Dŵr Cymru Welsh Water

Environmental Assessment of Llannerch Boreholes Drought Permit (8012-5)

Final

March 2019

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*As part of a share purchase agreement in August 2015, Cascade Consulting (Environment & Planning) Ltd transferred its business to Ricardo plc. All employees transferred to Ricardo Energy & Environment, a trading name of Ricardo-AEA Ltd which is a wholly owned subsidiary of Ricardo plc. The work described in this report spanned the pre-acquisition and post-acquisition period and throughout this time the consultants involved maintained a continuity of service both as employees of Cascade Consulting and then subsequently as employees of Ricardo Energy & Environment.

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NON-TECHNICAL SUMMARY

INTRODUCTION AND PURPOSE OF THIS REPORT

Welsh Water's Drought Plan provides a comprehensive statement of the actions Welsh Water will consider implementing during drought conditions to safeguard essential water supplies to customers and minimise environmental impact. It encompasses a number of drought management options that will only be implemented if and when required and includes drought permit / order options.

A drought permit or order is a management action that, if granted, can allow more flexibility to manage water resources and the effects of drought on public water supply and the environment.

The objective of this report is to provide an independent and robust assessment of the potential environmental effects of implementing a drought permit Llannerch boreholes, over and above those arising due to natural effects of drought and those which would occur under "normal" abstraction licence conditions.

The Clwyd Coastal WRZ covers the coastal region from Prestatyn to Colwyn Bay and then further inland to St.Asaph.

The assessment also considers how the proposed drought permit may affect the environment in combination with the effects of other existing abstraction licences, environmental permits and other drought management plans.

This report is a 'shelf-copy' report which would be updated to support an application to Natural Resource Wales for a drought permit at Llannerch boreholes, which may be required by Welsh Water in the future.

PROPOSED DROUGHT PERMIT DETAILS

In order to protect public water supplies within Welsh Water's Clwyd Coastal WRZ in the event of a future severe drought, Welsh Water would make an application to Natural Resource Wales for a drought permit to vary the conditions of abstraction from Llannerch boreholes.

If granted, the drought permit involves a relaxation of the Llannerch boreholes annual licence.

The drought permit is most likely to occur during the autumn and winter period, and is considered not to extend outside the period November to March. This has been confirmed by Welsh Water's water resources modelling.

The revised abstraction arrangements under the drought permit would be authorised

for a maximum of five months (November to March), but would be removed sooner if the water resources situation within the Clwyd Coastal WRZ returns to adequate levels to safeguard essential water supplies, as agreed with NRW.

NEED FOR THE DROUGHT PERMIT

Application for a drought permit is a precautionary approach. Due to the time needed to determine a drought permit application, Welsh Water will potentially apply for a drought permit more frequently than it will be used.

The justification for the drought permit sought will be set out in a "Needs Statement". This will be produced by Welsh Water at the time of a potential future application, and will form part of the full drought permit application.

ALTERNATIVE SOURCES CONSIDERED

Details of alternative sources considered by Welsh Water will be completed at the time of application for the drought permit at Llannerch boreholes. This will demonstrate justification for the proposed drought option details applied for.

POTENTIAL IMPACTS OF DROUGHT PERMIT IMPLEMENTATION

The scope of the assessment has been defined by a screening and scoping exercise.

Summary of the Hydrological Assessment

The assessment has concluded that there is a moderate impact on flows in the Nant Padrig as a result of implementing the drought permit. These hydrological impacts are assessed as leading to minor impacts on the physical environment of the river, including water quality. Impacts on flow in the Afon Clwyd have been assessed as negligible.

Summary of the Environmental Features Screening

Environmental assessment is required and included for features where screening has identified a major or moderate impact.

Screening identified WFD status and Community Assessment / Environment (Wales) Act Section 7 Species as environmental features for which an environmental assessment was required.

The assessment has concluded that there are moderate impacts on fish, minor impacts on macroinvertebrates and negligible impacts on macrophytes and phytobenthos in Nant Padrig.

Cumulative Impacts

No cumulative effects of implementing the drought permit with other existing licences, consents and plans are currently anticipated. However, this should be reviewed at the time of any future application for a drought permit at Llannerch boreholes.

MITIGATION AND MONITORING

The environmental assessment has identified significant impacts of implementation of a drought permit at Llannerch boreholes. Consequently, in line with the DPG, an Environmental Monitoring Plan has been proposed. Potential mitigation measures have also been proposed and further discussion with NRW is required in order to develop suitable mitigation measures.

CONCLUSIONS

In summary, it has been concluded that the environmental effects on river flows, water quality and ecology of implementing a drought permit at Llannerch boreholes during November to March inclusive, over and above those conditions that already exist under "normal", i.e. licensed, baseline conditions, with the onset of a natural drought, would be **moderate**.

Contents

1 INTRODUCTION

1.1 PURPOSE OF THE ENVIRONMENTAL ASSESSMENT

The objective of this Environmental Assessment Report (EAR) is to provide an independent and robust assessment of the potential environmental effects of the implementation of a drought permit by Dŵr Cymru Welsh Water (Welsh Water) to relax the Llannerch boreholes annual licence. Water abstracted from Llannerch boreholes is used to provide public water supplies to Welsh Water's Clwyd Coastal Water Resource Zone (WRZ) (see Section 2.1).

This EAR is a 'shelf-copy' report which would be updated in the event that Welsh Water needs to make an application during any future drought to Natural Resources Wales (NRW) for a drought permit at Llannerch boreholes. A drought permit is a management action that, if granted, can help ensure essential water supplies are maintained to homes and businesses. The circumstances under which a drought permit may be required is set out in the Welsh Water Drought Plan.

The assessment presented in this EAR considers the effects of implementation of the drought permit over the months of November to March inclusive, the period for which Welsh Water has determined it might require a drought permit for this water source. The purpose of the assessment is to determine the environmental impacts of the drought permit over and above any effects arising from natural drought conditions.

The study area and focus of this environmental assessment of the Llannerch boreholes drought permit, covers the following waterbodies:

- the Clwyd – tidal limit to Hesbin (GB110066059960)
- the Wheeler – lower (GB110066059930).

This EAR includes discussion of the following:

- an assessment of the likely changes in river flow / water level regime due to implementing the proposed drought permit (**for a summary, see Section 4 of this report**)
- identification of the environmental features that are sensitive to these changes and an assessment of the likely impacts on these features (**see Section 5 of this report**)
- identification of mitigation measures that may be required to prevent or reduce impacts on sensitive features (**see Section 6 of this report**)
- recommendations for baseline, in-drought and post-drought permit monitoring requirements (**see Section 9 of this report**).

The environmental assessment has been conducted in accordance with Government

regulations and using the Welsh Government / Natural Resources Wales Drought Plan Guideline[1] (DPG); specifically Section 5 and Appendices I and J, and Welsh Government / Defra / NRW / Environment Agency guidance on drought permits and drought orders[2].

Consideration has been given to the potential impacts of drought permit implementation on statutory designated sites, including those designated under international law (Habitats Directive, Birds Directive and the Ramsar Convention) and national legislation (notably Sites of Special Scientific Interest (SSSIs).

In accordance with the DPG, the assessment also considers how the proposed drought permit may affect the environment in combination with the effects of existing abstraction licences, environmental permits and other relevant activities and plans. This is discussed further in Sections 3 and 7.

1.2 SUPPORTING STUDIES

The DPG identifies in Section 5.4 that EARs are required as supporting documents to any drought permit or drought order application. The circumstances for which an environmental assessment is required are set out in **Box 1** below.

Box 1: Drought Plan Guidance - requirement for environmental assessment

The DPG requires that all features that could be affected by implementation of a drought order /permit are listed in the EAR and that an assessment is made of how sensitive each feature is to the likely changes in hydrology, hydrogeology and geomorphology, due to implementing the drought order /permit.

The DPG requires a detailed environmental assessment for applications where sensitive features are likely to be subject to a major or moderate impact, or a minor impact where this applies to environmentally designated features. Further environmental assessment is **not** required for those drought orders / permits where there is certainty that there are no such impacted sensitive features.

This environmental assessment is based on data available at the time of writing and includes the environmental features and data types determined by Box 1 in Appendix I of the DPG (except where these are considered not to be relevant to this drought permit). Data were requested from key consultees (including NRW).

Where appropriate, this report also identifies areas where there are deficiencies in data availability and makes recommendations for future data / information gathering and

[1] Natural Resources Wales (2017) *Water Company Drought Plan Technical Guideline*. Available at https://cdn.naturalresources.wales/media/684414/final-wc-drought-plan-guidance-2017.pdf?mode=pad&rnd=131656713580000000, Accessed 04 February 2019.
[2] Welsh Government / Defra / Natural Resources Wales / Environment Agency (2015) *Apply for a drought order or emergency drought order*, https://www.gov.uk/government/collections/apply-for-a-drought-permit-drought-order-or-emergency-drought-order Accessed 21 December 2018.

monitoring. Welsh Water will continue to engage closely with NRW to ensure that adequate and sufficient data / information are collated and kept up-to-date in subsequent years to inform future environmental assessments.

1.3 CONSULTATION

Consultation is identified as an essential exercise in the preparation of the EAR. In preparing this 'shelf-copy' EAR for a drought permit at Llannerch boreholes, consultation with regulators and wider stakeholders has been undertaken to gain feedback on potential adverse effects, gather data and discuss any required monitoring and / or mitigation measures.

Further consultation will be also be undertaken at the time of any future applications for the drought permit.

1.4 STRUCTURE AND CONTENT OF THE REPORT

This EAR comprises the following sections:

Section 1: Introduction

Section 2: Background to the Drought Permit

Section 3: Approach

Section 4: Hydrology and the Physical Environment

Section 5: Environmental Features Assessment

Section 6: Mitigation

Section 7: Cumulative Impacts

Section 8: Summary of Residual Impacts

Section 9: Environmental Monitoring Plan (EMP)

Section 10: Conclusions

2 BACKGROUND TO THE DROUGHT PERMIT

2.1 WELSH WATER'S SUPPLY SYSTEM

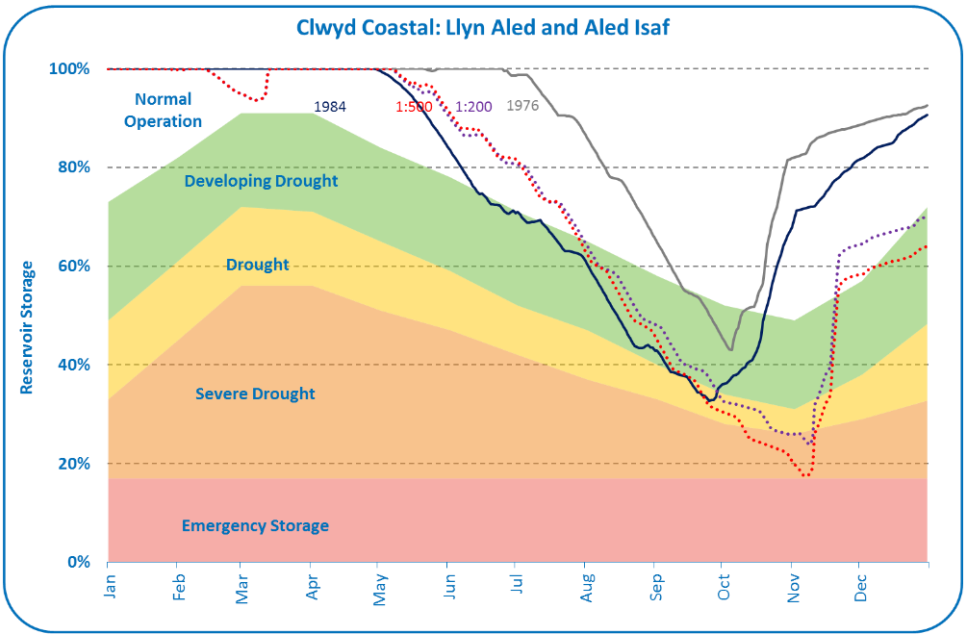
Welsh Water supplies water to more than 3 million people. The Welsh Water supply area covers the majority of Wales and a small part of England. It is split into 24 WRZ's (see **Figure 2.1**).

Figure 2.1 Welsh Water Water Resource Zones

The Clwyd Coastal WRZ covers the coastal region from Prestatyn to Colwyn Bay and then further inland to St. Asaph.

The trigger levels for applying for a drought permit at Llannerch boreholes are based on water levels in Llyn Aled and Aled Isaf falling below a defined threshold level as shown in **Figure 2.2** (orange shading labelled 'severe drought'). Welsh Water's assessment in its draft Drought Plan 2020 indicates that drought conditions severe enough to require an application for this drought option are unlikely to occur more frequently than at a return period of around once every 200 years. Fuller details of the work undertaken to assess this risk are provided in Annex 1 to the draft Drought Plan 2020.

Figure 2.2 Clwyd Coastal WRZ : Llyn Aled and Aled Isaf Drought Action Zones and Historic Droughts



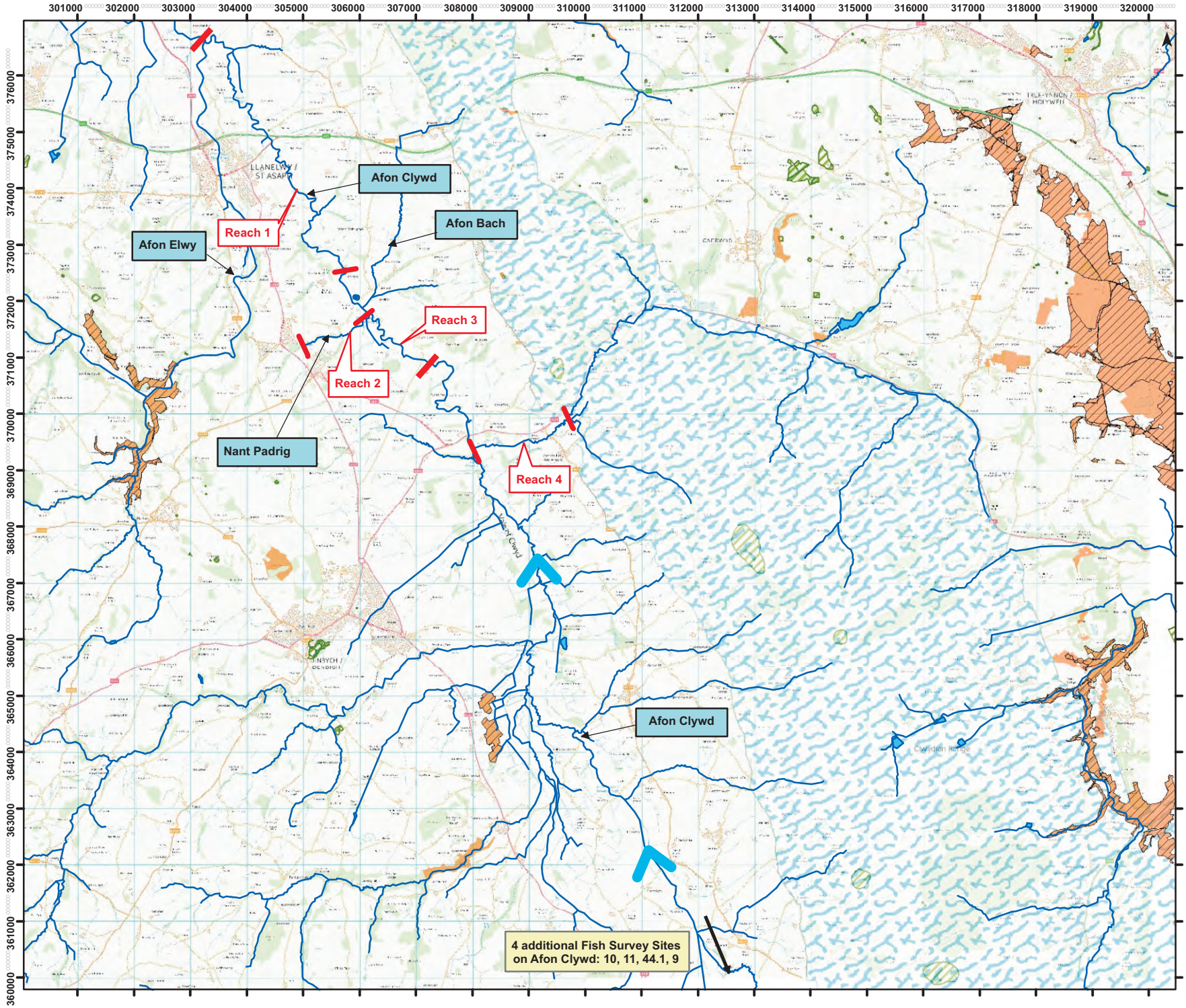
2.2 DESCRIPTION OF EXISTING ARRANGEMENTS AT LLANNERCH BOREHOLES

Welsh Water's licence (24/66/3/48/G) is to abstract groundwater under the Water Resources Act 1991 at three boreholes adjacent to the Afon Clwyd at Llannerch boreholes includes the following conditions:

- 3,409.5 million litres (Ml) authorised to be abstracted per annum
- At an abstraction rate not exceeding 13.64Ml/d
- On any day when flow in the Afon Clwyd, measured at the Pont y Cambwll gauging station is less than 146.9Ml/d, a daily quantity of water not less than the average actual abstraction from the boreholes shall be discharged from the Alwen aqueduct (located south west of the study area) and/or boreholes from which Welsh Water has been licensed to abstract water for the purposes of controlled discharges. This condition is referred to as the Clwyd Augmentation Scheme.

The annual licence condition is specific to a 12 month period (1 April-31 March) and equates to an average daily abstraction of 9.34Ml/d, 4.3Ml/d less than that permissible on a particular day of 13.64Ml/d. For the period 2011-2015 actual abstraction averaged 8.62Ml/d. Groundwater is abstracted through a number of electrically driven borehole pumps, treated on site (chlorine dosing) and transferred to Glascoed water treatment works (WTW) for further treatment and public supply in the Clwyd Coastal Water Resource Zone (WRZ). The boreholes are drilled into the underlying Permo-Triassic sandstone aquifer and do not exceed 122m in depth.

The study area is illustrated on **Figure 2.3**.



Legend

- Water Courses
- Hydrological Reach
- Flow Direction
- Reservoir

1:62,500

Note: All locations are approximate

Project Title: Welsh Water Drought Plan Environmental Assessment

Figure Title: Study Area: 8012-5 Llannerch boreholes

Figure Number:

Date: February 2019

2.3 WELSH WATER'S DROUGHT PLANNING PROCESS

Water companies in England and Wales are required to prepare and maintain Statutory Drought Plans under Sections 39B and 39C of the Water Industry Act 1991, as amended by the Water Act 2003, which set out the management and operational steps a water company will take before, during and after a drought. The Water Industry Act 1991 defines a drought plan as '*a plan for how the water undertaker will continue, during a period of drought, to discharge its duties to supply adequate quantities of wholesome water,* with *as little recourse as reasonably possible to drought orders or drought permits*'.

The Drought Direction (Wales) 2017 states that revised Drought Plans should be submitted according to the following schedule:

> *4(b) for a revised drought plan –*
>
> *if section 39B(6)(a) of the Act applies, within 6 months after the date on which the material change of circumstances occurs; and*
>
> *if section 39B(6)(c) of the Act(c) applies, no later than 4 years after the date on which its drought plan, or its last revised drought plan, is published.*

2.4 STATEMENT OF THE NEED FOR DROUGHT PERMIT

This section will be completed at the time of application for a drought permit.

2.5 DROUGHT PERMIT– REGULATORY ARRANGEMENTS

In periods of unusually low rainfall, when water resources become scarce, the Water Resources Act 1991, as amended by the Environment Act 1995 and the Water Act 2003, allows for three mechanisms for temporarily augmenting water supplies from rivers, lakes, reservoirs and groundwaters: drought permits; ordinary drought orders; emergency drought orders.

Drought permits are granted by NRW, and allow a water company powers to abstract from specified water sources, or to modify or suspend the conditions set out in existing abstraction licences. Drought orders are granted by the Welsh Ministers and give powers either to a water company or to NRW to abstract from specified water sources, or to modify or suspend the conditions set out in existing abstraction licences, but also to allow the discharge of water to specified places, modify or suspend conditions relating to a discharge or prohibit or limit particular non-essential uses of water as set out in the Drought Plan (Wales) Direction 2017. Emergency drought orders grant the same powers as a drought order, but in addition, confer powers to prohibit or limit water uses as specified by the water company and allow the set up and supply of water by means of standpipes and/or water tanks or rota cuts.

Drought permits and orders may be granted for a period of up to six months and they can be extended for up to a further six months.

As part of the drought order/permit application process, water companies are required to prepare an Environmental Report setting out anticipated effects of the proposal, including the effect on other abstractors and sufficient information to inform assessments, where applicable, in relation to the Habitats Directive, Countryside and Rights of Way Act (CRoW), and the Water Framework Directive (WFD).

Further information on the requirements for the environmental assessment and reporting according to legislation and national guidance are provided in Section 3.

2.6 REVIEW OF ALTERNATIVE OPTIONS

This section will be completed at the time of application for a drought permit, setting out the alternative options to the drought permit that Welsh Water has considered in addressing the risks to essential public water supplies due to drought.

2.7 PROPOSED DROUGHT PERMIT DETAILS

In order to protect essential public water supplies within Welsh Water's Clwyd Coastal WRZ in the event of a future severe drought, Welsh Water may need to make an application to NRW for a drought permit to vary the conditions of its abstraction licence from Llannerch boreholes.

If granted, the drought permit involves a proposed change in the abstraction licence at Llannerch boreholes through a temporary cessation of the annual abstraction rate condition. The maximum daily abstraction rate of 13.64Ml/d would still be applicable. The average daily abstraction that would be permissible within 12 months would be raised by 4.3Ml/d from 9.34Ml/d to 13.64Ml/d. This would allow abstraction at a maximum rate of 13.64Ml/d throughout the drought permit implementation period. This would provide a modest increase in water resource during a drought and increase the security of supply in the Clwyd Coastal WRZ by assisting post-drought winter refill of the Aled Reservoirs, by reducing demand from that resource. This EAR therefore presents an assessment of an increase in abstraction rate of 4.3Ml/d, noting that this is a worst case scenario. At the time of any future drought permit application, an updated assessment would reflect the available portion of the annual licence limit remaining at that time.

The Clwyd Augmentation Scheme involves supplementing low flow in the Afon Clwyd through release of groundwater from several boreholes within the upper Clwyd catchment and from the neighbouring Dee catchment via the Alwen aqueduct. The drought permit would not alter the licence conditions under which the Clwyd augmentation occurs, i.e. topping up river flows by the volume of water abstracted at the Llannerch boreholes.

Details of the existing and proposed drought permit abstraction at Llannerch boreholes are presented in **Table 2.1**.

The drought permit is most likely to occur during the autumn and winter period, considered to not extend outside the period November to March. This has been confirmed by Welsh Water's water resources modelling.

Table 2.1 Llannerch Boreholes Existing and Proposed Drought Permit Abstraction

Abstraction Water Source	NGR	Normal Abstraction	Proposed Drought Permit Abstraction	Benefit Ml/d
Llannerch Boreholes	SN 03737 24275	Welsh Water's licence (24/66/3/48/G) is to abstract groundwater under the Water Resources Act 1991 at three boreholes adjacent to the Afon Clwyd at Llannerch includes the following conditions: • 3,409.5 million litres (Ml) authorised to be abstracted per annum • At an abstraction rate not exceeding 13.64Ml/d • On any day when flow in the Afon Clwyd, measured at the Ponty Cambwll gauging station is less than 146.9Ml/d, a daily quantity of water not less than the average actual abstraction from the boreholes shall be discharged from the Alwen aqueduct (located south west of the study area) and/or boreholes from which Welsh Water has been licensed to abstract water for the purposes of controlled discharges. This condition is referred to as the Clwyd Augmentation Scheme. The annual licence condition is specific to a 12 month period (April-March) and equates to an average daily abstraction of 9.34Ml/d, 4.3Ml/d less than that permissible on a particular day of 13.64Ml/d.	The drought permit involves a proposed change in the abstraction licence at Llannerch through a temporary cessation of the annual abstraction rate condition. The maximum daily abstraction rate of 13.64Ml/d would still be applicable. The average daily abstraction that would be permissible within 12 months would be raised by 4.3Ml/d from 9.34Ml/d to 13.64Ml/d.	1.00 Ml/d

[Note: it will probably be necessary to remove the NGR for any public domain version]

2.8 DROUGHT PERMIT PROGRAMME

Drought actions and any future application for a drought permit would be managed by the Aled Consultative Group which would be convened under the terms of the Section 20 Operating Agreement with NRW. Decisions around which permit to apply for in the Clwyd Coastal WRZ will be made in liaison with the Section 20 consultative groups to ensure the best option for the environment and water resource situation is chosen.

Drought permits may remain in force for a period of up to six months, and they can be extended for up to a further six months. However, the period of implementation for this drought permit is restricted to November to March, as confirmed by water resources modelling carried out by Welsh Water.

Prevailing weather conditions and rainfall in the intervening period may delay the requirement for applications, or even result in no requirement to apply. A permit may be granted but not actually implemented if weather conditions improve or, equally, the permit may only be partially implemented.

2.9 DROUGHT PERMIT BASELINE

It is important for the assessment to establish the environmental "baseline" conditions that would exist in drought conditions but in the absence of the drought permit being implemented. For the purposes of this assessment, the "without drought permit" baseline includes the continuation of abstraction at the three Llannerch boreholes under current licence conditions. The assessed drought scenario relates to a cessation of the 12 month abstraction rate, and relates to an increase in daily abstraction rates to 13.64Ml/d.

3 APPROACH

3.1 INTRODUCTION

The DPG states that the environmental report must include:

i. the likely changes in flow, level, channel/riparian form and sediment due to implementing the action;
ii. the features that are sensitive to these changes;
iii. potential impacts on sensitive features;
iv. a plan of baseline, in-drought and post-drought monitoring; and
v. mitigation or compensation measures that may be required

Items i and ii above were subject to an initial screening process as part of the scoping exercise. Section 3.2 below describes the approach taken. This has provided the relevant study area and a list of features scoped into the environmental assessment which are the subject of this EAR.

Section 3.3 describes how the environmental assessment has been undertaken, including discussion of the general approach, guidance used, provision of data, assessment methodologies and consideration of mitigation and monitoring. Limitations to the environmental assessment are described in Section 3.4, 4 and 5.

To set the context of the studies, it should be noted that EAR considers the environmental impacts of implementing a drought permit during the worst environmental conditions (natural drought) that the permit could be implemented in.

In accordance with the DPG and the Habitats Regulations, the assessment considers how the proposed drought permit may affect the environment in combination with the effects of other existing abstraction licences, environment permits and other plans. This includes assessment of the potential cumulative effects of the following:

- Welsh Water's existing abstraction licences that operate within the hydrological zone of influence of the drought option, as well as other abstraction and discharge consents
- Assessment of cumulative impacts of the drought permit with other Welsh Water supply side and drought permit / order options within the hydrological zone of influence (including both intra- and inter- zone options)
- Other plans and projects of relevance, including:
    - Welsh Water's WRMP schemes which are scheduled to be implemented and become operational within the time period of the revised Drought Plan (i.e. before 2025)

- Drought options from other neighbouring water company Drought Plans, Natural Resource Wales Drought Plans
- National Policy Statements for Wastewater and Renewable Energy Infrastructure.

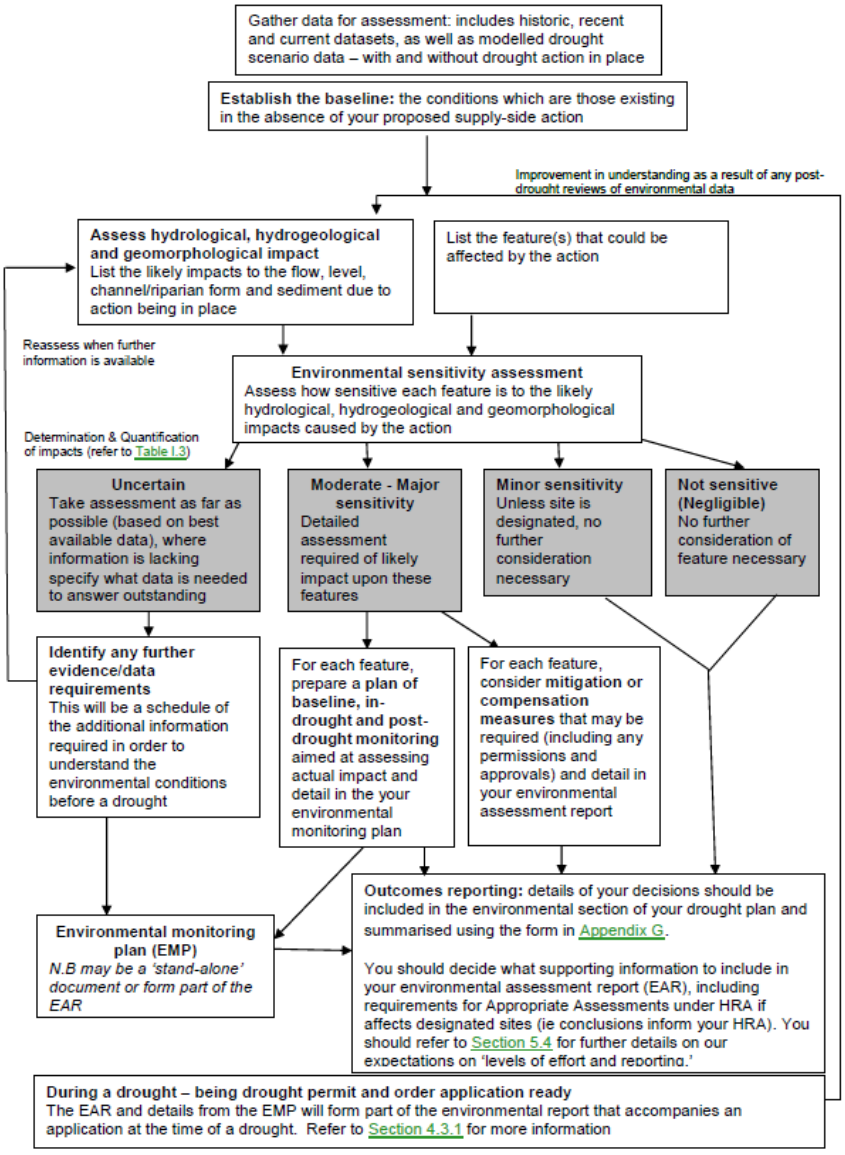
This is discussed further in Section 7.

3.2 APPROACH TO SCREENING AND SCOPING

3.2.1 Screening

Screening was undertaken using the DPG; specifically Section 5 and Appendix I. Figure 2 of the DPG (replicated in **Figure 3.1** below) identifies the environmental impact activities required.

Figure 3.1 Environmental Impact Activities Identified in the Drought Plan Guideline



The screening fulfils the requirement to "Assess how sensitive each feature is to the likely hydrological, hydrogeological and geomorphological impacts caused by the action". Stage 1 (hydrological impact) fulfils the requirement to "List the likely impacts to the flow, level, channel/riparian form and sediment due to action being in place". Stage 2 (environmental sensitivity) fulfils the requirement to "list the feature(s) that could be affected by the action" and to "Assess how sensitive each feature is to the likely hydrological, hydrogeological and geomorphological impacts caused by the action"

It is important to acknowledge the basis of the assessment; i.e. impacts of drought permit implementation should be considered in the context of what would occur without drought permit implementation (see Sections 2.2, 2.7 and 2.9).

The approach to undertaking Stages 1 and 2 is described below.

Stage 1 – Hydrological and Hydrogeological Impact

Consideration is required (by the DPG) of the likely impacts on the hydrology, hydrogeology and geomorphology of every river reach, wetland or lake area influenced by the proposed drought management action, specifically:

- identify the drought conditions which trigger the proposed action;
- identify any changes that the action is likely to bring about, specifying their length, severity and location in relation to existing natural and artificial features;
- describe the likely conditions in the absence of the proposed action;
- describe how the likely conditions would differ with the action in place compared to the same (or analogous) watercourse under natural conditions; and
- identify the extent of the area affected by the planned actions.

The hydrogeological and hydrological information is used together with information on the other environmental features in the study area from Stage 2 - Environmental Sensitivity (see below) to identify the environmental risk of implementing the drought permit.

Although the DPG informs the hydrometric data to be used as part of environmental features for consideration within the environmental assessment (see Box 1 Appendix I of the DPG), it does not provide a methodology for identifying the hydrological impact. A bespoke assessment has therefore been undertaken.

The full hydrological assessment approach is set out in **Appendix A**.

The output from these studies provides an understanding of the scale of change in the

hydrological characteristics as a result of implementing the drought permit. Where changes have been identified, the potential significance of adverse or beneficial impacts has been assessed.

Quantitative and qualitative measures have been used to grade the impacts on surface waters. The assessment has identified the potential severity of impact based on the following criteria:

- **Positive or Negative Impact** – all impacts are considered to be negative unless otherwise stated in the feature assessment.
- **Extent** – the extent of the impact is covered as part of the magnitude consideration.
- **Magnitude** – the magnitude of the impact is identified as**:**
  - *High*: There is a long-term large-scale (i.e. catchment) change in the physical environment.
  - *Medium*: There is a short-term large-scale change or long-term short-scale (i.e. reach) change in the physical environment, however, no changes in the overall integrity of the physical environment.
  - *Low*: There is a short-term small-scale change in the physical environment, but its overall integrity is not impacted.
  - *Negligible*: No perceptible change in the physical environment.
- **Duration** – the duration of impact is considered to be for 6 months, which is the duration for which a drought option is implemented, unless otherwise stated.
- **Reversibility** – all hydrological impacts are considered to be reversible**.**
- **Timing and Frequency** – the drought option could be implemented at any point in the year, unless otherwise stated. The assessment is based upon the operation of a single drought permit, with subsequent applications for a drought permit required to consider cumulative effects of multiple drought permit.
- **Probability** – all impacts are considered to be probable, unless otherwise stated.

The hydrological impact assessment is described fully in **Appendix B**.

Section 4 provides a summary of the hydrology and physical environment assessment as a result of implementing a drought permit at Llannerch boreholes.

Stage 2 - Environmental Sensitivity

With the extent and level of flow impact mapped, using GIS and other data sources, potentially sensitive receptors (sites / features) located within the extents of impact

have been identified. Potentially sensitive features investigated in the screening have been drawn from Box 1 in Appendix I of the DPG. These include:

- designated biodiversity sites (Local Nature Reserve (LNR), National Nature Reserve (NNR), Marine Protected Areas, National Parks, Areas of Outstanding Natural Beauty (AONB), SSSI, Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar) and Environment (Wales) Act Section 7 species / habitats which are located on or within 500m of the impacted reaches;
- protected species;
- ecological communities (fish, bryophytes & lichen, macro-invertebrates, macrophytes, algae) and, where identified, Water Framework Directive (WFD) status of designated waterbodies which contain the impacted reaches;
- invasive non-native species;
- sensitive ecological features as advised by NRW;
- wider features which should be taken into account in determining the potential impacts of drought option implementation – specifically socio-economic & health, amenity & aesthetics, recreation, navigation, architectural & archaeological heritage.

Each of the identified sensitive receptors within the extent of impact have been listed, alongside a brief summary of their potential susceptibility to flow impacts. For designated sites, this has included an indication as to whether the sites have water dependent qualifying interests.

The environmental sensitivity of each site has been identified according to the ecological and nature conservation interests of the area and, in particular, the proximity of and / or connectivity with the designated protected area. Each site has been assessed according to whether the extent of hydrological influence includes or is considered to affect a designated or protected site. Designated or protected sites outside the extent of hydrological influence are considered not to be influenced by the drought permit.

The outcome of Stage 1 and Stage 2 of the screening exercise are presented in Sections 4 and 5 respectively.

3.2.2 Scope

The screening exercise establishes the study area for the Llannerch boreholes drought permit together with identification of relevant, sensitive environmental features within those study areas (based on the risk of them being impacted by the drought permit during the period of its operation).

As set out in **Figure 3.1**, the environmental sensitivity screening identifies the outcome for each listed feature. Four outcomes are possible from the screening: uncertain; moderate-major sensitivity; minor sensitivity; not sensitive (negligible); and identifies appropriate next steps. Sections 4.2 and 5.2 present the findings which show that a number of features were identified as either: 1) uncertain; 2) moderate-major sensitivity; or 3) minor sensitivity in a designated site and in accordance with the DPG are features for which further assessment work will be required. These features alone form the scope of monitoring, environmental assessment, and consideration of mitigation actions.

The DPG states that environmental assessment, mitigation and / or monitoring is not required for features where screening has identified a minor (unless a site is designated) or negligible impact. However, the requirement for assessment, monitoring and / or mitigation has been reviewed on a case-by-case basis. In some cases, mitigation and / or monitoring has been recommended where minor impacts are identified, where considered appropriate on a precautionary basis.

3.3 APPROACH TO ASSESSING IMPACTS, MITIGATION AND MONITORING

3.3.1 General Approach

The assessment approach is in accordance with legislation, national regulations and guidance, including:

- NRW (2017) Water Company Drought Plan Technical Guideline (DPG)
- Welsh Ministers (2017) The Drought Plan (Wales) Direction
- Institute of Environmental Management and Assessment (2004) Guidelines for Environmental Assessment
- Chartered Institute of Ecology and Environmental Management (CIEEM) (2018) Guidelines for Ecological Impact Assessment in the UK and Ireland[3]
- UKWIR (2007, updated 2012) Strategic Environmental Assessment – Guidance for Water Resources Management Plans and Drought Plans. Prepared by Cascade Consulting
- Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive)
- Council Directive 2009/147/EC of 30 November 2009 on the conservation of wild birds

[3] CIEEM, Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial. Freshwater and Coastal. September 2018.

- The Convention on Wetlands of International Importance especially as Waterfowl Habitat , December 1975
- Conservation of Habitats and Species Regulations 2017
- The Countryside and Rights of Way Act 2000.

All aspects of the drought permit of potential environmental significance are considered in the environmental assessment.

The DPG states that a water company should clearly show what evidence and data have been used in decision making, that uncertainties should be identified, and which additional data requirements are provided for through the environmental monitoring plan.

In accordance with the DPG the approach to the assessment addresses the following: i) potential effects on each sensitive receptor; ii) definitions for impacts (adverse / beneficial); iii) the data requirements; iv) assessment methodology (including the treatment of uncertainty where the complete data requirements are not available).

This EAR presents the environmental baseline, i.e. habitats and environmental pressures (including flow and water quality) in the study identified zone of hydrological influence without the drought permit in place, utilising a description of the catchment, geomorphology, anthropogenic features and water quality. Key changes to the physical environment as a result of implementing the drought permit have been identified and described and, where appropriate, this information is used to frame and support the assessments of features which have been scoped in further to the screening and scoping exercise (see Section 3.2).

