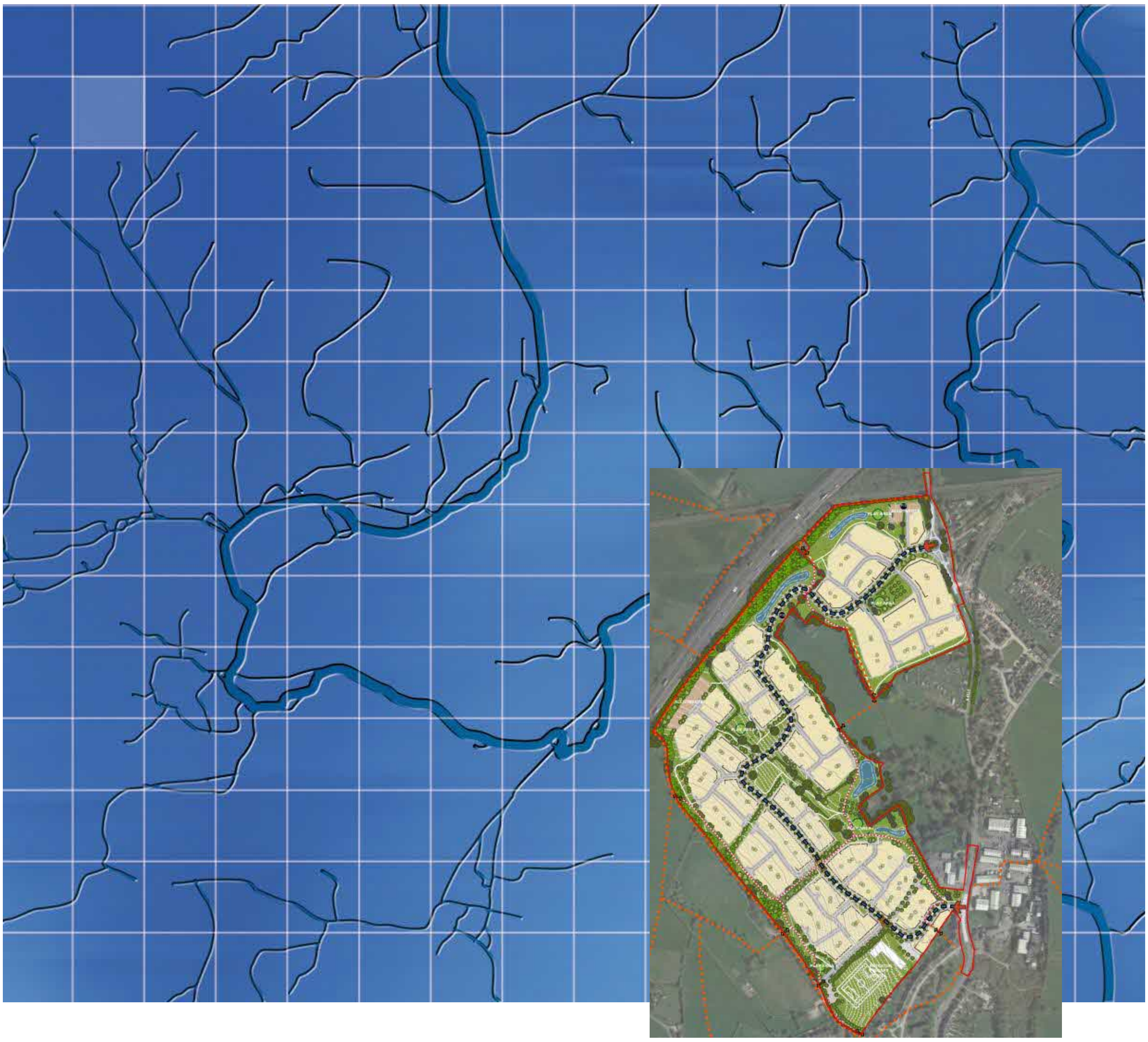
Persimmon Homes and Robert Hitchins

May 2021

Land at Draycott, Cam

Flood Risk Assessment and Outline Drainage Strategy



WHS

Persimmon Homes and Robert Hitchins

Land at Draycott, Cam - Flood Risk Assessment

Document issue details

WHS1714

Version	Issue date	Issue status	[redacted]
1.0	06/11/2020	Draft	
2.0	30/04/2021	Draft	
3.0	07/05/2021	Final	

For and on behalf of Wallingford HydroSolutions Ltd.

CERTIFIED ISO 9001 · ISO 14001 UKAS MANAGEMENT SYSTEMS 001

The WHS Quality & Environmental Management system is certified as meeting the requirements of ISO 9001:2015 and ISO 14001:2015 providing environmental consultancy (including monitoring and surveying), the development of hydrological software and associated training.

WHS

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1 Introduction

1.1 Background

Wallingford HydroSolutions Ltd (WHS) has been commissioned by Persimmon Homes and Robert Hitchins to undertake a Flood Risk Assessment (FRA) in accordance with the National Planning Policy Framework (NPPF). This is required to support our clients' planning applications residential development on a 39ha site, which lies to the west of the A4135 at Draycott, Cam, Gloucestershire (NGR 374468, 201608).

The eastern boundary of the site lies 120m from the River Cam. The dominant flooding mechanism for the site is however pluvial. A review of Environment Agency flood maps indicates that the entirety of the site lies within Flood Zone 1.

This FRA seeks to demonstrate that the proposed development can remain compliant with NPPF for the lifetime of development and that the risk of flooding can be managed to an acceptable level.

1.2 Scope

Due to the site being over 1ha in size, a site-specific FRA is required. This report will fulfil the requirements of an FRA established within the NPPF and is appropriate for submission with the planning application. It also includes recommendations for the management of surface water run-off at the site and a foul sewer strategy for the site.

In summary, this report;

- Collates and analyses environmental and flood risk information obtained from a desk-based review of available data to identify and quantify the flood risks associated with the development.
- Outlines a surface water drainage strategy to manage and discharge the increase in surface water runoff as a result of the development proposal.
- Outlines a foul sewer strategy for the site, with reference to Severn Trent Water communications.

1.3 Sources of Information

The main sources of data used to inform this FRA and drainage strategies include:

- EA Fluvial Flood Mapping – to assess fluvial flood risk to the Site.
- EA Surface Water Flood Mapping – To quantify the pluvial flood risk to the site.
- EA Reservoir Flood Mapping – to assess reservoir flood risk to the Site.
- 1m LiDAR data to map the topography of the Site and surrounding area.
- Topographical survey information for the Site[1].
- Infiltration testing and geological data for the Site[2].

[1] Ruxton Surveys. 2019. Land at Cam, Dursley Site Survey.
[2] Hamson Barron Smith. 2020.

2 Site Description

2.1 Location

The existing site is located at Draycott, Cam, Gloucestershire (NGR 374468, 201608), on land bounded by the A4135 to the east, the M5 motorway to the west, the west-coast mainline to the north and Everside Lane to the south. The site is located on undeveloped agricultural fields, with a few farm buildings to the east. The River Cam flows south to north, at a distance of 120m from the site boundary to the east. A minor watercourse is also located across the M5 from the site, which is connected to drainage ditches within the site, by a culvert under the motorway.

Figure 1 shows the site boundary and location.

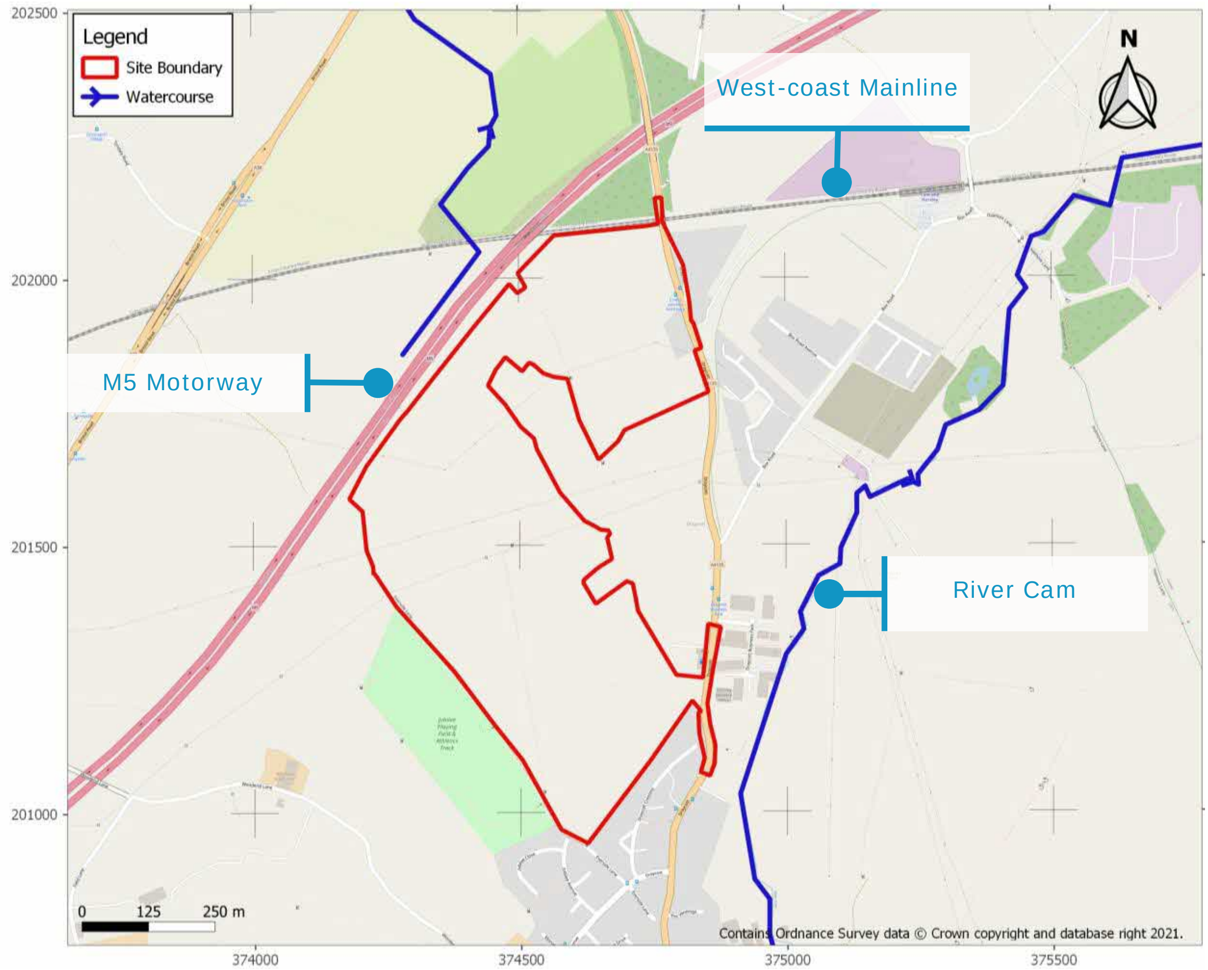

Figure 1 Site Location

2.2 Topography

The topography of the site shows a general fall in elevations from south to north, with maximum elevations along the southwestern boundary at 45mAOD and lowest along the northern boundary adjacent to the railway, at 25mAOD. Figure 2 shows the topography across the site and surrounding area, as indicated by 1m resolution LiDAR data.

