A proposal for amending the hydrology environmental standards for lakes.

Authors: Richard Gosling (SEPA) Tristan Hatton- Ellis (CCW) for the UKTAG Water Resources Task Team

1 Background

1.1 The environmental standards for lake levels were developed from work undertaken by SNIFFER project WFD48 .

1.2 A variation from the natural lake level regime has a number of ecological implications.These impacts include alterations to the underwater light climate and changes to the spatial distribution of erosion and deposition zones. The different sensitivities of lake types to such changes were explored in an expert workshop held as part of the WFD48 project and degrees of change in lake level likely to result in some ecological deterioration were put forward.

1.3 In the workshop, experts were asked to consider the absolute changes in lake levels likely to lead to an impact. The WFD 48 report indicates that a drawdown of 1 metre was put forward as a maximum permissable alteration for macrophytes.

1.4 When asked to express an opinion on the maximum allowable drawdown expressed as a percentage of the natural, a figure of 30% was proposed. This was translated into a precautionary figure of 20%.

2 Effectiveness of the existing lake standards

2.1 The hydrology environmental standards for lakes proposed within WFD48 attempted to reconcile absolute and relative changes by making some simplifying assumptions about lake level behaviour. The limited amount of data available for WFD48 showed that annual lake level ranges fell between 0.3 and 2.0m. Using the 20% drawdown figure proposed at the workshop, this was reported as translating to a drawdown in absolute values of between 6 and 40cm, which fell comfortably within the 1 metre value expressed as a maximum permissable allowance for macrophytes.

2.2 Having suggested a value relative to the annual lake level range, the authors go on to express the limit as a percentage of the daily natural lake level, as measured above the sill. In so doing, the standards become dependent upon the relationship between lake level and sill level. If it is assumed that when lake levels are drawn down naturally during the summer, the lake level approaches the sill level, then the allowable abstraction drops towards zero.

2.3 In order to aid the application of the environmental standards by regulatory bodies, the lake level standards were expressed in terms of changes to the natural net inflow. The conversion from lake level to net inflow was achieved using a simple hydraulic equation. The result was a set of standards based upon inflow which allowed abstractions from the lake of between 5 and 30% of the net inflow.

2.4 The thresholds, originally developed as percentages of net inflow, did not account for lake storage and to remedy this the thresholds were subsequently applied to lake outflows instead. To some extent this addressed the problem of diminishing abstraction rates with reduced flow since low flows at the outflow are elevated in comparison with inflows. Nevertheless, without setting a minimum flow level at which the allowable take is calculated, a realistic allowable continuous abstraction rate is hard to achieve with the current thresholds.

2.5 This last point is illustrated in the following example which demonstrates the lake level variations in Lochindorb resulting from an application of the existing standards at outflows above Q95.

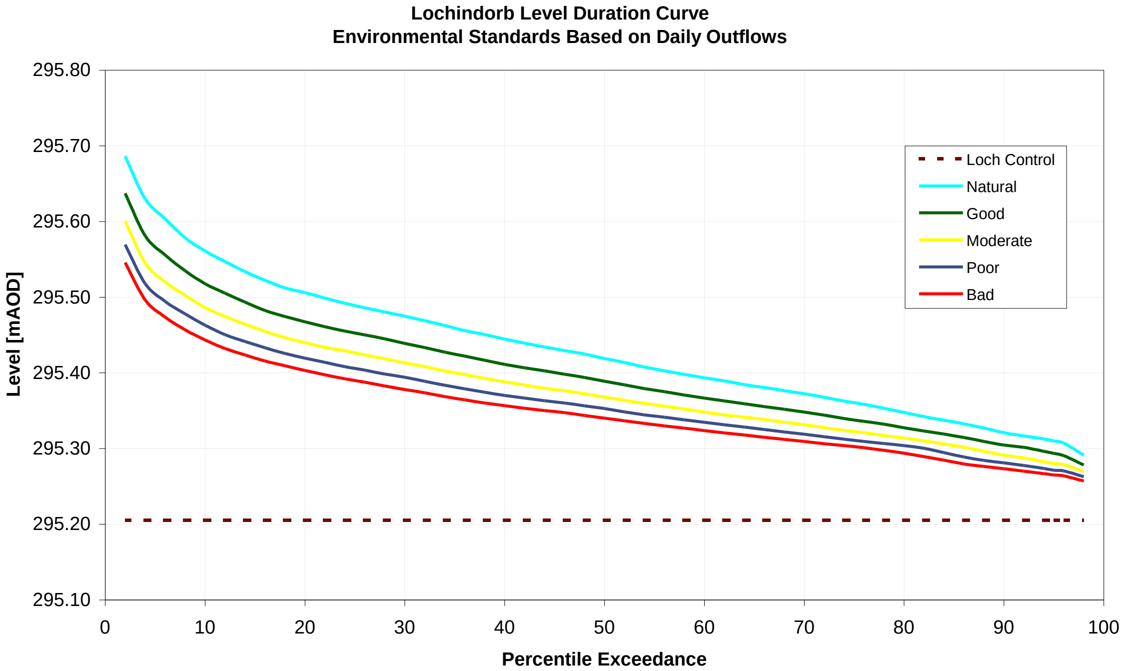


Figure 1. Lake level duration curves of the existing environmental standards for Lochindorb

