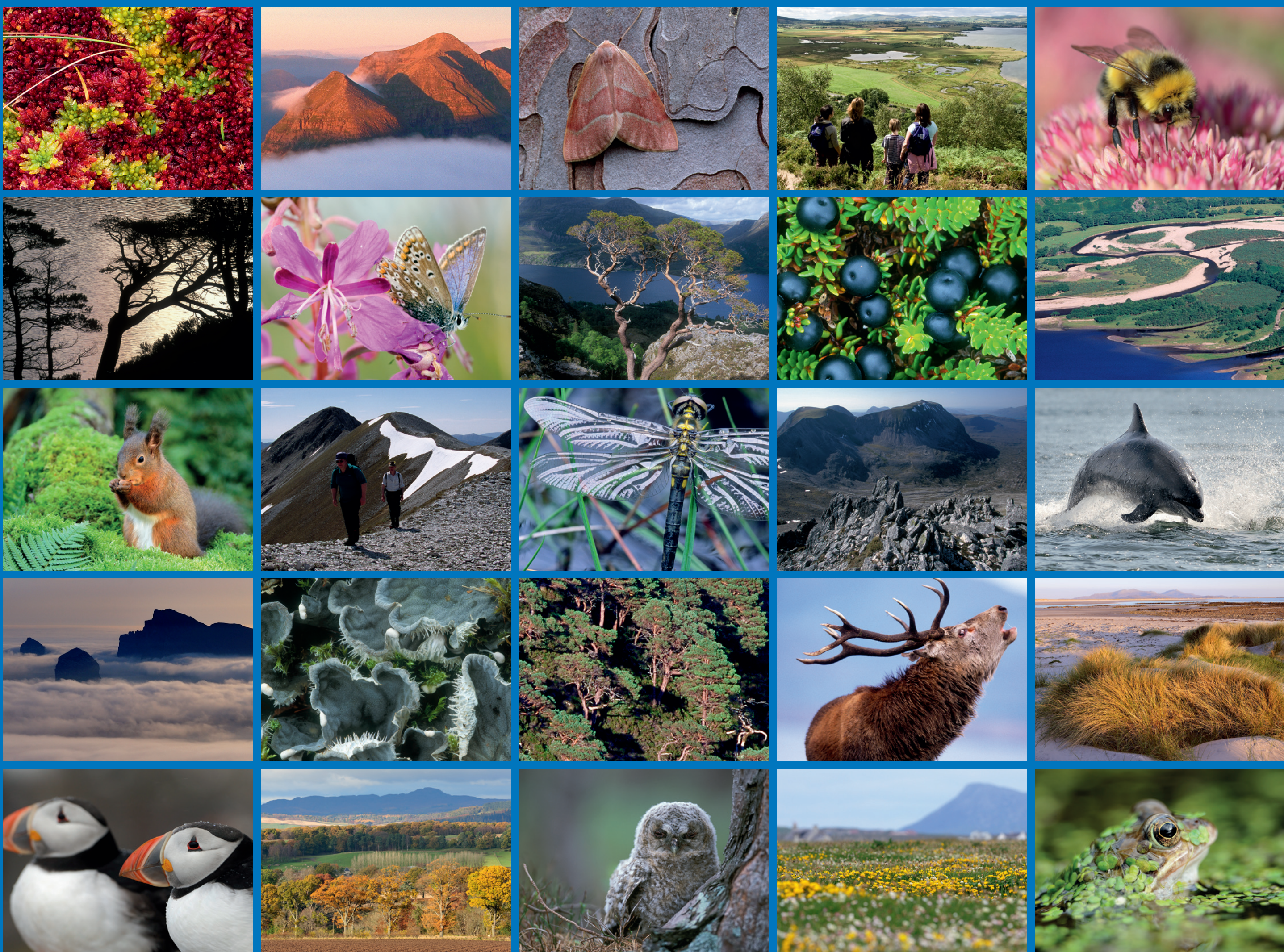
Scottish Natural Heritage
Research Report No. 1110

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



Scottish Natural Heritage
Dualchas Nàdair na h-Alba
nature.scot

RESEARCH REPORT

Research Report No. 1110

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

For further information on this report please contact:

Deborah Spray
Scottish Natural Heritage
Strathallan Business Park
STIRLING
FK9 4TZ
Telephone: 01786 450362
E-mail: deborah.spray@nature.scot

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 – Torrs Moss SSSI. *Scottish Natural Heritage Research Report No. 1110.*

RESEARCH REPORT
Summary

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

Research Report No. 1110
Contractor: OHES Environmental Ltd
Year of publication: 2019

Keywords

nutrients; Torrs Moss 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 Torrs Moss, in order to assess the trophic status of the designated wetland and identify any likely sources of nutrient input.

Main findings

- Torrs Moss is one of a series of former lochs (now terrestrialised) surrounded by agricultural land. It remains one of the best examples in the District of intact basin fen, containing a rich mosaic of swamp, fen, raised mire, rush pasture and willow carr. It also contains a form of S24 *Phragmites australis-Peucedanum palustre* tall-herb fen, which is normally only recorded from Broadland.
- The site receives inflows from a number of spring issues, which pass through intensively farmed land before entering the site. However, some of the communities present indicate at least part of the Moss relies on rainwater to maintain raised mire conditions. A layer of sloppy peat beneath the surface was also recorded across much of the site, which suggests some sub-surface lateral water flow across the Moss.
- Groundwater samples taken at Torrs Moss have been compared with the nutrient level requirements of the vegetation types known on site. This indicates that the groundwater quality is reasonably consistent with the type of vegetation currently found around the sample locations, (ER37). The exception is Phosphate levels within parts of the Reedbed (GW4) and Total Nitrogen levels within the fen (GW2 & GW3), both of which exceed the Upper quartile range recorded for these wetland types in Scotland.
- Water chemistry data from one of the northern inflows indicates that the surface waters are bringing in significantly higher levels of Phosphorus and Nitrogen than is present in the groundwater. By the time water beings to exit the site (at SW2), the less enriched groundwater and/or rainwater has begun to dilute the surface water enrichment. Even further downstream, at SW1, Nitrate and Nitrogen concentrations continue to decline.
- No surface water data was available for the major inflows from the south. However, Phosphate concentrations are notably higher in the groundwater nearest to these

southern inflow channels (GW4). GW4 showed a layer of "very sloppy peat" between 70 to 120 cm below ground level, which could indicate sub-surface movement of water from upland areas is infiltrating this part of the Moss.

- Surface water results were compared to SNIFFER data (ER37 report) for the various vegetation communities at Torrs Moss. It showed that the surface water sources within the site are consistently higher in Nitrogen and Phosphate than the upper quartile range observed for reedbeds and fens across Scotland. However, it is probable that the raised mire communities in the centre of the site are at least partially protected from enriched waters by the greater contribution rainwater will make to these floating areas.
- Assessment of vulnerability showed Torrs Moss was most at high risk from agricultural practices and potentially some residential properties.
- Soil chemistry results showed that in the north of the site, Phosphorus and Total Nitrogen levels were high within the root zone and below the roots. The soil sample taken in the centre of the site (within the area of M9 mire) recorded Total Phosphorus levels notably lower than in the other parts of the site (both in the root zone and below it). This would suggest sub-surface and surface enriched waters are not reaching this part of the site (at least at the time of sampling). Sample 4, taken towards the south of the site, again showed high concentrations of Phosphorus within the root zone.
- Further investigations are recommended for the site (such as an NVC survey, water quality sampling on all inflows and outflows and seasonal water level recording). A range of remedial options are proposed for consideration, once additional data has been gathered.

