Eckersley O'Callaghan

Panther House, Camden
Flood Risk Assessment & Drainage Strategy

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Prepared by: M. Jones
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*Note: Amended Clauses are marked with the suffix B

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1 Introduction

1.1 Eckersley O'Callaghan are appointed by Panther House Developments Ltd. to provide flood risk and below ground drainage consultancy in relation to the development of Panther House, Grays Inn Road, London, WC1X 0AN.

1.2 The site is approximately 0.2 hectares in area and contains a number of office buildings of varying height. Planning permission is sought for the provision of additional floors onto the existing buildings and some infill development.

1.3 Although the site is located in Flood Zone 1 and is not within 20m of a Main River, a Flood Risk Assessment (FRA) is required as it is within Critical Drainage Area Group3_003 as defined in London Borough of Camden's Surface Water Management Plan. Furthermore the Camden Local Plan demands that a Flood Risk Assessment and Drainage Statement is submitted as the development is considered to be "Major". This includes *'developments of 10 or more homes or a floorspace of 1,000sqm or more, including student housing and non-residential development'*.

1.4 The assessment has been carried out in accordance with the guidelines set out in the National Planning Policy Framework (NPPF), London Borough of Camden (LBC) planning policy and LBC's requirements acting as the Lead Local Flood Authority (LLFA).

1.5 This report should be read in conjunction with architectural reports and drawings and other relevant documents supporting the planning application.

2 Planning Policies

2.1 The following policies relevant to flood risk mitigation are taken from The London Plan and incorporate the Further Alterations to the London Plan, which were implemented in March 2015.

Policy 5.12
Flood risk management
Strategic
A. The Mayor will work with all relevant agencies including the Environment Agency to address current and future flood issues and minimise risks in a sustainable and cost effective way.
Planning decisions
B. Development proposals must comply with the flood risk assessment and management requirements set out in the NPPF and the associated Technical Guidance on flood risk over the lifetime of the development and have regard to measures proposed in Thames Estuary 2100 (TE2100 – see paragraph 5.55) and Catchment Flood Management Plans.
C. Developments which are required to pass the Exceptions Test set out in the NPPF and the Technical guidance will need to address flood resilient design and emergency planning by demonstrating that:
a) the development will remain safe and operational under flood conditions
b) a strategy of either safe evacuation and/ or safely remaining in the building is followed under flood conditions
c) key services including electricity, water etc will continue to be provided under flood conditions
d) buildings are designed for quick recovery following a flood.
D. Development adjacent to flood defences will be required to protect the integrity of existing flood defences and wherever possible should aim to be set back from the banks of watercourses and those defences to allow their management, maintenance and upgrading to be undertaken in a sustainable and cost effective way.
Policy 5.13
Sustainable drainage
Planning decisions
A. Developments should utilise sustainable urban drainage systems (SUDS) unless there are practical reasons for not doing so, and should aim to achieve greenfield runoff rates and ensure that surface water runoff is managed as close to its source as possible in line with the following drainage hierarchy:
1) Store rainwater for later use
2) Use infiltration techniques, such as porous surfaces in non-clay areas
3) Attenuate rainwater in ponds or open water features for gradual release
4) Attenuate rainwater by storing in tanks or sealed water features for gradual release
5) Discharge rainwater direct to a watercourse
6) Discharge rainwater to a surface water sewer/drain
7) Discharge rainwater to the combined sewer.
Drainage should be designed and implemented in ways that deliver other policy objectives of this Plan, including water use efficiency and quality, biodiversity, amenity and recreation.

2.2 In addition to the London Plan policies, Section 3.4 'Flooding' within the Sustainable Design and Construction Supplementary Planning Guidance supporting The Mayor's London Plan requires the post-development peak runoff rate to be no greater than 50% of the pre-development runoff rate.

2.3 The current Draft London Plan (July 2019) retains similar principles with a slight change of emphasis towards green infrastructure and avoidance of impermeable paving. The target of greenfield run-off rates is continued 'depending on site conditions'.

2.4 The policies detailed below have been extracted from LBC's Core Strategy and Development Policies:

CS13 – Tackling climate change through promoting higher environmental standards
Water and surface water flooding
We will make Camden a water efficient Borough and minimise the potential for surface water flooding by: …
i) requiring development to avoid harm to the water environment, water quality or drainage systems and prevents or mitigates local surface water and downstream flooding, …
DP22 – Promoting sustainable design and construction
The Council will require development to incorporate sustainable design and construction measures. Schemes must:...
b) incorporate green or brown roofs and green walls wherever suitable.…
The Council will require development to be resilient to climate change by ensuring schemes include appropriate climate change adaptation measures, such as: …
g) limiting run-off;
h) reducing water consumption;…
DP23 – Water
The Council will require developments to reduce their water consumption, the pressure on the combined sewer network and the risk of flooding by:
a) incorporating water efficient features and equipment and capturing, retaining and re-using surface water and grey water on-site;
b) limiting the amount and rate of run-off and waste water entering the combined storm water and sewer network through the methods outlined in part a) and other sustainable urban drainage methods to reduce the risk of flooding;
c) reducing the pressure placed on the combined storm water and sewer network from foul water and surface water run-off and ensuring developments in the areas identified by the North London Strategic Flood Risk Assessment and shown on Map 2 as being at risk of surface water flooding are designed to cope with the potential flooding;
d) ensuring that developments are assessed for upstream and downstream groundwater flood risks in areas where historic underground streams are known to have been present; and
d) encouraging the provision of attractive and efficient water features.

2.5 From April 2019, London's 33 Lead Local Flood Authorities (LLFAs) have introduced the London Sustainable Drainage Proforma, which is required to accompany Sustainable Drainage strategies submitted with planning applications and will form part of planning application validation requirements. The completed Proforma is included in Appendix 5.

3 Discussion

3.1 The London Plan and the Camden Core Strategy address new development and development on so called 'brownfield' land. Neither discuss refurbishment projects where there is no change to the building footprint and where existing drainage connections would be re-used. From the writer's experience it would not be the norm for extensive sustainable drainage improvements to be imposed on a refurbishment project. Only those elements of a development that add floor area or increase the amount of external impermeable surfacing would normally generate a SuDS requirement.

3.2 The layout of Panther House presents particular challenges in terms of meeting the various sustainable drainage targets listed. Whereas the western catchment is being completely rebuilt and has scope for stormwater attenuation storage below the small covered courtyard area, the eastern catchment (the slightly larger of the two) is essentially a refurbishment project. Furthermore in the eastern catchment there is no available surface at ground level to locate any attenuation storage as there is an existing basement under the entire footprint. Attenuation storage could be positioned below the basement floor level (as proposed by previous planning application for this site) but the depth of the outgoing sewer severely limits the depth available for storage. This means that a very large proportion of the basement floor would need to be removed in order to fit in shallow attenuation storage. Also, by routing roofwater down to basement level, the flood risk to the building would arguably be increased as it relies on fully functioning flow controls and non-return valves, without the comfort of an overland flow route as a failsafe mechanism. With a practicable upper limit to the size of attenuation it is inevitable that at some point the basement would flood, which is undoubtedly contrary to the aims of the London Plan, particularly as in this case there is electrical infrastructure located at basement level.

3.3B In previous submissions of this report the strategy was to over-attenuate run-off from the western part of the site and not reduce or attenuate run-off from the eastern site. Following feedback from Camden's flood risk officer it has become clear that a more stringent control of run-off is required for the whole site. The project team has therefore introduced areas of green/blue roof on the eastern sector of the development and these have been factored into the drainage calculations to achieve a minimum 50% reduction in run-off rate for the 30 and 100 year storm return periods including climate change allowances.

3.4 The following assessment and drainage proposals provide more detail on this overall strategy and demonstrate how the drainage proposals are in compliance with the various planning policies listed.

4 Flood Risk

4.1 **Vulnerability Classification -** With reference to Table 2 of the Technical Guidance to the NPPF, the vulnerability classification of the existing site is "Less Vulnerable" due to the office uses. There is no proposed change of use therefore the vulnerability classification of the proposed development will remain as "Less Vulnerable", which is acceptable within Flood Zone 1.