2.6 Figure 1 shows that the existing outflow standards for lakes can result in small deviations in lake level. Here, the Moderate status threshold is breached for deviations from the natural levels of between 3 and 9 cm and for 70% of the time, a drop of under 10cm would result in a Bad status classification.

2.7 The hydrology standards have been used to classify lakes for a number of years by the UK environment agencies and it is now possible to compare their effectiveness at identifying ecological impacts against the biological quality element classifications.

SEPA 2009 Hydrology Lochs Classification

		Macrophyte classification	
		Pass	Fail
Hydrology classification	Pass	232	**15** *(0)*
	Fail	**79** *(47)*	7*(1)*

Table 1. Comparison of Hydrology and Macrophyte classification for lochs in Scotland. Values refer to numbers of waterbodies with italicised values in brackets referring to numbers of waterbodies deemed to be 'Bad' status

2.8 Table 1 illustrates that in Scotland, around 1 quarter of lochs are classified as failing the hydrology standards whilst less than 10% fail the macrophyte classification. Of these, 47 lochs are deemed to be Bad status using the hydrology standards whereas only 1 is classified as Bad for macrophytes.

2.9 Visualising the degree of impact which corresponds to the existing Bad status threshold as a time series demonstrates how this level change impacts throughout the year. In figure 2 the impact of the existing Bad status threshold is shown in comparison to the modelled impact that would arise from the operation of the lake as a storage reservoir with a 2m impoundment. It is more obvious how the latter scenario could result in a measurable ecological impact than for the former.

