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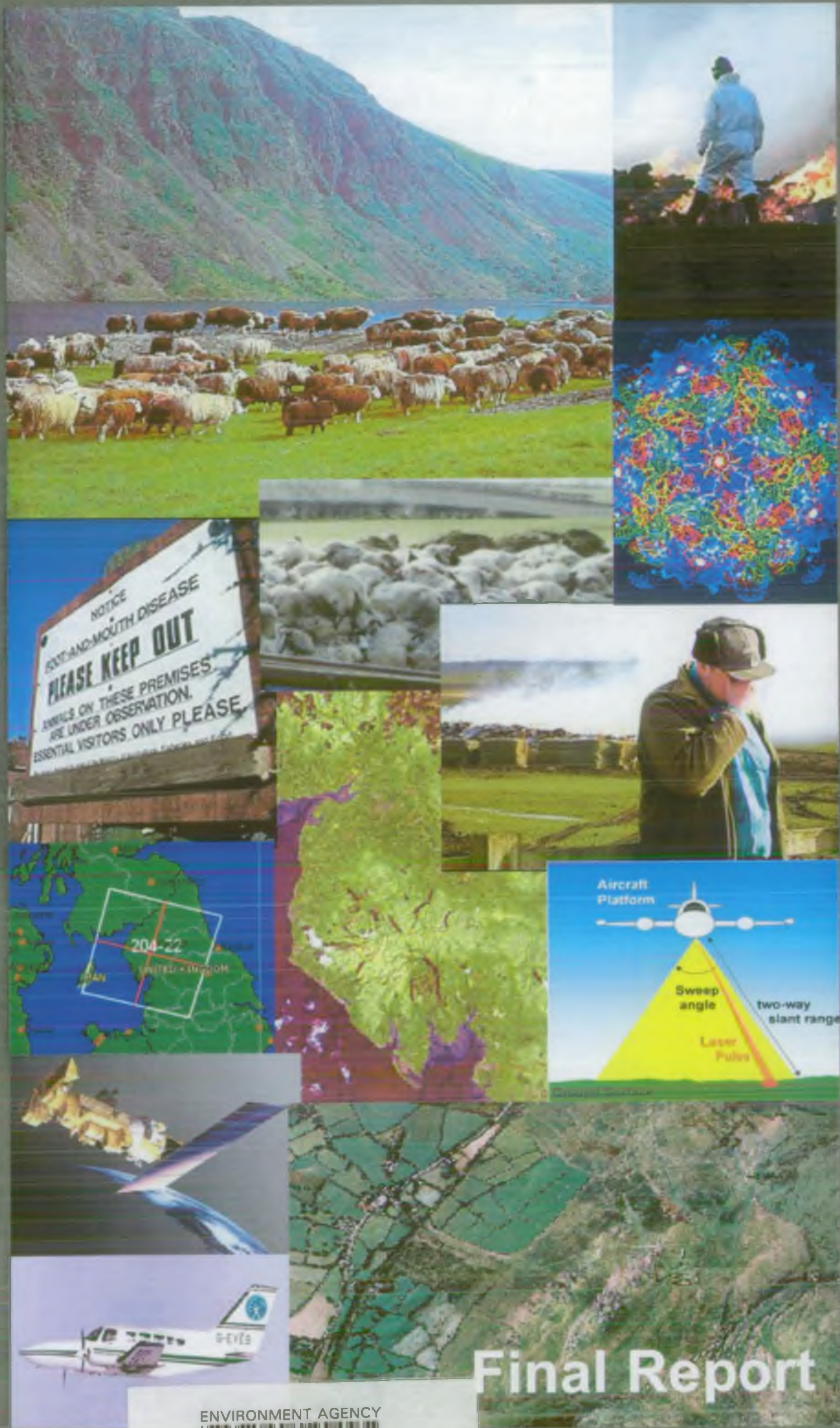

Remote Surveillance Data for Assessing Landscape Change as a Result of Foot and Mouth

A Study in the Lake District

Final Report

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Remote Surveillance Data for Assessing Landscape Change as a Result of Foot and Mouth – A Study in the Lake District

Final Report

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Executive Summary

Concern has been raised by staff from the Penrith office of the North West Region of the Environment Agency that as a result of the cull associated with the 2001 foot and mouth disease epidemic there are very few sheep on the high fells in the Lake District. Casual observations, for example in bird populations, suggest that the landscape might be changing.

