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Engineering Services Report

Strategic Housing Development

Frankfort Castle, Old Frankfort, Dundrum, Dublin 14

Client: Pembroke Partnership Ltd

Job No. H081

August 2021

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ENGINEERING SERVICES REPORT

STRATEGIC HOUSING DEVELOPMENT

FRANKFORT CASTLE, OLD FRANKFORT, DUNDRUM, DUBLIN 14

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BS 1192 FIELD	**H081-CSC-ZZ-XX-RP-C-0001-P3**

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H081	GS	NB	NB	21.12.2020	P1

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1.0 INTRODUCTION

Cronin & Sutton Consulting Engineers (CS Consulting) have been commissioned by Pembroke Partnership Limited to prepare an Engineering Services Report for a proposed strategic housing development at Frankfort Castle, Old Frankfort, Dundrum, Dublin 14.

This report assesses the proposed development under the following headings:

- Foul Drainage Infrastructure
- Stormwater Drainage Infrastructure
- Potable Water Infrastructure

In preparing this report, CS Consulting has made reference to the following:

- Dún Laoghaire-Rathdown County Development Plan 2016–2022
- Regional Code of Practice for Drainage Works
- The Greater Dublin Strategic Drainage Study
- Irish Water Code of Practice for Water
- Irish Water Code of Practice for Wastewater
- Local Authority Drainage Records

The Engineering Services Report is to be read in conjunction with the engineering drawings and documents submitted by CS Consulting and with the various additional information submitted by the other members of the design team.

2.0 SITE LOCATION AND PROPOSED DEVELOPMENT

2.1 Site Location

The site of the proposed development lies immediately east of Dundrum Road, approximately 750m to the north of Dundrum village centre in Dublin 14. The site has a total area of approx. 0.9ha and is located in the administrative jurisdiction of Dún Laoghaire-Rathdown County Council.

Figure 1 – Location of proposed development site
(*map data and imagery: EPA, NTA, OSM Contributors, Google*)

The location of the proposed development site is shown in Figure 1 above; the indicative extents of the development site, as well as relevant elements of the surrounding road network, are shown in more detail in Figure 2.

The site is bounded to the north, south and east by existing residential properties and to the west by the Luas Green Line. The site has extensive

street frontage on Frankfort, on its eastern boundary and on Frankfort Court on its southern boundary.

Figure 2 – Site extents and environs
(*map data and imagery: NTA, OSM Contributors, Google*)

2.2 Existing Land Use

The site of the proposed development is brownfield and comprises the existing properties of 97A Highfield Park, Dundrum, Dublin 14, D14 P710; 1 Frankfort Castle, Old Frankfort, Dublin 14, D14 HY03; 2 Frankfort Castle, Old Frankfort, Dublin 14, D14 DE72; and Frankfort Lodge, Old Frankfort, Dublin 14, D14 C9P2.

2.3 Proposed Development

The proposed development will consist of 115no. residential units comprising 45no. one-bed units and 70no. two-bed units. The proposed units will be

accommodated in the partially retained Frankfort Castle building and in 3no. blocks with a maximum height of 5 storeys. The subject proposal also includes for the demolition of the existing 97A Highfield Park residence (192.5sqm) and for the demolition of annexe buildings associated with Frankfort Castle including Frankfort Lodge (368sqm).

Additional works proposed include the provision of a childcare facility (80sqm), car and cycle parking at surface and basement level, hard and soft landscaping, surface water drainage infrastructure and attenuation tank, and all associated site development and infrastructure works.

3.0 FOUL DRAINAGE

3.1 Existing Foul Drainage Infrastructure

Dún Laoghaire-Rathdown County Council's drainage records indicate a 750mm diameter concrete foul sewer flowing south to north on Luas Green Line railway; and a 225mm uPVC foul sewer on Frankfort Court which flows to east into the 750mm diameter concrete foul sewer. See **Appendix A** for Dún Laoghaire-Rathdown County Council's drainage records.

As part of the *Greater Dublin Strategic Drainage Study* (GDSDS), an analysis of the drainage network surrounding the subject has not indicated any hydraulic issue. See **Appendix A** for drainage records and GDSDS 2031 system performance map extract.

The proposed development will be serviced by a new drainage system with separate sewers and manholes for both foul and storm water within the sites boundary. The proposed foul network has been designed in accordance with the *Building Regulations & the Regional Code of Practice for Drainage* Works, Version 6.

3.2 Proposed Foul Drainage Arrangements

The proposed development is to consist of 115no. residential units. Based on Irish Water guidelines, the foul effluent generated will be:

- <u>For the residential units:</u>
  - ⇒ based on 2.7 persons per unit x 150l/person/day
  - ⇒ 0.54 l/s or 46.6m^3/day Average Flow (DWF)
  - ⇒ 3.23l/sec Peak Flow (= 6 x DWF)

All foul effluent generated from the proposed development from the upper floors of all proposed block apartments and redeveloped Frankfort Castle shall be collected in separate foul pipes and flow under gravity, to the proposed plant room on the ground floor level. From this plant room a foul pump sump shall be pumped to a stand-off manhole outside of the proposed development boundary before connection via gravity into the existing 225mm diameter uPVC foul sewer on Frankfort Court.

For the basement level, all foul effluent shall be collected in pipe of 150mm in diameter flowing under gravity to a pump station located in the basement to a stand-off manhole at ground level.

The drainage network for the development will be in accordance with Part H of the Building Regulations and to the requirements and specifications of Irish Water.

A Pre-Connection Enquiry for a scheme of 122no. residential units has been submitted to Irish Water and we have received a Confirmation of Feasibility Letter. Irish Water noted that approximately 20m of new foul sewer would be required to be constructed in Frankfort Court. See **Appendix B** for a copy of this letter. However, a review of the available levels and taking cognisance of the presence of an existing public storm water sewer it is proposed to pump the developments foul effluent beyond the storm sewer and outfall same into a stand-off manhole from which the effluent will flow by gravity into the main network. Refer to CS Consulting drawing no. H081-CSC-XX-GL-DR-C-0003 for details.

The development's proposed drainage arrangements have been submitted to Irish Water for review and a Statement of Design Acceptance has been received in response. This is also included in **Appendix B**.

Although the proposed building will generate a larger volume of effluent than the existing, the proposed building will incorporate a storm water

attenuation system (sub surface storm management chambers such as StormTech or similar approved) which will restrict the volume of stormwater entering the public drainage network during periods of extreme rainfall. The overall result will be that while the foul component of the effluent from the new building will be greater than the existing the percentage of storm water will be greatly reduced giving an overall net benefit in terms of reducing the hydraulic pressure placed on the Local Authorities public system.

The proposed foul water drainage infrastructure and routing plan is shown on CS Consulting drawing nos. H081-CSC-XX-GL-DR-C-0003, H081-CSC-XX-GL-DR-C-0004, and H081-CSC-XX-GL-DR-C-0005 included with this submission.

4.0 SURFACE WATER DRAINAGE

4.1 Existing Stormwater Drainage Infrastructure

Following receipt of Dún Laoghaire-Rathdown County Council's drainage records (see **Appendix A**) there is an existing 225mm diameter uPVC storm water sewer on Frankfort Court which flows toward Slang River.

As part of the *Greater Dublin Strategic Drainage Study* (GDSDS), an analysis of the drainage network surrounding the subject has not indicated any hydraulic issue. See **Appendix A** for Irish Water drainage records and GDSDS 2031 system performance map extract.

4.2 Proposed Stormwater Drainage Arrangements

In accordance with the requirements of DLRCC Drainage Division all new developments are to incorporate the principles of Sustainable Urban Drainage Systems, (SuDs). The SuDs principles require a two-fold approach to address storm water management on new developments.

The **first** aspect is to reduce any post development run-off to pre-development discharge rates. The development is to retain storm water volumes predicted to be experienced during extreme rainfall events. This is defined as the volume of storm water generated during a 1 in 100 year storm event increased by 20% for predicted climate change factors.

To ensure an accurate calculation of the required attenuation for the site Met Eireann was contacted to provide:

a) The SAAR (Standard Annual Average Rainfall) for the area: 820mm/year.

b) The sliding duration table for the site indicating the 1:100 year rainwater intensities to be used.

c) Soil type value obtained from the Flood Studies Report (for the subject site, this has been established as soil type 4).

These parameters allow the Q-Bar value (greenfield runoff rate) to be calculated. The Q-Bar value for the site is based on the gross area; i.e. red line boundary, and calculated as 5.81l/sec/ha, with an allowable discharge rate of 5.1l/sec for all storm water events. See **Appendix C** for Met Eireann Data.

The site area of the development subject to stormwater design is approximately 0.88ha which gives an attenuation volume requirement of 343m^3 for the 1 in 100 year storm event, (including a climate change factor of 20%). The restricted discharge rate of 5.1l/s will be applied to the entire site. This allowable discharge rate will be divided between the hydro-brake (4.6l/s) located at last down stream tank and orifice plate (0.5l/s) at down stream end of bio-retention area.

The outfall into the public system will be onto the existing 225mm diameter uPVC stormwater on Frankfort Court and the last public manhole shall be constructed in accordance with Local Authority's requirements and the storm water flow will be restricted by the use of a flow control device to limit the flow to the public system. See **Appendix C** for the Attenuation Calculation.

The **second** aspect is the policy of the Local Authority is to include Sustainable Urban Drainage Systems, SuDS, for all new applications. The aim of including SuDs systems is to enhance the overall water quality prior to ultimate discharge. Ideally storm water should be directed to infiltration areas to allow storm generated on site to drain into the water table. To establish the sites potential for infiltration disposal systems a number of on-site insitu tests were carried out to BRE 365. The results of same indicate that the site is underlain with clay and the corresponding infiltration rates preclude large areas from draining into the subsoil, small local areas can

be accommodated. As such large scale infiltration would be unsuitable for the proposed scheme. See **Appendix D** for extracts from the site investigation pertaining to the infiltration rates.

As such it is proposed to use a range of SuDS devises for the scheme they are listed below:

SuDS proposals are as follows:

- Green roof technology to the flat roof to cater for the initial interception storage. See **Appendix E** for specification or similar, and refer also to CS Consulting drawing no. H081-CSC-XX-GL-DR-C-0017.
- Local water butts to retain storm water for re-use as part of the developments landscaping maintenance regime. See CS Consulting drawing nos. H081-CSC-XX-GL-DR-C-0003 and H081-CSC-XX-GL-DR-C-0020 for details.
- Low water usage appliances, to restrict potable water demand.
- Attenuation tank with flow control device, sized to contain a 1-in-100-year storm event and increased by 20% for predicted climate change, to limit discharge from the site during extreme rainfall events,
- Permeable paving areas of the subject site are located on the western and northern sections of the internal road, around the residential and amenity space of Block B (see CS Consulting drawing nos. H081-CSC-XX-GL-DR-C-0003 and H081-CSC-XX-GL-DR-C-0020 for details).
- Bio-retention area (see CS Consulting drawing nos. H081-CSC-XX-GL-DR-C-0003 and H081-CSC-XX-GL-DR-C-0020 for details).

The proposed surface water system is simulated to assess the impacts from a surcharged network namely during the unlikely scenario where only half of the allowable discharge rate is occurring. The system is simulated under this condition and shows no surface water flooding at any part of the site. Refer to the Microdrainage simulation results for further information.

See CS Consulting drawing nos. H081-CSC-XX-GL-DR-C-0003, H081-CSC-XX-GL-DR-C-0004, and H081-CSC-XX-GL-DR-C-0005 for the proposed drainage layout.

5.0 POTABLE WATER SUPPLY

5.1 Existing Potable Water System

Records obtained from Dún Laoghaire-Rathdown County Council indicate public watermains adjacent to the development site on Frankfort Court and Frankfort.

5.2 Proposed Potable Water System

It is proposed to make a new connection off the existing 110mm diameter watermain on Frankfort to the development site and supply a 100mm internal diameter watermain to the proposed development site.

The proposed development is to consist of 115no. residential units.

Based on Irish Water guidelines, the potable water requirements will be:

- For the residential units:
  - ⇒ based on 2.7 persons per unit x150l/person/day.
  - ⇒ 0.67 l/sec Average water demand (including loss factor of 1.25)
  - ⇒ 3.37 l/s Peak Demand (5 times the average water demand).

A Pre-Connection Enquiry has been submitted to Irish Water based on the above water demand and we have received a Confirmation of Feasibility Letter (please see **Appendix B**).

The proposed watermain infrastructure and routing plan is shown on CS Consulting drawing no. H081-CSC-XX-GL-DR-C-0006 included with this submission.

The development's proposed water supply arrangements have been submitted to Irish Water for review and a Statement of Design Acceptance has been received in response. This is also included in **Appendix B**.

6.0 RESPONSE TO AN BORD PLEANÁLA OPINION

An Bord Pleanála has in February 2020 issued an opinion enumerating the items of specific information that should be submitted with any application for permission. The following items among these are of relevance to this Engineering Services Report:

8. *Addition detail in relation to surface water proposals, having regard to the report of the Drainage Division of the Planning Authority (dated 16th January 2020), and having regards to discussions at the tripartite meeting, namely the need to provide more detail in relation to the surface water infrastructure to be provided on site, the feasibility or otherwise of the proposed planting over the attenuation tanks as well as details of green roofs. In addition, a Stormwater Audit will be required at application stage.*

See below the comments from the council and CS Consulting's responses.

Drainage Planning Section

Report Date: 16th January 2020

Surface Water Report – General

As the SHD process does not provide for further information the Applicant should be strongly advised to consult with and reach agreement with the Drainage Planning Section of Municipal Services on surface water drainage proposals for this site of the lodgement (subject to the consent of An Bord Pleanála following this stage of the process) of a planning application. The Applicant is advised that in the absence of a detailed technical submission at this stage of the process, issues may arise that have not been covered in the observations that follow.

1. As standard, the Applicant is required to provide fully dimensioned plans and sections of the storage system. All relevant inlet and outlet levels, dimensioned clearances between other utilities, and actual depths of cover to the system shall be provided. The Applicant shall include confirmation from the chosen manufacturer of the storage system that the specific model chosen, with the depth of cover being provided, has the required load bearing capacity to support vehicular traffic loading that may be imposed upon it. An in-line attenuation storage tank proposal will be required.

   Response

   *Please refer to CS Consulting drawing **H081-CSC-XX-GL-DR-C-0003** for details of the development's proposed stormwater attenuation storage system, including fully dimensioned plans, sections, all relevant inlet and outlet levels, dimensioned clearances between other utilities, and depths of cover. An in-line attenuation storage tank is provided as part of the proposed storage system.*

   *The proposed attenuation storage tank is designed using arch-shaped Stormtech modular storage units. As shown on CS Consulting drawing **H081-CSC-XX-GL-DR-C-0003**, a minimum cover of approx. 600mm is provided to the top of each arch. **Appendix G** to this report includes the BBA (British), DIBt (German), and CCFAT (French) technical certification documents for this product, as well as an explanatory note provided by the Irish-market distributor (Resolute Group). These documents indicate that – when provided with the minimum cover of 460mm – a Stormtech assembly may support a live vehicle axle load of up to 142kN.*

   For comparison, TII technical document AM-STR-06026 (The Assessment of Road Bridges and Structures) indicates that the heaviest Group 1 fire engines have a maximum axle load of 99.8kN (10.17 tonnes). The maximum axle loading permitted by the Road Traffic (Construction and Use of Vehicles) Regulations 2003 for a typical construction HGV (with 2-axle non-

driving rear bogie) equates to 9 tonnes (88.3kN). The proposed attenuation storage design is therefore considered to have load-bearing capacity in excess of that required to support the maximum vehicular traffic loading to which it will be subjected during either construction or operation of the proposed development.

2. As standard, proposals demonstrating how the proposed attenuation storage is to be maintained will be required. The Applicant is required to provide penstock in the flow control device chamber and ensure that the flow control device provided does not have a bypass door.

   Response

   The proposed attenuation storage system employs a Stormtech design, featuring an Isolator Row within each tank. "Isolating" sediments to just one row reduces the cost of periodic maintenance by eliminating the need to clean out each row of the entire storage bed. If inspection indicates the potential need for maintenance, access is provided via a manhole(s) located on the end(s) of the row for cleanout. Maintenance is accomplished by jetting the Isolator Row. The jetting process utilizes a high-pressure water nozzle to propel itself down the Isolator Row while scouring and suspending sediments. As the nozzle is retrieved, the captured pollutants are flushed back into the manhole for vacuuming.

   CS Consulting drawing ***H081-CSC-XX-XX-DR-C-0017*** *shows details of the proposed Hydrobrake flow control device, including penstock. The proposed flow control device does not incorporate a bypass door.*

3. As standard, the Applicant is required to show the options being proposed for interception and treatment volume storage with contributing area on a

drawing together with an accompanying text and tabular submission showing the calculations, to demonstrate compliance with GDSDS requirements. Over-provision in one location does not compensate for under provision elsewhere.

Response

*CS Consulting Drawing **H081-CSC-XX-XX-DR-C-0021** shows details of the proposed SuDS arrangements for interception and treatment. This drawing includes calculations for the required interception storage volume and treatment volume, in accordance with GDSDS requirements. The contributing impermeable areas are also identified and quantified on this drawing, as are areas of green roof and permeable paving.*

4. As standard the Applicant is required to provide information on the proposed hydrobrake and to submit supporting calculations, in Microdrainage or other format, for the drainage design.

Response

*CS Consulting drawing **H081-CSC-XX-XX-DR-C-0017** shows details of the proposed Hydrobrake flow control device. **Appendix C** to this report includes Micro Drainage calculations in respect of the proposed development's drainage design.*

5. The Applicant has stated that the site area is .90Ha with a positively drained area of 0.49Ha. It appears the full site area (0.9ha) has been used to generate the allowable outflow, with a resultant value of 5.1l/s. However only the positively drained area should be included in the calculation for allowable outflow (areas such as the car park which drains to a soakaway should be removed from the site area, as well as grassed areas not draining

to the surface water network). The Applicant is requested to show on a drawing the positively drained area and use this figure to calculate QBar as well as the revised attenuation requirements.

Response

The Q-bar value for the subject site has been calculated in accordance with the provisions of the Greater Dublin Regional Code of Practice for Drainage Works, which specifies that "the maximum permitted surface water outflow from any new development is to be restricted to that of a Greenfield site". The allowable stormwater discharge rate has therefore been determined on the basis of the entire site area, as though this were in a greenfield condition.

The required attenuation storage volume is likewise calculated on the basis of the proposed development's total site area, with differing runoff rates for hardstanding and softstanding areas. Refer to ***Appendix C*** *for the relevant calculations. The development's drainage areas are illustrated and tabulated on CS Consulting drawing* ***H081-CSC-XX-XX-DR-C-0021****.*

For the avoidance of doubt, it is noted that the total effective site area for drainage purposes is 0.88ha, although certain non-technical references in reports give the site area to 1 decimal place as 0.9ha. It is also noted that the permeable paving areas within the development serve a treatment and attenuation function but do not drain to a soakaway.

6. Notwithstanding the above, there is a slight discrepancy between the proposed Q-Bar value in the report and the calculated allowable outflow in Appendix C, with 5.25l/s noted in the report with 5.1l/s in the calculation and in the drawings. The Applicant is requested to ensure consistence throughout the documents and drawings.

Response

The Q-bar value has been established at 5.81l/sec/ha, resulting in an allowable discharge rate of 5.1l/sec. This is the value used in all calculations, and that referenced in this report and on the relevant drawings.

7. As standard, the Applicant is required to demonstrate on a drawing that all infiltration SuDS proposals, including the attenuation systems, have a 5m separation distance from building foundations and 3m separation from site boundaries or provide a justification for a reduced separation distance.

   Response

   No infiltration SuDS systems are proposed within the development. As shown on CS Consulting drawing ***H081-CSC-XX-XX-DR-C-0021****, the bio retention area and permeable paving areas are lined with an impermeable membrane; these serve a retention and treatment function but do not drain to soakaways. All water collected in these systems (and that does not evaporate) drains to the attenuation storage tank and ultimately discharges to the public drainage network.*

8. As standard, the Applicant shall ensure that other disciplines drawings, including landscape drawings, are compatible with engineering drawings.

   Response

   The compatibility of drawings across disciplines has been ensured.

9. The Applicant appears to have demonstrated by calculation and by representation on a drawing that the proposed green roof extents are in accordance with the Council's Green Roof Policy such that the minimum

coverage requirement of 60% is achieved. The Applicant shall provide details of maintenance access to the green roofs and should note that, in the absence of a stairwell type access to the roof, provision should be made for alternative maintenance and access arrangements such as external mobile access that will be centrally managed. A detailed cross section of the proposed build-up of the green roof should be provided, including dimensions.

Response

*CS Consulting drawing **H081-CSC-XX-RF-DR-C-0009** and **Appendix E** to this report provide details of the proposed green roof build-ups. For details of maintenance access provisions, please refer to the architectural drawings submitted with this application.*

10. The Applicant has noted that mounting with tree planting will be provided over the attenuation tank to the south of Block A. Planting has also been proposed around the covered cycle parking area to the south of Block B, where another attenuation tank is located. The Applicant shall be requested to remove planting in this area or provide evidence that the proposed planting will not interfere with the attenuation system, this may include a root barrier system. As standard, the Applicant shall ensure that other disciplines drawings, including landscape drawings, are compatible with engineering drawings.

Response

The development's final landscaping proposals do not include significant planting over or around the attenuation tanks. While some planting is proposed in these areas, the Stormtech systems to be employed for the attenuation tanks are not susceptible to root ingress; the stone bedding surrounding the Stormtech arch units functions as a root barrier and, as the system will be dry except during intense rainfall events, the attenuation

tanks will not attract persistent root growth in their direction. Refer to landscape drawings and to CS Consulting drawing ***H081-CSC-XX-RF-DR-C-0021*** *for further details.*

11. The Applicant is required to submit supporting standard details, including cross-sections and long-sections, and commentary that demonstrates that all types of proposed Permeable Paving have been designed in accordance with the recommendations of CIRIA C753 (SuDS manual).

Response

The development's proposed permeable paving areas comprise permeable block paving on a 50mm deep bedding layer, underlain with permeable structural layers of crushed stone (total thickness 460mm) and lined with an impermeable membrane. A 150mm diameter perforated overflow pipe provides drainage to the attenuation storage tank. Refer to CS Consulting drawing ***H081-CSC-XX-RF-DR-C-0021*** *for cross-section. The permeable paving design accords with the recommendations of the CIRIA SuDS Manual.*

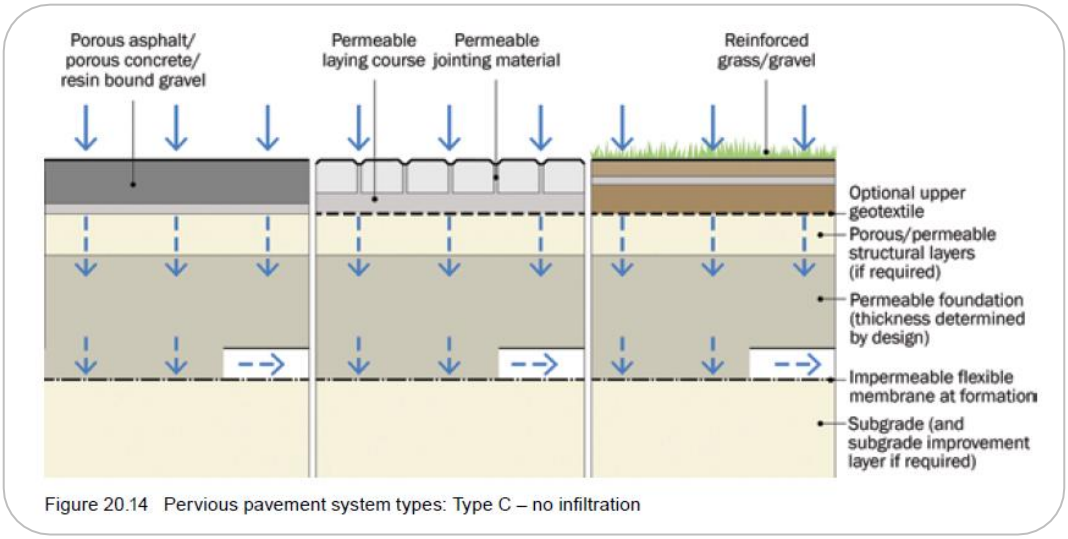

Figure 3 – Pervious pavement systems without infiltration
(*source: CIRIA SuDS Manual*)

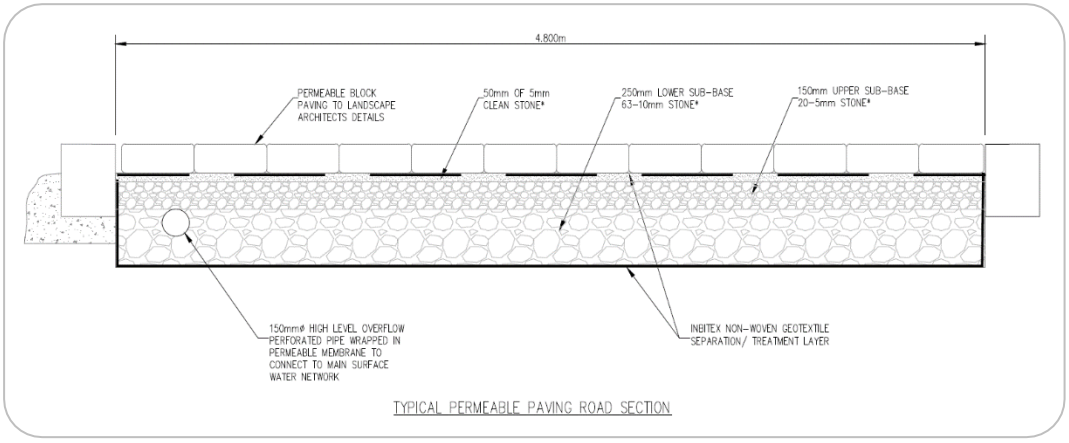

Figure 4 – Proposed permeable paving cross-section
(*extract of CS Consulting drawing H081-CSC-XX-RF-DR-C-0021*)

12. As standard, a Stormwater Audit will be required for this application. In accordance with the Stormwater Audit Policy, the audit shall be forwarded to DLRCC prior to lodgement of the planning application. All recommendations shall be complied with, unless agreed in writing otherwise with DLRCC.

    Response

    A Stormwater Audit of the proposed development has been conducted by JBA Consulting. The Audit report document and Audit Feedback Form are provided as ***Appendix F*** *to this report.*

Appendix A

DRCC Drainage Records & GDSDS Hydraulic Performance Map

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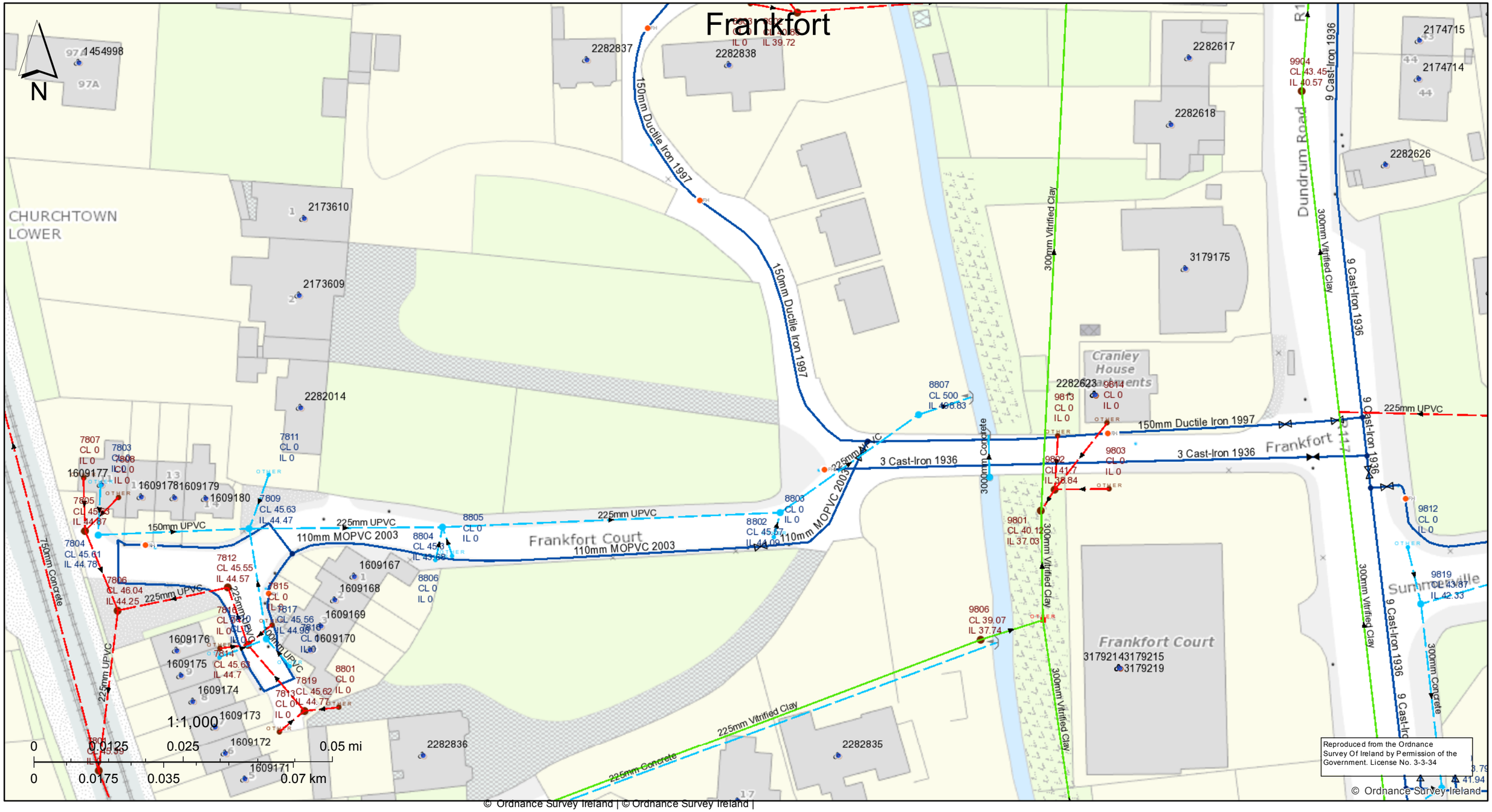

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17 May 2018 08:16:21

Legend

Stormwater Gravity Mains (Irish Water Owned)
- Surface

Stormwater Gravity Mains (Non-Irish Water Owned)
- Surface

Storm Manholes
- Cascade
- Catchpit
- Hatchbox
- Lamphole
- Standard
- Other; Unknown

Storm Inlets
- Gully
- Standard
- Other; Unknown

Storm Fittings
- Vent/Col
- Other; Unknown

Storm Discharge Points
- Outfall
- Overflow
- Soakaway
- Other; Unknown

Storm Culverts

Storm Clean Outs

Sewer Gravity Mains (Irish Water owned)
- Combined
- Foul
- Overflow
- Unknown

Sewer Gravity Mains (Non-Irish Water owned)
- Combined
- Foul
- Overflow
- Unknown

Appendix B

Irish Water Confirmation of Feasibility and Statement of Design Acceptance

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Irish Water
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www.water.ie

Gessica Silva
CS Consulting
19-22 Dame Street
Dublin 2
Dublin, Ireland D02E267

10 April 2019

Dear Gessica Silva,

Re: Connection Reference No CDS19002259 pre-connection enquiry - Subject to contract | Contract denied

Connection for Housing Development of 122 units at Frankfort Castle, Old Frankfort, Dublin 14.

Irish Water has reviewed your pre-connection enquiry in relation to a water connection at Frankfort Castle, Old Frankfort, Dublin 14.

Based upon the details that you have provided with your pre-connection enquiry and on the capacity currently available in the network(s), as assessed by Irish Water, we wish to advise you that, subject to a valid connection agreement being put in place, your proposed connection to the Irish Water network(s) can be facilitated.

Water:
New connection to the existing network is feasible without upgrade.

Wastewater:
In order to complete the proposed connection at the Premises, the Irish Water network will have to be extended for approximately 20 m in Frankfort Court. Should you wish to progress with the connection, the extension works will be calculated in connection offer for the Development.

Strategic Housing Development

Irish Water notes that the scale of this development dictates that it is subject to the Strategic Housing Development planning process. Therefore:

A. In advance of submitting your full application to An Bord Pleanala for assessment, you must have reviewed this development with Irish Water and received a Statement of Design Acceptance in relation to the layout of water and wastewater services.

B. You are advised that this correspondence does not constitute an offer in whole or in part to provide a connection to any Irish Water infrastructure and is provided subject to a connection agreement being signed and appropriate connection fee paid at a later date.

All infrastructure should be designed and installed in accordance with the Irish Water Codes of Practice and Standard Details.

A connection agreement can be applied for by completing the connection application form available at **www.water.ie/connections**. Irish Water's current charges for water and wastewater connections are set out in the Water Charges Plan as approved by the Commission for Regulation of Utilities.

If you have any further questions, please contact Marina Zivanovic Byrne from the design team on 01 89 25991 or email mzbyrne@water.ie. For further information, visit **www.water.ie/connections.**

Yours sincerely,

Maria O'Dwyer

Connections and Developer Services

Gessica Silva
CS Consulting
19-22 Dame Street
Dublin 2
Dublin, Ireland D02E267

Uisce Éireann
Bosca OP 448
Oifig Sheachadta na
Cathrach Theas
Cathair Chorcaí

Irish Water
PO Box 448,
South City
Delivery Office,
Cork City.

www.water.ie

13 April 2021

Re: Design Submission for Frankfort Castle, Old Frankfort, Dublin (the "Development") (the "Design Submission") / Connection Reference No: CDS19002259

Dear Gessica Silva,

Many thanks for your recent Design Submission.

We have reviewed your proposal for the connection(s) at the Development. Based on the information provided, which included the documents outlined in Appendix A to this letter, Irish Water has no objection to your proposals.

This letter does not constitute an offer, in whole or in part, to provide a connection to any Irish Water infrastructure. Before you can connect to our network you must sign a connection agreement with Irish Water. This can be applied for by completing the connection application form at www.water.ie/connections. Irish Water's current charges for water and wastewater connections are set out in the Water Charges Plan as approved by the Commission for Regulation of Utilities (CRU)(https://www.cru.ie/document_group/irish-waters-water-charges-plan-2018/).

You the Customer (including any designers/contractors or other related parties appointed by you) is entirely responsible for the design and construction of all water and/or wastewater infrastructure within the Development which is necessary to facilitate connection(s) from the boundary of the Development to Irish Water's network(s) (the "**Self-Lay Works**"), as reflected in your Design Submission. Acceptance of the Design Submission by Irish Water does not, in any way, render Irish Water liable for any elements of the design and/or construction of the Self-Lay Works. Water and wastewater network cannot be taken in charge by the LA/IW in future.

If you have any further questions, please contact your Irish Water representative:
Name: Alvaro Garcia
Email: agarcia@water.ie

Yours sincerely,

Yvonne Harris

Yvonne Harris
Head of Customer Operations

Appendix A

Document Title & Revision

H081-CSC-XX-GL-DR-C-0003_Proposed Drainage Layout
H081-CSC-XX-GL-DR-C-0006_Proposed Watermain Layout
H081-CSC-XX-XX-DR-C-0010_Surface Water Longitudinal Sections
H081-CSC-XX-XX-DR-C-0011_Foul Longitudinal Sections

*For further information, visit **www.water.ie/connections***

Notwithstanding any matters listed above, the Customer (including any appointed designers/contractors, etc.) is entirely responsible for the design and construction of the Self-Lay Works. Acceptance of the Design Submission by Irish Water will not, in any way, render Irish Water liable for any elements of the design and/or construction of the Self-Lay Works.

LEGEND:

RED LINE BOUNDARY

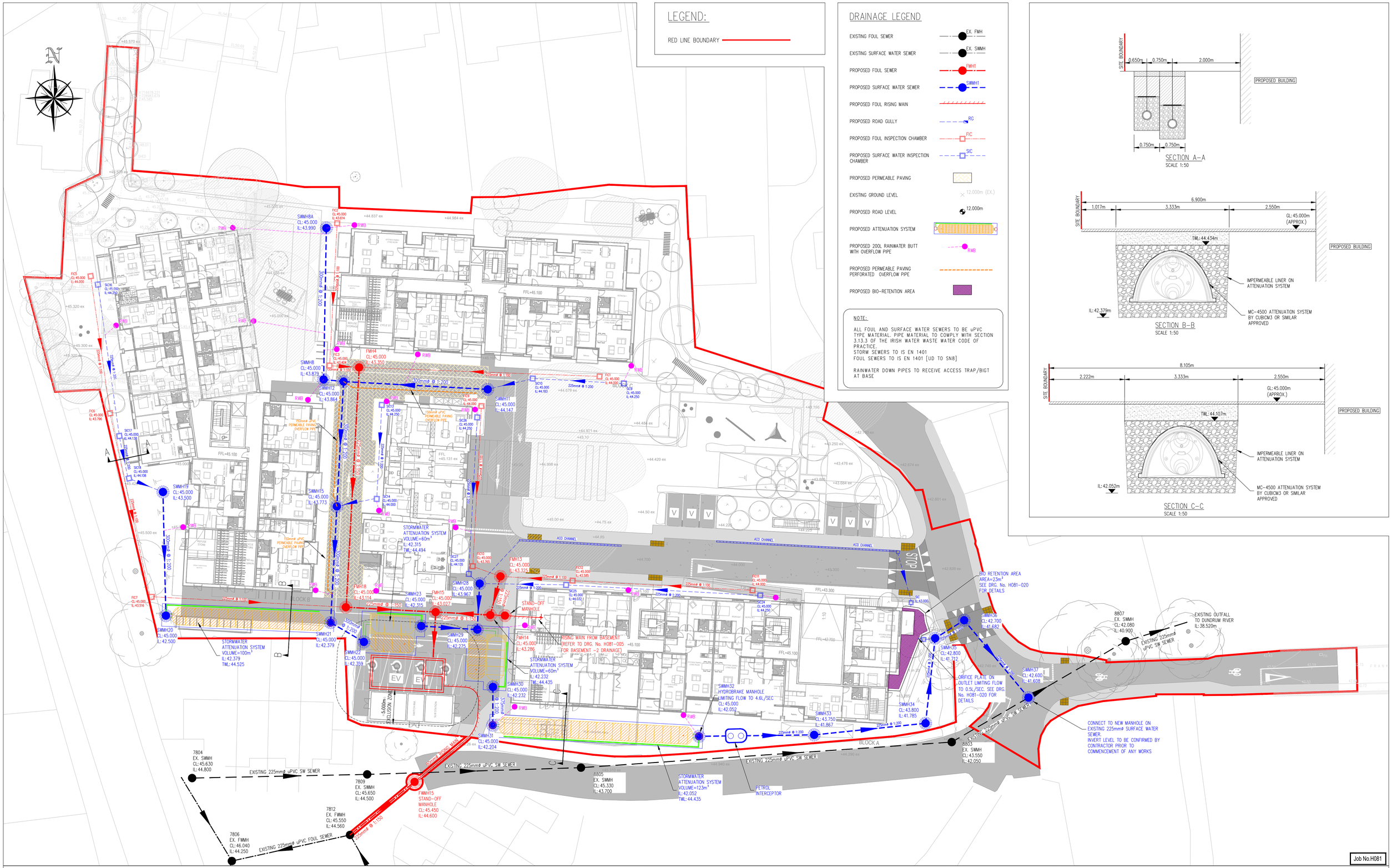
DRAINAGE LEGEND

- EXISTING FOUL SEWER — EX. FMH
- EXISTING SURFACE WATER SEWER — EX. SWMH
- PROPOSED FOUL SEWER — FMH1
- PROPOSED SURFACE WATER SEWER — SWMH1
- PROPOSED FOUL RISING MAIN
- PROPOSED ROAD GULLY — RG
- PROPOSED FOUL INSPECTION CHAMBER — FIC
- PROPOSED SURFACE WATER INSPECTION CHAMBER — SIC
- PROPOSED PERMEABLE PAVING
- EXISTING GROUND LEVEL — 12.000m (EX.)
- PROPOSED ROAD LEVEL — 12.000m
- PROPOSED ATTENUATION SYSTEM
- PROPOSED 200L RAINWATER BUTT WITH OVERFLOW PIPE — RWB
- PROPOSED PERMEABLE PAVING PERFORATED OVERFLOW PIPE
- PROPOSED BIO-RETENTION AREA

NOTE:

ALL FOUL AND SURFACE WATER SEWERS TO BE uPVC TYPE MATERIAL. PIPE MATERIAL TO COMPLY WITH SECTION 3.13.3 OF THE IRISH WATER WASTE WATER CODE OF PRACTICE.
STORM SEWERS TO IS EN 1401
FOUL SEWERS TO IS EN 1401 [UD TO SN8]

RAINWATER DOWN PIPES TO RECEIVE ACCESS TRAP/BIGT AT BASE



SECTION A–A
SCALE 1:50

SECTION B–B
SCALE 1:50

SECTION C–C
SCALE 1:50

Job No.H081

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Rev. No.	Date	REVISION NOTE	Drn. By	Chkd. By

Architect	OMP
Project	Proposed Residential Development at Frankfort Castle.
Title	Proposed Drainage Layout. Ground Level.
Dwg. No.	H081-CSC-XX-GL-DR-C-0003

Date	Drn by	Chkd by	Aprvd by	Scale	Revision
FEB 2021	DD	NB	NB	1:250 @A1	

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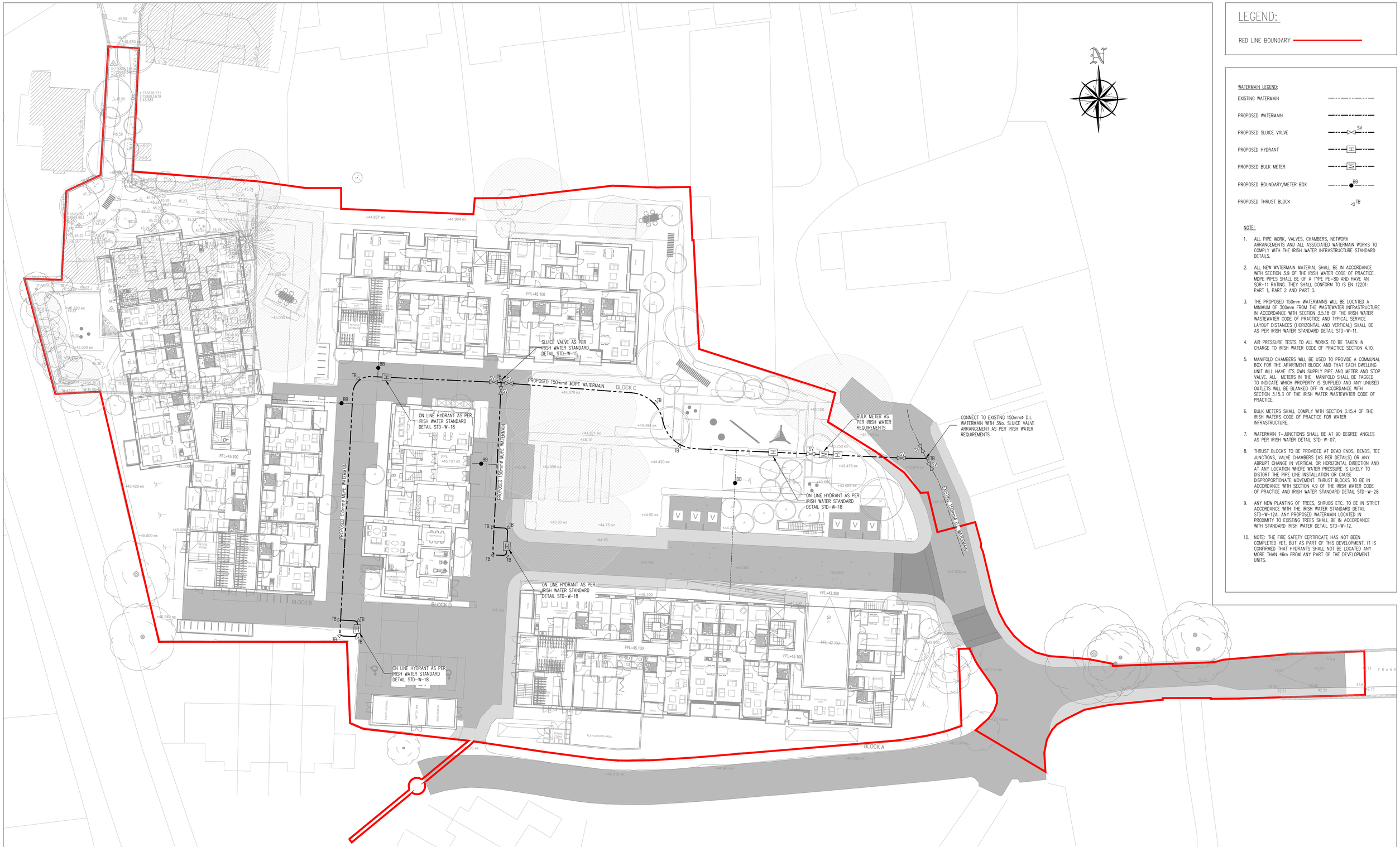

LEGEND:

RED LINE BOUNDARY

WATERMAIN LEGEND:

- EXISTING WATERMAIN
- PROPOSED WATERMAIN
- PROPOSED SLUICE VALVE (SV)
- PROPOSED HYDRANT
- PROPOSED BULK METER
- PROPOSED BOUNDARY/METER BOX (BB)
- PROPOSED THRUST BLOCK (TB)

NOTE:

1. ALL PIPE WORK, VALVES, CHAMBERS, NETWORK ARRANGEMENTS AND ALL ASSOCIATED WATERMAIN WORKS TO COMPLY WITH THE IRISH WATER INFRASTRUCTURE STANDARD DETAILS.
2. ALL NEW WATERMAIN MATERIAL SHALL BE IN ACCORDANCE WITH SECTION 3.9 OF THE IRISH WATER CODE OF PRACTICE. MDPE PIPES SHALL BE OF A TYPE PE-80 AND HAVE AN SDR-11 RATING. THEY SHALL CONFORM TO IS EN 12201: PART 1, PART 2 AND PART 3.
3. THE PROPOSED 150mm WATERMAINS WILL BE LOCATED A MINIMUM OF 300mm FROM THE WASTEWATER INFRASTRUCTURE IN ACCORDANCE WITH SECTION 3.5.18 OF THE IRISH WATER WASTEWATER CODE OF PRACTICE AND TYPICAL SERVICE LAYOUT DISTANCES (HORIZONTAL AND VERTICAL) SHALL BE AS PER IRISH WATER STANDARD DETAIL STD-W-11.
4. AIR PRESSURE TESTS TO ALL WORKS TO BE TAKEN IN CHARGE TO IRISH WATER CODE OF PRACTICE SECTION 4.10.
5. MANIFOLD CHAMBERS WILL BE USED TO PROVIDE A COMMUNAL BOX FOR THE APARTMENT BLOCK AND THAT EACH DWELLING UNIT WILL HAVE IT'S OWN SUPPLY PIPE AND METER AND STOP VALVE. ALL METERS IN THE MANIFOLD SHALL BE TAGGED TO INDICATE WHICH PROPERTY IS SUPPLIED AND ANY UNUSED OUTLETS WILL BE BLANKED OFF IN ACCORDANCE WITH SECTION 3.15.3 OF THE IRISH WATER WASTEWATER CODE OF PRACTICE.
6. BULK METERS SHALL COMPLY WITH SECTION 3.15.4 OF THE IRISH WATERS CODE OF PRACTICE FOR WATER INFRASTRUCTURE.
7. WATERMAIN T-JUNCTIONS SHALL BE AT 90 DEGREE ANGLES AS PER IRISH WATER DETAIL STD-W-07.
8. THRUST BLOCKS TO BE PROVIDED AT DEAD ENDS, BENDS, TEE JUNCTIONS, VALVE CHAMBERS (AS PER DETAILS) OR ANY ABRUPT CHANGE IN VERTICAL OR HORIZONTAL DIRECTION AND AT ANY LOCATION WHERE WATER PRESSURE IS LIKELY TO DISTORT THE PIPE LINE INSTALLATION OR CAUSE DISPROPORTIONATE MOVEMENT. THRUST BLOCKS TO BE IN ACCORDANCE WITH SECTION 4.9 OF THE IRISH WATER CODE OF PRACTICE AND IRISH WATER STANDARD DETAIL STD-W-28.
9. ANY NEW PLANTING OF TREES, SHRUBS ETC. TO BE IN STRICT ACCORDANCE WITH THE IRISH WATER STANDARD DETAIL STD-W-12A. ANY PROPOSED WATERMAIN LOCATED IN PROXIMITY TO EXISTING TREES SHALL BE IN ACCORDANCE WITH STANDARD IRISH WATER DETAIL STD-W-12.
10. NOTE: THE FIRE SAFETY CERTIFICATE HAS NOT BEEN COMPLETED YET, BUT AS PART OF THIS DEVELOPMENT, IT IS CONFIRMED THAT HYDRANTS SHALL NOT BE LOCATED ANY MORE THAN 46m FROM ANY PART OF THE DEVELOPMENT UNITS.

