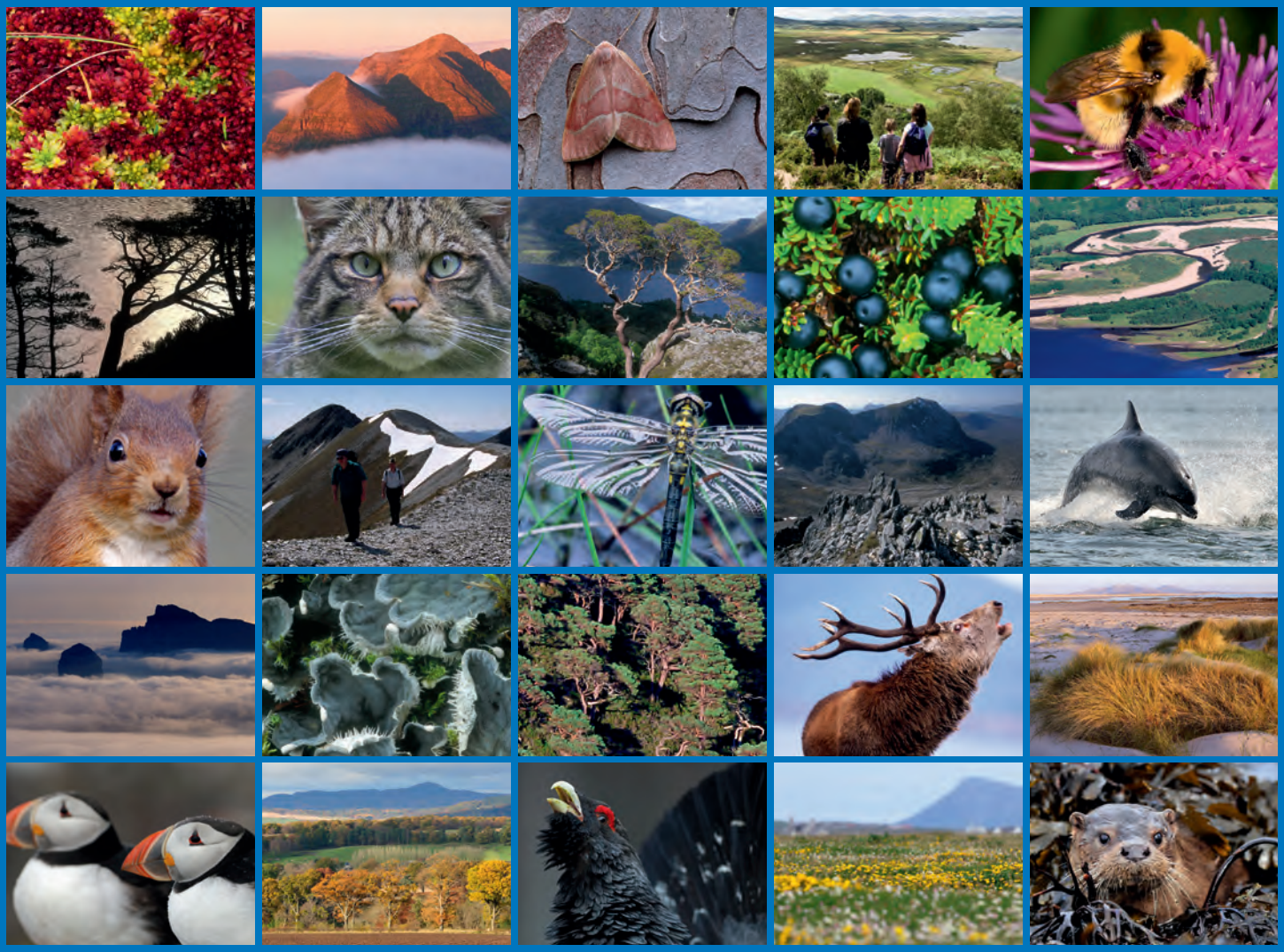
Scottish Natural Heritage
Commissioned Report No. 726

Investigation of Standing Water and Wetland SSSIs thought to be under Diffuse Pollution Pressure: Loch Spynie



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COMMISSIONED REPORT

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Investigation of Standing Water and Wetland SSSIs thought to be under Diffuse Pollution Pressure: Loch Spynie

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COMMISSIONED REPORT

Summary

Investigation of Standing Water and Wetland SSSIs thought to be under Diffuse Pollution Pressure: Loch Spynie

Commissioned Report No. 726
Project No: 13700
Contractor: EnviroCentre Ltd.
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Keywords

Diffuse pollution; SSSIs; wetland; water; soil; samples; recommendation.

Background

SNH contracted EnviroCentre to look at a number of Sites of Special Scientific Interest across Scotland thought to be adversely affected by diffuse pollution. EnviroCentre was asked to carry out a number of tasks to help SNH understand better whether sites are being affected by diffuse pollution and if so, what activities might be contributing to this pressure and how SNH could improve the condition of the sites.

If sites are identified as being affected by diffuse pollution, SNH hope that the results of this report will inform their work with managers of the sites to improve their condition.

Main findings

- The desk study identified a trend of elevated nutrients within the site, confirming eutrophic conditions in Loch Spynie. This could be a consequence of natural conditions, nutrient input from the bird assemblage at the loch and, to a lesser extent, agricultural activities and suburban land use in the catchment.
  Analytical data confirmed the presence of elevated nutrients. It should be noted that the sampling assessment was undertaken as a single full visit and the limited scoped dataset and a lack of historical data constrains the ability to draw accurate conclusions to fully inform current site conditions.
- A series of recommendations are proposed to seek to aid the understanding of the site and afford a greater insight into the perceived changes taking place within the SSSI.

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Acknowledgements

EnviroCentre Ltd would like to thank the SNH Operations staff for their time and assistance in providing access to the site files held at the local office, providing landowner contact details, and in aiding the preliminary understanding of the site to assist with the health and safety evaluation prior to the initial visit.

Thanks are also extended to the site landowners for affording access to the site to enable the agreed scope of work to be undertaken.

1. INTRODUCTION

EnviroCentre Ltd was contracted by Scottish Natural Heritage (SNH) in August 2012 to deliver the 'Investigation of Standing Water and Wetland SSSIs under diffuse pollution pressure' project. The data collected from the project will be used to inform management decisions on standing water and wetland Sites of Special Scientific Interest (SSSI).

1.1 Site Location

Loch Spynie is located 3 km to the northeast of Elgin, to the west of the B9135. See Figure 1.1 in Annex 1.

1.2 Site Description

Loch Spynie is designated as an SSSI, Special Protection Area (SPA) and a Ramsar site. This loch is one of very few large eutrophic water bodies in northern Scotland. The SSSI extends over 93.6 hectares (SNH, 2011a).

The site supports a diverse aquatic flora with extensive reedbeds fringing and adjacent to the open water body and various stages of hydroseral succession including mesotrophic fen, willow scrub and swamp alder woodland (SNH, 2011a). Loch Spynie has regularly supported internationally important numbers of roosting Icelandic greylag geese (*Anser anser).* The site has recently suffered the same drop in wintering greylag numbers as seen at other sites in north-east Scotland (SNH, 2008).

Spynie Canal runs along the northern boundary of the site and the A941 borders the site to the west.

The bedrock geology at the site is cut by a fault orientated southwest to northeast, which also transects the loch. To the north of the fault the bedrock consists of the Kingsteps Sandstone Formation. To the south the Stotfield Cherty Rock Formation (Sandstone, Chert and Limestone) underlies the majority of the loch, with the Dunrobin Bay Formation (Interbedded Sandstone and Siltstone) to the west, and the Lossiemouth Sandstone Formation to the east. The superficial geology across the majority of the site consist of Lacustrine Deposits (clay, silt and sand), with Flandrian Raised Marine Deposits present to the northwest and southeast (British Geological Survey, n.d.).

1.3 Site Hydrology

A catchment area of 7.11km^2 drains to Loch Spynie and the northern end of the SSSI, and a small catchment of 0.65km^2 drains to the wetland in the western part of the site as shown in Figure 1.2. These two catchments are artificially separated by a disused railway embankment. The annual average rainfall in the area is 648mm (Centre for Ecology and Hydrology, 2009).

The main inflow to the site is a small unnamed burn which flows from Findrassie Wood to the southwest of the site and enters the loch at the southern end. Additional inflow will result from groundwater seepage (SNH, n.d.) and surface runoff over adjacent farmland located within the loch and wetland catchments as shown in Figure 1.2. The outlet drains to the Spynie Canal. An embankment artificially constrains the waters at the north eastern end of the loch where the main outflow is located. This is controlled by a weir and sluice (SNH, n.d.).

The loch has a surface area of 17 hectares. It is shallow throughout (~1m deep) with a short water retention time of 48 days (SNH, n.d.). The loch is surrounded by reedswamp, with a large area of swamp at its western end. The loch and its catchment have a complex history

of water level modification and drainage. This is primarily for the purposes of flood prevention and land improvement. It is understood that previous to engineering works (see section 1.4), the catchment area was much larger than it is at present. The loch was also significantly larger, extending to the north and east of its current location (SNH, n.d.).

The Spynie Canal is understood to have been constructed in 1808-11 from a culmination of attempts to drain Loch Spynie (which survived as a small loch) and the low lying areas between Spynie Palace and Lossiemouth, the surplus water flowing through sluice gates at Lossiemouth (Historic Scotland, n.d.). The Spynie Canal to the north of the site, and a dismantled railway embankment to the south west prevent inflow to the loch from an additional much larger catchment area to the west. The railway and canal embankments are considered to be impermeable preventing an exchange of water with the site. The canal discharges to the sea 2 kilometres downstream of the loch and is subject to tidal influences (SNH, n.d.).

1.4 Site History

Until the 16th century the loch was part of the sea, reflected in its unusual water chemistry and plant assemblage (SNH, n.d.). The loch and surrounding wetlands are the remnants of a much more extensive wetland which was progressively drained for agriculture purposes. The present day loch is maintained by artificial banks which, along with the disused railway line embankment which bisects the site, are Victorian in origin. In 1989/90 the requirements of the Reservoirs Act (1975) led to substantial engineering works being undertaken including upgrading of the railway, canal and northeast embankments (and abandoning of the former southwest bank) and installation of new sluices and penstocks at the western and northeast outlets. These works were funded by the Nature Conservancy Council under the terms of a Management Agreement. These works allowed a constant water level to be maintained in the loch, provide for better flushing of the loch and enable the loch to be drained (for emergencies or management) by means of the west outlet. Three ponds were created in the north eastern fen in November/December 1991 to increase the open water habitat (SNH, 2011b).

