PROSIECT LIFE+ CORSYDD MÔN A LLŶN
ANGLESEY AND LLŶN FENS LIFE+ PROJECT

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Restoration of hydrological and hydrochemical regimes at Cors Hirdre, Corsydd Llyn SAC: results of water level monitoring and hydrological investigations 2012-14.

(*LIFE* project actions A5, C10 & C11)

Final Report of the Anglesey & Llyn Fens LIFE Project: Technical Report No. 1.

Version	Final
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LIFE+ Nature aims to:
Fund the implementation of the objectives of the EU Birds' Directive 79/409/EEC and the EU Habitats' Directive 92/43/EEC including the Natura 2000 network of sites and focuses on sustainable long-term investments in Natura 2000 sites.

Project title:
Restoring alkaline fen and calcareous fen within the Corsydd Mon and Llyn (Anglesey and Llyn Fens) SACs in Wales.

Project Objectives:
The objective of this project is to bring 751 ha of fen within the Corsydd Mon/Anglesey Fens SAC and Corsydd Llyn/Lleyn Fens SAC into favourable or recovering condition through measures aimed at tackling the factors adversely affecting their condition and by delivering more sympathetic
management.

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Cover photo: Cors Hirdre with Yr Eifl in the background. All photos P.S. Jones, NRW.

CRYNODEB

Ffen pen dyffryn sy'n agos at arfordir gogledd-orllewin Llŷn (SH 260383), 3 km i'r de-orllewin o Forfa Nefyn, yw Cors Hirdre. Mae'r safle'n rhan o Ardal Cadwraeth Arbennig (ACA) Corsydd Llŷn. Ffen alcalïaidd (a gynrychiolir yma gan M9 ac M13) yw'r nodwedd o ddiddordeb yn yr ACA.

Mae ffos echelinol yn rhedeg o un pen i'r safle i'r llall ac ar ddechrau'r prosiect *LIFE* roedd gwaddod a llystyfiant wedi cau rhannau helaeth ohoni. Roedd hynny'n arwain at bryder bod y safle'n mynd yn wlypach bob yn dipyn ac yn llai rheo-topogenaidd. Roedd pryder hefyd y gallai'r maethynnau a oedd yn mynd i'r brif ffos o'r ffosydd eraill sy'n rhedeg iddi gael effaith ar glytiau cyfagos o ffen alcalïaidd. Yr ateb oedd cael prosiect i glirio llystyfiant a gwaddod i ddyfnder digonol er mwyn adfer llif y dŵr, cael lle i storio dŵr yn y sianel a chael graddiant hydrolegol o ymyl y fignen i'r canol: rhoddwyd y prosiect hwn ar waith dan gamau gweithredu LIFE C10 (codi a sefydlogi lefelau dŵr – ond yn yr achos hwn prosiect i adfer lefelau dŵr priodol) a C11 (adfer llwybrau hydrolegol pwysig).

Cliriwyd y ffos yn Awst a Medi 2013, gan ddefnyddio peiriant cloddio arbenigol ar draciau na fyddai'n gwasgu'r ddaear yn ormodol. Cliriwyd llystyfiant a gwaddodion i ddyfnder a oedd o gwmpas gwaelod y ffos wreiddiol, er, yn ddelfrydol, ni ddylid bod wedi cloddio'n ddyfnach na gwaelod y proffil mawn yn union gerllaw'r mannau lle ceir ffen alcalïaidd o'r ansawdd gorau yn hanner gorllewinol y safle. Mae monitro hydrolegol dilynol wedi dangos darlun cymysg. Nid oedd tystiolaeth bod lefel y trwythiad yn gostwng yn yr ardaloedd gorau o ffen alcalïaidd ar y safle (trawslun DW1-SW1), ond roedd tystiolaeth bod lefelau dŵr yn is mewn ardal o ffen alcalïaidd M9 yn hanner dwyreiniol y safle. Mae argaeau pren a osodwyd er mwyn ceisio codi lefelau dŵr i bwynt sy'n cyfateb i waelod y mawn wedi bod yn rhannol lwyddiannus a dylent annog gwaddodi yng ngwaelod proffil y ffos. Mae angen rhagor o waith i wneud y ddau argae sydd ymhellach i lawr (D3 a D4) yn effeithiol. Bydd y gwaith o fonitro lefelau dŵr mewn ardaloedd o ffeniau alcalïaidd yn parhau.

Mae'r prosiect hwn wedi arwain at welliant cyffredinol yn system hydrolegol y safle. Mae'n annhebygol erbyn hyn y bydd dyddodion yn dod dros ochr y brif ffos a'r ffosydd eraill sy'n rhedeg iddi, a bydd hyn o gymorth mawr er mwyn lleihau'r risg bwysig y bydd lefel y maethynnau yn yr ardaloedd cyfagos o ffen alcalïaidd yn codi. Mae lefel y dŵr yn y brif ffos erbyn hyn yn ffafriol i'r system hydrolegol yr anelir tuag ati ar gyfer y safle. Dylai'r safle fod yn fwy atyniadol ar gyfer pori nawr hefyd.

SUMMARY

Cors Hirdre is a valley-head fen located close to the north-west coast of the Llŷn Peninsula (SH 260383), 3 km SW of Morfa Nefyn. It is a component site of the Llŷn Fens Special Area of Conservation (SAC). Alkaline fen (represented here by M9 and M13) comprises the SAC interest feature.

An axial ditch runs along the length of the site and at the beginning of the *LIFE* project was largely occluded with sediment and vegetation, leading to concerns that the site was gradually becoming wetter and less rheo-topogenous in character, and also that nutrients entering the main drain from lateral feeders might influence areas of adjacent alkaline fen. The solution was a project to remove vegetation and sediment to a sufficient depth to restore flow and channel storage and also a mire edge to centre hydrological gradient: this project was implemented under LIFE actions C10 (raise and stabilise water levels – but in this case a project to restore appropriate water levels) and C11 (restoration of critical hydrological pathways).

Ditch clearance was undertaken during August and September 2013, using a specialist low ground pressure tracked excavator. Vegetation and sediment was removed to a depth approximating to the original ditch floor, though, ideally, excavation should have been no deeper than the base of the peat profile in areas directly adjacent to the best quality stands of alkaline fen in the western half of the site. Subsequent hydrological monitoring has shown a mixed picture, with no evidence of water table drawdown into the best stands of alkaline fen at the site (transect DW1-SW1), but with evidence that water levels have been lowered in a stand of M9 alkaline fen in the eastern half of the site. Timber dams installed to try and raise water levels to a point corresponding with the base of the peat have been partially successful and should encourage sedimentation in the base of the ditch profile. Further work is needed to make the two downstream dams (D3 and D4) effective. Monitoring of water levels within alkaline fen stands will be continued.

This project has resulted in an overall improvement in the hydrological regime of the site. Over-banking of the main ditch and its lateral feeder ditches is now unlikely, thus greatly reducing an important enrichment risk to areas of adjacent alkaline fen. The water level in the main ditch is now conducive to the target hydrological regime of the site. The site should also now be more attractive for grazing.

1. INTRODUCTION

Cors Hirdre is a valley-head fen located close to the north-west coast of the Llŷn Peninsula (SH 260383), 3 km SW of Morfa Nefyn. It is a component site of the Llŷn Fens Special Area of Conservation (SAC). The SSSI is 26.4 ha in area and can be characterised as a broad crescent shaped area of fen extending W-E over *c*. 1100 m in a shallow valley bottom bounded by wide low ridges to the N and S. The widest point of the SSSI is approximately 330 m but is generally of the order of 200 m. The site lies at an elevation of 31 - 34 m AOD.

The main fen interest at this site has been characterised by recent phase II[1] survey (Smith, 2004) and includes areas of fen meadow vegetation referable to the *Juncus subnodulosus* – *Cirsium palustre* fen meadow community (**M22**) and *Carex disticha* dominated fen vegetation, and alkaline fen (H7230) represented by small stands of *Schoenus nigricans* mire (**M13**) and *Carex rostrata* – *Calliergon giganteum/cuspidatum* mire (**M9**): other wetland features of interest at the site include stands of *Carex acutiformis* fen (**S7**), patches of *Phragmites* reedbed (**S4**) adjacent to the main axial drain and a small stand of *Carex rostrata* – *Sphagnum squarrosum* mire (**M5**). Much of the site consists of *Juncus acutiflorus* rush pasture (**M23a**) and extensive patches of wet woodland along the shallow valley bottom. Sizable stands of *Agrostis stolonifera* dominated fen vegetation on the valley bottom may indicate the loss of more typical fen vegetation as a result of enrichment, and represent potential areas for the future expansion of alkaline fen (probably mainly M9). The collective area of Annex I vegetation (all of it alkaline fen at this site) is *c*. 0.75 ha based on the recent Phase II survey (Figure 1).

Figure 1. Location of stands of alkaline fen at Cors Hirdre SSSI: purple, M13; pink, M9. Map prepared by Kathryn Birch, NRW.

An axial drain extending along the entire long axis of the fen is a key feature of the site (Figure 3 & 5). It has in the past been canalised and excavated to some depth, but at the start of the LIFE project the drain had become heavily vegetated and infilled, with little or no discernable flow except at its eastern tip. Feeding into this ditch are a number of side ditches, some of which receive enriched runoff and more focussed flow from adjacent farm holdings. Chief among these is the side ditch leading from Hirdre Uchaf (Figure A.3.8) which yielded a nitrate concentration of 22.3 mg/l during the June 2010 LIFE project sampling round[2]. This sampling round also showed elevated phosphorus in the axial ditch relative to the streams feeding into it.

[1] Phase II survey describes detailed survey of the vegetation cover of a site to plant community/sub-community level. See Bosanquet *et al* (2013) for details of the methodology used at this and other Welsh peatland sites.
[2] This sample is from sample point K3 at SH 25774.38203, see LIFE project spreadsheet *Cors Hirdre WQ data June 2010*.

