River Marchnant Intake Flow Split Weir

Geomorphology Impact Assessment

North Midland Construction Plc

27 November 2018

Final report

Notice

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This document has 39 pages including the cover.

Document history

Rev	Purpose description	Originated	Checked	Reviewed	Authorised	Date
1.0	Draft for client comment	M Tomlinson L Baker	E McLaughlin	K Skinner	A Lorenz	16/11/18
2.0	Draft for client comment	M Tomlinson L Baker	E McLaughlin	K Skinner	A Lorenz	27/11/18

Client signoff

Client	North Midland Construction Plc
Project	River Marchnant Intake Flow Split Weir
Job number	5168368
Client signature / date	

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Executive Summary

Atkins was commissioned by North Midland Construction plc to develop the design to enable construction of works on two intakes on the Afon Cownwy and River Marchnant. The purpose of the construction works is to provide environmental flow releases below the Cownwy and Marchnant diversion intakes that supply Vyrnwy Reservoir (Llyn Efyrnwy). This report constitutes the geomorphological impact assessment for the River Marchnant only, a separate report for the Afon Cownwy will also be produced.

The report aims to record past and current geomorphological conditions, and to provide a summary of potential impacts and recommendations for future management resulting from the proposed works. The assessment undertook a desk study to examine the surrounding landscape, the geological and topographical character, identify historic and current pressures, including channel change, and to outline the status of the water bodies with reference to the Water Framework Directive (WFD). Consultation with Natural Resources Wales (NRW) was undertaken at an early stage to understand their expectations and to ensure their views were captured in this assessment.

A site walkover was also undertaken along the River Marchnant from just upstream of the weir to the confluence with the River Vyrnwy. The walkover recorded the geomorphological character, including identifying dominant processes of sediment transport (erosion and deposition), and inferring broad patterns of sediment transfer through a fluvial system.

The existing abstraction at the Marchnant intake consists of a diversion weir, which diverts flows via an intake structure directly for transfer to Lake Vyrnwy. The tunnel is estimated to be part-full at 3.5 m^3/s and head losses increase markedly when full, limiting the maximum tunnel capacity to about 4.5 m^3/s once surcharged. There is a 400 mm dia. low level scour outlet at the base of the weir with an upstream valve. However, modelled flow series data indicate it is unlikely that the weir has ever spilled over between 1979 and 2017.

The River Marchnant is not classified as 'Main River'. However, it is situated within the *Vyrnwy - Lake Vyrnwy to conf Afon Cownwy* water body catchment under the Water Framework Directive legislation. The catchment is classified as Moderate Potential status and is heavily modified. The water body is failing to attain Good status due to copper pollution. The water environment in the area has been significantly impact through impoundments and abstraction processes, primarily as a result of the construction of the Vyrnwy Dam in the 1880's.

A walkover was undertaken along the River Marchnant which found a moderately steep, forested upland watercourse with coarse gravel and cobble substrate upstream of the Marchnant weir. Downstream of the weir, the channel is overgrown and ponded. Observed ochre (assumed iron) deposits also suggest poor water quality and potentially contaminated sediments downstream of the weir, although it may also be a build-up of natural substances. Therefore, an assessment of potential contamination is strongly recommended prior to reconnection. However, the channel does begin recover around the village of Abertridwr, with more flow (due to accretion from upstream tributaries) and morphological diversity before it joins with the River Vyrnwy where the potential impacts from the weir are considered to be attenuated.

The proposed scheme intends to amend the existing structure to enable a 25%:75% proportional flow split, including a Q99 hands-off flow (HoF). This will result in 25% of flow being released downstream into the river channel. The restoration of flow resulting from the proposed works is considered to be a significant benefit to the water environment, however there does remain some residual risks that require some mitigation. These include potential for contamination, a lack of well-defined channel downstream and starvation of coarse sediment from upstream.

Further actions and consultation have been recommended, however it is stressed that the proposed works will restore a natural flow regime and therefore morphological conditions to the River Marchnant.

Glossary and abbreviations

Terminology	Abbreviation	Description
Baseline		The existing conditions which form the basis or start point of the environmental assessment.
Bedrock		Hard rock that lies beneath a superficial cover of soils and sediments.
Biodiversity		Biological diversity or species richness of living organisms present in representative communities and populations.
Catchment		The area contributing flow to a point on a drainage system.
Channel morphology		Physical characteristics of stream channels, such as width/depth ratio and sinuosity.
Desk study		Assessment of a site usually preceding ground investigations typically incorporating a review of available site information, consultation with relevant bodies and a site visit.
Ecology		The branch of biology concerned with the relations of organisms to one another and to their physical surroundings.
Exchange		A reach which exhibits both erosion and deposition processes in similar measures.
Flow Duration Curve	FDC	A flow duration curve shows the percentage of time flow in a stream is likely to equal or exceed a specified value of interest.
Fluvial geomorphology		The study of landforms associated with river channels and the sediment processes which form them.
Geomorphology		The branch of geology concerned with the structure, origin and development of topographical features of the earth's crust.
Habitat		Refers to the place in which a species lives, but also used to describe plant communities or agglomerations of plant communities, as used, for example in a Phase 1 Habitat Survey.
Hydromorphology		A term largely created for the Water Framework Directive comprising a blend of hydrology and geomorphology.
Landscape		Human perception of the land, conditioned by knowledge and identity with a place.
Lateral adjustment		Adjustment of the bank line (through erosion and deposition) leading to changes in planform i.e. sinuosity.
Main River (water body)		Designated under the WFD and visible on 1:50k OS maps.
Minor watercourse		Not shown on 1:50k OS maps.
Mitigation		Term used to indicate avoidance, remediation or alleviation of adverse impacts.
National Grid Reference	NGR	Map reference system used by the Ordnance Survey to identify the geographical position of any feature.

Natural Resources Wales	NRW	Principal adviser and regulator for the Welsh Government, and adviser to industry and the wider public and voluntary sector, and communicator about issues relating to the environment and its natural resources.
Ordnance Survey	OS	Mapping provider.
Planform		Channel shape and composition as viewed from above.
Pool and riffle sequence		In a flowing stream a riffle-pool sequence develops as an area of alternating areas of relatively shallow and deeper water. Riffles describe shallow water where the flow is rippling over gravel deposits whereas pools are deeper and calmer areas.
Residual impacts		Residual impact means the environmental impact after the provision of mitigation measures, if any.
River Basin Management Plan	RBMP	A plan setting out actions required within a river basin to achieve environmental quality objectives, reviewed on a six-yearly basis.
Runoff		Water that flows over the ground surface to the drainage system. This occurs if the ground is impermeable or if permeable ground is saturated.
Sink		Sediment input to the reach is greater than sediment output to the next reach downstream.
Site of Special Scientific Interest	SSSI	A conservation designation denoting a protected area in the United Kingdom.
Special Protection Area	SPA	A conservation designation denoting a protected area in the United Kingdom a designation under the European Union Directive on the Conservation of Wild Birds.
Source		Sediment output from the reach is greater than sediment supply from upstream.
Transfer		Sediment output is approx. equal to input from upstream, sediment is transmitted through the reach.
Water Body		A body of surface water, or a body of groundwater. The WFD defines discrete surface water bodies, but not necessarily a whole river, while groundwater bodies should be distinct.
Water Framework Directive	WFD	Wide-ranging European environmental legislation (2000/60/EC). Addresses inland surface waters, estuarine and coastal waters and groundwater. The fundamental objective of the WFD is to maintain "high status" of waters where it exists, preventing any deterioration in the existing status of waters and achieving at least "good status" in relation to all waters by 2015.
Water quality		The chemical and biological status of various parameters within the water column and their interactions, for example dissolved oxygen, indicator metals such as dissolved copper, or suspended solids (the movement of which is determined by hydrological process and forms geomorphological landforms).

1. Introduction

1.1. Background

Atkins was commissioned by North Midland Construction Plc to develop the design to enable construction of works on two intakes along the Afon Cownwy and River Marchnant. The purpose of the construction works is to provide environmental flow releases below the Cownwy and Marchnant diversion intakes that supply Vyrnwy Reservoir (Llyn Efyrnwy).

This report constitutes the geomorphological impact assessment for the River Marchnant only.

1.2. Aims and objectives

The aim of this report is to document the methodology, past and current geomorphological conditions and provide a summary of potential impacts and recommendations for future management resulting from the proposed works.

