PROPOSED DEVELOPMENT ACROSS LAND BEHIND WILLOWMERE, GARDEN HOUSE LANE, RICKINGHALL, SUFFOLK

FLOOD RISK ASSESSMENT AND SURFACE WATER DRAINAGE/SUDS STRATEGY

APRIL 2017

REPORT REF: 1806/RE/04-17/01

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CONTRACT

Evans Rivers and Coastal Ltd has been commissioned by Mr Colin and Mrs Helen Arnold to carry out a Flood Risk Assessment and Surface Water Drainage/SUDS Strategy for a proposed development across land behind Willowmere, Garden House Lane, Rickinghall, Suffolk.

QUALITY ASSURANCE, ENVIRONMENT AND HEALTH AND SAFETY

Evans Rivers and Coastal Ltd operates a Quality Assurance, Environmental, and Health and Safety Policy.

This project comprises various stages including data collection; hydrological and hydrogeological assessments; surface water drainage designs; and reporting. Quality will be maintained throughout the project by producing specific methodologies for each work stage. Quality will also be maintained by initiating internal quality procedures including the validation of third party deliverables; creation of an audit trail to record any changes made; and document control using a database and correspondence log file system.

To adhere to the Environmental Policy, data will be obtained and issued in electronic format and alternatively by post. Paper use will also be minimised by communicating via email or telephone where possible. Documents and drawings will be transferred in electronic format where possible and all waste paper will be recycled. Meetings away from the office of Evans Rivers and Coastal Ltd will be minimised to prevent unnecessary travel, however for those meetings deemed essential, public transport will be used in preference to car journeys.

The project will follow the commitment and objectives outlined in the Health and Safety Policy operated by Evans Rivers and Coastal Ltd. All employees will be equipped with suitable personal protective equipment prior to any site visits and a risk assessment will be completed and checked before any site visit. Other factors which have been taken into consideration are the wider safety of the public whilst operating on site, and the importance of safety when working close to a water source and highway. Any designs resulting from this project and directly created by Evans Rivers and Coastal Ltd will also take into account safety measures within a “designers risk assessment”.

Report carried out by:

Rupert Evans, BSc (Hons), MSc, CEnv, C.WEM, MCIWEM, PIEMA

DISCLAIMER

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1. INTRODUCTION

1.1 Project Scope

1.1.1 Evans Rivers and Coastal Ltd has been commissioned by Mr Colin and Mrs Helen Arnold to carry out a Flood Risk Assessment and Surface Water Drainage/SUDS Strategy for a proposed development across land behind Willowmere, Garden House Lane, Rickinghall, Suffolk.

1.1.2 It is understood that this application will be submitted to the Planning Authority as part of a planning application. Specifically, this assessment intends to:

1) Carry out an assessment of the practical use of sustainable drainage (SUDS) measures using the relevant soil maps, software and other literature;

2) Determine the existing surface water drainage regime across the site using appropriate methods;

3) Develop a post-development management plan/drainage strategy for surface water across the site, which considers the use of SUDS and alternative methods of surface water disposal;

4) Make an assessment of the flood risk to the site during return period events up to the climate change enhanced 1 in 100 year storm event and recommend mitigation measures accordingly;

5) Carry out an appraisal of flood risk from all sources as required by NPPF;

6) Report findings and recommendations.

1.1.3 This assessment is carried out in accordance with the requirements of the National Planning Policy Framework (NPPF) dated March 2012. Other documents which have been consulted include:

- Woods-Ballard., et al. 2015. *The SUDS Manual, Report C753*. London: CIRIA.
- Woods-Ballard., et al. 2007. *The SUDS Manual, Report C697*. London: CIRIA.
- BS8582:2013 entitled *Code of practice for surface water management for development sites*.
- DEFRA document entitled *Sustainable Drainage Systems – Non statutory technical standards for sustainable drainage systems* dated March 2015.
- LASOO document entitled *Non statutory technical standards for sustainable drainage systems – Best Practice Guidance* dated 2015.
- DEFRA/EA document entitled *Rainfall runoff management for developments* dated 2013.
- Communities and Local Government 2007. *Improving the Flood Performance of New Buildings*. HMSO.
- Suffolk County Council Local SUDS Design Guide dated October 2015.

- Suffolk County Council SUDS Guidance, Standards and Information Appendix A dated March 2016.
- Mid Suffolk District Council Strategic Flood Risk Assessment (SFRA) dated 2008.
- Suffolk Local Flood Risk Management Plan dated 2012.
- Suffolk County Council Preliminary Flood Risk Assessment dated 2011.
- DEFRA/EA document entitled *The flood risks to people methodology (FD2321/TR1),* 2006;
- EA *Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose*, 2008;
- National Planning Practice Guidance – Flood Risk and Coastal Change.
- UK Government's climate change allowances guidance dated February 2016.

2. DATA COLLECTION

2.1 To assist with this report, the data collected included:

- Ordnance Survey 1:10,000 street view map obtained via Promap (Evans Rivers and Coastal Ltd OS licence number 100049458).
- British Geological Survey, *Online Geology of Britain Viewer*.
- British Geological Survey, *Groundwater flooding susceptibility map.*
- Filtered LIDAR data at 2m resolution.
- Infiltration testing results provided by the Client and interpreted by Paddock Geo-Engineering Ltd (Appendix A).
- 1:250,000 *Soil Map of Eastern England* (Sheet 4) published by Cranfield University and Soil Survey of England and Wales 1983.
- 1:625,000 *Hydrogeological Map of England and Wales*, published in 1977 by the Institute of Geological Sciences (now the British Geological Survey).
- 1:125,000 *Hydrogeological Map of Southern East Anglia* published in 1981 by the Institute of Geological Sciences (now the British Geological Survey).

3. SITE CHARACTERISTICS

3.1 Existing Site Characteristics and Location

3.1.1 The site is located across land to the rear of Willowmere, Garden House Lane, Rickinghall, Suffolk. The approximate Ordnance Survey (OS) grid reference for the site is 604548 275149 and the location of the site is shown on Figure 1.

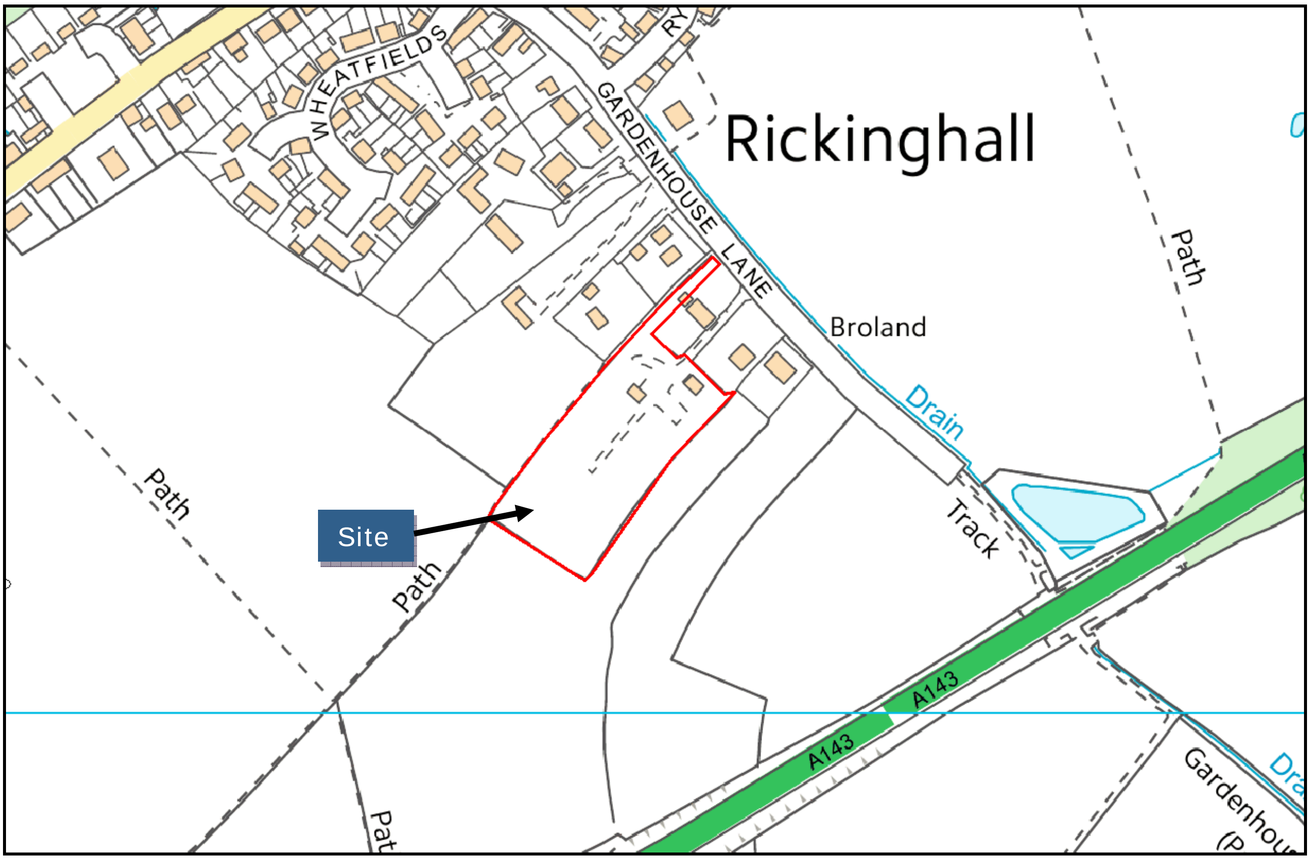


Figure 1: Site location plan (Source: Ordnance Survey)

3.1.2 The site covers an area of approximately 1 ha and currently comprises land to the rear of Willowmere which is a dwelling accessed from Garden House Lane. The site covered by grassed areas and some areas of hardstanding together with a number of sheds and workshops.

3.1.3 Filtered LIDAR data at 2m resolution has also been obtained to determine and illustrate the topography of the site and surrounding area (Figure 2). It can be seen that ground levels across the site typically fall in a north easterly direction.

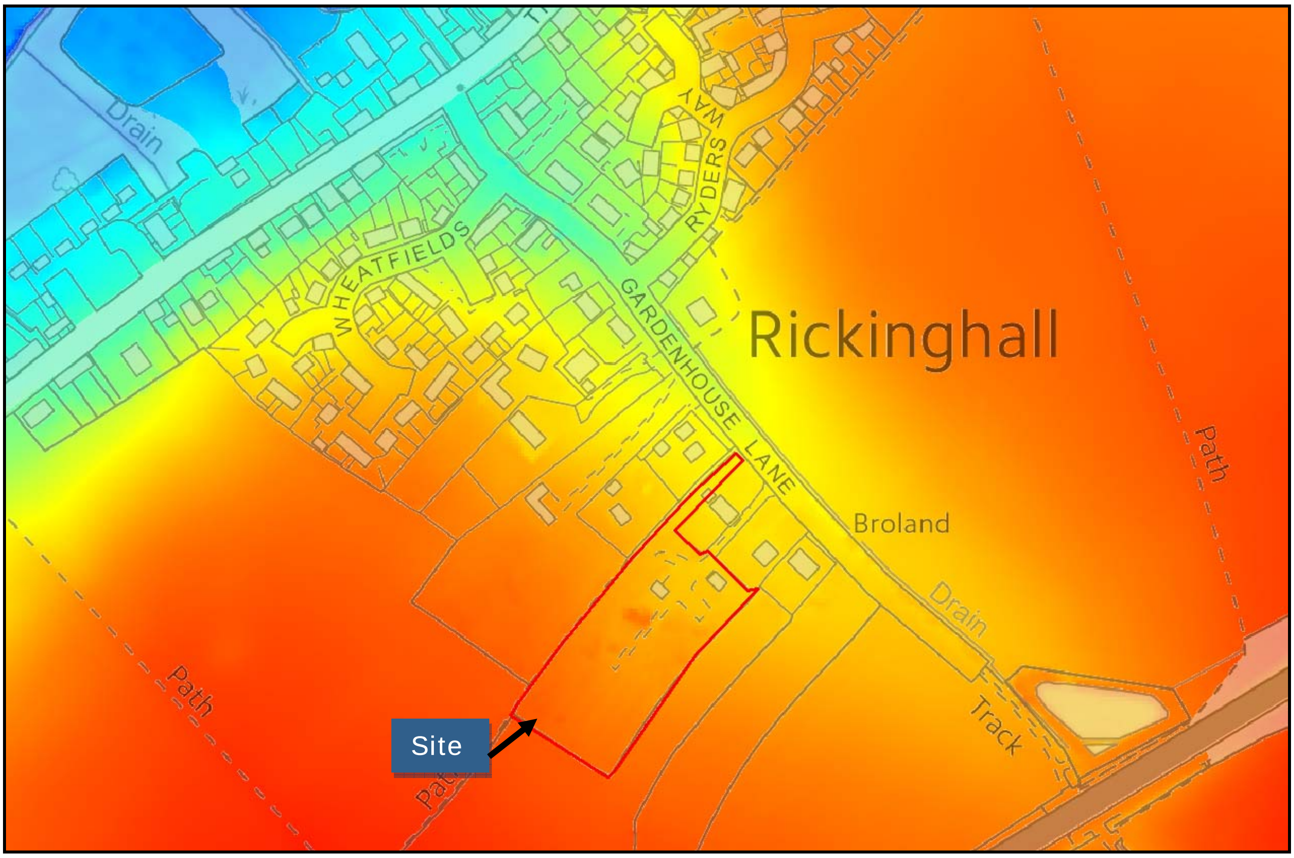


Figure 2: LIDAR survey data where higher ground is denoted as red, orange and yellow colours and lower areas denoted by blue and green colours

3.2 Site Proposals

3.2.1 It is the Client's intention to develop the site with up to 10 dwellings together with gardens, driveways and access road. Access onto to the site will be provided from Garden House Lane. The site proposals can be seen on Drawing Number 444-SK01.