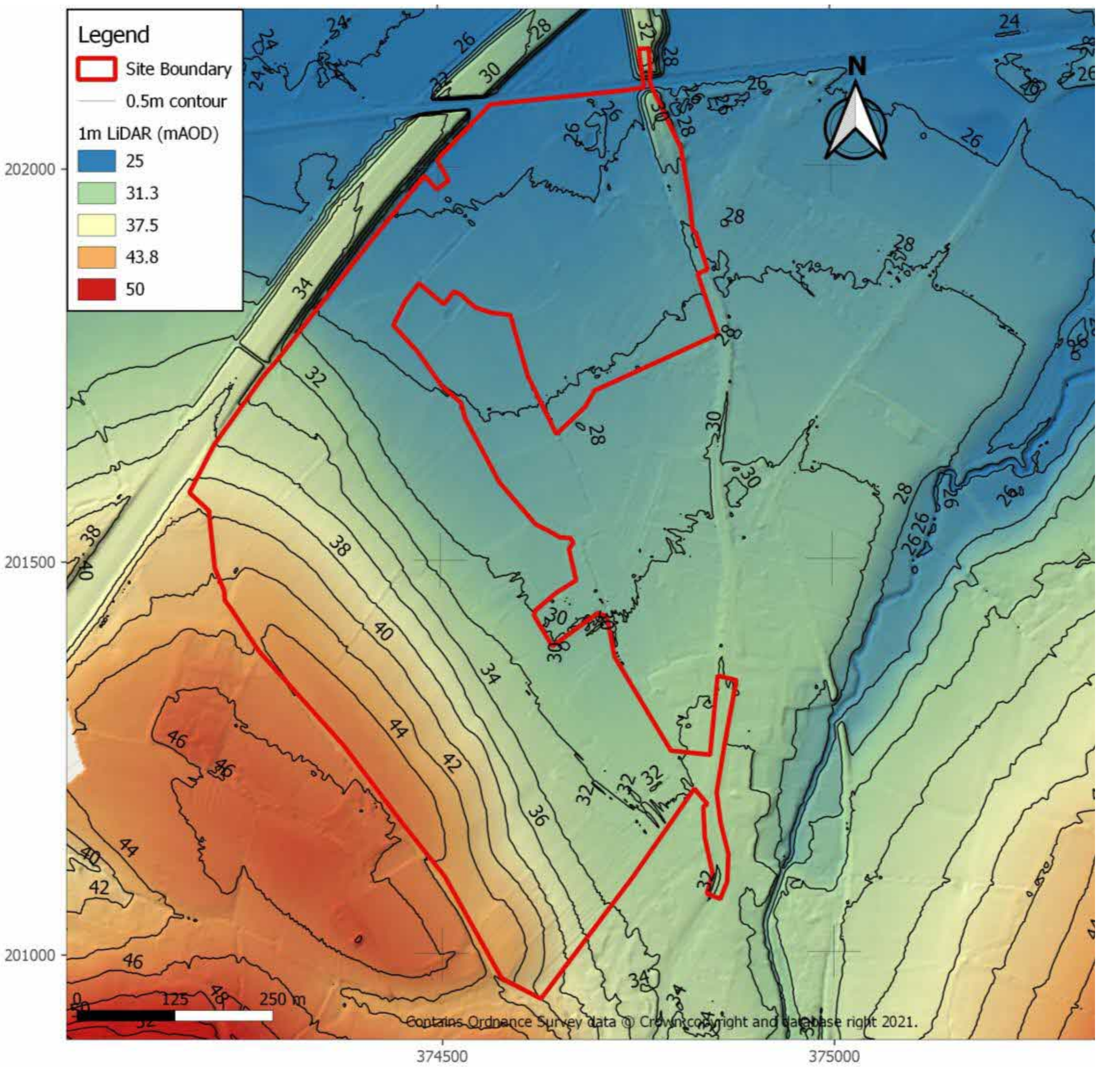

Figure 2 - Site topography

2.3 Proposed Development

An indicative framework plan for the development is shown in Figure 3 which has been provided by the client. It is proposed that up to 1,030 without a school, 950 with a 1.5 form entry primary school. Vehicular and pedestrian access is to be provided via two entrance points along the A4135.

A full resolution site framework plan is provided in Appendix 1.

Figure 3 – Site framework Plan

3 Flood Risk

3.1 Fluvial Flood Risk

To assess the risk of fluvial flooding at the site, the Environment Agency (EA) flood maps were reviewed. The EA flood maps consider the flood risk associated with fluvial and tidal flood events during an undefended scenario, i.e. the presence of the fluvial or tidal defences are not considered. They are based on model data and recorded historical flood outlines where these show a greater extent than the model outputs.

Figure 4 shows the EA flood map, which demonstrates the development site lies outside of both Flood Zone 2 and Flood Zone 3, with less than 1 in 1000-year probability of flooding from rivers. Only the Highways Land to the south-east of the site, lies within Flood Zone 2. The River Cam, located to the east of the site boundary, lies at an elevation approximately 6m lower than the south-eastern spur of the site (closest to the watercourse), which is the nearest area of the site earmarked for development. Due to the relative elevation of the watercourse and the extent of the modelled Flood Zones, the development site is not considered to be at risk from fluvial flooding and thus further analysis from this potential source is scoped out of this assessment.

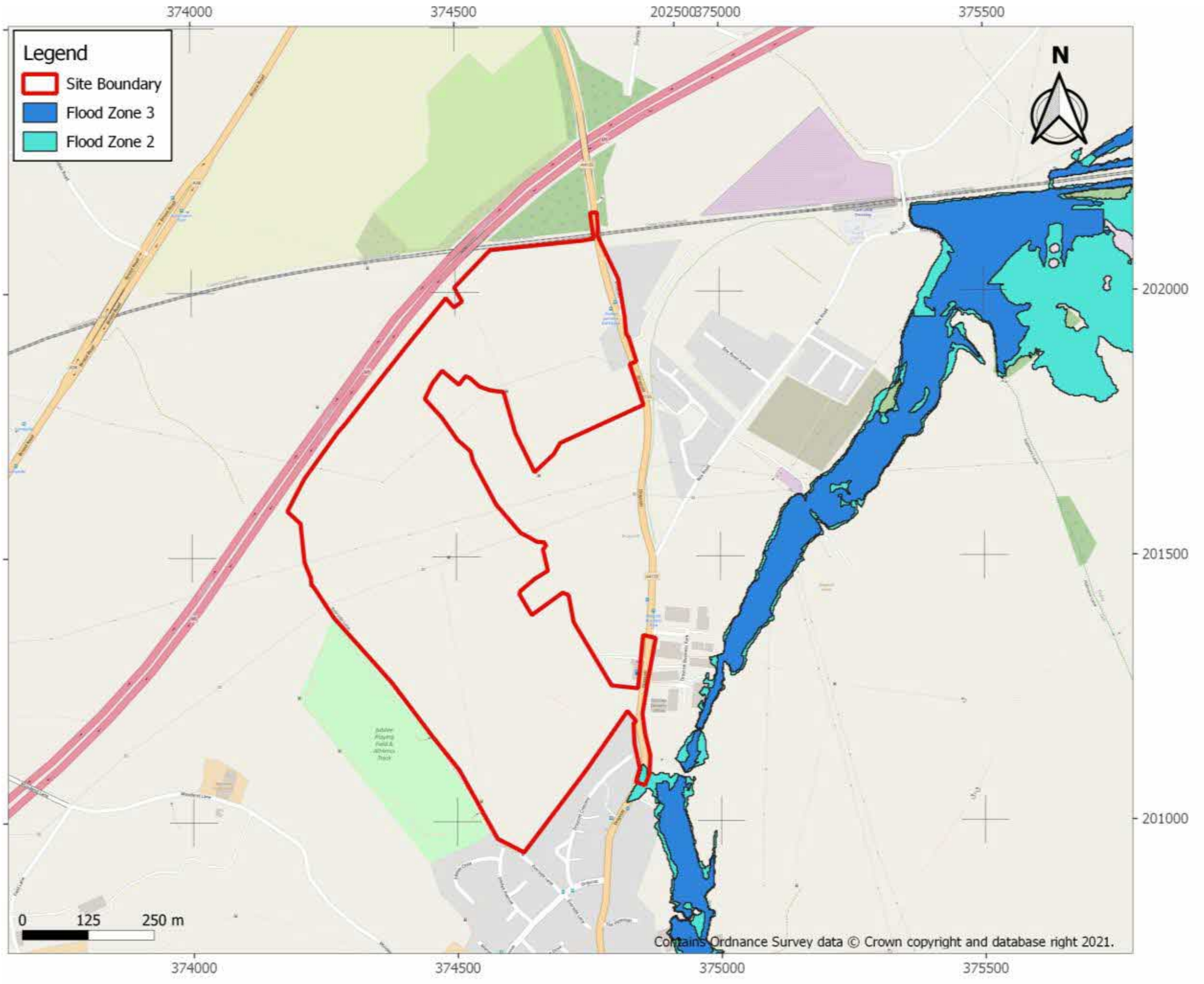

Figure 4 EA Fluvial Flood Map

3.2 Historical Flood Risk

EA online flood maps (given in Figure 5) show there to be no historical flood risk at the site, with the nearest recorded extent of flooding from the River Cam located adjacent to the site boundary on the opposite side of the A4135. Contact has also been made with Gloucestershire County Council for any known historic or current flood risk pertinent to the site. No further information has been provided.

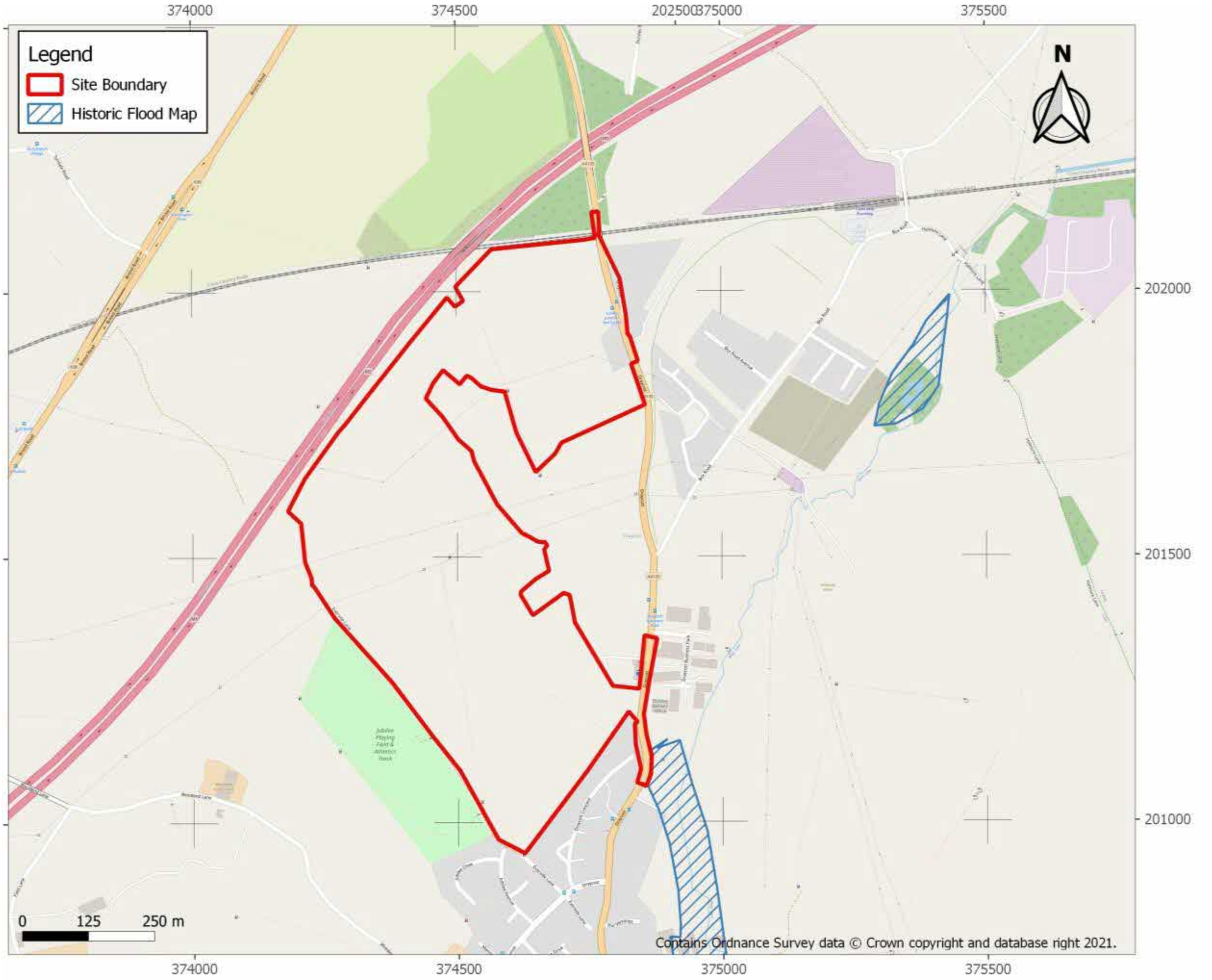

Figure 5 EA Historical Flood Map[3]

[3] EA Historical Flood Map. 2020. Available at: https://data.gov.uk/dataset/76292bec-7d8b-43e8-9c98-02734fd89c81/historic-flood-map Accessed on: 26/03/2020.

