Pentwyn Lake: Hydraulic Modelling Report

Final

April 2025

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Cardiff Council

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Contract

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JBA Project Code	2025s0081

This report describes work commissioned by Cardiff Council, by an instruction dated 4 February 2025. The Client's representative for the contract was Mark Synan. Ellen Corry and Gavin Hodson of JBA Consulting carried out this work.

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The methodology adopted and the sources of information used by JBA in providing its services are outlined in this Report. The work described in this Report was undertaken between February and April 2025 and is based on the conditions encountered and the information available during the said period. The scope of this Report and the services are accordingly factually limited by these circumstances.

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Acknowledgements

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AOD	Above Ordnance Datum
BFI	Base Flow Index
CEH	Centre for Ecology and Hydrology
DPLBAR	Index describing catchment size and drainage path configuration
DPSBAR	FEH index of mean drainage path slope
DTM	Digital Terrain Model
EA	Environment Agency
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FPEXT	FEH index describing floodplain extent
HEC-RAS	Hydrologic Engineering Center – River Analysis System (developed by the US Army)
LiDAR	Light Detection And Ranging
NRW	Natural Resources for Wales
PM	Project Manager
PROPWET	FEH index of proportion of time that soil is wet
SAAR	Standard Average Annual Rainfall (mm)
US	Upstream
XS	Cross Section

Executive Summary

Overview

JBA were commissioned by Cardiff Council to undertake a hydrological assessment of the Nant Glandulas watercourse at Pentwyn Lake, Cardiff. Works had recently been undertaken on a pipe abstraction which takes flow from the Nant Glandulas to Pentwyn Lake. The works involved raising and replacing the existing pipe outfall to the level of a weir crest just downstream from the abstraction location. The works were not carried out to the design specification with a larger 300mm pipe installed just above the designed weir crest level.

Hydraulic Modelling

A 1D hydraulic model was built using HEC-RAS 6.7 to determine the portioning of flow between the main river channel and the abstraction system. Two separate scenarios were modelled; the 'as-built' scenario models the abstraction system as it is today, and the 'baseline' scenario represents how the system was originally.

- Baseline: a single 150mm pipe from the river to the lake, with an inlet invert level of 10.62m AOD.
- As-built: includes a short section of 300mm pipe at the inlet (invert level 11.02m AOD), connecting to a new manhole. The original 150 mm pipe from the manhole to the lake is retained.

Table 1-1 shows the results of the model simulations for a series of hydrological inputs estimated using LowFlows2 and REFH2 software to determine how the abstraction functions during more commonly occurring flows (Qn) and lower return period storm events (REFH2 n-year flows).

Table 1-1: Flow apportionment between the weir and pipe flow (m^3/s)

Event (flow applied)	Baseline weir flow	Baseline Pipe flow (10.62mAOD, 150mm) (% of applied flow)	As-built Weir flow	As-built Pipe flow (11.02mAOD, 300mm) (% of applied flow)
REFH2 5-year (5.07)	5.051	0.020 (0.39%)	5.051	0.020 (0.4%)
REFH2 2-year (3.7)	3.681	0.019 (0.51%)	3.681	0.020 (0.54%)
REFH2 1-year (3.26)	3.241	0.019 (0.58%)	3.240	0.019 (0.58%)
Q10 (0.497)	0.487	0.015 (2.99%)	0.485	0.013 (2.62%)

Event (flow applied)	Baseline weir flow	Baseline Pipe flow (10.62mAOD, 150mm) (% of applied flow)	As-built Weir flow	As-built Pipe flow (11.02mAOD, 300mm) (% of applied flow)
Q50 (0.102)	0.133	0.014 (9.59%)	0.147	0.001 (0.68%)
Q75 (0.046)	0.096	0.014 (12.8%)	0.110	0.000 (n/a)
Q95 (0.023)	0.079	0.014 (15.2%)	0.095	0.000 (n/a)
*flows have been rounded to 3 decimal places				

Conclusion

The model demonstrates the following:

- The reconfigured offtake pipe begins to receive flow from the Q50 scenario and becomes active by Q10, due to the raised invert level of the new 300mm pipe section. As a result, abstraction to the lake is reduced compared to the original configuration, which operated at lower flow levels (including Q95).
- Maximum peak pipe flows are 0.02m^3/s, which is the same as the baseline. This is due to a section of the 150mm diameter pipe being retained in the new arrangement.

Table 1-1 summarises the response to queries issued by NRW to Cardiff Council regarding the functioning of the new pipe abstraction.

Table 1-2:NRW hydrological information request summary

NRW information request	JBA response
Flow split/ flow apportionment across the range of flows (so a range of flow percentiles with flow volumes both over the weir and through the pipe).	In the as-built configuration, the abstraction pipe takes no more than 2% of the total flow in the Nant Glandulas immediately upstream of the offtake, across the range of modelled flows.
Confirmation of the relationship between the low point on the weir and the bottom of the pipe which will then tell us whether this is a hands-off flow as it is built, and if so, what flow percentile this is equivalent to.	The inlet invert of the reconfigured abstraction pipe is positioned at 11.02 m AOD, which is 60 mm higher than the lowest point of the downstream weir crest (10.96 m AOD). The reconfigured offtake pipe begins to receive flow from the Q50 scenario and becomes active by Q10. In contrast, the previous (baseline) pipe was active during Q95 flows (0.023m^3/s), abstracting approximately 43% of the flow. There is consequently a significant reduction in abstraction during low flow conditions.

1 Introduction

1.1 Overview

Pentwyn Lake is a fishing lake located in Parc Coed Y Nant, an urban woodland in northeast Cardiff (Figure 1-1). Nant Glandulas, a tributary of the Afon Rhymni, flows roughly 30m north of the lake. Flow is abstracted from Nant Glandulas watercourse via a culvert connecting to the northwest corner of the lake. Cardiff Council undertook works to this abstraction system however this work deviated from the plans approved by Natural Resources Wales (NRW). Concerns over the volume of water abstracted from Nant Glandulas under low flow conditions were raised by NRW who have requested a hydrological assessment of the abstraction to understand how it performs under a range of flow conditions.

