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Research Report No. 1106

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

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RESEARCH REPORT

Summary

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Research Report No. 1106
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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 Laird's Loch, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input.

Main findings

- The loch is a small waterbody with both mesotrophic and oligotrophic elements, contained within a small surface water catchment. It is believed to be principally fed by mineral-enriched groundwater. A dam at the western end of the loch currently controls the water levels, with water entering the site from the east and south.
- Groundwater samples taken at Laird's Loch have been compared with nutrient levels recorded in vegetation types known on site. They indicate that the vegetation currently found around the sample locations is typically consistent with the data recorded for Scotland (ER37) and is within guideline/threshold values for nutrient concentrations.
- Using the 2012 surface water sample and the SRBDD 2014 standards, the loch appears to exceed standards for Total Ammonia and also slightly exceeds JNCC guidelines for Total Nitrogen. However it is emphasised that this is from a single sample. Loch Phosphate levels appear inconsistent, with some readings within High Ecological Status and others falling short of Good Ecological Status.
- The results suggest that the loch could be receiving enriched run-off from the south and east of the loch. However, given that species such as *Littorella uniflora* has healthy populations within the loch, the water quality would seem to be good. Explanations for this could be that spring inputs into the loch are compensating for any enriched run-off contributions, or that the samples taken were not representative of typical conditions. There is no data for downstream of the loch, and the loch sample was taken immediately at the inflow point of the eastern stream, so it is possible loch conditions are much better than the 2012 data would suggest.
- From the 2012 data, it could be concluded the trophic state of Laird's Loch surface water is Eutrophic. However, other evidence (such as the TP level of 12.4 micrograms per litre

recorded in the 2004 loch survey, and the macrophytes known to be present) would suggest the trophic class is Oligotrophic to Mesotrophic. This needs to be confirmed by further sampling at a location within the loch which is away from surface water inflows.

- Assessment of vulnerability showed Laird's Loch was most at risk from agricultural practices and possibly release of stored nutrient from loch sediments.
- Further investigations are recommended for the site (such as additional water quality sampling on all inflows and within the loch itself, sediment sampling within the loch and a baseline NVC survey). 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 Laird's 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 but 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 Laird's 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 15 cm 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 – 0.02mg/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 condition 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 and is due to be published later this year. 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

Laird's Loch lies in a shallow, flat basin and is situated 6km southeast of Coupar Angus in the Sidlaw Hills (Figure 1). The 6.88ha site is important for its open water, aquatic plant communities and extensive fringing acidic mires. Figure 2 shows the site in the 1800s.

The loch is a small waterbody with both mesotrophic and oligotrophic elements. It has associated mire forming a transition between open-water and flushed meadow communities. A large number of plant species associated with these habitat types occur here.

The bed of the loch is recorded as mud and silt, lying over gravel and stones. The loch is between 1 and 2 metres deep but is deeper at its western end where it is dammed and drained by a small stream.

Laird's Loch has been used by anglers for many years, first for coarse fishing, then more recently for trout. It was once artificially stocked but is now thought to be self-sustaining. Agreement has been reached on techniques to clear pondweed from part of the loch, to prevent it snagging fish tackle, which safeguard the site's plant interest.

The catchment of the loch is dominated by commercial coniferous forestry plantations which do not appear to be having a negative impact on the loch. Well planned forestry operations will minimise the likelihood of sediment and nutrient enrichment through run-off to the loch.

An area of community woodland lies immediately adjacent to the loch in the east, with a footpath running along the northern edge of the loch. The path is heavily used by walkers and picnickers but they do not appear to be having a significant impact on the loch, other than localised litter problems.

Figure 1. Site Boundary – Laird's Loch

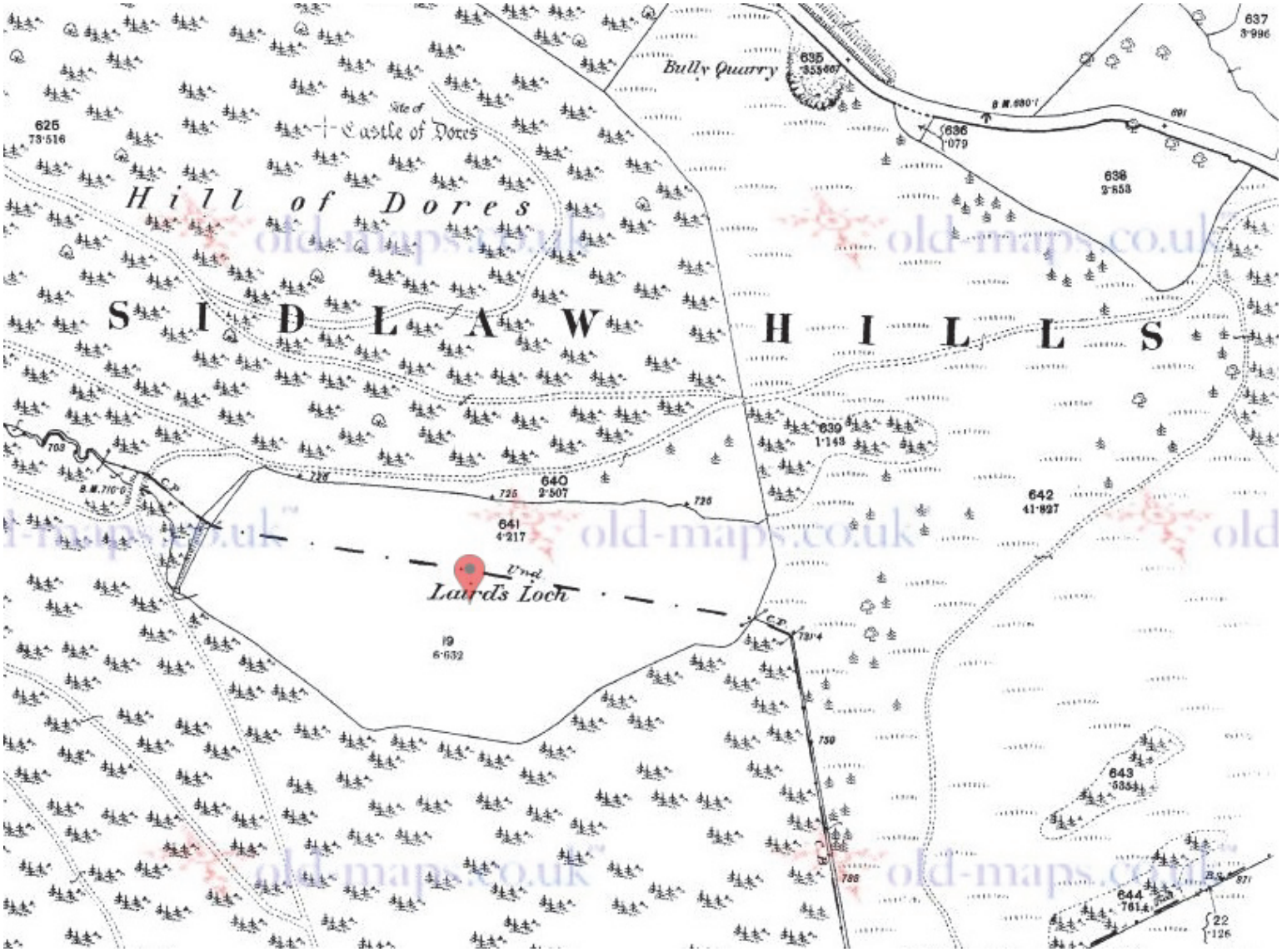

Figure 2. Ordnance Survey Six Inch 1896 map (Source: National Library of Scotland)

3.1.1 Site designation and specific targets

The site was first designated in 1984. The features for which the site is designated are detailed in Table 1, along with their associated pressures. The loch is notable for the number of pondweed species which grow in it. The mineral-rich groundwater produces sedge-rich meadow, grading into 'poor fen' on the flatter ground by the loch edge. The acidic mires are the most extensive of their type in the Sidlaw Hills.

