



CELTIC ENERGY LIMITED

NANT HELEN COMPLEMENTARY RESTORATION EARTHWORKS

DRAINAGE STRATEGY
APRIL 2020

ARUP



Celtic Energy

**Nant Helen Complementary
Restoration Earthworks**

**Surface Water Drainage Strategy
Report**

Issue P01 | April 2020

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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Contents

	Page
1 Project Overview	1
2 The Site	2
2.1 Site Location and Description	2
2.2 Site Topography	2
2.3 Published Flood Risk Maps	3
3 Existing Hydrology	6
3.1 Rainfall Runoff Catchments	6
3.2 Greenfield Runoff Rate	7
4 Proposed Stormwater Drainage	8
4.1 Introduction	8
4.2 Schedule 3 of the Flood and Water Management Act	8
4.3 S2 - Hydraulic Control	10
4.4 Drainage Features	19
4.5 S3 - Water Quality	21
4.6 S4 - Amenity	21
4.7 S5 - Biodiversity	21
4.8 S6 - Construction, Operation and Maintenance	22
5 Conclusion	23

Appendices

Appendix A

Restoration and Existing Topography Drawing

Appendix B

Original and Proposed Catchment Boundaries Drawing

Appendix C

Celtic Energy Restoration Drainage Proposals

Appendix D

Hydrological Calculations Technical Note

Appendix E

Proposed Drainage Drawings

Appendix F

Microdrainage Attenuation Calculations

1 Project Overview

The Nant Helen site to the north of Onllwyn is an open cast mine owned and operated by Celtic Energy. The mining operations currently being undertaken will cease in 2021, at which point Celtic Energy will be required to restore the land in accordance with regulatory requirements and the agreements with Powys County Council (PCC). A restoration scheme for the site has been submitted for approval through the Planning process.

Following discussions with both PCC and Neath Port Talbot County Borough Council (NPTCBC), the local authorities have expressed a desire to develop restoration proposals for the Nant Helen site which will create long term, sustainable jobs.

As such, the Nant Helen Complementary Earthworks Scheme looks to provide a flexible landform that can be used or adapted for a diverse set of future uses. This could range from the traditional agriculture, woodland and nature conservation purposes, to amenity, leisure and tourism uses.

Other potential uses for the site could also include industrial purposes such as the Welsh Government's (WG) proposal to develop a rail testing and storage facility, known as the Global Centre of Rail Excellence (GCRE) at this site together with the adjacent Onllwyn Washery.

For the proposed scheme, an earthworks plateau is proposed that can be adapted for all the above purposes. Consideration has been given to providing suitable longitudinal gradients and track radii should the GRCE project proceed. It is proposed that the construction of this earthworks plateau will be undertaken in tandem with the restoration scheme for the site.

A planning application has been prepared for the Nant Helen Complementary Earthworks. A separate planning application will be submitted at a future date to cover any additional infrastructure required to bring the site to its selected future use.

This report has been prepared to detail the drainage strategy pertaining to the Nant Helen Complementary Restoration Earthworks.

2 The Site

2.1 Site Location and Description

The proposed site is currently an open cast quarry site owned and operated by Celtic Energy. The quarrying works being undertaken are nearing completion for the site. Following completion, the land is proposed to be restored in accordance with the proposed restoration scheme which has been prepared separately by Celtic Energy.

The site is located on the border between Neath Port Talbot and Powys, south of Caehopkin and north of Onllwyn. The site is bounded at the east by the A4221 highway and Onllwyn Road. The northern boundary of the site is formed by the Sustrans Cycle Route 43 and the southern boundary by an existing rail corridor. There are numerous engineered and natural ditches located within and around the site.

The site is located at approximate National Grid reference 283000, 210000. The area encompassed within the planning application boundary is approximately 416ha. See Figure 1 for an image depicting the site location.



Figure 1: Site Location on OS Mapping (red – planning application boundary)

2.2 Site Topography

The proposed site is located around a ridgeline which runs from east to west on the site. To the north of this ridge, the land slopes down at a moderate gradient to the Sustrans cycle route. Similarly, the land south of the ridge falls at a moderate

gradient to the rail line. The ridgeline finishes within the site extent to the east and small portion at the eastern extent of the site slopes down towards the A4221.

Owing to the opencast mining operations which take place on the western area of the site, the topography within the site changes due to the large scale earthworks taking place and the movement of earthworks material.

Celtic Energy have provided their proposed restoration contours which cover a portion of the site. The proposals broadly represent the existing topography described above, although the ridge line contained within the restoration proposals has been shifted to the north and a flat plateau is proposed at the ridgeline.

Where the proposed development is within the extent of the restoration scheme, the restoration levels have been applied as the baseline for the proposed drainage and earthworks. Outside of the restoration extent, 2m resolution LIDAR data has been applied for the baseline model.

A drawing has been produced which showing the topography of the site on this basis. This is shown in Appendix A.

2.3 Published Flood Risk Maps

The Flood Risk maps hosted on the Natural Resources Wales (NRW) web portal have been checked for the site. These are detailed in the following subsections.

2.3.1 Development Advice Maps

The Development Advice Map has been consulted to determine whether the site is located within a surface water flood zone. The map shows that the proposed development is located entirely within Zone A, which is considered to be at little or no risk of fluvial or tidal/coastal flooding (See Figure 2).

As such, a Flood Consequence Assessment will not be required.



Figure 2: Long term flood risk Development Advice Map for the site. Yellow – Zone B, Blue – Zone C2

2.3.2 Fluvial, Reservoir, Coastal and Surface Water Flooding

Owing to the location and elevation of the site, there is no risk from Fluvial, Reservoir or Coastal Flooding.

The surface water flood maps show a number of areas within the site at low, medium and high risk of surface water flooding. These are centred around the numerous water features and ponds, which is typical for a site (see Figure 3: Fluvial, coastal, reservoir and surface water flood risk map based on the NRW Long Term Flood Risk Maps (yellow and orange – surface water flooding, blue – fluvial flooding).Figure 3 below).

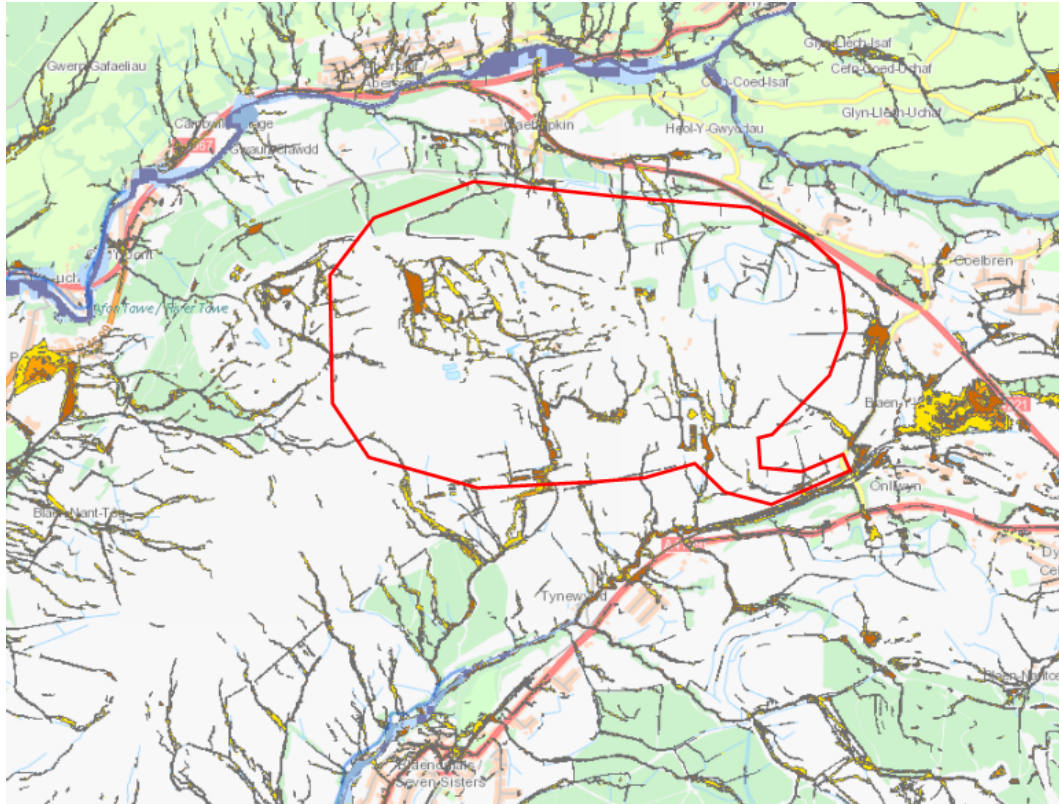


Figure 3: Fluvial, coastal, reservoir and surface water flood risk map based on the NRW Long Term Flood Risk Maps (yellow and orange – surface water flooding, blue – fluvial flooding).

3 Existing Hydrology

3.1 Rainfall Runoff Catchments

As described in Section 2.2, the site encompasses a central ridgeline. This ridgeline forms the boundary between three overarching catchments. Stormwater runoff from these catchments is ultimately conveyed to three major watercourses:

- The River Tawe, to the north of the site
- The River Dulais, to the south-west of the site
- The Afon Pyrddin, to the east of the site

Within the site, these larger catchments are separated into a number of smaller sub-catchments which are served by ditches and small watercourses. These serve as tributaries, conveying the runoff from the site to the major watercourses.

Unusually, for this site there are two different catchments scenarios to consider. The first are the natural catchment areas that were present prior to the mining operations on the site (referred to as the “Original Catchments”). The second is the catchments modified as part of the restoration proposals (referred to as the “Restoration Catchments”).

3.1.1 Original Catchment Boundaries

The original catchment information for the site has been provided by Celtic Energy. This information was extracted and digitized from the Flood Estimation Handbook (FEH) 1999.

To validate these catchment boundaries, a visual comparison was undertaken with the catchment data available on the FEH Online portal. The boundaries for the sub-catchments were shown to be visually similar. The shapefile for the overarching River Tawe, River Dulais and Afon Pyrddin catchments was also downloaded and compared. The ridgeline for the site demarcating the catchment boundaries matched the information provided by Celtic Energy.

A drawing showing the original catchments has been provided in Appendix B. Table 1 below provides a summary of the existing catchments. For ease of reference, the catchment names used by Celtic Energy have been applied for the proposals.

3.1.2 Restoration Catchments

The catchments and associated discharge rates based on the restoration earthwork proposals have been provided by Celtic Energy. These are contained within Appendix C. This information highlights that the majority of the proposed catchments will have reduced discharge rates compared to the original discharge rates.

During discussions with Celtic Energy, it was highlighted that the reduction to discharge rates for the River Tawe catchments has been provided to alleviate historical flooding issues in downstream tributaries. This was mainly achieved by shifting the ridgeline north and consequently reducing the contributing catchment areas. Attenuation ponds have also been proposed in some catchments to further restrict stormwater runoff.

A reduction in discharge rate has also been provided in the restoration scheme for the River Dulais catchments. However, this is not provided to alleviate downstream flooding but due to the presence of existing settlement ponds which have been incorporated into the restoration proposals as proposed attenuation features.

3.1.3 Summary of Rainfall Runoff Catchments

Based on the above, for the Nant Helen Complementary Earthworks Scheme it is proposed that the original catchment areas are compared the proposed catchment areas to ensure the natural runoff regime for the site is replicated.

However, for the River Tawe catchments only, the reduction in peak discharge rates proposed by the restoration scheme will be applied to the proposals to avoid reducing the betterment provided.

3.2 Greenfield Runoff Rate

A hydrological analysis has been undertaken for the three major catchments to determine the Greenfield Runoff Rate (GRR). The IH124, ReFH2.2 and FEH Statistical methods have been applied and compared to calculate the GRR for the 1:1, 1:30 and 1:100-year rainfall events.

Of these methods, ReFH2.2 was selected as the most appropriate as it is a widely accepted method for plot-scale sites and uses the updated FEH13 DDF curves. It also demonstrated a better correlation with the observed QMED at river monitoring station 58008, located downstream in the River Dulais at Cilfrew.

The GRR for each catchment was therefore calculated to be the values as shown in Table 1 below. For further details of the assumptions, calculations and conclusions, refer to the Hydrology Calculations technical note in Appendix D.

Table 1 – Greenfield Runoff Rate for the site calculated using the ReFH2.2 summer profile

Catchment	Greenfield Runoff Rate		
	1:1 year	1:30 year	1:100 year
River Tawe	17.8	42.2	53.0
River Dulais	19.8	46.3	57.9
Afon Pyrddin	16.9	40.5	51.0

4 Proposed Stormwater Drainage

4.1 Introduction

The proposed earthwork cuttings and embankments to form the plateau will, in plan, alter the rainfall runoff paths and catchment boundaries within the site. As such, a number of drainage features will be required on the site to convey runoff to the proposed outfall watercourses and ditches for each catchment.

This section outlines the drainage strategy for each catchment area and the proposed attenuation and conveyance features. The proposed drainage drawings have been included in Appendix E.

4.2 Schedule 3 of the Flood and Water Management Act

Schedule 3 of the Flood and Water Management Act 2010 establishes SABs (SuDS Approving Body) in local authorities. Since the 7th January 2019, developments greater than 100m² or developments containing more than one building will be required to submit a SAB application. This application requires developers to utilise Sustainable Drainage Systems (SuDS) in their surface water management for a development.

SuDS aim to manage rainfall on site using methods that mimic natural processes, by making use of the landscape and vegetation to control the flow, volume and quality of the surface water runoff. In addition to this, SuDS also provide amenity benefits by providing aesthetically pleasing and natural landscapes, and biodiversity benefits by creating habitats for wildlife and vegetated areas.

The Welsh Governments “Statutory Standards for Sustainable Drainage Systems” contains six standards, which details the requirements for any SuDS proposed. These sections are as follows:

- S1. Runoff destination
- S2. Hydraulic control
- S3. Water quality
- S4. Amenity
- S5. Biodiversity
- S6. Construction, operation and maintenance

These form a set of principles which must be considered in the design of the SuDS features in order to obtain approval by the SAB.

4.2.1 S1 - Runoff Destination

The Welsh Governments SuDS Standard S1 provides a discharge hierarchy for surface water from developments, as well as exemption criteria for each level that

must be met before the next level can be considered. The discharge hierarchy is shown below:

- Level 1: Surface water runoff is collected for use;
- Level 2: Surface water runoff is infiltrated to ground;
- Level 3: Surface water runoff is discharged to a surface water body;
- Level 4: Surface water runoff is discharged to a surface water sewer, highway drain, or another drainage system;
- Level 5: Surface water runoff is discharged to a combined sewer.

The aim of this is to encourage developments to use runoff as a resource and ensure that runoff is sustainably managed to avoid any negative impacts from the development, such as increased flood risk.

4.2.2 Collected for Use

This drainage strategy covers the proposed earthworks scheme for the site. As such, there is no requirement for non-potable water to be used. Therefore, this does not provide a viable discharge point for the site.

Depending on the final use of the site, there may facilities in the future which could utilise harvested rainwater. As such, the viability of rainwater harvesting will need to be re-assessed during any future planning application.

4.2.3 Infiltrate to Ground

Much of the current site has been previously open casted, whilst other areas have remained unaffected. Both the natural and returned ground are within material of low permeability. Therefore, infiltration is not a viable outfall source for the site.

However, some infiltration is likely to occur and may be suitable to provide infiltration the first 5mm of rainfall and prevent discharge in small return period events. This is discussed further under Standard S2 - Hydraulic Control.

4.2.4 Discharge to a Surface Water Body

There are a number of existing ditches and watercourses within the site extents. These form the natural pathway for surface water runoff to communicate to the downstream watercourse. As such, it is proposed to outfall runoff from the site to these existing water bodies.

Since this will provide the runoff destination for the site, Level 4 and 5 have not been considered.

4.3 S2 - Hydraulic Control

Standard S2 details the requirements for hydraulic runoff from the site. The existing GRR for the site as well as the original and restoration catchment areas have been assessed and compared in Section 3 of this report.

The proposed earthwork cuttings and embankments could affect the rainfall runoff within the catchment areas, preventing sheet runoff and changing the flow path. Further to this, the restoration scheme has also modified the areas when compared to the original catchment boundaries by shifting the ridgeline further to the north. The flows from each catchment will be compared to the original catchment discharge rates to determine if there would be any increase in flow. Should an increase in discharge rate be shown for a sub-catchment, then the flows will be attenuated back to match the original discharge rate.

The following subsections detail the hydraulic control requirements from the site to cater for a 1:100-year storm events. Consideration has been given to the potential future impermeable areas. A 40% allowance has been made to accommodate for climate change from the potential future impermeable areas only. During subsequent design stages, each proposed catchment will also be assessed against the 1:1 year and 1:30 year GRR to ensure sufficient hydraulic control is provided for the scheme.

Note that the catchment names applied have been selected to match the restoration scheme for the site. As such, some catchments listed below are outside of the proposed scheme extents and are therefore not be affected by the proposals. They have been included for completeness only.

The proposed catchment drawing has been attached in Appendix B.

4.3.1 Catchments 1A and 1B

Catchments 1A and 1B are located to the east of the site. Runoff from these catchments is collected through ditches and conveyed via tributaries to the River Tawe. Catchment 1A is outside of the planning boundary and therefore not affected by the proposed scheme.

Based on the catchment shapefiles derived from the FEH Online service, Catchment 1B has 9.5Ha of area within the extent of the outer planning boundary line. However, the proposed changes to the topography by the restoration proposals result in this area being attributed to neighbouring catchments. As such, there is no contributing area to Catchment 1B within the extents of the scheme.

4.3.2 Catchment 1C

Catchment 1C is located at the western extent of the site. As part of the restoration proposals, runoff from this catchment will be collected by an engineered watercourse, communicating with an existing watercourse that has been severed during the mining operations on the site. Attenuation ponds are also included within the restoration proposals to attenuate the contributing runoff from the catchment.

Table 2 below provides a summary of the original catchment area (based on FEH Online), restoration catchment area, proposed catchment area and track area within the catchment.

Table 2 - Comparison of the original, restoration and proposed catchment areas for Catchment 1C

Catchment	Original Catchment Area (ha)	Restoration Catchment Area (Ha)	Proposed Catchment Area (including track area) (Ha)	Proposed Track Area (Ha)
1C	7.5	12.7	3.0	0.0

This demonstrates that the proposed catchment area within the site extents will be reduced when compared to both the original and restoration areas. The reason for the reduction is that at this location, the track is in a relatively deep cut. It is therefore not viable to convey surface runoff from the area inside the track loop to the restoration watercourse.

The proposed catchment area outside the track loop is unaffected by the proposals. As such, it is proposed that runoff in this area will continue to discharge to the restoration watercourse as sheet runoff.

Since there is an overall reduction in catchment area and no contributing impermeable areas, no attenuation is required as part of this scheme.

4.3.3 Catchment 1D

Catchment 1D incorporates an area from the ridgeline to the western boundary of the site. As part of the restoration proposals, runoff from this catchment will be collected by an engineered watercourse, communicating with an existing watercourse that has been severed during the mining operations on the site. This watercourse will need to be culverted under the proposed track.

The existing watercourse has downstream settlement ponds created to control sediment from the mining operations. These are also proposed to be converted to an attenuation pond as part of the restoration scheme.

Table 3 below provides a summary of the original catchment area (based on FEH Online), restoration catchment area, proposed catchment area and track area within the catchment.

Table 3 - Comparison of the original, restoration and proposed catchment areas for Catchment 1D

Catchment	Original Catchment Area (ha)	Restoration Catchment Area (Ha)	Proposed Catchment Area (including track area) (Ha)	Proposed Track Area (Ha)
1D	55.2	27.4	25.4	0.6

As shown, the proposed catchment area is slightly lower than the existing catchment area, meaning a slightly reduced discharge rate to the engineered watercourse. However, the potential future use of the track plateau may result in the development of impermeable area, which consequently would increase the runoff rate and volume from that area.

It is therefore proposed that the area discharging from the plateau is treated as impermeable and is attenuated to the GRR for the 1:1, 1:30 and 1:100-year rainfall events. A 40% allowance for climate change has been applied for the 1:100-year event.

The pond was simulated using the source control module within Microdrainage. To cater for the 1:100-year event (+40% allowance for climate change), a pond providing 380m³ of storage is required. The outfall from this pond will discharge through an orifice plate to throttle the outgoing flow to the GRR. The Microdrainage calculations are contained within Appendix F.

4.3.4 Catchment 1E

Catchment 1E encompasses the area between the ridgeline and the northern boundary of the site. A portion of the catchment area is contained within the restoration scheme. For the restoration proposals, an engineered watercourse has been proposed to capture some of the runoff and communicate with an unnamed ditch which runs parallel to Sustrans Cycle Route 43. Other areas within the catchment also discharge to this unnamed ditch as sheet runoff.

The alignment of the restoration watercourse will need to be diverted and culverted as part of the Nant Helen Complimentary Earthworks Scheme. Sheet runoff from the catchment will be collected at the base of the embankments in cut-off ditched and conveyed to the same culvert.

Table 4 provides a summary of the original catchment area (based on FEH Online), restoration catchment area, proposed catchment area and track area within the catchment. This is shown below.

Table 4 - Comparison of the original, restoration and proposed catchment areas for Catchment 1E

Catchment	Original Catchment Area (ha)	Restoration Catchment Area (Ha)	Proposed Catchment Area (including track area) (Ha)	Proposed Track Area (Ha)
1E	39.6	23.2	41.0	2.1

The size of the proposed catchment is slightly larger than the original catchment area. Although the restoration catchment area is shown to be much smaller, this is due to the restoration scheme only covering a part of the site. Therefore, this area has not been considered for comparison.

As part of the restoration scheme, a reduced discharge from the catchment was proposed when compared with the original discharge rate. Discussions with Celtic Energy highlighted that this was done to reduce discharge to downstream tributaries, which had experienced flooding issues in the past.

It is therefore proposed that for the 23.2ha contained within the restoration scheme for the site, a reduced discharge rate of 45.9l/s/ha for the 1:100-year event is applied. This is based on the proposed 1:100-year discharge rate contained within the “*Restoration of Watercourses – Design Statement*” attached in Appendix D. The remaining 16.4 ha is proposed to discharge at the calculated GRR.

A calculation was undertaken using source control within Microdrainage to determine the attenuation volume required to achieve the above. For this calculation, the area discharging from the track plateau has been treated as impermeable, with other areas treated as 40% impermeable. No allowance for climate change has been made for undeveloped areas, but a 40% allowance for climate change has been applied to the track plateau area.

This resulted in a required attenuation pond volume of 3550m³. The discharge from this pond is proposed to outfall through an orifice plate to throttle the flow to the reduced discharge rate. For calculations outputs from microdrainage, refer to Appendix F.

4.3.5 Catchment 1F

Catchment 1F is located within the north eastern section of the site. A portion of the catchment is contained within the restoration proposals, which as per the original catchment discharges as sheet runoff to the ditch running parallel to Sustrans Cycle Route 43.

Owing to the topography of the site and the proposed earthworks embankment, the existing catchment 1F will be separated into two sub-catchments. Stormwater runoff from these catchments will be collected at the base of embankments via cut-off ditches and be conveyed through a culvert in the proposed embankment before merging with the existing ditch.

Table 5 provides a summary of the original catchment area (based on FEH Online), restoration catchment area, proposed catchment area and track area within the catchment. This is shown below.

Table 5 - Comparison of the original, restoration and proposed catchment areas for Catchment 1F

Catchment	Original Catchment Area (ha)	Restoration Catchment Area (Ha)	Proposed Catchment Area (including track area) (Ha)	Proposed Track Area (Ha)
1F	42.3	20.6	44.3	1.5

Similar to Catchment 1E, the size of the proposed catchment is slightly larger than the original catchment area. The restoration scheme only covers part of the site; therefore, the restoration catchment area has not been considered for comparison.

However, the restoration scheme proposes a reduced discharge rate from the catchment when compared with the original discharge rate. It is therefore proposed that the 20.6ha contained within the restoration scheme is discharged at the reduced rate of 46.5l/s/ha for the 100-year event. This discharge rate is based on the proposed 1:100-year rate contained within the “*Restoration of Watercourses – Design Statement*” attached in Appendix D. The remaining 24.0ha is proposed to discharge at the calculated GRR.

A calculation was undertaken using source control within Microdrainage to determine the attenuation volume required to achieve the above. For this calculation, the area discharging from the track plateau has been treated as impermeable, with other areas treated as 40% impermeable. No allowance for climate change has been made for undeveloped areas, but a 40% allowance for climate change has been applied to the track plateau area.

This resulted in a required attenuation pond volume of 3600m³. The discharge from this pond is proposed to outfall through an orifice plate to throttle the flow to the reduced discharge rate. For calculations outputs from microdrainage, refer to Appendix F.

4.3.6 Catchment 1G

Catchment 1G contains the area between the ridgeline and the north western boundary of the site. As part of the restoration proposals, runoff from this catchment will be collected by an engineered watercourse, communicating with an existing watercourse that has been severed during the mining operations on the site. This watercourse will need to be culverted under the proposed track.

Table 6 provides a summary of the original catchment area (based on FEH Online), restoration catchment area, proposed catchment area and track area within the catchment. This is shown below.

Table 6 - Comparison of the original, restoration and proposed catchment areas for Catchment 1G

Catchment	Original Catchment Area (ha)	Restoration Catchment Area (Ha)	Proposed Catchment Area (including track area) (Ha)	Proposed Track Area (Ha)
1G	36.2	7.3	16.4	1.0

The proposed catchment area is significantly less than the original catchment area. However, it is also significantly higher than the contributing restoration catchment. Runoff from the catchment will outfall to the engineered watercourse proposed as part of the restoration proposals. It is therefore suggested that the runoff is attenuated to the peak discharge rate associated with the restoration catchment area to avoid introducing additional flows to the engineered watercourse.

Therefore, the discharge rate from the catchment has been restricted to 332 l/s based on the flows provided in the restoration proposals. For the 1:100-year event, the attenuation volume required to achieve this discharge rate was calculated within the Microdrainage source control module to be 2600m³. No allowance for climate change has been made for undeveloped areas, but a 40% allowance for climate change has been applied to the track plateau area during the 1:100-year event.

4.3.7 Catchment 1H

Catchment 1H lies to the north east of the site. Runoff from this catchment is proposed to be collected via a ditch which is assumed to convey flows to the Nant Llech, a tributary of the River Tawe.

Table 7 provides a summary of the original catchment area (based on FEH Online), proposed catchment area and track area within the catchment. This catchment is outside of the restoration scheme.

Table 7 - Comparison of the original, restoration and proposed catchment areas for Catchment 1H

Catchment	Original Catchment Area (ha)	Proposed Catchment Area (including track area) (Ha)	Proposed Track Area (Ha)
1H	24.6	8.3	1.5

As shown, the proposed catchment area is significantly lower than the existing catchment area. However, the potential future use of the proposed track plateau will result in the development of impermeable area, which consequently would increase the runoff rate and volume.