The objectives of the report are:

- **The baseline**: Summarise the existing geomorphological processes within the study area to understand the sediment dynamics and identify receptors likely to be affected by the proposed works.
- **The future**: Understand and anticipate future sediment issues resulting from the proposed works.
- **Evaluate risk**: Evaluate the potential implications on the downstream receptors from an increase in sediment supply, in particular, on the chemical status.
- **The next steps**: Provide recommendations future management and identify any further assessment required (as necessary):
    - Provide a sediment management plan; and,
    - Identify opportunities for river restoration downstream of the weir structure

1.3. Assessment methodology

1.3.1. Data sources

The following data was used as part of the survey:

- Ordnance Survey (OS) OpenData
- Historical aerial imagery using Google Earth ® Pro
- Historical mapping using online mapping sources, such as National Library of Scotland (NLS, 2018)
- Environment Agency’s Catchment Data Explorer (Environment Agency, 2018)
- National River Flow Archives (NRFA) published by the Centre for Ecology and Hydrology (CEH, 2018)
- MAGIC Map (DEFRA, 2018)
- British Geological Society GIS shapefiles/online mapping outlining the geological profiles around the site (BGS, 2018)
- Relevant reports, designs and investigations

1.3.2. Geomorphological Assessment

Fluvial geomorphology is the study of the processes, forms and dynamics of river channels and their catchments. Geomorphological assessments can provide a cost-effective and sustainable approach to managing the water environment. A Rapid Geomorphological Assessment (RGA) is considered a pragmatic, targeted assessment of a specific sediment-related issue in a river catchment. It is used to provide a solution-focused understanding of fluvial geomorphology at the reach scale or to assess the need for a more detailed investigation.

It is important to note that the approach is qualitative only. It does not consider quantitative data relating to flow or suspended sediment. It is based on best professional judgement of the evidence derived from the methodology as outlined above and on the day of assessment.

The RGA comprises an integrated approach including a site walkover and desk study. The approach for this study is described below.

Desk study and consultation

A desk study was undertaken to understand the surrounding landscape, geological and topographical character, to identify historic and current pressures, including channel change, and to outline the status of the water bodies with reference to the Water Framework Directive (WFD).

Consultation with the regulator, in this case Natural Resources Wales (NRW), was undertaken at an early stage to understand their expectations and ensure their views were addressed.

Site walkover

The site walkover broadly aims to identify dominant processes of sediment transport (erosion and deposition) which are inferred from field observations and supported by the desk study findings. These observations are consolidated and divided into geomorphologically homogenous reaches (typically restricted to short lengths, i.e. <1km), which help identify broad patterns of sediment movement through a fluvial system. The reaches are categorised into four primary sedimentary function types: source, sink, exchange and transfer, further described in Table 1-1 below.

Table 1-1 – Reach categories

Classification type	Description
Source	Sediment output from the reach is greater than sediment supply from upstream
Sink	Sediment input to the reach is greater than sediment output to the next reach downstream
Transfer	Sediment output is approx. equal to input from upstream. Sediment is transmitted through the reach, which features few sites of active erosion, or deposition either because the channel is adjusted and naturally stable or because the bed and banks have been stabilised artificially
Exchange	Sediment output is approx. equal to input from upstream (as for a transfer reach), but incoming sediment is exchanged with that derived within the reach, featuring active erosion and depositional sites

Adapted from Skinner and Thorne (2005)

In this study reach names are prefixed with the first three letters of the river (e.g. River Marchnant is *MAR*), followed by a three-digit number, e.g. *MAR001*. The survey started from upstream to downstream, with inaccessible reaches identified where relevant.

The site walkover was undertaken using ESRI's ArcCollector application (App) hosted on two iPad Mini's. Atkins have created bespoke shapefiles to collect the reach summary information. The iPads also allow a series of geo-referenced photographs to be collected throughout the survey as a record of the conditions and features.

1.3.3. Survey extent

The site lies in central Wales, to the east of Snowdonia National Park. The Vyrnwy reservoir lies between the upland area of Rhiwargor and the dam is located at the town of Llanwddyn, 7.2 km downstream. The River Marchnant is a northern tributary of the River Vyrnwy (also called Afon Efyrnwy) with its confluence located downstream of the Vyrnwy dam. The channel naturally flows from the north-east direction, through the town of Abertridwr where it would join the Vyrnwy 2.6 km downstream of the Vyrnwy dam. However, under its current abstraction, the majority of the flow is diverted into the reservoir.

The site walkover covered the main stem of the River Marchnant, from the confluence with the incoming tributary 200 m upstream of the weir at Ty Cerrig, to its confluence with the River Vyrnwy at Abertridwr, approximately 1.85 km in total. Some areas immediately downstream of the weir were inaccessible due to dense vegetation and steep/unsteady (and therefore unsafe) ground conditions.

Spot checks upstream of the proposed works and downstream along the River Vyrnwy were also undertaken where accessible.

The walkover extent is shown on Figure 1-1.

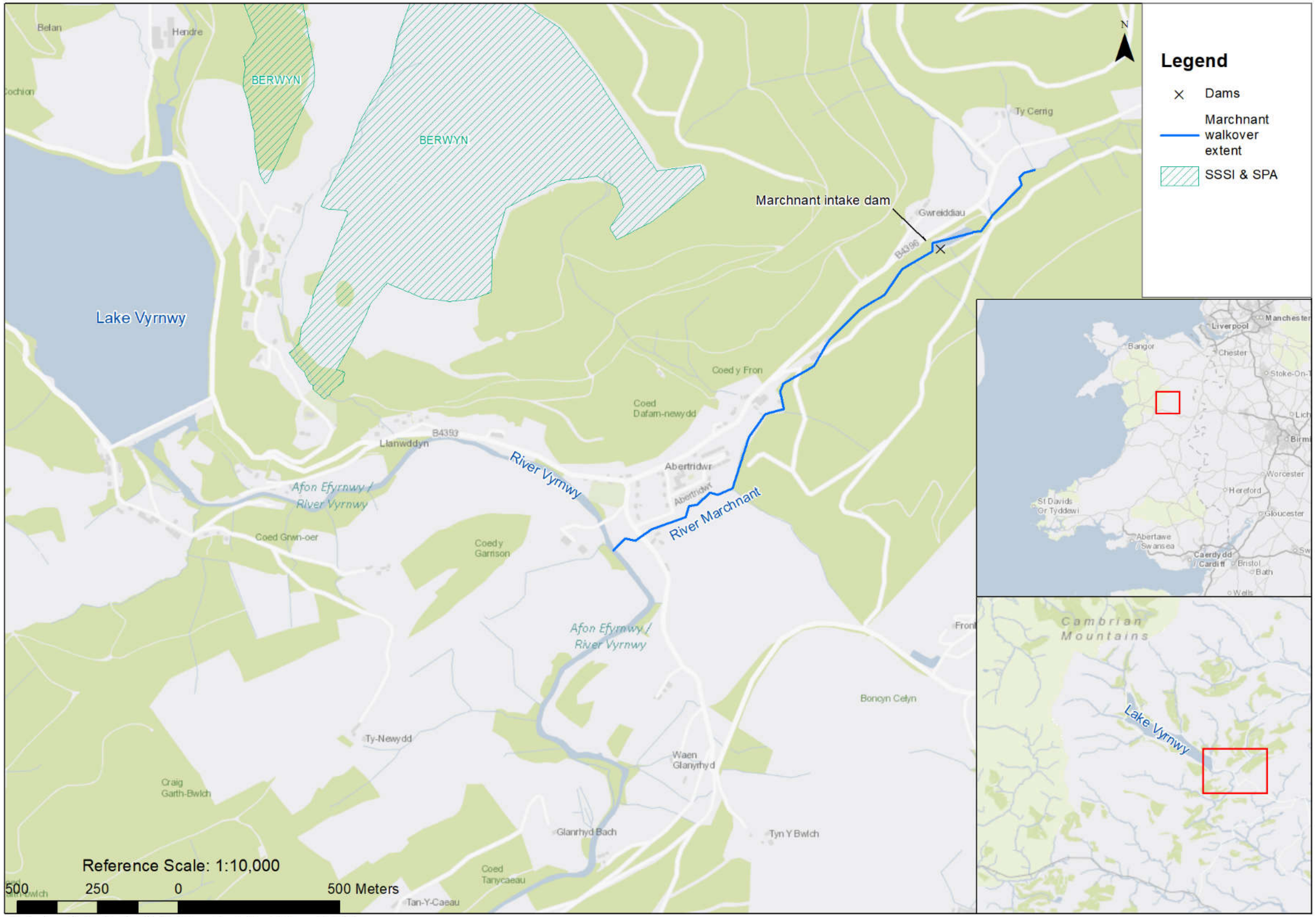

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Figure 1-1 – Afon Marchnant walkover extent

2. Baseline conditions

2.1. Overview

This section provides includes:

- **The baseline**: Summarise the existing geomorphological processes within the study area to understand the sediment dynamics and identify receptors likely to be affected by the proposed works.

2.2. Existing abstraction operation

In the late 1870's, a new reservoir was needed to provide water to the city of Liverpool due to the expanding population. This led to the construction of the Vyrnwy Reservoir in 1880. At the time it was the first masonry dam and largest reservoir in Europe. The foundations of the dam were constructed on a large rock bed, 2 miles downstream of the now submerged town of Llanwddyn. The construction of the dam and the closure of the valves were completed in 1888 and the reservoir filled within a year.

