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Flood Risk and Drainage Briefing Note

Land at Shortstown, Bedford

Date: 10th June 2020

Client Name: Gallagher Developments Group Ltd

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This document has been prepared and checked in accordance with
Waterman Group's IMS (BS EN ISO 9001: 2015, BS EN ISO 14001: 2015 and BS EN ISO 45001:2018)

Issue	Prepared by	Checked & Approved by
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1. Introduction

1.1. Waterman Infrastructure and Environment have been instructed to undertake a Flood Risk Assessment (FRA) and preliminary drainage strategy to support the Local Plan submission for the 'Land at Shortstown' development near Bedford (hereafter referred to as 'the Site'). The Site is located in Bedford Borough, and within the statutory district of the Bedfordshire and River Ivel Internal Drainage Board (IDB).

1.2. This Briefing Note has been produced to outline the flood risk constraints relevant to the Site, and to produce a preliminary surface and foul water drainage strategy to feed into and inform the development masterplan. It is important that spatial constraints such as indicative floodplains and Sustainable Drainage Systems (SuDS) are incorporated into the scheme proposal during early stages of the design, to ensure that the scheme is robust moving forwards.

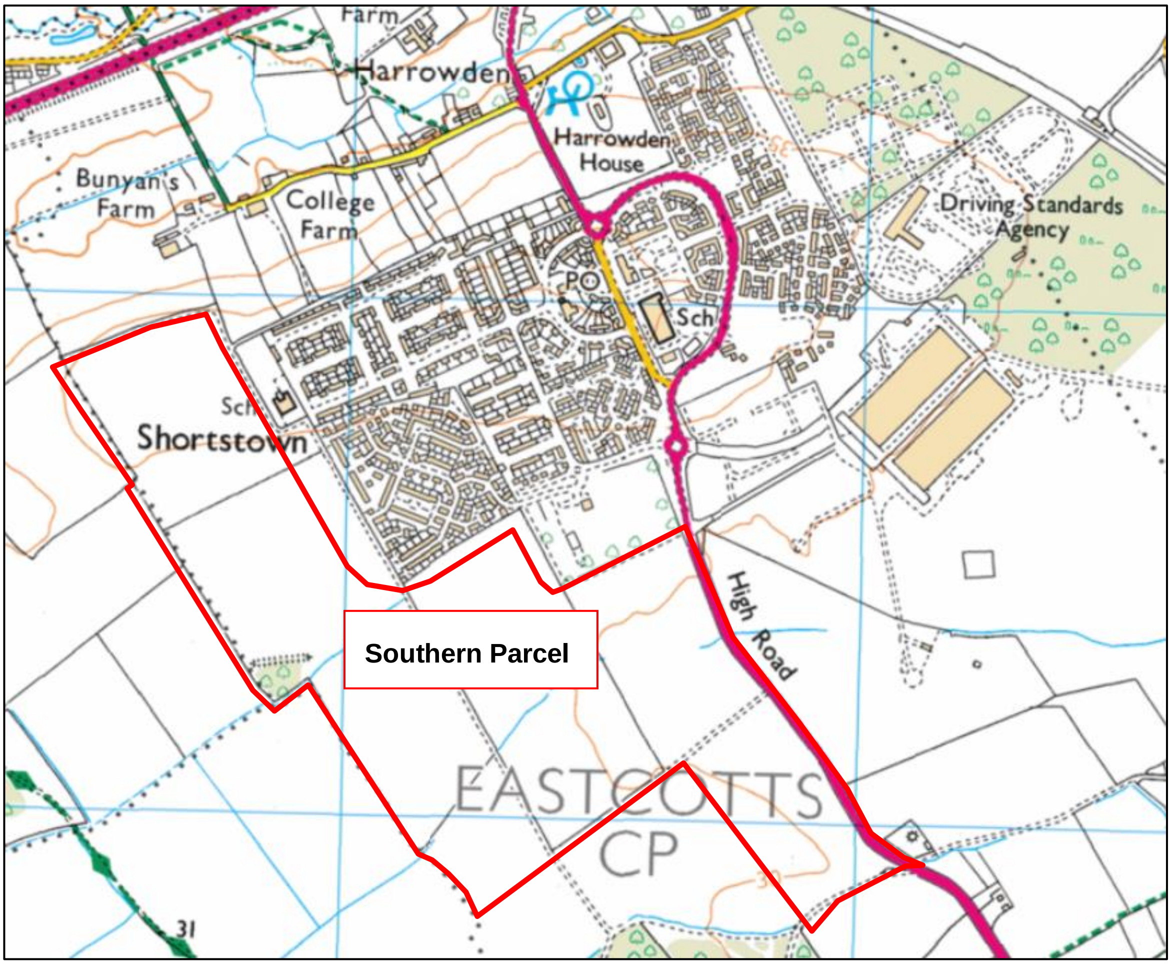
1.3. The drainage strategy outlined in this note is indicative only, based on the current masterplan concept plan. As the masterplan develops, the drainage strategy would be amended accordingly to suit.

1.4. Subsequent to the issue of this Briefing Note, Waterman Infrastructure and Environment were commissioned to undertake an exploratory modelling exercise to investigate potential options to reduce the flood extent to the north of the Cople Brook and therefore to increase the net developable area. This modelling exercise is discussed in Section 4 of this Note.

Existing Site

1.5. The Site (Figure 1 overleaf) comprises 74.83 ha and currently comprises agricultural land across two main land parcels. The Site is bounded to the east and north by Shortstown and High Road, and to the west and south by agricultural land. Cople Brook (a tributary to the River Great Ouse) and other smaller ditches cross through the parcel.

Figure 1: Site Location Plan



Key

Site Location

Source: https://www.bing.com

1.6. The topographic survey (Appendix A) indicates that the the north of the southern parcel falls northwards (from 40.0m AOD to 36.4m AOD) and southwards (from 40.0m AOD to 32.7m AOD). The rest of the Site is generally flat, with gentle slopes towards the drainage ditches located at the field boundaries, with levels generally between 30.0 and 31.0m AOD.