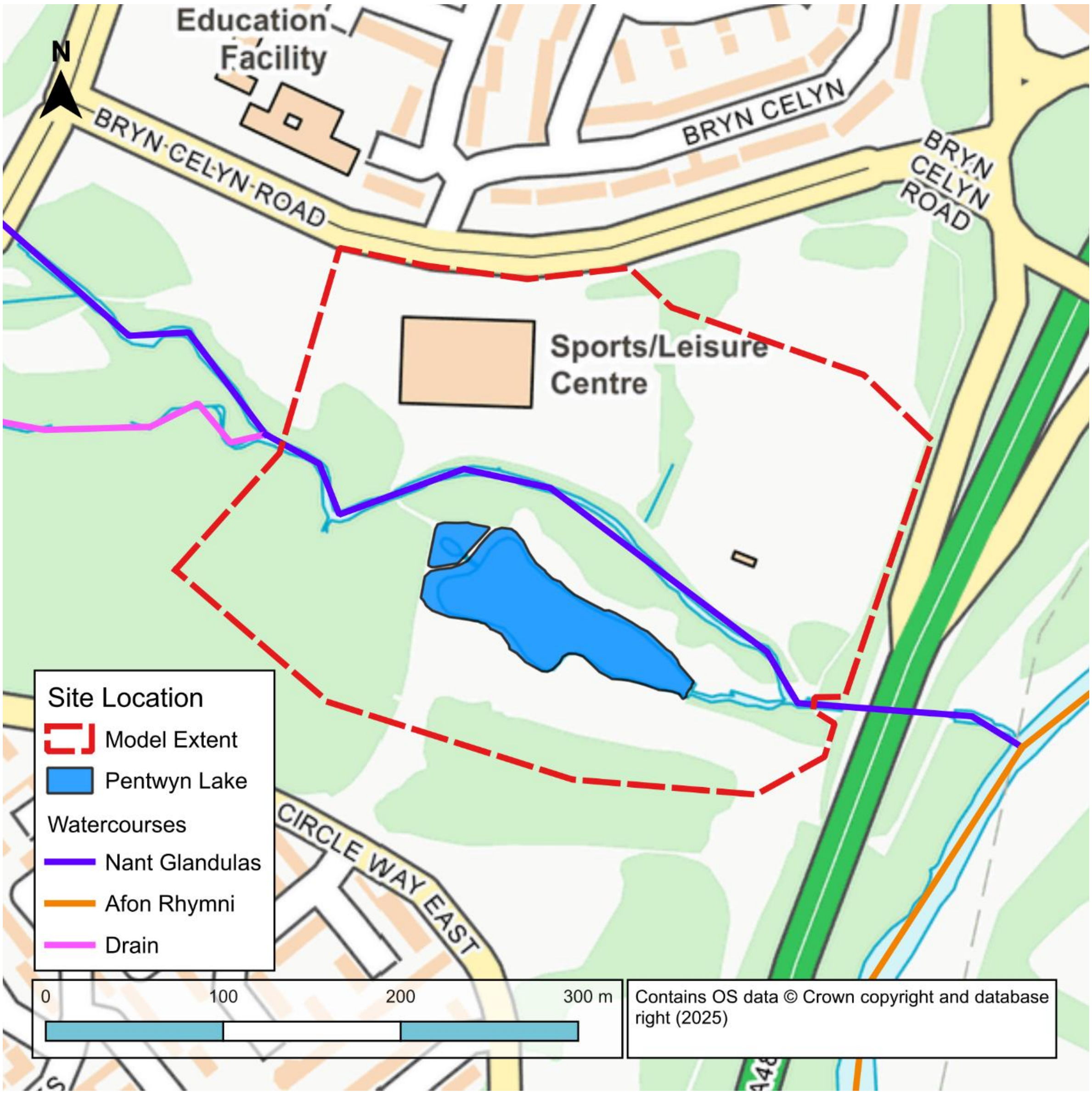


Figure 1-1: Site location

1.2 General Arrangement

Works were undertaken to alter the offtake pipe that supplies water to Pentwyn Lake. The existing pipe (150mmm) connected the watercourse directly to the lake. Following the works, a short section of pipe (300mm dia) was added from the river to a newly constructed manhole. From the manhole to the lake the 150mm diameter pipe was retained. The arrangement of the as-built abstraction system is shown in Figure 1-2. The figure also shows the location of a weir on the Nant Glandulas, situated a short distance downstream of the offtake pipe inlet.

