

Flood Risk Assessment



Site:
Barns at Risegate House Farm, Hedgefield Hurn, Gosberton, Spalding PE11 4JE

Applicant:
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Introduction

Origin Design Studio Ltd have been appointed by Mr D Charlton to prepare a Flood Risk Assessment to accompany a planning application to South Holland District Council for a residential development.

The site is contained within a Flood Zone 3 and this is the basis upon which a Flood Risk Assessment is required. The approach to flood risk is set out in the National Planning Policy Framework (NPPF), refer to Appendix A with more local planning policy set out in the South East Lincolnshire Local Plan (SELLP), refer to Appendix B. This Flood Risk Assessment assesses the site in accordance with the policy requirements of the NPPF and the SELLP.

The Site

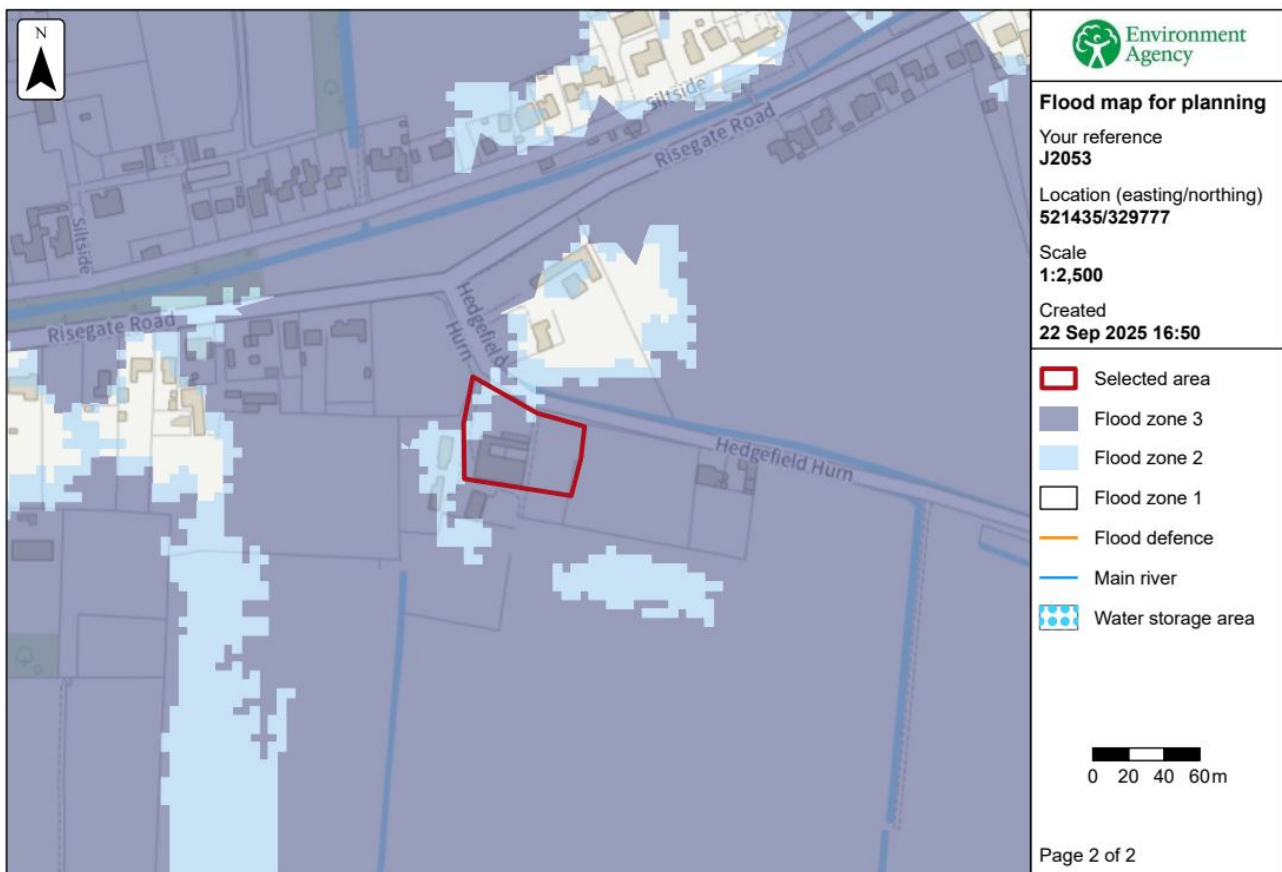
The site is located to the south of Hedgefield Hurn to the south of Hubbert's Bridge. The site has a number of agricultural buildings on it. These include a traditional range, potentially 18th Century and more modern 20th Century buildings. The site is adjoined on the western side of the farm access track by an existing bungalow. To the east and south of the site are agricultural fields. The proposed development is for the conversion of the existing agricultural dwellings to form 1No. dwelling and the creation of a new build single storey dwelling.

Findings

Risk of Flooding from River and Seas

Flood Zone

The site is contained mainly within a Flood Zone 3 with parts in a Flood Zone 2. Flood Zone 3 shows the area at risk of flooding for an undefended flood event with: a 1% or greater probability of flooding from rivers or 0.5% or greater probability of flooding from the sea.



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Figure 1 - Flood zone map (the site is marked with a red line).

Historic Flooding

The Environment Agency do not have any information about historical flooding on the site, refer to Appendix E.

Sequential & Exception Test

The proposed development is residential and will result in 2No. dwellings. This includes one from the conversion of the existing agricultural buildings and one new build. Therefore, flood risk is considered on this basis.

Developments need a sequential test when the development is in flood zone 2 or 3 and a sequential test hasn't already been done for a development of the type planned on the proposed site.

The purpose of the sequential test is to direct development to land of lower flood risk. The sequential test compares the proposed development site with other available sites to find out which has the lowest flood risk.