Proposed Development

1.7. The proposed College Farm development (Appendix B) would comprise residential units (approximately 21.2 ha) with associated infrastructure, as well as public open space and woodland.

2. Policy

Flood Risk

2.1. The National Planning Policy Framework[i] (NPPF) last revised in February 2019 and its supporting Planning Practice Guidance[ii] (PPG) states that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk (existing or future). Where development is necessary in such areas, the development should be made safe for its lifetime without increasing flood risk elsewhere.

2.2. The Bedford Borough Council Local Flood Risk Management Strategy (LFRMS)[iii] states that within the Borough, the IDBs and the Environment Agency (EA) have byelaws to protect the water corridor and manage flood risk placing restrictions on the corridor adjacent to the watercourse/river channels an flood defences that prevent them from being developed or obstructed. They also protect flood risk by placing restrictions on floodplains.

2.3. The watercourses within and in the vicinity of the Site area are governed by the Bedfordshire and River Ivel IDB. The IDB stated in their consultation response (Appendix C) that any watercourse or land drainage ditch within the Board's area is subject to its byelaws, the most pertinent being:

- No development will be permitted within 9m of a watercourse, measured from the top of bank on both sides of the watercourse

Surface Water Drainage

2.4. The NPPF states that major developments should incorporate SuDS unless there is clear evidence that this would be inappropriate. The systems used should:

- Take account of advice from the Lead Local Flood Authority (LLFA) and IDB where applicable;
- Have appropriate proposed minimum operational standards;
- Have maintenance arrangements in place to ensure an acceptable standard of operation for the lifetime of the development, and
- Where possible, provide multifunctional benefits.

2.5. The Bedford Borough Council LFRMS states that in their aim to provide resilience against climate change, SuDS should be delivered through the planning process, with all major developments managing rainwater and surface water that replicated natural drainage.

2.6. The Bedford Borough Council Supplementary Planning Document (SPD) for SuDS[iv] states that the most preferable options for drainage are discharge into ground (minimum acceptable rate of 1×10^{-5} m/s) and discharge into a surface water body, with the least preferential option being discharge into a surface water sewer.

2.7. Bedford Borough Council as LLFA stated the following requirements (Appendix D) relating to surface water drainage:

- Attenuation should be designed to accommodate flows for the 1 in 100 year event plus a 40% allowance for climate change;
- 10% allowance for urban creep; and
- Discharge rate as agreed by Bedford and River Ivel IDB.

2.8. The Bedfordshire and River Ivel IDB confirmed (Appendix C) that any surface water discharge should be restricted to 4 l/s per contributing impermeable hectare.

2.9. For discharge into the ground, the Bedford Borough Council SPD limits the acceptable depth of infiltrating SuDS to 2.0m below ground level (bgl), with a minimum of 1.2m clearance between the base of the infiltration SuDS and peak seasonal groundwater levels. It further states that at steep sites with permeable superficial deposits and impermeable bedrock, infiltrating SuDS could result in sloping instabilities, requiring a geotechnical investigation to confirm the feasibility.

2.10. Appropriate pollution prevention measures should be incorporated into the design. As per the Bedford Borough Council SPD, clean water from roofs can be directly discharged to any soakaway or watercourse. The SuDS Mitigation Index approach as per the CIRIA SuDS Manual[v] should be used for runoff from all other hardstanding areas.

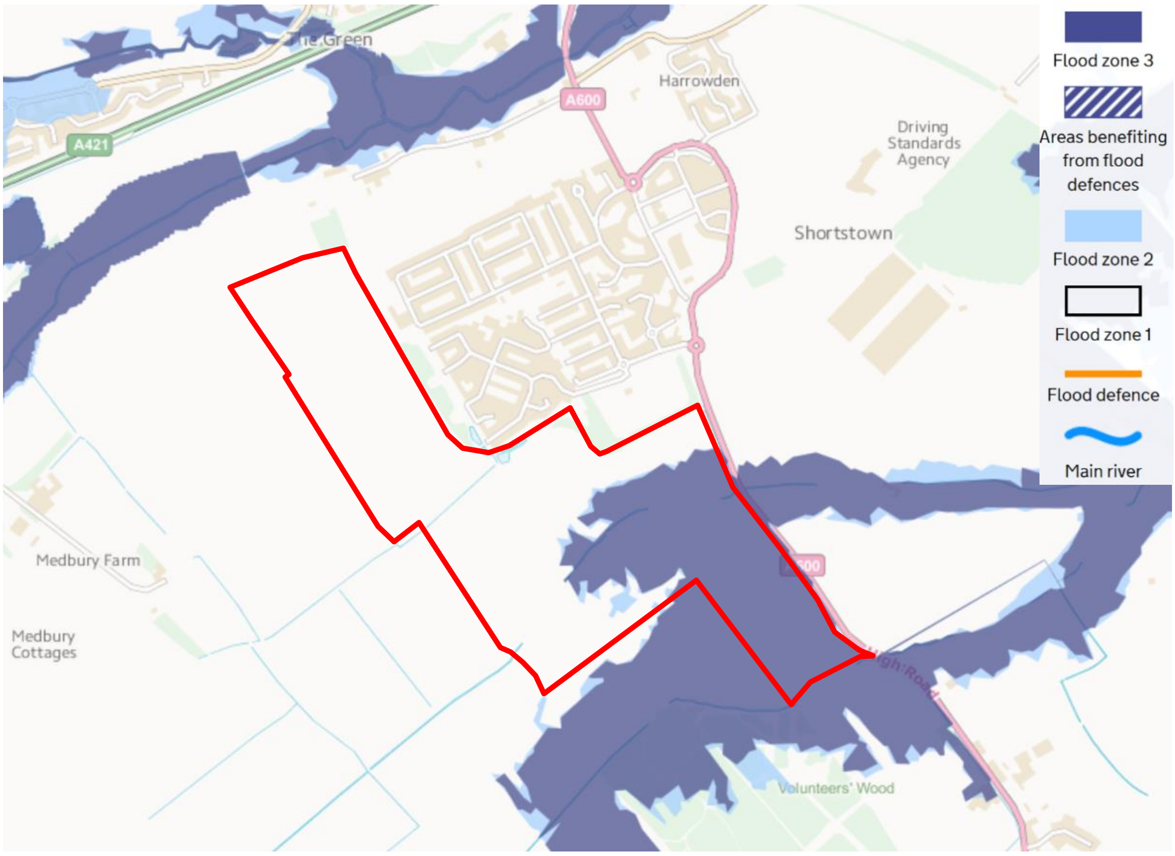
3. Flood Risk

Tidal/Fluvial

3.1. There are no tidal watercourses in the vicinity of the Site, therefore the risk of flooding from tidal sources is negligible.