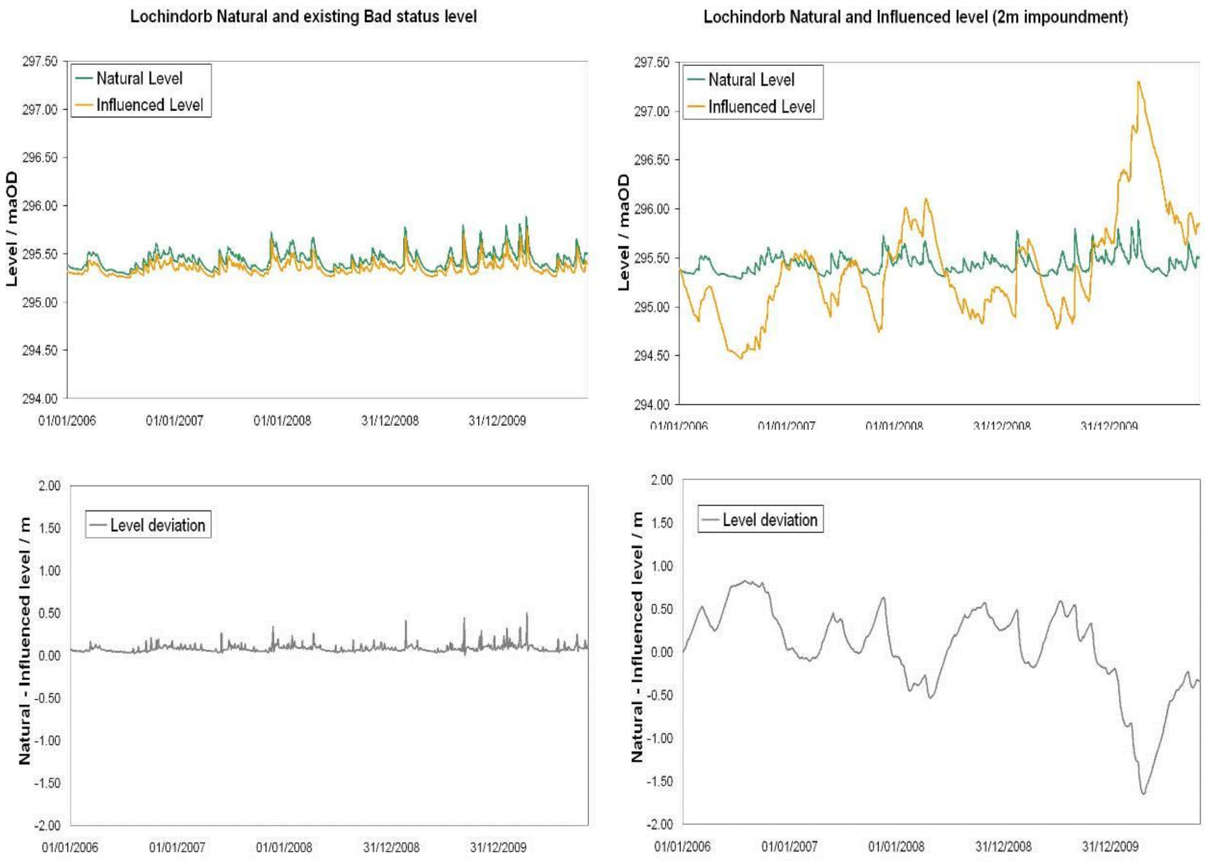


Figure 2. Lochindorb level time series graphs of level variation from 2 modelled impacts: the existing Bad status threshold (left) and a 2m impounded reservoir (right)

2.10 Figure 2 demonstrates that the existing Bad status lake standard for hydrology translates to a very small impact on level. In this case the amount of level change is approximately half the estimated wave base height. The relevance of this is that the wave base height was identified in WFD49a (SNIFFER 2008) as a threshold which could be used to determine minimum levels to minimise the scour of littoral macrophytes (from Kirk and Henriques 1986)

2.11 Determining the degree of change in level which would result in a significant impact upon lake ecology depends upon the sensitivity of lake habitats to water level fluctuation. In both WFD48 and more recently WFD104, systems have been proposed for characterising lakes by virtue of the differences in the hydromorphological processes which influence the composition and abundance of species

2.12 Lake typologies are used to discriminate the sensitivity of lake ecology to changes in level via the scales of change in habitat conditions per unit of level change. For example, in WFD48 peaty lakes were identified as most sensitive to level change as they are characterised by a narrow zone of light penetration (euphotic zone) and consequently, macrophytes are limited to a small littoral zone. In a clearer water lake, with a more extensive euphotic zone, a similar change in lake level would have a proportionately smaller impact upon the natural littoral macrophyte communities. There are many published values indicating the extent of the euphotic zones in lakes. These typically fall within a range of 1 to 10 metres depending upon the turbidity of the water.

2.13 Where the degree of alteration has a significant relative impact upon the size and location of the euphotic zone it is reasonable to assume that an impact upon the lake ecology could occur. Using the lake typology to detemine sensitivity to changes in lake level, the development of the lake environmental standards, in part ,attempted to express the degree of ecological impact for a given level change by considering the change in relation to the size of zone impacted e.g. the euphotic zone or the shore erosion zone.

2.14 An assessment of the relative change in lake zones is a concept used in the Lake-MiMAS tool for assessing hydromorphological impacts in which impact scores for the ‘shore’ and ‘pelagic’ zones are derived for ranges of lake level regulation. Here, impacts scores have been derived for bands of level regulation which vary by lake sensitivity. Under this scheme, peaty, very shallow lakes are again identified as the most sensitive to level regulation yet changes of less than 0.5m are not considered sufficient to cause a failure of Good status. Such a result appears to conflict with the existing hydrology standard for lakes where changes of less than 10cm can result in a failure of Good status.

2.15 With a combination of lake level data and an understanding of lake bathymetry, it is possible to express water resource impacts on a lake in terms of the relative change in lake habitat zones, provided some simplifying assumptions can be made about the partitioning of zones.

2.16 In figure 3. using surveyed bathymetric data, Lochindorb has been divided into the following zones using standard lake habitat definitions (CEN 2011):

- The terrestrial zone – the area above the maximum lake water level
- The eulittoral zone – the area between the maximum and minimum lake water level
- The littoral zone – the habitat extending from the water’s edge to the lakeward limit of rooted macrophytes or algae on the lake bed
- The pelagic and profundal zones - the open water zone extending from the littoral zone to the centre of a lake; in the deeper parts of the pelagic zone (known as the profundal zone) light does not penetrate and there is no photosynthetic activity

2.17 By comparing the area and depths within the lake that these zones occupy between the natural and an impounded condtion, it is possible to visualise the potential ecological impacts that an altered level regime may have. It's worth noting here that the impact resulting from the level variation corresponding to the existing hydrology Bad status threshold is not shown here as it is practically indistinguishable from the natural condition.

