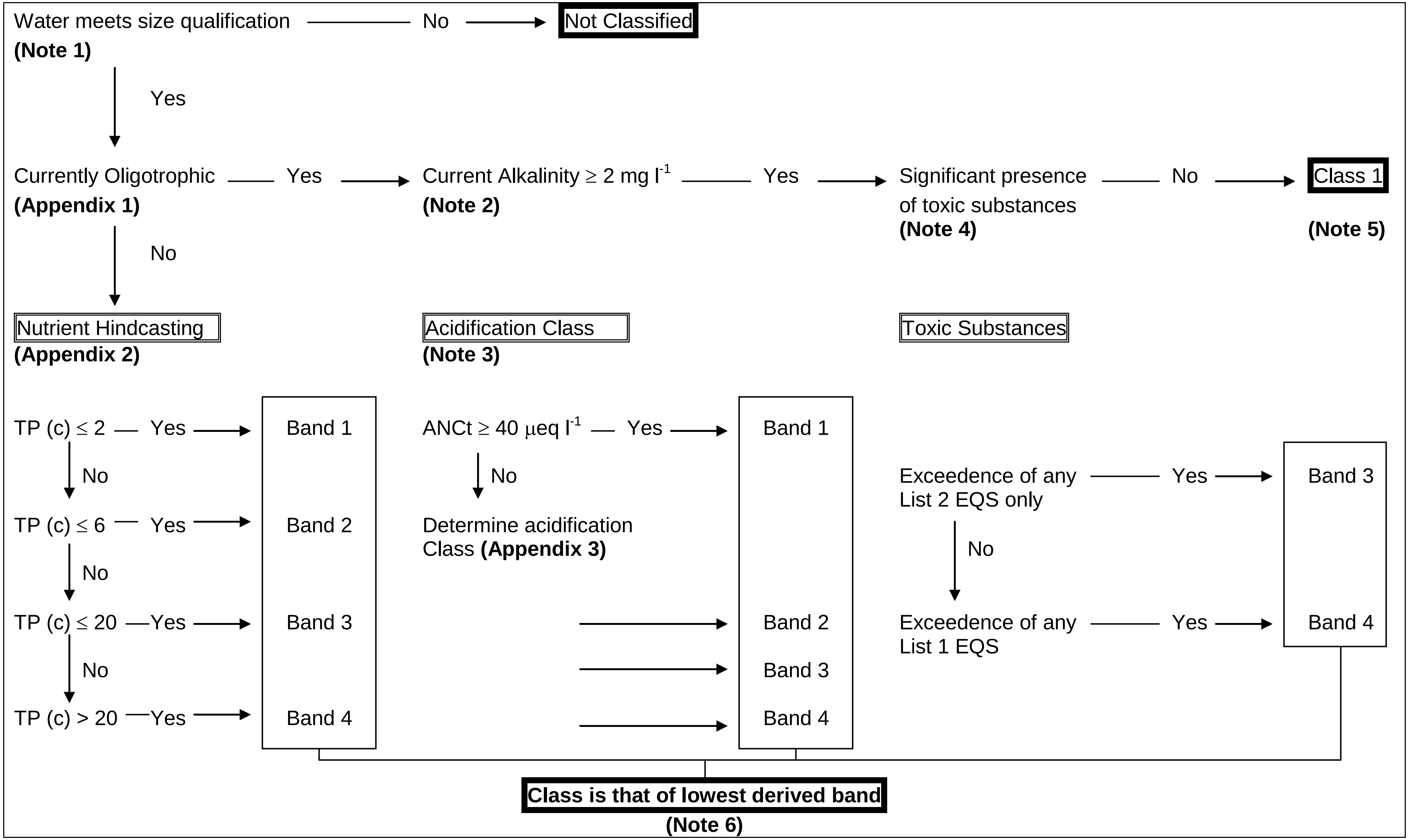
Annex E: Classification for Scotland’s Standing Waters



CLASSIFICATION OF STANDING WATERS

NOTES

1. All standing waters greater than or equal to 1 square kilometre in area must be classified. Other waters similar in area but deemed to be of particular significance by the regulatory authority may also be classified.

