



Resilience and
Flood Risk

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Ratby Sports Club

FLOOD RISK ASSESSMENT

1st February 2021

Version 1.0

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Revision History

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Quality Control

Action	Signature	Date
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1.0 Introduction

RAB Consultants has prepared this Flood Risk Assessment (FRA) in support of the proposed change of use planning application at Ratby Sports Club.

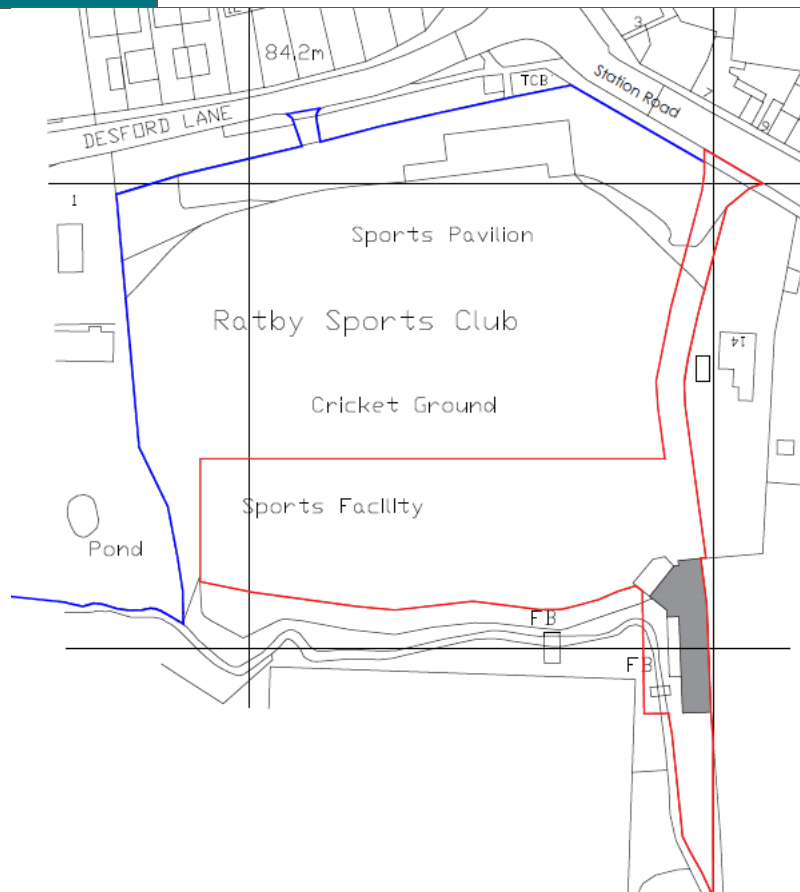
The development site is partially located in Flood Zone 3 according to the Environment Agency's Flood Map for Planning (Rivers and Sea). A Flood Risk Assessment for this site is required under the Planning Practice Guidance for the National Planning Policy Framework (NPPF) as it located in Flood Zone 3. The site-specific FRA is required to ensure that the development is safe from flooding and will not increase the risk of flooding elsewhere.

2.0 Site details

2.1 Site location

TABLE 1: SITE LOCATION

Site address:	Station Road, Ratby, Leicester, LE6 0JP
Site area:	Education building 0.43m ²
Existing land use:	Existing changing room block with adjacent sports fields.
OS NGR:	SK 51189 05627
Local Planning Authority:	Hinckley and Bosworth Borough Council





2.2 Site description

The proposed site lies within a wider plot of land (which is owned by the client) that consists of 7.2 ha of sports and recreation land, of which approximately 1.5ha is overgrown scrub. The site is located to the south west of Ratby village with the site's northern boundary abutting Desford Road and Main Street in the village centre. The wider site is dissected east to west by a tributary of the River Soar, which continues to flow to the east into the city of Leicester. The river is the lowest point within the site, with the land rising to the north and south by approximately 8m.

The site to which this FRA specifically applies is located along the eastern boundary of the wider plot of land, adjacent to the watercourse. It contains a single building, currently used as changing rooms for the sports facility, with a small patio area extending to the north of the building. The site is accessed directly from Desford Road along the northern boundary of the site.

2.3 Development proposal

It is proposed to convert the existing changing block to an education facility. This would provide 8 classrooms on the ground floor, with the first floor becoming a dining area for staff and children. Additional external openings will be required, but the existing footprint of the building will remain the same.

3.0 Flood Risk

3.1 Sequential test

According to the Environment Agency's Flood Map for Planning the site lies partially in Flood Zone 3, which is described in the NPPF as land having a 1 in 100 or greater annual probability of river flooding (1% or greater Annual Exceedance Probability, AEP); or land having a 1 in 200 or greater annual probability of sea flooding (0.5% AEP or greater).

The NPPF follows a sequential risk-based approach in determining the suitability of land for development in flood risk areas, with the intention of steering all new development to the lowest flood risk areas. NPPF Planning Practice Guidance (PPG) Table 2 confirms the 'Flood risk vulnerability classification' of a site, depending upon the proposed usage. This classification is subsequently applied to Table 3 'Flood risk vulnerability and flood zone compatibility' to determine whether:

- The proposed development is suitable for the flood zone in which it is located; and
- Whether an Exception Test is required for the proposed development.

The proposed development is classed as 'more vulnerable' in accordance with NPPF PPG. The development is therefore appropriate for the Flood Zone. Both a sequential test and exception test would normally be required in accordance with Table 3, however as the development is change of use the tests do not need to be applied (second note to Table 3).

3.2 Flooding history

There is no direct indication of the proposed site flooding in the Hinkley and Bosworth 2019 Strategic Flood Risk Assessment (SFRA). The 2019 Hinkley and Bosworth SFRA does indicate that there were a few significant flood events Borough-wide in July 2013, January 2014, March 2016, June 2016 and January 2018. These events included fluvial and pluvial flooding.

The Environment Agency hold a record of flooding at this location, with the mapped flood extents extending into the site area. This is flood event happened in February 1977, with the cause of flooding recorded as channel capacity exceeded.

The site owner has no knowledge of flooding affecting the existing building within the site.

3.3 Fluvial (Rivers)

The nearest watercourse to the proposed change of use development is a small arm of Rothley Brook, a tributary of the River Soar. According to the Hinkley and Bosworth 2019 SFRA, the Rothley Brook poses a fluvial risk to a number of properties within the village of Ratby. The small arm of Rothley brook crosses Desford road upstream of the site via a double arch culvert and then remains essentially an open channel with the exception of two small pedestrian crossings immediately upstream and adjacent to the development site. Pictures of these structures are shown below in Table 2.

TABLE 2: PICTURE OF HYDRAULIC STRUCTURES ALONG WATERCOURSE



FIGURE 1: WATERCOURSE PASSING UNDERNEATH DESFORD LANE VIA A DOUBLE ARCH CULVERT, 250M UPSTREAM OF DEVELOPMENT SITE



FIGURE 2: FIRST PEDESTRIAN CROSSING APPROXIMATELY 25M UPSTREAM OF SITE



FIGURE 3: SECOND PEDESTRIAN CROSSING ADJACENT TO THE SITE.

The Environment Agency's flood map for planning rivers and sea (Figure 4), indicates that part of the site is located within Flood Zone 3.

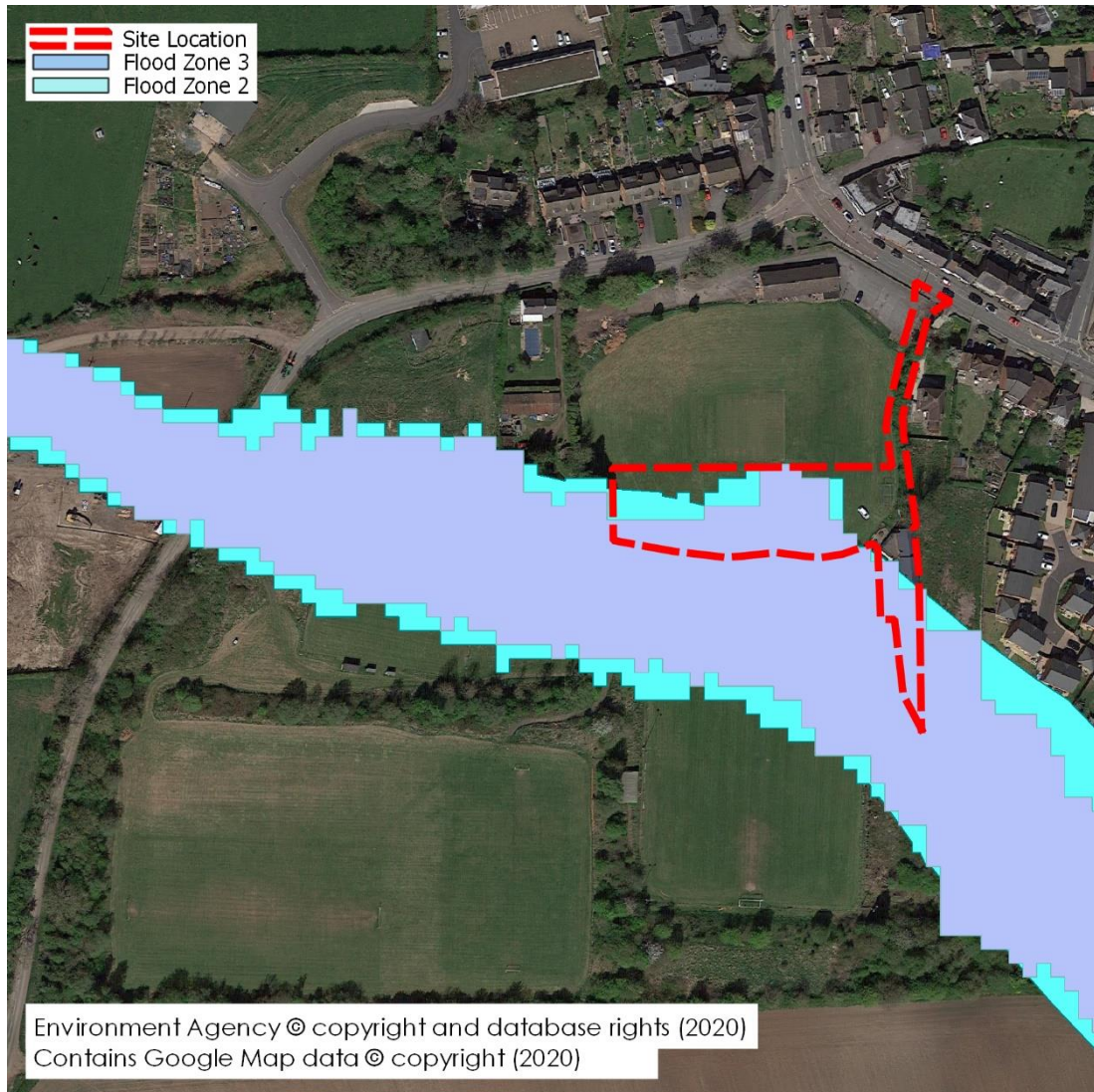


FIGURE 4: ENVIRONMENT AGENCY FLOOD MAP FOR PLANNING

There are no detailed modelled flood levels available from the Environment Agency at this location. Site specific flood risk from the small tributary of the Rothley brook at the site has therefore been modelled using Flood Modeller Pro / TUFLOW to create a 1D-2D model. The model extents and peak levels for a range of flood scenarios are summarised in the figures below, with the full hydrology and hydraulic reports included in Appendix C of this report.

Ground levels at the site and cross sections detailing the adjacent watercourse was provided by Ramowski Clarke Ltd in December 2020 (Appendix B). Additional upstream cross sections were also used from a previous survey provided by Green Hatch Group Ltd (November 2019, Appendix B).

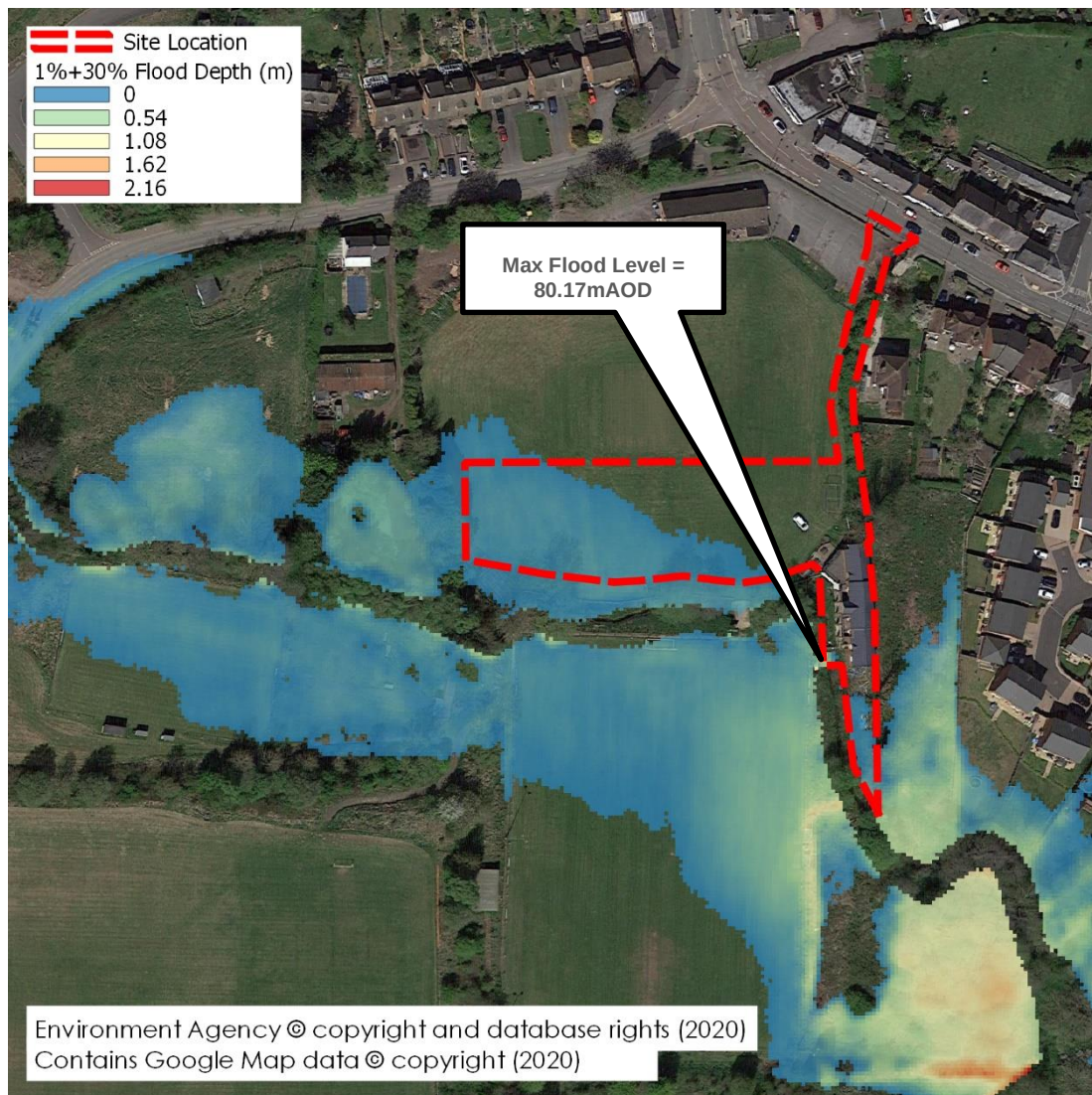


FIGURE 5: MAXIMUM FLOOD EXTENT OF THE 1% PLUS CLIMATE CHANGE (30%) FLOOD EVENT

Figure 5 shows the maximum flood extent at the proposed site during the 1%AEP plus (30%¹) climate change design flood. As can be seen, a large proportion of the surrounding area is expected to flood, although the proposed building itself is expected to remain dry. Both the left and right bank of the watercourse experience flooding, although more extensive flooding is present on the right bank, which is expected given that this land is topographically lower across this bank. The mechanism of flooding is simply that the channel capacity is exceeded during such an event. Comparing the modelled flood levels of 80.17mAOD with the topographic survey suggests that building is expected to remain dry. The threshold level of the existing building is 81.00mAOD, which is 0.83m above the peak flood level at closest approach to the building.