3.3.2 Assessment Methodologies

The aim of the Environmental Assessment is to provide:

- A clear summary of the outcome of each assessment (per feature) from which NRW can readily identify the significance of the impact when determining the drought permit application
- Identification of those predicted impacts which are to be taken forward to consider additional monitoring and mitigation actions.

The assessment considers the environmental impacts of implementing the drought permit against baseline operating conditions of Welsh Water's abstraction licence in advance of drought permit implementation. Environmental sensitivity has been assessed considering the context of the timing of drought permit implementation. **It is important to acknowledge the basis of the assessment; i.e. impacts of drought permit implementation are assessed against what would occur without drought permit implementation**.

The impact assessment for sensitive features is feature specific and is dependent on the availability and resolution of available data. Where possible, quantitative assessments have been undertaken. However, for many features, it is acknowledged that the assessments are qualitative and based on professional judgement, and using, where relevant, experience of local knowledge and reference to literature. This introduces uncertainty into the impact assessment. A precautionary approach has been used to assigning impact significance where data are absent or found not to be robust.

The assessment of impacts on designated sites has been undertaken using professional judgement with reference to conservation objectives and condition status of habitats and species, for which a site has been designated. The ecological assessment has been undertaken recognising the IEMA[4,5] and the CIEEM study guidelines[6]. The assessment of impacts on other environmental receptors e.g. recreation and landscape has been carried out largely by qualitative expert judgement.

Assessment of impacts on specific features has then been undertaken. Specific assessment methodologies have been developed for key environmental features. These are set out in **Appendix C** (assessment methodologies for the ecological assessment of Environment (Wales) Act Section 7 species, designated sites and other flora and fauna).

Other abstractors, including other water company abstractions, are features that have been reviewed within the assessment. This has been undertaken to determine whether other abstractors could potentially be affected by changes to surface water flows and levels as a result of implementation of the drought permit.

3.3.3 Mitigation and Monitoring

Section 5.3 of the DPG identifies the specific requirements for mitigation of serious impacts on the environment as a result of implementing a drought management measure. The assessments undertaken in this EAR confirm the features requiring consideration of mitigation and appropriate monitoring triggering mitigation. Appropriate mitigation actions identified are both available and practicable.

The DPG also identifies the specific requirements for monitoring. The assessments undertaken in this EAR inform the features requiring consideration for monitoring prior to, during, or after implementation of the drought permit.

The mitigation and monitoring proposals (see Sections 6 and 10) will act as a safeguard that responds and is responsive to both predicted and unpredicted drought impacts.

[4] IEMA (2004) Guidelines for Environmental Impact Assessment.
[5] IEMA (2011) Special Report – The State of Environmental Impact Assessment Practice in the UK
[6] CIEEM (2018) Guidelines for Ecological Impact Assessment in the UK and Ireland.

Future data collection and monitoring can then be focused to identify the aquatic ecosystem interaction to better quantify the potential impacts where gaps in the evidence base are identified and ensure the appropriate targeting of monitoring and mitigation response. The EMP will need to be finalised in agreement with NRW.

3.4 LIMITATIONS OF THE ASSESSMENT AND UNCERTAINTIES

The DPG states that a water company should clearly show what evidence and data have been used in decision making, that uncertainties should be identified, and which additional data requirements are provided for through the environmental monitoring plan.

The assessment presented in this document draws on available information from surveys and investigations undertaken by Welsh Water, NRW, as well as other bodies over a number of years. Reference has also been made to wider studies from published and grey literature, i.e. academic literature that is not formally published, where appropriate.

Specific details are provided on the quality of the data collected and used in the assessment. Where uncertainties remain with respect to the quantification and prediction of impacts, the limitations and any assumptions made are included in the relevant technical sections (Sections 4 and 5).

Overall, it is considered that the conclusions are based on information that is robust and valid at the time of writing. However, it should be noted that this EAR would be updated to support any future actual application, including a review of data.

4 LLANNERCH BOREHOLES DROUGHT PERMIT - HYDROLOGY AND THE PHYSICAL ENVIRONMENT

4.1 INTRODUCTION

Consideration of hydrology and the water physical environment sets the context for the potential range of environmental effects of the drought permit. **Appendix B** sets out an assessment of the potential impacts on the physical environment of Llannerch boreholes during the period of implementation of the drought permit. The "without drought permit" baseline is set out in Section 2.9.

The water physical environment assessment includes consideration of hydrology and hydrodynamics; geomorphology; and water quality. The assessment has three key objectives:

1. It is used to "list likely changes in flow, level, channel/riparian form and sediment due to implementing the action' as required by the DPG and set out in Figure 2 of the DPG

2. It is used to support the screening and assessment of sensitive features (including ecological features and designated sites) as required by the DPG and set out in Section 5 of this report

3. Where sensitive features are the physical environment itself, it provides supporting technical information for their screening and assessment.

Each of these are summarised below.

4.2 SUMMARY OF STAGE 1 SCREENING

This fulfils the DPG requirements of Stage 1 of the screening of potential drought permit impacts, identifying the likely changes in flow/ level regime due to implementing the drought permit. The specific requirements of the DPG are summarised as:

- identify any changes that the drought permit is likely to bring about, specifying their length, severity and location in relation to existing natural and artificial features (e.g. flow, water level, channel dynamics and sediment changes);
- describe the likely conditions in the absence of the drought permit;
- describe how the likely conditions would differ with the drought permit in place compared to the same (or analogous) watercourse under natural conditions; and

- identify the extent of the area affected by your planned actions.

These requirements are addressed in the following sections.

1. The perceived extent of potential impact:

The study area (see **Figure 2.3**) is identified as a broad zone largely to the south and east of the abstraction.

2. The nature and duration of the potential impact:

A description of the likely conditions with the drought permit in place, in comparison to the baseline conditions (absence of the proposed action) is provided in **Appendix B**. Given the conditions of the proposed drought permit, the key areas for the assessment of the physical environment have been identified as:

- Change in river flows Afon Clwyd and Nant Padrig.

The **Appendix B** assessment has been summarised in **Table 4.1** in terms of the magnitude and duration of each of these potential physical environment impacts.

3. The length of the potential impact:

The **Appendix B** assessment has been summarised in **Table 4.1** in terms of the timing of each of the potential physical environment impacts. The drought permit is most likely to occur during the autumn and winter period, considered to not extend outside the period November to March.

4.3 SUMMARY OF POTENTIAL EFFECTS ON THE PHYSICAL ENVIRONMENT

The potential changes to the physical environment (water quality and geomorphology) due to implementation of the drought permit are summarised in **Table 4.1.** These impacts are presented in detail in **Appendix B**.

Table 4.1 Summary of Potential Hydrodynamic and Water Quality Impacts of the Drought Permit

Afon Clwyd (Reach 1)	
Flows in the Afon Clwyd *Negligible impacts*	• Up to 3.6% reduction in low flows.
Water quality in the Afon Clwyd *Minor risk during the implementation of the drought permit*	• Minor risk to ammonia and dissolved oxygen. Moderate risk to soluble reactive phosphorous.
Nant Padrig (Reach 2)	
Flows in the Nant Padrig *Major (uncertain) impacts*	• Up to 45.3% reduction in low flows.
Geomorphology *Moderate (uncertain) impacts during the implementation of the drought permit period.*	• Due to the moderate (uncertain) hydrological impact the impact on geomorphology would also be minor (uncertain). The reach is unmanaged, and a potential decrease in flow could impact the wetted width of the channel and habitat availability. During drought conditions, bedload and suspended sediment transport will decrease, and due to the lack of management in the reach e.g. weirs, there is a decreased chance of ponding and sediment build-up.
Water quality in the Nant Padrig *Minor risk during the implementation of the drought permit*	• Medium risk to ammonia, dissolved oxygen and soluble reactive phosphorous.
Afon Clwyd (Reach 3)	
Flows in the Afon Clwyd *Negligible impacts*	• No reduction in flow.
Water quality in the Afon Clwyd *Minor risk during the implementation of the drought permit*	• Low risk to ammonia and dissolved oxygen and soluble reactive phosphorous.
Afon Wheeler (Reach 4)	
Flows in the Afon Clwyd *Negligible impacts*	• Up to 3.6% reduction in low flows.
Water quality in the Afon Clwyd *Minor risk during the implementation of the drought permit*	• Low risk to ammonia, dissolved oxygen and soluble reactive phosphorous.

4.3.1 Support to the Screening and Assessment of Sensitive Features

The assessment included in **Appendix B** has provided information to support the screening and assessment of sensitive features in Section 5. This includes information on short and long term (acute and chronic) direct and indirect, cumulative, and permanent and temporary effects. The assessment is also specific on the difference between the drought permit impacts and the baseline condition without a drought permit in place.

4.3.2 Supporting Technical Information for Assessment of any Physical Environment Sensitive Features

As described in Section 5, several sensitive features relate to the physical environment, rather than ecology or human interaction (e.g. landscape, recreation). The assessment included in **Appendix B** has provided supporting technical information for their screening and assessment in Section 5.

5 LLANNERCH BOREHOLES DROUGHT PERMIT ENVIRONMENTAL FEATURES ASSESSMENT

5.1 INTRODUCTION

As set out in **Box 1** above, environmental sensitivity screening of the drought permit was undertaken in line with the approach recommended by the DPG, and scoping undertaken in line with the methodology described in Section 3.2. The screening and scoping has subsequently been reviewed and refined further to discussions and consultation with NRW (see Sections 1.2 and 1.3). The outcome of this process is described in Section 5.2 which shows that a number of features were identified as either: 1) uncertain; 2) moderate-major sensitivity; or 3) minor sensitivity in a designated site. These features form the scope of environmental assessment, which is further described in Section 5.3.

The features assessment is informed by the assessment of the physical environment presented in Section 4 (which includes hydrology, geomorphology and water quality) and identifies the significance of any potential impacts. Consideration of mitigation actions and monitoring is described in Sections 6 and 10 respectively.

Points of interest referred to throughout the text in Section 5 are indicated on **Figure 2.3**.

5.2 SUMMARY OF STAGE 2 SCREENING AND SCOPING

5.2.1 Designated Sites and Other Sensitive Fauna and Flora

In accordance with the DPG, **Table 5.1** identifies designated biodiversity sites (including LNR, NNR, SSSI, SAC, SPA), Environment (Wales) Act Section 7 species / habitats and other sensitive receptors that could be affected by the drought permit. Susceptibility to the flow / level impacts resulting from the drought permit (see Section 4) is identified according to whether interest features of the site or the species are water dependent. Sensitivity is then determined according to professional judgment based on susceptibility and the level of hydrological impact at the location.

Table 5.1 Designated Sites and Other Sensitive Receptors Within the Zone of Influence of the Llannerch boreholes Drought Permit

Site/Feature and designation	Hydrological Impact at Location (Major, Moderate, Minor)	Susceptibility to flow and level impacts	Sensitivity (Uncertain, Moderate/ Major, Minor, Negligible)	Further Consideration Required (Yes/No)
Afon Clwyd, Nant Padrig, Afon Bach and Afon Wheeler (Reaches 1 to 4)				
Notable Species - Fish Atlantic Salmon *Salmo salar* Sea/Brown Trout *Salmo trutta* Lamprey *Lampetra sp.* European Eel *Anguilla Anguilla* Bullhead *Cottus gobio*	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	A number of fish species are likely to be present within the Afon Clwyd, Nant Padrig, Afon Bach and Afon Wheeler. Reduction to wetted width, depth and velocity in Reach 2 are likely to impact these species. The negligible impacts associated with Reach 1, 3 and 4 upon implementation are not expected to have any adverse impacts upon these species or the fish community present in the reaches.	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	Yes (Reach 2 only)
Notable Species – Mammals Otter *Lutra lutra* Water voles *Arvicola terrestris*	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	Otter are known to be present along the Afon Clwyd. Otter are water-dependent, foraging in, over or adjacent to water for fish and aquatic invertebrates. However this species are not expected to be significantly impacted by the drought permit implementation, as habitat availability and quality for otter is not anticipated to be significantly altered. Water vole are also known to be present along the impacted reaches of the Afon Clwyd and would not be expected to be impacted by the implementation of this drought permit.	Negligible (Reaches 1 to 4)	No
Notable Species – Lichen River Jelly Lichen *Collema dichotomum*	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	River jelly lichen is susceptible to reductions in flow which can lead to exposure of the species. The negligible hydrological impacts associated with this drought permit are not expected to increase the exposure of river jelly lichen and therefore the species will not be adversely impacted.	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	Yes (Reach 2 only)
Macrophyte community	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	The hydrological impacts associated with the implementation of this drought permit are not expected to affect the ecological integrity of the macrophyte community present in the Afon Clwyd, Nant Padrig, Afon Bach and Unnamed Brook.	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	Yes (Reach 2 only)
Macroinvertebrate community	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	The hydrological impacts associated with the implementation of this drought permit are not expected to affect the ecological integrity of the macroinvertebrate community present in the Afon Clwyd, Nant Padrig, Afon Bach and Unnamed Brook.	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	Yes (Reach 2 only)
Phytobenthos community	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	The hydrological impacts associated with the implementation of this drought permit are not expected to affect the ecological integrity of the phytobenthos community present in the Afon Clwyd, Nant Padrig, Afon Bach and Unnamed Brook	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	Yes (Reach 2 only)
Cultural Landscape	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	Four Cultural Landscape areas were found within the study reach; the A55 and A55 corridor, St Asaph local settlement and the Vale of Clwyd agricultural area. It is unlikely these areas will be affected by the changes in the Drought permit.	Negligible	No

Site/Feature and designation	Hydrological Impact at Location (Major, Moderate, Minor)	Susceptibility to flow and level impacts	Sensitivity (Uncertain, Moderate/ Major, Minor, Negligible)	Further Consideration Required (Yes/No)
Recreation	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	The Llannerch Boreholes and the Afon Clwyd are located east of Snowdonia National Park. The area presents year-round attractions for walking, riding and several other recreational pursuits. Canoeing is concentrated around the town of St Asaph due to the easier navigable and lower waters. The negligible impacts associated with Reaches 1, 3 and 4 are not expected to impact upon these activities. The popular walking route the Clwydian Way passes over the Nant Padrig although this is upstream of the limits of Reach 2. The reach which comprises 300m of Nant Padrig offers little recreational use and therefore the drought permit is unlikely to impact upon recreational activities.	Negligible (Reaches 1 to 4)	No
Archaeology	Negligible (Reaches 1, 3 and 4) Major (Reach 2)	One ancient monument site was found within the study area described as a modern bridge. It is unlikely this site will be affected by the Drought Permit.	Negligible (Reaches 1 to 4)	No

5.2.2 WFD Waterbody Status

- **Table 5.2** identifies the WFD status classification of the WFD waterbodies that may be impacted by implementation of the drought permit. Waterbodies classified as overall high / good status / potential, and / or high / good ecological status for fish or macroinvertebrates are likely to be more sensitive to flow impacts. **Table 5.2** summarises the risk to WFD status and indicates where further assessment has been carried out as reported in Section 5.3 below.

Table 5.2 WFD Status Classifications

Waterbody Name	Clwyd – Tidal limit to Hesbin (GB110066059960)		Wheeler – lower (GB110066059930)	
Hydrological Impact at Location (Major, Moderate, Minor, Negligible)	Moderate		Negligible	
Heavily Modified Waterbody (Y/N)	Yes		No	
RBMP Cycle	RBMP2 (2015)[7]	2018 C2 Interim	RBMP2 (2015)[8]	2018 C2 Interim
Overall Biological	Moderate	Moderate	Moderate	Good
Fish	Moderate	High	Moderate	Good
Macrophytes	Good	Good	Moderate	Good
Phytobenthos	Good	Good	Moderate	Good
Macro-invertebrates	Good	High	High	High
Total P/ Phosphate	Moderate	Moderate	Good	Good
Ammonia	High	High	High	High
Dissolved Oxygen	High	High	High	High
pH	High	High	High	High
Sensitivity (Uncertain, Moderate/ Major, Minor, Not sensitive)	Moderate		Not sensitive	
Further Consideration Required (Y/N)	Yes		No	

5.3 FEATURES ASSESSMENT

5.3.1 Basis of Features Assessment

This section describes and assesses the potential impacts on the sensitive features during the period of implementation of the drought permit.

Based on the sensitive features identified in Section 5.2.2, the degree of impact has been assessed and analysed in Section 5.3. Desk-based assessments have been completed for each of the sensitive receptors, where applicable, in permit to determine the magnitude of impact in the Llannerch boreholes drought permit hydrological zone of impact. Each feature assessment describes the analyses carried out and a statement of the assessed impact. All impacts are considered to be negative / adverse unless

[7] NRW (2017) https://drive.google.com/file/d/0B2hsDbbdxz1tZHItRU9lNkg1YWs/view.
[8] NRW (2018 https://drive.google.com/file/d/14w17jL05sNuToVELqMCK_yc6DdHU7STb/view.

otherwise stated in the feature assessment. The approach is described in Section 3.3.

The hydrological assessment is summarised in Section 4 and is presented in full in **Appendix B**.

5.3.2 Summary of Features Assessment

Table 5.3 presents the overall summary of the significance of potential impacts of the drought permit identified from the assessment of designated sites, and other ecologically significant receptors and their relevant reaches. Full details of the features assessment are provided in **Appendix D**. A brief summary of the features assessment is also provided below in Sections 5.3.3 – 5.3.8.

Table 5.3 Summary of Impacts of Drought Permit Implementation Pre-Mitigation

Month		J	F	M	A	M	J	J	A	S	O	N	D
Nant Padrig (Reach 2)													
Macrophytes		N	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N	N
Macroinvertebrates					N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Risk to WFD waterbody macroinvertebrate status		N	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N	N
Atlantic salmon	Spawning and juveniles				N/A	N/A	N/A	N/A	N/A	N/A	N/A		
	Water quality				N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Brown / sea trout	Spawning, egg survival, and juveniles				N/A	N/A	N/A	N/A	N/A	N/A	N/A		
	Water quality				N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Lamprey	Adult migration				N/A	N/A	N/A	N/A	N/A	N/A	N/A		
	Juveniles (habitat loss)				N/A	N/A	N/A	N/A	N/A	N/A	N/A		
	Water quality				N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Bullhead					N/A	N/A	N/A	N/A	N/A	N/A	N/A		
European eel		N	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N	N
Other fish species-					N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Risk to WFD waterbody fish status					N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Phytobenthos					N/A	N/A	N/A	N/A	N/A	N/A	N/A		

Key to Environmental Effects:

N/A	Outside implementation period
N	Negligible impacts are considered likely
	Minor adverse impacts are considered likely
	Moderate adverse impacts are considered likely
	Major adverse impacts are considered likely
	Potential minor beneficial impacts are considered likely
	Potential moderate beneficial impacts are considered likely

5.3.3 WFD and Community Assessment

This section considers the potential impact on the feature community within each reach as well as identifying the risk of deterioration in status / potential under the WFD.

WFD Definitions

The following definitions are provided for the determination of status under the WFD.

High ecological status - the values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions and show no, or only very minor, evidence of distortion.

Good ecological status - the values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.

Moderate ecological status - the values of the biological quality elements for the surface water body type deviate moderately from those normally associated with the surface water body type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status.

Poor ecological status - waters showing evidence of major alterations to the values of the biological quality elements for the surface water body type and in which the relevant biological communities deviate substantially from those normally associated with the surface water body type under undisturbed conditions, shall be classified as poor.

Bad ecological status - waters showing evidence of severe alterations to the values of the biological quality elements for the surface water body type and in which large portions of the relevant biological communities normally associated with the surface water body type are absent, shall be classified as bad.

Good ecological potential - there are slight changes in the values of the relevant biological quality elements as compared to the values found at high ecological potential.

Moderate ecological potential - there are moderate changes in the values of the relevant biological quality elements as compared to the values found at maximum ecological potential.

The Environment Agency[9] identify that a number of different factors need be considered when making an assessment of the ecological potential of HMWBs. Of primary importance is the need to put a specified range of mitigation measures in place to address the effects of the anthropogenic impact. Selected ecological quality elements may also be required to be at GES for the waterbody to be classified as GEP. Where the designated use includes for impacts on flow and flow-related mitigation measures the measured status of the fish and macroinvertebrate communities do not affect the classification of GEP.

Assessment

A summary of the potential impacts of the drought permit on macrophyte, macroinvertebrate, phytobenthos and fish communities and WFD status is presented below. Full details, including detailed baseline information, can be found in **Appendix D**.

[9] Environment Agency (2011) Method statement for the classification of surface water bodies v2.0 (external release) Monitoring Strategy v2.0 July 2011

Macrophytes

Table 5.5 presents a summary of the potential impacts of the drought permit identified from the assessment of macrophytes.

Table 5.5 Summary of Impacts of Drought Permit Implementation on Macrophytes

WFD Status/ Community	Impact	Significance of Impact
Clwyd – Tidal limit to Hesbin (GB110066059960) Current Status: Good	There is a negligible risk of short term deterioration in the status of the macrophyte community	**Negligible**
Feature	**Impact**	**Significance of Impact**
Reach 2 – Nant Padrig		
Macrophytes	• Changes to community composition due to changes to flow velocities and habitat loss due to reduction in wetted width and depth. • Major increase in SRP leading to increased proliferation of species with preference for high nutrient concentrations including filamentous algae.	**Negligible**

Macroinvertebrates

Table 5.6 presents a summary of the potential impacts of the drought permit identified from the assessment of macroinvertebrates.

Table 5.6 Summary of Impacts of Drought Permit Implementation on Macroinvertebrates

WFD Status/ Community	Impact	Significance of Impact
Clwyd – Tidal limit to Hesbin (GB110066059960) 2018 status: High	• There is a negligible risk of short term deterioration in the status of the macroinvertebrate community	**Negligible**
Feature	**Impact**	**Significance of Impact**
Reach 2 – Nant Padrig		
Macroinvertebrates	• Reduction in species diversity and abundance as a result of reduced recruitment. • Reduction in species diversity as a result of the loss of flow-sensitive taxa • Loss of marginal habitats and reduction in abundance and distribution of species utilising such habitats. • Reduction in species diversity as a result of deterioration to water quality.	**Minor**

Fish

Table 5.7 presents a summary of the potential impacts of the drought permit identified from the assessment of fish.

Table 5.7 Summary of Impacts of Drought Permit Implementation on Fish

WFD Status/ Community		Impact	Significance of Impact
Clwyd – Tidal limit to Hesbin (GB110066059960) 2018 status: High		• There is a negligible risk of short term deterioration in the status of the macroinvertebrate community	**Negligible**
Feature		**Impact**	**Significance of Impact**
Reach 2 – Nant Padrig			
Environment (Wales) Act Section 7 Species	Lamprey sp.	• Loss of juvenile habitat as a result of reduced river levels. • Reduced water quality.	**Moderate (uncertain)**
	Bullhead	• Increase in mortality due to water quality and habitat loss.	**Moderate (uncertain)**
	Atlantic salmon	• Reduced water quality • Reduction in spawning and juvenile survival due to habitat loss.	**Moderate (uncertain)**
	Brown/sea trout	• Reduced water quality • Reduction in spawning and juvenile survival due to habitat loss.	**Moderate (uncertain)**
	European eel	• Habitat loss	**Negligible**
Other fish species		• Habitat loss and reduced water quality	**Minor (uncertain)**

Phytobenthos

Table 5.8 presents a summary of the potential impacts of the drought permit identified from the assessment of phytobenthos.

Table 5.8 Summary of Impacts of Drought Permit Implementation on Phytobenthos

WFD Status/ Community	Impact	Significance of Impact
Clwyd – Tidal limit to Hesbin (GB110066059960)2018 Status: Good	Not assessed	**N/A**
Feature	**Impact**	**Significance of Impact**
Reach 2 – Nant Padrig		
Phytobenthos communities	• Decrease in flow affecting phytobenthos community composition • Moderate increase in SRP affecting phytobenthos community composition and TDI score	Minor

5.3.4 Archaeology, Cultural Landscape and Recreation

Table 5.10 presents a summary of the potential impacts of the drought permit identified from the assessment of cultural landscape, archaeology and recreation.

Table 5.10 Summary of Impacts of Drought Permit Implementation on Cultural Landscape, Archaeology and Recreation

Feature	Impact	Significance of Impact
Afon Clwyd, Nant Padrig, Afon Bach and Afon Wheeler (Reaches 1 to 4)		
Cultural Landscape	Four Cultural Landscape areas were found within the study reach; the A55 and A55 corridor, St Asaph local settlement and the Vale of Clwyd agricultural area. It is unlikely these areas will be affected by the changes in the Drought permit.	**Negligible**
Recreation	The Llannerch Boreholes and the Afon Clwyd are located east of Snowdonia National Park. The area presents year-round attractions for walking, riding and several other recreational pursuits. Canoeing is concentrated around the town of St Asaph due to the easier navigable and lower waters. The negligible impacts associated with Reaches 1, 3 and 4 are not expected to impact upon these activities. The reach which comprises 300m of Nant Padrig offers little recreational use and therefore the drought permit is unlikely to impact upon recreational activities.	**Negligible**
Archaeology	One ancient monument site was found within the study area described as a modern bridge. It is unlikely this site will be affected by the Drought Permit.	**Negligible**

6 LLANNERCH BOREHOLES DROUGHT PERMIT– MITIGATION

The environmental assessment has identified some significant impacts, including major hydrological impacts, moderate aquatic ecology impacts including on fish and macroinvertebrates.

For those receptors with a potential impact or risk identified as being significant as a result of implementation of the drought permit, precautionary monitoring and mitigation measures have been identified, and will be further developed in consultation with NRW.

Mitigation measures are feature, location, species and community specific, and are targeted only to those impacts that arise specifically as a result of drought permit implementation (as opposed to those arising due to environmental drought pressures). Similarly, monitoring and the targeting of mitigation measures to impacts that arise specifically as a result of drought permit implementation will help identify the responsible party for the specific actions relating to the associated measure. Information attained through monitoring undertaken during future droughts and potential drought permit implementation events will provide a tool for discussions regarding best working practices between Welsh Water, NRW and any other interested parties.

The range of mitigation measures that are possible for the features identified fall into three general activity types:

1) measures to reduce impacts at source

2) measures to modify environmental conditions in the river/lake

3) management of sensitive ecological species and communities.

The first activity type looks at mitigation measures that will reduce the pressure at source by reducing the hydrological impact. In the circumstances, the options are limited because the drought permit is required to safeguard public water supply. The second activity focuses on mitigation measures that involve undertaking actions within the waterbodies to reduce the pressure at sensitive locations. The third activity type involves direct action to manage impact by movement or management of the receptor / feature itself.

The mitigation measures that could be considered at the on-set of drought, during implementation of the drought permit and post-drought permit implementation include:

6.1 Potential Generic Mitigation Measures Considered to Address Adverse Effects of the Drought Permit

Type of Mitigation	Typical Application
Temporary reduction or cessation of the terms of the Drought Order/Permit	Where continuous water quality monitoring (typically dissolved oxygen) and/or fish distress monitoring indicate a sharp deterioration in aquatic conditions, modifications to abstraction licence conditions under the terms of the order/permit may need to be reduced or cease altogether until conditions have improved. The precise trigger levels for considering such action would be set out in discussion with NRW at the time of application taking account of the time of year and prevailing environmental conditions. Temporary cessation of the implementation of the order/permit may be required as a means of mitigating ecological effect, balanced against the need to safeguard public water supplies.
Fish distress monitoring with triggers and response plan	Regular visual observations carried out on key stretches of rivers or lakes to detect signs of large scale fish distress and agree appropriate mitigation with NRW specific to the conditions identified. This might include temporary oxygenation measures.
Protection of 'spate flows'	Temporary increases in river flows following periods of rain can be important to flush sediment/pollutants from the system or promote fish passage. Where possible, the terms of the drought order/permit could be temporarily reduced/suspended so that these spate flows are preferentially allowed to pass through the system. This decision would need to be taken in dialogue with NRW to take account of the prevailing conditions and considering the merits of encouraging fish migration during a drought.
Reduce fish predation	Consider (where feasible) a limited and targeted reduction of predation risk on fish through either the provision of refugia, in the form of artificial or natural habitat provision or improvement, or the placement of piscivorous bird scarers (in areas remote from residential locations). The merits of each option and subsequent deployment would be subject to review on a case-by-case basis in consultation with NRW.
Physical works	In some cases, temporary physical in-river works such as channel narrowing or provision of refugia could be carried out to mitigate environmental risks. If any physical works are likely to impact fish passage, appropriate mitigation measures will need to be considered as part of the design of the works.
Compensation flows	In some cases, it may be possible to use other sources of water to provide compensation flows within surface water courses to temporarily mitigate the impact of the drought order/permit
Provision of alternative water supplies	If there is a risk of derogation of other abstractors from the drought order/permit, it may be possible for Welsh Water to provide alternative water supplies or lower pumps in boreholes. Provision is otherwise provided in legislation[10] for compensation to be agreed with the abstractor.

A suggested suite of mitigation measures for environmental features with potentially significant impacts relating to implementation of the Llannerch boreholes drought permit are given in **Table 9.1**. For these features, a range of precautionary monitoring and triggers leading to enabling of appropriate mitigation measures are also described.

[10] Schedule 9 of the Water Resources Act (WRA) 1991

7 CUMULATIVE IMPACTS

In accordance with the DPG and the Habitats Regulations, consideration has been given to how the proposed drought permit may affect the environment in combination with the effects of existing abstraction licences, environmental permits and other plans. This includes assessment of the potential cumulative effects of the following:

- Welsh Water's existing abstraction licences that operate within the hydrological zone of influence of the drought option, as well as other abstraction licences and discharge permits, as identified in NRW Review of Consents reports;
- Assessment of cumulative impacts of the drought permit with other Welsh Water supply-side and drought permit options within the hydrological zone of influence (including both intra- and inter- zone options);
- Other plans and projects of relevance, including;
    - Any Welsh Water WRMP schemes which are scheduled to be implemented and become operational within the time period of the Drought Plan (i.e. before 2025).
    - Drought supply-side and drought order / permit options from NRW Drought Plans.
    - National Policy Statements for Wastewater and Renewable Energy Infrastructure.
- Environmental monitoring before, during and after drought permit implementation (see Section 10).

If a drought permit application is progressed in the future, the potential for cumulative effects will be reviewed and revised to reflect any changes which are relevant to the timing of the drought permit specified in the application.

Welsh Water's existing abstraction licences and other abstraction licences and discharge permits

The assessment of hydrological impacts presented in **Appendix B**, and summarised in Section 4, has considered how the proposed drought permit may affect the environment in combination with the effects of existing licences and consents. Therefore no relevant licences or consents have been identified as relevant for assessment of cumulative effects.

Other relevant Welsh Water drought permit / orders

No other cumulative effects of implementing the drought permit with existing licences, consents and plans are currently anticipated. However, this should be reviewed at the

time of any future application for a drought permit at Llannerch boreholes.

Welsh Water WRMP schemes

No WRMP schemes identified with cumulative impacts.

NRW Drought Plans

No cumulative impacts of options in NRW Drought Plan with a drought permit at Llannerch boreholes are anticipated. However, this should be reviewed at time of future application for a drought permit.

National Policy Statements for Wastewater and Renewable Energy Infrastructure

No cumulative schemes have been identified for assessment.

Environmental Monitoring

Recommendations for environmental monitoring before, during and after drought permit implementation have been made in the EMP which is presented in Section 10 of this EAR. The EMP has been developed in consultation with NRW.

It is assumed that all monitoring activities will be undertaken with the best interests of the site in mind, and in discussion and agreement with NRW. Where activities which require in-river working are proposed, a method statement for the survey will be prepared and agreed with NRW in advance of the survey.

Assuming rigorous implementation of the method statements, there will be no adverse impacts of the monitoring on hydrology, water quality or ecology, and no adverse impacts of environmental monitoring on the site are anticipated.

8 LLANNERCH BOREHOLES DROUGHT PERMIT - SUMMARY OF RESIDUAL IMPACTS

The residual impact on environmental features is dependent on the effects observed during environmental monitoring, and the mitigation measures that are taken forward and their timely and effective application once the trigger for their need has been identified. Consequently, at this stage it is not possible to provide an accurate indication as to the residual impacts on environmental features due to implementation of mitigation measures. However, should the mitigation measures be effectively applied in all situations in a timely manner, it is anticipated that the magnitude of impacts, and in some cases the significance of impacts, will be reduced from those summarised in **Table 5.3**.

Should the application of mitigation measures applicable during the drought permit implementation period not reduce the impact magnitude or significance, compensatory measures such as restocking will be considered to help ensure pre-drought conditions return and reduce the significance of any post-drought permit impacts.

9 ENVIRONMENTAL MONITORING PLAN (EMP)

9.1 INTRODUCTION

The overall scope of the EMP for the Llannerch boreholes drought permit meets the requirements of Section 5.2 (Monitoring) and informs the requirements of Section 5.3 (Mitigation) of the DPG. As required by the DPG, the level of monitoring identified in the EMP is risk-based. The EMP is tailored to the characteristics of the study area and is informed by the knowledge and assessment of environmental sensitivity (presented in Sections 4 and 5 of this EAR). The EMP fulfils several requirements, including:

- Establishing required baseline environmental monitoring and data acquisition to maintain and update the understanding of the environmental baseline conditions and to reduce uncertainties in the assessment.
- Pre-drought permit monitoring describes the prevailing environmental conditions prior to drought permit implementation. This will inform the implementation and management of any mitigation actions during the drought.
- During-drought permit monitoring describes the environmental conditions during the implementation of the drought permit. Surveillance monitoring of sensitive locations, informed by, for example, walkover surveys and pre-drought monitoring, will provide early warnings of any unpredicted environmental impacts and ensure that mitigation actions are operating as designed.
- Post-drought permit monitoring describes the recovery of environmental conditions following the cessation of a drought permit, and establishes whether the affected ecosystems have recovered to conditions prevailing in the pre-drought permit period.

The basis of the development of the EMP is provided in Section 9.2. Monitoring recommendations are set out in Section 9.3.

9.2 BASIS OF THE EMP

Guidance on the objectives and content of the EMP is given in Section 5.2 and Appendix J of the DPG.

The guidance states that:

- Water companies are responsible for understanding the effects of a drought and its drought management actions on the environment and that companies can demonstrate this by assessing the impacts of drought management actions during and after a drought and completing the environment assessment.
- Companies should ensure that adequate arrangements for environmental monitoring are detailed in an EMP within its drought plan.

- The level of monitoring needed should be risk-based. Not all sites will require in-drought and post-drought monitoring.
- Surveys may be needed to support/inform the decisions on environmental sensitivity and likely impact or to ascertain baseline conditions.
- In-drought permit monitoring is required to assess the impacts from the implementation of the drought management action and for the management of mitigation actions during a drought.
- Post-drought permit monitoring aims to assess a site's recovery.
- Sites with moderate to major environmental risk should focus monitoring on those feature(s) sensitive to the likely impacts from implementing drought management actions. For Habitats Directive sites, data collected will be sufficient to demonstrate there is no adverse effect on the interest features. For SSSIs, data collected will need to be sensitive enough to pick up the likelihood of damage at the site. For WFD sites data collected will be to assess any potential 'deterioration' to status and allow you to comply with the requirements of Articles 4.6 to 4.9.
- Control sites are important to provide a comparison between the 'natural' impacts of the drought and the impacts of the drought management action.
- The EMP should include details of any surveys to support the environmental assessment, in-drought and post-drought data needs, including:
    - the feature/s to be monitored and the methods used
    - the location of survey sites
    - the timing and frequency of monitoring
    - who will undertake the monitoring.
- Separating the 'natural' impacts of a drought from those resulting from the implementation of drought management actions can be complex and made more difficult where data problems and/or a lack of hydro-ecological understanding exists. Water companies must ensure that their EMP is adequate to assess the most significant environmental impacts of its proposed drought actions and associated mitigation measures.
- The EMP needs to be agreed with NRW. Consultation with NRW should be undertaken to ensure that the monitoring proposed within the EMP to assess the potential impacts at these sites is adequate.
- A water company must provide details in the Drought Plan of likely mitigation or compensation needed against serious impacts on the environment or other water users of any proposed drought action. The EMP should assist in identifying sites that may require mitigation. In some cases, mitigation actions may be necessary to prevent derogation of other abstractions (for example, by providing alternative supplies or releasing compensation water into watercourses to limit the impact of

reduced flows).

9.3 MONITORING RECOMMENDATIONS

The EMP describes the nature and extent of the baseline and drought year data that would be required in permit to differentiate the impacts resulting solely from the implementation of a drought permit with those resulting naturally as a result of the drought itself. The EMP is site specific and the scope is based on the current assessment of the drought permit.

Recommendations for pre-drought, in drought and post-drought monitoring, based on the outcome of the current environmental assessment, are provided in **Table 9.1** and are illustrated on **Figure 9.1**.

Monitoring outside of drought conditions is also recommended to address the baseline data limitations to the environmental assessment identified in this report and ensure a robust baseline exists for all sensitive features.

Data and results from baseline monitoring will increase the robustness of the assessment, and will be incorporated at the time of EAR preparation to support any future application for drought powers. The impact assessment has adopted a precautionary approach where baseline data limitations have been identified.

Control sites are crucial in assessing the ecological impact of flow pressure resulting from water resource activities. They can help determine whether any ecological impact being observed is a result of the water resource activity being investigated, rather than wider environmental influences. Good control sites for hydroecological assessment should be chosen where there are no significant water quality problems or pressures which could undermine relationships between ecology and flow. They must not be affected by the water resource activity being investigated nor have additional water resource activity upstream that could affect the flow regime. It is imperative that they are as similar in nature to the baseline conditions of the impact sites as possible, most importantly stream size and channel gradient. Possible options could include reaches upstream of those impacted, or other watercourses where the watercourses are comparable and not subject to a drought permit/order application. Control sites will need to be identified at the time of application following a review of where drought permit/orders are required to be implemented. Consultation with NRW to determine suitable control sites will be undertaken at the time of application of this drought permit.

The following monitoring programme is an initial draft and will be iterated and agreed with NRW prior to EMP implementation. Any updates to the EMP will consider:

- Any potential changes in the assessment of the hydrological, water quality and geomorphological impacts based on baseline conditions at the onset of

drought;

- Any potential changes in the assessment of impacts on environmental features based on baseline conditions at the onset of drought; and
- Any changes in assessment and/or monitoring methodologies and biological indices.