The loch was used for wildfowling for much of the 20th century with considerable keepering activity taking place. Habitat management for sporting interests included cutting back of reeds from the loch margin, burning of fen vegetation, cutting of reeds to allow access and creating and maintaining pools. Most of the wildfowling took place from butts in the West fen and across the loch, however, no wildfowling has taken place since 1981. The site was formerly of importance for angling and was stocked with several species of fish. Only very limited angling has occurred since 1981. Grazing of the northeast part of the site by Highland cattle (which had ceased by 1981), was recently re-introduced annually for up to 6-8 weeks. A small area in the northeast of the site was planted with Sitka Spruce more than 50 years ago (SNH, 2011b).

1.5 Recent Site Management Practices

Under the terms of a Management Agreement, positive management works are agreed between the landowner and SNH, with the latter providing funding for the works at Loch Spynie. These works are implemented through an annually agreed programme by Pitgaveny Estate, the landowner. The Loch Spynie Advisory Committee, a voluntary body comprised of local naturalists, also provides the owner with advice regarding the management of the site. Members of the Committee also carry out some habitat management work and have provided interpretive material for a hide on site.

Recently, fen and grassland communities have been mowed annually and scrub invading the northeast part of the site has been controlled. Two outlets to raise the water level in this

part of the site were installed in 2000 and permanent gauges are situated to monitor water levels. A number of conservation management works such as creating tern breeding platforms and clearing scrub from the margin of the loch have been undertaken by volunteers.

There is a well-used bird hide on the south eastern shore and bird-watching is considered to be an important activity at the loch.

The Reservoirs Act 1975 requires the loch to be subject to an annual engineering inspection. Maintenance and repair of the embankments, sluices, penstocks and silt trap are occasionally required. Such works may also include removal of trees and scrub from embankments.

The owner of the site occasionally uses the site for skating, boating or angling. There is considerable recreational use of the site by birdwatchers visiting the hide via a small car park at Scarffbanks Farm. Access to this hide is unrestricted but is not deliberately publicised. The site is visited by organised groups such as the Royal Society for the Protection of Birds (RSPB). The site is occasionally used for research projects. The disused Elgin to Lossiemouth railway line, which bisects the site, is maintained by the landowner as an access route for agricultural vehicles; maintenance includes occasional management of encroaching vegetation. The former railway line is also a popular footpath and cycleway, although it is not a public right of way. Small numbers of visitors access the loch from the disused railway line. There have been very occasional instances of unauthorised shooting of wildfowl at the loch. A transmission line wayleave in the West Fen is occasionally cleared of trees.

Spynie Canal, which runs through the SSSI, provides drainage for a large area of agricultural land which occupies the site of the historical wetland. The canal, including the section within the SSSI, is dredged on an annual basis. The inlet burn to the loch is also occasionally cleared out to maintain the drainage of adjacent farmland.

Roe Deer control is undertaken in the north eastern and western fens in order to protect adjacent commercial woodland from browsing damage (SNH, 2011b).

2. METHODOLOGY

The following sections outline the approach undertaken to fulfil the scope of works established by SNH in the Statement of Requirements (SOR).

2.1 Pre-site Attendance Desk Study

Before the initial site visit was undertaken the local SNH officer was contacted and a meeting held at the corresponding local office to discuss the local understanding of the site and review SNH records.

The meetings were also used to provide an insight into any health and safety constraints not readily apparent from the site maps.

Landowners of the site were notified of the planned site visit a week before the proposed visiting date. This allowed an opportunity to ask any questions and also gave EnviroCentre staff a chance to a gain a greater understanding of the workings of the site and the site surrounds.

2.2 Site Attendance

The site was accessed and samples collected on two different days (Visit 1 & Visit 2) as work was interrupted during Visit 1 due to shooting on site. A follow up visit to the wider catchment (Visit 3) was undertaken once the analytical data was available and was appraised in context with the information obtained from the desk based exercise.

Table 2.1: Site Conditions

Loch Spynie	Date of Visit	Weather Conditions	Grid References
Visit 1	13/11/2012	Cold, overcast, light rain	NJ 234661
Visit 2	26/02/2013	Clear, mild and sunny	NJ 234661
Visit 3	21/03/2013	Clear, cold and sunny	NJ 234661

2.3 Sampling Approach

SNH had determined the preferred locations for the collection of soil and water samples – as detailed in Figure 2.1 in Annex 1. EnviroCentre was not involved in determining these locations and had not assessed the suitability to access such before Visit 1. Due to certain restrictions, the locations of samples that EnviroCentre collected had to be changed and are as detailed in Figure 2.2 in Annex 1. Changes to locations were kept to a minimum and are generally not deemed to have a significant impact on the sampling or conclusions.

All sampling methods were carried out by trained personnel. Photographs of each sampling location were taken (see Figure 2.3 in Annex 1) and grid references for each location recorded.

2.4 Sample Equipment

The following sample kit was used to undertake site field work:

- Handheld GPS to record specific grid references;
- Handheld soil augers;
- Plastic bailers;
- Sample bottles (all sample bottles were written on to record locations, date and time); and

- Personal Protection Equipment –PPE- (in line with the requirements of the site specific health & safety risk assessment).

All samples were given unique identification names and packaged in cool boxes with ice packs so as to keep samples at appropriate temperatures prior to being despatched to a United Kingdom Accreditation Service (UKAS) accredited laboratory for analysis.

2.5 Health and Safety

Site specific risk assessments were carried out before attending site. The assessment was based on information obtained from the meeting with the local officer and from EnviroCentre's extensive experience of undertaking previous work of this nature.

The risk assessment, which was carried out by staff attending the site visit, included details of the landowner, nearest emergency services and identified risks and proposed means of mitigation. Field operatives notified EnviroCentre head office when entering and leaving site and wore the following appropriate PPE at all times:

- Warm and waterproof clothing;
- Waders;
- Waterproof footwear; and
- Hi-vis vest.

Biosecurity measures were implemented when entering and leaving site. Boots and equipment were washed when leaving site so as not to cross contaminate subsequent sites.

2.6 Water Samples

Surface water samples were collected from strategic locations within the site boundary to provide an understanding for the whole site, comprising standing water, inflows and outflows. Samples were taken from the shore which can introduce a bias as it may not reflect average conditions in the water body.

Groundwater samples were collected using plastic bailers from slotted pipes installed with hand augered holes where soil samples were originally collected. The sampling methodology employed a geosock membrane for coarse filtration so as to minimise samples being heavily loaded with suspended solids and organic material.

Samples underwent initial on-site field tests using an OTT Quanta Handheld probe for the following parameters:

- pH;
- Temperature;
- Electrical Conductivity (EC);
- Dissolved Oxygen (DO);
- Oxidation-Reduction Potential (ORP); and
- Salinity.

The water samples were submitted for the following analyses to a UKAS accredited laboratory:

- Total calcium (Ca), magnesium (Mg) and sodium (Na);
- Nitrogen Species – total nitrogen, nitrate and ammonium;
- Phosphorus Species – orthophosphate and total phosphorus; and

- Total iron (Fe).

Dissolved and ferrous iron analyses were scheduled in but could not be undertaken by the laboratory due to insufficient sample. This data would have supported interpretation of results if available but is not considered critical for determining the presence or potential sources of diffuse pollution.

2.7 Soil Samples

Soil samples were collected from specific locations on site by hand augering holes into the ground. The soil samples were collected at two depths:

- The rooting zone; and
- A depth of approximately one metre below the rooting zone.

  NB - In the corresponding results tables the samples are differentiated by the suffix 'A' for the rooting zone; and 'B' for below the rooting zone.

Soil samples were analysed for the following suite:

- Moisture content;
- Extractable nitrogen and phosphorus;
- Total nitrogen (N) and phosphorus (P); and
- Total calcium (Ca); magnesium (Mg) and potassium (K).

Bulk density analysis was scheduled in but could not be undertaken by the laboratory due to insufficient sample. Total sodium (Na) and total organic carbon (TOC) were not scheduled in properly and analyses were not undertaken. The lack of this data is not considered to affect interpretation of results in terms of determining the presence and potential sources of diffuse pollution.

2.8 Field Observations

On accessing the site for the first visit, and the wider catchment for the second visit, the following field observations were noted:

- Geo-referenced photograph locations of surrounding land use (refer to Figure 2.4 in Annex 1);
- Adjacent land use;
- Identified and potential pollution sources; and
- Atypical or unusual site features (*e.g.* fly tipping, vandalism, *etc*.).

In addition, mapping of the immediate surrounding catchment was completed following the second site visit (see Figure 1.2 in Annex 1). This process utilised the Flood Estimation Handbook (Centre for Ecology and Hydrology (CEH), 2009) catchments and Land Cover data (Land Cover Map 2007) to populate GIS mapping. The output was used to aid the interpretation of results and further inform the study conclusions.

3. STUDY LIMITATIONS

The scope of the commissioned study presented a series of limitations which should be borne in mind when reviewing this report. These are outlined below:

- Sampling was undertaken on two visits. The weather conditions preceding and at the time of the visit may have directly influenced the observations made and the analytical results obtained.

- For the same reasons outlined above, access to certain parts of the site may have been restricted and limited access to the predetermined sampling locations.

- Sampling comprised a single set of samples from each of the pre-determined locations. Repeat or continuous sampling over an extended (seasonal) period would be preferred to enable a greater dataset to be collected. This would present a more representative assessment of the site and allow for seasonal/climatic variations.

- The dataset provides a 'snapshot' of the site condition. Due to the limited availability of historical data (see section 5) there is very limited scope for comparisons to be made with previous records or allowance for assessment of seasonal or climatic factors.

- The scope of work did not include the assessment of rainfall within the catchment, measure water levels or the inflow(s)/outflow(s) of associated watercourses.

- The limited dataset does not allow for any statistical analysis of the results to be undertaken. No adjustment has been made for anomalous results or to determine trends over time.