As part of this development two intakes were constructed on the Afon Cownwy (inflow to the south) and the River Marchant (inflow from the north) to direct flow into the reservoir. The Marchnant intake consists of a weir located on the Afon Marchnant (NGR: SJ 0420 1979), which diverts flows via an intake structure directly into a 2.2 km long diversion tunnel for transfer to Lake Vyrnwy. The intake is shown in Figure 2-1 below.

Figure 2-1 – Intake on the River Marchnant (Source: North Midlands Construction 31/10/18)

The tunnel is 2.1m in diameter and brick lined, running at a slope of approximately 0.0007 m/m. The tunnel is estimated to be part-full at 3.5 m^3/s and head losses increase markedly when full, this limits the maximum tunnel capacity to about 4.5 m^3/s once surcharged (Jacobs, 2017).

There is a 400 mm dia. low level scour outlet at the base of the weir with an upstream valve. However, modelled flow series data covering the period between 1979 and 2017, indicate it is unlikely that the weir has rarely ever spilled between.

2.3. Desk study

2.3.1. Topography

The site lies within the foothills of the Cambrian Mountains south east of Snowdonia National Park. The Marchnant catchment is surrounded by well forested rolling hills, a wide valley and gentle valley sides. The upstream section of the catchment is occupied by wide flood plain and agricultural land which quickly becomes more constrained and taken over by large wooded areas. The gradient of the Marchnant is averaged at 0.02. The topography of the River Marchnant catchment looking upstream from the River Vyrnwy is shown in Figure 2-2.

Figure 2-2 – Drone image of catchment (Source: North Midlands Construction 31/10/18)

2.3.2. Background geology

The geology of the area is shown in Figure 2-3. The Marchnant consists of mainly sedimentary bedrock containing Mudstone, Siltstone and Sandstone formed approximately 444 to 461 million years ago in the Ordovician Period (BGS, 2018).

Superficial deposits in the area consist of Clay, Silt, Sand and Gravel formed up to 3 million years ago in the Quaternary Period through Glacial mechanisms. (BGS, 2018).

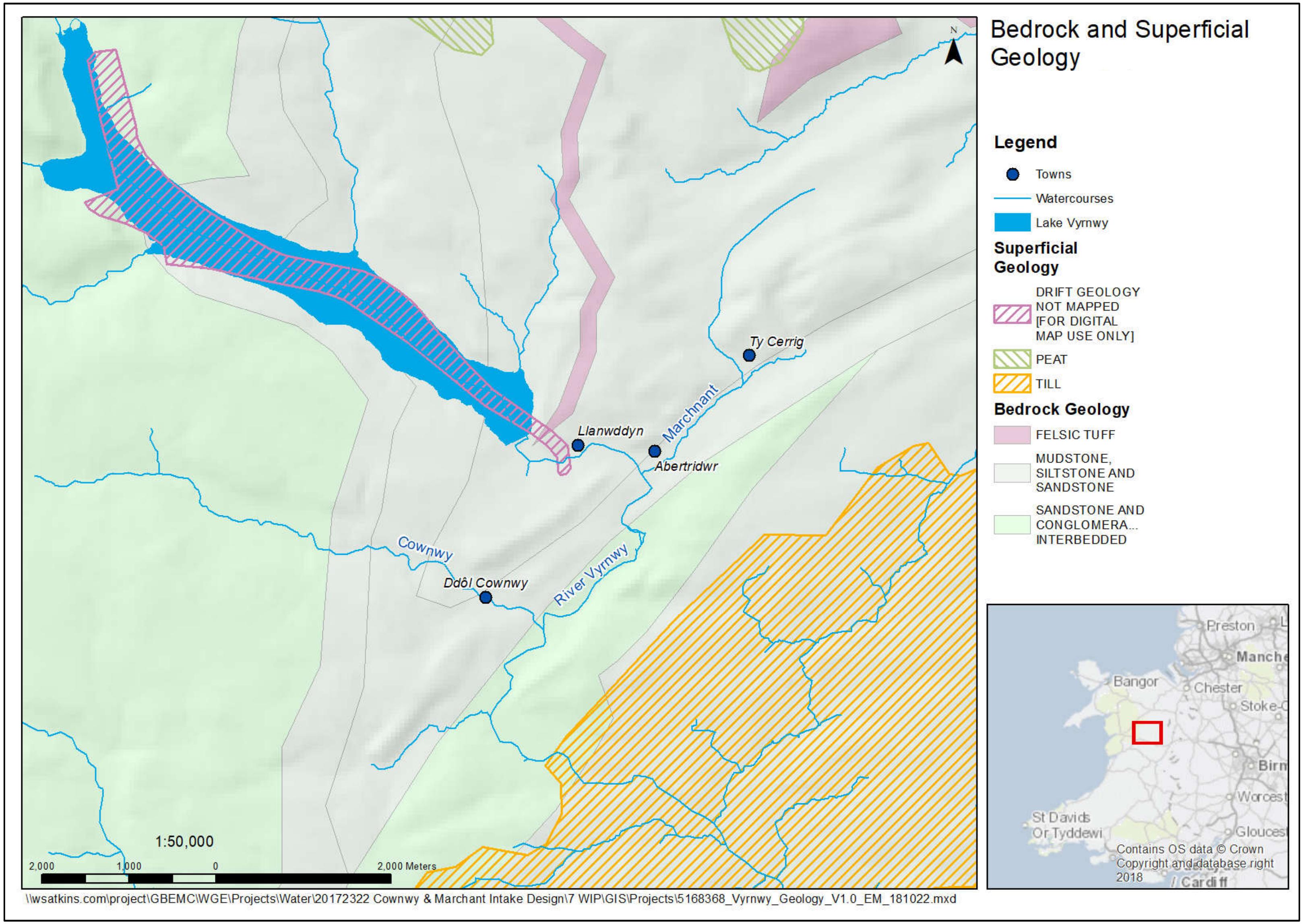

Figure 2-3 – Bedrock and superficial geology

2.3.3. Hydrology

As stated in Section 2.2, the 2017 Jacobs report indicated that the Marchnant weir had not spilled (Jacobs, 2017), at least not between 1979 and 2017 and this is supported by the mean daily Flow Duration Curve (FDC) as shown in Figure 2-4 below. The tunnel is part-full at 3.5 m^3/s before it begins surcharging, the FDC shows the most infrequent flows <2.0 m^3/s. However, please note this FDC was based on limited flow data from gauged flows for the diversion channel from 2013 to 2017. An extended inflow series (1979 to 2017) was generated based the correlation with daily mean flows for Cownwy.

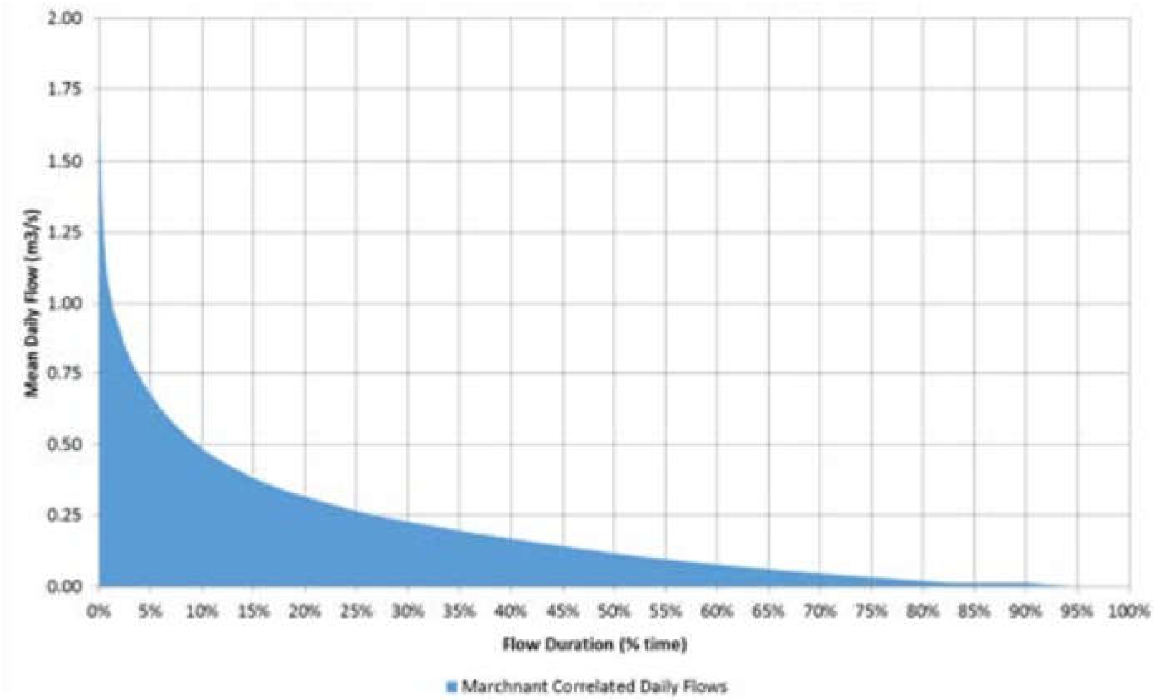

Figure 2-4 – Marchnant Mean Daily Flow Duration Curve (Jacobs, 2017)

No flood flows are available for the Marchnant, therefore these have been estimated based on a flow correlation with the Cownwy catchment. The estimated flood flows are shown in Table 2-1, and indicate that there is potential for the weir to spill during a 1 in 10-year return period.