Most of the alkaline fen interest at the site occurs within 50-70 m of the ditch (Figure 1) and at a similar elevation to ditch water levels, raising the possibility that poor axial drainage might be leading to nutrient retention and possibly the spread of enrichment. The increasing amount of *Phragmites* within the stands of alkaline fen[3] might be an indication of this, though the general wetness of the site would also be a contributory factor.

The *LIFE* project has enabled a significant restoration project to restore a functional axial drain at Cors Hirdre by removing vegetation and sediment from its largely occluded channel. This was undertaken for the following reasons:

(i) to prevent overbanking of potentially enriched water onto adjacent areas of alkaline fen both from the ditch itself and side ditches feeding into it (notably the feature described above entering the site from Hirdre Uchaf);
(ii) to reduce the extent of prolonged winter/spring flooding;
(iii) to restore a more obviously rheo-topogenous hydrological regime consistent with the key wetland water supply mechanisms at the site.

Re-opening the main drain posed obvious potential impacts on water levels in adjacent stands of alkaline fen. This report assesses the hydrological consequences to-date of the restoration work, with particular reference to effects on water levels within adjacent stands of alkaline fen.

2. CONCEPTUAL UNDERSTANDING OF SITE HYDROLOGY

Cors Hirdre is one of the Welsh sites included in the Wetland Framework Project (Wheeler *et al*., 2009, Wheeler & Shaw, 2009) and the following account of site hydrogeology and hydrology draws heavily on their account.

Cors Hirdre is underlain by a range of Pre-Cambrian and Cambrian bedrock formations, with rocks of the Gwna Melange being prominent. The bedrock is likely to be well cemented with very limited primary permeability, although some fracture flow is likely to occur in the weathered near-surface zone. The bedrock is likely to be largely isolated from the surface by a pervasive low permeability till cover: there are no known outcrops of bedrock within the site. Glacial sand and gravel deposits are stated to form a minor aquifer perched over the till aquitard[4] and flanking the wetland to the N and S: these may correspond to the locally prominent break of slope along parts of the S margin. The wetland appears to have cut through these deposits to the underlying till. A relatively thin (typically 50 – 100 cm) cover of peat occupies the valley bottom: the peat stratigraphy at station DWM9 (see below) is consistent with a cut-over surface and the peat may not have been this thin originally. The sand and gravel deposits are considered to act as sources of groundwater to the wetland trough, with seepage being focussed in the thin superficial peat as a result of the underlying cover of till (Figure 2). Direct measurements of groundwater head levels and groundwater chemistry in the putative marginal outcropping sands and gravels will become available through a Natural Resources Wales investigation of possible groundwater impacts at this site.

[3] Wheeler & Shaw (2009) comment that by 2003 "the *Schoenus* area had been considerably invaded by *Phragmites*, with loss of species from the rather rank vegetation".
[4] Note though that University of Liverpool & Enviros (2003) characterise the land to the S and N of Cors Hirdre as till , with no sand or gravel deposits mapped directly abutting the site.

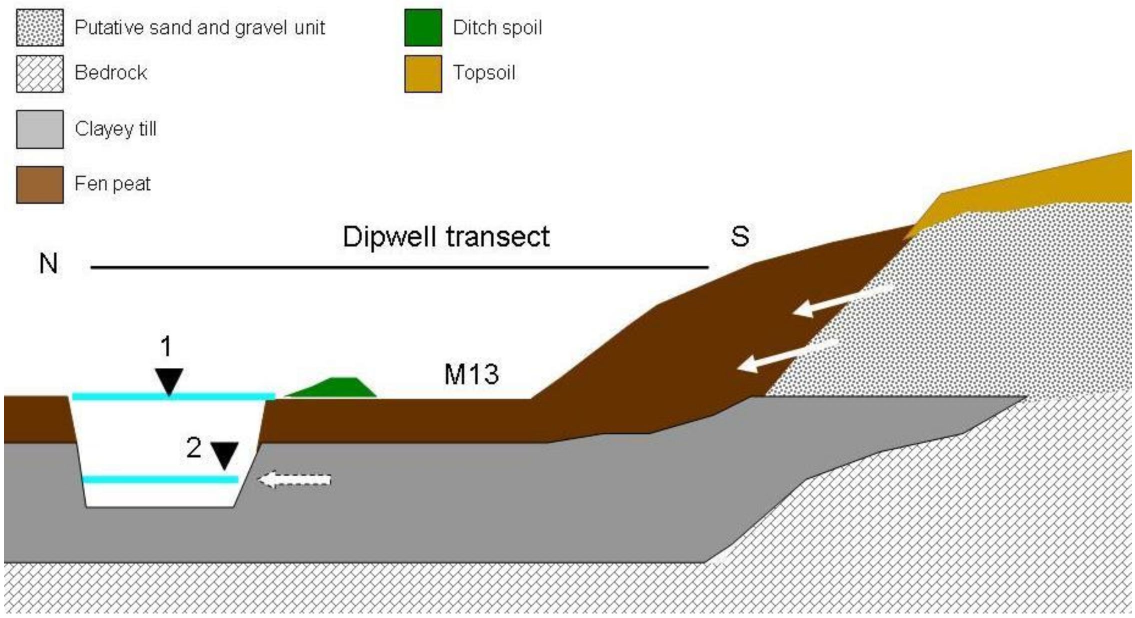

Figure 2. Diagrammatic portrayal of the possible sequence of the main stratigraphic units at Cors Hirdre. Water levels in the main ditch are shown as pre- (1) and post (2) restoration levels. Further work being undertaken by NRW will inform understanding of the sequence of deposits along the S (right-hand in this picture) margin of the site. Weak groundwater flow may occur into the ditch, with stronger seepage into the peat from the sand and gravel unit..

The axial ditch would presumably have sustained a seepage gradient from the edge to the central axis of the site, with rheo-topogenous[5] conditions prevailing in the wet sump of the fen (including areas supporting alkaline fen) consistent with WETMEC type 13a (Seepage Percolation Surface) identified at this site by Wheeler *et al.* (2009). Occlusion of the ditch is presumed to have resulted in more obviously stagno-topogenous[6] conditions which over time would be expected to favour *Phragmites* and possibly *Juncus subnodulosus* and *Carex acutiformis* at the expense of *Schoenus* and the open M9 expressions of the alkaline fen interest at the site. The latter community is especially significant in providing the main habitat at the site for the nationally rare *Eriophorum gracile*.

3. OUTLINE OF DRAINAGE DITCH REINSTATEMENT WORK.

Work to re-open the main axial drain commenced on 30 August 2013 and was undertaken working from east to west (Figure 3). A site visit (DVJ & PSJ) on 10 September 2013 reviewed the work to-date which at that time had resulted in deweeding and desilting of the ditch as far east as *c*. SH 2585.3829, approximately 80 m east of the main area of M13 alkaline fen habitat. Most of the ditch up until that point had been subject to desilting and deweeding to a depth judged by the machine operator to yield a satisfactory profile. In most places this meant the drain fully penetrated the peat and often extended some distance into the underlying drift, though probably not deeper than its original floor. The operator was instructed to undertake shallow desilting only W of SH 2585.3829 (this corresponding approximately to the eastern limit of the best area of alkaline fen vegetation close to the ditch) sufficient to remove shallow organic infill but not to extend the profile deeper than the base of the peat. This was because of concerns over the possible consequences of water level drawdown into the stand of alkaline fen.

[5] Topogenous surfaces with significant lateral water movement (percolation) – Wheeler *et al* (2009).
[6] Topogenous surfaces with little water throughflow – Wheeler *et al* (2009).

Figure 3. The main ditch at Cors Hirdre upstream (W) of the plank bridge close to dipwell DWM9. The L image (30/8/13) shows the ditch immediately after being cleaned, the R image shows the same location on 16/6/14: note the significant reed growth through the spoil (all of which was deposited on the N bank at this location) and also dam D3 in the distance of the RH image.

Ditch cleaning reached the position of the main M13 water level transect on 11 September and the point at which water levels dropped in the drain in response to cleaning was recorded by the datalogger at SW1 (see Figure 5 for location) as occurring between 11:00 and 12:00 on the 11th. Unfortunately, the operator had continued to desilt beneath the peat below the top of the till but probably not deeper than the original depth of the ditch. Two timber board dams (D1 and D2) were subsequently installed in the main ditch at locations west and east of the main dipwell transect (Figures 4 & 5) to raise water levels back to a position approximating to the peat/till boundary and to encourage sedimentation. Two further dams (D3 and D4) were installed further to the east in Spring 2014. Unfortunately when first visited after installation (25 November 2013) Dams D1 and 2 were suffering substantial leakage beneath the lowest timber board. On 17 December 2013 the base of both dams was backfilled with peat dug by hand, but this was also ineffective. Plastic sheeting was installed on the upstream side of Dams D1 and D2 on 19th. February 2014 and this did prove effective (Figure 4), though this approach has failed to prevent ongoing severe leakage for Dams 3 and 4.

Figure 4. View of dam D2 looking upstream on 6 February 2014 (L) when dam leakage was resulting in similar water levels both up and downs-stream, and 13 June 2014 (R) following measures to line the dam. The dam is sustaining a water level difference of 48.2 cm upstream (water level at dam crest) and downstream of the dam in the R hand image.

4. HYDROLOGICAL CONSEQUENCES OF DITCH REINSTATEMENT

4.1. Dipwell and instrumentation network

Hydrological monitoring to enable understanding of the relationship between ditch water levels and the hydrology of adjacent alkaline fen was put in place at Hirdre in 2008 following the initial appraisal of the site under the EA Wales/CCW Water Level Management Project[7] (WMC, 2008). Two dipwell transects were installed (see Annex 1), but only the western transect (DW1-5 and SW1) has been adopted by the current project (Figure 5). A single additional dipwell was installed by the *LIFE* project in January 2013 in a stand of M9 close to the main drain but some distance E of the main monitoring transect (DWM9). All dipwells are constructed of high density plastic slotted pipe of 32 mm internal diameter and fitted with an external geowrap membrane and outer mesh to minimise clogging from sediment. All the wells are fitted with caps with breather holes.