4. BASELINE INFORMATION

4.1 Environment Agency Flood Zone Map

4.1.1 The Environment Agency Flood Map (Figure 3) shows that the site is located within the NPPF Flood Zone 1, 'Low Probability' which comprises land as having less than a 1 in 1000 year annual probability of fluvial or tidal flooding (i.e. an event more severe than the extreme 1 in 1000 year event). NPPF states that all uses of land are appropriate in this zone.

Figure 3: Environment Agency Flood Map (Source: Environment Agency, 2017)

4.2 Catchment Characteristics

4.2.1 The FEH CD-ROM Version 3 (Figure 4) shows the location of the site within the catchment. Catchment descriptors extracted from the FEH CD-ROM Version 3 (Figure 5) indicate that the area receives a standard average annual rainfall (SAAR) of 583mm. The catchment has a moderate gradient (DPSBAR = 21.2m/km) and is of moderate elevation (ALTBAR = 52).

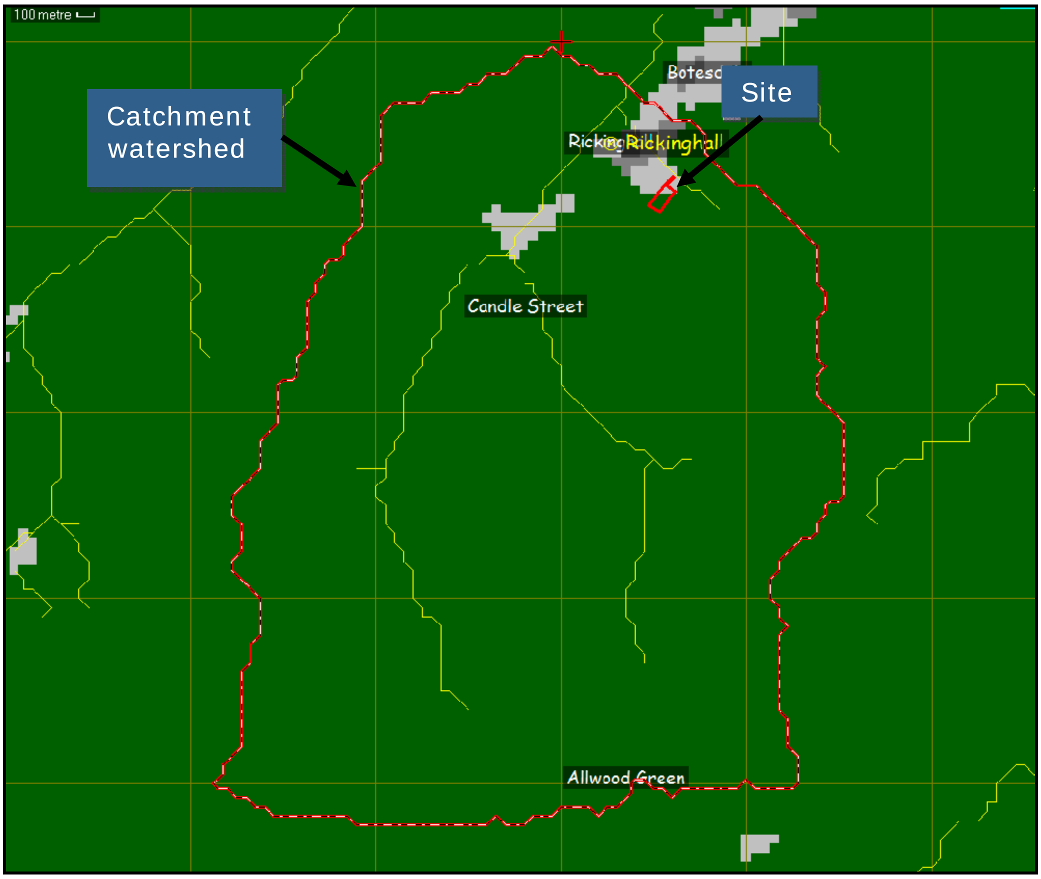
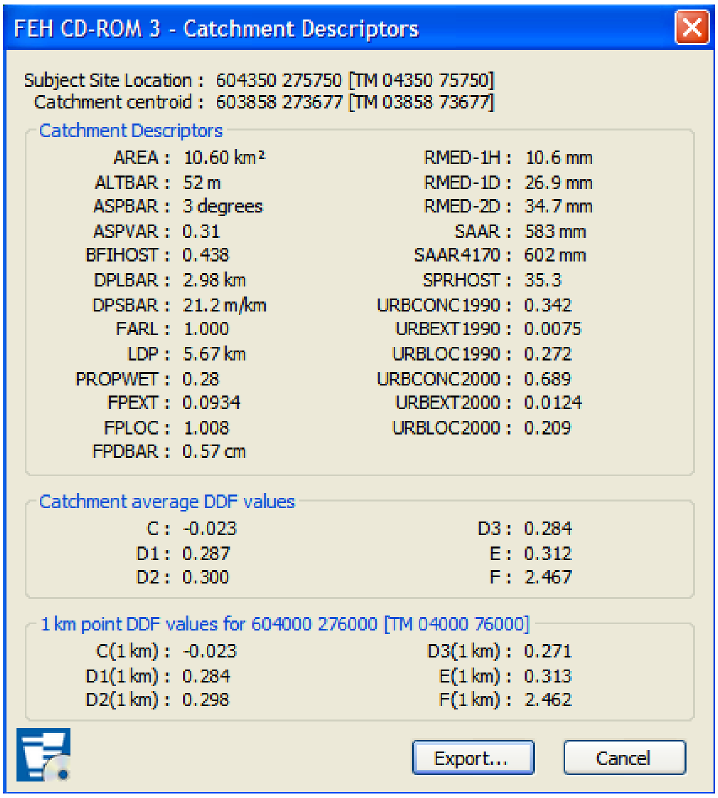


Figure 4: Location of site in relation to catchment watershed (Source: FEH CD-ROM Version 3)



FEH CD-ROM 3 - Catchment Descriptors

Subject Site Location : 604350 275750 [TM 04350 75750]
Catchment centroid : 603858 273677 [TM 03858 73677]

Catchment Descriptors

AREA : 10.60 km^2
ALTBAR : 52 m
ASPBAR : 3 degrees
ASPVAR : 0.31
BFIHOST : 0.438
DPLBAR : 2.98 km
DPSBAR : 21.2 m/km
FARL : 1.000
LDP : 5.67 km
PROPWET : 0.28
FPEXT : 0.0934
FPLOC : 1.008
FPDBAR : 0.57 cm

RMED-1H : 10.6 mm
RMED-1D : 26.9 mm
RMED-2D : 34.7 mm
SAAR : 583 mm
SAAR4170 : 602 mm
SPRHOST : 35.3
URBCONC1990 : 0.342
URBEXT1990 : 0.0075
URBLOC1990 : 0.272
URBCONC2000 : 0.689
URBEXT2000 : 0.0124
URBLOC2000 : 0.209

Catchment average DDF values

C : -0.023
D1 : 0.287
D2 : 0.300

D3 : 0.284
E : 0.312
F : 2.467

1 km point DDF values for 604000 276000 [TM 04000 76000]

C(1 km) : -0.023
D1(1 km) : 0.284
D2(1 km) : 0.298

D3(1 km) : 0.271
E(1 km) : 0.313
F(1 km) : 2.462

Figure 5: Catchment descriptors (Source: FEH CD-ROM Version 3)

5. OTHER SOURCES OF FLOODING

5.1 Groundwater Flooding

5.1.1 In order to assess the potential for groundwater flooding during higher return period rainfall events, the Jacobs/DEFRA report entitled *Strategy for Flood and Coastal Erosion Risk Management: Groundwater Flooding Scoping Study*, published in May 2004, was consulted, together with the guidance offered within the document entitled *Groundwater flooding records collation, monitoring and risk assessment (ref HA5)*, commissioned by DEFRA and carried out by Jacobs in 2006.

5.1.2 According to Cobby et al (2009), groundwater flooding can be defined as flooding caused by the emergence of water originating from subsurface permeable strata. The greatest risks of groundwater flooding are considered to be from either:

- a rise of groundwater in unconfined permeable strata, such as Chalk, after prolonged periods of extreme rainfall;
- a rise of groundwater in unconsolidated, permeable superficial deposits, which are in hydraulic continuity with local river water levels and where the hydraulic gradient of the water table is low.

5.1.3 As described above, it is widely accepted that groundwater flooding generally occurs from both permeable strata (e.g. Chalk) and superficial deposits (e.g. sands and gravels). In particular, unconfined water-bearing deposits (i.e. those with permeable soils above them) are susceptible to a rise in groundwater during prolonged, extreme rainfall and during periods of high recharge throughout autumn and winter. Antecedent conditions, such as, above average groundwater levels prior to the rainfall event, are also a contributing factor to a variation in the water table.

5.1.4 Permeable superficial deposits can also hold quantities of groundwater, although these tend to be insignificant compared to the stored quantities within consolidated aquifers. Unconsolidated deposits such as sand and gravels are sufficiently permeable to store water; however such deposits which yield a low quantity of water are commonly termed a non-aquifer.

5.1.5 Deposits comprising a mixture of permeable and impermeable soils can lead to a presence of perched water. Perched water tables are located above less permeable deposits such as clay and are located within water-bearing soils such as sand and gravel. If perched water is unconfined then the potential for recharge and groundwater flooding can be high. If the perched water is confined by less permeable clay deposits, then the clay deposits will have a buffering effect on percolating surface water and thus the recharge potential and rise in the water table is low.

Soil and Geology at the Site

5.1.6 It can be seen from the various soil and hydrogeological data, listed in Section 2, that the soils beneath the site comprise sand and gravel deposits overlying Chalk.

Groundwater Flooding Potential at the Site

5.1.7 Reference to the *Hydrogeological Map Northern East Anglia* indicates that the water table associated with the Chalk is likely to be set at approximately 28m AOD (i.e. a minimum of 10m below the site).

5.1.8 There have been no recorded groundwater flood events across the area between 2000 and 2003, as indicated by the Jacobs study. The BGS *Groundwater Flooding Susceptibility Map* shows that there is “Limited Potential for Groundwater Flooding to Occur”.

5.1.9 Therefore, it is considered that there is an overall low risk of groundwater flooding at the site.

5.2 Surface Water Flooding and Sewer Flooding

5.2.1 Surface water and sewer flooding across urban areas is often a result of high intensity storm events which exceed the capacity of the sewer thus causing it to surcharge and flood. Poorly maintained sewer networks and blockages can also exacerbate the potential for sewer flooding. Surface water flooding can also occur as a result of overland flow across poorly drained rural areas.

5.2.2 The Agency’s Surface Water Flooding Map (Figure 6) indicates that there is generally a very low surface water flooding risk across the site (i.e. less than 1 in 1000 year chance).

5.2.3 There are small localised parts of the site with a low surface water flood risk (i.e. chance between 1 in 1000 years and 1 in 100 years).

5.2.4 By comparing the proposed site layout and the surface water flood map (Figure 7), it can be seen that generally proposed garden areas and a small part of the proposed access road will be affected during low risk events. Only one of the proposed dwellings would be affected as shown on Figure 7.

5.2.5 The data associated with the map shows that during low risk events the flood depth would be below 0.3m and the velocity greater than 0.25 m/s. The hazard to people would therefore be *Very low* using the hazard equation outlined in paragraph 13.7.2 of *FD2320/TR2.*

5.2.6 It is therefore recommended that finished floor levels are set up to 150mm higher than ground level in order to reduce the risk of internal flooding.

5.2.7 When considering safe access/egress, Figure 7 and the Agency’s data shows that people would be able to safely access/leave the site via the internal access road. However, Garden House Lane is shown to have a low to high surface water flood risk (i.e. chance between 1 in 1000 years and events greater than 1 in 30 years).

5.2.8 During high risk events the depth would generally be below 0.3m and therefore the hazard to people would be *Very low* and safe access/egress available. During the medium and low risk events there would be some parts of Garden House Lane which would have a depth of between 0.3m and 0.9m. The hazard would be *Dangerous for Most* for people and therefore safe access/egress would not be available during these events.

5.2.9 It is recommended that under these circumstances people reside across the dwellings (or do not access the site) where they will remain safe.

