

4. Site Selection and RS Data Availability

4.1 Site Selection

Our initial selection of sites proposed for study included Wedholme Flow in Cumbria, the priority site identified by English Nature, Cors Caron (Tregaron Bog) in mid-Wales, and one or more sites from the Vale of York, for example Thorne Moors. Following discussion with the client, Ballynahone Bog in Northern Ireland was substituted for the site in the Vale of York.

Our previous experience with Landsat TM and SPOT XS/Pan suggested that neither of these systems would be suitable as the basis for a nationwide operational system for mapping raised peat bogs. Problems of cloud cover in the British Isles and the coarse spatial resolution of these sensors relative to the features of interest on peat bogs would be the main problems, but, following the review of raised bog habitat classifications presented above, we also anticipated needing information on surface micro relief which could not be provided either by Landsat or SPOT. Nonetheless, Landsat has shown itself capable of providing useful assessments of 'active bog' over large geographic areas at a resolution of around 30 metres (Quarmby, Everingham & Reid 1997), so offers the possibility of operating as a relatively inexpensive initial coarse filter covering a wide area, provided cloud-free images can be obtained.

Remote sensing methods (Table 4) which could provide sufficiently detailed information on bog surface topography include analogue or digital stereo photogrammetry from an aerial platform, airborne interferometric synthetic aperture radar (InSAR) and airborne LIDAR. Photogrammetry would be the most accurate method, but also the most labour intensive, requiring specialist skills to extract the necessary information from the imagery. The main problem with InSAR was its limited availability for the sites of interest. However, this situation is about to change markedly due to the NEXTMap programme which is planning to acquire InSAR data for most of England and Wales during 2003. With this in mind, we have included a InSAR-based approach in the relative costings presented in Section 8.2.

Table 4. RS data availability for the main sites

	Wedholme Flow	Cors Caron	Ballynahone	Comment
High resolution satellite sensor data	Three Ikonos images were available from September and October 2001.		None available	Infoterra, the UK agent for Ikonos originally stated that Ikonos data were available for Ballynahone, but this proved not to be the case
Airborne multispectral data	CASI data possibly available for part of the site from the Environment Agency.	Daedalus Airborne Thematic Mapper and CASI data available for three dates from NERC	None available	
Airborne LIDAR	Partial coverage available from the Environment Agency.		None available	
Airborne InSAR	The NextMap programme is currently acquiring interferometric SAR data for England and Wales (February 2003).			
Comment			Copies of colour aerial photographs of Ballynahone Bog were made available in January 2003	

4.2 Ikonos Satellite Sensor Data

Ikonos multispectral imagery, which has been commercially available since early 2000, (www.spaceimaging.com, 2002), was chosen as the main data source for the Wedholme Flow test site. It is a reliable source of high resolution data with the sensor acquiring panchromatic imagery (1 band) at one metre resolution and multispectral imagery (4 bands) at four metre resolution (Table 5). The multispectral data were found to be more useful as the different bands contain more information concerning surface cover than panchromatic data for the present purpose.

Table 5. The spectral range of the 4 Ikonos bands. (Source: Infoterra, 2002)

Band	Region	Spectral Range (nm)
1	Blue	445-516
2	Green	506-595
3	Red	632-698
4	Near Infrared	757-853

The data were obtained from Infoterra, a company specialising in geographic information and who offer a range of remotely sensed data from both airborne and satellite sources.

The precise location of the area of interest was given as 54.5212° latitude and -3.1329° longitude as this is the centre of the Wedholme Flow lowland raised bog. Archive data was stipulated as a preferable source as it would be readily available and cheaper than obtaining a new data set. Infoterra offered three archive images which were acquired in September and October 2001. The October image, dated 24 October 2001, is the only one in which the area of immediate interest (i.e. the peat bog itself) is completely cloud free and was thus preferable over the other two, the exact geographical reference of this image is 54.9151° latitude and -3.32404° longitude. The data were provided on a CD-ROM in a format which preserved the maximum dynamic range (11 bits per pixel).

4.3 Airborne Multispectral Data

Several data sets were available for the Cors Caron site as a result of it having been used for a PhD research project within the University of Southampton. These are described in Table 6 and Table 7. Aerial photographs were also collected during each flight and a large number of ground spectra were collected from vegetation communities on the raised bog.