3.2. The EA Flood Map for Planning (Figure 2) shows that parts of the Site are located in Flood Zones 2 and 3, denoting a medium (between 1% and 0.1% annual probability) and high risk (greater than 1% annual probability) of flooding from rivers.

Figure 2: Environment Agency Flood Map for Planning



Key

Site Location

Source: https://flood-map-for-planning.service.gov.uk

3.3. According to the Bedford Borough Council LFRMS, the primary source of flooding in the Borough is fluvial, from the River Great Ouse, which is denoted a Main River and located approximately 5.2km to the north east of the Site. The Harrowden Brook runs north of the Site and Cople Brook runs through the southern part of the site. Both are tributaries to the River Great Ouse. In addition, there are a number of unnamed watercourses/ditches crossing the Site. The Bedfordshire and River Ivel IDB modelled flood extents of the Harrowden Brook (Appendix C) approximately correspond with the EA outlines, such that confidence in the flood zone extents is relatively high.

3.4. However, the IDB have not modelled the Cople Brook and the other ditches in the south of the site. In addition, the EA have confirmed (Appendix E) that the flood zones associated with the southern watercourses were defined by a TUFLOW 2-D only model. This does not include an explicit representation of river channels. The EA model reports were assessed which showed that the hydrology used to produce the inflows to the hydraulic model for the two watercourses was a proportion of the inflow to a larger catchment and was not specific to the catchments in question.

3.5. A hydraulic model has been prepared for the two southern watercourses to better represent the flood risk at the Site. The baseline model results (Appendix F) show that there is a small area in the centre of the Site located within the 1 in 20 year fluvial floodplain, which is an indication of the functional floodplain. No built development would be proposed in this area. The modelled flood extents in the design 1 in 100 year + 35% climate change scenario are reduced along the eastern Site boundary, freeing up a considerable amount of developable area, however, flood extents have increased in size further westwards along the central watercourse, due to flows being constricted within the culverted section of the watercourse. Any built development or land raising would be avoided within the design fluvial flood extents.

3.6. The existing network of ditches/watercourses within the Site is presented in Appendix I, showing the sections where the ditches are culverted. It is recommended that the culverts are opened up as part of the development proposals. This would increase the capacity of the ditches as well as provide amenity and biodiversity benefits to the wider area. The potential options to improve the existing watercourse and increase the developable area on-site have been explored through an investigative modelling exercise. The results of this exercise are discussed in Section 4.

Pluvial

Overland Surface Water Flow

3.7. As per the EA Flood Risk from Surface Water mapping (Figure 3 overleaf), there are areas of low, medium, and high risk of surface water flooding within the Site.

3.8. The 'low risk' areas within the fields appear to correlate to field lines, which would be re-graded as a result of the development. The proposed surface water drainage strategy would manage any rainwater falling onto the Site, providing the appropriate attenuation to prevent flooding up to the design rainfall event (1 in 100) including for the impacts of climate change. This would prevent ponding as shown within the fields on the EA map in the post-development scenario.

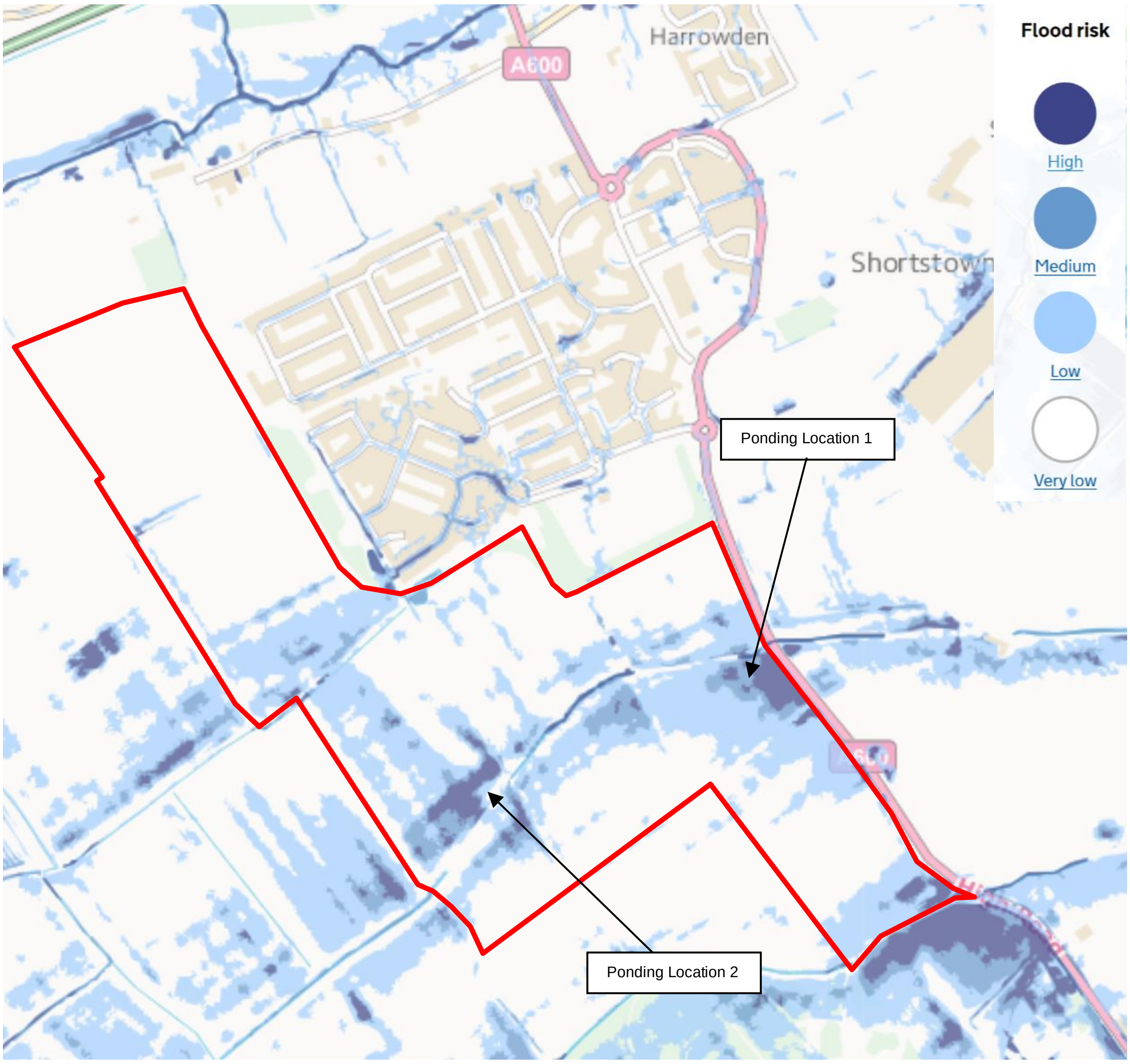
3.9. The area of 'medium' and 'high' risk to the south of the watercourse adjacent to High Road (A600) (ponding location 1 on Figure 3), provides a good indication of the likely fluvial flood extents of the watercourse, once it is modelled. No development is therefore proposed within this area.