The residential use is classified as "more vulnerable" in accordance with Table 2 – Flood Risk Vulnerability Classification.

| Flood Zones | Flood Risk Vulnerability Classification | | | | |
|-------------|---|-------------------------|-------------------------|-----------------|------------------|
| | Essential infrastructure | Highly vulnerable | More vulnerable | Less vulnerable | Water compatible |
| Zone 1 | ✓ | ✓ | ✓ | ✓ | ✓ |
| Zone 2 | ✓ | Exception Test required | ✓ | ✓ | ✓ |
| Zone 3a † | Exception Test required † | X | Exception Test required | ✓ | ✓ |
| Zone 3b * | Exception Test required * | X | X | X | ✓* |

Key:

✓ Development is appropriate

X Development should not be permitted.

Figure 2 - Table 3 – Flood Risk Vulnerability and Flood Zone Compatibility (www.gov.uk)

In accordance with Table 3 where a site is located in a Flood Zone 3 with a vulnerability classification of “more vulnerable” development is considered to be compatible providing the exception test is satisfied. Therefore, the development will need to pass both a sequential test and exception test.

In this case one of the plots of the proposed development is for a ‘Change of Use’, accordingly it will pass both the Sequential and Exception Test.

On the other hand, the new build dwelling does not automatically pass the Sequential and Exception Test. However, in this case a ‘fallback’ for the conversion of the existing modern agricultural building exists and accordingly it is considered the proposed scheme would be at worse equal to that proposed. At best it is considered the new build offers an opportunity to improve the mitigation and flood resilience of the dwelling given the ability to choose the materials used in construction of the dwelling. As such it is considered to pass the sequential and exception test.

Site Levels

A topographical survey has been undertaken to inform the design for the proposed development, refer to Appendix C. The site is generally flat. The lowest levels on the site are located centrally on the site between the single storey traditional building and the modern portal frame shed at around +2.35mAOD with the highest levels located closer to the road where the land ramps up to join Hedgefield Hurn at around +3.41mAOD. The road, Hedgefield Hurn to the north of the site, is shown to be around +3.35mAOD. The existing floor levels of the buildings vary at +3.02mAOD up to +3.14mAOD. The average ground level around the perimeter of the buildings is around +3.0mAOD.

Calculating the Flood Level

Where possible all habitable floors should be above the flood level. Where the accommodation is proposed to be two storeys the 1 in 100/200-year flood level plus climate change will be used to ensure habitable floors are above the flood level. In the case where a single storey building is proposed habitable floors should be above the 1 in 1000-year flood level plus climate change. In both cases a safe point of refuge can be established and therefore provide protection to the inhabitants of the building.

In this case it is proposed to create a 1No. two-storey dwelling and 1No. one storey dwellings. To determine the flood level the fluvial and tidal sources will be looked at to determine the worst case and an appropriate floor level.

Tidal Flood Sources

The site is not at risk from tidal sources of flooding.

Fluvial Flood Sources

The site is at risk of fluvial flooding from main rivers. The main risk to the site is the River Glen approximately 3.5km to the southeast of the site at its nearest point.

The site is protected by fluvial flood defences from the River Glen. These include earth embankments. They are in a fair condition and reduce the risk of flooding (at the defence) to a 1% (1 in 100) chance of occurring in any year.

Data from the Environment Agency includes in channel data for the River Glen in the Welland Glen Model, refer to Appendix D. It does not contain Hazard mapping for modelled breaches or overtopping which may affect the site.

A simplistic breach model using the in-channel levels of the River Glen offer a basic way to establish a 1:100-year flood level including climate change for the site. The worst-case levels for the River Glen local to the site are from node 4901 & 4825.07. A topographical survey profiling the watercourse has not been undertaken of the River Glen however information available on OS maps suggest the embankment levels are around 3-4m. The simplistic model only considers an oncoming wave depth and assumes the land downstream of the breach to be taken down to 1.7m. The breach of the River Glen is discussed in this section. It also assumes the defences have been raised to meet the calculated in-channel level, thus creating a larger head for the purposes of calculating the flood depth on site.

Global warming is now recognised that it is likely to affect the frequency and severity of extreme events such as both tidal and fluvial flooding. The climate change allowances in the NPPF Guidance were updated on the 19th February 2016 and again on 17th December 2019. The site lies within the Welland Management Catchment and allowances for climate change should be made on the following basis. For a worst-case scenario, the site shall be considered to be in a Flood Zone 3a and the use classification is 'more vulnerable' therefore Peak River flows use the higher central and upper end to assess a range of allowances.

The adjustments for peak flows can be seen in the table below. Under guidance of the Planning Practice Guidance for developments that are 'more vulnerable' in a flood zone 3 the central allowance shall be used for design. It will be tested for sensitivity using the upper allowance.

| River basin district | Allowance category | Total potential change anticipated for the '2020s' (2015 to 2039) | Total potential change anticipated for the '2050s' (2040 to 2069) | Total potential change anticipated for the '2080s' (2070 to 2115) |
|----------------------|--------------------|---|---|---|
| Witham | Upper | 22% | 26% | 53% |
| | Higher | 10% | 10% | 28% |
| | Central | 5% | 4% | 17% |

Figure 3 - Table 1 peak river flow allowances by river basin district (use 1961 to 1990 baseline)

A flow discharge curve can be established using the increase in flow to calculate and establish in-channel levels of the River Glen for the additional climate change scenarios.

