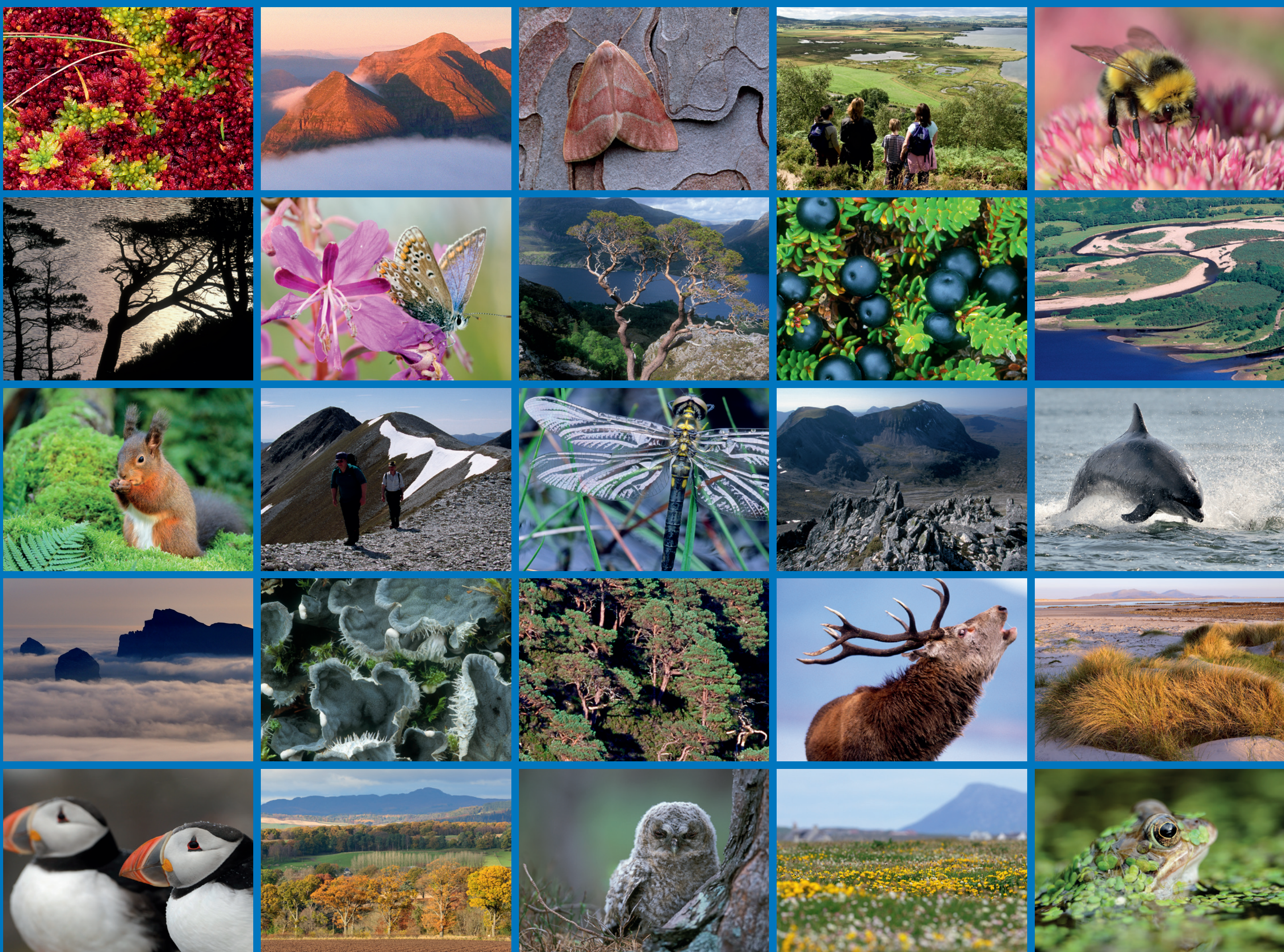
Scottish Natural Heritage
Research Report No. 1101

An assessment of the results of soil and water samples from a range of wetland sites – Bishop Loch SSSI



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RESEARCH REPORT

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An assessment of the results of soil and water samples from a range of wetland sites – Bishop Loch SSSI

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RESEARCH REPORT

Summary

An assessment of the results of soil and water samples from a range of wetland sites – Bishop Loch SSSI

Research Report No. 1101
Contractor: OHES Environmental Ltd
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Keywords

nutrients; diffuse pollution; wetland; Bishops Loch SSSI; water; soil

Background

In 2012, SNH conducted soil and water sampling from 17 designated wetland sites (Sites of Special Scientific Interest and Special Areas of Conservation). The samples were collected to establish whether the sites were subject to nutrient enrichment from either diffuse or point source pollution. The aim of this report is to analyse the data collected at Bishop Loch, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input.

Main findings

- Bishop loch has a moderately sized surface water catchment. The loch appears to be fed by a combination of groundwater and surface water.
- Groundwater samples taken at Bishop Loch have been compared with the nutrient level requirements of the vegetation types known on site. This indicates that the groundwater quality is consistent with the requirements of the vegetation currently found around the sample locations (and is consistent with the data recorded for Scotland (ER37) and for guideline/threshold levels for these habitats). However, both of the vegetation types (swamp and reedbed) are able to tolerate eutrophic situations and therefore are no indication of a low trophic status. In fact, the higher than typical Total Nitrogen levels recorded are some cause for concern.
- Using the 2008 NVC quadrat data, Ellenberg Indicator Values for Nitrogen and Moisture have been calculated and are displayed. They indicate that the most eutrophic communities (S28 and S4) are located close to inflows (such as the three ditches entering the loch from the west) or around the edges of the loch itself.
- If the groundwater samples are also used to assess their suitability to supply nearby fen communities (such as S27) it becomes apparent that Nitrogen levels exceed the indicated levels for good condition.
- Using the 2012 surface water samples and the Scottish River Basin District Directions 2014 standards, the loch exceeds standards for Total Phosphorus and JNCC guidelines for Total Nitrogen. However it is emphasised that this is from a single within-loch sample. At the time of the survey, the loch was within Ammonia concentrations for Good Ecological Status. Phosphate levels were recorded between Moderate Ecological Status and Poor Ecological Status

- Given that both Total Nitrogen and Phosphorus levels are significantly above standards for GES, this report concludes that the trophic state of Bishop Loch surface water is Eutrophic.
- Assessment of vulnerability showed Bishop Loch was most at risk from agricultural practices, sewage input, and possible on-site enrichment from bird guano. Stored nutrient within the loch sediments may also be an issue.
- Further investigations are recommended for the site (such as monthly water quality sampling, sediment sampling within the waterbody and seasonal water level recording). A range of remedial options are proposed for consideration, once additional data has been gathered.

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Acknowledgements

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1. INTRODUCTION

1.1 Project background and aims

In 2012, SNH conducted soil and water sampling from 17 designated wetland sites (Sites of Special Scientific Interest and Special Areas of Conservation). The samples were collected to establish whether the sites were subject to nutrient enrichment from either diffuse or point source pollution. The aim of this report is to analyse the data collected at Bishop Loch, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input. The results will then be used to inform site management and also contribute to a wider project to develop eco-hydrological thresholds for wetland sites.

2. METHODS

The following methodology was used at all 17 sites studied under this project, including Bishop Loch.

2.1 Sampling methodology

The soil and water samples used in this report were collected by a team co-ordinated by SNH and were undertaken in two phases.

Soil samples were collected at specific sample locations at each site by hand augering holes into the peat. Soil samples were collected at two depths:

1. From the rooting zone.
2. From within the anoxic layer below the rooting zone.

The precise depth of the anoxic layer varied from site to site according to the vegetation that was present. Generally this was approximately 15cm depth for the root zone sample and 45-60cm depth for the sample below the root zone.

Groundwater samples were collected using plastic bailers from slotted pipes installed within hand augured holes.

Surface water samples were also collected from strategic locations within surface water courses at each site.

The two sampling rounds took place in the weeks commencing the 6th February 2012 and the 20th February 2012.

Samples were delivered to the EnviroCentre Glasgow office and the SNH office at Perth for dispatch to the project laboratory. Samples were packed in cool boxes with ice to ensure that the samples remained cool in transit to minimise sample deterioration. Unfortunately some samples from some sites were misplaced by the laboratory and could therefore not be processed. All samples were tested using accredited methods or where accreditation was not available, using in-house procedures with routine QA / QC checks in place to ensure data quality.

The soil sample analysis was undertaken on dry samples, which were analysed for the following suite:

- Soil type
- Bulk density
- Water content
- Organic carbon content
- Extractable N and P
- Total N and P
- Total Calcium, Magnesium, Sodium and Potassium

Water samples were analysed for the following suite:

- Calcium, Magnesium and Sodium
- N species – total N, nitrate and ammonium
- P species – orthophosphate and total P, low level P (LOD – 0.02 mg/l)
- Iron species – Fe^{2+} and Fe^{3+}

2.2 Analysis of results

The following data sets were used to assess the site, where available:

- Vegetation descriptions, varying in detail from observations within site condition monitoring assessments to full National Vegetation Classification surveys (NVC)
- Groundwater chemistry
- Surface water chemistry
- Soil chemistry
- Details of the designated site features, site management statements and condition monitoring assessments

Sufficient vegetation information was available for some sites to allow classification of the wetland communities that were (or could be) present at each of the sites and their water quality requirements. For those sites containing measured species data (for example NVC quadrat data) it was possible to apply Ellenberg's Indicator Values[1], weighted to species abundance, to achieve a score for each sample near to a sampling point. This method can indicate, for example, how nutrient-rich the conditions are where the sample was recorded. Mapping these scores then gives an indication of the distribution of eutrophic fen types. Such maps allow a geographical appreciation of distribution of habitat factors, always understanding these values are inferred from the vegetation and not measured directly.

Where NVC data was not available, assumptions were made based on i) vegetation described within the field notes when samples were collected[2] and ii) from the site condition monitoring reports and citation. Each site was split into 'wetland types' (as defined by the SNIFFER report (2009), such as marshy grassland, fen, springs and seepages, or swamp. Originally it was also intended to apply the Wetland Water Supply Mechanisms (WetMecs) framework to define the types of wetland present, as described in Wheeler, Shaw and Tanner (2009). However, in the majority of cases, there was insufficient data available on both the hydrological operation of the site and the substrate present to be able to assign WetMec types with confidence.

A number of published and unpublished sources were then used to define water quality guidelines for the wetland types. This included UKTAG reports on Water Framework Directive targets but was principally based on a draft report commissioned by SNH, SEPA and SNIFFER (known here as the ER37 report) which aims to define suitable targets for wetland types in Scotland. The ER37 report provides data on groundwater, surface water and soil based on the various wetland communities sampled throughout Scotland. These draft guidelines were used to classify the SNH data collected in 2012 and to establish if the results were within normal ranges observed in Scotland.

For sites with open water bodies, the surface water results were compared to Scotland River Basin District (Standards) Directive 2014, along with JNCC targets and Ecoframe targets (Moss *et al*., 2003). In order to apply the correct standards, in was necessary to classify the lochs in terms of their depth, altitude, alkalinity and bedrock, as well as whether they were freshwater or saline, coarse or salmonid. Very limited data on some of these variables meant that assumptions were necessary in the classification process (for example, alkalinity data was rarely available to aid classification).

[1] The Ellenberg values (Hill *et al*., 1999) are a numerical rating given to each plant species according to its place on the spectrum of each determinant. So, for salinity, saltmarsh species have a high salinity value, freshwater marsh species a low one.

[2] Note that water samples were collected in February and this would necessarily limit the amount of species data able to be obtained.

Each site has been provided with an Assessment of Vulnerability to eutrophication, along with the relative importance of each nutrient source. Catchment nutrient modelling was beyond the scope of this project, and would not have been possible with the current data available. Instead, an 'interpretation' was made by eye of the available data of how each loch should be regarded in terms of trophic status. Any sites which would especially benefit from further more detailed study were flagged up within the report.