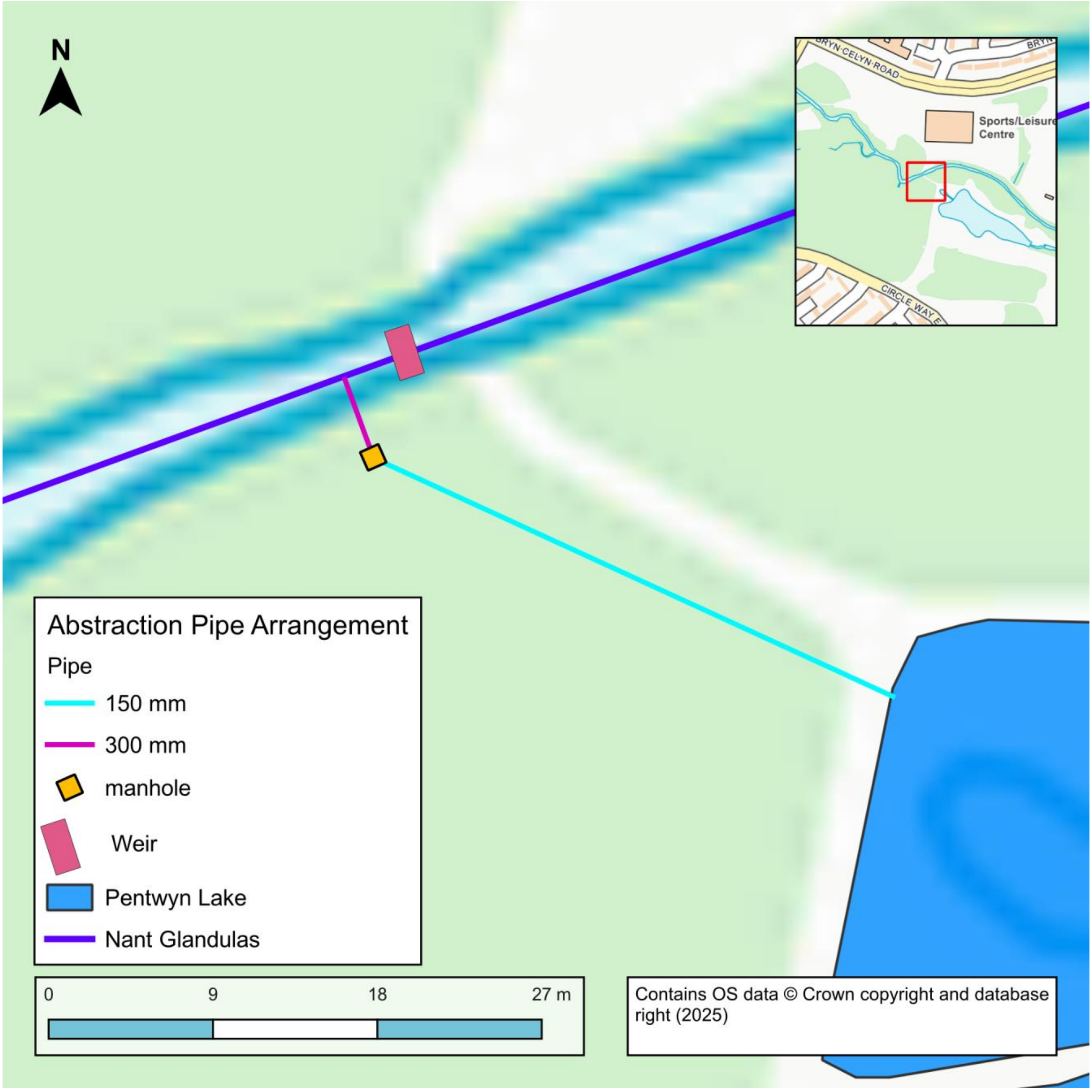


Figure 1-2: As-built abstraction pipe arrangement

1.3 Requirements

JBA were commissioned to conduct the hydrological assessment of the abstraction from Nant Glandulas into Pentwyn Lake. The work involved calculating low flows and peak flows for a variety of events; the values from which have been used in a 1D hydraulic model to model two scenarios listed below:

1. Baseline: past survey data used to reproduce and investigate the performance of the abstraction prior to the works.
2. As-built: Using the new survey data to investigate the performance of the abstraction in its current configuration.

2 Hydrology

2.1 Catchment overview

The Nant Glandulas catchment upstream of Pentwyn Lake, as shown in Figure 2-1, is 9.74km^2. The watercourse is a tributary of the Afon Rhymni, which flows into the mouth of the River Severn to the east of Cardiff.

Nant Glandulas starts in open farmland north of Pontprennau where it flows southwest, joined by Nant y Felin originating from fields north of the M4. The river flows south towards Cardiff, remaining mostly open channel as it passes through suburban areas in northwest Cardiff before meeting the Afon Rhymni 150m southeast of Pentwyn Lake.

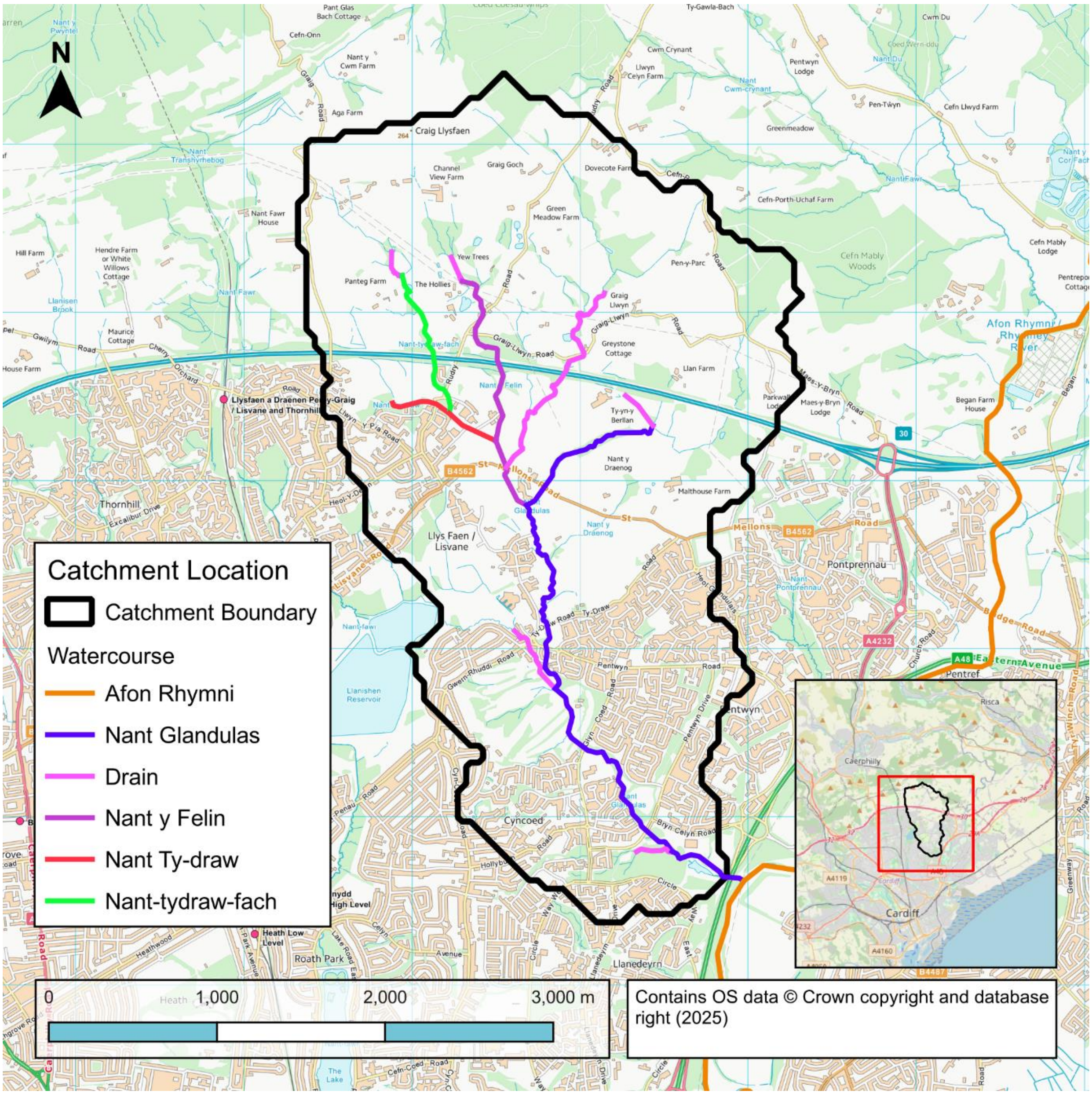


Figure 2-1: Catchment location

2.2 Flow Estimation

2.2.1 Catchment Characteristics

The Flood Estimation Handbook (FEH) Web Service[1] was used to download catchment characteristics for Nant Glandulas. Key catchment characteristics are listed in Table 2-1 and were derived for the Nant Glandulas catchment to a sample point at the downstream boundary of the model. This is approximately 40m northwest of the A48 (ST 20850 80650).