3.3 Pluvial Flooding

The risk of surface water flooding has been assessed by reviewing the surface water flood maps published by the EA, shown in Figure 6. The pluvial flood extents show most of the site is not affected by surface water flooding. The gradients across much of the site means that significant ponding of surface water is not likely to occur.

This is except for the northern region, where there is significant ponding occurring against the M5 motorway, extending beyond the railway out of the site boundary to the north. Mapping suggests that this ponding is fed by a minor overland flow route, potentially emanating from outside of the south-eastern boundary of the site. This mechanism may be linked to overland runoff along both the A4135 and from Draycott Crescent, whereupon at the intersection of these roads the flow splits, with some diverted towards the River Cam and a smaller flow route appearing to emerge through the site. It is noted that the surface water modelling is not likely to have included the culvert under the M5, which would convey flow from the site under the M5 towards the watercourse to the north. The current masterplan shows that developments are located away from this worst affected area along the north-western boundary of the site.

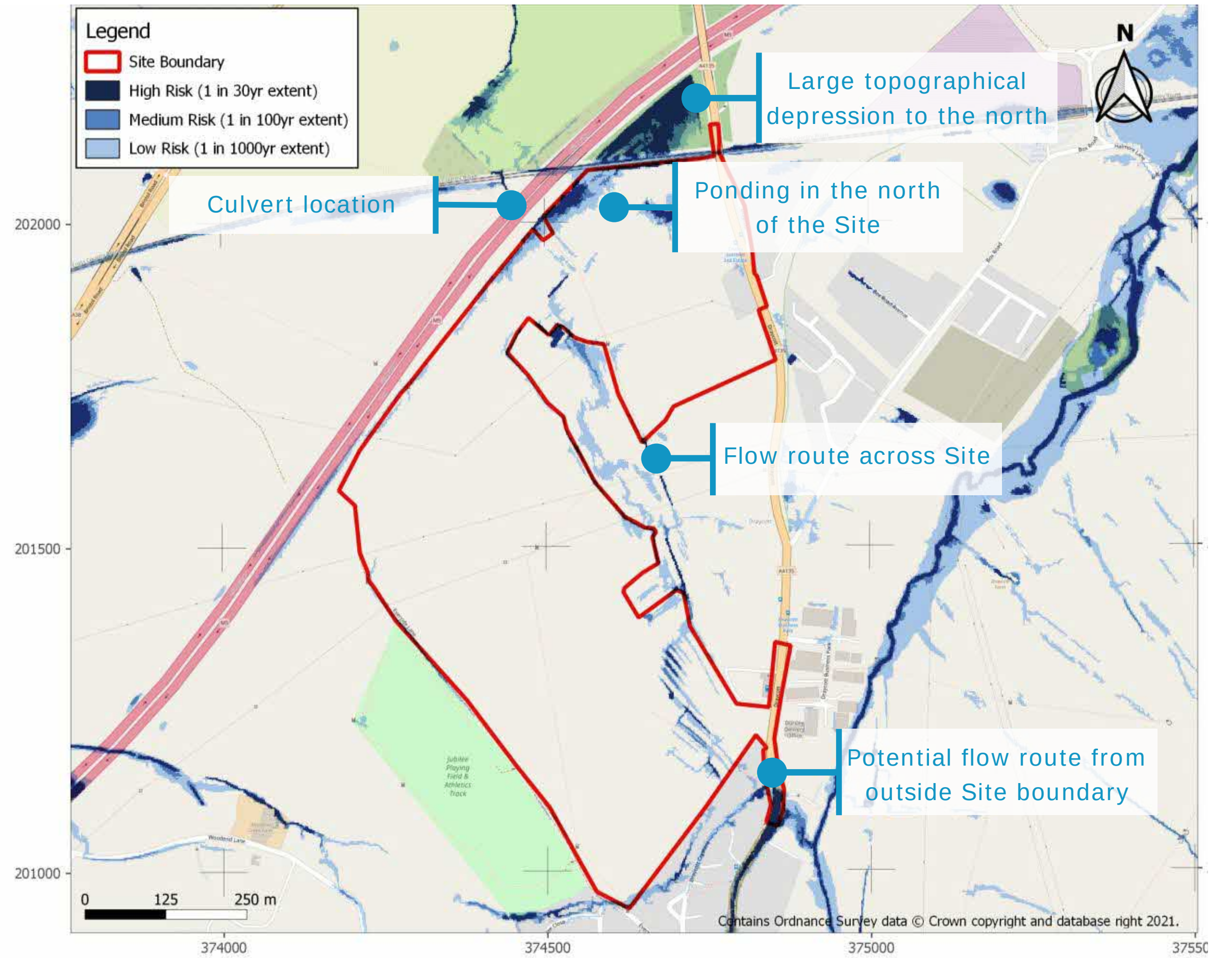

Figure 6 Surface Water Flood Map

It is considered that pluvial flood risk can be suitably managed at the Site with a well-designed drainage strategy based upon conservative assumptions. This is to include measures to intercept the runoff from outside of the site boundary.

3.4 Groundwater Flooding

Groundwater flooding is defined as the emergence of groundwater at ground level. British Geological Survey information shows the site to be underlain by the Charmouth Mudstone Formation, overlain by Cheltenham sand and gravel deposits.

Local borehole information positioned along the route of the M5 motorway dug between 1.5 to 30m depth, confirms the presence of silty clayey soils. Infiltration testing was also undertaken at the site[4]. The samples dug, generally showed a pattern of shallow topsoil up to 0.2m (silty, sandy composition), which is then underlain by a much deeper silty, clay strata, which generally then extends to the depth of the sample (over 3m depth). Just under half of the 14 trial pits dug, indicate that water seepage occurred through the sides of the hole, suggesting a water table of less than approx. 3m depth, below a large part of the site. The shallowest groundwater occurred in the northern areas of the site, in proximity to the M5 motorway.

This information indicates that flooding from rising groundwater is not likely to be an issue at this location.

3.5 Sewer Flooding

The Gloucestershire Level 1 SFRA[5] has been consulted to understand historic sewer related flooding in the region. It indicates that sewer flooding risk across the Stroud region is medium to low. Severn Trent Water sewer records have been provided as part of this assessment.

3.6 Reservoir Flooding

Reservoir flood extents provided by EA reservoir flood mapping[6] show that the site is not at risk.

[4] Hamson Barron Smith. 2020. Cam Draycott.
[5] Halcrow. 2008. Gloucestershire Strategic Flood Risk Assessment Level 1.
[6] Environment Agency. Online, available at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?easting=475189&northing=260342&map=RiversOrSea accessed on: 02/11/2020

3.7 Access/Egress routes

An access/egress route has been identified which is flood free up to and including the 1 in 1000yr event, avoiding the small area of inundation of the A4135 to the south of the site indicated by EA mapping. This is illustrated in Figure 7, which shows a flood free route from the southern site entrance, traversing northwards along the A4135 under the M5 carriageway and then turning left, southbound along the A38.

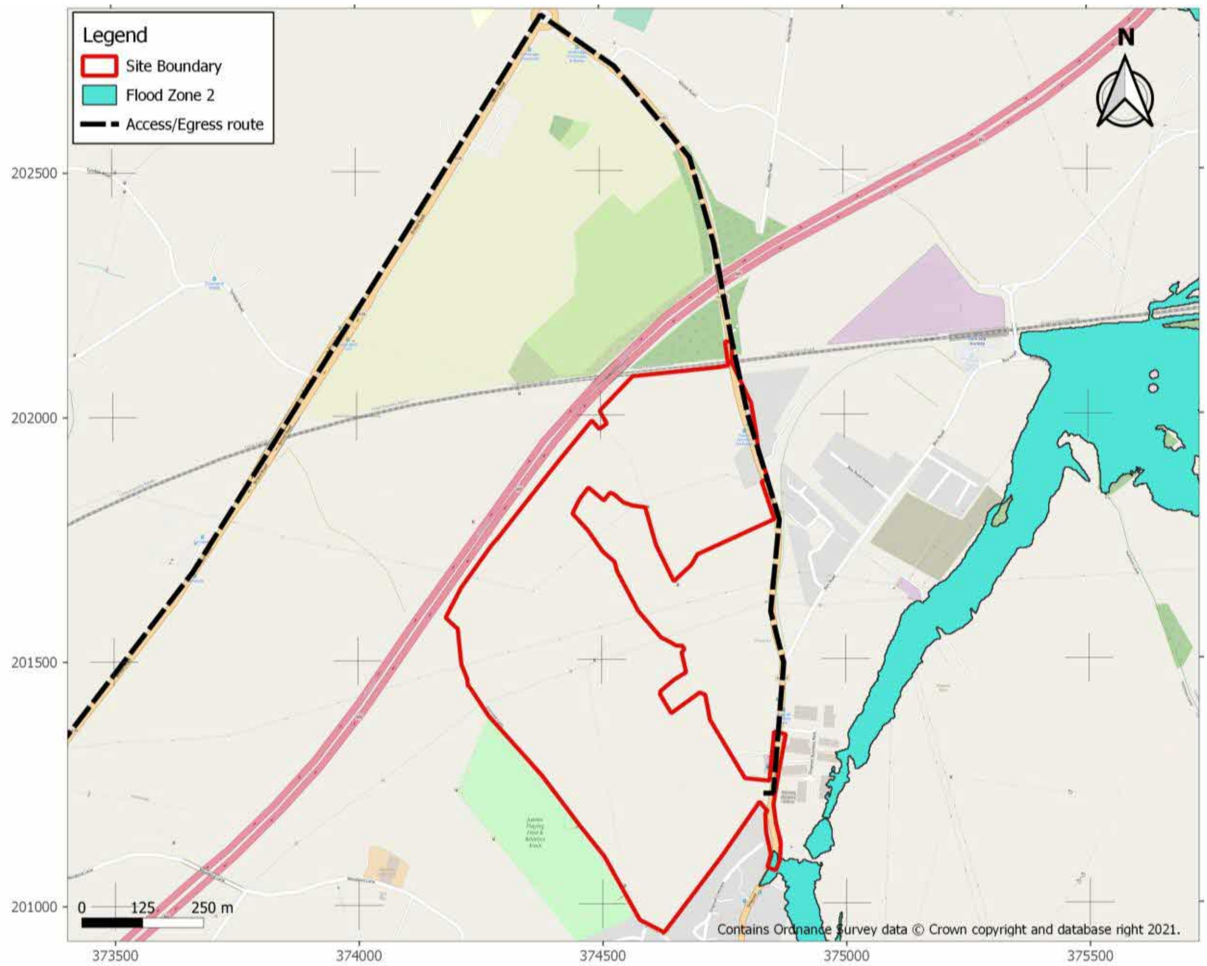

Figure 7 Access/egress route

3.8 Vulnerability Classification and Justification for Development

In terms of flood risk, a residential development is proposed which based on NPPF guidance is classed as 'more vulnerable' infrastructure. As shown in Table 1, more vulnerable infrastructure is appropriate in Flood Zone 1 and 2. The masterplan shows the development to be entirely located within Flood Zone 1 and thus there is no requirement for the application of sequential or exception tests for the development.

