

Ian Pick Associates Ltd.

**Flood Risk Assessment and Surface
Water Management Plan for
residential development at**

**Barr Farm,
Deeping St. Nicholas, Spalding,
Lincolnshire, PE11 3BN**

Report K0776/2 (Rev.0)

June 2017

Prepared and submitted by



**Hydro-Logic Services (International) Ltd
(part of Hydro International Ltd)**

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East Yorkshire, YO25 8NJ

Ref: K0776/02/ac

22nd June 2017

Dear Ian,

**FLOOD RISK ASSESSMENT AND SURFACE WATER MANAGEMENT PLAN:
AGRICULTURAL WORKERS DWELLING AT 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) It is proposed that an agricultural workers dwelling is constructed at Barr Farm, Deeping St Nicholas, on existing agricultural land immediately to the west of the existing farm buildings;
- 2) The proposed development site is shown on Environment Agency flood zone mapping to be in Flood Zone 3a, with a 1:100 or greater annual probability of fluvial flooding and a 1:200 or greater annual probability of tidal flooding;
- 3) South East Lincolnshire's Strategic Flood Risk Assessment (South East Lincolnshire Joint Planning Unit, 2017) shows the site to be beyond the limits of tidal flooding associated with The Wash and therefore flood risk at the site is limited to fluvial flooding or flooding associated with infrastructure failure;
- 4) The site is protected by flood defences, which are shown to generally have sufficient freeboard to protect the site from the 1:1,000 year fluvial flood. Flood risk at the site is therefore considered a residual risk, providing the flood defences are adequately maintained and upgraded;
- 5) The site and access road leading to Littleworth Drive (A1175) is shown to be at 'very low' risk of surface water flooding, with less than 1:1,000 annual probability of flooding;
- 6) There are no historic records of flooding occurring at the site;
- 7) In terms of the National Planning Policy Framework (NPPF), residential dwellings are classified as 'More Vulnerable' developments, which are considered appropriate for land shown to be in Flood Zone 1, 2 and 3a, providing the Exception Test is passed;
- 8) The Sequential Test has been applied to the proposed development and has been found to be satisfied. As the whole of Barr Farm is shown to be in Flood Zone 3a, no alternative location is available at lower flood risk to locate the proposed agricultural workers dwelling, which by definition needs to be at/near the farm;



- 9) The proposed development passes the Exception Test for several reasons; the provision of accommodation for farm workers at the site would enhance the sustainability of the farm, flood risk at the site is considered a residual risk, the proposed finished floor level of the dwelling is calculated from a residual risk scenario therefore meaning that if required the occupants could remain in the 'safe haven' of the dwelling if flooding were to occur;
- 10) It is suggested that the proposed dwelling could be set with a finished floor level of at least 2.2 mAOD (1:100 year+CC flood level + 300mm). This value is based on the worst-case residual risk 1:100 year+CC flood event mapped as occurring at the access track in front of the proposed location of the dwelling on the site and is therefore a conservative recommendation;
- 11) The proposed agricultural workers dwelling and associated features would involve the construction of 110 m² of impermeable surfaces on site, runoff from which must be managed. A surface water management plan has been designed for the site, so as not to increase the risk of flooding elsewhere;
- 12) Allowance is made for climate change by increasing the design rainfall by 40%, the NPPF and Environment Agency recommended allowance;
- 13) Published soil mapping shows soils at the site to be located on 'loamy and clayey soils of coastal flats with naturally high groundwater';
- 14) Runoff from the existing impermeable areas at Barr Farm is currently managed by an attenuation basin located to the west of the poultry units. Due to the distance between the proposed dwelling and the existing attenuation system it is not considered a feasible option to manage runoff from the proposed dwelling using the existing system;
- 15) Greenfield runoff rates were calculated for the 110 m² of proposed impermeable surface and were found to be extremely low, meaning that attenuation would not be a feasible management option as the outflow control for the system would need to be extremely small and would therefore be at high risk of blockage;
- 16) An indicative soil infiltration rate of 0.018 m/hr was therefore used to design a soakaway capable of managing runoff from the 110 m² of impermeable surfaces;
- 17) MicroDrainage modelling showed that a soakaway with a basal area of 32 m² and a depth of 1 m (32 m² cover area), filled with 30% porosity granular material e.g. scalpings or gavel, would be capable of managing runoff from the proposed development during the 1:100 year+40%CC rainfall event;
- 18) The soakaway was shown to reach a maximum depth of 0.971 m during the 1:100 year+40%CC rainfall event and drain from full to half full within the 24 hours permitted by CIRIA C753 (2015) regulations;
- 19) It is proposed that existing ground level at the site, of about 1m AOD, would be raised to an elevation similar to that of the land surrounding the adjacent building (~1.9 mAOD). Using 1.9 mAOD as an approximate level for the working platform on which the property will be built, it is estimated that groundwater level (derived from nearby borehole log) would be approximately 2.5 m below this raised ground level and therefore the invert level of the soakaway would be located at least 1 m above groundwater level, a requirement of CIRIA C753 (2015) regulations;

- 20) As the proposed soakaway would be located within a volume of made ground, it is recommended that the geotechnical design of the fill takes into account the fact that water will on occasions flow through the material – thus it should be resistant to the washout of fines. It may be that the made ground and the soakaway material are the same. However if they are different then the soakaway could be isolated from the surrounding ground by a permeable membrane/geotextile or similar if deemed necessary;
- 21) Residual risks include the need to manage storms of a significantly greater magnitude than those considered in this report. It is possible that the soakaways could surcharge during a rainstorm of greater magnitude than 1:100 year+CC allowances. To mitigate the risk of any surcharged flow from the soakaways affecting the site, it is recommended that surcharged flow should be directed west, away from the proposed development into the adjacent field.
- 22) Structures which manage surface water runoff require little maintenance, however a regular maintenance schedule, on a monthly basis and after heavy rainfall, should be established by the site owner to reduce the risk of blockage within the drainage system e.g. by leaves or plastic bags and ensure the systems remain in good working order.

In summary, flood risks at the site is considered a residual risk and therefore flood risk is considered to be 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,



Alan Corner
Head of Water Engineering
07990 976003

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.

Flood Risk Assessment Template based on the NPPF Practice Guide¹

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.

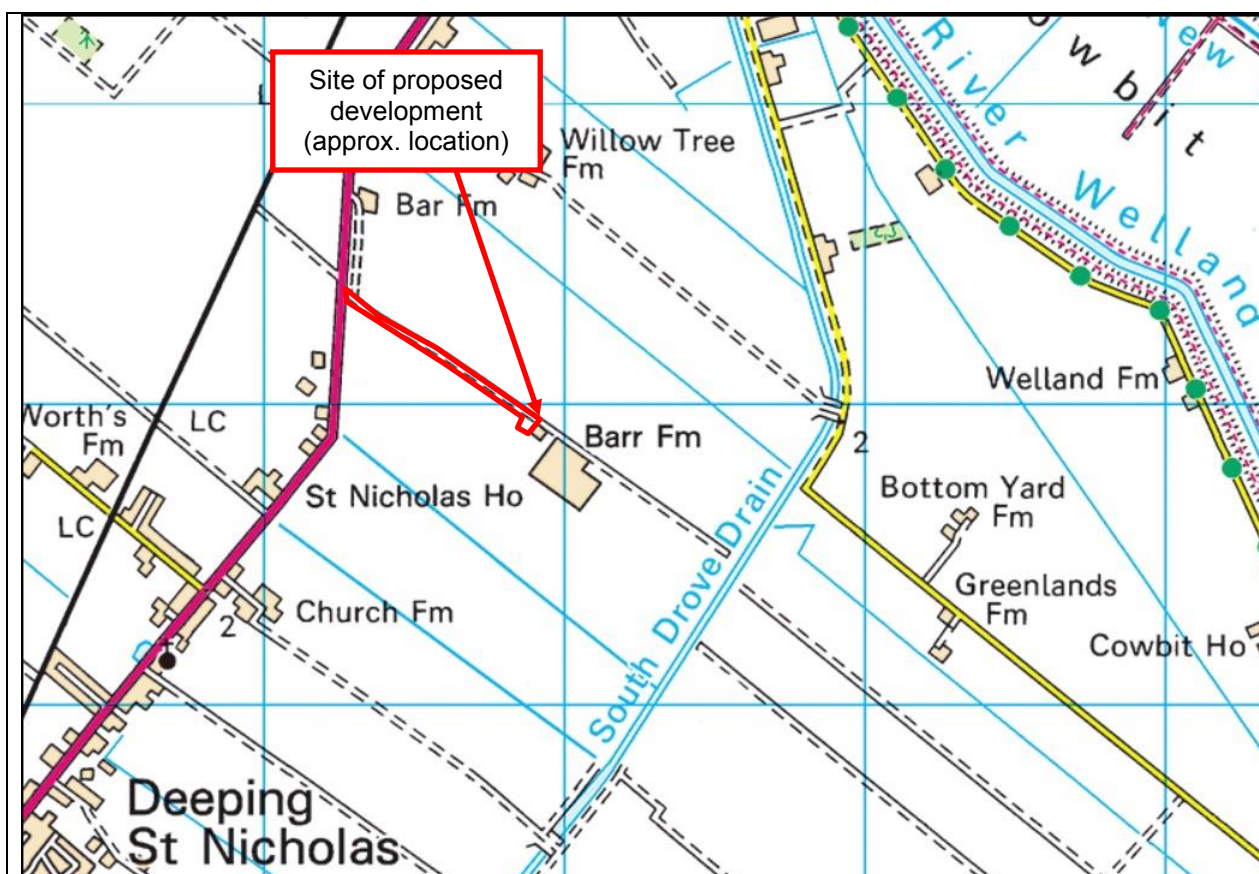
The site of proposed development, Barr Farm, Deeping St. Nicholas, Spalding, Lincolnshire PE11 3BW, is located approximately 1.5 km north-east of the village of Deeping St Nicholas (

OS X (Eastings)	522922
OS Y (Northings)	316910
Nearest Post Code	PE11 3HA
Lat (WGS84)	N52:44:09 (52.735860)
Long (WGS84)	W0:10:51 (-0.180863)
Lat,Long	52.735860, -0.180863
Nat Grid	TF229169 / TF2292216910
Council	South Holland District Council

to Figure 3 and Table 1) and approximately 6.5 km south-west of the market town of Spalding. Access to the site is by a private road running south-east from Littleworth Drove. The nearest watercourse is the South Drove drain which is located approximately 750 m south-east of the site and the River Welland flows approximately 2 km south-east of the site. It is proposed that an agricultural workers dwelling is constructed north-west immediately north-west of the existing farm buildings.

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

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



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Table 1 Approximate coordinates of the location of the site

OS X (Eastings)	522922
OS Y (Northings)	316910
Nearest Post Code	PE11 3HA
Lat (WGS84)	N52:44:09 (52.735860)
Long (WGS84)	W0:10:51 (-0.180863)
Lat, Long	52.735860, -0.180863
Nat Grid	TF229169 / TF2292216910
Council	South Holland District Council

Source: Street Map²

Figure 2 Aerial photo of the site of proposed development

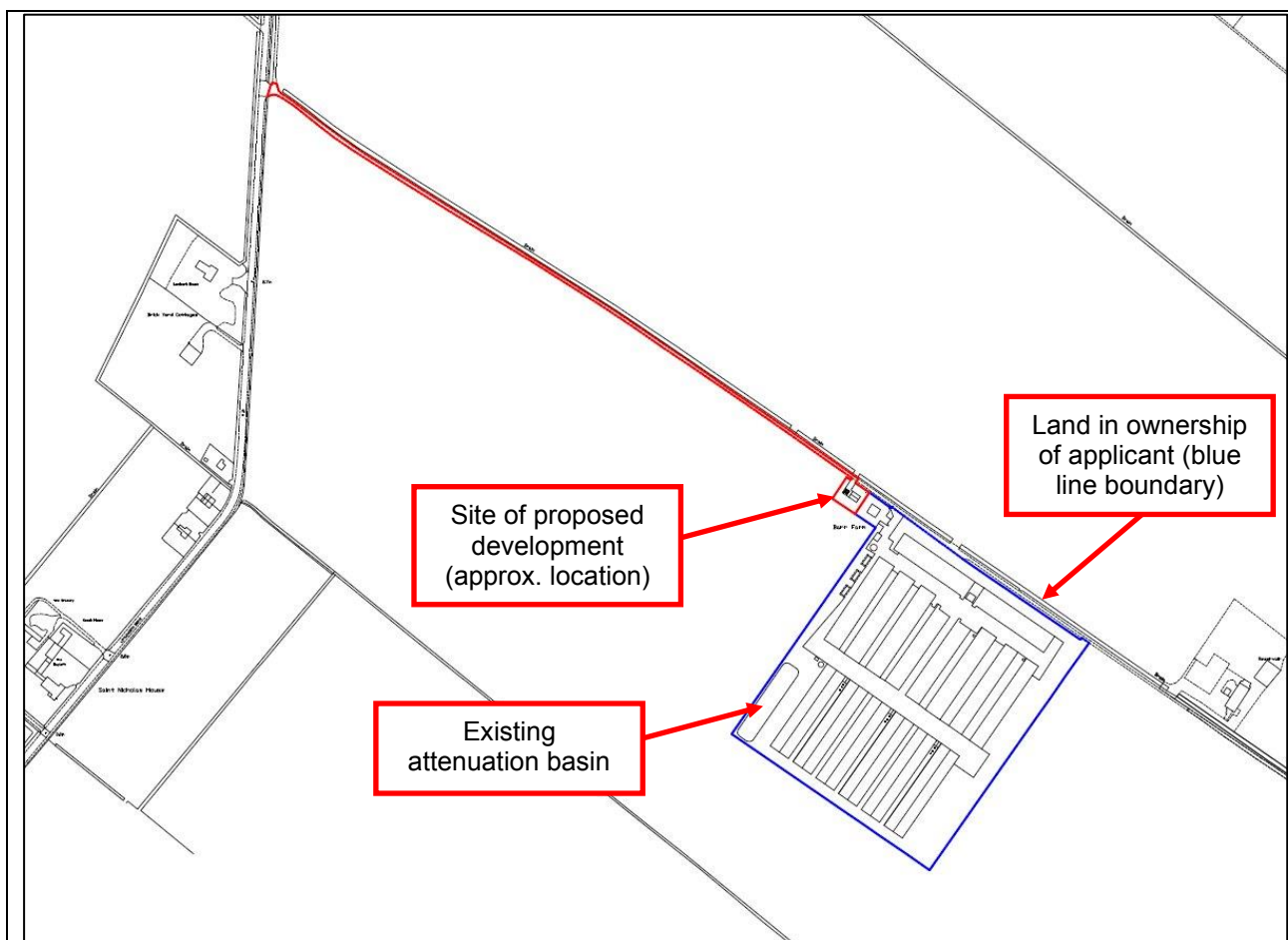
² <http://www.streetmap.co.uk/ids.srf?>



Source: Google Maps³

Figure 3 Location plan of the site (site boundary as red line)

³ <https://www.google.co.uk/maps>



Source: Ian Pick Associates Ltd.