¹ See Section 3.3.1

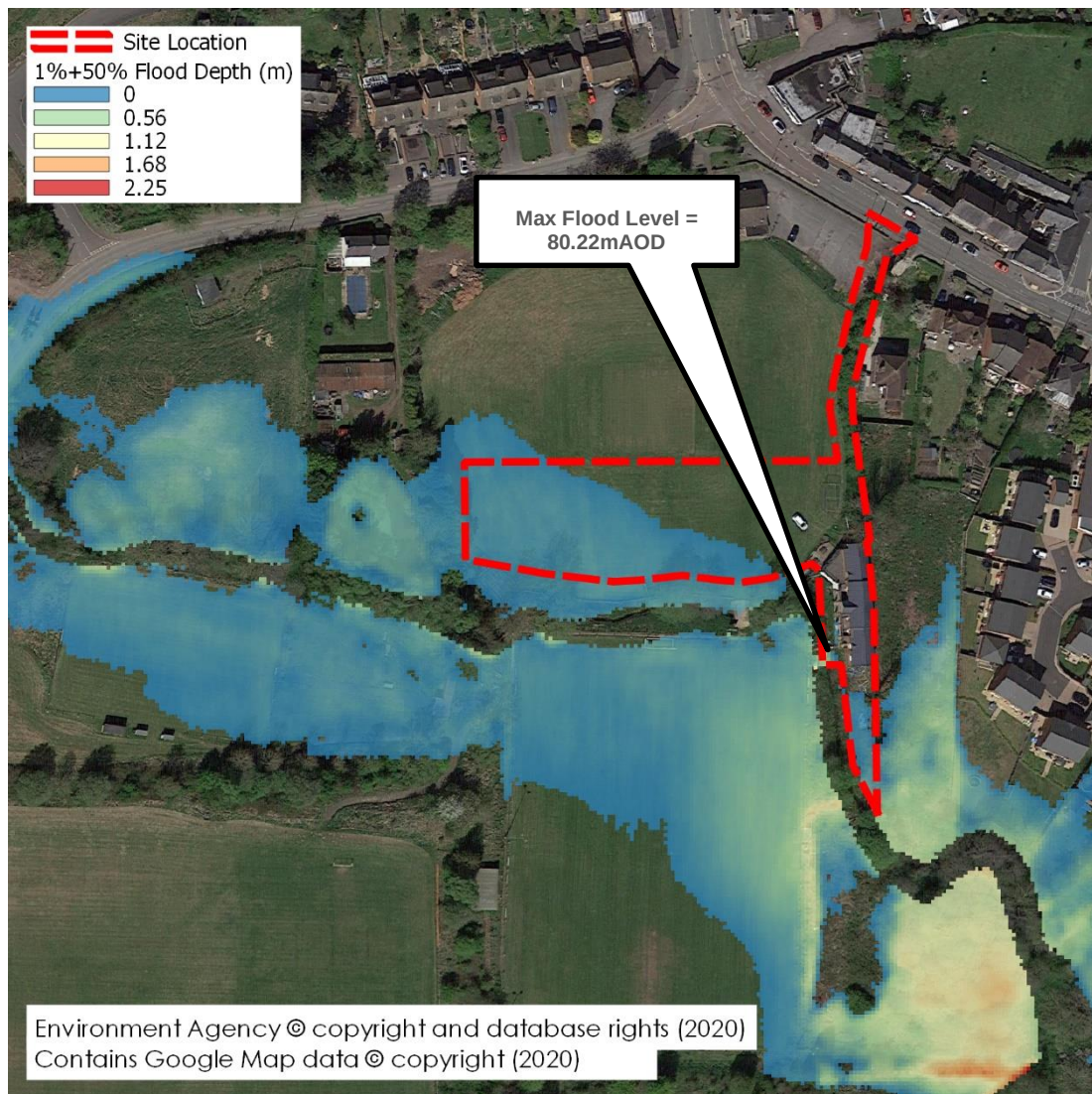


FIGURE 6: MAXIMUM FLOOD EXTENT OF THE 1% PLUS CLIMATE CHANGE (50%) FLOOD EVENT

Figure 6 shows the maximum flood extent for the 1%AEP flood extent with a more onerous allowance of climate change (plus 50%²). The mechanism of flooding is the same as before, but a small increase in extent is observed given the increase in flow. Comparing the modelled flood level of 80.22m AOD with the topographic survey once again suggests that building is expected to remain dry. The threshold level of the existing building is 81.00m AOD, which is 0.78m above the peak flood level at closest approach to the building.

² See Section 3.3.1

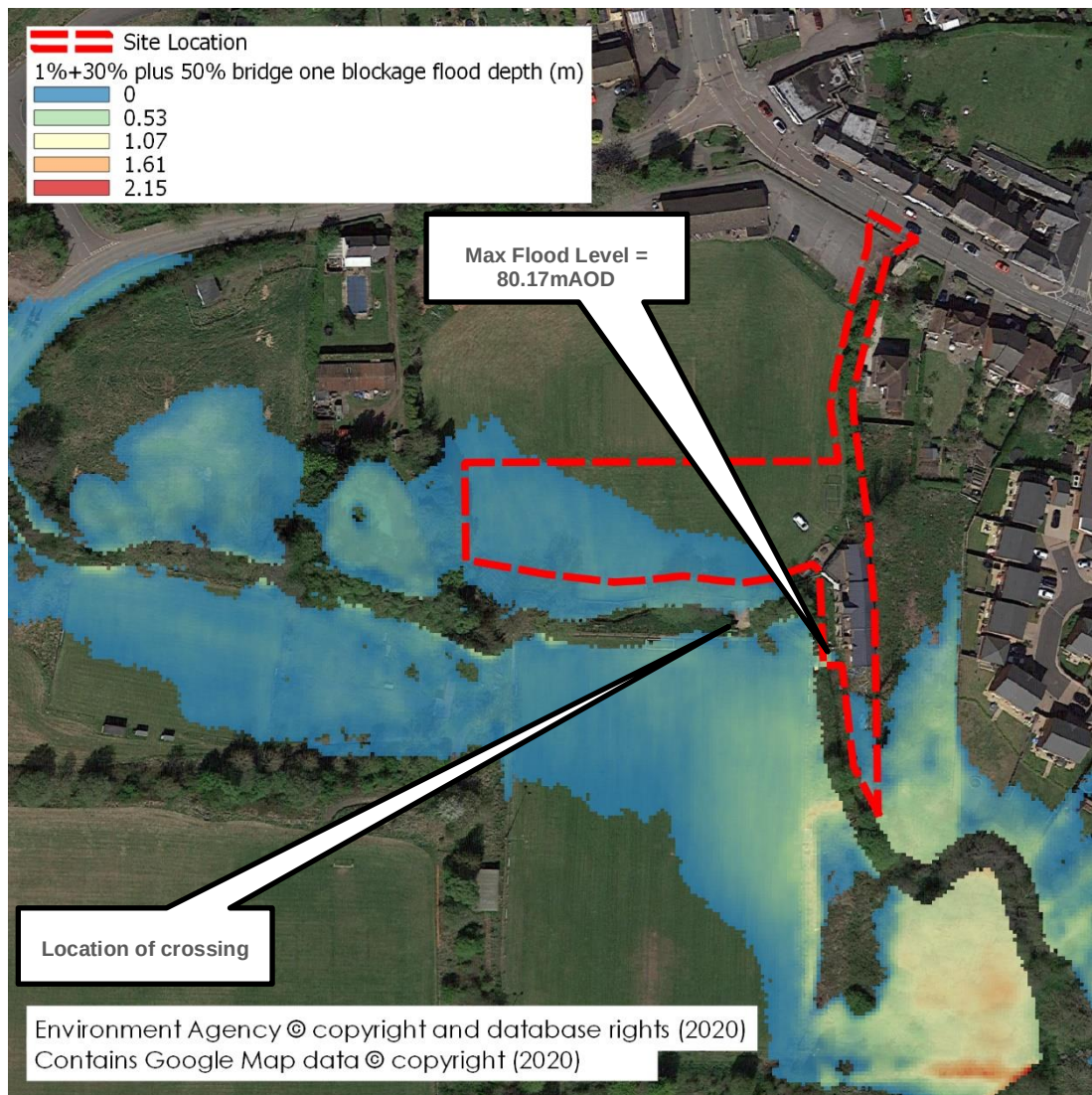


FIGURE 7: MAXIMUM FLOOD EXTENT OF THE 1% PLUS CLIMATE CHANGE (30%) PLUS FIRST PEDESTRIAN BRIDGE BLOCKAGE (50%) FLOOD EVENT

Figure 7 above shows the modelled flood extent with the cross-sectional area of the first pedestrian crossing reduced by 50% (see Figure 2). It can be seen that a reduction in cross sectional area has very little impact on the flood extent both to the development and surround land. The modelled flood level at the proposed building demonstrates no increase, when compared to the baseline scenario, indicating that the finished floor level is still 0.83m above the peak flood level at closest approach. Flood levels on the left and right bank immediately adjacent to the crossing do see a small increase of typically 0.03m, although this increased flood level is only recorded approximately 25m upstream. The minor impact of blockage on this crossing is not surprising given that there is no structure (for example a wall) to impede flow across the deck.

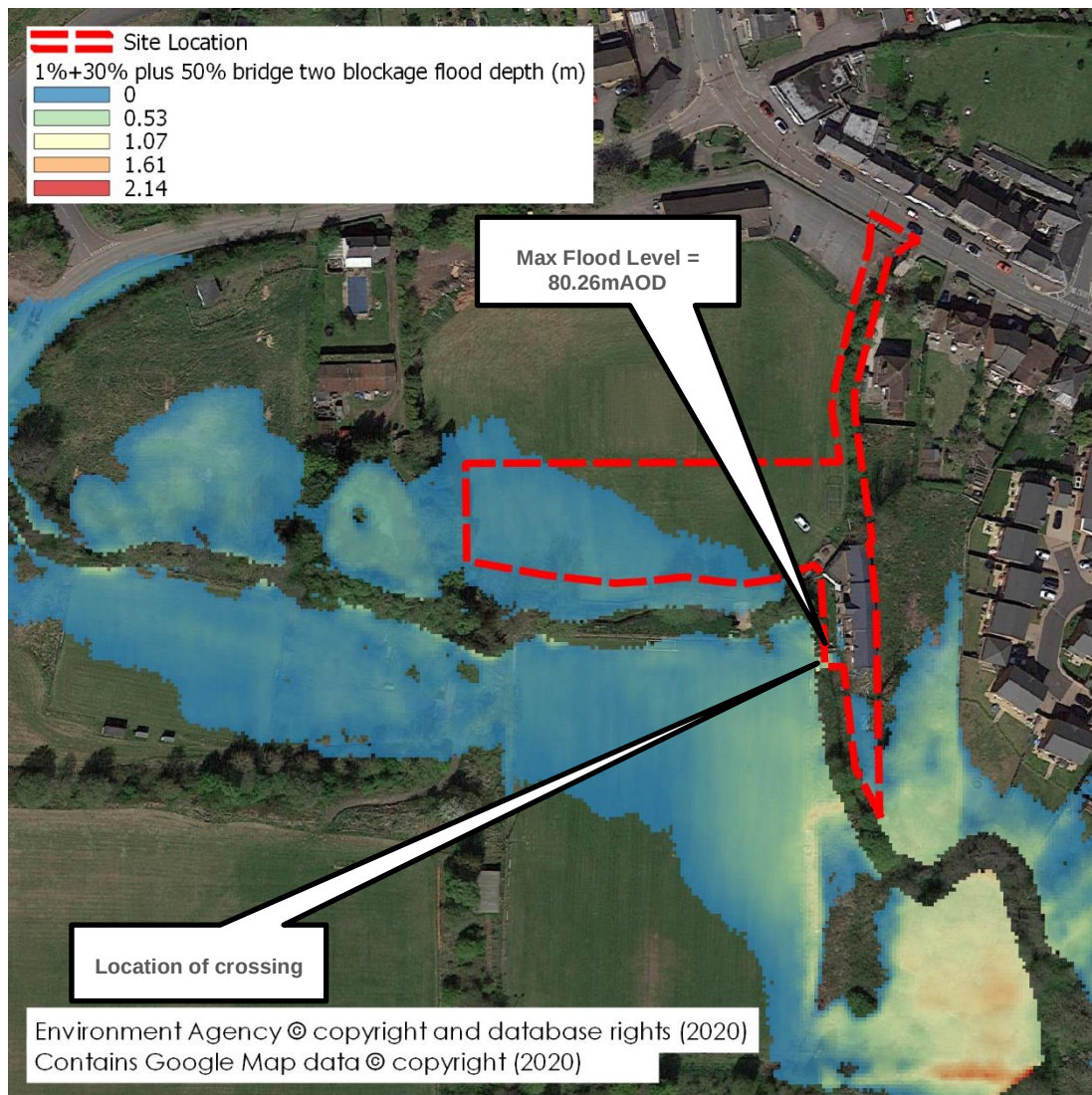


FIGURE 8: MAXIMUM FLOOD EXTENT OF THE 1% PLUS CLIMATE CHANGE (30%) PLUS SECOND PEDESTRIAN BRIDGE BLOCKAGE (50%) FLOOD EVENT

Figure 8 above shows the modelled flood extent with the cross-sectional area of the second pedestrian crossing, adjacent to the site, reduced by 50% (see Figure 3). Again, the flood extent for the surrounding area is largely unchanged. The constriction at this structure does drive a slightly higher flood level across the adjacent land, however, the proposed building is still expected to remain dry with the finished floor level of the building still 0.74m above the peak flood level at closest approach. Flood levels on the right bank also slightly increase by approximately 0.06m adjacent to this crossing. As before, this is a very localised increase with no significant change in flood levels recorded beyond 25m upstream.