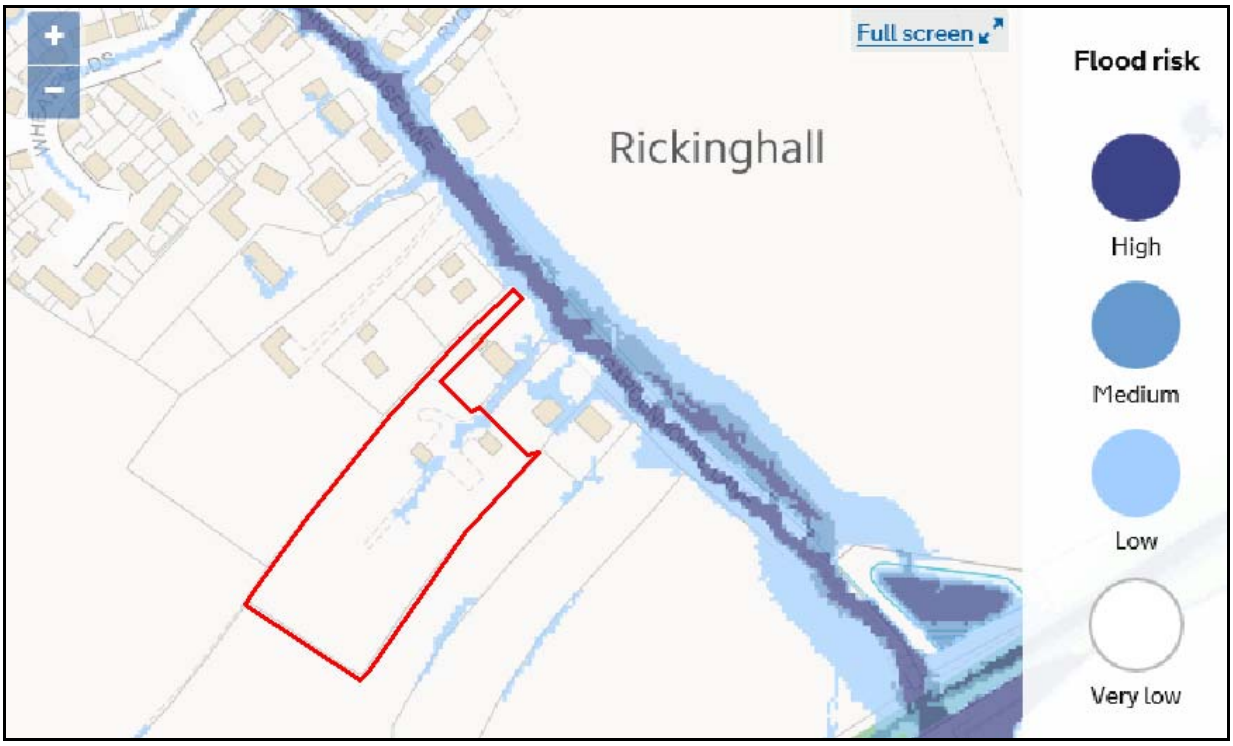


Figure 6: Environment Agency Surface Water Flooding Map and site extent (Source: Environment Agency, 2017)

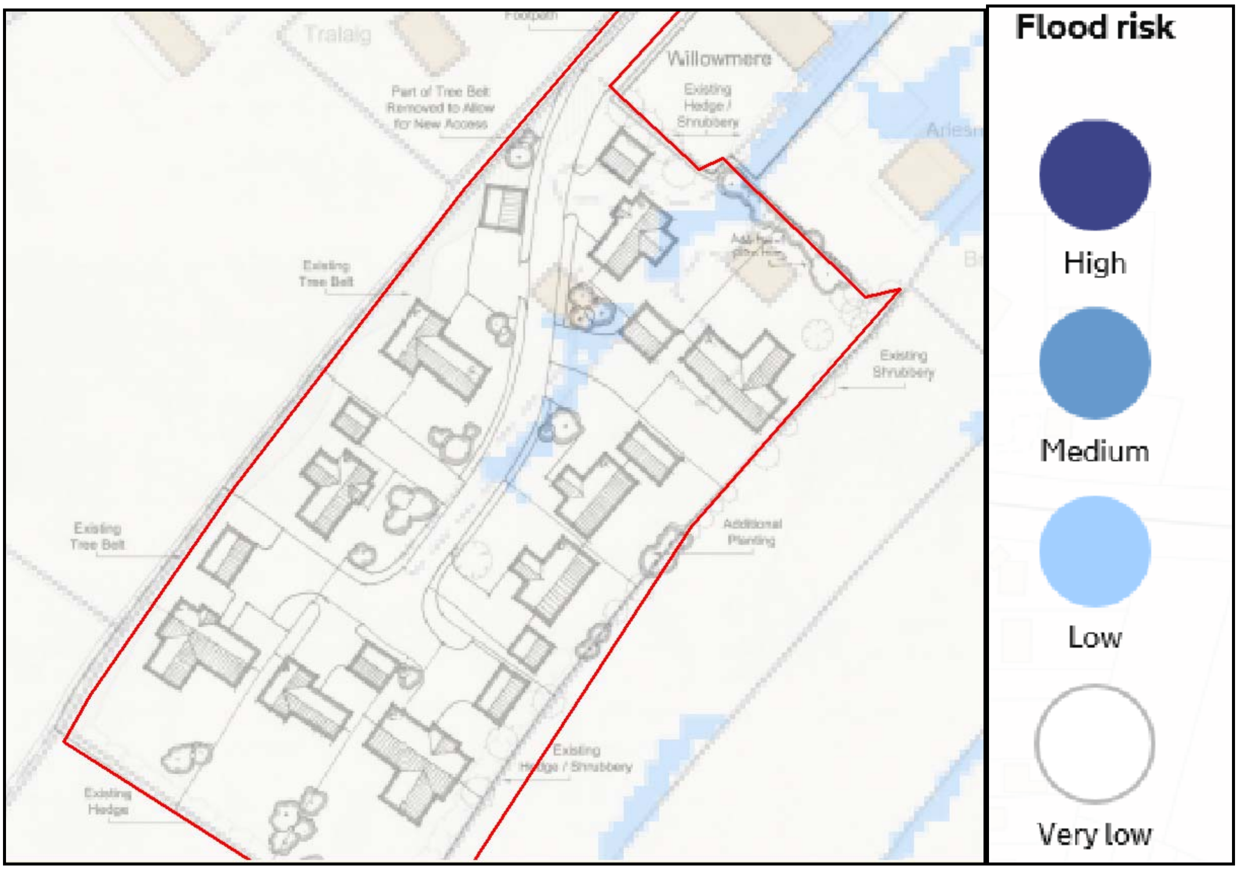


Figure 7: Environment Agency Surface Water Flooding Map together with proposals

5.3 Reservoirs, Canals And Other Artificial Sources

5.3.1 The failure of man-made infrastructure such as flood defences and other structures can result in unexpected flooding. Flooding from artificial sources such as reservoirs, canals and lakes can also occur suddenly and without warning, leading to high depths and velocities of flood water which pose a safety risk to people and property.

5.3.2 The Environment Agency's "Risk of flooding from reservoirs" map suggests that the site is not at risk from such features.

6. SURFACE WATER DRAINAGE AND SUDS

6.1 Introduction

6.1.1 Planning policy recommends the maximum practical use of Sustainable Drainage Systems (SUDS) within proposals for new sites. There is a requirement that sustainable drainage systems (SUDS) be installed where appropriate, in order to limit the amount of surface water runoff entering drainage systems and to return surface water into the ground to follow its natural drainage path.

6.1.2 The National Planning Policy Framework (NPPF) and the Environment Agency require that the effects of climate change to be considered in any assessment of flood risk for developments. When considering the impacts of climate change on rainfall intensity, Table 2 of the UK Government's climate change allowances guidance dated February 2016, advises that when designing surface water drainage systems, an increase in peak rainfall intensity of up to 40% should be considered.

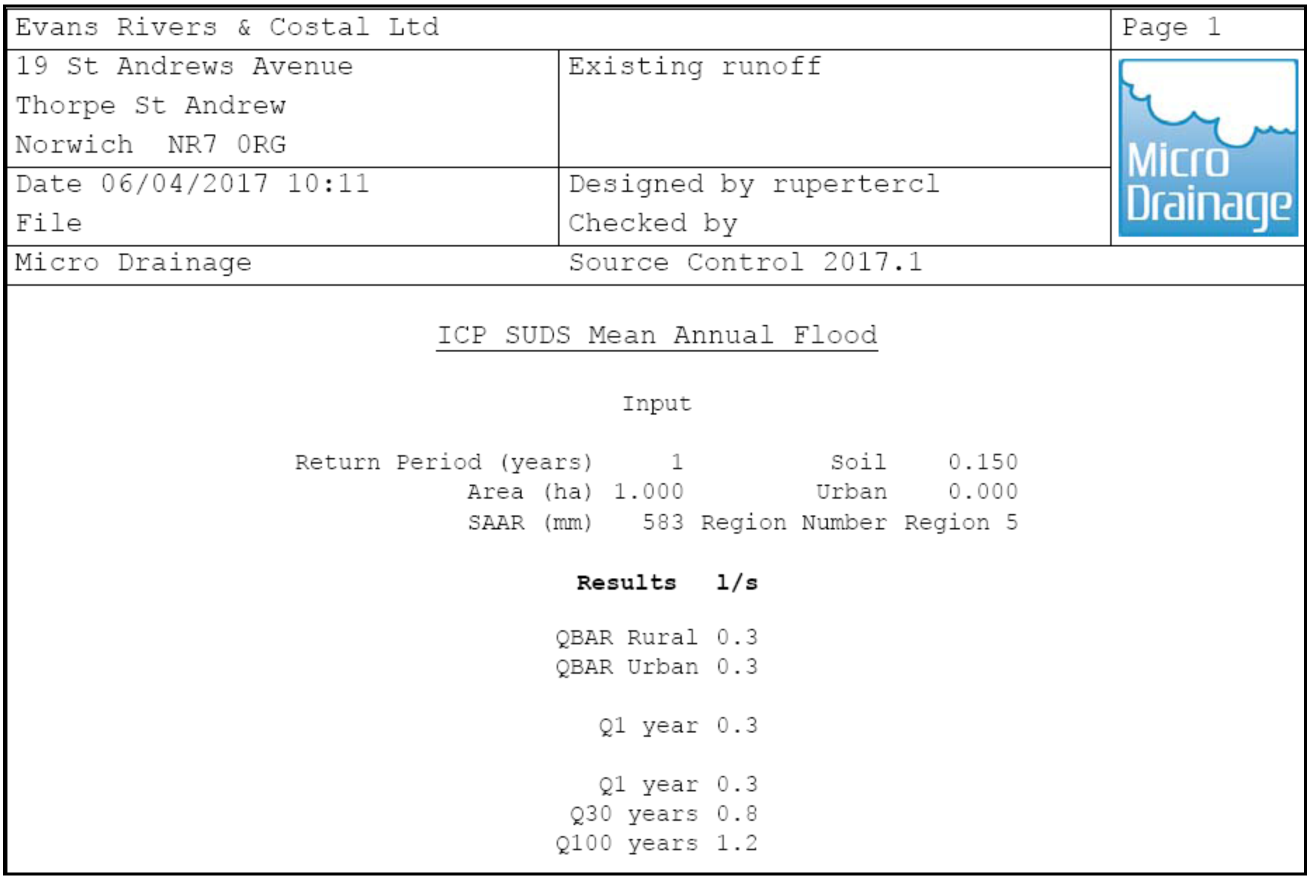
6.1.3 In addition to the consideration of the design event for the SUDS techniques adopted in this report, the possibility of exceedance has been considered further in Section 6.8, and as outlined in CIRIA 635 entitled *Designing for exceedance in urban drainage – good practice,* and the CIRIA/HR Wallingford document entitled *Drainage of development sites – a guide* dated 2004. Although the guidance does not specify a return period event, the exceedance event is usually considered as the event which would exceed the design requirements of the drainage system in question. For example, SUDS attenuation/infiltration devices are usually designed to consider the climate change 1 in 100 year event and therefore the exceedance event in this instance could be considered as the 1 in 1000 year storm event.

6.2 Existing Surface Water Drainage

6.2.1 A proportion of the surface water landing across the site will be infiltrating into the soils of the site and this proportion is denoted by an SPRHOST catchment descriptor value of 35.3 (i.e. 35.3% of the surface water landing on the site typically runs off leaving 64.7% to infiltrate).

6.2.2 In order to quantify the existing runoff rate from the site, the methodology outlined within the Institute of Hydrology Report Number 124 (IoH 124) entitled *Flood Estimation for Small Catchments*, has been adopted. This document together with the guidance stipulated in the *Interim Code of Practice for Sustainable Drainage Systems*, compiled by the National SUDS Working Group in July 2004, suggests that an estimation of peak runoff rates from areas below 50 ha, and up to 200 ha, can be derived from the calculated mean annual flood flow, QBAR.

6.2.3 The ICPSUDS function within the Microdrainage software Version 2017.1 can be used which implements IoH 124 method with a pro-rata below 50 ha. The SAAR value of 583mm has been determined from the catchment descriptors taken from the FEH CD-ROM Version 3. The soil value has been determined using the information from the Winter Rain Acceptance Potential (WRAP) map within the Flood Studies Report, 1975, together with Table 6 and equation 12 of the ADAS document entitled Pipe Size Design for Field Drainage, 1980. The resultant soil value of 0.15 was also checked for consistency with the digital geographical data within the Microdrainage software. The results can be seen on Figure 8.



Evans Rivers & Costal Ltd		Page 1
19 St Andrews Avenue Thorpe St Andrew Norwich NR7 0RG	Existing runoff	
Date 06/04/2017 10:11 File	Designed by rupertercl Checked by	
Micro Drainage	Source Control 2017.1	

```
                    ICP SUDS Mean Annual Flood

                              Input

          Return Period (years)      1          Soil     0.150
                      Area (ha)  1.000         Urban     0.000
                      SAAR (mm)    583 Region Number Region 5

                          Results   l/s

                        QBAR Rural  0.3
                        QBAR Urban  0.3

                           Q1 year  0.3

                           Q1 year  0.3
                          Q30 years 0.8
                         Q100 years 1.2
```

Figure 8: Greenfield runoff rates for the existing site (Source: Microdrainage Version 2017.1)

6.3 Soil Types and SUDS Suitability

6.3.1 Part H of the Building Regulations and Section 3.2.3 of CIRIA 753 prioritises discharges to the ground and then a watercourse, with discharge to a sewer only to be considered when both infiltration and discharge to a watercourse is not reasonably practicable.

