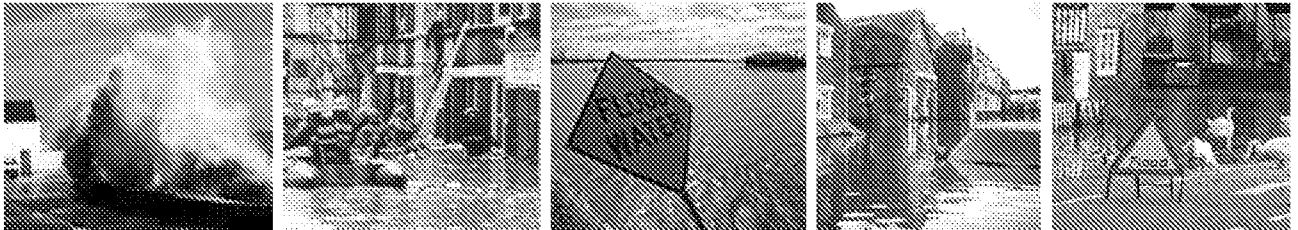


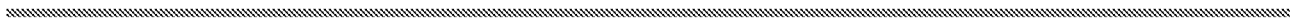
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CONSULTING LIMITED



Client: Angmering Park Estate
Flood Risk Assessment for the
Proposed Development at Land off
Queens Lane, Arundel

June 2018



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Client: Angmering Park Estate

Flood Risk Assessment for the Proposed Development at Land off Queens Lane, Arundel

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1 Background and Scope of Appraisal

Flooding is a major issue in the United Kingdom. The impacts can be devastating in terms of the cost of repairs, replacement of damaged property and loss of business. The objectives of the Flood Risk Assessment (FRA) are therefore to establish the following:

- whether a proposed development is likely to be affected by current or future flooding from any source
- whether the development will increase flood risk elsewhere within the floodplain
- whether the measures proposed to deal with these effects and risks are appropriate
- whether the site will pass the second element of the Exception Test (where applicable).

Herrington Consulting has been commissioned by Angmering Park Estate to prepare a Flood Risk Assessment (FRA) for the proposed development at **Land off Queen Lanes, Arundel, West Sussex, BN18 9JN.**

This appraisal has been undertaken in accordance with the requirements of the National Planning Policy Framework (March 2012) and the National Planning Practice Guidance Suite (March 2014) that has been published by the Department for Communities and Local Government. The *Flood Risk and Coastal Change* planning practice guidance included within the Suite represents the most contemporary technical guidance on preparing FRAs. In addition, reference has also been made to Local Planning Policy.

To ensure that due account is taken of industry best practice, this FRA has been carried out in line with the CIRIA Report C624 'Development and flood risk - guidance for the construction industry'.

2 Development Description and Planning Context

2.1 Site Location and Existing Use

The site is located at OS coordinates 501859, 106816, off Queens Lane in Arundel. In total the site covers an area of approximately 0.1 hectares and currently comprises a garage surrounded by undeveloped land. The location of the site in relation to the surrounding area and the River Arun is shown in Figure 2.1.

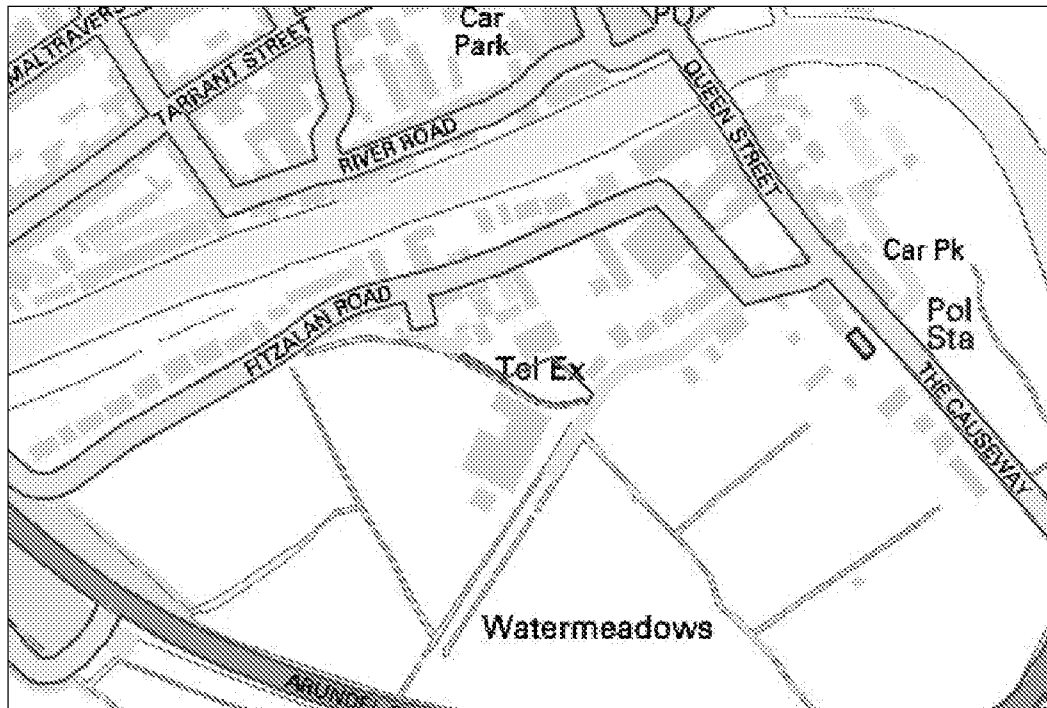


Figure 2.1 – Location map (Contains Ordnance Survey data © Crown copyright and database right 2018). Site boundary delineated in red.

The site plan included in Appendix A.1 of this report provides more detail in relation to the site location and layout.

2.2 Proposed Development

The proposals for development comprise two residential dwellings with associated parking as shown in Figure 2.2 below.

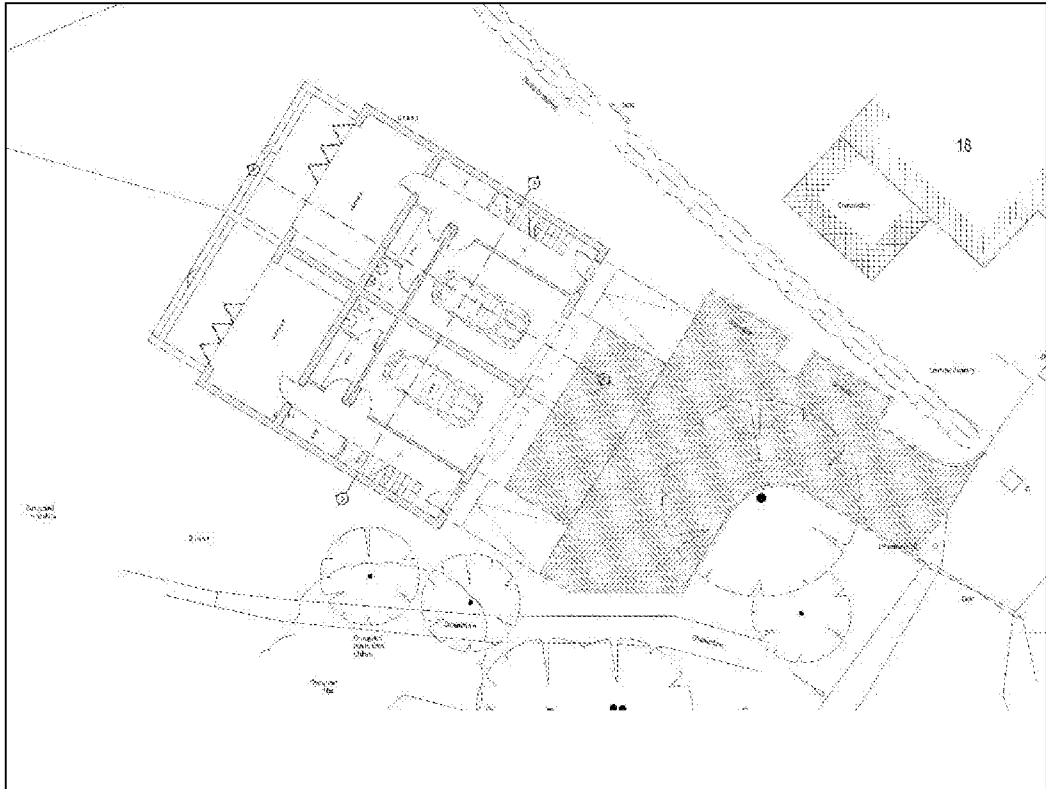


Figure 2.2 – Proposed scheme layout.

More detailed drawings of the proposed scheme are included in Appendix A.1 of this report.

2.3 The Sequential Test

Local Planning Authorities (LPA) are encouraged to take a risk-based approach to proposals for development in areas at risk of flooding through the application of the Sequential Test. The objectives of this test are to steer new development away from high risk areas towards those areas at lower risk of flooding. However, in some areas where developable land is in short supply there can be an overriding need to build in areas that are at risk of flooding. In such circumstances, the application of the Sequential Test is used to ensure that the lower risk sites are developed before the higher risk ones.

The National Planning Policy Framework (NPPF) requires the Sequential Test to be applied at all stages of the planning process and generally the starting point is the Environment Agency's flood zone maps. These maps and the associated information are intended for guidance and cannot provide details for individual properties. They do not take into account other considerations such as existing flood defences, alternative flooding mechanisms and detailed site-based surveys. They do, however, provide high level information on the type and likelihood of flood risk in any particular area of the country. The flood zones are classified as follows:

Zone 1 – Low probability of flooding – This zone is assessed as having less than a 1 in 1000 annual probability of river or sea flooding in any one year.

Zone 2 – Medium probability of flooding – This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding or between 1 in 200 and 1 in 1000 annual probability of sea flooding in any one year.

Zone 3a – High probability of flooding - This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding or 1 in 200 or greater annual probability of sea flooding in any one year.

Zone 3b – The Functional Floodplain – This zone comprises land where water has to flow or be stored in times of flood and can be defined as land which would flood during an event having an annual probability of 1 in 20 or greater. This zone can also represent areas that are designed to flood in an extreme event as part of a flood alleviation or flood storage scheme.

The location of the site is shown on the Environment Agency's flood zone map in Figure 2.2 and the information provided by this map has been interrogated and summarised in Table 2.2 below.

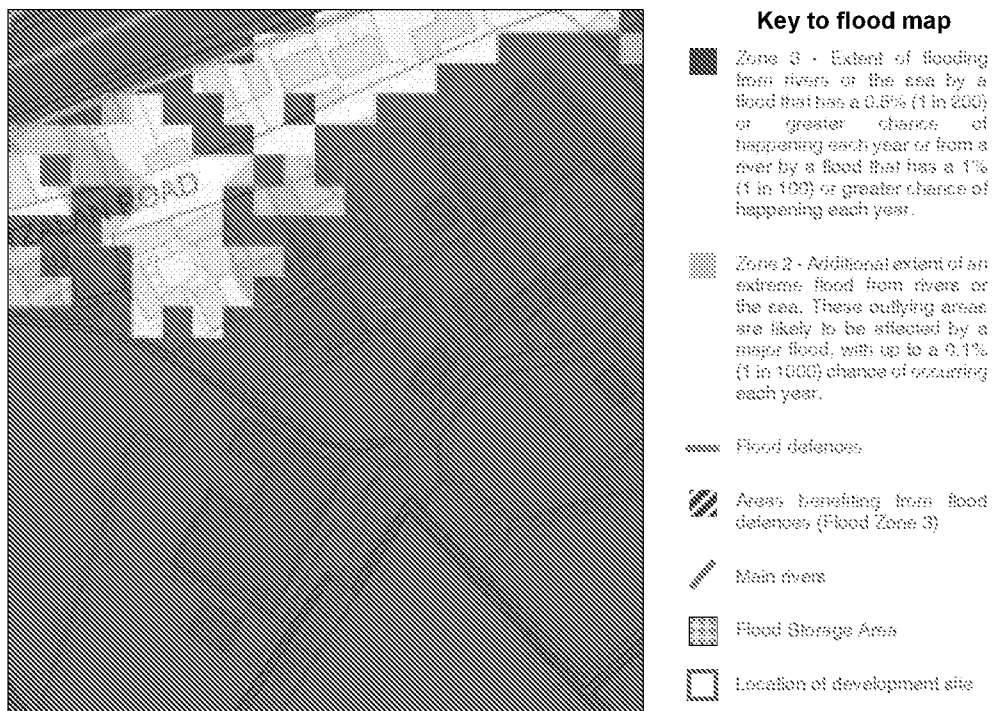


Figure 2.2 – Flood zone map showing the location of the development site (© Environment Agency)

The above mapping shows the development site to be located within Flood Zone 3 and not to be benefiting from existing flood defences that have been constructed in the last 5 years. This mapping does not distinguish between high risk areas and the functional floodplain, i.e. Zones 3a and 3b. This is an important differentiation that needs to be made by the FRA because the NPPF states that no development, other than essential transport and utilities infrastructure, should be located within the functional floodplain.

The functional floodplain is defined by the NPPF as land where water has to flow or be stored in times of flood during events that have a probability of occurrence of 1 in 20 (5%) or greater in any one year. The Planning Practice Guidance goes on to further clarify this by adding the following definition:

The identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. But land which would flood with an annual probability of 1 in 20 (5%) or greater in any year, or is designed to flood in an extreme (0.1%) flood, should provide a starting point for consideration and discussions to identify the functional floodplain. Areas which would naturally flood with an annual exceedance probability of 1 in 20 (5%) or greater, but which are prevented from doing so by existing infrastructure or solid buildings will not normally be defined as functional floodplain.

Based on information provided by the Environment Agency and that derived as part of this appraisal, the following functional floodplain test is applied:

Do predicted flood levels show that the site will be affected by an event having a return period of 1 in 20 years or less?	X
Is the site defended by flood defence infrastructure that prevents flooding for events having a return period of 1 in 20 years or greater?	✓
Does the site provide a flood storage or floodwater conveyance function?	X
Does the site contain areas that are 'intended' to provide transmission and storage of water from other sources?	X
Is site within the functional floodplain (Zone 3b)	No

Table 2.1 – Functional floodplain test.

The flood zone mapping and associated information has been summarised in Table 2.2 below.

Flood Zone (percentage of site within zone)		Source of flooding	Benefiting from existing flood defences*
Zone 1	0%		
Zone 2	0%		
Zone 3a	100%	River (Tidal/Fluvial)	No
Zone 3b	0%		
(*) The flood zone maps only recognise defences constructed within the last 5 years			

Table 2.2 – Flood zone classification.

The NPPF states that the Local Planning Authority (LPA) should apply the sequential approach as part of the identification of land for development in areas at risk from flooding. The overarching objective of the Sequential Test is to ensure that lower risk sites are developed before sites in higher risk areas. When applying the Sequential Test, it is also necessary to ensure that the subject site is compared to only those sites that are available for development and are similar in size.

In this case a Sequential Test assessment has not been undertaken in support of this FRA. However, from the work that has been undertaken as part of this site-specific appraisal it is possible to provide evidence that can help in the application of the Sequential Test.

The second level of appraisal is through the application of the more detailed and refined flood risk information contained within the Strategic Flood Risk Assessments (SFRA). Such a document has been prepared for Arun District Council and this has been referenced as part of this site-specific FRA.

The most detailed stage at which the sequential approach can be applied is at a site based level. Careful consideration of the site's topography and development uses can provide opportunities to locate more vulnerable buildings on the higher parts of the site and placing less vulnerable elements such as car parking or recreational use in the areas exposed to higher risk. This approach is examined later on in this FRA.

2.4 The Exception Test

According to the NPPF, if following the application of the Sequential Test it is not possible, consistent with wider sustainability objectives, for the development to be located in zones of lower probability of flooding, the Exception Test can be applied.

As part of this process it is necessary to consider the type and nature of the development. The Planning Practice Guidance: *Flood Risk and Coastal Change* defines the type and nature of different development classifications in the context of their flood risk vulnerability. This has been summarised in Table 2.3 below.

Flood Risk Vulnerability Classification	Zone 1	Zone 2	Zone 3a	Zone 3b
Essential infrastructure – Essential transport infrastructure, strategic utility infrastructure, including electricity generating power stations	✓	✓	e	e
High vulnerability – Emergency services, basement dwellings caravans and mobile homes intended for permanent residential use	✓	e	x	x
More vulnerable – Hospitals, residential care homes, buildings used for dwelling houses, halls of residence, pubs, hotels, non-residential uses for health services, nurseries and education	✓	✓	e	x
Less vulnerable – Shops, offices, restaurants, general industry, agriculture, sewerage treatment plants	✓	✓	✓	x
Water compatible development – Flood control infrastructure, sewerage infrastructure, docks, marinas, ship building, water-based recreation etc.	✓	✓	✓	✓
Key: ✓ Development is appropriate x Development should not be permitted e Exception Test required Shaded cell represents the classification of this development				

Table 2.3 – Flood risk vulnerability and flood zone compatibility.

From Table 2.3 above it can be seen that the development falls into a classification that requires the Exception Test to be applied. For the Exception Test to be passed there are two criteria that must be satisfied, and these are listed below:

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

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

Demonstrating that the development provides wider sustainability benefits to the community that outweigh flood risk is outside the scope of this report, nevertheless, reference is made to the SFRA to establish the key risks associated with flooding to help demonstrate that this objective can be

achieved. The key focus of this FRA is therefore to establish whether the site is likely to pass the second element of the Exception Test.

3 Definition of Flood Hazard

3.1 Site Specific Information

In addition to the high level flood risk information shown in the Environment Agency (EA) flood zone maps, additional data from detailed studies, and other information sources is referenced. This section summarises the additional information collected as part of this FRA.

Site specific flood level data provided by the EA – The EA has been consulted as part of the development of this FRA and a copy of their response is included in Appendix A.2 of this report.

Information contained within the SFRA – The Arun District Council SFRA (2008) contains detailed mapping of flood extents from a wide range of sources. This document has been referenced as part of this site-specific FRA.

Information provided by Southern Water – Southern Water has provided the results of an asset location search for the site. Their response is included in Appendix A.3.

Site specific topographic surveys – A topographic survey has been undertaken for the site and a copy of this is included in Appendix A.1. From this it can be seen that the level of the site varies between 1.18m and 2.26m Above Ordnance Datum Newlyn (AODN) with ground levels gradually reducing from northwest to southeast.

Geology – Reference to the British Geological Survey map shows that the underlying solid geology in the location of the subject site is Spetisbury Chalk Member (chalk). Overlying this are superficial deposits of Raised Marine Deposits (clay, silt, sand and gravel)

Historic flooding – The EA has confirmed that there are no historic records of flooding at the development site from main rivers or the sea. In addition, information contained within the Arun District Council SFRA reveals that there are no records of flooding at the site from any other sources in the past.

3.2 Potential Sources of Flooding

The main sources of flooding have been assessed as part of this appraisal. The specific issues relating to each one and its impact on this particular development are discussed below. Table 3.1 at the end of this section summarises the risks associated with each of the sources of flooding.

Flooding from Rivers (Fluvial) – The site lies within Flood Zone 3 of the River Arun (main river) as shown on the EA's flood map. The flood zone maps are used as a consultation tool by planners to highlight areas where more detailed investigation of flood risk is required. Consequently, given the location of the site within Flood Zone 3, the risk of flooding from this source has been examined in more detail as part of this FRA.

Flooding from Rivers (Tidal) – The site lies within Flood Zone 3 of the tidal reaches of the River Arun (main river) as shown on the EA's flood zone mapping. Consequently, the risk of flooding from this source has been examined in more detail as part of this FRA.

Flooding from Ordinary or Man-made Watercourses – Natural watercourses that have not been enmained and man-made drainage systems such as irrigation drains, sewers or ditches could potentially cause flooding.

Inspection of OS mapping of the site and surrounding area reveals that there is a drainage ditch along the southern site boundary which forms part of a wider drainage network to the south of the development site. The primary purpose of this network is to reduce the groundwater level within the surrounding area. Extreme rainfall or high water levels within the adjacent River Arun may result in increased water levels in the network of drains and ditches. The consequence of such an event is likely to be water logging of the ground and shallow flooding in the lower-lying areas to the south. However, inspection of the topographic survey reveals that the area of proposed development is located approximately 0.5m above the lower-lying area and as such, it is considered extremely unlikely that floodwater within the lower-lying land could reach a depth that could affect the development site.

Therefore, the risk of flooding from this source is considered to be significantly less than risk of flooding a tidal/fluviat event which is appraised further in Section 5 of this report. In addition, the mitigation measures discussed in later sections of this report, which are aimed at reducing the risk of flooding from all sources, will be more than adequate in preventing flooding from this source. As such, the risk of flooding from this source is considered to be *low*.

Flooding from the Sea – The site is a significant distance inland and whilst the River Arun is still tidally influenced at this location, the risk of flooding from the sea is considered to be extremely low and is not investigated further as an independent source of flooding.

Flooding from Land (overland flow and surface water runoff) – Overland flooding typically occurs in natural valley bottoms as normally dry areas become covered in flowing water and in low spots where water may pond. This flooding mechanism can occur almost anywhere, but is likely to be of particular concern in any topographical low spot, or where the pathway for runoff is restricted by terrain or man-made obstructions.

Figure 3.1 below is an extract of the Environment Agency's 'Risk of Flooding from Surface Water' map which can be interrogated to identify whether the site is located in an area at risk of surface water flooding.