Table 2-1 – Estimated Marchnant flood flows

Flood Return Period (Years)	Marchnant Flood Flows	
	Ml/d	M^3/s
1:10	715	8.3
1:30	920	10.7
1:50	1,037	12.0
1:75	1,146	13.3
1:100	1,229	14.2

Source: Jacobs (2017)

2.3.4. Environmental designated sites

The existing impoundment on the River Marchnant is approximately 1 km east of the Berwyn Special Protection Area (SPA) and Berwyn Site of Special Scientific Interest (SSSI). As the sites are situated upstream of the watercourse they are unlikely to be affected by the proposed works.

There are also a number of listed buildings in the vicinity of the works, although again most are situated upstream on the Vyrnwy, with the exception of the primary school in Abertridwr (Ysgol Efyrnwy). This is set back from the river and unlikely to be affected by the proposals.

2.3.5. Water Framework Directive (WFD) status

Detailed information on WFD water body classifications are provided in Appendix A.

2.3.5.1. Surface Water Bodies

The River Marchnant is not classified as a Main River. It is part of the *Vyrnwy - Lake Vyrnwy to conf Afon Cownwy* water body catchment (GB109054049880). The catchment is classified as Moderate Potential status and is heavily modified. The primary reason for the water body not achieving Good status is due to ecological elements. The proposed alteration of flow in the Marchnant channel has potential impacts on downstream water bodies. This includes the *Vyrnwy from the Afron Conwy to the Afon Banwy* (GB109054049720).

Table 2-2 summarises the status of all water bodies within the vicinity of the works along with Reasons for Not Achieving Good (RNAG) status.

Table 2-2 – WFD classification for Vyrnwy Catchment

Water body name (water body ID)	Overall water body status (2015 Cycle 2)	Reasons for not attaining good (RNAG) status	Objective*
Vyrnwy - Lake Vyrnwy to conf Afon Cownwy (GB109054049880)	Moderate Potential	Specific Pollutants (Moderate) • Copper	Good Potential by 2021
Afon Vyrnwy - conf Afon Cownwy to conf Afon Banwy (GB109054049720)	Moderate Potential	Specific Pollutants (Moderate) • Copper	Good Potential by 2021

Objectives as published on Catchment Explorer (http://environment.data.gov.uk/catchment-planning)

The copper pollution is the primary RNAG and is under investigation within the area. The objective (as listed in the Catchment Explorer) is to attain Good Potential by 2021.

2.3.5.2. Groundwater bodies

The site lies within the *Severn Uplands - Lower Palaeozoic* groundwater body (GB40902G205300) which currently is classified as Poor status. This groundwater body covers nitrate vulnerable zones and drinking water protected areas.

Table 2-3 – Groundwater WFD classification

Water body name (water body ID)	Overall water body status (2015 Cycle 2)	Reasons for not attaining good (RNAG) status	Objective*
Severn Uplands - Lower Palaeozoic (GB40902G205300)	Poor	Chemical Status (Poor) • Chemical dependant surface water body status	Poor by 2015

Objectives as published on Catchment Explorer (http://environment.data.gov.uk/catchment-planning)

The only RNAG for this groundwater body is due to surface water body dependency's. This is currently under investigation with no known cause. The objective (as listed in the Catchment Explorer) is to maintain Poor status by 2015. This is due to having no known technical solution.

2.3.6. Historical channel analysis

Channel modification and management

Lake Vyrnwy Dam was constructed between 1880 and 1888 along with a smaller weir along the Marchnant channel. There have been minor alterations to the Marchnant channel between the construction of the Vyrnwy dam and present day. This includes the construction of two bridges upstream of the Marchnant weir. The channel has also been culverted around the saw mill just upstream of the town of Abertridwr. There are several fords and weirs listed in OS mapping between 1888-1913 (NLS, 2018) and more broadly the surrounding landscape has been affected by forestry practices and channel straightening.

Natural channel adjustment

Since 1888, the Marchnant channel appears to have migrated slightly in certain locations, but this is limited. The planform downstream around Abertridwr does appear to show some (albeit limited) signs of a bifurcating, braided channel planform with island clearly illustrated and some slight shift in the course suggesting some minor lateral adjustment (or realignment).

Generally, the channel is constrained by the surrounding topography and there are few signs of natural channel change along its course.

3. Field Results

The site walkover was undertaken on the 25th and 26th October 2018 by a team of experienced fluvial geomorphologists. The weather was dry during the survey and flow conditions were considered low to moderate.

The river was separated into five reaches and these are shown on Figure 3-1, which also shows the inaccessible length of river. The sediment dynamics and geomorphological characteristics observed during the walkover are summarised in Table 3-1.

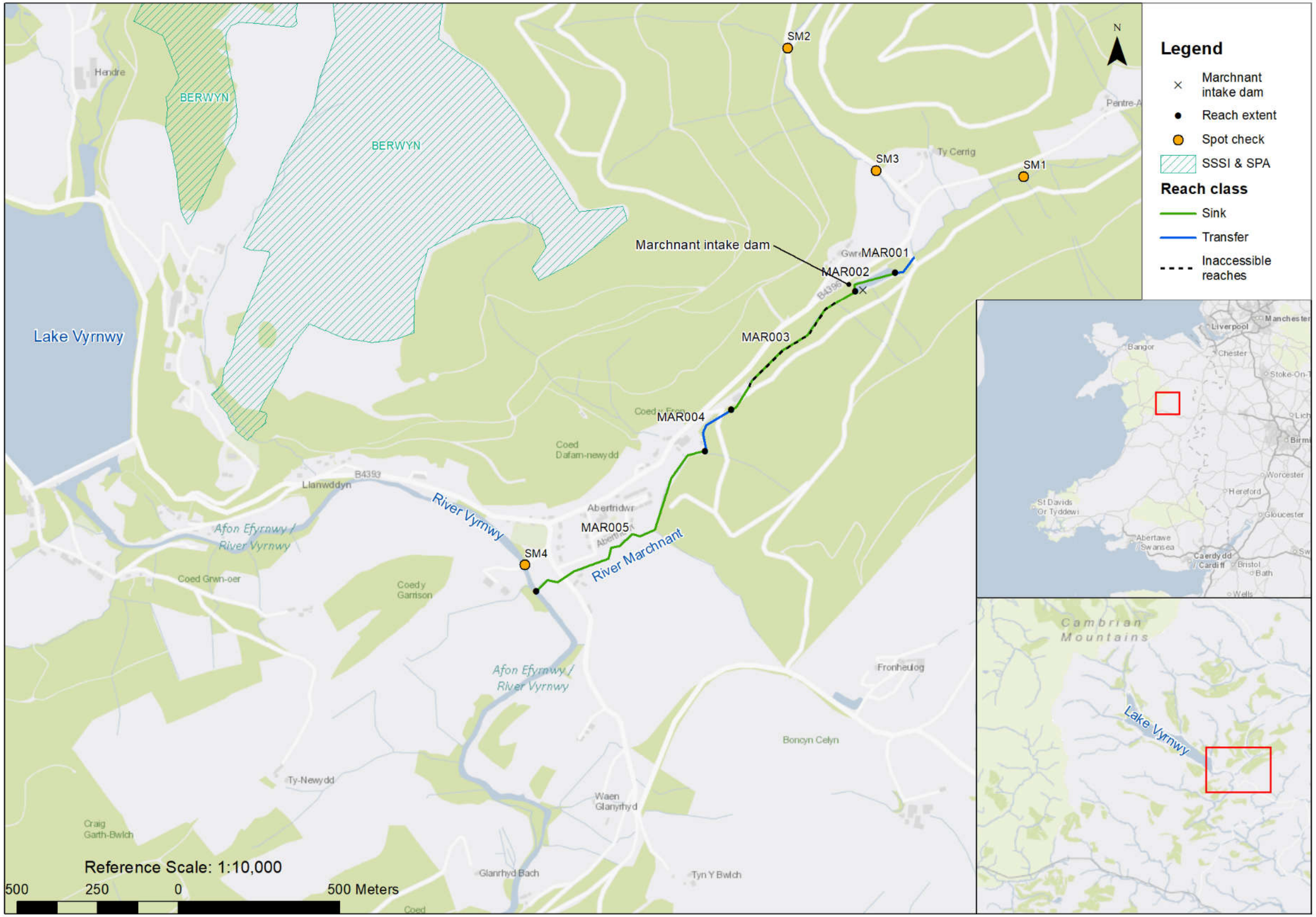

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Figure 3-1 – River Marchnant geomorphological reaches

Table 3-1 – Geomorphological summary – River Marchnant

River Marchnant		Reaches: MAR001 to MAR005	
Reach types – total number: 5			
Source: 0	**Sink**: 3	**Exchange**: 0	**Transfer**: 2

As described above in Section 2.3.1, the river is initially situated within a naturally constrained, steep-sided valley, with limited floodplain either side. Further downstream, around the village of Abertridwr, the topography broadens and the valley widens, with a floodplain developing off of the left-hand bank, albeit quite limited. The planform too was constrained by the topography and moderately steep gradient, and generally follows a straightened course. As the gradient lowers through reach MAR005 into the village, and with the presence of a floodplain, the channel develops a more sinuous planform.