This study assesses the use of remotely sensed imagery from aircraft and satellites in assessing any medium or long term impact on the gross landscape as a result of the epidemic. The key area of interest is the Lake District due to its high conservation value. Specifically, it aims to determine the remotely sensed data that are most suitable for a baseline and future monitoring, as well as the availability of these data.

It is part of a proposed wider study to investigate the establishment of a long term remote sensing monitoring strategy which will be developed in consultation with other parties such as DEFRA and English Nature.

The foot and mouth epidemic of 2001 hit the Cumbrian farming community very hard. The combination of worsening antecedent economic conditions, the epidemic and changes to Government Policy towards farming and the countryside will mean that farming, and the local economy of Cumbria is unlikely to ever be the same as it was before the epidemic.

Cumbrian highland farming has some unique characteristics that make it vulnerable to the removal and culling of its sheep. The practice of hefting, that is instilling in the collective flock memory of the extent of their grazing area has kept the pressures on the higher parts of the Lake District uniform. This maintains the plant species, and accordingly the landscape character. The flocks cannot simply be replaced, they have no hefted knowledge of their grazing limits. Untouched by the last epidemic of 1967, the removal of at least a quarter of the hefted flocks may leave many areas of the high fells free of sheep as they preferentially graze elsewhere. At the time of writing, March 2002, there are no sheep on the Skiddaw massif.

Early indications of farmers' attitudes are that few of them are likely to abandon their profession but how many are to change their practices, and in what way, is very uncertain. The Government is considering redirecting subsidies towards more environmental stewardship schemes.

If the landscape of the Lake District Changes, there will be consequences for the environment and biodiversity as well as the local economy. The "character" of the Lake District landscape is one of the key attractions of the area, which relies on tourism. If changes occur, it is important to identify them so that impacts can be considered and management implemented.

Characterising the landscape is a complex and somewhat subjective task. Breaking

the landscape into key units and isolating indicators gives a framework within which it is possible to identify changes and rates of change. Within the Lake District two landscape units have been identified, with associated "landscape structure" elements providing information on the aesthetic character of the landscape.

The changes in economic pressure that lead to landscape change are continuous. It is likely that there will be a "step" change in the landscape due to the epidemic. This step change will occur against the background of changes from other causes. Any monitoring to establish if there is a change in the landscape associated with the epidemic should consider three time frames:

- The post war period to 2000, this will establish the rate of change due to non-epidemic related pressures, and establish a baseline.

- The period immediately before the epidemic in 2000, to establish a checkpoint to measure any step changes from.

- 2002/3 and successive periods to establish if any significant "step change" has occurred and if the landscape stabilises in the medium term, or continues to change.

Archives of aerial photography and satellite imagery offer a unique retrospective data source for the assessment, in a cost-effective manner, of the land cover and structure of relatively large areas. Air photos and imagery have the detail to provide early qualitative measures of landscape structures, and future quantitative measures of landscape structure. An archive of satellite imagery that starts in 1984 exists with the spectral sensitivity to quantitatively isolate changes in vegetation composition.

By combining these data sources with future bespoke surveys and further ground surveys the continuum of change can be characterised, and changes due to the epidemic can be identified.

There is sufficient cloud free satellite and aircraft imagery to establish these baselines, and to continue into the future.

In order to achieve this, the first surveys must be undertaken in the 2002-growing season before any changes in species composition take hold.

A hierarchical survey framework based on the combination of satellite, airborne and satellite data, along with the steps necessary to establish it, is proposed.

The Environment Agency has unique capability within the UK public sector to undertake these surveys and collate the information. Whilst the Agency does not have a direct remit for such work, there are many potential interested stakeholders and interested parties in identifying landscape changes in the Lake District. A partnership between key data holders, stakeholders and interested parties should be rapidly established. If necessary, the Environment Agency should undertake foundational survey work before the partnership is established.

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1. Study Objectives and Methodology

1.1. Objectives.

During the FMD outbreak, the Environment Agency was responsible for assessment and reporting on the disposal of FMD carcasses and related waste. The Agency has worked to minimise the environmental impact of the efforts to control the disease since the first case was reported. Additionally, the Agency has established long term monitoring around sites of mass disposal.