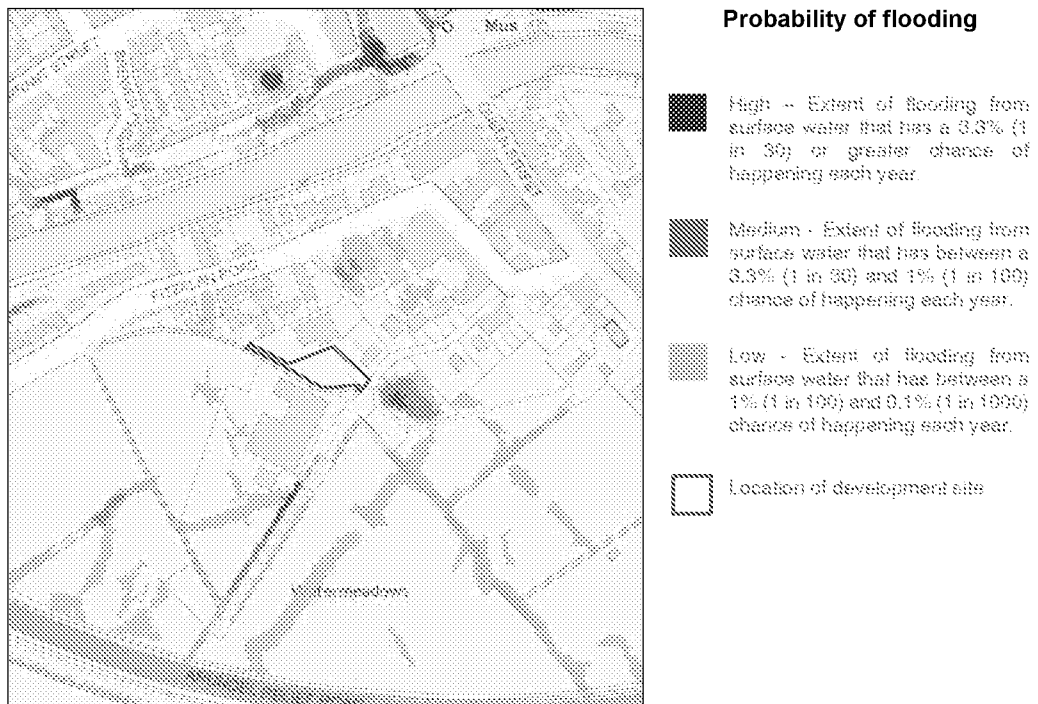


Figure 3.1 – Surface water flooding map showing the location of the development site
(© Environment Agency)

The above mapping does not include an allowance for climate change, but as it includes an event that exceeds the 1 in 100 year design rainfall event, it can be used to consider the impact that climate change may have over the lifetime of the development. In this circumstance the proposed development site is shown to be located outside the flood extents of an extreme pluvial event with a return period of 1 in 1000 years (i.e. it has a very low probability of flooding).

Inspection aerial height data and a site specific topographic survey shows that land levels fall naturally across the site towards the southeast. In addition, there are no topographical low points within the site which could encourage flood water to pond. It is therefore considered that flooding through this mechanism is *low*.

Flooding from Groundwater – Water levels below the ground rise during wet winter months and fall again in the summer as water flows out into rivers. In very wet winters, rising water levels may lead to the flooding of normally dry land, as well as reactivating flow in ‘bournes’ (streams that only flow for part of the year). Where land that is prone to groundwater flooding has been built on, the effect of a flood can be very costly, and because groundwater responds slowly compared with rivers, floods can last for weeks or months.

Groundwater flooding is most likely to occur in low-lying areas that are underlain by permeable rock (aquifers). The underlying geology in this area is Septisbury Chalk Member, with overlaying superficial Raised Marine deposits. While chalk is characteristically impermeable, chalk formations can be susceptible to groundwater flooding as water rises through faults and discontinuities within

the rock. Additionally, the more permeable superficial deposits can also be susceptible to groundwater emergence.

Information contained within the Arun District Council SFRA shows that the development site lies within an area susceptible to groundwater emergence. In addition, the more detailed mapping on groundwater emergence provided as part of the Defra Groundwater Flood Scoping Study (May 2004) shows that the site itself is located near an area where groundwater emergence is predicted.

Nevertheless, the role of the drainage network to the south of the development site is to retain a low groundwater table in this area. Consequently, if the groundwater table was to rise, water would be intercepted by the drainage network in the lower-lying land to the south. If the drainage network becomes overwhelmed, the mechanism of flooding is comparable to the risk of flooding from watercourses, which has been discussed further above and is considered to be low.

This is supported by information contained within the Arun District Council SFRA which reveals that there are no records that the site has been subject to groundwater flooding in the past. Consequently, the risk of groundwater flooding is considered to be *low*.

Flooding from Sewers – In urban areas, rainwater is frequently drained into surface water sewers or sewers containing both surface and wastewater known as “combined sewers”. Flooding can result when the sewer is overwhelmed by heavy rainfall, becomes blocked, or is of inadequate capacity; this will continue until the water drains away. When this happens to combined sewers, there is a high risk of land and property flooding with water contaminated with raw sewage as well as pollution of rivers due to discharge from combined sewer overflows.

Inspection of asset location data provided by Southern Water (Appendix A.3) identifies that there are no sewers within close proximity of the site. Additionally, there is no record of historic sewer flooding in this location contained within the Arun District Council SFRA. Consequently, the risk of flooding from this source is considered to be *low*.

Flooding from Reservoirs, Canals and other Artificial Sources – Non-natural or artificial sources of flooding can include reservoirs, canals and lakes where water is retained above natural ground level, operational and redundant industrial processes including mining, quarrying and sand and gravel extraction, as they may increase floodwater depths and velocities in adjacent areas. The potential effects of flood risk management infrastructure and other structures also need to be considered. Reservoir or canal flooding may occur as a result of the facility being overwhelmed and/or as a result of dam or bank failure.

Inspection of the Ordnance Survey mapping for the area shows that there are no artificial sources of flooding within close proximity to the site. In addition, the EA’s ‘Risk of Flooding from Reservoirs’ website shows that the site is not within an area considered to be at risk of flooding from reservoirs. Therefore, the risk of flooding from this source is considered to be *low*.

A summary of the overall risk of flooding from each source is provided in Table 3.1 below.

Source of flooding	Initial level of risk	Appraisal method applied at the initial flood risk assessment stage
Rivers (fluvial)	Appraised further in Section 5	OS mapping and Environment Agency flood zone map
Rivers (tidal)		OS mapping and Environment Agency flood zone map
Sea/Estuaries	Low	OS mapping and Environment Agency flood zone map
Ordinary and man-made watercourses	Low	OS mapping and aerial height data
Overland flow	Low	Environment Agency 'Risk of Flooding from Surface Water' flood maps, aerial height data, OS mapping, topographic survey
Groundwater	Low	BGS geological data, Defra Groundwater Flood Scoping Study, aerial height data, OS mapping, topographic survey, historic records within the Arun District Council SFRA
Sewers	Low	Southern Water asset location data and historic records contained within the Arun District Council SFRA
Artificial sources	Low	OS mapping and Environment Agency 'Risk of Flooding from Reservoirs' flood map

Table 3.1 – Summary of flood sources and risks.

3.3 Existing Flood Risk Management Measures

The flood defences in this area are in the form of an embankment along the River Arun with a 1 in 200 standard of protection. The condition grade of this defence infrastructure is good.

4 Climate Change

When the impact of climate change is considered it is generally accepted that the standard of protection provided by current defences will reduce with time. The global climate is constantly changing, but it is widely recognised that we are now entering a period of accelerating change. Over the last few decades there have been numerous studies into the impact of potential changes in the future and there is now an increasing body of scientific evidence which supports the fact that the global climate is changing as a result of human activity. Past, present and future emissions of greenhouse gases are expected to cause significant global climate change during this century.

The nature of climate change at a regional level will vary: for the UK, projections of future climate change indicate that more frequent short-duration, high-intensity rainfall and more frequent periods of long-duration rainfall of the type responsible for the recent UK flooding could be expected.

These effects will tend to increase the size of flood zones associated with rivers, and the amount of flooding experienced from other inland sources. The rise in sea level will change the frequency of occurrence of high water levels relative to today's sea levels. It will also increase the extent of the area at risk should sea defences fail. Changes in wave heights due to increased water depths, as well as possible changes in the frequency, duration and severity of storm events are also predicted.

To ensure that any recommended mitigation measures are sustainable and effective throughout the lifetime of the development, it is necessary to base the appraisal on the extreme flood level that is commensurate with the planning horizon for the proposed development. The NPPF and supporting Planning Practice Guidance Suite state that residential development should be considered for a minimum of 100 years, but that the lifetime of a non-residential development depends on the characteristics of the development. The development that is the subject of this FRA is classified as residential.

4.1 Potential Changes in Climate

Extreme Sea Level

Global sea levels will continue to rise, depending on greenhouse gas emissions and the sensitivity of the climate system. The relative sea level rise in England also depends on the local vertical movement of the land, which is generally falling in the south-east and rising in the north and west. The accompanying Planning Practice Guidance Suite to the NPPF provides allowances for the regional rates of relative sea level rise and these are shown in Table 4.1.

Administrative Region	Net Sea Level Rise (mm/yr) Relative to 1990			
	1990 to 2025	2026 to 2055	2056 to 2085	2086 to 2115
East of England, East Midlands, London, SE England (south of Flamborough Head)	4.0	8.5	12.0	15.0
South West	3.5	8.0	11.5	14.5
NW England, NE England (north of Flamborough Head)	2.5	7.0	10.0	13.0

Table 4.1 – Recommended contingency allowances for net sea level rise

The development site is not subject to coastal flooding, however, the River Arun is a tidal river and therefore the figures above are still applicable.

Peak River Flow

Recognising that the impact of climate change will vary across the UK, the peak river flow allowances show the anticipated changes to peak river flow by river basin district. The proposed development site is covered by the South East River Basin District, as defined by the Environment Agency River Basin maps.

For each district a range of climate change allowances are provided for different time epochs over the next century, which correlate with the planning horizons for the varying classifications of development.

For each epoch there are three climate change allowances defined. These represent different levels of statistical confidence in the possible emissions scenarios on which they are calculated. The three levels of allowance are as follows:

- Central: based on the 50th percentile
- Higher Central: based on the 70th percentile
- Upper End: based on the 90th percentile

As well as encouraging sustainable development to meet the demands of a growing population, the NPPF also promotes a precautionary approach. For more vulnerable development in areas of higher risk of flooding, a higher percentile allowance is recommended in order to manage the risk of flooding over the lifetime of the proposed development. The Environment Agency has therefore provided guidance regarding the application of the climate change allowances and how they should be applied in the planning process. The range of allowance for the river basin in which the development site is located are shown in Table 4.2 below.

River Basin District	Allowance Category	2015 to 2039	2040 to 2069	2070 to 2115
South East	Upper End	25%	50%	105%
	Higher Central	15%	30%	45%
	Central	10%	20%	35%

Table 4.2 – Recommended peak river flow allowances for each epoch for the South East river basin district (1961 to 1990 baseline).

For more vulnerable development with a design life of 100 years in Flood Zone 3a, a **Higher Central** climate change allowance is recommended. From Table 4.2 above, it can be seen that the recommended climate change allowance for this site is a **45%** increase for all peak river flows.

Peak Rainfall Intensity

The recommended allowances for increases in peak rainfall intensity are applicable nationally. There is a range of values provided which correspond with the central and upper end percentiles (the 50th and 90th percentile respectively) over three time epochs. The recommended allowances are shown in Table 4.3 below.

Allowance Category (applicable nationwide)	Total potential change anticipated for each epoch		
	2015 to 2039	2040 to 2069	2070 to 2115
Upper End	+10%	+20%	+40%
Central	+5%	+10%	+20%

Table 4.3 – Recommended peak rainfall intensity allowance for small and urban catchments (1961 to 1990 baseline).

Typically, for a residential development a design life of 100 years is assumed and therefore an increase of 20% in peak rainfall intensity should be used in the calculations in the outline surface water management strategy (refer to Section 8). However, Arun District Council requires the drainage system to be designed to consider a 30% increase in peak rainfall intensity and as such, the calculations have been based on an extreme pluvial event with a 1 in 100 year return period including a 30% allowance for climate change.

All of the above recommended allowances for climate change should be used as a guideline and can be superseded if local evidence supports the use of other data or allowances. Additionally, in the instance where flood mitigation measures are not considered necessary at present but will be required in the future (as a result of changes in climate), a “managed adaptive approach” may be adopted whereby development is designed to allow the incorporation of appropriate mitigation measures in the future.

5 Probability and Consequence of Flooding

When appraising the risk of flooding to new development it is necessary to assess the impact of the 'design flood event' to establish depths, velocities and the rate of rise of floodwater under such conditions. Flood conditions can be predicted for a range of return periods and these are expressed in either years or as a probability, i.e. the probability that the event will occur in any given year, or Annual Exceedance Probability (AEP). The design flood event is taken as the 1 in 100 year (1% AEP) event for fluvial flooding and the 1 in 200 year (0.5% AEP) event for sea or tidal flooding.

5.1 The Fluvial Risk of Flooding

The EA has been consulted as part of this appraisal and a copy of their response is included in Appendix A.2. The information has been taken from the Lower Tidal River Arun Strategy Study Model completed in 2010 (by others). The data provided contains modelled flood level data for different return periods for node points on site. The location of the node points in relation to the development site is shown in Figure 5.1 below.



Figure 5.1 – Flood node location map (provided by the EA). Development site outlined in red.

Inspection of the modelled flood levels for the node points shows that the site is located outside of the predicted flood extents under an event with a 1 in 100 year return period. However, this modelled flood level for the 1 in 100 year event does not include an allowance for climate change

as defined by the Environment Agency's climate change guidance, which would require a 45% increase in peak river flow to be considered over the lifetime of the development.

In this instance, modelled in-channel flow and stage values have been provided by the Environment Agency in addition to node points across the site. As such, it is possible to estimate the design flood level for the site using the 'intermediate' approach, which is considered to provide a more accurate estimation of the impacts of climate change on the predicted flood level at the development site.

The 'intermediate' approach involves constructing a stage-flow rating curve for current day conditions, which is extrapolated to derive a flood level based on the increase in peak flow (45%). Figure 5.2 below shows the stage-flow curve constructed for the nearest in-channel node to the development site, which has been identified as node point LOW054.

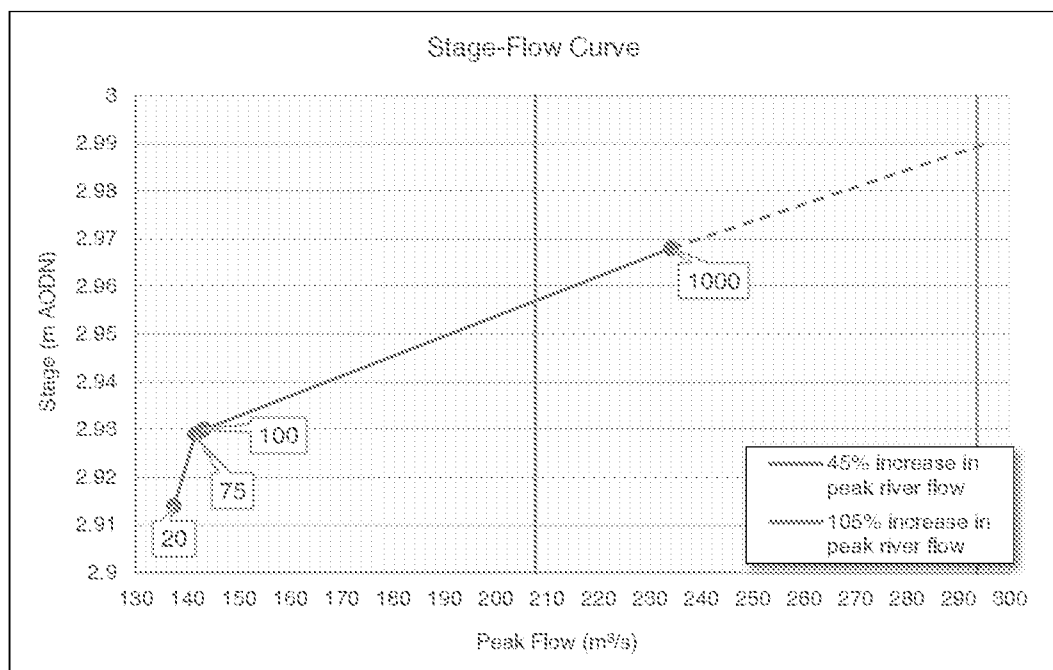


Figure 5.2 – Stage-flow curve for in-channel node LOW054.

From Figure 5.2 above, it can be seen that the maximum predicted in-channel water level for a 45% increase in peak river flow is approximately 2.96m AODN. However, comparison of the in-channel water level for other return periods (provided by the EA) with the predicted land levels on site shows that the direct application of the derived flood level would significantly over-estimate the risk of flooding at the site.

Therefore, given the small difference in the in-channel flood levels between the derived level including a 45% allowance for climate change (i.e. 2.96m AODN) and the 1 in 1000 year flood level (i.e. 2.97m AODN), a conservative approach has been adopted and the flood extent under the 1 in 1000 year return period has been referenced as a direct substitute for the design flood event. Under this scenario, the data provided by the EA shows that the maximum predicted flood level on site is **1.75m AODN**.

When the design flood level is compared to the land levels shown on the topographic survey, it can be seen that the proposed dwelling is situated on land raised above the design flood level. However, inspection of the scheme drawings identifies that the ground floor of the dwellings is to be lowered slightly (below the existing ground level) to provide vehicular access.

Notwithstanding this, the external parking area will be raised slightly to a level of 1.82m AODN before the driveway slopes towards the dwellings, and will prevent floodwater from reaching the dwelling. **Consequently, the ground floor is likely to remain dry under the design flood event.**

It is only if the water level were to exceed 1.82m AODN (e.g. as a result of an exceedance event or a bow wave from moving vehicles) that floodwater could flow down the driveway subjecting the ground floor of the development to shallow flooding. Based on the proposed internal floor levels, the maximum depth of flooding under this scenario is predicted to not exceed 300mm within the garage area and 150mm where the resident's access to the first floor is proposed. As the ground floor will only comprise non-habitable uses (i.e. W/C, garage etc.), opportunities to reduce the impact of such an event have been explored in the following sections of this report.

5.2 The Tidal Risk of Flooding

In addition to the above, the River Arun is tidally influenced in this location. As part of their response, the EA has therefore also provided tidal modelled flood level data for the three node points on site (refer to Figure 5.1) for different future climate change scenarios. As discussed in Section 4 of this report, the proposed development is assumed to have a lifetime of 100 years. As such, the design flood event is taken as the 1 in 200 year flood event including an appropriate allowance for climate change (i.e. future year 2110).

The EA has provided flood level data for the development site for a current day (2010) and a future climate change scenario (2110) for both 'defended' and 'undefended' scenarios. Using the undefended level to define the design flood level at the site will result in a significant over-estimation of risk and therefore in such situations it is necessary to reference the more realistic 'defended' flood level at the site.

Inspection of the data provided shows that the development site is currently defended under a 1 in 200 year flood event. However, when an allowance for climate change is considered (i.e. future year 2110), it can be seen that the predicted maximum flood level on site is 3.5m AODN. When this level is plotted using aerial height data, it is evident that the site and a large area surrounding the site would be affected by flooding (Figure 5.3).

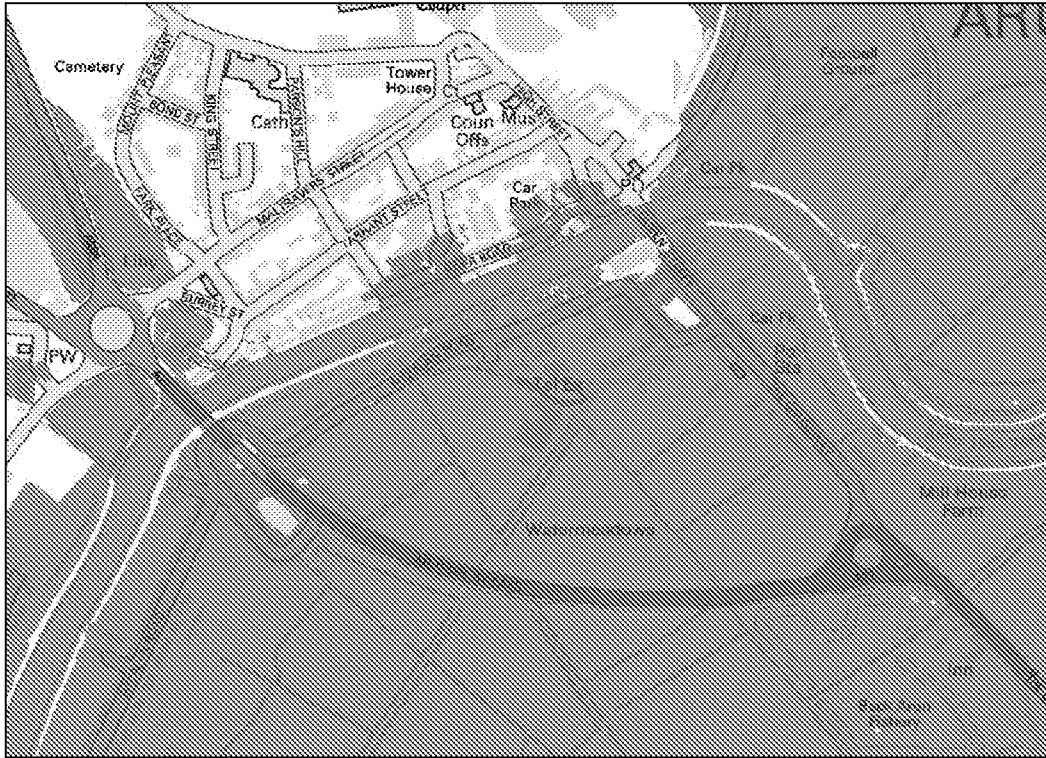


Figure 5.3 – Modelled flood extents for the 'defended' 1 in 200 year return period event including an appropriate allowance for climate change. Site boundary delineated in red.