3.10. The 'high' risk area near the south western Site boundary (ponding location 2 on Figure 3) is anticipated to be the result of overland flows from the slightly sloping field being unable to enter into the watercourse as it is culverted in this location. Opening up this culvert would increase the watercourse's capacity and allow surface water to enter the watercourse. In addition, this area would be used as a storage area for surface water arising from this catchment in the post-development scenario, mimicking the existing situation. This is further explained in Chapter 3.

3.11. Any watercourse or land drainage ditch within the IDB's area (Appendix C) is subject to its byelaws. As per their requirements, a 9m buffer would be respected either side of the ditches with no development or ground raising proposed. For the purposes of this high-level assessment, a 9m offset has been respected either side of all ditches within the Site, also those falling outside of the Board's area. The requirement for this would be refined as the scheme progresses.

3.12. No potential flood water is therefore displaced off-Site as a result of the development. It is therefore considered that the risk of overland surface water flooding is low.

Figure 3: Environment Agency Surface Water



Key

Site Location

Source: https://flood-warning-information.service.gov.uk

Sewer Flooding

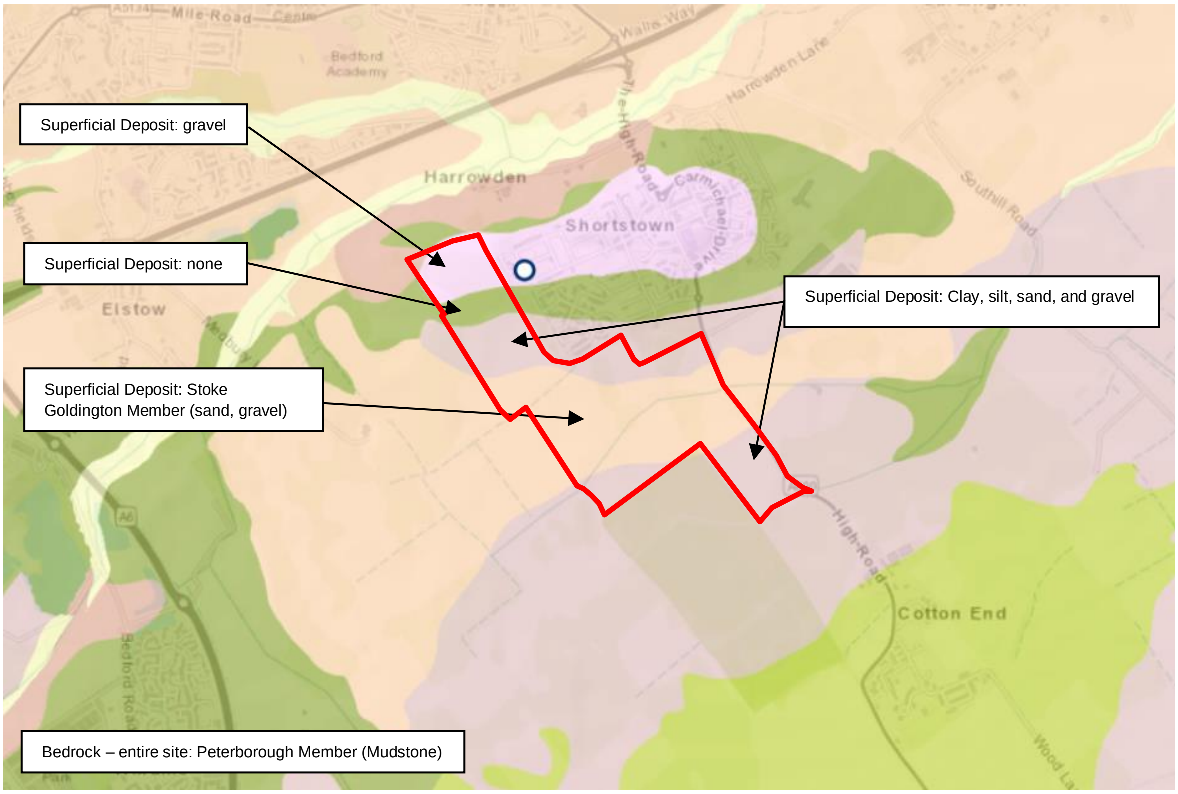
3.13. The Bedford Borough Council LFRMS states that 5,280 properties have been identified as being at risk of surface water flooding in the Borough, with 3,400 of these are located within Bedford town. It states this surface water flooding relates to urban areas where rapid runoff from impermeable areas exceeds the drainage capacity, i.e. sewer flooding.