Table 6. Airborne Multispectral Data available for the Cors Caron site

Date	Sensor	Nominal Pixel Size (metres)	Wavebands
8 May 2001	CASI	3	Up to 288 spectral bands between blue and near infra-red.
27 June 2001	CASI	3	
12 Oct 2001	CASI	3	
8 May 2001	ATM	4	10 bands in the visible, near infra-red and thermal wavelengths.
27 June 2001	ATM	4	
12 Oct 2001	ATM	4	

Table 7. Bands sensed by the Daedalus Airborne Thematic Mapper (Source: NERC, 2003)

Channel	Wavelength (μm)	Corresponding Landsat TM Band
1	0.42-0.45	
2	0.45-0.52	1
3	0.52-0.60	2
4	0.60-0.62	
5	0.63-0.69	3
6	0.69-0.75	
7	0.76-0.90	4
8	0.91-1.05	
9	1.55-1.75	5
10	2.08-2.35	7
11	8.5-13.0	6

4.4 Lidar Data

Airborne lidar data covering part of the Wedholme Flow site were purchased from the archive maintained by the Environment Agency. These data were provided as a 2km x 2km tile, with a nominal pixel size of 2 metres, and covered only part of the complete bog area (see Figure 1). The stated precision of height was ± 25 cm. Both filtered and unfiltered data were provided. Due to the additional height uncertainty introduced by the filtering process it was decided to use only the unfiltered data.

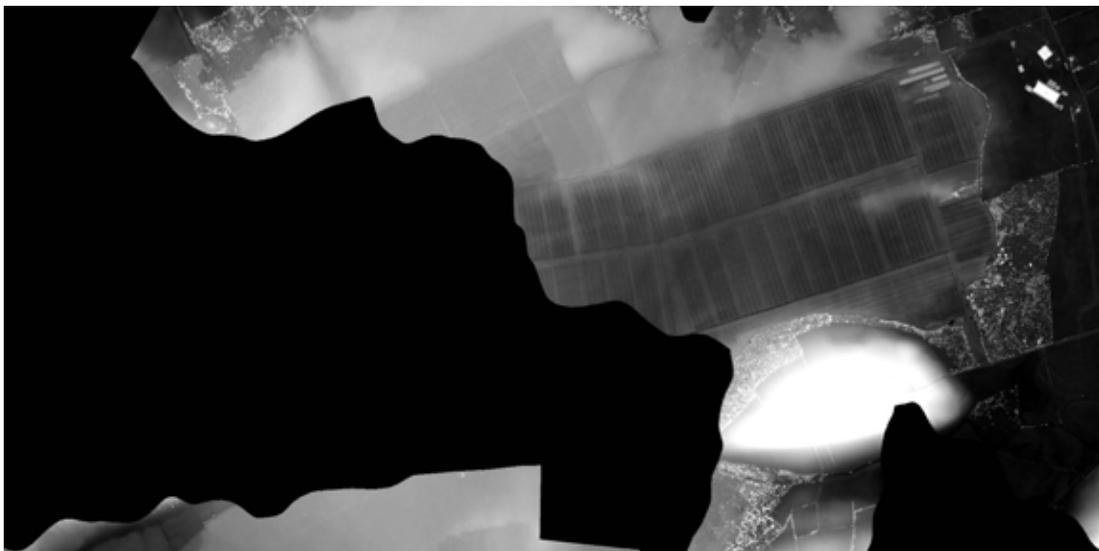


Figure 1. A grey scale image of the LIDAR coverage available from the Environment Agency archive covering part of Wedholme Flow

The initial plan was to use the lidar data as the primary source of quantitative information on surface micro relief over the whole bog area, and it would have been very useful for this task. However, the limited spatial extent of the available lidar coverage meant that this was not possible. Instead, we investigated a number of ways in which lidar data may be processed so as to provide useful information for bog habitat classification, and in particular as a means of discriminating primary from secondary bog surfaces. Various digital processing techniques were applied to the lidar coverage, including fourier transform analysis and geostatistical techniques designed to extract repetitive patterns from digital image arrays. Although these were reasonably successful, the results they produced required specialist knowledge to interpret and it was felt that they added little to what could be achieved by simple visual interpretation of a relief-enhanced lidar image (Figure 2). This image was produced by first colour-coding the lidar image according to the height value (green = low, red = high), and then illuminating the colour-coded image from the north-east, at a low elevation angle so that the relief features on the bog were enhanced. In this example, a single illumination geometry was sufficient to enhance the surface relief features within the land parcels on the bog. However, in other cases it may be necessary to produce several images, each illuminated from a different direction in order to optimise the visual interpretation of microrelief.