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Rev. No.	Date	REVISION NOTE	Drn. By	Chkd. By

Architect	OMP
Project	Proposed Residential Development at Frankfort Castle.
Title	Watermain Layout
Dwg. No.	H081-CSC-XX-GL-DR-C-0006

Date	Drn by	Chkd by	Aprvd by	Scale	Revision
FEB 2021	DD	NB	NB	1:250 @A1	

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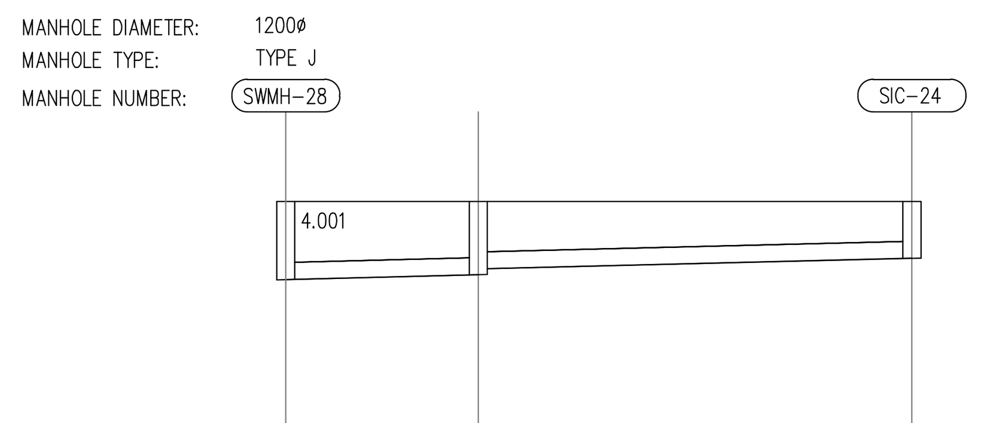

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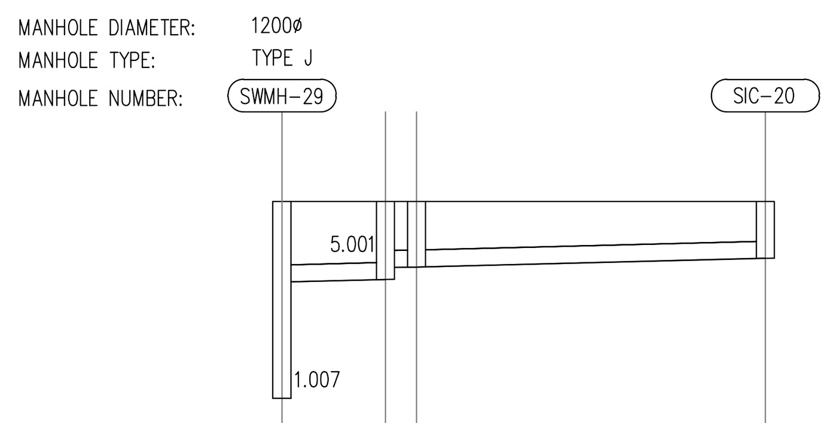
DIA (mm)		225
SLOPE (1:X)		200.0
COVER LEVEL (m)	45.000 45.000	45.000
INVERT LEVEL (m)	43.968 44.032	44.107 44.250
LENGTH (m)		28.650

SURFACE WATER SEWER FROM SIC-24 TO SWMH-28
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



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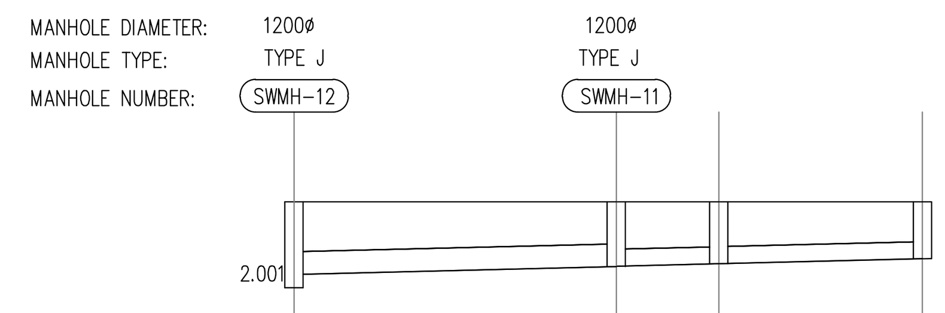
PN			S4.000
DIA (mm)			225
SLOPE (1:X)			200.0
COVER LEVEL (m)	45.000 45.000		45.000
INVERT LEVEL (m)	43.934 43.968	44.135	44.250
LENGTH (m)			23.053

SURFACE WATER SEWER FROM SIC-20 TO SWMH-29
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

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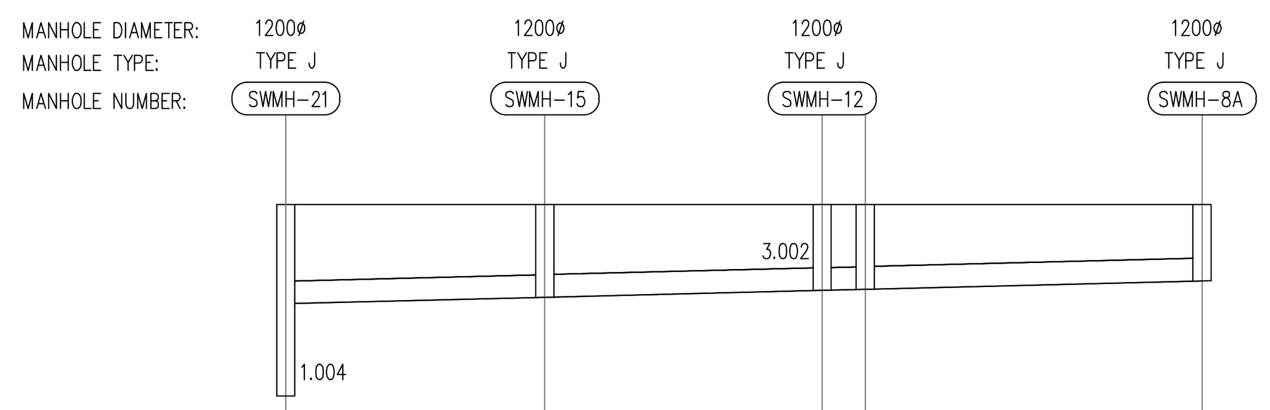
DIA (mm)	300		
SLOPE (1:X)	200.0		
COVER LEVEL (m)	45.000 45.000	45.000	45.000
INVERT LEVEL (m)	44.041 21.296 44.147	44.149 44.183	44.183 44.250
LENGTH (m)			

SURFACE WATER SEWER FROM SWMH-11 TO SWMH-12
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

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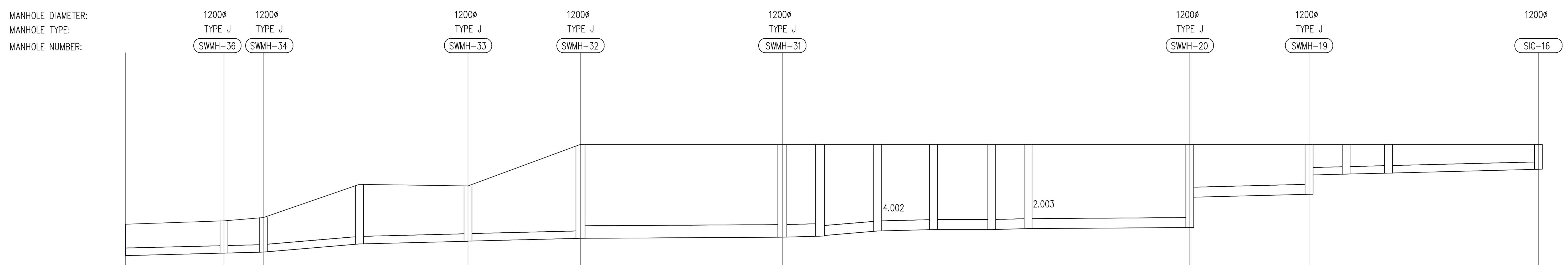
SLOPE (1:X)	200.0	200.0		200.0
COVER LEVEL (m)	45.000 45.000	45.000	45.000	45.000
INVERT LEVEL (m)	43.687 43.773	43.773 43.865	43.879	43.879 43.990
LENGTH (m)	17.118	18.323		22.247

SURFACE WATER SEWER FROM SWMH-8A TO SWMH-21
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

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DIA (mm)	225		225	225	225	375	300	300	225
SLOPE (1:X)	200.0		58.5	206.0	200.0	843.0	737.0	200.0	200.0
COVER LEVEL (m)	42.600 42.700	42.800	43.800	43.750	45.000	45.000	45.000 45.000 45.000 45.000 45.000 45.000	45.000	45.000 45.000 45.000
INVERT LEVEL (m)	41.658 41.732	41.732 41.762	41.762 42.009	42.009 42.088	42.091 42.176	42.176 42.212	42.212 42.240 42.248 42.397 42.397 42.439 42.439 42.440 42.440 42.467 42.467 42.500	43.410 43.500	44.077 44.105 44.105 44.137 44.137 44.250
LENGTH (m)	14.808		14.455	16.337	16.909	30.355	24.323	17.938	22.550

SURFACE WATER SEWER FROM SWMH-16 TO SWMH-36
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100

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Rev. No.	Date	REVISION NOTE	Drn. By	Chkd. By
P01	12.02.2021	ISSUED TO IRISH WATER	IK	NB

Architect	OMP
Project	Proposed Residential Development at Frankfort Castle.
Title	Surface Water Longitudinal Sections
Dwg. No.	H081-CSC-XX-XX-DR-C-0010

Date	Drn by	Chkd by	Aprvd by	Scale	Revision
FEB 2021	IK	AB	NB	H 1:500; V 1:250	P01

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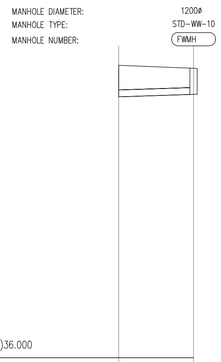
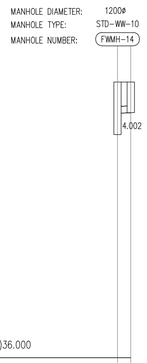


Datum (m)36.000

PN		
DIA (mm)		
SLOPE (1:X)		
COVER LEVEL (m)	45.550	45.450
INVERT LEVEL (m)	44.579	44.600
LENGTH (m)		

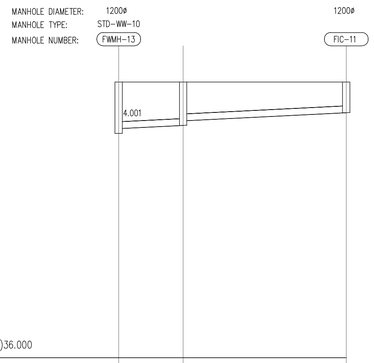
FOUL SEWER
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

PN		
DIA (mm)		
SLOPE (1:X)		
COVER LEVEL (m)	45.000	
INVERT LEVEL (m)		
LENGTH (m)		

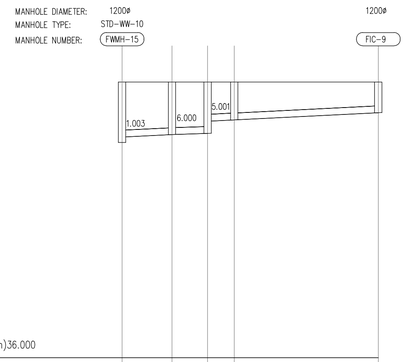
FOUL SEWER TO FWMH-14
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

PN			F5.000	
DIA (mm)			225	
SLOPE (1:X)			100.0	
COVER LEVEL (m)	45.000	45.000		45.000
INVERT LEVEL (m)	43.480	43.585 43.504		44.000
LENGTH (m)			26.625	

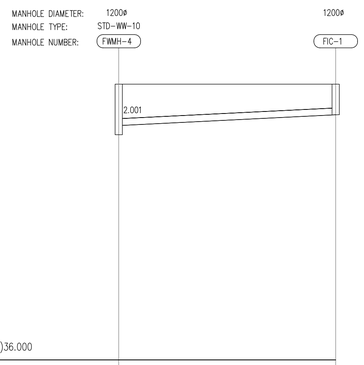
FOUL SEWER FROM FWMH-13 TO FIC-11
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

PN				F4.000	
DIA (mm)				225	
SLOPE (1:X)				100.0	
COVER LEVEL (m)	45.000	45.000	45.000	45.000	45.000
INVERT LEVEL (m)	43.205	43.386 43.296	43.325	43.765 43.765	44.000
LENGTH (m)				23.514	

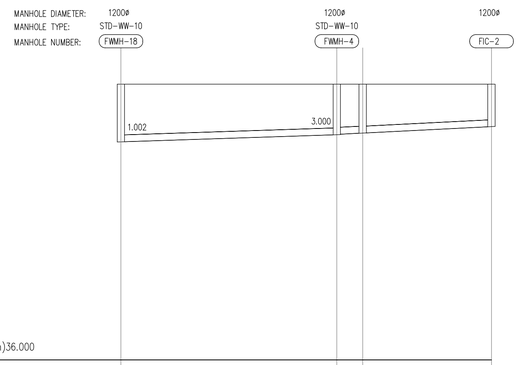
FOUL SEWER FROM FIC-9 TO FWMH-15
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

PN	F3.000	
DIA (mm)	225	
SLOPE (1:X)	100.0	
COVER LEVEL (m)	45.000	45.000
INVERT LEVEL (m)	43.846	44.000
LENGTH (m)	35.412	

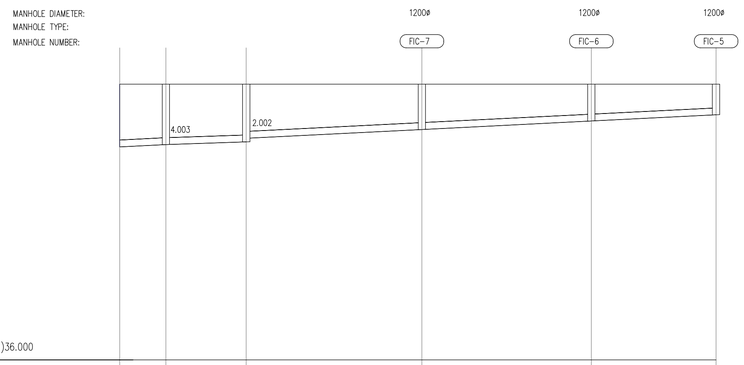
FOUL SEWER FROM FIC-1 TO FWMH-4
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

PN	F2.002			F2.000
DIA (mm)	225			225
SLOPE (1:X)	150.0			100.0
COVER LEVEL (m)	45.000	45.000	45.000	45.000
INVERT LEVEL (m)	43.115	43.350	43.404 43.404	43.614
LENGTH (m)	35.242			21.020

FOUL SEWER FROM SIC-4 TO FWMH-18
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



Datum (m)36.000

PN			F1.002	F1.001	F1.000	
DIA (mm)			225	225	225	
SLOPE (1:X)			100.0	100.0	100.0	
COVER LEVEL (m)	45.000	45.000	45.000	45.000	45.000	45.000
INVERT LEVEL (m)	42.952	43.008 43.008	43.115 43.233	43.520 43.520	43.796 43.796	44.000
LENGTH (m)			28.673	27.670	20.357	

FOUL SEWER FROM FIC-5 TO FIC-7
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100

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Rev. No.	Date	REVISION NOTE	Drn. By	Chkd. By
P01	12.02.2021	ISSUED TO IRISH WATER	IK	NB

Architect	OMP
Project	Proposed Residential Development at Frankfort Castle.
Title	Foul Longitudinal Sections
Dwg. No.	H081-CSC-XX-XX-DR-C-0011

Date	Drn by	Chkd by	Aprvd by	Scale	Revision
FEB 2021	IK	AB	NB	H 1:500; V 1:250	P01

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Energy I.S. EN ISO 50001:2011
Health & Safety OHSAS 18001:2007

Appendix C

Attenuation Calculation & Met Eireann Data

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GROUP

Met Eireann
Return Period Rainfall Depths for sliding Durations
Irish Grid: Easting: 316806, Northing: 228888,

	Interval		Years											
DURATION	6months,	1year,	2,	3,	4,	5,	10,	20,	30,	50,	75,	100,	150,	200,	250,	500,
5 mins	2.5,	3.7,	4.4,	5.4,	6.2,	6.7,	8.6,	10.8,	12.3,	14.5,	16.4,	17.9,	20.3,	22.2,	23.8,	N/A ,
10 mins	3.5,	5.2,	6.1,	7.6,	8.6,	9.4,	12.0,	15.1,	17.2,	20.2,	22.9,	25.0,	28.3,	30.9,	33.1,	N/A ,
15 mins	4.1,	6.1,	7.2,	8.9,	10.1,	11.0,	14.1,	17.8,	20.2,	23.7,	26.9,	29.4,	33.3,	36.4,	39.0,	N/A ,
30 mins	5.5,	8.0,	9.4,	11.5,	13.0,	14.1,	17.9,	22.3,	25.3,	29.5,	33.3,	36.3,	41.0,	44.7,	47.7,	N/A ,
1 hours	7.2,	10.4,	12.1,	14.8,	16.6,	18.0,	22.7,	28.1,	31.7,	36.8,	41.4,	44.9,	50.5,	54.8,	58.4,	N/A ,
2 hours	9.5,	13.6,	15.8,	19.1,	21.3,	23.0,	28.8,	35.3,	39.7,	45.8,	51.3,	55.5,	62.1,	67.3,	71.5,	N/A ,
3 hours	11.2,	15.8,	18.3,	22.1,	24.6,	26.6,	33.1,	40.4,	45.2,	52.1,	58.2,	62.9,	70.2,	75.8,	80.5,	N/A ,
4 hours	12.6,	17.7,	20.4,	24.5,	27.3,	29.5,	36.5,	44.4,	49.7,	57.0,	63.6,	68.7,	76.5,	82.6,	87.6,	N/A ,
6 hours	14.8,	20.7,	23.8,	28.4,	31.6,	34.0,	41.9,	50.8,	56.7,	64.9,	72.1,	77.7,	86.4,	93.1,	98.6,	N/A ,
9 hours	17.5,	24.1,	27.7,	33.0,	36.5,	39.3,	48.1,	58.1,	64.6,	73.7,	81.8,	88.0,	97.6,	104.9,	111.0,	N/A ,
12 hours	19.6,	27.0,	30.8,	36.6,	40.5,	43.5,	53.1,	63.9,	70.9,	80.8,	89.4,	96.1,	106.4,	114.2,	120.8,	N/A ,
18 hours	23.1,	31.5,	35.9,	42.4,	46.8,	50.2,	61.0,	73.1,	80.9,	91.8,	101.4,	108.8,	120.1,	128.8,	136.0,	N/A ,
24 hours	25.9,	35.2,	40.0,	47.1,	51.9,	55.6,	67.3,	80.4,	88.8,	100.6,	110.9,	118.8,	130.9,	140.2,	147.9,	174.4,
2 days	32.0,	42.5,	47.9,	55.8,	61.0,	65.0,	77.7,	91.5,	100.5,	112.8,	123.5,	131.6,	144.0,	153.5,	161.3,	188.0,
3 days	36.9,	48.4,	54.2,	62.7,	68.3,	72.6,	86.1,	100.7,	110.1,	123.0,	134.1,	142.6,	155.4,	165.1,	173.1,	200.3,
4 days	41.2,	53.5,	59.8,	68.8,	74.8,	79.3,	93.5,	108.8,	118.6,	131.9,	143.5,	152.2,	165.4,	175.4,	183.6,	211.5,
6 days	48.7,	62.5,	69.5,	79.4,	85.9,	90.8,	106.3,	122.8,	133.2,	147.5,	159.7,	169.0,	182.9,	193.4,	202.0,	231.1,
8 days	55.4,	70.4,	77.9,	88.7,	95.7,	100.9,	117.4,	135.0,	146.0,	161.0,	173.9,	183.6,	198.2,	209.2,	218.1,	248.3,
10 days	61.5,	77.6,	85.6,	97.1,	104.5,	110.1,	127.5,	146.0,	157.6,	173.3,	186.7,	196.8,	212.0,	223.4,	232.6,	263.8,
12 days	67.1,	84.3,	92.8,	104.9,	112.7,	118.6,	136.8,	156.2,	168.3,	184.6,	198.6,	209.0,	224.7,	236.5,	246.0,	278.2,
16 days	77.7,	96.6,	106.0,	119.2,	127.7,	134.1,	153.9,	174.7,	187.7,	205.2,	220.1,	231.2,	247.8,	260.3,	270.4,	304.2,
20 days	87.4,	108.0,	118.1,	132.4,	141.5,	148.3,	169.5,	191.6,	205.4,	223.9,	239.5,	251.3,	268.7,	281.8,	292.4,	327.8,
25 days	98.8,	121.2,	132.2,	147.6,	157.4,	164.7,	187.4,	211.0,	225.7,	245.3,	261.9,	274.3,	292.7,	306.5,	317.6,	354.7,

NOTES:
N/A Data not available
These values are derived from a Depth Duration Frequency (DDF) Model
For details refer to:
'Fitzgerald D. L. (2007), Estimates of Point Rainfall Frequencies, Technical Note No. 61, Met Eireann, Dublin',
Available for download at www.met.ie/climate/dataproducts/Estimation-of-Point-Rainfall-Frequencies_TN61.pdf

Project: Frankfort Castle
Project No.: H081
Calculation: Attenuation 100-year
Calcs By: DD
Checked By:
Date: 9/4/19

CS CONSULTING GROUP
DUBLIN - LONDON - LIMERICK

Site Location:	Dublin		
Design Storm Return Period:	100 years		
Climate Change Factor:	20 %		
Soil Type:	4		
Total Site Area:	0.880 ha		
Hardstand Area:	0.530 ha	.....@	80% Impervious
Softstand Area:	0.350 ha	.....@	20% Impervious
Effective Impermeable Area:	0.494 ha		

Allowable Outflow	**Calculate**	
IH124: QBAR = 0.00108 x $AREA^{0.89}$ x $SAAR^{1.17}$ x $SOIL^{2.17}$		
AREA:	0.01 km^2	
SAAR:	820 mm	
SOIL:	0.47	
QBAR/ha	5.81 l/s/ha	
Allowable Outflow	**5.1 l/s**	Smallest Allowable Discharge Rate (2l/s)

Storage required =	**343 m^3**	

Duration (min)	Rainfall 100-Year (mm)	Rainfall 100-Year with CCF (mm)	Intensity (mm/hr)	Discharge (Q = 2.71iA) (l/s)	Proposed Runoff (m^3)	Contiguous Land Runoff (m^3)	Total Runoff (m^3)	Allowable Outflow (m^3)	Storage Required (m^3)
5	17.9	21.5	257.8	345	104	0	104	2	102
10	25.0	30.0	180.0	241	145	0	145	3	142
15	29.4	35.3	141.1	189	170	0	170	5	165
30	36.3	43.6	87.1	117	210	0	210	9	201
60	44.9	53.9	53.9	72	260	0	260	18	241
120	55.5	66.6	33.3	45	321	0	321	37	284
180	62.9	75.5	25.2	34	364	0	364	55	309
240	68.7	82.4	20.6	28	397	0	397	74	324
360	77.7	93.2	15.5	21	449	0	449	110	339
540	88.0	105.6	11.7	16	509	0	509	166	343
720	96.1	115.3	9.6	13	556	0	556	221	335
1080	108.8	130.6	7.3	10	629	0	629	331	298
1440	118.8	142.6	5.9	8	687	0	687	442	245
2880	131.6	157.9	3.3	4	761	0	761	883	-122
4320	142.6	171.1	2.4	3	825	0	825	1325	-500
5760	152.2	182.6	1.9	3	880	0	880	1767	-887
8640	169.0	202.8	1.4	2	977	0	977	2650	-1673
11520	183.6	220.3	1.1	2	1062	0	1062	3534	-2472
14400	196.8	236.2	1.0	1	1138	0	1138	4417	-3279
17280	209.0	250.8	0.9	1	1209	0	1209	5301	-4092
23040	231.2	277.4	0.7	1	1337	0	1337	7068	-5730
28800	251.3	301.6	0.6	1	1453	0	1453	8834	-7381
36000	274.3	329.2	0.5	1	1586	0	1586	11043	-9457

STORM SEWER DESIGN by the Modified Rational Method

Design Criteria for Storm

Pipe Sizes STANDARD Manhole Sizes STANDARD

FSR Rainfall Model - England and Wales

Return Period (years)	5	Add Flow / Climate Change (%)	0
M5-60 (mm)	18.000	Minimum Backdrop Height (m)	0.000
Ratio R	0.277	Maximum Backdrop Height (m)	0.000
Maximum Rainfall (mm/hr)	500	Min Design Depth for Optimisation (m)	0.000
Foul Sewage (l/s/ha)	0.00	Min Vel for Auto Design only (m/s)	1.00
Volumetric Runoff Coeff.	0.750	Min Slope for Optimisation (1:X)	500
PIMP (%)	80		

Designed with Level Inverts

Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)
S1.000	22.163	0.111	199.7	0.102	5.00	0.0	0.600	o	300
S1.001	2.986	0.015	199.1	0.009	0.00	0.0	0.600	o	300
S2.000	21.158	0.106	199.6	0.027	5.00	0.0	0.600	o	300
S1.002	18.299	0.091	201.1	0.029	0.00	0.0	0.600	o	300
S1.003	17.034	0.085	200.4	0.026	0.00	0.0	0.600	o	300
S3.000	18.110	0.091	199.0	0.037	5.00	0.0	0.600	o	300
S3.001	24.113	0.121	199.3	0.014	0.00	0.0	0.600	o	300
S1.004	5.972	0.020	298.6	0.018	0.00	0.0	0.600	o	300
S1.005	8.874	0.044	201.7	0.010	0.00	0.0	0.600	o	300
S1.006	8.041	0.040	201.0	0.011	0.00	0.0	0.600	o	300
S4.000	6.831	0.034	200.9	0.090	5.00	0.0	0.600	o	300
S1.007	8.609	0.043	200.2	0.010	0.00	0.0	0.600	o	300

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
S1.000	66.01	5.33	43.990	0.102	0.0	0.0	0.0	1.11	78.4	18.2
S1.001	65.81	5.38	43.879	0.111	0.0	0.0	0.0	1.11	78.5	19.8
S2.000	66.09	5.32	44.147	0.027	0.0	0.0	0.0	1.11	78.4	4.9
S1.002	64.56	5.65	43.864	0.167	0.0	0.0	0.0	1.11	78.1	29.2
S1.003	63.45	5.91	43.773	0.193	0.0	0.0	0.0	1.11	78.2	33.1
S3.000	66.30	5.27	43.500	0.037	0.0	0.0	0.0	1.11	78.5	6.6
S3.001	64.64	5.63	42.500	0.050	0.0	0.0	0.0	1.11	78.5	8.8
S1.004	62.98	6.02	42.379	0.261	0.0	0.0	0.0	0.90	63.9	44.5
S1.005	62.43	6.15	42.359	0.270	0.0	0.0	0.0	1.10	78.0	45.7
S1.006	61.95	6.28	42.315	0.281	0.0	0.0	0.0	1.11	78.1	47.2
S4.000	67.11	5.10	43.967	0.090	0.0	0.0	0.0	1.11	78.1	16.4
S1.007	61.43	6.41	42.275	0.381	0.0	0.0	0.0	1.11	78.3	63.4

Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)
S1.008	5.576	0.028	199.1	0.000	0.00	0.0	0.600	o	375
S1.009	30.309	0.152	199.4	0.034	0.00	0.0	0.600	o	375
S1.010	16.972	0.085	199.7	0.046	0.00	0.0	0.600	o	225
S1.011	16.360	0.082	199.5	0.000	0.00	0.0	0.600	o	225
S1.012	14.552	0.073	200.0	0.000	0.00	0.0	0.600	o	225
S1.013	5.992	0.030	200.0	0.000	0.00	0.0	0.600	o	225
S1.014	14.934	0.075	200.0	0.000	0.00	0.0	0.600	o	225

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
S1.008	61.15	6.48	42.232	0.381	0.0	0.0	0.0	1.28	141.4	63.4
S1.009	59.67	6.87	42.204	0.415	0.0	0.0	0.0	1.28	141.3	67.1
S1.010	66.14	5.31	42.052	0.000	4.6	0.0	0.0	0.92	36.6	4.6
S1.011	64.78	5.60	41.867	0.000	4.6	0.0	0.0	0.92	36.7	4.6
S1.012	63.63	5.87	41.785	0.000	4.6	0.0	0.0	0.92	36.6	4.6
S1.013	63.18	5.97	41.712	0.000	4.6	0.0	0.0	0.92	36.6	4.6
S1.014	62.07	6.24	41.682	0.000	4.6	0.0	0.0	0.92	36.6	4.6

Manhole Schedules for Storm

MH Name	MH CL (m)	MH Depth (m)	MH Connection	MH Diam.,L*W (mm)	Pipe Out PN	Pipe Out Invert Level (m)	Pipe Out Diameter (mm)	Pipes In PN	Pipes In Invert Level (m)	Pipes In Diameter (mm)	Backdrop (mm)
SMH8A	45.000	1.010	Open Manhole	1200	S1.000	43.990	300				
SMH8	45.000	1.121	Open Manhole	1200	S1.001	43.879	300	S1.000	43.879	300	
SMH11	45.000	0.853	Open Manhole	1200	S2.000	44.147	300				
SMH12	45.000	1.136	Open Manhole	1200	S1.002	43.864	300	S1.001	43.864	300	
								S2.000	44.041	300	177
SMH15	45.000	1.227	Open Manhole	1200	S1.003	43.773	300	S1.002	43.773	300	
SMH19	45.000	1.500	Open Manhole	1200	S3.000	43.500	300				
SMH20	45.000	2.500	Open Manhole	1200	S3.001	42.500	300	S3.000	43.409	300	909
SMH21	45.000	2.621	Open Manhole	1200	S1.004	42.379	300	S1.003	43.688	300	1309
								S3.001	42.379	300	
SMH22	45.000	2.641	Open Manhole	1200	S1.005	42.359	300	S1.004	42.359	300	
SMH23	45.000	2.685	Open Manhole	1200	S1.006	42.315	300	S1.005	42.315	300	
SMH28	45.000	1.033	Open Manhole	1200	S4.000	43.967	300				
SMH29	45.000	2.725	Open Manhole	1200	S1.007	42.275	300	S1.006	42.275	300	
								S4.000	43.933	300	1658
SMH30	45.000	2.768	Open Manhole	1350	S1.008	42.232	375	S1.007	42.232	300	
SMH31	45.000	2.796	Open Manhole	1350	S1.009	42.204	375	S1.008	42.204	375	
SMH32	45.000	2.948	Open Manhole	1350	S1.010	42.052	225	S1.009	42.052	375	
SMH33	45.000	3.133	Open Manhole	1200	S1.011	41.867	225	S1.010	41.967	225	100
SMH34	43.800	2.015	Open Manhole	1200	S1.012	41.785	225	S1.011	41.785	225	
SMH35	42.800	1.088	Open Manhole	1200	S1.013	41.712	225	S1.012	41.712	225	
SMH36	42.700	1.018	Open Manhole	1200	S1.014	41.682	225	S1.013	41.682	225	
S	42.600	0.992	Open Manhole	0		OUTFALL		S1.014	41.608	225	

PIPELINE SCHEDULES for Storm

Upstream Manhole

PN	Hyd Sect	Diam (mm)	MH Name	C.Level (m)	I.Level (m)	D.Depth (m)	MH Connection	MH DIAM., L*W (mm)
S1.000	o	300	SMH8A	45.000	43.990	0.710	Open Manhole	1200
S1.001	o	300	SMH8	45.000	43.879	0.821	Open Manhole	1200
S2.000	o	300	SMH11	45.000	44.147	0.553	Open Manhole	1200
S1.002	o	300	SMH12	45.000	43.864	0.836	Open Manhole	1200
S1.003	o	300	SMH15	45.000	43.773	0.927	Open Manhole	1200
S3.000	o	300	SMH19	45.000	43.500	1.200	Open Manhole	1200
S3.001	o	300	SMH20	45.000	42.500	2.200	Open Manhole	1200
S1.004	o	300	SMH21	45.000	42.379	2.321	Open Manhole	1200
S1.005	o	300	SMH22	45.000	42.359	2.341	Open Manhole	1200
S1.006	o	300	SMH23	45.000	42.315	2.385	Open Manhole	1200
S4.000	o	300	SMH28	45.000	43.967	0.733	Open Manhole	1200
S1.007	o	300	SMH29	45.000	42.275	2.425	Open Manhole	1200
S1.008	o	375	SMH30	45.000	42.232	2.393	Open Manhole	1350
S1.009	o	375	SMH31	45.000	42.204	2.421	Open Manhole	1350
S1.010	o	225	SMH32	45.000	42.052	2.723	Open Manhole	1350
S1.011	o	225	SMH33	45.000	41.867	2.908	Open Manhole	1200
S1.012	o	225	SMH34	43.800	41.785	1.790	Open Manhole	1200
S1.013	o	225	SMH35	42.800	41.712	0.863	Open Manhole	1200
S1.014	o	225	SMH36	42.700	41.682	0.793	Open Manhole	1200

Downstream Manhole

PN	Length (m)	Slope (1:X)	MH Name	C.Level (m)	I.Level (m)	D.Depth (m)	MH Connection	MH DIAM., L*W (mm)
S1.000	22.163	199.7	SMH8	45.000	43.879	0.821	Open Manhole	1200
S1.001	2.986	199.1	SMH12	45.000	43.864	0.836	Open Manhole	1200
S2.000	21.158	199.6	SMH12	45.000	44.041	0.659	Open Manhole	1200
S1.002	18.299	201.1	SMH15	45.000	43.773	0.927	Open Manhole	1200
S1.003	17.034	200.4	SMH21	45.000	43.688	1.012	Open Manhole	1200
S3.000	18.110	199.0	SMH20	45.000	43.409	1.291	Open Manhole	1200
S3.001	24.113	199.3	SMH21	45.000	42.379	2.321	Open Manhole	1200
S1.004	5.972	298.6	SMH22	45.000	42.359	2.341	Open Manhole	1200
S1.005	8.874	201.7	SMH23	45.000	42.315	2.385	Open Manhole	1200
S1.006	8.041	201.0	SMH29	45.000	42.275	2.425	Open Manhole	1200
S4.000	6.831	200.9	SMH29	45.000	43.933	0.767	Open Manhole	1200
S1.007	8.609	200.2	SMH30	45.000	42.232	2.468	Open Manhole	1350
S1.008	5.576	199.1	SMH31	45.000	42.204	2.421	Open Manhole	1350
S1.009	30.309	199.4	SMH32	45.000	42.052	2.573	Open Manhole	1350
S1.010	16.972	199.7	SMH33	45.000	41.967	2.808	Open Manhole	1200
S1.011	16.360	199.5	SMH34	43.800	41.785	1.790	Open Manhole	1200
S1.012	14.552	200.0	SMH35	42.800	41.712	0.863	Open Manhole	1200
S1.013	5.992	200.0	SMH36	42.700	41.682	0.793	Open Manhole	1200
S1.014	14.934	200.0	S	42.600	41.608	0.767	Open Manhole	0

Area Summary for Storm

Pipe Number	PIMP Type	PIMP Name	PIMP (%)	Gross Area (ha)	Imp. Area (ha)	Pipe Total (ha)
1.000	-	-	100	0.102	0.102	0.102
1.001	-	-	100	0.009	0.009	0.009
2.000	-	-	80	0.034	0.027	0.027
1.002	-	-	80	0.036	0.029	0.029
1.003	-	-	80	0.032	0.026	0.026
3.000	-	-	80	0.046	0.037	0.037
3.001	-	-	80	0.017	0.014	0.014
1.004	-	-	80	0.022	0.018	0.018
1.005	-	-	80	0.012	0.010	0.010
1.006	-	-	80	0.014	0.011	0.011
4.000	-	-	100	0.090	0.090	0.090
1.007	-	-	80	0.012	0.010	0.010
1.008	-	-	100	0.000	0.000	0.000
1.009	-	-	100	0.034	0.034	0.034
1.010	-	-	80	0.058	0.046	0.046
1.011	-	-	80	0.000	0.000	0.000
1.012	-	-	80	0.000	0.000	0.000
1.013	-	-	80	0.000	0.000	0.000
1.014	-	-	80	0.000	0.000	0.000
				Total	Total	Total
				0.518	0.461	0.461

Free Flowing Outfall Details for Storm

Outfall Pipe Number	Outfall Name	C. Level (m)	I. Level (m)	Min I. Level (m)	D,L (mm)	W (mm)
S1.014	S	42.600	41.608	0.000	0	0

Simulation Criteria for Storm

Volumetric Runoff Coeff	0.840	Additional Flow - % of Total Flow	20.000
Areal Reduction Factor	1.000	MADD Factor * 10m³/ha Storage	2.000
Hot Start (mins)	0	Inlet Coeffiecient	0.800
Hot Start Level (mm)	0	Flow per Person per Day (l/per/day)	0.000
Manhole Headloss Coeff (Global)	0.500	Run Time (mins)	5760
Foul Sewage per hectare (l/s)	0.000	Output Interval (mins)	24

Number of Input Hydrographs 0	Number of Offline Controls 0	Number of Time/Area Diagrams 0
Number of Online Controls 1	Number of Storage Structures 4	Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model	FSR	Profile Type	Winter
Return Period (years)	100	Cv (Summer)	0.750
Region	Scotland and Ireland	Cv (Winter)	0.840
M5-60 (mm)	18.000	Storm Duration (mins)	2880
Ratio R	0.277		

Online Controls for Storm

Hydro-Brake® Manhole: SMH32, DS/PN: S1.010, Volume (m³): 7.4

Design Head (m) 2.620 Hydro-Brake® Type Md14 Invert Level (m) 42.052
Design Flow (l/s) 4.6 Diameter (mm) 45

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	0.9	0.800	2.5	2.000	3.9	4.000	5.5	7.000	7.3
0.200	1.2	1.000	2.7	2.200	4.1	4.500	5.8	7.500	7.5
0.300	1.5	1.200	3.0	2.400	4.3	5.000	6.1	8.000	7.8
0.400	1.7	1.400	3.3	2.600	4.4	5.500	6.4	8.500	8.0
0.500	1.9	1.600	3.5	3.000	4.8	6.000	6.7	9.000	8.2
0.600	2.1	1.800	3.7	3.500	5.1	6.500	7.0	9.500	8.5

Storage Structures for Storm

Tank or Pond Manhole: SMH21, DS/PN: S1.004

Invert Level (m) 42.467

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	50.0	1.200	50.0	2.400	0.0	3.600	0.0	4.800	0.0
0.200	50.0	1.400	50.0	2.600	0.0	3.800	0.0	5.000	0.0
0.400	50.0	1.600	50.0	2.800	0.0	4.000	0.0		
0.600	50.0	1.800	50.0	3.000	0.0	4.200	0.0		
0.800	50.0	2.000	50.0	3.200	0.0	4.400	0.0		
1.000	50.0	2.001	0.0	3.400	0.0	4.600	0.0		

