Gyfarwyddeb Fframwaith Dŵr Methodoleg asesu risg asideiddio

Water Framework Directive Acidification risk assessment methodology

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Contents

1. Crynodeb gweithredol

Mae’r asesiad risg hwn ar gyfer asideiddio afonydd, llynnoedd a chamlesi yng Nghymru’n cyfuno dangosyddion effeithiau cemegol a biolegol gyda mesurau hyder sensitifrwydd i lunio dealltwriaeth gyffredinol o berygl asideiddio yn nhermau categorïau adrodd WFD ynghylch perygl. Mae’r asesiad wedi golygu adolygu’r asesiad risg Cylch 1, gyda diweddariadau i ddata cemeg a bioleg, datblygiadau mewn gwybodaeth wyddonol o nodyn cyngor UKTAG ar berygl asideiddio, a defnyddio canlyniadau modelu mwy rhagfynegol i ddyddiadau allweddol WFD gan gynnwys 2027.

Un o’r elfennau allweddol wrth asesu effeithiau asideiddio yw amcangyfrif y gormodiant llwyth critigol, ar sail amcanestyniadau o ddyddodiad atmosfferig yn y dyfodol o’i gymharu â gallu’r amgylchedd i niwtralu asidau. Mae’r prosiect hwn wedi cynnwys diweddariad i’r asesiad o ormodiannau llwyth critigol a wnaethpwyd gan y Ganolfan Ecoleg a Hydroleg gan ddefnyddio ei model MAGIC ar gyfer dyddiadau hyd at 2027.

Mae model MAGIC yn cynnwys amcanestyniadau o ddyddodiad atmosfferig allyriadau SO_2 ac NO_X ar sail model FRAME (Fine Resolution Atmospheric Multi-pollutant Exchange), ac yn cymharu hyn â’r Gallu Niwtralu Asidau sydd wedi’i fodelu ar gyfer 344 o safleoedd ar draws Cymru. Felly mae’r asesiad risg yn diweddaru’r pwysau ffynhonnell allweddol y bernir mai ef yw prif achos asideiddio, ac yn ystyried y perygl yn y dyfodol.

Mae’r asesiad risg yn cynnwys 6 dangosydd effaith pwysau, 2 ddangosydd sensitifrwydd (3 ar gyfer llynnoedd), a mesur hyder newydd wedi’i seilio ar argaeledd data, a gafwyd gan gydweithio gyda Cyfoeth Naturiol Cymru a’r Ganolfan Ecoleg a Hydroleg. Mae’r dadansoddiad wedi cynnwys deilliant:

- Cyfuniad wedi’i bwysoli o chwe dangosydd cemeg a bioleg i lunio sgôr effaith gyffredinol. Mae un o’r rhain yn ‘fetrig effaith graddfa fras’, a ddefnyddir i ymdrin â bylchau yn y data, gan ddefnyddio setiau data sy’n cynnwys Cymru gyfan.
- Deilliant metrig sensitifrwydd wedi’i bwysoli, wedi’i seilio ar Ddosbarth Sensitifrwydd Dŵr Croyw, fel yng Nghylch 1, ond gyda diweddariad i gynnwys Llwyth Critigol fel mesur sensitifrwydd ychwanegol, a metrig arall sensitifrwydd palaeo-ecolegol ar gyfer llynnoedd.
- Risg gyfan ar sail cynnyrch effeithiau wedi’u pwysoli a sgorau sensitifrwydd. Cynhyrchodd hyn ystod o sgorau risg cyffredinol sydd wedi cael eu dosbarthu gan ddefnyddio dadansoddiad sensitifrwydd.
- Sgôr Hyder – wedi’i seilio ar argaeledd data, a’r pwysau ar gyfer pob dangosydd
- Categori Adrodd UKTAG a ddeilliwyd gan ddefnyddio cyfuniad o risg gyfan a hyder gan ddefnyddio’r canllawiau a ddarparwyd, a thrwy osod ffiniau dosbarthiadau ar sail dadansoddiad sensitifrwydd.

Dangosodd asesiad o’r data cemeg oedd ar gael ar gyfer Camlesi fod perygl asideiddio’n fach (ar sail data pH ac Alcalinedd).

Mae’r gwahanol sgorau effaith, sensitifrwydd a risg gyffredinol wedi cael eu cyfuno yn y map yn Atodiad D.

2. Executive summary

This risk assessment for the acidification of rivers, lakes and canals in Wales, combines indicators of chemical and biological impacts with sensitivity measures of confidence to formulate an overall understanding of the risk of acidification in terms of WFD risk reporting categories. The assessment has involved a review of the Cycle 1 risk assessment, with updates to chemistry and biology data, advances in scientific knowledge from the UKTAG advice note on acidification risk, and use of more predictive modelling results to key WFD dates including 2027.

A key element in assessing the impacts of acidification is estimating the critical load exceedance, based on estimates of future atmospheric deposition compared with predicted acid neutralising capacity of the environment. This project has included an update to the assessment of critical load exceedances undertaken by the Centre for Ecology and Hydrology (CEH) using their MAGIC model for dates up to 2027.

MAGIC incorporates estimates of atmospheric deposition of SO_2 and NO_X emissions based on the FRAME (Fine Resolution Atmospheric Multi-pollutant Exchange) model, and compares this against the modelled Acid Neutralising Capacity (ANC) for 344 sites across Wales. Thus the risk assessment updates the key source pressure considered to be the primary cause of acidification, and considers future risk.

The risk assessment incorporates 6 pressure impact indicators, 2 sensitivity indicators (3 for lakes), and a new confidence measure based on data availability, that has been derived working together with Natural Resources Wales (NRW) and CEH. The analysis has included the derivation of:

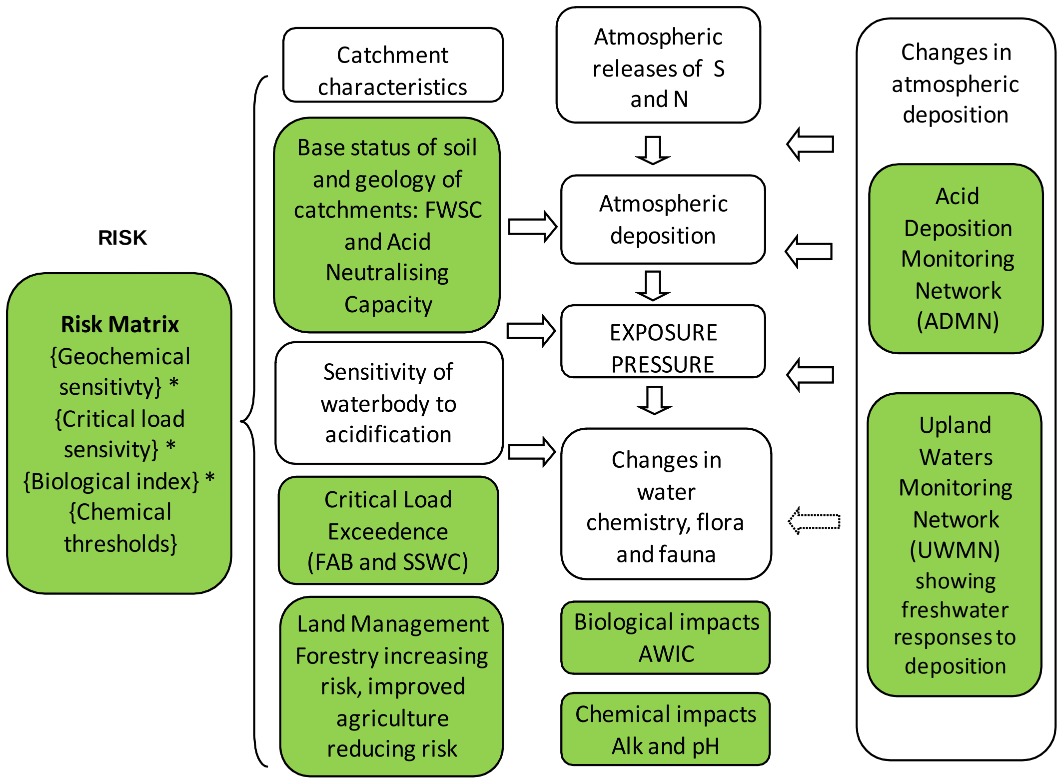
- A weighted combination of six chemistry and biology indicators to form an overall impact score. One of these is a new ‘coarse scale impact metric’, used to address data gaps, using datasets with complete coverage of Wales.
- Derivation of a weighted sensitivity metric, based on Fresh Water Sensitivity Class, as per Cycle 1, but with an update to include Critical Load as an additional measure of sensitivity, and a further metric of palaeo-ecological sensitivity for lakes.
- Total risk based on the product of weighted impacts and sensitivity scores. This generated a range of overall risk scores that have been classified using a sensitivity analysis.
- A Confidence score - based on data availability, and the weights for each indicator
- The UKTAG Reporting Category derived using a combination of total risk and confidence using the guidance provided, and by setting class boundaries based on a sensitivity analysis.

An assessment of available chemistry data for Canals highlighted that the acidification risk was low (based on pH and Alkalinity data)

The different impact, sensitivity and overall risk scores have been combined and are presented in the map provided in Appendix D.

2. Conceptual model

Acidification is the outcome of a complex set of chemical processes dependent on the local geology, the capacity of the local environment to buffer or neutralise acidity, the pollution environment and local land-use. The basic pressure-impact-sensitivity-risk conceptual model for this risk assessment for acidification in Wales is presented in Figure 1. A detailed description of each of the components of the conceptual model is provided below.



2.1 Activities

The key source-pressures for acidification stem from emissions of sulphur and nitrogen from range of point and diffuse sources. These include large point sources such as power stations, refineries, diffuse sources such as traffic, releases from burning domestic fuel and industries, releases of N from agriculture, shipping, and emissions from upwind sources in the USA or Europe. When sulphur and nitrogen compounds are released into the atmosphere, oxides of sulphur and nitrogen, particularly sulphur dioxide (SO_2), nitrogen oxide (NO) and nitrogen dioxide (NO_2) react with water in the atmosphere to form sulphuric and nitric acids. This leads to an increase in the acidity of moisture in the atmosphere which ultimately falls to earth as acid deposition. The effects of this acid deposition are most pronounced in regions where geo-chemical weathering rates are relatively poor, including many upland areas in Wales where acidic peaty soils overlie poorly weatherable lithologies such as granites, sandstones and shales. Plantation forestry on acid-sensitive soils can have an exacerbating effect on acidification, primarily by enhancing deposition rates via canopy 'filtering' of pollutants from the atmosphere.

2.2 Source Pressures:

The FRAME model is a Lagrangian atmospheric transport model used to assess the long-term annual mean deposition of reduced and oxidised nitrogen and sulphur over the United Kingdom. Deposition for 2017, 2021 and 2027 was estimated from UK FRAME deposition scenarios for 2020 & 2030 (UEP43 scenarios) together with FRAME trends in deposition from 1970 to 2005. A detailed description of the FRAME model is contained in Singles et al., 1998.

For the purposes of the Habitats Directive, the FRAME model was adapted to predict the impact of individual large combustion sources, such as power stations, as well as more diffuse sources, such as reduced nitrogen released from agricultural land (Dore, et al., 2005), and used for this assessment. More details of the different sources included in the model are included in the Cycle 1 assessment report.

Wet and dry acid deposition due to these emissions are predicted by the model on a 5km grid square basis for NO_X, SO_2 and NH_X. The model includes estimates of deposition for varying vegetation types (specifically for forests and grasslands/moorlands), and these can be averaged over the grid square based on the land use within the square. Deposition 'averaged' over land-use has been used in this risk assessment.

The emissions scenarios used here were based on a scenario developed by DEFRA for use in assessing the requirements for the UK to comply with the Gothenburg protocol (UNECE protocol to Abate Acidification, Eutrophication and Ground-level Ozone 1999 http://www.unece.org/env/lrtap/multi_h1.htm). This scenario was adapted for NRW use by replacing generalised sector emissions with estimated emissions from individual large combustion sources.

2.3 Sensitivity

The assessment of sensitivity to acidification is based on the mapping of the base status of soil and geology of catchments, the Fresh Water Sensitivity Class, (FWSC) (Hornung et al., 1995) without any modification for land use.

This has the advantage of providing a map of most of Wales (excluding large urban areas) whereas calculated freshwater critical loads, ANC values and measurements of calcium and alkalinity levels are available from only a limited number of locations at which water samples have been collected. The Freshwater Sensitivity Map shows the sensitivity of UK soils to acidification on a $1km^2$ basis, and divides the sensitivity into 5 classes, with class 1 being the most sensitive, and class 5 the least sensitive.

2.4 Trends

The UK Upland Waters Monitoring Network (formerly Acid Waters Monitoring Network) demonstrates that acidified waters have benefited from a substantial drop in the rate of sulphur deposition over the last two decades (Monteith et al 2005); severely acidified sites have shown reductions in inorganic aluminium concentration, while pH and alkalinity show increases in less acidic waters.

More recent research (Ormerod and Durance, 2009) states that SO_2 emissions in the UK have now declined to < 15% of their peak in the 1970s and 1980s, with sulphur deposition falling in many locations by at least 50%, and that this reduction is reflected in the Welsh data.

This Risk Assessment has focussed on the future predicted sensitivity using 2027 data, where available, but the changes to total number of water bodies at risk through time based on 2017 and 2021 Critical Load Exceedence and ANC data were also examined. This showed that the total number of water bodies (rivers) is predicted to change very slowly between 2015 and 2027, by 1% at most for lakes (see Figure 2-2).