1b. What is its vulnerability classification?

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

In terms of the National Planning Policy Framework (NPPF), residential buildings are classified as "More Vulnerable" developments.

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 in this case.

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 HS12 – Agricultural, Forestry and Other workers' dwellings

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 the proposed agricultural workers dwelling is classified as 'More Vulnerable'. More Vulnerable developments are considered appropriate in Flood Zone 1, Flood Zone 2 and Flood Zone 3a providing the Exception Test is passed, however they are not permitted in Flood Zone 3b (functional floodplain, corresponding to the 1 in 20 year flood extent).

The South-east Lincolnshire (SEL) Strategic Flood Risk Assessment (SFRA) (South East Lincolnshire Joint Planning Unit (SELJPU), 2017) and the South Holland District Council (SHDC) Strategic Flood Risk Assessment (SFRA) (Royal Haskoning, January 2010) and are reviewed in sections 2b and 3b. The SFRA's confirm 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 therefore the Exception Test must be applied.

Since the site is located within Flood Zone 3a, it is subject to the Sequential Test and as stated in Paragraph 5 of the NPPF Technical Guide:

"The overall aim should be to steer new development to Flood Zone 1. Where there are no reasonably available sites in Flood Zone 1, local planning authorities allocating land in local plans or determining planning applications for development at any particular location should take into account the flood risk vulnerability of land uses (see table 2) and consider reasonably available sites in Flood Zone 2, applying the Exception Test if required (see table 3). Only where there are no reasonably available sites in Flood Zones 1 or 2 should the suitability of sites in Flood Zone 3 be considered, taking into account the flood risk vulnerability of land uses and applying the Exception Test if required" (DCLG, 2012, Pg.3).

The question is therefore "are there reasonably available sites for this development, which are located in an area at lower risk of flooding?" The answer to this is that there is not. The proposed development is for an agricultural worker dwelling to support Barr Farm, which by definition needs

to be at/ near Barr Farm and as the whole farm is shown to be in Flood Zone 3a, there is no alternative location at lower flood risk.

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	$100 < T_{fluv} < 1,000$ $200 < T_{tidal} < 1,000$	✓	✓	Exc	✓	✓
3a	$T_{fluv} < 100$ $T_{tidal} < 200$	Exc.	✓	X	Exc	✓
3b (functional floodplain)	$T_{fluv} < 20$	Exc	✓	X	X	X

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

Notes:

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

Section 102 of the NPPF states that for the Exception Test to be passed, the proposed development must satisfy two requirements:

- “it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared; and
- a site-specific flood risk assessment must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

Both elements of the test will have to be passed for development to be allocated or permitted.”

The proposed agricultural worker dwelling would enhance the sustainability of Barr Farm by allowing workers to live on site, therefore reducing the commuter traffic entering the site as well as providing greater facilities for farm workers. As discussed in Section 2b, the site is protected by flood defences, which are shown in SHDC SFRA (Royal Haskoning, 2010) to generally have sufficient freeboard to protect the site from the 1:1,000 year fluvial flood. Fluvial flood risk at the site is therefore a residual risk and the flood maps shown in Section 2b (Figure 7, Figure 9, Figure 10, Figure 11) therefore depict a worse-case scenario. Given that the proposed finished floor level discussed in Section 6, is calculated from the worst-case residual risk scenario of the 1:100 year+CC fluvial flood, it is considered that the proposed dwelling would be beyond the risk of inundation. In the event of the residual risk 1:100 year+CC fluvial flood occurring, occupants of the proposed dwelling would be able to remain within the ‘safe haven’ of the dwelling until flooding subsided. The recommended surface water management plan, outlined within Section 7b of this report would ensure that the proposed development would not lead to an increase in flood risk elsewhere. Considering all of this information, it is considered that the proposed development passes the Exception Test.

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 would increase the number of people living at the site. However, the location of the site benefits from flood 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).

The possible sources of flood risk which could affect the site are listed in Table 3. The proposed development is located within Flood Zone 3 (Figure 4), with a 1:100 or greater annual probability of fluvial flooding and a 1:200 or greater annual probability of tidal flooding. Note Environment Agency flood mapping does not take into account the presence of flood defences. Flood risk at the site is therefore discussed further in Section 2b.

The site and access road to Littleworth Drive, A1175 is shown to be at 'very low' risk of surface water flooding, with less than 1:1,000 annual probability of flooding (Figure 5). No records of groundwater flooding have been found at the site. No records of sewer flooding at or near the site were found. Figure 6 shows that the site has a residual risk of flooding associated with upstream reservoir failure. This is considered a very small risk as the infrastructure associated with reservoirs is robust.

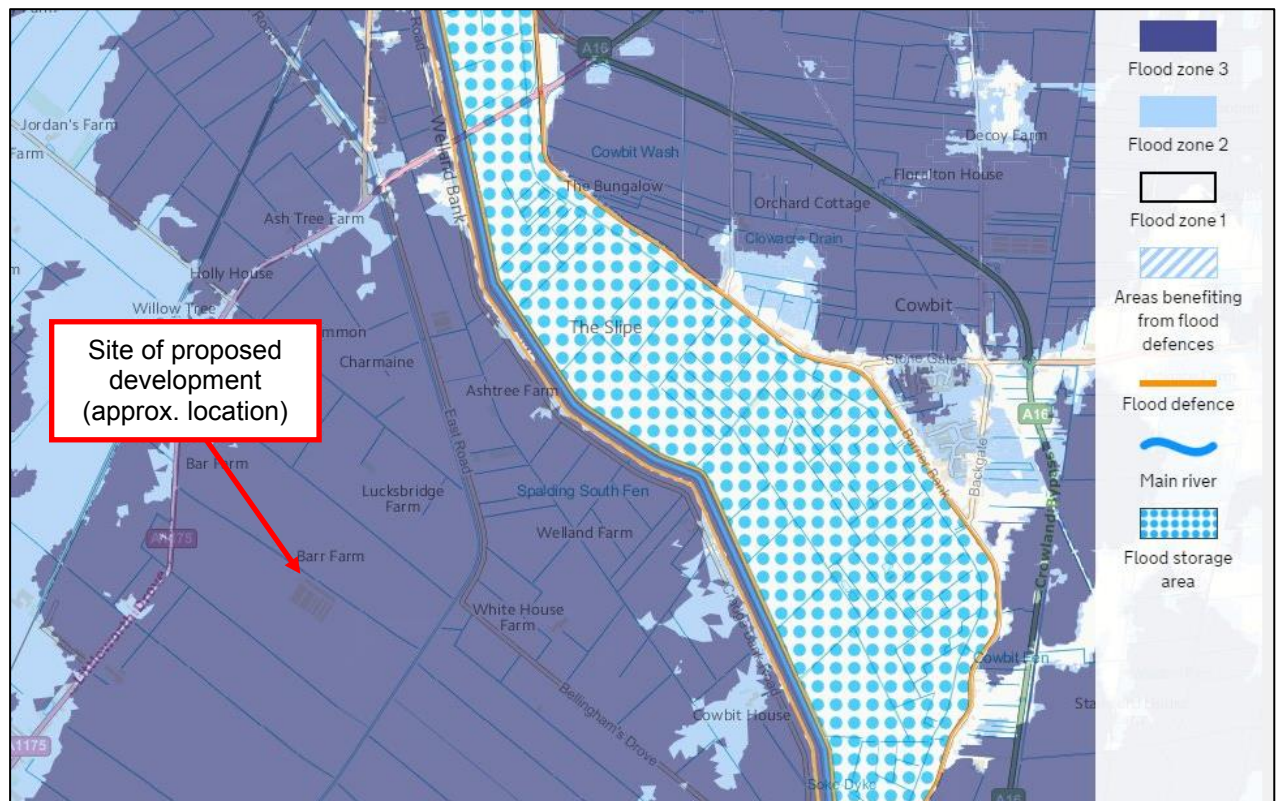
Table 3 Sources of flooding which could affect the site

Key sources of flooding	Possibility at Site
Fluvial	<i>Flood Zone 3 – 1:100 or greater annual probability</i>
Tidal	<i>Flood Zone 3 – 1:200 or greater annual probability</i>
Groundwater	<i>No records found of groundwater flooding at the site.</i>
Sewers	<i>No records found of sewer flooding at the site.</i>
Surface water	<i>Very Low risk – less than 1:1,000 annual probability</i>
Infrastructure failure	<i>The Environment Agency Flood Risk from Reservoirs Map confirms the site is at risk of flooding due to reservoir failure.</i>

List taken from NPPF Practice Guide, Paragraph 24

⁴ <http://planningguidance.planningportal.gov.uk/blog/guidance/flood-risk-and-coastal-change/planning-and-flood-risk/what-is-flood-risk/>

Figure 4 Fluvial Flood Risk Map

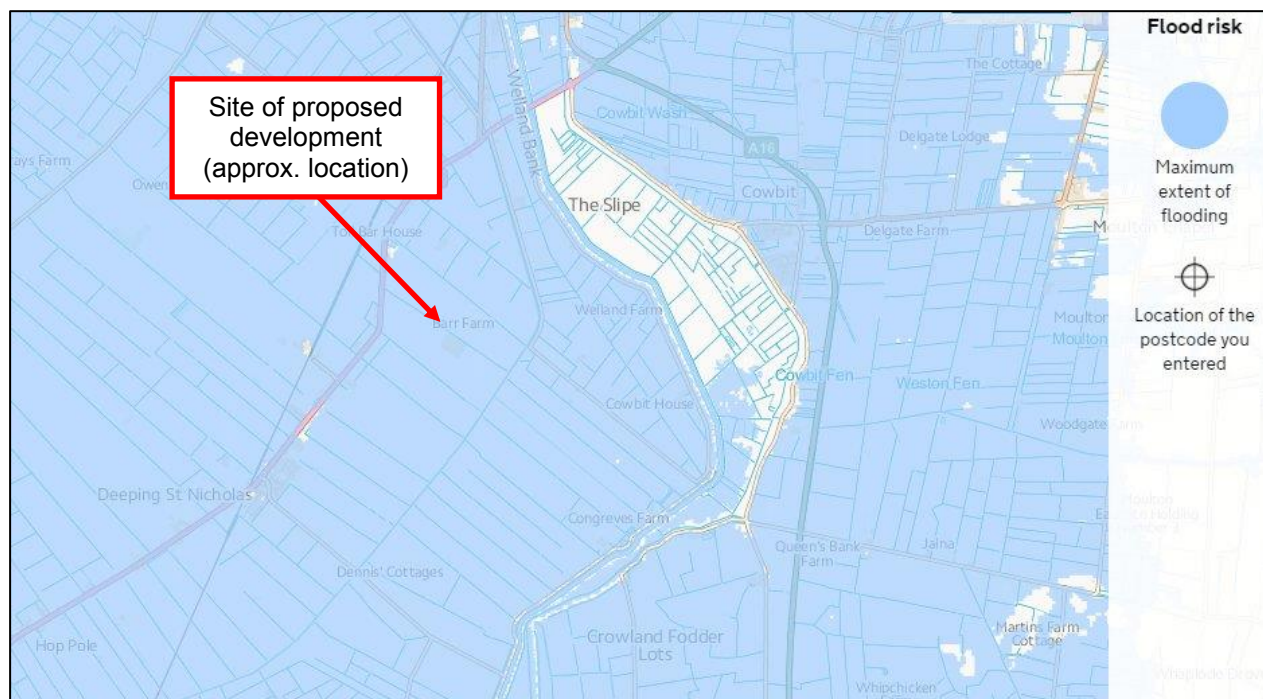


Source: Environment Agency

Figure 5 Surface Water Flood Risk Map



Source: Environment Agency

Figure 6 Flood Risk from Reservoirs Map

Source: Environment Agency

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 textual 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-East Lincolnshire Strategic Flood Risk Assessment (SEL SFRA) (South East Lincolnshire Joint Planning Unit (SELJPU), 2017) is referenced as a source of information throughout this section. Information has also been taken from the '2016 Update of South Holland Strategic Flood Risk Assessment – Modelling and Mapping Note' (Royal Haskoning DHV, 2017) and from South Holland District Council Strategic Flood Risk Assessment (SHDC SFRA) (Royal Haskoning, 2010).

Flood risk at the location of 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.

As indicated in Table 3 and Figure 4, 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. Figure 7 however shows that the site is beyond the effects of tidal flooding and therefore flooding at the site is limited to fluvial flooding or flooding associated with infrastructure failure.

The Environment Agency flood zone mapping (Figure 4) 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 (Figure 4). 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.

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 South Holland District Council (SHDC) SFRA (Royal Haskoning, 2010) Appendix A, Table 6L, confirms the Welland defences have sufficient freeboard to protect against the 1:1,000 year fluvial flood event. The SHDC SFRA (Royal Haskoning, 2010) Appendix A, Table 7R, confirms the Glen defences generally to have sufficient freeboard to protect against the 1:1,000 year fluvial flood event, although several locations distant from the site may not be secure at peak flood levels. Figure 6 of the SHDC SFRA (Royal Haskoning, 2010) indicates the Welland and Glen defences are in fair to good condition.