Tank or Pond Manhole: SMH23, DS/PN: S1.006

Invert Level (m) 42.398

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	28.6	1.200	28.6	2.101	0.0	3.600	0.0	4.800	0.0
0.200	28.6	1.400	28.6	2.600	0.0	3.800	0.0	5.000	0.0
0.400	28.6	1.600	28.6	2.800	0.0	4.000	0.0		
0.600	28.6	1.800	28.6	3.000	0.0	4.200	0.0		
0.800	28.6	2.000	28.6	3.200	0.0	4.400	0.0		
1.000	28.6	2.100	28.6	3.400	0.0	4.600	0.0		

Tank or Pond Manhole: SMH30, DS/PN: S1.008

Invert Level (m) 42.240

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	30.0	1.200	30.0	2.400	0.0	3.600	0.0	4.800	0.0
0.200	30.0	1.400	30.0	2.600	0.0	3.800	0.0	5.000	0.0
0.400	30.0	1.600	30.0	2.800	0.0	4.000	0.0		
0.600	30.0	1.800	30.0	3.000	0.0	4.200	0.0		
0.800	30.0	2.000	30.0	3.200	0.0	4.400	0.0		
1.000	30.0	2.001	0.0	3.400	0.0	4.600	0.0		

Tank or Pond Manhole: SMH32, DS/PN: S1.010

Invert Level (m) 42.176

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	61.5	1.200	61.5	2.400	0.0	3.600	0.0	4.800	0.0
0.200	61.5	1.400	61.5	2.600	0.0	3.800	0.0	5.000	0.0
0.400	61.5	1.600	61.5	2.800	0.0	4.000	0.0		
0.600	61.5	1.800	61.5	3.000	0.0	4.200	0.0		
0.800	61.5	2.000	61.5	3.200	0.0	4.400	0.0		
1.000	61.5	2.001	0.0	3.400	0.0	4.600	0.0		

Summary of Results for 15 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.219	-0.071	0.000	0.60	0.0	41.4	OK
S1.001	SMH8	44.174	-0.005	0.000	0.84	0.0	42.9	OK
S2.000	SMH11	44.230	-0.217	0.000	0.17	0.0	11.4	OK
S1.002	SMH12	44.160	-0.004	0.000	0.94	0.0	63.5	OK
S1.003	SMH15	44.076	0.003	0.000	1.08	0.0	72.1	SURCHARGED
S3.000	SMH19	43.598	-0.202	0.000	0.23	0.0	15.6	OK
S3.001	SMH20	42.813	0.013	0.000	0.29	0.0	20.4	SURCHARGED
S1.004	SMH21	42.805	0.126	0.000	1.36	0.0	60.5	SURCHARGED
S1.005	SMH22	42.780	0.121	0.000	1.03	0.0	61.3	SURCHARGED
S1.006	SMH23	42.768	0.153	0.000	0.86	0.0	50.4	SURCHARGED
S4.000	SMH28	44.151	-0.116	0.000	0.68	0.0	38.3	OK
S1.007	SMH29	42.765	0.190	0.000	1.34	0.0	79.4	SURCHARGED
S1.008	SMH30	42.763	0.156	0.000	0.56	0.0	49.9	SURCHARGED
S1.009	SMH31	42.762	0.183	0.000	0.45	0.0	56.1	SURCHARGED
S1.010	SMH32	42.761	0.484	0.000	0.07	0.0	2.3	SURCHARGED
S1.011	SMH33	41.906	-0.186	0.000	0.07	0.0	2.3	OK
S1.012	SMH34	41.825	-0.185	0.000	0.07	0.0	2.3	OK
S1.013	SMH35	41.755	-0.182	0.000	0.08	0.0	2.3	OK
S1.014	SMH36	41.722	-0.186	0.000	0.07	0.0	2.3	OK

Summary of Results for 30 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.148	-0.142	0.000	0.51	0.0	35.6	OK
S1.001	SMH8	44.091	-0.088	0.000	0.75	0.0	38.4	OK
S2.000	SMH11	44.221	-0.226	0.000	0.14	0.0	9.5	OK
S1.002	SMH12	44.080	-0.084	0.000	0.86	0.0	57.6	OK
S1.003	SMH15	44.012	-0.061	0.000	0.99	0.0	66.2	OK
S3.000	SMH19	43.588	-0.212	0.000	0.19	0.0	12.9	OK
S3.001	SMH20	42.953	0.153	0.000	0.24	0.0	16.9	SURCHARGED
S1.004	SMH21	42.952	0.273	0.000	1.18	0.0	52.4	SURCHARGED
S1.005	SMH22	42.950	0.291	0.000	0.88	0.0	52.4	SURCHARGED
S1.006	SMH23	42.947	0.332	0.000	0.58	0.0	33.9	SURCHARGED
S4.000	SMH28	44.128	-0.139	0.000	0.56	0.0	31.6	OK
S1.007	SMH29	42.945	0.370	0.000	1.05	0.0	62.1	SURCHARGED
S1.008	SMH30	42.943	0.336	0.000	0.40	0.0	35.5	SURCHARGED
S1.009	SMH31	42.942	0.363	0.000	0.34	0.0	43.0	SURCHARGED
S1.010	SMH32	42.940	0.663	0.000	0.08	0.0	2.6	SURCHARGED
S1.011	SMH33	41.909	-0.183	0.000	0.08	0.0	2.6	OK
S1.012	SMH34	41.827	-0.183	0.000	0.08	0.0	2.6	OK
S1.013	SMH35	41.758	-0.179	0.000	0.09	0.0	2.6	OK
S1.014	SMH36	41.725	-0.183	0.000	0.08	0.0	2.6	OK

Summary of Results for 45 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.124	-0.166	0.000	0.41	0.0	28.6	OK
S1.001	SMH8	44.057	-0.122	0.000	0.61	0.0	31.1	OK
S2.000	SMH11	44.213	-0.234	0.000	0.11	0.0	7.6	OK
S1.002	SMH12	44.049	-0.115	0.000	0.69	0.0	46.7	OK
S1.003	SMH15	43.978	-0.095	0.000	0.81	0.0	53.8	OK
S3.000	SMH19	43.578	-0.222	0.000	0.15	0.0	10.3	OK
S3.001	SMH20	43.056	0.256	0.000	0.19	0.0	13.3	SURCHARGED
S1.004	SMH21	43.056	0.377	0.000	0.84	0.0	37.5	SURCHARGED
S1.005	SMH22	43.054	0.395	0.000	0.65	0.0	38.8	SURCHARGED
S1.006	SMH23	43.051	0.436	0.000	0.38	0.0	22.2	SURCHARGED
S4.000	SMH28	44.108	-0.159	0.000	0.45	0.0	25.2	OK
S1.007	SMH29	43.050	0.475	0.000	0.80	0.0	47.5	SURCHARGED
S1.008	SMH30	43.048	0.441	0.000	0.29	0.0	25.4	SURCHARGED
S1.009	SMH31	43.047	0.468	0.000	0.26	0.0	32.7	SURCHARGED
S1.010	SMH32	43.045	0.768	0.000	0.08	0.0	2.7	SURCHARGED
S1.011	SMH33	41.911	-0.181	0.000	0.08	0.0	2.7	OK
S1.012	SMH34	41.829	-0.181	0.000	0.09	0.0	2.7	OK
S1.013	SMH35	41.759	-0.178	0.000	0.10	0.0	2.7	OK
S1.014	SMH36	41.726	-0.181	0.000	0.09	0.0	2.7	OK

Summary of Results for 60 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.113	-0.177	0.000	0.35	0.0	24.2	OK
S1.001	SMH8	44.040	-0.139	0.000	0.52	0.0	26.4	OK
S2.000	SMH11	44.209	-0.238	0.000	0.09	0.0	6.4	OK
S1.002	SMH12	44.031	-0.133	0.000	0.59	0.0	39.7	OK
S1.003	SMH15	43.957	-0.116	0.000	0.69	0.0	45.9	OK
S3.000	SMH19	43.572	-0.228	0.000	0.13	0.0	8.7	OK
S3.001	SMH20	43.133	0.333	0.000	0.16	0.0	11.2	SURCHARGED
S1.004	SMH21	43.133	0.454	0.000	0.68	0.0	30.3	SURCHARGED
S1.005	SMH22	43.131	0.472	0.000	0.53	0.0	31.7	SURCHARGED
S1.006	SMH23	43.128	0.513	0.000	0.31	0.0	17.9	SURCHARGED
S4.000	SMH28	44.096	-0.171	0.000	0.38	0.0	21.4	OK
S1.007	SMH29	43.127	0.552	0.000	0.65	0.0	38.6	SURCHARGED
S1.008	SMH30	43.125	0.518	0.000	0.24	0.0	21.3	SURCHARGED
S1.009	SMH31	43.124	0.545	0.000	0.22	0.0	27.5	SURCHARGED
S1.010	SMH32	43.122	0.845	0.000	0.09	0.0	2.8	SURCHARGED
S1.011	SMH33	41.912	-0.180	0.000	0.09	0.0	2.8	OK
S1.012	SMH34	41.830	-0.180	0.000	0.09	0.0	2.8	OK
S1.013	SMH35	41.760	-0.177	0.000	0.10	0.0	2.8	OK
S1.014	SMH36	41.727	-0.180	0.000	0.09	0.0	2.8	OK

Summary of Results for 90 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.097	-0.193	0.000	0.27	0.0	18.9	OK
S1.001	SMH8	44.016	-0.163	0.000	0.40	0.0	20.4	OK
S2.000	SMH11	44.200	-0.247	0.000	0.07	0.0	5.0	OK
S1.002	SMH12	44.007	-0.157	0.000	0.46	0.0	30.7	OK
S1.003	SMH15	43.930	-0.143	0.000	0.53	0.0	35.3	OK
S3.000	SMH19	43.564	-0.236	0.000	0.10	0.0	6.8	OK
S3.001	SMH20	43.241	0.441	0.000	0.13	0.0	8.8	SURCHARGED
S1.004	SMH21	43.241	0.562	0.000	0.54	0.0	23.9	SURCHARGED
S1.005	SMH22	43.239	0.580	0.000	0.42	0.0	25.0	SURCHARGED
S1.006	SMH23	43.238	0.623	0.000	0.24	0.0	14.0	SURCHARGED
S4.000	SMH28	44.079	-0.188	0.000	0.30	0.0	16.7	OK
S1.007	SMH29	43.236	0.661	0.000	0.52	0.0	30.9	SURCHARGED
S1.008	SMH30	43.234	0.627	0.000	0.19	0.0	17.0	SURCHARGED
S1.009	SMH31	43.234	0.655	0.000	0.18	0.0	22.0	SURCHARGED
S1.010	SMH32	43.231	0.954	0.000	0.09	0.0	3.0	SURCHARGED
S1.011	SMH33	41.913	-0.179	0.000	0.09	0.0	3.0	OK
S1.012	SMH34	41.831	-0.179	0.000	0.09	0.0	3.0	OK
S1.013	SMH35	41.761	-0.176	0.000	0.11	0.0	3.0	OK
S1.014	SMH36	41.728	-0.179	0.000	0.09	0.0	3.0	OK

Summary of Results for 120 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.086	-0.204	0.000	0.23	0.0	15.6	OK
S1.001	SMH8	44.001	-0.178	0.000	0.33	0.0	17.0	OK
S2.000	SMH11	44.195	-0.252	0.000	0.06	0.0	4.2	OK
S1.002	SMH12	43.992	-0.172	0.000	0.38	0.0	25.5	OK
S1.003	SMH15	43.912	-0.161	0.000	0.44	0.0	29.4	OK
S3.000	SMH19	43.558	-0.242	0.000	0.08	0.0	5.6	OK
S3.001	SMH20	43.319	0.519	0.000	0.10	0.0	7.2	SURCHARGED
S1.004	SMH21	43.318	0.639	0.000	0.44	0.0	19.8	SURCHARGED
S1.005	SMH22	43.317	0.658	0.000	0.35	0.0	20.7	SURCHARGED
S1.006	SMH23	43.316	0.701	0.000	0.20	0.0	11.8	SURCHARGED
S4.000	SMH28	44.067	-0.200	0.000	0.25	0.0	13.8	OK
S1.007	SMH29	43.314	0.739	0.000	0.44	0.0	25.9	SURCHARGED
S1.008	SMH30	43.312	0.705	0.000	0.16	0.0	14.5	SURCHARGED
S1.009	SMH31	43.311	0.732	0.000	0.15	0.0	18.8	SURCHARGED
S1.010	SMH32	43.310	1.033	0.000	0.09	0.0	3.1	SURCHARGED
S1.011	SMH33	41.913	-0.179	0.000	0.09	0.0	3.1	OK
S1.012	SMH34	41.832	-0.178	0.000	0.10	0.0	3.1	OK
S1.013	SMH35	41.762	-0.175	0.000	0.11	0.0	3.1	OK
S1.014	SMH36	41.729	-0.178	0.000	0.10	0.0	3.1	OK

Summary of Results for 180 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.074	-0.216	0.000	0.17	0.0	12.0	OK
S1.001	SMH8	43.984	-0.195	0.000	0.25	0.0	13.0	OK
S2.000	SMH11	44.188	-0.259	0.000	0.05	0.0	3.2	OK
S1.002	SMH12	43.974	-0.190	0.000	0.29	0.0	19.6	OK
S1.003	SMH15	43.893	-0.180	0.000	0.34	0.0	22.6	OK
S3.000	SMH19	43.549	-0.251	0.000	0.06	0.0	4.3	OK
S3.001	SMH20	43.425	0.625	0.000	0.08	0.0	5.6	SURCHARGED
S1.004	SMH21	43.424	0.745	0.000	0.35	0.0	15.6	SURCHARGED
S1.005	SMH22	43.423	0.764	0.000	0.27	0.0	16.4	SURCHARGED
S1.006	SMH23	43.422	0.807	0.000	0.16	0.0	9.3	SURCHARGED
S4.000	SMH28	44.055	-0.212	0.000	0.19	0.0	10.6	OK
S1.007	SMH29	43.420	0.845	0.000	0.34	0.0	20.4	SURCHARGED
S1.008	SMH30	43.419	0.812	0.000	0.13	0.0	11.6	SURCHARGED
S1.009	SMH31	43.418	0.839	0.000	0.12	0.0	15.0	SURCHARGED
S1.010	SMH32	43.416	1.139	0.000	0.10	0.0	3.2	SURCHARGED
S1.011	SMH33	41.914	-0.178	0.000	0.10	0.0	3.2	OK
S1.012	SMH34	41.832	-0.178	0.000	0.10	0.0	3.2	OK
S1.013	SMH35	41.763	-0.174	0.000	0.12	0.0	3.2	OK
S1.014	SMH36	41.730	-0.178	0.000	0.10	0.0	3.2	OK

Summary of Results for 240 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.065	-0.225	0.000	0.14	0.0	9.8	OK
S1.001	SMH8	43.973	-0.206	0.000	0.21	0.0	10.7	OK
S2.000	SMH11	44.185	-0.262	0.000	0.04	0.0	2.6	OK
S1.002	SMH12	43.963	-0.201	0.000	0.24	0.0	16.1	OK
S1.003	SMH15	43.880	-0.193	0.000	0.28	0.0	18.6	OK
S3.000	SMH19	43.544	-0.256	0.000	0.05	0.0	3.5	OK
S3.001	SMH20	43.492	0.692	0.000	0.07	0.0	4.6	SURCHARGED
S1.004	SMH21	43.492	0.813	0.000	0.29	0.0	12.9	SURCHARGED
S1.005	SMH22	43.490	0.831	0.000	0.23	0.0	13.5	SURCHARGED
S1.006	SMH23	43.487	0.872	0.000	0.13	0.0	7.8	SURCHARGED
S4.000	SMH28	44.045	-0.222	0.000	0.15	0.0	8.7	OK
S1.007	SMH29	43.485	0.910	0.000	0.29	0.0	17.0	SURCHARGED
S1.008	SMH30	43.484	0.877	0.000	0.11	0.0	9.8	SURCHARGED
S1.009	SMH31	43.483	0.904	0.000	0.10	0.0	12.7	SURCHARGED
S1.010	SMH32	43.484	1.207	0.000	0.10	0.0	3.3	SURCHARGED
S1.011	SMH33	41.915	-0.177	0.000	0.10	0.0	3.3	OK
S1.012	SMH34	41.833	-0.177	0.000	0.10	0.0	3.3	OK
S1.013	SMH35	41.763	-0.174	0.000	0.12	0.0	3.3	OK
S1.014	SMH36	41.730	-0.177	0.000	0.10	0.0	3.3	OK

Summary of Results for 360 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.055	-0.235	0.000	0.11	0.0	7.4	OK
S1.001	SMH8	43.959	-0.220	0.000	0.16	0.0	8.1	OK
S2.000	SMH11	44.180	-0.267	0.000	0.03	0.0	2.0	OK
S1.002	SMH12	43.949	-0.215	0.000	0.18	0.0	12.1	OK
S1.003	SMH15	43.866	-0.207	0.000	0.21	0.0	14.0	OK
S3.000	SMH19	43.576	-0.224	0.000	0.04	0.0	2.7	OK
S3.001	SMH20	43.576	0.776	0.000	0.05	0.0	3.4	SURCHARGED
S1.004	SMH21	43.576	0.897	0.000	0.22	0.0	10.0	SURCHARGED
S1.005	SMH22	43.575	0.916	0.000	0.18	0.0	10.5	SURCHARGED
S1.006	SMH23	43.574	0.959	0.000	0.11	0.0	6.2	SURCHARGED
S4.000	SMH28	44.035	-0.232	0.000	0.12	0.0	6.5	OK
S1.007	SMH29	43.573	0.998	0.000	0.22	0.0	13.2	SURCHARGED
S1.008	SMH30	43.571	0.964	0.000	0.09	0.0	7.9	SURCHARGED
S1.009	SMH31	43.570	0.991	0.000	0.08	0.0	10.0	SURCHARGED
S1.010	SMH32	43.568	1.291	0.000	0.10	0.0	3.4	SURCHARGED
S1.011	SMH33	41.915	-0.177	0.000	0.10	0.0	3.4	OK
S1.012	SMH34	41.834	-0.176	0.000	0.11	0.0	3.4	OK
S1.013	SMH35	41.764	-0.173	0.000	0.12	0.0	3.4	OK
S1.014	SMH36	41.731	-0.177	0.000	0.11	0.0	3.4	OK

Summary of Results for 720 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.040	-0.250	0.000	0.07	0.0	4.5	OK
S1.001	SMH8	43.941	-0.238	0.000	0.10	0.0	4.9	OK
S2.000	SMH11	44.172	-0.275	0.000	0.02	0.0	1.2	OK
S1.002	SMH12	43.930	-0.234	0.000	0.11	0.0	7.4	OK
S1.003	SMH15	43.844	-0.229	0.000	0.13	0.0	8.6	OK
S3.000	SMH19	43.687	-0.113	0.000	0.02	0.0	1.6	OK
S3.001	SMH20	43.687	0.887	0.000	0.03	0.0	2.1	SURCHARGED
S1.004	SMH21	43.687	1.008	0.000	0.14	0.0	6.4	SURCHARGED
S1.005	SMH22	43.686	1.027	0.000	0.11	0.0	6.7	SURCHARGED
S1.006	SMH23	43.686	1.071	0.000	0.07	0.0	4.3	SURCHARGED
S4.000	SMH28	44.019	-0.248	0.000	0.07	0.0	4.0	OK
S1.007	SMH29	43.705	1.130	0.000	0.15	0.0	8.6	SURCHARGED
S1.008	SMH30	43.691	1.084	0.000	0.07	0.0	5.9	SURCHARGED
S1.009	SMH31	43.718	1.139	0.000	0.06	0.0	6.9	SURCHARGED
S1.010	SMH32	43.685	1.408	0.000	0.11	0.0	3.5	SURCHARGED
S1.011	SMH33	41.916	-0.176	0.000	0.11	0.0	3.5	OK
S1.012	SMH34	41.834	-0.176	0.000	0.11	0.0	3.5	OK
S1.013	SMH35	41.765	-0.172	0.000	0.13	0.0	3.5	OK
S1.014	SMH36	41.732	-0.176	0.000	0.11	0.0	3.5	OK

Summary of Results for 1440 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.028	-0.262	0.000	0.04	0.0	2.8	OK
S1.001	SMH8	43.926	-0.253	0.000	0.06	0.0	3.0	OK
S2.000	SMH11	44.162	-0.285	0.000	0.01	0.0	0.7	OK
S1.002	SMH12	43.915	-0.249	0.000	0.07	0.0	4.5	OK
S1.003	SMH15	43.829	-0.244	0.000	0.08	0.0	5.2	OK
S3.000	SMH19	43.637	-0.163	0.000	0.01	0.0	1.0	OK
S3.001	SMH20	43.637	0.837	0.000	0.02	0.0	1.3	SURCHARGED
S1.004	SMH21	43.637	0.958	0.000	0.10	0.0	4.3	SURCHARGED
S1.005	SMH22	43.636	0.977	0.000	0.07	0.0	4.5	SURCHARGED
S1.006	SMH23	43.635	1.020	0.000	0.05	0.0	3.2	SURCHARGED
S4.000	SMH28	44.007	-0.260	0.000	0.04	0.0	2.4	OK
S1.007	SMH29	43.634	1.059	0.000	0.10	0.0	5.8	SURCHARGED
S1.008	SMH30	43.632	1.025	0.000	0.05	0.0	4.1	SURCHARGED
S1.009	SMH31	43.632	1.053	0.000	0.04	0.0	4.9	SURCHARGED
S1.010	SMH32	43.629	1.352	0.000	0.11	0.0	3.5	SURCHARGED
S1.011	SMH33	41.916	-0.176	0.000	0.11	0.0	3.5	OK
S1.012	SMH34	41.834	-0.176	0.000	0.11	0.0	3.5	OK
S1.013	SMH35	41.765	-0.173	0.000	0.12	0.0	3.5	OK
S1.014	SMH36	41.731	-0.176	0.000	0.11	0.0	3.5	OK

Summary of Results for 2880 minute 100 year Winter (Storm)

Margin for Flood Risk Warning (mm) 300.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

PN	US/MH Name	Water Level (m)	Surcharged Depth (m)	Flooded Volume (m³)	Flow / Cap.	Overflow (l/s)	Pipe Flow (l/s)	Status
S1.000	SMH8A	44.022	-0.268	0.000	0.02	0.0	1.7	OK
S1.001	SMH8	43.916	-0.263	0.000	0.04	0.0	1.9	OK
S2.000	SMH11	44.156	-0.291	0.000	0.01	0.0	0.5	OK
S1.002	SMH12	43.903	-0.261	0.000	0.04	0.0	2.8	OK
S1.003	SMH15	43.815	-0.258	0.000	0.05	0.0	3.2	OK
S3.000	SMH19	43.513	-0.287	0.000	0.01	0.0	0.6	OK
S3.001	SMH20	43.482	0.682	0.000	0.01	0.0	0.8	SURCHARGED
S1.004	SMH21	43.482	0.803	0.000	0.07	0.0	2.9	SURCHARGED
S1.005	SMH22	43.481	0.822	0.000	0.05	0.0	3.0	SURCHARGED
S1.006	SMH23	43.480	0.865	0.000	0.04	0.0	2.4	SURCHARGED
S4.000	SMH28	43.999	-0.268	0.000	0.03	0.0	1.5	OK
S1.007	SMH29	43.479	0.904	0.000	0.07	0.0	4.0	SURCHARGED
S1.008	SMH30	43.477	0.870	0.000	0.04	0.0	3.2	SURCHARGED
S1.009	SMH31	43.480	0.901	0.000	0.03	0.0	3.7	SURCHARGED
S1.010	SMH32	43.475	1.198	0.000	0.10	0.0	3.3	SURCHARGED
S1.011	SMH33	41.915	-0.177	0.000	0.10	0.0	3.3	OK
S1.012	SMH34	41.833	-0.177	0.000	0.10	0.0	3.3	OK
S1.013	SMH35	41.763	-0.174	0.000	0.12	0.0	3.3	OK
S1.014	SMH36	41.730	-0.177	0.000	0.10	0.0	3.3	OK

MH Name	SMH21	SMH15	SMH12		SMH8A	
Hor Scale 500 Ver Scale 100 Datum (m) 40.000		3.001		2.000		
PN		S1.003	S1.002		S1.000	
Dia (mm)		300	300		300	
Slope (1:X)		200.4	201.1		199.7	
Cover Level (m)	45.000	45.000	45.000	45.000	45.000	
Invert Level (m)		43.688	43.773	43.773	43.864	43.879	43.879	43.990	
Length (m)		17.034	18.299		22.163	

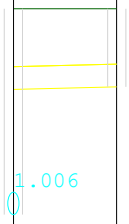
MH Name	SMH31		SMH29	SMH23	SMH22		
Hor Scale 500 Ver Scale 100 Datum (m) 40.000			4.000			3.001	
PN			S1.007	S1.006	S1.005		
Dia (mm)			300	300	300		
Slope (1:X)			200.2	201.0	201.7		
Cover Level (m)	45.000	45.000	45.000	45.000	45.000	45.000	
Invert Level (m)		42.204	42.232	42.232	42.275	42.275	42.315	42.315	42.359	42.359	42.379	
Length (m)			8.609	8.041	8.874		

MH Name	SMH34	SMH33	SMH32	SMH31	
Hor Scale 500 Ver Scale 100 Datum (m) 40.000					
PN		S1.011	S1.010	S1.009	
Dia (mm)		225	225	375	
Slope (1:X)		199.5	199.7	199.4	
Cover Level (m)	43.800	45.000	45.000	45.000	
Invert Level (m)		41.785 41.867	41.967 42.052	42.052 42.204	
Length (m)		16.360	16.972	30.309	

MH Name	S	SMH36		SMH34	
Hor Scale 500 Ver Scale 100 Datum (m) 39.000					
PN		S1.014		S1.012	
Dia (mm)		225		225	
Slope (1:X)		200.0		200.0	
Cover Level (m)	42.600	42.700	42.800	43.800	
Invert Level (m)		41.608 41.682	41.682 41.712	41.712 41.785	
Length (m)		14.934		14.552	

MH Name	SMH12	SMH11	
Hor Scale 500 Ver Scale 100 Datum (m) 41.000		1.001	
PN		S2.000	
Dia (mm)		300	
Slope (1:X)		199.6	
Cover Level (m)	45.000	45.000	
Invert Level (m)	44.041	44.147	
Length (m)		21.158	

MH Name	SMH21	SMH20	SMH19	
Hor Scale 500 Ver Scale 100 Datum (m) 40.000		1.003		
PN		S3.001	S3.000	
Dia (mm)		300	300	
Slope (1:X)		199.3	199.0	
Cover Level (m)	45.000	45.000	45.000	
Invert Level (m)		42.379 42.500	43.409 43.500	
Length (m)		24.113	18.110	

MH Name	SMH29	SMH28	
Hor Scale 500 Ver Scale 100 Datum (m) 40.000			
PN		S4.000	
Dia (mm)		300	
Slope (1:X)		200.9	
Cover Level (m)	45.000	45.000	
Invert Level (m)		43.933	43.967
Length (m)		6.831	

Appendix D

Extract from the Site Investigation Report

CS CONSULTING
GROUP

SOAKAWAY TEST f-Value Calculations SIL

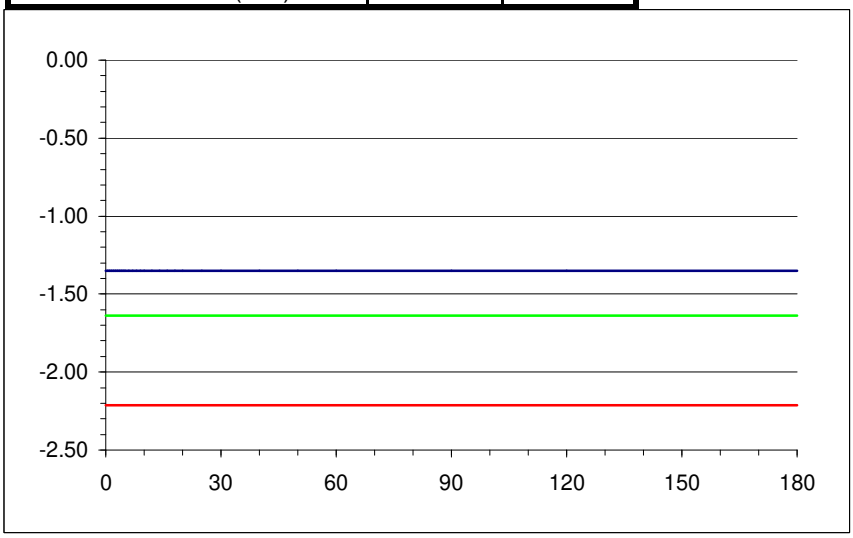
Project Reference:	5328
Contract name:	Frankfort Housing Development
Location:	Dundrum, Dublin 14
Test No:	SA01
Date:	19/09/2016

Ground Conditions

From	To	
0.00	0.20	TOPSOIL.
0.20	0.80	MADE GROUND: light brown silty gravelly fine sand with low cobble content and some red brick and bone fragments.
0.80	1.40	MADE GROUND: brown slightly sandy gravelly silty clay with high cobble and low boulder content and some red brick fragments.
1.40	2.30	Firm grey brown slightly sandy gravelly silty CLAY with medium cobble content.
2.30	2.50	Stiff dark grey slightly sandy gravelly silty CLAY with medium cobble content.

Elapsed Time	Fall of Water (m)
0	-1.35
0.5	-1.35
1	-1.35
1.5	-1.35
2	-1.35
2.5	-1.35
3	-1.35
3.5	-1.35
4	-1.35
4.5	-1.35
5	-1.35
6	-1.35
7	-1.35
8	-1.35
9	-1.35
10	-1.35
12	-1.35
14	-1.35
16	-1.35
18	-1.35
20	-1.35
25	-1.35
30	-1.35
40	-1.35
50	-1.35
60	-1.35
90	-1.35
120	-1.35
180	-1.35

Pit Dimensions (m)		
Length (m)	2.90	m
Width (m)	0.50	m
Depth	2.50	m
Water		
Start Depth of Water	1.35	m
Depth of Water	1.15	m
75% Full	1.6375	m
25% Full	2.2125	m
75%-25%	0.575	m
Volume of water (75%-25%)	**0.83375**	m3
Area of Drainage	**17**	m2
Area of Drainage (75%-25%)	**5.36**	m2
Time		
75% Full	N/A	min
25% Full	N/A	min
Time 75% to 25%	**N/A**	min
Time 75% to 25% (sec)	**N/A**	sec



f = Fail or **Fail**

m/min **m/s**

SOAKAWAY TEST f-Value Calculations SIL

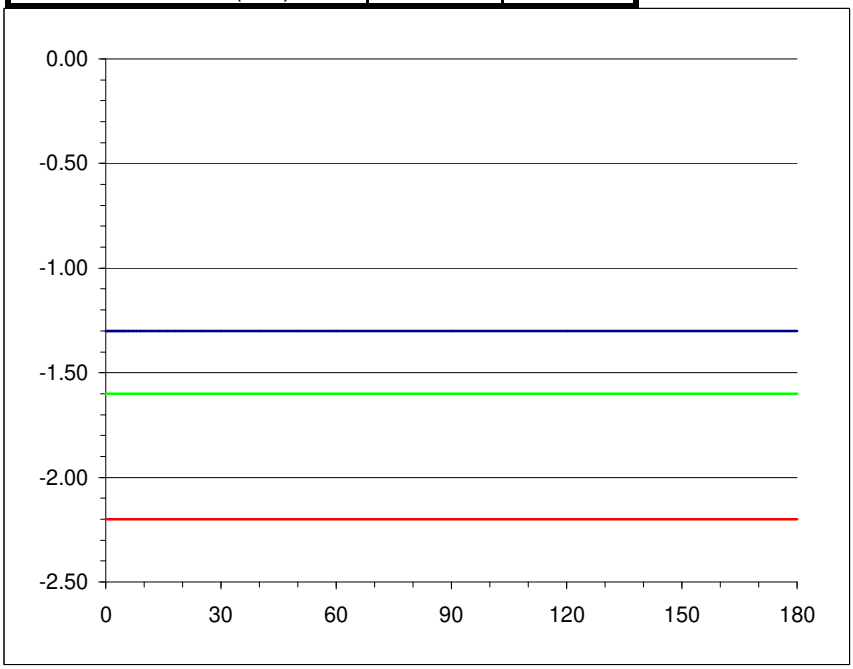
Project Reference:	5328
Contract name:	Frankfort Housing Development
Location:	Dundrum, Dublin 14
Test No:	SA02
Date:	19/09/2016

Ground Conditions

From	To	
0.00	0.15	TOPSOIL.
0.15	1.10	Light brown silty gravelly fine SAND with high cobble content.
1.10	2.00	Firm grey brown slightly sandy gravelly silty CLAY with high cobble content.
2.00	2.50	Stiff dark grey slightly sandy gravelly silty CLAY with medium cobble content.

Elapsed Time	Fall of Water (m)
0	-1.30
0.5	-1.30
1	-1.30
1.5	-1.30
2	-1.30
2.5	-1.30
3	-1.30
3.5	-1.30
4	-1.30
4.5	-1.30
5	-1.30
6	-1.30
7	-1.30
8	-1.30
9	-1.30
10	-1.30
12	-1.30
14	-1.30
16	-1.30
18	-1.30
20	-1.30
25	-1.30
30	-1.30
40	-1.30
50	-1.30
60	-1.30
90	-1.30
120	-1.30
180	-1.30

Pit Dimensions (m)		
Length (m)	3.00	m
Width (m)	0.50	m
Depth	2.50	m
Water		
Start Depth of Water	1.30	m
Depth of Water	1.20	m
75% Full	1.6	m
25% Full	2.2	m
75%-25%	0.6	m
Volume of water (75%-25%)	**0.9**	m3
Area of Drainage	**17.5**	m2
Area of Drainage (75%-25%)	**5.7**	m2
Time		
75% Full	N/A	min
25% Full	N/A	min
Time 75% to 25%	**N/A**	min
Time 75% to 25% (sec)	**N/A**	sec



f = Fail or **Fail**

m/min **m/s**

SOAKAWAY TEST f-Value Calculations SIL

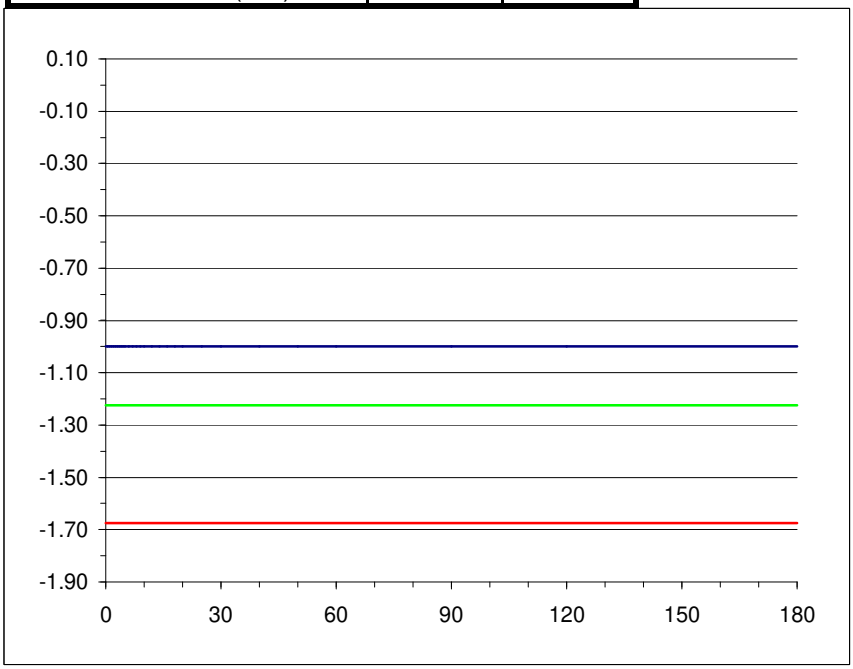
Project Reference:	5328
Contract name:	Frankfort Housing Development
Location:	Dundrum, Dublin 14
Test No:	SA03
Date:	19/09/2016

Ground Conditions

From	To	
0.00	0.20	TOPSOIL.
0.20	1.10	MADE GROUND: light brown silty slightly gravelly fine sand with high cobble and low boulder content and some red brick fragments.
1.10	1.90	Firm grey brown slightly sandy gravelly silty CLAY with high cobble content.

Elapsed Time	Fall of Water (m)
0	-1.00
0.5	-1.00
1	-1.00
1.5	-1.00
2	-1.00
2.5	-1.00
3	-1.00
3.5	-1.00
4	-1.00
4.5	-1.00
5	-1.00
6	-1.00
7	-1.00
8	-1.00
9	-1.00
10	-1.00
12	-1.00
14	-1.00
16	-1.00
18	-1.00
20	-1.00
25	-1.00
30	-1.00
40	-1.00
50	-1.00
60	-1.00
90	-1.00
120	-1.00
180	-1.00

Pit Dimensions (m)		
Length (m)	3.10	m
Width (m)	0.50	m
Depth	1.90	m
Water		
Start Depth of Water	1.00	m
Depth of Water	0.90	m
75% Full	1.225	m
25% Full	1.675	m
75%-25%	0.45	m
Volume of water (75%-25%)	**0.6975**	m3
Area of Drainage	**13.68**	m2
Area of Drainage (75%-25%)	**4.79**	m2
Time		
75% Full	N/A	min
25% Full	N/A	min
Time 75% to 25%	**N/A**	min
Time 75% to 25% (sec)	**N/A**	sec



f = Fail or **Fail**

m/min **m/s**

SOAKAWAY TEST f-Value Calculations SIL

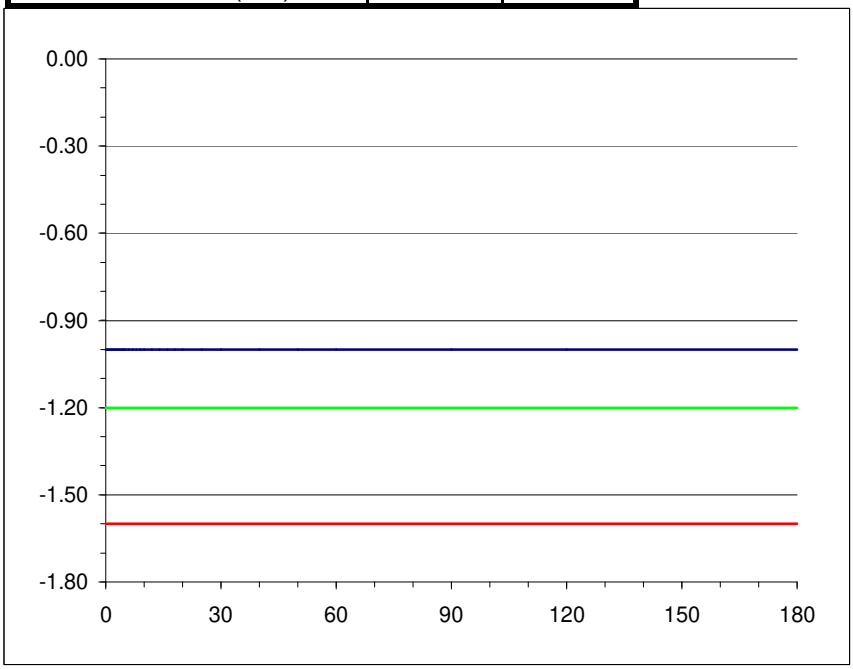
Project Reference:	5328
Contract name:	Frankfort Housing Development
Location:	Dundrum, Dublin 14
Test No:	SA04
Date:	19/09/2016

Ground Conditions

From	To	
0.00	0.20	TOPSOIL.
0.20	0.90	Light brown silty slightly gravelly fine SAND with medium cobble content.
0.90	1.70	Firm bec. stiff slightly sandy gravelly silty CLAY with medium cobble content.
1.70	1.80	Stiff dark grey slightly sandy gravelly silty CLAY with medium cobble content.

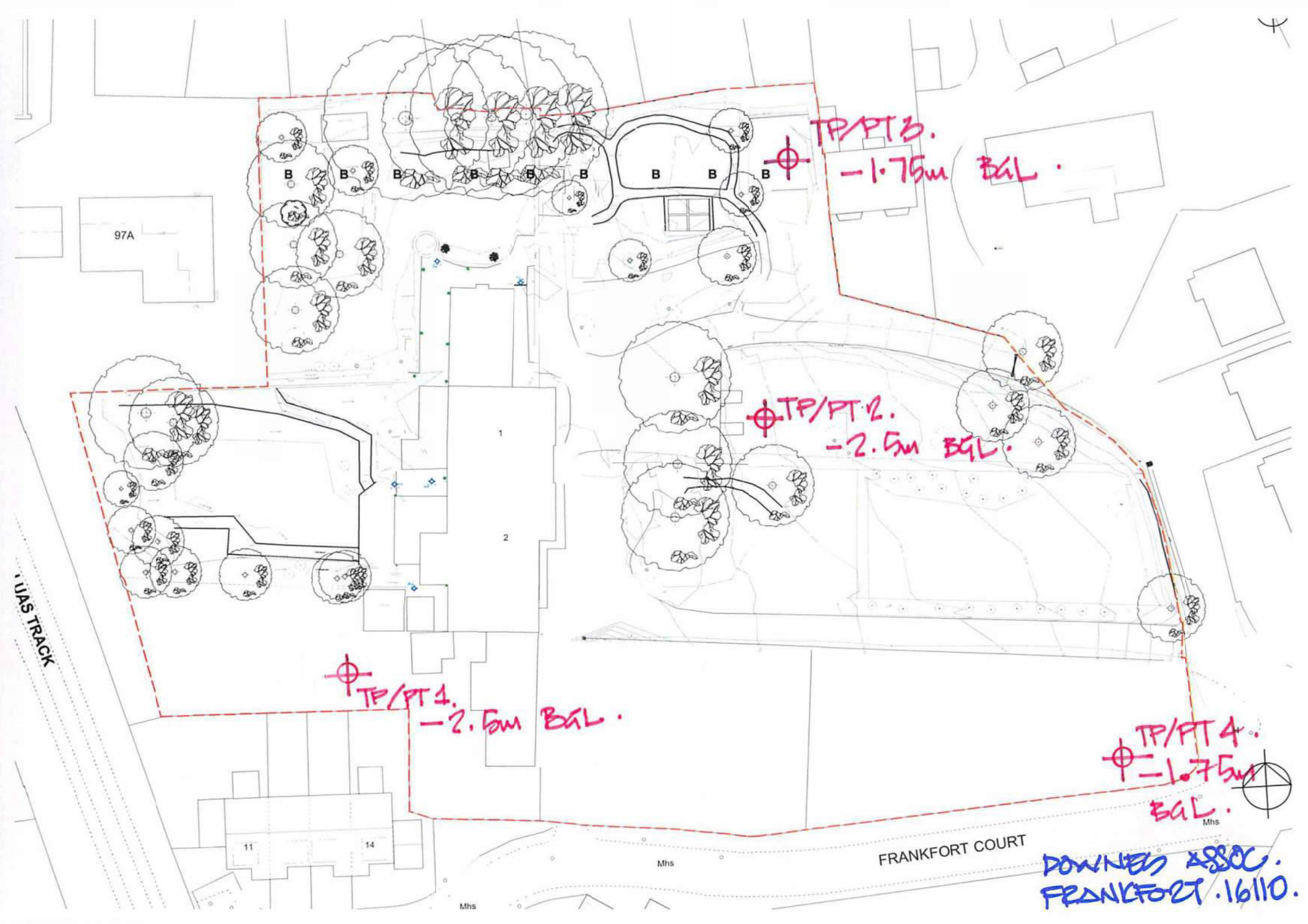
Elapsed Time	Fall of Water (m)
0	-1.00
0.5	-1.00
1	-1.00
1.5	-1.00
2	-1.00
2.5	-1.00
3	-1.00
3.5	-1.00
4	-1.00
4.5	-1.00
5	-1.00
6	-1.00
7	-1.00
8	-1.00
9	-1.00
10	-1.00
12	-1.00
14	-1.00
16	-1.00
18	-1.00
20	-1.00
25	-1.00
30	-1.00
40	-1.00
50	-1.00
60	-1.00
90	-1.00
120	-1.00
180	-1.00

Pit Dimensions (m)		
Length (m)	2.20	m
Width (m)	0.50	m
Depth	1.80	m
Water		
Start Depth of Water	1.00	m
Depth of Water	0.80	m
75% Full	1.2	m
25% Full	1.6	m
75%-25%	0.4	m
Volume of water (75%-25%)	**0.44**	m3
Area of Drainage	**9.72**	m2
Area of Drainage (75%-25%)	**3.26**	m2
Time		
75% Full	N/A	min
25% Full	N/A	min
Time 75% to 25%	**N/A**	min
Time 75% to 25% (sec)	**N/A**	sec



f = **Fail** or **Fail**

m/min **m/s**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Appendix E

Green Roof Specification

CS CONSULTING
GROUP

BAUDER

GREEN ROOFS

BIODIVERSE, EXTENSIVE AND INTENSIVE SYSTEMS

OUR COMPANY

Who We Are

Bauder is one of Europe's leading manufacturers of flat roof waterproofing membranes and insulation products that has been owner-operated for over 150 years across 13 countries. We have an enviable reputation and track record for delivering the highest quality materials and service through supplying and project managing the installation of premier flat roof systems.