- The sampling methodology used to obtain groundwater samples (obtained from a *circa* 1m depth coupled with geosock membrane for coarse filtration) typically results in these samples being heavily loaded with suspended solids and organic material meaning that the samples appear 'dirty' to the naked eye. To avoid interference with the laboratory analytical instrumentation and erroneous results, on receipt at the laboratory these are processed on a x10 dilution. It is this dilution process which explains why some of the results are reported as a less than value rather than the equivalent level of detection of 'clean' samples. The same dilution approach is applied to heavy silted surface water samples.

- The weather conditions prior to and during the site visit should be taken into consideration when reviewing the results. According to the Met Office (n.d.) the seasonal rainfall totals for summer, autumn and winter 2012 in eastern Scotland were 161%, 89% and 82% respectively of the annual average rainfall levels for the period 1981-2010. This should be taken into consideration when reviewing the results as it could result in bias when compared with years where average rainfall levels were recorded. The higher rainfall will directly influence runoff, dilution and catchment water levels/throughput which have not been assessed.

- Due to limitations in the mapping data used to compile the Flood Estimation Handbook (FEH) catchment boundary, the area defined in the Annex 1 maps does not necessarily present a fully accurate reflection of the hydrological catchment for the site. The groundwater catchment area was not determined as part of this study.

4. ANALYTICAL DATA

The following tables show the results obtained from Visit 1 and Visit 2, in which samples from the pre-determined locations (or as close to as practically possible) were collected. Where the pre-determined locations were not accessible comparable alternative locations with the same habitat features were sampled. Samples LS1-3 were taken during Visit 1 and samples Spy1-10 were taken during Visit 2.

Table figures in red indicate relative atypical (e.g. high or low values) or anomalous results relative to the remaining dataset or which would typically have been expected to be observed from a site of this nature. These are discussed further in section 6.2.

4.1 Field Test Data

The following data was collected by a suitably qualified operative using the methods outlined in section 2.

Table 4.1: Water Samples – Field Data

Sample ID	Nat. Grid Reference		Temp (°C)	pH	Sal %	DO (%)	DO (ppm)	ORP (mV)	EC (µS/cm)	General Field Observations
LS 1	NJ 23200	65910	10.31	7.05	0.44	25.4	3.01	-60	913	Surface Water - Cloudy brown, fine brown suspended solids, red 1-2mm suspended solids, mild sulphur odour
LS 2	NJ 23359	65741	10.82	7.40	0.27	82.6	9.19	232	575	Surface Water - Clear with only a few minor suspended solids, no odour
LS 3	NJ 23288	66192	10.92	7.46	0.23	67	8.05	232	476	Surface Water - Clear with only a few minor suspended solids, no odour
Spy 01	NJ 23360	65755	4.06	6.85	0.29	94.1	11.86	-566	617	Surface Water -Clear with fine suspended solids, no odour
Spy 02	NJ 23392	66010	4.23	5.74	0.32	46	5.86	-578	681	Groundwater - Dark cloudy brown with large brown suspended solids, mild sulphur odour
Spy 03	NJ 23360	66270	3.97	7.39	0.24	81.5	11.17	-561	513	Surface Water - Clear, pondweed on surface, no odour
Spy 04	NJ 23133	65921	4.64	8.03	0	81.4	9.44	-602	N/A	Surface Water - Dark cloudy brown with large suspended solids
Spy 05	NJ 22928	66223	4.35	7.23	0.53	53.2	5.36	-590	1098	Groundwater - Cloudy dark green/brown with large brown suspended solids, strong sulphur odour
Spy 06	NJ 22168	60289	4.65	6.05	0.17	67.8	8.9	-589	372	Surface Water – Light brown with mixed sized suspended solids, no odour
Spy 07	NJ 24063	66608	4.95	7.99	0.19	108.4	13.1	-575	411	Surface Water - Clear with very fine suspended solids, no odour
Spy 08	NJ 24105	67005	4.51	5.03	0.14	46.3	6.71	-546	300	Groundwater - Dark cloudy brown with lots of fine sandy suspended solids, mild sulphur odour
Spy 09	NJ 24213	67202	4.62	7.67	0.28	102.2	12.57	-562	585	Surface Water - Clear with fine suspended solids, no odour

Sample ID	Nat. Grid Reference		Temp (°C)	pH	Sal %	DO (%)	DO (ppm)	ORP (mV)	EC (µS/cm)	General Field Observations
Spy 10	NJ 24306	67120	5.01	6.21	0.04	90.1	13.02	-554	98	Groundwater - Dark grey/brown with thick sandy suspended solids, strong sulphur odour

Red text denotes samples that are above typical ranges for the observed dataset
N/A - EC reading for Spy 04 not available due to probe error.

4.2 Laboratory Results

The data in the following tables was collected by a suitably qualified operative using the methods outlined in section 2.

Table 4.2: Water Samples – Laboratory Analysis

Sample ID	Nat. Grid Reference		Sample Type[+]	Total Ca (mg/l)	Total Mg (mg/l)	Total Na (mg/l)	Total Fe (mg/l)	Amm N (mg/l)	Nitrate as N (mg/l)	Phosphate as P (mg/l)	Total P (mg/l)	Total N as N (mg/l)
LS 1	NJ 23200	65910	SW (I)	127	7	30	0.01	0.2	<0.2	0.07	0.5	<1
LS 2	NJ 23359	65741	SW (I)	71	6	29	0.43	<0.01	6	<0.01	<0.1	6
LS 3	NJ 23288	66192	SW	45	4	20	<0.01	<0.01	<0.2	<0.01	<0.1	<1
Spy01	NJ 23360	65755	SW (I)	74	6	29	1.05	0.03	6.5	0.40	0.1	7
Spy02	NJ 23392	66010	GW	90	10	33	108	1.30	<0.2	0.28	4.7	5
Spy03	NJ 23360	66270	SW (OW)	51	5	23	1.71	0.13	0.3	0.27	0.4	<1
Spy04	NJ 23133	65921	SW (I)	196	9	27	8.44	0.03	0.2	0.32	3.2	1
Spy05	NJ 22928	66223	GW	94	20	99	40.7	0.07	<0.2	1.05	2.4	10
Spy06	NJ 22168	60289	SW (I)	28	4	39	39.1	0.20	<0.2	0.16	1.0	3
Spy07	NJ 24063	66608	SW (O)	66	5	30	0.15	0.30	1.2	0.18	0.2	2
Spy08	NJ 24105	67005	GW	18	8	31	63.8	0.40	5.8	1.85	2.8	25
Spy09	NJ 24213	67202	SW (O)	68	7	30	3.19	0.02	2.3	0.13	0.1	4
Spy10	NJ 24306	67120	GW	17	9	12	69.3	0.07	<0.2	0.13	1.3	9

Surface water samples are designated either inflow (I), outflow (O), open water (OW) or ground water (GW)
Red text denotes samples that are above typical ranges for the observed dataset

Table 4.3: Soil Samples – Laboratory Analysis

Sample ID	Nat. Grid Reference		Soil Type*	Extract-able N (mg/Kg)	Total Ca (mg/Kg)	Total Mg (mg/Kg)	Total P (mg/Kg)	Total K (mg/Kg)	Tot Moisture** 105°C (%)	Total N (mg/Kg)	Nitrate (mg/l)	Nitrogen (%)	Extract-able P (mg/l)	Total Na (mg/Kg)
Spy02A	NJ 23392	66010	Fibrous peat	0.6	37700	3490	1200	2460	93.3	<1.0	<0.2	1.82	34.2	801
Spy02B	NJ 23392	66010	Sloppy peat	0.6	8670	1290	987	2410	78.5	<1.0	<0.2	2.28	35	1500
Spy05A	NJ 22928	66223	Fibrous peat	<0.5	6560	2230	1240	1920	89.7	<0.9	0.2	0.83	37.4	402
Spy05B	NJ 22928	66223	Sandy, grey clay	<0.5	3400	2500	307	1950	65.5	<0.9	<0.2	0.25	7.5	418
Spy08A	NJ 24105	67005	Light brown, very fine sand	0.6	1240	465	321	521	25.8	<1.0	<0.2	0.36	20.5	150
Spy08B	NJ 24105	67005	Grey, fine sandy clay	0.5	910	871	143	763	19.1	<0.9	<0.2	0.01	7.5	127
Spy10A	NJ 24306	67120	Organic sand	2.5	1600	746	316	636	29.4	3.3	0.4	0.41	11.4	81
Spy10B	NJ 24306	67120	Grey, fine sandy clay	0.6	564	709	88	581	20.8	<1.0	<0.2	0.05	<6	63

** Soil types are field observations*
*** Total Moisture = Water content*
*A/B suffix: **A** = Rooting Zone and **B** = Below Root Zone*
Red text denotes samples that are above typical ranges for the observed dataset

5. SITE OBSERVATIONS

To enhance understanding of Loch Spynie and the surrounding area, preliminary research was undertaken and complemented with an additional site walkover to further understand the landforms, drainage configurations, potential environmental sensitivities and possible diffuse pollution sources influencing the site.

5.1 Desk Study

The Site Management Statement (SNH, 2011b) records an 'Objective for management' of maintaining the assemblage of wetland habitats including open water, swamp, fen, fen-meadow and wet woodland and the fauna and flora that these support. Maintaining suitable conditions for wintering and breeding birds and maintaining existing facilities for allowing public awareness and understanding are also objectives at the site.

The notified features of the SSSI are: eutrophic loch, basin fen, open water transition fen, wet woodland, greylag goose and breeding bird assemblage. All of the notified features are in favourable condition except for the eutrophic loch which is in unfavourable declining condition due to an increase in nutrient levels in the loch and the loss of vegetation structure (SNH, 2011b).

The open water habitat feature at Loch Spynie SSSI was monitored in 2004 and found to be declining due to an increase in nutrient levels in the loch and loss of vegetation structure. Water quality was generally poor, coloured green-brown, with high levels of phosphorus. The loch's unusual water chemistry makes it vulnerable to enrichment, particularly from phosphates. The inflow burn drains an area of intensively farmed agricultural land and further residential/industrial development of the catchment could adversely affect the site (SNH, 2011b). Macrophyte growth has been found to be very dense throughout the water body (SNH, n.d.).

Monitoring in 2001 of the fen and fen-meadow to the northeast of the loch has highlighted the need for grazing or scrub control in the northeast of the site. Elsewhere, the wet woodland was not encroaching onto the adjacent fen but is regenerating under its own canopy (SNH, 2011b).

