Evidence Review of Lake Eutrophication in Wales

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NRW Evidence Report No 135

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- Securing our data and information;
- Having a well-resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

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Mae Cyfarwyddeb Nitradau'r UE yn mynnu bod yn rhaid i aelod-wladwriaethau nodi a dynodi Parthau Perygl Nitradau bob pedair blynedd, yn seiliedig ar dystiolaeth bod crynodiadau nitradau'n uwch na'r lefelau sy'n ddiogel i iechyd pobl, neu bod lefelau nitrogen yn debygol o fod yn achosi anghydbwysedd niweidiol yn yr amgylchedd dŵr (ewtroffigedd).

Yn flaenorol, roedd Cymru a Lloegr wedi cytuno ar ddull o asesu'r dystiolaeth ar gyfer ewtroffigedd drwy grŵp technegol a oedd yn cynnwys cynrychiolwyr o'r llywodraeth, asiantaethau'r llywodraeth, arbenigwyr annibynnol a rhanddeiliaid, gan gynnwys yr undebau ffermio a'r cwmnïau dŵr. Yn fras, defnyddir dull o gyfuno tystiolaeth o feysydd cemeg dŵr a bioleg. Yna, mae modd nodi gyda gwahanol lefelau o hyder y dyfroedd sydd wedi eu hewtroffeiddio. Mae'r adroddiad hwn yn adolygu'r dystiolaeth sydd ar gael o ewtroffigedd ar lynnoedd Cymru drwy ddefnyddio'r dull hwn, gan gynnwys rhai newidiadau sy'n ganlyniad dulliau asesu amgylcheddol a ddiweddarwyd ers yr adolygiad diwethaf.

Cafodd data ansawdd dŵr ei goladu o 88 o lynnoedd a data ecolegol o 101 o lynnoedd ledled Cymru drwy ddefnyddio data CNC, ac o drydydd partïon pan oedd y data hwnnw ar gael. Defnyddiwyd setiau data a oedd eisoes yn bodoli, yn enwedig y gwaith monitro a gwblhawyd ar gyfer y Gyfarwyddeb Fframwaith Dŵr a'r Gyfarwyddeb Cynefinoedd. Credir mai hwn yw'r adolygiad mwyaf cynhwysfawr o ewtroffigedd llynnoedd yng Nghymru a gwblhawyd hyd heddiw. Er bod gan y rhain gwmpas gofodol da, nid oedd digon o ddata ar gael bob amser ar gyfer yr holl gyrff dŵr yr ystyrir eu bod mewn perygl o ewtroffigedd.

Nodwyd bod 25 o gyrff dŵr o bosibl yn agored i ewtroffigedd yn seiliedig naill ai ar ddata cemegol neu ecolegol, ac fe'u harchwiliwyd mewn mwy o fanylder a chan ystyried yr hyder yn y canlyniadau o safbwynt ystadegol. Mae prif ganfyddiadau'r asesiad hwn fel a ganlyn:

- Roedd naw corff dŵr yn dangos tystiolaeth o ewtroffigedd â hyder uchel: roedd hyn yn cynnwys yr holl Barthau Perygl Nitradau a oedd eisoes yn bodoli (Llyn Coron, Llyn Syfaddan, Llyn Hanmer a Llynnoedd Bosherston), ynghyd â phum corff dŵr ychwanegol (Llyn Maelog, Llyn yr Wyth Eidion, Llynnoedd y Cwm, Llyn Traffwll a Llyn Pencarreg).
- Roedd tri o'r cyrff dŵr yn dangos rhywfaint o dystiolaeth o ewtroffigedd. Y rhain yw Llyn Tegid, cronfeydd dŵr Plas Uchaf a Dolwen, a Phwll Witchett.
- Roedd yr 14 o gyrff dŵr eraill yn dangos naill ai dim tystiolaeth neu ddiffyg tystiolaeth o ewtroffigedd i gael eu hystyried yn Barthau Perygl Nitradau, neu gellid eu diystyru am resymau eraill.

Mae'r dystiolaeth o'r adroddiad hwn wedi'i hadolygu gan arbenigwr annibynnol i'w chraffu. Mae CNC wedi derbyn yr holl argymhellion canlyniadol ynglŷn â'r dynodiad. O ganlyniad, ein cyngor i Lywodraeth Cymru ynglŷn â dynodi Parthau Perygl Nitradau (Llynnoedd, Ewtroffig) yw'r canlynol:

- Dylid ail-gadarnhau'r pedwar Parth Perygl Nitradau sydd eisoes yn bodoli (Llyn Bosherston, Llyn Syfaddan, Llyn Hanmer a Llyn Coron), gyda man newidiadau i Lyn Bosherston a Llyn Hanmer. Amcangyfrifir mai cyfanswm arwynebedd y tir hwn yw 6,200 ha.

- Dylai dalgylchoedd y cyrff dŵr ychwanegol hyn gael eu dynodi: Llyn Maelog, Llyn yr Wyth Eidion (y ddau ohonynt ar Ynys Môn), Llyn Pencarreg (Sir Gaerfyrddin). Amcangyfrifir mai cyfanswm arwynebedd y tir hwn yw 2,148 ha.
- Ni ddylai dalgylchoedd yr holl gyrff dŵr eraill a aseswyd yn yr adroddiad hwn gael eu dynodi'n Barthau Perygl Nitradau ar sail ewtroffigedd y llyn, oherwydd mae tystiolaeth naill ai'n bodoli sy'n nodi nad ydynt wedi eu hewtroffeiddio, neu nid oes digon o dystiolaeth i'w dynodi.

Yn ystod ein gwaith, nodwyd sawl gwelliant posibl i'r arferion samplu a'r safonau amgylcheddol. Yn benodol, ystyrir datblygu safon nitrogen neu safon maethynnau unedig ar gyfer llynnoedd yn flaenoriaeth, ac argymhellir y dylai Llywodraeth Cymru ofyn i'r WFD UKTAG ddatblygu hyn. Argymhellir hefyd y dylai'r Grŵp Technegol Parthau Perygl Nitradau ailymgynnull i gytuno ar ddiweddariadau i'r dull asesu yn y dyfodol. Argymhellir hefyd y dylid gwneud mân newidiadau i rwydwaith samplu CNC er mwyn sicrhau bod pob llyn a allai ewtroffeiddio sy'n bwysig o safbwynt bioamrywiaeth yn cael ei fonitro yn y dyfodol.

Fel adolygiad cyffredinol o bwysau ar faethynnau llynnoedd Cymru, mae'r gwaith hwn hefyd yn berthnasol i waith rheoli'r amgylchedd ehangach, gan gynnwys blaenoriaethu gweithredol, targedu cynlluniau amaeth-amgylchedd, rheoli SoDdGAau ac ACAau, Cynlluniau Rheoli Basnau Afonydd, a Datganiadau Ardal sydd ar ddod. Fodd bynnag, dylid nodi bod y dull asesu Parthau Perygl Nitradau yn gymharol geidwadol, ac felly gallai llynnoedd lle nad yw dynodiad Parth Perygl Nitradau'n briodol fod yn destun mesurau rheoli dalgylch o hyd fel mesur rhagofalus, yn enwedig pan fo'r rhain â chost isel a/neu'n gydweithredol. Mae hyn yn arbennig o bwysig ar gyfer rheoli llynnoedd, oherwydd mae gwella o ewtroffigedd fel arfer yn cymryd sawl degawd.

2. Executive Summary

The EU Nitrates Directive requires Member States to identify and designate Nitrate Vulnerable Zones every four years based on evidence that nitrate concentrations exceed safe levels for human health, or that nitrogen levels are likely to be causing harmful imbalances on the aquatic environment (eutrophication).

England and Wales have previously agreed a method for assessing the evidence for eutrophication via a technical group that included representatives from Government, Government Agencies, independent experts and stakeholders, including the farming unions and water companies. In brief, the method uses a weight of evidence approach to combine evidence from water chemistry and biology. Waters that are eutrophicated can then be identified with different levels of confidence. This report reviews the available evidence of eutrophication on Welsh Lakes using this method, including some changes that have resulted from updated environmental assessment methods since the last review.

Water quality data was collated from 88 lakes and ecological data from 101 lakes throughout Wales using data from NRW and where available from third parties. Existing datasets were used, especially monitoring carried out for the Water Framework Directive and the Habitats Directive. This is believed to be the most comprehensive review of lake eutrophication in Wales to date. Although these gave good spatial coverage, sufficient data was not always available for all water bodies considered at risk of eutrophication.

Twenty-five water bodies were identified as being potentially at risk of eutrophication based on either chemical or ecological data and were examined in greater detail and taking into account statistical confidence in the results. The key findings of this assessment are as follows:

- Nine water bodies showed evidence of eutrophication with high confidence: this included all of the existing NVZs (Llyn Coron, Llangorse Lake, Hanmer Mere and Bosherston Lakes), plus five additional water bodies (Llyn Maelog, Llyn yr Wyth Eidion, Valley Lakes, Llyn Traffwll and Llyn Pencarreg).
- Three water bodies exhibited some evidence of eutrophication. These are Llyn Tegid, Plas Uchaf & Dolwen Reservoirs, and Witchett Pool
- The remaining fourteen water bodies showed no or insufficient evidence of eutrophication to be considered as NVZs, or could be ruled out for other reasons.

The evidence from this report has been reviewed by an independent expert for scrutiny. NRW has accepted all of the resulting recommendations in relation to designation. As a consequence, our advice to Welsh Government with respect to designation of NVZs (Lakes, Eutrophic) is as follows:

- The four existing NVZs (Bosherston Lake, Llangorse Lake, Hanmer Mere and Llyn Coron) should be reaffirmed, with minor boundary changes to Bosherston Lake and Hanmer Mere. The total area of this land is estimated as 6200 ha.
- The catchments of the following additional water bodies should be designated: Llyn Maelog, Llyn yr Wyth Eidion (both Anglesey), Llyn Pencarreg (Carmarthenshire. The total area of this land is estimated as 2148 ha.

- The catchments of all other water bodies assessed in this report should not be designated as NVZs on grounds of lake eutrophication, as the evidence either exists that they are not eutrophicated, or there is insufficient evidence to designate.

During the course of the work, several potential improvements to sampling practices and environmental standards were identified. In particular, development of a nitrogen or unified nutrient standard for lakes is considered a priority and it is recommended that Welsh Government request the WFD UKTAG to develop this. It is also recommended that the NVZ Technical Group reconvene to agree future updates to the assessment method. Minor changes to NRW's sampling network are also recommended to ensure that all potentially eutrophicated lakes of biodiversity importance are monitored in future.

As a general review of nutrient pressures on lakes in Wales, this work is also relevant to wider environmental management, including operational prioritisation, agri-environment scheme targeting, SSSI and SAC management, River Basin Management Planning and forthcoming Area Statements. However, it should be noted that the NVZ assessment method is relatively conservative and therefore lakes where NVZ designation is not appropriate could still be subject to catchment management measures on a precautionary basis, especially where these are low-cost and / or collaborative. This is especially important for lake management since recovery from eutrophication typically takes several decades.

3. Introduction

This report presents a synthesis of the evidence base relating to nutrient pressures in Welsh lakes. The context for this work is the 2015-16 review of Nitrate Vulnerable Zones (NVZs) in support of Wales's obligations under the Nitrates Directive. However, the evidence thus collated is extensive and can be used in other operational and policy contexts. Eutrophication is a relevant pressure in many situations, and levels of evidence for eutrophication vary, both due to the extent of monitoring data available and because ecosystems are inherently variable. An understanding of the impacts of nutrients on Welsh lakes is therefore useful for a variety of purposes.

There are about 550 lakes of 1 ha or more in area in Wales (Hughes *et al*. 2004 – Figure 3.1). These cover a combined catchment area of approximately 305,000 ha. About 150 of these have some survey or monitoring data.

The general definition of eutrophication used by European legislation is as follows (Carvalho *et al*. 2006):

> *'The enrichment of water by nutrients, especially compounds of phosphorus (P) and/or nitrogen (N), causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned'*

In other words, demonstrating eutrophication requires <u>both</u> (i) evidence of elevated nutrient levels compared to what would be expected and (ii) ecological evidence of impacts related to nutrients.

3.1. The Nitrates Directive Evidence Review Process

The Nitrates Directive (91/676/EEC) is intended to protect waters against nitrate pollution from agricultural sources. Member States are required to identify waters that are or could become polluted by nitrates and to designate all land draining to them and contributing to the pollution as Nitrate Vulnerable Zones (NVZs). Farmers in designated areas must follow an Action Programme to reduce pollution from agricultural sources of nitrate. The criteria for identifying waters as polluted are established in the Directive, which also sets out monitoring requirements. NVZ designations must be reviewed at least every four years.

Waters that are or could be affected by pollution are to be identified using the following criteria:

- surface freshwaters which contain or could contain, if preventative action is not taken (i.e. Action Programme measures), more than 50 mg l^{-1} nitrate;
- groundwaters which contain or could contain, if preventative action is not taken, more than 50 mg l^{-1} nitrate;
- natural freshwater lakes, other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic or in the near future may become eutrophic if preventative action is not taken.

Figure 3.1. Left: Distribution of the lakes (here defined as water bodies > 1ha in area) in Wales. Right: Map of their catchments. Data from Hughes *et al*. (2004). Base mapping © Crown Copyright and database right 2013. Ordnance Survey 100019741.

This report analyses the data in respect of current and potential new lake Nitrate Vulnerable Zones in Wales against the ‘eutrophic’ criteria. NRW is undertaking separate reviews of the status of surface and groundwaters against the 50 mg l^{-1} threshold.

The Directive also specifies that the following considerations must be taken into account when applying these criteria:

- the physical and environmental characteristics of the water and land;
- current (scientific) understanding of the behaviour of nitrogen compounds in the environment (water and soil); and,
- current understanding of the impact of preventative action.

Under Article 6 for the purpose of designating and revising the designation of vulnerable zones, Member States shall: “review the eutrophic state of their fresh surface waters, estuarial and coastal waters every four years”.

At each NVZ review, changes and factors unforeseen at the previous review must be taken into account. The periodic nature of reviewing NVZs means that each review necessarily presents a ‘snapshot’ assessment of nitrate pollution up to the time of the review. This latest review was undertaken using data from 2009 onwards.

3.2. The Eutrophic Waters NVZ Criteria

In contrast to the surface waters and groundwaters criteria, which are defined with respect to a single threshold of 50 mg l^{-1} nitrate based on water quality monitoring data, the identification of eutrophic waters requires the balancing of an often complex evidence base. Eutrophication in lakes can result in a variety of different ecological symptoms of damage which may manifest themselves to different extents depending on the type of water concerned. These different strands of evidence need to be combined in a consistent manner to arrive at a judgment as to whether a water body is negatively affected by eutrophication. Examples of this include:

- Changes to the aquatic plant community;
- Low dissolved oxygen, especially in deep lakes;
- Nuisance growths of certain plant species, especially filamentous algae (blanket weed);
- Loss of sensitive fish species requiring high oxygen levels, such as trout and charr and;
- Algal blooms.

The existing method statement for identifying lake NVZs includes a structured and evidence-based method for combining these criteria (Environment Agency 2012), which was agreed by a technical group of regulators, scientists and stakeholders. This method makes extensive use of existing monitoring methods and standards used for implementation of the Water Framework Directive (WFD). This approach was used as a means of maximising efficiency by reducing monitoring costs and aligning Directives. Lakes were initially screened against chemical data, using thresholds identified in the scientific literature, to establish whether eutrophication was likely. Candidate lakes were then assessed against other ecological data to identify impacts (Environment Agency 2012).

The process for identifying candidate waters follows the following stages:

1. **Focusing in on water bodies of concern** – using data from national monitoring programmes, operational investigations, risk assessments and local knowledge to identify water bodies likely to be at risk of eutrophication which warrant more detailed examination.
2. **Detailed investigation** of individual water bodies – evidence collated from various sources and compared against the suites of criteria outlined above.
3. **Quality assurance** and submission to national panel – since much lake data is held nationally, a local consultation is held prior to consideration of the evidence by an expert national panel, ensuring consistency in the assessment procedure.
4. **Identification of land** – land draining directly to the candidate polluted water (eutrophic), and the WFD catchments of surface waters upstream of the eutrophic water are identified and mapped.

This report deals with the first two stages of this process and constitutes the evidence base for consideration by the national panel (Stage 3). Indicative catchment maps are also provided to inform stage 4.

Since the previous review, a number of updates to the technical method used have become necessary, reflecting changes to WFD classification tools (WFD-UKTAG 2013, 2014a; 2014b; 2014c). In addition, the Environment Agency have developed a Weight of Evidence tool for assessing eutrophication impacts in a more structured and objective way that takes into account statistical confidence in the data (Environment Agency, unpublished). The details of these updates are explained in the methods section. However, the essential principle of the NVZ review, that evidence of eutrophication requires both evidence of elevated nutrient levels and evidence of ecological changes linked to nutrient enrichment, remains unchanged.

4. Methods

As described in the introductory section, the NVZ method operates on the principle of assessing evidence relevant to eutrophication. This evidence generally falls into three categories:

- Chemical data (nutrient concentrations).
- Plant community structure and function, (including algal production). This is the main biological response to elevated nutrient concentration. There are already well-established ecological methods for measuring the impact of eutrophication on lakes using WFD classification tools.
- Secondary and other effects, such as low dissolved oxygen, effects on other flora and fauna and effects on water use, such as recreation. These are assessed using environmental standards where available, as well as other evidence.
- Evidence that the lake is nitrogen limited

4.1. Nitrogen Thresholds

There is good evidence to indicate the effects of nitrogen concentrations on lake ecology (Maberly *et al*. 2002, 2003; James *et al*. 2005; see also the review by Durand *et al*. 2011). However, this information has not yet been translated into nitrogen standards for freshwater in the UK. Instead, Environment Agency (2012a) risk classes have been used (Table 4.1.1), reflecting the threshold of 1-2 mg l^{-1} as either the mean total nitrogen or the 75%ile total oxidised nitrogen, which is related to aquatic plant species richness (James *et al*. 2005). It should be noted that these risk classes reflect the statistical distribution of nitrogen concentrations in at risk lakes in England and Wales in the 2012 assessment, rather than reflecting evidence-based ecological thresholds.

As for phosphorus, it is possible that different standards may be appropriate for upland lakes, but no suitable standard has been proposed. Accordingly the ‘Very low’ category used by Environment Agency (2012) has been subdivided into ‘Very low’ (<0.5 mg l^{-1}) and ‘Low’ (0.5-1 mg l^{-1}). This is purely for information purposes and does not affect the analysis. Ideally, a unified eutrophication standard reflecting the impact of both nitrogen and phosphorus on lake ecosystems could be produced.

Risk Class	75%ile TON-N (mg l^{-1})	Annual Mean TN (mg l^{-1})
Very Low	<0.5	<0.5
Low	0.5 - 1.0	0.5 - 1.0
Low-Medium	>1.0 - 1.7	>1.0 - 1.5
Medium	> 1.7 - 3.5	>1.5 - 2.0
Medium – High	> 3.5 - 6.0	>2.0 - 4.0
High	> 6.0	> 4.0

Table 4.1.1. Risk classes used in the 2012 assessment (Environment Agency 2012).

It is not considered that the risk categories in the existing published method are supported by evidence, and additionally they do not incorporate an assessment of confidence in the data. To address these issues, for future assessments it is recommended that the bands used in Table 4.1.1 are replaced by the risk categories as shown in Table 4.1.2.

		Confidence			
		>95%	75-95%	25-75%	<25%
Higher of 75%ile TON-N or Annual Mean TN (mg l^{-1})	0.5	L	L	L	VL
	1.0	M	ML	L	L
	2.0	H	MH	M	L

Table 4.1.2. Recommended confidence-based risk categories for nitrogen risk categories. H = High; MH = Medium-High; M = Medium; ML = Medium-Low; L = Low; VL = Very Low. Where a value fits more than one risk category, the worse risk category applies.

In order to comply with the existing method, NRW has decided to report against the existing categories (Table 4.1.1.). However, confidence in failing the nitrogen target is reported as both the confidence of failing the 1 mg l^{-1} and 2 mg l^{-1} values, which represent the lower and upper ends of the range over which nitrogen impacts were reported by James *et al*. (2005), using the confidence categories in section 4.5 below. This approach provides a statistically robust basis for decision making that relates directly to the ecological evidence.

4.2. Updates to the WFD monitoring methods

Although every effort has been made to follow the previous NVZ designation method, some updates to the NVZ assessment method have been necessary, primarily to ensure that the assessment of eutrophic impacts in lakes for the NVZ review remains aligned with current assessment and reporting under the Water Framework Directive. The NVZ review will therefore be making use of the most recent data and most reliable ecological assessment tools.

Since the last round of NVZ reviews and designation, NRW has extended the scope of the national lake monitoring programme, resulting in an improved national data set. We have updated the data used to assess compliance with the nitrogen thresholds to cover the period 2010 – 2014, for existing designations and any other lakes which have sufficient data available for assessment. Where there is doubt regarding the status of a lake, we will include longer-term data to provide context where it is available.

For supporting evidence of eutrophication impacts from the WFD classification (phosphorus and biological elements), we have used the latest version of the classification currently available, carried out in 2014 using data from 2011-2013 (or 2008-2013 for macrophytes). In cases where formal classification data are not available, we will still assess them against WFD tools where possible.

There has been significant research and development undertaken under the direction of the WFD UK Technical Advisory Group (UKTAG) to improve the performance of our WFD biological tools. These tools have, in some cases, been substantially revised, and have been tested against the assessment methods used in other European Member States through the process of intercalibration, ensuring that the good/moderate class boundaries set within different Member States to define good status are essentially equivalent. The current versions of the tools therefore represent the best available measure of the biological elements under consideration, and in particular their response to nutrient conditions.

The revised versions of the tools were adopted for use in reporting water body status for the WFD for the second River Basin Management Plans, published in 2015, after public consultations by both the WFD UK Technical Advisory Group (UKTAG 2013), and DEFRA (2014).

There have been no changes to the environmental standards for supporting elements for lakes relevant to the NVZ Eutrophic method (total phosphorus and dissolved oxygen).

The updated biological tools are as follows:

Phytoplankton

This classification tool has been substantially revised; the new tool is referred to as PLUTO (Phyto**pl**ankton Classification with **U**ncertainty **To**ol – WFD-UKTAG 2014c). This now includes three, rather than two, metrics. The previous tool used chlorophyll and percentage of nuisance cyanobacteria (blue-green algae). In the new tool, the phytoplankton abundance is still measured with chlorophyll *a* (an indicator of algal biomass), species composition is assessed using the Plankton Trophic Index (PTI), and bloom intensity assessed from the biovolume of cyanobacteria. Ecological quality ratios (EQRs) are calculated for the individual metrics, then combined to produce an overall EQR and hence a status class for phytoplankton. It is possible to derive a classification based only on the chlorophyll metric if detailed taxonomic information is not available to calculate the PTI and biovolume metrics.

NRW collects phytoplankton data annually as part of its WFD monitoring in lakes, as well as from a few lakes not identified as WFD water bodies. Limited data are also available from protected sites (SSSIs and SACs). The WFD classification is based on data from the preceding three years.

Macrophytes (aquatic plants)

Lake LEAFPACS 2 (WFD-UKTAG 2014b) is a revised version of the original macrophyte tool, based on the same survey methodology, and comprising five metrics describing different aspects of the lake macrophyte community. The metrics are as described for the original Lake LEAFPACS method, with the exception of relative cover of invasive alien species, which has been removed from the tool (as there was no evidence of a relationship with nutrients). There are also minor changes to the nutrient scores for some of the macrophytes.

NRW collects macrophyte survey data from a wide range of water bodies in Wales, including WFD water bodies and other sites. This sampling method is also used in monitoring of protected sites (SSSIs and SACs) designated for lake habitat. Results are based on all data from the preceding 6 years, normally 1-2 surveys.

Phytobenthos (benthic diatoms)

The updated tool (DARLEQ 2 – WFD-UKTAG 2014a), is based on a single metric, the Lake Trophic Diatom Index (LTDI). There has been some revision of the LTDI scores in the new tool, based on a re-analysis of diatom-nutrient relationships using an improved data set for lakes.

NRW collects phytobenthos data from WFD surveillance lakes only, resulting in a smaller dataset available than for phytoplankton and macrophytes. Results are based on data from the preceding three years.

4.3. Impact of the classification tool updates

UKTAG carried out a detailed assessment of the likely impact of adopting the new versions of the tools on classification results, for its public consultation (WFD-UKTAG, 2013). Although there have been changes in the detail, the overall picture remains broadly similar in terms of the proportion of water bodies at Good Status or better (WFD-UKTAG 2013).

4.4. Interpretation of other evidence

The NVZ method also requires other evidence to be taken into account, much of which is also included in the Weight of Evidence tool (see 4.5 below). These data include evidence of high nutrient concentrations in inflow streams; low dissolved oxygen; fish kills or declines of sensitive fish species; and failures to meet favourable condition for Special Areas of Conservation (SAC) designated under the Habitats Directive and / or Sites of Special Scientific Interest (SSSI) designated under the Wildlife and Countryside Act.

4.5. Update to the Environment Agency Weight of Evidence (WoE) Tool

In addition to the updated biological classification tools, the EA has developed an improved assessment of the Weight of Evidence (WoE) of eutrophication impact in lakes. This tool is designed to collate and assess the ecological, chemical and social evidence of eutrophication in a single, objective manner.

In the previous NVZ method, the confidence of eutrophication assessment is based on combining the confidence derived from individual biological classifications into an overall confidence of eutrophication. This involved combining the results of quality elements in a rule-based way to reach a judgment regarding impact. However, the rules used did not take into account the statistical confidence in the evidence, and consequently the resulting judgments had the potential to be rather arbitrary.

The EA has developed this concept further, for use in WFD, by developing a Weight of Evidence spreadsheet tool to assess the likelihood of eutrophication impact. This is based on both the relevant WFD classification results and the reported statistical confidence in those results, but also allows a “wider weight of evidence” to be taken into consideration, including a specified range of non-WFD indicators and evidence from third parties if available.

The method has four elements:

1. Combination of the core eutrophication sensitive WFD classification results (total phosphorus, phytoplankton overall, chlorophyll, macrophytes, diatoms) using their reported statistical confidence of class, to produce a certainty of eutrophication impact based on the classification tools alone. This is similar to the confidence of eutrophication assessment in the current NVZ method, but the inclusion of confidence in class is an important addition;
2. Pressure indicators – a weighted score is allocated to a restricted range of pressure indicator data, primarily related to wider evidence of phosphorus pressure, to give a “pressure related score”;
3. Ecological indicators – weighted scores are allocated to evidence from other WFD tools which reflect nutrient pressure (e.g. the chironomid tool CPET), and a wider set of ecological indicators (e.g. algal blooms, fish kills, dissolved oxygen, palaeoecological evidence) to give an “ecological indicator score”;
4. Use indicators - scores allocated to e.g. Drinking Water Protected Area risk, Conservation condition assessment with respect to nutrients, to give a “use related score”.

Within the WoE tool, indicator scores are combined into a total score, which is then translated into a recommendation on whether the certainty obtained from the core WFD classification tools should be increased or decreased, to give a final certainty of eutrophication impact. Details of the rules used for combining results are provided in Appendix 1.

The following confidence values are used in the WoE tool in relation to classification tool results (Table 4.5.1). These have also been used for reporting confidence intervals of nitrogen concentrations:

Confidence that the tool classification result is worse than Good Status	Descriptive Terminology
No Data	No Data
0-25%	Good or Better
>25-75%	Uncertain Evidence of Eutrophication
>75-95%	Quite Certain Evidence of Eutrophication
>95%	Very Certain Evidence of Eutrophication

Table 4.5.1. Confidence levels used in this report.

NRW Operational staff have been consulted and have added information for their lakes to this WoE assessment, which has been used to inform risk assessment for eutrophication for the second River Basin Plans. For water bodies where this WoE assessment has been completed, this protocol brings a more formal and structured process to the consideration of the wider evidence already used in the current NVZ method.

We have therefore adopted the WoE approach, to replace the WFD confidence of eutrophication assessment described in section 4.3.2 of the existing method statement. This will result in a statement of the certainty of eutrophication impact, ranging from uncertain to very certain, for each water body, to be included in the final assessment for consideration by the Panel. This has been combined with the evidence of nitrogen concentrations to identify water bodies affected by eutrophication involving elevated nitrogen levels.

4.6. Combination of nitrogen and WoE results

Nitrogen and WoE tool results have been combined following the rules used by Environment Agency (2012, Table 4.5), modified to allow for the revised category descriptions used by the WoE tool. These are shown in Table 4.6.1 below, which has been reformatted for clarity.

It should be noted that according to the screening rules in Environment Agency (2012), there should be a category of lakes with high nitrogen but weak evidence of eutrophication. However, no rules for classifying the evidence base for these lakes are described in Environment Agency (2012). It is here assumed that lakes falling into this category would be considered as having ‘marginal’ evidence (Table 4.6.1).

		Nitrogen Risk Category					
		High	Med-High	Medium	Medium-Low	Low	Very Low
WoE Confidence of Eutrophication	Very Certain	VH	VH	H	MH	MH	MH
	Quite Certain	ML	ML	L	Ma	Ma	Ma
	Uncertain	Ma	Ma	Ma	Ma	N	N
	Good or Better	N	N	N	N	N	N

Table 4.6.1. Matrix showing the rules for combining WoE confidence of eutrophication and nitrogen risk categories to reach an overall assessment of the evidence base supporting eutrophication. Strength of evidence categories used in the cells are VH = very high; H = High; MH = Medium-High; ML = Medium-Low; L = Low; Ma = Marginal; N = No or insufficient evidence of eutrophication.

In making recommendations for the next stage (consideration by expert panel), NRW has taken the following approach in relation to the evidence strength as identified in Table 4.6.1:

- Medium-high or greater: Submit to Expert Panel for review with recommendation to designate as NVZ.
- Marginal to Medium-Low: Submit to Expert Panel for their opinion with no specific recommendation.
- No / Insufficient Evidence: Do not submit to Expert Panel.

All of the above also require the following conditions to be met:

1. The water body is not a pumped storage reservoir

2. Agriculture contributes at least 17% of the estimated nitrogen loading as estimated by source apportionment.[1]

4.7. Nitrogen Limitation

In order to help understand the likely role of nitrogen in the eutrophication of candidate lakes, monitoring data for each lake considered potentially eutrophic has been examined to establish whether they show evidence of seasonal nitrogen-limitation of primary production. In lakes where nitrogen limitation is important, nitrate-N concentrations of may drop to very low levels during the growing season. A molar N:P ratio of 16:1 or less is widely used to indicate the point at which the transition from phosphorus to nitrogen limitation occurs, and although not universal it remains a good overall ratio (Kolzau *et al*. 2014). Although nitrogen limitation can be predicted with some confidence using nutrient ratios (Kolzau *et al*. 2014), it can only be confirmed using bioassay techniques. This type of work requires detailed experimental work and is beyond the scope of the NVZ method.

Evidence of nitrogen limitation does not necessarily mean that nutrient N is not contributing to eutrophic disturbance (Environment Agency 2012). Where a lake is enriched with phosphorus, additional nitrogen supports increased production and may directly suppress the growth of certain species (e.g. James *et al*. 2003). Likewise, reductions in nitrogen loading are expected to help reduce primary production and possibly increase the period of seasonal nutrient N limitation, leading to a reduced risk of eutrophic disturbance.

Where chemical data are sufficient to allow identification of seasonal patterns of nitrogen limitation, this is identified in the text and using graphical analysis.

[1] The 17% threshold arises from European Court of Justice case law, in which a judgment against the Belgian Government established that 17% contribution of nitrogen loading from agriculture was still significant and therefore than NVZ designation was warranted.

4.8. Data used in the Assessment

Datasets used in this report are summarised in Table 4.8.1. In line with the requirements of the NVZ method, only recent data have been used for assessing the eutrophication status of lakes. Wider data sources have been used as additional information, in particular to provide relevant context.

Data Type	Date Range	Datasets
Water chemistry	2009-2015	NRW water chemistry dataset; Lake condition assessments.
Dissolved Oxygen	2009-2015	WFD classifications; Lake condition assessments; other published sources.
Phytoplankton	2009-2015	WFD classifications
Macrophytes	2009-2015	WFD classifications; Lake condition assessments.
Diatoms	2009-2015	WFD classifications.
Additional Nutrient Impacts	Any	Published Sources.
Chironomids (invertebrates)	2009-2015	WFD classifications.
Damage to Fish	Any	Published Sources
Relevant Palaeolimnological Evidence (change in Di-TP)	Any	Lake condition assessments; published sources.
Algal blooms	2009-2015	NRW Operational Data.
Land Cover Data	1985 onwards	Phase 1 Habitat Survey

Table 4.8.1. List of datasets used in this report.

4.9. Catchment Land Use

Catchment land use details have been provided as contextual information with the individual lake accounts considered at risk of eutrophication in Section 6. This is based on the Phase 1 Habitats Survey dataset, a comprehensive land cover GIS dataset collected to a standard method covering the whole of Wales (Howe *et al*. 2005; Blackstock *et al*. 2010). Habitat Types have been graded into three different categories reflecting their nutrient risk:

<u>Semi-natural Habitats and Low Intensity Agriculture</u>. These are habitat types that reflect either the absence of agriculture, or low intensity farming methods. The following habitats were assigned to this category:

A. Woodland and Scrub. All types except A1.2.2 (Planted Coniferous Woodland) and A.4.2 (Felled Coniferous Woodland);
B. Grassland and Marsh. All types except B.4 (Improved Grassland);
C. Tall Herb and Fern. All types;
D. Heathland. All types;
E. Mire. All types;
F. Swamp, Marginal and Inundation. All types;

G. Open water. All types (but see below);
H. Coastland. All types, though in practice many of these would not be found in the catchment of freshwater lakes;
I. Rock Exposure and Waste. Type I.1.x only (Natural Rock Exposures).

Intensive Agriculture. These are habitat types that reflect more intensive farming practices considered likely to result in leaching of nutrients that could cause eutrophication:

B.4. Improved Grassland;
J.1.1. Arable

Other Land Uses. These are a mixture of other non-agricultural land uses that could result in elevated nutrient levels. Coniferous forestry has been included here because elevated nutrient levels in several lakes may be linked to forestry. Other land uses in this category are mainly linked to housing or built-up areas, where risks are mainly linked to waste arrangements (sewers, septic tanks and storm drains), but road drainage and leachate from refuse tips may also be relevant.

I.2.x. Quarries, Spoil, Mine and Refuse-tip;
J.1.2 - J.1.5 Amenity Grassland, Ephemeral / short perennial, Introduced scrub, Gardens.
J3.x. Caravan site, Sea-wall, Buildings, Tracks.
J.4.Bare ground.

For details of the classification method, see JNCC (2010).

Some lakes in the assessment had a relatively high lake : catchment ratio, thus artificially inflating the proportion of low intensity land use in the catchment. Where standing water covered more than 5% of the overall catchment and there were no upstream lakes that could account for this, land use percentages were recalculated excluding the standing water category. This has been indicated in the land use summary tables.

4.10. Source Apportionment

Where source apportionment had already been carried out, this information was utilised again. Specific details are provided in Appendix 2 (Environment Agency, undated). Since the available input data have not changed, source apportionment values calculated for the previous NVZ review have been used where available.

Lakes that had not previously been assessed were subject to source apportionment using a spreadsheet tool (Edwards, 2016). In brief, the total N load to the lakes from all sources was estimated by multiplying the total catchment flow by the 75%ile concentration of total oxidised nitrogen in each lake. All NRW-consented discharges were identified for each of the lake catchments, and the average N load was estimated for each of these point sources, based on consented flows and actual or estimated N concentrations. The N load from consented discharges was then subtracted from the total N load to give an estimate of the N load from diffuse sources.

The apportionment of the N load from diffuse sources was based on the breakdown of land use. In the absence of any other information it was assumed that there is no difference in N yields between different land use categories. This method should provide a minimum estimate of the N contribution from agricultural land, assuming that, in reality, intensively farmed land will have a higher N yield than other types of land use.

4.11. Pumped Storage Reservoirs

During the previous NVZ review, a policy decision was taken to exclude certain man-made lakes lacking conservation value and where lakes have artificial catchments (Environment Agency 2012a). The following criteria were used for a lake to qualify for exclusion and are referred to as 'Pumped Storage' reservoirs throughout this report:

- Must be classed as an artificial water body under WFD, or it must be possible to show that it would qualify using existing WFD criteria and;
- The majority of water is derived by engineered means (e.g. pumped or large inter-catchment transfers).

Examples of this are purpose-built water storage reservoirs which provide temporary water storage in concrete / stone / clay lined bowls. In contrast, impounded catchment reservoirs, particularly where they have significant value to society, e.g. for recreational or conservation wildlife reasons, are not eligible for exclusion. Likewise, man-made lakes (e.g. broads, gravel and clay pits), especially where they are of sufficient age to be considered "naturalised" (e.g. Bosherston Lake) are not excluded on this basis.

Where a lake/reservoir is included as an NVZ and it has a mix of engineered and natural water supply, the natural (topographically defined) catchment of these waters should be designated as an NVZ but the source of any pumped water should not be included. The Nitrates Directive refers to land draining to waters, but the engineered process of pumping is not a natural draining process and breaks the environmental link between catchment and water body (Environment Agency 2012a).

4.12. Managing Uncertainty

All datasets contain uncertainty, and those shown here are no exception. All the data collected has been subjected to quality assurance procedures designed to minimise uncertainty, including the data analysis, sampler and surveyor training and rigorous quality control checks at all stages. Statistical uncertainty also arises from the effects of small sample size, and from the true answer being close to a boundary value.

Although these uncertainties cannot be eliminated, their effect on the eventual outcome can still be managed. Throughout this report, <u>uncertainty is reported in terms of its consequences for decision making</u>, rather than its absolute value.

Several specific sources of uncertainty are discussed below and individually in the assessments.

4.12.1 Phosphorus Model and Humic Lakes

Some lakes in Wales are humic (peat-stained). These lakes naturally have higher phosphorus concentrations and productivity than corresponding lakes with clear water (Nurnberg & Shaw 1999) but are nevertheless sensitive to further nutrient additions (Donali *et al*. 2005; Kaste & Solheim 2005). The phosphorus model does not take account of this, with the result that phosphorus classifications in humic lakes tend to be lower than in clear water lakes of comparable ecological quality. This has been taken account of by downgrading the certainty of phosphorus failures in humic lakes to 'Uncertain'.

4.12.2 Detection limits for total phosphorus

NRW has access to two methods for measuring phosphorus, referred to here as the standard method and the high-resolution method. The standard phosphorus method has a detection limit of 20 µg l^{-1}. The more expensive high-resolution method is used in circumstances where measurements of low concentrations are required, and has a detection limit of about 2 µg l^{-1}. Certain lakes have mean nutrient concentrations that are just above 20 µg l^{-1} and in this case some readings are often below the detection limit of the standard method, which potentially affects the calculation of the mean. When calculating the mean value for small datasets a value of half the detection limit (10 µg l^{-1}) has been used for any datapoints below the detection limit: for larger datasets a statistical approach based on the frequency of different measurements has been used. Where relevant, the potential consequences for the decision of using different values for readings below the detection limit is discussed.

4.12.3 Other factors affecting the tools

In certain water supply reservoirs where water levels fluctuate substantially over the course of a year, the composition and abundance of the aquatic plant community may be substantially affected, resulting in a low classification using the macrophytes tool that is not related to nutrients. Where this situation occurs, the results of the macrophytes tool have been excluded. In situations where other factors are thought likely to have affected the classification for any tool, confidence levels have been adjusted accordingly. These and other statistical and ecological outcomes that may have affected the outcome of the assessment are discussed in the individual accounts.

4.13. Independent Expert Review

Independent expert review has been carried out by Dr Helen Bennion, a researcher on lakes based at the Department of Geography, University College London. The findings of the review have been summarised in the report and the full text is reproduced in Appendix 3.

5. Results

Ecological and water quality data for the relevant time period were available from 101 different lakes across Wales (Appendices 3 and 4), comprising a wide range of water body types. For the assessment, data were used from January 2009 to December 2014 (more recent data were not available at the time of analysis in summer 2015 due to quality assurance procedures). As monitoring intensity and timescales varied widely, we have reported on the number of samples and confidence intervals.

Due to the monitoring requirements of the Water Framework Directive, water supply reservoirs were over-represented in the monitoring network relative to natural lakes. Conversely, a number of SSSI lakes that had previously received condition assessments and been identified as Unfavourable due to eutrophication (Burgess *et al*. 2006, 2009) lacked more recent water quality monitoring data and so could not be assessed against the NVZ criteria.

5.1. Nitrogen concentrations

Mean total nitrogen and 75%ile total oxidised nitrogen results for 88 Welsh lakes where adequate data were available are summarised in figures 5.1.1 and 5.1.2 respectively. For both determinands, the majority of lakes had low concentrations that were very unlikely to be a cause for concern (<0.5 mg/l). For TON,10 lakes had 75%ile concentrations exceeding 1 mg l^{-1} of which 6 also exceeded 2 mg l^{-1} (Figure 5.1.1). For TN, 14 lakes had mean TN levels exceeding 1 mg l^{-1}, of which 5 also exceeded 2 mg l^{-1} (Figure 5.1.2). There was a good correlation between TN and TON, especially at higher nitrogen concentrations (Figure 5.1.3), suggesting that absence of either TN or TON data is unlikely to significantly alter the conclusion in most cases.

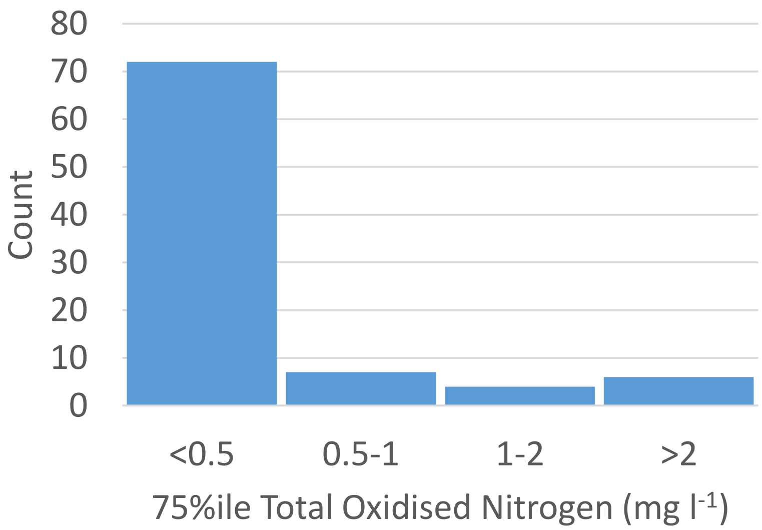


Figure 5.1.1. Frequency distribution of the 75%ile TON concentrations of Welsh lakes.

