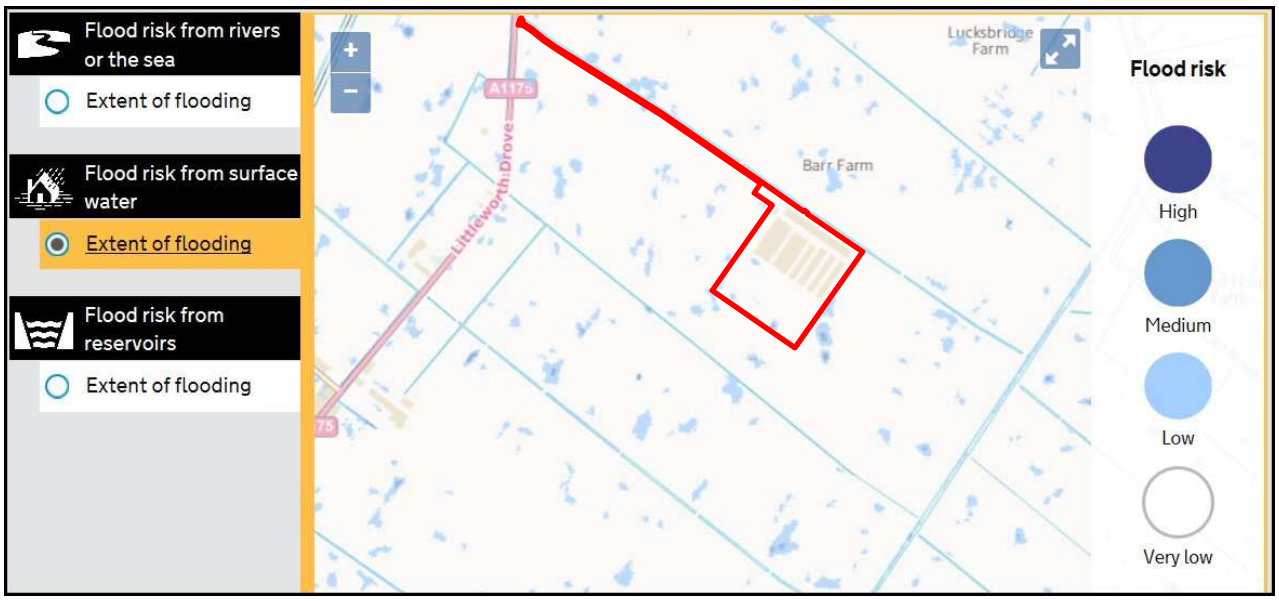
- *Relevant flooding history is post 1953, i.e. after the Coronation Channel in Spalding was opened and after remedial works to the tidal defences were completed following the 1953 tidal flood event.*
- *The tidal event of January 1978 remains the highest recorded tide in this area.*
- *None of the flood events recorded in the SFRA resulted in flooding at the location of the site.*

*The SFRA also records the following extreme rainfall events affecting the District since 1953.*

- *Event of 11th July 1968, with 130mm rain recorded at Pinchbeck Marsh, just north of Spalding.*
- *Event of 24th August 1987, with 110mm rain in 3 hours recorded at Holbeach.*
- *Event of 9th-13th April 1998, with 115mm rain recorded at Thorney, in the North Level.*
- *No flooding at the location of the site resulting from these event is recorded in the SFRA.*

*The Environment Agency Flood Risk from Surface Water Map shown in Figure 4 confirms the risk of surface water flooding is generally very low across the site, with small isolated areas of low risk.*

***Figure 4 Environment Agency Flood Risk from Surface Water Map (site boundary as red line)***




*Source: Environment Agency*

2c. What are the existing surface water drainage arrangements for the site?

- Details of any existing surface water management measures already in place, such as sewers and drains and their capacity.

*The site includes existing commercial / agricultural buildings and areas of currently undeveloped agricultural land. It is understood that a surface water management scheme based on attenuation*



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*has been implemented at the site as part of the existing development. The currently undeveloped part of the site would have no special drainage arrangements in place.*

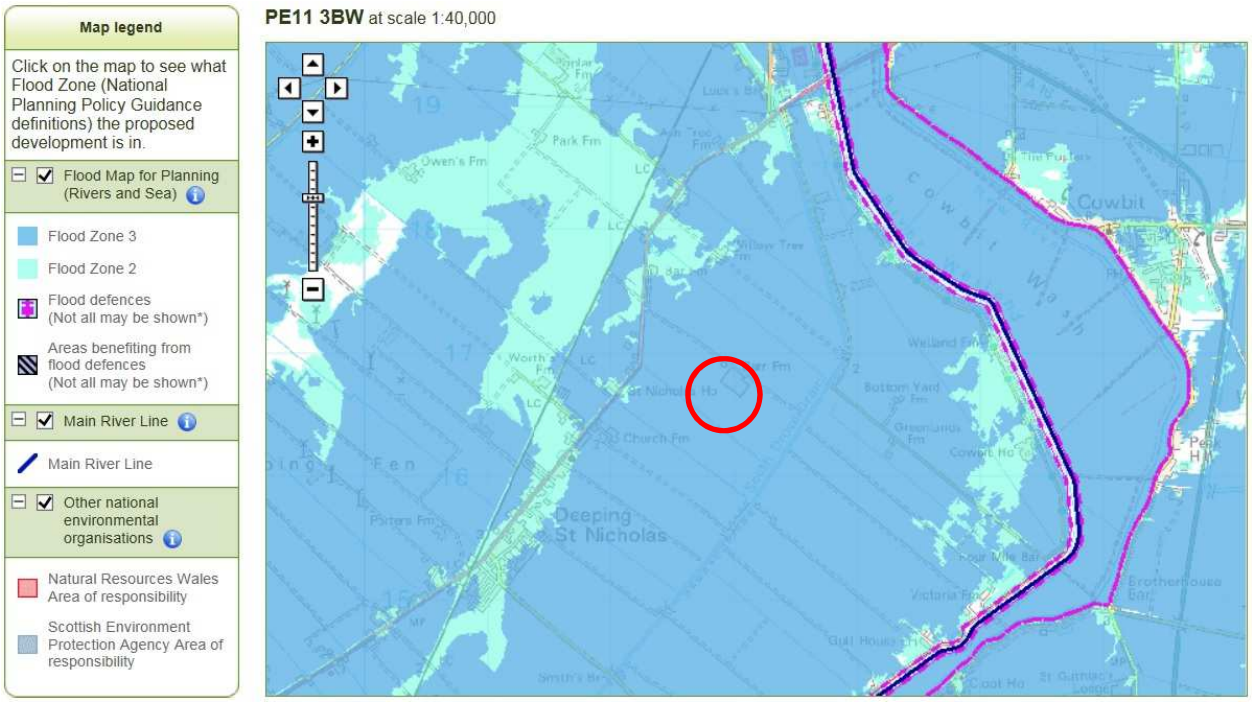
## 3. Probability

3a Which flood zone is the site within?

- The flood zones are defined in Table 2, NPPF Technical Guide.

*The Environment Agency Flood Map is reproduced in Figure 5. The map confirms the site is located in Flood Zone 3, inside the combined 1:100 year fluvial and 1:200 year tidal flood extent. The flood zone mapping ignores the effects of defences.*

***Figure 5 Environment Agency Flood Map for Planning (site location shown by red circle)***




*Source: Environment Agency*

3b If there is a Strategic Flood Risk Assessment covering this site, what does it show?

- The planning authority can advise on the existence and status of the SFRA.

*The location of the site is covered by the South Holland District Council (SHDC) Strategic Flood Risk Assessment (SFRA) (Royal Haskoning, January 2010). The SFRA is referenced in the preceding section 2b. The SFRA confirms that the defences are adequate protect against the 1 in 1,000 year fluvial event (see Section 2b).*

*The Flood Zone Map is shown as SFRA Figure 7. This map shows significant differences to the current Environment Agency Flood Zone Map shown in Figure 5 of this report, most likely due to revisions of the modelling and mapping of the flood zones since the publication of the SFRA. Accordingly, the Actual Flood Risk maps (i.e. the risk of flooding where the effects of defences are included) for the present day (Map 5), up to 2055 (Map 12) and up to 2115 (Map 13) may not be current. However, the SFRA provides the following information which is likely to be current at the location of the site.*

- *The site is outside the Rapid Inundation Zone of flooding from the River Welland for the present day up to 2115 (SFRA Map 16).*
- *The Environment Agency provide a Flood Warning Service across the District. The location of the site is subject to warning of fluvial flooding from the River Welland*



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*(Stamford to Spalding). The minimum lead time is 2 hours.*

*The SFRA makes no direct references to flood risk at Barr Farm, Deeping St. Nicholas, Market Deeping or any other locations close to the site.*

3c What is the probability of the site flooding taking account of the contents of the SFRA and of any further site-specific assessment?

