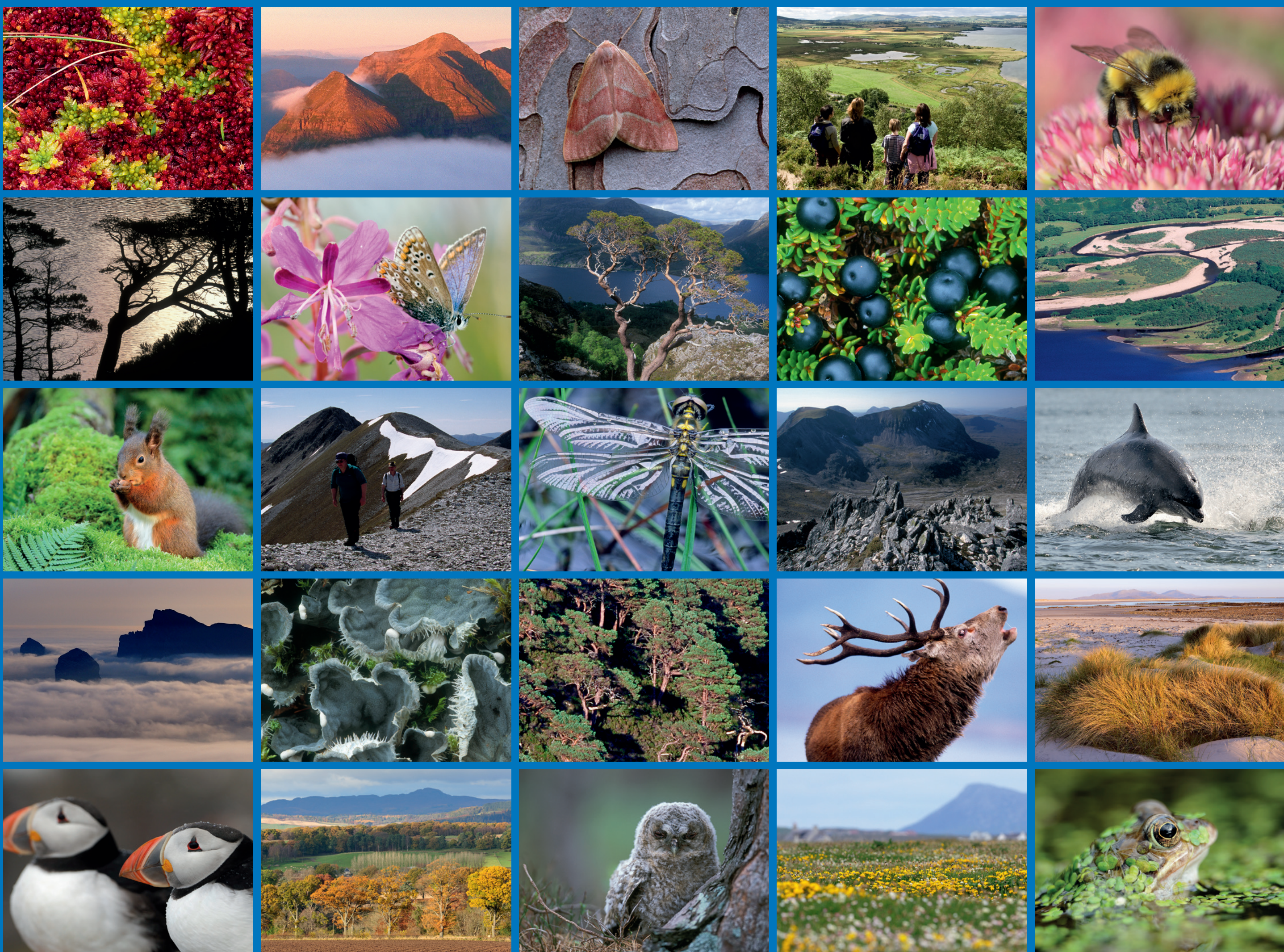
Scottish Natural Heritage
Research Report No. 1099

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

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This report should be quoted as:

Spencer, K.L. & Pitcher, A. 2019. An assessment of the results of soil and water samples from a range of wetland sites – Balshando Bog SSSI. *Scottish Natural Heritage Research Report No. 1099.*

RESEARCH REPORT
Summary

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

Research Report No. 1099
Contractor: OHES Environmental Ltd
Year of publication: 2019

Keywords

nutrients; Balshando Bog SSSI; diffuse pollution; wetland; 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 Balshando Bog, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input.

Main findings

- The surface water catchment for Balshando Bog is relatively small. The site is believed to be fed by a combination of surface and groundwater. However the presence of these springs suggests groundwater from outside of the surface water catchment is also reaching the site.
- Balshando Bog was historically much wetter and is thought to have dried out due to the conduit allowing more drainage of the surrounding land. There does not appear to be control of water levels on the site through the conduit.
- The feeder ditch to the west appears to be bringing in some forms of Nitrogen but not to the extent observed within the fen communities in the north of the site. The southern feeder ditch also appears to be bringing in enriched water, which appears to be affecting the vegetation nearest to the ditch.
- The results of groundwater samples taken at Balshando Bog have been compared to the eco-hydrological requirements of the wetland communities present on the site. It appears that the north of the site is less consistent with water quality results observed in Scotland (with Calcium, Magnesium, Sodium and Nitrogen being above the recorded ranges both in the marshy grassland and fen communities). Some samples are also higher in Total Nitrogen and Phosphate, suggesting that a midden is enriching this part of the SSSI.
- The higher than typical Nitrate levels within the sample occurring near S4 reedbed are still within the recorded Scottish range for this community, but could indicate either the enrichment from the north-west is reaching the waterbody, or drier conditions within the central area are releasing previously stored nutrient within the peat.
- Assessment of vulnerability showed Balshando Bog was most at risk from agricultural practices, site management operations and drainage.

- 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

OHES Environmental wish to thank Deborah Spray, Andrew McBride and the team of SNH Operations staff for their assistance in providing information on each site. We would also like to thank SNH, SEPA and SNIFFER for the release of the ER37 draft report on proposed eco-hydrological guidelines for Scottish wetlands before publication, in order to inform this report.

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 Balshando Bog, 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. METHODOLOGY

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

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 near 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

Balshando Bog Site of Special Scientific Interest (SSSI) (Figure 1) is located approximately 14 km north-west of Dundee in the Tayside and Grampian area. The 3.6 ha site lies within the Sidlaw Hills and is one of the best examples of a basin fen in Angus. The bog lies in a basin at 205 m between Smithton Hill (324 m) and Balshando Hill (266m). The site is thought to be a kettlehole (a basin produced by glacial till accumulating around a large fragment of glacier). A small coniferous plantation lies to the eastern edge of the site, with the remainder of the site being surrounded by arable land and improved pasture.

Old maps suggest the site was once much larger, with the area of open water, known as Balshando Loch, having reduced in recent years (Figure 2). The site was also much wetter than it is today and was traditionally cut for peat. However, there is currently no active management and no domestic stock grazing. The land is used for raising and shooting pheasants and there is a feeding / release pen to the north-east of the site.