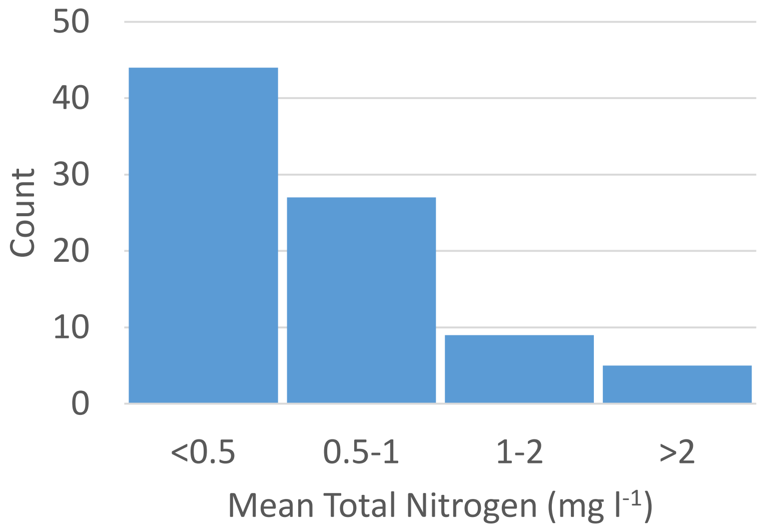


Figure 5.1.2. Frequency distribution of the mean TN concentrations of Welsh lakes.

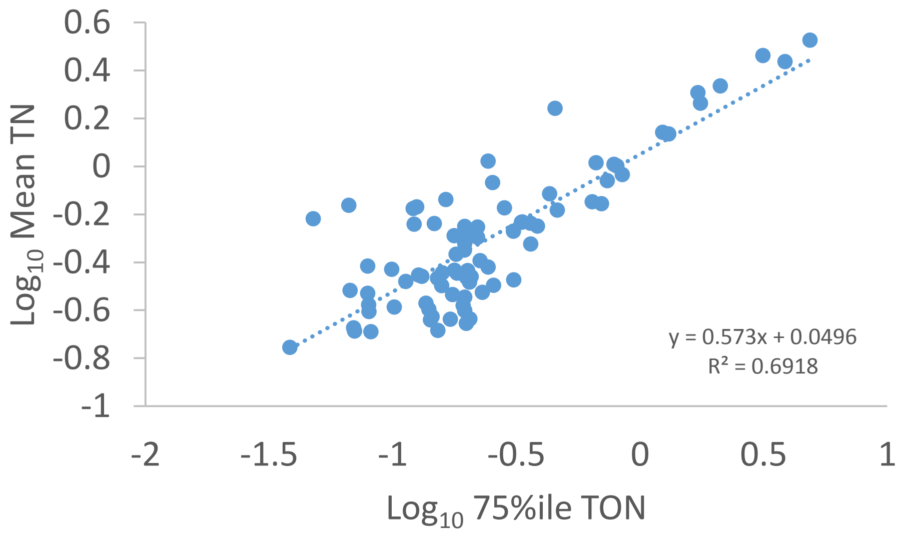


Figure 5.1.3. Relationship between Mean TN and 75%ile TON concentrations (mg l^{-1}).

There was a weaker relationship between TN and TP (Figure 5.1.4). Although there was a fairly good correlation at phosphorus concentrations below about 50 µg l^{-1} TP and about 0.5 mg l-1 TN, there was much more scatter in the relationship above these concentrations (Figure 5.1.4). This presumably reflects enrichment by either nitrogen or phosphorus starting to alter nutrient availability in the lakes.

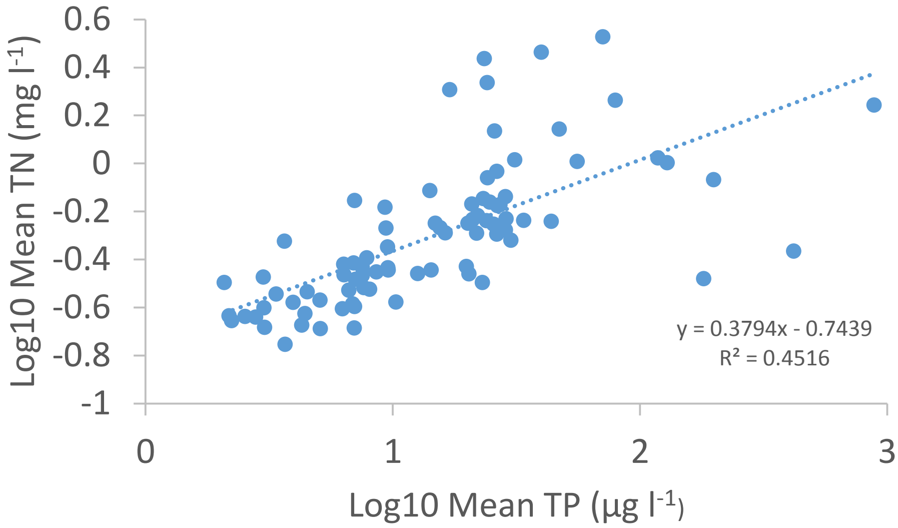


Figure 5.1.4. Relationship between Mean TN (mg l^{-1}) and geometric Mean TP (µg l^{-1}) concentrations.

Based on the nitrogen data alone, the following lakes have high nitrogen levels (>2 mg l^{-1}) and therefore are considered at high risk of eutrophication:

- Bosherston Lakes (Western, Central and Eastern)
- Plas Uchaf & Dolwen Reservoirs
- Llyn Maelog
- Llyn yr Wyth Eidion

The following additional lakes have elevated nitrogen levels (>1 mg l^{-1}) and are at risk of eutrophication:

- Llyn Coron
- Llandegfedd Reservoir
- Cefni Reservoir
- Hanmer Mere
- Llys-y-Fran Reservoir
- Llyn Dinam
- Llyn Alaw
- Llangorse Lake

5.2. Ecological Evidence using the WoE Tool

Ecological evidence was compiled from 101 lakes throughout Wales in relation to the eutrophication pressure. Of these, 80 were considered to have either no eutrophication problem, or a problem that was uncertain. These are listed in Appendix 5.

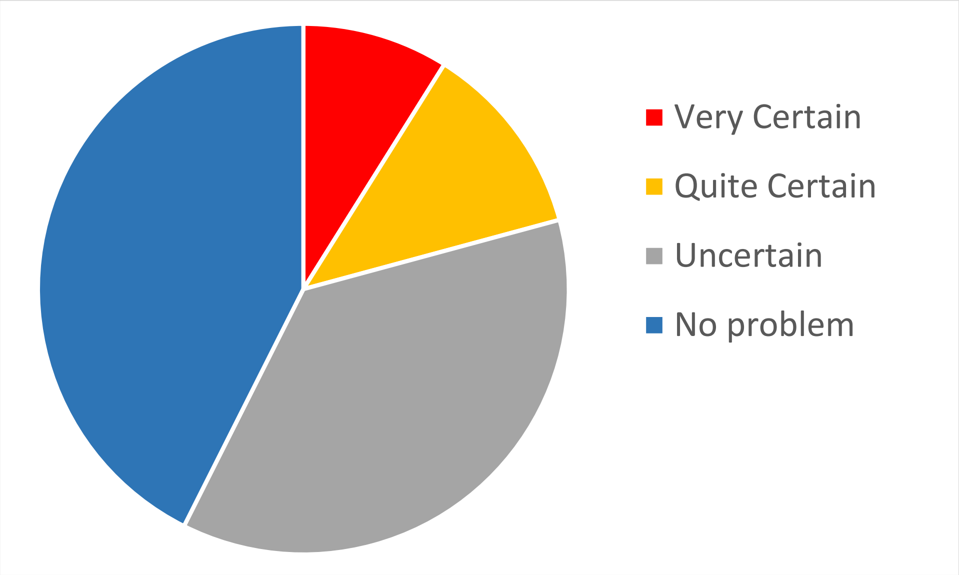


Figure 5.2.1. Confidence of eutrophication impact in Welsh lakes

21 lakes were considered to have either a ‘quite certain’ or ‘very certain’ confidence of eutrophication impact (Figure 5.2.1). These are as follows:

Very Certain:

- Bosherston Lakes (Eastern Arm)
- Hanmer Mere
- Llandegfedd Reservoir
- Llangorse Lake
- Llyn Coron
- Llyn Dinam
- Llyn Pencarreg
- Llyn Tegid
- Witchett Pool

Quite Certain:

- Eglwys Nunnydd Reservoir
- Llwyn-On Reservoir
- Llyn Bedydd
- Llyn Elsi Reservoir
- Llyn Padarn
- Llyn Tryweryn
- Pant-yr-Eos Reservoir
- Plas Uchaf and Dolwen Reservoirs
- Ty Mawr Reservoir
- Wentwood Reservoir
- Ynysyfro Reservoir

Potentially, any or all of the above lists could be included in NVZs. The evidence relating to each of these water bodies is summarised in greater detail in section 6, such that a decision can be made in relation to potential NVZ designation and / or other potential actions.

Fifteen lakes were considered at risk of eutrophication based on previous data, but lacked sufficient chemical data information to be considered for NVZ designation in this review. These are listed in Appendix 6. All are SSSI lakes that are not considered as water bodies under WFD.

6. Summary Information for Individual Lakes

This section outlines the status of individual lakes considered either eutrophic, or at risk of being eutrophic, in greater detail, in order to inform decision making.

6.1. Bosherston Lakes

Bosherston Lakes are a series of partially connected artificial lakes near the village of Bosherston on the south coast of Pembrokeshire, created by damming a small limestone stream for ornamental purposes between 1780 and 1860 (www.nationaltrust.org.uk). They are owned by the National Trust and much valued as a tourist attraction.

Water Body IDs: GB31047014 (Central Arm); GB31047013 (Eastern Arm); GB31047015 (Western Arm / Central Lake)
Alkalinity: Marl
Humic Type: Clear
Depth Type: Very Shallow
Naturalness: Artificial, naturalised
Protected Area: Natura 2000, SSSI
Catchment Area: 1807 ha

The lakes are very shallow and alkaline, with water levels that fluctuate substantially. The lakes are subdivided into several hydrological units by a series of causeways which function as water control structures in summer, but are overtopped in winter (Holman *et al*. 2009). The larger Eastern Arm is predominantly surface water fed from a sandstone catchment, whereas the smaller Western and Central Arms are predominantly groundwater fed from a karstic limestone aquifer (Holman *et al*. 2009). In the Western and Central Arms the plant community consists mainly of *Chara hispida*, whereas the Eastern Arm tends to be dominated by nutrient-tolerant species such as *Potamogeton crispus*, *Myriophyllum spicatum* and *Elodea canadensis*.

Bosherston Lakes are part of the Pembrokeshire Bat Sites and Bosherston Lakes Special Area of Conservation (SAC) designated under the Habitats Directive for their ‘Hard oligotrophic waters with benthic vegetation of *Chara* Spp.’ habitat. This feature is currently considered unfavourable with high confidence due to eutrophication (Hatton-Ellis & Culyer 2014). Patterns of nitrogen availability in the lakes indicate that they are occasionally nitrogen limited in summer (Hatton-Ellis & Culyer 2014).

The catchment of Bosherston Lakes is medium sized (just over 1800 ha – see Figure 6.1.1) and consists of about 66% intensive farmland, 30% semi-natural habitats and less than 5% other land use types (Table 6.1.1.). Most of the agriculture is intensive dairy farming (Environment Agency 2012b). Environment Agency (2012b) estimated the nitrogen loading from agriculture as being 99.5% of the total N loading.

There are 194 water samples for the Bosherston lakes (71 from the Eastern Arm, 70 from the Central Arm and 53 from the Western Arm), covering a period from January 2009 to December 2014. These cover all three water quality determinands, but only

TON data are available from the Western Arm and Central Lake. Ecological data comprises macrophyte surveys, phytoplankton and diatoms. This is an excellent quality dataset.

Land Use	Area (ha)	% of Catchment
Semi-natural broadleaved woodland	83.06	4.7
Planted broadleaved woodland	6.91	0.4
Semi-natural mixed woodland	11.3	0.6
Planted mixed woodland	65.99	3.8
Dense scrub	29.33	1.7
Semi-improved neutral grassland	253.53	14.5
Bracken	3.03	0.2
Tall ruderal herb	7.77	0.4
Swamp	4.52	0.3
Standing water	31.47	1.8
Dune slack	1.52	0.1
Dune grassland	24.13	1.4
Coastal grassland	1.88	0.1
Illegible code	1.54	0.1
Total Semi-natural and Low Intensity Agriculture		**30.1**
Arable	370.4	21.1
Improved grassland	784.88	44.8
Total Intensive Agriculture		**65.9**
Amenity grassland	7.35	0.4
Gardens	2.42	0.1
Buildings	46.34	2.6
Bare ground	2.09	0.1
Quarry	8.76	0.5
Total Other		**3.7**

Table 6.1.1. Land use in the Bosherston Lakes catchment.

Figure 6.1.1. Surface water catchment of Bosherston Lakes (Hughes *et al*. 2004). Base mapping © Crown Copyright and database right 2013. Ordnance Survey 100019741.

The Key Indicators for Bosherston Lakes are as follows:

Western Arm and Central Lake

Indicator	Result	Certainty < Good
Total Oxidised Nitrogen 75%ile	3.97	**Very Certain > 2**
Total Phosphorus	No Data	
Phytoplankton	Good	Good or Better
Macrophytes	Good	Good or Better
Diatoms	High	Good or Better
Condition Assessment	Unfavourable	
Palaeolimnology	Decline	
Overall WoE Tool Conclusion	Uncertain Eutrophication Problem	
Overall Eutrophication Evidence	**Marginal**	

Central Arm

Indicator	Result	Certainty < Good
Total Oxidised Nitrogen 75%ile	3.87	**Very Certain > 2**
Total Phosphorus	Good	Good or Better
Phytoplankton	High	Good or Better
Macrophytes		
Diatoms	High	Good or Better
Palaeolimnology		
Overall WoE Tool Conclusion	Certain No Eutrophication Problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Eastern Arm

Indicator	Result	Certainty < Good
Total Oxidised Nitrogen 75%ile	4.88	**Very Certain > 2**
Total Phosphorus	Poor	**Very Certain**
Phytoplankton	Good	Uncertain
Macrophytes	Poor	**Very Certain**
Diatoms	Bad	**Very Certain**
Overall WoE Tool Conclusion	Very Certain Eutrophication Problem	
Overall Eutrophication Evidence	**Very High**	

Table 6.1.2 Key indicators for Bosherston Lakes. See Table 4.6.1 for an explanation of evidence categories.

The overall picture for Bosherston Lakes is consistent with long-term monitoring data and previous studies of the ecology of the lakes (Holman *et al*. 2009; Hatton-Ellis & Culyer 2014).

Source Apportionment

NRW source apportionment for the Bosherston Lakes catchment indicated that the % N contribution from agricultural land was 94.6%, with the contribution from intensive agriculture being 64.9% (Table 6.1.3). These results indicate that agriculture is the main contributor to nitrogen loading in the catchment and agree with the previous Environment Agency (2012b) assessment.

Catchment area (ha)	1807
% Semi-Natural and Low Intensity Agriculture	30.1
% Intensive Agriculture	65.9
% Semi-Natural and All Agriculture	96
Number of consented discharges in catchment	3
Total N load from consented discharges (kg/day)	1.80
Mean catchment TON concentration (mg/l)	4.9
Total catchment flow (l/s)	290.0
Total catchment N load (kg/day)	122.3
Total catchment diffuse N load (kg/day)	120.5
Total catchment agricultural/semi-natural N load (kg/day)	115.7
Total catchment intensive agricultural N load (kg/day)	79.4
% N contribution from all agricultural/semi-natural land	94.6
% N contribution from intensive agriculture	64.9

Table 6.1.3. Source Apportionment results for Bosherston Lakes.

Recommendation: Bosherston Lakes

Due to high nutrient concentrations and associated ecological impacts indicative of eutrophication in the larger Eastern Arm, it is recommended that Bosherston Lakes remain a Nitrate Vulnerable Zone. The majority of the estimated nitrogen loading is considered to be agricultural.

Since the catchment of all three lakes is small and with a strong groundwater component, it needs to be managed as a single unit. In particular, de-designation of the catchments of the better quality Western and Central Arms but retention of the NVZ for the Eastern Arm would likely encourage increased spreading of N in the catchment of the Western and Central Arms and thereby risk deterioration. Therefore, major boundary changes to the NVZ are not recommended. However, there is a small anomaly in the existing NVZ boundary near the Devils Quoit (SM981951) where the NVZ boundary does not correspond with the contour map. This is presumably a digital elevation modelling error and needs to be corrected. It would result in a small increase in the area of the NVZ of about 1 ha.

Following external peer review, the independent expert supported NRW's recommendation that Bosherston Lakes remain an NVZ, including the comments in relation to the boundary.

Therefore it is recommended that the Bosherston Lakes NVZ is retained.

6.2. Plas Uchaf and Dolwen Reservoirs

These are two connected artificial reservoirs in Denbighshire impounding a small tributary of the Afon Elwy. They are shallow and alkaline, and are designated as a drinking water protected area, and contribute to the main water supply for the Vale of Clwyd. Plas Uchaf Reservoir is partly fed by an abstraction from the Afon Aled, supported by releases from Aled Reservoir. Dolwen Reservoir is fed by surface water drainage. The immediate catchment of the lakes is 85% intensive agriculture (Table 6.2.1). Source apportionment estimates that the % N contribution from intensive agriculture is 86.8% (Edwards 2016).

Water Body ID: GB31033261
Alkalinity: High
Humic Type: Clear
Depth Type: Shallow
Naturalness: Artificial, Impounded (Dolwen); Pumped (Plas Uchaf)
Protected Area: Drinking Water
Catchment Area: 226 ha

There are 20 water quality samples from Plas Uchaf and Dolwen Reservoirs, sampled approximately quarterly between July 2010 and November 2014. These include TN, TON and TP. Two phosphorus readings were below the 20 µg l^{-1} detection limit and were set to 10 µg l^{-1} for the purposes of analysis. The only ecological data available are for phytoplankton.

Water quality results indicate that levels of both nitrogen and phosphorus are high, with both TON and TN levels exceeding the 2 mg l^{-1} threshold with high confidence (TN = 2.90 ± 0.38 mg l^{-1} (95% CI)). Although classified as moderate, calculation using the most recent data places the phosphorus classification as just within Poor status, with confidence of being worse than good Very Certain (Table 6.2.2).

Biological data at Plas Uchaf and Dolwen Reservoiors are poor, with only phytoplankton data being available. The phytoplankton tool indicates that the lakes are failing to reach Good Status under WFD. This is based only on chlorophyll data. Since no confidence in class data are available, this has been treated as ‘Uncertain’ (Table 6.2.2) and results in an overall eutrophication evidence confidence of ‘Low’.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	2.69	0.8
Dense scrub	2.47	0.7
Unimproved acid grassland	2.85	0.8
Semi-improved acid grassland	0.53	0.2
Semi-improved neutral grassland	3.14	0.9
Bracken	2.84	0.8
Dry acid heath	6.68	1.9
Dry heath / acid grassland mosaic	1.73	0.5
Standing water	11.11	3.2
Illegible code	2.14	0.6
Total Semi-Natural and Low Intensity Agriculture		**10.4**
Arable	7.63	2.2
Improved grassland	297.49	84.6
Total Intensive Agriculture		**86.8**
Planted coniferous woodland	6.59	1.9
Buildings	3.65	1.0
Total Other		**2.9**

Table 6.2.1. Land use in the Plas Uchaf & Dolwen Reservoirs catchment (excludes abstraction catchment).

Indicator	Result	Certainty <Good
Total Oxidised Nitrogen 75%ile	3.14	**Very Certain > 2**
Total Phosphorus	Poor	**Very Certain**
Phytoplankton	Moderate	Uncertain
Weight of Evidence Tool Conclusion	Quite Certain Eutrophication Problem	
Overall Eutrophication Evidence	**Low**	

Table 6.2.2 Key indicators for Plas Uchaf and Dolwen Reservoirs. See Table 4.6.1 for an explanation of evidence categories.

Welsh Water report that the lakes have a history of bluegreen algal blooms, causing problems at water treatment works (R. Bowen pers. comm.). This provides some support for the phytoplankton status.

Source Apportionment

Source apportionment for the Dolwen Reservoir catchment (Edwards 2016) indicated that the % N contribution from agricultural land was 97.2%, with the contribution from intensive agriculture being 86.8% (Table 6.2.3). There are no consented discharges in the catchment. These results indicate that agriculture is the dominant source of nitrogen loading in the catchment.

Catchment area (ha)	226
% Semi-Natural and Low Intensity Agriculture	10.4
% Intensive Agriculture	86.8
% Semi-Natural and All Agriculture	97.2
Number of consented discharges in catchment	0
Total N load from consented discharges (kg/day)	0.0
Mean catchment TON concentration (mg/l)	3.1
Total catchment flow (l/s)	36.0
Total catchment N load (kg/day)	9.8
Total catchment diffuse N load (kg/day)	9.8
Total catchment agricultural/semi-natural N load (kg/day)	9.5
Total catchment intensive agricultural N load (kg/day)	8.5
% N contribution from all agricultural/semi-natural land	97.2
% N contribution from intensive agriculture	86.8

Table 6.2.3. Source Apportionment results for Dolwen Reservoir.

Recommendation: Plas Uchaf and Dolwen Reservoirs

Nutrient levels in these water bodies exceed the values required by both WFD and the Nitrates Directive method, resulting in blue-green algal blooms. This is in principle consistent with the NVZ method definition of ‘eutrophic’ and it is therefore recommended that the catchment of these reservoirs should be considered for NVZ designation. However, the overall evidence strength is considered to be Low.

In reaching a decision it should be noted that the ecological data supporting designation are relatively low confidence, and that the effects of the abstraction on Plas Uchaf Reservoir are uncertain. Water quality in the Aled catchment is reasonably good, but it is possible that high algal loads are nevertheless being sustained by constant replenishment of nutrients from upstream.

Following external peer review, the independent expert recommended that Plas Uchaf and Dolwen Reservoirs should not be designated as an NVZ on grounds of insufficient evidence.

NRW agrees with this recommendation and therefore an NVZ is not recommended at this location.

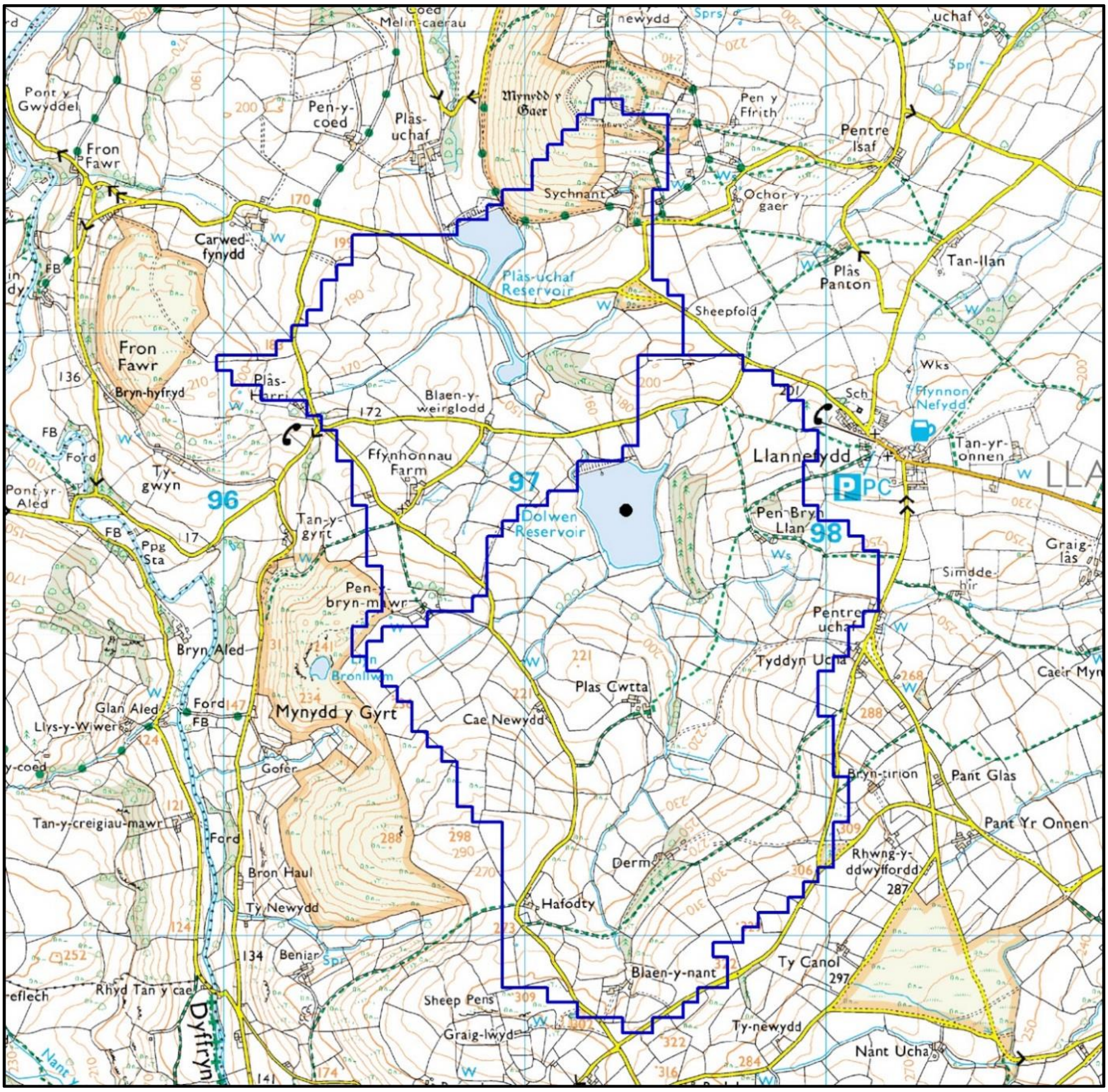


Figure 6.2.1. Surface water catchment of Plas Uchaf and Dolwen Reservoirs (Hughes *et al*. 2004). The additional area incorporated due to the abstraction is not shown.

6.3. Llyn Coron

Llyn Coron is a natural, high alkalinity, very shallow lake about 28ha in area lying at the head of the Aberffraw Dune system in southern Ynys Môn. It is fed by a small stream, the Afon Ffraw, and probably also by groundwater from the adjacent dunes. The lake habitat of Llyn Coron is designated as a Special Area of Conservation (SAC) feature under the Habitats Directive.

The catchment area is 2044 ha (Hughes *et al*. 2004), about 88% of which is intensive agriculture (Table 6.3.1). Environment Agency (2012c) calculated that more than 99% of nitrogen loading in the catchment is from agriculture.

Water Body ID: GB31033337
Alkalinity: High
Humic Type: Clear
Depth Type: Very Shallow
Naturalness: Natural
Protected Area: Natura 2000, SSSI
Catchment Area: 2044 ha

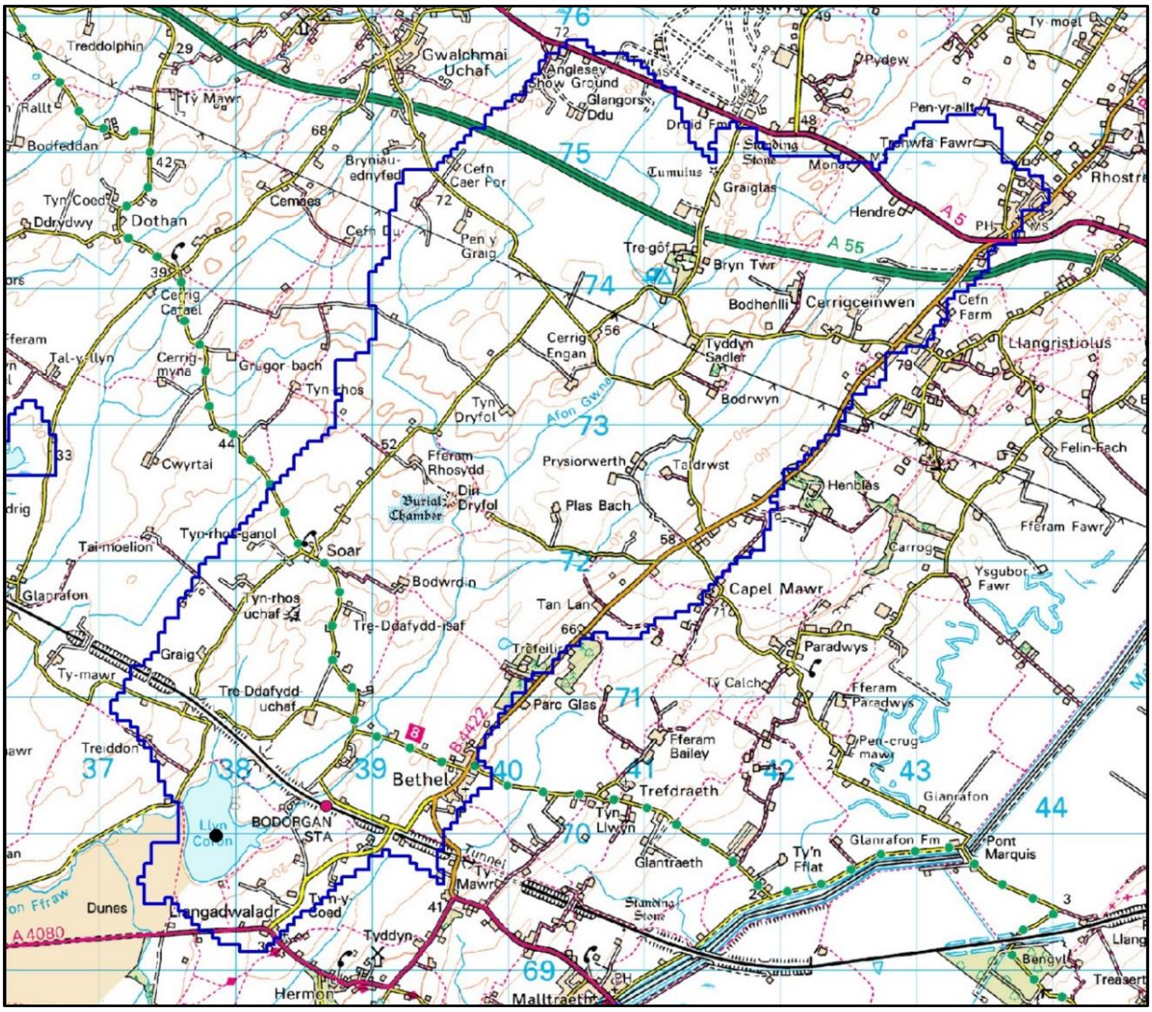


Figure 6.3.1. Surface water catchment of Llyn Coron.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	5.71	0.3
Planted broadleaved woodland	1.32	0.1
Planted mixed woodland	4.23	0.2
Dense scrub	17.08	0.9
Semi-improved acid grassland	1.89	0.1
Semi-improved neutral grassland	62.78	3.2
Marshy grassland	37.12	1.9
Bracken	4.68	0.2
Swamp	2.6	0.1
Standing water	27.05	1.4
Dune grassland	14.49	0.7
Acid / neutral cliff	1.98	0.1
Total Semi-Natural and Low Intensity Agriculture		**9.2**
Improved grassland	1728.16	87.3
Arable	21.49	1.1
Total Intensive Agriculture		**88.4**
Gardens	2.24	0.1
Planted coniferous woodland	1.09	0.1
Caravan site	2.21	0.1
Buildings	38.07	1.9
Tracks	2.16	0.1
Total Other		**2.3**

Table 6.3.1. Land use in the Llyn Coron catchment.

Data quality for Llyn Coron is excellent, with data for three different ecological tools and 72 water samples collected monthly over the review period. There are data for all relevant ecological indicators (phytoplankton, macrophytes and diatoms).

Water quality results indicate that levels of both nitrogen and phosphorus are high, with nitrogen levels exceeding the 1mg/l threshold and high phosphorus concentrations (geometric mean of c. 80 µg l^{-1}) indicative of Poor ecological status using the WFD classification tool. In spite of the presence of an existing NVZ, nitrogen concentrations have been increasing over the course of the assessment period, from a 12 monthly mean TN of 1.5 mg l^{-1} in 2009-10 to more than 2 mg l^{-1} in 2013-14 (Figure 6.3.2).

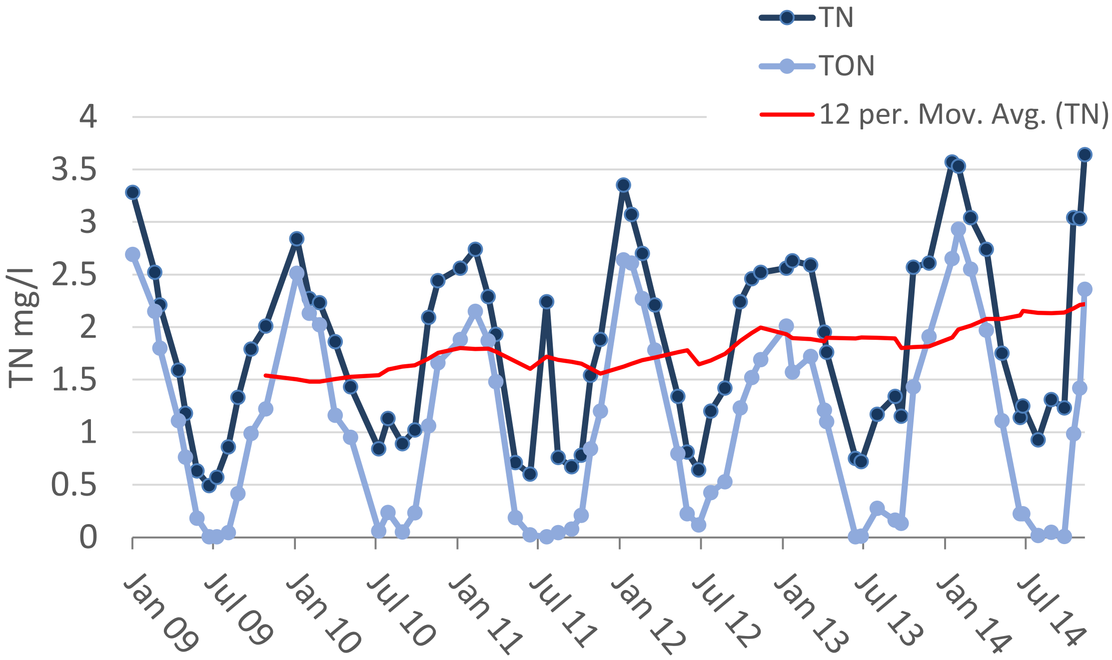


Figure 6.3.2. Nitrogen concentrations in Llyn Coron 2009-2014. The red line shows the mean TN calculated over the previous 12 months.

All of the classification tools used indicate that Llyn Coron is worse than Good status, with high confidence in the case of macrophytes and diatoms (Table 6.3.2). Aquatic plant, planktonic algae and diatom species present are restricted to those tolerant of high nutrient concentrations.

The WoE tool indicates evidence of eutrophication with high confidence, with the lake being classified at Poor Ecological Status overall and none of the classification tools indicating that the lake is at Good status. Llyn Coron is also failing to meet its performance indicators for the Habitats Directive and is therefore considered Unfavourable.

Indicator	Result	Certainty <Good
Mean Total Nitrogen	1.83	**Very Certain > 1mg**
		Quite Certain < 2 mg
Total Phosphorus	Poor	**Very Certain**
Phytoplankton	Moderate	Uncertain
Macrophytes	Moderate	**Very Certain**
Diatoms	Moderate	**Very Certain**
SAC Condition Assesment	Unfavourable	**Very Certain**
Weight of Evidence Tool Conclusion	Very Certain Eutrophication Problem	
Overall Eutrophication Evidence	**High**	

Table 6.3.2 Key indicators for Llyn Coron. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llyn Coron

Nutrient levels (both nitrogen and phosphorus) in Llyn Coron exceed the values required by both WFD and the Nitrates Directive method. In addition, there is very strong, high confidence ecological evidence of ecological impacts of eutrophication (Table 6.3.1). More than 99% of the nitrogen loading to the lake comes from agricultural sources (Environment Agency 2012c).

This is consistent with the NVZ method definition of ‘eutrophic’ and it is therefore recommended that Llyn Coron should be retained as an NVZ. The increasing nitrogen levels in the lake are a cause for concern and suggest that the NVZ measures are not having the desired effect in this catchment.

Following external peer review, the independent expert supported NRW’s recommendation that Llyn Coron remain an NVZ. Therefore, it is recommended that Llyn Coron remain an NVZ.

6.4. Llyn Maelog

Llyn Maelog is a very shallow, natural alkaline lake in southwest Ynys Môn, again lying close to sea level at the head of a dune system and designated as a Site of Special Scientific Interest (SSSI) for its lake habitat. It is very similar in area to Llyn Coron (23.8 ha).

The catchment area is 1840 ha (Hughes *et al*. 2004), 81% of which is intensive farmland (Table 6.4.1). Environment Agency (2012f) estimated the contribution of agriculture to be just over 98% of the total nitrogen loading to the lake.

Water Body ID: 33160
Alkalinity: High
Humic Type: Clear
Depth Type: Very Shallow
Naturalness: Natural
Protected Area: SSSI
Catchment Area: 1840ha

As it is not designated as a SAC and is less than 50 ha in area, Llyn Maelog is not considered to be a water body under UK rules and therefore no formal WFD classification results are available. However, recent macrophyte survey and phosphorus data using the WFD method are available and these data have been used to assess whether the lake is eutrophic. Additionally, orthophosphorus rather than total phosphorus data are available and therefore the phosphorus concentration in the lake will have been underestimated. 24 water samples are available, collected monthly over a two year period (2013-2014). This is sufficient for analysis.

Water quality results indicate that levels of both nitrogen and phosphorus are high, with 75%ile TON levels exceeding the 2mg/l threshold. Orthophosphorus concentrations are just over 60 µg l^{-1}, placing the lake in Moderate status. The Good/Moderate boundary for this lake is 35 µg l^{-1} and the Moderate / Poor boundary 71 µg l^{-1}, so there is a significant risk of the lake dropping into the 'Poor' category if total phosphorus instead of orthophosphorus were measured.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	3.33	0.2
Dense scrub	34.49	1.9
Semi-improved acid grassland	10.54	0.6
Semi-improved neutral grassland	40.67	2.3
Marshy grassland	66.62	3.7
Bracken	8.00	0.4
Wet heath	1.86	0.1
Dry heath / acid grassland mosaic	3.07	0.2
Valley mire	33.17	1.9
Basin mire	2.07	0.1
Swamp	8.37	0.5
Standing water	24.93	1.4
Dune grassland	1.40	0.1
Quarry	17.37	1.0
Unknown	16.35	0.9
Total Semi-Natural and Low Intensity Agriculture		**15.3**
Improved grassland	1394.56	78.3
Arable	44.98	2.5
Total Intensive Agriculture		**80.8**
Amenity grassland	1.42	0.1
Gardens	7.77	0.4
Buildings	57.44	3.2
Tracks	1.73	0.1
Total Other		**3.8**

Table 6.4.1. Land use in the Llyn Maelog catchment.

The plant community was surveyed in September 2014. Although a reasonably diverse community is present, Leafpacs2 gave a result of Poor ecological status due to the dominance of nutrient-tolerant species, high cover of filamentous algae and low cover of aquatic plants, with 99% confidence that the ecological quality is worse than good.

A diatom based palaeolimnological study of Llyn Maelog (Burgess *et al*. 2009) recorded a high degree of floristic change in the diatom assemblages between the top and bottom of the core, with a squared chord distance dissimilarity score of 1.44 between core top and bottom. This was reflected in the di-TP trophic index scores which increased from 94 at the bottom of the core to 235 at the core top, indicating nutrient enrichment, reduced water clarity and a switch from benthic to pelagic production (Burgess *et al*. 2009).

These results are reflected by a SSSI condition assessment from 2009 (Burgess *et al*. 2009) which concluded that the lake was in unfavourable condition due to nutrient enrichment.

Indicator	Result	Certainty <Good
Total Oxidised Nitrogen 75%ile	3.09	**Very Certain > 2**
Total Phosphorus	Moderate	**Very Certain**
Macrophytes	Poor	**Very Certain**
Palaeolimnology	Decline	**Very Certain**
Weight of Evidence Conclusion	Very Certain Eutrophication Problem	
Overall Eutrophication Evidence	**High**	

Table 6.4.2 Key indicators for Llyn Maelog. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llyn Maelog

There is high confidence evidence both of elevated nitrogen and phosphorus at Llyn Maelog, with resulting ecological impact on the aquatic plant community. This is a high confidence evidence base consistent with the NVZ method definition of ‘eutrophic’ and it is therefore recommended that the catchment of the lake should be considered for NVZ designation.

The high proportion of agricultural land in the catchment suggests that agriculture is likely to be a major source of nutrients to the lake and therefore that an NVZ could be beneficial. It should be noted however that there are active sewage discharge consents in the catchment which should be taken into account.

> Following external peer review, the independent expert supported NRW’s recommendation that Llyn Maelog be designated an NVZ.
>
> Therefore, it is recommended that the catchment of Llyn Maelog be designated as an NVZ.

Figure 6.4.1. Surface water catchment of Llyn Maelog.

6.5. Cefni Reservoir

Cefni Reservoir is an artificial water body, one of the main drinking water supplies for Ynys Môn. It is near the centre of the island and close to the town of Llangefni. It is fed by water from the catchment. More than 85% of the catchment consists of intensive agriculture (Table 6.5.1).

Water Body ID: GB31032926
Alkalinity: High
Humic Type: Clear
Depth Type: Very Shallow
Naturalness: Artificial, impounded
Protected Area: Drinking Water
Catchment Area: 4068 ha

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	62.06	1.6
Planted mixed woodland	10.09	0.3
Dense scrub	7.1	0.2
Semi-improved neutral grassland	63.87	1.6
Marshy grassland	103.65	2.6
Wet heath	8.28	0.2
Valley mire	89.34	2.2
Swamp	11.13	0.3
Standing water	64.12	1.6
Total Semi-Natural and Low Intensity Agriculture		**10.6**
Improved grassland	3287.64	82.6
Arable	108.55	2.7
Total Intensive Agriculture		**85.3**
Planted coniferous woodland	62.67	1.6
Felled coniferous woodland	8.93	0.2
Buildings	67.65	1.7
Illegible code	15.32	0.4
Total Other		**3.9**

Table 6.5.1. Land use in the Cefni Reservoir catchment.

There were 56 water samples from Cefni Reservoir over the period 2010-2014, coupled with phytoplankton and aquatic plant data. This is considered to represent a high quality dataset.