3. ASSESSMENT

3.1 Site review

Bishop Loch SSSI is located just north-east of Easterhouse, near Glasgow (Figure 1). The 76.16 ha site is one of the best examples in central Scotland of a base-rich loch and is one of a group of base-rich lochs to the north-east of Glasgow. Much of the east, south-east and north of the site are areas of semi-improved pasture for grazing or arable fields.

The loch was created during the last ice age and lies in a depression about 20 m lower than the highest surrounding land. Within the City of Glasgow it is one of the largest standing waterbodies. Over the centuries the loch and surrounding habitat have changed substantially due to enrichment and subsequent considerable reedswamp expansion (see Figure 2). The build-up of nutrients within the loch has resulted in a base-rich loch with a great diversity of transitional aquatic vegetation.

Bishop Loch supports a large, diverse community of breeding water-birds, including the water rail and one of the largest swallow roosts in central Scotland. The common grasshopper warbler, which is a bird of conservation concern in the UK, is present in the reedbeds as a summer migrant. The loch holds the best example of freshwater invertebrates from a series of lochs on the northern fringe of Glasgow and supports the Nationally Scarce water beetle *Agabus unguicularis*.

Submerged remains of crannogs in the north east of the Loch are of historical interest and importance.

Builders refuse from construction work at Gartloch Hospital in the 1990s, including rock and sub-soil, was dumped over an extensive area of the marginal vegetation within the site. Footpath construction took place in the south of the site and local schools have been encouraged to use the site for various projects and activities.

Scrub removal is carried out periodically in the fields to the southeast, including treatment of cut shrub stumps with herbicide (not within 20-30 m of the loch shore). Stockproof fencing was erected in the southeast of the site and planting was undertaken along the existing hedge line.

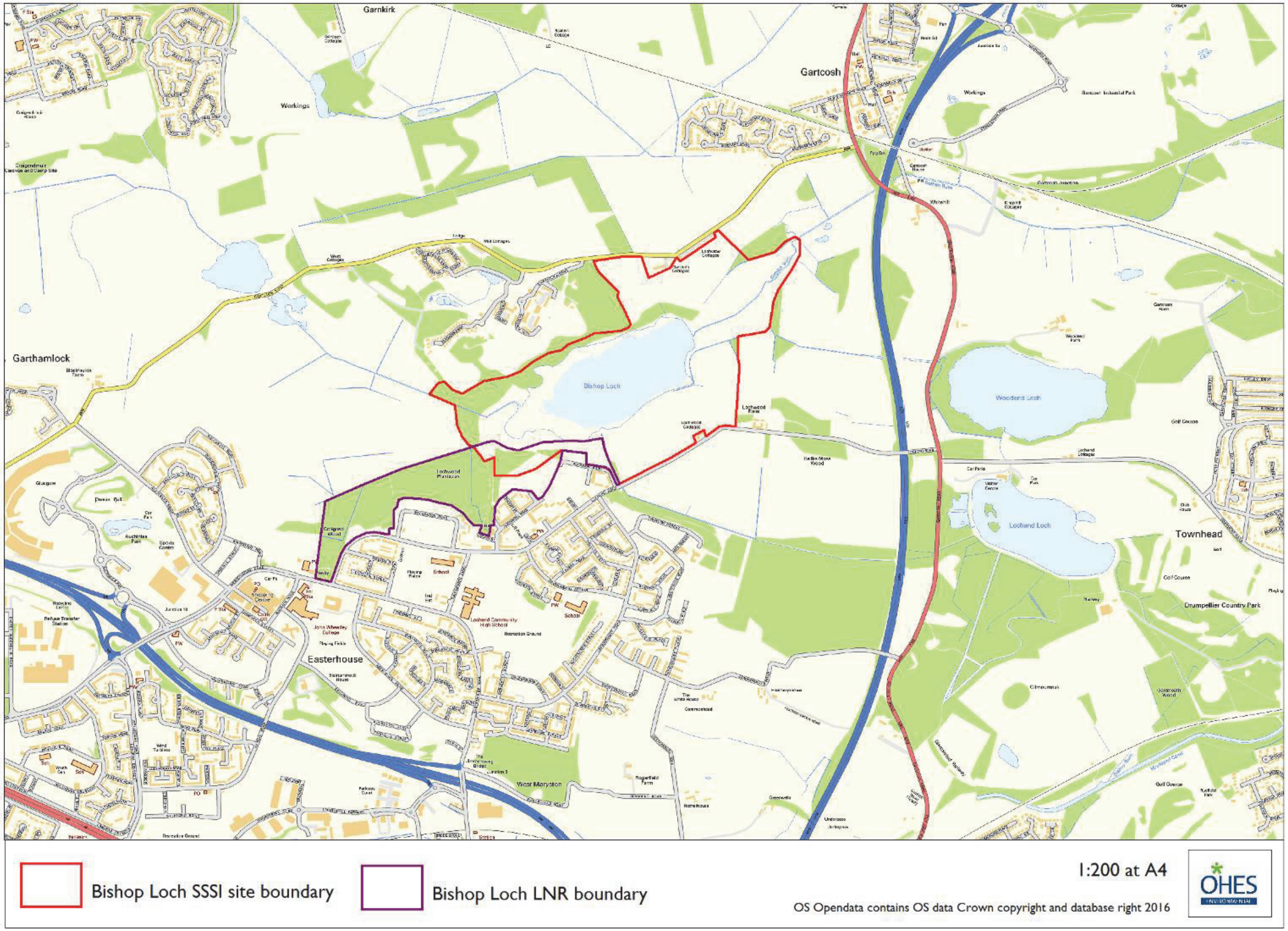

Figure 1. Site boundary and designation – Bishop Loch

Figure 2. Ordnance Survey Six Inch 1843 – 1882 map (Source: National Library of Scotland)

3.1.1 Site designation and specific targets

Bishop Loch supports a full transition of vegetation from open water to fen, marsh, grassland and woodland which provides a rich biological diversity. The site was first notified in 1971 and was re-notified in 1986 with a reduction in area of 24 ha. Emergent vegetation includes the Nationally Scarce slender-leaved pondweed and tufted loosestrife, the latter of which is in abundance. Ivy-leaved duckweed and bulrush are present, although they are absent from much of north and west of Scotland. The SSSI features for which the site is notified are detailed in Table 1. A section of the site was designated as a Local Nature Reserve (LNR) in 1995.

Table 1. Bishop Loch SSSI notified features and their pressures

SSSI features	Feature Category	Summary Condition / Latest Condition	Pressure
Base-rich loch	Freshwater habitats	Favourable Declining (Sep 2009)	a)Recreation / disturbance
Open water transition fen	Wetlands	Unfavourable No Change (Aug 2008)	a) Agricultural operations b) Water management

The base-rich loch feature is in a favourable condition due to the extensive and species rich transitional zone but declining due to recreational disturbance (including fly-tipping, vandalism and grassland fires). The site is also used for game shooting and fishing. Together, these activities lead to the disturbance of wildlife, trampling of vegetation and erosion of the loch banks.

The open water transition fen feature is considered to be in an unfavourable condition due to over-abundance of reed canary grass and common reed. This may reflect some enrichment due to runoff from agricultural land but also some drying out of the loch margins, possibly due to historical drainage or earthworks.

Site specific targets at Bishop Loch based on the 2002 condition survey include:

1. To maintain the range and extent of NVC communities with <10 % expansion of tall-herb fen communities and / or *Epilobium hirsutum* community at the expense of swamp communities.
2. Ensure standing water is present over at least 80 % of any swamp area.
3. Ensure continued presence of locally uncommon plant species.

3.1.2 Site hydrology

Bishop Loch has a moderately sized surface water catchment, which has been obscured in places where housing development has occurred (see figure 3). Three main ditches feed into the loch (Figure 4) but they are mainly overgrown or silted up through a lack of maintenance, which makes the flow into the loch quite sluggish. Water exits the loch to the north-east along Bothlin Burn. The loch is lined with boulder clay, which if broken could allow water to drain out of the site.

Bishops Loch is potentially linked to a series of lochs, including Woodend Loch (1 km to the east) and Lochend Loch (also 1 km to the east) as well as other lochs to the north. The management of the other lochs could therefore have an impact on the water quality and volume of Bishop Loch.

British waterways have the right to draw water from the loch to supply the Forth and Clyde Canal and this has the potential to lower water levels. There are two standing water monitoring points in the vicinity of Bishop Loch. These are located at Woodend Loch and Lochend Loch, both of which may be hydrologically linked to Bishop Loch.

Bishop Loch is underlain by the Clydebank and Kirkintilloch bedrock and localised sand and gravel aquifers. The quality of the groundwater was classified as 'Poor' in 2008 with 'Good' quantity. There are no trends for pollutants for this waterbody.

Evaluating the impact of nutrient sources on a wetland feature depends on a good understanding of how that wetland feature functions hydrologically and ecologically. One of the best systems to describe wetland functioning developed so far is the WetMec system (short for Wetland Mechanism) developed by Wheeler et al (2009). Each WetMec describes an assemblage of hydrological characteristics that determine functioning, and this is usually linked to a characteristic ecology. Crucially, wetland sites are not viewed as a single type (such as floodplain fen or groundwater fed valley fen), but are understood as inter-linked hydrologies composed of more than one WetMec type.

One of the limitations to this study is that little data was available to define detailed hydrological functioning or substrate for this site. However, the presence of vegetation communities such as *Carex rostrata* swamp (S27) and *C. rostrata - Sphagnum* mire (M5) suggest the presence of either WetMec 13: Seepage Percolation Basins or WetMec 20: Percolation Basins. These communities are typically fed by water discharging around the margins of topogenous hollows, either by groundwater outflow from a mineral aquifer or from surface water streams and run-off (Wheeler, Shaw & Tanner, 2009). It is therefore possible that water from the higher ground surrounding Bishop Loch percolates through the wetland margins (either near the surface or along sub-surface flow paths) to then outfall into the loch (possibly beneath buoyant vegetation mats in some areas).