The upper reaches were surrounded by plantation forestry, some of which had been clear felled, particularly downstream of the weir. In this vicinity, the hillside was densely vegetated by thick scrub, rushes, ferns, bramble and grasses, as well as emerging young trees. Because of this, access was restricted for much of the reach downstream of the weir to the saw mill (MAR003).

The channel upstream of the weir is constrained by the B4396 on the right-hand bank and crossed several times. The road generally follows the channel, but at a farther distance until Abertridwr. The channel was culverted around the saw mill upstream of the village (MAR004, SJ 0369 1932). The channel downstream was far more affected by housing, agriculture (pasture land) and several roads.

The cross-section along much of the upper reaches was primarily trapezoidal (approximately around 1.0-1.5 m in width) due to the surrounding constraints and lack of floodplain. However, there were some localised sections where low level berms and gravel bars form leading towards the weir pool. The substrate comprised coarse gravels and cobbles forming riffle and run sequences (see ATT6_Photo1), which in turn create diverse flow types. As the watercourse nears the weir pool upstream of the weir (MAR001) gravel deposition increased as energy reduces and a large spit formed at the entrance to the weir pool. However, for the most part the upper reaches are primarily transfer reaches.

ATT6_Photo1 – upstream of impoundment, diverse flow over coarse substrate (MAR001).

ATT8_Photo2 – a view of the Marchnant weir, tunnel intake and weir pool (MAR002).

DJI_0252-HDR – Drone image taken looking upstream showing the stagnant channel immediately downstream, the weir structure and the weir pool (MAR002 and MAR003) (Source: North Midlands Construction 31/10/18).

Downstream of the weir through reach MAR003 (see Figure 2-2), and despite limited access, it was difficult to identify a defined channel. There was no flowing water at the time of the survey, and by all accounts the Marchnant does not spill often, except during significant flood events (see Section 2.2). The water that was present suggested good groundwater connection, but was ponded and accumulating some localised ochre coloured deposits (assumed to be iron, although the water body is also known to be failing due to copper pollution, see Section 2.3.5), as well as algae and other organic matter (ATT14_Photo1). The bed was not visible, although some gravels were noted along the shallower margins. The channel here was devoid of any morphological form and was densely overgrown, and (along with weir pool, MAR002) was classified as a sink. Observations from a separate aquatic ecology survey suggested a slightly more defined and flowing channel (albeit no more than 1.0 m wide) did form 100-150 m downstream of the weir, and the substrate comprised primarily silt, with large amounts of woody material present too.

Downstream of the culverted section leading into the village (MAR004) the channel recovered some flow. The channel here was much narrower than observed upstream of the weir, approximately 1.0 m wide, but possess similar diversity in flows, with coarse gravel/cobble substrate, but overall quite limited in morphological diversity and therefore classified as a transfer.

As the woodland is replaced by pasture, the channel gradually developed an asymmetrical, two-stage cross-section, with frequent gravel bars through MAR005 (ATT28_Photo2). Riffles and pools create diverse flows, with a noticeable increase in fine sediment overlaying the coarse substrate in the pools and other areas of slacker flow. There were some signs of potential previous scour indicating potential for lateral adjustment (supported by the historical mapping, see Section 2.3.6). However, these features appear to be relic and no longer active. The channel was generally considered relatively stable. That said, the reach was classified as a sink due to the gravel deposits.

As the Marchnant joins the River Vyrnwy it is evident that any potential impact from the proposed works will not extend beyond the confluence. The Vyrnwy is significantly larger in size (and therefore flow), being approximately 15-30 m in width (ATT34_Photo2).

River Marchnant	Reaches: MAR001 to MAR005
	
ATT14_Photo1 – View downstream of weir showing stagnant, ponded water (MAR003).	**ATT27_Photo1** – Downstream view along reach through village of Abertridwr (MAR005).
	
ATT29_Photo2 – Flows recover downstream of the culverted section through the village of Abertridwr. Increase gravel deposits and an open, wider floodplain (MAR005).	**ATT34_Photo2** – River Vyrnwy close to the confluence with the River Marchnant, and much wider than the Marchnant.

A photographic library has been supplied separately in Appendix B.

4. Summary and recommendations

4.1. Overview

This section analyses the outcome of the desk study and site walkover to assess the existing patterns and examine the following:

- **The future**: Understand and anticipate future sediment issues resulting from the proposed works.
- **Evaluate risk**: Evaluate the potential implications on the downstream receptors from an increase in sediment supply, in particular, on the chemical status.

4.2. Proposed scheme

4.2.1. Amended weir structure

The proposed scheme intends to amend the existing structure to enable a 25%:75% proportional flow split. A Q99 hands-off flow (HoF) has also been agreed equating to 0.664 Ml/d (0.01 m^3/s). Therefore 75% of the incoming flow in excess of the Q99 HoF will continue to be abstracted, with the remaining 25% released downstream into the river channel. Along with similar proposed works at the Afon Cownwy intake, this equates to an estimated yield reduction for the Vyrnwy Reservoir of approximately 7 Ml/d, which represents 3.6% of Lake Vyrnwy's current total deployable output of 197 Ml/d or 23% of the incremental yield of the existing diversions (for the Marchnant and the Cownwy).

A representative schematic of the proposed works to the weir is shown in Figure 4-1 and a photographic illustration in Figure 4-2. The schematics show a new 'weir splitter structure' installed in front of the current intake and a concrete diversion channel replacing the existing spillway, with scour protection proposed at the downstream end. The existing 400 mm scour pipe would be retained.

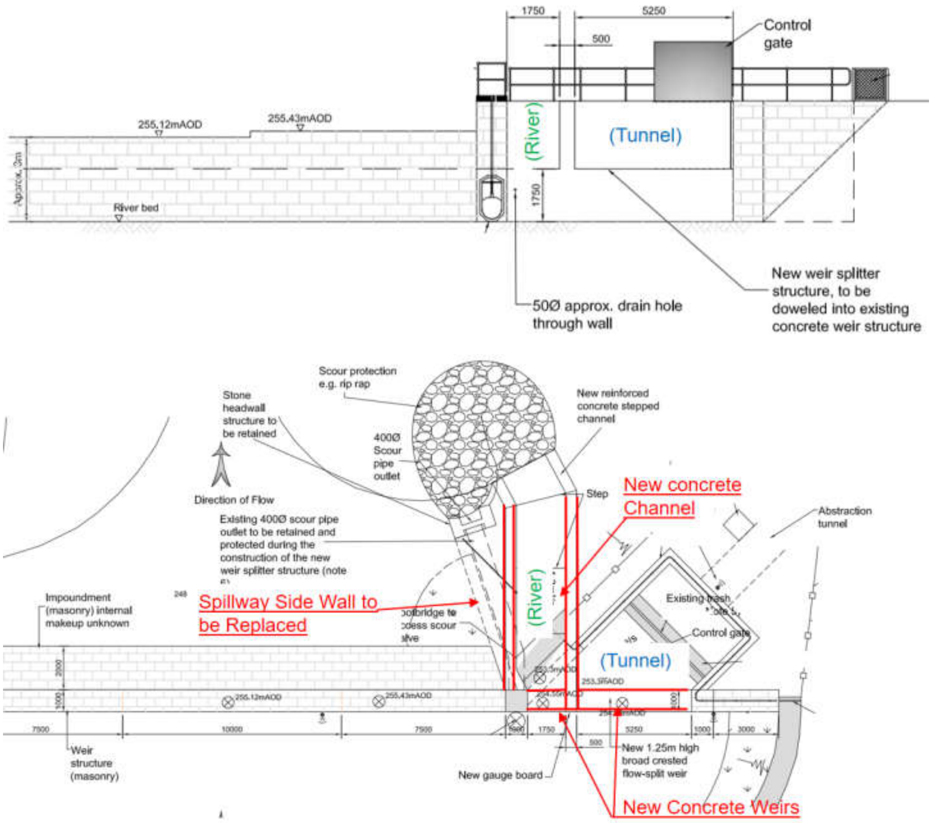

Figure 4-1 – Proposed solution (top) schematic (bottom) photographic illustration

Figure 4-2 – Photographic illustration of Marchnant intake structure

4.2.2. Proposed changes to downstream flow conditions

The downstream channel currently did not appear to receive any spill over from the weir except during high flow events, 1:10 year events and above (see Section 2.2). The channel will now receive a Q99 HoF as a minimum, but also 25% of all incoming flows, including low flows and flood events resulting in more natural flow variation. This will be a significant increase in flows compared to existing environment.