Water quality results indicate that levels of both nitrogen and phosphorus are elevated, with nitrogen levels exceeding both the 1mg/l thresholds and phosphorus concentration consistent with Moderate Ecological Status. Although these levels constitute risk factors, they are not reflected in the biological data, with both phytoplankton and macrophytes showing Good Status. Confidence levels in all of these results were very certain (Table 6.5.2).

Indicator	Result	Certainty < Good
MeanTotal Nitrogen	1.39	**Very Certain > 1mg**
		Not > 2mg
Total Phosphorus	Moderate	**Very Certain**
Phytoplankton	Good	Good or Better
Macrophytes	Good	Good or Better
Weight of Evidence Tool Conclusion	Uncertain Eutrophication Problem	
Overall Eutrophication Evidence	**Marginal**	

Table 6.5.2. Key indicators for Cefni Reservoir. See Table 4.6.1 for an explanation of evidence categories.

These results are best interpreted as reflecting a situation where the water chemistry constitutes a risk factor to future eutrophication. It is not known why increased nutrient levels are not reflected in the plants, but potential explanations may include the use of the lake as a water supply reservoir resulting in relatively high flushing rates; the relatively high dissolved organic carbon content of the water suppressing plant growth, or grazing of algae by zooplankton. Nevertheless, it is recommended that preventative works be undertaken in the catchment of Cefni Reservoir to reduce the risk of future eutrophication.

Recommendation: Cefni Reservoir

Phosphate and Nitrate levels in Cefni Reservoir exceed the values required by both WFD and the Nitrates Directive method. At present there is no evidence of these elevated nutrient levels stimulating increased algal or plant growth. However, these nutrient levels pose a potential risk factor for future eutrophication.

At this stage the evidence does not support the designation of Cefni Reservoir as a Nitrate Vulnerable Zone. However, elevated nutrient levels provide some cause for concern and in the light of the reservoir’s importance for public water supply, would potentially justify preventative catchment measures in order to prevent possible future deterioration.

Following external peer review, the independent expert supported NRW’s recommendation that Cefni Reservoir should not be designated an NVZ.

NRW agrees with this recommendation and therefore it is recommended that Cefni Reservoir should not be designated an NVZ.

Figure 6.5.1. Surface water catchment of Cefni Reservoir.

6.6. Valley Lakes

The Valley Lakes are a cluster of eight interconnected lakes and ponds adjacent to the RAF Valley airbase in western Ynys Môn. Like many other lakes on the island they are coastal, very shallow and alkaline. The largest lakes are Llyn Penrhyn (22.3ha) and Llyn Dinam (9.7ha) (Hughes *et al*. 2004) and these are the only ones that are regularly monitored. Both are natural in origin. Llyn Traffwll is immediately adjacent to these, but lies in a different catchment and so is assessed separately.

Water Body ID: GB31032948 (Dinam); 32968 (Penrhyn)
Alkalinity: High
Humic Type: Humic (Dinam); Clear (Penrhyn)
Depth Type: Very Shallow
Naturalness: Natural
Protected Area: Natura 2000 and SSSI (Dinam); SSSI (Penrhyn)
Catchment Area: 223 ha (Dinam); 160 ha (Penrhyn)

All of the Valley Lakes are protected areas, designated as the Llynnau y Fali SSSI. Llyn Dinam is additionally designated as a Special Area of Conservation (SAC) under the Habitats Directive for its eutrophic lakes feature. The catchments of the two lakes differ markedly. Llyn Dinam has a rural catchment with (Table 6.6.1) nutrients coming predominantly from diffuse sources, whereas the smaller catchment of Llyn Penrhyn is heavily influenced by the RAF Valley air force base and associated housing, including sewage discharge and road runoff (Figure 6.6.1). Both lakes have a groundwater influence.

Llyn Dinam

The Llyn Dinam catchment originally digitised by Hughes *et al*. (2004) has been redigitised as the original catchment map is not consistent with more up to date information on the local topography and drainage patterns. Intensive agriculture covers 75% of the catchment (Table 6.6.1).

There are 69 water samples from Llyn Dinam, covering a period from January 2009 to October 2014. Ecological data comprises phytoplankton, macrophytes and diatoms. This is an excellent dataset.

A single measurement for total nitrogen of 3.75 mg l^{-1} was much higher than any other value in the TN dataset. However, it should be noted that concentrations adjacent in the series were also elevated to a lesser extent, so this value is not necessarily an error. Removal of this datapoint would have resulted in a small reduction in the overall mean total nitrogen, to 1.01 mg l^{-1}.

Three values of total phosphorus of 811, 1430 and 961 µg l^{-1} were much higher than any other values in the dataset, and were not consistent either with TP measurements in previous or subsequent months, or with Ortho-P samples from the same sample. These were removed from the analysis.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	0.72	0.3
Dense scrub	5.48	2.5
Semi-improved acid grassland	6.29	2.9
Semi-improved neutral grassland	7.17	3.3
Marshy grassland	5.16	2.4
Bracken	0.81	0.4
Dry heath / acid grassland mosaic	0.28	0.1
Swamp	8.28	3.8
Standing water	9.46	4.4
Illegible code	3.18	1.5
Total Semi-Natural and Low Intensity Agriculture		**21.6**
Improved grassland	161.55	74.7
Arable	0.75	0.3
Total Intensive Agriculture		**75.0**
Buildings	6.75	3.1
Tracks	0.45	0.2
Total Other		**3.3**

Table 6.6.1. Land use in the Llyn Dinam catchment.

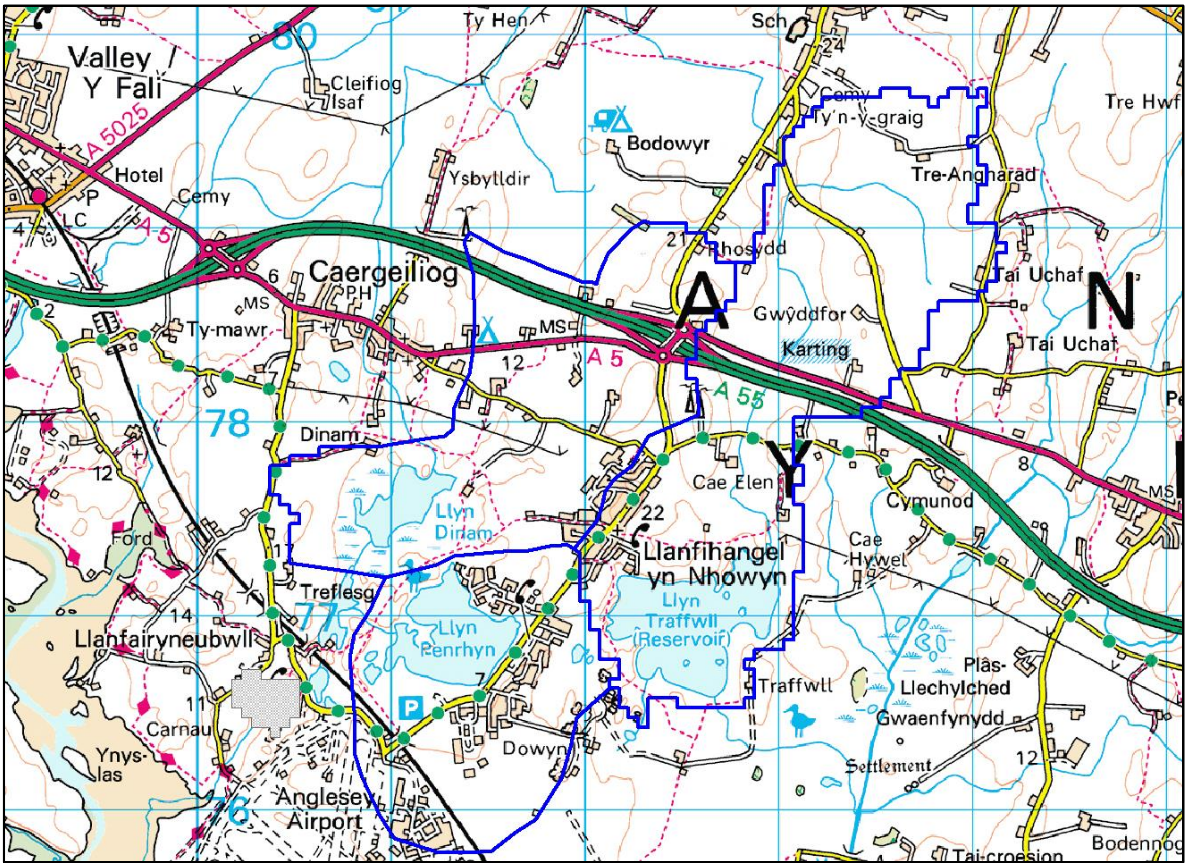


Figure 6.6.1. Surface water catchments of the Valley Lakes (left) and Llyn Traffwll (right)

Nitrate concentrations in Llyn Dinam are generally fairly low for a low altitude lake. TON concentrations drop to near zero during the growing season (Figure 6.6.2). In contrast, phosphorus concentrations are high throughout the year, with orthophosphorus generally reaching a minimum in February-March (Figure 6.6.3). This is consistent with Poor status with High confidence (Table 6.6.2).

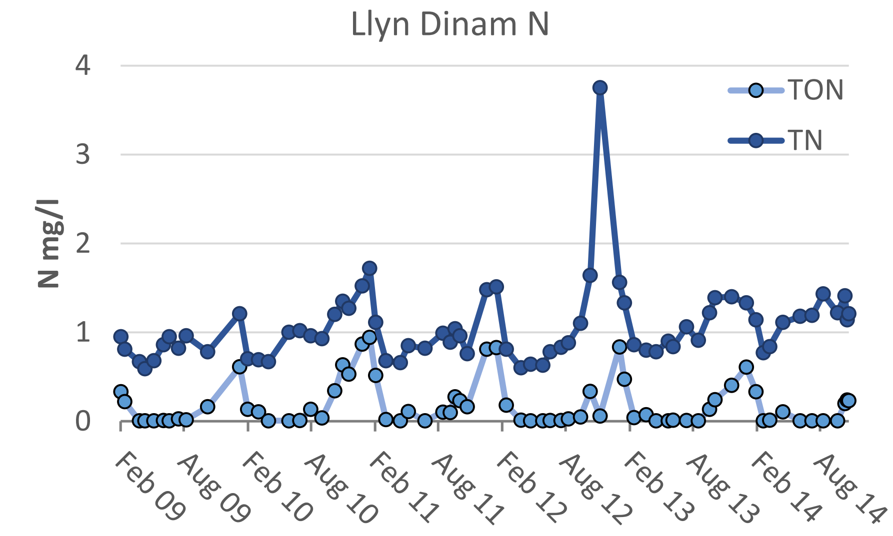


Figure 6.6.2. Nitrogen concentrations in Llyn Dinam, 2009-2014.

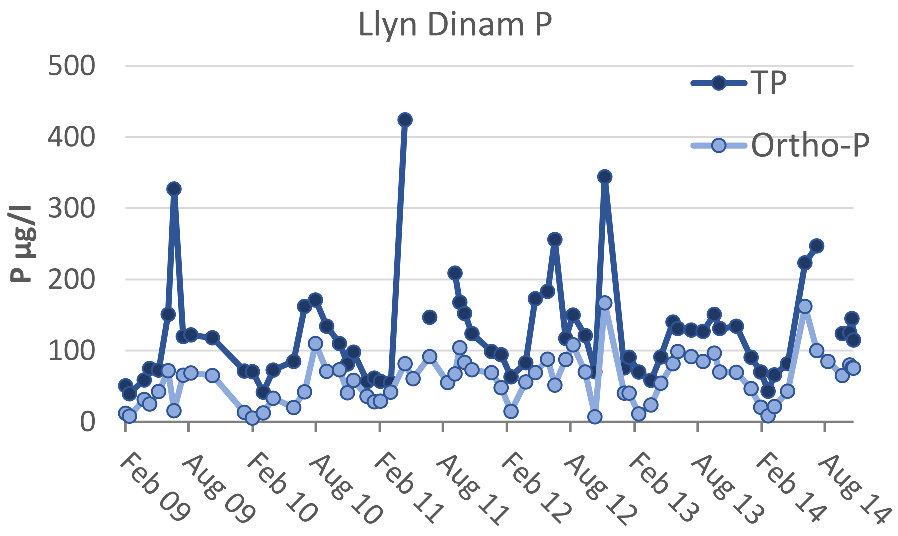


Figure 6.6.3. Phosphorus concentrations in Llyn Dinam, 2009-2014.

Nitrogen: Phosphorus ratios in the lake indicate that nitrogen limitation is possible in the lake between about May and September, with phosphorus being more likely to be limiting the rest of the time (Figure 6.6.4). However, the relatively high concentrations of phosphorus throughout most of the year mean that P is only likely to be limiting in early spring.

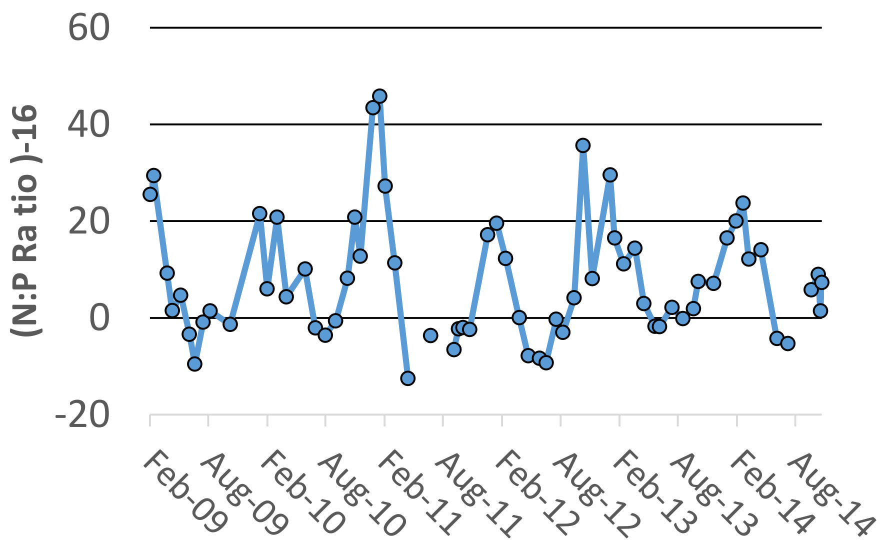


Figure 6.6.4 Molar TN:TP ratio in Llyn Dinam, adjusted so that zero is the level at which nitrogen is likely to be limiting, based on the Redfield ratio.

The ecological tools in Llyn Dinam indicate that the lake is not at Good status, and the lake is failing its SAC conservation objectives. Whilst the phytoplankton data are indicative of Good status, both the macrophyte and diatom tools indicate eutrophication. Using the WoE tool, this gives an overall Very Certain confidence of eutrophication.

Indicator	Result	Certainty < Good
Mean Total Nitrogen	1.05	Uncertain > 1 mg
Total Phosphorus	Poor	**Very Certain**
Phytoplankton	Good	Good or Better
Macrophytes	Moderate	Uncertain
Diatoms	Moderate	**Very Certain**
Weight of Evidence Tool Conclusion	Very Certain Eutrophication Problem	
Overall Eutrophication Evidence	**Medium-High**	

Table 6.6.2 Key indicators for Llyn Dinam. See Table 4.6.1 for an explanation of evidence categories.

Source Apportionment

Source apportionment for the Llyn Dinam catchment (Edwards 2016) indicated that the % N contribution from agricultural land was 88.4%, with the contribution from intensive agriculture being 68.7% (Table 6.6.3). These results indicate that agriculture is the main contributor to nitrogen loading in the catchment.

Catchment area (ha)	223
% Semi-Natural and Low Intensity Agriculture	21.6
% Intensive Agriculture	75
% Semi-Natural and All Agriculture	96.6
Number of consented discharges in catchment	4
Total N load from consented discharges (kg/day)	0.05
Mean catchment TON concentration (mg/l)	0.2
Total catchment flow (l/s)	27.1
Total catchment N load (kg/day)	0.6
Total catchment diffuse N load (kg/day)	0.5
Total catchment agricultural/semi-natural N load (kg/day)	0.5
Total catchment intensive agricultural N load (kg/day)	0.4
% N contribution from all agricultural/semi-natural land	88.4
% N contribution from intensive agriculture	68.7

Table 6.6.3. Source Apportionment results for Llyn Dinam.

Llyn Penrhyn

Seventy-four water samples have been collected from Llyn Penrhyn, covering a period from January 2009 to September 2015. These water samples have been collected and paid for by RSPB as part of their routine monitoring of the site. Although data for phosphorus are available for all samples, TON data are only available for 38 of these and chlorophyll for nine. Of the ecological indicators, only macrophyte data are available. This is considered an adequate dataset.

Nitrogen concentrations in Llyn Penrhyn are very low for a lowland lake, reflecting low levels of agricultural activity and extended periods when the lake is nitrogen limited in summer. In contrast, phosphorus concentrations are very high, reflecting the long-term impact of the RAF Valley sewage treatment works, which discharges into the lake. Improvements to the treatment at this works have resulted in a considerable drop in TP from an annual mean of c. 1000 µg l^{-1} in the early 1990s to about 250 µg l^{-1} today. However, this value is still consistent with Bad ecological status. The WFD Good / Moderate boundary value for this lake is a geometric mean of 34 µg l^{-1}.

Macrophyte survey data indicates that the lake is not meeting its condition assessment targets (Burgess *et al*. 2006; Goldsmith *et al*. 2014b), with high cover of nutrient tolerant taxa and desirable species restricted to small areas of the lake and / or shallow water. This conclusion also applies to two smaller lakes in the system, Llyn Cerrig-bach and Llyn Treflesg, for which no water quality data are available (Goldsmith *et al*. 2014c).

Indicator	Result	Certainty
Total Oxidised Nitrogen 75%ile	0.16	Not > 1 mg
Total Phosphorus	Bad	**Very Certain**
Macrophytes	Moderate	Quite Certain
Weight of Evidence Tool Conclusion	Very Certain Eutrophication Problem	
Overall Eutrophication Evidence	**Medium-High**	

Table 6.6.3. Key indicators for Llyn Penrhyn. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Valley Lakes

There is very certain evidence of elevated phosphorus at both Llyn Dinam and Llyn Penrhyn, with resulting ecological impacts on the aquatic plant and diatom communities. Nitrate concentrations are relatively lower in both lakes, and in Llyn Penrhyn especially there is evidence that plant growth is nitrogen limited in summer. This is consistent with the NVZ method definition of 'eutrophic'.

For Llyn Dinam, the majority of nitrogen and phosphorus are likely to come from agriculture. This is not the case for Llyn Penrhyn, however, where a high proportion of nutrient loading comes from the sewage treatment works. A previous Review of Consents study showed that although some backflow did occasionally occur from Llyn Penrhyn to Llyn Dinam, nutrient transfer via this method was insignificant. Rukin (in prep) estimated that about 14.5% of phosphorus entering Llyn Penrhyn was from agriculture. The proportion of N from agriculture is likely to be higher because sewage discharges tend to be relatively phosphate-rich. It is therefore possible that less than 18% of the nitrogen entering Llyn Penrhyn originate from agriculture and the very low measured nitrate values in the lake tend to support this.

It is therefore recommended that the catchment of Llyn Dinam be designated as an NVZ. No specific recommendation is provided on designation of the Llyn Penrhyn catchment but its close proximity and hydrological connections to Llyn Penrhyn via groundwater suggest that its incorporation in an NVZ for management purposes may be justified.

Following external peer review, the independent expert recommended that Valley Lakes should not be designated as an NVZ due to the uncertain role of nitrogen in the enrichment of the lakes, but that further data relating to potential nitrogen limitation should be collected and that the lakes be considered again at the next review.

NRW accepts this recommendation and therefore Valley Lakes is no longer proposed as an NVZ.

Llyn Traffwll

Llyn Traffwll is another shallow, alkaline lake in western Anglesey adjoining the Valley Lakes. It is owned and managed by the RSPB as a nature reserve and designated as a Site of Special Scientific Interest for Lake Habitat. It has a small catchment (Figure 6.6.1), 89% of which consists of intensive agriculture (Table 6.7.1).

Water Body ID: 32964
Alkalinity: High
Humic Type: Clear
Depth Type: Very Shallow
Naturalness: Natural
Protected Area: SSSI
Catchment Area: 312 ha

The dataset from Llyn Traffwll is not as extensive as for many other lakes. The RSPB collected fourteen water samples between December 2009 and January 2011. These samples have been analysed for Total Phosphorus, Total Nitrogen and Orthophosphorus but not Nitrate. NRW surveyed the site for macrophytes and carried out an SSSI condition assessment (Goldsmith *et al*. 2014b) but there are no chlorophyll, diatom or palaeolimnology data.

Water chemistry data are similar to the Valley Lakes, with high levels of phosphorus consistent with Bad Ecological Status, but low nitrogen concentrations well below the 1 mg l^{-1} threshold. Extended periods of nitrogen concentrations below the detection limit in summer suggest the lake may be nitrogen limited, but due to the relatively high detection limit of 0.2 mg l^{-1} used it was not possible to confirm this.

Land Use	**Area (ha)**	**% Cover**
Dense scrub	2.02	0.7
Semi-improved acid grassland	2.68	1.0
Semi-improved neutral grassland	2.63	1.0
Marshy grassland	5.52	2.0
Bracken	4.65	1.7
Swamp	0.6	0.2
Standing water*	38.09	N/A
Illegible code	1.11	0.4
Total Semi-Natural and Low Intensity Agriculture		**7.0**
Improved grassland	238.37	86.2
Arable	7	2.5
Total Intensive Agriculture		**88.7**
Buildings	11.77	4.3
Total Other		**4.3**

Table 6.7.1. Land use in the Llyn Traffwll catchment. Standing water has been excluded from the cover calculations due to the high lake : catchment area ratio.

Using the macrophytes classification tool, the biology was on balance assessed as moderate, with 68% confidence of being worse than Good. Overall, the WoE tool gave a result of Very Certain Eutrophication Problem. The SSSI condition assessment of Unfavourable due the nutrient impacts (Goldsmith *et al*. 2014b) supported this conclusion

Indicator	Result	Confidence <Good
Total Oxidised Nitrogen 75%ile	0.63	Good or better
Total Phosphorus	Bad	**Very Certain**
Macrophytes	Moderate	Uncertain
SSSI Condition Assessment	Unfavourable	**Very Certain**
Weight of Evidence Tool Conclusion	Very Certain Eutrophication Problem	
Overall Eutrophication Evidence	**Medium-High**	

Table 6.7.2 Key indicators for Llyn Traffwll. See Table 4.6.1 for an explanation of evidence categories.

Source Apportionment

Source apportionment for the Llyn Traffwll catchment (Edwards 2016) indicated that the % N contribution from agricultural land was 95.7%, with the contribution from intensive agriculture being 88.7% (Table 6.1.3). There are no consented discharges in the catchment. These results indicate that agriculture is the dominant source of nitrogen loading in the catchment.

Catchment area (ha)	312
% Semi-Natural and Low Intensity Agriculture	7
% Intensive Agriculture	88.7
% Semi-Natural and All Agriculture	95.7
Number of consented discharges in catchment	0
Total N load from consented discharges (kg/day)	0.0
Mean catchment TON concentration (mg/l)	0.6
Total catchment flow (l/s)	38.9
Total catchment N load (kg/day)	2.1
Total catchment diffuse N load (kg/day)	2.1
Total catchment agricultural/semi-natural N load (kg/day)	2.0
Total catchment intensive agricultural N load (kg/day)	1.9
% N contribution from all agricultural/semi-natural land	95.7
% N contribution from intensive agriculture	88.7

Table 6.7.3. Source Apportionment results for Llyn Traffwll.

Recommendation: Llyn Traffwll

There is evidence of elevated phosphorus at Llyn Traffwll, with resulting ecological impacts on the aquatic plant community and SSSI feature. Nitrate concentrations are low, however, and it is probable that plant growth is nitrogen limited in summer. Confidence in this conclusion is moderate, due to the relatively small dataset, but it is consistent with the pattern also observed in the adjacent Valley Lakes.

Due to the high confidence of eutrophication in the WoE tool, Llyn Traffwll is considered to be eutrophic with Medium-High confidence. This is consistent with the NVZ method definition of 'eutrophic' and it is therefore recommended that the catchment should be considered for NVZ designation.

Following external peer review, the independent expert recommended that Llyn Traffwll should not be designated as an NVZ due to the uncertain role of nitrogen in the enrichment of the lakes, but that further data especially relating to nitrogen limitation should be collected and that the lake be considered for designation again at the next review.

NRW accepts this recommendation and therefore Llyn Traffwll is no longer proposed as an NVZ.

6.7. Llyn Alaw

Llyn Alaw is an artificially constructed reservoir and at 308 ha is the largest lake on Ynys Môn. It is the main public water supply for the northern part of the island and is moderate alkalinity and very shallow. The reservoir was constructed on a lowland fen and hence the water is naturally rather peaty. It is designated as a Drinking Water Protected Area and Site of Special Scientific Interest for its lake habitat.

Water Body ID: GB31032538
Alkalinity: Moderate
Humic Type: Humic
Depth Type: Very Shallow
Naturalness: Artificial, impounded.
Protected Area: Drinking Water, SSSI
Catchment Area: 3339 ha

The catchment of Llyn Alaw consists mainly of intensive agriculture (91%).

There are 69 water samples from Llyn Alaw, from January 2009 to December 2014. This is coupled with biological data on both phytoplankton and macrophytes. This is considered an excellent quality dataset.

Nitrogen concentrations in Llyn Alaw are slightly elevated, with TN exceeding the 1 mg l^{-1} threshold with low confidence (TN = 1.03 ± 0.07 mg l^{-1} (95% CI)). The 75%ile winter nitrate was lower at 0.66 mg l^{-1}. The phosphorus data from Llyn Alaw is indicative of Moderate ecological status, with high confidence. However, it should be noted that because Llyn Alaw is peat influenced, total phosphorus levels may be naturally higher than expected, hence the phosphorus model may in this case be unduly pessimistic. For this reason the confidence of less than Good for phosphorus has been reduced to ‘Uncertain’ (Table 6.8.2).

Land Use	**Area (ha)**	**% Cover**
Semi-natural broadleaved woodland	7.88	0.3
Planted broadleaved woodland	5.17	0.2
Planted mixed woodland	1.9	0.1
Dense scrub	19.01	0.6
Semi-improved acid grassland	2.08	0.1
Semi-improved neutral grassland	32.05	1.1
Marshy grassland	44.21	1.5
Fen	5.99	0.2
Valley mire	19.28	0.6
Swamp	21.35	0.7
Standing water*	288.25	N/A
Inundation vegetation	12.98	0.4
Acid / neutral rock	6.89	0.2
Illegible code	2.45	0.1
Total Semi-Natural and Low Intensity Agriculture		**6.1**
Improved grassland	2587.23	86.9
Arable	127.56	4.3
Total Intensive Agriculture		**91.2**
Planted coniferous woodland	11.78	0.4
Amenity grassland	5.71	0.2
Buildings	58.15	2.0
Tracks	2.18	0.1
Total Other		**2.7**

Table 6.8.1. Land use in the Llyn Alaw catchment. Standing water has been excluded from the cover calculations due to the high lake : catchment area ratio.

Both the macrophyte and phytoplankton results indicate that Llyn Alaw is Good Status with high confidence. This results in an overall WoE conclusion of Certain No Eutrophication Problem.

Indicator	Result	Confidence < Good
Mean Total Nitrogen	1.03	Uncertain > 1 mg
Total Phosphorus	Moderate	Uncertain
Phytoplankton	Good	Good or Better
Macrophytes	Good	Good or Better
Weight of Evidence Tool Conclusion	Certain no eutrophication problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Table 6.8.2 Key indicators for Llyn Alaw. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llyn Alaw

As for Cefni Reservoir, the chemistry in Llyn Alaw shows some signs of enrichment. This is not reflected in ecological impacts, suggesting that the lake is at present sufficiently resilient to absorb this pressure. However, these nutrient levels may pose a potential risk factor for future eutrophication.

At this stage the evidence does not support the designation of Llyn Alaw as a Nitrate Vulnerable Zone. However, slightly elevated nutrient levels provide some cause for concern and in the light of the reservoir's importance for public water supply, would justify preventative catchment measures in order to prevent possible future deterioration.

> Following external peer review, the independent expert agreed with NRW's recommendation that Llyn Alaw should not be designated as an NVZ. NRW agrees with this recommendation and therefore Llyn Alaw is not recommended for NVZ designation.

Figure 6.8.1. Surface water catchment of Llyn Alaw.

6.8. Llyn yr Wyth Eidion

Llyn yr Wyth Eidion is a small, alkaline, shallow kettle-hole lake within the Cors Erddreiniog fen system, designated for the ‘Hard oligotrophic lakes with *Chara*’ lake type. There have been 19th century modifications to the drainage patterns that are thought to have contributed to long term damage to the lake (Davidson *et al*. 2009). The lake is not designated as a water body under WFD and therefore the targets used are the SAC management plan targets (CCW 2008).

Water Body ID: 32761
Alkalinity: Marl
Humic Type: Clear
Depth Type: Shallow
Naturalness: Natural
Protected Area: SAC, SSSI
Catchment Area: c. 273 ha (but with groundwater influence)

The catchment of Llyn yr Wyth Eidion is smaller than that shown on the UKLakes dataset, because the drainage of about 100ha of land to the north of the lake was recently diverted away. The catchment area and land use has consequently been modified (see Figure 6.9.1 and Table 6.9.1). About 70% of the land use of Llyn yr Wyth Eidion consists of intensive agriculture (mainly improved grassland) with most of the remainder being habitats associated with the Cors Erddreiniog fen system (Table 6.9.1).

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	11.65	4.3
Planted mixed woodland	7.3	2.7
Dense scrub	3.84	1.4
Semi-improved neutral grassland	2.38	0.9
Marshy grassland	7.81	2.9
Bracken	0.73	0.3
Wet heath	1.01	0.4
Basic flush	2.69	1.0
Valley mire	21.06	7.7
Swamp	0.68	0.2
Standing water	0.65	0.2
Total Semi-Natural and Low Intensity Agriculture		**22.0**
Improved grassland	182.68	66.9
Arable	8.68	3.2
Total Intensive Agriculture		**70.1**
Quarry	6.36	2.3
Caravan site	10.61	3.9
Buildings	1.43	0.5
Total Other		**6.7**

Table 6.9.1. Land use in the Llyn yr Wyth Eidion surface water catchment.

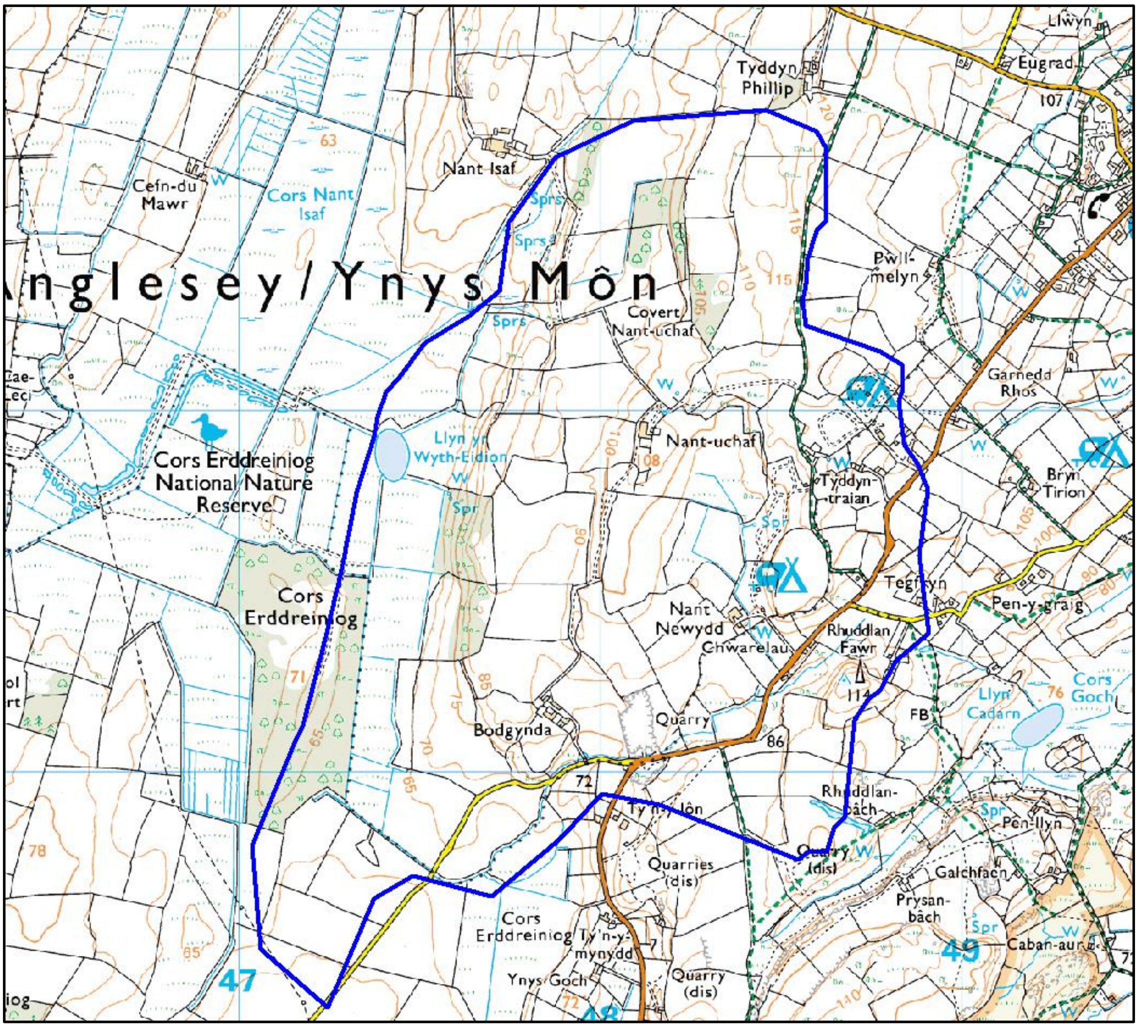


Figure 6.9.1. Surface water catchment of Llyn yr Wyth Eidion.

There are only five water samples collected from the lake itself within the sampling period. These consist of a sample from January 2009 that was part of the CCW condition assessment (Burgess *et al*. 2015) and five samples collected by EA Wales. Three additional samples collected in April, July and October 2008 (Burgess *et al*. 2012) are added for context. The CCW samples included data for TP, TN and TON. The EA Wales samples included only one TP measurement, and data for orthophosphorus was measured using the standard detection limit. All four samples were below the detection limit. Additional water quality data has been collected during various projects associated with the Anglesey Fens Life Project, and although this could not be used to directly assess the standard NVZ metrics, it has been used to provide context. Biological data is restricted to a macrophyte survey (Goldsmith *et al*. 2014c), but there is a full SAC condition assessment (Burgess *et al*. 2013), detailed palaeolimnological data for this site (Goldsmith *et al*. 2013) and for the nearby Llyn Cadarn (Davidson *et al*. 2009).

Despite the small sample size, chemical data are indicative of high nitrogen levels. Mean TN was 2.03 ± 0.44 mg l^{-1} (95% CI) and the estimated 75%ile TON was 1.72 mg l^{-1}. This is well above the 1 mg l^{-1} TN target for the site in the NRW SAC Core

Management Plan, and supported by data from two nearby boreholes[2] which record mean Nitrate-N between 2009 and 2015 as 4.47 and 3.23 mg l^{-1} respectively. Total phosphorus concentrations in the lake were estimated as 19.53± 4.23 µg l^{-1} (95% CI) which is above the SAC management target of 15 µg l^{-1} with high confidence. Confidence in this conclusion is very certain.

The condition assessment (Burgess *et al*. 2013) concluded that the SAC feature was unfavourable with high confidence due to elevated nutrient levels, absence of the stoneworts that are a characteristic feature of this lake type and loss of sensitive aquatic plant species (Table 6.9.2). The current plant community consists predominantly of *Fontinalis antipyretica* and water lilies. Underwater photography indicates a total lack of macrophytes below about 3 m depth. More recent plant survey data (Goldsmith *et al*. 2014c) indicate that this situation still pertains.

A palaeolimnological study (Goldsmith *et al*. 2013) indicates a dramatic switch from a stonewort dominated marl-producing lake to a degraded more peaty lake during the mid to late 19th century, probably associated with drainage works carried out at this time. This lends support to the conclusion that the lake is damaged, but suggests that other causes than nutrient enrichment are contributing to the damage. However, there is little doubt that there are both elevated nutrient levels and consequent ecological impacts at Llyn yr Wyth Eidion.

Indicator	Result	Confidence < Good
Total Nitrogen	2.03	**Very Certain > 1mg**
		Uncertain > 2mg
Total Phosphorus	Unfavourable	**Very Certain**
Dissolved Oxygen	Good	Uncertain
Macrophytes	Unfavourable	**Very Certain**
Palaeolimnology	Decline	**Very Certain**
Expert Judgment Conclusion	Very certain eutrophication problem	
Overall Eutrophication Evidence	**High**	

Table 6.9.2. Key indicators for Llyn yr Wyth Eidion. See Table 4.6.1 for an explanation of evidence categories.

Due to the type of data available it has not been possible to use the WoE tool as per other assessments. Instead an expert judgment conclusion of Very Certain Eutrophication Problem has been reached based on the principles used in the WoE tool (Table 6.9.2).

[2] Sample points 28110 and 28111.

Source Apportionment

Source apportionment for the Llyn yr Wyth Eidion catchment indicated that the % N contribution from agricultural land was 92.1%, with the contribution from intensive agriculture being 70.1% (Table 6.1.3). There are no consented discharges in the catchment. These results indicate that agriculture is the dominant source of nitrogen loading in the catchment.

Catchment area (ha)	273
% Semi-Natural and Low Intensity Agriculture	22.0
% Intensive Agriculture	70.1
% Semi-Natural and All Agriculture	92.1
Number of consented discharges in catchment	0.0
Total N load from consented discharges (kg/day)	0.0
Mean catchment TON concentration (mg/l)	2.0
Total catchment flow (l/s)	47.8
Total catchment N load (kg/day)	8.4
Total catchment diffuse N load (kg/day)	8.4
Total catchment agricultural/semi-natural N load (kg/day)	7.7
Total catchment intensive agricultural N load (kg/day)	5.9
% N contribution from all agricultural/semi-natural land	92.1
% N contribution from intensive agriculture	70.1

Table 6.9.3. Source Apportionment results for Llyn yr Wyth Eidion.

Recommendation: Llyn yr Wyth Eidion

Despite a relatively small dataset, there is strong evidence of both elevated nutrient concentrations and consequent ecological impacts at Llyn yr Wyth Eidion, with High Confidence. This gives an overall High quality evidence base for eutrophication (Table 4.6.1). It should be noted that irrespective of the true nitrogen concentration, the confidence of eutrophication is at least Medium-High and potentially Very High. When considering whether NVZ designation is appropriate, consideration should be given to downgrade the overall risk to Medium-High in the light of the relative paucity of water chemistry data. Source apportionment indicates that agriculture is the principal source of N loading in this lake.

Based on the above, Llyn yr Wyth Eidion should be considered for NVZ designation. It should be noted that the best chance of restoring the lake should also include other measures including diverting the present inflow stream from the south away from the lake, as was the case in the 19th century.

Following external peer review, the independent expert agreed with NRW's recommendation that Llyn yr Wyth Eidion should be designated as an NVZ.

It is therefore recommended that the catchment of Llyn yr Wyth Eidion be designated as an NVZ.

6.9. Llangorse Lake

Llangorse Lake is a large (140 ha), shallow, high alkalinity lake in the Brecon Beacons National Park, and is the largest natural lake in South Wales. The lake is designated as an SSSI and SAC for lake habitat and is much valued for recreational uses including boating, windsurfing and swimming.

The catchment is rural and consists mainly of a mixture of improved pasture and upland grassland and heath (Figure 6.10.1). About two-thirds of the catchment consists of intensive agriculture (Table 6.10.1). Environment Agency (2012d) calculated that just over 99% of nitrogen loading in the Llangorse Lake catchment comes from agricultural sources.

Water Body ID: GB30940067
Alkalinity: High
Humic Type: Clear
Depth Type: Very Shallow
Naturalness: Natural
Protected Area: Natura 2000, SSSI
Catchment Area: 2254

The environmental history and eutrophication status of Llangorse Lake has been very well studied. Historically, the main focus has been on pollution from two sewage treatment works which caused very severe eutrophication impacts during the mid 1970s (Duigan *et al*. 1999; Bennion & Appleby 1999; Benson-Evans *et al*. 1999; Wade 1999). These were diverted by the early 1990s and since then the lake has undergone a marked recovery in quality. However, nutrient concerns and associated ecological problems persisted (Burgess *et al*. 2006; Hatton-Ellis 2012a) and a study of catchment nutrient inputs (May *et al*. 2008) demonstrated that these needed reducing and that the lake was nitrogen limited during the growing season (May *et al*. 2010). The catchment of the lake was designated a Nitrate Vulnerable Zone in 2012.

There are 67 water samples from Llangorse Lake, from January 2009 to November 2014. This is coupled with biological data on phytoplankton, diatoms and macrophytes. This is an excellent quality dataset.

Nitrogen concentrations in Llangorse Lake are slightly elevated, marginally exceeding the 1 mg l^{-1} threshold with peaks occurring in winter (TN = 1.01 ± 0.12 mg l^{-1} (95% CI); 75%ile TON = 0.81 mg l^{-1}). In the growing season (around April-October), nitrate levels are very low, although total nitrogen remains fairly significant, indicating that all available nitrogen is being absorbed by phytoplankton and other plants (Figure 6.10.2).

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	66.25	3.0
Planted mixed woodland	3.67	0.2
Felled broadleaved woodland	1.15	0.1
Unimproved acid grassland	4.86	0.2
Semi-improved acid grassland	18.89	0.9
Semi-improved neutral grassland	74.53	3.4
Marshy grassland	34.58	1.6
Bracken	174.93	7.9
Dry acid heath	93.07	4.2
Wet heath	2.17	0.1
Dry heath / acid grassland mosaic	15.23	0.7
Wet heath / acid grassland mosaic	4.1	0.2
Swamp	15.79	0.7
Standing water	123.15	5.6
Total Semi-Natural and Low Intensity Agriculture		**28.8**
Improved grassland	1371.81	61.8
Arable	94.38	4.3
Total Intensive Agriculture		**66.1**
Planted coniferous woodland	65.55	3.0
Amenity grassland	2.16	0.1
Caravan site	1.29	0.1
Buildings	37.95	1.7
Illegible code	10.65	0.5
Total Other		**5.4**

Table 6.10.1. Land use in the Llangorse Lake surface water catchment.