2. If current alkalinity, measured as equivalent concentration of calcium carbonate, is greater than or equal to 2 mg l^{-1} then acidification band is 1.

3. Acidification class is calculated according to the method given in Appendix 3. Where the current Acid Neutralising Capacity (ANC$_t$) is greater than or equal to 40 μeq l^{-1} the acidification band is 1.

4. Toxic substances are defined as those on Lists I and II of the EC Dangerous Substances Directives. Significant concentrations of toxic substances are defined as exceedence of the Environmental Quality Standards (EQS). EQS information is available from WRc publications, the SNIFFER EQS database and other literature.

   The EQS for ammonia should be taken as that standard required by the Freshwater Fisheries Directive.

5. If the standing water is currently observed to meet those criteria categorising it as oligotrophic, and with alkalinity of at least 2 mg l^{-1}, and with no exceedence of any List I or II EQS then it is automatically a Class 1 water.

6. The final Standing Waters Class is determined as the lowest band derived from any of the three categories of water quality, i.e. nutrient hindcasting, acidification or toxic substances.

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12. The final Standing Waters Class is determined as the lowest band derived from any of the three categories of water quality, i.e. nutrient hindcasting, acidification or toxic substances.

Appendices

1. Criteria for determining current trophic status of a sanding water using menu of available information and, where appropriate chemistry unavailable, substituting median total phosphorus values given in Table 2 for nutrient hindcasting. Where current trophic status is determined as oligotrophic then nutrient class is 1 and hindcasting is unnecessary.

2. Methodology for nutrient hindcasting.

3. Methodology for acidification classification.

4. Methodology for toxic substances classification.

Appendix 1

Assessment of current trophic status

The objective of this appendix is:

To guide the allocation of a currently applicable annual mean total phosphorus concentration to a standing water. This will permit a trophic classification and provide a basis for comparison with a derived baseline total phosphorus concentration.

1.0. Rationale of method and chosen parameter

1.1. Overview

In order to produce a quality classification of the nutrient status of standing waters it is necessary to adopt a “changed state” or temporal framework comparing current condition with that pertaining at a date before man’s activities caused change. The alternative, a spatial classification comparing the current status of waterbodies, is considered inappropriate since it takes no account of the variability of the nutrient status in natural and semi natural systems. The method requires the measurement or estimation of a parameter indicating the current nutrient status, and the comparison of this parameter with a derived baseline value representing the earlier more natural state.

1.2. Total phosphorus

For a variety of practical and theoretical reasons, the parameter selected is annual mean total phosphorus concentration. It is accepted that this is not a direct measure of eutrophication, algal biomass generally being of most direct relevance, and this is influenced by factors in addition to phosphorus concentration such as colour, turbidity and water residence time. Nevertheless, there appears to be little alternative to the use of total phosphorus due to the lack of any practical method for deriving hindcast algal biomass or chlorophyll values.

1.3. Other limiting factors

It may be possible to incorporate an adjustment to take account of situations where phosphorus levels are elevated due to discharges, but where the typical signs of eutrophication (e.g. increased algal biomass) are not present due to limitation by other factors (e.g. humic discolouration). However, it has not proved possible to apply any quantitative solution to this problem due to the lack of good data, and furthermore, it can be argued that although colour and turbidity (for example) may inhibit the immediate production of phytoplankton chlorophyll the potential would remain for enhanced algal or macrophyte production in shallow littoral areas and downstream rivers. Damage to the ecology of a loch may also result, for example damage to nutrient sensitive macrophyte communities of potential conservation value. These assemblages would only be found in shallow areas where light penetration was adequate for photosynthesis and would therefore not be limiting algal production.

2.0. Methods if (TP) data are available

2.1. If sufficient data are available for the calculation of a currently applicable annual mean total phosphorus concentration, normally monthly samples over a 12 month period, this is the preferred option. Reference to Table 2 (overleaf), under “Chemical factors”, will enable the waterbody to be classified. If oligotrophic the quality class is Class 1 (see decision tree). If not oligotrophic the calculated annual mean total phosphorus concentration should be noted and used in the estimation of percentage change (see Appendix II).

