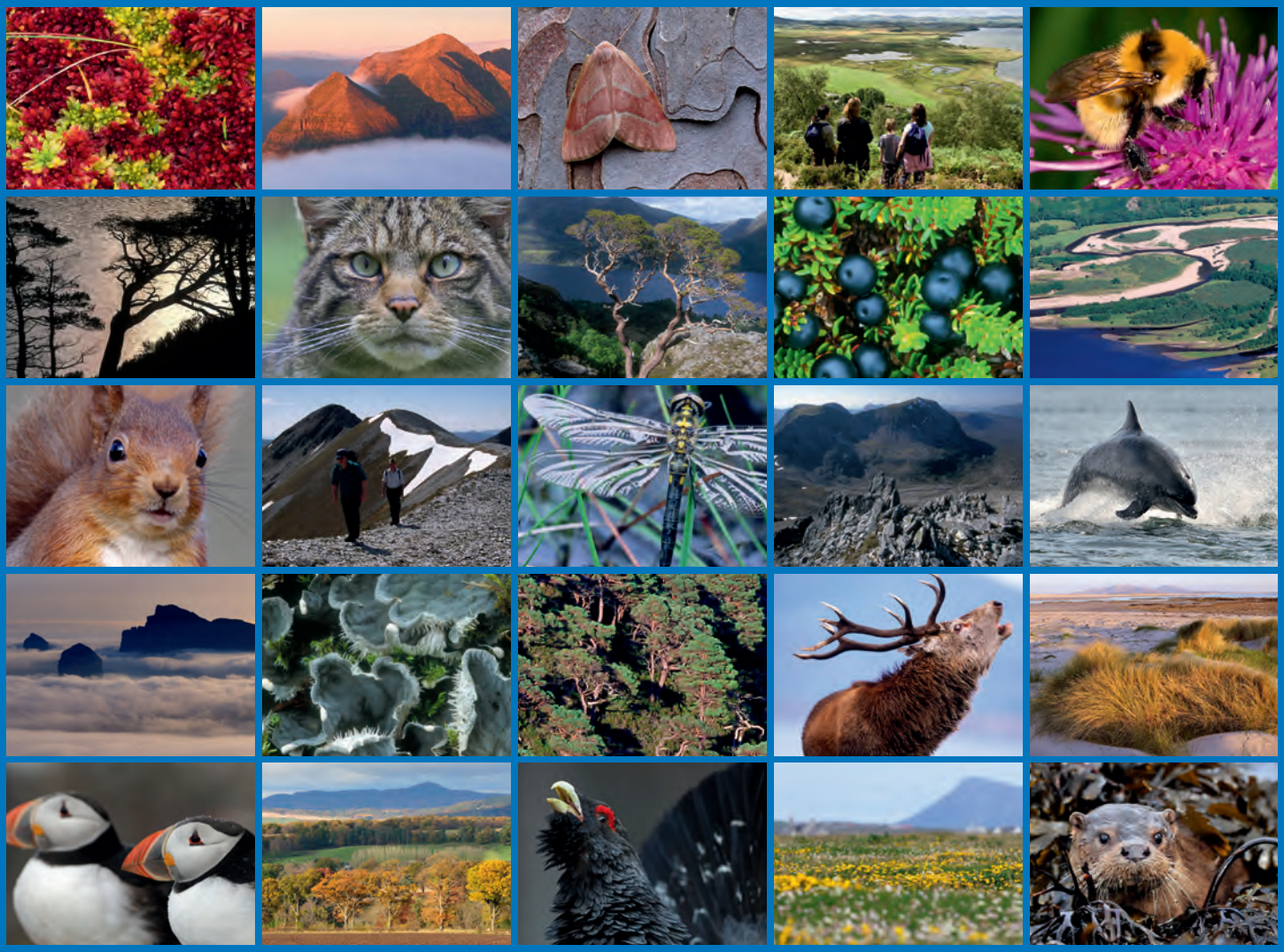
Scottish Natural Heritage
Commissioned Report No. 723

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



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COMMISSIONED REPORT

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

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COMMISSIONED REPORT

Summary

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

Commissioned Report No. 723
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

- Analytical data supported previous findings of elevated nutrient status from the surrounding historical and recent land use, particularly linked to urban and recreational use in the wider catchment. It should be noted that the sampling assessment was undertaken as a single visit and the limited scoped dataset and a lack of historical data constrain the ability to draw accurate conclusions to fully inform current site condition.
- Site walkover revealed possible additional inflows not previously identified and potential land use practices within the immediate catchment that could adversely affect the hydrology and nutrient availability within the site.
- A series of recommendations are proposed to determine the site hydrology and understand the impact of identified inflow sources. It is considered that this additional information will help further the understanding of the perceived changes taking place at the site.

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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 wetland and standing water Sites of Special Scientific Interest (SSSI).

1.1 Site Location

Duddingston Loch is located three kilometres to the east of Edinburgh city centre, to the west of the village of Duddingston. Access to the site is gained off Duddingston Road West, via a gated entrance to the Scottish Wildlife Trust (SWT) car park. See Figure 1.1 in Annex 1.

1.2 Site Description

Duddingston Loch SSSI covers an area of 25.2 hectares and is the only remaining natural freshwater loch in the City of Edinburgh. The loch is bordered along the northern and eastern perimeter by a road and by a footpath/bridleway along its southern boundary. The south east corner of the site is easily accessible with clear footpaths for carp fishing and picnic benches to provide areas of recreation.

The site has been notified a SSSI for the clearly visible transition of habitats from freshwater, through fen, to woodland. It has also been notified for its geological interest.

Duddingston Loch is a small lowland eutrophic (nutrient-rich) loch, with characteristic aquatic and fringing marshland vegetation. Extensive *Phragmites* reed beds are present around the loch and developing willow scrub and a small area of mixed deciduous woodland complete the transition from freshwater to woodland. A number of uncommon aquatic and marsh plants occur within the site, including several that are rare in a Scottish context, such us nodding bur marigold, greater spearwort, fennel, lesser water plantain, and fool's water-cress.

Although not qualifying as a notified feature for this site, the number of breeding and wintering wildfowl present on the loch is of importance within the Lothian area. The loch supports a number of breeding waterbirds, such as heron, great crested grebe, mute swan, tufted duck, mallard and coot, while birds such as the sedge warbler breed in the reed bed and associated scrub. In winter, populations of mallard, common pochard, tufted duck, teal and shoveler are present (SNH, 2010).

Drift deposits at the site consist mainly of lacustrine deposits, including clay, silt and sand, with glacial till to the north and glaciofluvial ice contact deposits comprising sand and gravel to the southeast. The majority of the site is underlain by sandstone of the Ballagan Formation with the northern part underlain by tuffs of the Arthur's Seat Volcanic Formation (British Geological Survey, n.d.).

1.3 Site Hydrology

The catchment area draining to the loch is 1.22km^2 and receives an annual average rainfall of 655mm (Centre for Ecology and Hydrology, 2009).

A spring rising at the western extent of the site feeds a minor unnamed burn which provides the main known inflow to the loch. A number of additional spring inflows are noted on the Ordnance Survey (OS) mapping. The site will also receive surface water runoff from the surrounding catchment, which encompasses the localised steep topography to the north,

Prestonfield golf course to the south, urban development to the west and residential properties within Duddingston village to the east.

A man-made drainage network consisting of a series of minor, inter-connecting channels is situated at the south-western shore of the loch. A straightened channel forms the main outflow of the site, conveying flow from the site in a south-easterly direction to the Braid Burn.

1.4 Site History

Duddingston Loch is known to have covered a larger area in prehistoric times. Its reduced size is likely to have been a result of drainage, and historical accumulation of silt and organic matter.