To determine the pond size, a hydraulic analysis has been undertaken using the Microdrainage source control module. This demonstrated that the required attenuation volume for the 1:100 year rainfall event with a 40% allowance for climate change is 740m³. The simulation results can be found in Appendix F.

4.3.8 Catchment 1I

Catchment 1I lies to the north west of the site. Runoff from this catchment is proposed to be communicated to a ditch which runs perpendicular to the Sustrans Cycle Route.

This catchment sits between the original Catchments 1E and 1G. It originally discharged to the ditch as sheet runoff, so has been included within the previous catchment areas. It is proposed to discharge this catchment at GRR, as such, no attenuation is required.

4.3.9 Catchment 2A

Catchment 2A lies to the south west of the site. Runoff from this catchment communicates with the Nant Ystalwyn, a tributary of the River Dulais.

Table 8 provides a summary of the original catchment area (based on FEH Online), restoration catchment area, proposed catchment area and track area within the catchment. This is shown below.

Table 8 - Comparison of the original, restoration and proposed catchment areas for Catchment 2A

Catchment	Original Catchment Area (ha)	Restoration Catchment Area (Ha)	Proposed Catchment Area (including track area) (Ha)	Proposed Track Area (Ha)
2A	33.0	17.3	28.8	1.3

It was noted that the proposed catchment area is lower than the original catchment but higher than the restoration catchment. During discussions with Celtic Energy, it was noted that there is no flooding issues with the downstream tributary in this area. A review of aerial imagery for the Nant Ystalwyn shows that there are currently no structures between the start of the watercourse and it merging as a tributary to the River Dulais.

Based on this, it was determined that the reduction of peak discharge to the watercourse within the restoration proposals is not required. Subsequently, it is proposed that the original catchment area is used as the baseline for comparing the discharge rate with the proposed catchment area. Since the proposed catchment area is lower, no attenuation is required for the undeveloped areas. However, as per the previous catchments, the track area will be considered impermeable and flows from this area will be attenuated to the GRR.

To determine the pond size, a hydraulic analysis has been undertaken using the Microdrainage source control module. This demonstrated that the required

attenuation volume for the 1:100-year rainfall event with a 40% allowance for climate change is 580m³. The simulation results can be found in Appendix F.

4.3.10 Catchment 2B

Catchment 2B incorporates the area from the ridgeline at the centre of the site to the southern boundary. Surface water runoff from this catchment collects to form the Nant Ystalwyn. The Nant Ystalwyn is a tributary to the River Dulais.

Table 9 provides a summary of the original catchment area (based on FEH Online), restoration catchment area, proposed catchment area and track area within the catchment. This is shown below.

Table 9 – Comparison of existing GRR and reduced GRR for Catchment 2B

Catchment	Original Catchment Area (ha)	Restoration Catchment Area (Ha)	Proposed Catchment Area (including track area) (Ha)	Proposed Track Area (Ha)
2B	55.7	48.0	115.3	5.0

The size of the proposed catchment is significantly larger than the original catchment area. Although the restoration catchment area is shown to be smaller, this is due to the restoration scheme only covering a part of the site. Therefore, this area has not been considered for comparison.

Owing to the large difference between the existing and proposed areas, attenuation will be required to ensure the stormwater discharge rate is equivalent to the original discharge from the catchment. Further to this, the proposed track area may in future be surfaced and therefore be made impermeable, increasing runoff.

Due to the size of the catchment, it is proposed that the attenuation is staged, creating ponds at different points within the catchment. This will increase the amenity and biodiversity for the scheme by spreading the different habitats at different locations around the site.

The catchment has been split into two regions which outfall to existing ditches that communicate with the Nant Ystalwyn. The western region is 63.5ha with no track area, whilst the eastern region is 51.8ha which includes 5.0ha of track. There is an existing pond in the western region which is used for attenuation in the restoration scheme.

A Microdrainage source control model was produced for each of these regions to simulate the 1:100 year event. The first model, covering the western region, drains undeveloped areas only and requires three cascading ponds:

- Pond 2B-1: 2700m³ volume
- Existing pond: 2000m³ volume

- Pond 2B-2: 2400m³ volume

The second hydraulic model also requires three cascading ponds. This covers the remaining undeveloped area as well as the track plateau. Proposed Pond 2B-3 and 2B-4 attenuate discrete areas before both converging at Pond 2B-5. The required volumes are as follows:

- Pond 2B-3: 3500m³ volume
- Pond 2B-4: 2400m³ volume
- Pond 2B-5: 4700m³ volume

As previously stated, no allowance for climate change has been made for undeveloped areas when sizing the attenuation basins. A 40% allowance for climate change has been provided for the track area to accommodate the potential future development. The Microdrainage results can be found in Appendix F.

4.3.11 Catchment 2C

Catchment 2C is the area to the south east of the site. Runoff from this catchment communicates directly with the River Dulais through a number of smaller ditches and sheet runoff.

Table 10 provides a summary of the original catchment area (based on FEH Online), proposed catchment area and track area within the catchment. This is shown below.

Table 10 – Comparison of existing and proposed areas for Catchment 2C.

Catchment	Existing Catchment Area (ha)	Proposed Catchment Area (includes Track Area) (Ha)	Proposed Track Area (Ha)
2C	77.6	72.7	4.1

The potential future use of the proposed track area would likely result in a strip of impermeable area within the catchment, which consequently would increase the runoff rate and volume. However, it is likely that the outfall locations for track will differ in the permanent case from those proposed as part of this application.

The track constructed as part of this application will not be impermeable. Therefore, since the runoff from the proposed catchment will be significantly lower than for the existing catchment, it is proposed that no attenuation should be installed as part of these works.

4.3.12 Catchment 3A

Catchment 3A lies to the east of the site. Runoff from this catchment outfalls to a ditch which serves as a tributary to the Afon Pyrdin.

The existing and proposed catchment area have been compared in Table 11 below. The table also references the proposed area of track which will drain within the catchment. Overall, the existing catchment area is slightly larger than the proposed catchment area.

Table 11 – Comparison of existing and proposed areas for Catchment 3A.

Catchment	Existing Catchment Area (ha)	Proposed Catchment Area (including track) (Ha)	Proposed Track Area (Ha)
3A	34.8	34.4	1.7

The proposed catchment area is slightly lower than the existing catchment area. However, the potential future use of the track plateau could result in the development of an impermeable surface, which consequently would increase the runoff rate and volume in these areas. It is proposed that this is accommodated for within this earthworks package

To determine the required pond size to attenuate the track area to the GRR, a hydraulic analysis has been undertaken using the Microdrainage source control module. This demonstrated that the required attenuation volume for the 1:100-year rainfall event with a 40% allowance for climate change is 1000m³. The simulation results can be found in Appendix F.

4.4 Drainage Features

To facilitate conveyance of flow around the site, as part of the Nant Helen Complementary Restoration Earthworks a number of drainage features are proposed. These are detailed briefly in the following subsections.

For the location of these drainage features, refer to drawings CG1050 to CG1053 in Appendix E.

4.4.1 Cut-off Ditches

To collect and convey runoff from the base of embankments and top of cuttings, cut-off ditches have been proposed throughout the site. These will capture sheet runoff from upland areas and convey them to the low points within the catchments.

Similarly, at either edge of the track plateau it is proposed to use cut-off ditches to capture runoff from the track and cutting slopes. These will be designed as swale features and will be grass lined owing to the shallow 1:100 longitudinal gradient and relatively small areas.

Three types of ditch will be used around the site:

- In areas of low flow, low velocity and shallow longitudinal gradients (less than 1 in 35), grass lined channels will be used. These will generally be towards the start of the ditches where runoff will be less concentrated.

- Where higher flows are anticipated or for longitudinal gradients steeper than 1 in 35, stone bedded channels will be proposed. This will provide channels with long-term stabilization and erosion protection. The stone size will be determined based on the anticipated flows in the ditch.
- Finally, at longitudinal gradients steeper than 1:12 or where flow would become supercritical (Froude number > 1), the ditches will be rock reinforced bedded on a concrete bed. Longitudinally, these would be stepped with slight ponding on each step to dissipate energy from the water.

It is noted that whilst the cut-off ditches at the base of embankments and top of cuttings will remain, the ditches on the track plateau may be replaced with an alternative drainage system during future development of the plateau.

4.4.2 Culverts

Water collected by cut-off ditches at the base of the embankments will need to be conveyed under the plateau at discreet low points. To do this, a number of culverts will be installed as part of the scheme.

During subsequent design stages, the culverts will be designed in accordance with CIRIA C689 - *“Culvert Design and Operation Guide”*. Culverts will be sized to accommodate flows from the 1:100-year event including a 40% allowance for climate change.

At the inlet and outlet for the culverts, a headwall will be required. These are likely to be precast or in-situ concrete headwalls. However, for smaller diameter culverts alternative soft engineered options may be considered.

4.4.3 Cascades

At a number of locations on site, the cut-off ditches are required to flow down the side of the proposed engineered slopes. To do this, cascade features will be required.

These will be designed during the subsequent design stages to have sufficient capacity for the 1:100-year event (+40% climate change) and dissipate energy from the flow as required.

4.4.4 Attenuation Ponds

A number of attenuation ponds are required for the scheme and have been sized for the various catchments as described in Section 4.2. A 300mm freeboard will be provided above the highest water level for each pond.

The attenuation ponds will be lined to provide a permanent wet base and increase the amenity and biodiversity value to the scheme. An access track has also been provided around the pond to provide an area for inspection and maintenance. The outlet to each pond will discharge through an orifice plate which will restrict the discharge rate to the GRR.

4.4.5 Further Considerations

For the Nant Helen Complementary Restoration Earthworks discussed in this report, there will be no impermeable surfacing. As such, stormwater falling on the catchment will infiltrate and evapotranspire at the same rate it does in the existing case. Therefore, there is no requirement to review the proposals to reduce discharge from the site for rainfall events less than 5mm. This will need to be reviewed during any subsequent planning application for the site.

For each sub-catchment, the runoff rate will be controlled to the GRR to mitigate any increase in flood risk and prevent morphological and ecological damage downstream. For the River Tawe catchments, the betterment provided as part of the restoration scheme has been incorporated into the proposals, resulting in an overall reduction from the GRR.

Volumetric control will also need to be considered for each catchment based on the potential future impermeable area. This will be achieved through long-term storage areas discharging at a reduced discharge rate within the attenuation ponds.

4.5 S3 - Water Quality

The Welsh Standard S3 covers the necessary water quality requirements for a scheme.

During construction, it is likely that silts will be mobilised by rainfall which if uncontrolled will be conveyed to the downstream watercourses. Celtic Energy have noted this and propose to use a combination of settlement ponds and Siltbusters to capture silt during the earthworks. This will be detailed in the Contractor's method statements.

Following completion of the earthworks, the engineered slopes will be grass seeded. Once the roots have taken, the site will be effectively green and therefore no dedicated treatment train is required at this stage. However, it is noted that the grass lined channels and attenuation ponds will provide water quality benefits for the scheme.

4.6 S4 - Amenity

The Welsh Standard S4 states that the surface water management systems should maximise amenity benefits.

The proposed use of grass lined ditches will provide a more natural looking drainage on the site which will be visually appealing. Similarly, the ponds can be shaped to look visually appealing and provide provision for additional flora, fauna and wildlife habitats.

4.7 S5 - Biodiversity

Standard S5 requires that surface water management systems also maximise biodiversity benefits.

The use of grass lined ditches and attenuation ponds will provide a diverse range of habitats for flora and fauna.

4.8 S6 - Construction, Operation and Maintenance

Standard S6 requires that the proposed surface water drainage systems are designed such that they can be constructed, operated and maintained easily, safely and cost effectively for the whole design life of the systems. They should also aim to minimise the use of natural resources and embedded carbon.

By combining the proposed earthworks with the restoration proposals, the construction will be more environmentally friendly compared to undertaking the works as the restoration is complete. The use of green features will also assist in offsetting carbon.

The drainage proposals minimise the requirement for hard engineering solutions by utilising ditches for conveyance and attenuation ponds for storage. Stone for the ditches will likely be from site won material rather than being imported.

An access track has been provided around each of the attenuation ponds to facilitate an area for inspection and maintenance.

5 Conclusion

A drainage strategy has been prepared for the Nant Helen Complementary Restoration Earthworks at the Nant Helen site.

The drainage has been designed in accordance with the Welsh Governments Statutory Standards for Sustainable Drainage Systems. Consideration has been given to the proposed runoff destination, hydraulic control, water quality, amenity and biodiversity for the scheme.

The proposed earthworks will result in modifications to the original catchment and restoration catchment areas. For each sub-catchment, to ensure the runoff rate from the site is not increased, the catchment areas for the original and proposed catchments were compared. Where the proposed catchment is larger, flows have been attenuation to the GRR for the smaller catchment area. In addition to this, for the River Tawe catchments, the betterments to the GRR proposed in the Celtic Energy Restoration Plan have been adopted. Table 12 below provides a summary for the sub catchments as well as the overarching River Tawe, River Dulais and Afon Pyrddin.

Table 12 – Summary of the original and proposed catchment areas and discharge rates for the Nant Helen site for the 1:100-year event.

Catchment	Original Catchment Area (ha)	Proposed Catchment Area (including track area) (ha)	Original 1:100 Discharge Rate (m ³ /s)	Proposed 1:100 Discharge Rate (m ³ /s)
1B	9.5	0.0	0.5	0.0
1C	7.5	3.0	0.4	0.2
1D	55.2	25.4	2.9	1.3
1E	39.6	41.0	2.1	1.9
1F	42.3	44.3	2.2	2.1
1G	36.2	16.4	1.9	0.3
1H	24.6	8.3	1.3	0.4
1I	0.0	26.3	0.0	1.4
River Tawe	214.9	164.7	10.9	7.7
2A	33.0	28.8	1.9	1.7
2B	55.7	115.3	3.2	3.2
2C	77.6	72.7	4.5	4.2
River Dulais	166.2	216.8	9.6	9.1
3A	34.8	34.4	1.8	1.7
Afon Pyrddin	34.8	34.4	1.8	1.7
Total	415.9	415.9	22.3	18.5

For the River Tawe catchment, the reduction in contributing area coupled with the reduction in discharge rates proposed as part of the restoration scheme results in a total 30% reduction in peak flow to the River Tawe, which includes a 40% allowance for climate change for future impermeable areas.

Conversely, the River Dulais Catchment has an overall increase in impermeable area, particularly attributed to Catchment 2B. To mitigate the associated increase in site runoff, a series of ponds have been proposed within the catchment to attenuate stormwater to the original peak discharge rate.

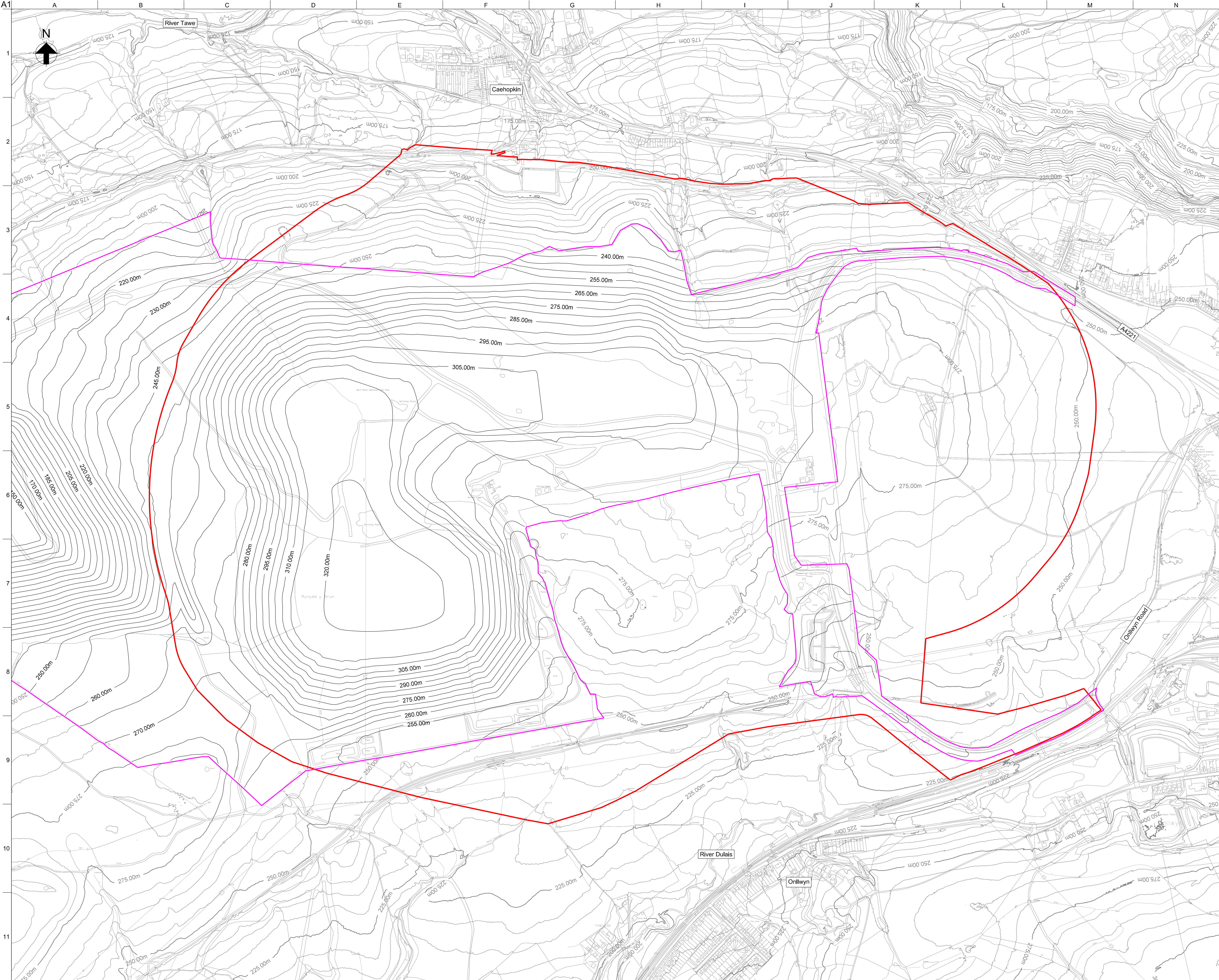
The Afon Pyrddin also has a small increase in catchment area, resulting in the flows being attenuated to match the original discharge rate.

The principles of the stormwater conveyance have been discussed. The stormwater runoff will be captured and conveyed within the catchments utilising engineered cut-off ditches, culverts, cascades and attenuation ponds. The ditches and attenuation ponds will provide both amenity and biodiversity value by blending into the natural landscape and providing a contrast between dry and wet area.

Appendix A

Restoration and Existing Topography Drawing

A1



Legend

Planning Application Boundary

Restoration Works Boundary

285.000m Restoration Topography

285.000m Existing Topography

- Notes
1. All dimensions are in metres unless noted otherwise. All elevations are in metres Above Ordnance Datum (AOD). Do not scale.

2. Levels shown within the Restoration Works Boundary are based on the restoration scheme proposed by Celtic Energy and provided to Arup on 17/10/2019. No responsibility is taken for the accuracy of this information.

3. Levels outside the Restoration Contour Boundary are based on 2m resolution LIDAR data. No responsibility is taken for the accuracy of this information.

4.Slight discrepancies between LIDAR data and restoration proposals to be reviewed once topographical survey is undertaken on site.

P01	06/12/19	CB	RV	JS
Issued for Planning				
Issue	Date	By	Chkd	Appd

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Client

Celtic Energy

Job Title

Nant Helen Complementary
Restoration Earthworks

Drawing Title

Existing Site Plan,
Restoration Topography and
Planning Boundary

Scale at A1

1:5000

Discipline

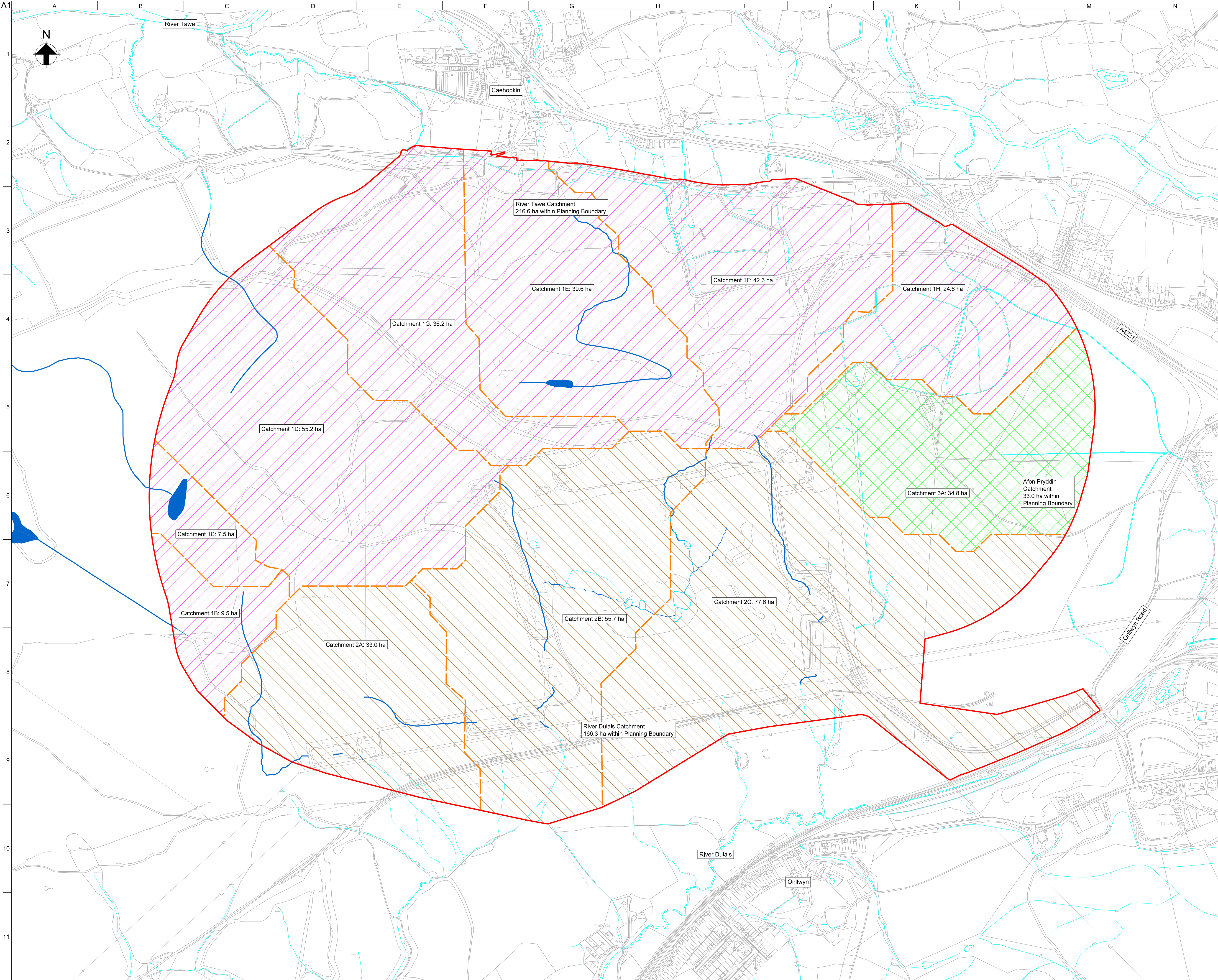
Infrastructure

Drawing Status		
Planning		
Job No	Drawing No	Issue
264904	CG1000	P01

Appendix B

Original and Proposed Catchment Boundaries Drawing

B1



Legend

Planning Application Boundary

River Tawe Catchment

River Dulais Catchment

Afon Pryddin Catchment

Existing Watercourses

Restoration Watercourses

Tributary Catchments

- Notes
1. All dimensions are in metres unless noted otherwise. All elevations are in metres Above Ordnance Datum (AOD). Do not scale.

2. The overarching catchment boundaries shown have been downloaded from the FEH Online Service. These were preferred over catchments derived from the Lidar model due to the open cast mining works undertaken on the site.

3. Tributary catchments are based on the existing catchments prepared by the restoration works and compared to the online catchments using the FEH Online Tool.

P01

06/12/19

CB

RV

JS

Issued for Planning

Issue

Date

By

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Client

Celtic Energy

Job Title

Nant Helen Complementary
Restoration Earthworks

Drawing Title

Existing Drainage Catchments

Scale at A1

1:5000

Discipline

Infrastructure

Drawing Status

Planning

Job No

Drawing No

Issue

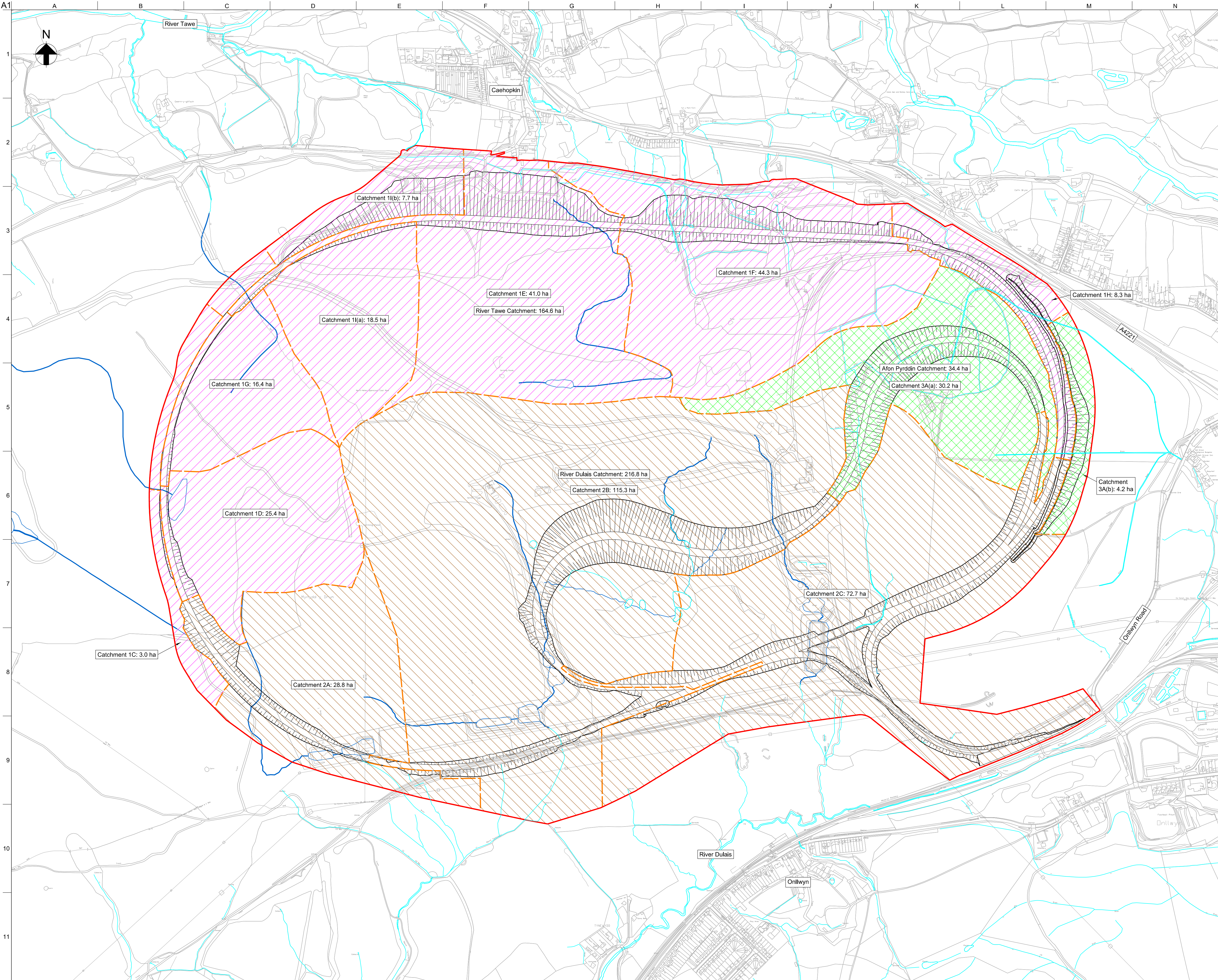
264904

CG1040

P01

Do not scale

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Legend

Planning Application Boundary

River Tawe Catchment

River Dulais Catchment

Afon Pryddin Catchment

Proposed Catchment Boundary

Existing Watercourse

Restoration Watercourses

Notes

1. All dimensions are in metres unless noted otherwise.
All elevations are in metres Above Ordnance Datum (AOD). Do not scale.