Concern has been raised by staff from the Northern Area Office of the North West Region of the Agency that there are very few sheep on the high fells in the Lake District, and casual observations of changes in bird populations suggested that the landscape may be changing.

This study aims to assess the use of utility of remotely sensed imagery in assessing any medium and long term impacts on the gross landscape as a result of the Foot and Mouth Disease (FMD) outbreak of 2001. The key area of interest is the Lake District due to its high conservation value. Specifically, it aims to determine the remotely sensed data that are most suitable for a baseline and future monitoring, as well as the availability of these data.

It is part of a proposed wider study to investigate the establishment of a long term remote sensing monitoring strategy which will be developed in consultation with other parties such as DEFRA and English Nature.

The study was commissioned and managed by the Agency National Centre for Environmental Data and Surveillance, Bath.

1.2. Methodology.

This study is concerned with the pragmatic, operational use of remote sensing technology for providing an overview of landscape change. The logic of the study is presented in figure 1.1.

The starting point for the study is the likely nature and causes of landscape change as a result of FMD (Section 2). This is used to establish the criteria for the use of remote sensing systems, and to lay down requirements for a monitoring framework.

Using criteria established in section 2, section 3 identifies remote sensing systems that are technically suitable for landscape change. These are further refined using the criteria of cost and availability to provide input into the framework.

Terrestrial data sets that can be used to identify pressures that lead to landscape change, and are measures of landscape change are considered in section 4.

Section 5 proposes a framework for identifying and quantifying landscape change, based on inputs from sections 1 to 4. Recommendations arising from the study are give in section 6.