3.14. As the Site is currently an undeveloped greenfield land, the risk of flooding due to a potential blockage is considered negligible. The risk of sewer flooding is therefore considered to be low.

Groundwater

3.15. Groundwater flooding is most likely to occur in low-lying areas underlain by permeable rocks. According to the British Geological Survey (BGS) Geology of Britain viewer (Figure 4), the Site is underlain by the Peterborough Formation, which is made up of mudstone. Mudstone is generally considered an impermeable stratum.

Figure 4: Geology of Britain Viewer



Source: British Geological Survey Geology of Britain Viewer

3.16. According to the Bedford Borough Council LFRMS, none of the bedrock underlying the Borough support major aquifers, meaning that they lack the potential to store and transmit large quantities of water. The LFRMS states that consequently the risk of groundwater flooding in the Borough is generally considered to be low. Where there are superficial deposits of sands and gravels, such as on this Site, there may be groundwater present.

3.17. The LFRMS confirms that the EA, the IDB, and the Council themselves hold no records of historical groundwater flooding. In addition, the development would not comprise basements which could interfere with any potential groundwater. It is therefore considered that the risk of groundwater flooding is low.

Artificial Sources

3.18. As per the EA mapping, the Site is not at risk of flooding in the event of a failure or overtopping of a reservoir.

3.19. The Flood Map for Planning indicates the presence of four basins located at the south western corner of Shortstown. A site walkover has confirmed that these are man-made and excavated below-ground. The topography of Shortstown generally falling in this direction and the vicinity of an existing drainage ditch as a potential outfall from the basins, further suggests that these basins form part of the surface water strategy of a part of Shortstown. The ponds are therefore likely managed and maintained appropriately. The risk of overtopping from these ponds into the Site is therefore considered to be low.

3.20. The risk of flooding from artificial sources is therefore considered to be low.

4. Options Modelling Exercise

Modelling Approach

4.1. Following the completion of the recent baseline modelling exercise, Waterman were commissioned to undertake an exploratory hydraulic modelling exercise to investigate the potential options to reduce the flood extent on the northern bank of the Cople Brook and therefore to increase the net developable area.

4.2. As part of this exercise, 5 options scenarios were investigated. The options were:

- Option A – remove the two upstream culverts on-site;
- Option B – remove the two downstream culverts on-site;
- Option C – remove all culverts on-site;
- Option D – improve the floodplain storage to the southern side of the Cople Brook; and
- Option E – re-align the Cople Brook channel

Results

Option A

4.3. In the Option A scenario, the two westernmost culverts (upstream within the Site boundary) on the Cople Brook were removed and the channel dimensions were interpolated between the model cross sections upstream and downstream of the culverts.

4.4. Appendix G presents the results of this model scenario. As can be seen in these results, during the 1 in 20 year flood event, which defines the functional floodplain, the area of flooding on-site to the north of the Cople Brook has been removed. However, flooding downstream of the site, in the vicinity of Southill Road has increased in both extent and depth. Flood depths in this area are expected to increase by a maximum of 0.13m.

4.5. During the 1 in 100 year event plus 35% climate change, the on-site flood depths have decreased by a maximum of 0.16m and the flood extent has reduced substantially (Appendix G). As a result of the reduction in flood depths and extent on-site, there has been a corresponding increase in flood depths and extent downstream of the Site. Flood depths are seen to increase by approximately 0.006m over a significant area, and up to a maximum of 0.1m in some areas surrounding Southill Road.

Option B

4.6. In the Option B scenario, the two easternmost culverts on-site (downstream within the Site boundary) on the Cople Brook were removed. The channel dimensions were interpolated between the model cross sections upstream and downstream of the culverts.

4.7. During the 1 in 20 year event, the area of flooding on-site has again been removed, and the flood depths and extent downstream of the Site have increased accordingly. Flood depths in the vicinity of Southill Road have increased by a maximum of 0.13m (Appendix G).

4.8. During the 1 in 100 year plus 35% climate change event, the central and eastern areas of the Site are removed from the flood extent completely, and flood depths within the western part of the Site are shown to decrease by a maximum of 0.12m (Appendix G). Flooding downstream of the Site is indicated increase on a scale commensurate with the decrease seen on-site, with flood depths expected to increase by a maximum of 0.11m within the land to the north and south of the Cople Brook south of the Cardington Airfield, and 0.1m to the north of Southill Road. The increase in flooding is largely up to 0.006m in most areas (Appendix G).

Option C

4.9. The Option C scenario comprised the removal of all four culverts within the College Farm Site boundary. The channel dimensions were again interpolated between the model cross sections upstream and downstream of the culverts.

4.10. During the 1 in 20 year event, all flooding on-site has been removed and flood depths and extents downstream of the Site have increased accordingly. Flood depths in the vicinity of Southill Road have increased by a maximum of 0.13m (Appendix G).

4.11. During the 1 in 100 year plus 35% climate change event, the Site has again been removed completely from the flood extent. However, downstream of the Site there is a significant increase in both flood extent and depths. Areas surrounding the Cople Brook to the South of the Cardington Airfield have increased by a maximum of 0.25m and areas in the vicinity of Southill Road have increased by a maximum of 0.12m. However, the majority of areas are indicated to increase in flood depths by up to 0.015m (Appendix G).

Option D

4.12. In the Option D scenario, ground levels on the north bank of the Cople Brook were raised to between 30.6m AOD at the upstream extent and 30.2m AOD at the downstream extent to prevent flood water spilling out to the north. In addition to this, ground levels to the south of the Cople Brook were lowered by 0.25m to improve the floodplain storage and to compensate for any loss of floodplain to the north of the Brook.