2. The catchment boundaries shown have been downloaded from the FEH Online Service.

P01	06/12/19	CB	RV	JS
Issued for Planning				
Issue	Date	By	Chkd	Appd

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Client

Celtic Energy

Job Title

Nant Helen Complementary
Restoration Earthworks

Drawing Title

Proposed Drainage Catchment
Overview

Scale at A1

1:5000

Discipline

Infrastructure

Drawing Status

Planning

Job No

264904

Drawing No

CG1041

Issue

P01

Appendix C

Celtic Energy Restoration Drainage Proposals

C1

CELTIC ENERGY LTD

NANT HELEN REMAINDER SURFACE COAL MINE SITE

Condition 45: Restoration of Watercourses – Design Statement Revision C

1.0 Introduction

The overall site restoration strategy was established through the original planning consent, to which reference has been made in developing these proposals to restore the watercourses affected by the site workings. The site covers the head of the local catchment areas, with the larger part of the site draining towards the north to the Afon Tawe and the southern part of the site draining towards the south to the Dulais. A very small triangle of land to the east drains towards the Afon Pyrrddin.

A restoration scheme has been submitted under condition 45 of the current Planning Permission and the restoration of the watercourses is specifically referenced in part g) to enhance biodiversity and in part i) to create attenuation ponds, water features, wetlands and reed beds to achieve maximum ecological diversification.

2.0 Design Principles

The restoration of the watercourses has been designed to incorporate attenuation ponds, wetlands and rush-lined channel beds in accordance with the submitted scheme. These water features will slow down and reduce surface water flows away from the site and re-connect the restored on-site watercourses to the existing downstream watercourses that were severed by the site operations.

Wherever gentler gradients permit, the watercourses will be clay-lined and planted with rushes; wetlands are located into the proposed landscape where possible. The gradients along some of the watercourses are steep and for slopes in excess of 1 in 12 the channel beds will need to be reinforced with rock. These sections will be stepped and formed with back-fall areas to provide small pools and to help slow the flows.

In between the more gentle and steep gradients the watercourse beds will be lined with loose stone/gravel. The size of the gravel beds that will be required for stability have been determined by calculation and typical details of each of the three types of construction are included on the watercourse restoration drawings.

Of the total length of new watercourses, an estimated 17% will be rush-lined, 53% formed with stone/gravel beds and 30% will need to be reinforced with rock. Natural materials will be sourced from the site as much as possible for use in the construction of the new watercourses.

Reference has been made to the original planning application documents to compare the original surface water run-off from the site and the long-term surface run-off resulting from the restoration proposals. Preliminary designs have been undertaken for the proposed

on-site water features to act as attenuation ponds and reduce the surface water run-off from the site to lower flow rates than were experienced before the site was brought into operation. The principle of reducing the flows away from the site also serves to reduce possible flood risk in the downstream receiving watercourses including the main rivers, the Afon Tawe and the Dulais.

A summary comparison table of the pre- and post-operational surface water run-off rates to each of the original catchment areas follows, together with a second table showing the results of the preliminary attenuation assessments. Calculations for each watercourse and the associated attenuation assessments are included as separate attachments.

3.0 Q₁₀₀ Off-Site Flow Comparisons

Original Site Catchment	Original Q ₁₀₀ Site Run-off (cumec)	Proposed Watercourse	Proposed Q ₁₀₀ Site Run-off (cumec)	Difference in Flows Off-site (Percentage)
1a	0.310	Site run-off	0.268	-14%
1b	3.000	Site run-off	0.251	-92%
1c	3.600	A	1.080	-70%
1d	4.200	C	1.522	-64%
1e	1.480	E	1.066	-28%
1f	1.010	Site run-off	0.967	-4%
1g	1.090	D	0.441	-60%
2a	1.330	H	0.397	-70%
2b	1.620	G1 and G2	0.819	-49%
2c	0.830	F	0.216	-74%

4.0 Preliminary Q₁₀₀ Attenuation Assessments

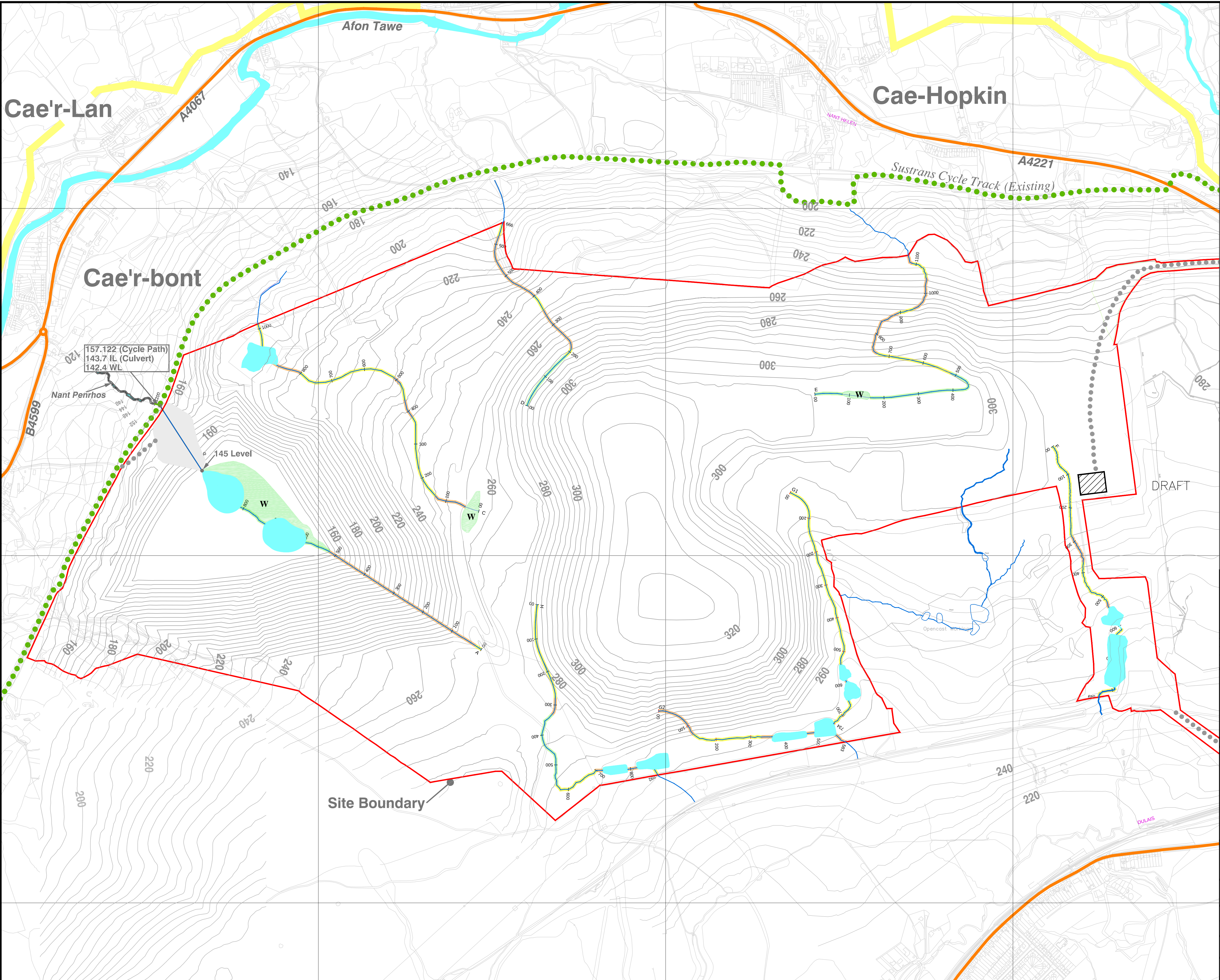
Attenuation Pond	Flow Control Structure (m)	Maximum Q ₁₀₀ Attenuation Volume (cum)	Maximum Q ₁₀₀ Water Level Variations (m)	Maximum Q ₁₀₀ Outflow (cumec)
A1 UPPER	1.000	4528	0.495	0.594
A2 LOWER	1.000	6477	0.615	0.820
C	1.400	2534	0.443	0.704
F UPPER	1.000	716	0.313	0.299
F LOWER	1.000	1974	0.252	0.216
G1 UPPER	1.100	1037	0.910	1.627
G1 LOWER	0.700	1758	0.896	1.011
G2 UPPER	0.300	1229	0.570	0.220
G2 LOWER	0.550	2597	0.914	0.819
H UPPER	1.000	801	0.481	0.568
H LOWER	1.000	1213	0.379	0.397

5.0 Condition 45 Drawings

2363-D01-C	Proposed Restoration Water Features
2363-D02-C	Restoration Watercourses Catchment Plan
2363-D04-C	Watercourse A Longitudinal Section
2363-D05-C	Watercourse C Longitudinal Section
2363-D06-C	Watercourse D Longitudinal Section
2363-D07-B	Watercourse E Longitudinal Section
2363-D08-B	Watercourse F Longitudinal Section
2363-D09-B	Watercourse G1 Longitudinal Section
2363-D10-B	Watercourse G2 Longitudinal Section
2363-D11-B	Watercourse H Longitudinal Section
2363-D12-B	Restoration Watercourse Details
2363-D13-C	Water Features and Landscape

6.0 Condition 45 Calculations

2363-C01-C	Restoration Watercourse A
2363-C02-C	Restoration Watercourse C
2363-C03-C	Restoration Watercourse D
2363-C04-B	Restoration Watercourse E
2363-C05-B	Restoration Watercourse F
2363-C06-B	Restoration Watercourse G1
2363-C07-B	Restoration Watercourse G2
2363-C08-B	Restoration Watercourse H
2363-C09-C	Site Run-off to Areas 1a, 1b, 1c, 1d, 1e and 1f



- KEY**
- SITE BOUNDARY
 - WATERCOURSE
 - RUSH-LINED WATERCOURSE
 - STONE BED WATERCOURSE
 - ROCK REINFORCED WATERCOURSE
 - POND
 - WETLAND
 - HARDSTANDING
 - CYCLE ROUTE
 - RETAINED ACCESS

C WESTERN PONDS AMENDED	30.09.19
B RESTORATION CONTOURS AMENDED	23.11.18
A FIRST ISSUE FOR PLANNING AUTHORITY	19.8.16
Revision Details	By Date

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NANT HELEN RESTORATION

PROPOSED RESTORATION WATER FEATURES

Scale at A1
1:5000

Drawn	Date 6 Jul 2016
Checked	Date

Project No: **2363**

Drawing No: **D01-C**

Appendix D

Hydrological Calculations Technical Note

D1

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Project title	Nant Helen Complementary Restoration Earthworks	Job number	264904
cc	File reference		
Prepared by	Date		
	04 December 2019		
Subject	Nant Helen Complementary Restoration Earthworks - Hydrological Assessment		

1 Introduction

The Nant Helen site to the north of Onllwyn is an open cast mine owned and operated by Celtic Energy. The mining operations currently being undertaken will cease in 2021, at which point Celtic Energy will be required to restore the land in accordance with regulatory requirements and the agreements with Powys County Council (PCC). A restoration scheme for the site has been submitted for approval through the Planning process.

Following discussions with both PCC and Neath Port Talbot County Borough Council (NPTCBC), the local authorities have expressed a desire to develop restoration proposals for the Nant Helen site which will create long term, sustainable jobs.

As such, the Nant Helen Complementary Earthworks Scheme looks to provide a flexible landform that can be used or adapted for a diverse set of future uses. This could range from the traditional agriculture, woodland and nature conservation purposes, to amenity, leisure and tourism uses.

Other potential uses for the site could also include industrial purposes such as the Welsh Government's (WG) proposal to develop a rail testing and storage facility, known as the Global Centre of Rail Excellence (GCRE) at this site together with the adjacent Onllwyn Washery.

For the proposed scheme, an earthworks plateau is proposed that can be adapted for all the above purposes. Consideration has been given to providing suitable longitudinal gradients and track radii should the GRCE project proceed. It is proposed that the construction of this earthworks plateau will be undertaken in tandem with the restoration scheme for the site.

A planning application has been prepared for the Nant Helen Complementary Earthworks. A separate planning application will be submitted at a future date to cover any additional infrastructure required to bring the site to its selected future use.

This technical note details the hydrological calculations undertaken to determine the Greenfield Runoff Rate (GRR) for the scheme.

Technical Note

264904

04 December 2019

2 Overview of site

2.1 Site Description

The Nant Helen Complementary Earthworks Scheme consists of an inner and an outer track loop. The outer track loop encompasses a ridgeline running from east to west across the centre of the site. This ridgeline forms the catchment boundary for three adjacent watercourses:

- The River Tawe, located to the north of the site (River Tawe Catchment)
- The River Dulais, located to the south of the site (River Dulais Catchment)
- The Afon Pyrddin, located to the east of the site (Afon Pyrddin Catchment)

The extent of each of these catchments relative to the planning boundary has been shown in Appendix A. The total area within the Planning boundary is approximately 416ha.

Stormwater runoff from the site is conveyed via a number of smaller streams and ditches, which discharge into the major watercourses as tributaries. A number of these tributaries have been severed during the open cast mining operations that have taken place on the site.

As part of the Celtic Energy restoration scheme, these tributaries and associated catchment areas are proposed to be reinstated. However, the proposed restoration scheme highlights that the discharge rate from these catchments will be attenuated to discharge rates significantly less than the calculated Greenfield Runoff Rate (GRR). This was queried during a meeting with Celtic Energy, where it was established that a number of tributaries within the River Tawe Catchment have experienced fluvial flooding issues in the past. Therefore, the proposed discharge from the reinstated catchments had been reduced from the GRR to help alleviate these downstream flooding issues.

This note has been prepared to establish the GRR for the site, and as such the restoration scheme is not considered. However, these reductions to the GRR for the River Tawe catchment have been adopted as discussed in the overarching drainage strategy report for the scheme.

2.2 Site Catchment Descriptors

The descriptors for the three catchments were obtained from the FEH Online Service. The catchments selected were the smallest catchments that included the largest possible portion of the study site, so the catchment descriptors were site-specific as possible. This meant that to represent the River Tawe and River Dulais Catchments, a smaller tributary was selected to minimise the inclusion of adjacent areas and therefore obtain catchment descriptors representative of the site.

The purchased descriptors were subsequently compared (Table 1), and the below findings noted:

- The FARL index demonstrates that the watercourses are not controlled upstream of the site by lakes or reservoirs.

Technical Note

264904

04 December 2019

- The FPEXT descriptor shows that a larger proportion of the Afon Pyrddin catchment would be inundated during a 1:100-year flooding event, although the value is still relatively small.
- The Base Flow Index (BFIHOST) is relatively similar for all catchments, but slightly higher for the Afon Pyrddin catchment.
- The Standard Average Annual Rainfall 1961-1990 (SAAR6190) is similar between the three sites.
- The urban extent is higher for the Afon Pyrddin catchment as the catchment area encompasses a portion of the village of Coelbren.
- The descriptor SPRHOST indicates that the soil within all catchments has a relatively low permeability.

Table 1 - Comparison of the River Tawe, River Dulais and Afon Pyrddin Catchment Descriptors			
Catchment Descriptor	River Tawe Catchment	River Dulais Catchment	Afon Pyrddin Catchment
AREA (km ²)	0.54	1.04	0.61
FARL	1	1	1
FPEXT	0.0092	0.0241	0.0776
BFIHOST	0.306	0.286	0.319
SAAR6190 (mm)	1775	1826	1789
SPRHOST (%)	50.86	52.90	44.77
URBEXT2000	0.000	0.000	0.0245

Technical Note

264904

04 December 2019

3 Hydrological Assessment

To design the cut off ditches, culverts, cascades and attenuation volumes required for the scheme, the GRR for the 1, 30 and 100-year return period events is required.

To calculate these, a hydrological analysis has been undertaken on the River Dulais, Afon Pyrddin and River Tawe Catchments. Although each of these catchments have been separated into a number of sub-catchments serving individual tributaries, these would be too small to analyse individually. Therefore, an analysis has been undertaken on each overarching catchment and the results will be applied to each sub-catchment area.

Three calculation methods have been used to derive this rate, the FEH Statistical, ReFH rainfall-runoff (Version 2.2) and IH124 methods. The parameters used and results from each analysis are detailed in the sections below.

Refer to Section 4 for a summary of the results.

3.1 River Dulais Catchment

3.1.1 IH124 Method

To undertake the IH124 Method, the source control module within Microdrainage was applied.

The point SAAR value of 1800mm was applied using the interactive map within the microdrainage software. This value of 1800mm is between the values obtained for the three catchments, which demonstrates this will be a good representative of the average SAAR value for the site.

The area of the River Dulais catchment contained within the planning application boundary was measured to be 167Ha. This area was applied within the software to determine the peak GRR for the total site. The peak GRR has been calculated for the 1 year, 30 year and 100-year return period events and was subsequently scaled by the area to give the GRR per hectare:

- 1:1 year rainfall event – 12.8l/s/ha
- 1:30 year rainfall event – 25.7l/s/ha
- 1:100 year rainfall event – 31.8l/s/ha

Refer to *Figure 1: IH124 Calculation undertaken within Microdrainage for the River Dulais Catchment* Figure 1 for the Microdrainage summary of results.

Technical Note

264904

04 December 2019

The screenshot shows the 'Rural Runoff Calculator' software window. The 'IH 124 Input' form is active, with the following values: Return Period (Years) = 100, Area (ha) = 167.000, SAAR (mm) = 1800, Soil = 0.500, Growth Curve = (None), and Partly Urbanised Catchment (QBAR) = 0.000. The 'Calculate' button is visible. To the right, the 'Results' section shows QBAR rural (l/s) = 2438.2 and QBAR urban (l/s) = 2438.2. Below the input form is a table titled 'Return Period Flood' with columns for Region, QBAR (l/s), and various return periods (Q (100yrs) to Q (100 yrs)). The table lists results for various regions and catchments, including ICP SUDS, ADAS 345, FEH, ReFH2, Greenfield Volume, and Ireland East. The bottom of the window has 'OK', 'Cancel', and 'Help' buttons, and a note: 'Enter Return Period between 1 and 1000'.

Region	QBAR (l/s)	Q (100yrs) (l/s)	Q (1 yrs) (l/s)	Q (2 yrs) (l/s)	Q (5 yrs) (l/s)	Q (10 yrs) (l/s)	Q (20 yrs) (l/s)	Q (25 yrs) (l/s)	Q (30 yrs) (l/s)	Q (50 yrs) (l/s)	Q (100 yrs) (l/s)
Region 4	2438.2	6266.3	2023.7	2185.1	2999.0	3633.0	4333.7	4579.0	4777.3	5369.0	6266.3
Region 5	2438.2	8680.1	2121.3	2178.8	3145.3	4035.3	5097.9	5515.3	5857.8	6929.5	8680.1
Region 6/Region 7	2438.2	7778.0	2072.5	2148.1	3120.9	3949.9	4884.3	5237.3	5525.8	6388.2	7778.0
Region 8	2438.2	5900.5	1901.8	2154.4	2999.0	3633.0	4265.0	4476.6	4647.9	5164.2	5900.5
Region 9	2438.2	5315.3	2145.6	2264.6	2950.3	3462.3	3976.8	4154.7	4299.0	4720.4	5315.3
Region 10	2438.2	5071.5	2121.3	2271.0	2901.5	3364.8	3833.4	3998.7	4133.9	4510.7	5071.5
Ireland National	2438.2	4486.3	2072.5	2340.7	2925.9	3291.6	3661.2	3779.3	3875.8	4145.0	4486.3
Ireland East	2438.2	4632.6	2072.5	2340.7	2950.3	3364.8	3752.8	3876.8	3973.4	4242.5	4632.6

Figure 1: IH124 Calculation undertaken within Microdrainage for the River Dulais Catchment

3.1.2 ReFH Version 2.2

The catchment descriptors purchased from the FEH Online service were imported into the ReFH2 software (version 2.2). Within the software, the FEH13 DDF rainfall model was applied as this updated method removes the need to derive an alpha correctional factor. This factor was used to modify the initial soil moisture content (C_{ini}) of the model and was often derived using results from the FEH Statistical Method.

By removing the alpha factor, the peak flows estimated by the ReFH2 method are independent of those generated using the FEH Statistical Method, resulting in improved decision making and higher flexibility when selecting the appropriate GRR (ReFH2 Technical Report).

The default storm duration recommended by ReFH2 was used to calculate the GRR. This corresponded to the 2 hour 54 minute storm event. A timestep of 6 minutes was applied.

The 1, 30 and 100-year peak flow outputs were scaled by the subject catchment area to obtain GRR per hectare and are shown in Table 2 below. Both the winter and summer seasonal values have been provided:

Technical Note

264904

04 December 2019

Table 2 – Derived GRR from the ReFH2 Analysis for the River Dulais		
Return Period	Winter (l/s/ha)	Summer (l/s/ha)
1:1 Year	18.4	19.8
QMED	20.7	22.4
1:30 Year	42.2	46.3
1:100 Year	52.7	57.9

The proposed scheme predominantly involves sizing cut-off ditches, culverts, cascades and attenuation features which are suitable for conveying and attenuating predominantly undeveloped land. It is important that the critical storm event is used to size these features to ensure they have sufficient capacity. Since the GRR was calculated to be higher for the summer seasonality, these values will be applied in the design, to ensure adequate sizing of proposed drainage features.

3.1.3 FEH Statistical Method

To undertake the FEH Statistical analysis, the WINFAP4 software was used. Within the software, the latest version of the HiFlows UK data set was applied (version 8), to ensure the latest available station data was utilised.

DEFRA/EA Science Report SC090031 provides guidance and best practice on estimating peak flows and hydrographs for small catchments. The report recommends that for ungauged catchments, the QMED obtained from catchment descriptors should be modified using data transfer from a local donor station with annual maxima data.

The use of a geographically close catchment prevents introducing uncertainties from local flooding factors that may not be contained within catchment descriptors. The QMED adjustment factor in the data transfer equation is moderated based on distance between catchment centroids, so only geographically close stations will have a larger influence.

Using the WINFAP Donor Adjustment method provided a list of the ten closest catchments, and selected the nearest 6 of these by default:

- Station 58008: Dulais at Cilfrew
- Station 59001: Tawe @ Ynystanglws
- Station 58002: Neath @ Resolven
- Station 58006: Mellte @ Pontneddfechan
- Station 60009: Sawdde @ Felin-Y-Cwm
- Station 58012: Afan @ Marcroft Weir

A review of the catchment descriptors for these donor sites was undertaken. Stations 59001, 60009 and 58012 were all removed due to the difference of the SPRHOST, BFIHOST and AREA with the subject catchment. Station 58002 was also removed due to the large AREA difference and the noted combined effect on observed flows from reservoirs, water abstraction and effluent returns.

The donor catchments used for the QMED adjustment were therefore:

Technical Note

264904

04 December 2019

- Station 58008: Dulais at Cilfrew
- Station 58006: Mellte @ Pontneddfechan

Station 58006 provided the closest correlation with the target sites catchment descriptors. Station 58008 also provided a good correlation and is downstream of the site in the River Dulais. Given this station includes the area within the site catchment, it is likely to give a reasonable representation of the QMED adjustment required. It was noted that the observed flows for both stations are affected by effluent, but since they are suitable for QMED this was deemed to be acceptable.

A comparison of QMED was undertaken between the calculated value using catchment descriptors and the measured value observed from annual maxima data. This comparison is shown in Table 3 below.

Table 3 – Comparison of calculated and observed QMED values for donor sites			
Station	Observed QMED (m3/s)	Calculated QMED (m3/s)	Difference (QMED _{calc} /QMED _{obs})
River Dulais (From FEH Online)	N/A	2.4	N/A
58008 (Dulais @ Cilfrew)	56.4	46.9	1.20
58006 (Mellte @ Pentneddfechan)	87.4	75.3	1.16

The use of data transfer from these donor sites results in an uplift of the GRR from 23.0 l/s/ha (using the QMED catchment descriptor equation) to 25.7 l/s/ha.

The default pooling group contained 16 stations with a total of 515 years of data. This pooling group had a standardised test value (H2) of 1.36, indicating that the pooling group was possibly heterogeneous and a review of the group was optional.

A review of the pooling group was undertaken and the following stations removed:

- Station 49005 – Bollingey Stream at Bollingey Cocks Bridge. Rationale: Short records, only 8 years. Different seasonality of flooding. Negative L-kurtosis. High BFIHOST (0.627) compared to target site. High discordancy value of 2.803.
- Station 69047 – Roch @ Littleborough. Rationale: Low FARL value (0.890)

It was also noted that Station 45816 (Haddeo at Upton) had a steeper growth curve than other stations and a high BFIHOST (0.590). However, a review of the site showed that it has had two relatively large annual maxima events during its recording period. These signify extreme events which have occurred and offer an important contribution to the pooled growth curve. Therefore, it was decided that this station should be included within the group.

The resulting pooling group consisted of 14 stations with a total of 466 years of data. One station was added to achieve the required 500 years:

- Station 21017 – Ettrick Water @ Brockhoperig

Technical Note

264904

04 December 2019

This brings the total years of data within the group to 507 years. The modifications to the pooling group resulted in a reduced H2 value of 1.10. The group therefore remained possibly heterogeneous, but there were no obvious justifications to make further amendments.

The goodness of fit test was used which recommended the Generalised Logistic fit. This was applied to produce peak flow estimates for the QMED, 30 and 100-year return period events. These were then scaled by the catchment area to determine the GRR.