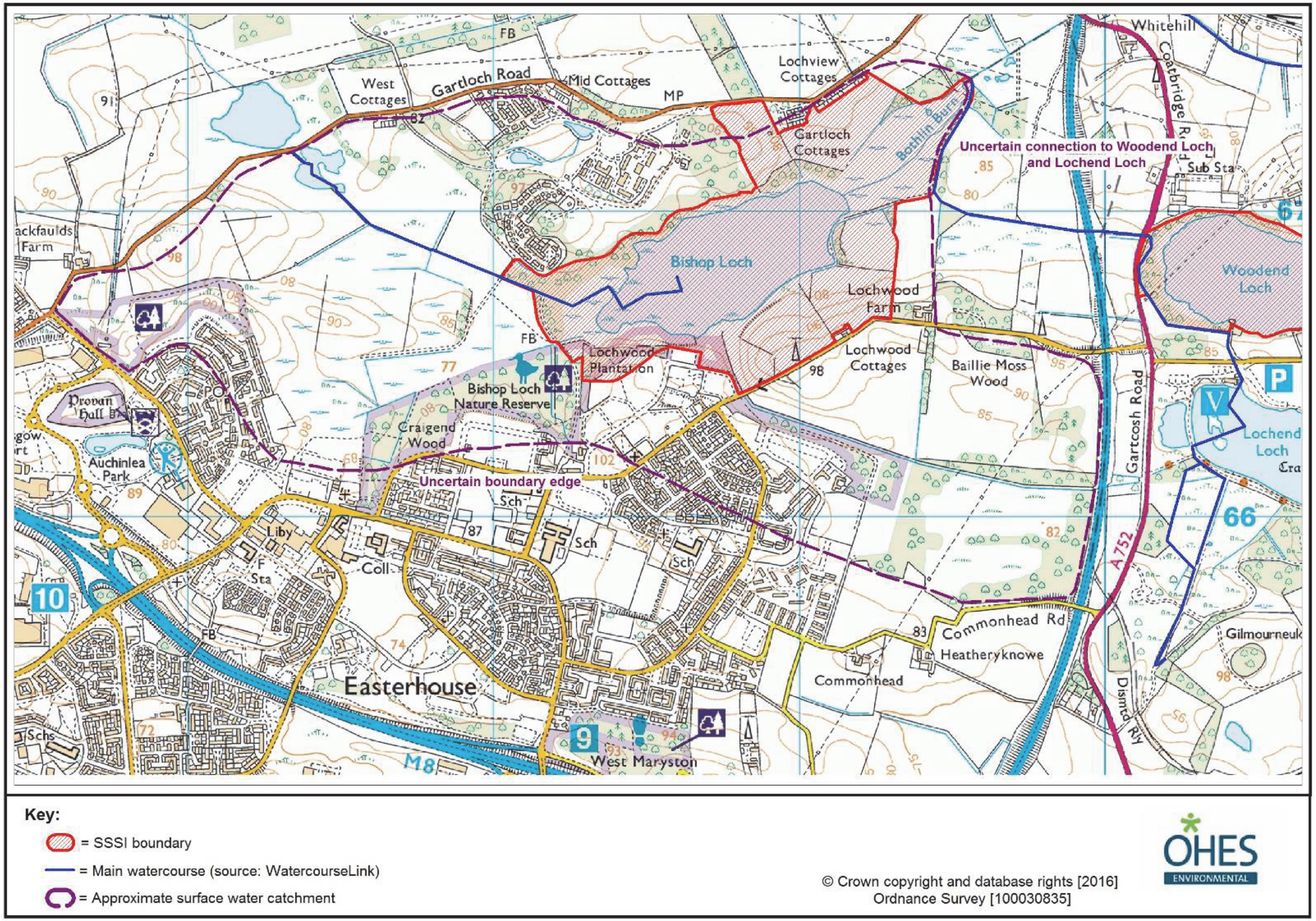

Figure 3. Bishop Loch – approximate surface water catchment

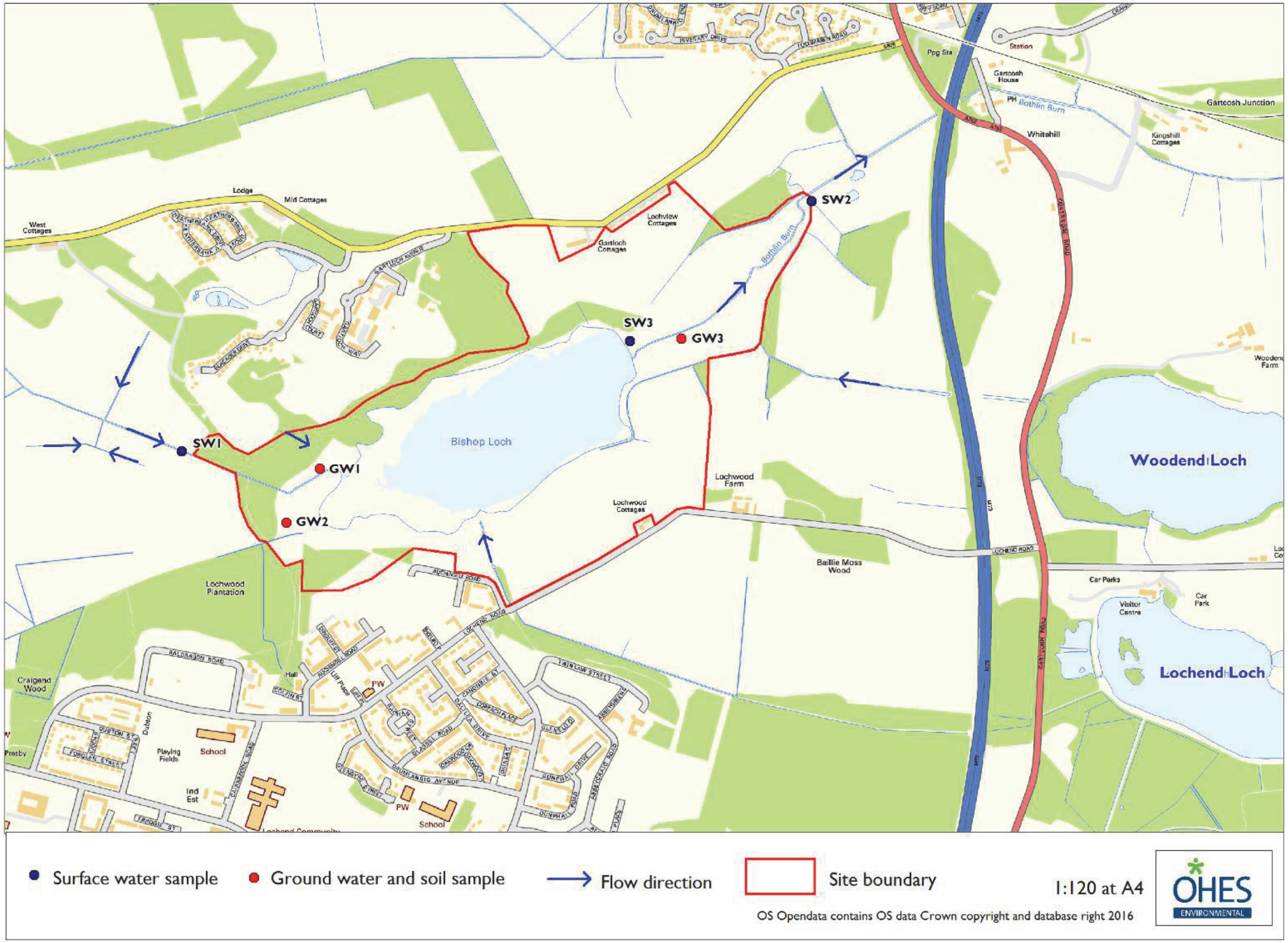

Figure 4. Bishop Loch – Hydrology and Sample Locations

3.1.3 Site soils / sediments

Bishop Loch is situated over the Scottish Lower Coal Measures Formation, which is a Sedimentary Bedrock formed approximately 312 to 313 million years ago in the Carboniferous Period. It consists of sandstone, siltstone and mudstone in repeated cycles that most commonly coarsen upwards. The mudstone and siltstone are usually grey to black, while the sandstone is fine to medium-grained and off-white to grey. Coal seams are common and many exceed 0.3 m in thickness.

The superficial deposits include a zone of peaty alluvial soils immediately to the west of the loch, which extends as far west as the B806. At the eastern end of the loch, Basin Peat is recorded at more than 1 m depth. The remainder of the catchment is recorded as imperfectly drained non-calcareous gleys of the Rowanhill Association, derived from shales, sandstones, cementstones, limestones and coals of the Carboniferous age. Figure 5 shows the distribution of soil types at Bishop Loch.

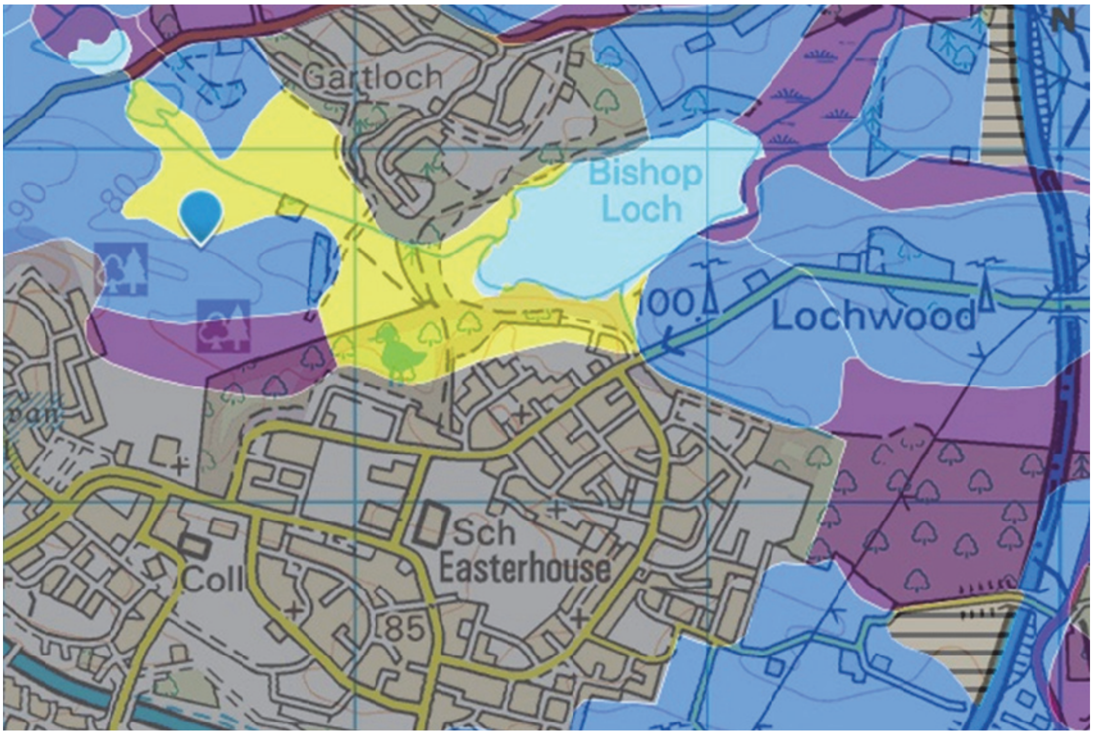

Figure 5. Bishop Loch – Soil types (source: Soil Survey of Scotland Staff. 1987). Yellow = Alluvial Soils, Blue = Rowanhill Association, Purple = Organic Soils

3.1.4 Site specific issues

The increase in nutrients into the loch is attributed to agricultural runoff, an influx of sewage from Gartloch Hospital (now a housing estate) and the neglect / blocking of the outlet ditches causing nutrients to remain in the lake. Fertiliser runoff from arable fields to the south of the site may be encouraging the growth of reed-canary grass. Figure 6 shows the locations of these possible sources of nutrients.