For further information on this project contact:
Deborah Spray, Scottish Natural Heritage, Strathallan Business Park, Stirling, FK9 4TZ.
Tel: 01786 450362 or deborah.spray@nature.scot
For further information on the SNH Research & Technical Support Programme contact:
Research Coordinator, Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness, IV3 8NW.
Tel: 01463 725000 or research@nature.scot

Table of Contents **Page**

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 Torrs Moss 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 Torrs Moss.

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 45-60 cm 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 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

Torrs Moss is located 1km south-east of Castle Douglas and lies in a depression surrounded by undulating drumlin knolls. The 14.59 ha site forms part of a series of basins which were all once small lochs, many of which have been partially degraded by drainage and scrub colonisation (Figure 1). Torrs Moss remains one of the best examples in the Stewartry District of an intact basin fen with a rich mosaic of vascular plant communities. There is a remaining central fen area that is dominated by reed, with some scrub removal undertaken in 1993.

The 1853 OS map shows extensive drainage to surrounding land (Figure 2) and a description of 'Torrs Loch'. Torrs Moss has been positively managed under a series of SNH management agreements to enhance the open reed and fen habitats. One hectare of the SSSI is under an SNH management agreement. A further 13.78 ha of the SSSI is currently managed under a Rural Development Contract under which the water table is maintained via a sluice, with light cattle grazing taking place during mid-summer.

Limited burning of reed takes place and willow and birch scrub is removed from within the fen. The site is part of a game shooting enterprise with pheasants in two pens on the site. Foxes, mink and crows are controlled.

3.1.1 Site designation and scientific targets

Torrs Moss was notified in 1992. The features for which it is notified and their pressures are detailed in Table 1. A mosaic of tall fen communities has developed, with open reed and fen communities in the north and central parts, whilst elsewhere willow carr is dominant. There are nationally rare vegetation communities on site, which are otherwise only found in the Borders, Anglesey and Norfolk. The *Phragmites-Sphagnum* community, normally only recorded from Broadland fens, has formed a floating raft of vegetation, which thus avoids base-rich ground water and instead is supplied with nutrients mainly by rainfall.

Table 1. Torrs Moss SSSI notified features and their associated pressures.

SSSI features	Feature Category	Summary Condition / Latest Condition	Pressure
Basin fen	Wetland	Unfavourable Declining (Jun 2015)	a) Invasive species b) No proactive management c) Water quality

Site specific targets outlined in the Site Condition Monitoring reports and the SNH management objectives include:

1. No loss of NVC M9 and S24 against the baseline.
2. To maintain the extent of the open reed and fen habitats and prevent succession to woodland by grazing, burning and scrub control.
3. To retain the current range of habitats and species by maintaining high seasonally fluctuating water levels.
4. To retain the current range of habitats and species by maintaining the water quality and avoiding nutrient enrichment from agricultural land.

Figure 1. Site Boundary – Torrs Moss

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

3.1.2 Site hydrology

Torrs Moss has a small surface water catchment and is thought to be kept moist by springs. The site is separated from arable land in the west by a deep ditch, which acts as the main flow round the site and is cleared every 5 years or so. This ditch runs west to east across the northern part of the SSSI, linking up with issues to the north. At the head of the system in the south, major inflows are recorded from Corra and from spring water passing under the road. The ditch around the eastern perimeter of the site is noted as having no apparent flow.

The site also relies on precipitation (to an unknown extent) within its water balance. Water is held back by a sluice located in the far north of the SSSI.

There are no SEPA monitoring points at or in the vicinity of Torrs Moss SSSI. Torrs Moss is underlain by the Castle Douglas bedrock and localised sand and gravel aquifers. In 2008 the quality and quantity of groundwater was classified as 'Good' with no trends in pollutant identified. There is no historic rainfall data available for Torrs Moss.

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

One of the limitations to this study is that little data was available to define detailed hydrological functioning for this site. Similarly, little information is available on the substrates present at Torrs Moss (other than the presence of a firm layer of peat overlying varying degrees of unconsolidated and sloppy peat). 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 WetMec 13: Seepage Percolation Basins (groundwater-fed basins and sumps containing quaking and buoyant surfaces). WetMec 13 is known to contain communities such as S24 *Phragmites-Peucedanum* tall-herb fen (though its occurrence in floodplains is much more common). Reference is also made within the Site Environmental Audit to "raised mire" (such as M4 *Carex rostrata-Sphagnum recurvum* or M5 *Carex rostrata-Sphagnum squarrosum* mire, recorded on the site within the SNH site files). This could mark out areas of WetMec 3: Buoyant Weakly Minerotrophic Surfaces (Transitional bogs), where the quaking raft of vegetation is a little above the influence of groundwater so that precipitation probably represents a significant component of the budget (Wheeler, Shaw and Tanner, 2009).