4.13. During the 1 in 20 year event, the area of functional floodplain to the north of the Cople Brook has been removed and a considerable area to the south of the Brook is indicated to flood to depths of up to 0.3m (Appendix G).

4.14. During the 1 in 100 year plus 35% climate change event, the areas to the north of the Brook have been removed from the floodplain and flooding to the south of the Brook is shown to be more extensive. Flood depths to the south of the Brook are expected to increase by up to 0.26m (Appendix G).

4.15. Due to the loss of floodplain to the north of the Brook, there has been some increase in flood extent downstream of the Site, however, this is significantly less extensive compared to the increases seen in Options A to C. The flood extent is expected to increase to the north and south of the Cople Brook to the south of Cardington Airfield, where depths are predicted to increase by a maximum of 0.1m. There are also smaller areas of increasing depth and extent seen in the areas surrounding Southill Road and further downstream, however, the increases in extent are expected to be minimal and depths are expected to increase by a maximum of 0.07m in isolated areas (Appendix G).

Option E

4.16. The Option E scenario comprised the realignment of the Cople Brook across the Site to provide a steeper channel gradient and improve the channels conveyance through the Site.

4.17. During the 1 in 20 year event, the area of functional floodplain on-site has been removed. Due to this loss of storage on-site, flood risk downstream of the Site has increased. Within the vicinity of Southill Road, flood depths are expected to increase by a maximum of 0.13m in isolated areas, while larger areas would experience increases of up to 0.09m (Appendix G).

4.18. During the 1 in 100 year plus 35% climate change event, all flooding within the Site boundary has been removed, however, significant increases in flood extent and depth are expected to occur downstream of the Site. To the south of the Cardington Airfield, large areas to the north and south of the Cople Brook are now predicted to flood, with depths increasing by up to 0.15m. flood depths are expected to increase by up to 0.15m over large areas surrounding Southill Road and further downstream, and isolated areas are predicted to experience increases in flood depths of up to 0.65m (Appendix G).

Summary

4.19. The results of the options modelling exercise have shown that there are a number of potential options to mitigate on-site flooding to the north of the Cople Brook and to improve the developable area. In all of the options modelled, it was found that removing flooding to the north of the Brook resulted in an increase in flood extents and depths downstream of the Site, which would generally be considered unacceptable by the EA.

4.20. Out of the 5 options investigated, Option D was shown to have the largest impact in reducing the flood extent to the north of the Cople Brook, while having the smallest impact on flood extents and depths downstream of the Site. However, raising the banks to the north of the watercourse may be difficult to agree with the EA and Bedford IDB.

4.21. Options A to C, comprising the removal of various culverts throughout the Site were also shown so substantially reduce the flood extent to the north of the Brook while having a lesser impact downstream than that seen in Option E.

4.22. Therefore, it is recommended that the removal of the culverts, to reduce water levels in the brook is combined with some form of flood compensation to remove the downstream impacts of the removal of these culverts. Initial calculations shows that approximately 3700m^3 of flood compensation would be required to mitigate the downstream increases in flooding. It is currently proposed to provide this in an area of wet woodland to the south of the watercourse. The exact location of this will be confirmed as part of the planning application and will depend on the depths to groundwater found on site and the specification of the proposed wet woodlands.

5. Surface Water Drainage

5.1. A preliminary surface water drainage strategy is outlined below in order to ensure that considerations and spatial requirements of SuDS features are incorporated into the early stages of design. This would ensure that the masterplan is robust. The developable area and space available for SuDS has been assumed based on the result of the modelling options exercise discussed in Chapter 4.

Existing Drainage

5.2. Anglian Water sewer records (Appendix H) indicate the presence of a number of existing surface water sewers in the vicinity of the Site, summarised in Table 1.

Table 1: Existing Sewers

Location	Sewer
Field west of Shortstown (Brabazon Close height)	Anglian Water surface water sewer (diameter unknown)
Roundabout on south eastern corner of Shortstown	Anglian Water surface water sewer with outfall into what appears to be a ditch (600mm diameter)
Western corner of Shortstown	Anglian Water surface water sewer (525mm diameter)

5.3. It is anticipated that the existing drainage regime is a combination of shallow infiltration and overland flows towards the ditches within the Site, as dictated by topography.

Discharge Rate and Location

5.4. The Bedfordshire and River Ivel IDB confirmed that they require surface water discharge from the Site to be restricted to 4 l/s/ha applied to the proposed impermeable area.

5.5. Due to the Site being previously undeveloped (i.e. greenfield), attenuation should be provided in the most sustainable manner through the use of SuDS. Water quality should be considered to ensure that pollutants are appropriately managed prior to discharge.

5.6. The Building Regulations and the Planning Policy Guidance set out a hierarchy of surface water discharge, which should be adhered to in decreasing order of preference:

- Discharge to ground;
- Discharge to a surface water body;
- Discharge to a surface water sewer; and
- Discharge to a combined sewer.

5.7. BGS records indicate that the Site is underlain by the generally impermeable Peterborough Member Formation made up of mudstone. However, parts of the Site (Figure 4) have superficial deposits made up of gravel and/or sand. Drainage via infiltration may be possible for these parts of the Site. It is recommended that soakage tests are undertaken as soon as possible to determine the feasibility of discharge into ground and the infiltration rates at the Site. The Site is not located within a Source

Protection Zone as defined by the EA and it is not anticipated that there would be contamination within the ground as it is currently an undeveloped greenfield.

5.8. In addition to the Harrowden Brook to the north and the Cople Brook in the south, there are a number of ditches running through the Site (Appendix I). In lieu of soakage testing and in accordance with the hierarchy of surface water discharge, it is proposed to discharge into the two watercourses and the ditches within and surrounding the Site.

Surface Water Drainage Strategy

5.9. The Site has been divided into six drainage catchments, defined based on topography and discharge location. This is considered to mimic the existing situation. The strategy aims to keep the catchments lengths short and drainage networks shallow to minimise land raising requirements.