Table 2-1 Catchment descriptors for the Nant Glandulas catchment

Catchment Descriptor	Value
Area ($km^{2)}$	9.74
BFIHOST19	0.557
DPLBAR	3.65
DPSBAR	72.8
FARL	0.968
FPEXT	0.0489
PROPWET	0.47
SAAR	1187
URBEXT2000	0.108
Definitions of the above catchment descriptors can be found here.	

2.2.2 Revitalised Flood Hydrograph (REFH2)

The Revitalised Flood Hydrograph (REFH2) method was used to estimate peak flows resulting from an estimated rainfall depth for a given frequency and duration. The catchment characteristics given in Table 2-1 were applied to the REFH2 software. The urban model was selected over the rural model to derive the peak flows for the Nant Glandulas for 1, 2 and 5-year events which are shown in Table 2-2.

Table 2-2 Peak flows for a given event frequency derived from the REFH2 method

Design Event Frequency (years)	Peak Flow (m^3/s)
1	3.26
2	3.70
5	5.07

[1] https://fehweb.ceh.ac.uk/Map

2.2.3 Low Flows (LowFlows2)

The hydrological software LowFlows2 was used to estimate a series of low flows. This software calculates the river flow for a set of flow exceedance percentiles in an ungauged catchment based on hydrological estimation methods developed by the Centre for Ecology and Hydrology (CEH) and the Environment Agency (EA). The inputs used to derive the low flows are indicated in Table 2-3: Catchment characteristics applied to the LowFlows2 method for flow estimation. An updated value for the Nant Glandulas catchment area was used, as the catchment shapefile needed to be trimmed to fit within the Taff area boundary. This is simply a workaround for a bug in the software. A scaling value of 1.07 ($\frac{\text{Original catchment area}}{\text{New catchment area}}\ \frac{9.74}{9.09}$) has therefore been applied to the LowFlows2 results herein to account for this alteration and produce the flow related to the true catchment area.

Table 2-3: Catchment characteristics applied to the LowFlows2 method for flow estimation

Catchment Characteristic	Input
Region	England: Wales
Area	(57) Taff
Boundary Source	Imported Polygon
Catchment Area (km²) (updated)	9.09
Significant Lakes in Catchment	No
Grid-resolution used for derivation of catchment characteristics (m)	50
Runoff (mm)	707.2
BFI	0.55

Table 2-4 shows the low flow values that have been applied to the hydraulic models. The flow percentile number denotes the percentage of time that flows equal or exceed the given value. For example, the Q95 value of 0.023 m^3/s means that flow at the point of interest is equal to or greater than 0.023 m^3/s for 95% of the time in a given year. The lowflows2 output has not been validated against local hydrometric data.

Table 2-4 Low flows for a given flow percentile derived from the LowFlows2 method.

Flow Percentile	Low flow (m^3/s)
Q1	1.842
Q5	0.815
Q10	0.497
Q50	0.102
Q75	0.046
Q95	0.023

3 Hydraulic Model Build

3.1 Overview

A 1D hydraulic model was built using HEC-RAS 6.7 to determine the portioning of flow between the main river channel and the abstraction system. Two separate scenarios were modelled; the 'as-built' scenario models the abstraction system as it is today, and the 'baseline' scenario represents how the system was originally. Details of the representation of the weir and pipe abstraction are provided in Section 3.3.

3.2 Available data

Table 3-1 summarises the available data used in the two model scenarios. Data related to the state of the abstraction system before the alterations were made are labelled 'baseline'. The 'as-built' scenario denotes the condition of the abstraction system as it appears today and is labelled as such.

LiDAR data obtained from NRW was updated using the channel cross section survey data collected by Storm Geomatics in February 2025 and bed levels in Pentwyn Lake were updated by survey data collected by Azimuth Land Surveys Limited in October 2020. This data was used to create a detailed DTM for the hydraulic models. Additionally, drawings from Cardiff Council (Table 3-1) were used as the data source for the pipe invert level and diameter in the 'baseline' scenarios. The invert level and diameter of the pipe in its current configuration was measured by Storm Geomatics as part of the topographic survey. These levels are important to determine the partition of flow between the abstraction pipe and Nant Glandulas under the variety of flows required to satisfy the modelling assessment and determine the impact the alterations have had. The abstraction system pre-works and the condition of the system post-alteration is shown in Figure 3-1 and Figure 3-2 respectively.

Table 3-1: Available Data

Data	Source	Information	Baseline / As-built (Date produced)
Topographic Survey	Storm Geomatics	Topographic survey gathered in February 2025 used to edit LiDAR. Thirteen channel cross sections were taken along a 400m reach which includes three sections along the weir structure as well as pipe invert level and	Baseline (cross sections only)/ As-built (pipe survey) (February 2025)

Data	Source	Information	Baseline / As-built (Date produced)
		diameter measurements.	
Topographic Survey	Azimuth Land Surveys Limited	Job Number: SC3818 Drawing Number: SC3818-01 Topographic survey of Pentwyn Lake used to update the DTM representing bed levels in the lake	Baseline / As-built (October 2020)
Site Photos	JBA	Images of key structures including weir, abstraction pipe and downstream lake dam	As-built (09/01/2025)
Site Drawings	Salt Consulting	Drawing: Location of works and proposed details (Project No. 2022-17) Drawing Number: SCL/001 Revision: B Schematic for proposed alterations to pipe invert level which includes original level and pipe diameter.	Baseline (April 2022)
Site Photos	Earth Science Partnership (ESP)	Photo of original abstraction pipe inlet with metal grid in place.	Baseline (June 2023)
LiDAR	NRW	1m LiDAR data required for the hydraulic model. This data has been updated using data gathered from the topographic survey.	Baseline / As-built (April 2022)

Figure 3-1: Abstraction pipe pre-alteration, photograph taken by ESP in June 2023.