Table 9.1 Baseline, Pre, Onset, During and Post Drought Permit Monitoring and Mitigation Recommendations

Feature and reach	Potential Impact identified in EAR	Pre-drought baseline monitoring	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit	Responsibility
		Key locations	**Monitoring and trigger setting**	**Trigger and monitoring to inform mitigation action**	**Mitigation actions triggered by monitoring**	**Monitoring and post-drought mitigation (where applicable)**	
N/A		Groundwater abstractions and groundwater levels	Continuous	Continuous	N/A	Continuous	Welsh Water
		Spot flow gauging surveys	One site per hydrological reach. Three occasions.	One site per hydrological reach. Three occasions.	N/A	One site per hydrological reach. Three occasions.	Welsh Water
		Biochemical water quality sampling.	One site per hydrological reach. Monthly. Consider continuous monitoring.	One site per hydrological reach. Weekly. Consider continuous monitoring.	N/A	One site per hydrological reach. Monthly, until recovery to pre-drought levels. Consider continuous monitoring.	Welsh Water
Fish (including salmon, brown trout, lamprey, bullhead, eel, shad) **Reach 2**	Decreased growth, alteration to feeding and migration Siltation of spawning gravels Loss of important habitats (spawning gravels, nursery habitat, resting pools) Increased mortality (density dependant) as a result of increased predation and competition Stranding of individuals as a result of a reduction in velocity Fragmentation of habitats and increased	Carry out walkover (where survey site identification is required) and electric-fishing surveys to monitor fish populations at one site in each of the impacted reaches. One site in each of the impacted reaches. To complement any existing NRW monitoring, in discussion with NRW. If any lamprey are recorded during standard electric fishing surveys then further monitoring must be undertaken. Quantitative, lamprey-specific electric fishing surveys targeting known optimal and sub-optimal habitat identified during preliminary walkover.	Electric-fishing surveys to monitor fish populations at one site in each of the impacted reaches. One site in each of the impacted reaches. Quantitative, lamprey-specific electric fishing surveys targeting known optimal and sub-optimal habitat. One site in each of the impacted reaches. In severe drought conditions, no fish population surveys are advised during drought as this may cause further stress. Walkover of key sections known to be susceptible to lower flows: • Identification of key habitats which are at risk of fragmentation. • Identification of key structures which may provide a barrier at lower	No fish population surveys are advised during drought as this may cause further stress. Additional walkovers, if situation is expected to deteriorate in stream sections known to contain to contain high fish densities, spawning, nursery and cover habitats. Record extent of exposed marginal habitats, spawning habitats, bed substrates and estimates of overlaying silt cover. Frequency of walkovers to be determined based on the on-set of environmental drought walkover and expert judgement of the resolution required to	Targeted installation of woody debris features to provide fish with the habitat required to support feeding and development (growth). If the results of the walkovers deem spawning gravels to be at risk to siltation, the following mitigation action/s may be undertaken: • Gravel washing of key spawning areas to be undertaken prior to salmonid spawning period (winter)[11] • Targeted installation of woody debris features to increase localised flow velocity/scour at impacted spawning	Two years of annual post-drought fish population surveys at baseline monitoring sites (corresponding with a control and impact site/s) to determine any changes in population dynamics both temporally and spatially. Quantitative, lamprey-specific electric fishing surveys targeting known optimal and sub-optimal habitat. One site in each of the impacted reaches. The results of the fish population surveys should help inform mitigation targeting habitat restoration where deemed to be appropriate to support and enhance affected populations.	Welsh Water

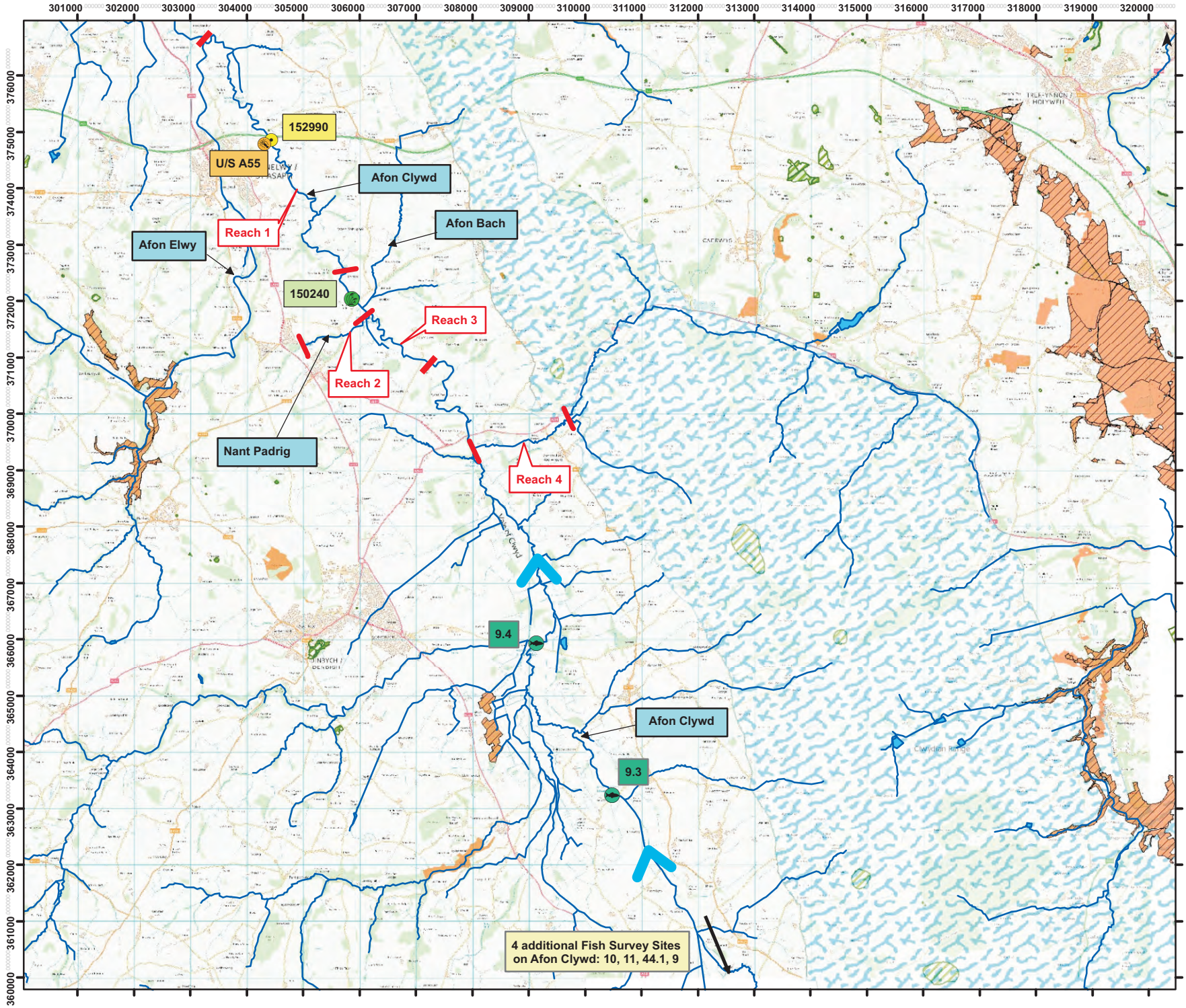
[11] Wild Trout Trust Habitat Management Sheet – Gravel Cleaning http://www.wildtrout.org/sites/default/files/library/Gravel_Cleaning_Apr2012_WEB.pdf

Feature and reach	Potential Impact identified in EAR	Pre-drought baseline monitoring Key locations	On-set of environmental drought Monitoring and trigger setting	During Drought Permit Implementation Period Trigger and monitoring to inform mitigation action	 Mitigation actions triggered by monitoring	Post Drought Permit Monitoring and post-drought mitigation (where applicable)	Responsibility
	significance of obstacles/barriers Changes in flows and water levels may delay or prevent passage over barriers to migration Mortality as a result of water quality deterioration (oxygen stress, gill clogging) Alteration to species distribution and abundance as a result of water quality deterioration.		flows. • Identification of key spawning locations recording the number of redds potentially affected, undertaken during the salmonid winter spawning period (depending on permit being implemented during the salmonid winter spawning period). Record extent of exposed marginal habitats, spawning habitats, composition of the bed substrate and estimates of overlaying silt cover. Approximation of the number of each fish species (e.g. 10s, 100s) in each ponded reach, where safe and practical to do so. Measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment. Appropriate trigger values would be set for level and flow for spawning habitats based on local circumstances, timing, seasonality and expert opinion.	monitor the impacts of the drought. Targeted fish passage assessment of barriers /obstructions to fish passage and any associated fish passes should be undertaken to ascertain if they pose an increased risk to the free movement of fish during key migration periods. Frequency of fish passage assessments to be determined based on the on-set of environmental drought walkover and expert judgement of the resolution required to monitor the impacts of the drought. Measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment. Deployment of automated water quality equipment that continuously monitors for dissolved oxygen.	gravels (to aid sediment transport and increase water depth for spawning depth) If the results of the walkovers deem important habitats to be at risk to exposure/ reduction (in extent), the following mitigation action/s may be undertaken: • Targeted installation of woody debris features to increase flow heterogeneity/scour and marginal cover in shallow areas of the channel[12] • Deployment of aeration equipment in key reaches that have standing or slow flowing water with low oxygen levels. • Targeted installation of woody debris features to provide submerged and overhead cover from predation where	Walkover of key spawning locations recording the number of redds potentially affected, undertaken during the winter spawning period. Record extent of exposed marginal habitats, spawning habitats, composition of the bed substrate and estimates of overlaying silt cover. If the results of the walkovers deem spawning gravels to have suffered from siltation, the following mitigation action/s may be undertaken: Gravel washing of key spawning areas to be undertaken prior to salmonid spawning period (winter)[13] Targeted installation of woody debris features to: • increase flow heterogeneity/scour and marginal cover in shallow areas of the channel[14] • increase localised flow velocity/scour at impacted spawning	

[12] Wild Trout Trust Chalkstream Habitat Manual – Use of Large Woody Debris http://www.wildtrout.org/sites/default/files/library/Large_Woody_Debris.pdf
[13] Wild Trout Trust Habitat Management Sheet – Gravel Cleaning http://www.wildtrout.org/sites/default/files/library/Gravel_Cleaning_Apr2012_WEB.pdf
[14] Wild Trout Trust Chalkstream Habitat Manual – Use of Large Woody Debris http://www.wildtrout.org/sites/default/files/library/Large_Woody_Debris.pdf

Feature and reach	Potential Impact identified in EAR	Pre-drought baseline monitoring	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit	Responsibility
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions triggered by monitoring	Monitoring and post-drought mitigation (where applicable)	
					significant abundances of fish have been identified by walkover surveys. Consider provision of physical deterrents to deter piscivorous birds at significant locations (e.g. scare crows) in consultation with NRW. In extreme cases (where environmental parameters such as dissolved oxygen and temperature allow), consider removal of concentrated abundances of fish deemed to be stranded/at risk, relocating fish to suitable locations outside of the impacted reach within more suitable catchment, but would need to be discussed with NRW to ensure compliance with the Keeping and Introduction of Fish Regulations 2014. Modify any impacted fish passes (where possible) to ensure passage is maintained during key migration periods (e.g. agree to provide an appropriate proportion of flow into the pass to enable	gravels (to aide sediment transport and increase water depth for spawning depth) If the results of the walkovers deem important habitats to be at risk to exposure/ reduction (in extent), the following mitigation action/s may be undertaken: • Targeted fish passage assessment of barriers /obstructions to fish passage and any associated fish passes should be undertaken to ascertain if they pose an increased risk to the free movement of fish during key migration periods, i.e. during juvenile eel migration (spring/summer). • Modify any impacted fish passes (where possible) to ensure passage is achievable during key migration periods (e.g. agree to provide an appropriate proportion of flow into the pass to enable passage). Where fish passage is not currently provided at a barrier, investigate appropriate	

Feature and reach	Potential Impact identified in EAR	Pre-drought baseline monitoring	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit	Responsibility
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions triggered by monitoring	Monitoring and post-drought mitigation (where applicable)	
					passage). Consider 'Trap & Transport' of concentrated abundances of migrating fish accumulated below impassable barrier/s to spawning grounds upstream of the impacted reach (where environmental parameters such as dissolved oxygen and temperature allow). Alternatively, mitigation should seek to protect any populations 'trapped' as a result of the barrier/s until flows increase for example by using aeration (if dissolved oxygen levels are low) or preventing predation (see Increased Mortality impact mitigation actions outlined above). Deployment of aeration equipment in key reaches that have standing or slow flowing water with low oxygen levels.	methods of improving passage (e.g. fish passage design and installation).	



Legend

- Fish Survey Site
- Macroinvertebrate Survey
- Phytobenthos_survey
- Macrophyte Survey
- Water Courses
- Hydrological Reach
- Flow Direction
- Reservoir

1:62,500

Note: All locations are approximate

Project Title: Welsh Water Drought Plan Environmental Assessment

Figure Title: Environmental Monitoring: 8012-5 Llannerch boreholes

Figure Number:

Date: February 2019

10 CONCLUSIONS

This EAR provides an assessment of the potential environmental impacts relating to the implementation of the Llannerch boreholes drought permit. If granted and implemented, the drought permit would enable Welsh Water to relax the Llannerch boreholes annual licence.

The scope of the assessment has been defined by an impact screening and scoping exercise. In accordance with the DPG, the screening exercise involved two stages, a hydrological impact assessment (Stage 1) and the identification of the environmental features that could be affected by the drought permit (Stage 2).

The assessment has concluded that there is a moderate impact on flows in the Nant Padrig as a result of implementing the drought permit. These hydrological impacts are assessed as leading to minor impacts on the physical environment of the river, including water quality. Impacts on flow in the Afon Clwyd have been assessed as negligible.

An environmental assessment was therefore required and included for features where screening has identified a major or moderate impact. Screening identified WFD status and Community Assessment / Environment (Wales) Act Section 7 Species as environmental features for which an environmental assessment was required. The assessment has concluded that there are moderate impacts on fish, minor impacts on macroinvertebrates and negligible impacts on macrophytes and phytobenthos in Nant Padrig.

No cumulative effects of implementing the drought permit with other existing licences, consents and plans are currently anticipated. However, this should be reviewed at the time of any future application for a drought permit at Llannerch boreholes.

The environmental assessment has identified significant impacts of implementation of a drought permit at Llannerch boreholes. Consequently, in line with the DPG, mitigation measures have been proposed and further discussion with NRW is required in permit to develop suitable mitigation measures.

In summary, it has been concluded that the environmental effects on river flows, water quality and ecology of implementing a drought permit at Llannerch boreholes during November to March inclusive, over and above those conditions that already exist under "normal", i.e. licensed, baseline conditions, with the onset of a natural drought, would be **moderate**.

APPENDIX A
HYDROLOGY AND HYDROGEOLOGY METHODOLOGY

A.1 HYDROLOGICAL AND HYDROGEOLOGY IMPACT METHODOLOGY (STAGE 1 SCREENING)

Consideration is required (by the DPG[1]) of the likely changes in flow / level regime due to implementing the drought management action, specifically:

- the perceived extent of potential impact
- the nature and duration of the potential impact
- the timing of the potential impact.

The hydrogeological and hydrological information is used together with information on the other environmental features in the study area from Stage 2 - Environmental Sensitivity (see Section 3.2.1 in main report) to identify the environmental risk of the drought order / permit.

Although the DPG informs the hydrometric data to be used as part of environmental features for consideration within the environmental assessment (see Box 1 Appendix H of the DPG), it does not provide a methodology for identifying the hydrological impact.

Cascade has developed a flexible approach[2] to identifying the spatial extent of the study area from hydrological information and characterising the hydrological impact within the study area, in terms of the scale, nature, duration and timing of impacts, although this is only appropriate to apply to reaches that do not dry naturally. A hydrological methodology for watercourses that naturally dry for part of the year is also presented that characterises the hydrological impact within the study area, in terms of the scale, nature, duration and timing of impacts. These are presented below.

Perennially flowing watercourse hydrological methodology

This methodology is applied to watercourses that flow throughout the year and that are potentially impacted on by the drought order / permit.

Core to this approach is the use of relevant long term flow statistics to inform the scale of hydrological impact and thereby delimit the zone of influence in the downstream river system. To determine these, potential reductions in flow resulting from implementation of the drought order / permit are compared with flows without the drought order / permit in place (i.e. the additional abstraction advocated by the drought order / permit over and above the existing abstraction). This helps to determine the scale of potential impact at any particular site/ feature using the matrix in **Figure A.1** or **Figure A.2** depending on the altitude of the waterbody and whether it is classified as lowland or upland[3]. Where possible, the hydrological assessments presented in previous EMPs and EARs of the drought options have been used to

1 Welsh Government / Defra / NRW / Environment Agency (2011). Water Company Drought Plan Guideline. June 2011.
2 Hydrological impact approach used in previous drought plan environmental assessments for water companies including Thames Water, Yorkshire Water and United Utilities
3 The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. ISBN 978-0-85521-192-9.
The Directions set out the principles of classification of surface water and groundwater bodies, including the use of 80m above Ordnance Datum as the altitude that differentiates water quality requirements for upland and lowland biology. Where there are ambiguities, or thresholds are crossed, upland is assumed to apply to ensure a precautionary assessment.

help identify the spatial extent of the study area from hydrological information and characterising the hydrological impact within the study area.

Figure A.1 Hydrological Assessment Matrix (Upland)

		Summer Q99		
	% reduction in flow	<10%	10-25%	>25%
Summer Q95	<10%	Negligible	Minor	Moderate
	10-25%	Minor	Moderate	Major
	>25%	Moderate	Major	Major

Figure A.2 Hydrological Assessment Matrix (Lowland)

		Summer Q99		
	% reduction in flow	<10%	10-25%	>25%
Summer Q95	<20%	Negligible	Minor	Moderate
	20-50%	Minor	Moderate	Major
	>50%	Moderate	Major	Major

Figure A.1 illustrates that at the time of implementation of a drought order / permit, upland river systems of relevance to each of these proposed options will exhibit high sensitivity to changes in low flow (represented by Q_{95}, summer[4]) and very high sensitivity to changes in extreme low flow (represented by Q_{99}, summer). As illustrated by **Figure A.2**, lowland rivers of relevance to each of these proposed options are considered to be less sensitive to reductions in summer low flows (summer Q_{95}), but similarly sensitive to reductions in extreme summer low flows (summer Q_{99}).

Figures A.1 and **A.2** are appropriate for the assessment of hydrological impacts on low flow regimes in watercourses during the spring, summer and autumn. However, in some cases there is a need to assess the impacts of drought order schemes on watercourses during the winter. For example, a reduction in compensation release may remain in force during the winter high flow period, to increase the probability of reservoir refill prior to the following year's spring/summer drawdown period. During the winter season, watercourses have relatively lower sensitivity to changes in low flow, and moderate sensitivity to changes in moderate flow. This can be reflected by the use of the matrices in **Figures A.3** and **A.4** for the assessment of drought order / permit schemes which are only likely to impact on a watercourse during the winter. The categorisation of impacts as negligible, minor, moderate or major is based on the percentage reduction in year round low flow (Q95) and year round median flow (Q50).

Figure A.3 Hydrological Assessment Matrix (Upland / Winter)

		Year round Q95		
	% reduction in flow	<10%	10-25%	>25%
Year round Q50	<10%	Negligible	Minor	Moderate
	10-25%	Minor	Moderate	Major
	>25%	Moderate	Major	Major

[4] Flow statistics indicate the proportion of days a flow is equalled or exceeded. Therefore Q95 indicates flow equalled or exceeded on 95% of days in the measured record (equivalent to an average of 347 days per year)

Figure A.4 Hydrological Assessment Matrix (Lowland / Winter)

		Year round Q95		
	% reduction in flow	<10%	10-25%	>25%
Year round Q50	<20%	Negligible	Minor	Moderate
	20-50%	Minor	Moderate	Major
	>50%	Moderate	Major	Major

The matrices are used to identify 1) the overall study area – which extends downstream of the abstraction until the hydrological impact has reduced to negligible; 2) reaches with similar scales of impact within the overall study area; and 3) the scale of hydrological impact within each reach. Typically reaches have been delimited by the addition of flow from a significant tributary or discharge; although the similarity of geomorphological characteristics of the reach may also be important in reach specification. The matrices can be applied to a variety of upland or lowland catchments respectively including those dominated by groundwater, and can be applied until the tidal limit.

In addition to the information provided by summary flow statistics in the matrix, information on the timing, duration and relevant seasons of the drought order / permit impacts have been informed by licence details and river gauging data have also been used to characterise the likely nature of the drought order / permit impacts.

If the drought order / permit does not impact on the magnitude of low flows in a watercourse, but does cause changes in the duration of low flow periods (which can be quantified), then the matrix in **Figure A.5** may be appropriate. The assessment is based on the percentage increase in the number of days for which flow is at or below the low flow (Q95) value. Typically this would be the case when the low flow regime in a watercourse downstream of a reservoir is protected by a statutory compensation release from the reservoir, but the reservoir may be drawn down below top water level for longer periods due to increased direct abstraction under the drought order / permit conditions.

If low flows in a watercourse are adversely affected in both magnitude and duration, then the impacts on magnitude are always used to determine the significance of hydrological impacts, using the appropriate matrix from **Figures A.1** to **A.4** inclusive. **Figure A.5** is only used when the impacts on low flows are on duration only.

Figure A.5 Hydrological Assessment Matrix (Low Flow Duration)

Percentage increase in low flow duration	Significance
<5%	Negligible
5-10%	Minor
10-25%	Moderate
>25%	Major

Intermittently flowing watercourse hydrological methodology

This methodology is applied to watercourses, potentially impacted on by the drought order / permit, that flow for most of the time but seasonally or occasionally ceasing to flow in response to decreased water availability e.g. due to increased evapotranspiration or bed seepage. . Such watercourses are identified from previous investigations and available data. Examples of watercourses where this methodology would be applied include winter bournes or watercourses that dry along their route due to losses to underlying aquifers. The impact classification of this methodology is as follows:

- Major - If the drought order / permit resulted in sections drying that did not dry up anyway
- Moderate - If the drought order / permit resulted in sections drying earlier (by more than a week) and / or recovering later (by more than a week) and hence flow reduction occurring in the channel for more than a week
- Minor - If the drought order / permit resulted in sections drying earlier (up to a week) and/or recovering later (by up to a week) and hence flow reduction occurring in the channel for up to a week OR if the drought order / permit were a secondary flow driver (e.g. flow through gravels being primary cause of flow losses rather than the drought order / permit)
- Negligible - No significant impact

In addition to the derived classifications, information on the timing, duration and relevant seasons of the drought order / permit impacts have been informed by licence details, available data and findings of previous investigations. These have been used to characterise the likely nature of the drought order / permit impacts.

Reservoir hydrological methodology

More recently Cascade has developed a similar approach to categorise the significance of hydrological impacts of drought order / permit operations on reservoirs. The assessment requires an estimate of the relative change in duration of reservoir drawdown (i.e. the period for which water in the reservoir is below top water level), and the percentage decrease in the minimum reservoir level reached during the drawdown period. These two parameters are then compared against the reservoir impacts hydrological assessment matrix in **Figure A.6**.

This approach would be a suitable method to assess the impacts of a drought order / permit which involves significant changes to the reservoir water level regime (that would not normally be experienced during a drought without any additional measures implemented). For example, a drought order / permit may involve increasing daily or annual licensed abstraction limits to allow an increased rate of direct abstraction from the reservoir. This may enable some or all of a reservoir's emergency storage volume to be utilised, but is likely to lead to both lower water levels and increased periods of time below top water level.

Figure A.6 Hydrological Assessment Matrix (Reservoir Impacts)

	% Increase in duration of reservoir drawdown			
% Decrease in minimum reservoir level	<5%	5-10%	10-25%	>25%
<5%	Negligible	Negligible	Minor	Moderate
5-10%	Negligible	Minor	Moderate	Major
10-25%	Minor	Moderate	Major	Major
>25%	Moderate	Major	Major	Major

Additional Considerations

For groundwater schemes, hydrogeological data, where available, has been reviewed to inform the study area and duration of any impacts (noting impacts on groundwater may extend beyond the six month period of drought order / permit implementation - see below). An increase in groundwater abstractions would lead to an increased cone of depression in groundwater levels for groundwater abstraction. This impact can affect other non-surface water receptors such as other wells, springs or groundwater dependent ecosystems. It could also mean that surface water impacts would extend upstream of the abstraction point or, in significant instances, to other watercourses some distance from the abstraction.

For groundwater abstractions, the impact of a drought order / permit could extend beyond the six month period (time limited) of abstraction depending on the local hydrogeology of the area. During drought situations, where there is limited recharge to the aquifer system, the abstraction can be mainly at the expense of groundwater stored in the aquifer. This can, in the long run, delay groundwater level recovery and have a knock on effect on baseflow contributions to watercourses. Flows could, therefore, be reduced for longer than the six month period during which the drought order / permit could be implemented and, as such, has been considered as part of the assessment described in this report.

APPENDIX B – 8012-5 HYDROLOGY AND PHYSICAL ENVIRONMENT ASSESSMENT

B1 INTRODUCTION

This appendix assesses the potential impacts on the physical environment of the Afon Clwyd as a result of implementation of the Llannerch boreholes drought permit.

For the purposes of this assessment, the "without drought permit" baseline includes the continuation of abstraction at the three Llannerch boreholes under current licence conditions. The assessed drought scenario relates to a cessation of the 12 month abstraction rate, and relates to an increase in daily abstraction rates to 13.64Ml/d.

B.1.1 Welsh Water's Existing Operations

Welsh Water's licence (24/66/3/48/G) is to abstract groundwater under the Water Resources Act 1991 at three boreholes adjacent to the Afon Clwyd at Llannerch includes the following conditions:

- 3,409.5 million litres (Ml) authorised to be abstracted per annum
- At an abstraction rate not exceeding 13.64Ml/d
- On any day when flow in the Afon Clwyd, measured at the Pont y Cambwll gauging station is less than 146.9Ml/d, a daily quantity of water not less than the average actual abstraction from the boreholes shall be discharged from the Alwen aqueduct (located south west of the study area) and/or boreholes from which Welsh Water has been licensed to abstract water for the purposes of controlled discharges. This condition is referred to as the Clwyd Augmentation Scheme.

The annual licence condition is specific to a 12 month rolling period and equates to an average daily abstraction of 9.34Ml/d, 4.3Ml/d less than that permissible on a particular day of 13.64Ml/d. For the period 2011-2015 actual abstraction averaged 8.62Ml/d. Groundwater is abstracted through a number of electrically driven borehole pumps, treated on site (chlorine dosing) and transferred to Glascoed water treatment works (WTW) for further treatment and public supply in the Clwyd Coastal Water Resource Zone (WRZ). The boreholes are drilled into the underlying Permo-Triassic sandstone aquifer and do not exceed 122m in depth.

B.1.2 Welsh Water's Proposed Drought Permit Operations

The drought permit involves a change in the abstraction licence at Llannerch through a temporary cessation of the annual abstraction rate condition. The maximum daily abstraction rate of 13.64Ml/d would still be applicable. The average daily abstraction that would be permissible within 12 months would be raised by 4.3Ml/d from 9.34Ml/d to 13.64Ml/d. This would allow abstraction at a maximum rate of 13.64Ml/d throughout the drought permit implementation period. This would provide a modest increase in water resource during a drought and increase the security of supply in the Clwyd Coastal WRZ by assisting post-drought winter refill of the Aled Reservoirs, by reducing demand from that resource. This EAR therefore presents an assessment of an increase in abstraction rate of 4.3Ml/d, noting that this is a worst case scenario. At the time of any future drought permit application, an updated assessment would reflect the available portion of the annual licence limit remaining

at that time.

Based on Welsh Water's water resource modelling the timing of the drought permit implementation is most likely to occur during period from November to March inclusive.

The Clwyd Augmentation Scheme involves supplementing low flow in the Afon Clwyd through release of groundwater from several boreholes within the upper Clwyd catchment and from the neighbouring Dee catchment via the Alwen aqueduct. The drought permit would not alter the licence conditions under which the Clwyd augmentation occurs, i.e. topping up river flows by the volume of water abstracted at the Llannerch boreholes. However, the number of days when augmentation occurs and the volume of augmentation releases may be increased during the drought period, noting that this is not constrained by the augmentation licence condition.

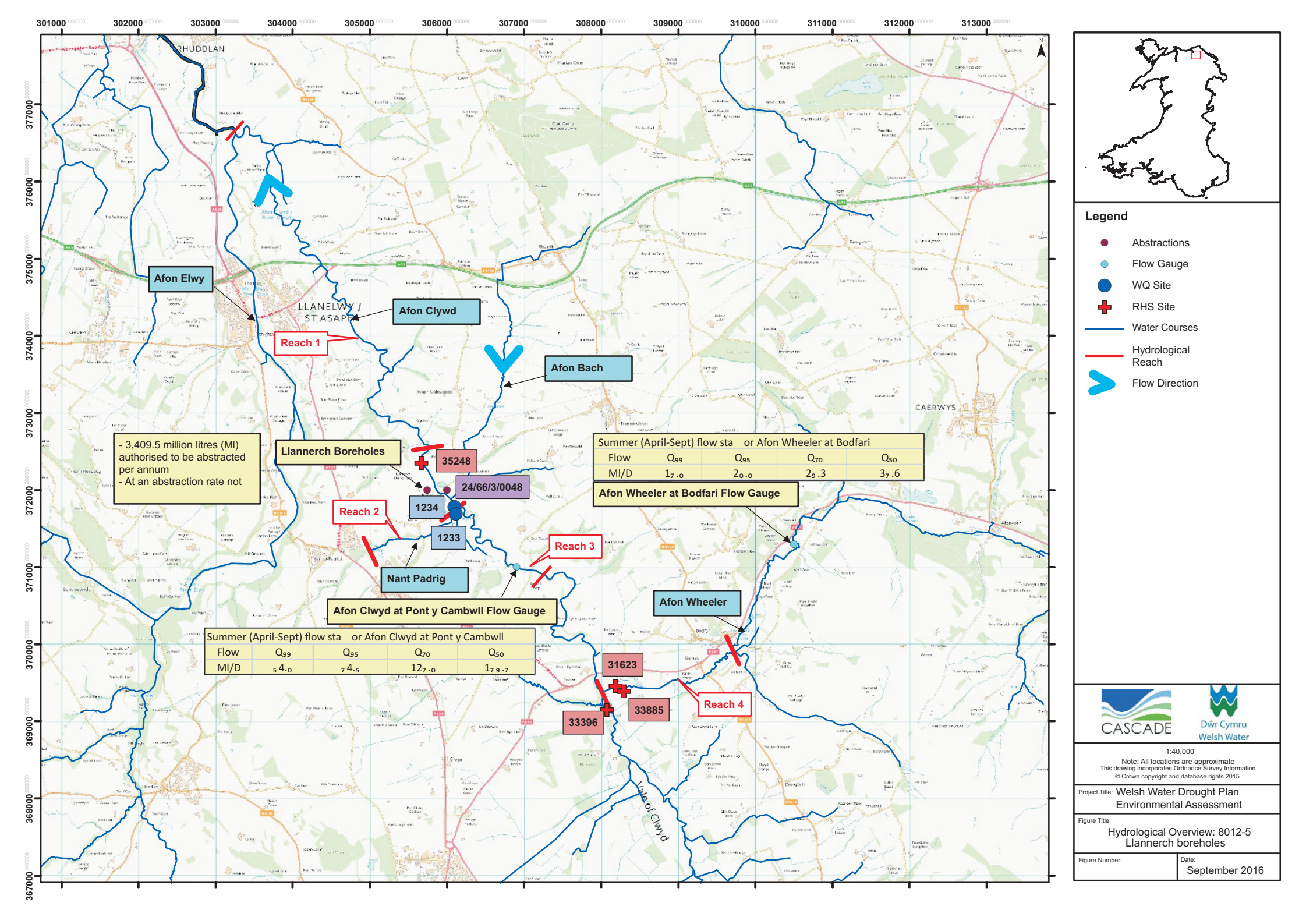
The assessment includes the Afon Clwyd, Afon Wheeler, Afon Bach and Nant Padrig, comprising of four distinct hydrological reaches. The study area is shown on **Figure B1.1**. The Afon Elwy is the largest sub-catchment of the Afon Clwyd, and joins approximately 8km downstream of the boreholes. Due to its location and underlying geology, the Afon Elwy is not considered to be at risk from abstraction at Llannerch.

The physical environment includes consideration of hydrology and hydrodynamics; geomorphology; and water quality. The assessment has three principal objectives:

1. It is used to "list the likely impacts to the flow, level, channel/riparian form and sediment due to action being in place" as required by the DPG[1] and set out in Figure 2 of the DPG.
2. It is used to support the screening and assessment of sensitive features (including ecological features and designated sites) as required by the DPG and set out in Section 5 of this report.
3. Where sensitive features are the physical environment itself, it provides supporting technical information for their screening and assessment.

This appendix is set out in the following sections:

[1] Natural Resources Wales (2017) *Water Company Drought Plan Technical Guideline*. Available at https://cdn.naturalresources.wales/media/684414/final-wc-drought-plan-guidance-2017.pdf?mode=pad&rnd=131656713580000000, Accessed 04 February 2019.



Legend

- Abstractions
- Flow Gauge
- WQ Site
- RHS Site
- Water Courses
- Hydrological Reach
- Flow Direction

CASCADE

Dŵr Cymru Welsh Water

1:40,000

Note: All locations are approximate

Project Title: Welsh Water Drought Plan Environmental Assessment

Figure Title: Hydrological Overview: 8012-5 Llannerch boreholes

Figure Number:

Date: September 2016

B2 HYDROLOGICAL AND HYDROGEOLOGICAL IMPACT

B.2.1 Reference Conditions

B.2.1.1 Catchment Overview

The Llannerch boreholes are situated next to the Afon Clwyd south east of St Asaph, Denbighshire. The boreholes are part of the Clwyd Coastal WRZ and abstracted groundwater is transferred via pipeline to the Glascoed WTW to the north west.

The Afon Clwyd is the second largest river that discharges into the Irish Sea along the North Wales Coast. The total length of the Afon Clwyd is over 46km, with Clocaenog Forest (at a height of 357m) being its source. The Afon Elwy is the largest sub-catchment of the Afon Clwyd, and joins approximately 8km downstream of the boreholes. The Clwydian Range bounds the catchment of the Afon Clwyd to the east, with the Denbigh Moors bounding it to the west.

The Afon Clwyd meanders gently across extensive deposits of glacial drift of various thicknesses which in turn overly Carboniferous and Triassic rocks and it therefore receives a significant component of baseflow from these aquifers. This contrasts with the Afon Elwy which flows over relatively impermeable Silurian rocks. As a result, the Afon Elwy is given to flashy flows following heavy rainfall and extreme low flows during dry periods.

B.2.1.2 Baseline Data Availability

Continuous river level monitoring is undertaken by Natural Resources Wales (NRW) on the Afon Clwyd, Afon Wheeler and Afon Elwy in the vicinity of the Llannerch boreholes. Data are available for:

- Pont y Cambwll flow gauge, Afon Clwyd upstream of Llannerch boreholes, daily river flow from 1959-2015;
- Pont Dafydd flow gauge, Afon Clwyd downstream of Llannerch boreholes, daily river flow from 1995-2015[2]; and
- Bodfari flow gauge, Afon Wheeler, tributary of Afon Clwyd 5km upstream of Llannerch boreholes, daily river flow from 1970-2014.

In addition to the permanent flow gauging monitoring, a set of historical spot flow gauging measurements are available at Pont y Cambwell, Llannerch and Pont Dafydd (Afon Clwyd) and on Afon Bach and Nant Padrig (tributaries of Afon Clwyd).

Groundwater level data are available for a series of sandstone and drift wells in the vicinity of the Llannerch boreholes (recorded by Welsh Water) and at Natural Resources Wales regional boreholes.

[2] Note that due to data quality issues at this site NRW are closing the station.

Daily abstraction returns are available for the Llannerch boreholes for the period 2000-2015.

B.2.1.3 Hydrology

The Afon Clwyd rises in the Clocaenog Forest, north west of Corwen, and, in the area of interest, flows north eastwards through the Vale of Clwyd and Clwyd valley. Approximately 5km upstream of Llannerch, the Afon Clwyd is joined from the east by the Afon Wheeler which has a catchment area of 70.5km^2 and is primarily sourced from Carboniferous Limestone and Silurian strata. Immediately upstream of the Llannerch boreholes, two minor tributaries flow into the Afon Clwyd; Nant Padrig (from the west) and Afon Bach (from the east) and have catchment areas of 3.2km^2 and 11.7km^2 respectively.

Approximately 8km north (i.e. downstream) of Llannerch and after flowing past the town of St Asaph, the river is joined by a significant tributary, the Afon Elwy. At the confluence of the Elwy and Clwyd, the river becomes tidal and enters a narrow estuary before flowing into the Irish Sea at Rhyl. Immediately upstream of the confluence, the Afon Clwyd and Afon Elwy drain catchment areas of 438km^2 and 253km^2 respectively.

Flow in the Afon Clwyd is gauged at Pont y Cambwll and Pont Dafydd, 2.4km and 4.8km upstream and downstream of the Llannerch boreholes respectively. Data have been provided by NRW for the period 1959-2015 (Pont y Cambwll) and 1995-2015 (Pont Dafydd) and, for the periods of data availability, indicate Q95 and Q99 flows to be 82.8Ml/d and 61.8Ml/d respectively at Pont y Cambwll (see **Figure B2.1** and **Table B2.2**) and 82.6Ml/d and 50.4Ml/d respectively at Pont Dafydd[3] (see **Figure B2.2** and **Table B2.4**).

For the period of overlapping data (i.e. 1995-2015), Q95 and Q99 flows are 84.7Ml/d and 71.5Ml/d respectively at Pont y Cambwll and 82.7Ml/d and 50.6Ml/d respectively at Pont Dafydd.

[3] The accuracy of the Pont Dafydd gauging station is known to be poor.