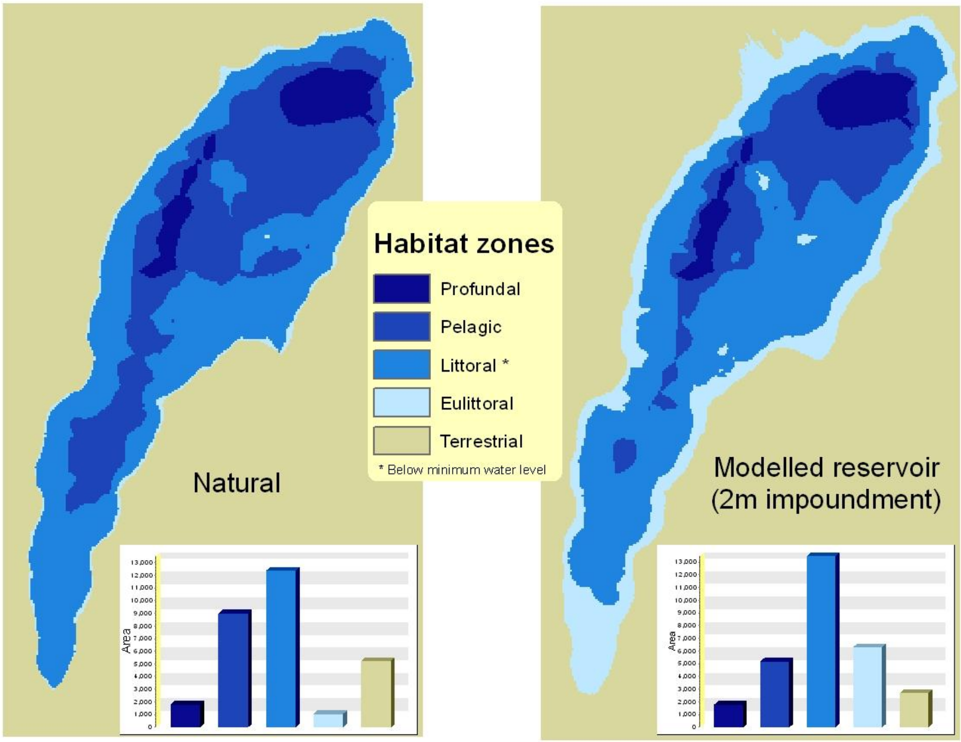


Figure 3 A visualisation of habitat zones for Lochindorb under natural (left) and impounded conditions (right). Note; the bar charts show the relative areas of each zone. Note: the modelled impoundment of Lochindorb is used to demonstrate the impact on habitat zones and does not reflect current or proposed conditions in the loch.

2.18 Figure 3 demonstrates the impact of the increase in level range under impounded conditions. The eulittoral zone is greatly increased by the effect of increased level range with a more than doubling of the area subject to much of the erosional power of waves.

2.19 As well as the impact on the size of the eulittoral zone, the increased level range has caused a shift downwards of the base of the eulittoral zone, with the effect of exposing areas previously permanently submerged and bringing new areas of the lake within the permanently submerged littoral zone.

2.20 Expressing the relative impact upon the natural zones within a lake provides a method of assessing the potential degree of impact upon lake ecology and is a technique used within the Lake MImAS methodology. The relative impact upon the habitat zones can be derived from the degree of change in the lake level regime plus an estimate of typical habitat zone depths.

2.21 It is critical that revised environmental standards take into account the impacts on the entire lake. These are not limited to the littoral zone; indeed, as the lake adjusts to the new hydrological regime we can expect it to expand downwards in response to regular drawdown events. Pelagic zones can also be expected to shrink. This suggests that deeper water plant species such as *Isoetes*, *Nitella* and *Potamogeton praelongus* can be expected to be affected. *Lobelia dortmanna* is a widespread species in the marginal community of upland lakes. It is quite sensitive to desiccation and would therefore seem to be a potential indicator of Good Status or better.

2.22 Some large, deep lakes have populations of potentially sensitive fish, especially Arctic charr (*Salvelinus alpinus*), whitefish (*Coregonus spp.*) and genetically distinct ferox trout (*Salmo trutta*). These populations are of conservation importance and are sensitive to some of the secondary effects of drawdown such as changes to primary productivity, thermal regime and exposure of spawning gravels in winter. Their requirement for large water bodies also makes them especially likely to occur in lakes that are also of interest to industry. Some of these fish appear able to tolerate quite significantly modified hydrological conditions in the absence of other pressures.