This may need to include

- a description of how any existing flood risk management measures affect the probability of a flood occurring at the site FRA Pro-forma
- supporting evidence and calculations for the derivation of flood levels for events with a range of annual probability
- inundation plans of, and cross sections through, the existing site showing flood extents and levels associated with events with a range of annual probability
- a plan and description of any structures which may influence the probability of a flood occurring at the site. This may include bridges, pipes/ducts crossing a watercourse, culverts, screens, embankments or walls, overgrown or collapsing channels and their likelihood to choke with debris.
- details of any modelling studies completed to define the exiting degree of flood risk

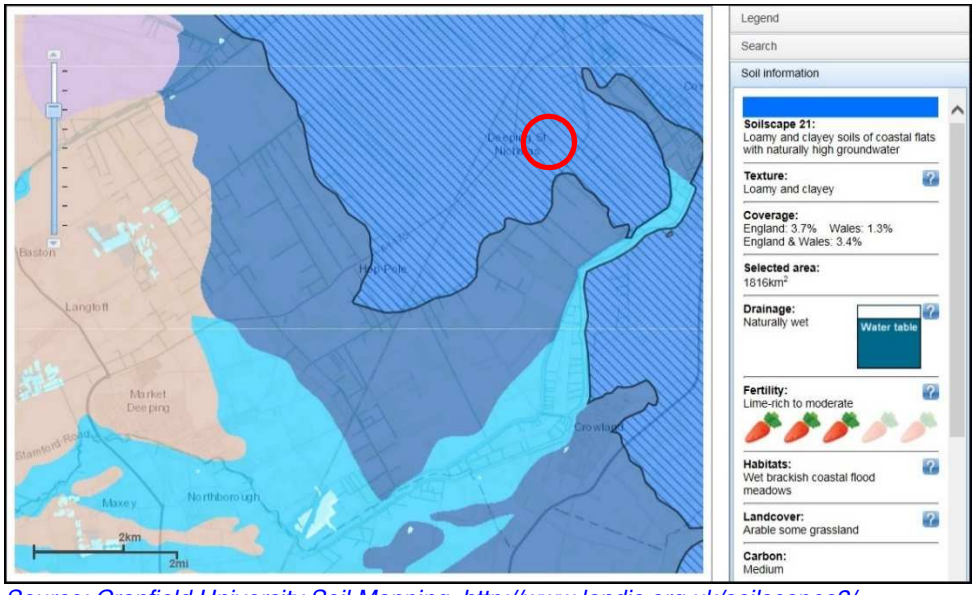
*As described in section 2b, the site is defended, and flood risk at the site derives from the interaction of fluvial flooding, flooding from the sea, defence failure, shortfall in capacity and/or failure of infrastructure in the internal drainage network. It is therefore not possible to attribute a precise value to the probability of the site flooding. However, given the standard of protection afforded by the defences, it is reasonable to assume the probability is below that of the joint 1:100 year fluvial and 1:200 year tidal flood probabilities, and possibly as high as the 1 in 1,000 year standard of protection suggested by the SFRA.*

3d What are the existing rates and volumes of run-off generated by the site?

- This should generally be accompanied by calculations of run-off rates and volumes from the existing site for a range of annual probability events (see Section 21 of the NPPF Practice Guide).

*The British Geological Society Geology of Britain viewer indicates the location of the site is characterised by superficial deposits of tidal flat deposits clay and silt) overlying Oxford Clay Formation mudstone. The Soilscapes map (Figure 6) shows that the site lies on soils described as "loamy and clayey soils of coastal flats with naturally high groundwater". The geology and soil characteristics indicate the site is likely to exhibit impeded drainage. Further, the naturally high groundwater makes it unlikely that surface water could be managed using infiltration, in terms of the guidance presented in the SuDS Manual (CIRIA C753).*

***Figure 6 Soil map of the location of the site (site location shown by red circle)***



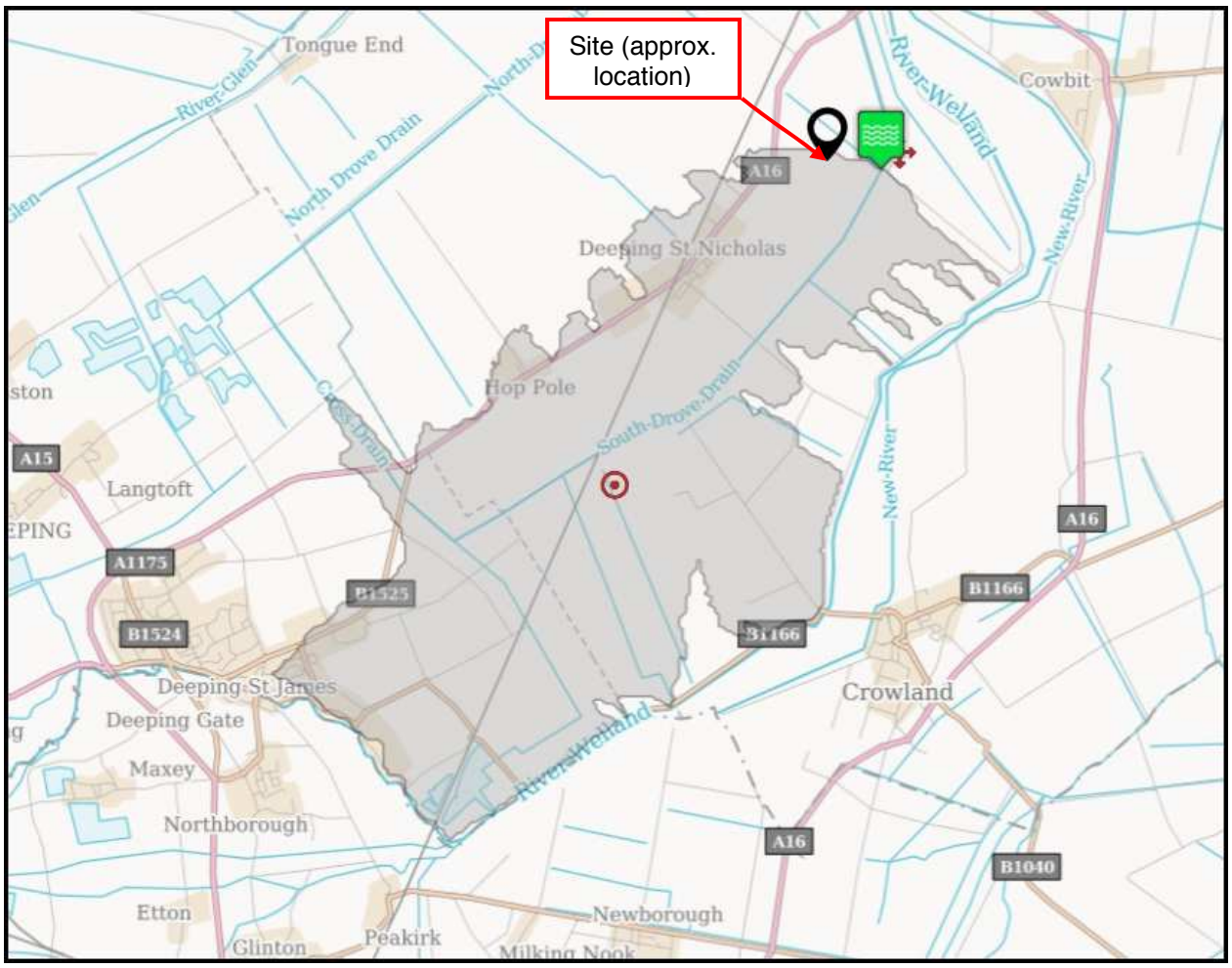

*Source: Cranfield University Soil Mapping http://www.landis.org.uk/soilscapes2/*



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*Flood Estimation Handbook (FEH) Web Service was used to retrieve the characteristics of the catchment that incorporates the site. The catchment boundary is shown in Figure 7, and its characteristics are listed in Table 4. The percentage runoff (SPRHOST) of the catchment as a whole is approximately 23%, low for the UK. However, the south-western part of the catchment incorporates significant areas of "loamy and sandy" soils (turquoise area in Figure 6) and "freely draining" soils (pink area in Figure 6) which would act to reduce the average runoff for the catchment as a whole. The soil map therefore indicates that the site lies on soils that are less permeable than the average for the catchment and characterised by regional mapping as poorly draining.*