Records suggest that there may have been a Bronze Age settlement located here. In the late 17th century work was carried out to enrich the land by the margins of the loch, and in the latter part of the 18th century the loch was dredged for marl (a calcium-rich clay) to improve surrounding agricultural land. Weavers are known to have used the reeds at the west end of the loch to supply their homes with thatch.

During the 18th century the loch tended to freeze over in winter allowing skating and other sports to take place – with the game of curling thought to have originated at the loch. Duddingston was also once an important site for shooting before it became part of the Royal Park in 1923. Boating was also permitted until its notification as a bird reserve in 1925.

After the loch was designated as a Bird Sanctuary in 1925, management was conducted by the Bird Sanctuary Committee, appointed by the First Commissioner of Works. This continued until 1967 and whilst limited work was carried out between the years 1940-1950 due to World War II, management activities included habitat creation, habitat maintenance and protection, control of 'pest' bird species, survey work and the building of the Sanctuary and Curling Pond hide. In 1963, 13 greylag geese were introduced from a feral flock in North Fife, probably originating from Western Isles stock. Carp were introduced to the loch by anglers and appear to have established a thriving population.

In 1967, the Ministry of Public Buildings and Works agreed to the Scottish Wildlife Trust (SWT) becoming their advisors on wildlife matters concerning Holyrood Park, including the loch. In 1971, SWT took over the management of the loch and the adjacent Bawsinch woodland. Management aimed to protect the sanctuary, enhance grazing for waterfowl, create new habitats for wildlife and to provide opportunities for wildlife education (SNH, 2010).

1.5 Recent Site Management Practices

A range of management work has been carried out over the years by SWT and key aspects of this are summarised as follows. Two ponds were constructed in the reedbeds in 1967. In 1985, the western reedbed was divided by channels to create new reedbed edges and 30 islands, to benefit the birds and fish. There has also been routine clearing of the loch outflow to minimise flooding and to help counteract high phosphorus levels by flushing the loch.

In the woodland, south of the loch, some diseased elm and non-native species have been removed. The loch and surrounding reedbeds are managed as part of the Bawsinch SWT Wildlife Reserve, in accordance with their Management Plan. There is a bird hide but this is only accessible to keyholders who have access to the Bawsinch part of the SWT reserve, lying to the south. SWT volunteers occasionally lead guided walks around the reserve. The north shore of the loch was reinforced in 1996 with the installation of a stone ramp.

Light seasonal grazing (winter/spring) with Highland cattle was introduced in 1997 at Wells o' Wearie, a field in the west part of the SSSI, to try and reduce rank grass and increase the floral diversity of the grassland.

A new pond was created at Wells o' Wearie in 1997, by Historic Scotland, and pillwort, a nationally rare aquatic plant, was introduced to this pond shortly after its creation. Pillwort had previously been recorded in the Duddingston Loch area but had become extinct due to loss of suitable habitat, as disturbed, shallow margins of ponds or lochs are required. This reintroduction does not appear to have been successful, with pillwort so far having failed to re-establish itself at this location (SNH, 2010).

2. METHODOLOGY

The following sections outline the approach undertake 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 meeting was also used to provide an insight into any health and safety constraints not readily apparent from the site maps.

Historic Scotland, the owner of the site, was notified of the planned site visit a week before the proposed visiting date. A consent had to be obtained for accessing the site which resulted in longer lead in times. Landowner details are provided in Annex 2.

2.2 Site Attendance

The site was accessed and samples collected over a one day period – termed Visit 1. A follow up visit to the wider catchment – Visit 2 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 below shows site conditions on the day of each visit

Table 2.1: Site Conditions

Duddingston Loch	Date of Visit	Weather Conditions	Grid References
Visit 1	29 November 2012	Clear, cold, sunny	NT 281724
Visit 2	27 February 2013	Clear, cold, sunny	NT 281724

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 suitably to access such before Visit 1. Due to certain access 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 fieldwork:

- Handheld Global Positioning System (GPS) unit 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 completed 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 accessing 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 rigorously 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 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);
- N Species – total nitrogen, nitrate and ammonium;
- P 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 and phosphorus; 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 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 2.5 in Annex 1). This process utilised the Flood Estimation Handbook (Centre for Ecology and Hydrology, 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 a single visit. Whilst this afforded consistency for the samples collected, 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 1.4) 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 loch 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 the initial site visit (Visit 1) 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.

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

4.1 Water Quality Field 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	Salinity (psu)	DO (%)	DO (ppm)	ORP (mV)	EC (mS/cm)	General Field Observations
DL01	NT 21849	72587	4.47	6.20	0.24	76.7	9.65	298	0.509	Surface water - clear with fine suspended solids; no odour
DL02	NT 28413	72549	4.55	6.02	0.24	80.8	10.52	298	0.519	Surface water - clear with fine suspended solids; no odour
DL03	NT 28558	72486	4.06	5.85	0	20.9	2.64	6	0.001	Groundwater - dark brown with significant suspended solids; strong organic (sulphur) odour
DL04	NT 28247	72306	3.70	6.19	0.25	47.1	8.49	21	0.540	Groundwater - dark brown with significant suspended solids; strong organic (sulphur) odour
DL05	NT 28390	72369	4.11	5.86	0.65	20.4	2.87	114	1.330	Groundwater - dark brown with significant (large sized) suspended solids; slight organic (sulphur) odour
DL06	NT 28403	72202	4.19	6.06	0.28	71.4	9.13	23	0.590	Surface water - clear with large sized suspended solids; no odour
DL07	NT 28485	72139	3.82	6.03	0.27	75.0	9.86	27	0.573	Surface water - clear with some fine suspended solids; no odour
DL08	NT 27759	72331	3.75	6.02	0.031	85.9	15.49	77	0.660	Surface water - clear with fine suspended solids; no odour

Red figures denote samples that are out with typical ranges for the observed dataset

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 Results

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)
DL01	NT 21849	72587	SW (OW)	45	9	15	<0.01	<0.01	4.6	0.06	<0.1	4
DL02	NT 28413	72549	SW (OW)	47	10	22	<0.01	<0.01	<0.2	0.05	<0.1	1
DL03	NT 28558	72486	GW	65	10	225	16.30	0.20	<0.2	0.07	0.3	3
DL04	NT 28259	72309	GW	70	21	40	86.40	0.40	<0.2	0.05	4.6	1
DL05	NT 28390	72369	GW	112	38	98	220	0.70	<0.2	0.05	10	3
DL06	NT 28403	72202	SW (OW)	46	10	26	0.37	<0.01	<0.2	0.05	0.4	1
DL07	NT 28485	72139	SW (O)	54	12	24	0.07	<0.01	<0.2	0.04	0.2	1
DL08	NT 27759	72331	SW (I)	86	19	29	0.07	<0.01	0.7	0.04	<0.1	2

+ Surface water samples are designated either inflow (I), outflow (O) or open water (OW)
Red figures denote 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 (%)	Extrac-table P (mg/l)
DL03A	NT 28558	72486	High organic, wet black sludge	0.6	6320	3360	1740	1140	80.5	<0.8	<0.2	1.32	8.52
DL03B	NT 28558	72486	High organic, wet black sludge	0.5	3860	1660	511	646	57.6	0.9	0.4	0.55	4.28
DL04A	NT 28259	72309	High organic, wet black sludge	0.9	9130	4700	1320	1670	89.2	<1.1	<0.2	1.31	6.29
DL04B	NT 28259	72309	High organic, wet black sludge	4.3	3920	3830	958	1090	57.6	<4.5	<0.2	0.32	2.99
DL05A	NT 28390	72369	High organic, wet black sludge	0.7	3230	1220	902	350	79.6	<0.9	<0.2	0.83	7.57
DL05B	NT 28390	72369	Thin soil with signif. gravels	0.6	1520	2170	235	826	22.1	0.8	0.2	0.07	<2.0

** 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.
Differences in levels of detection for Total N and Nitrate were due to dilution factor used.