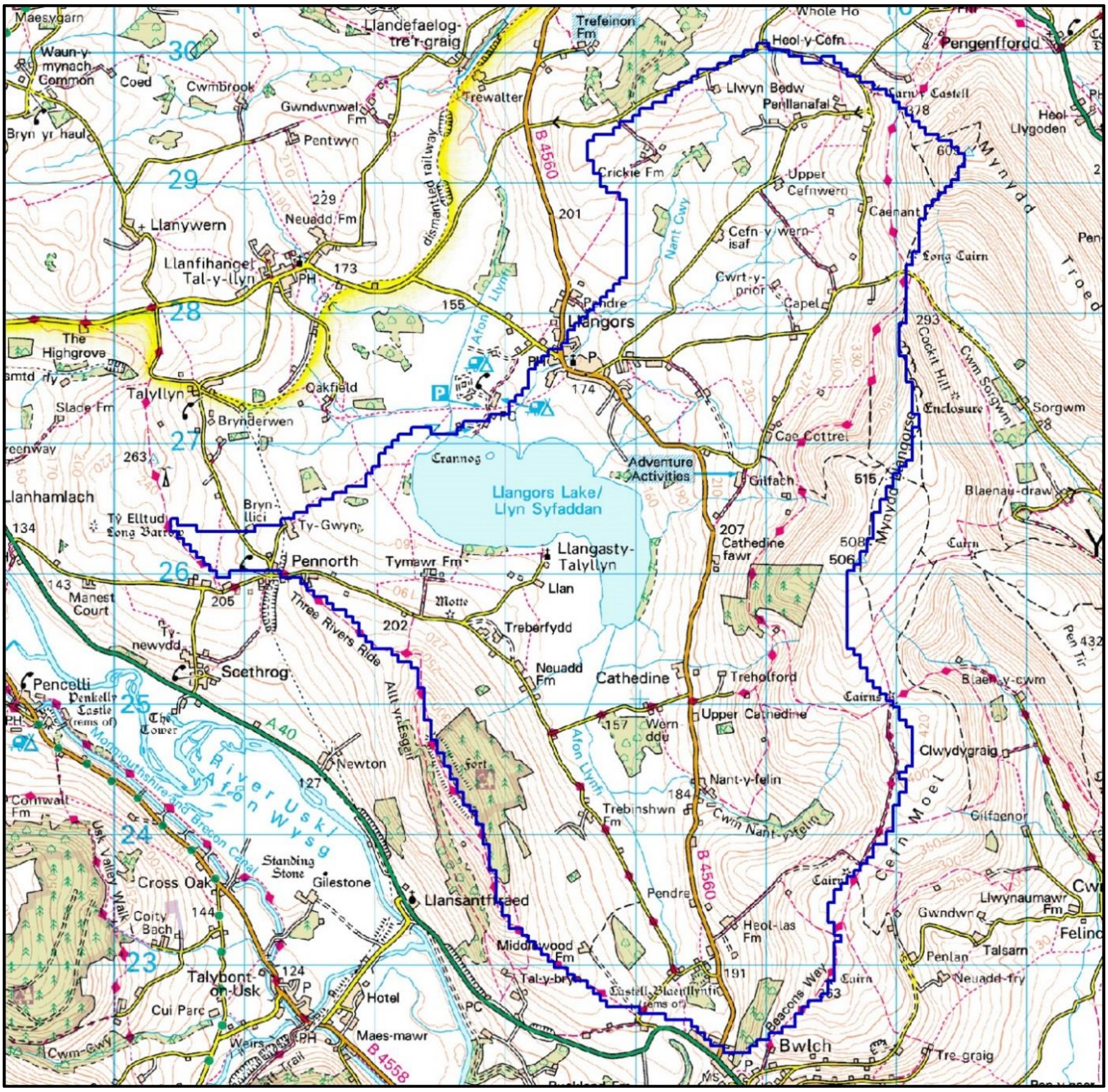


Figure 6.10.1. Surface water catchment of Llangorse Lake.

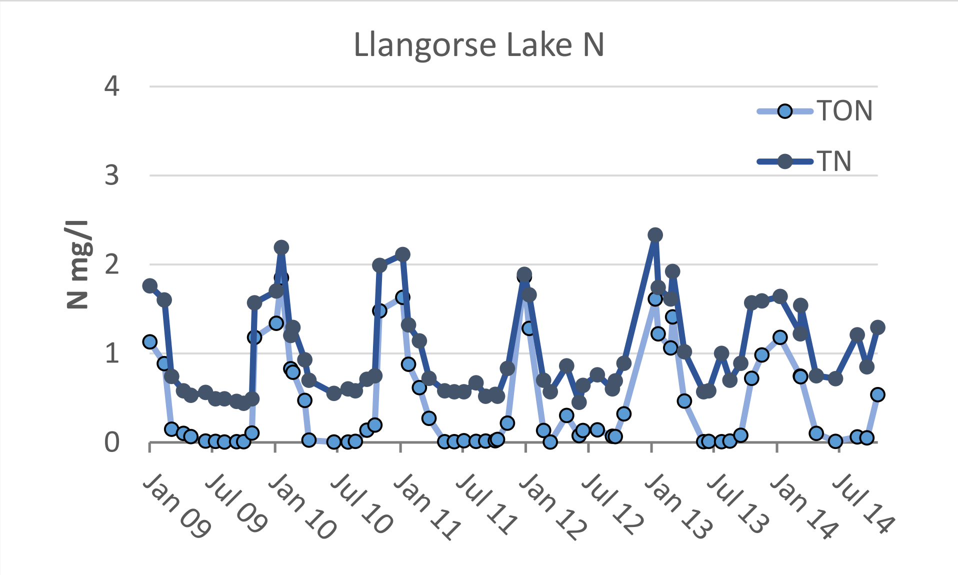


Figure 6.10.2. Nitrogen concentrations in Llangorse Lake, 2009-2014.

Phosphorus concentrations in Llangorse Lake remain very high, and may even be increasing slightly. Using the WFD phosphorus model, they are suggestive of Bad Ecological Status. This may in part be due to phosphorus being released from lake sediments, but also reflects high phosphorus loadings from the catchment (May et al. 2008, 2010).

Biological data from Llangorse Lake indicate significant ecological evidence of eutrophication. All three classification tools resulted in a result worse than good, two of them with Very Certain levels of confidence. This results in an overall WoE conclusion of Very Certain Eutrophication Problem (Table 6.10.2). These results support the SAC Condition Assessment results of Hatton-Ellis (2012a) who concluded that Llangorse Lake was in unfavourable condition due to eutrophication.

Indicator	Result	Confidence < Good
Total Nitrogen 75%ile	1.01	Uncertain > 1
Total Phosphorus	Bad	**Very Certain**
Phytoplankton	Moderate	**Very Certain**
Macrophytes	Moderate	Uncertain
Diatoms	Poor	**Very Certain**
Weight of Evidence Tool Conclusion	Very certain eutrophication problem	
Overall Eutrophication Evidence	**Medium-High**	

Table 6.10.2 Key indicators for Llangorse Lake. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llangorse Lake

Llangorse Lake has well-documented historical evidence of eutrophication and it is not surprising that this is reflected in recent data. Phosphorus concentrations remain high throughout the year. Nitrate concentrations are an important factor restricting plant growth during the growing season. There is very certain evidence demonstrating ecological impacts of eutrophication in Llangorse Lake. Using the decision matrix (Table 4.6.1), this gives an overall evidence base confidence of Medium-High. Just over 99% of nitrogen loading to the lake is estimated to come from agriculture (Environment Agency 2012d).

On this basis it is recommended that the NVZ for Llangorse Lake should be retained.

Following external peer review, the independent expert agreed with NRW's recommendation that Llangorse Lake should remain an NVZ. It is therefore recommended that Llangorse Lake remain an NVZ.

6.10. Hanmer Mere

Hanmer Mere is a natural kettle-hole mere, one of the Shropshire-Cheshire mosses and meres complex and the only one of any significant size in Wales. It is designated as a Site of Special Scientific Interest and National Nature Reserve for its lake habitat and is part of the Shropshire-Cheshire wetlands Ramsar site. The lake is predominantly groundwater-fed and was designated a Nitrate Vulnerable Zone in 2009.

Water Body ID: GB31134780
Alkalinity: High
Humic Type: Humic
Depth Type: Very Shallow
Naturalness: Natural
Protected Area: Ramsar, SSSI
Catchment Area: 93 ha

The catchment of Hanmer Mere consists mainly of intensive farmland (75%), with 17% cover of semi-natural habitats and 8% cover of other, much of which is part of the village of Hanmer to the north of the lake (Table 6.11.1; Figure 6.11.1). Just over 78% of nitrogen loading to the lake is estimated to come from agricultural sources (Environment Agency 2012e)

There are 68 water samples from Hanmer Mere, from January 2009 to November 2014. This is coupled with biological data on phytoplankton, diatoms and macrophytes. This is considered an excellent quality dataset.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	5.7	7.8
Planted broadleaved woodland	4.01	5.5
Planted coniferous woodland	0.06	0.1
Planted mixed woodland	1.6	2.2
Dense scrub	0.06	0.1
Semi-improved neutral grassland	0.79	1.1
Swamp	0.16	0.2
Standing water*	17.57	N/A
Total Semi-Natural and Low Intensity Agriculture		**17.0**
Improved grassland	50.75	69.5
Arable	4.46	6.1
Total Intensive Agriculture		**75.7**
Amenity grassland	0.66	0.9
Gardens	1.46	2.0
Buildings	3.26	4.5
Total Other		**7.4**

Table 6.11.1. Land use in the Hanmer Mere surface water catchment. Standing water has been excluded from percentage calculation due to high lake area : catchment area ratio.

Total nitrogen concentrations in Hanmer Mere are elevated, exceeding the 1 mg l^{-1} threshold (TN = 1.74 ± 0.15 mg l^{-1} (95% CI); 75%ile TON = 0.45 mg l^{-1}). Total phosphorus concentrations are very high, with an annual mean of 886 µg l^{-1}, equivalent to Bad ecological status. Very low nitrogen concentrations in summer suggest that Hanmer Mere may be nitrogen limited, as is the case for several other of the Shropshire-Cheshire meres (James *et al*. 2003).

These results are reflected in the biological classification data. Both the macrophyte and phytoplankton results indicate that Hanmer Mere is at Moderate Status, whilst the diatom tool indicates gives a classification of Poor status. All three tools are very certain that the water body is worse than Good status. This results in an overall WoE conclusion of Very Certain Eutrophication Problem (Table 6.11.2).

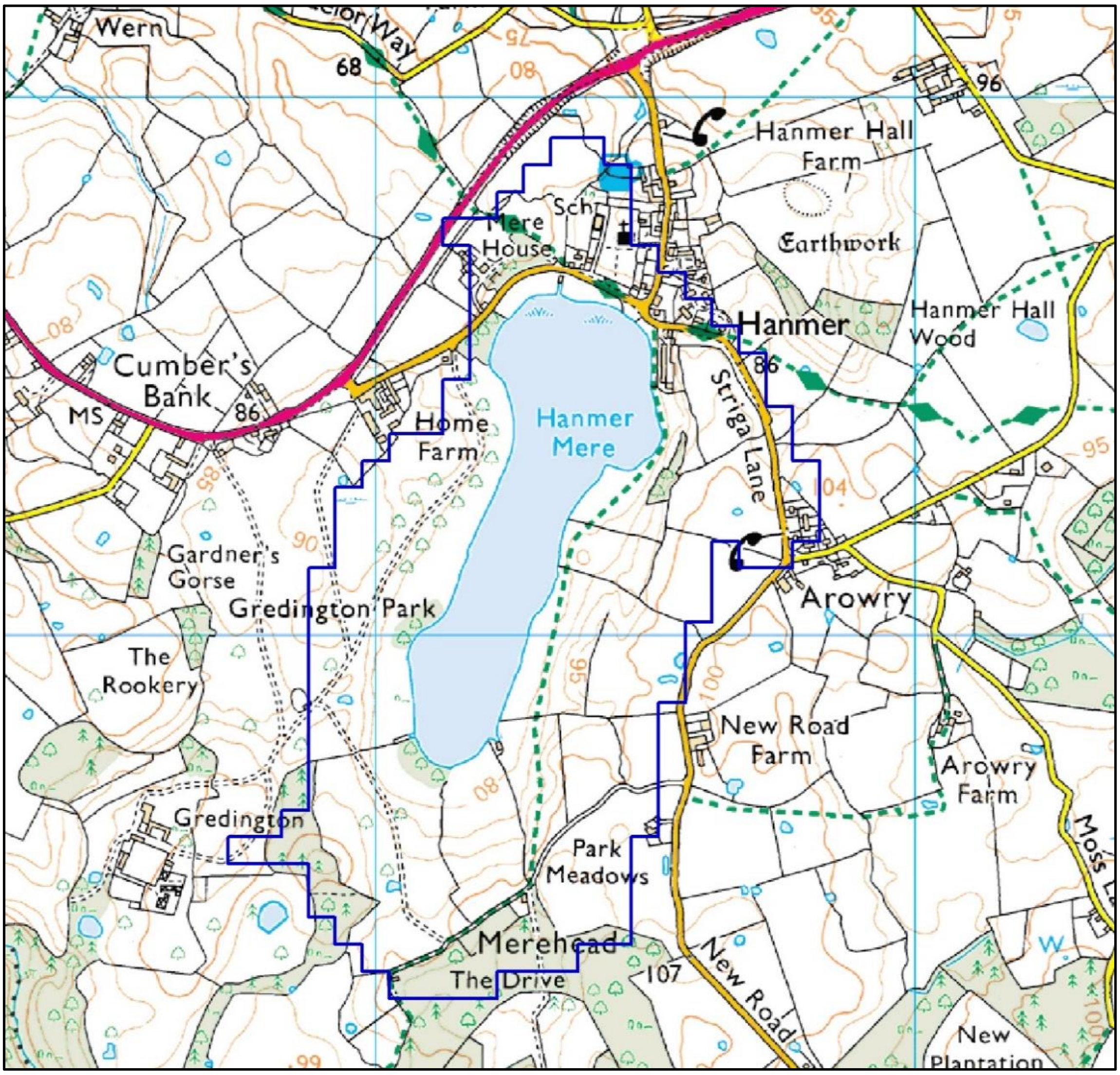


Figure 6.11.1. Surface water catchment of Hanmer Mere.

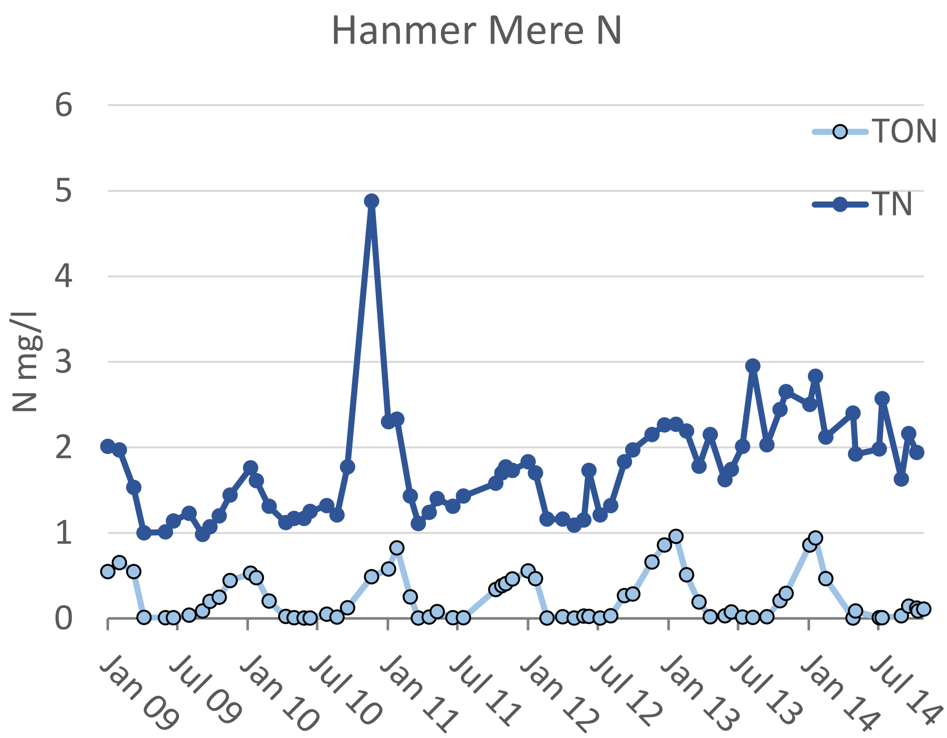


Figure 6.11.2. Nitrogen concentrations in Hanmer Mere, 2009-2014.

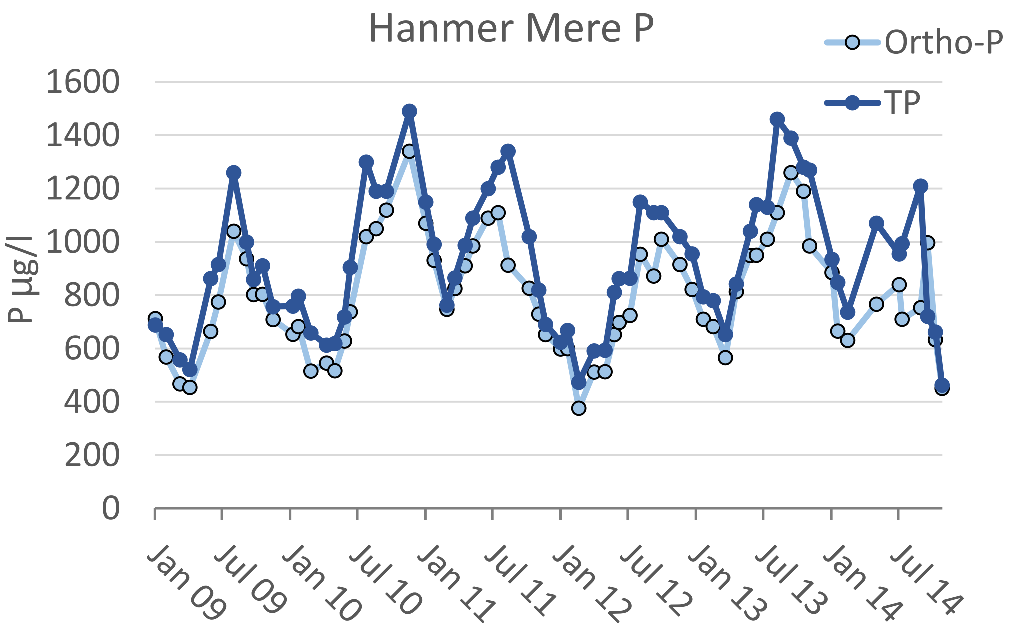


Figure 6.11.3. Phosphorus concentrations in Hanmer Mere, 2009-2014. Note the very high concentrations in this lake.

Indicator	Result	Confidence < Good
Mean Total Nitrogen	1.75	**Very Certain > 1**
		Not > 2
Total Phosphorus	Bad	**Very Certain**
Phytoplankton	Moderate	**Very Certain**
Macrophytes	Moderate	**Very Certain**
Diatoms	Poor	**Very Certain**
Weight of Evidence Tool Conclusion	Very certain eutrophication problem	
Overall Evidence Base	**High**	

Table 6.11.2. Key indicators for Hanmer Mere. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Hanmer Mere

Both the chemical and biological data from Hanmer Mere show clear and significant eutrophication impacts, with high confidence (Table 6.11.2). This is consistent with the definition of ‘eutrophic’ under the Nitrates Directive and therefore supports the retention of this NVZ.

The nearby Llyn Bedydd, which lies just outside the NVZ, also shows evidence of significant eutrophication (Shilland & Monteith 2001; Burgess *et al*. 2009), but monitoring data from within the relevant period are not available.

Environment Agency (2012e) estimated that approximately 75% of nitrogen loading to Hanmer Mere is from agricultural sources. It should be noted that there is a long-standing issue with sewage pollution at this lake which has resulted in elevated phosphorus concentrations. This is now thought to have been resolved.

The existing NVZ for Hanmer Mere excludes an area of land to the west of the lakes within the catchment. This should be investigated. Groundwater influences to the lake should also be considered and incorporated into the NVZ if necessary.

Following external peer review, the independent expert agreed with NRW’s recommendation that Hanmer Mere should remain an NVZ.

It is therefore recommended that Hanmer Mere remain an NVZ.

6.11. Llyn Pencarreg

Llyn Pencarreg is a low alkalinity natural kettle-hole lake of 8.5 ha and a maximum depth of 12 m. It is situated in the Teifi catchment in Carmarthenshire, mid Wales. It is designated as a Site of Special Scientific Interest and National Nature Reserve for its lake habitat (Goldsmith *et al*. 2014b). As it is relatively small and not designated as an SAC, the lake is not designated as a water body under the Water Framework Directive and for this reason monitoring data are limited. There is no inflow or outflow and the lake is groundwater fed. The very small catchment consists mainly of farmland.

Water Body ID: 39303
Alkalinity: Low
Humic Type: Clear
Depth Type: Shallow (stratifies)
Naturalness: Natural
Protected Area: SSSI
Catchment Area: 35

There are 10 water samples from Llyn Pencarreg, from November 2011 to November 2014. This is coupled with biological data on chlorophyll and macrophytes. Dissolved oxygen data was also collected during the macrophyte survey. This is considered an adequate dataset, though due to the relatively small number of water samples the statistical power is reduced.

Total Nitrogen concentrations in Llyn Pencarreg are below the 1 mg $^{l-1}$ threshold and TON concentrations were very low even in winter. However, total Phosphorus concentrations were very high, with an annual mean of 199 µg l^{-1}, equivalent to Bad ecological status. The dataset is too small to assess whether the lake is nitrogen limited, but initial assessments suggest that neither nitrogen or phosphorus are limiting.

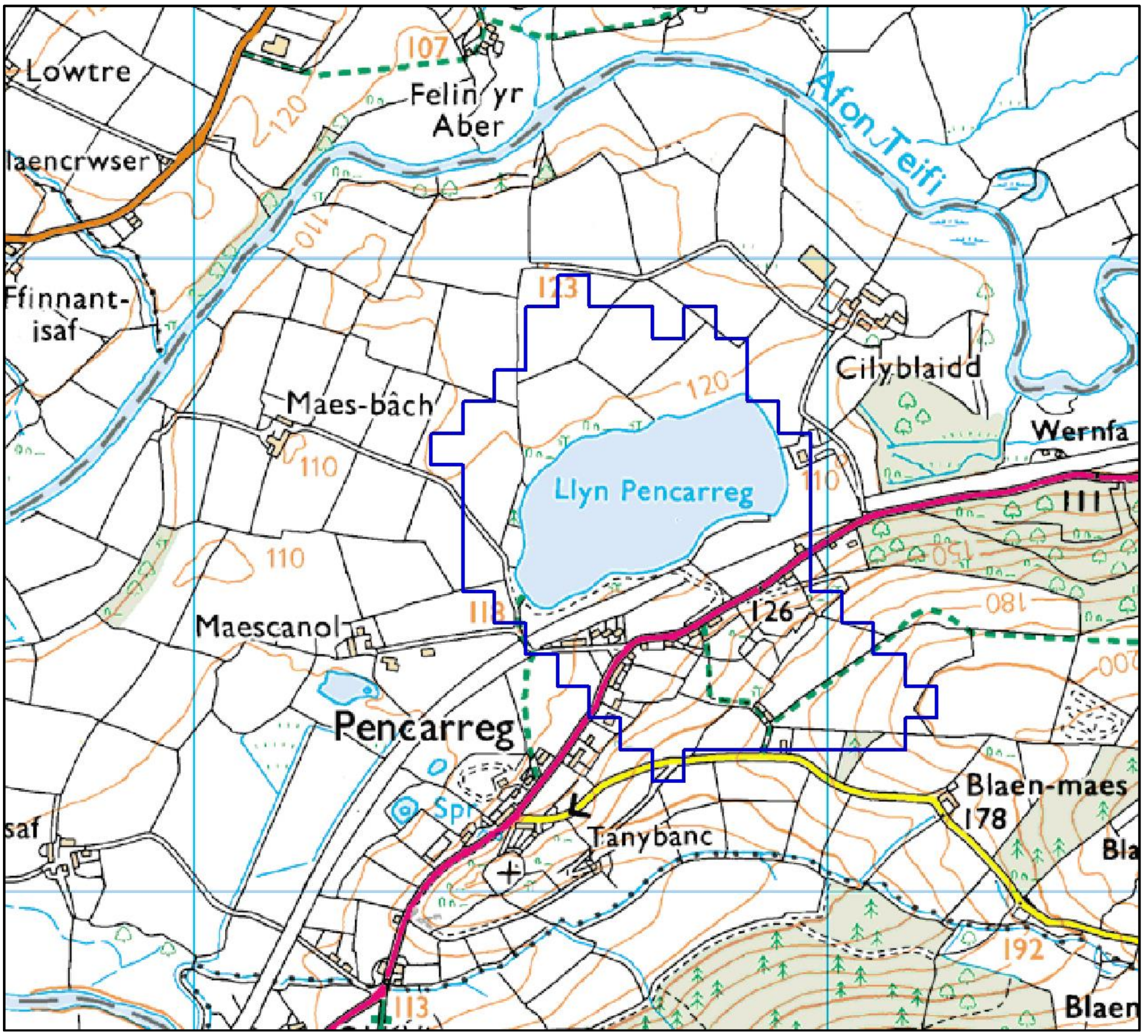


Figure 6.12.1. Surface water catchment of Llyn Pencarreg.

Land Use	**Area (ha)**	**% Cover**
Semi-natural broadleaved woodland	0.07	0.3
Planted broadleaved woodland	0.09	0.4
Dense scrub	1.57	6.2
Semi-improved neutral grassland	4.15	16.5
Bracken	0.3	1.2
Standing water*	8.61	N/A
Total Semi-Natural and Low Intensity Agriculture		**24.6**
Improved grassland	16.27	64.7
Total Intensive Agriculture		**64.7**
Planted coniferous woodland	0.12	0.5
Gardens	0.16	0.6
Buildings	1.55	6.2
Bare ground	0.83	3.3
Illegible code	0.05	0.2
Total Other		**10.9**

Table 6.12.1. Land use in the Llyn Pencarreg surface water catchment. *Standing water has been excluded from the cover calculations due to the high lake: catchment area ratio.

These results are reflected in the biological data. Macrophytes indicate that Llyn Pencarreg is at Moderate Status, whilst the phytoplankton tool indicates gives a classification of Poor status. Both tools are quite certain that the water body is worse than Good status. Other data indicating eutrophication include severe deoxygenation of the water column below 6 m depth, palaeolimnological evidence indicative of significant nutrient enrichment over the last 60 years, and records of blue-green algal blooms (Goldsmith *et al*. 2014b). This results in an overall WoE conclusion of Very Certain Eutrophication Problem, and agrees with the Unfavourable, High Confidence conclusion reached by Goldsmith *et al*. (2014b).

Indicator	Result	Confidence < Good
Total Nitrogen 75%ile	0.86	Not > 1
Total Phosphorus	Bad	**Very Certain**
Phytoplankton	Poor	Quite Certain
Macrophytes	Moderate	Quite Certain
Palaeolimnology	1.19	Significant enrichment
Weight of Evidence Tool Conclusion	Very certain eutrophication problem	
Overall Evidence Base	**Medium-High**	

Table 6.12.2 Key indicators for Llyn Pencarreg. See Table 4.6.1 for an explanation of evidence categories.

During the aquatic plant survey it was noted that ploughing had taken place to within 1 m of the lake edge, and extensive poaching by livestock was also noted. Blue-green algal blooms have also been recorded in the lake, including in winter.

Source Apportionment

Source apportionment for the Llyn Pencarreg catchment (Edwards 2016) indicated that the % N contribution from agricultural land was 89.3%, with the contribution from intensive agriculture being 64.7% (Table 6.1.3). There are no consented discharges in the catchment. These results indicate that agriculture is the main source of nitrogen loading in the catchment.

Catchment area (ha)	35
% Semi-Natural and Low Intensity Agriculture	24.6
% Intensive Agriculture	64.7
% Semi-Natural and All Agriculture	89.3
Number of consented discharges in catchment	0
Total N load from consented discharges (kg/day)	0.0
Mean catchment TON concentration (mg/l)	0.3
Total catchment flow (l/s)	9.3
Total catchment N load (kg/day)	0.2
Total catchment diffuse N load (kg/day)	0.2
Total catchment agricultural/semi-natural N load (kg/day)	0.2
Total catchment intensive agricultural N load (kg/day)	0.1
% N contribution from all agricultural/semi-natural land	89.3
% N contribution from intensive agriculture	64.7

Table 6.12.3. Source Apportionment results for Llyn Pencarreg.

Recommendation: Llyn Pencarreg

There is very good evidence that Llyn Pencarreg has undergone significant ecological changes. Although the evidence base is not as comprehensive as for other Welsh lakes, the magnitude of the eutrophication impact is so large as to justify a conclusion of Very Certain Eutrophication Problem. This gives an overall evidence base confidence of Medium-High. Source apportionment indicates that a high proportion of N loading is from agricultural sources.

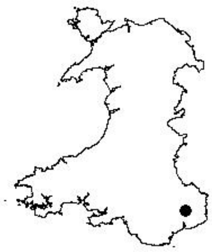
Therefore, Llyn Pencarreg should be considered for NVZ designation.

Following external peer review, the independent expert agreed with NRW’s recommendation that Llyn Pencarreg should be designated an NVZ.

It is therefore recommended that the catchment of Llyn Pencarreg be designated an NVZ.

6.12. Llandegfedd Reservoir

Llandegfedd Reservoir is an artificially constructed public water supply reservoir between Usk and Cwmbrân, in South Wales. It is a pumped storage reservoir for the Rivers Usk and Wye abstractions and forms part of the south east Wales strategic water supply network: consequently the catchment and land use is not shown. The lake is alkaline and shallow, and stratifies in summer.



Water Body ID: GB30941363
Alkalinity: High
Humic Type: Clear
Depth Type: Shallow (stratifies)
Naturalness: Artificial, pumped storage
Protected Area: Drinking Water
Catchment Area: 650

There are 74 water samples from Llandegfedd Reservoir, dating between March 2009 and December 2014. This is accompanied by macrophyte and phytoplankton data. This is considered a very good dataset.

Chemical data from the lake shows evidence of eutrophication. Phosphorus concentrations are consistent with Moderate ecological status, and both Total Nitrogen and winter nitrate exceed the 1 mg l^{-1} threshold.

Biological data shows a mixed picture. Phytoplankton classification data shows no evidence of impact with only 5% confidence that the lake is worse than Good status, although this result needs to be tempered by reports of blue-green algal blooms in the lake, suggesting that the classification may be too optimistic. On the other hand, macrophyte data gives an overall classification of Poor status, with high certainty (100%) of being less than Good. However, the macrophyte tool is likely to be affected by water level fluctuations in heavily used reservoirs, as hydrological pressures affect the composition and abundance of aquatic plants. Consequently, the poor status for macrophytes cannot confidently be ascribed to nutrient pressures alone. In order to reflect this, the confidence in the macrophyte tool has been reduced to ‘Uncertain’. Confidence in the phytoplankton tool is unchanged because the WoE tool takes blue-green algal blooms into account separately. There is also evidence that the lake becomes deoxygenated in deeper water in summer.

Indicator	Result	Confidence < Good
Mean Total Nitrogen	1.37	**Very Certain > 1** Not > 2
Total Phosphorus	Moderate	**Very Certain**
Phytoplankton	Good	Good or Better
Macrophytes	Poor	Uncertain
Weight of Evidence Tool Conclusion	Quite / Very certain eutrophication problem	
Overall Eutrophication Evidence	**Marginal**	

Table 6.13.1 Key indicators for Llandegfedd Reservoir. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llandegfedd Reservoir

The evidence base for Llandegfedd Reservoir shows that both chemical and biological impacts occur. These are not as acute as in some of the other lakes and there is some uncertainty regarding the biology. Collection of diatom data is recommended as this might provide a more accurate classification than either phytoplankton or macrophytes in this case. However, the occurrence of both blue-green algal blooms and deoxygenation of the deeper waters of the lake indicate that eutrophication pressure does occur at Llandegfedd Reservoir and therefore that it meets the technical definition of ‘eutrophic’ under the Nitrates Directive.

In previous NVZ designation rounds, Llandegfedd and other pumped storage reservoirs were excluded from consideration as NVZs due to the difficulty of identifying the catchment, and it is therefore not recommended that Llandegfedd Reservoir be designated as an NVZ. However, other routes for controlling the impact of nutrients on the reservoir should be investigated in accordance with maintaining drinking water supply.

> Following external peer review, the independent expert agreed with NRW’s recommendation that Llandegfedd Reservoir should not be designated an NVZ.
>
> It is therefore recommended that Llandegfedd Reservoir should not be designated an NVZ.

6.13. Llyn Tegid

At 415 ha, Llyn Tegid is the largest natural lake in Wales (Hughes *et al*. 2004). It is deep and low alkalinity, and has a substantial catchment of almost 15,000 ha incorporating much of the Upper Dee (Hughes *et al*. 2004). The lake forms part of the River Dee and Llyn Tegid SAC and is designated as a lake SSSI for its habitat and several rare species including the unique gwyniad (*Coregonus lavaretus*), a glacial relict fish that requires deep, cold, well-oxygenated water. Llyn Tegid is also used as additional storage for water resources as part of the River Dee regulation system, resulting in a ‘back to front’ water level regime with low levels in winter and higher levels in summer.

There are long-standing concerns regarding eutrophication in Llyn Tegid and the lake has been well studied with respect to the impact of nutrients (Winfield 2001; Duigan *et al*. 2003; Bennion *et al*. 2003; Burgess *et al*. 2006; Winfield *et al*. 2013). A particular cause for concern is the maintenance of suitable deep-water oxygen conditions for gwyniad (Winfield 2001).

Water Body ID: GB31134987
Alkalinity: Low
Humic Type: Clear
Depth Type: Deep (stratifies)
Naturalness: Natural
Protected Area: Natura 2000, SSSI
Catchment Area: 14,920

Llyn Tegid has a mixed catchment which includes substantial areas of upland. In total almost 55% of the lake’s catchment is semi-natural habitats or low intensity agriculture (Table 6.14.1). Intensive agriculture occupies about 28% of the catchment. Most of the remainder is coniferous plantation (16%).

Monthly water chemistry data for Llyn Tegid are available from January 2009 until November 2014, comprising 82 samples (Figs 6.14.2 and 6.14.3). The location of the water quality sampling point was moved in June 2012 as the previous sampling location was thought to have been affected by backflow from the Afon Tryweryn, but there is no evidence that the data have been substantially affected. In addition, dissolved oxygen data have been collected annually. Phytoplankton, macrophyte and diatom classification data are all available as well as condition assessment information. This is an excellent quality dataset.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	300.16	2.0
Planted broadleaved woodland	8.94	0.1
Unimproved acid grassland	3416.95	23.2
Semi-improved acid grassland	254.81	1.7
Semi-improved neutral grassland	125.63	0.9
Marshy grassland	390.29	2.7
Bracken	278.13	1.9
Dry acid heath	716.3	4.9
Wet heath	131.73	0.9
Dry heath / acid grassland mosaic	112.96	0.8
Wet heath / acid grassland mosaic	47.56	0.3
Blanket bog	1073.55	7.3
Wet modified bog	114.9	0.8
Dry modified bog	142.46	1.0
Acid/neutral flush	374.09	2.5
Basin mire	8.94	0.1
Standing water	425.84	2.9
Running water	30.94	0.2
Acid / neutral cliff	9.31	0.1
Scree	19.41	0.1
Total Semi-Natural and Low Intensity Agriculture		**54.4**
Improved grassland	4099.7	27.8
Total Intensive Agriculture		**27.8**
Planted coniferous woodland	2372.53	16.1
Felled coniferous woodland	85.62	0.6
Amenity grassland	11.52	0.1
Caravan site	11.5	0.1
Buildings	63.68	0.4
Tracks	7.72	0.1
Illegible code	49.24	0.3
Total Other		**17.7**

Table 6.14.1. Land use in the Llyn Tegid surface water catchment.

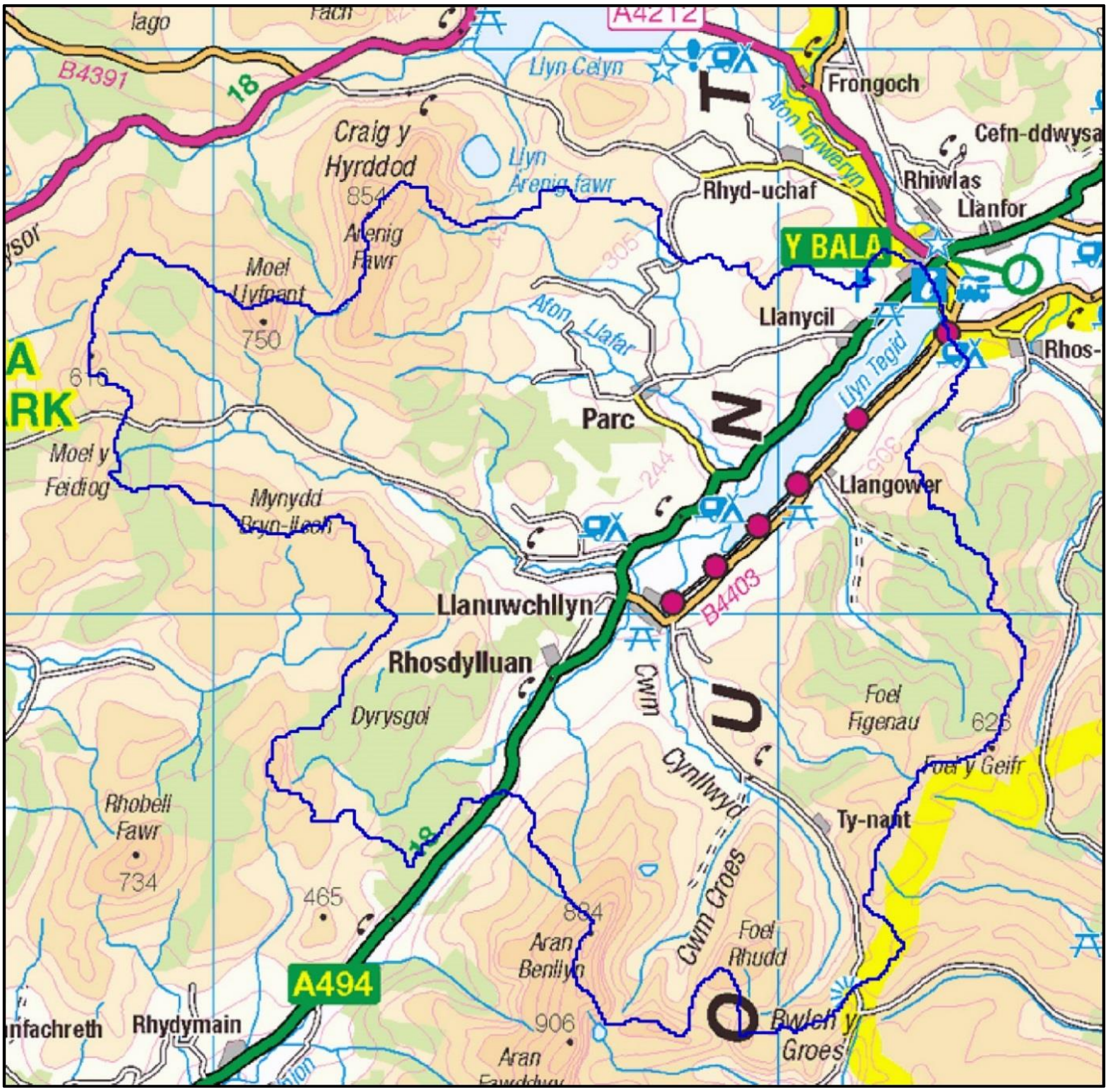


Figure 6.14.1. Surface water catchment of Llyn Tegid.

Chemical data for Llyn Tegid are suggestive of some eutrophication, with phosphorus results giving a classification of Moderate with High Confidence. However, both total nitrogen and TON levels are low and do not give cause for concern (Fig 6.11.2). The data are also not suggestive of nitrogen limitation, with N levels remaining above 0.1 mg l^{-1} throughout the year.

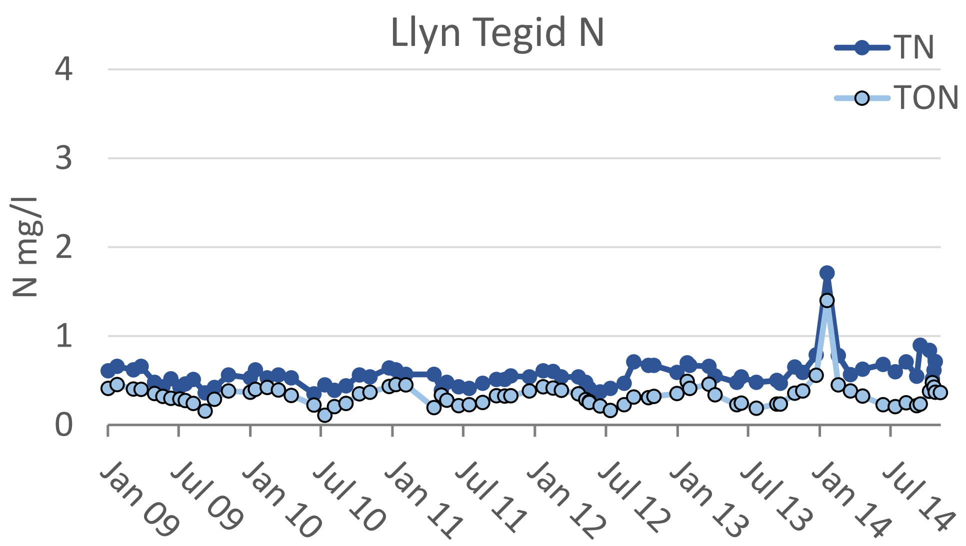


Figure 6.11.2. Nitrogen concentrations in Llyn Tegid, 2009-2014.

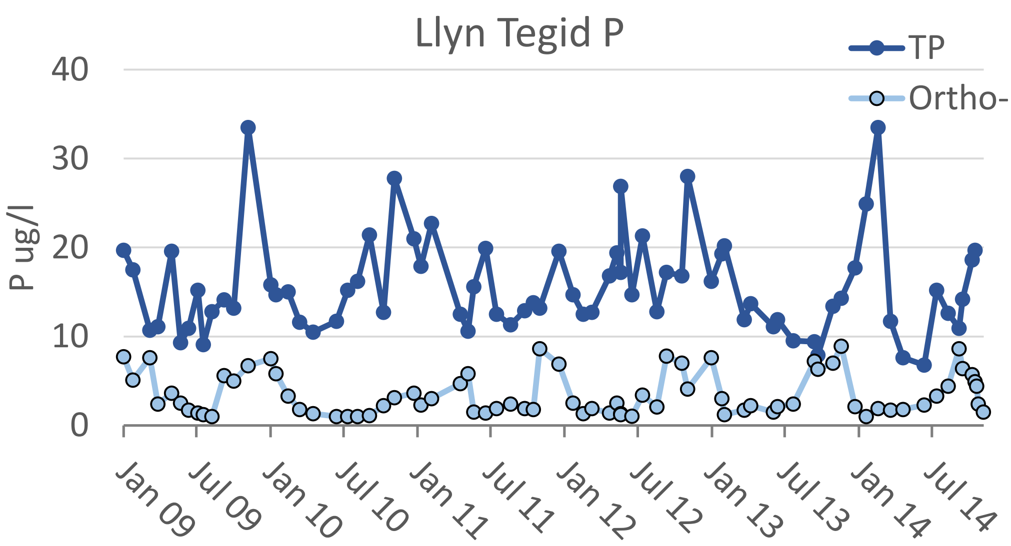


Figure 6.11.3. Phosphorus concentrations in Llyn Tegid, 2009-2014.