***Figure 7 FEH web service catchment containing the site (catchment as grey polygon)***




*Source: © Centre for Ecology & Hydrology 2016*



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***Table 4 Selected catchment characteristics***

| | Location: | Barr Farm |
|---|---|---|
| | NGR (site): | TE 23000 16770 |
| | NGR (catchment): | TE 23750 16750 |
| AREA | Catchment area (km$^2$) | 41.18 |
| ALTBAR | Base flow index | 7 |
| ASPBAR | Base flow index | 90 |
| ASPVAR | Base flow index | 0.18 |
| BFIHOST | Base flow index | 0.722 |
| DPLBAR | Mean drainage path length (km) | 7.75 |
| DPSBAR | Mean drainage path slope | 3.2 |
| FARL | Index of lakes | 0.97 |
| LDP | Longest drainage path (km) | 15.67 |
| PROPWET | Proportion of time soil is wet | 0.21 |
| RMED-1H | Median 1 hour rainfall (mm) | 11.7 |
| RMED-1D | Median 1 day rainfall (mm) | 28.8 |
| RMED-2D | Median 2 day rainfall (mm) | 36.2 |
| SAAR | Average annual rainfall (mm) | 554 |
| SAAR4170 | Ditto for 1941-1970 (mm) | 553 |
| **SPRHOST** | **Percentage runoff** | **22.88** |
| URBEXT2000 | Urban extent 2000 | 0.0138 |

*Source: © Centre for Ecology & Hydrology 2016*

*As summarised in Section 2c, the site includes existing commercial / agricultural buildings and areas of currently undeveloped agricultural land. It is understood that a surface water management scheme based on attenuation has been implemented at the site as part of the existing development, and so the presumption is that runoff rates from this part of the site would be equivalent to either Greenfield rates, or rates determined to be acceptable part of the previous planning process. The currently undeveloped part of the site has no special drainage arrangements in place, such that runoff rates are likely to be equivalent to Greenfield rates.*

*Referencing a subset of the catchment descriptors reproduced in Table 3, and modifying BFIHOST from 0.722 to 0.45 to better reflect the impeded drainage at the site, the Greenfield runoff calculations presented in Appendix A indicate that peak Greenfield runoff rates for the 2, 30 and 100 year return period storms are approximately 2.66, 6.64 and 9.71 l/s/ha respectively.*

## 4. Climate change

How is flood risk at the site likely to be affected by climate change?

- Paragraphs 11-15, of the NPPF Technical Guide provide guidance on how to assess the impacts of climate change.

*The Environment Agency and NPPF require a consideration of the impacts of climate change on the flood risk for any proposed development. In February 2016, the Environment Agency updated the climate change allowances required in Flood Risk Assessments (Environment Agency, 2016). This advice updates previous climate change allowances to support the NPPF (DCLG, 2012). The Environment Agency (2016) state:*

> *"Making an allowance for climate change in your flood risk assessment will help to minimise vulnerability and provide resilience to flooding and coastal change in the future. The climate change allowances are predictions of anticipated change for:*
>
> - *peak river flow by river basin district;*
> - *peak rainfall intensity;*



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- *sea level rise;*
- *offshore wind speed and extreme wave height."*

*For this site, located as it is in Flood Zone 3, it is considered that the anticipated climate change allowances for increase in peak river flows would potentially increase the risk of fluvial flooding at the site. However, the site is defended and it is anticipated that allowance for increase in peak river flows would be factored into any improvement in level of protection above that afforded by the existing defences.*

*For rainfall, Table 5 shows the anticipated changes in small catchments, recommending a progressive increase, reaching 20% for the 'Central' allowance by 2115; this allowance would be recommended for this proposed development. This value is based on the 50% percentile, meaning that there is a 50% chance that rainfall will increase by less than this value (20%) and a 50% chance that rainfall will increase by more. It is considered appropriate to use this allowance, in view of the low vulnerability of the site, and the relatively minor consequences of exceedence.*

***Table 5 Peak rainfall intensity allowance in small and urban catchments***

| | ***Total potential change anticipated*** | | |
|---|---|---|---|
| ***Applies across all of England*** | ***2010 to 2039*** | ***2040 to 2059*** | ***2060 to 2115*** |
| *Upper end* | *10%* | *20%* | *40%* |
| *Central* | *5%* | *10%* | *20%* |

*Source: Environment Agency (2016)*

**5. Detailed development proposals**

Where appropriate, are you able to demonstrate how land uses most sensitive to flood damage have been placed in areas within the site that are at least risk of flooding, including providing details of the development layout?

- Reference should be made to vulnerability classification, Table 2 of the NPPF Technical Guide.
- Section 4 of the NPPF Practice Guide provides guidance on how the sequential approach can be used to inform the lay-out of new development sites.

*The layout of the site and its key features are shown in Figure 8. The estimated total area of the site indicated by the red line boundary (excluding access road) is approximately 82,330 $m^2$.*

*The proposed development includes six new poultry rearing units, located adjacent to and south-west of the existing buildings. A new area of hardstanding (concrete apron) to be used for periodic waste washing and vehicular access is proposed between the existing and new units. Locations for a generator, fresh water tank, feed bins, control room(s), and an area for an attenuation basin are also indicated.*

*The site is generally level and a sequential approach to the allocation of land use with regard to flood risk is not required.*

*The proposed impermeable surface areas at the site are reproduced in Table 6.*

***Table 6 Proposed additional impermeable surfaces on site***

| ***Description*** | ***Area ($m^2$)*** | ***Attenuated?*** |
|---|---|---|
| *Proposed new poultry units (6 units, 109.729m x 24.389m)* | *16,056* | *yes* |
| *Proposed concrete apron* | *5,052* | *yes* |
| *Proposed access road (estimated) (765m x 4m)* | *3,825* | *no* |
| *Proposed total impermeable surface area to be attenuated* | *21,108* | |



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***Figure 8 Layout of the proposed development (site shown as red line)***




*Source: Ian Pick Associates*

## 6. Flood risk management measures

How will the site be protected from flooding, including the potential impacts of climate change, over the development's lifetime?

- This should show that the flood risk management hierarchy has been followed and that flood defences are a necessary solution. This should include details of any proposed flood defences, access/egress arrangements, site drainage systems (including what consideration has been given to the use of sustainable drainage systems) and how these will be accessed, inspected, operated and maintained over the lifetime of the development. This may need to include details of any modelling work undertaken in order to derive design flood levels for the development, taking into account the presence of any new infrastructure proposed.

*The risk of flooding at the site is very low from all sources, and is considered to be a residual risk. This is not expected to change over the 60 year lifetime of the proposed development, allowing for the effects of climate change of the scale anticipated and described in Section 4. The proposed land use has a low vulnerability and no special measures to protect the site from flooding are considered necessary.*



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## 7. Off Site impacts

7a How will you ensure that your proposed development and the measures to protect your site from flooding will not increase flood risk elsewhere?

This should be over the lifetime of the development taking climate change into account. The assessment may need to include:

- Details of the design basis for any mitigation measures (for example trash screens, compensatory flood storage works and measures to improve flood conveyance). A description of how the design quality of these measures will be assured and of how the access, operation, inspection and maintenance issues will be managed over the lifetime of the development.
- Evidence that the mitigation measures will work, generally in the form of a hydrological and hydraulic modelling report.
- An assessment of the potential impact of the development on the river, estuary or sea environment and fluvial/coastal geomorphology. A description of how any impacts will be mitigated and of the likely longer-term sustainability of the proposals.

*As shown in Figure 5, the site is located within Flood Zone 3, but located on land benefitting from defences, and so with the exception of runoff from the proposed impermeable surfaces, flood risk elsewhere will not be affected. Management of surface water runoff is considered in the following section (Section 7b).*

7b How will you prevent run-off from the completed development causing an impact elsewhere?

- Evidence should be provided that drainage of the site will not result in an increase in the peak rate or in the volumes of run-off generated by the site prior to the development proceeding.

*In order not to increase flood risk elsewhere in the catchment, runoff from impermeable surfaces would need to be managed within the site. The soils at the site are indicated to have impeded drainage. Accordingly, a surface water management plan based on attenuation has been prepared and is presented in Appendix A.*

*Appendix A shows that runoff from the proposed new impermeable surfaces within the main area of the site could be managed by routing rainfall runoff to an attenuation basin prior to discharge to a border drain. An attenuation basin of basal area 1,800 $m^2$, top area 2,180 $m^2$ and depth 0.9 m, with a compound outlet structure comprising a 75 mm diameter orifice at invert 0 m and a 100 mm orifice at invert 0.45, would reduce runoff rates resulting from the 2, 30 and 100 year plus climate change storms to below current, Greenfield rates. The maximum depth of water in the basin (resulting from the 100 year plus climate change storm) would be 0.768 m, providing 0.132 m freeboard.*

*Runoff from the access road would be managed by routing to the drainage channel adjacent and to the north.*

## 8. Residual risks

8a What flood-related risks will remain after you have implemented the measures to protect the site from flooding?