6.3.2 Infiltration testing results provided by the Client and interpreted by Paddock Geo-Engineering Ltd are provided in Appendix A. A total of two test pits were excavated and the results indicate that the lowest recorded infiltration rate to be taken forward in the SUDS design is 1.41 x 10^{-4} m/s. Therefore, the soil types and infiltration rates across the site are considered sufficient for the infiltration of surface water.

6.3.3 Section 25.2.2 of CIRIA 753 requires a distance of at least 1m of soil depth between the base of the device and the maximum expected groundwater level. Groundwater was not encountered during the infiltration testing and the local borehole data suggests that the water table is at depth and therefore this requirement will be met.

6.3.4 Therefore, it is proposed that permeable paving could be used to cleanse and infiltrate surface water from proposed hardstanding areas such as driveways and access road. Alternatively, pervious paving in the form of grass reinforcement/plastic grids with gravel could be used (See Section 20.1.3 of CIRIA 753).

6.3.5 In order to drain the roof area of the proposed dwellings it is recommended that a Geocellular or modular system is used to construct a soakaway which could be positioned across the garden area of each dwelling.

6.4 Pervious Surfaces

6.4.1 It is proposed that the driveways and access road are constructed using pervious surfaces such as permeable block paving (or reinforcement/plastic grids with gravel).

6.4.2 The Building Regulations state that "infiltration devices should not be built within 5m of a building or road or in areas of unstable land". However, the CIRIA Susdrain factsheet entitled "Using SUDS Close to Buildings", suggests that the 5m rule was originally devised for soakaways, as these devices concentrate runoff into a quite small area of ground (i.e. point infiltration), whereas permeable paving acts as a blanket and promotes diffuse infiltration.

6.4.3 The aforementioned CIRIA Susdrain document continues to state that permeable paving that collects and drains rainwater falling directly on it can be used against any building providing there is no point source of water from any other impermeable surfaces connected to it. Despite this, the document also states that allowing water to soak into the ground close to foundations should always be done in consultation with a geotechnical advisor or registered ground engineering professional (also acknowledged in Section 25.2.3 of CIRIA 753).

6.4.4 The Interpave document entitled *Understanding permeable paving: Guidance for designers, planners and local authorities* dated 2013, states that on many sites even when the flow from roofs is considered, the ratio of area drained to the area of infiltration for paving is much less than a traditional soakaway. An impermeable membrane can be introduced to protect the foundations if foundation design alterations are not possible (Figure 9). Therefore, it is considered that this approach remains viable providing that an appropriate technical professional is consulted throughout the foundation design.

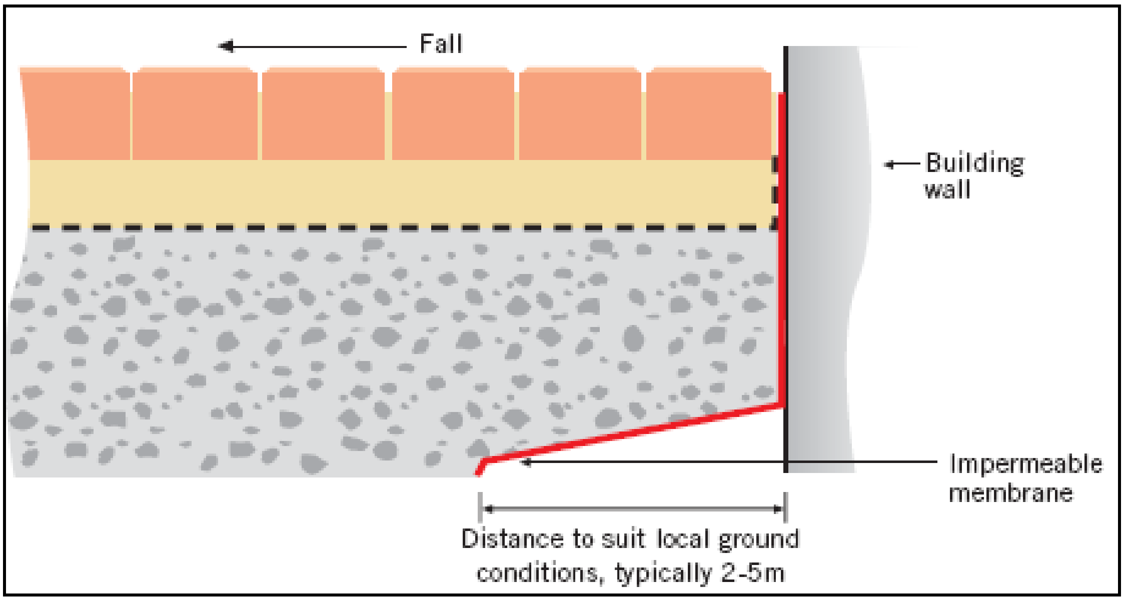


Figure 9: Section through a permeable surface close to building (Source: Interpave *Permeable pavements – guide to the design construction and maintenance of concrete block permeable pavements* dated 2013)

6.4.5 The Interpave document entitled *Understanding permeable paving: Guidance for designers, planners and local authorities* dated 2013, suggests that permeable paving can permit a flow rate of up to 4000mm/hr. Figure 10 shows the permeable surface in more detail.

6.4.6 A hydraulically bound coarse aggregate base will be required to withstand heavy vehicles. Figure 11 shows the typical dimensions of the permeable paving for this load category.

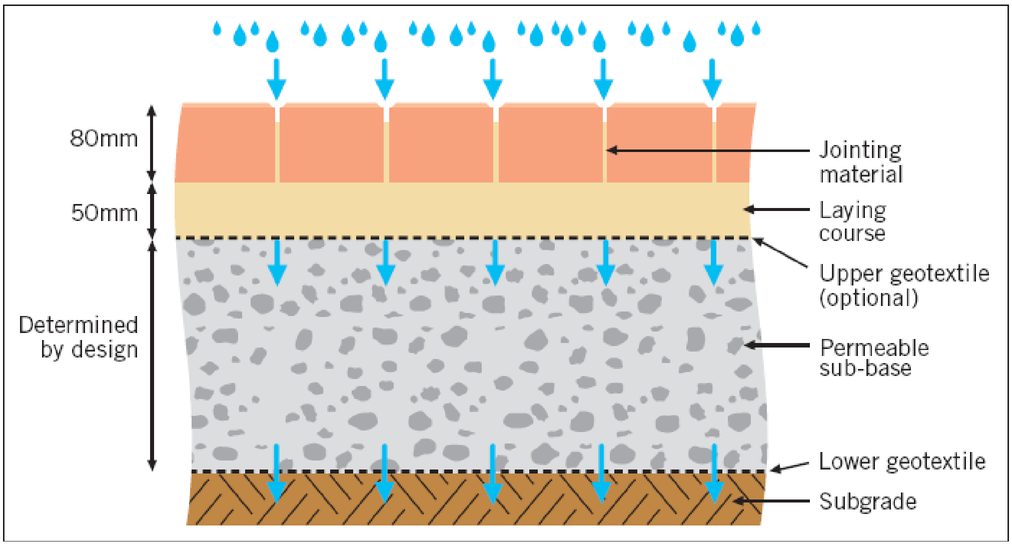


Figure 10: Section through a permeable surface (Source: Interpave *Permeable pavements – guide to the design construction and maintenance of concrete block permeable pavements* dated 2013)

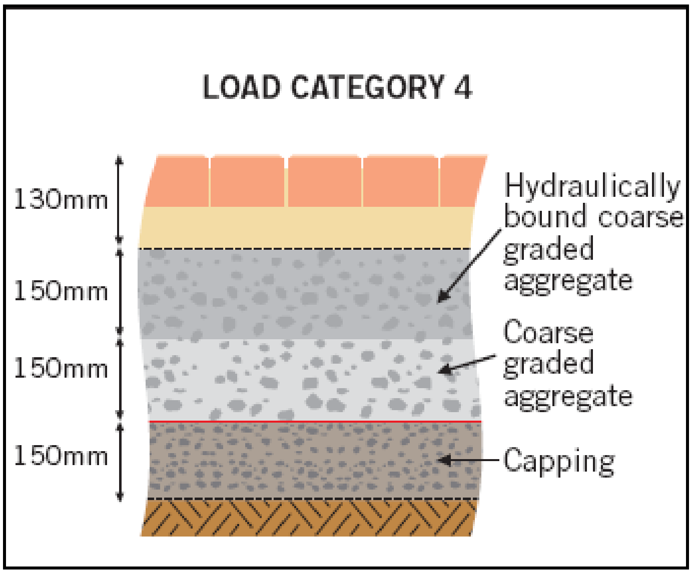


Figure 11: Section through a permeable surface for expected load category (Source: Interpave *Permeable pavements – guide to the design construction and maintenance of concrete block permeable pavements* dated 2010)

6.4.7 To provide an example of the performance of the pervious surface, using the design criteria outlined within CIRIA 697 *The SUDS Manual* and CIRIA 582 *Source control using pervious surfaces*, the proposed car parking areas and access road (i.e. covering 2620 sq m) has been modelled collectively as a pervious surface within the Microdrainage – *Source Control* function.

6.4.8 Additionally, a 10% increase in impermeable area has been included in the paved area calculations in order to consider urban creep as specified by BS8582:2013 and Section 24.7.2 of CIRIA 753 (i.e. total area increases to 2882 sq m).

6.4.9 In accordance with Table 25.2 of CIRIA 753 (Table 1 below) and Section 20.5 CIRIA 753, a safety factor of 5 has been applied to the surface infiltration rate/membrane percolation and infiltration rate of 1.41 x 10^{-4} m/s in the software to represent the gradual silting up effects of the concrete block paving joints over its design life (i.e. assuming that there will be a gradual fall across the paving surface away from the buildings).

Table 1: Recommended safety factors applied to infiltration rate (CIRIA, 753)

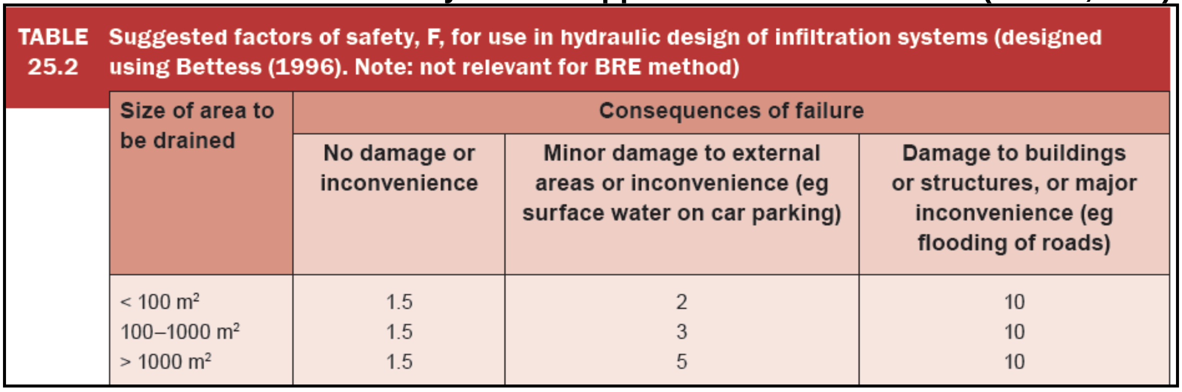


TABLE 25.2 Suggested factors of safety, F, for use in hydraulic design of infiltration systems (designed using Bettess (1996). Note: not relevant for BRE method)

Size of area to be drained	Consequences of failure		
	No damage or inconvenience	Minor damage to external areas or inconvenience (eg surface water on car parking)	Damage to buildings or structures, or major inconvenience (eg flooding of roads)
< 100 m^2	1.5	2	10
100–1000 m^2	1.5	3	10
> 1000 m^2	1.5	5	10

6.4.10 Section 25.6 of CIRIA 753 states that infiltration devices are commonly designed for return periods up to the 1 in 100 year event plus an allowance for climate change. Therefore, the model was run to consider the 1 in 100 year plus 40% climate change rainfall event and the DDF rainfall characteristics from the FEH CD-ROM Version 3 have also been entered into the software.

6.4.11 The results in Appendix B indicate that during the design event there will be no surface flooding and a freeboard of 0.154m between the ground surface and maximum water level will be maintained to account for design uncertainties and to accommodate additional surface water flows during consecutive rainfall events.

6.5 Roof Drainage

6.5.1 In order to drain the roof area of the proposed dwellings it is recommended that a Geocellular or modular system is used to construct a soakaway for each dwelling which could be positioned across the garden. These systems provide a higher porosity (i.e. up to 95%) which will promote more efficient infiltration of surface water (see Chapters 13 and 21 of CIRIA 753).

6.5.2 The soakaway design has been based on the guidance provided by Polypipe and considers a Polystorm-Lite design which is appropriate for untrafficked areas. The typical dimension of each geocellular unit is 1m x 0.5m x 0.4m. The design guidance suggests a minimum depth between the top of the device and ground surface of 0.5m and a maximum effective depth of 2m.

6.5.3 The model was run to consider the 1 in 100 year plus 40% climate change rainfall event and the DDF rainfall characteristics from the FEH CD-ROM Version 3 have also been entered into the software.

