

# **Development of a risk based prioritisation protocol for standing waters in Great Britain based on a georeferenced inventory– Phase 2**

R&D Technical Report P2-260/2/TR1

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The purpose of this report is to inform the Agency and other partner organisations of the approach developed in Phase 2 of this project to develop an inventory of standing waters in Great Britain and a protocol that can be used to prioritise work on standing waters.

## **Keywords**

Standing waters, inventory, risk assessment, prioritisation, eutrophication, acidification, sensitivity, water quality, hindcasting, Water Framework Directive, Great Britain.

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# EXECUTIVE SUMMARY

## Introduction

In order to implement a number of EU directives, the Environment Agency, the Scottish Environment Protection Agency and the Nature Conservation bodies all require a procedure to identify lakes at risk of a deterioration in water quality as a result of the presence of a hazard(s) in their catchment. A protocol using a three-tiered hierarchical prioritisation system was developed to assess environmental harm using nutrients and acid deposition as example hazards. In order to carry out these prioritisations, basic information was required on the location, number and size of lakes, in association with ecological and water quality data and target (reference) conditions. Since no single comprehensive inventory of lakes and reservoirs in Great Britain existed, prior to this study, the development of a georeferenced inventory of standing waters in Great Britain and their physical, chemical and ecological properties was an integral part of the project.

## Methodology

The project was comprised of two phases, Phase 2 of which is reported here. Phase 1, completed in 2001, was a scoping study to identify the content and structure of the inventory and to design the risk based prioritisation protocol. During Phase 2, the inventory has been populated and the risk based prioritisation protocol further developed, tested and refined. The approach used to develop the risk based prioritisation protocol largely follows the framework for environmental risk assessment and management detailed by the DETR (2000). The scheme is based on the three properties, importance, hazard and sensitivity, and appropriate measures of each were determined. A three-tiered approach was adopted whereby an initial rapid assessment is made at Risk Tier 1 for all standing waters in Great Britain (approximately 14,000 greater than 1ha), based on the minimum of information gained from already available data sources. This assessment is then used to guide the acquisition of further data for more detailed evaluation of a subset of standing waters at Risk Tier 2 (a few hundred to a few thousand) and, in even finer detail at Risk Tier 3 on a very small subset of waters (a few tens) for which remedial action is likely to be taken. Worked examples of the scheme for 30 lakes are presented and the approach to be followed in order to develop a full three-tier, risk-based prioritisation system for lakes with respect to acidification and eutrophication is outlined.

In our protocols, three criteria were used to determine importance to society: large lakes (>50 ha), lakes within Ramsar, SPA or SAC designations and lakes designated as bathing waters. A lake was deemed important if it fell into any one or more of these categories. The list of criteria could be extended relatively easily in the future. Examples of other criteria would be: drinking water abstraction sites; SSSIs; sites with BAP species present; popular tourist sites and or fisheries, etc.

## The eutrophication prioritisation scheme

The anthropogenic phosphorus (P) load (human sewage, run-off from land and domestic farm animal waste – the latter data were not available for Scotland) was used as a measure of the eutrophication hazard. The loads were converted into in-lake concentrations using relevant OECD equations, and lakes were given a rank on the basis of the standard Vollenweider classifications of lake trophic status. Lakes in classes 3-5 (high trophic status) were passed through to the first sensitivity analysis. Retention time was used to identify lakes where the algae would remain in the lake long enough to utilise the P in the water. Depth data were unavailable for most lakes so that modelled depths were used in calculations. This has the

potential to introduce major errors into the assessment. Lakes in classes 1 and 2 (retention time >30 days and 3-30 days, respectively) were passed through to the final sensitivity analysis. The Wederburn depth, i.e. an estimate of the average summer thermocline depth, was used to assess the response of a lake to restoration management. This was based on practical experience which shows that deep lakes tend to recover very quickly when P loadings are reduced but shallow lakes often take several decades to recover. Five stratification classes were developed. Lakes in classes 4 and 5 (polymictic but mainly stratified and fully stratified, respectively) were considered sensitive to remediation and were passed for assessment at Risk Tier 2.

### **The acidification prioritisation scheme**

The Risk Tier 1 estimation of hazard and sensitivity to acidification was much simpler since the appropriate data sets had already been compiled for other purposes. Total acid deposition load was used to identify the level of hazard. Five classes were defined and only those in class 1 (<0.5 keq/ha/yr) were not passed through to the sensitivity assessment. Data were already available on the sensitivity of lakes to acidification. The data are available at 1 km square grid scale and relate to the buffering capacity of the dominant soil type and baseline geology within each square. Five sensitivity classes were defined. Only classes 1 and 2 (High and medium-high, respectively) were passed on to the final Risk Tier 1 assessment. The acid deposition class and freshwater sensitivity class for each lake was assessed jointly and lakes with specified combinations of deposition class and sensitivity class were passed through to the Risk Tier 2 assessment.

### **Risk Tiers 2 and 3**

Risk Tier 2 assessments for both acid and eutrophic waters consisted of obtaining data to confirm the Risk Tier 1 model classifications. Assuming these were confirmed, Government policy and other non-quantifiable criteria are likely to be used to select lakes to pass through to Risk Tier 3. Risk Tier 3 assessment is carried out on a very small number of lakes which are likely to receive remedial action. For eutrophic lakes the case for investment is developed, including the quantification of relevant sources and the development and testing of appropriate management strategies using models.

### **The inventory**

The inventory itself contains basic physical characteristics for all standing waters in Great Britain derived from the 1:50 000 Ordnance Survey Panorama digital dataset. For those water bodies >1 hectare (N=14, 353), catchment boundaries were generated and associated attribute data were derived, to allow implementation of the risk based prioritisation protocol. The inventory was linked to external databases using a meta-data system and summary water chemistry data were collated from some of these databases for approximately 400 water bodies. It is hoped that further meta-data and summary data can be added in the future as and when data become available. The database includes a number of queries to allow the risk based prioritisation protocol to be implemented.

All data and documentation are currently available for download from a secure server (<http://ecrc.geog.ucl.ac.uk/gblakes>).

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# 1. INTRODUCTION AND OBJECTIVES

The Environment Agency (EA) need to be in a position to establish priorities and work loads that will arise as a result of the requirement to return the quality of standing waters (lakes and reservoirs) to a reference condition. This need arises from a number of drivers, the most urgent of which are the requirements to assess the ecological status of standing waters under the Water Framework Directive (WFD) (European Union, 2000), the coordination of actions which arise from the Eutrophic and Mesotrophic Lake Habitat Action Plans (HAPs) and the implementation of the EA's Eutrophication Strategy. Other agencies in Great Britain have similar requirements and, therefore, this project involves collaboration with English Nature (EN), Countryside Council for Wales (CCW), The Scottish Environment Protection Agency (SEPA) and Scottish Natural Heritage (SNH) represented by SNIFFER. The EA is the lead organisation responsible for coordinating the Eutrophic Lakes HAP and is collaborating with SEPA, the lead agency for the Mesotrophic Lakes HAP. DETR (2000) recommend a risk based approach to investment prioritisation and this approach has been approved by the UK steering group for Mesotrophic and Eutrophic Lakes HAPs.

This project aims to develop a risk based prioritisation system both to identify waters at risk of eutrophication and acidification, and to assess their potential for restoration. In order to prioritise actions and to track progress information is required about the location, size, use, ecological and water quality status, and target (reference) conditions of all standing waters in Great Britain. However, at present no comprehensive inventory of lakes and reservoirs in Great Britain exists and the Agencies have very little information about standing water bodies. Although some information is available from a variety of external sources, none are currently accessible in a co-ordinated format. Hence there is an additional need to develop a geo-referenced inventory of standing waters in Great Britain

A previous Phase (1) of this project, completed in 2001, proposed a tiered approach to prioritising actions based on the risks posed to lakes from activities in their catchments, their sensitivity to these risks and their relative importance to society, and developed the basic characteristics of a standing waters inventory and prioritisation protocol (Bennion *et al*, 2001).

Specific objectives of Phase 2 are:

- 1) To extend the development of a tiered risk methodology for standing waters.
- 2) To develop an inventory of standing waters in Great Britain which can hold information relating to the morphometric, use-related and summary data which describe the past, present and target ecological conditions.
- 3) To populate this inventory with the data required to carry out the tiered risk prioritisation, concentrating on information describing site importance, risks posed by catchment hazards and site sensitivity.
- 4) To test the prioritisation approach on 30 lakes.

The following chapters describe developments in Phase 2: i) the approach to be followed in order to develop a full three tier, risk-based prioritisation system for lakes with respect to

eutrophication and acidification, ii) worked examples of the scheme for a small number of lakes, and iii) the data types in the inventory.



## **2. RISK BASED PRIORITISATION PROTOCOL**

### **2.1 The three tier approach**

It was agreed in Phase 1 of the project that the approach used to develop the risk based prioritisation protocol would largely follow the framework for environmental risk assessment and management detailed in the DETR guidelines (DETR, 2000). The prioritisation of work on standing waters should enable the risk of harm to be placed into an objective framework, ensuring that actions are focussed where they are most beneficial to society (Pollard *et al*, 2000). The approach aims to identify lakes with the highest need for management action, either to prevent harm or to reduce that which has already occurred.

The approach is iterative, with initial simple assessments being used to refine and prioritise subsequent assessments. The scheme, therefore, has been developed in a way that allows relative harm assessments to become progressively more sophisticated via a three tier system (Figure 1). In this way, an initial rapid assessment is made at Risk Tier 1 for all standing waters in Great Britain (approximately 14,000 greater than 1 ha), based on the minimum of information gained from already available data sources. This assessment can then be used to guide the acquisition of further data for more detailed evaluation of a subset of standing waters at Risk Tier 2 (a few hundred to a few thousand) and, in even finer detail at Risk Tier 3 on a very small subset of waters (a few tens) for which remedial action is likely to be taken.

The prioritisation system for lakes is based on three or four, essentially independent, properties:

- 1) Importance or value to society
- 2) Hazard posed to a lake from sources of nutrients and acidity
- 3) Sensitivity of a lake to deterioration in water quality, i.e. following an increase in hazard
- 4) If deterioration has taken place, for some hazards (e.g. nutrients) it may be possible to assess the likelihood that the damage can be reversed following a managed reduction of the hazard.

There are a number of different ways in which the value of a lake to society could be defined. It was established very early in the development, however, that trying to put a monetary value on lakes was fraught with difficulty, especially when issues of species conservation were the most important feature of the lake. As a result the concept of “Importance” was developed, which is the reason why a lake is of value to society, and is a more easily defined descriptor.

Environmental risk can be defined as the probability of the environment suffering harm from a hazard. In terms of lakes the most important hazards are nutrients and acid deposition. These hazards can cause changes in the ecological condition of the lake, depending on their magnitude. Whilst we are aware that lakes may be exposed to a range of other hazards such as toxic substances, at the current stage of method development, these are not included in the present scheme. However, the scheme could be equally well applied to a range of such hazards, e.g. mine waste, toxic paints, or even hazards such as species introductions.

The degree to which hazards can cause changes in the ecological condition of waters depends on the sensitivity of the system. Sensitivity will depend on physical features (e.g. depth,

residence time, exposure etc) and catchment features such as geology and soil type. As for hazard, appropriate measures of sensitivity have been selected according to data availability and the number of lakes being assessed.

Whilst the general approach is the same for all lakes (see Figure 1), the hazard and sensitivity criteria for nutrients (leading to eutrophication) and acidity (leading to acidification) are different and, therefore, the prioritisation protocols for eutrophication and acidification are described separately in chapters 4 and 5, respectively. The importance criteria, however, are the same in both schemes and are described in chapter 3.

As well as identifying a number of lakes to carry through to Risk Tier 2, the Risk Tier 1 analysis suggests a series of different management/monitoring options for many of the other groups of lakes identified (see box numbers in Figures 2 and 4). In addition to the candidate lakes which have potential for restoration, these include:

- i) Lakes that are not susceptible to eutrophication or acidification, where only a minimum surveillance would be appropriate.
- ii) Lakes likely to be in good condition, but sufficiently sensitive to be at risk of harm; for example a change in trophic or acidity status. These lakes require a precautionary approach to preventative management and/or monitoring to ensure that critical loads of pollutants are not exceeded.
- iii) Lakes that are already harmed, for example significantly more eutrophic or acidic than their pristine state, but are unlikely to respond rapidly to remedial management. These lakes would require a policy of no further deterioration or dereliction.
- iv) Lakes which have not previously been considered as important but which are likely to be near to their pristine state (i.e. minimally impacted). These lakes require further investigation and could subsequently be designated as conservation sites. Such lakes have particular relevance to the WFD which requires the identification of high status reference lakes.

At Risk Tier 2, where we are dealing with a more manageable number of lakes, data availability constraints are less of a problem than at Risk Tier 1. The main objective of the Risk Tier 2 analysis is to confirm that the assessments made on the basis of models in Risk Tier 1 give a reliable picture of the status of the lake and its likely response to remediation. An important part of Risk Tier 2 assessments is to incorporate local knowledge, by both helping to identify data sets to confirm the physical and ecological properties of the lake and identifying lakes which are particularly sensitive locally for reasons which are not considered in the Risk Tier 1 assessment. It should be an important part of the protocol that issues raised during this process allow previously unprioritised lakes to be included in the prioritised list on the basis of local knowledge (Figure 1). Since the main objective of Risk Tier 2 is to confirm the Risk Tier 1 predictions it may be necessary to commission measurements on lakes where no data exist. In this case, no attempt should be made to obtain all the information identified in the test case tables (Tables 4 and 5). Only the lowest cost measurement(s), giving acceptable confidence in defining the trophic class or acidity status, should be obtained. Data, particularly physical properties such as mean and maximum depth should feed back into the inventory and be used in preference to modelled values in further prioritisation exercises.

Risk Tier 3 assessments are lake specific. They are expected to focus towards collecting new data to identify the main sources of the hazard and to suggest likely remediation strategies, which should be tested, if necessary, by collecting additional new data. The number of lakes which pass through to Risk Tier 3 cannot be determined on purely objective, ecological criteria. The total budget for remedial works available for a particular period, Government policy and objectives and other non-quantifiable factors will be included in the decision making process and may well carry more weight than the quantifiable measures such as hazard loadings. For example, a number of different decision strategies could be used for nutrients. These include:

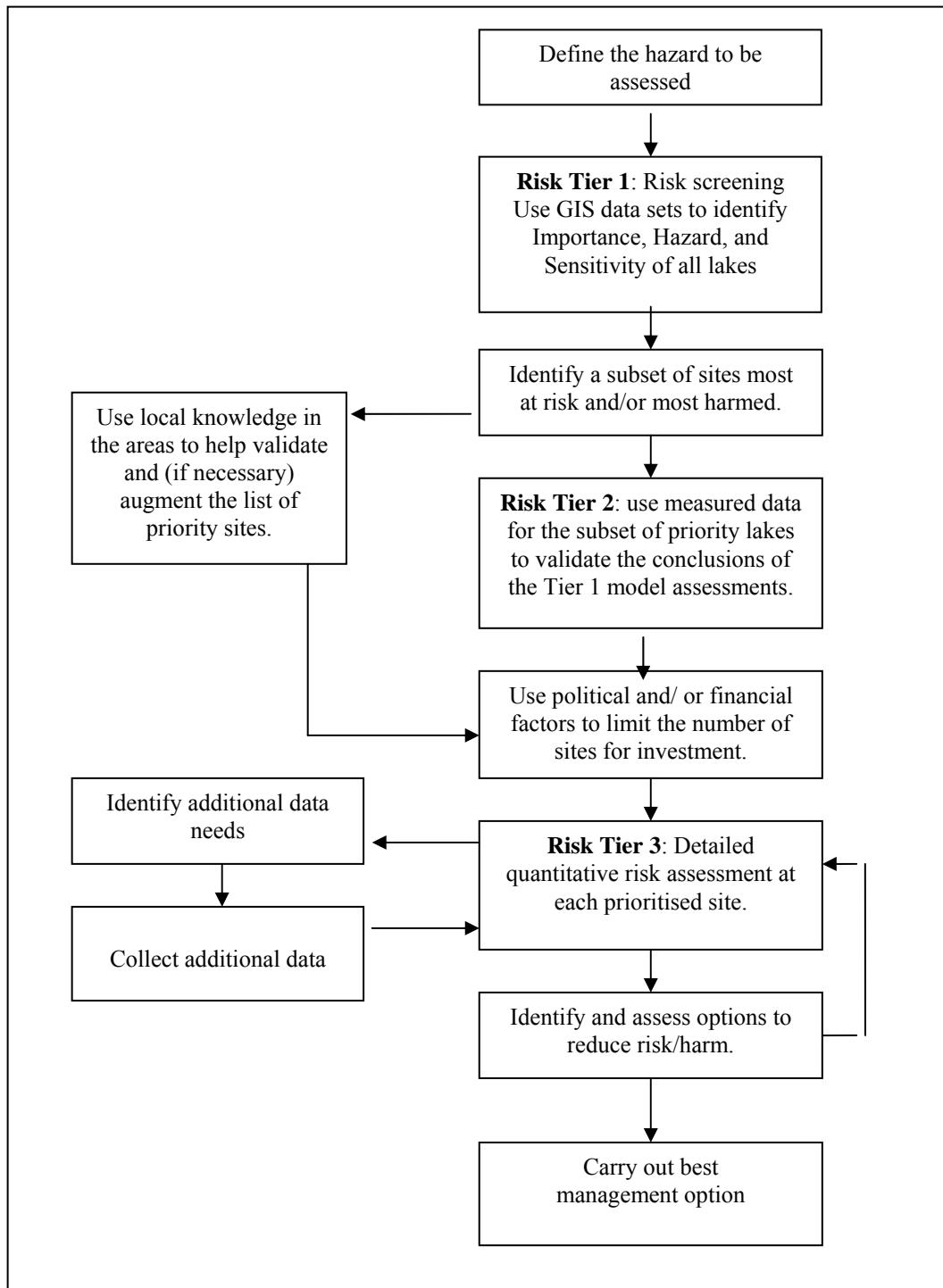
- i) choosing a small number of the most contaminated lakes,
- ii) choosing a larger number of lakes which are not too contaminated, giving improvements to a larger number of lakes,
- iii) choosing lakes where particular Red List species are at risk due to the pollution, etc.

No further development of the importance assessment is required at Risk Tier 3 beyond that made at Risk Tier 2. Although, in the absence of other criteria, the total number of importance criteria that each site falls into could be summed to identify those with the highest importance. Local information and political decision making, however, will be critical at this stage. The output from the Risk Tier 3 analyses is a clear strategy for investment, specific to each lake, which should bring about an improvement in its status.

## **2.2 Results of the Risk Tier 1 assessment**

The results of the Risk Tier 1 assessment for all 14, 342 lakes >1 ha in Great Britain (excludes 11 lakes in the Isle of Man) are supplied with this report on CD-ROM as a Microsoft Excel97 spreadsheet (tier1\_classification.xls). The file contains the list of lake OS names along with their country and water body ID (WBID) and the classes for the criteria used in the eutrophication and acidification prioritisation protocols, as follows:

- i) Importance: 0 = low importance; 1 = high importance.
- ii) Trophic Status Class: 1 (low trophic status) to 5 (high trophic status).
- iii) Retention Class: 1 = high; 2 = intermediate; 3 = low.
- iv) Stratification Class: 1 = shallow mixed <3 m; 2 = completely mixed >3 m; 3 = polymictic but mainly mixed; 4 = polymictic but mainly stratified; 5 = stratified.
- v) Acid Deposition Class: 1 = <0.5 keq/ha/yr; 2 = 0.5-1.0 keq/ha/yr; 3 = 1.0-1.5 keq/ha/yr; 4 = >1.5 keq/ha/yr.
- vi) Freshwater Sensitivity Class (dominant): 1 = high; 2 = medium-high; 3 = medium-low; 4 = low; 5 = none.



**Figure 1** Outline of the risk based prioritisation protocol approach for lakes (modified from DETR, 2000)

### 3. IMPORTANCE

During Phase 1, it was agreed that the concept of a lake’s “importance” or “value to society” should be a critical feature of any prioritisation protocol. Therefore, a scoping study was conducted at the start of Phase 2 to agree a set of criteria to be used in assessing the importance of a lake. This study involved wider consultation with the EA, SEPA, the conservation bodies and other relevant parties. It was considered necessary for the indicators of importance to satisfy the key requirements of the WFD, Lake HAPs and the implementation of the Agency’s Eutrophication Strategy. Details of the scoping study are reported in the Project Record (Bennion *et al.*, 2003).

Many of the criteria suggested by the consultees were considered either to be too complex or the data were too difficult to obtain for inclusion at Risk Tier 1, where importance has to be assessed for all lakes in Great Britain. It was agreed that data for Risk Tier 1 must be available at the national level, preferably as GIS layers. Therefore, the indicators of importance were finally selected on practical grounds since the data required were relatively easy to obtain, enabling importance to be a key component of site prioritisation in Risk Tier 1 of the protocol. The importance indicators are common to both the eutrophication and acidification schemes and the following were adopted as producing a manageable set of lakes for further analysis at Risk Tier 2:

- i) Size (TBL\_LD): The WFD requires at least all lakes >50 ha to be classified.
- ii) Conservation status: Lakes with high conservation status were identified by the following conservation designations: Ramsar (TBL\_RAM), SPA (TBL\_SPA) or SAC with aquatic interest (TBL\_SAC).
- iii) Bathing Waters (TBL\_BDIR): There is a legal requirement to control the quality of waters designated under the EU Bathing Waters Directive.

A lake was considered to be important if it had one or more of these attributes. Table 1 illustrates the criteria used for assessment of importance for a subset of lakes.

**Table 1 The criteria used for assessing lake importance**

(1 indicates that the lake satisfies a criterion; 0 indicates that the lake does not satisfy a criterion)

WBID	OSNAME	Lake Area >50 ha	RAMSAR	SPA	SAC Aquatic	Bathing Water	Importanc e
35640	Hickling Broad	1	1	1	1	0	1
35655	Barton Broad	1	1	1	1	0	1
20986	Loch Avon	1	1	1	1	0	1
21189	Loch Kinord	1	1	1	1	0	1
21191	Loch Einich	1	1	1	1	0	1
18682	Loch Druidibeag	1	1	1	1	0	1
29844	Malham Tarn	1	1	0	1	0	1
28847	Bassenthwaite Lake	1	0	0	1	0	1
2712	Loch Watten	1	1	1	1	0	1
24843	Loch Leven	1	1	1	0	0	1



An ACCESS query was written (QRY\_importance-criteria) to identify important lakes. The query was based on the following tables : TBL\_RAM; TBL\_BDIR; TBL\_SPA; TBL\_SAC and KEY\_SAC + KEY\_SACX; TBL\_SSSI and KEY\_SSSI; TBL\_UK and KEY\_UK and XTB\_BAP-species-latest-observation. The query includes a number of criteria in addition to those given in Table 1 (e.g. SSSI, BAP species) so that extra criteria can be added by the user as required (see below).

An attempt was made to assess the relative importance of the criteria identified and to develop an appropriate scoring system. Efforts to rank these various indicators, however, were largely unsuccessful and, following extensive discussion, a scoring system was ultimately abandoned. The simple scheme was, therefore, retained, such that a lake is deemed to be important if it meets one or more of the above importance criteria; for example, all lakes shown in Table 1 would be classed as important. When applied to all lakes greater than 1 ha for which catchment based attribute data were generated (N= 14,342), the importance criteria result in a total of 2362 important lakes (England 470, Scotland 1795, Wales 97). Whilst this importance assessment is clearly biased towards certain lake characteristics and omits others, it satisfies the key requirements of the project whilst remaining flexible enough for users to adapt the scheme according to their specific needs. For instance, the conservation bodies may consider the criterion ‘SAC designation’ to be of higher priority than ‘lake size’ for HAP purposes whilst EA and SEPA may wish to place greater emphasis on large lakes for WFD purposes.

Owing to the large numbers of lakes designated as SSSIs (N = 3248) which leads to an additional 886 important lakes, SSSI designation was not included as one of the key criteria for assessing importance. However, this information is available in the inventory for sites in Great Britain (TBL\_SSSI) and has been included as an additional importance assessment criterion in the query ‘QRY\_importance-criteria’. SSSI status can, therefore, be included in the importance assessment if required. It was recognised that a number of other importance indicators may usefully be introduced to Risk Tier 1 at a later date, once datasets become available, or could be included at Risk Tier 2, as follows:

- 1) Waters where protected species are present (BAP priority species and Red List species) although many of these lakes are designated as Ramsar, SPA or SACs (or SSSIs). Note that this leads to an additional 525 important lakes. Sites in which protected species are present are given in TBL\_BAP. This table includes a field which describes how a record has been associated with a specific water body. The field ‘Matched?’ has the entry ‘direct-hit’ if the grid reference and name gave an exact match with a water body or ‘matched’ to indicate that the site was matched manually using grid reference and/or name on the map. National Biodiversity Network (NBN) species codes are given in the field ‘NBN’. An extra column in the query ‘QRY\_importance-criteria’ identifies those lakes which contain a BAP species, in addition to all the previous criteria.
- 2) Waters used for drinking water abstraction (data not currently available in the inventory).
- 3) Waters supporting commercial activities such as tourism, hydroelectric power supply and fish farming (data not currently available in the inventory).

Risk Tier 2 analysis for importance will include more thorough checks on the conservation designation to identify those sites where the designation relates specifically to the standing water component and not other factors; for example, a Ramsar site or a Special Protected Area

(SPA) may be designated on the basis of its importance to wildfowl but the lake may have little intrinsic conservation value itself. Indeed maintenance of good water quality may not be a key issue for sites where bird populations are the main conservation interest. Conversely, a SSSI may hold a strong population of a threatened or endangered species where good water quality is crucial for its survival. Local knowledge of individual lakes will be important at this stage of the prioritisation. At Risk Tier 2 higher priority may be afforded to some sites because of a local sensitivity or lake specific pollution issue. For instance, damage to salmonid fisheries is a specific issue associated with acidification problems and thus important trout lakes might assume high priority.

In the absence of other factors carrying more weight (chapter 2) one possible method for identifying the highest priority lakes for remediation (i.e. passing from Risk Tier 2 to Risk Tier 3) would be to simply count the number of importance factors which are attributed to each lake. The lakes with the highest counts receive the highest priority.



## 4. THE EUTROPHICATION PRIORITISATION SCHEME

### 4.1 Risk Tier 1: Risk screening

A system was developed to screen all lakes in Great Britain with a surface area greater than 1ha with respect to their level of eutrophication. The method systematically reduced the number of lakes passed onto the next stage as shown in Figure 2.

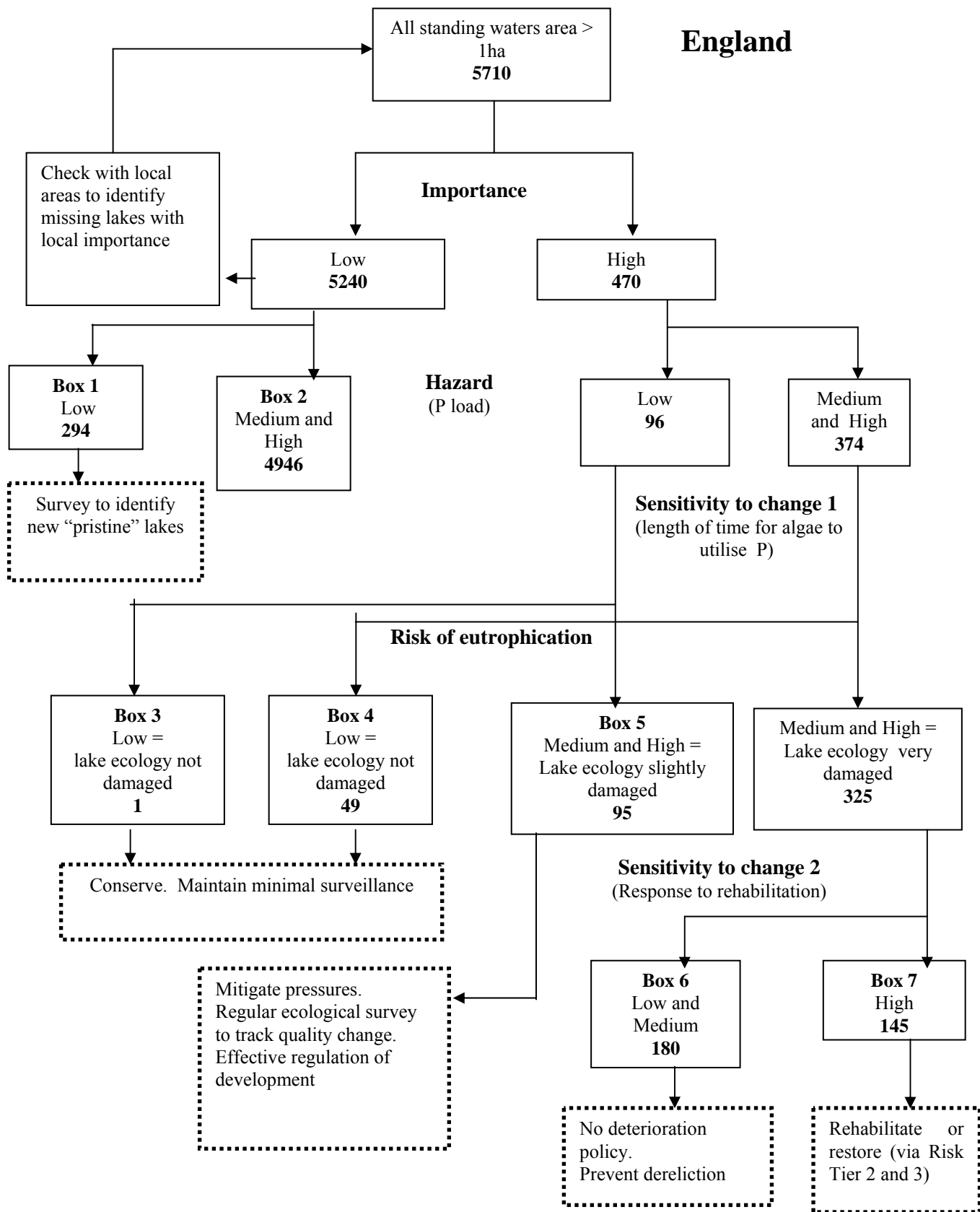
#### 4.1.1 Hazard

Loadings of the nutrient phosphorus (P) were chosen as the relevant parameter to define the level of hazard that each lake is exposed to. However, P loadings have only been measured for a small number of lakes. As a result nutrient loads at Risk Tier 1 were estimated from GIS-derived catchment land use and population data. The total P discharged to each lake from agricultural loss and from humans was estimated using a simplified set of P export coefficients from the literature (KEY\_LC from Hilton *et al.*, 1999) for a range of land cover types (QRY\_Pload\_LC), animals (QRY\_Pload\_animals) and people (QRY\_Pload\_human). Total P load (QRY\_Pload\_catchment), expressed as kg/yr, was then calculated for each lake catchment by summing the total contribution from land use (QRY\_Pload\_LC\_sum), animals (QRY\_Pload\_animals\_sum) and humans (QRY\_Pload\_human). Animal density data are currently available for England and Wales only and, therefore, were not included in the fully worked P load calculations in order to give Great Britain-wide comparability between the results. The loads including animals were included in the tables for England and Wales and have been compared with loads excluding animals in chapter 6. It is recommended, however, that if animal density data become available for Scotland, that P load from livestock is included in the total P load calculations by summing the contributions.