5. SITE OBSERVATIONS

To enhance the understanding of Duddingston Loch and the surrounding area, preliminary research was undertaken and complemented with a second 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, 2010) records 'Objectives for Management' of:

1. Maintaining access to and visibility of the geological feature by ensuring that it is not obscured by vegetation;
2. Improving the condition of the open water and transition open fen features by decreasing phosphorus levels, via maintenance of the outflow ditch and a reduction in nutrient inputs; and
3. Improving the condition of the transition open fen feature through appropriate habitat works, including reed cutting and removal of trees and other invasive non-native species.

The eutrophic loch and transition open water fen features are in unfavourable declining and recovering status respectively. The geological feature is in favourable condition and it remains intact and visible; however, vegetation control may be required in the future.

Information provided by SNH (SNH, n.d.) states that total phosphorus levels of 405.7 mg/l (N.B.: more likely to be 0.4057 mg/l) were recorded, which is an excessively high level for a eutrophic loch. However, low confidence should be attached to this datum as it is based upon a single sample.

Current issues and proposed management at the site as described in SNH documents (SNH, 2010 and n.d.) can be summarised as follows:

Succession is naturally occurring within the site. Woodland is gradually encroaching onto the reedbed. SWT aim to prevent this by removing trees from the reedbeds. In the longer term, it is considered that water management or reedbed management will be required, with reed cutting being the preferred option. Open water within ponds is reducing due to the formation of marsh. The ponds are maintained through periodic clearance of aquatic plants, and managed to show all stages of succession from water to marsh. Some parts of the marsh are succumbing to reedbed development and regular cutting of reeds may be necessary in these parts. Monitoring of the reedbed and marsh areas will be carried out by SWT.

Eutrophication: the loch is prone to severe eutrophication in some summer months and algal blooms have occurred in the past. Phosphorus levels were higher than expected in the loch. It is likely that the waterbirds' faeces add to nutrient levels, as do carp, which stir up sediment releasing stored nutrients. Fertilisers added to nearby golf courses may also be causing enrichment. Regular clearance of the outflow ditch and also the incisions in the reedbeds will increase the flushing rate of the loch and are expected to prevent excess nutrients and algal blooms.

Invasive non-native species: exotic species are invading in areas but are difficult to remove. Creeping dogwood, planted around 1926, has become particularly abundant and is invading the reedbeds. Control of snowberry is on-going. The introduced carp are thought to be thriving at the expense of native fish species and it has been suggested that they are also causing detrimental changes to the aquatic vegetation communities of the loch.

Pond maintenance: the Wells o' Wearie pond constructed in 1997 is very overgrown and the introduced pillwort is not doing well, due to competition from other plants. It has been suggested that limited winter grazing and constant water levels of the pond are not providing enough disturbance to enable the plants' survival. The large population of feral greylag geese which graze the surrounding margins has the potential to be a problem through associated nutrient input and/or excessive poaching.

Water levels: in recent years, the level of the loch has risen due to the recent closure of nearby whisky distilleries which used to utilise the aquifers leading into the loch - estimates have been made at a rise of 40mm (SNH 2010).

The 2009 SCM assessment of the transition open fen feature found it to be in unfavourable (recovering) condition, primarily due to the encroachment of woodland into areas which were previously swamp habitats. A further reason for the decline in condition is that the composition of the plant communities has changed and key indicator plant species are no longer present (SNH, 2009).

The 2004 site condition monitoring (SCM) assessment of the loch found it to be in unfavourable condition for a number of reasons. Water sampling found there to be excessively high levels of phosphorus, which is resulting in high frequencies of undesirable species such as fringed water-lily and extensive growths of filamentous algae. In addition, the loch does not support the required number of pondweed species, indicators of favourable condition. The high levels of nutrients are thought to be caused by the large number of water birds regularly fed by members of the public, which leads to an increase in organic matter input from faecal waste and feeding itself to a lesser extent, and/or by surface water and diffuse pollution.

5.2 Catchment Walkover

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

- The site was free of litter and no visible pollution sources were observed within the site boundary.
- Access to the margins of the loch was limited due to the soft ground and restricted access routes. A footpath exists on the eastern boundary and public access is encouraged within the north-eastern part of the shore. There is no designated access on the western or southern part of the loch.
- Extensive artificial drainage has been undertaken to the western part of the site.
- No grazing was observed at the site during the site visits.
- The site receives surface runoff from the surrounding topography, including the southern and south-eastern face of Arthur's Seat.
- Drainage from neighbouring roads and urban development are considered likely to flow to the loch and be a potential source of pollution. Road drains which flow into the site are readily evident along Duddingston Low Road and off Duddingston Road West. There are also surface water drains evident along the footpath/bridleway which runs along the southern boundary of the site.
- The main inflow to the site is from a spring and culverted runoff from surrounding urban area.

5.3 Summary

Table 5.1 provides a summary of the key site features which were observed during the site visits undertaken as part of the initial works.

Table 5.1: Summary of key observations

Activities	Observations
Fencing	Site is not fenced. It is expected that there may be some grazing from deer but this is expected to be minimal due to the steep sided nature of the northern access, urban nature of the eastern access and largely inaccessible (wet) areas of the southern (also a high wall) and western areas.
Fishing	It is known that the loch has been stocked with non-native carp. Fishing is permitted from the north shore only and requires a permit from the Holyrood Park Rangers office.
Grazing	Light seasonal grazing (winter/spring) with Highland cattle introduced in 1997 at Wells o' Wearie to increase the floral diversity of the grassland.
Monitoring	Condition monitoring was carried out in 2004, 2008 and 2009. No detailed historical soil or water records were available from the desk study review.
Public Access	Site has open access within Duddingston village (north-east shore) and footpath access and a designated route along the eastern boundary. There is gated access to the site (from the SWT car park) but a high wall along the entire length of the southern boundary. Due to the wet nature of the site and existing drainage configuration, access is more constrained on the western boundary of the site.
Shooting	None.
Point Pollution Sources	None observed within the SSSI boundary. Direct connections with surface water drains from roads which may convey pollutants in the form of suspended solids, vehicle related compounds and salt from winter gritting applications. Potential input from drainage from an adjacent golf course (unconfirmed).
Properties in Catchment	Numerous – includes large areas of Duddingston village, Prestonfield and the city area, including University of Edinburgh's Pollock Halls of Residence.
Unusual, Distinctive or Atypical Features	Site is considered likely to receive drainage from the aforementioned urban areas and from Prestonfield golf course which abuts the southern boundary of the site. Significant bird population on site. The site is both managed by Scottish Wildlife Trust and is a designated Scheduled Ancient Monument site and is managed by Historic Scotland.

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

6. INTERPRETATION OF RESULTS

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

6.1 General Summary

Nutrients levels were variable across the monitoring locations with the highest nitrate value recorded in open water at DL01. Elevated levels of phosphate were encountered in some surface water samples, including the outflow, and in groundwater.

pH was typically slightly acidic, recording a pH of 6 at the majority of surface water monitoring locations, with slightly more acidic water recorded in groundwater monitoring points. Dissolved oxygen was typically higher in surface water samples with the lowest values recorded in groundwater samples, as would be expected. Electrical conductivity was fairly uniform between surface water locations with the highest value recorded in groundwater sample DL05, indicating the influence of more mineralised groundwater.