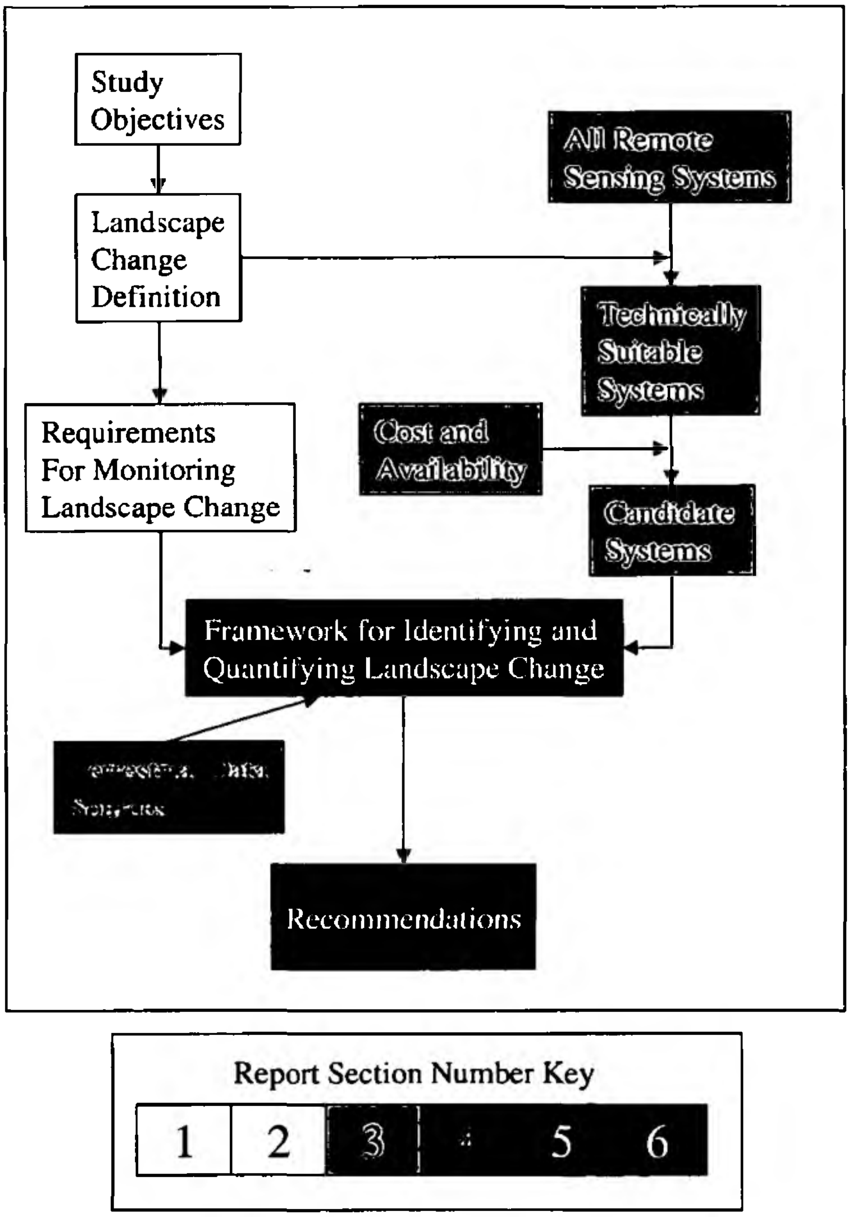

Figure 1.1: Study Logic

2. Section 2: Defining Landscape Change for the Study

2.1. Defining landscape changes for the purposes of this study

This study is concerned with the medium and long term landscape changes that are due, at least in part, to the effects of FMD on the rural economy. Short-term changes such as the immediate environmental impacts of carcass disposal and restrictions on movement and grazing management are outside the scope of this study.

The term landscape can be defined as the "aspect of the land characteristic of a particular region", or "an expanse of scenery that can be seen in a single view". These definitions show that landscape is a descriptive term for an intangible quality that is made up of many elements, many of which are aesthetic rather than measurable.

In order to define change in landscape, the factors that make up a landscape must be understood. All landscapes within the UK are the result of a combination of natural and anthropogenic factors. Geology, elevation, climate, soils and past events such as glaciations set the constraints on the landscape. Man's influence is then overlain on the natural. Man's activities are constrained by socio-economic processes and technological possibilities. As this study is concerned with changes within a relatively few years, natural influences on the landscape are considered stable.

Landscapes can be broken down into distinct units, and processes that may change the nature of man's influence on the landscape can be considered within each unit. This study is focussing on the Lake District. The Countryside Agency delineates the area as the "Cumbria High Fells"[1]. The show the area as being dominated by Cattle and Sheep farming with two economic classifications: – lowland and upland "less favoured areas" [2]. Thus the Lake district can be broadly characterised into two major landscape types: First is the lower slopes where the land is split into distinctly owned parcels and actively managed, the "Enclosed Areas". Second is the upland moorland areas where there are no visible boundaries to the land ownership and usage, and the land is generally not actively managed, the "Open Areas". The boundary between these areas is assumed to be at about 600 metres altitude.

The study was directed to consider these two geographically distinct areas independently as landscape changes were likely to have different characteristics in the two areas. Additionally, the study was directed to consider structural change as a third type of landscape change. Structural change would be characterised by a loss of hedgerows, field boundaries or

[1] State of the countryside report:2001, Countryside Agency: http://www.countryside .gov.uk/northwest/
[2] MAFF/FRCA: 1998: Agricultural Census, dominant farm type by parish.

farm buildings.

2.1.1. Changes in enclosed areas

The enclosed grasslands are used for lambing, early pasture and winter forage production. They are often "improved" and are typically the result of re-seeding, drainage, artificial fertilisation, and herbicide application either singly or in combination. Despite being bright green and often lush they may be dominated by a limited range of grass species (such as rye grass, *Lolium perenne*) often derived from commercially available seed, and very few herb species, but often including white clover *Trifolium repens.* Many improved fields may start to revert to less improved forms if intensive treatment is not maintained.

Semi-improved grassland is a transition category that has a range of species often less diverse than unimproved grassland, as a consequence of either having been partially modified by artificial fertilisers, liming, slurry, herbicides, or re-seeding, or having reverted towards a more natural composition following a reduction in intensive treatment.

Any change in the intensity of agriculture in these areas will result in a change in the species composition and seasonal length of sward. If remote monitoring techniques are to be used to identify change, these are the characteristics that must be identified.

2.1.2. Changes in "open" areas

The land over 600 metres is broadly classified as "Mountain" and comprises rugged and steep land, crag, scree, fell or other bare rock and associated rough vegetation, including semi-natural upland vegetation. This may include areas of bracken, scattered trees, open water, rivers, streams, bogs, mires, bare peat, or a mosaic of these. Some areas over 600 metres can be classified as "Moor" which is of an open character with semi-natural vegetation such as mires (including blanket bog), heaths (referring to the vegetation community), rough unimproved acid grassland, and upland calcareous grassland. This may include areas of unimproved bent-fescue grassland, scattered trees, scrub, bracken, open water, rivers, streams, bare peat, rock outcrops or other bare ground, or a mosaic of these.