Our comprehensive portfolio of flat roof waterproofing systems, green roofs and photovoltaic energy delivers an extensive range of solutions to meet individual project needs without compromise.

"Manufacturing the highest quality roofing materials is one thing, but here at Bauder it is our total commitment and passion to work closely together with our clients to successfully deliver every product to the highest possible standard, that sets us above the rest."

Andrew Mackenzie
Managing Director
Bauder Ltd

What We Do

Bauder is fully committed to providing a complete service with an unrivalled level of support on all roofing projects, whether it's for a new build project or the refurbishment of an existing building.

Technical Expertise

Our large team of regionally based technical managers and site technicians will be on hand throughout the process, from specification design through to inspection of the installation and project completion to ensure a defect free finish.

Our technical department is the envy of the industry, providing a comprehensive and superior service with bespoke specifications individual to each project. Our support services ensure that products and materials all arrive on site when required providing an efficiency that all our clients demand.

Assured Quality

To ensure a consistent and proficient service, Bauder approved contractors are the only people fully trained and certified to install our products. We only approve contracting companies that possess the technical expertise and the organisational capacity to maintain an efficient and well-run site.

We have always operated a policy where we train and approve the individual installer and not just the company they work for. By taking installers with proven experience and demonstrating the techniques particular to our system, we can ensure the quality of workmanship that meets our clients' expectations.

Every operative receives an identity badge providing proof of competence, which is available for inspection at all times.

Guaranteed Satisfaction

Bauder is noted throughout the industry for the range of guarantees we offer that can cover design, products and installation. We unreservedly issue our guarantees on all projects because we monitor quality every step of the way from manufacture to finished installation.

GREEN ROOF SYSTEMS











Committed to utilising the very latest manufacturing technology, Bauder invests in a programme of continuous research and development to ensure every product and installation is ahead of industry standards, and that the needs of the environment are always kept in focus.

GREEN ROOF SYSTEMS

Each green roof brings back a piece of nature and on some buildings a recreational space can be created for people to access and enjoy.

A Bauder green roof combines the finished planting scheme and all its supportive components with a high quality and secure waterproofing system to give you the best results every time.

Designing a green roof can be complex and your local technical manager is best placed to advise you on the implications your green roof will have on the building and its construction as well as the ongoing maintenance of the vegetation and roof.

We have produced a design considerations guidw for green roofs which can be downloaded from our website.

bauder.co.uk/technical-centre/design-guides

Recreational Gardens, Terraces and Spaces Accessed Intensive Green Roofs

Rooftops where the design may include flowerbeds, lawns, shrubs and trees intermixed with paths, driveways and patios. The combinations of finishes will impact on the design, construction, drainage and components used to deliver to each element's requirements.

Sedum System Non-Accessed Extensive Green Roof

Lightweight, all in one vegetation system comprising mature sedums pre-grown on an integrated multifunctional water retention and filter layer with 20mm of extensive substrate. The system has been developed for use directly over the waterproofing without the need for a secondary layer of substrate.

Substrate Roofs
Non-Accessed Extensive Green Roofs

Substrate green roofs are designed to be comparatively lightweight, work towards providing some storm water mitigation and support a wide variety of low maintenance plant species which are generally self-sustaining, and wind, frost and drought tolerant. They are primarily used for their ecological benefits and not intended for general access or for leisure purposes.

Biodiverse Habitats

A natural living habitat to encourage a wider spread of birds, insects and plant species into the area and generally replicates the ecological environment of the site upon which construction development is taking place, particularly if a Biodiversity Action Plan (BAP) is to be met with priority species.

Precultivated Vegetation Blankets

Lightweight option with precultivated vegetation for instant planting of the roof. Two options are available; XF118 wildflower blanket contains a mixture of 24 species of annual and perennial native wildflowers and XF300 incorporates perennial sedums with some grasses and mosses.

Plug Planted Systems

Individually planted roof usually incorporating sedums, grasses, herbs, succulents and wildflowers. These can be planted to accommodate location and expected weather conditions, colour or layout designs to the client's preference.

Seeded Roofs

The vegetation is grown and colonised entirely on the roof from seed with full plant establishment taking between 18-24 months. The plant selection can incorporate native and priority species to gain BREEAM points and meet a BAP.

BioSOLAR Roofs

Combining a substrate green roof with a solar PV array where the substrate and vegetation provide the ballast for the installation. The mounting system raises the modules above the substrate to allow liberal growing room for the plants, which are specified explicitly so that their maximum height does not block light to the array that would otherwise reduce the efficiency of the panels.

ENVIRONMENTAL CREDENTIALS

Aiding Biodiversity and Meeting a Biodiversity Action Plan (BAP)

A green roof can provide a natural habitat specifically designed to support a particular species of plant or wildlife. Created for the local ecology, in which vegetation will establish and provide a home for smaller elements of wildlife as well as insects and invertebrates. The provision of a healthy habitat in a place that could otherwise be empty encourages wildlife to remain in the area, provides support for the natural colonisation of locally arising plants, birds and small animals, boosting a wider spread of species in the area.

Our vegetation options include our XF118 wildflower blanket and Flora Seed Mixes, which are all specifically devised to meet BAP criteria through their inclusion of species within the RHS 'Perfect for Pollinators' and Flora Locale 'native origins criteria'.

Storm Water Management

Green roofs are one method of retaining rainwater by inception storage in the substrate, drainage/reservoir board and plants. This water is then used by the vegetation or evaporates back into the atmosphere.

Improving Air Quality of Local Surroundings

Localised air quality is improved as the vegetation assists in reducing both gaseous pollutants and dust particles by removing a proportion of them from the immediate environment, effectively purifying the air.

Urban Heat Island Effect

The urban heat island effect is reduced because the substrate of a green roof will absorb some of this heat and the natural evaporation of water from both the plants and soil helps to cool and humidify the air, thus lowering the ambient air temperature.

Recycled Content of Green Roof Components

Many recycled or waste materials are used within our green roof build ups to enable us to provide environmental solutions to the industry.

Water Retention and Drainage Layers

Our DSE 20, 40 and 60 boards are manufactured from recycled high density polyethylene.

Protection Layers

Our protection layers FSM600 and FSM1100 for extensive green roofs are made from a mixture of two recycled materials, reground polyester and polypropylene fibre.

Our ProMat for intensive green roofs is made of granulate from recycled shredded tyres.

Our Ecomat product is created from mechanically bonded recycled Polyester clothing and fabric.

Substrates and Growing Mediums

Our substrates are based around recycled crushed brick and composted organic material.

Separation and Slip Layer

Our PE Foil is manufactured from recycled polyethylene granulate.

Recycling and Reusing Green Roof Components

The level of recycled content within our components clearly demonstrates that these products are then easily returned to the conventional recycling processes at the end of their required lifespan.

BREEAM 2014 Accreditation

The BREEAM assessment method evaluates the sustainability of built environments through the different stages of their life cycle. The schemes include:

Our green roofs have the potential to count towards these sections of BREEAM:

Land Use and Ecology

LE 03 Mitigating Ecological Impact.
Criteria 1&2
Potential credit 1

LE 04 Enhancing Site Ecology.
Criteria 1&2
Potential credit 1

LE 05 Long Term Impact on Biodiversity
Criteria 8
Potential credit 1

Our green roofs can be specified with our XF118 native species wildflower blanket or Bauder Flora seed mixes 3,5,7,9,11 which are accredited by the RHS as 'Perfect for Pollinators' and certified by Flora Locale.

Health and Wellbeing

Hea 05 Acoustic performance
Criteria 2
Potential credit 1

Our XF301 sedum system on a metal deck has been tested in accordance with BS EN ISO 140-18: 2006. The sedum plants intercept the impact of rainfall and mitigate the noise so that a figure of 33.5 dB was achieved.

Management

Man 04 Stakeholder Participation
Criteria 12
Potential credits 1

Green roofs for fully accessible recreational use provide facilities that can be shared by the relevant parties.

Energy

Ene 04 Low and Zero Carbon Technologies
Compliance CN10
Potential credits 2

A Bauder BioSOLAR Green Roof PV array creates local energy generation from renewable sources which can supply a compliant

TECHNICAL CREDENTIALS

Adopting Standards
Throughout Europe, the standards most widely recognised as comprehensively covering green roofs are those of the Forschungsgesllschaft Landschaftsentwicklung Landschafttsbau (FLL), which is a research society for the development of the landscape.

We have adopted these well respected standards, which cover all aspects of waterproofing, root protection, landscaping, installation and maintenance and we will continue to do so whilst also working in conjunction with the GRO Code of Best Practice for the UK.

Protection of the Waterproofing
A green roof protects the waterproofing from UV damage and thermal movement. Research has shown that the life expectancy of the waterproofing is significantly extended and in many cases may last the estimated design life of the building, which can eliminate future replacement costs.

Fire Testing
Bauder XF301 was the first sedum blanket in the UK to be awarded an EXT. F.AA fire rating by the Building Research Establishment.

The full XF 301 sedum system, including the vegetation waterproofing, and insulation was tested, and awarded an EXT. F.AA.

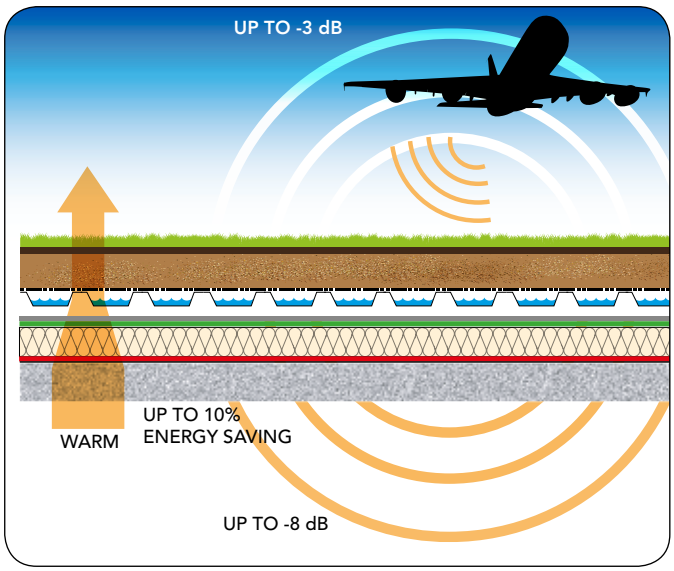
The same system was tested in a sloped orientation to ensure that the fire behaviour is not affected by roof slope and is also classified EXT.S.AA.

Increased Efficiency and Output of a BioSOLAR PV Array
A green roof helps to maximise solar energy generation as the vegetation preserves ambient rooftop temperatures, keeping the modules at optimal output. The cooling effect increases panel output by up to 5-7%.

Productivity in the Workplace
Research has shown that people working in offices that overlook green spaces have a higher productivity and a reduction in stress levels than those with a poorer outlook on a hard, impervious buildings.

Health
Hospitals are greening overlooked roofs or incorporating rooftop garden areas for the benefit of patients as they find that this speeds recovery.

Reduction of external noise within the building
Green roofs have excellent acoustic qualities for both external sound (up to 3dB) and internal noise (up to 8dB). This can prove to be both economically and environmentally effective when used on structures close to airports or industrial developments.



Reduced Building Running Costs
The enhanced thermal performance provided by a green roof provides a more balanced temperature within the building. This reduces heating costs in the winter and air conditioning expenses during the summer.

Reduced Lifecycle Costs
The main reduction in lifecycle costs comes from the green roof providing protection from the damaging effects of the weather, which effectively 'ages' the waterproofing, thus the time span between replacement is extended significantly, and in many cases replacement will become unnecessary.

Aid to Planning Consent
Many local authorities favour planning proposals that incorporate green roofs within the application, particularly if it meets their policies towards a sustainable environment or supports priority species.

Offset Construction Costs
In large construction projects a green roof can mean that storm water holding tanks are reduced in size or no longer required, as the roof itself will retain a proportion of the rainfall.

Creates an Amenity Space
The roof is often an under utilised asset of a building, as it offers the unique potential to replace the land lost to the construction as reusable space. Large roof areas covering underground car parks can provide parkland or sports facilities.

Increases Property Value
As an additional dimension is created, the property will maximise the potential available for the sites, and so increase the value.

RECREATIONAL GREEN ROOFS

Intensive green roofs provide recreational gardens and amenity spaces at roof level, with all the benefits usually associated with ground level landscaping. Typically they will feature landscapes combining shrubs, perennial and herbaceous plants, grassed areas, trees or hard landscaping for foot or vehicular traffic.

When to Specify

Maximising the full potential of a building by utilising all available space to deliver leisure spaces. Typically created on new build roof constructions, over underground car parks and podiums. The landscape variations are practically limitless for both design and use.

Key Features

These features are in addition to those associated with all green roofs.

- Assists in maximising the building's potential.
- Provides valuable recreational space.
- Offers storm water management benefits due to the depths of substrate used, particularly when specified in conjunction with permeable paving.
- Increases the overall value of the property.

The plants used make a heavy demand on the green roof and will require maintenance, irrigation and management throughout the year to ensure the upkeep of the landscape and allow the vegetation to flourish.

It is important to first establish the landscape finish you are looking to achieve. There is little to restrict the scope for design, other than the overall weight of the system dictating the construction of the supporting structure and the height and level of exposure of the roof.

All our green roof systems meet with FLL Guidelines

Specification Support

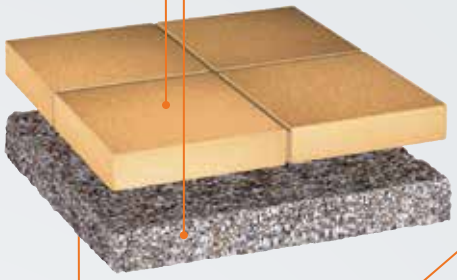
Specification downloads:
www.bauder.co.uk/technical-centre

Telephone helpline:
0845 271 8800

Example System Configuration

Our lightweight substrates combined with specially developed water storage and drainage components all ensure that the modern green roof can replicate a traditional landscape at roof level at only a fraction of the weight and with a substantially shallower build up.

It is crucial that an integrated approach is taken to the design and specification of both the waterproofing and landscaping components, so that the desired outcomes are achieved. We can work with you from the earliest design stage to ensure that your green roof project is successful.



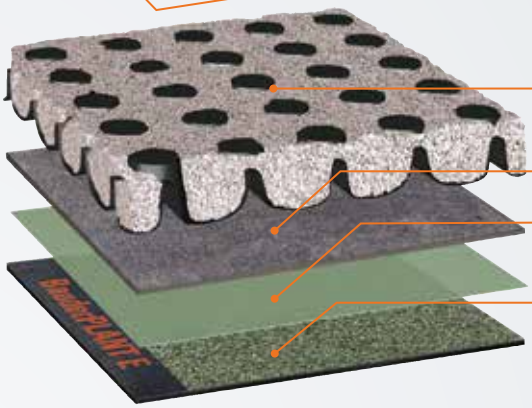
Paving/Pebble Ballast

Granite Chipping Base

Vegetation
specifically selected for each individual roof, from turf to trees.

Bauder Intensive Substrate
lightweight growing medium manufactured to meet FLL guidelines.

Bauder Filter Fleece
filtration layer that prevents substrate fines from washing into the drainage layer.



Bauder DSE60
60mm thick, water storage and drainage layer, infilled with Bauder Mineral Drain for structural stability.

Bauder FSM 1100 Protection Mat
recycled polyester and polythene fibre mix.

Bauder PE Foil
polythene foil separation and slip layer manufactured from recycled granules.

Bauder Plant E or AP2
root resistant, SBS modified bitumen membrane reinforced with 250g/m^2 recycled spunbond polyester.

SUBSTRATE GREEN ROOFS

These extensive green roof systems are primarily used for their ecological benefits or aesthetic appearance rather than for general access or for leisure purposes.

A traditional extensive substrate green roof system provides a depth of growing medium usually around 80-120mm to allow for the specification of a broader range of species and planting schemes. The plants are generally low maintenance, wind, frost and drought resistant and can be installed by different methods, including plug planting, vegetation mat and seeding.

When to Specify

The system is lightweight and offers the advantage of a bespoke vegetation finish with a substrate depth to support the plants, suitable for new build construction and retrofit or refurbishment projects.

Key Features

- Comparatively lightweight.
- Plants chosen to suit the project and location.
- Significant scope for creating a natural habitat to encourage plants and small wildlife to remain, so aiding biodiversity.
- Can be designed specifically to support particular flora and fauna.
- Aid to planning consent as biodiversity roofs help to meet local authority policies towards a sustainable environment.
- Aid to meeting BREEAM requirements of a development through points secured by the use of accredited native species plants.
- Develop another dimension through a unique opportunity to maximise the potential of the building to support the environment.
- Good levels of rainwater attenuation, depending on substrate depth.
- Cost effective on large roof areas.

Creating a Biodiverse Roof

This specific type of green or 'living' roof typically either tries to replicate as closely as is practical the ecological environment of the site where construction has taken place or sets out to create a natural habitat to support a variety of flora and fauna so aiding biodiversity.

When to Specify

Biodiverse roofs can be created on new build construction and refurbishment or retrofit projects. Ideal for meeting biodiversity action plans (BAP) and delivering to BREEAM and planning requirements.

All our green roof systems comply with FLL Guidelines.

Specification Support

Specification downloads:
www.bauder.co.uk/technical-centre

NBS Plus BIM DWG

Telephone helpline:
0845 271 8800

BALI gro ECO PLATFORM EPD EN 15804 VERIFIED

flora LOCALE RHS PERFECT FOR POLLINATORS bre

Example System Configuration

Substrate-based extensive green roofs can incorporate a variety of vegetation finishes.

Vegetation Mats

The installation of a precultivated vegetation mat allows instant coverage of the roof. Native species wildflower blanket XF118 meets the growing demand to satisfy the requirements of BREEAM and to meet a biodiversity action plan for the site.

Sedum Blanket XF300 provides dense sedum foliage featuring up to 11 species of sedum with some mosses and grasses for plant diversity.

Plug Planting

This method gives the client both a much greater choice of plant species and the opportunity to plan the layout. The individual immature plants or 'plugs' are planted out into the substrate by hand, which can then grow on to give good cover over the next two full growing seasons.

Seeding

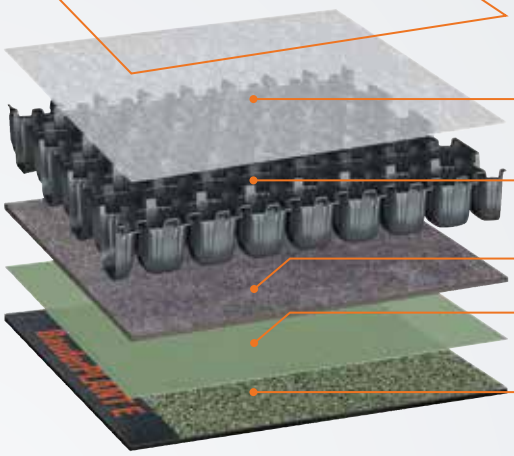
This is an economical and practical method for vegetating larger roof areas. Plant establishment and full coverage will take between 18-24 months, depending upon the time of year sowing takes place and the weather conditions during the period of establishment.

Vegetation Mat

Seeded Roof

Plug Plants

Biodiverse Habitat



Bauder Filter Fleece
filtration layer that prevents substrate fines from washing into the drainage layer.

Bauder DSE40
40mm water storage layer that provides multi directional drainage.

Bauder FSM600 Protection Mat
recycled polyester and polypropylene fibre mix.

Bauder PE Foil
polyethylene foil separation and slip layer manufactured from recycled granules.

Bauder Plant E or AP2
root resistant, SBS modified bitumen membrane reinforced with 250g/m^2 recycled spunbond polyester.

Substrate Pitch Roof Systems - Configurations Over 10°

An extensive substrate system on a pitch greater than 10° requires a water retention and storage board that will hold the substrate firmly in place and be sufficiently rigid to prevent board flexure and manage the imposed sheer load.

The extensive or biodiverse substrate is applied directly to the profiled surface of the board so that the green roof is stabilised whilst retaining sufficient levels of water to support the vegetation.

Sedum Vegetation on Bauder Extensive Substrate
variety of sedum species with some grasses and moss.

Vegetation on Bauder Biodiverse Substrate
generally provided through plug planting, vegetation mat or seeding. Selected species can be chosen to suit the project and location.

Bauder Substrate
applied directly to the profiled surface of the reservoir board.

Bauder Reservoir Board
lightweight rigid expanded polystyrene water storage and drainage layer.

Bauder FSM600 Protection Mat
polyester and polypropylene fibre mix.

Bauder PE Foil
polyethylene foil separation and slip layer manufactured from recycled granules.

Bauder Plant E or AP2
root resistant, SBS modified bitumen membrane reinforced with 250g/m² recycled spunbond polyester.

www.bauder.co.uk/technical-centre

BioSOLAR Green Roof System

Bauder BioSOLAR is a revolutionary solar PV mounting system for biodiverse or extensive green roofs. Well suited to new build applications where environmentally friendly solutions are required to meet planning and BREEAM requirements. Our BioSOLAR system can also be retrofitted on many existing roofs without the need for any structural modification to the building.

A key element is that the front edge of the PV panel is set 300mm above the level of the substrate, which allows liberal growing room for the vegetation without blocking light to the array that would otherwise reduce the efficiency of the panels. This height setting also enables light and moisture to reach beneath the panel to support the plants below.

Vegetation Mats

Native Species Wildflower Blanket XF118 meets the growing demand for a native species vegetation blanket to satisfy the requirements of BREEAM and to meet a biodiversity action plan for the site.

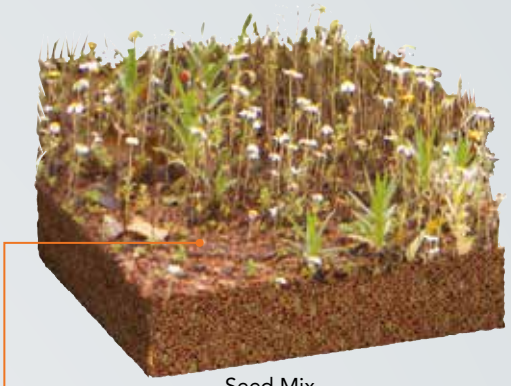
Sedum Blanket XF300 provides dense sedum foliage cover featuring up to 11 species of sedum with some mosses and grasses for plant diversity.

Plug Planting

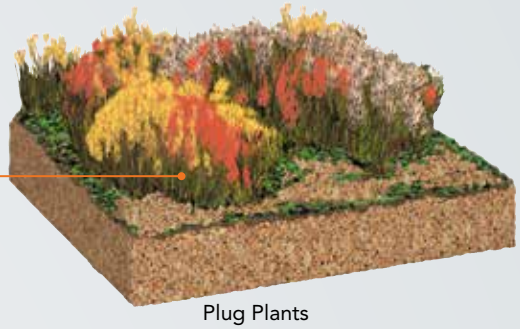
Individual immature plants or 'plugs' are planted out into the substrate by hand to give a variety of species, which can then grow on to give good cover over the next two full growing seasons.

Bauder Flora 3 Seed Mix

Ideal for vegetating large roof areas with species selected for their maximum growing height that meet BREEAM requirements.

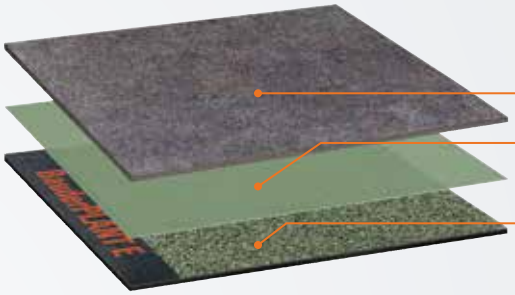


Seed Mix



Plug Plants

Vegetation Mat



Bauder FSM600 Protection Mat
recycled polyester and polypropylene fibre mix.

Bauder PE Foil
polyethylene foil separation and slip layer manufactured from recycled granules.

Bauder Plant E or AP2
root resistant, SBS modified bitumen membrane reinforced with 250g/m^2 recycled spunbond polyester.

www.bauder.co.uk/technical-centre

LIGHTWEIGHT SEDUM SYSTEM

Bauder XF301 extensive sedum blanket system is constructed using low maintenance planting (succulents) that provide excellent cover and increased protection to the waterproofing system.

When to Specify

The Xero Flor sedum blanket is a very versatile green roof system and is suitable for both new build and refurbishment projects. It is ideal for buildings where weight loading is a consideration or planning requirements stipulate the inclusion of a green roof.

Key Features

- The Xero Flor sedum blanket is installed as a complete system
- The most lightweight green roof system available, making it ideal for retrofitting or refurbishment projects
- Delivers instant greening of a roof with sedums and other species able to flourish in our climate
- Ideal solution where a green roof needs to be specified to meet planning requirements
- Cost effective
- Sedum blankets are grown on our farm in the UK and delivered to site within 24 hours of harvesting
- Blanket features up to 11 species of sedums, some mosses and grasses to ensure plant diversity

The plants are grown on a 'blanket' that is harvested like turf and installed by rolling out on top of the waterproofing and any other landscaping components required. The blankets are very lightweight, easy to maintain and provide instant greening to the roof.

All our green roof systems comply with FLL guidelines.

Specification Support

Specification downloads:
www.bauder.co.uk/technical-centre

Telephone helpline:
0845 271 8800

System Configuration

The multi-functional XF301 sedum system combines the vegetation support layer with a moisture retention fleece to provide the perfect base for all roofing scenarios with a labour efficient installation.

Our patented geo-textile carrier fleece with its ultraviolet resistant nylon loops provides a support base for the specially developed substrate growing medium and gives stability to the established vegetation whether on a low pitch flat roof or a 25° slope.

The pre-attached fleece is a unique feature of our XF301 sedum system, retaining moisture after rainfall and thus allowing the plants to take up the water for future use. The sedums are grown to maturity before being harvested, thus ensuring that they acclimatise quickly to their new rooftop location.

We currently cultivate 60,000m^2 of XF301 and are able to harvest the sedum and deliver to site within 24 hours.

Bauder XF301 Sedum System
pre-cultivated vegetation blanket on a patented nylon loop and geo-textile base carrier with special substrate and a pre-attached integral 8mm moisture retention fleece.

Bauder SDF Mat
multifunctional drainage, filtration and protection layer manufactured from ultraviolet resistant nylon woven loops which are thermally bonded to geo-textile filter fleece facings.

System Installation

Long length rolls being craned into position and installed.

Short 2m rolls of XF301 Sedum System installed by hand.

BAUDER PLANTING & VEGETATION

XF118 Native Species Wildflower Blanket

This vegetation blanket meets the growing demand for native species plants to satisfy the requirement of BREEAM. The 24 species of wildflowers and herbs incorporated into the blanket have been selected to provide a viable and vibrant plant that will be present on most of the biodiversity action plan lists that project specific ecology reports now demand.

XF300 Sedum Blanket and XF301 Sedum System

Both of these vegetation blankets provide dense sedum foliage cover featuring up to 11 species of sedum with some mosses and grasses for plant diversity.

The plants provide a lot of colour and are selected to suit our climate, and provide 90% ground coverage at installation.

Plug Planting

The use of small seedling plants have a number of advantages, each individual species can be chosen and the location and density of the planting can be controlled.

We supply a wide range of British provenance plug plant species for a Bauder green roof project.

Seeding

Seeding is a proven way to establish vegetation, however at roof level, the environment makes this a challenge without the correct provisions.

We supply a range of British and Scottish provenance seed mixes which have a unique blend of seed species, adhesive to bind the seed to the substrate, organic fertiliser for nutrients and mycorrhizal fungi to increase the root surface area and establish the plants as they grow.

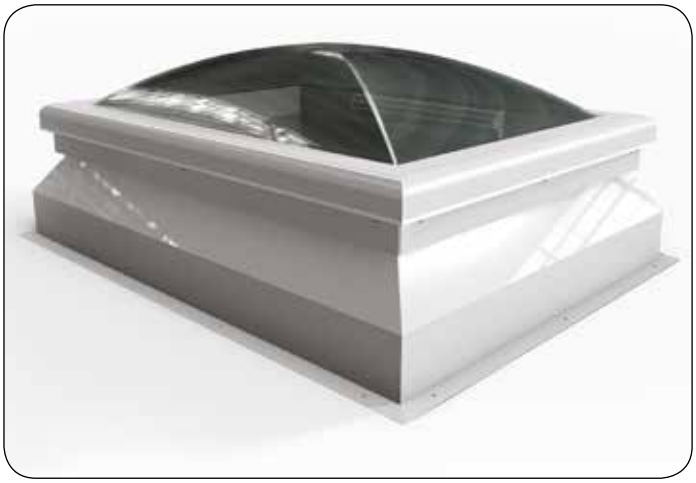
COMPLETING THE PACKAGE

As a responsible manufacturer and specialist, it is important to us to work with other key manufacturers that produce accompanying rooftop products that may affect the integrity of our waterproofing, such as rooflights, outlets and trims.

All these items need securing to the roof, which means finding a solution to roof details and working with the approved roofing contractor to ensure the installation is precise, accurate and robust.

Rooflights

Bauder Euroglaze and BauderDOME are the most advanced rooflight designs available. With high standards of illumination, insulation and ventilation, Bauder offers rooflights for all flat roofed buildings. All these glazing products are fully compatible with our roof waterproofing systems and the standard products all hold BBA certification. They are installed with a comprehensive guarantee to give total confidence and complete peace of mind.

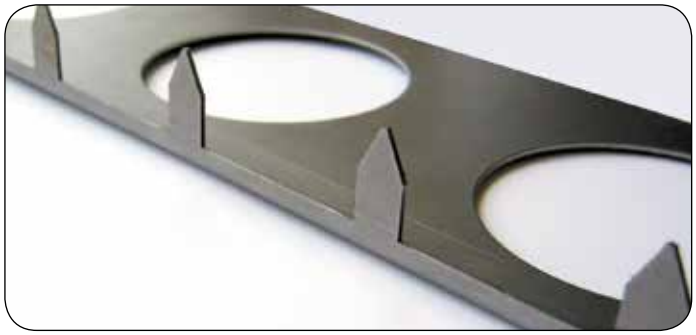


BBA BRITISH BOARD OF AGRÉMENT 05/4297

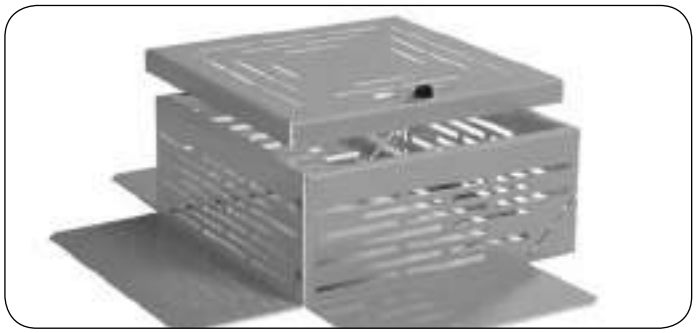
Accessories

Our full range of accessories complement a Bauder green roof and give a single point of contact for all elements required in the design. These are some examples of our range.

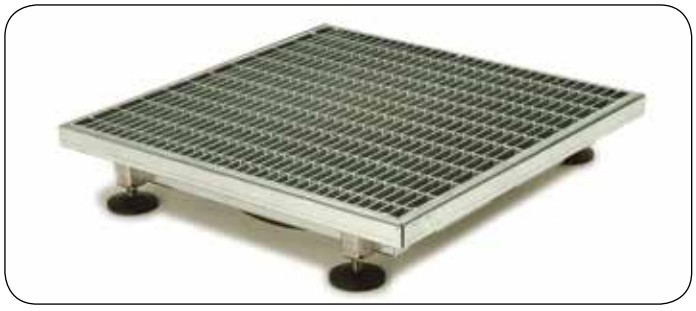
Bauder AL40 Sedum Blanket Edge Trim



Sedum Blanket Retention Strip



Inspection Chamber ALU250



Linear Drain Rainwater Outlet Access Cover

OUR SERVICE

Your project is important to us and our service is dedicated to providing a green roof solution that fully understands all the individual issues of the project, answers the waterproofing requirement and satisfies the needs of the vegetation.

New Build and Refurbishment Projects

Your green roof design can be complex, so we work with you to ensure all the roof detailing is robust and accurate. Our technical managers will meet you and from your plans they will produce, alongside our technical department, a specification package ready for the tendering process.

A typical specification and report package can include the following:

- Building type and usage.
- Recommended system configuration.
- Detailed specification.
- Green roof construction and design.
- Thermal analysis and calculations.
- Falls and drainage design.
- Wind uplift and restraint calculations.
- Detailing on all roof penetrations.
- Roof plans and tapered insulation layouts.
- Recommended approved contractors.

Creating a Biodiverse Landscape

We support the architect in the design and development of the biodiverse roof, ensuring it complies with the ecological requirements for maximum BREEAM credits and fulfils all the planning requirements.

Our technical team can produce comprehensive specifications for the roof and, if required, detailed roof plans and management plans for the design to satisfy both BREEAM inspection and local planning authorities.

Biodiverse Roof Plans

In discussions with architects we can interpret the ecological requirements to show a detail 'layout' drawing for the mounding of substrate and location of planting and surface finishes, ensuring the loading of the roof is compatible with the roof structure.

Biodiverse Green Roof Management Plans

Increasingly, local authorities require 3-5 year site specific management plans to ensure the roof establishes correctly and produces the habitat it was designed to deliver.

We offer a project specific management programme which enables the planning requirements to be discharged with our maintenance and monitoring team carrying out the work.

Vegetation

All BAP's are focused on the enhancement of the local ecosystems, to this end the provenance and suitability of the plant stock is key.

Our vegetation blankets are grown in the UK and all wildflower plugs are of British provenance.

Our Flora Seed Mix range uses seed from sources who are signatures to the Flora Locale code of practice.

Bauder Flora Seed Mix Range

Bauder Flora 3: General Purpose Mix
Bauder Flora 5: Urban Seed Mix
Bauder Flora 7: Chalk Grassland
Bauder Flora 9: Coastal Mix
Bauder Flora 11: Scottish Mix

SIX STEPS

1: Brief and Consultation
You give us your remit and together we discuss the green roof project; site suitability, level of access required, falls and drainage, weight loadings, performance expectations, preferred system application, your budget and how the works can be formulated.

2: Roof Review
Upon determining which green roof and vegetation finish is suitable for your building we will perform a detailed appraisal of all roof areas to fully assess the structural and design considerations, and propose the appropriate green roof components.

3: Report, Design and Specification Service
Designing to protect the building's construction and flat roof waterproofing is vital when delivering a green roof as many forces can affect the structure. Your detailed report and specification package takes into account these factors and will answer your original brief.

4: Contractor Selection
The Bauder approved contractors best placed to deliver your green roof will competitively tender for your project. Our national network of contractors undergo a rigorous selection process and their installers are trained specifically in the application of our systems, so you are ensured an expert installation.

5: Green Roof Installation
Once the Bauder approved contractor has been appointed, a pre-contract meeting will make sure the project delivery is well coordinated. The works are closely monitored by Bauder site technicians to ensure quality and waterproof integrity of the roof and correct installation of the green roof components.

6: Sign Off, Guarantee and Maintenance
A full final inspection is completed on the works by our site technician team following rigorous approval criteria before the guarantee is issued.

BAUDER INSTALLATIONS

Installations

You can be assured that the waterproofing, PV and green roof installation performed on your building's roof will be of the absolute highest quality, as we only allow fully trained and certified Bauder approved contractors to install our roofing solutions.

Approved Contractors

Our national network of approved contractors are given all the training, support and expert advice they need in order to deliver a high quality roof installation that we are proud to put our name to.

We look to build strong working relationships with all of our approved contractors, as we recognise just how essential the quality and experience of the installing operative is to ensuring a successful project.

Badged Operatives

Excellent workmanship is crucial to the guarantee that accompanies Bauder installations and so we have always operated a policy to train and approve the individual installer, and not simply the contracting roofing company. Each individual fixer is required to display their approved operative badge at all times showing photographic identification, name, badged operative number and the systems that they are trained to install.

Bauder Site Technicians

Once your roofing works commence, our experienced team of site technicians will monitor and inspect the workmanship at key stages to ensure that the standards required to meet our guarantee are fulfilled, as well as providing you with easy to understand reports on how the works are progressing.

Our national team is the largest of all the manufacturer-suppliers, ensuring all our sites receive the attention they deserve.

QUALITY GUARANTEED

Guarantees

A full final inspection is undertaken by our site technician team on completion of the waterproofing before the installation of the green roof commences.

Your completed roof package will be backed up by what we can confidently claim to be the most comprehensive guarantee range in today's roofing industry, giving you total reassurance with regards to the future performance of your building's roof.

Unlike others in the market, Bauder offers a full range of guarantees that map to the building's and client's requirements. Our guarantee provides you with complete satisfaction and will be bespoke to your project and its requirements.

We issue our guarantees unreservedly as part of our service because we monitor quality every step of the way from manufacture to installation.

Guarantee Options

- Products supplied by Bauder (exclusions exist).
- Workmanship and installation of Bauder products by our approved contractors.
- Design, advice, formula and specification where Bauder products are concerned.
- Financial loss from building damage due to faulty manufacture or installation of Bauder products.
- Consequential damage through Bauder waterproofing system failure due to faulty manufacture or installation of Bauder products.

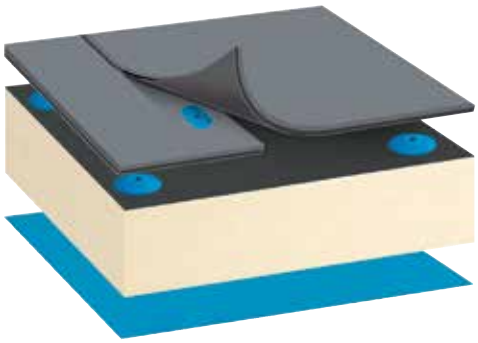
WATERPROOFING OPTIONS

Our portfolio of waterproofing systems ensures we impartially match the right solution for every project whether new build or refurbishment.

Single Ply Systems

Our single roofing systems are ideal for lightweight, fast track and cost effective construction projects. The systems provide solutions that are durable, resistant to the natural elements and are able to support extensive green roofs.

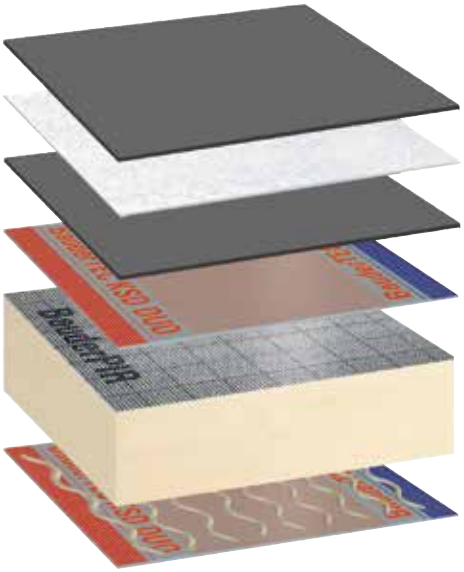
- Projects: New build or refurbishment.
- Construction: Warm, cold and inverted roofs.
- Upgrades: Extensive Green roofs and BauderSOLAR
- Certification: BBA, FM Approval.
- Guarantees: Full range.



Cold Liquid Applied Waterproofing

Our cold liquid applied systems are based on the most advanced PMMA technology. Simple to install, fast curing and long lasting; they are suitable for use in all kinds of flat roof, balcony, walkway, and terrace waterproofing and surfacing applications.

- Projects: New build or refurbishment.
- Construction: Warm, cold and inverted roofs.
- Upgrade: Extensive Green Roofs
- Certification: BBA
- Guarantees: Full range.



Bitumen Membrane Systems

Our long-established and fully integrated roof systems incorporate SBS modified elastomeric bitumen membranes and highly efficient PIR insulation to give a robust waterproofing solution with long-term durability and life-expectancy. These systems are ideal for all types of green roof scenarios and solar PV.

- Projects: New build or refurbishment.
- Construction: Warm, cold and inverted roofs.
- Upgrades: Green roofs and BauderSOLAR flat roof or BioSOLAR photovoltaics.
- Certification: BBA.
- Guarantees: Full range.

Hot Melt Structural Waterproofing

The Bauder Hot Melt Structural Waterproofing System can be installed on decks with zero degree falls.

- Projects: New build.
- Construction: Cold and inverted roofs.
- Upgrades: Green roofs and BioSOLAR photovoltaics.
- Certification: BBA
- Guarantees: Full range to accompany BioSOLAR PV system.

ONLINE TECHNICAL RESOURCES

bauder.co.uk/technical-centre

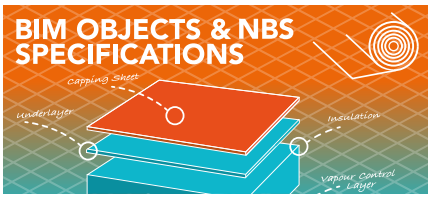
Get your specification right

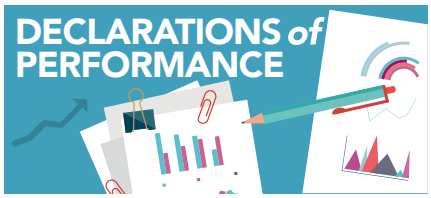
Online technical resources for your flat roof project

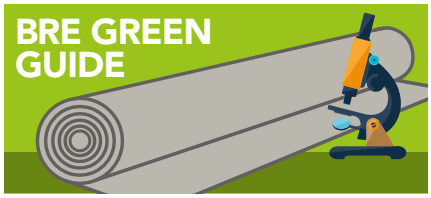
At Bauder our service is free to you and covers all elements for a successful project delivery from initial concept or site survey, through to specification package with bespoke drawings and calculations, on site monitoring and final sign-off and handover.

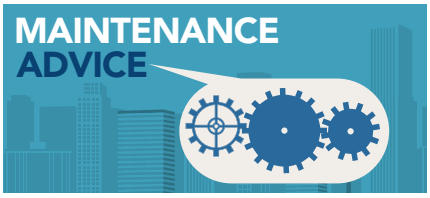
We appreciate that there are times when you need resources to get your project started and the Bauder Online Technical Centre will support you.