Figure B2.1 Flow Duration Curve at Pont y Cambwll Gauging Station in the Afon Clwyd (Annual, Summer and Winter FDC)

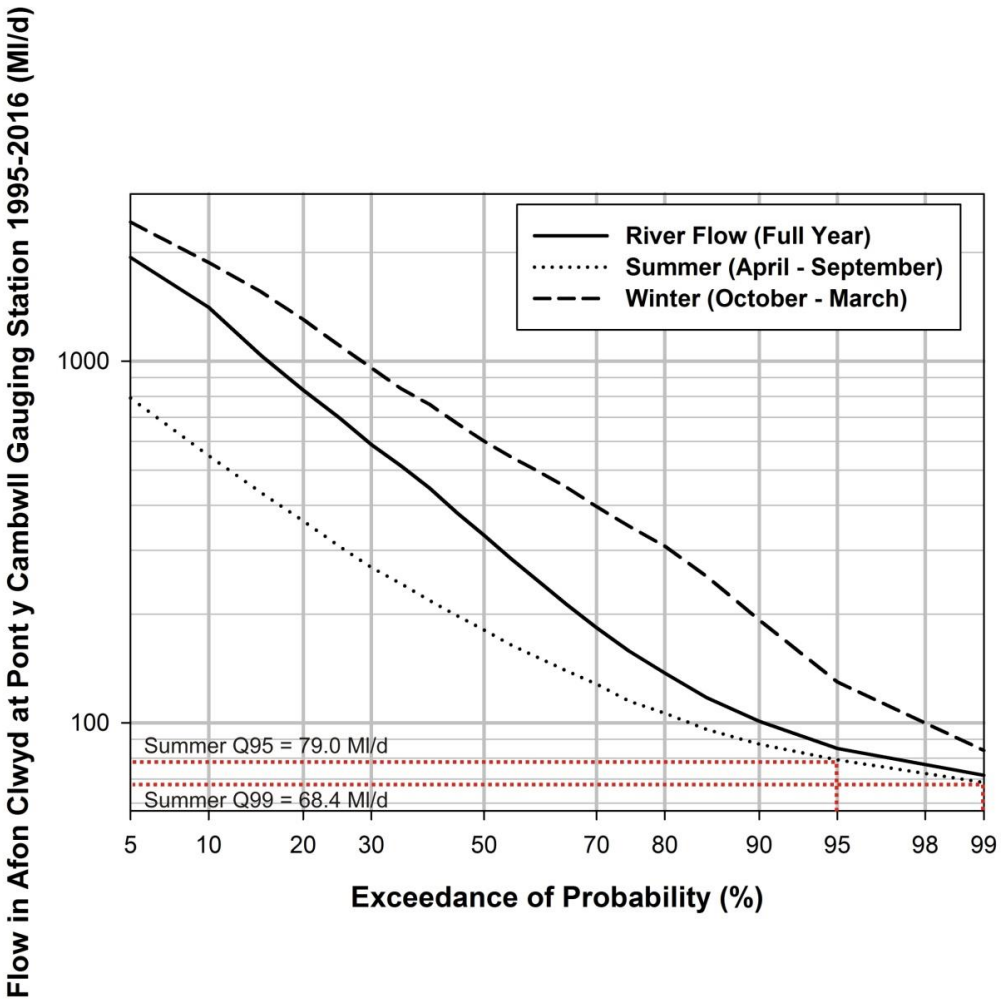


Table B2.1 Summary of Recorded Mean Daily Flow in the Afon Clwyd at Pont y Cambwll gauging station (March 1995 – February 2016)

Percentage of time river flow equalled or exceeded	Mean daily flow Ml/d, per month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All year
Maximum flow*	4812.5	4795.2	3715.2	3395.5	2376.0	5209.9	2609.3	1166.4	4095.4	6238.1	7672.3	6367.7	7672.3
10% (high flow)	2288.7	1856.7	1123.2	890.8	581.5	368.6	521.9	309.3	397.3	1235.5	1901.7	2281	1408.3
30%	1356.5	950.4	591	527	334.4	216.5	168.5	174.5	191.7	546.1	970.3	1339.2	588.4
50%	898.6	641.1	425.1	361.6	262.7	167.2	122.7	127.9	126.6	234.1	628.6	864	330.1
70%	516	396	303.3	199.4	187.5	124.4	90.7	85.7	87.1	115.8	335.9	460.51	183.2
80%	515.98	395.88	303.26	199.41	187.49	124.42	90.72	85.71	87.09	115.78	335.92	460.5	137.4
90%	356.1	314.2	249.7	163.2	152.1	109.6	79.6	76.2	80.8	92.5	182.8	345.6	101.1
95% (low flow)	261.8	239.7	216.9	148.1	127.4	96.8	74.9	70.7	75.6	80.3	136.5	269.1	85
99% (extreme low flow)	214.3	195.3	157.7	129.4	105	87.3	68.3	64.5	69.1	71.9	108.3	197.9	71.6
Minimum flow*	190.1	184.0	141.7	112.3	95.9	82.2	64.8	59.2	65.1	62.4	97.6	178.0	59.2

*The maximum and minimum flow as recorded each month over the period of record at the gauging station

Table B2.2 Summary of Seasonal Recorded Mean Daily River Flow in the Afon Clwyd at Pont y Cambwll (1995 – 2015)

Percentage of time flow equalled or exceeded	Mean daily river flow (Ml/d), summer and winter		
	Summer	Winter	All year
Maximum flow*	5209.9	7672.3	7672.3
10% (flow)	548.5	1874.9	1408.3
30%	268.7	659	588.4
50%	180.6	601.3	330.1
70%	127.9	396.6	183.2
80%	106.3	307.6	137.4
90%	87.3	192.3	101.1
95%	79	129.6	85
99% (flow)	68.4	83.9	71.6
Minimum flow*	62.4	59.2	59.2

*The maximum and minimum flow as recorded in summer/winter over the period of record at the gauging station

Figure B2.2 Flow Duration Curve at Bodfari Gauging Station in the Wheeler (Annual, Summer and Winter FDC)

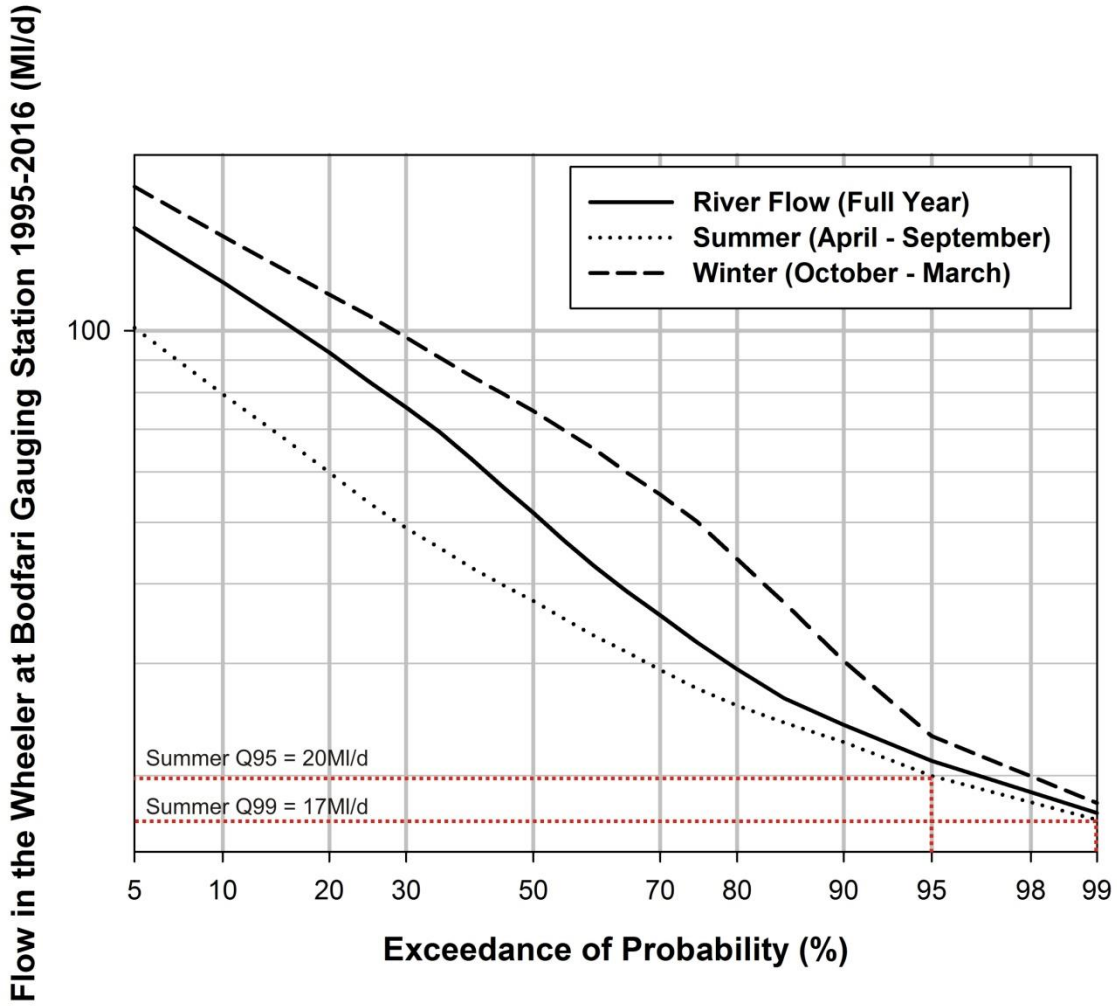


Table B2.3 Summary of Recorded Mean, Maximum and Minimum Daily Flow in the Wheeler at Bodfari gauging station (March 1995 – February 2016)

Percentage of time river flow equalled or exceeded	Mean daily flow Ml/d, per month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All year
Maximum flow	300.7	437.2	318	324.9	293.8	291.2	264.4	214.3	309.3	376.7	552.1	317.1	552.1
10% (high flow)	150.0	146.9	133.1	120.1	81.6	67.3	57.6	59.8	51.2	115.8	126.1	155.2	119.2
30%	116.1	102.0	88.1	83.4	58.1	45.7	37.8	33.4	36.0	55.1	85.3	107.1	75.8
50%	94.2	81.9	72.3	64.8	47.1	38.4	31.0	28.1	27.1	33.4	65.1	86.1	51.8
70%	74.3	69.3	59.1	48.0	39.5	32.2	26.5	24.5	22.8	25.0	43.2	66.1	35.7
80%	62.3	61.3	53.2	42.7	35.9	29.6	24.6	22.5	21.4	21.9	36.9	58.0	29.4
90%	52.0	51.8	45.9	38.2	32.7	26.2	22.8	19.5	18.8	19.5	28.0	46.3	24
95% (low flow)	45.5	39.9	41.3	36.1	29.9	24.8	20.5	18.3	17.5	17.8	23.0	32.3	21.1
99% (extreme low flow)	37.8	33.4	35.1	32.0	24.6	21.5	18.5	16.0	15.7	16.1	20.6	25.1	17.5
Minimum flow	32.6	30.4	32.1	28.1	22.9	19.9	17.4	14.9	14.6	15.1	18.7	21.4	14.6

Table B2.4 Summary of Seasonal Recorded Mean Daily River Flow in the Wheeler at Bodfari (1995 – 2015)

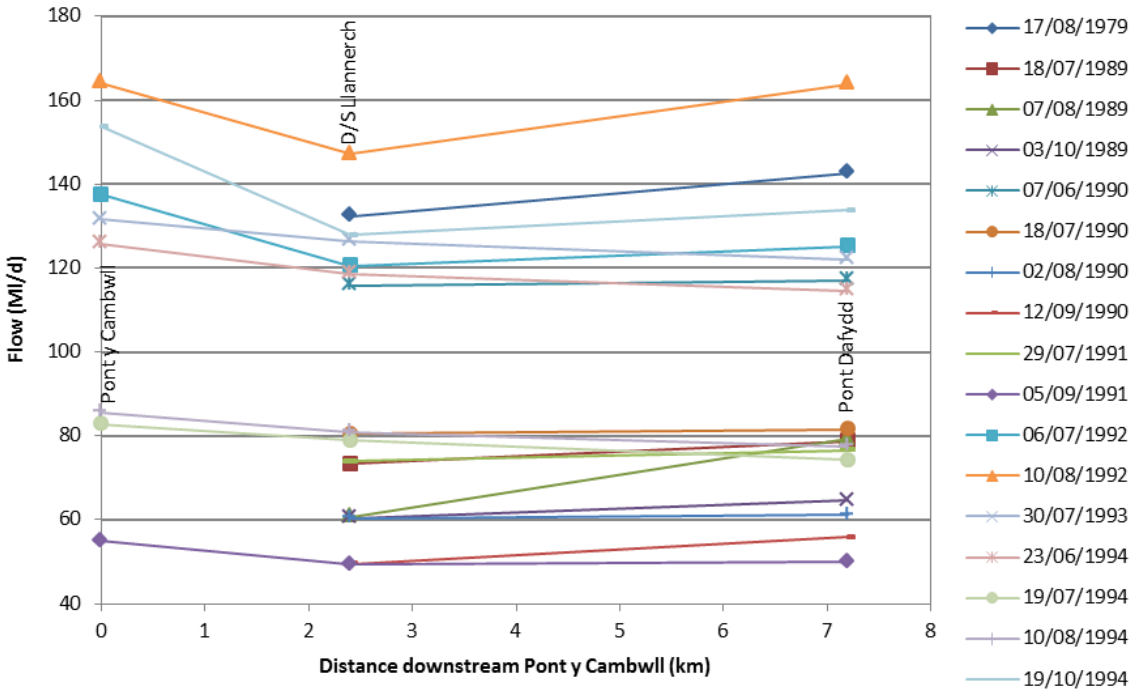
Percentage of time flow equalled or exceeded	Mean daily river flow (Ml/d), summer and winter		
	Summer	Winter	All year
Maximum flow	324.9	552.1	552.1
10% (flow)	79.6	140.8	119.2
30%	49	97.6	75.8
50%	37.6	74.8	51.8
70%	29.3	55.3	35.7
80%	25.7	43.7	29.4
90%	22.6	30.2	24
95%	20	23	21.1
99% (flow)	17	18.1	17.5
Minimum flow	14.6	552.1	14.6

The flow statistics suggest that there is a loss of flow at very low flows along the Afon Clwyd between Pont y Cambwll and Pont Dafydd of up to 20Ml/d. This is much larger than the recent actual abstraction at Llannerch (8.62Ml/d) which suggests that the apparent flow reduction may not be entirely related to groundwater abstraction. There are no known surface water abstractions or discharges along this reach[4] and the watercourse is joined by two tributaries which contribute a total catchment area of approximately 15km^2 (Nant Padrig and Afon Bach). It has previously been reported[5] that the Pont y Cambwll station is affected by weed growth in summer and by sand and gravel movement and therefore the accuracy of the flow data is unknown (for example it may overestimate flows, potentially contributing to the observed flow loss).

Evidence for flow loss along this reach includes some limited spot flow gauging undertaken at the two gauging stations and immediately downstream of the Llannerch boreholes. Accretion profiles are shown in **Figure B2.3**. Between Pont y Cambwll and downstream Llannerch boreholes, losses of 4 to 26Ml/d are recorded between September 1991 and October 1994. Although much of this is regained before Pont Dafydd, there is an overall loss on all occasions when a spot flow gauging measurement is available at Pont y Cambwll. Whilst this suggests abstraction at Llannerch is a contributory cause of flow loss, it is difficult to separate this effect from potential natural losses to the gravel and possible measurement errors at the continuous flow gauges.

[4] ESI Ltd (2003). Vale of Clwyd Aquifer Study Phase 2 Report: Conceptual model and water balance in support of RAM assessment. Report ref: 6338R2, July 2003.
[5] ESI Ltd (2003). Vale of Clwyd Aquifer Study Phase 2 Report: Conceptual model and water balance in support of RAM assessment. Report ref: 6338R2, July 2003.

Figure B2.3 Spot Flow Gauging on Afon Clwyd



Flows in the main river channel (Afon Clwyd) are subject to the Clwyd Augmentation Scheme which has been licensed since 1977. Boreholes in the lower Clwyd are licensed to abstract up to a rate not exceeding 13.6Ml/d. When river flows are less than 147Ml/d (approximately equivalent to Q75-Q80 flows) at Pont y Cambwll, the abstractions at Llannerch must be supported by augmentation from the combined contributions from the Alwen aqueduct (water diverted from the Dee catchment) and several boreholes in the central Clwyd valley. The water released into the Clwyd river system through several sewage treatment works is offset against the required volume.

It is reported that flow in the Afon Clwyd is actually enhanced by 1Ml/d in addition to the public water supply (PWS) requirement[6]. However, the Llannerch abstraction represents only 2.5% of the average daily flow at Pont y Cambwll and the river levels have only fallen below the threshold of 147Ml/d between early May and early November, and so the river is generally only augmented during this period.

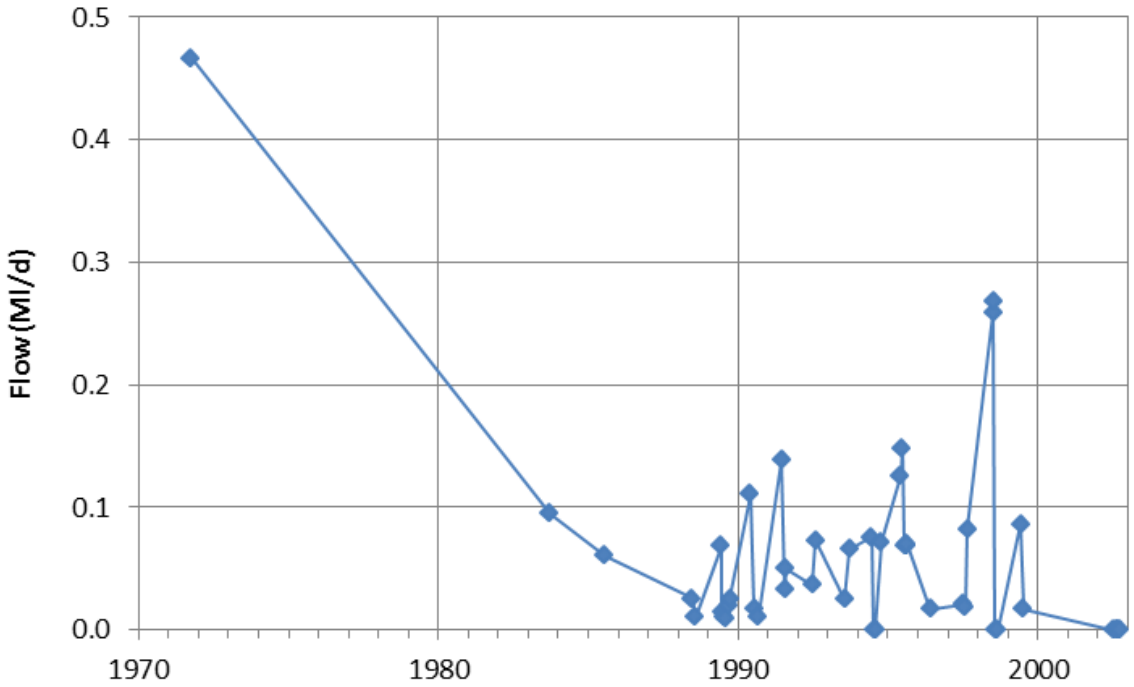
The Afon Wheeler is gauged at Bodfari, approximately 4km upstream of the confluence with the Afon Clwyd. Flow data for the period 1970-2014 indicate Q95 and Q99 flows of 21.1Ml/d and 17.5Ml/d (all year round). This is equivalent to approximately 25% of flow in the Afon Clwyd at Pont y Cambwll (catchment area of Afon Wheeler at Bodfari is approximately 15% of Afon Clwyd at Pont y Cambwll).

Limited spot flow gauging data are available for the Afon Bach and Nant Padrig, two tributaries of the Afon Clwyd that confluence immediately upstream of the Llannerch boreholes. During

[6] Environment Agency, (2008). Underground, Under threat: The state of groundwater in England and Wales. (Bristol: Environment Agency.)

the 1990s flow in Nant Padrig (**Figure B2.4**) was typically up to 0.15Ml/d, although higher readings were recorded in July 1998 (0.26Ml/d). A considerably higher reading was recorded in September 1971 of 0.47Ml/d. Whilst this is before abstraction had commenced at Llannerch, there is insufficient information to confirm that this suggests flow reductions in Nant Padrig due to abstraction.

Figure B2.4 Spot Flow Gauging on Nant Padrig (SJ 05678 71403)



A gauging run was undertaken by Amec on the Afon Bach in May 2011 following a prolonged dry period. The results suggest flow in the region of 1-2Ml/d with a general pattern of accretion downstream. Flow loss between Site 6 (SJ 0629 7209) and Site 4 (SJ 0622 7207) is recorded as the watercourse leaves the clay and begins to flow over the alluvial deposits.

B.2.1.4 Geology

The Vale of Clwyd lies between the Conwy and Clwydian blocks which comprise uplifted horsts of Carboniferous and older strata. The area is at the southern limit of the Permo-Triassic Irish Sea Basin, which is characterised by a series of tilted, stepped fault blocks which generally trend north-south. These faults displace the succession of Carboniferous and Permo-Triassic strata, resulting in a progressive offset of the outcrop in a south east direction.

In the study area, the river catchment is underlain predominantly by Permo-Triassic rocks of the Kinnerton Sandstone Formation of the Sherwood Sandstone Group. The Permo-Triassic rocks are aeolian, weakly cemented fine to medium grained sandstones. The aquifer is divided into northern and southern blocks by a strip of Carboniferous strata. Llannerch is within the southern block of the Vale of Clwyd Permo-Triassic Sandstone which is bounded to the west and east by the north-south trending Denbigh and Vale of Clwyd Faults respectively.

Geophysical surveys have suggested that the sandstone is at least 300m thick[7] and a gravity model of the basin indicates it may be up to 550m thick[8].

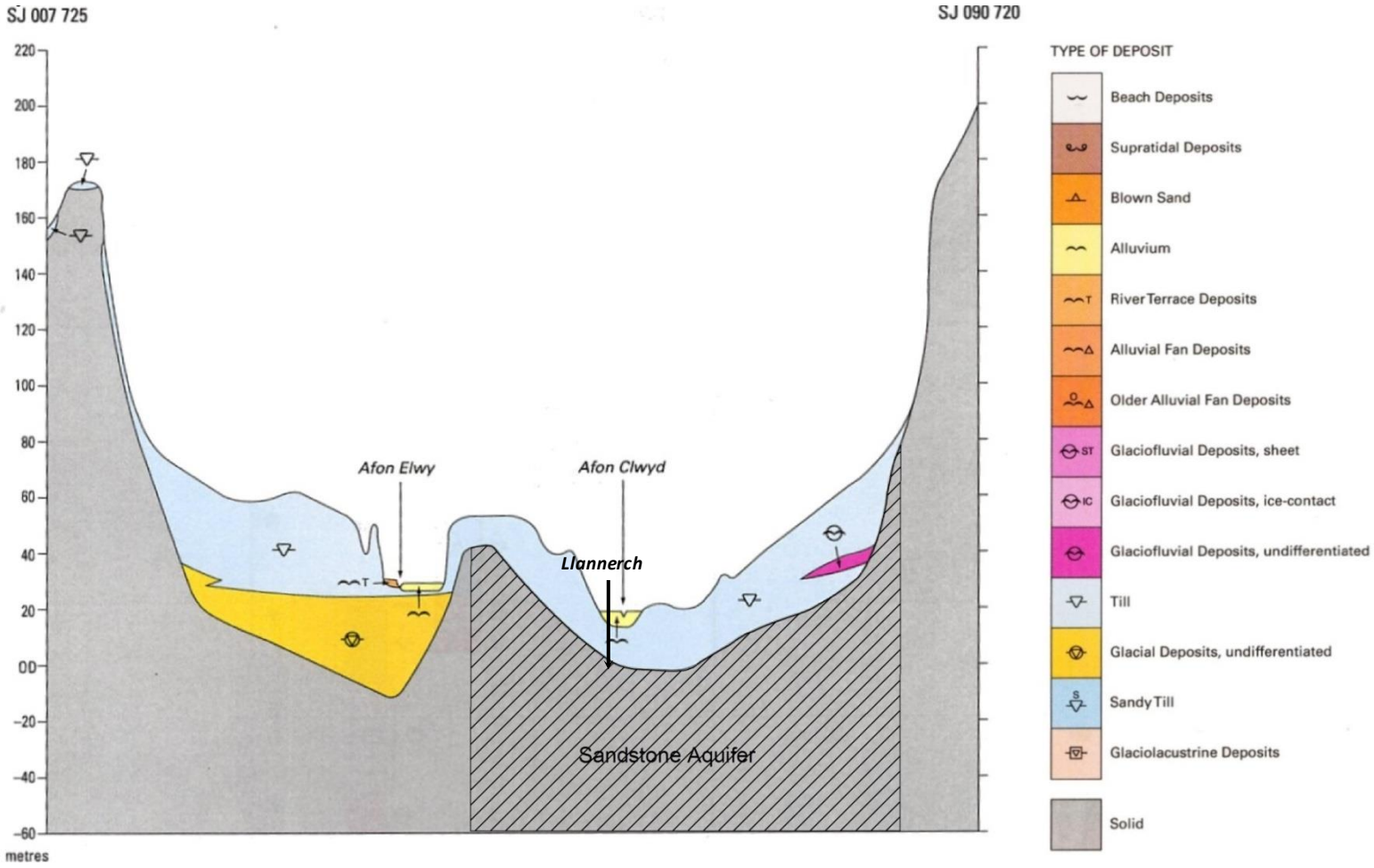
The Permo-Triassic Sandstone is underlain by the Warwickshire Group of Silesian (Upper Carboniferous) age, although faults result in the lateral juxtaposition of a considerable thickness of sandstone against the Warwickshire Group at depth. The Warwickshire Group is formed from alternating thin to thick bedded mudstones, siltstones and sandstones with localised thin coal seams and is at outcrop to the north of the Llannerch boreholes.

There is a wide range of glacial, late-glacial, and post-glacial superficial deposits in the Vale of Clwyd, forming a thick sequence locally up to 90m thick. They mainly occur in two basins located on the northern and southern aquifer blocks – in the northern area, the drift basin is generally broad and steep-sided, with the sandstone aquifer underlying the central part of the basin, whereas the southern drift basin is a broad valley representing a palaeo channel of the River Clwyd.

Superficial deposits are predominantly low permeability glacial till deposits. Within the Vale of Clwyd there are two distinct types of glacial till; the Welsh Till and Irish Sea Till deposited by the Welsh and Irish Sea ice sheets respectively. In the vicinity of Llannerch (and as far south as Denbigh), the till is defined as Irish Sea till and comprises predominantly red and brown stiff sandy silty clay with scattered gravel sized clasts and a variable proportion of sand lenses. Whilst glacial till dominates, much lateral and vertical variation exists due in drift deposits, and glaciofluvial sands and gravels, alluvial fan deposits and river terrace deposits are also present[9]. The Afon Clwyd and surrounding channels all flow through alluvium. A cross-section through the drift deposits in the Trefnant area between the Gwaynynog Fault and Llanrhaiadar Fault, incorporating the Afon Elwy and Afon Clwyd are shown in **Figure B2.5**.

[7] Wilson, C. D. V. (1961), Geophysical investigations in the Vale of Clwyd. Geol. J., 2: 253–270
[8] Wilson, D; Waters, C; and Rollin, K E. (2002). A geological and geophysical desk study of the Vale of Clwyd. British Geological Survey Commissioned Report, CR/02/177.
[9] Fahrner, S, Gomme, J, Farr, G, and Mann, A. (2007). Groundwater quality review: Clwyd Permo-Triassic sandstone. Environment Agency, Bristol, Technical Report.

Figure B2.5 Schematic Section through the Drift Deposits of the Trefnant Area[10]



[10] Wilson, D; Waters, C; and Rollin, K E. (2002). A geological and geophysical desk study of the Vale of Clwyd. British Geological Survey Commissioned Report, CR/02/177.

B.2.1.5 Hydrogeology

The Kinnerton Sandstone Formation is the Principal Aquifer[11] within the study area and is the lithology from which the Llannerch boreholes abstract groundwater. Analysis of pumping test data across the aquifer gives estimated hydraulic conductivities in the range 0.2-3m/d for matrix flow, with values up to 25m/d associated with probable fissure flow[12]. Bulk permeabilities have been reported in the range 0.17 to 20m/d with storage coefficients of $1x10^{-4}$ to $2x10^{-3}$ (reported in the aquifer properties manual[13]). Although transmissivities of 660-2170m^2/d have been recorded at Llannerch, geophysical evidence suggests these may be associated with fissure flow and it is likely that the lower transmissivity values recorded elsewhere in the aquifer (50-100m^2/d) are more representative of bulk matrix permeability.

The lithology is productive via inter-granular flow with some fissure flow. On a local scale, marl horizons and layering within the unit can cause the system to behave as a multi-layered aquifer. Geophysical studies suggest that fault-gouge along the major north-south faults through the outcrop may be sufficient to restrict groundwater movement between different parts of the basin[14]. Perturbation in the base of the aquifer unit, caused by faulting, may also affect flow at depth and active groundwater flow is likely to be restricted to the upper 200m of the aquifer block. Furthermore, geophysical surveys have indicated that the key influence to the main abstraction borehole were associated with a series of fractures in a zone between 28 to 35mbgl[15], although the borehole has a total depth of 91.4m.

As discussed in Section B.2.1.4, the majority of the sandstone is overlain by superficial deposits and considerable lateral and vertical variation in the nature of these deposits exists within the Vale of Clwyd. These exert an important control on recharge to the underlying sandstone and connectivity of the sandstone aquifer with surface watercourses. The glacial till which overlies much of the southern aquifer block is generally low permeability, as are the glaciolacustrine deposits found at depth. Higher permeabilities are associated with the glaciofluvial deposits, fan deposits, terrace gravels and alluvium found in the central southern part of the aquifer.

The Vale of Clwyd aquifer study[16] identified three layers vertically within the superficial deposits; a shallow permeable layer (in hydraulic continuity with the Afon Clwyd), a deeper low permeability zone and a higher permeability layer at depth (likely to be in continuity with the underlying sandstone). For example, at Llannerch, the shallow permeable layer is absent, but underlying 1.5m of surface clayey material, 6m of gravels were present and then a further 4.5 to 5m of clays overlying the sandstone.

[11] Principal Aquifers are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer (Environment Agency, WIYBY, 2015).
[12] ESI Ltd (2003). Vale of Clwyd Aquifer Study Phase 2 Report: Conceptual model and water balance in support of RAM assessment. Report ref: 6338R2, July 2003.
[13] Allen, D.J., Brewerton, L.J., Coleby, L.M., Gibbs, B.R., Lewis, M.A., MacDonald, A.M., Wagstaff, S.J., and Williams, A.T. (1997). The physical properties of major aquifers in England and Wales. Technical Report WD/97/34. R&D Publication 8.
[14] Wilson, D; Waters, C; and Rollin, K E. (2002). A geological and geophysical desk study of the Vale of Clwyd. British Geological Survey Commissioned Report, CR/02/177.
[15] Hyder Consulting, (1998). Llannerch Park Assessment of Borehole C.
[16] ESI Ltd (2003). Vale of Clwyd Aquifer Study Phase 2 Report: Conceptual model and water balance in support of RAM assessment. Report ref: 6338R2, July 2003.

Where the till/boulder clay is thick enough, it effectively seals the groundwater from surface water and permits the formation of substantial artesian heads in the underlying sandstone[17]. Much of the southern block of sandstone is confined by low permeability drift and artesian conditions exist in the area north of Ruthin to south of Bodfari (several kilometres south of the borehole site), with heads up to 8m above ground level[18,19,20]. Whilst this artesian zone is not mapped to extend to Llannerch (see **Figure B2.6**), it is known that, prior to the onset of abstraction in 1979, a low permeability basal layer within the drift deposits partially confined the underlying sandstone resulting in artesian conditions (groundwater heads within the sandstone were approximately 1m above those in the drift). Since the start of abstraction this has been reversed and groundwater heads in the drift deposits are approximately 0.5m higher than those in the sandstone (as reported in the Llannerch source evaluation report[21]).

Pumping tests undertaken in 1976 confirmed preliminary observations [22] that there is naturally a substantial upward flow of sandstone groundwater back to the Afon Clwyd via the semi-permeable drift. The following observations were made during the 1976 pumping test[23]:

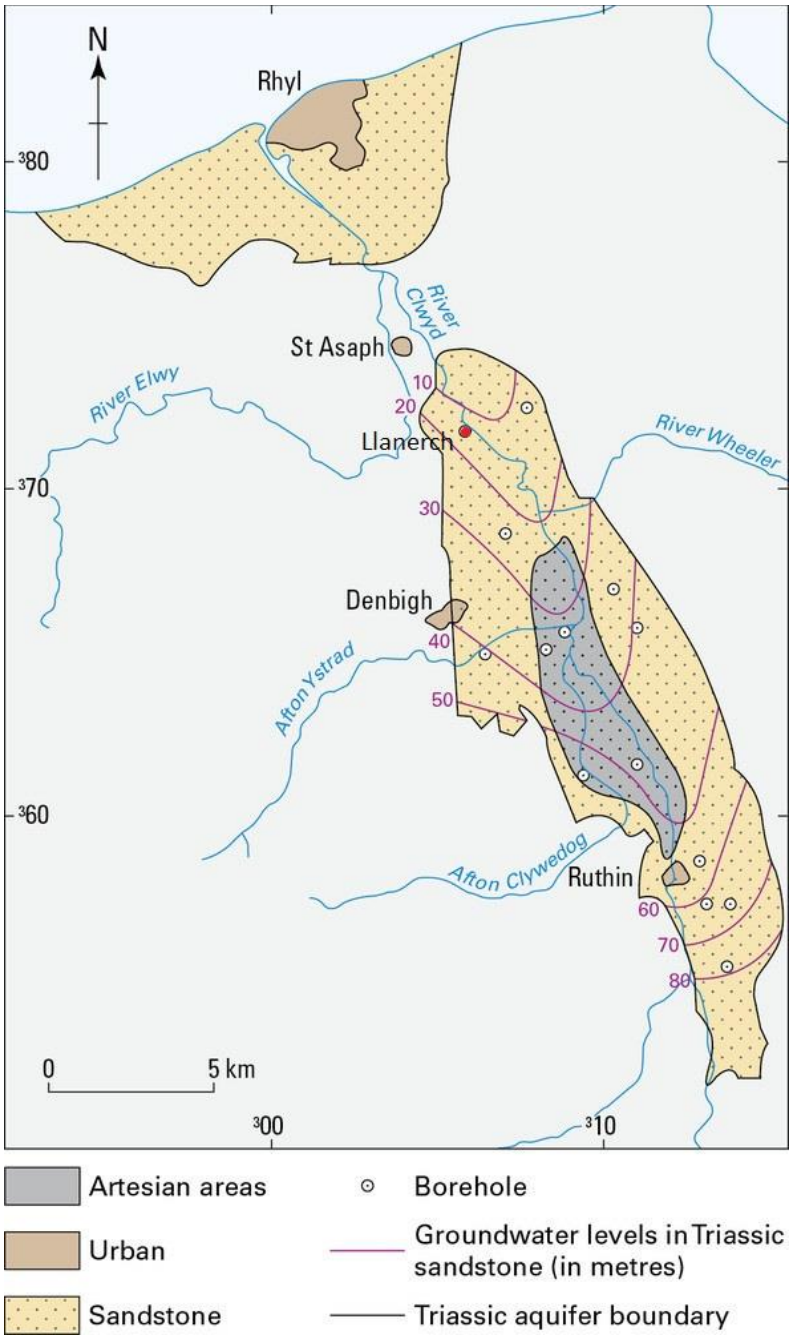
- Boreholes at the Llannerch site could intercept 7Ml/d of this natural flow; and that if the boreholes were pumped at rates in excess of 7Ml/d (i.e. under extended abstraction), the local lowering of piezometric levels in the sandstone, and overlying drift, created an induced recharge from the river to the sandstone via the drift.

- Stability of groundwater levels (in relation to river levels) could be achieved within two or three days at pumping rates up to 14Ml/d (borehole drawdowns up to 10m), but no stability of borehole levels could be achieved at 18Ml/d.

- On reduction of pumping to less than 7Ml/d, the upward flow mechanism was rapidly re-established with pumping intercepting natural flow from the sandstone to the river (note that recent abstraction for the period 2000-2016 is in the region of 9Ml/d).

[17] Water Resources Board (1973). Groundwater resources of the Vale of Clwyd.
[18] ESI Ltd (2003). Vale of Clwyd Aquifer Study Phase 2 Report: Conceptual model and water balance in support of RAM assessment. Report ref: 6338R2, July 2003.
[19] Fahrner, S, Gomme, J, Farr, G, and Mann, A. (2007). Groundwater quality review: Clwyd Permo-Triassic sandstone. Environment Agency, Bristol, Technical Report.
[20] Environment Agency, (2008). Underground, Under threat: The state of groundwater in England and Wales. (Bristol: Environment Agency.)
[21] ESI Ltd (2013). Llannerch Park Source Evaluation Report. Report ref: 60159R, February 2013.
[22] Water Resources Board (1973). Groundwater resources of the Vale of Clwyd.
[23] Lambert, A.O. (1981). The River Clwyd Augmentation/Abstraction Scheme. Journal of the Institution of Water Engineers and Scientists, Vol. 35, 125-134.

Figure B2.6 Hydrogeological setting of the Vale of Clwyd[24]



Groundwater movement within the catchment is affected by the superficial deposits with glacial tills acting as impermeable layers of low hydraulic conductivity and deposits of alluvium, terrace deposits and glacio-fluvial sands and gravels acting as minor aquifers. Generally, groundwater in the major aquifer flows in a northerly direction (see **Figure B2.6**). Typical groundwater levels in the sandstone are 80mAOD at Llanfair Dyffryn Clwyd (SJ 1374 5556) and 17mAOD at Pont y Cambwll (SJ 0704 7081). Annual variations in groundwater level are minimal, typically less than 1.5m, suggesting relatively small changes in storage

[24] N.S. Robins and J. Davies (undated), Hydrogeology of Wales: Permo-Triassic and Jurassic aquifers – Vale of Clwyd, available online at: http://earthwise.bgs.ac.uk/index.php/Hydrogeology_of_Wales:_Permo-Triassic_and_Jurassic_aquifers_-_Vale_of_Clwyd

(confirming the largely confined nature of the aquifer). The Vale of Clwyd aquifer study[25] notes a general trend of falling groundwater levels following extended periods of low rainfall. This decline is more rapid, and recovery slower, at boreholes in the vicinity of Llannerch PWS, suggesting the abstraction may be impacting groundwater levels in its vicinity.

Location of key observation boreholes are shown in **Figure B2.7**. Groundwater levels within the sandstone aquifer (C1) and drift deposits (S6) for representative wells at Llannerch are shown in **Figure B2.8** in comparison to annual abstraction. This confirms the observations noted above that prior to the start of abstraction, sandstone groundwater levels were artesian and higher than drift groundwater levels. The gradient was not reversed until abstraction rates of between 7 and 9Ml/d were applied from the 1990s onwards after which water is drawn into the gravels from the river.

Data from surrounding monitoring wells were used as part of a previous study[26] to determine the likely zone of the sandstone and drift aquifers affected by the abstraction. **Figure B2.9** shows that sandstone water levels at Brynbella and Maes y Parc observation boreholes have declined by approximately 1m since the onset of abstraction. There is no groundwater level monitoring at Pont y Cambwll prior to abstraction, but groundwater levels exhibit a very similar pattern to those at Brynbella and are likely similarly affected by abstraction. Groundwater levels at sandstone observation boreholes further afield (e.g. Pentre Mawr) show no clear response to abstraction, suggesting they are outside the zone affected by abstraction.