2.23 Although the typologies derived from WFD48 indicated the increased sensitivity of peaty lakes due to a restricted euphotic zone, it is possible to draw a different conclusion. Macrophyte growth in peaty lakes is typically restricted to shallow littoral areas which are also likely to be periodically exposed and / or wind stressed. In extreme situations peaty lakes contain no macrophytes. It therefore follows that any macrophyte community in peaty lakes will be tolerant of a certain amount of drawdown and conversely is less likely to contain sensitive species (with the possible exception of Lobelia). Indeed, by broadening the littoral zone, drawdown may promote the development of macrophytes along the margins of peaty lakes. Peaty lakes also tend not to support fish species likely to be sensitive to drawdown. However, if the substrate is primarily peaty, drawdown may resuspend fine material, thus further reducing water clarity.

2.24 In contrast, clear lakes may be sensitive to drawdown for the reverse reasons. Clear lakes often show a pronounced zonation that is more likely to be affected by drawdown, and may support a wider range of species that are likely to be sensitive. Resuspension of sediment following drawdown is likely to reduce water clarity and increase phosphorus availability. The sensitivity of these habitats is likely to be affected by bathymetry, and in particular by the areal extent of the habitat that is affected by the drawdown.

3 Revised Standards

3.1 It is proposed that standards are based on the areal extent of the lake that will be affected, as a proportion of lake habitat area. This should be counted as (i) All eulittoral areas affected PLUS (2) The change in area of the permanently submerged littoral zone habitat (if any) PLUS (3) the change in area of the pealgic habitat (if any). It should be carried out as an assessment of bathymetric data under natural and modified conditions.

3.2 The proposed standards can be applied to all lakes. These standards do not require a typology, but are based on the assumption that the lake bathymetry and level variation can be derived

3.3 Proposed Standards for All Lake Types.

This standard is intended to protect the entire lake ecosystem by restricting the area of habitat that will be altered by any drawdown, thereby restricting the magnitude of any change and reducing the likelihood of system level changes in ecosystem status and / or function.

Standards are the boundaries for the 99th percentile of the percentage area of the lake affected by the drawdown relative to reference, determined by modelling.

	High	Good	Moderate	Poor	Bad
All Lake Types	1	5	10	20	>20

3.4 Habitat zone definitions.

The standards above refer to the total percentage change in habitat zone area. The habitat zone area is the combined area of the littoral and pelagic zones impacted by level change. The depth to which lake level changes impact upon lake habitats will vary from lake to lake. Peaty lakes may have narrow littoral zones but if level change results in significant additional sediment erosion and deposition, impacts to benthic ecology may be evident well into the pelagic zone.

In the absence of field data to the contrary, the depth to which light penetration to the lake bed is sufficient to enable the growth of rooted plants or bottom-living algae may be taken to be 5 metres for peaty lakes and 10 metres for all other lake types. The influence of lake level variation is unlikely to be significant below 20m and therefore a total habitat depth extended to10m below the base of the littoral zone is recommended.

4 Examples of applications of the proposed lake area standards.

The proposed environmental standards for lakes habitat area change have been tested on a small number of lakes in Scotland and Northern Ireland to visualise the impacts corresponding to the status classes. The tests are presented below demonstrating the impact on:

4.1.1 The maximum allowable abstraction for Good status and its impact upon the lake level hydrograph in Lochindorb in N.E Scotland
4.1.2 The loss of lake shore habitat in 2 lakes in Scotland and 2 in Northern Ireland.
4.1.3 The proposed habitat standards expressed as change in median lake level for a range of lake basin forms

4.2 Maximum allowable abstraction and the impact on the lake level hydrograph of Lochindorb

4.3 The lake level regime and outflow of Lochindorb has been modelled to investigate the impact of abstraction upon lake level and lake habitats. It can be shown that a continuous abstraction of up to 100% of the natural outflow Q95 would, under the proposals, result in Good status or better. Such an abstraction would result in a 99th percentile lake level change of 24cm. The impact of this abstraction on the lake level regime is shown in figure 4.