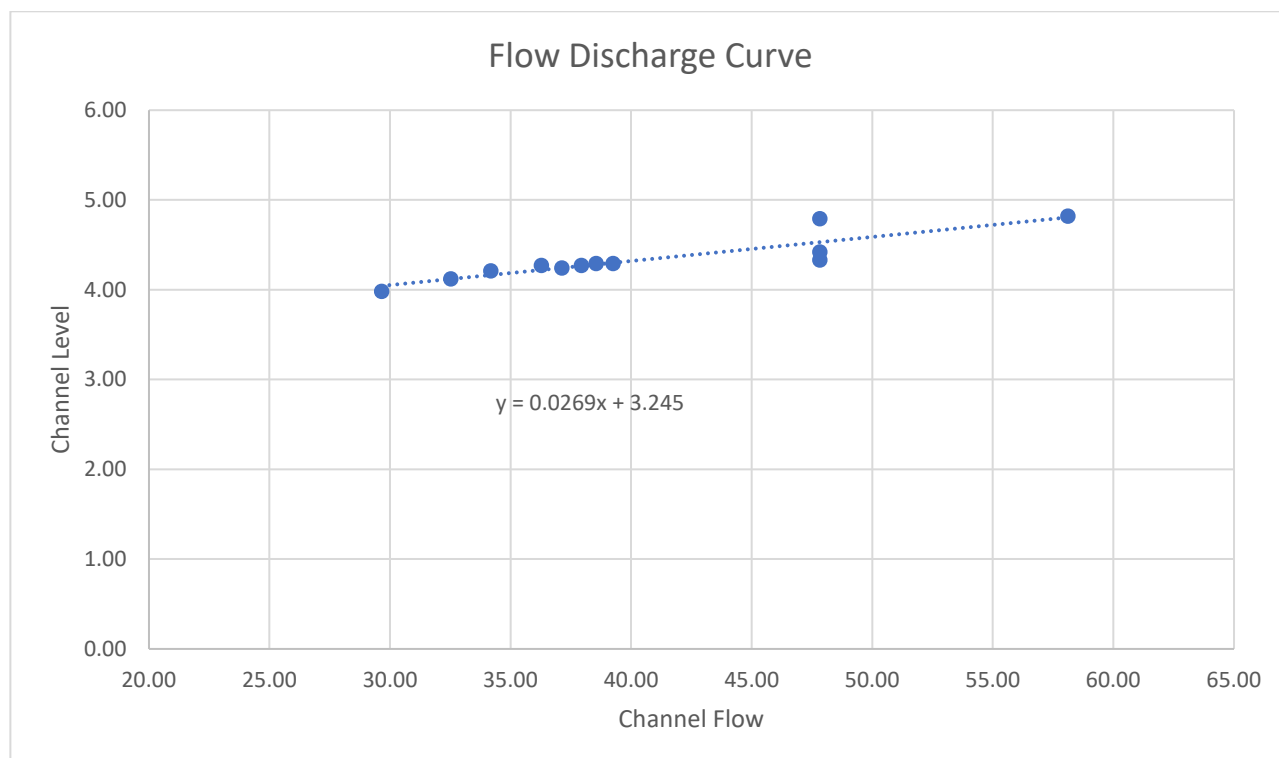


Figure 4 - Flow discharge curve for River Glen nodes 4901 & 4825.07

| Event & Climate Change (%) | Flow (m³) | Level (m) |
|----------------------------|-----------|-----------|
| 1% +53%CC | 61.98 | 4.85 |
| 0.1% +53%CC | 75.05 | 5.26 |

Figure 5 - Calculated Levels for Climate Change for nodes 4901 & 4825.07

The climate change levels for the central allowance i.e. 17% are lower than the 20% increase allowed for in the EA model. Therefore, the central allowance will use the 20% value for both the 1% and 0.1% for design purposes. The climate change levels for the 53% scenarios using a growth curve result in a higher levels than the 1 in 100 year plus 20% for climate change. Consequently, the in-channel level for the 53% climate change breach analysis will use the levels in Figure 5 above, and test the resulting design.

A breach analysis using data for nodes 4901 & 4825.07 is contained in Appendix D. The 1:100-year and 1:1000-year level including 17% climate change for the buildings are +0.115m and +0.116m above ground level respectively. These will be the design events for the proposed dwellings.

The 1:100-year and 1:1000-year level including 53% climate change for the buildings are +0.117m and +0.135m above ground level respectively. These levels will be used to test the flood resilience of the proposed dwellings.

Given the significant distance between the fluvial source and the site and the simplistic nature of the calculation it is considered the breach scenario is a worst case and flood routing may not result in the site being flooded to the extent indicated by simple breach calculation.

Drainage Board Flood Sources

The site is located in an area of an Internal Drainage Board (IDB). In this case Welland & Deepings IDB who maintain drains near to the site. The nearest board-maintained drain is the Risegate Eau, located approximately 125m to the north of the site and the site lies in the catchment area of the Risegate Eau. Data from the IDB indicates that the level of the Risegate Eau for the 1:100-year level would be +1.79m. No further information about more extreme events i.e. 1 in 1000 year including climate change scenarios are held by the IDB.