- Guidance on residual risks is provided in Section 14 of the NPPF Practice Guide.

*Residual risks include the possibility of a rainstorm of magnitude greater than the 1:100 year plus climate change event considered in Appendix A. Under these circumstances, additional reassurance is provided by allowing a 0.132 m freeboard above the maximum 1:100 year plus climate change depth 0.768 m, allowed by the basin depth of 0.9 m.*

*If the embankment was overtopped, overflow could possibly cut through a natural earth embankment. It is therefore recommended that basin be stabilised by planting grass throughout and particularly along the embankment. A 2 m wide weir should be constructed at the outflow, at an invert of 0.85 m above the base of the basin, which would act as a spillway to convey exceedance flows. The spill should route outflow to a concrete channel and towards the receptor drain at the northern boundary of the site.*



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| |
|---|
| *Due to the use of orifices at the outlet from the attenuation basin, there would be a risk of blockage. In order to mitigate against this, it is suggested that the outflow orifices be set within a perforated riser with protected orifice plates, designed to filter out solid material such as vegetation that could enter the basin.*<br><br>*It is recommended that a maintenance program should be adopted with regular inspections to ensure that the orifice remains clear of blockage. The attenuation basin should be inspected on a monthly basis and after heavy rain or high winds, not only in order ensure correct function of the orifice, but also to ensure structural integrity of the basin.* |
| 8b How, and by whom, will these risks be managed over the lifetime of the development?<br>• Reference should be made to flood warning and evacuation procedures, where appropriate, and to likely above ground flow routes should sewers or other conveyance systems become blocked or overloaded. This may need to include a description of the potential economic, social and environmental consequences of a flood event occurring which exceeds the design standard of the flood risk management infrastructure proposed and of how the design has sought to minimize these – including an appraisal of health and safety issues. |
| *The responsibility of maintaining the attenuation basin and associated structures would be with the property owner.* |



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**REFERENCES**


| Author | Date | Title/Description |
|---|---|---|
| Centre for Ecology and Hydrology | 2016 | The Flood Estimation Handbook Web Service. Available from: https://fehweb.ceh.ac.uk/ (last accessed 1st September 2016) |
| CIRIA | 2015 | CIRIA Report c753: The SuDS Manual v3. Available from: http://www.ciria.org/Memberships/The_SuDs_Manual_C753_Chapters.aspx (last accessed 1st September 2016) |
| DCLG | Mar 2012(a) | National Planning Policy Framework. |
| DCLG | Mar 2012(b) | Technical Guidance to the National Planning Policy Framework. |
| DEFRA / Environment Agency | Oct 2013 | Rainfall Runoff Management for Development Report SC030219 Available from: http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/Rainfall_Runoff_Management_for_Developments_-_Revision_E.sflb.ashx (last accessed 1st September 2016) |
| Environment Agency | April 2016 | Guidance - Flood risk assessments: climate change allowances. Available from: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1 (last accessed 1st September 2016) |
| Royal Haskoning | Jan 2010 | South Holland District Council Strategic Flood Risk Assessment 2010 Available from: http://www.sholland.gov.uk/article/4193/Strategic-Flood-Risk-Assessment-2010 (last accessed 13th October 2016) |
| South Holland District Council | Jul 2006 | South Holland Local Plan Available from: http://localplan.sholland.gov.uk/ (last accessed 13th October 2016) |
| Wallingford HydroSolutions Ltd | 2015 | ReFH2: The Revitalised Flood Hydrograph Modelling Tool Version 2. |




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# Appendix A Surface Water Management Plan

## *A.1 Overview*

In order that runoff from the proposed development does not increase flood risk elsewhere, it is recommended that measures are taken to mitigate the rates of runoff from the site. As discussed in Section 3d, the site is underlain by soils described as *loamy and clayey soils of coastal flats with naturally high groundwater*. On site infiltration is unlikely to be a practical means of surface water management, since the soil infiltration rate is unlikely to be sufficiently rapid to half drain the infiltration structure within 24 hours and the invert of the structure would be within 1 m of the water table. Since these are both requirements for infiltration structures defined in the SuDS Manual (CIRIA, 2015), it is recommended that the runoff from the impermeable surfaces on site is detained and released at attenuated rates.

The site includes existing commercial / agricultural buildings and areas of currently undeveloped agricultural land. It is understood that a surface water management scheme based on attenuation has been implemented at the site as part of the existing development. The currently undeveloped part of the site has no special drainage arrangements in place, such that runoff rates from this part of the site are likely to be equivalent to Greenfield rates.

Accordingly, the aim of the surface water management plan is to manage runoff from the proposed new impermeable surfaces only. The plan presented below outlines an attenuation system that would reduce runoff rates to no greater than Greenfield rates.

## *A.2 Greenfield Runoff Rates*

The estimation of peak rates of pre-development runoff (i.e. Greenfield runoff) has previously used the IH 124[3] (Marshall and Bayliss) method. This method uses parameters related to catchment and soil characteristics to establish a peak rate of runoff. More recently, the rainfall runoff modelling approach of ReFH version 2 (ReFH2) has been used. This method was found in work by the CEH (2015) to give a closer match to observed peak rates of runoff, and also provides a full hydrograph, rather than simply the peak flow derived by the former method. Following additional research and testing, ReFH2 was released in 2015. In particular, and with significance for the current site, ReFH2 incorporates a set of adjustments for “plot scale” conditions. These adjustments address the use of models and data for catchments to the scale of individual development plots. This is important since such plots tend to be much smaller than topographic catchments.

ReFH2 runoff calculations reference a subset of catchment descriptors generated by the FEH web service, imported as an .xml file. Several descriptors are then changed in order to achieve the “plot-scale” adjustments. The base flow descriptor BFIHOST for the catchment as a whole is unlikely to be representative of the site, and so this descriptor was changed from 0.72 to 0.45 to better reflect the impeded drainage at the site. The AREA descriptor for the catchment was changed from approximately 0.955 $km^2$ to 0.5 $km^2$, in order to calibrate several routing and base flow parameters, and then finally to 0.021 $km^2$ to reflect the area of the proposed impermeable surface (21,108 $m^2$). These adjustments enabled the generation of Greenfield runoff hydrographs in l/s for the site. Scaling from the area of the impermeable surface to an area of 1 ha enabled the determination of target, peak Greenfield rates in l/s/ha.

The peak Greenfield runoff rates determined using ReFH2 are shown in Table A-1. The peak Greenfield rates in l/s for the impermeable area are shown in column 2. The equivalent rates in l/s/ha are shown in column 3.

[3] IH124: Institute of Hydrology Report No. 124 Flood Estimation for Small Catchments, June 1994



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**Table A-1 Greenfield (target) runoff rates (proposed impermeable surfaces only)**

| *Return period (years)* | *Greenfield Runoff rates (l/s)* | *Greenfield Runoff rates (l/s/ha)* |
|---|---|---|
| ***2*** | 5.60 | 2.66 |
| ***30*** | 13.94 | 6.64 |
| ***100*** | 20.39 | 9.71 |

### *A.3 Attenuation Basin Design*

The characteristics of the attenuation features were analysed using the *Source Control* module of the industry leading WinDES suite of software developed by Micro Drainage/XP Solutions. The following conservative assumptions and design parameters were applied within the Source Control module.

- Point rainfall time series were obtained using the FEH methodology, based on the catchment descriptors for the site generated by the FEH web service.
- Rainfall values were increased by 20% to allow for climate change over the 60 year design life of the proposed commercial / agricultural development, as described in Section 4 of the main report, and in line with the requirements of NPPF.
- The proposed impermeable area on site as listed in Table *6* of the main report, equal to approximately 21,108 $m^2$ (excluding access road). The top surface area of the basin was added to the proposed impermeable area in order to determine the total rainfall catchment area.
- 100% of the runoff from the proposed impermeable surfaces is directed to a single attenuation basin.
- A 100% void ratio was modelled, corresponding to an empty open basin.
- The outflow is regulated by a compound structure comprising a lower and upper orifice overflows.
- A factor of safety of 2 was applied, as recommended in CIRIS C753, to reflect the minor consequences of exceedence

Using an iterative, trial and error approach to varying the attenuation basin area, and the diameter and invert of the lower and upper orifice overflows, a range of attenuation designs were assessed. The software was used to analyse the response of the designs to the 1 in 2, 1 in 30 and 1 in 100 year plus climate change summer and winter storms of durations between 15 minutes and 10080 minutes (7 days). The design imperatives were that outflow rates should ideally be no greater than the target, Greenfield rates for the site, while at the same time being within practical limits for the attenuation feature area, depth and diameter of outflow devices.