Figure 1. Site Boundary – Balshando Bog

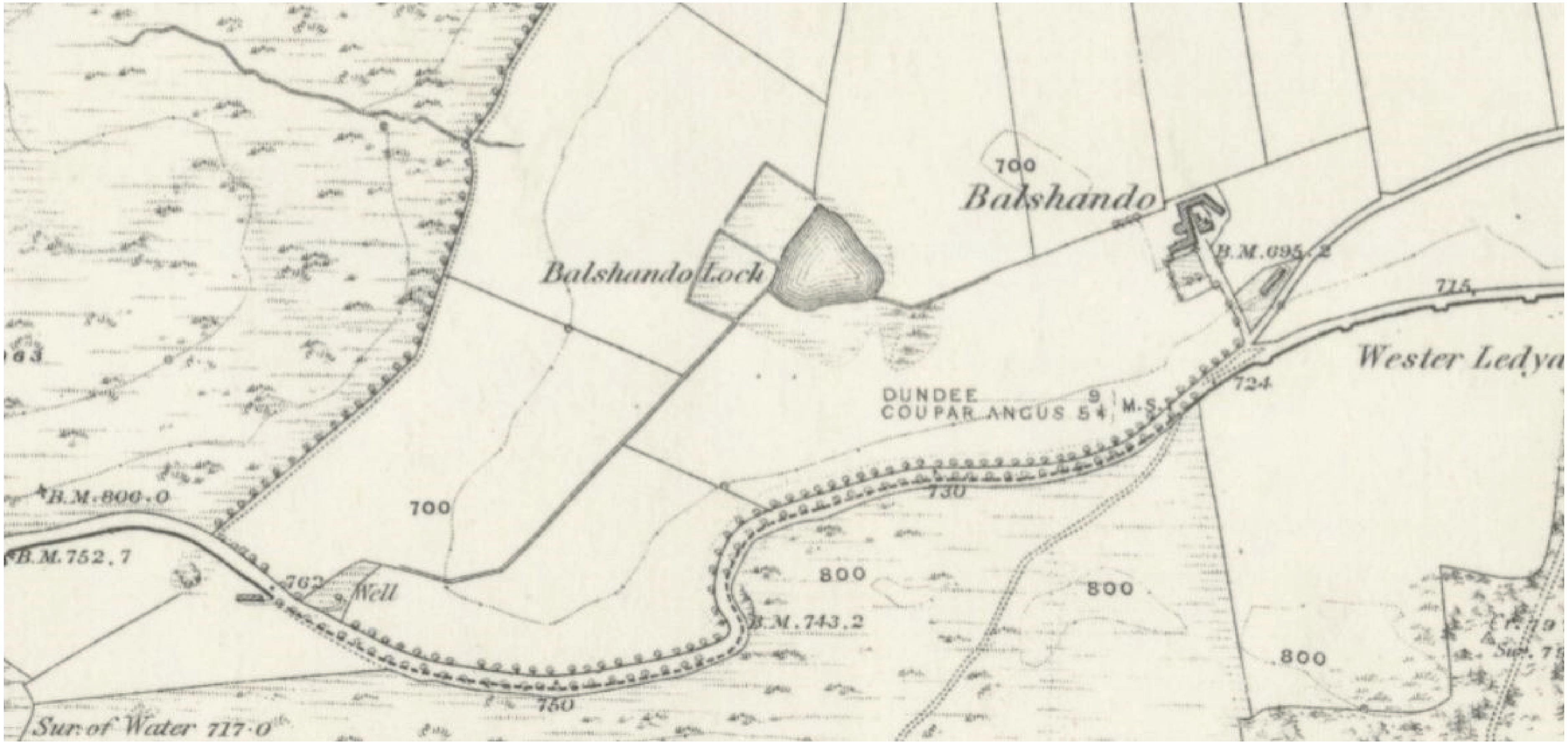

Figure 2. Ordnance Survey Six Inch 1843 – 1882 map (Source: National Library of Scotland)

3.1.1 Site designation and specific targets

Balshando Bog SSSI was first designated in January 1984. The feature for which it is designated is detailed in Table 1. The fen comprises tall herb meadow, with areas dominated by meadowsweet, brown sedge, willow carr and a small area of open water containing yellow water lily. Brown sedge is uncommon in this part of Scotland.

Table 1. Balshando Bog SSSI designated features and their pressures

SSSI features	Feature Category	Summary Condition / Latest Condition	Pressure
Basin Fen	Wetland	Unfavourable Declining (Sept 2003)	a) Water management

The long-term goal for the site is to maintain a fully functioning and sustainable basin fen system and encourage greater diversity of the fen and the supported species. To achieve this the site requires: i) control of water levels, ii) control of nutrient inputs, iii) control of willow scrub and iv) sensitive grazing management and / or winter cutting. The site specific targets based on the 2002 condition survey are:

1. To maintain open water and optimum water levels for plant species (i.e. increase water levels by control of the conduit) with standing water present between stems over ≥80 % of swamp area.
2. Maintain water quality through nutrient enrichment / eutrophication control by creating a 30 m buffer zone around the SSSI which is left unploughed and no artificial fertiliser added.
3. To remove and control willow scrub and reinstate winter cutting or grazing to increase species diversity and help control water levels.
4. To ensure the existing extent of habitat is comparable with previous monitoring, while taking natural succession into account with no loss of NVC communities present within the habitat.
5. Maintain the mosaic of habitats / vegetation communities with a maximum invasion of 10 % by scrub of open communities.
6. Ensure cover of tall invasive graminoids in no more than 25 % of samples.
7. Common reed should form a closed or open stand >50 % cover in 100 % of samples.

3.1.2 Site hydrology

The surface water catchment for Balshando Bog is relatively small (Figure 3). There are two burns (Figure 4) which are fed by springs and transported via field drains into the site. However the presence of these springs suggests groundwater from outside of the surface water catchment is also reaching the site.

Water leaves the site via transpiration and a conduit running off site at the south-eastern corner. The site was historically much wetter and is thought to have dried out due to the conduit allowing more drainage of the surrounding land. The planting of trees in 1989/90 and the encroachment of willow scrub into the area of open water will also have contributed to the fall in water levels through evapotranspiration (Site Management Statement). There does not appear to be control of water levels on the site through the conduit.

There is a water monitoring point near Lundie, approximately 2.4km to the east. Historic rainfall data is not available for Balshando Bog.

The site is underlain by the Sidlaw Hills bedrock and localised sand and gravel aquifer, which in 2008 had an overall quality status of ‘Poor’ with an upward trend in diffuse source pollutants. The quantity of groundwater has been classified as Good with high confidence.

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.