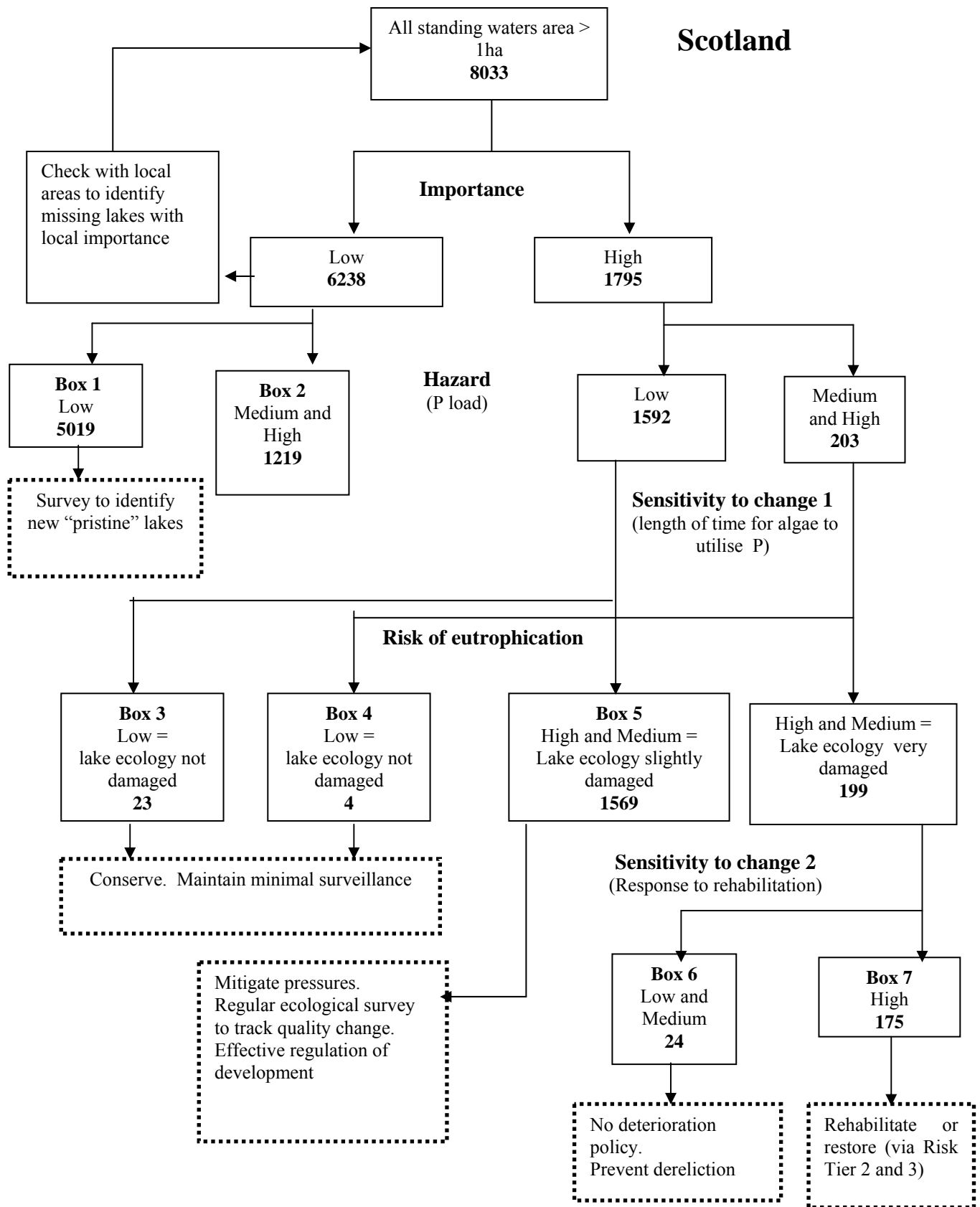
The discharge of water into each lake was calculated (QRY\_water\_discharge) from the runoff depth (TBL\_ROFF) multiplied by the catchment area (TBL\_CT). The total P loads were then converted (QRY\_Trophic\_status) into in-lake annual mean P concentrations ( $\mu\text{g l}^{-1}$ ) and then into annual mean chlorophyll a concentrations ( $\mu\text{g l}^{-1}$ ) using the relevant OECD regression equations which take account of retention time (OECD, 1982; Vollenweider and Kerekes, 1980, respectively). For simplicity, the P concentration values were then classed according to the OECD-Vollenweider trophic classification system (OECD, 1982) as follows:

Trophic Status Class		TP concentration ( $\mu\text{g l}^{-1}$ )
Class 1	Low	<4
Class 2	↓	4-10
Class 3		10-35
Class 4		35-100
Class 5	High	>100

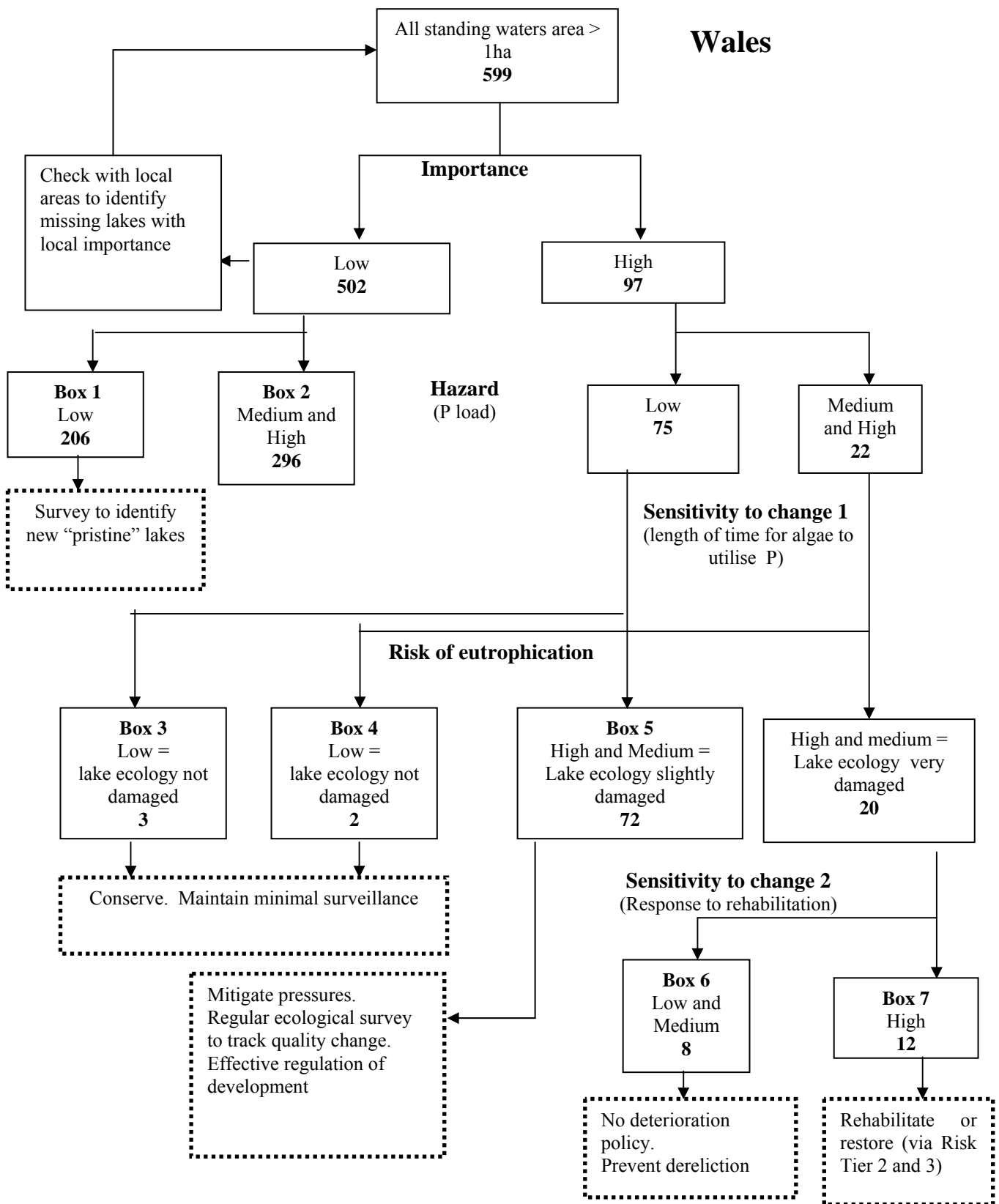
Lakes in Trophic Status Classes 3, 4 and 5 were considered to be potentially exposed to high levels of hazard and were passed onto the sensitivity assessment.



**Figure 2a Outline of the Risk Tier 1 eutrophication prioritisation scheme for England**



**Figure 2b Outline of the Risk Tier 1 eutrophication prioritisation scheme for Scotland**



**Figure 2c Outline of the Risk Tier 1 eutrophication prioritisation scheme for Wales**

## 4.1.2 Sensitivity

At Risk Tier 1 for eutrophication, two sensitivity measures have been applied sequentially. Firstly, the lake retention time was used to provide an indication of the ability of algae to utilise the nutrients. The higher the retention time, the greater the opportunity for the algae to use the P and thus the more sensitive the lake to eutrophication. Retention time was one of the criteria proposed by Reynolds in Phase 1 for assessing sensitivity of lakes to eutrophication (Bennion *et al.*, 2001).

Where possible, measured mean lake depth data were used in the calculation of retention time (QRY\_water\_discharge) but, owing to the lack of bathymetric surveys for the majority of lakes, mean depth was based on modelled data in most cases (see section 7.3 for details). The use of modelled depth data introduces possible errors into the calculations. The retention times are classed into three groups, according to the Reynolds scheme, as follows:

Retention Class	Sensitivity to change	Retention time
Class 1	Very sensitive	High retention (>30 days)
Class 2	Slightly sensitive	Intermediate retention (3-30 days)
Class 3	Insensitive	Low retention (<3 days)

Lakes falling into Retention Class 3 were not passed onto the next assessment. Reynolds (in Bennion *et al.*, 2001) also suggested incorporating alkalinity (as a surrogate for major cation concentrations) into the sensitivity estimation in order to take account of the reduced sorption of P onto suspended and bed sediments at high ionic strengths, but a national coverage of alkalinity data was not available in time to be included in the model. He also proposed the inclusion of an assessment of the area of sediment surface less than 3 m deep as an indicator of the rate of sediment P recycling. However, these data were unavailable for most lakes. There was an option to use the stratification class as a surrogate but, in the end, it was decided not to incorporate this factor since, a) the Vollenweider equations take some account of sediment recycling and b) the stratification class was found to be more useful in the next stage of the assessment and its use at two stages had potential to heavily bias the analyses.

Current experience of lake restoration schemes for eutrophic lakes suggests, that deep lakes, where there is little interaction between the sedimentary P store and the water column, recover rapidly following reductions in nutrients. Conversely, shallow lakes, where the sediments are continuously resuspended and are in intimate contact with the water column often take many decades to recover their earlier trophic status. In this context, the terms “shallow” and “deep” are relative terms, being more related to the mixing status of a lake than to the actual depth. Reynolds (1992) showed that the stability of the water column can be predicted with reasonable reliability using the ratio between the Wederburn depth at an 8 m/s wind speed and the maximum depth. The Wederburn depth is calculated from the following equation:

$$H_s = \frac{[\rho_w (u^*)^2 L]^{1/2}}{[g \Delta \rho_w]}$$

where:



$H_s$  = depth of the seasonal thermocline where density gradient  $>0.02 \text{ kg m}^{-3} \text{ m}^{-1}$

$\rho_w$  = density of water =  $1000 \text{ kg m}^{-3}$

$$(u^*)^2 = (\rho_a c (u_{10})^2 / \rho_w)$$

where  $\rho_a$  is the density of air =  $1.2 \text{ kg m}^{-3}$

$c$  = coefficient of frictional drag of the water on the wind =  $1.3 \cdot 10^{-3}$

$u_{10}$  = wind speed at 10 m above water surface (m/s)

$L$  = lake width/maximum fetch. ( $\approx (\text{Surface area} / \pi)^{0.5}$ )

$g$  = gravitational constant =  $9.81 \text{ m s}^{-2}$

$\Delta \rho_w = 0.9 \text{ kg m}^{-3}$  (minimum difference for sustained thermocline)

If the ratio derived from the Wederburn depth (QRY\_Wederburn-depth) divided by the maximum depth is less than or equal to 1 then the lake is unlikely to stratify for significant periods of the summer. Lakes with values of the ratio significantly greater than 1 are likely to stratify all of the summer. However, lakes do not immediately change from being fully stratified to being fully mixed but go through a state known as polymictic, where the lake stratifies more or less of the time, depending on how far the ratio departs from the value of 1. The thermocline depth at wind speeds of 4 m/s and 16 m/s (0.5x and 2x the reference wind speed) were chosen to indicate boundaries where lakes were likely to move from polymictic conditions to be either more completely stratified or more completely fully mixed. This resulted in five classes (QRY\_tier1-class), as follows:

Stratification Class	Response to restoration	Degree of stratification
Class 1	Low ↓ High	Shallow mixed (<3 m max depth)
Class 2		Completely mixed (>3 m max depth)
Class 3		Polymictic but mainly mixed
Class 4		Polymictic but mainly stratified
Class 5		Stratified

Stratification Classes 4 and 5 were assumed to be more likely to recover quickly following a reduction in nutrient loading and were passed through to the Risk Tier 2 assessment.

#### 4.1.3 Risk assessment

In the Risk Tier 1 analysis, the different criteria (importance, hazard, sensitivity 1, sensitivity 2) were applied sequentially, the number of lakes passing to the next filter reducing at each step (QRY\_tier1-class) (Figure 2). All ‘important’ lakes were passed forward. The lakes were then separated into low hazard (Trophic Status Classes 1 and 2) and medium and high hazard (Trophic Status Classes 3, 4 and 5). Trophic Status Classes 3, 4 and 5 were passed onto the first sensitivity assessment (i.e. the likelihood that the algae can utilise the P during its stay in the lake). In our analysis we have assumed that all lakes in Retention Class 3 (short retention time/rapidly flushed) are unlikely to be damaged and that medium/ high trophic status lakes with Retention Class 3 are damaged but not sufficiently seriously that remedial work is required. Conversely all lakes in the high trophic status/medium to long retention time classes are assumed to be seriously degraded ecologically and passed onto the second sensitivity assessment. It is possible to be more subtle at this stage, particularly with respect to the low trophic status, high retention time lakes. In these cases, even though the load is relatively low, at long retention times it may be possible for algae to utilise all the P and attain significant algal concentrations. Hence, there is a case for re-combining low trophic

status/high retention time lakes back into the damaged group requiring rehabilitation. We have not included this step in our assessment. Further work, using data from low and medium loaded lakes with high retention times is required to clarify the criteria for passing lakes through this last Risk Tier 1 assessment. High trophic status lakes with long retention times were classified according to their stratification potential. Lakes in Stratification Classes 4 and 5, which stratify, were passed onto the Risk Tier 2 assessment. This does not mean that remedial measures should not be attempted on lakes in Stratification Classes 1, 2 and 3 but it should be recognised that the returns will be achieved very slowly. Figure 2 gives the number of lakes passed through at each stage of the assessment for the three countries in Great Britain. Box numbers have been allocated to identify the key groups of lakes arising from the scheme, as follows (produced using QRY\_NutrientBox\_England, QRY\_NutrientBox\_Scotland and QRY\_NutrientBox\_Wales):

Box 1: Low Importance, Low Hazard. Some of these lakes may be useful as reference lakes and therefore a survey is recommended to identify new “pristine” lakes.

Box 2: Low Importance, Medium-High Hazard. These lakes are therefore low priority.

Box 3: High Importance, Low Hazard, Low Sensitivity to enrichment. It is assumed that owing to their low sensitivity the ecology of these lakes is not likely to be damaged

Box 4: High Importance, Medium-High Hazard, Low Sensitivity to enrichment. It is assumed that owing to their low sensitivity the ecology of these lakes is not likely to be damaged.

Box 5: High Importance, Low Hazard, Medium-High Sensitivity to enrichment. In spite of low P loads, it is assumed that owing to their high sensitivity the ecology of these lakes may be slightly damaged.

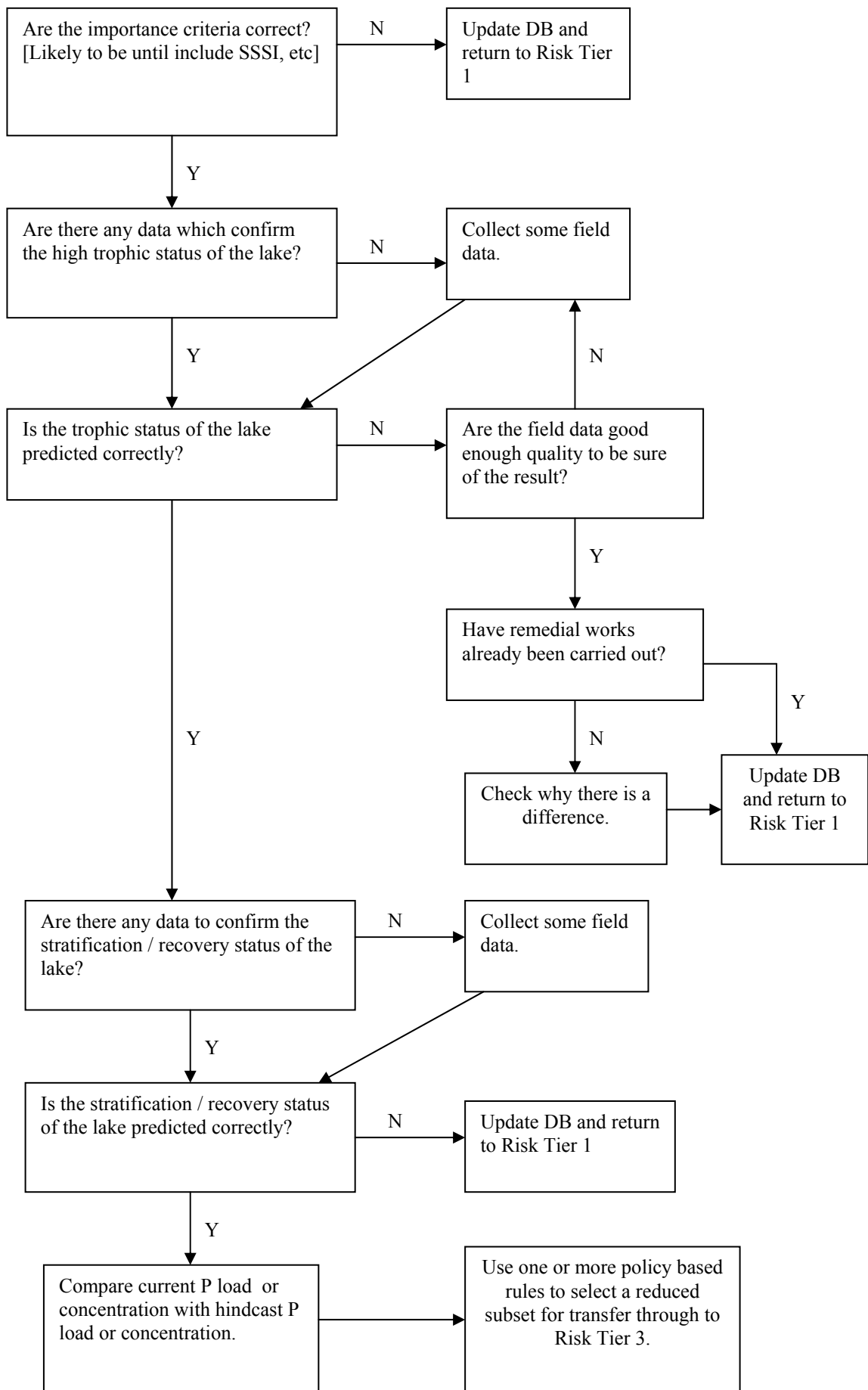
Box 6: High Importance, Medium-High Hazard, Medium-High Sensitivity to enrichment, Low-Medium Sensitivity to rehabilitation. Owing to high P load and their high sensitivity the ecology of these lakes is likely to be damaged. Given their low likelihood of response to rehabilitation, these lakes should be monitored and managed to prevent further deterioration.

Box 7: High Importance, Medium-High Hazard, Medium-High Sensitivity to enrichment, High Sensitivity to rehabilitation. Owing to high P load and their high sensitivity the ecology of these lakes is likely to be damaged. Given their high likelihood of response to rehabilitation, these lakes should be high priority for restoration.

Table 2 provides an illustration of the criteria used for the risk assessment at Risk Tier 1 of the eutrophication scheme for a subset of 15 lakes. Lakes in Box 7 such as Tatton Mere, Grafham Water, Llangorse Lake, Loch Ussie, Windermere and Hanmer Mere are at high risk of enrichment but are likely to respond well to restoration whereas Upton Broad, Loch Gelly, Loch of Skene, and Kenfig Pool are at high risk of enrichment but are not likely to respond well to remediation (Box 6). Bassenthwaite Lake, Loch of Swannay, Lake Bala, Loch Lomond and Llyn Cwellyn are at lower risk of enrichment than the former lochs but in spite of low P loads, the ecology of these lakes may be slightly damaged owing to their high sensitivity (Box 5).

**Table 2 The criteria used for the risk assessment at Risk Tier 1 of the eutrophication scheme for a subset of 15 lakes**

WBID	OSNAME	Trophic Status Class	Retention Class	Stratification Class	Eutrophication scheme box number
32804	Tatton Mere	5	1	5	7
38310	Grafham Water	4	1	5	7
36202	Upton Broad	4	1	1	6
29233	Windermere	3	1	5	7
28847	Bassenthwaite Lake	2	2	5	5
25077	Loch Gelly	5	1	1	6
20757	Loch of Skene	4	2	1	6
16456	Loch Ussie	3	1	5	7
1678	Loch of Swannay	2	1	3	5
24447	Loch Lomond	1	1	5	5
34780	Hanmer Mere	5	1	4	7
42170	Kenfig Pool	4	1	1	6
40067	Llangorse Lake	3	1	4	7
34987	Llyn Tegid or Bala Lake	2	1	5	5
34002	Llyn Cwellyn	1	1	5	5



**Figure 3 Outline of protocol for checking that a lake has correctly passed from Risk Tier 1 to Risk Tier 2 and for moving lakes from Risk Tier 2 to Risk Tier 3 in the eutrophication scheme**

## **4.2 Risk Tier 2: Generic quantitative risk assessment on sub-set of lakes**

As stated earlier, the main objective of Risk Tier 2 screening is to confirm the assessment developed in Risk Tier 1 of the most vulnerable lakes. This more detailed assessment of lake status uses measured data to demonstrate whether a site has been affected by eutrophication. Figure 3 outlines the protocol for checking that a lake has correctly passed from Risk Tier 1 to Risk Tier 2 and for moving lakes through from Risk Tier 2 to Risk Tier 3. Firstly the importance assessment is checked against more detailed data on conservation and ecological value to confirm that the lake itself is important. Next, the modelled current trophic status class (hazard) is compared with measured data that describe trophic status to confirm whether the trophic status has been correctly predicted. It is possible that the model may have significantly over- or underestimated measured lake TP and the reason for this should be established. A check should be made on whether any remedial work has already been undertaken to reduce nutrient loads. Next, data to confirm the stratification status, and thereby the recovery potential of the lake, should be collated and compared with the modelled data to assess the accuracy of the predictions. If at any stage there are discrepancies between modelled and measured data, the database should be amended and the protocol re-run. Finally a state-changed assessment should be made by comparing current P loads or concentrations with hindcast values, or better, palaeolimnological data.

### **4.2.1 Current status**

At Risk Tier 2 measured chemical variables of in-lake nutrient concentrations and loadings can be included to assess the current trophic status of the lake more accurately than that modelled at Risk Tier 1. Available data on simple measures of trophic status such as annual mean TP, SRP, nitrate, chlorophyll a, Secchi depth and oxygen should be collated, and where possible measured P load data. Additionally, available biological data can be collated, for example, on macrophytes (including the Palmer TRS and lake type), contemporary diatom assemblages and occurrence of algal blooms, to further confirm current trophic status. Again, it is important to stress that the objective is to confirm the Risk Tier 1 trophic state classification. It is useful to collect all available data but new data should be limited to the most cost-effective means of making the confirmation. The meta-database contained within the georeferenced inventory provides a useful starting point for sourcing data for specific lakes. However, these measures only show the current trophic status. They cannot, in isolation, indicate whether a water body is naturally nutrient rich, or has been enriched from its pristine state.

### **4.2.2 Damage or temporal change**

At Risk Tier 2, the smaller number of lakes being assessed allows the sensitivity to enrichment measures to be further refined. Lake retention times can be more accurately established by including measured depth data rather than modelled depth data. Where lake depth measurements are unavailable, it is recommended that a bathymetric survey be undertaken to collect such data. Furthermore, measured profile data, where available, could be incorporated to confirm the stratification status of the lakes, which was simply modelled at Risk Tier 1.

A temporal or state-changed perspective can be introduced at Risk Tier 2 to assess degree of enrichment. Export-coefficient models to hindcast nutrient load and lake nutrient concentrations are available for England and Wales (Johnes *et al.*, 1996; Moss *et al.*, 1996)

and for Scotland (Ferrier *et al*, 1997). The Johnes *et al* (1996) model can be applied to any lake in England and Wales and to date the model for Scotland has been applied to around 200 lochs (Fozzard *et al*, 1999). A comparison of the hindcast P load or concentration with the current P load or concentration allows an assessment of the extent of eutrophication at a given site to be made. However, it should be noted that the Johnes *et al*. (1996) hindcast model only models nutrient enrichment from a limited number of anthropogenic sources. The discharge from, for example, a sewage treatment works into the lake from a population located outside the catchment would not be identified. The same would be true for a naturally eutrophic catchment or if remedial action had already been implemented. In these cases input of local knowledge is vital.

Palaeolimnology can also be employed to assess whether a lake has become enriched and has the benefit that it does include sources of P other than agriculture and sewage treatment works. Diatoms (*Bacillariophyceae*: unicellular, siliceous algae) are sensitive to water quality changes and are good indicators of lake nutrient levels. Consequently, diatoms have been successfully employed to develop models (transfer functions) for quantitatively inferring past lake TP (e.g. Bennion, 1994; Bennion *et al*, 1996a). The approach is able to provide estimates of baseline (reference) TP concentrations in lakes, and when coupled with dating of sediment cores, can determine the timing, rates and possible causes of eutrophication at a particular site (e.g. Bennion *et al*, 1996b; Bennion *et al*, 2000). At Risk Tier 2, a low resolution analysis of diatoms preserved in a lake sediment core could be undertaken to assess degree of eutrophication.

### **4.3 Risk Tier 3: Detailed quantitative risk assessment at site specific level**

Lakes that passed the Risk Tier 2 filter into Risk Tier 3 would then need to be subjected to a very detailed local assessment to develop the case for investment and to fully assess the management options (methods) and targets for recovery or remediation. For eutrophication, this step would be the development of a Eutrophication Control Action Plan (ECAP) (Environment Agency, 2000).

#### **4.3.1 Current status**

Firstly, a site specific assessment of local importance and uses should be carried out and any local or regional political issues identified. A comprehensive chemical and biological survey is then required. For the measurement of mean phosphorus and/or chlorophyll a concentrations, periodic analysis over at least one year should be undertaken, with a minimum resolution of quarterly (seasonal) sampling, and ideally at least a fortnightly sampling regime. This would enable the seasonal characterisation of the site, which is important because of the high seasonal variation in nutrient concentration, with possibly serious biological implications that might not be detected through less frequent sampling. A full biological survey should also be carried out to identify the presence (or absence) of nutrient sensitive taxa, e.g. for diatoms, macrophytes and invertebrates.

GIS export coefficient modelling, validated by in river concentration monitoring, could be employed to quantify the main sources of nutrients in the catchment. The collection of nutrient budget data is advised to assess the relative contribution from diffuse and point sources. These mass balance data could then be used, along with in-lake chlorophyll-a concentrations, to populate and validate a Phytoplankton Responses to Environmental Change model (PROTECH) of the lake (Reynolds and Irish, 1997). PROTECH simulates the

dynamics of phytoplankton and can subsequently be used to test different management scenarios.

#### **4.3.2 Extent of damage and targets for recovery**

A detailed palaeoecological assessment, building on that carried out at Risk Tier 2, would provide information on the baseline biology of the site and an independent measure of the baseline nutrient status via multi-proxy methods and transfer functions (e.g. Sayer *et al*, 1999; Bennion *et al*, 2000). Modern analogue techniques could be used to identify targets for recovery or remediation (Flower *et al*, 1997).