Figure 3-2: Abstraction pipe post alteration, photograph taken by JBA on 09/01/2025.

3.3 Model build

The model represents the ~387m reach of Nant Glandulas. Details of how the watercourse, lake and structures have been represented are provided in Table 3-2. Two structures have been included in the model; the weir and abstraction pipe. These have both been represented based on the available data (Table 3-1). The abstraction pipe connects the watercourse to Pentwyn Lake. As mentioned in Section 1.2, the only physical change on the ground is at the inlet: a short section (~1.25 m) has been replaced with a larger 300 mm pipe, and a new manhole has been installed. The original 150 mm pipe from the manhole to the lake has been retained.

In the hydraulic model, the abstraction is represented differently for each scenario:

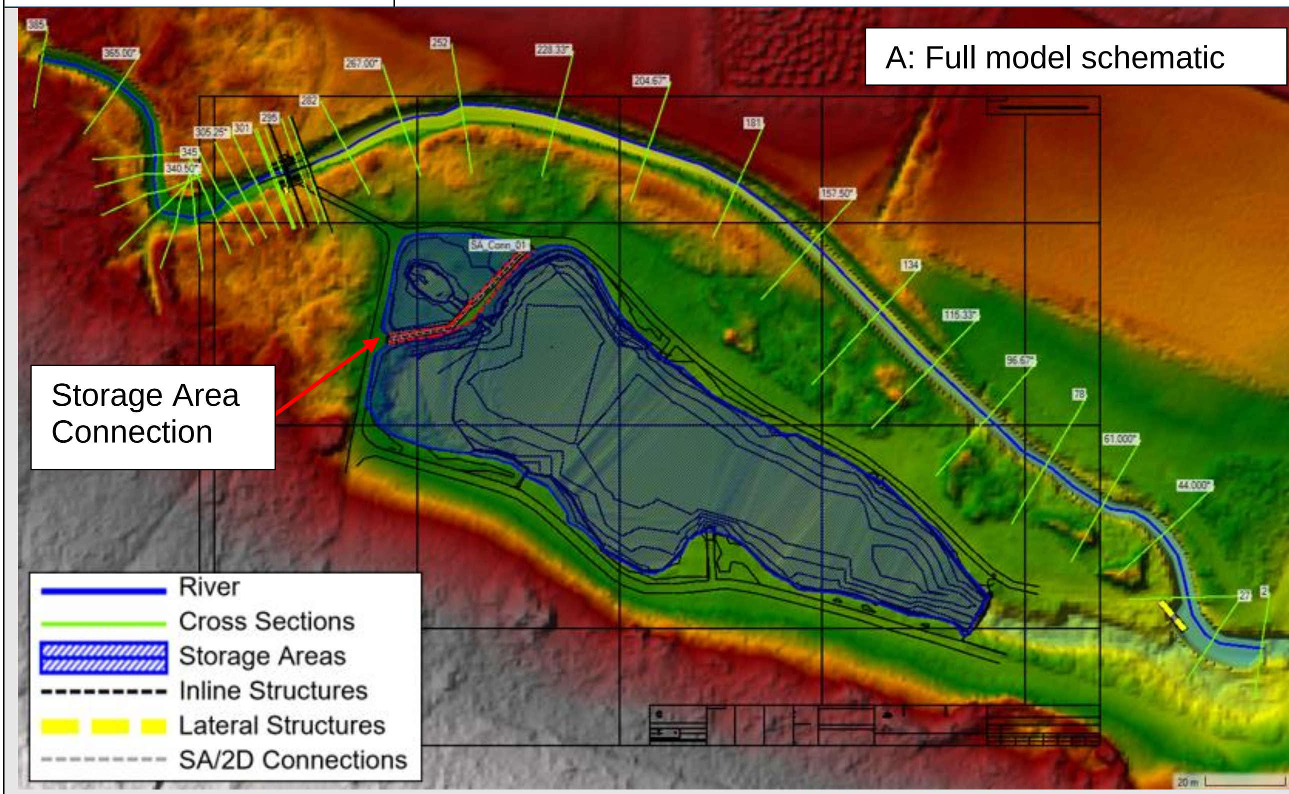
- Baseline: a single 150 mm pipe with an invert level of 10.62m AOD.
- As-built: two sections - the first (inlet) section is a 300mm pipe with an invert level of 11.02m AOD, connecting the Nant Glandulas to a manhole; the second section is the original 150 mm pipe connecting the manhole to the lake.

The model schematic 'b' in Table 3-2 shows the representation of the abstraction for the as-built scenario.