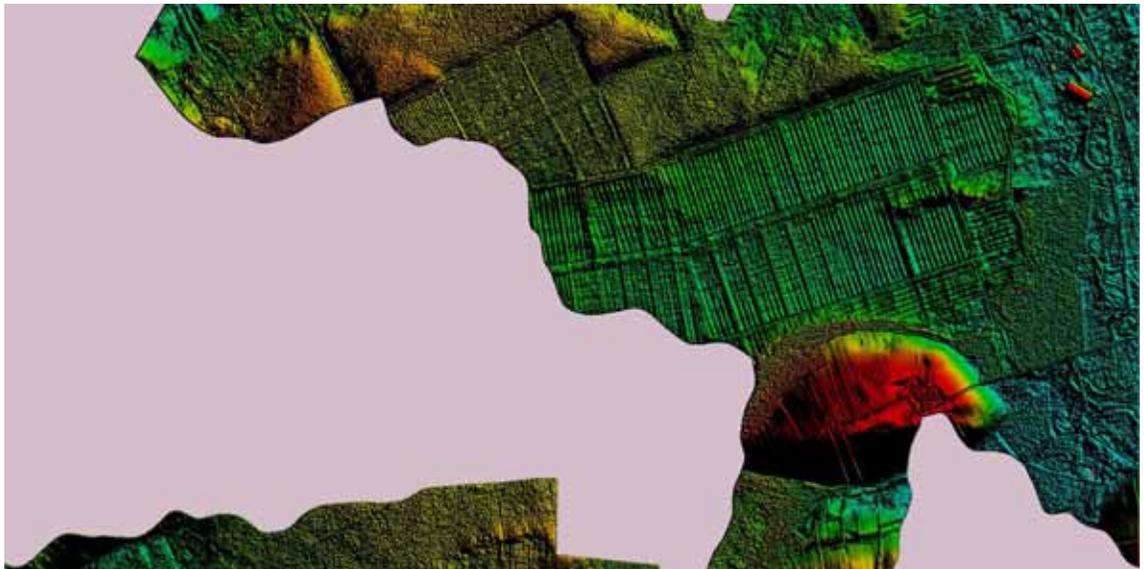


Figure 2 : Enhanced lidar image of part of Wedholme Flow. The lidar data have been colour coded according to altitude and then relief shading applied. Blank areas indicate no lidar data

5. Field Sites and Ecological Methods

5.1 Wedholme Flow, Cumbria (Grid Reference: NY 2253)

Wedholme Flow, an extensive lowland raised bog, is situated at the head of the Solway Firth in Cumbria at an altitude of 13 m. Annual rainfall is about 900 mm /yr and evapotranspiration 471 mm/yr (McMullen, 2000) The peat deposits, whose thickness reaches over 7 m overlie reddish till and marine alluvium (Burton and Hodgson, 1987). Wedholme Flow covers 780 ha¹. The area of uncut *Sphagnum*-rich raised bog of 125 ha is still among the largest in England. Wedholme Flow includes several existing “Sites of Special Scientific Interest” and is also proposed as a Special Area of Conservation (SAC) as part of the Natura 2000 network under the EC Habitats Directive. The Scotts Company undertook peat extraction in an east-west direction, separating two big uncut areas in the northern part of the site and in the south. In early 2002 the peat extraction ceased, after Scotts agreed to sell 1,526 ha of lowland raised bog to English Nature for £17.3 million¹. Wedholme Flow is managed by English Nature as part of the South Solway Mosses NNR.

The site was visited for fieldwork 13 until 15 September 2002. To obtain an overview of the vegetation cover of Wedholme Flow, 20 quadrats of 3 x 3 m were mapped at representative locations according to the land cover classes of the Lowland Raised Bog Inventory (LRBI) (Lindsay and Immirzi, 1996). Additionally the mapped areas had to be representative of the surrounding vegetation in terms of colour and reflectance. Therefore, areas which are distinctive because of the growth of vegetation patches with a contrasting reflectance (e.g. *Narthecium ossifragum* hollows) within the uncut areas were excluded from mapping.