Dissolved oxygen concentrations in the lake are reported as Good Status with moderate confidence in the latest WFD classification results. However, this result is not supported by the data. Using data on dissolved oxygen below the thermocline, as specified by the UKTAG dissolved oxygen standard for lakes (WFD-UKTAG 2008b), dissolved oxygen concentrations are consistent with Moderate status for every year between 2010 and 2015, and are worse than Good status with high confidence for every year except for 2010. These results are consistent with previous reports of low summer dissolved oxygen in deep water parts of the lake (Winfield 2001, Burgess *et al*. 2006). However, the most recent condition assessment (Winfield *et al*. 2012) considered oxygen conditions in Llyn Tegid to be favourable for gwyniad.

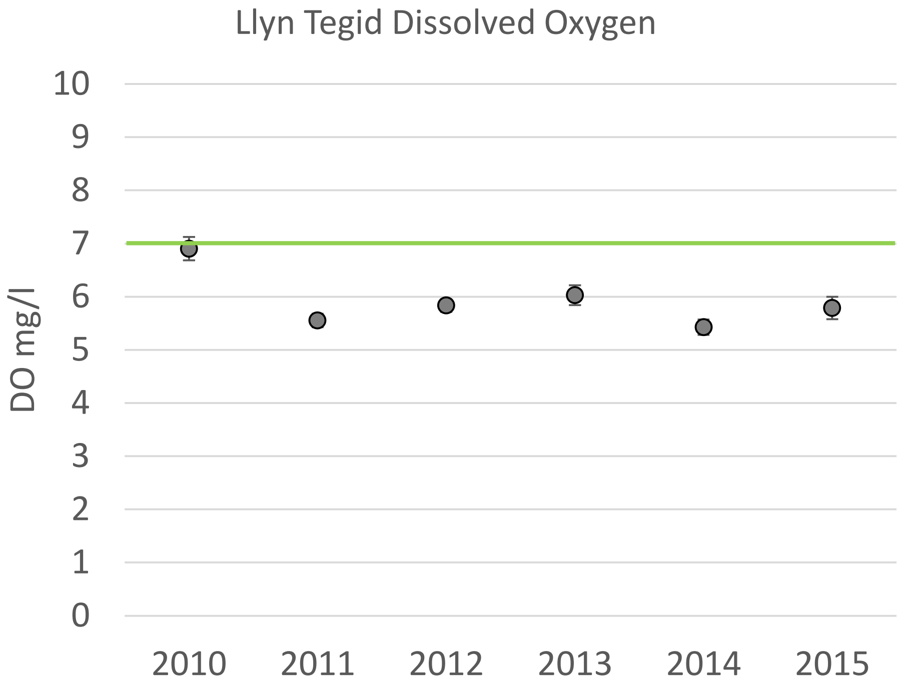


Figure 6.14.2. Mean dissolved oxygen concentrations below the thermocline in Llyn Tegid, 2010-2015. Error bars indicate the 95% confidence interval in the mean. The green line indicates the Good / Moderate boundary.

Biological data from the lake are mixed, with both phytoplankton and diatom tools giving a result of Good or better with high confidence (Table 6.14.2). Macrophytes give a result of Poor status, but the unnaturally fluctuating water levels in Llyn Tegid are likely to be affecting the composition and abundance of the aquatic plants, resulting in a classification that is not only due to eutrophication. For this reason confidence in the macrophyte classification has been downgraded to 'Uncertain', resulting in an overall WoE assessment of 'Quite Certain'.

Indicator	Result	Confidence < Good
Mean Total Nitrogen	0.56	Not > 1
Total Phosphorus	Moderate	Very Certain
Phytoplankton	Good	Good or Better
Macrophytes	Poor	Uncertain
Diatoms	Good	Good or Better
Dissolved Oxygen	Moderate	Very Certain
Weight of Evidence Tool Conclusion	Quite Certain eutrophication problem	
Overall Eutrophication Evidence	**Marginal**	

Table 6.14.2 Key indicators for Llyn Tegid. See Table 4.6.1 for an explanation of evidence categories.

Other data generally corroborates this evidence of eutrophication. The SSSI lake condition assessment (Burgess *et al*. 2006) was unfavourable due to various impacts including high nutrient levels, low dissolved oxygen, algal blooms and palaeolimnological evidence of eutrophication (Bennion *et al*. 2003). There have also been regular reports of blue-green algal blooms, in 2009, 2010, 2011 and 2015 (NRW, unpublished data).

Source Apportionment

Source apportionment for the Llyn Tegid catchment indicated that the % N contribution from agricultural land was 78.6%. However, the contribution from intensive agriculture was lower at 26.6% (Table 6.1.3). These results indicate that agriculture is an important source of nitrogen loading in the catchment, but intensive agriculture has a comparatively low contribution.

Catchment area (ha)	14,920
% Semi-Natural and Low Intensity Agriculture	54.4
% Intensive Agriculture	27.8
% Semi-Natural and All Agriculture	82.2
Number of consented discharges in catchment	18
Total N load from consented discharges (kg/day)	10.79
Mean catchment TON concentration (mg/l)	0.4
Total catchment flow (l/s)	7,299.0
Total catchment N load (kg/day)	245.9
Total catchment diffuse N load (kg/day)	235.2
Total catchment agricultural/semi-natural N load (kg/day)	193.3
Total catchment intensive agricultural N load (kg/day)	65.4
% N contribution from all agricultural/semi-natural land	78.6
% N contribution from intensive agriculture	26.6

Table 6.14.3. Source Apportionment results for Llyn Tegid.

Recommendation: Llyn Tegid

There is some evidence of eutrophication affecting both the chemistry and biology of Llyn Tegid. Phosphorus and dissolved oxygen data are indicative of moderate status with high confidence. However, nitrogen levels are not elevated. Macrophyte data suggest that the biology of the lake is worse than good and algal blooms occur regularly. In broad terms the overall status of the lake from a nutrient impacts perspective is considered to be slightly below Good Status.

Using the matrix in Table 4.6.1 this gives a 'Marginal' overall evidence base. It is recommended that further measures to control eutrophication at Llyn Tegid be further examined. However, due to the relatively low contribution from intensive agriculture, an NVZ may not necessarily be the most effective means of achieving nutrient targets.

> Following external peer review, the independent expert recommended on balance that Llyn Tegid should not be designated an NVZ. However, it was noted that there is a long-standing nutrient issue at the lake and that other routes for controlling nutrients in the lake's catchment need to be considered. It was also recommended that the evidence for this lake be reviewed again at the next NVZ review.
>
> NRW accepts this recommendation and accordingly recommends that Llyn Tegid is not designated as an NVZ.

6.14. Witchett Pool

Witchett Pool is a small and very shallow (<1 m deep), alkaline dune lake in the Pendine Burrows, Carmarthenshire, with an extensive fringing reedbed. It is situated on MoD land within a firing range, but has a small catchment that incorporates agricultural land as well as a lugworm farm (Goldsmith *et al*. 2014b). About 19% of the catchment consists of intensive agriculture (Table 6.15.1). Although the lake has been fairly frequently visited by local botanists, only one systematic survey has been carried out (Goldsmith *et al*. 2014b).

Water Body ID: Not listed
Alkalinity: High
Humic Type: Clear
Depth Type: Very Shallow
Naturalness: Natural
Protected Area: SSSI
Catchment Area: Unknown

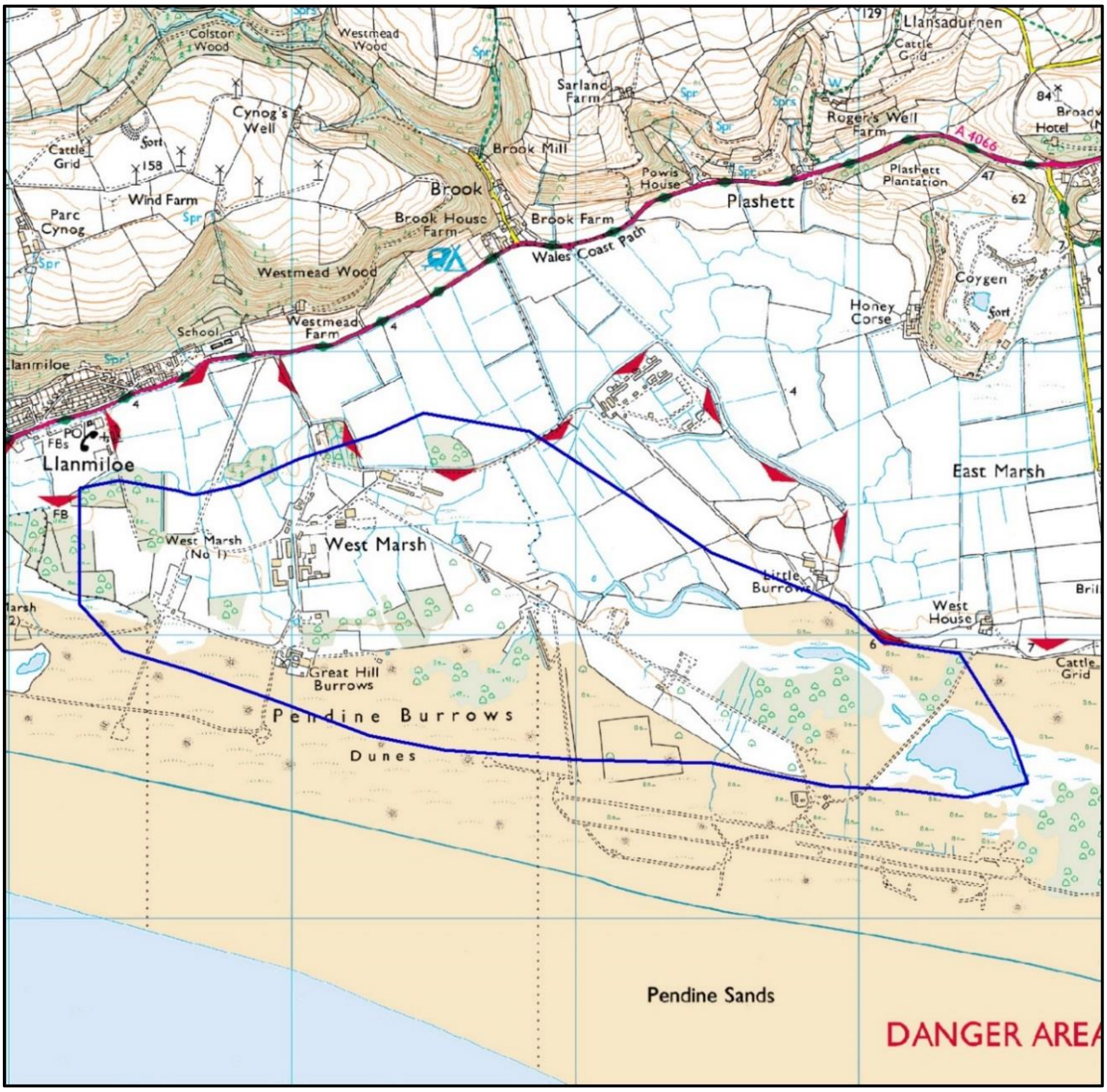


Figure 6.15.1. Surface water catchment of Witchett Pool.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	0.4	0.2
Dense scrub	15.68	6.0
Semi-improved neutral grassland	44.29	17.0
Marshy grassland	17.71	6.8
Swamp	17.57	6.7
Standing water	6.41	2.5
Running water	1.02	0.4
Dune slack	6.6	2.5
Dune grassland	16.87	6.5
Dune scrub	23.35	8.9
Open dune	44.63	17.1
Total Semi-Natural and Low Intensity Agriculture		**74.6**
Arable	3.49	1.3
Improved grassland	44.81	17.2
Total Intensive Agriculture		**18.5**
Planted coniferous woodland	0.73	0.3
Amenity grassland	2.43	0.9
Buildings	10.5	4.0
Tracks	0.25	0.1
Illegible code	4.17	1.6
Total Other		**6.9**

Table 6.15.1. Land use in the Witchett Pool surface water catchment.

Existing data for Witchett Pool comprises only four water samples and an aquatic plant survey. No data are available for total nitrogen. This is a small dataset and this potentially compromises confidence in the final result.

Nitrogen concentrations in Witchett Pool are low throughout the year, with three of the four samples showing levels below the detection limit. In contrast, phosphorus concentrations are very high. This is suggestive of nitrogen limitation, though both the size of the dataset and the N detection limit of 0.2 mg l^{-1} are insufficient to confirm this.

Biological data are restricted to a macrophyte survey and four chlorophyll samples (Goldsmith *et al*. 2014b). Macrophyte survey data found a fairly diverse assemblage of aquatic plants characteristic of high alkalinity, high nutrient environments. Plant cover was very high with aquatic plants growing throughout the lake, and filamentous algal cover was low.

The annual geometric mean chlorophyll a was 11.4 µg l^{-1}. No calculated reference data are available for this site, but using reference data for the ecologically similar Kenfig Pool, this would place Witchett Pool in Good Status and close to the High-Good boundary. It should be noted that following the UKTAG phytoplankton method (WFD-UKTAG 2014c), four samples is insufficient to produce a formal classification and therefore this result has not been used in the Weight of Evidence tool.

Indicator	Result	Confidence < Good
Total Oxidised Nitrogen 75%ile	0.39	Not > 1
Total Phosphorus	Bad	**Very Certain**
SSSI Condition Assessment	Unfavourable	Quite Certain
Weight of Evidence Tool Conclusion	Quite certain eutrophication problem	
Overall Eutrophication Evidence	**Marginal**	

Table 6.15.2 Key indicators for Witchett Pool. See Table 4.6.1 for an explanation of evidence categories.

The SSSI condition assessment (Goldsmith et al. 2014b) recorded a conclusion of Unfavourable Condition with High Confidence for Witchett Pool due to nutrient enrichment, primarily on the basis of the high phosphorus concentrations and relatively high cover of species associated with nutrient enrichment. High cover of these species is not taken into account in the lakes Leafpacs tool and this accounts for the discrepancy between the results of the condition assessment and Leafpacs. The extreme shallowness of Witchett Pool also means that the WFD tool is likely to give a slightly overoptimistic view. Goldsmith et al. (2014b) also noted loss of the nutrient-sensitive *Chara hispida* and *Utricularia vulgaris,* and identified nitrogen as being the likely limiting nutrient. However, the water was reported as clear and well-oxygenated.

Source Apportionment

Source apportionment for the Witchett Pool catchment indicated that the % N contribution from agricultural land was 92%. However, the contribution from intensive agriculture was lower at 18.3% (Table 6.1.3). These results indicate that agriculture is an important source of nitrogen loading in the catchment, but intensive agriculture has a comparatively lower importance.

Catchment area (ha)	254
% Semi-Natural and Low Intensity Agriculture	74.6
% Intensive Agriculture	18.5
% Semi-Natural and All Agriculture	93.1
Number of consented discharges in catchment	1
Total N load from consented discharges (kg/day)	0.02
Mean catchment TON concentration (mg/l)	0.4
Total catchment flow (l/s)	43.6
Total catchment N load (kg/day)	1.5
Total catchment diffuse N load (kg/day)	1.5
Total catchment agricultural/semi-natural N load (kg/day)	1.4
Total catchment intensive agricultural N load (kg/day)	0.3
% N contribution from all agricultural/semi-natural land	92.0
% N contribution from intensive agriculture	18.3

Table 6.15.3. Source Apportionment results for Witchett Pool.

Recommendation: Witchett Pool

There is very high confidence of elevated phosphorus concentrations at Witchett Pool, though this is not accompanied by elevated nitrogen levels. It is probable although uncertain that nitrogen is the limiting nutrient at the lake.

Despite the high phosphorus concentrations, aquatic plant and phytoplankton data both suggest that the ecological impacts of these raised nutrient levels are at present fairly small. The relative lack of data makes this conclusion rather uncertain. This could reflect nitrogen limitation in the lake, or increasing nutrient pressure that is not yet being reflected in ecological impacts.

Overall, there is good evidence to indicate that actions to combat eutrophication are needed at Witchett Pool, but further assessment is required to determine whether a Nitrate Vulnerable Zone is the most appropriate approach.

Following external peer review, the independent expert recommended that Witchett Pool should not be designated an NVZ and that further data are gathered to identify the sources of eutrophication. NRW accepts this recommendation and accordingly recommends that Witchett Pool is not designated as an NVZ.

6.15. Eglwys Nunnydd Reservoir

Eglwys Nunnydd Reservoir is an artificial reservoir, constructed as a water supply for the nearby steelworks at Port Talbot and about 91 ha in area. It is a moderate alkalinity, shallow water body that does not stratify, and is principally fed by an abstraction from the River Kenfig; consequently the catchment has not been mapped. The lake is used recreationally for sailing and angling. It is also designated as a SSSI for its bird fauna, but these are not thought to be sensitive to nutrient enrichment. The lake is one of two sites in Wales that have been colonised by the invasive non-native killer shrimp (*Dikerogammarus villosus*), where it was first found in 2010 (GB Non-native Species Secretariat 2012).

Water Body ID: GB31042079
Alkalinity: Moderate
Humic Type: Clear
Depth Type: Shallow
Naturalness: Artificial, pumped storage
Protected Area: SSSI
Catchment Area: 247

There is an extensive dataset on water quality and ecology at Eglwys Nunnydd Reservoir, comprising 54 water quality samples, phytoplankton and diatom data. Data on both TON and TN are available, but the total phosphorus data have been analysed using a protocol with too high a detection limit. The implications of this on the conclusion are discussed below.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	12.18	5.3
Planted broadleaved woodland	0.72	0.3
Dense scrub	2.56	1.1
Semi-improved acid grassland	0.21	0.1
Semi-improved neutral grassland	2.35	1.0
Bracken	2.29	1.0
Swamp	1.86	0.8
Standing water	97.67	42.7
Illegible code	8.17	3.6
Total Semi-Natural and Low Intensity Agriculture		**55.9**
Improved grassland	73.23	32.0
Arable	15.97	7.0
Total Intensive Agriculture		**39.0**
Planted coniferous woodland	0.25	0.1
Amenity grassland	2.8	1.2
Introduced scrub	2.41	1.1
Gardens	0.43	0.2
Buildings	5.03	2.2
Tracks	0.46	0.2
Total Other		**5.0**

Table 6.16.1. Land use in the Eglwys Nunnydd Reservoir surface water catchment.

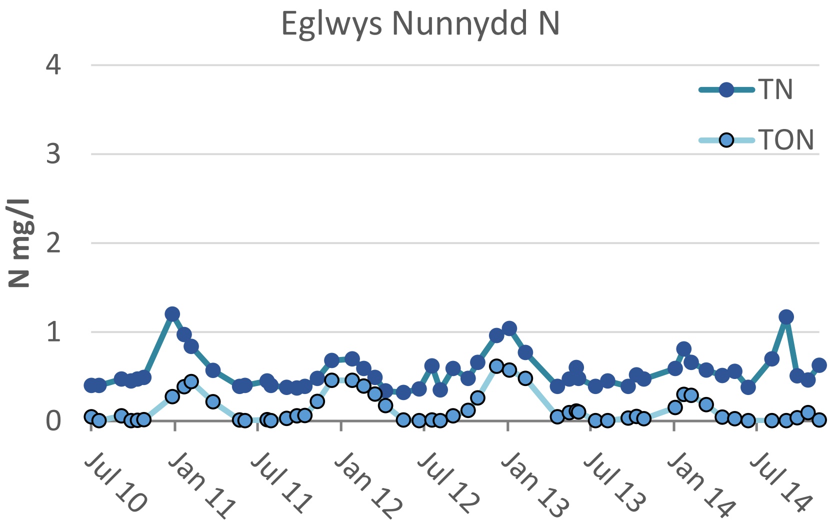


Figure 6.16.1. Nitrogen concentrations in Eglwys Nunnydd Reservoir

Both total nitrogen and total oxidised nitrogen concentrations in Eglwys Nunnydd Reservoir are rather low throughout the year (Figure 6.16.1). Nitrogen concentrations in summer are regularly close to the lower limit of detection, suggesting that the lake may be nitrogen limited for part of this time.

The estimate of total phosphorus is compromised by the detection limit used during sampling, which is 20 µg l^{-1}. Of the 54 samples collected, 18 gave phosphorus concentrations that were below this detection limit. Examination of the frequency distribution of values above this limit gave a modal value for phosphorus concentrations of between 20 and 24 µg l^{-1} (Figure 6.16.2). The remaining 18 datapoints were allocated to TP concentration categories in order to estimate the most likely TP concentration.

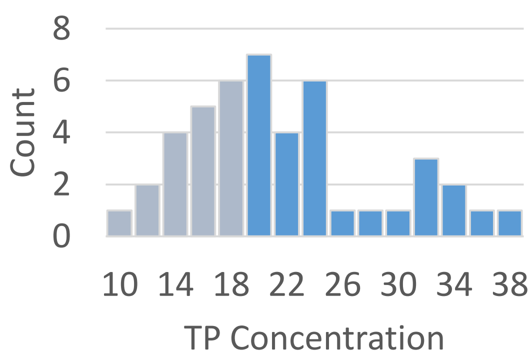


Figure 6.16.2. Estimated frequency distribution for total phosphorus concentrations at Eglwys Nunnydd used for modelling the geometric mean phosphorus concentration.

This gave an estimated TP of 25.6 µg l^{-1}, slightly above the Good/Moderate boundary for the lake of 25 µg l^{-1}. If a value of 20 µg l^{-1} for all samples below the detection limit were used, the value mean total phosphorus concentration is 27.65 µg l^{-1}, which is just below the Good/Moderate boundary for WFD; if 10 µg l^{-1} is used then the geometric mean TP would be 21.5 µg l^{-1} which is equivalent to Good Status.

Overall the data indicate that the TP concentration in Eglwys Nunnydd Reservoir is very close to the Good / Moderate boundary. On balance it is considered slightly more likely that the phosphorus concentrations are consistent with Moderate status, but there is considerable uncertainty regarding this conclusion.

Indicator	Result	Confidence < Good
Mean Total Nitrogen	0.56	Not > 1
Total Phosphorus	Moderate	Uncertain
Phytoplankton	Moderate	**Very Certain**
Macrophytes	Moderate	**Very Certain**
Weight of Evidence Tool Conclusion	Quite certain eutrophication problem	
Overall Eutrophication Evidence	**Marginal**	

Table 6.16.2 Key indicators for Eglwys Nunnydd Reservoir. See Table 4.6.1 for an explanation of evidence categories.

Both the biological tools are below Good status with High confidence. However, interpretation of this result is complicated by the presence of *D. villosus*, which interferes with food webs and nutrient dynamics (Dick *et al*. 2002; van Riel *et al*. 2006) and may therefore cause the classification tools to behave unpredictably. However, there are long-term records of blue-green algal blooms in the lake (NRW, unpublished data) which suggest an ongoing nutrient issue that predates invasion by killer shrimp. Therefore, the biological tool results are probably providing an accurate picture of the ecological status. Heavy fish stocking may be exacerbating the effects of nutrients.

Recommendation: Eglwys Nunnydd Resrvoir

The chemical data in Eglwys Nunnydd Reservoir provide only marginal evidence of phosphorus eutrophication, with low confidence. However, the biological tools both indicate eutrophication with high confidence. This discrepancy is likely to be either due to (i) improving water quality or (ii) in-lake conditions such as high fish numbers, recreational impacts or the effects of *Dikerogammarus* creating conditions that resemble nutrient enrichment.

Although ecological conditions in Eglwys Nunnydd Reservoir are likely to require management, there are insufficient grounds for designation as an NVZ, as the chemical data do not indicate eutrophication with reasonable confidence.

Following external peer review, the independent expert agreed with NRW's recommendation that Eglwys Nunnydd Reservoir should not be designated an NVZ.

Accordingly, it is recommended that the catchment of Eglwys Nunnydd Reservoir should not be designated an NVZ.

6.16. Llwyn-On Reservoir

Llwyn-On Reservoir is a moderately alkaline artificial reservoir of just over 50 ha in Merthyr Tydfil, constructed by damming the upper Afon Taf Fawr. It is the lowest of three water supply reservoirs in the valley (the others are Cantref and Beacons Reservoirs). The water is rather peaty, and although classified as shallow the lake stratifies in summer.

Water Body ID: GB30940648
Alkalinity: Moderate
Humic Type: Humic
Depth Type: Shallow (stratifies)
Naturalness: Artificial, impounded
Protected Area: Drinking Water
Catchment Area: 4388

Over 80% of the land use in the catchment of Llwyn-On Reservoir is low intensity, with most of the remainder consisting of forestry (16%). Intensive agriculture accounts for only 2% of land use (Table 6.17.1)

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	21.69	0.5
Planted broadleaved woodland	4.31	0.1
Planted mixed woodland	5.86	0.1
Dense scrub	2.96	0.1
Felled coniferous woodland	58.38	1.3
Unimproved acid grassland	1192.83	27.4
Semi-improved acid grassland	21.52	0.5
Semi-improved neutral grassland	7.24	0.2
Unimproved calcareous grassland	9.59	0.2
Marshy grassland	1464.12	33.6
Bracken	17.69	0.4
Dry acid heath	48.14	1.1
Wet heath	3.98	0.1
Dry heath / acid grassland mosaic	62.84	1.4
Wet heath / acid grassland mosaic	3.41	0.1
Blanket bog	40.03	0.9
Wet modified bog	426.7	9.8
Acid/neutral flush	48.7	1.1
Standing water	93.65	2.2
Running water	10.73	0.2
Other rock exposure	2.91	0.1
Total Semi-Natural and Low Intensity Agriculture		**81.4**
Improved grassland	89.43	2.1
Total Intensive Agriculture		**2.1**
Planted coniferous woodland	704.66	16.2
Buildings	2.88	0.1
Illegible code	3.16	0.1
Total Other		**16.4**

Table 6.17.1. Land use in the Llwyn-On Reservoir surface water catchment.

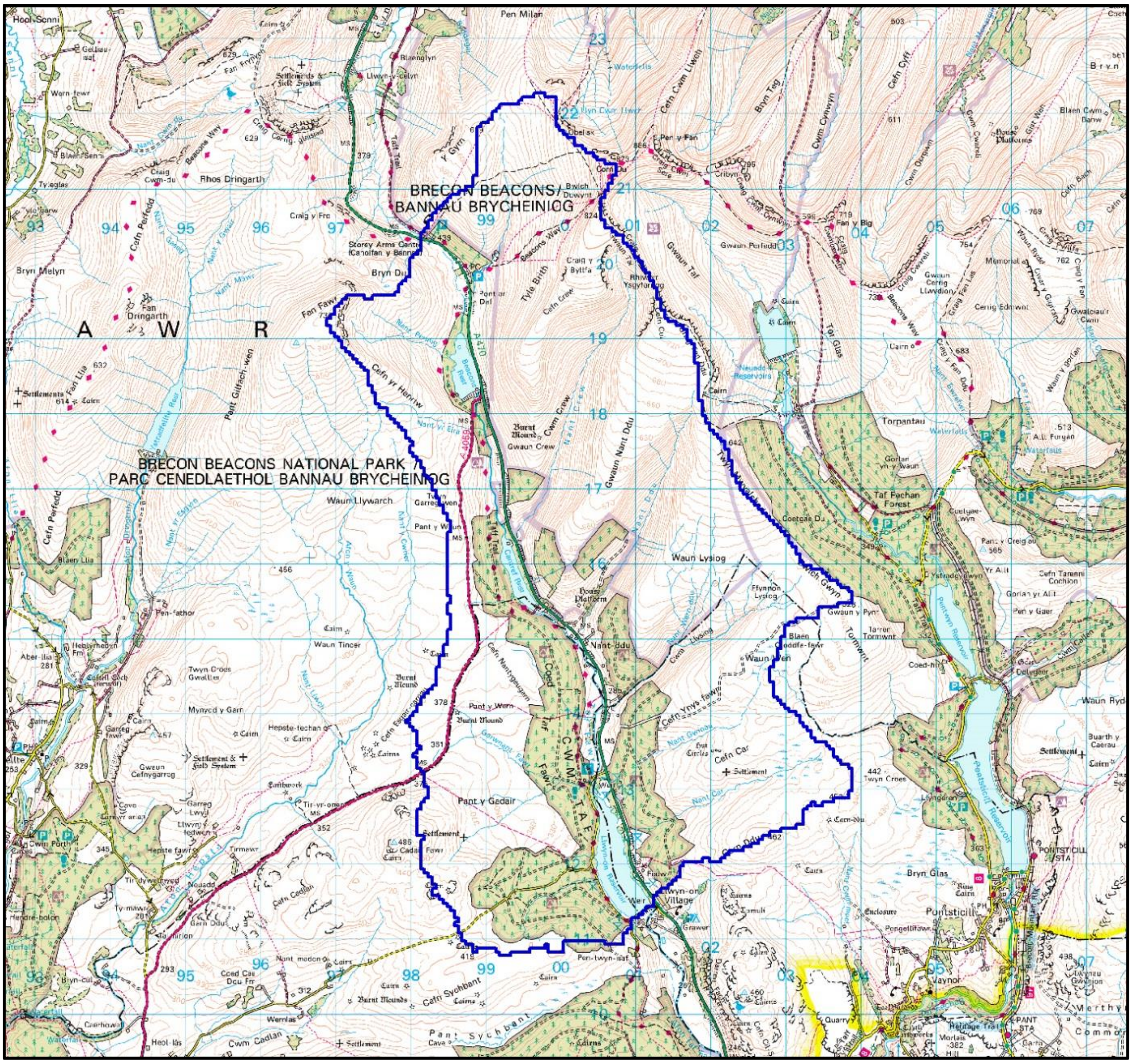


Figure 6.17.1. Surface water catchment of Llwyn-On Reservoir.

There are 72 water samples from Llwyn-On Reservoir, covering the entire assessment period from January 2009 to November 2014. Biological data comprises phytoplankton and macrophyte surveys, but due to the likelihood of significant water level fluctuations the macrophyte data has not been used in the assessment. This is considered an acceptable dataset.

Nitrogen concentrations in Llwyn-On Reservoir are low (TON = 0.18 mg l^{-1}, TN = 0.51 ± 0.11 (95% CI) mg l^{-1}) and not a significant cause for concern (Table 6.17.2). The phosphorus concentration of 16.3 µg l^{-1} is consistent with Moderate ecological status; however peaty waters naturally tend to have higher phosphorus concentrations which is not accounted for in the MEI model. Consequently, confidence in the phosphorus classification has been reduced to Uncertain (Table 6.17.2).

The phytoplankton tool result was High status, with high confidence of being Good or better (Table 6.17.2). This is supported by dissolved oxygen data which complied with Good Status.

	Result	Confidence < Good
Mean Total Nitrogen	0.51	Not > 1
Total Phosphorus	Moderate	Uncertain
Phytoplankton	High	Good or better
Macrophytes	Data not used	
Weight of Evidence Tool Conclusion	Certain no eutrophication problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Table 6.17.2 Key indicators for Llwyn-On Reservoir. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llwyn-On Resrvoir

There is no compelling evidence of either elevated nutrient levels or of biological impacts associated with eutrophication at Llwyn-On Reservoir. The face value TP failure is considered most likely to be due to the humic waters rather than eutrophication and the limited biological data indicate High status. These data are not indicative of a eutrophication problem on this lake.

Consequently it is recommended that Llwyn-On Reservoir should not be considered for designation as a Nitrate Vulnerable Zone.

Following external peer review, the independent expert agreed with NRW’s recommendation that Llwyn-On Reservoir should not be designated an NVZ.

Accordingly, it is recommended that the catchment of Llwyn-On Reservoir should not be designated an NVZ.

6.17. Llyn Elsi Reservoir

Llyn Elsi is a 9 ha reservoir in Snowdonia, constructed by damming three small streams to raise the water level of two pre-existing small lakes, Llyn Rhisgog and Llyn Enoc. It is used as the water supply for Betws-y-Coed, and as a put and take trout fishery by the local angling club. The lake is low alkalinity, has a maximum depth of about 9 m and has a fairly small catchment with a high proportion of forestry. There is no intensive agriculture within the catchment (Table 6.18.1).

Water Body ID: GB31034008
Alkalinity: Low
Humic Type: Clear
Depth Type: Shallow
Naturalness: Natural
Protected Area: Drinking Water
Catchment Area: 61 ha

There are 56 water quality samples from the lake with information on both nitrogen and phosphorus, coupled with phytoplankton data. This is considered an adequate dataset.

Land Use	**Area (ha)**	**% Cover**
Semi-natural broadleaved woodland	1.76	3.5
Dense scrub	0.26	0.5
Semi-improved neutral grassland	0.1	0.2
Dry acid heath	4.04	8.1
Wet heath	0.41	0.8
Standing water*	10.43	N/A
Illegible code	0.22	0.4
Total Semi-Natural and Low Intensity Agriculture		**13.5**
Total Intensive Agriculture		**0.0**
Planted coniferous woodland	43.07	86.3
Total Other		**86.3**

Table 6.18.1. Land use in the Llyn Elsi surface water catchment.

Nitrogen concentrations in Llyn Elsi are low (TON = 0.19 mg l^{-1}, TN = 0.51 ± 0.02 (95% CI) mg l^{-1}). Phosphorus concentrations were relatively high for a low alkalinity lake, with a geometric mean TP of 21.9 µg l^{-1}, consistent with Poor ecological status (Table 6.18.2).

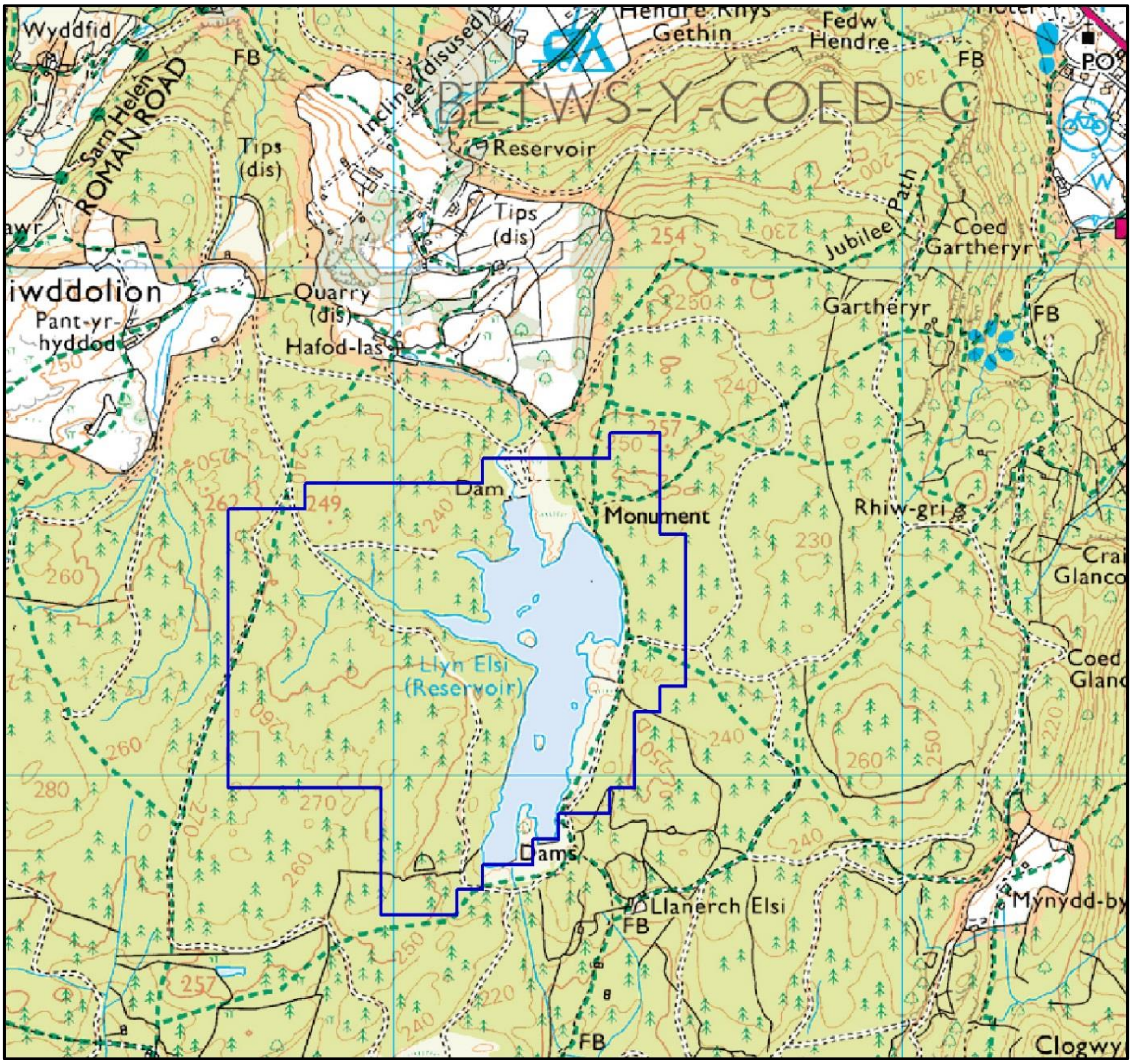


Figure 6.18.1. Surface water catchment of Llyn Elsi.

The PLUTO phytoplankton tool gave a classification of Moderate for Llyn Elsi, but this conclusion was uncertain (Table 6.18.2). No other ecological data are available.

	Result	Confidence < Good
Mean Total Nitrogen	0.51	Not >1
Total Phosphorus	Poor	Very Certain
Phytoplankton	Moderate	Uncertain
Weight of Evidence Tool Conclusion	Quite certain eutrophication problem	
Overall Eutrophication Evidence	**Marginal**	

Table 6.18.2. Key indicators for Llyn Elsi Reservoir. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llyn Elsi Reservoir

There is evidence of both elevated phosphorus concentrations and consequent ecological impact in Llyn Elsi. Whilst confidence in the nutrient conclusion is fairly high, there is uncertainty regarding the evidence of ecological impact.

In spite of the conclusions above, there is no agricultural source of catchment nutrients in Llyn Elsi that could explain the elevated nutrient concentrations. Sources of nutrients must therefore come from forestry or from fishery practices. Further work is needed to understand any nutrient issues at the lake, and therefore NVZ designation is not recommended.

Following external peer review, the independent expert agreed with NRW's recommendation that Llyn Elsi Reservoir should not be designated an NVZ. Accordingly, it is recommended that the catchment of Llyn Elsi should not be designated an NVZ.

6.18. Llyn Padarn

Llyn Padarn is a large (98 ha – Hughes *et al*. 2004), low alkalinity, deep lake on the northern edge of Snowdonia National Park. It stratifies in summer and contains one of only three extant natural populations of Arctic charr (*Salvelinus alpinus*) in North Wales, as well as a large population of floating water-plantain (*Luronium natans*), and is designated as an SSSI. The lake lies adjacent to the town of Llanberis, an important tourist centre for Snowdonia, and is important for water-based recreation and amenity. In 2014 the lake was designated as Wales's only inland Bathing Water.

Water Body ID: GB31033730
Alkalinity: Low
Humic Type: Clear
Depth Type: Shallow (stratifies)
Naturalness: Natural
Protected Area: SSSI
Catchment Area: 4901

Llyn Padarn has a fairly large catchment of about 4,900 ha, which includes part of Snowdon. Much of this land (88%) is unenclosed upland habitats, predominantly grassland and heath (Table 6.19.1), and less than 3% of the catchment is intensive farmland (Table 6.19.1). The lake receives treated sewage effluent from the Llanberis sewage treatment works (Griffiths *et al*. 2012) and periodic storm overflow from Llanberis. The catchment just above the lake is heavily modified due to the construction of the Dinorwic pumped storage scheme, which has implications for the hydrology and morphology of the catchment. There are also long-standing impacts from mine effluent, from which the lake is slowly recovering (Bennion *et al*. 2010).

There is an unusually large amount of monitoring data for Llyn Padarn due to an EA / NRW investigation following concerns regarding the impact of eutrophication on the lake (NRW 2014). This has resulted in 114 water samples and data on all relevant biological quality elements as well as palaeolimnology and recent condition assessment data. A single datapoint from 26th April 2012 was removed from the dataset as the unusually high reading was considered likely to reflect sample contamination, and in a few cases there were some minor discrepancies between the TON result and the corresponding TN. Nevertheless, this is considered an excellent quality dataset.