Where these data were not available, further monitoring and data analysis would need to be undertaken to produce sufficient data to enable management decisions to be made.

## 5. THE ACIDIFICATION PRIORITISATION SCHEME

### 5.1 Risk Tier 1: Risk screening

For risk screening at the national scale the acidification scheme has been developed as detailed below, which as for the eutrophication scheme, systematically reduces the number of lakes passed onto the next stage as shown in Figure 4.

#### 5.1.1 Hazard

For acid deposition, the estimate of hazard at Risk Tier 1 is more straightforward than for nutrients because national maps of loads of sulphur and nitrogen deposition have already been developed.

The total acid deposition load best represents the pollution hazard for acidification. Acid deposition data (non-marine sulphate, nitrate, ammonium and chloride minus non-marine calcium and magnesium), expressed in keq/ha/yr, were provided by CEH Edinburgh, the most recent available data being for the period 1995-97 (TBL\_DEP). The data are modelled on a 5km grid and provide the best available picture of the acidification hazard for the whole country. The scheme does not include the hazard associated with acid mine drainage but could be adapted if suitable data become available.

The acid deposition values were classified into four classes:

Acid Deposition Class		Total acid deposition load (keq/ha/yr)
Class 1	Low	<0.5
Class 2	↓	0.5-1.0
Class 3	↓	1.0-1.5
Class 4	High	>1.5

Lakes in Acid Deposition Class 1 are considered not to be at risk because of the low load and thus do not pass on to Risk Tier 2.

#### 5.1.2 Sensitivity

As for the hazard assessment, the sensitivity assessment for the acid deposition scheme is somewhat simpler than for the nutrients scheme. A large amount of research was conducted in the 1980s on the susceptibility of surface waters to acidification.

A published national map of the sensitivity of surface waters to acidification is already available (Hornung *et al*, 1995). The map was developed specifically to identify areas where lakes and streams were likely to be sensitive to acidification by acid deposition, using national geology, soils and land-use datasets. The data are available nationally on a 1 km grid. A sensitivity classification related to buffering capacity was allocated based on the dominant soil type within each square. The geology data are based on the sensitivity map produced by Edmunds and Kinniburgh (1986) whereby each of the geological map units from the 1:650,000 Geology Map of Britain was allocated to one of four buffering capacity classes. The sensitivity map used in this project is not modified for land use. Twelve possible



combinations of geological and soil sensitivities were generated which were subsequently aggregated to five classes of sensitivity to acidification:

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**Freshwater Sensitivity Class (FWS)**

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Class 1	High sensitivity
Class 2	Medium-high sensitivity
Class 3	Medium-low sensitivity
Class 4	Low sensitivity
Class 5	Non-sensitive

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For the purposes of this project, the dominant freshwater sensitivity class (FWS) for each lake catchment was calculated (i.e. the freshwater sensitivity class of the largest area in the catchment) (TBL\_FWCX). There are no freshwater sensitivity data for Orkney and the Shetlands. In order to include all waterbodies in the scheme at Risk Tier 1, sensitivity classes were ascribed for lochs on Shetland and Orkney using solid and drift geology data.

All lakes in Freshwater Sensitivity Classes 3, 4 or 5 are considered not to be at risk because of their insensitivity to acidification and therefore do not pass on to Risk Tier 2.

**5.1.3 Risk assessment**

By combining classes of acid deposition load and freshwater sensitivity, lakes where the likelihood of acidification is greatest and those areas where there is no risk of acidification can be identified. The following deposition-sensitivity combinations are used in the scheme to identify lakes at risk of acidification. This accounts for the fact that relatively low deposition in highly sensitive areas may cause acidification.

<b>Acid Deposition Class</b>	<b>Freshwater Sensitivity Class</b>
2	1
3	1
3	2
4	1
4	2

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In the Risk Tier 1 analysis, the different criteria (importance, hazard, sensitivity) were applied sequentially, the number of lakes passing to the next filter reducing at each step (Figure 4). All important lakes were passed forward. The lakes were then separated into low hazard (Acid Deposition Class 1) and medium and high hazard (Acid Deposition Classes 2, 3 and 4) and the latter were passed onto the sensitivity assessment. All Acid Deposition Class 1 sites are considered not to be at risk of acidification as the loads are very low. All Freshwater Sensitivity Class 3 to 5 sites are considered not to be at risk of acidification because of their low sensitivity. Furthermore, any lake with >5% tilled or agriculturally improved land in the catchment is considered not to be at risk because it is assumed that the land will be subject to liming. Lakes in the combined Acid Deposition-Freshwater Sensitivity classes given above as at risk were passed onto the Risk Tier 2 assessment. Figure 4 gives the number of lakes passed through at each stage of the assessment for the three countries in Great Britain. Box numbers have been allocated to identify the key groups of lakes arising from the scheme, as follows (produced using the set of queries ‘QRY\_AcidBox’ listed on page A1-25):

Box 1: Low Importance, Low Hazard. Some of these lakes may be useful as reference lakes and therefore a survey is recommended to identify new “pristine” lakes.

Box 2: Low Importance, Medium-High Hazard. These lakes are therefore low priority.

Box 3: Low risk of acidification. It is assumed that owing to either their low hazard and/or their low sensitivity the ecology of these lakes is not likely to be damaged by acidification.

Box 4: High risk of acidification. Owing to high acid deposition load and their high sensitivity the ecology of these lakes is likely to be damaged by acidification. These lakes should be monitored and given high priority for restoration.

Table 3 provides an illustration of the criteria used for the risk assessment at Risk Tier 1 of the acidification scheme for a subset of 13 lakes. All of the lakes classified in acidification scheme Box 2 have low importance but have relatively high acid deposition loads. Those classified into Box 4 are important waters with high acid deposition loads and high sensitivity to acidification. Those lakes with Acid Deposition Class 4 and Freshwater Sensitivity Class 1 are at the highest risk, i.e. Loch Middle and Widdop Reservoir.

**Table 3 The criteria used for the risk assessment at Risk Tier 1 of the acidification scheme for a subset of 13 lakes**

WBID	OSNAME	Acid Deposition Class	Freshwater Sensitivity Class	Acidification scheme box number
2200	Loch na h-Uamhachd	2	1	4
11600	Loch na Bà Ruaidhe	2	1	2
22920	Loch Anlaimh	2	1	2
23086	Lochan Gaineamhach	3	1	4
22932	Loch Finnart	3	1	4
22700	Dubh Lochan	3	1	2
24091	Dubh Loch	3	2	2
28060	Loch Middle	4	1	2
30604	Widdop Reservoir	4	1	4
28854	Bowscale Tarn	4	2	4
24606	Lochan Dubh Mhuilinn	4	2	2
27540	Moodlaw Loch	4	2	2
29081	Bleaberry Tarn	4	3	2

## 5.2 Risk Tier 2: Generic quantitative risk assessment on sub-set of lakes

After the identification of the most vulnerable areas through the screening process in Risk Tier 1, the next stage allows a more detailed assessment of lake status by incorporating measured data to demonstrate whether a site has been affected by acidification. Figure 5 outlines the protocol for checking that a lake has correctly passed from Risk Tier 1 to Risk Tier 2 and for moving lakes through from Risk Tier 2 to Risk Tier 3. Firstly the importance assessment is checked against more detailed data on conservation and ecological value to confirm that the lake itself is important. Next, the current acidity status is assessed with measured chemical and biological data to confirm whether the lake is acid and thus likely to

be sensitive to acidification. A check should be made on whether any remedial work has already been undertaken to reduce acidity, e.g. liming. Next, critical loads and exceedances are calculated for each lake to assess the accuracy of the Risk Tier 1 risk assessments based on acid deposition load and dominant freshwater sensitivity classes. If at any stage there are discrepancies between modelled and measured data, the database should be amended and the protocol re-run. Finally a state-changed assessment should be made by comparing current pH or Acid Neutralising Capacity (ANC) with hindcast values.

### **5.2.1 Current status**

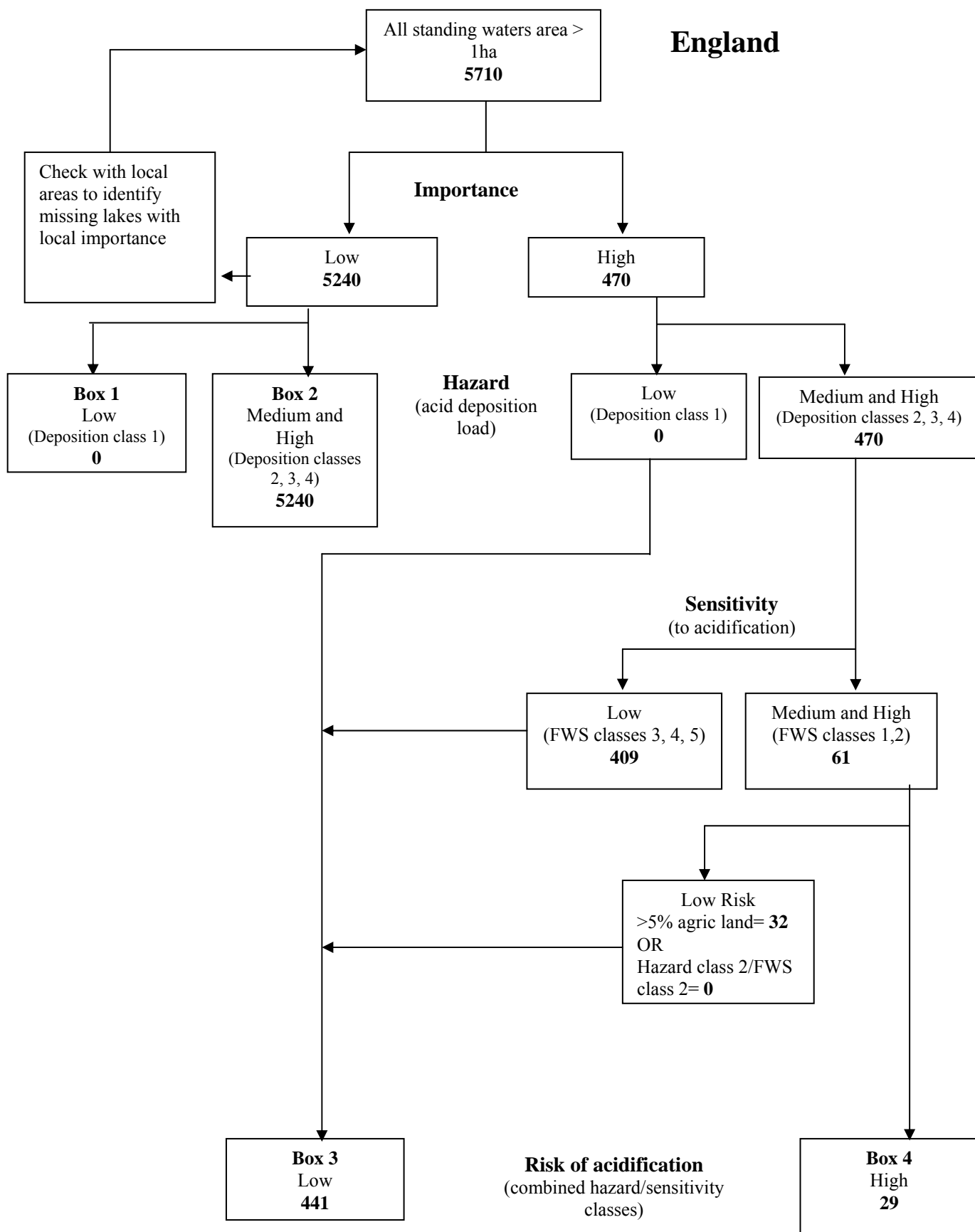
For any water body the current acidity status is provided by simple measures of pH and alkalinity (or ANC). For example, a pH based classification scheme (the “spatial state” for acidification) was proposed under the EA Lake Classification project (Johnes *et al.*, 2000). Additionally, available biological data can be collated, for example, on macrophytes (including the Palmer TRS and lake type), contemporary diatom assemblages and fish populations, to further confirm current acidity status. If the lake is currently alkaline, then it is unlikely to be sensitive to acidification. The meta-database contained within the georeferenced inventory provides a useful starting point for sourcing data for specific lakes. Such measures, however, cannot indicate whether a water body is naturally acid, or has been acidified from its pristine, pre-industrial state by acid deposition.

### **5.2.2 Damage or temporal change**

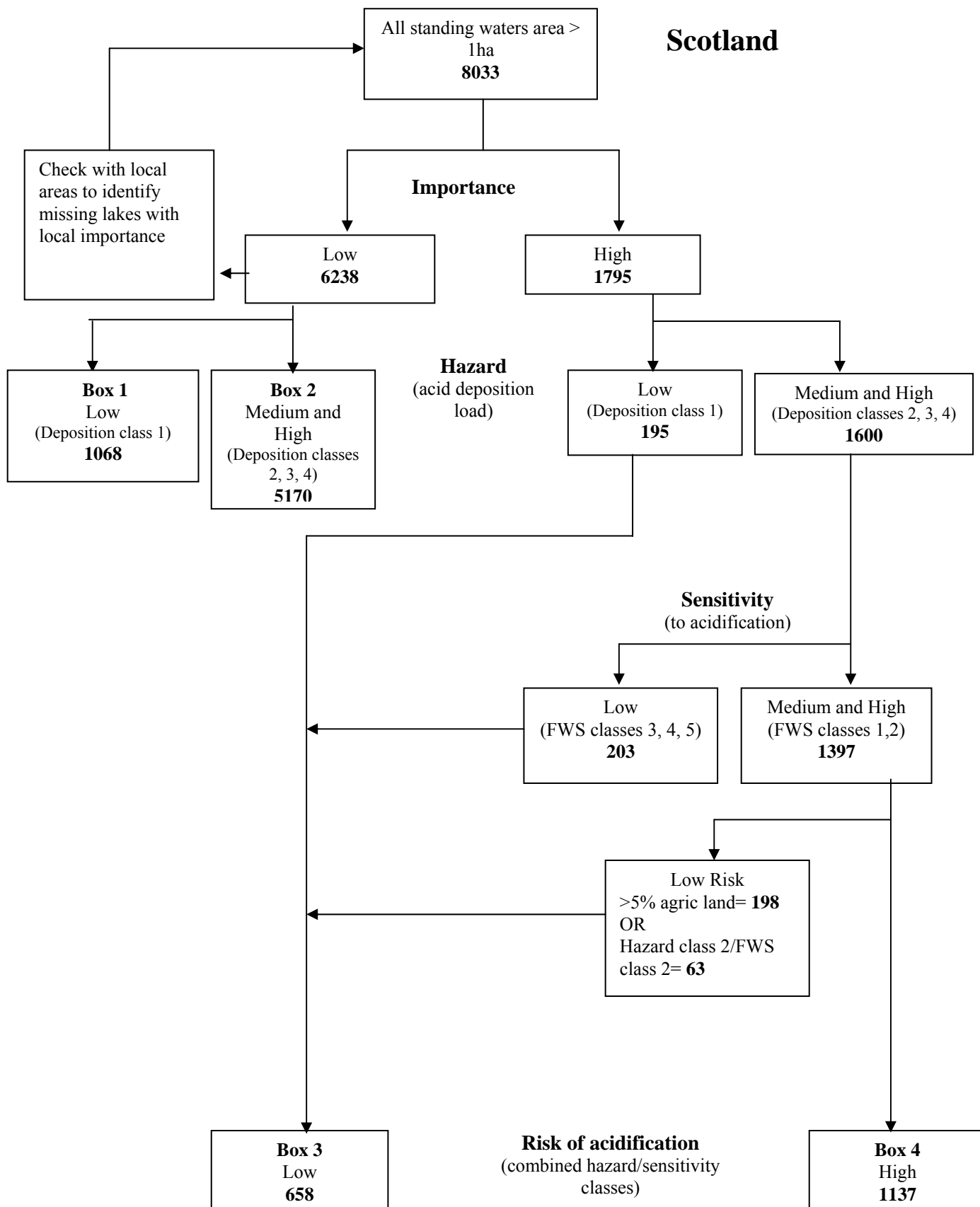
At Risk Tier 2, critical loads can be used in place of the Risk Tier 1 Freshwater Sensitivity classes to improve the sensitivity assessment. Critical load models determine the maximum loading that can be placed on a lake system without the likely occurrence of long term damage to ecosystem structure and function. They provide a direct measure of both current damage and potential damage from acid deposition when used in conjunction with acid deposition data (i.e. hazard). For linking damage to the deposition load, critical load exceedance is used. The difference between using Freshwater Sensitivity classes and critical loads is that the latter are lake specific and require actual data to be collected for each site. In order to calculate critical loads for sulphur deposition, full analysis of major ion water chemistry is required (Ca, K, Mg, Na, NH<sub>4</sub>, Cl, SO<sub>4</sub>, NO<sub>3</sub>). For the inclusion of nitrogen in the models (as recommended internationally) further catchment data are required to quantify the retention of N which reduces the net acidification effect of N deposition; they are lake area, catchment area, landcover data (available nationally at 30 m resolution), proportions of each soil type within the catchment and total N deposition (NO<sub>x</sub> + NH<sub>x</sub>). These models are well developed under a DETR funded programme for UK freshwaters and are used to feed into policy formulation for emissions reductions (Curtis *et al.*, 2000). The models can be used to quantify the change in ANC from a pre-industrial state (cf. EA Lake Classification state-changed scheme – Johnes *et al.*, 2000, and the Scottish standing waters classification scheme – Fozzard *et al.*, 1999).

Palaeolimnology can be employed to assess whether a lake has been acidified. Diatoms are sensitive to water quality changes and are particularly good indicators of lake pH. Consequently, diatoms have been successfully employed to develop models (transfer functions) for quantitatively inferring past lake pH (e.g. Stevenson *et al.*, 1991). The approach is able to provide estimates of baseline (reference) pH concentrations in lakes, and when coupled with dating of sediment cores, can determine the timing, rates and possible causes of acidification at a particular site (e.g. Flower and Battarbee, 1983). At Risk Tier 2, a low

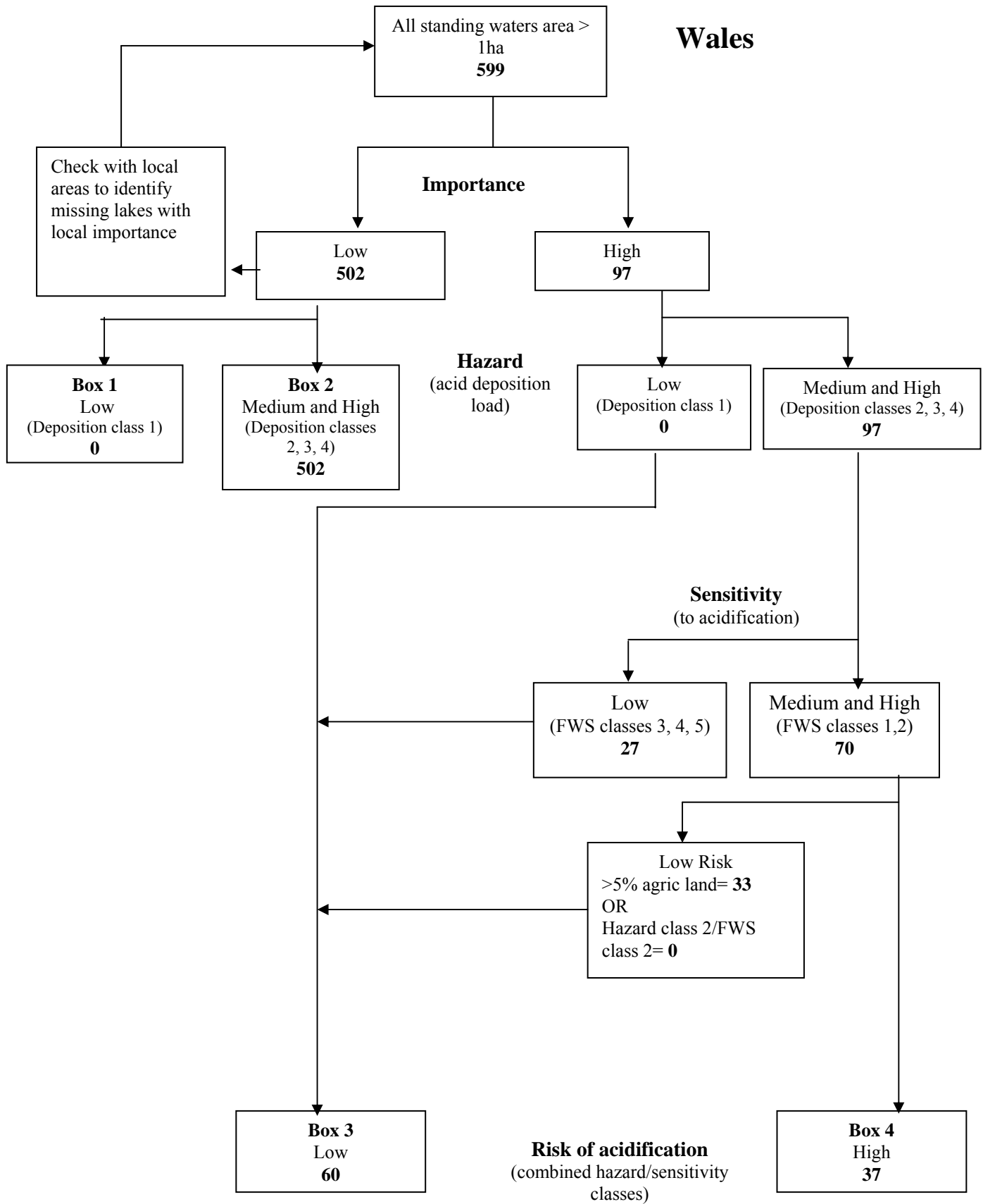
resolution analysis of diatoms preserved in a lake sediment core could be undertaken to assess degree of acidification.



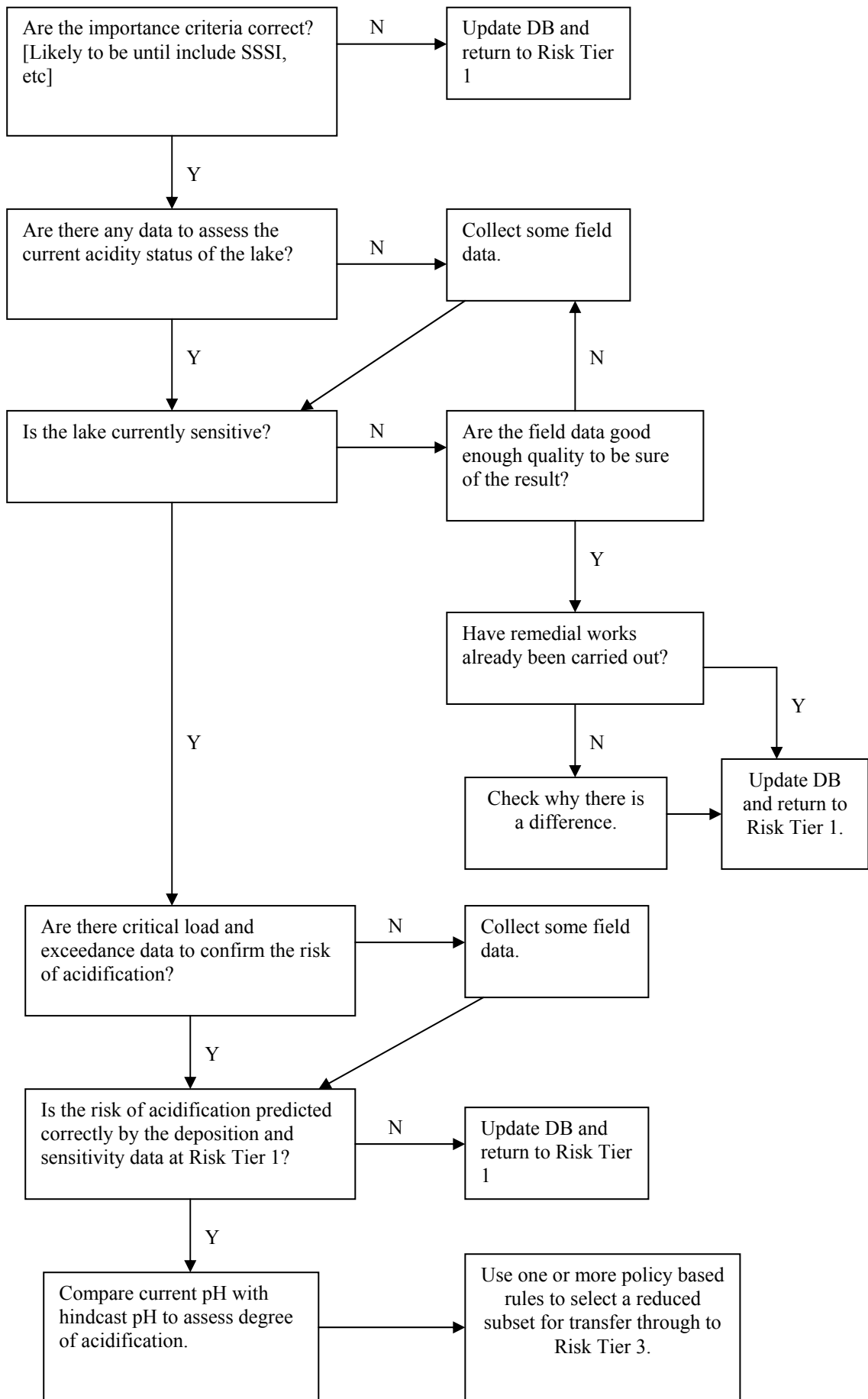
**Figure 4a Outline of the Risk Tier 1 acidification prioritisation scheme for England**



**Figure 4b Outline of the Risk Tier 1 acidification prioritisation scheme for Scotland**



**Figure 4c Outline of the Risk Tier 1 acidification prioritisation scheme for Wales**



**Figure 5 Outline of protocol for checking that a lake has correctly passed from Risk Tier 1 to Risk Tier 2 and for moving lakes from Risk Tier 2 to Risk Tier 3 in the acidification scheme**



### **5.3 Risk Tier 3: Detailed quantitative risk assessment at site specific level**

Lakes that passed the Risk Tier 2 filter into Risk Tier 3 would then need to be subjected to a very detailed local assessment to develop the case for investment and to fully assess the management options (methods) and targets for recovery or remediation.

#### **5.3.1 Current status**

Firstly, a site specific assessment of local importance and uses should be carried out and any local or regional political issues identified. Where current data are absent, a comprehensive chemical and biological survey is required. For chemistry, periodic analysis over at least one year should be carried out, with a minimum resolution of quarterly (seasonal) sampling, and ideally at least a monthly sampling regime. This would enable the seasonal characterisation of the site, which is important because of the potential seasonal variation in acid anion leaching and in acidity status, with possibly serious biological implications that might not be detected through less frequent sampling. A full biological survey should also be carried out to identify the presence (or absence) of acid sensitive taxa, e.g. for diatoms, macrophytes, invertebrates, fish.

#### **5.3.2 Extent of damage and targets for recovery**

A detailed palaeoecological assessment, building on that carried out at Risk Tier 2, would provide information on the baseline biology of the site and an independent measure of the baseline acidity status (see critical loads models in Risk Tier 2) via multi-proxy methods and transfer functions (e.g. Jones *et al*, 1993). Modern analogue techniques could be used to identify targets for recovery or remediation (Flower *et al*, 1997). The Model of Acidification of Groundwater in Catchments (MAGIC) is a dynamic, process-oriented mathematical model and can be used to hindcast and forecast pH under a range of future scenarios (Jenkins *et al*, 1990, 1997). MAGIC uses data on soil chemistry, deposition history, land use history and knowledge of physical and chemical processes such as weathering rates in order to predict chemical status of a water body at any given time. The model requires many data and is unsuitable for application at the national scale but nevertheless could be applied at Risk Tier 3. The MAGIC model hindcast pH values and trends can be compared with those produced by the diatom pH transfer function (e.g. Jenkins *et al*, 1990). Alternatively, the more sophisticated but less data hungry models, WHAM and SCAMP (Tipping, 1998), can be used.

Where these data were not available, further monitoring and data analysis would need to be undertaken to produce sufficient data to enable management decisions to be made.

## 6. APPLICATION OF THE PRIORITISATION PROTOCOL TO 30 TEST LAKES

### 6.1 The testing procedure

A total of 30 lakes were selected to test the performance of the prioritisation protocol. The objective was to test how well importance, hazard and sensitivity (and thereby risk) estimates at Risk Tier 1 were supported by measured data or more sophisticated modelled data, and thereby how the risk assessments can be improved at Risk Tier 2. If at any stage there are discrepancies between modelled and measured data, the database should be amended and the protocol re-run.

Thus on a lake-by-lake basis, following the procedures outlined in Figures 3 and 5, the aim was to:

- i) Confirm that the importance criteria for each priority lake, as identified in Risk Tier 1, are correct by checking against more detailed data on conservation and ecological value.
- ii) Confirm that the current trophic status of the lake has been correctly predicted at Risk Tier 1 in the eutrophication scheme, and assess the current acidity status of the lake in the acidification scheme by collating chemical and biological data.
- iii) Confirm that no previous remediation schemes have been carried out, e.g. P removal at point sources in the catchment of the lake or liming of acid lakes.
- iv) Confirm whether the depth, stratification and recovery status of the lake has been correctly estimated at Risk Tier 1 in the eutrophication scheme.
- v) Calculate critical loads and exceedances to assess accuracy of risk assessments made at Risk Tier 1 in the acidification scheme.
- vi) Assess degree of enrichment by comparing current P loads or concentrations (preferably measured but otherwise modelled at Risk Tier 1) with those hindcast by export-coefficient models and/or diatom transfer functions in the eutrophication scheme. Likewise, assess degree of acidification by comparing current pH or ANC with values hindcast by diatom transfer functions in the acidification scheme.