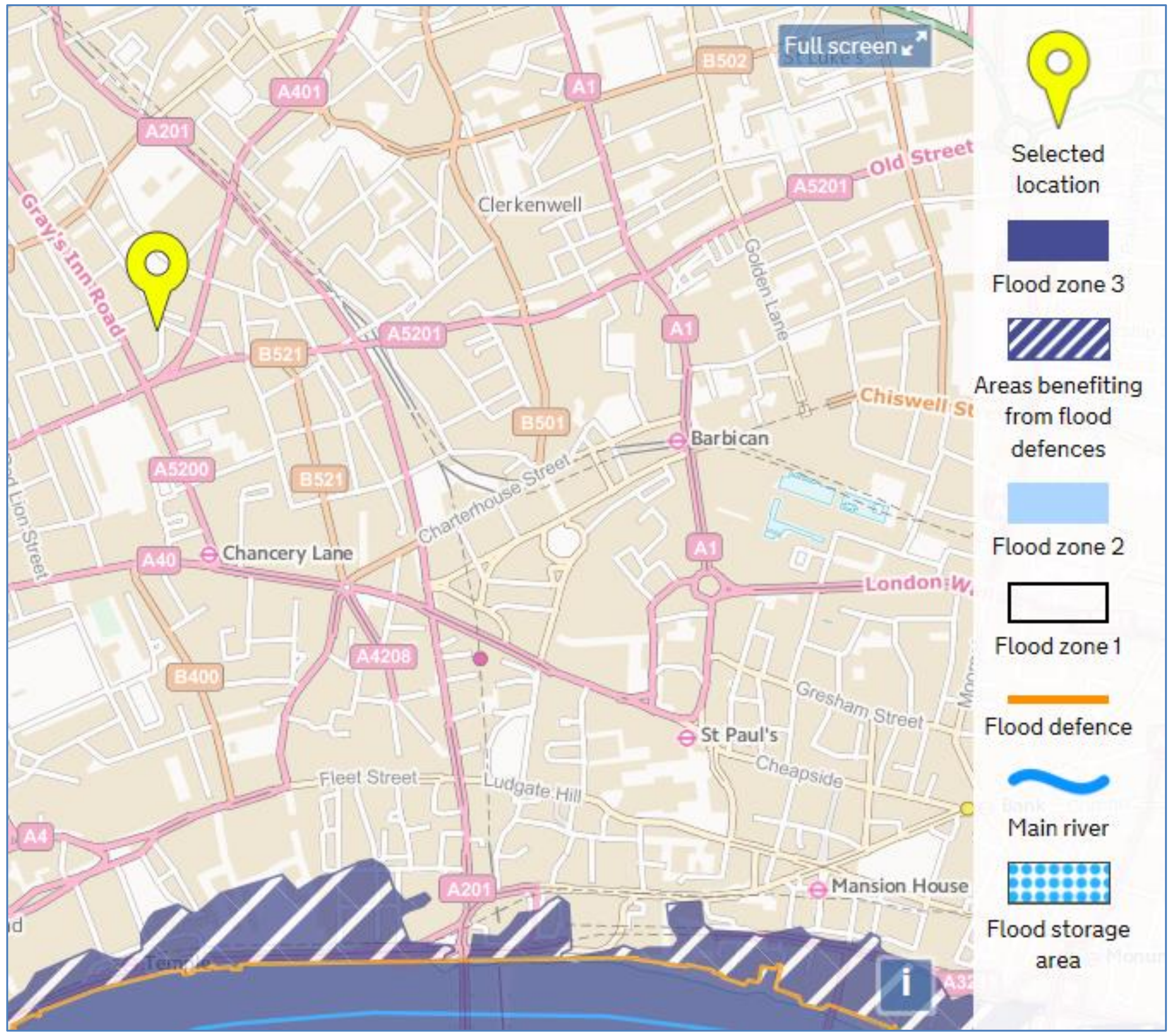


Figure 1 – EA Flood Map Extract

4.2 **Sources of Flooding:**

4.2.1 *Fluvial flooding* - An extract from the on-line Environment Agency Flood Maps is shown in Figure 1 below. This confirms that the site is in Flood Zone 1 with the nearest fluvial flood risk zone located over a kilometer away to the south associated with the River Thames. Fluvial flood risk is therefore considered to be **low.**

4.2.2 *Pluvial flooding* - Localised flooding problems arising from drainage and/or sewer systems with limited capacity will inevitably occur. Sewer systems are generally designed (in accordance with current Government guidance) to cater for 1 in 30 year storms. Some historic London sewers have a higher capacity due to their method of construction and/or the design methodology applied at the time. Storms in excess of the sewer capacity would result in localised flooding and the generation of overland flow driven by the local topography. However, no incidents of surface water or sewer flooding in the vicinity of the Site have been recorded in the Camden SFRA or the Camden Surface Water Management Plan, which confirms that the Critical Drainage Area Group3_003 designation is for administrative purposes rather than to address particular drainage issues at the site itself. The EA's Lidar based Risk of Flooding from Surface Water map (See Figure 2) suggests that there are some areas of the site which would be at low to medium risk of flooding during a pluvial flood event. The pluvial flood maps are based on Lidar topographical data and are therefore a relatively crude but useful assessment of where surface water may accumulate during extreme storm events. The degree of flood risk is based on the parameters in Figure 4 extracted from the Environment Agency's explanatory document for the flood maps. In order to ensure the residual risk of such flooding does not increase post-development, the new drainage system will be designed to store rainfall generated by events up to a 100year return period including allowance for climate change. Thus the proposed attenuation storage will absorb the medium and high risk pluvial flood volume. With these provisions in place, pluvial flood risk is considered to be **low.**

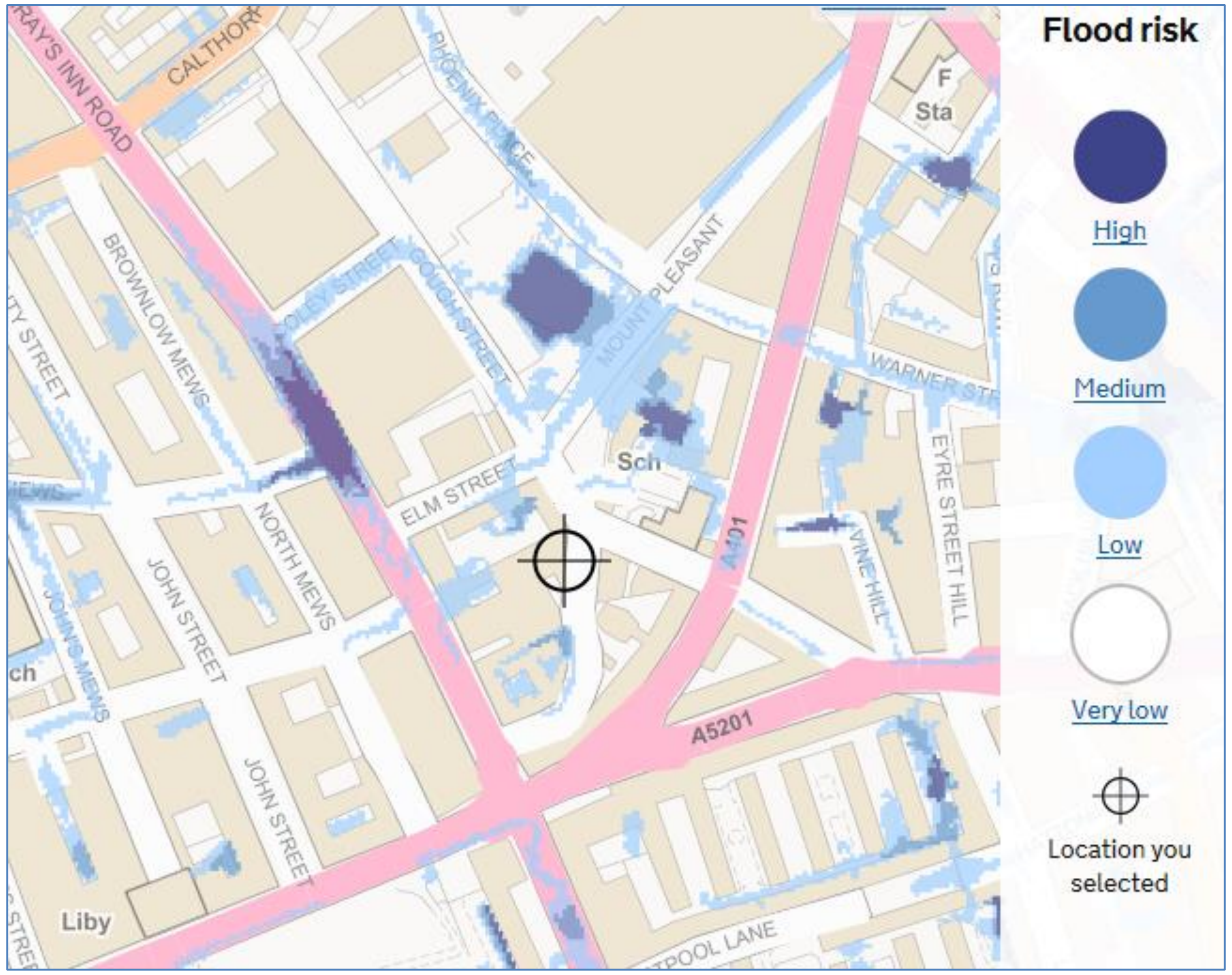


Figure 2 – Surface Water (Pluvial) Flood Risk from gov.uk website (EA data)

High	Flooding occurring as a result of rainfall with a greater than 1 in 30 chance in any given year (annual probability of flooding 3.3%)
Medium	Flooding occurring as a result of rainfall of between 1 in 100 (1%) and 1 in 30 (3.3%) chance in any given year
Low	Flooding occurring as a result of rainfall of between 1 in 1000 (0.1%) and 1 in 100 (1%) chance in any given year
Very Low	Flooding occurring as a result of rainfall with less than 1 in 1000 (0.1%) chance in any given year

Figure 3 – EA Surface Water Flood Map – Zone Definitions

4.2.3 *Sewer Flooding* – The Camden SFRA contains a summary of the Thames Water DG5 records of internal and external sewer flooding. No flooding has been recorded at the application site. New drainage systems will be designed to prevent backflows from sewers and critical drainage manholes will be fitted with sealed hatchboxes where required to prevent surcharging within the building footprint. With these facilities in place and site levels designed to direct overland flows away from critical thresholds, flood risk from this source is considered to be **low.**

4.2.4 *Groundwater flooding* - The Camden SFRA includes data obtained from the British Geological Society showing areas of 'Increased Susceptibility to Elevated Groundwater'. Although there are patches of land north of the application site where groundwater vulnerability is considered to be a factor, the site itself is not affected. Furthermore the site does not have basements that are set wholly below adjacent land without an escape route for groundwater seepages. Walls that are retaining and floors built off natural ground will be fully waterproofed and formally drained internally so as to prevent any damage to the building fabric. Flood risk from this source is therefore considered to be **low.**

4.2.5 *Flooding from Reservoirs, Canals and artificial water bodies* – Neither the EA website or the Camden SFRA show any risk of flooding from this source therefore the flood risk is considered to be **low.**

5 Drainage Strategy

5.1B In developing a strategy for the drainage changes necessary to accommodate the proposed building works the following overarching principles have been considered:

- New foul and storm systems will be designed as separate drainage networks, which will combine at the final manhole(s) prior to connecting to the public sewer network.
- Existing systems will be retained where they are in a suitable condition and will continue to discharge at the existing connection points. Some relining and localised replacement may be required subject to detailed CCTV survey work.
- As most of the site is occupied by buildings, infiltration systems are not feasible, therefore attenuation storage will be used to limit off-site flows and thus reduce downstream flood risk.
- In terms of the attenuation design, the western and eastern catchments will be treated individually, but the overall effect is to reduce existing run-off by at least 50% whilst allowing for climate change.