Table 1. Laird's Loch SSSI notified features and their pressures

SSSI features	Feature Category	Summary Condition / Latest Condition	Pressure
Mesotrophic loch	Freshwater habitats	Favourable / Favourable Maintained (Jul 2003)	a)Invasive Species
Open water transition fen	Wetlands	Favourable / Favourable Maintained (Jul 2003)	No identified pressures

There are no site specific targets outlined in the Condition Management assessment, however the SNH site management objectives include:

- To maintain the SSSI as a moderately nutrient-poor loch with its associated vegetation communities.
- To control nutrient inputs, water flow and level.

3.1.2 Site hydrology

Laird's Loch has a small surface water catchment and is believed to be principally fed by mineral-enriched groundwater. There is a management agreement with SNH over the maintenance of water levels and partial pondweed clearance. A dam at the western end of the loch currently controls the water levels, with water entering the site from the east and south (Figures 3 and 4).

There is an SNH standing water sample point at Laird's Loch, however there are no sediment or water monitoring points nearby. Historic rainfall data is not available for Laird's Loch.

Laird's Loch is underlain by the Vale of Stratmore bedrock and extensive sand and gravel aquifers. In 2008, the quality of the groundwater was classified as 'Good' and the quantity as 'Poor' due to abstraction. There was also an upward trend in pollutants identified.

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.