6.5.4 A typical proposed dwelling roof area of 193 sq m has been used in order to provide an example of the performance of the soakaway. Additionally, a 10% increase in impermeable area has been included in the roof area calculations in order to consider urban creep as specified by BS8582:2013 and Section 24.7.2 of CIRIA 753 (i.e. area increases to 212.3 sq m).

6.5.5 In accordance with Table 25.2 of CIRIA 753 (Table 1 above) and Section 20.5 CIRIA 753, a safety factor of 5 has been applied to the infiltration rate in the software to represent the gradual silting up effects of the soakaway over its design life, as the soakaways will be positioned sufficiently away from the dwellings and in the gardens.

6.5.6 In order to determine the size of the soakaway and its performance up to the design 1 in 100 year plus climate change (40%) event, the *Source Control – Cellular Storage* function within the Microdrainage software, Version 2017.1, has been used together with the DDF rainfall characteristics from the FEH CD-ROM Version 3.

6.5.7 The optimum dimensions of the soakaway are 4m wide x 4m long and 1.1m effective depth. The results in Appendix C show that the soakaway is sufficiently sized to accommodate surface water without surface flooding during the design climate change (40%) 1 in 100 year event.

6.5.8 BRE Digest 365 and Section 13.4 of CIRIA 753 require that the time taken for infiltration devices to empty to 50% should be within 24 hours and the results indicate that this will be achieved during the design event.

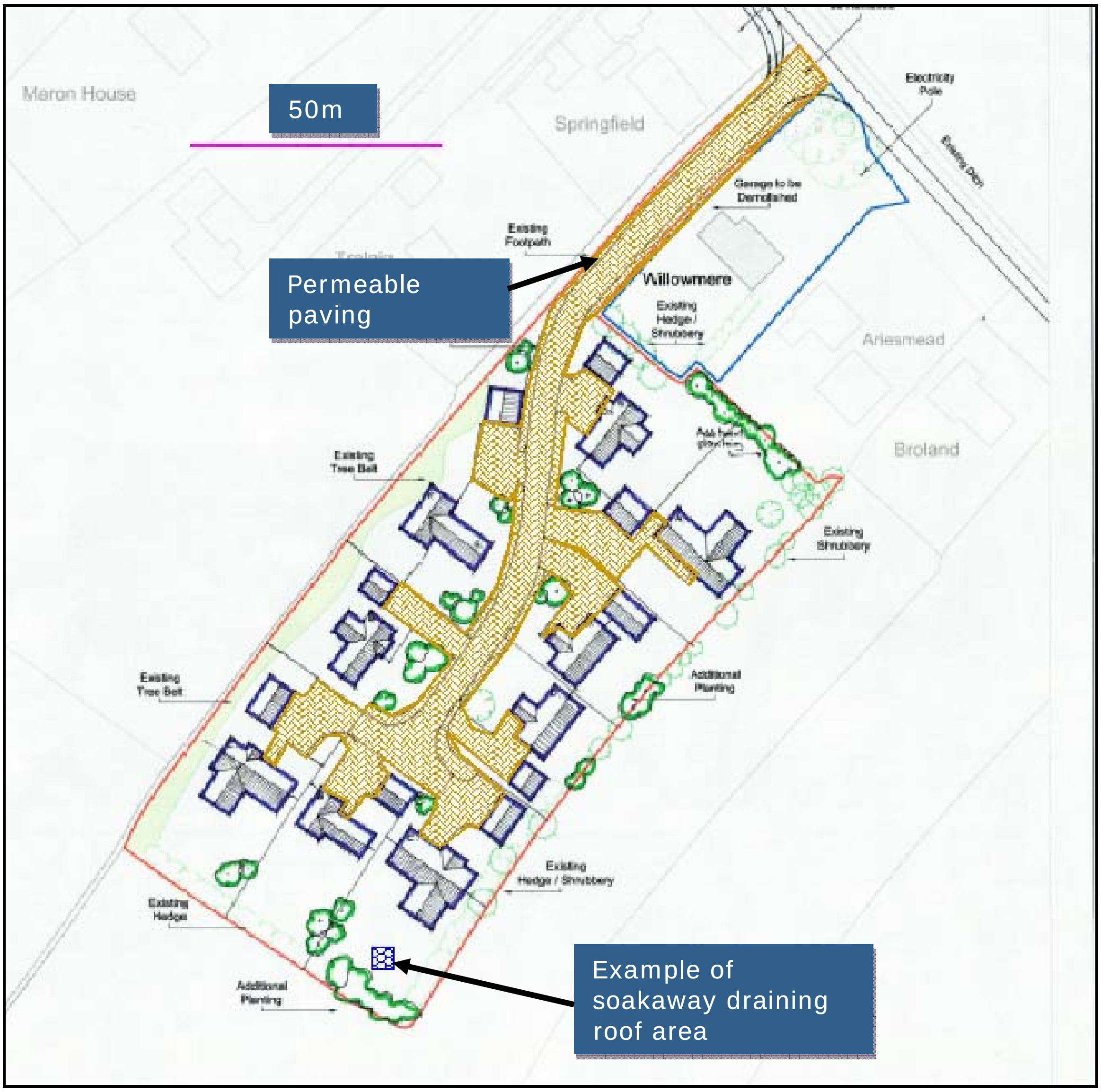


Figure 12: SUDS Strategy

6.6 Pollution Prevention

6.6.1 Table 26.2 of CIRIA 753 shows that roof water has a very low pollution hazard level. Table 26.2 of CIRIA 753 shows that residential car parking areas and low traffic roads have a low pollution hazard level.

6.6.2 Permeable paving will sufficiently cleanse surface water from hardstanding areas such as driveways and low traffic roads. Chapter 20 of CIRIA 753 confirms that permeable paving can improve water quality by sedimentation, filtration, adsorption and biodegradation.

6.6.3 Chapter 13 of CIRIA 697 states that geocellular systems have a low potential to remove suspended solids and heavy metals and no potential to remove nutrients. CIRIA 753 states in Section 21.6 that geocellular systems do not provide any form of treatment of surface water runoff and should therefore be combined in a Management Train.

6.6.4 In accordance with the Simple Index Approach outlined in Section 26.7.1 of CIRIA 753 and more specifically Table 26.4 of CIRIA 753, proprietary treatment systems will be used to cleanse the roof water before it enters the soakaway. Section 13.2 of CIRIA 753 states that effective upstream pre-treatment is required to remove sediment and silt loads to prevent long-term clogging. Chapter 16 of CIRIA 697 and Chapter 14 of CIRIA 753 suggests that pre-treatment measures could comprise, for example, proprietary filtration systems which trap particulates and soluble pollutants from the runoff prior to discharge into the soakaway. Section 21.9.9 of CIRIA 753 indicates that a sediment sump could be included or sediment traps.

6.6.5 It is therefore considered that (collectively) the SUDS measures included within this report will sufficiently improve water quality across the proposed site and comply with Box 4.3 of CIRIA 753.

6.6.6 When considering water quality treatment, the Simple Index Approach set out in 26.7.1 of CIRIA 753 needs to be considered. Using Tables 26.2 and 26.4 in CIRIA 753, it can be seen on Table 2 below, that the SUDS measures will meet the pollution mitigation requirements (i.e. values in Table 2 for SUDS components should be equal to, or greater than the values for Land Use).

Table 2: Simple Index Approach

Land Use	Total Suspended Solids index	Metals index	Hydrocarbons index
Driveways and Low traffic roads	0.5	0.4	0.4
Roofs	0.2	0.2	0.05
SUDS Component for treatment	**Total Suspended Solids index**	**Metals index**	**Hydrocarbons index**
Permeable Paving	0.7	0.6	0.7
Proprietary treatment systems	Designed and specified to cleanse surface water from roof and to meet indices above.		

6.7 Adoption and Maintenance

6.7.1 The *Interim Code of Practice for Sustainable Drainage Systems*, compiled by the National SUDS Working Group in July 2004, states that Local Authorities have powers to adopt SUDS features providing they form part of the provision of open space.

6.7.2 The SUDS measures comprising the permeable paving and soakaways will be privately adopted and maintained by the homeowner. A management company could maintain the permeable paving across the access road.

6.7.3 The permeable paving and soakaways should be maintained in accordance with Table 20.15 and Table 13.1 respectively of CIRIA 753, shown as Tables 3 and 4 hereafter.

Table 3: Maintenance regime for permeable paving (Source: taken from Table 20.15 of CIRIA 753)

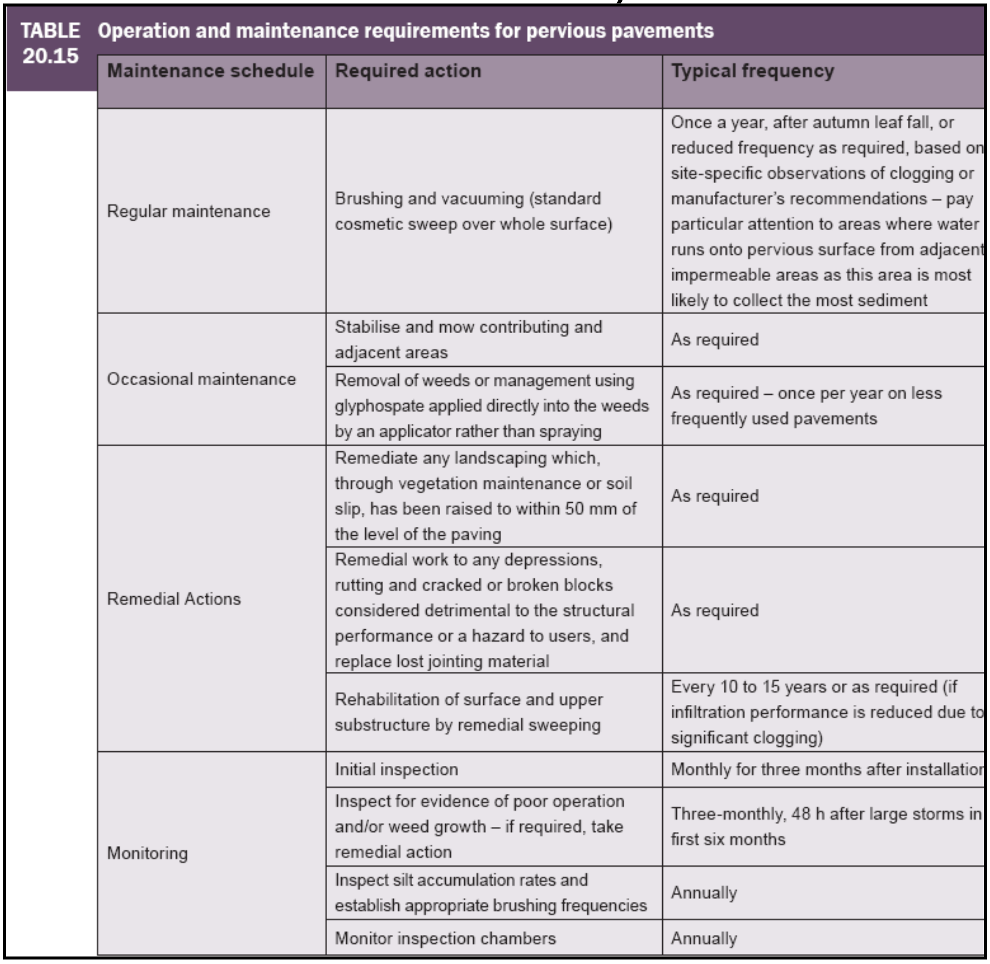


TABLE 20.15 Operation and maintenance requirements for pervious pavements

Maintenance schedule	Required action	Typical frequency
Regular maintenance	Brushing and vacuuming (standard cosmetic sweep over whole surface)	Once a year, after autumn leaf fall, or reduced frequency as required, based on site-specific observations of clogging or manufacturer's recommendations – pay particular attention to areas where water runs onto pervious surface from adjacent impermeable areas as this area is most likely to collect the most sediment
Occasional maintenance	Stabilise and mow contributing and adjacent areas	As required
	Removal of weeds or management using glyphospate applied directly into the weeds by an applicator rather than spraying	As required – once per year on less frequently used pavements
Remedial Actions	Remediate any landscaping which, through vegetation maintenance or soil slip, has been raised to within 50 mm of the level of the paving	As required
	Remedial work to any depressions, rutting and cracked or broken blocks considered detrimental to the structural performance or a hazard to users, and replace lost jointing material	As required
	Rehabilitation of surface and upper substructure by remedial sweeping	Every 10 to 15 years or as required (if infiltration performance is reduced due to significant clogging)
Monitoring	Initial inspection	Monthly for three months after installation
	Inspect for evidence of poor operation and/or weed growth – if required, take remedial action	Three-monthly, 48 h after large storms in first six months
	Inspect silt accumulation rates and establish appropriate brushing frequencies	Annually
	Monitor inspection chambers	Annually

Table 4: Maintenance regime for soakaway (Source: taken from Table 13.1 of CIRIA 753)