Both mountain and moorland areas are made up of a mosaic of vegetation types constrained by topography and management practices. In the Lake District, the upland sheep are often referred to as the "gardeners", grazing heather and grass evenly, and keeping bracken and scrub under control. This keeps the world-famous "Lake District look" to the scenery.

Landscape change in this area is likely to be the result of changes in the balance of the mosaic of land cover types. For example an increase in bracken, shrub and woodland could be attributed to a reduction in grazing intensity.

Any remote monitoring systems to identify and monitor changes in the mosaic must have a resolution sufficient to detect changes in the mosaic structure.

2.1.3. Changes to landscape structure.

Both the managed and open areas in the Lake District have a distinctly unique character. "Character" is a subjective term that is often based on aesthetics and notoriously difficult to quantify. However, some features of the landscape such as hedgerows, copses or walls contribute to the character and can be quantified.

The extent of field boundaries has been in decline nationally with increasing sizes of fields to accommodate machinery and lack of financial incentives to re-build walls.

Any remote monitoring method of identifying landscape structure change must be able to resolve small-scale features such as walls and hedgerows.

2.2. Causes of landscape change in the UK.

Landscape change is the "response" element of a pressure / state / response system that has defined the character of the UK countryside. The pressures on this system can come from natural or anthropogenic sources.

Natural changes, such as the effects of climate change, tend to be relatively slow moving, affecting changes in terms of decades. Anthropogenic changes, such as the decision to move from grassland to arable, are sudden in comparison. Changes in farming practice are themselves the response to pressures on the farmer.

Changes in farming practice, in common with all markets, are frequently based on the economic viability of the particular method and the constraints of the environment and legislation; only a certain set of crops are suited to the UK environment, and there are legislative instruments to prevent damaging practices. The changes in subsidy legislation within the EC are a good example of such "**socio-economic**" pressures.

Some changes in farming practice are due to an unplanned "**trigger**" event that forces extra legislative controls or threatens the economic basis of farming. The large scale conversion of grassland to arable farming during the second world war would be a good example of such a change.

When combined, these two type of pressures can have a lasting effect on the landscape. Much of the marginal grassland converted to food production in the 1940s did not revert as the drive to greater productivity, and technology triggers such as improved herbicides and fertilisers, allowed such areas to be farmed economically.

Much has been written on the policy drivers of landscape change, and it is beyond the remit of this study to repeat such work. A good summary can be found in Seymour (2001)[3], where the drivers are listed as:

EU Level Developments
1. Models for sustainability
2. Land Use and Planning Policy
3. Rural Development Policy

British Level Developments
1. Models for Sustainability
2. Rural Policy and Institutions
3. Rural Development
4. Population Change
5. Land Use and Planning Policy
6. Housing
7. Changes in Rural Industries

[3] Seymour, 2001, Drivers of Countryside Change: Rural Sustainability and Countryside Change: http://www.cs2000.org.uk/

2.3. The 2001 Foot and Mouth Epidemic

2.3.1. Economic Background.

Many commentators viewed the position prior to the outbreak as desperate. Lord Haskin's report to the Prime Minister[4] summarises the economic situation pre-FMD as:

- "For over 40 years it has been clear that farming in the remoter, hilly parts of the country would not survive without substantial special financial support, in addition to the subsidies paid to all other farmers. This is because the land and the climate are not suitable for commercial farming.

– In recent years, the position of hill farming has further deteriorated as the strong pound, an excessive supply of sheep, and chaos in the beef market following B.S.E, have all contrived to reduce incomes significantly.

– The Farming population has been declining for generations as farms have become fewer and larger, and people sought more remunerative work elsewhere. This has lead to a progressive reduction in the supply of services, including shops and transport."

Winter and Smith (2001)[5] give an excellent review of the key trends in agriculture in the 1990s. Once again, it is outside the remit of this study to repeat this work. Their assessment of the market trends, especially in livestock leaves no doubt that there was a significant economic downturn in the 1990s, especially in the sheep sector. Table 2.1 shows the change in net farm income in Less Favoured Area (Upland) and Lowland sheep and cattle farms:

Full Time Farms Only	Net Farm Income (£/Farm)			Annual % Change	
	1997/8	1998/9	1999/0	1998/9	1999/0
		(prov)	(forecast)	1997/8	1998/9
Lowland Cattle / Sheep	13,600	8,100	6,000	-40%	-25%
LFA Cattle / Sheep	10,800	5,800	4,500	-47%	-20%

Table 2.1: Net Farm Income: Cattle and Sheep Farms in England. Source, HMSO.