Table 1 Flood risk vulnerability and flood zone 'compatibility' extracted from Technical Guidance to NPPF[7]

Flood risk vulnerability classification (see table 2)		Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood zone (see table 1)	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test required	✓	✓
	Zone 3a	Exception Test required	✓	×	Exception Test required	✓
	Zone 3b functional floodplain	Exception Test required	✓	×	×	×

The development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere. Runoff rates from the development will be controlled to greenfield rates.

Access routes have also been assessed for the site and show that safe emergency access and egress is possible, with the entirety of the proposed access/egress route being flood free for the 1 in 1000yr event and above.

[7] Communities and Local Government (2012), Technical Guidance to the National Planning Policy Framework.

4 Management of Surface Water Run-Off

4.1 Planning Requirements

Based on guidance set out in National Planning Policy Framework (NPPF), any development should include measures to manage post development surface water run-off rates.

The following sections provide recommendations for a drainage strategy to both minimise the risk of flooding at the site, and to ensure the development does not increase the risk or magnitude of flooding elsewhere.

4.2 Proposed Land Use

The proposed development consists of up to a 1,030 unit (without a school), or 950 unit (with school) residential development. There will be an increase in the impermeable area within the proposed development site, which if not managed will increase the existing surface water run-off rates. Hence a surface water management strategy is required to reduce the post development rates to existing greenfield rates, thus safeguarding against any increase in third party flood risk.

The current drainage pathways across the site are directed towards the existing field drains which outfall through a culvert to an unnamed watercourse under the M5 carriageway (which marks the western boundary of the site). Flows from the south of the site are directed northwards across the relatively steep topography, which are then intercepted by existing field drains. The north of the site is much flatter, with flows diverted to the north and western site boundary through a perimeter drain towards the culvert under the M5. A portion of this permitter drain has been identified through the topographical survey, however heavy vegetation prevented the full length to the drain from the railway line to the culvert under the M5 (on the western boundary of the site) being mapped. The presence of this drain was instead inferred from depressions adjacent the boundary from 1m LiDAR elevations. These flow patterns are demonstrated in Figure 8.

The surface water mapping also shows a similar pattern of surface runoff (Figure 9), with flows flowing out of site from the south-east, through the existing drainage ditch towards the culvert. The culvert under the M5 is however not represented in this EA mapping, where instead there is shown to be significant ponding in the corner of the site.

It is proposed in the following surface water drainage scheme that the existing drainage pathways are maintained as closely as possible throughout the site, with the existing drainage ditches in the site area used for the discharge of flows from the development.

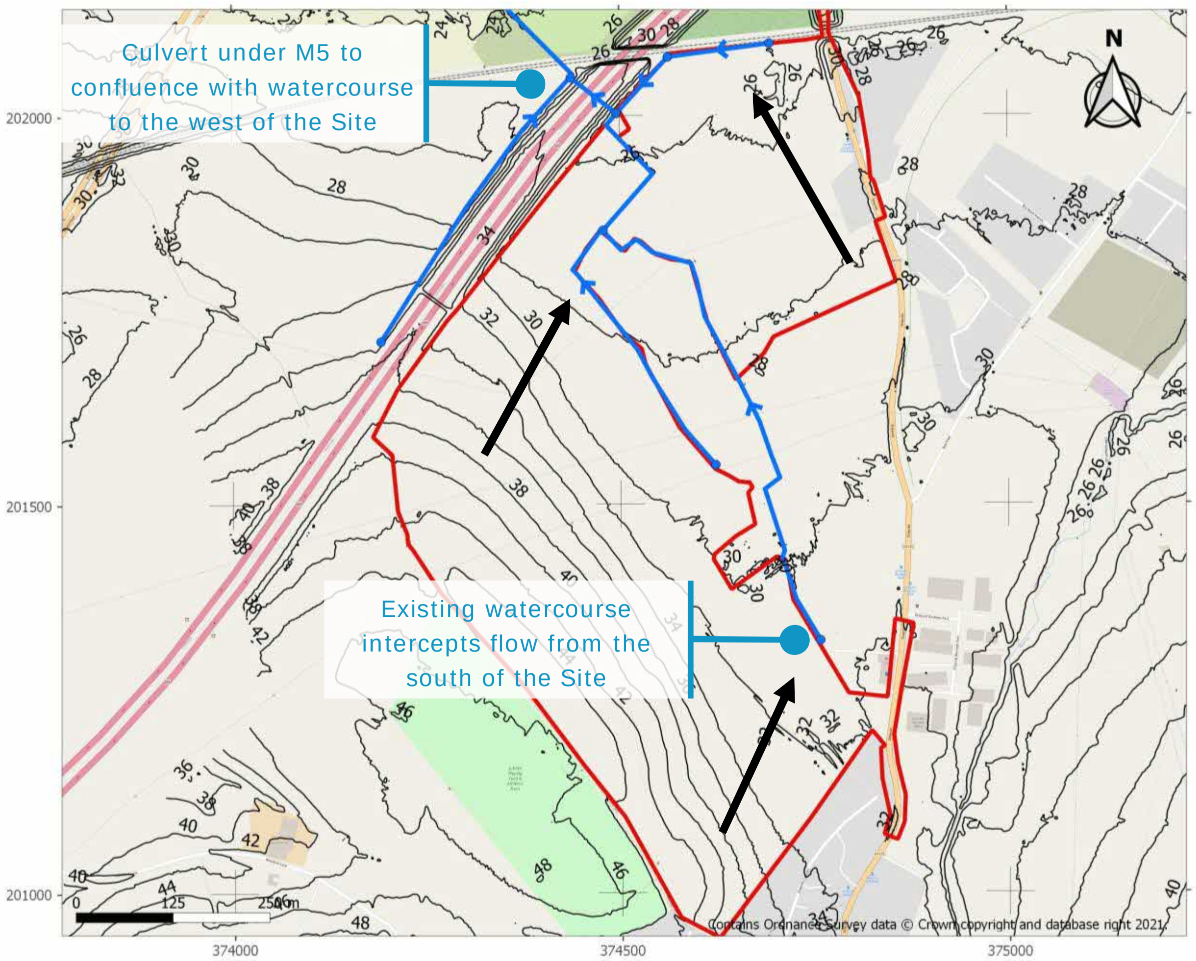

Figure 8 Natural drainage catchments across the Site

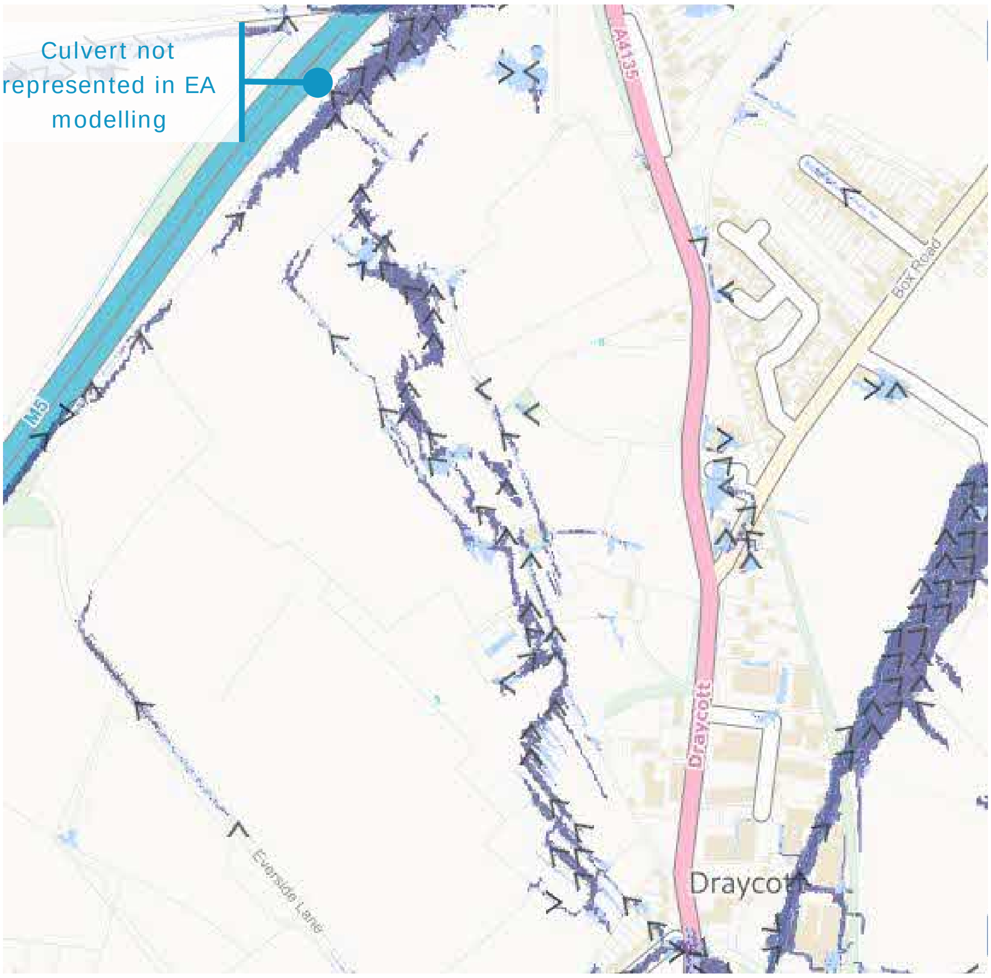

Figure 9 Surface water runoff as represented by EA pluvial mapping

A housing phasing plan has been provided for the entirety of the Persimmon land (Appendix 6), from which impermeable areas have been measured. For the Hitchins land, no housing plan has yet been formulated, therefore it has been assumed that 55% of the areas marked for residential development will be impermeable surfacing. This includes roofed area, roads, pavement, and driveways. Based upon these two methods, Table 2 tabulates the estimated impermeable areas for each parcel of developed land within the site boundary. The land areas are illustrated in Figure 10.