4.3. Summary of impacts

The restoration of flow to the River Marchnant, albeit still only partial restoration, can only be viewed as a significant benefit to the downstream water environment. The observed channel conditions downstream of the weir, as explained in Section 3, suffers greatly from a lack of flow resulting in a stagnant and ponded environment, with an ill-defined and overgrown channel. This has encouraged a higher than expected accumulation of fine sediment and organic matter, culminating in what is assumed to be potentially poor water quality and diverging aquatic conditions away from fluvial to pond and wetland habitats. The diversity of the aquatic species is also likely to be affected (please note a separate aquatic ecological assessment has been undertaken).

The extent of the abstraction impact downstream is uncertain as access along the channel was not possible due to the unsafe ground conditions and dense vegetation. There is a tributary that enters approximately 100 m downstream from the left-hand bank with some limited flow input (see Figure 4-3) and other observations from an ecological walkover support a channel beginning to form around this location. Given the relative size of the River Vyrnwy it is considered the overall extent of impact from the proposed works would not extend beyond the confluence with the River Marchnant.

In the long-term the increase in flow will certainly restore some of the aquatic flow conditions which have been lost for over 100 years, and more importantly restore a natural variation in the flows which are important to maintain a diverse and functional fluvial system.

The observations during the site visit and the historic map analysis showed the downstream reaches have the potential for lateral adjustment, albeit minimal, and there are several gravel deposits situated through Abertridwr. These are unlikely to be mobilised during the current scenario except during flood events. With the increased (restored) flows there is greater potential for this gravel to be mobilised, and although some fine and coarse gravel material is provided by tributaries joining just upstream of the village, there is likely to be a shortfall in supply caused by the upstream impoundments, including the culverted section through the saw mill. However, with that said, it is considered unlikely that there will be any significant bank or bed erosion, and therefore lateral adjustment, in the downstream reaches.

However, in the short-term without any intervention, the accumulated and potentially contaminated organic material immediately downstream of the weir would likely be mobilised resulting in potential pollution impacts further downstream. It would also take time for a defined channel to establish given how overgrown the channel was. This would still likely be a short-term impact and reliant on higher flows to flush the organic material through.

Figure 4-3 – Photographs of incoming tributaries
Left: approximately 100 m downstream of weir entering from left-hand bank (ATT16_Photo1)
Right: situated slightly upstream of Abertridwr entering from left-hand bank (ATT21_Photo1)

5. Recommendations

5.1. Overview

Based on the risk assessment and reach categorisation this section will look at the potential options for future planning, including:

- **The next steps**: Provide recommendations for future management and identify any further assessment required (as necessary)

5.2. Recommendations

Whilst the overall proposed works are considered a significant benefit, there remains some residual risks as outlined above in Section 4.3.

The observed ochre deposits suggest poor water quality and potentially contaminated sediments downstream of the weir. Therefore, an assessment of potential contamination is strongly recommended prior to reconnection.

The form of the 'natural channel' does not appear to have been considered as part of the design, except for the inclusion of scour protection downstream of the diversion channel. As part of the works the downstream channel should be cleared of vegetation (and contaminated sediment as necessary) to enable a free-flowing channel upon reconnection. Potential for importation of the substrate to form the bed should be considered depending on the extent of any removal (if any, depending on contamination). This is recommended to extend at least as far as the nearest incoming tributary, approximately 100 m downstream.

Following consultation with NRW, consideration of a sediment management plan was requested. The increase in flow will provide additional suspended/finer sediments, however the coarser sediment is likely to drop out into the weir pool as is the case in the current scenario (see Figure 5-

1). Therefore, there is still potential for the channel to be starved of coarse sediment with an increased likelihood of mobilisation due to higher flows downstream.

Figure 5-1 – Photograph of accumulating coarse sediment within the weir pool

The establishment of a sediment management plan is currently outside the scope of this assessment. However, consultation with Severn Trent Water and NRW should be undertaken to ascertain the extent of the continued maintenance commitments. This could include the periodic translocation of coarse sediments from the weir pool downstream along the Marchnant, enabling the natural redistribution of the coarse sediment. The regularity of the sediment translocations may depend on the rate of deposition in the weir pool and extent of sediment being mobilised downstream. Therefore, a monitoring plan is recommended during the first 1 to 3 years following the establishment of the works, using fixed-point photography and potentially bathymetry to measure the rate of deposition within the weir pool. The rate of sediment transport is dependent on the types of flows experienced, in particular high flows events. Therefore, any observations during the monitoring should also take into account the preceding flow conditions.

5.3. Next steps

The potential impacts and recommendations should be embedded within the proposed design. Consultation with Severn Trent Water and NRW should be undertaken on the conclusions of this assessment and appropriate actions agreed, including consideration of the following:

- Contamination assessment of downstream reaches;
- Restoration of the channel downstream;
- Future monitoring and establishment of a sediment management plan.

6. Conclusion

This report has undertaken a baseline assessment of the River Marchnant and considered the potential impacts from the proposed reinstatement of flow to the river. The proposed works will release 25% of the incoming flow to the downstream watercourse, which in the current scenario does not receive any water except during high flow conditions. The remaining 75% above a Q99 HoF will continue to be abstracted.

Under the Water Framework Directive (WFD) the River Marchnant is not classified as a Main River. However, it situated within the *Vyrnwy - Lake Vyrnwy to conf Afon Cownwy* water body catchment. The catchment is classified as Moderate Potential status and is heavily modified. The water body is failing to attain Good status due to copper pollution.

The water environment in the area has been significantly impacted through impoundments and abstraction processes, primarily as a result of the construction of the Vyrnwy Dam in the 1880's.

A walkover was undertaken along the River Marchnant which found a moderately steep, forested upland watercourse with coarse gravel and cobble substrate upstream of the Marchnant weir. Downstream of the weir, the channel is overgrown, ponded and accumulating potentially contaminated sediment. However, the channel does recover downstream, especially around the village of Abertridwr. There is more flow and morphological diversity apparent before the confluence with the River Vyrnwy, where the potential impacts from the weir are assumed to be attenuation.

The restoration of flow resulting from the proposed works would have a significant benefit to the water environment, however there does remain some residual risks that require some mitigation. These include potential for contamination, a lack of well-defined channel downstream and starvation of coarse sediment from upstream.

Further actions and consultation have been recommended, however it is stressed that the proposed works will restore a more natural flow regime and therefore improve morphological conditions to the River Marchnant.

7. References

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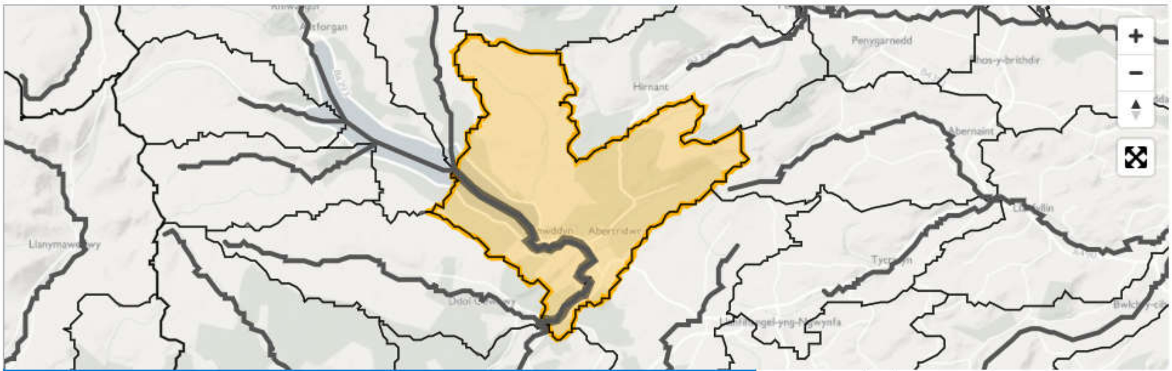
Appendices

Appendix A. Water Framework Directive

The following appendix provides screenshots of the water body status information as provided on the Environment Agency's Catchment Data Explorer (Environment Agency, 2018).