The test exercise, therefore, involved the collation of existing data, where available, for the selected lakes, as follows:

- i) Data related to conservation interest such as reason for SAC or SSSI designation, and presence of rare plant/animal species or important communities, to confirm aquatic importance.
- ii) For the eutrophication scheme, current mean TP concentration, mean chlorophyll a and OECD trophic status class to confirm trophic status of the lake, plus additional data to confirm trophic status such as occurrence of hypolimnetic deoxygenation, frequency of algal blooms, changes in diatom assemblages and the Trophic Ranking Score and Lake Type based on macrophyte community data (Palmer *et al*, 1992). For

the acidification scheme, current measured mean pH and mean alkalinity to assess status of the lake, plus additional data to confirm status such as changes in diatom assemblages, the Trophic Ranking Score and Lake Type based on macrophyte community data (Palmer *et al*, 1992) and fish data.

- iii) Data on management actions and remediation schemes to confirm whether any restoration has been carried out to date.
- iv) Measured mean and maximum lake depth, retention time and stratification data, to confirm stratification and recovery status for the eutrophication scheme.
- v) Critical load and exceedance data to improve upon risk assessments made using acid deposition loads and dominant freshwater sensitivity classes at Risk Tier 1 in the acidification scheme. Two sets of critical loads and exceedance data were collated: the Henriksen critical load and exceedance values (Henriksen *et al*, 1992) which are based on the critical loads for brown trout, and the diatom model critical load and exceedance values (Battarbee *et al*, 1996). Since the diatom community is regarded as the most sensitive aspect of the biota, it can be argued that the diatom model critical load can be used to identify the point of first change within the lake ecosystem. Negative critical load exceedance values indicate that the load is not exceeded whilst positive values indicate that the load is exceeded.
- vi) For the eutrophication scheme, hindcast P concentration from the Reading model for England and Wales (Johnes *et al*, 1996) and the PLUS model for Scotland (Ferrier *et al*, 1997) and/or P concentration from diatom P transfer functions (e.g. Bennion *et al*, 1996a). The hindcast TP concentrations produced by the export-coefficient models were compared with those derived from the diatom models. For the acidification scheme, hindcast ANC and/or hindcast pH from diatom transfer functions (e.g. Stevenson *et al*, 1991).

## 6.2 Application of the protocol to 30 test lakes

The results for each of the test lakes are given in Tables 4 and 5 and are summarised below. In each case the box number into which the lake falls in either the eutrophication (Figure 2) or acidification (Figure 4) prioritisation scheme, as appropriate, is given.

### 1. Llyn Tegid (Bala) / 34987

Aquatic importance is confirmed (Ramsar, SSSI, BAP species). The lake contains nationally scarce plant species and the internationally rare *Luronium natans*, as well as a unique fish community. Both retention class and stratification class are correctly modelled. The modelled trophic status class of 2 slightly underestimates the measured class of 3, although if animals are included then trophic status is correctly predicted. The high retention time suggests that the lake is sensitive to enrichment and available data suggest that the lake has become enriched and is currently productive; e.g. there is a shift to more nutrient-rich diatom taxa from 1980, summer hypolimnetic deoxygenation occurs, blue-green algal blooms have been observed since 1995 and the macrophyte classification puts the lake in the eutrophic category. Stratification class 5 indicates that the lake would respond to restoration. The lake is classified into Box 5 in the eutrophication scheme.

## 2. Llangorse Lake / 40067

Aquatic importance is confirmed (cSAC, SSSI, BAP species). The lake is a cSAC for its Magnopotamion-Hydrocharition plant communities. Both retention class and stratification class are correctly modelled. The modelled trophic status class of 3 (or 4 with animals included) underestimates the measured class of 5. The high retention time suggests that the lake is sensitive to enrichment and available palaeolimnological and monitoring data indicate enrichment from c.1950; e.g. a shift to planktonic, nutrient-rich diatom taxa in 1950s, summer hypolimnetic deoxygenation, an increase in frequency of algal blooms in 1960s and 1970s, and a eutrophic macrophyte classification. However, sewage diversions were introduced in 1981 and 1992 and a subsequent return to more mesotrophic diatom taxa has been observed since 1985. The stratification class of 4 indicates that the lake would respond to restoration and, therefore, the data support the risk assessment results. The lake is classified into Box 7 in the eutrophication scheme.

## 3. Butterstone Loch / 23531

Aquatic importance is confirmed (cSAC, SSSI, BAP species). The lake is a cSAC for its oligotrophic to mesotrophic character (*Littorelletae uniflorae* / Isoeto-Nanojuncetea) and also contains *Najas flexilis*. Both retention class and stratification class are correctly modelled. The modelled trophic status class of 3 agrees with the current measured trophic status. The high retention time suggests that the lake is sensitive and both the palaeolimnological data and PLUS model indicate enrichment, e.g. an increase in nutrient-rich planktonic diatom taxa since 1960. Fish cages were installed on the loch in 1980. The stratification class of 5 indicates that the lake would respond to restoration. The loch is classified into Box 7 in the eutrophication scheme.

## 4. Loch Davan / 21123

Aquatic importance is confirmed (Ramsar, cSAC, SPA, SSSI, BAP species). The lake is a cSAC for its oligotrophic to mesotrophic character (*Littorelletae uniflorae*/Isoeto-Nanojuncetea) and contains *Elatine hexandra* and *Nuphar pumila*. Both retention class and stratification class are correctly modelled. The modelled trophic status class of 3 agrees with the current measured trophic status. The intermediate retention time suggests that the lake is only slightly sensitive to enrichment and whilst there has been an increase in nutrient-rich diatom taxa since c.1960, the lake is still in relatively good condition with relatively few plankton and a mesotrophic macrophyte flora. The stratification class of 1 indicates that the lake would have limited response to restoration. The loch is classified into Box 6 in the eutrophication scheme.

## 5. Loch Eck / 24996

This loch was classed as important at Risk Tier 1 based on size only but a more thorough assessment of conservation status at Risk Tier 2 highlights its aquatic importance (SSSI, BAP species) as the lake contains *Coregonus lavaretus*. Stratification class is correctly modelled. The modelled trophic status class of 1 slightly underestimates current measured TP values but nevertheless the loch is correctly modelled as being nutrient poor. Whilst the lake is sensitive to enrichment (retention time class 1), the nutrient hazard is low and therefore the lake is at low risk of enrichment. This is confirmed by palaeolimnological and PLUS data which both

indicate stable nutrient concentrations and the loch currently has an oligotrophic macrophyte community. The stratification class of 5 indicates that the lake would respond to restoration. The loch is classified into Box 5 in the eutrophication scheme.

## **6. Loch of Harray / 1753**

This loch was classed as important at Risk Tier 1 based on size only but a more thorough assessment of conservation status at Risk Tier 2 highlights its aquatic importance (SSSI, BAP species). The lake contains a number of protected species including *Potamogeton friesii*, *Potamogeton filiformis*, *Ruppia cirrhosa*, *Chara baltica*, *Chara curta*, *Chara aspera* v. *curta*, *Chara aspera*, and *Tolypella nidifica* v. *glomerata*. Measured retention time and stratification data are not available to compare with the modelled values. The modelled trophic status class of 3 agrees with the current measured trophic status. The high retention time suggests that the lake is sensitive to enrichment and indeed palaeolimnological data, the PLUS model and monitoring data indicate enrichment, e.g. an increase in nutrient-rich diatom taxa and algal blooms observed since the mid 1990s. The stratification class of 2 indicates that the lake would have limited response to restoration. The loch is classified into Box 6 in the eutrophication scheme.

## **7. Kilbirnie Loch / 26566**

The lake has no aquatic importance other than its large size. Stratification class is correctly modelled. The modelled trophic status class of 4 agrees with the current measured trophic status. The high retention time (class 1) suggests that the lake is sensitive to enrichment and this is supported by palaeolimnological data and PLUS model data which both indicate eutrophication, e.g. an increase in nutrient-rich, planktonic diatom taxa from c.1915 and large ratio between hindcast and current TP concentrations. Furthermore, algal blooms have been frequently observed. The stratification class of 5 indicates that the lake would respond to restoration. The loch is classified into Box 7 in the eutrophication scheme.

## **8. Loch Leven / 24843**

Aquatic importance is confirmed (Ramsar, NNR, SPA, SSSI, BAP species). The lake contains a number of protected species including *Potamogeton filiformis*, *Ranunculus reptans*, *Ranunculus hederaceus*, *Limosella aquatica*, *Chara aspera* v. *aspera*, and *Tolypella nidifica* v. *glomerata*. The modelled trophic status class of 4 agrees with the current measured trophic status. The retention class is correctly modelled. The high retention time (class 1) suggests that the lake is sensitive to enrichment and the available data provide clear evidence of eutrophication, e.g. regular cyanobacteria blooms since 1960s, and an increase in nutrient-rich, planktonic diatom taxa from c.1850 and particularly from 1940. The modelled stratification class of 5 is based on the measured maximum depth of the loch which is c. 25 m and indicates that the lake would respond to restoration. There is indeed evidence of recovery since c.1985 following the cessation of P effluent entry to the loch from a woollen mill in 1988 and the introduction of STW tertiary treatment and sewage diversion in the mid-1990s, e.g. decline in phytoplankton abundance from mid-1970s and decrease in nutrient-rich diatom taxa. However the recovery has been relatively slow because most of the loch is shallow and well-mixed with a mean water depth of 4.5m and thus the measured stratification class is closer to 3. The loch is classified into Box 7 in the eutrophication scheme.

## **9. Loch Lomond / 24447**

Aquatic importance is confirmed (National Park, Bathing Water, BAP species). The lake contains a number of protected species such as *Pilularia globulifera*, *Elatine hydropiper*, *Rumex aquaticus*, and *Coregonus lavaretus*. Both retention class and stratification class are correctly modelled. The modelled trophic status class of 1 slightly underestimates current measured TP values but nevertheless the loch is correctly modelled as being nutrient poor. The high retention time suggests that the lake is sensitive to enrichment. Whilst the PLUS model and monitoring data indicate stable conditions, the palaeolimnological data provide an indication of slight enrichment, e.g. the North basin core is dominated by nutrient-poor diatom taxa throughout but there are slight changes since 1950 with the appearance of more nutrient-rich planktonic taxa. The loch currently has an oligotrophic macrophyte community. The stratification class of 5 indicates that the lake would respond to restoration. The loch is classified into Box 5 in the eutrophication scheme.

#### **10. Loch of the Lowes / 23559**

Aquatic importance is confirmed (cSAC, SSSI, BAP species). The lake is a cSAC for its oligotrophic to mesotrophic character (*Littorelletae uniflorae* / Isoeto-Nanojuncetea) and also contains a number of protected plant species including *Potamogeton filiformis*, *Najas flexilis*, and *Elatine hexandra*. Both retention class and stratification class are correctly modelled. However, the modelled trophic status class of 2 underestimates the current trophic status class of 3. The loch has a mesotrophic macrophyte community. The high retention time (class 1) suggests that the lake is sensitive to enrichment and indeed both the palaeolimnological and PLUS model data indicate enrichment, e.g. an increase in nutrient-rich diatom taxa especially since c.1940. The stratification class of 5 indicates that the lake would respond to restoration. The loch is classified into Box 5 in the eutrophication scheme.

#### **11. Loch Lubnaig / 24459**

Aquatic importance is confirmed (cSAC, BAP species). The lake contains *Pilularia globulifera*, *Ranunculus hederaceus*, and *Nuphar pumila*. The stratification class is correctly modelled. The modelled trophic status class of 1 slightly underestimates current measured TP values but nevertheless the loch is correctly modelled as being nutrient poor. The lake has moderate sensitivity to enrichment (retention time class 2) and the nutrient hazard is low and, therefore, the lake is at low risk of enrichment. This is confirmed by palaeolimnological and PLUS data which both indicate stable nutrient concentrations, and the loch currently has an oligotrophic macrophyte community. The stratification class of 5 indicates that the lake would respond to restoration. The loch is classified into Box 5 in the eutrophication scheme.

#### **12. Lake of Menteith / 24919**

This lake was classed as important at Risk Tier 1 based on size only but a more thorough assessment of conservation status at Risk Tier 2 highlights its aquatic importance (SSSI, BAP species). The lake contains a number of protected species such as *Najas flexilis*, *Nuphar pumila*, *Elatine hexandra*, and *Elatine hydropiper*. The modelled trophic status class of 2 slightly underestimates the current trophic status class of 3. The loch has a mesotrophic macrophyte community. The retention class is correctly modelled. A high retention time (class 1) suggests that the lake is sensitive to enrichment and available data provide evidence of eutrophication, e.g. an increase in nutrient-rich planktonic diatom taxa since 1920, and still further since 1980, the first reports of algal blooms in the 1980s, and a relatively high ratio

between hindcast and current TP concentrations. There has been a fishery on the loch since the 1980s. The modelled stratification class of 5 indicates that the lake would respond to restoration. However, this is based on the maximum water depth of 23.5m and in fact most of the lake is shallow and well-mixed (mean water depth 6m) and thus the measured stratification class is likely to be closer to 3. The lake is classified into Box 5 in the eutrophication scheme.

### **13. Grasmere / 29184**

The lake has no aquatic importance other than its large size, although there is a 1977 record of *Elatine hexandra*. Both retention class and stratification class are correctly modelled. However, the modelled trophic status class of 2 underestimates the current trophic status class of 3. The export model takes no account of the large numbers of tourists which increase the load to the sewage treatment works which discharges to the lake. Currently treated sewage is discharged into the hypolimnion in an attempt to reduce the P available for algal uptake in the hypolimnion in the summer, thus making the data difficult to interpret. The lake has an oligotrophic macrophyte community. The lake has moderate sensitivity to enrichment (retention time class 2) and the export coefficient model suggests that there has been an increase in TP concentrations. The stratification class of 5 indicates that the lake would respond to restoration. The lake is classified into Box 5 in the eutrophication scheme.

### **14. Windermere / 29233**

Aquatic importance is confirmed (Bathing Waters, BAP species). The lake contains the protected species *Austropotamobius pallipes* and there are a number of old records of rare plant species. Both retention class and stratification class are correctly modelled. The modelled trophic status class of 3 agrees with the current measured trophic status. The high retention time (class 1) suggests that the lake is sensitive to enrichment and available data provide evidence of eutrophication, most notably in the more productive south basin, e.g. an increase in nutrient-rich planktonic diatom taxa from c. 1930, most markedly since 1970, an increase in *Oscillatoria* blooms in the late 1960s and an increase in blue-green algal blooms since the late 1980s. A major STW was installed in 1964. The stratification class of 5 indicates that the lake would respond to restoration. The recent introduction of P stripping to the STW at Windermere has induced a significant improvement in trophic status, confirming the model predictions. The lake is classified into Box 7 in the eutrophication scheme.

### **15. Esthwaite Water / 29328**

Aquatic importance is confirmed (Ramsar, SSSI, BAP species) and the lake contained the rare plant species *Najas flexilis* prior to 1982. Both retention class and stratification class are correctly modelled. The modelled trophic status class of 3 agrees with the current measured trophic status although the model underestimates actual concentrations. The lake has a mesotrophic macrophyte community. The high retention time (class 1) suggests that the lake is sensitive to enrichment and available data provide evidence of eutrophication, e.g. an increase in nutrient-rich planktonic diatom taxa from c.1950, algal blooms recorded since 1970s, a relatively high ratio between hindcast and current TP concentrations, and an increase in measured SRP concentrations. The enrichment appears to be attributed largely to the start of STW discharge in 1973. The stratification class of 5 indicates that the lake would respond to restoration. In spite of external P load reduction since 1986 from the STW, the lake has been slow to recover. Data suggest that this is because P inputs from fish farm cages on the

lake, which were introduced after the P removal was introduced at the sewage treatment works, almost exactly match the amount of P removed from the STW. The lake is classified into Box 7 in the eutrophication scheme.

#### **16. Bassenthwaite Lake / 28847**

Aquatic importance is confirmed (cSAC, NNR, SSSI, BAP species). The lake is a cSAC for its oligotrophic to mesotrophic character (*Littorelletae uniflorae*/Isoeto-Nanojuncetea). The lake also contains a number of protected species including *Luronium natans* and *Coregonus albula*. The retention class of 2 is correctly modelled but the stratification status is modelled as 5 when in fact measured data places the lake in stratification class 3. The modelled trophic status class of 2 underestimates the current trophic status class of 3 and according to the Palmer classification the lake has a predominantly eutrophic macrophyte community. The lake has moderate sensitivity to enrichment (retention time class 2) and available data provide evidence of enrichment, e.g. the export coefficient model suggests that there has been an increase in TP concentrations, and an increase in nutrient-rich planktonic diatom taxa was observed, most markedly from c. 1960. The measured stratification class of 3 indicates that the lake would have a moderate response to restoration. P stripping was introduced at the STW in 1995 and further P reduction at Keswick STW is in progress. The lake is classified into Box 5 in the eutrophication scheme.

#### **17. Chew Valley Lake / 43096**

Aquatic importance is confirmed (SPA, SSSI, BAP species), The lake contains a number of protected species including *Limosella aquatica*, and there is an old record of *Austropotamobius pallipes*. The lake is also a drinking water supply. Retention class is correctly modelled but the stratification status is modelled as 5 whereas measured data places the lake in stratification class 3. This is because the depth model has considerably overestimated maximum lake depth. The modelled trophic status class of 5 agrees with the current measured trophic status which is hypertrophic. The macrophyte community is classified as eutrophic. The high retention time (class 1) suggests that the lake is sensitive to enrichment and available data provide evidence of eutrophication, e.g. a high ratio between hindcast and current TP concentrations using the export-coefficient model. Deoxygenation is common in the hypolimnion, during periods of stratification, and a bubbler destratifier has been installed which although inefficient moves the stratification class towards the boundary of classes 2 and 3. The lake, therefore, would have only a moderate response to restoration. The lake is classified into Box 7 in the eutrophication scheme.

#### **18. Rutland Water / 36479**

Aquatic importance is confirmed (Ramsar, SPA, SSSI, BAP species). The lake contains the protected species *Limosella aquatica* and is also a drinking water supply. The stratification status is modelled as 5 whereas measured data places the lake in stratification class 4. This is because the depth model has considerably overestimated maximum lake depth. The modelled trophic status class of 4 overestimates the measured trophic status class of 2. This probably resulted from the introduction of iron salts into river water pumped into the reservoir (a practice subsequently stopped) which precipitated large amounts of P. The high modelled retention time (class 1) suggests that the lake is sensitive to enrichment although there are insufficient data to confirm that eutrophication has occurred. However, deoxygenation is common in the hypolimnion and algal blooms are frequently observed. The measured



stratification class of 4 indicates that the lake would have a relatively good response to restoration although underpowered destratification equipment has been installed in the lake. The lake is classified into Box 7 in the eutrophication scheme.

#### **19. Darwell Reservoir / 44955**

The lake has no conservation importance but it is a large water body and is used for drinking water supply. Retention class is correctly modelled but the stratification status is modelled as 1 whereas measured data places the lake in stratification class 5. This is because the depth model has considerably underestimated maximum lake depth. The lake has been artificially deepened using a dam. The modelled trophic status class of 3 underestimates the current trophic status class of 5, largely because the lake receives pumped water from a local river, a nutrient source that is not accounted for by the model. The high retention time (class 1) suggests that the lake is sensitive to enrichment although there are insufficient data to confirm that eutrophication has occurred. However, deoxygenation is common in the hypolimnion soon after stratification. The measured stratification class of 5 indicates that the lake would respond to restoration. The lake is classified into Box 6 in the eutrophication scheme.

#### **20. Slapton Ley / 46472**

This lake was classed as important at Risk Tier 1 based on size only but a more thorough assessment of conservation status at Risk Tier 2 highlights its aquatic importance (NNR, SSSI, BAP species). The lake contains the protected species *Chara connivens*, and there are old records of other rare plant species. Retention class has been modelled as 1 whereas the measured class is 2 and likewise stratification class has been modelled as 4 whereas the measured data places the lake in class 1. These errors arise because both mean and maximum lake depth have been overestimated by the depth model. The modelled trophic status class of 4 slightly underestimates the current trophic status class of 5. The macrophyte community is classified as eutrophic. The lake has moderate sensitivity to enrichment (measured retention class 2) and available data provide evidence of enrichment, e.g. the export coefficient model suggests that there has been an increase in TP concentrations, an increase in nutrient-rich planktonic diatom taxa was observed, most markedly from c. 1960, hypolimnetic deoxygenation has been observed most notably since 1970 and frequency of blooms has increased since the 1970s. The measured stratification class of 1 indicates that the lake would have limited response to restoration. The lake is classified into Box 7 in the eutrophication scheme.

#### **21. Crose Mere / 35211**

Aquatic importance is confirmed (Ramsar, SSSI). Both retention class and stratification class are correctly modelled. The modelled trophic status class of 4 slightly underestimates the current trophic status class of 5 and this may be due to the naturally high P concentrations in the Shropshire meres region owing to geological sources of P. The macrophyte community is classified as eutrophic. The high retention time (class 1) suggests that the lake is sensitive to enrichment and available data provide evidence of eutrophication, e.g. an increase in nutrient-rich planktonic diatom taxa from c. 1900 and frequent algal blooms have been observed for many decades. The measured stratification class of 5 indicates that the lake would respond to restoration. The lake is classified into Box 7 in the eutrophication scheme.

#### **22. Barton Broad / 35655**

Aquatic importance is confirmed (Ramsar, NNR, SPA, cSAC, SSSI, BAP species). The lake is a cSAC for natural eutrophic lakes with Magnopotamion or Hydrocharition-type vegetation. The retention class is correctly modelled but stratification class is modelled as 4 whereas measured data gives a class of 1. This is because maximum lake depth is overestimated by the depth model. The modelled trophic status class of 5 slightly overestimates the current trophic status class of 4. This is most likely because the lake has recently undergone a P removal programme. A lake restoration programme has been in place since the late 1970s which has involved reduction in P load from STWs and sediment removal in the 1990s. The lake has moderate sensitivity to enrichment (retention class 2) and available data provide evidence of enrichment, e.g. export coefficient modelled increase in TP concentrations, an increase in nutrient-rich planktonic diatom taxa from c. 1970, loss of submerged macrophyte community, hypolimnetic deoxygenation and algal blooms. The measured stratification class of 1 indicates that the lake would have limited response to restoration. The lake is classified into Box 7 in the eutrophication scheme.

### **23. Rollesby Broad / 35981**

Aquatic importance is confirmed (cSAC, SSSI, BAP species). The lake is a cSAC for natural eutrophic lakes with Magnopotamion or Hydrocharition-type vegetation, and is also used as a drinking water supply. The stratification class is modelled as 5 whereas measured data gives a class of 1. This is because maximum lake depth is considerably overestimated by the depth model. The modelled trophic status class of 5 agrees with the current measured trophic status although the model overestimates actual concentrations. The high modelled retention time (class 1) suggests that the lake is sensitive to enrichment and available data provide evidence of eutrophication, e.g. an increase in nutrient-rich planktonic diatom taxa from c. 1940, a high ratio between export-coefficient hindcast and current TP concentrations, loss of submerged macrophyte community, and hypolimnetic deoxygenation. The measured stratification class of 1 indicates that the lake would have limited response to restoration. The lake is classified into Box 7 in the eutrophication scheme.

### **24. Malham Tarn / 29844**

Aquatic importance is confirmed (Ramsar, cSAC, NNR, SSSI, BAP species). The lake is a cSAC for hard oligo-mesotrophic waters with benthic vegetation of *Chara* sp. Retention class is correctly modelled and although profile data were not available the modelled stratification class of 4 seems intuitively to be correct. The modelled trophic status class of 3 agrees with the current measured trophic status. The macrophyte community is classified as eutrophic (*Chara* sub-group). The high retention time (class 1) suggests that the lake is sensitive to enrichment but owing to the relatively low hazard, the lake is at reasonably low risk of enrichment. Indeed palaeolimnological data indicate little change in nutrient conditions with a relatively stable diatom assemblage dominated by non-planktonic species. The modelled stratification class of 4 indicates that the lake would have a relatively good response to restoration. The lake is classified into Box 7 in the eutrophication scheme.

### **25. Coniston Water / 29321**

The lake has no conservation importance but it is a large water body. Both retention class and stratification class are correctly modelled. The modelled trophic status class of 2 agrees with the current measured trophic status and the macrophyte community is also classified as oligotrophic. The high retention time (class 1) suggests that the lake is sensitive to enrichment but owing to the relatively low hazard, the lake is at reasonably low risk of enrichment. Palaeolimnological diatom data provide evidence of slight nutrient enrichment but there is still minimal oxygen reduction in the hypolimnion. The stratification class of 5 indicates that the lake would respond well to restoration. The lake is classified into Box 5 in the eutrophication scheme.

#### **26. Priest Pot / 29323**

This lake was classed as important at Risk Tier 1 based on size only but a more thorough assessment of conservation status at Risk Tier 2 highlights its aquatic importance (Ramsar, SSSI). The stratification class is correctly model even though maximum depth is considerably overestimated by the depth model. The modelled trophic status class of 3 slightly underestimates the current trophic status class of 4. The lake has moderate sensitivity to enrichment (retention class 2) and whilst there are insufficient data to provide evidence of enrichment, the lake is currently productive with complete anoxia for four months each year and regular dense algal blooms. The stratification class of 5 indicates that the lake would respond well to restoration. The lake is classified into Box 7 in the eutrophication scheme.

#### **27. Llyn Idwal / 33836**

Aquatic importance is confirmed (Ramsar, cSAC, SSSI, BAP species). The lake is a cSAC for its oligotrophic to mesotrophic character (*Littorelletae uniflorae* / Isoeto-Nanojuncetea). The lake contains a number of protected species including *Isoetes echinospora*, *Pilularia globulifera* and *Elatine hexandra*. This lake has high acid deposition (class 4) and high sensitivity (class 1) but it is not identified as at high risk of acidification in the scheme because, according to the land cover data, there is >5% agriculturally improved land in the catchment and thus it is assumed that the land will be subject to liming. However, catchment studies indicate that there is no improved grassland in the catchment of Llyn Idwal and liming does not take place and therefore the land cover data appear to be incorrect for this site. Palaeolimnological studies indicate that the lake has not acidified as the diatom record is dominated by taxa indicative of circumneutral, nutrient-poor conditions. The lack of sensitivity to acidification can be attributed to a high buffering capacity (Ca = 89 µeq/l). The macrophyte community is classified as oligotrophic. The lake is classified into Box 3 in the acidification scheme.

#### **28. Llyn Cwellyn / 34002**

Aquatic importance is confirmed (cSAC, SSSI, BAP species). The lake is a cSAC for its oligotrophic to mesotrophic character (*Littorelletae uniflorae*/Isoeto-Nanojuncetea). The lake contains a number of protected species including Arctic charr and *Luronium natans*. This lake has high acid deposition (class 4) and high sensitivity (class 1) but it is not identified as at high risk of acidification because there is >5% agriculturally improved land in the catchment and thus it is assumed that the land will be subject to liming. Palaeolimnological studies demonstrate that the lake has acidified with a marked decline in planktonic diatom taxa and an increase in acid tolerant taxa since the 1860s. However, there are signs of recovery since the

mid 1980s with a decline in acid taxa. This appears to be a response to a combination of a decline in S deposition and agricultural liming. The diatom critical load is only slightly exceeded. The macrophyte community is classified as oligotrophic. The lake is classified into Box 3 in the acidification scheme.

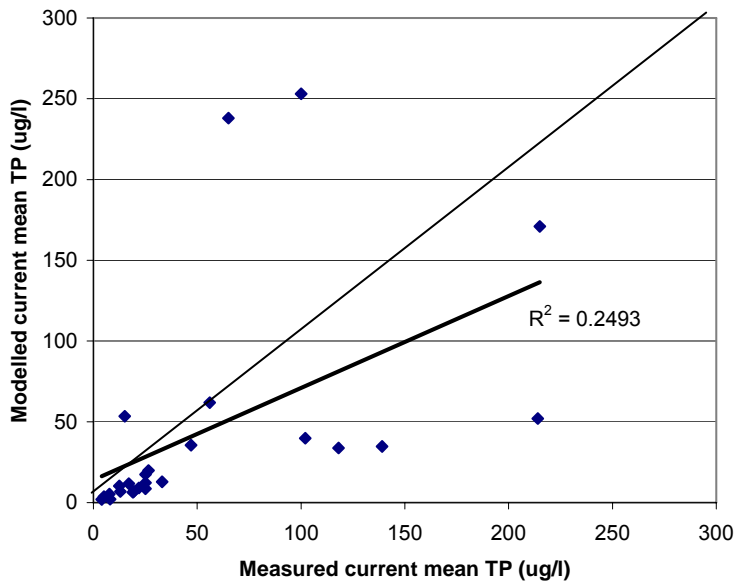
### **29. Loch Chon / 24754**

The lake has no conservation importance but it is a large water body. This lake has high acid deposition (class 4) and high sensitivity (class 1) and is thus at high risk of acidification. Palaeolimnological studies confirm that the lake has acidified with an increase in acid tolerant diatom taxa since 1850. The diatom critical load suggest reasonable high exceedance. Chemical and biological monitoring data indicate that lake pH has increased since the late 1980s but the exact causes of recovery are yet to be fully established. The macrophyte community is classified as oligotrophic. The loch is classified into Box 4 in the acidification scheme.