Total nitrogen was noted to be generally low with elevated levels only recorded on the eastern end of the loch at DL01, with all nitrogen noted as nitrate (4.6 mg/l). Elevated nitrogen levels at this open water location could be influenced by a relatively nutrient-rich inflow from the north. Moderate levels were observed at the north-western inflow and in two of three groundwater samples. Ammonia was only present in groundwater samples, which reflects typical reduced hydro-geochemical conditions in this media and is likely attributable to the degradation of organic matter.

Total phosphorus was variable across the site with the highest levels recorded in groundwater samples, which is also linked to reducing conditions in this media. Elevated total phosphorus levels were also observed in surface water at DL06 (0.4mg/l), a small area of open water to the south of the loch, and DL07 (0.2mg/l), at the main outflow. In the loch, total phosphorus was below the analytical level of detection (<0.1mg/l). Phosphate levels were generally uniform (0.04-0.07mg/L) across the site with no obvious variation between groundwater and surface water.

For a eutrophic water body, the water column typically contains at least 0.035mg/l total phosphorus (which includes phosphorus bound up in plankton) and 0.5mg/l or more total inorganic nitrogen (mainly in the form of dissolved nitrates) (Environment Agency, 2012). Whilst such levels simplify the complex interaction between plant nutrients and the hydrological and physical characteristics of individual water bodies, they serve to show the sensitivity of the trophic state to artificially increased levels of nitrogen and phosphorus. Phosphate concentrations of 0.05-0.06mg/l in open water would confirm eutrophic conditions in the loch, as total phosphorus concentrations will be equal or higher than this.

Calcium and magnesium were generally uniform in surface water samples and higher in groundwater samples suggesting accumulation of minerals in sediments. Iron was highest in groundwater samples, as would be expected, highlighting the natural geochemical processes within the anaerobic soil environment.

Total nitrogen levels in soil samples were fairly uniform in all samples with the exception of DL04 in the below root zone sample. All this nitrogen was extractable and is likely to be present as ammonia considering the system is low in oxygen and organic matter is likely to be undergoing degradation. Nitrate was below the limit of detection in all samples with the exception of DL03B.

Total and extractable phosphorus was typically higher in the root zone samples at all sample locations.

6.2 Atypical Results

No consistent atypical results were recorded from the soil or water samples at Duddingston Loch. Of the limited data set the only observations of note are as discussed below:

- Very low electrical conductivity recorded at DL03 and conversely high (relatively) conductivity at DL05 both reflecting the variation in groundwater chemistry. DL05 was noted to have high dissolved iron and higher calcium, magnesium and sodium.

- Elevated nitrate at DL01 is noted to be significantly higher than all other monitoring locations and is likely to highlight migration of nutrients onto the site from offsite sources.

- DL05 soil sample recorded a number of the highest results including iron, ammonia and total phosphorus. All these elevated results are considered to reflect natural environmental conditions within the saturated soils, and do not necessarily highlight anthropogenic influence, although elevated phosphorus may indicate accumulation of nutrients in sediments.

- DL04 below root zone sample recorded the highest extractable nitrogen and total nitrogen. The extractable nitrogen is likely ammonia present as a result of organic matter degradation which is typical in the waterlogged soils.

6.3 Additional Considerations

For the reasons detailed in section 5.1, the qualitative data reviewed during the desk study was not deemed suitable for comparative purposes.

No detailed 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.

7. CONCLUSIONS

The analytical results show a definitive trend of elevated inorganic nutrients within the site. The site appears to be influenced by drainage of the surrounding land and from the wider catchment which over time has had a direct influence on water and soil quality. There is also a significant bird population (fed partly by the public) on the site which is likely an important source of nutrients.

The site drains an area of ~1.2km^2, with Prestonfield golf course to the south, Arthur's Seat and some managed park areas to the north and urban areas immediately to the northeast and to the west of the golf course. The site appears to be predominantly supplied by a series of spring sources which are located throughout the site boundary – many of which are considered likely to be seasonal and unlikely to be formally mapped. The main inflow to the site is from the northwest; it has been described as a spring in the past but could also be associated with drainage from nearby urban areas.

The transition open fen and loch features are in an unfavourable condition, primarily due to the encroachment of woodland into areas which were previously swamp habitats, and high levels of phosphorus in the loch, which is resulting in high frequencies of undesirable species such as fringed water-lily and extensive growths of filamentous algae.

Nutrients levels were variable across the monitoring locations with the highest of nitrate value recorded in open water in the north-eastern corner. Elevated levels of phosphate were encountered in some surface water samples, including the outflow, and in groundwater. Phosphate concentrations of 0.05-0.06mg/l in open water would confirm eutrophic conditions in the loch. The lack of any useful historical water quality data or frequency of algal blooms (re: frequency, composition *etc.*) restricts the conclusions which can be drawn in proving the level of enrichment and associated trophic status of the waterbody.

The nature of the underlying geology is expected to aid migration of nutrients to groundwater from the intensively urbanised catchment. This will be enhanced through the potential input of nutrients from surface drains (as above), combined sewer overflows (unconfirmed), septic tanks (unconfirmed) and intensively managed land in the adjacent Prestonfield golf course – where the routine application of soil conditioners, artificial fertilisers and herbicides, the extent and volumes of which are unknown, will be applied. Consideration should also be given to the potential for additional nutrient input from the wildfowl population. Overfeeding of birds has been reported in the past and a significant population descending on the loch could potentially add a notable nutrient load to the loch sediments.

Flows from the catchment will have leached nutrients from the surrounding catchment to the loch which in turn acts as a sink for the surrounding landform. The nutrients will have encouraged plant growth which over time has decayed and, coupled with the inflow of suspended solids from the wider catchment, will have created a nutrient rich substrate. It is this continued infilling and accumulation which furthers successional change that is presently observed and is to the detriment of the designated site condition. It is highly probable that there are significant historical sediment accumulations within the loch. These will afford a plentiful supply of nutrients through disturbance by, and variations in, seasonal inflows as the shallow depth of the loch means it is unlikely to release nutrients through stratification. Carp in the loch will further disturb nutrient rich sediments.

The artificial changes to the site drainage - namely that on the western and southern boundary - are considered to have a direct effect on the site. In addition, the road drains of the Duddingston Low Road, which have not been traced into the site, will be influenced by the adjacent upland topography and corresponding land use practices as well as from the frequent vehicle use and seasonal application of salt.

The desk study estimated that the level of the loch has risen ~40mm in recent years due to the closure of nearby whisky distilleries which used to abstract groundwater. Subtle changes in the site water levels are likely to lead to direct changes in vegetation types so understanding the seasonal and annual variations in site hydrology will help understand how this is influenced.

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 one year). The data from such should be compared alongside water levels, rainfall data and seasonal abnormalities to seek to understand the nutrient dynamics taking place within the site.

ii. In conjunction with i, assess the seasonal flow and nutrient loads of the inflow from the west of the site and other spring/drainage inflows and compare these with those of the outflow from the south-east end of the loch. This data would be of direct value in being able to assess the flow dynamics of the loch and to understand retention times and season variations in throughput.

8.2 Other Commissioned Studies

iii. Undertake a detailed hydrological and hydrogeological assessment of the spring and drainage sources within the site catchment in order to determine the quality and quantity. This should also cover recent changes in water levels at the site (both due to changes in the regional aquifer and local variations due to management of the outflow), as well as recommendations for future management.

iv. Undertake core sampling of loch sediments to understand the concentration of retained nutrients.

v. Review the loss of standing water within the loch and determine the extent of progressive vegetation encroachment. Consideration should be made to monitoring the seasonal and annual variations of such and if appropriate, seeking to manage through flow accordingly. Potential links with nutrient enrichment and changes in water level should be assessed.

vi. Review bird data as bird populations could provide a significant additional nutrient load to the loch as well as further sediment disturbance and aid the release of 'locked in' nutrients.