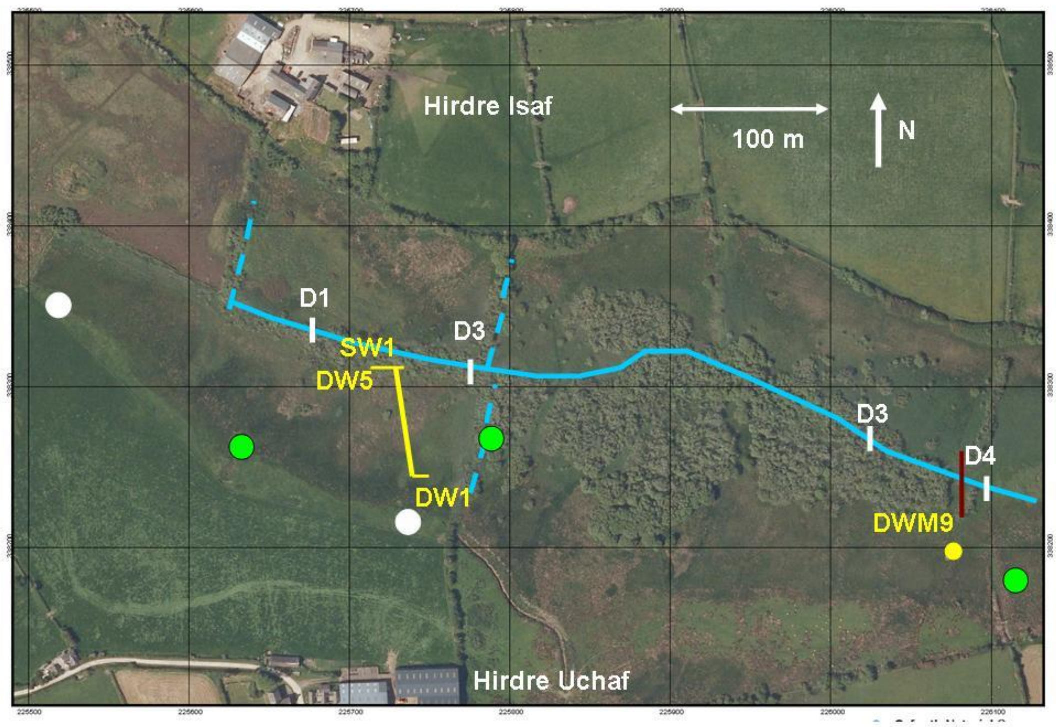

Figure 5. Aerial photograph of the western half of Cors Hirdre showing the approximate position of the main dipwell transect (DW1-5, yellow line – see also Fig. 7) cutting through the largest stand of M13, dipwell DWM9 in a stand of M9, and part of the axial ditch and side drains cleaned as part of this project (solid and dashed blue lines respectively). The white lines indicate the approximate position of the four timber dams (D1-D4) installed to adjust ditch water levels. White solid circles denote the location of piezometers installed along the southern boundary of the site by Natural Resources Wales, 19 March 2014. Green circles denote the approximate location of constructed treatment wetlands installed by the *LIFE* project. The brown line close to D4 indicates the plank bridge and boardwalk. Fine black lines represent 100 m grid lines of the British OS National Grid.

Partial instrumentation of the dipwell network was undertaken in late 2012/early 2013 by the *LIFE* project in advance of work to re-open the axial ditch – post-restoration monitoring is also available. The instruments deployed are Diver type DI501 data-loggers manufactured by Schlumberger Water Services. These instruments are inserted into dipwell liners and record the sum of water column pressure head and atmospheric pressure. To interpret the data record the atmospheric pressure contribution has been subtracted using an hourly atmospheric pressure dataset available for Cors Geirch as a result of the ongoing CCW/EA Wales (now NRW) wetland SACs groundwater investigation programme (WMC, 2008).

[7] Abbreviated to WLMP

Details of the dipwell network at Cors Hirdre are summarised in Table 1 and the main dipwell transect is shown in Figures 6 and 7. Dipwell elevations on the main transect were obtained during the WLMP programme but were re-determined in December 2012 because of the possibility that installations might have been disturbed since the original 2008 survey in 2008; these data are shown in Table 2.

Hourly rainfall data was made available by Liam Perrott of NRW Hydrometry for the nearby Edern station at SH 27693.39235 (station no. 529571) 2.5 km NE of the site.

Figure 6. Looking along the main water level monitoring transect from DW1 in foreground with Hirdre Isaf in background. Transect bearing 180 degrees magnetic. Photo taken 29 November 2013.

Table 1. Details of dipwell installations at Cors Hirdre SSSI. Dipwell numbers are prefixed DW for peat wells and SW for open water installations. Eastings and northings for wells DW1 - 5 are as recorded in the Water Level Management Plan (WLMP) investigation. The grid reference for SW1 provided by the WLMP survey does not correspond with the position of this station on orthorectified aerial photographs and the value reported in the table is based instead on a hand-held GPS measurement (29/11/13). The grid reference for DWM9 is based on a hand-held GPS measurement taken on 29 Nov 2013. Heights for wells DW1 - 5 are as recorded in the WLMP investigation and date from 4 December 2008. Heights for DW2 - 5 and SW1 have been superseded by the values shown in Table 2 based on re-levelling from DW1. Heights for top of casing (TOC) above ground are based on measurements undertaken on 21 December 2012 ([a]), 25 November 2013 ([b]) and 29 November 2013 ([c]). * based on tape measurements. The barometric pressure record has been obtained from well GR2 at Cors Geirch, 4.6 km from Hirdre.

Dipwell number	*Easting (SH)*	*Northing (SH)*	*Height (mAOD)*	*Height TOC > ground (cm)*	*Liner diameter (mm)*	*Liner length (cm)*	*Logger serial number*	*Distance (m) from DW1**
DW1	25739	38238	33.682	6.5[a],6.0[b]	32	>105	None	0
DW2	25737	38262	32.259	5.5[a],6.2[b]	32	120	None	25
DW3	25735	38283	31.961	8.0[a],6.5[b]	32	114.5	L5145	45.2
DW4	25734	38300	31.971	9.5[a],7.5[b]	32	120	L4883	62.9
DW5	25734	38310	32.001	5.5[a],3.7[b]	32	110	None	73
SW1	25741	38323	32.408	NA	32	96.5	L5152	81
DWM9	26063	38213		9.5[c]		98	H6409	
GR2	30350	37969	Barometric pressure record				C0859	4600

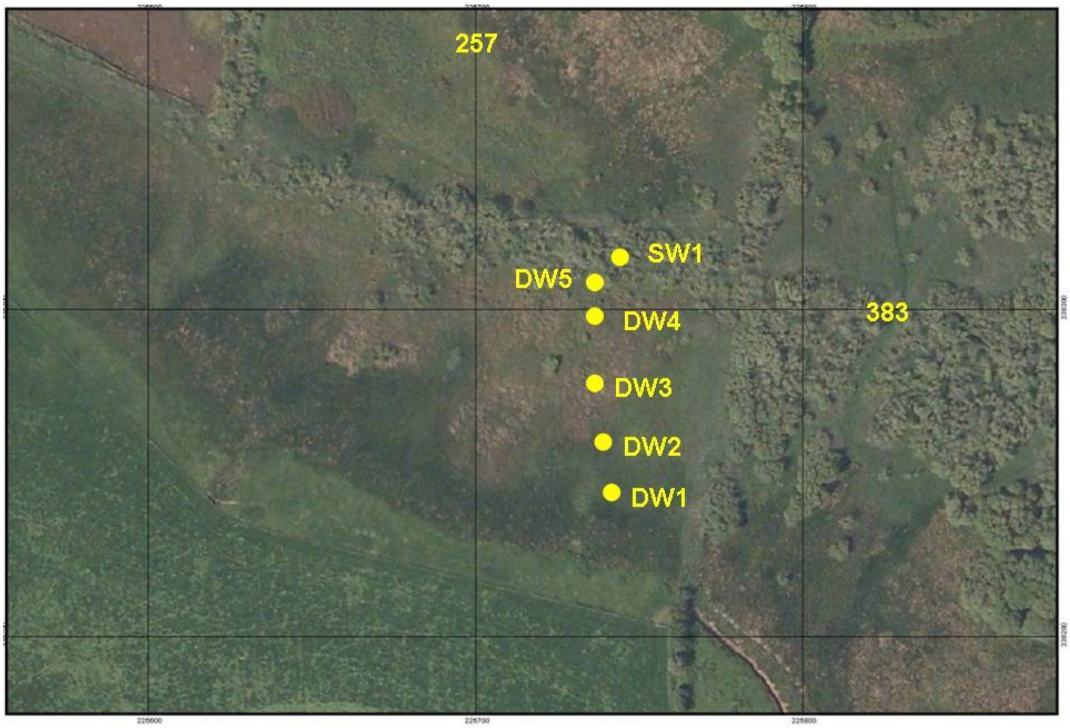

Figure 7. Aerial photograph showing location of dipwells (DW) 1 - 5 and the ditch water level monitoring station SW1 at Cors Hirdre SSSI. The fine black lines are 100 m squares of the British National Grid. 257 and 383 label easting and northing lines respectively.