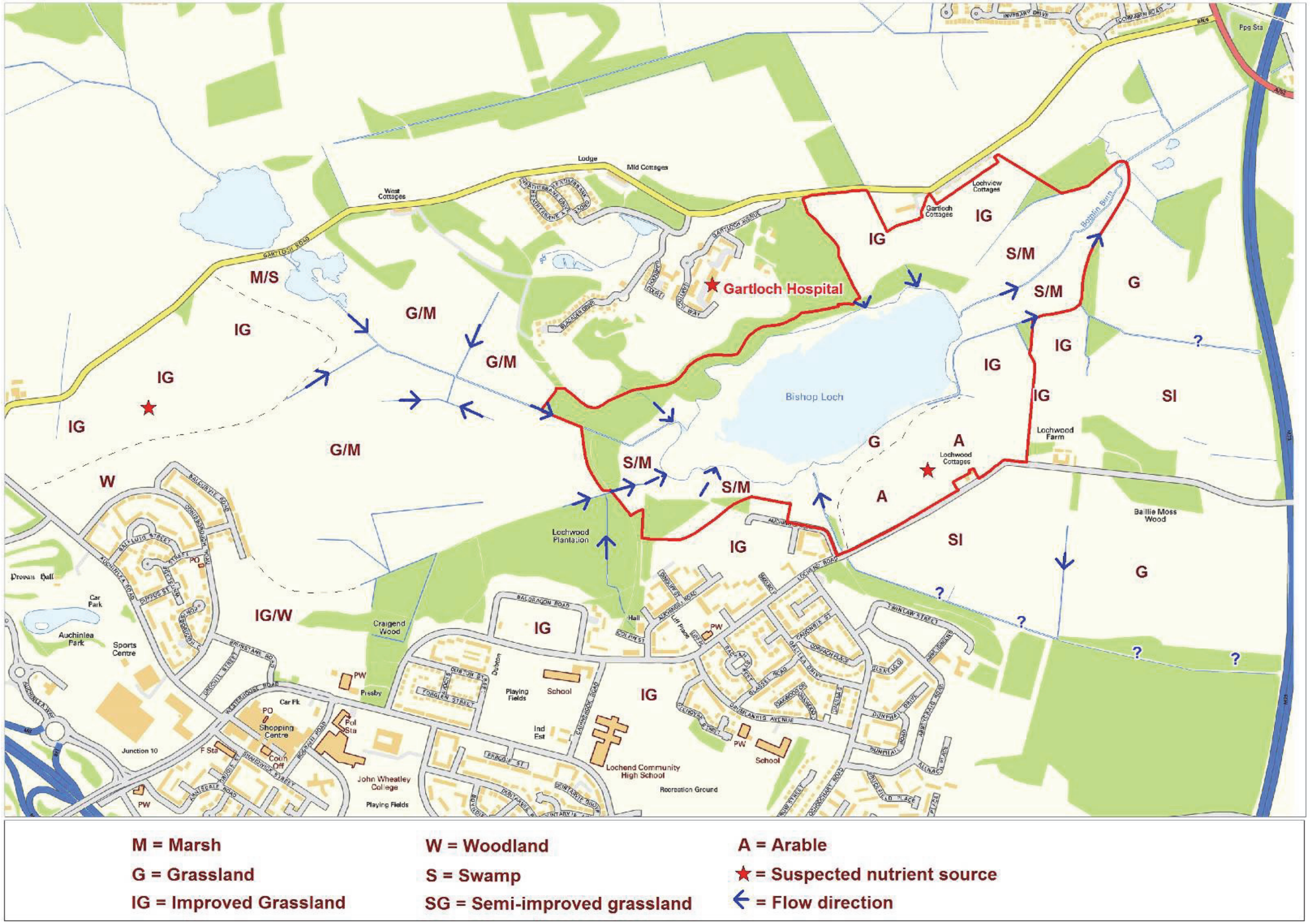

Figure 6. Land use and potential nutrient sources at Bishop Loch

3.2 Assessment of vegetation data

Bishop Loch contains a range of open water transitional fen and swamp communities, principally located around the margins of the loch and the terrestrialised eastern and western ends of the historic loch boundary. Observations on the vegetation have been recorded in the late 1980's, 2003, 2008 and 2013. However, NVC communities are only mapped for the whole site in years 2003 and 2008, with quadrat data also being available from 2008. Figure 7 shows the NVC communities recorded in 2008.

The historic data suggests the continued presence of the following communities:

- S4 *Phragmites australis* swamp
- S9 *Carex rostrata* swamp
- S10 *Equisetum fluviatile* swamp
- S12 *Typha latifolia* swamp
- S27 *Carex rostrata – Potentilla palustris* tall-herb fen
- S28 *Phalaris arundinacea* tall-herb fen

With additional sporadic recording of:

- M5 *Carex rostrata – Sphagnum squarrosum* mire
- M23 *Juncus acutiflorus – Galium palustre* rush-pasture
- M27 *Filipendula ulmaria – Angelica sylvestris* mire
- S7 *Carex acutiflorus* swamp
- S8 *Scirpus lacustris* swamp

3.2.1 Historic evidence of community change

There are unfortunately insufficient data to quantify changes in the total coverage of each community. However, some key points are summarised below;

- The earliest detailed study of the site appears to be the 1984 biological survey carried out by Glasgow College of Technology. The most significant impact has been the decline in agriculture and the urbanisation of the land around the loch since the 1950s. This has resulted in the drainage system around the loch being neglected and increased recreational pressure.

- The 1984 report describes the fen-swamp as rich and extending around most of the loch, except for a short section of the southern shore. The vegetation included a wide range of species but was dominated by distinct patches of *Typha latifolia*, *Phragmites australis*, *Phalaris arundinacea* and *Carex rostrata*.

- In 1995, a section of the south-west of the site was included in the newly designated Bishop Loch LNR which has led to increased public use of the site.

- The 2003 Site Condition Assessment survey showed the SSSI as Unfavourable - No change, due to the lack of species other than *P. australis* and the frequency of *P. arundinacea* in S4a swamp, the frequency of *P. arundinacea* in S9 (*C. rostrata*) swamp and the lack of indicator species and cover and frequency of *P. arundinacea* in S27a (*C. rostrata*) tall-herb fen. The reasons for these target failures were thought to include diffuse pollution from agricultural and domestic sources, as well as the effects of past discharges of sewage from the hospital and increased nutrient levels in the loch due to blocking of old drains by siltation. The survey also produced an NVC map of the site which shows large areas of S28 swamp around the inflow and outflow of the loch.

- The NVC survey conducted in 2006 showed large areas of species-poor S4 around the inflow and outflow of the loch mixed with smaller areas of S28. However the large stands of species-poor S28 which were found in previous surveys were not reported.

- The 2008 Site Condition Assessment again recorded the feature in Unfavourable condition due to the frequency of *P. australis* in S12 (*Typha latifolia*) swamp, frequency of *P. australis* and *P. arundinacea* in S9 and S27 and lack of indicator species in S27. The previous NVC survey was noted to be unreliable. A large proportion of the fen was found to consist of species-poor *P. arundinacea* stands and little S4 was found. Apart from these areas of *P. arundinacea* dominated vegetation, the feature was noted to be in good condition.

- The 2013 Site Condition Assessment showed the feature remained in unfavourable condition due to the failure to meet attribute targets for indicator species on S4a.

- The 2013 Site Condition Assessment raised the critical issue of whether species-poor stands of S28 *Phalaris* swamp are spreading into other communities due to eutrophication and/or drying. Two of the seven locally uncommon species listed for the site were found during this survey (*Lysimachia thyrsiflora* and *Lemna trisulca*) but the three target *Potamogeton* species do not appear to have been seen on the site since the 1984 survey. *Carex acutiformis* appears to have been last recorded on the site in 1984, while *Salix pentandra* was found during 2003 and 2008 SCM surveys.

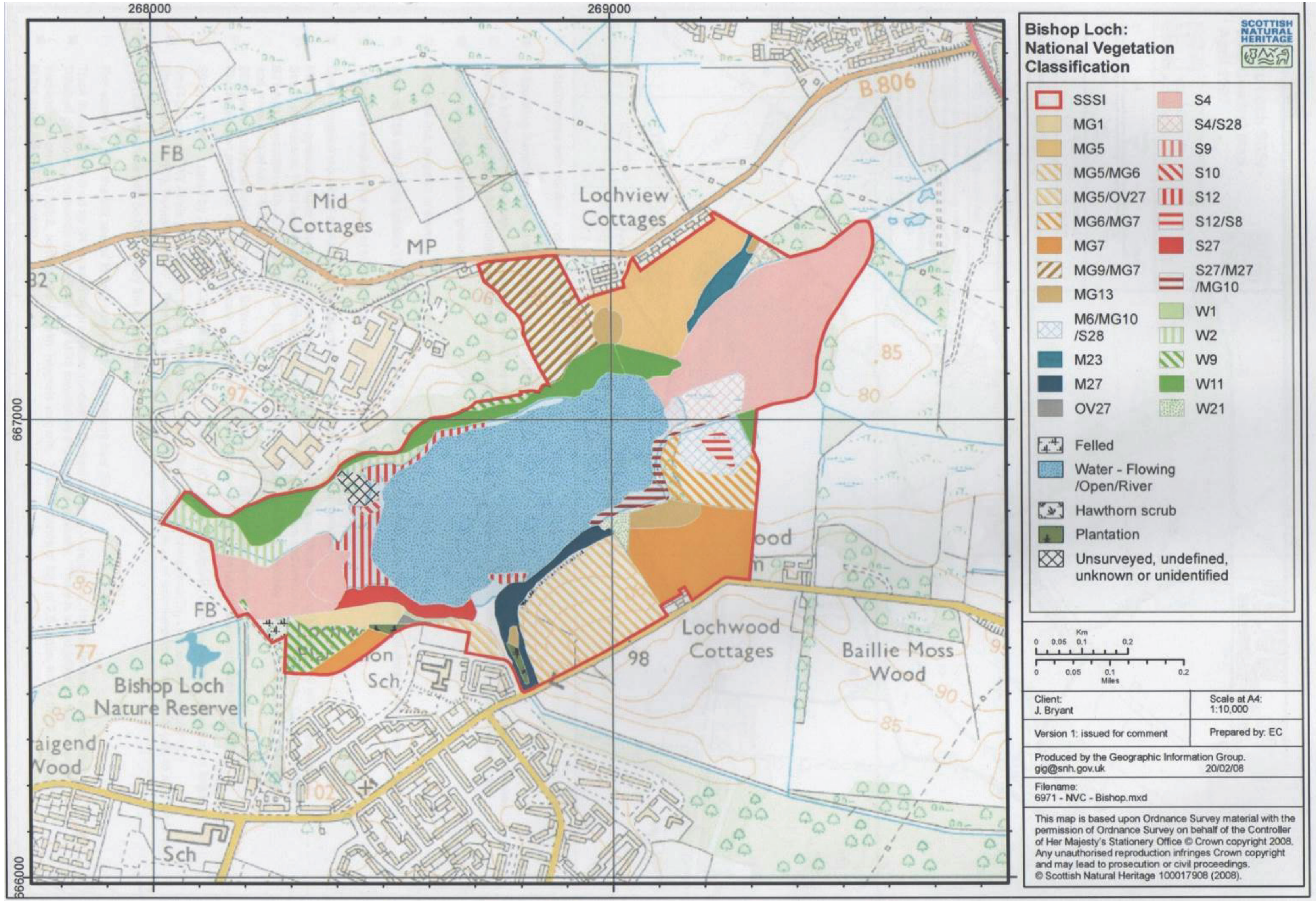

Figure 7. NVC communities recorded in 2008 (Source: SNH Site Management Statement)

Using the 2008 NVC quadrat data, Ellenberg Indicator values for Nitrogen and Moisture have been calculated and are displayed in Figures 8 and 9. They indicate that the most eutrophic tolerant communities (S28 and S4) are located close to inflows (such as the three ditches entering the loch from the west) or around the edges of the loch itself. As expected, moisture levels appear to be highest in the S4, S9 and S12 stands, with S27 and S28 marking slightly drier situations.

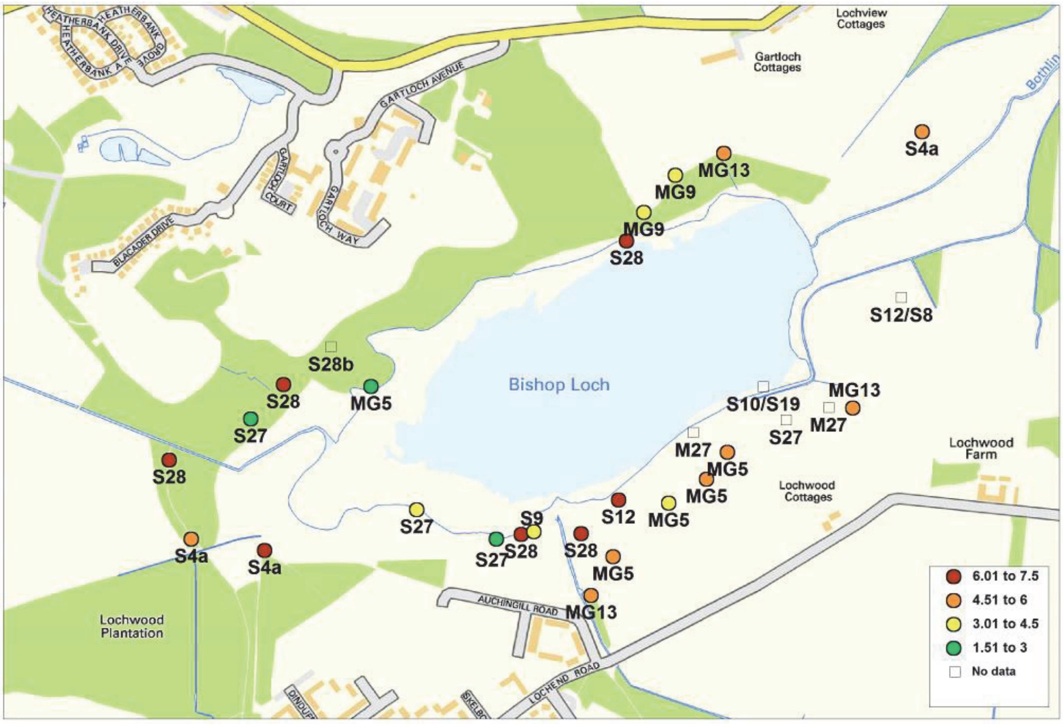

Figure 8. Ellenberg Indicator Values for Nitrogen at Bishop Loch (from 2008 NVC).