### **30. Loch Dee / 27948**

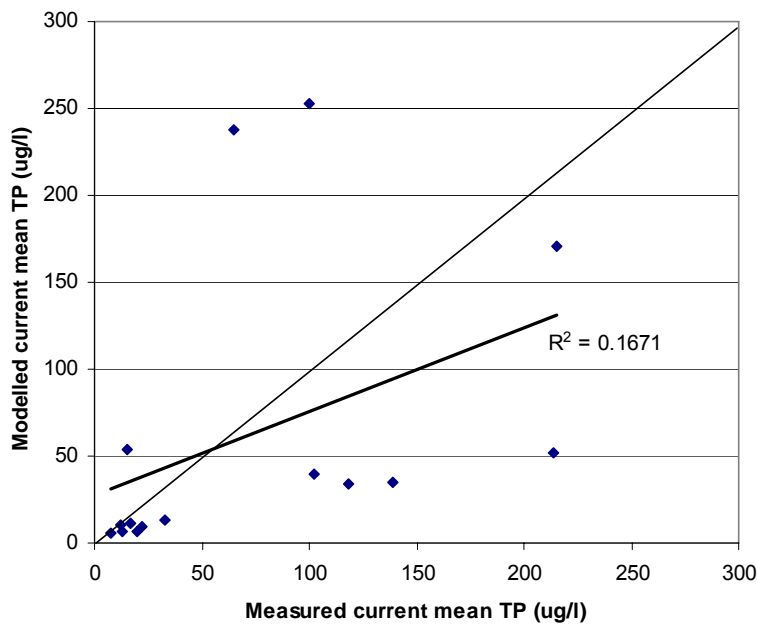
The lake has no conservation importance but it is a large water body. This lake has high acid deposition (class 4) and high sensitivity (class 1) and is thus at high risk of acidification. Palaeolimnological studies confirm that the lake has strongly acidified with an increase in acid tolerant diatom taxa since 1850. The loch is classified into Box 4 in the acidification scheme.

In addition to the individual site results, a comparison was made between the measured current TP concentrations of all of the test lakes and those modelled by the eutrophication prioritisation protocol. Figure 6a shows the scatterplot of measured current mean TP concentrations against those modelled for lakes in England, Wales and Scotland using nutrient inputs from people and land cover only (i.e. without animals). The most striking observation is that, with a small number of exceptions, the modelled values generally underestimate the measured concentrations. It appears that the model performs reasonably well at concentrations less than  $50 \mu\text{g l}^{-1}$  but that larger errors occur at concentrations above these and thus the  $R^2$  value is low. To examine the effect of including the animal component in the modelled TP concentrations, a comparison was made between the measured current TP concentrations and the modelled data both without (Figure 6b) and with (Figure 6c) animals for those lakes in England and Wales where animal density data were available. Whilst notable outliers remain, especially in the most productive waters, the overall relationship between measured and modelled data is improved with the inclusion of the animal component. There are site-specific reasons for the strongest outliers, for example at Crose Mere the TP is underestimated by the model owing to geological inputs of P and at Barton Broad, P has been removed from Stalham and North Walsham STWs and therefore the model overestimates measured values. Anomalies such as these would be identified at Risk Tier 2 when local information is collated for each site.



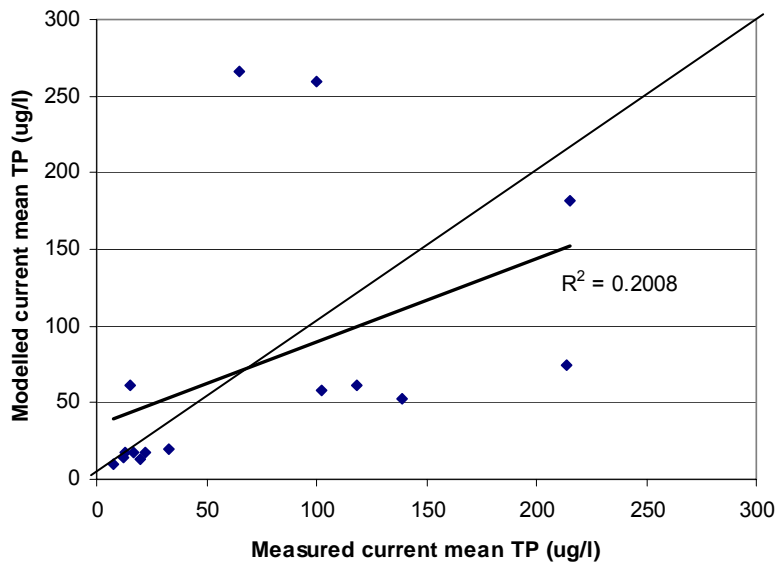
**Figure 6a** Scatterplot of measured current mean TP concentrations versus those modelled by the eutrophication protocol using people and land cover only for selected test lakes in England, Wales and Scotland.

The linear regression line, the  $R^2$  value and the 1:1 line are shown.

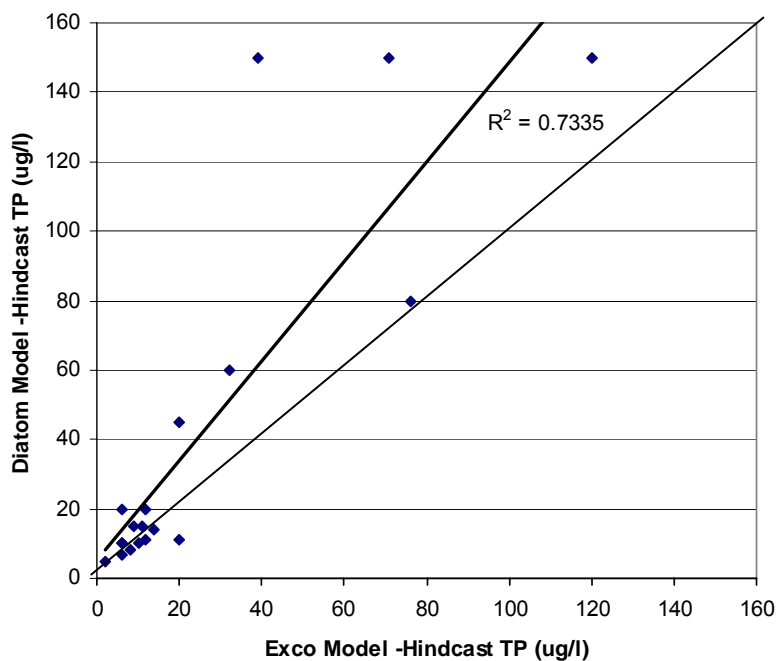


**Figure 6b** Scatterplot of measured current mean TP concentrations versus those modelled by the eutrophication protocol using people and land cover only for selected test lakes in England and Wales.

The linear regression line, the  $R^2$  value and the 1:1 line are shown.



**Figure 6c** Scatterplot of measured current mean TP concentrations versus those modelled by the eutrophication protocol using people, land cover and animals for selected test lakes in England and Wales. The linear regression line, the  $R^2$  value and the 1:1 line are shown.



**Figure 7** Scatterplot of Hindcast TP concentrations produced by the export coefficient models versus the diatom models for selected test lakes in England, Wales and Scotland. The linear regression line, the  $R^2$  value and the 1:1 line are shown.

A comparison was also made between the hindcast TP concentrations produced by the export-coefficient approach and those derived from the diatom models to evaluate the reliability of using these techniques for assessing changes in nutrient levels (Figure 7). In the absence of historical measured values to provide a three-way validation, it is not possible to state whether the values produced by the methods are correct or which of the models gives the closest estimate of actual past concentrations in situations when discrepancies between the two sets of data occur. However, Figure 7 illustrates that there is good agreement between the export-coefficient and diatom hindcast concentrations with a  $R^2$  value of 0.73.

### 6.3 Conclusions based on the test exercise

A number of general conclusions can be drawn from the test exercise:

- i) The eutrophication protocol reliably models high risk of enrichment in most cases. For example palaeolimnological and export coefficient data provide evidence of enrichment at a number of lakes predicted to be at high risk including Llyn Tegid, Llangorse Lake, Butterstone Loch, Loch of Harray, Kilbirnie Loch, Loch Leven, Loch of the Lowes, Lake of Menteith, Windermere, Esthwaite Water, Bassenthwaite Lake, Slapton Ley, Crose Mere, Barton Broad and Rollesby Broad.
- ii) The eutrophication protocol reliably models low risk of enrichment in most cases. For example palaeolimnological and export coefficient data provide little evidence of enrichment at a number of lakes predicted to be at relatively low risk including Loch Eck, Loch Lomond, Loch Lubnaig, Malham Tarn and Coniston Water.
- iii) The eutrophication protocol appears to reliably model likelihood of response to restoration based on the limited number of examples available. For example there is evidence of recovery following nutrient reduction at Windermere and Llangorse Lake, which have stratification classes of 5 and 4, respectively. In contrast, Barton Broad with a stratification class of 1 has been slow to respond to remediation. In a few cases, however, the stratification class is over-estimated by the model because the model is based on maximum rather than mean water depth. The greatest errors occur in largely shallow, well-mixed waters where the deep water zones represent a relatively small area of the water body as a whole (e.g. kettle holes in Loch Leven and Lake of Menteith).
- iv) The modelled current P concentration in the eutrophication protocol frequently underestimates measured current P concentration. Data in Table 5 and illustrated in Figure 6 suggest that the main reason for this is that the modelled values are based on nutrient inputs from people and land cover only and do not include the animal component. For England and Wales, where data are available for P load estimates with and without animals, six give the same predicted trophic status class for both load estimates, both of which agreed with the measured class. In four other cases the inclusion of animals increased the predicted trophic status class by one to give the same class as field observations. In the other cases there were special, site-specific situations which explained the differences. If a catchment has been poorly defined this will introduce additional error into the modelled current P loads and thus concentrations.

- v) There is a poor match between modelled and measured current P concentrations for a small number of the test lakes which cannot be explained simply by the absence of animal data. In these cases there is a site-specific reason for the discrepancy. For example, at Rutland Water trophic status is overestimated because large amounts of P are precipitated by Fe; at Barton Broad trophic status is overestimated most likely because the lake has recently undergone a P removal programme; at Darwell Reservoir trophic status is underestimated because the lake receives pumped water from a local river, a nutrient source that is not accounted for by the model; and at Crose Mere trophic status is underestimated probably because of the naturally high P concentrations in the region arising from the P-rich geology. Clearly any source of P other than people and land cover or any major sink/removal of P will result in a poor match between modelled and measured P concentrations.
- vi) In the eutrophication scheme, retention times and stratification classes are modelled incorrectly for a small number of lakes owing to errors in the lake depth model used to estimate lake mean and maximum depth. In most of these cases, the model overestimates the depths, resulting in a higher stratification class than that produced from measured profile data, thereby suggesting that the lake will respond better to restoration than it is likely to in reality. This problem arises especially for lowland lakes with large surface areas because the depth model utilises the positive relationship between lake area and depth. Of the test lakes, this problem was apparent at Chew Valley Lake, Rutland Water, Slapton Ley, Barton Broad and Rollesby Broad. As a result, lakes fall through to Risk Tier 2 when they should not. This is, in effect, a fail safe situation and the measurement of actual depths as part of Risk Tier 2 should allow the real situation to be reassessed. There was only one case, Darwell Reservoir, where the model underestimates actual depth data and this is because the lake has been artificially deepened. Stratification class is also incorrectly modelled in lakes such as Loch Leven and Lake of Menteith which are mostly shallow and well mixed but which have a deep basin (see point iii above).
- vii) There was good agreement between the modelled hindcast TP concentrations produced by the export-coefficient approach and the diatom transfer function approach. Given that the former is based on nutrient export from catchment sources and the latter is based on the relationship between algal taxa and TP concentrations in the actual water column, the concordance between the two data sets was encouraging. The results for the test lakes suggest that for most sites, these techniques can be used with reasonable confidence to assess degree of enrichment.
- viii) The acidification protocol appears to work well for assessing the risk of acidification, although only a small number of test cases were used here. At Lochs Chon and Dee, palaeolimnological evidence of acidification confirms that the lochs are correctly predicted as being at high risk. At Llyn Idwal and Llyn Cwellyn the scheme predicted lower risk of acidification owing to the presence of agriculturally improved land in the catchments. In the case of Llyn Idwal, however, the land cover data are incorrect as there is no improved grassland in the catchment. This is a data resolution issue. The test results also highlight the issue of data resolution with the dominant freshwater sensitivity classes. These are based on a 1 km grid and therefore cannot be expected to capture all local influences on lake water chemistry, e.g. Llyn Idwal has a high modelled sensitivity class of 1 but in fact has a high buffering capacity with Ca concentrations of 89  $\mu\text{eq/l}$  and, therefore, has not experienced acidification. In



contrast, Llyn Cwellyn did experience acidification from the mid 1800s but there appears to be evidence of recovery in recent decades which can be attributed partly to agricultural liming, as correctly modelled by the risk protocol.

- ix) Overall, the text exercise illustrates that the risk protocol performs well. Inevitably, however, the need for nationally available datasets at Risk Tier 1 means that there will always be issues of data resolution and errors may occur. The test results highlight the importance of data validation and more thorough checks using lake specific information at Risk Tier 2.

**Table 4 Summary of data collated for a subset of lakes used to test the acidification protocol**

Site name/ WBID	Measured		Modelled		Modelled	Modelled Critical loads				Measured		Hindcast Diatom pH	Palmer TRS/ Lake type
	Mean depth (m)	Max depth (m)	Acid deposition load (keq/ha/yr)	Acid deposition class	Domfws class	Henriksen critical load - total acidity (keq/ha/yr)	Henriksen critical load exceedance (keq/ha/yr)	Diatom critical load - total acidity (keq/ha/yr)	Diatom critical load exceedance (keq/ha/yr)	Current mean pH	Current mean alkalinity (ueq/l)		
Llyn Idwal 33836	3.4	13	2.58	4	1	4.19	-2.21	1.07	0.9	6.72	70	6.48	5.48 / 3
Llyn Cwellyn 34002	22.6	36	1.97	4	1	2.8	-1.54	0.97	0.146	6.35	37	6.73	5.68 / 3
Loch Chon 24754	7.6	25	1.99	4	1	1.39	-0.08	0.63	0.69	5.68	12	6.3	/ 2
Loch Dee 27948	4.3	14	2.23	4	1	na	na	na	na	5.27	na	6.9	na

**Table 5 Summary of data collated for a subset of lakes used to test the eutrophication protocol**

Site name / WBID	Modelled		Measured		Modelled			Measured			Current Modelled (note 1)			Current Measured			Hindcast data (note 2)		Palmer TRS/ Lake type
	Mean depth (m)	Max depth (m)	Mean depth (m)	Max depth (m)	Strat. class	Ret. time (yrs)	Ret. class	Strat. class	Ret. time (yrs)	Ret. class	Mean TP conc (ug/l)	Mean annual chl a (ug/l)	Trophic status class	Mean TP conc (ug/l)	Mean annual chl a (ug/l)	Trophic status class	TP conc - export coefficient models (ug/l)	TP conc - Diatom model (ug/l)	
Llyn Tegid (Bala) 34987	na	na	24	43	5	0.45	1	5	0.24	1	6.8 (17.7)	3.1 (10.2)	2	13	7.2	3	6	10	6.87 / 8
Llangorse Lake 40067	na	na	2	7.5	4	0.24	1	4	0.19	1	33.8 (61.3)	17.3 (35.9)	3	118	14.5	5	39	150	8.43 / 10a
Butterstone Loch 23531	na	na	3.4	7.6	5	0.12	1	5	0.11	1	12.2 (-)	5.2 (-)	3	25	na	3	6	20	/ 5a
Loch Davan 21123	na	na	1.2	2.7	1	0.03	2	1	0.024	2	19.8 (-)	8.4 (-)	3	26.5	na	3	20	11	6.97 / 5a
Loch Eck 24996	na	na	15.3	42.4	5	0.29	1	5	na	na	1.9 (-)	0.6 (-)	1	4	na	2	2	5	5.87 / 3
Loch of Harray 1753	na	na	2.7	4.3	2	0.38	1	na	na	na	17.5 (-)	8.0 (-)	3	25	na	3	10	10	/ 7
Kilbirmie Loch 26566	na	na	3	9.1	5	0.13	1	5	na	na	61.8 (-)	37.3 (-)	4	56	na	4	11	15	na
Loch Leven 24843	na	na	4.5	25.3	5	0.62	1	3	0.43	1	35.5 (-)	20.2 (-)	4	47	28	4	20	45	na
Loch Lomond 24447	na	na	37	189.9	5	2.1	1	5	1.9	1	3.7 (-)	1.6 (-)	1	5 (N)	2.5 (N)	2	2 to 8 (N)	8 (N)	/ 3 (N)
Loch of the Lowes 23559	na	na	6.2	16.2	5	0.63	1	5	0.62	1	8.6 (-)	3.7 (-)	2	25	na	3	14	14	/ 4
Loch Lubnaig 24459	na	na	13	44.5	5	0.08	2	5	na	na	2.1 (-)	0.7 (-)	1	8	na	2	6	7	6.17 / 3
Lake of Menteith 24919	na	na	6	23.5	5	0.87	1	3	0.75	1	6.3 (-)	2.6 (-)	2	19	na	3	12	11	6.38 / 3
Grasmere 29184	na	na	7.7	21.5	5	0.07	2	5	0.068	2	6.9 (13.4)	2.8 (6.3)	2	19.5	10.6	3	6	na	6.61 / 3
Windermere 29233	na	na	21.3	64	5	0.7	1	5	0.49 (N)	1	10.3 (14.2)	5.2 (7.6)	3	12.4 (N) 20.5 (S)	5.4 (N) 24.6 (S)	3	6	10 (S)	7.00 / 3
Esthwaite Water 29328	na	na	6.4	15.5	5	0.24	1	5	0.27	1	12.8 (20.0)	5.9 (10.2)	3	33	24	3	9	15	6.24 / 5a
Bassenthwaite Lake 28847	na	na	5.3	19	5	0.04	2	3	0.082	2	9.0 (17.1)	3.7 (8.1)	2	21.8	13.4	3	12	20	7.51 / 9
Chew Valley Lake 43096	10.7	27.4	4.27	11.5	5	1.58	1	3	0.71	1	171 (182)	151 (164)	5	215	36	5	23	na	/ 10
Rutland Water 36479	26.1	66.7	10.7	34	5	19.9	1	4	na	na	53.5 (61.4)	43.0 (50.9)	4	15	11	2	28	na	na
Darwell Reservoir 44955	0.61	1.6	6.47	16	1	0.099	1	5	0.095	1	34.7 (52.8)	16.0 (26.6)	3	139	25	5	46	na	na

Site name / WBID	Modelled		Measured		Modelled			Measured			Current Modelled (note 1)			Current Measured			Hindcast data (note 2)		Palmer TRS/ Lake type
	Mean depth (m)	Max depth (m)	Mean depth (m)	Max depth (m)	Strat. class	Ret. time (yrs)	Ret. class	Strat. class	Ret. time (yrs)	Ret. class	Mean TP conc (ug/l)	Mean annual chl a (ug/l)	Trophic status class	Mean TP conc (ug/l)	Mean annual chl a (ug/l)	Trophic status class	TP conc - export coefficient models (ug/l)	TP conc - Diatom model (ug/l)	
Slapton Ley 46472	2.5	6.3	1.55	2.5	4	0.15	1	1	0.047	2	39.8 (58.1)	21.5 (34.0)	4	102	54	5	32	60	8.09 / 9
Croze Mere 35211	3.64	na	na	9.3	5	1.19	1	5	2.25	1	52.0 (74.3)	31.9 (49.4)	4	214	10	5	76	80	8.41 / 8
Barton Broad 35655	na	5.8	1.55	c. 2	4	0.04	2	1	0.05	2	238 (266)	180 (206)	5	65	50	4	120	150	na
Rollesby Broad 35981	na	12.6	2.5	c. 3	5	0.7	1	1	na	na	253 (260)	211 (217)	5	c. 100	18	4 to 5	71	150	na
Malham Tarn 29844	na	na	2.6	4.4	4	0.33	1		0.19	1	11.7 (17.8)	4.9 (8.2)	3	17	8	3	9	na	/ 10B
Coniston Water 29321	na	na	24	56	5	1.04	1	5	0.93	1	5.3 (9.5)	2.3 (4.8)	2	7.62	na	2-3	9	na	6.79 / 2
Priest Pot 29323	4.42	11.3	2.5	3.7	5	0.048	2	5	na	na			3	45	20 to 700	4		na	/ 3

Note 1: These data are based on current P loads modelled using export-coefficients for people and land cover only. Animal data are not available for Scotland. However, animal data are available for England and Wales and the values calculated with the animal component included are given in brackets. The in-lake P and chlorophyll a concentrations were estimated from the modelled P load using OECD regression equations and ranked according to Vollenweider's Trophic classification to give a Trophic status class from 1 to 5 where 1=low and 5=high.

Note 2: The export coefficient models of Johnes *et al* (1996) for England and Wales and the PLUS model for Scotland (Ferrier *et al*, 1997) were used to hindcast TP concentrations. The TP concentration hindcast from diatom transfer functions (Bennion *et al*, 1996a) is given where available.



## 7. GEOREFERENCED INVENTORY

### 7.1 Introduction

There have been several attempts during the last 100 years to describe the extent and distribution of standing waters in Scotland (Murray and Pullar, 1910; Lyle and Smith, 1994) and Great Britain as a whole (e.g. Smith and Lyle, 1979; Barr *et al*, 1994; Fuller *et al* 1994; Haines-Young *et al*, 2000). Many of these surveys have been based on stratified random sampling techniques or remote sensing. The Smith and Lyle survey, which was based on a visual inspection of 1:250,000 paper maps from Ordnance Survey (OS), remains the most comprehensive account so far. At this scale however, the lower level for inclusion is about 4 hectares and this, coupled with the fact the survey data are not held digitally, meant that it was necessary to start with a fresh approach.

### 7.2 Data Source

In choosing the data source for the inventory the main consideration was the degree of detail needed. The basic requirements were for an outline of the water body from which the coordinates of its centroid, surface area and perimeter could be derived. It was decided at an early stage to concentrate on water bodies with a surface area of at least 1 hectare. OS Land-Form PANORAMA<sup>®</sup> contour data at 1:50,000 contains features representing contours, spot heights, breaklines, coastline, lakes, and ridge and form lines as seen on the 1:50,000 Landranger paper map series. Data capture took place in 1983. Each lake outline has an associated elevation attribute (to the nearest metre) and all line objects have a quoted spatial accuracy of 3m root mean square error (RMSE) (Ordnance Survey, 2001). A visual inspection of the data indicates that water bodies with surface areas as small as 0.5 ha are accurately represented and although smaller water bodies do exist in the dataset (the smallest being 0.02 ha), their representation is somewhat generalised. However, the dataset remains relatively manageable in terms of computer processing whereas data at a larger scale (such as OS Land-Line<sup>®</sup>) would have introduced problems of data processing and unnecessary complexity.

The main drawback of using PANORAMA is that it is a ‘static’ dataset, i.e. OS do not update this product, and so the database reflects the state of Britain’s water bodies in 1983. Sample tests with new web-based 1:50,000 maps indicate that approximately 4% of the water bodies in the database have changed shape or are now missing – mainly in areas around quarries, docks, industrial works and extractive industries, urban areas and dunes. A large proportion of these ‘missing’ lakes are probably due to mistakes in the original dataset (i.e. land parcels or contour lines being incorrectly coded as water) and cartographic errors on the new map. Also, any reservoirs or alterations to water level which have taken place since 1983 will not be included.

During the course of this project the Countryside Council for Wales independently developed a GIS layer of lake outlines based on more recent OS data. This is largely identical to the data used for this survey except for the addition of several hundred smaller (<1 ha) water bodies, the enlargement of two reservoirs (Llyn Gwynant and Marchlyn Mawr), the addition of a new reservoir (Cwm Reidol) and 31 additional water bodies between 1 and 10 ha surface area. Interestingly, comparison between the two datasets reveals that some 85 water bodies in the original dataset no longer exist, 25 of which are larger than 1 ha.

### 7.3 Data Processing

Each of the 812 20 km square PANORAMA tiles was processed individually to extract the lake features using 3 SPARC Ultra-5 workstations and ESRI software. Tiles were converted to ArcInfo coverages using ESRI's MapManager software and subsequently lake features were extracted automatically and converted to polygons using custom scripts in ArcInfo (AML). Each lake polygon was then assigned a pair of geometric centroid coordinates (to the nearest metre) and basic physical parameters (surface area in hectares, altitude and perimeter both to nearest metre, number of islands).

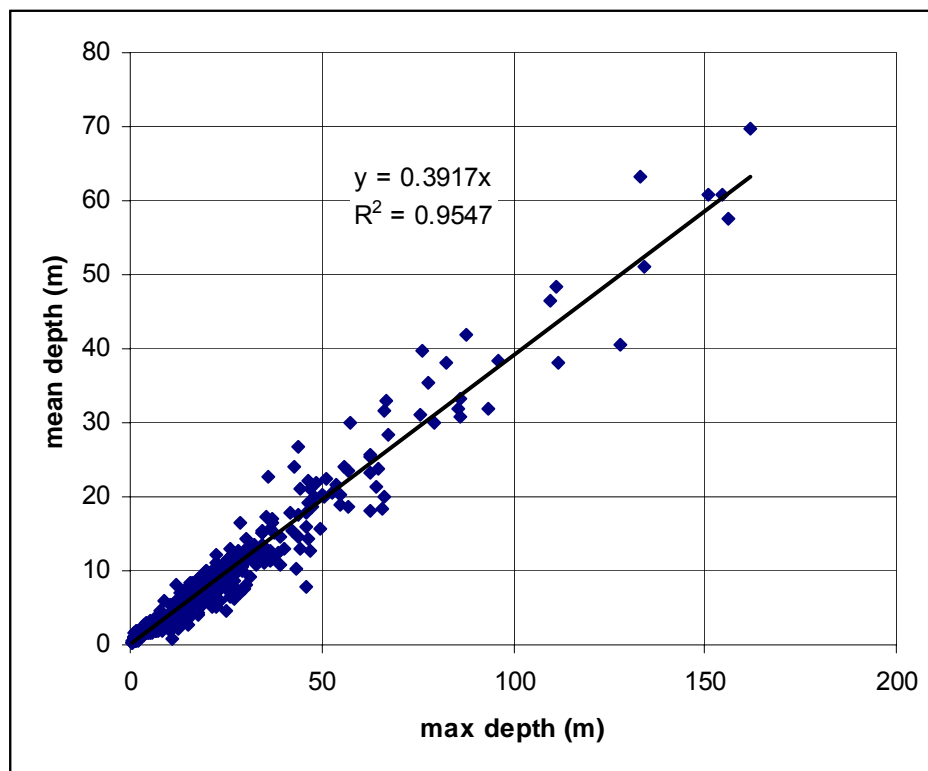
The data were error-checked using a variety of methods, both automatic and manual. Lake features that did not form whole polygons were closed automatically using an iterative process where snapping distance was gradually increased from 2 m to 10 m. Open polygons with gaps larger than 10m were edited manually with reference to the paper map, resulting in more than 700 additional water bodies. The process of converting to polygons occasionally produced slivers (very small polygons adjacent to 'real' polygons) and these were searched for automatically (by size) but checked visually against the map. Some 300 polygons were rejected as being slivers. It was noticed that the original dataset contained large rivers (coded as lakes and split into sections) appearing as long chains of adjacent rectangular polygons. These were removed manually, resulting in the loss of a further 2200 polygons. The final number of polygons in the database was 46570, of which 43738 were lakes and the remaining 2832 were islands.

Additional parameters were derived for each lake polygon. OS-style grid references, geographic coordinates, distance to sea, shoreline development index (a measure of shoreline complexity) and length and bearing of line of maximum fetch were all computed using Microsoft Excel, ArcView and ArcInfo. Attribute data were managed in a Microsoft Access97 database and linked to the GIS using a unique identification code. The lake centroids were used in a series of overlays to identify co-occurrence with a range of national datasets.

Measured depth data for approximately 5% of the water bodies >1 ha were collected from a wide range of sources (including Murray and Pullar, 1910) and used in a simple multiple regression model to predict mean and maximum lake depths, for the calculation of volume and retention time. The basic model for predicting maximum lake depth was developed using lake easting, northing, surface area, altitude and shoreline development index (from TBL\_LD and TBL\_SDI). Actual maximum depth values were collated for 824 water bodies (see TBL\_DP). Multiple regression analysis was carried out on the above parameters and maximum depth for lakes where the latter was known. England, Scotland and Wales were treated separately due to the different physical nature of water bodies in each country. The relationships were used to predict maximum depth for the remaining water bodies > 1ha in England, Scotland and Wales (TBL\_MDP). The predictive power of these relationships is not strong and the models all underestimate significantly at the lower end of the depth range (< 5m). A better model would also take account of the surrounding relief and lake shape as an indicator of lake type (e.g. corrie, glacial, lowland etc).

Mean depths (TBL\_MDP) (where an actual mean depth was not known) were predicted using a simple relationship between mean and max depth (obtained by analysis of the training data

where both mean and max depth were known,  $n = 597$ , TBL\_DP). This relationship is shown in Figure 8.



**Figure 8** Scatterplot showing the relationship between measured maximum lake depth and measured mean lake depth in the training set of lakes

#### 7.4 Catchment Delineation

Catchment areas were derived for all water bodies with a surface area larger than 1 hectare. The lake polygons ( $n = 14353$ ) were extracted and processed with a flow grid derived from the Institute of Hydrology digital terrain model (DTM) (Morris and Flavin, 1990) to generate catchment polygons. This 50 metre resolution DTM is based on digitised contours from the Ordnance Survey 1:50,000 map (PANORAMA) but has been adjusted to conform to a digitised stream network for greater accuracy.

The lake outline was used to select grid cells from the flow grid, and the cell with the greatest value (i.e. maximum flow) was selected as the pour point. ArcView's Spatial Analyst Watershed function was used to generate a catchment outline from the pour point, which was saved as a polygon. The catchment polygons were subsequently processed to calculate their area, perimeter and lake to catchment ratio. Catchment polygons were then used in the GIS to extract data from national datasets.

The catchment overlay process for each dataset took one of two forms depending on the data type. A catchment-weighted procedure was used for overlay with gridded maps of distributed data (such as acid deposition and P load) whereby a mean value is found by calculating the proportion of each gridded data cell overlaid by the catchment polygon. For datasets containing categorical data in discrete units (such as geology and land cover) the proportion of each category was calculated as an actual area (in hectares) and percentage of catchment.



(Note: many of the national datasets did not cover the Isle of Man and so these were excluded from the risk prioritisation exercise.)