Storm Drainage

5.1 A proposed layout of the storm drainage system is included on the drawing in Appendix 1.

5.2 The criteria for determining the stormwater strategy comes primarily from the local planning strategies listed previously and will also need to comply with any restrictions applied by Thames Water where the discharge is to their sewer network. Thames Water's criteria should be coincident with the Camden policies but this will be verified and if necessary formalised through a Section 106 drainage connection application in due course. A Section 106 application should not be required for the eastern catchment as this will utilise the same building footprint and drainage connection as existing.

5.4B The following hierarchy of stormwater disposal methods has been considered in line with current best practice for Sustainable Drainage Systems (SUDS):

1st – Recycle

2nd – Infiltration/Soakaways;

3rd – Discharge to a Watercourse;

4th – Discharge to a Sewer.

Roofwater recycling has been discounted on the basis that the roof area is small compared to the number of potential users and the disproportionate investment required to distribute a small water resource over a large number of occupants. Irrigation demand from any soft landscaping is minimal, which further weighs against the cost and ongoing management implications of a roofwater recycling system.

Infiltration systems are not viable for the site given the extent of building foundations and basement areas as well as the proximity to roads and adjacent buildings.

There is no watercourses in reasonable proximity to the site for a direct connection therefore the most sustainable drainage option that can be achieved in the hierarchy is a discharge to the local sewer network at an attenuated rate. Due to the intensity of development already on the site it is considered that achieving a 50% run-off reduction in line with the minimum London Plan and Camden SFRA requirements whilst mitigating climate change impacts would be a practicable response to the site constraints. To establish the required attenuation volumes, Microdrainage calculations have been carried out based on a split in the total run-off to the existing sewer branches in the north east and south west corners of the site. The resulting calculations are shown in Appendices 2-4.

5.5B The discharge rates used in the attenuation design are based on not exceeding the existing 1yr return period flow, which keeps the orifice size up to avoid blockages in compliance with the London Plan Supplementary Planning Guidance (SPG) Para. 3.4.9. This rate has been used because the target of greenfield rates would require controls so small as to encourage drainage blockages and possibly *increase* the flood risk. Thus although there will be only slight reduction of peak flows in 1yr storm events to provide protection against climate change, this is not the critical event likely to generate downstream flooding. The more critical 30 year and 100 year flows are reduced by over 50% compared to the total predevelopment flows, thus achieving the minimum 50% reduction required by the London Plan SPG Para. 3.4.8. See Appendix 2. The attenuation on the eastern half of the development will be achieved at roof level through the use of 260m2 of green roof and 104m2 of blue roof. The blue and green roof areas have been modelled as a shallow tank with an orifice control using Microdrainage. Actual outlet controls will be provided by the selected roof system manufacturer and will be checked to ensure they meet or exceed the performance of the system modelled in the calculations.

5.6 As the below ground volume of attenuation connects to a combined sewer system the risk of backflows from the sewers weighs against the use of cellular crates as the clean up after a flood event would be problematic (despite manufacturers' claims to the contrary). The tank construction will therefore be a combination of in situ and precast concrete with access points to facilitate inspection, jetting and de-silting.

5.7 Consideration has been given to the implications of system failure. This could be a rainfall event in excess of the design, on site drainage blockages or failure/surcharge of the local public drainage system. The site levels in the western catchment will be arranged such that surface water always has a route out of the site towards the existing highway infrastructure. This will ensure the depth of water flowing during exceedance events is controlled such that is does not reach door thresholds or overflow into basement areas.

5.8 The eastern catchment has restricted capacity for overland flow routes during exceedance events as the buildings will fully occupy the site. The existing central courtyard area will have a canopy fitted over it so whereas this area can currently flow directly out onto the surface of Mount Pleasant, in future this will be achieved by a system of canopy drains at high level directing the run-off into the existing roofwater outlets with overflow weirs at the site perimeter to allow exceedance flows to overspill onto the adjacent streets, thus reflecting the pre-development conditions.

5.9 Roof drainage outlet positions on the existing buildings and their outlet branches to the local drainage systems in the eastern catchment will be re-used where practical. Some re-routing at high level in the basement will be needed to suit the revised occupancy and use categories in the basement area. Basement drainage systems below the basement floor carrying any surface water will be fitted with hatchbox chambers to limit the potential for drainage surcharging at basement level.

5.10 Construction of surface finishes and wall bases will utilise water resilient materials where they could potentially be affected by shallow flooding or overland flow routes. Electrical distribution and other critical services will be routed at high level in the basements to limit potential impacts of drainage exceedance.

Foul Drainage

5.11 Flows from sanitary fittings at or above ground level will be picked up in a network of sanitary floats discharging to the main soil stacks running adjacent to structural columns and/or positioned in dedicated service risers. The foul drainage scheme at ground floor and basement level is shown in Appendix 1. Essentially the site is split into two catchments, one discharging eastwards via the existing sewer branch to the Grays Inn Road TW sewer, the other discharging via the existing basement drainage connection into the Mount Pleasant TW sewer network.

5.12 Existing sewer connections will be utilised to avoid disturbance of existing services in the surrounding streets and to avoid the traffic disruption caused by new branches.

Groundwater/Waterproofing - Drainage Issues

5.13 The basement area will be refurbished to minimise dampness & groundwater ingress. Where a Type C internal environment to BS8102 is required this will involve cavity drainage and sumps with pumps to remove interstitial water, which will be drained to the foul system due to the potential risk of pollution.

5.14 Cavity drainage water would be classified as groundwater by Thames Water, which is normally not permitted to be discharged into the sewer network. Discussions will be needed with TW to establish their position on this issue given the very low flow anticipated. From experience TW will charge a license fee for agreed groundwater discharges.

Below Ground Drainage Specification Generally

5.15 New storm and foul drainage will be provided in accordance with BSEN 752 and Building Regulations. Pipe materials for external gravity systems above the groundwater level may be plastic or clay. Internal to the buildings materials will be plastic or ductile iron. External manholes and inspection chambers will typically be plastic non-man-entry type compliant with latest Sewers for Adoption standards and positioned to provide full maintenance access for future inspection/rodding/jetting, augmented with suitably sized access points at gullies, downpipes etc. all as required by current Building Regulations. Larger manholes for silt traps and the like will be constructed using pre-cast concrete sections and large access covers to enable silt removal as part of the ongoing maintenance regime. Any drainage at risk of being affected by elevated groundwater levels will be constructed in a fully welded HDPE system including preformed HDPE inspection chambers welded to the drain runs and capable of resisting external hydrostatic pressure.

5.16 During construction and on completion of the drainage works the entire storm and foul drainage pipe network will be tested, cleaned and inspected with CCTV equipment. Any faults discovered will be corrected and re-tested/re-surveyed until the entire system is suitable for commissioning.

6 Climate Change

5.1 Climate change is a factor to be assessed for both predicted flood levels and for allowances to be added to rainfall events in order to mitigate the potential impacts of increased site run-off.

The design life of the project will be approximately 50 years in line with current structural Eurocodes. The wording on life spans in the NPPF is as follows (our emphasis) - *Residential development should be considered for a minimum of 100 years, unless there is specific justification for considering a shorter period. For example; the time in which flood risk or coastal change is anticipated to impact on it, where a development is controlled by a time-limited planning condition.*

The lifetime of a non-residential development depends on the characteristics of that development. Planners should use their experience within their locality to assess how long they anticipate the development being present for. Developers would be expected to justify why they have adopted a given lifetime for the development, for example, when they are preparing a site-specific flood risk assessment.

6.2 As far as the influence of climate change on site run-off is concerned, the EA have reasonably recently revised their climate change predictions upwards and therefore the proposed attenuation storage will be designed to contain an additional 40% climate change induced rainfall. This complies with the EA requirement and will ensure that the effect of potential higher rainfall rates is reasonably mitigated to below pre-development conditions for the anticipated lifespan of the building.

7 Flood Risk Management Measures

7.1 To avoid any increase in flood risk due to the development's own drainage network the proposed site drainage systems will be designed so that they are easy to inspect and simple to clean with plenty of access points and provision for the use of conventional jetting equipment. The developer will employ experienced facility managers to operate, inspect and maintain the drainage system as part of the overall building maintenance schedule.