As shown in **Figure B2.8**, the 'natural' hydraulic gradient is reversed as a result of abstraction at the series of observation wells in the immediate vicinity of Llannerch (within 200m of the abstraction boreholes). Whilst drift and sandstone water levels are available for Glan Clwyd, 1.7km north east of Llannerch, the drift well is monitoring the deeper drift (which is in hydraulic continuity with the sandstone) rather than the shallower drift. Drift levels are approximately 0.25m higher, but typically mirror, sandstone levels. Drift levels monitored at Trefnant, 450m to the south of Llannerch, are inferred to be very similar to sandstone levels[27], suggesting that the reversal of hydraulic gradient is limited to the immediate vicinity of the Llannerch boreholes.

[25] ESI Ltd (2003). Vale of Clwyd Aquifer Study Phase 2 Report: Conceptual model and water balance in support of RAM assessment. Report ref: 6338R2, July 2003.
[26] ESI Ltd (2013). Llannerch Park Source Evaluation Report. Report ref: 60159R, February 2013.
[27] ESI Ltd (2013). Llannerch Park Source Evaluation Report. Report ref: 60159R, February 2013.

Figure B2.7 Location of Key Sandstone and Drift Observation Boreholes

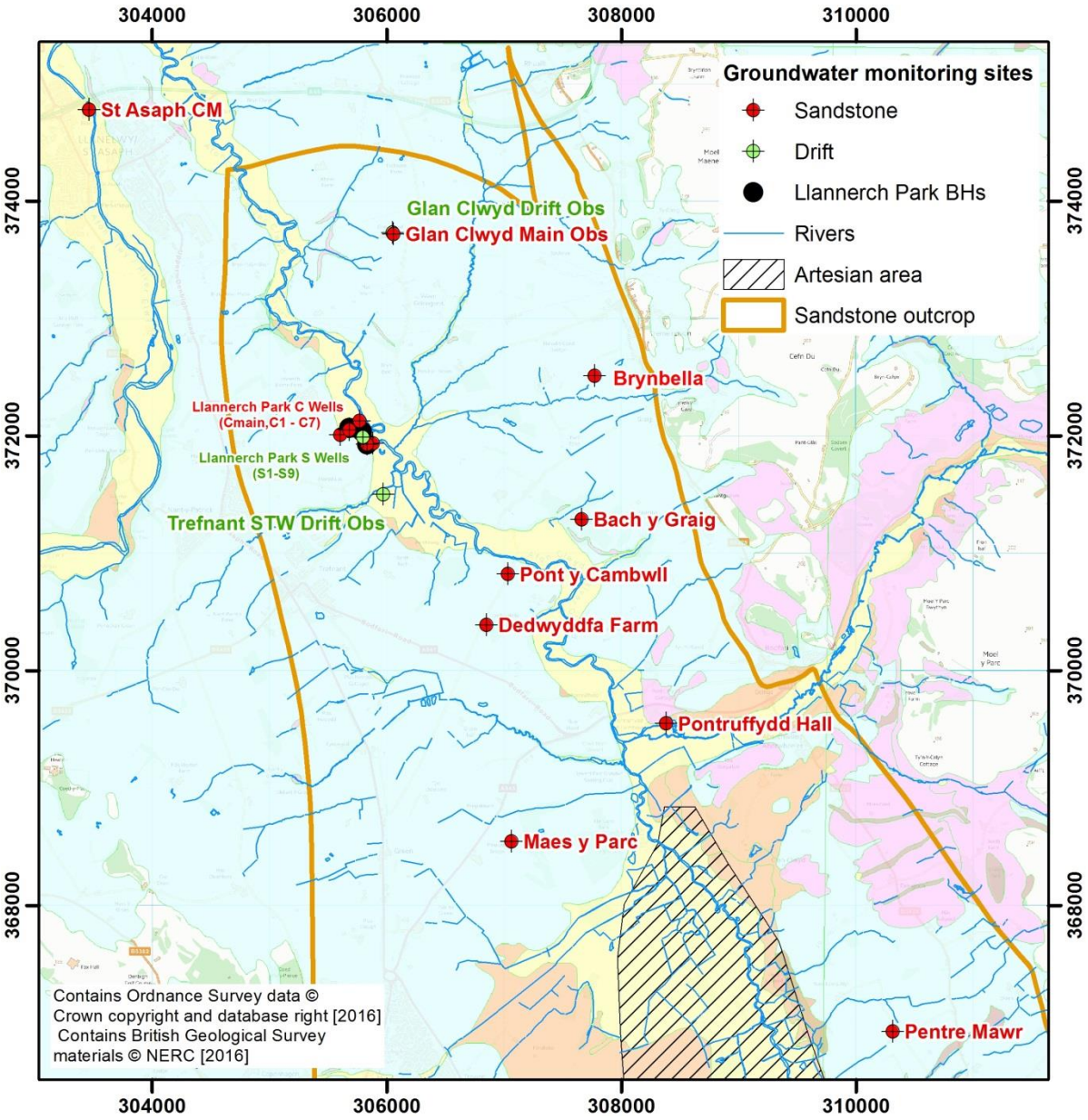


Figure B2.8 Comparison of Drift and Sandstone Groundwater Levels at Llannerch

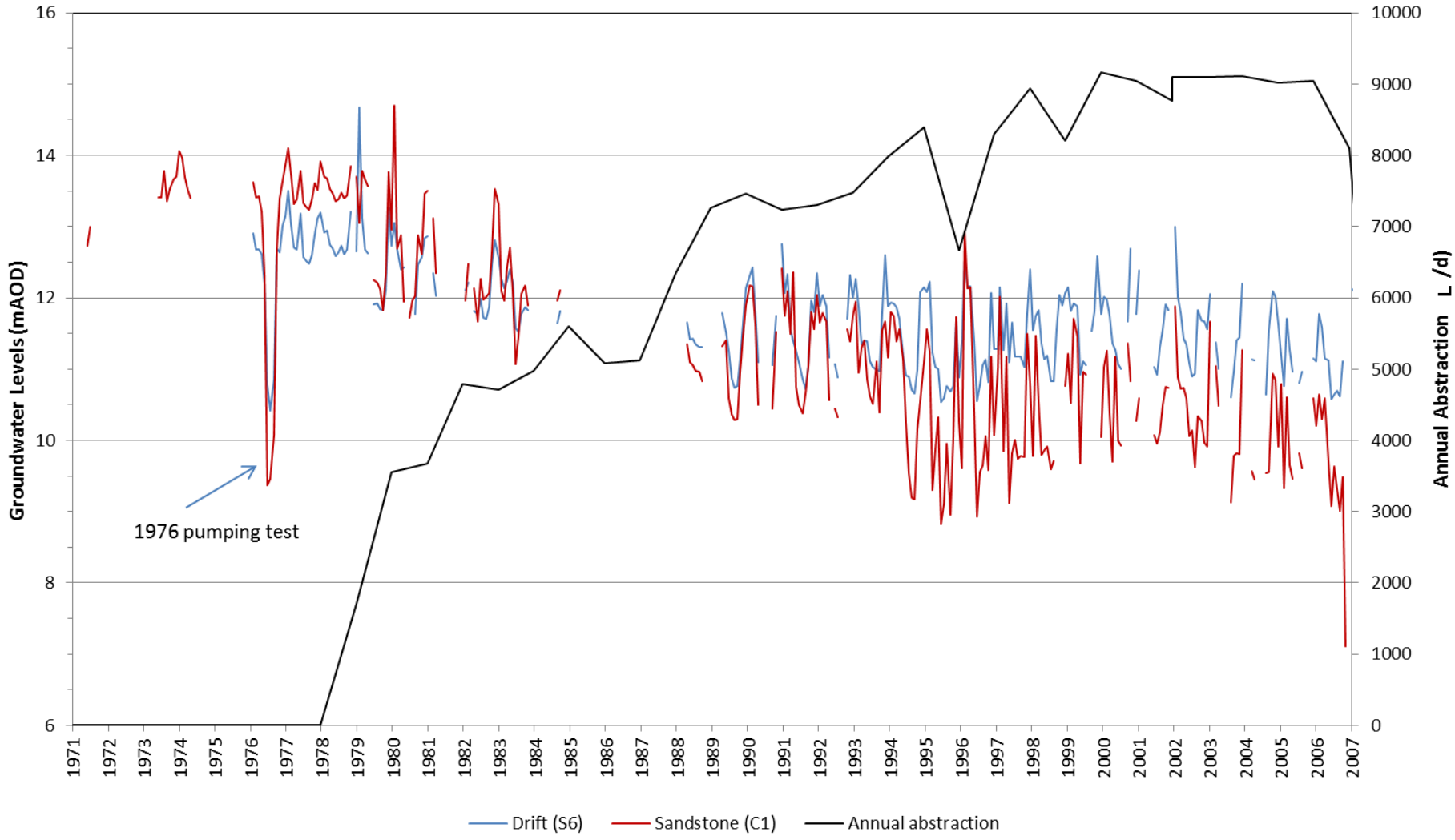
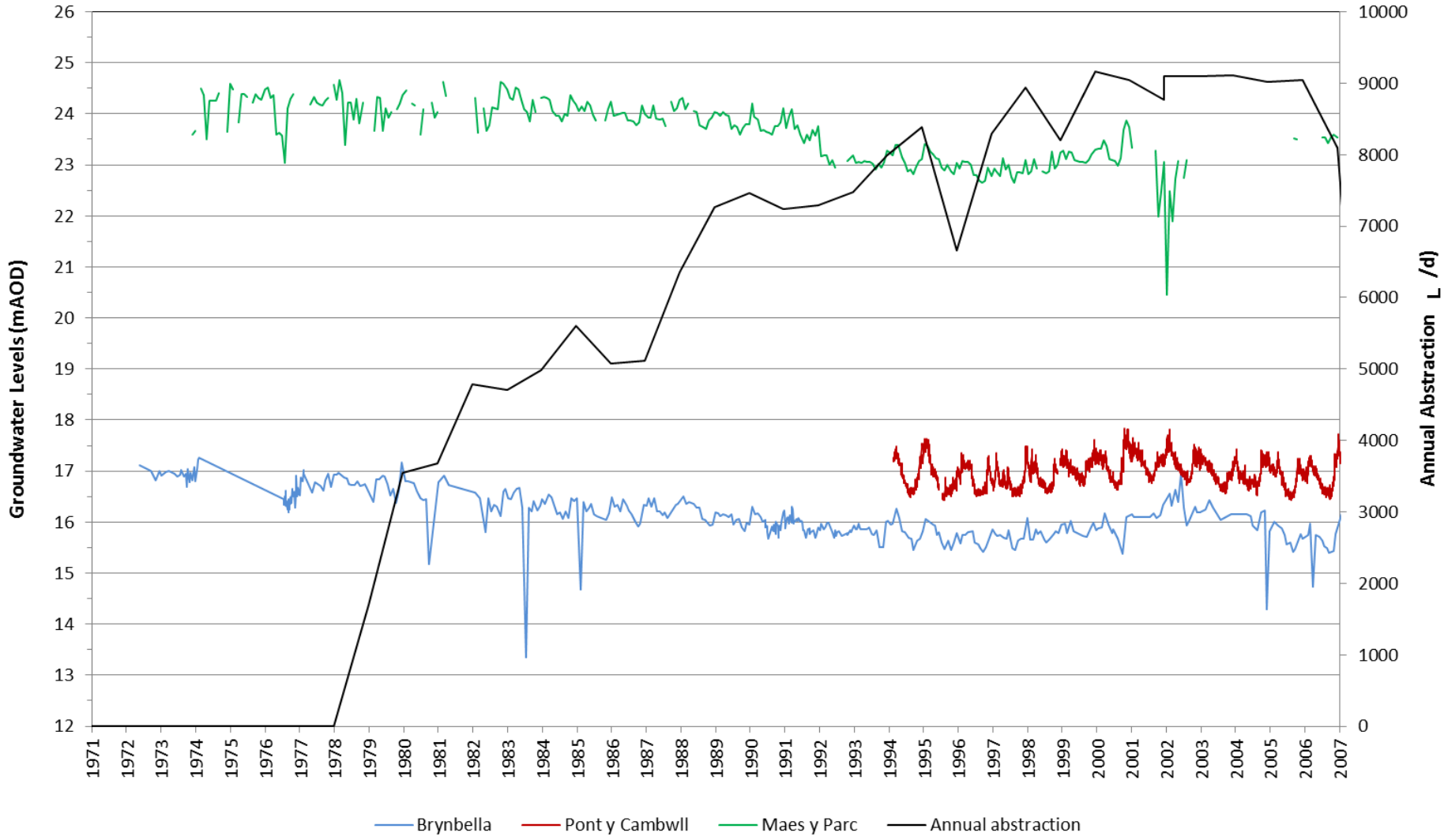


Figure B2.9 Regional Groundwater Levels in Comparison to Abstraction at Llannerch



The Warwickshire Group (Upper Carboniferous) is classed as a Secondary Aquifer[28] with a low primary porosity and is productive via fissure flow through well cemented sandstone units which are divided by mudstone and shale aquicludes. The sandstone is in hydraulic continuity with the Carboniferous strata both along the western edge and beneath the Vale of Clwyd. For the most part, the Permo-Triassic sandstone overlies the Warwickshire Group, and due to the nature of the Warwickshire Group, hydrogeological continuity between the two at depth is very limited[29], 1984). However, in isolated sections along both eastern and western edges, faulting has juxtaposed Permo-Triassic sandstone against the Warwickshire Group at depth. There are few data to determine the hydraulic nature of this boundary, but it is thought that cross boundary groundwater flow may be minimal. It is believed that the Warwickshire Group subcrop at St Asaph provides an impermeable barrier to groundwater flow to the north (P Neve, pers comm) although there is a possibility that flow could occur through overlying drift deposits.

B.2.2 Hydrological and Hydrogeological Impact

B.2.2.1 Hydrogeological Zone of Influence

The conceptual understanding of the Afon Clwyd and Llannerch boreholes under current pumping conditions is such that abstracted water is predominantly thought to be sourced from intercepted baseflow and/or induced recharge from the river via the superficial deposits (see Section B.2.1.5). The drift is in hydraulic continuity with the surface water and contributes the majority of river baseflow (approximately 90%[30]), the remainder sourced from upward leakage from the sandstone. Due to the extensive cover of low permeability till that overlies and confines the sandstone, whilst some abstraction will be at the expense of baseflow from the superficials in the immediate vicinity of the abstraction, the zone of influence of the abstraction is very extensive as it expands out through the confined zone to reach areas in which the overlying drift is more permeable and allows recharge through. The recharge area of the abstraction was estimated during the Llannerch source evaluation study[31] and covers a total area of 12km^2 (see **Figure B2.10**). This will be explained further below.

The operation of the proposed drought permit will affect local groundwater levels, thus influencing the Afon Clwyd and other watercourses in connectivity through the superficial deposits by reduction of baseflow. However, the aquifer system and its connection to the local surface waters is complex and is not easily resolved without recourse to a groundwater model (which doesn't exist). Simple analytical solutions such as IGARF are not considered to be appropriate and, in this context, professional hydrogeological judgement is required.

The original water resource assessments from 1976 suggest that an increase in abstraction

[28] Secondary A Aquifers are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers (Environment Agency, WIYBY, 2015).
[29] Warren, P T, Price, D, Nutt, M J C, and Smith, E G. (1984). Geology of the country around Rhyl and Denbigh. Memoir of the British Geological Survey, Sheets 95 and 107 and parts of sheets 94 and 106 (England and Wales).
[30] ESI Ltd (2003). Vale of Clwyd Aquifer Study Phase 2 Report: Conceptual model and water balance in support of RAM assessment. Report ref: 6338R2, July 2003.
[31] ESI Ltd (2013). Llannerch Park Source Evaluation Report. Report ref: 60159R, February 2013.

from 7 to 14 Ml/d 'settles down' quickly (within a few days) which would imply that the zone of influence was relatively small (<1km using the Theis equation and typical aquifer properties). However, it is also clear from the groundwater hydrographs that the abstractions have had a gradual, long term effect on groundwater levels over a large area (up to 5km) as presented in Section B.2.1.5.

The drought permit can be in operation for periods of up to 6 months, and is considered to be required during the period November to March, which would allow the effects of the abstraction to spread over a relatively wide area (say 2-3km).

The hydrogeological zone of influence (shown in **Figure B2.10**) has therefore been defined as a broad zone largely to the south and east of the abstraction. Delineation was based on previous estimates of the recharge area[32], groundwater level data and expert hydrogeological judgement. The eastern extent is coincident with the edge of the Permo-Triassic Sandstone and the southern extent is delimited by the zone of artesian conditions. Groundwater impacts are not expected to extend to the north and west of the boreholes due to the presence of thick till deposits. In contrast, on the eastern side of the valley there are areas of more permeable glaciofluvial deposits.

B.2.2.2 Hydrological Impact Assessment

Due to the specific hydrogeological characteristics of the area, not all hydrological reaches within the hydrogeological zone of influence will be affected by abstraction. In terms of defining the hydrological reaches over which the drought permit might affect flows the following approach has been adopted:

i An inner zone, coincident with the inner SPZ of the source (defined during Llannerch study evaluation study[33]), is used to define the approximate extent of the zone in which hydraulic gradients between the sandstone and the overlying drift is reversed and relatively quick responses on baseflow are expected[34]. This can be divided into two sub zones:

   a. The River Clwyd up and downstream of Llannerch (Reach 1);

   b. The lower reaches of the Nant Padrig (Reach 2).

ii The River Clwyd from upstream of the inner zone (i) to the edge of the artesian zone shown on **Figure B2.10** (Reach 3). Along this reach, the superficial deposits overlying the sandstone are relatively impermeable and, as the zone of influence of the abstraction expands through this zone, water will predominantly be taken from groundwater storage (i.e. groundwater levels in the sandstone will fall). As a result, the effect on stream flows will be negligible in this reach. There are a number of minor tributaries that join in this reach but these are also not considered to be likely to be affected to a significant degree.

[32] ESI Ltd (2013). Llannerch Park Source Evaluation Report. Report ref: 60159R, February 2013.
[33] ESI Ltd (2013). Llannerch Park Source Evaluation Report. Report ref: 60159R, February 2013.
[34] Whilst the sandstone is reported to 'settle down' within a few days in response to additional abstraction, it is expected that it may take longer for this to be transferred all the way through the superficial deposits to intercept baseflow.

iii The River Wheeler, a tributary of the Clwyd, where it flows across the estimated 'recharge' area based on the Llannerch source evaluation study[35], but only the reach overlying Permo-Triassic sandstone (Reach 4). In this reach there is likely to be relatively good connection between the Permo-Triassic sandstone and surface waters. It is anticipated that when the zone of influence of the additional groundwater abstraction reaches this point, perhaps after 2-4 months, there will be some effect on baseflow.

iv There are a number of minor tributaries that cross the 'recharge' area from east to west between the Afon Bach and the Wheeler. The topography in this area is relatively steep and it is concluded that these are unlikely to receive baseflow from the Permo-Triassic sandstone in this area (i.e. this is an area of recharge to the sandstone not a discharge area). The Afon Bach is not considered to be significantly at risk due to the presence of underlying low permeability drift (it is not within the 'recharge zone' for Llannerch based on the source evaluation report[36]).

The study area therefore includes a length of the Afon Clwyd, Afon Wheeler and Nant Padrig and comprises four hydrological reaches as identified in **Figure B2.10**. The potential hydrological impact of the drought permit has been reviewed for each hydrological reach and is summarised below.

As discussed above, due to the hydrogeological complex setting of the abstraction, quantification of the abstraction effect on surface water flows will be a question of hydrogeological judgement in the context of the conceptual understanding described above. On this basis the following scales and timings of abstraction effect have been defined:

- **Reach 1 and Reach 2:** Assume that 80% of the additional abstraction during operation of the drought permit is at the expense of surface water in this zone and that this develops steadily over the first 10 days of abstraction. Due to the relative size of the Afon Clwyd and Nant Padrig it is assumed that the flow effect is split 90%:10% respectively between the two watercourses (i.e. 72% and 8% of additional abstraction).

- **Reach 3:** Assume no significant effect on flows in this zone. Initially, and for the duration of the drought permit, the additional groundwater abstraction would be sourced from confined sandstone groundwater in this zone.

- **Reach 4:** Assume that the remaining 20% of abstraction starts to influence the lower parts of this zone after two months and reaches full extent after four months at which point the abstraction effect is evenly distributed along the whole reach.

It should also be noted that the drought permit would not alter the licence conditions under which the Clwyd Augmentation Scheme operates – this involves topping up river flows by the volume of water abstracted at the Llannerch boreholes (through release of groundwater from several boreholes within the upper Clwyd catchment and from the neighbouring Dee

[35] ESI Ltd (2013). Llannerch Park Source Evaluation Report. Report ref: 60159R, February 2013.
[36] ESI Ltd (2013). Llannerch Park Source Evaluation Report. Report ref: 60159R, February 2013.

catchment via the Alwen aqueduct). This needs to be accounted for when considering the effect on flows in the main course of the Afon Clwyd.

Continuous measurement of flow against which to assess the impact of an increase in abstraction is available for the Afon Clwyd at Pont y Cambwll (Reach 2) and Afon Wheeler at Bodfari (upstream of Reach 4). Estimates of year round Q_{50} and Q_{95} flow for the downstream extent of each hydrological reach have been derived using a scaling factor based on catchment area and are summarised in **Table B2.5**. Flows in Reaches 1 and 3 are scaled by catchment area based on gauged flow at Pont y Cambwll and flows in Reach 4 are scaled by catchment area based on gauged flow at Bodfari. Characteristics of the Nant Padrig catchment are more similar to those in the Afon Elwy than the Afon Clwyd (i.e. till covered, flashy) and gauged flows at Pont y Gwyddel and Pant yr Onen (Afon Elwy) were used to estimate Q95 and Q99 flows in the region of 0.5Ml/d and 0.4Ml/d respectively. This is supported by the fact that similar flow statistics were derived based on flow at Bodfari and Pont y Cambwll.

Table B2.5 Estimates of year round Q_{50} and Q_{95} flow for endpoint of each hydrological reach

Hydro-logical Reach	Location	Watercourse	Catchment area (km²)	Year round Q_{50} flow (Ml/d)	Year round Q_{95} flow (Ml/d)
-	*Pont y Cambwll (NRW gauging station)*	*Afon Clwyd*	*404.7*	*334.4*	*82.8*
1	Afon Clwyd downstream Llannerch boreholes	Afon Clwyd	423.4	346.7	83.5
2	Nant Padrig at confluence Afon Clwyd	Nant Padrig	3.2	2.85	0.42
3	Afon Clwyd upstream confluence Nant Padrig	Afon Clwyd	406.8	336.1	83.2
-	*Bodfari (NRW gauging station)*	*Afon Wheeler*	*62.9*	51.8	21.1
4	Afon Wheeler at confluence Afon Clwyd	Afon Wheeler	70.5	57.15	22.77

For each hydrological reach identified, the change in abstraction from fully licensed to drought permit conditions has been calculated as a percentage of these flows. It should be noted that the estimated Q_{50} and Q_{95} flows are based on historical gauged flows which encompass a range of abstraction conditions and may not be representative of flows prevalent under fully licensed abstraction rates which are likely to precede implementation of the drought permit. The estimated percentage reductions in river flow statistics are presented in **Table B2.6** and have been compared against the summer hydrological assessment matrix for lowland locations (Figure A.2 in **Appendix A**), to determine the significance of the hydrological impacts.

Reach 1 – Afon Clwyd immediately upstream and downstream of Llannerch boreholes

Along this reach, hydraulic gradients between the Permo-Triassic sandstone and the overlying drift are expected to be reversed as a result of abstraction and therefore reductions in river baseflow are expected. As a result of increased abstraction, river leakage could be expected to increase steadily over a period of 10 days and as a worst-case scenario it has been assumed that after 5 months (the potential duration of the drought), leakage will be equivalent to the increase in abstraction as a result of switching from fully licensed to drought permit conditions (4.3Ml/d). However, as stated above it has been assumed that only 80% of the additional abstraction impact will occur within the inner zone (i). Of this 80% additional impact within zone (i) an estimated 90% is attributable to Reach 1 (Afon Clwyd) and 10% to Reach 2 (Nant Padrig), due to the relative size of the watercourses. This equates to reductions in summer Q_{50} and Q_{95} flow of 0.9% and 3.6% respectively in Reach 1. However, since the Clwyd Augmentation Scheme must continue to operate during the drought permit when flows at Pont y Cambwll are less than 147Ml/d, these flow reductions are not expected to occur in reality and no change is flow in expected. Indeed, since it is reported that flow is actually augmented by 1Ml/d in addition to the PWS requirement[37], a flow gain could be expected. At flows above 147Ml/d, flows could be reduced relative to fully licensed, but the flow reduction as a result of the drought permit will be less than 2%. Therefore, the potential hydrological impact of the drought permit in Reach 1 is considered to be **negligible**.

Reach 2 – Lower reaches of Nant Padrig

As described for Reach 1 above, an increase in river leakage is expected along the lower reaches of Nant Padrig as a result of the drought permit. It has been assumed that only 80% of the additional abstraction impact will occur within the inner zone (i). Of this 80% additional impact within inner zone (i) an estimated 90% is attributable to Reach 1 (Afon Clwyd) and 10% to Reach 2 (Nant Padrig), due to the relative size of the watercourses. This equates to reductions in summer Q_{50} and Q_{95} flow of 10.8% and 45.3% respectively in Reach 2. The Clwyd Augmentation Scheme will be of no benefit to Nant Padrig as only the main watercourse is augmented. Therefore, the potential hydrological impact of the drought permit in Reach 2 is **moderate (uncertain)**.

The assessment is uncertain due to the absence of gauged flow data on Nant Padrig. However, to attain an assessment of minor would require at least a 1Ml/d increase in Q_{95} and Q_{99} flow. This is unlikely based on the available spot flow gauging data and low flow estimates from nearby continuous gauging stations.

Reach 3 – Afon Clwyd U/S Afon Wheeler and U/S confluence with Nant Padrig

Along this reach there is not expected to be any reduction in flow since the superficial deposits overlying the Permo-Triassic sandstone are relatively impermeable, and, as the zone of

[37] Environment Agency, (2008). Underground, Under threat: The state of groundwater in England and Wales. (Bristol: Environment Agency.)

influence of the abstraction expands through this zone, water will predominantly be taken from confined groundwater storage in the sandstone. Furthermore, as in Reach 1, low flows will continue to be supported by the Clwyd Augmentation Scheme. Therefore, the potential hydrological impact of the drought permit in Reach 3 is considered to be **negligible**.

Reach 4 – Afon Wheeler at Bodfari to confluence with Afon Clwyd

Due to the absence of extensive till deposits, there is likely to be a relatively good connection between the Permo-Triassic sandstone and surface water along this reach. For short periods of increased abstraction, it is unlikely that the zone of influence of additional abstraction will reach the Afon Wheeler catchment. However, after 2-4 months of sustained higher abstraction under the drought permit, there may be some effect on base flow. As a worst-case scenario, it has been assumed that 20% of the increase in abstraction affects this watercourse. This equates to reductions in summer Q_{50} and Q_{95} flow of 1.5% and 3.6% respectively. Therefore, the potential hydrological impact of the drought permit in Reach 4 is considered to be **negligible**.

B.2.2.3 Hydrological Impact Summary

Four hydrological reaches were identified (shown in **Table B2.6**), three of which have a **negligible** hydrological impact for the Drought Permit from Fully Licensed conditions. Nant Padrig (Reach 2) has been identified as **moderate (uncertain)** hydrological impact; whilst it is at significant risk of a significant reduction in flow, there is a relatively high degree of uncertainty in the flow statistics.

Table B2.6 Hydrological Reaches Identified in the Study Area

				Licensed abstraction to drought permit (4.3Ml/d increase in abstraction)		
Hydrological Reach	**Reach Boundary**		**Reach Length (km)**	**% flow reduction**		**Hydrological Impact**
				Year round Q_{50}	**Year round Q_{95}**	
1 Afon Clwyd	Afon Clwyd immediately upstream Nant Padrig confluence at SJ061717	Afon Clwyd downstream Llannerch boreholes at SJ057725	1.3km	0.9% (0.0%*)	3.6% (0.0%*)	Negligible
2 Nant Padrig	Nant Padrig at SJ059715	Nant Padrig at confluence Afon Clwyd	0.3km	10.8%	45.3%	Moderate (Uncertain)
3 Afon Clwyd	Afon Clwyd upstream confluence Afon Wheeler at SJ082687	Afon Clwyd immediately upstream Nant Padrig confluence at SJ061717	6.0km	0.0%	0.0%	Negligible
4 Afon Wheeler	Afon Wheeler near Bodfari at SJ097699	Afon Wheeler at confluence Afon Clwyd	2.3km	1.5%	3.6%	Negligible

*Due to the continued operation of the Clwyd Augmentation Scheme during the drought permit there is not expected to be any flow reductions on the main course of the Afon Clwyd. Indeed, since it is reported that flow is actually augmented by 1Ml/d in addition to the PWS requirement[38], a flow gain could be anticipated.

[38] Environment Agency, (2008). Underground, Under threat: The state of groundwater in England and Wales. (Bristol: Environment Agency.)

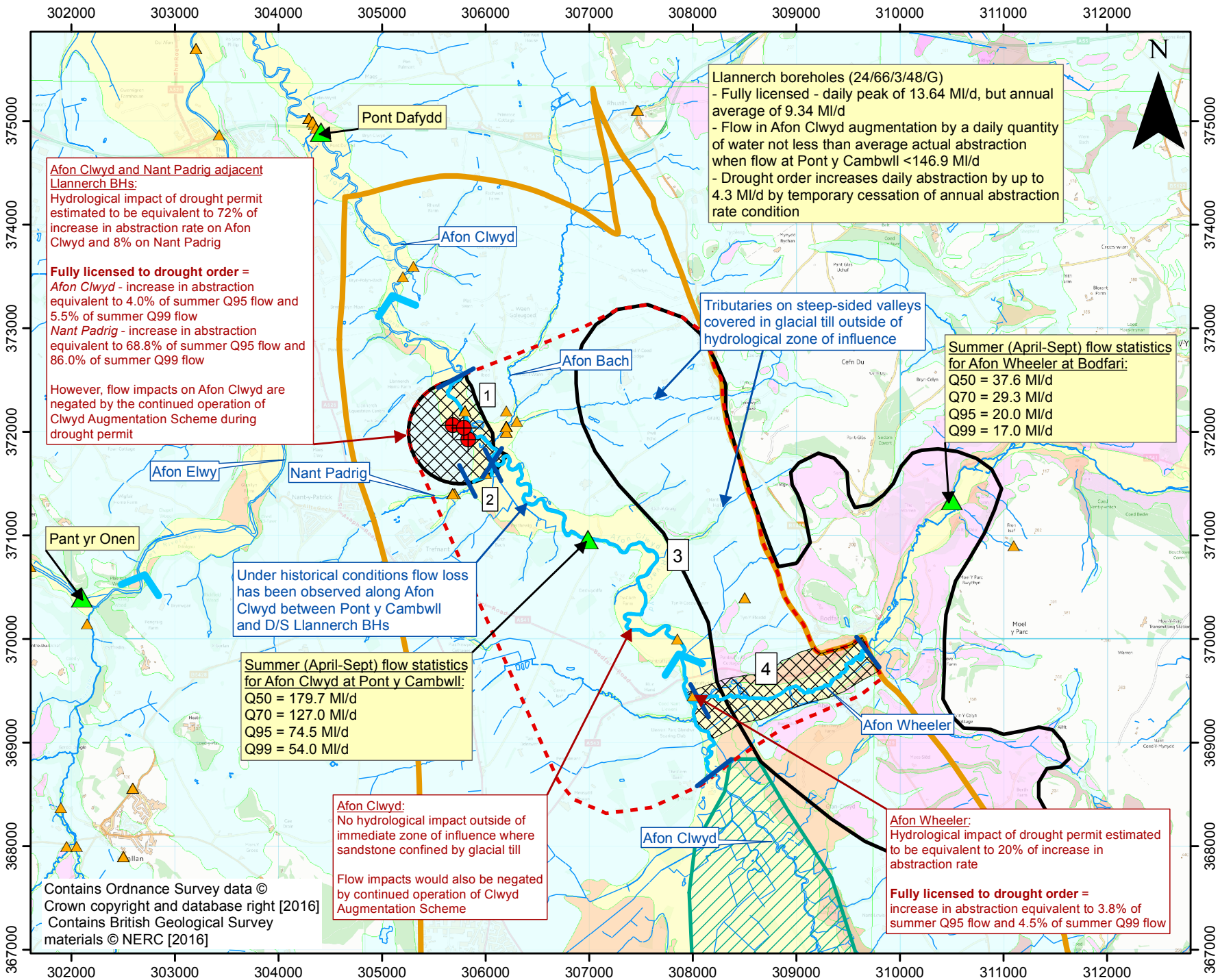


Figure B2.10
Llannerch (8012-5) drought order: Preliminary zone of hydrological influence

- Continuous flow gauges
- Spot flow gauging
- Llanerch BHs
- Hydrological reaches
- Hydrological zone of influence
- Hydrogeological zone of influence
- Estimated recharge zone (ESI, 2013)
- Artesian area
- Area of sandstone aquifer
- Direction of flow

Superficial Geology

- Alluvium
- Sand and Gravel (River Terrace Deposits)
- Till
- Sand and Gravel (Glaciofluvial Deposits)

CASCADE
Dŵr Cymru Welsh Water
esi Environment Specialists

Date: June 2016	Drawn: ERF
Scale: 1:50,000	Checked: MJS
Original: A4	Revision: 1

File Reference
O:\62232A Welsh Water Drought Permit Work\GIS\Map documents\8012-5_Llannerch\8012-5_Llannerch_IA.mxd

B3 PHYSICAL ENVIRONMENT ASSESSMENT

B.3.1 Geomorphology

One RHS survey is located in Reach 1 (site ID 35248), one in Reach 3 (site ID 33396), and two in Reach 4 (site ID 33885 and 31623). There are no RHS surveys in Reach 2. RHS survey data is supplemented by extant aerial imagery.

The reaches are underlain by Permian lithologies comprised of sandstone and conglomerate and Carboniferous lithologies comprised of siltstone and sandstone. Superficial material is comprised of till and alluvium.

Reaches 1, 3 and 4 have a negligible impact on hydrology. However, the RHS data within these reaches will be used to assess reach 2, where there are no RHS surveys. Reaches 1, 3, and 4 contain numerous pool and riffles sequences. Within reach 3 a run-glide sequence is also seen (site ID 33396). Bed substrate was not observed at all RHS sites, but where present was unconsolidated cobbles and pebbles. Surrounding vegetation suggests the banks are comprised of earth. Riparian tree cover is semi-continuous within all RHS survey sites.

Reach 2, which has a moderate (uncertain) hydrological impact, is 0.4km long, and falls 4m, a gradient of 0.64°. The reach is relatively sinuous and riparian tree cover is semi-continuous along the reach. No in-channel depositional features can be observed using extant aerial imagery and channel substrate is assumed to be similar to the other hydrological reaches where RHS surveys were conducted. The reach is unmodified, and comprised of earth. In the absence of RHS data, the banks are assumed to contain a mixture of steeper and shallow banks. Steep outer banks will be apparent on the more sinuous parts of the channel. There are no weirs within the reach that could pose an obstruction to fish migration or sediment transport. In-channel macrophytes could not be observed using extant aerial imagery.

B.3.2 Water Quality

This section sets out the baseline water quality and examines changes over time and with respect to river flows. Environmental pressures on river water quality (such as discharges from sewage treatment works (STWs)), which may cause increased deterioration in water quality with the drought permit in place, are discussed separately in Section B.3.3.

To support the assessment of potentially sensitive environmental features (see Section 5 of the main report), an understanding has been developed of the water quality of the rivers within the zone of influence of the drought permit, including trends over time and with respect to river flow. For WFD classification, the Environment Agency has set out[39] following UKTAG evidence[40] what pressures, including water quality pressures, each biological quality element is capable of responding to. For the purposes of assessment here, the supporting water quality

[39] Environment Agency (2011) Method statement for the classification of surface water bodies v2.0 (external release) Monitoring Strategy v2.0 July 2011 Table 2
[40] UK Technical Advisory Group on the Water Framework Directive (2008) Recommendations on Surface Water Classification Schemes for the purposes of the Water Framework Directive December 2007 (alien species list updated – Oct 2008 and Nov 2008). Appendix 1

parameters are set out: for fish and macroinvertebrates (where identified as sensitive features) as dissolved oxygen saturation and total ammonia concentration; and for macrophytes and algae (phytobenthos / diatoms) (where identified as sensitive features) as soluble reactive phosphorus (SRP). Specifically, for macrophytes, if the hydrological impacts of drought permit implementation have been identified within the main macrophyte growing season (April to September), an assessment of SRP has been undertaken.

Potential impacts on other water quality parameters, such as temperature, have been considered where appropriate (e.g. temperature influences dissolved oxygen and if sufficient information is available on dissolved oxygen and is being reviewed it may not be necessary to undertake a separate temperature assessment). Where data are lacking, the assessment has been undertaken using professional judgement.

NRW monitoring data were reviewed to provide an overview of water quality in the hydrological zone of impact. On the Llannerch, within the extent of influence of the drought permit, 2 sites have been used for this report, these are the River Clwyd d/s Trefnant (Site 1234) and the River Clwyd u/s Trefnant (Site 1233), (**Table B3.1** and **Figure B1.1**). Data is available from 2011 to 2013 for both sites, 1233 and 1234, and include measurements of a suite of parameters. No data were available for Reaches 2 and 4.

Where data are lacking the assessment has been undertaken using professional judgement. Values at the limit of detection were halved in line with standard NRW practice.

Table B3.1 Details of NRW Water Quality Sampling Points on the Afon Clwyd

Reach	Site Name	NRW Site Code	Grid reference	Location
1	River Clwyd d/s Trefnant	1234	SJ0610071790	On the Afon Clwyd, roughly 100m before the confluence with the Nant Padrig
3	River Clwyd u/s Trefnant	1233	SJ0612071690	On the Afon Clwyd, just past the confluence with the Nant Padrig

Reach 1 - Afon Clwyd downstream Llannerch boreholes to Afon Clwyd immediately upstream Nant Padrig confluence:

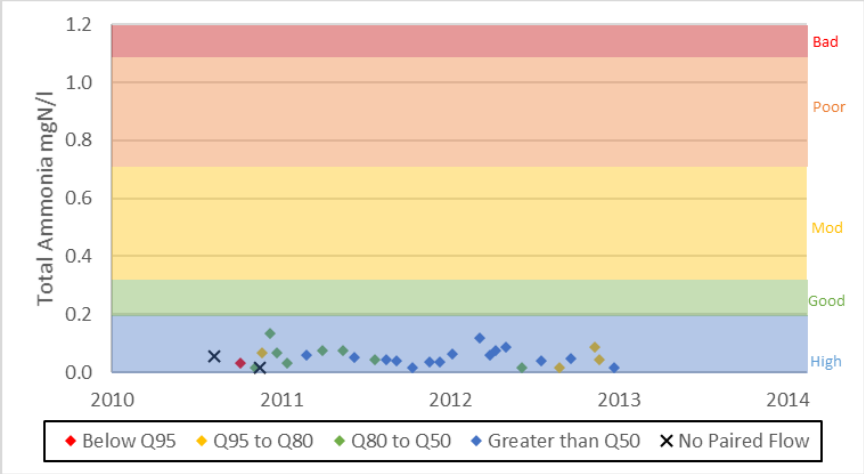
Water quality data were available for one NRW monitoring point in this Afon Clwyd reach (negligible hydrological impact); River Clwyd d/s Trefnant (site 1234).