A.1. Vrynwy – Lake Vyrnwy to Conf Afon Cownwy

Table A-1 – Vrynwy – Lake Vyrnwy to Conf Afon Cownwy water body information



Vrynwy - Lake Vrynwy to conf Afon Cownwy

Download Water Body as CSV / GeoJSON

Overall classification for 2015
Moderate

Overview

Id	GB109054049880
Type	River
Hydromorphological designation	heavily modified
NGR	SJ0259119171
Catchment area	2602.56 ha
Length	7.439 km
Surveillance Water Body	No
Catchment area	26.026 km2

Cont…

Classifications

Cycle 2 classifications

Download as CSV

Classification Item	2013	2014	2015	2016
Overall Water Body	Moderate	Moderate	Moderate	-
Ecological	Moderate	Moderate	Moderate	-
Supporting elements (Surface Water)	Moderate	Moderate	Moderate	-
Mitigation Measures Assessment	Moderate or less	Moderate or less	Moderate or less	-
Biological quality elements	-	Good	High	-
Fish	-	Good	High	-
Hydromorphological Supporting Elements	-	Supports Good	-	-
Hydrological Regime	-	Supports Good	-	-
Physico-chemical quality elements	-	High	Good	-
Ammonia (Phys-Chem)	-	High	High	-
Dissolved oxygen	-	High	High	-
pH	-	High	High	-
Phosphate	-	High	Good	-
Temperature	-	High	High	-
Specific pollutants	Moderate	Moderate	Moderate	-
Triclosan	High	High	-	-
Copper	Moderate	Moderate	Moderate	-
Zinc	High	High	-	-
Chemical	Good	Good	Good	-
Priority substances	Good	Good	Does not require assessment	-
Lead and Its Compounds	Good	Good	-	-
Nickel and Its Compounds	Good	Good	-	-
Other Pollutants	Does not require assessment	Does not require assessment	Does not require assessment	-
Priority hazardous substances	Good	Good	Does not require assessment	-
Cadmium and Its Compounds	Good	Good	-	-
Di(2-ethylhexyl) phthalate (Priority hazardous)	Good	Good	-	-
Nonylphenol	Good	Good	-	-
Tributyltin Compounds	Good	Good	-	-

Cont…

Upstream water bodies

Name
Afon Cedig - source to Lake Vyrnwy
Afon Nadroedd - source to Lake Vyrnwy

Downstream water bodies

Name
Afon Vyrnwy - conf Afon Cownwy to conf Afon Banwy

Investigations into classification status

Download as CSV

Classification Element	Cycle	Year	Status	Outcome
No data to show				

Reasons for not achieving good status and reasons for deterioration

Download as CSV

Reason Type	SWMI	Activity	Category	More	Classification Element
RNAG	Physical modification	Other (not in list, must add details in comments)	No sector responsible	Details	Mitigation Measures Assessment
RNAG	Unknown (pending investigation)	Unknown (pending investigation)	Sector under investigation	Details	Copper

Objectives

Download as CSV

Classification Item	Status	Year	Reasons
Overall Water Body	Good	2021	
Ecological	Good	2021	
Supporting elements (Surface Water)	Good	2021	
Mitigation Measures Assessment	Good	2021	
Biological quality elements	High	2015	
Fish	High	2015	
Hydromorphological Supporting Elements	Not assessed	2015	
Physico-chemical quality elements	Good	2015	
Ammonia (Phys-Chem)	High	2015	
Dissolved oxygen	High	2015	
pH	High	2015	
Phosphate	Good	2015	
Temperature	High	2015	
Specific pollutants	High	2021	
Copper	High	2021	
Chemical	Good	2015	
Priority substances	Does not require assessment	2015	
Other Pollutants	Does not require assessment	2015	
Priority hazardous substances	Does not require assessment	2015	

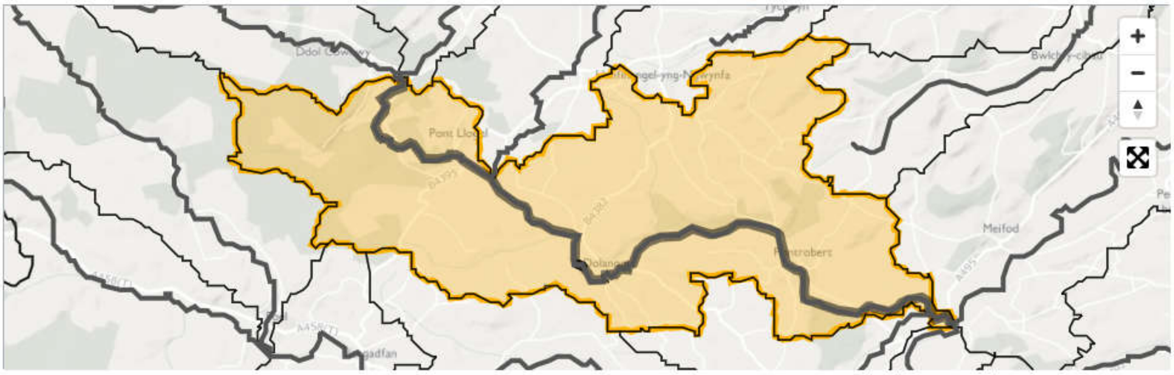
Protected areas

Download as CSV

PA Name	ID	Directive	Type	More information
Berwyn	UK9013111	Conservation of Wild Birds Directive		Natural England
R Vrynwy - Lake Vrynwy to conf Afon Cownwy	UKGB109054049880	Drinking Water Protected Area		

A.2. Afon Vyrnwy - conf Afon Cownwy to conf Afon Banwy

Table A-2 – Afon Vyrnwy – conf Afon Cownwy to conf Afon Banwy water body information



Afon Vyrnwy - conf Afon Cownwy to conf Afon Banwy

Download Water Body as CSV / GeoJSON

Overall classification for 2015
Moderate

Overview

Id	GB109054049720
Type	River
Hydromorphological designation	heavily modified
NGR	SJ0340015272
Catchment area	5837.86 ha
Length	19.169 km
Surveillance Water Body	No
Catchment area	58.379 km2

Cont…

Classifications

Cycle 2 classifications

Download as CSV

Classification Item	2013	2014	2015	2016
Overall Water Body	Moderate	Moderate	Moderate	-
Ecological	Moderate	Moderate	Moderate	-
Supporting elements (Surface Water)	Good	Good	Good	-
Mitigation Measures Assessment	Good	Good	Good	-
Biological quality elements	High	Good	Good	-
Macrophytes and Phytobenthos Combined	-	Good	Good	-
Fish	-	-	Good	-
Invertebrates	High	High	High	-
Hydromorphological Supporting Elements	-	Supports Good	-	-
Hydrological Regime	-	Supports Good	-	-
Physico-chemical quality elements	-	High	High	-
Ammonia (Phys-Chem)	-	High	High	-
Dissolved oxygen	-	High	High	-
pH	-	High	High	-
Phosphate	-	High	High	-
Temperature	-	High	High	-
Specific pollutants	Moderate	Moderate	Moderate	-
Triclosan	High	High	-	-
Copper	Moderate	Moderate	Moderate	-
Zinc	High	High	-	-
Chemical	Good	Good	Good	-
Priority substances	Good	Good	Does not require assessment	-
Lead and Its Compounds	Good	Good	-	-
Nickel and Its Compounds	Good	Good	-	-
Other Pollutants	Does not require assessment	Does not require assessment	Does not require assessment	-
Priority hazardous substances	Good	Good	Does not require assessment	-
Cadmium and Its Compounds	Good	Good	-	-
Di(2-ethylhexyl) phthalate (Priority hazardous)	Good	Good	-	-
Nonylphenol	Good	Good	-	-
Tributyltin Compounds	Good	Good	-	-

Cont…

Investigations into classification status

Download as CSV

Classification Element	Cycle	Year	Status	Outcome
No data to show				

Reasons for not achieving good status and reasons for deterioration

Download as CSV

Reason Type	SWMI	Activity	Category	More	Classification Element
RNAG	Unknown (pending investigation)	Unknown (pending investigation)	Sector under investigation	Details	Copper

Objectives

Download as CSV

Classification Item	Status	Year	Reasons
Overall Water Body	Good	2021	
Ecological	Good	2021	
Supporting elements (Surface Water)	Good	2015	
Mitigation Measures Assessment	Good	2015	
Biological quality elements	Good	2015	
Macrophytes and Phytobenthos Combined	Good	2015	
Fish	Good	2015	
Invertebrates	High	2015	
Hydromorphological Supporting Elements	Not assessed	2015	
Physico-chemical quality elements	High	2015	
Ammonia (Phys-Chem)	High	2015	
Dissolved oxygen	High	2015	
pH	High	2015	
Phosphate	High	2015	
Temperature	High	2015	
Specific pollutants	High	2021	
Copper	High	2021	
Chemical	Good	2015	
Priority substances	Does not require assessment	2015	
Other Pollutants	Does not require assessment	2015	
Priority hazardous substances	Does not require assessment	2015	