The attenuation basin design is open and receives direct rainfall, and therefore the area of the attenuation basin was added to the impermeable surface area for the purpose of calculating total rainfall catchment area and Greenfield (target) attenuated rates.

It was found that an attenuation basin with the following attributes would enable runoff rates from the proposed impermeable area to be reduced to below target Greenfield rates for the critical duration 1 in 2, 1 in 30 and 1 in 100 year storms plus an allowance for climate change. It is assumed that outflow would be below Greenfield rates at all return periods within this range.

- a basal surface area of 1,800 $m^2$;
- a depth of 0.9 m;
- side slope of 1 in 3 (approximately 18 degrees), resulting in a top surface area of approximately 2,180 $m^2$;
- a compound outflow structure comprising a lower 75 mm diameter orifice outlet at an invert of 0 m (base of the basin), and an upper 100 mm diameter orifice outlet orifice at an invert of 0.45 m.



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The performance of the attenuation basin is summarised in Table A-2. The full results produced by the software are reproduced in Appendix B.

**Table A-2 Attenuation basin performance**

| *Return period (years)* | *Target Attenuated Outflow Rates (l/s/ha)* | *Target Attenuated Outflow Rates (l/s)* | *Peak Outlow Rates (l/s)* | *Maximum Water Depth (m)* |
|---|---|---|---|---|
| ***2*** | 2.66 | 6.21 | 6.2 | 0.318 |
| ***30*** | 6.64 | 15.46 | 15.0 | 0.591 |
| ***100*** | 9.71 | 22.61 | 20.8 | 0.768 |

*Note: the target attenuated outflow rates are calculated using the Greenfield rates in l/s/ha, multiplied by the sum of the impermeable surface area and attenuation basin (top) area.*

The results confirm that the design attenuation basin would reduce peak runoff rates to or below Greenfield rates for the critical 1 in 2, 1 in 30 and 1 in 100 year plus climate change winter storms, and is assumed to do so for all intermediate return period storms. The maximum depth indicated is 0.768 m for the 1 in 100 year plus climate change storm. An attenuation basin of depth 0.9 m would therefore be of sufficient depth to accommodate the maximum depth of water (with a freeboard of 132 mm).

### *A.4 Interception and routing of Runoff*

Runoff from the roofs of the proposed poultry units should be collected via gutters located downslope of the roofs, and discharged via downpipes to interceptor channels positioned along the base of each unit. A range of solutions are possible, but a simple arrangement of 0.5 m wide and 0.5 m deep drainage channels along the length of each unit should be adequate to intercept and convey runoff to a large diameter pipe, that would drain eastwards to the attenuation basin. The grading of drainage channels and drainage pipe should be 1:100 or steeper.

Runoff from the concrete apron will also need to be routed to the attenuation basin. The concrete apron is also used for waste washing, and the facility to switch outflows from the attenuation basin (for rainfall runoff collection) to the waste processing tank would be implemented at the site. The concrete apron would be surrounded by a low wall to contain all washed process waste, which is routed to underground tanks during the cleaning phase.

### *A.5 Location, Elevation and Outlet of Attenuation Basin*

A shown in Figure 8 of the main report, the preferred location of the attenuation basin would be to the west of the proposed poultry units. The attenuation basin top surface area of approximately 2,180 $m^2$ easily fits into this location.

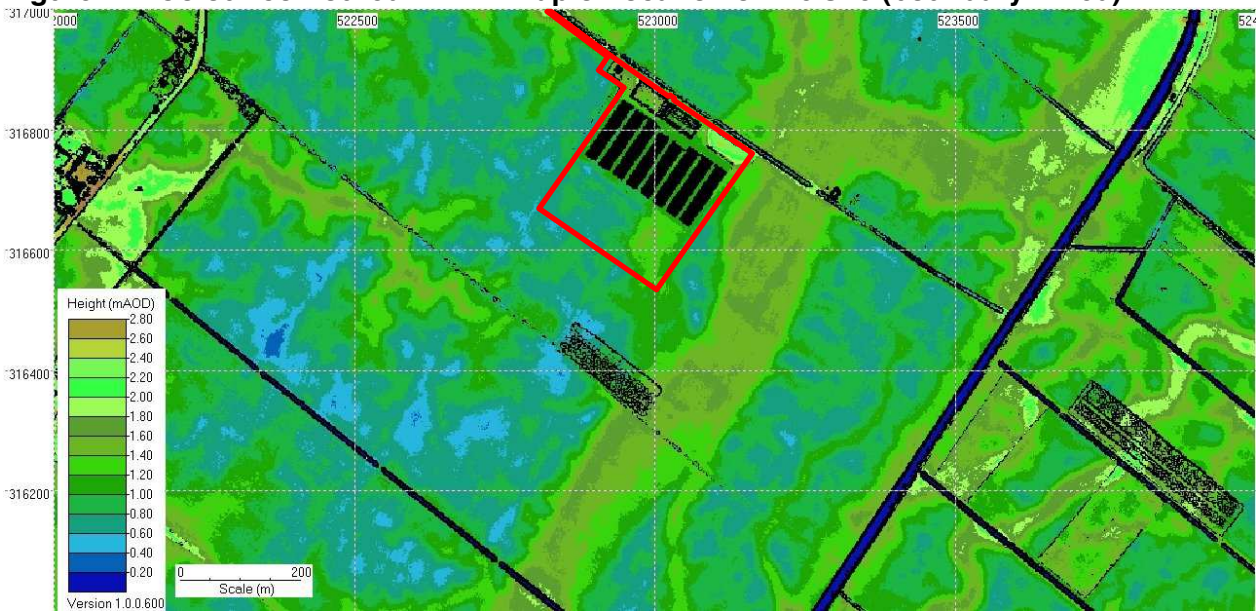
The colour contoured LiDAR of the location of the site is shown in Figure A-1 below. It may be seen that the average ground elevation at the location of the basin is between 0.8 mAOD and 1.0 mAOD. It is recommended that the top of the basin be built up to at least 1.0 mAOD, ideally higher, notwithstanding providing adequate slope from the proposed impermeable surfaces to enable runoff to be routed to the basin. Allowing for a basin top elevation of 1.0 mAOD and a depth of 0.9m would result in a base elevation of 0.1 mAOD.

Outflow from the basin should be routed to the existing drainage channel adjacent to the northern boundary if the site, a distance of approximately 190 m. It is recommended that a survey be conducted at the site in order to determine the practical arrangements for this aspect of the attenuation design.



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**Figure A-1 Colour contoured LiDAR map of location of the site (boundary in red)**




## *A.6 Residual Risks*

The text below relates to the risks in relation to the attenuation basin only and are summarised in Section 8 of the main report.

In the event that partial blockage went undetected or a rainstorm occurred which was in excess of the 1:100 year plus climate change design storm, water level within the basin could rise above the calculated maximum depth of 0.768 m summarised in Table A-2. The recommended basin depth of 0.9 m allows for a freeboard of 132 mm above the maximum water level.

For rainfall events greatly exceeding the 1:100 year plus climate change design rainstorm, the basin embankment could be overtopped, and the resulting overflow could possibly cut through a natural earth embankment and lead to failure. It is therefore recommended a 2 m wide weir be constructed at an invert of 0.85 m above the base of the basin, which would act as a spillway to convey exceedance flows away from sensitive areas of the site and towards the drain at the northern boundary of the site.

## *A.7 Conclusion*

The attenuation scheme described above would maintain the peak outflow from the proposed impermeable surfaces at the site at a level below no greater than Greenfield runoff rates for all return periods. Other combinations of basin dimensions and outflow regulators are of course possible, but the analysis illustrates one way in which the necessary reduction in flood risk can be achieved.