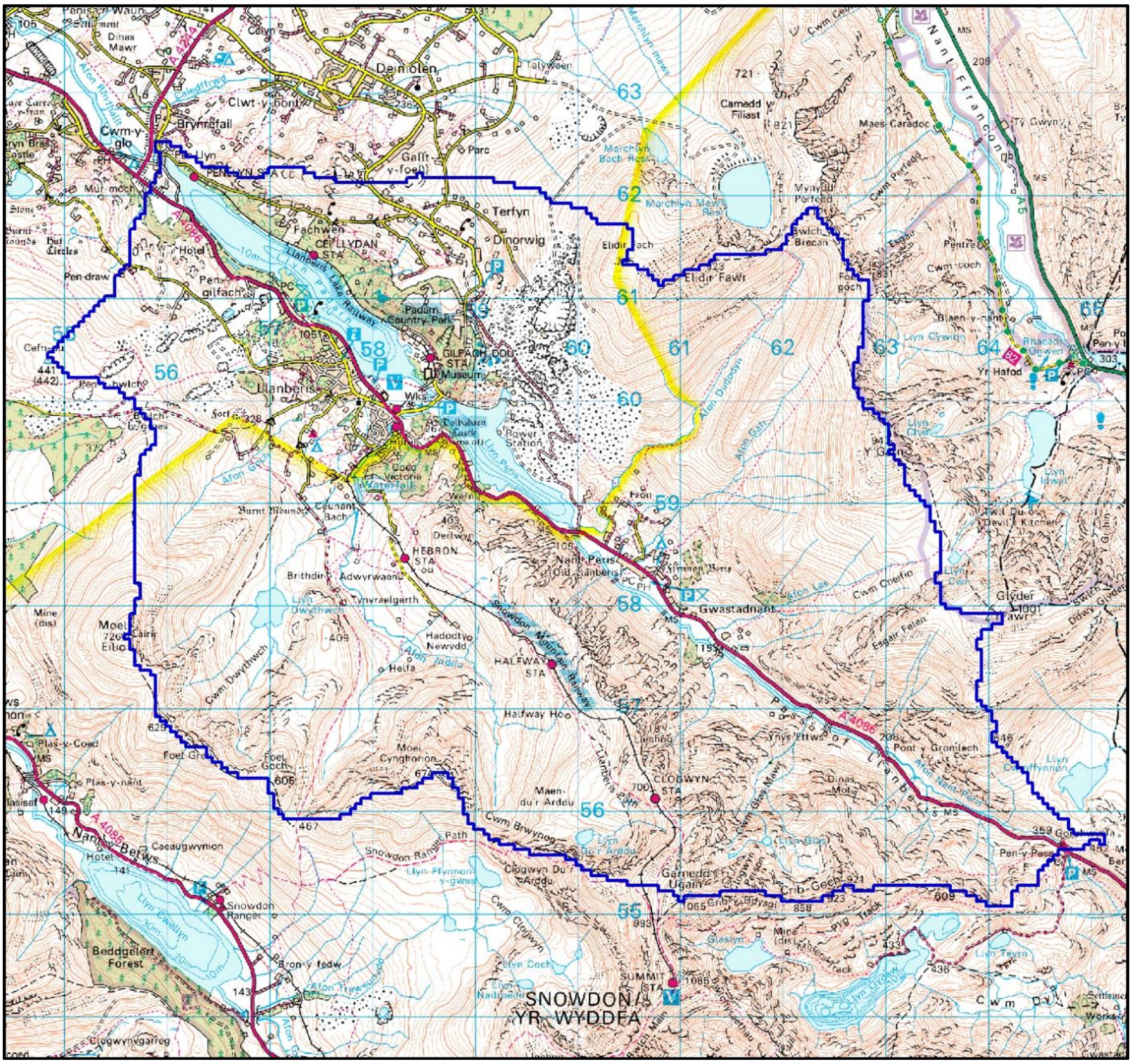


Figure 6.19.1. Surface water catchment of Llyn Padarn.

Water quality data on Llyn Padarn are not generally indicative of eutrophication. Nitrogen concentrations are well below the thresholds of concern and rarely exceeded 0.4 mg l^{-1}. There was comparatively little fluctuation in N concentrations with summer concentrations rarely dropping much below 0.1 mg l^{-1}: consequently Llyn Padarn will be phosphorus limited throughout the year. Geometric mean total phosphorus concentrations in the lake were low and typically less than 10 µg l^{-1}, consistent with Good Status for this lake type according to the WFD phosphorus model.

These results are not fully mirrored in the ecological tools, which tended to show evidence of some eutrophication. The phytoplankton and diatom tools recorded Good status, but the macrophyte tool recorded a conclusion of Moderate with moderate confidence of being less than good. Dissolved oxygen was worse than good with high certainty.

Land Use	**Area (ha)**	**% Cover**
Semi-natural broadleaved woodland	193.36	4.0
Dense scrub	6.46	0.1
Unimproved acid grassland	2687.14	55.4
Semi-improved acid grassland	153.14	3.2
Semi-improved neutral grassland	24.81	0.5
Marshy grassland	42.34	0.9
Bracken	122.47	2.5
Upland species rich ledges	17.31	0.4
Dry acid heath	398.38	8.2
Wet heath	65.47	1.3
Lichen/bryophyte heath	4.63	0.1
Dry heath / acid grassland mosaic	129.27	2.7
Dry modified bog	2.93	0.1
Acid/neutral flush	125.5	2.6
Standing water	16.68	0.3
Running water	151.15	3.1
Scree	57.26	1.2
Acid / neutral scree	37.95	0.8
Other rock exposure	11.44	0.2
Acid / neutral rock	6.94	0.1
Total Semi-Natural and Low Intensity Agriculture		**87.7**
Improved grassland	134.2	2.8
Total Intensive Agriculture		**2.8**
Planted coniferous woodland	17.33	0.4
Quarry	126.6	2.6
Spoil	177.77	3.7
Amenity grassland	5.31	0.1
Ephemeral / short perennial	12.97	0.3
Gardens	5.54	0.1
Buildings	54.57	1.1
Tracks	12.49	0.3
Bare ground	8.04	0.2
Illegible code	14.67	0.3
Total Other		**9.1**

Table 6.19.1. Land use in the Llyn Padarn surface water catchment.

Evidence of eutrophication is supported by other data. Arctic charr numbers in the lake have been declining rapidly since the early 1990s (Clabburn *et al*. 2014), with deoxygenation of the deep waters in the lake being considered an important cause.

Palaeolimnology (Bennion *et al*. 2010) and specialist review of the lake's phytoplankton community (Happey-Wood 2010) both indicated long-term nutrient enrichment of the lake during the latter half of the 20th century.

	Result	Confidence < Good
Mean Total Nitrogen	0.30	
Total Phosphorus	Good	Good or better
Phytoplankton	Good	Good or better
Macrophytes	Moderate	Quite Certain
Diatoms	Good	Good or better
Dissolved Oxygen	Moderate	**Very Certain**
Palaeolimnology	1.27	Uncertain
Weight of Evidence Tool Conclusion	Quite certain eutrophication problem	
Overall Eutrophication Evidence	**Marginal**	

Table 6.19.2 Key indicators for Llyn Padarn. See Table 4.6.1 for an explanation of evidence categories.

There was a well-documented algal bloom on Llyn Padarn in summer 2009 which resulted in the temporary closure of the lake to recreational activities. This resulted in various studies and actions to manage urban pollution from Llanberis and the associated sewage treatment works.

Recommendation: Llyn Padarn

There is evidence of eutrophication in Llyn Padarn, though this does not fully comply with the NVZ definition. Nitrogen levels are low and phosphorus concentrations in the lake are within the WFD standard. However, several strands of ecological evidence, in particular the low dissolved oxygen concentrations in deep water and consequent decline of the Arctic charr population, provide good evidence of a eutrophication problem in the lake.

However, NRW (2014) investigation work considered that agricultural nutrient loading were *de minimus* in the Llyn Padarn catchment. Therefore, it is unlikely that an NVZ would deliver environmental benefits and it is recommended that other measures, in particular control of phosphorus inputs from sewage, are implemented in order to restore ecological quality in Llyn Padarn.

Following external peer review, the independent expert agreed with NRW's recommendation that Llyn Padarn should not be designated an NVZ.

Accordingly, it is recommended that the catchment of Llyn Padarn should not be designated an NVZ.

6.19. Llyn Tryweryn

Llyn Tryweryn is a 7.9 ha, peaty, low alkalinity upland lake lying between Bala and Trawsfynydd. It is within the Migneint-Arenig-Dduallt SAC and contributes to the dystrophic lakes feature of the site. It has a mean depth of 2.7 m and a maximum depth of 8.5 m (Goldsmith *et al*. 2006), and is nitrogen limited (Burgess *et al*. 2013).

The catchment consists of about 50% plantation forestry and 50% natural upland habitats such as heath and bog (Goldsmith *et al*. 2006)(Figure 6.20.1). There is no intensive agriculture in the catchment (Table 6.20.1)

Water Body ID: GB31134854
Alkalinity: Low
Humic Type: Polyhumic
Depth Type: Shallow
Naturalness: Natural
Protected Area: SAC, SSSI
Catchment Area: 129 ha

Llyn Tryweryn has good monitoring data, with 61 water samples spanning a period from May 2010 to December 2014. Data for all three key determinands was available and there were no problems with detection limits or anomalous datapoints. There are also phytoplankton and macrophyte data, and a recent condition assessment (Burgess *et al*. 2013). Palaeolimnological data are available (Goldsmith *et al*. 2006) but have not been analysed for nutrient impacts and so are not considered here.

Total nitrogen concentrations in Llyn Tryweryn are consistently low over the assessment period (TN = 0.57 ± 0.04 (95% CI) mg l^{-1}), though there is some indication of an increase over the assessment period (Figure 6.20.2). Oxidised nitrogen concentrations are very low throughout the year (TON 75%ile = 0.12 mg l^{-1}). In contrast, geometric mean total phosphorus concentrations of 43.8 µg l^{-1} are high for this type of lake and consistent with WFD 'Bad' status. Although some of this is likely to be due to the occurrence of naturally higher phosphorus concentrations in humic lakes that is not accounted for in the MEI model, measured phosphorus concentrations are still relatively high (Burgess *et al*. 2013). The confidence of a phosphorus failure has therefore been downgraded to 'uncertain' (Table 6.20.2).

Ecological data gave a relatively low confidence indication of a eutrophication problem (Table 6.20.2). Phytoplankton gave a High status result with high confidence, whereas the macrophyte data gave a moderate status result. Dissolved oxygen profiles indicate that the lake is well oxygenated throughout (Burgess *et al*. 2013). The overall condition assessment for the lake concluded Unfavourable condition due to problems related to acidity, high chloride levels which may have been related to road drainage, and potential nutrient issues (Burgess *et al*. 2013).

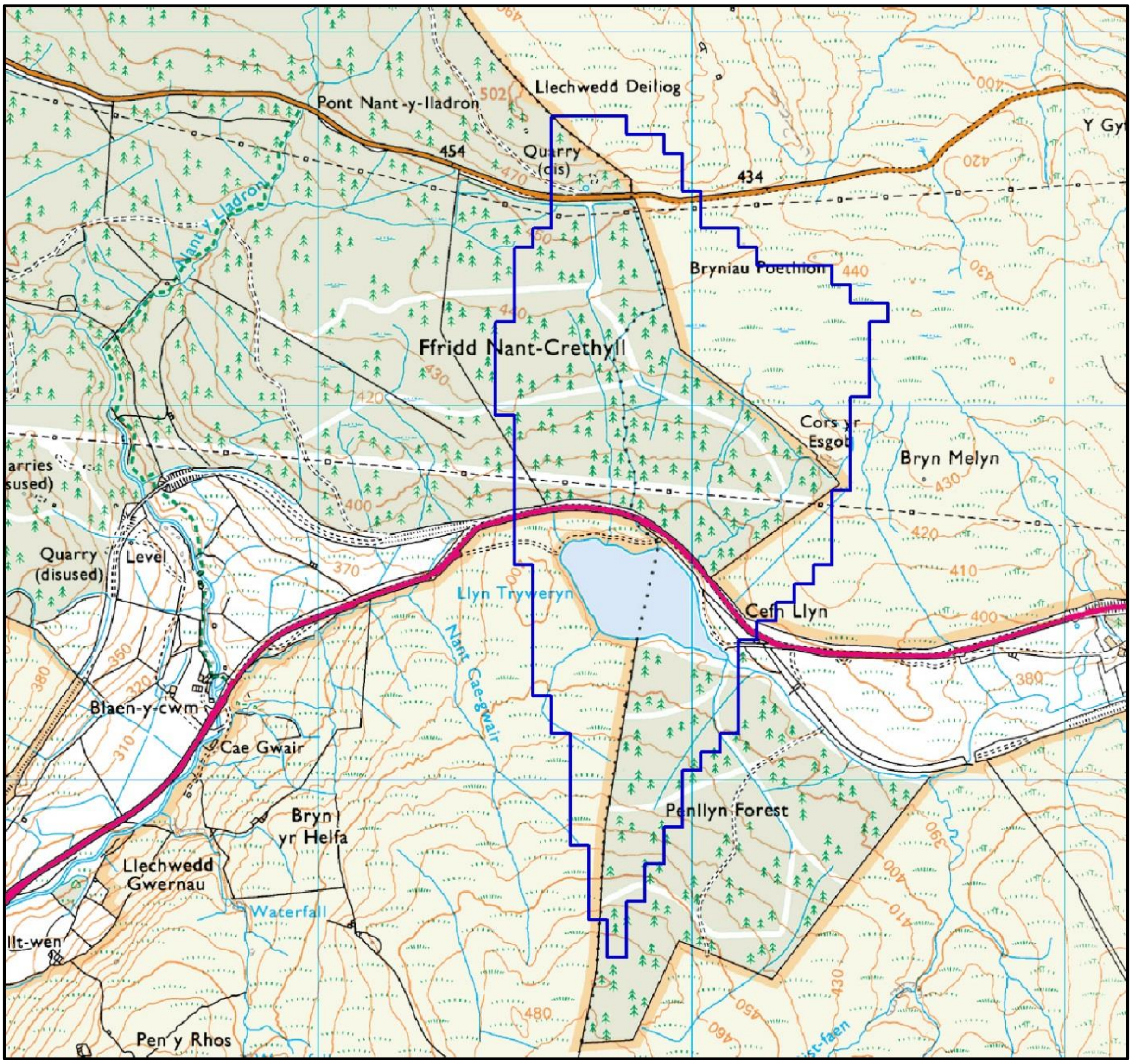


Figure 6.20.1. Surface water catchment of Llyn Tryweryn.

Land Use	Area (ha)	% Cover
Marshy grassland	0.93	0.7
Dry acid heath	6.79	5.4
Wet heath	3.69	2.9
Blanket bog	35.04	27.8
Bare peat	5.33	4.2
Inaccessible Land	7.3	5.8
Standing water*	7.67	N/A
Total Semi-Natural and Low Intensity Agriculture		**46.9**
Total Intensive Agriculture		**0.0**
Planted coniferous woodland	66.51	52.8
Tracks	0.34	0.3
Total Other		**53.1**

Table 6.20.1. Land use in the Llyn Tryweryn surface water catchment. *Standing water has been excluded from the cover calculations due to the high lake: catchment area ratio.

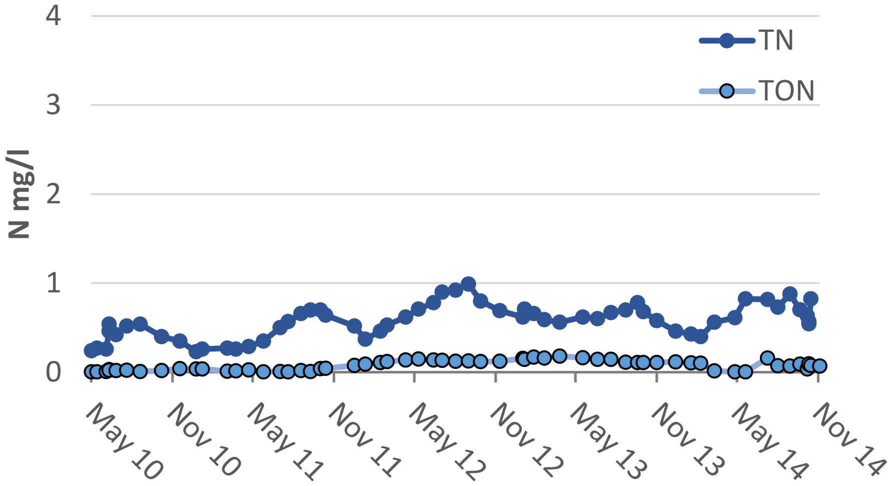


Figure 6.20.2. Nitrogen concentrations in Llyn Tryweryn.

	Result	Confidence < Good
Mean Total Nitrogen	0.57	Not > 1
Total Phosphorus	Bad	Uncertain
Phytoplankton	High	Good or better
Macrophytes	Moderate	Quite Certain
Weight of Evidence Tool Conclusion	Uncertain eutrophication problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Table 6.20.2. Key indicators for Llyn Tryweryn. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llyn Tryweryn

Despite the face value Bad status classification for phosphorus in Llyn Tryweryn, the overall evidence for eutrophication is relatively weak. Nitrogen levels are low and the only biological evidence of nutrient enrichment is in the plant community. Moreover, there is no intensive farmland in the catchment. It is considered likely that the phosphorus failure in Llyn Tryweryn is predominantly related to the high concentrations of humic acids in the lake.

For these reasons it is not considered likely that NVZ designation would be beneficial and consequently designation of the catchment is not recommended. However, further investigations to determine and mitigate any catchment nutrient and other pollution sources are recommended, in particular from forestry, road drainage from the adjacent A4212 and effluent from the property near the outflow of the lake.

Following external peer review, the independent expert agreed with NRW’s recommendation that Llyn Tryweryn should not be designated an NVZ.

Accordingly, it is recommended that the catchment of Llyn Tryweryn should not be designated an NVZ.

6.20. Pant-yr-Eos Reservoir

Pant-yr-Eos Reservoir is a 7.5 ha artificial reservoir near Newport, South Wales. It is shallow and high alkalinity. Land use in the catchment is mixed but has a fairly high proportion (69%) of intensive agriculture. Most of the remaining land is woodland, both broad-leaved and forestry (Table 6.21.1).

Water Body ID: GB30941829
Alkalinity: High
Humic Type: Clear
Depth Type: Shallow
Naturalness: Artificial, impounded
Protected Area: Drinking Water
Catchment Area: 105

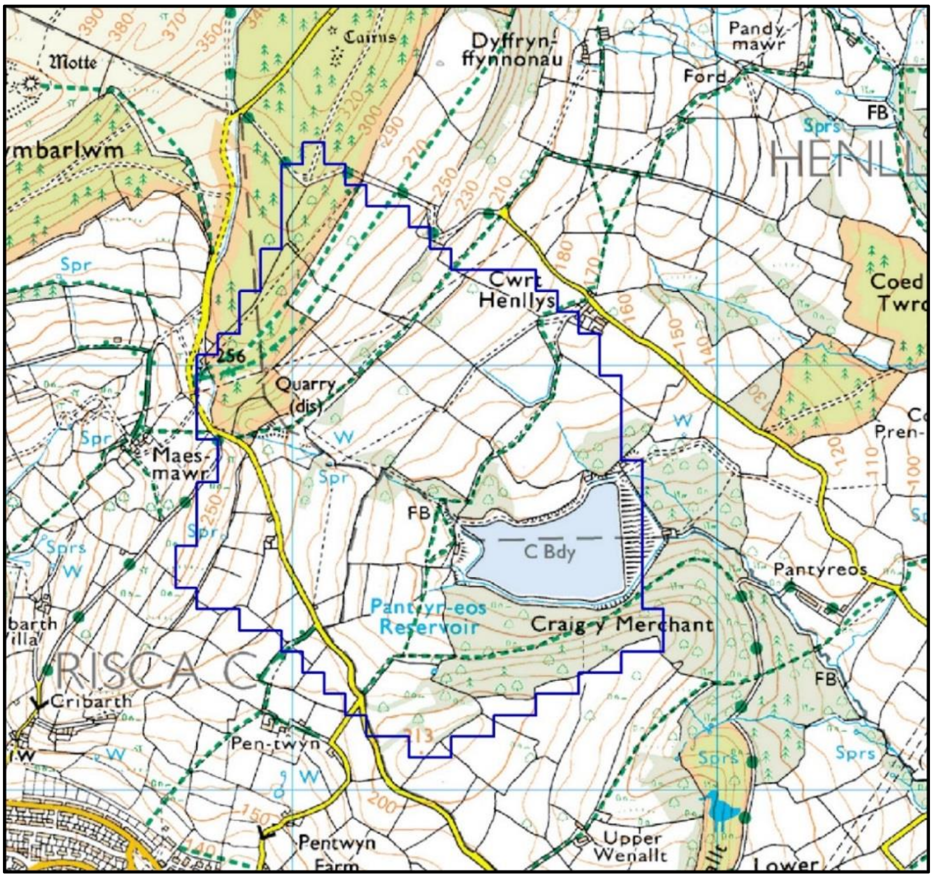


Figure 6.21.1. Surface water catchment of Pant-yr-Eos Reservoir.

There are 18 water quality samples for the reservoir, covering a period from June 2010 to October 2014. These are sampled approximately quarterly over this period and therefore give a good representation of seasonal variation. Five samples were below the standard phosphorus detection limit of 20 µg l^{-1}. Ecological data are restricted to phytoplankton data, for which there is no confidence in class information. This is considered to be a poor quality dataset.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	11.9	12.3
Unimproved acid grassland	1.57	1.6
Semi-improved acid grassland	0.85	0.9
Standing water*	6.28	N/A
Illegible code	3.92	4.1
Total Semi-Natural and Low Intensity Agriculture		**18.9**
Improved grassland	66.75	69.0
Total Intensive Agriculture		**69.0**
Planted coniferous woodland	11.6	12.0
Tracks	0.14	0.1
Total Other		**12.1**

Table 6.21.1. Land use in the Pant-yr-Eos Reservoir surface water catchment. * Standing water has been excluded from the cover calculations due to the high lake: catchment area ratio.

Nitrogen concentrations in Pant-yr-Eos Reservoir are fairly low (TN = 0.71 ± 0.03 mg l^{-1}; TON 75%ile = 0.64 mg l^{-1}). TP concentrations were consistent with Moderate Status, but with low confidence of being worse than good, and phytoplankton were reported as being at Good status (Table 6.21.2).

	Result	Confidence < Good
Mean Total Nitrogen	0.71	Not > 1
Total Phosphorus	Moderate	Uncertain
Phytoplankton	Good	Unknown
Weight of Evidence Tool Conclusion	Certain no eutrophication problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Table 6.21.2.Key indicators for Pant-yr-Eos Reservoir. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Pant-yr-Eos Reservoir

Chemical data suggest that there may possibly be elevated phosphorus concentrations in Pant-yr-Eos Reservoir, but with low confidence. There are no ecological data that are indicative of eutrophication. However, the biological evidence base in particular for this lake is poor. Consequently the lake does not meet the criteria for NVZ designation.

More detailed ecological information, especially for phytoplankton and diatoms, would be needed to assess any ecological impacts of elevated phosphorus at this site. This should be carried out on a risk basis.

Following external peer review, the independent expert agreed with NRW's recommendation that Pant-yr-Eos Reservoir should not be designated an NVZ.

Accordingly, it is recommended that the catchment of Pant-yr-Eos Reservoir should not be designated an NVZ.

6.21. Ty Mawr Reservoir

Ty Mawr Reservoir is an 8.6 ha artificial water supply reservoir near Wrexham, receiving water from the Eclusham and Eglwyseg Mountains. It is moderate alkalinity, humic and shallow with a mean depth of 10 m, and part of a system of several small reservoirs and water transfers for public water supply. A substantial proportion of the water for the reservoir is supplied from the adjacent Afon Eitha catchment, with much of the remainder coming via a transfer from the nearby Cae Llwyd Reservoir (NRW License data).

Water Body ID: GB31134331
Alkalinity: Moderate
Humic Type: Humic
Depth Type: Shallow
Naturalness: Artificial, pumped storage
Protected Area: Drinking Water
Catchment Area: TBC

The natural catchment of Ty Mawr Reservoir is very small and is only slightly larger than the area of the lake itself (Figure 6.22.1). It consists almost entirely of improved grassland (96% - Table 6.22.1).

There are 20 water samples from Ty Mawr Reservoir, covering the period from June 2010 to November 2014 at approximately quarterly intervals. The first phosphorus sample had a problem with the detection limit but this was corrected in subsequent samples. Other ecological data is restricted to phytoplankton sampling. This is considered an adequate dataset.

Nitrogen concentrations were generally fairly low, with a mean TN of 0.77 ± 0.05 mg l^{-1}. The TON 75%ile was 0.43 mg l^{-1}, indicating that winter nitrate levels were low. The phosphorus classification was Moderate, with a geometric mean TP of 14.1 µg l^{-1} being just above the Good/Moderate boundary of 13 µg l^{-1}. Confidence in this result has been downgraded from 'Very Certain' to 'Uncertain' due to the uncertainty associated with the performance of the MEI model in humic lakes.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	0.16	1.7
Semi-improved neutral grassland	0.07	0.7
Acid/neutral flush	0.16	1.7
Standing water*	8.6	N/A
Total Semi-Natural and Low Intensity Agriculture		**4.1**
Improved grassland	9.09	95.9
Total Intensive Agriculture		**95.9**
Total Other		**0**

Table 6.22.1. Land use in the Ty-Mawr Reservoir surface water catchment. Standing water has been excluded from the cover calculations due to the high lake: catchment area ratio.

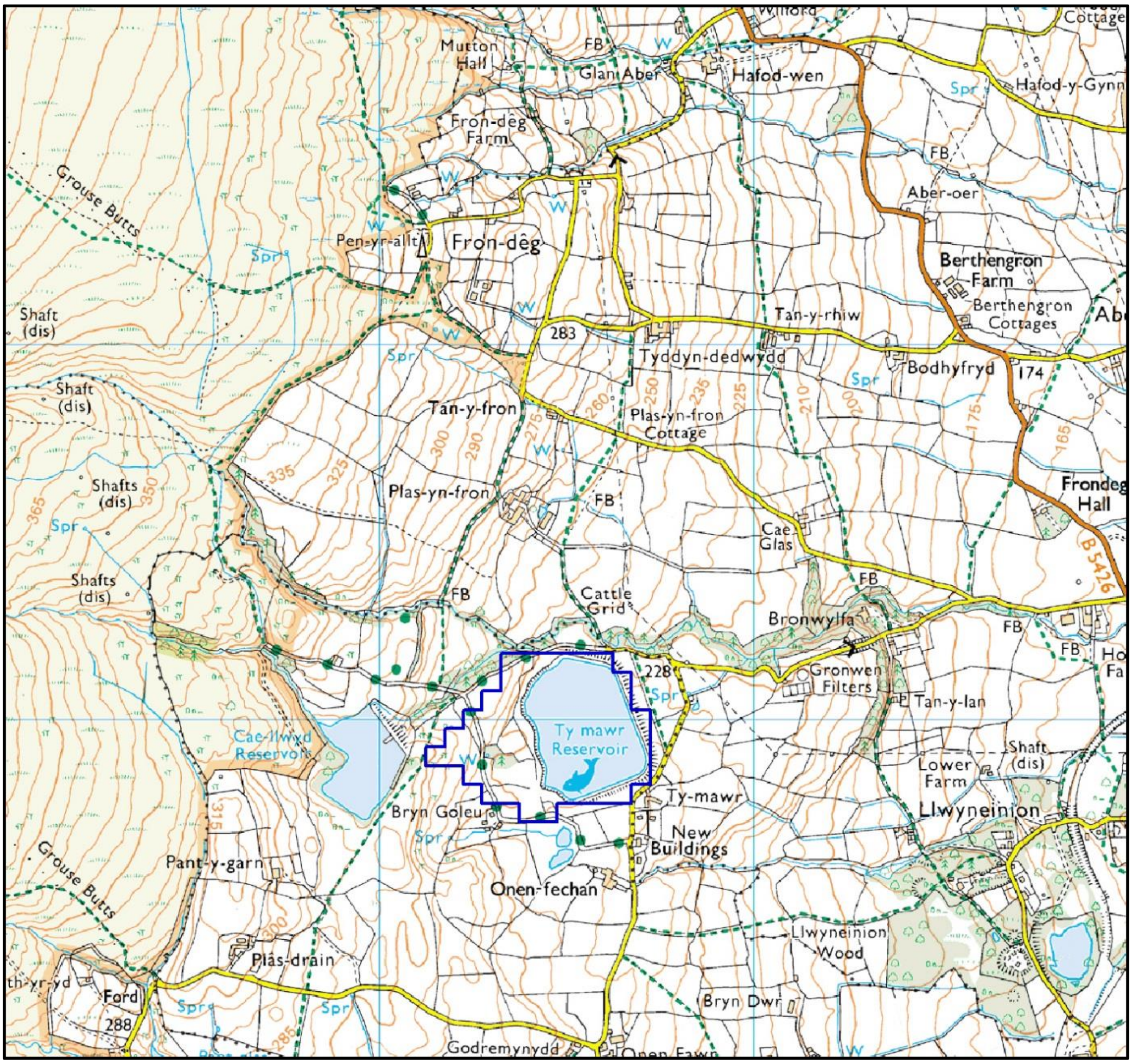


Figure 6.22.1. Surface water catchment of Ty-Mawr Reservoir.

Phytoplankton data are recorded as Moderate status, with Uncertain confidence. However, no actual confidence in class values were available. This gives an overall assessment of Uncertain eutrophication problem using the WoE tool. No additional data were available to modify this conclusion.

	Result	Confidence < Good
Mean Total Nitrogen	0.77	Not > 1
Total Phosphorus	Moderate	Uncertain
Phytoplankton	Moderate	Uncertain
Weight of Evidence Tool Conclusion	Uncertain eutrophication problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Table 6.22.2.Key indicators for Ty Mawr Reservoir. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Ty Mawr Reservoir

There is some evidence of both elevated nutrient levels and consequent ecological impacts from Ty Mawr Reservoir, and thus in principle it meets the NVZ criteria. However, confidence in both conclusions is low. Moreover, the unnatural catchment of the lake means that it can be excluded from further consideration because it is a pumped storage reservoir. Overall, the evidence base is considered insufficient to support designation of an NVZ.

If further investigations are considered necessary, the collection of evidence from additional ecological tools, such as diatoms, is recommended.

Following external peer review, the independent expert agreed with NRW’s recommendation that Ty Mawr Reservoir should not be designated an NVZ.

Accordingly, it is recommended that the catchment of Ty Mawr Reservoir should not be designated an NVZ.

6.22. Wentwood Reservoir

Wentwood Reservoir is a 16 ha public water supply reservoir about 7 km northwest of Newport, with a catchment of 162 ha (Hughes *et al*. 2004). It is high alkalinity, clear and shallow, with a mean depth of just over 10 m.

Water Body ID: GB30941762
Alkalinity: High
Humic Type: Clear
Depth Type: Shallow
Naturalness: Artificial, impounded
Protected Area: Drinking Water
Catchment Area: 162

Much of the catchment consists of plantation forestry (47%), with smaller amounts of improved grassland near the lake (Fig. 6.23.1; Table 6.23.1). The proportion of land use under intensive agriculture is about 22%. Wentwood Reservoir is managed as a trout fishery.

Land Use	**Area (ha)**	**% Cover**
Semi-natural broadleaved woodland	7.15	5.1
Planted broadleaved woodland	2.59	1.8
Unimproved acid grassland	3.12	2.2
Semi-improved acid grassland	3.66	2.6
Semi-improved neutral grassland	2.46	1.7
Bracken	22.34	15.8
Standing water*	15.9	N/A
Total Semi-Natural and Low Intensity Agriculture		**29.2**
Improved grassland	31.54	22.3
Arable	0.13	0.1
Total Intensive Agriculture		**22.4**
Planted coniferous woodland	65.71	46.5
Felled broadleaved woodland	0.27	0.2
Amenity grassland	0.25	0.2
Gardens	1.11	0.8
Buildings	1.01	0.7
Total Other		**48.4**

Table 6.23.1. Land use in the Wentwood Reservoir surface water catchment. Standing water has been excluded from the cover calculations due to the high lake: catchment area ratio.

There are 24 water samples from Wentwood Reservoir, including measurements for all three water quality determinands. Seven of the phosphorus measurements had readings below the detection limit of the method used; as the dataset was too small to estimate a distribution these were assumed to be half the detection limit for calculating the mean (i.e. 10 µg l^{-1}). Ecological data is limited to phytoplankton, for which confidence is reported as uncertain but no calculated values are provided.

Nitrogen concentrations were generally fairly low, with a mean TN of 0.59 ± 0.06 mg l^{-1}. The TON 75%ile was 0.33 mg l^{-1}, consistent with low winter nitrate levels. The phosphorus classification was Moderate, with a geometric mean TP of 21 µg l^{-1} being above the Good/Moderate boundary of 18 µg l^{-1}. Confidence in this result is Quite Certain.

Figure 6.23.1. Surface water catchment of Wentwood Reservoir.

The phytoplankton classification was given as Moderate, with Uncertain confidence of being worse than Good (Table 6.23.2). This is supported by records of frequent blue-green algal blooms at the reservoir, which has had persistent blue-green algal problems with consequent impacts on water supply. This gives an overall WoE conclusion of Uncertain eutrophication problem (Table 6.23.2). No additional data are available.

	Result	Confidence < Good
Mean Total Nitrogen	0.59	Not > 1
Total Phosphorus	Moderate	Quite Certain
Phytoplankton	Moderate	Uncertain
Weight of Evidence Tool Conclusion	Uncertain eutrophication problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Table 6.23.2.Key indicators for Wentwood Reservoir. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Wentwood Reservoir

There is some evidence of both elevated nutrient levels and consequent ecological impacts from Wentwood Reservoir, and thus in principle it meets the NVZ criteria. However, confidence in the ecological conclusions is rather low and this should be taken into consideration when reaching a decision. On the whole, it is considered that the evidence base is too weak to support NVZ designation. However, catchment actions to reduce phosphorus loading to the lake from both forestry and agriculture may help to reduce the frequency and intensity of blue-green algal blooms.

Following external peer review, the independent expert agreed with NRW's recommendation that Wentwood Reservoir should not be designated an NVZ.

Accordingly, it is recommended that the catchment of Wentwood Reservoir should not be designated an NVZ.

6.23. Ynysyfro Reservoirs

Ynysyfro Reservoirs are a pair of artificial water supply reservoirs near Newport. The Upper Reservoir is 2.8 ha in area, and the lower 5.4 ha. They are high alkalinity, clear and shallow. The lakes are managed as a put and take trout fishery.

Water Body ID: GB30941926
Alkalinity: High
Humic Type: Clear
Depth Type: Shallow
Naturalness: Artificial, impounded
Protected Area: Drinking Water
Catchment Area: 120

The catchment is estimated at 120 ha (Hughes *et al*. 2004) and is a mixture of intensive farmland (49%), urban (33%) and forestry (13%) (Table 6.24.1).

There are 28 water samples from Ynysyfro Reservoirs covering a period from January 2009 to November 2014, though only 21 of these include TP and TON data starting in July 2010. Samples are collected quarterly and are therefore representative of conditions throughout the year. Five of the samples were below the phosphorus detection limit of 20 µg l^{-1}; for this analysis these were assumed to be half the detection limit. Biological data are restricted to phytoplankton only. Monitoring data are from the lower reservoir.

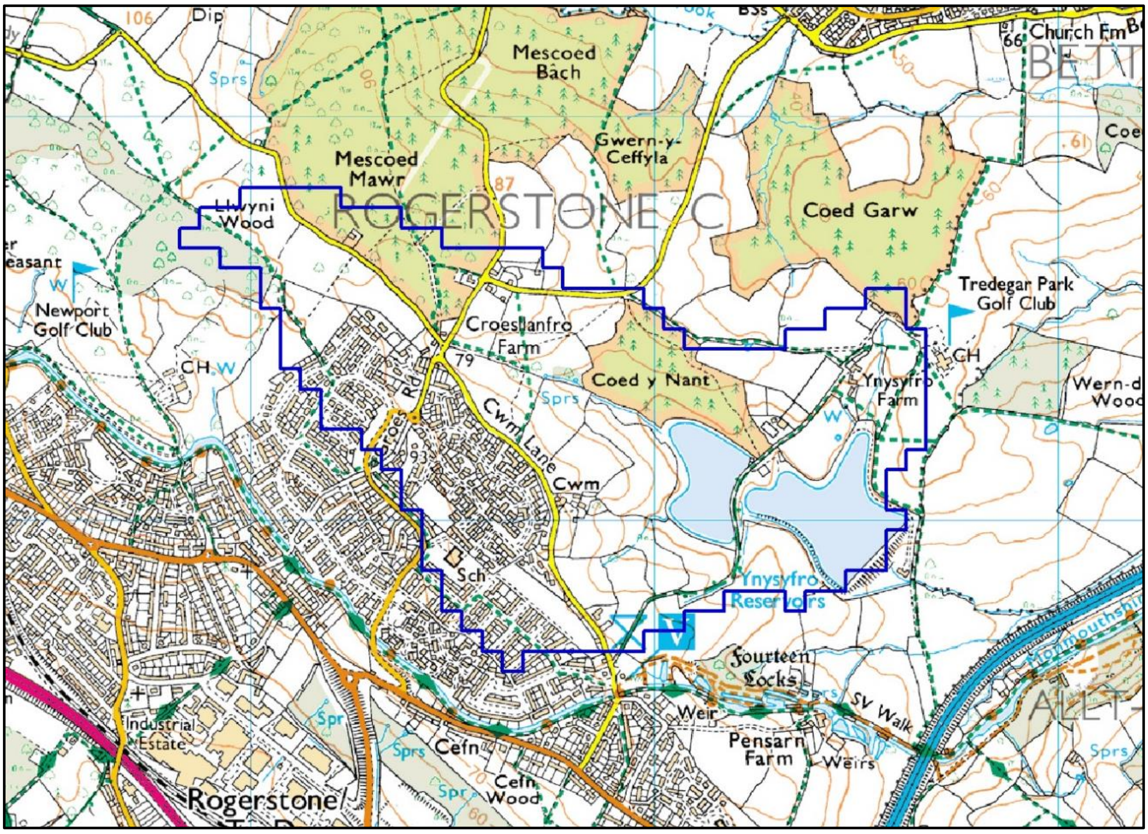


Figure 6.24.1. Surface water catchment of Ynysyfro Reservoirs.

Land Use	**Area (ha)**	**% Cover**
Semi-natural broadleaved woodland	2.67	2.5
Planted broadleaved woodland	0.48	0.5
Semi-improved neutral grassland	1.83	1.6
Standing water*	9.7	N/A
Total Semi-Natural and Low Intensity Agriculture		**4.6**
Improved grassland	48.12	45.2
Arable	4.44	4.2
Total Intensive Agriculture		**49.4**
Amenity grassland	9.28	8.7
Buildings	25.42	23.9
Planted coniferous woodland	14.31	13.4
Total Other		**42.2**

Table 6.24.1. Land use in the Ynysyfro Reservoirs surface water catchment. Standing water has been excluded from the cover calculations due to the high lake: catchment area ratio.

Nitrogen concentrations are fairly low, with mean TN of 0.67 ± 0.07 mg l^{-1} and 75%ile TON of 0.28 being below that expected to affect the plant community. TP concentrations of 27.2 µg l^{-1} were worse than the Good / Moderate boundary of 25 µg l^{-1} and show evidence of increasing rapidly over the assessment period: the geometric mean for 2010-12 was 21 µg l^{-1} compared with 35.5 µg l^{-1} for 2013-14. Confidence in the phosphorus failure has therefore been increased to ‘very certain’ (Table 6.24.2). This trend is not mirrored by the nitrogen which remains broadly stable over the assessment period.

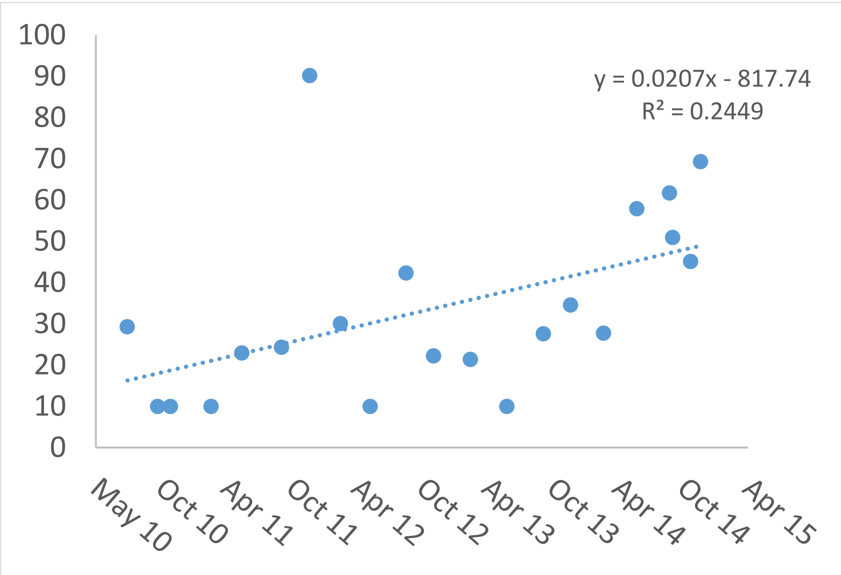


Figure 6.24.2. Trend in total phosphorus concentrations for Ynysyfro Reservoir, 2010-2015.

The phytoplankton class is listed as Moderate with unknown confidence. In the absence of confidence data, the confidence of being less than Good status is treated as Uncertain (Table 6.24.2). No additional data are available.

Indicator	Result	Confidence < Good
Mean Total Nitrogen	0.67	Not > 1
Total Phosphorus	Moderate	**Very Certain**
Phytoplankton	Moderate	Uncertain
Weight of Evidence Tool Conclusion	Uncertain eutrophication problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Table 6.24.2.Key indicators for Ynysyfro Reservoirs. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Ynysyfro Reservoirs

There is evidence of both elevated nutrient levels and consequent ecological impacts from Ynysyfro Reservoirs, and thus in principle they meet the NVZ criteria. However, confidence in the ecological conclusions is rather low. This and the evidence of increasing phosphorus concentrations should be taken into consideration when reaching a decision. On balance, it is recommended that Ynysyfro Reservoirs not be designated as an NVZ.

Investigative work is recommended in the catchment of these lakes to identify sources of phosphorus such as septic tanks, farmyards, storm overflows, increased fertilizer use or slurry spreading that may be contributing to deterioration.

Following external peer review, the independent expert agreed with NRW's recommendation that Ynysyfro Reservoirs should not be designated an NVZ. Accordingly, it is recommended that the catchment of Ynysyfro Reservoirs should not be designated an NVZ.

6.24. Llys-y-Frân Reservoir

Llys-y-Frân Reservoir is a large (74 ha) public water supply reservoir impounding part of the Eastern Cleddau, supplying a significant area of south-west Wales. It is moderate alkalinity, clear and very shallow. The lake is managed as a put and take trout fishery. The lake is within the Afonnydd Cleddau SAC which is designated for various fish species and otter, but not for lake habitat.

Water Body ID: GB31040087
Alkalinity: Moderate
Humic Type: Clear
Depth Type: Very Shallow
Naturalness: Artificial, impounded
Protected Area: SAC, SSSI, Drinking Water
Catchment Area: 2762 ha

The catchment of Llys-y-Frân reservoir is large (2762 ha) and consists of a mixture of intensively managed and semi-natural habitats. Semi-natural habitats (21%) occur mainly in the upland headwater areas and consist of a mixture of grassland, heathland and broadleaved woodland (Table 6.25.1). Intensive agriculture (62%) is the largest land use in the catchment, and this is predominantly improved pasture. Much of the remaining 17% is coniferous plantation.