## 7.5 Data Types

The inventory consists of two components: i) GIS coverages of lake centroids and catchment boundaries (available as ArcView shape files or MapInfo files) and ii) an Access database containing all derived attribute data, referenced by water body ID. The attribute data are summarised in Table 6 and documented fully in Appendix 1, along with details of the available queries. All data and documentation are currently available for download from a secure server (<http://ecrc.geog.ucl.ac.uk/gblakes>). The database can be downloaded in either Microsoft Access97 or Access2000 formats. Information on data coverage and quality are given in Appendix 2.

**Table 6 List of data available in the lakes inventory**

Data available for lake centroids	Data available for catchments
Agency (EA/SEPA) Region co-occurrence	LCM90 Landcover class (Fuller <i>et al</i> , 1994)
1995-97 Acid Deposition (CEH)	Drift Geology (1:625,000)
Freshwater Sensitivity (CEH)	Solid Geology (1:625,000)
Protected areas co-occurrence (includes National Park, Forest Park, National Nature Reserve (NNR), RAMSAR , Special Area of Conservation (SAC), Special Protection Area (SPA), Site of Special Scientific Interest (SSSI))	1995-97 Acid Deposition (CEH)
EN Character Area co-occurrence	Freshwater Sensitivity (Hornung <i>et al</i> , 1995)
EN Natural Area co-occurrence	Animal stocking density (MAFF)
OS Landranger Map sheet	Modelled hindcast P load (Johnes <i>et al</i> , 2000)
	Modelled current P load
	1991 Population - SURPOP91 (Bracken and Martin, 1995)
	Mean annual runoff (CEH)

The inventory contains 43,738 water bodies in England, Scotland, Wales and Isle of Man. A breakdown of distribution by surface area and country is given in Table 7. The majority of water bodies in each country have a surface area smaller than 1 hectare with less than 10% having a surface area larger than 10 hectares. The total surface area of standing waters in the inventory is 213,911 hectares, covering approximately 1% of the land surface of Great Britain.

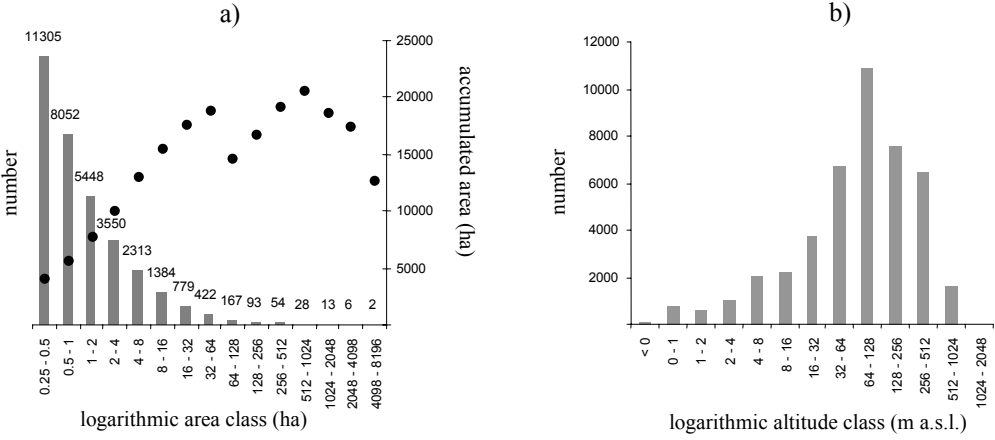
**Table 7 The distribution of lakes by surface area (ha) and country**

	≤1 ha*	>1 to ≤5 ha	>5 to ≤10 ha	>10 to ≤50 ha	>50 to ≤100 ha	>100 ha	Total
England	10765	4233	710	625	64	51	16448
Scotland	17748	5273	1195	1205	168	171	25760
Wales	894	394	88	90	10	17	1493
Isle of Man	26	9	0	2	0	0	37

\* the dataset contains no water bodies < 0.02 ha and the number between 0.02 and 0.2 are almost certainly under-represented

In their survey of Scottish lochs Smith and Lyle (1979) grouped water bodies larger than 25 hectares into logarithmic area classes to investigate the relationships between numbers of lochs, accumulated area and volume. They found that there was a natural order in the frequency of occurrence based on surface area, which is confirmed by the present study. The

relationship between numbers of water bodies and accumulated areas for logarithmic area classes is shown in Figure 9a and shows that although the number of water bodies increase as the logarithmic area class decreases, the accumulated area decreases, something which Lyle and Smith (1994) predicted but were unable to demonstrate with their dataset.



**Figure 9** a **Numbers of water bodies (grey bars) and accumulated areas (black dots) for logarithmic area classes;**  
 b **Numbers of water bodies for logarithmic altitude classes**

Table 8 and Figure 9b show the distribution of water bodies by altitude and country and by logarithmic altitude class, respectively. Here there are two different distributions influenced by topography: England with the majority of its water bodies at lower altitudes and Scotland and Wales with the majority at slightly higher altitudes. In terms of the Water Framework Directive ‘System A’ ecotype altitude classes, 75.8% of water bodies (by number) occur in the lowland ecotype (<200 m), 23.8% in the mid-altitude ecotype (200-800 m) and the remaining 0.4% in the highland ecotype (>800 m).

**Table 8 Numbers of water bodies by country and altitude (metres above sea level)**

	<10	10 to <50	50 to <100	100 to <300	300 to <500	500 to <750	≥750
England	2686	4826	4757	3866	245	66	2
Scotland	1828	4651	4481	9001	4205	1327	267
Wales	183	180	213	468	345	102	2
Isle of Man	4	21	2	10	0	0	0

**7.6 Meta-data**

The inventory was linked to external databases using a meta-data system. Table TBL\_MD in the inventory database contains a list of water body IDs with a meta-data code. This code refers to external databases such as the JNCC Standing Waters database, which contains macrophyte and some water chemistry data or the CLAG Critical Loads database which contains water chemistry and critical load calculations. Another table (KEY\_MD) contains details about the meta-datasets such as availability, type of data, published references etc. There are more than 8900 entries in the meta-data table; the majority of these refer to the JNCC and CLAG meta-datasets, although there are currently 17 meta-datasets included. The database also contains a table with summary water chemistry data from some of these external

databases (TBL\_SUMM). There are currently 470 entries for 399 water bodies including data on pH, conductivity, total phosphorus (TP) and alkalinity, many of which are annual means. It is hoped that both meta-data and summary data can be added in the future as and when data become available.

During the lake naming exercise, there was the opportunity to gather additional information from features on the 1:50,000 map, e.g. whether or not the lake is in a quarry or whether the catchment is forested. Despite its subjectivity, such information was entered into a Microsoft Access2000 database. Unfortunately time restrictions meant that the additional information fields were incomplete at the time of writing and for this reason the Access database has not been incorporated into the main database. The data are provided as an additional output of the project as an Access2000 database on CD-ROM and details of the data fields are given in the Project Record (Bennion *et al.*, 2003).

## **7.7 Lake Typology**

The WFD requires that Member States characterise lakes into ecotypes according to one of two methodologies, either system A or B, which differentiate lakes according to a set of key descriptors. In both systems, typology needs to include, altitude, depth, size and geology. This project has collated information required to develop such a lake typology and, although not one of the original aims, a preliminary exploratory analysis of the data was performed during Phase 2. The lakes >1 ha were classified into broad types using a neural network which essentially finds the optimal way of mapping data points into a specified number of clusters. Six variables were initially used as descriptors: the System B obligatory criteria set out in WFD Annex II (altitude, size, depth, solid and drift geology) as well as one optional factor, freshwater sensitivity (as a surrogate for acid neutralising capacity). Latitude and longitude were not included in the analysis as they added nothing other than to tell us that there are lakes in England, Scotland and Wales.

The data analysis identified five broad clusters of sites: i) lakes which are large, deep, lie on siliceous geology and are highly sensitive to acidification - predominantly in the Scottish Highlands, southern Wales, Cumbria, and the Pennines with a few in south-west England, ii) lakes which are high, small, relatively deep, and highly sensitive to acidification with no peat in their catchments – in similar regions to those in (i) but differ in that they are at higher altitudes and are generally smaller, have less peat and higher percentage of calcareous geology in their catchments, iii) lakes of intermediate altitude, size and depth, with low sensitivity to acidification and low % peat - predominantly in the Midlands and northern England, south-west England, central and northern Wales, and central Scotland, iv) lakes which are lowland, small and shallow with low sensitivity to acidification - predominantly in lowland areas of south-east and eastern England, and southern Wales, v) lakes which are generally high, of intermediate size, relatively deep, and highly sensitive to acidification with high % peat – predominantly in upland areas of south-west England, Wales, the Pennines, Cumbria and Scotland, especially the far north-east. The lakes, however, formed a continuum rather than discrete lake types and it was agreed that more clusters were required to produce a workable typology.

In an attempt to improve upon the first analysis and to introduce more ecologically relevant descriptors, the analysis was subsequently re-run with the addition of Stratification Class and Fetch and with the number of specified clusters increased to 10. The results are given in the Project Record (Bennion *et al.*, 2003). In summary, this second analysis improved upon the

first but there were still concerns over whether a typology based on essentially physical descriptors had any ecological meaning. Furthermore, errors associated with the depth model resulted in lakes potentially being placed into the wrong class as the modelled depth data were used to derive a number of the descriptors such as maximum lake depth and Stratification Class. Further work is required, therefore, to develop a lake typology for the Great Britain ecoregion but once a system has been agreed, it could be introduced into the risk prioritisation protocol. For example, the importance assessment could be stratified by lake type to ensure full representation of all key ecotypes at Risk Tier 2.



## 8. SUMMARY AND RECOMMENDATIONS

This project has successfully developed and refined a three-tier, risk-based prioritisation system for lakes with respect to acidification and eutrophication and developed a georeferenced inventory of standing waters in Great Britain containing morphometric, use-related and summary meta-data. Application of the risk protocol to 30 lakes illustrates that the schemes for both eutrophication and acidification produce reliable risk assessments in most cases.

There are, however, a number of limitations and areas for improvement which should be addressed in future.

- i) Although not included in our test lake assessments, it is vital that local knowledge is incorporated into the prioritisation exercise at Risk Tiers 2 and 3 so that lakes with special local significance, which would not be identified with the normal Tier 1 assessment, can be incorporated into the Tier 2 assessment and if prioritised, the Risk Tier 3 assessment.
- ii) In the eutrophication scheme, modelled P loads currently exclude animal data owing to the absence of livestock data in a suitable format for Scotland. This results in potential underestimates of P loads for many water bodies. We recommend that animal data are incorporated into the calculations once they become available for Scotland. Further, where point sources of nutrients from consented discharges are known, for example fish cage units, we recommend that these also be included.
- iii) There are reasonably large errors associated with the lake depth models used to derive mean and maximum depth for lakes where measured data are lacking. We recommend that the depth models are further developed and refined, and efforts are made to collect more measured depth data in future.
- iv) In several cases catchment-derived attribute data for certain lakes were suspect, leading to an incorrect risk assessment. Closer inspection revealed that the catchment delineation process had failed to produce an accurate watershed for the lake concerned. The majority of these ‘errors’ occur when a small water body is close to a large river. The cell that gets selected as the pour point for the catchment is the one with the highest accumulated flow and if a lake cell coincides with a river cell then the river catchment will actually be computed. In the risk assessment protocol this leads to a small water body being erroneously attributed large nutrient and acid loads. Another type of error that may occur is poor catchment delineation in areas of low relief – such as in the Fens. The vertical resolution of the DTM is insufficient in these cases to allow the accurate mapping of a lakes catchment. A confounding factor in these areas is that lake catchments are often determined by man-made drainage features, which are not represented in the DTM. Clearly, these lowland water bodies represent a challenge. Higher resolution digital surface models (DSM’s) from LiDAR data could be used as a means to more accurately delineate their catchments. We recommend that catchments are checked locally where possible and that a method for revising and updating catchments where necessary, is considered.
- v) The inventory does not currently allow heavily modified waters to be identified. For WFD purposes, we recommend that a method for separating these from other water

bodies is considered in future. For example, it would be possible to identify lakes with a long straight side, which probably highlights a dam, and check at least the largest ones against a map. Additionally, the county councils keep a register of all water bodies which have dams and store water above the ordnance datum, as well as registers of flooded quarries and gravel extractions.

- vi) Currently the importance assessment considers only one of the major statutory designations (in addition to conservation status), i.e. Bathing Waters Directive. We advise that further statutory designations be added in future as data become available, particularly with regard to the Surface Water Abstraction Directive and the Fisheries Directive.
- vii) A scoring system to assess the relative importance of sites requires further development. A simple count of the number of importance factors attributed to each lake is proposed. In order to do this, however, one would need to ensure that there was no double counting. New work would require making some rules about how to add scores together.
- viii) The Wederburn depth is a good starting point for modelling stratification class and thus for assessing sensitivity to restoration in the eutrophication protocol. However, we recommend that the modelled data are validated against measured values and that the class boundaries are modified accordingly. A further class could be added for shallow lakes where sediment is continually resuspended, following a different equation.
- ix) Further work, using data from low and medium P loaded lakes with high retention times, is required to clarify the criteria for passing lakes through the second sensitivity assessment of eutrophication risk at Risk Tier 1.
- x) Since rehabilitation management is most effective for deep lakes, the method assumes that rehabilitation of shallow lakes with high risk of eutrophication damage is not an option to be followed. Further work should be carried out to define the selection criteria at this point more clearly, since rehabilitation can work in these systems but recovery may take decades to be achieved. Indeed one might argue that restoration at such sites should receive urgent priority because recovery may be slow.
- xi) The inventory provides an invaluable resource for assisting with the characterisation of river basins in Great Britain and highlighting the range of pressures that occur in various lake typologies. Whilst this project involved a preliminary analysis of the data, a lake typology clearly urgently requires further development.
- xii) This project does not attempt to quantify relationships between pressure and response. However, there is clearly scope to build on the scheme developed here to establish such relationships. These could be used to set site- or type- specific boundaries for assessments of pressure which have a quantified link to various levels of ecological quality.
- xiii) Chapter 7 introduced some of the problems arising from the use of PANORAMA data as the inventory data source. A new OS dataset, still in development during the early stages of this project, is now available called MasterMap – the definitive digital map

database for the UK, developed through the Digital National Framework (DNF) project. Potentially, this dataset could provide detailed data on the location of water bodies, including those smaller than 0.0025ha (5m x 5m), but data costs could be prohibitive. The use of MasterMap for mapping water bodies needs to be investigated further.

- xiv) The data in the database will be continually increased and updated. A mechanism for storing and updating the data must be instigated.
- xv) Access to the inventory is currently restricted to project partners via the website (file download). Users will require a good working knowledge of Microsoft Access as there are no graphical user interfaces and only a few ready-made queries. A prototype web-based query interface has been tested and seems to be a good method for making data available whilst ensuring it is current. This could be easily expanded to meet the needs of users and the public; indeed summary data should be made available to the public in any case. However, such a system would need maintaining and managing and the Agency must consider how this is to be done.





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## GLOSSARY OF TERMS AND ABBREVIATIONS

**Acid neutralising capacity (ANC).** Ability of a natural water to buffer the effects of loading of strong acid ions, usually from atmospheric sources, thus preventing severe decrease in pH.

**Acidification.** Reduction in pH value (increase in hydrogen ion concentration) in a natural water.

**Acid sensitive.** Waters which have a naturally low pH and low concentrations of base cations and thus a low potential acid neutralising capacity.

**Algae.** General term applied to photosynthetic organisms that are generally aquatic, may be microscopic or very large (e.g. seaweeds), and may be floating or attached.

**ArcView.** GIS software package from ESRI.

**Baseline state.** A reference condition of an ecosystem with which the current condition can be compared and hence the degree of deviation or change determined.

**Biodiversity (Biological diversity).** The variety of life, as indicated by the number of species present.

**Biomass.** Total quantity or weight of organisms in a given area or volume - e.g. algal biomass.

**Blue-green algae (cyanobacteria).** Group of largely microscopic, photosynthetic organisms with a bacterial structure, but containing chlorophyll a and a photosynthetic biochemistry unlike other bacteria but similar to that of other algae and higher plants.

**Catchment.** Area drained by a river or a river system.

**Chlorophyll a.** The major photosynthetic pigment of algae and plants.

**Diatoms.** Group of brown or yellow coloured algae commonly found in natural waters. The cell wall is made of polymerised silicate which is readily preserved in sediments when the organic part of the organism decays.

**Diffuse source.** Supplies of nutrients or other pollutants that come from a myriad of small-sized locations.

**Ecotype.** A water body type as defined using either system A or system B descriptors identified in the Water Framework Directive.

**Environmental risk.** A combination of the probability of occurrence of a defined hazard and the magnitude of the consequences of the occurrence; that is in simple terms, the likelihood of suffering harm from a hazard.

**Eutrophic.** A description of water which is rich in nutrients and is highly productive.

**Eutrophication.** The enrichment of water, by inorganic plant nutrients, which results in the stimulation of an array of symptomatic changes. These include the increased production of algae and/or other aquatic plants, affecting the quality of the water and disturbing the balance

of organisms present within it. Such changes may be undesirable and interfere with water uses (Environment Agency, 2000).

**Export coefficient model.** Technique for calculating nutrient loadings and concentrations in a stream or lake from a knowledge of land use, numbers of stock and number of people in the catchment, stream discharge and the rates at which the nutrients are leached or excreted from the various sources.

**Fetch.** Distance (from shore to shore in a given direction) of open water surface over which the wind can blow uninterrupted to create waves.

**Harm.** The damage or adverse effect resulting from a hazard.

**Hazard.** A property or situation that in particular circumstances could lead to harm.

**Hindcasting.** The process of estimating the state of a waterbody at a given point in the past, in the absence of appropriate baseline water quality data. This is achieved by considering natural catchment characteristics e.g. morphology, geology and soil type, and historic records of land-use, or by the assessment of past diatom communities preserved in the lake sediment.

**Hypertrophic.** A description of water which is extremely nutrient-enriched, and typically affected by heavy growth of algae and other water plants.

**Importance.** The value (both non-monetary and monetary) which society in general attaches to a lake in respect to its chemical and ecological quality.

**Inventory of standing waters.** A list of all lakes or reservoirs (fresh standing waters) in Great Britain contained in the 1:50 000 Ordnance Survey Panorama digital dataset (1993) along with basic physical data.

**Lake.** Any standing water body contained in the 1:50 000 Ordnance Survey Panorama digital dataset. Catchment boundaries and related data for standing waters of less than 1 hectare are not included within the inventory.

**Limiting Nutrient.** Nutrient in an ecosystem which is in short supply relative to demand, and can thus inhibit efficient and productive ecological development.

**Macrophyte.** Any plants large enough to be seen with the naked eye, including all higher aquatic plants, together with macroscopic algal species that typically form mats or dense growths.

**Mesotrophic.** A description of water which is of medium nutrient status and medium biological productivity (between oligotrophic and eutrophic).

**MIMAS.** Manchester Information and Associated Services - national data centre providing the UK higher education, further education and research community with networked access to key data.

**National Biodiversity Network.** A union of likeminded organisations that are collaborating to create an information network of biodiversity data that is accessible through the Internet.

**National Nature Reserve (NNR).** Land declared under the National Parks and Access to the Countryside Act 1949 or Wildlife and Countryside Act (1981).

**Nutrient.** Substance providing nourishment for plants (or animals) e.g nitrogen, phosphorus, silicon, potassium, etc.

**Nutrient export coefficient.** A measure of the nutrient loss from a specific land use, typically measured as  $\text{kg ha}^{-1}\text{yr}^{-1}$

**Oligotrophic.** A description of water which has a low nutrient status and low biological productivity.

**Orthophosphate.** A fraction of phosphorus, often approximately equated to Soluble Reactive Phosphorus, as measured by the molybdenum blue assay on a filtered sample. (If the determination is carried out on an unfiltered sample, the fraction measured is Total Reactive Phosphorus).

**OS.** Ordnance Survey, UK National Mapping Agency.

**Palaeolimnology.** The science that studies lake histories based on analysis of biological, chemical and physical characteristics of lake sediments.

**PANORAMA.** Ordnance Survey's Digital Height Dataset with data available as vectorised contours (at 10m vertical intervals).

**Phytoplankton.** Community of largely microscopic algae suspended or floating in natural waters. Most species are denser than water and tend to sink, but are maintained in suspension by wind-generated water currents.

**Point source.** Supplies of nutrients or other pollutants that come from discrete, identifiable, comparatively large origins (e.g sewage treatment works).

**Pristine state.** Nature of an ecosystem that is not influenced by any human activity, or at least by technologically sophisticated activity.

**PROTECH.** A universal model of phytoplankton dynamics in lakes based on fundamental ecological and physiological equations. It is able to test lake system sensitivity and quantify the impacts of change.

**RAMSAR site.** Land listed as a Wetland of International Importance under the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention) 1973.

**Retention time.** The period on average in which a parcel of water is retained in a lake. Retention time is the reciprocal of replacement rate, also called hydraulic flushing rate.

**Sensitivity.** The degree to which a lake responds to external factors such as exposure to, or removal of, a hazard.

**Site of Special Scientific Interest (SSSI).** An area given a statutory designation by English Nature or the Countryside Council for Wales (under the Wildlife and Countryside Act, 1981) because it is particularly important, on account of its nature conservation value.

**Special Area of Conservation (SAC).** An area designated for protection as part of the Natura 2000 network in the 1992 EC Habitats Directive (92/43/EEC), because it supports rare, endangered or vulnerable natural habitats and species of plants and animals.

**Special Protection Area (SPA).** Land classified under Directive 79/409 on the Conservation of Wild Birds.

**SURPOP.** Population estimates for 200 m cells derived from the 1981 Census of Population in England, Wales and Scotland, and the 1991 Census in England, Wales, Scotland and Northern Ireland.

**SWAD.** Surface Water Abstraction Directive.

**Total Phosphorus.** The sum of dissolved and particulate phosphorus (water) fractions.

**Transfer function.** A predictive equation based on the relationship between modern biological assemblages and contemporary environmental data for a set of lakes. It is used to infer a selected environmental variable from fossil assemblages in sediment cores.

**Trophic state.** The category of a water in relation to the process of eutrophication, typically assessed on the basis of nutrient and chlorophyll concentrations, and transparency. Waters have traditionally been classified into five trophic states: ultra-oligotrophic; oligotrophic; mesotrophic; eutrophic; and hypertrophic (see individual definitions).

**Ultra-oligotrophic.** A description of water with extremely low nutrient availability for the growth of algae or other plants.

**Water Framework Directive (WFD).** Directive of the European Parliament and of the Council 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy (European Union, 2000).

## REFERENCES

- Barr C J, Howard D C and Benefield C B (1994). Countryside Survey 1990. Inland Water Bodies. Department of the Environment, London (Countryside 1990 Series).
- Battarbee R W, Allott T E H, Juggins S, Kreiser A M, Curtis C and Harriman R (1996). Critical loads of acidity to surface waters – an empirical diatom-based palaeolimnological model. *Ambio*, 25, 366-369.
- Bennion H (1994). A diatom-phosphorus transfer function for shallow, eutrophic ponds in south-east England. *Hydrobiologia*, 275/6, 391-410.
- Bennion H, Juggins S and Anderson N J (1996a). Predicting epilimnetic phosphorus concentrations using an improved diatom-based transfer function and its application to lake eutrophication management. *Environmental Science and Technology*, 30, 2004-2007.
- Bennion H, Duigan C A, Haworth E Y, Allott T E H, Anderson N J, Juggins S and Monteith D M (1996b). 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.
- Bennion H, Monteith D T and Appleby P G (2000). Temporal and geographical variation in lake trophic status in the English Lake District: evidence from (sub)fossil diatoms and aquatic macrophytes. *Freshwater Biology*, 45, 394-412.
- Bennion H, Hilton J, Carvalho L, Clark J, Curtis C, Hughes M, Phillips G and Reynolds C (2001) Development of a georeferenced based inventory of standing waters for England and Wales, together with a risk based prioritisation protocol – Phase 1. R&D Interim Technical Report P2-239/TR1, pp 40.
- Bennion H, Clark J., Simpson G. & Hughes, M. (2003). Development of a risk based prioritisation protocol for standing waters in Great Britain based on a georeferenced inventory– Phase 2. R&D Project Record P2-260/2/PR1.
- Bracken I. and Martin D (1995). Linkage Of The 1981 And 1991 UK Censuses Using Surface Modelling Concepts. *Environment and Planning A*, 27, 379-390.
- Curtis C J, Allott T E H, Hughes M, Hall J, Harriman R, Helliwell R, Kernan M, Reynolds B and Ulliyett J (2000) Critical loads of sulphur and nitrogen for fresh waters in Great Britain and assessment of deposition reduction requirements with the First-order Acidity Balance (FAB) model. *Hydrology and Earth System Sciences*, 4, 125-140.
- Department of the Environment, Transport and the Regions (DETR) (2000). *Guidelines for Environmental Risk Assessment and Management*. Revised Departmental Guidance. <http://www.environment.detr.gov.uk/eramguide/>.
- Edmunds W M and Kinniburgh D J (1986). The susceptibility of UK groundwaters to acidic deposition. *J. Geol. Soc.*, 143, 707-720.



Environment Agency (2000). *Aquatic eutrophication in England and Wales: a management strategy*. Environmental Issues Series, Environment Agency, Bristol.

European Union (2000). Directive of the European Parliament and the Council 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy. Luxembourg.

Ferrier R C, Owen R, Edwards A C, Malcolm A and Morrice J G (1997). Hindcasting of phosphorus concentrations in Scottish standing waters. In Boon, P.J. and D. L. Howell (eds.) *Freshwater Quality: Defining the Indefinable?*, pp. 144-148., HMSO, Edinburgh.

Flower R J and Battarbee R W (1983) Diatom evidence for recent acidification of two Scottish lochs. *Nature*, 305, 130-133.

Flower R J, Juggins S J and Battarbee R W (1997). Matching diatom assemblages in lake sediment cores and modern surface sediment samples: the implications for conservation and restoration with special reference to acidified systems. *Hydrobiologia*, 344, 27-40.

Fozzard I R, Doughty C R, Ferrier R C, Leatherland T M and Owen R (1999). A quality classification for management of Scottish standing waters. *Hydrobiologia*, 395/396: 433-453.

Fuller R M, Groom G B and Jones A R (1994). The Land Cover Map of Great Britain: an automated classification of Landsat Thematic Mapper data. *Photogrammetric Engineering and Remote Sensing*, 60, 553-562.

Haines-Young R H, Barr C J, Black H I J, Briggs D J, Bunce R G H, Clarke R T, Cooper A, Dawson F H, Firbank L G, Fuller R M, Furse M T, Gillespie M K, Hill R, Hornung M, Howard D C, McCann T, Morecroft M D, Petit S, Sier A R J, Smart S M, Smith G M, Stott A P, Stuart R C and Watkins J W (2000). *Accounting for nature: assessing habitats in the UK countryside*. DETR, London.

Henriksen A, Kamari J, Posch M and Wilander A (1992). Critical loads of acidity: Nordic surface waters. *Ambio*, 21, 356-363.

Hilton J, Irons G P and McNally S (1999) Pilot Catchment Study of Nutrient Sources – Control Options and Costs. pp.107. Environment Agency. Technical Report P345.

Hornung M, Bull K R, Cresser M, Ullyet J, Hall, J R, Langan S D and Loveland P J (1995). The sensitivity of surface waters of Great Britain to acidification predicted from catchment characteristics. *Environmental Pollution*, 87, 207-214.

Jenkins A, Whitehead P G, Cosby B J and Birks H J B (1990). Modelling long-term acidification: a comparison with diatom reconstructions and the implications for reversibility. *Philosophical Transactions of the Royal Society of London series B*, 327, 209-214,

Jenkins A, Renshaw M, Helliwell R, Sefton C, Ferrier R and Swingewood P (1997). *Modelling surface water acidification in the UK. Application of the MAGIC model to the Acid Waters Monitoring Network*. IH Report No. 131. Institute of Hydrology, Wallingford.

Johnes P J, Moss B and Phillips G L (1996). The determination of water quality by land use, livestock numbers and population data – testing of a model for use in conservation and water quality management. *Freshwater Biology*, 36, 451-473.

- Johnes P J, Curtis C, Moss B, Whitehead P, Bennion H and Patrick S (2000) *Trial classification of lake water quality in England and Wales: a proposed approach*. Research and Development Technical Report E53. Environment Agency, Bristol: 80 pp.
- Jones V J, Flower R J, Appleby P G, Natkanski J, Richardson N., Rippey B, Stevenson A C and Battarbee R W (1993). Palaeolimnological evidence for the acidification and atmospheric contamination of lochs in the Cairngorm and Lochnagar areas of Scotland. *Journal of Ecology*, 81, 3-24.
- Lyle A A and Smith I R (1994). Standing Waters. In *The Fresh Waters of Scotland* (Maitland P.S., Boon P.J. and McLusky D.S. eds.), John Wiley and Sons.
- Morris D G and Flavin R W (1990). A Digital Terrain Model for Hydrology. Proc 4<sup>th</sup> International Symposium on Spatial Data Handling, Vol 1, July 23-27 Zurich, pp 250 – 262.
- Moss B, Johnes P and Phillips G (1996). The monitoring of ecological quality and the classification of standing waters in temperate regions: a review and proposal based on a worked scheme for British waters. *Biological Reviews*, 71, 301 – 339.
- Murray J and Pullar L (1910). *Bathymetrical Survey of the Fresh Water Lochs of Scotland*. Challenger Office, Edinburgh.
- OECD (1982). *Eutrophication of waters, monitoring, assessment and control*. Organisation for Economic Co-operation and Development, Paris.
- Ordnance Survey (2001). *Land-Form PANORAMA User Guide v3.0*. Ordnance Survey, Southampton.
- Palmer M A, Bell S L and Butterfield I. (1992) A botanical classification of standing waters in Britain: applications for conservation and monitoring. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 2, 125-143.
- Pollard S, Duarte-Davidson R, Yearsley R, Twigger-Ross C, Fisher J, Willows R and Irwin J (2000). *A Strategic Approach to the Consideration of Environmental Harm*. NCRAOA, Report Number 36.
- Ratcliffe D A (1977). *A Nature Conservation Review*. Cambridge University Press, Cambridge.
- Reynolds C S (1992) Dynamics, selection and composition of phytoplankton in relation to vertical structure in lakes. *Arch Hydrobiol. Beih. – ergrbn. Limnol.*, 35, 13-31.
- Reynolds C S and Irish A E (1997). Modelling phytoplankton dynamics in lakes and reservoirs: the problem of in-situ growth rates. *Hydrobiologia*, 349, 5-17.
- Sayer C, Roberts N, Sadler J, David C and Wade P M (1999). Biodiversity changes in a shallow lake ecosystem: a multi-proxy palaeolimnological analysis. *Journal of Biogeography*, 26, 97-114.