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# Appendix B Attenuation Design Results

## B.1 1 in 2 year plus climate change storm

| Hydro Consultancy | | Page 1 |
|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

Summary of Results for 2 year Return Period (+20%)

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 15 min Summer | 0.115 | 0.115 | 3.3 | 210.6 | O K |
| 30 min Summer | 0.139 | 0.139 | 3.7 | 254.6 | O K |
| 60 min Summer | 0.167 | 0.167 | 4.2 | 306.1 | O K |
| 120 min Summer | 0.197 | 0.197 | 4.7 | 364.3 | O K |
| 180 min Summer | 0.216 | 0.216 | 5.0 | 400.1 | O K |
| 240 min Summer | 0.230 | 0.230 | 5.1 | 425.2 | O K |
| 360 min Summer | 0.247 | 0.247 | 5.4 | 458.3 | O K |
| 480 min Summer | 0.257 | 0.257 | 5.5 | 478.1 | O K |
| 600 min Summer | 0.263 | 0.263 | 5.6 | 490.0 | O K |
| 720 min Summer | 0.268 | 0.268 | 5.6 | 498.7 | O K |
| 960 min Summer | 0.276 | 0.276 | 5.7 | 514.3 | O K |
| 1440 min Summer | 0.286 | 0.286 | 5.9 | 532.7 | O K |
| 2160 min Summer | 0.290 | 0.290 | 5.9 | 541.3 | O K |
| 2880 min Summer | 0.289 | 0.289 | 5.9 | 538.5 | O K |
| 4320 min Summer | 0.266 | 0.266 | 5.6 | 495.5 | O K |
| 5760 min Summer | 0.245 | 0.245 | 5.3 | 454.6 | O K |
| 7200 min Summer | 0.226 | 0.226 | 5.1 | 418.3 | O K |
| 8640 min Summer | 0.209 | 0.209 | 4.9 | 386.4 | O K |
| 10080 min Summer | 0.195 | 0.195 | 4.7 | 358.7 | O K |
| 15 min Winter | 0.129 | 0.129 | 3.5 | 235.9 | O K |
| 30 min Winter | 0.155 | 0.155 | 4.0 | 285.3 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 15 min Summer | 48.780 | 0.0 | 139.7 | 27 |
| 30 min Summer | 29.657 | 0.0 | 175.3 | 41 |
| 60 min Summer | 18.030 | 0.0 | 266.9 | 70 |
| 120 min Summer | 10.962 | 0.0 | 329.6 | 128 |
| 180 min Summer | 8.193 | 0.0 | 371.8 | 188 |
| 240 min Summer | 6.664 | 0.0 | 404.5 | 246 |
| 360 min Summer | 4.981 | 0.0 | 454.2 | 364 |
| 480 min Summer | 4.052 | 0.0 | 491.5 | 482 |
| 600 min Summer | 3.452 | 0.0 | 521.1 | 590 |
| 720 min Summer | 3.028 | 0.0 | 545.4 | 634 |
| 960 min Summer | 2.473 | 0.0 | 585.6 | 760 |
| 1440 min Summer | 1.859 | 0.0 | 632.8 | 1018 |
| 2160 min Summer | 1.397 | 0.0 | 835.9 | 1432 |
| 2880 min Summer | 1.141 | 0.0 | 905.5 | 1848 |
| 4320 min Summer | 0.824 | 0.0 | 958.0 | 2644 |
| 5760 min Summer | 0.654 | 0.0 | 1076.7 | 3456 |
| 7200 min Summer | 0.547 | 0.0 | 1121.9 | 4184 |
| 8640 min Summer | 0.472 | 0.0 | 1156.9 | 4936 |
| 10080 min Summer | 0.417 | 0.0 | 1180.8 | 5664 |
| 15 min Winter | 48.780 | 0.0 | 159.9 | 26 |
| 30 min Winter | 29.657 | 0.0 | 199.1 | 41 |

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## 1 in 2 year plus climate change storm (contd.)

| Hydro Consultancy | | Page 2 |
|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

Summary of Results for 2 year Return Period (+20%)

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 60 min Winter | 0.186 | 0.186 | 4.5 | 343.2 | O K |
| 120 min Winter | 0.221 | 0.221 | 5.0 | 409.0 | O K |
| 180 min Winter | 0.242 | 0.242 | 5.3 | 449.7 | O K |
| 240 min Winter | 0.257 | 0.257 | 5.5 | 478.5 | O K |
| 360 min Winter | 0.277 | 0.277 | 5.7 | 516.9 | O K |
| 480 min Winter | 0.290 | 0.290 | 5.9 | 540.8 | O K |
| 600 min Winter | 0.298 | 0.298 | 6.0 | 556.1 | O K |
| 720 min Winter | 0.303 | 0.303 | 6.0 | 565.8 | O K |
| 960 min Winter | 0.309 | 0.309 | 6.1 | 578.6 | O K |
| 1440 min Winter | 0.318 | 0.318 | 6.2 | 594.7 | O K |
| 2160 min Winter | 0.318 | 0.318 | 6.2 | 594.6 | O K |
| 2880 min Winter | 0.311 | 0.311 | 6.1 | 581.2 | O K |
| 4320 min Winter | 0.277 | 0.277 | 5.7 | 515.4 | O K |
| 5760 min Winter | 0.246 | 0.246 | 5.4 | 456.9 | O K |
| 7200 min Winter | 0.220 | 0.220 | 5.0 | 406.9 | O K |
| 8640 min Winter | 0.198 | 0.198 | 4.7 | 365.0 | O K |
| 10080 min Winter | 0.179 | 0.179 | 4.4 | 329.7 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 60 min Winter | 18.030 | 0.0 | 302.1 | 70 |
| 120 min Winter | 10.962 | 0.0 | 372.1 | 126 |
| 180 min Winter | 8.193 | 0.0 | 419.3 | 184 |
| 240 min Winter | 6.664 | 0.0 | 455.7 | 242 |
| 360 min Winter | 4.981 | 0.0 | 510.4 | 356 |
| 480 min Winter | 4.052 | 0.0 | 551.2 | 470 |
| 600 min Winter | 3.452 | 0.0 | 583.6 | 580 |
| 720 min Winter | 3.028 | 0.0 | 610.3 | 686 |
| 960 min Winter | 2.473 | 0.0 | 653.6 | 794 |
| 1440 min Winter | 1.859 | 0.0 | 699.4 | 1090 |
| 2160 min Winter | 1.397 | 0.0 | 938.4 | 1548 |
| 2880 min Winter | 1.141 | 0.0 | 1016.0 | 1992 |
| 4320 min Winter | 0.824 | 0.0 | 1072.3 | 2852 |
| 5760 min Winter | 0.654 | 0.0 | 1207.9 | 3640 |
| 7200 min Winter | 0.547 | 0.0 | 1259.0 | 4408 |
| 8640 min Winter | 0.472 | 0.0 | 1299.1 | 5192 |
| 10080 min Winter | 0.417 | 0.0 | 1327.1 | 5952 |

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## 1 in 2 year plus climate change storm (contd.)

| Hydro Consultancy | | Page 3 |
|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

### Rainfall Details

| | |
|---|---|
| Rainfall Model | FEH |
| Return Period (years) | 2 |
| Site Location | GB 523750 316750 TE 23750 16750 |
| C (1km) | -0.023 |
| D1 (1km) | 0.298 |
| D2 (1km) | 0.312 |
| D3 (1km) | 0.213 |
| E (1km) | 0.317 |
| F (1km) | 2.490 |
| Summer Storms | Yes |
| Winter Storms | Yes |
| Cv (Summer) | 0.750 |
| Cv (Winter) | 0.840 |
| Shortest Storm (mins) | 15 |
| Longest Storm (mins) | 10080 |
| Climate Change % | +20 |

### Time Area Diagram

Total Area (ha) 2.329

| Time From: | (mins) To: | Area (ha) | Time From: | (mins) To: | Area (ha) | Time From: | (mins) To: | Area (ha) |
|---|---|---|---|---|---|---|---|---|
| 0 | 4 | 0.776 | 4 | 8 | 0.776 | 8 | 12 | 0.776 |

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## 1 in 2 year plus climate change storm (contd.)

| Hydro Consultancy | | Page 4 |
|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

### Model Details

Storage is Online Cover Level (m) 0.800

### Tank or Pond Structure

Invert Level (m) 0.000

| Depth (m) | Area (m²) | Depth (m) | Area (m²) |
|---|---|---|---|
| 0.000 | 1800.0 | 0.800 | 2179.1 |

### Complex Outflow Control

#### Orifice

Diameter (m) 0.075 Discharge Coefficient 0.600 Invert Level (m) 0.000

#### Orifice

Diameter (m) 0.100 Discharge Coefficient 0.600 Invert Level (m) 0.450

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## B.2 1 in 30 year plus climate change storm

| Hydro Consultancy | | Page 1 |
|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

Summary of Results for 30 year Return Period (+20%)