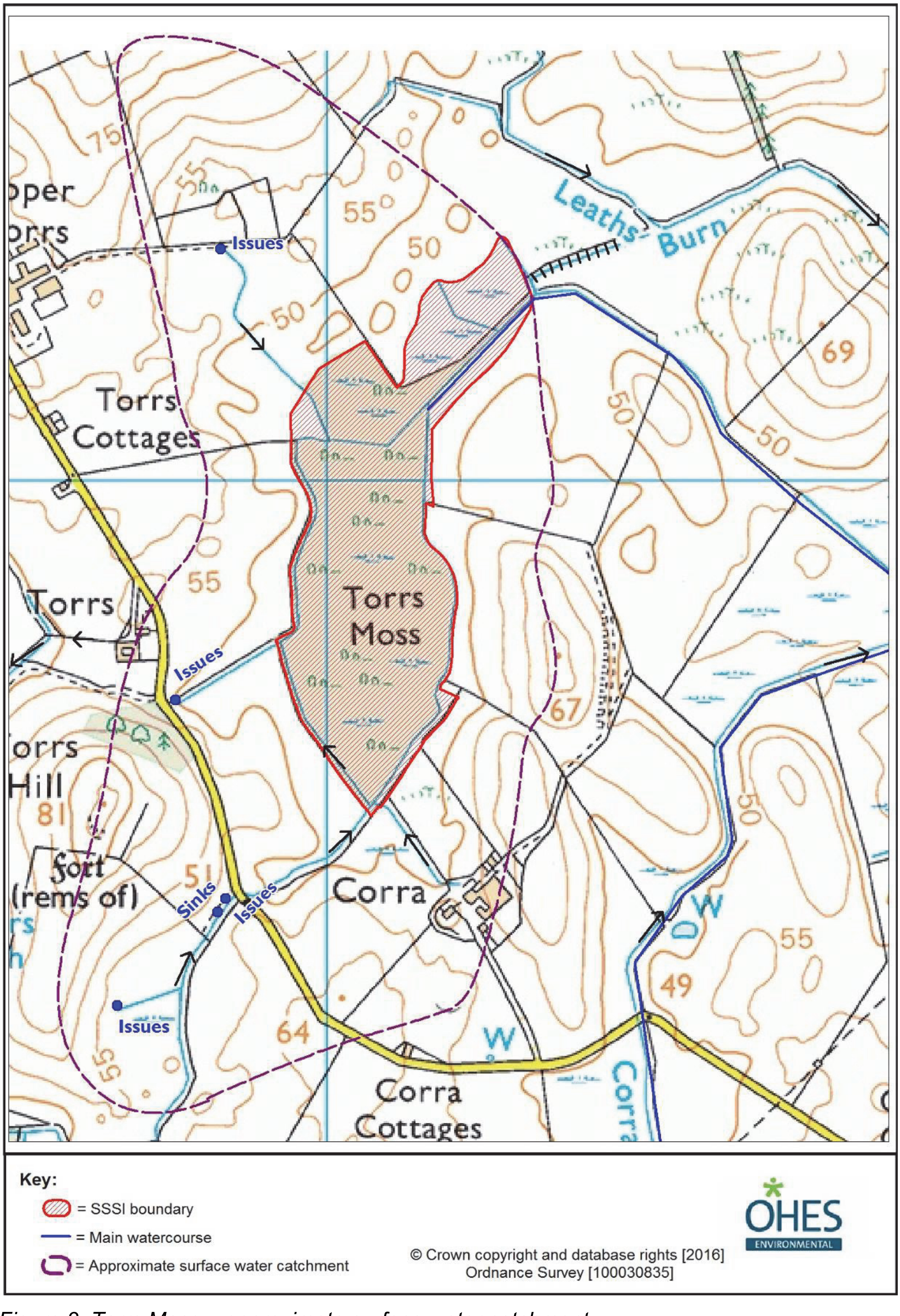


Figure 3. Torrs Moss – approximate surface water catchment

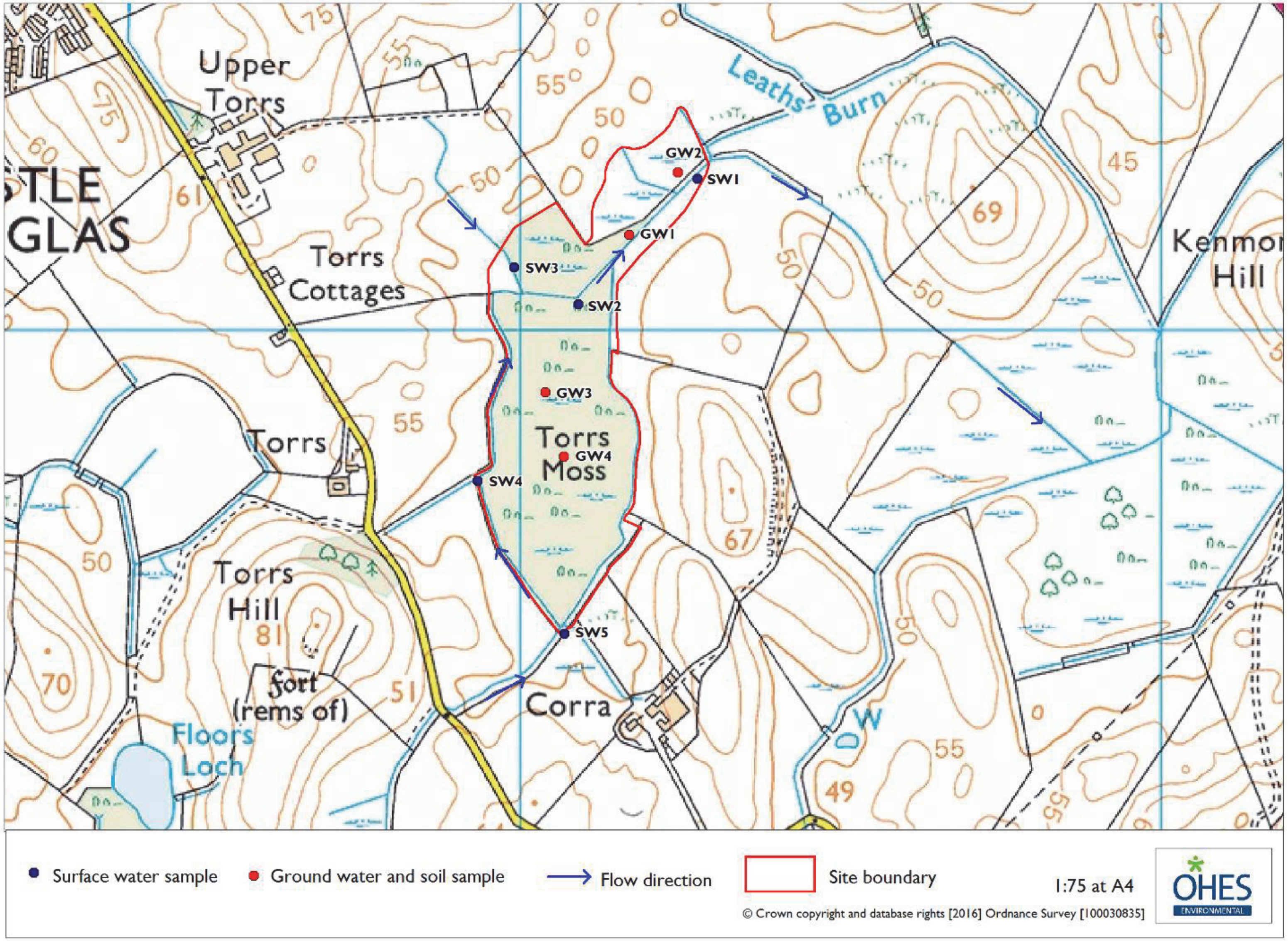


Figure 4. Torrs Moss – Hydrology and Sample Locations

3.1.3 Site soils / sediments

Torrs Moss is underlain by the Rhins Association, which are developed on red-brown clayey tills containing Ordovician and Silurian greywacke stones. Partial water sorting has given rise to sandy loam textures in the upper layers of some tills and some soils developed on thin, stoney red-brown sandy loam drifts are also included.

Deep peat underlies the site which is kept permanently moist by moderately base-rich water.