Table 2. Comparison of differences in top of casing (TOC) elevation between DW1 and the other wells in the main M13 transect at Cors Hirdre SSSI based on two measurement sets, the original WLMP 2008 survey and a subsequent Laser levelling survey undertaken by the *LIFE* team on 21 December 2012. * = revised elevation for DW5 TOC from levelling off DW4 TOC on 25 November 2013 – this was required because of possible disturbance to DW5 during deposition of ditch spoil. ** The original SW1 datum was destroyed during the ditch cleaning work,

Station	*TOC height relative to DW1 TOC, 2008 survey (m)*	*TOC height relative to DW1 TOC, 21 December 2012 (m)*	*Difference (cm) between 2008 and 2012 estimates*	*Elevation of TOC/other points based on levelling off DW1 TOC datum for this survey*
DW2	-1.423	-1.447	-2.5	32.235
DW3	-1.721	-1.743	-2.2	31.939
DW4	-1.711	-1.737	-2.6	31.945
DW5	-1.681	-1.712	-3.1	31.970
DW5	Rev. elevation*			31.974
SW1	Error	-1.274		32.408**

4.2. Site stratigraphy

Basic information on site stratigraphy was collected to aid interpretation of the hydrological data. A core at DW3 some 36 m from the main drain (Table 3) revealed fresh loose superficial peat with increasingly humified peat at depth, with a relatively sharp boundary at the surface of the most humified (Von Post H7) at -45 cm. Clay was encountered at -70 cm, with the elevation of its surface (31.169 m aOD) being just over 10 cm deeper than the top of the clay observed in the ditch profile (31.278 m aOD, Table 7). The clay at DW3 appears to include relatively pure unlaminated clay (Figure 8) which after 20 cm or so passes at depth into a sandy clay with clasts. This latter unit is well exposed in the ditch profile (much less apparent is the overlying ‘pure’ clay observed at DW3) and includes a very diverse clastic assemblage (Figure A.3.1). Its texture is also variable, with some sandy clays oozing water (and iron) onto the ditch face and fairly sloppy.

Ponding of seepage water from the overlying peat onto the surface of the clay was noted when a ‘step’ was cut into the side of the ditch into the overlying peat (Figure 9). The thickness of the clay could not be determined by hand augering due to its stony content, but the base of the ditch appears to have been cut into essentially similar material, suggesting a minimum thickness of 0.41 m (Table 7).

The underlying clay unit was also encountered further east at DWM9 (Table 8) and this core also shows a similar stratigraphy to DW3 in as much as a basal consolidated peat (Figure A.3.3) with a high H number (based on texture and expressability of water, but still with abundant macrofossils) is succeeded up the profile by less humified and then more or less fresh unhumified raft peat (Figure A.3.2). An important feature of the stratigraphy here is a thin inorganic band above the rather dry basal peat. This might indicate a period of mineral inwash, possibly into a flooded peat cutting. The surface of the clay in the ditch profile at DWM9 is 0.366 m lower than the water level of -11.7 cm TOC on 29 November 2013 – much shallower than the minimum depth of 0.7 m recorded for this unit in the stand of M9 (though note there is some ambiguity concerning the actual depth of the clay surface – see Table 5). The clay is at least 40 cm thick in the ditch profile at DWM9.

Peat thickness at the relatively upslope location of DW1 is over 100 cm (Table 4), the deepest peat recorded to date at Hirdre. This location is obviously sloping with, therefore, limited potential for water detention. The thickness of the peat could indicate sustained groundwater income from upslope from the putative sand and gravel unit. This latter unit has not be proven in this study but a total of 65 cm of a grey fine sand overlying a wet sand was noted by Farr (2012) from the NE corner of the site at SH 26498.38391. Farr’s stratigraphy indicate some overlap of this unit by what appears to be the same grey clay noted here. A definite break of slope (apparently complicated in places by past tipping of waste) occurs in some places upslope and to the S of the fen basin in the area of the DW1-5 transect. Casual coring at the edge of this feature in December 2013 revealed 0-50 cm of a sandy gravely clay-rich brown loam (Figure A.3.4) with abundant clasts overlying a sandy brown clay lacking clasts, though this hole was only pursued to a depth of 68 cm. More detailed examination of these deposits and, critically, their functional significance to the fen interest, is now underway as part of an NRW funded investigation (July 2014 onwards).

The extent to which the underlying clay acts as a competent aquitard is unclear, though the uppermost 20 cm of clay noted at DW3 probably would limit seepage. Seepage from sandy facies of this clay into the ditch has already been noted and its stone content is locally high to the point where the unit could almost be described as a sandy gravely wet clay. These observations suggest that the principle of excavating the ditch no deeper than the base of the peat in the vicinity of the main stand of alkaline fen was correct, though unfortunately this was not achieved. However, the dams should aid sedimentation within the ditch profile and some replacement of ditch spoil into the channel could be considered.

Table 3. Near surface stratigraphy for M13 alkaline vegetation within 1 m of DW3 (SH25739.38238) based on coring undertaken on 4 December 2013. Depth ranges are given relative to ground level (31.869 m aOD).

Depth (cm)	*Description*
0 – 20	Fresh loose H1/2 peat.
20 – 45	Still quite fresh H5 dark brown fen peat.
45 – 70	Consolidated H7 sedge/moss peat with live *Phragmites* rhizomes
70 - 100	Stiff grey clay. Uppermost layer (70-90 cm) more or less pure unlaminated grey clay with no clasts, then (90+) more of a sandy clay with some small clasts. Base not proven. Surface of clay (at -70 cm) at 31.169 m aOD.

Table 4. Near surface stratigraphy for dipwell DW1 (SH25739. 8283) based on a coring undertaken on 4 December 2013. Depth ranges are given relative to the water surface when water levels were 1.7 cm below top of casing.

Depth (cm)	*Description*
0 - 55	Silty brown well humified peat, brown at first then gingery with some much darker > 3 cm wide patches.
55 – 110	Well humified H7 blackish peat without silt and with some graminoid remains and patches of brushwood.
110	Base of core – base of peat not proven. Base of core at 32.582 m aOD.

Table 5. Near surface stratigraphy for M9 alkaline vegetation at SH 26064.38211 based on corings undertaken on 10 January and 29 November 2013. Depth ranges are given relative to the water surface and based on the 10/1/13 visit when water levels were 3.2 cm below tbm level. See also Figure A.3.2. The surface of the clay was determined as -70 cm on 29/11/13 and between 86 and 97 cm on 10 January 2013.

Depth (cm)	*Description*
0 – 15	Loose superficial vegetation raft and unhumified peat – H1/2.
15 – 47	Better humified very wet H4/5 peat at surface overlying mid-brown moderately well humified silty peat with macrofossil content increasing with depth.
47 – 49	Silty grey clay. Missed during the coring of 29 November 2013.
49 – 86	Dark brown/ginger peat with abundant macrofossils. Markedly dry and easily broken into pieces, with no expressible water on squeezing. H6/7.
97? -	Grey silty clay with small clasts. Thickness not determined.

Figure 8. The top 20 cm of the clay underlying the peat at DW3 (70-90 cm) based on a coring on 4 December 2013.

Figure 9. Accumulation of seepage water at the junction between peat and underlying till in the recently cleaned ditch section, Cors Hirdre SSSI. Location of image SH 25741.38323. The top of the till is shown by the shelf cut into the profile. Image reference IMG_3323, 29 November 2013. Image shows S bank of ditch.

Significant precipitation of ochre was noted in the main drain during the November 2013 site visits (Figure 10), with many iron rich seeps (and oily bacterial films) noted entering the drain from the surface of the peat profile down to (and beyond) its junction with the till. This is likely to be due to oxidation of reduced ferrous iron as groundwater discharges onto the ditch face following years of strongly impeded drainage during which excess water is likely to have ponded on the surface and then gradually dissipated as surface flow along the ditch axis. Whether this is a temporary effect remains to be seen. Raising water levels within the ditch at least to the level of the peat/till interface and then establishing mini linear constructed wetlands in-between dams could be used to trap and treat ochre *in-situ* should it remain an issue. The N side of the ditch face appears to be associated with the most pronounced ochre.

Figure 10. Ochre deposition resulting from seepage onto N face of recently cleaned ditch at Cors Hirdre, 25 November 2013. The boulder just visible to the left is immediately downstream of Dam 1 at SH 25691.38332. View looking NNE with Hirdre Isaf farm visible top left

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4.3. Water level monitoring before and after clearance of the axial drain.

Manual measurements of water table level in the monitored wells (Annex 2) indicate a very stable hydrological regime for wells DW2 –DW5, with water levels near or above surface for much of the time. Only well DW1 shows any significant drawdown during the summer of 2014, and the lowest recorded manual dip measurement for the well closest to the drain (DW5) was only -8 cm in a dry period (July 14) following re-opening of the drain. The data-logger records for DW's 3 and 4 (located in the core area of alkaline fen) show barely more than 10 cm fluctuation in level for much of the year (Figure 11), with a notably conservative regime demonstrated for well DW4 despite it being only 18.1 m from the axial drain and with no evidence to suggest an enhanced drainage impact following re-opening of the drain (Table 6). This is confirmed for DW4 by a plot of manual water level measurements (Figure 12), which shows that the trend of limited fluctuations in level continues following ditch clearance. However, the time-series plot of water levels determined by manual measurement for well DWM9 further east (Figure 12) does indicate that drain deepening has had an effect at this location.

Table 6. Summary of hydrological observations for Cors Hirdre well DW4 based on the automatic hourly record. A comparison of levels before and after re-opening of the drain is provided for April 2013 and 2014 respectively which show similar rainfall totals. Water levels are slightly higher in April 2014. All values are cm relative to peat surface unless otherwise stated.