The northern and southern uncut areas possess active peat forming vegetation dominated by *Sphagnum*, which covers 30 to 70 % of the ground. The most common *Sphagnum* species in the uncut areas are *S. magellanicum*, *S. papillosum* and *S. tenellum* along with *S. subnitens* and *S. capillifolium*. Accompanying vascular plants include *Calluna vulgaris*, *Erica tetralix*, *Andromeda polifolia*, together with *Eriophorum vaginatum*, *E. angustifolium*, *Rhynchospora alba* and *Drosera rotundifolia*. *Narthecium ossifragum* is also present, growing in clusters. In the Southern part of the bog some *Sarracenia purpurea* plants were encountered. This carnivorous species is a North American native and was introduced to Wedholme Flow (McMullen, 2000). Altogether the southern part of the uncut areas possesses a much higher *Sphagnum* cover and is in better condition than the northern part, which has to be considered as somewhat degraded. All uncut areas are drier along their edges, which are dominated by vigorous growth of *Calluna vulgaris*. In the north eastern part of the northern section of uncut bog the vegetation is disturbed and modified due to an air accident in the Second World War (Frank Mawby, site manager, personal communication).

¹ <http://www.defra.gov.uk/news/2002/020227a.htm>

Adjacent to the east side of the southern uncut compartment, there are domestic peat cuttings which have been re-vegetated by peat forming plant communities. Areas where sod-cut peat has been extracted are mainly situated in the western part of the central cut area. Vegetation there is quite heterogeneous varying between very wet artificial hollows to dry baulks, which lie adjacent to each other. In the hollows *Sphagnum cuspidatum* and *Eriophorum vaginatum* are dominant, whereas the ridges are mainly covered by *Calluna vulgaris*. Along the western slope where the ground rises towards to the mineral soil the area becomes generally dryer and *Calluna vulgaris* is predominant. The central / eastern part of the site has been excavated until very recently and consists mainly of a bare milled peat surface without vegetation.

At the northern edge of the bog there are minerotrophic fringes of cut-over peat, which are now wooded. These woodlands consist mainly of *Betula pubescens* and have a *Sphagnum*-rich field layer. At the southern edge the wooded fringes are probably uncut peat and could be related to a former lagg zone.

5.2 Cors Caron, Ceredigion, West Wales (Grid Reference: SN 685622)

Cors Caron, also known as Tregaron Bog, is situated near Tregaron village in the Teifi valley in Ceredigion, west Wales. The bog complex developed from a late glacial lake, which was formed behind an end-moraine (Godwin and Conway, 1939). It is an extensive lowland raised bog complex of 816 ha, consisting of three hydrologically independent peat domes. All three suffer from marginal peat cutting at different scales. There may have been three further raised peat domes, which are destroyed now due to peat extraction for domestic fuel (CCW, 1994). The least disturbed bog is the West Bog, stretching 2 km parallel to the Teifi river on its western side. At the eastern side of the Teifi are the Northeast Bog and the Southeast Bog, separated by a mineral ridge. These two bogs are more affected by peripheral peat cutting, but the central peat domes of all three bogs are still structurally intact. In contrast to many other raised bog remnants they still show the ecological differentiation of plant communities typical of the crown (mire expanse), rand and (partly) lagg (Fojt, 1995). Peat cutting occurred only for domestic purposes and ceased in 1960 (CCW, 1995). The composition of the surface vegetation at Cors Caron underwent a dramatic change over the last 65 years. On the West Bog Godwin and Conway (1939) noted, in the field seasons of 1936 and 1937, numerous pool features and extended *Sphagnum*-rich areas that appear to have been largely replaced by 'drier' communities sixty-five years on, despite an annual rainfall of about 1600 mm/yr (Paul Culyer, site manager, pers. communication). Comparisons of the vegetation data of Godwin and Conway (1939) with recent surveys (Schulz, in preparation) reveal a substantial retreat of the *Sphagnum* cover and a significant increase of ericaceous dwarf shrubs.

Cors Caron became a National Nature Reserve (NNR) in 1955 and it was added to the Ramsar site list in 1993. It supports a range of rare plant species such as the nationally rare bog moss *Sphagnum pulchrum* and rare animals such as the rosy marsh moth *Coenophida subrosea*. The Cors Caron NNR is managed by the Countryside Council for Wales.