Since the site is protected by defences, the risk of flooding derives mainly from the failure of those defences. The potential breach locations of these defences are mapped in Figure 8. The South Holland, South Kesteven and Rutland Planning Summary Report (Scott Wilson Ltd. 2011, Pg.59) states that:

“The District is reliant on flood protection given by the various defence systems and related flood risk management measures, which currently sustain a largely satisfactory level of flood risk within the District. However, the SFRA concluded that if the currently projected effects of climate change materialise (with higher sea levels and increased river flows), but the defence systems are not upgraded from their present form, there will be significant flood risk within the District by the Year 2115, with impact in the main urban areas as well as in agricultural areas. The flood risk to people would become unacceptable. A lesser, but notable, increase in flood risk would also be apparent by the Year 2055.”

The SEL SFRA (2017) contains new hydraulic modelling results for the district, which include the flood hazard maps associated with the site. The flood hazard map (Figure 9) is a result of flood depth (Figure 10) and flood velocity (Figure 11) being assessed against the ‘Danger to people’ table (Table 4). Model results show the effects of the 1:100 year+CC fluvial flood event, taking into account the presence of flood defences. The scenarios mapped represent the residual risk of the current flood defences being overtopped and therefore represent a worse-case scenario.

Overall the flood, depth and velocity mapping shows that a very large area is flooded with slow moving water.

Figure 10 shows that the existing ground within the area the site (location of proposed dwelling) to have a peak flood depth of 0.25 m to 1 m during the 1:100 year+CC residual risk fluvial flood, with the access track having flood depths varying between 0 m to 1 m in depth along its length.

Velocities at the proposed location of the dwelling and along the access track are shown to be between 0 to 0.3 m/s during the 1:100 year+CC residual risk fluvial event. These velocities and flood depths correspond to a flood hazard between 1.25 and 2.0 at the location of the proposed dwelling, representative of a flood hazard presenting ‘danger for most’ (Figure 9, Table 4). Flood hazards along the access track range from <0.75 to 2.0, representing flood hazards ranging between a ‘low hazard’, a ‘danger for some’ and a ‘danger for most’.

The working platform, upon which the property will be constructed will be at a level of 1.9m which is some 0.9m above existing ground level which reduces the predicted flood depths and hence risk detailed above.

As discussed in Section 6, it is recommended that the finished floor level of the proposed agricultural workers dwelling is at least 300 mm above the residual risk 1:100 year+CC fluvial and

tidal flood level (i.e. finished floor level of at least 2.2 mAOD). A finished floor level of this order would place the dwelling beyond the limits of the 1:100 year+CC residual risk fluvial flood event (Figure 6, Figure 7) therefore reducing the flood hazard to the proposed residents as the site would be flood free during this residual risk flood event.

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 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% (1:100) 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 (Royal Haskoning, 2010) 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.

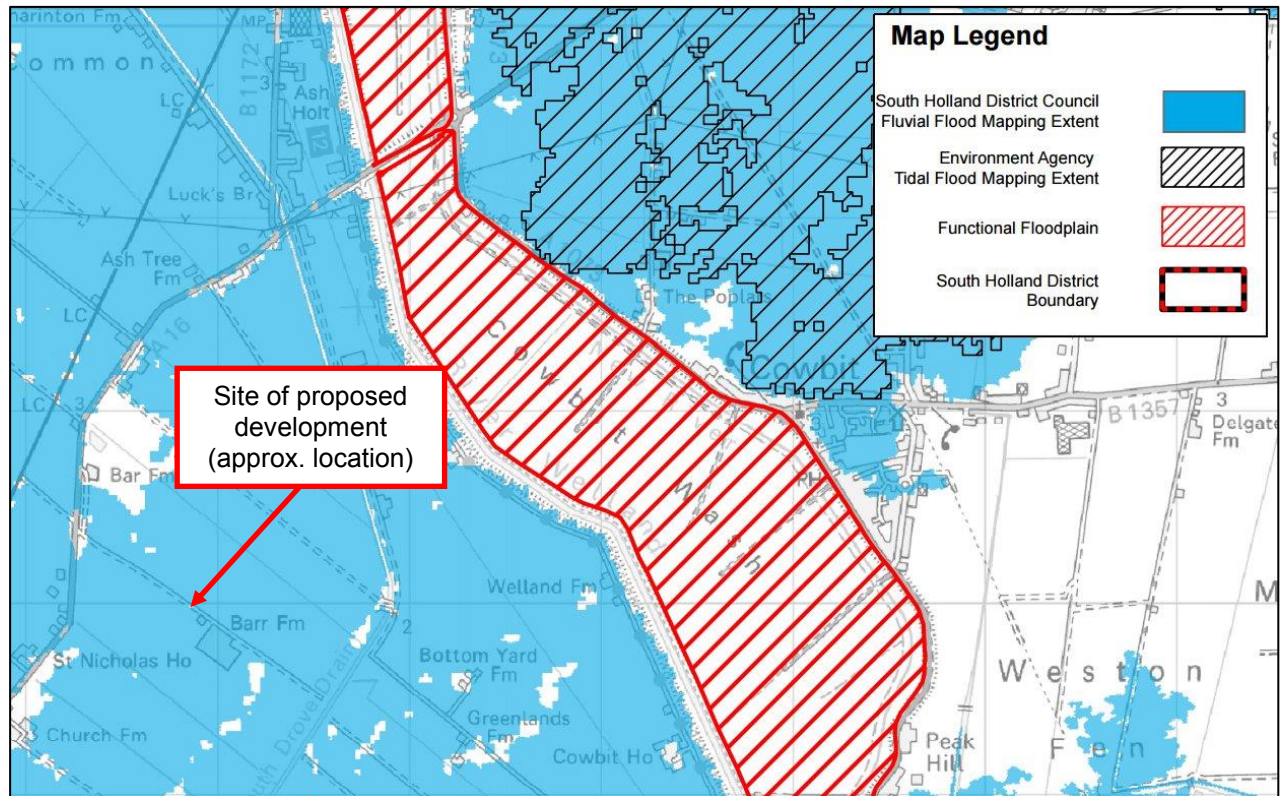
The SFRA (Royal Haskoning, 2010) also records the following extreme rainfall events affecting the District since 1953.

- 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.

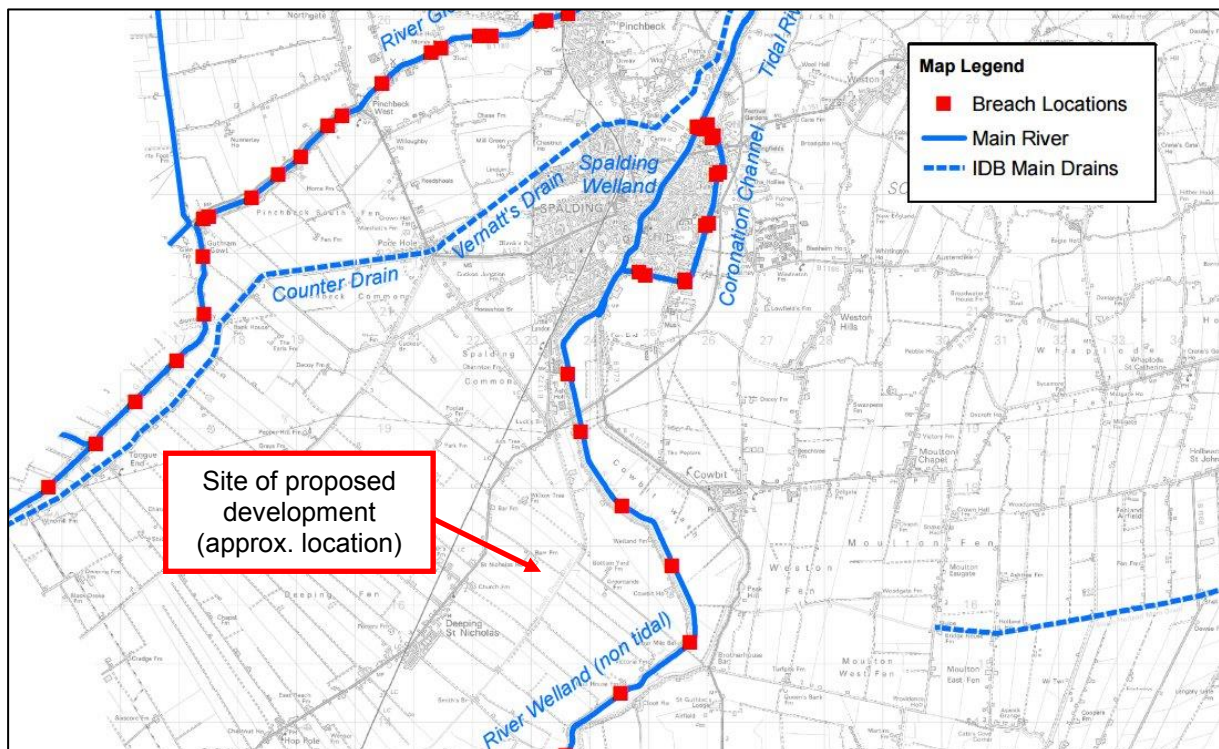
Overall, the site is protected from flooding by the presence of flood defences and therefore the mapped flood risks at the site are considered a residual risk, associated with the failure of the flood defences. The risk of flooding associated with the internal drainage network is considered low and unlikely to have a significant impact on the site.

Figure 7 Extract of SEL SFRA (2017) map showing fluvial and tidal flood extents for 2115



Source: SEL SFRA (2017)

Figure 8 Extract of breach locations map taken from SEL SFRA (2017)

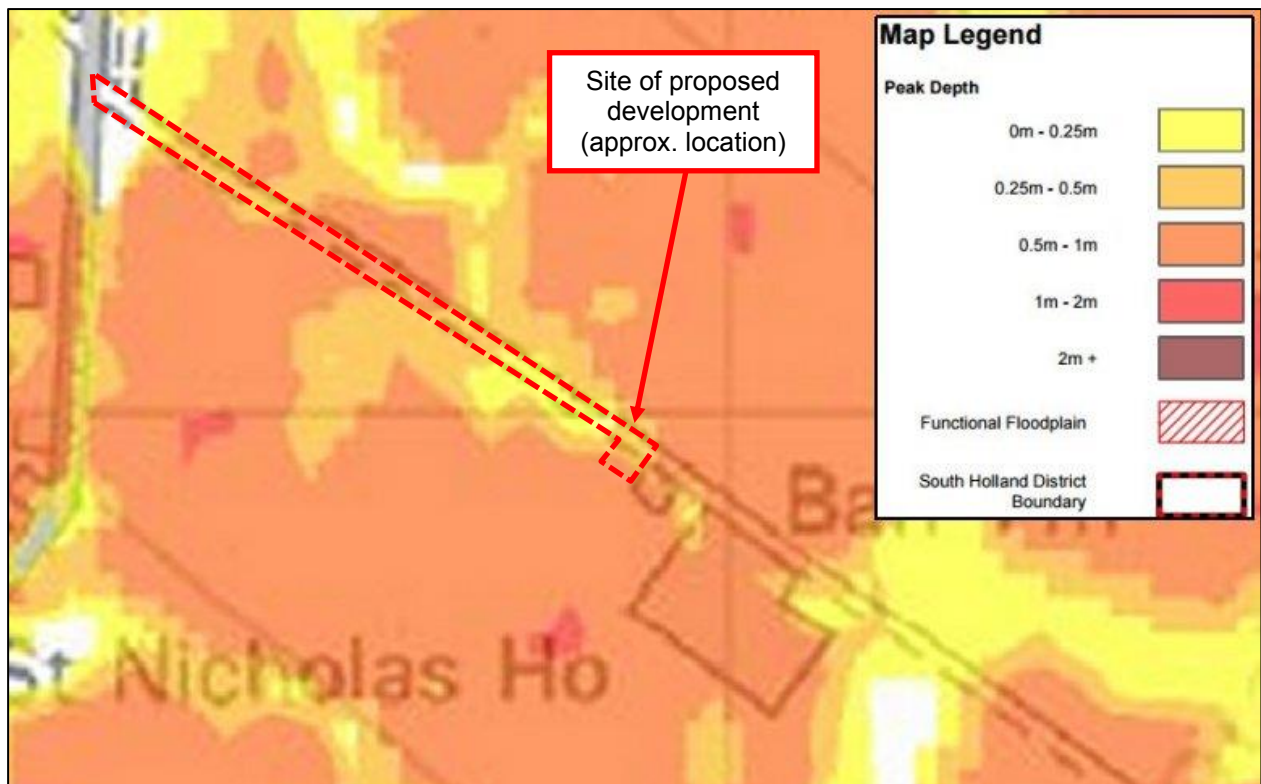


Source: SEL SFRA (2017)