The modified pooling group was used to produce peak flow estimate for the QMED, 30 and 100 year return period events. These were then scaled by the catchment area to determine the GRR.

The derived Greenfield Runoff Rate is shown below:

- QMED (1:2 year) rainfall event – 25.7 l/s/ha
- 1:30 year rainfall event – 52.2 l/s/ha
- 1:100 year rainfall event – 67.9 l/s/ha

3.2 Afon Pyrddin Catchment

3.2.1 IH124 Method

The IH124 Method was applied within Microdrainage as described for the River Dulais catchment (see Section 3.1.1). The area of the Afon Pyrddin catchment within the planning application boundary was measured to be 33Ha. The point SAAR value of 1800mm was applied.

As the IH124 method was derived for sites over 50ha, it is common practice to undertake the calculation based on an area of 50ha and then linearly interpolate this down for the catchment area. This has been shown in Table 4 below. The results from Microdrainage are shown in Figure 2:

Table 4 – Derived GRR from the IH124 Analysis for the Afon Pyrddin			
Return Period	Total GRR for 50ha (l/s)	Scaled Catchment (33ha) GRR (l/s)	GRR per ha (l/s/ha)
1:1 Year	733.5	484.1	14.7
1:30 Year	1469.7	970.0	29.4
1:100 Year	1817.2	1199.4	36.3

Technical Note

264904

04 December 2019

Region	QBAR (l/s)	Q (100yrs) (l/s)	Q (1 yrs) (l/s)	Q (2 yrs) (l/s)	Q (5 yrs) (l/s)	Q (10 yrs) (l/s)	Q (20 yrs) (l/s)	Q (25 yrs) (l/s)	Q (30 yrs) (l/s)	Q (50 yrs) (l/s)	Q (100 yrs) (l/s)
Region 4	833.6	2142.3	691.9	747.0	1025.3	1242.0	1481.6	1565.4	1633.2	1835.5	2142.3
ICP SUDS	833.6	2967.5	725.2	744.9	1075.3	1379.6	1742.8	1885.5	2002.6	2369.0	2967.5
ADAS 345	833.6	2659.1	708.5	734.4	1067.0	1350.4	1669.8	1790.5	1889.1	2183.9	2659.1
FEH	833.6	2017.2	650.2	736.5	1025.3	1242.0	1458.1	1530.4	1589.0	1765.5	2017.2
ReFH2	833.6	1817.2	733.5	774.2	1008.6	1183.7	1359.5	1420.4	1469.7	1613.8	1817.2
Region 10	833.6	1733.8	725.2	776.4	991.9	1150.3	1310.5	1367.1	1413.3	1542.1	1733.8
Ireland National	833.6	1533.8	708.5	800.2	1000.3	1125.3	1251.7	1292.0	1325.0	1417.1	1533.8
Ireland East	833.6	1583.8	708.5	800.2	1008.6	1150.3	1283.0	1325.4	1358.4	1450.4	1583.8

Figure 2: IH124 Calculation undertaken within Microdrainage for the Afon Pyrddin Catchment

3.2.2 ReFH Version 2.2

The ReFH2 method was applied as described for the River Dulais catchment (see section 3.1.2). Catchment descriptors were exported from FEH Online and analysed for both winter and summer seasonality. The default recommended storm duration of 2 hours, 42 minutes with 6-minute intervals was used.

The 1, 30 and 100-year peak flows from the analysis were scaled by the subject catchment area to obtain GRR per hectare estimates. These are shown in Table 5 below.

Table 5 - Derived GRR using the ReFH2 Analysis for the Afon Pyrddin		
Return Period	Winter Seasonality (l/s/ha)	Summer Seasonality (l/s/ha)
1:1 Year	15.6	16.9
QMED	17.5	19.2
1:30 Year	36.6	40.5
1:100 Year	45.9	51.0

As with the River Dulais catchment, the summer seasonality has been applied due to the proposed use of the GRR to size culverts and ditches from predominantly undeveloped areas.

3.2.3 FEH Statistical Method

As per the River Dulais analysis, the latest HiFlows UK data set was used (version 8).

Technical Note

264904

04 December 2019

The data transfer method from donor catchments was used to estimate QMED. Applying the donor adjustment method within the WINFAP software provided a list of the ten geographically closest catchments, selecting the closest six of these by default. These are listed below in order of proximity, as well as whether they were included for data transfer:

- Station 58008: Dulais at Cilfrew - Included
- Station 58002: Neath @ Resolven – Discounted
- Station 59001: Tawe @ Ynystanglws – Discounted
- Station 58006: Mellte @ Pontneddfechan - Included
- Station 57017: Rhondda Fawr @ Tynewydd – Discounted
- Station 58012: Afan @ Marcroft Weir - Discounted

The catchment descriptors for these are shown in Table 4 below. Stations 58002 and 59001 were discounted owing to the significantly larger catchment area (more than 200 times larger than the target catchment). Station 58012 was discounted as it has a significantly higher BFIHOST value than the target site. Station 57017 was discounted owing to its much higher SAAR value than the target site.

The two remaining donor catchments are larger than the subject site but are similar from a hydrological perspective. For the selected donor site, a comparison was undertaken between QMED calculated using catchment descriptors and the measured values observed from annual maxima data. This comparison is shown in Table 6 below.

Table 6 – Comparison of calculated and observed QMED values for Afon Pyrddin donor sites			
Station	Observed QMED (m ³ /s)	Calculated QMED (m ³ /s)	Difference (QMED _{calc} /QMED _{obs})
River Dulais (From FEH Online)	N/A	2.388	N/A
58008 (Dulais @ Cilfrew)	56.3	46.9	1.20
58006 (Mellte @ Pentneddfechan)	87.4	75.3	1.16

The data transfer from the selected donor sites resulted in an uplift to the QMED value from 1.399m³/s to 1.551m³/s.

The default pooling group consisted of 14 stations with a total of 516 years of data. This pooling group had a standardised test value (H2) of 1.48, indicating that it was possibly heterogeneous and a review of the group was optional.

A review of the pooling group was subsequently undertaken and the following stations removed:

- Station 69047 – Roch at Littleborough: Low FARL value (0.890) relative to target catchment (1.000).

Technical Note

264904

04 December 2019

- Station 47022 – Tory Brook at Newnham Park: Low FARL value (0.942) relative to target catchment (1.000).
- Station 27073 – Brompton Beck at Snainton Ings: High FPEXT (0.2373) and BFIHOST (0.887) compared to the target site (0.0776 and 0.319 respectively).

The resulting pooling group consisted of 11 stations with a total of 416 years of data. Two stations were added to achieve the required 500 years:

- Station 46005 – East Dart @ Bellever
- Station 21017 – Ettrick Water @ Brockhoperig

This brings the total data within the group to 511 years. The modifications to the pooling group resulted in a reduced H2 value of 1.29. This means it remains possibly heterogeneous, however there are no obvious justifications to make further changes.

The goodness of fit test was used which recommended the Generalised Logistic fit. This was applied to produce peak flow estimates for the QMED, 30 and 100-year return period events. These were then scaled by the catchment area to determine the GRR.

The derived Greenfield Runoff Rate is shown below:

- QMED (1:2 year)– 25.3 l/s/ha
- 1:30 year– 52.0 l/s/ha
- 1:100 year– 68.6 l/s/ha

3.3 River Tawe Catchment

3.3.1 IH 124 Method

The IH124 Method was applied within Microdrainage as described for the River Dulais catchment.

The area of the River Tawe catchment contained within the planning application boundary was measured to be 217Ha. This area was applied within the software to determine the peak GRR for the total site. The peak GRR was been calculated for the 1 year, 30 year and 100-year return period events and was subsequently scaled by the area to give the GRR per hectare:

- 1:1 year rainfall event – 12.4l/s/ha
- 1:30 year rainfall event – 25.0l/s/ha
- 1:100 year rainfall event – 30.9l/s/ha

The results from the Microdrainage analysis are shown in Figure 3.

Technical Note

264904

04 December 2019

The screenshot shows the 'Rural Runoff Calculator' software. The 'IH 124' tab is active, displaying input parameters and a table of results. The input parameters are: Return Period (Years) 100, Area (ha) 217,000, SAAR (mm) 1800, Soil 0.500, Growth Curve (None), and Partly Urbanised Catchment (QBAR) Urban 0.000, Region 9. The 'Results' section shows QBAR rural (l/s) 3078.3 and QBAR urban (l/s) 3078.3. Below this is a table titled 'Return Period Flood' with columns for Region, QBAR (l/s), and peak flows Q (100 yrs), Q (1 yrs), Q (2 yrs), Q (5 yrs), Q (10 yrs), Q (20 yrs), Q (25 yrs), Q (30 yrs), Q (50 yrs), and Q (100 yrs) (l/s). The table lists results for various regions and catchments, including ICP SUDS, ADAS 345, FEH, ReFH2, Greenfield Volume, and Ireland National/Ireland East.

Region	QBAR (l/s)	Q (100 yrs) (l/s)	Q (1 yrs) (l/s)	Q (2 yrs) (l/s)	Q (5 yrs) (l/s)	Q (10 yrs) (l/s)	Q (20 yrs) (l/s)	Q (25 yrs) (l/s)	Q (30 yrs) (l/s)	Q (50 yrs) (l/s)	Q (100 yrs) (l/s)
Region 4	3078.3	7911.2	2555.0	2758.7	3786.3	4586.6	5471.3	5781.0	6031.4	6778.3	7911.2
Region 5	3078.3	10958.6	2678.1	2750.7	3971.0	5094.5	6436.0	6963.0	7395.5	8748.4	10958.6
Region 6/Region 7	3078.3	9819.7	2616.5	2712.0	3940.2	4986.8	6166.4	6612.1	6976.3	8065.1	9819.7
Region 8	3078.3	7449.4	2401.1	2720.0	3786.3	4586.6	5384.5	5651.7	5867.9	6519.8	7449.4
Region 9	3078.3	6710.6	2708.9	2859.1	3724.7	4371.1	5020.7	5245.4	5427.5	5959.5	6710.6
Region 10	3078.3	6402.8	2678.1	2867.1	3663.1	4248.0	4839.7	5048.4	5219.1	5694.8	6402.8
Ireland National	3078.3	5664.0	2616.5	2955.1	3693.9	4155.7	4622.3	4771.3	4893.3	5233.1	5664.0
Ireland East	3078.3	5848.7	2616.5	2955.1	3724.7	4248.0	4737.9	4894.4	5016.4	5356.2	5848.7

Figure 3: IH124 Calculation undertaken within Microdrainage for the River Tawe Catchment

3.3.2 ReFH2

Similarly, the ReFH2 method was applied as described for the River Dulais catchment (see section 3.1.2). The default recommended storm duration of 2 hours, 42 minutes with a 6-minute time step was used to calculate the GRR.

The 1, 30 and 100-year peak flows from the analysis were scaled by the subject catchment area to obtain GRR per hectare estimates. These are shown in Table 7 below.

Table 7 - Derived GRR using the ReFH2 Analysis for the River Tawe		
Return Period	Winter Seasonality (l/s/ha)	Summer Seasonality (l/s/ha)
1:1 Year	16.3	17.8
QMED	18.5	20.2
1:30 Year	38.0	42.2
1:100 Year	47.6	53.0

As with the other catchments, the larger summer seasonality values will be adopted.

3.3.3 FEH Statistical Assessment – Pooled Analysis

Reviewing the FEH Statistical Method for the Afon Pyrddin and River Dulais catchments highlighted that the pooling groups and donor stations were very similar for the two catchments, resulting in very similar discharge rates.

Technical Note

264904

04 December 2019

The catchment descriptors between the River Tawe and River Dulais/Afon Pyrrdin are very similar. As such, it is presumed that an FEH pooled analysis would result in very similar results for the River Tawe Catchment. As such, the values derived from the River Dulais catchment have been adopted for the scheme.

4 Conclusion

4.1 Results and Comparison

A hydrological study of the River Tawe, River Dulais and Afon Pyrrdin catchments have been undertaken using the IH124, ReFH2 and FEH Statistical methods. The statistical method was not undertaken for the River Tawe catchment due to the similarities between the catchment descriptors, and as such the outputs from the River Dulais catchment have been adopted for the River Tawe. A summary of the results has been included in Table 8:

Table 8 – Summary of Hydrological Analysis for the GCRE Project				
Catchment	Return Period (yr)	IH124 Peak Flows (l/s/ha)	ReFH2 Peak Flows (l/s/ha)	WINFAP Peak Flows (l/s/ha)
River Tawe	1	12.4	17.8	N/A
River Dulais		12.8	19.8	N/A
Afon Pyrrdin		14.7	16.9	N/A
River Tawe	QMED (2 year)	N/A	20.2	25.7
River Dulais		N/A	22.4	25.7
Afon Pyrrdin		N/A	19.2	25.3
River Tawe	30	25.0	42.2	52.2
River Dulais		25.7	46.3	52.2
Afon Pyrrdin		29.4	40.5	52.0
River Tawe	100	30.9	53.0	67.9
River Dulais		31.8	57.9	67.9
Afon Pyrrdin		36.3	51.0	68.6

The results of the IH124 method are shown to correlate well between the three catchments. However, this is due to the only variable within the equation within the three catchments being the catchment area. The IH124 QBAR equation contains a factor of $(0.01 \times \text{AREA})^{0.89}$. Therefore, a larger area such as the River Tawe catchment will have a reduced discharge rate when compared to a smaller area such as the Afon Pyrrdin catchment.

The GRR estimate provided using the FEH Statistical and ReFH2 methods are significantly higher than the estimate provided by the IH 124 method. IH124 is a relatively coarse method based on regional growth curves, which utilises no site-specific information. In addition to this, NRW Guidance Note GN008 provides a preference for the FEH Statistical and ReFH2 methods. Given this, the results of the IH124 method has been discounted.

Technical Note

264904

04 December 2019

The ReFH2 discharge rates show a reasonable correlation between the three catchments. The results from the WINFAP4 method show a better correlation, with less than 1 l/s/ha difference between the two catchments. This is due to the similarity between the pooling groups, initial QMED estimate from catchment descriptors and the suitable donor catchments based on Geographical distance. Therefore, the closer correlation of the FEH method does not in this instance indicate that it is more accurate. There is a large difference between the results generated by the two methods, particularly when comparing the QMED values.

As mentioned previously, there is a station downstream in the River Dulais. The QMED value measured from this station is 56.4m³/s, which equates to 13.1 l/s/ha. As this is downstream and serves a larger area, a larger GRR would be expected when analysing a smaller area owing to the longer time of concentration and catchment losses through infiltration and evapotranspiration. However, the values estimated using the WINFAP method are almost double the observed QMED, which is significantly higher than would be expected.

The WINFAP method uses a catchment descriptor equation to estimate QMED which was derived from regression analysis and based on observed information from gauging stations. However, most of the gauged catchments used to compare the equations are between 50km² and 500km², whilst the target catchments are 1km² or less. A smaller area used within the derived FEH QMED equation results in higher peak flow rates, which explains why using this method would result in a significantly higher QMED value. Owing to the small catchment sizes, it is likely that this equation is overestimating QMED.

ReFH2.2 is widely accepted for use on plot-scale sites, as it uses site specific catchment descriptors with updated FEH13 DDF curves. ReFH2.2 is also used on the plot scale, which is more appropriate for the catchment sizes being reviewed. Given the smaller catchment areas, since the ReFH2 provides a reasonably consistent GRR for the catchments that is slightly higher than the observed downstream QMED in the River Dulais, this method has been chosen as the preferred method.

Therefore, it is recommended that the GRR applied to the Nant Helen Complementary Earthworks scheme should be as shown in Table 9:

Table 9 – GRR to be Applied for the Nant Helen Complementary Earthworks Scheme		
Catchment	Return Period (yr)	ReFH2 Peak Flows (l/s/ha)
River Tawe	1	17.8
River Dulais		19.8
Afon Pyrrdin		16.9
River Tawe	30	42.2
River Dulais		46.3
Afon Pyrrdin		40.5
River Tawe	100	53.0
River Dulais		57.9
Afon Pyrrdin		51.0

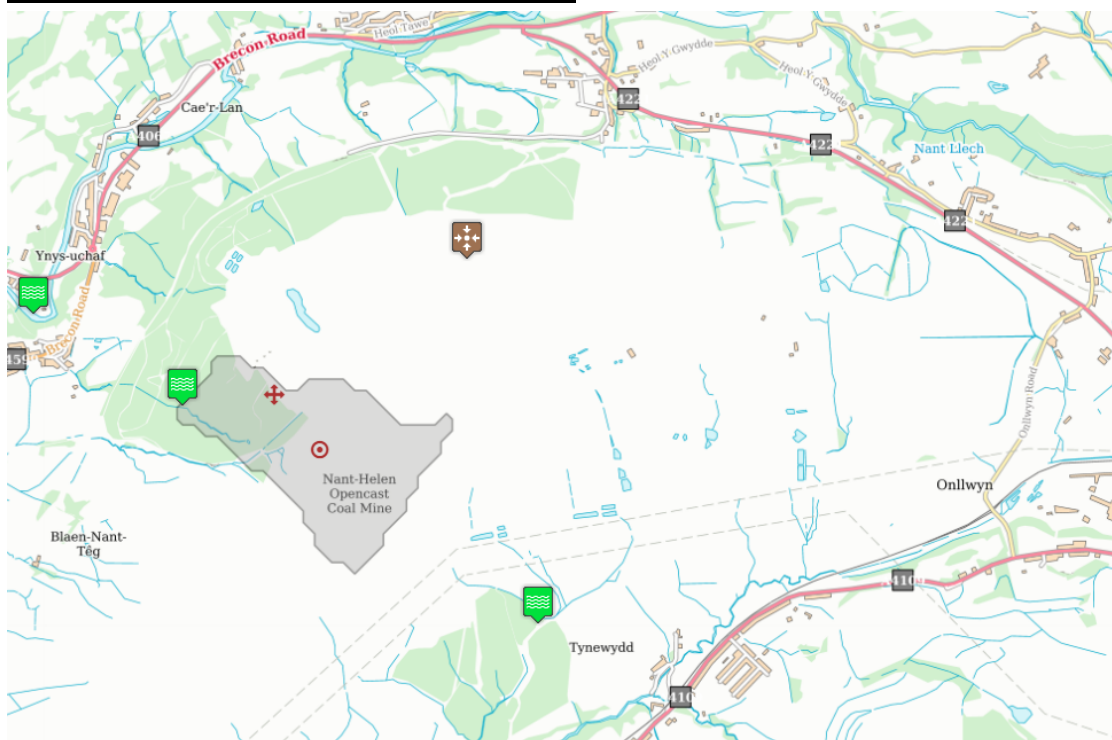
Technical Note

264904

04 December 2019

Appendix A – FEH Catchment Downloads

River Tawe Catchment from FEH Online

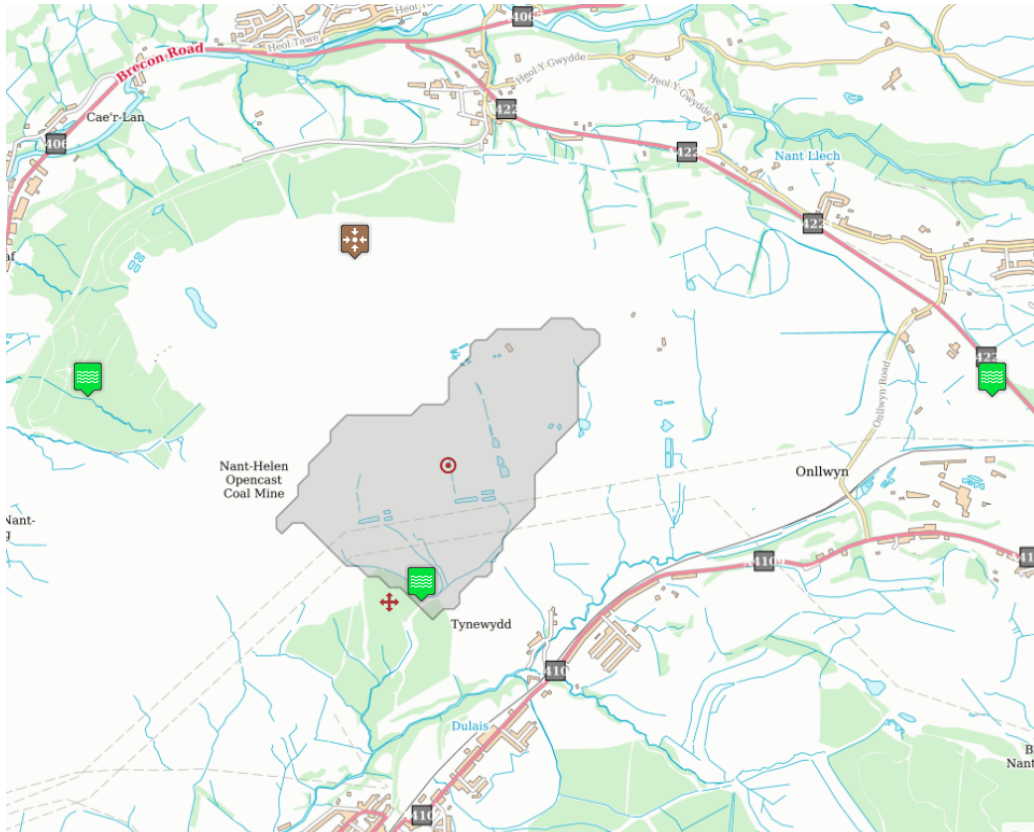


Technical Note

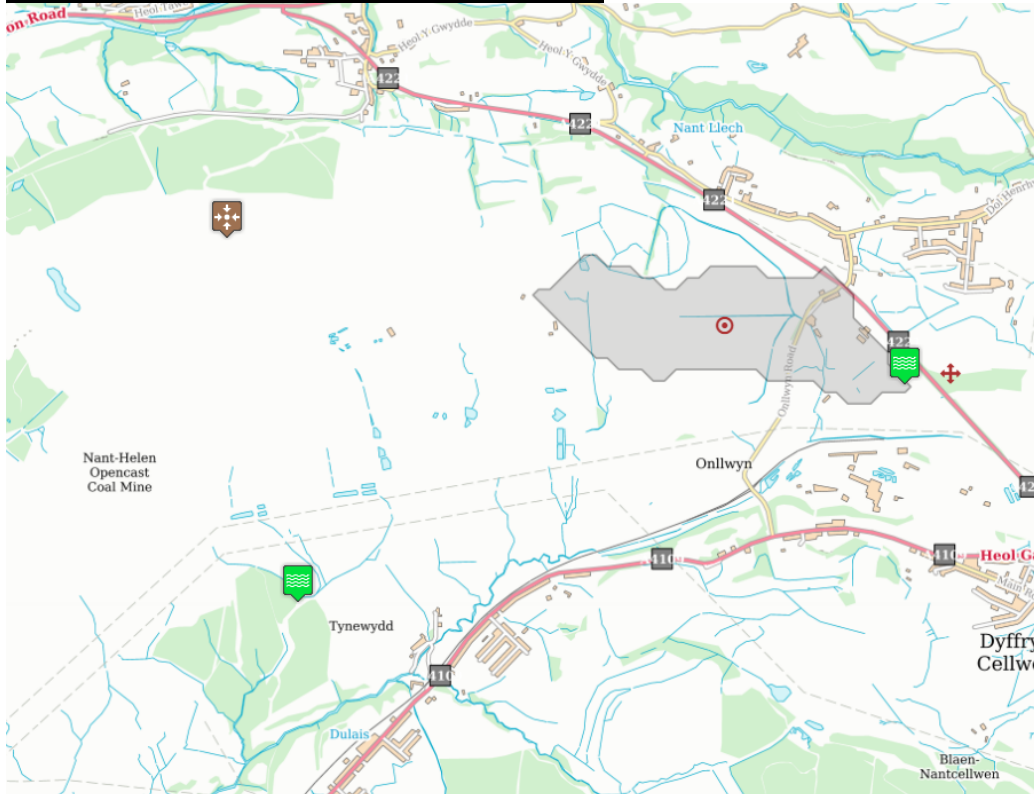
264904

04 December 2019

River Dulais Catchment from FEH Online



Afon Pyrddin Catchment from FEH Online

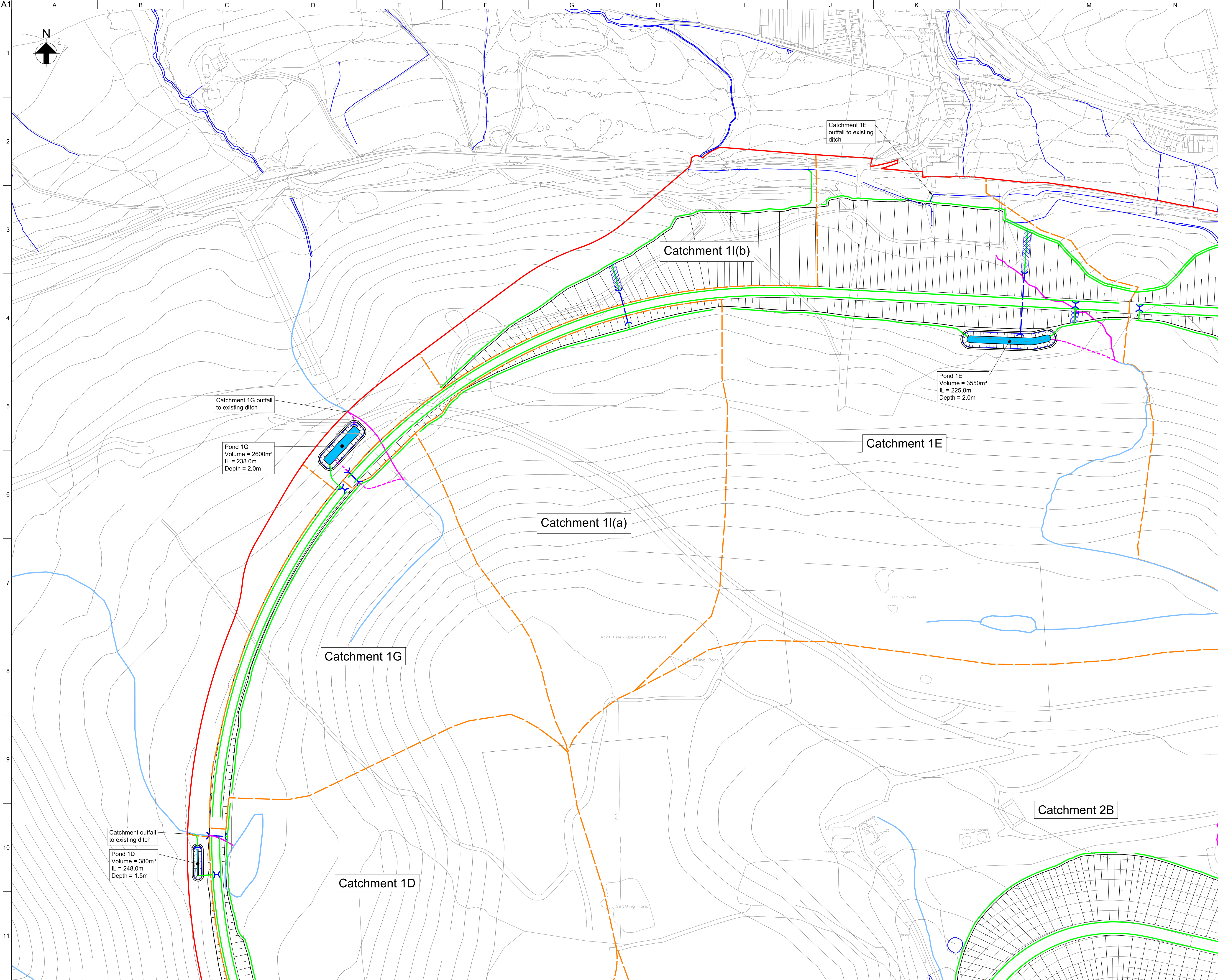


J:\264000\264904-004 INTERNAL PROJECT DATA\4-40 CALCULATIONS\CIVILS\DRAINAGE\HYDROLOGY\GCRE - HYDROLOGY REPORT.DOCX

Appendix E

Proposed Drainage Drawings

E1



Legend

Planning Application Boundary

Existing Watercourse

Restoration Watercourse

Restoration Watercourse to be Removed

Restoration Watercourse to be Diverted

Proposed Catchment

Proposed Cut Off Ditch

Proposed Pond

Proposed Culvert

Proposed Headwall

Proposed Cascade

- Notes
1. All dimensions are in metres unless noted otherwise. All elevations are in metres Above Ordnance Datum (AOD). Do not scale.