2.2. If only limited phosphorus data are available, but this is supported by other chemical and biological information, Table 2 should be consulted and an informed decision made as to whether the available phosphorus data is representative of the general nutrient status of the waterbody. If it is deemed to be representative then either a mean of the data or the appropriate surrogate mean given in the first column should be noted. If oligotrophic the quality class is Class 1. If not oligotrophic, the value is used in the estimation of percentage change (see Appendix II).

Table 2. Nutrient status classification scheme for Lentic Waters

Description	Biological Factors	Chemical Factors
Oligotrophic (surrogate mean [TP] value; 8 $\mu g\ l^{-1}$)	High diversity, low biomass of biota. Phytoplankton blooms rare, macrophytes may be rare or adapted to low nutrient levels. Profundal benthos and plankton typical of nutrient poor lakes.	Mean total phosphorus $\leq$ 10 $\mu g\ l^{-1}$. Mean chlorophyll-<u>a</u> $\leq$ 2.5 $\mu g\ l^{-1}$. Max. chlorophyll-<u>a</u> $\leq$ 8.0 $\mu g\ l^{-1}$. Mean Secchi transparency $\geq$ 6.0 m. High oxygen concentration in hypolimnion.
Mesotrophic (surrogate mean [TP] value; 25 $\mu g\ l^{-1}$)	High diversity, variable biomass of biota. Phytoplankton blooms occur, macrophytes often diverse and abundant. Profundal benthos and plankton often intermediate between oligotrophic and eutrophic types.	Mean total phosphorus 10-35 $\mu g\ l^{-1}$. Mean chlorophyll-<u>a</u> 2.5-8 $\mu g\ l^{-1}$. Max. chlorophyll-<u>a</u> 8-25 $\mu g\ l^{-1}$. Mean Secchi transparency 6-3 m. Oxygen concentration may show some depletion in hypolimnion.
Eutrophic (surrogate mean [TP] value; 80 $\mu g\ l^{-1}$)	Lower diversity, high biomass of biota. Phytoplankton blooms occur regularly, macrophytes may be limited in diversity and abundance. Profundal benthos and plankton typical of nutrient rich lakes.	Mean total phosphorus 35-100 $\mu g\ l^{-1}$. Mean chlorophyll-<u>a</u> 8-25 $\mu g\ l^{-1}$. Max. chlorophyll-<u>a</u> 25-75 $\mu g\ l^{-1}$. Mean Secchi transparency 3-1.5 m. Oxygen concentration frequently depleted in hypolimnion.
Hypertrophic	Low diversity of tolerant biota, biomass may be very high. Severe phytoplankton blooms may be almost continuous, macrophytes may be limited to tolerant taxa or absent. Profundal benthos and plankton dominated by tolerant forms.	Mean total phosphorus $\geq$ 100 $\mu g\ l^{-1}$. Mean chlorophyll-<u>a</u> $\geq$ 25 $\mu g\ l^{-1}$. Max. chlorophyll-<u>a</u> $\geq$ 75 $\mu g\ l^{-1}$. Mean Secchi transparency $\leq$ 1.5 m. Severe oxygen concentration depletion in hypolimnion.

3.0. Method if [TP] data are not available

Collection of some total phosphorus data will generally be the most cost effective and reliable option. However, in certain circumstances, for example where a waterbody is well studied (internally or reported in the literature) but with no total phosphorus data, it is recommended that a surrogate mean total phosphorus concentration be derived from Table 2 on the basis of the distribution of the biological and chemical factors between the class descriptions. This may prove an economical option in terms of reduced sampling and analytical effort but will entail professional evaluation of the biological and chemical data available and may be less reliable. As many of the factors as possible should be considered but it is not essential to seek information on them all. If a clearwater loch is reliably known to never support any significant phytoplankton blooms this may be considered adequate to enable a judgement to be made, but it should not preclude the use of any other available and relevant information. The references listed below provide a guide to the biological factors referred to in the table. If the waterbody is deemed oligotrophic then the quality class is Class 1. If not oligotrophic, then the appropriate surrogate value should be noted and used in the estimation of percentage change (see Appendix II).