3.3.1. Climate Change Impact on Fluvial Risk

The Environment Agency guidance document 'Flood risk assessments: climate change allowances' was released in February 2016 and included statistical increases in peak fluvial flows by river basin district and allowance categories based on epochs and development vulnerability classification. Referring to the NPPF PPG, the development is classified as 'more vulnerable' and has an expected lifetime of 100 years; therefore the 'higher central' and 'upper end' allowance categories apply. These equate to an increase of '30%' and '50%' on flows for the Humber Basin. These climate change scenarios have been assessed in section 3.3.



3.4 Flood defence breach or overtopping

3.4.1. Breach risk

The site does not benefit from flood defences therefore there is no breach flood risk for the site.

3.4.2. Overtopping risk

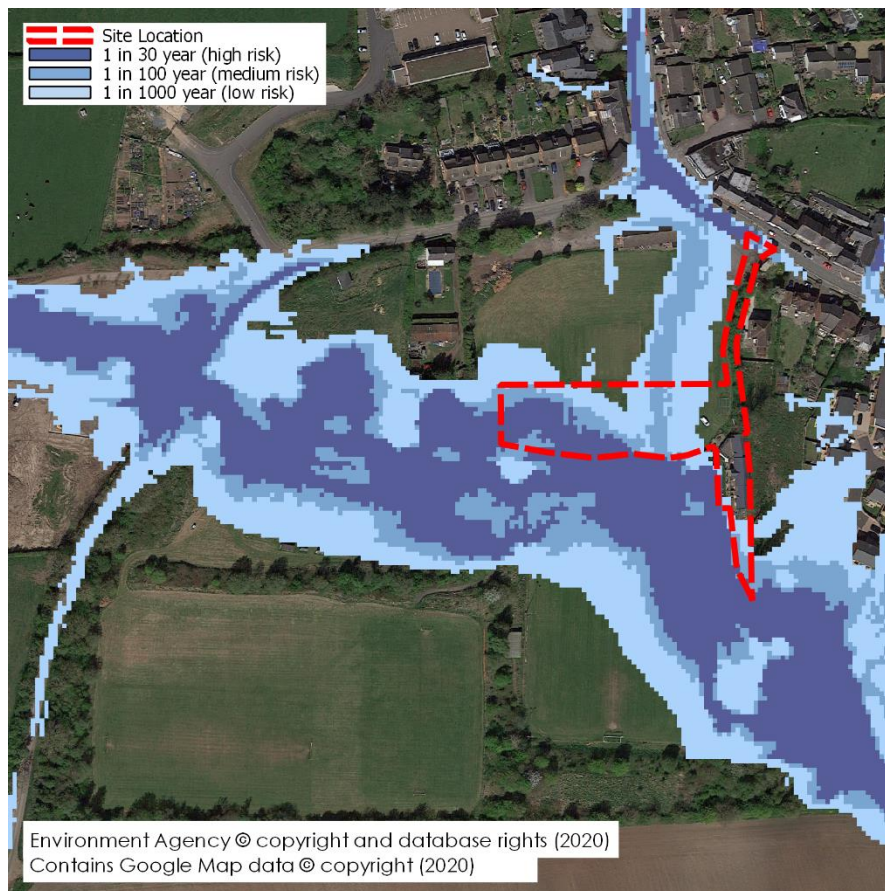
The site does not benefit from flood defences therefore there is no overtopping flood risk for the site.

3.5 Coastal/tidal

The site is not affected by coastal or tidal flood risk.

3.6 Pluvial (Surface water)

The surface water risk to the proposed education facility is indicated to be 'very low', a chance of flooding from surface water (a chance of flooding of less than 0.1% AEP). The surface water map also shows a 'low risk' (a chance of flooding of between 0.1% AEP and 1% AEP) and a 'medium risk' (a chance of flooding of between 1% and 3.3% AEP) surface water flow route originating from Desford / Station Road which passes through part of the sports fields within the site boundary. It is important to note that the surrounding land is located within the fluvial flood plain, the highlighted surface water risk around the watercourse is a reflection of the fluvial risk, but without the detail of the fluvial model. This risk has already been assessed in section 3.3.



3.7 Figure 9: Environment Agency Surface Water flood mappingArtificial water bodies

The Environment Agency's Reservoir Flood Map indicates that the site is not at risk from this source of flooding.

There are no raised canals near the proposed site to pose a significant flood risk.

3.8 Groundwater

The 2019 SFRA for Hinckley and Bosworth Borough Council indicates that the proposed site is not at risk from groundwater flooding. The SFRA states that *'The Areas Susceptible to Groundwater Flooding map shows that, in general, the majority of Hinckley and Bosworth borough is within the <25% susceptible classification, therefore it is at lower risk of groundwater flooding'*. It goes on to say that there are areas in the borough with elevated risk, specifically areas located along side watercourses.

With the site being so close to a watercourse, groundwater is expected to essentially match river levels, therefore fluvial flood levels will be used to assess risk in this report.

3.9 Sewers

According to the 2019 SFRA for Hinckley and Bosworth Borough Council, information on flooding from sewers is currently in the process of being modelled by Severn Trent Water. This includes a fully integrated model for Hinckley, in a partnership scheme between LCC and Severn Trent Water. The outputs were due to be completed in late 2019/2020 and will be able to indicate areas at risk from sewer flooding. At the time of writing this information was not yet available.



There are no known instances of sewer flooding affecting the site according to the client.

4.0 Mitigation measures

4.1 Risk to buildings

4.1.1. Finished floor levels

In order to afford a level of protection against flooding it is normally recommended that finished floor levels are set 0.6m above the modelled 1%AEP plus climate change (30%) design flood level. In this case the existing finished floor level is 81.0mAOD which is 0.83m above the peak flood level and 0.74m above a more onerous scenario of a blockage to the adjacent crossing. The existing finished floor level is therefore appropriate for the assessed risk.

4.1.2. Flood resistance

The use of flood resistance measures is not considered appropriate given the rarity of flooding and the existing finished floor level.

4.1.3. Flood resilience

The use of flood resilience measures is not considered appropriate given the rarity of flooding and the existing finished floor level.

4.2 Risk to occupiers

4.2.1. Safe access/egress

Given that the building and adjacent access route is not expected to flood during the modelled scenarios, staff, pupils and visitors will have safe and dry access available to the north of the site which would lead them to Station Road / Desford Road

4.2.2. Flood warning and evacuation plan

There is currently no Flood Warning service available for the site, however, there is a Flood Alert area available as shown below.

- **034WAF403 Rothley Brook in Leicestershire** - Rothley Brook Rothley Brook and tributaries from Botcheston to the River Soar at Rothley.

Given the site is not expected to flood it is not necessary to include a flood warning and evacuation plan.

4.3 Risk to others

4.3.1. Floodplain compensation

The development is a change of use and as such, there will be no change to the building footprint and no loss of floodplain storage volume. In any case, the proposed site is not expected to experience flooding during the design flood event.

4.3.2. Surface water run-off.

Existing surface water run-off arrangements includes downpipes from the building roofs, which is expected to discharge to the adjacent watercourse, given that numerous outfalls to the watercourse were documented in the topographic survey.

The SuDS Manual (2015), discusses the SuDS approach to managing surface water runoff which is intended to mimic the natural catchment process as closely as is possible. The approach sets out the design objectives in respect of SuDS:

- Use of surface water runoff as a resource;
- Manage rainwater close to where it falls (at source);
- Manage runoff on the surface (above ground);
- Allow rainwater to soak into the ground (infiltration);
- Promote evapotranspiration;
- Slow and store runoff to mimic natural runoff rates and volumes;
- Reduce contamination of runoff through pollution prevention and by controlling the runoff at source; and
- Treat runoff to reduce the risk of urban contaminants causing environmental pollution.

Depending on the characteristics of the site and local requirements, these may be used in conjunction and to varying degrees. Table 3 presents the functions of the SuDS components (from which a management train can be created) and their feasibility in respect of the site.

TABLE 3: FEASIBILITY OF SuDS TECHNIQUES AT THE DEVELOPMENT SITE

Technique	Description	Feasibility Y / N / M (Maybe)
Good building design and rainwater harvesting	Components that capture rainwater and facilitate its use within the building or local environment.	Maybe – A formal water harvesting system is not feasible due to the scale of the development; however, water butts could be used.
Porous and pervious surface materials	Structural surfaces that allow water to penetrate, thus reducing the proportion of runoff that is conveyed to the drainage system (green roofs, pervious paving).	Maybe – If there are any exterior alterations to the property then porous and pervious surface materials could be considered.
Infiltration Systems	Components that facilitate the infiltration of water into the ground. These often include temporary storage zones to accommodate runoff volumes before slow release to the soil.	No – The proposal is change of use with no alteration planned for the existing drainage. In any case with the close proximity of the watercourse infiltration is not considered appropriate.

Conveyance Systems	Components that convey flows to downstream storage systems (e.g., swales, watercourses).	No – The proposal is change of use with no alteration planned for the existing drainage.
Storage Systems	Components that control the flows and, where possible, volumes of runoff being discharged from the site, by storing water and releasing it slowly (attenuation). These systems may also provide further treatment of the runoff (eg ponds, wetlands, and detention basins).	No - The proposal is change of use with no alteration planned for the existing drainage. In any case there is insufficient space for this approach.
Treatment Systems	Components that remove or facilitate the degradation of contaminants present in the runoff.	No - The proposal is change of use with no alteration planned for the existing drainage

There are limited alterations proposed within the proposal, therefore, there is little opportunity for the incorporation of SuDS. Some benefit could be achieved by the incorporation of water butts. No change is planned to the existing drainage system and as such no change to runoff rates and volumes will occur.

5.0 Conclusion

Planning permission is sought to convert the existing replacement changing block to an education facility at Ratby sports club, Station Road, Ratby.

The proposed site is partially located in Flood Zone 3, according to the Environment Agency's Flood Map for Planning.

A detailed modelling exercise has been undertaken to assess the site-specific flood risk from the adjacent watercourse, which shows that the proposed building is expected to remain dry in all but the most of extreme scenarios.

The main access route for the sports club will remain dry in all but the most extreme flood event.

As the proposed is a change of use application, there will be no change to flood plain storage capacity or surface water runoff. There is little opportunity for the incorporation of SuDS.

It can be concluded that the proposed development is appropriate for the flood risk and is not expected to increase the flood risk elsewhere.

6.0 Recommendations

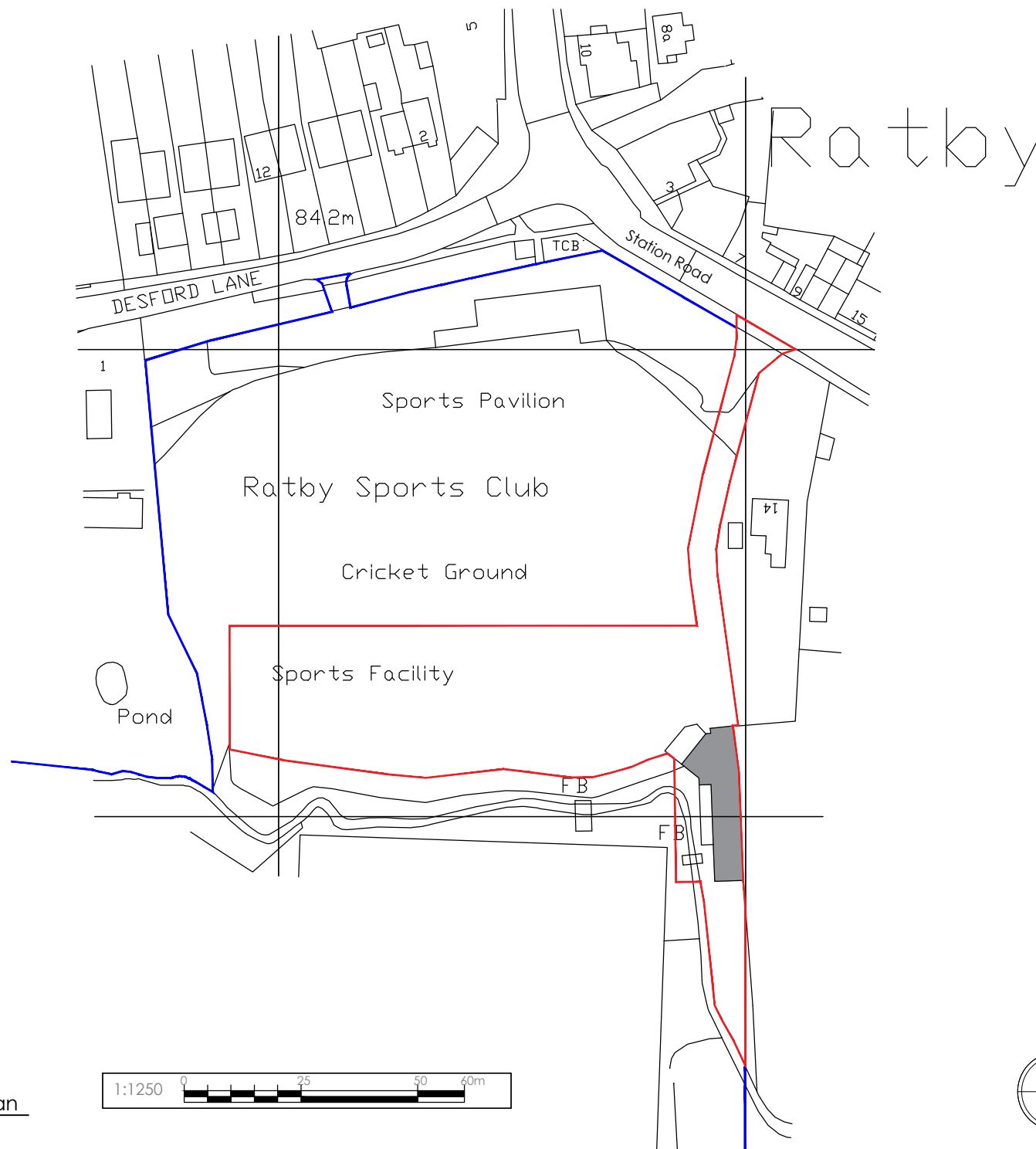
- Consider registering for Environment Agency Flood Alerts.
- Consider the use of water-butts on down-pipes.