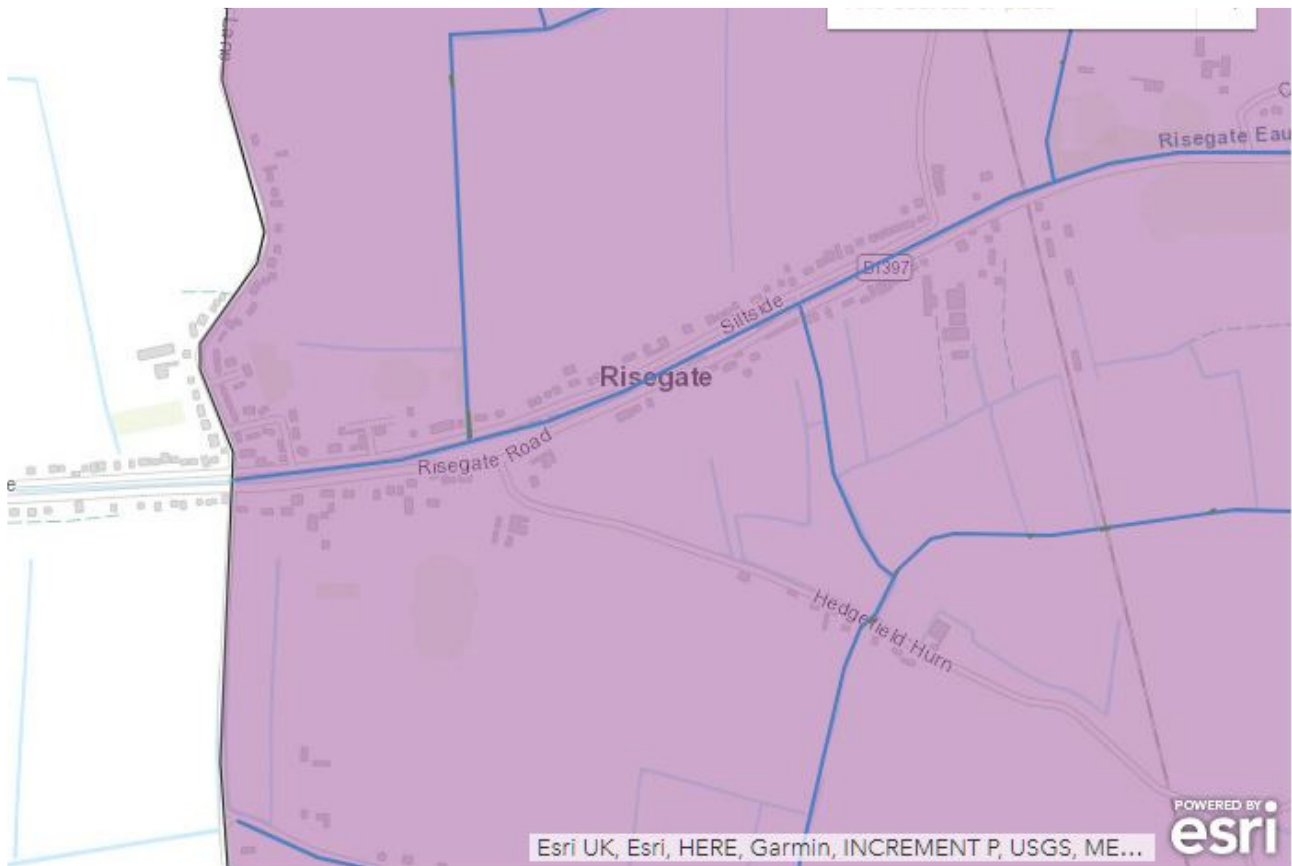


Figure 6 - Map of Welland & Deepings Drains

Risk of Flooding from Surface Water

The risk of flooding from surface water is very low in the area of the buildings with a small area of low-risk flooding immediately south of the buildings, according to the surface water flood map shown in Figure 7.

The maps for surface water define the risk as High, Medium, Low and Very Low. The chance of flooding for the area defined in any given year is shown below:

- High: greater than 1 in 30 (3.3%).
- Medium: between 1 in 100 (1%) and 1 in 30 (3.3%).
- Low: between 1 in 1000 (0.1%) and 1 in 100 (1%).
- Very Low: less than 1 in 1000 (0.1%)