When the predicted flood level is compared to land levels on site, it can be seen that the depth of flooding varies between 1.2m in the northern half of the site to 2.3m towards the ditch to the south of the site. The depth within the ground floor of the dwellings is predicted to reach a maximum of 2.05m. The following sections of this report discuss the opportunities for mitigating the risk of flooding to the proposed occupants under such an event.

5.3 Velocity and Rate of Rise of Floodwater

Information on the velocity and rate of rise of floodwater at the development site has not been provided. However, given the relatively close proximity of the development to the tidal River Arun, it is likely that floodwater will reach the site rapidly once water exceeds the river banks. From this point, the rate of rise is likely to be gradual as the flood compartment in which the proposed development is located is relatively large and unconfined. As such, it is concluded that the velocity of floodwater at the site will be low.

6 Offsite Impacts and Other Considerations

6.1 Displacement of Floodwater

The construction of a new building within the floodplain has the potential to displace water and to increase the risk elsewhere by raising flood levels. A compensatory flood storage scheme can be used to mitigate this impact, ensuring the volume of water displaced is minimised.

The proposed dwellings have been shown to be at risk of flooding from both tidal and fluvial sources, however, it is generally accepted by the EA that development within the tidal floodplain is unlikely to impact on maximum tidal flood levels. In addition, it has been demonstrated that the dwellings are located outside the 1 in 100 year fluvial flood extent, including an appropriate allowance for climate change. Consequently, the development will not displace floodwater, nor will it increase the risk of flooding elsewhere and as such, compensatory flood storage is not required.

6.2 Public Safety and Access

The NPPF states that safe access and escape should be available to/from new developments located within areas at risk of flooding. The Practice Guide goes on to state that access routes should enable occupants to safely access and exit their dwellings during design flood conditions and that vehicular access should be available to allow the emergency services to safely reach the development.

During a fluvial flood event, the ground floor has been shown to remain unaffected by flooding. Consequently, residents will have safe access to/from the development during the entire flood event. Even in the unlikely event that floodwater were to exceed the crest height of the driveway (i.e. due to an exceedance event or bow waves from moving vehicles), the ground floor can only flood up to a depth of 150mm where the resident's access to the first floor is proposed and therefore safe access will be possible.

Under a tidal flood event, the entire site is shown to flood and depths are predicted to reach a maximum of 2.05m at the buildings. As such, dry and safe access will not be available. Reference to the Practice Guide shows that in circumstances where it is not possible to provide dry access, the flood hazard to people under the design flood conditions needs to be quantified. In this instance, no data has been provided by the EA with regard to the hazard rating on site. However, given the extent of the surrounding area which would also be affected during such an event, it is considered unlikely that residents will be able to leave the dwellings during the peak of the flood event. As such, it will be necessary for the occupants to sign up to the EA's Early Flood Warning System (refer to Section 7.4 below), which will enable residents to receive forewarning of a potential flood event and be prepared to evacuate the site *before* an extreme flood occurs.

If insufficient time is available to evacuate, residents should seek safe refuge within their dwellings. Inspection of the scheme drawings shows that only non-habitable use is specified for the ground floor and all living and sleeping accommodation will be located on the first floor and above. This

approach to raising the more vulnerable elements of the development will provide the occupants with a means of safe refuge in the extremely unlikely event of a flood.

6.3 Proximity to Watercourse

Inspection of OS mapping shows that there is a drainage ditch to the south of the development. To clarify the ownership of this ditch, both the Lead Local Flood Authority (LLFA) and Local Planning Authority (LPA) have been contacted. The LPA has confirmed that the drainage ditch is owned by the Internal Drainage Board (IDB) which is currently formed by the EA in this location. However, it should be recognised that this responsibility is in the progress of being dissolved.

Referencing the information provided, both the EA and Arun District IDB have been contacted regarding the proximity of the proposed buildings to the watercourse. From this correspondence it has been confirmed that the current scheme layout would be acceptable with regard to the distance to the adjacent drainage ditch. In addition, it has been stated that in this instance, the maintenance of the ditch will be the responsibility of the riparian owner.

Notwithstanding this, the EA has confirmed that a Flood Risk Activity Permit is required for construction within 3 to 5 metres of the ditch.

7 Flood Mitigation Measures

The key objectives of flood risk mitigation are:

- to reduce the risk of the development being flooded.
- to ensure continued operation and safety during flood events
- to ensure that the flood risk downstream of the site is not increased by increased runoff
- to ensure that the development does not have an adverse impact on flood risk elsewhere

The following section of this report examines ways in which the risk of flooding at the development site can be mitigated.

Mitigation Measure	Appropriate	Comment
Careful location of development within site boundaries (i.e. Sequential Approach)	✓	Refer to Section 7.1
Raising floor levels	✓	Refer to Section 7.2
Land raising	X	Not required
Compensatory floodplain storage	X	Not required
Flood resistance & resilience	✓	Refer to Section 7.3
Alterations/ improvements to channels and hydraulic structures	X	Not required
Flood defences	X	Not required
Flood warning	✓	Refer to Section 7.4
Management of development runoff	✓	Refer to Section 8

Table 7.1 – Appropriateness of mitigation measures.

7.1 Application of the Sequential Approach at a Local Scale

The sequential approach to flood risk management can also be adopted on a site based scale and this can often be the most effective form of mitigation. For example, on a large scheme this would mean locating the more vulnerable dwellings on the higher parts of the site and placing parking, recreational land or commercial buildings in the lower lying and higher risk areas.

For the development that is subject of this FRA, it can be seen that this approach has been adopted. The ground floor only comprises non-habitable uses, whilst all living and sleeping accommodation have been located on the first floor and above.

7.2 Raising Floor Levels

The EA recommends that the minimum floor level of buildings at risk of flooding should be raised above the design flood level including an appropriate freeboard allowance. In this case, the risk of tidal flooding is greatest, and therefore the finished floor levels are considered in relation to the the 1 in 200 year extreme water level plus the appropriate allowance for climate change. The EA's guidance requires that all living accommodation be raised 300mm above the design flood level, with sleeping accommodation raised a minimum of 600mm above the design flood level.

Based on a design flood level of 3.5m AODN (i.e. tidal flood level), the minimum floor levels are as follows:

Living accommodation = 3.8m AODN

Sleeping accommodation = 4.1m AODN

Inspection of the scheme drawings shows that these minimum floor levels have been achieved.

7.3 Flood Resistance and Resilience

During a flood event, floodwater can find its way into properties through a variety of routes including:

- Ingress around closed doorways.
- Ingress through airbricks and up through the ground floor.
- Backflow through overloaded sewers discharging inside the property through ground floor toilets and sinks.
- Seepage through the external walls.
- Seepage through the ground and up through the ground floor.
- Ingress around cable services through external walls.

Since flood management measures only manage the risk of flooding rather than eliminate it completely, flood resilience and resistance measures may need to be incorporated into the design of the buildings. The two possible alternatives are:

Flood Resistance or 'dry proofing', where flood water is prevented from entering the building. For example, using flood barriers across doorways and airbricks, or raising floor levels. These measures are considered appropriate for 'more vulnerable' development where recovery from internal flooding is not considered to be practical.

Flood Resilience or 'wet proofing', accepts that flood water will enter the building and allows for this situation through careful internal design for example raising electrical sockets and fitting tiled floors. The finishes and services are such that the building can quickly be returned to use after the flood. Such measures are generally only considered appropriate for some 'less vulnerable' uses and where the use of an existing building is to be changed and it can be demonstrated that no other measure is practicable.

It has been demonstrated that the ground floor level of the existing development is at risk of flooding, to an estimated depth of 2.05m during a tidal flood event. Therefore, it is recommended that flood resilient measures are incorporated into the design of the ground floor to minimise the impact of such an event. These measures could comprise the use of;

- Solid concrete floors
- No stud walls
- Bringing the electrical supply in at first floor
- Placing boilers and meter cupboards on the first floor
- Water-resistant plaster/tiles on the walls of the ground floor

Details of flood resilience and flood resistance construction techniques can be found in the document 'Improving the Flood Performance of New Buildings; Flood Resilient Construction', which can be downloaded from the Communities and Local Government website.

7.4

Flood Warning

The EA operate a flood forecasting and warning service in areas at risk of flooding from rivers or the sea, which relies on direct measurements of rainfall, river levels, tide levels, in-house predictive models, rainfall radar data and information from the Met Office. This service operates 24 hours a day, 365 days a year.

Whilst the probability of an event of sufficient magnitude to cause floodwaters to reach the levels discussed in this report is very low, the risk of such an occurrence is always present. With the

sophisticated techniques now employed by the EA to predict the onset of flood events the opportunity now exists for all residents within the flood risk area to receive early flood warnings.

This forewarning could be sufficient to either allow residents to evacuate the area or prepare themselves and their property for a flood event. It is therefore recommended that the occupants of the site sign up to the EA's Flood Warning Service either by calling 0345 988 1188, or by visiting;

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

8 Surface Water Management Assessment

8.1 Background and Policy

The general requirement for all new development with respect to surface water runoff is to ensure that the runoff is managed sustainably and that the drainage solution for the development does not increase the risk of flooding at the site, or within the surrounding area.

For undeveloped greenfield sites, the impact of the proposed development will therefore require mitigation to ensure that the runoff from the site replicates the natural drainage characteristics of the pre-developed site. In the case of brownfield sites, drainage proposals are typically measured against the existing performance of the site, although it is preferable (where practicable) to provide runoff characteristics that are similar to greenfield behaviour.

The Flood and Water Management Act 2010 National Standards (Schedule 3 – paragraph 5) for design, construction, maintenance and operation of Sustainable Drainage Systems (SuDS), defines requirements not initially covered by the NPPF, and are (non-statutory) Technical Standards for SuDS.

These National Technical SuDS Standards specify criteria to ensure sustainable drainage is included within developments of 10 dwellings or more; or equivalent non-residential, or mixed development (as set out in Article 2(1) of the Town and Country Planning (Development Management Procedure) (England) Order 2010). It is, however, recognised that SuDS should be designed to ensure that the maintenance and operation requirements are economically proportionate.

In this instance, the proposed development is for the construction of two dwellings on land totalling 0.1ha. The development is classified as 'minor development' and therefore, the National Technical SuDS Standards will not apply. Nevertheless, reference to the Standards has been made throughout the following sections of this report to ensure that the principles of sustainable drainage are still considered.

8.2 Surface Water Management Overview

The main characteristics of the site that have the potential to influence surface water drainage are summarised in Table 8.1 below.

Site Characteristic	Value
Total area of site	0.1 ha
Impermeable area (existing)	72 m²
Impermeable area (proposed)	Roof area = 178 m ² Hardstanding = 150 m ² Total = 328 m²
Current site condition	Brownfield
Greenfield runoff rates (based on the ICP SuDS methodology)	QBar = 2.1 l/s/ha Q30 = 4.7 l/s/ha Q100 = 6.5 l/s/ha
Infiltration coefficient	~0.01 m/hr (assumed based on underlying geology and typical soil conditions)
Current surface water discharge method	Unknown
Is there a watercourse within close proximity to site?	Yes

Table 8.1 – Site characteristics affecting rainfall runoff.

Synthetic rainfall data has been derived using the variables obtained from the Flood Studies Report (FSR) and the routines within the Causeway Flow+ software. The peak surface water flows generated on site for the existing and post-development conditions have been calculated by using the Modified Rational Method.

Runoff rates have been calculated for a range of annual return probabilities including the 100 year return period event with a 30% increase in rainfall intensity to account for future climatic changes. These values are summarised in Table 8.2 for a range of return periods.

Return period (years)	Peak runoff (l/s)	
	Existing site	Developed site
1	2	9
30	5	21
100	6	28
100 + 30%	8	37

Table 8.2 – Summary of peak runoff.

The total volume of water discharged from the site for the 100 year 6 hour event is also summarised in Table 8.3 below, for both the existing and proposed site conditions.

Site condition	Total volume discharged
Existing site (present day)	2 m ³
Existing site including a 30% increase in rainfall intensity to account for climate change	3 m ³
Proposed development including a 30% increase in rainfall intensity to account for climate change (prior to any mitigation)	14 m ³
Difference in volume between existing site (present day) and proposed development (including allowance for climate change)	12 m ³

Table 8.3 – Total volume discharged from the 100 yr+30%cc 6 hour event.

Reference to the tables above shows the proposed development will increase the percentage of impermeable area within the boundaries of the site and consequently, this will increase the rate and volume of surface water runoff discharged from the site. However, the development subject to this report is classified as ‘minor development’ and as such, it is not strictly necessary to reduce the rate of runoff from the site in accordance with the National Technical SuDS Standards. Nevertheless, the potential use of SuDS within the proposed development will be considered to assess the opportunity to replicate pre-developed runoff behaviour and provide a betterment if feasible.

8.3 Opportunities to Discharge Surface Water Runoff

Part H of the Building Regulations summarises a hierarchy of options for discharging surface water runoff from developments. The most preferential option is to **infiltrate** water into the ground, as this deals with the water at source and serves to replenish groundwater. If this option is not viable, the next option of preference is for the runoff to be discharged into a **watercourse**. Only if neither of

these options are possible, the water should be conducted into the **public sewer** system. The opportunities for managing surface water runoff from the proposed development are outlined below.

Water re-use - Water re-use systems can rarely manage 100% of the surface water runoff discharged from a development, as this requires the yield from the building and hardstanding area to balance perfectly with the demand from the proposed development. Consequently, whilst rainwater recycling systems will be considered for inclusion within the scheme, an alternative solution for attenuating storm water will still be required.

Infiltration – Site-specific ground investigations have not been carried out at this stage in the development process. However, the geology in this area is Spetisbury Chalk Member overlain by Raised Marine Deposits. The superficial deposits within the area suggest some potential for infiltration, however, the close proximity to the adjacent watercourse and Defra ground water maps indicates the area is susceptible to ground water flooding.

Given the high ground water, and with the absence of ground investigations, infiltration is considered to be an unsuitable option for draining this site.

Discharge to Watercourses – There is an existing drainage ditch adjacent to the southern site boundary. OS mapping for the area surrounding the site has been inspected and it is concluded that this ditch is likely to drain to the wider catchment of the River Arun. Due to the proximity of this ditch to the site, it is likely a direct connection will be possible and therefore, will present the most sustainable solution for draining surface water runoff from the proposed development.

Discharge to Public Sewer System – Southern Water has been contacted with regard to the location of the sewer network and inspection of the data provided shows that the site is not in close proximity to any existing sewer connections. In addition, the only sewers in this area are designated for foul effluent only. Whilst there is sometimes the option to drain surface water runoff to the public foul sewer system, given a more sustainable solution is available, it is highly unlikely Southern Water will permit any surface water runoff to be discharged to the existing public sewer system. Consequently, this option has been discounted.

8.4 Sustainable Drainage Systems (SuDS) Suitability Assessment

Appropriately designed SuDS can be utilised such that they not only attenuate runoff but also provide a level of improvement to the quality of the water passed on to watercourses or into the groundwater table. This is known as source control and is a fundamental part of the SuDS philosophy.

A range of typical SuDS that can be used to improve the environmental impact of a development is listed in Table 8.4 below along with the relative benefits of each feature and the appropriateness for the subject site.

SuDS	Description	Constraints/Comments	Appropriate for site?
Rainwater harvesting systems	Collecting of rainwater and storing for reuse on site.	There are no known constraints.	Yes
Green roofs	Provide landscaping and planting at roof level to reduce surface water runoff rates.	Proposed roof design unsuitable.	No
Infiltration Systems	Allow water to percolate into the ground at a controlled rate via natural infiltration.	Potentially high groundwater and for localised silt deposits.	No
Filter strips	Wide gently sloping densely planted areas promoting sedimentation and filtration.	Insufficient space.	No
Filter drains	Trenches infilled with stone/gravel providing attenuation, sedimentation and filtration.	Insufficient space.	No
Swales	Broad shallow channels that convey and store runoff and allow infiltration.	Topography	No
Bioretention systems / rain gardens	A shallow landscaped depression allowing runoff to pond temporarily on the surface.	There are no known constraints.	Yes
Permeable pavements	Runoff is allowed to soak into structural paving and stored potentially being allowed to infiltrate.	Potentially high groundwater. There are no other known constraints.	Yes
Underground storage	Below ground storage which can be used to temporarily store storm water.	There are no known constraints.	Yes
Detention basins	A landscaped depression for attenuation with a restricted runoff.	Insufficient space.	No
Ponds and wetlands	A permanent pool of water which can be used for attenuation and controlled outflows by water levels.	Insufficient space.	No

Table 8.4 – Suitability of SuDS.

From Table 8.4 it can be seen that there are a number of SuDS which could potentially be suitable for use at this site. Arun District Council promotes the use of open (at source) SuDS, however, due to the location of the site in relation to the floodplain and the potential risk of flooding to the surrounding area, it is considered unlikely that this option can be achieved. The use of attenuation storage has been considered, which could be provided by installing a crate system within the rear gardens of the proposed development. Nevertheless, given the topography in this area it might not be possible to achieve the required invert levels to the adjacent drainage ditch.

Therefore, at this stage in the planning process it is envisaged that permeable paving will be used to discharge the surface water runoff at an attenuated rate into the adjacent drainage ditch.

8.5 Proposed Drainage System

To ensure the risk of flooding is not increased by the development proposals it will be necessary to restrict the discharge of surface water runoff from the entire site under the design rainfall event.

The drainage strategy below discusses the different elements of the proposed system along with basic calculations that have been undertaken to demonstrate how the overall objectives can be achieved. This does not represent a detailed surface water management drainage design; it is simply an assessment to demonstrate that the objectives and requirements of the NPPF and LPA can be met at the planning stage.

Arun District Council requires the discharge of surface water runoff to a watercourse to be restricted to greenfield runoff rates, or where this is not feasible, runoff rates should be restricted to the existing pre-developed rates. Due to the size of the site, greenfield runoff rates are less than 0.2l/s and it is therefore deemed unfeasible to achieve greenfield runoff rates for this site. Instead, given that the existing site is defined as a brownfield site, ideally the proposed development should not increase the rate of surface water runoff from the site and where possible, provide a betterment., A minimum discharge rate of 2l/s is suggested to avoid any blockages and to provide the attenuation required for the 1 in 100 year event, including a 30% allowance for climate change as requested by Arun District Council.

Based on the above, a storage estimation tool using the Causeway Flow+ software has been used and a summary of the analysis is shown in Table 8.5 below.

Storage Parameter	Value
Return period	100 years
Climate change	30%
Impermeable area	0.033 ha
Peak discharge	2 l/s
Infiltration coefficient	0.0 m/hr
Maximum required storage	23 m ³

Table 8.5 – Summary of Causeway Flow+ software storage estimate.

Although the soil may have some level of percolation, the development site lies within an area susceptible to high groundwater. Consequently, in the absence of any infiltration testing, a conservative approach has been considered when designing the storage underneath the permeable paving and the infiltration coefficient has been set to zero. Notwithstanding this, it should

be recognised that if infiltration is considered achievable, the proposed system could be used for infiltration SuDS only instead of discharging into the adjacent drainage ditch.

The analysis has shown that a storage volume of 23m³ will be required when considering the 1 in 100 year event with a 30% increase in rainfall intensity. Based on this, the surface water runoff from the entire impermeable area can be discharged to permeable surfacing located across the driveways located at the front of the proposed development. The permeable paving will be underlain by a minimum 600mm deep open graded sub-base, used to store the water before it is discharged at a restricted into the adjacent drainage ditch. A summary of the derived parameters is shown in Table 8.6 below.

Parameter	Value
SuDS Feature	Permeable paving
Area draining to permeable paving	330 m ²
Area of permeable paving	120 m ²
Sub-base depth	600mm
Assumed infiltration	None
Flow control device	Orifice plate
Limited discharge rate	2.0l/s

Table 8.6 – Summary of SuDS parameters for the permeable paving (100 yr+30%cc).

Figure 8.2 below is an indicative drainage layout plan delineating how the proposed SuDS can be incorporated into the scheme proposals.