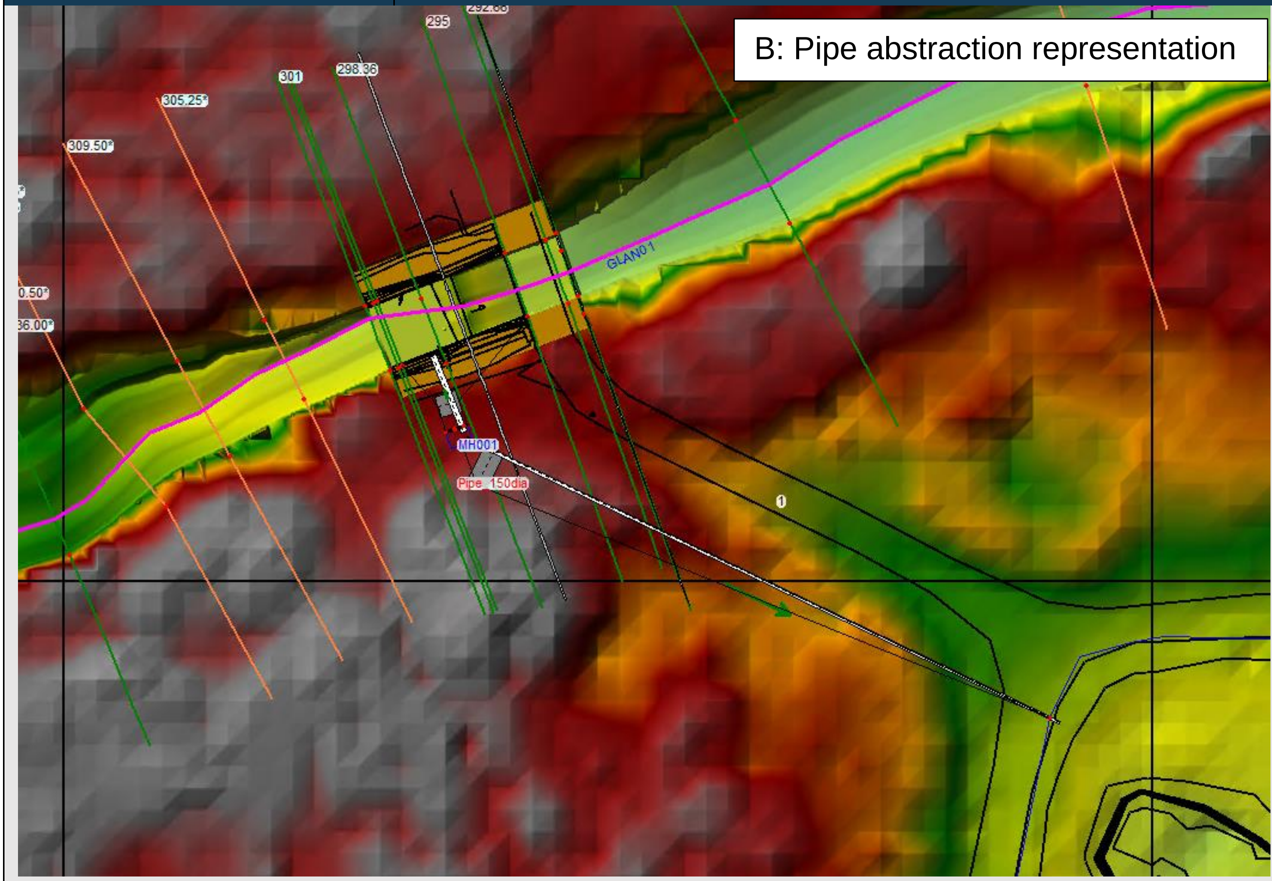
Table 3-2: Model Overview

Model Overview	
Model name	Pentwyn_Lake
Software (version)	HEC-RAS (6.7 (beta))
Model type	1D
Length of modelled watercourse	387m
Simulation Parameters	Start Time: 04/03/2025 - 00:00 End Time: 04/03/2025 - 02:00 Computation interval: 1 second Output interval (Hydrograph, Mapping, Detailed): 10 minutes
Hydrological Boundary Conditions	Upstream - flow hydrograph - range of LowFlows2 and REFH2 flows from Table 2-4 and Table 2-2. Downstream - normal depth (0.0071) Initial water levels: Pentwyn Lake - 10.32mAOD, SA_2 (smaller pond) - 10.35mAOD.
Model terrain	Terrain_Topo_XS_100mm_v02
Storage areas	1. Pentwyn_Lake 2. SA_2 - Smaller Pond receiving the Nant Glandulas abstraction

Model Overview	
Cross sections	11 survey sections 18 interpolated cross sections
Inline structures	Station 297.1: Initial weir crest Station 292.01: Final weir crest in the weir sequence
Lateral structures	1. Represents culvert 2. Represents the lake outfall and downstream connection to Nant Glandulas
Storage Area Connections	SA_Conn_01: Represents the culvert connection between the smaller pond and Pentwyn Lake.
Topographic alteration	The NRW LiDAR terrain has been edited with surveyed channel bed levels and topographic survey of the lake.
Mannings N Roughness	Cross sections were given a mannings n roughness coefficient based on photographs collected during the topographic survey. The Roughness values range between 0.035 and 0.04 for the bed and 0.04 and 0.06 for the banks.