2. This drawing is for planning purposes only and is to be read in conjunction with the Drainage Strategy report.

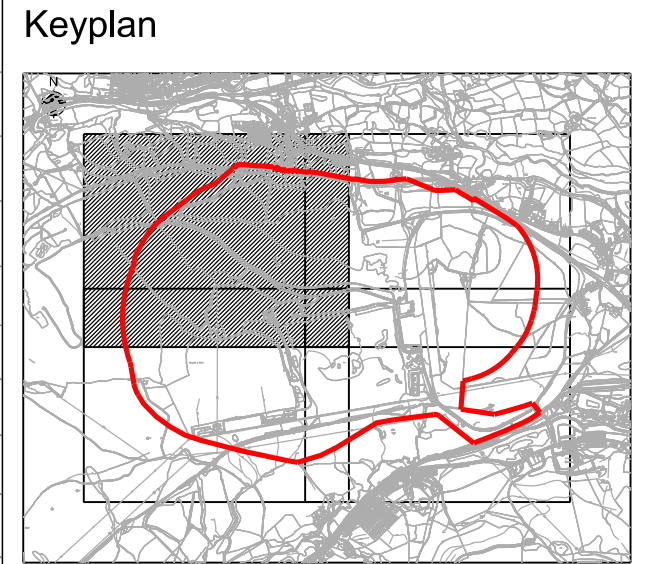
3. For cut-off ditch typical details, refer to drawing CG1055.

4. The diameter of culverts and sizing of headwall structures is to be determined during subsequent design stages.

5. Existing watercourses that will be removed as part of the site restoration works have not been shown for clarity.

6. The restoration watercourses have been shown based on the current restoration proposals for the site. Should the track earthworks be undertaken at the same time as the restoration earthworks, the restoration watercourses shown as to be removed will not be installed.

7. The attenuation ponds shown are indicative based on the sizing determined from hydraulic calculations as discussed in the Drainage Strategy report. The depth and profile may change in subsequent design stages to accommodate topography and improve aesthetics.



P01	06/12/19	CB	RV	JS
Issued for Planning				
Issue	Date	By	Chkd	Appd

ARUP

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www.arup.com

Client

Celtic Energy

Job Title

Nant Helen Complementary
Restoration Earthworks

Drawing Title

Proposed Drainage
Sheet 1 of 4

Scale at A1

1:2500

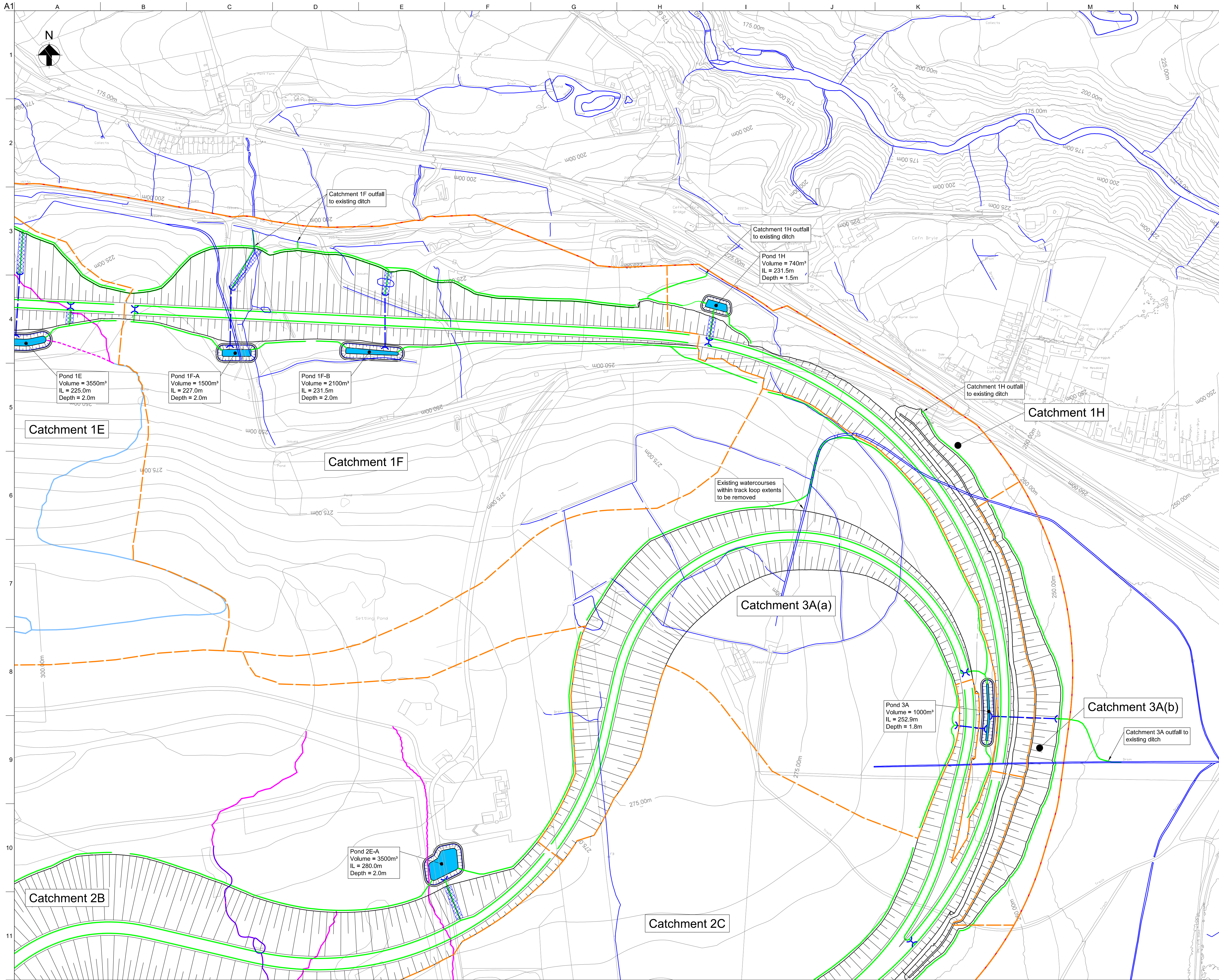
Discipline

Infrastructure

Drawing Status

Planning

Job No	Drawing No	Issue
264904	CG1050	P01



Legend

Planning Application Boundary

Existing Watercourse

Restoration Watercourse

Restoration Watercourse to be Removed

Restoration Watercourse to be Diverted

Proposed Catchment

Proposed Cut Off Ditch

Proposed Pond

Proposed Culvert

Proposed Headwall

Proposed Cascade

- Notes
1. All dimensions are in metres unless noted otherwise. All elevations are in metres Above Ordnance Datum (AOD). Do not scale.

2. This drawing is for planning purposes only and is to be read in conjunction with the Drainage Strategy report.

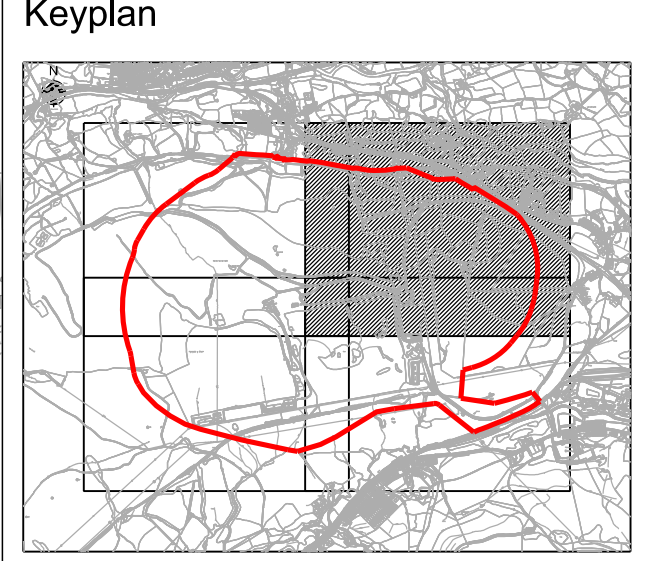
3. For cut-off ditch typical details, refer to drawing CG1055.

4. The diameter of culverts and sizing of headwall structures is to be determined during subsequent design stages.

5. Existing watercourses that will be removed as part of the site restoration works have not been shown for clarity.

6. The restoration watercourses have been shown based on the current restoration proposals for the site. Should the track earthworks be undertaken at the same time as the restoration earthworks, the restoration watercourses shown as to be removed will not be installed.

7. The attenuation ponds shown are indicative based on the sizing determined from hydraulic calculations as discussed in the Drainage Strategy report. The depth and profile may change in subsequent design stages to accommodate topography and improve aesthetics.



P01

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CB

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JS

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Drawing Title

Proposed Drainage
Sheet 2 of 4

Scale at A1

1:2500

Discipline

Infrastructure

Drawing Status

Planning

Job No

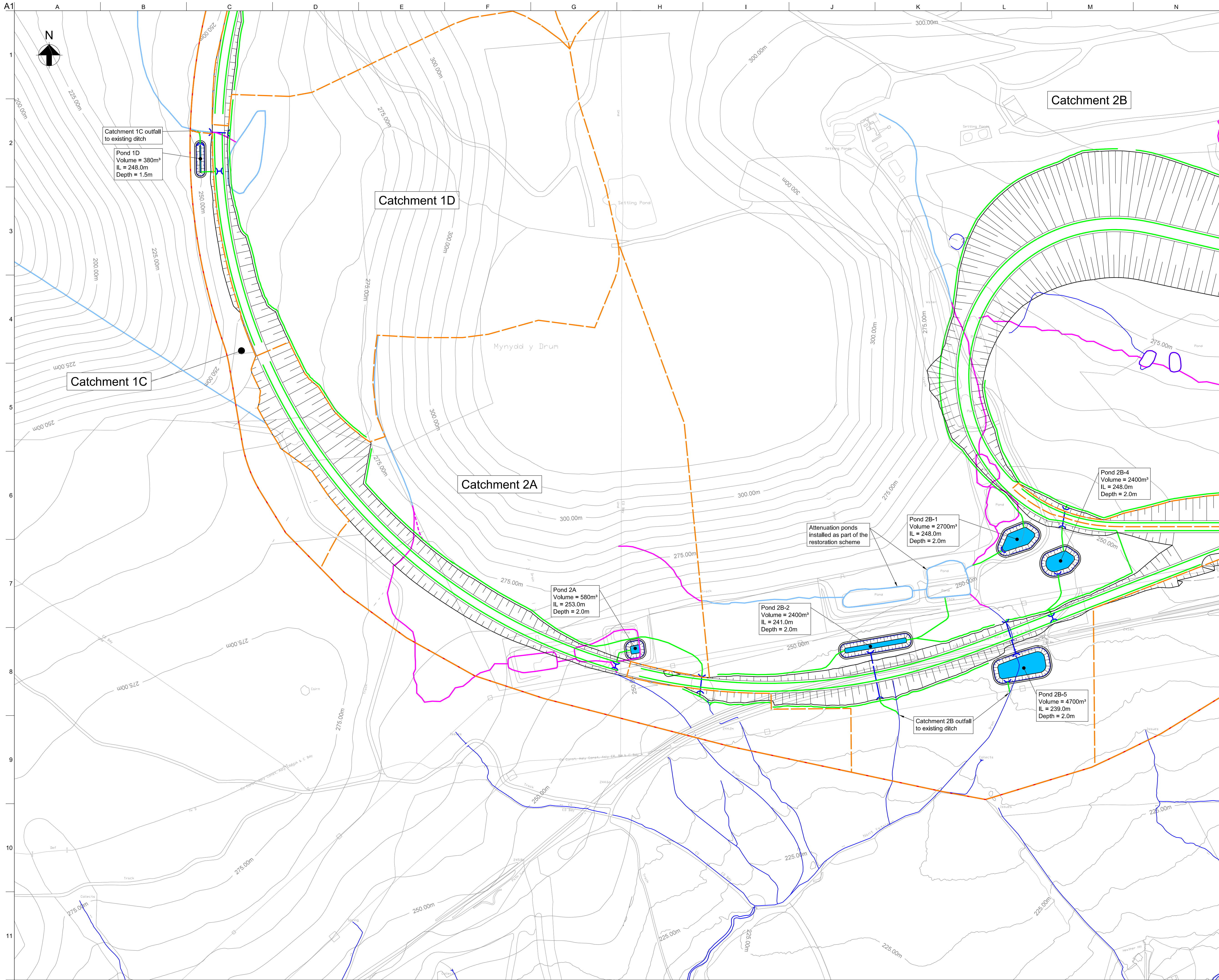
Drawing No

Issue

264904

CG1051

P01



Legend

Planning Application Boundary

Existing Watercourse

Restoration Watercourse

Restoration Watercourse to be Removed

Restoration Watercourse to be Diverted

Proposed Catchment

Proposed Cut Off Ditch

Proposed Pond

Proposed Culvert

Proposed Headwall

Proposed Cascade

- Notes
1. All dimensions are in metres unless noted otherwise. All elevations are in metres Above Ordnance Datum (AOD). Do not scale.

2. This drawing is for planning purposes only and is to be read in conjunction with the Drainage Strategy report.

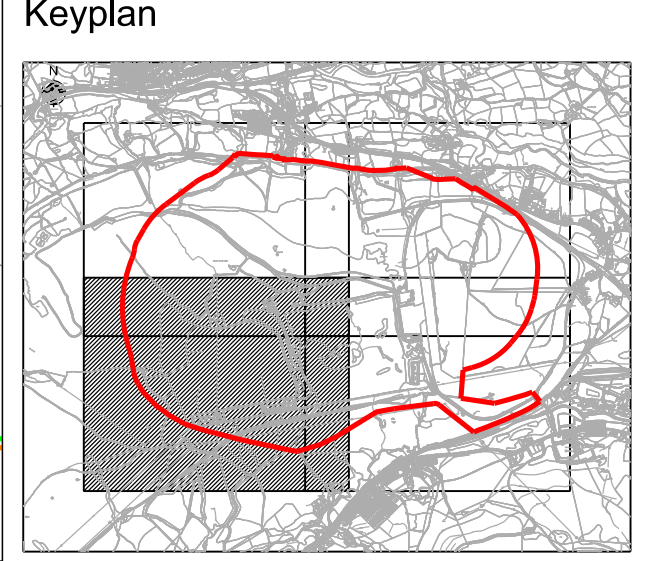
3. For cut-off ditch typical details, refer to drawing CG1055.

4. The diameter of culverts and sizing of headwall structures is to be determined during subsequent design stages.

5. Existing watercourses that will be removed as part of the site restoration works have not been shown for clarity.

7. The restoration watercourses have been shown based on the current restoration proposals for the site. Should the track earthworks be undertaken at the same time as the restoration earthworks, the restoration watercourses shown as to be removed will not be installed.

8. The attenuation ponds shown are indicative based on the sizing determined from hydraulic calculations as discussed in the Drainage Strategy report. The depth and profile may change in subsequent design stages to accommodate topography and improve aesthetics.



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Client

Celtic Energy

Job Title

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Restoration Earthworks

Drawing Title

Proposed Drainage
Sheet 3 of 4

Scale at A1

1:2500

Discipline

Infrastructure

Drawing Status

Planning

Job No

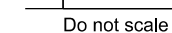
264904

Drawing No

CG1052

Issue

P01



removed started otherwise. am	
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Legend

- Planning Application Boundary
- Existing Watercourse
- Restoration Watercourse
- Restoration Watercourse to be Removed
- Restoration Watercourse to be Diverted
- Proposed Catchment
- Proposed Cut Off Ditch
-  Proposed Pond
-  Proposed Culvert
-  Proposed Headwall
-  Proposed Cascade

Notes

1. All dimensions are in metres unless noted otherwise. All elevations are in metres Above Ordnance Datum (AOD). Do not scale.
2. This drawing is for planning purposes only and is to be read in conjunction with the Drainage Strategy report.
3. For cut-out ditch typical details, refer to drawing CG1055.
4. The diameter of culverts and sizing of headwall structures is to be determined during subsequent design stages.
5. Existing watercourses that will be removed as part of the site restoration works have not been shown for clarity.
6. The restoration watercourses have been shown based on the current restoration proposals for the site. Should the track earthworks be undertaken at the same time as the restoration earthworks, the restoration watercourses shown as to be removed will not be installed.
7. Sedimentation ponds shown are indicative based on the sizing determined from hydraulic calculations as discussed in the Drainage Strategy report. The depth and profile may change in subsequent design stages to accommodate topography and improve aesthetics.

Keyplan



P01	06/12/19	CB	RV	JS
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Job Title

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Drawing Title

Proposed Drainage
Sheet 4 of 4

Scale at A1

1:2500

Discipline

Infrastructure

Drawing Status

Planning

Job No

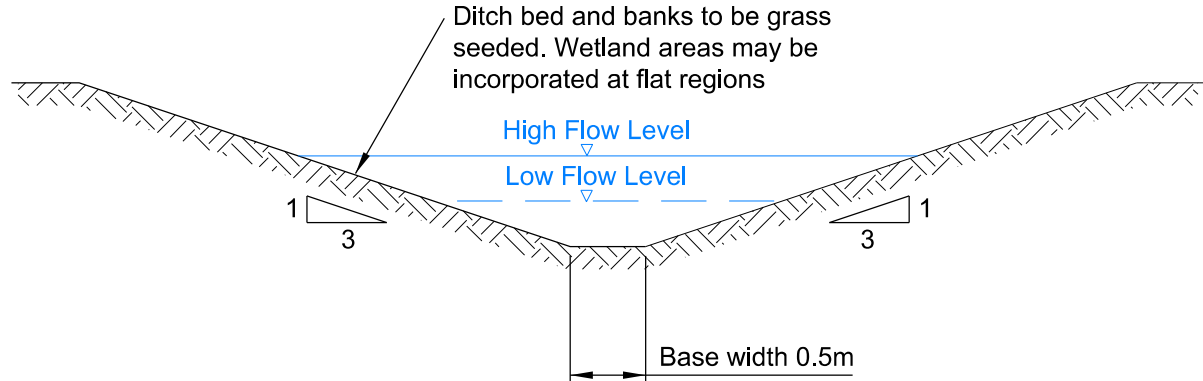
264904

CG1053

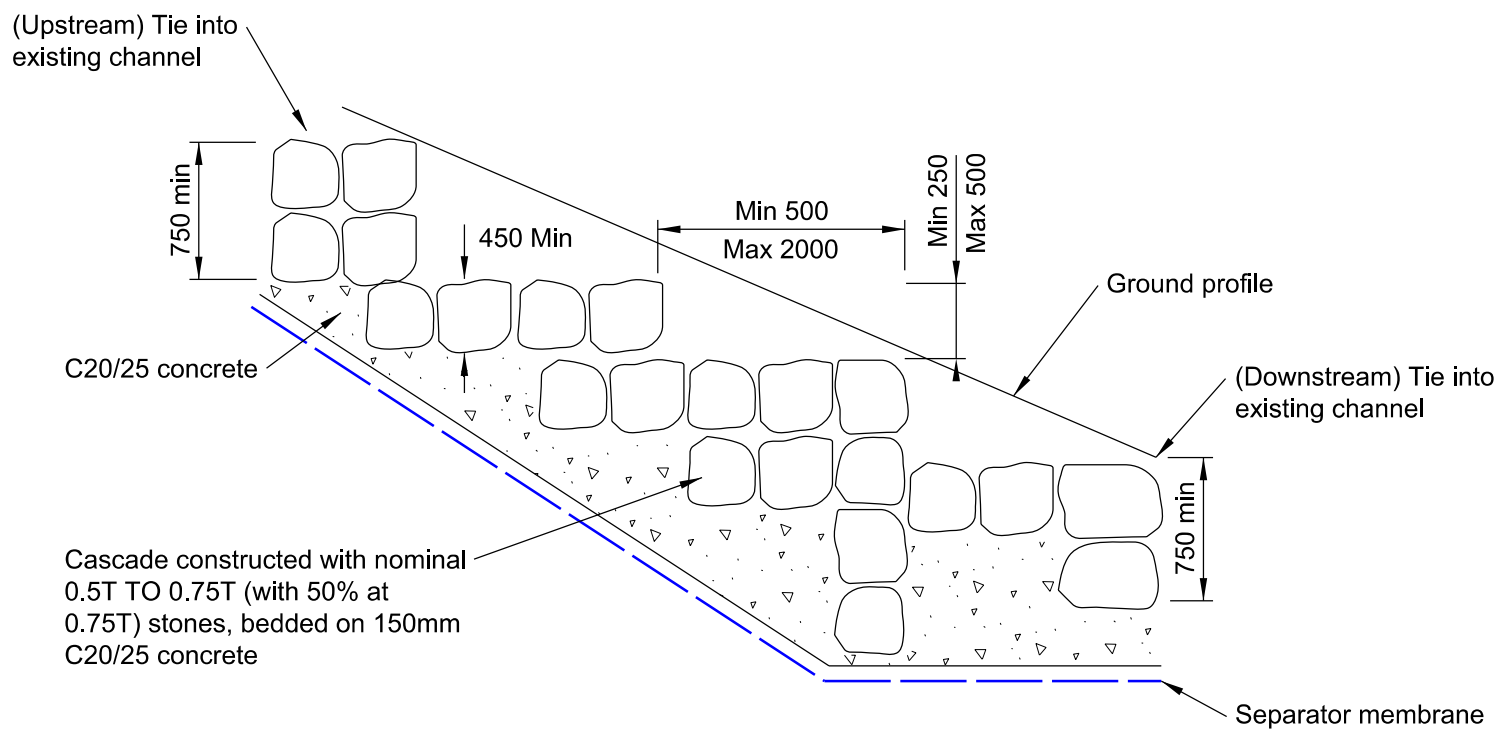
P01

A1
1
2
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11

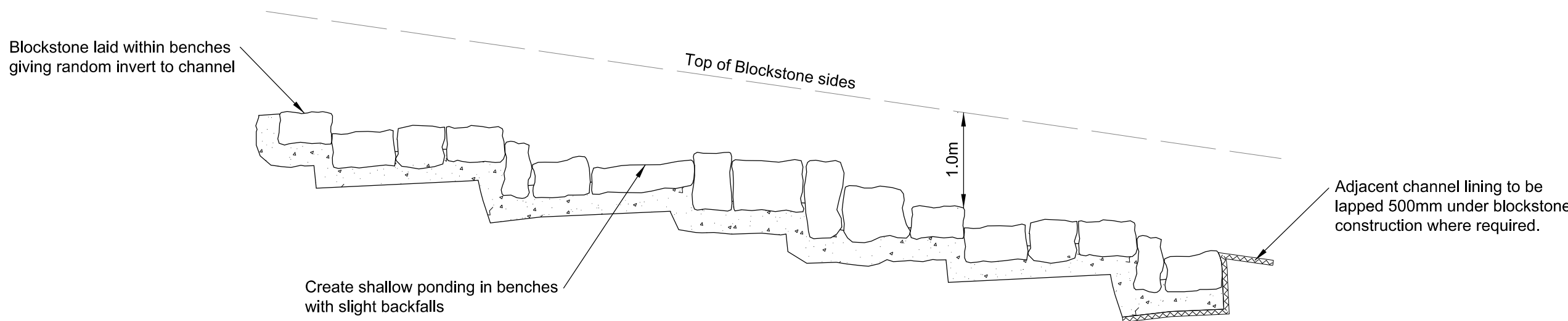
A B C D E F G H I J K L M N



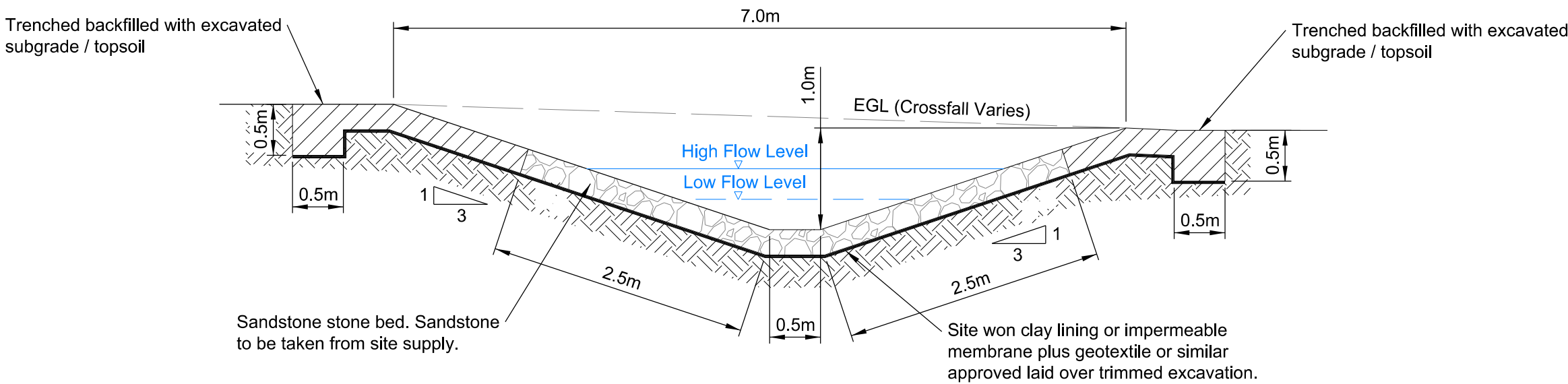
Typical Section - Grass Lined Channel (See Note 4)
N.T.S