Technical Centre
BIM objects and NBS specifications
CAD detail drawings
System summaries
Certification
Declarations of Performance
Products
Design guides
Brochures
BRE Green Guide
Maintenance advice
Technical CPD seminars









Specification Hotline: 0845 271 8800

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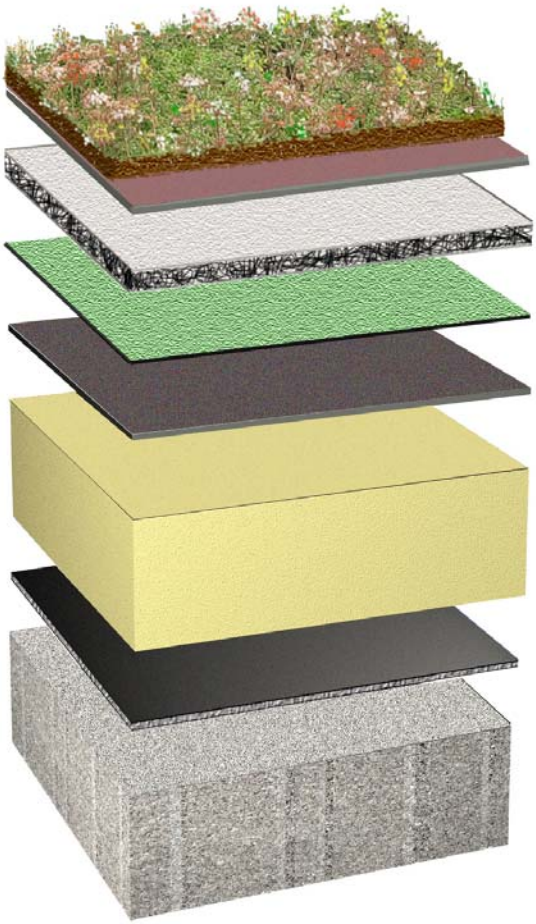
bauder.ie

Date: 11-02-2005

TECHNICAL DATA SHEET

Xero Flor sedum blanket system – Construction and Saturated loading
Insulated with roof fall of 1°-2°



Bauder Xeroflor XF301
Sedum combination blanket

Bauder SDF mat

Bauder Plant-E capping sheet

Bauder G4E

Bauder PIR insulation

Bauder DS1 DUO vapour barrier

Specification Build-up	Thickness / mm	Weight kgs / m²
Vapour barrier – DS1 DUO	3.5	4.3
Insulation	140	5.32
G4E Underlayer	4	4.8
Plant-E capping sheet	5	6.0
SDF Mat	20	0.6
XF301 sedum blanket	33	43.8
System build-up	185.5	
Overall saturated weight in kgs / m²		64.06

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BAUDER

SERVICE

GREEN ROOF MAINTENANCE

GREEN ROOF MAINTENANCE

A green roof is a real asset to a building and for it to continue to deliver the environmental and aesthetic benefits for which it was originally designed, it is important to carry out maintenance on a regular basis.

A well maintained green roof will:

- Look at its best and ensure the optimum range of species for maximum coverage and longer flowering periods
- Sustain healthy plant growth to provide a habitat for wildlife
- Improve air quality by reducing airborne dust and help local air cooling
- Offer protection to the waterproofing beneath
- Help conserve and control rainwater runoff
- Maximise the building's asset value

Common Problems

Lack of Nutrients can lead to unhealthy plants and loss of vegetation coverage, resulting in bare patches and a reduction in the variety of species present.

Invasive Weeds, Fallen Leaves and Debris can spoil the aesthetic appearance and function of your green roof, and in some circumstances can even damage the waterproofing. The removal of leaf litter from overhanging trees and other accumulated debris is essential to prevent plants from being suffocated.

Impeded Drainage can be detrimental to plant health and roof performance. For example, when the growing medium is not free-draining it can become wet and lead to root rot or invasive grasses and weeds. Regular maintenance and inspection checks ensure that the outlets and areas surrounding outlet inspection chambers remain clear and perform as intended.

Health & Safety Considerations

Following health and safety best practice is essential to all successful green roof maintenance and should be carried out by fully trained personnel who should be:

- Familiar with working at rooftop levels
- Able to carry out risk assesments
- Inspecting mansafe equipment prior to use
- Competent users of all apparatus
- Wear all necessary personal protective equipment

OUR SERVICE

With over 35 years' experience in the design and supply of green roofs throughout the UK and Ireland, we offer unparalleled knowledge and horticultural expertise for rooftop vegetation and green roof maintenance.

Our national coverage assures you of a prompt reliable service to fully meet your requirements and comprises a full inspection and evaluation of your green roof.

Our experienced maintenance team will fully comply with relevant health and safety legislation throughout the duration of the work to access the roof with suitable edge protection or fall protection systems; carry out pre-use inspections of all maintenance equipment, wear personal protective equipment where necessary; and risk assess all works prior to commencement.

Following each visit you will be provided with a bespoke report that highlights the work carried out, the condition of the roof and any necessary future works to be considered.

Call our team for a no obligation quote.

Green Roof Maintenance Team

Telephone: 0845 271 8802

Email: greenmaintenance@bauder.co.uk

Sedum Roof Maintenance

It is a common misconception that extensive green roofs are maintenance free, but this is not the case and annual maintenance is required. Our sedum maintenance service typically concentrates on:

- Ensuring adequate fertilisation of the sedum blanket
- Evaluating colour and growth rate of vegetation
- Removal of leaves, debris and any unwanted invasive weeds
- Repairing of any bare patches
- Clearance of outlets and testing of irrigation

Biodiverse & Wildflower Maintenance

The level of maintenance of the horticultural element of this type of green roof varies significantly depending on the species of vegetation incorporated, and our biodiverse and wildflower maintenance service typically focuses on:

- Ensuring a suitable balance of species on the roof
- Removal of leaves, debris and any unwanted invasive weeds
- Strimming back of vegetation and sward growth where applicable
- Ensuring adequate fertilisation of the vegetation
- Examining and testing of irrigation

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Appendix F

Stormwater Audit - Stage 1 Report and Feedback Form

CS CONSULTING
GROUP

STORMWATER AUDIT (STAGE 1)

JBA Project Code	2021s0137
Contract	Frankfort Castle Development
Client	Pembroke Partnership Ltd.
Date	08th February 2021
Author	Jamie Cullen
Subject	**Stormwater Audit - Stage 1 Report**

1 Proposed Residential Development, Frankfort Castle, Dundrum, Dublin 14.

1.1 Introduction

JBA Consulting have been requested by CS Consulting Engineers (CSC) to undertake a Stage 1 audit of the surface water drainage design for the proposed residential development at Frankfort Castle, Old Frankfort, Dundrum, Dublin 14 on behalf of the applicant Pembroke Partnership Limited. The surface water audit was undertaken in advance of a planning submission.

The audit has been completed in accordance with Dún Laoghaire Rathdown County Council's (DLRCC) Stormwater Management Policy and Stormwater Audit Procedure (Rev 0, Sept. 2012).

1.2 Stage 1 Audit

Design Parameter	Audit Result
Proposed Development	The existing site currently comprises of 2 No. residential units (No. 1 Frankfort Castle; No. 2 Frankfort Castle; and 97A Highfield Park) as well as a formerly occupied residential property currently in a state of disrepair at Frankfort Lodge. The site is bounded to the north, south and east by existing residential properties and to the west by the Luas Green Line. The site has extensive street frontage on Frankfort, on its eastern boundary and on Frankfort Court on its southern boundary. See Figure 1-1 below for the site location map.  *Figure 1-1: Site Location* The proposed development will consist of the: construction of a residential scheme comprising 115 No. apartments (44 No. one-bedroom apartments and 71 No. two-bedroom apartments) arranged in 3 No. new two-four-storey blocks (identified as Blocks A, B & C on the architects' drawings) and within the refurbished and adapted existing Frankfort Castle building (Block D). The total site area is stated to be 0.864 hectares (ha) and it appears that CSC will be developing the whole site as the net site area drained as part of the subject development is also 0.864ha. The subject of this Stage 1 stormwater audit is to review the proposed surface water drainage design and sustainable urban drainage system proposals for the proposed development.

Relevant Studies/Documents	The following documents were considered as part of this surface water audit: • Greater Dublin Strategic Drainage Strategy (GDSDS). • Greater Dublin Regional Code of Practice for Drainage Works. • The SuDS Manual (CIRIA C753). • DLRCC Green Roof Guidance Document (September 2011). • BRE Digest 365. • The audit is based on CSC Engineering Services Report dated 21st December 2020 (Rev. D1) and associated drawings.
Key Considerations & Benefits of SUDs	The key benefits and objectives of SUDs considered as part of this audit and listed below include: • Reduction of run-off rates. • Provision of volume storage. • Volume treatment provided. • Reduction in volume run-off. • Water quality improvement. • Biodiversity.
Site Characteristics	**Soil:** Infiltration tests were carried out by Downes Associates Ltd. on the 19th September 2016. These tests were carried out in 4 No. locations throughout the site and each of the tests were terminated at end of the first cycle. It was determined that the site is unsuitable for soakaway design and is made up of clay and silt soils. CSC indicated a Soil Type 4 (SPR = 0.47) was used for their calculation of Qbar. It is noted that the soakage test pits trail pits to a depth of 1.8-2.5m did not report hitting ground water. The full SI may have more information on this. **Rainfall (basis for surface water pipeline network design):** Rainfall parameters can be estimated using Met Eireann data, using the Flood Studies Report (FSR) values or the values in the GDSDS. The Met Eireann method can be more representative of a site if selected correctly. A comparison of values estimated by CSC and JBA is shown below: **CSC value** / **JBA Value** Rainfall model: Met Éireann / Met Éireann M5-60 (mm): 16.40mm / 18.00mm Ratio R: 0.277 / 0.277 **Greenfield Runoff Rate (basis of surface water attenuation design):** The Greenfield Runoff Rate has been estimated by CSC using guidance from the GDSDS, which states that surface water runoff from the overall development site would be limited to the equivalent of Qbar or 2l/s/ha (whichever is greater). Greenfield Runoff Rate has been estimated using the Institute of Hydrology Report 124 (IH124) method for flood estimation on small catchments (www.uksuds.com web site). Using the same values as CSC used for their input yielded the following Qbar values: **CSC value** / **JBA value** Qbar: 5.25 l/s / 5.02 l/s The variation between the values is minimal therefore, it is acceptable. **Windes Calculations** The Windes models as submitted for the storm sewer calculations account for 0.88ha (area prior to applying run-off factors) which is greater than the site area indicated in section 4.2 of the Engineering Services Report. The design of the storm network is indicated as 100 years return period which is

	deemed acceptable. 20% has also been added for climate change purposes. **Gradient:** There is a topographical fall across the site in a eastern direction from a high of c. 45.3m to a low of c. 43m at the eastern boundary. The adopted finished floor levels together with final site levels would allow for most SuDS technologies being feasible for the site.
SuDS Measures Considered	CS Consulting Engineers confirmed the following SuDS measures were considered and conclusions reached:

SUDS Technology	Comments
Green / Blue Roofs	Excluding the roof area of the existing block the proposed green roofs will provide coverage of 64% of the new roof areas which is above the minimum requirement of 60% by DLRCC.
Swale/ Filter Drain / Infiltration trench	None proposed for the development.
Permeable Paving	In the ESR it is stated that permeable paving will be used for the surface car parking. On drawing H081-003 permeable paving is shown on the roadway to the north and west of Block D while no permeable paving is shown to the parking bays located to the north and west of Block A.
Soakaways	A soakaway is shown on drawing H081-003 however, according to the site investigation the site is not suitable for soakaway design due to the failure of the soakaway tests.
Petrol Interceptor	A petrol interceptor is proposed downstream of the attenuation structures and hydro-brake prior to the flows entering the existing drainage network.
Other Sediment Management	No other treatment systems are proposed for the development. It is proposed to use low water usage appliances, to restrict potable water demand.
Surface Water Attenuation	Attenuation Storage will be provided to ensure that there is adequate storage for the required limited discharge of surface water volumes. Attenuation will be provided for events up to, and including, the 1.0% AEP rainfall event + 20% for Climate Change.
Site Run-off Rates	CSC propose to limit discharge to Qbar (5.25l/sec) for all storm events from the proposed new development. However, in Appendix C of the report the allowable outflow for sizing the attenuation structure is 5.1l/sec and in the Microdrainage output on pg.4 the hydro-brake has a design flow of 2.6l/sec.
Rainwater Harvesting	Local 'water butts' are proposed to retain storm water for re-use as part of the developments landscaping regime.

	Detention Basins, Retention Ponds, Stormwater Wetlands — Not included in design. **Tree Root Structural Cell Systems, Bio-retention, rain garden** — In section 4.2 of the report it is stated that tree pits will drain local hardstanding areas. It is not clear on drawing H081-003 where these tree pits will be located.
SUDs Management Train	**Source Control** and **Site Control** are addressed by the use of infiltration (interception storage) and attenuation with outflow controlled by a Hydro-brake. Interception has been provided below green roofs, tree pits, permeable paving, and soakaway. It is not clear from drawing H081-003 or the report what impermeable areas are being drained to the SuDS features and if interception requirements will be satisfied as set out in Table 24.6 of the CIRIA manual. It is not clear how interception of the impermeable roof areas will be provided. It is stated in the report that tree pits will drain local hardstanding areas, but these areas are not shown on drawing H081-003. The entrance road to the north of Block A, east and south of Block D, and south of Block B interception of this roadway is not provided. 2 No. double road gullies are shown to connect to a soakaway however, site investigations carried out determined the soil was not suitable for soakaway design. An ACO Channel is shown to collect some drainage but this does not provide interception as it is connected directly to the stormwater network. It was stated in the report that permeable pavement will be used on the surface car parking however, the permeable paving is shown on the roadway to the north and west of block D while the parking spaces to the north and west of Block A is shown as an impermeable area. **Regional Control** does not apply at the level of this development. As recommended with the SUDs Manual (Table 3.3) assuming effective pre-treatment is in place the following number of treatment train components are recommended:

	No. of treatment train components recommended	Comment/Proposals
Roof areas (apartments)	1	Green roof, local ‘water butts’
Residential roads, parking areas, commercial zones	2	Permeable pavement, soakaway (to be confirmed if this will be used), tree pits
Refuse collection, industrial areas, loading bays, lorry parks and highways.	3	Not displayed on drawings.

	Generally, site proposals meet the treatment train recommendations within the SuDS Manual. However, it is not clear if interception requirements for all areas is provided on site.
Climate Change	An allowance of 20% increase in flows has been included for climate change, both for the storm sewer calculations provided and for the rainfall intensities for the purposes of sizing the attenuation structures which is in accordance with Section 6.3.2.4 of the GDSDS.
Discharge Rate / Flow Control	From the IH124 method, the Qbar discharge rate, using FSR growth curves, from the development site is 5.25l/s. This is in accordance with the requirements of the GDSDS. However, in Appendix C a spreadsheet is used to size the attenuation structure using allowable discharge rate of 5.1l/s from which a volume of 343m^3 is estimated. This is based on an effective impermeable area derived from a total site area of 0.88ha (0.53x0.8 paved and 0.35x0.2 soft). In the Microdrainage output on pg.4 the hydro-brake is designed with a design flow of 2.6l/s and a combined storage available of 343m^3. Using the UKSuds website for an estimate of storage for a total area of 0.86ha. and an impermeable area of 0.53ha. give a Qbar of 5.46 l/s and an estimated storage volume of 217m^3. Following geotechnical site investigations it is likely that some runoff from landscaped areas will occur and the spreadsheet design has allowed for a 20% runoff factor for such areas within the positively drained area. The SPR value of 0.47 may be considered to be more appropriate. However, the Microdrainage assessment is considered to be more relevant and the impermeable area is given as 0.467 ha. based on a gross area of 0.48 ha. The permeable paving runoff is given as 50% but if there is no infiltration then this figure should be 100% but it is noted that in itself this will make little difference. The proposed hydro-brake in the Microdrainage output (which was designed for a flow of 2.6l/sec) will have a minimum outlet diameter of 75mm. Clear passages less than 75mm can be particularly susceptible to blockage. A minimum of 500mm freeboard from TWL in the attenuation structures to FFL is proposed which is in accordance with GDSDS guidance. No flooding at ground level is indicated in the Microdrainage output for the 100-year storm + 20% Climate Change (CC).
Volume Storage	CSC have provided calculations for the proposed attenuation volumes. Currently, CSC are proposing an attenuation volume of c.343m^3 (which has been sized for the 100-year return period + 20% climate change) however, this was designed with an allowable outflow of 5.1l/sec and not Qbar (5.25l/sec) which would be conservative.
Treatment Volume / Water Quality Improvement	As per Table 24.6 of the CIRIA manual, 5mm of interception storage can be assumed to be achieved for all green roof areas. It is not clear if interception will be provided in the permeable pavement as there is no details if these areas will be lined or drain additional impermeable areas. The tree pit areas are not marked on the drawing therefore making it very difficult to tell what areas are contributing to these areas. Interception of the entrance road does not appear to have been adequately provided either.
Biodiversity	Unless a permanent pond is incorporated into the design, not deemed viable to enhance biodiversity any further given current proposals incorporate green roof, tree pits, and 'water butts'.

Return Period	A 100-year return period plus 20% for climate change has been used in the design for the attenuation systems.
Exceedance flows	No indication for exceedance flows has been provided by CSC for the development.
Health & Safety and Maintenance Issues	The proposed drainage system comprises manholes, green roof's, tree pits, underground pipes, and infiltration capacity to the underside of the interception storage units. These elements are considered acceptable from a Health & Safety perspective once supplier/manufacturers guides are followed and complied with during the detailed design, construction, and operation. Optimum performance of the SuDS treatment train is subject to the frequency of maintenance provided. At detailed design stage, it is recommended that a maintenance regime be adopted. Regular maintenance of the Hydro-brake will be required to remove any blockages, particularly in the wake of heavy rainfall events or local floods. It is recommended that the bypass oil separator be fitted with an audible high-level silt and oil alarm for maintenance and safety purposes. Regular inspection and maintenance of the petrol interceptor is recommended. Please note that silt and debris removed from the petrol interceptor during maintenance will be classified as contaminated material and should only be handled and transported by a suitably licensed contractor and haulier and disposed of at a suitably licensed landfill only.
Audit Result	JBA Consulting have highlighted some areas which required further consideration by CSC in their stormwater design which can be found in the Feedback Form in Appendix A of this report.

Audit Report Prepared by: Jamie Cullen BEng (Hons) MSc.
Assistant Engineer

Approved by: Chris Wason BEng CEng MICE
Principal Engineer

Note:

JBA Consulting Engineers & Scientists Ltd. role on this project is as an independent reviewer/auditor. JBA Consulting Engineers & Scientists hold no design responsibility on this project. All issues raised and comments made by JBA are for the consideration of the Design Engineer. Final design, construction supervision, with sign-off and/or commissioning of the surface water system so that the final product is fit for purpose with a suitable design, capacity and life-span, remains the responsibility of the Design Engineers.

Appendix A – Audit Feedback Form

JBA Consulting Stormwater Audit - Stage 1 Feedback Form	
Project:	Proposed Residential Development Frankfort Castle, Dundrum, Dublin 14
Date:	08/02/2021
JBA Reviewers	Jamie Cullen - Assistant Engineer
Project Number:	2021s0137

Item No.	JBA Review Comment	Comment/Clarification Request/Suggested Mitigation	Response from Client/Client Representative	Acceptable / Not Acceptable
	08/02/2021	08/02/2021	15/02/2021	04/03/2021
	Reference Documents - H081-001 Site Location - H081-002 Topo Survey - H081-003 Drainage Layout GL - H081-004 Drainage Layout B-1 - H081-005 Drainage Layout B-2 - H081-017 Green Roof - H081-ZZ-XX-RP-C-0003_ESR_Draft (Rev. D1) 21/12/2020			
1	Engineering Services Report The Qbar calculation appears to be based off the total site area (0.864ha) is this also the NET area to be developed? Also in Appendix C for sizing the attenuation tank this is based off a total site area of 0.88ha and not 0.864ha.	CS Consulting to review and advise.	**The Qbar is calculated based on gross area i.e. red line boundary.**	Acceptable
2	Engineering Services Report & Drawing H081-003 In section 4.2 of the report it is stated that permeable paving will be used for surface car parking. However, on drawing H081-003 the permeable paving is shown on the road surface to the north and west of Block D. The parking bays to the north and west of Block A do not appear to be made up of permeable paving.	CS Consulting to review and advise.	**Noted, ESR report to be updated to reflect the actual locations of the permeable paving. Permeable paving cannot be located in the parking bays to the north of Block A as the basement extends into these bays beneath and permeable paving cannot be located to the west of Block A as there is a pumping station beneath.**	Acceptable
3	Drawing H081-003 On drawing H081-003 a soakaway is shown to drain some of the impermeable road area. However, according to the site investigation the site is unsuitable for soakaways due to failure of the soakaway tests and the description of the soil (clay and silt soils).	CS Consulting to review and advise.	**Noted, a bio retention area has been introduced immediately east of Block A. This will drain the area above the basement at the entrance. The bio retention area will have an attenuation volume of 15m3 and will discharge to the surface water system at a rate of 0.5l/sec. See revised drawing H081-003 for drainage layout and new drawing H081-020 for details.**	Acceptable
4	What type of attenuation structure will be used?	CS Consulting to review and advise.	**The proposed attenuation facility will be sub surface stormwater management chambers like StormTech or similar approved.**	Acceptable

Appendix G

Stormtech Technical Certification Documents

CS CONSULTING
GROUP

Resolute Group

1A Moyne Road,
Baldoyle,
Dublin 13
Tel: 01-4853184
e-mail: sales@resolutegroup.ie
www.resolutegroup.ie

Vat no. 3689429RH
Company Reg. No. 671068

Live Loading:

I draw your attention to page 9 and table 5 design values of the StormTech BBA attached. Here loadings are explained in further detail.

Design load basis case 1 & case 2: (Axles at 1220 mm centres, wheels at 1830 mm centres, in each case tyre contact area = 508 x 254 mm)

- *142 kilonewton axel load*
  - *Factor up 1.27 for dynamic impact*
  - *Factor up 1.2 for multiple presence*
  - *Factor up 1.75 as safety factor*
- *378 Kilonewton per axel*
- *Per BBA, based on a wheel size of 508mm * 254mm = 1,472Kilonewtown/m2*

Note that above figures are based on the minimum cover of 460mm.
If that cover level is greater which is will be, then the live loading capacity increases.

StormTech
A Division of ADS, Inc.
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Rocky Hill
Connecticut 06067
USA

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Agrément Certificate
07/4480
Product Sheet 1

STORMTECH SUBSURFACE STORMWATER MANAGEMENT SYSTEM

STORMTECH SC-310 AND SC-740 CHAMBERS

This Agrément Certificate Product Sheet(1) relates to StormTech Sc-310 and Sc-740 Chambers, used for the control and management of stormwater run-off from impermeable and permeable surfaces.

(1) Hereinafter referred to as 'Certificate'.

CERTIFICATION INCLUDES:

- factors relating to compliance with Building Regulations where applicable
- factors relating to additional non-regulatory information where applicable
- independently verified technical specification
- assessment criteria and technical investigations
- design considerations
- installation guidance
- regular surveillance of production
- formal three-yearly review.

KEY FACTORS ASSESSED

Hydraulic design — data is provided in this Certificate to assist in the design of a sub-surface stormwater management system incorporating the chambers (see section 5).

Structural performance — when used in accordance with this Certificate, the chambers have adequate strength and stiffness to resist short- and long-term loading (see section 6).

Maintenance — information is provided to assist in planning the maintenance of a completed installation of the chambers (see section 10).

Durability — when installed in accordance with this Certificate, the chambers will have a service life in excess of 50 years (see section 11).

The BBA has awarded this Certificate to the company named above for the products described herein. These products have been assessed by the BBA as being fit for their intended use provided they are installed, used and maintained as set out in this Certificate.

On behalf of the British Board of Agrément

Date of Second issue: 12 September 2017

Originally certificated on 12 October 2007

Brian Chamberlain
Head of Technical Excellence

Claire Curtis-Thomas
Chief Executive

The BBA is a UKAS accredited certification body – Number 113.

The schedule of the current scope of accreditation for product certification is available in pdf format via the UKAS link on the BBA website at www.bbacerts.co.uk
Readers are advised to check the validity and latest issue number of this Agrément Certificate by either referring to the BBA website or contacting the BBA direct.

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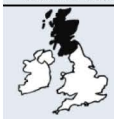
Regulations

In the opinion of the BBA, StormTech Sc-310 and Sc-740 Chambers, if installed, used and maintained in accordance with this Certificate, can satisfy or contribute to satisfying the relevant requirements of the following Building Regulations (the presence of a UK map indicates that the subject is related to the Building Regulations in the region or regions of the UK depicted):

The Building Regulations 2010 (England and Wales) (as amended)

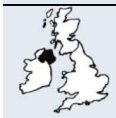
Requirement:	**H3(3)**	**Rainwater drainage**
Comment:		The products can be used in a construction to satisfy this Requirement. See section 5 of this Certificate.
Regulation:	**7**	**Materials and workmanship**
Comment:		The products are acceptable. See section 11 and the *Installation* part of this Certificate.



The Building (Scotland) Regulations 2004 (as amended)

Regulation:	**8(1)(2)**	**Durability, workmanship and fitness of materials**
Comment:		The products can contribute to satisfying this Regulation. See section 11 and the *Installation* part of this Certificate.
Regulation:	**9**	**Building standards applicable to construction**
Standard:	3.6(a)	Surface water drainage
Comment:		The products can contribute to a construction satisfying this Standard, with reference to clauses 3.6.1[(1)(2)] to 3.6.5[(1)(2)]. See section 5 of this Certificate.
Standard:	7.1(a)(b)	Statement of sustainability
Comment:		The system components can contribute to meeting the relevant requirements of Regulation 9, Standards 1 to 6 and therefore will contribute to a construction meeting a bronze level of sustainability as defined in this Standard.
Regulation:	**12**	**Building standards applicable to conversions**
Comment:		Comments in relation to the products under Regulation 9, Standards 1 to 6 also apply to this Regulation, with reference to clause 0.12.1[(1)(2)] and Schedule 6[(1)(2)].

(1) Technical Handbook (Domestic).
(2) Technical Handbook (Non-Domestic).



The Building Regulations (Northern Ireland) 2012 (as amended)

Regulation:	**23(a)(i) (iii)(b)(i)**	**Fitness of materials and workmanship**
Comment:		The products are acceptable. See section 11 and the *Installation* part of this Certificate.
Regulation:	**15**	**Rainwater drainage**
Comment:		The products can be used in a construction to satisfy this Regulation. See section 5 of this Certificate.

Construction (Design and Management) Regulations 2015
Construction (Design and Management) Regulations (Northern Ireland) 2016

Information in this Certificate may assist the client, designer (including Principal Designer) and contractor (including Principal Contractor) to address their obligations under these Regulations.

See sections: 3 *Delivery and site handling* (3.4) and 14 *Procedure* (14.1) of this Certificate.

Additional Information

This Certificate is a confirmation of Avis Technique 17/13-273*-V1 issued by CSTB, France to ADS Europe B.V. Marco Polostraat 2-14, 3165 AL Rotterdam, The Netherlands.

Technical Specification

1 Description

1.1 StormTech SC-310 and SC-740 Chambers consist of interlocking tunnels and end caps (see Figure 1) made from injection moulded yellow polypropylene. The chambers are assembled to form an underground structure. The characteristics and material properties of the products are given in Tables 1 and 2.

Figure 1 Components

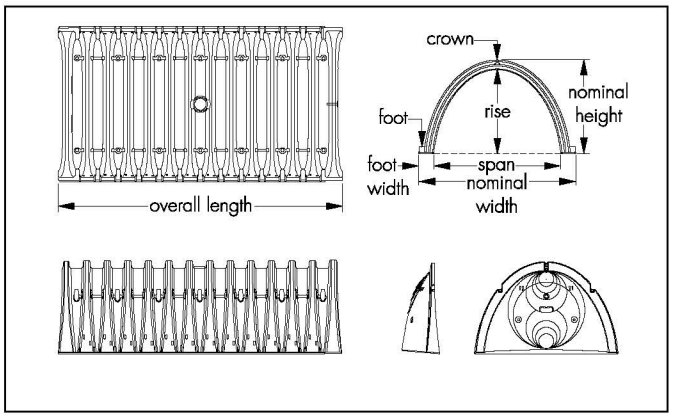


Table 1 Characteristics

Characteristic (unit)	SC-310	SC-740
Overall length (mm)	2300	2300
Installed length (mm)	2170	2170
Nominal width (mm)	864	1295
Nominal height (mm)	406	762
Span (mm)	617±10	1082±10
Rise (mm)	333±10	678±10
Foot width (mm)	100	100
Minimum wall thickness (mm)	3.18	4.45
Pitch of corrugations (mm)	165	165
Nominal mass (kg)	16	34
Maximum cut-out diameter for end cap (mm)	300	600
Nominal chamber storage volume (m^3)	0.4	1.3
Minimum installed storage volume (m^3)(1)	0.9	2.1

(1) Based on a minimum thickness of 150 mm of crushed stone above, below and between chambers assuming a porosity of 40% for the stone.

Table 2 Material properties

Property	Test method	Required specification
Tensile strength	ASTM D 638	Minimum 21 MPa (3100 psi)
Flexural modulus (1% secant)	ASTM D 790 procedure A	Minimum 931 MPa (135000 psi)
Melt flow rate	ASTM D 1238	16_5 g/10 min
Izod impact resistance	ASTM D 256 method A	Minimum 215 Jm^{-1} (4 ft-lb/in)
50-year creep modulus at 3.5 MPa (500 psi) and 23°C (73°F)	As ASTM D 2990 except test duration 10 000 hours or ASTM D 6992	Minimum 166 MPa (24000 psi)

1.2 The specification for the infill material is washed (clean), crushed stone to BS EN 13242 : 2013, sizes 20/40 or 20/32.

1.3 Spacers used to help maintain the correct spacing between adjacent rows are made from lengths of pipe to the dimensions given in Table 1.

1.4 The end caps are marked to allow holes to be cut to suit pipes up to 300 mm diameter for SC-310 or 600 mm for SC-740. Connection pipework for use with the products is outside the scope of this Certificate.

1.5 The chambers and the crushed stone edge are wrapped in a non-woven geotextile to prevent migration of fines from surrounding soils for infiltration and combined applications. A geomembrane is used to surround the crushed stone for attenuation applications where infiltration is not permitted or possible (see section 7 for additional information on geotextiles and geomembranes). Specifications of the geotextile and geomembrane are project specific and outside the scope of this Certificate. For more information, advice should be sought from the Certificate holder.

1.6 It is recommended that an isolator row (see section 5.8) is installed to prevent silting of the chambers and to allow for periodic maintenance cleaning. The isolator row traps silt, preventing it spreading to other rows, and allows access for periodic maintenance cleaning. A silt management plan should be put into effect on all sites.

1.7 Adequate venting must be provided where the chambers are wrapped with a geomembrane, see section 7.

1.8 Ancillary items used with the chambers to form a stormwater management system, but outside the scope of this Certificate, include:

- surface water connection pipework
- non-woven geotextiles and geomembranes
- air vent and ventilation systems
- silt trap and isolator row
- infiltration inlet modules
- flow control/chamber devices.

2 Manufacture

2.1 The products are manufactured by injection-moulding from polypropylene to a defined specification.

2.2 As part of the assessment and ongoing surveillance of product quality, the BBA has:

- agreed with the manufacturer the quality control procedures and product testing to be undertaken
- assessed and agreed the quality control operated over batches of incoming materials
- monitored the production process and verified that it is in accordance with the documented process
- evaluated the process for management of nonconformities
- checked that equipment has been properly tested and calibrated
- undertaken to carry out the above measures on a regular basis through a surveillance process, to verify that the specifications and quality control operated by the manufacturer are being maintained.

3 Delivery and site handling

3.1 The chambers are delivered banded onto wooden pallets with the end caps stored in the voids.

3.2 Chambers should be stored on level ground protected from accidental damage, eg by vehicular movements or other site activity.

3.3 The chambers should not be stored near fuel tanks, fuel bowsers or solvents to avoid potential chemical spillages. The units must be protected from direct sunlight if likely to be stored in excess of 12 months.

3.4 Individual chambers may be carried by two persons, normal manual handling precautions should be taken. The mass of the chambers is given in Table 1.

Assessment and Technical Investigations

The following is a summary of the assessment and technical investigations carried out on StormTech Sc-310 and Sc-740 Chambers.

Design Considerations

4 Use

4.1 The StormTech Subsurface Stormwater Management System incorporating the chambers is satisfactory for the control of stormwater run-off from impermeable and permeable surfaces. It can be utilised in three main ways:

- infiltration (retention/recharge/soakaway) — stormwater is collected in the chambers during rainfall and allowed to drain away by soaking into the surrounding ground over a substantial period of time, during and following a storm event
- attenuation (detention) — water is collected in the chambers during rainfall and released at a reduced flow rate through a flow control device, into an appropriate outfall. This reduces peak flows in the watercourse and, therefore, minimises the risk of flooding
- combination system — excess flow attenuation with a controlled outlet and soakaway provisions for infiltration of a portion of the total flow.

4.2 The design of the stormwater management system incorporating the chambers must be in accordance with the Certificate holder's instructions. Guidance on the application of sustainable drainage systems (SUDS) for new developments, such as the StormTech Stormwater Management System, can also be found in the Planning Policy Statement PPS25 *Development and Flood Risk*.

4.3 Design of the appropriate system for a specific project must always be preceded by a detailed audit of the proposed site to establish:

- existing factors and considerations applicable to the site
- predicted factors relating to the site's use following the planned development, and the parameters within which the installation is required to function
- the type of function of application required by the audit.

4.4 Once the project criteria have been established from the site audit, there are two main parts to the design procedure:

- hydraulic design and
- structural design.

5 Hydraulic design

Infiltration

Calculation principles

5.1 There are two approaches, either of which may be adopted: the Construction Industry Research and Information Association (CIRIA) Report R156 or BRE Digest 365: 2016. Further information on the design of SUDS may be obtained from CIRIA C697.

5.2 A simplified approximate approach can be used on a very small site (ie a single-house development) where detailed site infiltration rate information may not be required nor available (see Table 3). Approved Document H of the England and Wales Building Regulations allows a storage volume equal to the area to be drained multiplied by 10 mm, for areas up to 25 m^2. Beyond this size, design should be carried out in accordance with BS EN 752 : 2008 or BRE Digest 365 : 2016. It is suggested in BS EN 752 : 2008 that a storage volume equal to 20 mm multiplied by the area to be drained may be used. In Scotland, guidance for the design of single-house soakaways is given in Mandatory Standard 3.6, clause 3.6.5(1).

(1) Technical Handbook (Domestic).

5.3 When the BRE or CIRIA approach is used, the design volumes for the chambers are given in Table 4.

Table 3 Simplified soakaway design for single-house development(1)

Number of units	Storage volume (m^3)		Max area to be drained (m^2)	
	SC-310	SC-740	SC-310	SC-740
1	0.42	2.12	25(2)	106(3)
2	0.84	4.24	42(3)	212(3)
3	1.26	6.36	63(3)	318(3)
4	1.68	8.48	84(3)	424(3)

(1) When doubt exists over suitability of ground for infiltration, permeability figures should be derived by test (see BRE Digest 365).
(2) In accordance with Approved Document H.
(3) In accordance with BS EN 752 : 2008, Clause NA 4.4.8.

Table 4 Volumetric data for infiltration applications

No of rows	SC-310				SC-740			
	Volume ($m^3 \cdot m^{-1}$)	Side area ($m^2 \cdot m^{-1}$)	Base area ($m^2 \cdot m^{-1}$)	End-of-chamber area ($m^2 \cdot m^{-1}$)	Volume ($m^3 \cdot m^{-1}$)	Side area ($m^2 \cdot m^{-1}$)	Base area ($m^2 \cdot m^{-1}$)	End-of-chamber area ($m^2 \cdot m^{-1}$)
1	0.19	0.81	1.17	0.94365	0.98	1.52	1.60	2.4244
2	0.39	0.81	2.18	1.76580	1.95	1.52	3.04	4.6208
2	0.58	0.81	3.20	2.58795	2.93	1.52	4.49	6.8172
4	0.78	0.81	4.21	3.41010	3.91	1.52	5.93	9.0136
5	0.97	0.81	5.23	4.23225	4.89	1.52	7.38	11.2100

Attenuation

Calculation principles

5.4 The anticipated run-off volume (A) from the site must be estimated. The most commonly used method for evaluating storm rainfall events in the UK is the Wallingford Procedure by which the total rainfall level of storms over defined time periods ranging from five minutes up to 48 hours are assessed. The depth of water (mm) found can be multiplied by the catchment area to assess the size of attenuation systems and is traditionally based upon a two-hour storm and of a return period appropriate for the catchment. The allowable discharge rate from the site to an appropriate outfall is established but will normally be set by the Environment Agency or Planning Authorities. The outflow volume (B) to be discharged at this rate over the two-hour period is calculated and subtracted from the run-off volume (A–B). This defines the excess volume (C) to be stored in the chambers constructed as an underground tank. The number of chambers needed to contain this excess is calculated on the basis that the storage volume of the chambers is in accordance with the values given in Table 4.

5.5 The outlet of detention systems should incorporate a flow control device. The flow control device and the connecting pipe work are outside the scope of this Certificate.

Connection

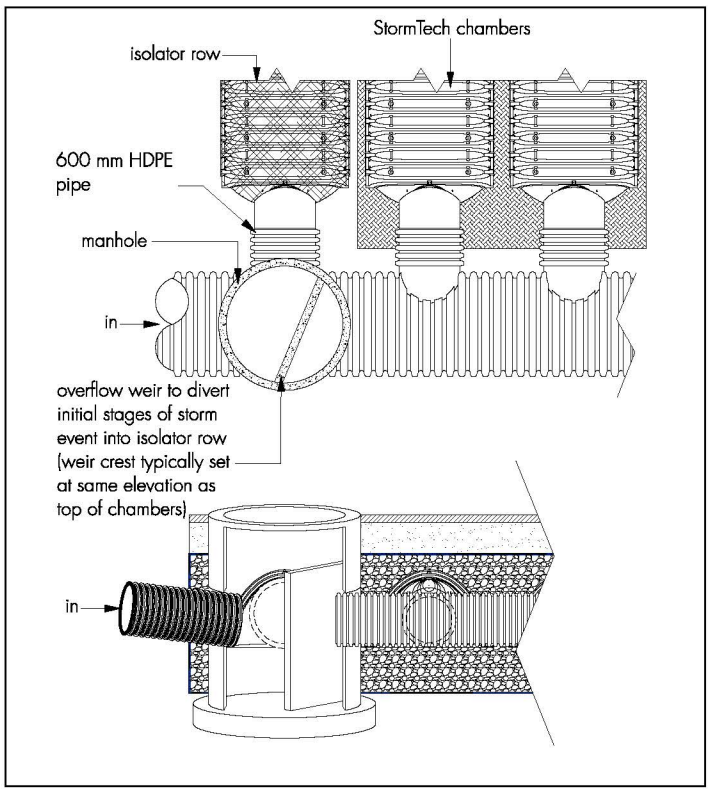
5.6 Connection is made from the chamber rows to inlet and outlet pipework through the end plates. The inlet pipework must be sized to ensure unimpeded flow for a design storm event. The inlet should be free of obstructions and, in some applications, it may be necessary to use multiple inlet pipes in a manifold configuration.

5.7 The inlet pipework should normally connect to an isolator row for capture of sediment and debris, see section 5.8. Oil separators may also need to be incorporated where there is a likelihood of contamination or the discharge site is particularly sensitive.

Isolator row

5.8 To control the build-up of sediment, chambers are normally configured with isolator rows. Chambers in the isolator row are completely enclosed with geotextile filter fabric. Sediment is captured in the isolator row and water passes through the fabric. Isolator rows are normally located at all inlet locations that receive sediments in stormwater and are configured with an upstream manhole and large diameter pipe access for inspection and removal of sediments. A high flow bypass (see Figure 2) is incorporated to enable flows that exceed the capacity of the isolator row to bypass the isolator row and feed the chamber bed directly. At the base of the chambers in the isolator row, a heavy duty woven geotextile, able to withstand jetting operations to remove sediment, must be used. The geotextile wrapped over the isolator row chambers is a non-woven geotextile generally to the same specification as that used around the crushed stone infill (see section 7).

Figure 2 Isolator row



Manifold design

5.9 The capacity of the inlet pipe must be sufficient for the anticipated flow load. The flow load may be split between a number of pipes from the adjacent manhole.

5.10 The maximum inlet pipe velocity into the chamber row is limited to prevent scouring of the stone foundation (see the *StormTech Design Manual* for maximum velocities for various inlet pipe diameters).

Flow control

5.11 The outflow from the tank must be controlled to comply with the discharge rate consent for the site. The main methods to achieve outflow control are by orifice plate, vortex control or small pipe. Comparative features and benefits of these various control flow devices should be considered before selection. However, these devices are outside the scope of this Certificate.

Outflow positioning and head calculations

5.12 There are generally two components to the outflow piping design:

- an outflow pipe or manifold of outflow pipes connecting the chambers directly to the outflow control structure
- a perforated underdrain pipe to drain the stone bedding under the chambers into the outlet control structure. These can be designed in combination or independent of each other based on the design objectives.

5.13 The invert level of the outflow pipe should be approximately flush with the bottom of the chambers to allow the chambers to drain. The outflow pipe is sized to convey the peak outflow to the outflow control structure. In some applications peak flows may be high enough to warrant multiple outflow pipes in a manifold configuration.

5.14 The underdrain is set to drain the volume of water in the stone voids below the outflow pipe. Since peak flows are conveyed through the outlet pipe, the underdrain is not sized for peak flow conveyance. Underdrains are located either along the perimeter of the bed or in trenches below the chamber array.

5.15 As the chambers fill, a depth of water develops on the upstream side of the outflow control. For design purposes, the head used in calculations is taken as that at the centre line of the outflow device.

6 Structural performance

6.1 The chambers may be placed under a wide variety of landscaped or trafficked areas and must be designed to carry all loads that will be applied, including dead and imposed loads. Design parameters and estimated loads in accordance with *AASHTO LRFD Bridge Design Manual*, Section 12.12, have been used to determine the maximum depth of installation and the maximum and minimum cover depths.

Table 5 Design values[1][2]

	Short-term (vehicle) loading[3]	**Long-term loading**
Minimum cover depth (mm)	460	460
Maximum cover depth (mm)	2440	2440
Expected service life (years)	Greater than 50	Greater than 50
Safety factor	1.75	1.95
Design load basis	Case 1: Design truck Single axle 142 kN Wheels at 1830 mm centres Case 2: Design tandem Two axles 111 kN each Axles at 1220 mm centres Wheels at 1830 mm centres In each case tyre contact area = 508 x 254 mm	18.9 $kN \cdot m^{-3}$
Dynamic impact load factor	1.27 for 460 mm depth N/A (varies linearly from 1.33 at 0 mm cover to 1.00 at 2440 mm cover)	N/A
Multiple presence multiplier	1.2	N/A
Lane load (kPa)	3.1	N/A
Strain limits[4]	3.3% for factored loads	3.3% for factored loads
Modulus for design condition	931 MPa	50 yr modulus = 166 MPa
Arch stiffness constant[5]	4.4 $kN \cdot m^{-1}\%^{-1}$	4.4 $kN \cdot m^{-1}\%^{-1}$

(1) Design vehicles, loads and load multipliers are based on *AASHTO LRFD Bridge Design Specifications*, Section 3. AASHTO is the American Association of State Highway Transportation Officials, who set design standards for all aspects of highway construction in the United States.
(2) Structural performance is dependent upon the properties of the materials and the section properties of the chamber wall. The moment of inertial (I) and cross sectional area of the chamber wall are controlled by ensuring minimum wall thicknesses of 3.18 mm for SC-310 and 4.45 mm for the SC-740 chambers.
(3) Parked and moving vehicles and construction equipment may impose load durations from instantaneous to several days. The live load design is based on the most severe combination of live load duration, load factors and modulus that is likely to occur.
(4) Design methods are based on *AASHTO LRFD Bridge Design Specifications*, Section 12.12. The product strain limit is based on compression testing of the product. Actual strains have been determined by finite element analysis and verified by test.
(5) Arch stiffness constant is defined as the load per unit length required to cause a 2% deflection in the chamber when the chamber feet are restrained laterally (see section 6.9).