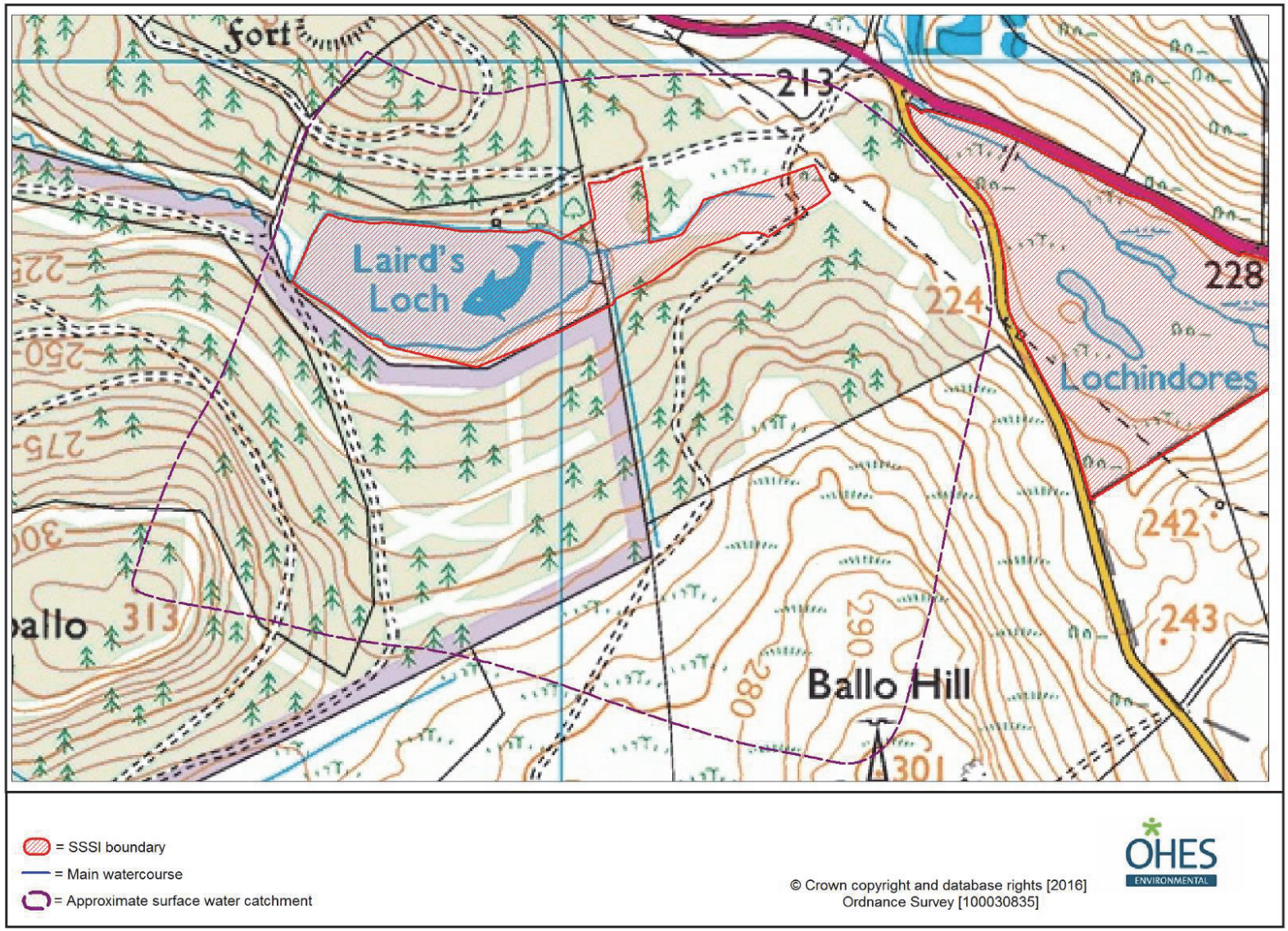

Figure 3. Laird's Loch – approximate surface water catchment

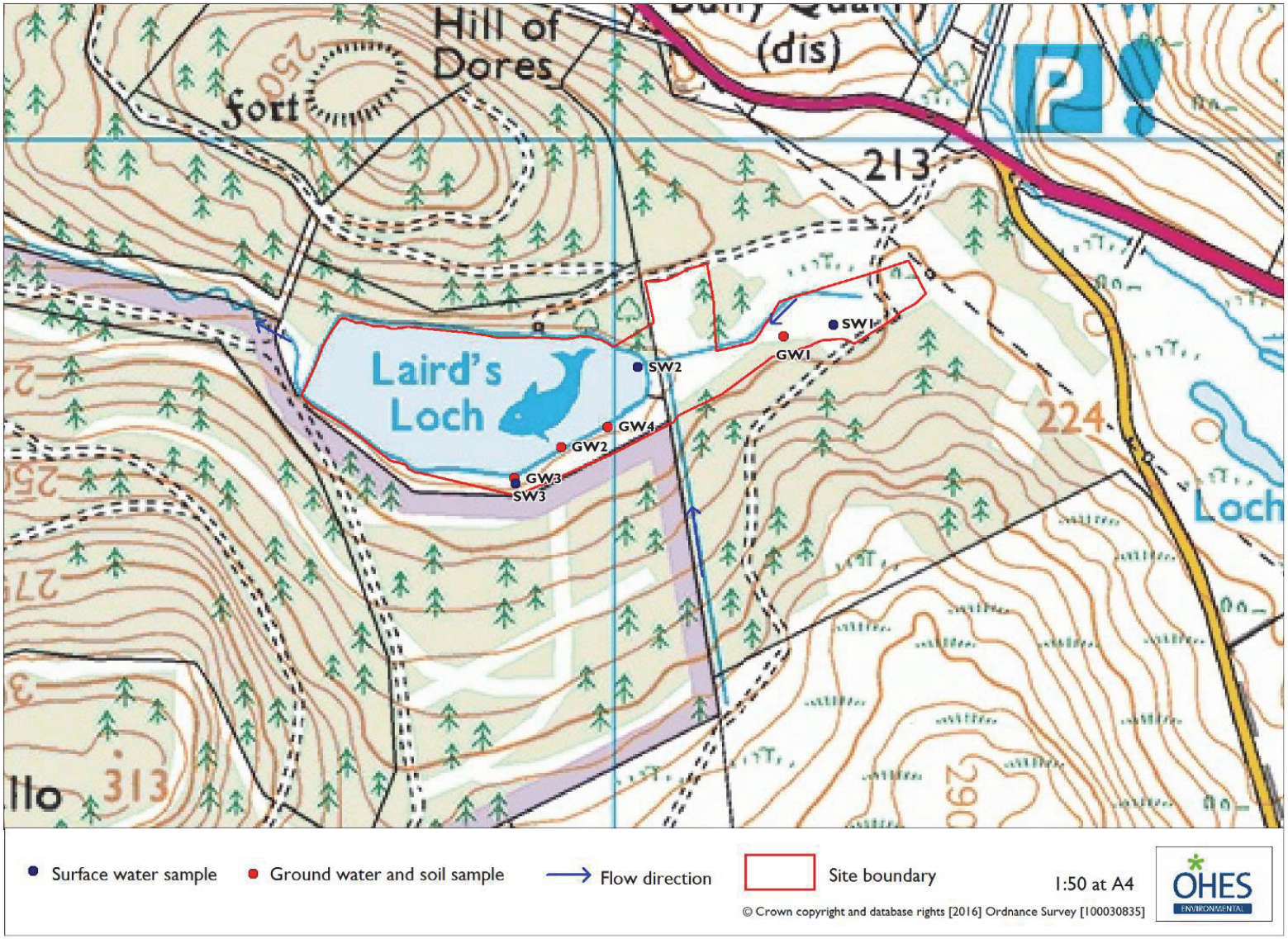

Figure 4. Laird's Loch – Hydrology and Sample Locations

One of the limitations to this study is that little data was available to define detailed hydrological functioning for this site (such as dipwell data). Similarly, little information is available on the substrates present at Laird's Loch (other than the presence of mud and silt over stones and gravels, with freedraining surrounding upland). Application of systems such as the WetMecs scheme requires detailed information on both these factors before it can be accurately applied. As a consequence, it can only be postulated that the site would be classified as either WetMec 13: Seepage Percolation Basins (groundwater-fed basins typically with a transmissive surface layer and a buoyant surface) or possibly WetMec 20: Percolation Basins (where some groundwater feed can occur but the status of the supply compared to surface water is unclear). Both of these classifications have sub-groups for "Water Fringe" situations, as appears to occur at Laird's Loch. Communities M9 mire and S27 swamps are both frequently recorded within WetMec 13 and would seem to occur here at Laird's Loch. Around the margins of the loch, there may also be either WetMec 10: Permanent Seepage Slopes (summer wet surfaces usually on sloping, shallow peat) or WetMec 11: Intermittent Seepage Slopes (as 10 but seasonal spring presence).

3.1.3 Site soils / sediments

Laird's Loch is situated over the Mountboy Association (shown in blue), which is derived mainly from Old Red Sandstone lavas and sandstone. The imperfectly drained drifts vary in texture from loam to sandy clay loam. In some areas a coarse-textured drift derived largely from Old Red Sandstone sediments overlies lava rock. The remainder of the catchment is situated over the Darleith Association (shown in brown), derived from basaltic lavas and various basic intrusive rocks. The freely drained drifts are derived from a wide range of igneous rock, resulting in a range of textures. Figure 5 shows the distribution of soil types at Laird's Loch.

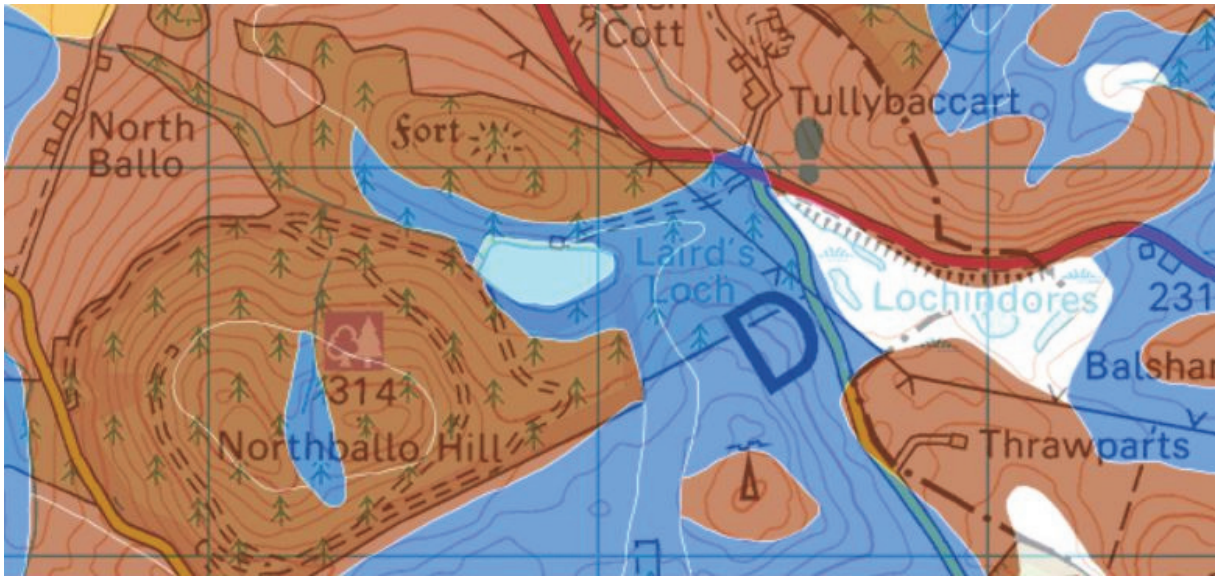

Figure 5. Laird's Loch – Soil types (source: Soil Survey of Scotland Staff, 1987).