Figure 2-2 Change in percentage of waterbodies in each risk categories through time

	Count of Rivers 1a, "At Risk"	Count of Rivers 1b "Probably at risk"	Count of Rivers 2a/2b	Total Rivers		Count of Lakes 1a, "At Risk"	Count of Lakes 1b "Probably at risk"	Count of Lakes 2a and 2b	Total Lakes
2015	9.2%	9.1%	81.8%	100%		5.1%	15.82%	79.1%	100%
2021	9.2%	8.6%	82.2%	100%		4.4%	16.46%	79.1%	100%
2027	9.2%	8.2%	82.6%	100%		4.4%	16.46%	79.1%	100%

2.5 Classification

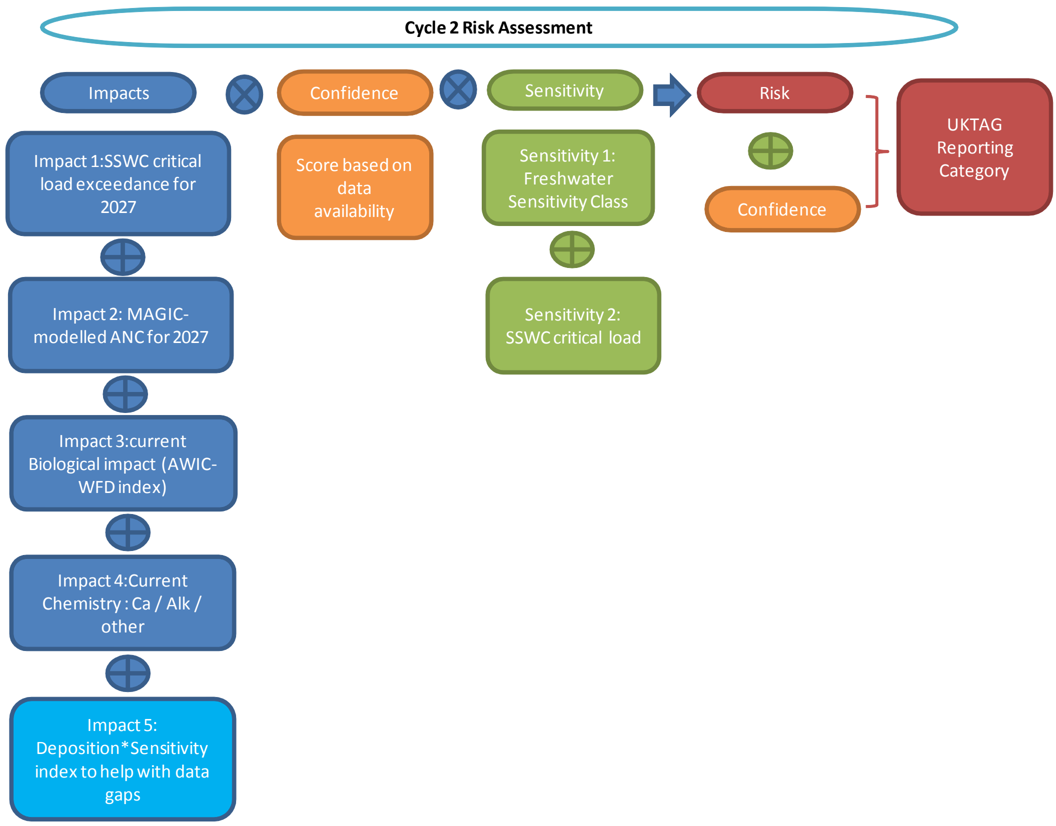
The classification data used to assess acidification in rivers for the WFD is based on pH, and is computed by NRW each year. The UKTAG group has advised that this is a good proxy for labile Aluminium, which is considered to be the primary toxic control on biological communities. For future classification UKTAG has recommended that pH is used in combination with a humic/clear typological classification. For Wales, the majority of sites are classed as ‘clear’, based on a threshold of 10mg/l for Dissolved Organic Carbon (DOC), although through consultation with CEH, this threshold for humic/clear classification was considered to be too high. A value of 5 mg/l was considered be a more appropriate threshold. However, the data coverage for DOC in Wales was found to be 34%, or 246 out of 718 waterbodies, with very few waterbodies having DOC > 10 mg/l.

3. Methodology

3.1 General approach

This Risk Assessment considers key impacts of acidification and the sensitivity of water bodies to formulate a risk matrix approach, similar to that used in Cycle 1 of River Basin Management, but improved with more recent data and model outputs summarised in Figure 3-1. An additional sensitivity metric was included for lakes, based on palaeo-ecological data derived by NRW. This was found to be generally in agreement with the other sensitivity indicators. The biological impact data also differed slightly for lakes, in that it was based on the littoral invertebrate method (LAMM) as described in the UKTAG acidification guidance. Here the minimum class over the last 3 years was used, in place of the AWIC scores used for rivers.

Figure 3-1: Cycle 2 Risk Assessment Matrix (Rivers)



The impacts were based upon predicted critical load exceedance, biological impacts, chemistry impacts (with lesser weighting), and were combined with sensitivity measures based on FWSC and Acid Neutralising Capacity (ANC) to derive an overall measure of risk. This was translated into the four UKTAG reporting categories, using a confidence measure based on data availability.

3.2 Data sources

Table 1 includes a headline description of data used, sources of data (national or area database), the limitations of data sets, ownership, licenses and accessibility. .

Dataset	Source / ownership	Purpose	Used in Cycle 1?	Limitations of dataset	Accessibility
NRW Cycle 2 Waterbodies and catchment GIS data	NRW	Updated spatial definition for reporting to EU	In part	This study used Cycle 2 waterbodies	None
WFD waterbody grouping ID	NRW	Used in Cycle 1 to assign waterbodies with no data to others supported by data	Yes	Not entirely up to date since relationships were set for the cycle 1 waterbodies	
Acidification classification / reasons for failure 2009,2010, 2011	NRW	Reporting of latest Acidification	No	2012 data not available yet	Provided against unique WBID
Biological impact data: AWIC for 2010, 2011, 2012	NRW	index measuring biological impacts	Yes	Provided against unique WBID, but there are some large data gaps, so can only be used in some water bodies	Provided against unique WBID
Biological impact data: minimum Littoral Invert Class over 2010, 2011, 2012 for lakes	NRW	index measuring biological impacts	No	Provided against unique WBID and available for lakes only	Provided against unique WBID
Biological sensitivity data: palaeo ecological record for lakes	NRW	Index measuring historical sensitivity of acidity	No	Provided against unique WBID and available for lakes only	Provided against unique WBID
WIMS Chemical impact data: Alkalinity	NRW	index measuring chemical impacts	Yes	Provided against unique WIMS code. Good distribution of data with risk categorisation reflecting current WFD classification	A spatial join between waterbodies and WIMS sample points grid references must be undertaken, taking the minimum value if there are multiple sites.
WIMS Chemical impact data: pH	NRW	index measuring chemical impacts	No	Provided against unique WIMS code. If this is used it needs to be compared to the	A spatial join between waterbodies and WIMS sample points