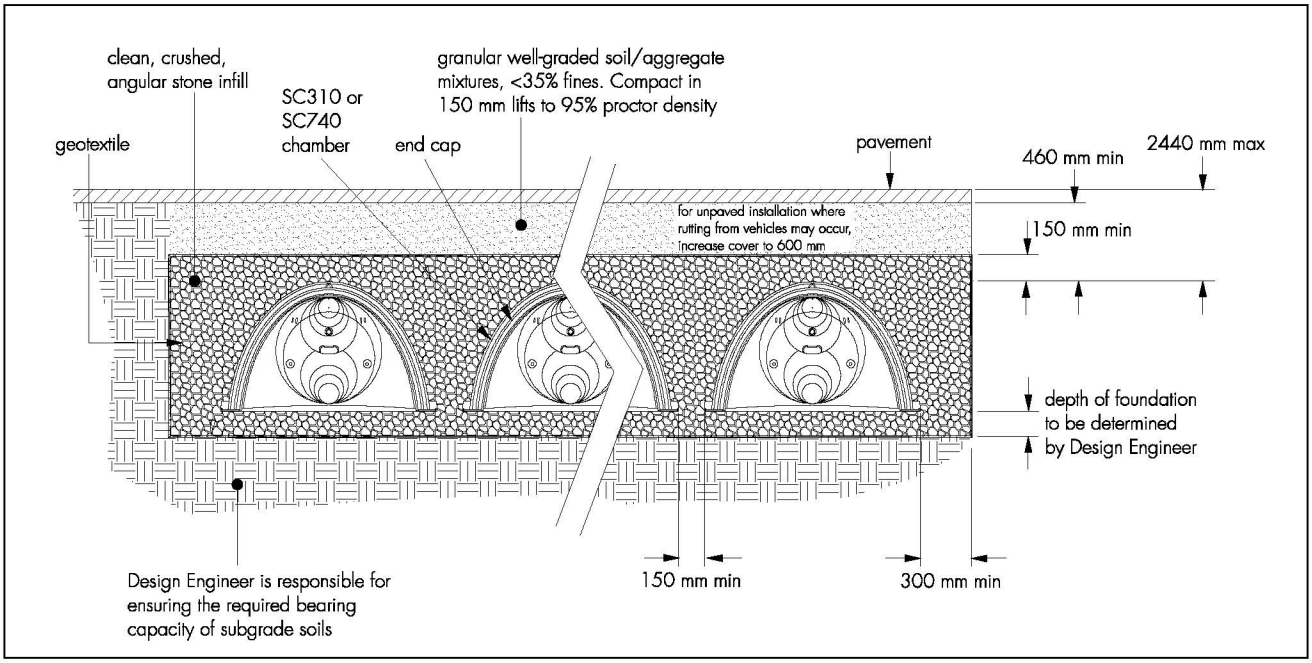
6.2 The Certificate holder does not vary the installation recommendations for lightly loaded scenarios, but instead recommends that all installations be designed to withstand vehicle traffic.

6.3 In accordance with AASHTO design methods, the maximum burial depth is limited by the long-term modulus of the polypropylene resin. Maximum burial depths given in this Certificate are based on the minimum 50-year creep modulus of 166 MPa.

6.4 One standard cross-section (see Figure 3) that details bedding and backfill requirements is specified to ensure that all installations provide the stated safety factors of 1.75 for live load design and 1.95 for long duration load design[1].

(1) These safety factors have been determined by evaluation of live loads and long-duration loads using the appropriate time-dependent (creep) material properties in accordance with *AASHTO LRFD Bridge Design Specifications*. This is a similar approach to that defined in BS 8006-1 : 2010 for polymeric soil reinforcement design.

Figure 3 Structural design cross-section



6.5 All foundation and infill stone to 150 mm above the crown of the chambers must be nominal 200 to 400 mm, clean, crushed stone in accordance with BS EN 13242 : 2013, sizes 20/40 or 20/32. Recycled crushed concrete may be an acceptable fill material but its use is outside the scope of this Certificate. Further details may be obtained from the Certificate holder.

6.6 The required minimum subgrade bearing capacity is dependent upon the cover height over the chambers and the depth of foundation stone under the chambers. Required bearing capacities range from 96 kPa for 460 mm of cover and a foundation depth of 460 mm, to 182 kPa for 2440 mm of cover and a foundation depth of 150 mm (see Table 6).

Table 6 Minimum required subgrade bearing capacity in (kPa)

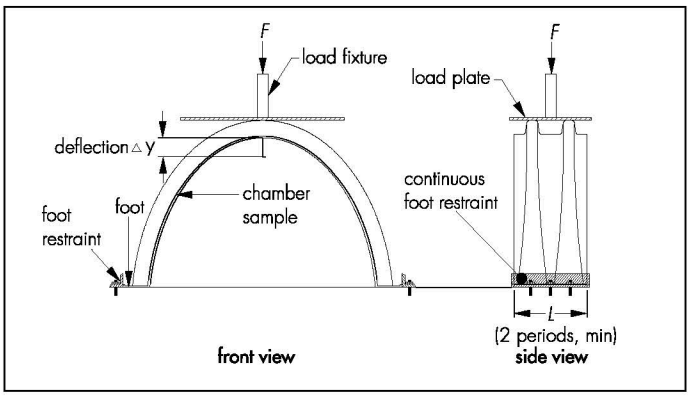
	Foundation depth (mm)		
Cover height (m)	**150**	**305**	**460**
2.44 (Max allowable)	182	134	110
2.29	172	129	105
2.13	168	124	101
1.98	158	120	96
1.83	153	115	96
1.68	148	110	96
1.50	144	110	96
1.37	144	105	96
1.22	139	105	96
1.07	139	105	96
0.91	134	101	96
0.76	129	96	96
0.61	124	96	96
0.46 (Min allowable)	120	96	96

6.7 For small-scale applications, such as soakaways for individual house roof drainage, the system is typically located at a minimum of 5 m away from the building beneath the garden.

6.8 For lightly-loaded applications, the bearing capacity of the underlying soils should typically not be exceeded by the stormwater management system. Therefore, settlement of the underlying soils should be negligible. On weak or compressible soils, the bearing capacity and settlement characteristics should be confirmed by a geotechnical engineer.

6.9 To determine the arch stiffness constant of the units, a section of chamber, at least two full periods of corrugation in length, is tested in the apparatus shown in Figure 4. The chamber foot is restrained laterally at the outer edge but is free to rotate and the load is applied at a constant crosshead speed of 2±0.2% of the rise of the chamber per minute. The arch stiffness constant is defined as the load required to cause 2% deflection divided by two times the length of the specimen. The sample is then taken to 6% deflection at the same crosshead speed to ensure its load carrying capacity is maintained and breakage does not occur.

Figure 4 Arch stiffness constant test apparatus



7 Geotextiles and geomembranes

7.1 A system incorporating the chambers requires a geotextile wrapping (see Table 7) in infiltration applications to:

- prevent clogging of the soil which surrounds the unit with silt present in run-off
- prevent soil entering the units and in storage applications to protect the geomembrane (when specified).

Table 7 Typical properties for a polypropylene geotextile

Property	Value	Test method
Mass per unit area (gm^{-2})	200	ASTM D 5261/ISO 9864
Thickness (mm)	1.5	ASTM D 5199
Grab tensile strength (N)	775	ASTM D 4632
Elongation at break (%)	60	—
Wide width tensile strength ($kN \cdot m^{-1}$)	15.0	ASTM D 4595
Elongation at break (%)	50	—
Trapezoidal tear (N)	350	ASTM D 4533
Mullen burst (kPa)	2340	ASTM D 3786
Puncture strength (N)	485	ASTM D 4833
CBR burst (N)	2670	BS EN ISO 12236
Cone drop (mm)	21	BS EN ISO 13433
Pore size (095) (mm)	0.150	ASTM D 4751 (Dry)
Permeability ($cm\ sec^{-1}$)	0.32	ASTM D 4491
Permittivity (sec^{-1})	1.8	ASTM D 4491
Water flow rate ($l \cdot min^{-1} \cdot m^{-2}$)	4885	ASTM D 4491
UV resistance (% retained at 500 hours)	70	ASTM D 4355

7.2 The selection of a suitable geotextile material for a specific StormTech infiltration system should be considered carefully, particularly with reference to the surrounding soil properties and required performance. The following points are to be considered in the selection:

- pore size — should be designed and specified to assist infiltration and prevent migration of fine soil particles
- permeability and breakthrough head — the geotextile should not limit flow of water in the system, and should have a similar or greater permeability than the surrounding materials
- puncture resistance — the geotextile must be able to resist the punching stresses caused by loading on sharp points of contact

- tensile strength — the geotextile should have sufficient strength to resist the imposed forces (eg from wheel loads)
- durability.

7.3 The Certificate holder advises that an AASHTO M288, Class 2, non-woven geotextile meets StormTech requirements. A specialist's advice should be sought if surrounding soil characteristics exhibit a high degree of fines/low infiltration capacity and/or there is risk of damage from ground contaminants.

7.4 A geomembrane is wrapped around the system in attenuation/storage applications where infiltration is not possible or permitted and acts to:

- prevent release of attenuated/stored water to surrounding ground
- prevent inflow of pollutants from contaminated subsoil into the storage reservoir.

7.5 The specification and selection of the impermeable geomembrane must be correct for the installation envisaged, to ensure it performs to the level required. It is essential that the specified material:

- withstands the rigours of installation
- resists puncture
- resists multi-axial elongation stress and strains associated with settlement
- resists environmental stress cracking
- resists damage from ground contaminants
- remains intact for the full design life.

7.6 Geomembranes less than 1 mm thick are unlikely to meet these criteria(1), and are not recommended for use with the chambers(2). A specification for a typical polypropylene geomembrane is shown in Table 8.

(1) Except in shallow, domestic installations.
(2) Further details can be supplied by the Certificate holder.

7.7 To ensure total impermeability, joints between adjacent sheets of impermeable geomembranes should be sealed correctly using proprietary welding techniques. The integrity of joints should be demonstrated by non-destructive testing(1).

(1) Advice on seam testing is given in CIRIA SP124 : 1996.

7.8 The upper surface of the isolator row is wrapped in a geotextile of the same specification as surrounding the excavation. The base of the isolator row is covered by an AASHTO M288, Class 1, woven geotextile, this must be sufficiently strong to resist damage from jetting when the isolator row is cleaned out. A typical specification for this is given in Table 9. Further information on suitable geotextiles can be supplied by the Certificate holder.

Table 8 Typical specification for a polypropylene geomembrane

Property	Value	Test Method
Thickness ±10% (mm)	1.0	ASTM D 751
Density (min) (g cm^{-3})	0.9	ASTM D 792
Tensile stress at break (min) (N·mm^{-2})	18	ASTM D 638
Elongation at break (%)	>700	ASTM D 638
Puncture resistance (min) (N)	150	FTMS 101C method 2065
Tear resistance (min) (N)	60	ASTM D 1004
Dimensional stability (max) (% change)	±2.0	ASTM D 1204 1 hour at 100°C
Stress crack resistance (%)	100	ASTM D 5397
Volatile loss 5% loss max	0.2	ASTM D 1203 method A
Ozone resistance	No cracks	ASTM D 1149
Carbon black content	2–3%	ASTM D 1603
Moisture vapour (gm^{-2}·day^{-1})	<0.1	ASTM E 96
Friction angle non-woven geotextile)	21°	Shear box
Methane permeability (gm^{-2}·day^{-1}·atm^{-1})	0.11	ASTM D 1434
Methane transmission rate (m^3·m^{-2}·s^{-1}·atm^{-1})	0.8×10^{-9}	BRE Digest 365
Permeability coefficient	1.8×10^{-12}	ASTM D 1434
Application temperature (°C)	>4	—

Table 9 Typical specification for a non-woven geotextile for isolator row

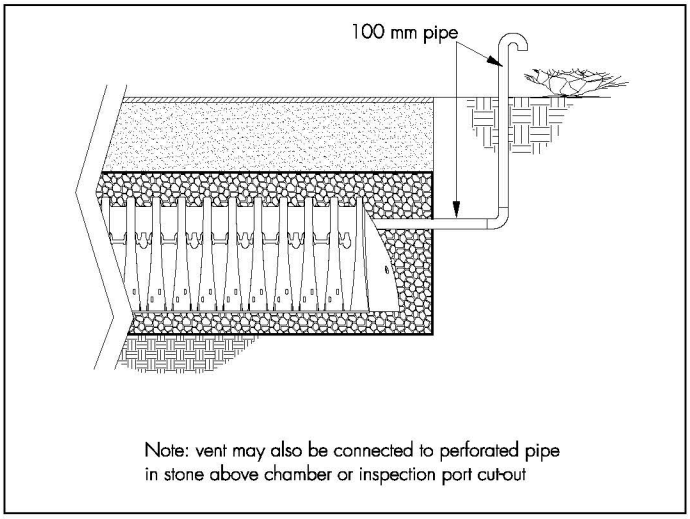
Property	Value	Test Method
Mass per unit area (g·m^{-2})	220	ASTM D 5261
Thickness (mm)	0.5	ASTM D 5199
Grab tensile strength (N)(1)	1400 x 1400	ASTM D 4632
Elongation at break (%)(1)	15 x 15	ASTM D 4632
Wide-width tensile strength (kN·m^{-1})(1)	30.6 x 35	ASTM D 4595
Elongation at break (%)(1)	10 x 8	ASTM D 4595
Trapezoidal tear (N)(1)	530 x 530	ASTM D 4533
Mullen burst (kPa)	4475	ASTM D 3786
CBR burst (N)	4780	BS EN ISO 12236
Apparent opening (mm)	0.212	ASTM D 4751
Permeability (cm sec^{-1})	0.03	ASTM D 4491
Permittivity (sec^{-1})	0.05	ASTM D 4491
Water flow rate (l min^{-1} m^{-2})	161	ASTM D 4491
Resistance (% retained at 500 hours)	90	ASTM D 4355

(1) Values for warp and fill respectively.

8 Venting

8.1 For most chamber applications, venting back through the inlet piping is sufficient. However, some applications, where inlet piping may be submerged, require additional vent capacity. A typical detail to achieve additional venting is shown in Figure 5. However, the consulting engineer may specify alternative details.

Figure 5 Typical air vent design



8.2 As a minimum, one 110 mm diameter air vent per 7500 m^2 of impermeable catchment area to be drained is generally sufficient. Venting should be positioned in a non-trafficked area, where possible.

9 Resistance to chemicals

9.1 An assessment of the polypropylene properties indicates that the products are suitable for use in contact with the chemicals likely to be found in rainwater.

9.2 An assessment of the suitability for use of the chambers on brownfield sites should be made only after a suitable site investigation (outside the scope of this Certificate) to determine the possibility for chemical attack. Particular care must be taken where acids and organic solvents are present at high concentrations. Further information can be supplied by the Certificate holder.

10 Maintenance

10.1 The owner of the structure is responsible for maintenance of the system incorporating the chambers.

10.2 The open design of the chambers allows inspection of the inside of the structure provided adequate access is available. Each chamber has a preformed socket that may be cut out to accept a 100 mm pipe to provide an inspection port. One inspection port for each isolator row is recommended.

10.3 For soakaways to individual houses, the only necessary maintenance of the system is to keep gullies clear of debris such as leaves and grass.

10.4 For large installations or where the receiving waters are environmentally sensitive, a programme of regular inspections should be established to prevent siltation of the system which, if allowed to develop, would reduce effectiveness. Chamber systems are normally inspected annually.

10.5 It is recommended that an isolator row (see section 5.8) or other silt trap is incorporated into the pipework at the inlet to the tank. There must be a maintenance plan that ensures regular cleaning of the trap to ensure correct performance. Other types of silt traps for use with the chambers are outside the scope of this Certificate.

10.6 For all flow control devices, it is sensible to incorporate access (via a manhole or similar) to the location of the pipe entry, orifice or vortex control. This will enable easy removal of any blockage. The orifice itself may be protected by a debris screen.

11 Durability

11.1 The polypropylene used to manufacture the chambers will not deteriorate significantly over the life of the structure. It will remain chemically stable under exposure to contaminants normally found in a stormwater environment and will not be susceptible to environmental stress cracking.

11.2 In common with all thermoplastic structures, the chambers will creep with time. This is taken into account in the long-term design by the use of a 50-year modulus for the material to allow for accumulated strain under a dead load. In the opinion of the BBA, the products, when used and installed in accordance with this Certificate will have a life in excess of 50 years.

12 Reuse and recyclability

StormTech Sc-310 and Sc-740 Chambers are manufactured from polypropylene materials, which are readily recyclable.

Installation

13 General

StormTech Sc-310 and Sc-740 Chambers must be installed in accordance with the Certificate holder's installation instructions and this Certificate. Special attention must be paid to temporary work requirements in excavations.

14 Procedure

14.1 The hole or trench is excavated to the required depth, dimensions and levels. It must be ensured that the plan area is sufficient to allow compaction plant access around sides to compact backfill material (300 mm minimum). The subgrade must be smooth and level without sharp drops or humps. Slopes must be cut to a safe angle or adequately supported and safe access must be provided to allow personnel to enter the excavation. Excavation should be carried out in accordance with BS 6031 : 2009, with particular attention paid to safety procedures.

14.2 The subgrade must be inspected for soft spots in the formation and if any are present, they must be excavated and replaced with compacted granular fill material to achieve the design loads in accordance with Table 5 of this Certificate or the structural engineer's requirements.

14.3 The geotextile and/or geomembrane should be placed over the prepared subgrade soils and up the side walls of the excavation. Where a membrane is used, the manufacturers' recommendations for making joints should be followed and care must be taken to prevent damage to the membrane during construction.

14.4 A layer of clean, crushed, angular, structural aggregate is placed over the entire base of the excavation and mechanically compacted to achieve a flat surface. The minimum thickness of this layer must be 150 mm (see Figure 6).

Figure 6 Installing foundation layer

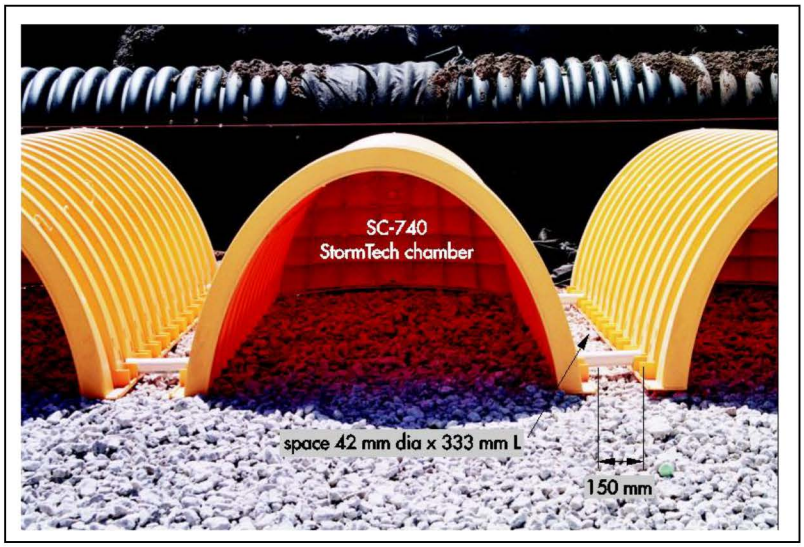
14.5 The correct position of the inlet pipe should be established and chambers laid from this point. The first chamber should be oriented with the end labelled 'Build rows in this direction' closest to the edge of the bed and the arrows pointing in the direction of build; the edge of the chambers should be a minimum of 300 mm from the perimeter of the excavation.

14.6 The row of chambers is laid with successive chambers overlapping its predecessor by the end corrugation.

14.7 End caps are placed into the end corrugation of the last chamber, which may have to be lifted to complete this operation.

14.8 Adjacent rows must be spaced at least 150 mm apart, measured at the toe of the chambers. Spacers as described in section 1.4 may be used between adjacent rows to maintain correct spacing (see Figure 7).

Figure 7 Spacing of chambers



14.9 When installing an isolator row, a woven geotextile is placed on the foundation layer immediately below the row of chambers and a non-woven geotextile is placed over the top of the isolator row (see Figure 8).

Figure 8 Isolator row

14.10 Where required, inlet and outlet connections are made by cutting holes in the end caps using a reciprocating saw. When installing a sealed system, particular care must be taken to ensure correct sealing of inlet and outlet pipes to the membrane.

14.11 Clean, crushed structural aggregate is placed between the adjacent rows and around the perimeter of the chambers. Care must be taken to ensure that the chambers are not displaced and the minimum 150 mm spacing is maintained. The aggregate must cover the crown of the chambers by at least 150 mm.

14.12 The geotextile and/or geomembrane is laid over the top of the aggregate.

14.13 The backfill above the geotextile should be Type 1 or Type 2 sub-base-selected granular material in accordance with *The Manual of Contract Documents for Highway Works*, Volumes 1 and 2. It should be compacted in 150 mm thick layers and carried out to a minimum 95% of the standard proctor density. Compaction plant should not exceed a maximum gross vehicle weight of 5 tonnes.

14.14 The overall thickness of the backfill above the crown of the chambers must be a minimum of 460 mm to the bottom of the pavement and a maximum of 2440 mm to the top of the pavement. Where it is unpaved, rutting from vehicles may occur, the minimum cover must be increased to 600 mm.

14.15 The pavement construction or landscaping is completed over the system.

Technical Investigations

15 Investigations

15.1 The manufacturing process was evaluated, including the methods adopted for quality control, and details obtained on the quality and composition of the material used.

15.2 The technical data in the confirmation report of the CSTB's Commission Chargée de Formuler des Avis Techniques were evaluated in the context of UK practice.

15.3 A site visit was made to assess the practicability and ease of installation and connection.

Bibliography

ASTM D 256 : 2006 *Standard Test Methods for determining the Izod Pendulum Impact Resistance of Plastics*

ASTM D 638 : 2014 *Test Method for Tensile Properties of Plastics*

ASTM D 751 : 2011 *Standard Test Methods for Coated Fabrics*

ASTM D 790 : 2015 *Standard Test Methods for flexural properties of unreinforced and reinforced plastics and electrical insulating materials*

ASTM D 792 : 2013 *Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement*

ASTM D 1004 : 2013 *Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting*

ASTM D 1149 : 2016 *Standard Test Method for Rubber Deterioration – Surface Ozone Cracking in a Chamber*

ASTM D 1203 : 2016 *Standard Test Methods for Volatile Loss From Plastics Using Activated Carbon Methods*

ASTM D 1204 : 2014 *Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperatures*

ASTM D 1238 : 2013 *Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer*

ASTM D 1434 : 2015 *Standard Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting*

ASTM D 1603 : 2014 *Test Method for Carbon Black in Olefin Plastics*

ASTM D 2990 : 2017 *Test Methods for tensile, compressive, and flexural creep and creep-rupture of plastics*

ASTM D 3786 : 2013 *Test Method for Bursting Strength of Textile Fabrics —Diaphragm Bursting Strength Tester Method*

ASTM D 4355 : 2014 *Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus*

ASTM D 4491 : 2017 *Test Methods for Water Permeability of Geotextiles by Permittivity*

ASTM D 4533 : 2015 *Test Method for Trapezoid Tearing Strength of Geotextiles*

ASTM D 4595 : 2011 *Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method*

ASTM D 4632 : 2015 *Test Method for Grab Breaking Load and Elongation of Geotextiles*

ASTM D 4751 : 2016 *Test Method for Determining Apparent Opening Size of a Geotextile*

ASTM D 4833 : 2013 *Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products*

ASTM D 5199 : 2012 *Test Method for Measuring the Nominal Thickness of Geosynthetics*

ASTM D 5261 : 2010 *Test Method for Measuring Mass Per Unit Area of Geotextiles*

ASTM D 5397 : 2012 *Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test*

ASTM D 6992 : 2016 *Test Method for accelerated tensile creep and creep-rupture of geosynthetic materials based on time-temperature superposition using the stepped isothermal method*

ASTM E 96 : 2016 *Test Methods for Water Vapor Transmission of Materials*

BRE Digest 365 : 2016 *Soakaway Design*

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BS 8006-1 : 2010 + A1:2016 *Code of practice for strengthened/reinforced soils and other fills*

BS EN 752 : 2008 *Drain and sewer systems outside buildings*

BS EN 13242 : 2013 + A1 : 2007 *Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction*

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BS EN ISO 13433 : 2006 *Geosynthetics — Dynamic perforation test (Cone Drop Test)*

CIRIA C697 *The SUDS Manual*

CIRIA Report R156 *Infiltration Drainage — Manual of Good Practice*

CIRIA SP124 : 1996 *Barrier, liners and cover systems for containment and control of land contamination*

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Manual of Contract Documents for Highway Works, Volume 1 *Specification for Highway Works*, May 2014 (as amended)

Manual of Contract Documents for Highway Works, Volume 2 *Notes for Guidance on the Specification for Highway Works*, May 2014 (as amended)

16 Conditions

16.1 This Certificate:

- relates only to the product/system that is named and described on the front page
- is issued only to the company, firm, organisation or person named on the front page – no other company, firm, organisation or person may hold claim that this Certificate has been issued to them
- is valid only within the UK
- has to be read, considered and used as a whole document – it may be misleading and will be incomplete to be selective
- is copyright of the BBA
- is subject to English Law.

16.2 Publications, documents, specifications, legislation, regulations, standards and the like referenced in this Certificate are those that were current and/or deemed relevant by the BBA at the date of issue or reissue of this Certificate.

16.3 This Certificate will remain valid for an unlimited period provided that the product/system and its manufacture and/or fabrication, including all related and relevant parts and processes thereof:

- are maintained at or above the levels which have been assessed and found to be satisfactory by the BBA
- continue to be checked as and when deemed appropriate by the BBA under arrangements that it will determine
- are reviewed by the BBA as and when it considers appropriate.

16.4 The BBA has used due skill, care and diligence in preparing this Certificate, but no warranty is provided.

16.5 In issuing this Certificate the BBA is not responsible and is excluded from any liability to any company, firm, organisation or person, for any matters arising directly or indirectly from:

- the presence or absence of any patent, intellectual property or similar rights subsisting in the product/system or any other product/system
- the right of the Certificate holder to manufacture, supply, install, maintain or market the product/system
- actual installations of the product/system, including their nature, design, methods, performance, workmanship and maintenance
- any works and constructions in which the product/system is installed, including their nature, design, methods, performance, workmanship and maintenance
- any loss or damage, including personal injury, howsoever caused by the product/system, including its manufacture, supply, installation, use, maintenance and removal
- any claims by the manufacturer relating to CE marking.

16.6 Any information relating to the manufacture, supply, installation, use, maintenance and removal of this product/system which is contained or referred to in this Certificate is the minimum required to be met when the product/system is manufactured, supplied, installed, used, maintained and removed. It does not purport in any way to restate the requirements of the Health and Safety at Work etc. Act 1974, or of any other statutory, common law or other duty which may exist at the date of issue or reissue of this Certificate; nor is conformity with such information to be taken as satisfying the requirements of the 1974 Act or of any statutory, common law or other duty of care.

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Deutsches Institut für Bautechnik

DIBt

General building approval / general design approval

Approval body for construction products and types of construction
Building inspection office

One from the federal and state administration jointly funded agency established under public law
Member of EOTA, UEAtc and WFTAO

Date: 13th Feb 2020

Reference: III 55-1.42.1-30/19

Number:
Z-42.1-525

Valid Period:
from: **13th Feb. 2020**
to: **13th Feb.2025**

Applicant

ADS Europe b.v.
Marco Polotraat 2-14
3165 AL ROTTERDAM
NETHERLANDS

Subject matter of this note:

"StormTech" rainwater infiltration tunnel system made of PP and PE

The subject matter mentioned above is with this generally approved/approved by the building authorities.
This notice includes 13 pages and five annexes.

I GENERAL PROVISIONS

1 This notice confirms the usability or/and applicability of the subject matter in line with the building codes.

2 This notice does not replace the permits, consents, and certificates required by law for the execution of building projects.

3 This notice is issued without prejudice to the rights of third parties, in particular private property rights.

4 The user or operator of the subject matter is to be provided with copies of this notice, without prejudice to more extensive provisions in the “Special Provisions“. Besides, the user or operator of the subject matter should be informed that this notice has to be available at the point of use or operation. At request, copies must be made available to the authorities involved.

5 This notice may only be reproduced in full. Publication in extracts requires the consent of the German Institute for Structural Engineering (Deutsches Institut für Bautechnik). Texts and drawings of advertising collateral must not contradict this notice, and all translations must contain the note “translation of the German original version not verified by Deutsches Institut für Bautechnik“.

6 This notice is revocable. Provisions may be supplemented and amended afterwards, in particular, if required because of new technical knowledge.

7 That notice shall cover the particulars and documents submitted by the applicant. Modifications of these particulars and documents are not covered by this notice and must be disclosed to the German Institute for Structural Engineering (Deutsches Institut für Bautechnik) immediately.

8 The general design approval covered by this notice is also the general building approval for the type of design.

II SPECIAL PROVISIONS

1 The subject matter of the regulation and scope of use or application

The subject matter of this general building approval is a tunnel system made of high-density polyethylene (HD-PE) or polypropylene (PP) with the designation “STORMTECH“ for underground infiltration and retention systems where rainwater is percolated.

The approval applies to the “StormTech“ tunnel system, including

- chambers with the designation “StormTech SC 160“ made of PP,
- chambers with the designation “StormTech SC 310“ made of PP or HD-PE,
- chambers with the designation “StormTech SC 740“ made of PP,
- chambers with the designation “StormTech MC 3500“ made of PP,
- chambers with the designation “StormTech MC 4500“ made of PP and
- the corresponding end caps made of PP or HD-PE.

The tunnel systems may only be installed and used in combination with the specified backfill material with defined properties.

The rainwater infiltration facilities consisting of the tunnel system mentioned above, here referred to as infiltration facilities, may only be used for the infiltration of rainwater into the ground under the scope of DWA-A 138[1]. Other applications, such as the percolation of untreated rainwater runoff from contaminated and suspected contaminated sites and from areas where substances harmful to water are handled (e. g. petrol stations), are not included in the scope of this approval.

The tunnel system shall be installed with an earth cover of 1.00 m or more.

The areas above infiltration systems may not be built over - except for traffic areas. The traffic load of areas above infiltration systems must not exceed the load class Bk3.2, according to RStO 12[2].

The general building approval is only valid for the use of the tunnel system in areas not endangered by earthquakes.

The infiltration systems consist of a maximum of one tunnel layer with a total height of 305 mm (SC 160), 406 mm (SC 310), 762 mm (SC 740), 1143 mm (MC 3500) or 1524 mm (MC 4500). The tunnels may be installed parallel to each other with a minimum distance of 150 mm (SC 160, SC 310, SC 740), or 250 mm (MC 3500, MC 4500) at base height, but not in multiple layers.

The tunnel systems are considered as not accessible in the sense of the applicable health and safety regulations.

[1] DWA-A 138 Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfälle. V. (DWA) - Worksheet 138: Planning, construction and operation of rainwater infiltration systems, edition: 2005-04

[2] RStO 12 Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV): Guidelines for the superstructure standardization of traffic areas; FGSV publishing house; Edition: 2012

2 Provisions related to the components of the tunnel system

2.1 Properties and composition

2.1.1 General information

An infiltration system consists of one or more chambers installed in series, which are closed at the end by an end cap. Chambers and caps are joined together by positive locking without any fastening elements, with the adjacent elements overlapping each other by at least one profile rib.

Each infiltration system is backfilled with specified material after the tunnels have been installed and covered with geotextiles.

2.1.2 Material and material characteristics

The components of the tunnel system consist of high-density polyethylene or polypropylene produced by the material specifications deposited with the German Institute for Structural Engineering (Deutsches Institut für Bautechnik (DIBt)).

As a minimum, the material must have the following properties before processing:

Polyethylene

- Density according to DIN EN ISO 1183-1[3] 0.961 g/cm³ ± 0.020 g/cm³
- Melt mass flow rate (MFR 230 °C/2.16 kgs) according to DIN EN ISO 1133[4] 12.0 g/10 min ± 1.0 g/10 min
- Tensile strength σ_M according to DIN EN ISO 527-1[5] ≥ 18.0 MPa
- Flexural modulus of elasticity E_f according to DIN EN ISO 178[6] ≥ 900 MPa

Polypropylene

- Density according to DIN EN ISO 1183-1[3] 0.900 g/cm³ ± 0.020 g/cm³
- Melt mass flow rate (MFR 230 °C/2.16 kgs) according to DIN EN ISO 11334 12.0 g/10 min ± 1.0 g/10 min
- Tensile strength σ_M according to DIN EN ISO 527-1[5] ≥ 23.0 MPa
- Flexural modulus of elasticity E_f according to DIN EN ISO 178[6] ≥ 1,100 MPa

After processing, the material must have at least the following properties:

Polyethylene

- Density according to DIN EN ISO 1183-1[3] 0.955 g/cm³ ± 0.020 g/cm³
- Melt mass flow rate (MFR 230 °C/2.16 kgs) according to DIN EN ISO 1133[4] 11.0 g/10 min ± 1.5 g/10 min
- Tensile strength σ_M according to DIN EN ISO 527-1[5] ≥ 18.0 MPa
- Flexural modulus of elasticity E_f according to DIN EN ISO 178[6] ≥ 900 MPa
- Flexural strength σ_{fM} according to DIN EN ISO 178[6] ≥ 30.0 MPa
- Oxidation induction time OIT according to DIN EN 728[7] > 80.0 min

[3] DIN EN ISO 1183-1 Plastics - Method for determining the density of non-foamed plastic materials - Part 1: Immersion method, liquid pycnometer method and titration method (ISO 1183-1:2004); German version of EN ISO 1183-1:2004; Edition: 2004-05

[4] DIN EN ISO 1133 Plastics - Determination of melt mass flow rate (MFR) and melt volume flow rate (MVR) of thermoplastics (ISO 1133:2005); German version of EN ISO 1133-2005; Edition: 2005-09

[5] DIN EN ISO 527-1 Plastics - Determination of tensile properties - Part 1: General principles (ISO 527-1:1993 including Cor.1:1994); German version of EN ISO 527-1: 1996; Edition: 1996-04

[6] DIN EN ISO 178 Plastics - Determination of flexural properties (ISO 178:2001 + Amd.1:2004); German version of EN ISO 178:2003 + A1:2005; Edition: 2006-04

Polypropylene

- Density according to DIN EN ISO 1183-1[3] 0.900 g/cm³ ± 0.020 g/cm³
- Melt mass flow rate (MFR 230 °C/2.16 kgs) according to DIN EN ISO 1133[4] 13.5 g/10 min ± 1.5 g/10 min
- Tensile strength σ_M according to DIN EN ISO 527-1[5] ≥ 20.0 MPa
- Flexural modulus of elasticity E_f according to DIN EN ISO 1786 1,000 MPa
- Flexural strength σ_{fM} according to DIN EN ISO 178[6] ≥ 30.0 MPa
- Oxidation induction time OIT according to DIN EN 728[7] > 25.0 min

2.1.3 Dimensions and weight

Shape, dimensions, and tolerances of the tunnel system shall be as specified in Appendices 1 to 5.

The minimum weight of the chambers and end caps shall be:

- "STORMTECH SC 160" made of PP,	chambers	10.9 kgs
	End caps	0.9 kgs
- "STORMTECH SC 310" made of PP,	chambers	16.6 kgs
	End caps	1.63 kgs
- "STORMTECH SC 310" made of HD-PE,	chambers	17.5 kgs
	End caps	1.64 kgs
- "STORMTECH SC 740" made of PP,	chambers	34.9 kgs
	End caps	5.5 kgs
- "STORMTECH SC 740" made of HD-PE,	chambers	33.6 kgs
	End caps	5.53 kgs
- "STORMTECH MC 3500" made of PP	chambers	60.8 kgs
	End caps	19.5 kgs
- "STORMTECH MC 4500" made of PP	chambers	54.4 kgs
	End caps	54.4 kgs

2.1.4 Conditions of the tunnel system

When inspected without optical aids, the components of the tunnel system shall have a smooth surface as specified for the manufacturing process and be free of defects, grooves, bubbles, impurities, and sunken areas or other irregularities.

All surfaces shall be free of burrs.

2.1.5 Colour

The colour of the tunnel system components shall be yellow throughout.

2.1.6 Mechanical properties

To respect the maximum permissible deformation of Δh_{MAX} = 2% of the chamber component height and the associated end caps height, the vertical apex crushing force $F_{S,ASC}$ calculated according to the f section 2.3.2 item 8, shall be at least equal to the values given in Table 1.

[7] DIN EN 728 Plastic piping and protective conduit systems - Pipes and fittings made of polyolefines - Determination of the oxidation induction time; German version of EN 728:1997; Edition: 1997-03

Table 1: Characteristic values to determine the bending stiffness of the tunnel elements

	$F_{S,MAX}$ [kN/m]	Δh_{MAX} [mm]
"STORMTECH SC 160"	8.8	4.9
"STORMTECH SC 310"	8.8	6.9
"STORMTECH SC 740"	8.8	13.7
"STORMTECH MC 3500"	7.3	20.6
"STORMTECH MC 4500"	7.3	27.4

2.1.7 Geotextiles

Use for the construction of infiltration systems only geotextiles with the technical specifications deposited with the DIBt (German Institute for Construction Technology), which also meet the requirements of DIN EN 13252[8].

Cover those areas of the tunnel floor where high-pressure flushing is to be carried out as part of the tunnel maintenance, in particular in the entrance areas of the tunnels, with geotextiles of stretched and woven tapes as laid down in the technical specifications deposited with the DIBt, which also meet the requirements of DIN EN 132499.

2.2 Production, packaging, transport, storage, and labelling

2.2.1 Production

The chambers and end caps of the tunnel system shall be manufactured by injection moulding, in compliance with the f Section 2.3.2, having the characteristics described in Section 2.1, as laid down in the specifications of Appendices 1 to 5.

As a minimum, the following manufacturing parameters must be calibrated and continuously logged each time the machine is started for production of the chambers and end caps:

- cycle time,
- injection pressure and
- extruder temperature.

Only the material deposited with DIBt and designated with the trade name, manufacturer, and characteristic values shall be used for production, as specified in section 2.1.2.

Circulating material of the same recipe from the applicant's production facilities may be used.

2.2.2 Packaging, transport, and storage

The components of the tunnel system shall be fixed for storage and transport such a way that no inadmissible deformation or damage occurs.

The relevant storage and transport instructions of the applicant and the relevant regulations on health and safety must be observed.

2.2.3 Identification

The components of the tunnel system must be labelled by the applicant with the German mark of conformity (Ü) according to the conformity mark regulations of the countries, including the approval no. Z-42.1-525 as well. Components shall only be labelled if they meet the requirements of section 2.3.

[8] DIN EN 13252 Geotextiles and geotextile-related products - required characteristics for the application in drainage systems; German version of EN 13252:2014; Edition: 2014-06

[9] DIN EN 13249 Geotextiles and geotextile-related products - required characteristics for use in road construction and construction of other traffic surfaces (except railway construction and asphalt pavements); German version of EN 13249:2014; Edition: 2014-06

Besides, all components of the tunnel system shall be clearly and permanently marked, at least once, with the following information:

- Type designation
- Material HDPE/PP
- Dimensions
- Manufacturing plant
- Date of manufacture

2.3 Certificate of conformity

2.3.1 General information

Each manufacturing plant shall confirm the conformity of the tunnel system components with the f this general building approval through a certificate of conformity based on their production control and regular third-party monitoring, including an initial inspection of the tunnel system components according to the provisions below.

The applicant shall involve a recognised certification body and an inspection body recognised for this purpose to pursue the issuance of the certificate of conformity and the external monitoring, including the product tests to be carried out.

The applicant shall declare that a certificate of conformity has been issued by marking the construction components with the mark of conformity (Ü) indicating the intended use.

The certification body shall provide the German Institute for Structural Engineering (Deutsches Institut für Bautechnik DIBt)) with a copy of the certificate of conformity issued by it.

Also, a copy of the initial test report shall be sent to the German Institute for Structural Engineering (Deutsches Institut für Bautechnik (DIBt)) for information.

2.3.2 Factory production control system

A factory production control system shall be established and implemented in each manufacturing plant. Factory production control means the continuous monitoring of production to be carried out by the applicant to ensure that their manufactured products comply with the f this general building approval.

The factory production control shall include at least the measures listed below:

- Description and verification of the raw material and components:

  The characteristics of the material used and their verification shall meet the requirements specified in section 2.1.2. The manufacturer of the tunnel system components shall have the material's conformity with the specifications laid down in Section 2.1.2 confirmed by the raw material supplier at each delivery by presenting an inspection certificate 3.1 based on DIN EN 1020410.

  The compliance with the requirements on density and melt mass flow rate of the delivered material shall be checked once randomly with each delivery within the scope of the factory production control.
- Inspections and tests to be carried out during manufacture: The requirements of section 2.2.1 shall be met.
- Evidence and tests to be carried out on the finished component: As a minimum, the requirements of the following sections shall be verified:

[10] DIN EN 10204 Metallic products - Types of inspection documents; German version EN 10204:2004; Edition: 2005-01

1. Check the melt mass flow rate of the processed polypropylene once a week and at any change of raw material following DIN EN ISO 1133[4] to determine compliance with section 2.1.2 and the threshold values specified.
2. Check compliance of the tensile strength σ_M mentioned in section 2.1.2 any time the raw material is changed and also randomly once a month following DIN EN ISO 527-2[11].
3. Check compliance with the oxidation induction time OIT specified in section 2.1.2 at any change of raw material and also randomly once a month, following DIN EN 728[7].
4. Check the conformity of the tunnel system components dimensions specified in Section 2.1.3, at the start of production and continuously after that once a day and at any change of raw material or installation parameters.

   Check all dimensions related to function, including the following, as a minimum:
   - Length, width, and height,
   - rib geometry and
   - wall thickness.
5. Check the compliance of the weight of the tunnel system components, as specified in item 2.1.3, at the start of production and continuously after that once a day, and at any change of raw material or installation parameters.
6. Check the compliance with the specifications on the tunnel system components, set out in section 2.1.4, on an ongoing basis by optical methods at the start of production and continuously once a day after that, and in case of changed raw materials or changed parameters of the installation.
7. Check the conformity of the tunnel system components colour specified in Section 2.1.5 continuously at the start of production and after that in every shift.
8. To check the strength properties specified in section 2.1.6. The chambers and the associated end caps of the infiltration system shall be conditioned for at least 24 hours at 22 °C to 23 °C room temperature and then tested with laterally secured supports and an increasing force applied longitudinally over the apex.

   Apply the load at a test speed of 2 % (the clear height of the component tested) per minute and increase continuously until the maximum test load $F_{S,ASC}$ has been reached.

   The load input and the vertical deformation in the apex area shall be logged continuously during the entire test.

   A failure of the tested component is present if there is:
   - a drop in force before reaching the maximum test load,
   - a loss of stability before reaching the maximum test load, or
   - a vertical deformation in the apex area > Δh_{MAX} before reaching the maximum test load $F_{S,ASC}$.

[11] DIN EN ISO 527-2 Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion compounds (ISO 527-2:1993 including Cor.1:1994); German version of EN ISO 527-2:1996; Edition: 1996-07

The verification of the strength properties of the infiltration tunnels shall be carried out at the start of production, after any change of raw material or installation parameters, at least once a day.

9. Verify the compliance with the f manufacture and marking specified in sections 2.2.1 and 2.2.3 on a running basis during manufacture.

Record and evaluate the results of factory production control. The records shall contain at least the following information:

- Designation of the produced component or the starting product and its constituents
- Type of inspection or audit
- Date of manufacture and testing of the component or the starting material
- Results of the checks and inspections and, where applicable, comparison with the requirements
- Signature of the people responsible for factory production control

The records are to be kept for a minimum of five years and presented to the inspection agency engaged for external inspection. These records must be submitted to German Institute for Structural Engineering (Deutsches Institut für Bautechnik) and the responsible supreme building supervisory authority at request.

If the test result is unsatisfactory, the applicant shall immediately take the necessary measures to remedy the failure. Components that do not comply with the requirements shall be handled accordingly to avoid confusion with conforming products. When the defect has been remedied, repeat the checks in question insofar as technically possible and necessary to prove that the defect has been remedied.

2.3.3 External inspection

The production control of each manufacturing plant must be regularly checked by external inspection, at least twice a year.

Besides, an initial inspection of the chambers with the designation “StormTech SC 160“ must be carried out as part of the external inspection. The fulfilment of the requirements of section 2.3.2 shall be checked at random, in particular, if

- The material properties requirements specified in section 2.1.2 are met and
- the mechanical properties of the tunnel system components are tested as specified in Section 2.1.6.

Sampling and testing are the responsibility of the recognised inspection body.

The results of certification and external inspection must be kept for five years as a minimum. The certification body or the inspection body has to present them to the German Institute for Structural Engineering (Deutsches Institut für Bautechnik) and the competent supreme building inspection authority at request.

3 Provisions for planning, dimensioning and execution

3.1 Provisions for dimensioning

3.1.1 Infiltration performance

Unless otherwise specified below, the design principles and conditions of Worksheet DWA-A 138[1] and technical bulletin ATV-DVWK-M 153[12] of the German Association for Water Management, Wastewater and Waste (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfälle) V. shall apply to the design of infiltration systems.