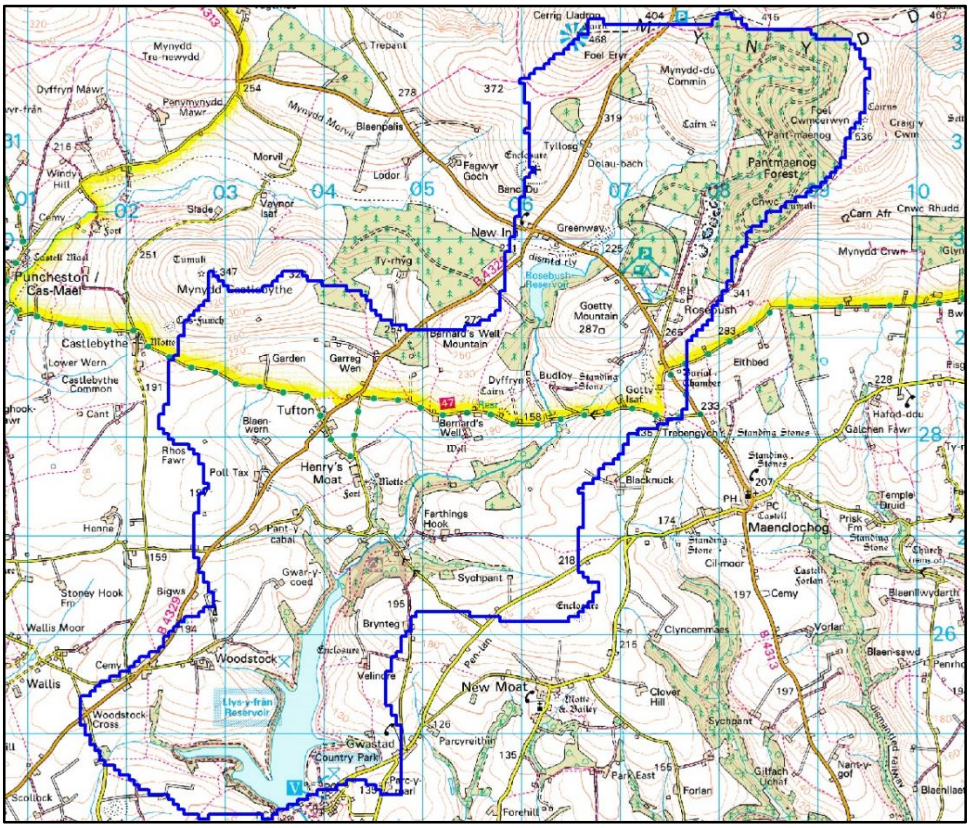


Figure 6.25.1. Catchment of Llys-y-Frân Reservoir.

Land Use	Area (ha)	% Cover
Semi-natural broadleaved woodland	96.96	3.7
Planted broadleaved woodland	6.91	0.3
Dense scrub	27.03	1.0
Unimproved acid grassland	23.77	0.9
Semi-improved acid grassland	97.58	3.7
Semi-improved neutral grassland	25.94	1.0
Marshy grassland	99.53	3.8
Bracken	23.06	0.9
Dry acid heath	14.18	0.5
Wet heath	27.22	1.0
Dry heath / acid grassland mosaic	76.63	2.9
Wet modified bog	4.82	0.2
Acid/neutral flush	2.04	0.1
Standing water	13.32	0.5
Total Semi-Natural and Low Intensity Agriculture		**20.5**
Improved grassland	1604.1	61.0
Arable	36.61	1.4
Total Intensive Agriculture		**62.4**
Planted coniferous woodland	385.07	14.7
Amenity grassland	9.77	0.4
Caravan site	2.33	0.1
Buildings	35.42	1.3
Quarry	9.4	0.4
Tracks	3.13	0.1
Total Other		**17.0**

Table 6.25.1. Land Use types in the Llys-y-Frân Reservoir surface water catchment.

There are 54 water samples from Llys-y-Frân Reservoir, spanning a period from June 2010 to December 2014 and including TON, TN and TP. Biological data are restricted to a chlorophyll-only classification from the phytoplankton tool.

Both nitrogen and phosphorus in Llys-y-Frân Reservoir are elevated. TON and TN both exceed 2 mg l^{-1} (TN = 2.16 mg l^{-1} ± 0.08 mg l^{-1}; TON = 2.12 mg l^{-1}) and there is relatively little fluctuation in nitrogen concentrations throughout the year (Figure 6.25.2), reflecting the large catchment. There is some evidence of a decline in nitrogen concentrations over the assessment period (Figure 6.25.2). Phosphorus concentrations are somewhat elevated with a concentration of 24.09 ± 0.11 µg l^{-1}, although it should be noted that 16 of these values were below the detection limit of 20 µg l^{-1}. A value of 15 µg l^{-1} has been used for these measurements. The Good-Moderate boundary for this lake is 22 µg l^{-1}. There is some evidence for an increase in TP over the assessment period (Figure 6.25.3).

Biological evidence is restricted to the phytoplankton tool, which classified the lake as being at Good status. As a result, the overall WoE tool gave a conclusion of Uncertain eutrophication problem.

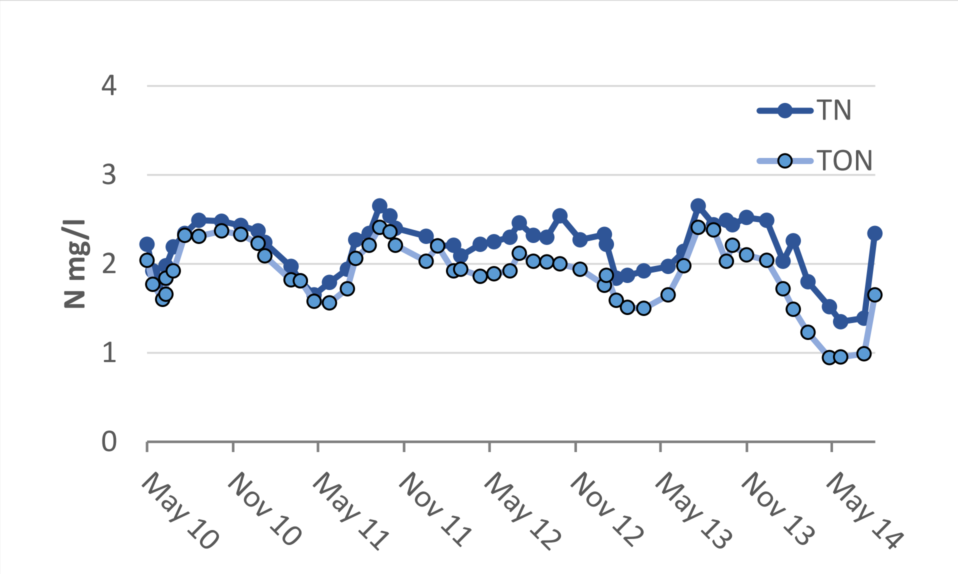


Figure 6.25.2. Trends in nitrogen for Llys-y-Frân Reservoir.

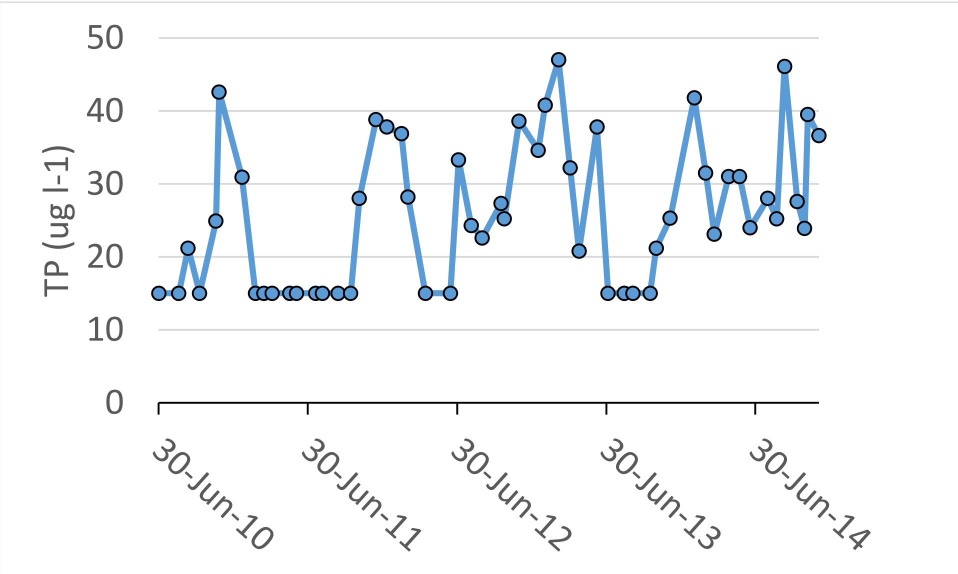


Figure 6.25.3. Trends in phosphorus for Llys-y-Frân Reservoir.

Indicator	Result	Confidence < Good
Mean Total Nitrogen	2.16	**Very Certain > 2**
Total Phosphorus	Moderate	**Very Certain**
Phytoplankton	Good	Good or better
Weight of Evidence Tool Conclusion	Uncertain eutrophication problem	
Overall Eutrophication Evidence	**Evidence does not support NVZ Designation**	

Table 6.25.2. Key indicators for Llys-y-Frân Reservoir. See Table 4.6.1 for an explanation of evidence categories.

Recommendation: Llys-y-Fran Reservoir

There is evidence of both elevated nitrogen and slightly elevated phosphorus concentrations in Llys-y-Fran Reservoir. However, there is no evidence of consequent ecological impacts at present, albeit with a small dataset. In general, this evidence does not support NVZ designation.

The elevated nutrient levels do pose a potential risk factor for the future, and it is therefore recommended that catchment measures be instigated to reduce nutrient loading to the lake, especially in the light of its importance for public water supply. Further monitoring of the lake using a wider range of ecological tools (e.g. the diatom method) is recommended in order to gain a better understanding of potential ecological impacts.

Following external peer review, the independent expert agreed with NRW’s recommendation that Llys-y-Fran Reservoir should not be designated an NVZ and that more ecological data are needed.

Accordingly, it is recommended that the catchment of Llys-y-Fran Reservoir should not be designated an NVZ.

7. Discussion

This review has summarised the evidence of eutrophication for more than 100 Welsh lakes, taking into account a broad suite of chemical and biological datasets. This constitutes about 20% of all lake water bodies in Wales greater than 1 ha in area (Hughes *et al*. 2004). By area, this figure is much greater, because monitored lakes disproportionately fall into the larger size classes. This is the most comprehensive single review of its kind for Welsh lakes.

All lakes are potentially vulnerable to eutrophication from nitrogen and / or phosphorus. However, about three quarters of all Welsh lakes for which data were available showed no clear evidence of nutrient enrichment, either in terms of elevated nutrient levels or consequent ecological symptoms. This reflects a combination of factors, including the upland nature of many Welsh lakes and sustainable land management in many areas.

7.1. Consequences of the Review for NVZs (Lakes, Eutrophic) in Wales

Twenty-nine lakes showed some evidence of eutrophication and were examined in detail. The results of this and potential consequences for NVZ designation are summarised in Table 7.1 below and shown in Figure 7.1.

All four of the existing NVZs designated due to eutrophication (Bosherston Lakes, Hanmer Mere, Llangorse Lake and Llyn Coron) still met the eutrophic lakes criteria (Table 7.1). The overall evidence strength was Very High for Bosherston, High for Hanmer Mere and Llyn Coron, and Medium-High for Llangorse Lake. The total area of these NVZs is approximately 6,200 ha (c. 0.3% of the land area of Wales).

Five potential new NVZs were identified during this process with either High or Medium-High confidence (Table 7.1; Figures 7.1-7.3). Of these, four (Llyn Maelog, Llyn Traffwll, Llyn yr Wyth Eidion and Valley Lakes) were on Anglesey and reflect long-term concerns regarding the impact of high nutrient levels on the lakes of the island (Bennion 1995; Duigan *et al*. 1996; Millband 1997, 1999; Haworth *et al*. 1998; Burgess *et al*. 2006, 2008, 2012; Goldsmith *et al*. 2013, 2014b, Hatton-Ellis 2014). The poor state of the other lake, Llyn Pencarreg in Carmarthenshire, appears to be linked to unusually poor farming practice in the catchment (Goldsmith *et al*. 2014b). Based on the good quality and high confidence evidence available, measures to control nutrient loading are required and in this context it is recommended that these are considered for NVZ designation. The total area of these recommended NVZs is approximately 2,705 ha (c. 0.1% of the land area of Wales).

For a further seven lakes, there is some evidence of eutrophication, but the evidence base is not as strong. These are Eglwys Nunnydd Reservoir, Llyn Tegid, Llyn Padarn, Llyn Elsi, Plas Uchaf & Dolwen Reservoirs, Llandegfedd Reservoir, and Witchett Pool. This is generally either because (i) the actual status of the lakes is close to a threshold value and it is therefore difficult to draw firm conclusions or (ii) there are insufficient data to draw firm conclusions. Four of these lakes (Eglwys Nunnydd Reservoir, Llyn Padarn, Llyn Elsi, Llandegfedd Reservoir) have been excluded from further consideration as NVZs because either they are pumped storage water bodies, or because the likely nutrient loading from agriculture is considered to be insignificant.

The remaining three lakes were submitted to the Expert Panel for further scrutiny without a specific NRW recommendation regarding their suitability for NVZ designation at this stage. The combined catchment area of these potential NVZs is just over 15,400 ha, most of which is the catchment of Llyn Tegid (14,920 ha). Following expert review, it was decided not to recommend designation of these lakes.

For the remaining nine lakes, the evidence base does not support NVZ designation. This is because there is no compelling evidence of eutrophication (Llyn Alaw, Llyn Cefni, Llwyn-On Reservoir, Pant-yr-Eos Reservoir, Ty-Mawr Reservoir); because although the lakes are eutrophic under the NVZ criteria, the contribution of agriculture to such eutrophication is negligible (Llyn Elsi, Llyn Padarn, Llyn Tryweryn) or because the reservoir is a pumped storage water supply reservoir and it is therefore not possible to identify the catchment with certainty (Llandegfedd Reservoir).

The final results following independent expert peer review are summarised in Table 7.1.

Lake Name	Ecosystem Importance			Area	Catchment Area (ha)	Final NVZ Recommendation	NVZ Eutrophic Evidence	Comments
	B	W	R					
Cefni Reservoir		✓		Anglesey	4068	**Do not designate**	Insufficient	Evidence of elevated nutrient levels suggests potential risk.
Llyn Alaw	✓	✓	✓	Anglesey	3339	**Do not designate**	Insufficient	Evidence of elevated nutrient levels suggests potential risk.
Llyn Coron	✓		✓	Anglesey	2044	**Retain existing NVZ**	High	
Llyn Maelog	✓			Anglesey	1840	**Designate as NVZ**	High	
Llyn Traffwll	✓			Anglesey	312	**Do not designate following expert review.**	Med-High	Better data are required especially for water chemistry. Evidence of N limitation required.
Llyn yr Wyth Eidion	✓			Anglesey	273	**Designate as NVZ**	High	Groundwater catchment needs confirmation.
Valley Lakes	✓		✓	Anglesey	148	**Do not designate following expert review.**	Med-High	Clear evidence of nitrogen limitation is required.
Llangorse Lake	✓		✓	Brecon Beacons NP	2254	**Retain existing NVZ**	Med-High	
Llyn Pencarreg	✓			Carmarthen-shire	35	**Designate as NVZ**	Med-High	
Witchett Pool	✓			Carmarthen-shire	262*	**Do not designate**	Marginal	
Llyn Elsi Reservoir		✓	✓	Conwy	61	**Do not designate**	Marginal	Eutrophication is not from agricultural sources.

Lake Name	Ecosystem Importance			Area	Catchment Area (ha)	Final NVZ Recommendation	NVZ Eutrophic Evidence	Comments
	B	W	R					
Plas Uchaf & Dolwen Reservoirs		✓		Conwy	226	**Do not designate**	Low	Better ecological data would be desirable.
Llyn Padarn	✓		✓	Gwynedd	4,901	**Do not designate**	Marginal	Eutrophication is not from agricultural sources.
Llwyn-On Reservoir		✓		Merthyr Tydfil	4,388	**Do not designate**	Insufficient	No evidence of eutrophication.
Eglwys Nunnydd Reservoir		✓	✓	Neath Port Talbot	247	**Do not designate**	Marginal	Pumped storage reservoir
Pant-yr-Eos Reservoir		✓		Newport	105	**Do not designate**	Insufficient	Poor quality data
Wentwood Reservoir		✓	✓	Newport	162	**Do not designate**	Insufficient	Increasing nutrient trend
Ynys-y-Fro Reservoir		✓	✓	Newport	120	**Do not designate**	Insufficient	Increasing nutrient trend
Bosherston Lakes	✓		✓	Pembrokeshire	1,807	**Retain existing NVZ**	Very High	
Llys-y-Frân Reservoir		✓	✓	Pembrokeshire	2,762	**Do not designate**	Insufficient	Elevated nutrients but inadequate biological data.
Llandegfedd Reservoir	✓			Torfaen	650†	**Do not designate**	Marginal	Pumped storage reservoir.
Llyn Tegid	✓	✓		Snowdonia NP	14,920	**Do not designate**	Marginal	
Llyn Tryweryn	✓			Snowdonia NP	129	**Do not designate**	Insufficient	Very humic lake. Eutrophication not from agricultural sources.

Lake Name	Ecosystem Importance			Area	Catchment Area (ha)	Final NVZ Recommendation	NVZ Eutrophic Evidence	Comments
	B	W	R					
Hanmer Mere	✓			Wrexham	93	**Retain existing NVZ**	High	
Ty Mawr Reservoir		✓	✓	Wrexham	19†	**Do not designate**	Insufficient	

Table 7.1. Summary of the conclusions for the lakes examined in Section 6. Ecosystem importance: B = biodiversity; W = water supply; R = recreation. * = catchment area requires confirmation; † = pumped storage reservoir.

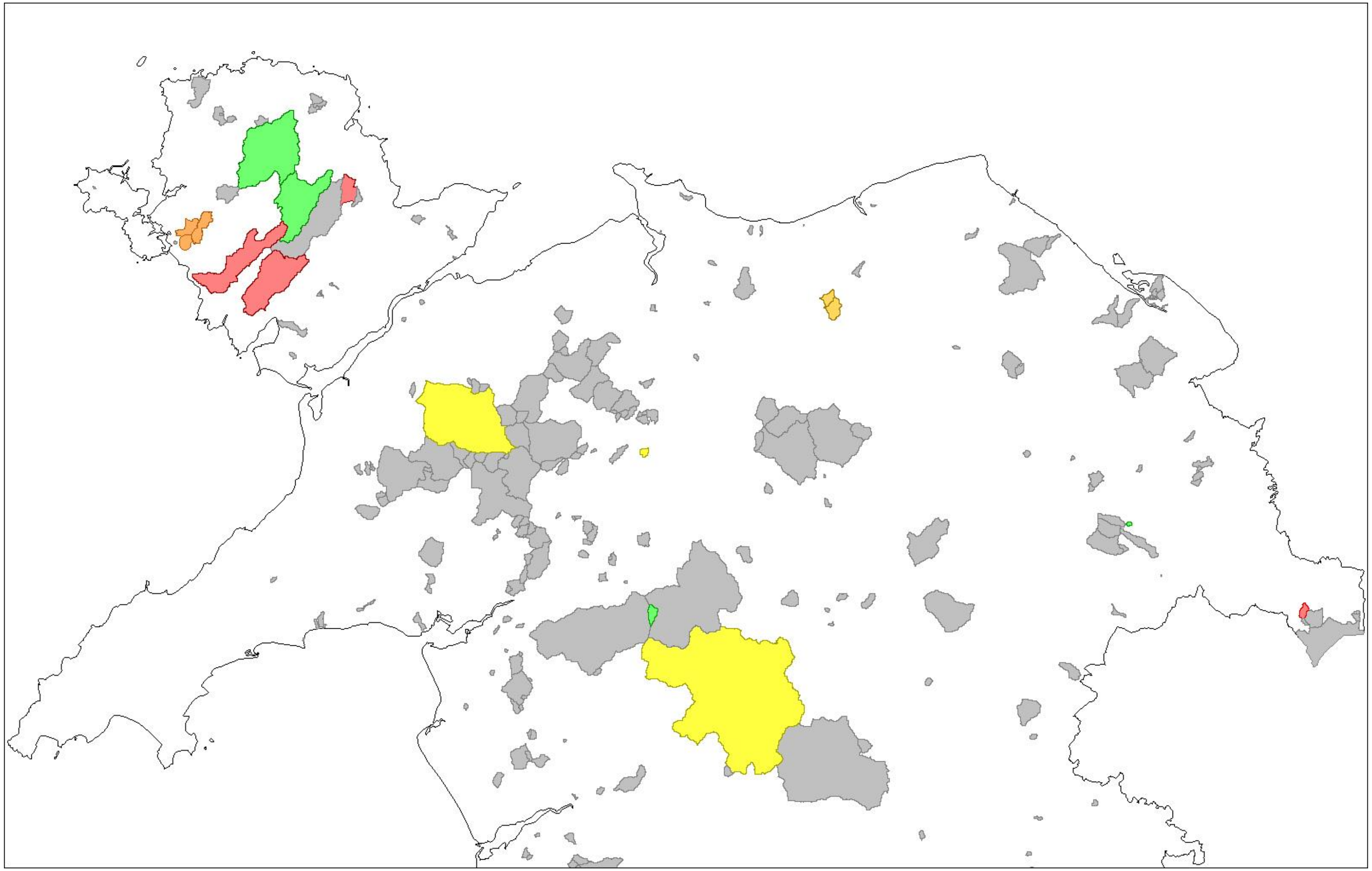


Figure 7.1 (a). Evidence strength for lakes in North Wales following detailed review. Green: Insufficient evidence of eutrophication, or eutrophication not considered likely to be a genuine pressure. Yellow: Marginal evidence of eutrophication. Light orange: Low evidence of eutrophication. Dark orange: Medium-High evidence of eutrophication. Red: High Evidence of Eutrophication. Grey: water bodies that were not monitored or where screening data showed very low risk of eutrophication. Polygons represent lake catchments.

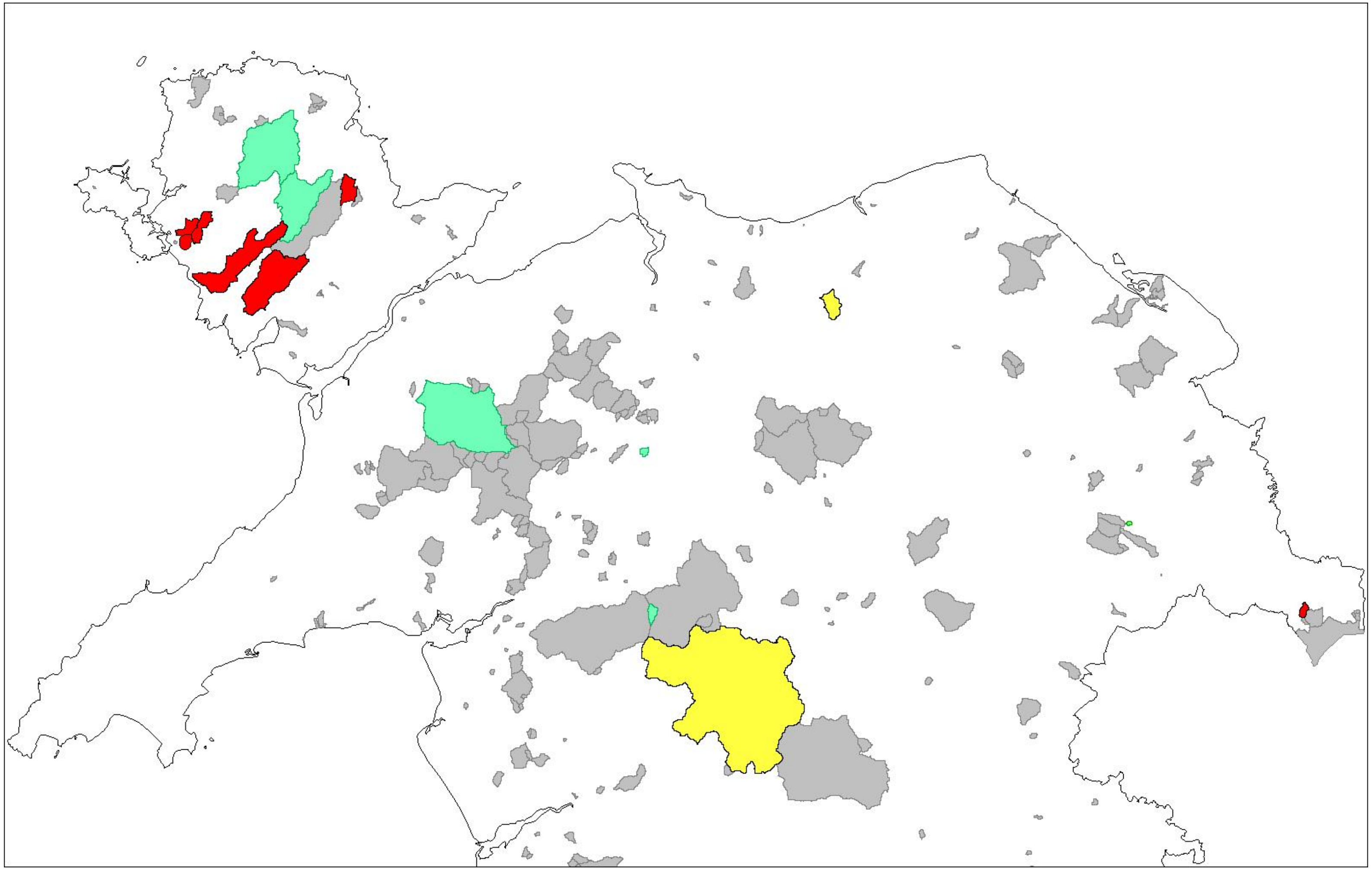


Figure 7.1 (b) Potential North Wales NVZs that were considered by the expert panel. Red: strong evidence; Yellow: Weaker evidence where expert opinion was required; Green: NVZ designation not recommended. See Table 7.1 for final recommendations

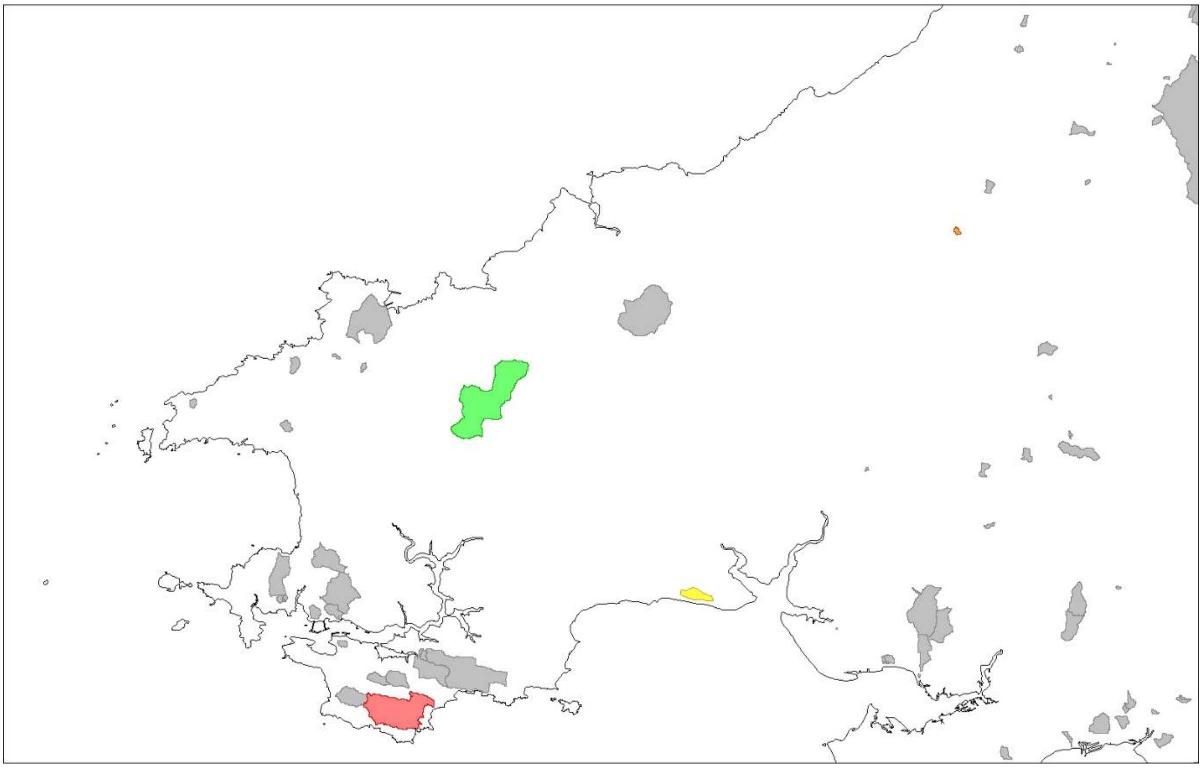


Figure 7.2 (a). Evidence strength for lakes in southwest Wales following detailed review. Colours as for 7.1 (a).

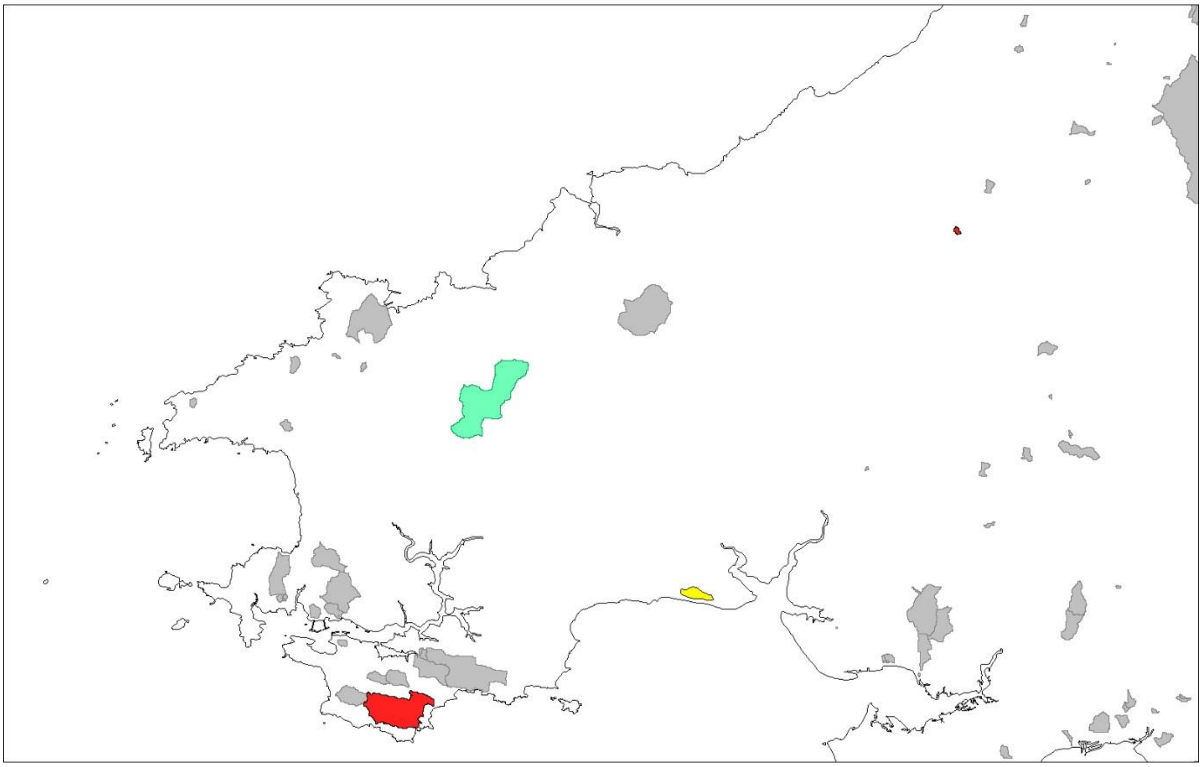


Figure 7.2 (a). Potential southwest Wales NVZs that were considered by expert panel. Colours as for 7.1 (b).

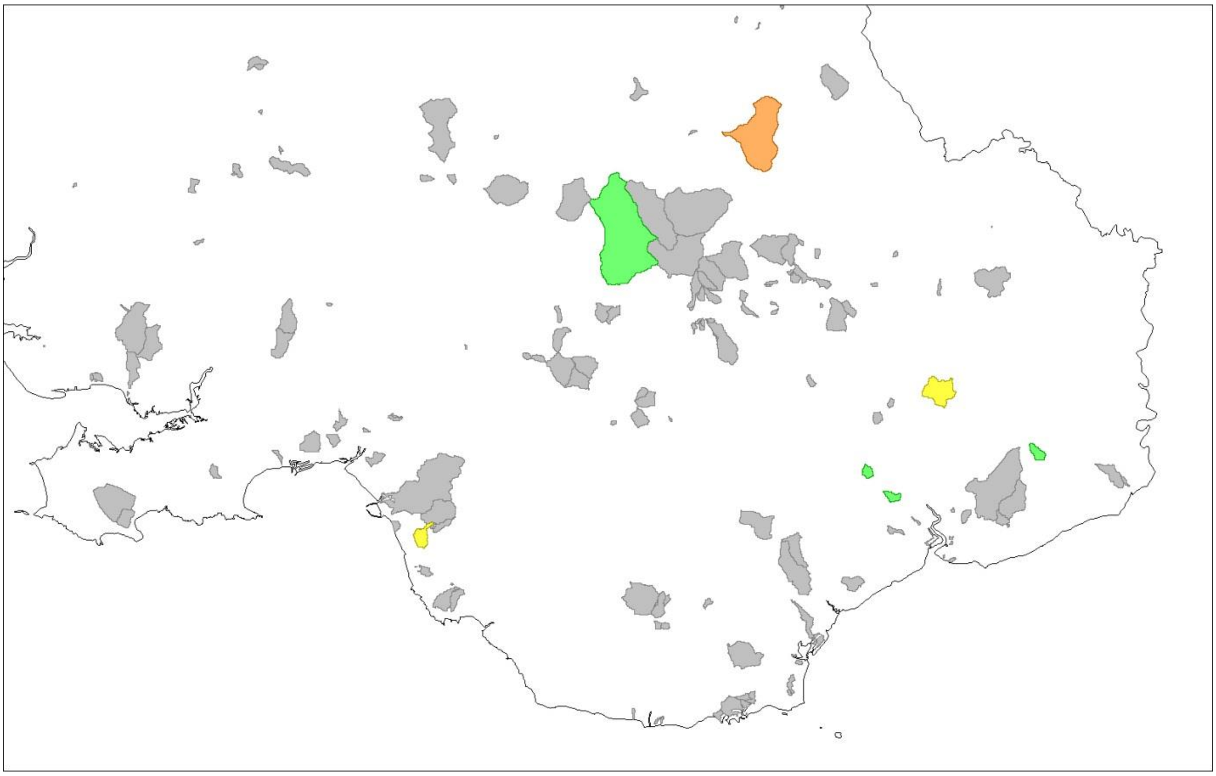


Figure 7.3 (a). Evidence strength for lakes in southeast Wales following detailed review. Colours as for 7.1 (a).

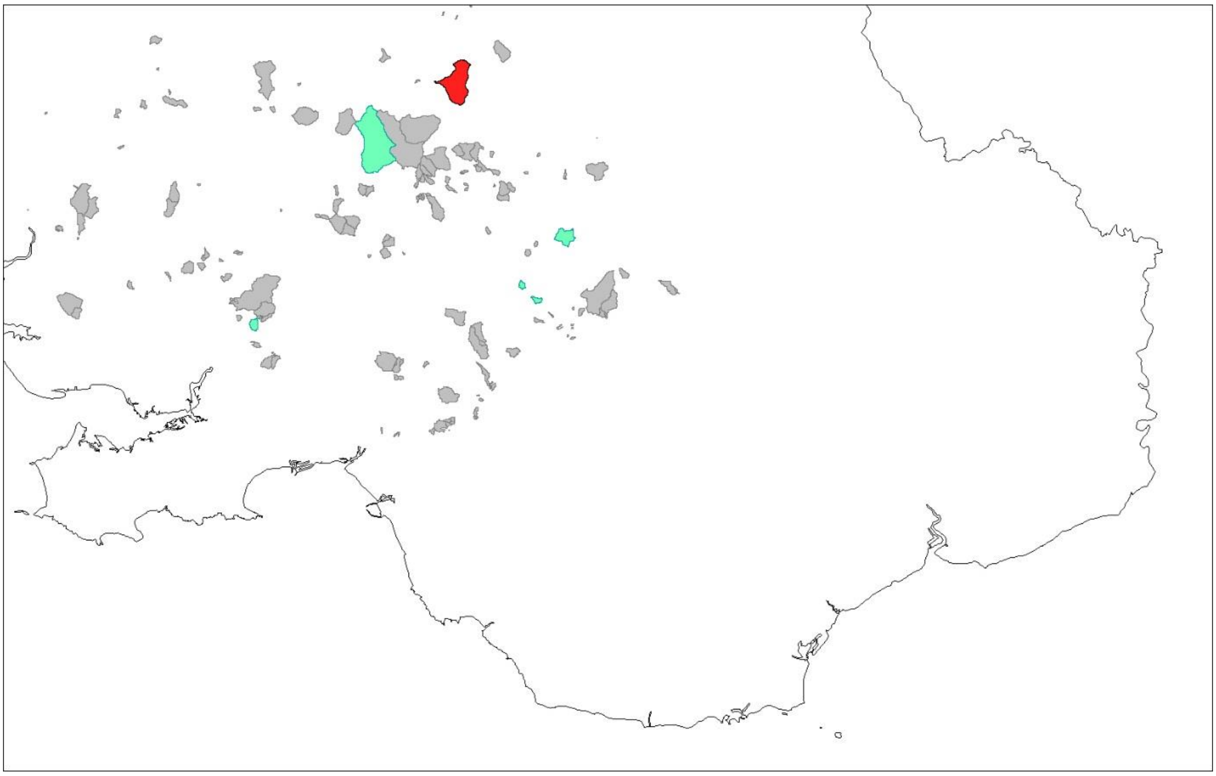


Figure 7.3 (b). Potential southeast Wales NVZs that were considered. Colours as for 7.1 (b).

7.2. Uncertainty and Data Quality

In general terms, NRW's monitoring network has provided a good evidence base against which to assess the eutrophication status of Welsh lakes. Data from about 25% of all lakes were available for assessment, including all WFD water bodies and the majority of protected areas for nature conservation. For most of these, sufficient data were available to make a judgment of their eutrophic status.

There were exceptions to this, however. NRW's monitoring network is currently heavily skewed towards the requirements of the Water Framework Directive, and a consequence of this is that monitoring for other drivers is not necessarily adequate. In particular, water quality monitoring of freshwater Sites of Special Scientific Interest (SSSIs) that are not also designated as Natura 2000 sites, the principal domestic nature conservation designation in Wales, is poor. As a consequence it has not been possible to assess the current status of fifteen lake SSSIs that are currently in unfavourable condition due to eutrophication, or have previously been identified as being at risk (e.g. Burgess *et al*. 2006, 2009).

NRW is currently reviewing its monitoring procedure and network and it is important that monitoring of both water quality and biology on these vulnerable lakes is carried out so that future actions to combat eutrophication can be implemented.

The evidence base was also relatively weak for a number of the water supply reservoirs currently monitored. In this case, biological evidence tended to be weak in comparison to water chemistry data. This is not surprising as the available ecological tools for assessing the status of water supply reservoirs are more restricted due to their modified nature. In the case of pumped storage reservoirs, there is no requirement for further monitoring from the Nitrates Directive perspective, though continued monitoring may be required in support of other legislative requirements.

7.3. Technical Development of Methods

The basic principles of lake eutrophication assessment in support of the requirements of the Nitrates Directive are now well established in the UK, requiring demonstration of both elevated nutrient levels and consequent ecological effects using recent data (Environment Agency 2012a). NRW has adhered to these principles and so far as possible to the specific technical details of the methods (see Section 3).

In relation to future development, there are technical improvements that would help to give greater confidence to the assessment method and improve alignment with the Water Framework Directive. First, the development of WFD standards for nitrogen in lakes, or else the incorporation of nitrogen targets into the existing phosphorus model, could provide a much more robust basis for assessing nitrogen levels that takes into account the type-specific sensitivity of different lakes. Second, there are now well-documented problems with the WFD phosphorus model in very humic lakes, such as for example Llyn Tryweryn. It is recommended that Welsh Government request UKTAG to add these two tasks to their work programme.

The other area that needs refinement are the rules for combining the nitrogen and WoE data. The rules that were established by the NVZ technical group are incomplete, as they do not indicate how sites with Uncertain confidence of eutrophication are to be addressed. Moreover, the existing nitrogen risk categories do not relate to ecological impact, and the existing method does not include a statistical test of the probability of exceeding a key value. It is recommended that these issues are addressed by reconvening the NVZ technical group, preferably with both England and Wales representation.

7.4. Relevance of this Work to Other Processes

The NVZ lakes eutrophication assessment provides a robust, evidence-based approach to the identification of lakes where eutrophication is considered a significant problem. It therefore represents best practice from an evidence perspective and in that context provides a valuable source of evidence that can be used for other purposes, such as for example agri-environment scheme prioritisation, NRW operational prioritisation, local Biodiversity Action Plans and Natural Resource Management.

The above notwithstanding, it is important to note that this assessment is relatively conservative in its conclusions. Although this is considered appropriate for NVZ designation, it is not necessarily compliant with other Directives. For example, WFD and the Habitats Directive both use ‘one out, all out’ approaches to monitoring. Lakes which fail on one or a few criteria under WFD classifications or Habitats Directive condition assessments will still be reported as failing to meet their targets even though the NVZ assessment identifies them as having low confidence of eutrophication impact.

A conservative approach to management is not necessarily the best way to manage lakes. Eutrophication is a slow process that tends to occur over a number of years as nutrients accumulate in the lake. Once a lake is eutrophied, recovery can be slow and restoration actions very costly.

In contrast, lower cost catchment management measures such as sediment traps, farmyard clean and dirty water separation, streamside corridors, swales and shelter belts can all prevent nutrients reaching the lake in the first place, at much lower cost to society. These measures also have other environmental benefits. In NVZs, it is recommended that mechanisms be sought to prioritise these measures as well, as they are likely to greatly enhance the effectiveness of nitrate regulations. However, these measures, especially where they are low cost, should also be applied to other lakes where eutrophication is considered a risk, irrespective of whether the NVZ criteria are met.

8. Recommendations and Conclusions

Nitrates Directive Assessment

Water quality and ecological data from over 100 lakes has been collated and analysed using the standard method identified by the NVZ Technical Group. Twenty-five lakes were identified as being potentially vulnerable to eutrophication based on either or both factors.

- More detailed analysis identified eight lakes with high confidence of eutrophication, with a total catchment area of 8,900 ha (0.4% of the land area of Wales). These lakes were to the Expert Panel for scrutiny and quality assurance with an NRW recommendation that they be designated as NVZs.
- Three additional lakes had low confidence of eutrophication. These were also submitted to the Expert Panel for their views, but without a specific NRW recommendation.
- The remaining 14 lakes were considered after detailed review to have insufficient or no clear evidence of eutrophication, or else were ineligible because they were a pumped storage system. Accordingly, NRW does not recommend that they be designated as NVZs.