				typology	grid references must be undertaken, taking the minimum value if there are multiple sites.
CEH Critical Loads (SSWC)	CEH, but licensed to NRW	Sensitivity Index measuring capacity of environment to buffer acidity	No	Provided against 344 unique CEH sample points	A spatial join between waterbodies and CEH sample points grid references must be undertaken, taking the minimum value if there are multiple sites.
CEH predicted ANC 2027	impact metric of future capacity to neutralise deposition	Impact metric of future likely buffering capacity	No	MAGIC modelled pH and ANC values for 2017, 2021, 2027, for 333 of the Welsh sites.	A spatial join between waterbodies and CEH sample points grid references must be undertaken, taking the maximum (to be conservative) value if there are multiple sites.
CEH predicted Critical Load Exceedance, 2015, 2021, 2027	impact metric of future acidification	Given FRAME deposition rates in 2027, provides the predicted exceedance of critical loads	No	Provided for 344 Welsh sites based on (a) SSWC model; (b) First-order Acidity Balance (FAB) model, for 2015, 2021, 2027	A spatial join between waterbodies and CEH sample points grid references must be undertaken.
Freshwater Sensitivity Class (FWSC)	Key sensitivity metric	Sensitivity Index	Yes	1km grid 1 = highly sensitive to acidification 2 = medium-high sensitivity 3 = medium-low sensitivity 4 = low sensitivity 5 = non-sensitive	The minimum FWSC over each WBID
FRAME deposition predictions	Useful in combination with FWSC to fill data gaps	Source pressure - modelled atmospheric deposition	Yes for 2004 and 2010	Wales_FRAME_deposition: FRAME deposition for all 5x5km squares in Wales. Values derived for 2017, 2021 and 2027 from FRAME data for 2005, 2020 and 2030	The deposition rates for moorland and woodland require differentiating - this requires LCM2007

3.3 Description of methodology

The Cycle 1 acidification matrix has been updated using the approach summarised in Figure 3-1 and data in Table 1. Whilst data has been prepared for different horizons associated with the Water Framework Directive, the modelled impacts for 2027 have been used in the final risk matrix to provide a forward looking risk assessment.

The Cycle 2 risk assessment uses the following four stages to define risk category:

- Weighted combination of chemistry and biology scores (weights are in parentheses):
  - Critical Load predicted in 2027 [2]
  - ANC predicted in 2027 [2]
  - AWIC over the last three years [3]
  - pH from samples in the last 3 years [1]
  - Alkalinity from samples in the last 3 years [1]
  - CSIM index as described in section [1]
- Weighted combination of sensitivity scores (weights are in parentheses):
  - FWSC [1]
  - Critical Load (using SSWC) [1]
- Total risk - product of weighted impacts and sensitivity scores
- Confidence score - based on data availability and using the weights for each metric
- UKTAG Reporting Category – derived from a total risk and confidence using the guidance provided

Figure 3-2 summarises the spreadsheet implementation of the revised risk matrix and further details on the data used in each assessment category are provided below. Separate spreadsheets were generated for rivers and lakes.

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Figure 3-2 Spreadsheet implementation of risk assessment (see Appendices E and F)

Calculation of Risk Matrix

weight:	2	2	3	1	1	1		Confidence Score		weight: 1	1		TOTAL RISK		count 1a / count 1b
	Impact 1	Impact 2	Impact 3	Impact 4	Impact 5	Impact 6	Weighted Impact			Sensitivity 1	Sensitivity 2	Weighted sensitivity			
EA_WB_ID	CL Exceedence 2027	MAGIC ANC 2027	AWIC	Alkalinity	pH	CSIM		based on data availability	Confidence Class	FWSC	CL 2027		Product of impact and sensitivity	Risk Class	Confidence Class
GB111067				0	0	0	0	3	H	0		0	0	L	H
GB111067					0	0	0	2	H	0		0	0	L	H
GB111067						0	0	1	H	1		0.5	0	L	H
GB111067						0	0	1	H	0		0	0	L	H
GB111067					0	0	0	2	H	0		0	0	L	H
GB111067						0	0	1	H	0		0	0	L	H
GB111067					0	0	0	2	H	1		0.5	0	L	H
GB111067						0	0	1	H	1		0.5	0	L	H
GB111067	1	0			0	3	0.5	6	H	3	2	2.5	1.25	H	H
GB111067				0	0	0	0	3	H	0		0	0	L	H
GB111067				0	0	0	0	3	H	0		0	0	L	H
GB111067				0	0	0	0	3	H	1		0.5	0	L	H
GB111067					0	0	0	2	H	2		1	0	L	H
GB111067					0	0	0	2	H	3		1.5	0	L	H
GB111067					0	0	0	2	H	1		0.5	0	L	H
GB111067					0	0	0	2	H	1		0.5	0	L	H
GB111067						0	0	1	H	0		0	0	L	H
GB111067				0	0	0	0	3	H	1		0.5	0	L	H

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3.4 Derivation of Impact

The Cycle 2 risk matrix is designed to consider biological and chemical impacts. However, only one category of biological impact is considered, this being the UKTAG recommended version of AWIC, and the lake equivalent score based on LAMM as described above. The phytobenthos/diatom measurements in lakes and rivers data were examined for use, but did not provide wide coverage, and for lakes were observed to misclassify lakes known to be alkaline as at risk of acidification. Instead two other measures were used, described at the start of Section 3, those of an impact metric based on LAMM, and a sensitivity metric based on palaeo-ecological records of acidity.

Each of the individual impact categories is weighted, with the highest factor of 3 applied to the biological impact and the lowest impact of 1 applied to a number of the chemical impacts. The weighted scores for each of the 6 impact categories are summed to generate the overall impact score.

The Risk Assessment was carried out for rivers and lakes separately; with the main difference being that AWIC was used for Rivers and LAMM for Lakes.

The six impact measures above are now described, along with their respective impact scores.

3.4.1 Biological Impact: AWIC EQR Score

The AWIC method describes the impact of acidification pressures on river macro-invertebrate communities, by assessing the development of specialist communities that are adapted to low pH but not high L-AL.

43 of the 718 water bodies in Wales have AWIC data available from 2010 -2012 for the Cycle 2 risk assessment. The risk matrix allocates a score to each of the 43 water bodies based on the WFD-EQR scores provided by Natural Resources Wales as summarised to 2 decimal places in Table 3-2. A weighting of 3 (maximum weighting) has been allocated to this category to reflect the importance of biological data in evaluating continuous impacts.

Table 3-2: Evidence of impacts: Mean AWIC EQR for 2010-2012 data (using EA/NRW class boundaries)

upper	lower	WFD class	Impact Score
0	0.67	BAD	3
0.67	0.78	POOR	3
0.78	0.89	MODERATE	2
0.89	0.98	GOOD	1
>0.98		HIGH	0

3.4.2 Critical Load Exceedence predicted in 2027

UK freshwater critical loads exceedences have been used in the Cycle 2 risk matrix as the highest ranked measure of chemical impact. Critical loads are a measure of environmental sensitivity, described as the “highest deposition of acidifying compounds that will not cause chemical changes leading to long term harmful effects on ecosystem structure and function" in Nilsson and Grennfelt (1988), and remain fixed for a site.