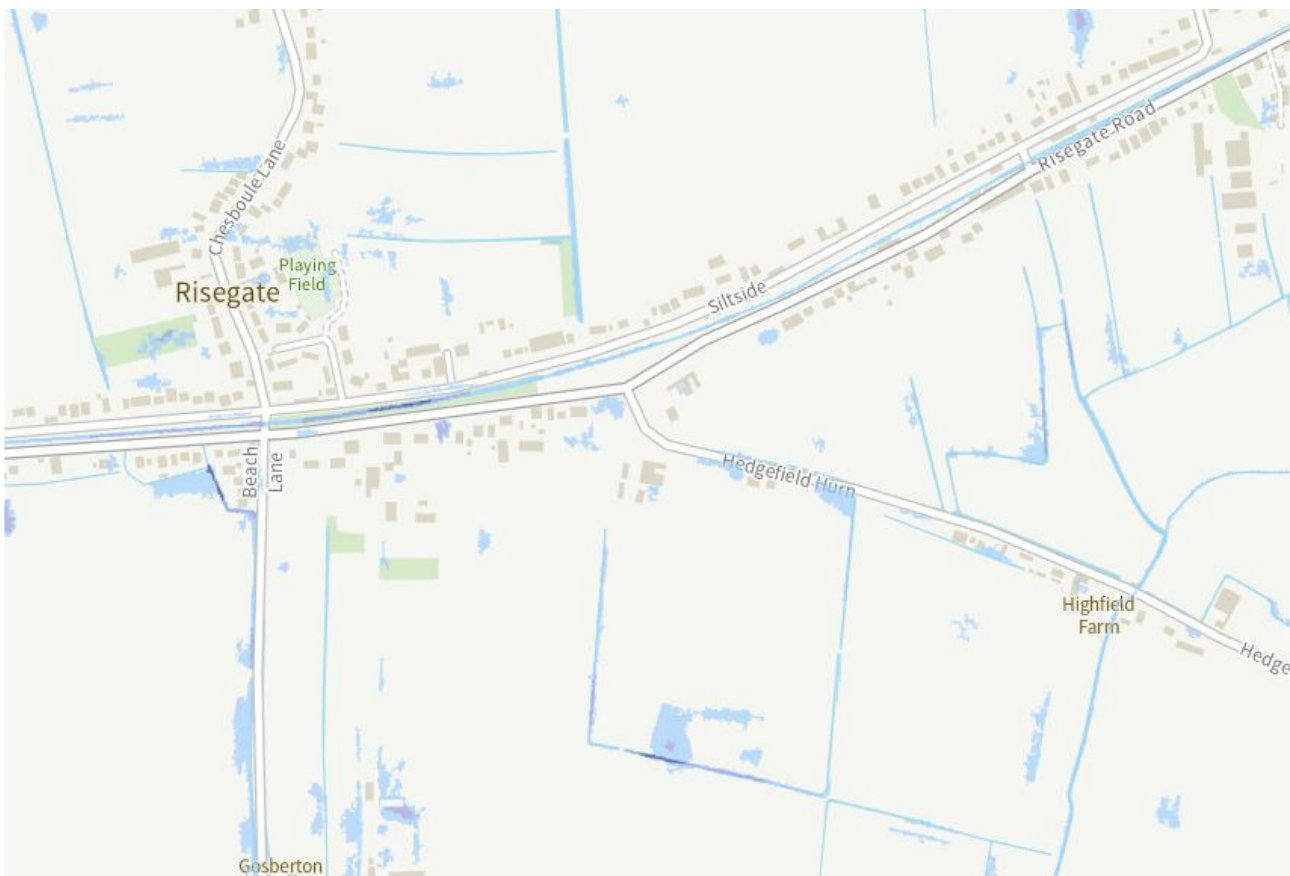


Figure 7 - Surface Water Flood Map (www.gov.uk)

Unlike the fluvial mapping, which is based on a detailed hydraulic model, this mapping is based purely on applying rainfall to a digital terrain model. As such this mapping serves to represent a worst-case scenario which may well overstate the actual probability of flooding in this area.

There is a caveat on the Defra Data website, as to the use of these maps and that they are not to be used to identify that an individual property will flood. Because of the way they have been produced and the fact that they are indicative, these maps are not appropriate to act as the sole evidence for any specific planning or regulatory decision or assessment of risk in relation to flooding at any scale without further supporting studies or evidence.

The Environment Agency and the Lead Local Flood Authority (custodians of the surface water flood risk dataset) have subsequently confirmed that the published high-level data should not be used on a site-specific basis and that mapping is only suitable for National to County Scale use.

Risk of Flooding from Reservoirs

There is no risk of flooding from reservoirs when there is flooding from rivers. The following map shows this on the Environment Agency's Risk of Flooding from Reservoirs map:



Figure 8 - Reservoir Flood Map (www.gov.uk)

The source of reservoir flooding is not clear by observing maps. However, the nearest reservoir is located near Tumby Woodside some 15km to the north. Given the site does not flood when river levels are normal it is considered that the flooding will be worse from fluvial and tidal flooding sources identified above. The mitigation measures considered for these will provide sufficient protection against flooding from reservoirs.

Risk of Flooding from Sewers

There are no known public surface water and foul water sewers that currently exist on the site that are known to suffer from sewer surcharging. All new infrastructures to service the dwelling shall be appropriately designed to the relevant standards to ensure failures do not present a problem.

Safe Access & Egress

The proposed ground floor level will be above the predicted worse case flood level and provide a safe refuge. The road to the front of the site may remain passable allowing for safe passage along Harrison's Drove away from the site.

Setting the floor level

Standing advice requires finished floor levels (FFL) should be a minimum of whichever is higher of 300mm above the:

- Average ground level of the site
- Adjacent road level to the building
- Estimated river or sea flood level

In this case it is proposed that the minimum FFL should be set at a minimum of +0.3m above the existing ground level which provides sufficient freeboard for both the predicted 1 in 100-year flood level plus 17% climate change for the site (+0.115m) and 1 in 1000-year flood level plus 17% climate change for the site (+0.116m).

Based on an average ground level of 3.0mAOD the floor should be set at +3.3mAOD for all buildings.

Conclusion

The proposed development is for 1No. two-storey dwelling and 1No single storey dwellings. The site is contained mainly within a Flood Zone 3.

The site is not at risk from tidal flooding but is at risk from fluvial flooding. The site is protected by adequate tidal and fluvial flood defences which are maintained by the Environment Agency. A residual risk to breaching of these defences exist and this has the potential to impact the site.

The residential use falls within "more vulnerable" uses of land in Table 2 Flood Risk Vulnerability Classification and Table 3 shows that developments of this nature are appropriate in flood zone 3 subject to passing the Sequential and Exception Test.

In this case the proposed scheme is for a change of use and a new build dwelling and there is a 'fallback' that exists to construct 3 dwellings. Therefore it is considered to pass the Sequential and Exception Test.

The predicted fluvial flood depth for the design event (1 in 100-year plus climate change) for the site is +0.115 above existing ground level. The predicted fluvial flood depth for the design event (1 in 1000-year plus climate change) for the site is +0.116 above existing ground level. Therefore, minimum floor level of +3.3mAOD is to be used for all dwellings. Flood resilient construction to a height 300mm above the predicted flood depth shall also be installed.

At the detailed design stage of the development advice contained in "Improving the Flood Performance of New Buildings - Flood Resilient Construction" should be followed.

Further to this the property will register to Floodline to receive advance warning of potential flooding.

New foul and surface water drains will be designed to the relevant standards.

Appendices

Appendix A – National Planning Policy Framework

PLANNING AND FLOOD RISK

170. Inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk (whether existing or future). Where development is necessary in such areas, the development should be made safe for its lifetime without increasing flood risk elsewhere.
171. Strategic policies should be informed by a strategic flood risk assessment, and should manage flood risk from all sources. They should consider cumulative impacts in, or affecting, local areas susceptible to flooding, and take account of advice from the Environment Agency and other relevant flood risk management authorities, such as lead local flood authorities and internal drainage boards.
172. All plans should apply a sequential, risk-based approach to the location of development—taking into account the current and future impacts of climate change – so as to avoid, where possible, flood risk to people and property. They should do this, and manage any residual risk, by:
- a) applying the sequential test and then, if necessary, the exception test as set out below;
 - b) safeguarding land from development that is required, or likely to be required, for current or future flood management;
 - c) using opportunities provided by new development to reduce the causes and impacts of flooding (where appropriate through the use of natural flood management techniques); and
 - d) where climate change is expected to increase flood risk so that some existing development may not be sustainable in the long-term, seeking opportunities to relocate development, including housing, to more sustainable locations.
173. A sequential risk-based approach should also be taken to individual applications in areas known to be at risk now or in future from any form of flooding, by following the steps set out below.
174. Within this context the aim of the sequential test is to steer new development to areas with the lowest risk of flooding from any source. Development should not be allocated or permitted if there are reasonably available sites appropriate for the proposed development in areas with a lower risk of flooding. The strategic flood risk assessment will provide the basis for applying this test.
175. The sequential test should be used in areas known to be at risk now or in the future from any form of flooding, except in situations where a site-specific flood risk assessment demonstrates that no built development within the site boundary, including access or escape routes, land raising or other potentially vulnerable elements, would be located on an area that would be at

risk of flooding from any source, now and in the future (having regard to potential changes in flood risk).