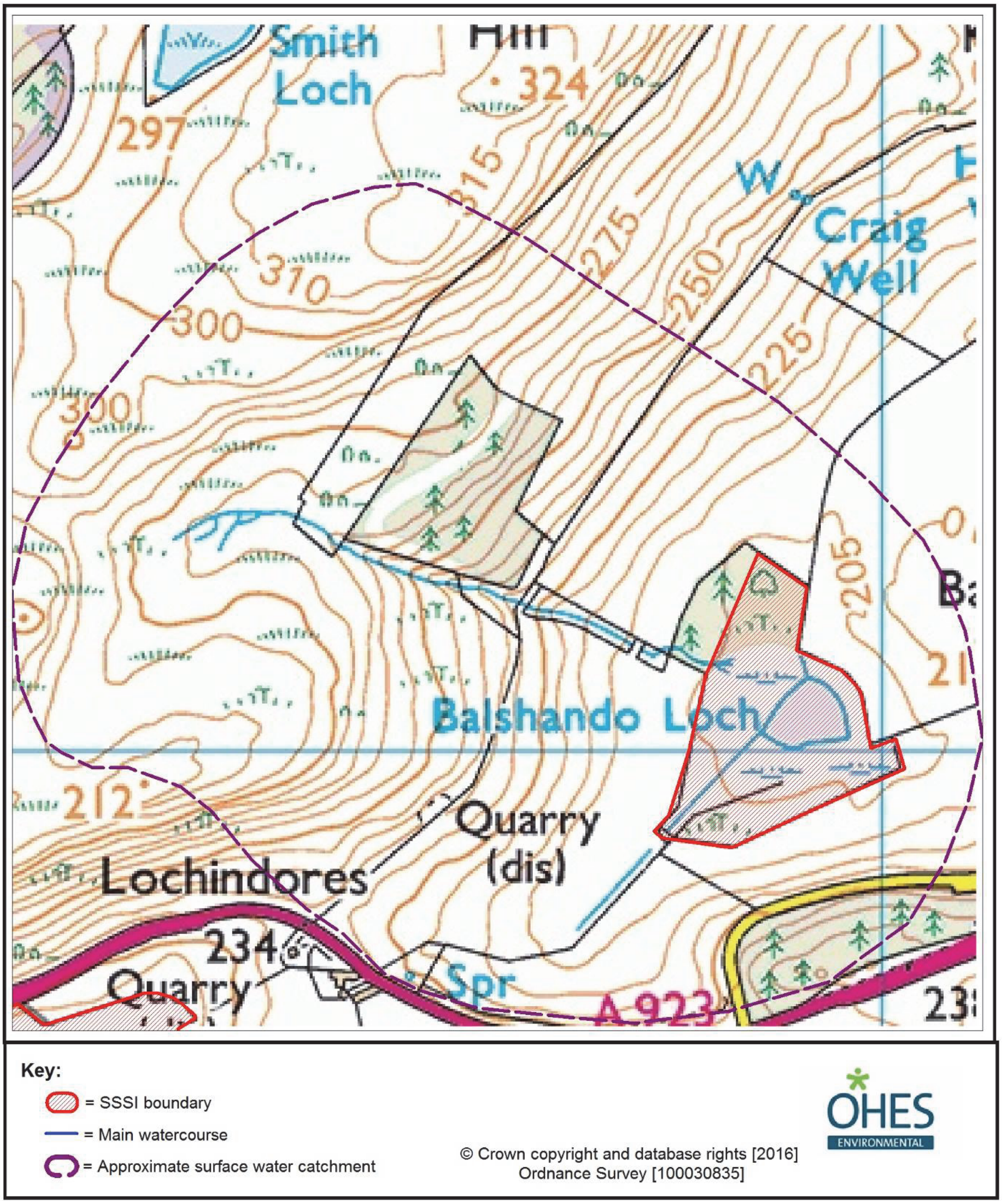

Figure 3. Balshando Bog – approximate surface water catchment

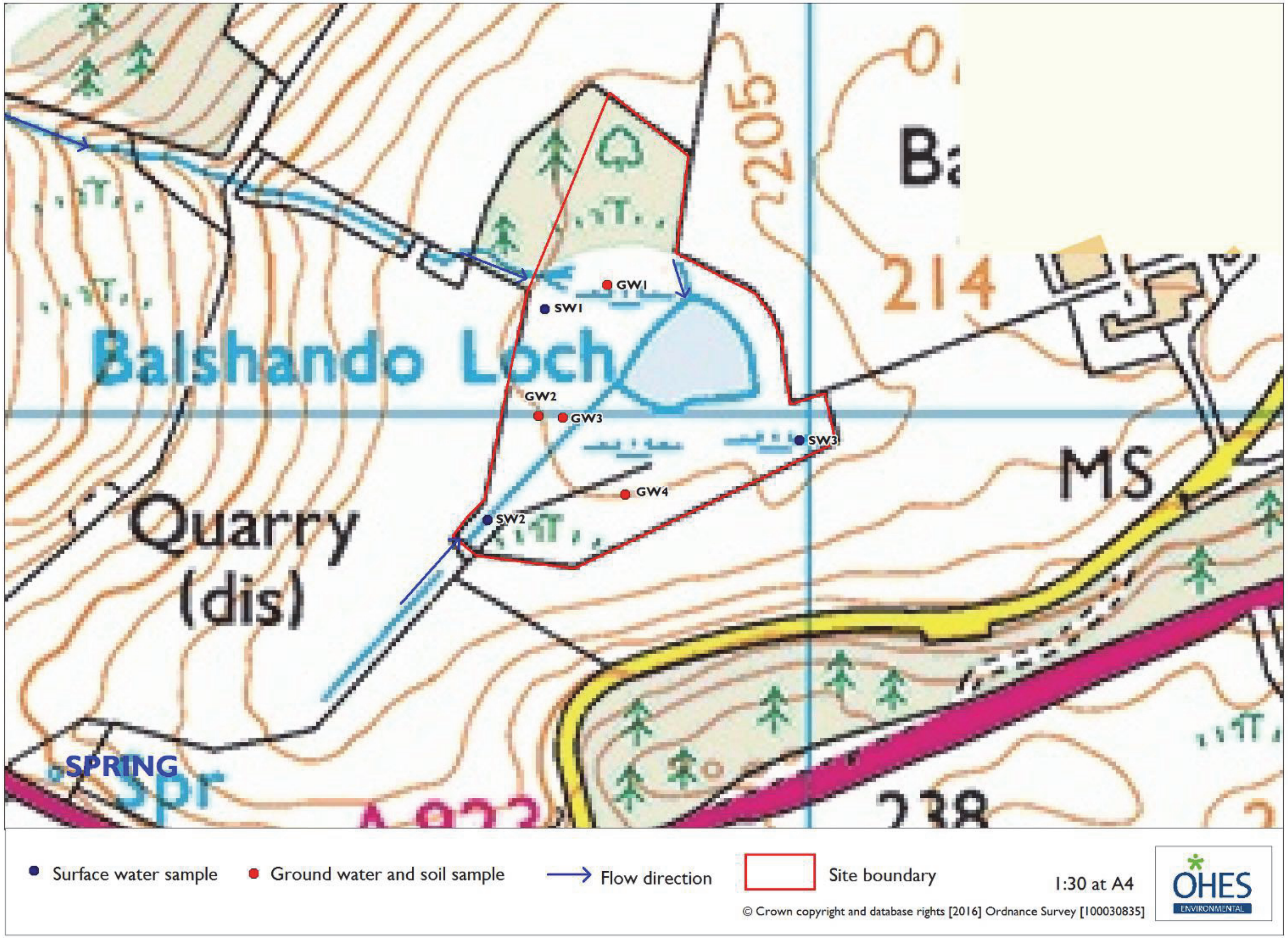

Figure 4. Balshando Bog – Hydrology and Sample Locations

One of the limitations to this study is that little data were available to define detailed hydrological functioning for this site. Similarly, only general information is available on the substrate present at Balshando Bog. Application of systems such as the WetMec scheme requires detailed information on both these factors before it can be accurately applied. It is therefore only possible to postulate that, due to the presence of springs at some distance from the site, and the substrate consisting of peat over clay (with some sloppy peat layers), the most appropriate category would appear to be WetMec 20: Percolation Basin (where some groundwater feed can occur but the status of the supply compared to surface water is unclear).