Appendix A – Development Plans



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Location Plan

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Project.
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LE6 0LE

Title.
Location Plan

Scale. 1:1250	Drawn. KES	Checked. -	Date. Dec 2020
Drawing No. 8265_01_01	Revision. -		

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Appendix B – Topographic Survey



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OS Note:
Some services may have been omitted due to parked vehicle.

OS Buildings ☐ Surveyed Buildings ☐

This survey has been orientated to the Ordnance Survey (O.S.) National Grid OSGB36(15) via Global Navigation Satellite

A true OSGB36 coordinate has been established near to the site centre via a transformation using the OSTN15GB & OSGM15GB transformation models.

No scale factor has been applied to the survey therefore the coordinates shown are arbitrary & not true O.S. Coordinates which have a scale factor applied.

1	11.11.19	Additional topo/sections	WA	GH63
Rev	Date	Description	Drawn	Q. R.



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CLIENT _____

**West Hart
Partnership**

PROJECT

**Desford Lane,
Ratby
LE6 0LE**

TITLE **Topographical Survey**

SCALE	DATE
100-100	28 06 19

DRAWN	QUALITY REF
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JS	GH5391
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Level datum	See note
Point of origin	See note

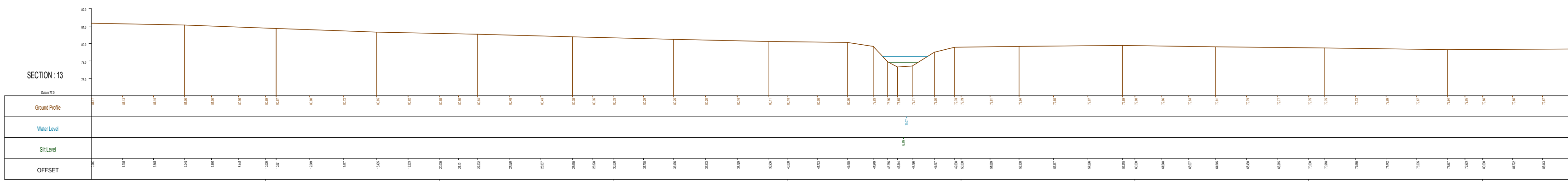
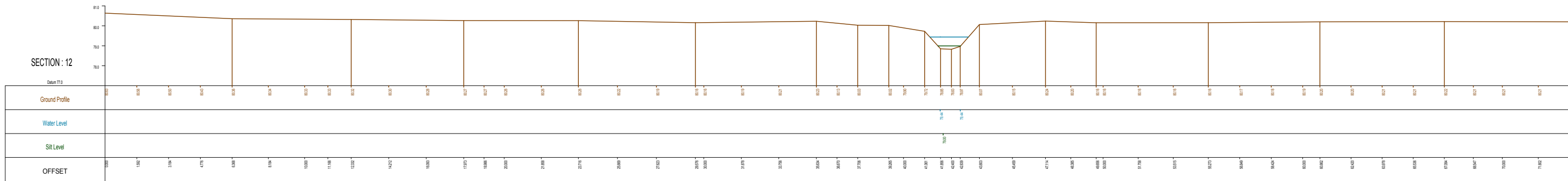
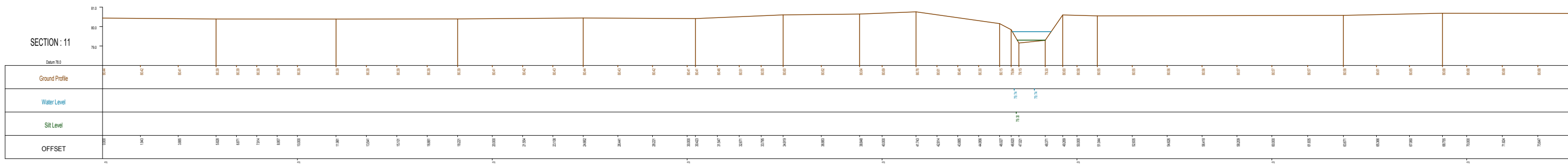
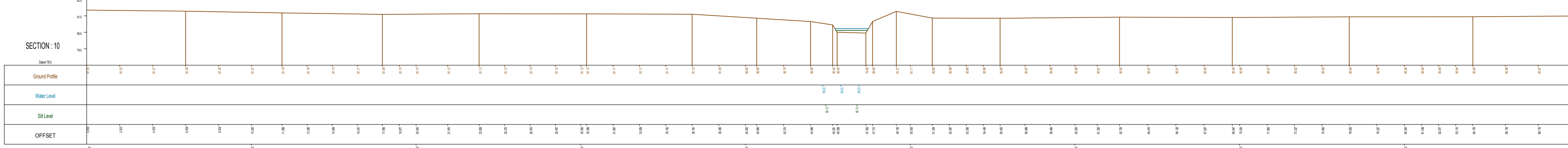
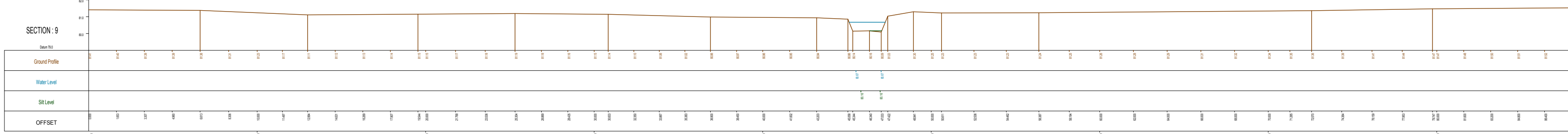
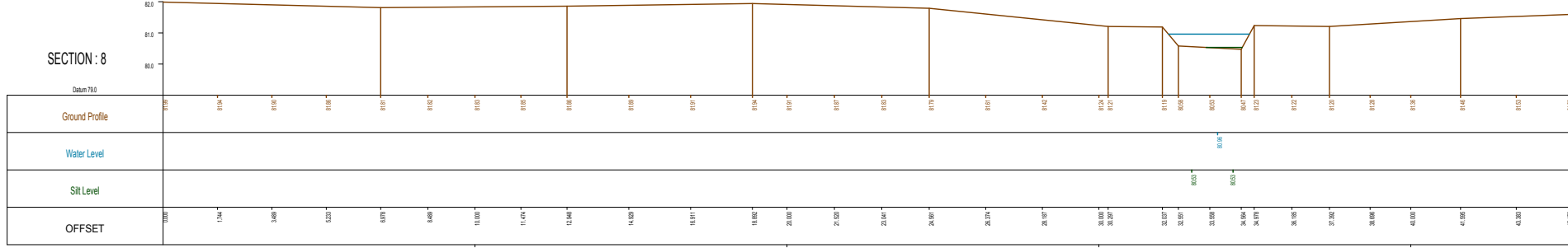
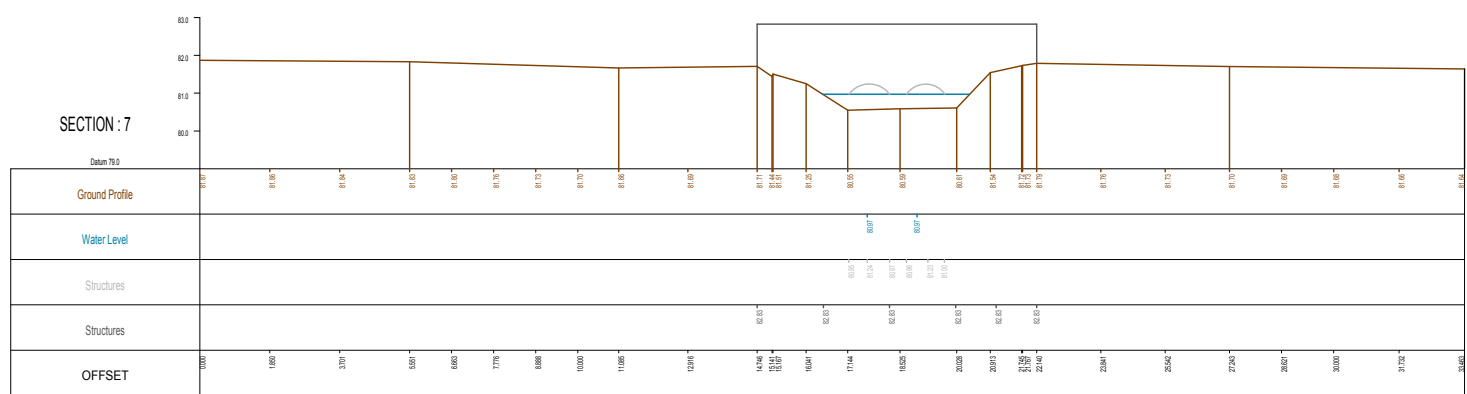
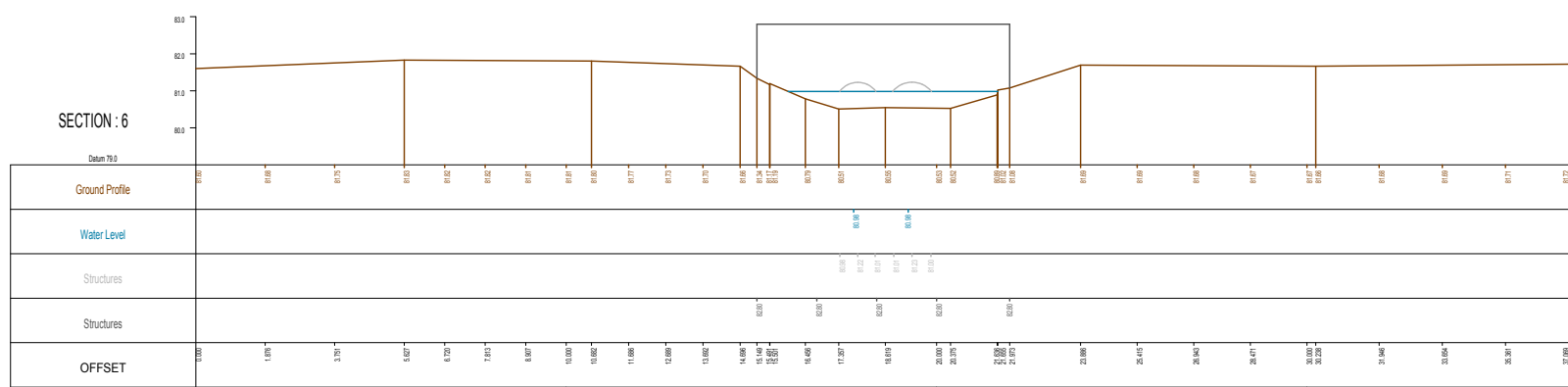
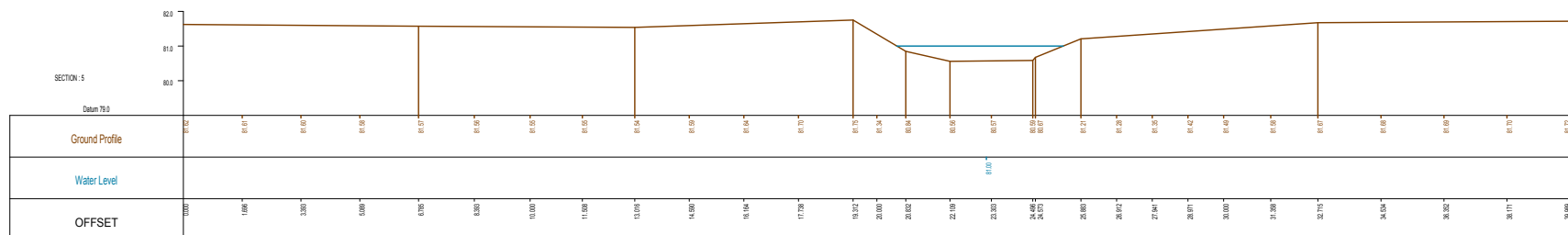
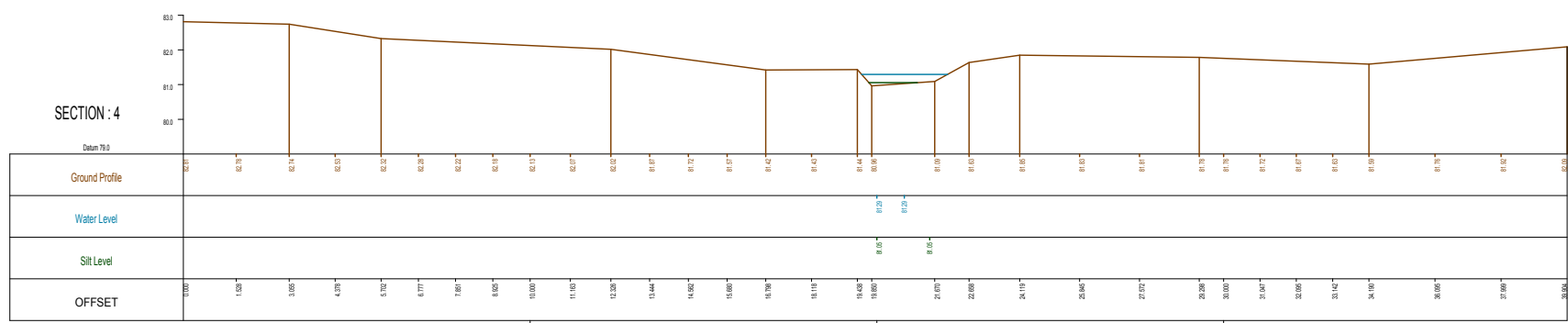
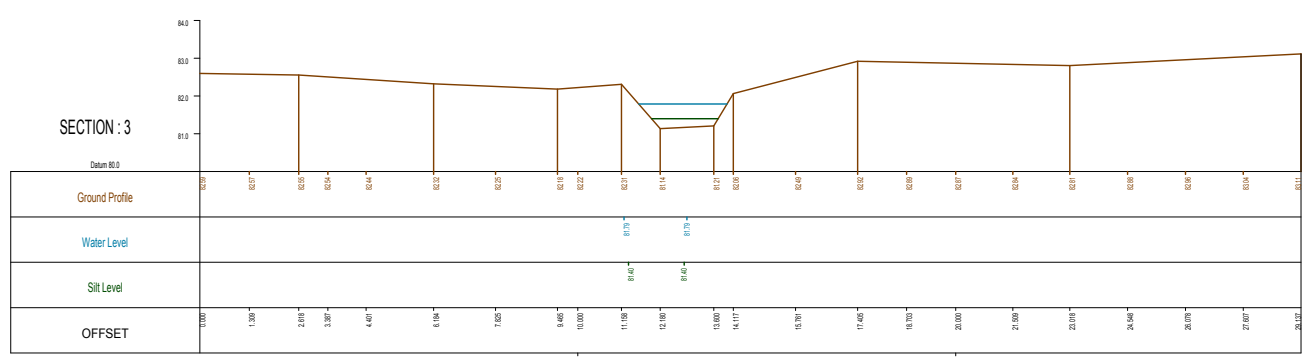
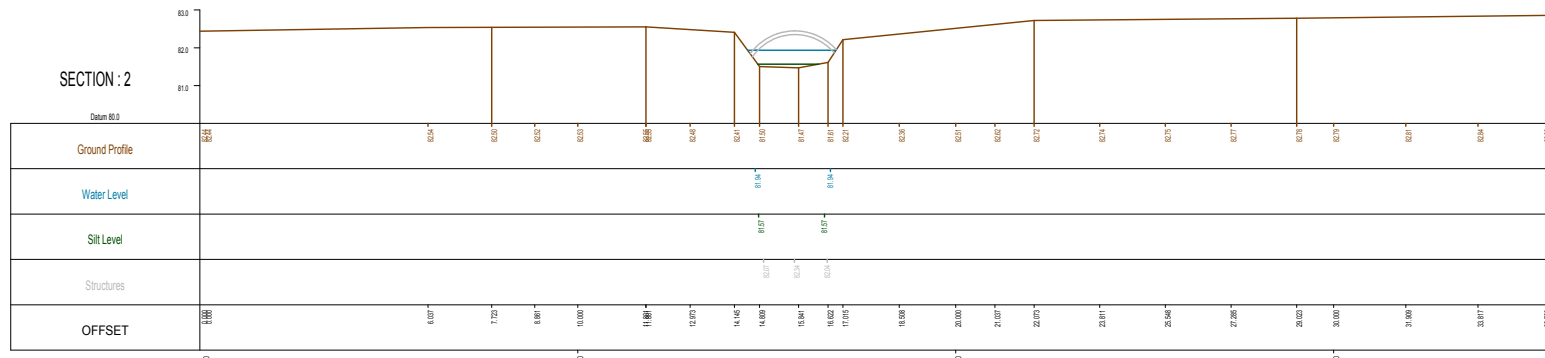
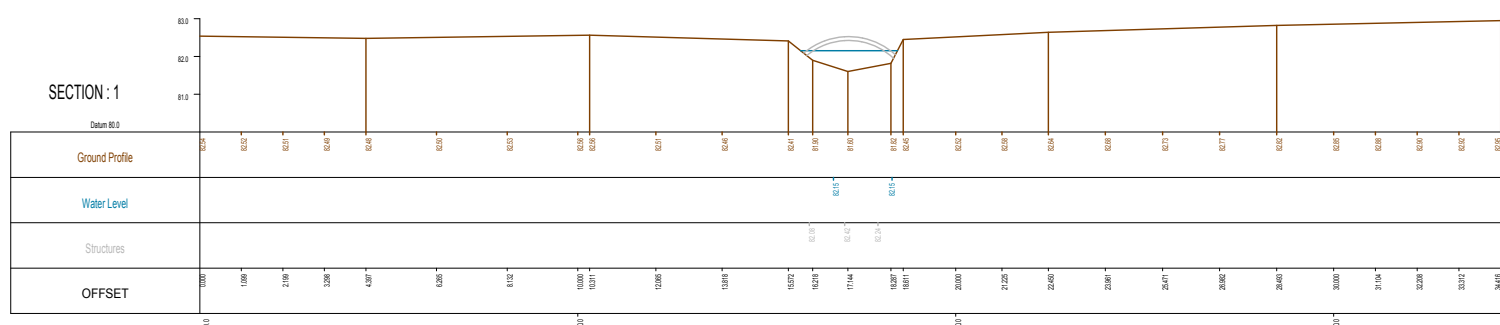
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Comments
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Rev	Date	Description	Drawn	C	Ref