176. Applications for some minor development and changes of use⁶² should also not be subject to the sequential test, nor the exception test set out below, but should still meet the requirements for site-specific flood risk assessments set out in footnote 63.
177. Having applied the sequential test, if it is not possible for development to be located in areas with a lower risk of flooding (taking into account wider sustainable development objectives), the exception test may have to be applied. The need for the exception test will depend on the potential vulnerability of the site and of the development proposed, in line with the Flood Risk Vulnerability Classification set out in Annex 3.
178. The application of the exception test should be informed by a strategic or site-specific flood risk assessment, depending on whether it is being applied during plan production or at the application stage. For the exception test to be passed it should be demonstrated that:
- a) the development would provide wider sustainability benefits to the community that outweigh the flood risk; and
 - b) 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.
179. Both elements of the exception test should be satisfied for development to be allocated or permitted.
180. Where planning applications come forward on sites allocated in the development plan through the sequential test, applicants need not apply the sequential test again. However, the exception test may need to be reapplied if relevant aspects of the proposal had not been considered when the test was applied at the plan-making stage, or if more recent information about existing or potential flood risk should be taken into account.
181. When determining any planning applications, local planning authorities should ensure that flood risk is not increased elsewhere. Where appropriate, applications should be supported by a site-specific flood-risk assessment⁶³. Development should only be allowed in areas at risk of flooding where, in the light of this assessment (and the sequential and exception tests, as applicable) it can be demonstrated that:
- a) within the site, the most vulnerable development is located in areas of lowest flood risk, unless there are overriding reasons to prefer a different location;

⁶² This includes householder development, small non-residential extensions (with a footprint of less than 250m²) and changes of use; except for changes of use to a caravan, camping or chalet site, or to a mobile home or park home site, where the sequential and exception tests should be applied as appropriate.

⁶³ A site-specific flood risk assessment should be provided for all development in Flood Zones 2 and 3. In Flood Zone 1, an assessment should accompany all proposals involving: sites of 1 hectare or more; land which has been identified by the Environment Agency as having critical drainage problems; land identified in a strategic flood risk assessment as being at increased flood risk in future; or land that may be subject to other sources of flooding, where its development would introduce a more vulnerable use.

- b) the development is appropriately flood resistant and resilient such that, in the event of a flood, it could be quickly brought back into use without significant refurbishment;
- c) it incorporates sustainable drainage systems, unless there is clear evidence that this would be inappropriate;
- d) any residual risk can be safely managed; and
- e) safe access and escape routes are included where appropriate, as part of an agreed emergency plan.

182. Applications which could affect drainage on or around the site should incorporate sustainable drainage systems to control flow rates and reduce volumes of runoff, and which are proportionate to the nature and scale of the proposal. These should provide multifunctional benefits wherever possible, through facilitating improvements in water quality and biodiversity, as well as benefits for amenity. Sustainable drainage systems provided as part of proposals for major development should:

- a) take account of advice from the lead local flood authority;
- b) have appropriate proposed minimum operational standards; and
- c) have maintenance arrangements in place to ensure an acceptable standard of operation for the lifetime of the development;

Appendix B – South East Lincolnshire Local Plan

POLICY 4: APPROACH TO FLOOD RISK

Development proposed within an area at risk of flooding (Flood Zones 2 and 3 of the Environment Agency's flood map or at risk during a breach or overtopping scenario as shown on the flood hazard and depths maps in the Strategic Flood Risk Assessment) will be permitted, where:

1. It can be demonstrated that there are no other sites available at a lower risk of flooding (i.e. that the sequential test is passed). The sequential test will be based on a Borough or District wide search area of alternative sites within the defined settlement boundaries, unless local circumstances relating to the catchment area for the development justify a reduced search area, i.e. there is a specific need for the development in that location. The sequential test is not required for sites allocated in the Local Plan, minor development¹ or change of use (except for a change of use to a caravan, camping or chalet site, or to a mobile home or park home site).
2. It can be demonstrated that essential infrastructure in FZ3a & FZ3b, highly vulnerable development in FZ2 and more vulnerable development in FZ3 provide wider sustainability benefits to the community that outweigh flood risk.
3. The application is supported with a site-specific flood risk assessment, covering risk from all sources of flooding including the impacts of climate change and which:
 - a) demonstrate that the vulnerability of the proposed use is compatible with the flood zone;
 - b) identify the relevant predicted flood risk (breach/overtopping) level, and mitigation measures that demonstrate how the development will be made safe and that occupants will be protected from flooding from any source;
 - c) propose appropriate flood resistance and resilience measures (following the guidance outlined in the Strategic Flood Risk Assessment), maximising the use of passive resistance measures (measures that do not require human intervention to be deployed), to ensure the development maintains an appropriate level of safety for its lifetime;
 - d) include appropriate flood warning and evacuation procedures where necessary (referring to the County's evacuation routes plan), which have been undertaken in consultation with the authority's emergency planning staff;
 - e) incorporates the use of Sustainable Drainage Systems (SuDS) (unless it is demonstrated that this is not technically feasible) and confirms how these will be maintained/managed for the lifetime of development (surface water connections to the public sewerage network will only be permitted in exceptional circumstances where it is demonstrated that there are no feasible alternatives);
 - f) demonstrates that the proposal will not increase risk elsewhere and that opportunities through layout, form of development and green infrastructure have been considered as a way of providing flood betterment and reducing flood risk overall;
 - g) demonstrates that adequate foul water treatment and disposal already exists or can be provided in time to serve the development;
 - h) ensures suitable access is safeguarded for the maintenance of water resources, drainage and flood risk management infrastructure.