3.1.3 Site soils / sediments

Balshando Bog is underlain by the Mountboy association, which is derived from grits, sandstones and conglomorates of the Old Red Sandstone age (with some basic and intermediate lava). These soils are poorly drained and form undulating lowlands and foothills with both gentle and strong slopes.

The superficial deposits within the immediate area of the SSSI consist of alluvium, (normally soft to firm consolidated, compressible silty clay, but which can contain layers of silt, sand, peat and basal gravel). They are noted as potentially containing a stronger, desiccated surface zone (British Geological Society website). The fen peat deposits in the basin have probably accumulated over several millennia since the kettlehole was formed. Figure 5 shows the distribution of soil types at Balshando Bog.

Figure 5. Balshando Bog – Soil types (source: Soil Survey of Scotland Staff. 1987). Blue = Mountboy Association, Brown = Darleith Association

3.1.4 Site specific issues

During the condition survey in 2003 it was noted that the dumping / spreading and storage of materials was having a negative influence on the site. The location and type of this material was not documented but it could be a source of pollution.

Agricultural practices are also a concern within the SSSI, with the site being surrounded by arable or improved grassland (Figure 6). It is believed that field drains discharge directly into the peat, as is common for similar mires elsewhere in Scotland. A conifer plantation is present alongside the western feeder ditch of the SSSI. It is therefore possible forestry practices may be mobilising sediment into the fen during rainfall events.

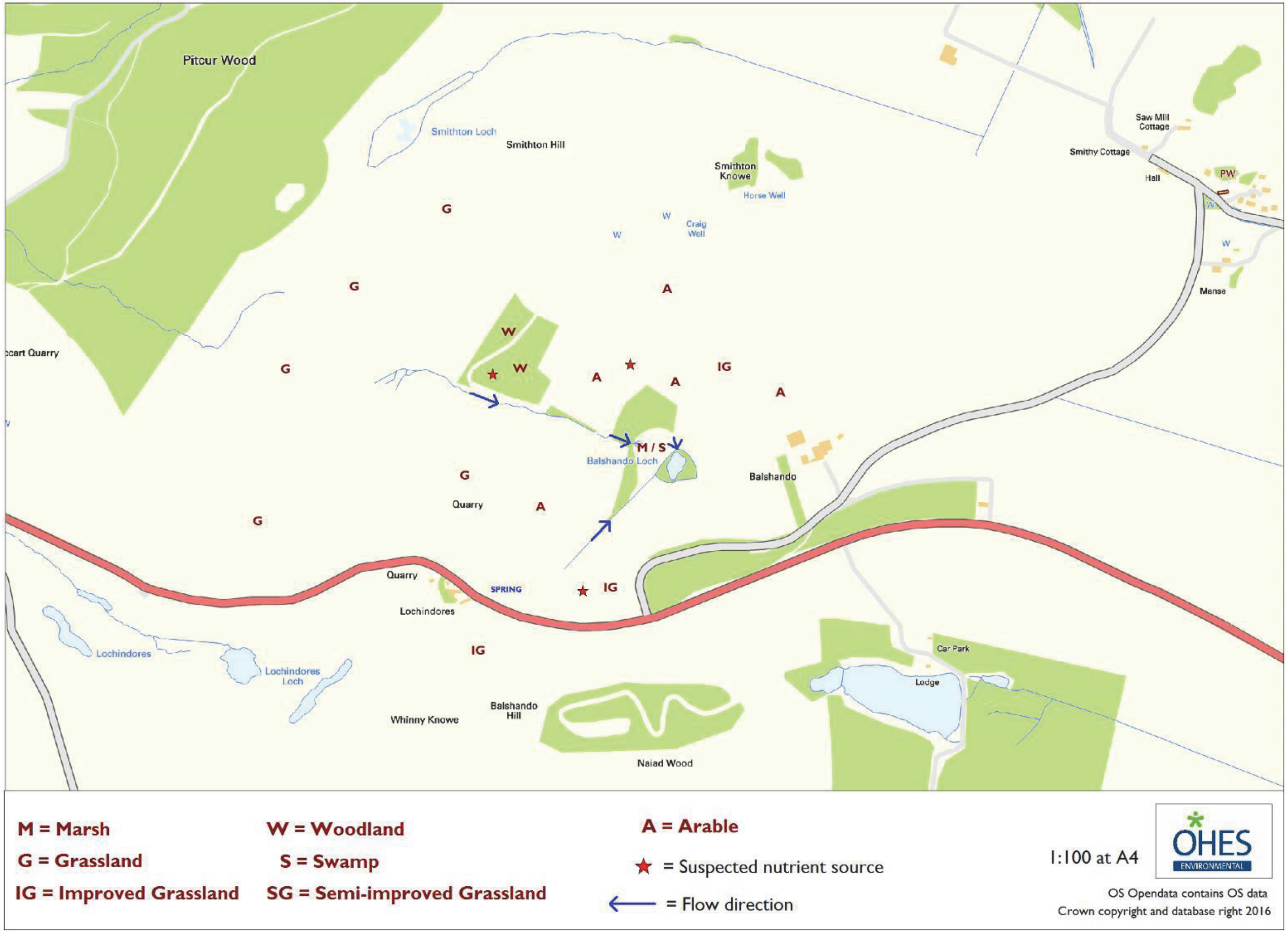

Figure 6. Land use and potential nutrient sources at Balshando Bog

3.2 Assessment of vegetation data

Balshando Bog contains a range of open water transition mire with rich fen vegetation and swamp communities, located around the margins of the loch. Observations on the vegetation have been recorded in 1998, 1999 and 2003; however NVC communities are only mapped for the whole site in 2003 with no quadrat data available. Figure 7 shows the NVC communities recorded in 2003.