8.3 Landowners

vii. Proactively engage with local landowners to understand the existing and (foreseeable) proposed changes to the immediate catchment including field usage and soil conditioning approaches. Consider appropriate management strategies accordingly - for example, nutrient management planning, treatment of outflows (e.g. Sustainable Drainage System - SuDS), buffer strips, exclusion zones, routine spot monitoring *etc*. This should include engagement with the management of the neighbouring Prestonfield golf course to understanding site drainage and soil conditioning activities which routinely take place at the site and how these may impact on the SSSI site.

viii. Proactively engage with Scottish Wildlife Trust (SWT) and Historic Scotland to understand the existing information and management practices which are routinely undertaken at the site and how these can influence water quality and nutrient

availability. Of specific interest is the routine clearance of the loch outflow channel and the disposal route of the removed material.

8.4 External consultations

ix. Engage with SEPA to further the understanding of the inflows to the site, including any authorised discharges from the urban catchment.

x. Liaison with Edinburgh City Council as to the configuration and discharge of road drain (surface drainage) flows to the site. Where possible these should be diverted away from the loch to reduce the contributing pollutant load – notably suspended solids and salt from winter applications.

xi. Liaison with Scottish Water to understand the urban drainage configuration of the adjacent residential areas. This should include an assessment of combined sewer overflows which can discharge to the cacthment. This information may be readily available from an Urban Pollution Management (UPM) study commissioned by the company.

From the stated conclusions and identified pressures (Figure 5.1) the key actions to seek to reverse the present unfavourable status of the site are to:

1. Address the inputs to the site from the catchment including the load in the associated groundwater and surface water contribution and input from the urban and recreational sources, and wildfowl (i-iii, vi, vii, ix);
2. Assess the contribution from the sewerage network notably any non-sewered properties (*i.e.* those on septic tanks) and combined sewer overflows (ix-xi);
3. Assess the contribution and effects of nutrients retained within the accumulated loch sediments (iv); and
4. Assess the water levels/loch throughput and how this is affecting vegetation encroachment and the nutrient regime (iii, v).

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ANNEX 1: FIGURES

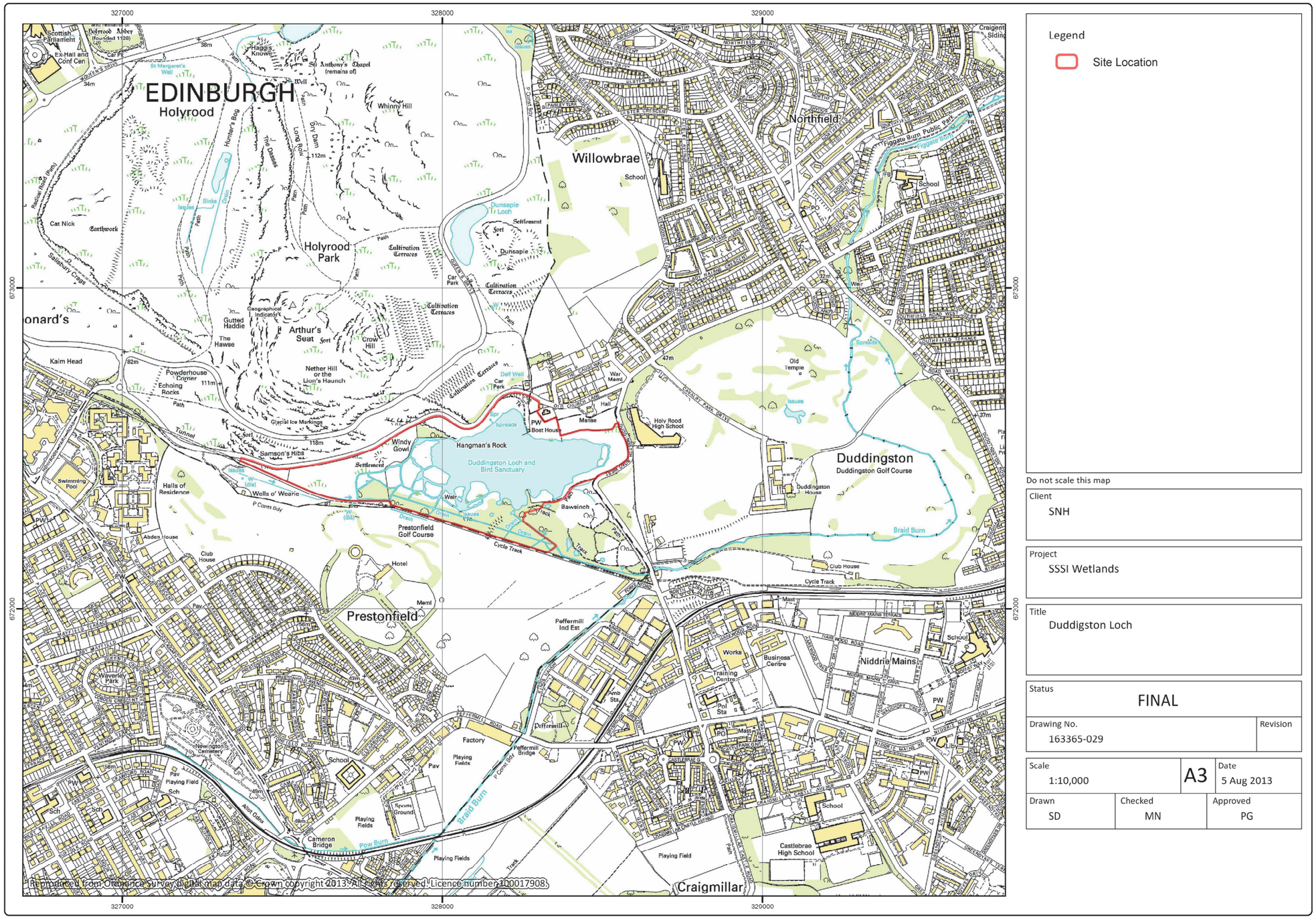
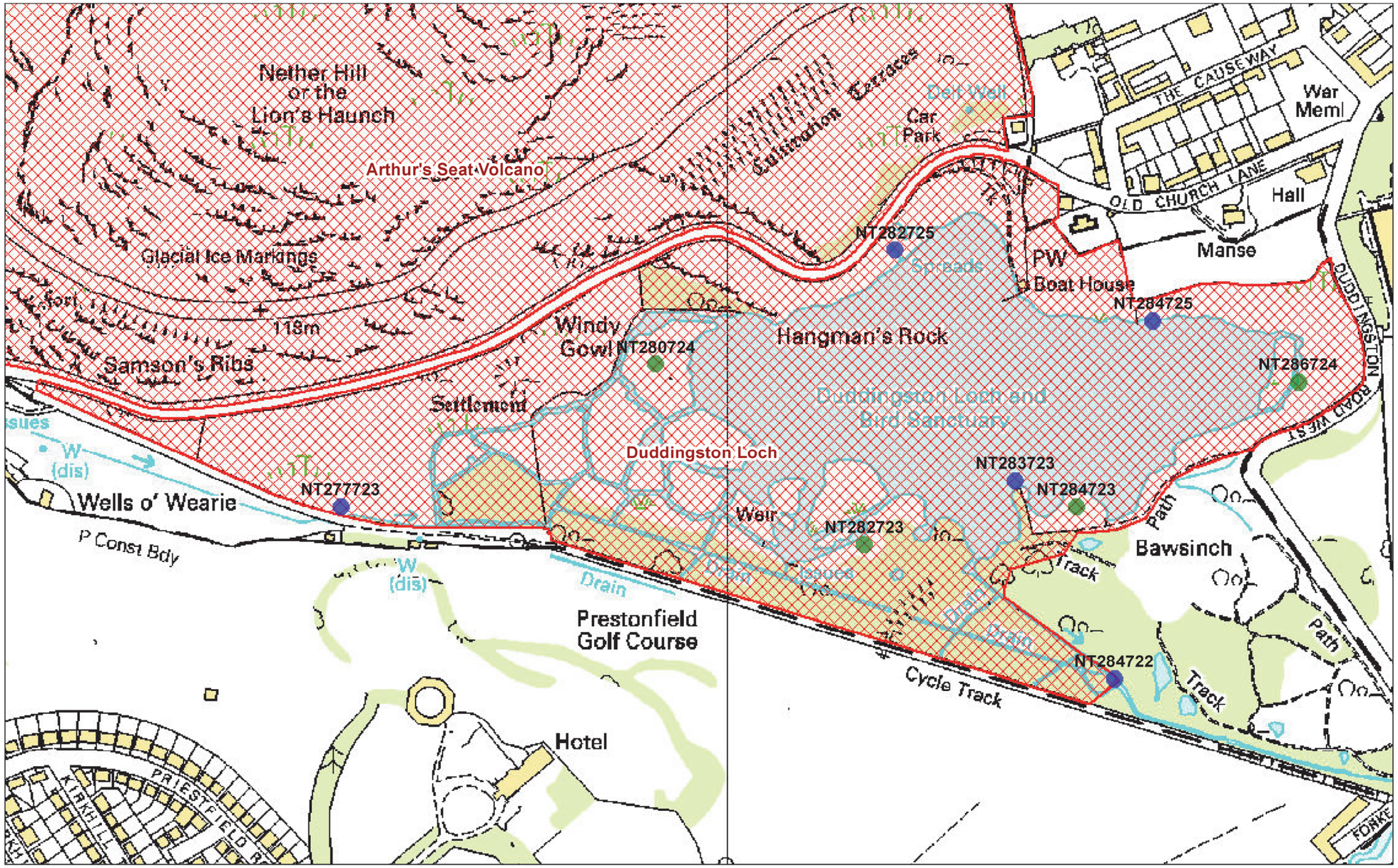