Model Overview



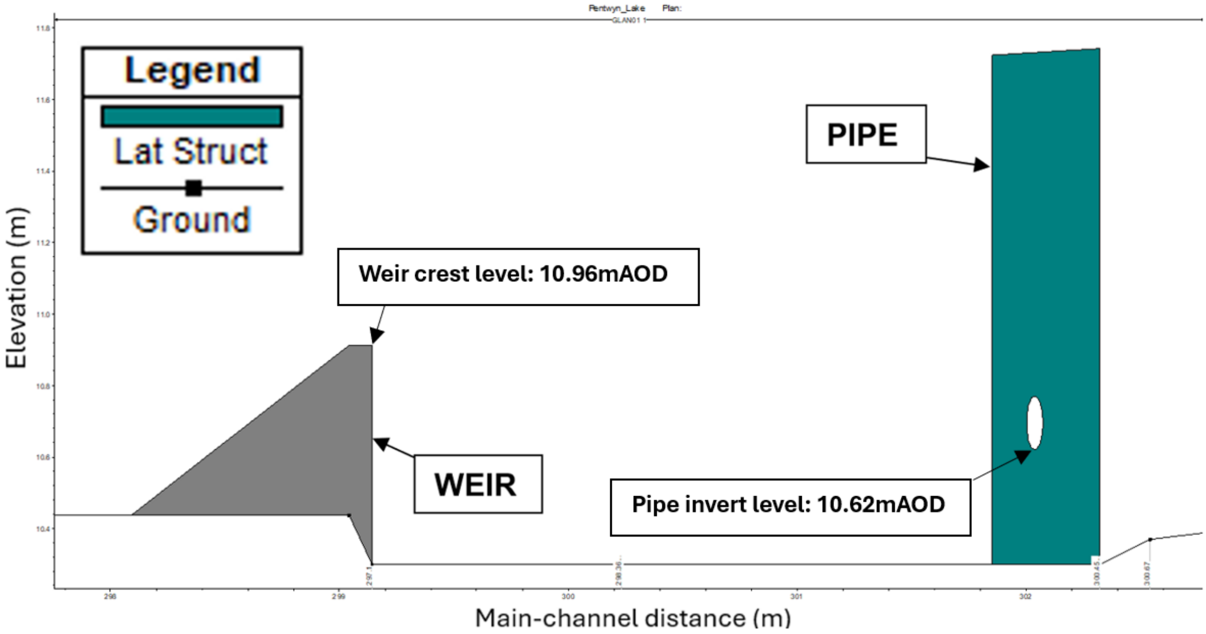


Figure 3-3: Baseline model weir and pipe (150mm) representation

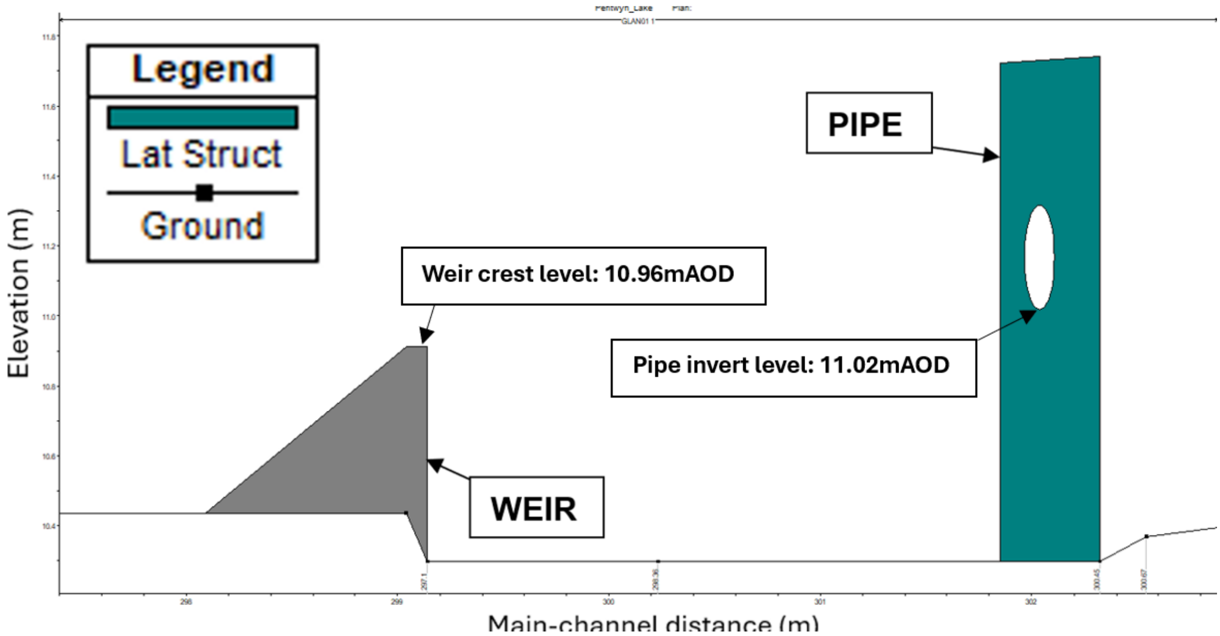


Figure 3-4: As-built model weir and pipe (300mm) representation.

4 Offtake flow assessment

4.1 Flow apportionment

The baseline and as-built scenarios, as set out in Section 3, were run for a range of low flows and small flood events. The model demonstrates that the baseline 150mm diameter pipe would be active across all scenarios. Under the new configuration, the pipe would begin to receive flow from the Q50 scenario (0.001m^3/s) with a more significant flow registered by the Q10 scenario (0.013m^3/s) (Table 4-1). Table 4-1 also shows the division of flow between the pipe and over the weir for each modelled event, with pipe flow reported as a percentage of the flow applied to the model.

This also demonstrates there are no increases in flows entering the lake. Even though the pipe diameter has increased, downstream of the manhole the 150mm pipe is retained and this still acts as a control. Thus, there is no increase in flows entering the lake in higher flow events (REFH2 flows). The model shows that water levels within the river channel are mostly unaffected by the installation of the 300mm pipe as shown in Figure 4-1 and Figure 4-2 within only 10mm difference for Q75 and Q95.

Table 4-1: Flow apportionment between the weir and pipe flow (m^3/s)

Event (flow applied)	Baseline weir flow	Baseline Pipe flow (10.62mAOD, 150mm) (% of applied flow)	As-built Weir flow	As-built Pipe flow (11.02mAOD, 300mm) (% of applied flow)
REFH2 5-year (5.07)	5.051	0.020 (0.39%)	5.051	0.020 (0.4%)
REFH2 2-year (3.7)	3.681	0.019 (0.51%)	3.681	0.020 (0.54%)
REFH2 1-year (3.26)	3.241	0.019 (0.58%)	3.240	0.019 (0.58%)
Q10 (0.497)	0.487	0.015 (2.99%)	0.485	0.013 (2.62%)
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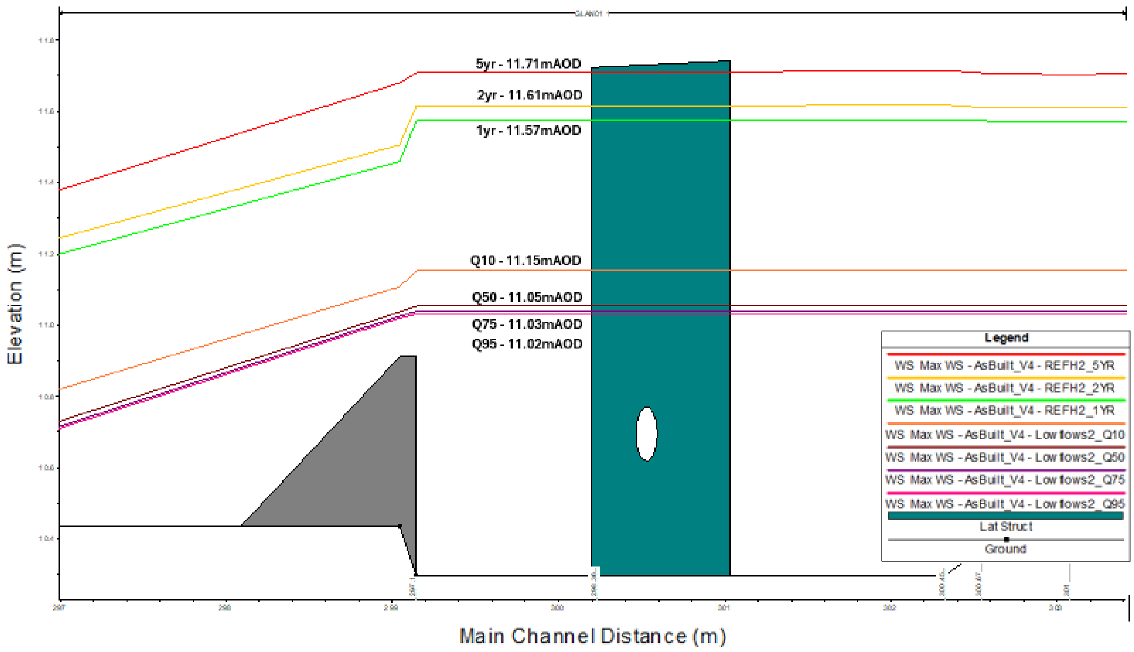