The NVC communities recorded at Balshando Bog are:

- MG1 *Arrhenatherum elatius* grassland
- M27b *Filipendula ulmaria - Angelica sylvestris* mire, of the *Urtica dioica-Vicia cracca* sub-community
- MG9a *Holcus lanatus-Deschampsia cespitosa* grassland, of the *Poa trivialis* sub-community
- S26a *Phragmites australis-Urtica dioica* fen, of the *Filipendula ulmaria* sub-community
- S27a *Carex rostrata-Potentilla palustris* fen, of the *Carex rostrata-Equisetum fluviatile* sub-community
- S4 *Phragmites australis* swamp and reed-beds
- W3 *Salix pentandra-Carex rostrata* woodland

With additional sporadic recording of:

- S9b - *Carex rostrata* swamp, of the *Carex rostrata* sub-community

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 2003 Site Condition Assessment noted that a comparison between 1998 survey, 1999 NVC survey and 2003 survey indicates an invasion by swamp communities south of the midden. Colonisation by thistles and nettles had reduced the extent of S26/S4 community by over 25 %. This resulted in a failure of the target to maintain the extent of wetland habitat.
- The 2003 SCA noted that S4, S9 and S27 communities are thought to be expanding at the expense of the small area of remaining open water. The scrub was of an even age but may expand further as a result of the dry conditions experienced that year.
- Standing water was not present between stems over at least 80 % of the swamp area during the 2003 SCA, as it was a very dry year. This resulted in target failure.
- In 2003 there was an increase in the size of S4 and S27 communities because of natural succession.
- In 2003 *Carex rostrata* was in 100 % of samples and covered over 90 % of the area, resulting in the target being met for the site.
- Species listed during the water and soil sampling in 2012 (SNH) suggest that some areas previously mapped in 2003 as M27 may now fit better within MG9. For example, GW1 lists "*Deschampsia, Carex disticha* and mostly *Agrostis stolonifera*", with no mention of M27 species such as *Filipendula ulmaria*.

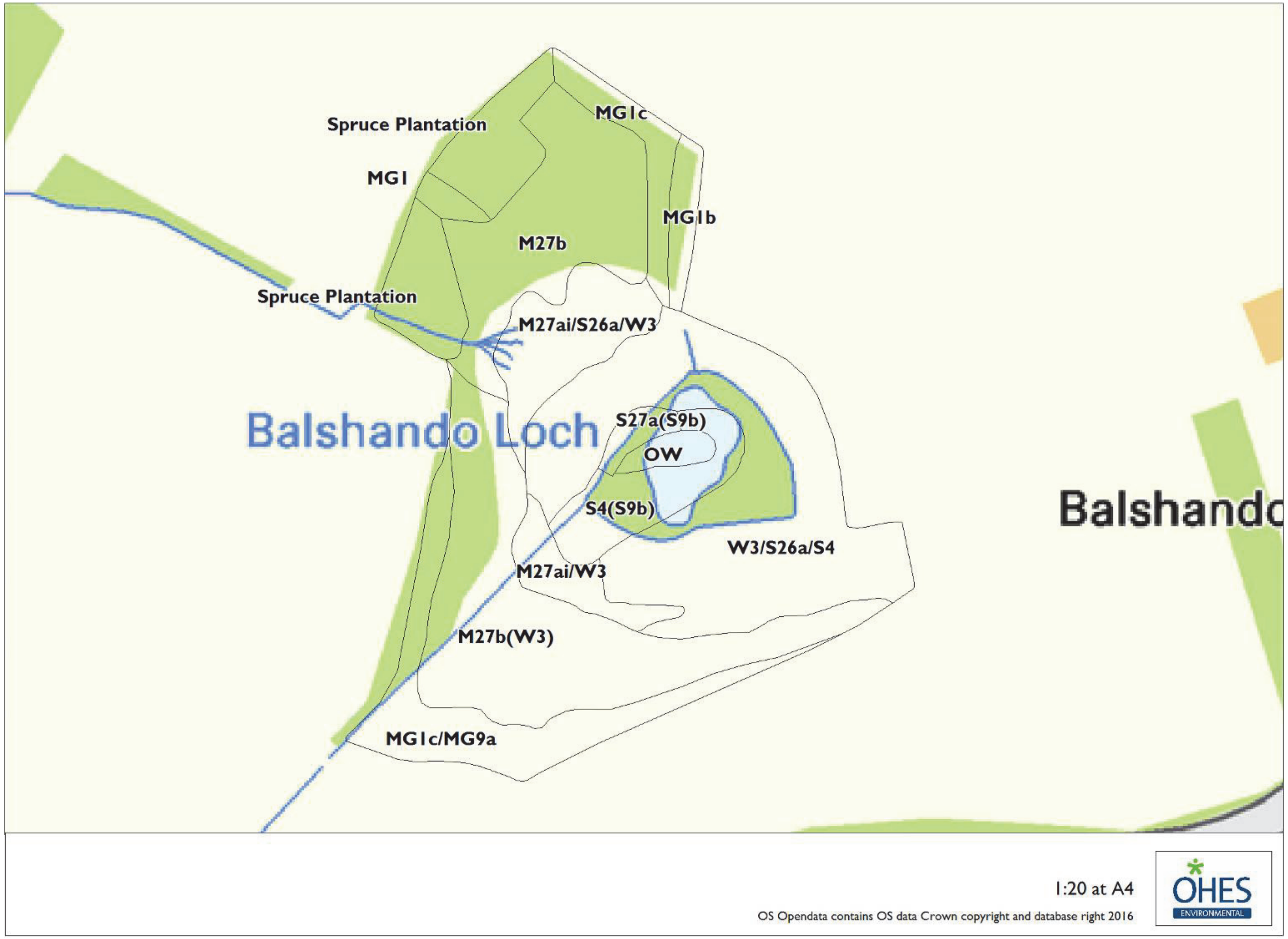

Figure 7. NVC communities recorded in 2003 (Source: SNH Natural Spaces)

3.2.2 Community requirements

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 relevant to Balshando Bog are:

- Type 2a: Marshy grassland
- Type 4: Fen
- Type 5: Swamp
- Type 6: Reedbed

The guidance below is therefore based primarily on the ER37 report findings, but with additional information on individual community types where known.

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 communities contained within these types are considerable, but those relevant to Balshando Bog include:

- MG9 *Holcus lanatus-Deschampsia cespitosa* grassland – this community is typically species-poor, with a widespread distribution across Scotland. The hydrology consists of a moderate water table, sufficiently close to the surface to keep the soils moist 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)

3.2.2.2 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 SNIFFER (2009) and which are found at Balshando Bog are:

- 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-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-PO_4 for mesotrophic and oligotrophic fen respectively (ER37). Mean values for fen in poor conditions are 0.034 mg/l P-PO_4 and 0.064 mg/l P-PO_4 for mesotrophic and oligotrophic groups. ER37 reports that median Phosphate concentrations in Scottish fens are 0.10 mg/l P-PO_4 (for groundwater) and 0.046 mg/l P-PO_4 (for surface water). These figures exceed mean values given for good condition under UKTAG, 2012. No guideline value has currently been set for Phosphate. ER37 reports however that "groundwater results are skewed by the analytical level of detection of 0.2 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-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)

3.2.2.3 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 which are found at Balshando Bog are:

- 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.