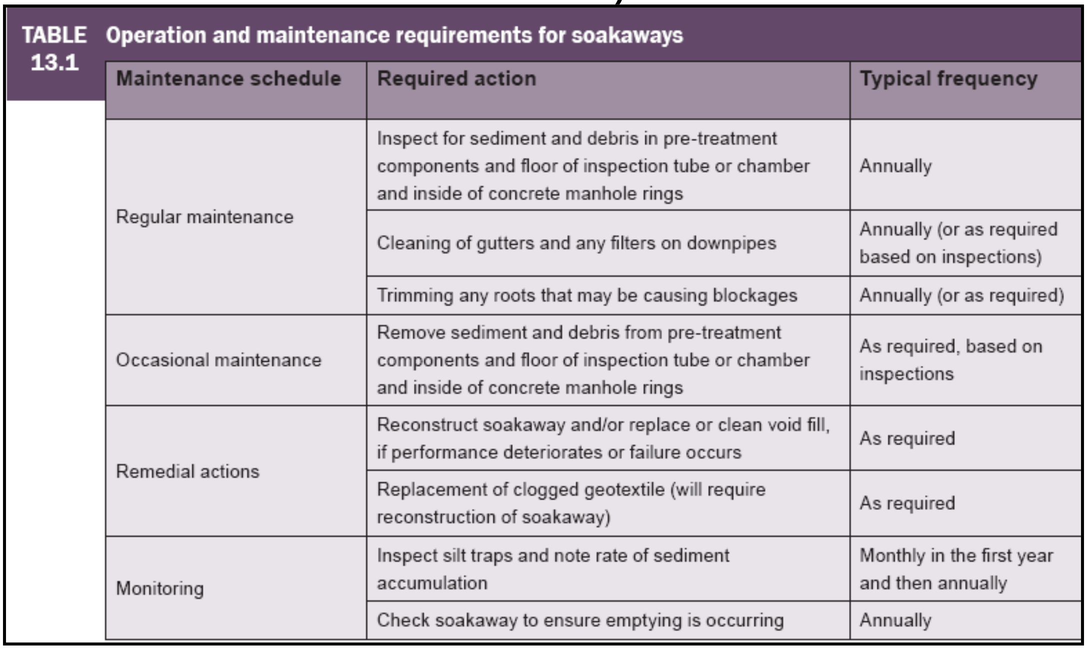


TABLE 13.1 Operation and maintenance requirements for soakaways

Maintenance schedule	Required action	Typical frequency
Regular maintenance	Inspect for sediment and debris in pre-treatment components and floor of inspection tube or chamber and inside of concrete manhole rings	Annually
	Cleaning of gutters and any filters on downpipes	Annually (or as required based on inspections)
	Trimming any roots that may be causing blockages	Annually (or as required)
Occasional maintenance	Remove sediment and debris from pre-treatment components and floor of inspection tube or chamber and inside of concrete manhole rings	As required, based on inspections
Remedial actions	Reconstruct soakaway and/or replace or clean void fill, if performance deteriorates or failure occurs	As required
	Replacement of clogged geotextile (will require reconstruction of soakaway)	As required
Monitoring	Inspect silt traps and note rate of sediment accumulation	Monthly in the first year and then annually
	Check soakaway to ensure emptying is occurring	Annually

6.8 Designing For Exceedance

6.8.1 Section 3.2.6 of CIRIA 753 states that the designated drainage system may include areas that are only designed to flood on an infrequent basis such as car parks, roads and recreational areas. For larger events, the site layout should be designed so that exceedance flows are managed in safe conveyance and storage zones so that the risk of flooding is acceptable for all people and property. Section 13.4.5 of CIRIA 753 states that an exceedance flow route or temporary storage area will be required for rainfall events that exceed the design capacity of the system.

6.8.2 The soakaway and paving calculations in this FRA consider the climate change (40%) 1 in 100 year event and therefore are designed to accommodate flows during the design event. The exceedance return period event has been assumed to be the 1 in 1000 year event as this yields a storage depth and volume higher than the design event.

6.8.3 The results in Appendix D and E indicate that the soakaway and paving are able to accommodate all of the surface water during the exceedance return period event without surface flooding.

6.8.4 It is recommended that the proposed dwellings have a finished floor level of 150mm higher than ground levels to ensure no internal flooding caused by wave action from vehicles.

6.8.5 Permeable paving areas should be graded so that runoff onto neighbouring areas is prevented. Ground levels at the site entrance are shown on the LIDAR survey to fall towards Garden House Lane. Therefore the entrance should either be graded to ensure no offsite runoff during exceedance events and/or a linear drainage channel (e.g. infiltration trench) included which would capture any exceedance runoff towards the road.

6.8.6 It is considered that flood routing can be investigated further at the detailed design stage and that the measures outlined in this FRA provide sufficient reassurance that there is scope when designing for exceedance at this site. This element could be conditioned as part of any planning approval.

7. CONCLUSIONS

7.1 A review of the relevant guidance documents and various types of data collected at the site has enabled a full assessment of the flood risks to be quantified.

7.2 The site is located within the Flood Zone 1 therefore all uses of land are appropriate in this zone.

7.3 This assessment has investigated the possibility of groundwater flooding and flooding from other sources at the site. It is considered that there will be low risk of groundwater flooding across the site and a low to very low risk of flooding from other sources such as surface water.

7.4 An assessment of the practical use of sustainable drainage techniques has been carried out. As the soil types will support the effective use of infiltration devices, it is proposed that surface water from driveways and access road will be drained using permeable paving, and surface water from roofs drained to soakaways.

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APPENDIX A – INFILTRATION TESTING RESULTS

Infiltration Test to BRE365 -TP1 Test 1

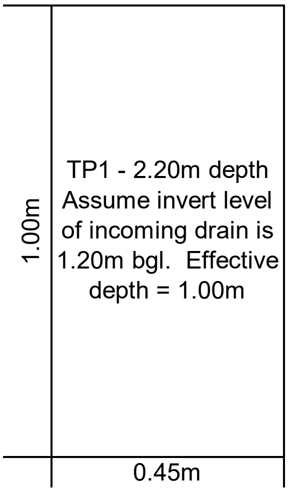
Field Data

Location: TP1 **TEST 1**
Weather: Unknown
Engineer: Client
Date: 27/03/17

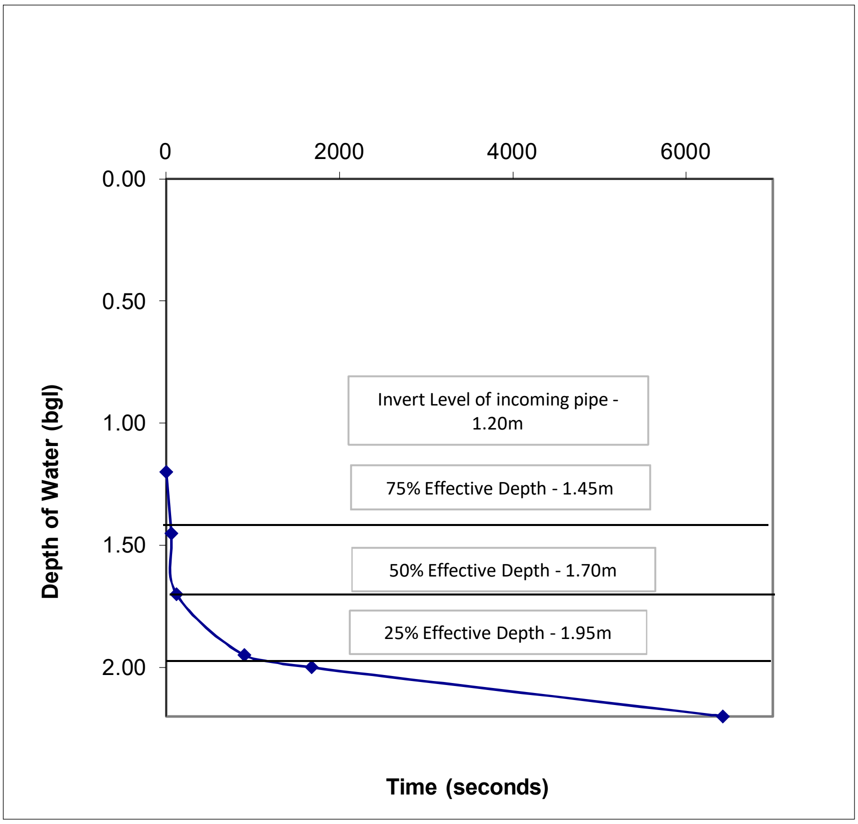
Strata Tested Unknown

Time	Time Elapsed (min)	Time Elapsed (sec)	Depth of Water below GL (m)
	0	0	1.20
	1.0	60	1.45
	2.0	120	1.70
	15	900	1.95
	28	1680	2.00
	107	6420	2.20

▨ Linear extrapolated values for calculation
🟨 Calculation parameters values



Pit Depths (m bgl)
Length
1
Width
0.45
Depth
2.2
25% Effective Depth
0.75
75% Effective Depth
0.25
Inlet Depth
1.2



CALCULATION:

Soil Infiltration Rate(f) =
Vp75-25 / (ap50 x tp75-25)

Where:
Vp75-25 = effective storage volume between 75% and 25% effective depth
1.00 x 0.45 x ((0.75+0.00)-(0.25+0.00)
= **0.225**

ap50 = internal area of TP upto 50% effective depth + base of TP
2(1.00 x 0.50) + 2(0.45 x 0.50) + (1.00 x 0.45)
= **1.9**

Tp75-25 = the time for water level to fall from 75% - 25% effective depth
= **840** secs

f= **1.41E-04** m/s

Comment
Test carried out by Client in 2.20m total depth pit filled to 1.20m depth.

Client: Evans Rivers and Coastal Limited
Project No: P17-060
Project: Willowmere, Garden House Lane, Rickinghall

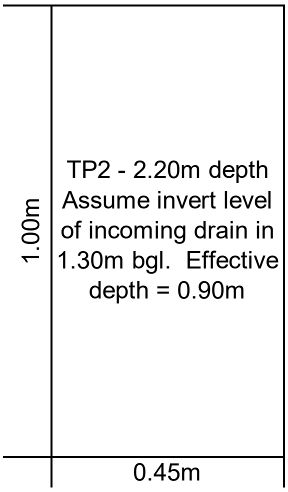
Infiltration Test to BRE365 -TP2 Test 1

Field Data

Time	Time Elapsed (min)	Time Elapsed (sec)	Depth of Water below GL (m)
	0	0	1.30
	1.5	90	1.45
	11	660	1.53
	21	1260	1.98
	35	2100	2.20

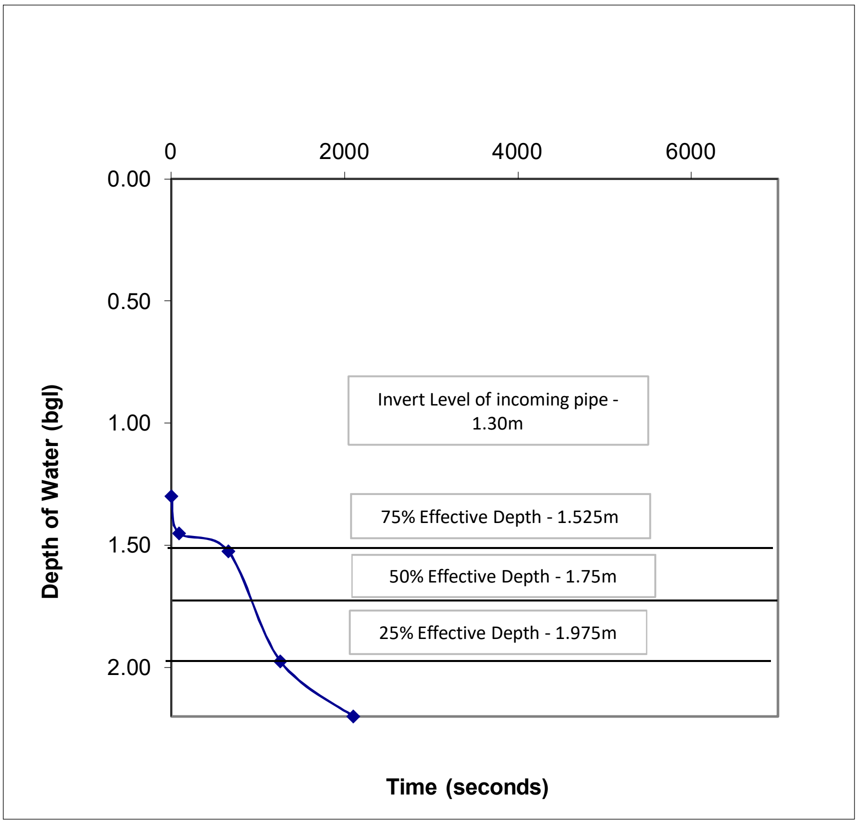
Location: TP2 **TEST 1**
Weather: Unknown
Engineer: Client
Date: 28/03/17

Strata Tested Unknown



Pit Depths (m bgl)
Length
1
Width
0.45
Depth
2.2
25% Effective Depth
0.675
75% Effective Depth
0.225
Inlet Depth
1.3

▨	Linear extrapolated values for calculation
🟨	Calculation parameters values



CALCULATION:

Soil Infiltration Rate(f) =
Vp75-25 / (ap50 x tp75-25)

Where:
Vp75-25 = effective storage volume between 75% and 25% effective depth
1.00 x 0.45 x ((0.675+0.00)-(0.225+0.00)
= **0.2025**

ap50 = internal area of TP upto 50% effective depth + base of TP
2(1.00 x 0.45) + 2(0.45 x 0.45) + (1.00 x 0.45)
= 1.755

Tp75-25 = the time for water level to fall from 75% - 25% effective depth
= **600** secs

f= **1.92E-04** m/s

Comment
Test carried out by Client in 2.20m total depth pit filled to 1.30m depth.