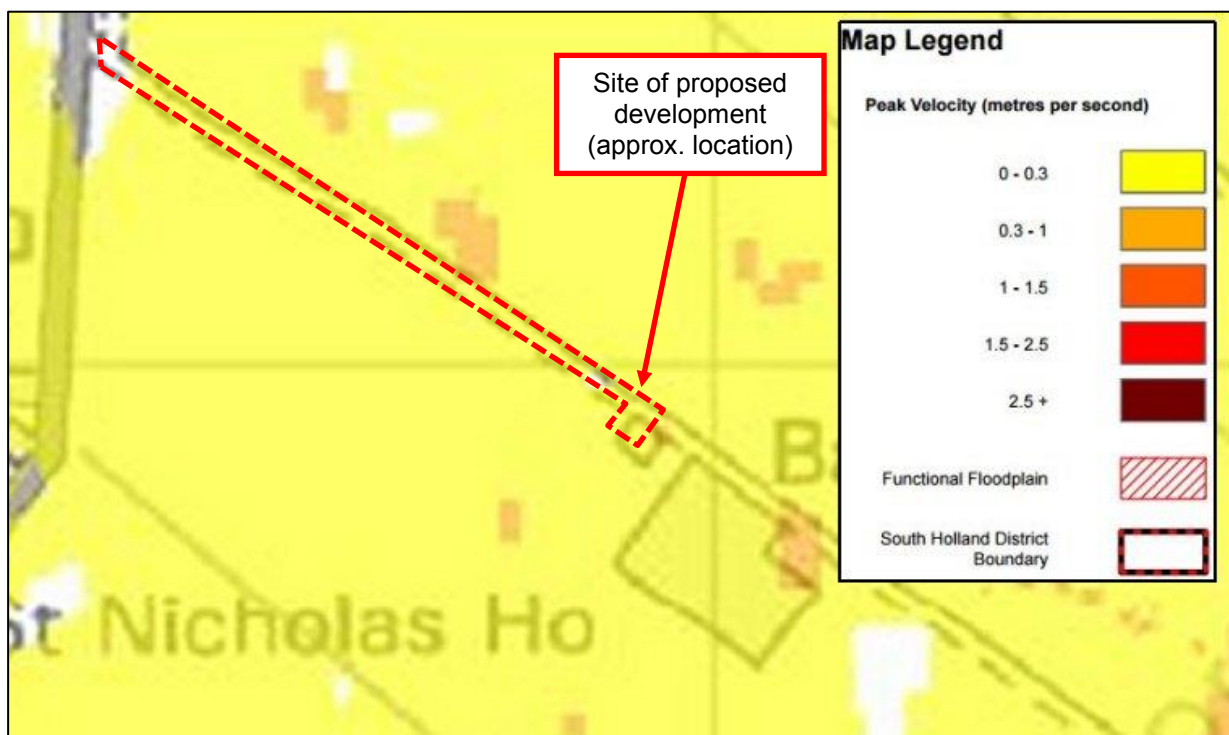
Figure 9 Map showing flood hazard for 2115, 1:100 year+CC fluvial flood event



Source: SEL SFRA (2017)

Figure 10 Map showing peak flood depths for 2115, 1:100 year+CC fluvial flood event

Source: SEL SFRA (2017)

Figure 11 Map showing peak flood velocities for 2115, 1:100 year+CC fluvial flood event

Source: SEL SFRA (2017)

Table 4 Danger to people for different combinations of depth and velocity, taken from SEL SFRA (2017), original source Defra/ Environment Agency (2005)

Table 13.1 Danger to people for different combinations of depth and velocity

Velocity (m/s)	Depth of flooding (m)											
	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.00												
0.10												
0.25												
0.50												
1.00												
1.50												
2.00												
2.50												
3.00												
3.50												
4.00												
4.50												
5.00												

Key:
 Danger for some
 Danger for most
 Danger for all

(Source Table 13.1 of FD2320/TR2)

Source: SEL SFRA (2017) – original source Defra/ Environment Agency (2005)⁵

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. Runoff from the existing site is currently managed by an attenuation basin located to the west of the poultry units (Figure 3). 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 4. 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 (See Section 2b).

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-East Lincolnshire (SEL) Strategic Flood Risk Assessment (SFRA) (South East Lincolnshire Joint Planning Unit (SELJPU, 2017). This SFRA builds on the previous South Holland District Council (SHDC) Strategic Flood Risk Assessment (SFRA) (Royal Haskoning, 2010) by including new hydraulic modelling results. The findings of

⁵ http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/FD2320_3364_TRP_pdf.sflb.ashx

the SEL SFRA (SELJPU, 2017) are discussed in Section 2b, the main findings of which are listed below:

- *The site is protected by flood defences, which are shown in SHDC SFRA (Royal Haskoning, 2010) to have sufficient freeboard to protect the site from the 1:1,000 year fluvial flood. The South Holland, South Kesteven and Rutland Planning Summary Report (Scott Wilson Ltd. 2011) however raises concerns that if the existing flood defences are not upgraded and maintained then they will not be capable of managing flood risk associated with predicted climate change allowances by the year 2115.*
- *New hydraulic model outputs (Figure 7, Figure 9, Figure 10, Figure 11) show the residual risk of flooding at the site associated with the 1:100 year+CC fluvial flood event, including the presence of the flood defences. The model results are considered to show a worse-case scenario as they show the residual risk of the flood defences being overtopped. Model results show the site to:*
 - *Be at high risk of fluvial flooding (Figure 7).*
 - *Be beyond the limits of tidal flooding (Figure 7).*
 - *Be predominantly categorised as having a 'danger for most' due to flooding, however sections of the access track are shown to pose a lower hazard rating; 'danger for some' and 'low hazard' categories (Figure 9).*
 - *Have flood depths ranging between 0 m to 1 m along the access road and flood depths ranging between 0.25 m and 1 m at the location of proposed dwelling (Figure 10).*
 - *Have flood velocities of 0 m/s to 0.3 m/s (Figure 11).*

The SHDC SFRA (Royal Haskoning, 2010) also provided 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 (SHDC 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 (Stamford to Spalding). The minimum lead time is 2 hours.*

Neither of the SFRA's considered within this report make a direct reference 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 SHDC SFRA (Royal Haskoning, 2010).

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

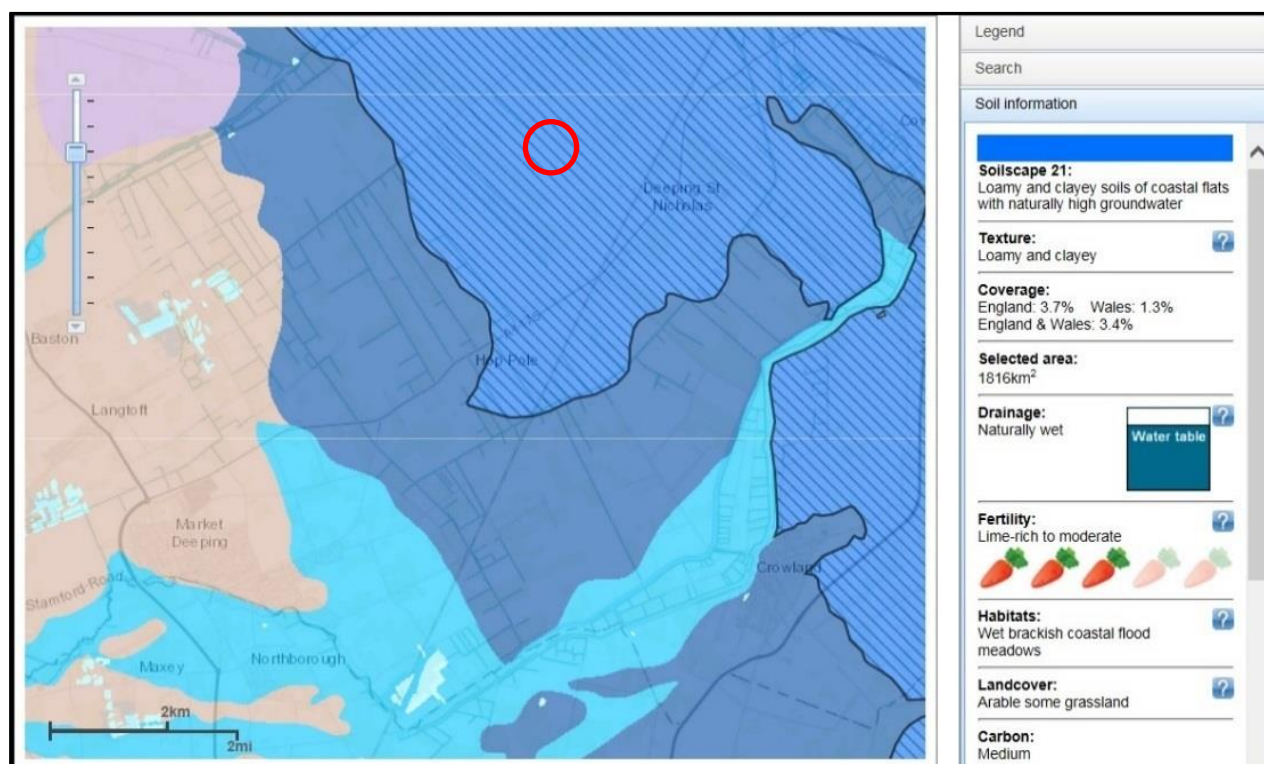
- This should generally be accompanied by calculations of run-off rates and volumes from the existing site for a range of annual probability events (see Section 21 of the NPPF Practice Guide).

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. Cranfield Universities Soilsmapes map (Figure 12) 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.

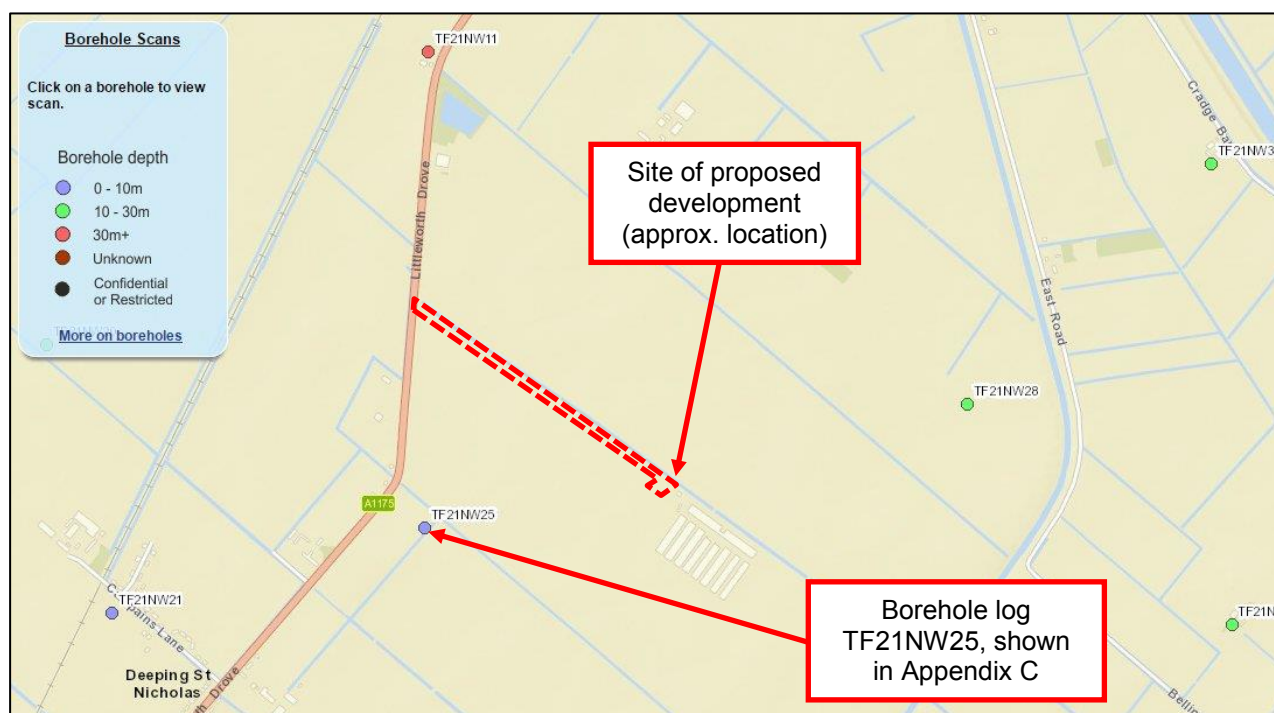
A nearby borehole log (Figure 13, Appendix C) shows that groundwater was struck at '6.4 m and 6.7 m' below ground level and that the standing water level was '1.6 m' (Appendix C). Groundwater level is therefore taken to be 1.6 m below the ground surface at the borehole, which is shown on LiDAR DTM mapping (

Figure 14) to be approximately 1 mAOD. Note as the proposed dwelling would be built on made ground, to the level of the adjacent building (approximately 1.4 mAOD), groundwater would be located approximately 2 m below the ground surface of the site.

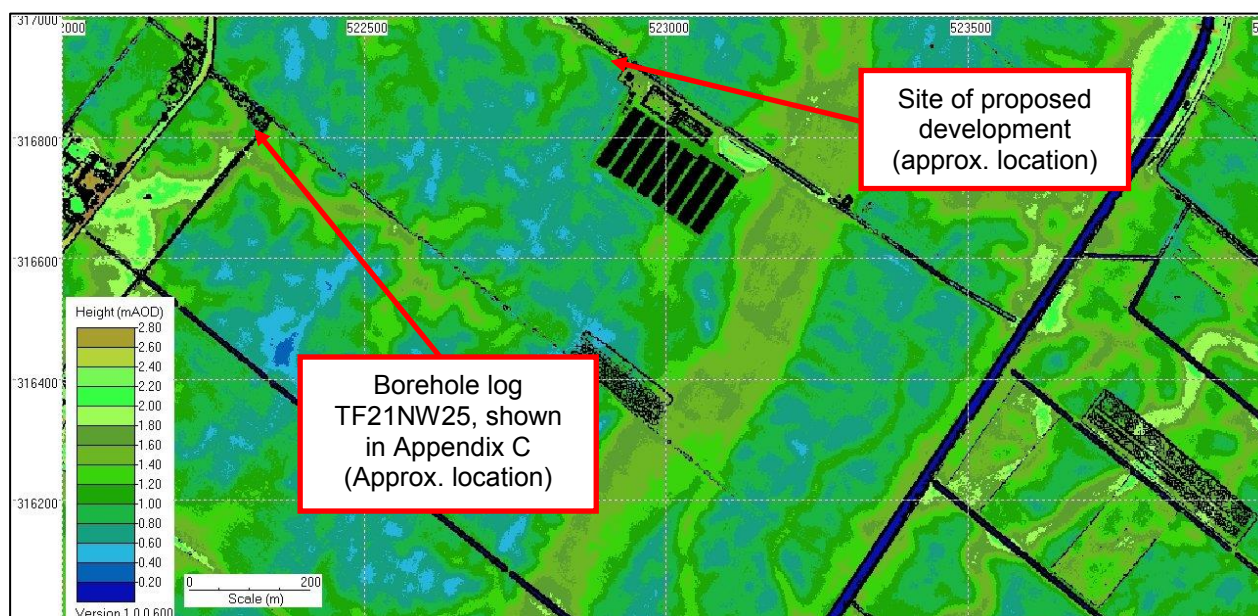
Figure 12 Soil map of the location of the site (site location shown by red circle)



Source: Cranfield University Soil Mapping <http://www.landis.org.uk/soilsmapes2/>