7.2B Potential issues that will need to be addressed in order to sustain the low level of flood risk on the site will be:

- Regular checking of the attenuation tank(s) and the associated outlet controls to ensure the system is functioning properly, together with clearing of any contributing drainage gullies and silt traps.
- Regular checking of green roof and blue roof outlet controls to ensure they are not blocked by debris
- Periodical inspection and jetting of drain runs.
- Clearing of drainage channels and gutters to prevent carry-over of debris to the attenuation tank (where necessary leaf guards will be fitted to gutters and downpipe outlets to prevent the ingress of leaves and moss from roofs as the development becomes more mature).

Where regular checks are required these would be carried out at no more than 6 monthly intervals for the drainage system initially and the need for checking would be reviewed on an ongoing basis depending on how the various elements are performing.

8 Off Site Impacts

8.1 Potential off site impacts are addressed through the use of a sustainable drainage strategy as described herein. With the proposed sustainable drainage measures in place together with the drainage management procedures described, it is considered that there will be negligible increase in flood risk to off-site receptors, including for the effects of climate change.

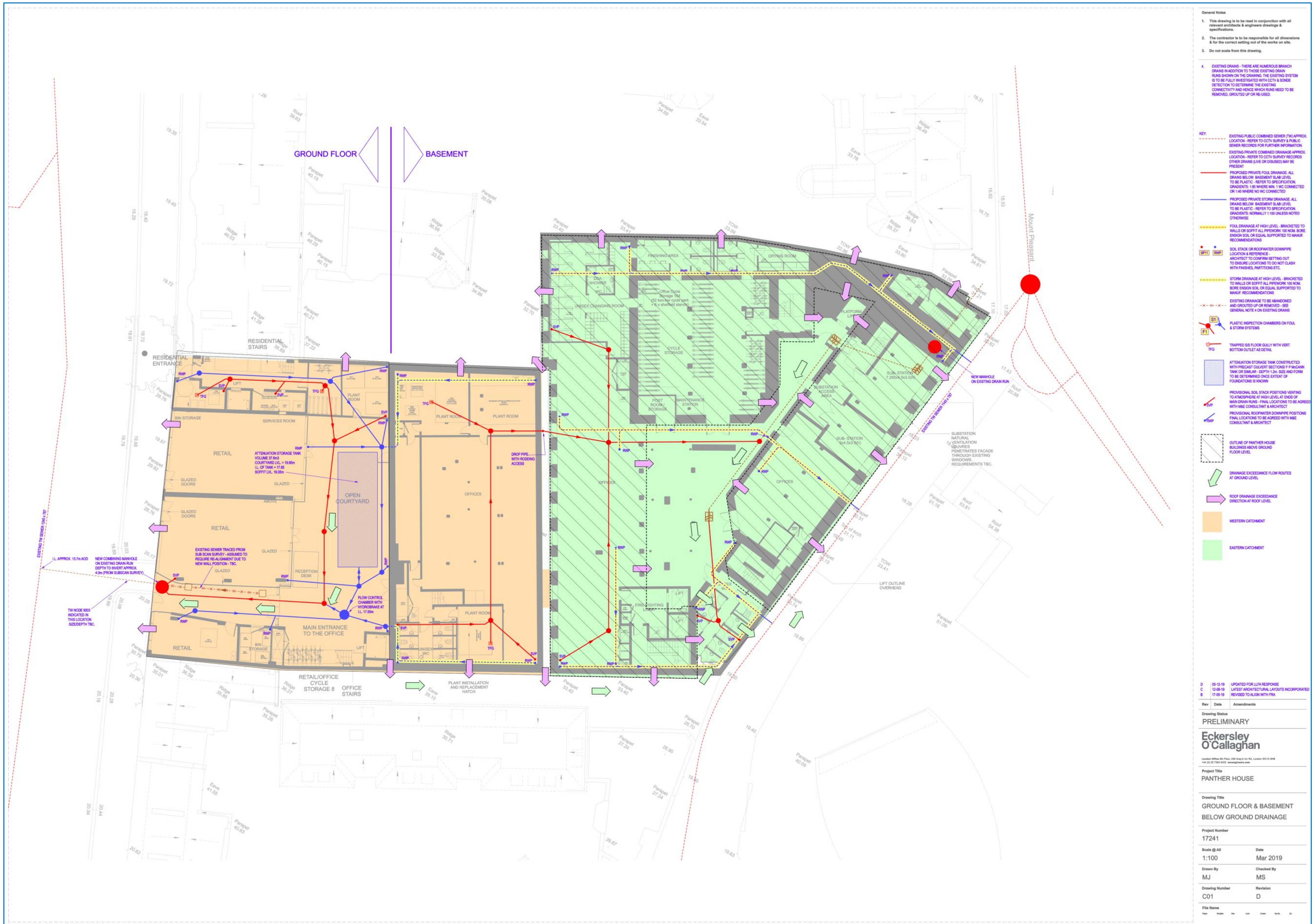
9 Residual Risks

9.1 The residual flood risks to the application site following development taking account of climate change effects are considered to be as follows:

- Less than 1% annual probability of fluvial flooding.
- Less than 1% annual probability of pluvial flooding.
- 1% annual risk of exceedance flows due to surcharged drain systems within the site but negligible risk of flood damage from this source bearing in mind the site levels, which are designed to marshal exceedance flows safely towards adjacent lower land.
- Risk of downstream flooding due to run-off from the development significantly reduced through sustainable drainage measures, with 40% capacity allowance for climate change.

Overall residual flood risk post-development is therefore considered to be **low**.

Appendix 1 – Proposed Drainage Scheme Drawing



Appendix 2 – Existing v Proposed Run-off

To determine the amount of attenuation required we have assessed the existing run-off from the site using a Wallingford calculation as follows:

Wallingford Method: Calculation of Pre development run-off rates

The Rational Formula: Qp=CiA (formula 7.18 Wallingford Procedure Vol. 1)

Where Qp = discharge rate
C = Coefficient where C = Cv x Cr (Cv=volumetric run-off coefficient & Cr=routing coefficient) (formula 7.19)
i = mean rainfall intensity mm/hr
A = Area (ha).

For Qp in litres per second the formula becomes Qp=CiA÷0.36

Determination of C:

From Wallingford Procedure Vol.1 Cv = 0.9 for full urbanised catchment and Cr = 1.3.
∴ C= 1.17

The storm duration will be taken as 30 minutes as standard practice

Determination of i from FEH for OS Grid Reference E531014 N182085
1 year 30 min. rainfall depth = 7.61mm mean rainfall for design = 15.22mm/hr
30 year 30 min. rainfall depth = 30.17mm mean rainfall for design = 60.34mm/hr
100 year 30 min. rainfall depth = 40.4mm mean rainfall for design = 80.8mm/hr

Using these values the following existing flow rates have been generated for comparison with the Microdrainage calculations for proposed run-off shown in Appendix 3 & 4:

EXISTING FLOW RATES							PROPOSED RATES l/s		
Catchment	Area m2	% imp. area	Imp. area m2	1 yr 30min. Rate l/s	30 yr 30min. Rate l/s	100 yr 30min. Rate l/s	1 yr	30 yr	100 yr
West	966	100	966	4.78	18.94	25.37	4.78	4.78	4.78
East	1154	100	1154	5.71	22.63	30.30	4.41	15.54	21.35
Whole Site	2120	100	2120	10.49	41.57	55.67	9.19	20.32	26.13

By comparing the proposed and existing flows it can be seen that the post development peak flow reduction is as follows:

Catchment	1yr Reduction	30yr reduction	100yr reduction
West	0%	74.8%	81.1%
East	22.8%	31.3%	29.5%
Whole Site	12.4%	51.1%	52.1%

Appendix 3 – Proposed Run-off Calculation- West Catchment 1yr

Infrastructure Design Studio		Page 1
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	Micro Drainage
Date 21/05/2019 17:29 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

Summary of Results for 1 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	17.964	0.114	4.6	4.3	O K
30 min Summer	17.967	0.117	4.6	4.4	O K
60 min Summer	17.950	0.100	4.6	3.8	O K
120 min Summer	17.909	0.059	4.6	2.2	O K
180 min Summer	17.877	0.027	4.6	1.0	O K
240 min Summer	17.857	0.007	4.6	0.3	O K
360 min Summer	17.850	0.000	3.9	0.0	O K
480 min Summer	17.850	0.000	3.2	0.0	O K
600 min Summer	17.850	0.000	2.7	0.0	O K
720 min Summer	17.850	0.000	2.3	0.0	O K
960 min Summer	17.850	0.000	1.9	0.0	O K
1440 min Summer	17.850	0.000	1.4	0.0	O K
2160 min Summer	17.850	0.000	1.0	0.0	O K
2880 min Summer	17.850	0.000	0.8	0.0	O K
4320 min Summer	17.850	0.000	0.6	0.0	O K
5760 min Summer	17.850	0.000	0.5	0.0	O K
7200 min Summer	17.850	0.000	0.4	0.0	O K
8640 min Summer	17.850	0.000	0.4	0.0	O K
10080 min Summer	17.850	0.000	0.3	0.0	O K
15 min Winter	17.984	0.134	4.6	5.0	O K
30 min Winter	17.988	0.138	4.6	5.2	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	46.523	0.0	8.4	17
30 min Summer	29.955	0.0	10.8	26
60 min Summer	18.628	0.0	13.4	42
120 min Summer	11.334	0.0	16.3	74
180 min Summer	8.429	0.0	18.1	102
240 min Summer	6.823	0.0	19.6	130
360 min Summer	5.037	0.0	21.8	0
480 min Summer	4.049	0.0	23.3	0
600 min Summer	3.417	0.0	24.6	0
720 min Summer	2.975	0.0	25.7	0
960 min Summer	2.391	0.0	27.5	0
1440 min Summer	1.757	0.0	30.4	0
2160 min Summer	1.292	0.0	33.5	0
2880 min Summer	1.039	0.0	35.9	0
4320 min Summer	0.763	0.0	39.5	0
5760 min Summer	0.613	0.0	42.4	0
7200 min Summer	0.517	0.0	44.7	0
8640 min Summer	0.450	0.0	46.7	0
10080 min Summer	0.401	0.0	48.5	0
15 min Winter	46.523	0.0	9.3	17
30 min Winter	29.955	0.0	12.2	27