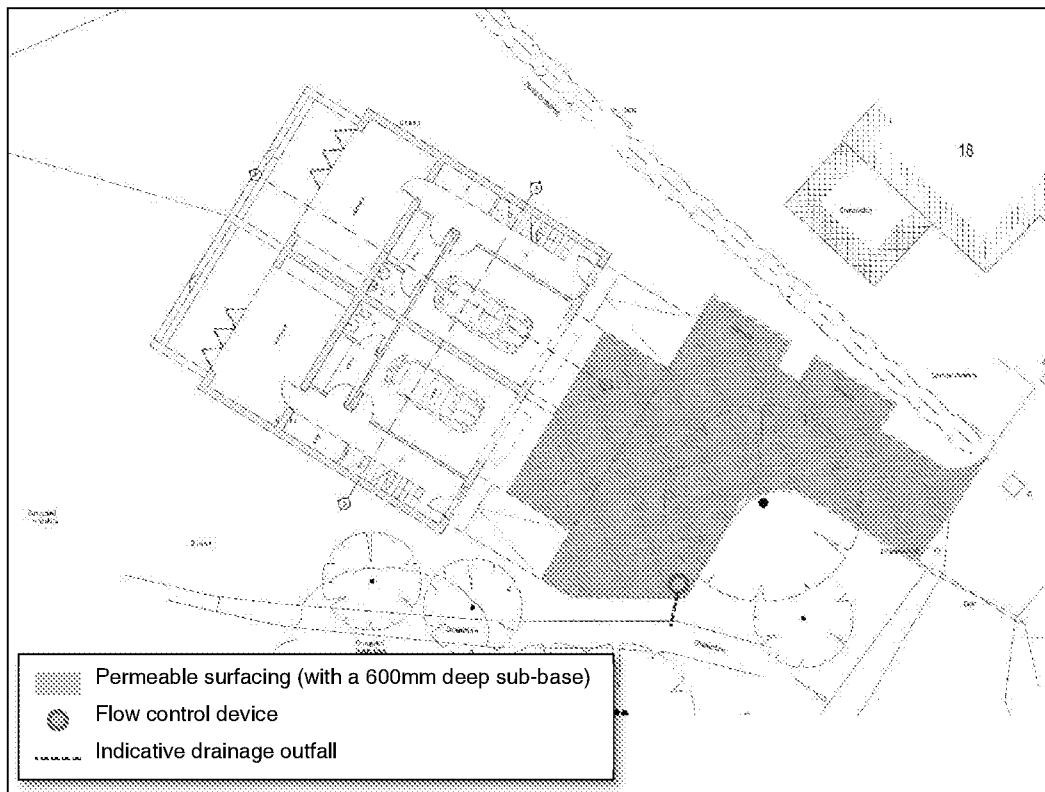


Figure 8.2 – Indicative drainage layout plan showing the proposed location of SuDS.

From the information above, it is evident that with the inclusion of permeable surfacing, there is potential to accommodate the surface water runoff from the impermeable areas up to, and including, the design rainfall event. In addition, it has been shown that the runoff rates from the proposed development can be attenuated to that of the existing site. When considering the pre-development conditions, the introduction of SuDS provides a significant betterment to surface runoff conditions, and therefore reduces the risk of flooding at the development site and surrounding area.

8.6 Sensitivity Testing

The proposed drainage system considers storage for an extreme rainfall event with a return period of 1 in 100 years, including a 30% increase in peak rainfall intensity (to account for the impacts of climate change). Nonetheless, based on the EA's most contemporary climate change guidance an Upper End climate change allowance of 40% has been used to test the proposed drainage system to reflect further increases in peak rainfall intensity.

Under this exceedance scenario, an additional storage of 2m³ would be required. Consequently, it is evident that the permeable surfacing could surcharge under the exceedance event including a 40% increase in peak rainfall intensity. This could result in a small amount of localised flooding at the site. Notwithstanding this, the additional volume of floodwater discharged from the site is relatively small and if spread evenly across the permeable surfacing to the front of the properties, it is unlikely to result in flooding greater than 20mm in depth. Consequently, the risk to the proposed development and surrounding area is considered to be low.

Nonetheless, in the event of a design exceedance scenario, the local topography lends itself to overflow into the adjacent watercourse and away from local properties which mimics the predevelopment site runoff behaviour.

Based on the analysis above, it is therefore concluded that with the inclusion of the proposed SuDS discussed, the development will not increase the risk of flooding on or offsite and is therefore considered appropriate.

8.7 Management and Maintenance

For any surface water drainage system to operate as originally designed, it is necessary to ensure that it is adequately maintained throughout its lifetime.

The key requirements of any management regime are routine inspection and maintenance, when the development is taken forward to the detailed design stage an 'owner's manual' will need to be prepared. This should include:

- A description of the drainage scheme,
- A location plan showing all of the SuDS features and equipment such as flow control devices etc.
- Maintenance requirements for each element, including any manufacturer specific requirements
- An explanation of the consequences of not carrying out the specified maintenance
- Details of who will be responsible for the ongoing maintenance of the drainage system.

For the SuDS features recommended by this assessment, the most obvious maintenance tasks will be the cleaning of the permeable paving and the de-silting and inspection of the flow control device.

For developments such as this that rely to some extent on the ongoing inspection and maintenance of SuDS, it will be necessary to ensure that measures are in place to maintain the system for the lifetime of the development. In this case, it is considered likely that the individual residents will be tasked with the maintenance of the SuDS. However, it is recognised that measures will need to be put in place to ensure occupants are made aware of the maintenance schedules.

9 Conclusions

The key aims and objectives for a development that is to be sustainable in terms of flood risk are summarised in the following bullet points:

- the development should not be at a significant risk of flooding and should not be susceptible to damage due to flooding.
- the development should not be exposed to flood risk such that the health, safety and welfare of the users of the development, or the population elsewhere, is threatened
- normal operation of the development should not be susceptible to disruption as a result of flooding and safe access to and from the development should be possible during flood events
- the development should not increase flood risk elsewhere
- the development should not prevent safe maintenance of watercourses or maintenance and operation of flood defences by the EA
- the development should not be associated with an onerous or difficult operation and maintenance regime to manage flood risk; the responsibility for any operation and maintenance required should be clearly defined
- the development should not lead to degradation of the environment
- the development should meet all of the above criteria for its entire lifetime, including consideration of the potential effects of climate change

In determining whether the proposals for development at Queens Lane, Arundel are sustainable in terms of flood risk and are compliant with the NPPF and its Planning Practice Guidance, all of the above have been taken into consideration as part of this FRA.

In this case, a Sequential Test has not been undertaken as part of this FRA, however, the evidence provided within this report can be used to support the application of the Sequential Test.

In addition to the Sequential Test, it is also necessary to consider the type of the development and whether the Exception Test is applicable. From Table 2.3, it can be seen that the proposed development is situated within a Flood Zone 3 and is a development type that is classified as being 'more vulnerable'. Consequently, it has been necessary to apply the Exception Test to determine whether suitable and appropriate mitigation can be incorporated into the design of the scheme to ensure that it is sustainable in terms of flood risk.

The risk of flooding has therefore been appraised across a wide range of sources and it is only the risk of flooding from the River Arun (fluvial and tidal) that is shown to have an impact on the development.

When the fluvial risk of flooding is considered in more detail, it has been shown that under an extreme fluvial flood event with a 1 in 100 year return period (including a 45% increase in peak river flow), the site is located outside of the fluvial flood extents. Whilst the ground floor has been lowered due to ridge height restrictions, it has been shown that floodwater would be prevented from entering the building by the raised land levels along the crest of the driveway. It is therefore only in the unlikely event that the water level was to exceed 1.82m AODN that the ground floor could be subject to shallow flooding with flood depths predicted to range between 150mm to 300mm. In recognition of this, the ground floor will comprise non-habitable uses, and is proposed to include flood resistance and resilience measures in order to limit the impact of such an event (i.e. exceedance or bow waves from vehicles).

With respect to the tidal risk of flooding, it has been demonstrated that the development is currently protected under a tidal flood event with a 1 in 200 year return period. It is only when an allowance for climate change is considered (i.e. future year 2110), that the development site is shown to be affected by flooding, with flood depths predicted to reach a maximum of 2m adjacent to the proposed buildings. Consequently, safe access/egress to/from the site will not be achievable during the peak of a flood event. As such, it is recommended that residents sign up to the EA's Early Flood Warning to enable the site to be evacuated before floodwater reaches the development.

If insufficient time is available, the residents of the building will be able to seek safe refuge within their houses. The proposed development has been designed to only accommodate non-habitable use on the ground floor with all living and sleeping accommodation shown to be located on the first floor and above and therefore, located well above the predicted flood level. Consequently, safe refuge will be available throughout the duration of the flood event.

In addition to appraising the risk of flooding to the development, it is also necessary to consider the impact that the proposed development could have on the surrounding area with regard to surface water runoff. The Surface Water Drainage Strategy that has been identified at this early stage shows that the objective of reducing peak discharge rates to ~2.0l/s can be achieved through the use of permeable surfacing, in conjunction with a flow control device. When considering the pre-development conditions, the introduction of SuDS provides a significant betterment to surface runoff conditions, and therefore reduces the risk of surface water flooding at both the development site and within the surrounding area.

In conclusion, following the recommendations of this report, the occupants of the development will be safe and the development will not increase the risk of flooding elsewhere. Consequently, it has been demonstrated that the development can pass the second element of the Exception Test and will therefore meet the requirements of the NPPF.

10 Recommendations

The findings of this report conclude that the development will not increase the risk of flooding at the site, or elsewhere. However, in order to achieve this a number of recommendations are listed below. These comprise the following.

- The finished floor level for all living accommodation shall be set at least 300mm above the design flood level, at a minimum of 3.8m AODN. The finished floor level for all sleeping accommodation shall be set at least 600mm above the design flood level, at a minimum of 4.1m AODN. Inspection of the scheme drawings shows that this has been achieved.
- The flood resilience measures outlined in Section 7.3 of this report are to be incorporated into the design of the building where possible.
- The residents of the proposed dwellings should sign up to the EA's floodline warnings. The flood warnings provide residents with the opportunity to prepare the buildings and evacuate in the unlikely event that an exceedance event should occur.
- The surface water management strategy for the development will need to be developed to a detailed design stage and this will need to take into account the requirements set out in Section 8.
- It will be necessary to undertake site-specific investigations at the detailed design stage in order to quantify the available infiltration, the groundwater level and any contamination that may be present in the soils.

With the above mitigation measures incorporated into the design of the development the proposals will meet the requirements of the NPPF and its Planning Practice Guidance and will therefore be acceptable and sustainable in terms of flood risk.

11 Appendices

Appendix A.1 – Drawings

Appendix A.2 – Environment Agency Flood Report

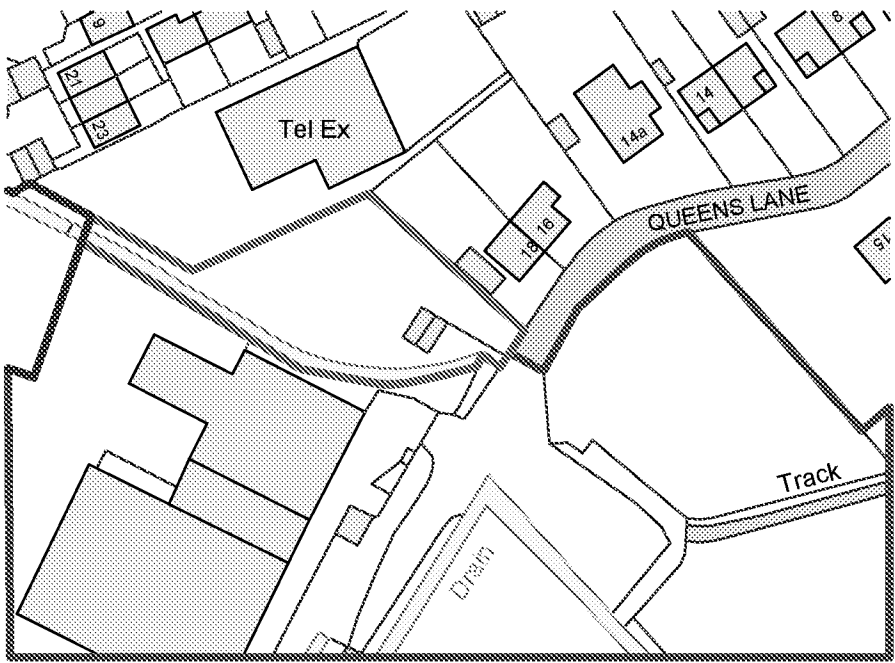
Appendix A.3 – Southern Water Asset Location Data

Appendix A.4 – Surface Water Management Calculations

Appendix A.1 – Drawings

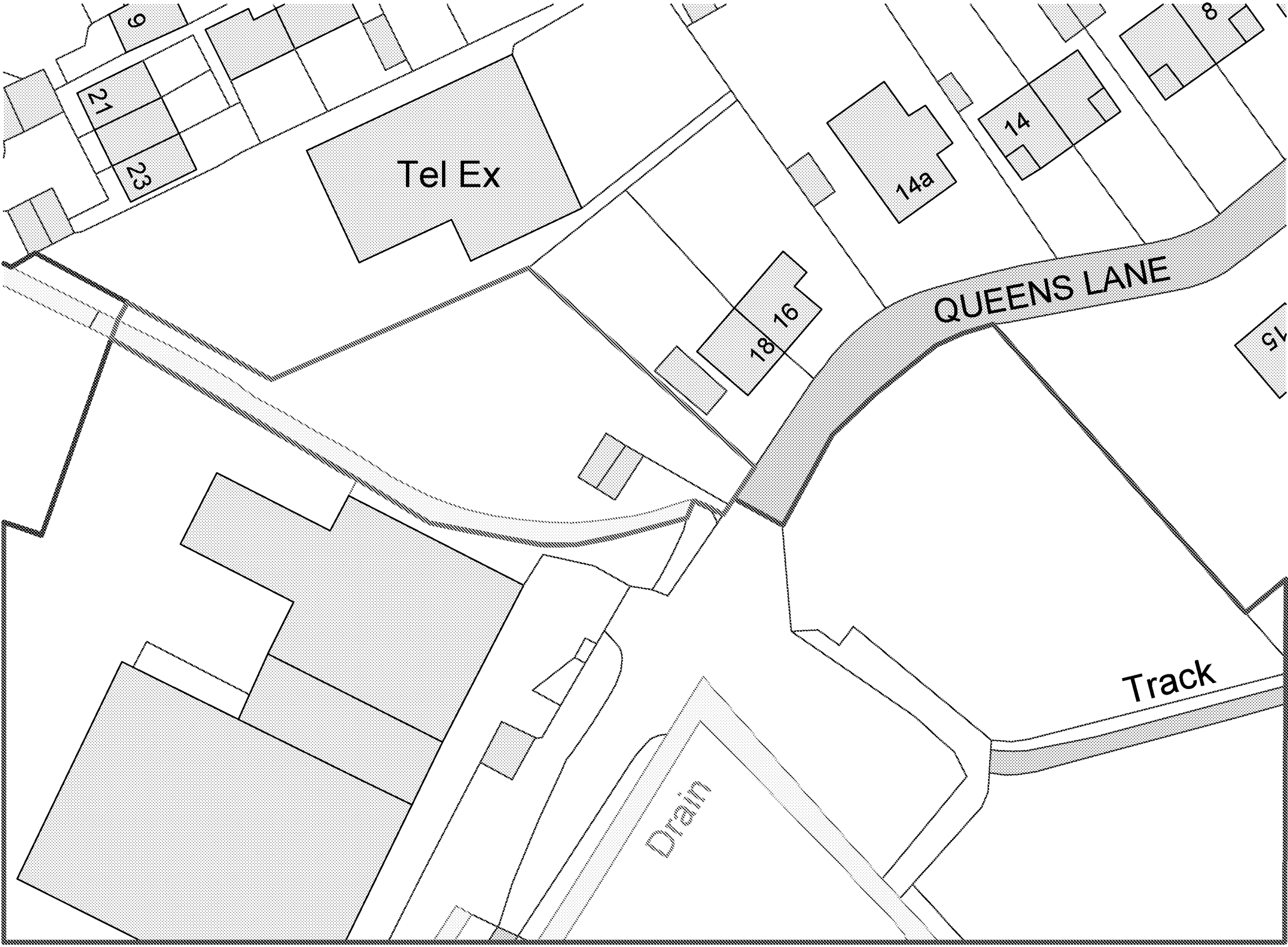
KEY

- SITE BOUNDARY
- ANGMERING PARK ESTATE
- DUKE OF NORFOLK ESTATE



SITE LOCATION PLAN
SCALE 1:1250

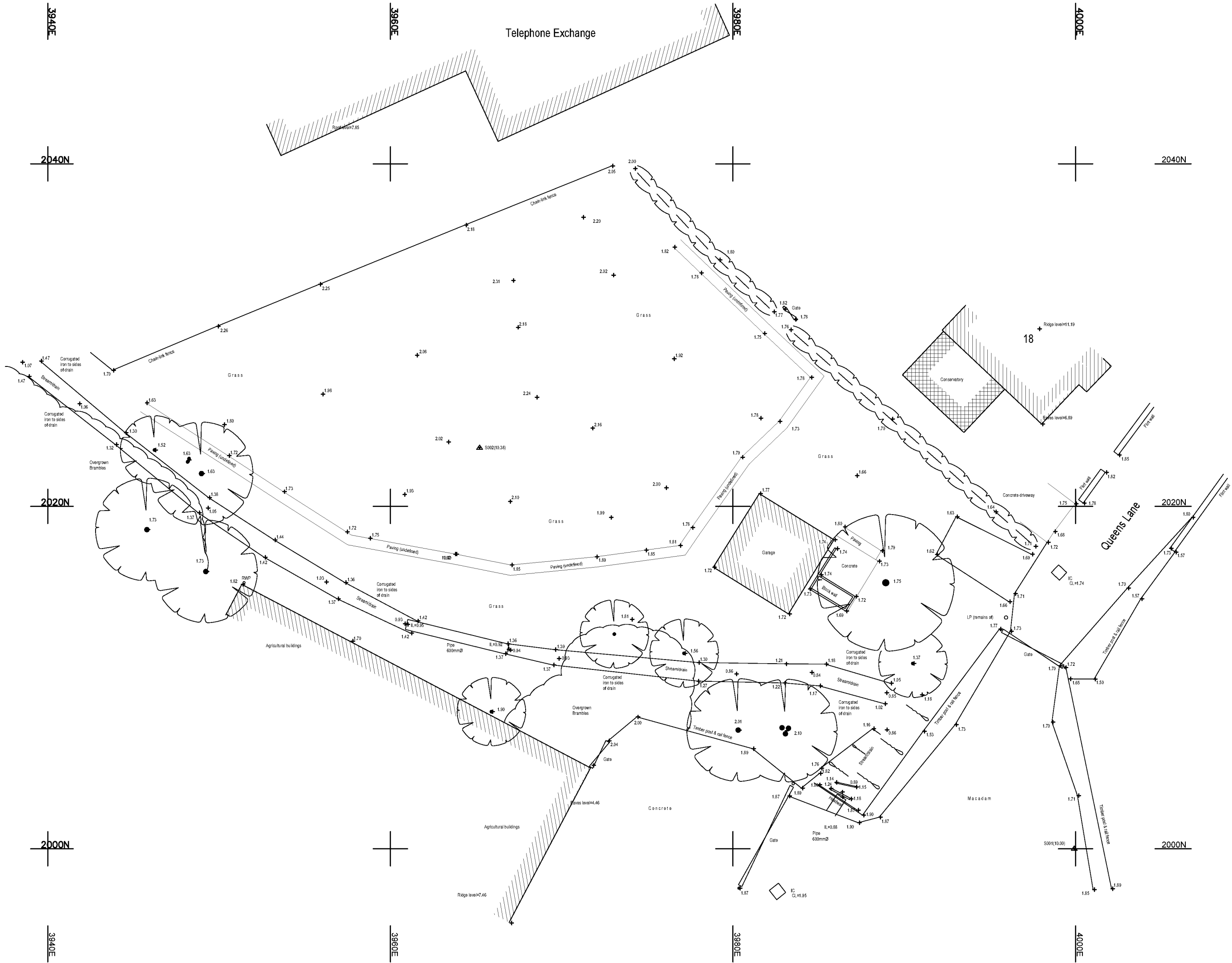
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0 10 20 30 40 50 100



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EXISTING SITE PLAN
SCALE 1:500

Scale in Metres
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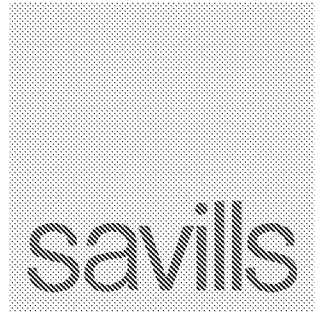


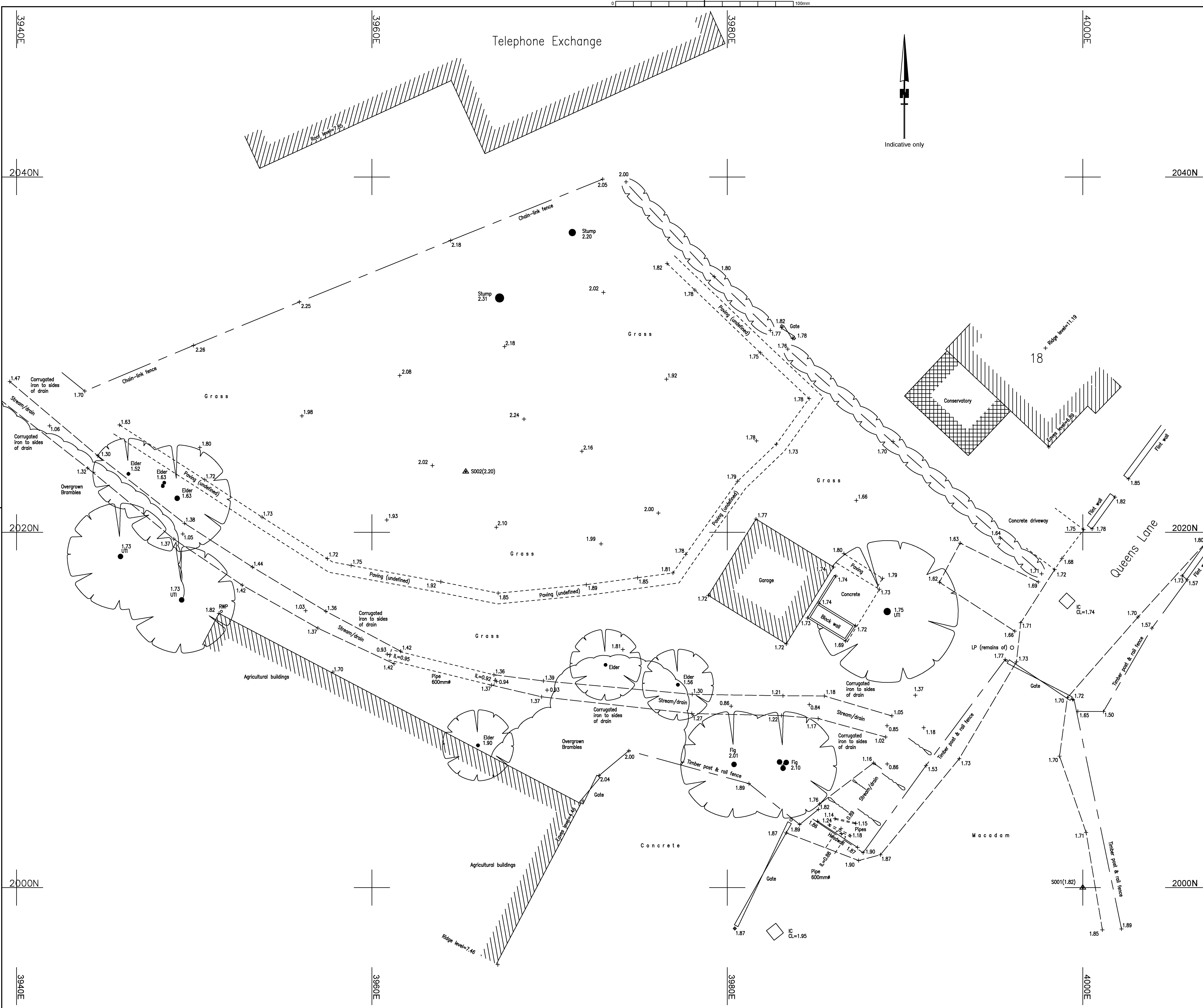
TOPOGRAPHICAL SURVEY
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Scale in Metres
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Rev	Description	By	Date
Drawing Status			
DRAFT			
 RURAL CONSULTANCY SERVICES Savills (UK) Limited Exchange House, Petworth West Sussex. GU28 0BF Telephone: + 44 (0)1798 345 980 Fax: + 44 (0)1798 345 998 www.savills.co.uk			
Client Angmering Park Farms LLP			
Project Queens Lane Arundel BN18 9JN			
Drawing Title Site Plan Existing			
Scale 1:200@ A1	Date 28/02/18	Drawn ES	Checked AB
Drawing Number 001	Rev.	Project Number PWDJ140372	



- NOTES**
- All measurements are in metres. This plan has been produced at the equivalent of 1:100 scale. Any enlargement or use at larger scales will not enhance the accuracy level and should be treated with extreme care.
 - Grid is Arbitrary in Origin.
 - Levels are related to O.S.B.M located on No.4 Queen Street.
(Value = 2.91m A.O.D).
 - Drainage pipe sizes and connections surveyed by visual inspection only and therefore the accuracy cannot be guaranteed.
UTL = Unable to lift.
 - Species of trees must be confirmed by a qualified Arboriculturist prior to any design work takes place.
UTI = Unable to identify.