Royal Haskoning undertook an assessment on the management of eight standing water features in unfavourable condition due to nutrient enrichment on behalf of SNH (SNH, n.d.), with water sampling undertaken in February, March, July and September 2010. The study included Loch Spynie and physico-chemical results are summarised as follows:

- pH in Loch Spynie ranged from 7.93 in spring to 9.04 in summer, with a mean of 8.24.

- High alkalinities were recorded in the loch ranging from 1.02 meq/l in summer to 2.39 meq/l in spring with a mean of 1.81 meq/l.

- The total phosphorus (as P) concentration for Loch Spynie ranged from 0.041mg/l (summer); -0.098mg/l (late summer) with a mean of 0.065mg/l. Soluble reactive phosphorus (SRP) in the loch accounted for a very small proportion of total phosphorus in all samples (generally <0.01mg/l). Total phosphorus in the main inflow ranged between 0.057 – 0.079 mg/l (highest in summer).

- Nitrate (as N) in the loch ranged from 0.017mg/l in late summer to 1.98mg/l in spring with a mean of 0.67mg/l (no results for winter).

In SNH (n.d.) the nutrient budget at Loch Spynie was estimated based on actual phosphorus concentrations. A model was also used to predict the budget. The budget based on actual concentrations was approximately 35% of the modelled budget. This indicates that nutrient export rates based on land use in the catchment are considerably lower than expected. Despite that more than half of the catchment is taken up by improved grassland and horticulture, land uses with characteristically high export rates. This could suggest that some improvements in land use or reduction in point sources may have occurred in this catchment. It should be noted that the site lies within Moray, Aberdeenshire / Bank and Buchan Nitrate Vulnerable Zone (NVZ) designated in 2002. A legally binding Action Programme is therefore in place on farms within the catchment, controlling the movement, storage and application of manures and chemical fertilisers in order to reduce the amount of nitrate entering groundwaters.

Nutrient budgeting has also indicated that twice as much phosphorus may come from the large bird assemblage as from the main inflow. Input from surface runoff would be 8% and input from nearby septic tanks was considered to be minor. The main catchment land uses exporting nutrients to the loch would be horticulture (non-rotational & arable), followed by suburban/rural development and improved grassland.

SNH (n.d.) also indicated that Loch Spynie is within the expected range of total phosphorus for its eutrophic designation, according to the Organisation for Economic Co-operation and Development (OECD,1982). However, in relation to a standing water feature in Scotland, total phosphorus levels would not be expected to be higher than 0.05 mg/l and targets would be more likely to be set below this level. The range of total phosphorus values in the water column of the loch was 0.041 to 0.098 mg/l and the variability in these levels suggested an unstable system. Chlorophyll values were elevated and the concentration of dissolved inorganic nitrogen measured in water from the loch was also very high for a Scottish body of standing water. Also, work undertaken in relation to Biodiversity Action Plan habitats Mesotrophic Lakes and Eutrophic Standing Waters included hindcasting of water column total phosphorus concentration in Loch Spynie, and produced an estimate of an 'original' total phosphorus level of 0.0288 mg/l (SNH, n.d.). Despite possible model errors, this figure may be used for illustrative purposes and would indicate that the loch is naturally eutrophic but also artificially enriched. Macrophyte data from the Site Condition Management (SCM) undertaken in 2009 assessed in SNH (n.d.) would indicate that there has been an adverse impact on the loch.

Total phosphorus concentrations were indicated to be high enough to support a switch from macrophyte to phytoplankton dominance, and so the loch may be in a vulnerable state. The presence of a large population of grazing birds gives cause for concern as they provide a potential switching mechanism. Analysis showed the spring phytoplankton to be dominated by chlorophyta and by diatoms, and cryptophyta in late summer. Cyanobacteria may therefore not be at nuisance levels in the loch and there was no anecdotal evidence of cyanobacterial blooms. It should however be noted that dominance of green algae may be indicative of a greater degree of enrichment than cyanobacterial blooms.

The overall conclusion was therefore that the loch is enriched and may be vulnerable to further adverse impacts, so should be monitored closely over the coming years. Potential measures for reducing nutrient loadings to the loch should be investigated.

Given that the bird population is likely to be valued by the local human population, as well as being of high conservation importance (SSSI designation including breeding bird assemblage and SPA and Ramsar designation for birds at the site), any measures related to the bird population may be difficult to implement. In addition to the legally binding Action Programme introduced under NVZ legislation, consideration should be given to whether the management measures in the catchment are sufficient to reduce loadings of phosphorus in

addition to those of nitrogen. As nutrient loadings from improved grassland and horticulture have been found to be high elsewhere, the present efficacy of control measures associated with these land-uses should be examined (SNH, n.d.).

5.2 Catchment Walkover

From the second site visit post-receipt of the analytical results, the following observations of the surrounding catchment were made:

- With exception of the area directly surrounding Spynie Palace, the site was free of litter. No visible pollution sources were observed within the site boundary. Plastic wrappers and bottles left in the immediate vicinity of Spynie Palace.

- A disused railway runs through the site and is used as an access track with dog walkers observed at the time of the second visit.

- No discernible algal blooms were observed, however this is not atypical given the time of year the site visits were undertaken.

- The site comprises large areas of *Phragmites spp* throughout the entire site area and they are encroaching on the central open water body. The loch is very shallow and no evidence of accelerated sediment transport into the loch was observed from any of the catchment locations/features assessed.

- Intensive agriculture was observed in the catchment to the south of the site. Woodland is present in the eastern and southern areas of the site.

- The site catchment includes a residential area at the northern end of the city of Elgin.

- Man-made drainage networks were observed to the west and northwest of the site.

- A large sand and gravel quarry is shown on Ordnance Survey (OS) maps to the northeast of the site. These activities could potentially have altered the hydrology and potentially the water quality entering the catchment over time. No direct observations were made of these activities.

- Potential evidence of wild boar was observed at the north eastern corner of the site.

5.3 Summary

The following table provides a summary the key site features which were observed during the site visits undertaken as part of the initial study.

A mapped summary of the perceived catchment pressures is detailed in Figure 5.1 (see Annex 1).

Table 5.1: Summary of key observations

Activities	Observations
Fencing	Eastern boundary of the site is fenced, between the farmland and the loch. The completeness and condition was not further assessed as part of scoping.
Fishing	No fishing is understood to regularly take place at the site.
Grazing	Fields adjacent to eastern boundary grazed by cattle. Intensive agriculture (arable land) undertaken to the south of the site.
Monitoring	Water quality monitoring was undertaken by Royal Haskoning on behalf of SNH in 2010 (SNH, n.d.). A loch survey was undertaken by SNH in 1996. Condition monitoring was carried in 2004 and 2009 for the loch feature, in 2002 for the wet woodland feature and 2001 for the fen features.
Public Access	A disused railway runs through the middle of the site. This is used as an access track and for recreational purposes by the local community, *e.g.* dog walking, cycling, horse riding.
Shooting	Pheasant shooting and duck flighting occur on site.
Point Pollution Sources	None observed within the SSSI boundary but some located within the wider catchment as noted below.
Properties in Catchment	Spynie Palace Cottage and Spynie House are located in close proximity of the site. Scarffbanks Farm is located to the east of the loch. Given the rural nature of the catchment it is assumed that these properties will likely be served by septic tanks. Silage pits/ slurry tanks are present at farms, which depending on their maintenance could also lead to nutrient enrichment.
Unusual, Distinctive or Atypical Features	The large population of breeding birds at the site is a significant source of nutrients at the site. The northern end of Elgin is within the site catchment boundary and is considered to be a likely input of nutrients to the site. A disused railway traverses the western boundary of the site. The A941 borders the site to the west. Spynie Castle, (a scheduled historic monument) is located in the south western corner of the site. A quarry deemed to be operational is located to the east of the site. The Spynie Canal located along the northern boundary of the site, is dredged regularly. Dredged materials could leach nutrients to the site if placed in unsuitable locations within catchment boundary. Potential presence of wild boar.

6. INTERPRETATION OF RESULTS

The following assessment is based on the field tests and laboratory analytical results only.

6.1 General Summary

Two sampling visits were undertaken. Three samples were collected on the initial visit (LS1-LS3) and 10 samples collected on the subsequent site visit (Spy01-Spy10). For the purposes of interpretation the dataset has been appraised as a single entity.

Nutrient levels in surface water samples were quite variable across the site with the highest total phosphorus and nitrogen levels recorded in groundwater. This variability is likely related to varying hydro-geochemical conditions (i.e. samples taken from groundwater, open water and ditches with little or no flow) and the complex history of the site (e.g. much larger wetland system and loch in the past; impermeable embankments put in place affecting local groundwater table). Relatively elevated levels of phosphate and low levels of nitrogen were encountered in the loch and at the loch outflow. Results for the loch and the main inflow were typically consistent with those obtained in SNH (n.d.) for pH and nitrate, however, levels of total phosphorus in surface water generally exceeded the ranges recorded in 2010. Nitrate, total nitrogen and phosphate levels were relatively elevated at the main inflow (Spy01) during the second site visit.

pH was typically uniform across the monitoring locations ranging from circumneutral to alkaline for surface water and slightly acidic for groundwater. Dissolved oxygen levels were variable across the site with groundwater, as expected, typically recording lower levels than surface water. The lowest dissolved oxygen level was recorded at LS2 (main inflow) during the first site visit and may be attributable to decaying vegetation or stagnant standing water.

The highest electrical conductivity as well as the highest sodium level was recorded at Spy05 to the east of the A941. This may suggest influence of road runoff, with road salt in particular impacting in this area of the site.

The nutrient levels (nitrogen and phosphorus) were typically higher in surface water samples in the west of the site at Spy01 and LS2 in the main inflow. Spy05 and Spy08 (groundwater) recorded elevated nitrogen and phosphate when compared to the other groundwater samples. This may be due to historical accumulation of nutrients (Spy08 is located in the old loch bed) and/or effects of agricultural practices (Spy05 located within drainage network linked with adjacent fields).

The total phosphorus concentration in the loch sample (Spy03) was 0.4mg/l, exceeding the OECD and Scottish targets presented in section 5.1 of 0.1mg/l or 0.05mg/l for eutrophic water bodies. This confirms enriched conditions. The concentration of phosphate in the loch was also high at 0.27mg/l. It should be noted however that the concentrations of total phosphorus and phosphate recorded at the main outflow of the loch (Spy09) were both ~0.1mg/l, suggesting that the loch sample might have been influenced by local shore conditions (*e.g.* biological processes in area of dense aquatic vegetation affecting biochemical conditions and nutrient concentrations). Nitrogen concentration in the loch was low with total nitrogen at <1mg/l and nitrate at 0.3mg/l. Levels in the outflow however were higher in this case with total nitrogen at 4mg/l and nitrate at 2.3mg/l. Again, this could be due to local shore conditions.