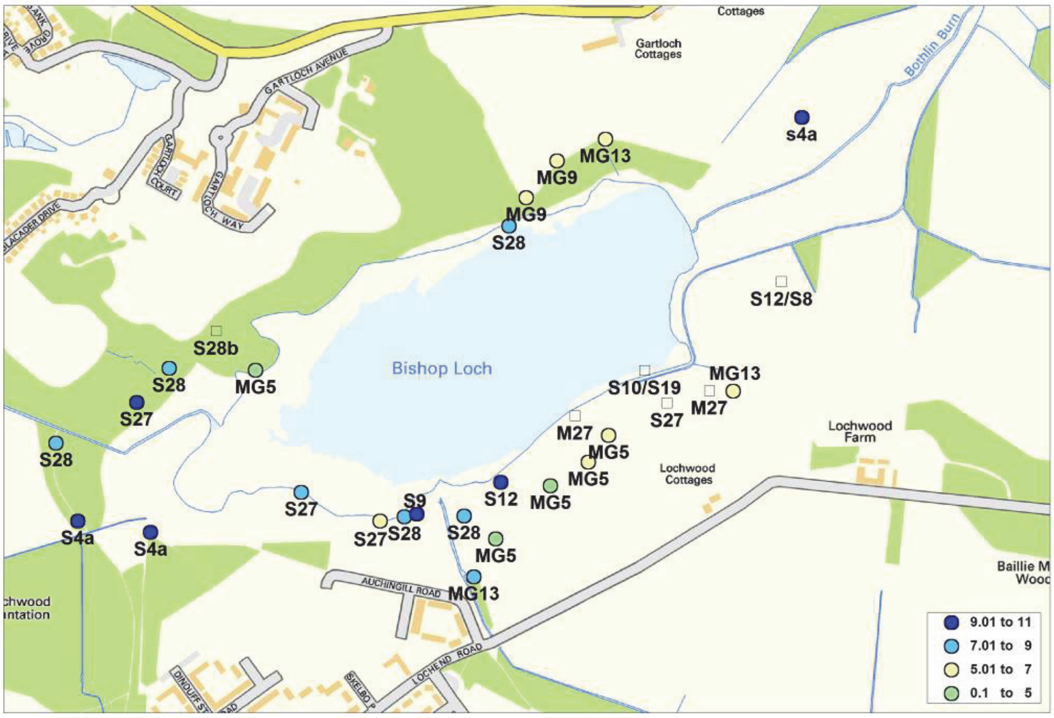

Figure 9. Ellenberg Indicator Values for Moisture at Bishop Loch (from 2008 NVC).

3.2.2 *Community requirements and targets*

The requirements of wetland communities have been discussed in several publications over the past decade, some of which are specifically aimed at providing guidance on the implementation of WFD regulations. Considerable advances have also recently been made in determining the environmental conditions under which particular vegetation types can be found in Scotland, through a collaboration of SNH, SEPA and SNIFFER (Draft report: ER37, February 2016). The ER37 document presents guidance on the eco-hydrological requirements of the different Scottish wetland types as described in SNIFFER (2009). The report emphasises that “they are meant to be adequate for broad-scale appraisal but site specific data is likely to be required for more detailed assessments”. Therefore, further sampling is needed for many habitats before definitive thresholds can be set, with the draft ER37 report referring to thresholds, guidelines or indicators, depending on the level of sampling that has so far been conducted for that habitat. The three confidence levels used throughout the ER37 report are described as:

Indicator: Reflects best professional judgement based upon limited data
Guideline: Reflects adequate data for risk screening but not to establish a hydroecological standard
Threshold: Represents a wide range of consistent data with confidence to set a standard.

Where there has been insufficient sampling of a particular habitat in Scotland, the tables refer back to the UK TAG figures.

The wetland types potentially relevant to Bishop Loch are:

- Type 2a:Marshy grassland
- Type 3: Spring flush and seepage
- Type 4: Fen
- Type 5: Swamp
- Type 6: Reedbed

3.2.2.1 Type 2a Marshy grassland

Marshy grassland communities are present across a wide range of environmental situations with several different potential water supply mechanisms. Three types are recognised within ER37.

- Type 1: water supply by rainfall, local snow-melt, overland flow and interflow
- Type 2: groundwater seepages or springs
- Type 3: surface and groundwater flooding (characteristic of floodplains and other localities such as ground adjacent to loch shores)

The equivalent NVC types contained within these types are considerable, but those relevant to Bishop Loch include:

- M23 *Juncus effuses/acutiflorus – Galium palustre* rush-pasture
- MG9 *Holcus lanatus-Deschampsia cespitosa* grassland
- MG10 *Holcus lanatus-Juncus effusus* rush-pasture
- MG13 *Agrostis stolonifera-Alopecurus geniculatus* grassland

These communities range from relatively species-poor communities whose distribution is widespread across Scotland (such as MG9), to those which can contain considerable plant diversity (such as M23). The hydrology is typically one of a high water table close to the surface for most of the year (ER37), with periodic flooding.

SNIFFER data and guidelines for marshy grassland are presented in Table 2. Mean nitrate results for wet grassland in good condition are given in UKTAG (2014) as 6 mg/l N. The UK third quartile value is 5.9 mg/l $N\text{-}NO_3$. The SNIFFER values in groundwater for Scotland are significantly lower, with a third quartile value of 0.25 mg/l $N\text{-}NO_3$ (ER37).

Mean Phosphate values indicated by the UKTAG (2012) for the UK in wet grassland are 0.045 mg/l for good condition and 0.024 mg/l for bad condition. However the UKTAG 2014 states "there is no clear distinction in phosphate concentrations between wetlands in good condition and those in poor condition or with a likely nutrient risk." Thus no targets are given.

Table 2. Groundwater guidelines for Marshy Grassland in Good Condition (Source: ER37 – DRAFT)

	Marshy grassland			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Indicator/guideline**
pH (-)	6.3	6.6	7.1	5 to 8
Dissolved Oxygen (%)	32	35	40	
Electric Conductivity (mS/cm)	0.093	0.13	0.18	
Calcium (mg/l)	8	18	24	
Magnesium (mg/l)	2.5	4.5	8.7	
Sodium (mg/l)	6.2	9.2	12	
Phosphate (mg/l)	0.041	0.06	0.065	Indicator: 0.065
Nitrogen (total) (mg/l)	2.5	4	7	
Nitrate (mg/l $N\text{-}NO_3$)	0.25	0.25	0.25	Guideline: 6 (or 26 mg/l as N-NO3) for <175 m AOD

3.2.2.2 Type 3 Springs, flushes and seepages

This is another broad category, defined by direct irrigation from groundwater at near-surface water levels for much of the year. SNIFFER record 30 NVC communities which may occur in spring, flush and seepage wetlands in Scotland. However, of those communities typically encountered, only M5 *Carex rostrata-Sphagnum squarrosum* mire has been recorded at Bishop Loch. As this has been discussed under Type 4 fens (below) it will not be considered further here.

3.2.2.3 Type 4 Fen

Type 4 Fens contain a wide range of vegetation communities, which may be fed by either surface water (topogenous) or ground water (soligenous). The group includes 7230 Alkaline fens (an Annex 1 habitat covered by the EC Habitats Directive) such as M24, and 7210 Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* (including vegetation types which can support great fen-sedge *C. mariscus).*

The main NVC communities listed in ER37 and which are found at Bishop Loch are:

- M5 *Carex rostrata-Sphagnum squarrosum* mire – can occur on slopes, stream-sides, lochsides and valley bottom/basins. It grades to S9 swamp in deeper water and is sometimes mixed with S27 tall-herb fen. The community is typically found as a semi-floating raft, where the water level is generally close to the surface all year round. It is of moderate to low fertility. Shaw and Wheeler (1991) found that base enrichment was associated with an increase in species richness, while P enrichment was related to a decrease in numbers of principal fen species.

- M27 *Filipendula ulmaria-Angelica sylvestris* mire - occurs on slopes, floodplains, stream-sides, lochsides and valley bottoms and is associated with high water level fluctuation (ER37). It is generally associated with moderate to high fertility.

- S27 *Carex rostrata-Potentilla palustris* tall-herb fen - occurring in wet valley bottom/basin locations. Despite containing a high number of total species, most stands are relatively species-poor (Wheeler, Shaw & Tanner, 2009). It is typically of moderate fertility, with transitions to M9 in mesotrophic conditions, and S9 in deeper, oligotrophic waters (ER37). Stands of S27 may be resistant to moderate nutrient inputs, but high levels of eutrophication lead to impoverishment, with an increased prominence of species like *Agrostis stolonifera, Juncus effusus* and *Phragmites australis* (Wheeler, B.D., Shaw, S., & Tanner, K, 2009).

ER37 data and thresholds for Fens are presented in Table 3. UKTAG (2012 and 2014) states that mean nitrate levels in groundwater fed fens in good condition are 3.4 and 2.9 mg/l $N\text{-}NO_3$ for mesotrophic and oligotrophic fen respectively, and the 3^{rd} quartile values are 5.7 and 5.0 mg/l $N\text{-}NO_3$. However, ER37 reports that Nitrate levels in Scotland are significantly lower, with a 3rd quartile value of 0.25 mg/l $N\text{-}NO_3$ for groundwater, suggesting that most fen samples for Scotland are in good condition.

Mean Phosphate values for the UK (UKTAG, 2012) for fens in good condition are 0.033 and 0.021 mg/l $P\text{-}PO_4$ for mesotrophic and oligotrophic fen respectively (ER37). Mean values for fen in poor conditions are 0.034 mg/l $P\text{-}PO_4$ and 0.064 mg/l $P\text{-}PO_4$ for mesotrophic and oligotrophic groups. ER37 reports that median Phosphate concentrations in Scottish fens are 0.10 mg/l $P\text{-}PO_4$ (for groundwater) and 0.046 mg/l $P\text{-}PO_4$ (for surface water). These figures exceed the mean values given for good condition under UKTAG, 2012. No guidance value has currently been set for Phosphate. ER37 reports however that "groundwater results are skewed by the analytical level of detection of 0.20 mg/l used in laboratory tests for some of the samples".

Table 3. Groundwater thresholds for Fen in Good Condition (Source: ER37)

	Fen			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Threshold**
pH (-)	6.4	7.1	7.4	
Dissolved Oxygen (%)	18	21	28	
Electric Conductivity (mS/cm)	0.37	0.55	0.69	
Calcium (mg/l)	12	25	55	
Magnesium (mg/l)	3.4	6.4	14	
Sodium (mg/l)	5.4	9.7	14	
Phosphate (mg/l)	0.064	0.1	0.1	None set
Nitrogen (total) (mg/l)	1	3	5.1	
Nitrate (mg/l $N\text{-}NO_3$)	0.25	0.25	0.25	Threshold: <175 m AOD Meso = 5 (or 22 mg/l as NO3) Olig = 4.5 (or 20 mg/l as NO3)

3.2.2.4 Type 5 Swamp

Swamps occupy the transition between open water and dry land across a range of different trophic states. They typically occur where water levels are above the ground for most of the year, with the main water supply from surface waters (such as in floodplains and around loch shores). However, groundwater can be important in the absence of a surface water supply.