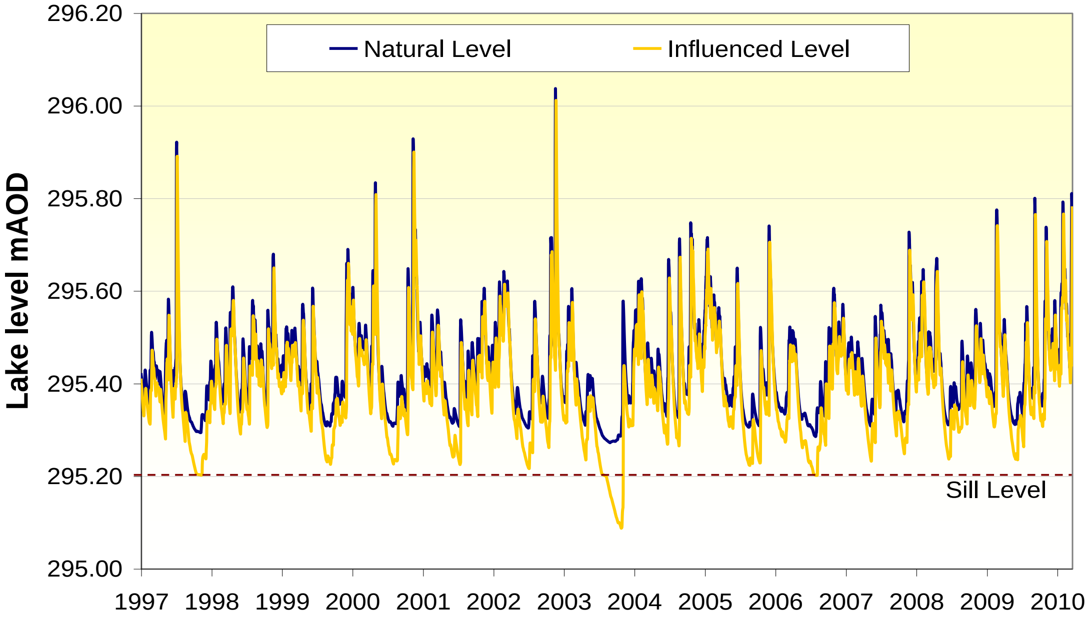


Figure 4 The impact upon Lochindorb's level regime from a hypothetical abstraction resulting in a 5 % loss of lake habitat . The abstraction is equivalent to 100% of the outflow Q95.

4.4 Figure 5 visualises the loss of 1,5,10, 20 and greater than 20% of habitat area corresponding to the High, Good, Moderate, Poor and Bad status classes.