Infrastructure Design Studio		Page 2
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Causeway	Source Control 2017.1.2	

Summary of Results for 1 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	17.957	0.107	4.6	4.0	O K
120 min Winter	17.892	0.042	4.6	1.6	O K
180 min Winter	17.852	0.002	4.5	0.1	O K
240 min Winter	17.850	0.000	3.8	0.0	O K
360 min Winter	17.850	0.000	2.8	0.0	O K
480 min Winter	17.850	0.000	2.3	0.0	O K
600 min Winter	17.850	0.000	1.9	0.0	O K
720 min Winter	17.850	0.000	1.7	0.0	O K
960 min Winter	17.850	0.000	1.4	0.0	O K
1440 min Winter	17.850	0.000	1.0	0.0	O K
2160 min Winter	17.850	0.000	0.7	0.0	O K
2880 min Winter	17.850	0.000	0.6	0.0	O K
4320 min Winter	17.850	0.000	0.4	0.0	O K
5760 min Winter	17.850	0.000	0.3	0.0	O K
7200 min Winter	17.850	0.000	0.3	0.0	O K
8640 min Winter	17.850	0.000	0.3	0.0	O K
10080 min Winter	17.850	0.000	0.2	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	18.628	0.0	15.1	44
120 min Winter	11.334	0.0	18.3	76
180 min Winter	8.429	0.0	20.4	100
240 min Winter	6.823	0.0	22.0	0
360 min Winter	5.037	0.0	24.4	0
480 min Winter	4.049	0.0	26.1	0
600 min Winter	3.417	0.0	27.6	0
720 min Winter	2.975	0.0	28.8	0
960 min Winter	2.391	0.0	30.8	0
1440 min Winter	1.757	0.0	34.0	0
2160 min Winter	1.292	0.0	37.5	0
2880 min Winter	1.039	0.0	40.2	0
4320 min Winter	0.763	0.0	44.3	0
5760 min Winter	0.613	0.0	47.4	0
7200 min Winter	0.517	0.0	50.1	0
8640 min Winter	0.450	0.0	52.3	0
10080 min Winter	0.401	0.0	54.3	0

Appendix 3 – Proposed Run-off Calculation- West Catchment 1yr

Infrastructure Design Studio		Page 3
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	
Date 21/05/2019 17:29 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	1	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.700	Shortest Storm (mins)	15
Ratio R	0.443	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.096

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.048	4	8	0.048

Appendix 3 – Proposed Run-off Calculation- West Catchment 30yr

Infrastructure Design Studio		Page 1
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	Micro Drainage
Date 21/05/2019 17:24 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

Summary of Results for 30 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	18.349	0.499	4.6	18.7	O K
30 min Summer	18.441	0.591	4.6	22.2	O K
60 min Summer	18.445	0.595	4.6	22.3	O K
120 min Summer	18.453	0.603	4.6	22.6	O K
180 min Summer	18.415	0.565	4.6	21.2	O K
240 min Summer	18.351	0.501	4.6	18.8	O K
360 min Summer	18.214	0.364	4.6	13.7	O K
480 min Summer	18.094	0.244	4.6	9.2	O K
600 min Summer	18.000	0.150	4.6	5.6	O K
720 min Summer	17.932	0.082	4.6	3.1	O K
960 min Summer	17.859	0.009	4.6	0.3	O K
1440 min Summer	17.850	0.000	3.4	0.0	O K
2160 min Summer	17.850	0.000	2.4	0.0	O K
2880 min Summer	17.850	0.000	1.9	0.0	O K
4320 min Summer	17.850	0.000	1.3	0.0	O K
5760 min Summer	17.850	0.000	1.1	0.0	O K
7200 min Summer	17.850	0.000	0.9	0.0	O K
8640 min Summer	17.850	0.000	0.8	0.0	O K
10080 min Summer	17.850	0.000	0.7	0.0	O K
15 min Winter	18.427	0.577	4.6	21.6	O K
30 min Winter	18.539	0.689	4.6	25.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	132.279	0.0	23.7	20
30 min Summer	84.469	0.0	30.3	33
60 min Summer	51.378	0.0	37.0	58
120 min Summer	32.718	0.0	47.0	92
180 min Summer	24.557	0.0	53.1	126
240 min Summer	19.794	0.0	56.9	158
360 min Summer	14.333	0.0	62.1	222
480 min Summer	11.282	0.0	64.9	282
600 min Summer	9.334	0.0	67.2	338
720 min Summer	7.978	0.0	68.8	392
960 min Summer	6.212	0.0	71.6	496
1440 min Summer	4.354	0.0	75.2	0
2160 min Summer	3.061	0.0	79.4	0
2880 min Summer	2.396	0.0	82.8	0
4320 min Summer	1.716	0.0	88.9	0
5760 min Summer	1.367	0.0	94.5	0
7200 min Summer	1.155	0.0	99.8	0
8640 min Summer	1.011	0.0	104.9	0
10080 min Summer	0.909	0.0	109.9	0
15 min Winter	132.279	0.0	26.6	20
30 min Winter	84.469	0.0	34.0	33

Infrastructure Design Studio		Page 2
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	Micro Drainage
Date 21/05/2019 17:24 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

Summary of Results for 30 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	18.559	0.709	4.6	26.6	O K
120 min Winter	18.557	0.707	4.6	26.5	O K
180 min Winter	18.499	0.649	4.6	24.3	O K
240 min Winter	18.406	0.556	4.6	20.9	O K
360 min Winter	18.186	0.336	4.6	12.6	O K
480 min Winter	18.015	0.165	4.6	6.2	O K
600 min Winter	17.901	0.051	4.6	1.9	O K
720 min Winter	17.850	0.000	4.5	0.0	O K
960 min Winter	17.850	0.000	3.5	0.0	O K
1440 min Winter	17.850	0.000	2.5	0.0	O K
2160 min Winter	17.850	0.000	1.7	0.0	O K
2880 min Winter	17.850	0.000	1.4	0.0	O K
4320 min Winter	17.850	0.000	1.0	0.0	O K
5760 min Winter	17.850	0.000	0.8	0.0	O K
7200 min Winter	17.850	0.000	0.7	0.0	O K
8640 min Winter	17.850	0.000	0.6	0.0	O K
10080 min Winter	17.850	0.000	0.5	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	51.378	0.0	41.5	60
120 min Winter	32.718	0.0	52.5	98
180 min Winter	24.557	0.0	59.3	136
240 min Winter	19.794	0.0	64.1	174
360 min Winter	14.333	0.0	69.4	236
480 min Winter	11.282	0.0	72.7	292
600 min Winter	9.334	0.0	75.3	340
720 min Winter	7.978	0.0	77.2	0
960 min Winter	6.212	0.0	80.2	0
1440 min Winter	4.354	0.0	84.3	0
2160 min Winter	3.061	0.0	88.9	0
2880 min Winter	2.396	0.0	92.7	0
4320 min Winter	1.716	0.0	99.6	0
5760 min Winter	1.367	0.0	105.8	0
7200 min Winter	1.155	0.0	111.7	0
8640 min Winter	1.011	0.0	117.5	0
10080 min Winter	0.909	0.0	123.1	0

Appendix 3 – Proposed Run-off Calculation- West Catchment 30yr

Infrastructure Design Studio		Page 3
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	
Date 21/05/2019 17:24 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

Rainfall Details

Rainfall Model	FEH	Winter Storms	Yes
Return Period (years)	30	Cv (Summer)	0.750
FEH Rainfall Version	2013	Cv (Winter)	0.840
Site Location	GB 531001 182083	Shortest Storm (mins)	15
Data Type	Point	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.096

Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)
0	4	0.048	4	8	0.048

Appendix 3 – Proposed Run-off Calculation- West Catchment 100yr

Infrastructure Design Studio		Page 1
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	
Date 21/05/2019 17:23 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