Development in all flood zones, and development over 1 hectare in size in Flood Zone 1, will need to demonstrate that surface water from the development can be managed and will not increase the risk of flooding to third parties.

Change of use of existing buildings will be supported providing they do not pose an increase in risk to people. Change of use that would result in self-contained ground floor residential accommodation in areas of hazard rating 'danger for some', 'danger for most' and 'danger for all' will not be supported. In these areas unrestricted access to a habitable room above the flood level and an emergency evacuation plan will be required.

Caravans, mobile homes and park homes intended for permanent residential use will not be permitted in areas at risk of flooding. Caravan, chalet, log cabin, camping and touring sites at risk of fluvial flooding where there is a 'danger for most' and 'danger for all' will not be permitted. Occupancy of caravan, chalet, log cabin, camping and touring sites at risk of tidal flooding will not be permitted to open between 1st November in any one year and the 14th March in the succeeding year.

No development will be permitted within a 50m buffer from the toe of the raised Witham Haven Banks (flood defences), as shown on the indicative Plan contained in Appendix 10, to allow access for construction and maintenance.

Flood risk management infrastructure shall be provided at the strategic level, where development opportunities allow, to reduce the hazard and probability of flooding.

Appendix C – Topographical Survey

Appendix D – Breach Analysis

River Glen - 1:100-year event + 17% Climate Change

| | | |
|--|-------|--------------------------------|
| Defence Crest Levels (h1) | 4.79 | m |
| Average Ground Level behind defences (h2) | 2 | m |
| 1 in 100 year flood level plus climate change (h3) | 4.79 | m |
| Assumed length of breach (B) | 40 | m |
| Max head over breach (h) | 2.79 | m |
| Peak flow (Q) = $1.7 \times B \times h^{3/2}$ | 316.9 | m ³ s ⁻¹ |

| | | |
|-------------------------------|-------|--------------------------------|
| Peak flow (Q) | 316.9 | m ³ s ⁻¹ |
| Assuming Energy Grad (S) | 0.001 | - |
| Assume % obstructions to flow | 0 | - |
| Assuming mannings (n) | 0.03 | - |

| | Scenario | | | | | |
|--|----------|-------|-------|-------|---------|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Distance from breach | 0 | 1000 | 2000 | 3000 | 3500 | 4000 |
| Perimeter of Flood Wave (Assumed Channel Width) | 40 | 3182 | 6324 | 9466 | 11037.0 | 12608 |
| Effective perimeter (P) | 40 | 3182 | 6324 | 9466 | 11037.0 | 12608 |
| Normal Depth $y = ((Qn)/(b \times S^{0.5}))^{0.6}$ | 3.354 | 0.243 | 0.161 | 0.126 | 0.115 | 0.106 |

Time to Reach Development

| | | | | | | |
|--|-------|--------|--------|---------|---------|---------|
| Distance from breach above plus 1.0m | 1 | 1001 | 2001 | 3001 | 3501 | 4001 |
| Perimeter of Flood Wave (Assumed Channel Width) | 43.1 | 3185.1 | 6327.1 | 9469.1 | 11040.1 | 12611.1 |
| Normal Depth $y = (Qn/(b \times S^{0.5}))^{0.6}$ | 3.205 | 0.243 | 0.161 | 0.126 | 0.115 | 0.106 |
| Volume in Additional 1.0m | 138.3 | 772.8 | 1017.0 | 1194.9 | 1270.6 | 1340.1 |
| Speed to cover additional 1.0m (m/s) | 2.29 | 0.41 | 0.31 | 0.27 | 0.25 | 0.24 |
| Average time to reach radius (secs) | - | 2197.0 | 5779.4 | 10184.5 | 12633.7 | 15227.2 |
| Average time to reach radius (mins) | - | 36.6 | 96.3 | 169.7 | 210.6 | 253.8 |

River Glen - 1:100-year event + 53% Climate Change

| | | |
|--|-------|--------------------------------|
| Defence Crest Levels (h1) | 4.85 | m |
| Average Ground Level behind defences (h2) | 2 | m |
| 1 in 100 year flood level plus climate change (h3) | 4.85 | m |
| Assumed length of breach (B) | 40 | m |
| Max head over breach (h) | 2.85 | m |
| Peak flow (Q) = $1.7 \times B \times h^{3/2}$ | 327.2 | m ³ s ⁻¹ |

| | | |
|-------------------------------|-------|--------------------------------|
| Peak flow (Q) | 327.2 | m ³ s ⁻¹ |
| Assuming Energy Grad (S) | 0.001 | - |
| Assume % obstructions to flow | 0 | - |
| Assuming mannings (n) | 0.03 | - |

| | Scenario | | | | | |
|--|----------|-------|-------|-------|---------|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Distance from breach | 0 | 1000 | 2000 | 3000 | 3500 | 4000 |
| Perimeter of Flood Wave (Assumed Channel Width) | 40 | 3182 | 6324 | 9466 | 11037.0 | 12608 |
| Effective perimeter (P) | 40 | 3182 | 6324 | 9466 | 11037.0 | 12608 |
| Normal Depth $y = ((Qn/(b \times S^{0.50}))^{0.6}$ | 3.419 | 0.247 | 0.164 | 0.129 | 0.117 | 0.108 |