[12] ATV-DVWK-M 153 German Association for Water Management, Wastewater and Waste (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfälle) V. (DWA) - Leaflet 153: Recommendations on handling rainwater; Edition: 2000-02

To ensure the performance of the infiltration system, the corresponding hydraulic proofs of the soil infiltration capacity and the local groundwater conditions, including subsoil expertise, must be obtained as the basis of system design.

3.1.2 Stability

The stability of the infiltration systems must be verified in each case by a static calculation or by a certified static type calculation to determine the ultimate limit state (GZT) and the serviceability limit state (GZG) for the maximum permissible limit deformations of $\Delta h_{permissible} \leq$ 20 mm after a scheduled service life of 50 years after installation and backfilling.

$$\sigma_{E,d} \leq \sigma_{R,d} \quad (1)$$

where $\sigma_{E,d}$ is the design value of the stress/actions on the component

$\sigma_{R,d}$ is the rated value of the component resistance

A testing office or a test engineer specialized in stability calculations must check the static calculation. The proof is provided if the load-bearing capacity, according to equation (1) is demonstrated. Type statics may be created for standard installations, which must be checked by a structural analysis testing office. We recommend to commission testing offices, or testing engineers specialized in stability calculations which/who have special knowledge of plastics construction, e. g. G.:

- the testing office for stability of the LGA located in Nuremberg,
- the German Institute for Structural Engineering (for type approvals).

The determination of the loads (actions) $\sigma_{E,d}$ is based on a failure model with lateral bedding.

The effects must be determined

- for permanent, constant loads $\sigma_{G,k}$ according to DIN EN 1997-1[13] and DIN 1054[14], with a partial safety factor γ_G to the above standards applied, which, however, is at least equal to the value in Table 2.
- for variable loads $\sigma_{Q,k}$ according to DIN EN 1991-2[15] with a partial safety factor γ_Q, which is at least equal to the value in Table 2.

To calculate the design value $\sigma_{R,d}$ related to the resistance of infiltration system components, we assume a typical maximum short-term compressive strength $\sigma_{R,k}$ of the infiltration system for the ultimate limit state given in Table 3, and/or for the serviceability limit state given in Table 4, considering a partial safety value γ_M for the component resistance, which is equal or better than the value in Table 2.

To calculate the reduction of resistance of the tunnel system components, we apply the reduction factors in Table 5 as a minimum.

The verification for the limit states is then based on the following equation:

$$\sigma_{E,d} = \Sigma\, \sigma_{G,k} \times \gamma_G + \Sigma\, \sigma_{Q,k} \times \gamma_Q \leq \sigma_{R,k} / (\gamma_M \times A_1 \times A_2 \times A_3 \times A_4 \times A_5) = \sigma_{R,d} \quad (2)$$

13	DIN EN 1997-1	Eurocode 7 - Design, calculation and dimensioning in geotechnology - Part 1: General rules; German version EN 1997-1:2004 + AC:2009 + A1:2013; Edition: 2014-03
14	DIN 1054	Building soil - Safety demonstrations in earthworks and foundation engineering - Supplementary regulations to DIN EN 1997-1; Edition: 2010-12
15	DIN EN 1991-2	Eurocode 1: Actions on support structures - Part 2: Traffic loads on bridges; German version of EN 1991-2:2003 + AC:2010; Edition: 2010-12

Table 2: Partial safety factors to consider

Partial safety factor for		GZT	GZG
constant acting loads	γ_G	1.35	1.0
variable loads	γ_Q	1.5	1.0
component resistance	γ_M	1.3	1.0

Table 3: Typical maximum short-term compressive strength $\sigma_{R,k}$ for the ultimate limit state

	$\sigma_{R,k}$ [kN/m]
"SC 160"	80.2
"SC 310"	48.0
"SC 740"	83.4
"MC 3500"	122.0
"MC 4500"	178.5

Table 4: Typical maximum short-time compressive strength $\sigma_{R,k}$ for the serviceability limit state with maximum allowable deformation limit $\Delta h_{permitted}$

	$\Delta h_{permitted}$ [mm]	$\sigma_{R,k}$ [kN/m²]
"SC 160"	- / - a)	- / - a)
"SC 310"	- / - a)	- / - a)
"SC 740"	- / - a)	- / - a)
"MC 3500"	20.0	169.0
"MC 4500"	20.0	113.0

a) GZT failure with deformations < 20 mm

Table 5: Reduction factors to consider for the component resistance

		SC 160	SC 310	SC 740	MC 3500	MC 4500
Creep behaviour	A_1^{f} a) A_1^{E} b)	4.4	1.75	1.49	2.01 1.64	1.81 1.69
Media interaction	A_2	1.0				
Temperature influence	A_3	1.0				
Inhomogeneities (including influence of connections and fittings)	A_4	1.0				
Influence of dynamic loads	A_5	1.0				

a) for the ultimate limit state
b) for the serviceability limit state

3.2 Provisions for implementation

To assemble the individual tunnel system components of the infiltration installation intended, the provisions for design in section 3.1.1 and 3.1.2 apply. Unless otherwise specified below, the following technical rules must be observed as a matter of principle:

- DWA-A 138[1]
- ATV-DVWK-M 153[11]
- DIN 1054[16]

Install the infiltration systems only with pipes, fittings, and shafts that comply with the generally recognised state of technology and bear an Ü mark.

The applicant shall include installation instructions with each delivery. The installation must be carried out according to the installation instructions and in compliance with the regulations below.

Only people who have the necessary specialist knowledge may assemble the system.

The principles of DIN 4124[16] and the requirements based on DIN EN 1610[17] apply to the construction of the excavation pit.

To lay the system, prepare a horizontal, levelled and load-bearing subgrade of non-cohesive, compactable soil material, which has a minimum load-bearing capacity of E_{v2} = 45 MN/m².

The subgrade must be covered with geotextiles, ensuring a minimum overlap of at least 50 cm between the individual sheets. Make these overlaps in such a way that no backfill material can enter the infiltration system.

The tunnel systems are installed on a support layer of backfill material and are also backfilled with this material.

Install the backfill material always from the front-end side, for example, using a wheel loader or excavator.

Install the backfill material in layers; ensure that the maximum height difference of the backfill material during installation does not exceed 30 cm.

The backfill material will not be compacted. Use crushed rock with a maximum grain size D ≤ 56 mm and a minimum grain size d ≤ 16 mm as backfill material. The particle size distribution shall correspond to G_c 90/10, the fines content to f_4, and the broken grains content to C95/1. The contractor must have these values confirmed by the supplier with each delivery of backfill material.

Ensure careful vertical and horizontal alignment when installing the individual components of the tunnel system. The minimum distance between the tunnels measured at the tunnel floor must be at least 150 mm (“SC 160“, “SC 310“, “SC740“) or 250 mm (“SC 3500“, “SC 4500“). Do not install damaged chambers or end caps.

Provide each tunnel of an infiltration system with a separate venting device at apex height. The dimensioning of the venting device must always be determined based on the expected inlet volume flows.

16	DIN 4124	Pits and trenches - embankments, shoring, working area widths; Edition: 2002-10
17	DIN EN 1610	Laying and testing of sewers and drains; German version of EN 1610:1997; Edition:1997-10 in conjunction with supplement 1; Edition: 1997-10

The inlet area of the chambers and the tunnel areas designed for HP flushing shall be covered with two layers of stretched and woven tapes following section 2.1.7, with the inlet area including a section 4.0 m long from the inlet (“SC 160“, “SC 310“ and “SC 740“), or a section 5.0 m long from the inlet (“MC 3500“ and “MC 4500) as a minimum.

It is not permitted to drive over the infiltration system during the installation of the infiltration system, lateral backfilling operations, and covering of the construction pit.

The company carrying out the work for each infiltration system constructed must declare in writing that their execution complies with the f this general building approval.

The relevant regulations on health and safety are to be observed during execution.

3.3 Identification of the infiltration facility

The infiltration system shall be identified above ground by signs with the following permanent and legible inscription:

- Size of the infiltration system
- Depth of the infiltration system
- Product designation
- Year of manufacture

Besides, the tunnels in which high-pressure flushing is provided shall be marked accordingly.

3.4 Certificate of compliance

The installer of the infiltration system as specified in section 1, must declare to the client (builder) in writing that the design of the implemented system complies with the f sections 3.1, 3.2, and 3.3 of this general design approval related to the application of the subject of approval.

4 Conditions for use and maintenance

The use and maintenance of the infiltration system composed of the tunnel system components shall comply with the relevant regulations on health and safety and the maintenance instructions of the applicant.

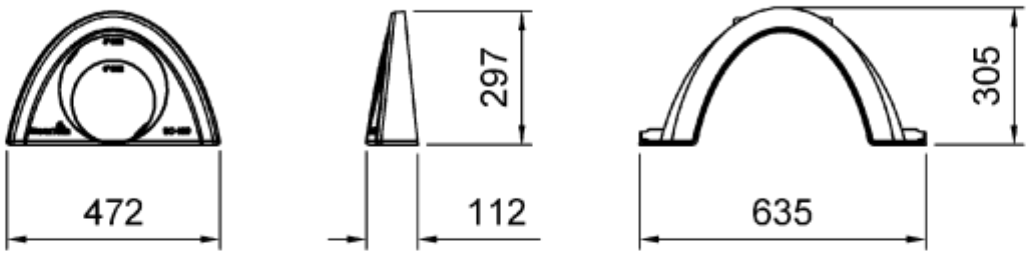
Only geotextile stretched and woven tapes used in the tunnel inlet area are suitable for HP flushing.

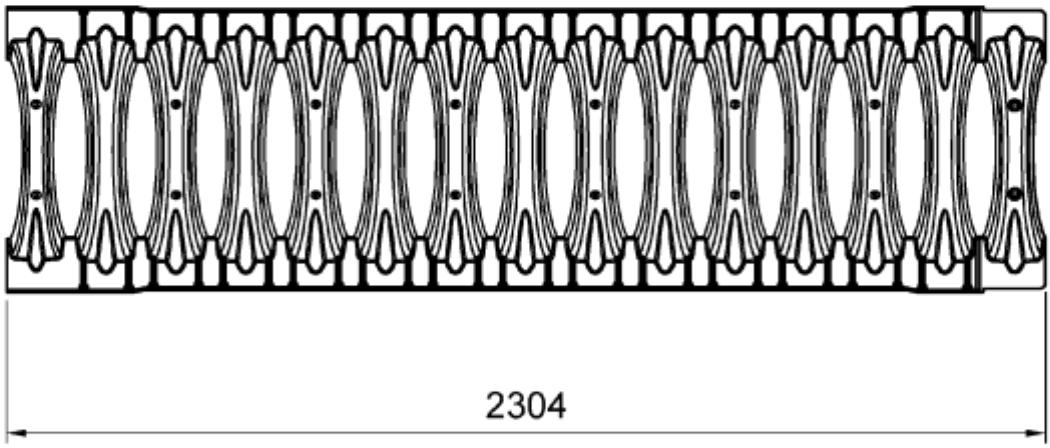
Within the period of validity of this approval, the applicant shall submit at least three reports to the German Institute for Structural Engineering (Deutsches Institut für Bautechnik) listing the inspections carried out on the infiltration systems.

Rudolf Kersten
Head of Unit

Certified

Deutsches Institut für Bautechnik DIBt





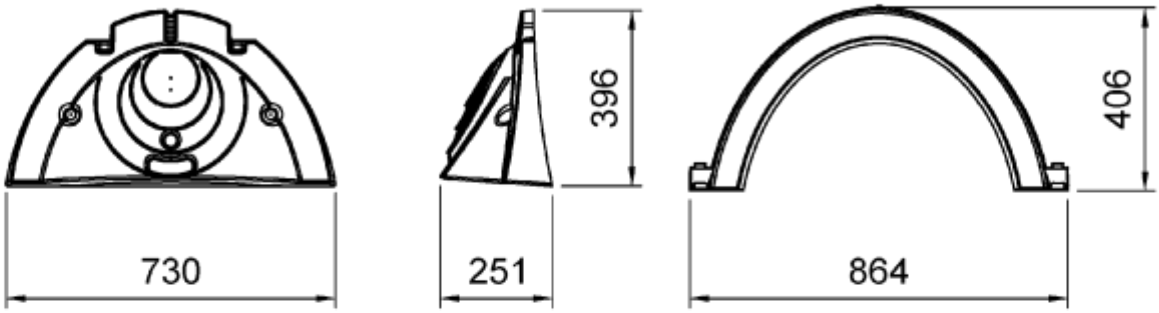
All dimension in millimetres (tolerance +/- 4%)

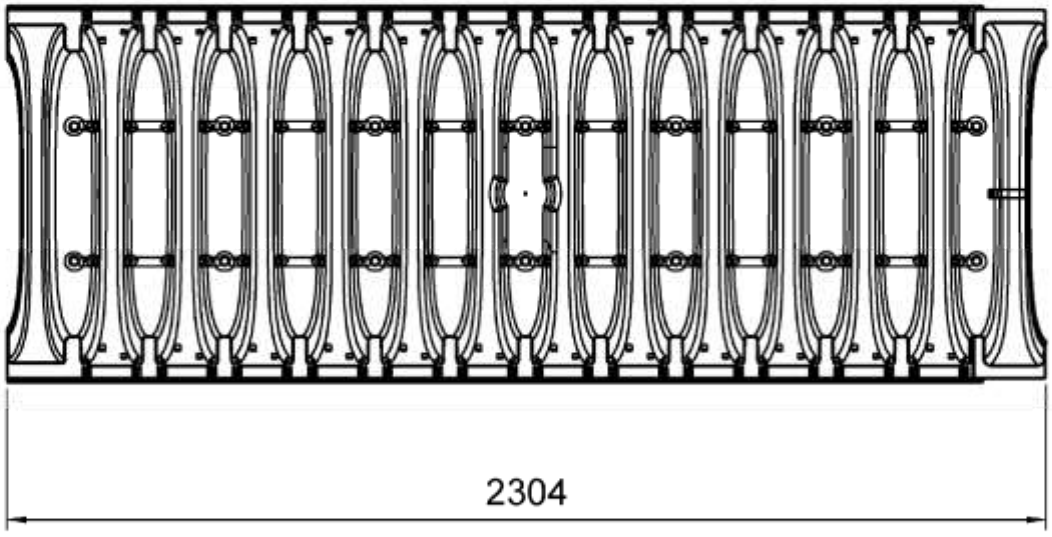
Rainwater infiltration tunnel system "StormTech" made of PP

StormTech SC-160LP

Annex 1

Deutsches Institut für Bautechnik DIBt





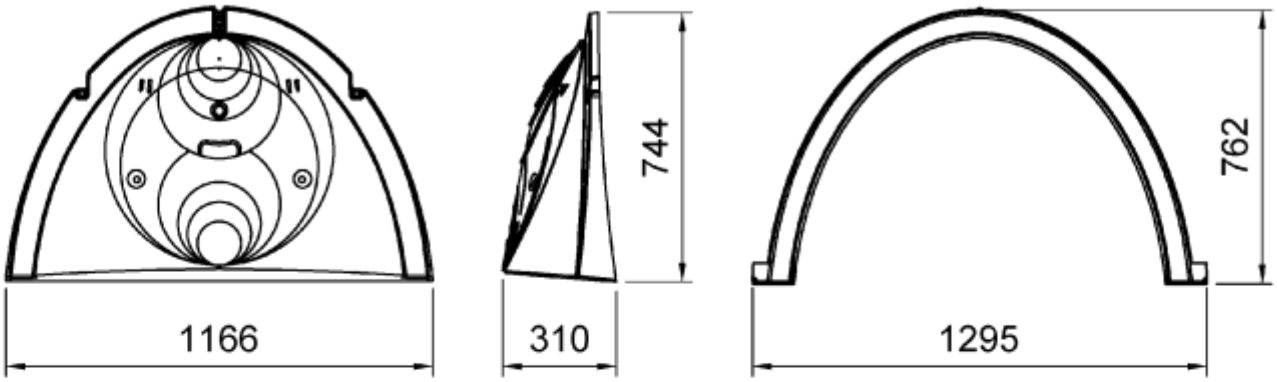
All dimension in millimetres (tolerance +/- 4%)

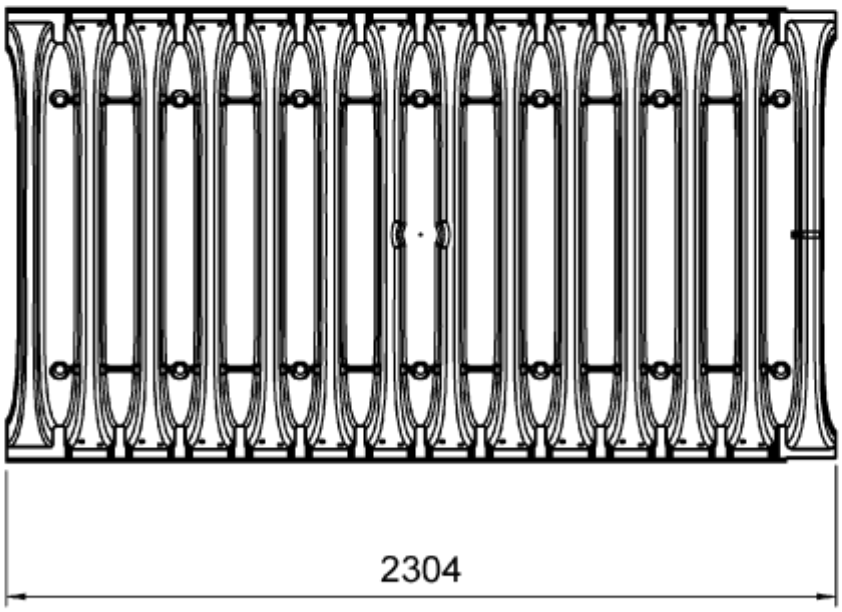
Rainwater infiltration tunnel system "StormTech" made of PE and PP

StormTech SC-310

Annex 2

Deutsches Institut für Bautechnik DIBt



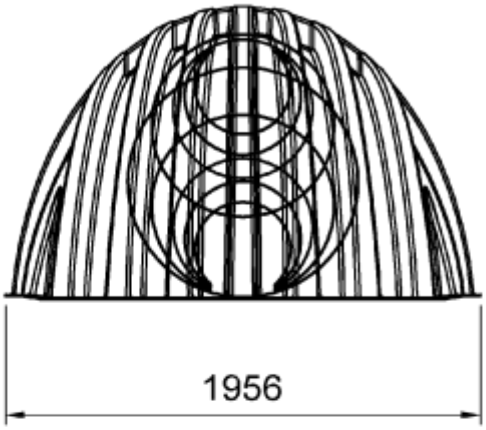


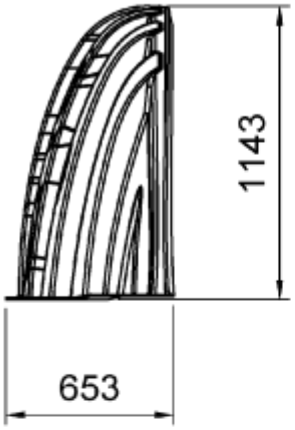
All dimension in millimetres (tolerance +/- 4%)

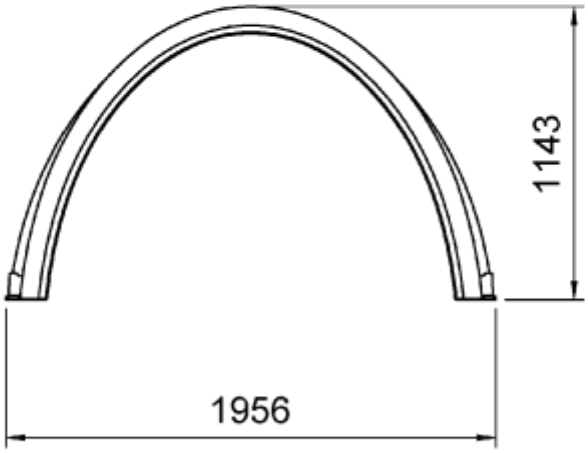
Rainwater infiltration tunnel system "StormTech" made of PP only.
End caps made of PE and PP.

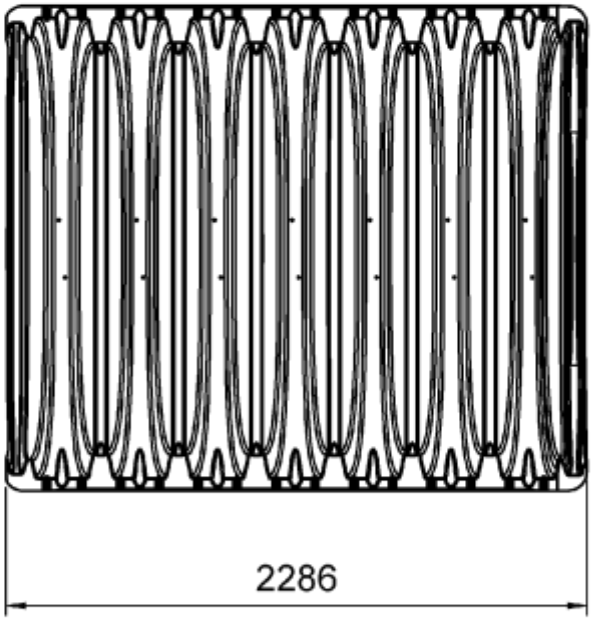
StormTech SC-740

Annex 3









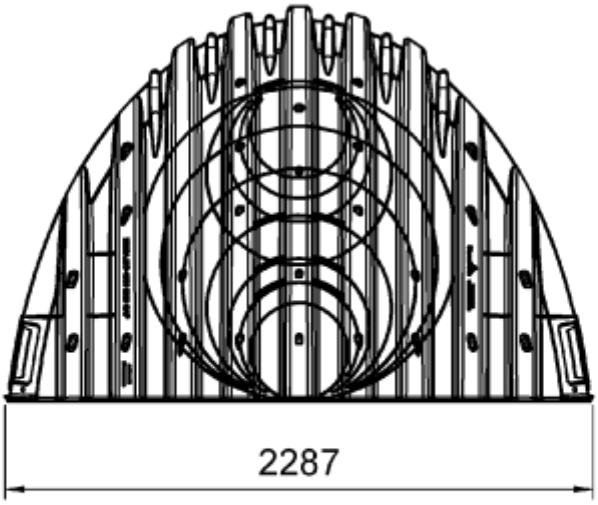
All dimension in millimetres (tolerance +/- 4%)

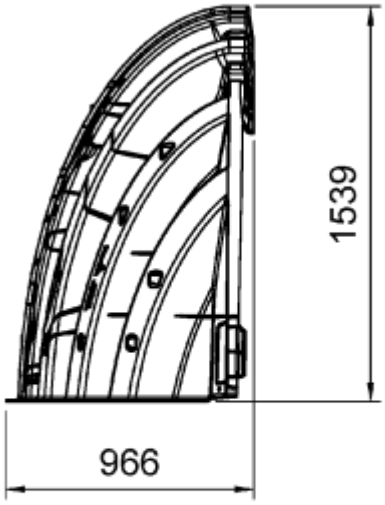
Rainwater infiltration tunnel system "StormTech" made of PP.

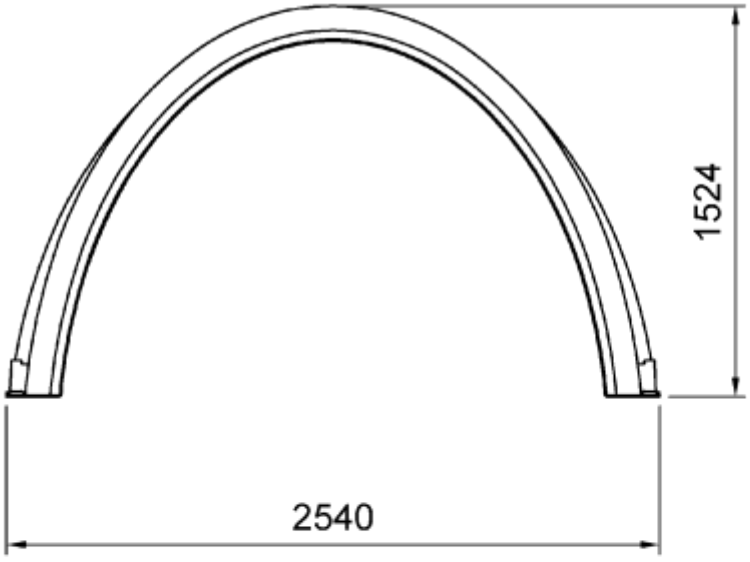
StormTech MC-3500

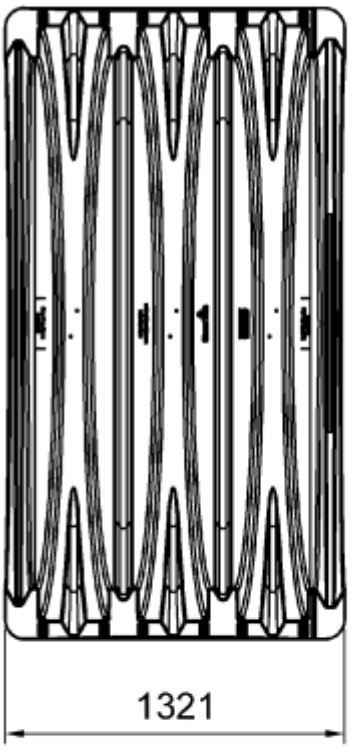
Annex 4

Deutsches Institut für Bautechnik DIBt









All dimension in millimetres (tolerance +/- 4%)

Rainwater infiltration tunnel system "StormTech" made of PP.

StormTech MC-4500

Annex 5

Technical Appraisal 17.2/13-273_V2

Cancels and supersedes Technical Appraisal 17/13-273*V1

Procédé de stockage d'eau pluviale

Rainwater storage process

STORMTECH PP RANGE

Holder: ADS Inc.
4640 Trueman Blvd
HILLIARD (OH) 43026-2438
USA

Tel.: +1 614 6580255
E-mail: jay.molnar@ads-pipe.com
Internet: ads-pipe.com

Plant: Winchester (USA)

Specialized Group No. 17.2

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Specialized Group No. 17 "Réseaux et Epuration" (Networks and Treatments) of the Commission in charge of issuing Technical Appraisals examined on the 4th October 2018, the procedure relating to STORMTECH PP chambers as presented by the ADS company. The present document, with in Appendix the Technical File drawn up by the applicant, transcribes the Appraisal formulated by Specialized Group No. 17 "Réseaux et Epuration" (Networks and Treatments) on the system and implementation arrangements proposed for its use, in the area of usage intended, and under the conditions of European France, its departments, regions and Overseas communities and territories (DROM-COM). This Appraisal replaces Technical Appraisal 17/13-273*V1.

1. Brief definition

1.1 Brief description

The STORMTECH storm water collection system consists of bottomless thermoplastic chambers. STORMTECH PP chambers interlock lengthwise and juxtapose so as to form a reservoir capable of holding storm waters.

The STORMTECH PP range chambers are manufactured from polypropylene virgin resins.

The principal characteristics of the STORMTECH chambers are as follows:

Chambers	Volume per section (liters)	Total height (m)	Color
STORMTECH SC310	410	0.41	yellow
STORMTECH SC740	1,300	0.76	
STORMTECH MC3500	3,110	1.14	
STORMTECH MC4500	3,010	1.52	

1.2 Identification

Each chamber comprises, in accordance with the QB mark, the following permanent indications:

- Commercial designation: according to model of the range STORMTECH PP, STORMTECH SC310, STORMTECH SC740, STORMTECH MC3500 et STORMTECH MC4500
- The factory identification
- The material: PP
- The resistance classification: HS 20
- Date of manufacture
- The QB logo followed by the certificate reference.

2. APPRAISAL

2.1 Area of use

STORMTECH PP chambers are intended to build buried retention basins, in the conditions defined in § 1 and 6 of the Technical File, in order to permit:

- the retention of rainwater when the structure is enveloped in a watertight geomembrane
- or, infiltration into soil where the construction is not designed to be watertight.

It should be remembered that:

- STORMTECH chambers should never be located in flood plains.
- The presence of an outlet is mandatory: overflow and connection to a rainwater evacuation network in all collective type applications.

2.2 Appraisal of the product

2.21 Meets current laws and regulations and other fitness-for-use qualities

2.211 Environmental data

The products do not possess any environmental declarations (DE) and therefore cannot claim any specific environmental performance. It should be noted that the DE do not enter into the fitness-for-use examination of the said products.

2.212 Hygiene data

The present appraisal is formulated in relation to the written undertaking of the holder to respect the regulations, and particularly the ensemble of regulatory obligations relating to dangerous substances, for their manufacture, integration into works in the accepted area of use and the exploitation of them. Inspection of information and declarations issued in application of the regulations in force does not fall within the remit of this present appraisal. The holder of this appraisal remains fully liable for this information and these declarations.

2.213 Other fitness-for-use qualities

The trials and studies carried out on STORMTECH PP chambers in the USA, in France at the CSTB, and by the applicant during the Technical Appraisal deliberations, concern the references supplied, and demonstrate that this product gives satisfaction in the envisaged area of use as described in 2.1.

The monitoring carried out within the framework of external inspections as well as the references supplied confirm the fitness-for-use of the STORMTECH PP product range.

Compliance with the design and installation conditions defined in the Technical File is an essential condition for correct operation of the system.

The useful volumes of the structures installed limit the volume of the excavations required.

The design of the chambers permits their adaptation to the topographic constraints of works.

Works carried out using STORMTECH chambers must ensure certain functions that require scrutiny:

Mechanical strength

A knowledge of and taking into account of the geo-technical characteristics of the ground is essential for the design and fabrication of the structure.

For retention basins and storm water regulation application, the respecting of the arrangements recommended by ADS (or their representative), in relation to the specifics of the site, is imperative in order to ensure the stability of the works and compatibility with future possible highway applications.

Hydraulics

The arrangements used for calculation of ground infiltration flow rates and the volume of the works are defined in the Technical Guide *"Les structures Alvéolaires Ultra légères (SAUL) pour la gestion des eaux pluviales (2011)"* and in Fascicule 70 Title II.

When the system collects rainwater that is not exclusively roof runoff, the sustainability of hydraulic performance is indissociable from the existence of pretreatment and respect of the maintenance conditions.

2.22 Durability – Maintenance

Given the nature of the material of construction, the durability of the components is not a particular problem.

The sustainability of the hydraulic function of the works essentially relies on the performance of the pretreatment arrangements and the isolator row.

Accessibility for investigation tools must be ensured.

Accessibility for cleaning tools is limited to the isolator row.

2.23 Manufacture and inspection

Manufacturing STORMTECH PP elements range is by injection molding and subject to detailed inspections laid out in a Quality Assurance Plan based on the NF EN ISO 9001 (2008) Standard.

The internal and external inspections as described in the Technical File ensure that an acceptably consistent quality is achieved.

This Appraisal only concerns manufacturing for which the self-testing and verification methods, described in the Technical File drawn up by the Applicant have been carried out.

2.24 Implementation

The installation of the product offers no particular difficulties if it is carried out in accordance with the instructions in the Technical File.

For all retention and rainwater regulation basins, a rigorous monitoring of the installation conditions must be carried out.

The respect of the installation conditions laid out in paragraph 7 is indispensable for the correct operation of STORMTECH installations. Particular care must be taken with the installation of geotextiles around the rim of the basin and the suitability of the backfill material in relation to the Technical File.

2.3 Technical Specifications

2.31 Product characteristics

The characteristics of STORMTECH PP elements must comply with the indications found in the Technical File.

2.32 Manufacturing and inspection

Inspection as described in the Technical File must be implemented by the manufacturer.

2.33 Design

For the retention basin and regulation application, the elements to include in the framework of the preliminary study are defined in the documents: *"Les Structures Alvéolaires Ultra Légères (SAUL) en assainissement pluvial"* of 2011, in Fascicule 70 title II and in the Technical File.

These include in particular the following elements:

- Linked to the physical environment: terrain topography, height of water table, permeability and geo-technical characteristics of the soil.
- Linked to urbanization: re-use of space, presence of buildings, water quality and usage, traffic.
- Assessment of water variables: catchment area, active surface, volumes and flows based on Technical Instruction 77/284.

2.34 Installation

The conditions for execution of the work given in the Technical File must imperatively be respected.

Conclusions

Use of the STORMTECH PP chambers in the areas of use proposed is favorably assessed.

Validity

Until November 30, 2023.

For Specialized Group No. 17
The Chairman

3. Additional comments from the Specialized Group

Specialized Group No. 17 draws to the designer's attention the importance of protecting such works from the introduction of any settling solids.

Whilst the STORMTECH PP range does not come under the SAUL guide, sections that apply are found in the Technical File.

Rapporteur of Specialized Group No. 17

Technical File
drawn up by the applicant

A. Description

1. Principle

1.1 General description

STORMTECH PP chambers are designed for management and retention of rainwater runoff in the framework of buried basins, in the public works and civil engineering domain, but may also be implemented in private applications (detached houses).

This system is composed of polypropylene (PP) chambers manufactured since 1986. STORMTECH chambers ensure the following functions:

Service functions:

The service functions ensured by works constructed with STORMTECH PP chambers are storage and/or infiltration:

- The storage of effluents when the works are enveloped by a watertight geomembrane.
- Infiltration if the structure is enveloped in geotextile.

Technical functions:

The technical functions ensured by the structures constructed with the STORMTECH PP chambers are as follows:

Collection and restitution:

These two functions are carried out via additional components including manholes (or inspection hatches) implemented on the periphery.

In the case of a watertight construction, the evacuation flow rate is a function of the fill height of the basin and the internal diameter of the evacuation orifice leading to the network or regulated via a suitable arrangement.

This principle excludes the construction of works that can be reached by the water table.

Structural:

STORMTECH PP chambers allow the keeping and use of the above ground surface.

The gravel backfill around the chambers supports the main load. The bearing capacity of the ground determines the reliability of the construction and its performance. In such cases where the ground in place is unable to support a highway, the treatment or substitution of ground necessary to obtain a minimum bearing capacity must be carried out before implementing the use of the chambers.

Access:

Access to the internal structure of the construction is effected via manholes or inspection hatches, connected to the chambers, and where an isolator row has been implemented. The accessibility of the remainder of the construction is limited to video inspection.

Ventilation:

The structure must allow air pressure to equilibrate during filling and emptying phases.

1.2 The different components

1.21 Chambers

The range comprises 4 models of chamber with heights between 0.41 m and 1.53 m solving, where necessary, issues linked to the height of the water table.

The various chambers manufactured are as follows:

Chambers	Height of chambers
STORMTECH SC310	0.41 m
STORMTECH SC740	0.76 m
STORMTECH MC3500	1.14 m
STORMTECH MC4500	1.53 m

STORMTECH PP chambers are manufactured with interlocking ridges, allowing them to be assembled together. The assembly of the chambers is via the interlocking of the last and next corrugation.

1.22 End caps

STORMTECH PP chambers are manufactured to use end caps whose corrugation fits over the top of either end of the chamber. Inlets and outlets can be connected after cutting the inverts; cutting guides are provided for tubes of the following dimensions:

Chambers	Range of tube diameters
STORMTECH SC310	DN/OD 110 to 315
STORMTECH SC740	DN/OD 110 to 630
STORMTECH MC3500	DN/OD 110 to 1050
STORMTECH MC4500	DN/OD 110 to 1050

In the SC series, the end caps interlock on each corrugation, thus allowing a cutting to length of a chamber or the partitioning of a row to facilitate operations.

In the MC series, the end caps interlock only with the very last corrugation.

End caps are manufactured and suited to each model *(See figures 1, 2, 3 and 4).*

1.23 Vent

A DN/OD 110 vent can be installed on SC series chambers (minimum 1 vent per 100 m²). A DN/OD 250 vent can be installed on MC series chambers (minimum 1 vent per 100 m²).

This vent also allows for inspection of the height of any accumulated sediment via a video inspection system (*see figure 11*) or a suitable probe.

2. Method of manufacture and materials

2.1 Manufacture

2.11 Chambers

ADS Inc. manufactures STORMTECH PP chambers using injection molding at its WINCHESTER plant (USA). The injection molding machines are supplied with a hot dry polymer mix.

2.12 End caps

ADS Inc. equally manufactures the end caps via the same procedure.

2.2 Materials

2.21 STORMTECH SC310 and STORMTECH SC740 chambers

The SC310 and SC740 chambers and their end caps are manufactured in polypropylene using virgin resins. The characteristics of the materials are as follows:

Characteristics	Specifications	Test parameters	Test methods
Density	895 - 1100 kg/m³	T=23 ±2°C	NF EN ISO 1183-2
Thermal stability* (OIT)	≥ 8 min.	200°C	NF EN 728
Melt flow index	11-21 g/10 min.	T= 230°C / 2.16 kg	NF EN ISO 1133
Flex modulus	≥930 MPa	Speed 2 mm/min T=23 ± 2°C	NF NE ISO 178
Tensile strength at flow limit	≥ 21.4 MPa	Speed 50 mm/min T=23 ± 2°C	NF EN ISO 527
Elongation at break	≥ 150%		

*Finished product value.

An anti-UV additive is incorporated in the material. These values correspond to the values of the final product

2.22 STORMTECH MC3500 and STORMTECH MC4500 chambers

The STORMTECH MC3500 and STORMTECH MC4500 chambers and their end caps are manufactured from virgin resin polypropylene. The characteristics of the materials are as follows:

Characteristics	Specifications	Test parameters	Test methods
Density	895 - 1100 kg/m³	T=23 ±2°C	NF EN ISO 1183-2
Thermal stability* (OIT)	≥ 8 min.	200°C	NF EN 728
Melt flow index	11-21 g/10 min.	T= 230°C / 2.16 kg	NF EN ISO 1133
Flex modulus	≥1000 MPa	Speed 2 mm/min T=23 ± 2°C	NF EN ISO 178
Tensile strength at flow limit	≥ 21.4 MPa	Speed 50 mm/min T=23 ± 2°C	NF EN ISO 527
Elongation at break	≥ 150%		

*Finished product value.

An anti-UV additive is incorporated in the material. These values correspond to the values of the final product

3. Description of the finished product

3.1 Appearance – color status of the finish

STORMTECH PP chambers have profiles intended to favor infiltration and reinforce their rigidity. The chambers are yellow, and their surface is smooth, free of faults, such as air bubbles or inclusions.

3.2 Dimensions of chambers

The dimensional characteristics of the chambers are shown in Table 1 in the Appendix.

3.3 Density

The density of the chambers (minimum density) is equivalent to:

Chambers	Weight of the chambers (kg)	Weight of end caps (kg)
STORMTECH SC310	15.9	2
STORMTECH SC740	34.5	5.22
STORMTECH MC3500	60.8	22.22
STORMTECH MC4500	58.1	54.43

3.4 Usable volume

3.41 Volume of the chambers

The useful volume inside a chamber and determined by CAD, is:

Reference	Useful volume (m^3)
STORMTECH SC310	0.42
STORMTECH SC740	1.30
STORMTECH MC3500	3.11
STORMTECH MC4500	3.01

The useful volume of the retention basin must take into account the useful length of the assembled chambers.

3.42 Volume of the end caps

The useful volume inside an end cap, determined by CAD, is:

Reference	Volume (m^3)
STORMTECH SC310	0.02
STORMTECH SC740	0.08
STORMTECH MC3500	0.42
STORMTECH MC4500	1.01

3.5 Mechanical characteristics of STORMTECH chambers – Resistance of chambers

3.51 Impact resistance

Impact resistance is measured in laboratory on a sample taken from a manufacturing batch of chambers, and carried out in accordance with ASTM D5420.

3.52 Rigidity of the chamber vault

The minimum vault rigidity of the chambers is defined according to the ASTM F2418-12 Standard on the basis of a test carried out on 2 complete sections and with deflection of 2%.

Chamber	Rigidity (kN/m.%)
STORMTECH SC310	4.4
STORMTECH SC740	4.4
STORMTECH MC3500	3.7
STORMTECH MC4500	3.7

Note: The rigidity of the vault is a characteristic of the final product. It does not permit the mechanical dimensioning of the construction.

3.53 Design

The design of the chambers and end caps has been apprehended via simulation, via the finite elements method, taking into account long-term moduli of 186 MPa for MC3500 and MC4500 and 165 MPa for SC310 and SC740 chambers.

4. Marking

The marking on STORMTECH PP products complies with the indications defined in the Technical Appraisal.

5. Packaging, handling, storage

5.1 Packaging

The STORMTECH PP chambers are stacked on pallets to a total maximum height of 2.50 m.

5.2 Handling

The transportation and handling of STORMTECH PP chambers do not present particular difficulties. However, usual precautions must be taken, in order to avoid any deterioration or deformation of the product.

When STORMTECH chambers of the STORMTECH PP range are unpacked, it is necessary to avoid:

- Bulk storage
- Rough handling
- Important flexing, overhangs
- Contact with or blows from hard objects (metal parts, stones, etc.)
- Falls to the ground or unloading by tipping
- Dragging of the chambers over the ground

5.3 Storage

Unpacked storage of chambers must be horizontal on a flat surface, with stacking on pallets. The maximum outdoor storage is one year.

6. Preliminary study and dimensioning

6.1 The dimensioning of storage systems and evacuation via infiltration of the rainwater from detached houses

To determine the volume necessary and define the number of chambers required for individual installations, and when implementing only a few chambers at the foot of the gutter downfall, the infiltration flow rate is considered zero during the duration of the rainfall; this confers a safety margin.

6.2 Dimensioning of buried retention basins

For large installations, refer to the corresponding sections (§3) of the technical guide *"Les Structures Alvéolaires Ultra-Légères pour la gestion des eaux pluviales" (2011).*

6.21 Geological and hydrological environment

A soil study must be carried out prior to any dimensioning, including among other things the geological and hydrological environment in which the work is to be implemented, notably the EH height of water and the permeability of the infiltration basins.

The dimensioning is the responsibility of the Prime Contractor.

Note: EH: the highest level of the 10-year flood water height of the site

6.22 Determining the volume

The hydraulic dimensioning of a retention basin made up from chambers and end caps is defined hereafter, in relation to the following elements:

- The possible slope of the bottom of the basin
- The leak rate for an infiltration basin.

6.221 Infiltration

This volume must take into account:

- In the framework of an infiltration work, the net volume is identical to the maximum theoretical volume
- The possible slope of the basin bottom
- The permeability of the ground in the case of an infiltration basin
- The unit volume of each arch and end cap, depending on whether or not they are superposed, in relation to the useful length of the assembled chambers.

The useful storage volume of the construction may also take into account the 20/40 washed crushed stone around the arches and end caps. In particular, the Prime Contractor may consider the following elements:

- The void ratio of the aggregate used as backfill, located around 30% to 40% Without specific measures, the porosity of the aggregate shall be equal to 30%
- The lateral spacing area shall be equal to:
  - SC series: 15 cm of aggregate each side of the arch and end cap,
  - MC series: 23 cm of aggregate each side of the arch and end cap,
- Normal permeability according to (NF EN ISO 11058) > 0.002 m/s
- The volume of the plastic deducted from the total
- The areas of aggregate above the arches and the aggregate beneath the arches
- The spacing areas of the excavation including 50 cm of aggregate 20/40 around the periphery of the work.

The Prime Contractor may choose to include slopes in the calculation.

6.222 Retention

The volume must take into account:

- Dimensions of the outgoing water flow. The dead volume present in the case of a retention basin (see hereafter),
- The level of the outgoing water flow
- The possible slope of the bottom of the construction
- The unit volume of each arch and end cap, depending on whether or not superposed

The useful storage volume of the construction may also take into account the 20/40 washed crushed stone around the arches and end caps. In particular, the Prime Contractor may consider the following elements:

- The void index of the aggregate used as backfill, between 30% and 40%. Without specific measures, the porosity of the aggregate shall be equal to 30%
- The area of aggregate above the arches, according to the level of the overflow
- The spacing area of the excavation including 20/40 aggregate around the periphery of the construction.
- The lateral spacing equal to 15 cm or 23 cm of aggregate on each side of the arch and end cap, i.e. 30 cm in all
- The volume of plastic subtracted from the total

Table 2 indicates the volume not available, between the foot of the chambers and the outlet side.

The Prime Contractor may choose to include slopes in the calculation.