Two methods are generally used for calculating critical loads for freshwaters: the Steady State water Chemistry (SSWC); and Freshwater Acid Balance (FAB) methods. SSWC is considered more optimistic, as it assumes no future increase in freshwater nitrate concentrations (best case scenario), whereas the FAB critical load anticipates a situation in which all short-term sinks for atmospheric nitrogen have been exhausted (which usually implies a substantial increase in nitrate leaching relative to current conditions). FAB is the official method adopted by UKTAG for reporting to the EC.

Critical Load exceedance is calculated as the amount of deposition above the critical load, and for this assessment, exceedances have been calculated for the 334 sites across Wales by CEH using deposition sequences from FRAME for three time horizons (2017, 2021, 2027). A level of deposition which exceeds the critical load does not mean that damage has actually occurred at the measured site, but that the capacity of the landscape to neutralise acid deposition is being exceeded and ecological damage may result in the short or long term.

182 of the 718 water bodies in Wales have critical load exceedance data available for the risk assessment. The risk matrix uses critical load estimations from both the SSWC and FAB methods, with the score reflecting whether the critical load from both or either of the methods is exceeded (Table 3-3). Failing SSWC is worse than FAB, as the former is the more optimistic. A weighting of 2 is allocated to this category.

Table 3-3: Evidence of Impact: Critical Load Exceedence impact scores (based on Cycle 1)

FAB CL	SSWC CL	Evidence of Impact	Impact Score
Exceeded	Exceeded	H	3
Not Exceeded	Exceeded	M	2
Exceeded	Not Exceeded	L	1
Not Exceeded	Not Exceeded	L	0
No data	No data	D	Null

3.4.3 Acid Neutralising Capacity ANC

Acid Neutralising Capacity (ANC) is a measure of available buffering capacity in aquatic systems and can be measured in a number of ways. UKTAG considers ANC to be an effective indicator of anthropogenic acidification, so the consequences of changing acid deposition can be directly assessed in terms of changing ANC.

MAGIC is a dynamic ecosystem biogeochemical model that predicts freshwater acidification status for a given time horizon (up to 2100) based on knowledge of critical loads and the predicted deposition rates of SO_2 and NOx from the FRAME model. It has been used to compute ANC for 2017, 2021 and 2027 for the 334 sites across Wales, and the 2027 predictions have been used in this assessment to make it forward looking.

The advantage of using MAGIC in the risk assessment is that it can be used to directly predict ecosystem status in a given year, based on current forecasts of future deposition, the main pressure on acidification. It can also take account of land-use factors such as forest management.

175 of the 718 water bodies in Wales have MAGIC ANC 2027 data available. The risk matrix allocates a score to each of the 175 water bodies based on the UKTAG Acidification Environmental Standards 2012 (Table 3-4). A weighting of 2 is allocated to this category.

Table 3-4 Evidence of Impact: ANC Impact Scores (based on UKTAG, 2012)

Boundary	ANC WFD class boundary $ueql^{-1}$	ANC Impact Score
High-Good	80	0
Good-Moderate	40	1
Moderate-poor	15	2
Poor / Bad	-10	3

3.4.4 Alkalinity

Natural Resources Wales monitoring data from 2010-2012 has been used to derived the mean alkalinity at each sampling site, restricting analysis to sites with greater than 12 data points. Appendix B summarises the sampling purpose codes included and restricted from the analysis. Alkalinity titrated to pH 4.5, has been used to define water body alkalinity. When more than one sampling point is located within a water body the site with the minimum mean has been used.

267 of the 718 water bodies in Wales have measured alkalinity data available for the risk assessment, with at least 12 measurements. The 2010, 2011 and 2012 data were used, where there were at least 12 samples. The risk matrix allocates a score to each of the 267 water bodies based on Table 3-5, and a weighting of 1 is applied to this chemistry impact score. In Cycle 2, CEH advised that an alkalinity of > 20 should be used to denote low risk, as opposed to 25, so this has changed the cycle 1 threshold slightly as below.

Table 3-5 Evidence of Impact: Alkalinity Impact Scores (based on CEH update of Cycle 1 scores)

Alkalinity titrated to pH 4.5 as $CaCO_3$ (mg/l)	Evidence of Impact
<5	H
5-10	M
10-20	L
>20	N

3.4.5 Acidity, pH

The pH of a water body reflects acidity rather than acidification, but UKTAG (*UKTAG 2012*) report that it is correlated (non-linearly) with labile aluminium. For this reason it has been brought into the risk assessment; it was not included in Cycle 1.

Natural Resources Wales monitoring data from 2010-2012 has been used to derived the mean pH at each sampling site, restricting analysis to sites with greater than 12 data points. Appendix B summarises the sampling purpose codes included and restricted from the analysis. These data have been used to define water body pH. When more than one sampling point is located within a water body the site with the minimum mean value has been used in the risk assessment.

It is important to take into account the ambient water chemistry, for which the UKTAG group recommends using DOC to set 2 typologies of 'humic' and 'clear'. Humic rivers and lakes have a naturally low pH, due to the presence of organic acids, which is not generally associated with high levels of labile aluminium or therefore with ecological degradation.

475 of the 718 water bodies in Wales have measured pH data available for the risk assessment, but there is a shortage of DOC data (34% of water bodies) available to permit the typology of each water body to be defined. Practically all water bodies with DOC measurements are classified as clear using the UKTAG threshold of 10mg/l. The risk matrix therefore uses the UKTAG 2012 pH standards for clear waters, as summarised in Table 3-6. A more complete analysis to derive humic waters in the future has been recommended that takes into account peat content in each water body. Because the risk of deterioration is already managed in relation to afforestation for high peat content sites, the risk in more humic waters is in any case already managed to some degree. This means it is expected that a more detailed assessment would be undertaken in these higher risk, peaty areas.

Table 3-6 Evidence of Impact: pH Impact Scores (based on UKTAG, 2012)

Boundary	WFD pH Wales	Impact Score
High-Good	6.54	0
Good-Moderate	5.95	1
Moderate-poor	5.44	2
Poor / Bad	4.89	3

3.4.6 Coarse Scale Impact Metric (CSIM)

This impact category is the product of the FRAME 2027 acid deposition data (for S and N) and the Freshwater Sensitivity Class. This metric is intended to reflect the combination of geological sensitivity and pressure from atmospheric pollution, and is therefore somewhat analogous to freshwater critical load exceedance, but based on a simpler method that can be applied without the requirement for measured water chemistry.