Fieldwork was carried out in August and September 2002 using the same methodology as on Wedholme Flow. The uncut areas are mainly dominated by a degraded M18 community (National Vegetation Classification, NVC; Rodwell, 1991), with very little *Sphagnum* (2-23 %) and a high cover of ericaceous dwarf shrubs. The eastern slope of the West Bog is chiefly

covered by *Molinia caerulea*. This species also forms an extensive canopy on most cut-over areas of the Northeast and the Southeast Bogs. Despite peripheral peat cutting, these two peat domes also possess an altogether higher *Sphagnum* cover (about 20 %) and less ericaceous shrubs than the West Bog. Wooded areas occur on cut-over peat, especially in the north-western compartment (willow carr) and along the edges of the eastern peat domes. In recent years many dams around the crowns of the bogs have been built in order to prevent surface runoff. Behind these dams, bodies of standing water have formed, which support renewed colonisation by *Sphagnum cuspidatum*

5.3 Ballynahone Bog, Co. Londonderry, Northern Ireland (Grid Reference: H 860980)

Ballynahone Bog, which is one of the largest lowland raised bogs in Northern Ireland, formed as a basin mire in the valley of the Moyola River, to the south of the Glenshane Pass. The raised peat dome, which extends to 243 ha, is structurally undisturbed over central parts but exhibits, on its southern half, a regular pattern of recently blocked drains. Marginally, the bog has been cut² for domestic fuel supply and there is no natural rand left. The cut parts are mostly minerotrophic and covered with carr woodlands. The domed part of Ballynahone Bog possesses characteristic *Sphagnum*-rich raised bog vegetation with hummock, hollow and pool complexes, supporting species which have become scarce. Rare species include *Sphagnum pulchrum*² and the liverwort *Pleurozia purpurea* as well as the Large Heath butterfly *Coenonympha tullia*. In 1991 a peat extraction company called Bulrush dug 13 miles of drains on the southern part of the bog in preparation for future peat extraction. Due to public action and pressure from several organisations,³ including the Ulster Wildlife Trust and Friends of the Earth, planning permission was revoked³ and the site declared a NNR in 1993. Further declarations² of the bog as an Area of Special Scientific Interest (ASSI) in 1995 and as a Ramsar site in 1998² followed.

Fieldwork on Ballynahone Bog took place 15 and 16 October 2002, using the same methods as on Wedholme Flow and Cors Caron. At the South-eastern part of the bog the vegetation has been almost completely killed off due to lead contamination. About 15 tons of lead was deposited on the site when it was used as a clay pigeon shooting ground (Dermot Hughes, Ulster Wildlife Trust, pers. communication). The pellets, which dispersed onto the bare peat, are still visible and are a significant threat to the surrounding vegetation and ground water.

The central part of the peat dome is characterised by a high percentage cover of *Sphagnum tenellum*, *S. cuspidatum* and *S. papillosum* along with *S. capillifolium* and *S. subnitens*. However, there is also vigorous growth of young *Calluna vulgaris* shoots, which often cover more than 30 % of the ground. In some hollows in the western half of the bog *S. pulchrum* was encountered and in the northern area, occasionally *Vaccinium oxycoccus*. At the cut margins mature *Calluna vulgaris* dominates and reaches nearly 1m in height.

2 http://www.ehsni.gov.uk/natural/designated/ramsar/ramsar_ballynahone.shtml

3 http://www.geographyinaction.co.uk/Landscapes/Landscapes_bog.html

There are some areas at the margin of the peat dome where sod cutting took place. They have re-vegetated forming a pattern of *Sphagnum cuspidatum*-rich pits adjacent to *Calluna vulgaris* dominated balks as on Wedholme Flow. The wooded areas closed to the uncut peat dome are covered by *Betula pubescens* carr with *Sphagnum palustre*, *S. fimbriatum* and *Polytrichum commune* in the moss layer.

5.4 Methodology of the vegetation survey at the investigated sites

To gain an overview of the vegetation cover of the investigated sites, approximately 20 quadrats of 3 x 3 m were surveyed in representative areas, according to the land cover classes of the Lowland Raised Bog Inventory (LRBI) (Lindsay and Immirzi, 1996). Additionally, the mapped areas had to be representative of the surrounding vegetation in terms of colour and spectral reflectance. Therefore, some distinctive patches with contrasting reflectance had to be excluded from mapping. (For example, *Narthecium ossifragum* patches) The areas to be surveyed were chosen with the aid of aerial photographs and after consultation with the site managers.

In the vegetation tables the plant frequency was noted as percentage cover of the ground and the location of each quadrat within the National Grid was acquired using a handheld GPS. On Wedholme Flow, Ballynahone and some parts of the Cors Caron West Bog digital photographs of each quadrat were taken.

Nomenclature follows Stace (1991) for vascular plants, Daniels and Eddy (1990) for *Sphagnum*, Smith (1978) for non-*Sphagnum* bryophytes, Hodgetts (1992) for *Cladonia* and Molberg and Holmasen (1992) for Lichens.