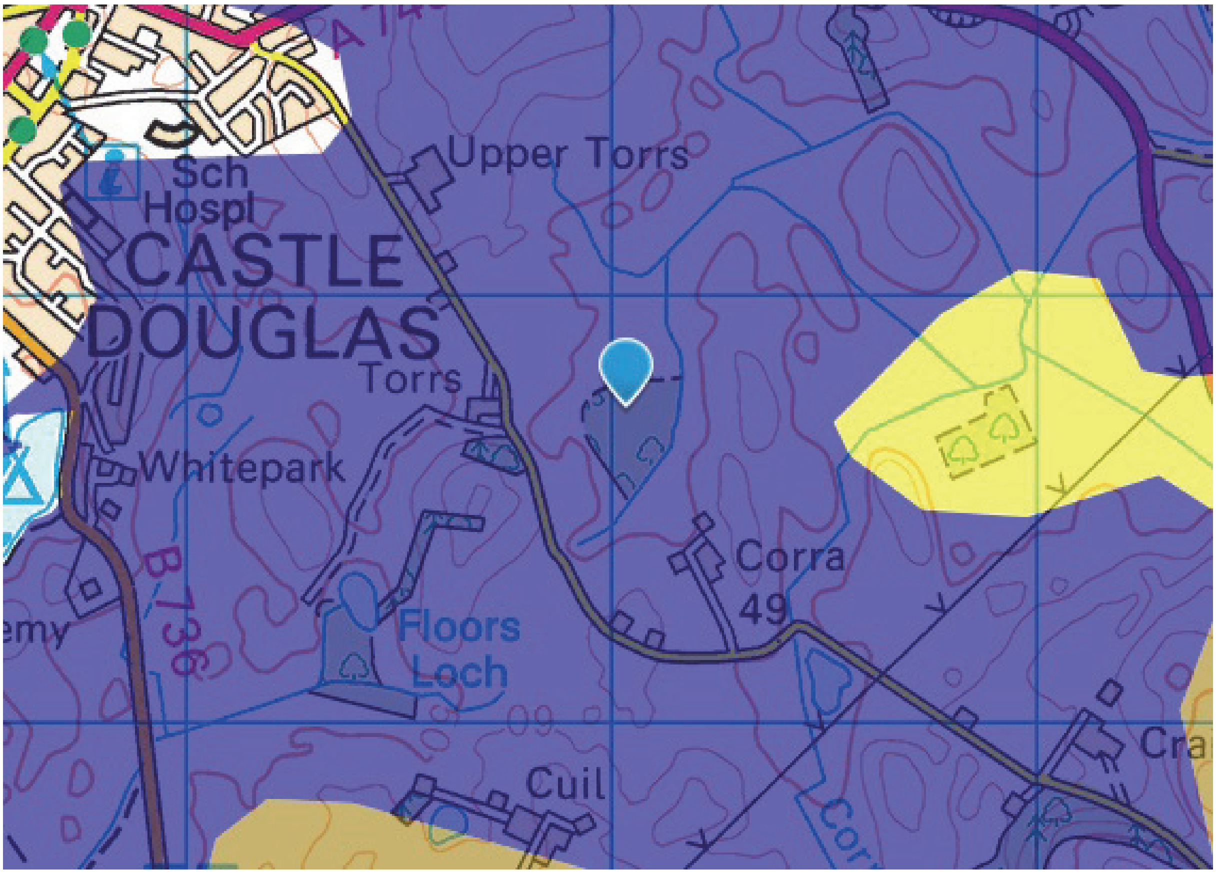


Figure 5. Torrs Moss – Soil types (source: Soil Survey of Scotland Staff, 1981).

3.1.4 Site specific issues

It is believed that diffuse pollution from drainage derived from farms and adjacent improved fields are transporting nutrients into Torrs Moss. Evidence of nutrient enrichment is present along the drain from Torrs Farm. It is believed that this area of the site is acting as a silt trap and that nutrient rich water is washing over the surface in times of flood and entering the wetland groundwater (marked by the sloppy peat below the firm surface peat). Figure 6 shows the locations of these possible sources of nutrients.

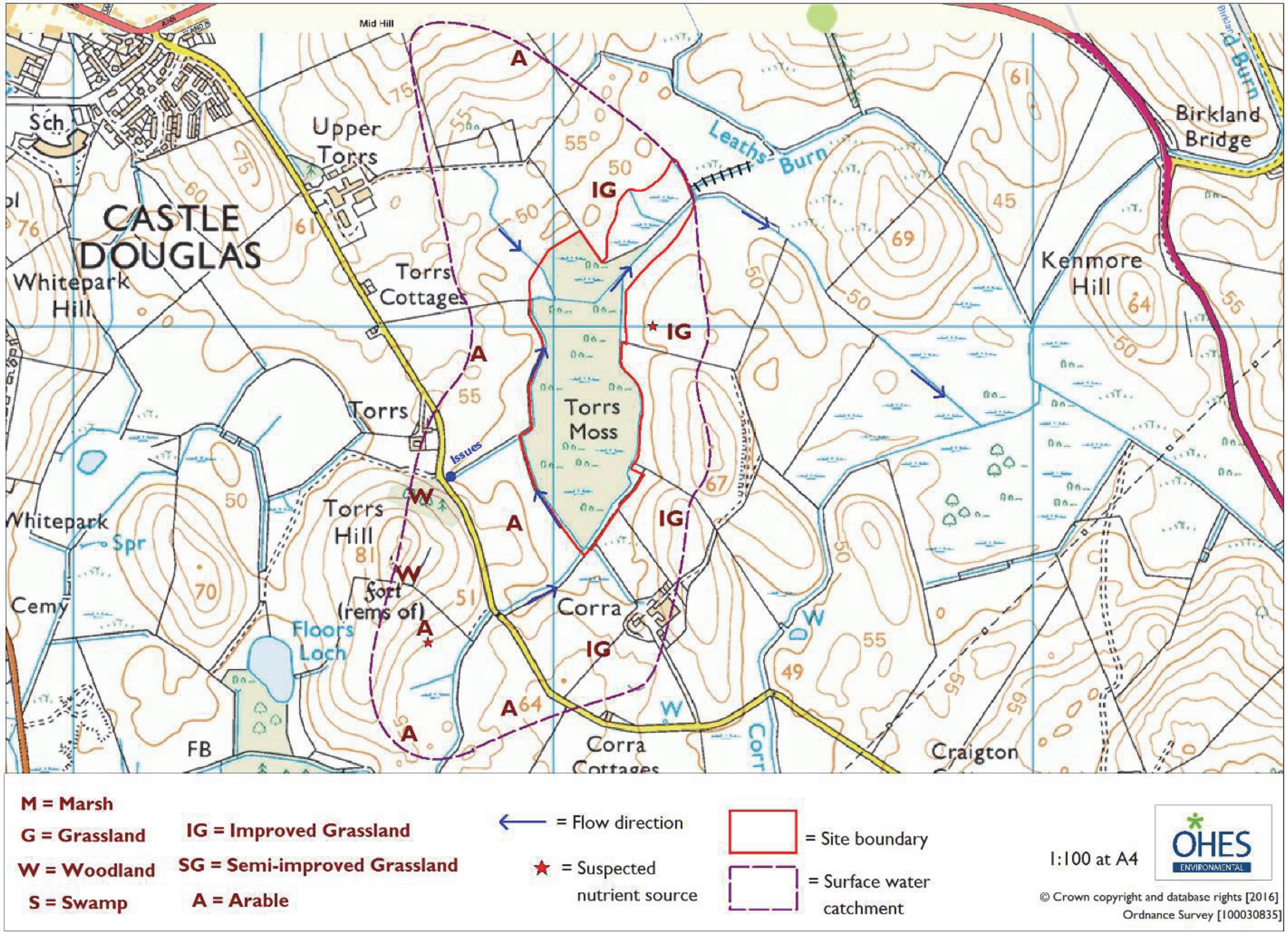


Figure 6. Land use and potential nutrient sources at Torrs Moss

3.2 Assessment of vegetation data

Torrs Moss contains a range of basin fen communities. Observations on the vegetation have been recorded in 1984, 1987, 1989, 2010 and 2015. NVC communities have not been mapped for the whole site and are therefore not available for analysis. Figure 7 indicates the types of vegetation communities at Torrs Moss - mapped from the environmental audit.