This category has been added to the risk matrix to address data gaps in chemical impact data; all water bodies will have a score for this category, as summarised in Table 3-7. This therefore means that there are no longer any sites for which there is no data. A weighting of 1 is allocated to this category.

Table 3-7 Evidence of Impact: Coarse Scale Impact Metric (set based on 'calibration' at CEH monitoring points*)

CSIM Score	Impact score
>=5	3
<5	0
No data	Null

* The threshold of >=5 as corresponding to high impact was derived by comparison of the metric against the values of SSWC Critical Load at the 344 CEH monitoring sites. It was found (see Appendix C) that there was a greater probability that SSWC CL was exceeded for sites where CSIM>=5. This does not imply that where CSIM>=5 the site will have a positive critical load.

3.5 Derivation of Confidence Score

The confidence score is based on the availability of impacts data, utilising the weighting of each impact category as summarised in Table 3-8. Table 3-9 summarises the intervals used in defining the confidence score scale. For example, Water bodies for which data is available for all 6 impact categories will have the highest confidence score, 10, and be classed as high confidence.

Table 3-8 Summary of Impact Weightings used to derive the overall confidence score.

Impact Category	Weight
CL Exceedence 2027	2
MAGIC ANC 2027	2
AWIC/Littoral invert class	3
Alkalinity	1
pH	1
CSIM	1

Table 3-9 Scale used to define the confidence score

Confidence Score Scale		lower boundary	Upper boundary
High	H	6	
Medium	M	2	6
Low	L	0	2
No Data	N		

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3.6 Derivation of Sensitivity

The assessment of sensitivity to acidification is calculated as the weighted sum of two sensitivity indicator scores each carrying equal weighting: the Freshwater Sensitivity class and the SSWC Critical Load exceedance for 2027 scores. Conversion of both data sets into sensitivity scores is summarised in Table 3-10. Both categories have an equal weighting, of 1.

The freshwater sensitivity class was used to define sensitivity in the RBC2 method. The freshwater sensitivity class utilises mapping of the base status of soil and geology of catchments (Hornung et al., 1995) without any modification for land use. This has the advantage of providing a map of most of the UK (excluding large urban areas) whereas calculated freshwater critical loads, ANC values and measurements of calcium and alkalinity levels are available from only a limited number of locations at which water samples have been collected. The Freshwater Sensitivity Map shows the sensitivity of UK soils to acidification on a 1km^2 basis, and divides the sensitivity into 5 classes, with class 1 being the most sensitive, and class 5 the least sensitive.

Table 3-10 Combination of Freshwater Sensitivity Class and Critical Load to define Sensitivity*

FWSC	Score 1
1	3
2	2
3	1
4 or 5	0
No data	Null

SSWC_CL (keq/ha/yr)	Score 2
>4	0
2-4	1
0.5-2	2
<=0.5	3
No data	Null

*The overall sensitivity was the (equally) weighted sum of the two scores at each location

3.7 Overall risk score

The overall ‘risk’ was derived as the product of the overall impact score and the overall sensitivity score, in accordance with the guidance. This was then combined with the confidence score to generate the UKTAG reporting categories, based on the sensitivity analysis that is reported in Appendix D.

3.8 Thresholds and risk classification

The WFD RBC2 Risk Assessment Guidance has been applied to combine the final risk and confidence scores in deriving the final risk reporting category. This is summarised in Table 3-11 along with the risk and confidence score boundaries that have been applied in the Cycle 2 assessment

Table 3-11 Derivation of the final UKTAG Risk Reporting Category

UKTAG reporting category	Risk score	Confidence score	Risk score	Confidence score
1a Water bodies at significant risk: At Risk	H	H	>2	>6
	H	M	>2	2-6
	M	H	0.45-2	>6
1b Water bodies probably at significant risk (but for which further information will be needed to make sure this view is correct: Probably at risk	H	L	>2	0-2
	M	M	0.45-2	2-6
	M	L	0.45-2	0-2
2a Water bodies not at significant risk on the basis of available information (confidence in the available information being comprehensive and reliable is low): Probably not at risk	L	L	0-0.45	0-2
	N	L	0	0-2
	N	M	0	2-6
2b Water bodies not at significant risk on the basis of available information (confidence in the available information being comprehensive and reliable is high): Not at Risk	N	H	0	>6
	L	H	0-0.45	>6
	L	M	0-0.45	2-6

3.9 Pedigree and validation of method

The method is based on an update to the risk matrix approach that was used for Cycle 1, but incorporating some improved future projections of deposition rates. The EA Risk Assessment guidance has been followed, so the method is based on existing regulatory approaches. The future predicted deposition rates are based on the well documented FRAME (Fine Resolution Atmospheric Multi-Pollutant Exchange) model predictions, and additional analyses have been undertaken in consultation with CEH.

3.10 Confidence in Risk Assessment outputs

Data confidence scores were incorporated into the classification as recommended in the UKTAG classification. The scores are a simple combination of the weights for each impact variable, so as more data is available, a greater confidence is given. A greater confidence is given to biological data to reflect the information on continuous impacts that this data provided. Further details on derivation of confidence and impact weightings are provided in Section 3.3.2.

3.11 Output

Process spreadsheets have been produced for the Cycle 2 risk assessment, treating lakes and rivers separately (as illustrated in Figure 3-2). These spreadsheets log and process the following information and calculate the final risk category:

- Data Inputs – raw data at a water body level (as summarised in Section 3-2)
- Method/Data Processing – conversion of the raw data into impact, sensitivity and confidence scores for each water body (as summarised in Section 3-3)
- Risk Assessment Output – final acidification risk category at a water body level (as summarised Section 3-4). ‘Acidfctn Risk To Water bodies’ sheet

The ‘Acidfctn Risk To Water bodies’ sheet uses lookup formulae to pull in the input data stored within the individual sheets. The spreadsheet is constructed to automatically re-calculate the risk category following amendments to the water body data in any of the input data sheets.

The metadata template has been completed to summarise the input data, data processing methods applied and the outputs (see Appendix B).

3.12 Assumptions and limitations

Summary of assumptions and limitation of the Cycle 2 risk assessment are provided in Table 3-12.

Table 3-12 Assumptions and Limitations of the Cycle 2 Acidification Risk Assessment methodology.