Ammonia was generally higher in groundwater samples, reflecting typical hydro-geochemical conditions for groundwater.

Iron was recorded highest within groundwater samples as would be expected as its solubility increases with lower pH and low oxygen concentrations.

In soils, the highest extractable nitrogen, nitrate and ammonia were all recorded in SPY10A within the root zone sample. This sample point is located to the east of the site. Elevated nutrients were also recorded within the groundwater at this site and may indicate the migration of nutrients into the eastern section of the wetland from surface drainage from the agricultural lands to the east.

Calcium levels were noted to be higher in the west of the site. High extractable phosphorus was recorded in the western section of the wetlands (Spy02 and Spy05), which could be due to accumulation of calcium phosphate minerals in this area. This is likely due to natural sources but could have been augmented by agricultural sources in the catchment. High phosphorus was recorded in the groundwater in this area further indicating that there is likely an influence from the main inflow at SP02 and agricultural practices to the southwest of the site.

6.2 Atypical Results

A summary of results considered to be atypical from the dataset are detailed below:

- Elevated phosphate, nitrate and ammonia within groundwater in Spy02, Spy05 and Spy08, in the wetland areas to the west and east of the loch respectively, may be attributed to current and historical drainage from the land uses to the east of the site and/or historical accumulation in the loch sediments, but further assessment would be required to establish if this is the case.

- High extractable and total nitrogen levels were recorded in Spy10A, the root zone sample. This suggests local accumulation of nutrients or influence from the adjacent field.

- The high calcium result in sample Spy02A (root zone) and high sodium in Spy02B (below root zone) may be attributed to the underlying geology of the site. Although the figures are high compared to other locations they are not deemed to be elevated.

6.3 Additional Considerations

No records or reports (anecdotal or otherwise) of algal blooms or fishing records were identified or reviewed during this study. Information of this nature could be of value in understanding long-term trends and changes within the site.

SEPA provided water quality data for the Spynie Canal at Spynie Palace (NJ 22605 66418; immediately upstream of the site) and at Oakenhead (NJ 24574 68771; ~2km downstream of the loch). Samples at these locations were taken on a monthly basis and data is available from January 2009 to December 2010 for Spynie Palace and January 2009 to July 2010 for Oakenhead. The loch discharge is considered to be a main inflow to the canal between these sampling locations. Relevant information derived from this data can be summarised as follows:

- pH levels in the canal both upstream and downstream of the site were alkaline (~8 in average) and there was not a significant difference in levels at these two locations. Levels were consistent with those measured in surface water on the site for this study.

- Electrical conductivity levels were generally higher in the canal at Oakenhead (mean concentration: 0.865mg/l) than at Spynie Bridge (mean concentration: 0.803mg/l), which reflects a relative mineral enrichment. Levels recorded were in general consistent with those measured at the site for this study with the exception of Spy 10, which was significantly lower, suggesting greater influence from rainwater at this location.

- Dissolved oxygen levels were generally high in the canal, with higher levels recorded at Oakenhead and levels <6mg/l recorded in summer (particularly at Spynie Palace).

- Mean nitrate concentrations were 2.24mg/l at Spynie Palace and 2.72mg/l at Oakenhead, showing an enrichment moving downstream. Lowest levels were generally recorded in summer and highest in winter and spring. Levels recorded at the loch outflow for this study were consistent with these levels.

- Mean total phosphorus concentrations were 0.074mg/l at Spynie Palace and 0.070mg/l at Oakenhead, showing a very slight decrease moving downstream. No clear temporal trends were observed. Levels recorded at the loch outflow for this study were higher than these mean levels but consistent with overall concentration ranges observed.

7. CONCLUSIONS

The analytical results and desktop study showed a trend of elevated nutrients within the site, confirming eutrophic conditions in Loch Spynie and surrounding wet woodland. This is likely a consequence of natural conditions (geology and soils) combined with nutrient input from the bird assemblage at the loch and, to a lesser extent, agricultural activities and suburban land use in the catchment.

The open water habitat feature at Loch Spynie SSSI was found to be declining when monitored in 2004 due to an increase in nutrient levels in the loch and loss of vegetation structure, whereas the wetland feature was in favourable maintained condition in 2002. The loch is shallow throughout (~1m deep) and small (17ha), but has a relatively large catchment area (~6.5km^2). There are wet woodland areas to the west and east of the loch.

The hydrology of the area is modified and complex, as the loch was historically part of a much larger wetland system, and was originally reclaimed from the sea. Loch levels are maintained by an artificial embankment (also impermeable) to the north; the outflow is located at the north western end and is controlled by a weir and sluice. The loch was also significantly larger in the past, extending to the north and east of its current location. A disused railway embankment (impermeable) runs between the loch and the western wetland area and the Spynie Canals forms the northern boundary of the site.

A catchment area of 7.11km^2 drains to Loch Spynie and the wet woodland to the east of the loch (in hydraulic connectivity with the loch), and a small catchment of 0.65km^2 drains to the wetland to the west of the disused railway. The larger catchment is mainly under agricultural use (primarily horticulture and improved grassland) but has also areas of forestry and includes the northern end of the city of Elgin. The main inflow to the site is a small unnamed burn which enters the loch at the southern end, with additional inflow from groundwater seepage and surface run off from adjacent farmland. The catchment of the western wetland comprises improved and rough grassland and a forestry plantation. No distinct inflow was observed in this area.

An extensive study undertaken on behalf of SNH at the loch in 2010, including water monitoring over a year at different locations to those of this study and other detailed surveys, concluded that the loch is nutrient-enriched. Total phosphorus concentrations were considered to be high enough to support a switch from macrophyte to phytoplankton dominance and hence the loch may be vulnerable to further adverse impacts. The presence of a large population of grazing birds gives cause for concern as they provide a potential switching mechanism. The 2010 report recommended that the loch should be monitored closely over the following years and potential measures for reducing nutrient loadings to the loch should be investigated.

Nutrient budgeting undertaken for the loch (and therefore the eastern wetland which is in the same catchment) as part of the aforementioned study, indicated that twice as much phosphorus may come from the large bird assemblage as via the main inflow. The main catchment land uses exporting nutrients to the main inflow would be horticulture (non-rotational and arable), followed by suburban/rural development and improved grassland. Input from surface runoff was assessed as 8% and input from nearby septic tanks was considered to be minor. This assessment also indicated that nutrient export rates based on land use in the catchment were considerably lower than expected suggesting that some improvements in land use or reduction in point sources may have occurred in this catchment. It should be noted that the site lies within Moray, Aberdeenshire / Bank and Buchan Nitrate Vulnerable Zone (NVZ) which was designated in 2002 and that a legally binding Action Programme has recently been put in place on farms within the catchment.

Nutrient levels recorded by EnviroCentre in surface water samples were generally elevated but showed variations across the site with the highest phosphate, total phosphorus and nitrogen levels recorded in groundwater both in the wet woodland areas to the west and east of the loch. This variability is likely related to varying hydro-geochemical conditions (*i.e*. samples taken from groundwater, open water and ditches with little or no flow) and the complex history of the site (*e.g.* much larger wetland system and loch in the past; impermeable embankments put in place affecting local groundwater table).

Relatively elevated levels of phosphate and low levels of nitrogen were encountered in the loch and at the loch outflow. Nitrate, total nitrogen and phosphate levels were relatively elevated at the main inflow during the second site visit. High extractable phosphorus concentration recorded in the western section of the wetland and in proximity of the main inflow could be due to historical accumulation of calcium phosphate minerals in these areas, associated with adjacent agricultural practices and nutrient inputs from the wider catchment. These results confirm that the loch and wet woodland are eutrophic but do not provide further information as to the nutrient sources. Results for the loch and the main inflow were in general consistent with those obtained in 2010 by the aforementioned study, for pH and nitrate. Levels of total phosphorus in surface water generally exceeded the ranges recorded in 2010. This could be due to variations in preceding weather conditions.

Recent water quality data provided by SEPA for the Spynie Canal at Spynie Palace (immediately upstream of the site) and at Oakenhead (~2km downstream of the loch) were in general consistent with concentrations recorded in the main loch outflow, a main inflow to the canal between these two stations. Mean nitrate concentrations showed an enrichment in the canal in the downstream location but no clear spatial trend was observed for total phosphorus.

The bird population is clearly valued by the local population as well as being of high conservation importance (SSSI designation including breeding bird assemblage and SPA and Ramsar designation for birds at the site). Therefore, any measures related to the bird population may be difficult to implement. Although pollution control measures are in place in farms as part of the NVZ action programme, as nutrient loadings from improved grassland and horticulture are typically high in Scotland, there might be scope for further improving the efficacy of control measures associated with these land uses.

8. RECOMMENDATIONS

Based on the understanding gained from the sampling exercise and catchment visits, the following recommendations are proposed:

8.1 Monitoring

i. Undertake a long-term targeted monitoring study at selected locations within the site for key nutrients – to include orthophosphate and bioavailable (extractable) nitrogen. Ideally this would be undertaken over the course of several seasons (*e.g.* for a minimum of one year). This should be compared with previous monitoring results and alongside groundwater levels, rainfall data and seasonal abnormalities to seek to further understand the nutrient dynamics taking place within the site.

ii. In conjunction with (i), assess the seasonal flow and nutrient loads of the main unnamed inflow and groundwater.