The historic data suggests the presence of the following communities:

- M9 *Carex rostrata-Calliergon cuspidatum/giganteum* mire
- M27 *Filipendula ulmaria – Angelica sylvestris* mire
- S4 *Phragmites australis* swamp
- S24 *Phragmites australis-Peucedanum palustre* tall-herb fen (see note below)
- W2 *Salix cinerea-Betula pubescens-Phragmites australis* woodland

The reference within the citation to *Phragmites-Sphagnum fimbriatum* bog moss community within the context of S24 tall herb fen, is not typical of those communities presented in Rodwell, 1995. No species lists were available of the floristics of the S24 at Torrs Moss. However, a resurvey of Norfolk Broadland communities (undertaken by OHES in 2007-10) noted a community where *Phragmites* and *Sphagnum fimbriatum* were associates, which may be akin to the vegetation present at Torrs Moss. This community was coded **BS5 *Dryopteris cristata-Sphagnum* species fen** and consisted of a mixed mire community with close affinity with S24, having nearly all of the characteristic associates Rodwell uses to define this community. However, the poor-fen ground layer and, in particular, the rich community of *Sphagnum* species, suggested it could not be accommodated in this essentially calcareous tall herb fen community of S24.

It is a rare community in Broadland, and has, to our knowledge, not been described nationally. The community can be very small in extent (Wheeler 1978 indicates stands can be as little as 1-2m across) and is consequently easily overlooked. Giller and Wheeler (1988) regard this as a primary fen type, not recorded in regularly mown stands, perhaps explaining the tendency of the community to include a component of birch scrub. In BS5 *Dryopteris cristata-Sphagnum* fen, a quite different hydrology has led to the development of a “mixed mire” flora. Deep rooted species in the community are typical of the base-rich and calcareous flora of S24, although they are much reduced in frequency and abundance. Shallow rooted species and the bryophyte flora are mostly poor-fen species. This suggested there was a perched, very shallow, surface water table which was maintained just above the base-rich water table, even when the surrounding rich-fen community may be inundated. In some Broadland locations, the hydrological equilibrium was maintained by the floating nature of the substrate. The peat body rising and falling as the broad water level changed, maintaining a constant vertical relationship between base rich and base poor layers. Giller and Wheeler (1988) suggest that the floating rhizome mat in old peat cuttings operates in the same way, while on solid peat the shrinking and expansion of the peat body performs the same function. They suggest that in extensive areas of what appear to be similar floating or solid substrate, small differences in rhizome mat buoyancy or peat absorptive capacity may be enough to provide the required isolation of the surface in the very small areas that the vegetation occupies. They found no difference in the chemical properties of the peat - *Sphagnum* did not develop over specifically acidic peats. The ability of the peat surface to rise above the base-rich water table thus provided suitable conditions for the ingress of the first *Sphagnum* species. The ability of bog moss to retain base-poor rainwater within its tissue, and to acidify the surrounding surface, subsequently increased the potential for acid fen development.

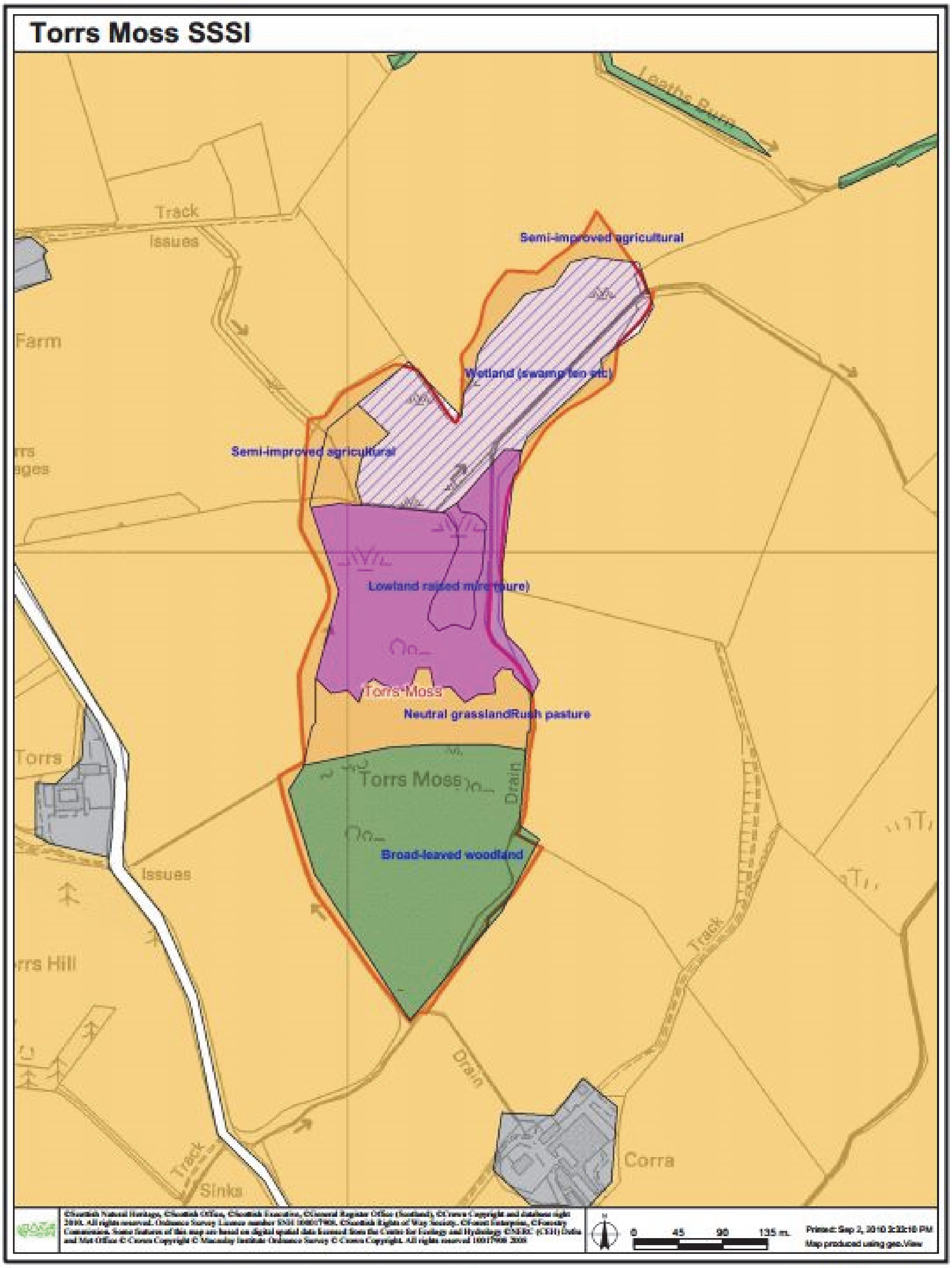


Figure 7. Habitat types at Torrs Moss (2010)

The successional development of BS5 fen is not clear. Being primary fen, readily invaded by trees, stands of this vegetation would, if left unmanaged, progress rapidly to trees. Giller and Wheeler (1988) indicate the *Sphagnum* carpet would persist under the canopy, as might an impoverished version of the flora[3], and they assert that there is evidence of long term of die-back of the tree canopy. Consequently, they speculate that these acid nodes within rich-fen represent the beginnings of ombrotrophic bog development. However, some Broadland sites (where a considerable layer of sloppy peat persists beneath the surface) showed signs that this community was temporary, and that once trees reached a certain age, the floating mat was weighed down sufficiently to take it into the influence of base-rich waters, and thus appeared to result in a loss of the "acid" component.