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 15 min Summer | 0.289 | 0.289 | 5.9 | 539.6 | O K |
| 30 min Summer | 0.334 | 0.334 | 6.4 | 625.9 | O K |
| 60 min Summer | 0.383 | 0.383 | 6.9 | 723.0 | O K |
| 120 min Summer | 0.436 | 0.436 | 7.4 | 828.7 | O K |
| 180 min Summer | 0.467 | 0.467 | 7.8 | 891.8 | O K |
| 240 min Summer | 0.489 | 0.489 | 8.6 | 934.5 | O K |
| 360 min Summer | 0.514 | 0.514 | 10.0 | 985.1 | Flood Risk |
| 480 min Summer | 0.526 | 0.526 | 10.6 | 1009.8 | Flood Risk |
| 600 min Summer | 0.531 | 0.531 | 10.9 | 1020.2 | Flood Risk |
| 720 min Summer | 0.533 | 0.533 | 11.0 | 1024.4 | Flood Risk |
| 960 min Summer | 0.538 | 0.538 | 11.3 | 1035.0 | Flood Risk |
| 1440 min Summer | 0.543 | 0.543 | 11.7 | 1045.4 | Flood Risk |
| 2160 min Summer | 0.541 | 0.541 | 11.6 | 1042.1 | Flood Risk |
| 2880 min Summer | 0.534 | 0.534 | 11.1 | 1027.9 | Flood Risk |
| 4320 min Summer | 0.499 | 0.499 | 9.1 | 955.2 | O K |
| 5760 min Summer | 0.463 | 0.463 | 7.7 | 882.0 | O K |
| 7200 min Summer | 0.426 | 0.426 | 7.3 | 808.2 | O K |
| 8640 min Summer | 0.393 | 0.393 | 7.0 | 743.0 | O K |
| 10080 min Summer | 0.364 | 0.364 | 6.7 | 686.0 | O K |
| 15 min Winter | 0.323 | 0.323 | 6.3 | 604.5 | O K |
| 30 min Winter | 0.372 | 0.372 | 6.8 | 701.5 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 15 min Summer | 124.740 | 0.0 | 373.1 | 27 |
| 30 min Summer | 72.652 | 0.0 | 418.0 | 41 |
| 60 min Summer | 42.315 | 0.0 | 652.6 | 70 |
| 120 min Summer | 24.646 | 0.0 | 755.3 | 130 |
| 180 min Summer | 17.965 | 0.0 | 819.6 | 188 |
| 240 min Summer | 14.354 | 0.0 | 866.5 | 248 |
| 360 min Summer | 10.463 | 0.0 | 933.7 | 364 |
| 480 min Summer | 8.360 | 0.0 | 980.0 | 482 |
| 600 min Summer | 7.025 | 0.0 | 1013.3 | 600 |
| 720 min Summer | 6.094 | 0.0 | 1038.4 | 650 |
| 960 min Summer | 4.889 | 0.0 | 1076.0 | 760 |
| 1440 min Summer | 3.584 | 0.0 | 1103.3 | 1010 |
| 2160 min Summer | 2.627 | 0.0 | 1584.1 | 1424 |
| 2880 min Summer | 2.108 | 0.0 | 1674.1 | 1844 |
| 4320 min Summer | 1.484 | 0.0 | 1670.4 | 2688 |
| 5760 min Summer | 1.157 | 0.0 | 1916.0 | 3528 |
| 7200 min Summer | 0.954 | 0.0 | 1970.4 | 4328 |
| 8640 min Summer | 0.815 | 0.0 | 2012.0 | 5104 |
| 10080 min Summer | 0.713 | 0.0 | 2037.7 | 5856 |
| 15 min Winter | 124.740 | 0.0 | 407.5 | 27 |
| 30 min Winter | 72.652 | 0.0 | 453.5 | 41 |

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## 1 in 30 year plus climate change storm (contd.)

| Hydro Consultancy | | Page 2 |
|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

Summary of Results for 30 year Return Period (+20%)

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 60 min Winter | 0.427 | 0.427 | 7.3 | 810.7 | O K |
| 120 min Winter | 0.486 | 0.486 | 8.5 | 929.6 | O K |
| 180 min Winter | 0.520 | 0.520 | 10.3 | 998.4 | Flood Risk |
| 240 min Winter | 0.542 | 0.542 | 11.6 | 1043.2 | Flood Risk |
| 360 min Winter | 0.567 | 0.567 | 13.3 | 1094.5 | Flood Risk |
| 480 min Winter | 0.578 | 0.578 | 14.1 | 1118.4 | Flood Risk |
| 600 min Winter | 0.583 | 0.583 | 14.4 | 1128.0 | Flood Risk |
| 720 min Winter | 0.584 | 0.584 | 14.5 | 1129.9 | Flood Risk |
| 960 min Winter | 0.590 | 0.590 | 14.9 | 1141.9 | Flood Risk |
| 1440 min Winter | 0.591 | 0.591 | 15.0 | 1144.8 | Flood Risk |
| 2160 min Winter | 0.581 | 0.581 | 14.3 | 1124.2 | Flood Risk |
| 2880 min Winter | 0.567 | 0.567 | 13.3 | 1095.0 | Flood Risk |
| 4320 min Winter | 0.523 | 0.523 | 10.4 | 1003.5 | Flood Risk |
| 5760 min Winter | 0.482 | 0.482 | 8.3 | 920.8 | O K |
| 7200 min Winter | 0.435 | 0.435 | 7.4 | 825.7 | O K |
| 8640 min Winter | 0.391 | 0.391 | 7.0 | 738.4 | O K |
| 10080 min Winter | 0.353 | 0.353 | 6.6 | 664.2 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 60 min Winter | 42.315 | 0.0 | 729.1 | 70 |
| 120 min Winter | 24.646 | 0.0 | 841.0 | 128 |
| 180 min Winter | 17.965 | 0.0 | 912.2 | 184 |
| 240 min Winter | 14.354 | 0.0 | 965.0 | 242 |
| 360 min Winter | 10.463 | 0.0 | 1041.0 | 356 |
| 480 min Winter | 8.360 | 0.0 | 1094.1 | 466 |
| 600 min Winter | 7.025 | 0.0 | 1133.9 | 570 |
| 720 min Winter | 6.094 | 0.0 | 1164.6 | 658 |
| 960 min Winter | 4.889 | 0.0 | 1211.6 | 742 |
| 1440 min Winter | 3.584 | 0.0 | 1251.6 | 1046 |
| 2160 min Winter | 2.627 | 0.0 | 1778.6 | 1496 |
| 2880 min Winter | 2.108 | 0.0 | 1878.2 | 1936 |
| 4320 min Winter | 1.484 | 0.0 | 1856.3 | 2820 |
| 5760 min Winter | 1.157 | 0.0 | 2147.7 | 3752 |
| 7200 min Winter | 0.954 | 0.0 | 2208.6 | 4616 |
| 8640 min Winter | 0.815 | 0.0 | 2255.4 | 5440 |
| 10080 min Winter | 0.713 | 0.0 | 2286.2 | 6160 |

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## 1 in 30 year plus climate change storm (contd.)

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|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

### Rainfall Details

| | |
|---|---|
| Rainfall Model | FEH |
| Return Period (years) | 30 |
| Site Location | GB 523750 316750 TE 23750 16750 |
| C (1km) | -0.023 |
| D1 (1km) | 0.298 |
| D2 (1km) | 0.312 |
| D3 (1km) | 0.213 |
| E (1km) | 0.317 |
| F (1km) | 2.490 |
| Summer Storms | Yes |
| Winter Storms | Yes |
| Cv (Summer) | 0.750 |
| Cv (Winter) | 0.840 |
| Shortest Storm (mins) | 15 |
| Longest Storm (mins) | 10080 |
| Climate Change % | +20 |

### Time Area Diagram

Total Area (ha) 2.329

| Time From: | (mins) To: | Area (ha) | Time From: | (mins) To: | Area (ha) | Time From: | (mins) To: | Area (ha) |
|---|---|---|---|---|---|---|---|---|
| 0 | 4 | 0.776 | 4 | 8 | 0.776 | 8 | 12 | 0.776 |

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## 1 in 30 year plus climate change storm (contd.)

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|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

### Model Details

Storage is Online Cover Level (m) 0.800

### Tank or Pond Structure

Invert Level (m) 0.000

| Depth (m) | Area (m²) | Depth (m) | Area (m²) |
|---|---|---|---|
| 0.000 | 1800.0 | 0.800 | 2179.1 |

### Complex Outflow Control

### Orifice

Diameter (m) 0.075 Discharge Coefficient 0.600 Invert Level (m) 0.000

### Orifice

Diameter (m) 0.100 Discharge Coefficient 0.600 Invert Level (m) 0.450

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## B.3 1 in 100 year plus climate change storm

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|---|---|---|
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| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

Summary of Results for 100 year Return Period (+20%)