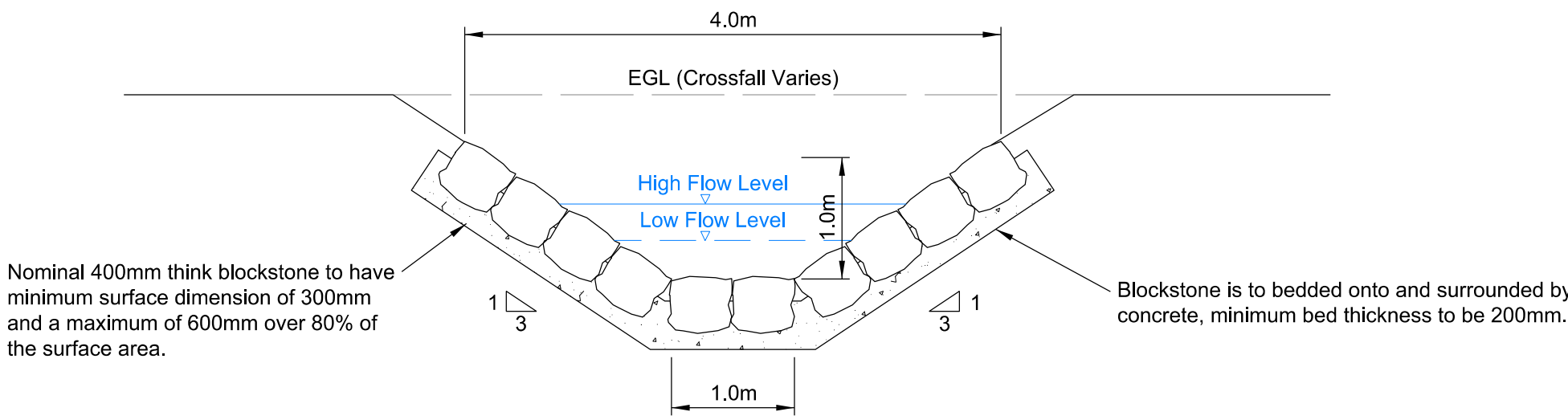
Typical Cascade Detail
N.T.S



Typical Longitudinal Section - Rock Reinforced Ditch
N.T.S



Typical Section - Stone Bedded Ditch (See Note 4)
N.T.S



Detail C - Rock Reinforced Ditch (See Note 4)
N.T.S

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Client
Celtic Energy

Job Title
Nant Helen Complementary
Restoration Earthworks

Drawing Title
Typical Channel and Pond Details

Scale at A1
As Shown

Discipline
Civils

Drawing Status

Job No 264904	Drawing No CG1055	Issue P01
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Appendix F

Microdrainage Attenuation Calculations

F1 Catchment 1D

Ove Arup & Partners International Ltd					Page 1
The Arup Campus Blyth Gate Solihull B90 8AE					
Date 29/11/2019 11:55		Designed by			
File Catchment 1D Track		Checked by			
XP Solutions		Source Control 2018.1.1			
<u>Summary of Results for 100 year Return Period (+40%)</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	248.565	0.565	21.0	105.2	O K
30 min Summer	248.762	0.762	24.8	152.1	O K
60 min Summer	248.941	0.941	27.7	199.9	O K
120 min Summer	249.052	1.052	29.4	232.3	O K
180 min Summer	249.084	1.084	29.9	241.9	O K
240 min Summer	249.092	1.092	30.0	244.6	O K
360 min Summer	249.078	1.078	29.8	240.2	O K
480 min Summer	249.046	1.046	29.4	230.7	O K
600 min Summer	249.009	1.009	28.8	219.6	O K
720 min Summer	248.970	0.970	28.2	208.3	O K
960 min Summer	248.893	0.893	27.0	186.6	O K
1440 min Summer	248.760	0.760	24.7	151.5	O K
2160 min Summer	248.611	0.611	21.9	115.5	O K
2880 min Summer	248.506	0.506	19.7	92.0	O K
4320 min Summer	248.374	0.374	16.6	64.8	O K
5760 min Summer	248.301	0.301	14.5	50.7	O K
7200 min Summer	248.253	0.253	13.0	41.8	O K
8640 min Summer	248.218	0.218	11.8	35.6	O K
10080 min Summer	248.193	0.193	10.8	31.1	O K
15 min Winter	248.625	0.625	22.2	118.7	O K
30 min Winter	248.838	0.838	26.1	171.9	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer	113.158	0.0	126.8	29	
30 min Summer	83.568	0.0	187.5	40	
60 min Summer	59.033	0.0	265.5	62	
120 min Summer	39.536	0.0	355.6	98	
180 min Summer	30.634	0.0	413.4	132	
240 min Summer	25.518	0.0	459.1	168	
360 min Summer	19.633	0.0	529.9	236	
480 min Summer	16.249	0.0	584.7	304	
600 min Summer	14.005	0.0	630.0	368	
720 min Summer	12.389	0.0	668.8	434	
960 min Summer	10.189	0.0	733.3	560	
1440 min Summer	7.728	0.0	834.2	806	
2160 min Summer	5.877	0.0	951.9	1168	
2880 min Summer	4.850	0.0	1047.4	1528	
4320 min Summer	3.726	0.0	1206.9	2248	
5760 min Summer	3.119	0.0	1347.2	2952	
7200 min Summer	2.722	0.0	1469.7	3680	
8640 min Summer	2.434	0.0	1577.1	4408	
10080 min Summer	2.214	0.0	1673.4	5136	
15 min Winter	113.158	0.0	142.1	30	
30 min Winter	83.568	0.0	210.1	41	
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The Arup Campus Blyth Gate Solihull B90 8AE					
Date 29/11/2019 11:55 File Catchment 1D Track		Designed by Checked by			
XP Solutions		Source Control 2018.1.1			
<u>Summary of Results for 100 year Return Period (+40%)</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	249.035	1.035	29.2	227.2	O K
120 min Winter	249.152	1.152	30.9	263.2	O K
180 min Winter	249.178	1.178	31.3	271.5	O K
240 min Winter	249.177	1.177	31.2	271.2	O K
360 min Winter	249.138	1.138	30.7	258.7	O K
480 min Winter	249.080	1.080	29.9	240.8	O K
600 min Winter	249.018	1.018	28.9	222.1	O K
720 min Winter	248.956	0.956	28.0	204.2	O K
960 min Winter	248.840	0.840	26.1	172.5	O K
1440 min Winter	248.656	0.656	22.8	126.1	O K
2160 min Winter	248.476	0.476	19.1	85.7	O K
2880 min Winter	248.367	0.367	16.4	63.4	O K
4320 min Winter	248.252	0.252	13.0	41.7	O K
5760 min Winter	248.197	0.197	11.0	31.9	O K
7200 min Winter	248.168	0.168	9.7	26.8	O K
8640 min Winter	248.155	0.155	8.6	24.6	O K
10080 min Winter	248.145	0.145	7.9	23.0	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
60 min Winter	59.033	0.0	297.4	64	
120 min Winter	39.536	0.0	398.3	104	
180 min Winter	30.634	0.0	463.0	142	
240 min Winter	25.518	0.0	514.2	180	
360 min Winter	19.633	0.0	593.5	254	
480 min Winter	16.249	0.0	654.9	324	
600 min Winter	14.005	0.0	705.6	392	
720 min Winter	12.389	0.0	749.0	458	
960 min Winter	10.189	0.0	821.3	586	
1440 min Winter	7.728	0.0	934.4	832	
2160 min Winter	5.877	0.0	1066.2	1188	
2880 min Winter	4.850	0.0	1173.1	1536	
4320 min Winter	3.726	0.0	1351.8	2248	
5760 min Winter	3.119	0.0	1508.8	2944	
7200 min Winter	2.722	0.0	1646.0	3648	
8640 min Winter	2.434	0.0	1766.4	4400	
10080 min Winter	2.214	0.0	1874.3	5096	
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The Arup Campus Blyth Gate Solihull B90 8AE		
Date 29/11/2019 11:55	Designed by	
File Catchment 1D Track	Checked by	
XP Solutions		Source Control 2018.1.1

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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.600

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 0.120	8	12 0.120	16	20 0.120
4	8 0.120	12	16 0.120		

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The Arup Campus Blyth Gate Solihull B90 8AE		
Date 29/11/2019 11:55 File Catchment 1D Track	Designed by Checked by	
XP Solutions Source Control 2018.1.1		

Model Details

Storage is Online Cover Level (m) 249.500

Tank or Pond Structure

Invert Level (m) 248.000

Depth (m)	Area (m ²)	Depth (m)	Area (m ²)
0.000	150.0	1.500	380.0

Orifice Outflow Control

Diameter (m) 0.119 Discharge Coefficient 0.600 Invert Level (m) 248.000

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F2 Catchment 1E

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The Arup Campus Blyth Gate Solihull B90 8AE					
Date 29/11/2019 12:03		Designed by			
File Catchment 1E.SRCX		Checked by			
XP Solutions		Source Control 2018.1.1			
<u>Summary of Results for 100 year Return Period</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	226.190	1.190	1318.4	1808.2	O K
30 min Summer	226.523	1.523	1610.4	2463.7	O K
60 min Summer	226.761	1.761	1777.4	2977.7	Flood Risk
120 min Summer	226.813	1.813	1811.5	3093.9	Flood Risk
180 min Summer	226.730	1.730	1756.3	2907.6	Flood Risk
240 min Summer	226.628	1.628	1686.3	2687.1	O K
360 min Summer	226.441	1.441	1548.8	2296.2	O K
480 min Summer	226.293	1.293	1431.4	2004.8	O K
600 min Summer	226.192	1.192	1321.5	1811.9	O K
720 min Summer	226.117	1.117	1205.6	1673.8	O K
960 min Summer	226.003	1.003	1030.4	1471.4	O K
1440 min Summer	225.860	0.860	811.2	1226.6	O K
2160 min Summer	225.738	0.738	631.5	1028.2	O K
2880 min Summer	225.658	0.658	523.7	902.5	O K
4320 min Summer	225.550	0.550	407.1	737.7	O K
5760 min Summer	225.493	0.493	341.9	653.5	O K
7200 min Summer	225.462	0.462	298.5	609.3	O K
8640 min Summer	225.440	0.440	267.2	577.7	O K
10080 min Summer	225.423	0.423	243.1	553.5	O K
15 min Winter	226.291	1.291	1429.4	1999.5	O K
30 min Winter	226.657	1.657	1706.6	2749.6	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer	80.827	0.0	2843.5	27	
30 min Summer	59.691	0.0	4202.5	35	
60 min Summer	42.167	0.0	5945.1	52	
120 min Summer	28.240	0.0	7963.3	84	
180 min Summer	21.881	0.0	9255.2	114	
240 min Summer	18.227	0.0	10279.5	146	
360 min Summer	14.024	0.0	11863.5	206	
480 min Summer	11.606	0.0	13090.9	264	
600 min Summer	10.004	0.0	14104.0	324	
720 min Summer	8.849	0.0	14972.0	384	
960 min Summer	7.278	0.0	16416.2	504	
1440 min Summer	5.520	0.0	18675.8	744	
2160 min Summer	4.198	0.0	21306.4	1108	
2880 min Summer	3.464	0.0	23444.0	1472	
4320 min Summer	2.662	0.0	27017.5	2204	
5760 min Summer	2.228	0.0	30152.5	2936	
7200 min Summer	1.944	0.0	32893.6	3616	
8640 min Summer	1.739	0.0	35300.4	4344	
10080 min Summer	1.581	0.0	37457.7	5064	
15 min Winter	80.827	0.0	3185.4	27	
30 min Winter	59.691	0.0	4707.4	36	
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XP Solutions		Source Control 2018.1.1																																																																																																																																																																																																									
<u>Summary of Results for 100 year Return Period</u> <table><tr><th>Storm Event</th><th>Max Level (m)</th><th>Max Depth (m)</th><th>Max Control (l/s)</th><th>Max Volume (m³)</th><th>Status</th></tr><tr><td>60 min Winter</td><td>226.885</td><td>1.885</td><td>1858.3</td><td>3261.0</td><td>Flood Risk</td></tr><tr><td>120 min Winter</td><td>226.849</td><td>1.849</td><td>1835.2</td><td>3177.8</td><td>Flood Risk</td></tr><tr><td>180 min Winter</td><td>226.679</td><td>1.679</td><td>1721.5</td><td>2796.1</td><td>O K</td></tr><tr><td>240 min Winter</td><td>226.515</td><td>1.515</td><td>1604.5</td><td>2447.6</td><td>O K</td></tr><tr><td>360 min Winter</td><td>226.261</td><td>1.261</td><td>1404.7</td><td>1943.0</td><td>O K</td></tr><tr><td>480 min Winter</td><td>226.123</td><td>1.123</td><td>1215.7</td><td>1686.0</td><td>O K</td></tr><tr><td>600 min Winter</td><td>226.027</td><td>1.027</td><td>1066.6</td><td>1512.7</td><td>O K</td></tr><tr><td>720 min Winter</td><td>225.953</td><td>0.953</td><td>953.3</td><td>1384.1</td><td>O K</td></tr><tr><td>960 min Winter</td><td>225.848</td><td>0.848</td><td>792.9</td><td>1206.7</td><td>O K</td></tr><tr><td>1440 min Winter</td><td>225.722</td><td>0.722</td><td>607.3</td><td>1001.9</td><td>O K</td></tr><tr><td>2160 min Winter</td><td>225.602</td><td>0.602</td><td>463.0</td><td>815.8</td><td>O K</td></tr><tr><td>2880 min Winter</td><td>225.528</td><td>0.528</td><td>383.5</td><td>704.7</td><td>O K</td></tr><tr><td>4320 min Winter</td><td>225.460</td><td>0.460</td><td>295.7</td><td>606.3</td><td>O K</td></tr><tr><td>5760 min Winter</td><td>225.426</td><td>0.426</td><td>247.3</td><td>557.8</td><td>O K</td></tr><tr><td>7200 min Winter</td><td>225.404</td><td>0.404</td><td>216.0</td><td>526.5</td><td>O K</td></tr><tr><td>8640 min Winter</td><td>225.382</td><td>0.382</td><td>193.0</td><td>495.0</td><td>O K</td></tr><tr><td>10080 min Winter</td><td>225.361</td><td>0.361</td><td>175.5</td><td>465.8</td><td>O K</td></tr></table> <table><tr><th>Storm Event</th><th>Rain (mm/hr)</th><th>Flooded Volume (m³)</th><th>Discharge Volume (m³)</th><th>Time-Peak (mins)</th></tr><tr><td>60 min Winter</td><td>42.167</td><td>0.0</td><td>6658.5</td><td>54</td></tr><tr><td>120 min Winter</td><td>28.240</td><td>0.0</td><td>8918.9</td><td>86</td></tr><tr><td>180 min Winter</td><td>21.881</td><td>0.0</td><td>10365.8</td><td>118</td></tr><tr><td>240 min Winter</td><td>18.227</td><td>0.0</td><td>11513.1</td><td>150</td></tr><tr><td>360 min Winter</td><td>14.024</td><td>0.0</td><td>13287.2</td><td>208</td></tr><tr><td>480 min Winter</td><td>11.606</td><td>0.0</td><td>14661.9</td><td>266</td></tr><tr><td>600 min Winter</td><td>10.004</td><td>0.0</td><td>15796.6</td><td>326</td></tr><tr><td>720 min Winter</td><td>8.849</td><td>0.0</td><td>16768.8</td><td>386</td></tr><tr><td>960 min Winter</td><td>7.278</td><td>0.0</td><td>18386.5</td><td>506</td></tr><tr><td>1440 min Winter</td><td>5.520</td><td>0.0</td><td>20917.6</td><td>746</td></tr><tr><td>2160 min Winter</td><td>4.198</td><td>0.0</td><td>23863.3</td><td>1112</td></tr><tr><td>2880 min Winter</td><td>3.464</td><td>0.0</td><td>26257.4</td><td>1472</td></tr><tr><td>4320 min Winter</td><td>2.662</td><td>0.0</td><td>30260.6</td><td>2196</td></tr><tr><td>5760 min Winter</td><td>2.228</td><td>0.0</td><td>33770.2</td><td>2912</td></tr><tr><td>7200 min Winter</td><td>1.944</td><td>0.0</td><td>36840.9</td><td>3672</td></tr><tr><td>8640 min Winter</td><td>1.739</td><td>0.0</td><td>39536.5</td><td>4376</td></tr><tr><td>10080 min Winter</td><td>1.581</td><td>0.0</td><td>41953.9</td><td>5032</td></tr></table>						Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status	60 min Winter	226.885	1.885	1858.3	3261.0	Flood Risk	120 min Winter	226.849	1.849	1835.2	3177.8	Flood Risk	180 min Winter	226.679	1.679	1721.5	2796.1	O K	240 min Winter	226.515	1.515	1604.5	2447.6	O K	360 min Winter	226.261	1.261	1404.7	1943.0	O K	480 min Winter	226.123	1.123	1215.7	1686.0	O K	600 min Winter	226.027	1.027	1066.6	1512.7	O K	720 min Winter	225.953	0.953	953.3	1384.1	O K	960 min Winter	225.848	0.848	792.9	1206.7	O K	1440 min Winter	225.722	0.722	607.3	1001.9	O K	2160 min Winter	225.602	0.602	463.0	815.8	O K	2880 min Winter	225.528	0.528	383.5	704.7	O K	4320 min Winter	225.460	0.460	295.7	606.3	O K	5760 min Winter	225.426	0.426	247.3	557.8	O K	7200 min Winter	225.404	0.404	216.0	526.5	O K	8640 min Winter	225.382	0.382	193.0	495.0	O K	10080 min Winter	225.361	0.361	175.5	465.8	O K	Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	60 min Winter	42.167	0.0	6658.5	54	120 min Winter	28.240	0.0	8918.9	86	180 min Winter	21.881	0.0	10365.8	118	240 min Winter	18.227	0.0	11513.1	150	360 min Winter	14.024	0.0	13287.2	208	480 min Winter	11.606	0.0	14661.9	266	600 min Winter	10.004	0.0	15796.6	326	720 min Winter	8.849	0.0	16768.8	386	960 min Winter	7.278	0.0	18386.5	506	1440 min Winter	5.520	0.0	20917.6	746	2160 min Winter	4.198	0.0	23863.3	1112	2880 min Winter	3.464	0.0	26257.4	1472	4320 min Winter	2.662	0.0	30260.6	2196	5760 min Winter	2.228	0.0	33770.2	2912	7200 min Winter	1.944	0.0	36840.9	3672	8640 min Winter	1.739	0.0	39536.5	4376	10080 min Winter	1.581	0.0	41953.9	5032
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Ove Arup & Partners International Ltd		Page 3
The Arup Campus Blyth Gate Solihull B90 8AE		
Date 29/11/2019 12:03	Designed by	
File Catchment 1E.SRCX	Checked by	
XP Solutions		Source Control 2018.1.1

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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 18.800

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 3.760	8	12 3.760	16	20 3.760
4	8 3.760	12	16 3.760		

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The Arup Campus Blyth Gate Solihull B90 8AE										
Date 29/11/2019 12:03 File Catchment 1E.SRCX										
Designed by Checked by										
XP Solutions		Source Control 2018.1.1								
<u>Model Details</u> Storage is Online Cover Level (m) 227.000 <u>Tank or Pond Structure</u> Invert Level (m) 225.000 <table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Depth (m)</th> <th>Area (m²)</th> <th>Depth (m)</th> <th>Area (m²)</th> </tr> </thead> <tbody> <tr> <td>0.000</td> <td>1200.0</td> <td>2.000</td> <td>2400.0</td> </tr> </tbody> </table> <u>Orifice Outflow Control</u> Diameter (m) 0.859 Discharge Coefficient 0.600 Invert Level (m) 225.000			Depth (m)	Area (m ²)	Depth (m)	Area (m ²)	0.000	1200.0	2.000	2400.0
Depth (m)	Area (m ²)	Depth (m)	Area (m ²)							
0.000	1200.0	2.000	2400.0							
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F3 Catchment 1F

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The Arup Campus Blyth Gate Solihull B90 8AE					
Date 29/11/2019 12:08		Designed by			
File Catchment 1F.SRCX		Checked by			
XP Solutions		Source Control 2018.1.1			
<u>Summary of Results for 100 year Return Period</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	228.197	1.197	1398.9	1821.5	O K
30 min Summer	228.520	1.520	1748.7	2458.1	O K
60 min Summer	228.746	1.746	1925.0	2945.2	Flood Risk
120 min Summer	228.789	1.789	1956.6	3040.5	Flood Risk
180 min Summer	228.697	1.697	1888.2	2836.4	O K
240 min Summer	228.593	1.593	1807.8	2611.7	O K
360 min Summer	228.406	1.406	1652.9	2225.5	O K
480 min Summer	228.270	1.270	1520.7	1960.7	O K
600 min Summer	228.179	1.179	1369.1	1788.1	O K
720 min Summer	228.105	1.105	1246.5	1652.6	O K
960 min Summer	227.994	0.994	1063.8	1454.9	O K
1440 min Summer	227.853	0.853	835.2	1215.7	O K
2160 min Summer	227.734	0.734	647.8	1021.6	O K
2880 min Summer	227.647	0.647	539.0	884.5	O K
4320 min Summer	227.542	0.542	418.6	726.4	O K
5760 min Summer	227.495	0.495	351.4	656.4	O K
7200 min Summer	227.465	0.465	306.4	613.9	O K
8640 min Summer	227.444	0.444	274.3	583.4	O K
10080 min Summer	227.428	0.428	249.2	560.5	O K
15 min Winter	228.295	1.295	1554.0	2007.3	O K
30 min Winter	228.651	1.651	1852.7	2735.0	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer	80.827	0.0	2920.1	27	
30 min Summer	59.691	0.0	4315.2	35	
60 min Summer	42.167	0.0	6103.3	52	
120 min Summer	28.240	0.0	8175.2	82	
180 min Summer	21.881	0.0	9501.5	114	
240 min Summer	18.227	0.0	10553.0	144	
360 min Summer	14.024	0.0	12179.1	204	
480 min Summer	11.606	0.0	13439.3	262	
600 min Summer	10.004	0.0	14479.3	322	
720 min Summer	8.849	0.0	15370.4	382	
960 min Summer	7.278	0.0	16853.3	502	
1440 min Summer	5.520	0.0	19173.3	744	
2160 min Summer	4.198	0.0	21873.1	1108	
2880 min Summer	3.464	0.0	24067.6	1472	
4320 min Summer	2.662	0.0	27736.8	2204	
5760 min Summer	2.228	0.0	30953.8	2936	
7200 min Summer	1.944	0.0	33769.1	3672	
8640 min Summer	1.739	0.0	36239.3	4344	
10080 min Summer	1.581	0.0	38454.6	5136	
15 min Winter	80.827	0.0	3271.1	27	
30 min Winter	59.691	0.0	4833.6	35	
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Ove Arup & Partners International Ltd					Page 2																																																																																																																																																																																																						
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Winter</td><td>227.944</td><td>0.944</td><td>981.9</td><td>1367.9</td><td>O K</td></tr><tr><td>960 min Winter</td><td>227.841</td><td>0.841</td><td>815.5</td><td>1194.7</td><td>O K</td></tr><tr><td>1440 min Winter</td><td>227.718</td><td>0.718</td><td>621.8</td><td>995.7</td><td>O K</td></tr><tr><td>2160 min Winter</td><td>227.592</td><td>0.592</td><td>475.6</td><td>800.8</td><td>O K</td></tr><tr><td>2880 min Winter</td><td>227.523</td><td>0.523</td><td>394.1</td><td>697.8</td><td>O K</td></tr><tr><td>4320 min Winter</td><td>227.463</td><td>0.463</td><td>303.3</td><td>610.7</td><td>O K</td></tr><tr><td>5760 min Winter</td><td>227.431</td><td>0.431</td><td>253.7</td><td>564.2</td><td>O K</td></tr><tr><td>7200 min Winter</td><td>227.405</td><td>0.405</td><td>221.5</td><td>528.0</td><td>O K</td></tr><tr><td>8640 min Winter</td><td>227.379</td><td>0.379</td><td>197.9</td><td>491.4</td><td>O K</td></tr><tr><td>10080 min Winter</td><td>227.359</td><td>0.359</td><td>180.1</td><td>463.0</td><td>O K</td></tr></table> <table><tr><th>Storm Event</th><th>Rain (mm/hr)</th><th>Flooded Volume (m³)</th><th>Discharge Volume (m³)</th><th>Time-Peak (mins)</th></tr><tr><td>60 min Winter</td><td>42.167</td><td>0.0</td><td>6835.7</td><td>52</td></tr><tr><td>120 min Winter</td><td>28.240</td><td>0.0</td><td>9156.3</td><td>86</td></tr><tr><td>180 min Winter</td><td>21.881</td><td>0.0</td><td>10641.5</td><td>118</td></tr><tr><td>240 min Winter</td><td>18.227</td><td>0.0</td><td>11819.3</td><td>148</td></tr><tr><td>360 min Winter</td><td>14.024</td><td>0.0</td><td>13640.6</td><td>206</td></tr><tr><td>480 min Winter</td><td>11.606</td><td>0.0</td><td>15052.1</td><td>266</td></tr><tr><td>600 min Winter</td><td>10.004</td><td>0.0</td><td>16217.0</td><td>326</td></tr><tr><td>720 min Winter</td><td>8.849</td><td>0.0</td><td>17215.0</td><td>386</td></tr><tr><td>960 min Winter</td><td>7.278</td><td>0.0</td><td>18875.9</td><td>506</td></tr><tr><td>1440 min Winter</td><td>5.520</td><td>0.0</td><td>21474.7</td><td>750</td></tr><tr><td>2160 min Winter</td><td>4.198</td><td>0.0</td><td>24498.0</td><td>1108</td></tr><tr><td>2880 min Winter</td><td>3.464</td><td>0.0</td><td>26955.7</td><td>1472</td></tr><tr><td>4320 min Winter</td><td>2.662</td><td>0.0</td><td>31066.1</td><td>2192</td></tr><tr><td>5760 min Winter</td><td>2.228</td><td>0.0</td><td>34668.3</td><td>2880</td></tr><tr><td>7200 min Winter</td><td>1.944</td><td>0.0</td><td>37820.8</td><td>3664</td></tr><tr><td>8640 min Winter</td><td>1.739</td><td>0.0</td><td>40588.5</td><td>4400</td></tr><tr><td>10080 min Winter</td><td>1.581</td><td>0.0</td><td>43070.4</td><td>5136</td></tr></table>						Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status	60 min Winter	228.867	1.867	2012.8	3218.4	Flood Risk	120 min Winter	228.812	1.812	1973.0	3091.6	Flood Risk	180 min Winter	228.632	1.632	1838.0	2693.8	O K	240 min Winter	228.467	1.467	1704.8	2348.5	O K	360 min Winter	228.239	1.239	1469.3	1901.7	O K	480 min Winter	228.109	1.109	1253.9	1660.7	O K	600 min Winter	228.015	1.015	1099.0	1492.1	O K	720 min Winter	227.944	0.944	981.9	1367.9	O K	960 min Winter	227.841	0.841	815.5	1194.7	O K	1440 min Winter	227.718	0.718	621.8	995.7	O K	2160 min Winter	227.592	0.592	475.6	800.8	O K	2880 min Winter	227.523	0.523	394.1	697.8	O K	4320 min Winter	227.463	0.463	303.3	610.7	O K	5760 min Winter	227.431	0.431	253.7	564.2	O K	7200 min Winter	227.405	0.405	221.5	528.0	O K	8640 min Winter	227.379	0.379	197.9	491.4	O K	10080 min Winter	227.359	0.359	180.1	463.0	O K	Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	60 min Winter	42.167	0.0	6835.7	52	120 min Winter	28.240	0.0	9156.3	86	180 min Winter	21.881	0.0	10641.5	118	240 min Winter	18.227	0.0	11819.3	148	360 min Winter	14.024	0.0	13640.6	206	480 min Winter	11.606	0.0	15052.1	266	600 min Winter	10.004	0.0	16217.0	326	720 min Winter	8.849	0.0	17215.0	386	960 min Winter	7.278	0.0	18875.9	506	1440 min Winter	5.520	0.0	21474.7	750	2160 min Winter	4.198	0.0	24498.0	1108	2880 min Winter	3.464	0.0	26955.7	1472	4320 min Winter	2.662	0.0	31066.1	2192	5760 min Winter	2.228	0.0	34668.3	2880	7200 min Winter	1.944	0.0	37820.8	3664	8640 min Winter	1.739	0.0	40588.5	4400	10080 min Winter	1.581	0.0	43070.4	5136
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Ove Arup & Partners International Ltd		Page 3
The Arup Campus Blyth Gate Solihull B90 8AE		
Date 29/11/2019 12:08	Designed by	
File Catchment 1F.SRCX	Checked by	
XP Solutions		Source Control 2018.1.1