PADDOCK GEO ENGINEERING

Client: Evans Rivers and Coastal Limited
Project No: P17-060
Project: Willowmere, Garden House Lane, Rickinghall

APPENDIX B – PERMEABLE PAVING

Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 21 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
15 min Summer	0.322	0.322	46.3	79.5	Flood Risk
30 min Summer	0.319	0.319	45.9	78.0	Flood Risk
60 min Summer	0.306	0.306	43.9	71.5	Flood Risk
120 min Summer	0.275	0.275	39.5	57.7	Flood Risk
180 min Summer	0.247	0.247	35.5	46.7	Flood Risk
240 min Summer	0.225	0.225	32.3	38.7	Flood Risk
360 min Summer	0.190	0.190	27.3	27.7	O K
480 min Summer	0.165	0.165	23.7	20.9	O K
600 min Summer	0.146	0.146	20.9	16.3	O K
720 min Summer	0.131	0.131	18.8	13.1	O K
960 min Summer	0.109	0.109	15.6	9.1	O K
1440 min Summer	0.082	0.082	11.8	5.1	O K
2160 min Summer	0.060	0.060	8.6	2.7	O K
2880 min Summer	0.049	0.049	6.8	1.8	O K
4320 min Summer	0.041	0.041	4.9	1.3	O K
5760 min Summer	0.036	0.036	3.8	1.0	O K
7200 min Summer	0.033	0.033	3.2	0.8	O K
8640 min Summer	0.031	0.031	2.7	0.7	O K
10080 min Summer	0.029	0.029	2.4	0.6	O K
15 min Winter	0.346	0.346	49.7	91.4	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	216.498	0.0	15
30 min Summer	122.480	0.0	24
60 min Summer	69.291	0.0	40
120 min Summer	39.200	0.0	74
180 min Summer	28.092	0.0	106
240 min Summer	22.177	0.0	136
360 min Summer	15.892	0.0	196
480 min Summer	12.546	0.0	256
600 min Summer	10.444	0.0	314
720 min Summer	8.991	0.0	376
960 min Summer	7.127	0.0	492
1440 min Summer	5.136	0.0	736
2160 min Summer	3.702	0.0	1100
2880 min Summer	2.934	0.0	1452
4320 min Summer	2.091	0.0	2132
5760 min Summer	1.645	0.0	2936
7200 min Summer	1.365	0.0	3640
8640 min Summer	1.173	0.0	4392
10080 min Summer	1.031	0.0	5136
15 min Winter	216.498	0.0	16

Summary of Results for 100 year Return Period (+40%)

Storm Event	**Max Level (m)**	**Max Depth (m)**	**Max Infiltration (l/s)**	**Max Volume (m³)**	**Status**
30 min Winter	0.341	0.341	48.9	88.7	Flood Risk
60 min Winter	0.320	0.320	45.9	78.3	Flood Risk
120 min Winter	0.276	0.276	39.7	58.3	Flood Risk
180 min Winter	0.239	0.239	34.4	43.8	Flood Risk
240 min Winter	0.210	0.210	30.1	33.7	Flood Risk
360 min Winter	0.168	0.168	24.1	21.5	O K
480 min Winter	0.139	0.139	19.9	14.8	O K
600 min Winter	0.118	0.118	17.0	10.7	O K
720 min Winter	0.103	0.103	14.8	8.2	O K
960 min Winter	0.083	0.083	11.9	5.3	O K
1440 min Winter	0.060	0.060	8.7	2.8	O K
2160 min Winter	0.047	0.047	6.3	1.7	O K
2880 min Winter	0.041	0.041	4.9	1.3	O K
4320 min Winter	0.035	0.035	3.5	0.9	O K
5760 min Winter	0.031	0.031	2.7	0.7	O K
7200 min Winter	0.028	0.028	2.3	0.6	O K
8640 min Winter	0.026	0.026	1.9	0.5	O K
10080 min Winter	0.024	0.024	1.7	0.4	O K

Storm Event	**Rain (mm/hr)**	**Flooded Volume (m³)**	**Time-Peak (mins)**
30 min Winter	122.480	0.0	25
60 min Winter	69.291	0.0	44
120 min Winter	39.200	0.0	78
180 min Winter	28.092	0.0	110
240 min Winter	22.177	0.0	142
360 min Winter	15.892	0.0	200
480 min Winter	12.546	0.0	260
600 min Winter	10.444	0.0	318
720 min Winter	8.991	0.0	376
960 min Winter	7.127	0.0	494
1440 min Winter	5.136	0.0	734
2160 min Winter	3.702	0.0	1072
2880 min Winter	2.934	0.0	1468
4320 min Winter	2.091	0.0	2192
5760 min Winter	1.645	0.0	2928
7200 min Winter	1.365	0.0	3664
8640 min Winter	1.173	0.0	4416
10080 min Winter	1.031	0.0	5216

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	1999
Site Location	GB 604350 275750 TM 04350 75750
C (1km)	-0.023
D1 (1km)	0.284
D2 (1km)	0.298
D3 (1km)	0.271
E (1km)	0.313
F (1km)	2.462
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.288

Time (mins) From:	To:	Area (ha)
0	4	0.288

Model Details

Storage is Online Cover Level (m) 0.500

Porous Car Park Structure

Infiltration Coefficient Base (m/hr)	0.50700	Width (m)	51.0
Membrane Percolation (mm/hr)	400	Length (m)	51.0
Max Percolation (l/s)	289.0	Slope (1:X)	100.0
Safety Factor	5.0	Depression Storage (mm)	5
Porosity	0.30	Evaporation (mm/day)	3
Invert Level (m)	0.000	Membrane Depth (m)	0

APPENDIX C – SOAKAWAY

Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 143 minutes.

Storm Event	**Max Level (m)**	**Max Depth (m)**	**Max Infiltration (l/s)**	**Max Volume (m³)**	**Status**
15 min Summer	0.526	0.526	0.7	8.0	O K
30 min Summer	0.568	0.568	0.7	8.6	O K
60 min Summer	0.588	0.588	0.7	8.9	O K
120 min Summer	0.565	0.565	0.7	8.6	O K
180 min Summer	0.537	0.537	0.7	8.2	O K
240 min Summer	0.510	0.510	0.7	7.7	O K
360 min Summer	0.461	0.461	0.7	7.0	O K
480 min Summer	0.417	0.417	0.6	6.3	O K
600 min Summer	0.378	0.378	0.6	5.8	O K
720 min Summer	0.343	0.343	0.6	5.2	O K
960 min Summer	0.283	0.283	0.6	4.3	O K
1440 min Summer	0.189	0.189	0.5	2.9	O K
2160 min Summer	0.098	0.098	0.5	1.5	O K
2880 min Summer	0.054	0.054	0.5	0.8	O K
4320 min Summer	0.038	0.038	0.4	0.6	O K
5760 min Summer	0.030	0.030	0.3	0.5	O K
7200 min Summer	0.025	0.025	0.2	0.4	O K
8640 min Summer	0.021	0.021	0.2	0.3	O K
10080 min Summer	0.019	0.019	0.2	0.3	O K
15 min Winter	0.592	0.592	0.7	9.0	O K

Storm Event	**Rain (mm/hr)**	**Flooded Volume (m³)**	**Time-Peak (mins)**
15 min Summer	216.498	0.0	18
30 min Summer	122.480	0.0	32
60 min Summer	69.291	0.0	62
120 min Summer	39.200	0.0	104
180 min Summer	28.092	0.0	134
240 min Summer	22.177	0.0	168
360 min Summer	15.892	0.0	236
480 min Summer	12.546	0.0	304
600 min Summer	10.444	0.0	372
720 min Summer	8.991	0.0	436
960 min Summer	7.127	0.0	566
1440 min Summer	5.136	0.0	808
2160 min Summer	3.702	0.0	1148
2880 min Summer	2.934	0.0	1472
4320 min Summer	2.091	0.0	2200
5760 min Summer	1.645	0.0	2936
7200 min Summer	1.365	0.0	3616
8640 min Summer	1.173	0.0	4408
10080 min Summer	1.031	0.0	5104
15 min Winter	216.498	0.0	18

Summary of Results for 100 year Return Period (+40%)

Storm Event	**Max Level (m)**	**Max Depth (m)**	**Max Infiltration (l/s)**	**Max Volume (m³)**	**Status**
30 min Winter	0.643	0.643	0.7	9.8	O K
60 min Winter	0.673	0.673	0.8	10.2	O K
120 min Winter	0.654	0.654	0.7	9.9	O K
180 min Winter	0.618	0.618	0.7	9.4	O K
240 min Winter	0.584	0.584	0.7	8.9	O K
360 min Winter	0.516	0.516	0.7	7.8	O K
480 min Winter	0.453	0.453	0.7	6.9	O K
600 min Winter	0.397	0.397	0.6	6.0	O K
720 min Winter	0.346	0.346	0.6	5.3	O K
960 min Winter	0.260	0.260	0.6	4.0	O K
1440 min Winter	0.134	0.134	0.5	2.0	O K
2160 min Winter	0.048	0.048	0.5	0.7	O K
2880 min Winter	0.038	0.038	0.4	0.6	O K
4320 min Winter	0.027	0.027	0.3	0.4	O K
5760 min Winter	0.022	0.022	0.2	0.3	O K
7200 min Winter	0.018	0.018	0.2	0.3	O K
8640 min Winter	0.016	0.016	0.1	0.2	O K
10080 min Winter	0.014	0.014	0.1	0.2	O K

Storm Event	**Rain (mm/hr)**	**Flooded Volume (m³)**	**Time-Peak (mins)**
30 min Winter	122.480	0.0	32
60 min Winter	69.291	0.0	60
120 min Winter	39.200	0.0	114
180 min Winter	28.092	0.0	142
240 min Winter	22.177	0.0	180
360 min Winter	15.892	0.0	256
480 min Winter	12.546	0.0	328
600 min Winter	10.444	0.0	398
720 min Winter	8.991	0.0	468
960 min Winter	7.127	0.0	598
1440 min Winter	5.136	0.0	836
2160 min Winter	3.702	0.0	1104
2880 min Winter	2.934	0.0	1468
4320 min Winter	2.091	0.0	2204
5760 min Winter	1.645	0.0	2904
7200 min Winter	1.365	0.0	3664
8640 min Winter	1.173	0.0	4400
10080 min Winter	1.031	0.0	5112

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
FEH Rainfall Version	1999
Site Location	GB 604350 275750 TM 04350 75750
C (1km)	-0.023
D1 (1km)	0.284
D2 (1km)	0.298
D3 (1km)	0.271
E (1km)	0.313
F (1km)	2.462
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.021

Time (mins) From:	To:	Area (ha)
0	4	0.021

Model Details

Storage is Online Cover Level (m) 1.100

Cellular Storage Structure

Invert Level (m) 0.000 Safety Factor 5.0
Infiltration Coefficient Base (m/hr) 0.50700 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.50700

Depth (m)	**Area (m²)**	**Inf. Area (m²)**
0.000	16.0	16.0
1.100	16.0	33.6
1.200	0.0	33.6

APPENDIX D – PERMEABLE PAVING EXCEEDANCE

Summary of Results for 1000 year Return Period

Half Drain Time : 27 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
15 min Summer	0.424	0.424	60.9	137.8	Flood Risk
30 min Summer	0.412	0.412	59.2	130.1	Flood Risk
60 min Summer	0.389	0.389	55.8	115.7	Flood Risk
120 min Summer	0.346	0.346	49.7	91.8	Flood Risk
180 min Summer	0.311	0.311	44.7	74.2	Flood Risk
240 min Summer	0.283	0.283	40.7	61.3	Flood Risk
360 min Summer	0.240	0.240	34.4	43.9	Flood Risk
480 min Summer	0.208	0.208	29.8	33.0	Flood Risk
600 min Summer	0.183	0.183	26.3	25.7	O K
720 min Summer	0.164	0.164	23.5	20.5	O K
960 min Summer	0.135	0.135	19.4	14.0	O K
1440 min Summer	0.101	0.101	14.5	7.8	O K
2160 min Summer	0.073	0.073	10.5	4.1	O K
2880 min Summer	0.057	0.057	8.2	2.5	O K
4320 min Summer	0.045	0.045	5.8	1.5	O K
5760 min Summer	0.039	0.039	4.4	1.2	O K
7200 min Summer	0.035	0.035	3.6	1.0	O K
8640 min Summer	0.033	0.033	3.1	0.8	O K
10080 min Summer	0.030	0.030	2.6	0.7	O K
15 min Winter	0.454	0.454	65.2	157.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	342.679	0.0	16
30 min Summer	186.864	0.0	25
60 min Summer	101.898	0.0	42
120 min Summer	55.565	0.0	74
180 min Summer	38.972	0.0	108
240 min Summer	30.300	0.0	138
360 min Summer	21.251	0.0	198
480 min Summer	16.523	0.0	258
600 min Summer	13.592	0.0	318
720 min Summer	11.588	0.0	376
960 min Summer	9.046	0.0	494
1440 min Summer	6.381	0.0	736
2160 min Summer	4.501	0.0	1100
2880 min Summer	3.513	0.0	1468
4320 min Summer	2.451	0.0	2156
5760 min Summer	1.899	0.0	2856
7200 min Summer	1.557	0.0	3672
8640 min Summer	1.325	0.0	4264
10080 min Summer	1.155	0.0	4976
15 min Winter	342.679	0.0	16