Figure 1.1: Site Location Map

Duddingston Loch



Notes:

0 0.035 0.07 0.14 0.21 0.28 km

N

Map produced using geo.View 3.0
Printed: Sep 20, 2012 14:39:11

Figure 2.1: SNH Proposed Sampling Location Plan

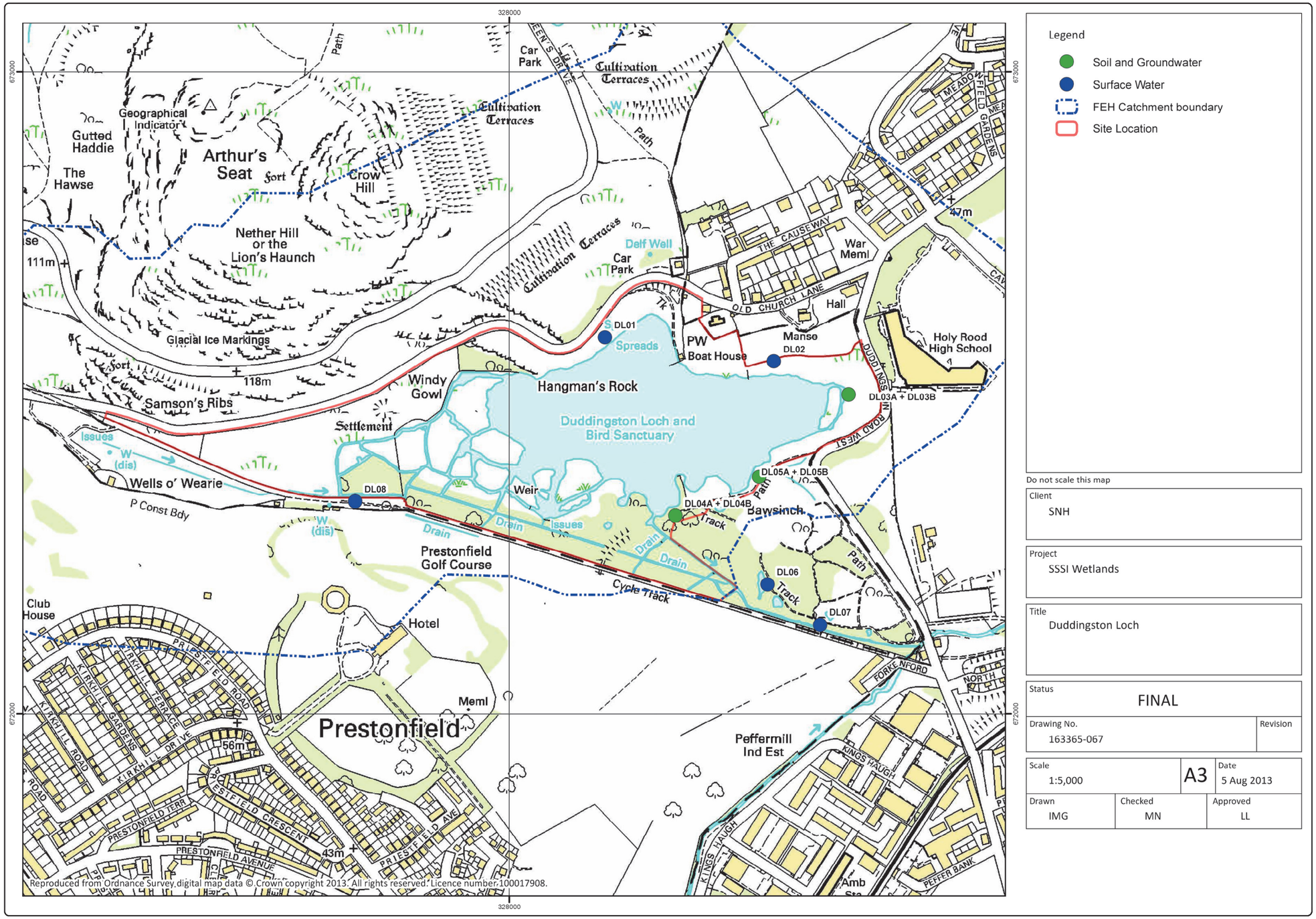
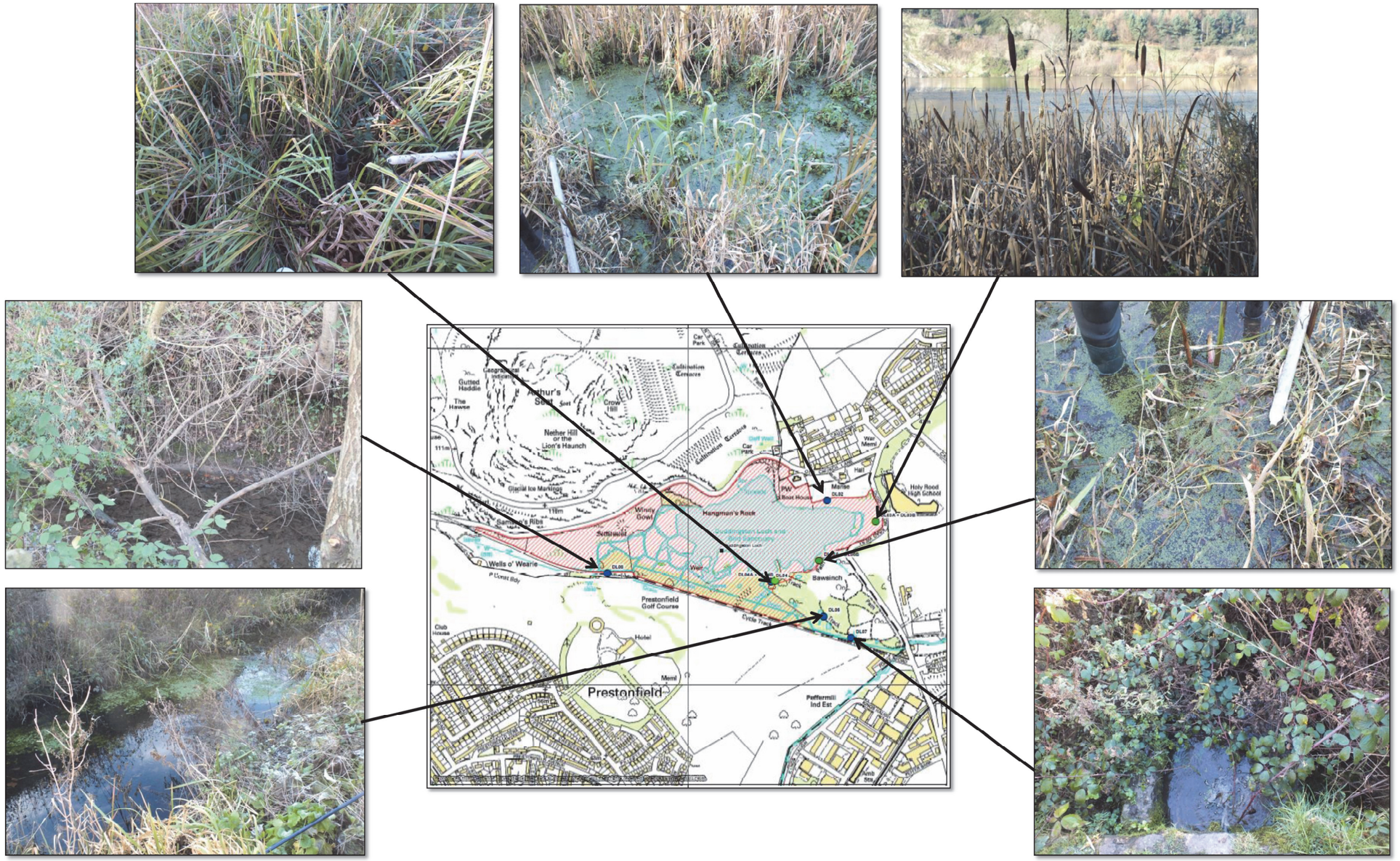