Reference is also made within the Torrs Moss Site Environmental Audit to "raised mire" (such as M4 *Carex rostrata-Sphagnum recurvum* or M5 *Carex rostrata-Sphagnum squarrosum* mire, recorded on the site within the SNH site files).

3.2.1 Historic evidence of community change

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

- In 1984 a survey by Wheeler, Shaw and Fojt recorded the central area as being markedly free from scrub, due to recent management, however the 2015 survey noted that scrub (willow and birch) were encroaching significantly.
- In 1984 reed was the dominant species with variable height and density. In 2015 reed was still dominant but the lack of management was causing a build up of leaf litter, which was potentially detrimental to the community M9.
- *Ranunculus lingua* was previously recorded as a 'large population', but in 2015 only a few plants were seen on an area of disturbed ground (tracks of vehicles) in a central swathe (pheasant flushing area).
- The northern carr was overgrown with willow trees and reed, to a greater extent than was recorded in 2011, and is likely to be having a negative effect on the previous open glade areas with the S24 community.
- The neutral grassland and rush pasture in the centre of the site remains free from reed inundation, as does the northern end of the site when comparing the 2010 and 2015 SCM. In other areas, reed appears to be taking over the site and dominating communities such as the M9 mire.
- Management for pheasants appears to be having a negative impact upon the site, particularly in the M9 area, as noted in the 2015 SCM.
- A number of site targets were not met during the 2015 SCM due to a dominance of reed and woody species.

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 SEPA, SNH 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

[3] The community may therefore succeed to the *Sphagnum* sub-community of W2 *Salix cinerea-Betula pubescens-Phragmites australis* woodland, where Rodwell (1991a) originally placed all of this vegetation – see *Results* section of this report.

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. SEPA and SNH plan to conduct further monitoring at wetlands across Scotland[4].

The wetland types potentially relevant to Torrs Moss are:

- Type 4: Fen
- 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 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 (or are indicated) at Torrs Moss are:

- M4 *Carex rostrata- Sphagnum recurvum* mire – occurs in pools and seepage areas across a range of mire situations, where waters are fairly acid and only slightly enriched (Rodwell, 1995). Calcium content in the source waters for M4 are believed to be less than those of M5 *C.rostrata-S.squarrosum* mire.

- 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.

[4] 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.

- M9 *Carex rostrata–Calliergon cuspidatum / Calliergon giganteum* mire – occurs on slopes, stream-sides, loch-sides 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 occurs in transition with S9 *Carex rostrata* swamp, S10 *Equisetum fluviatile* swamp and M5 *Carex rostrata-Sphagnum squarrosum* mire. No pH data were available for Scotland but it is quoted as always >5 and usually >6 for all of its range (Rodwell, 1991).

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

- S24 *Phragmites australis-Peucedanum palustre* tall-herb fen - occurs typically in floodplain situations over much of Broadland, but some variants can also occur in basin and valley head situations (Wheeler *et al*., 2004). The community is typically surface-water fed but can have some groundwater input also. Mean summer water levels show considerable variation, depending on which of the several different sub-communities is present. It is associated with solid fen peat or semi-floating pond infill over peat.

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-NO_3 for mesotrophic and oligotrophic fen respectively, and the 3rd quartile values are 5.7 and 5.0 mg/l N-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 0.20 mg/l used in laboratory tests for some of the samples”.

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

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

3.2.2.2 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. ER37 notes that "Although reedbed grows best in wet, eutrophic habitats (Rodwell, 1995), it also occurs in oligotrophic or hypertrophic conditions which are more frequently found in Scotland (Mountford, 2004)".

ER37 data and thresholds for Reedbed are presented in Table 4. 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 4. Groundwater thresholds for Reedbed in Good Condition (Source: ER37)

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

3.3 Assessment of ground water samples

Groundwater samples taken at Torrs Moss have been compared with the levels recorded in vegetation types as shown in section 3.2. Groundwater thresholds were used as opposed to surface water thresholds 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 thresholds.

Table 5 indicates that the vegetation currently found around the sample locations is generally consistent with the data recorded for Scotland (ER37) and for guideline/threshold values. The exception is the Phosphate levels within parts of the Reedbed (GW4) and Total Nitrogen levels within the fen (GW2 & GW3), both of which exceed the Upper quartile range recorded for that wetland type in Scotland.

Table 5. Groundwater samples at Torrs Moss compared to Wetland Type for Scotland. Red text denotes sample exceeds 3rd quartile.

	Torrs Moss	Torrs Moss	Reedbed			Torrs Moss	Torrs Moss	Fen		
Sample	**GW1 (in S4?)**	**GW4 (in S4?)**	**1st Quartile**	**3rd Quartile**	**Guideline**	**GW2 (in M27)**	**GW3 (in M9)**	**1st Quartile**	**3rd Quartile**	**Threshold**
pH (-)			5.7	6.5				6.4	7.4	
Dissolved Oxygen (%)			18	22				18	28	
Conductivity (mS/cm)			0.13	0.28				0.37	0.69	
Calcium (mg/l)	43	13	36	59		34	20	12	55	
Magnesium (mg/l)	6.9	2.5	5.8	18		4.7	3.8	3.4	14	
Sodium (mg/l)	6	7.6	12	19		5.5	7.3	5.4	14	
Phosphate (mg/l)	0.059	0.2	0.043	0.1	None set	0.056	0.057	0.064	0.1	None set
Nitrogen (total) (mg/l)	5.48	5.77	1.1	6.9		6.08	7.31	1	5.1	
Nitrate (mg/l N-NO_3)	<0.5	<0.5	0.25	0.25	Threshold: 5 (or 22 mg/l as NO3)	<0.5	<0.5	0.25	0.25	Threshold: <175 m Meso = 5 (or 22 mg/l as NO3) Olig = 4.5 (or 20 mg/l as NO3)

3.4 Assessment of surface water samples

3.4.1 Current surface water quality status

Five surface water samples appear to have been taken from Torrs Moss, however only three sets of results were provided by the laboratory (SW1, 2 & 3). It is presumed the labelling of the lab results is consistent with the sample codes used in the field. If this is the case, two of the major inputs into the Moss, namely the drain from Corra and the spring feed from Torrs Hill do not have lab results available.