STATION DETAILS			
Station No.	Eastings	Northings	Level
S001	4000.000	2000.000	1.824
S002	3965.281	2023.419	2.204

A.	Levels adjusted to O.S.Datum.			11/02/18
Rev	Revision details	Chkd	Appd	Date
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Drawn:	Taurus Surveys.			19/02/2018
Chkd:				
Appd:				

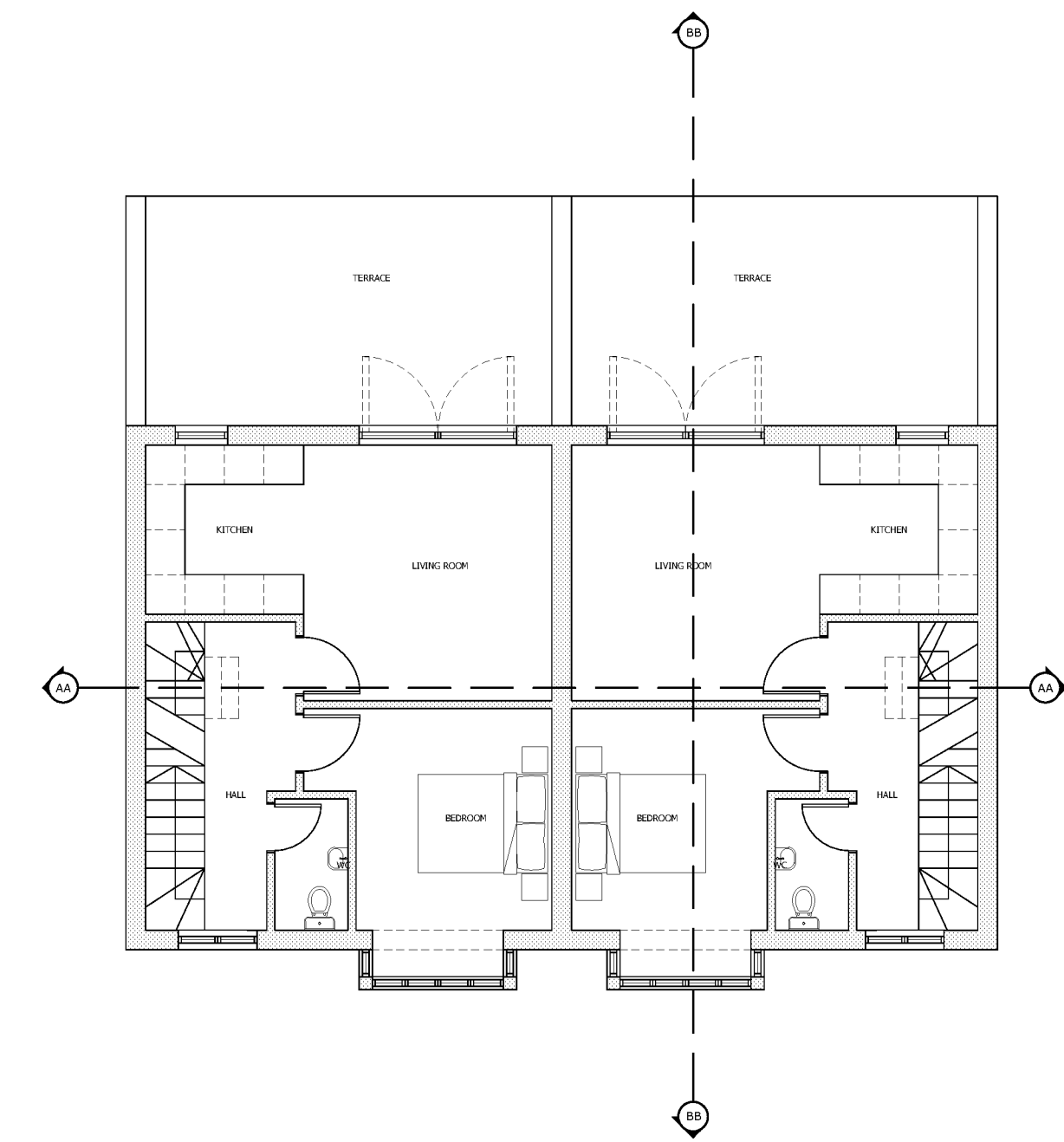
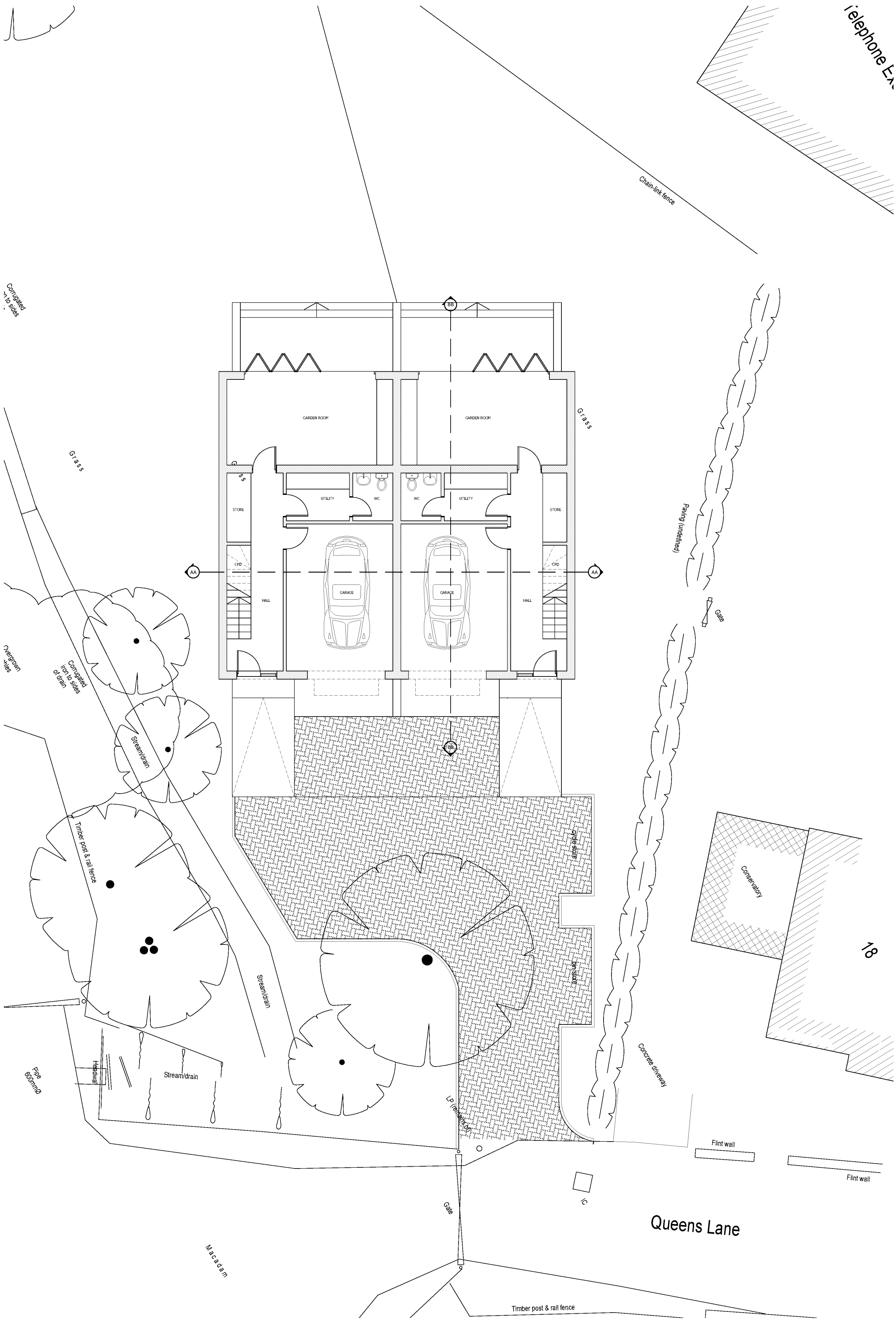


Client:
Angmering Park Estate.
The Estate Office, Upper Broomhurst Farm,
Cross Bush Lane, Crossbush,
West Sussex. BN18 9PQ.

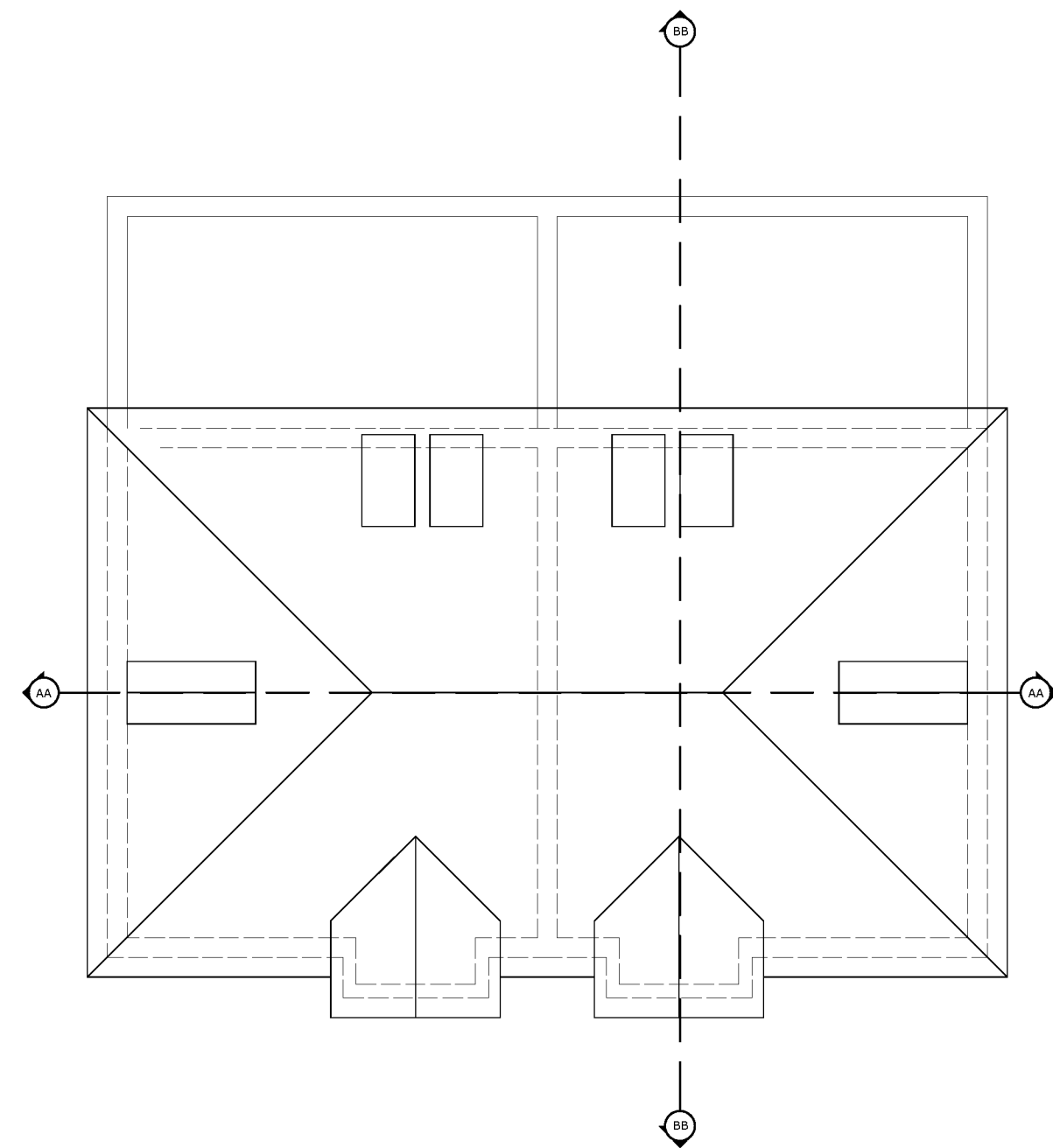
Project Name:
**Queens Lane, Arundel,
West Sussex. BN18 9JN.**

Drawing Title:
Topographical Survey.

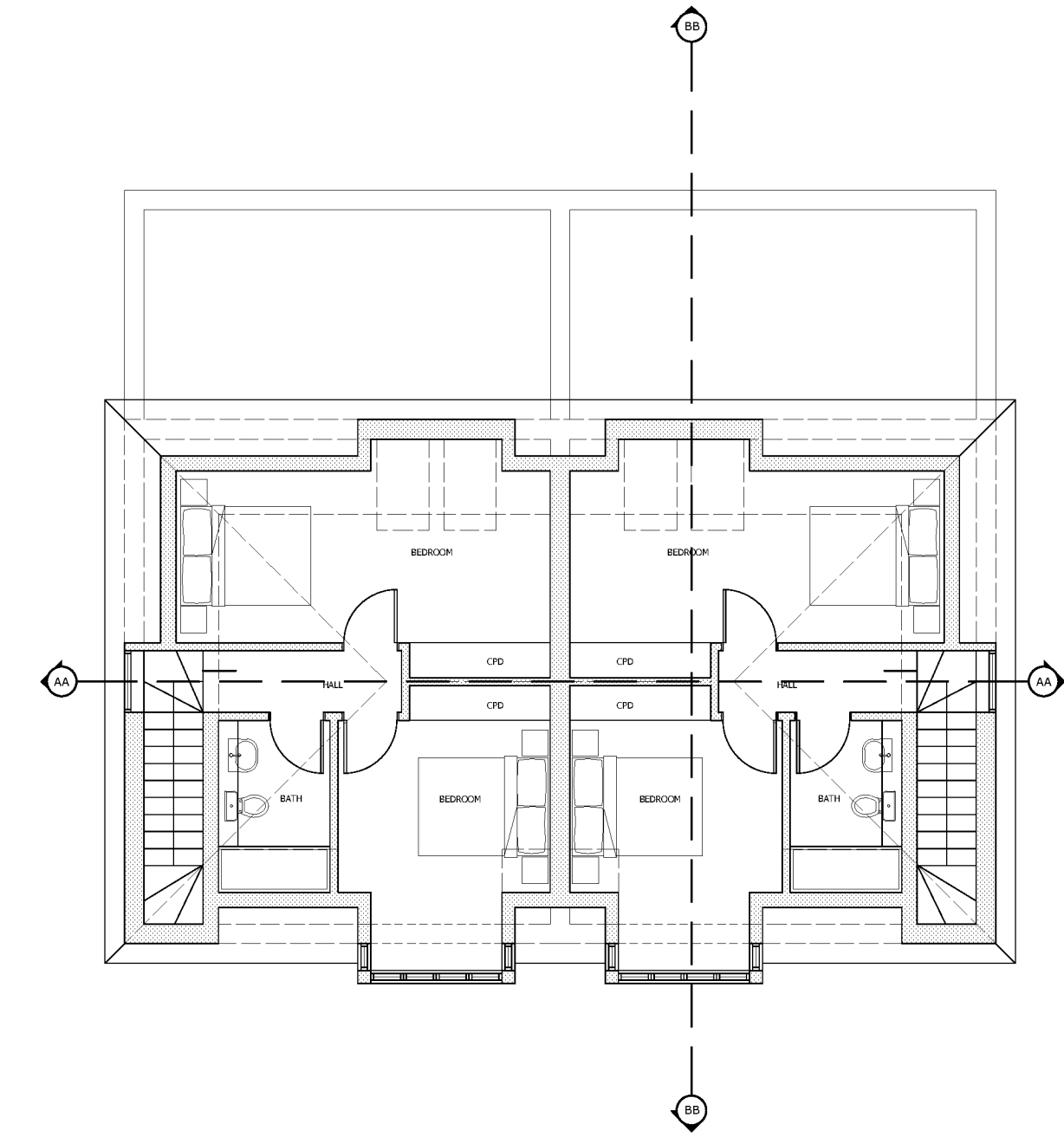
Original Drawing Size:		A1	
Scale: 1 : 100.		Dimensions:	Metres
Drawing No: 18-03/S/1			Rev A