They usually consist of species-poor, emergent vegetation but are still important as a UK BAP priority habitat.

The main NVC communities listed in WWF Consulting (2009) and which are found at Bishop Loch are:

- S8 *Scirpus lacustris* ssp. *lacustris* swamp – characteristic of standing or slow moving waters, where water depth is up to 1.5 m (but no less than 25 cm) in pools, lakes streams and occasionally ditches. It occupies a range of nutrient states across several sub-communities. It is predominantly a lowland community, with more extensive stands in the north and west of the UK (Rodwell, 1995).
- S9 *Carex rostrata* swamp– occurring within shallow to moderately deep swamps within oligotrophic to mesotrophic waterbodies/wetlands. It can occur at variable altitudes on organic substrates, or more infrequently on silty or sandy substrates (Rodwell, 1995). It is widespread across the north and west of the UK in suitable situations.
- S10 *Equisetum fluviatile* swamp – occurs in shallow to moderately deep, standing waters with substrate ranging from fine inorganic material (such as silt or sand) to peaty soils. It can occupy both eutrophic and oligotrophic waters and has a wide distribution across the UK.
- S12 *Typha latifolia* swamp – characteristic of mesotrophic to eutrophic waters within still or slow moving waters. S12 is highly tolerant of water level variations and prefers circumneutral to basic waters on silty substrates (Rodwell, 1995). It is generally rather species-poor and has a distribution throughout the UK, though it tends to be more uncommon in the north.

ER37 data and guidelines for Swamps are presented in Table 4. Mean Nitrate levels for groundwater-fed swamp in good condition are reported in UKTAG 2012 as 4.9 and 3.5 mg/l N-NO_3 for mesotrophic and oligotrophic swamp respectively (ER37). Swamp groundwater sampled in Scotland was significantly lower than this (third quartile value of <0.25 mg/l N-NO_3). This suggests that all sampled Scottish swamps are in good condition.

Phosphate samples reported in the UKTAG (2012) show mean values for swamp in good condition of 0.050 and 0.034 mg/l P-PO_4 for mesotrophic and oligotrophic swamp respectively (ER37). However the results for poor condition suggest condition is not strongly related to groundwater Phosphate levels in swamps. The UKTAG values for good condition are comparable with Scottish samples. However a threshold value has not been set at this stage due to inconclusive results.

Table 4. Groundwater guidelines for Swamp in Good Condition (Source: ER37)

	Swamp			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Guideline**
pH (-)	5.7	6.3	7.1	
Dissolved Oxygen (%)	15	24	36	
Electric Conductivity (mS/cm)	0.24	0.26	0.43	
Calcium (mg/l)	10	26	44	
Magnesium (mg/l)	3.6	5.4	16	
Sodium (mg/l)	5.5	9	18	
Phosphate (mg/l)	0.024	0.062	0.1	None set
Nitrogen (total) (mg/l)	2	3	7	
Nitrate (mg/l N-NO_3)	0.25	0.25	0.25	Guideline: Meso = 5 (or 22 mg/l as NO3) Olig = 4.1 (or 18 mg/l as NO3)

3.2.2.5 Type 6 Reedbed

Equivalent NVC types covered:

- S4a *Phragmites australis* sub-community (present at Bishops Loch)
- S4b *Galium palustre* sub-community
- S4c *Menyanthes trifoliata* sub-community

These are generally species-poor stands, heavily dominated by *Phragmites australis* with few associate species. They are however, valuable in their own right, particularly for bird and invertebrate species and consequently are a UK Biodiversity Action Plan (BAP) Priority Habitat under the fen, marsh and swamp UK BAP broad habitat. S4 can occur across a wide range of wetland conditions, with hydrological inputs including surface water, ground water or often combinations of the two. Water levels are typically above the surface for several months of the year, and can reach significant depths. ER37 notes that "Although reedbed grows best in wet, eutrophic habitats (Rodwell, 1995), it also occurs in oligotrophic or hypertrophic conditions which are more frequently found in Scotland (Mountford, 2004)".

ER37 data and thresholds for Reedbed are presented in Table 5. Nitrate guidelines under UK TAG for groundwater are 22 mg/l but this value is significantly higher than was observed in Scottish reedbeds. Thus ER37 state values between observed 1 mg/l and UKTAG threshold of 22 mg/l should be viewed as an increasing risk.

Table 5. Groundwater thresholds for Reedbed in Good Condition (Source: ER37)

	Reedbed			
Parameter	**1st Quartile**	**Median**	**3rd Quartile**	**Threshold**
pH (-)	5.7	6.1	6.5	
Dissolved Oxygen (%)	18	20	22	
Electric Conductivity (mS/cm)	0.13	0.2	0.28	
Calcium (mg/l)	36	48	59	
Magnesium (mg/l)	5.8	12	18	
Sodium (mg/l)	12	13	19	
Phosphate (mg/l)	0.043	0.1	0.1	None set
Nitrogen (total) (mg/l)	1.1	3	6.9	
Nitrate (mg/l N-NO_3)	0.25	0.25	0.25	Threshold: 5 (or 22 mg/l as NO_3)

3.3 Assessment of ground water samples

Groundwater samples taken at Bishop Loch have been compared with the levels recorded in vegetation types as shown in section 3.2. Groundwater concentrations were used as opposed to surface water concentrations for several reasons; firstly that almost all wetlands will have a component of groundwater influence, secondly that groundwater thresholds can often be more demanding than surface water thresholds, and thirdly that the presence of a sandy base to the loch (as proved during the soil sampling) suggests some movement of water through the loch bed is possible.

Table 6 indicates that the vegetation currently found around the sample locations is typically consistent with the data recorded for Scotland (ER37) and for guideline/threshold levels. However, both of these vegetation types are able to tolerate eutrophic situations and therefore are no indication of a low trophic status. In fact, the higher than typical Total Nitrogen levels recorded are some cause for concern.

If the groundwater samples are also used to assess their suitability to supply nearby fen communities (such as S27) it becomes apparent that Nitrogen levels exceed the indicated levels for good condition. This would suggest that unless these areas receive water from a different source (such as seepage from the south) the condition of the fen communities is likely to deteriorate over time.

No groundwater samples were taken within/near to the marshy grassland habitat present on site and therefore no comparison could be made with published levels for this wetland type.

Table 6. Groundwater samples at Bishop Loch compared to Wetland Type for Scotland. Red text denotes sample exceeds 3rd quartile.

	Bishop Loch	Swamp			Bishop Loch	Bishop Loch	Reedbed			Bishop Loch	Fen		
Sample	**GW1 (in S28)**	**1st Quartile**	**3rd Quartile**	**Guideline**	**GW2 (in S4)**	**GW3 (in S4)**	**1st Quartile**	**3rd Quartile**	**Threshold**	**GW2 (near S27)**	**1st Quartile**	**3rd Quartile**	**Threshold**
pH (-)		5.7	7.1				5.7	6.5			6.4	7.4	
Dissolved Oxygen (%)		15	36				18	22			18	28	
Conductivity (mS/cm)		0.24	0.43				0.13	0.28			0.37	0.69	
Calcium (mg/l)	35	10	44		48	42	36	59		48	12	55	
Magnesium (mg/l)	6.4	3.6	16		6.1	4.9	5.8	18		6.1	3.4	14	
Sodium (mg/l)	20	5.5	18		21	17	12	19		21	5.4	14	
Phosphate (mg/l)	0.049	0.024	0.1	None set	0.05	0.085	0.043	0.1	None set	0.05	0.064	0.1	None set
Nitrogen (total) (mg/l)	12.22	2	7	None set	6.93	5.55	1.1	6.9	None set	6.93	1	5.1	None set
Nitrate (mg/l N-NO_3)	<0.5	0.25	0.25	Meso = 5 (or 22 mg/l as NO3) Olig = 4.1 (or 18 mg/l as NO3)	<0.5	<0.5	0.25	0.25	5 (or 22 mg/l as NO_3)	<0.5	0.25	0.25	Meso = 5 (or 22 mg/l as NO3) Olig = 4.5 (or 20 mg/l as NO3)

3.4 Assessment of surface water samples

3.4.1 Threshold levels

There are currently several relevant documents providing guidance on water quality standards for surface waters in order to achieve Good Ecological Status (GES) or High Ecological Status (HES). The most up-to-date of these include the Scotland River Basin District (standards) Directions 2014 (SRBDD, 2014) and the JNCC Common Standards Monitoring for Freshwater Lakes (2015). However useful information is also available within the ECOFRAME report on implementation of the WFD by Brian Moss (2003).

For the purposes of this study, the primary standards used for variables are sourced from the SRBDD 2014 because they are the latest interpretation of the European WFD for Scotland and are therefore highly relevant. The standards referred to in the other documents (such as JNCC targets) are referred to in some circumstances but it should be noted that, where they exist, the SRBDD standards are more stringent than CSM targets and therefore GES standards should be used for Favourable Condition targets of SSSI's. Where SRBDD standards are not provided, a range of published documents are used to define those standards.

Under the SRBDD 2014, Bishop Loch (situated within the Clyde River Basin District) is classified as shallow (3 to 15 m depth), freshwater, salmonid, low altitude (less than 80mAOD) lake of high alkalinity (>50 mg/l) and 50 % calcareous bedrock. This equates to Ecotype 14 (Small temperate lake, with a catchment geology of rock and conductivity between 100 – 800 uScm) within the ECOFRAME document (Moss, 2003). Table 7 presents the SRBDD 2014 standards compared to those recorded from Bishop Loch, but owing to the fluid nature of the research and advice, represent a starting point.

Table 7. Water Quality standards for Bishop Loch

Variable	SRBDD 2014		JNCC	ECOFRAME		Bishop Loch
	GES	HES		Good	High	
Total Ammonia as N	0.6 mg/l	0.3 mg/l	-	-	-	0.1 mg/l (Ammonium only)
Total Nitrogen	-	-	<1.5 mg/l	0.6 – 1.0 mg/l	<0.6 mg/l	5.48 mg/l
Acid Neutralising Capacity	>20 µeq/l	>40 µeq/l	>40 µeq/l	-	-	?
Dissolved oxygen	7 mg/l	9 mg/l	As SRBDD	-	-	9 – 9.2 mg/l
Salinity/Conductivity	<1000 µScm		-	100 – 800 µScm		350-400 µScm
Total Phosphorus	23 µg/l	16 µg/l	35 µg/l	30-50 µg/l	<30 µg/l	71 µg/l (Phosphate only)
pH	-	-	7 - 9	6 - 9		6.5 - 7.2

3.4.2 Current surface water quality status

Three surface water sampling points were monitored by SNH during the single sampling round (conducted in February 2012). These include: the main input channel (SW1), surface water immediately adjacent to the loch (SW3) and the outlet channel (SW2) (see Appendix 1 for raw data). Additional historic loch water quality data is available from sampling conducted by the Clyde River Purification Board in 1990.

Figure 10 shows the results of Ammonium recording at Bishop Loch against SRBDD 2014 standards for Total Ammonia. It indicates that, at the time of survey, the loch was at acceptable concentrations and may be acting as a sink for Ammonia, so that water quality is improved after exiting the loch.

Total Nitrogen levels (as shown in Figure 11) indicate other forms of Nitrogen are more problematic, with TN recorded in all surface samples exceeding ECOFRAME and JNCC levels.