Assumption	Limitation
pH – assumption of standard for 'clear' typology	The clear water standards have been assumed throughout, on the assumption that in the more peat-dominated catchments, the potentially humic water acidification risk will be managed more carefully through existing controls on afforestation. This means that a more detailed acidification assessment would be expected before there were any changes in these locations.
Biology – data gaps	AWIC monitoring was only undertaken at a small number of river sites, with LAMM data available for 45 lake sites. For lakes, the minimum class over the last 3 years of littoral invertebrate score was used. In addition palaeo-ecological data was used to derive an additional sensitivity metric for lakes. The project group considered that use of available phytobenthos data as a measure of sensitivity to acidification yielded contradictions in the locations that would be classified as high risk (for example lakes known to be alkaline would be classified as at risk).
Impact data – CSIM	The calibration of the Coarse Scale Impact Metric is approximate and is based on the relationship observed between the product (predicted deposition*sensitivity) and the SSWC CL Exceedance. The relationship showed there was a higher probability that sites with a value CSIM>5 would have a positive CL Exceedance

4. Further Development

The next cycle of assessment could be improved upon in three core ways:

- Research whether the phytobenthos data for lakes and rivers can be used alongside the AWIC and LAMM data to support the ecological impact assessment. In this review, the data appeared to give contradictions with alkaline lakes being classified as at risk using the UKTAG classifications in relation to the available phytobenthos data..
- The MAGIC library approach used in Sweden could be developed to improve the estimate of critical load exceedence at sites without monitoring, although the CSIM index attempts in part to fill in data gaps.
- The Fresh Water Sensitivity Classification data could be improved to check whether some soils were incorrectly classified as sensitive.

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Appendix A: Chemical data analysis assumptions

Filtering was undertaken to use the following WIMS ***purpose codes***:

- MN - Monitoring (National Agency Policy)
- MP - Environmental Monitoring (GQA & RE only)
- MS - Environment Monitoring Statutory (EU Directives)
- MU - Monitoring (UK Govt Policy – Not GQA or RE)

The following WIMS Purpose codes were **not included** in the analysis:

- CA - Compliance audit (permit)
- PN - Planned Investigation (National Agency Policy)
- SI - Statutory failures (follow ups at non-designated points)
- MI - Statutory Failures (follow ups at designated points)

Filtering was undertaken to use the following WIMS ***sample point types***:

- F* - Freshwater (includes river, canal, lakes)
- GA – Water for potable supply – reservoir/lake/pond
- GB – Water for potable supply – reservoir feed
- GC - Water for potable supply – river abstraction
- GD - Water for potable supply – EU Directive class A1
- GE - Water for potable supply – EU Directive class A2
- GF - Water for potable supply – EU Directive class A3
- GG - Water for potable supply – pumped storage from lowland river
- GI - Water for potable supply – canal abstraction

The following sample types were **not included**:

- PE – Pollution / Investigation points - Environment
- ZZ - Unspecified

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Appendix B: Calibration of CSIM threshold

The Coarse Scale Impact Metric (CSIM) was derived to fill in data gaps for this acidification risk assessment. It was derived as the product of the FRAME deposition data and the (reverse) Freshwater Sensitivity Class (FWSC). The reverse FWSC was used such that a higher score indicates a higher sensitivity. These two datasets were available for the whole of Wales, along with a forestry coverage dataset. This was used to extract the correct deposition rates from the FRAME data, as these are strongly influenced by woodland.

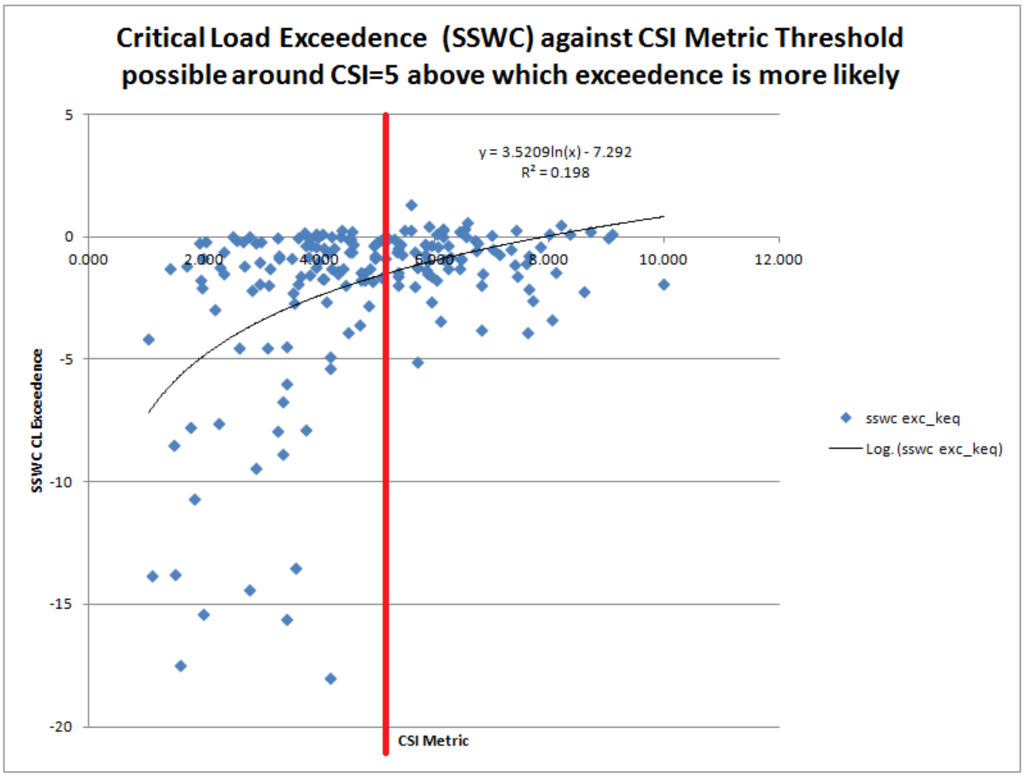
FRAME predicted N and S depositions for 2027 (S, NOx and NHx) were provided on a 5km grid for woodland and moorland.

The proportion of woodland in each 5km^2 was derived for the Forestry Commission's 2012 Registry of woodland[1].

The total deposition over each 5km^2 grid was calculated as the sum of the deposition over each land type weighted by extent.

CSIM was then regressed against the critical loads at all the CEH monitoring sites, where it was available as both FAB and SSWC. The relationship is not strong, but there is a considerably greater probability of critical loads being larger or positive to the right of the red line signifying CSIM>5 in Figure C-1.

Figure C-1 Calibration of Coarse Scale Impact Metric



1 http://www.forestry.gov.uk/datadownload

Appendix C: Sensitivity Analysis of UKTAG class boundaries

A sensitivity analysis was undertaken to assess what ranges of the overall risk score should be assigned to at risk/probably at risk and probably not at risk/not at risk. Figure D-1 shows three natural clusters of scores that were evident for the lakes (also evident for rivers), and from a sensitivity analysis shown in Figure D-2, the low/moderate class boundary was found to be the most sensitive (due to the peak at around 0.6 in figure D-1). The low/moderate boundary was therefore set at 0.45 to reflect the observed division