Figure 4-1: Water levels at the abstraction pipe - Baseline configuration

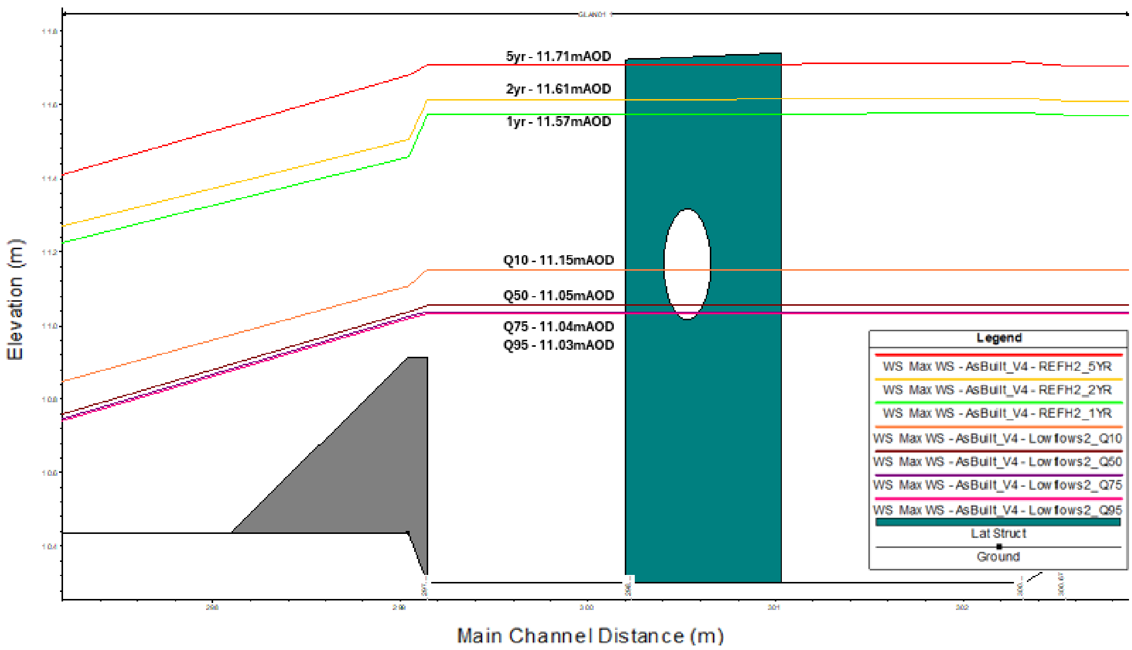

Figure 4-2: Water levels at abstraction pipe - As-built configuration

4.2 Hands off flow

NRW has requested confirmation of the relationship between the weir crest level and the invert level of the abstraction pipe, in order to determine whether the as-built configuration functions as a Hands-off Flow (HoF), and if so, the flow percentile it corresponds to.

A HoF is described by NRW as 'the flow rate at which abstraction should stop as streamflow falls… The protected low flow rate is usually equivalent to a low summer flow and termed a Q95 flow when described as a flow duration statistic'[2]. A HoF rate is usually clarified in an abstraction license for a given abstraction, dependent on the characteristics of the watercourse, particularly the channel bed gradient.

In the as-built arrangement, the invert of the abstraction pipe is positioned at 11.02 m AOD. The lowest point of the downstream weir crest is at 10.96 m AOD. The hydraulic modelling of Nant Glandulas has identified that the as-built the pipe begins to receive flow from the Q50 scenario and becomes active by Q10 duration or flows equal to 0.497m^3/s. The previous pipe configuration was active for lower flow durations and took approximately 43% of the available Q95 flow or flows equal to 0.023m^3/s.

This confirms that the as-built configuration provides an effective HoF, preventing abstraction at low flows.

[2] Natural Resources Wales / Abstraction rates for hydropower

5 Summary

The model demonstrates the following:

- The reconfigured offtake pipe begins to receive flow from the Q50 scenario and becomes active by Q10, due to the raised invert level of the new 300mm pipe section. As a result, abstraction to the lake is reduced compared to the original configuration, which operated at lower flow levels (including Q95).
- Maximum peak pipe flows are 0.02m^3/s due to a section of the 150mm diameter pipe being retained in the new arrangement.

Error! Reference source not found. summarises the response to queries issued by NRW to Cardiff Council regarding the functioning of the new pipe abstraction.

Table 5-1:NRW hydrological information request summary

NRW information request	JBA response
Flow split/ flow apportionment across the range of flows (so a range of flow percentiles with flow volumes both over the weir and through the pipe).	In the as-built configuration, the abstraction pipe takes no more than 2% of the total flow in the Nant Glandulas immediately upstream of the offtake, across the range of modelled flows.
Confirmation of the relationship between the low point on the weir and the bottom of the pipe which will then tell us whether this is a hands-off flow as it is built, and if so, what flow percentile this is equivalent to.	The inlet invert of the reconfigured abstraction pipe is positioned at 11.02 m AOD, which is 60 mm higher than the lowest point of the downstream weir crest (10.96 m AOD). The reconfigured offtake pipe begins to receive flow from the Q50 scenario and becomes active by Q10. In contrast, the previous (baseline) pipe was active during Q95 flows (0.023m^3/s), abstracting approximately 43% of the flow. There is consequently a significant reduction in abstraction during low flow conditions.

A Available Data

Table 5-2: Appendix data

Data	Source	Information	Date produced
Topographic Survey	Storm Geomatics	File name: 2025s0024_DCS_GLAN01_XS 2025s0024_DPP_GLAN01_LS+LP Topographic survey gathered in February 2025 used to edit LiDAR. Thirteen channel cross sections were taken along a 400m reach which includes three sections along the weir structure as well as pipe invert level and diameter measurements.	February 2025
Topographic Survey	Azimuth Land Surveys Limited	File name: SC3818-01 Job Number: SC3818 Drawing Number: SC3818-01 Topographic survey of Pentwyn Lake used to update the DTM representing levels in the lake	October 2020
Site Drawings	Salt Consulting	File name: Parc Y Nant_ 2022-17-SCL001_ B Drawing: Location of works and proposed details (Project No. 2022-17) Drawing Number: SCL/001 Revision: B Schematic for proposed alterations to pipe invert level which includes original level and pipe diameter.	April 2022

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