- S26 *Phragmites australis-Urtica dioica* tall-herb fen – this type of swamp is classified within 4 sub-communities, to reflect the very variable floristics and physiognomy. Overall, it is a community of eutrophic situations, within mires and water margins. Water levels are sufficiently high to keep the substrate moist through most of the year, although surface flooding can occur in winter (Rodwell, 1995). Though the community marks enriched conditions, this can either be from external nutrient input or from drainage and disturbance of mires resulting in oxidation of organic material and the subsequent release of nutrients. Thus S26 is generally a secondary community (partly or wholly replacing richer fens as a result of enrichment and/or disturbance).

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)

3.2.2.4 Type 6 Reedbed

Equivalent NVC types covered:

- S4a *Phragmites australis* sub-community
- 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 (SNIFFER). SNIFFER note 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 UKTAG for groundwater are 4.9 mg/l N-NO_3 for groundwater feeding mesotrophic swamp and reedbed in good condition and 5.1 mg/l N-NO_3 for poor conditions, but this value is significantly higher than was observed in Scottish reedbed. ER37 reports that "site specific investigations indicate mean concentrations of Welsh and Scottish swamp and reedbed of 0.3 and 0.5 mg/l N-NO_3 (16 wetlands in good condition) and 6.2 and 5.6 mg/l N-NO_3 (9 wetlands poor condition). On this basis a threshold value of 5.0 mg/l N-NO_3 has been adopted by UKTAG (2012)". However, ER37 concludes values between observed 1mg/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 mg/l N-NO_3 (or 22 mg/l as NO_3)

3.3 Assessment of ground water samples

Groundwater samples taken at Balshando Bog have been compared with the levels recorded in vegetation types as shown in section 3.2. Groundwater targets were used as opposed to surface water targets for several reasons; firstly that almost all wetlands will have a component of groundwater influence and secondly that groundwater thresholds can often be more demanding than surface water targets. Table 6 indicates that the vegetation currently found around the sample locations is fairly consistent with the data recorded for Scotland.

It appears that the north of the site (GW1) is less consistent with results observed in Scotland, with Calcium, Magnesium, Sodium and Nitrogen being above the recorded SNIFFER range both in the marshy grassland and fen communities. This is possibly the result of base-rich waters being supplied to this part of the SSSI from spring sources to the west. However, as the sample is also higher in Total Nitrogen and Phosphate, it is also probable that the midden is enriching this part of the SSSI.

GW2 in the south-west of the site also had elevated levels of Calcium and Sodium, but not Phosphate or Total Nitrogen. When GW2 is compared to GW3 (which contains a diffuse top layer of *Phragmites*) GW3 recorded slightly higher values of Phosphate and Total Nitrogen. As sample GW3 is nearer to a feeder ditch, this could be the result externally sourced enriched waters entering the site, or once again oxidation of the peat due to drier conditions.

The higher than typical Nitrate levels within GW4 (which occurs near S4 reedbed) are still within the recorded levels for this community, but could indicate either the enrichment from the north-west is reaching the waterbody, or drier conditions within the central area are releasing previously stored nutrient within the peat.

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

	Balshando Bog	Balshando Bog	Marshy Grassland			Balshando Bog	Reedbed		
Sample	**GW1 (in MG9)**	**GW2 (in MG9)**	**1st Quartile**	**3rd Quartile**	**Indicator/Guideline:**	**GW4 (nr S4)**	**1st Quartile**	**3rd Quartile**	**Threshold:**
pH (-)			6.3	7.1	5 to 8		5.7	6.5	
Dissolved Oxygen (%)			32	40			18	22	
Conductivity (mS/cm)			0.093	0.18			0.13	0.28	
Calcium (mg/l)	770	26	8	24		21	36	59	
Magnesium (mg/l)	63	6.7	2.5	8.7		4.5	5.8	18	
Sodium (mg/l)	16	15	6.2	12		7.8	12	19	
Phosphate (mg/l)	0.071	0.056	0.041	0.065	Indicator: 0.065	0.06	0.043	0.1	None set
Nitrogen (total) (mg/l)	15	6	2.5	7		4	1.1	6.9	
Nitrate (mg/l N-NO_3)	<0.5	<0.5	0.25	0.25	Guideline: <175 m 5.9 (or 26 mg/l as N-NO_3)	0.84	0.25	0.25	Threshold: 5 (or 22 mg/l as NO_3)

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

	Balshando Bog	Balshando Bog	Balshando Bog	Balshando Bog	Fen			Balshando Bog	Swamp		
Sample	**GW1 (in M27?)**	**GW2 (in M27)**	**GW3 (in M27)**	**GW4 (nr M27)**	**1st Quartile**	**3rd Quartile**	**Threshold**	**GW4 (nr S26)**	**1st Quartile**	**3rd Quartile**	**Indicator**
pH (-)					6.4	7.4			5.7	7.1	
Dissolved Oxygen (%)					18	28			15	36	
Conductivity (mS/cm)					0.37	0.69			0.24	0.43	
Calcium (mg/l)	770	26	14	21	12	55		21	10	44	
Magnesium (mg/l)	63	6.7	3.6	4.5	3.4	14		4.5	3.6	16	
Sodium (mg/l)	16	15	10	7.8	5.4	14		7.8	5.5	18	
Phosphate (mg/l)	0.071	0.056	0.062	0.06	0.064	0.1	None set	0.06	0.024	0.1	None set
Nitrogen (total) (mg/l)	15	6	7.5	4	1	5.1		4	2	7	
Nitrate (mg/l N-NO_3)	<0.5	<0.5	<0.5	0.84	0.25	0.25	Threshold: <175m Meso = 5 (or 22 mg/l as NO3) Olig = 4.5 (or 20 mg/l as NO3)	0.84	0.25	0.25	Guideline: Meso = 5 (or 22 mg/l as NO3) Olig = 4.1 (or 18 mg/l as NO3)

3.4 Assessment of surface water samples

3.4.1 Current surface water quality status

Three surface water samples were taken from Balshando Bog (GW1 and 2 were from inflows and GW3 presumably marks the area of the conduit). Due to the likely interaction of groundwater and surface water samples, the two sets of results were compared to assess their similarities.

The surface and groundwater results can be found in Table 7. The surface water results from the western feeder ditch do not mirror the high values of various determinants (including nutrients) recorded in the enriched sample GW1, suggesting this feeder ditch is not the main source of eutrophication. In contrast, higher Nitrate levels within the feeder ditch from the south corroborate the higher Nitrogen levels in GW3 sample nearer this ditch.

Table 7. Comparison of Surface water and Groundwater at Balshando Bog

	Balshando	Balshando	Balshando	Balshando	Balshando	Balshando	Balshando	Balshando
Sample	**SW1 (nr inflow)**	**GW1**	**SW2 (nr inflow)**	**GW2**	**GW3**	**GW4**	**SW3**	**GW4**
Calcium (mg/l)	27	770	12	26	14	21	31	21
Magnesium (mg/l)	6.1	63	4.2	6.7	3.6	4.5	7.6	4.5
Sodium (mg/l)	25	16	11	15	10	7.8	31	7.8
Phosphate (mg/l)	0.059	0.071	0.059	0.056	0.062	0.06	0.063	0.06
Nitrogen (total) (mg/l)	2	15	4.5	6	7.5	4	2	4
Nitrate (mg/l N-NO_3)	5.6	<0.5	12	<0.5	<0.5	0.84	<0.5	0.84

Surface water results were compared to ER37 targets for the various vegetation communities at Balshando Bog. Water chemistry guidelines generally refer to groundwater rather than surface water and therefore comparison can only typically be made between Balshando bog and the SNIFFER dataset for wetlands in Scotland. Table 8 indicates that the vegetation currently found around the sample locations is fairly consistent with the data recorded for Scotland (ER37). Phosphate levels were higher than those of the SNIFFER data in two samples (SW2 and SW3 taken near the southern inflow and east of the site respectively), while SW1 was higher for Nitrate (taken near the western inflow).