3.1.4 Site specific issues

There are no known point sources of pollution into the loch, though it is possible some diffuse nutrient input from the agricultural land nearby may be occurring. Sediment could also become an issue if this were mobilised (for example by felling activities) and enter the loch from the surrounding land. Figure 6 shows the locations of these possible sources of nutrients.

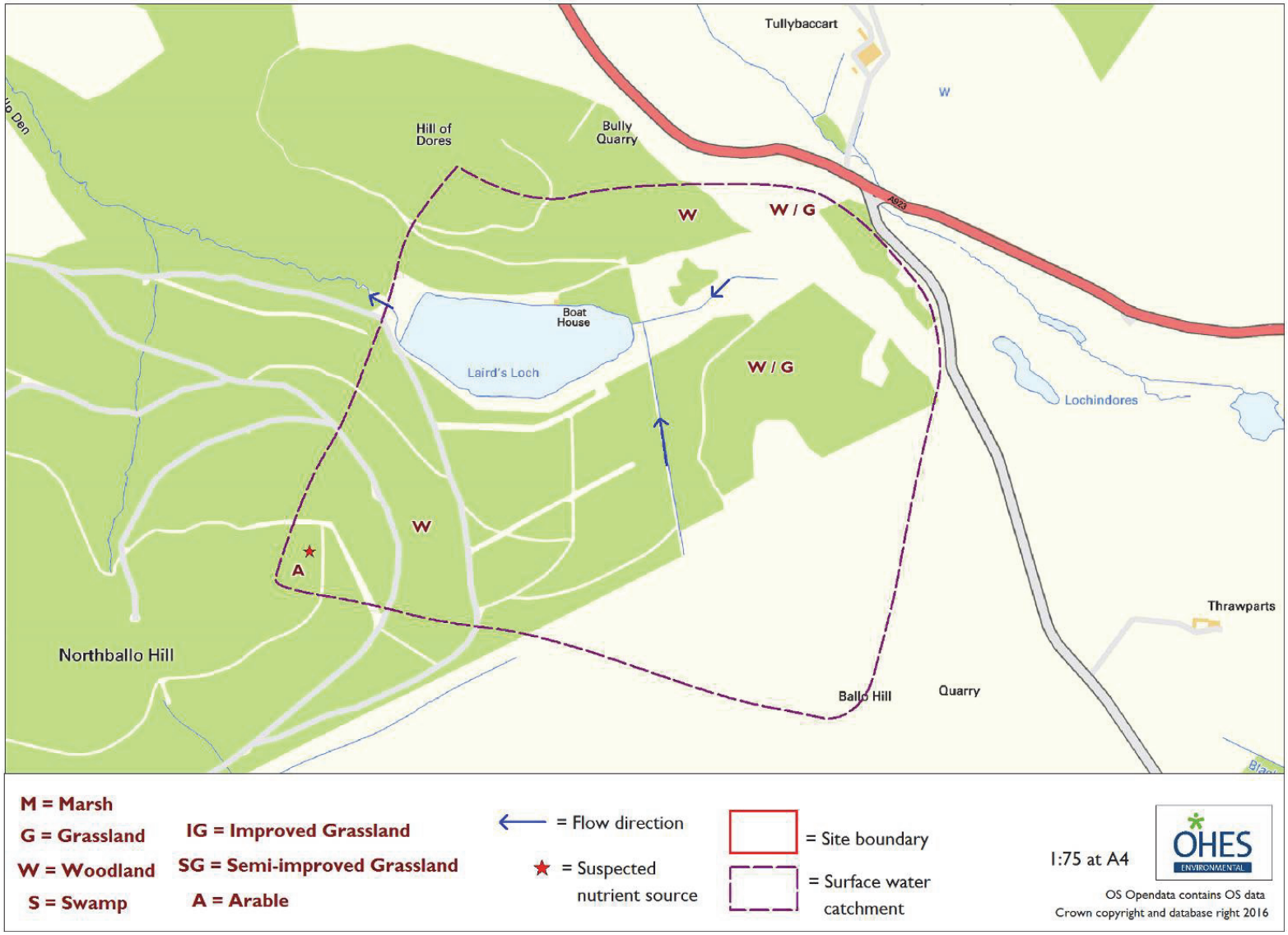

Figure 6. Land use and potential nutrient sources at Laird's Loch

3.2 Assessment of vegetation data

Laird's Loch contains a range of open water transitional fen and swamp communities. Observations on the vegetation were recorded in 1997, 2003, 2004, 2010 and 2012 however NVC communities are not available for the site.

The Site Condition Monitoring form lists many mire and swamp communities to assess the SSSI condition against, but it is not clear whether these have been observed at the site or are merely possible communities given in the absence of NVC data for the site.

The Management Statement and SCM for the site refer to sedge-rich, flushed meadow to the east of the loch, grading into poor fen by the loch edge. In similar circumstances on other basin fens this would be occupied by communities such as M9 mire, S27 tall-herb fen and S9 swamp. Furthermore, some species were recorded during the water sample collection in 2012. These records suggest that samples fall within the following communities:

- GW1 (to the east) was taken in M23 *Juncus effusus/acutiflorus – Galium palustre* rush-pasture,
- GW2 (on the southern shore and lying over "watery slop") was taken in either S27 *Carex rostrata-Potentilla palustris* tall-herb fen or M9 *Carex rostrata-Calliergon cuspidatum/giganteum* mire
- GW3 (on the southern shore and recorded with a groundwater flow) was taken in either S27 *Carex rostrata-Potentilla palustris* tall-herb fen or M9 *Carex rostrata-Calliergon cuspidatum/giganteum* mire. Note that some of the species are more reminiscent of M29 *Hypericum elodes-Potamogeton polygonifolius.*
- GW4 (on the southern shore) was taken in M5 *Carex rostrata-Sphagnum squarrosum* mire.

For the purposes of this study, samples will therefore be based on assessment against both fen and swamp wetland types, with the exception of GW1 which will be compared against wet grassland.

3.2.1 Historic evidence of community change

There is unfortunately insufficient data to quantify changes in the total coverage of wetland communities. However, some key points are summarised below:

- During the 2003, 2004 and 2010 SCM the total extent of key communities had not decreased in relation to the baseline, resulting in the site target being met.
- The 2004 and 2010 SCM found a very similar aquatic flora to that found in the 1997 survey, with the feature being assessed as Favourable, maintained.
- Some of the historically recorded *Potamogeton* species had been lost from Laird's Loch during the 2004 SCM, but the current aquatic macrophyte community was broadly similar to recent surveys and remained indicative of the site as a whole.
- The fringing acidic mires forming a transition between the open water and flushed meadow communities were still present during the 2003 Site Condition Monitoring.
- Standing water was present between the stems of over 80% of the swamp area during the 2003 Site Condition Monitoring.
- The emergent / edge communities were characteristic of oligotrophic – mesotrophic conditions and were more diverse than the open water communities with a good transition zone between the open water and adjacent mire systems during the 2004 SCM.

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). The ER37 document presents guidelines on the eco-hydrological requirements of the different Scottish wetland types as described by WWF Consulting (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 refering 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. SEPA and SNH plan to conduct further monitoring at wetlands across Scotland[3].