Smith I R and Lyle A A (1979). Distribution of Freshwaters in Great Britain. Institute of Terrestrial Ecology, Edinburgh.

Stevenson A C, Juggins S, Birks H J B, Anderson D S, Anderson N J, Berge F, Davis R B, Flower R J, Haworth E Y, Jones V J, Kingston J C, Kreiser A M, Line J M, Munro M A R and Renberg I (1991). *The Surface Waters Acidification Project Palaeolimnology Programme: Modern Diatom/Lake-water Chemistry Data-set*. ENSIS Publishing, London, 86pp.

Tipping E (1998) Humic ion-binding model VI: An improved description of the interactions of protons and metal ions with humic substances. *Aquatic Geochemistry*, 4, 3-48

Vollenweider R A (1968). *Scientific fundamentals of eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication*. OECD, Paris.

Vollenweider R A and Kerekes J (1980). The loading concept as basis for controlling eutrophication philosophy and preliminary results of the OECD programme on eutrophication. *Progress in Water Technology*, 12(2), 5 – 38.

## APPENDIX 1

### GB LAKES DATABASE PROJECT DOCUMENTATION

The current version (2.1) of the GB Lakes Database exists as a Microsoft Access database containing 79 tables and 44 queries. The structure of these tables and queries is described below. Use the index to find the relevant section.

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### TBL\_WB - Water Body ID's

**Description:** Internal GIS ID's for water body polygons.

**Coverage:** Record for every water body in the database (43738).

**Data source:** Ordnance Survey PANORAMA dataset.

**Notes:** WBID field used to link tables within database and to external databases using lookup tables. Note that numbers are not consecutive.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID

### TBL\_LD - Water Body Details

**Description:** List of water body ID's (WBID) and associated physical data.

**Coverage:** Records for every water body (43738).

**Data source:** OS PANORAMA dataset.

**Method:** The original dataset required a large amount of pre-processing in ArcInfo to obtain these data - see additional notes.

**Notes:** WBID is used throughout the database to link tables and is unique to this database. These ID's are not consecutive numbers since the island polygon ID's were originally included but have now been stored in a separate table (TBL\_ID).

**Link:** <http://www.ordnancesurvey.gov.uk/productpages/landformpanorama/>

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
WBEAST	LONG INT	Easting of water body centroid
WBNORTH	LONG INT	Northing of water body centroid
WBALT	LONG INT	Altitude of water body in metres
WBSAREA	DBL	Surface area of water body in hectares
WBPERIM	LONG INT	Perimeter of water body in metres

### TBL\_GR - Grid Reference

**Description:** 100km grid square letter code with 6 and 8 figure grid references (100m and 10m respectively) for each water body centroid.

**Coverage:** Records for every water body (43738).

**Data source:** Water body centroids

**Method:** Calculated in Microsoft Excel using centroid coordinates.

**Notes:** Also given is the 1:10,000 map sheet name.

**Link:** <http://www.ordnancesurvey.co.uk/products/natgrid/nghelp1.html>

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
OS100M	TEXT 10	6 figure grid reference based on water body centroid
OS10M	TEXT 10	8 figure grid reference based on water body centroid
OS10KMAP	TEXT 10	1:10,000 map sheet on which water body centroid falls

### TBL\_LL - Geographic Coordinates

**Description:** Latitude and longitude in decimal degrees, to 5 decimal places.

**Coverage:** Records for every water body (43738).

**Data source:** Water body centroids.

**Method:** OSBG36 --> WGS84 (ETRS 89) conversion using Grid InQuest freeware. Uses the Ordnance Survey OSTN97 datum transformation model and the OSGM91 geoid model.

**Link:** <http://www.geodetic-solutions.com/>

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
WBLAT	DBL	Latitude of centroid in decimal degrees
WBLON	DBL	Longitude of centroid in decimal degrees

### **TBL\_OS - Ordnance Survey Landranger Map**

**Description:** Ordnance Survey 1:50,000 Landranger map sheet number on which water body centroid occurs.

**Coverage:** Records for every water body (43738).

**Data source:** OS Map Index (ECRC) and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Since this is based on water body centroid it is possible that part of a water body may occur on adjacent map sheets. Where a water body centroid falls on the overlapping sections of one or more maps only one sheet number is given for simplicity. OS mapcode (OSID) links to KEY\_OS.

**Link:** [http://www.ordnancesurvey.gov.uk/products\\_new/Landranger/](http://www.ordnancesurvey.gov.uk/products_new/Landranger/)

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID
OSID	LONG INT	Unique OS map ID

### **KEY\_OS - Key to TBL\_OS**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
OSID	LONG INT	Unique OS map ID
OSMAP	TEXT 50	1:50,000 OS map name

### **TBL\_UK - UK District Co-occurrence**

**Description:** UK district in which water body centroid occurs.

**Coverage:** Records for every water body (43738).

**Data source:** Digital boundaries supplied by EA and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** UK district code (UKID) links to KEY\_UK. Data derived from multiple coverages provided by EA - includes latest boundary changes and new Welsh administrative regions.

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID
UKID	LONG INT	UK District ID in which water body centroid occurs - relates to KEY_UK

### **KEY\_UK - Key to TBL\_UK**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
UKID	LONG INT	UK District ID
UKNAME	TEXT 50	District name
ADMINID	TEXT 5	District type ID - relates to KEY_UKA
UKCOUNTY	TEXT 50	County name
UKCNTRY	TEXT 20	Country name
UKCODE	TEXT 10	UK District code

### **KEY\_UKA - Key to KEY\_UK**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
ADMINID	TEXT 10	District type ID
ADMINDES	TEXT 70	District type description



### TBL\_NAME - Water Body Name

**Description:** Water body name as appears on OS 1:50,000 map.

**Coverage:** 6642 records.

**Data source:** OS 1:50,000 map as appears on streetmap.co.uk website (2002).

**Method:** Microsoft Access / Web browser.

**Notes:** All lakes > 1ha have been included where a name exists for them on the map and a selection of lochs < 1ha are also included. Gaelic names with accents are given for Scotland. Where a name applies to more than one water body then the name is given more than once in the database.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
OSNAME	TEXT 50	Name as appears on 1:50,000 Ordnance Survey map
OSCOMMENT	TEXT 255	Comment, includes other loch names associated with polygon

### TBL\_NAM2 - Water Body Alternative Name

**Description:** Alternative Water body name.

**Coverage:** 1841 records.

**Data source:** See altnsrc field.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
ALTNAME	TEXT 100	Alternative name
ALTNSRC	TEXT 100	Alternative name source

### TBL\_FT - Maximum Fetch

**Description:** Start and finish coordinates, length in metres and bearing of lines of maximum fetch for each water body.

**Coverage:** Records for every water body (43738).

**Data source:** Water body polygons from OS Panorama data.

**Method:** Calculated using ArcView 'Longest Straight Line' script.

**Link:** [http://www.jennessent.com/arcview/arcview\\_extensions.htm](http://www.jennessent.com/arcview/arcview_extensions.htm)

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
FETX1	DBL	Start easting of fetch line
FETY1	DBL	Start northing of fetch line
FETX2	DBL	End easting of fetch line
FETY2	DBL	End northing of fetch line
FETDIST	DBL	Distance of fetch line in metres
FETBNG	DBL	Bearing of fetchline (0 to 180 degrees)

### TBL\_DS - Nearest Distance to Sea

**Description:** Nearest distance from water body perimeter to sea in metres.

**Coverage:** Records for every water body (43738).

**Data source:** Ordnance Survey PANORAMA data and water body centroids.

**Method:** Calculated using ArcView 'Nearest Features' script.

**Link:** [http://www.jennessent.com/arcview/arcview\\_extensions.htm](http://www.jennessent.com/arcview/arcview_extensions.htm)

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
D2CX	DBL	Easting of point on water body nearest coast
D2CY	DBL	Northing of point on water body nearest coast
NRDIST2C	DBL	Distance from nearest edge to nearest coastline arc in metres
D2CBNG	DBL	Bearing to nearest coastline arc in degrees

### TBL\_AD - Average Distance to Sea

**Description:** Distance from water body centroid to sea in metres.

**Coverage:** Records for every water body (43738).

**Data source:** Ordnance Survey PANORAMA coast line and water body centroids.

**Method:** Calculated using ESRI ArcInfo NEAR function.

**Notes:** See also TBL\_DS - nearest distance to sea.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
AVDIST2C	DBL	Distance in metres of water body centroid to nearest coastline arc

### TBL\_DP - Depth data

**Description:** List of water bodies for which some data is known about depth or volume.

**Coverage:** There are 967 records (with data for one or more parameter), 953 of which are attributable to water bodies in the database.

**Data source:** Various.

**Notes:** Some water bodies have multiple entries.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
SRCNAME	TEXT 50	Name given by source
SRCCODE	TEXT 20	Site code given by source
MNDEP	DBL	Mean depth (m)
MXDEP	DBL	Maximum depth (m)
VOL	DBL	Volume (x 10 <sup>6</sup> m <sup>3</sup> )
RET	DBL	Retention time (days)
SOURCE	TEXT 20	Source of data

### TBL\_MDP - Measured and Modelled Depths

**Description:** Measured and modelled mean and max depths.

**Coverage:** All water bodies with catchments except Isle of Man (14342).

**Data source:** Measured values (see TBL\_DP) and modelled values.

**Notes:** Contains measured values from TBL\_DP where possible.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
MNDP	DBL	Mean depth in metres, has been limited to a minimum 0.05m
MNDPMETH	TEXT 20	Modelled or measured? if measured see TBL_DP for source
MXDP	DBL	Max depth in metres, has been limited to a minimum 0.1m
MXDPMETH	TEXT 20	Modelled or measured? if measured see TBL_DP for source

### TBL\_VOL - Volume

**Description:** Water body volume (m<sup>3</sup>) derived from mean depth and surface area.

**Coverage:** Record for every water body in the database with catchment except those on Isle of Man (14342).

**Data source:** TBL\_MDP and TBL\_LD.

**Notes:** This table can be updated by running the query MTB\_VOL which is a make table query and gets any new values from table the TBL\_MDP. The volume is an estimate based on mean depth which may be either modelled or measured (see TBL\_MDP).

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
VOL	DBL	Water body volume in m <sup>3</sup> (TBL_MDP:MNDP * TBL_LD:WBAREA * 10000)

### TBL\_STR - Stratification Index

**Description:** Stratification index.

**Coverage:** Record for every water body in the database with catchment (14353).

**Data source:** CEH.

**Notes:** The stratification class has been calculated based on fetch and maximum depth.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
STRCLASS	LONG INT	Modelled stratification class 1: <3m, 2: >3m mixed, 3: >3m stratified

### TBL\_SDI - Shoreline Development Index

**Description:** Shoreline Development Index for each water body.

**Coverage:** Records for every water body (43738).

**Data source:** Water body polygons.

**Method:** Calculated using Microsoft Excel.

**Notes:** Indicates complexity of shoreline - values range from 1 (approximating to a circular lake) upwards.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
SDI	DBL	Water body shoreline development index

### **TBL\_IS - Water Bodies with Islands**

**Description:** List of water body ID's with islands and number of islands.

**Coverage:** Records for 1306 water bodies.

**Data source:** Ordnance Survey PANORAMA dataset.

**Method:** Calculated using ArcInfo.

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID
ISCOUNT	LONG INT	Number of islands in water body

### **TBL\_ID - Island details**

**Description:** Internal GIS ID's and basic physical data for island polygons.

**Coverage:** Records for 2832 water bodies.

**Data source:** Ordnance Survey PANORAMA dataset.

**Method:** Calculated using ArcView.

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
ISID	LONG INT	Unique island ID
WBID	LONG INT	Unique water body ID to which island belongs
ISEAST	LONG INT	Easting of island centroid
ISNORTH	LONG INT	Northing of island centroid
ISALT	LONG INT	Altitude of island in metres
ISSAREA	DBL	Surface area of island in hectares
ISPERIM	LONG INT	Perimeter of island in metres

### **TBL\_AG - Agency Management Area Co-occurrence**

**Description:** Agency (Environment Agency, Scottish Environmental Protection Agency or Isle of Man) management area in which water body centroid occurs.

**Coverage:** Records for every water body (43738).

**Data source:** Digital boundaries supplied by the agencies and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Agency water management area ID relates to KEY\_AG. Some water body centroids were manually placed into areas since they fell just outside polygon boundaries.

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID
AGID	LONG INT	Agency water management area ID - relates to KEY_AG

### **KEY\_AG - Key to TBL\_AG**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
AGID	LONG INT	Agency water management area ID
AGNAME	TEXT 50	Agency name (EA, SEPA or IOM)
AGREGION	TEXT 50	Agency water management region / team
AGAREA	TEXT 50	Agency water management area
AGADDR1	TEXT 50	Agency address 1
AGADDR2	TEXT 100	Agency address 2
AGPCODE	TEXT 10	Agency postcode
AGTEL	TEXT 50	Agency telephone number
AGFAX	TEXT 50	Agency fax number

### **TBL\_RIV - River Basin Co-occurrence**

**Description:** A list of water bodies and their corresponding river catchment codes.

**Coverage:** Records for every water body (43738).

**Data source:** Digital boundary supplied by Environment Agency.

**Method:** Calculated using ArcView geoprocessing functions.

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID
BASINID	TEXT 10	River basin ID (derived from NAT_CODE for England and Wales - see KEY_RIV for more details, Hydrometric Area objectid code for Scotland, prefixed with SC to avoid confusion with certain English id's, IoM for Isle of Man)

### **KEY\_RIV - Key to TBL\_RIV**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
BASINID	TEXT 10	River basin id (NAT_CODE)
LOC_CODE	TEXT 10	Location code (England and Wales only)
NRA_REG	LONG INT	NRA region (England and Wales only)
REG_CODE	LONG INT	Region code (England and Wales only)

### **TBL\_FDIR - Fisheries Directive Co-occurrence**

**Description:** List of water bodies which are designated under EU Fisheries Directive.

**Coverage:** Records for 3631 water bodies.

**Data source:** Point and line datasets provided by EA / SEPA and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Many water bodies in England and Wales have been missed out because the agency point co-ordinates provided did not always exactly overlap the water body. Data provided for Scotland was higher quality since it consisted of lines rather than points.

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID

### **TBL\_BDIR - Bathing Waters Directive Co-occurrence**

**Description:** List of water bodies which are designated under Bathing Waters Directive.

**Coverage:** Records for 8 water bodies.

**Data source:** Environment Agency database and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID

### TBL\_NP - National Park Co-occurrence

**Description:** National Park in which water body centroid occurs.

**Coverage:** 1014 records.

**Data source:** Digital boundary supplied by EA.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** England and Wales only (No National Parks in Scotland).

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
NPID	LONG INT	National Park ID in which water body centroid falls - relates to KEY_NP

### KEY\_NP - Key to TBL\_NP

FIELD NAME	DATA TYPE	DESCRIPTION
NPID	LONG INT	National Park ID in which water body centroid falls - relates to KEY_NP
NPNAME	TEXT 50	National Park name

### TBL\_FP - Forest Park Co-occurrence

**Description:** List of water bodies which occur within Forest Parks.

**Coverage:** Records for 244 water bodies.

**Data source:** Bartholomews digital datasets (MIMAS) and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID

### TBL\_SPA - Special Protection Area Co-occurrence

**Description:** Lists water bodies whose centroid occurs within the boundaries of a Special Protection Area (SPA).

**Coverage:** 5775 records.

**Data source:** English Nature website (digital data download), SNH digital data, CCW digital data and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** SPA code (SPAID) links to KEY\_SPA. Note that some water bodies occur in SPA's with the same SPACODE but different SPAID's - this is because some SPA's are divided up into several components with the same SPACODE. Sometimes these components have separate names (SPACOMP).

**Link:** <http://www.jncc.gov.uk/idt/default.htm>

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body id
SPAID	LONG INT	Unique SPA id - relates to KEY_SPA

### KEY\_SPA - Key to TBL\_SPA

FIELD NAME	DATA TYPE	DESCRIPTION
SPAID	LONG INT	Unique SPA id
SPACODE	TEXT 12	SPA EU code (e.g. UK9009281)
SPANAME	TEXT 80	SPA name
SPACOMP	TEXT 80	SPA component name
SPADATE	TEXT 20	internal (EN) GIS date (England only)
SPAVERS	LONG INT	internal (EN) GIS version (England only)

### TBL\_NA - Natural Area Co-occurrence

**Description:** English Nature Natural Area in which water body centroid occurs.

**Coverage:** Records for 16447 water bodies (England only).

**Data source:** English Nature website (digital data download) and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Currently only exists for England. Natural Area code (NAID) links to KEY\_NA.

**Link:** [http://www.english-nature.org.uk/science/natural/na\\_search.asp](http://www.english-nature.org.uk/science/natural/na_search.asp)

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
NAID	LONG INT	Natural Area ID in which water body centroid occurs - relates to KEY_NA

### KEY\_NA - Key to TBL\_NA

FIELD NAME	DATA TYPE	DESCRIPTION
NAID	LONG INT	Natural Area ID
NANAME	TEXT 60	Natural Area description

### TBL\_CA - Character Area Co-occurrence

**Description:** Countryside Agency Character Area in which water body centroid occurs.

**Coverage:** Records for 16447 water bodies (England only).

**Data source:** English Nature website (digital data download) and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Classification only exists for England. Character Area code (CAID) links to KEY\_CA.

**Link:** [http://www.english-nature.org.uk/pubs/gis/tech\\_na.htm](http://www.english-nature.org.uk/pubs/gis/tech_na.htm)

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
CAID	LONG INT	Character Area ID in which water body centroid occurs - relates to KEY_CA

### KEY\_CA - Key to TBL\_CA

FIELD NAME	DATA TYPE	DESCRIPTION
CAID	LONG INT	Character Area ID
CANAME	TEXT 60	Character Area description

### TBL\_SSSI - Site of Special Scientific Interest Co-occurrence

**Description:** List of water bodies whose centroid occurs within the boundaries of a Site of Special Scientific Interest (SSSI).

**Coverage:** 6931 records.

**Data source:** English Nature website (digital data download) and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Note:** Currently, fields LEV1FEAT and LEV1DESC in KEY\_SSSI can be used to filter for SSSI's with aquatic features since the field is not null if there is an aquatic description.

**Link:** <http://www.english-nature.gov.uk/special/sssi/>

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
SSSIID	LONG INT	Unique SSSI ID- relates to KEY_SSSI

### KEY\_SSSI - Key to TBL\_SSSI

FIELD NAME	DATA TYPE	DESCRIPTION
SSSIID	LONG INT	Unique SSSI ID
SSSINAME	TEXT 80	SSSI Name
SSSIDES	TEXT 32	Designation status
ENSISID	LONG INT	Internal (EN) GIS id Sensitivity
SSSIDATE	TEXT 20	Internal (EN) GIS date
SSSIVERS	LONG INT	Internal (EN) GIS version
LEV1FEAT	TEXT 50	Internal (EN) GIS Level 1 Natural Feature Code (EN only)
LEV1DESC	TEXT 100	Internal (EN) GIS Level 1 Natural Feature Description / SNH Reporting category
LEV1NAME	TEXT 255	Internal (EN) GIS Level 1 Natural Feature Name / SNH Feature name
SSSIINFO	TEXT 255	Additional information (SNH only)

### **TBL\_SAC - Special Area of Conservation Co-occurrence**

**Description:** Lists water bodies whose centroid occurs within the boundaries of a Special Area of Conservation (SAC).

**Coverage:** 5382 records.

**Data source:** English Nature website (digital data download) and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** SAC code (SACID) links to KEY\_SAC. Note that some water bodies occur in SAC's with the same SACCODE but different SACID's - this is because some SAC's are divided up into several components with the same SACCODE. Sometimes these components have separate names (SACCOMP).

**Link:** <http://www.jncc.gov.uk/idt/default.htm>

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID
SACID	LONG INT	Unique SAC ID - relates to KEY_SAC

### **KEY\_SAC - Key to TBL\_SAC**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
SACID	LONG INT	Unique SAC ID
SACCODE	TEXT 12	SAC EU code (e.g. UK0014778)
SACNAME	TEXT 100	SAC name
SACCOMP	TEXT 80	SAC component name
SACDATE	TEXT 20	Internal (EN) GIS date (England and Wales only)
SACVERS	LONG INT	Internal (EN) GIS version (England and Wales only)

### **KEY\_SACX - Additional key to KEY\_SAC**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
SACCODE	TEXT 12	SAC EU code (e.g. UK0014778)
SACLEVEL	TEXT 50	Aquatic interest - level code
SACTYPE	TEXT 255	Aquatic interest - description

### **KEY\_SACWEB - Additional key to KEY\_SAC**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
SACCODE	TEXT 12	SAC EU code (e.g. UK0014778)
SACNAME	TEXT 100	SAC name
SACWEBID	TEXT 10	web code
SACWEB	HYPERLINK	web address of SAC info on JNCC database

### **TBL\_RAM - RAMSAR co-occurrence**

**Description:** Lists water bodies whose centroid occurs within the boundaries of a.

**Coverage:** 4596 records (across GB).

**Data source:** English Nature website (digital data download) and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** RAM code (RAMID) links to KEY\_RAM. Note that some water bodies occur in RAMSAR sites with the same RAMCODE but different RAMID's - this is because some RAM's are divided up into several components with the same RAMCODE. Sometimes these components have separate names (RAMCOMP).

**Link:** <http://www.defra.gov.uk/wildlife-countryside/ewd/ewd10.htm> and <http://www.jncc.gov.uk/idt/default.htm>

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body id
RAMID	LONG INT	Unique RAMSAR id - relates to KEY_RAM
RAMCODE	TEXT 12	RAMSAR code - relates to KEY_RAM

### **KEY\_RAM - Key to TBL\_RAM**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
RAMID	LONG INT	Unique RAMSAR id
RAMCODE	TEXT 12	RAMSAR EU code (e.g. 7UK108)
RAMNAME	TEXT 80	RAMSAR name
RAMCOMP	TEXT 80	RAMSAR component name
RAMDATE	TEXT 20	Internal (EN) GIS date
RAMVERS	LONG INT	Internal (EN) GIS version

### **KEY\_RAMX - Additional key to KEY\_RAM**

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
RAMCODE	TEXT 12	RAMSAR EU code (e.g. 7UK108)
RAMLEVEL	TEXT 50	Aquatic interest - level code
RAMTYPE	TEXT 255	Aquatic interest - description



### TBL\_NNR - National Nature Reserve Co-occurrence

**Description:** Lists water bodies whose centroid occurs within the boundaries of a National Nature Reserve.

**Coverage:** 737 records.

**Data source:** English Nature website (digital data download) and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** NNR code (NNRID) links to KEY\_NNR.

**Link:** [http://www.english-nature.org.uk/special/nnr/nnr\\_what.htm](http://www.english-nature.org.uk/special/nnr/nnr_what.htm)

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
NNRID	LONG INT	National Nature Reserve ID in which water body centroid falls - relates to KEY_NNR

### KEY\_NNR - Key to TBL\_NNR

FIELD NAME	DATA TYPE	DESCRIPTION
NNRID	LONG INT	Unique National Nature Reserve ID
NNRNAME	TEXT 80	National Nature Reserve name
NNRCODE	TEXT 10	National Nature Reserve code (Scotland only)
NNRDATE	TEXT 20	Internal (EN) GIS date (England only)
NNRVERS	LONG INT	Internal (EN) GIS version (England only)

### TBL\_BAP - BAP Priority Species Co-occurrence

**Description:** Lists water bodies with known records for BAP Priority species together with summary of record.

**Coverage:** 5062 records at present.

**Data source:** Conservation agencies / Biological Records Centre / SEPA.

**Link:** <http://www.searchnbn.net/> and <http://www.ukbiodiversity.net/>

FIELD NAME	DATA TYPE	DESCRIPTION
RECORDID	AUTO	Unique record ID
WBID	LONG INT	Unique water body ID
OSNAME	TEXT 255	Water body name from TBL_NAME
SITENAME	TEXT 255	Site name according to site record
SPNAME	TEXT 255	Species name according to site record
GRIDREF	TEXT 255	Grid ref according to site record
YEAR	LONG INT	Year of record
MATCHED?	TEXT 255	How well the site record was matched to an actual water body
RESOLUTION	TEXT 255	Resolution at which match was made
NBN	TEXT 16	National Biodiversity Network species code

### TBL\_CT - Catchment Details

**Description:** List of water body ID's for which catchments have been computed and associated physical data.

**Coverage:** All water bodies with catchments (14353).

**Data source:** Digital catchment boundaries computed by CEH.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Currently, CTMETH field is blank, all were derived from the same model.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
CTAREA	DBL	Area of catchment in hectares
CTPERIM	DBL	Perimeter of catchment in metres
LCRATIO	DBL	Lake:catchment area ratio (=TBL_CT:CTAREA / TBL_LD:SAREA)
CTMETH	TEXT 50	Method by which catchment derived

### TBL\_CTQA - Catchment Details - Quality Assessment

**Description:** List of water body ID's for which catchments have been computed and some quality assessment data.

**Coverage:** All water bodies with catchments (14353).

**Data source:** various.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** MISSING field is derived from manual check with OS extract on Streetmap website - if a water body centroid does not coincide with a mapped water body it is marked as missing. URBAN - catchment polygons in urban areas might be regarded as suspect since drainage will not necessarily be topographically influenced.

CATCHECK describes a comparison with 6% of catchments which were previously digitised by hand.

LCCHECK uses lake area:catchment area ratio as an indicator of quality. A very small L:C ratio indicates that the catchment delineation process has erroneously attributed the catchment area of an adjacent river to a water body. 0.001 has been used as a threshold although larger L:C ratios may still be due to mistakes in the catchment delineation process.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
MISSING	LONG INT	1 for yes (lake centroid does not coincide with lake on OS map), else 0
URBAN	LONG INT	1 for yes (entire lake within Bartholomews Urban area GIS layer), else 0
CATCHECK	LONG INT	1 for checked and OK, 3 for checked and not OK, else 0 (checked against digitised catchments in ECRC database)
LCCHECK	LONG INT	LC ratio check: 1 for LC ratio < 0.001 therefore suspect, 2 for LC ratio >=1 therefore suspect, else 0 (checked against TBL_CT)

### TBL\_FWC - Freshwater Sensitivity by catchment

**Description:** Proportion (%) of Freshwater Sensitivity class in each catchment.

**Coverage:** 19311 records for 13451 water bodies.

**Data source:** CEH Freshwater Sensitivity map adjusted for soil type and catchment polygons.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** FSCLASS has values ranging from 1 (high sensitivity) to 5 (low sensitivity). An additional class (0) was in the original dataset but has been left out. It referred to areas where no soil information was available and so sensitivity was unclassified (Orkney, Shetland and some coastal and urban areas). Proportions have been rounded to nearest % and values < 1 have been excluded.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
FSCLASS	LONG INT	Freshwater sensitivity class
FSPCENT	LONG INT	Area in percent of catchment containing FSCLASS

### TBL\_FWCX - Freshwater Sensitivity by catchment - crosstab with extra data

**Description:** Proportion (%) of Freshwater Sensitivity class in each catchment in crosstab format with additional parameters. Also given is the maximum and dominant (by area) freshwater sensitivity class for all but 51 catchments, those with no data coverage in the CEH dataset have been calculated using solid and drift geology from this database.

**Coverage:** Records for each water body with catchment (14353) 51 of which are null.

**Data source:** CEH Freshwater Sensitivity map adjusted for soil type or geology data (this database) and catchment polygons.

**Method:** Calculated using ArcView geoprocessing functions.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
FWSC0	LONG INT	Percentage of catchment containing Freshwater Sensitivity Class 0 - derived from TBL_FWC (unclassified)
FWSC1	LONG INT	Percentage of catchment containing Freshwater Sensitivity Class 1 - derived from TBL_FWC
FWSC2	LONG INT	Percentage of catchment containing Freshwater Sensitivity Class 2 - derived from TBL_FWC
FWSC3	LONG INT	Percentage of catchment containing Freshwater Sensitivity Class 3- derived from TBL_FWC
FWSC4	LONG INT	Percentage of catchment containing Freshwater Sensitivity Class 4 - derived from TBL_FWC
FWSC5	LONG INT	Percentage of catchment containing Freshwater Sensitivity Class 5 - derived from TBL_FWC
DOMFWS	LONG INT	Freshwater Sensitivity Class of largest area in catchment (dominant FWSC) - derived from TBL_FWC, ignores percentages of unclassified FWS Class (0) except where all of catchment is unclassified, adjusted for FWS method 2
MAXFWS	LONG INT	Maximum Freshwater Sensitivity Class present in catchment - derived from TBL_FWC, ignores percentages of unclassified FWS Class (0) except where all of catchment is unclassified
FWSMETH	LONG INT	Method used to calculate data in this table: 0 = catchment not covered by any freshwater sensitivity data, 1 = data derived from Freshwater Sensitivity Map, 2 = data derived using geology data and Kinniburgh and Edmunds sensitivity classes.

### TBL\_FWP - Freshwater Sensitivity by water body centroid

**Description:** Freshwater Sensitivity class in which water body centroid occurs.

**Coverage:** Record for every water body in database (43738).

**Data source:** CEH Freshwater Sensitivity map adjusted for soil type and water body centroids.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** FSCLASSP has values ranging from 1 (high sensitivity) to 5 (low sensitivity). Class 0 refers to areas where no soil information was available and so sensitivity was unclassified (Orkney, Shetland and some coastal and urban areas). Proportions have been rounded to nearest %.