8.2 Other Commissioned Studies

iii. Undertake hydrological and hydrogeological assessment of the contributing catchment in order to further determine the quality and quantity of the source flows, including connectivity and quality of the regional aquifer.

iv. Assess the potential for raising the loch level (or deepening certain areas) and whether this would have a positive impact on water quality and particularly aquatic vegetation.

v. Undertake a detailed review of the sewerage network in the upstream (Elgin) part of the catchment.

vi. Undertake a detailed assessment into the effect of the population of birds on water quality and possible management options.

vii. Re-visit the nutrient balance when further monitoring and nutrient source data is available to confirm main nutrient sources at the site.

viii. Consider contingency measures for a potential switch from macrophyte to phytoplankton dominance and/or algal blooms such as encouraging the establishment of macrophytes and sustaining populations of filter-feeding invertebrates as well as short-term solutions including the use of straw bales, phosphorus binders (*e.g.* Phoslock) or algicides.

ix. Undertake core sampling of loch sediments to understand historic source pollution and retained nutrients. The previous study undertaken at the loch referred to other studies which may have included soil probing. Although the loch is shallow, and therefore unlikely to stratify, artificial disturbance of the sediments could result in extensive nutrient release and significantly alter the nutrient availability within the loch and plant margins. It is considered likely that there will be a significant volume of nutrient bound up in the loch sediments (notably phosphorus in varying forms) which may be being slowly released into the water column and aiding successional change.

x. Review the fish stocks and consider any potential disturbance of sediments with regards nutrient release.

xi. Undertake a detailed library review, including historical mapping and local data sources, to seek to understand historical changes to the wetland system, loch and

land use and information relating to the site, including railway, canal and embankment construction and drainage on the site and its surrounds.

8.3 Landowners

xii. Proactively engage with local landowners to understand the existing and (foreseeable) proposed changes to the immediate catchment including field usage, crop type and fertiliser/soil conditioning approaches. Consider appropriate management strategies accordingly - for example, nutrient management planning, treatment of outflows *e.g.* constructed wetlands, buffer strips, exclusion zones, routine spot monitoring, improved/repaired fencing, improved use of fertilizers, *etc*.

xiii. Review potential issues with disposal of dredged canal (and any other) sediments within the site catchment.

xiv. Proactively engage with catchment landowners to understand the historical land use practices to determine any changes which are likely to have influenced the site.

xv. Proactively engage with local authority to further assess current road drainage and consider re-directing any drainage off-site.

xvi. Review the forestry management practices undertaken within the wider catchment.

xvii. Engage with surrounding households to ensure septic tanks are adequately maintained.

8.4 External Consultations

xviii. Engage with SEPA to:

a. get a better understanding of the current NVZ action programme and discuss whether there is scope for further pollution prevention/control options regarding current regulatory controls on the use of nutrients in the catchment for agricultural purposes (especially horticulture and improved grasslands). Also contact Rural Payments and Inspections Directorate regarding this issue.

b. Obtain information on urban nutrient sources including the sewerage system and any combined sewer overflows (CSOs). Scottish Water should be contacted as well to obtain information on the latter.

From the stated conclusions and identified pressures the key actions to seek to reverse the present declining status of the site are to:

1. Undertake further monitoring at the site to further establish the nutrient regime (i, ii);
2. Revisit the nutrient balance to confirm relevance of different nutrient sources, particularly the bird assemblage and wider catchment (iii, v, vi, ix); and
3. Address the inputs to the surface water and groundwater from the bird assemblage and agricultural and urban sources within the wider catchment (vi, xii, xvii, xviii).