References to aid the interpretation of the biological factors of Table 2.

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Ravera, O. (1980) *Effects of eutrophication on zooplankton* in “Eutrophication of deep lakes” Ed. S.H. Jenkins, pp 141 – 159, Pergamon Press, Oxford.
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Slack, H.D. (1965) *The profundal fauna of Loch Lomond, Scotland.* Proc. Roy. Soc. Edinb. **69**, 272 – 297.
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Appendix II

Assessment of baseline trophic status

The objective of this appendix is:

To provide methodologies for the derivation of a baseline total phosphorus concentration for a standing water. This baseline to represent the phosphorus concentration in a waterbody derived from natural and semi natural sources before the import into the catchment of substantial quantities of phosphorus in the form of plant fertilizers or animal (including human) foodstuff.

1.0. Rationale of method

1.1. A description of the overall rationale is given in Appendix I.

1.2. Hindcasting

Derivation of baseline phosphorus concentrations by hindcasting is currently the subject of research by several organizations. Two broad approaches are evident; the use of sub-fossil diatoms in lake sediments and the land us / phosphorus loss coefficient approach. The NRA has been funding the latter and is now considering a joint appraisal study to validate methods. Land use and loss coefficients offer the only realistic option for the study of a large number of lochs in the short time scale imposed by the 1995 WQ survey. Some work on sub fossil diatoms will take place in Scotland and should provide validation, but it is unlikely to cover a large number of sites or be finished by 1995/96. For the purposes of the 1995 WQS relatively simple approaches are proposed.

1.3. Proposed method

The basis of the land use / phosphorus loss coefficient methods is a two part process; firstly the calculation of an overall total phosphorus load to a waterbody from a summing of both point sources and an estimate of diffuse sources from land use areas and loss coefficients. This total load is then used to calculate an in-lake total phosphorus concentration using OECD equations. The only other data required for the application of the OECD models are loch volume and annual water throughput to calculate water residence time. This basic method may be executed using the **MINDER** model developed by the WRc for SNIFFER. The various options are described more fully below, choice of the appropriate option will be dependent on the information available about the loch and its catchment. In general, more information will permit a fuller analysis of the phosphorus balance of the catchment and give more confidence that a realistic hindcast value has been arrived at.

1.4. Waterbodies with internal loading

Since this method focuses entirely on external phosphrus loads to waterbodies it will produce a hindcast value which ignores any internal phosphorus load which may have been a longstanding feature of the waterbody. This may produce an unrealistic quality classification. For example, a shallow productive waterbody with a small catchment and water throughput may currently have a high annual mean total phosphorus concentration derived largely from sediment recycling. Hindcasting by the method outlined will produce a relatively small total phosphorus load and probably a low in-lake phosphorus concentration, this may be unrepresentative of the true baseline nutrient status which may have been determined as much by internal cycling in the past as it is currently. There is no method available for the hindcasting of internal loads. It is recommended therefore that where substantial internal phosphorus loading is suspected of making a significant contribution to the annual average total phosphorus value, the hindcast value is treated with caution. To circumvent this problem it may be possible to apportion current mean phosphorus values between internal and external sources and apply the ratio to the external loading generated by hindcasting. Waterbodies in this category may need to be flagged in the quality classification.

2.0. Hindcasting method for well documented waterbodies and catchments

Where a loch is well studied and a reasonably good understanding of the relative magnitude of the point and diffuse sources of phosphorus exists, a current budget may be constructed balancing external phosphorus load with in-lake mean annual concentration. This may be done manually or by using the MINDER annual model. Following the calibration phase MINDER is run excluding all point sources and diffuse sources supplying enhanced loads of phosphorus, for example intensively farmed arable land. For waterbodies receiving the sewage effluent from substantial settlements some judgement may need to be made if exclusion of all point sources is deemed excessively stringent. The calibration of the MINDER model for a lake with several years run of data is necessarily a subjective exercise, nevertheless, use of this method will give added confidence that, firstly an understanding of the relationship between load and concentration has been gained, and secondly that the subsequent hindcast value is realistic.