Summary of Results for 1000 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
30 min Winter	0.440	0.440	63.2	148.2	Flood Risk
60 min Winter	0.410	0.410	58.9	128.4	Flood Risk
120 min Winter	0.353	0.353	50.7	95.5	Flood Risk
180 min Winter	0.307	0.307	44.1	72.2	Flood Risk
240 min Winter	0.270	0.270	38.8	55.9	Flood Risk
360 min Winter	0.216	0.216	31.1	35.7	Flood Risk
480 min Winter	0.179	0.179	25.7	24.5	O K
600 min Winter	0.152	0.152	21.9	17.7	O K
720 min Winter	0.132	0.132	18.9	13.3	O K
960 min Winter	0.105	0.105	15.0	8.4	O K
1440 min Winter	0.075	0.075	10.7	4.3	O K
2160 min Winter	0.053	0.053	7.6	2.1	O K
2880 min Winter	0.045	0.045	5.9	1.6	O K
4320 min Winter	0.038	0.038	4.1	1.1	O K
5760 min Winter	0.033	0.033	3.2	0.8	O K
7200 min Winter	0.030	0.030	2.6	0.7	O K
8640 min Winter	0.028	0.028	2.2	0.6	O K
10080 min Winter	0.026	0.026	1.9	0.5	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
30 min Winter	186.864	0.0	26
60 min Winter	101.898	0.0	44
120 min Winter	55.565	0.0	80
180 min Winter	38.972	0.0	112
240 min Winter	30.300	0.0	144
360 min Winter	21.251	0.0	204
480 min Winter	16.523	0.0	264
600 min Winter	13.592	0.0	320
720 min Winter	11.588	0.0	382
960 min Winter	9.046	0.0	498
1440 min Winter	6.381	0.0	734
2160 min Winter	4.501	0.0	1088
2880 min Winter	3.513	0.0	1420
4320 min Winter	2.451	0.0	2140
5760 min Winter	1.899	0.0	2864
7200 min Winter	1.557	0.0	3552
8640 min Winter	1.325	0.0	4248
10080 min Winter	1.155	0.0	4992

Rainfall Details

Rainfall Model	FEH
Return Period (years)	1000
FEH Rainfall Version	1999
Site Location	GB 604350 275750 TM 04350 75750
C (1km)	-0.023
D1 (1km)	0.284
D2 (1km)	0.298
D3 (1km)	0.271
E (1km)	0.313
F (1km)	2.462
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+0

Time Area Diagram

Total Area (ha) 0.288

Time From:	**(mins) To:**	**Area (ha)**
0	4	0.288

Model Details

Storage is Online Cover Level (m) 0.500

Porous Car Park Structure

Infiltration Coefficient Base (m/hr)	0.50700	Width (m)	51.0
Membrane Percolation (mm/hr)	400	Length (m)	51.0
Max Percolation (l/s)	289.0	Slope (1:X)	100.0
Safety Factor	5.0	Depression Storage (mm)	5
Porosity	0.30	Evaporation (mm/day)	3
Invert Level (m)	0.000	Membrane Depth (m)	0

APPENDIX E – SOAKAWAY EXCEEDANCE

Summary of Results for 1000 year Return Period

Half Drain Time : 188 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
15 min Summer	0.845	0.845	0.8	12.9	Flood Risk
30 min Summer	0.890	0.890	0.9	13.5	Flood Risk
60 min Summer	0.904	0.904	0.9	13.7	Flood Risk
120 min Summer	0.858	0.858	0.8	13.0	Flood Risk
180 min Summer	0.804	0.804	0.8	12.2	Flood Risk
240 min Summer	0.758	0.758	0.8	11.5	O K
360 min Summer	0.680	0.680	0.8	10.3	O K
480 min Summer	0.616	0.616	0.7	9.4	O K
600 min Summer	0.562	0.562	0.7	8.5	O K
720 min Summer	0.513	0.513	0.7	7.8	O K
960 min Summer	0.432	0.432	0.6	6.6	O K
1440 min Summer	0.304	0.304	0.6	4.6	O K
2160 min Summer	0.174	0.174	0.5	2.6	O K
2880 min Summer	0.095	0.095	0.5	1.4	O K
4320 min Summer	0.044	0.044	0.4	0.7	O K
5760 min Summer	0.034	0.034	0.3	0.5	O K
7200 min Summer	0.028	0.028	0.3	0.4	O K
8640 min Summer	0.024	0.024	0.2	0.4	O K
10080 min Summer	0.021	0.021	0.2	0.3	O K
15 min Winter	0.951	0.951	0.9	14.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	342.679	0.0	18
30 min Summer	186.864	0.0	33
60 min Summer	101.898	0.0	62
120 min Summer	55.565	0.0	116
180 min Summer	38.972	0.0	144
240 min Summer	30.300	0.0	174
360 min Summer	21.251	0.0	242
480 min Summer	16.523	0.0	310
600 min Summer	13.592	0.0	380
720 min Summer	11.588	0.0	446
960 min Summer	9.046	0.0	578
1440 min Summer	6.381	0.0	824
2160 min Summer	4.501	0.0	1188
2880 min Summer	3.513	0.0	1528
4320 min Summer	2.451	0.0	2200
5760 min Summer	1.899	0.0	2936
7200 min Summer	1.557	0.0	3600
8640 min Summer	1.325	0.0	4408
10080 min Summer	1.155	0.0	5104
15 min Winter	342.679	0.0	18

Summary of Results for 1000 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
30 min Winter	1.004	1.004	0.9	15.3	Flood Risk
60 min Winter	1.028	1.028	0.9	15.6	Flood Risk
120 min Winter	0.990	0.990	0.9	15.1	Flood Risk
180 min Winter	0.926	0.926	0.9	14.1	Flood Risk
240 min Winter	0.872	0.872	0.8	13.3	Flood Risk
360 min Winter	0.773	0.773	0.8	11.8	O K
480 min Winter	0.686	0.686	0.8	10.4	O K
600 min Winter	0.610	0.610	0.7	9.3	O K
720 min Winter	0.542	0.542	0.7	8.2	O K
960 min Winter	0.429	0.429	0.6	6.5	O K
1440 min Winter	0.258	0.258	0.6	3.9	O K
2160 min Winter	0.096	0.096	0.5	1.5	O K
2880 min Winter	0.046	0.046	0.4	0.7	O K
4320 min Winter	0.032	0.032	0.3	0.5	O K
5760 min Winter	0.025	0.025	0.2	0.4	O K
7200 min Winter	0.021	0.021	0.2	0.3	O K
8640 min Winter	0.018	0.018	0.2	0.3	O K
10080 min Winter	0.015	0.015	0.1	0.2	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
30 min Winter	186.864	0.0	32
60 min Winter	101.898	0.0	60
120 min Winter	55.565	0.0	116
180 min Winter	38.972	0.0	150
240 min Winter	30.300	0.0	186
360 min Winter	21.251	0.0	262
480 min Winter	16.523	0.0	336
600 min Winter	13.592	0.0	410
720 min Winter	11.588	0.0	478
960 min Winter	9.046	0.0	616
1440 min Winter	6.381	0.0	866
2160 min Winter	4.501	0.0	1208
2880 min Winter	3.513	0.0	1472
4320 min Winter	2.451	0.0	2188
5760 min Winter	1.899	0.0	2936
7200 min Winter	1.557	0.0	3632
8640 min Winter	1.325	0.0	4384
10080 min Winter	1.155	0.0	5136

Rainfall Details

Rainfall Model	FEH
Return Period (years)	1000
FEH Rainfall Version	1999
Site Location	GB 604350 275750 TM 04350 75750
C (1km)	-0.023
D1 (1km)	0.284
D2 (1km)	0.298
D3 (1km)	0.271
E (1km)	0.313
F (1km)	2.462
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+0

Time Area Diagram

Total Area (ha) 0.021

Time (mins)		**Area**
From:	**To:**	**(ha)**
0	4	0.021

Model Details

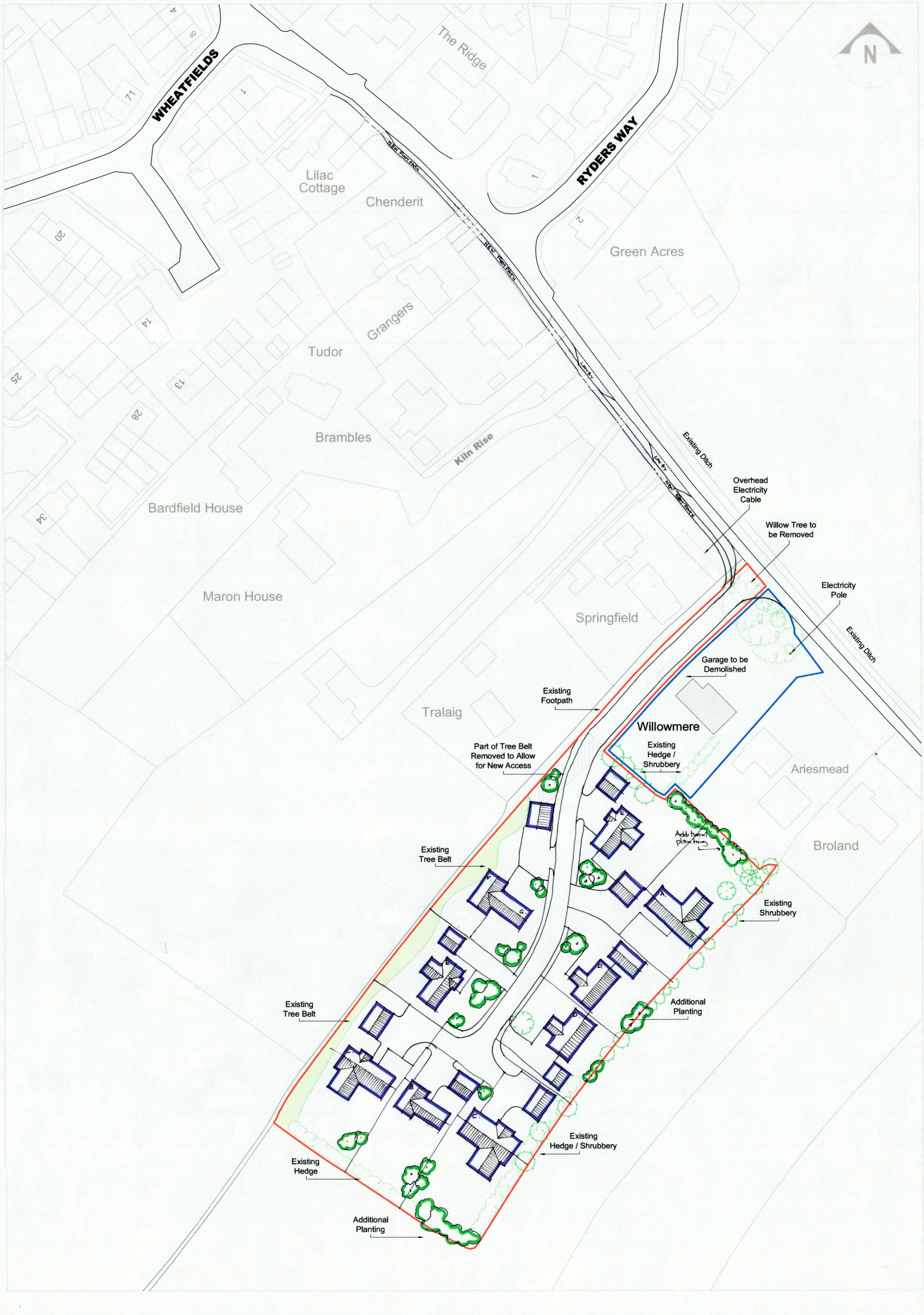
Storage is Online Cover Level (m) 1.100

Cellular Storage Structure

Invert Level (m) 0.000 Safety Factor 5.0
Infiltration Coefficient Base (m/hr) 0.50700 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.50700

Depth (m)	**Area (m²)**	**Inf. Area (m²)**
0.000	16.0	16.0
1.100	16.0	33.6
1.200	0.0	33.6

DRAWINGS



1. This drawing must not be scaled & if in doubt consult the architect.
2. This drawing to be checked & read conjunctionwith all Engineers, Architectural, Service Engineers & any specialistdrawings, together any relevant additional specifications.
3. Where site information or adjoining building details are contrary to issued details then the Engineer is to be informed immediately.
4. No strucural members are to be cut, notched , or jointed unless shown on the Engineers details unless otherwise noted all connections of structural members including laps & anchorages of reinforcement shall be capable of mobilising the full structural capacity of the member.
5. Under the provisions of the party wall act 1998 if the excavations are within 3m of adjacent buildings written agreement for the works from the owner & the tenant (If applicable) of adjacent buildings must be obtained before building work commence & one months notice must be given before building work commences. if the work applies to the party wall two months notice must be given. Note, if foundations, soffits, gutters, etc encroach across the boundary a written agreement from the owner of the adjoining land / buildings must be obtained & the boundary agreed before building works commence .
6. Health & Safety CDM regulations may apply to this project. Generaly if the construction work is likely to last for thirty days or will involve more than five hundred person days of work or involve five or more persons on site at any one time then the regulations apply to the CDM must be notified & a main contractor and planning supervisor appointed by the client to oversee the whole contract under the provisions of the CDM regulations of Health & Safety .

Rev	Description	Name	Date

Drawn: LB
Checked:
Approved:
Scale @ A1: 1:500
Date: May 16
Job No: 444

DO NOT SCALE : All figured dimensions to be checked on site and the Architect notified of any variation

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Project Title: Residential Development at Land Behind Willowmere, Garden House Lane IP22 1EA
For: Mr Colin and Mrs Helen Arnold
Drawing Title: Proposed Sketch Site Plan
Drawing No: 444-SK01
Revision:

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