Table 2 Summary of impermeable areas

Land Use Type	Impermeable Area (ha)
Area 1	3.69
Area 2	3.51
Area 3	2.79
Area 4	3.47
Total	13.47
Total (+10% Urban Creep)	14.82

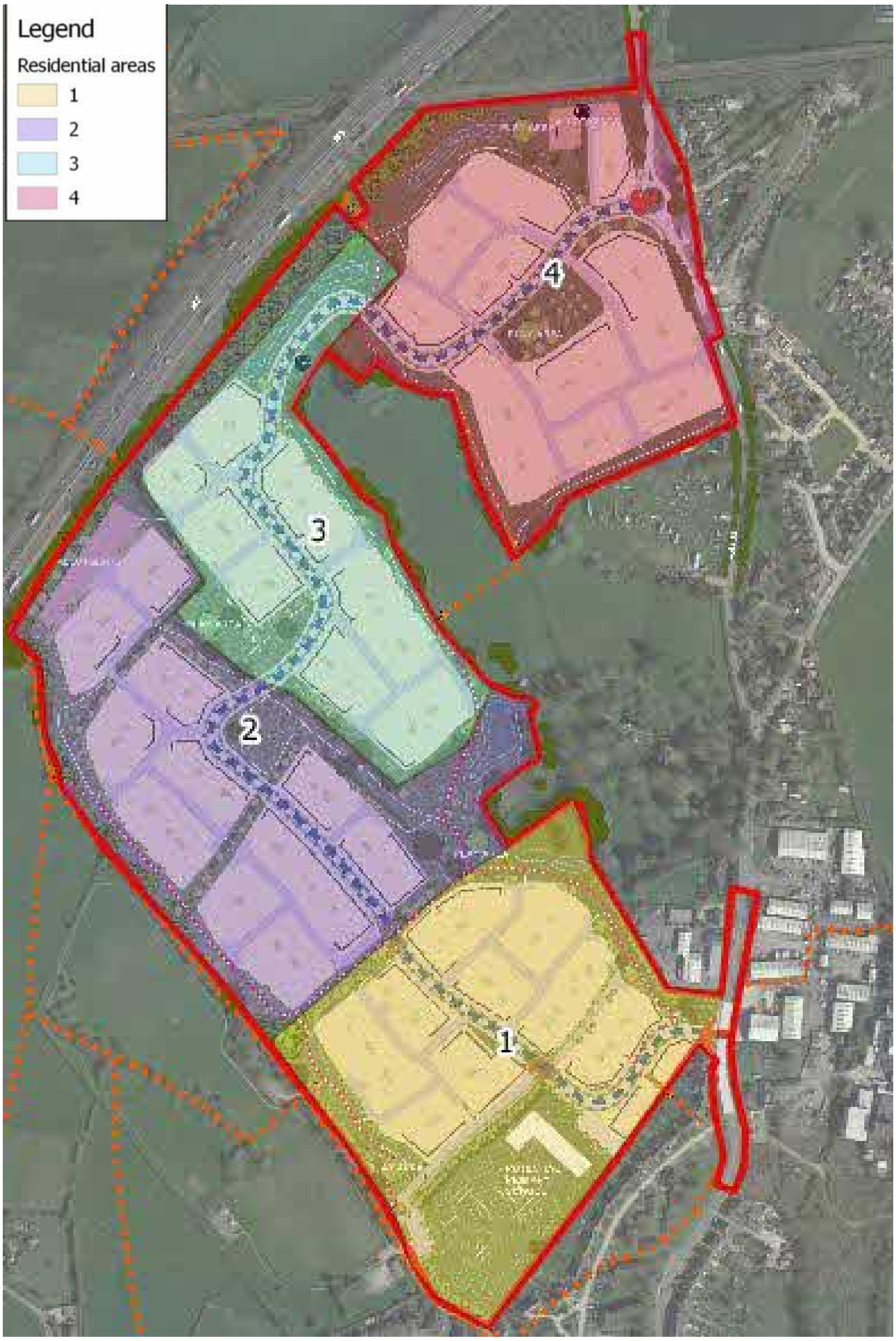

Figure 10 Development areas

4.3 Greenfield runoff rates

To estimate runoff and the storage requirements for on-site attenuation features, greenfield runoff rates have been calculated for the site.

Based on guidance set out in the non-statutory technical standards for sustainable drainage systems[8], the drainage system should be designed for a range of storms up to and including the 1 in 100-year event. The greenfield run-off rates have been calculated using ReFH2, which is the current recommended method outlined in the CIRIA SuDS manual[9].

Existing run-off rates have been estimated using an area of 50 ha before being linearly scaled based on the estimated area of the site. Table 3 below, presents the greenfield runoff rates as the unit rate per hectare and then total rate over each of the development areas outlined above.

Table 3- Greenfield Runoff Rates for areas including 10% urban creep

Return period	Peak Flow (l/s/ha)	Peak runoff rates (l/s)				
		Area 1	Area 2	Area 3	Area 4	Total
1	3.68	14.94	14.22	11.31	14.07	54.54
QBAR	4.39	17.82	16.96	13.50	16.78	65.06
30	9.65	39.15	37.26	29.66	36.87	142.94
100	13.18	53.48	50.90	40.51	50.36	195.25
100 +40%CC	18.45	74.87	71.26	56.71	70.51	273.35

The greenfield run-off rates presented are based on FEH point descriptor data for the site. The point data gave a Standard Average Annual Rainfall (SAAR) of 732mm, a base flow index (BFIHOST) of 0.45 and a proportion of time soils are wet (PROPWET) of 0.33mm.

4.4 Hierarchy of SuDS Strategies

It is a recognised development requirement that the post development run-off rate needs to be limited to the pre-development run-off rate. This prevents any increase in run-off and minimises the risk of increased flooding downstream and to third party land.

A SuDS approach will be utilised to manage surface water runoff generated from the impermeable areas on site. To ensure that surface water run-off from the site does not result in an increase in flood risk, the management of run-off has been considered using a sequential approach in line with current guidance and the requirements of the NPPF. The following options for the disposal of surface water run-off were considered, in order of preference:

Infiltration systems - Surface water drainage should discharge to a soakaway or other infiltration device where ground conditions are favourable.

[8] DEFRA (2015) Sustainable Drainage Systems Non-statutory technical standards for sustainable drainage systems March 2015, https://bit.ly/2LzDBWU
[9] CIRIA (2015). The SuDS Manual.C753

Attenuated discharge to a watercourse – The LLFA will require the rate of discharge to be attenuated to the existing run-off rates for the site, to prevent any increase in runoff and minimise the risk of increased flooding downstream.

Attenuated discharge to a sewer – where other forms of outlet are not achievable discharge should be made to a sewer.

4.4.1 Infiltration SuDS

To assess the viability of the site for infiltration, British Geological Survey (BGS) mapping has been reviewed. This shows the site to be underlain by the Charmouth Mudstone Formation, overlain by Cheltenham sand and gravel deposits.

Infiltration testing was undertaken at the site in May 2020, to BRE365 standards. This involved three infiltration trial pits across the site, with the infiltration rates tabulated in Table 4. The average infiltration rate across the site is 4.64 $x10^{-6}$, with none of the pits dug shown to drain substantially beyond the first hour of the test. The samples pits dug (14 in total, with three for infiltration testing) generally show a pattern of shallow topsoil up to 0.2m depth (of silty, sandy composition), which is then underlain by a much deeper silty, clay strata, which generally then extends to the full depth of the sample (over 3m depth). Just under half of the 14 trial pits dug indicated that water seepage occurred through the sides of the hole, suggesting a water table of less than 3m depth below a large part of the site.

It is concluded that significant employment of SuDS infiltration features across the site would not therefore be practical, on the basis of the clayey soil composition, relatively shallow groundwater levels and the low infiltration rates encountered. During detailed design however, small scale distributed use of infiltration features will be considered as part of the design.

Table 4 Infiltration rates

	Trial pit 1	Trial pit 2	Trial pit 3
Infiltration rates	2.07 x10-6	8.17 x10-6	3.69 x10-6

4.4.2 Attenuated discharge to a watercourse

Given that the potential for infiltration SuDS appears very limited, it is necessary to assess the feasibility of discharging surface water run-off into an existing watercourse/waterbody. There are existing watercourses which run through the site boundary, which presently drain almost the entirety of the site. These connect with a watercourse which drains under the M5 carriageway by means of a culvert. Figure 11 shows the location of the features described above.

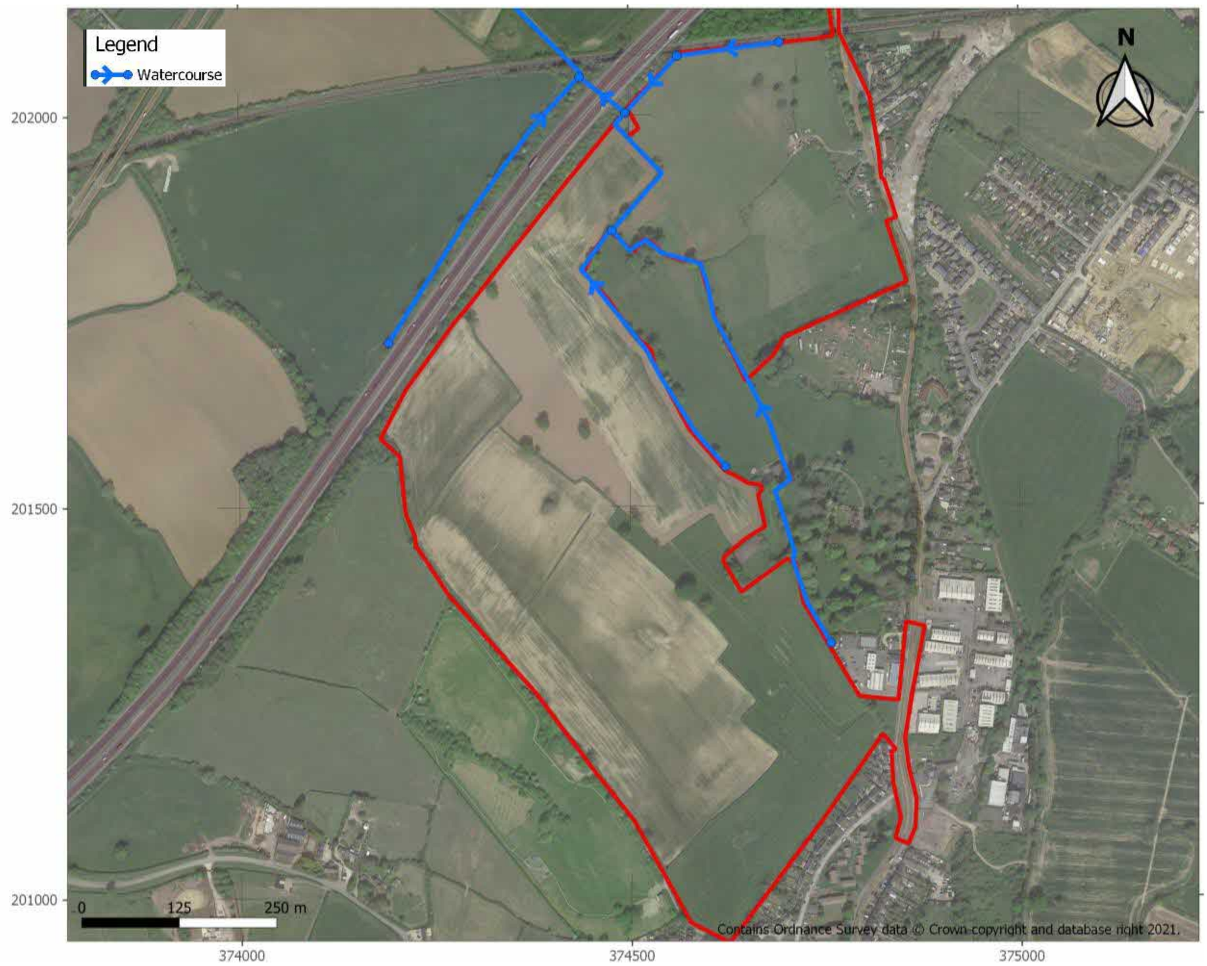

Figure 11 Draining watercourses

The LLFA in their pre-app advice for the site has indicated that when discharging to a watercourse, 'there would need to be proof that the site will still be able to drain or there is sufficient storage onsite for when the watercourse is in high flow or when the watercourse is in flood' (see Appendix 2). It is noted that the field drains through the site and the watercourse through the M5 motorway are both at the headwaters of the river network. It is therefore considered that the requirement to provide additional storage for an occasion where the river is in flood, is diminished.