Total Phosphorus levels were recorded at Bishop Loch but the levels of determination were below those useful in assessment against threshold values (i.e. all samples were marked as <0.2 mg/l). Instead, Phosphate low levels were recorded between Moderate Ecological Status (MES) and Poor Ecological Status (PES) (Figure 12). Given that these values do not take into account the full Phosphorus concentration it can therefore be assumed that TP levels exceed SRBDD 2014 standards. The data also suggest the loch may be acting as a source of Phosphorus, so that water quality leaving the loch is in poorer condition than when entering the loch. This may be due to release of Phosphorus from stores within the sediments (of which there is no data available), or it may be that the monitored inflow point (SW1) is not the main source of Phosphorus, and other inputs are significantly adding to the concentrations within the loch. One such possibility is the ditch flowing in from the agricultural land immediately to the south of the loch. However, this cannot be confirmed without further sampling as no data is currently available on this feeder ditch.

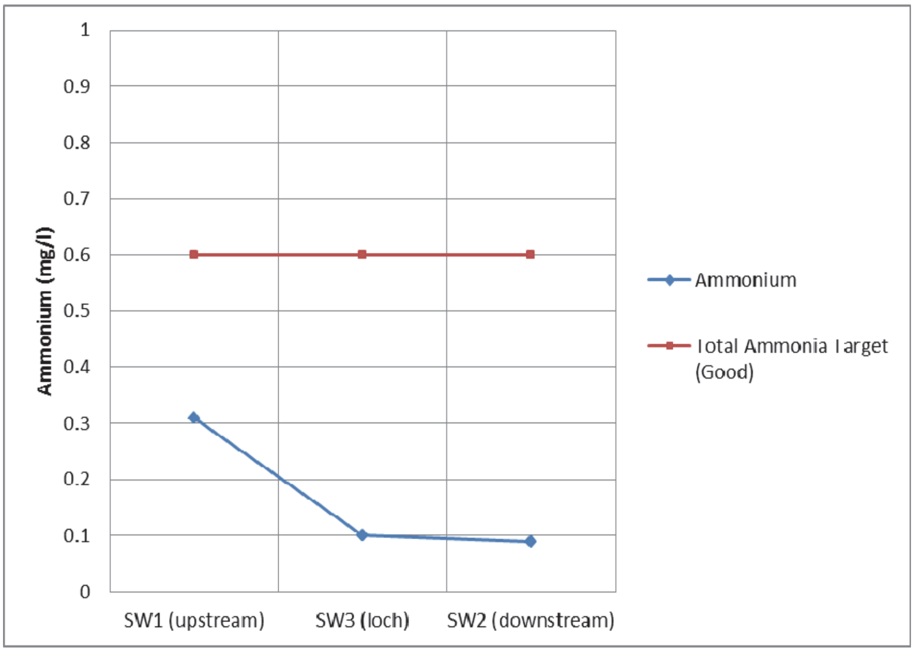

Figure 10. Ammonium recording at Bishop Loch (blue line) against SRBDD standards for Total Ammonia

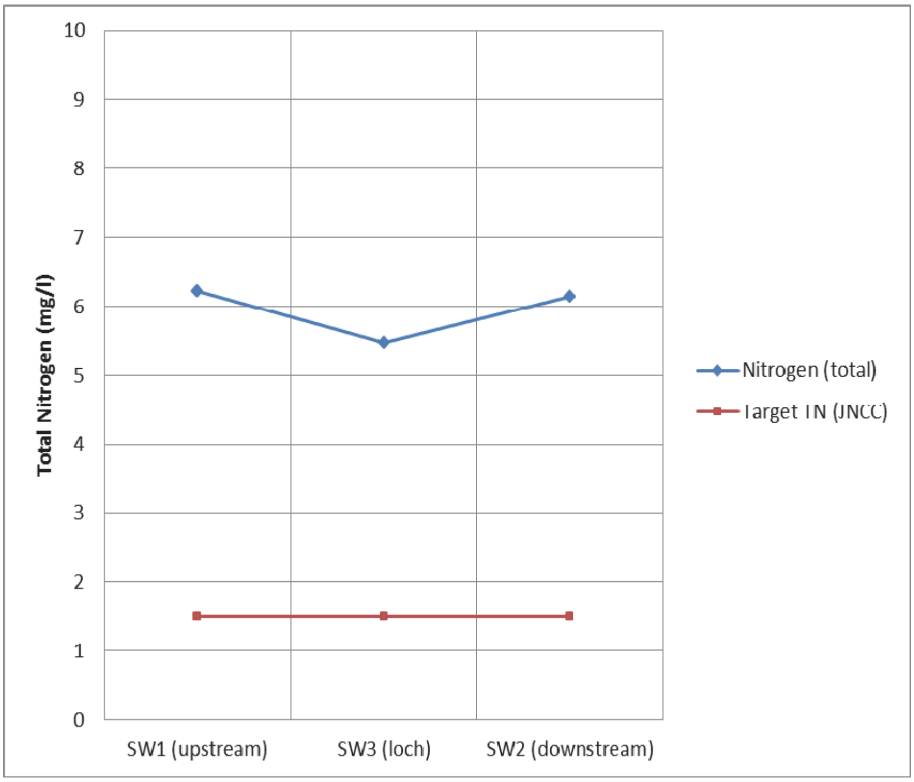

Figure 11. Total Nitrogen recording at Bishop Loch (blue line) against JNCC

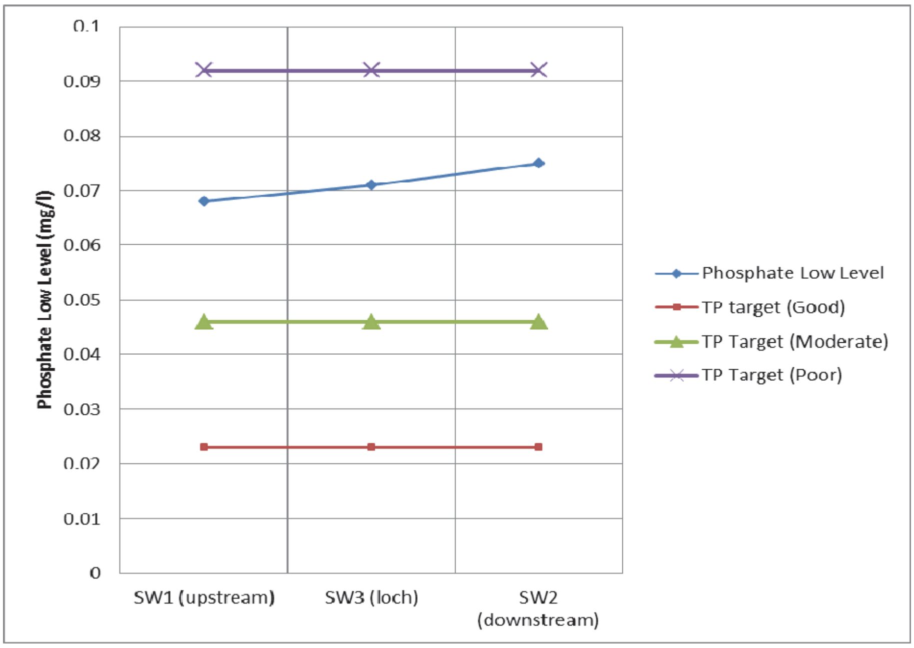

Figure 12. Total Phosphorus/Phosphate recording at Bishop Loch (blue line) against SRBDD 2014 standards

3.4.3 Summary of trophic state and site vulnerability

<u>Trophic state:</u>

The categories of trophic state used within this report are as follows:

- **Dystrophic:** referring to those waterbodies with brownish waters as a result of high concentrations of humic substances and organic acids suspended in the water (also referred to as Humic lakes). They are typically acidic and nutrient-poor (though this is not always the case).
- **Oligotrophic:** those waterbodies with low productivity as a result of low nutrient content. As a consequence, algal production is low and the waterbody retains very clear waters.
- **Mesotrophic:** namely lakes with an intermediate level of productivity, usually with clear waters and moderate cover of submerged plants.
- **Eutrophic:** referring to those waters with high biological productivity due to high levels of Nitrogen and Phosphorus. The water body may be dominated by either aquatic plants or algae.
- **Hypereutrophic:** those very nutrient-rich waterbodies which are characterised by frequent algal blooms and low visibility in the water column (less than 3 feet).

In addition to the definitions of trophic state provided in the JNCC CSM for freshwater lakes and the SRBDD 2014, the relationships between Trophic State/class and variables such as Phosphorus and Chlorophyll are shown in Table 8.

Table 8. Nutrient status classification scheme (SEPA).

Description	Biological Factors	Chemical Factors
Oligotrophic (surrogate mean [TP] value; 8 µg 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 ≤ 10 µg l^{-1}. Mean chlorophyll-a ≤ 2.5 µg l^{-1}. Max. chlorophyll-a ≤ 8.0 µg l^{-1}. Mean Secchi transparency ≥ 6.0 m. High oxygen concentration in hypolimnion.
Mesotrophic (surrogate mean [TP] value; 25 µg 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 µg l^{-1}. Mean chlorophyll-a 2.5-8 µg l^{-1}. Max. chlorophyll-a 8-25 µg l^{-1}. Mean Secchi transparency 6-3 m. Oxygen concentration may show some depletion in hypolimnion.
Eutrophic (surrogate mean [TP] value; 80 µg 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 µg l^{-1}. Mean chlorophyll-a 8-25 µg l^{-1}. Max. chlorophyll-a 25-75 µg 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 ≥ 100 µg l^{-1}. Mean chlorophyll-a ≥ 25 µg l^{-1}. Max. chlorophyll-a ≥ 75 µg l^{-1}. Mean Secchi transparency ≤ 1.5 m. Severe oxygen concentration depletion in hypolimnion.

Given that both Total Nitrogen and Phosphorus levels are significantly above standards for GES, this report concludes that the trophic state of Bishop Loch surface water is Eutrophic.

An assessment of vulnerability of the site to enrichment is given in Table 9 below.

Table 9. Assessment of the vulnerability of Bishop Loch to eutrophication from catchment sources and their relative importance. Negative factors are shown in black, positive factors in blue.

Source	Bishop Loch	
	Vulnerability	**Details of Factors**
EXTERNAL SOURCES		
1. Agriculture	Moderate	- A proportion of the catchment is in arable production or used for intensive grassland, some of which is in close proximity to the loch. - Drainage of the catchment permits the flushing of fertiliser and nutrients into nearby watercourses which will eventually lead into the loch.
2. Human population	Moderate	- Historic input of sewage from the nearby hospital. - Residential areas to the north and south of the loch represent a considerable nutrient source to the SSSI. - Potential run-off from the M73 via a ditch leading east from the Loch.
3. Aerial deposition	Low-Moderate	- Deposition rates within this part of the UK are lower than recorded in the south. Thus atmospheric Total Phosphorus input into the catchment is small, although Total Nitrogen remains a major contributor.
4. Regional Groundwater	Low	- Regional groundwater was not felt to significantly contribute to the water balance within the catchment, due to the reported clay bed of the loch.
INTERNAL SOURCES		
1. Wildlife	Low – Moderate	- Several bird species are recorded in large numbers on the reserve, which may represent a significant source of nutrient input, depending on the species. For example, species such as coots (which feed within the waterbody) will not represent an input of nutrients, whereas species such as geese (which often feed outside of a catchment but roost within it) can contribute significantly to Phosphorus and Nitrogen levels. - Roost sites (such as those of swallows within the reedbed) will cause eutrophication of the waterbody on a local scale. - However, Total Phosphorus coefficients for individual birds are very small so that, even when occurring in large numbers, overall contribution to the nutrient budget is likely to be small.
2. Lake Sediment	Unknown	- A considerable store of nutrient may be present within the loch in sediment form. The seasonal release of stored nutrients within the loch sediments will occur naturally under certain conditions. - If excess nutrients continue to be generated from other practises within the catchment, the subsequent store of nutrients available for release within the site will continue to build up.

3.5 Assessment of soil samples

Soil chemistry was sampled at three locations within Bishop Loch (2 of which were in S4 Reedbed 1 within S28 *Phalaris arundinacea* swamp). Very little has been published about soil chemistry targets in terms of wetland types or NVC communities. However, the ER37 report presents summaries of the soil chemistry recorded across a number of sample locations in Scotland, which are used here as an indicator of any site abnormalities.