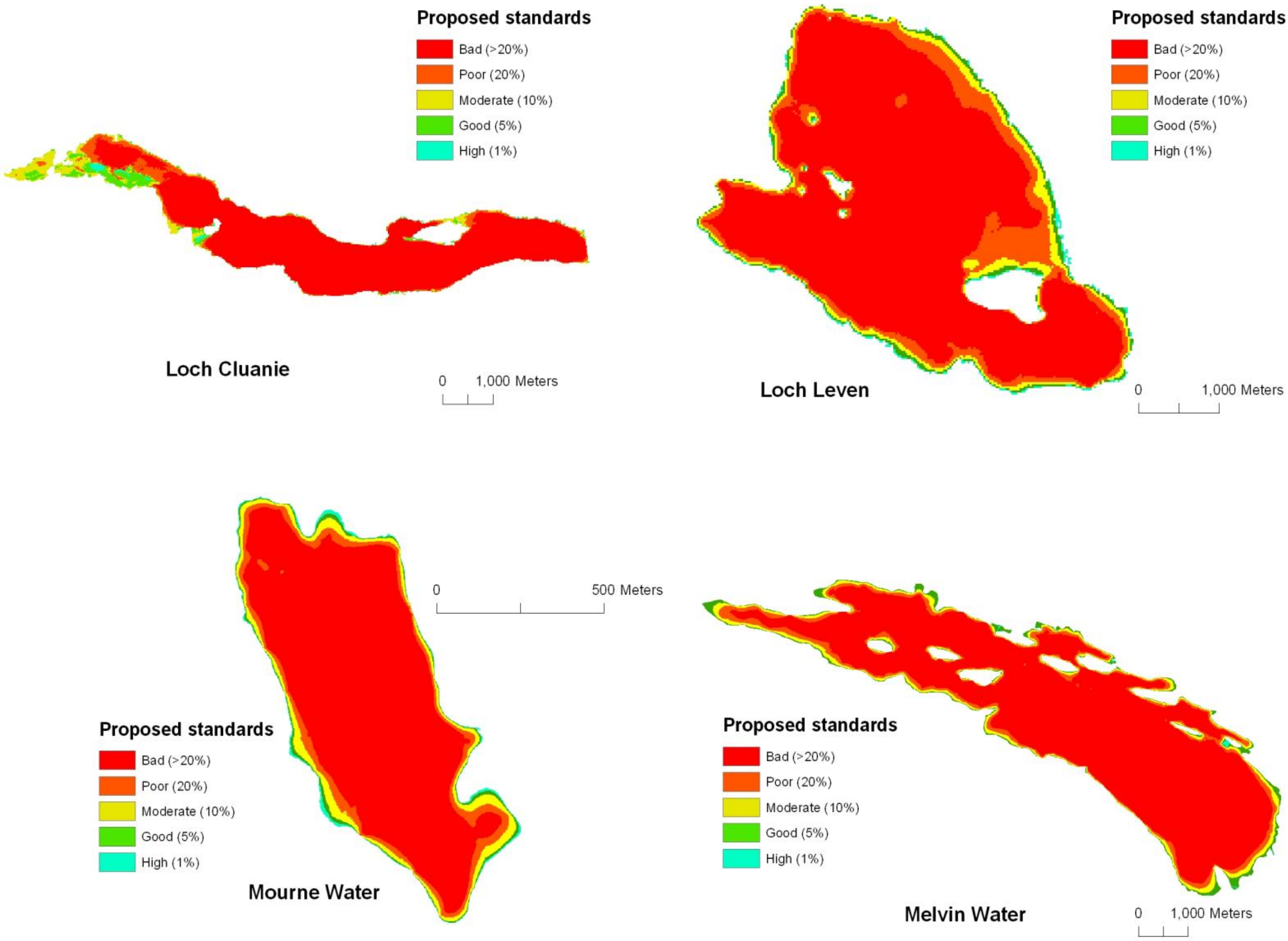
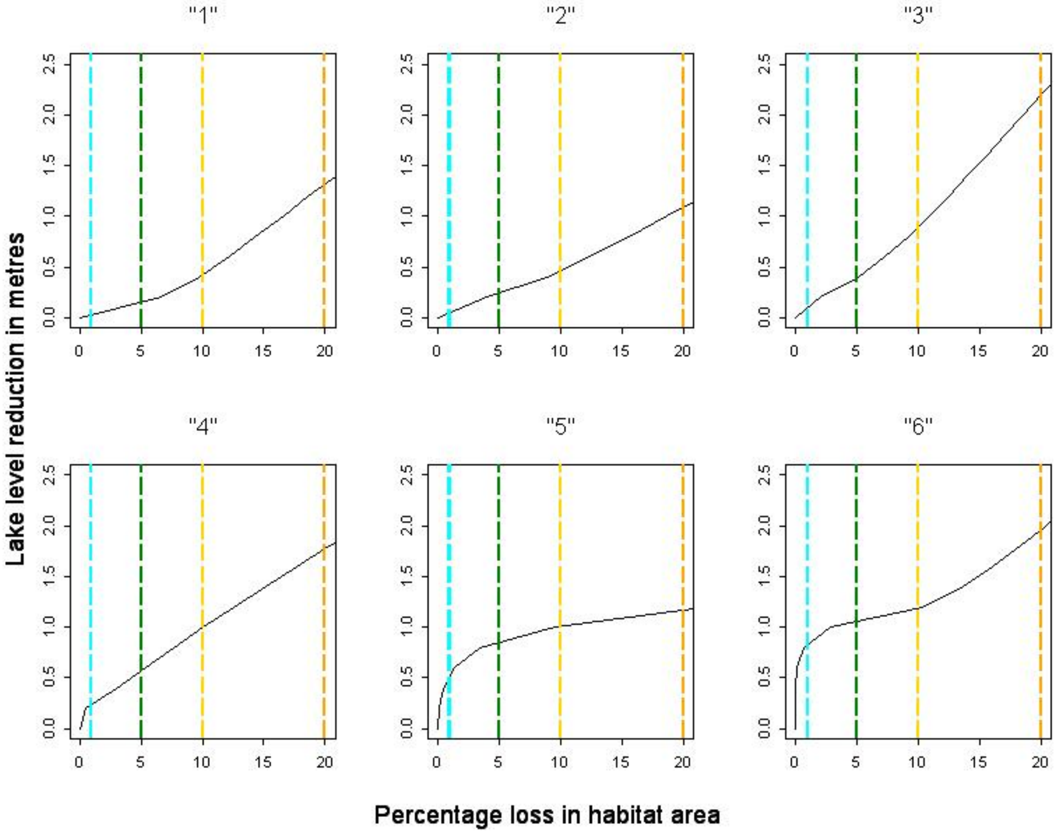


Figure 5. Visualisations of the lake shore changes associated with the proposed standards. Note max lake depths are 49, 41, 26 and 15m for Cluanie, Melvin, Leven and Mourne respectively.

4.5 Figure 6 shows the change in median lake level corresponding to the proposed status classes for a variety of lake basin forms in Scotland and Northern Ireland.



1 – Spelga Water (NI) 2 – Lochnindorb (Scotland) 3 – Melvin Water (NI)
4 – Loch Leven (Scotland) 5 – Loch Cluanie (Scotland) 6 – Loch Fannich(Scotland)

Figure 6 The change in water level corresponding to loss in habitat area for 6 lakes.
Note: the vertical dotted lines indicate the proposed habitat thresholds i.e Blue = High, Green = Good, Yellow = Moderate, Orange = Poor

Figure 6 indicates that the degree of level change leading to a unit loss in habitat area varies widely depending upon basin form. Changes of between 0.2 and 1m coincide with the loss of 5% of habitat area (Good / Moderate threshold) in the shallowest and steepest sided lakes respectively.