Table 3 gives the data requirements for the MINDER input file. Use of the MINDER annual model requires practice and familiarity with the multiple options offered. It is recommended that before embarking on a programme of data collection for a suite of lochs, a trial run should be carried out on a single loch for which the relevant data exist.

The selection of appropriate loss coefficients to represent phosphorus loss from unfertilized catchments is a critical step in the process and effectively determines the hindcast phosphorus concentration of the waterbodies. To ensure a comparable assessment across Scotland it would be desirable to have a fixed menu of loss co-efficients representing the spectrum of “natural” land use categories and various geological / soil types. This requires further work. In the interim period the undernoted loss coefficients may be applied in any test applications of the method (includes some fertilized land uses and gives a range for each, supplied by MW Marsden).

Land Use	**TP Loss rate, range, kg ha^{-1} year^{-1}**
Wetlands	0.01 – 0.10
Blanket bog	0.03 – 0.10
Montane	0.05 – 0.12
Coarse grassland	0.08 – 0.15
Smooth grassland	0.09 – 0.20
All heather types	0.07 – 0.20
Bracken	0.09 – 0.25
Coniferous plantation	0.15 – 0.25
Mixed woodland	0.15 – 0.30
Broadleaved woodland	0.15 – 0.40
Improved grass	0.40 – 0.80
Young plantation	0.40 – 1.00
Ploughed land	0.50 – 1.50
Felled woodland	0.50 – 1.50
Arable	0.80 – 3.00

Table 3. Data requirements for the *params.ega* file of MINDER

1. Catchment area (ha)*.
2. Lake surface area (ha)*.

3. Lake volume (million cubic metres)*.
4. Maximum depth (m)*.
5. Mean depth (m)*.
6. [TP] at start of period (mg l^{-1}) (may be guessed)*.
7. Start year of period*.
8. End year of period*.
9. Septic tank per capita years. (i.e. 100 people in residence for six months = 50 capita years).
10. Soil retention coefficient (value between 0 and 1).
11. Septic tank export coefficient (kg $capita^{-1}$ $year^{-1}$).
12. Rainfall (mm).
13. Evaporation (mm).
14. Runoff (equals inflow to loch, probably not available, may be omitted).
15. Outflow from loch (million cubic metres) (surrogate for 14)*.
16. Phosphorus load from point sources (kg $month^{-1}$)*.
17. Extra flow from point sources (million cubic metres).
18. Observed [TP] if available (mg l^{-1}).
19. Atmospheric export coefficient (kg ha^{-1} $year^{-1}$).
20. Lake effective volume, % (to account for stratification).
21. Sediment total phosphorus, % of current annual lake [TP], (to account for loss / gain to water column).
22. Water transparency, e.g. Secchi disc depth (m).
23. Land use area (ha)*.
24. Total phosphorus loss coefficients for each land use area (kg ha^{-1} yr^{-1})*.

Note: this list is a guide, some of the data may not be required for particular applications. For example, rainfall and evaporation may be replaced by outflow, and runoff is unlikely to be available. Those marked * are considered to be indispensable for any application.

3.0. Hindcasting method for waterbodies where only in-lake data is available

The recommended method for waterbodies where some in-lake total phosphorus data is available, enabling an approximation of an annual mean value, but where little information exists for the catchment, is superficially similar to that proposed in 2.0 above. Essentially the phosphorus concentration may be used to estimate a total load which can be apportioned between estimates of the point sources and diffuse sources in the catchment. This may be done using the MINDER annual model (note: since MINDER is a modeling tool it will not accept a minimum of two years data in the annual mode, this may be circumvented by doubling up the annual data as two years consecutive data).