No pH data available for the assessment period at this location. The maximum water temperature was 17.5°C.

Total Ammonia Concentration

Total ammonia concentrations at River Clwyd d/s Trefnant were reviewed and data presented in **Figure B3.1** against the relevant WFD standards for an upland low alkalinity river[41].

Figure B3.1 Total Ammonia at River Clwyd d/s Trefnant, Incorporating Appropriate WFD Status Bands



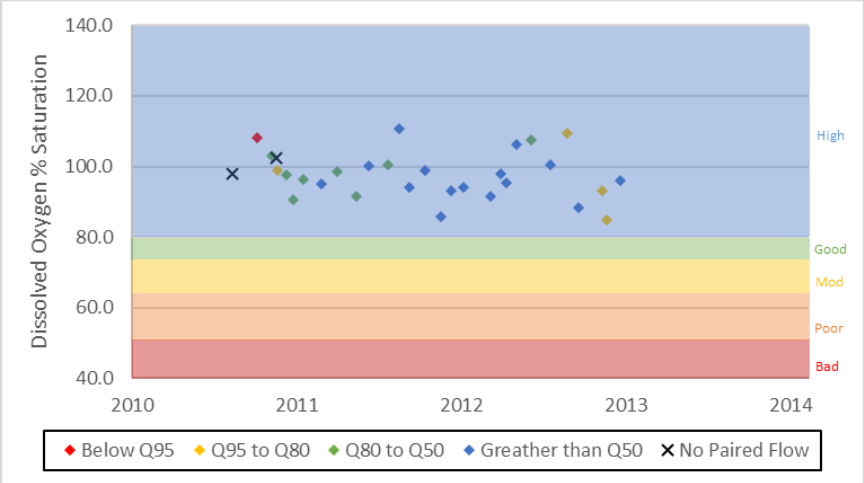
Total ammonia concentrations at River Clwyd d/s Trefnant (see **Figure B3.1**) were all consistent with the WFD standard to support good status for fish and invertebrates (0.3mg/l). Some seasonality is apparent with elevated ammonia concentrations occurring in summer months. No change over time or association with river flows is apparent at this location.

Dissolved Oxygen Saturation

Dissolved oxygen saturation data at River Clwyd d/s Trefnant, were reviewed and data presented in **Figure B3.2** against the relevant WFD standards for an upland low alkalinity river[42].

[41] The Water Environment (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.
[42] The Water Environment (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.

Figure B3.2 Dissolved Oxygen Saturation at River Clwyd d/s Trefnant, Incorporating Appropriate WFD Status Bands

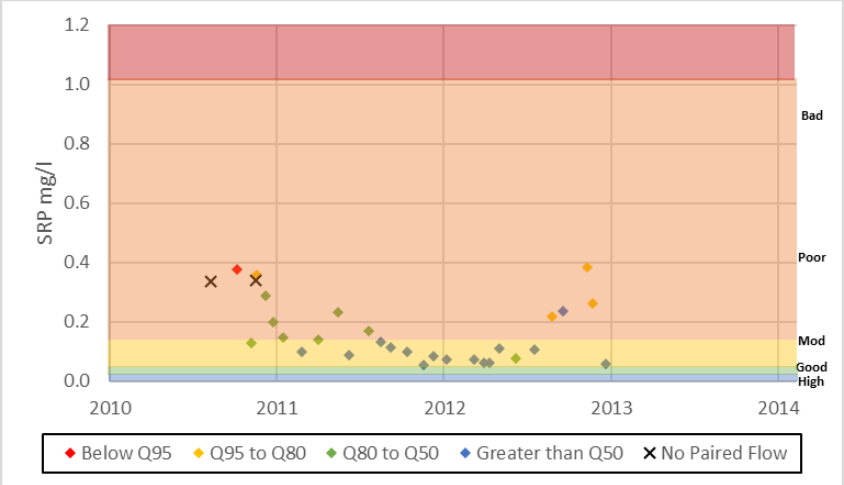


Dissolved oxygen saturation measurements at River Clwyd d/s Trefnant (see **Figure B3.2**) were all consistent with the WFD standard to support good status for fish and invertebrates (75%). Some seasonality is apparent with higher dissolved oxygen saturation during spring and summer. No change over time or association with river flows is apparent at this location.

Soluble Reactive Phosphorus

Soluble reactive phosphorus concentration at River Clwyd d/s Trefnant was reviewed and data are presented in **Figure B3.3** against the relevant WFD site specific standards provided by NRW[43].

Figure B3.3 SRP at River Clwyd d/s Trefnant, Incorporating Appropriate WFD Status Bands



Soluble reactive phosphorus concentration at River Clwyd d/s Trefnant was not consistent with the WFD standard to support good status for fish and invertebrates (0.05mgP/l). None of the values measured were graded as either Good or High. No seasonality or change over

[43] The Water Environment (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.

time is apparent. Association with river flows is clear at this location with lower flows resulting in elevated SRP concentration.

Reach 2 - Nant Padrig, Nant Padrig at confluence Afon Clwyd to Nant Padrig at SJ059715

No monitoring undertaken in this reach.

Reach 3 - Afon Clwyd, immediately upstream of Nant Padrig confluence to confluence with Afon Wheeler:

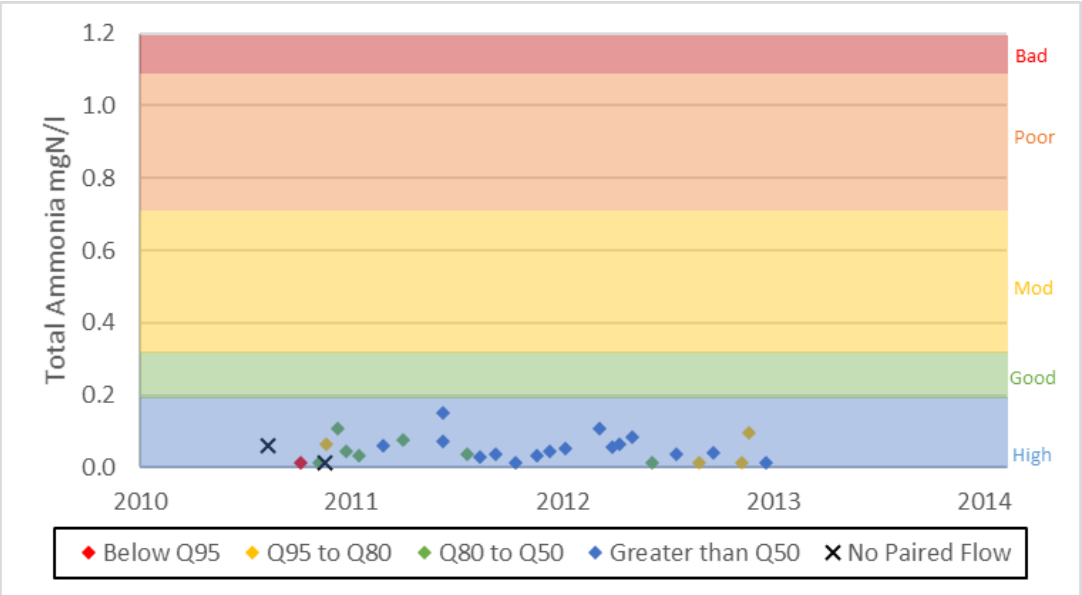
Water quality data are available for one NRW monitoring point in this Afon Clwyd reach (negligible hydrological impact); River Clwyd u/s Trefnant (site 1233).

No pH data were available at this location. The maximum temperature over the monitoring period was 17.3°C.

Total Ammonia Concentration

Total ammonia concentrations at River Clwyd u/s Trefnant were reviewed and data presented in **Figure B3.4** against the relevant WFD standards for an upland low alkalinity river[44].

Figure B3.4 Total Ammonia at River Clwyd u/s Trefnant, Incorporating Appropriate WFD Status Bands



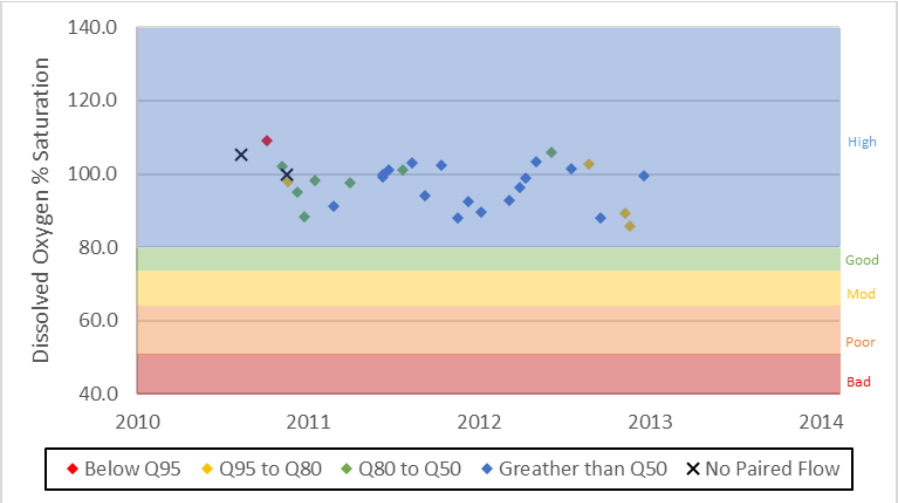
Total ammonia concentrations at River Clwyd u/s Trefnant (see **Figure B3.1**) were all consistent with the WFD standard to support at least good status for fish and invertebrates (0.3mg/l). Some seasonality is apparent with elevated ammonia concentrations occurring in summer months. No change over time or association with river flows is apparent at this location.

[44] The Water Environment (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.

Dissolved Oxygen Saturation

Dissolved oxygen saturation data at River Clwyd u/s Trefnant, were reviewed and data presented in **Figure B3.5** against the relevant WFD standards for an upland low alkalinity river[45].

Figure B3.5 Dissolved Oxygen Saturation at River Clwyd u/s Trefnant, Incorporating Appropriate WFD Status Bands



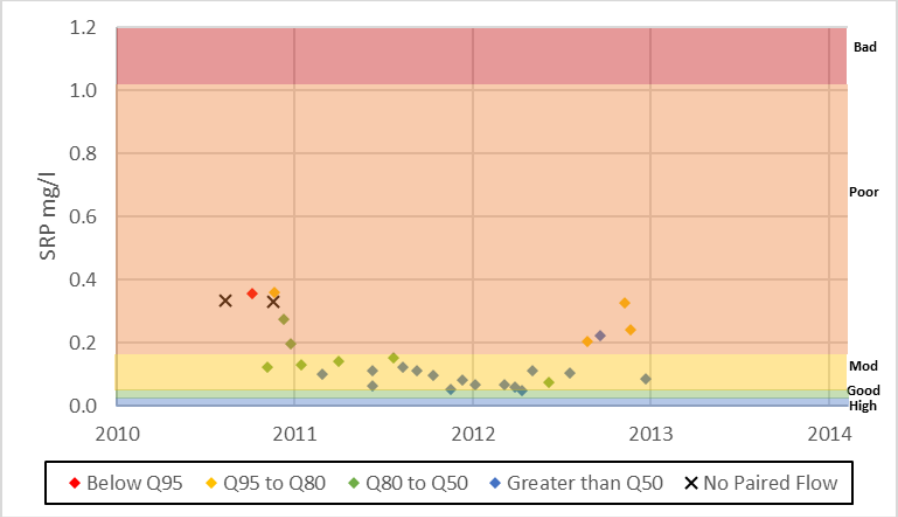
Dissolved oxygen saturation measurements at River Clwyd u/s Trefnant (see **Figure B3.2**) were all consistent with the WFD standard to support at least good status for fish and invertebrates (75%). Seasonality is apparent with higher dissolved oxygen saturation during spring and summer. No change over time or association with river flows is apparent at this location.

Soluble Reactive Phosphorus

Soluble reactive phosphorus concentration at River Clwyd u/s Trefnant was reviewed and data are presented in **Figure B3.6** against the relevant WFD site specific standards provided by NRW[46].

[45] The Water Environment (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.
[46] The Water Environment (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.

Figure B3.6 SRP at River Clwyd u/s Trefnant, Incorporating Appropriate WFD Status Bands



Soluble reactive phosphorus concentration at River Clwyd u/s Trefnant was not consistent with the WFD standard to support good status for fish and invertebrates (0.05mgP/l). No measured values were compliant with either High or Good WFD status. No seasonality or change over time is apparent at this location. A relationship between is noted with lower flows resulting in elevated SRP concentration.

Reach 4 - Afon Wheeler, Afon Wheeler at confluence with Afon Clwyd to Afon Wheeler near Bodfari

No monitoring undertaken in this reach.

Water Quality Summary

While no water quality data were available for Reaches 2 and 4 For Reach 2 assumptions have been made based upon similar river reach assessment in the region using professional judgement. For Reach 4 upstream water quality data was used as an indication of inflowing water quality.

Total ammonia concentrations were all consistent with the standard to support high status for fish and invertebrates throughout the zone of influence of the Llannerch boreholes drought permit. Seasonal variability in total ammonia concentration was low. The risk of the drought permit to total ammonia concentration levels within the zone of influence is therefore **low** in Reaches 1, 3 and 4 of the Llannerch boreholes drought permit. Given the severity of the hydrological impact in Reach 2 the risk to ammonia is assumed to be **low**.

Dissolved oxygen saturations were also all consistent with the standard to support high status for fish and invertebrates throughout the zone of influence of the Llannerch boreholes drought permit. The risk of the drought permit to dissolved oxygen saturation levels within the zone of influence is therefore **low** in Reaches 1, 3 and 4 of the Llannerch boreholes drought permit. Given the severity of the hydrological impact in Reach 2 the risk to ammonia is assumed to be

low.

Soluble reactive phosphorus was inconsistent with the standard to support high status for fish and invertebrates throughout the zone of influence of the Llannerch boreholes drought permit. The risk of the drought permit to soluble reactive phosphorus concentration within the zone of influence is considered **low** in Reaches 1, 3 and 4 of the Llannerch boreholes drought permit. Given the severity of the hydrological impact in Reach 2 the risk to soluble reactive phosphorus assumed to be **medium**.

B.3.3 Environmental Pressures

B.3.3.1 Flow Pressures

During a drought, abstractions put pressure on flow by removing water from rivers and groundwater aquifers and potentially exacerbating natural low flows. As a result of a drought order, there may be less water available in the zone of influence for licence holders to abstract, and any abstractions that do occur may reduce the amount of surface water available – affecting the wetted perimeter of the habitat, velocities within the wetted area and the ability to dilute any pollutants entering the system. For surface water abstractions, this includes consumptive abstraction and partially consumptive / non-consumptive abstraction – where some or all of the water is returned to the river locally after use, with the potential to reduce flow in the river if the discharge is downstream of the abstraction.

A review of licensed surface water abstractions based on information received from NRW indicates there are no licensed surface water abstractions in the study area.

B.3.3.2 Water Quality Pressures

Discharges put pressure on water quality during a drought as lower than normal river flows mean that there is less water available to dilute discharges such as final effluent from STWs. Discharges impacting the oxygen balance and ammonia concentration in the river reaches have been reviewed. Significant pressures (discharges of over 0.5Ml/d) are shown on **Figure B1.1**. Any discharges may be considered as beneficial to river flow but may also pose risks to water quality (noting that only abstractions are considered as flow pressures in the section above).

There are two sewage treatment works (STW) discharging into the Afon Clwyd or tributaries (**Table B3.2**). Due to the size and location of these discharges they are considered of **minor** risk.

Table B3.2 Consented Discharges in Area of Influence of the Llanerch Drought Permit

Reach	**No.**	**Permit no.**	**Site name**	**Zone of influence**	**Flow: Daily total (Ml/day)**	**Flow: DWF (Ml/day)**	**BOD: 5 Day ATU (mg/l)**	**Ammoniacal Nitrogen as N (mg/l)**	**Suspended Solids at 105 C (mg/l)**	**Consideration of water quality pressure** (during baseline low flow conditions)
Afon Clwyd Reach 3	1	CM0049001	Trefnant STW	Afon Clwyd	No limit	0.6307	35	15	50	Minor
Afon Wheeler Reach 4	2	CM0019301	Aberwheeler STW	Afon Wheeler	No limit	0.0886	47	-	60	Minor

B4 PHYSICAL ENVIRONMENT IMPACT SUMMARY

Potential impacts on the physical environment associated with the Llanerch drought permit are summarised in **Table B4.1**

Table B4.1 Summary of Potential Changes to the Physical Environment of the Impacted Reaches from Implementation of Llanerch Permit

Afon Clwyd (Reach 1)	
Flows in the Afon Clwyd *Negligible impacts*	• Up to 3.6% reduction in low flows.
Water quality in the Afon Clwyd *Minor risk during the implementation of the drought permit*	• Minor risk to ammonia and dissolved oxygen. Moderate risk to SRP.
Nant Padrig (Reach 2)	
Flows in the Nant Padrig *Moderate (uncertain) impacts*	• Up to 45.3% reduction in low flows.
Geomorphology *Moderate (uncertain) impacts during the implementation of the drought permit period.*	• Due to the moderate (uncertain) hydrological impact the impact on geomorphology would be minor (uncertain). The reach is unmanaged, and a potential decrease in flow could impact the wetted width of the channel and habitat availability. During drought conditions, bedload and suspended sediment transport will decrease, and due to the lack of management in the reach e.g. weirs, there is a decreased chance of ponding and sediment build-up.
Water quality in the Nant Padrig *Low risk during the implementation of the drought permit*	• Medium risk to ammonia, dissolved oxygen and SRP.
Afon Clwyd (Reach 3)	
Flows in the Afon Clwyd *Negligible impacts*	• No reduction in flow.
Water quality in the Afon Clwyd *Minor risk during the implementation of the drought permit*	• Low risk to ammonia and dissolved oxygen. Low risk to SRP.
Afon Wheeler (Reach 4)	
Flows in the Afon Clwyd *Negligible impacts*	• Up to 3.6% reduction in low flows.
Water quality in the Afon Clwyd *Low risk during the implementation of the drought permit*	• Low risk to ammonia and dissolved oxygen. Low risk to SRP.

B5 CUMULATIVE IMPACTS

The focus of this EAR is the Llannerch boreholes drought permit. The assessment, as described in previous sections, has considered how the proposed drought permit may affect the environment in combination with the effects of existing licences and consents. In accordance with the DPG the assessment also considers the potential cumulative effects of Welsh Water implementing other drought permits / orders within a similar timeframe. The potential for options to act in combination is set out in **Table B5.1**.

Consideration has also been given to the potential for cumulative impacts of drought options implemented by neighbouring water companies (see **Table B5.1**). The assessment of the potential for cumulative impacts of Welsh Water's supply side and drought permit / order options with drought options listed in neighbouring water companies' drought plans has also been undertaken as part of the Strategic Environmental Assessment (SEA) of Welsh Water's Draft Statutory Drought Plan. The SEA was informed by the most recent information available on the neighbouring water companies' drought plans.

Table B5.2 Cumulative Impacts of the Llannerch Boreholes Drought Permit with other Drought Options

Organisation	Potential In-combination Impacts	Further Consideration Required (Yes/No)
Welsh Water - other drought options in the North Eryri Ynys Mon WRZ / Afon Clwyd catchment	8012-2 (Reduced compensation flow from Aled Isaf Reservoir) - In-combination effects are not anticipated.	No
	8012-6 (Pumped transfer from Aled Isaf to Llyn Aled) - In-combination effects are not anticipated.	No

APPENDIX C
ENVIRONMENTAL FEATURES ASSESSMENT METHODOLOGY

A.1 ENVIRONMENTAL FEATURES ASSESSMENT METHODOLOGIES

The assessments undertaken in the EARs will use available environmental data. The following methodologies detail the preferred approach to impact assessment for the sensitive receptors identified in the screening process.

However, in certain circumstances the supporting data on hydrological conditions, habitat availability and species occurrence may not be currently available. In these cases, other supporting data will be used, where available, and the assessment will be undertaken using expert judgement. An example may be where flow-induced river habitat for fish would ideally be defined through the total wetted area, depth and flow velocities to describe the habitat preferences of a species and its lifestages. Where these data are currently unavailable, the use of habitat walkover, RHS and / or aerial survey data may be used in combination with judgements on the hydrological change resulting from the drought option (e.g. reduction in river flows) to arrive at a statement on habitat reduction and consequent impact on the fish species. The analysis will detail the increased uncertainty prevalent in the approach and will therefore adopt a precautionary approach to impact prediction (possibly assigning a higher impact where fewer substantiating data are available).

The gaps in data and evidence will be noted and monitoring proposals established.

Assessment sheets are included for the following features:

- Flow pressures
- Water quality pressures.
- WFD Status: Fish
- WFD Status: Aquatic macroinvertebrates
- Environment (Wales) Act Section 7 species, designated sites and other sensitive fauna and flora.

FLOW PRESSURES

Potential Effects

In support of understanding the physical environment and the risk assessment in the zone of influence of each drought option, a review will be undertaken of additional flow pressures from licensed surface water and groundwater abstractions. Relevant pressures have been identified and risk assessed in terms of in-combination flow impacts from implementation of a drought option. Abstractions have the potential to exacerbate low river flows or, in the case of groundwater-dominated catchments where rivers seasonally run dry (ephemeral watercourses), to increase the length of river that is dry and the period of time for which it remains so, potentially beyond the period for which the drought option is in place.

As a result of a drought option, there may be less water available in the zone of influence (rivers and groundwater bodies) for licence holders to abstract, and any abstractions that do occur reduce the amount of surface water available – affecting the wetted perimeter of the habitat, velocities within the wetted area and the ability to dilute any pollutants entering the system. For surface water abstractions, this includes consumptive abstraction and partially consumptive/non-consumptive abstraction – where some or all of the water is returned to the river locally after use, with the potential to reduce flow in the river if the discharge is downstream of the abstraction.

Definition of Risk

Continuously flowing watercourses

In order to define the potential risk to flow from river and groundwater abstractions in a readily understandable manner, a series of criteria have been defined. The assessment is informed by long term gauged flow data. The impact of the drought option will be considered against baseline 'drought' conditions (without drought option implementation). The assessment will use the following criteria, based on the potential severity of the risk to river water quality and flow during an ongoing drought.

- High: A major reduction in low river flows, including the influence of the drought option - typically >25% reduction in summer Q95 (with drought option in place)
- Medium: A moderate risk to low river flows (as above) , including the influence of the drought option - typically 10-25% reduction in summer Q95 (with drought option in place)
- Low: A minor risk to low river flows, including the influence of the drought option - typically <10% reduction in summer Q95 (with drought option in place)
- Negligible: Indicative of no significant change from the "without drought" option baseline situation.

Ephemeral watercourses

In line with the methodology for hydrology, an alternative approach to risk is required for

watercourses that naturally dry for part of the year that are potentially impacted upon by the drought option. Such watercourses are identified from previous investigations and available data. The assessment will use the following criteria, based on the potential severity of the risk to river water quality and flow during an ongoing drought.

- High: If the abstraction resulted in sections drying (with drought option in place) that would not (without drought option in place)
- Medium: If the abstraction resulted in sections drying earlier (by more than a handful of days) and/or returning to flow later (by more than a handful of days) and hence flow reduction occurring in the channel for more than just a handful of days (with drought option in place)
- Low: If the abstraction resulted in sections drying earlier (by just a handful of days) and/or returning to flow later (by just a handful of days) and hence flow reduction occurring in the channel for more than just a handful of days OR if the abstraction were a secondary flow driver (e.g. flow through gravels being primary cause of flow losses rather than the drought permit) (with abstraction in place)
- Negligible: Indicative of no significant change from the "without drought" option baseline situation.

Data Requirements

- Relevant zone of influence (as identified from screening)
- Surface water and groundwater abstraction licences in the zone of influence
- River flow representative of the zone of influence (daily gauged flow and spot flow surveys) – all available records
- Flow predictions and zones of hydrological impact for each drought option.

Assessment Methodology and Uncertainty

1. Identify relevant abstraction licences within the zone of hydrological impact for the drought option: both groundwater abstractions from the aquifer(s) impacted by the drought option (confined and unconfined) and surface water abstractions from the impacted river reaches.

Groundwater abstractions

2. For groundwater abstractions, identify which aquifer they abstract from and key characteristics of the aquifer (confined/unconfined) if available. List relevant details from each abstraction licence including licence number, holder, use, depth abstracted from and maximum daily abstraction rate.
3. Use depths of abstraction to identify which of these abstractions are likely to be affected by reduced groundwater levels in the aquifer with the drought option in place. If depth information is not available, take a precautionary approach and assume all abstractions within the relevant area (or, if known, from the relevant aquifer) are affected.
4. Calculate the maximum volume of groundwater abstractions from each aquifer at low flows (i.e. the sum of abstractions of sufficient depth from the aquifer) with a drought option in place.

5. Use expert judgement to assess the in-combination significance of these groundwater abstractions on river flows in impacted reaches (both continuously flowing and ephemeral watercourses), based on known (measured or modelled) relationships between groundwater levels and river flows in that area and the definition of risk set out above.

Surface water abstractions – continuously flowing watercourses

6. Assign relevant abstraction licences to an impacted river reach, and list relevant details from the licence including licence number, holder, use, type (consumptive or non-consumptive), location (mainstem or tributary) and daily maximum abstraction rate (including any Hands-Off Flow restrictions). Identify which of these abstractions are likely to be affected by reduced water levels in the river with the drought option in place.
7. Calculate the maximum volume of surface water abstractions in each reach at low flows (i.e. the sum of consumptive, unrestricted abstractions on the main stem of the river) as a proportion of summer Q95 river flow with a drought option in place.
8. Assess the in-combination significance of these pressures on river flow with respect to hydrological assessment methodologies described in Section 2.2.2 of the main report.
9. Use expert judgement to assess the significance of these pressures on river flows based on the definition of risk set out above.

Surface water abstractions – ephemeral watercourses

10. Assign relevant abstraction licences to an impacted river reach, and list relevant details from the licence including licence number, holder, use, type (consumptive or non-consumptive), location (mainstem or tributary) and daily abstraction maximum (including any Hands-Off Flow restrictions). Identify which of these abstractions are likely to be affected by reduced water levels in the river with the drought option in place.
11. Use expert judgement to assess the significance of these pressures on river flows based on the definition of risk set out above.

All abstractions

12. For both groundwater and surface water abstractions, incorporate any flow pressure risks identified as significant into the assessment of impacts on significant features and the selection of appropriate mitigation measures for the drought option.

WATER QUALITY PRESSURES

Potential Effects

In support of the physical environment understanding and risk assessment in the zone of influence of each drought option, a review will be undertaken of additional water quality pressures from consented surface water discharges. Discharges put pressure on water quality during a drought as lower than normal river flows mean that there is less water available to dilute discharges such as final effluent from STW. A drought option may exacerbate these low flows and contribute to a reduction in water quality, with potentially detrimental impacts on sensitive features in the impacted reach. Discharges impacting the oxygen balance and ammonia concentration (to support fish and macroinvertebrates, where these are identified as sensitive features) and soluble reactive phosphorus (SRP) concentration (to support macrophytes and algae, where these are identified as sensitive features) in the river have been reviewed.

Intermittent discharges from combined sewer overflows (CSOs) may also contribute to a reduction in water quality during an environmental drought. CSOs relieve strain on the sewers during storm events by temporarily diverting water into nearby watercourses to prevent sewer flooding. As there is usually a time lag between discharges from CSOs and rises in river levels during a storm event, the potential exacerbation of low flows by the drought option may decrease the amount of water immediately available to dilute CSO discharges, leading to a temporary reduction in river water quality if a storm event occurs during implementation of the drought option.

Definition of Risk

Continuously flowing watercourses

In order to define the potential risk to water quality from discharges into the river in a readily understandable manner, a series of criteria have been defined. The assessment will use the following criteria, based on the potential severity of the risk to water quality during an ongoing drought.

- High: A major risk to water quality under low river flow conditions (without the drought option) which affects the suitability of the water quality to support *Good* or *High* status for fisheries and macroinvertebrates, macrophytes and algae (as relevant); and exacerbation of the risk by the flow reduction from the drought option
- Medium: A moderate risk to water quality under low river flow conditions (without the drought option) which affects the suitability of the water quality to support *Good* or *High* status for fisheries and macroinvertebrates, macrophytes and algae (as relevant); or exacerbation of a minor risk by the flow reduction from the drought option
- Low: A minor risk to water quality under low river flow conditions (without the drought option) which affects the suitability of the water quality to support *Good* or *High* status for fisheries and macroinvertebrates, macrophytes and algae (as relevant); or exacerbation to a minor risk by the flow reduction from the drought option
- Negligible: Indicative of no significant risk without the drought option nor exacerbation of risk by the flow reduction from the drought option

Ephemeral watercourses

In line with the methodology for hydrology, an alternative approach to risk is required for

watercourses that naturally dry for part of the year that are potentially impacted upon by the drought option. Such watercourses are identified from previous investigations and available data. The assessment will use the following criteria, based on the potential severity of the risk to river water quality during an ongoing drought.

- High: A major risk to water quality under low river flow conditions (without the drought option) which affects the suitability of the water quality to support *Good* or *High* status for fisheries and macroinvertebrates, macrophytes and algae (as relevant); and exacerbation of the risk if the drought option resulted in sections drying (with drought option in place) that would not (without drought option in place)
- Medium: A moderate risk to water quality under low river flow conditions (without the drought option) which affects the suitability of the water quality to support *Good* or *High* status for fisheries and macroinvertebrates, macrophytes and algae (as relevant); or exacerbation of a minor risk by the flow reduction from the drought option occurring in the channel for more than just a handful of days.
- Low: A minor risk to water quality under low river flow conditions (without the drought option) which affects the suitability of the water quality to support *Good* or *High* status for fisheries and macroinvertebrates, macrophytes and algae (as relevant); or exacerbation to a minor risk by the flow reduction from the drought option occurring in the channel for just a handful of days.
- Negligible: Indicative of no significant risk without the drought option nor exacerbation of risk by the flow reduction from the drought option

Data Requirements

- Relevant zone of influence (as identified from screening)
- Surface water discharge consents in the zone of influence (including numeric water quality and flow conditions)
- Routine NRW / Environment Agency riverine water quality monitoring data for the water quality determinands dissolved oxygen saturation, SRP concentration and total ammonia concentration for relevant monitoring sites in the zone of influence and significant tributaries
- River flow representative of the zone of influence (daily gauged flow and spot flow surveys) – all available records
- Flow predictions and zones of hydrological impact for each drought option
- CSO locations and previous assessments of intermittent discharges from Welsh Water.

Assessment Methodology and Uncertainty

1. Identify sensitive features (fish, macroinvertebrates, macrophytes and algae) which may be impacted by the drought option. Use this information to determine whether assessment of oxygen balance, ammonia concentration and/or SRP concentration is required.
2. Identify all discharge consents within the zone of hydrological impact for the drought option.
3. Assign relevant discharge consents to an impacted reach, and list relevant details from the consent including consent number, holder, use, location (mainstem or tributary) and relevant numeric

consent conditions (Dry Weather Flow, BOD, ammonia (N), total phosphorous)[1].

4. Identify those discharge consents which relate to effluent from Welsh Water's sewage treatment works (STWs).

Continuously flowing watercourses

5. Model the maximum current contribution of each STW to BOD, ammonia (N) and total phosphorous concentrations (as relevant) in the river at low flows (based on the water quality consents, DWF and upstream flows).
6. Model the maximum potential increase in each STW's contribution to river BOD, ammonia (N) and total phosphorous concentrations (as relevant) at low flows as a result of the drought option (based on the water quality consents, DWF, upstream flows and maximum flow reduction from drought option).
7. Assess the potential risk that the STW could pose to river ammonia quality (using the consented discharge condition total ammonia) using modelled data and the appropriate matrix below. This combines an acknowledgement of existing conditions and potential variation as a result of the drought option.

Upland low alkalinity river		% increase in contribution as result of drought option(s)	
		<20%	≥20%
Current contribution to ammonia concentrations at low flows [a]	<0.2mgN/l	Minor	Moderate
	≥0.2mgN/l	Moderate	Major

[a] Standards are WFD high/good threshold for ammonia (N) of 0.2mg/l for upland low alkalinity rivers[2].

Lowland high alkalinity river		% increase in contribution as result of drought option(s)	
		<20%	≥20%
Current contribution to ammonia concentrations at low flows [b]	<0.3mgN/l	Minor	Moderate
	≥0.3mgN/l	Moderate	Major

[b] Standards are WFD high/good threshold for ammonia (N) of 0.3mg/l for lowland high alkalinity rivers[3].

8. Assess the potential risk that the STW could pose to river oxygen balance (using the consented discharge condition BOD) using modelled data and the matrix below. This combines an acknowledgement of existing conditions and potential variation as a result of the drought option.

Upland low alkalinity river		% increase in contribution as result of drought option(s)	
		<20%	≥20%
Current contribution to BOD concentrations at low flows [c]	<1mg/l	Minor	Minor
	1-3mg/	Minor	Moderate
	≥3mg/l	Moderate	Major

[c] Standards are WFD high/good threshold for BOD of 3mg/l and good/moderate threshold of 4mg/l for upland low alkalinity rivers[4].

Lowland high alkalinity river		% increase in contribution as result of drought option(s)	
		<20%	≥20%
Current contribution to BOD concentrations at low flows [d]	<1mg/l	Minor	Minor
	1-4mg/	Minor	Moderate
	≥4mg/l	Moderate	Major

[d] Standards are WFD high/good threshold for BOD of 4mg/l and good/moderate threshold of 5mg/l for lowland high

[1] Note that not all STWs have water quality consents relating to ammonia or total phosphorous (depends on size and location of STW). Consents are set with respect to total phosphorous rather than SRP.

[2] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. ISBN 978-0-85521-192-9.

[3] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. ISBN 978-0-85521-192-9.

[4] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. ISBN 978-0-85521-192-9.

alkalinity rivers[5].

9. Assess the potential risk that the STW could pose to river phosphorous quality (using the consented discharge condition total phosphorous) using modelled data and the matrix below. This combines an acknowledgement of existing conditions and potential variation as a result of the drought option. Consents are set with respect to total phosphorous rather than SRP (on which WFD river standards are based), therefore this approach conservatively assumes that all phosphorous from STWs is reactive and has direct implications for ecology in the river.

Upland low alkalinity river		% increase in contribution as result of drought option(s)	
		<20%	≥20%
Current contribution to ammonia concentrations at low flows [e]	<0.2mgN/l	Minor	Moderate
	≥0.2mgN/l	Moderate	Major

[e] Standards are WFD high/good threshold for SRP of 0.02mg/l and good/moderate threshold of 0.04mg/l for upland low alkalinity rivers[6].

Lowland low alkalinity river[7]		% increase in contribution as result of drought option(s)	
		<20%	≥20%
Current contribution to ammonia concentrations at low flows [f]	<0.03mgN/l	Minor	Moderate
	≥0.03mgN/l	Moderate	Major

[f] Standards are WFD high/good threshold for SRP of 0.03mg/l and good/moderate threshold of 0.05mg/l for lowland low alkalinity rivers[8].

Upland/ lowland high alkalinity river		% increase in contribution as result of drought option(s)	
		<20%	≥20%
Current contribution to ammonia concentrations at low flows [g]	<0.05mgP/l	Minor	Moderate
	≥0.05mgP/l	Moderate	Major

[g] Standards are WFD high/good threshold for SRP of 0.05mg/l and good/moderate threshold of 0.12mg/l for upland/ lowland high alkalinity rivers[9].

10. Identify those discharges which relate to effluent from Welsh Water's combined sewer overflows (CSOs).
11. If required, carry out qualitative analysis using previous assessments of intermittent discharges to evaluate whether any CSOs are likely to present a significant water quality pressure as a result of the drought option.
12. Use expert judgement to assess the significance of these pressures on river flows based on the definition of risk set out above.
13. Incorporate any water quality pressure risks identified as significant into the assessment of impacts on significant features and the selection of appropriate mitigation measures for the drought option.

Ephemeral watercourses

14. Calculate the maximum concentrations of BOD, ammonia (N) and SRP (as relevant) in the final effluent of each STW under consented conditions (i.e. concentrations in the river with no natural dilution).

[5] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. ISBN 978-0-85521-192-9.

[6] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. ISBN 978-0-85521-192-9.

[7] Note that "Lowland low alkalinity" is a category that only exisits for SRP standards, and not for total ammonia or BOD.

[8] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. ISBN 978-0-85521-192-9.

[9] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. ISBN 978-0-85521-192-9.

15. Identify those discharges which relate to effluent from Welsh Water's combined sewer overflows (CSOs).
16. If required, carry out qualitative analysis using previous assessments of intermittent discharges to evaluate whether any CSOs are likely to present a significant water quality pressure as a result of the drought option.
17. Use expert judgement to assess the significance of these pressures on river flows based on the definition of risk set out above.
18. Incorporate any water quality pressure risks identified as significant into the assessment of impacts on significant features and the selection of appropriate mitigation measures for the drought option.

WATER FRAMEWORK DIRECTIVE STATUS: FISH

Potential Effects

For WFD river waterbodies within the zone of influence of the drought option, where screening of the drought option has identified that the fish element of biological status is *High* or *Good*, the potential impact is to be investigated. This investigation is specific to the risk of deterioration below the *Good* status band to the *Moderate* status band, as advised by NRW / Environment Agency.

Definition of Impacts

In order to define the potential WFD status impacts for fish in a readily understandable manner, a series of criteria have been defined. The assessment will use the following criteria, based on the potential severity of the drought option impacts during an ongoing drought.

- Major: A major impact is one that results in deterioration in the WFD classification of the waterbody, or specifically the fish biological element of the classification.
- Moderate: A moderate impact on fish status occurs when the fish population is predicted to be materially influenced, including effects on density, abundance or community composition, but where no deterioration in WFD classification is predicted. Consideration should be given to the scale of the impact and the potential for recovery of the populations.
- Minor: A minor impact occurs when there is a predicted impact on fish abundance, density or community composition that is within the usual variability for the site and which will recover within a short timescale.
- Negligible: A negligible impact is one where the predicted impact will not result in a detectable change in the fish population.