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- ☐ Topographical Surveys
- ☐ Site Engineering
- ☐ Utility / CCTV Surveys
- ☐ Measured Building Surveys
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- ☐ Revit & BIM Models

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CLIENT

West Hart Partnership

PROJECT

Desford Lane, Ratby DE6 0LE

TITLE

Cross Sections

SCALE	DATE
A0@ 1: 200	NOV 2019

DRAWN	QUALITY REF
WA	GH6325

Level datum	OS
Grid orientation	NA

Job number	33962_T_S
Drawing No.	33962_S

Rev.	0
Comments	This plan should only be used for its original purpose. Greenhatch Group accepts no responsibility for this plan if supplied to any party other than the original client.

Notes:

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OS Note:
Some services may have been omitted due to parked vehicles.
The Ordnance Survey tile is to be used as a guide only.

OS Buildings  Surveyed Buildings 

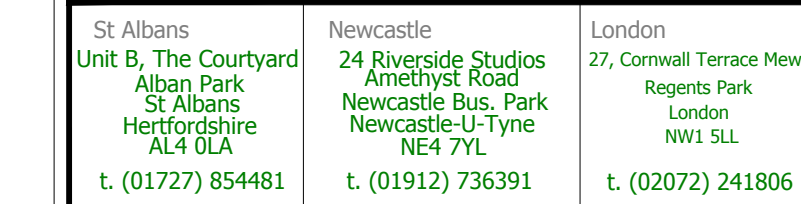
This survey has been orientated to the Ordnance Survey (O.S.) National Grid OSG36(15) via Global Navigation Satellite Systems (GNSS) and the O.S. Active Network (OS Net).

A true OSG36 coordinate has been established near to the site centre via a transformation using the OSTN15GB & OSGM15GB transformation models.

No scale factor has been applied to the survey therefore the coordinates shown are arbitrary & not true O.S. Coordinates which have a scale factor applied.

Please refer to Survey Station Table to enable establishment of the on-site grid and datum.

1	11.11.19	Additions topo/sections	WA	GH632
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CLIENT

**West Hart
Partnership**

PROJE

**Desford Lane
Ratby**

TITLE **Topographical Survey**

SCALE	DATE
A0@ 1: 500	28.06.19

DRAWN	QUALITY REF
JS	GH5391

Level datum	See note
Grid orientation	See note

Job number	33962_T_S	
Drawing No.	33962_T	Rev. 1

Comments

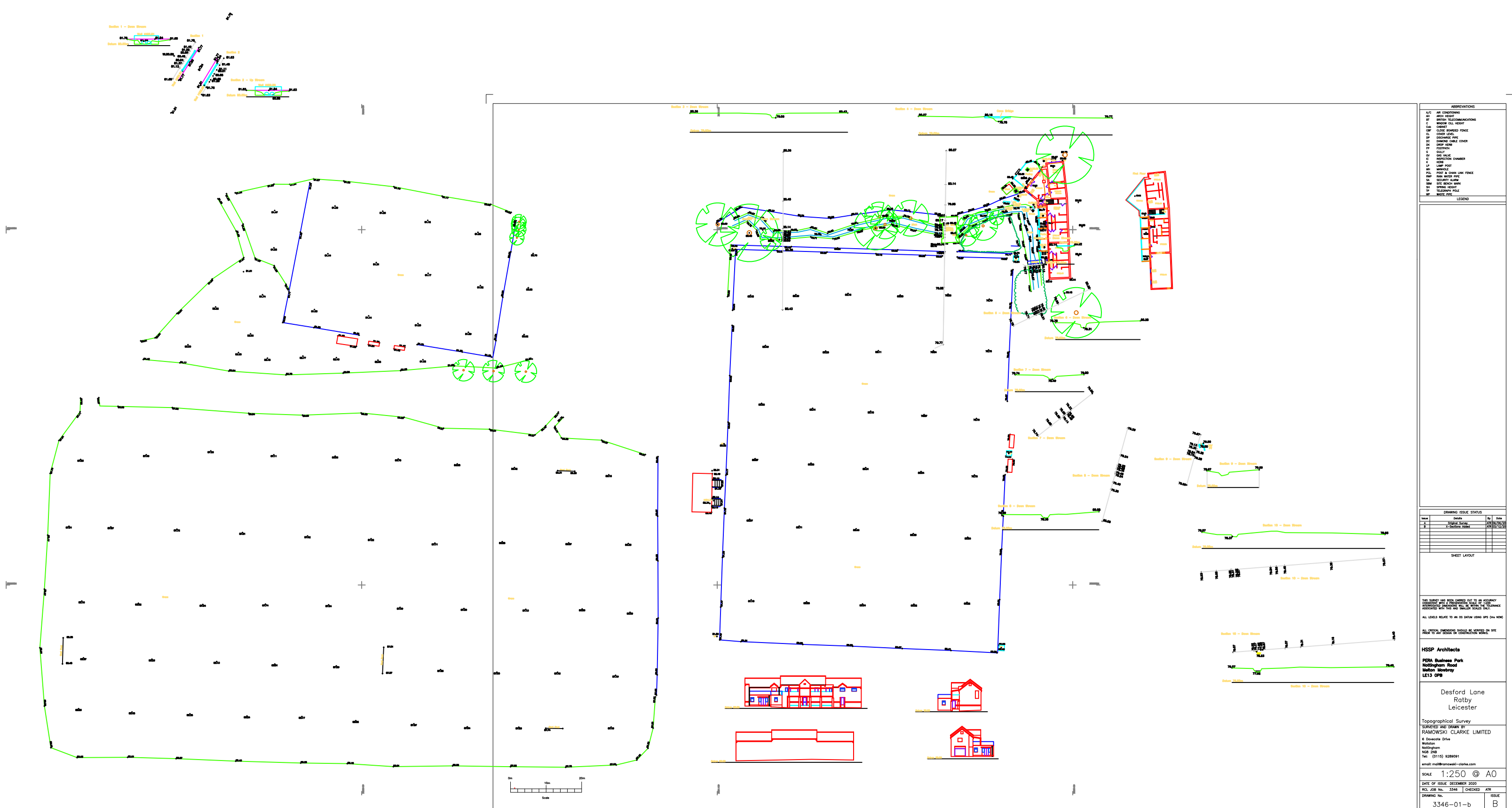
This plan should only be used for its original purpose. Greenhatch Group accepts no responsibility for this plan if supplied to any party other than the original client.

All dimensions should be checked on site prior to design and construction.

Drainage information (where applicable) has been visually inspected from the surface and therefore should be treated as approximate only.

Notes





Appendix C – Hydraulic and Hydrological Assessment

The nearest watercourse to the proposed change of use development is a small arm of Rothley Brook, a tributary of the River Soar. According to the Hinkley and Bosworth 2019 Strategic Flood Risk Assessment (SFRA) Rothley Brook poses a fluvial risk to a number of properties within the village of Ratby. The small arm of the Rothley brook crosses Desford road upstream of the site via a double arch culvert and then remains essentially an open channel with the exception of two small pedestrian crossings immediately upstream and adjacent to the development site.