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 6.

Table 6. Comparison of Surface water and Groundwater at Torrs Moss.

Sample	SW2	SW3	GW1	GW3	GW4	SW1	GW2
Calcium (mg/l)	50	55	43	20	13	47	34
Magnesium (mg/l)	9.8	10	6.9	3.8	2.5	10	4.7
Sodium (mg/l)	6.9	8	6	7.3	7.6	6.9	5.5
Phosphate (mg/l)	0.32	0.14	0.059	0.057	0.2	0.34	0.056
Nitrogen (total) (mg/l)	6.94	8.19	5.48	7.31	5.77	5.96	6.08
Nitrate (mg/l N-NO_3)	8.9	17	<0.5	<0.5	<0.5	7	<0.5

The results in Table 6 show that the surface water and groundwater results in the north of Torrs Moss (SW2, SW3 & GW1) are fairly consistent in terms of Calcium, magnesium and sodium concentrations, but that the surface waters are bringing in significantly higher levels of Phosphorus and Nitrogen than is present in the groundwater. SW3 is of particular concern as it has high concentrations of Nitrogen and Nitrate. However by the time water beings to exit the site (at SW2), the less enriched groundwater has begun to dilute the surface water enrichment. Even further downstream, at SW1, Nitrate and Nitrogen concentrations continue to decline.

No surface water data is available for the south of the site, where the main inflow of enriched water is believed to occur. However, Phosphate concentrations are notably higher in the groundwater nearest to the main surface water input (GW4). GW4 showed a layer of “very sloppy peat” between 70 to 120cm below ground level, which could indicate sub-surface movement of water from the main inflows is infiltrating this part of the Moss.

Surface water results were compared to SNIFFER data (ER37 report) for the various vegetation communities at Torrs Moss. Water chemistry guidelines generally refer to groundwater rather than surface water and therefore comparison can only typically be made between Torrs Moss and the SNIFFER dataset for wetlands in Scotland.

Table 7 indicates that the surface water sources within the site are consistently higher in Nitrogen and Phosphate than the upper quartile range observed for reedbeds and fens across Scotland (ER37). It should also be noted that the surface waters sampled are not likely to be the main contributors to enrichment on the site and therefore the situation may well be worse than this data indicates. However, it is probable that the raised mire communities in the centre of the site are at least partially protected from enriched waters by the greater contribution rainwater will make to these higher areas.

Table 7. Surface water samples at Torrs Moss compared with Wetland Type for Scotland (ER37 Draft). Red text denotes sample exceeds 3rd quartile.

	Torrs Moss	Torrs Moss	Torrs Moss	Fens		Reedbeds	
Parameter	**SW1**	**SW2**	**SW3**	**1st Quartile**	**3rd Quartile**	**1st Quartile**	**3rd Quartile**
pH (-)						6.7	7.4
Dissolved Oxygen (%)						53	57
Electric Conductivity (mS/cm)						0.25	0.62
Calcium (mg/l)	47	50	55	24	44	13	38
Magnesium (mg/l)	10	9.8	10	4	5.6	5	8
Sodium (mg/l)	6.9	6.9	8	6	20	7	12
Phosphate (mg/l)	0.34	0.32	0.14	0.01	0.055	0.02	0.084
Nitrogen (total) (mg/l)	5.96	6.94	8.19	1.8	6	1.8	5
Nitrate (mg/l N-NO_3)	7	8.9	17	0.21	4.6	0.25	5.2

3.4.2 Summary of site vulnerability

Surface water input from a number of sources (such as Torrs Farm and Corra) appears to be the primary source of enrichment at Torrs Moss, as well as potentially sub-surface movement of enriched waters through the layer of sloppy peat underlying parts of the site. Water leaving the site has lower Nitrogen levels than went it enters. This could mean the site is acting as a sink for nutrients, but may also be the result of less enriched water sources (such as rainwater) diluting the high nutrient concentrations.

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

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

Source	**Torrs Moss**	
	Vulnerability	**Details of Factors**
EXTERNAL SOURCES		
1. Agriculture	High	- The site receives surface waters from drains passing through an intensive agricultural landscape.
2. Human population	Low	-Few residential properties are present within the surface water catchment, though the contributions of these properties is unknown.
3. Aerial deposition	Low	- 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	-Regional groundwater may be contributing to the site's water balance, which is understood to be of good 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	Low - Moderate	-Practices such as Pheasant rearing have been noted as a negative factor to the sites condition. However light cattle grazing across the site should reduce the risk of nutrient build-up over time.

3.5 Assessment of soil samples

Soil chemistry was sampled at four locations within Torrs Moss (one within M27, one within S24, one within M9 and one within S4). 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
12 samples across 5 sites for Springs, Seepages and Flushes.

Table 9 presents the soil chemistry data for Torrs Moss samples against the ER37 data.

Soil sample 1 (GW1) was taken in the north of the site in shallow peat over sloppy peat (with some wood found at the base of the sample). The water level was 5 cm below ground level at this location, with high moisture content both within the root layer and below it. Phosphorus and Total Nitrogen levels were high within the root zone and below the roots at this location.

Soil sample 2 (GW2) was taken in the north-east of the site, downstream of the sites outlet sluice. It showed peat to 1.5 m depth, underneath which a sloppy layer was again present (with wood found at the base). Moisture content was again high in both zones and the watertable was recorded at ground level.

Soil sample 3 (GW3) was taken in the centre of the site, within the area of M9 mire. In this sample, 50cm depth of firm peat was underlain by 80cm of sloppy peat, with the water table recorded at the ground surface. Total Phosphorus levels were notably lower in GW3 than in the other three samples, both in the root zone and below it. This would suggest sub-surface and surface enriched waters are not reaching this part of the site (at least at the time of sampling).

Sample 4 (GW4) was taken towards the south of the site, in an area which may fit with S24 tall herb fen, or possibly S4 reedbed. It is the closest soil sampling point to surface water inputs from Corra and land to the south west. It showed 70 cm of firm peat, underlain by 50 cm of very sloppy peat. The water table was recorded 5 cm below the ground surface and moisture content was high (around 90 %). Available Phosphorus was found at high concentrations within the root zone, but not below the root zone (suggesting the substrate itself is not likely to be a significant source of enrichment).

Table 9. Soil samples at Torrs Moss and soil chemistry recorded by Wetland Type in Scotland (ER37). Red text denotes sample exceeds typical range.