Data Requirements

Fish status baseline assessment requires data from standard NRW / Environment Agency monitoring programmes in the potentially impacted zone, and preferably in a control site outside of the zone of influence. Fish data should include species presence, abundance and density. Environmental supporting data should include habitat availability, hydrology (flow, velocity, wetted area (width and depth) as follows:

- Relevant study area (as identified in the screening report)
- Hydrology at or close to the monitoring sites to link to fish data, including full flow hydrograph, wetted width and depth, velocity profile. Will include daily gauged flow and spot flow surveys, all available records
- Meteorology (where flow data insufficient) from available NRW / Environment Agency rain gauges
- Habitat data for the monitoring sites, which may include recent RHS or Habscore surveys
- Routine NRW / Environment Agency water quality monitoring data (dissolved oxygen, BOD, ammonia, pH, hardness, water temperature, conductivity) representative of the study area.

Assessment Methodology and Uncertainty
The WFD classification for the waterbody will be identified and the reasons for classification established from the NRW / Environment Agency. The data used to support the assessment will be reviewed to ensure that the classification is accurate. Baseline conditions for sites within the zone of influence of the drought option will be established through existing data. These will include graphing the hydrology, water quality, habitat and fish variation temporally over the monitored period. The analysis will consider the relationship between fish status and the supporting environmental variables over the period, with an emphasis on changes to fish status and environmental conditions between low, average and high flow years. The purpose of the analysis is to establish whether fish status responds to changes in flow and associated environmental variables inter-annually relating to changes in flow, climate, quality (dissolved oxygen and temperature) and/or habitat quality and availability. Having established the baseline conditions and variability outside the drought option conditions (care will be taken to avoid using periods in the baseline analysis within which a drought option may have been in operation), a prediction will be made of the changes in the supporting environmental variables (flow, habitat and water quality) resulting from application of the drought option. This will be undertaken for the hydrological data by overlaying the drought option flows over the baseline flow hydrograph, and, where cross sectional data are available, how the wetted width and depth will vary with the drought option. This can be extrapolated to the habitat data to consider whether the key features are compromised by the change in water depth. Once the flow, habitat and water quality drought option predictions have been established, their implications for existing fish species will be assessed. The flow and habitat environmental envelope of the key fish species is known. The predicted changes in supporting environmental variables (flow, depth, velocity, habitat quality, dissolved oxygen levels and temperature) due to the drought option will be assessed against the fish population data. Where the supporting environmental variables for fish species are modified to take them outside of their preferred envelope it can be assumed that there will be a moderate or major impact on that fish population. Consideration will be given to the potential for density dependent mortality where data show that the fish population has an existing good density, and where the drought option reduces habitat availability significantly The assessment will consider the scale and longevity of any fish status impacts. The WFD classification is calculated on a 3 year rolling basis. A deterioration in classification would require a long term (2+ breeding seasons) and significant effect on fish population structure to allow prediction of a deterioration in status. Where data are not available the assessment will be undertaken using expert judgement and drawing on broad-scale evidence from other similar catchments if applicable. The prediction of impacts of hydrological and water quality changes on aquatic ecology remains subject to significant uncertainty. This is exacerbated where few data or

surveillance data are used for impact assessment purposes. Lastly the environmental envelopes within which fish species can successfully exist, and the relationship between populations in stressed river conditions remains subject to debate. The assessment must therefore be undertaken in recognition that the outcome prediction will be subject to large potential variability. The study will therefore adopt a precautionary approach, with potential impact highlighted where doubt exists. Monitoring and mitigation proposals for the drought option can then be specified so that, should an option be enacted, the actual impact can be recorded and adaptive mitigation/management of the option undertaken to safeguard where possible the fish populations.

WATER FRAMEWORK DIRECTIVE STATUS: MACROINVERTEBRATES

Potential Effects

For Water Framework Directive (WFD) river waterbodies within the zone of influence of the drought option, where screening of the drought option has identified that the aquatic macroinvertebrate component of ecological status is *High* or *Good*, the potential impact is to be investigated. This investigation is specific to the risk of deterioration below the *Good* status band to the *Moderate* status band.

Definition of Impacts

In order to define the potential WFD status impacts for aquatic macroinvertebrates in a readily understandable manner, a series of criteria have been defined. The assessment will use the following criteria, based on the potential severity of the drought option impacts during an ongoing drought.

- Major: A major impact is one that results in deterioration in the WFD classification of the waterbody, or specifically the macroinvertebrate biological element of the classification.
- Moderate: A moderate impact on macroinvertebrate status occurs when the macroinvertebrate community is predicted to be materially influenced, including reduction in the LIFE score, or in community density +/or abundance, but where no deterioration in WFD classification is predicted. Consideration should be given to the scale of the impact and the potential for recovery of the community.
- Minor: A minor impact occurs when there is a predicted impact on macroinvertebrate abundance, density or composition that is within the usual variability for the site and which will recover within a short timescale.
- Negligible: A negligible impact is one where the predicted impact will not result in a detectable change in the macroinvertebrate community.

Data Requirements

The baseline for macroinvertebrates will be established from existing data together with a comparison of species flow preference and taxon abundance. The analysis will provide an assessment of the community type and its sensitivity.

Macroinvertebrate status baseline assessment requires data from standard NRW / Environment Agency monitoring programmes in the potentially impacted zone, and preferably in a control site outside of the zone of influence. Macroinvertebrate data should include the LIFE and BMWP scores, together with abundance and density data where available. Environmental supporting data should include habitat availability, hydrology (flow, velocity, wetted area (width and depth) and other environmental variables as follows:

- Relevant study area (as identified by screening)
- Hydrology at or close to the monitoring sites to link to macroinvertebrate data, including full flow hydrograph, wetted width and depth, velocity profile. Will include daily gauged flow and spot flow surveys, all available records
- Meteorology (where flow data insufficient) from available NRW / Environment Agency

rain gauges

- Habitat data for the monitoring sites, which may include recent RHS or Habscore surveys, to calculate HQA / HMS.
- Routine NRW / Environment Agency water quality monitoring data (dissolved oxygen, BOD, ammonia, pH, hardness, water temperature, conductivity) representative of the study area.

Assessment Methodology and Uncertainty

Having established the baseline, the relative changes expected as a result of the drought actions (in relation to normal drought conditions) in river hydrology, geomorphology and water quality will be identified (see WFD fish assessment). An assessment will then been made of the habitat requirements of the key riverine macroinvertebrate communities present, using existing knowledge of their range of preferences. Depending on the resolution of baseline data available, detailed statistical analysis of the datasets may be possible. However, in some cases, where relatively limited spatial and/or temporal datasets are available, the impact assessment of the drought actions will be based on qualified expert judgement of the potential effects of the predicted changes in the environmental variables on the macroinvertebrate communities. The analysis is supplemented by consideration of the implications of environmental change on the key macroinvertebrate metrics, including LIFE scores.

The WFD macroinvertebrate classification for the water body will be identified and the reasons for classification established from the NRW / Environment Agency. The data used to support the assessment will be analysed to ensure that the classification is accurate.

Baseline conditions for sites within the zone of influence of the drought option will be established through existing data. These will include graphing the hydrology, water quality, and macroinvertebrate (ASPT and LIFE scores) variation temporally over the monitored period.

The analysis will consider the relationship between macroinvertebrate status and the supporting environmental variables over the period, with an emphasis on changes to status and environmental conditions between low, average and high flow years. The purpose of the analysis is to establish whether status responds to changes in flow and associated environmental variables inter-annually relating to changes in flow, climate, quality (dissolved oxygen and temperature) and/or habitat quality and availability.

Having established the baseline conditions and variability outside the drought option conditions (care will be taken to avoid using periods in the baseline analysis within which a drought option may have been in operation), a prediction will be made of the changes in the supporting environmental variables (flow, habitat and water quality) resulting from application of the drought option. This will be undertaken for the hydrological data by overlaying the drought option flows over the baseline flow hydrograph, and, where cross sectional data are available, how the wetted width and depth will vary with the drought option. This can be extrapolated to the habitat data to consider whether the key features are compromised by the change in water depth. These data may have been developed for the WFD fish status assessment and duplication of effort will be avoided.

Once the flow, habitat and water quality drought option predictions have been established, their implications for the existing macroinvertebrate community will be assessed. The linkage between flow and habitat environmental envelope for upland macroinvertebrate communities is subject to continuing debate but has been shown to be linked (see for example, Dunbar et al 2009; 2010). The predicted changes in supporting environmental variables (flow, habitat quality) due to the drought option should be assessed against the macroinvertebrate community LIFE scores. Consideration will be given to the relationships between flow, habitat and LIFE scores in the DRIED-UP research papers. The predicted relative change in Q_{95} low flow value for the drought option should be compared to the Q_{95}/reduction in LIFE score; HQA/reduction in LIFE score in Dunbar *et al* 2010 to develop an approximation of the scale of change in macroinvertebrate community that could be expected.

The assessment will consider the scale and longevity of any macroinvertebrate community impacts. The WFD classification is calculated on a 3 year rolling basis. A deterioration in classification would require a long term and significant effect on macroinvertebrate community structure to establish prediction of a deterioration in status.

Where data are not available the assessment will be undertaken using expert judgement and drawing on broad-scale evidence from other similar catchments within the reservoir group.

The prediction of impacts of hydrological and water quality changes on aquatic ecology remains subject to significant uncertainty. This is exacerbated where few data or surveillance data are used for impact assessment purposes. Lastly the environmental envelopes within which the macroinvertebrate community can successfully exist, and the relationship between populations in stressed river conditions remains subject to debate. For macroinvertebrates the evidence base for the prediction of flows and changes to LIFE score remain subject to significant debate. The assessment must therefore be undertaken in recognition that the outcome prediction will be subject to large potential variability. The study should therefore adopt a precautionary approach, with potential impact highlighted where doubt exists. Monitoring and mitigation proposals for the drought option can then be specified so that, should an option be enacted, the actual impact can be recorded and adaptive mitigation/management of the option undertaken to safeguard where possible the macroinvertebrate community.

NOTABLE SPECIES, DESIGNATED SITES AND OTHER SENSITIVE FAUNA AND FLORA

Potential Effects

Where screening of the drought option has identified that a notable species or designated site is present within the zone of influence of the drought option and screening has indicated that it is sensitive to the impacts of the drought option, the potential impact is to be investigated. Notable species are defined as Environment (Wales) Act Section 7 species or species with significant ecological sensitivity in the specified locality including species listed on IUCN red list and those not included in the red list which are nonetheless uncommon. This investigation will consider the habitat preferences of the species and its lifestages (if appropriate) and the impacts of the variation in flow (and consequent physical habitat and ecosystem) on these preferences. Potential effects are associated either 1) directly to a reduction in river flow; or 2) a reduction in water quality; 3) secondary effects of reduced velocity, for example on sediment characteristics.

Definition of Impacts

In order to define the potential impacts for sensitive ecological features in a readily understandable manner, a series of criteria have been defined. The significance of impacts upon the sensitive ecological feature will be identified following the Institute of Ecology and Environmental Managements (CIEEM) Ecological Impact Assessment (EcIA) guidance[10]. The potential significance of the impacts is identified using the following:

- **Value of the Ecological Receptor** – each ecological receptor is attributed a geographic value based upon its legislative and conservation status, as identified in Table 1.

Table 1 Value of Ecological Receptor

Ecological Value	Example
International	Existing or warranting designation as a e.g SPA and/or of significant conservation status for Europe (e.g European Protected Species (EPS)).
National	Existing or warranting designation as a SSSI and/or of significant conservation status for England (i.e. identified as a NERC / Environment Act (Wales) Section 7 species).
Regional	Habitats or species valuable at a regional level and/or of significant conservation status for the region (e.g viable breeding populations of Nationally Scarce species).
County	For example, existing or warranting designation as a County Wildlife Site (CWS) and/or of significant conservation status for the county (e.g viable breeding populations of species of county/metropolitan rarities).
District	For example, habitats or species of significant conservation status for the district (e.g viable breeding populations of species listed as rare in the district or borough).
Parish (local)	Species whose presence is considered to appreciably enrich biodiversity within the context of the parish or local neighbourhood, including as a local recreational/educational resource.
Site (within zone of influence only)	Species which are so low grade or widespread so as to be considered as not contributing to biodiversity value outside the boundaries of the site.

- **Positive or Negative Impact** – all impacts are considered to be negative unless

[10] CIEEM (2018) *Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine.* Chartered Institute of Ecology and Environmental Management, Winchester.

otherwise stated in the feature assessment.

- **Extent** – the extent of the impact is covered as part of the magnitude consideration.
- **Magnitude** – the magnitude of the impact is identified using the criteria identified in **Table 2**

Table 2 Magnitude of Impact

Impact Magnitude	Description
High	There is a long-term large-scale (i.e. catchment) change in the ecological receptor and/or changes in the overall integrity of the ecological receptor.
Medium	There is a short-term large-scale change or long-term short-scale (i.e. reach) change in the ecological receptor, however no changes in the overall integrity of the ecological receptor.
Low	There is a short-term small-scale change in the ecological receptor, but its overall integrity is not impacted.
Negligible	No perceptible change in the ecological receptor.

- **Duration** – the duration of impact is considered to be for 6 months, which is the duration for which a drought option is implemented, unless otherwise stated.
- **Reversibility** – all impacts are considered to be reversible unless they are identified to have a likely impact upon the overall integrity of the ecological receptor.
- **Timing and Frequency** – the drought option could be implemented at any point in the year, however the different life stages of the sensitive ecological features will be taken into account. The assessment is based upon the operation of a single drought permit, with subsequent applications for a drought permit required to consider cumulative effects of multiple drought permits.
- **Probability** – all impacts are considered to be probable, unless otherwise stated.

Once the value of the ecological receptor, magnitude of impacts and other parameters listed above have been identified, these are used to inform the assessment of significance of impact on the ecological receptor.

Data Requirements

Sensitive ecological features baseline review requires data from standard NRW / Environment Agency monitoring programmes in the potentially impacted zone, and preferably in a control site outside of the zone of influence. Data should include species presence, abundance and density. It is likely that most fisheries data will be for O and O+ lifestages, with some indication of older echelons. Environmental supporting data should include habitat availability, hydrology and water quality as follows:

- Relevant study area (as identified in the screening report)
- Hydrology at or close to the monitoring sites to link to fish data, including full flow hydrograph, wetted width and depth, velocity profile. Will include daily gauged flow and spot flow surveys, all available records

- Meteorology (where flow data insufficient) from available NRW / Environment Agency rain gauges
- Habitat data for the monitoring sites, which may include recent RHS or Habscore surveys
- Routine NRW / Environment Agency water quality monitoring data (dissolved oxygen, BOD, ammonia, pH, hardness, water temperature, conductivity) representative of the study area
- Habitat preferences for the given sensitive ecological features will be described, against which habitat change can be assessed.

Assessment Methodology and Uncertainty

The NERC / Environment (Wales) Act Section 7 species status for the watercourses will be identified and the reasons for its inclusion in the NERC / Environment (Wales) Act Section 7 established from the relevant bodies (start with NRW / Environment Agency). The data used to support the Environment (Wales) Act Section 7 assessment will be reviewed to ensure that it is accurate.

Baseline conditions for sites within the zone of influence of the drought option will be established through existing data. These should include graphing the hydrology, water quality, habitat and fish variation temporally and, if multiple sites, spatially over the monitored period. The analysis will consider the relationship between sensitive ecological feature lifestages and the supporting environmental variables over the period, with an emphasis on changes to status and environmental conditions between low, average and high flow years. The purpose of the analysis is to establish whether the sensitive ecological features population responds to changes in flow and associated environmental variables inter-annually relating to changes in flow, climate, quality (dissolved oxygen and temperature) and/or habitat quality and availability.

Having established the baseline conditions and variability outside the drought option conditions (care will be taken to avoid using periods in the baseline analysis within which a drought permit may have been in operation), a prediction will be made of the changes in the supporting environmental variables (flow, habitat and water quality) resulting from application of the drought option conditions. Ideally this will be undertaken for the hydrological data by overlaying the drought option flows over the baseline flow hydrograph, and, where cross sectional data are available, how the wetted width and depth will vary with the drought option. This can be extrapolated to the habitat data to consider whether the key features are compromised by the change in water depth. In many cases these data are currently unlikely to exist and proxy measures such as RHS and/or aerial survey data will be used.

Once the flow, habitat and water quality drought option predictions have been established, their implications for the sensitive ecological features will be assessed. The flow and habitat environmental preferences of the sensitive ecological features will be described. The predicted changes in supporting environmental variables (flow, depth, velocity, habitat quality, dissolved oxygen levels and/or temperature) due to the drought option should be assessed against the sensitive ecological features population data.

Where data are not available the assessment will be undertaken using expert judgement and

drawing on broad-scale evidence from other similar catchments.

The prediction of impacts of hydrological and water quality changes on aquatic ecology remains subject to significant uncertainty. This is exacerbated where few data or surveillance data are used for impact assessment purposes. Lastly the environmental preferences within which species can successfully exist, and the relationship between populations in stressed river conditions remains subject to debate. The assessment must therefore be undertaken in recognition that the outcome prediction will be subject to large potential variability. The study will therefore adopt a precautionary approach, with potential impacts highlighted where doubt exists. Monitoring and mitigation proposals for the drought option can then be specified so that, the actual impact can be recorded and adaptive mitigation/management of the option undertaken to safeguard where possible the sensitive ecological features populations.

Habitat Preferences

Habitat Preferences		**Unfavourable Habitat**	**Potential Impacts**
Type/ Age Class	**Description**		
Atlantic salmon *Salmo salar* and Brown/Sea trout *Salmo trutta*			
Spawning	• Clean and unconsolidated gravels typically in the transitional area between pools and riffles where the flow is accelerating and depth is decreasing	-	Deposition of silt
			Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
Nursery (fry and parr life stage)	• Shallow areas with a low water velocity and pebble substrate, often at the margins of riffles	• Deep and/or high velocity habitats.	Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
Adults	Deep habitats that provide shelter including one or more of the following: • submerged structures • undercut banks • overhanging vegetation < 50cm above the water surface • water surface turbulence causing a broken surface • Deep pools downstream of obstacles and sufficient water quantity through structures to enable passage across obstacles.	• Open and shallow habitats, but will use these during migration to reach spawning gravels. • Habitats upstream of significant obstructions.	Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Increased significance of barriers to impede migration as a result of decreased flows
			Deterioration in water quality
Brook lamprey *Lampetra planeri*			
Spawning	• Clean, unconsolidated spawning gravels with suitable sheltering areas, usually located at the tail end of pools where flows are increasing.	- -	Deposition of silt
			Reduction in velocity, depth or wetted width resulting in exposure of river bed
			Increased water velocity and depth
Nursery	• Areas of sandy silt with slow water velocity, often in the margins of watercourses, above the estuary. • Variation in depth between 2 cm and 30 cm (>15cm is optimal) with a relatively high organic content.		Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake

Habitat Preferences		Unfavourable Habitat	Potential Impacts
Type/ Age Class	**Description**		
			Deterioration in water quality
Adults	• Cover (stones and vegetation) in the vicinity of spawning gravels.		Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
River lamprey *Lampetra fluviatilis*			
Spawning	• Clean and unconsolidated spawning gravels with suitable sheltering areas, usually located at the tail end of pools where flows are increasing.	-	Deposition of silt
			Reduction in velocity, depth or wetted width resulting in exposure of river bed
			Increased water velocity and depth
Nursery	• Areas of sandy silt with slow water velocity, often in the margins of watercourses, above the estuary. Variation in depth between 2cm and 30cm (>15cm is optimal) with a relatively high organic content.	-	Reduction in velocity, depth or wetted width resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
Adults	• Suitable estuarine conditions, that is free from pollution and with suitable prey species available. • Clear migration routes from the estuary to spawning grounds with suitable river flows and no barriers.	• Areas with significant pollution or limited prey availability. • Habitats upstream of significant obstructions.	Increased significance of barriers to impede migration as a result of decreased flows
			Increased risk of entrainment into water intake
			Deterioration in water quality
Sea lamprey, *Petromyzon marinus*			
Spawning	• Clean and unconsolidated spawning gravels with suitable sheltering areas, usually located at the tail end of pools where flows are increasing.	-	Deposition of silt
			Reduction in velocity, depth or wetted width resulting in exposure of river bed
			Increased water velocity and depth
Nursery	• Areas of sandy silt with slow water velocity, often in the margins of watercourses, above the estuary. Variation in depth between 2cm and 30cm (>15cm is optimal) with a relatively high organic content.	-	Reduction in velocity, depth or wetted width resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
Adults	• Suitable estuarine conditions, that is free from pollution and with suitable prey species available. • Clear migration routes from the estuary to spawning grounds with suitable river flows and no barriers.	• Areas with significant pollution or limited prey availability. • Habitats upstream of significant obstructions.	Increased significance of barriers to impede migration as a result of decreased flows
			Increased risk of entrainment into water intake
			Deterioration in water quality
Bullhead, *Cottus gobio*			
Spawning	• Coarse, hard substrate of gravel and stones.	• Deep, silty watercourses with high flow velocities and little or no cover.	Deposition of silt
			Reduction in velocity, depth and/or wetted width
			Increased water velocity and depth

Habitat Preferences		Unfavourable Habitat	Potential Impacts
Type/ Age Class	**Description**		
Nursery	• Shallow, stony riffles		Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
Adult	• Sheltered sections created by woody debris, tree roots, leaf litter, macrophyte cover or larger stones.		Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
European eel, *Anguilla anguilla*			
Juvenile (<30cm)	• Wetland habitats within 30km of tidal limit with high diversity and cover of vegetation, soft substrates and high productivity.	• Low productivity watercourses with dominance of coarse substrates and low macrophyte cover and diversity. • Habitats upstream of significant obstructions.	Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
Adult (>30cm, female >45cm)	• Deep, slow flowing watercourses and wetland habitats within 80km of tidal limit with high diversity and cover of vegetation, soft substrates and high productivity.		Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased significance of barriers to impede migration as a result of decreased flows
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
Barbel *Barbus barbus*			
Spawning	• Run/glide flow • Less than 50cm deep • Velocities greater than 0.5m/s • Substrate composed of clean and uncompacted gravel	-	Deposition of silt
			Reduction in velocity, depth or wetted width resulting in exposure of river bed
			Increased water velocity and depth
Nursery	• Marginal shallow bays set back from or within margins of main channel • Depths between 1cm and 30cm • No discernible to minimal flow • Substrate composed of >30% gravel and sand with low silt content • Lack of or very little riparian shading		Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Increased water velocity and depth
			Increased risk of entrainment into water intake
			Deterioration in water quality
Adults	• Commonly associated with stretches of clean gravel and macrophyte beds, showing a preference to relatively fast-flowing stretches in the middle reaches of larger rivers. • The species also occupies deep water habitats at the foot of weirs,		Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
			Impedance to movement upstream
			Increased water velocity and depth
			Increased risk of entrainment into water intake

Habitat Preferences		Unfavourable Habitat	Potential Impacts
Type/ Age Class	**Description**		
	in the lee of large woody debris, rock ledges or other obstructions on the river bed.		Deterioration in water quality Increased water velocity and depth
Fine-lined pea mussel, *Pisidium tenuilineatum* and depressed river mussel *Pseudanodonta complanata*			
All life stages	• Fine sediments of lowland rivers and canals,	• High velocity watercourses with coarse substrates.	Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed
White-clawed crayfish *Austropotamobius pallipes*			
All life stages	• Slow-flowing sections of stony rivers • Boulder riffles in chalk or clay streams • Submerged tree roots • Debris dams • Crevices in old or damaged submerged brickwork, stonework, cracked concrete or rotten wooden structures • Un-mortared stone revetting which protects banks from erosion • Stands of submerged and emergent aquatic plants • Old gravel workings and chalk pits • Good water quality	• Uniform clay channels • Areas of deep or soft silt • Dense filamentous algae • Narrow fast-flowing channels • Areas of sand and gravel, or bedrock, which are lacking in cobble or boulder (though they may feed in or commute through these areas) • Pebble or cobble shingle regularly exposed by changing river levels • Areas of armoured bed where the substrate is compacted by the river flow • Acidic streams or ochreous drainage • Poor water quality or salinity	Reduction in velocity, depth and/or wetted width, possibly resulting in exposure of river bed Increased water velocity and depth Increased risk of entrainment into water intake Transfer of non-native species or disease Deterioration in water quality

APPENDIX D – 8012-5 ENVIRONMENTAL FEATURES ASSESSMENT

D1 INTRODUCTION

This appendix presents information regarding the environmental features associated with the Llannerch boreholes drought permit. Baseline data and the impact assessments are presented for the environmental features that form part of the scope of the assessment (established by the screening exercise described in Section 3.2.2 of the EAR and results of which are summarised in Section 5.2). The features assessment presented in full below is summarised in Section 5.3 of the EAR.

Points of interest referred to throughout the text are indicated in **Figure D1.1**.

The approach to the assessment addresses the following: i) potential effects on each sensitive receptor; ii) definitions for impacts (adverse / beneficial), i.e. the significance criteria (quantitative and / or qualitative measures used to grade the severity of impacts of the drought order for the impact criteria major, moderate, minor, negligible; following the requirements of the DPG); iii) the data requirements; iv) assessment methodology (including the treatment of uncertainty where the complete data requirements are not available).

The assessment of environmental features is informed by the assessment of the physical environment (which includes hydrology and hydrodynamics; geomorphology; and water quality), this is summarised in Section 4 presented in full in **Appendix B**.

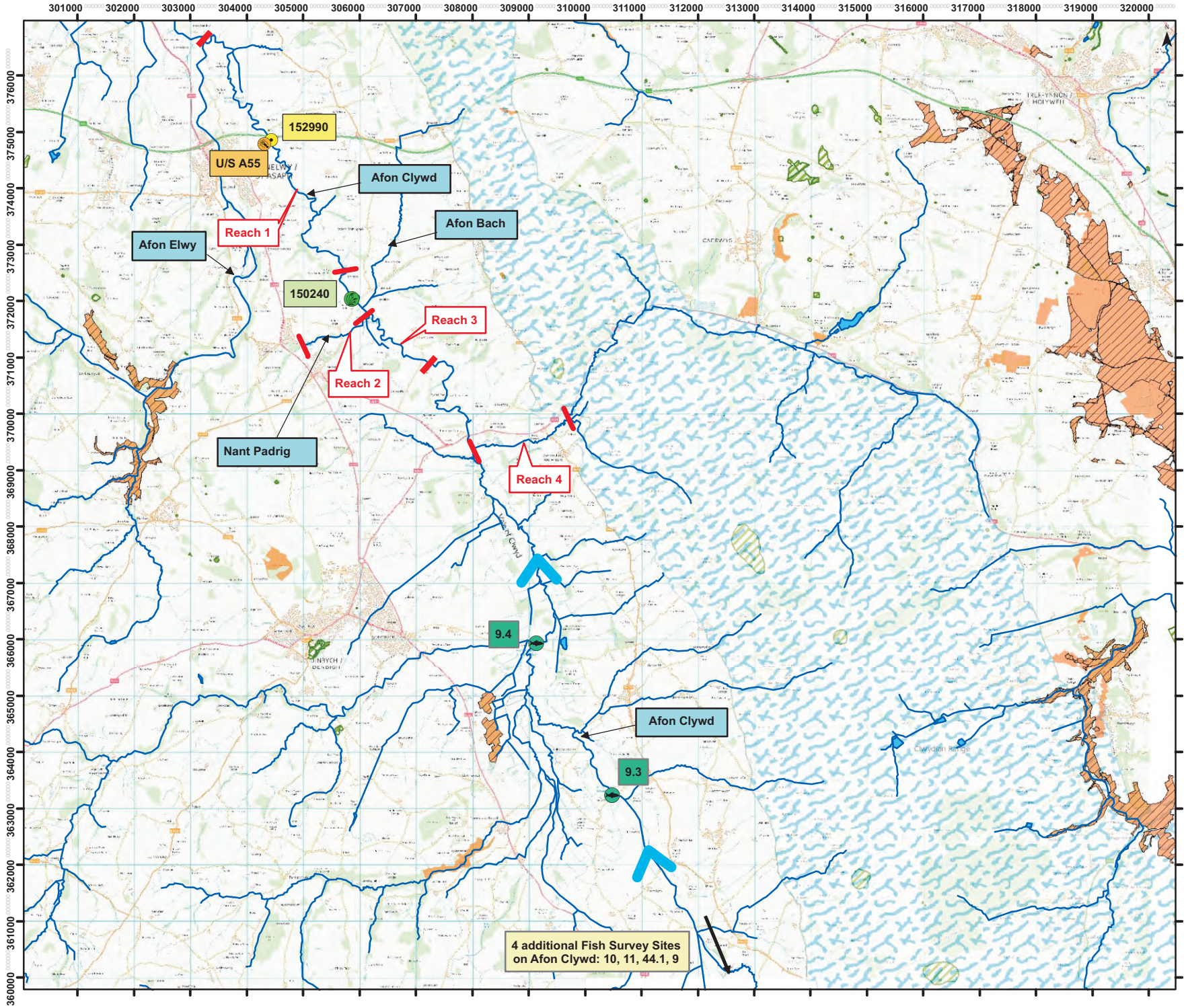
The ecological assessment has been undertaken recognising the Institute of Environmental Management and Assessment (IEMA)[1][2] and the Chartered Institute of Ecology and Environmental Management (CIEEM) study guidelines[3]. The assessment of impacts on other environmental receptors e.g. recreation and landscape has been carried out largely by qualitative expert judgement. Specific assessment methodologies for key environmental features are set out in **Appendix C**.

Desk-based assessments have been completed for each of the sensitive receptors, where applicable, in order to determine the magnitude of impact in the relevant river reaches for the Llannerch boreholes drought permit. Each feature assessment describes the analyses carried out and a statement of the assessed impact. All impacts are considered to be negative / adverse unless otherwise stated in the feature assessment.

This appendix is set out in the following sections:

Section D.2 WFD Status and Community Assessment / Notable Species

[1] IEMA (2004) Guidelines for Environmental Impact Assessment.
[2] IEMA (2011) Special Report – The State of Environmental Impact Assessment Practice in the UK
[3] CIEEM (2018) Guidelines for Ecological Impact Assessment in the UK and Ireland.



Legend

- Fish Survey Site
- Macroinvertebrate Survey
- Phytobenthos_survey
- Macrophyte Survey
- Water Courses
- Hydrological Reach
- Flow Direction
- Reservoir

1:62,500

Note: All locations are approximate

Project Title: Welsh Water Drought Plan Environmental Assessment

Figure Title: Environmental Features: 8012-5 Llannerch boreholes

Figure Number:

Date: February 2019

D2 WFD STATUS AND COMMUNITY ASSESSMENT / NOTABLE SPECIES

D.2.1 Macrophytes

D.2.1.1 Baseline

The impacted reaches for the Llannerch boreholes drought permit are located in WFD waterbody GB110066059960 (Clywd, Tidal limit to Hesbin). Baseline data has been provided by NRW for one macrophyte sampling location in this waterbody. The Llannerch Hall sampling site is located on the Afon Clwyd within Reach 1, downstream of the confluence between Afon Back and Afon Clwyd. Three macrophyte surveys have been carried out at this site, in 2007, 2010 and 2014.

Hydrological impacts, summarised in Appendix B, describe negligible impacts from the drought permit on Reaches 1, 3 and 4, with major adverse impacts confined to Reach 2 (Nant Padrig). As no data is available from Reach 2, macrophyte data from the site Llannerch Hall will be utilised to provide an understanding of the probable macrophyte community expected in Reach 2. Consideration of the different river characteristics between the Afon Clwyd and Nant Padrig, and therefore the likely differences in the macrophyte communities expected to be present are included below.

The baseline description and assessment provided below is based on the assumption that the data available provides a relatively reliable representation of the likely communities present within the impacted reaches. However, macrophyte survey of the impacted reaches is strongly recommended in order to increase confidence in this assessment.

Macrophyte analysis results were provided by NRW using the standard LEAFPACS2 methodology[4] in accordance with the requirements of the Water Framework Directive (WFD). This methodology is based on the principle that different combinations, quantities, and numbers of macrophytes are associated with different flow conditions and nutrient availability in a river. The LEAFPACS2 method assesses the condition of river macrophyte communities using data on presence and abundance of species and groups of species recorded during a standard survey comprising a 100m river section. These indices are briefly described below:

(i) River Macrophyte Nutrient Index (RNMI): an index of eutrophication (high scores indicate enriched conditions);

(ii) Number of macrophyte taxa which are truly aquatic, i.e. hydrophytes (NTAXA);

(iii) Number of functional groups of macrophyte taxa which are hydrophytes (NFG): an assessment of the structural diversity of the plant community; and

(iv) Percentage cover of all green filamentous algal taxa over the whole of the surveyed river sections (ALG).

[4] WFD-UKTAG (2014) UKTAG river assessment method – macrophytes and phytobenthos (River LEAFPACS2).

In addition to the above scores, observed Mean Trophic Rank (MTR) and Macrophyte Flow Ranking (MFR) scores were also provided. **Table D3.1** provides a summary of RMNI, MTR and MFR scores recorded at sites within the study reach. **Table D3.2** and **Table D3.3** identify the interpretation of MFR and MTR scores.

RMNI and RMHI are biotic indices used to determine the nutrient preference and flow preference of macrophyte communities respectively and are updated versions of the MTR and MFR biotic indices. To calculate RMNI scores, macrophyte communities are identified and assessed on a scale of 1 to 10 based on individual species cover values and their combined preference for nutrient enrichment. High scores are associated with communities in eutrophic waters, low scores are associated with oligotrophic waters. Following the same premise communities with high RMHI scores are associated with low energy flow velocities and low scores are associated with high energy flow velocities.

Table D3.1 Macrophyte Biotic indices scores for site Llannerch Hall

Site	Grid Reference	Year	MFR	MTR	RMNI	RMHI
LLANNERCH HALL	SJ-05866-72046	2007	2.5	33.7	6.98	6.85
		2010	2.4	37.9	7.16	7.09
		2014	3.33	67.3	4.89	5.26

Table D3.2 Interpretation of MFR Scores Used for this Assessment

MFR Score	Interpretation of Score
1	Community preferring slow flow velocity
2	Community preferring slow to moderate flow velocity
3	Community preferring moderate flow velocity
4	Community preferring moderate to fast flow velocity
5	Community preferring fast flow velocity

Table D3.3 Interpretation of MTR Scores (from Holmes *et al.*, 1999[5])

MTR Score	Interpretation of Score
<25	Site is badly damaged by eutrophication, organic pollution, toxicity or is physically damaged.
25-65	Site is likely to be either eutrophic or at risk of becoming eutrophic
>65	Site is unlikely to be eutrophic

RMNI and RMHI are biotic indices used to determine the nutrient preference and flow preference of macrophyte communities respectively and are updated versions of the MTR and MFR biotic indices. To calculate RMNI scores, macrophyte communities are identified and assessed on a scale of 1 to 10 based on individual species cover values and their combined

[5] Holmes, N T H, Newman, J R, Chadd, S, Rouen, K J, Saint, L and Dawson, F H (1999) *Mean Trophic Rank: A Users Manual.* R&D Technical Report E38, Environment Agency, Bristol.

preference for nutrient enrichment. High scores are associated with communities in eutrophic waters, low scores are associated with oligotrophic waters. Following the same premise communities with high RMHI scores are associated with low energy flow velocities and low scores are associated with high energy flow velocities.

Environmental variables would allow for the use of the LEAFPACS tool for in depth interpretation of biotic indices scores. LEAFPACS is a data classification tool that calculates what the macrophyte communities should be like at reference state for any given site based on its environmental variables. It compares these predictions with the actual results recorded from surveys carried out at the site. Through these means we would be able to produce WFD classifications for individual surveys. As the environmental data was not available, this assessment is based on the interpretation of all available indices scores and raw survey data.

During the three surveys conducted at the Llannerch Hall site between 14 and 18 macrophytes were recorded on each survey occasion (of which between 8 and 9 were hydrophytes). The nutrient metric RMNI provides scores of 4.89 and 7.16, respectively. These scores describe a large degree of variation in the nutrient preference of the communities over the monitoring period. The surveys in 2007 and 2010 show a community with preference for high nutrient levels with the site likely to be eutrophic, whereas in 2014 the surveys show a community with preference for considerably lower nutrient levels. The functional group driving this variation is filamentous algae, in particular the taxa *Cladophora sp* is recorded in high cover values in 2007 and 2010 with covers of 10 to 25% and 25 to 50% respectively. Total cover of algae (Algal PCT index) is an indication of acute nutrient releases, with high cover values coinciding with sudden increases in nutrient levels. This community suggests acute nutrient increases within the Afon Clwyd are likely to have occurred in 2007 and 2010. There is no evidence of this in the 2014 data. It is not possible to determine if the source of any nutrient enrichment in the Afon Clywd will have impacted the macrophyte community of the Nant Padrig, as a precautionary approach it is assumed the community is sensitive to nutrient enrichment as is evident in the 2014 survey data recorded at Llannerch Hall.

The community is otherwise composed of low cover values of bryophyte species including *Brachythecium rivulare* and *Fontinalis antipyretica* as well as a number of marginal emergent species including *Sparganium erectum* and *Oenanthe crocata* with little variation across the three years of monitoring.

RMHI also appears to be influenced by the high cover values of nutrient preferring taxa including *Cladophora sp* with disparity between 2007 / 2010 survey RMHI scores and that calculated for 2014. These results indicate a community with preference for moderate to fast flowing waters which is consistent with the MFR scores calculated from the same data set. Within the Nant Padrig, the slope of the waterbody is expected to be greater with faster flows expected as a result. As such the macrophyte community in Nant Padrig will be expected to show relatively higher RMHI and MFR scores in comparison to those calculated from Llannerch Hall.

Notable Species

No notable species were present in the available macrophyte survey data.

D.2.1.2 Assessment

The assessment of impacts to the macrophyte community within the zone of influence is confined to Reach 2 (Nant Padrig) as the hydrological impacts in the remaining reaches have been assessed as negligible. Impacts in Reach 2 should be considered in the context of the watercourse under baseline conditions. Whilst no baseline data is available for Reach 2 the site Llannerch Hall, located in Reach 1 is used to provide an indication of the macrophyte community likely to be present in Reach 2. Baseline data from Llannerch Hall indicates that the macrophyte communities in Reach 2 of the hydrological zone of influence of the drought permit are bryophyte dominated, adapted to moderate to fast velocities and may be subjected to intermittent nutrient enrichment.