4.4.3 Attenuated discharge to a sewer

A pre-developer's enquiry was submitted to Severn Trent Water[10], including the feasibility of draining part of the site towards the River Cam via existing surface water sewers. Severn Trent Water confirmed that this option may be viable, however runoff rates would be restrictive due to the capacity of existing infrastructure and construction of a new connection to the River Cam would be preferable.

[10] Severn Trent Water. 2020. Pre-developer enquiry, Lower Cam. Ref: 8404754.

4.5 Required Level of SuDS Treatment

Current best practice takes a risk-based approach to managing discharge of surface water runoff to the receiving environment. The SuDS manual[11] has been used to classify the hazard rating associated with this type of residential development. Table 5 has been extracted from the SuDS manual, where it shows the hazard rating for the proposed development is low.

Table 5 – Minimum water quality management requirements for discharges to receiving surface waters and ground water

Land Use	Pollution Hazard Level	Requirement for discharge to surface waters
Residential Roofs	Very low	Removal of gross solids and sediments only
Individual property driveways, residential car parks and low traffic roads (e.g. cul de sacs)	Low	Simple Index Approach (Note: Extra measures may be required for discharging to protected resources)
Commercial yard and delivery areas, non-residential car parking with frequent change, all roads except low traffic roads and trunk roads/motorways	Medium	Simple Index Approach (Note: Extra measures may be required for discharging to protected resources)

The management approach for water quality where the hazard is low can be assessed using the Simple Index Approach. The Simple Index Approach is a three staged approach, where:

Stage 1 – Allocate suitable pollution hazard indices for the proposed land use.

Stage 2- Select SuDS with a total pollution mitigation index that equals or exceeds the pollution hazard index.

Stage 3 - Where discharge is to a protected surface water of ground water, consider the need for a more precautionary approach.

The SuDS manual recommends pollution hazard indices for low hazard sources such as those associated with the proposed development. SuDS mitigation indices are also identified within the SuDS manual. To deliver adequate treatment the selected SuDS components should have a total pollution index that equals or exceeds the pollution hazard index. For the outline strategy, swales are proposed for the site. It is proposed that these are combined with filter strips where space allows. These should provide adequate treatment for the pollution hazard associated with the development, in addition to the attenuation ponds.

[11] SuDS Manual C753

Table 6- Simple Index Approach for Water Quality Management

	Total Suspended Solids (TSS)	Metals	Hydrocarbons
Maximum Hazard Indices for Proposed Development (medium)	0.5	0.4	0.4
Swale	0.5	0.6	0.6
Filter strip	0.2	0.2	0.25
Pond	0.35	0.35	0.25
Mitigation ≥ Hazard Index	Yes	Yes	Yes

4.6 Groundwater Protection Zones

Review of EA groundwater mapping shows that the site is not within a ground water source protection zone, therefore no further consideration is required.

5 Attenuation Requirements & Provision

5.1 Design Criteria

With respect to other design criteria for the surface water drainage system the DeFRA SuDS technical standards[12] offers the following guidance that shall be complied with during the detailed design of the drainage systems:

> S2 For greenfield developments, the peak run-off rate from the development to any highway drain, sewer or surface water body for the 1 in 1-year rainfall event and the 1 in 100-year rainfall event should never exceed the peak greenfield runoff rate for the same event.
>
> S7. The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur on any part of the site for a 1 in 30-year rainfall event.
>
> S8. The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur during a 1 in 100 year rainfall event in any part of: a building (including a basement); or in any utility plant susceptible to water (e.g. pumping station or electricity substation) within the development.
>
> S.9. The design of the site must ensure that, so far as is reasonably practicable, flows resulting from rainfall in excess of a 1 in 100-year rainfall event are managed in exceedance routes that minimise the risks to people and property.

In addition, some advice taken from some other design standards includes:

> Drainage of rainwater from the roofs of buildings and paved areas around buildings should additionally comply with the 2002 amendment to Approved Document H – Drainage and waste disposal, of the Building Regulations (BR part H).

[12] Department for Environment, Food and Rural Affairs. Sustainable Drainage Systems. Non-statutory technical standards for sustainable drainage systems. (May. 2016)

The Gloucestershire SuDS design guide recommends that, where long term storage is not provided, the peak runoff rate should be limited to QBar greenfield rates (mean annual flood)[13].

5.2 Storage Requirements

Conceptual design solutions for the main SuDS techniques to be employed on each site are described below. Based on a review of potential drainage options at the site (see Section 4.4) attenuated discharge to a waterbody is considered the most viable option.

The estimated storage requirements and target runoff rate for the whole site are shown in Table 7 below. Storage volumes have been derived using Causeway Flow v9.0 considering a worst case 100-Year (+40% Climate Change) event. The greenfield rates were estimated based on the QBAR rate per hectare (4.39 l/s/ha), which is the required allowable discharge, multiplied by the impermeable area. The requirement to attenuate to Qbar and provision of climate change allowances, are outlined in the Lead Local Flood Authority (LLFA) guidance document for SuDS. It is noted that the option to provide long term storage, attenuating instead to the equivalent greenfield rates up to the 1 in 100-year event is also available. This route may serve to reduce the storage requirements and is a possibility to examine in detailed design. The impermeable areas are based on the assumptions outlined in Section 4.2 and account for 10% Urban Creep. Supporting calculations are provided in Appendix 3.

Table 7 Storage requirements, based upon Qbar attenuation requirements

Storage requirements (m^3) with attenuation of peak flows to Qbar rates				
Area 1	Area 2	Area 3	Area 4	Total
3161-4105	3009-3908	2394-3109	2976-3865	11540-14987

It is proposed that the entire site surface water drainage will outfall to the existing watercourse within the site boundary at NGR 374516, 201957, which presently drains the site. This will be broken to two separate systems, one draining the Persimmon land to the south (Areas 1, 2 and 3), and another draining the Robert Hitchins land parcel to the north (Area 4). For this initial outline design it is assumed freeboard is accounted for within the inclusion of climate change and urban creep allowances into the storage calculations. It is considered that due to the conservative assumption for attenuation of flows to Qbar, there will be significant betterment upon storm flows to the receiving watercourse for events above the 2yr storm.

For both sites, it is proposed that the existing ditch system through the site is maintained, with the new network not intersecting with these features, other than at the outfall near the culvert.

5.2.2 Persimmon surface water drainage strategy

According to Table 7, an upper end volume of storage of 11122m^3 is required to service this land (areas 1, 2 and 3). It is intended that the attenuation be provided as close as possible to each land parcel, rather than reliance on one larger end of pipe solution near the outfall of the entire system. In consideration of the high groundwater table identified in the intrusive ground tests undertaken at the site[14], there is a principle of shallow SuDS features.

[13] Gloucestershire County Council. 2015. Gloucestershire DuDS Design and Maintenance Guide.
[14] Hamson Barrow Smith. May 2020. Cam, Trial Pit Log Sheet.

It is proposed that area 1 be serviced by a swale (to which surface water sewers from the developed land will outfall) circumventing the northern perimeters of this land parcel, which will then outfall to a pond located at NGR 374722, 201354. This arrangement is illustrated in Figure 12. The invert of the pond is proposed to be approximately 29mAOD, giving an average depth of 1.3m and accommodating 1:3 side slopes. With a surface area of 2300m^2, this leads to an approximate volume of 2580m^3. The swale features along the north-eastern boundary of the development area will placed along a relatively flat gradient and will therefore serve to create further attenuative storage within the system. Based upon a 3m^2 cross sectional area and total length of 300m, this provides a further 900m^3 of storage.

As shown in Table 8, the features outlined above provide a storage volume within the attenuative requirements of development area 1. It is considered that the upper bound of storage requirement estimated at this stage is very conservative, taking into account the uncertainty of the model parameters at an outline planning stage.

Table 8 Attenuative storage volumes

Attenuation requirements (m^3)	Pond volume (m^3)	Swale volume (m^3)	Total volume (m^3)
3161-4105	2580	900	3480

Figure 12 Drainage layout for development area 1

It is proposed that area 2, also be serviced by a swale which will outfall to a pond located at NGR 374612, 201450. This arrangement is illustrated in Figure 13. The invert of the pond is proposed to be approximately 28.80mAOD at the inlet and 28.50mAOD at the outlet, giving an average depth of 1m and accommodating 1:3 side slopes. With a surface area of 2300m², this leads to an approximate volume of 2054m³. The swale will create further attenuative storage within the system. Based upon a 3m² cross sectional area and total length of 380m, this provides a further 1140m³ of storage.

As shown in Table 9, the features outlined above provide a volume storage above the attenuative requirements of development area 2.

Table 9 Attenuative storage volumes

Attenuation requirements (m³)	Pond volume (m³)	Swale volume (m³)	Total volume (m³)
3009-3908	2054	900	3480

Figure 13 Drainage layout for development area 2

The third development area is to be serviced by a pond located immediately before an outfall to the existing watercourse (at NGR 374521, 201932), and is sized to have a surface area of approximately 2860m² (see Figure 14). Based upon an invert at the northern end of 25.7mAOD and at the southern end of 25.8mAOD, there will be an average storage depth of 0.9m, giving an approximate volume of 2350m³. It is noted that a groundwater level of approximately 24.6mAOD was found near this location.

It is noted that the swales which act to convey the surface water from the development towards and between the attenuation features also provide an amount of volume storage. Based upon a depth of 0.75m, top width of 4.5m and length of 380m, this would offer another 605m³ of storage.

Table 10 shows the total attenuative storage provided by these features in combination, which provides near to the upper-level estimate for the development parcel.

Table 10 Attenuative storage volumes

Attenuation requirement (m³)	Pond volume (m³)	Swale volume (m³)	Total volume (m³)
2394-3109	2350	605	2955