	Torrs Moss		Torrs Moss		Torrs Moss		Fen		Torrs Moss		Reedbed	
Sample	**Soil 2 Root (in M27)**	**Soil 2 below (in M27)**	**Soil 3 Root (in M9)**	**Soil 3 below (in M9)**	**Soil 4 Root (in S24?)**	**Soil 4 below (in S24)**	**1st Quartile**	**3rd Quartile**	**Soil 1 Root (in S4)**	**Soil 1 below (in S4)**	**1st Quartile**	**3rd Quartile**
Calcium (mg/kg)	1600	2200	490	580	850	680	960	12,000	1100	1200	1,700	13,000
Magnesium (mg/kg)	1990	160	31	36	90	46	1,500	3,800	70	80	200	2,700
Sodium (mg/kg)	12	8.5	8	7.5	16	8	74	280	11	23	32	44
Phosphate (available) (mg/l)	7	6	6.1	4.1	11	4.9	2.7	9.5	12	8.6	1.1	6
Nitrogen (total) (%)	1.8	1.6	2.1	1.9	2.6	2.1	0.25	1.4	2.1	1.7	0.99	1.7
Nitrogen (extractable) (mg/kg)	<0.1	0.12	<0.1	0.17	<0.1	0.11	0.4	1.4	<0.1	0.12	0.39	0.56
Total organic carbon (%)	6.4	6.1	1.8	3.1	3.2	4.2	3.7	12	5.3	6	5.5	22
Potassium (total)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	-	-	<5.0	<5.0	-	-
Soil Moisture Content %	81.3	85.4	91.2	92.2	91.1	90.8	-	-	86.1	87.1	-	-

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 NVC quadrat data was available for the site, which would have enabled more in-depth analysis of the vegetation communities present.
- Some of the key surface water pathways did not appear to have water chemistry analysis undertaken.
- No site visit was possible as part of the analysis within this report and therefore there has been no opportunity to gain first-hand knowledge of the site.
- Data was collected from a single sampling round which, though providing consistency of timing could be very misleading if for example weather conditions were atypical. Clearly a single sample round will also not reflect conditions experienced through the various seasons (such as those times of the year when heavy rain may increase the amount of suspended solids or surface water flushing and therefore nutrient loadings).
- Analysis of the samples could only be conducted by eye as there was insufficient data for any statistical analysis.
- As stated in the ER37 report, insufficient numbers of samples within certain wetland types have limited the possibility of defining target thresholds, and therefore certain wetland types will need to be revisited once additional data has been gathered. In the short term, this means that wetland types such as Fens, which currently contains a wide range of NVC communities, may appear to be more tolerant of nutrient-rich situations than is actually the case. For example, assessment of lowland wetland communities across England and Wales (by Wheeler, Shaw and Tanner, 2009), states that M5 has a mean substrate fertility[5] (mg phytometer) of 13.8 (and a range of 4 to 29), whereas M10 has a mean substrate fertility of 6.5 (and a range of 3 to 18).

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 for Torrs Moss, based on a single sampling round, suggests enriched water is present within the site but the limited sample data prevents any clarification of the main contributing inflow/s.

---

[5] Wheeler, Shaw and Tanner state that “Experience has shown that N and P data derived from soil analysis has only limited use in assessing fertility of wetlands. Consequently the technique of phytometry (measuring the biomass of test species (phytometers) grown on soil samples) was developed. Typical phytometer yields (dry wt.); low fertility = <8mg, high fertility>18mg.

Thus the next step for putting in place remedial measures for Torrs Moss would need to be a clearer understanding of the site by undertaking:

- Additional surface water sampling within all inflow and outflow points (ideally 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.
- An NVC survey to establish the pattern and extent of vulnerable wetland communities across the site and their associated hydrological requirements.
- Further detail on the seasonal water levels present on the site (either through discussion with the site manager or, ideally, through collection of water level data by means of a gauge board or dipwell).

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

- ***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 around the edge of the site and directly into the outlet ditch if it represents a particular problem to site water quality. The existing data is not detailed enough to suggest which sources feeding the site are best in terms of water quality. However, this method requires careful consideration of the water balance for the site to ensure sufficient water will still be available to supply the wetland. It is possible such a scheme could be detrimental to the site.

- ***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. Consequently, use of buffer zones would not be effective within fields containing steeply sloping land. Furthermore, the presence of a layer of sloppy peat underlying much of the site may mean that buffer zones are bypassed by sub-surface movement of water, thus their placement is of key importance.

  The effectiveness of the buffer zone will be dependant on management, to ensure nutrients are removed via, for example, cutting and removal of vegetation.

  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”).

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**	07/02/2012	07/02/2012	07/02/2012	07/02/2012	07/02/2012	07/02/2012	07/02/2012
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	0.49	0.53	1.9	0.17	0.11	0.15	0.26
Nitrate	mg l^{-1}	0.5	Water	<0.50	<0.5	<0.5	<0.5	7	8.9	17
Phosphate Low Level	mg l^{-1}	0.02	Water	0.059	0.056	0.057	0.2	0.34	0.32	0.14
Nitrogen (total)	mg l^{-1}	1	Water	5.48	6.08	7.31	5.77	5.96	6.94	8.19
Calcium	mg l^{-1}	5	Water	43	34	20	13	47	50	55
Magnesium	mg l^{-1}	0.5	Water	6.9	4.7	3.8	2.5	10	9.8	10
Sodium	mg l^{-1}	0.5	Water	6	5.5	7.3	7.6	6.9	6.9	8
Iron (II)	µg l^{-1}	20	Water	500	170	200	300	30	20	<20
Iron (III)	µg l^{-1}	20	Water	500	830	100	300	190	270	250
Iron (total)	µg l^{-1}	20	Water	1000	1000	300	600	220	290	250

Soil samples

			Sample ID	S1	S1	S2	S2	S3	S3	S4	S4
			Other ID	Below	Below	Root	Below	Root	Below	Below	Below
Parameter	**Unit**	**Detection Limit**	**Sample Date**	07/02/2012	07/02/2012	07/02/2012	07/02/2012	07/02/2012	07/02/2012	07/02/2012	07/02/2012
Moisture	%	0.02	Soil	86.1	87.1	81.3	85.4	91.2	92.2	91.1	90.8
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	12	8.6	7	6	6.1	4.1	11	4.9
Phosphorus (total)	mg kg^{-1}	-	Soil	1600	500	700	230	280	160	530	300
Nitrogen (total)	%	0.02	Soil	2.1	1.7	1.8	1.6	2.1	1.9	2.6	2.1
Nitrite (extractable)	mg kg^{-1}	0.1	Soil	<0.1	0.12	<0.1	0.12	<0.10	0.17	<0.1	0.11
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	1100	1200	1600	2200	490	580	850	680
Potassium (total)	mg kg^{-1}	0.2	Soil	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Sodium (total)	mg kg^{-1}	0.2	Soil	11	23	12	8.5	8	7.5	16	8
Magnesium (total)	mg kg^{-1}	0.5	Soil	70	80	1990	160	31	36	90	46
Total Organic Carbon	%	0.2	Soil	5.3	6	6.40	6.1	1.8	3.1	3.2	4.2
Moisture content	%	-	Soil	551	611	448	613	1261	1031	1225	800
Bulk density	Mg/m3	-	Soil	1.07	1.07	0.99	0.99	0.9	1.05	0.97	1.01
Dry density	Mg/m3	-	Soil	0.16	0.15	0.48	0.14	0.07	0.09	0.07	0.11

www.nature.scot

ISBN: 978-1-78391-755-6

Great Glen House, Leachkin Road, Inverness, IV3 8NW
T: 01463 725000

You can download a copy of this publication from the SNH website.

recycle

Scottish Natural Heritage
Dualchas Nàdair na h-Alba
nature.scot