Figure 13 Nearby borehole data to the site

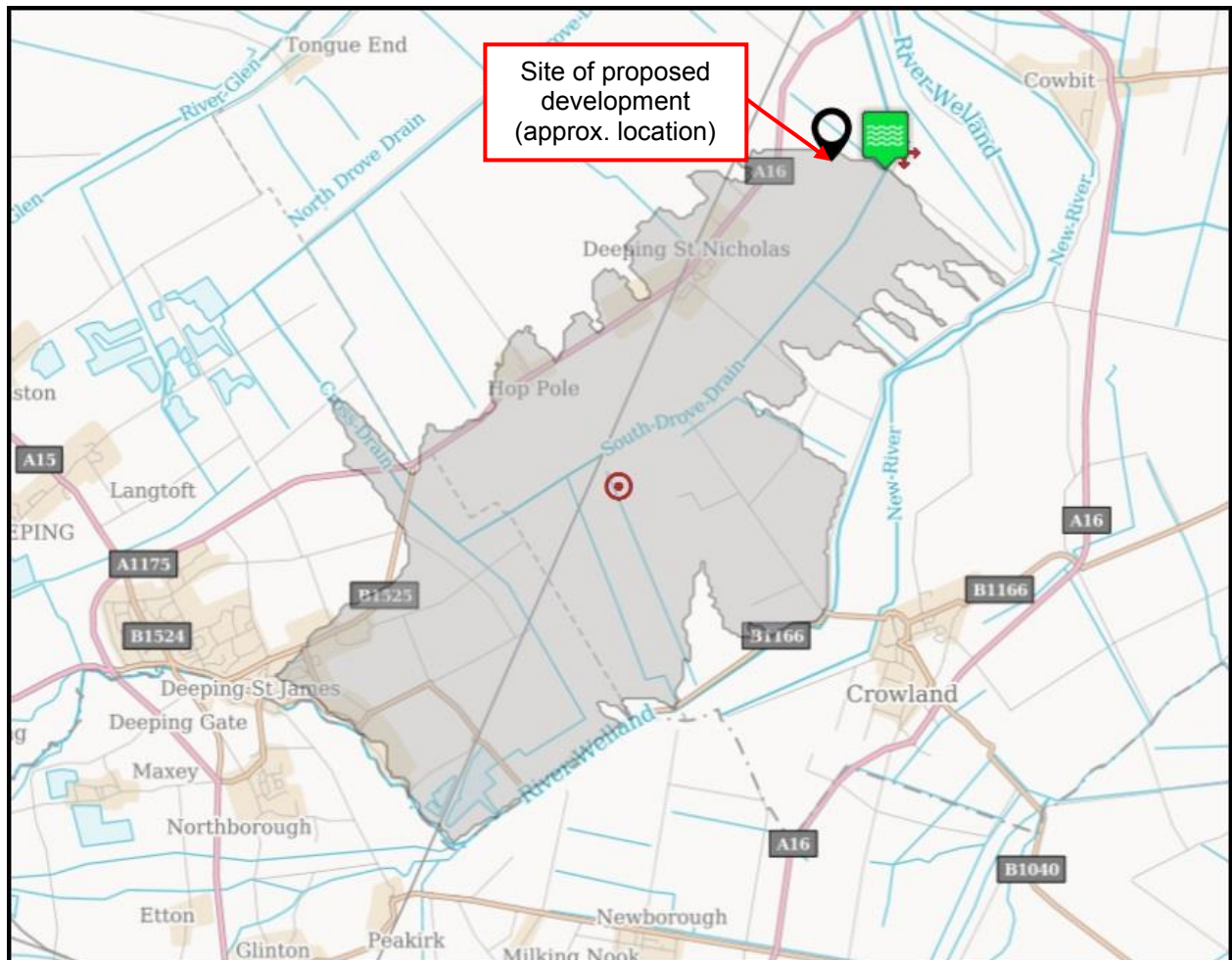
Source: British Geological Survey

Figure 14 LiDAR DTM mapping of the site and surrounds, plotted at 0.2 m intervals

The 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 15, and its characteristics are listed in Table 5. 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 12) and “freely

draining” soils (pink area in Figure 12) 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 15 FEH web service catchment containing the site (catchment as grey polygon)



Source: © Centre for Ecology & Hydrology 2016

Table 5 Selected catchment characteristics

	Location:	Barr Farm
	NGR (site):	TF 22928 16898
	NGR (catchment):	TF 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 5, 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 110 m² of proposed impermeable areas ranged from 0.03 l/s for the 1:2 year rainfall event to 0.11 l/s for the 1:100 year rainfall event.

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;*
- *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 precipitation, Table 6 shows the anticipated changes in small catchments, recommending a progressive increase, reaching 40% for the ‘Upper End’ allowance by 2115; this allowance would be recommended for this proposed development as it is classified as ‘More Vulnerable’ with a 100 year design life. This value is based on the 90th percentile, meaning that there is a 90% chance that rainfall will not increase by more than the 40% increment.

Table 6 Peak rainfall intensity allowance in small and urban catchments

Applies across all of England	Total potential change anticipated		
	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.

It is proposed that an agricultural workers dwelling is constructed adjacent (to the north-west) of the existing farm building at Barr Farm, Deeping St. Nicholas, Spalding, Lincolnshire, PE11 3BN (Figure 16, Figure 17). Access to the site would be via the existing farm track, linking Barr Farm to Littleworth Drove (A1175), approximately 0.8 km north-west of the proposed dwelling. As shown in Table 7, a total of 106.02 m² of impermeable surface areas are proposed on site, runoff from which must be managed.

Table 7 Proposed impermeable surfaces on site

Impermeable Surface	Area (m ²)
Agricultural workers dwelling (10.156 m x 7.736 m)	78.6
Patio	12
Paths (7.3 m ² and 6.62 m ²)	13.92
Porch	1.5
TOTAL:	106.02

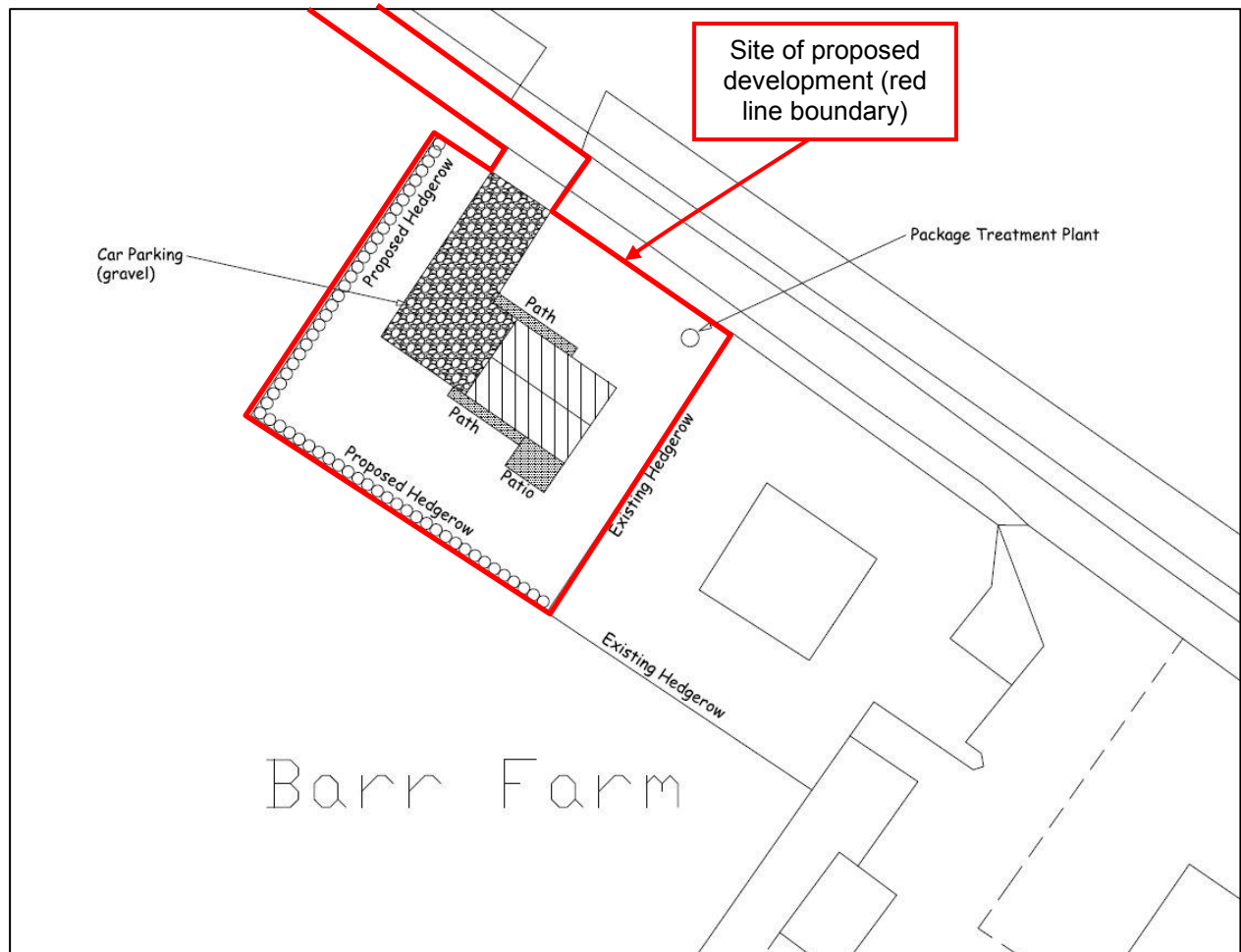
Figure 16 Elevations and plans of proposed agricultural workers dwelling



Source: Ian Pick Associates

K0776_Spalding_Deeping_Farm_Agricultural_Dwelling_Issue_June2017

Figure 17 Layout of the proposed development



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.

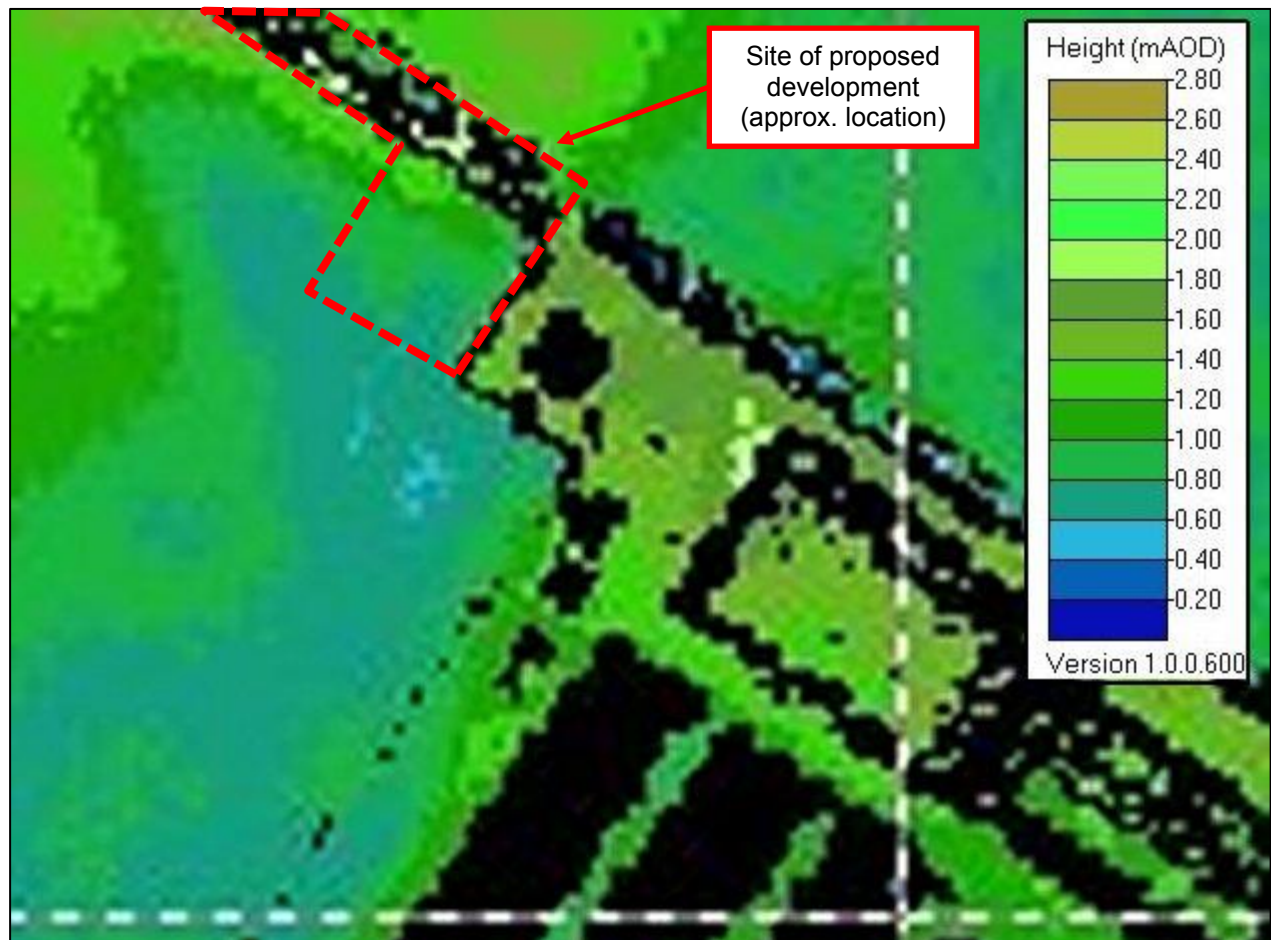
The risk of flooding at the site is very low for surface water and ground water. The site is defended hence fluvial and tidal are a residual risk. There is a mapped reservoir risk but due to the need to regularly inspect reservoirs this risk is considered to be low.

This is not expected to change over the 100 year lifetime of the proposed development, allowing for the effects of climate change of the scale anticipated and described in Section 4.

It is recommended that the finished floor level of the proposed agricultural workers dwelling is at least 300 mm above the 1:100 year+CC flood level as the flood extent covers a wide area.