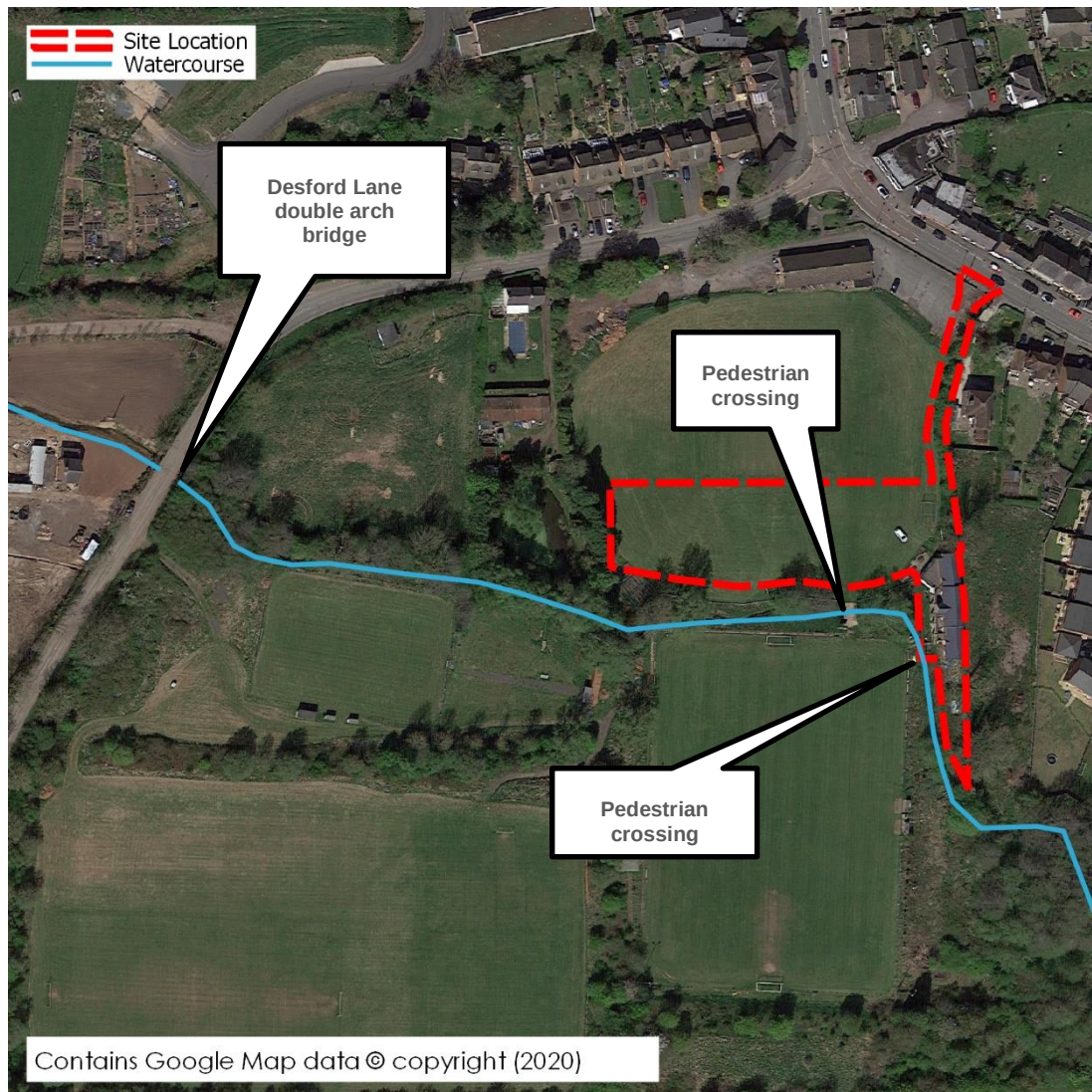


FIGURE 10: MAP SHOWING ROUTE OF THE WATERCOURSE



FIGURE 11: UPSTREAM SECTION OF THE WATERCOURSE, BEFORE DOUBLE ARCH CULVERT



FIGURE 12: DOUBLE ARCH CROSSING AT DESFORD LANE



FIGURE 13: STRETCH OF WATERCOURSE DOWNSTREAM OF DOUBLE ARCH CROSSING



FIGURE 14: FIRST PEDESTRIAN CROSSING APPROXIMATELY 25M UPSTREAM OF SITE



FIGURE 15: CROSSING ADJACENT TO THE SITE.



FIGURE 16: STRETCH OF WATERCOURSE ADJACENT TO THE SITE

The purpose of this work is to estimate the peak flows for the catchment relevant to the development site. The calculated flows have been used to model flood levels at the site.

FEH statistical method

A catchment area and associated descriptors were obtained from the FEH Web Service for a location on the downstream side of the site shown below in Figure 17 and Figure 18.

As there is no gauged data available for the watercourse under consideration the 'single site' and 'enhanced single site' analysis methods are not possible. Consequently the 'pooled method' was used.

QMED was estimated from the FEH web service catchment descriptors using the latest methodology captured in WINFAP 4.

$$QMED_{\text{rural}} = 1.507\text{m}^3/\text{s}$$

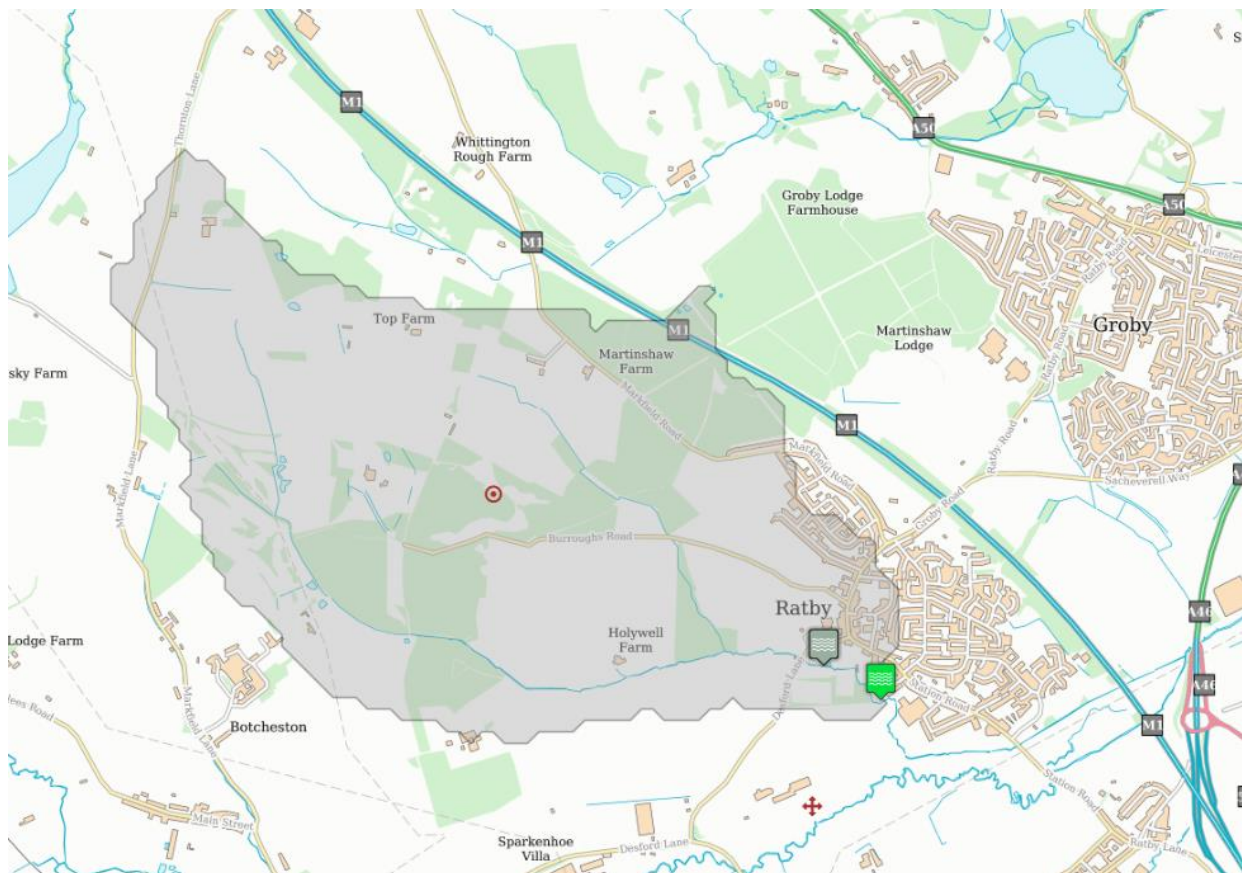


FIGURE 17: FEH WEB SERVICE, CATCHMENT AREA

Outlet	451300, 30541
NGR	SK 51300 054
Area	5.18 km ²
Altbar	118 m
Aspbar	143 degrees
Aspvar	0.48
Bfihost	0.328
Bfihost19	0.335
CentroidEasting	449,606 m
CentroidNorthing	306,362 m
Dplbar	2.53 km
Dpsbar	44.70 m/km
Farl	1.0000
Fpext	0.0299
Fpdbar	0.247 cm
Fploc	0.715
Ldp	5.10 km
Propwet	0.300
Rmed1H	11.0 mm
Rmed1D	31.3 mm
Rmed2D	39.5 mm
Saar6190	675 mm
Saar4170	693 mm
Sprhost	42.18 %
Urbconc1990	0.7610
Urbext1990	0.0244
Urbloc1990	0.3360
Urbconc2000	0.8040
Urbext2000	0.0342
Urbloc2000	0.4000
CatchmentRainC	-0.027
CatchmentRainD1	0.358
CatchmentRainD2	0.350
CatchmentRainD3	0.252

FIGURE 18: CATCHMENT DESCRIPTORS

The derived QMED value was adjusted using the latest donor site procedure (using the top 6 donor sites identified with WINFAP 4).

A pooling group was created from all available gauging stations (omitting those tagged as unsuitable for QMED and pooling), with in excess of 500 years of records.

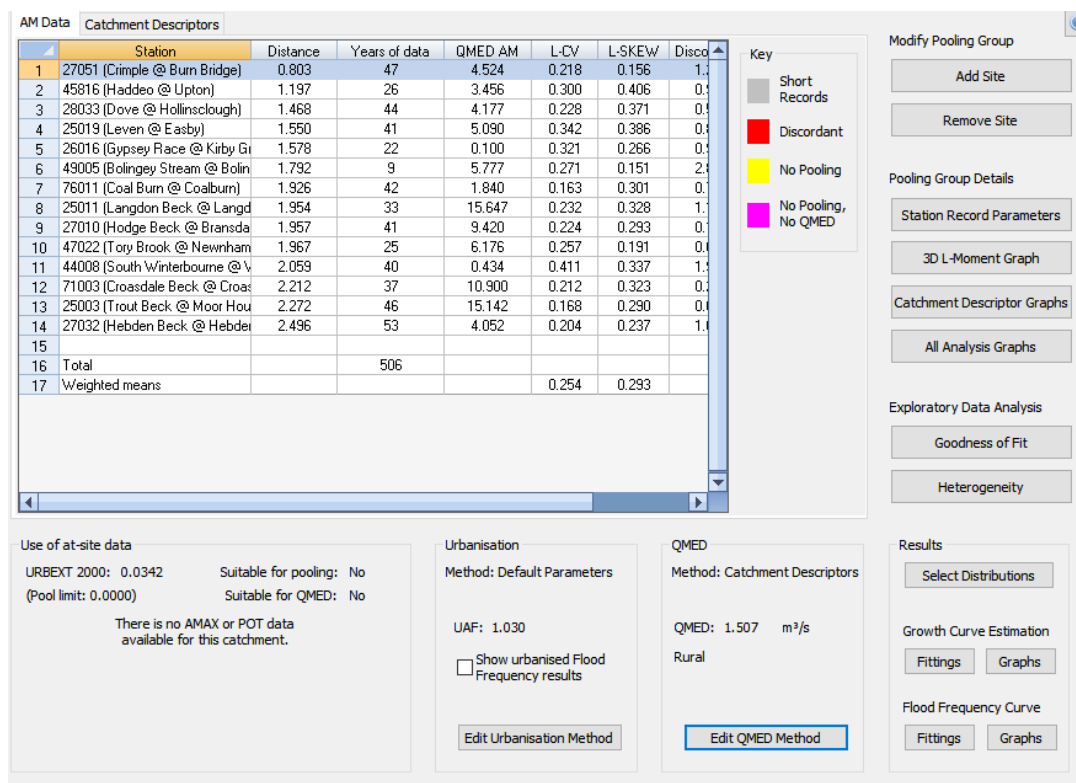


FIGURE 19: POOLING GROUP

A growth curve was produced from the pooling group using a Generalised Logistical distribution and applied to QMED to give a flood frequency curve, given in Table 4.

TABLE 4: FEH STATISTICAL METHOD FREQUENCY CURES

Annual exceedance probability (AEP)	Peak flood flow rate (m ³ /s)			
	Stat method (derived from catchment descriptors)		Stat method (donor adjusted)	
	No urban adjustment	With urban adjustment	No urban adjustment	With urban adjustment
50%	1.51	1.55	1.37	1.41
10%	2.66	2.72	2.42	2.48
5%	3.26	3.33	3.01	3.03
2%	4.23	4.32	3.85	3.93
1%	5.14	5.26	4.68	4.79
1%+CC(30%)	6.68	6.84	6.08	6.23
1%+CC(50%)	7.71	7.89	7.02	7.19

Revitalised FSR/FEH rainfall runoff method

The catchment descriptors, as shown above, were entered into the FEH ReFH2 software package, using default model parameters. The default 30-min timestep and 6.5-hour rainfall duration were used. The flood frequency curve from the ReFH2 method is given in Table 5 below.

TABLE 5: REFH2 FLOOD FREQUENCY CURVES

Annual exceedance probability (AEP)	Peak flood flow rate (m ³ /s)
	ReFH2 method - Rural
50%	2.41
10%	3.69
5%	4.32
2%	5.38
1%	6.53
1%+CC(30%)	8.49
1%+CC(50%)	9.79

The statistical method is generally the preferred approach for estimating flood frequency curves as it is based on a much larger data set of flood events compared to the other methods.

However, the ReFH2 method has been chosen in this instance as it provides the most conservative estimate compared to the statistical method, given there is no gauge information with which to calibrate / validate the model.

The rural flows have been used as the catchment is essentially rural.

Hydraulic modelling

The hydraulic modelling was developed using Flood Modeller Pro / TUFLOW. The model included a 600m stretch of the adjacent watercourse. The upstream extent of the model was 450m north-west of the site and the downstream extent was 150m south-east of the site. Given the nature of the study area, and the potential for out of bank flooding a combined 1D-2D hydrodynamic model was selected as the most appropriate method to estimate flood risk to the site.

The topography of the watercourse was assessed via a river cross section survey (Appendix B). In addition, 1m resolution LiDAR has been used to provide the topographic data for the floodplain. Figure 20 **Error! Reference source not found.** shows the model schematisation.