5.10. Attenuation would be provided within detention basins (Appendix I) at the topographic low point of each catchment, to maximise the potential for gravity drainage. Surface water would then be discharged into the network of ditches within the Site.

5.11. MicroDrainage Source Control module has been used (Appendix J) to calculate the required attenuation volumes for the 1 in 100 year plus 40% climate change to restrict runoff to 4 l/s/ha. Source Control runs all storm durations and return periods. The discharge rate and corresponding attenuation volumes required for each catchment is outlined in Table 2. It has been assumed that 15% of the required attenuation volume would be provided at high-level within each plot, for example within permeable paving sub-base.

Table 2: Discharge Rates and Attenuation Requirements

Catchment	Area (ha)	Impermeable Area (ha)	Discharge Rate (l/s)	Attenuation On Plot (m^3)	Attenuation in Strategic Basin (m^3)
1	3.90	2.15	8.6	257	1,454
2	6.11	3.36	13.4	402	2,278
3	10.38	5.71	22.8	683	3,870
4	8.27	4.55	18.2	544	3,083
5	9.07	4.99	20.0	597	3,382
6	1.58	0.87	3.5	104	589
TOTAL	**39.31**	**21.62**	**86.4**	**2,586**	**14,656**
TOTAL					**17,242**

5.12. Catchments 4, 5, and 6 have a relatively flat topography, with levels around 30.0m AOD. In order to achieve gravity drainage, the bank level of the proposed basins need to be raised by approximately 1m. It is anticipated that the cut gained from excavating the basins could be used to complement the fill requirement. In addition, swales are proposed either side of proposed roads to provide a high-level conveyance route for the runoff. Runoff arising from each property would be directed onto permeable paving driveways and access roads with underdrains to connect into the swales at a high level.

5.13. Land raising of up to approximately 1m is required to achieve gravity drainage for southern parts of the Site, indicated indicatively on the drainage strategy plan (Appendix I). The amount of ground raising/re-profiling required is subject to the developing masterplan and would be confirmed during detailed design with cut and fill calculations.

5.14. The strategy as shown is very tight in terms of levels. Further design development might result in more ground raising being required to achieve gravity drainage from all parts of the Site than what is considered cost effective and sustainable. In this event, surface water would need to be pumped into the basins, however this is considered a less favourable/sustainable option.

5.15. The following assumptions have been made for the purposes of this high-level assessment:

- Percentage impermeable area (PIMP): 50% including 10% urban creep allowance (55% total PIMP);
- Detention basins designed as dry, with no permanent water level;
- Detention basin dimensions: 1m total depth (0.7m attenuation depth, 0.3m freeboard), 1 in 4 side slopes, 4m maintenance buffer;
- Shallow swales conveying runoff into basins: 0.5m depth, 1 in 500 slope; and
- Permeable paving driveways/access roads with underdrains (1 in 300 slope) to convey runoff from properties into swales.

5.16. As the scheme develops, it is recommended that a wide range of additional SuDS are considered, including permeable paving for private driveways, access roads, and car park, swales, rain gardens, and green roofs for selected outbuildings and garage roof areas. In addition to water quality benefits, these would provide further attenuation, thus reducing the required land-take for the basins.

Water Quality

5.17. At this early stage of the scheme, the basins were sized in order to contain all the required storage volume for each catchment. However, in order to fulfil the treatment requirements as outlined in the CIRIA SuDS Manual, it is suggested that a variety of additional SuDS features are considered; outlined in Table.

Table 3: Sustainable Drainage Techniques

Device	Description	Comments	✓/✗
Green / brown roofs (source control).	Provide soft landscaping at roof level which reduces surface water runoff.	Depending on the pitch of the proposed roofs, green / brown roofs could potentially be incorporated. This would be dependent upon the purpose of the building and are not generally considered appropriate for private residential dwellings. Therefore, appropriate locations may be limited.	✓
Pervious surfaces (source control).	Storm water is allowed to infiltrate through the surface into a storage layer, from which it can either infiltrate and / or slowly release to sewers.	Infiltration may be feasible for some parts of the Site subject to soakage testing. In lieu of test results, the inclusion of lined permeable paving / sub-base storage is encouraged for all hardstanding areas such as car parking/pavements/roads.	✓

Device	Description	Comments	✓/✗
Rainwater harvesting (source control).	Reduces the annual average rate of runoff from a site by reusing water for non-potable uses e.g. toilet flushing or water butts.	There are no constraints to the incorporation of rainwater harvesting. However, the reduction of surface water runoff cannot be quantified with certainty as this would be dependent on the demand for harvested rainwater. Water butts could be considered for individual properties.	✓
Swales (permeable conveyance).	Broad shallow channels that convey / store runoff, and allow infiltration (ground conditions permitting).	Infiltration may be feasible for some parts of the Site subject to soakage testing. Swales are suggested throughout the Site as a means of surface water conveyance at high-level. The attenuation provided within the swales would be quantified as the masterplan progresses into more detail.	✓
Filter drains & perforated pipes (permeable conveyance).	Trenches filled with granular materials (which are designed to take flows from adjacent impermeable areas) that convey runoff while allowing infiltration (ground conditions permitting).	Infiltration may be feasible for some parts of the Site subject to soakage testing. Filter drains are encouraged within the development to provide treatment through conveyance.	✓
Bioretention Systems / Rain Garden (end of pipe treatment).	A shallow landscaped depression which allows runoff to pond temporarily on the surface before filtering through vegetation and underlying soils.	Infiltration may be feasible for some parts of the Site subject to soakage testing. Bioretention systems/rain gardens could provide amenity benefits as well as attenuation and treatment of surface water.	✓
Ponds (end of pipe treatment)	Depressions in the surface designed to store runoff without infiltration through the base.	Dry ponds are recommended as the principal form of SuDS for the development, providing amenity and biodiversity benefits in addition to attenuation.	✓

6. Foul Drainage

6.1. The proposed foul drainage would be designed in accordance with BS EN 752 – Drain and Sewer Systems Outside Buildings, BS EN 12056 – Gravity Drainage Systems Inside Buildings, and Approved Document H of Building Regulations.