Figure 2.2: Plan of Actual Sampled Location Plan



Photograph Log - Sample Locations
(Photographs taken on 29th November 2012)

Figure 2.3: Sampling Location Photographs

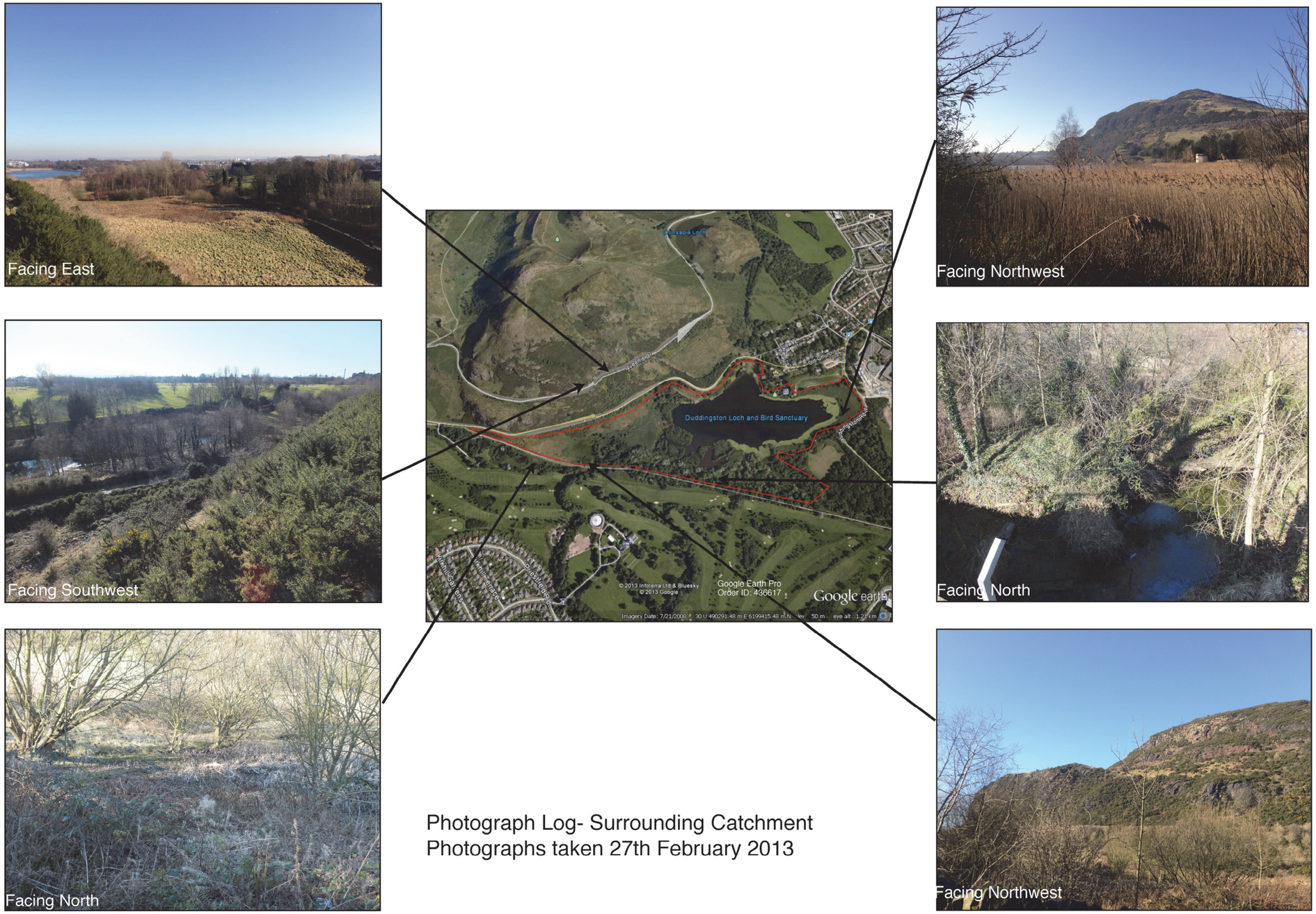


Figure 2.4: Surrounding Land Use Photographs

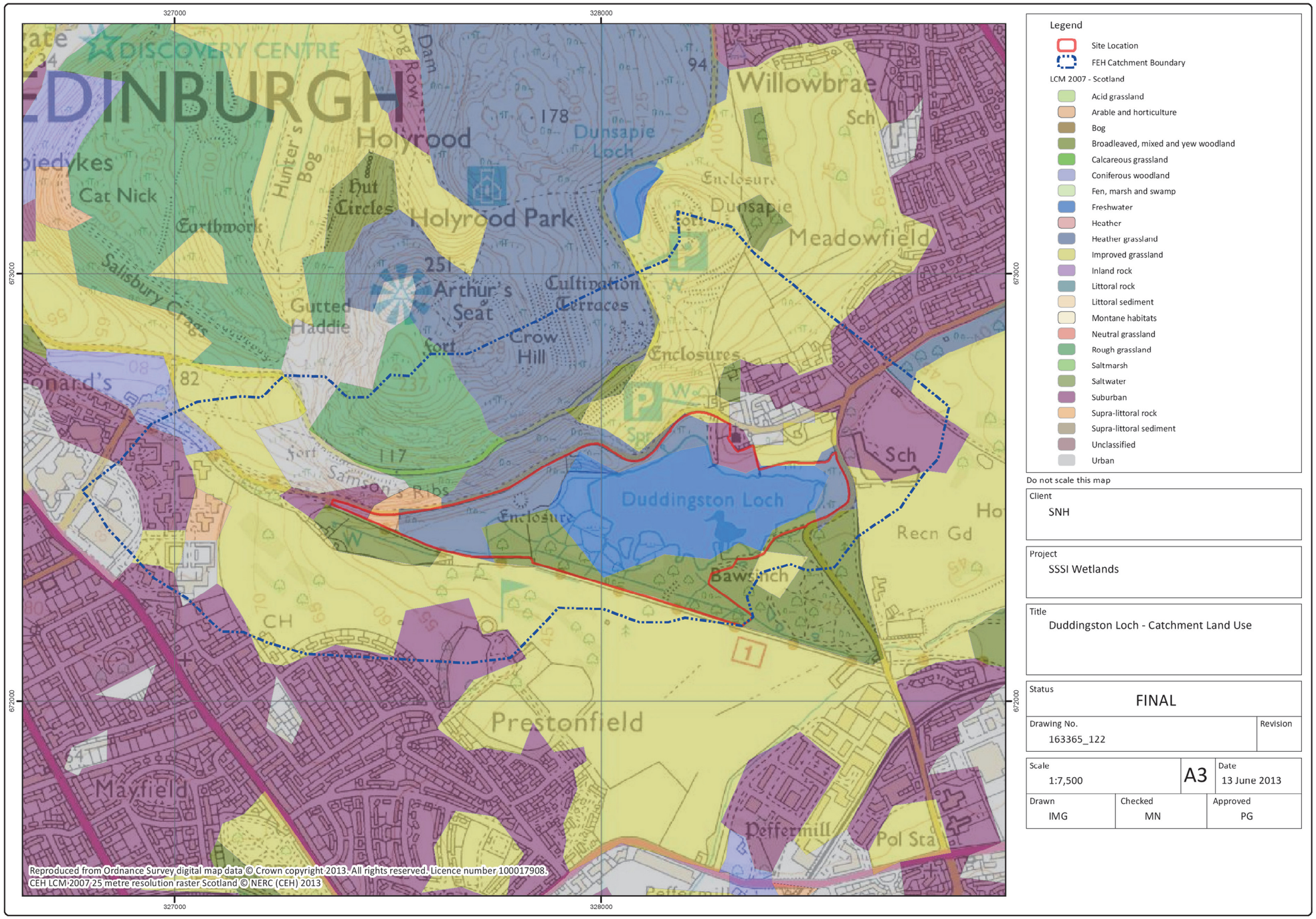
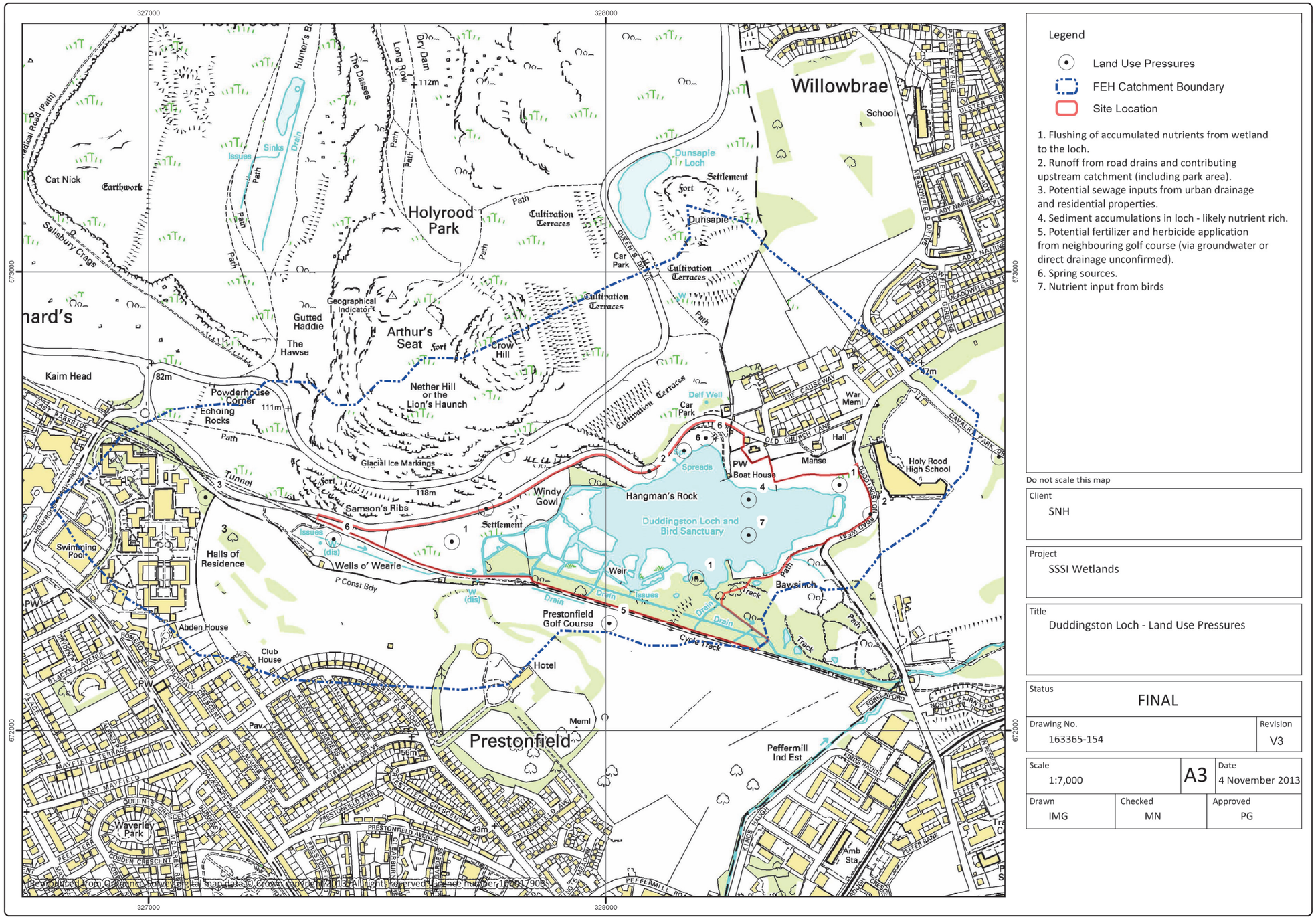


Figure 2.5: Catchment Land Use Characteristics



Legend

- Land Use Pressures
- FEH Catchment Boundary
- Site Location

1. Flushing of accumulated nutrients from wetland to the loch.
2. Runoff from road drains and contributing upstream catchment (including park area).
3. Potential sewage inputs from urban drainage and residential properties.
4. Sediment accumulations in loch - likely nutrient rich.
5. Potential fertilizer and herbicide application from neighbouring golf course (via groundwater or direct drainage unconfirmed).
6. Spring sources.
7. Nutrient input from birds

Do not scale this map

Client	SNH
Project	SSSI Wetlands
Title	Duddingston Loch - Land Use Pressures
Status	FINAL
Drawing No.	163365-154
Revision	V3
Scale	1:7,000
A3	
Date	4 November 2013
Drawn	IMG
Checked	MN
Approved	PG

Figure 5.1: Catchment Pressures Summary

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