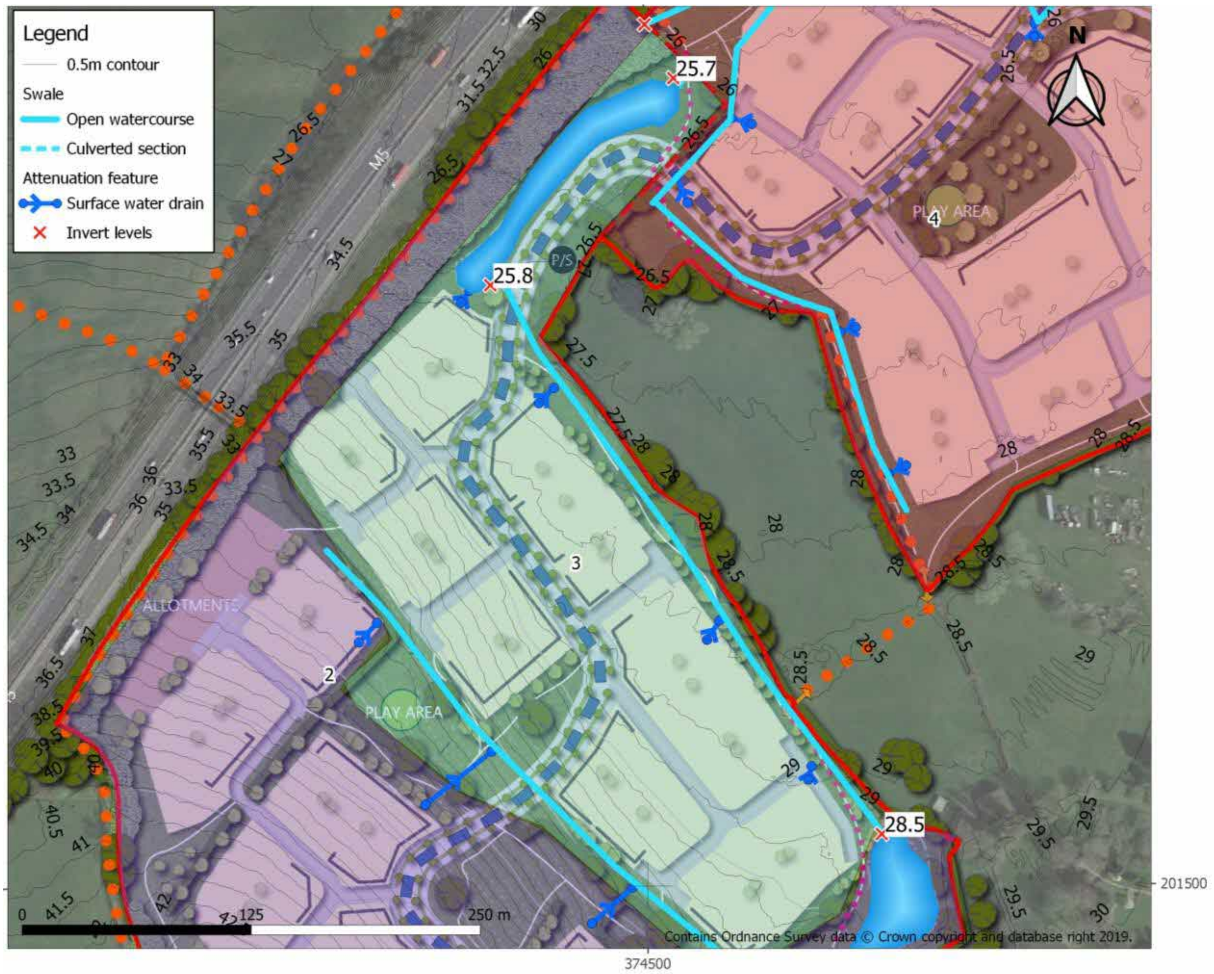

Figure 14 Drainage layout for development area 3

5.2.3 Robert Hitchins surface water drainage strategy (Area 4)

The land across the northern portion of the site is relatively flat, with a shallow slope towards the north-west. It is proposed that this region will drain in this direction towards a large, shallow pond. This pond will have an approximate top area of 3230m² and a depth of 0.6m, giving a volume of approximately 1830m³ (see Table 11). The pond outlet is to be set at 25.15mAOD. As this area is relatively low-lying it will be necessary for ground raising to occur in order to achieve the required pond depths and drainage gradients. Swales are proposed around the northern and western perimeters of the site. Based upon a depth of 0.75m and width of 5m and total length of 650m, this would provide a further 1220m³ of storage. The general arrangement of the surface water drainage design is given in Figure 15.

Table 11 Attenuative storage volumes

Attenuation requirement (m³)	Pond volume (m³)	Swale volume (m³)	Total volume (m³)
2976-3865	1830	1220	3050

Figure 15 Drainage layout for development area 4

To enable sufficient gradient through the surface water sewer system, it is anticipated that much of the northern area of this development parcel will require an amount of ground raising, in the order of between 0.4-0.7m. The widespread incorporation of swales to the design has lessened the requirement for ground raising as much as possible, such that any future use of piped systems as an alternative to these would serve increase the ground raising requirements.

Survey data for the site indicates that average ground levels at the position of the proposed pond range from 25.40mAOD to 25.83mAOD. It is expected that some bunding will be required particularly around the northern perimeter of the pond (the lowest elevations are found at this location). Groundwater levels at this location are taken from the infiltration testing results to be approximately 24.5mAOD, which is 0.65m below the invert of the pond. On the basis that infiltration is not proposed for this SuDS feature, this is considered to be acceptable.

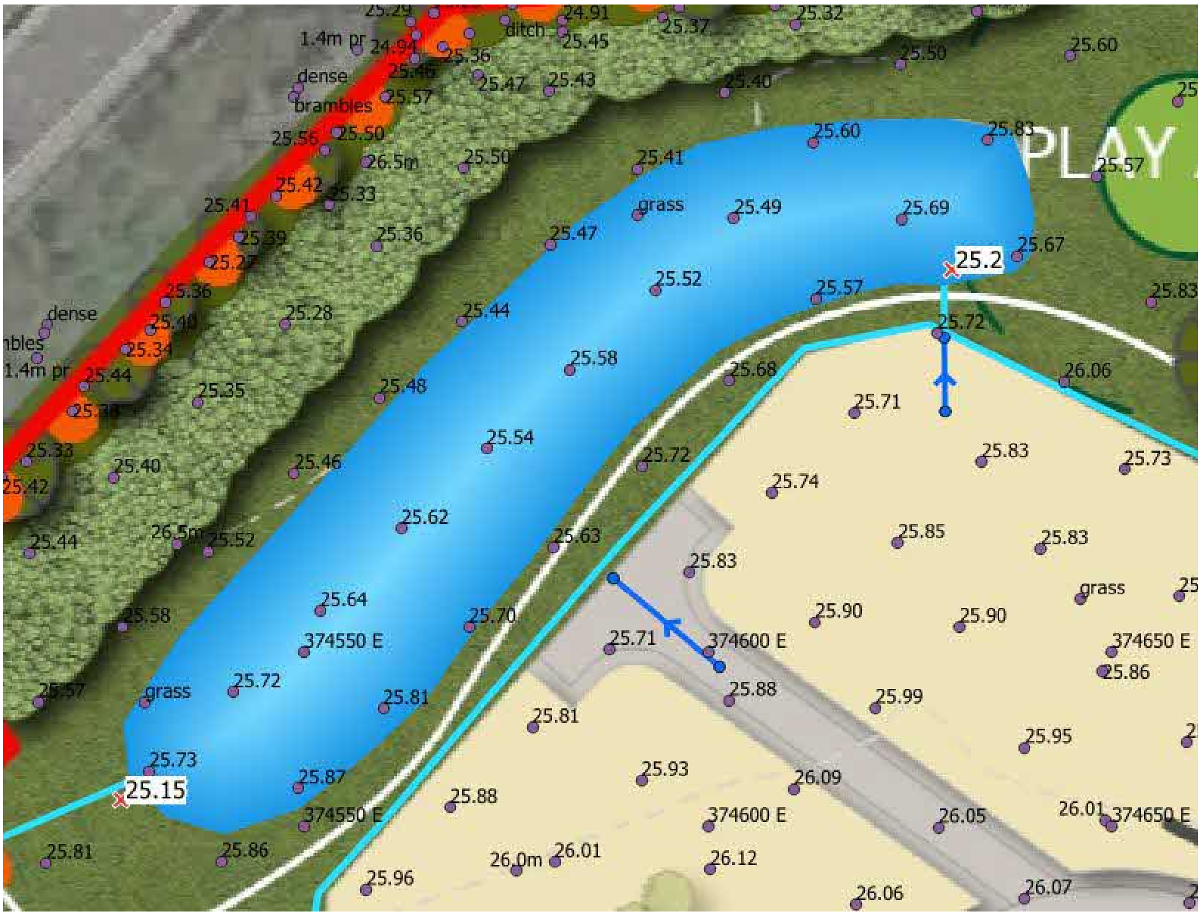

Figure 16 Surveyed ground levels

An out-of-site flow route was also identified in the surface water flood section within the FRA. This showed flow coming from the south of the development emanating in Draycott, to a location shown in Figure 17. The existing drainage ditch at this location is to be maintained, running parallel to the swale system (to the west), which will serve to intercept the flow route and convey to the culvert outfall. It is noted that the current EA surface water modelling of this flow route is likely at too coarse a resolution to represent this system, thus over representing the scale of surface water flood extents in this region. During detailed design, the merit in the provision of a small bund to the east of this feature may be investigated to provide further protection to the housing development, from any significant out-of-site flows.

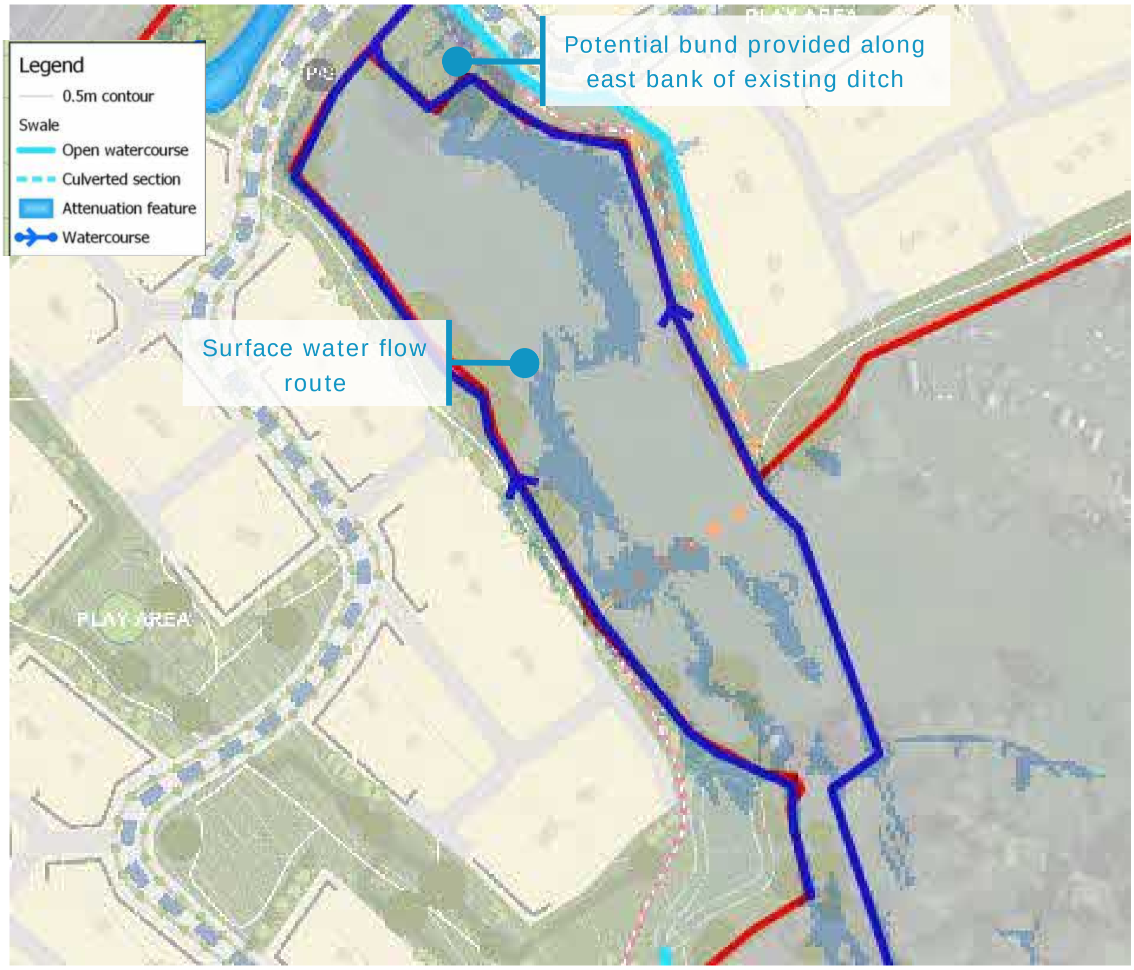

Figure 17 Out of site flow route

Exceedance routes from the system have been considered to ensure that there is sufficient capacity outside of the developed areas to store runoff in the event of a storm exceeding that of the 100yr plus 40% climate change event. Likely exceedance routes from the system are illustrated in Figure 18 (based upon 1m LiDAR levels), showing a general pattern of routing away from any of the developed areas. Where runoff exceedance routes are directed from the southern site, this would then flow across undeveloped agricultural land towards the northern site area, whereupon it would be intercepted by the swale feature (as described above).