The wetland types potentially relevant to Laird's Loch are:

- Type 2a: Marshy grassland
- Type 3: Springs, flushes and seepages
- Type 4: Fen
- Type 5: Swamp

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 assumed to be relevant to Laird's Loch include:

- M23 *Juncus effuses/acutiflorus – Galium palustre* rush-pasture - this community has a fairly widespread distribution across Scotland and can contain considerable plant diversity. The hydrology is typically one of a high water table close to the surface for most of the year (ER37), with periodic flooding.

[3] This new data as well as any new or historic data from partners will be added to the next review of this document in 2019.

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 6mg/l N. The UK third quartile value is 5.9 mg/l N-NO_3. The SNIFFER values in groundwater for Scotland are significantly lower, with a third quartile value of 0.25 mg/l N-NO_3 (ER37).

Mean Phosphate values indicated by the UKTAG (2012) for the UK in wet grassland are 0.045mg/l for good condition and 0.024mg/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-NO_3)	0.25	0.25	0.25	Guideline: 2 (or 9 mg/l as N-NO_3) 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 evidence for M5 *Carex rostrata-Sphagnum squarrosum* mire presence has been recorded at Laird's 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 Laird's Loch are:

- M5 *Carex rostrata–Sphagnum squarrosum* mire – occurring on soft, spongy peats or as a floating raft within topogenous and soligenous sites. This community is typically supplied by mildly acidic to moderately calcareous waters, which can be oligotrophic to moderately fertile in nature. It can be found in base-poor catchments where slates and shales predominate, but is also sometimes associated with more calcareous rocks.

  In successional terms, M5 can form part of a sequence from open water through to drier mineral soils, or represent localised areas of oligotrophic conditions within stands

of S27 *Carex rostrata–Potentilla palustris* tall herb fen, M9 *Carex rostrata–Calliergon cuspidatum/giganteum* mire or swamps such as S9 *Carex rostrata* swamp (Wheeler, Shaw & Tanner, 2009). It has been observed by Wheeler, Shaw and Tanner that hydrochemical characterisation of this community is complicated by the short, vertical hydrochemical gradients which can occur as a result of thin layers of acidic peat overlying base-rich waters. The community has been found to show increases in species-richness associated with base enrichment, but decreases in the number of principal fen species where P enrichment occurs.

- M9 *Carex rostrata–Calliergon cuspidatum (Calliergonella cuspidata)/ Calliergon giganteum* mire – occurs on slopes, stream-sides, lochsides and valley bottoms/basins which are fed by oligotrophic to mesotrophic waters, typically at lower altitudes (up to 800m). The vegetation (a type of slender sedge fen) can form a soft mat of quaking or semi-floating material, with variable depths of peat/fluid underneath it. It typically occur in transition with S9 *Carex rostrata* swamp, S10 *Equisetum fluviatile* swamp and M5 *Carex rostrata-Sphagnum squarrosum* mire. No pH data available for Scotland but quoted as always >5 and usually >6 for all of its range (Rodwell, 1991).

- S27 *Carex rostrata-Potentilla palustris* tall-herb fen - occurring in wet valley bottom/basin locations, where strongly sub-surface water levels are outside of normal conditions for the community. 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, Shaw & Tanner, 2009).

ER37 data and thresholds for Fens are presented in Table 3. Under the UKTAG report (2012 & 2014), 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 3rd 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 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 0.20mg/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 = 2.04 (or 9 mg/l as NO_3) Olig = 0.91 (or 4 mg/l as NO_3)

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.

Several swamp communities may exist at Laird's Loch, such as S9 *Carex rostrata* swamp and S12 *Typha latifolia* swamp. In the absence of NVC data, the exact communities' presence cannot be confirmed.

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**	**Indicator**
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 NO_3) Olig = 4.1 (or 18mg/l as NO_3)

3.3 Assessment of ground water samples

Groundwater samples taken at Laird's Loch have been compared with the levels recorded in vegetation types as shown in section 3.2. Groundwater standards were used as opposed to surface water standards for several reasons; firstly that almost all wetlands will have a component of groundwater influence, secondly that groundwater standards can often be more demanding than surface water standards 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 5 indicates that the vegetation currently found around the sample locations is typically consistent with the data recorded for Scotland (ER37) and is within guideline/threshold values for nutrient concentrations. GW1 showed high Calcium and Magnesium content, reflecting the mineral-rich flushing by groundwater which is known to occur in the east. GW4 also showed high Total Nitrogen levels.

Table 5. Groundwater samples at Laird's Loch compared to Wetland Type for Scotland. Red text denotes sample exceeds 3rd quartile or guidelines/thresholds.

	Laird's Loch	Marshy grassland			Laird's Loch	Swamp		
Sample	**GW1 (in M23)**	**1st Quartile**	**3rd Quartile**	**Indicator**	**GW2 (nr S9?)**	**1st Quartile**	**3rd Quartile**	**Indicator**
pH (-)		6.3	7.1	5 to 8		5.7	7.1	
Dissolved Oxygen (%)		32	40			15	36	
Conductivity (mS/cm)		0.093	0.18			0.24	0.43	
Calcium (mg/l)	57	8	24		5.5	10	44	
Magnesium (mg/l)	11	2.5	8.7		3.1	3.6	16	
Sodium (mg/l)	3.6	6.2	12		7	5.5	18	
Phosphate (mg/l)	0.06	0.041	0.065	0.065 (indicator)	0.058	0.024	0.1	None set
Nitrogen (total) (mg/l)	1	2.5	7		3	2	7	
Nitrate (mg/l N-NO_3)	<0.5	0.25	0.25	Guideline: 2 (or 9 mg/l as N-NO_3) for >175 m AOD	<0.5	0.25	0.25	Guideline: Meso = 5 (or 22 mg/l as NO_3) Olig = 4.1 (or 18 mg/l as NO_3)

Table 5 continued. Groundwater samples at Laird's Loch compared to Wetland Type for Scotland. Red text denotes sample exceeds 3rd quartile or guidelines/thresholds.

	Laird's Loch	Laird's Loch	Laird's Loch	Fen		
Sample	**GW2 (in M9/S27)**	**GW3 (in M9/S27)**	**GW4 (in M5)**	**1st Quartile**	**3rd Quartile**	**Indicator**
pH (-)				6.4	7.4	
Dissolved Oxygen (%)				18	28	
Conductivity (mS/cm)				0.37	0.69	
Calcium (mg/l)	5.5	17	18	12	55	
Magnesium (mg/l)	3.1	6.6	5.9	3.4	14	
Sodium (mg/l)	7	13	9.3	5.4	14	
Phosphate (mg/l)	0.058	0.057	0.06	0.064	0.1	None set
Nitrogen (total) (mg/l)	3	3	11	1	5.1	
Nitrate (mg/l N-NO_3)	<0.5	<0.5	<0.5	0.25	0.25	Threshold: >175 m Meso = 2.04 (or 9 mg/l as NO_3) Olig = 0.91 (or 4 mg/l as NO_3)

3.4 Assessment of ground 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 standards) are referred to in some circumstances but it should be noted that, where they exist, the SRBDD standards are more stringent than CSM standards 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), Laird's Loch is classified as very shallow (<3m depth), freshwater, salmonid, high altitude (220mAOD) lake of medium alkalinity (10 to 50mg/l) and >50% siliceous and ≤90% siliceous bedrock. This equates to Ecotype 14 (Small temperate lake, with a catchment geology of rock and a conductivity between 100 – 800uScm) within the ECOFRAME document (Moss, 2003). Table 6 presents the SRBDD standards compared to those recorded from Laird's Loch, but owing to the fluid nature of the research and advice, represent a starting point.