Figure D-1 Classification of total risk scores

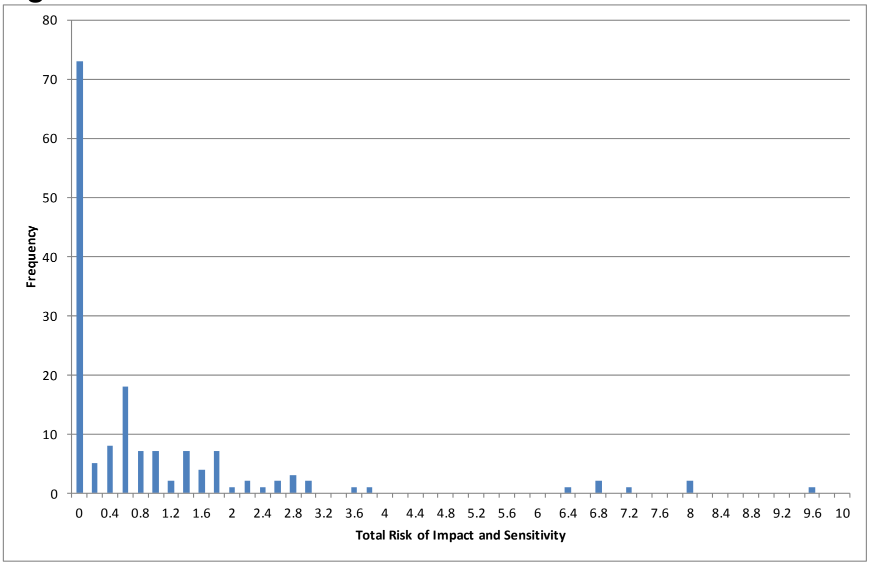
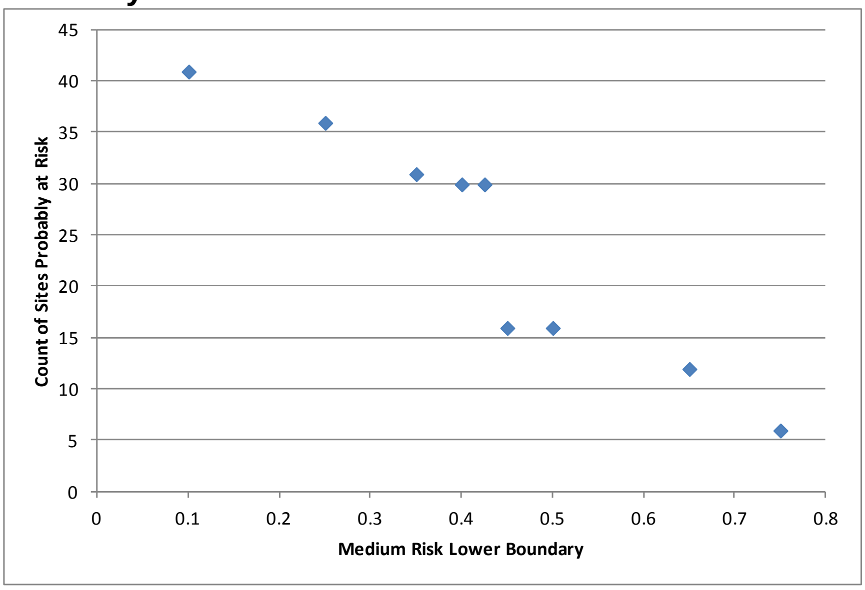


Figure D-2 Sensitivity of the number of sites probably at risk with the low/moderate boundary



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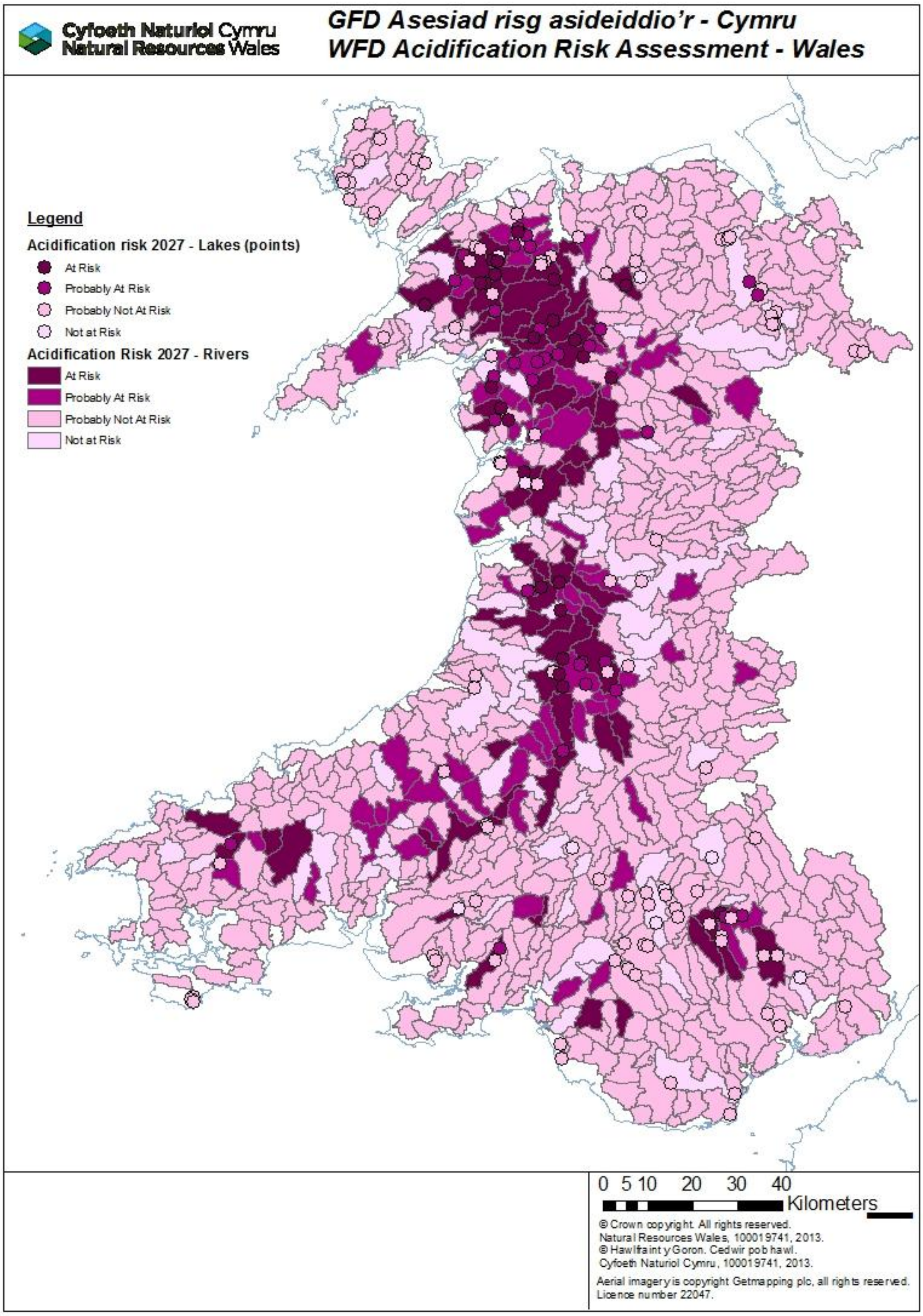
Appendix D: Acidification Risk Assessment Map



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