**Reference:** Hornung, M., Bull, K.R., Cresser, M., Ullyett, J., Hall, J.R., Langan, S., Loveland, P.J. 1995. The Sensitivity of Surface Waters of Great Britain to Acidification Predicted From Catchment Characteristics. Environmental Pollution 87, 207-214.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
FSCLASSP	LONG INT	Freshwater sensitivity class

### TBL\_DEP - Deposition in Catchment

**Description:** Atmospheric deposition in keq/ha/yr.

**Coverage:** Records for all water bodies (43738).

**Data source:** 95/97-deposition model (5km grid), CEH, Edinburgh.

**Method:** Calculated using ArcView geoprocessing functions. Area weighted values were calculated for water bodies with catchments that overlaid the source data (14341). Area weighted simply means that if a catchment overlays several cells in the deposition model then the deposition value is a weighted average of all values present according to their proportionate areas. For the remaining water bodies values were obtained by point overlay. 49 sites did not overlay the source data and so for these the values from the nearest cell in the source data were used. The field DEPMETH describes which method was used for each water body.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
NOX	DBL	NOx deposition in keq/ha/yr
NHX	DBL	NHx deposition in keq/ha/yr
NMS	DBL	Non-marine S deposition in keq/ha/yr
NMCAMG	DBL	Non-marine Ca+Mg deposition in keq/ha/yr
NMCL	DBL	Non-marine Cl deposition in keq/ha/yr
NETDEP	DBL	Net acidifying deposition (NOX+NHX+NMS+CL-NMCAMG) in keq/ha/yr
DEPMETH	TEXT 50	method used: POINT - estimate based on water body centroid, POLY - estimate based on catchment weighted calculation, POINT (est) - no data but nearest value taken

### TBL\_LC - Land Cover in Catchment

**Description:** Proportion of land cover class in each catchment.

**Coverage:** 156931 records for all catchments (although 20 have no land cover data LCID = 0, LCPERCENT = 100)).

**Data source:** CEH Land Cover Map of Great Britain, 1990 and catchment polygons.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Land cover code (LCID) links to KEY\_LC. Run query XTB\_LC to see a crosstab version of this table.

**Link:** <http://www.ceh.ac.uk/data/lcm/>

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
LCID	TEXT 10	Land cover class ID - relates to KEY_LC
LCPCENT	DBL	Percentage of catchment containing land cover class

### KEY\_LC - Key to TBL\_LC

FIELD NAME	DATA TYPE	DESCRIPTION
LCID	TEXT 10	Land cover class ID
LCNAME	TEXT 50	Land Cover Map of Great Britain class description
Export_coefSGL		Simplified set of EC from Hilton, Buckland and Irons, 2002. kg P/ha/y or kg P/head/y

### MTB\_AG - Amount of 'agricultural' land in each catchment

**Description:** Static table showing amount (%) of 'agricultural' land in each catchment.

**Data source:** CEH Land Cover Map of Great Britain, 1990 and catchment polygons.

**Method:** Table created from TBL\_LC. Original query was not included to increase speed of acid protocol queries.

**Notes:** Table used in acid protocol queries. Agricultural land for this purpose is defined as land cover classes 6, 7 and 18.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
Agricultural Land	DBL	Percentage of catchment containing agricultural land

### TBL\_SG - Solid Geology in Catchment

**Description:** Proportion of solid geology class in each catchment.

**Coverage:** Data for all catchments which intersect solid geology source data (14257).

**Data source:** British Geological Survey 1:625,000 dataset (CEH) and catchment polygons.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Solid Geology code (SGID) links to KEY\_SG. Use XTB\_SG to obtain crosstab version of this table.

**Link:** [http://www.bgs.ac.uk/products/digitalmaps/digmapgb\\_625.html](http://www.bgs.ac.uk/products/digitalmaps/digmapgb_625.html)

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
SGID	LONG INT	Solid geology class ID - relates to KEY_SG
SGPCENT	DBL	Area in percent of catchment containing solid geology class

### KEY\_SG - Key to TBL\_SG

**Notes:** Not all fields are complete in this table. SGCLASS has been given where known (1 = high sensitivity, 4 = low sensitivity).

FIELD NAME	DATA TYPE	DESCRIPTION
SGID	LONG INT	Solid geology class ID
SGNAME	TEXT	100Solid Geology description from BGS 1:625000 map
SGTYPE	TEXT 1	Geological type: S = Sedimentary, I = Igneous, M = Metamorphic
SGPERIOD	TEXT 20	Geological period
SGERA	TEXT 50	Geological era
SGSCCLASS	LONG INT	Kinniburgh and Edmunds sensitivity class
WFDCLASS	TEXT 1	Water Framework Directive class: S = Siliceous, C = Calcareous

### TBL\_DG - Drift Geology in Catchment

**Description:** Proportion of drift geology class in each catchment.

**Coverage:** 25885 records for all water bodies with catchments (14353) although some have no drift geology in their catchment (DGID = 0).

**Data source:** British Geological Survey 1:625,000 dataset (CEH) and catchment polygons.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Drift Geology code (DGID) links to KEY\_DG.

**Link:** [http://www.bgs.ac.uk/products/digitalmaps/digmapgb\\_625.html](http://www.bgs.ac.uk/products/digitalmaps/digmapgb_625.html)

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
DGID	LONG INT	Drift geology class ID - relates to KEY_DG
DGPCENT	DBL	Area in percent of catchment containing drift geology class

### KEY\_DG - Key to TBL\_DG

FIELD NAME	DATA TYPE	DESCRIPTION
DGID	LONG INT	Drift geology class ID
DGNAME	TEXT 50	Drift Geology description from BGS 1:625000 map

### TBL\_GEOL - Geology Summary

**Description:** Summary of geology types in catchments.

**Coverage:** All catchments which coincide with either solid or drift geology coverage (14259).

**Data source:** TBL\_SG and TBL\_DG

**Note:** Not all have data which sums to 100%. Major error corrected 28.6.02.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
SGEOL_CA	TEXT 10	% Calcareous geology in catchment (derived from TBL_SGEOL)
SGEOL_SI	TEXT 10	% Siliceous geology in catchment (derived from TBL_SGEOL)
DGEOL_PT	TEXT 10	% Peat in catchment (derived from TBL_DGEOL) 0.00 indicates trace presence i.e. < 0.001 %

### TBL\_LSTO - MAFF Animal Statistics

**Description:** Numbers of animals in catchment derived from MAFF data.

**Coverage:** Catchments which intersect animal data (6257).

**Data source:** MAFF 5km gridded data (England) and Small Area Statistics (Wales) converted to 5km grid.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Data for Wales from 2000 survey, England from 1999. Fowl data only available in Wales. Totals are amalgamated from several classes e.g. SHEEP includes breeding ewes, lambs, other sheep and goats. Blank fields indicate no data. Not all catchments are entirely covered by source data. No Scottish data was available.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
LCID	LONG INT	LCID - relates to KEY_LC describes animal
NUMBER	DBL	Number of animals of this type present in catchment according to MAFF data (1999/2000)

### TBL\_MAFF - MAFF Animal Statistics Coverage

**Description:** Percentage of catchment intersected by MAFF animal data.

**Coverage:** Catchments which intersect animal data (6257).

**Data source:** MAFF 5km gridded data (England) and Small Area Statistics (Wales) converted to 5km grid.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Data for Wales from 2000 survey, England from 1999. Fowl data only available in Wales. Totals are amalgamated from several classes e.g. SHEEP includes breeding ewes, lambs, other sheep and goats. Blank fields indicate no data. Not all catchments are entirely covered by source data. No Scottish data was available.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
MAFFCENT	DBL	Percentage of catchment for which MAFF animal data available (see TBL_LSTO)

### TBL\_POP - Population in Catchment

**Description:** Number of people living within catchment.

**Coverage:** Record for every water body in the database with catchment (14353).

**Data source:** SURPOP 91 (MIMAS) and catchment polygons.

**Method:** Calculated using ArcView geoprocessing functions and Microsoft Excel.

**Link:** <http://census.ac.uk/cdu/surpop/>

**Reference:** Bracken I. and Martin D.: 1995, 'Linkage of the 1981 and 1991 UK Censuses using surface modelling concepts', Environment and Planning A, 27, 379-390.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
SURPOP91	DBL	Catchment population according to SURPOP91 dataset

### TBL\_ROFF - Runoff data

**Description:** Runoff for 1995-97 period.

**Coverage:** Records for every water body (43738).

**Data source:** CEH Runoff grid (1km) 1995-97 reporting period.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** Table contains a mixture of data derived by catchment where catchments existed (14353) and by water body centroid for those remaining (see ROFFMETH). Use ROFFMN for mean runoff.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
ROFFCNT	LONG INT	number of 1km runoff cells used in calculation
ROFFMIN	LONG INT	minimum value of runoff (mm)
ROFFMAX	LONG INT	maximum value of runoff (mm)
ROFFRANG	LONG INT	range of runoff (mm)
ROFFMN	DBL	mean runoff (mm)
ROFFST	DDBL	standard deviation of runoff for all cells used in calculation
ROFFSUM	LONG INT	sum of runoff for all cells used in calculation (mm)
ROFFVAR	LONG INT	variety of runoff for all cells used in calculation i.e. number of different values
ROFFMAJO	LONG INT	majority value of runoff for all cells in calculation (mm)
ROFFMINO	LONG INT	minority value of runoff for all cells in calculation (mm)
ROFFMED	LONG INT	median value of runoff for all cells used in calculation (mm)
ROFFMETH	TEXT 12	method used: POINT - estimate based on water body centroid, POLY - estimate based on catchment boundary overlay, POINT (est) - no data but nearest value taken

### TBL\_PHOS - Modelled Current Phosphorus Load in Catchment

**Description:** Phosphorus load in catchment from different sources.

**Coverage:** Record for every water body in the database with catchment (14353) although there are many null fields indicating no data.

**Data source:** EA data, TBL\_LSTO, TBL\_POP and catchment polygons.

**Method:** Calculated using Microsoft Excel.

**Notes:** No animal data for Scotland at present. English data does not contain fowl numbers.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body id
PLOAD_LC	DBL	Phosphorus load (kg/yr) for catchment from landcover
PLOAD_CA	DBL	Phosphorus load (kg/yr) for catchment from cattle
PLOAD_SH	DBL	Phosphorus load (kg/yr) for catchment from sheep
PLOAD_PI	DBL	Phosphorus load (kg/yr) for catchment from pigs
PLOAD_FO	DBL	Phosphorus load (kg/yr) for catchment from fowl
PLOAD_HU	DBL	Phosphorus load (kg/yr) for catchment from humans

### TBL\_PLOAD - Modelled Hindcast Phosphorus Load in Catchment

**Description:** Phosphorus load in catchment from Reading hindcast model (1931).

**Coverage:** Catchments which intersect the original Land Use Region map (n=6090) - England and Wales.

**Data source:** EA data and catchment polygons.

**Method:** Calculated using ArcView geoprocessing functions.

**Notes:** This is a flat file format table, run query XTB\_PLOAD to see a crosstab version of this table. Some catchments do not completely overlap Land Use Region map - use SumOfHECTARES in XTB\_PLOAD to compare with TBL\_CT:CTAREA.

**Reference:** Johnes P.J., Curtis C., Moss B. Whitehead P., Bennion H. and Patrick S.: 2000, 'Trial Classification of Lake Water Quality in England and Wales: a proposed approach', Research and Development Technical Report E53, Environment Agency, Bristol.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Water body ID
HECTARES	DBL	Hectareage of intersected portion of catchment
PLOAD	DBL1931	hindcast P load (kg/yr) for portion of catchment
DISCHARGE	DBL1931	hindcast discharge (m3/yr) for portion of catchment

## QRY\_PLOAD - Hindcast Phosphorus Load Calculations

This query takes data from XTB\_PLOAD, TBL\_MDP, TBL\_LD, TBL\_VOL and TBL\_CT to generate the following parameters:

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Water body ID
CTAREA	DBL	Area of catchment in hectares
WBSAREA	DBL	Surface area of water body in hectares
MNDP	DBL	Mean depth in metres, has been limited to a minimum 0.05m
VOL	DBL	Water body volume in m3 = [TBL_MDP]![MNDP]*([TBL_LD:]![WBAREA]*10000)
SumOfDISCHARGE	DBL	Total discharge (Q) for catchment in m3/yr from XTB_PLOAD (note this is from hindcast runoff and nothing to do with TBL_ROFF)
Retention time (yrs)	DBL	Retention time (tw) in years = [TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE]
Areal water load	DBL	Areal water load (qs) in m/yr = [TBL_MDP]![MNDP]/([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE])
SumOfPLOAD	DBL	Total P load (Tpi) in kg/yr from XTB_PLOAD
Areal TP load	DBL	Areal TP load (Lp) in mg/m2/yr = ([XTB_PLOAD]![SumOfPLOAD]/ [TBL_LD]![WBSAREA])*100
Predicted inflow TP	DBL	Predicted inflow TP (Pi) in ug/l = (( [XTB_PLOAD]![SumOfPLOAD]/[TBL_LD]![WBSAREA])*100)/([TBL_MDP]![MNDP]/([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE]))
OECD X	DBL	OECD modelled flushing corrected inflow concentration (X) in ug/l = (( [XTB_PLOAD]![SumOfPLOAD]/[TBL_LD]![WBSAREA])*100)/([TBL_MDP]![MNDP]/([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE]))/(1+Sqr([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE]))
OECD Plake	DBL	OECD modelled lake mean TP (Pl) in ug/l = ((( [XTB_PLOAD]![SumOfPLOAD]/[TBL_LD]![WBSAREA])*100)/([TBL_MDP]![MNDP]/([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE])))/(1+Sqr([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE])) ^0.82)*1.55
OECD Chl	DBL	OECD modelled lake mean Chla (Chl) in ug/l = ((( [XTB_PLOAD]![SumOfPLOAD]/[TBL_LD]![WBSAREA])*100)/([TBL_MDP]![MNDP]/([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE]))/(1+Sqr([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE])) ^0.79)*0.37
OECD ChlMax	DBL	OECD modelled lake max Chla (Chlmax) in ug/l = ((( [XTB_PLOAD]![SumOfPLOAD]/[TBL_LD]![WBSAREA])*100)/([TBL_MDP]![MNDP]/([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE]))/(1+Sqr([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE])) ^0.89)*0.74
OECD SD	DBL	OECD modelled lake secchi depth (SD) in metres = ((( [XTB_PLOAD]![SumOfPLOAD]/[TBL_LD]![WBSAREA])*100)/([TBL_MDP]![MNDP]/([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE]))/(1+Sqr([TBL_VOL]![VOL]/[XTB_PLOAD]![SumOfDISCHARGE])) ^-0.39)*14.7



### TBL\_MD - Metadata Availability

**Description:** Metadata availability for water body. Refers to data stored elsewhere. Actual availability will depend on source.

**Data source:** Various.

**Notes:** The MDID field relates to KEY\_MD.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
MDCODE	TEXT 50	Site code according to data source (see KEY_MD)
MDID	LONG INT	Metadata ID (refers to KEY_MD)

### KEY\_MD - Key to TBL\_MD

FIELD NAME	DATA TYPE	DESCRIPTION
MDID	LONG INT	Metadata ID (refers to KEY_MD)
MNTITLE	TEXT 100	Metadata title
MNDESCR	TEXT 255	Metadata description
MNREF	TEXT 255	Metadata published reference
MNPERSON	TEXT 50	Metadata contact name
MNADDR	TEXT 255	Metadata address
MNEMAIL	TEXT 50	Metadata email
MNTEL	TEXT 50	Metadata telephone
MNPERIOD	TEXT 50	Metadata period of data collection
MNHREF	URL	GB Lakes Project web page giving more information on dataset
MNMACROP	YES/NO	Dataset contains macrophyte data
MNINVERT	YES/NO	Dataset contains invertebrate data
MNDIATOM	YES/NO	Dataset contains diatom data
MNCHEM	YES/NO	Dataset contains water chemistry data
MNZOOP	YES/NO	Dataset contains zooplankton data
MNPHYTO	YES/NO	Dataset contains phytoplankton data
MNFISH	YES/NO	Dataset contains fish data
MNUSE	YES/NO	Dataset contains use related data

### TBL\_SUMM - Summary water chemistry data

**Description:** Summary water chemistry data.

**Coverage:** Currently records for 399 sites.

**Data source:** See metadata ID MDID, relates to TBL\_MD.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
SUMMPH	DBL	Summary pH (units: pH)
SUMMCOND	DBL	Summary conductivity (units: uS cm-1)
SUMMALK1	DBL	Summary alkalinity (units: ueq l-1)
SUMMALK2	DBL	Summary alkalinity (units: mg CaCO3 l-1)
SUMMCA	DBL	Summary calcium (units: mg l-1)
SUMMTP	DBL	Summary total phosphorous (units: ug l-1)
SUMMTN	DBL	Summary total nitrogen (units: ug l-1)
SUMMNO3	DBL	Summary NO3- (units: ug l-1)
SUMMSRP	DBL	Summary soluble reactive phosphorous (units: ug l-1)
SUMMCHLA	DBL	Summary Chlorophyll A (units: ug l-1)
SUMMYEAR	TEXT 50	Year of summary data
SUMMSAMP	TEXT 255	Summary data sampling remarks
SUMMGR	TEXT 20	Grid reference of sampling point if available
MDCODE	TEXT 50	Site code according to data source (see KEY_MD)
MDID	LONG INT	Metadata ID - relates to KEY_MD

### TBL\_ALK - Alkalinity Data

**Description:** Average alkalinity from 10km grid square (units unknown) for each water body centroid.

**Coverage:** Records for every water body but 24418 have 'no data' value of -999.

**Data source:** CEH.

**Notes:** -999 indicates no data (mainly Scotland).

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	Unique water body ID
ALK	DBL	Average alkalinity from 10km grid square. -999 indicates no data (North S, some E and W). Provided by CEH.

### **Tier\_1\_classification – Summary data for acid protocol queries**

**Description:** A static table of data from this database and external sources to facilitate the running of the acid protocol queries.

**Data source:** Excel spreadsheet (tier1\_classification.xls) prepared for this contract.

<b>FIELD NAME</b>	<b>DATA TYPE</b>	<b>DESCRIPTION</b>
WBID	LONG INT	Unique water body ID
OSNAME	TEXT 50	Water body name from TBL_NAME
UKCNTRY	TEXT 50	UK Country from TBL_UK / KEY_UK
trophic-status	LONG INT	trophic status (from nutrient protocol)
retention-time(y)	DBL	retention time (from nutrient protocol)
retention-class	LONG INT	retention class (from nutrient protocol)
strat-code	LONG INT	stratification code (from nutrient protocol)
important-lakes	LONG INT	true if water body has lake importance (from nutrient protocol), else 0
NETDEP	DBL	net deposition from TBL_DEP
deposition-class	LONG INT	deposition class
DOMFWS	LONG INT	dominant freshwater sensitivity class from TBL_FWCX
Low Risk	LONG INT	1 if DOMFWS and deposition-class both == 2, else 0
Low Sensitivity	LONG INT	1 if DOMFWS >= 3, else 0

**LUT\_CCWG - Lookup table for CCW GIS site codes**

**Description:** Lookup table for CCW GIS site codes and lake names and WBID's in this database.

**Coverage:** There are 2202 entries of which 1318 are matched. Where a CCW code was not matched a WBID of 0 has been entered.

**Data source:** CCW GIS layer and database.

**Notes:** Some CCW sites are matched to the same water body (WBID).

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	water body ID, 0 indicates no match
CCWGCODE	LONG INT	CCW GIS code - NB some repeated values
CCWGNAME	TEXT 100	CCW GIS name
CCWGCODE	TEXT 50	comment

**LUT\_CLAM - Lookup table for ECRC CLAM site codes**

**Description:** Lookup table for ECRC CLAM site codes.

**Coverage:** There are 1971 entries of which 1904 are matched. Where a CLAM code was not matched a WBID of 0 has been entered.

**Data source:** ECRC CLAM2 Project.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	water body ID, 0 indicates no match
CLAM	TEXT 50	ECRC CLAM2 code

**LUT\_ECRC - Lookup table for ECRC site codes**

**Description:** Lookup table for ECRC site codes stored in AMPHORA.

**Coverage:** There are 2085 entries of which all are matched.

**Data source:** ECRC.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	water body ID, 0 indicates no match
AMPHORA	TEXT 50	ECRC AMPHORA code

**LUT\_EMER - Lookup table for ECRC EMERGE site codes**

**Description:** Lookup table for ECRC EMERGE site codes (Scotland).

**Coverage:** There are 399 entries of which all are matched.

**Data source:** ECRC.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	water body ID, 0 indicates no match
EMERGE	TEXT 50	ECRC EMERGE code

**LUT\_JNCC - Lookup table for JNCC Standing Waters Database site codes**

**Description:** Lookup table for JNCC Standing Waters Database site codes.

**Coverage:** There are 27682 entries of which 25906 are matched (10950 at quality 3, 14956 at quality 2, 1760 at quality 1 - unmatched). Where a JNCC code was not matched a WBID of 0 has been entered.

**Data source:** JNCC Standing Waters Database.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	water body ID, 0 indicates no match
JNCCCODE	TEXT 10	JNCC code
JNCCQUAL	LONG INT	Quality flag - 3: good match (location, name), 2: moderate match (e.g. within 150m), 1: unmatched

**LUT\_SNIF - Lookup table for SNIFFER Scottish Freshwater Database site codes**

**Description:** Lookup table for SNIFFER Scottish Freshwater Database site codes.

**Coverage:** There are 454 entries of which 453 are matched. Where a SNIFFER code was not matched a WBID of 0 has been entered.

**Data source:** SNIFFER.

FIELD NAME	DATA TYPE	DESCRIPTION
WBID	LONG INT	water body ID, 0 indicates no match
EMERGE	TEXT 10	SNIFFER code (actually gridref as used in SNIFFER database)

<b>QUERIES</b>
<p><b>Self-explanatory query examples present in database:</b></p> <p>eg: Catchments with no geology</p> <p>eg: Data for typology exercise</p> <p>eg: Lake details with aquatic features in SSSI's</p> <p>eg: Lakes in Welsh SAC's designated for aquatic features</p> <p>eg: Pop density for catchments &gt; 5ha, hindcast P &gt; 500 kg/yr</p>
<p><b>QRY_AcidBox1_England</b> Produces a summary list of water bodies in England that fall into box 1 of the acid protocol</p>
<p><b>QRY_AcidBox1_Scotland</b> Produces a summary list of water bodies in Scotland that fall into box 1 of the acid protocol</p>
<p><b>QRY_AcidBox1_Wales</b> Produces a summary list of water bodies in Wales that fall into box 1 of the acid protocol</p>
<p><b>QRY_AcidBox2_England</b> Produces a summary list of water bodies in England that fall into box 2 of the acid protocol</p>
<p><b>QRY_AcidBox2_Scotland</b> Produces a summary list of water bodies in Scotland that fall into box 2 of the acid protocol</p>
<p><b>QRY_AcidBox2_Wales</b> Produces a summary list of water bodies in Wales that fall into box 2 of the acid protocol</p>
<p><b>QRY_AcidBox3_England</b> Produces a summary list of water bodies in England that fall into box 3 of the acid protocol <i>Note: this query first runs QRY_AcidBox3_England_prequery</i></p>
<p><b>QRY_AcidBox3_Scotland</b> Produces a summary list of water bodies in Scotland that fall into box 3 of the acid protocol <i>Note: this query first runs QRY_AcidBox3_Scotland_prequery</i></p>
<p><b>QRY_AcidBox3_Wales</b> Produces a summary list of water bodies in Wales that fall into box 3 of the acid protocol <i>Note: this query first runs QRY_AcidBox3_Wales_prequery</i></p>
<p><b>QRY_AcidBox4_England</b> Produces a summary list of water bodies in England that fall into box 4 of the acid protocol</p>
<p><b>QRY_AcidBox4_Scotland</b> Produces a summary list of water bodies in Scotland that fall into box 4 of the acid protocol</p>
<p><b>QRY_AcidBox4_Wales</b> Produces a summary list of water bodies in Wales that fall into box 4 of the acid protocol</p>
<p><b>QRY_BAP-species-latest-observation</b> Produces intermediate table for nutrient protocol, feeds into XTB_BAP-species-latest-observation</p>
<p><b>QRY_full-code</b> Produces intermediate table for nutrient protocol, feeds into QRY_NutrientBox_England/Scotland/Wales</p>

<b>QRY_importance-criteria</b> Produces intermediate table for nutrient protocol, feeds into QRY_teir1-class
<b>QRY_Lake-ID-linked-with-name</b> Produces intermediate table for nutrient protocol, feeds into QRY_importance-criteria
<b>QRY_NutrientBox_England</b> Produces summary list for nutrient protocol, nutrient box numbers for England
<b>QRY_NutrientBox_Scotland</b> Produces summary list for nutrient protocol, nutrient box numbers for Scotland
<b>QRY_NutrientBox_Wales</b> Produces summary list for nutrient protocol, nutrient box numbers for Wales
<b>QRY_Pload_animals</b> Produces intermediate table for nutrient protocol, feeds into QRY_Pload_animals_sum
<b>QRY_Pload_animals_sum</b> Produces intermediate table for nutrient protocol, feeds into QRY_Pload_catchment
<b>QRY_Pload_catchment</b> Produces intermediate table for nutrient protocol, feeds into QRY_Trophic_status
<b>QRY_Pload_human</b> Produces intermediate table for nutrient protocol, feeds into QRY_Pload_catchment
<b>QRY_Pload_LC</b> Produces intermediate table for nutrient protocol, feeds into QRY_Pload_LC_sum
<b>QRY_Pload_LC_sum</b> Produces intermediate table for nutrient protocol, feeds into QRY_Pload_catchment
<b>QRY_Population_LCID</b> Produces intermediate table for nutrient protocol, feeds into QRY_Pload_human
<b>QRY_teir1-class</b> Produces intermediate table for nutrient protocol, feeds into QRY_full-code
<b>QRY_Trophic_status</b> Produces intermediate table for nutrient protocol, feeds into QRY_teir1-class
<b>QRY_water_discharge</b> Produces intermediate table for nutrient protocol, feeds into QRY_Trophic_status
<b>QRY_Wederburn-depth</b> Produces intermediate table for nutrient protocol, feeds into QRY_teir1-class
<b>XTB_BAP-species-latest-observation</b> Produces intermediate table for nutrient protocol, feeds into QRY_importance-criteria

## APPENDIX 2

### GB LAKES DATABASE: DATA COVERAGE AND QUALITY

The table below attempts to give some idea of data coverage and quality for each of the main tables in the database. Refer to Appendix 1 for a detailed explanation of each table.

#### Key to Table

**Coverage** – indicates the geographical coverage of the data.

- GB indicates England (E), Scotland (S) and Wales (W).
- \* indicates some missing data – see Appendix 1 entry for details.
- Not IoM means not including Isle of Man.

**Modelled** – indicates whether the data in the table has been modelled.

**Catchment** – indicates whether data relates to just the lake or lake centroid (P) or the lake catchment (C). If they relate to the catchment then the data reliability is relative to the quality of the catchment boundary – see TBL\_CTQA. If a catchment boundary is subsequently improved or re-modelled then these data will become out-of-date.

**Comment** – any additional information, e.g. whether source data may be updated in future.

TABLE	COVERAGE	MODELLED	CATCHMENT	COMMENT
MTB_AG	GB	no	C	
TBL_AD	GB	no	P	
TBL_AG	GB	no	P	
TBL_ALK	GB*	yes	P	
TBL_BAP	GB	no	P	Source data may be updated.
TBL_BDIR	GB	no	P	Source data may be updated.
TBL_CA	E	no	P	
TBL_CT	GB	yes	C	
TBL_DEP	GB*	yes	C	Data for 95/97.
TBL_DG	GB*	no	C	
TBL_DP	partial	no	P	Data available for <1000 water bodies. Source data may change.
TBL_DS	GB	no	P	
TBL_FDIR	GB			Incomplete data. Source data may be updated.
TBL_FP	GB	no	P	
TBL_FT	GB	no	P	
TBL_FWC	GB*	yes	C	
TBL_FWP	GB*	yes	P	
TBL_GEOL	GB*	yes	C	
TBL_GR	GB	no	P	
TBL_ID	GB	no	P	
TBL_IS	GB	no	P	
TBL_LC	GB*	yes	C	Data for 1990. Newer data is now available.
TBL_LD	GB	no	P	
TBL_LL	GB	no	P	

<b>TABLE</b>	<b>COVERAGE</b>	<b>MODELLED</b>	<b>CATCHMENT</b>	<b>COMMENT</b>
TBL_LSTO	E/W	yes	C	Data for 1999/2000.
TBL_MAFF	E/W	yes	C	Data for 1999/2000.
TBL_MDP	GB (not IoM)	yes / no	P	
TBL_NA	E	no	P	
TBL_NAM2	GB	no	P	
TBL_NAME	GB	no	P	
TBL_NNR	GB	no	P	Source data may be updated.
TBL_NP	E/W	no	P	
TBL_OS	GB	no	P	
TBL_PHOS	GB*	yes	C	
TBL_PLOAD	E/W*	yes	C	
TBL_POP	GB	yes	C	Data for 1991.
TBL_RAM	GB	no	P	Source data may be updated.
TBL_RIV	GB	no	P	
TBL_ROFF	GB	yes	C/P	Data for 95/97.
TBL_SAC	GB	no	P	Source data may be updated.
TBL_SDI	GB	no	P	
TBL_SG	GB*	no	C	
TBL_SPA	GB	no	P	Source data may be updated.
TBL_SSSI	GB	no	P	Source data may be updated.
TBL_STR	GB	yes	C	
TBL_SUMM	partial	no	P	Data for 399 sites.
TBL_UK	GB	no	P	
TBL_VOL	GB (not IoM)	yes / no	P	
TBL_WB	GB	no	P	