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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 19.300

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 3.860	8	12 3.860	16	20 3.860
4	8 3.860	12	16 3.860		

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The Arup Campus Blyth Gate Solihull B90 8AE										
Date 29/11/2019 12:08	Designed by									
File Catchment 1F.SRCX	Checked by									
XP Solutions		Source Control 2018.1.1								
<u>Model Details</u> Storage is Online Cover Level (m) 229.000 <u>Tank or Pond Structure</u> Invert Level (m) 227.000 <table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Depth (m)</th> <th>Area (m²)</th> <th>Depth (m)</th> <th>Area (m²)</th> </tr> </thead> <tbody> <tr> <td>0.000</td> <td>1200.0</td> <td>2.000</td> <td>2400.0</td> </tr> </tbody> </table> <u>Orifice Outflow Control</u> Diameter (m) 0.900 Discharge Coefficient 0.600 Invert Level (m) 227.000			Depth (m)	Area (m ²)	Depth (m)	Area (m ²)	0.000	1200.0	2.000	2400.0
Depth (m)	Area (m ²)	Depth (m)	Area (m ²)							
0.000	1200.0	2.000	2400.0							
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F4 Catchment 1G

Ove Arup & Partners International Ltd					Page 1
The Arup Campus Blyth Gate Solihull B90 8AE					
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File Catchment 1G Pond.SRCX		Checked by			
XP Solutions		Source Control 2018.1.1			
<u>Summary of Results for 100 year Return Period</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	238.928	0.928	213.6	928.3	O K
30 min Summer	239.241	1.241	254.0	1333.3	O K
60 min Summer	239.521	1.521	285.3	1738.7	O K
120 min Summer	239.693	1.693	302.9	2008.9	O K
180 min Summer	239.736	1.736	307.1	2078.1	Flood Risk
240 min Summer	239.741	1.741	307.6	2086.3	Flood Risk
360 min Summer	239.700	1.700	303.6	2020.7	Flood Risk
480 min Summer	239.636	1.636	297.2	1916.4	O K
600 min Summer	239.564	1.564	289.8	1804.2	O K
720 min Summer	239.492	1.492	282.2	1693.8	O K
960 min Summer	239.356	1.356	267.2	1493.4	O K
1440 min Summer	239.133	1.133	240.8	1187.3	O K
2160 min Summer	238.900	0.900	209.6	894.4	O K
2880 min Summer	238.746	0.746	186.2	715.5	O K
4320 min Summer	238.567	0.567	154.5	521.5	O K
5760 min Summer	238.481	0.481	135.0	432.7	O K
7200 min Summer	238.438	0.438	118.5	390.7	O K
8640 min Summer	238.407	0.407	106.2	359.7	O K
10080 min Summer	238.382	0.382	96.7	336.0	O K
15 min Winter	239.022	1.022	226.5	1044.8	O K
30 min Winter	239.364	1.364	268.1	1505.2	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer	80.827	0.0	1128.5	29	
30 min Summer	59.691	0.0	1670.5	39	
60 min Summer	42.167	0.0	2368.8	60	
120 min Summer	28.240	0.0	3173.9	96	
180 min Summer	21.881	0.0	3689.2	130	
240 min Summer	18.227	0.0	4097.7	164	
360 min Summer	14.024	0.0	4729.4	232	
480 min Summer	11.606	0.0	5218.9	298	
600 min Summer	10.004	0.0	5622.9	362	
720 min Summer	8.849	0.0	5968.9	426	
960 min Summer	7.278	0.0	6544.6	550	
1440 min Summer	5.520	0.0	7445.0	792	
2160 min Summer	4.198	0.0	8498.6	1152	
2880 min Summer	3.464	0.0	9350.4	1508	
4320 min Summer	2.662	0.0	10772.9	2216	
5760 min Summer	2.228	0.0	12028.5	2936	
7200 min Summer	1.944	0.0	13121.8	3672	
8640 min Summer	1.739	0.0	14080.4	4400	
10080 min Summer	1.581	0.0	14938.0	5136	
15 min Winter	80.827	0.0	1264.9	30	
30 min Winter	59.691	0.0	1871.9	40	
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Ove Arup & Partners International Ltd					Page 2																																																																																																																																																																																																						
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Winter</td><td>239.425</td><td>1.425</td><td>275.0</td><td>1594.6</td><td>O K</td></tr><tr><td>960 min Winter</td><td>239.230</td><td>1.230</td><td>252.7</td><td>1318.1</td><td>O K</td></tr><tr><td>1440 min Winter</td><td>238.942</td><td>0.942</td><td>215.5</td><td>944.9</td><td>O K</td></tr><tr><td>2160 min Winter</td><td>238.685</td><td>0.685</td><td>176.0</td><td>647.3</td><td>O K</td></tr><tr><td>2880 min Winter</td><td>238.543</td><td>0.543</td><td>149.6</td><td>495.6</td><td>O K</td></tr><tr><td>4320 min Winter</td><td>238.435</td><td>0.435</td><td>117.3</td><td>387.6</td><td>O K</td></tr><tr><td>5760 min Winter</td><td>238.387</td><td>0.387</td><td>98.5</td><td>340.2</td><td>O K</td></tr><tr><td>7200 min Winter</td><td>238.354</td><td>0.354</td><td>86.0</td><td>309.3</td><td>O K</td></tr><tr><td>8640 min Winter</td><td>238.331</td><td>0.331</td><td>77.0</td><td>286.9</td><td>O K</td></tr><tr><td>10080 min Winter</td><td>238.312</td><td>0.312</td><td>70.1</td><td>269.6</td><td>O K</td></tr></tbody></table> <table><thead><tr><th>Storm Event</th><th>Rain (mm/hr)</th><th>Flooded Volume (m³)</th><th>Discharge Volume (m³)</th><th>Time-Peak (mins)</th></tr></thead><tbody><tr><td>60 min Winter</td><td>42.167</td><td>0.0</td><td>2653.4</td><td>62</td></tr><tr><td>120 min Winter</td><td>28.240</td><td>0.0</td><td>3555.1</td><td>102</td></tr><tr><td>180 min Winter</td><td>21.881</td><td>0.0</td><td>4132.2</td><td>138</td></tr><tr><td>240 min Winter</td><td>18.227</td><td>0.0</td><td>4589.8</td><td>176</td></tr><tr><td>360 min Winter</td><td>14.024</td><td>0.0</td><td>5297.3</td><td>248</td></tr><tr><td>480 min Winter</td><td>11.606</td><td>0.0</td><td>5845.6</td><td>316</td></tr><tr><td>600 min Winter</td><td>10.004</td><td>0.0</td><td>6298.1</td><td>382</td></tr><tr><td>720 min Winter</td><td>8.849</td><td>0.0</td><td>6685.7</td><td>446</td></tr><tr><td>960 min Winter</td><td>7.278</td><td>0.0</td><td>7330.6</td><td>570</td></tr><tr><td>1440 min Winter</td><td>5.520</td><td>0.0</td><td>8339.4</td><td>810</td></tr><tr><td>2160 min Winter</td><td>4.198</td><td>0.0</td><td>9518.7</td><td>1164</td></tr><tr><td>2880 min Winter</td><td>3.464</td><td>0.0</td><td>10472.8</td><td>1508</td></tr><tr><td>4320 min Winter</td><td>2.662</td><td>0.0</td><td>12066.8</td><td>2208</td></tr><tr><td>5760 min Winter</td><td>2.228</td><td>0.0</td><td>13472.0</td><td>2936</td></tr><tr><td>7200 min Winter</td><td>1.944</td><td>0.0</td><td>14696.6</td><td>3672</td></tr><tr><td>8640 min Winter</td><td>1.739</td><td>0.0</td><td>15770.5</td><td>4408</td></tr><tr><td>10080 min Winter</td><td>1.581</td><td>0.0</td><td>16732.0</td><td>5128</td></tr></tbody></table>						Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status	60 min Winter	239.670	1.670	300.6	1971.8	O K	120 min Winter	239.842	1.842	317.4	2255.8	Flood Risk	180 min Winter	239.867	1.867	319.8	2299.7	Flood Risk	240 min Winter	239.850	1.850	318.2	2270.7	Flood Risk	360 min Winter	239.761	1.761	309.6	2120.6	Flood Risk	480 min Winter	239.649	1.649	298.5	1937.8	O K	600 min Winter	239.535	1.535	286.7	1758.8	O K	720 min Winter	239.425	1.425	275.0	1594.6	O K	960 min Winter	239.230	1.230	252.7	1318.1	O K	1440 min Winter	238.942	0.942	215.5	944.9	O K	2160 min Winter	238.685	0.685	176.0	647.3	O K	2880 min Winter	238.543	0.543	149.6	495.6	O K	4320 min Winter	238.435	0.435	117.3	387.6	O K	5760 min Winter	238.387	0.387	98.5	340.2	O K	7200 min Winter	238.354	0.354	86.0	309.3	O K	8640 min Winter	238.331	0.331	77.0	286.9	O K	10080 min Winter	238.312	0.312	70.1	269.6	O K	Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	60 min Winter	42.167	0.0	2653.4	62	120 min Winter	28.240	0.0	3555.1	102	180 min Winter	21.881	0.0	4132.2	138	240 min Winter	18.227	0.0	4589.8	176	360 min Winter	14.024	0.0	5297.3	248	480 min Winter	11.606	0.0	5845.6	316	600 min Winter	10.004	0.0	6298.1	382	720 min Winter	8.849	0.0	6685.7	446	960 min Winter	7.278	0.0	7330.6	570	1440 min Winter	5.520	0.0	8339.4	810	2160 min Winter	4.198	0.0	9518.7	1164	2880 min Winter	3.464	0.0	10472.8	1508	4320 min Winter	2.662	0.0	12066.8	2208	5760 min Winter	2.228	0.0	13472.0	2936	7200 min Winter	1.944	0.0	14696.6	3672	8640 min Winter	1.739	0.0	15770.5	4408	10080 min Winter	1.581	0.0	16732.0	5128
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status																																																																																																																																																																																																						
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120 min Winter	239.842	1.842	317.4	2255.8	Flood Risk																																																																																																																																																																																																						
180 min Winter	239.867	1.867	319.8	2299.7	Flood Risk																																																																																																																																																																																																						
240 min Winter	239.850	1.850	318.2	2270.7	Flood Risk																																																																																																																																																																																																						
360 min Winter	239.761	1.761	309.6	2120.6	Flood Risk																																																																																																																																																																																																						
480 min Winter	239.649	1.649	298.5	1937.8	O K																																																																																																																																																																																																						
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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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 7.500

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 1.500	8	12 1.500	16	20 1.500
4	8 1.500	12	16 1.500		

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File Catchment 1G Pond.SRCX	Checked by									
XP Solutions		Source Control 2018.1.1								
<u>Model Details</u> Storage is Online Cover Level (m) 240.000 <u>Tank or Pond Structure</u> Invert Level (m) 238.000 <table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Depth (m)</th> <th>Area (m²)</th> <th>Depth (m)</th> <th>Area (m²)</th> </tr> </thead> <tbody> <tr> <td>0.000</td> <td>800.0</td> <td>2.000</td> <td>1800.0</td> </tr> </tbody> </table> <u>Orifice Outflow Control</u> Diameter (m) 0.343 Discharge Coefficient 0.600 Invert Level (m) 238.000			Depth (m)	Area (m ²)	Depth (m)	Area (m ²)	0.000	800.0	2.000	1800.0
Depth (m)	Area (m ²)	Depth (m)	Area (m ²)							
0.000	800.0	2.000	1800.0							
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F5 Catchment 2A

Ove Arup & Partners International Ltd					Page 1	
The Arup Campus Blyth Gate Solihull B90 8AE						
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<u>Summary of Results for 100 year Return Period (+40%)</u>						
Storm Event		Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer		251.071	0.571	47.9	228.3	O K
30 min Summer		251.277	0.777	57.3	328.3	O K
60 min Summer		251.468	0.968	64.7	430.0	O K
120 min Summer		251.588	1.088	69.0	499.0	O K
180 min Summer		251.621	1.121	70.2	518.6	O K
240 min Summer		251.629	1.129	70.4	523.2	O K
360 min Summer		251.609	1.109	69.8	511.1	O K
480 min Summer		251.570	1.070	68.4	488.5	O K
600 min Summer		251.526	1.026	66.9	463.0	O K
720 min Summer		251.481	0.981	65.2	437.4	O K
960 min Summer		251.395	0.895	62.0	389.8	O K
1440 min Summer		251.251	0.751	56.2	315.0	O K
2160 min Summer		251.098	0.598	49.2	240.8	O K
2880 min Summer		250.995	0.495	44.0	193.7	O K
4320 min Summer		250.871	0.371	36.6	140.3	O K
5760 min Summer		250.804	0.304	31.9	112.9	O K
7200 min Summer		250.763	0.263	28.7	96.3	O K
8640 min Summer		250.742	0.242	25.8	88.3	O K
10080 min Summer		250.727	0.227	23.5	82.4	O K
15 min Winter		251.133	0.633	50.9	257.1	O K
30 min Winter		251.359	0.859	60.6	370.6	O K
Storm Event		Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer		113.158	0.0	273.8	29	
30 min Summer		83.568	0.0	405.3	40	
60 min Summer		59.033	0.0	574.8	62	
120 min Summer		39.536	0.0	770.1	96	
180 min Summer		30.634	0.0	895.1	132	
240 min Summer		25.518	0.0	994.3	166	
360 min Summer		19.633	0.0	1147.6	234	
480 min Summer		16.249	0.0	1266.4	300	
600 min Summer		14.005	0.0	1364.4	366	
720 min Summer		12.389	0.0	1448.4	428	
960 min Summer		10.189	0.0	1588.1	554	
1440 min Summer		7.728	0.0	1806.6	798	
2160 min Summer		5.877	0.0	2062.3	1160	
2880 min Summer		4.850	0.0	2269.0	1512	
4320 min Summer		3.726	0.0	2614.2	2220	
5760 min Summer		3.119	0.0	2918.8	2944	
7200 min Summer		2.722	0.0	3184.2	3672	
8640 min Summer		2.434	0.0	3416.8	4400	
10080 min Summer		2.214	0.0	3624.9	5136	
15 min Winter		113.158	0.0	306.9	30	
30 min Winter		83.568	0.0	454.2	40	
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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	251.568	1.068	68.3	487.3	O K
120 min Winter	251.692	1.192	72.6	561.7	O K
180 min Winter	251.717	1.217	73.4	576.7	Flood Risk
240 min Winter	251.711	1.211	73.2	573.3	Flood Risk
360 min Winter	251.661	1.161	71.5	542.2	O K
480 min Winter	251.592	1.092	69.2	501.0	O K
600 min Winter	251.520	1.020	66.6	459.4	O K
720 min Winter	251.450	0.950	64.1	420.3	O K
960 min Winter	251.325	0.825	59.2	352.8	O K
1440 min Winter	251.135	0.635	51.0	258.0	O K
2160 min Winter	250.961	0.461	42.0	178.4	O K
2880 min Winter	250.860	0.360	35.9	135.7	O K
4320 min Winter	250.760	0.260	28.5	95.3	O K
5760 min Winter	250.730	0.230	23.9	83.4	O K
7200 min Winter	250.710	0.210	20.9	75.7	O K
8640 min Winter	250.695	0.195	18.7	70.1	O K
10080 min Winter	250.684	0.184	17.0	65.8	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
60 min Winter	59.033	0.0	643.8	62	
120 min Winter	39.536	0.0	862.6	102	
180 min Winter	30.634	0.0	1002.7	140	
240 min Winter	25.518	0.0	1113.7	178	
360 min Winter	19.633	0.0	1285.4	250	
480 min Winter	16.249	0.0	1418.4	318	
600 min Winter	14.005	0.0	1528.2	386	
720 min Winter	12.389	0.0	1622.3	450	
960 min Winter	10.189	0.0	1778.8	578	
1440 min Winter	7.728	0.0	2023.7	822	
2160 min Winter	5.877	0.0	2309.8	1176	
2880 min Winter	4.850	0.0	2541.3	1528	
4320 min Winter	3.726	0.0	2928.2	2208	
5760 min Winter	3.119	0.0	3269.1	2936	
7200 min Winter	2.722	0.0	3566.3	3672	
8640 min Winter	2.434	0.0	3826.9	4408	
10080 min Winter	2.214	0.0	4060.2	5120	
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The Arup Campus Blyth Gate Solihull B90 8AE		
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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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.300

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 0.260	8	12 0.260	16	20 0.260
4	8 0.260	12	16 0.260		

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Model Details

Storage is Online Cover Level (m) 252.000

Tank or Pond Structure

Invert Level (m) 250.500

Depth (m)	Area (m ²)	Depth (m)	Area (m ²)
0.000	340.0	1.500	700.0

Orifice Outflow Control

Diameter (m) 0.182 Discharge Coefficient 0.600 Invert Level (m) 250.500

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F6 Catchment 2B

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Date 29/11/2019 15:18 File Catchment 2B-1 and		Designed by Checked by			
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<u>Summary of Results for 100 year Return Period</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	242.063	1.063	1067.3	3317.2	O K
30 min Summer	242.402	1.402	1394.7	4572.4	O K
60 min Summer	242.699	1.699	1590.1	5760.5	O K
120 min Summer	242.871	1.871	1692.8	6483.4	Flood Risk
180 min Summer	242.884	1.884	1700.3	6539.0	Flood Risk
240 min Summer	242.853	1.853	1682.0	6404.0	Flood Risk
360 min Summer	242.744	1.744	1617.2	5944.4	Flood Risk
480 min Summer	242.625	1.625	1543.8	5456.7	O K
600 min Summer	242.516	1.516	1472.6	5018.3	O K
720 min Summer	242.419	1.419	1406.6	4639.3	O K
960 min Summer	242.263	1.263	1293.3	4045.1	O K
1440 min Summer	242.079	1.079	1091.0	3375.3	O K
2160 min Summer	241.927	0.927	873.0	2842.8	O K
2880 min Summer	241.833	0.833	739.3	2523.4	O K
4320 min Summer	241.720	0.720	582.2	2146.3	O K
5760 min Summer	241.651	0.651	488.0	1922.9	O K
7200 min Summer	241.592	0.592	429.5	1736.7	O K
8640 min Summer	241.548	0.548	385.5	1598.4	O K
10080 min Summer	241.514	0.514	351.5	1492.5	O K
15 min Winter	242.163	1.163	1211.8	3678.9	O K
30 min Winter	242.539	1.539	1487.8	5109.0	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer	80.827	0.0	4079.6	28	
30 min Summer	59.691	0.0	6051.9	37	
60 min Summer	42.167	0.0	8614.3	56	
120 min Summer	28.240	0.0	11544.2	88	
180 min Summer	21.881	0.0	13419.6	122	
240 min Summer	18.227	0.0	14906.3	154	
360 min Summer	14.024	0.0	17204.9	218	
480 min Summer	11.606	0.0	18985.5	280	
600 min Summer	10.004	0.0	20454.6	342	
720 min Summer	8.849	0.0	21712.8	400	
960 min Summer	7.278	0.0	23805.1	520	
1440 min Summer	5.520	0.0	27074.4	756	
2160 min Summer	4.198	0.0	30931.3	1116	
2880 min Summer	3.464	0.0	34028.5	1480	
4320 min Summer	2.662	0.0	39189.7	2208	
5760 min Summer	2.228	0.0	43783.6	2944	
7200 min Summer	1.944	0.0	47761.7	3672	
8640 min Summer	1.739	0.0	51246.3	4408	
10080 min Summer	1.581	0.0	54352.1	5136	
15 min Winter	80.827	0.0	4575.9	29	
30 min Winter	59.691	0.0	6784.9	38	
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<u>Summary of Results for 100 year Return Period</u> <table><thead><tr><th>Storm Event</th><th>Max Level (m)</th><th>Max Depth (m)</th><th>Max Control (l/s)</th><th>Max Volume (m³)</th><th>Status</th></tr></thead><tbody><tr><td>60 min Winter</td><td>242.861</td><td>1.861</td><td>1686.7</td><td>6437.4</td><td>Flood Risk</td></tr><tr><td>120 min Winter</td><td>242.997</td><td>1.997</td><td>1764.2</td><td>7029.9</td><td>Flood Risk</td></tr><tr><td>180 min Winter</td><td>242.958</td><td>1.958</td><td>1742.1</td><td>6856.6</td><td>Flood Risk</td></tr><tr><td>240 min Winter</td><td>242.876</td><td>1.876</td><td>1695.7</td><td>6505.1</td><td>Flood Risk</td></tr><tr><td>360 min Winter</td><td>242.685</td><td>1.685</td><td>1581.1</td><td>5700.1</td><td>O K</td></tr><tr><td>480 min Winter</td><td>242.507</td><td>1.507</td><td>1466.6</td><td>4982.3</td><td>O K</td></tr><tr><td>600 min Winter</td><td>242.357</td><td>1.357</td><td>1363.0</td><td>4402.2</td><td>O K</td></tr><tr><td>720 min Winter</td><td>242.237</td><td>1.237</td><td>1273.8</td><td>3950.6</td><td>O K</td></tr><tr><td>960 min Winter</td><td>242.089</td><td>1.089</td><td>1105.4</td><td>3411.1</td><td>O K</td></tr><tr><td>1440 min Winter</td><td>241.920</td><td>0.920</td><td>862.3</td><td>2817.5</td><td>O K</td></tr><tr><td>2160 min Winter</td><td>241.781</td><td>0.781</td><td>665.6</td><td>2347.5</td><td>O K</td></tr><tr><td>2880 min Winter</td><td>241.698</td><td>0.698</td><td>552.8</td><td>2076.7</td><td>O K</td></tr><tr><td>4320 min Winter</td><td>241.589</td><td>0.589</td><td>426.0</td><td>1725.1</td><td>O K</td></tr><tr><td>5760 min Winter</td><td>241.521</td><td>0.521</td><td>358.0</td><td>1511.3</td><td>O K</td></tr><tr><td>7200 min Winter</td><td>241.477</td><td>0.477</td><td>313.3</td><td>1376.9</td><td>O K</td></tr><tr><td>8640 min Winter</td><td>241.452</td><td>0.452</td><td>280.2</td><td>1300.4</td><td>O K</td></tr><tr><td>10080 min Winter</td><td>241.433</td><td>0.433</td><td>255.1</td><td>1242.5</td><td>O K</td></tr></tbody></table> <table><thead><tr><th>Storm Event</th><th>Rain (mm/hr)</th><th>Flooded Volume (m³)</th><th>Discharge Volume (m³)</th><th>Time-Peak (mins)</th></tr></thead><tbody><tr><td>60 min Winter</td><td>42.167</td><td>0.0</td><td>9650.2</td><td>58</td></tr><tr><td>120 min Winter</td><td>28.240</td><td>0.0</td><td>12931.8</td><td>94</td></tr><tr><td>180 min Winter</td><td>21.881</td><td>0.0</td><td>15032.3</td><td>130</td></tr><tr><td>240 min Winter</td><td>18.227</td><td>0.0</td><td>16697.6</td><td>164</td></tr><tr><td>360 min Winter</td><td>14.024</td><td>0.0</td><td>19272.2</td><td>228</td></tr><tr><td>480 min Winter</td><td>11.606</td><td>0.0</td><td>21266.8</td><td>290</td></tr><tr><td>600 min Winter</td><td>10.004</td><td>0.0</td><td>22912.5</td><td>350</td></tr><tr><td>720 min Winter</td><td>8.849</td><td>0.0</td><td>24322.1</td><td>408</td></tr><tr><td>960 min Winter</td><td>7.278</td><td>0.0</td><td>26666.3</td><td>524</td></tr><tr><td>1440 min Winter</td><td>5.520</td><td>0.0</td><td>30330.2</td><td>764</td></tr><tr><td>2160 min Winter</td><td>4.198</td><td>0.0</td><td>34644.4</td><td>1124</td></tr><tr><td>2880 min Winter</td><td>3.464</td><td>0.0</td><td>38114.3</td><td>1484</td></tr><tr><td>4320 min Winter</td><td>2.662</td><td>0.0</td><td>43900.8</td><td>2212</td></tr><tr><td>5760 min Winter</td><td>2.228</td><td>0.0</td><td>49038.0</td><td>2944</td></tr><tr><td>7200 min Winter</td><td>1.944</td><td>0.0</td><td>53494.0</td><td>3672</td></tr><tr><td>8640 min Winter</td><td>1.739</td><td>0.0</td><td>57399.1</td><td>4384</td></tr><tr><td>10080 min Winter</td><td>1.581</td><td>0.0</td><td>60884.9</td><td>5112</td></tr></tbody></table>						Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status	60 min Winter	242.861	1.861	1686.7	6437.4	Flood Risk	120 min Winter	242.997	1.997	1764.2	7029.9	Flood Risk	180 min Winter	242.958	1.958	1742.1	6856.6	Flood Risk	240 min Winter	242.876	1.876	1695.7	6505.1	Flood Risk	360 min Winter	242.685	1.685	1581.1	5700.1	O K	480 min Winter	242.507	1.507	1466.6	4982.3	O K	600 min Winter	242.357	1.357	1363.0	4402.2	O K	720 min Winter	242.237	1.237	1273.8	3950.6	O K	960 min Winter	242.089	1.089	1105.4	3411.1	O K	1440 min Winter	241.920	0.920	862.3	2817.5	O K	2160 min Winter	241.781	0.781	665.6	2347.5	O K	2880 min Winter	241.698	0.698	552.8	2076.7	O K	4320 min Winter	241.589	0.589	426.0	1725.1	O K	5760 min Winter	241.521	0.521	358.0	1511.3	O K	7200 min Winter	241.477	0.477	313.3	1376.9	O K	8640 min Winter	241.452	0.452	280.2	1300.4	O K	10080 min Winter	241.433	0.433	255.1	1242.5	O K	Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	60 min Winter	42.167	0.0	9650.2	58	120 min Winter	28.240	0.0	12931.8	94	180 min Winter	21.881	0.0	15032.3	130	240 min Winter	18.227	0.0	16697.6	164	360 min Winter	14.024	0.0	19272.2	228	480 min Winter	11.606	0.0	21266.8	290	600 min Winter	10.004	0.0	22912.5	350	720 min Winter	8.849	0.0	24322.1	408	960 min Winter	7.278	0.0	26666.3	524	1440 min Winter	5.520	0.0	30330.2	764	2160 min Winter	4.198	0.0	34644.4	1124	2880 min Winter	3.464	0.0	38114.3	1484	4320 min Winter	2.662	0.0	43900.8	2212	5760 min Winter	2.228	0.0	49038.0	2944	7200 min Winter	1.944	0.0	53494.0	3672	8640 min Winter	1.739	0.0	57399.1	4384	10080 min Winter	1.581	0.0	60884.9	5112
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status																																																																																																																																																																																																						
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Ove Arup & Partners International Ltd		Page 3
The Arup Campus Blyth Gate Solihull B90 8AE		
Date 29/11/2019 15:18 File Catchment 2B-1 and		
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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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 27.300