Table 8. Surface water samples at Balshando Bog compared with Wetland Type for Scotland (ER37). Red text denotes sample exceeds 3rd quartile.

	Balshando Bog	Reedbed		Balshando Bog	Marshy grassland		Balshando Bog	Fen	
Parameter	**SW3 (nr S4)**	**1st Quartile**	**3rd Quartile**	**SW2 (in MG1 / MG9)**	**1st Quartile**	**3rd Quartile**	**SW1 (in M27)**	**1st Quartile**	**3rd Quartile**
pH (-)		6.6	6.8		6.5	7.5		6.7	7.4
Dissolved Oxygen (%)		63	81		61	70		53	57
Electric Conductivity (mS/cm)		0.23	0.26		0.2	0.71		0.25	0.62
Calcium (mg/l)	31	24	44	12	8.5	44	27	13	38
Magnesium (mg/l)	7.6	4	5.6	4.2	3.2	9	6.1	5	8
Sodium (mg/l)	31	6	20	11	6	14	25	7	12
Phosphate (mg/l)	0.063	0.01	0.055	0.059	0.005	0.058	0.059	0.02	0.084
Nitrogen (total) (mg/l)	2	1.8	6	4.5	1.5	6	2	1.8	5
Nitrate (mg/l N-NO_3)	<0.5	0.21	4.6	12	0.4	8.6	5.6	0.25	5.2

3.4.2 *Summary of site vulnerability*

The site is believed to be fed by a combination of surface and groundwater (sourced from the springs off-site). The feeder ditch to the west appears to be bringing in some forms of Nitrogen but not to the extent observed within the fen communities in the north of the site. The southern feeder ditch also appears to be bringing in enriched water, which appears to be affecting the vegetation nearest to the ditch.

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

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

Source	Balshando Bog	
	Vulnerability	**Details of Factors**
EXTERNAL SOURCES		
1. Agriculture	High	- A significant proportion of the land within the surface catchment is used as improved grassland or arable, some of which appears to be providing enriched waters into the site. - Further enrichment appears to be coming from the midden.
2. Human population	Low	- No residential properties are present within the surface water catchment.
3. Aerial deposition	Low-Moderate	- Deposition rates within this part of the UK are lower than recorded in England. Thus atmospheric Total Phopshorus input into the catchment is small, although Total Nitrogen remains a contributor.
4. Regional Groundwater	Low-Moderate	- Regional groundwater that may be contributing to the site's water balance is understood to be of poor water quality.
INTERNAL SOURCES		
1. Wildlife	Low	- The site does not contain large numbers of bird species which would significantly contribute to the nutrient balance.
2. Site management	Moderate	- The site is not grazed and therefore will be accumulating nutrients slowly over time.
3. Drainage	Low-Moderate	- Some observations suggest the site is becoming drier. This could result in the peat oxidising and a subsequent release of stored nutrients.

3.5 Assessment of soil samples

Soil chemistry was sampled at four locations within Balshando Bog (two of which were in marshy grassland and fen, one was in fen, and one was in reed, fen and 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 Balshando Bog samples against the ER37 data. It shows that levels of Magnesium, Calcium and Nitrogen are all at the lower end of the range observed in Scottish samples. Phosphate and sodium however were above those typically recorded in fen, marshy grassland and reedbed in all samples. Total organic carbon was also high in Soil sample 2 (GW2) and 4 (GW4) for fen and marshy grassland.

Soil sample 1 (GW1) was taken in the north of the site, near to the inflow from the west. The sample consisted of fibrous peat underlain by silky clay and organic rich peaty clay from c35cm. The soil moisture content was higher at the root layer than below.

Soil sample 2 was taken in the south-west of the site in fibrous humified peat over sloppy peat from c50 cm. The soil moisture content increased with depth within the peat layer. Soil sample 3 (GW3) was taken just east of sample 2 in unhumified sloppy peat with a band of peat and sand from 25-50 cm and then sloppy humified peat. The soil moisture content was higher within the root layer than below, which may reflect the influence of the sandy layer. Soil sample 4 was taken in the east of the site in fibrous peat underlain by peaty, silty gravel and then peat, which became sloppy at c60 cm. Again the moisture content was higher at the root layer than below.

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

	Balshando Bog		Balshando Bog		Balshando Bog		Balshando Bog		Fen		Balshando Bog		Balshando Bog		Marshy Grassland	
Sample	**Soil 1 Root (in M27)**	**Soil 1 below (in M27)**	**Soil 2 Root (in M27)**	**Soil 2 below (in M27)**	**Soil 3 Root (in M27)**	**Soil 3 below (in M27)**	**Soil 4 Root (in M27)**	**Soil 4 below (in M27)**	**1st Quartile**	**3rd Quartile**	**Soil 1 Root (in MG9?)**	**Soil 1 below (in MG9?)**	**Soil 2 Root (in MG9?)**	**Soil 2 below (in MG9?)**	**1st Quartile**	**3rd Quartile**
Calcium (mg/kg)	850	760	2,300	2,200	1,100	1,500	1,500	1,800	960	12,000	850	760	2,300	2,200	160	4,200
Magnesium (mg/kg)	2,200	1,500	1,600	2,300	2,300	2,200	150	2,100	1,500	3,800	2,200	1,500	1,600	2,300	1,100	2,700
Sodium (mg/kg)	400	300	300	70	530	500	430	210	74	280	400	300	300	70	43	200
Phosphate (available) (mg/l)	13	8.1	8.5	4.7	10	10	8.9	5.9	2.7	9.5	13	8.1	8.5	4.7	3.4	9.5
Nitrogen (total) (%)	0.78	0.72	1.2	0.09	0.8	0.96	0.97	0.39	0.25	1.4	0.78	0.72	1.2	0.09	0.05	0.78
Nitrogen (extractable) (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	1.4	<0.1	<0.1	<0.1	<0.1	0.35	0.93
Total organic carbon (%)	7.7	6.5	16	24	11	12	10	18	3.7	12	7.7	6.5	16	24	2.1	20
Potassium (total)	300	160	380	85	980	1,100	530	170	-	-	300	160	380	85		
Soil Moisture Content %	486	130	363	810	468	195	431	160	-	-	486	130	363	810		