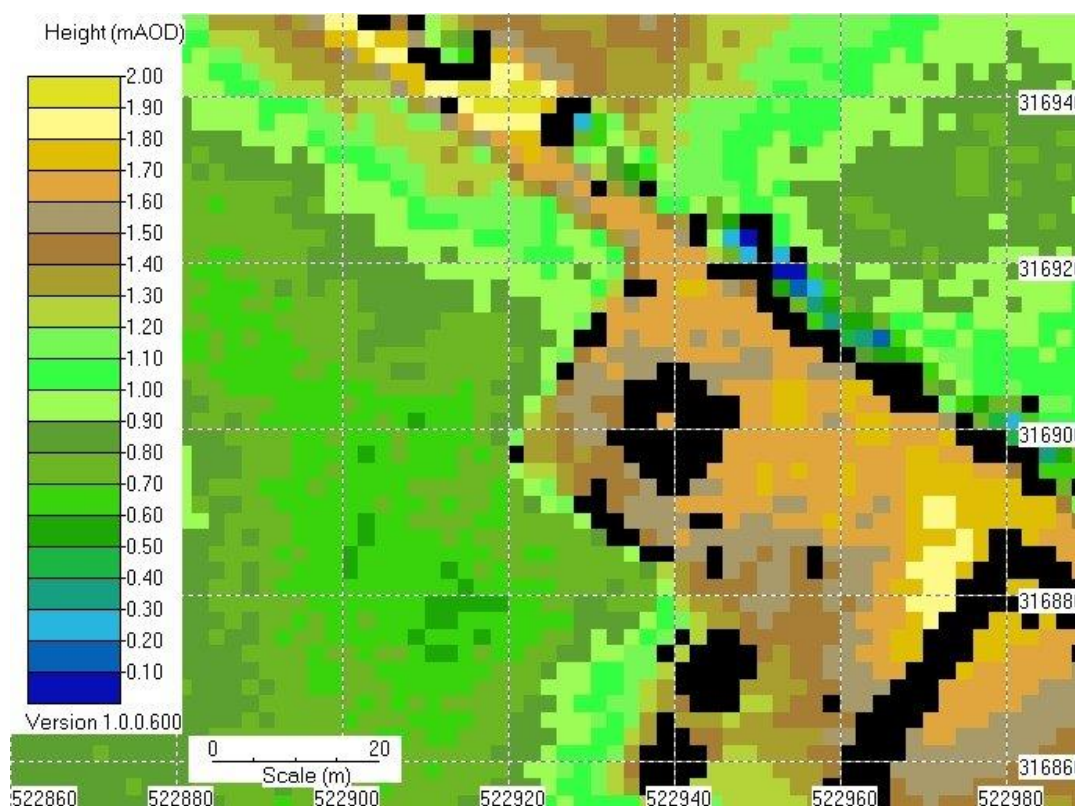
LiDAR DTM mapping of the site (Figure 18 and Figure 19) shows that the level of the track adjacent to the new dwelling is in the range of 1.6-1.7m. As this location floods to a depth of up to 0.25m (Figure 10) the peak flood level is taken to be 1.95m. The proposed working platform at the property is 1.9m so the FFL of the house, at 2.25m, should be 350mm above the ground surrounding the house and 550mm above the track.

Figure 18 LiDAR DTM mapping of the proposed location of the agricultural workers dwelling, plotted at 0.2 m intervals



house and 550mm above the track.

Figure 19 LiDAR DTM mapping of the proposed location of the agricultural workers dwelling, plotted at 0.1 m intervals



If the FFL of the property is set as above it is clear that inundation of the proposed dwelling during fluvial/tidal flooding is extremely unlikely. It is possible to incorporate elements of flood resilience as additional precautions. There are several suggestions made by DCLG (2007), particularly in Chapter 6, which have been summarised in Table 8. This list is not intended to be prescriptive, since the choice of materials may be determined by other factors such as strength and appearance but it is suggested that elements should be drawn from this list, where practicable, to enhance the flood resilience of the ground floor.

Occupants of the proposed dwelling could also sign up to the free Environment Agency's Flood Warning System⁶ which would provide the occupants with flood warnings either via phone, email or text. This advanced warning would enable future occupants to prepare for flooding, or evacuate if necessary, therefore reducing the risks to people.

⁶ <https://www.gov.uk/sign-up-for-flood-warnings>

Table 8 Elements of flood resilience which should be considered for inclusion within the proposed development

Feature		Method
1	Building materials	Building materials should be chosen taking into account the following flood resilient properties: • Water penetration: the seepage rate through the material • Drying ability: the capability to regain its original moisture conditions • Integrity: retention of pre-flood dimensions and lack of deformation or change
2	Foundations	Foundations are usually designed to suit site conditions, but improvements can be made to increase the resilience and minimise the passage of water. It is advised to either: • Concrete blocks in foundations should be sealed with an impermeable material or encased in concrete to prevent water movement. Or; • Use construction methods and materials that promote easy draining and drying
3	Floors	When designing floors for residences in food zones it is key to either • Carry out structural calculations to ensure the floor has the required strength to resist uplift forces from water without excessive deformation or cracking. Or: • Use materials that retain their integrity when subjected to flood water (such as concrete) or those that can be easily replaced (sacrificial materials). • Construction should allow easy access for cleaning an drainage
4	Walls	Construction materials for walls should be chosen based on water penetration, drying ability and integrity and ensure that a high quality workmanship at all stages of construction. • Mortar joints are thoroughly filled to reduce water penetration • Consider engineering bricks or aircrete blocks which dry rapidly and reduce water penetration and timber should be avoided • Consider external renders to create a barrier and external insulation as this is easier to replace after flooding
5	Doors & Windows	Doors, windows and air vents are potential flow paths into properties: • Door threshold should be raised as high as possible • Use PCV doors and windows and ensure a good fit and seal • Air vents are available on the market to prevent water ingress
6	Fittings	• The main principle is to use durable fittings that are not significantly affected by water and can be easily cleaned. • Fittings can also be raised to above flood levels. • Ensure high quality workmanship in the application of fittings.
7	Services	• All service entries should be well sealed (using expanding foam) • Electrical services, meters and heating systems should be fitted above the flood level • Communication wiring should be well insulated to prevent damage

Source: DCLG (2007)

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 4, 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.

Runoff from the existing impermeable areas on Barr Farm is presently managed by an attenuation basin. Given the presence of this existing system, the first preference would be to manage runoff from the proposed development using the existing attenuation basin, located to the west of the poultry units (Figure 3). However, to connect the runoff drainage from proposed dwelling to the existing attenuation basin, a conveyance channel measuring approximately 350 m would need to be installed. This distance of conveyance channel is not considered feasible considering the relatively small volume of runoff that would be generated by the proposed dwelling. It is therefore concluded that runoff from the proposed agricultural worker dwelling should be managed at the site, using a separate system to the existing attenuation system.

Greenfield runoff rates for the 110 m² of proposed impermeable surfaces were calculated (Appendix A, Section 3d) and found to range from 0.03 l/s for the 1:2 year rainfall event to 0.11 l/s during the 1:100 year rainfall event. In order to meet the requirement that runoff rates from the developed site should be at or below greenfield rates (CIRIA C753, 2015), the outflow control of an attenuation structure would need to be extremely small. An outflow control of this size would be unacceptable due to the high risk of blockage, it is therefore concluded that runoff from the site cannot be managed using attenuation. It is therefore proposed that runoff from the dwelling could be managed using infiltration.

In the absence of a soil infiltration test, an indicative value was obtained from the CIRIA C753 SuDS Manual (2015) (Table A-2). The indicative value was determined by consulting the soil type, which is shown in Figure 12 to be 'loamy and clayey soils of coastal flats with naturally high groundwater'. An infiltration coefficient of 5×10^{-6} m/s (0.018 m/hr), corresponding to a 'loam' 'Very silty clayey SAND' has been used within the soakaway calculations (Appendix A).

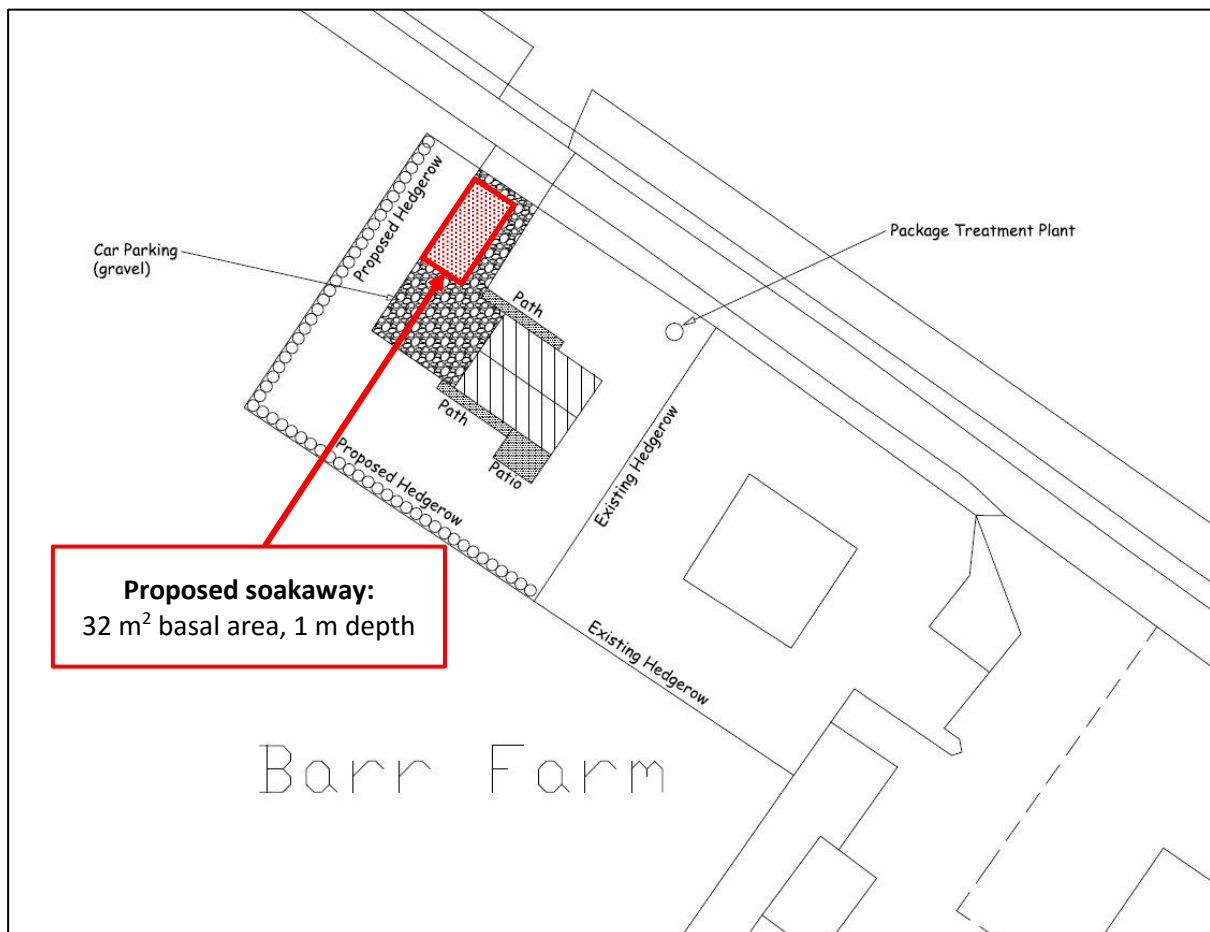
MicroDrainage modelling showed that runoff from the proposed 110 m² of impermeable surfaces, during the 1:100 year+40%CC rainfall event, could be managed by a soakaway with a basal area of 32 m² e.g. 8 m x 4 m, which is filled with 30% porosity granular material e.g. gravel or scalpings. The soakaway should be constructed to a depth of 1 m and have a cover area of 32 m². As discussed in Section 3d, groundwater level at the site is expected to be 2.5 m below the

raised working platform. A soakaway of this design would therefore meet the CIRIA C753 (2015, Pg. 547) requirement for the invert level of the soakaway to be located at least 1 m above groundwater level. It is suggested that the soakaway is located beneath the proposed gravel driveway (Figure 20) at a location at least 5 m away from any building, as required by CIRIA C753 (2015). As the soakaway would be located on made ground it is advised that the walls of the soakaway are reinforced with a structurally strong permeable material e.g. permeable bricks, as this will prevent the collapse of the soakaway.

Modelling results showed that a soakaway built to this design would have a maximum flood depth of 0.971 m during the 1:100 year+40%CC rainfall event and would drain from full to half full in 16.83 hrs, well within the 24 hours permitted by CIRIA C753 (2015) regulations.

Exceedance capacity, in terms of both storage and increased infiltration potential, is provided by the additional material used to form the access way and parking.

Figure 20 Indicative surface water management plan



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 need to manage storms of a significantly greater magnitude than those considered in this report. It is possible that the soakaways could surcharge during a rainstorm of greater magnitude than 1:100 year+CC allowances. To mitigate the risk of any surcharged flow from the soakaways affecting the site, it is recommended that surcharged flow should be directed west, away from the proposed development into the adjacent field.

Structures which manage surface water runoff require little maintenance, however a regular maintenance schedule, on a monthly basis and after heavy rainfall, should be established by the site owner to reduce the risk of blockage within the drainage system e.g. by leaves or plastic bags and ensure the systems remain in good working order.

As discussed in Section 2b, the site is protected from flood defences, however there remains the residual risk that the flood defences could be overtopped, or may become inadequate if not properly maintained and upgraded. This worst-case scenario has been mapped within the SEL SFRA (SELJPU, 2017) and the impacts of which have been considered within this report. Management strategies e.g. finished floor level of 2.5 mAOD, have been recommended and if adopted would help reduce the flood risk posed to the proposed development during this residual risk flood event.

8b How, and by whom, will these risks be managed over the lifetime of the development?

- 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 soakaway and associated structures would be with the property owner.