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ANNEX 1: FIGURES

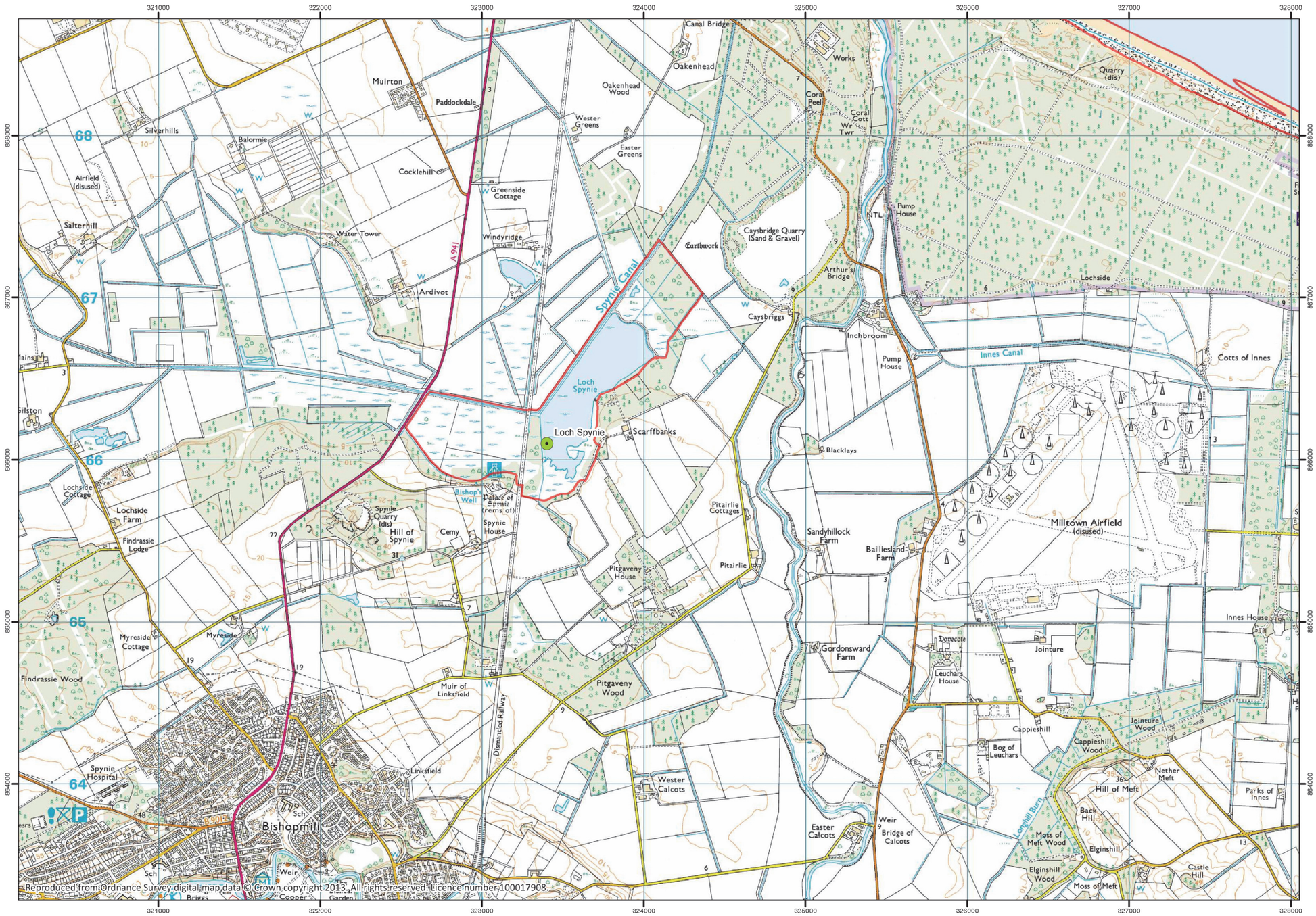


Figure 1.1: Site Location Map

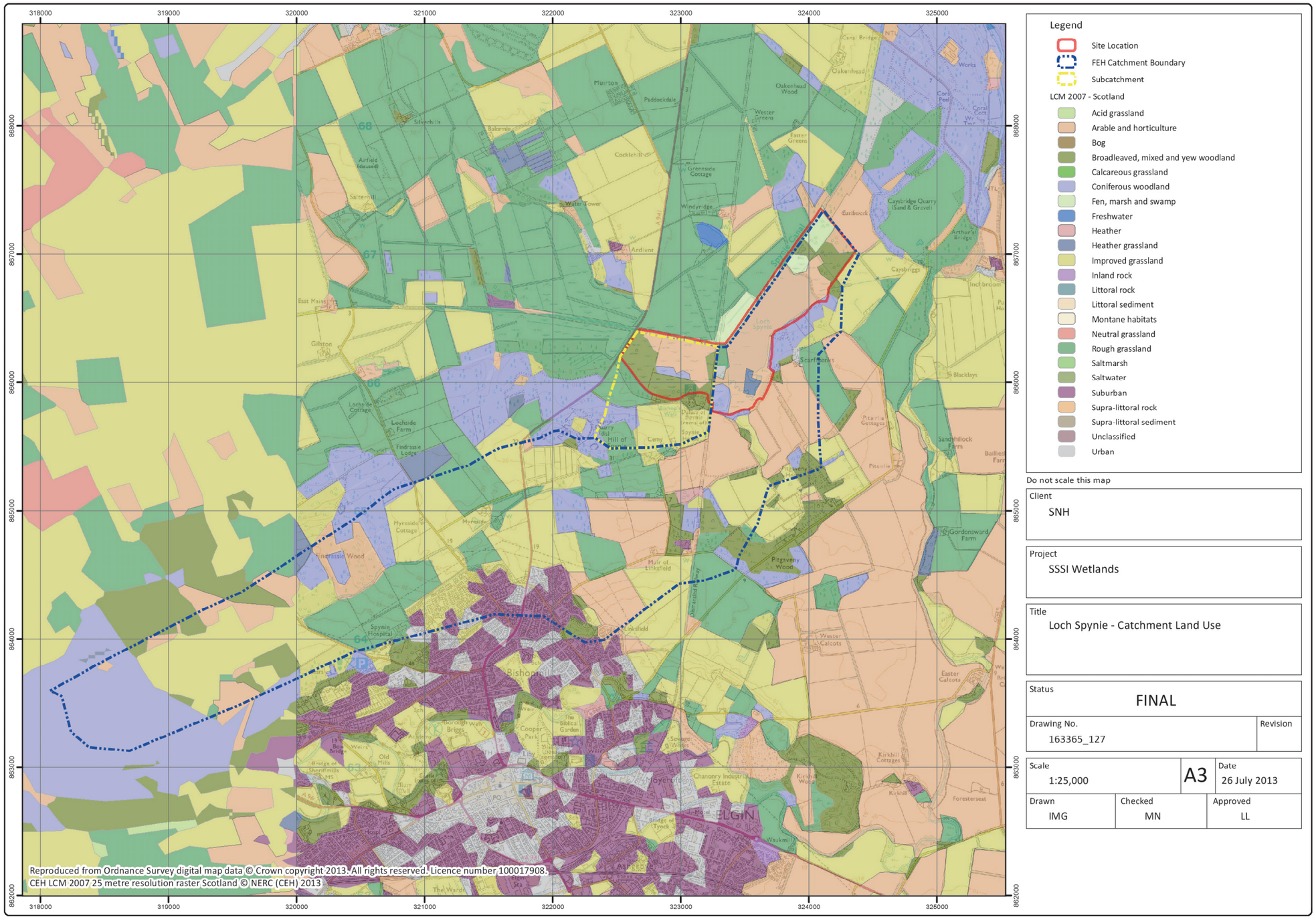


Figure 1.2: Catchment Land Use Characteristics

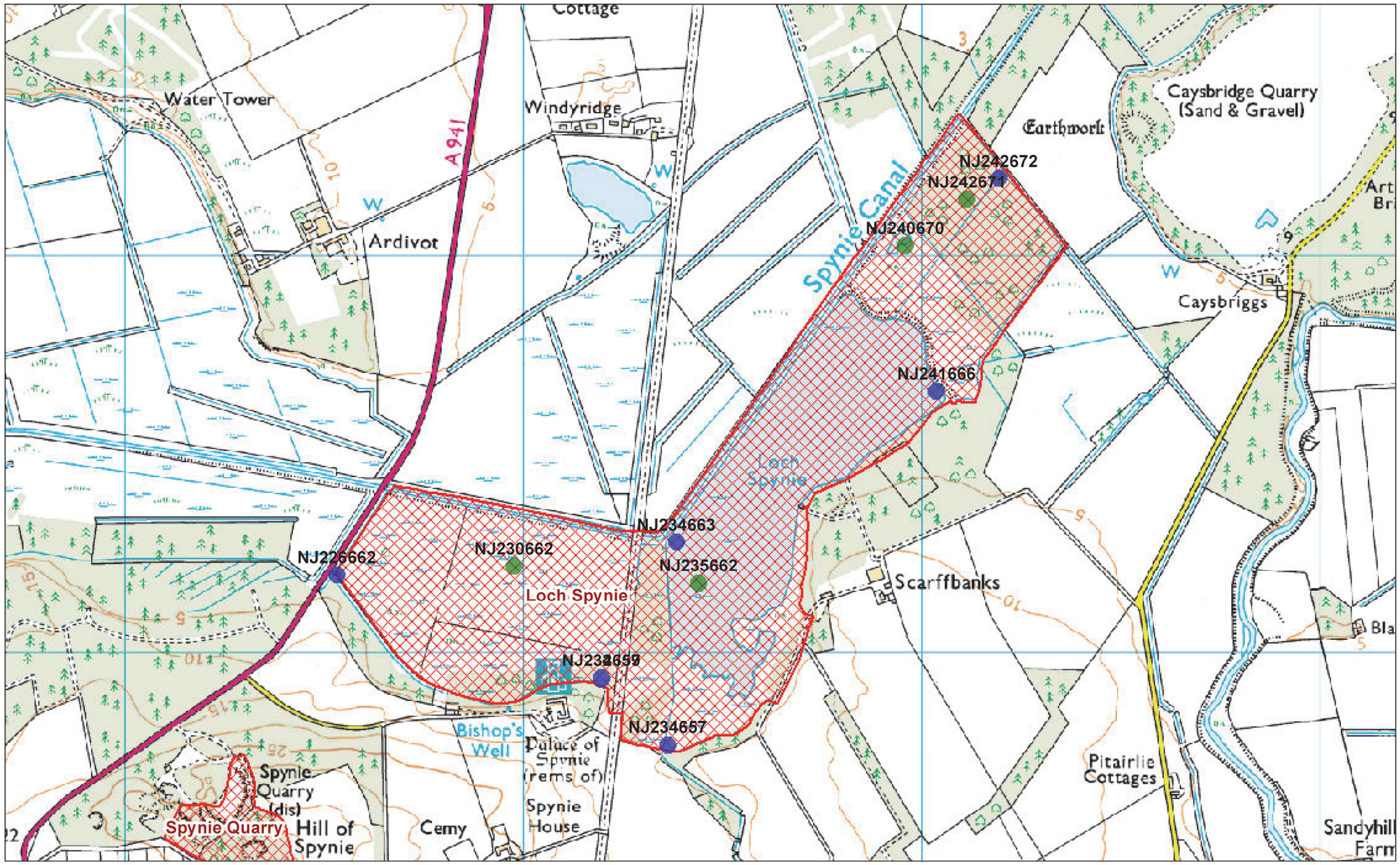
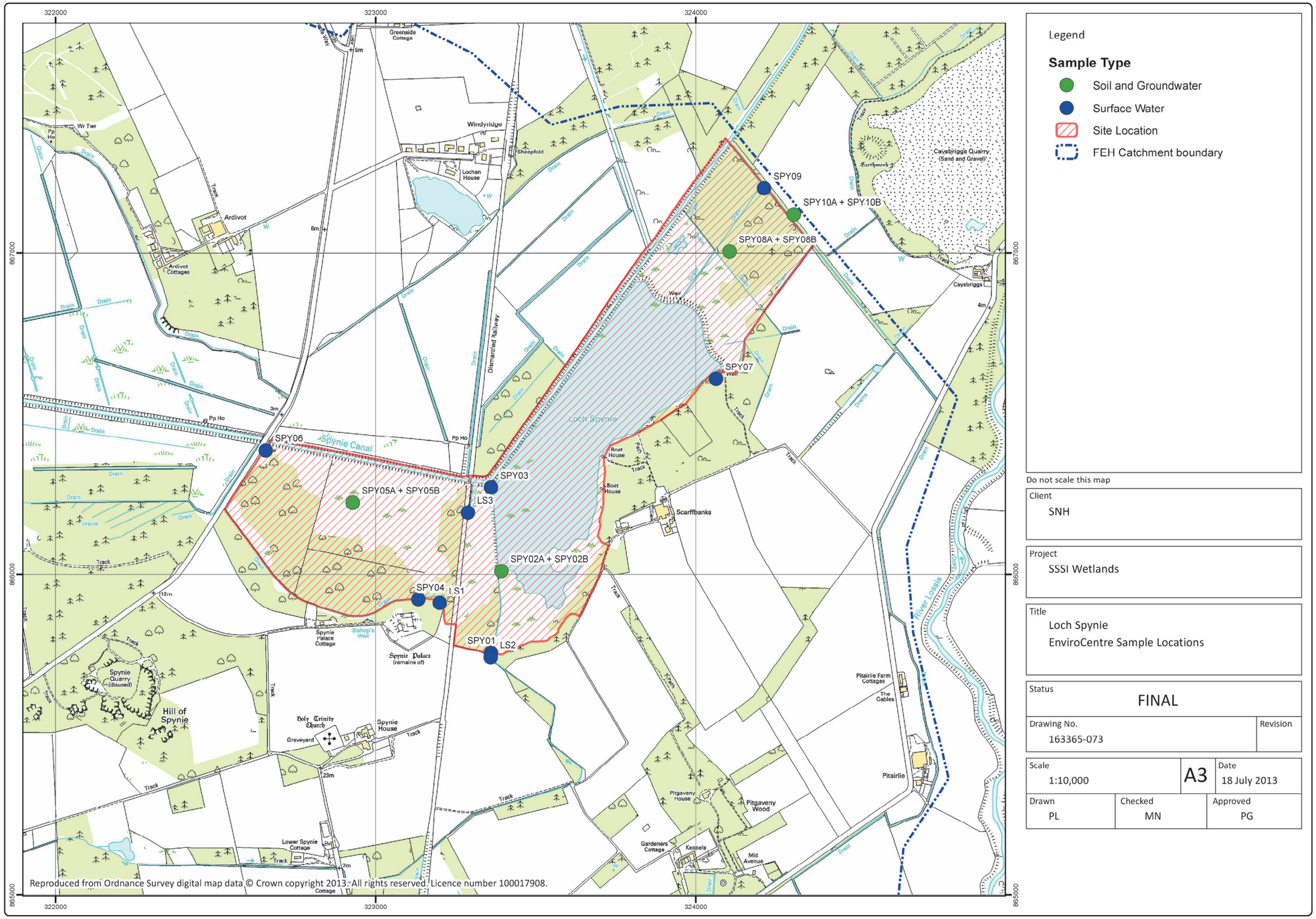