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

	Balshando Bog		Swamp		Balshando Bog		Reedbed	
Sample	**Soil 4 Root (nr S26)**	**Soil 4 below (nr S26)**	**1st Quartile**	**3rd Quartile**	**Soil 4 Root (nr S4)**	**Soil 4 below (nr S4)**	**1st Quartile**	**3rd Quartile**
Calcium (mg/kg)	1,500	1,800	140	5,800	1,500	1,800	1,700	13,000
Magnesium (mg/kg)	150	2,100	410	3,400	150	2,100	200	2,700
Sodium (mg/kg)	430	210	17	140	430	210	32	44
Phosphate (available) (mg/l)	8.9	5.9	2.9	12	8.9	5.9	1.1	6
Nitrogen (total) (%)	0.97	0.39	0.17	1.2	0.97	0.39	0.99	1.7
Nitrogen (extractable) (mg/kg)	<0.1	<0.1	0.43	0.9	<0.1	<0.1	0.39	0.56
Total organic carbon (%)	10	18	4.1	25	10	18	5.5	22
Potassium (total)	530	170	-	-	530	170	-	-
Soil Moisture Content %	431	160	-	-	431	160	-	-

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 were 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.
- There were insufficient data for any statistical analysis.
- Quadrat data was not available from the NVC survey, which prevented further examination of the vegetation types at Balshando Bog.

3.7 Recommendations on future measures and / or data requirements

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 Balshando Bog, based on a single sampling round, suggests enriched water is entering the SSSI from the north, from the south via the feeder drain and at lower levels from the western feeder drain. This indication would need to be confirmed by the following data requirements:

- Ideally, monthly surface water sampling within existing points SW1, SW2 and SW3 (but also an additional point SW4 within the central waterbody) 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 two 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.

Once these data have 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 and/or modification of a control structure at the outflow of the site*** – This would increase the chances that the site remains suitably wet and is therefore less vulnerable to peat oxidation. Higher water levels would discourage the growth of problematic species known to be increasing on the site (such as thistles and nettle).

- ***Implementation of a grazing plan*** – with livestock ideally removed from site at night (thus ensuring a net loss of nutrient from the site as well as providing greater opportunities to increase plant diversity).

- ***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, but as there is superficial evidence that the site is becoming drier this is not a recommended course of action.

- ***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 Balshando bog.

  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.

  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.

4. REFERENCES

Entec UK, 2009. A Functional Wetland Typology for Scotland. SNIFFER, Edinburgh.

Envirocentre, 2012. Wetland Soil and Water Samples: Summary report. SNH.

"ER37" EnviroCentre (draft February 2016).

Interagency Freshwater Group, 2015. Common Standards Monitoring Guidance for Freshwater Lakes. JNCC, Peterborough.

Moss, B. *et al*. 2003. The determination of ecological standards in shallow lakes – a tested system (ECOFRAME) for implementation of the European Water Framework Directive. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 13, 507-549.

Natural Scotland, 2009. The River Basin Management Plan for the Scotland River basin district 2009-2015.

Rodwell, J.S. 1995. British Plant Communities: Volume 4: Aquatic communities, swamps and tall-herb fens. Cambridge University Press: Cambridge.

Rodwell, J.S. 1991. British Plant Communities: Volume 2: Mires and heaths. Cambridge University Press: Cambridge.

The Water Framework Directive Directions (England and Wales) 2015.

UKTAG, 2008. UK Environmental Standards and Conditions (Phase 2).

UKTAG, 2014. Technical report on Groundwater Dependent Terrestrial Ecosystems (GWTDE) Threshold Values.

Wheeler, B.D., Gowing, D.J.G., Shaw, S.C., Mountford, J.O. & Money, R.P. 2004. Ecohydrological Guidelines for Lowland Wetland Plant Communities. Environment Agency, Anglian Region.

Wheeler, B.D., Shaw, S. & Tanner, K. 2009. A Wetland Framework for Impact Assessment at Statutory Sites in England and Wales. Environment Agency, Bristol.

WWT Consulting, 2007. Wetland Hydrogeomorphic Classification for Scotland. SNIFFER, Edinburgh.

ANNEX 1: WATER AND SOIL SAMPLES

Water samples

			Sample ID	GW1	GW2	GW3	GW4	SW1	SW2	SW3
Parameter	**Unit**	**Detection Limit**	**Sample Date**	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012
Phosphorus (total)	mg l^{-1}	0.2	Water	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ammonium	mg l^{-1}	0.01	Water	2.3	2.4	1.9	4.3	7.3	8.7	10
Nitrate	mg l^{-1}	0.5	Water	<0.5	<0.5	<0.5	0.84	5.6	12	<0.5
Phosphate Low Level	mg l^{-1}	0.02	Water	0.071	0.056	0.062	0.06	0.059	0.059	0.063
Nitrogen (total)	mg l^{-1}	1	Water	15	6	7.5	4	2	4.5	2
Calcium	mg l^{-1}	5	Water	770	26	14	21	27	12	31
Magnesium	mg l^{-1}	0.5	Water	63	6.7	3.6	4.5	6.1	4.2	7.6
Sodium	mg l^{-1}	0.5	Water	16	15	10	7.8	25	11	31
Iron (II)	µg l^{-1}	20	Water	<20	300	1000	850	<20	<20	500
Iron (III)	µg l^{-1}	20	Water	640	140	<20	<20	150	210	<20
Iron (total)	µg l^{-1}	20	Water	640	440	1000	850	150	210	500

Soil samples

Parameter	Unit	Detection Limit	Sample ID	S1	S1	S2	S2	S3	S3	S4	S4
			Other ID	Below	Root	Below	Root	Below	Root	Below	Root
			Sample Date	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012	21/02/2012
Parameter	**Unit**	**Detection Limit**	**Type**								
Moisture	%	0.02	Soil	61	66	86	76.9	68.5	61.7	77.4	70.5
Stones content (>50mm)	%	0.02	Soil	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Phosphorus (available)	mg l^{-1}	10	Soil	8.1	13	4.7	8.5	10	10	5.9	8.9
Phosphorus (total)	mg kg^{-1}	-	Soil	1100	1900	2100	2200	1500	1800	1100	1300
Nitrogen (total)	%	0.02	Soil	0.72	0.78	0.09	1.2	0.96	0.8	0.39	0.97
Nitrite (extractable)	mg kg^{-1}	0.1	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate (extractable)	g l^{-1}	0	Soil	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium (total)	mg kg^{-1}	100	Soil	760	850	2200	2300	1500	1100	1800	1500
Potassium (total)	mg kg^{-1}	0.2	Soil	160	300	85	380	1100	980	170	530
Sodium (total)	mg kg^{-1}	0.2	Soil	300	400	70	300	500	530	210	430
Magnesium (total)	mg kg^{-1}	0.5	Soil	1500	2200	2300	1600	2200	2300	2100	150
Total Organic Carbon	%	0.2	Soil	6.5	7.7	24	16	12	11	18	10
Moisture content	%	-	Soil	130	486	810	363	195	468	160	431
Bulk density	Mg/m3	-	Soil	1.31	1.08	1.04	1.08	1.13	1.08	1.21	1.02
Dry density	Mg/m3	-	Soil	0.57	0.18	0.11	0.23	0.38	0.19	0.47	0.19

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ISBN: 978-1-78391-594-1

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