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Author	Date	Title/Description
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Centre for Ecology and Hydrology	2017	The Flood Estimation Handbook Web Service. Available from: https://fehweb.ceh.ac.uk/ Accessed 22 nd May 2017
CIRIA	2015	CIRIA Report c753: The SuDS Manual v3. Available from: http://www.ciria.org/Memberships/The_SuDs_Manual_C_753_Chapters.aspx Accessed 2 nd June 2017
Cranfield University	2017	Soilscapes Map. Available at: http://www.landis.org.uk/soilscapes/ Access date: 22 nd May 2017
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DCLG	Mar 2012(b)	Technical Guidance to the National Planning Policy Framework.
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South Holland District Council	Jul 2006	South Holland Local Plan Available from: http://localplan.sholland.gov.uk/ Accessed: 7 th June 2017

Appendix A Surface Water Management Plan

This section describes a surface water management plan, designed to ensure that the proposed agricultural workers dwelling would not lead to an increase in flood risk elsewhere. As shown in Section 4, a total of 110 m² (0.00011 km²) of impermeable surfaces are proposed on site, runoff from which must be managed. Current surface water management practices at the site (attenuation basin) indicate that runoff the site would need to be managed using attenuation, as soils are shown to be 'loamy and clayey' (Figure 12), therefore indicating that the soils are not ideal to manage runoff using infiltration. A surface water management plan designed around runoff attenuation is therefore considered first.

A.1. Greenfield runoff rates

The estimation of peak rates of pre-development runoff (i.e. Greenfield runoff) has previously used the IH 124⁷ (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, associated with the site (GR 523750 316750) and generated by the FEH web service. In order to achieve the "plot-scale" adjustments required to generate an accurate greenfield runoff rate for the site, the AREA descriptor for the catchment was changed from approximately 41.2 km² to 0.5 km², in order to calibrate several routing and base flow parameters. The AREA descriptor was then changed to 0.001 km² (1,000 m², the closest value to the proposed impermeable areas on site allowed by ReFH2). The BFIHOST value was also changed from 0.722 to 0.45 to better represent the impede site drainage, as shown by the FEH catchment descriptors listed in Table 3. These adjustments enabled the generation of greenfield runoff hydrographs in l/s for the site. These greenfield runoff rates were then multiplied by 0.11 to generate greenfield runoff rates for the 110 m² of site (Table A-1).

The peak Greenfield runoff rates for the 1:2, 1:30 and 1:100 year rainfall events, determined using ReFH2 are shown in Table A-1. The peak Greenfield rates in l/s for the 110 m² of impermeable area are shown in column 3. Values have been adjusted from the 1,000 m² Greenfield runoff rates (column 2).

Table A-1 Greenfield runoff rates

Return period	Greenfield runoff rate (l/s)	
	1,000 m ² impermeable surface area	110 m ² impermeable surface area
1:2 year	0.27	0.03
1:30 year	0.66	0.07
1:100 year	0.97	0.11

⁷ IH124: Institute of Hydrology Report No. 124 Flood Estimation for Small Catchments, June 1994

The greenfield runoff rates associated with the 110 m² of impermeable site area are extremely low (Table A-1). In order to meet the requirement that runoff rates from the developed site should be at or below greenfield rates (CIRIA C753, 2015), the outflow control of the attenuation structure would need to be extremely small. An outflow control of this size would be unacceptable due to the high risk of blockage, it is therefore concluded that runoff from the site cannot be managed using attenuation. It is therefore proposed that runoff from the dwelling could be managed using infiltration.

A.2. Infiltration rates

In the absence of a soil infiltration test, an indicative value was obtained from the CIRIA C753 SuDS Manual (2015, Pg. 546) (Table A-2). The indicative value was determined by consulting the soil type, which is shown in Figure 12 to be 'loamy and clayey soils of coastal flats with naturally high groundwater'. An infiltration coefficient of 5×10^{-6} m/s (0.018 m/hr), corresponding to a 'loam', 'Very silty clayey SAND' has been used within the soakaway calculations.

Table A-2 Typical infiltration coefficients based on soil texture - taken from CIRIA C753 SuDS Manual (2015, pg. 546).

Soil type/texture	ISO 14688-1 description (after Blake, 2010)	Typical infiltration coefficients (m/s)
Good infiltration media - gravel - sand - loamy sand - sandy loam	Sandy GRAVEL Slightly silty slightly clayey SAND Silty slightly clayey SAND Silty clayey SAND	$3 \times 10^{-4} - 3 \times 10^{-2}$ $1 \times 10^{-5} - 5 \times 10^{-5}$ $1 \times 10^{-4} - 3 \times 10^{-5}$ $1 \times 10^{-7} - 1 \times 10^{-5}$
Poor infiltration media - loam - silt loam - chalk (structureless) - sandy clay loam	Very silty clayey SAND Very sandy clayey SILT N/A Very clayey silty SAND	$1 \times 10^{-7} - 5 \times 10^{-6}$ $1 \times 10^{-7} - 1 \times 10^{-5}$ $3 \times 10^{-8} - 3 \times 10^{-6}$ $3 \times 10^{-10} - 3 \times 10^{-7}$
Very poor infiltration media - silty clay loam - clay - till	– – Can be any texture of soil described above	$1 \times 10^{-8} - 1 \times 10^{-6}$ $< 3 \times 10^{-8}$ $3 \times 10^{-9} - 3 \times 10^{-6}$
Other rock* (note mass infiltration capacity will depend on the type of rock and the extent and nature of discontinuities and any infill)	N/A	$3 \times 10^{-9} - 3 \times 10^{-5}$

A.3. Outline soakaway design

MicroDrainage has been used to design a soakaway, to manage runoff from the impermeable surfaces on site (0.011 ha). The following assumptions have been used as part of this calculation:

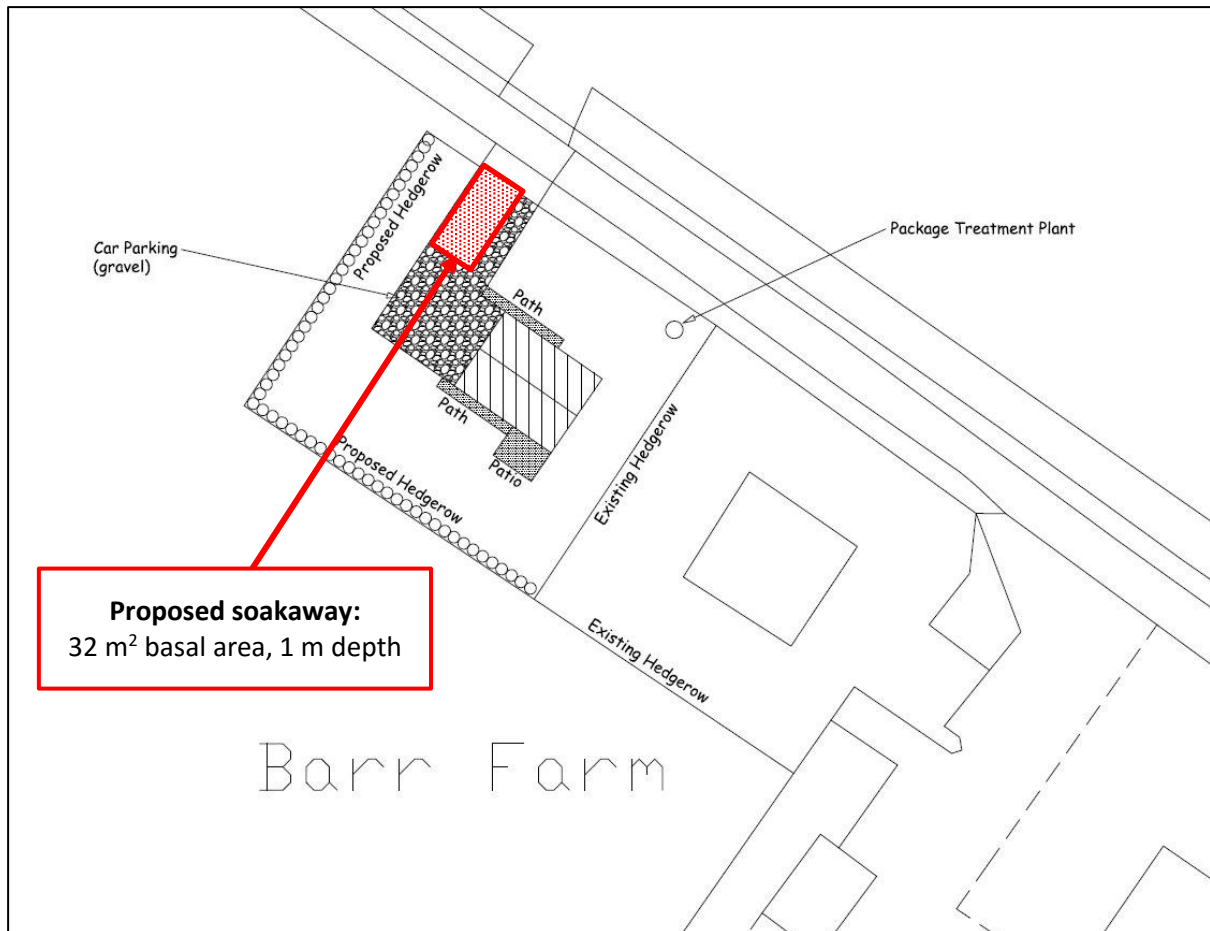
1. The total impermeable area (Table 7) has been rounded up to 110 m² (0.011 ha);
2. It will take 0 minutes for all of the impermeable surface's runoff to reach the soakaway;
3. A soil infiltration rate of 0.018 m/hr is representative of soils at the site;
4. The soakaway has been designed with vertical sides;
5. It has been assumed that infiltration would occur via the base and sides of the attenuation tank at a rate of 0.018 m/hr;
6. The soakaway would be filled with 30% porosity granular material e.g. scalpings or gravel;
7. The soakaway would be dug to a depth of 1 m below ground level;
8. A safety factor of 3 has been used, as recommended by CIRIA C753 (2015, Pg.553), when the consequences of exceedance would cause "Minor damage to external areas or inconvenience (e.g. surface water on car parking)" (CIRIA C753, Pg.553);
9. Design rainfall totals were derived from the Flood Estimation Handbook (web-service), catchment GR: 523750 316750, for the 1:100 year rainstorm with 40% climate change allowance, in line with Environment Agency and NPPF guidance;
10. The soakaway would be located at least 5 m away from any buildings.

Results showed that a soakaway with a basal area of 32 m² (e.g. 8 m x 4 m) and depth of 1 m, filled with 30% porosity granular material e.g. scalpings or gravel with no fines, would be capable of managing runoff from the 110 m² of impermeable surfaces during the 1:100 year+40%CC rainfall event (Table A-3). The soakaway was shown to reach a maximum depth of 0.971 m during this event and drained from full to half full in 16.83 hrs, well within the 24 hours permitted by CIRIA C753 (2015) regulations. It is suggested that the soakaway is located beneath the proposed gravel driveway (Figure A-1). As this section of the proposed development is likely to be made ground, it is recommended that the walls of the soakaway are reinforced by a structurally strong permeable material e.g. permeable bricks, as this will prevent the collapse of the soakaway.

Table A-3 Indicative soakaway design – results from 1:100 year+40%CC rainfall event

Impermeable Surface Area (m ²)	Soakaway dimensions	Max Depth (m)	Time to drain from full to half full (hrs)
110	Basal Area: 32 m ² Cover Area: 32 m ² Depth: 1 m	0.971	16.83

Figure A-1 Indicative surface water management plan



Appendix B MicroDrainage Results

Hydro Logic Services

Page 1

The Corner House 18-20 West End Road Mortimer RG7 3TF	K0776 Spalding Deeping Farm Soakaway - 110 m2 impermeable	
Date 02/06/2017 File K0776_Spalding_Deeping_F...	Designed by BHE Checked by CN	
Micro Drainage		

Source Control 2017.1

Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 1010 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
15 min Summer	0.000	0.000	0.0	0.0	O K
30 min Summer	0.000	0.000	0.0	0.0	O K
60 min Summer	0.484	0.484	0.1	4.6	O K
120 min Summer	0.625	0.625	0.1	6.0	O K
180 min Summer	0.710	0.710	0.1	6.8	Flood Risk
240 min Summer	0.765	0.765	0.1	7.3	Flood Risk
360 min Summer	0.823	0.823	0.1	7.9	Flood Risk
480 min Summer	0.843	0.843	0.1	8.1	Flood Risk
600 min Summer	0.843	0.843	0.1	8.1	Flood Risk
720 min Summer	0.833	0.833	0.1	8.0	Flood Risk
960 min Summer	0.802	0.802	0.1	7.7	Flood Risk
1440 min Summer	0.736	0.736	0.1	7.1	Flood Risk
2160 min Summer	0.650	0.650	0.1	6.2	O K
2880 min Summer	0.578	0.578	0.1	5.5	O K
4320 min Summer	0.460	0.460	0.1	4.4	O K
5760 min Summer	0.367	0.367	0.1	3.5	O K
7200 min Summer	0.000	0.000	0.0	0.0	O K
8640 min Summer	0.000	0.000	0.0	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	-5.600	0.0	0
30 min Summer	-2.800	0.0	0
60 min Summer	58.758	0.0	62
120 min Summer	38.934	0.0	122
180 min Summer	30.193	0.0	182
240 min Summer	24.955	0.0	242
360 min Summer	18.706	0.0	360
480 min Summer	15.034	0.0	480
600 min Summer	12.594	0.0	600
720 min Summer	10.851	0.0	714
960 min Summer	8.511	0.0	810
1440 min Summer	5.976	0.0	1052
2160 min Summer	4.156	0.0	1452
2880 min Summer	3.203	0.0	1872
4320 min Summer	2.212	0.0	2676
5760 min Summer	1.702	0.0	3456
7200 min Summer	-0.012	0.0	0
8640 min Summer	-0.010	0.0	0