5 The relationship between the existing and proposed standards

5.1 The existing hydrology environmental standards for lakes were developed to account for the same environmental impacts as those captured more explicitly within these revised standards. Variations in the degree of lake habitat area change for a given abstraction amount were accounted for by lake depth and basin form typology. Shallow, convex basin forms were assigned tighter environmental standards due to the fact that, for a given reduction in level, greater habitat change would result. Lake level change was represented as lake outflow change by making the assumption that the latter is a function of the former. The lake outflow standards do attempt to reflect changes in lake habitat but, partly since they are expressed as percentages of outflow rather than absolute change in level, they result in standards that assign Moderate, Poor and Bad status classes to very small degrees of habitat change.

5.2 Using the existing outflow standards

Since the existing lake outflow standards were developed to account for the same impacts as the proposed standards, yet are more precautionary, a pragmatic approach to applying the proposed standards would be to use the existing outflow thresholds to screen out those waterbodies which are at High or Good status. This would preclude the need for bathymetric and lake level data where lake outflow data already signify low levels of impact. For those waterbodies screened out as Good status or better using the lake outflow thresholds, there will be a higher degree of confidence that Good status has been achieved compared with those which do not pass the outflow thresholds.

5.3 Use of the new lake standards as a risk assessment tool.

5.4 It is envisaged that the proposed lake standards will provide a tool for assessing the risk posed by a new lake impact in the following ways:

5.5 For new abstractions not involving impoundment, the standards will demonstrate the likely impacts on lake habitat zones and can be used to assess the potential for deterioration of biological quality.

5.6 For proposed lake impoundment, impacts will largely relate to the following:

5.6.1 the inundation of former terrestrial habitat and raising of the euphotic zone,
5.6.2 the nature of the operation of lake levels post impact.

5.7 These standards will assist with an assessment of the latter of these 2 impacts if they are applied to the post-impact lake level regime i.e. resetting the post-impact reference habitat zones to those of the raised lake level. The standards will demonstrate how the operation of the impounded lake will impact upon the new habitat zones by including the inundated shore region within the lake bathymetry.

5.8 In order to assess the impacts of inundation, it will be necessary to consider the character of surrounding habitat such as the presence of wetlands, impacts upon tributaries etc.. This will require information beyond that required for the lake habitat assessment method

5.9 Use of the new lake standards to assist with mitigiation measures on HMWBs

5.10 An assessment of the impacts upon lake habitats will assist the prioritisation of mitigation measures on heavily modified lake water bodies. The assessment will demonstrate the impacts of modifying the operation of a lake level regime to improve ecological condition where this is feasible. Where there is a trade-off between improving the environmental flow release regime from an impoundment and maximising the benefit of lake level operation, the assessment of impact on lake habitat zones will be of use. For example, it may be possible to show that, during dry periods, particularly for shallow lochs, greater environmental benefit may be achieved by reducing impoundment flow releases to minimse lake drawdown than by maintaining an artifically high baseflow in the downstream river.

6 References

European Commission. 2000. *DIRECTIVE 2000/60/EC Of The European Parliament And Of The Council Of 23rd October 2000 Establishing A Framework For Community Action In The Field Of Water Policy.* European Commission, Brussels, Luxembourg.

Kirk, R.M. and Henriques, P.R. 1986. Physical and biological aspects of shoreline change: Lake Ohau, South Island, New Zealand, caused by high lake and storm wave runup. *Journal of Shoreline Management,* 2 305-326

Smith B.D., Maitland P.S., and Pennock S.M. 1987 A comparative study of water level regimes and littoral benthic communities in Scottish lochs. *Biological Conservation 39*, 291-316

SNIFFER WFD 48: Development Of Environmental Standards(Water Resources) Stage 3: Environmental Standards March 2006
Http://Www.Wfduk.Org/Stakeholder_Reviews/Standards_Jan_2006/Treports/Librarypublicdocs/Devtofeswaterresourcesstage3es
Downloaded 06/05/2008

SNIFFER WFD49a: Development of Decision Making Frameworks for Managing Alterations to the Morphology of Lakes (July 2005)

SNIFFER WFD104: Developing a Lake Hydromorphology Typology for the UK (January 2010)

UK TAG (2007) UK ENVIRONMENTAL STANDARDS AND CONDITIONS (PHASE 2) Final (SR1 – 2007) Updated March 2008
Http://Www.Wfduk.Org./Stakeholder_Reviews/Stakeholder_Review_1-2007/Librarypublicdocs/UKTAG_Report_Surface_Water_Standards_And_Conditions
Downloaded 06/05/2008