When a balanced phosphorus budget has been arrived at the model can be rerun excluding the point sources and enhanced diffuse sources as described in 2.0 above. This method will be less reliable than that described in 2.0 since annual variation in flushing, loads, and concentrations will not be known and will not have been used in calibrating the model.

4.0. Hindcasting method where few data are available

If little or no data pre-exists for a waterbody hindcasting will require the collection of the basic data marked by * in Table 3. These are the basic requirements for estimation of load from land use areas and loss coefficients, and the derivation of an in-lake concentration from that load using OECD equations. Again, the annual MINDER model may be employed in estimation of this hindcast total phosphorus concentration.

The proposed project on land use and loss coefficients for Scotland (see 2.0) would be of greatest use here. The method would entail the selection of appropriate catchment data for the waterbody, and the use of this with the simple hydrological data to estimate an in-lake concentration. In the absence of such a Scotland wide database it is recommended that appropriate land use categories and phosphorus loss coefficients (representing non-enhanced loss rates) are selected from those given in 2.0 and used to estimate an in-lake total phosphorus concentration derived solely from natural diffuse sources, for example moorland and woodland.

5.0. Derivation of nutrient quality bandings

When a current total phosphorus concentration has been calculated or estimated (see Appendix I), together with a hindcast total phosphorus concentration as described in this Appendix, the division of $[TP]_c$ by $[TP]_o$ (current and original) will give a ratio indicating the degree of change. This is used in the decision tree to ascribe the waterbody to band 1, 2, 3, or 4.

Appendix III

Methodology for Acidification Classification

3.1. Introduction

Many Scottish lochs are naturally acidic. It is therefore desirable that any classification scheme should be based on a comparison between acidification status and the natural, pre-industrialisation baseline level. In the absence of historical information on water quality and ecology, two techniques may be used to establish this baseline status:

a) Empirical models (e.g. the Henriksen model) can be used to predict baseline alkalinity or acid neutralizing capacity (ANC).

b) Historical pH changes can be reconstructed from diatoms or other identifiable remains in loch sediment cores. This method has been used to demonstrate acidification in a number of Scottish lochs. Although the techniques involved are beyond the current capabilities of RPAs, it may be appropriate to incorporate reliable published data into any classification scheme.

Two methods are given for producing an acidification classification based on the Henriksen model. Either method may be used, depending on availability of resources. Method I uses methodology developed for critical loads calculations to derive historical ANC which can then be compared with present day ANC. Method II is a simplified version which is likely to be less accurate, but requires fewer chemical determinands. The classification table has been derived using the relationship between present day ANC and fishery status established for Norwegian lakes.

Information is also given on the use of supporting data to validate or modify the final classification.

3.2. Method I

This method involves a preliminary screening step using alkalinity to reduce the analytical workload. If present alkalinity is < 2 mg l^{-1}, present ANC (ANC_t) is determined directly from alkalinity and DOC (TOC on a sample filtered through a 45 μm membrane is acceptable) using an empirical relationship. If ANC_t is < 40 μeq l^{-1}, base cations, chloride and sulphate are determined and used to calculate baseline ANC (ANC_o).

1. Determine alkalinity using the appropriate ‘blue book’ method. If alkalinity is ≥ 2 mg l^{-1}, then loch is Class 1.

2. If alkalinity is < 2 mg l^{-1}, redetermine the alkalinity by titration to pH 3.8 and 3.5, determine DOC and calculate ANC from:

   ANC_t (μeq l^{-1}) = Alk (μeq l^{-1}) + 4.5 DOC (mg l^{-1})

3. If ANC_t is ≥ 40 μeq l^{-1} then loch is Class 1.

4. If ANC_t is < 40 μeq l^{-1}, determine Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, and Cl^{-}. Subtract sea salt component using [Cl^{-}]. If non-marine component is negative, set to zero.

5. Calculate ANC_t indirectly from:

   ANC_t – [BC_t]* - [$SO_{4\,t}^{2-}$]*

where BC = total base cations.