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 15 min Summer | 0.435 | 0.435 | 7.4 | 825.8 | O K |
| 30 min Summer | 0.491 | 0.491 | 8.7 | 939.8 | O K |
| 60 min Summer | 0.551 | 0.551 | 12.2 | 1062.6 | Flood Risk |
| 120 min Summer | 0.611 | 0.611 | 15.8 | 1185.5 | Flood Risk |
| 180 min Summer | 0.642 | 0.642 | 17.0 | 1251.4 | Flood Risk |
| 240 min Summer | 0.661 | 0.661 | 17.7 | 1291.8 | Flood Risk |
| 360 min Summer | 0.681 | 0.681 | 18.3 | 1332.8 | Flood Risk |
| 480 min Summer | 0.686 | 0.686 | 18.5 | 1344.8 | Flood Risk |
| 600 min Summer | 0.688 | 0.688 | 18.5 | 1348.2 | Flood Risk |
| 720 min Summer | 0.689 | 0.689 | 18.6 | 1351.1 | Flood Risk |
| 960 min Summer | 0.693 | 0.693 | 18.7 | 1358.3 | Flood Risk |
| 1440 min Summer | 0.692 | 0.692 | 18.6 | 1356.2 | Flood Risk |
| 2160 min Summer | 0.679 | 0.679 | 18.2 | 1329.2 | Flood Risk |
| 2880 min Summer | 0.661 | 0.661 | 17.7 | 1291.6 | Flood Risk |
| 4320 min Summer | 0.605 | 0.605 | 15.6 | 1174.6 | Flood Risk |
| 5760 min Summer | 0.567 | 0.567 | 13.3 | 1095.0 | Flood Risk |
| 7200 min Summer | 0.536 | 0.536 | 11.2 | 1031.8 | Flood Risk |
| 8640 min Summer | 0.509 | 0.509 | 9.7 | 975.6 | Flood Risk |
| 10080 min Summer | 0.483 | 0.483 | 8.3 | 922.2 | O K |
| 15 min Winter | 0.484 | 0.484 | 8.4 | 925.1 | O K |
| 30 min Winter | 0.546 | 0.546 | 11.9 | 1051.7 | Flood Risk |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 15 min Summer | 190.647 | 0.0 | 507.5 | 27 |
| 30 min Summer | 108.907 | 0.0 | 554.3 | 41 |
| 60 min Summer | 62.213 | 0.0 | 946.8 | 70 |
| 120 min Summer | 35.539 | 0.0 | 1075.1 | 128 |
| 180 min Summer | 25.613 | 0.0 | 1155.4 | 186 |
| 240 min Summer | 20.302 | 0.0 | 1213.5 | 246 |
| 360 min Summer | 14.632 | 0.0 | 1296.7 | 362 |
| 480 min Summer | 11.597 | 0.0 | 1355.1 | 478 |
| 600 min Summer | 9.685 | 0.0 | 1398.7 | 522 |
| 720 min Summer | 8.358 | 0.0 | 1432.2 | 580 |
| 960 min Summer | 6.652 | 0.0 | 1484.6 | 702 |
| 1440 min Summer | 4.821 | 0.0 | 1533.7 | 974 |
| 2160 min Summer | 3.494 | 0.0 | 2119.7 | 1384 |
| 2880 min Summer | 2.781 | 0.0 | 2221.8 | 1792 |
| 4320 min Summer | 1.936 | 0.0 | 2174.6 | 2596 |
| 5760 min Summer | 1.498 | 0.0 | 2484.7 | 3400 |
| 7200 min Summer | 1.227 | 0.0 | 2538.8 | 4192 |
| 8640 min Summer | 1.043 | 0.0 | 2578.4 | 5024 |
| 10080 min Summer | 0.909 | 0.0 | 2599.9 | 5864 |
| 15 min Winter | 190.647 | 0.0 | 548.3 | 27 |
| 30 min Winter | 108.907 | 0.0 | 611.9 | 41 |

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## 1 in 100 year plus climate change storm (contd.)

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|---|---|---|
| Shearwater House<br>Clevedon<br>BS21 7RD | K0776 Deeping | |
| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

Summary of Results for 100 year Return Period (+20%)

| Storm Event | Max Level (m) | Max Depth (m) | Max Control (l/s) | Max Volume (m³) | Status |
|---|---|---|---|---|---|
| 60 min Winter | 0.612 | 0.612 | 15.9 | 1187.5 | Flood Risk |
| 120 min Winter | 0.678 | 0.678 | 18.2 | 1326.8 | Flood Risk |
| 180 min Winter | 0.714 | 0.714 | 19.3 | 1402.6 | Flood Risk |
| 240 min Winter | 0.736 | 0.736 | 19.9 | 1449.8 | Flood Risk |
| 360 min Winter | 0.759 | 0.759 | 20.6 | 1499.8 | Flood Risk |
| 480 min Winter | 0.767 | 0.767 | 20.8 | 1518.3 | Flood Risk |
| 600 min Winter | 0.768 | 0.768 | 20.8 | 1520.4 | Flood Risk |
| 720 min Winter | 0.766 | 0.766 | 20.8 | 1516.2 | Flood Risk |
| 960 min Winter | 0.768 | 0.768 | 20.8 | 1519.9 | Flood Risk |
| 1440 min Winter | 0.758 | 0.758 | 20.6 | 1498.9 | Flood Risk |
| 2160 min Winter | 0.731 | 0.731 | 19.8 | 1439.0 | Flood Risk |
| 2880 min Winter | 0.700 | 0.700 | 18.9 | 1372.8 | Flood Risk |
| 4320 min Winter | 0.624 | 0.624 | 16.4 | 1213.9 | Flood Risk |
| 5760 min Winter | 0.576 | 0.576 | 14.0 | 1113.7 | Flood Risk |
| 7200 min Winter | 0.542 | 0.542 | 11.6 | 1042.4 | Flood Risk |
| 8640 min Winter | 0.510 | 0.510 | 9.8 | 978.5 | Flood Risk |
| 10080 min Winter | 0.479 | 0.479 | 8.2 | 915.2 | O K |

| Storm Event | Rain (mm/hr) | Flooded Volume (m³) | Discharge Volume (m³) | Time-Peak (mins) |
|---|---|---|---|---|
| 60 min Winter | 62.213 | 0.0 | 1058.9 | 70 |
| 120 min Winter | 35.539 | 0.0 | 1202.0 | 126 |
| 180 min Winter | 25.613 | 0.0 | 1291.0 | 184 |
| 240 min Winter | 20.302 | 0.0 | 1356.4 | 240 |
| 360 min Winter | 14.632 | 0.0 | 1450.3 | 354 |
| 480 min Winter | 11.597 | 0.0 | 1516.6 | 464 |
| 600 min Winter | 9.685 | 0.0 | 1566.4 | 566 |
| 720 min Winter | 8.358 | 0.0 | 1605.2 | 594 |
| 960 min Winter | 6.652 | 0.0 | 1666.6 | 738 |
| 1440 min Winter | 4.821 | 0.0 | 1728.9 | 1042 |
| 2160 min Winter | 3.494 | 0.0 | 2377.4 | 1480 |
| 2880 min Winter | 2.781 | 0.0 | 2493.2 | 1908 |
| 4320 min Winter | 1.936 | 0.0 | 2434.1 | 2724 |
| 5760 min Winter | 1.498 | 0.0 | 2785.0 | 3520 |
| 7200 min Winter | 1.227 | 0.0 | 2845.3 | 4400 |
| 8640 min Winter | 1.043 | 0.0 | 2888.9 | 5280 |
| 10080 min Winter | 0.909 | 0.0 | 2910.1 | 6248 |

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## 1 in 100 year plus climate change storm (contd.)

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|---|---|---|
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| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

### Rainfall Details

| | |
|---|---|
| Rainfall Model | FEH |
| Return Period (years) | 100 |
| Site Location | GB 523750 316750 TE 23750 16750 |
| C (1km) | -0.023 |
| D1 (1km) | 0.290 |
| D2 (1km) | 0.312 |
| D3 (1km) | 0.213 |
| E (1km) | 0.317 |
| F (1km) | 2.490 |
| Summer Storms | Yes |
| Winter Storms | Yes |
| Cv (Summer) | 0.750 |
| Cv (Winter) | 0.840 |
| Shortest Storm (mins) | 15 |
| Longest Storm (mins) | 10080 |
| Climate Change % | +20 |

### Time Area Diagram

Total Area (ha) 2.329

| Time From: | (mins) To: | Area (ha) | Time From: | (mins) To: | Area (ha) | Time From: | (mins) To: | Area (ha) |
|---|---|---|---|---|---|---|---|---|
| 0 | 4 | 0.776 | 4 | 8 | 0.776 | 8 | 12 | 0.776 |

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## 1 in 100 year plus climate change storm (contd.)

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| Date 06/12/2016<br>File Attenuation_basin.srcx | Designed by HLS<br>Checked by PR | |
| Micro Drainage | Source Control 2016.1 | |

### Model Details

Storage is Online Cover Level (m) 0.800

### Tank or Pond Structure

Invert Level (m) 0.000

| Depth (m) | Area (m²) | Depth (m) | Area (m²) |
|---|---|---|---|
| 0.000 | 1800.0 | 0.800 | 2179.1 |

### Complex Outflow Control

### Orifice

Diameter (m) 0.075 Discharge Coefficient 0.600 Invert Level (m) 0.000

### Orifice

Diameter (m) 0.100 Discharge Coefficient 0.600 Invert Level (m) 0.450

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