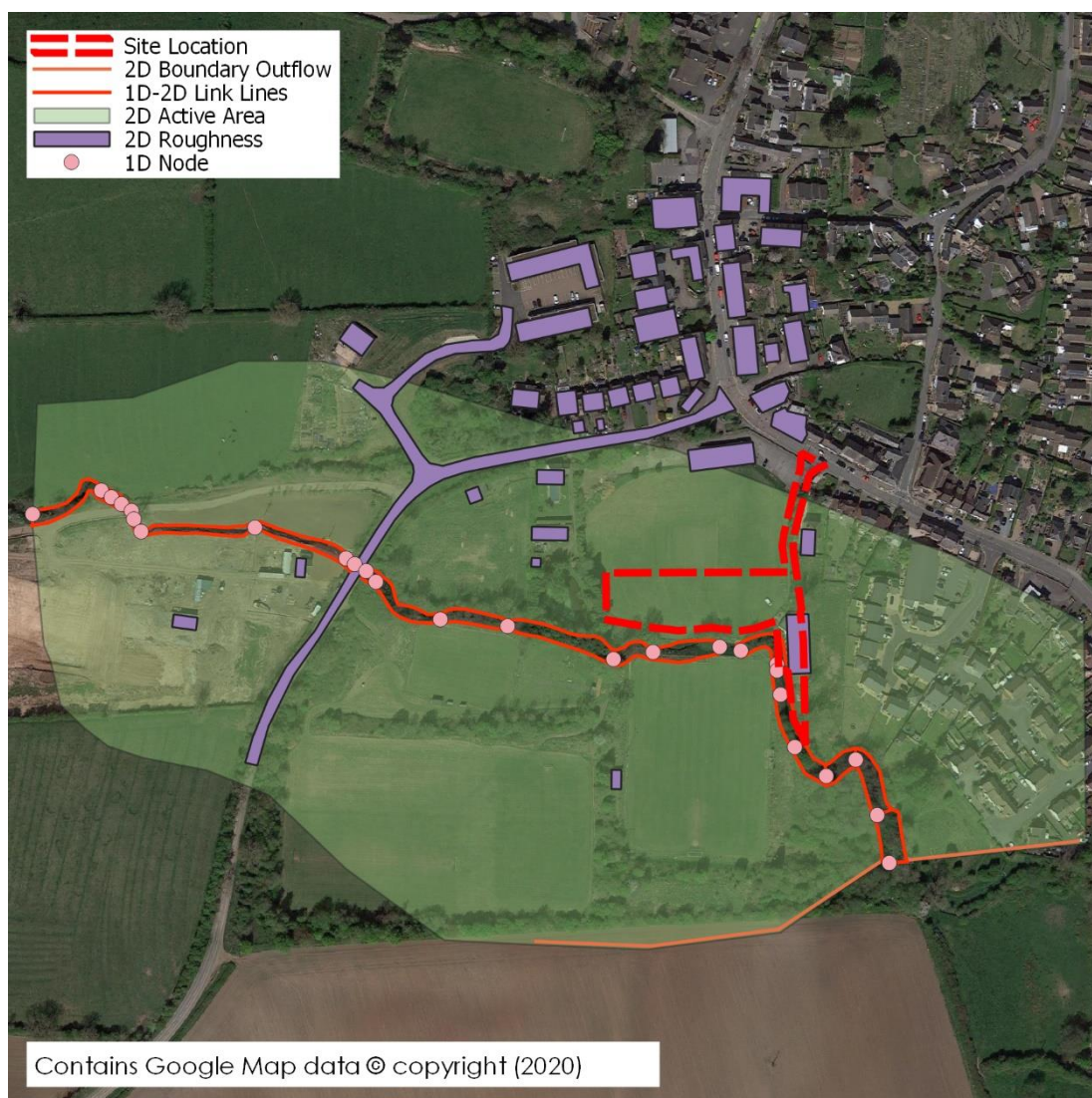


FIGURE 20: MODEL SCHEMATISATION

The river channel and floodplain were assigned a roughness value with reference to standard values (Chow, V.T, 1959, Open-Channel hydraulics, New York: McGraw-Hill). A variety of Manning's 'n' values were assigned for different sections of the channel and floodplain. In-channel sections of the watercourse were assigned a Manning's value of 0.035 (clean, straight, full stage, no rifts or deep pools, with stones and weeds – see Figure 14 for general channel condition), whilst a value of 0.015 was used for culvert / bridge structures. Manning's n values in the flood plain were zoned. A roughness shape file was used to represent

the varying surface types within the 2D area where flooding occurs. The manning's n roughness values applied are summarised in the Table below.

TABLE 6: MANNING'S N ROUGHNESS VALUES APPLIED

Surface Type	Roughness
Buildings	0.50
Road	0.02
General	0.04

A model grid size of 1m was selected to provide adequate representation of all flow paths. Link lines were used to connect the 1D and 2D elements. The link lines were set along the bank tops using data extracted from LiDAR. Inflow to the model was provided by a flow time boundary at the start of the model. The inflow hydrographs were based on the ReFH2 hydrograph shape. The flows before and after the peak were slightly increased in order to prevent low flows / the channel running dry, which improved the model stability.

The downstream boundary was represented by a Normal Depth boundary unit. The time-steps for the linked model runs were set at 1D = 0.25s and 2D = 0.5s. All culverts were assumed to be unblocked in all but the blockage scenario, where the impact of a partial blockage on the two nearby crossings was investigated. Model sensitivity testing was also undertaken, in line with best industry practice guidelines.

A hydraulic model review checklist is included at the end of this Appendix which outlines key parameters and choices made within the model.

Model Results Analysis

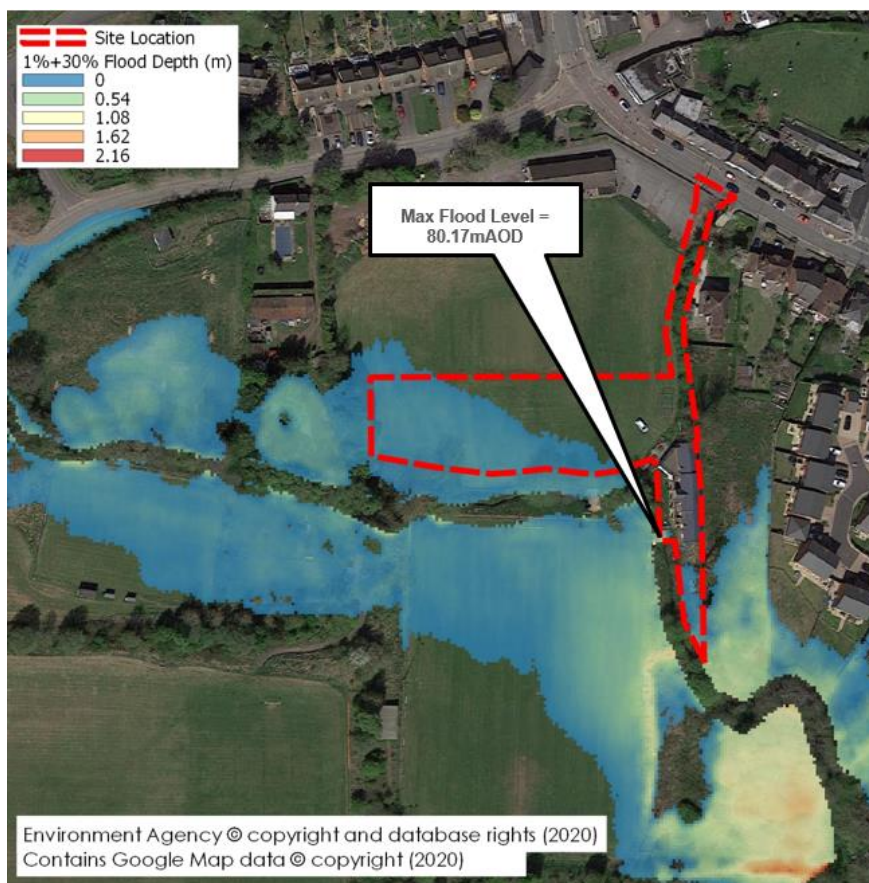


FIGURE 21: MAXIMUM FLOOD EXTENT OF THE 1% PLUS CLIMATE CHANGE (30%) FLOOD EVENT

Figure 21Figure 5 shows the maximum flood extent at the proposed site during the 1%AEP plus (30%) climate change design flood. As can be seen a large proportion of the surrounding area is expected to flood, although the building itself is expected to remain dry. Both the left and right bank of the water course experience flooding, although more extensive flooding is present on the right bank, which is expected given that this land is topographically across this bank. The mechanism of flooding is simply that the channel capacity is exceeded. Comparing the modelled flood levels with the topographic survey shows that building is expected to remain dry. The threshold level of the existing building is 81.00mAOD, which is 0.83m above the peak flood level at closest approach to the building.

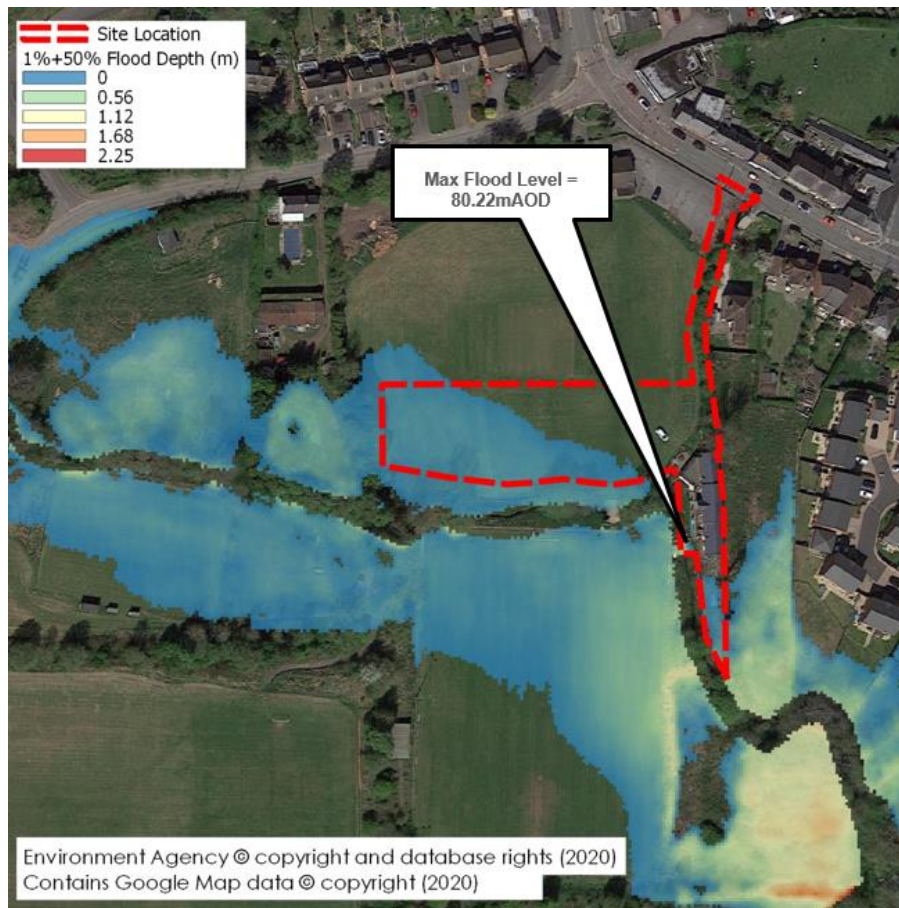


FIGURE 22: MAXIMUM FLOOD EXTENT OF THE 1% PLUS CLIMATE CHANGE (50%) FLOOD EVENT

Figure 22 shows the maximum flood extent for the 1%AEP flood extent with a more onerous estimation of climate change (plus 50%) the mechanism of flooding is the same as before, but a small increase in extent is observed given the increase in flows. Comparing the modelled flood levels with the topographic survey once again shows that building is expected to remain dry. The threshold level of the existing building is 81.00mAOD, which is 0.78m above the peak flood level at closest approach to the building.

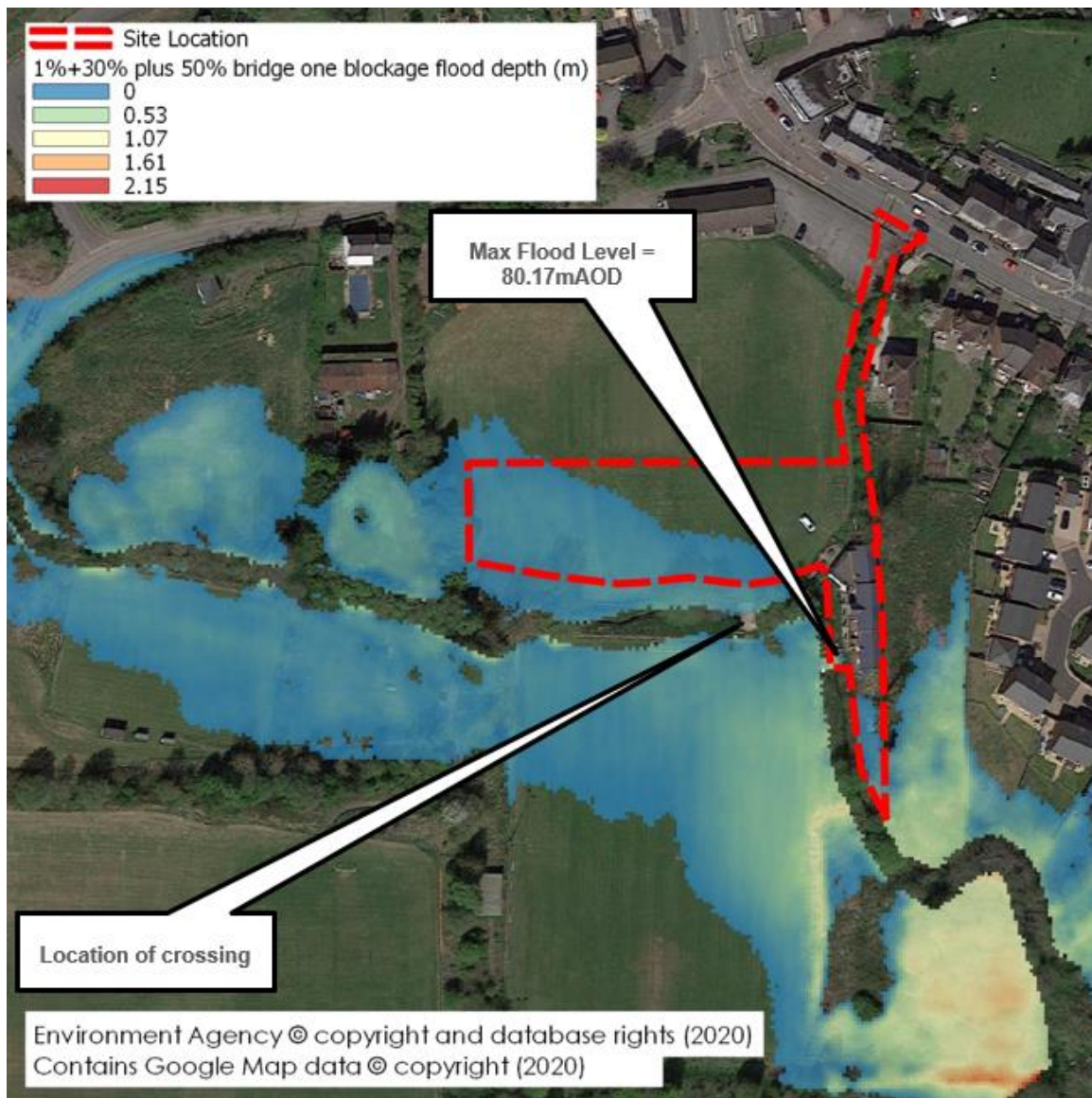


FIGURE 23: MAXIMUM FLOOD EXTENT OF THE 1% PLUS CLIMATE CHANGE (30%) PLUS FIRST PEDESTRIAN BRIDGE BLOCKAGE (50%) FLOOD EVENT

Figure 23 above shows the modelled flood extent with the capacity of the first pedestrian crossing is reduced by 50% (see Figure 2). It can be seen that a reduction in capacity has very little impact on the flood extent both to the development and surrounding area. The flood level at the proposed building sees no increase when compared to the baseline scenario, indicating that the finished floor level is still 0.83m above the peak flood level at closest approach. Flood levels on the left and right bank immediately adjacent to the crossing do see a small increase of typically 0.03m, although this increased flood level is only recorded approximately 25m upstream. The minor impact of blockage on this crossing is not surprising given that there no structure to impede flow across the deck.