6. If measured ANC_t (step 2) approximates to indirectly calculated ANC_t (step 5), proceed. If not, check calculations and analyses.
7. Calculate baseline ANC (ANC_o) from :

   $ANC_o = [BC_t]^* - F([SO_4{}^{2-}{}_t]^* - [SO_4{}^{2-}{}_o]^*) - [SO_4{}^{2-}{}_o]^*$

   where $F = \sin(90[BC_t]^*/S)$ and $S = 400$

   and $[SO_4{}^{2-}{}_o]^* = 15 + 0.16[BC_t]^*$

8. Refer to table below to obtain final class:

Baseline ANC	Present ANC					
	≥ 40	20 - 39	0 - 19	-1 - -20	-21 - -40	< -40
≥ 40	1	2	2	3	3	4
20 - 39		1	2	3	3	4
0 - 19			1	3	3	4

3.3. Method II

This is a simplified method based on the simplest version of the Henriksen model. Base cation leaching and background sulphate are ignored, but organic anions are taken into account. It is assumed that DOC does not change with acidification. The maximum number of determinands required is four: Ca, Alk, DOC and Cl^-.

1. Determine alkalinity using the appropriate ‘blue book’ method. If alkalinity is ≥ 2 mg l^{-1}, then loch is Class 1.
2. If alkalinity is < 2 mg l^{-1}, redetermine the alkalinity by titration to pH 3.8 and 3.5, determine DOC and calculate ANC from:

   ANC_t (μeq l^{-1}) = Alk (μeq l^{-1}) + 4.5 DOC (mg l^{-1})

3. If ANC_t is ≥ 40 μeq l^{-1} then loch is Class 1.
4. If ANC_t is < 40 μeq l^{-1}, then calculate baseline ANC (ANC_o) from:

   $ANC_o = 1.23\,[Ca^{2+}]^* - 10 + 4.5\,DOC$

   where DOC is in mg l^{-1}.

5. Refer to table to obtain final class.

3.4. Additional data

Where reliable information already exists on the ecology of a particular loch, it may be used to support or modify the classification, e.g.

a) Evidence of acidification from diatom remains in sediment cores.

b) Evidence of declining fish populations or changes in population structure which could be due to acidification.

c) Where reliable historical data are available, loss of acid-sensitive benthic invertebrates or zooplankton may indicate acidification.

Such additional evidence may be particularly useful in cases where applying Methods I or II results in a borderline classification.

Appendix IV

Toxic Substances

The existence of this classification criterion does not indicate any specific need to monitor any standing water for any toxic substances. However, it is likely that any loch receiving directly or indirectly a discharge of a dangerous substance will be monitored for that substance. Monitoring may also be carried out to follow up otherwise inexplicable biological observations, or suspected illegal discharges. The provisions of this appendix enable this information to be used to contribute to the overall quality classification.

The class boundaries proposed for the classification of standing water with respect to toxic substances are basically similar to those already embodied in ADRIS estuarine and coastal waters classification schemes. In their natural state, Scottish standing waters would contain no xerobiotic trace organic substances, but traces of naturally occurring List I and List II substances such as ammonia and trace metals (including Cd, Hg) will be present due to natural processes such as rock weathering. Mere presence of a dangerous substance is therefore insufficient to justify downgrading.

However, the exceedance of national or WRc proposed national freshwater EQS for any dangerous substance clearly indicates substantial change from the natural state, and therefore justifies downgrading. Exceedance of any List II substance EQS, on a whole loch, depth averaged basis, or in the outflow stream, indicates substantial quality downgrading, and hence Class 3 banding. Exceedance of any List I substance EQS on the same basis is indicative of gross pollution arising from anthropogenic activity, and hence Class 4 banding.

Class 2 standing waters are those which have been significantly altered from their natural state, but which are not significantly downgraded in the sense that this term is used for the purposes of this classification scheme. As even the regular detectable presence of potentially toxic zenobiotic organic substances is an obvious departure from the natural state, then the annual average presence of any such zenobiotic toxic substance at greater than one tenth of the EQS indicates Class 2 quality banding.