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

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	18.555	0.705	4.6	26.4	O K
30 min Summer	18.703	0.853	4.6	32.0	O K
60 min Summer	18.751	0.901	4.6	33.8	O K
120 min Summer	18.785	0.935	4.6	35.1	O K
180 min Summer	18.775	0.925	4.6	34.7	O K
240 min Summer	18.740	0.890	4.6	33.4	O K
360 min Summer	18.633	0.783	4.6	29.4	O K
480 min Summer	18.508	0.658	4.6	24.7	O K
600 min Summer	18.357	0.507	4.6	19.0	O K
720 min Summer	18.219	0.369	4.6	13.8	O K
960 min Summer	18.026	0.176	4.6	6.6	O K
1440 min Summer	17.859	0.009	4.6	0.3	O K
2160 min Summer	17.850	0.000	3.3	0.0	O K
2880 min Summer	17.850	0.000	2.5	0.0	O K
4320 min Summer	17.850	0.000	1.8	0.0	O K
5760 min Summer	17.850	0.000	1.4	0.0	O K
7200 min Summer	17.850	0.000	1.1	0.0	O K
8640 min Summer	17.850	0.000	1.0	0.0	O K
10080 min Summer	17.850	0.000	0.9	0.0	O K
15 min Winter	18.655	0.805	4.6	30.2	O K
30 min Winter	18.833	0.983	4.6	36.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	175.809	0.0	31.6	21
30 min Summer	113.111	0.0	40.8	34
60 min Summer	69.025	0.0	49.7	60
120 min Summer	44.121	0.0	63.4	96
180 min Summer	33.455	0.0	72.5	130
240 min Summer	27.202	0.0	78.4	166
360 min Summer	19.935	0.0	86.0	234
480 min Summer	15.794	0.0	90.8	304
600 min Summer	13.106	0.0	94.4	368
720 min Summer	11.215	0.0	96.9	422
960 min Summer	8.721	0.0	100.5	530
1440 min Summer	6.080	0.0	105.0	738
2160 min Summer	4.213	0.0	109.2	0
2880 min Summer	3.249	0.0	112.3	0
4320 min Summer	2.263	0.0	117.3	0
5760 min Summer	1.760	0.0	121.7	0
7200 min Summer	1.458	0.0	125.9	0
8640 min Summer	1.256	0.0	130.2	0
10080 min Summer	1.112	0.0	134.5	0
15 min Winter	175.809	0.0	35.3	21
30 min Winter	113.111	0.0	45.5	34

Infrastructure Design Studio		Page 2
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	
Date 21/05/2019 17:23 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

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

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	18.910	1.060	4.6	39.8	O K
120 min Winter	18.950	1.100	4.6	41.3	O K
180 min Winter	18.929	1.079	4.6	40.5	O K
240 min Winter	18.872	1.022	4.6	38.3	O K
360 min Winter	18.706	0.856	4.6	32.1	O K
480 min Winter	18.515	0.665	4.6	24.9	O K
600 min Winter	18.274	0.424	4.6	15.9	O K
720 min Winter	18.092	0.242	4.6	9.1	O K
960 min Winter	17.880	0.030	4.6	1.1	O K
1440 min Winter	17.850	0.000	3.4	0.0	O K
2160 min Winter	17.850	0.000	2.4	0.0	O K
2880 min Winter	17.850	0.000	1.8	0.0	O K
4320 min Winter	17.850	0.000	1.3	0.0	O K
5760 min Winter	17.850	0.000	1.0	0.0	O K
7200 min Winter	17.850	0.000	0.8	0.0	O K
8640 min Winter	17.850	0.000	0.7	0.0	O K
10080 min Winter	17.850	0.000	0.6	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	69.025	0.0	55.7	60
120 min Winter	44.121	0.0	71.0	102
180 min Winter	33.455	0.0	81.0	140
240 min Winter	27.202	0.0	87.7	178
360 min Winter	19.935	0.0	96.3	254
480 min Winter	15.794	0.0	102.1	328
600 min Winter	13.106	0.0	105.8	386
720 min Winter	11.215	0.0	108.6	436
960 min Winter	8.721	0.0	112.5	522
1440 min Winter	6.080	0.0	117.7	0
2160 min Winter	4.213	0.0	122.3	0
2880 min Winter	3.249	0.0	125.8	0
4320 min Winter	2.263	0.0	131.4	0
5760 min Winter	1.760	0.0	136.3	0
7200 min Winter	1.458	0.0	141.1	0
8640 min Winter	1.256	0.0	145.8	0
10080 min Winter	1.112	0.0	150.6	0

Appendix 3 – Proposed Run-off Calculation- West Catchment 100yr

Infrastructure Design Studio		Page 3
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	
Date 21/05/2019 17:23 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

Rainfall Details

Rainfall Model	FEH	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
FEH Rainfall Version	2013	Cv (Winter)	0.840
Site Location	GB 531001 182083	Shortest Storm (mins)	15
Data Type	Point	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.096

Time (mins) From:	To:	Area (ha)	Time (mins) From:	To:	Area (ha)
0	4	0.048	4	8	0.048

Infrastructure Design Studio		Page 4
31 Dyer Street Cirencester Glos GL7 2PP	Panther House West Catchment	
Date 21/05/2019 17:23 File 1461-TANK WEST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2017.1.2	

Model Details

Storage is Online Cover Level (m) 19.850

Tank or Pond Structure

Invert Level (m) 17.850

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	37.5	1.100	37.5	1.101	1.0	2.000	1.0

Hydro-Brake® Optimum Outflow Control

Unit Reference	MD-SHE-0096-4800-1500-4800
Design Head (m)	1.500
Design Flow (l/s)	4.8
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Application	Surface
Sump Available	Yes
Diameter (mm)	96
Invert Level (m)	17.550
Minimum Outlet Pipe Diameter (mm)	150
Suggested Manhole Diameter (mm)	1200

Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	1.500	4.8
Flush-Flo™	0.423	4.6
Kick-Flo®	0.860	3.7
Mean Flow over Head Range	-	4.1

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake® Optimum as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	3.1	1.200	4.3	3.000	6.6	7.000	9.9
0.200	4.2	1.400	4.6	3.500	7.1	7.500	10.2
0.300	4.5	1.600	4.9	4.000	7.6	8.000	10.5
0.400	4.6	1.800	5.2	4.500	8.0	8.500	10.8
0.500	4.6	2.000	5.5	5.000	8.4	9.000	11.1
0.600	4.5	2.200	5.7	5.500	8.8	9.500	11.4
0.800	4.0	2.400	6.0	6.000	9.2		
1.000	4.0	2.600	6.2	6.500	9.5		

Appendix 4 – Proposed Run-off Calculation- East Catchment 1yr

Infrastructure Design Studio		Page 1
31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
Date 04/03/2020 15:59 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

Summary of Results for 1 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	10.001	0.001	0.5	0.3	O K
30 min Summer	10.002	0.002	0.5	0.9	O K
60 min Summer	10.004	0.004	0.5	1.6	O K
120 min Summer	10.006	0.006	0.5	2.1	O K
180 min Summer	10.006	0.006	0.5	2.2	O K
240 min Summer	10.006	0.006	0.5	2.2	O K
360 min Summer	10.006	0.006	0.5	2.0	O K
480 min Summer	10.005	0.005	0.5	1.7	O K
600 min Summer	10.004	0.004	0.5	1.3	O K
720 min Summer	10.003	0.003	0.5	1.0	O K
960 min Summer	10.001	0.001	0.5	0.5	O K
1440 min Summer	10.000	0.000	0.5	0.0	O K
2160 min Summer	10.000	0.000	0.4	0.0	O K
2880 min Summer	10.000	0.000	0.3	0.0	O K
4320 min Summer	10.000	0.000	0.2	0.0	O K
5760 min Summer	10.000	0.000	0.2	0.0	O K
7200 min Summer	10.000	0.000	0.1	0.0	O K
8640 min Summer	10.000	0.000	0.1	0.0	O K
10080 min Summer	10.000	0.000	0.1	0.0	O K
15 min Winter	10.001	0.001	0.5	0.5	O K
30 min Winter	10.003	0.003	0.5	1.2	O K
60 min Winter	10.006	0.006	0.5	2.0	O K
120 min Winter	10.007	0.007	0.5	2.7	O K
180 min Winter	10.007	0.007	0.5	2.7	O K
240 min Winter	10.007	0.007	0.5	2.6	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	46.758	0.0	1.3	41
30 min Summer	30.115	0.0	2.2	54
60 min Summer	18.730	0.0	3.0	76
120 min Summer	11.397	0.0	4.1	120
180 min Summer	8.477	0.0	4.7	150
240 min Summer	6.862	0.0	5.2	182
360 min Summer	5.063	0.0	5.9	246
480 min Summer	4.070	0.0	6.5	308
600 min Summer	3.436	0.0	6.9	370
720 min Summer	2.991	0.0	7.4	430
960 min Summer	2.404	0.0	7.9	542
1440 min Summer	1.767	0.0	8.6	744
2160 min Summer	1.299	0.0	9.3	0
2880 min Summer	1.044	0.0	9.7	0
4320 min Summer	0.767	0.0	10.0	0
5760 min Summer	0.616	0.0	10.0	0
7200 min Summer	0.520	0.0	9.8	0
8640 min Summer	0.453	0.0	9.5	0
10080 min Summer	0.403	0.0	9.3	0
15 min Winter	46.758	0.0	1.7	44
30 min Winter	30.115	0.0	2.7	57
60 min Winter	18.730	0.0	3.6	78
120 min Winter	11.397	0.0	4.8	122
180 min Winter	8.477	0.0	5.5	160
240 min Winter	6.862	0.0	6.1	192

Infrastructure Design Studio		Page 2
31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
Date 04/03/2020 15:59 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