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Hydro Logic Services				Page 2	
The Corner House 18-20 West End Road Mortimer RG7 3TF		K0776 Spalding Deeping Farm Soakaway - 110 m2 impermeable			
Date 02/06/2017 File K0776_Spalding_Deeping_F...		Designed by BHE Checked by CN			
Micro Drainage		Source Control 2017.1			
<u>Summary of Results for 100 year Return Period (+40%)</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
10080 min Summer	0.000	0.000	0.0	0.0	O K
15 min Winter	0.000	0.000	0.0	0.0	O K
30 min Winter	0.000	0.000	0.0	0.0	O K
60 min Winter	0.544	0.544	0.1	5.2	O K
120 min Winter	0.705	0.705	0.1	6.8	Flood Risk
180 min Winter	0.803	0.803	0.1	7.7	Flood Risk
240 min Winter	0.867	0.867	0.1	8.3	Flood Risk
360 min Winter	0.937	0.937	0.1	9.0	Flood Risk
480 min Winter	0.965	0.965	0.1	9.3	Flood Risk
600 min Winter	0.971	0.971	0.1	9.3	Flood Risk
720 min Winter	0.965	0.965	0.1	9.3	Flood Risk
960 min Winter	0.932	0.932	0.1	8.9	Flood Risk
1440 min Winter	0.853	0.853	0.1	8.2	Flood Risk
2160 min Winter	0.743	0.743	0.1	7.1	Flood Risk
2880 min Winter	0.645	0.645	0.1	6.2	O K
4320 min Winter	0.482	0.482	0.1	4.6	O K
5760 min Winter	0.353	0.353	0.1	3.4	O K
7200 min Winter	0.000	0.000	0.0	0.0	O K
8640 min Winter	0.000	0.000	0.0	0.0	O K
Storm Event	Rain (mm/hr)		Flooded Volume (m³)	Time-Peak (mins)	
10080 min Summer	-0.008		0.0	0	
15 min Winter	-5.600		0.0	0	
30 min Winter	-2.800		0.0	0	
60 min Winter	58.758		0.0	62	
120 min Winter	38.934		0.0	120	
180 min Winter	30.193		0.0	178	
240 min Winter	24.955		0.0	238	
360 min Winter	18.706		0.0	354	
480 min Winter	15.034		0.0	468	
600 min Winter	12.594		0.0	582	
720 min Winter	10.851		0.0	692	
960 min Winter	8.511		0.0	902	
1440 min Winter	5.976		0.0	1122	
2160 min Winter	4.156		0.0	1576	
2880 min Winter	3.203		0.0	2020	
4320 min Winter	2.212		0.0	2856	
5760 min Winter	1.702		0.0	3640	
7200 min Winter	-0.012		0.0	0	
8640 min Winter	-0.010		0.0	0	
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Hydro Logic Services		Page 3																				
The Corner House 18-20 West End Road Mortimer RG7 3TF	K0776 Spalding Deeping Farm Soakaway - 110 m2 impermeable																					
Date 02/06/2017 File K0776_Spalding_Deeping_F...	Designed by BHE Checked by CN																					
Micro Drainage		Source Control 2017.1																				
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Date 02/06/2017 File K0776_Spalding_Deeping_F...	Designed by BHE Checked by CN									
Micro Drainage		Source Control 2017.1								
<u>Model Details</u> Storage is Online Cover Level (m) 1.000 <u>Infiltration Basin Structure</u> Invert Level (m) 0.000 Safety Factor 3.0 Infiltration Coefficient Base (m/hr) 0.01800 Porosity 0.30 Infiltration Coefficient Side (m/hr) 0.01800 <table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Depth (m)</th> <th>Area (m²)</th> <th>Depth (m)</th> <th>Area (m²)</th> </tr> </thead> <tbody> <tr> <td>0.000</td> <td>32.0</td> <td>1.000</td> <td>32.0</td> </tr> </tbody> </table>			Depth (m)	Area (m ²)	Depth (m)	Area (m ²)	0.000	32.0	1.000	32.0
Depth (m)	Area (m ²)	Depth (m)	Area (m ²)							
0.000	32.0	1.000	32.0							
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Appendix C British Geological Survey Borehole Log



**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

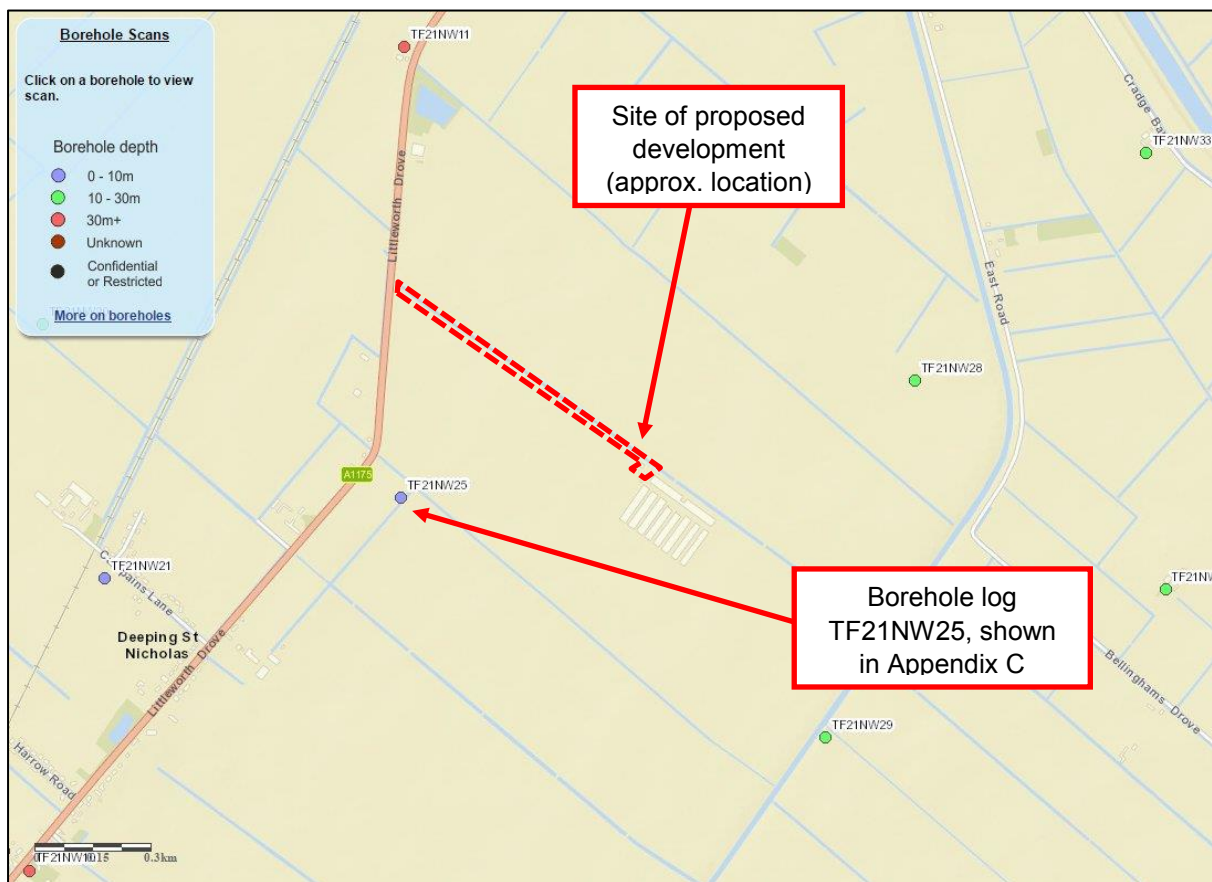
BGS ID: 473449 : BGS Reference: TF21NW25

British National Grid (27700) : 522310,316800

[Report an issue with this borehole](#)

<< < Prev Page 1 of 3 Next > >>

Figure C-1 Nearby borehole data to site



TF 21 NW 25

2231 1680

Near Church Farm, Deeping St Nicholas

British Geological Survey

Block F

Surface level +1.49 m (+5.0 ft)
 Water struck at -4.91 m and -5.21 m
 152 mm percussion
 October 1979

Waste 10.0 m
 Bedrock 0.5 m +

LOG

Geological classification British Geological Survey	Lithology British Geological Survey	Thickness m British Geological Survey	Depth m British Geological Survey
	Soil, firm to stiff, silty, clayey loam, with many root traces	1.1	1.1
Barroway Drove Beds (Buttery Clay)	Clay, firm to soft, thixotropic in parts, glutinous below 1.2 m, highly mottled brown with orange often associated with root traces; below 1.2 m becomes predominantly dark grey with many soft black, carbonaceous woody fragments, with peaty intercalations (especially between 3.0 and 3.5 m) and pockets of ?reed material often with a 'rank' smell; rare nodules of brown siltstone	c 3.9	c 5.0
Lower Peat	Peat, friable, dark brown to grey, organic matter with ? <i>Birch</i> bark fragments	c 1.0	c 6.0
River Terrace Deposits (Crowland Bed)	Clay to sandy clay, firm to soft, glutinous, ?layered, grey mottled with khaki brown; with much fine to medium, subrounded to rounded quartz sand and traces of gravel below 6.4 m; calcareous throughout	c 0.7	c 6.7
(First Terrace)	Sandy gravel, with traces of ?indigenous shell fragments Gravel: fine with some coarse; mostly subrounded to rounded oolitic and shelly limestone with angular to subangular brown and white flint; with some ironstone; with traces of indurated chalk and sandstone; with some well-worn belemnite guards, ammonite fragments and traces of ?indigenous cardiate lamellibranchs; rare greenish crystalline ?igneous clasts Sand: medium and coarse with fine; mainly subrounded oolitic limestone with ironstone with some flint and quartz; below 2 mm fraction mostly subrounded to rounded quartz with ironstone and white shell fragments Fines: slightly silty brown to greyish brown	1.0	7.7
Boulder Clay	Clay, firm to stiff, khaki-brown in upper part becoming greyish brown, with abundant chalk clasts and flint with sandstone gravel; rare pockets of orange-brown silty sand	2.3	10.0
Oxford Clay	Clay, stiff to indurated, grey, many sand-grade selenite crystals giving a 'gritty' texture, calcareous, with traces of shell fragments including belemnites and rare ammonites and crinoids	0.5 +	10.5

GRADING

Mean for deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand	Gravel				
				- 1/6	+ 1/6 - 1/4	+ 1/4 - 1/2	+ 1/2 - 1	+ 1 - 4	+ 4 - 16	+ 16 - 64 - 64 mm
3	62	35	6.7 - 7.7	3	6	34	22	32	3	0

(37)

Institute of Geological Sciences

Industrial Minerals Assessment Unit

British Geological Survey

British Geological Survey

BOREHOLE RECORD SHEET

Registration Number

6 in. quarter sheet

Accn. no.

Suffix

TF 21 NW

125

6

10

14

Temp. No. TF 21 NW L 2231 1680

Borehole diam. 6 in. O.A.

Water struck at 6.4 and 6.7m Standing level 1.6m

Remarks: Started: Thus 18th Oct 1979 11.40
 Finished: Thus 18th Oct 1979 16.40

NB 1. Thin shelled white fragments in gravel.

Classification	Thick- ness (m)	Lithology
Overburden	6.4	
Mudstone	1.0	
Gravel	2.3	
Bedrock	0.5+	

Lithostrat. Code	Description	Thick (m)	Depth to base (m)	Sample
TPS	Firm to stiff, silty, clayey in parts, loam, with many root traces	1.1	1.1	
FES/ BDB	'Buttery Clay' Firm to soft in upper 0.1m, highly mottled - predominantly brown with much orange coloration in vicinity of root traces giving 'rusty' appearance. Becomes predominantly gray to dark grey below 1.2m with many black carbonaceous woody fragments giving black streak to the clay, soft, glutinous, with occasional ? seed rooty patches with associated root shell 'Beard's Muck', with peaty pockets at depth, in parts thixotropic, (with x 10 hand lens - very fine silt / fine sand grains in some patches) With peaty intercalations between 3.4 - 3.5m. Rare nodules of fine brown silt / siltstone at 3.5m (Special ① at 3.5m)	3.9	5.0	
FBT	Dark brown to grey, friable, with a green plant / root material Almost complete section of ? Birch bark - the first of rooty tissue	1.1	6.1	(54-)

Lithostrat. Code	Description	Thick ⁿ (m)	Depth to base (m)	Sam
FES/ BDB 7C1	<u>Buttery Clay</u> - as above. Becomes progressively sandy	Φ 4	6.4	
RTD.	<u>Sandy clay</u> Predominantly pale grey, firm to soft, glutinous, somewhat mottled by khaki-brown, becomes layered pale grey with pale khaki-brown; with much fine to medium SR/R quartz sand and traces of fine to coarse gravel. White calcareous.	Φ 3	6.7	(Spe 6.4)
	<u>Pebbly Sand</u>	1-Φ	7.7	(SR 6.7)
	<u>Gravel</u> : Fine to coarse mainly fine in the +4-16mm range. Mostly SR/R oolitic and shelly limestone with A/SA brown and white flints. Ironstone rare above 8.0mm sieve but common in +4-8mm with occasional bonstones. With occasional well-worn derived Oxc frags. in bellerophonites and ammonites. Traces of worm tubes and white thin-shelled lamellibranchs. Rare greenish crystalline ? igneous fragments. Rare SR indurated chert. Traces of SR sandstone.			(Specimen 3A)
	<u>Sand</u> : Fine to coarse, mainly medium to coarse. In -4+2mm range mainly SR oolites with khaki ^{SR irregular} ironstone, SA/A flint chips and SR quartzite. Below 2mm predominantly SR/R quartz with ironstone, some sands and flint chips. White shell frags common especially below 2mm.			
	<u>Matrix</u> : Brown to greyish-brown, silty.			
CBC	<u>CLAY</u> Slightly weathered upper surface, khaki-brown, firm with chalk clasts. Becomes stiff, greyish-brown, with many clasts of SR/R chert with some flint and sandstone gravel. Rare pocket of khaki/orange-brown silty sand.	2.3	1Φ.Φ	(Specimen 4)
Oxc	<u>CLAY</u> Grey, stiff to indurated, full of selenite crystals giving a 'gritty' texture, rare shell fragments - bellerophonites. ? rarely flat whorled ammonites? Ramorbia, ? also pentamerids. Calcareous.	Φ 5+	10.5	(Specimen 5)



Offices at

Offices at

Bromyard

Exeter

Reading

Sheffield

Stirling

Registered office

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