Figure 18 Exceedance routes from system

6 Foul drainage strategy

A developer enquiry was submitted to Severn Trent for foul sewer records. A response in April 2020 indicated a number of foul, surface water and combined sewers exist through Draycott (see Appendix 4). Communication following this indicated a significant capacity issue relating to the existing sewer infrastructure in the north of Draycott, which lies adjacent to the northern areas of the site. It was subsequently indicated that a connection of the foul sewers for the entire site should instead be made to a manhole located at or near NGR 374851, 201252 (ref 8101 or 8102).

The invert of this manhole is approximately 29.5mAOD. Implications for the foul sewer network through the site (as visualised in Figure 20), is that significant land areas of the site to the north lie up to 4m below this level. As a result, it is anticipated that a pumped solution will be required, to provide the necessary pressure head for the network for the northern sections of the site. The location of the pumping station is likely to be situated in the northern site area, with a rising main southwards through the site to the manhole. The strategy for the Hitchins Site is shown in Figure 19.

A second pumped system will also be required to service the lower lying developed areas within the Persimmon land. On Figure 20, the areas likely to be gravity drained at present are indicated, it is though assumed that ground raising is likely to be carried out such that only land in development area 3 of Persimmon land will require a pumped solution.

The independent foul systems developed below, are a result of the current phasing requirements across the site. To reduce capital and maintenance costs, during detailed design opportunities will be sought to integrate the drainage arrangements to achieve a single rising main.

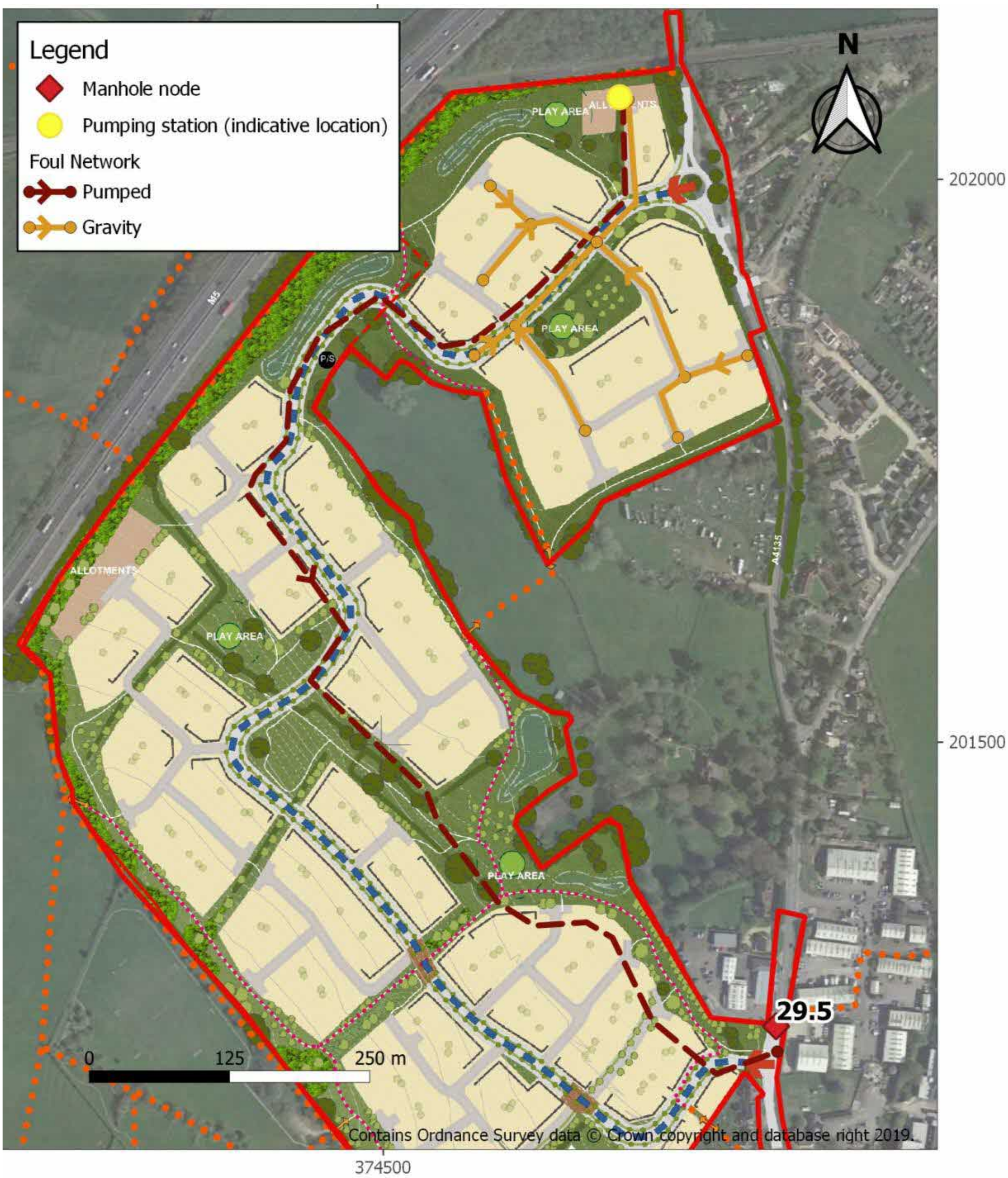

Figure 19 Foul sewer strategy for Hitchins land

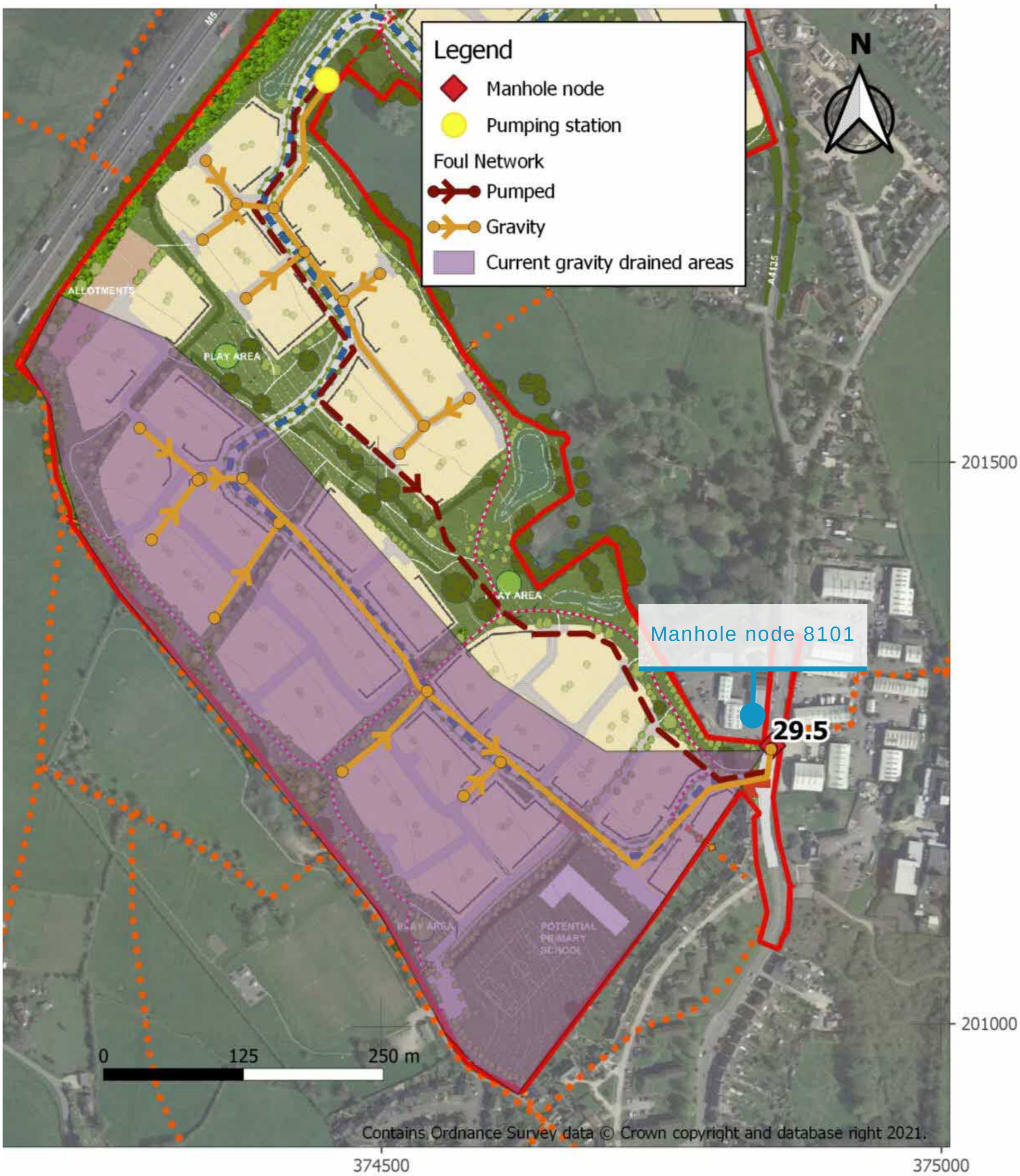

Figure 20 Foul sewer strategy for Persimmon land

7 Conclusions & Recommendations

The conclusions and recommendations from this FRA are outlined below:

Flood Risk

- The entirety of the proposed development lies within Flood Zone 1, with the closest flood extent from the River Cam being 80m from the site boundary.
- Overall, the site is at low risk of flooding from surface water. Most of the land where residential development is proposed, is either at low risk (0.1% AEP) or remains flood free. The overland flow route emanating from Draycott is to be intercepted by the surface water drainage strategy for the site.
- Though infiltration testing at the site indicated groundwater levels may be shallow through some parts of the site near the M5 motorway, the majority of the site is relatively steep, such that any emergence of groundwater is likely to runoff to the surface water drainage system for the site.
- The site is shown to be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere.

Outline Surface Water Drainage Strategy

- Based on the infiltration testing undertaken at the site, infiltration SuDS features are not considered to be an appropriate means of surface water disposal for the site, on the basis of high groundwater levels and low infiltration rates.
- Within this strategy it is assumed that the increase in peak flows as a result of the development will be controlled to the Qbar greenfield rate, with the use of an attenuation SuDS solution. The provision of long-term storage may be investigated within the detailed design phase, which will increase the allowable discharge rate.
- Runoff will be managed through several attenuation storage features throughout the site, with water conveyed to these features via swales, which will follow the natural topography of the site.
- Based on initial calculations the total storage volume required for a 100-Year (+40% Climate Change) rainfall event for the site is between 11540-14987m^3, assuming 10% urban creep.
- The increased management of surface water as a result of the development proposals, including the attenuation to Qbar rates for storm events up to the 100yr plus 40%CC, should serve to reduce runoff to the receiving watercourse beyond the M5 motorway, therefore alleviating downstream flooding.

Outline Foul Drainage Strategy

- Communication with Severn Trent Water indicates that a connection to existing foul sewer network is possible, however this is indicated as only being viable to a manhole adjacent to the south-east of the development.
- As a result of the invert level of the manhole at this location, a pumped solution will be required to service the lower lying areas of the development (particularly pertinent for the land areas to the north).

Appendix 1 Framework plan

Appendix 2 LLFA Preapplication advice - Draycott

Appendix 3 Attenuative Storage Calculations Sheet

Appendix 4 Severn Trent Sewer Enquiry

Appendix 5 Greenfield Runoff Calculations

Appendix 6 Persimmon Phasing Plan