Figure 2.1: SNH Proposed Sample Location Plan



Legend

Sample Type

- Soil and Groundwater
- Surface Water
- Site Location
- FEH Catchment boundary

Do not scale this map

Client
SNH

Project
SSSI Wetlands

Title
Loch Spynie
EnviroCentre Sample Locations

Status
FINAL

Drawing No.
163365-073

Revision

Scale
1:10,000

A3

Date
18 July 2013

Drawn
PL

Checked
MN

Approved
PG

Figure 2.2: Plan of Actual Sampled Locations

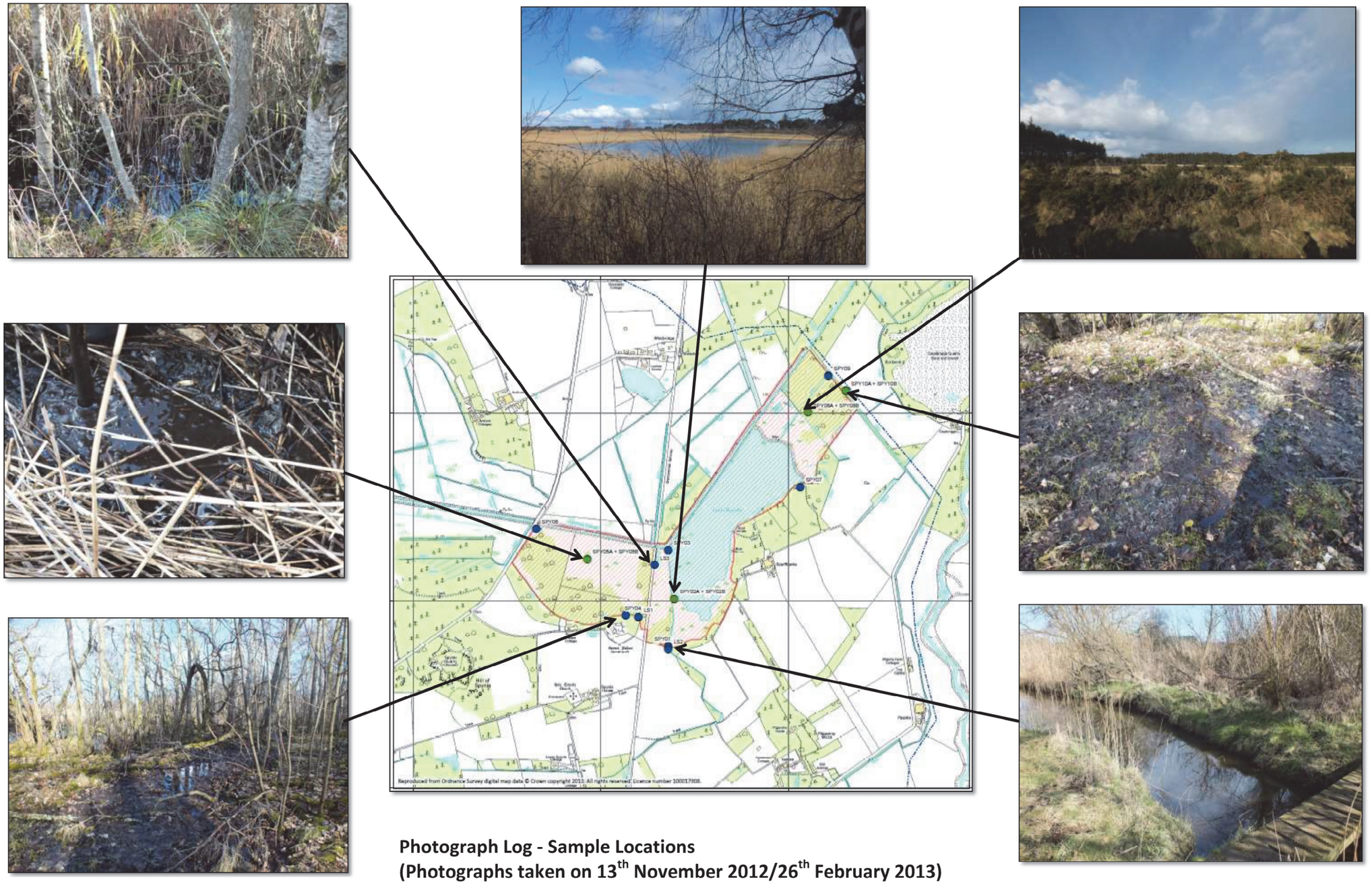


Figure 2.3: Sampling Location Photographs

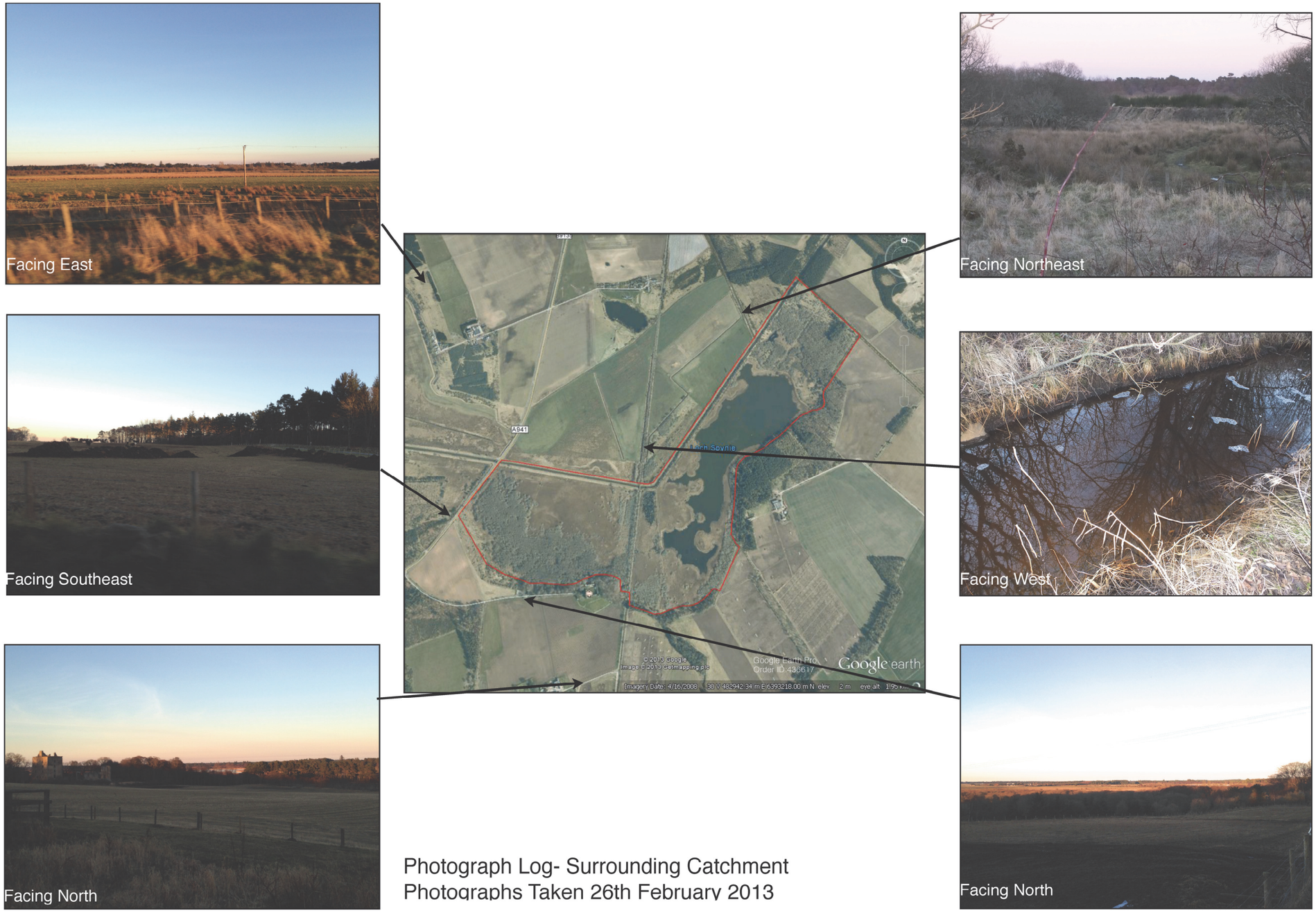
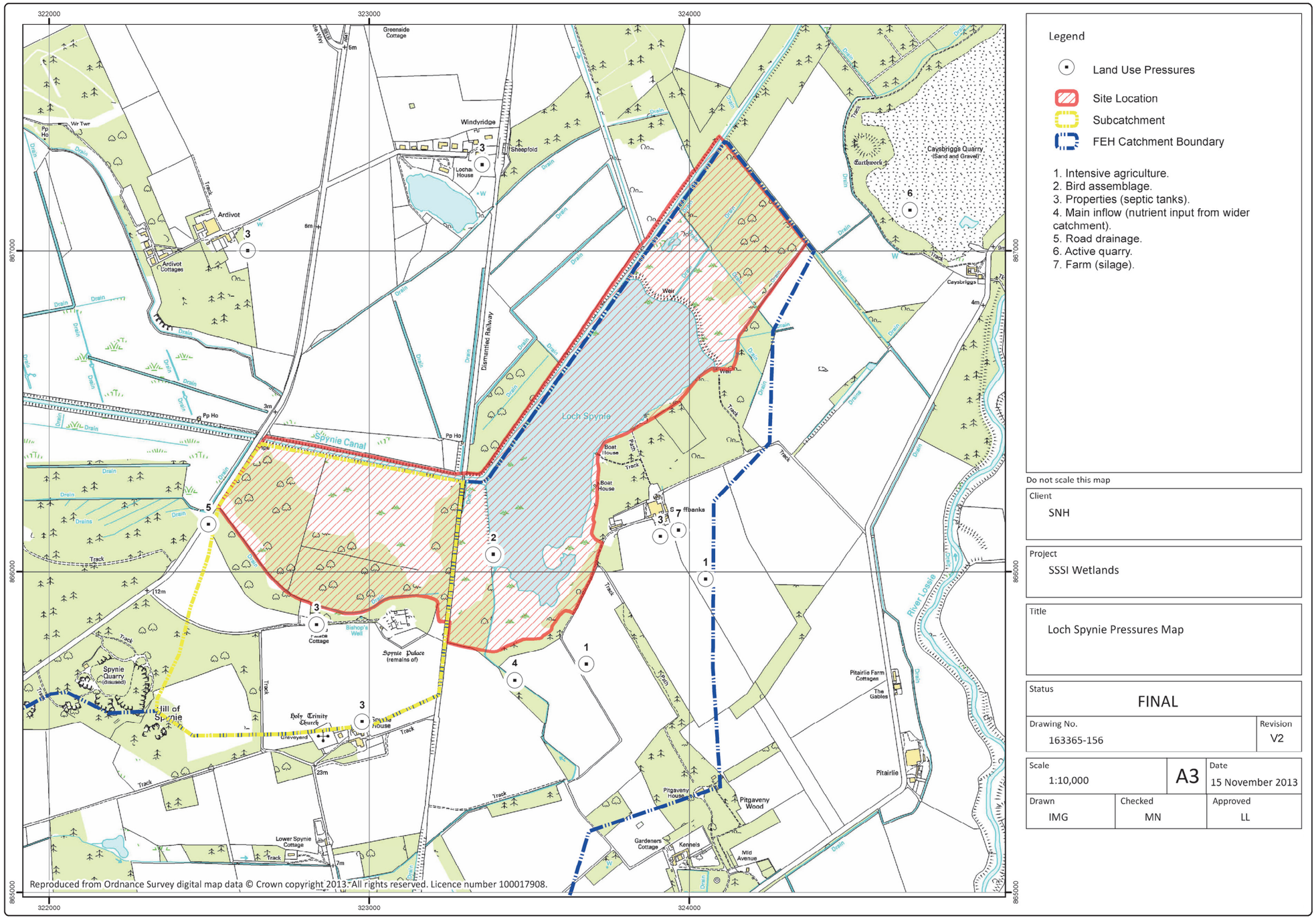


Figure 2.4: Surrounding Land Use Photographs



Legend

- Land Use Pressures
- Site Location
- Subcatchment
- FEH Catchment Boundary

1. Intensive agriculture.
2. Bird assemblage.
3. Properties (septic tanks).
4. Main inflow (nutrient input from wider catchment).
5. Road drainage.
6. Active quarry.
7. Farm (silage).

Do not scale this map

Client: SNH

Project: SSSI Wetlands

Title: Loch Spynie Pressures Map

Status: FINAL

Drawing No.: 163365-156

Revision: V2

Scale: 1:10,000

A3

Date: 15 November 2013

Drawn	Checked	Approved
IMG	MN	LL

Figure 5.1: Catchment Pressures

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