The ER37 data is based on: *20 samples across 8 sites for Reedbeds*
49 samples across 13 sites for Marshy Grassland
60 samples across 19 sites for Fens
87 samples across 23 sites for Swamps

Table 10 presents the soil chemistry data for Bishop Loch samples against the ER37 data. It shows that levels of Magnesium, Calcium, Sodium and Nitrogen are all at the lower end of the range observed in Scottish samples. However, Phosphate levels in all three samples from Bishop Loch were above those typically recorded in swamp, reedbed or fen. Soil Sample 3 (GW3) in particular was extremely high in Phosphate both within the root layer and below. This sample was taken from the eastern end of the loch, close to the loch outlet (but where flow is limited). It also lies within an area of swamp which was historically open water (see Figure 5.1.2). Therefore the substrate is one of accumulated silts and organic matter (as confirmed by the sample description of dark fen peat mixed with silt, and overlying sand). Soil moisture content is greater within the root zone than was found at depth, which may be explained by coarse sand being present at 70 cm below the surface.

Soil sample 1 (GW1, lying within S28 *Phalaris* swamp) also lies within a partially terrestrialised margin of the loch, consisting of black anoxic peats and silts over very fine peats and silts. It shows somewhat higher levels of soil moisture content, in keeping with the preference of *Phalaris* for drier conditions than other swamp communities. The soil moisture content increases with depth, as presumably both samples were still taken from within the peaty material.

Soil sample 2 (GW2) was taken from S4 reedbed and consisted of fibrous, humified peat over fen peat, then sandy material commencing at approximately 110 cm depth from the surface. As with Soil sample 1, the soil moisture context of Soil Sample 2 increases with depth within the peaty substrate.

Table 10. Soil samples at Bishop Loch and soil chemistry recorded by Wetland Type in Scotland (ER37). Red text denotes sample exceeds typical range.

	Bishop Loch		Swamp		Bishop Loch		Bishop Loch		Reedbed		Bishop Loch		Fen	
Sample	**Soil1 Root (in S28)**	**Soil1 below (in S28)**	**1st Quartile**	**3rd Quartile**	**Soil2 Root (in S4)**	**Soil2 below (in S4)**	**Soil 3 Root (in S4)**	**Soil 3 below (in S4)**	**1st Quartile**	**3rd Quartile**	**Soil 2 Root (near S27)**	**Soil 2 below (near S27)**	**1st Quartile**	**3rd Quartile**
Calcium (mg/kg)	400	750	140	5,800	750	1500	900	1000	1,700	13,000	750	1500	960	12,000
Magnesium (mg/kg)	34	70	410	3,400	46	75	90	85	200	2,700	46	75	1,500	3,800
Sodium (mg/kg)	7.5	20	17	140	37	41	46	30	32	44	37	41	74	280
Phosphate (available) (mg/l)	17	11	2.9	12	15	8.5	56	45	1.1	6	15	8.5	2.7	9.5
Nitrogen (total) (%)	0.71	0.84	0.17	1.2	1.3	1.4	1.4	1	0.99	1.7	1.3	1.4	0.25	1.4
Nitrogen (extractable) (mg/kg)	0.15	0.13	0.43	0.9	<0.1	0.16	<0.1	<0.1	0.39	0.56	<0.1	0.16	0.4	1.4
Total organic carbon (%)	4.7	4.9	4.1	25	5	6.5	4.4	4.5	5.5	22	5	6.5	3.7	12
Potassium (total)	<5.0	28	-	-	<5.0	<5.0	110	<5.0	-	-	<5.0	<5.0	-	-
Soil Moisture Content %	191	257	-	-	251	516	600	256	-	-	251	516	-	-

3.6 Limitations

A number of factors will limit the possibility of drawing reliable conclusions relating to the potential eutrophication of this site. They include:

- No site visit was possible as part of the analysis within this report and therefore there has been no opportunity to gain first-hand knowledge of the site.
- Data was collected from a single sampling round which, though providing consistency of timing, could be very misleading if for example weather conditions were atypical. Clearly a single sample round will also not reflect conditions experienced through the various seasons (such as those times of the year when fertiliser may be added or heavy rain may increase the amount of suspended solids and therefore nutrient loadings).
- The relationship between wetland types and Phosphorus targets is still under review and therefore levels which may appear to be acceptable now may change status if Phosphorus targets are more clearly defined.
- The sampling did not include measurements from all of the inflow channels. Therefore it cannot be determined which is the main contributor of nutrients into the loch
- There were insufficient data for any statistical analysis.

3.7 Recommendations on future measures and / or data requirement

There are a wide range of options for remedial measures within wetland systems. Some, such as the implementation of buffer zones, represent very little risk of negative impact and therefore can be implemented without the need for more detailed study. The risk with such early implementation is mainly that the measures may be placed in sub-optimal locations and therefore may result in an ineffective use of resources.

Other remedial measures, such as re-routing water supplies, de-silting or addition of water control structures, require a minimum level of supporting data in order to accurately assess their potential impact and effectiveness. These measures are not advisable without further investigation.

The recommendations for further investigation presented below are based on ensuring sufficient understanding exists so that any remedial measures focus on the area of greatest concern and can undergo risk/benefit assessment prior to implementation. The remedial options identified below are merely put forward for further consideration based on the characteristics of the site.

The initial assessment of Bishop Loch, based on a single sampling round, suggests enriched water is present within the SSSI, though the main source of this enrichment is unconfirmed. Confirmation would need to be obtained by the following data input:

- Ideally, monthly surface water sampling within all inflow and outflow channels for a full year to ascertain the patterns of enriched water movement across the site and whether it is acting as a sink for nutrients generated off-site.
- Rainfall data in the region for the period when surface water sampling takes place.
- At least three sediment samples within the waterbody to identify possible internal store of nutrients, as well as the average depth of sediment present. This could be combined with sampling of macrophytes presence (in order to better gauge the condition of the water body).
- *Either* a repeat of the NVC survey to detect the extent to which the site may be drying out or, ideally, installation of a simple dipwell or gauge board in order to build up a series of monthly water levels from this point forward.

- A basic hydrological walkover of the site/catchment to confirm whether the SSSI is connected to neighbouring waterbodies, the extent of silt within the ditches and the condition of the peat.

Once these data has been gathered and analysed it will be possible to assess the best means of protecting the ecological value of the site. Such measures could include:

- ***Installation of a control structure and dredging of the outlet of the site*** – This would increase the control of water levels within the site but allow flushing of nutrients at certain periods. Sites where water levels are high are less likely to be exposed to peat oxidation and subsequent release of nutrients.

- ***Reducing nutrient input*** – This is the most effective means of addressing eutrophication of the site. The primary exporters of nutrients appear to be a combination of agriculture to the south and west, as well as localised enrichment in the north. Reduction of nutrient would require the support of neighbouring landowners prepared to reduce the application of fertiliser and slurry to their land, or to change their land use to semi-improved grassland in addition to reducing their livestock units per hectare. The advantage of this approach is the long-term sustainability of the wetland interest in the catchment. There are also likely to be benefits to other habitats such as dry grassland through reduction in nutrients.

- ***Redirecting problematic water sources*** – It may be possible to redirect one of the feeder ditches to the site if it represents a particular problem to loch water quality. However, as there is superficial evidence that the site is becoming drier this is not a recommended course of action.

- ***Removing nutrient-rich sediments from the loch*** – This would be an expensive option and would need careful consideration to ensure such action did not risk damage to the bed of the loch, any geological or archaeological features or alter the water level regime. Consideration would also need to be given to suitable receiver sites and to whether long term measures (such as a change in landuse upstream of the SSSI) may also be required to prevent future build up of sediment.

- ***Soft engineering options*** – There are several generally accepted soft engineering options available, all of which work on the principle of protecting wetland through a combination of chemical, physical and biological processes. These might include:

  Buffer Zones; Buffer zones of various kinds can be used to remove nutrients before they can enter the wetland (such as reedbeds, grass strips and woodland buffers). Nitrate in particular is removed both by bacterial processes (such as denitrification) and plant uptake. However the effectiveness of the buffer zone will depend on its size, condition of the vegetation, flow rate of water through the buffer and the underlying substrate. Hence buffer strips are generally more effective when they are 30-40 m wide, with vegetation a few years old, on flat or gently sloping ground consisting of clay or humified organic material. Initial review of the available data would suggest that suitable substrate and topography is present at Bishop Loch.

  Ditch management; Ditches can be profiled to permit marginal wetland vegetation to establish, thus acting as a buffer strip. In addition, ditch clearance is only undertaken over short sections at a time and only when absolutely necessary, in order to maximise plant uptake, reduce velocity and increase residence time. Such ditch management is already likely to take place within the SSSI but could be extended into neighbouring agricultural land for additional benefit, *Vegetated filter strips and earth banks;* Filter strips are thin lines of vegetation (often only 2 m wide) which are located within field or at field edges and are generally used to reduce run-off and soil erosion (e.g. "contour grass strips"). Earth banks provide a similar role but both methods are ineffective when on free-draining soils and so are not recommended within this catchment.

Use of constructed wetland features; This includes the creation of new waterbodies as settling ponds to filter out nutrients and suspended sediment before they reach the SSSI. Once again, this can be a costly measure and consideration will need to be given to future maintenance of such features. However, they can be very effective at improving water quality and creating new habitat.

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ANNEX 1: WATER AND SOIL SAMPLES

Water samples

			Sample ID	GW1	GW2	GW3	GW4	SW1	SW2	SW4	SW5	SW6
Parameter	**Unit**	**Detection Limit**	**Sample Date**	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012
Phosphorus (total)	mg l^{-1}	0.2	Water	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ammonium	mg l^{-1}	0.01	Water	6.8	5.2	5.6	2.8	1.6	1.7	2.1	2.9	3
Nitrate	mg l^{-1}	0.5	Water	<0.5	<0.5	<0.5	2.7	16	26	32	22	18
Phosphate Low Level	mg l^{-1}	0.02	Water	0.06	0.062	0.061	0.061	0.067	0.065	0.059	0.062	0.061
Nitrogen (total)	mg l^{-1}	1	Water	3	4	2.5	4	22	8	9	6.5	15
Calcium	mg l^{-1}	5	Water	160	37	22	30	28	48	37	22	59
Magnesium	mg l^{-1}	0.5	Water	26	11	8	12	9	13	13	11	15
Sodium	mg l^{-1}	0.5	Water	7.1	20	11	10	20	17	20	12	17
Iron (II)	µg l^{-1}	20	Water	200	100	280	190	100	<20	<20	20	50
Iron (III)	µg l^{-1}	20	Water	410	250	<20	<20	430	250	130	390	290
Iron (total)	µg l^{-1}	20	Water	610	350	280	190	530	250	130	410	340

Soil samples

			Sample ID	GW1	GW2	GW3	GW4	SW1	SW2	SW4	SW5	SW6
Parameter	**Unit**	**Detection Limit**	**Sample Date**	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012	20/02/2012
Phosphorus (total)	mg l^{-1}	0.2	Water	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ammonium	mg l^{-1}	0.01	Water	6.8	5.2	5.6	2.8	1.6	1.7	2.1	2.9	3
Nitrate	mg l^{-1}	0.5	Water	<0.5	<0.5	<0.5	2.7	16	26	32	22	18
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Nitrogen (total)	mg l^{-1}	1	Water	3	4	2.5	4	22	8	9	6.5	15
Calcium	mg l^{-1}	5	Water	160	37	22	30	28	48	37	22	59
Magnesium	mg l^{-1}	0.5	Water	26	11	8	12	9	13	13	11	15
Sodium	mg l^{-1}	0.5	Water	7.1	20	11	10	20	17	20	12	17
Iron (II)	µg l^{-1}	20	Water	200	100	280	190	100	<20	<20	20	50
Iron (III)	µg l^{-1}	20	Water	410	250	<20	<20	430	250	130	390	290
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