Parameter	*Value*
Average water level	5.71
Minimum	-2.1
Maximum	11.7
Number of hourly records	13,839
Date span for records	22/12/12 (00:00) – 21/7/14 (13:00)
April 2013 **average** level, min - max (cm) / rainfall total (mm)	**3.6**, 1.2 – 5.9 / 46.4
April 2014 **average** level, min - max (cm) / rainfall total (mm)	**7.5**, 6.0 – 9.3 / 50

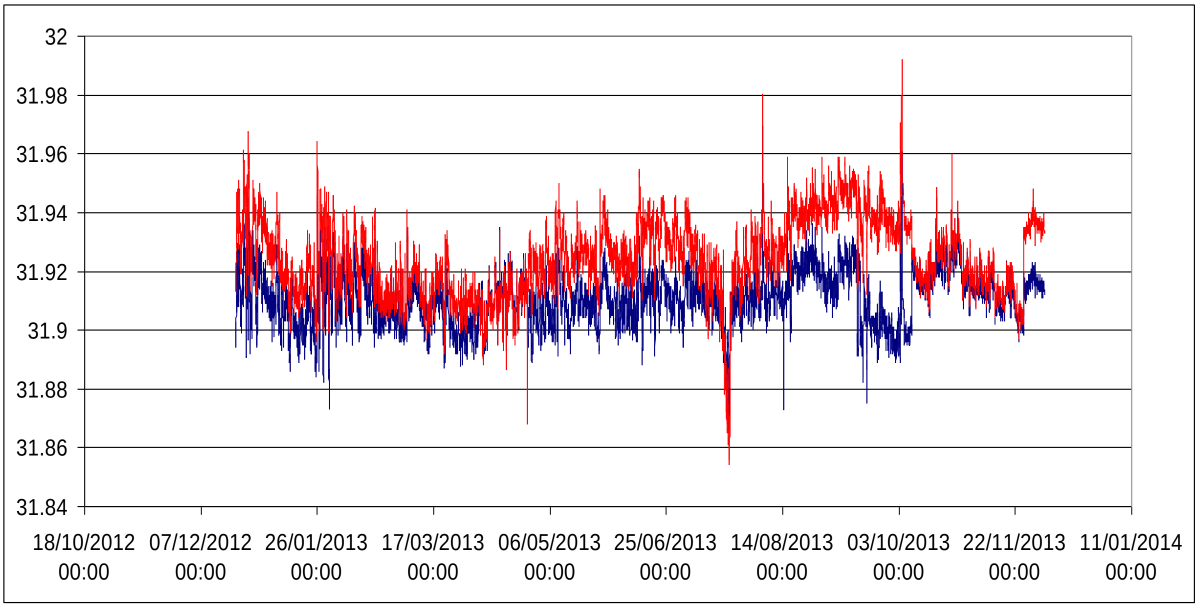

Figure 11. Comparison of hourly measurements of water table level (mAOD) at dipwells 3 (blue) and 4 (red) on the main M13 transect at Cors Hirdre. The jump in levels observed on the right-hand side of the plot on 25 November 2013 is believed to be due to the removal and subsequent replacement at a slightly different level of the respective well caps used for anchoring the suspensor cables. Ditch re-opening reached the approximate location of this transect on 11 September 2013.

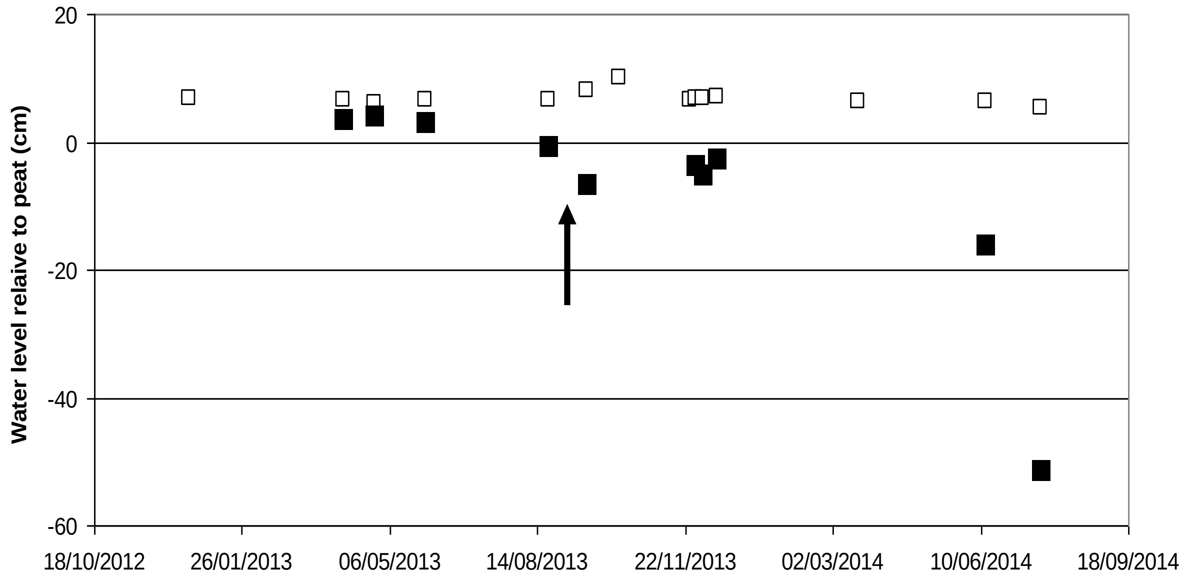

Figure 12. Plot of water levels determined by manual measurement for dipwells DW4 (open squares) and DWM9 (filled squares) before and after re-opening of the axial drain (the arrow marks the approximate date of ditch reinstatement work).

The data-logger record for the period prior to re-instatement of the ditch shows water table levels at DW4 were very slightly higher (1-3 cm) than ditch water levels for most of the time (Figure 13), but with occasional reversals during wet weather. (Figure 14). There is a trend towards late summer of a more obvious and sustained difference which might reflect the influence of evapotranspirational losses from the vigorous *Phragmites* swamp of the ditch and its margins. However, the relative stability of water levels in the main drain is notable given the relative dryness of the spring and summer of 2013. This may indicate a combination of sustained seepage income to the drain coupled with inefficient transmission of water as outflow along the drain, with the seepage apparently sufficient to partially counteract evapotranspirative losses for much of the summer.

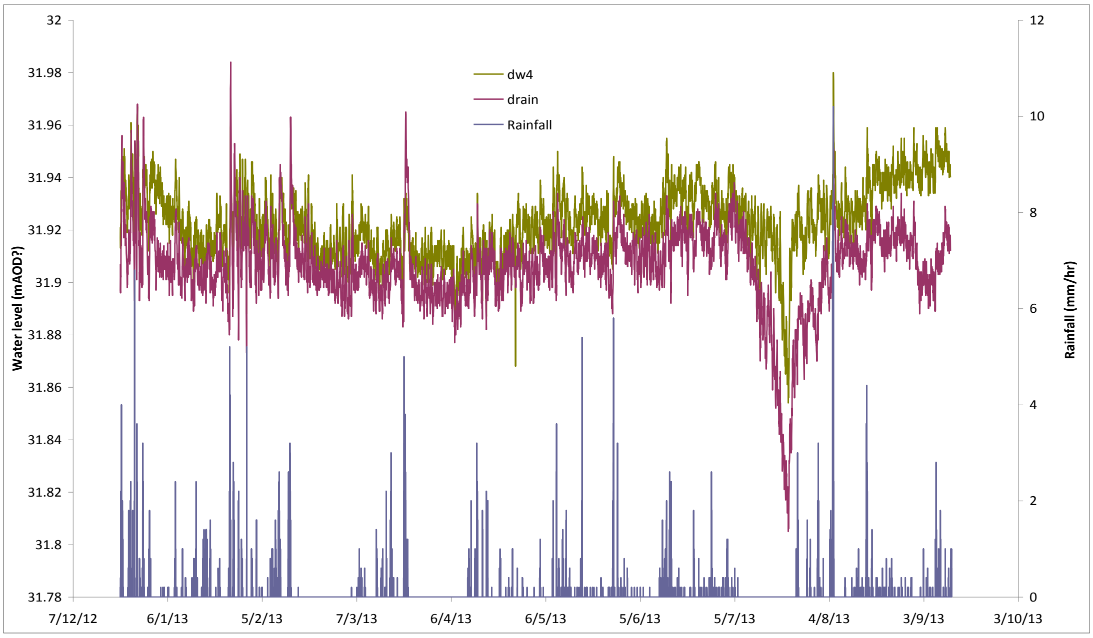

Figure 13. Hourly water level readings for dipwell DW4 (green) and the main drain SW1 (purple) expressed as metres above OD. This plot also shows hourly rainfall totals for the NRW rain gauge at Edern (SH 27693.39235 (station no. 529571) 2.5 km NE of Cors Hirdre. The plot terminates at the point when ditch re-opening reached the approximate location of this transect (11 September 2013). Plot drawn by Dr Rob Low.

The comparison shown in Figures 13 and 14 ends on 11 September 2013 when desilting of the ditch reached the SW1 logger. The height of the original spoil bank on the S side of the ditch may have been sufficient to prevent the spread of ditch water over the adjacent fen at this particular location (or at least limit the number of overbanking events), though whether this was the case elsewhere along the ditch is unclear. However, ground (peat) surface elevation was clearly lower than the original main drain water level for several areas within the M13 stand (Figure 15), illustrating the potential for overbanking or even seepage influence out from the ditch to peripheral areas of alkaline fen vegetation.