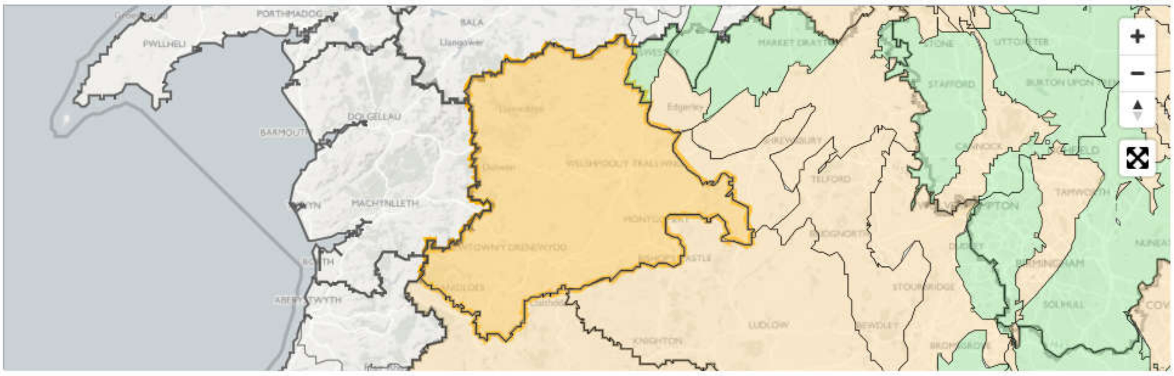
Protected areas

Download as CSV

PA Name	ID	Directive	Type	More information
No data to show				

A.3. Severn Uplands – Lower Palaeozoic

Table A-3 – Severn Uplands – Lower Palaeozoic groundwater body information



Download Water Body as CSV / GeoJSON

Severn Uplands - Lower Palaeozoic
Overview

Overall classification for 2016
Poor

Id	GB40902G205300
Type	Groundwater Body
Hydromorphological designation	not applicable
NGR	SJ1799505087
Groundwater area	203670.381 ha
Surface area	2036.704 km2
Surveillance Water Body	No

Cont…

Classifications

Cycle 2 classifications

Download as CSV

Classification Item	2013	2014	2015	2016
Overall Water Body	Poor	Poor	Poor	Poor
Quantitative	Good	Good	Good	Good
Quantitative Status element	Good	Good	Good	Good
Quantitative Saline Intrusion	Good	Good	Good	Good
Quantitative Water Balance	Good	Good	Good	Good
Quantitative GWDTEs test	Good	Good	Good	Good
Quantitative Dependent Surface Water Body Status	Good	Good	Good	Good
Chemical (GW)	Poor	Poor	Poor	Poor
Chemical Status element	Poor	Poor	Poor	Poor
Chemical Drinking Water Protected Area	Good	Good	Good	Good
General Chemical Test	Good	Good	Good	Good
Chemical GWDTEs test	Good	Good	Good	Good
Chemical Dependent Surface Water Body Status	Poor	Poor	Poor	Poor
Chemical Saline Intrusion	Good	Good	Good	Good

Cont…

Investigations into classification status

Download as CSV

Classification Element	Cycle	Year	Status	Outcome
No data to show				

Reasons for not achieving good status and reasons for deterioration

Download as CSV

Reason Type	SWMI	Activity	Category	More	Classification Element
RNAG	Unknown (pending investigation)	Unknown (pending investigation)	Sector under investigation	Details	Chemical Dependent Surface Water Body Status

Objectives

Download as CSV

Classification Item	Status	Year	Reasons
Overall Water Body	Poor	2015	No known technical solution is available
Quantitative	Good	2015	
Quantitative Status element	Good	2015	
Quantitative Saline Intrusion	Good	2015	
Quantitative Water Balance	Good	2015	
Quantitative GWDTEs test	Good	2015	
Quantitative Dependent Surface Water Body Status	Good	2015	
Chemical (GW)	Poor	2015	No known technical solution is available
Chemical Status element	Poor	2015	No known technical solution is available
Chemical Drinking Water Protected Area	Good	2015	
General Chemical Test	Good	2015	
Chemical GWDTEs test	Good	2015	
Chemical Dependent Surface Water Body Status	Poor	2027	No known technical solution is available
Chemical Saline Intrusion	Good	2015	

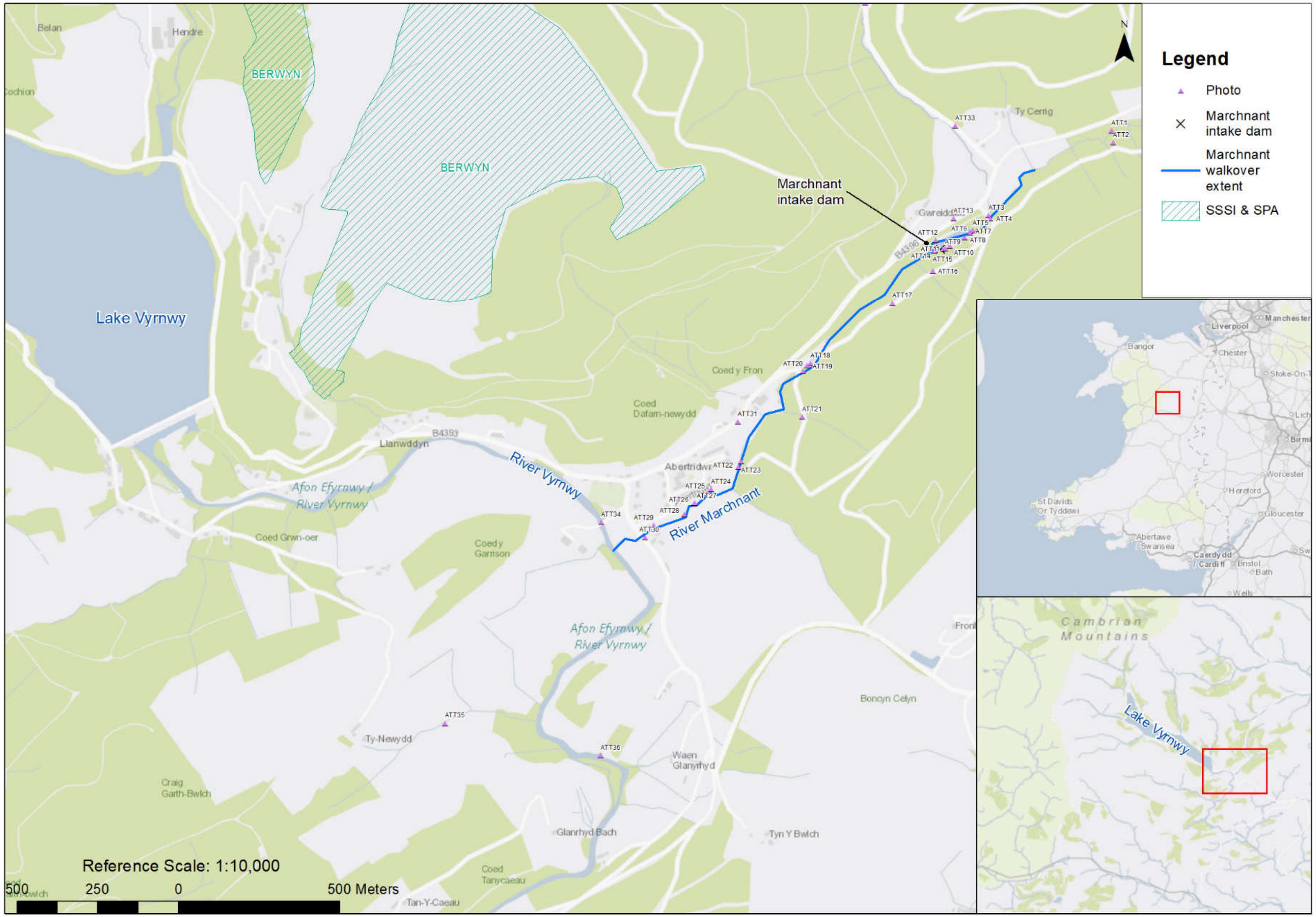
Protected areas

Download as CSV

PA Name	ID	Directive	Type	More information
153	NVZ12GW011530	Nitrates Directive		
Severn Uplands - Lower Palaeozoic	UKGB40902G205300	Drinking Water Protected Area		

Appendix B. Photographic library

A series of georeferenced photographs were collected during the fluvial audit. These have been provided separately to the report as a zipped folder due to the number and size.



Service Layer Credits: Contains OS data © Crown Copyright and database right 2018

Figure B-1 – Photograph locations

Lyndon Baker
Atkins
Chadwick House
Birchwood Park
Warrington, WA3 6AE

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