Abstraction from Llannerch boreholes is expected to result in reductions in year round Q50 and Q959 flow of 10.8% and 45.3% respectively in Reach 2. Therefore the potential hydrological impact of the drought permit in Reach 2 is assessed as moderate (uncertain). Reduction in flows may occur during any season and affect the macrophyte communities in a number of ways:

- Reduction in velocity favouring species adapted to slower flow conditions;
- Proliferation of filamentous algae due to decreases in velocity / increases in water temperature;
- Shading of macrophyte stands by epiphytic algae and floating macrophytes, due to decreases in velocity/increases in water temperature;
- Desiccation of macrophyte beds due to reduced wetted width and water depth;
- Encroachment of marginal emergent species into the channel; and
- Reduction or movement of the splash zone from where this usually occurs, both at the edges of the channel and around in-stream features such as boulders and exposed bedrock, leading to desiccation of species present within these areas, particularly bryophytes.

The assessment of water quality deterioration associated with soluble reactive phosphorous has determined that there is a major risk of deterioration within Reach 2. Increased SRP concentrations could increase the occurrence of more opportunistic, nutrient tolerant taxa, epiphytes, and filamentous algae. In turn, this could affect macrophyte condition or potentially community composition if slower growing species or those that prefer lower nutrient conditions are outcompeted.

Due to the potential change to wetted area, velocities, splash and humidity operation of the drought order has the potential to affect the condition, composition and extent of macrophyte communities. Riverine bryophytes (i.e. the species comprising the macrophyte communities recorded in the study reach) are generally well adapted to tolerate desiccation and rewetting

and communities can take a long time to react to changes in environmental conditions[6]. As such changes to the wetted area, velocities, splash and humidity operation for the duration of the drought permit's implementation may impact in the macrophyte community.

However the effects of the drought permit on the macrophyte community would be outside the main growing season. Considering the magnitude of hydrological and water quality impacts, and the sensitivity of the macrophyte communities present, impacts of the drought permit on the macrophyte community in Reach 2 are expected to be **negligible**.

Summary

The potential impacts of the Llannerch boreholes drought permit on the macrophyte community are summarised in **Table D3.4**. The impacts, and their magnitude, have been based on the hydrological impacts (see Section 4.2 of the main report), their influence on the physical environment (including geomorphology, water quality and likely habitat availability) (see Section 4.3 of the main report) and the sensitivities of the macrophyte community. The impacts presented in **Table D3.4** represent the worst case impacts of implementing a drought order, over and above the impacts potentially caused by a natural drought.

Table D3.4 Summary of Impacts on Macrophyte Community

Feature	Impact	Significance of Impact
Reach 2 – Nant Padrig		
Macrophytes	• Changes to community composition due to changes to flow velocities and habitat loss due to reduction in wetted width and depth. • Medium risk to SRP leading to increased proliferation of species with preference for high nutrient concentrations including filamentous algae.	**Negligible**

The WFD waterbody which encapsulates Reach 2, GB110066059960 (Clwyd, Tidal Limit to Hesbin) is currently classified as high for ecological status. Impacts to the macrophyte community within this waterbody have been assessed as major within Reach 2. Effects would be expected to be temporary and reversible following return to a normal hydrological regime. This reach which is 300m in length and located on Nant Padrig, a tributary of the Afon Clywd represents a small proportion the total waterbody. As such implementation of this drought permit poses a **negligible** risk of deterioration in WFD status in relation to macrophytes for waterbody GB110066059960 (Clwyd, Tidal Limit to Hesbin).

D.2.2 Macroinvertebrates

D.2.2.1 Baseline

The impacted reaches for the Llannerch boreholes drought permit are located in WFD

[6] Demars, B. O. L. and Britton, A. (2011). Assessing the impacts of small scale hydroelectric schemes on rare bryophytes and lichens. Scottish Natural Heritage and Macaulay Land Use Institute Funded Report. Scottish Natural Heritage Commissioned Report No.421

waterbody GB110066059960 (Clywd, Tidal limit to Hesbin). Baseline data has been provided by NRW for one macroinvertebrate sampling location in this waterbody. The U/S A55 sampling site is located on the Afon Clwyd downstream of Reach. Spring and autumn survey results are available for this sites from the years, 2010, 2011 and 2014. No other sampling locations were present within the study reach.

Hydrological impacts, summarised in **Appendix B**, describe negligible impacts from the drought permit on Reaches 1, 3 and 4, with major adverse impacts confined to Reach 2 (Nant Padrig). As no data is available from Reach 2, macroinvertebrate data from the site U/S A55 is utilised to provide an understanding of the macroinvertebrates community expected to be present in Reach 2. Consideration of the different river characteristics between the Afon Clwyd and Nant Padrig and therefore the macroinvertebrate communities expected to be present are included.

Sampling was conducted by following the standard NRW protocol involving a three minute kick / sweep sample encompassing all the available instream habitats in proportion to their occurrence. All data has been analysed to species or mixed taxon level. These datasets were used to calculate a series of standard biotic indices: Biological Monitoring Working Party (BMWP) scores; Average Score Per Taxon (ASPT) scores; Lotic Invertebrate Flow Evaluation (LIFE); and number of taxa (NTAXA).

BMWP is primarily used to monitor the impact of organic water quality but also responds to other pressures such as habitat reduction, siltation and toxic pollutants. High BMWPs are associated with good water and habitat quality. Comparisons between sites with BMWP scores must be used with caution as change to river type can have considerable influence over BMWP score. ASPT is derived from BMWP and provides the average BMWP sensitivity score of all the taxa found in the sample's macroinvertebrate assemblage. This index provides a more reliable means of comparing macroinvertebrate community quality between sites whilst also reducing the influence of sampling artefacts such as variable sampling effort. As such ASPT is used as the primary means of assessing macroinvertebrate response to water quality in this assessment. As a guide ASPT scores above 5 represent macroinvertebrate communities living in good water quality. Scores below 5 indicate water quality stress on the macroinvertebrate community.

Data collected in 2010 and 2011 describe a macroinvertebrate community which is relatively diverse, with between 23 and 34 taxa being recorded from each sample. The community is dominated by EPT (Ephemoptera, Plecoptera and Tricoptera) river fly species as would be expected for this type of river. In 2014 the diversity of the community is reduced, with 15 to 18 taxa being recorded in spring and autumn respectively. BMWP scores over this period mirror this trend.

The ASPT scores obtained from site U/S A55 show less variation over this period, ranging between 4.93 and 5.97 between 2010 and 2014. This reflects a macroinvertebrate community which is consistent with that found in moderate to good water quality. Assessment of water

quality in **Appendix B** summarises the baseline ammonia and dissolved oxygen conditions in the waterbody are consistent with standards to support high status. As such the macroinvertebrate community present appears to be impaired further than the supporting water quality data describes. It is possible water quality pressures, possibly of an intermittent nature, are present in the waterbody which the invertebrate community is responding to which is not picked up in NRW's routine water chemistry monitoring. Without Environmental Quality Ratios for this data it is not possible to ascertain with any certainty if this is the case.

Figure D3.1 ASPT Scores for Sites Located in Waterbody GB110066059960 (Clywd, Tidal limit to Hesbin)

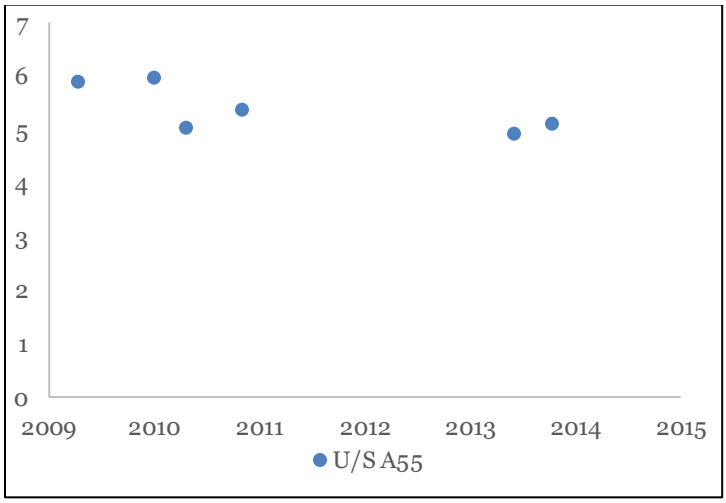
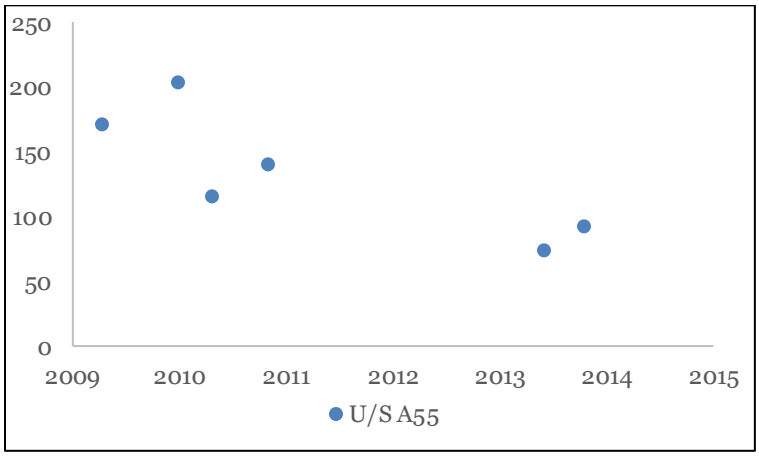


Figure D3.2 BMWP Scores for Sites Located in waterbody GB110066059960 (Clywd, Tidal limit to Hesbin)

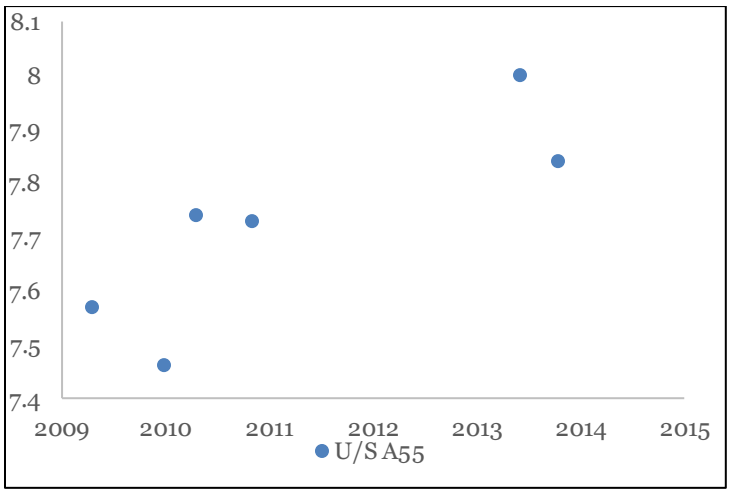


LIFE scores are used to assess how sensitive a macroinvertebrate community is to change in flow. Family LIFE scores are provided for all available data. Species LIFE scores which provide a more accurate assessment of flow sensitivity are provided between 2010 and 2014. See **Table D3.5** for interpretation.

Table D3.5 Interpretation of Macroinvertebrate Community LIFE Scores

LIFE score	Invertebrate community flow sensitivity
7.26 and above	High sensitivity to reduced flows
6.51 – 7.25	Moderately sensitive to reduced flows
6.5 and below	Low sensitivity to reduce flows

Figure D3.3 Family LIFE Scores Obtained from Sites Located in Waterbody GB110066059960 (Clywd, Tidal limit to Hesbin)



LIFE scores obtained from the site U/S A55 range between 7.46 and 8. This describes a macroinvertebrate community which is highly sensitive to reduced flows and therefore is consistent with that found in fast flowing water. The macroinvertebrate community which would be expected in Reach 2 is likely to reflect this high sensitivity to flow reductions, with further preference for high flow velocity being likely due to the greater slope of Nant Padrig in comparison to Afon Clywd.

Notable Species

There were no notable species of macroinvertebrates present in the available NRW data for the site U/S A55.

D.2.2.2 Assessment

The assessment of impacts to the macroinvertebrate community within the zone of influence is confined to Reach 2 (Nant Padrig). Impacts in this reach should be considered in the context of the watercourse under baseline conditions. Whilst no baseline data is available for Reach 2 the site U/S A55, located in on the Afon Clwyd downstream of Reach 1 is used to provide an indication of the macroinvertebrate community likely to be present in Reach 2. Baseline data from U/S A55 indicates that the macroinvertebrate communities in Reach 2 of the hydrological zone of influence of the drought permit is highly sensitive to flow reductions and show moderate to good levels of sensitivity to water quality pressures.

For Reach 2, operation of the drought permit is predicted to result in major hydrological impacts which may occur at any time of year with reductions in year round Q50 and Q959 flow of 10.8% and 45.3%respectively. This magnitude of flow change would be expected to have significant effects on velocities, wetted width and depth and therefore habitat availability, particularly in flow sensitive areas of the channel, e.g. riffles, which form important habitat for macroinvertebrate species.

Baseline data from the site U/S A55 describes a macroinvertebrate community downstream of Reach 1 which is highly sensitive to reduced flows, with a high proportion of species preferring fast flowing waters. In Reach 2 it is likely that in the short-term this impact will modify the macroinvertebrate community with a loss of species which prefer fast flows and proliferation of invertebrates which favour slower flows. Although this effect would occur during drought under normal operating conditions, the operation of the drought order is likely to magnify this effect as the availability of habitat niches and velocities is further reduced. This is likely be reflected by reduced LIFE scores and numbers of taxa.

The drought permit may be implemented during the period September to January therefore may impact a range of macroinvertebrate life stages. Reproduction may also be impacted, the majority of river fly species hatch in late summer/autumn and emerge in the following spring/summer to reproduce. Any impacts to these species during late summer/autumn may ultimately reduce recruitment to the next generation, especially sensitive periods including emergence and oviposition.

Typically, invertebrate communities can recover rapidly from short term flow impacts as a result of immigration from upstream habitats. In the context of Nant Padrig, recovery of the invertebrates will benefit from the upstream reaches of the waterbody as well as recolonisation from the Afon Clwyd. Invertebrate recovery will also involve aerial recolonization and refugium-use strategies. As such invertebrate recovery following the cessation of the drought order and return to standard compensation flow will likely be rapid.

The drought permit has been assessed as having a low risk to ammonia and dissolved oxygen in Reach 2, which has the potential to affect macroinvertebrate communities during drought permit implementation. This may manifest as a small reduction in pollution sensitive taxa in this reach. Taxa from families such as *Goeridae, Leptoceridae* and *Heptageniidae* with requirement for high dissolved oxygen levels will be most susceptible. BMWP and ASPT scores from a community impacted by this pressure will be slightly reduced. A number of crustacean taxa such as the freshwater shrimps (*Gammaridae*) which are recorded in high numbers at U/S A55 are particularly sensitive to ammonia. Consequently, there is potential that in the short-term this impact will modify the macroinvertebrate community with a reduction in abundance of ammonia sensitive species.

However, restoration of favourable ammonia and dissolved oxygen conditions is predicted following a recovery of flow. Hence given the ability of macroinvertebrate communities to recover as a result of effective re-colonisation strategies, the magnitude of impact of water

quality changes is considered to be low.

Overall therefore, due primarily to the moderate hydrological impact of the drought order, the potential impact to macroinvertebrate communities in Reach 2 is assessed as **minor**, adverse, short term and reversible.

Summary

The potential impacts of the Llannerch boreholes drought permit on the macroinvertebrate community are summarised in **Table D3.6**. The impacts, and their magnitude, have been based on the hydrological impacts (see Section 4.2 of the main report), their influence on the physical environment (including geomorphology, water quality and likely habitat availability) (see Section 4.3 of the main report) and the sensitivities of the macroinvertebrate community. The impacts presented in **Table D3.6** represent the worst case impacts of implementing a drought permit, over and above the impacts potentially caused by a natural drought.

Table D3.6 Summary of Impacts on Macroinvertebrate Community

Feature	Impact	Significance of Impact
Reach 2 – Nant Padrig		
Macroinvertebrates	• Reduction in species diversity and abundance as a result of reduced recruitment. • Reduction in species diversity as a result of the loss of flow-sensitive taxa • Loss of marginal habitats and reduction in abundance and distribution of species utilising such habitats • Reduction in species diversity as a result of deterioration to water quality	**Minor**

The WFD waterbody which encapsulates Reach 2, GB110066059960 (Clwyd, Tidal Limit to Hesbin) is currently classified as good for macroinvertebrates. Impacts to the macroinvertebrate community within this waterbody have been assessed as moderate within Reach 2. Effects would be expected to be temporary and reversible following return to a normal hydrological regime. This reach which is 300m in length and located on Nant Padrig, a tributary of the Afon Clywd represents a small proportion the total waterbody. As such implementation of this drought permit poses a **negligible** risk of deterioration in WFD status in relation to macrophytes for waterbody GB110066059960 (Clwyd, Tidal Limit to Hesbin).

D.2.3 Fish

D.2.3.1 Baseline

Baseline data has been provided by NRW for the WFD waterbody within which Reach 2 of this drought permit is located, GB110066059960 (Clywd, Tidal limit to Hesbin). Within this waterbody two NRW fish survey locations are provided, the classification sites 9.3 and 9.4, both of which are located on the Afon Clwyd and therefore are not located within the impacted zone of influence of this drought permit (Reach 2). Furthermore, three sites are located in the upstream waterbody GB110066054670 (Clwyd - upstream Hesbin) data from these sites are included for further context of the fish population present in the Clywd catchment.

Existing Data

NRW data from the five sites on the Afon Clwyd have been analysed as part of this assessment. Reach 2 (Nant Padrig) constitutes a considerably smaller waterbody than the downstream Afon Clwyd and therefore the available habitat and subsequent fish assemblage present in this reach are likely to differ significantly from that recorded in the available fish survey data. As such, professional judgement and a precautionary approach are used to predict the fish assemblage likely to be present in Reach 2 together with the assessment of the physical environment (**Appendix B**) and the baseline fish survey data provided by the NRW for the Afon Clwyd. **Table D3.7** provides the fish survey data available from the five sites.

GB110066059960 (Clywd, Tidal limit to Hesbin) was assessed as being moderate status for fish in 2015 (Cycle 2).

Table D3.7. NRW Fish Survey Data from Sites in the Afon Clwyd (2005-2016)

WFD Waterbody			Density per 100m²				Minor species				
	Site Code	Year	Sal fry	Trout fry	Sal par	Trout par	Bullhead	Stone loach	Minnow	Eel	Lamprey
GB110066059960	9.3	2015	0.7	33	0.7	1.6	14	0	0	2	0
	9.3	2013	5.3	0	0.3	0.3	35	0	4	3	1
	9.3	2007	0	0	1.8	0	28	6	5	3	0
	9.4	2015	5.4	8.6	0	1.1	17	3	16	8	2
	9.4	2009	4.3	0.4	0	0.4	0	7	0	0	0
GB110066054670	10	2015	0	66.7	0	12.9	8	2	0	1	0
	10	2009	5.2	7.9	2	1.6	5	0	7	3	0
	11	2015	0	52	0	29.4	11	0	0	4	0
	11	2009	0	45.3	1.8	17.8	41	0	0	0	0
	44.1	2009	0	51.8	2.1	15.9	80	0	0	1	0
	44.1	2003	0	40.6	1.2	6.5	25	0	0	1	0
	9	2015	0	119.2	5.8	16.3	26	0	0	1	0
	9	2014	4	14	12	9	37	0	0	1	0
	9	2013	13.6	14.2	4.5	8.5	17	0	0	4	0
	9	2011	1.7	22.7	9.3	5.2	15	0	0	6	0
	9	2010	21.7	7.8	7.2	4.4	9	0	0	3	0
	9	2009	1.5	5.1	10.6	4	13	0	0	0	0
	9	2008	31.5	12.8	0.5	3.4	20	0	0	5	0
	9	2007	2.1	1.3	2.1	1.3	22	0	0	1	0

Species Composition

Seven fish species have been identified in the Afon Clwyd: Atlantic salmon *Salmo salar (*Habitats Directive Annex II and Environment Act (Wales) Section 7 species), sea / brown trout *Salmo trutta* (Environment Act (Wales) Section 7 species), lamprey species *Lampetra* sp. (Habitats Directive Annex II and Environment Act (Wales) Section 7 species), European eel *Anguilla Anguilla* (Environment Act (Wales) Section 7 species and IUCN Red List 'critically endangered' species), bullhead *Cottus gobio* (Habitats Directive Annex II species), minnow *Phoxinus phoxinus* and stone loach *Barbatula barbatula.*

There are no significant barriers to fish migration on the Afon Clwyd except for upstream of the hydrological reaches. In Reach 2 (Nant Padrig), an assessment of the geomorphology determined there are no barriers within the reach to migratory fish. As such fish movement between the Afon Clwyd and Reach 2 is not impaired.

Atlantic Salmon

NRW data for the Afon Clwyd suggest that juvenile Atlantic salmon are present in both WFD waterbodies. National Fisheries Classification Scheme grading[7] suggests relatively low densities of the species in GB110066059960 (Clywd, Tidal limit to Hesbin) with E grade for Atlantic salmon, consistent with a poor quality fishery on the four survey occasions between 2007 and 2015. In 2013 a D grade for salmon was achieved, this is consistent with a fair quality fishery. Both fry and parr life stages have been recorded in this waterbody over the monitoring period in low densities. Further up the catchment in waterbody GB110066054670 (Clwyd - upstream Hesbin) Atlantic salmon densities increase, particularly at site 9, with high numbers of fry suggesting increased suitability of salmonid spawning and juvenile habitat.

In the context of Reach 2 (Nant Padrig), the reach is expected to provide suitable spawning and nursery habitat for the species with a predominantly cobble and pebble substrate. The 2015 NRW Clwyd Fisheries Summary suggests that Atlantic salmon are absent from the nearby Afon Bach, a tributary of the Afon Clwyd, similar in character to the Nant Padrig. However, it is not known whether this is due to barriers to migration and it is therefore assumed that the species is present within Reach 2.

Brown / Sea Trout

NRW data for the Afon Clwyd provides evidence for the presence of brown/sea trout in both WFD waterbodies. National Fisheries Classification Scheme grading suggests highly variable densities of the species being present in GB110066059960 (Clywd, Tidal limit to Hesbin) with gradings of B to F between 2007 and 2015, reflecting trout densities consistent with good quality fisheries in 2015 and no fish being recorded in 2007.

[7] For salmonids, a grading system is used based on the original Fisheries Classification System called the National Fisheries Classification (NFC). The electric fishing data are analysed to produce a juvenile salmon and trout density score for each site, using average values from the early 1990s as a baseline. The proportion of sites falling into different salmon abundance Classes (A to F) provides a measure of the health of the juvenile salmon populations for each river. Sites are typically grouped into those that are at or above average (Classes A to C), below average (Class D) and well below average or fishless (Classes E or F).

Further up the catchment in waterbody GB110066054670 (Clwyd - upstream Hesbin) brown/sea trout densities increase significantly which is reflected in NFC gradings between A and D across the sites consistent with fair to excellent quality fisheries. This is also likely a reflection of greater suitability of habitat further up the catchment.

In the context of Reach 2 (Nant Padrig), the reach is expected to provide suitable spawning and nursery habitat for the species with a predominantly cobble and pebble substrate. The 2015 NRW Clwyd Fisheries Summary describes the nearby Afon Bach, a tributary of the Afon Clwyd, similar in character to the Nant Padrig, as a fair quality fishery for brown trout. This is consistent with NRW survey data and suggests juvenile trout are likely to be present within Reach 2.

Bullhead

Bullhead were found to be present in both WFD waterbodies of the Afon Clwyd in high densities. Within Reach 2 (Nant Padrig) the cobble and pebble substrate combined with an expected shallow water depth and fast flow velocity are likely to provide good habitat for all life stages of bullhead (juvenile, adult and spawning). As a precautionary approach a healthy population of bullhead is assumed to be present in Reach 2.

European Eel

European eel have been found to be present at both sites in GB110066059960 (Clywd, Tidal limit to Hesbin) and are also present in the upstream GB110066054670 (Clwyd - upstream Hesbin). Densities are likely to be low in Reach 2 (Nant Padrig) as this shallow tributary with coarse substrate, does not provide optimal habitat for any European eel life stage.

Lamprey sp.

Lamprey species have been found to be present in low densities in the Afon Clwyd waterbody GB110066059960 (Clywd, Tidal limit to Hesbin), although the specific lamprey species found in the surveys in 2013 and 2015 has not been recorded. The shallower Nant Padrig within which Reach 2 is located consists of coarse cobble and pebble substrate which is not optimal for spawning or juvenile lamprey life stages. Optimal juvenile lamprey habitat typically consists of silt beds with organic detritus in shallow, slow moving marginal areas. As no RHS survey or habitat walkover has been carried out on Reach 2 it is not possible to definitively exclude the reach from providing suitable habitat for the species. As a precautionary approach lamprey species are included for further assessment.

Minnow and Stone Loach

These minor species have been recorded in variable densities within GB110066059960 (Clywd, Tidal limit to Hesbin). Reach 2 is likely to provide suitable habitat for both species.

Ecological Value of Fisheries Receptors

Atlantic salmon, brown / sea trout, European eel and lamprey species are Environment Act

(Wales) Section 7 species of principal importance and Habitats Directive Annex II species and, alongside bullhead (Habitats Directive Annex II species), are considered to be of National importance. Minnow and stone loach are considered to be of local importance only.

D.2.3.2 Assessment

Hydrological variability in rivers can have a significant influence on the distribution of fish. When extreme low flows, or prolonged periods of low flow, are experienced, for example under continued water abstraction during drought conditions, the resultant changes in the hydrological regime can have significant impacts on resident fish communities. Abstraction of water from a river or stream reduces the wetted area and volume with the potential for subsequent impacts on fish populations as a result of, for example, intra- and inter-specific interactions (e.g. increased competition for optimal habitat and food)[8,9], reduced water quality and reduced reproductive success, growth and condition[10].

Abstraction from Llannerch boreholes is expected to result in reductions in year round Q50 and Q959 flow of 10.8% and 45.3%respectively in Reach 2. The Clwyd Augmentation Scheme will be of no benefit to Nant Padrig as only the main watercourse is augmented. Therefore, the potential hydrological impact of the drought permit in Reach 2 is moderate (uncertain). The drought permit may be in operation at any time of year and therefore interact with all fish species life stages.

For all species the limited extent of the reach (300m) which is located directly upstream of the Afon Clwyd is a significant factor in determining the significance of the impact to the species expected to be present. It is expected that, with no significant barriers to fish movement, resident fish species will move out of the zone of influence and that rapid recolonization will take place once natural flows return. However, salmonid spawning migrations in autumn / winter and spawning migrations for bullhead, brook lamprey, minnow and stoneloach in spring and summer may also be impacted.

Atlantic Salmon

Atlantic salmon may migrate into Nant Padrig to spawn between November and January. However, this migration would be initiated by increased flows and so increased abstraction at the downstream end of Nant Padrig is unlikely to have a significant effect.

There is the potential for reduced flow to result in a decrease in river levels and wetted width. There is therefore the potential for a loss or degradation of juvenile habitat along with gravel spawning habitat. Provided minimum low flows are available, juvenile Atlantic salmon are likely to relocate to areas of suitable habitat if river levels decrease, however, competition and stress would increase. Due to the timing of a potential drought permit, gravels containing

[8] Magoulick, D.D. (2000). Spatial and temporal variation in fish assemblages of drying stream pools: the role of abiotic and biotic factors. Aquatic Ecology 34, 29-41
[9] Davey A.J.H. & Kelly D.J. (2007). Fish community responses to drying disturbances in an intermittent stream: a landscape perspective. Freshwater Biology 52, 1719–1733.
[10] Magoulick, D.D. and Kobza, R.M. (2003). The role of refugia for fishes during drought: a review and synthesis. Freshwater Biology 48, 1186-1198.

alevins and / or early-stage fry (likely to occur in April and May) will not be affected. Reduced river levels and wetted width may also result in reduced availability of spawning habitat.

Atlantic salmon create gravel nests (redds) in suitable substrate in which to lay and incubate eggs and these redds would be susceptible to reduced flows in the likely impact period of a drought permit. Reduced river levels resulting from increased abstraction have the potential to result in stranding of redds and subsequent desiccation of eggs. However, the impact would be limited to approximately 300m of river channel only.

Potential water quality impacts (e.g. reduced dissolved oxygen and increased water temperature) as a result of a reduction in flow are likely to act in tandem with a reduction in available habitat to increase stress and subsequent loss of condition. Atlantic salmon are susceptible to poor water quality and particularly dissolved oxygen and water temperature. Water quality impacts have been assessed as minor adverse in Reach 2.

The impact on juvenile Atlantic salmon is therefore considered to be **moderate (uncertain)** in Reach 2.

Brown / Sea Trout

Reach 2 is likely to provide suitable spawning and nursery habitat for brown / sea trout. Reductions in wetted width and depth will reduce the available habitat for brown / sea trout, however, Reach 2 is only 300m in length and is therefore unlikely to provide significant areas of spawning or nursey habitat and the impact magnitude is expected to be low. Furthermore, the high mobility of the species is expected to allow for movement away from the impacted reach during the period in which the drought permit is in operation. Low risks to dissolved oxygen and ammonia deterioration are likely to reduce the suitability of the reach, however, as the risk is low the species are likely to drop out of the Nant Padrig during drought permit implementation and return once natural flows have returned and water chemistry returns to favourable standards. Overall the impacts on this species are assessed as being **moderate (uncertain).**

Bullhead

A healthy population of bullhead is expected within Reach 2 with significant densities found in the Afon Clwyd downstream. Bullhead are a flow sensitive species. Spawning and egg incubation takes place from March to May, outside the drought permit implementation period, however sensitive juvenile lifestages during the summer autumn period may be impacted by te earlier part of the implementation of the drought permit. Therefore as a result of an increase in abstraction due to the drought permit, the reduction in flow of up to 45% is likely to have a significant effect on the bullhead population present in the 300m section of Reach 2. A low risk of deterioration to ammonia and dissolved oxygen may also contribute and reduce the favourability of the reach to the bullhead population. The impact on bullhead is therefore considered to be **moderate (uncertain).**

Lamprey sp.

Reach 2 may provide suitable habitat for juvenile lamprey. There is the potential for reduced flow to result in a decrease in river levels and wetted width. This has particular significance for juvenile (ammocoetes and transformer) lamprey habitat which tends to consist of silt in shallow, marginal areas. There is therefore the potential for a loss or degradation of this habitat. Provided minimum low flows are available, juvenile lamprey are likely to relocate to areas of suitable habitat if river levels decrease, however, competition and stress would likely increase. Lamprey migrate upstream during the autumn for spawning in the following spring once water temperature has risen to a suitable level. Reductions in flows may therefore interact with both of these life stages impairing upstream migration to suitable spawning locations. Low risks to dissolved oxygen and ammonia deterioration are not likely to have a significant effect upon lamprey which are not particularly sensitive to these effects. Overall the impacts on this species are assessed as being **moderate (uncertain).**

European Eel

Elver enter rivers in early spring and a general upstream migration occurs throughout the year. Elver migration is not linked to periods of increased flow and low flow conditions are unlikely to impact migration. The downstream migration of mature (silver) eel tends to occur between September and December in most rivers, however, there is expected to be no significant silver eel run out of Nant Padrig and so no significant impact is expected. European eel of a wide age range are likely to be present in low densities throughout the catchment but the species is tolerant of high temperatures and relatively poor water quality and is considered relatively resilient to drought conditions. The impacts on European eel are therefore considered to be limited to habitat loss within the 300m section of Reach 2. The overall impact is considered to be **negligible** in Reach 2.

Other Fish Species

Minnow and stone loach spawning occurs during spring and summer months, outside the period of implementation of this drought permit. Reductions in wetted width and depth combined with minor risk to deterioration of ammonia and dissolved oxygen are considered to present a **minor (uncertain)** impact to minnow and stone loach in Reach 2.

Summary

The potential impacts of the Llannerch Boreholes drought permit on the fish community are summarised in **Table D2.8**. The impacts, and their magnitude, have been based on the hydrological impacts (see Section 4.2 of the main report), their influence on the physical environment (including geomorphology, water quality and likely habitat availability) (see Section 4.3 of the main report) and the sensitivities of the fish community. The impacts presented in **Table D2.8** represent the worst case impacts of implementing a drought order, over and above the impacts potentially caused by a natural drought.

Table D2.8 Summary of Impacts on Fish Community

Feature	Impact	Significance of Impact
Reach 2 – Nant Padrig		
Atlantic salmon	• Reduced water quality • Reduction in habitat availability and juvenile survival	**Moderate (uncertain)**
Brown / sea trout	• Reduced water quality • Reduction in juvenile survival due to habitat loss.	**Moderate (uncertain)**
Bullhead	• Increase in mortality due to water quality and habitat loss.	**Moderate (uncertain)**
Lamprey sp.	• Loss of juvenile habitat as a result of reduced river levels. • Reduced water quality.	**Moderate (uncertain)**
European eel	• Habitat loss	**Negligible**
Other fish species	• Habitat loss and reduced water quality	**Minor (uncertain)**

There is a risk of short-term deterioration in status of the fish component of the WFD waterbody GB110066059960 (Clywd, Tidal limit to Hesbin) due to the drought permit. Impacts of drought permit implementation on the fish communities of the impacted reaches have been summarised as minor (uncertain) to moderate (uncertain). The impacted reach constitutes a small proportion of the whole extent of the waterbody with impacts being short-term, temporary and reversible. Consequently, the fish component of this waterbody is considered to be at a **negligible** risk of short-term deterioration.

D.2.4 Phytobenthos

D.2.4.1 Baseline

Baseline data has been provided by NRW for the one WFD waterbody within which the impacted reaches for this drought permit are located, GB110066059960 (Clywd, Tidal limit to Hesbin). Within this waterbody one NRW phytobenthos sampling location is provided, the site U/S A55 is located on the Afon Clwyd downstream of Hydrological Reach 1. Spring and autumn survey results are available for this sites from the years, 2010, 2011, 2012 and 2014. No other sampling locations were present within the study reach.

Hydrological impacts, summarised in **Appendix B**, describe negligible impacts from the drought permit on Reaches 1, 3 and 4, with major adverse impacts confined to Reach 2 (Nant Padrig). As no data is available from Reach 2, macroinvertebrate data from the site U/S A55 is utilised to provide an understanding of the macroinvertebrates community we would expect to find in Reach 2. Consideration of the different river characteristics between the Afon Clwyd and Nant Padrig and therefore the phytobenthos communities expected to be present are included.

The Trophic Diatom Index (TDI) describes the nutrient preferences of a phytobenthos community. It ranges from 1 (preference for extremely low nutrient levels) to 100 (preference for extremely high nutrient levels). The data provided were used to calculate TDI3 scores for all available data and TDI4 Scores in 2014, with TDI4 being the most recent version of the index. Percentage Motile Taxa is also provided, this gives the relative proportions of phytobenthos taxa within the community which are motile. When there are high numbers of

motile taxa, this can indicate that light availability is influencing the community, this can be brought about by pressures such as siltation and high covers of filamentous algae.

Table D3.13 DARLEQ Metrics for Phytobenthos data from the Afon Clwyd.

Site	Reach	Sample Date	River TDI3	River TDI4	Motile%
U/S A55	Downstream of Reach 1	15-Mar-10	71.83	60.48	29
		30-Nov-10	72.38	63.29	48
		22-Mar-11	66.53	65	57
		30-Sep-11	64.18	61.84	53
		05-Apr-12	64.42	60.49	59
		07-Sep-12	70.16	66.77	27
		30-Apr-14	61.81	65.04	63
		15-Sep-14	74.87	72.91	54

TDI4 scores, which range from 60.48 to 72.91 at the site U/S A55 suggest relatively high nutrient levels consistent with meso-eutrophic conditions downstream of Reach 1. SRP concentrations in Reach 1 are summarised in **Appendix B** and found to be inconsistent with the standard to support high status for fish and invertebrates. Variable scores for Percentage Motile Taxa indicate pressures such as siltation may be acting upon the community as an intermittent pressure downstream of Reach 1. The community in Nant Padrig is considered to be similar to that found in the site U/S A55 although it is not possible to determine whether failing SRP concentrations will be present in this tributary of Afon Clywd, as such the following assessment takes a precautionary approach in assessing sensitivity of the phytobenthos community to impacts associated with implementation of this drought permit.

D.2.4.2 Assessment

Impacts on the phytobenthos assemblages of Nant Padrig within Reach 2 could occur due to the operation of the drought permit, including changes in community composition due to: decreases in flow; changes to grazing pressure; increases in nutrient level; increases in water temperature; and increases in filamentous algae smothering the substrate. Due to the short lifecycle of algal species, phytobenthos communities can respond rapidly to environmental change and a response in phytobenthos community composition to the reduction in flows due to the drought permit would be expected. However the impacts would be limited to the end of the main growing season.

WFD metrics for phytobenthos (TDI4 in DARLEQ)[11] are designed to detect differences in nutrient levels, particularly SRP. An assessment of the risk to deterioration in SRP has determined that there is a major risk to deterioration in Reach 2. Phytobenthos communities sampled in the autumn may therefore be impacted by drought permit implementation with rapid community composition change favouring species associated with high nutrient

[11] WFD-UKTAG (2014) Phytobenthos: Phytobenthoss for Assessing River and Lake Ecological Quality (River DARLEQ2)

concentrations. Any impact as a result of SRP deterioration is expected to be short lived, with communities recovering rapidly following return to the normal hydrological regime.

The impacts of the drought order on phytobenthos communities are therefore assessed as **minor (uncertain)** during winter. All impacts are deemed short term and reversible.

Summary

The potential impacts of the Llannerch boreholes drought permit on the phytobenthos community are summarised in **Table D2.13**. The impacts, and their magnitude, have been based on the hydrological impacts (see Section 4.2 of the main report), their influence on the physical environment (including geomorphology, water quality and likely habitat availability) (see Section 4.3 of the main report) and the sensitivities of the phytobenthos community. The impacts presented in **Table D2.13** represent the worst case impacts of implementing a drought order, over and above the impacts potentially caused by a natural drought.

Table D2.13 Summary of Impacts on Phytobenthos Community

Feature	Impact	Significance of Impact
Reach 2 – Nant Padrig		
Phytobenthos	• Decrease in flow affecting phytobenthos community composition • Medium risk to SRP affecting phytobenthos community composition and TDI score	Minor

The WFD waterbody which encapsulates Reach 2, GB110066059960 (Clwyd, Tidal Limit to Hesbin) is currently classified as good for phytobenthos. Impacts to the phytobenthos community within this waterbody have been assessed as minor (uncertain) within Reach 2. Effects would be expected to be temporary and reversible following return to a normal hydrological regime. This reach which is 300m in length and located on Nant Padrig, a tributary of the Afon Clywd represents a small proportion the total waterbody. As such implementation of this drought permit poses a **negligible** risk of deterioration in WFD status in relation to phytobenthos for waterbody GB110066059960 (Clwyd, Tidal Limit to Hesbin).