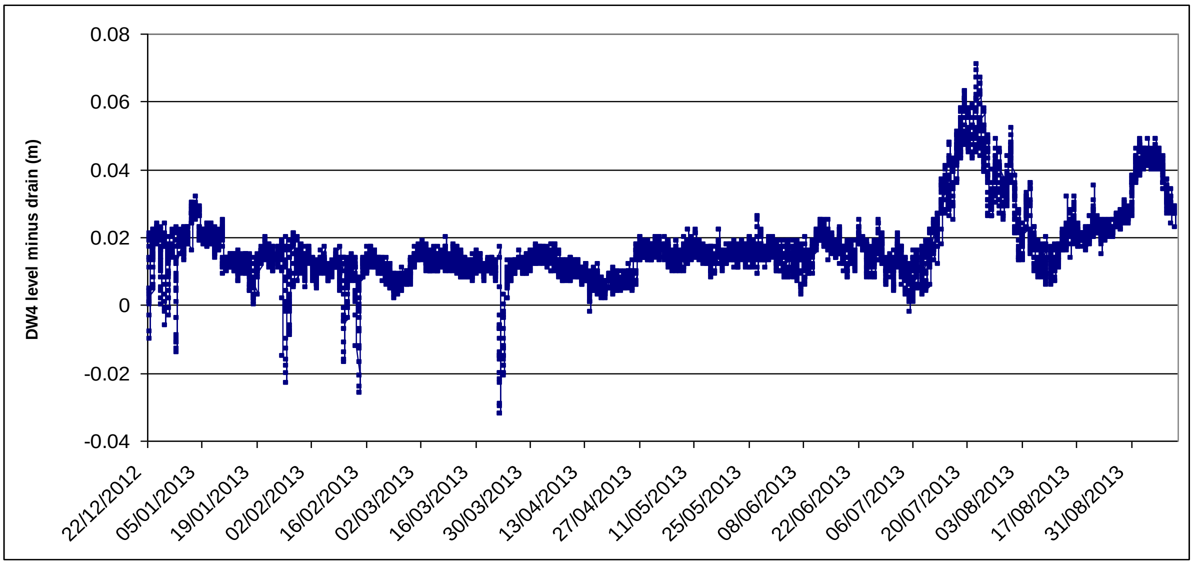

Figure 14. Re-plot of Fig. 13 showing hourly differences in water level elevation between well DW4 and the main drain. Negative numbers indicate occasions when ditch water levels exceed water table levels at DW4.

Ditch deweeding and desilting resulted in a drop in ditch water level of 94 cm at the main transect (Table 7) and 85 cm further downstream at DWM9 (Table 8), with a recovery of *c*. 35 cm upstream of dam D2 following measures to make it effective (namely lining with a plastic sheet). Following re-instatement of the drain and work to make dam D2 effective, the mean water level difference between DW4 and the main drain has decreased to -0.64 m (n=3, range -0.612 to -0.675m). Comparisons of water table profiles along transect DW1-SW1 before and after re-opening the main drain (Figure 16) show more or less identical profiles until within a few metres of the drain, though a potentially ecologically significant change in level of, for example, 10 cm would scarcely show at this scale. The drawdown effect may only ever be limited at this location, with seepage from upslope and rainfall sufficient to counteract any significant effect except during prolonged dry weather. This is supported by Table 6 which shows a very stable hydrological regime in the main M13 area following drain re-instatement.

Table 7. Elevation estimates for key levels at stations SW1 and DW5 on the main M13 dipwell transect (DW1-5 & SW1) at Cors Hirdre SSSI. All levels are for SH 25741.38323 and were determined on 29/11/13 unless stated otherwise.

Location	*Elevation, mAOD*
1. Top of clay exposed in drain section on main M13 dipwell transect	31.278
2. Ground surface adjacent to ditch.	31.854
3. Ditch base on main M13 transect.	30.855
4. Ditch water level, 21 Dec 2012 (pre cleaning)	31.941
4. Ditch water level, 25 Nov 2013 (post cleaning, dam D2 leaking)	30.995
4. Ditch water level, 29 Nov 2013 (post cleaning, dam D2 leaking)	30.975
4. Ditch water level, 4 Dec 2013 (post cleaning, dam D2 leaking)	30.975
4. Ditch water level, 19 March 2014 (post cleaning, dam D2 working)	31.328
4. Ditch water level, 21 July 2014 (post cleaning, dam D2 working)	31.255
5.Top of spoil heap of arisings from ditchl	32.255
6.Elevation of spoil 'shoulder'	32.125
7. Elevation of typical drainage gap left in spoil heap	31.927
8. Ground level at DW5.	31.936
Minimum thickness of clay at ditch (measurement 1 minus 3).	41.5 cm

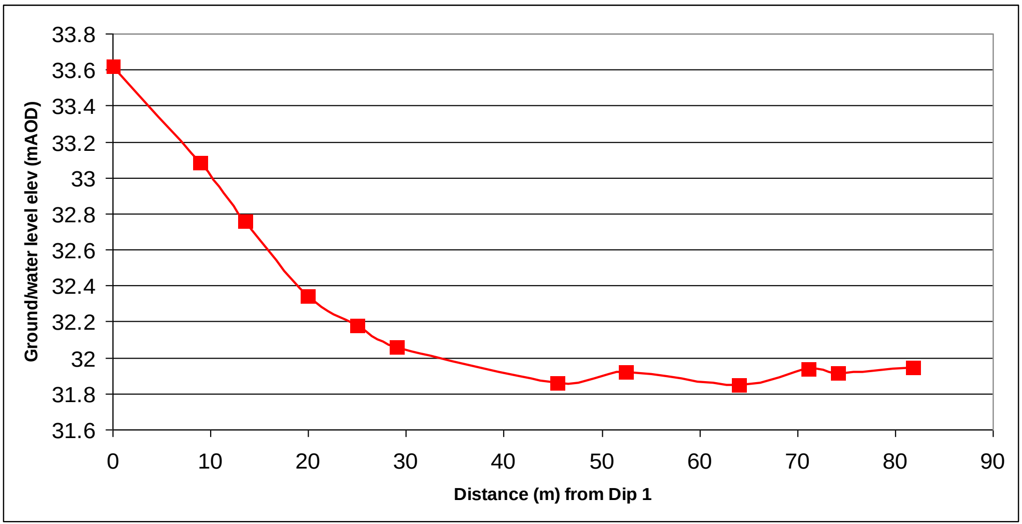

Figure 15.Variation in ground elevation along the dipwell 1 (0 m) to 5 (73 m) transect and water level elevation in the then occluded ditch at SW1 at 81.9 m. Ground level at dipwells 3 (45 m) and 4 (63 m) is lower than the ditch water level. Dipwell 2 is located at 25 m. Data for 21 December 2012.

Table 8. Elevation estimates for key levels at DWM9, Cors Hirdre SSSI.

Location	*Level relative to DWM9 TOC (m)*	
	10/1/2013	25/11/2013
2. Ditch water level slightly d/s at footbridge, SH 26083.38247	-0.038	-0.893
1. DWM9 TBM next to TOC, SH 26063. 38213	-0.005	-0.008
1. DWM9 peat level	-0.212	
2. Level of drain base slightly d/s at footbridge		-1.409
2. Level of bridge beam S side of ditch		0.036
1. DWM9 water level	-0.033	-0.117
3. Water level 14.2 m towards ditch from DWM9, SH 26064.38226		-0.168
4. Ditch water level in line with DWM9, SH 26070.38261.		-0.892
4. Top of clay in N bank of ditch at SH 26070.38261		-0.483
4. Ground level on ditch bank at SH 26070.38261		-0.279

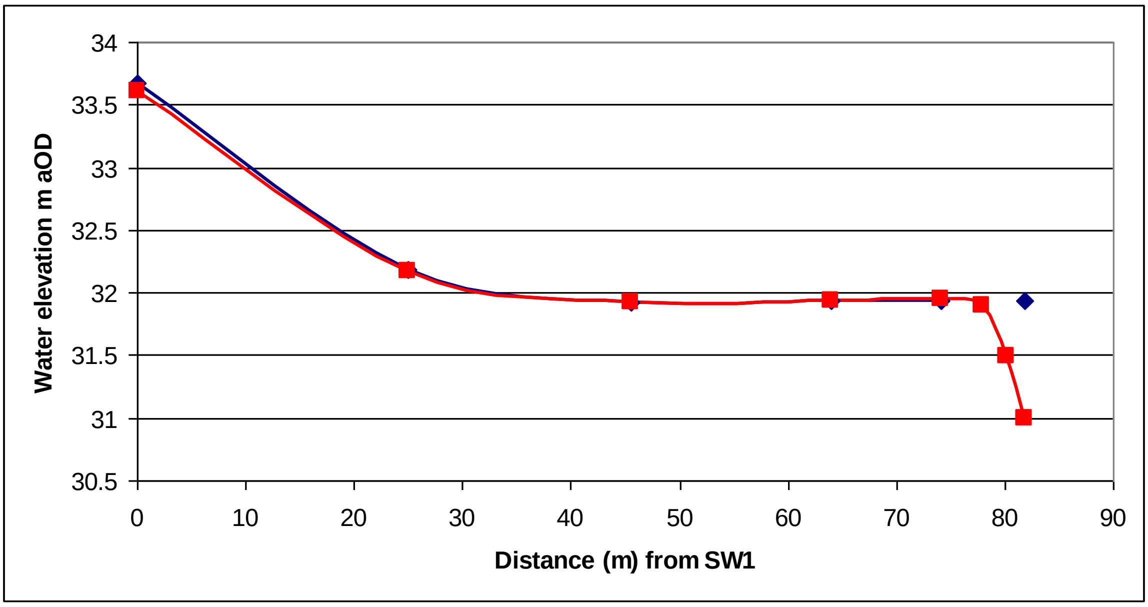

Figure 16. Water table profile plot running from DW1 (left) to the main drain (right) for 21 December 2012 (blue line, pre ditch cleaning) and 25 November 2013 (red line, post reinstatement of the ditch).

Comparison of water table recession at locations DW4 and DWM9 for dry periods confirms the very stable hydrological regime at DW5 and also shows evidence of enhanced drainage at DWM9 (Table 9), particularly during the summer. The recession is always greater at the M9 location, perhaps because of the very loose superficial peat deposit and the possibility that the substratum between the measurement point and the drain might be based on similarly unconsolidated material. The very modest recessions observed at DW4 may reflect (i) inherently poor drainage, and (ii) groundwater seepage into the peat body – it seems possible that the latter is sufficient to partly counteract the expected evapotranspirational losses for the summer-time periods included in Table 9. Taken together with Figure 12, these data indicate an enhanced drainage effect at station DWM9 following reinstatement of the drain, and no apparent effect at DW4.

Table 9. Water table levels and recession for periods with limited rainfall for stations DW4 and DWM9 at Cors Hirdre SSSI. Data are derived from the automatic data loggers at these locations and include periods before (B) and after (A) reintstatement of the ditch.