Summary of Results for 1 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
360 min Winter	10.006	0.006	0.5	2.2	O K
480 min Winter	10.004	0.004	0.5	1.6	O K
600 min Winter	10.003	0.003	0.5	1.0	O K
720 min Winter	10.002	0.002	0.5	0.6	O K
960 min Winter	10.000	0.000	0.5	0.0	O K
1440 min Winter	10.000	0.000	0.4	0.0	O K
2160 min Winter	10.000	0.000	0.3	0.0	O K
2880 min Winter	10.000	0.000	0.2	0.0	O K
4320 min Winter	10.000	0.000	0.2	0.0	O K
5760 min Winter	10.000	0.000	0.1	0.0	O K
7200 min Winter	10.000	0.000	0.1	0.0	O K
8640 min Winter	10.000	0.000	0.1	0.0	O K
10080 min Winter	10.000	0.000	0.1	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
360 min Winter	5.063	0.0	7.0	260
480 min Winter	4.070	0.0	7.6	326
600 min Winter	3.436	0.0	8.2	386
720 min Winter	2.991	0.0	8.6	440
960 min Winter	2.404	0.0	9.2	520
1440 min Winter	1.767	0.0	10.0	0
2160 min Winter	1.299	0.0	10.9	0
2880 min Winter	1.044	0.0	11.4	0
4320 min Winter	0.767	0.0	11.9	0
5760 min Winter	0.616	0.0	12.0	0
7200 min Winter	0.520	0.0	12.0	0
8640 min Winter	0.453	0.0	11.8	0
10080 min Winter	0.403	0.0	11.6	0

Appendix 4 – Proposed Run-off Calculation- East Catchment 1yr

Infrastructure Design Studio		Page 3
31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
Date 04/03/2020 15:59 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	1	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.800	Shortest Storm (mins)	15
Ratio R	0.443	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Green Roof

Area (m³)	364	Evaporation (mm/day)	3
Depression Storage (mm)	5	Decay Coefficient	0.050

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.006615	32	36	0.001335	64	68	0.000270	96	100	0.000054
4	8	0.005416	36	40	0.001093	68	72	0.000221	100	104	0.000045
8	12	0.004434	40	44	0.000895	72	76	0.000181	104	108	0.000036
12	16	0.003630	44	48	0.000733	76	80	0.000148	108	112	0.000030
16	20	0.002972	48	52	0.000600	80	84	0.000121	112	116	0.000024
20	24	0.002433	52	56	0.000491	84	88	0.000099	116	120	0.000020
24	28	0.001992	56	60	0.000402	88	92	0.000081			
28	32	0.001631	60	64	0.000329	92	96	0.000066			

Time Area Diagram

Total Area (ha) 0.000

Time From:	(mins) To:	Area (ha)
0	4	0.000

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31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
Date 04/03/2020 15:59 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

Model Details

Storage is Online Cover Level (m) 10.100

Tank or Pond Structure

Invert Level (m) 10.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	364.0	0.100	364.0

Orifice Outflow Control

Diameter (m) 0.025 Discharge Coefficient 0.600 Invert Level (m) 9.850

Appendix 4 – Proposed Run-off Calculation- East Catchment 30yr

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31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
Date 04/03/2020 15:58 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

Summary of Results for 30 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	10.011	0.011	0.5	4.0	O K
30 min Summer	10.016	0.016	0.5	6.0	O K
60 min Summer	10.021	0.021	0.5	7.8	O K
120 min Summer	10.026	0.026	0.5	9.3	O K
180 min Summer	10.027	0.027	0.5	9.7	O K
240 min Summer	10.026	0.026	0.5	9.5	O K
360 min Summer	10.025	0.025	0.5	8.9	O K
480 min Summer	10.023	0.023	0.5	8.3	O K
600 min Summer	10.021	0.021	0.5	7.7	O K
720 min Summer	10.020	0.020	0.5	7.1	O K
960 min Summer	10.017	0.017	0.5	6.1	O K
1440 min Summer	10.011	0.011	0.5	4.2	O K
2160 min Summer	10.006	0.006	0.5	2.0	O K
2880 min Summer	10.002	0.002	0.5	0.7	O K
4320 min Summer	10.000	0.000	0.4	0.0	O K
5760 min Summer	10.000	0.000	0.3	0.0	O K
7200 min Summer	10.000	0.000	0.3	0.0	O K
8640 min Summer	10.000	0.000	0.2	0.0	O K
10080 min Summer	10.000	0.000	0.2	0.0	O K
15 min Winter	10.013	0.013	0.5	4.8	O K
30 min Winter	10.019	0.019	0.5	7.0	O K
60 min Winter	10.025	0.025	0.5	9.1	O K
120 min Winter	10.030	0.030	0.5	10.8	O K
180 min Winter	10.031	0.031	0.5	11.4	O K
240 min Winter	10.031	0.031	0.5	11.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	114.845	0.0	5.7	59
30 min Summer	73.480	0.0	7.9	71
60 min Summer	44.885	0.0	10.3	92
120 min Summer	26.607	0.0	12.5	136
180 min Summer	19.397	0.0	13.7	184
240 min Summer	15.438	0.0	14.6	224
360 min Summer	11.172	0.0	16.0	286
480 min Summer	8.877	0.0	17.0	350
600 min Summer	7.423	0.0	17.7	416
720 min Summer	6.411	0.0	18.4	482
960 min Summer	5.085	0.0	19.4	612
1440 min Summer	3.665	0.0	20.9	866
2160 min Summer	2.639	0.0	22.3	1216
2880 min Summer	2.089	0.0	23.3	1544
4320 min Summer	1.502	0.0	24.4	0
5760 min Summer	1.188	0.0	24.9	0
7200 min Summer	0.990	0.0	25.1	0
8640 min Summer	0.853	0.0	25.1	0
10080 min Summer	0.752	0.0	25.0	0
15 min Winter	114.845	0.0	6.7	61
30 min Winter	73.480	0.0	9.1	73
60 min Winter	44.885	0.0	11.8	94
120 min Winter	26.607	0.0	14.3	138
180 min Winter	19.397	0.0	15.6	186
240 min Winter	15.438	0.0	16.7	236

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Causeway	Source Control 2019.1	

Summary of Results for 30 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
360 min Winter	10.029	0.029	0.5	10.5	O K
480 min Winter	10.027	0.027	0.5	9.7	O K
600 min Winter	10.024	0.024	0.5	8.8	O K
720 min Winter	10.022	0.022	0.5	7.9	O K
960 min Winter	10.017	0.017	0.5	6.3	O K
1440 min Winter	10.009	0.009	0.5	3.4	O K
2160 min Winter	10.002	0.002	0.5	0.6	O K
2880 min Winter	10.000	0.000	0.4	0.0	O K
4320 min Winter	10.000	0.000	0.3	0.0	O K
5760 min Winter	10.000	0.000	0.2	0.0	O K
7200 min Winter	10.000	0.000	0.2	0.0	O K
8640 min Winter	10.000	0.000	0.2	0.0	O K
10080 min Winter	10.000	0.000	0.1	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
360 min Winter	11.172	0.0	18.2	304
480 min Winter	8.877	0.0	19.3	374
600 min Winter	7.423	0.0	20.2	448
720 min Winter	6.411	0.0	21.0	520
960 min Winter	5.085	0.0	22.1	656
1440 min Winter	3.665	0.0	23.8	910
2160 min Winter	2.639	0.0	25.6	1220
2880 min Winter	2.089	0.0	26.7	0
4320 min Winter	1.502	0.0	28.0	0
5760 min Winter	1.188	0.0	28.7	0
7200 min Winter	0.990	0.0	29.1	0
8640 min Winter	0.853	0.0	29.3	0
10080 min Winter	0.752	0.0	29.3	0

Appendix 4 – Proposed Run-off Calculation- East Catchment 30yr

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Date 04/03/2020 15:58 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	30	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.800	Shortest Storm (mins)	15
Ratio R	0.443	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Green Roof

Area (m²)	364	Evaporation (mm/day)	3
Depression Storage (mm)	5	Decay Coefficient	0.050

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.006615	32	36	0.001335	64	68	0.000270	96	100	0.000054
4	8	0.005416	36	40	0.001093	68	72	0.000221	100	104	0.000045
8	12	0.004434	40	44	0.000895	72	76	0.000181	104	108	0.000036
12	16	0.003630	44	48	0.000733	76	80	0.000148	108	112	0.000030
16	20	0.002972	48	52	0.000600	80	84	0.000121	112	116	0.000024
20	24	0.002433	52	56	0.000491	84	88	0.000099	116	120	0.000020
24	28	0.001992	56	60	0.000402	88	92	0.000081			
28	32	0.001631	60	64	0.000329	92	96	0.000066			

Time Area Diagram

Total Area (ha) 0.000

Time From:	(mins) To:	Area (ha)
0	4	0.000

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31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
Date 04/03/2020 15:58 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

Model Details

Storage is Online Cover Level (m) 10.100

Tank or Pond Structure

Invert Level (m) 10.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	364.0	0.100	364.0

Orifice Outflow Control

Diameter (m) 0.025 Discharge Coefficient 0.600 Invert Level (m) 9.850

Appendix 4 – Proposed Run-off Calculation- East Catchment 100yr

Infrastructure Design Studio		Page 1
31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
Date 04/03/2020 15:57 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