Time to Reach Development

| | | | | | | |
|---|-------|--------|--------|---------|---------|---------|
| Distance from breach above plus 1.0m | 1 | 1001 | 2001 | 3001 | 3501 | 4001 |
| Perimeter of Flood Wave (Assumed Channel Width) | 43.1 | 3185.1 | 6327.1 | 9469.1 | 11040.1 | 12611.1 |
| Normal Depth $y = (Qn/(bxS^{0.5}))^{0.6}$ | 3.267 | 0.247 | 0.164 | 0.129 | 0.117 | 0.108 |
| Volume in Additional 1.0m | 141.0 | 787.8 | 1036.6 | 1218.0 | 1295.2 | 1366.0 |
| Speed to cover additional 1.0m (m/s) | 2.32 | 0.42 | 0.32 | 0.27 | 0.25 | 0.24 |
| Average time to reach radius (secs) | - | 2169.2 | 5706.0 | 10055.3 | 12473.5 | 15034.0 |
| Average time to reach radius (mins) | - | 36.2 | 95.1 | 167.6 | 207.9 | 250.6 |

River Glen - 1:1000-year event + 17% Climate Change

| | | |
|---|-------|--------------------------------|
| Defence Crest Levels (h1) | 4.82 | m |
| Average Ground Level behind defences (h2) | 2 | m |
| 1 in 1000 year flood level plus climate change (h3) | 4.82 | m |
| Assumed length of breach (B) | 40 | m |
| Max head over breach (h) | 2.82 | m |
| Peak flow (Q) = $1.7 \times B \times h^{3/2}$ | 322.0 | m ³ s ⁻¹ |

| | | |
|-------------------------------|-------|--------------------------------|
| Peak flow (Q) | 322.0 | m ³ s ⁻¹ |
| Assuming Energy Grad (S) | 0.001 | - |
| Assume % obstructions to flow | 0 | - |
| Assuming mannings (n) | 0.03 | - |

| | Scenario | | | | | |
|--|----------|-------|-------|-------|---------|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Distance from breach | 0 | 1000 | 2000 | 3000 | 3500 | 4000 |
| Perimeter of Flood Wave (Assumed Channel Width) | 40 | 3182 | 6324 | 9466 | 11037.0 | 12608 |
| Effective perimeter (P) | 40 | 3182 | 6324 | 9466 | 11037.0 | 12608 |
| Normal Depth $y = ((Qn/(b \times S^{0.50}))^{0.6}$ | 3.387 | 0.245 | 0.162 | 0.127 | 0.116 | 0.107 |

Time to Reach Development

| | | | | | | |
|---|-------|--------|--------|---------|---------|---------|
| Distance from breach above plus 1.0m | 1 | 1001 | 2001 | 3001 | 3501 | 4001 |
| Perimeter of Flood Wave (Assumed Channel Width) | 43.1 | 3185.1 | 6327.1 | 9469.1 | 11040.1 | 12611.1 |
| Normal Depth $y = (Qn/(bxS^{0.5}))^{0.6}$ | 3.236 | 0.245 | 0.162 | 0.127 | 0.116 | 0.107 |
| Volume in Additional 1.0m | 139.6 | 780.3 | 1026.8 | 1206.5 | 1282.9 | 1353.0 |
| Speed to cover additional 1.0m (m/s) | 2.31 | 0.41 | 0.31 | 0.27 | 0.25 | 0.24 |
| Average time to reach radius (secs) | - | 2183.0 | 5742.4 | 10119.3 | 12552.9 | 15129.8 |
| Average time to reach radius (mins) | - | 36.4 | 95.7 | 168.7 | 209.2 | 252.2 |

River Glen - 1:1000-year event + 53% Climate Change

| | | |
|---|-------|--------------------------------|
| Defence Crest Levels (h1) | 5.33 | m |
| Average Ground Level behind defences (h2) | 2 | m |
| 1 in 1000 year flood level plus climate change (h3) | 5.33 | m |
| Assumed length of breach (B) | 40 | m |
| Max head over breach (h) | 3.33 | m |
| Peak flow (Q) = $1.7 \times B \times h^{3/2}$ | 413.2 | m ³ s ⁻¹ |

| | | |
|-------------------------------|-------|--------------------------------|
| Peak flow (Q) | 413.2 | m ³ s ⁻¹ |
| Assuming Energy Grad (S) | 0.001 | - |
| Assume % obstructions to flow | 0 | - |
| Assuming mannings (n) | 0.03 | - |

| | Scenario | | | | | |
|--|----------|-------|-------|-------|---------|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Distance from breach | 0 | 1000 | 2000 | 3000 | 3500 | 4000 |
| Perimeter of Flood Wave (Assumed Channel Width) | 40 | 3182 | 6324 | 9466 | 11037.0 | 12608 |
| Effective perimeter (P) | 40 | 3182 | 6324 | 9466 | 11037.0 | 12608 |
| Normal Depth $y = ((Qn/(b \times S^{0.50}))^{0.6}$ | 3.933 | 0.285 | 0.189 | 0.148 | 0.135 | 0.125 |

Time to Reach Development

| | | | | | | |
|--|-------|--------|--------|--------|---------|---------|
| Distance from breach above plus 1.0m | 1 | 1001 | 2001 | 3001 | 3501 | 4001 |
| Perimeter of Flood Wave (Assumed Channel Width) | 43.1 | 3185.1 | 6327.1 | 9469.1 | 11040.1 | 12611.1 |
| Normal Depth $y = (Qn/(b \times S^{0.5}))^{0.6}$ | 3.759 | 0.285 | 0.188 | 0.148 | 0.135 | 0.125 |
| Volume in Additional 1.0m | 162.2 | 906.2 | 1192.5 | 1401.2 | 1489.9 | 1571.4 |
| Speed to cover additional 1.0m (m/s) | 2.55 | 0.46 | 0.35 | 0.29 | 0.28 | 0.26 |
| Average time to reach radius (secs) | - | 1975.7 | 5197.3 | 9158.7 | 11361.3 | 13693.5 |
| Average time to reach radius (mins) | - | 32.9 | 86.6 | 152.6 | 189.4 | 228.2 |

Appendix E – Environment Agency Flood Data