Period no	*Total rainfall (mm)*	*Start, date & time*	*End, date & time*	*DW4*	*DWM9*
B	6	14/02/2013 06:00	07/03/2013 12:00	5.8 - 3.8 / -2.0	8.9 - 0.6/ -8.3
B	0	23/03/2013 09:00	11/04/2013 05:00	4.6 - 2.9/-1.7	5.4 - 3.6/-2.8
B	1	06/07/2013 01:00	24/07/2013 21:00	4.6 - 3.8 / -0.8	2.3 - -10.7 / -13
B	1	11/07/2013 21:00	24/07/2013 21:00	4.1 - 3.8 / -0.3	1.3 - -10.7 / -12
A	0.2	20/11/2013 11:00	25/11/2013 10:00	4.6 - 2.7 / -1.9	0 - -3.7 / -3.7
A	1.2	7/04/2014 23:00	21/04/2014 19:00	8.1 – 8.0 / -0.1	0.5 - -8.3/-8.8
A	?	12/6/14 00:00	26/6/14 20:00	6.7 - 5.5/-1.2	-10.6 - -36.6 / -26

Substantial deposition of ditch arisings has occurred on both sides of the ditch (Figure 17), despite efforts to ensure this was focussed on the opposite (N) side of the ditch to the main stands of alkaline fen vegetation. The predominantly organic nature of the spoil confirms the digger operator generally avoided over-deepening beyond the original drain profile. Removal of at least a proportion of the spoil to the side opposite the alkaline fen would be desirable. The spoil will encourage ponding of water in the alkaline fen (undesirable) but by the same token it will help reduce drainage to the drain should adequate control of drain levels prove difficult. Some of the spoil could be replaced within the ditch profile to aid creation of a ditch floor corresponding to the base of the peat, or even slightly higher.

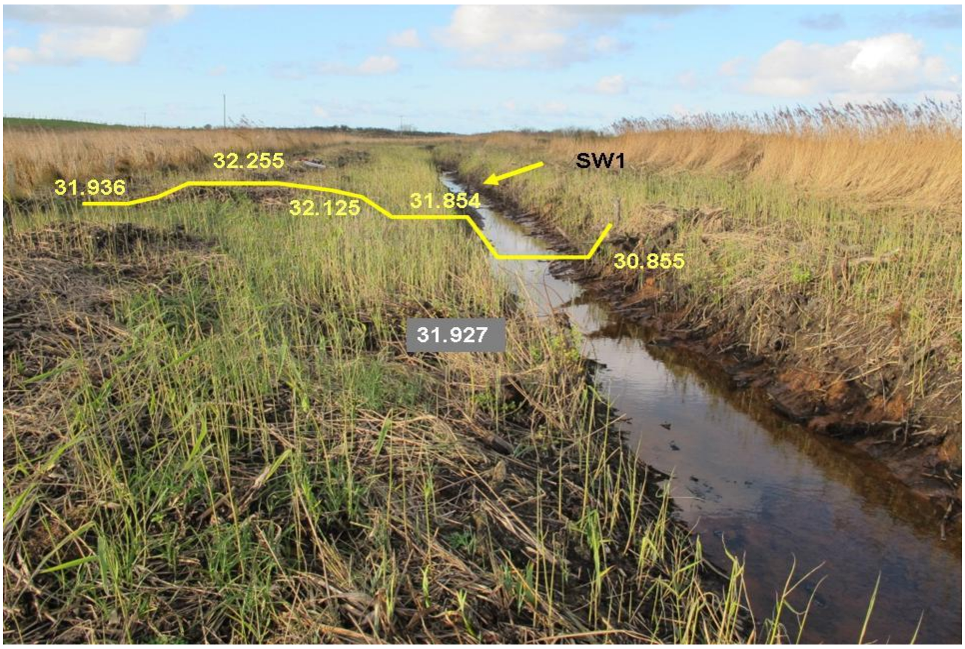

Figure 17. The main axial ditch looking west from dam D2 at SH25776.38312, 4 December 2013. The yellow profile is diagrammatic and note the ditch cross section and the rising pile of ditch arisings to the left (south of the ditch) with key measured spot elevations (m aOD) shown in yellow. The level in white with the grey background denotes the level of the occasional drainage points left by the digger operator to carry excess water to the drain – see also Figure A.3.5. Location SW1 is a short distance upstream of the conceptual profile. Note young reed growth (still green) to 1 m high through the spoil on both banks, compared with the full seasons (2013) growth (dead material) to the far right. This photograph was taken before work to ensure correct operation of the timber dams.

5. CONCLUSIONS AND RECOMMENDATIONS

- The project to restore a functioning axial drain has been successful, though some further work is required to raise water levels to the peat/till boundary (see below). The ditch reinstatement work will ensure that enriched lateral drains no longer pose a significant threat to the alkaline fen interest at Cors Hirdre. This is a critical step in the restoration of the site.
- Appointment of an experienced contractor and the use of a specialised wide-track excavator minimised ground damage (see Figure A.3.6).
- The restored ditch profile should eliminate over-banking for all but very exceptional events. Over-banking from the inflowing minor streams from the slopes to the N and S should also be prevented/greatly reduced. The stream leading into the main drain from Hirdre Uchaf has been shown to carry substantial amounts of inorganic N: this water will now be conveyed directly to the axial drain and ultimately out of the site.

- The restored ditch profile will help ensure seepage gradients towards the valley fen axis. The open ditch will provide habitat for macrophytes and early successional swamp vegetation, both of which would be encouraged by raising water levels to the approximate level of the top of the clay.
- More of the spoil dug out from the ditch should have been deposited on the N side of the ditch in the vicinity of the main M13 stands. Heaping of spoil on the S side of the ditch was unfortunate.
- Timber board dams D3 and D4 need to be made effective in advance of any water table drawdown in spring/summer 2015. The water level should be set as close to the level of the peat/clay interface as possible – i.e. at least 30 cm higher than its current level (Figure 18). This should still allow enough storage for most flood events, thus ensuring (i) overbanking does not occur and (ii) seepage profiles from the edge of the site to its axis are sustained.
- Continuous water level monitoring should be reinstated in the main ditch and continued in wells DW4 and DWM9. This should be continued at least throughout 2015 and for a full summer season after dams DW3 and 4 are made effective to determine if this helps restore a more favourable water level regime at well DWM9.
- Ongoing manual water level measurements should be continued, with at least a winter maximum and summer minimum level determined.
- Use of automatic loggers proved to be a mixed blessing, with insufficient staff resources available to make best use of the data and to ensure adequate quality assurance and checking of data after October 2013. Jumps in the data-record due to replacement of well caps and loggers at slightly different elevations complicated data analysis.
- The generally enriched character of Cors Hirdre is of the greatest concern and the focus of effort must now move to measurement of groundwater heads and characterisation of levels of N and P in the critical marginal sand and gravel aquifer and the development of any necessary remedial measures. The Natural Resources Wales project to install boreholes into marginal drift deposits at the site is a valuable development in this regard.

Figure 18. Water levels in the recently cleaned main drain upstream of Dam D2, 19 March 2014. The water level upstream of the dam is probably slightly above the base of the peat in this image, this is the recommended level.

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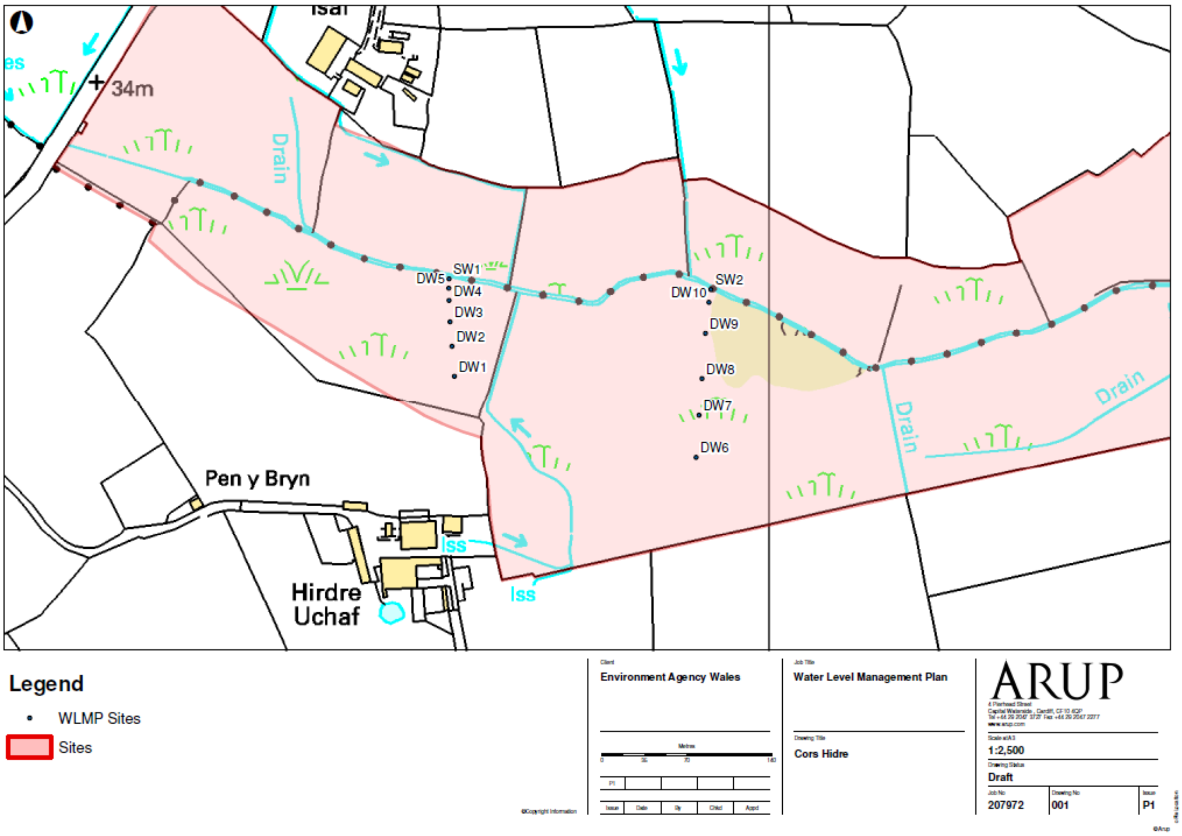
7. ACKNOWLEDGEMENTS

We wish to acknowledge the cooperation of the land-owner and tennant farmers at Cors Hirdre. We thank Rex Humphreys-Jones (NRW) for his role in negotiating management agreements at this site. We also thank G.H. James Cyf, the primary contractor with this contract, and in particular Messrs Huw Salt, Gwilym James and Dewi James. Dr Rob Low kindly re-plotted Figure 13 and contributed to discussions about the hydrology of the site. We thank Rachel Breen (NRW), Gareth Farr (BGS) and Paul Inman (Independent Hydrological Consultant) for other useful discussions about the site and for their respective efforts in improving our understanding of groundwater interactions. Finally, we thank the European Union *LIFE* programme, NRW and CCW for funding this project.