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

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	10.017	0.017	0.5	6.2	O K
30 min Summer	10.024	0.024	0.5	8.8	O K
60 min Summer	10.031	0.031	0.5	11.4	O K
120 min Summer	10.037	0.037	0.5	13.5	O K
180 min Summer	10.039	0.039	0.5	14.1	O K
240 min Summer	10.038	0.038	0.5	14.0	O K
360 min Summer	10.036	0.036	0.5	13.2	O K
480 min Summer	10.034	0.034	0.5	12.4	O K
600 min Summer	10.032	0.032	0.5	11.7	O K
720 min Summer	10.030	0.030	0.5	11.1	O K
960 min Summer	10.027	0.027	0.5	9.8	O K
1440 min Summer	10.021	0.021	0.5	7.5	O K
2160 min Summer	10.013	0.013	0.5	4.8	O K
2880 min Summer	10.007	0.007	0.5	2.7	O K
4320 min Summer	10.001	0.001	0.5	0.3	O K
5760 min Summer	10.000	0.000	0.4	0.0	O K
7200 min Summer	10.000	0.000	0.4	0.0	O K
8640 min Summer	10.000	0.000	0.3	0.0	O K
10080 min Summer	10.000	0.000	0.3	0.0	O K
15 min Winter	10.020	0.020	0.5	7.3	O K
30 min Winter	10.028	0.028	0.5	10.3	O K
60 min Winter	10.036	0.036	0.5	13.2	O K
120 min Winter	10.043	0.043	0.6	15.6	O K
180 min Winter	10.045	0.045	0.6	16.4	O K
240 min Winter	10.045	0.045	0.6	16.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	149.442	0.0	8.3	64
30 min Summer	96.326	0.0	11.2	76
60 min Summer	59.033	0.0	14.0	98
120 min Summer	34.948	0.0	16.9	140
180 min Summer	25.392	0.0	18.6	188
240 min Summer	20.134	0.0	19.7	242
360 min Summer	14.493	0.0	21.4	304
480 min Summer	11.475	0.0	22.7	368
600 min Summer	9.568	0.0	23.6	434
720 min Summer	8.244	0.0	24.4	500
960 min Summer	6.513	0.0	25.6	632
1440 min Summer	4.667	0.0	27.4	894
2160 min Summer	3.339	0.0	29.1	1264
2880 min Summer	2.631	0.0	30.3	1616
4320 min Summer	1.878	0.0	31.8	2256
5760 min Summer	1.478	0.0	32.5	0
7200 min Summer	1.226	0.0	32.9	0
8640 min Summer	1.053	0.0	33.0	0
10080 min Summer	0.925	0.0	33.0	0
15 min Winter	149.442	0.0	9.5	66
30 min Winter	96.326	0.0	12.8	78
60 min Winter	59.033	0.0	15.9	100
120 min Winter	34.948	0.0	19.2	142
180 min Winter	25.392	0.0	21.1	190
240 min Winter	20.134	0.0	22.4	240

Infrastructure Design Studio		Page 2
31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
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Causeway	Source Control 2019.1	

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

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
360 min Winter	10.043	0.043	0.6	15.6	O K
480 min Winter	10.040	0.040	0.6	14.6	O K
600 min Winter	10.037	0.037	0.5	13.6	O K
720 min Winter	10.035	0.035	0.5	12.7	O K
960 min Winter	10.030	0.030	0.5	10.8	O K
1440 min Winter	10.020	0.020	0.5	7.4	O K
2160 min Winter	10.009	0.009	0.5	3.4	O K
2880 min Winter	10.002	0.002	0.5	0.8	O K
4320 min Winter	10.000	0.000	0.4	0.0	O K
5760 min Winter	10.000	0.000	0.3	0.0	O K
7200 min Winter	10.000	0.000	0.3	0.0	O K
8640 min Winter	10.000	0.000	0.2	0.0	O K
10080 min Winter	10.000	0.000	0.2	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
360 min Winter	14.493	0.0	24.2	334
480 min Winter	11.475	0.0	25.7	392
600 min Winter	9.568	0.0	26.8	466
720 min Winter	8.244	0.0	27.7	540
960 min Winter	6.513	0.0	29.1	684
1440 min Winter	4.667	0.0	31.1	956
2160 min Winter	3.339	0.0	33.1	1320
2880 min Winter	2.631	0.0	34.6	1620
4320 min Winter	1.878	0.0	36.3	0
5760 min Winter	1.478	0.0	37.2	0
7200 min Winter	1.226	0.0	37.8	0
8640 min Winter	1.053	0.0	38.1	0
10080 min Winter	0.925	0.0	38.2	0

Appendix 4 – Proposed Run-off Calculation- East Catchment 100yr

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31 Dyer Street Cirencester Glos GL7 2PP	Existing Roof Attenuation East Catchment Panther House	Micro Drainage
Date 04/03/2020 15:57 File 1461-GREEN ROOF EAST.SRCX	Designed by E. Partridge Checked by M. Jones	
Causeway	Source Control 2019.1	

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.800	Shortest Storm (mins)	15
Ratio R	0.443	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Green Roof

Area (m³)	364	Evaporation (mm/day)	3
Depression Storage (mm)	5	Decay Coefficient	0.050

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.006615	32	36	0.001335	64	68	0.000270	96	100	0.000054
4	8	0.005416	36	40	0.001093	68	72	0.000221	100	104	0.000045
8	12	0.004434	40	44	0.000895	72	76	0.000181	104	108	0.000036
12	16	0.003630	44	48	0.000733	76	80	0.000148	108	112	0.000030
16	20	0.002972	48	52	0.000600	80	84	0.000121	112	116	0.000024
20	24	0.002433	52	56	0.000491	84	88	0.000099	116	120	0.000020
24	28	0.001992	56	60	0.000402	88	92	0.000081			
28	32	0.001631	60	64	0.000329	92	96	0.000066			

Time Area Diagram

Total Area (ha) 0.000

Time From:	(mins) To:	Area (ha)
0	4	0.000

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Causeway	Source Control 2019.1	

Model Details

Storage is Online Cover Level (m) 10.100

Tank or Pond Structure

Invert Level (m) 10.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	364.0	0.100	364.0

Orifice Outflow Control

Diameter (m) 0.025 Discharge Coefficient 0.600 Invert Level (m) 9.850

Appendix 5 – Sustainable Drainage Proforma – Sheet 1

Camden

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1. Project & Site Details

Project / Site Name (including sub-catchment / stage / phase where appropriate)	Panther House
Address & post code	Grays Inn Road, London, WC1X 0AN
OS Grid ref. (Easting, Northing)	E 530982 N 182069
LPA reference (if applicable)	
Brief description of proposed work	Redevelopment and addition of extra floors to existing commercial/office development
Total site Area	2120 m^2
Total existing impervious area	2120 m^2
Total proposed impervious area	2120 m^2
Is the site in a surface water flood risk catchment (ref. local Surface Water Management Plan)?	Critical Drainage Area Group3_003 - See FRA section 4.2.2
Existing drainage connection type and location	1 Connection onto Mount Pleasant & 1 connection onto Grays Inn Road
Designer Name	M. Jones
Designer Position	Director
Designer Company	IDS Ltd. (for Eckersley O'Callaghan)

2. Proposed Discharge Arrangements

2a. Infiltration Feasibility

Superficial geology classification	Lynch Hill Gravel	
Bedrock geology classification	London Clay	
Site infiltration rate	N/A	m/s
Depth to groundwater level	4	m below ground level
Is infiltration feasible?	No	

2b. Drainage Hierarchy

	Feasible (Y/N)	*Proposed (Y/N)*
1 store rainwater for later use	N	N
2 use infiltration techniques, such as porous surfaces in non-clay areas	N	N
3 attenuate rainwater in ponds or open water features for gradual release	N	N
4 attenuate rainwater by storing in tanks or sealed water features for gradual release	Y	Y
5 discharge rainwater direct to a watercourse	N	N
6 discharge rainwater to a surface water sewer/drain	N	N
7 discharge rainwater to the combined sewer.	Y	Y

2c. Proposed Discharge Details

Proposed discharge location	As existing
Has the owner/regulator of the discharge location been consulted?	See Drainage Strategy

Appendix 5 – Sustainable Drainage Proforma – Sheet 2

Camden

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LoDEG

3. Drainage Strategy

3a. Discharge Rates & Required Storage	Greenfield (GF) runoff rate (l/s)	Existing discharge rate (l/s)	Required storage for GF rate (m^3)	Proposed discharge rate (l/s)
Qbar	0.8			
1 in 1	0.6	10.49	26	9.19
1 in 30	1.7	41.57	57	20.32
1 in 100	2.5	55.67	71	26.13
1 in 100 + CC			108	26.13
Climate change allowance used		40%		

3b. Principal Method of Flow Control	Hydrobrake & Roof Outlet Orifice

3c. Proposed SuDS Measures	Catchment area (m^2)	Plan area (m^2)	Storage vol. (m^3)
Rainwater harvesting	0		0
Infiltration systems	0		0
Green roofs	260	260	11.7
Blue roofs	104	104	4.68
Filter strips	0	0	0
Filter drains	0	0	0
Bioretention / tree pits	0	0	0
Pervious pavements	0	0	0
Swales	0	0	0
Basins/ponds	0	0	0
Attenuation tanks	2120		38
Total	**2484**	**364**	**54.38**

4. Supporting Information

4a. Discharge & Drainage Strategy	Page/section of drainage report
Infiltration feasibility (2a) – geotechnical factual and interpretive reports, including infiltration results	5.4
Drainage hierarchy (2b)	5.4
Proposed discharge details (2c) – utility plans, correspondence / approval from owner/regulator of discharge location	Drainage Connections re-used 5.12
Discharge rates & storage (3a) – detailed hydrologic and hydraulic calculations	Appendix 2 - 6
Proposed SuDS measures & specifications (3b)	5.6

4b. Other Supporting Details	Page/section of drainage report
Detailed Development Layout	Appendix 1
Detailed drainage design drawings, including exceedance flow routes	Appendix 1
Detailed landscaping plans	Appendix 1
Maintenance strategy	Section 7
Demonstration of how the proposed SuDS measures improve:	
a) water quality of the runoff?	Roofwater discharge only
b) biodiversity?	No Change
c) amenity?	No Change