FIRST FLOOR PLAN - PROPOSED
SCALE 1:100
Scale in Metres
0 1 2 3 4 5 10



ROOF FLOOR PLAN - PROPOSED
SCALE 1:100
Scale in Metres
0 1 2 3 4 5 10



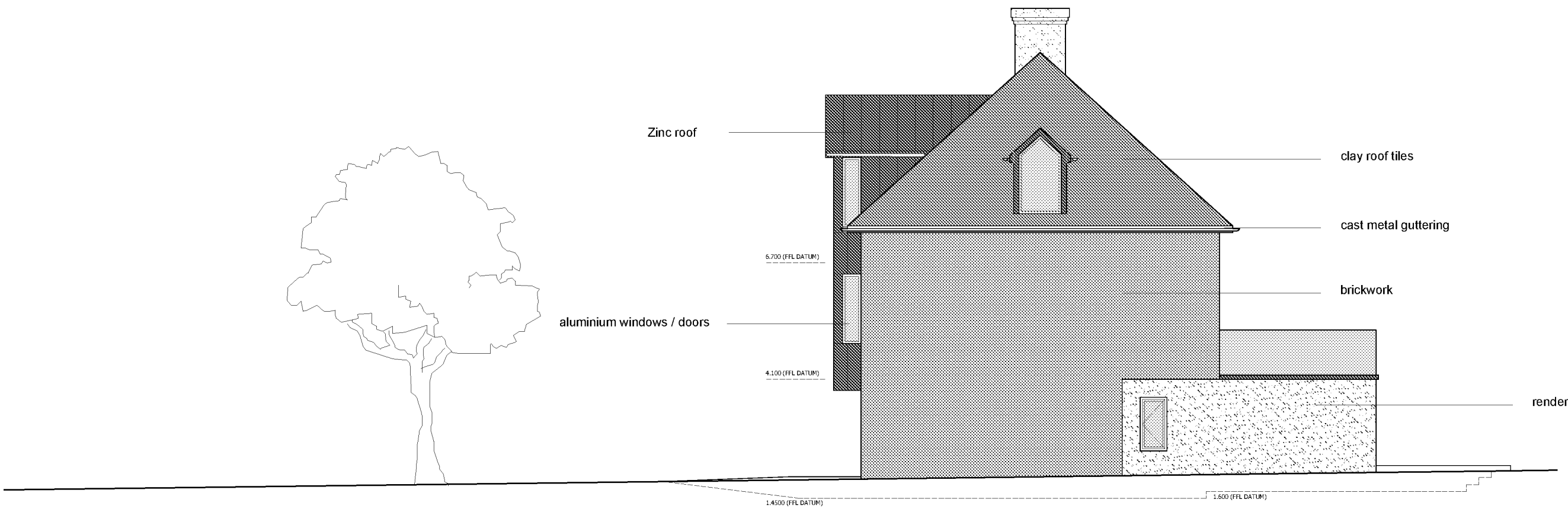
SECOND FLOOR PLAN - PROPOSED
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Scale in Metres
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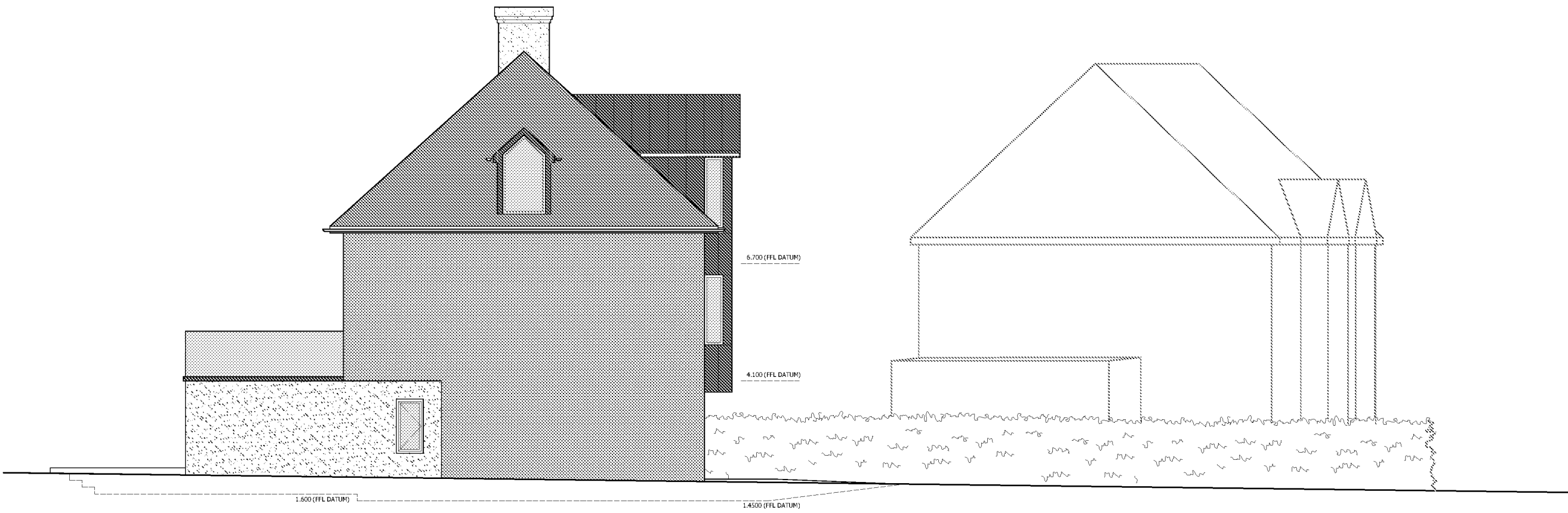
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Client Angmering Park Farms LLP			
Project Queens Lane Arundel BN18 9JN			
Drawing Title Floor Plans Proposed			
Scale 1:100@ A1	Date 28/02/18	Drawn ES	Checked AB
Drawing Number 100	Rev.	Project Number PWDJ140372	

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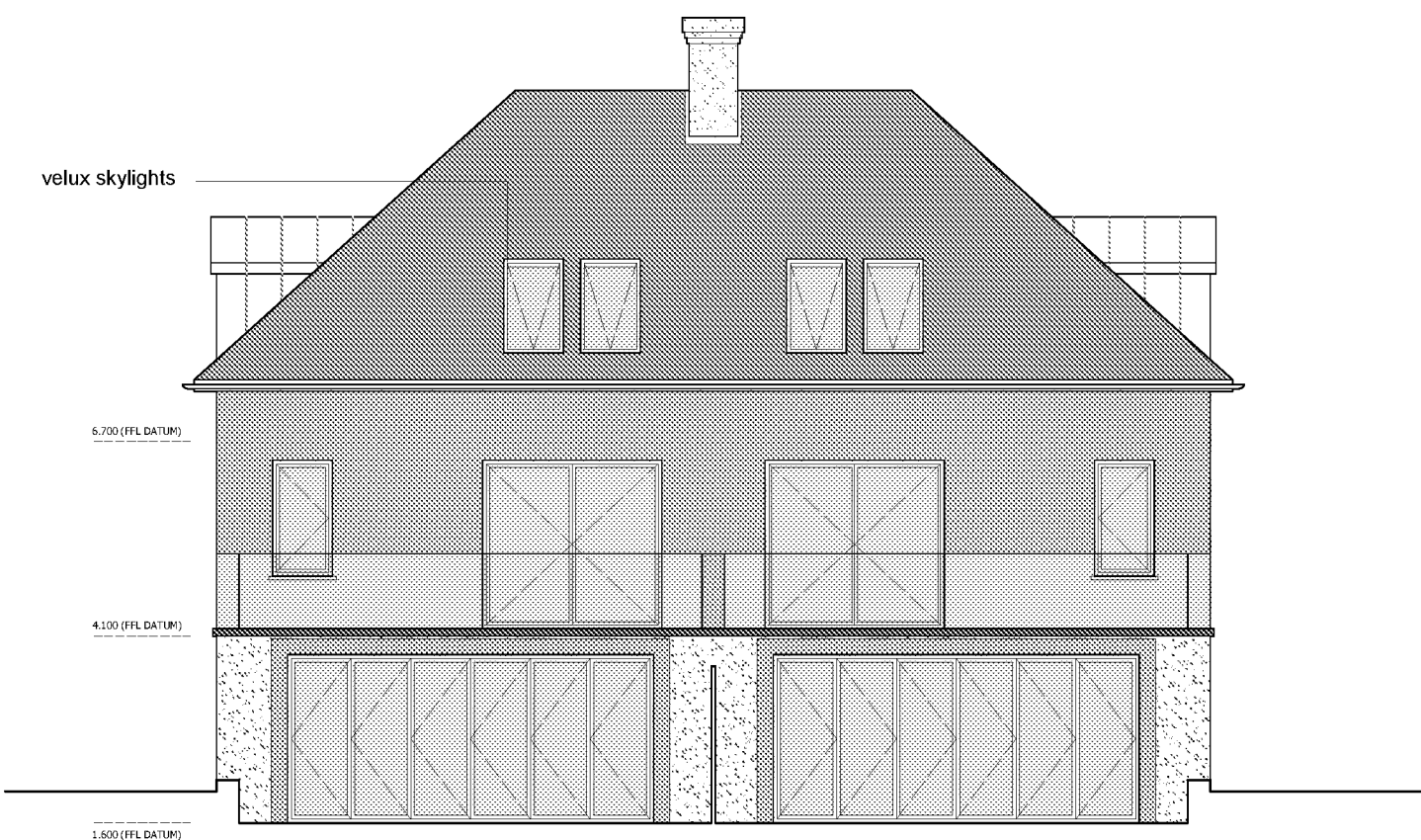
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SCALE 1:100



SOUTH ELEVATION - PROPOSED
SCALE 1:100



EAST ELEVATION - PROPOSED
SCALE 1:100



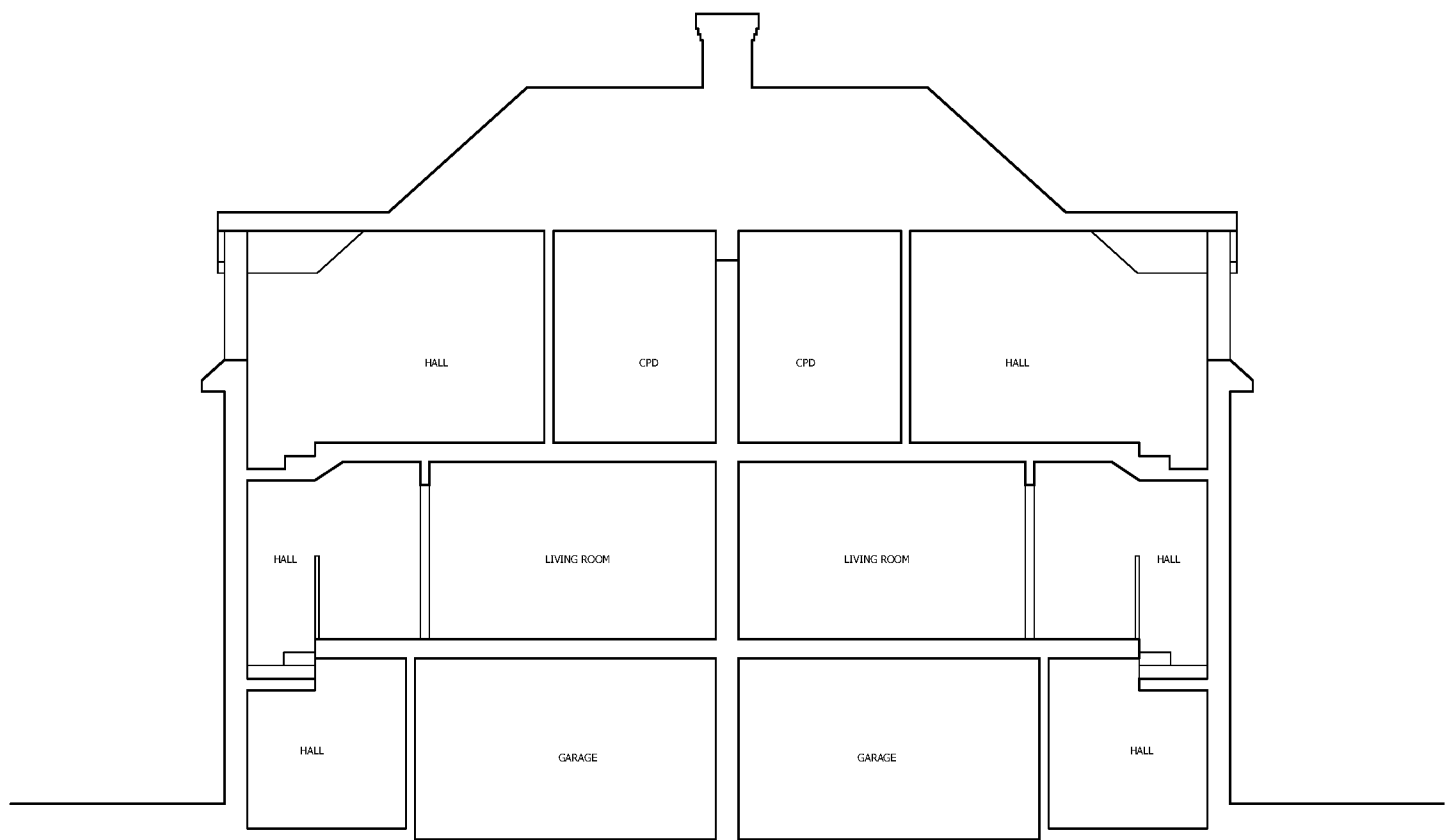
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SCALE 1:100



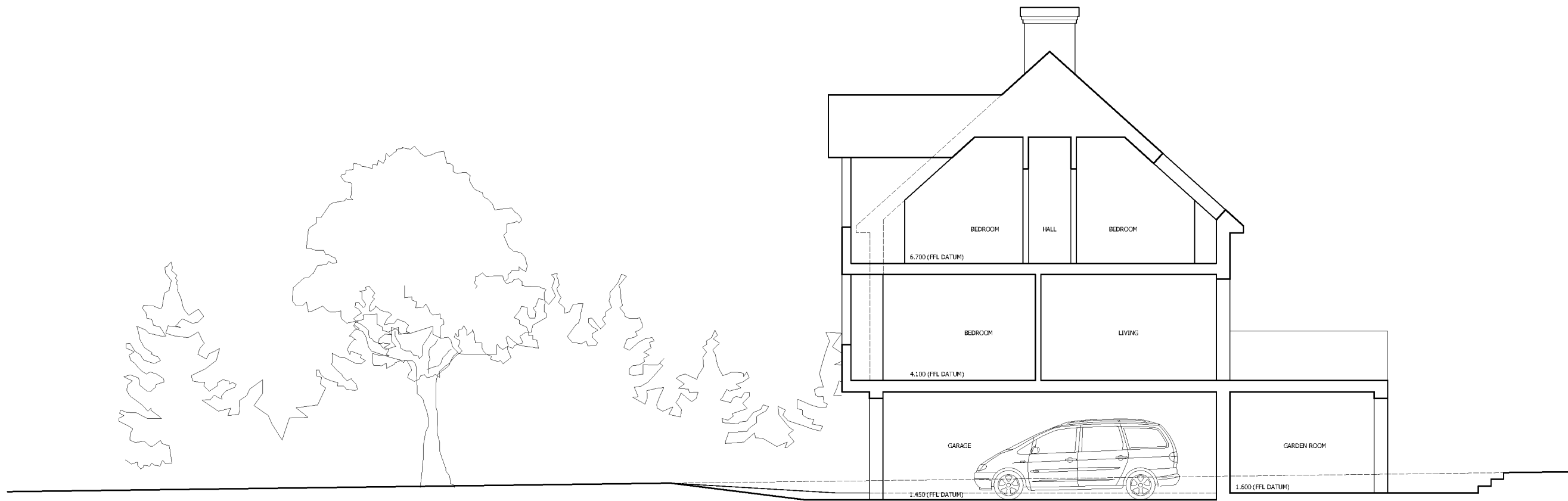
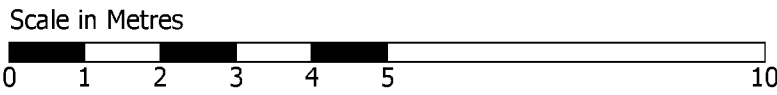
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Client			
Angmering Park Farms LLP			
Project			
Queens Lane Arundel BN18 9JN			
Drawing Title			
Elevations Proposed			
Scale	Date	Drawn	Checked
1:100@ A1	28/02/18	ES	AB
Drawing Number	Rev.	Project Number	
200		PWDJ140372	

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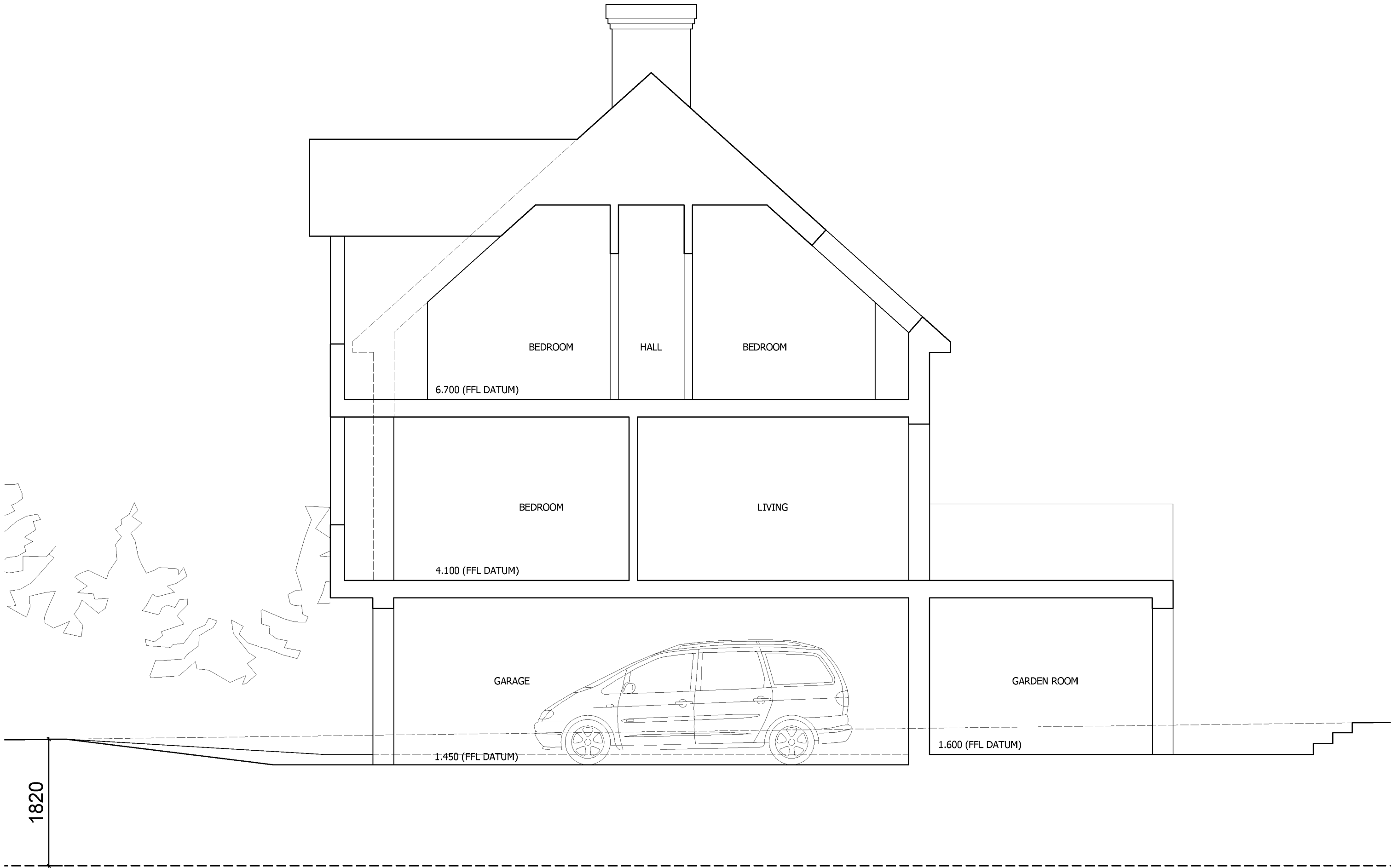
SECTION AA- PROPOSED
SCALE 1:100



SECTION BB - PROPOSED
SCALE 1:100



Rev	Description	By	Date
Drawing Status			
DRAFT			
 RURAL CONSULTANCY SERVICES Savills (UK) Limited Exchange House, Petworth West Sussex. GU28 0BF Telephone: + 44 (0)1798 345 980 Fax: + 44 (0)1798 345 998 www.savills.co.uk RIBA Chartered Practice			
Client			
Angmering Park Farms LLP			
Project			
Queens Lane Arundel BN18 9JN			
Drawing Title			
Sections Proposed			
Scale 1:100@ A1	Date 28/02/18	Drawn ES	Checked AB
Drawing Number 300		Rev.	Project Number PWDJ140372



Appendix A.2 – Environment Agency Flood Report

Rosie Brown
Herrington Consulting Limited
Barham Business Park
Elham Valley Road
Canterbury, Kent
CT4 6DQ

Our ref: SSD74562
Your ref:
Date: 05/02/2018

Dear Rosie,

Enquiry regarding Product 4 for Flood Risk Assessment (FRA)

Thank you for your enquiry which was received on the 1st of February 2018.

We respond to requests under the Freedom of Information Act 2000 and Environmental Information Regulations 2004. The information is attached.

The information on Flood Zones in the area relating to this address is as follows:

The site is in an area located within Flood Zone 3 as shown on our Flood Map for Planning (Rivers and Sea).

Note - This information relates to the area that the above named property is in and is not specific to the property itself as it is influenced by factors such as the height of door steps, air bricks or the height of surrounding walls. We do not have access to this information and is not currently used in our flood modelling.

Flood Zone definitions can be found at www.gov.uk/guidance/flood-risk-and-coastal-change#Table-1-Flood-Zones

Flood Defences

There are flood defences in the form of an embankment. The Asset ID is 155418. The downstream crest level is 4.12, and the upstream is 4.12. The estimated standard of protection is 1 in 200 (0.5% AEP). The estimated condition grade is good. This is maintained by the Environment Agency.

Model Information

The model used was the Lower Tidal River Arun Strategy Study Model which was completed in 2010 by Atkins.

Flood History

We hold no record of previous flooding events affecting this site.

Please note our records are not comprehensive and may not include all events. I recommend contacting the Lead Local Flooding Authority, **West Sussex County Council** or the Local Authority, **Arun District Council** for a more comprehensive flood history check.

FRA advisory text

Name	Product 4
Description	Detailed Flood Risk Assessment Map for Land at Queens Lane, Arundel (near Tel EX, Fitzalan Rd, Arundel, BN18 9JP)
Licence	<u>Open Government Licence</u>
Information Warnings	The majority of our models will not have the new climate change allowances. +20% is not suitable for the majority of planning purposes and the new allowances to use should be checked here: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.
Information Warning - OS background mapping	<i>The mapping of features provided as a background in this product is © Ordnance Survey. It is provided to give context to this product. The Open Government Licence does not apply to this background mapping. You are granted a non-exclusive, royalty free, revocable licence solely to view the Licensed Data for non-commercial purposes for the period during which the Environment Agency makes it available. You are not permitted to copy, sub-license, distribute, sell or otherwise make available the Licensed Data to third parties in any form. Third party rights to enforce the terms of this licence shall be reserved to OS.</i>
Attribution	Contains Environment Agency information © Environment Agency and/or database rights. Contains Ordnance Survey data © Crown copyright 2017 Ordnance Survey 100024198.