6.23 Determining the number of basin inlet and outlet pipes

- Peak flow rate at retention basin inlet:

The cross section of piping connected to end caps of chambers has diameters between DN/OD 110 and 1050. The peak flow rate is spread over several pipes. As an example, a 200 mm pipe on a 1% slope has a maximum flow rate of 30 l/s. Figure 5a shows an example of a retention basin in which several supply points are necessary

- Basin outlet drain flow rate:

This corresponds to the authorized leak flow rate towards the existing network. It is generally regulated by the choice of diameter of the piping and its slope. For large basins a flow rate regulator may be installed at the outlet.

The cutting guides necessary for connections are prepositioned, on upper and lower parts

6.24 Determining the number of elements for the chambers

The number of elements for each project will notably depend upon:

- The volume of the basin, which in the case of infiltration basins, depends on the surface area of the basin (variability of infiltration flow rate)
- The type of chambers used
- The thickness of the laying bed or backfill of aggregate whose porosity takes up part of the volume of storage necessary
- The distances between the rows of chambers as well as the width of the peripheral aggregate border
- Lastly, the shape and implantation of the chambers, as the number of chambers varies with the number of rows, depending on whether the basin is square or rectangular.

6.3 Mechanical behavior

The system can be installed beneath highway, parking lots, pavements, shoulders or green spaces within the limits defined in § 7.4. The dimensioning must take into account the heights of the backfill, the type of traffic and the dimensions of the structure.

7. Installation

7.1 General principles

Verify the pertinence of locating the STORMTECH structure in relation to neighboring works and/or constructions.

1) Carry out the excavation compatible with the application, the number, arrangement and dimensions of the unit(s) to employ and under the following conditions. Respect a minimum distance of 50 cm between arches and the edge of the excavation, and 30 cm between each row at the foot of the arch.
2) Level the bottom of the excavation; the maximum admissible slope is 1%.
3) It is obligatory to compact the bottom of the excavation. Put in place the geotextile. If the bearing capacity of the ground is insufficient to support the construction, a treatment or substitution of the ground in place will be necessary. Installation of a watertight sealing system may be required if infiltration is proscribed due to environmental constraints.
4) Control the level and place a layer of 20/40 crushed aggregate to a minimum level of 15 cm for the SC series and 23 cm for the MC.
5) Place the first STORMTECH PP chamber(s) in the bottom of the excavation.
6) Overlap the upper joint corrugation of one chamber over the lower joint corrugation of the next chamber.
7) Connect the STORMTECH PP chambers over the lengths necessary.
8) Rows are formed by overlapping the upper joint corrugation of the one chamber over the lower joint corrugation of the next chamber.
9) Put in place the pretreatment arrangement.
10) Backfill the work according to the conditions laid out in Figures 8 and 9. For retention basins, the installation of the backfill is carried out in accordance with the described procedure. The construction is finally closed using a geotextile covering.
11) Maneuvering of site vehicles on the installation, apart from those required for installation, is only authorized after backfill and final compaction.

7.2 Dimensions of the excavation according to chambers used

The site dimensions are as follows:

Type of chamber used	Min. width (meters)	Min. depth (meters)
STORMTECH SC 310	1.3	1.00
STORMTECH SC 740	1.8	1.36
STORMTECH MC 3500	2.45	1.97
STORMTECH MC 4500	3.04	2.35

Note: an additional thickness of aggregate shall be positioned on the flanks between chambers, and on the excavation adjacent to the periphery of the basin. This width shall be 50 cm minimum.

The minimum dimensions depend upon the load to which the chambers will be subjected *(see figures 6 to 9).*

7.3 Storage and evacuation system via infiltration of rainwater from detached houses.

7.31 Main principle

STORMTECH PP chambers are generally employed without rainwater evacuation networks; however when the infiltration soil has a vertical permeability of less than 10^{-6} m/s, it is recommended to connect to an evacuation network or to oversize the volume of the installation.

7.32 Detailed plans

See Figures 6 and 7.

7.33 Particular implementation arrangements

When the installation is in proximity of another construction, the minimum distance between the STORMTECH installation and the nearest other structure must be 2.50m.

7.4 Underground basin system carried out using STORMTECH SC310, SC740, MC3500, MC4500 chambers

7.41 Usable elements

STORMTECH PP chambers are usable. SC310 chambers shall be used for projects where the bottom of the basin cannot be buried too deeply, for example because of the level of the outlet or because of proximity to the water table level.

7.42 Conditions of use of the chambers

7.421 Cross section plans of chambers SC310, SC740, MC3500, MC4500

(See Figures 6, 7, 8 and 9).

7.422 Values of loads to support beneath a highway in relation to thickness of backfill

The calculation of the action due to moving loads is defined in *Fascicule n°70 – Méthode de dimensionnement mécanique des canalisations d'assainissement.* This model corresponds to the least favorable load system generated by a Bc type convoy allocated with dynamic increase coefficients. The height of the backfill varies in relation to the various chambers and their external loads. The Table below mentions the limits of each model:

Tables of backfill thicknesses above each chamber model in relation to loads:

Model of chamber	Minimum height of backfill above chambers (cm)		Maximum height of backfill above chambers (cm)
	Green spaces and light vehicles	Type Bc heavy loads	
STORMTECH SC310	45	60	250
STORMTECH SC740	45	60	250
STORMTECH MC3500	60	60	250
STORMTECH MC4500	60	60	210

7.423 Verification of soil characteristics in situ for installation of STORMTECH range chambers

The terracing having been carried out to depths linked to the type of chamber and the thickness of backfill to be used, the bottom of the excavation is located, according to the case, between 116 and 388 cm depth in relation to the terrain before the work.

At this depth, the soil type must be analyzed for:

- General load bearing ability
- Specific load bearing at the foot of the chambers
- The conditions of permeability where infiltration into the terrain is required.

The general load bearing ability is frequently ensured, except in cases of peat, silt or in general with materials undergoing change, or underconsolidated materials since the weight of the chambers is less than the soil removed.

Only to check is the specific load bearing ability in the bottom of the excavation, it being understood that the following constraints are applied:

Table of pressures at bottom of excavation in relation to height of backfill and loads:

- STORMTECH SC310 and SC740 chambers:

Total thickness of backfill (cm)	STORMTECH SC310			STORMTECH SC740		
	Pressure on bed of excavation (kN/m²)			Pressure on bed of excavation (kN/m²)		
	Green spaces	Mobile Loads	BC Convoy	Green spaces	Mobile Loads	BC Convoy
45	25	165	-	44	223	-
60	30	146	209	53	204	286
75	36	131	186	61	188	262
90	42	121	169	70	177	244
105	47	113	158	78	169	231
120	53	109	150	87	165	223
150	65	106	142	104	163	215
180	76	108	140	121	168	215
210	88	114	143	138	176	219
240	99	121	147	156	187	226
250	103	123	149	161	192	229

- STORMTECH MC3500 and STORMTECH MC4500 chambers

Total thickness of Backfill (cm)	STORMTECH MC-3500			STORMTECH MC-4500		
	Pressure on bed of excavation (kN/m²)			Pressure on bed of excavation (kN/m²)		
	Green spaces	Mobile Loads	BC Convoy	Green spaces	Mobile Loads	BC Convoy
60	62	186	254	83	198	263
75	71	178	242	94	195	257
90	80	173	233	104	193	254
105	89	170	227	114	193	252
120	98	169	223	124	195	252
150	116	171	222	145	202	256
180	134	179	225	165	213	263
210	152	189	232	185	226	273
240	170	201	241	-	-	-
250	176	206	244	-	-	-

Consequently, by approximating the pressure limits (pressure meter tests) at three times the constraints to support, we retain the following:

a) Implantation under green spaces

In the case whereby the chambers will be implanted below green spaces, so that the bearing ability at the foot of the chambers is ensured with the foreseen adjustment layer of crushed aggregate, it is sufficient to measure within the site:

- STORMTECH SC310 chambers: limit pressure > 0.16 MPa as long as the total thickness of backfill does not exceed 1.20 m, beyond limit pressure > 0.31 MPa;
- STORMTECH SC740 chambers: limit pressure > 0.27 MPa as long as the total thickness of backfill is less than 1.20 m, and above that limit pressure > 0.48 MPa;
- STORMTECH MC3500 chambers: limit pressure > 0.3 MPa as long as the total thickness of backfill is less than 1.20 m, and above that limit pressure > 0.53 MPa;
- STORMTECH MC4500 chambers: limit pressure > 0.37 MPa as long as the total thickness of backfill is less than 1.20 m, and above that limit pressure > 0.56 MPa;

b) Implantation under a light vehicles highway

In the case of heavy goods vehicles bearing BC convoy type loads and taking into account the reduction of constraints provided by a laying bed of 15 cm (STORMTECH SC310, STORMTECH SC740) or 23 cm (STORMTECH MC3500 and STORMTECH MC4500) (application of Boussinesq formula beneath continuous footings), it is necessary to measure in situ:

- limit pressure > 0.75 MPa for STORMTECH SC310 chambers
- limit pressure > 0.9 MPa for STORMTECH SC740 chambers
- limit pressure > 0.76 MPa for STORMTECH MC3500 chambers
- limit pressure > 0.8 MPa for STORMTECH MC4500 chambers

The thickness of the foundation layer, serving at the same time for adjustment of the foot of the chambers, does not require, by calculation, a thickness greater than 15 cm or 23 cm depending on the type of chamber in the majority of cases, and in particular with rocky or sand/gravel terrains.

An adaptation to loamy clay type soils sensitive to water shall be determined. In this case, when the bearing ability of the terrain is at the limits, improvement procedures for the bottom of the excavation shall be defined with, for example, an additional layer of aggregate, gravel or sand.

Equally, before work, the sensitivity of the soils to water shall be carried out with identification tests allowing classification of the soils according

to the SETRA classification (the lowest bearing ability being taken into account in calculations).

Class A Fine soils and soils of class B 4 to B 6 shall impose the installation of a gravel reinforcement layer.

In all cases, efficient tamping of the bottom of the platform shall be carried out. The conditions for this work will depend both on the nature of the material and the hydrometric conditions which may impose studding or substitution of part of the material.

c) The case of fire lanes

In the hypothesis where the implantation of a basin lies beneath firefighters fire lanes, it is necessary to ensure that the soil bearing ability is able to support a specific constraint corresponding to a load of 100 kN produced by the thrust plate of a stabilizer pad of 20 cm diameter, i.e., a surface constraint of 3060 kN/m².

By approximating the pressure limit at three times the constraint to support, we retain:

In the case of rocky ground, or soil of excellent quality with up to 0.6 MPa < limit pressure < 2 MPa, the chambers can be implanted beneath fire lanes without additional backfill beneath the laying bed (15 cm or 23 cm according to the chamber) by ensuring matching of the determined pressure limit with the projected height of backfill.

For other soils with limit pressure < 0.6 MPa, the thickness of an additional backfill beneath the feet of chambers shall be determined by calculation with Boussinesq formula, applied in the case of continuous footings.

7.424 Placing and assembling chambers

It is compulsory that the placing and assembling of chambers are supervised by the design study office.

Depending on the characteristics of the sites and in particular the facilities on site, between 150 and 300 chambers can be laid by 4 operatives per day.

When the chambers and end caps have been assembled and the connections made to the various inlets and outlets of the basin, the backfill of the construction can begin.

7.425 Backfilling of works

We distinguish backfill that constitutes the storage construction, i.e., the load bearing structure (called embedding area) and the clean crushed angular backfill that covers up to pavement, road or green spaces soil level.

a) Embedding zone

This phase begins after installation of a geotextile around the walls and in the bottom of the excavation.

This bedding foundation employs a crushed angular stone; its characteristics are provided further on.

During this phase, care is taken to chock the chambers in place using small quantities of stone dropped along the axis of the summit of the chambers. A continuous layer of 15 cm thickness minimum (STORMTECH SC310 and STORMTECH SC740) or 30 cm (STORMTECH MC3500 and STORMTECH MC4500) above the chambers is then to be obtained.

The construction is finally closed using a geotextile covering.

b) True backfill (above the basin)

The compaction of this backfill, at a level of + 45 cm minimum above the summit of the chambers, shall be carried out with a roller compactor not exceeding 10 tons dynamic load.

Under highways, the nature and compaction of this backfill are subject to a plate loading test and must permit obtaining the minimum values (reminder):

- With Westergaard plate, K > 4 bars/cm when the backfill is intended to support light vehicles only and is limited to 45 cm. This test, carried out with a truck with a 5 ton axle load, is compatible with a load to support without a road structure.

- When the backfill is greater than 45 cm thick, i.e., a level of + 0.60 m from the summit of the chambers, a value EV2 > 50 MPa with EV2/EV1 < 2 (verification of suitability of material compaction equivalent to a platform classified PF2 according to GTR LCPC-SETRA); with this thickness of backfill, a truck with 13 tons axle load is used for the test, circulating over the work without a highway structure.

c) Material employed

- Aggregates constituting the embedding of the storage construction or the load bearing area. The recommended material is 20/40 clean crushed angular stone classified R21, R41 or R61 (according to GTR SETRA-LCPC classification). This material shall have the following characteristics (according to NF EN 13242+A1 standard specifications)
  - Fines content: f_4
  - Crushed / rolled grains category: $C_{95/1}$

  Class D rolled material can only be employed on special authorization or instructions from the representative approved by ADS Inc. Class F materials (industrial waste products) are not to be used.
- The upper backfill of the basin beneath the highway and foundation layer beneath the storage structure. This backfill shall be made up of materials for embankments or sub-grades with a q3 type density objective according to the SETRA LCPC classification (classes B1, B3, D, C1B1, C1B3, C2B1, C2B3, R2, R4 or R6 non degradable, non fragmentable).
- Geotextile: for practical reasons, both for supplying sites and for inspection of the material used, the geotextile used for containing peripheral aggregate (hydraulic ability) and for covering the 1st layer of backfill (mechanical ability) shall be the same.

  It must meet the following characteristics:
  - Tensile strength (NF EN ISO 10319) > 16 kN/m.
  - Max stress strain (NF EN ISO 10319) > 20 %.
  - Normal permeability according to (NF EN ISO 11058) > 0.01 m/s.
  - Opening size of the geotextile (NF EN ISO 12956) < 125 μm.
- Geomembrane: It must have the following characteristics described in paragraph 3.4.8 of the SAUL guide for rainwater management.

7.426 Acceptance of ground characteristics formed by backfill

Depending on the case, the backfill shall be up to the excavation bed or up to the highway layer.

The bearing capacity of the ground shall be accepted after plate tests complying with the minimum values to be respected, whether they be standard or specific to a site.

7.5 Ventilation

In order to optimize the circulation of water inside the chambers, a vent tube of 100 mm diameter per 100 m² of basin surface area can be installed on the fittings provided at the summit of the chambers. The exit to free air of this vent tube is protected via a manhole or hatch (see *Figure 11 in Appendix*).

Adding a vent tube is recommended per isolator row (equally able to serve for inspection purposes).

7.6 Isolator row

Depending on the quality of the rainwater at the site and the desired level of clogging protection, retention basins can be fitted with a protection system, known as the isolator row. This system is formed from a STORMTECH chamber dedicated to the decanting of the water injected into the basin. This row (*see Figure 5a and 5b*) is not in direct contact with the ground. A geotextile envelopes the chamber which rests upon its foundation bed. This woven geotextile must have the following characteristics:

- Thickness (NF EN ISO 9863-1) > 1.5 mm
- Opening size of the geotextile (NF EN ISO 12956) < 425 μm.
- Punching (NF EN ISO 12236) > 1,8 kN
- Normal permeability according to (NF EN ISO 11058) > 0.002 m/s.
- Basis weight (NF EN ISO 9864) > 217 g/m².

8. Access to the structure

Access to the internal structure of the construction is via manhole or inspection hatch, connected to the chambers. The access is limited to video inspection.

The vents also permit inspection of the height of sediment via video inspection or a suitable probe.

9. Upkeep and maintenance

A pretreatment arrangement (decanting chamber, scrubber, possibly an oil separator) is installed upstream of the basin. In relation to the characteristics of the effluents, other arrangements may be implemented upstream or downstream of the construction. Even in the case of pretreatment, it is recommended that you equip the system with an isolator row that can be cleaned. The isolator chamber must be cleaned once sediments reach a height of 8 cm. It may be cleaned under the following conditions: Manual flushing at 170 bars and with a flow rate of 250 l/min.

Nozzles providing additional mechanical action are prohibited.

10. Product marketing

The marketing of STORMTECH PP chambers in Europe is ensured by ADS Europe BV. STORMTECH PP chambers are designed to create underground basins in the civil engineering and public works domain, but can also be used in private applications.

For individual applications, ADS supplies a technical data sheet detailing the installation conditions.

Each project is subject to technical design study, and particularly a soils study.

Whatever the application, the technical prescriptions of ADS must be respected.

11. Internal inspections

11.1 Raw materials inspection

Suppliers are required to deliver a certificate of conformity for each batch of material.

- On reception of raw materials, a batch number is allocated.
- A sample is taken to verify the conformity of the deliveries.
- Tests carried out in the plant notably include:
  - Hot viscosity
  - Density
  - Tensile strength
  - Tensile modulus (PP)
  - Flexural modulus (PE)

All the material analysis results (according to the characteristics described in paragraph 2.2 of the present document) are subject to recording and archiving. The raw materials are subject to analysis and the results stored in the laboratory at the plant.

11.2 Inspection during manufacture

The manufacturing process is subject to specific inspections.

11.3 Inspection of finished products

The in-plant inspections and their minimum frequency are defined hereafter:

- Dimensions, assembly between 2 chambers and markings: once per day
- Wall thickness: once per shift.
- Rigidity of chamber vaults: one test per production run.
- Tensile strength: one test per production run.
- Flexural modulus: one test per production run.

The results obtained are subject to recording with a statistical exploiting of the results.

12. Certification

12.1 Quality system

Manufacturing STORMTECH PP chambers range is via an ISO 9001 (2008) certified quality assurance system.

12.2 Product certification

STORMTECH PP chambers are subject to QB mark certification which attests, for each manufacturing plant, to the regularity and satisfactory results of the internal inspections.

Those products with a valid certificate are identified by the presence on the products of the QB logo.

The QB mark certifies as to the following characteristics:

- Dimensional characteristics (see. Table 1 in Appendix),
- Hot viscosity index,
- Tensile strength characteristics (see § 2.2).

In the framework of certification, CSTB audits the producing sites in accordance with the QB mark reference system, for the:

- Examination of the Quality System in place
- Examination of the results of internal inspections
- Sampling of an arch and carrying out the following laboratory tests (dimensional characteristics, mechanical flexural characteristics, OIT)
- Carrying out the following tests in the plant laboratory: assembly chamber to chamber.

The results of this monitoring are examined by the Certificate Assessment Committee. The certificate is available on the website: www.cstb.fr.

B. Experimental results

Validation of the mechanical dimensioning by CSTB:

- Report No. ER 552 02 0503 – 25th October 2002
- Report No. EN CAPE 041 CV0
- Report No. EN CAPE 14.053 C-V1 – 21st November 2014
- Long term mechanical behavior characteristics report: CAPE 18-9897 (CSTB/October 2018)

Additional tests:

- Test reports GPE 02-033, CAPE ST 08-036, CAPE ST 12-086, CAPE AT 13-155, CAPE AT 14-015, MFPA PB 5.2/13-022-3,
- Isolator row study report Evaluation of performance of a STORMTECH isolator row - September 2010

C. References

C1. Health and Environmental Data (1)

The products are not subject to an Environmental Declaration (DE). They cannot therefore claim any particular environmental performance.

C2. Other references

A list of French and European references is registered at the CSTB.

The STORMTECH SC310 and STORMTECH SC740 chambers have been marketed in Europe since 1992 and several thousand cubic meters are in service. They are subject to certification in the following countries: France, England and Canada.

The STORMTECH MC3500, STORMTECH MC4500 have been marketed in Europe for several years and several thousand cubic meters are in service.

(1) Not examined by the Specialized Group within this Technical Appraisal.

Tables and figures of the Technical File

Table 1 - Dimensional characteristics of STORMTECH PP chambers

Reference	Total length mm (± 3 %)	Total width mm (± 3 %)	Total height mm (± 3 %)	Minimum wall thickness (mm)
STORMTECH SC 310	2300	850	410	3.3
STORMTECH SC 740	2300	1300	760	4.6
STORMTECH MC 3500	2285	1955	1145	5.7
STORMTECH MC 4500	1320	2540	1525	6.2

Table 2 – Dead volume of chambers in the case of retention basins

Reference	Height of dead volume (mm) (Foot of chamber to height of outlet)	Corresponding volume (Liters)
STORMTECH SC 310	23	36
STORMTECH SC 740	30	74
STORMTECH MC 3500	34	133
STORMTECH MC 4500	39	110

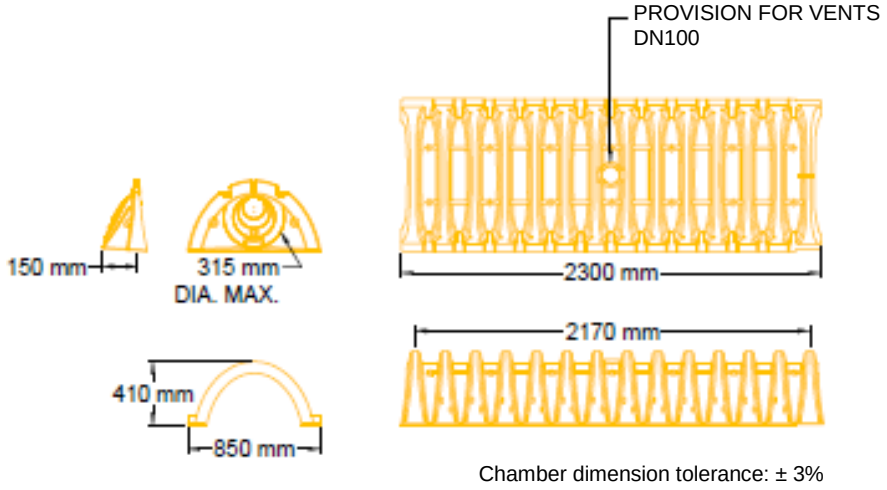

Figure 1 - Dimensions of the STORMTECH SC310 chamber

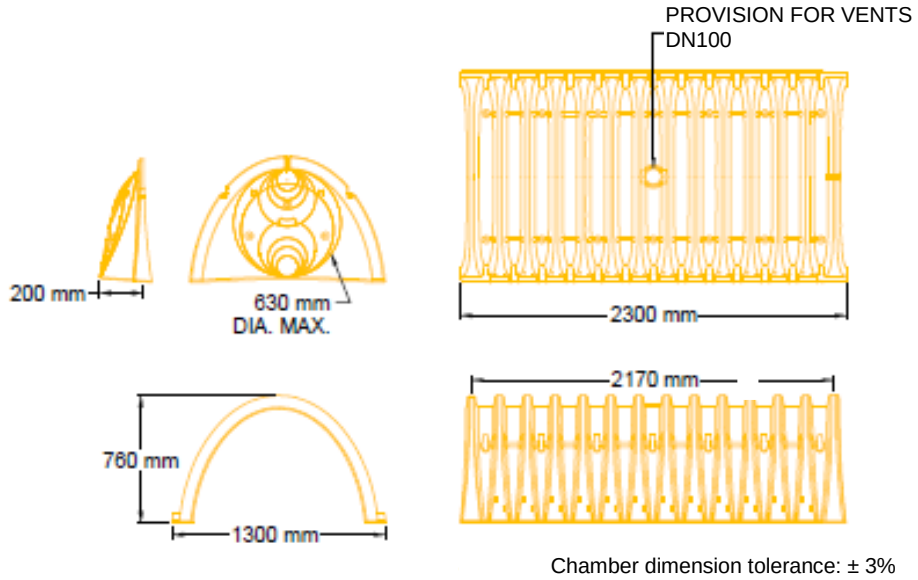

Figure 2 - Dimensions of the STORMTECH SC740 chamber

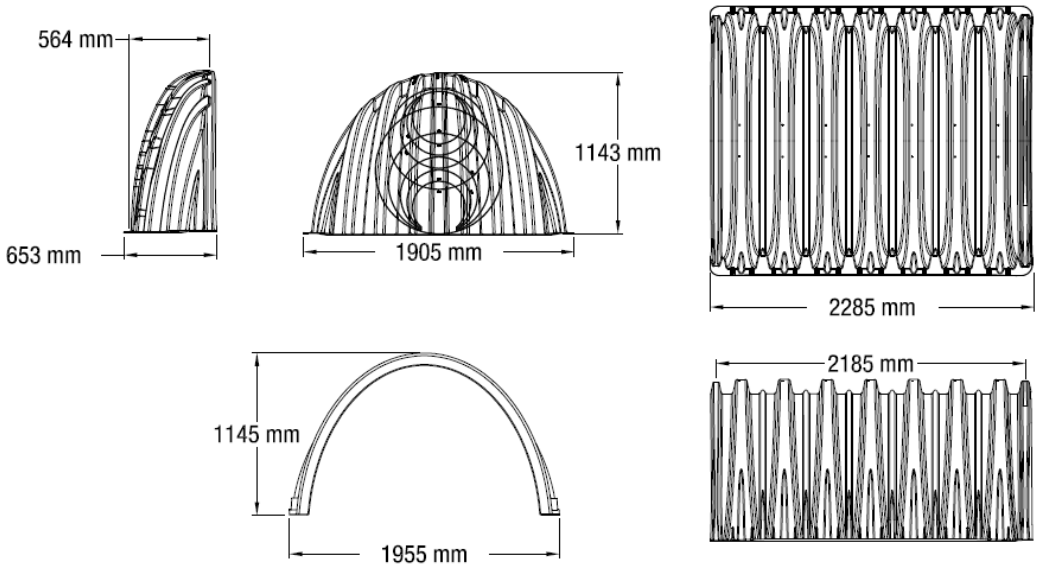

Figure 3 - Dimensions of the STORMTECH MC3500 chamber (tolerance: 3%)

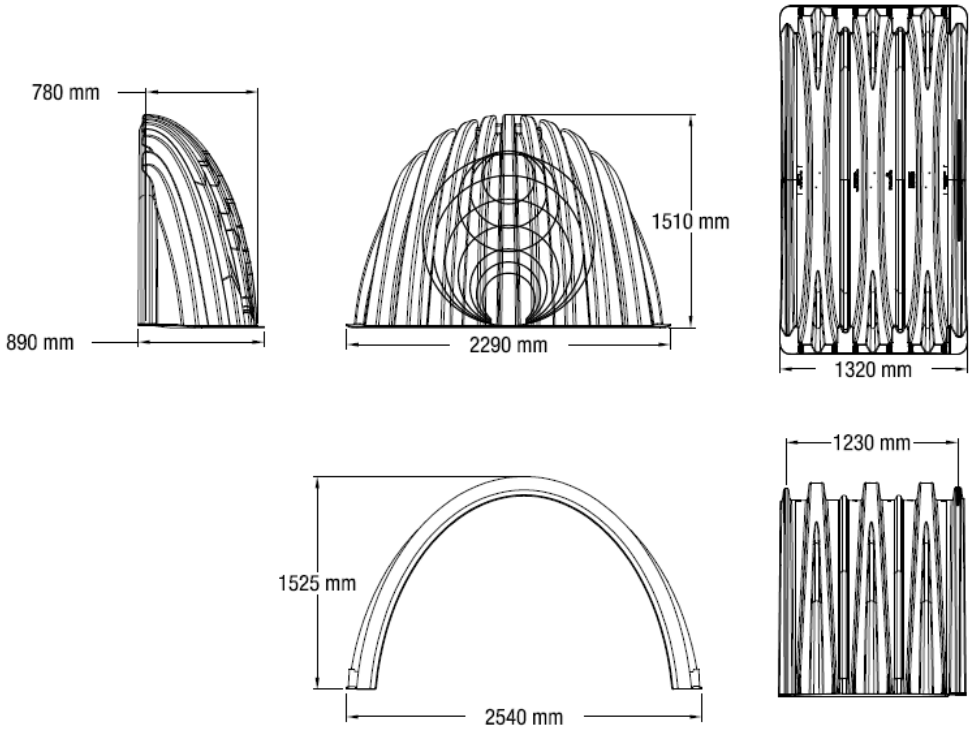

Figure 4 - Dimensions of the STORMTECH MC4500 chamber (tolerance: 3%)

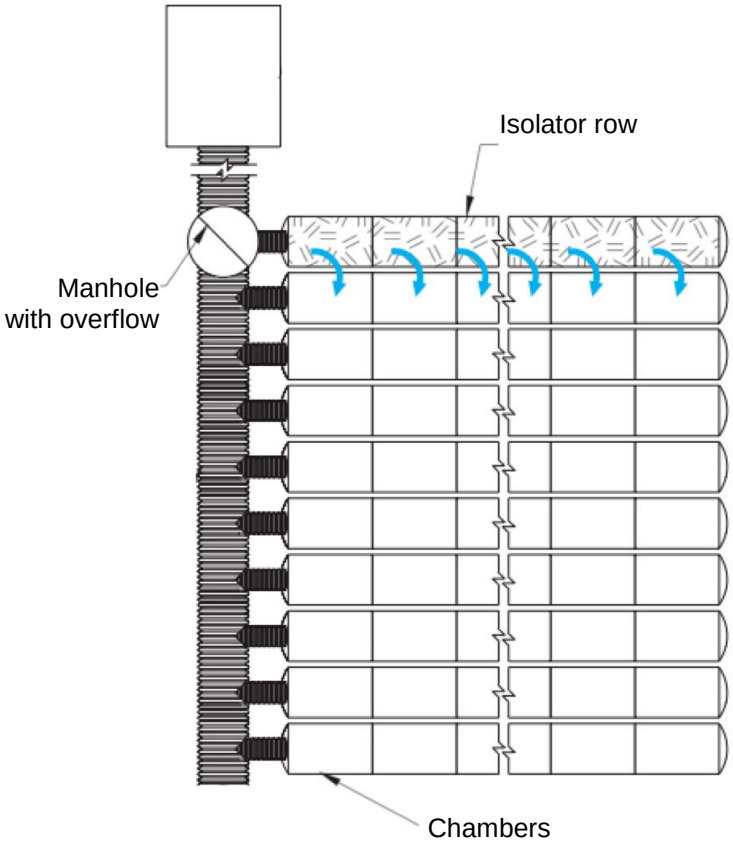

Figure 5a – Use of a row of STORMTECH chambers to favor decanting (isolator row)

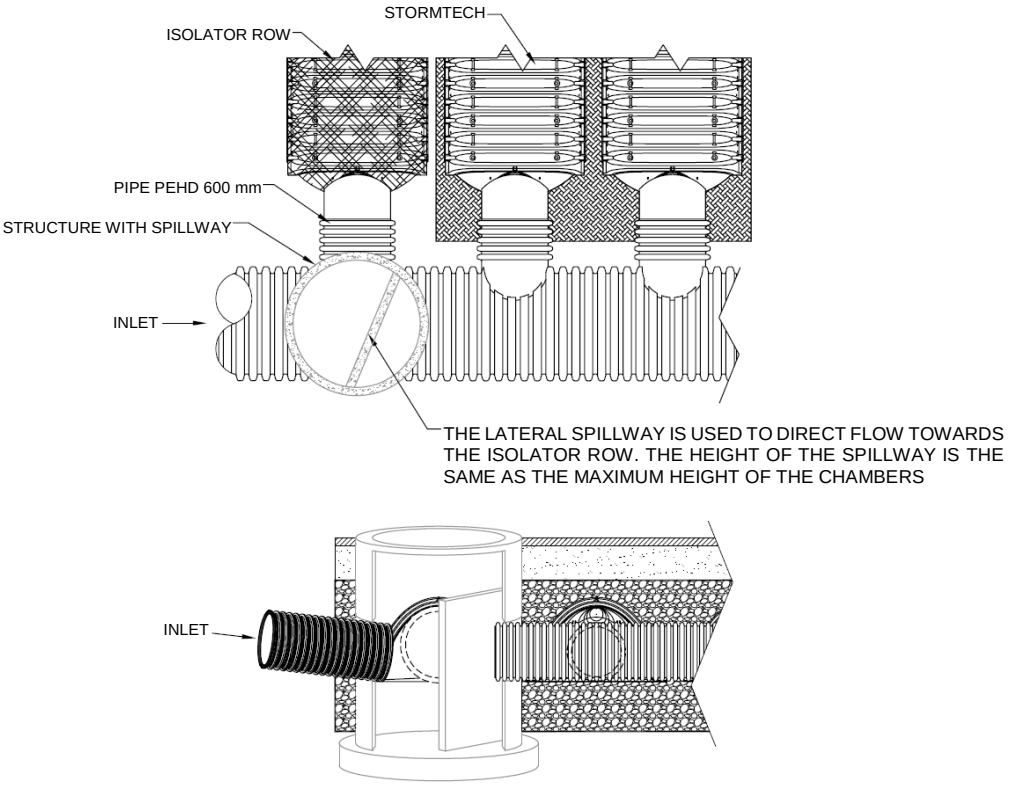

Figure 5b – Presentation of an isolator row arrangement

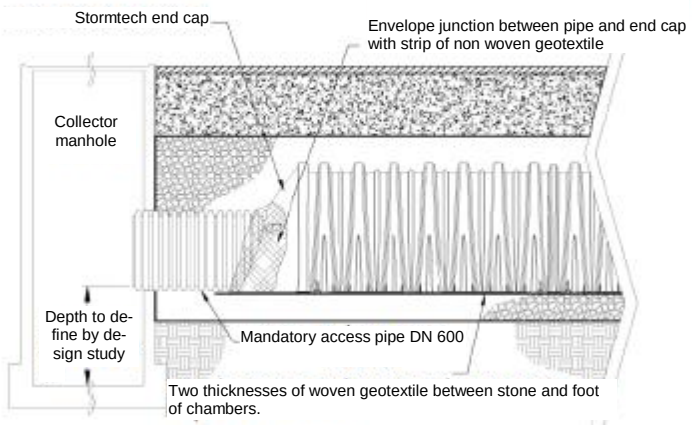

Figure 5c – Details of the isolator row arrangement

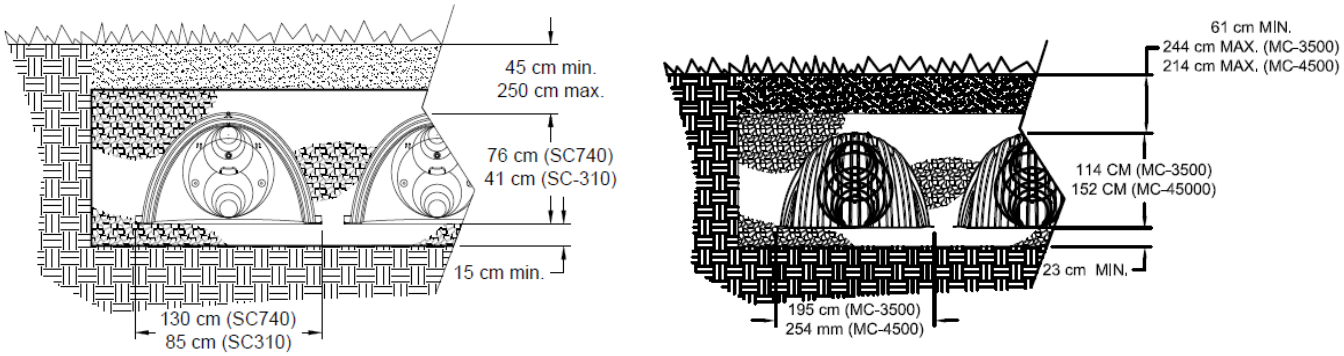

Figure 6 - Cross section of laying without mobile loads

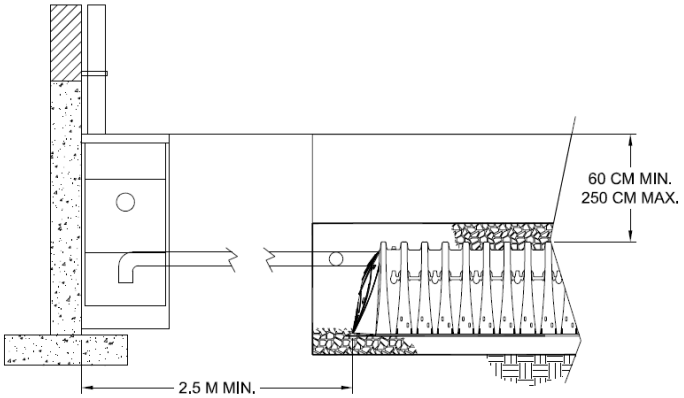

Figure 7 - Example of a detached house application using STORMTECH SC310 chambers

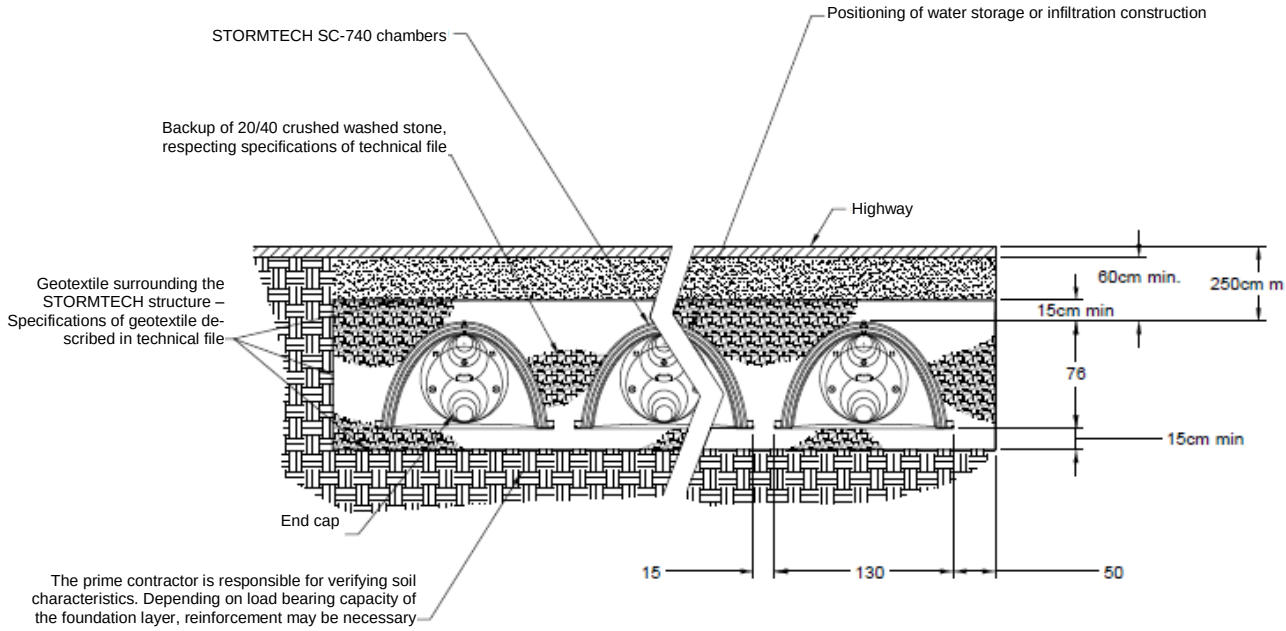

Figure 8 - Cross section of installation with or without mobile loads (STORMTECH SC310 + STORMTECH SC-740 chambers)

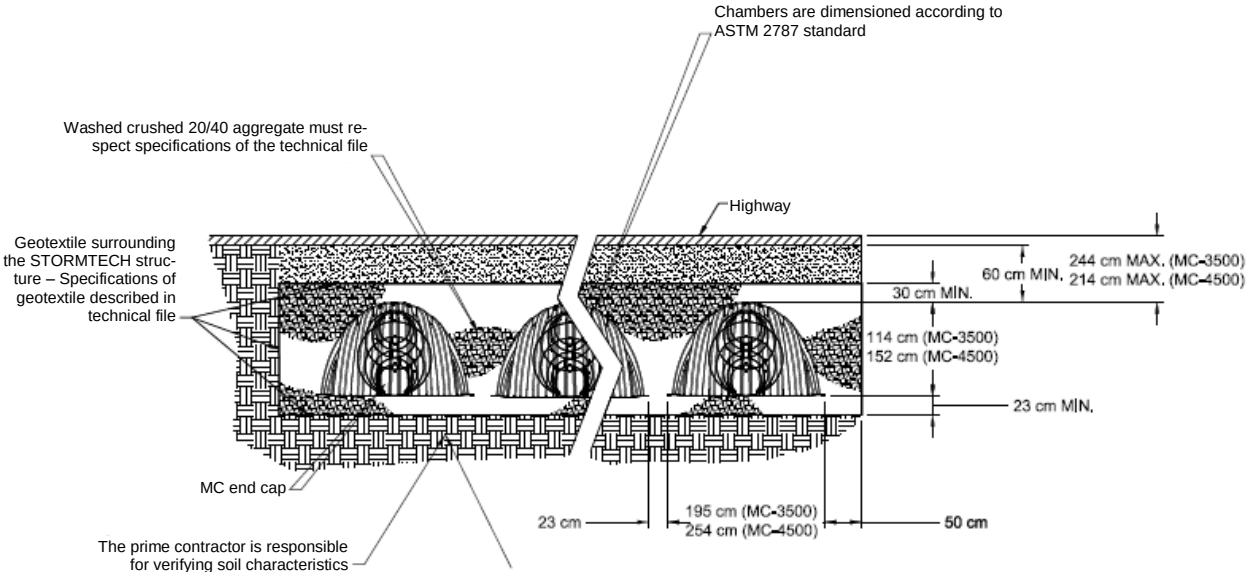

Figure 9 - Cross section of installation with or without mobile loads (STORMTECH MC3500 and STORMTECH MC4500 chambers)

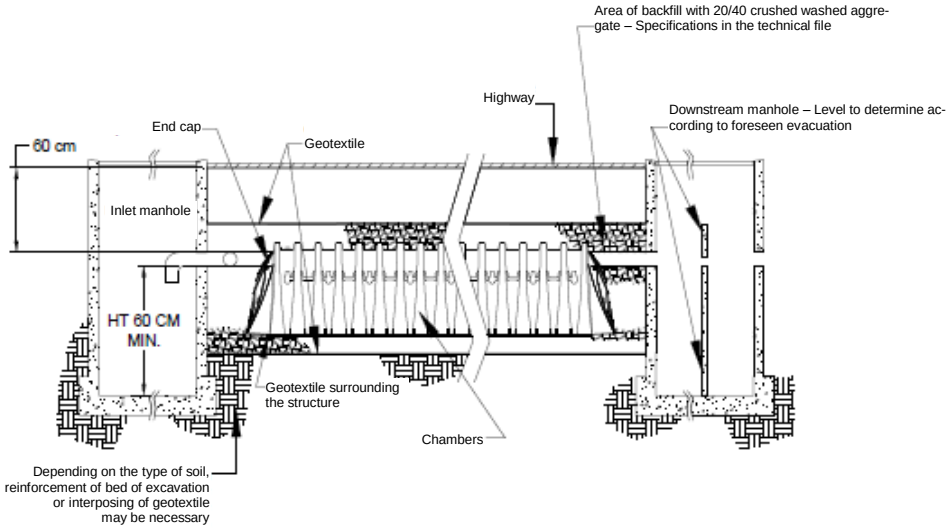

Figure 10 - Cross section of inlet and outlet – Example of STORMTECH SC740 or SC310 chambers.

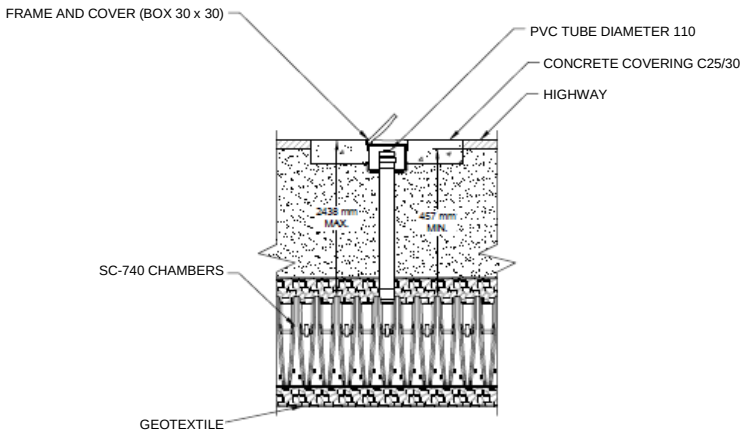

Figure 11 - Inspection access and vents for retention basin beneath green spaces