Table 6. Water Quality standards for Laird's Loch

Variable	SRBDD (2014)		JNCC	ECOFRAME		Laird's Loch
	GES	HES		Good	High	SW2
Total Ammonia as N	0.3 mg/l	0.2 mg/l	-	-	-	3.4 mg/l (Ammonium only)
Total Nitrogen	-	-	<1.5 mg/l	0.6 – 1.0 mg/l	<0.6 mg/l	2 mg/l
Acid Neutralising Capacity	>20 µeq/l	>40 µeq/l	>40 µeq/l	-	-	?
Dissolved oxygen	7 mg/l	9 mg/l	As WFD	-	-	?
Salinity/Conductivity	<1000 µScm		-	100 – 800 µScm		?
Total Phosphorus	22 µg/l	15 µg/l	35 µg/l	30-50 µg/l	<30 µg/l	12 to 60 µg/l (Phosphate only)
pH	-	-	7 - 9	6 - 9		?

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: surface water close to the main input channel (SW1), the surface water of the loch near the input channel (SW2) and surface water immediately adjacent to the loch (SW3), see Appendix 1 for raw data.

Figure 7 shows the results of Ammonium recorded at Laird's Loch against SRBDD standards for Total Ammonia. The results indicate that at the time of survey, the loch was above SRBDD concentrations at all three sample points, with water quality in the loch being better than at the upstream sampling point. The water quality of the outflow from the loch was not taken during the sampling.

The Total Nitrogen levels (as shown in Figure 8) indicate that other forms of Nitrogen may be less problematic, with TN recorded in the loch at only slightly higher levels than JNCC standards.

Total Phosphorus levels were recorded at Laird's Loch but the levels of determination were below those useful in assessment against standards (i.e. all samples were marked as <0.2mg/l). Instead, Phosphate low levels were recorded between Moderate Ecological Status (MES) and Poor Ecological Status (PES) (Figure 9). Given that these values do not take into account the full Phosphorus concentration it can therefore be assumed that TP levels exceed SRBDD standards.

The results suggest that the loch could be receiving enriched run-off from the south and east of the loch. However, given that species such as *Littorella uniflora* (a species typical of oligotrophic waters) has healthy populations within the loch, the water quality would seem to be good. Explanations for this could be that spring inputs into the loch are compensating for any enriched run-off contributions, or that the samples taken were not representative of typical conditions. There is no data for downstream of the loch, and the loch sample was taken immediately at the inflow point of the eastern stream, so it is possible loch conditions are much better than SW2 would suggest. This however cannot be confirmed without further sampling.

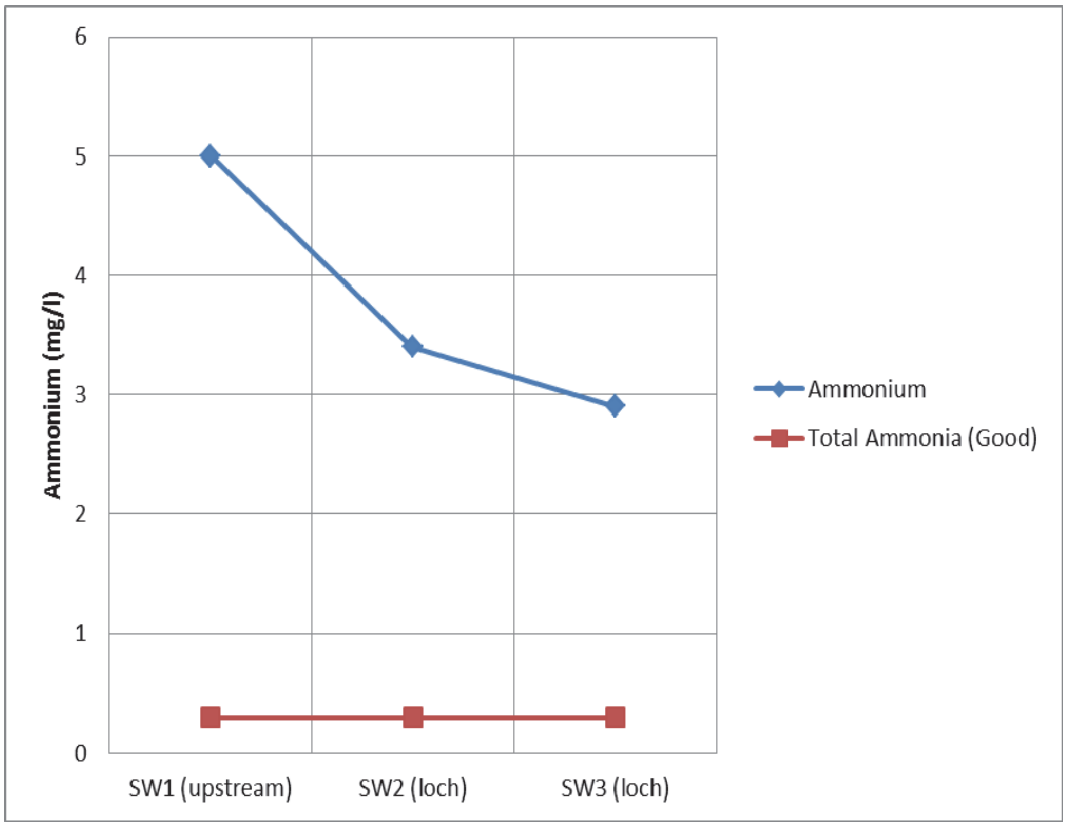

Figure 7. Ammonium recording at Laird's Loch (blue line) against SRBDD standards for Total Ammonia