Data Available Online

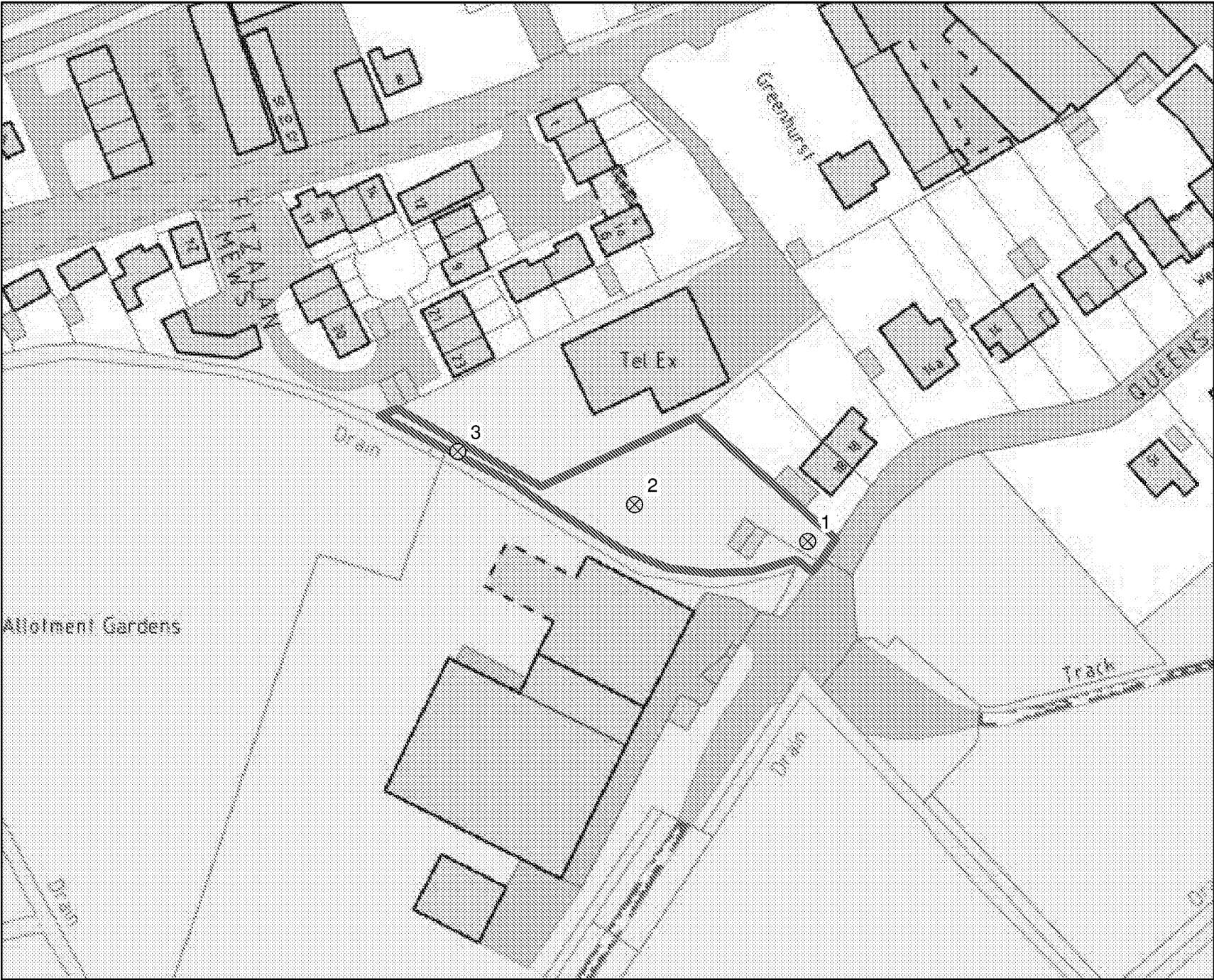
Many of our flood datasets are available online:

- Flood Map For Planning (Flood Zone 2, Flood Zone 3 ,Flood Storage Areas, Flood Defences, Areas Benefiting from Defences)
- Risk of Flooding from Rivers and Sea
- Historic Flood Map
- Current Flood Warnings

Please get in touch if you have any further queries or contact us within two months if you'd like us to review the information we have sent.

Yours sincerely,

Maurice Ntege
FCRM Officer – PSO West Sussex



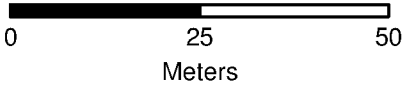
Environment
Agency



Legend

- Main River
- Site Nodes
- Site Boundary

Scale: 1:1,000



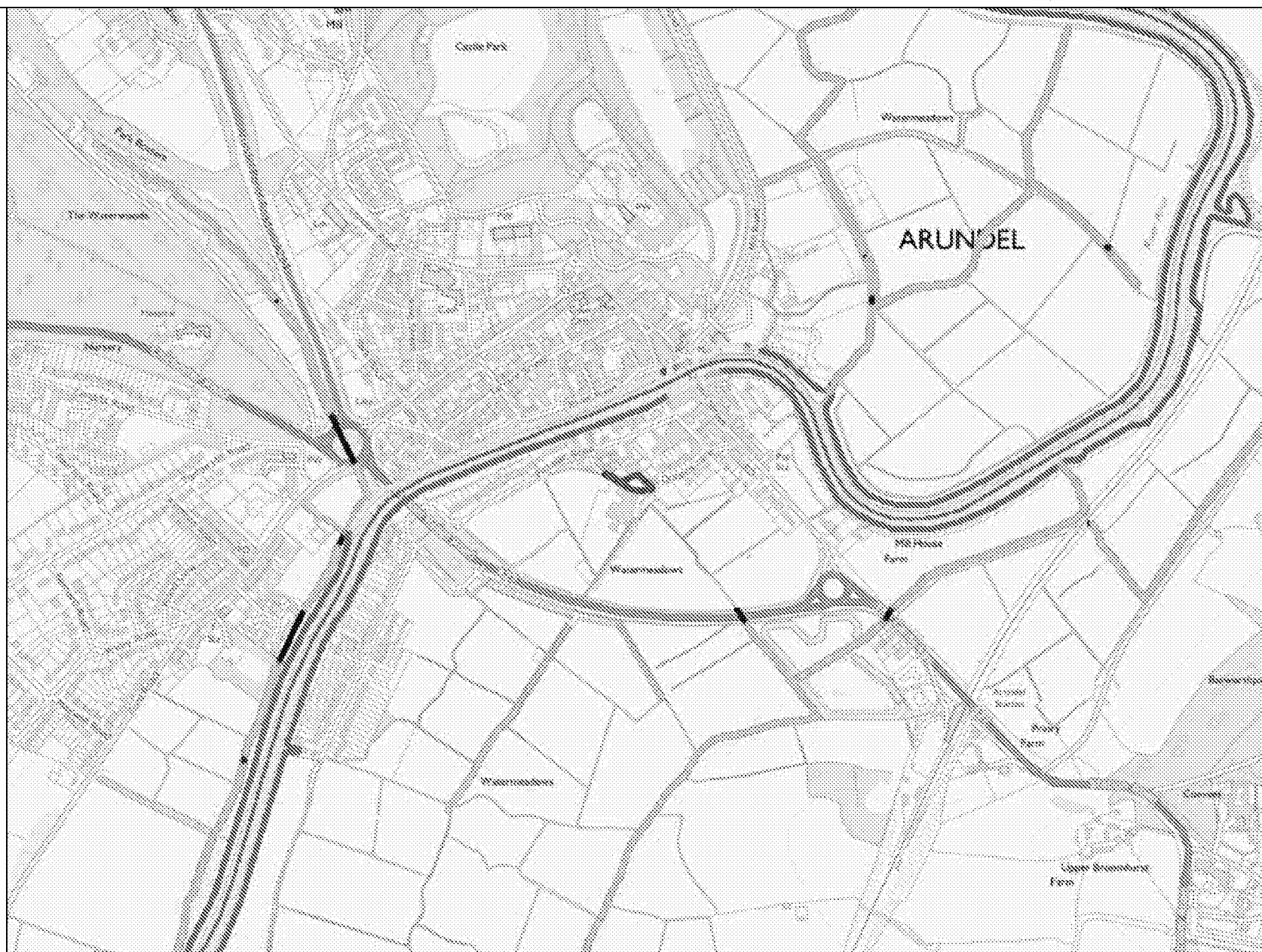
Flood Defences Map. Centred on BN18 9JP. Created on 05/02/18

Legend

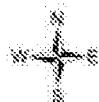
Statutory Main Rivers

Defences

- Embankment
- Wall
- Flood Gate
- Demountable Defence
- Bridge Abutment
- High Ground
- Beach
- Barrier Beach
- Promenade
- Quay
- Cliff
- Dunes
- Culvert



0 100 200 300
Metres



Flood Map for Planning (Rivers and Sea). Centred on BN18 9JP. Created on 05/02/2018



Scale 1: 10,000



Flood Map for Planning (Rivers & Sea)

- Sealed Main Rivers
- Defences
- Flood Storage Areas
- Areas benefiting from flood defences
- Flood Zone 3
- Flood Zone 2

Flood Map Areas (assuming no defences)

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 1 in 200 or greater chance of happening each year
- or from a river with a 1 in 100 or greater chance of happening each year.

Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to a 1 in 1000 chance of occurring each year.

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Product 4 Flood Risk Data Requested by: Herrington Consulting Limited

Site: Land at Queens Lane, Arundel, BN18 9JN

Table 1: Water Levels: Fluvial Undefended

Node Ref	NGR		Modelled Flood Levels in Metres			
	Eastings	Northings	Undefended Annual Exceedance Probability			
			5%	1%	1% +CC	0.1%
1	501897	106807	2.26	2.46	3.33	2.91
2	501865	106814	2.26	2.47	3.33	2.91
3	501832	106823	2.26	2.47	3.33	2.91

Table 2: Water Levels: Fluvial Defended

Node Ref	NGR		Modelled Flood Levels in Metres					
	Eastings	Northings	Defended Annual Exceedance Probability					
			20%	5%	1.3%	1%	1% + CC	0.1%
1	501897	106807	-	-	-	-	1.79	1.75
2	501865	106814	-	-	-	-	-	-
3	501832	106823	-	-	-	-	-	-

Table 3: Water Levels: Tidal Undefended

Node Ref	NGR		Modelled Flood Levels in Metres			
	Eastings	Northings	Undefended Annual Exceedance Probability			
			5%	0.5%	0.5% (2070)	0.1%
1	501897	106807	2.69	2.93	3.58	3.00
2	501865	106814	2.69	2.93	3.58	3.00
3	501832	106823	2.69	2.93	3.58	3.00

Table 4: Water Levels: Tidal Defended

	NGR		Modelled Flood Levels in Metres					
			Defended Annual Exceedance Probability					
Node Ref	Eastings	Northings	20%	5%	1.3%	0.5%	0.5% +CC	0.1%
1	501897	106807	-	-	-	-	3.50	-
2	501865	106814	-	-	-	-	3.50	-
3	501832	106823	-	-	-	-	3.50	-

Table 5: Water Depth: Fluvial Undefended

	NGR		Modelled Flood Depths in Metres			
			Undefended Annual Exceedance Probability			
Node Ref	Eastings	Northings	5%	1%	1% +CC	0.1%
1	501897	106807	0.34	0.54	1.41	0.99
2	501865	106814	0.22	0.43	1.30	0.87
3	501832	106823	0.20	0.41	1.28	0.85

Table 6: Water Depth: Fluvial Defended

	NGR		Modelled Flood Depths in Metres					
			Defended Annual Exceedance Probability					
Node Ref	Eastings	Northings	20%	5%	1.3%	1%	1% + CC	0.1%
1	501897	106807	0.00	0.00	0.00	0.00	0.10	0.16
2	501865	106814	0.00	0.00	0.00	0.00	0.00	0.00
3	501832	106823	0.00	0.00	0.00	0.00	0.00	0.00

Table 7: Water Depth: Tidal Undefended

	NGR		Modelled Flood Depths in Metres			
			Undefended Annual Exceedance Probability			
Node Ref	Eastings	Northings	5%	0.5%	0.5% + CC	0.1%
1	501897	106807	0.77	1.01	1.66	1.08
2	501865	106814	0.66	0.90	1.54	0.96
3	501832	106823	0.64	0.88	1.52	0.94

Table 8: Water Depth: Tidal Defended

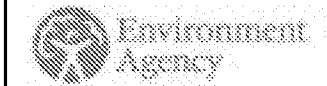
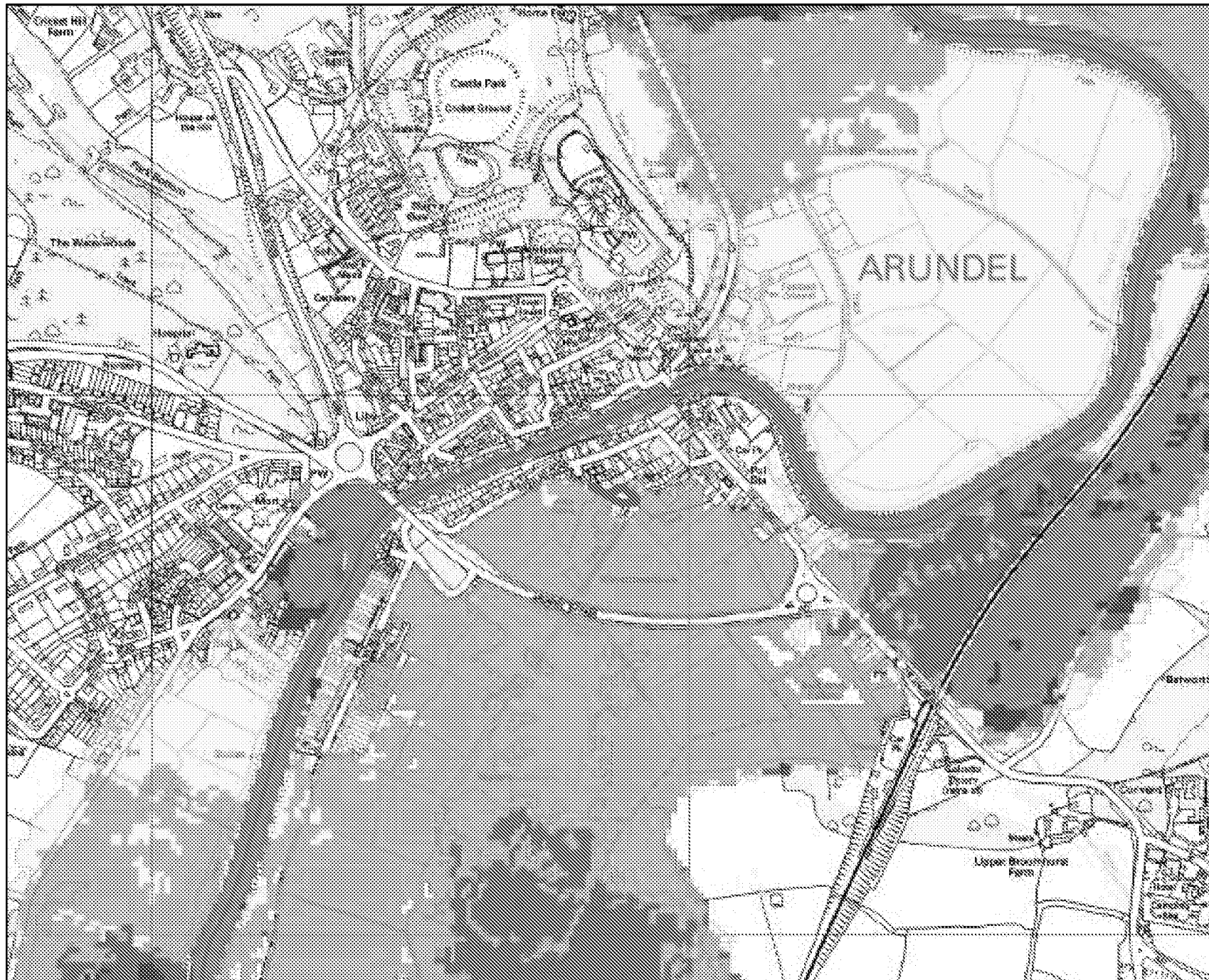
	NGR		Modelled Flood Depths in Metres					
			Defended Annual Exceedance Probability					
Node Ref	Eastings	Northings	20%	5%	1.3%	0.5%	0.5% + CC	0.1%
1	501897	106807	0.00	0.00	0.00	0.00	1.81	0.00
2	501865	106814	0.00	0.00	0.00	0.00	1.37	0.00
3	501832	106823	0.00	0.00	0.00	0.00	1.42	0.00

All levels taken from: Lower Tidal River Arun Strategy Study Mode

Produced on: 06/02/2018

There is no additional information or health warnings for these levels/depths or the model from which they have been produced.





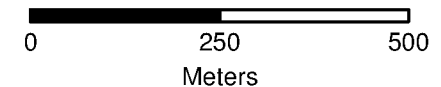
Legend

- Main River
- Site Boundary
- 20% AEP (Defended Fluvial)
- 5% AEP (Defended Fluvial)
- 1.3% AEP (Defended Fluvial)
- 1% AEP (Defended Fluvial)
- 1% AEP Plus Climate Change (Defended Fluvial)
- 0.1% AEP (Defended Fluvial)

Climate Change (CC) extent based on an increase of 20% in river flows.

Annual Exceedance Probability (AEP) The probability of a flood of a particular magnitude, or greater occurring in any given year.

Scale: 1:10,000



Modelled Flood Outlines (Defended Tidal). Centred at BN18 9JP. Created on 05/02/2018 (Ref: SSD74562)



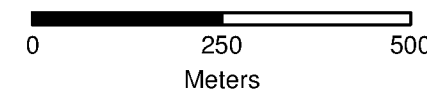
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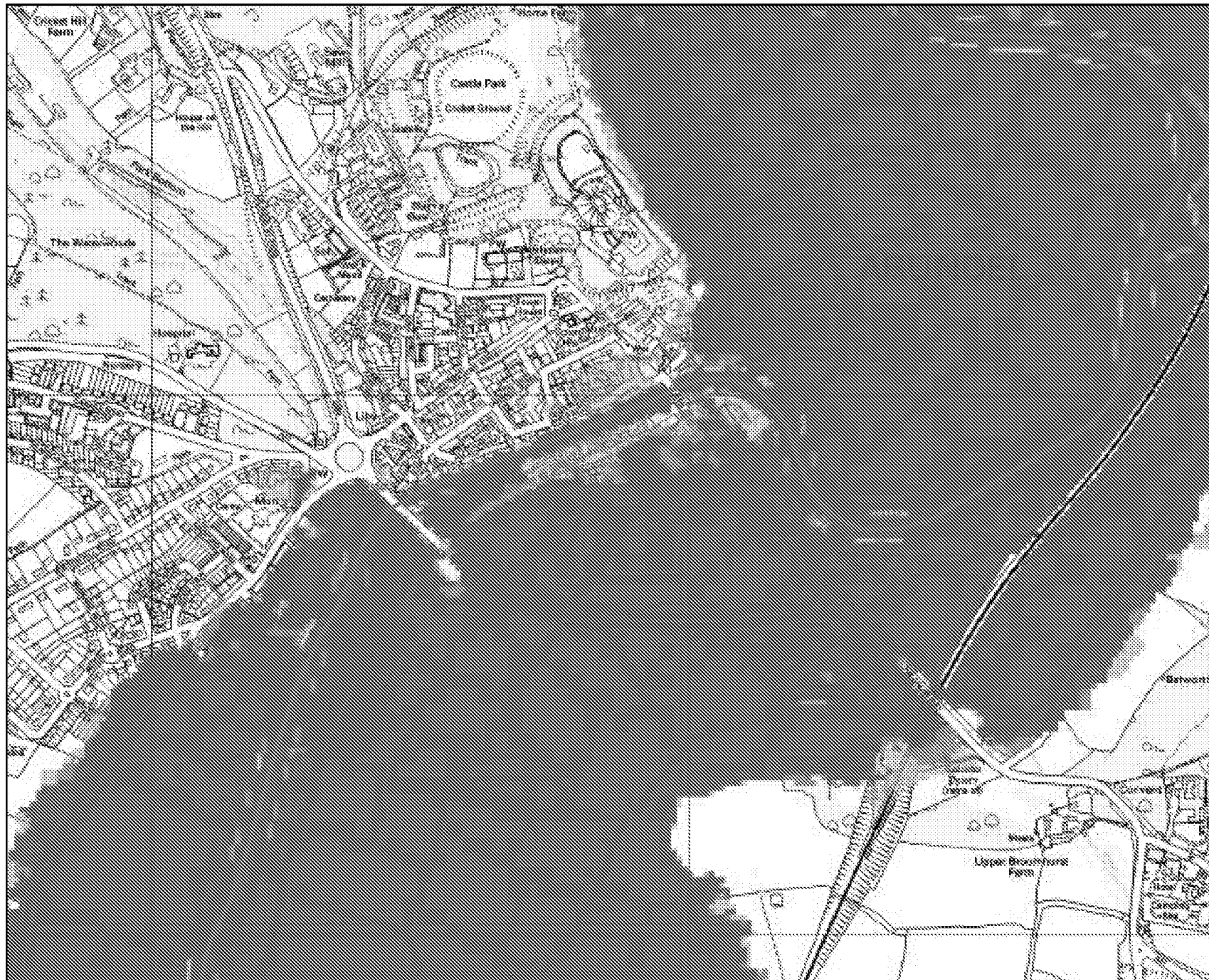
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- Legend:
- Main River
 - Site Boundary
 - 20% AEP (Defended Tidal)
 - 5% AEP (Defended Tidal)
 - 1.3% AEP (Defended Tidal)
 - 0.5% AEP (Defended Tidal)
 - 0.5% AEP (2110) (Defended Tidal)
 - 0.1% AEP (Defended Tidal)

Climate Change (CC) extent
based on an increase of 20%
in river flows.

Annual Exceedance Probability (AEP) The probability of a flood of a particular magnitude, or greater occurring in any given year.