Expert Review supported NRW’s recommendations in all but two cases, Llyn Traffwll and Valley Lakes. Additionally, the expert review recommended that the three additional lakes with low confidence of eutrophication should not be designated as NVZs.

Data Quality Recommendations

- Fifteen lake SSSIs at risk of eutrophication could not be included in this assessment due to lack of data. NRW will consider this issue in the current monitoring review to ensure that relevant data are available in future.

Following external peer review, the independent expert specifically endorsed this recommendation.

Recommendations for Technical Developments

- In order to improve the evidence base for nutrient standards, it is recommended that Welsh Government ask UKTAG to develop nitrogen standards for lakes, ideally as part of a single nutrients model.
- In order to improve the relationship between phosphorus concentrations and nutrient pressures, it is recommended that Welsh Government ask UKTAG to amend the phosphorus model to take into account the effect of humic acids.
- To improve the future precision and statistical robustness of the NVZ designation method, it is recommended that the NVZ technical group be reconvened to agree updates to the assessment methods that reflect current ecological knowledge, data quality and statistical confidence.

Use of this Assessment for non Nitrates Directive purposes

- The NVZ assessment method is based on sound principles, but is relatively conservative in its approach. For this reason it is likely to underestimate pressures in relation to the Habitats Directive and WFD targets, and is unsuitable where a precautionary approach is required or where prevention of deterioration is required.

- This lack of precaution and the lack of data for lake SSSIs should be taken into account in relation to operational decisions for targeting resources. In particular, relative lack of data should not be an impediment to action where relatively low-cost and more collaborative preventative actions are concerned.

9. Acknowledgements

Thanks to Paul Edwards who carried out the source apportionment work for lakes that had not previously been assessed. Catherine Duigan, Natalie Hall, Melissa Broad, Peter Jones and Mark Squire provided helpful comments and guidance on earlier drafts.

Dr Helen Bennion from the Department of Geography, University College London acted as the Independent Expert Reviewer for this document.

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11. Appendices

Appendix 1. Lookup tables for combining data in the Environment Agency weight of evidence (WoE) tool

(a) Rules for combining diatoms and macrophyte confidence of class. Confidence classes: V = Very Certain Worse than Good (>95% confidence); Q = Quite Certain Worse than Good (>75-95% confidence); U = Uncertain Worse than Good (>50-75% confidence); UGorB = UncertainGood or better (>25-50% confidence worse than good); GorB = Good or better (<25% confidence worse than good); ND = No Data.

		Diatom confidence worse Good					
		V	Q	U	ND	UGorB	GorB
Macrophyte confidence worse Good	V	V2	V	V	V	Q	U
	Q	V	V	Q	Q	U	U
	U	V	Q	Q	U	U	U
	ND	V	Q	U	ND	UGorB	GorB
	UGorB	Q	U	U	UGorB	UGorB	GorB
	GorB	U	U	U	GorB	GorB	GorB

(b) Rules for combining biological quality elements confidence in class. Categories as for (a.).

		Phytoplankton confidence worse Good					
		V	Q	U	ND	UGorB	GorB
Macrophyte & Diatom confidence worse Good	V2	V	V	V	V	V	Q
	V	V	V	V	Q	Q	Q
	Q	V	V	Q	Q	U	U
	U	V	Q	U	U	U	U
	ND	V	Q	U	ND	UGorB	GorB
	UGorB	Q	Q	U	UGorB	UGorB	GorB
	GorB	Q	U	U	GorB	GorB	GorB

(c) Rules for combining biological quality elements and phosphorus confidence in class. Categories as for (a.).

		Biology confidence worse Good					
		V	Q	U	ND	UGorB	GorB
Phosphorus confidence worse Good	V	V	V	Q	Q	Q	U
	Q	V	Q	Q	Q	U	U
	U	V	Q	U	U	U	U
	ND	Q	U	U	ND	UGorB	GorB
	UGorB	Q	U	U	UGorB	UGorB	GorB
	GorB	Q	U	U	GorB	GorB	GorB

Appendix 2. WFD Source Apportionment Method using SAGIS

Source Apportionment Concepts

Source apportionment may be characterised by

- load or concentration.
- input or in-river
- individually or cumulatively (down the river)

The table below lists the various combinations and what SAGIS functionality is required for their calculation.

Option	Physical	Location	Type	SAGIS functionality needed
1	Load	Input	Individual	Data table only (with query)
2	Load	Input	Cumulative	Run SIMCAT Plot Maps Create Graph Tables (Plot Sector Charts)
3	Load	In river	Individual	Not available
4	Load	In river	Cumulative	Run SIMCAT Plot Maps (Optional – Create Graph Tables, Plot Sector Charts)
5	Concentration	Input	Individual	Not available
6	Concentration	Input	Cumulative	Not available
7	Concentration	In river	Individual	Not available
8	Concentration	In river	Cumulative	Run SIMCAT Plot Maps

Recommendations

The following is recommended:

- In the absence of, or difficulties with, any other option, estimate the source apportionments via option 1.
- Use option 8 in preference to option 4, if both available, to produce source apportionment estimates.
- Where SIMCAT results from earlier models (option 8 type) are available, option 1 data may be used to decompose the diffuse components. Alternatively you may already have used other means to estimate the diffuse portioning, which is fine.
- Source apportionment done by other reasonable approaches (eg Integrated Lakes and Catchments) is also acceptable.

SAGIS Input Loads Tool

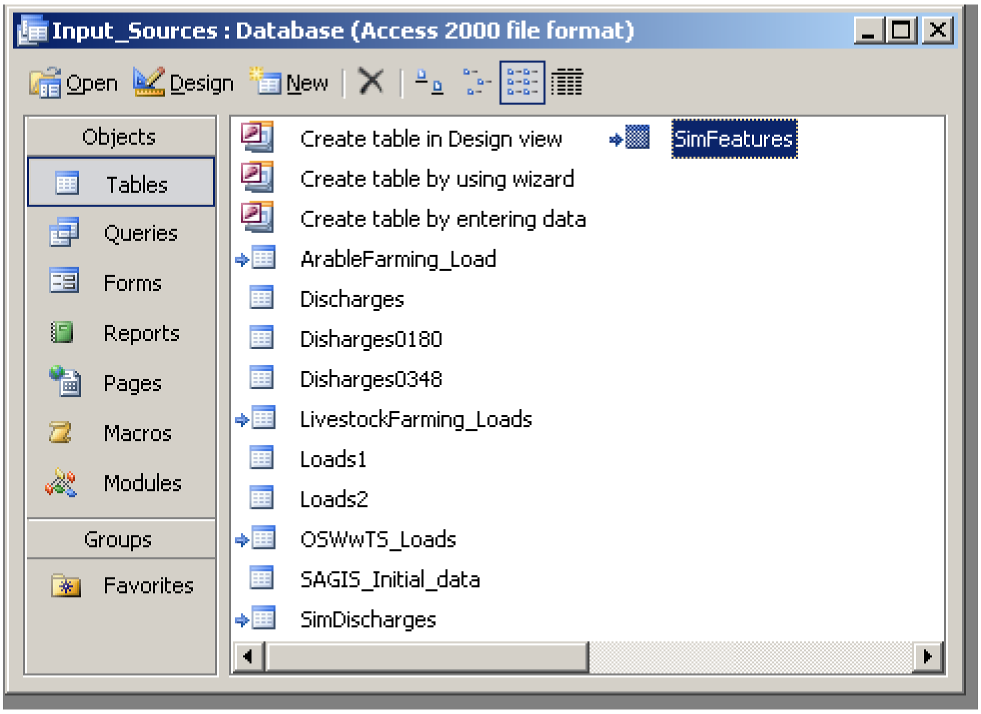
The database ‘Input_Sources.mdb’ produces a table containing the input loads, by waterbody, from a SAGIS SIMCAT model database.

(Currently set up for phosphorus … modify for other dets if needed.)

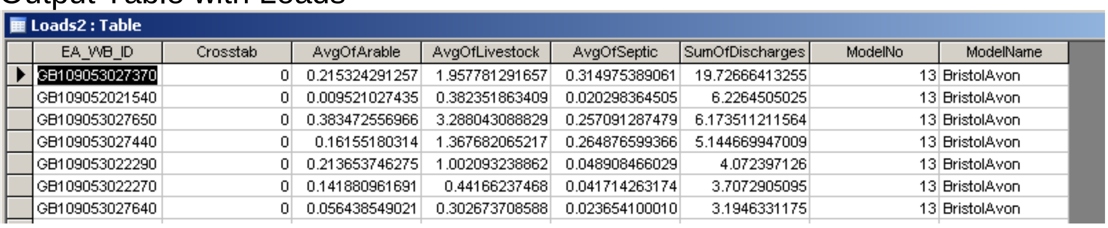
Steps:

- Open 'Input_sources.mdb'
- Link the following SIMCAT model tables to 'Input_sources.mdb' (see below)
    - ArableFarming_Load
    - LivestockFarming_Loads
    - OSWwTS_Loads
    - SimDischarges
    - SimFeatures
- Run the macro 'Input_Loads' in the 'Input_Sources' database. This will produce a table called 'Loads2' which contains the load components by water body. (See below)

Tables



Output Table with Loads


Loads2 : Table

EA_WB_ID	Crosstab	AvgOfArable	AvgOfLivestock	AvgOfSeptic	SumOfDischarges	ModelNo	ModelName
GB109053027370	0	0.215324291257	1.957781291657	0.314975389061	19.72666413255	13	BristolAvon
GB109052021540	0	0.009521027435	0.382351863409	0.020298364505	6.2264505025	13	BristolAvon
GB109053027650	0	0.383472556966	3.288043088829	0.257091287479	6.173511211564	13	BristolAvon
GB109053027440	0	0.16155180314	1.367682065217	0.264876599366	5.144669947009	13	BristolAvon
GB109053022290	0	0.213653746275	1.002093238862	0.048908466029	4.072397126	13	BristolAvon
GB109053022270	0	0.141880961691	0.44166237468	0.041714263174	3.7072905095	13	BristolAvon
GB109053027640	0	0.056438549021	0.302673708588	0.023654100010	3.1946331175	13	BristolAvon

Queries

The macro 'Input_Loads' calls the following queries:

- Assemble .. tabulates the diffuse and point source data (produces table SAGIS_Initial_data)
- Default_discharge_p … sets P discharge emission limits in absence of sample data
- MakeLoads_TPA .. calculates loads in tonnes per annum
- WB_Model_no_name .. finds the model number and name for inclusion in final table (…produces table WB_Model_ref)
- Loads_final … find the loads by water body (sums the discharges ... produces Loads2 table)

Notes

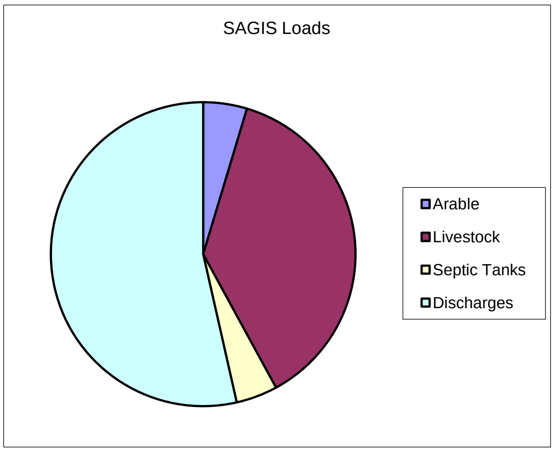
- Det 0180 is used for the discharge data rather than 0348, so as to be consistent with agri data (and river)
- The tables Disharges0180 and Disharges0348 were produced from the SimcatCommonTables. (If looking at another det, obtain corresponding discharge data and modify above queries)
- The default discharge for P used is 5mg/l .. modify if you think this is wrong for your Region.
- Industrial discharge concentrations set at zero… modify if you have info… eg for creameries.
- No data were available for atmospheric and natural .. in any case they are small
- CSOs .. some problems so not included… also relatively small

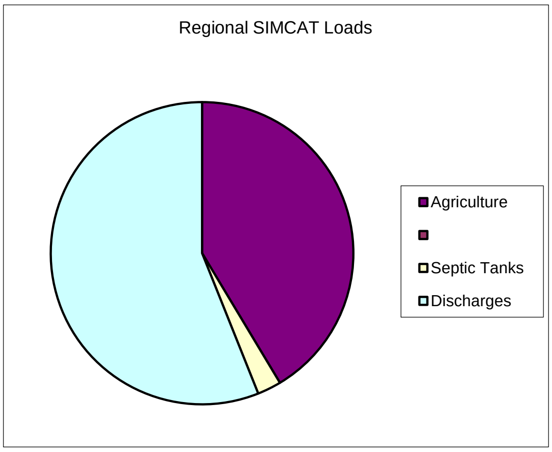
Validation

Shown below is a comparison between load assessments, one using the above SAGIS method and the other a calibrated SIMCAT model (Bristol Avon model).

The results correspond quite well.

	Arable	Livestock	Septic Tanks	Discharges	Total
SAGIS Loads	8	67	8	95	178
	Agriculture		Septic Tanks	Discharges	Total
Regional SIMCAT Loads	65		4	88	157


SAGIS Loads
Arable
Livestock
Septic Tanks
Discharges


Regional SIMCAT Loads
Agriculture
Septic Tanks
Discharges

Appendix 3. Reviewer Comments

Evidence Review of Lake Eutrophication in Wales by Natural Resources Wales

Hatton-Ellis, T.W. 2015. *Evidence Review of Lake Nitrate Vulnerable Zones in Wales*. NRW Evidence Report No: 135, 143pp, Natural Resources Wales, Bangor.

Quality Assurance Report by Dr Helen Bennion UCL

In carrying out the quality assurance exercise, I have:

(i) checked that NRW has followed the methodology so far as practicable (or where they have deviated from it that an appropriate substitute has been used);

(ii) checked that the supporting data and / or analysis are sufficient;

(iii) checked that key data of material importance to the outcome have not been omitted

(iv) reviewed the proposed NVZs and commented on whether I would support the proposals.

(v) checked that NRW has been clear and consistent in its answers to the questions raised by the farming unions.

The evidence review clearly details the methods employed, the datasets used, and the 2015 recommendations for designation of Lake Nitrate Vulnerable Zones (NVZs) in Wales. The procedure followed for identifying those sites to be submitted for review or comment by the expert panel appears to be scientifically sound and based on a weight of evidence approach. Having recently sat on the expert panel for the same exercise in England, I can confirm that the method follows that employed by the Environment Agency in their review of NVZ designations for English lakes and has been executed with the same level of rigour.

Based on the <u>nitrogen data alone</u>, four lakes have high nitrogen levels (>2 mg/l) and therefore are considered at high risk of eutrophication. Eight additional lakes have elevated nitrogen levels and are considered at risk of eutrophication. Based on the <u>ecological evidence</u>, nine lakes were considered to have a ‘very certain’ confidence of eutrophication impact while a further 12 had a ‘quite certain’ confidence of eutrophication impact. Some lakes in these latter two lists were the same as those identified as at risk based on the nitrogen data alone. The chemical and biological datasets used in this assessment cover a 5 or 6 year period from 2009 to 2014/2015 for most lakes and therefore provide values representative of current conditions and an indication of recent trends in water quality for some sites. NRW have evidently used all available data that they are aware of to make the assessments of eutrophication and, importantly, where data have not been used, they have clearly explained why this is the case (e.g. potential biases in the macrophyte tool in reservoirs).

In summary, 25 water bodies were identified as being ‘potentially at risk of eutrophication’ based on either chemical or ecological data and were examined in greater detail and taking into account statistical confidence in the results. The key findings of the NRW review as stated in the report are that:

i) eight water bodies with High Confidence of Eutrophication should be designated as NVZs subject to the results of source apportionment and peer review by the Expert Panel. These include four existing NVZs: Llyn Coron, Llangorse Lake, Hanmer Mere and Bosherston Lakes; and five new designations: Llyn Maelog, Llyn yr Wyth Eidion, Valley Lakes, Llyn Traffwll and Llyn Pencarreg. Note that there are actually <u>nine</u> lakes listed here (not eight) so this should be corrected in the text.

ii) three water bodies with lower confidence should be considered by the Expert Panel, noting that the evidence of eutrophication is weaker at these locations and that independent expert advice is needed - Llyn Tegid, Plas Uchaf & Dolwen Reservoirs, and Witchett Pool

iii) the remaining fourteen water bodies showed no or insufficient evidence of eutrophication or could be ruled out for other reasons and thus should not be designated as NVZs. Note that the report states fourteen water bodies but I could count only thirteen under the 'do not designate' category so this should be corrected in the text.

My comments on the results section of the report follow on a lake by lake basis.

Results

i) Should be designated as NVZs (9 sites)

Existing NVZs (4 sites):

Bosherston Lakes (6.1) – I agree; recommend continued designation. High N with ecological evidence of impact in Eastern Arm and condition assessment unfavourable; agricultural nutrient sources of N identified. I agree that it makes sense to manage all three parts of this waterbody as a single unit in order to protect all parts of the system. Note that the palaeolimnological study of the Central Lake included analysis of the aquatic macrofossils which suggested that there has been a significant shift in the aquatic macrophyte community of the Central Lake since 1900 (Davidson et al., 2002). Aquatic plant remains exhibit a gradual decline in Charophyte abundance and a shift to more nutrient tolerant species such as *Myriophyllum spicatum* and *Potamogeton* spp., indicative of enrichment. There is some evidence, therefore, of impact in the Central Lake.

Davidson, T., Bennion, H., Yang, H., Appleby, P.G. & Luckes, S. (2002). *Investigation of environmental change at the Bosherston Lakes, Pembrokeshire.* CCW Contract Science Report No. 496.

Llyn Coron (6.3) – I agree; recommend continued designation. A comprehensive chemical and ecological dataset and very strong evidence for continued designation. The increase in TN concentrations is a particular concern. Note that there is also palaeolimnological evidence of eutrophication over the last three to four decades at Llyn Coron as indicated by shifts in the diatom assemblages (Bennion et al., 1996).

Bennion, H., Duigan, C. A., Haworth, E. Y., Allott, T. E. H., Anderson, N. J., Juggins, S. & Monteith, D. T. (1996) The Anglesey Lakes, Wales, UK- Changes in trophic status of three standing waters as inferred from diatom transfer functions and their implications for conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **6**, 81-92.

Llangorse Lake (6.10) - I agree; recommend continued designation. This is a high quality dataset and there is plentiful evidence of elevated nutrient concentrations and ecological impacts as revealed through contemporary and palaeoecological surveys. There is insufficient evidence of an improvement in water quality to remove the designation in this round. Indeed the data suggest that any increase in N could potentially result in enhanced growth of primary producers so it is crucial to control N sources to the lake to promote recovery.

Hanmer Mere (6.11) – I agree; recommend continued designation. Both the chemical and biological data from Hanmer Mere show clear eutrophication impacts with high confidence. N and P levels are elevated but importantly N is limited in summer and it is therefore advised to retain the NVZ to prevent any increase in N and potentially consequent increase in algal growth.

New designations (5 sites):

Llyn Maelog (6.4) – I agree that this site should be designated. There is strong chemical and ecological evidence to support designation, the lake is currently in an unfavourable condition and agriculture has been identified as a major source of nutrients to the catchment. However, I am slightly confused by the line ‘A diatom based palaeolimnological study of Llyn Traffwll (Burgess *et al*. 2009) recorded a high degree of floristic change in the diatom assemblages between the top and bottom of the core’. I trust that this is a typo and should read ‘Llyn Maelog’? If so, then the palaeoecological findings, namely diatom shifts indicative of eutrophication, further support the proposal to designate Llyn Maelog.

Valley Lakes (Llyn Dinam and Llyn Penrhyn) (6.6) – I am not convinced that these lakes should be designated on the evidence provided in the report. In fact the report does not make a clear recommendation for the Valley Lakes on p 53. I note that the comments from the FUW also state that for Llyn Dinam “A clearer statement on designation is required. This report is unclear about the final decision for Lake Dinam and therefore more clarity is needed here.” I would agree that a clearer statement on designation is required.

The nutrient sources to Llyn Dinam and Penrhyn are clearly very different, the former having a rural catchment with nutrients coming predominantly from diffuse sources, whereas Llyn Penrhyn is heavily influenced by the RAF Valley air force base and associated housing, including sewage discharge and road runoff. It therefore makes good sense to consider each lake separately and, on the evidence presented, there are stronger grounds to designate Llyn Dinam than there are to designate Llyn Penrhyn. I note that comments to this effect are made by NRW in their response to the FUW and NUF queries on the Valley Lakes.

I agree that there is very certain evidence of elevated phosphorus at both Llyn Dinam and Llyn Penrhyn, with resulting ecological impacts on the aquatic plant and diatom communities. Additionally palaeolimnological studies provide evidence of eutrophication over the last three to four decades at Llyn Dinam as indicated by shifts in the diatom assemblages, although results were inconclusive for Llyn Penrhyn (Bennion et al., 1996). What is not entirely clear to me, however, is the role of N (as opposed to P) in the enrichment of these sites. There is some evidence of N limitation in summer at both lakes such that any increase in nitrogen may stimulate algal growth and ideally measures should, therefore, be in place to control N sources. I am not convinced, however, that there is sufficient evidence at this stage to designate the Valley Lakes as an NVZ. I suggest that they are considered again in the next review. I note that both the FUW and NUF also question the designation of these sites based on the data presented.

Bennion, H., Duigan, C. A., Haworth, E. Y., Allott, T. E. H., Anderson, N. J., Juggins, S. & Monteith, D. T. (1996) The Anglesey Lakes, Wales, UK- Changes in trophic status of three standing waters as inferred from diatom transfer functions and their implications for conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **6**, 81-92.

Llyn Traffwll (6.7) – I am not convinced that this lake should be designated on the rather limited evidence provided in the report.. While the low total nitrogen concentrations for 2009-2011 suggest that nitrogen limitation is likely, there are no nitrate data available to confirm this. There is clear evidence of eutrophication, high phosphorus concentrations and ecological impact (i.e. a macrophyte classification of moderate and unfavourable condition assessment) but given the rather sparse dataset, I consider there to be insufficient evidence to designate Llyn Traffwll as an NVZ in this review. I note that the text states that there are no palaeolimnological data yet Table 6.7.1 on 'Key indicators for Llyn Traffwll' lists palaeolimnology as one of the indicators. I assume that this is an error.

Llyn yr Wyth Eidion (6.9) – I agree that Llyn yr Wyth Eidion should be considered for NVZ designation. Notwithstanding the relatively small dataset, there is strong evidence of elevated nutrient concentrations, notably high N, and consequent ecological impacts with the confidence of eutrophication being at least Medium-High. The evidence for decline in the plant community, particularly the charophytes (stoneworts), as indicated by contemporary surveys, is strongly supported by the palaeolimnological study by Goldsmith *et al*. (2013). When considering whether NVZ designation is appropriate the Panel were asked to consider whether to downgrade the overall risk of eutrophication to Medium-High in the light of the relative paucity of water chemistry data. While there is a very certain eutrophication problem I do think that a downgrade to Medium-High would be appropriate.

Llyn Pencarreg (6.12) – This one is a borderline case but on balance I agree that Llyn Pencarreg should be considered for NVZ designation. Notwithstanding the relatively small dataset, there is strong evidence of elevated nutrient concentrations (though I note that this relates more to P than to N) and consequent ecological impacts with the confidence of eutrophication being at least Medium-High. The poor status as indicated by the contemporary ecological indicators is strongly supported by the palaeoecological evidence of declining status as a result of enrichment. The occurrence of blue-green algal blooms and severe deoxygenation adds to the weight of evidence and suggests that nutrient controls are required in this catchment to meet water quality objectives. Efforts should be made to enhance the dataset in time for the next review.

ii) Water bodies with lower confidence to be considered by the Expert Panel (3 sites)

Plas Uchaf and Dolwen Reservoirs (6.2)– rather limited ecological evidence and some uncertainties over role of abstraction in Plas Uchaf; however N and P are both high and blue-green algal blooms are recorded; largely agricultural catchment. In light of the uncertainties it would seem appropriate NOT to designate. Efforts should be made to fill in the gaps both in the knowledge of abstraction and in the ecological data and these waterbodies should be considered again in the next review.

Llyn Tegid (6.14) **–** This is a tricky case and I find it rather difficult to reach a decision on whether Llyn Tegid should be recommended for designation as an NVZ. I have been involved in the palaeoecological research on the lake and know the site reasonably well and indeed the NRW report sums up the evidence base for eutrophication and impact very clearly. The question is whether there is sufficient evidence for designation in this case. There is certainly no shortage of data but my difficulty in recommending designation lies in the low N concentrations and lack of evidence for N limitation. Nevertheless the regular reports of blue-green algal blooms in recent years give cause for concern. I think that on balance, and given the 'Marginal' overall evidence base, Llyn Tegid should NOT be designated as an NVZ in this round. However, other routes for controlling the impact of nutrients should be investigated and the evidence for this lake should be carefully considered in the next review.

Witchett Pool (6.15) – I agree completely with the recommendation in the report that: "Overall, there is good evidence to indicate that actions to combat eutrophication are needed at Witchett Pool, but further assessment is required to determine whether a Nitrate Vulnerable Zone is the most appropriate approach.". In summary I recommend that the lake is NOT designated in this round. I recommend that a larger dataset is collected to fill our knowledge gaps and the lake be considered again at the next review.

iii) Should not be designated as NVZs. (14 sites stated in the report but I count only 13)

Cefni Reservoir (6.5) – agree with recommendations.
Llyn Alaw (6.8) – agree with recommendations.
Llandegfedd Reservoir (6.13) – agree with recommendations.
Eglwys Nunnydd Reservoir (6.16) - agree with recommendations.

Llwyn-On Reservoir (6.17) - agree with recommendations.

Llyn Elsi Reservoir (6.18) - agree with recommendations.

Llyn Padarn (6.19) - agree with recommendations as the main nutrient source is sewage effluent rather than agriculture.

Llyn Tryweryn (6.20) - agree with recommendations.

Pant-yr-Eos Reservoir (6.21) - agree with recommendations.

Ty Mawr Reservoir (6.22) - agree with recommendations.

Wentwood Reservoir (6.23) - agree with recommendations.

Ynysyfro Reservoirs (6.24) – no clear recommendation is given in the text summary. However there appears to be insufficient evidence to recommend designation in this case.

Llys-y-Frân Reservoir (6.25) - agree with recommendations. Clearly more ecological data are needed.

The 'Discussion' (section 7) and 'Recommendations and Conclusions' (section 8) provide a useful, accurate and concise summary of the main findings. I would support NRWs statement that it is important to monitor both water quality and biology on the fifteen lake SSSIs that are currently in unfavourable condition due to eutrophication, or have previously been identified as being at risk.

I have reviewed the answers provided by NRW to the questions raised by the farming unions and can confirm that the responses are clear and consistent and are supported by the data presented in the report.

Concluding remarks
In summary I support all of the recommendations with the exception of those for the Valley Lakes (Llyn Dinam and Llyn Penrhyn) and Llyn Traffwll where new designations are proposed in the report but where I consider there to be insufficient evidence to designate these lakes as NVZs in this review. For the three water bodies identified as 'having lower confidence and to be considered by the Expert Panel', I recommend that all three are NOT designated in this round owing to the Low or Marginal overall evidence base.

<u>Minor comments/typographic errors</u>
P 11, I note that the text reads "eight water bodies showed evidence of eutrophication with high confidence: this included all of the existing NVZs (Llyn Coron, Llangorse Lake, Hanmer Mere and Bosherston Lakes), plus five additional water bodies (Llyn Maelog, Llyn yr Wyth Eidion, Valley Lakes, Llyn Traffwll and Llyn Pencarreg)." There are actually nine water bodies listed here not eight so the text should be amended.

P 15, the last sentence doesn't scan properly: 'Candidate lakes and then against other ecological data to identify impacts (Environment Agency 2012).'

P 30 Shouldn't Llyn Traffwll also be included in the lists on page 30 and in Appendix Tables on page 140?

P 43 'The plant community was surveyed in September 2014. Macrophyte results using the' This sentence is incomplete.

P 71 typo – 'Macrophytes indicate that Hanmer Mere is at Moderate Status,'. This should read Llyn Pencarreg not Hanmer Mere.

P 82 – Figure numbers are missing in the text and are written as Figure X.

END

Appendix 4. Nitrogen and Phosphorus Concentrations of Individual Lakes

Site Name	Determinand	Value	Start Date	End Date	Samples
Alwen Reservoir	NO_3	0.20	Jan-09	Nov-14	68
	TN	0.54	Jan-09	Nov-14	63
	TP	15.55	Jan-09	Nov-14	62
Blaen-y-Cwm Reservoir	NO_3	0.07	Jun-10	May-14	15
	TN	0.69	Oct-10	May-14	14
	TP	24.69	Jun-10	May-14	15
Bosherston (Central Arm)	NO_3	3.87	Jul-10	Dec-14	53
	TN	2.74	Jan-09	Dec-14	71
	TP	23.49	Jan-09	Dec-14	71
Bosherston (Eastern Arm)	TON	4.88	Feb-09	Dec-14	70
	TN	3.36	Jan-09	Dec-14	70
	TP	70.86	Feb-09	Dec-14	70
Bosherston (West Arm/ Central Lake)	NO_3	3.97	Jul-10	Dec-14	53
	TN	No data	No data	No data	No data
	TP	No data	No data	No data	No data
Caban-coch Reservoir	TON	0.23	Aug-10	Dec-14	52
	TN	0.40	Jan-09	Dec-14	69
	TP	7.86	Jan-09	Dec-14	69
Cantref Reservoir	TON	0.16	Jun-10	Dec-14	19
	TN	0.32	Sep-10	Nov-14	18
	TP	23.09	Jun-10	Nov-14	18
Lower Carno Reservoir	NO_3	0.20	Oct-09	Jun-14	15
	TN	0.48	Feb-10	Nov-14	25
	TP	30.05	Oct-10	Nov-14	19
Cefni Reservoir	TON	1.24	Jul-10	Nov-14	54
	TN	1.39	Jul-10	Nov-14	56

Site Name	Determinand	Value	Start Date	End Date	Samples
	TP	47.25	Jul-10	Nov-14	54
Claerwen Reservoir	TON	0.20	Jun-10	Dec-14	55
	TN	0.45	Jan-09	Dec-14	72
	TP	9.53	Jan-09	Dec-14	72
Craig-goch Reservoir	TON	0.18	Jun-10	Nov-14	20
	TN	0.37	Jun-10	Nov-14	20
	TP	7.52	Jun-10	Nov-14	20
Eglwys Nunnydd Reservoir	TON	0.22	Jul-10	Oct-14	54
	TN	0.56	Jul-10	Dec-14	54
	TP	25.59	Jul-10	Dec-14	54
Hanmer Mere	TON	0.45	Jan-09	Nov-14	70
	TN	1.75	Jan-09	Nov-14	68
	TP	886.36	Jan-09	Nov-14	68
Llandegfedd Reservoir	TON	1.31	Jul-10	Nov-14	57
	TN	1.37	Mar-09	Dec-14	74
	TP	25.80	Mar-09	Dec-14	74
Llangorse Lake	TON	0.81	Jan-09	Nov-14	67
	TN	1.01	Jan-09	Nov-14	67
	TP	130.95	Jan-09	Nov-14	67
Llangynidr Reservoir	NO_3	0.20	Jan-09	Jun-14	18
	TN	0.53	Jan-09	Nov-14	26
	TP	28.58	Jan-09	Jun-14	18
Lluest-wen Reservoir	TON	0.22	Sep-10	Nov-14	14
	TN	0.51	Sep-10	Nov-14	13
	TP	26.36	Jun-10	Nov-14	14
Llwyn-on Reservoir	TON	0.18	Jul-10	Oct-14	56
	TN	0.51	Jan-09	Dec-14	72
	TP	16.30	Jan-09	Nov-14	72
Llyn Alaw	TON	0.66	Jun-10	Nov-14	54
	TN	1.04	Jan-09	Nov-14	59
	TP	31.21	Jan-09	Nov-14	65
Llyn Brenig	TON	0.31	Jun-10	Nov-14	55
	TN	0.54	Jan-09	Nov-14	61
	TP	9.39	Jan-09	Nov-14	65
Llyn Celyn	TON	0.13	May-10	Dec-14	60
	TN	0.35	May-10	Dec-14	60
	TP	12.64	May-10	Dec-14	59
Llyn Clywedog	TON	0.46	Jul-10	Dec-14	50
	TN	0.66	Jan-09	Dec-14	68
	TP	9.32	Jan-09	Dec-14	67
Llyn Coron	NO_3	1.76	Jul-10	Nov-14	55
	TN	1.84	Jan-09	Nov-14	72
	TP	79.61	Jan-09	Nov-14	72

Site Name	Determinand	Value	Start Date	End Date	Samples
Llyn Dinam	TON	0.24	Feb-09	Nov-14	69
	TN	1.05	Feb-09	Nov-14	69
	TP	118.14	Feb-09	Nov-14	69
Llyn Efyrnwy	TON	0.20	Jul-10	Oct-14	40
	TN	0.37	Jan-09	Oct-14	56
	TP	9.57	Jan-09	Oct-14	56
Llyn Elsi	TON	0.19	May-10	Nov-14	56
	TN	0.51	May-10	Nov-14	56
	TP	21.88	May-10	Nov-14	56
Llyn Llywenan	NO_3	0.25	Aug-14	Nov-14	4
	TN	1.99	Aug-14	Nov-14	4
	TP	No data	No data	No data	No data
Llyn Maelog	NO_3	3.09	Jan-13	Nov-14	24
	TN	No data	-	-	-
	Ortho-P	60.18	Jan-13	Nov-14	24
Llyn Padarn	NO_3	0.23	Jan-09	Dec-14	114
	TN	0.30	Jan-09	Dec-14	113
	TP	8.06	Jan-09	Dec-14	113
Llyn Pencarreg	TON	0.261	Aug-11	Sep-12	11
	TN	0.857	Aug-11	Sep-12	11
	TP	198.98	Nov-11	Sep-12	10
Llyn Tegid	NO_3	0.39	Jan-09	Nov-14	83
	TN	0.56	Jan-09	Nov-14	82
	TP	14.89	Jan-09	Nov-14	82
Llyn Traffwll	TON	0.63	Dec-09	Jan-11	14
	TN	No data	Dec-09	Jan-11	14
	TP	142	Dec-09	Jan-11	14
Llyn Trawsfynydd	TON	0.16	Jun-10	Nov-14	57
	TN	0.36	Jun-10	Nov-14	57
	TP	14.33	Jun-10	Nov-14	57
Llyn Tryweryn	TON	0.12	May-10	Dec-14	61
	TN	0.57	May-10	Dec-14	60
	TP	43.80	May-10	Dec-14	61
Lower Lliw Reservoir	NO_3	0.85	Jan-09	Dec-14	38
	TN	0.93	Jan-09	Nov-14	33
	TP	26.41	Sep-10	Nov-14	18
Penderyn Reservoir	TON	0.11	Jul-10	Dec-14	19
	TN	0.33	Jul-10	Dec-14	19
	TP	181.01	Jul-10	Dec-14	19
Plas Uchaf & Dolwen Reservoirs	TON	3.14	Jul-10	Nov-14	20
	TN	2.90	Jul-10	Nov-14	20
	TP	33.99	Jul-10	Nov-14	20
	TON	0.33	Jun-10	Oct-14	20

Site Name	Determinand	Value	Start Date	End Date	Samples
Shon-Sheffrey's Reservoir	TN	0.59	Jul-10	Oct-14	19
	TP	28.73	Jun-10	Oct-14	20
Talybont Reservoir	NO_3	0.36	Mar-09	Apr-14	32
	TN	0.58	Mar-09	Dec-14	80
	TP	33.93	Mar-09	Dec-14	76
Ty Mawr Reservoir	TON	0.43	Jun-10	Nov-14	20
	TN	0.77	Jun-10	Nov-14	19
	TP	14.13	Jun-10	Nov-14	20
Wentwood Reservoir	TON	0.33	Jul-10	Oct-14	20
	TN	0.59	Feb-10	Oct-14	24
	TP	26.91	Jul-10	Oct-14	20
Witchett Pool	TON	0.39	Dec-11	Oct-12	4
	TN	No data	-	-	-
	TP	332.75	Dec-11	Oct-12	4

Table A.3a. Nitrogen and phosphorus concentrations of lakes in Wales. TON / NO_3 values are 75%iles; other values are annual means.

Appendix 5. Eutrophication Status of Individual Lakes.

Water Body ID	UKLakes ID	Lake Name
GB30938282	38282	Llyn Cerrigllwydion Isaf
GB30938356	38356	Penygarreg Reservoir
GB30938419	38419	Caban-coch Reservoir
GB30938525	38525	Llyn Gynon
GB30940429	40429	Upper Neuadd Reservoir
GB30940556	40556	Pentwyn Reservoir
GB31033571	33571	Llyn Eigiau Reservoir
GB31033578	33578	Melynllyn
GB31033686	33686	Llyn Cowlyd Reservoir
GB31033699	33699	Ffynnon Llugwy Reservoir
GB31033803	33803	Llyn Ogwen
GB31033836	33836	Llyn Idwal
GB31033974	33974	Llyn Cwmffynnon
GB31034002	34002	Llyn Cwellyn
GB31034033	34033	Llyn Llydaw
GB31034249	34249	Llyn Cwm Dulyn
GB31034490	34490	Llyn Cwmystradllyn
GB31034613	34613	Llyn Morwynion
GB31034866	34866	Llyn Tecwyn Uchaf
GB31034895	34895	Llyn y Garn
GB31035180	35180	Llyn Cwm Bychan
GB31035561	35561	Llyn Bodlyn
GB31035712	35712	Llyn Cynwch
GB31036405	36405	Tal-y-llyn Lake
GB31037641	37641	Llyn Llygad Rheidol
GB31037690	37690	Llyn Craigypistyll or Llyn Craig y Pistyll
GB31038390	38390	Llyn Teifi
GB31038394	38394	Llyn Hîr
GB31039020	39020	Llyn Brianne Reservoir
GB31040457	40457	Ystradfellte Reservoir
GB31041050	41050	Upper Lliw Reservoir
GB31042170	42170	Kenfig Pool
GB31047014	47014	Bosherston Lily Ponds (C Arm)
GB31133854	33854	Llyn Bran
GB31134167	34167	Pendinas Reservoir
GB31134864	34864	Llyn Arenig fawr

Table A.4a. Lakes considered to be at no risk of eutrophication.

Water Body ID	UKLakes ID	Lake Name
GB30935568	35568	Lake Vyrnwy / Llyn Efyrnwy
GB30937446	37446	Llyn Clywedog
GB30938240	38240	Llyn Fyrddon Fawr
GB30938427	38427	Claerwen Reservoir
GB30939967	39967	Usk Reservoir
GB30940302	40302	Cray Reservoir
GB30940441	40441	Beacons Reservoir
GB30940542	40542	Cantref Reservoir
GB30940600	40600	Pontsticill Reservoir
GB30940604	40604	Llangynidr Reservoir
GB30940635	40635	Carno Reservoir
GB30940636	40636	Blaen-y-cwm Reservoir
GB30940712	40712	Shon-Sheffreys Reservoir
GB30941303	41303	Lluest-wen Reservoir
GB31032435	32435	Llyn Llygeirian
GB31032538	32538	Llyn Alaw
GB31032926	32926	Cefni Reservoir
GB31034042	34042	Glaslyn
GB31034870	34870	Llyn Trawsfynydd
GB31035426	35426	Llyn Hywel
GB31036267	36267	Llyn Cau
GB31037596	37596	Nant-y-moch Reservoir
GB31037834	37834	Llynnoedd Ieuan
GB31039942	39942	Rosebush Reservoir
GB31040087	40087	Llys-y-frân Reservoir
GB31040990	40990	Penderyn Reservoir
GB31041177	41177	Lower Lliw Reservoir
GB31041219	41219	Llyn Fawr
GB31047015	47015	Bosherston Lily Ponds (W Arm & Central)
GB31133923	33923	Llyn Brenig
GB31133976	33976	Alwen Reservoir
GB31134038	34038	Llyn Cyfynwy
GB31134633	34633	Llyn Arenig Fach
GB31134644	34644	Llyn Celyn

Table A.4b. Lakes where there is weak evidence of eutrophication.

Water Body ID	UKLakes ID	Lake Name
GB30940365	40365	Talybont Reservoir
GB30940648	40648	Llwyn-on Reservoir
GB30941762	41762	Wentwood Reservoir
GB30941829	41829	Pant-yr-eos Reservoir
GB30941926	41926	Ynysyfro Reservoir
GB31033261	33261	Plas Uchaf and Dolwen Reservoirs
GB31033730	33730	Llyn Padarn
GB31034008	34008	Llyn Elsi Reservoir
GB31042079	42079	Eglwys Nunydd Reservoir
GB31134331	34331	Ty Mawr Reservoir
GB31134813	34813	Llyn Bedydd
GB31134854	34854	Llyn Tryweryn

Table A.4c. Lakes where there is some evidence of eutrophication.

Water Body ID	UKLakes ID	Lake Name
GB30940067	40067	Llangorse Lake
GB30941363	41363	Llandegfedd Reservoir
GB31032948	32948	Llyn Dinam
GB31033337	33337	Llyn Coron
GB31047013	47013	Bosherston Lily Ponds (E Arm)
GB31134780	34780	Hanmer Mere
GB31134987	34987	Llyn Tegid or Bala Lake

Table A.4d. Lakes where there is clear evidence of eutrophication.

Appendix 6. Lakes considered at risk of eutrophication and important for nature conservation that could not be reviewed due to insufficient evidence.

UK Lakes ID	Lake Name	SSSI Name	Area
32435	Llyn Llygeirian	Llyn Llygeirian	Anglesey
32746	Llyn Llywenan	Llyn Llywenan	Anglesey
32792	Llyn Cadarn	Cors Goch	Anglesey
39796	Upper Talley Lake	Llynnoedd Tal-y-Llechau (Talley Lakes)	Carmarthenshire
39813	Lower Talley Lake	Llynnoedd Tal-y-Llechau (Talley Lakes)	Carmarthenshire
38422	Llyn Eiddwen	Llyn Eiddwen	Ceredigion
38544	Llyn Fanod	Cors Llyn Farch a Llyn Fanod	Ceredigion
33631	Chwythlyn	Chwythlyn	Conwy
34622	Llyn Glasfryn	Llyn Glasfryn	Gwynedd
42721	Cosmeston Lakes	Cosmeston Lakes	Vale of Glamorgan
38321	Gwynllyn	Cwm Gwynllyn	Powys
37168	Llyn Mawr	Llyn Mawr	Powys
39267	Llanbwchllyn Lake	Llanbwchllyn Lake	Powys
41973	Serpentine Lake	Oxwich Bay	Swansea
34813	Llyn Bedydd	Llyn Bedydd	Wrexham

Data Archive Appendix

No data outputs were produced as part of this project.

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