6.2. As the Site is currently undeveloped greenfield land there are no existing public foul sewers within the Site.

6.3. Anglian Water sewer records (Appendix H) indicate the presence of a 150mm diameter foul water sewer routed north of Harrowden Road, with an invert level approximately 2.6m below ground level. There is a network of foul sewers serving the existing Shortstown settlement, to the east of the Site, including an existing sewage pumping station (SPS) at the western end of Sunderland Road within an area of open space. A further existing SPS is located off-site adjacent to the south eastern corner of the Site, on the opposite side of the A600, which lifts flows in a northerly direction via a rising main beneath the A600 (High Road) parallel to and alongside the south eastern Site boundary. There are no other existing foul public sewers across the remainder of the Site.

6.4. Foul flows from the locale ultimately discharge to the Bedford Southern Orbital Sewer which runs west to east to the north of Shortstown, eventually outfalling to Bedford Water Recycling Centre off Meadow Lane in Bedford.

6.5. Due to the gently sloping topography, pumping of foul water would be required for a significant proportion of the Site, with an estimated 3 no. pumping stations required on-Site with associated rising mains, shown indicatively on the drainage plan (Appendix I). Foul flows from the rest of the Site would flow to the pump stations by gravity.

6.6. Off-Site sewer connections would need to be requisitioned from Anglian Water, under S98 of the Water Industry Act 1991, to serve the Site. Towards the northern end of the Site, 1 no. SPS and rising main would need to be requisitioned, with the eastern extent of the rising main route traversing off-site land comprising open space and public highway. Further south, 1 no. gravity outfall sewer would need to be requisitioned, with the eastern extent of the rising main route traversing off-site land comprising open space into the existing SPS off Sunderland Road.

6.7. Due to the increase in foul flows post-development, it is anticipated that some off-site reinforcement works would be required to the existing Anglian Water network to accommodate the additional flows. The proposed foul flows would be quantified as the masterplan develops, and a pre-development enquiry to Anglian Water will be required to establish or confirm the preferred discharge points to the public sewer network and the level of reinforcement works required.

7. Conclusions and Recommendations

7.1. Parts of the Site are located in Flood Zones 2 and 3, denoting a medium and high risk of fluvial flooding.

7.2. The flood extents shown in the south of the Site result from a TUFLOW 2-D only mode, which does not accurately represent channel sections or area-specific hydrology. A Site-specific hydraulic model has been undertaken to better represent the flood risk at the Site. As a result, the fluvial flood extents associated with the ditches was reduced in the east of the Site, thus increasing developable area. However, the fluvial flood extents were shown to increase in the west of the Site due to the flows being constricted within the culverted section of the watercourse.

7.3. In order to mitigate the risk of flooding on-site and to potentially increase the developable area, an exploratory modelling exercise has been carried out to investigate potential on-site improvement works. It was found that there are a number of potential opportunities to improve the existing watercourse and floodplain to remove areas to the north of the Cople Brook from the flood extents.

7.4. It is recommended that all of the on-site culverts, or a combination of the culverts, are removed which will have a positive impact on water levels throughout the Site and reduce on-site flooding. In addition to this, it is recommended that improvements to the floodplain through ground raising to the north of the Cople Brook and ground lowering to the south of the Brook are carried out to compensate for any loss of floodplain storage, and to mitigate any increase in flood risk downstream as a result of the removal of culverts.

7.5. The majority of ditches within the Site are denoted Ordinary Watercourses and fall under the responsibility of the Bedfordshire and River Ivel Internal Drainage Board. No development or ground raising would be proposed within 9m of the ditches, therefore ensuring the no potential floodwater is displaced as a result of the development. The risk of overland surface water flood risk identified on Site would be managed appropriately within the proposed drainage strategy.

7.6. The Site is at low risk of flooding from all other sources (sewer, groundwater, and artificial).

7.7. The underlying geology in some parts of the Site (gravel and sand superficial deposits) suggests that infiltration may be feasible for parts of the development. It is recommended that soakage testing is undertaken to confirm the infiltration rates on Site. In lieu of test results, surface water would be restricted to 4 l/s/ha as requested by the IDB and attenuated within detention basins prior to discharging into the ditches within the Site.

7.8. The southern part of the Site has relatively flat topography. Shallow swales and lined/under-drained permeable paving would convey surface water at high-level into the basins. Some ground raising is required to facilitate gravity drainage and potentially pumping (however this should be avoided if possible).

7.9. The possibility of including a wide-range of SuDS would be assessed as the masterplan progresses, including permeable paving, rain gardens, green roofs on selected outbuildings and garage roof areas, and rainwater harvesting.

7.10. Foul flows from the development would be discharged, via a combination of gravity sewers and pumped rising mains to the nearby public foul sewer network. Off-Site sewer connections would need to be requisitioned from Anglian Water to serve the Site, although off-site routes generally traverse open space and public highway and, therefore, are expected to be deliverable.

7.11. Due to the increase in foul flows post-development, it is anticipated that some off-site reinforcement works would be required to the existing Anglian Water network to accommodate the additional flows. The proposed foul flows would be quantified as the masterplan develops, and a pre-development enquiry to Anglian Water will be required to establish or confirm the preferred discharge points to the public sewer network and the level of reinforcement works required.

7.12. Despite material, technical, and spatial constraints identified, a significant extent of developed land is available to accommodate a substantial quantum of residential units, associated infrastructure and landscaping.

8. References

[i] Ministry of Housing, Communities and Local Government, last revised February 2019. National Planning Policy Framework.

[ii] Ministry of Housing, Communities and Local Government, March 2014. Planning Practice Guidance.

[iii] Bedford Borough Council, November 2015. Local Flood Risk Management Strategy.

[iv] RAB Consultants/Bedford Borough Council, February 2018. Supplementary Planning Document for Sustainable Drainage Systems.

[v] CIRIA C753, 2015. The SuDS Manual.