Scale: 1:10,000





N



Legend

-  Main River
-  Site Boundary
-  5% AEP (Un defended Tidal)
-  0.5% AEP (Un defended Tidal)
-  0.5% AEP (2110) (Un defended Tidal)
-  0.1% AEP (Un defended Tidal)

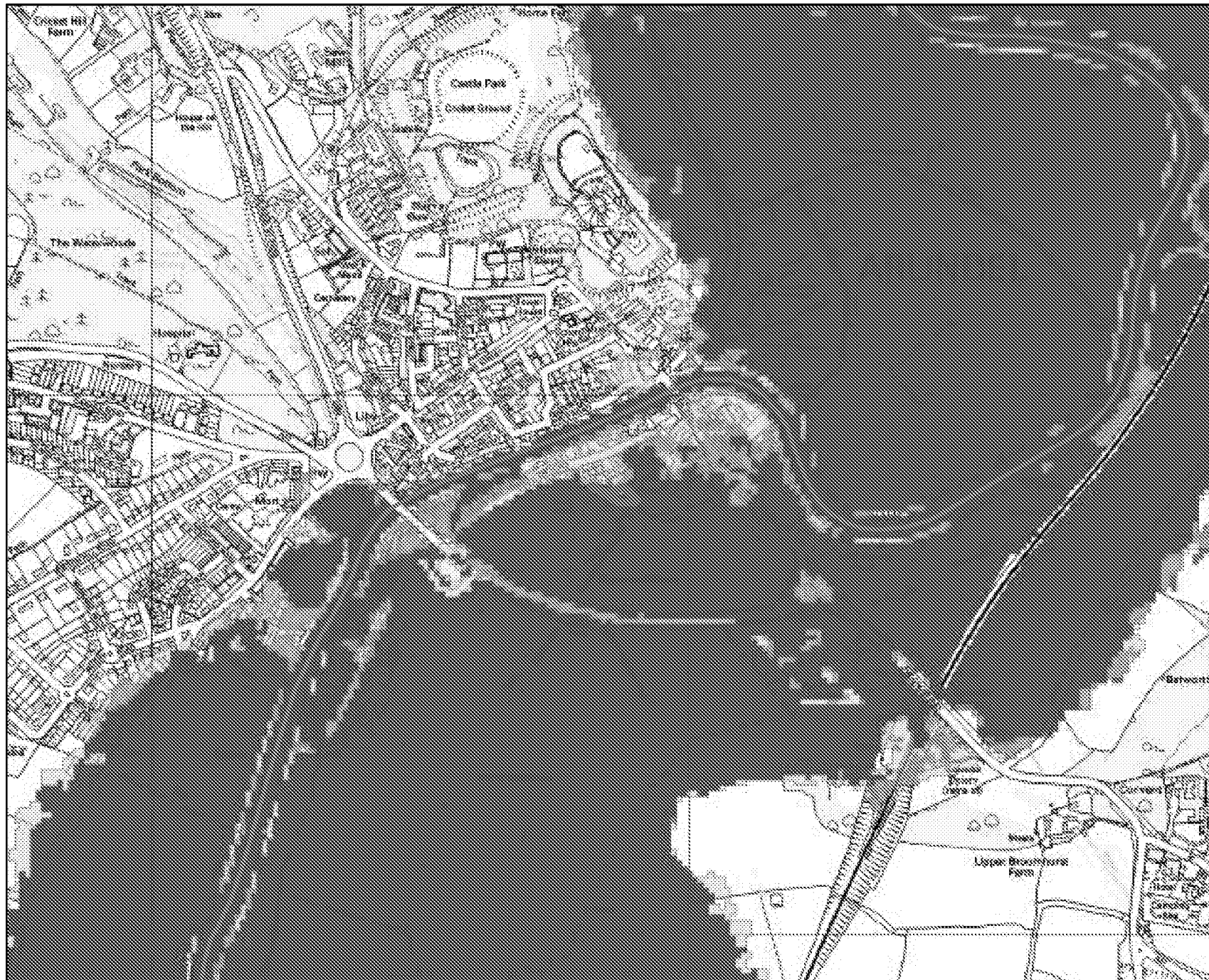
Climate Change (CC) extent based on an increase of 20% in river flows.

Annual Exceedance Probability (AEP) The probability of a flood of a particular magnitude, or greater occurring in any given year.

Scale: 1:10,000



Modelled Flood Outlines (Undefended Fluvial). Centred at BN18 9JP. Created on 05/02/2018 (Ref: SSD74562)



Legend

-  Main River
 Site Boundary
 5% AEP (Undefended Fluvial)
 1% AEP (Undefended Fluvial)
 1% AEP Plus Climate Change (Undefended Fluvial)
 0.1% AEP (Undefended Fluvial)

Climate Change (CC) extent based on an increase of 20% in river flows.

Annual Exceedance Probability (AEP) The probability of a flood of a particular magnitude, or greater occurring in any given year.

Scale: 1:10,000



Appendix A.3 – Southern Water Asset Location Data



Herrington Consulting Limited
Unit 6
Barham Business Park
Barham
CT4 6DQ

Your ref RB/2004
Our ref 279167
Date 06 February 2018

Attention: Herrington Consulting

Dear Customer

Re: Provision of public sewer and water main record extract

Location: Land at Queens Lane, Arundel, Kent, BN18 9JN

Thank you for your order regarding the provision of extracts of our sewer and/or water main records. Please find enclosed the extracts from Southern Water's records for the above location.

We confirm payment of your fee in the sum of £49.92 and enclose a VAT receipt for your records.

Customers should be aware that there are areas within our region in which there are neither sewers nor water mains. Similarly, whilst the enclosed extract may indicate the approximate location of our apparatus in the area of interest, it should not be relied upon as showing that further infrastructure does not exist and may subsequently be found following site investigation. Actual positions of the disclosed (and any undisclosed) infrastructure should therefore be determined on site, because Southern Water does not accept any responsibility for inaccuracy or omission regarding the enclosed plan. Accordingly it should not be considered to be a definitive document.

Should you require any further assistance regarding this matter, please contact the LandSearch team.

Yours faithfully

LandSearch

VAT receipt

Ordered by:

Herrington Consulting Limited
Barham Business Park
Barham
CT4 6DQ

VAT registration number: 813 0378 56

Order reference: 279167

Your reference: RB/2004

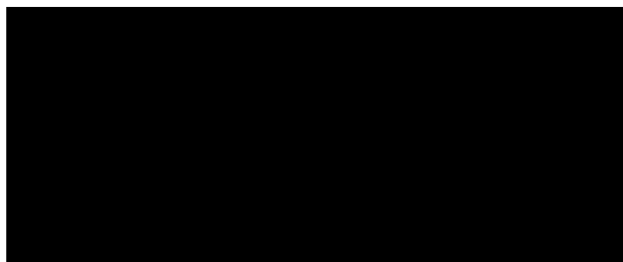
Receipt for provision of an extract from the public sewer and/or water main records.

Location	
Land at Queens Lane Arundel Kent BN18 9JN	

Thank you for your payment:

Received on: 2 February 2018

For enquiries regarding the information provided in this receipt, please contact the LandSearch team:



LandSearch
Southern Water Services
Southern House
Capstone Road
Chatham
Kent
ME5 7QA



106973



TQ0106NE



**Southern
Water**

ARUN DISTRICT COUNCIL AB/136/21/PL

SEWER RECORDS PAGE 2 OF 2

Node	Cover	Invert	Size	Material	Shape	Node	Cover	Invert	Size	Material	Shape	Node	Cover	Invert	Size	Material	Shape	Node	Cover	Invert	Size	Material	Shape
0801X	2.26		150	VC	CIRC																		
0802X	2.2		150	VC	CIRC																		
0803X	2.74	0.44	150	VC	CIRC																		
0804X	2.71		150	VC	CIRC																		
0805X			150	UNK	CIRC																		
0806X			150	UNK	CIRC																		
0807X			150	UNK	CIRC																		
0902X	3.01	0.75	150	VC	CIRC																		
0906X			150	VC	CIRC																		
1701X	1.68	0.74	150	VC	CIRC																		
6701X	1.76	-0.27	150	VC	CIRC																		
6902X	3.43	2.29	150	VC	CIRC																		
6903X	3.24	1.92	375	VC	CIRC																		
6904X	3.32	1.83	375	VC	CIRC																		
6906X			375	VC	CIRC																		
6911X			100	VC	CIRC																		
6912X			100	VC	CIRC																		
693DX			150	VC	CIRC																		
694DX			150	VC	CIRC																		
69ADX			375	VC	CIRC																		
7801X	2.99	-1.13	225	VC	CIRC																		
7802X	3.01	-1.27	225	VC	CIRC																		
7803X	3.18	-1.43	225	VC	CIRC																		
7804X	2.06	-0.94	150	VC	CIRC																		
780PX	2.79	2.78	100	CI	CIRC																		
7902X	3.19	2.24	200	VC	CIRC																		
7903X	3.65	2.08	375	VC	CIRC																		
7904X	3.17	1.98	375	VC	CIRC																		
7906X	3.5	2.38	375	VC	CIRC																		
7909X			UNK	UNK	CIRC																		
7910X			UNK	UNK	CIRC																		
7911X			UNK	UNK	CIRC																		
7912X			100	VC	CIRC																		
7913X			100	VC	CIRC																		
8801X	3.03	1.66	150	VC	CIRC																		
8802X	3.14	-0.88	225	VC	CIRC																		
8804X	3.12	1.52	150	VC	CIRC																		
8906X	3.45	1.7	150	VC	CIRC																		
8909X			100	VC	CIRC																		
8910X			100	VC	CIRC																		
9801X	2.33		225	VC	CIRC																		
9802X	2.42		225	VC	CIRC																		
9803X	2.66		150	VC	CIRC																		
9804X	2.56		150	VC	CIRC																		
9805X	2.69		150	VC	CIRC																		
9806X	2.74	1.96	150	VC	CIRC																		
9807X	2.675		225	VC	CIRC																		
9808X	2.635	0.01	250	DI	CIRC																		
9809X	2.545	0.03	225	VC	CIRC																		
980DX			UNK	UNK	UNK																		
9810X	2.535	0.06	225	VC	CIRC																		
9901X	3.54		150	VC	CIRC																		
9903X	3.01	-0.51	225	VC	CIRC																		
990PY	3.38	3.37	100	PVC	CIRC																	*	
990PX	3.38	3.37	150	CI	CIRC																	*	

LINE STYLES / COLOURS

Brown	-----Foul
	-----Foul Syphon Sewer
	-----Foul Vacuum Main
Red	-----Foul Rising Main
	-----Combined
	-----Combined Syphon Sewer
	-----Combined Rising Main
Orange	-----Lateral Drain
	-----Building Over Agreement Area
Dark Blue	-----Treated Effluent
Purple	-----Sludge
	-----Sewer Catchment
	-----Section 104 Area
Light Blue	-----Surface Water
	-----Surface Water Rising Main
Yellow	-----Private
Green	-----Access Shaft
	-----Decommissioned

MATERIALS

AK	Alkaline
BAC	Bonded Asbestos Cement
BRC	Brick (Common)
BRE	Brick (Engineering)
CC	Concrete Box Culvert
CI	Cast Iron
CO	Concrete (In-Situ)
CP	Concrete (Pre-Cast)
CSB	Concrete Segments (bolted)
CSU	Concrete Segments (unbolted)
DI	Ductile Iron
GRC	Glass Reinforced Concrete
GRP	Glass Reinforced Plastic
MAC	Masonry In regular Courses
MAR	Masonry In random Courses
PE	Polyethylene
PF	Pitch Fibre
PP	Polypropylene
PVC	Polyvinyl Chloride
RPM	Reinforced Plastic Matrix
SI	Spun Iron
ST	Steel
VC	Vitrified Clay
XXX	Other
ZZZ	Unknown

Manhole (SW)
Manhole (F&C)
Lamp hole (SW)
Lamp hole (F&C)
Pumping Station (SW)
Pumping Station (F&C)
Side entry manhole (SW)
Side entry manhole (F&C)
Blind shaft (SW)
Blind shaft (F&C)
Ejector station (SW)
Ejector station (F&C)
Watertight door (SW)
Watertight door (F&C)
Flushing ch. Min-e (SW)
Flushing ch. Min-e (F&C)
Flushing ch. No-e (SW)
Flushing ch. No-e (F&C)
Demanter Chamber

LEGEND - SEWERS

Washout (SW)
Washout (F&C)
Rodding Eye (SW)
Rodding Eye (F&C)
Gauging point (SW)
Gauging point (F&C)
Intercept chamber (SW)
Intercept chamber (F&C)
Storm Tank (SW)
Storm Tank (F&C)
Vortex chamber (SW)
Vortex chamber (F&C)
Label ellipse
Dummy/S24 manhole
Outfall
Penstock chamber
Demoboard
Storm Overflow
Backdrop manhole

Other (s)
Other
Change In sewer (s)
Change In sewer
Rafflux valve
Flap valve
Cascade
Anode
Valve
Closed Valve
Air Valve
Hatch box (SW)
Hatch box (F&C)
Direction arrow
Emptying valve
Catchpit
Soakaway
Inlet
Balancing Pond

SHAPES (S)

A	Arched	R	Rectangular
B	Barrel	S	Square
C	Circular	T	Trapezoidal
E	Egg	U	U Shape
H	Horseshoe	X	Other

NODE REFERENCING SYSTEM

1st digit:	hundred metre easting identifier
2nd digit:	hundred metre northing identifier
3rd digit:	sewer type identifier
4th digit:	next sequential node

Drawn by:	yadavs	
Title:	279167_Land at Queens Lane, Ar	
Date:	06/02/2018	

Appendix A.4 – Surface Water Management Calculations

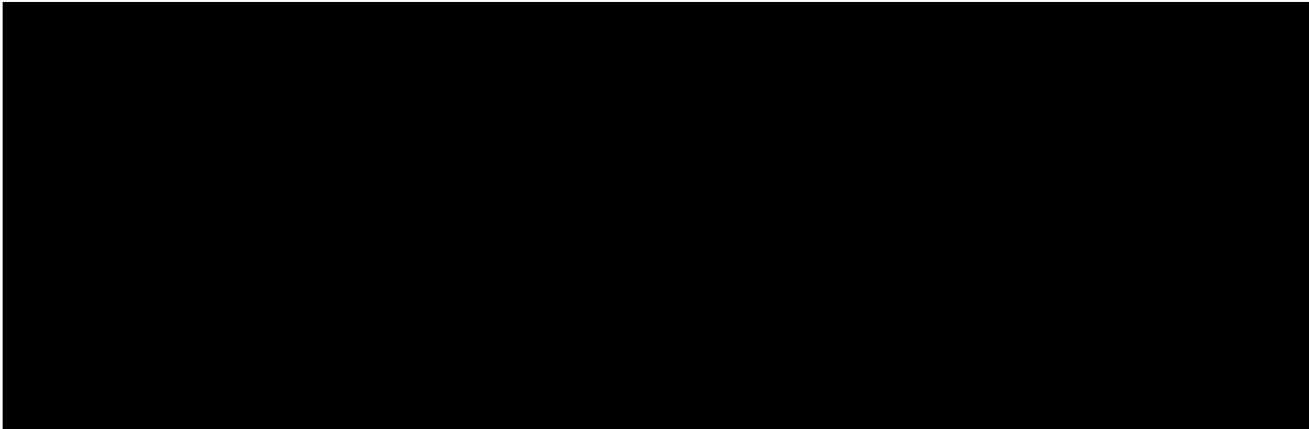


Drainage Design Report

Flow+

v6.0

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Technical support web portal:

<http://support.causeway.com>

Rainfall Methodology	FSR
Return Period (years)	100
Additional Flow (%)	30
FSR Region	England and Wales
M5-60 (mm)	23.400
Ratio-R	0.400
CV	1.000
Time of Entry (mins)	4.00
Maximum Time of Concentration (mins)	30.00
Maximum Rainfall (mm/hr)	100.0
Minimum Velocity (m/s)	1.00
Connection Type	Level Inverts
Minimum Backdrop Height (m)	0.200
Preferred Cover Depth (m)	1.200
Enforce best practice design rules	✓

Results for 1 year Critical Storm Duration, Lowest mass balance: 100.00%															
Event	US Node ID	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m²)	Status	Link ID	DS Node ID	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute summer	E.Impermeable	10	8.562	0.012	1.9	0.0175	0.0000	OK	E.Drain2	E.Outlet	1.9	2.138	0.000	0.0088	
15 minute summer	E.Outlet	10	7.303	0.003	1.9	0.0000	0.0000	OK	DrE.Outfall	E.Discharge	1.9	0.000	0.000	0.0305	0.7
15 minute summer	E.Discharge	10	6.803	0.003	1.9	0.0000	0.0000	OK							
15 minute summer	P.Impermeable	10	8.374	0.024	8.8	0.0443	0.0000	OK	P.Drain2	P.Outlet	8.8	3.560	0.001	0.0278	
15 minute summer	P.Outlet	10	7.508	0.008	8.8	0.0000	0.0000	OK	DrP.Outfall	P.Discharge	8.8	1.145	0.000	0.0700	3.4
15 minute summer	P.Discharge	10	6.808	0.008	8.8	0.0000	0.0000	OK							

Results for 30 year Critical Storm Duration. Lowest mass balance: 100.00%															
Event	US Node ID	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m²)	Status	Link ID	DS Node ID	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute summer	E.Impermeable	10	8.568	0.018	4.5	0.0269	0.0000	OK	E.Drain2	E.Outlet	4.5	2.883	0.000	0.0178	
15 minute summer	E.Outlet	10	7.305	0.005	4.5	0.0000	0.0000	OK	DrE.Outfall	E.Discharge	4.5	0.878	0.000	0.0512	1.8
15 minute summer	E.Discharge	10	6.805	0.005	4.5	0.0000	0.0000	OK							
15 minute summer	P.Impermeable	10	8.386	0.036	21.4	0.0656	0.0000	OK	P.Drain2	P.Outlet	21.4	4.568	0.002	0.0522	
15 minute summer	P.Outlet	10	7.513	0.013	21.4	0.0000	0.0000	OK	DrP.Outfall	P.Discharge	21.4	1.622	0.001	0.1319	8.3
15 minute summer	P.Discharge	10	6.813	0.013	21.4	0.0000	0.0000	OK							

Results for 100 year Critical Storm Duration. Lowest mass balance: 100.00%															
Event	US Node ID	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m²)	Status	Link ID	DS Node ID	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute summer	E.Impermeable	10	8.570	0.020	6.0	0.0309	0.0000	OK	E.Drain2	E.Outlet	6.0	3.141	0.001	0.0211	
15 minute summer	E.Outlet	10	7.306	0.006	6.0	0.0000	0.0000	OK	DrE.Outfall	E.Discharge	6.0	0.984	0.000	0.0010	2.3
15 minute summer	E.Discharge	10	6.805	0.006	6.0	0.0000	0.0000	OK							
15 minute summer	P.Impermeable	10	8.380	0.040	28.1	0.0741	0.0000	OK	P.Drain2	P.Outlet	28.1	4.842	0.003	0.0532	
15 minute summer	P.Outlet	10	7.515	0.015	28.1	0.0000	0.0000	OK	DrP.Outfall	P.Discharge	28.1	1.004	0.001	0.1558	10.9
15 minute summer	P.Discharge	10	6.815	0.015	28.1	0.0000	0.0000	OK							

Results for 100 year +30% Critical Storm Duration. Lowest mass balance: 100.00%															
Event	US Node ID	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m²)	Status	Link ID	DS Node ID	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute summer	E.Impermeable	10	8.573	0.023	7.7	0.0345	0.0000	OK	E.Drain2	E.Outlet	7.7	3.405	0.001	0.0252	
15 minute summer	E.Outlet	10	7.307	0.007	7.7	0.0000	0.0000	OK	DrE.Outfall	E.Discharge	7.7	1.086	0.000	0.0709	3.0
15 minute summer	E.Discharge	10	6.807	0.007	7.7	0.0000	0.0000	OK							
15 minute summer	P.Impermeable	10	8.385	0.045	36.5	0.0833	0.0000	OK	P.Drain2	P.Outlet	36.5	5.148	0.003	0.0780	
15 minute summer	P.Outlet	9	7.518	0.018	36.5	0.0000	0.0000	OK	DrP.Outfall	P.Discharge	36.5	1.996	0.001	0.1829	14.2
15 minute summer	P.Discharge	10	6.818	0.018	36.5	0.0000	0.0000	OK							

Results for 100 year +40% Critical Storm Duration. Lowest mass balance: 100.00%															
Event	US Node ID	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m²)	Status	Link ID	DS Node ID	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute summer	E.Impermeable	10	8.574	0.024	8.3	0.0355	0.0000	OK	E.Drain2	E.Outlet	8.3	3.492	0.001	0.0268	
15 minute summer	E.Outlet	10	7.307	0.007	8.3	0.0000	0.0000	OK	DrE.Outfall	E.Discharge	8.3	1.119	0.000	0.0742	3.3
15 minute summer	E.Discharge	10	6.807	0.007	8.3	0.0000	0.0000	OK							
15 minute summer	P.Impermeable	10	8.387	0.047	39.2	0.0860	0.0000	OK	P.Drain2	P.Outlet	39.3	5.241	0.004	0.0810	
15 minute summer	P.Outlet	9	7.518	0.018	39.3	0.0000	0.0000	OK	DrP.Outfall	P.Discharge	39.3	2.054	0.001	0.1914	15.3
15 minute summer	P.Discharge	10	6.819	0.019	39.3	0.0000	0.0000	OK							