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 5.460	8	12 5.460	16	20 5.460
4	8 5.460	12	16 5.460		

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The Arup Campus Blyth Gate Solihull B90 8AE		
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XP Solutions Source Control 2018.1.1		

Model Details

Storage is Online Cover Level (m) 243.000

Tank or Pond Structure

Invert Level (m) 241.000

Depth (m)	Area (m ²)	Depth (m)	Area (m ²)
0.000	2704.0	2.000	4408.0

Orifice Outflow Control

Diameter (m) 0.819 Discharge Coefficient 0.600 Invert Level (m) 241.000

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Ove Arup & Partners International Ltd					Page 1
The Arup Campus Blyth Gate Solihull B90 8AE					
Date 03/12/2019 11:25 File 2E(1) Cascade.CASX		Designed by Checked by			
XP Solutions		Source Control 2018.1.1			
<u>Cascade Summary of Results for Catchment 2B-3.SRCX</u>					
Upstream Structures		Outflow To		Overflow To	
(None)		Catchment 2B-5.SRCX		(None)	
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	280.865	0.865	182.6	1228.8	O K
30 min Summer	281.182	1.182	220.0	1771.2	O K
60 min Summer	281.496	1.496	251.6	2359.4	O K
120 min Summer	281.716	1.716	271.5	2803.3	Flood Risk
180 min Summer	281.796	1.796	278.4	2971.6	Flood Risk
240 min Summer	281.835	1.835	281.7	3054.1	Flood Risk
360 min Summer	281.848	1.848	282.8	3082.4	Flood Risk
480 min Summer	281.822	1.822	280.6	3026.6	Flood Risk
600 min Summer	281.779	1.779	277.0	2935.7	Flood Risk
720 min Summer	281.729	1.729	272.7	2830.7	Flood Risk
960 min Summer	281.623	1.623	263.3	2612.6	O K
1440 min Summer	281.428	1.428	245.1	2227.5	O K
2160 min Summer	281.198	1.198	221.7	1800.2	O K
2880 min Summer	281.027	1.027	202.6	1499.6	O K
4320 min Summer	280.801	0.801	174.1	1125.8	O K
5760 min Summer	280.662	0.662	154.1	909.9	O K
7200 min Summer	280.573	0.573	139.7	775.1	O K
8640 min Summer	280.508	0.508	128.2	680.0	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer	80.827	0.0	1389.4	30	
30 min Summer	59.691	0.0	2060.9	41	
60 min Summer	42.167	0.0	2931.3	64	
120 min Summer	28.240	0.0	3929.3	104	
180 min Summer	21.881	0.0	4568.2	138	
240 min Summer	18.227	0.0	5074.6	172	
360 min Summer	14.024	0.0	5857.8	242	
480 min Summer	11.606	0.0	6464.7	310	
600 min Summer	10.004	0.0	6965.5	376	
720 min Summer	8.849	0.0	7394.5	442	
960 min Summer	7.278	0.0	8108.2	572	
1440 min Summer	5.520	0.0	9223.2	824	
2160 min Summer	4.198	0.0	10533.9	1188	
2880 min Summer	3.464	0.0	11589.1	1544	
4320 min Summer	2.662	0.0	13350.3	2260	
5760 min Summer	2.228	0.0	14913.5	2992	
7200 min Summer	1.944	0.0	16267.7	3688	
8640 min Summer	1.739	0.0	17454.5	4416	
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The Arup Campus Blyth Gate Solihull B90 8AE					
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<u>Cascade Summary of Results for Catchment 2B-3.SRCX</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
10080 min Summer	280.461	0.461	119.3	612.5	O K
15 min Winter	280.957	0.957	194.2	1381.2	O K
30 min Winter	281.306	1.306	233.0	1997.1	O K
60 min Winter	281.652	1.652	265.8	2670.0	O K
120 min Winter	281.891	1.891	286.4	3174.4	Flood Risk
180 min Winter	281.966	1.966	292.5	3339.8	Flood Risk
240 min Winter	281.994	1.994	294.8	3403.0	Flood Risk
360 min Winter	281.977	1.977	293.4	3364.8	Flood Risk
480 min Winter	281.916	1.916	288.5	3230.3	Flood Risk
600 min Winter	281.839	1.839	282.0	3061.9	Flood Risk
720 min Winter	281.755	1.755	274.9	2884.8	Flood Risk
960 min Winter	281.590	1.590	260.3	2544.9	O K
1440 min Winter	281.307	1.307	233.1	1998.7	O K
2160 min Winter	281.006	1.006	200.1	1463.7	O K
2880 min Winter	280.808	0.808	175.1	1137.1	O K
4320 min Winter	280.582	0.582	141.3	789.3	O K
5760 min Winter	280.470	0.470	120.9	624.5	O K
7200 min Winter	280.425	0.425	106.4	560.7	O K
8640 min Winter	280.394	0.394	95.2	516.8	O K
10080 min Winter	280.370	0.370	86.7	483.1	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
10080 min Summer	1.581	0.0	18515.3	5144	
15 min Winter	80.827	0.0	1558.4	30	
30 min Winter	59.691	0.0	2310.4	42	
60 min Winter	42.167	0.0	3284.1	66	
120 min Winter	28.240	0.0	4402.0	110	
180 min Winter	21.881	0.0	5117.5	146	
240 min Winter	18.227	0.0	5684.8	186	
360 min Winter	14.024	0.0	6562.0	260	
480 min Winter	11.606	0.0	7241.7	332	
600 min Winter	10.004	0.0	7802.7	402	
720 min Winter	8.849	0.0	8283.2	472	
960 min Winter	7.278	0.0	9082.7	604	
1440 min Winter	5.520	0.0	10332.2	856	
2160 min Winter	4.198	0.0	11798.8	1220	
2880 min Winter	3.464	0.0	12981.0	1572	
4320 min Winter	2.662	0.0	14955.0	2288	
5760 min Winter	2.228	0.0	16703.4	2952	
7200 min Winter	1.944	0.0	18220.5	3672	
8640 min Winter	1.739	0.0	19550.4	4408	
10080 min Winter	1.581	0.0	20740.5	5136	
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The Arup Campus Blyth Gate Solihull B90 8AE		
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Cascade Rainfall Details for Catchment 2B-3.SRCX

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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 9.300

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 1.860	8	12 1.860	16	20 1.860
4	8 1.860	12	16 1.860		

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XP Solutions		Source Control 2018.1.1

Cascade Model Details for Catchment 2B-3.SRCX

Storage is Online Cover Level (m) 282.000

Tank or Pond Structure

Invert Level (m) 280.000

Depth (m)	Area (m ²)	Depth (m)	Area (m ²)
0.000	1225.0	2.000	2242.0

Orifice Outflow Control

Diameter (m) 0.323 Discharge Coefficient 0.600 Invert Level (m) 280.000

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The Arup Campus Blyth Gate Solihull B90 8AE					
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File 2B-3 to 2B-5 Cascade.CASX		Checked by			
XP Solutions		Source Control 2018.1.1			
Cascade Summary of Results for Catchment 2B-4 CORRECT.SRCX					
Upstream Structures		Outflow To		Overflow To	
(None)		Catchment 2B-5.SRCX		(None)	
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	249.203	1.203	1202.5	1222.7	O K
30 min Summer	249.558	1.558	1444.0	1691.7	O K
60 min Summer	249.782	1.782	1577.9	2016.8	Flood Risk
120 min Summer	249.794	1.794	1584.4	2034.1	Flood Risk
180 min Summer	249.676	1.676	1515.8	1859.8	O K
240 min Summer	249.551	1.551	1439.9	1682.1	O K
360 min Summer	249.339	1.339	1300.1	1395.2	O K
480 min Summer	249.183	1.183	1187.1	1197.0	O K
600 min Summer	249.087	1.087	1076.9	1079.5	O K
720 min Summer	249.014	1.014	975.2	993.5	O K
960 min Summer	248.907	0.907	826.7	870.2	O K
1440 min Summer	248.775	0.775	645.2	724.3	O K
2160 min Summer	248.664	0.664	498.7	607.7	O K
2880 min Summer	248.585	0.585	412.7	527.4	O K
4320 min Summer	248.489	0.489	319.2	431.9	O K
5760 min Summer	248.444	0.444	267.7	389.0	O K
7200 min Summer	248.418	0.418	233.7	363.8	O K
8640 min Summer	248.398	0.398	208.7	345.7	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer	80.827	0.0	2226.4	27	
30 min Summer	59.691	0.0	3289.1	35	
60 min Summer	42.167	0.0	4648.9	50	
120 min Summer	28.240	0.0	6227.0	82	
180 min Summer	21.881	0.0	7237.2	112	
240 min Summer	18.227	0.0	8038.1	142	
360 min Summer	14.024	0.0	9276.3	202	
480 min Summer	11.606	0.0	10236.2	262	
600 min Summer	10.004	0.0	11028.5	320	
720 min Summer	8.849	0.0	11707.4	380	
960 min Summer	7.278	0.0	12837.2	500	
1440 min Summer	5.520	0.0	14605.5	740	
2160 min Summer	4.198	0.0	16659.9	1104	
2880 min Summer	3.464	0.0	18331.3	1472	
4320 min Summer	2.662	0.0	21127.8	2200	
5760 min Summer	2.228	0.0	23576.7	2912	
7200 min Summer	1.944	0.0	25720.5	3648	
8640 min Summer	1.739	0.0	27602.4	4400	
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Ove Arup & Partners International Ltd					Page 2
The Arup Campus Blyth Gate Solihull B90 8AE					
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<u>Cascade Summary of Results for Catchment 2B-4 CORRECT.SRCX</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
10080 min Summer	248.384	0.384	190.1	331.9	O K
15 min Winter	249.316	1.316	1284.1	1365.7	O K
30 min Winter	249.701	1.701	1530.6	1896.1	Flood Risk
60 min Winter	249.903	1.903	1645.5	2201.8	Flood Risk
120 min Winter	249.797	1.797	1586.4	2039.1	Flood Risk
180 min Winter	249.580	1.580	1457.9	1723.3	O K
240 min Winter	249.393	1.393	1337.0	1466.7	O K
360 min Winter	249.136	1.136	1145.9	1139.6	O K
480 min Winter	249.010	1.010	970.3	989.1	O K
600 min Winter	248.921	0.921	846.6	886.3	O K
720 min Winter	248.854	0.854	753.6	811.1	O K
960 min Winter	248.759	0.759	624.6	707.8	O K
1440 min Winter	248.647	0.647	476.2	590.3	O K
2160 min Winter	248.534	0.534	363.2	476.3	O K
2880 min Winter	248.470	0.470	300.4	413.4	O K
4320 min Winter	248.416	0.416	231.1	361.9	O K
5760 min Winter	248.386	0.386	193.3	334.4	O K
7200 min Winter	248.365	0.365	168.8	314.2	O K
8640 min Winter	248.341	0.341	150.8	292.3	O K
10080 min Winter	248.323	0.323	137.3	275.7	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
10080 min Summer	1.581	0.0	29291.0	5112	
15 min Winter	80.827	0.0	2493.8	27	
30 min Winter	59.691	0.0	3683.9	35	
60 min Winter	42.167	0.0	5206.7	52	
120 min Winter	28.240	0.0	6974.2	84	
180 min Winter	21.881	0.0	8105.3	116	
240 min Winter	18.227	0.0	9002.3	146	
360 min Winter	14.024	0.0	10389.5	202	
480 min Winter	11.606	0.0	11464.6	262	
600 min Winter	10.004	0.0	12352.0	322	
720 min Winter	8.849	0.0	13112.3	382	
960 min Winter	7.278	0.0	14377.7	502	
1440 min Winter	5.520	0.0	16358.3	742	
2160 min Winter	4.198	0.0	18659.1	1104	
2880 min Winter	3.464	0.0	20531.1	1468	
4320 min Winter	2.662	0.0	23663.4	2168	
5760 min Winter	2.228	0.0	26405.5	2888	
7200 min Winter	1.944	0.0	28806.9	3616	
8640 min Winter	1.739	0.0	30914.7	4400	
10080 min Winter	1.581	0.0	32806.3	5136	
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The Arup Campus Blyth Gate Solihull B90 8AE		
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Cascade Rainfall Details for Catchment 2B-4 CORRECT.SRCX

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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 14.700

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 2.940	8	12 2.940	16	20 2.940
4	8 2.940	12	16 2.940		

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The Arup Campus Blyth Gate Solihull B90 8AE		
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Cascade Model Details for Catchment 2B-4 CORRECT.SRCX

Storage is Online Cover Level (m) 250.000

Tank or Pond Structure

Invert Level (m) 248.000

Depth (m)	Area (m ²)	Depth (m)	Area (m ²)
0.000	800.0	2.000	1600.0

Orifice Outflow Control

Diameter (m) 0.802 Discharge Coefficient 0.600 Invert Level (m) 248.000

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Ove Arup & Partners International Ltd					Page 1
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File 2B-3 to 2B-5 Cascade.CASX		Checked by			
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<u>Cascade Summary of Results for Catchment 2B-5.SRCX</u>					
Upstream Structures		Outflow To Overflow To			
Catchment 2B-3.SRCX		(None)		(None)	
Catchment 2B-4 CORRECT.SRCX					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	239.885	0.885	723.4	1807.1	O K
30 min Summer	240.191	1.191	1005.9	2536.4	O K
60 min Summer	240.537	1.537	1198.0	3430.6	O K
120 min Summer	240.777	1.777	1315.1	4097.8	Flood Risk
180 min Summer	240.842	1.842	1345.0	4283.9	Flood Risk
240 min Summer	240.856	1.856	1351.1	4322.7	Flood Risk
360 min Summer	240.803	1.803	1327.2	4172.0	Flood Risk
480 min Summer	240.709	1.709	1283.1	3905.2	Flood Risk
600 min Summer	240.610	1.610	1235.0	3630.4	O K
720 min Summer	240.517	1.517	1188.0	3378.5	O K
960 min Summer	240.357	1.357	1102.5	2957.6	O K
1440 min Summer	240.133	1.133	969.9	2393.2	O K
2160 min Summer	239.967	0.967	821.7	1997.0	O K
2880 min Summer	239.876	0.876	712.0	1786.3	O K
4320 min Summer	239.765	0.765	579.4	1535.3	O K
5760 min Summer	239.697	0.697	499.0	1385.6	O K
7200 min Summer	239.648	0.648	442.9	1279.7	O K
8640 min Summer	239.611	0.611	401.0	1200.5	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer	80.827	0.0	4268.4	40	
30 min Summer	59.691	0.0	6333.2	51	
60 min Summer	42.167	0.0	9017.9	74	
120 min Summer	28.240	0.0	12086.9	110	
180 min Summer	21.881	0.0	14051.3	140	
240 min Summer	18.227	0.0	15608.6	172	
360 min Summer	14.024	0.0	18016.4	234	
480 min Summer	11.606	0.0	19882.0	296	
600 min Summer	10.004	0.0	21421.5	356	
720 min Summer	8.849	0.0	22740.1	418	
960 min Summer	7.278	0.0	24933.0	538	
1440 min Summer	5.520	0.0	28359.2	776	
2160 min Summer	4.198	0.0	32399.0	1132	
2880 min Summer	3.464	0.0	35643.3	1496	
4320 min Summer	2.662	0.0	41050.9	2216	
5760 min Summer	2.228	0.0	45865.6	2944	
7200 min Summer	1.944	0.0	50031.7	3680	
8640 min Summer	1.739	0.0	53681.2	4408	
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<u>Cascade Summary of Results for Catchment 2B-5.SRCX</u>					
Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
10080 min Summer	239.582	0.582	367.8	1139.0	O K
15 min Winter	239.965	0.965	819.9	1993.4	O K
30 min Winter	240.304	1.304	1072.4	2820.7	O K
60 min Winter	240.683	1.683	1270.6	3832.2	O K
120 min Winter	240.941	1.941	1389.3	4573.4	Flood Risk
180 min Winter	240.978	1.978	1405.5	4683.4	Flood Risk
240 min Winter	240.949	1.949	1392.8	4597.6	Flood Risk
360 min Winter	240.802	1.802	1326.7	4168.7	Flood Risk
480 min Winter	240.640	1.640	1249.7	3713.1	O K
600 min Winter	240.494	1.494	1176.1	3316.7	O K
720 min Winter	240.368	1.368	1108.6	2985.8	O K
960 min Winter	240.172	1.172	994.5	2490.3	O K
1440 min Winter	239.971	0.971	826.5	2005.6	O K
2160 min Winter	239.834	0.834	661.7	1689.8	O K
2880 min Winter	239.749	0.749	561.0	1500.5	O K
4320 min Winter	239.646	0.646	441.1	1276.4	O K
5760 min Winter	239.588	0.588	374.1	1150.7	O K
7200 min Winter	239.535	0.535	327.3	1040.1	O K
8640 min Winter	239.494	0.494	293.0	954.9	O K
10080 min Winter	239.463	0.463	266.6	890.5	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
10080 min Summer	1.581	0.0	56934.9	5144	
15 min Winter	80.827	0.0	4787.9	41	
30 min Winter	59.691	0.0	7100.6	53	
60 min Winter	42.167	0.0	10103.0	76	
120 min Winter	28.240	0.0	13540.3	114	
180 min Winter	21.881	0.0	15740.4	146	
240 min Winter	18.227	0.0	17484.7	178	
360 min Winter	14.024	0.0	20181.7	242	
480 min Winter	11.606	0.0	22271.4	306	
600 min Winter	10.004	0.0	23995.9	368	
720 min Winter	8.849	0.0	25473.0	430	
960 min Winter	7.278	0.0	27930.0	550	
1440 min Winter	5.520	0.0	31769.9	782	
2160 min Winter	4.198	0.0	36288.8	1148	
2880 min Winter	3.464	0.0	39923.7	1508	
4320 min Winter	2.662	0.0	45986.2	2224	
5760 min Winter	2.228	0.0	51369.8	2944	
7200 min Winter	1.944	0.0	56037.1	3680	
8640 min Winter	1.739	0.0	60126.9	4416	
10080 min Winter	1.581	0.0	63778.2	5144	
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The Arup Campus Blyth Gate Solihull B90 8AE		
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Cascade Rainfall Details for Catchment 2B-5.SRCX

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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 4.600

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 0.920	8	12 0.920	16	20 0.920
4	8 0.920	12	16 0.920		

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The Arup Campus Blyth Gate Solihull B90 8AE										
Date 03/12/2019 11:37 File 2B-3 to 2B-5 Cascade.CASX										
Designed by Checked by										
XP Solutions		Source Control 2018.1.1								
<u>Cascade Model Details for Catchment 2B-5.SRCX</u> Storage is Online Cover Level (m) 241.000 <u>Tank or Pond Structure</u> Invert Level (m) 239.000 <table border="1"> <thead> <tr> <th>Depth (m)</th> <th>Area (m²)</th> <th>Depth (m)</th> <th>Area (m²)</th> </tr> </thead> <tbody> <tr> <td align="center">0.000</td> <td align="center">1800.0</td> <td align="center">2.000</td> <td align="center">3000.0</td> </tr> </tbody> </table> <u>Orifice Outflow Control</u> Diameter (m) 0.728 Discharge Coefficient 0.600 Invert Level (m) 239.000			Depth (m)	Area (m ²)	Depth (m)	Area (m ²)	0.000	1800.0	2.000	3000.0
Depth (m)	Area (m ²)	Depth (m)	Area (m ²)							
0.000	1800.0	2.000	3000.0							
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F7 Catchment 3A

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The Arup Campus Blyth Gate Solihull B90 8AE						
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File Catchment 3A Pond.SRCX		Checked by				
XP Solutions		Source Control 2018.1.1				
<u>Summary of Results for 100 year Return Period (+40%)</u>						
Storm Event		Max Level (m)	Max Depth (m)	Max Control (1/s)	Max Volume (m³)	Status
15 min Summer		253.799	0.899	59.5	295.6	O K
30 min Summer		254.067	1.167	68.7	429.3	O K
60 min Summer		254.299	1.399	75.7	565.6	O K
120 min Summer		254.440	1.540	79.7	657.7	O K
180 min Summer		254.479	1.579	80.7	684.7	O K
240 min Summer		254.490	1.590	81.0	692.4	O K
360 min Summer		254.473	1.573	80.6	680.4	O K
480 min Summer		254.434	1.534	79.5	653.9	O K
600 min Summer		254.388	1.488	78.2	622.8	O K
720 min Summer		254.339	1.439	76.8	590.6	O K
960 min Summer		254.239	1.339	73.9	528.3	O K
1440 min Summer		254.059	1.159	68.4	425.4	O K
2160 min Summer		253.849	0.949	61.3	318.8	O K
2880 min Summer		253.694	0.794	55.5	249.5	O K
4320 min Summer		253.493	0.593	46.9	170.2	O K
5760 min Summer		253.377	0.477	41.2	129.7	O K
7200 min Summer		253.300	0.400	36.9	104.9	O K
8640 min Summer		253.244	0.344	33.4	87.9	O K
10080 min Summer		253.203	0.303	30.6	75.9	O K
15 min Winter		253.882	0.982	62.5	334.3	O K
30 min Winter		254.168	1.268	71.8	486.1	O K
Storm Event		Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
15 min Summer		113.158	0.0	359.9	29	
30 min Summer		83.568	0.0	531.9	40	
60 min Summer		59.033	0.0	752.5	62	
120 min Summer		39.536	0.0	1008.0	100	
180 min Summer		30.634	0.0	1171.5	134	
240 min Summer		25.518	0.0	1301.2	168	
360 min Summer		19.633	0.0	1501.7	238	
480 min Summer		16.249	0.0	1657.1	306	
600 min Summer		14.005	0.0	1785.3	372	
720 min Summer		12.389	0.0	1895.2	436	
960 min Summer		10.189	0.0	2078.0	564	
1440 min Summer		7.728	0.0	2364.2	810	
2160 min Summer		5.877	0.0	2697.3	1172	
2880 min Summer		4.850	0.0	2967.8	1528	
4320 min Summer		3.726	0.0	3420.2	2248	
5760 min Summer		3.119	0.0	3817.2	2952	
7200 min Summer		2.722	0.0	4164.2	3680	
8640 min Summer		2.434	0.0	4468.8	4408	
10080 min Summer		2.214	0.0	4741.8	5136	
15 min Winter		113.158	0.0	403.2	30	
30 min Winter		83.568	0.0	595.8	41	
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The Arup Campus Blyth Gate Solihull B90 8AE					
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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	254.420	1.520	79.1	644.3	O K
120 min Winter	254.569	1.669	83.1	748.7	O K
180 min Winter	254.602	1.702	84.0	773.1	Flood Risk
240 min Winter	254.602	1.702	84.0	773.3	Flood Risk
360 min Winter	254.556	1.656	82.8	739.3	O K
480 min Winter	254.485	1.585	80.9	688.9	O K
600 min Winter	254.407	1.507	78.8	635.6	O K
720 min Winter	254.328	1.428	76.5	583.8	O K
960 min Winter	254.175	1.275	72.0	490.6	O K
1440 min Winter	253.918	1.018	63.8	352.3	O K
2160 min Winter	253.651	0.751	53.8	231.3	O K
2880 min Winter	253.481	0.581	46.4	166.0	O K
4320 min Winter	253.299	0.399	36.8	104.6	O K
5760 min Winter	253.210	0.310	31.1	78.1	O K
7200 min Winter	253.159	0.259	27.2	63.5	O K
8640 min Winter	253.137	0.237	24.4	57.6	O K
10080 min Winter	253.122	0.222	22.2	53.5	O K
Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)	
60 min Winter	59.033	0.0	842.8	64	
120 min Winter	39.536	0.0	1128.9	106	
180 min Winter	30.634	0.0	1312.1	144	
240 min Winter	25.518	0.0	1457.3	182	
360 min Winter	19.633	0.0	1681.9	256	
480 min Winter	16.249	0.0	1855.9	326	
600 min Winter	14.005	0.0	1999.6	396	
720 min Winter	12.389	0.0	2122.7	462	
960 min Winter	10.189	0.0	2327.5	590	
1440 min Winter	7.728	0.0	2648.0	836	
2160 min Winter	5.877	0.0	3021.0	1192	
2880 min Winter	4.850	0.0	3324.0	1540	
4320 min Winter	3.726	0.0	3830.7	2248	
5760 min Winter	3.119	0.0	4275.2	2944	
7200 min Winter	2.722	0.0	4663.9	3672	
8640 min Winter	2.434	0.0	5005.1	4400	
10080 min Winter	2.214	0.0	5311.0	5048	
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Ove Arup & Partners International Ltd		Page 3
The Arup Campus Blyth Gate Solihull B90 8AE		
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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	0.200	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.700

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From:	To:	From:	To:	From:	To:
0	4 0.340	8	12 0.340	16	20 0.340
4	8 0.340	12	16 0.340		

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Ove Arup & Partners International Ltd		Page 4
The Arup Campus Blyth Gate Solihull B90 8AE		
Date 03/12/2019 11:39 File Catchment 3A Pond.SRCX	Designed by Checked by	
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Model Details

Storage is Online Cover Level (m) 254.900

Tank or Pond Structure

Invert Level (m) 252.900

Depth (m)	Area (m ²)	Depth (m)	Area (m ²)
0.000	216.0	1.800	786.0

Orifice Outflow Control

Diameter (m) 0.178 Discharge Coefficient 0.600 Invert Level (m) 252.900

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