ANNEX 1. DIPWELL LOCATION MAP FOR ORIGINAL 2008 WATER LEVEL MANAGEMENT PLAN SITE INVESTIGATION PROGRAMME.



ANNEX 2. HYDROLOGICAL INFORMATION

Annex 2.1. Logger suspension cable – sensor point distances.

Data-loggers measure the height of water above the logger sensor. The position of the sensor is marked by a circumference line on the logger housing and the distance from this point to the top of casing is required to convert logger outputs to water levels relative to top of liner casing (TOC) and hence peat or OD.

Table A.2.1. Logger suspension details. The Diver loggers at SW1 and DWM9 are mounted on holes drilled into the side of the dipwell lines. The loggers in DW3 and 4 are attached to the well caps.

Dipwell no / logger number	*Suspension point to sensor line measurement (cm)*	*Suspension point distance below TOC (cm)*	*Total distance from TOC to sensor line (cm)*
DW3 / L5145	81.2	0	81.2
DW4 / L4883	88.4	0	88.4
SW1 / L5152	87.3	1.5	88.8
DWM9 / H6409	66.3	2.2	68.8

Annex 2.2. Diver performance tests.

Diver performance has been checked by programming loggers to record at 60 or 30 second intervals within a plain liner in which water levels are adjusted by adding or removing water. Data for logger H6409 were satisfactory and are not shown here. Logger readings are generally within 1 cm of measured level with the exception of water levels which result in only a relatively shallow head of water above the sensor line (notably the results for a -70 water level for logger L5145).

Table A2.2.1. Test results for logger L5145 (DW3).

Measured water below TOC	Water level logged by diver, Min (Average) Max	Number of observations	Measured minus average logged value (cm)
-70	-55.9 (-56.29) -56.7	7	13.7
-38.5	-37.8 (-37.8) -38.1	8	0.7
-28	-27.2 (-27.36) -27.6	8	0.64
-15.7	-15 (-15.14) -15.3	8	0.56
-6.2	-5.5 (-5.61) – 5.8	14	0.6
0	-0.7 (-0.48) -1.0	18	-0.48

Table A2.2.2. Test results for logger L4883 (DW4).

Measured water below TOC	Water level logged by diver, Min (Average) Max	Number of observations	Measured minus average logged value (cm)
-53.2	-52 (-52.2) –52.3	9	1
-38.6	-37.7 (-37.71) -38.2	10	0.89
-30.2	-28.9 (-29.06) -29.1	6	1.14
-16.7	-15.8 (-15.92) -16.1	6	0.78
0	-0.4 (-0.58) -0.7	4	-0.58

Table A2.2.3. Test results for logger L5152 (SW1)

Measured water below TOC	Water level logged by diver, Min (Average) Max	Number of observations	Measured minus average logged value (cm)
-67.2	-65.7 (-66.22) -67.6	82	0.98
-46.8	-45.9 (-46.25) -46.4	12	0.55
-33.8	-33.3 (-33.36) -33.5	10	0.44
-21.4	-21 (-21.2) -22.3	7	0.2
-4.5	-4.1 (-4.3) -4.4	6	0.2
0	(-0.3)	3	0.3

Annex 2.3. Diver download file names.

Dipwell DW_M9 *sws_h6409_131204181243_H6409*
Dipwell DW_M9 test results *sws_h6409_131204200618_H6409_test*
Dipwell DW_3 *sws_l5145_131206171649_L5145_and baro*
Dipwell DW_3 test results *test_sws_l5145_131206180902_L5145*
Main drain SW 1 *hirdre drain SW1_sws_l5152_131128164011_L5152*
SW1 test results *test_sws_l5152_131220101625_L5152*
Dipwell DW 4 *sws_l4883_131205002340_L4883_dip 4_master*
Dipwell D 4 test results *test_sws_l4883_131207185020_L4883*

Annex 2.4. Manual water level measurements

See spreadsheet *Hirdre Hydrological Data Master*.

ANNEX 3. ADDITIONAL SITE PHOTOGRAPHS.

Figure A.3.1. Clasts retrieved from sandy clay unit underlying peat in the exposed ditch section at Cors Hirdre at SW1.

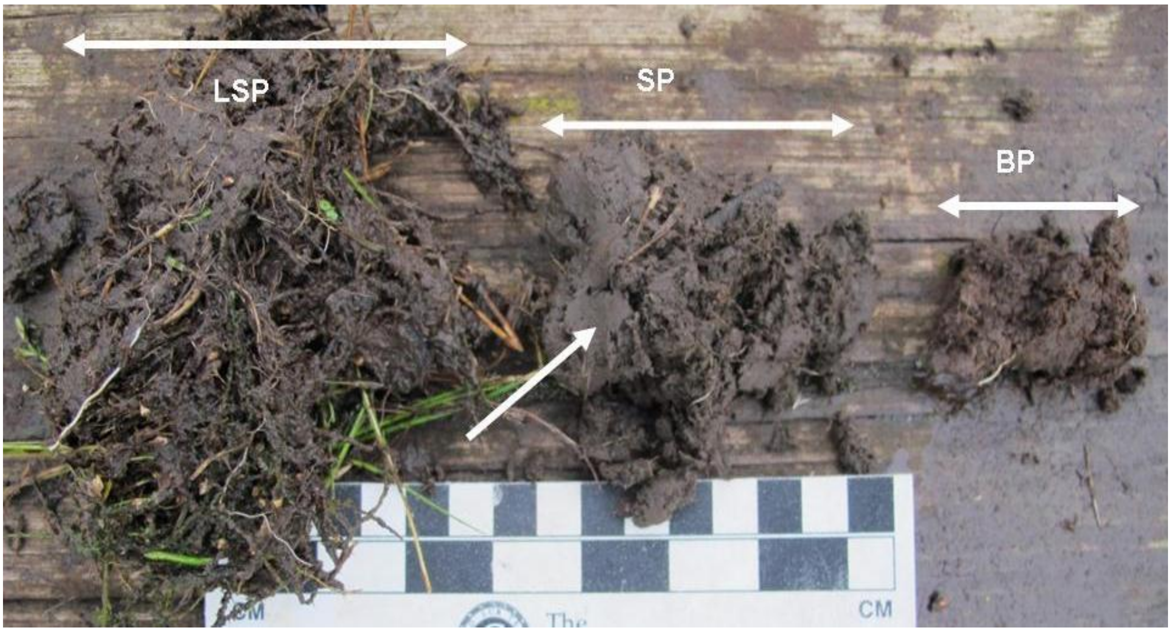


Figure A.3.2. Key organic units recorded from stratigraphic examination of M9 stand at SH 26064.38211 (see Table 5) at dipwell DWM9. Key to abbreviations: LSP, loose surface peat and vegetation raft material recorded from 0-15 cm: SP, greyish silty peat recorded from lower part of 15 – 47 cm: BP, basal peat recorded from 49 – 86 cm (see also Fig. A.3.3). The white arrow overlain on the SP sample shows a smear holding its form in this silty material. Image reference IMG_3311. Photo taken 29 November 2013.

F**igure A.3.3.** Close up image of basal peat recovered from Cors Hirdre station DWM9 on 29 November 2013 (SH 26063.38213). Macrofossils can be seen. Horizon depth 49-86 cm below water level. Sample approximately 4 cm wide.

Figure A.3.4. Core sample from c. SH 2570.3823 from just S of marked break of slope above sloping wetland edge. Photo shows the sandy gravely clay-rich brown loam recorded at this location.

Figure A.3.5. Looking east along S side of recently cleaned ditch with dipwell DW5 flagged to right. A channel (flooded) has been left in the spoil bank by the digger operator.

Figure A.3.6. Tracks of 'bog-master' machine on very soft peat. Photo taken from S side of axial ditch looking towards Hirdre Uchaf, December 2013. The vegetation has been flattened but the vegetation raft remains unbroken.

Figure A.3.7. Marked break in slope visible at *c*. SH 2570.3823 on S side of site looking NW. The core sample shown in Figure A.3.4 was taken close to this point.

Figure A.3.8. Point at which ditch from Hirdre Uchaf joins the main axial drain at Cors Hirdre, December 2013**.** Looking N from N side of axial ditch. This ditch was completely occluded, with overbanking water prior to ditch reinstatement. The main area of alkaline fen vegetation occurs to the right of this image. This ditch yielded high concentration of nitrate in June 2010 (see main text).

ANNEX 4. DETAILS OF DAM INSTALLATIONS AT CORS HIRDRE SSSI.

Dam No.	*NGR (all SH). by GPS*	*U/S-D/S water level difference, 19/3/14*	*U/S-D/S water level difference, 13/6/14*	*Water level relative to crest, U/S, D/S, 13/6/14*	*Elevation of dam crest (maOD)*
1	25691.38332	28.0	ND		31.304
2	25776.38315	49.2	-48.2	0, -48.2	ND
3	ND	ND	0	-31, -31	ND
4	ND	ND	0	-35, -35	ND