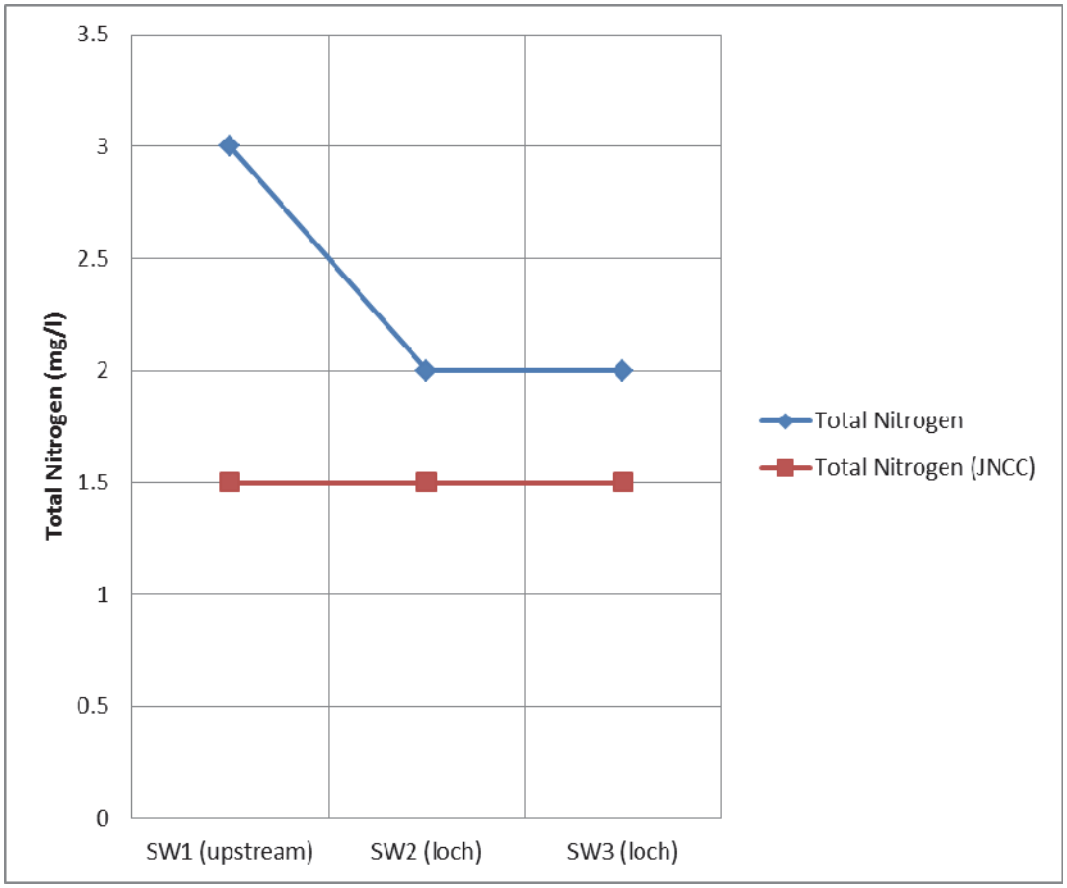

Figure 8. Total Nitrogen recording at Laird's Loch (blue line) against JNCC standards

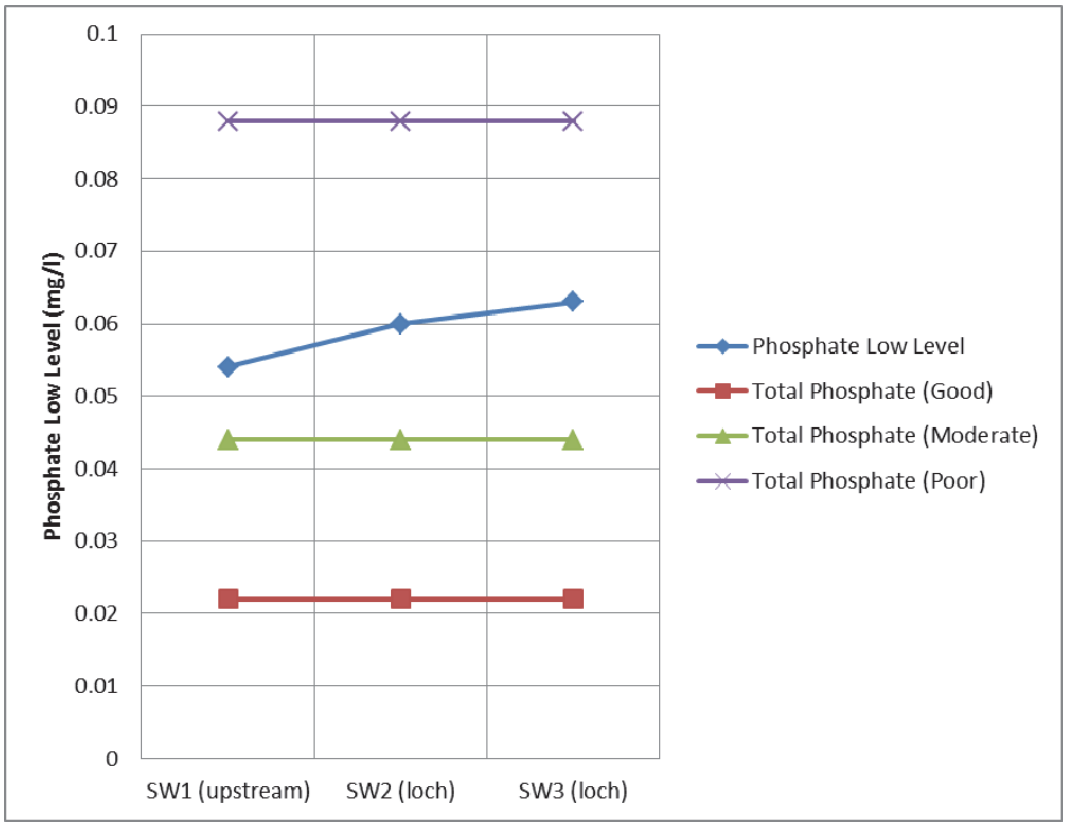

Figure 9. Total Phosphorus/Phosphate recording at Laird's Loch (blue line) against SRBDD standards

3.4.3 Summary of trophic state and site vulnerability

Trophic state:

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 characterized 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 7.

Table 7. Nutrient status classification scheme (SEPA).

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

From the 2012 data, both Nitrogen and Phosphorus levels are significantly above targets for GES, so that it could be concluded the trophic state of Laird's Loch surface water is Eutrophic. However, other evidence (such as the TP level of 12.4 micrograms per litre recorded in the 2004 loch survey, and the macrophytes known to be present) would suggest the trophic class is Oligotrophic to Mesotrophic. This needs to be confirmed by further sampling at a location within the loch which is away from surface water inflows.

An assessment of vulnerability of the site to enrichment is given in Table 8 below.

Table 8. Assessment of the vulnerability of Laird's Loch to eutrophication from catchment sources, and their relative importance. Negative factors are shown in black, positive factors in blue.

Source	Laird's Loch	
	Vulnerability	**Details of Factors**
EXTERNAL SOURCES		
1. Agriculture	Moderate	- The southern side of the surface water catchment contains improved grassland which, through existing drainage channels, will enable fertiliser and nutrients to enter the loch. - Forestry operations may result in the mobilisation of nutrient rich silt (fertilisers) and has the potential to enter the loch from the catchment. - There is potential for run-off from the A923 to enter the loch via a ditch from the east.
2. Human population	Low	- No residential properties are present in the catchment.
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	- The site is groundwater fed and therefore the regional groundwater contributes significantly to the water balance within the catchment. - The regional groundwater was recently classified as 'Good' quality.
INTERNAL SOURCES		
1. Wildlife	Low	- Large numbers of bird species may be present 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. - 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 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 reserve will continue to build up.
1. Site Management	Low	- It is unclear how much of the mire and tall-herb communities are currently being grazed or mown, but the absence of such management will inevitably lead to a build-up of plant litter and add to the nutrient store within the site.