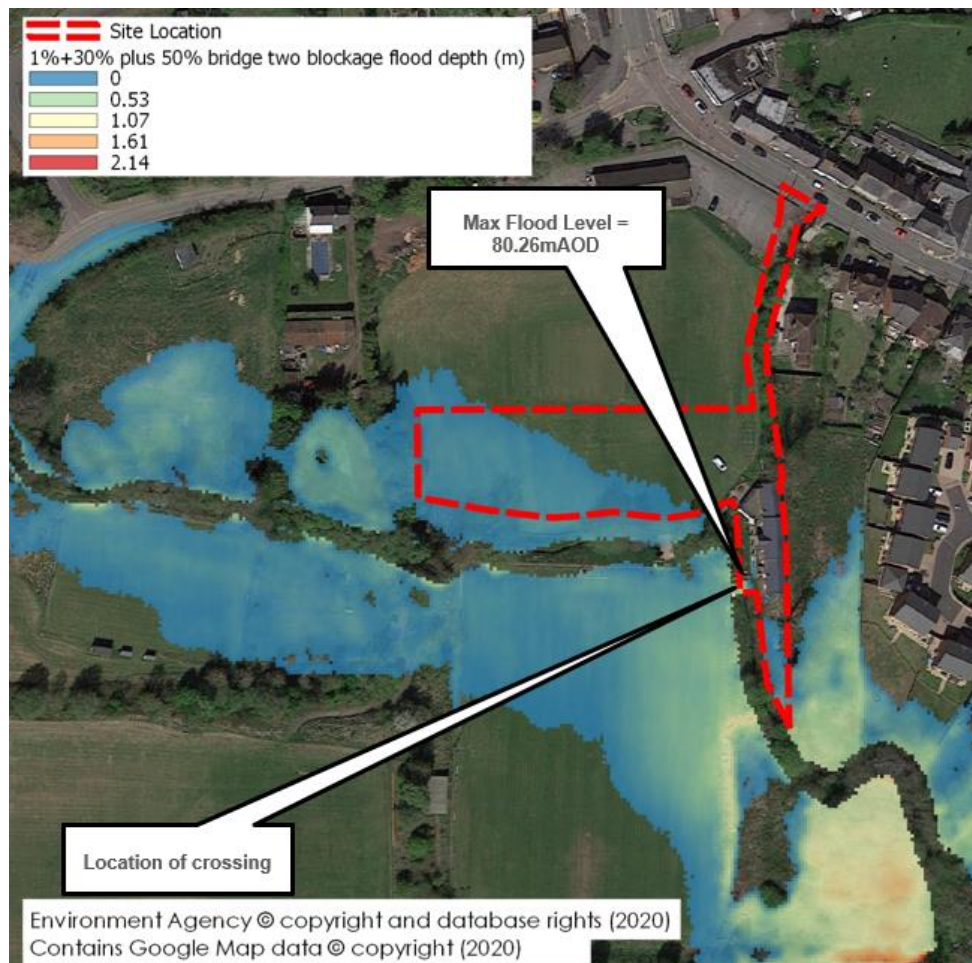


FIGURE 24: MAXIMUM FLOOD EXTENT OF THE 1% PLUS CLIMATE CHANGE (30%) PLUS SECOND PEDESTRIAN BRIDGE BLOCKAGE (50%) FLOOD EVENT

Figure 24 above shows the modelled flood extent with the capacity of the second pedestrian crossing reduced by 50% (see Figure 3). Again, we can see that the flood extent for the surrounding land is largely unchanged. The constriction at this structure does drive a slightly higher flood level across the adjacent land, however the proposed building is still expected to remain dry with the finished floor level of the building still 0.74m above the peak flood level at closest approach. Flood levels on the right bank also slightly increase by approximately 0.06m adjacent to this crossing. As before this is a very localised increase with no effects change in flood levels recorded beyond 25m upstream.

Model Calibration

There are no NRFA FEH gauges at this location and no quality flow / level data from which the model can be formally calibrated.

Uncertainty of results will be judged mainly based on sensitivity testing.

Model Sensitivity

In the absence of formal calibration, the model performance will be assessed by sensitivity testing. Sensitivity testing is the process of adjusting key parameters within the hydraulic model to assess the impact on the modelled outcome. The main parameters tested are:

- Manning's 'n' increased by 20% globally
- Manning's 'n' decreased by 20% globally
- Downstream boundary decreased
- Downstream boundary increased

All sensitivity tests were run with the 1% AEP + CC (30%) scenario.

TABLE 7: MODELLED SENSITIVITY RESULTS

Modelled scenario	Flood level at point (mAOD) (location shown in Figure 25)
1% AEP + CC (30%)	80.17
1% AEP + CC (50%)	80.22
1% AEP + CC (30%) & downstream boundary decreased (20%)	80.17
1% AEP + CC (30%) & downstream boundary increased (20%)	80.17
1% AEP + CC (30%) & manning's decreased (20%)	80.17
1% AEP + CC (30%) & manning's increased (20%)	80.17
1% AEP + CC (30%) & 50% blockage of first crossing	80.17
1% AEP + CC (30%) & 50% blockage of second crossing	80.26

Table 7 presents a summary of peak flood levels at a representative point within the site (see Figure 25 below), from which a comparison can be made in order to judge sensitivity.

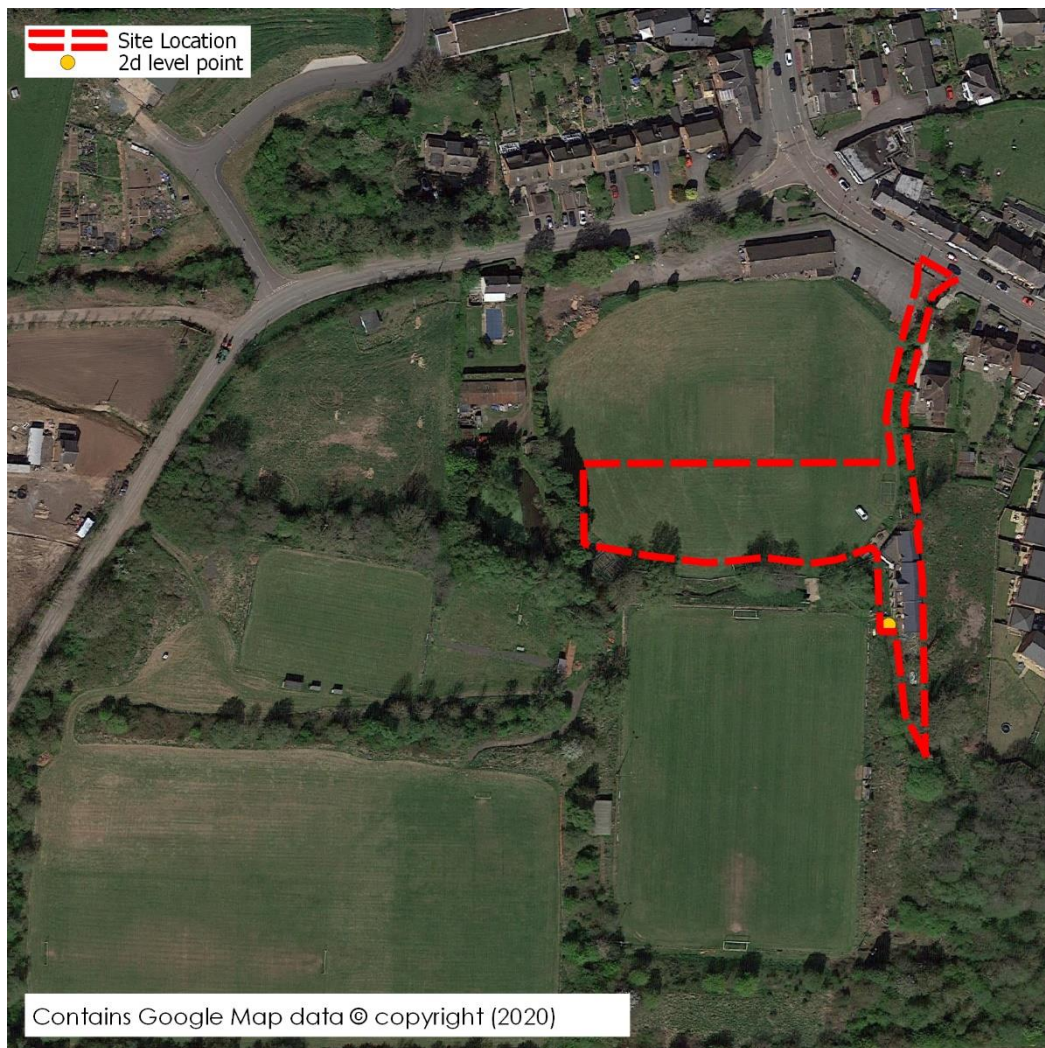


FIGURE 25: LOCATION AT WHICH LEVEL OF WATER WAS ANALYSED DURING SENSITIVITY TESTING

Manning's 'n'

As a result of both increasing and decreasing Manning's 'n' by 20%, there was no change in the peak water level. Minor changes in level are sometimes recorded when modifying the Manning's 'n', as this influences the flow profile of the channel and overland flows. The unchanged peak flood level suggests that the model is not particularly sensitive to choices relating to Manning's n roughness. This indicates that a reasonable level of confidence can be given to the results used in the report.

Downstream boundary

Normal depth is the depth of flow in a channel or culvert when the slope of the water surface and channel bottom is the same and the water depth remains constant. In Flood Modeller, the Normal Depth Boundary (NCDBDY) unit is a downstream boundary which automatically generates a flow-head relationship based on section data; it applies a normal depth from the Manning's equation. Both decreasing and increasing the gradient made no change to the modelled flood levels. This shows the model has very low sensitivity to downstream boundary condition.

Hydraulic Model Review Checklist

General Information and Modelling Approach	
Item	Comments
General Information & Modelling Approach	
Software choice?	Flood Modeller Pro / TUFLOW
Modelling Approach?	1D-2D linked
Modelling Scenarios Used?	• 1%+30% CC • 1%+50% CC • 1% AEP + CC (30%) & downstream boundary decreased (20%) • 1% AEP + CC (30%) & downstream boundary increased (20%) • 1% AEP + CC (30%) & manning's decreased (20%) • 1% AEP + CC (30%) & manning's increased (30%) • 1% AEP + CC (30%) & 50% blockage of first pedestrian crossing • 1% AEP + CC (30%) & 50% blockage of second pedestrian crossing
1D Model / Network	
How have roughness values been determined?	Roughness values have been chosen based on visual inspection from provided images.
Are all structures included or exclusions documented?	Yes – In line with provided survey and visual inspection
Are spill units included?	Yes
Is the model geo-referenced?	Yes
Have bank / bed markers been used?	Yes
1D Boundary Conditions	
What 1D Boundaries have been applied?	Flow Time Boundary & Normal Downstream Boundary
Has an appropriate location been chosen for the downstream model extents?	Yes. The downstream boundary is 150m south east of the site, which is far enough away to have minimal impact. (As verified by the sensitivity results).
1D structures	
Are all structures included or exclusions documented?	Yes – In line with provided survey information and supplied images
1D Run Parameters	
What time step has been used for the 1D model?	0.25 seconds
What initial conditions have been used?	Time 0, Steady State.
Have any of the parameters and advanced parameters been changed from the default. If so, has it been justified?	No changes to default parameters made
2D Model Build	
Number of domains?	One
What dataset has been used to define the DTM elevations?	1m LiDAR
What grid resolution has been used?	1m



How have buildings been represented within the DTM?	Yes – Using roughness shape files.
2D Boundary and Roughness	
Have any boundaries been used in the 2D domain?	Yes – a 2D normal depth boundary outflow
Is the model boundary suitably large?	Yes - the 2D area is large enough to prevent glass walling
What manning's n values have been used to define floodplain roughness?	A 2D shape file has been used to zone the model domain with values detailed in a table given in the model report.
2D Run Parameters	
What time step has been used for the 2D model?	0.5 second
Have initial water levels been applied?	No
What initial conditions have been used?	Time 0, Steady State
Are the other 2D model parameters reasonable	Default setting
1D/2D model Links	
How have the 1D/2D models been coupled?	Using 2D HX / CN link lines.
Have any default link parameters been changed?	No
Model Stability	
What warnings / errors are present on the logs?	No errors or warning that would affect results
Is mass balance within tolerable limits?	Yes, mass error is shown to peak at 1.6% but is typically below 1%.
Does a basic check of animations and graphed outputs give an indication of good model stability?	Yes, animations show no oscillation.
Do the 2D extents / outputs look sensible?	Yes, although no flood history to calibrate results.
Model Sensitivity	
Have appropriate model parameters been chosen for sensitivity testing?	• 1% AEP + CC (30%) & downstream boundary decreased • 1% AEP + CC (30%) & downstream boundary increased • 1% AEP + CC (30%) & manning's decreased (20%) • 1% AEP + CC (30%) & manning's increased (20%)
Do the results of the tests show the models to be particularly sensitive to certain parameters?	No