3.5 Assessment of soil samples

Soil chemistry was sampled at four locations within Laird's Loch (one was in M23 rush-pasture, two were in M9/S27 mire and one was in M5 mire). 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 9 presents the soil chemistry data for Laird's Loch samples against the ER37 data. The results show that for marshy grassland, levels of nutrients at Laird's Loch are all within the inter-quartile range observed in Scottish samples.

Calcium was particularly low across all samples and depths. Phosphate exceeded the 3rd quartile for Scottish samples within the fen samples (at below root depths, coinciding with high organic matter content) but, at the root layer, was often recorded at very low levels within the fen communities. Similarly, Total Nitrogen and Nitrate were recorded at low levels within the root layer (and often at depth also) across all samples. This would suggest the fen and marshy grassland communities are likely to be in good condition and are not exposed to excessive enrichment.

Soil sample 1 (GW1) was taken within M23 rush-pasture, with a thin layer of silty soil overlying rock and sandy soil. Soil moisture was recorded at its lowest here, with the water level at 15 cm below ground level.

Soil samples 2, 3 and 4 were recorded around the edge of the loch, with all three showing a fibrous rootmat at the surface, underlain by watery slop in samples 2 and 3, and humus rich silt in sample 4. All three samples showed combinations of silts, sands and clay. Water levels varied from at surface level to 15cm below ground level.

Table 9. Soil samples at Laird's Loch and soil chemistry recorded by Wetland Type in Scotland (ER37).

	Laird's Loch		Marshy grassland		Laird's Loch		Laird's Loch		Laird's Loch		Fen	
Sample	**Soil 1 Root (in M23)**	**Soil 1 below (in M23)**	**1st Quartile**	**3rd Quartile**	**Soil 2 Root (in M9/S27)**	**Soil 2 below (in M9/S27)**	**Soil 3 Root (in M9/S27)**	**Soil 3 below (in M9/S27)**	**Soil 4 Root (in M5)**	**Soil 4 below (in M5)**	**1st Quartile**	**3rd Quartile**
Calcium (mg/kg)	<100	<100	160	4200	<100	<100	<100	<100	<100	<100	960	12,000
Magnesium (mg/kg)	900	1100	1100	2700	430	2300	370	1000	1100	1600	1,500	3,800
Sodium (mg/kg)	95	35	43	200	35	30	75	20	60	30	74	280
Phosphate (available) (mg/l)	<2.0	<2.0	3.4	9.5	2.5	11	3.4	15	<2.0	9.7	2.7	9.5
Nitrogen (total) (%)	0.08	0.46	0.05	0.78	0.07	0.83	0.31	0.27	0.09	1.2	0.25	1.4
Nitrogen (extractable) (mg/kg)	<0.1	<0.1	0.35	0.93	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	1.4
Total organic carbon (%)	0.8	6.6	2.1	20	0.58	25	3.2	25	0.93	35	3.7	12
Potassium (total)	170	140	-	-	95	450	300	150	200	260	-	-
Soil Moisture Content %	46	153	-	-	44	1005	31	1149	87	1946	-	-

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.
- NVC data was not available; therefore categorisation of vegetation types for the groundwater and soil samples could only be based on field notes and other documents on the vegetation.
- 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, or the outflow of the loch. Therefore it cannot be determined which is the main contributor of nutrients into the Loch.
- Analysis of the samples could only be conducted by eye as there was insufficient data for any statistical analysis.

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 each site.

The initial assessment of Laird's Loch, based on a single sampling round, suggests some enriched water may be present within the SSSI, although other data (such as the site condition monitoring) suggests water quality is still good. The soil sample analysis generally indicates nutrient levels remain low over the fen and marshy grassland communities. However, further confirmation that the SSSI is not under threat of enrichment would need to be obtained by the following measures:

- Additional surface water sampling within all inflows, within the loch itself (away from the inflows) and the outflow channel to ascertain the source of any enriched water and whether it is affecting the ability of the loch to meet SRBDD standards. At least one

spring source should also be analysed if possible, to gauge whether regional groundwater is a contributing factor.
- Two sediment samples within the loch (i.e. eastern and western ends) to identify possible internal store of nutrients, as well as the average depth of sediment present.
- A baseline NVC survey so that direct comparisons of future conditions can be made, as well as remedial measures tailored to the full suite of vegetation communities currently present.

Once this data has been gathered and analysed it will be possible to assess if any remedial measures are required. Such measures could include:

- ***Reducing nutrient input*** - This is the most effective means of addressing eutrophication of the site. The primary risk of nutrient export would appear to be from farmland to the south. 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.

- ***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 Laird's Loch. However, without management, it is possible that the ability of the swamp to remove nutrients will have diminished.

  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.

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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	3.3	3.3	2.8	2.1	5	3.4	2.9
Nitrate	mg l^{-1}	0.5	Water	<0.5	<0.5	<0.5	<0.5	4.8	<0.5	0.78
Phosphate Low Level	mg l^{-1}	0.02	Water	0.06	0.058	0.057	0.06	0.054	0.06	0.063
Nitrogen (total)	mg l^{-1}	1	Water	1	3	3	11	3	2	2
Calcium	mg l^{-1}	5	Water	57	5.5	17	18	3.6	7.9	8
Magnesium	mg l^{-1}	0.5	Water	11	3.1	6.6	5.9	1.7	3.5	3.5
Sodium	mg l^{-1}	0.5	Water	3.6	7	13	9.3	6.5	8.6	7.6
Iron (II)	µg l^{-1}	20	Water	100	60	200	150	<20	<20	20
Iron (III)	µg l^{-1}	20	Water	310	110	540	400	74	220	360
Iron (total)	µg l^{-1}	20	Water	410	170	740	550	74	220	380

Soil samples

			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	25.5	66.2	22.4	92	57.3	91.9	29.8	92.7
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	<2.0	<2.0	2.5	11	3.4	15	<2.0	9.7
Phosphorus (total)	mg kg^{-1}	-	Soil	1300	1200	1500	1700	1900	1500	1100	1200
Nitrogen (total)	%	0.02	Soil	0.08	0.46	0.07	0.83	0.31	0.27	0.09	1.2
Nitrite (extractable)	mg kg^{-1}	0.1	Soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<.10	<0.1
Nitrate (exctractable)	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	<100	<100	<100	<100	<100	<100	<100	<100
Potassium (total)	mg kg^{-1}	0.2	Soil	170	140	95	450	300	150	200	260
Sodium (total)	mg kg^{-1}	0.2	Soil	95	35	35	30	75	20	60	30
Magnesium (total)	mg kg^{-1}	0.5	Soil	900	1100	430	2300	370	1000	1100	1600
Total Organic Carbon	%	0.2	Soil	0.8	6.6	0.58	25	3.2	25	0.93	35
Moisture content	%	-	Soil	46	153	44	1005	31	1149	87	1946
Bulk density	Mg/m3	-	Soil	1.71	1.21	1.68	0.92	1.8	0.98	1.41	0.88
Dry density	Mg/m3	-	Soil	1.17	0.48	1.16	0.08	1.37	0.08	0.76	0.04

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