[4] Rural Recovery after FMD, Christopher Haskins, October 2001, http://www.defra.gov.uk/footandmouth/rural/taskforce/haskins.pdf
[5] Winter and Smith, 2001, Drivers of Countryside Change: Study Review of Key Trends in Agriculture: http://www.cs2000.org.uk/

2.3.2. The 2001 and 1967 outbreaks contrasted

The last major epidemic of FMD in the UK before 2001 occurred in 1967-8. It is worth noting that in the thirteen years before the 1967 epidemic, there were only two years with no recorded outbreaks. The disease was endemic throughout Europe.

In 1967 there were just under 20 million sheep in England and Wales, in 2001, about 31 million. The numbers of cattle and pigs are roughly comparable. The average number of sheep and lambs per holding in 1967 was about 225, in 2001 it was over 500.

The 1967 outbreak had 2228 cases, concentrated on the Cheshire plain, being mainly found in cattle, largely being spread by wind. See figure 2.1. In total, some 442 thousand animals were slaughtered.

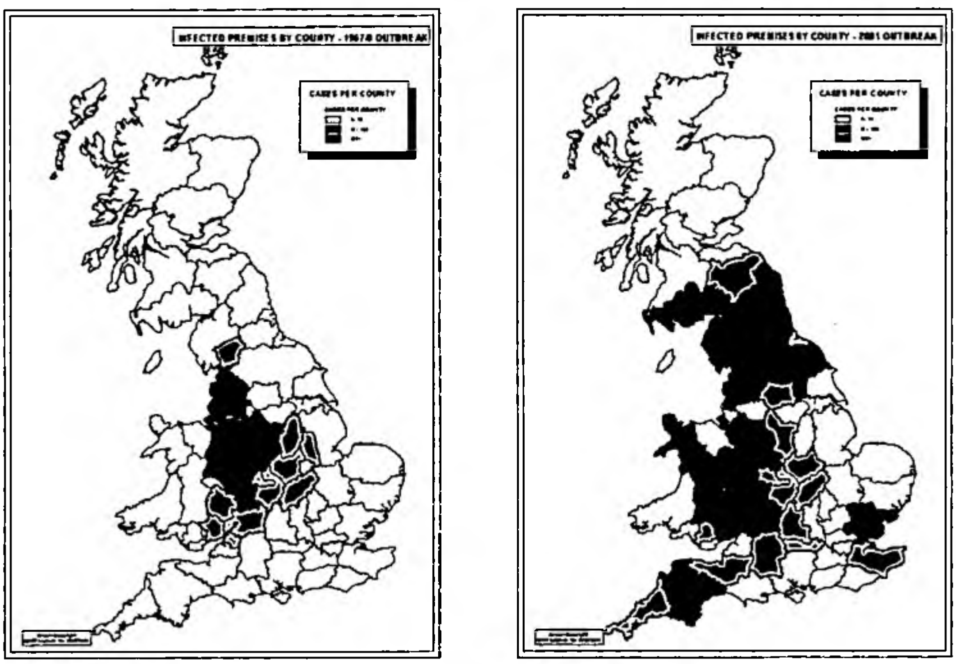

Figure 2.1: The Geographical Spread of the 1967 and 2001 Outbreaks. Source: DEFRA

The 2001 outbreak consisted of 2030 cases. The first case was reported on 19th February 2001, the last on 30th September 2001. It was spread over the country in two weeks, largely carried by sheep, which take longer to develop the symptoms (see figure 2.1). DEFRA figures show that some 4,129,000 animals were recorded as slaughtered (592,000 cattle, 3,390,000 sheep, 142,000 pigs, 2,000 goats, 1,000 deer, 2,000 other animals), over nine times the slaughter of 1967, though some estimates are as high as 6 million.

The timelines of the two outbreaks are shown in figure 2.2. It puts the

2001 outbreak in context especially in the latter stages of the epidemic, which was more drawn out in 1967. Movement and market restrictions are based on the time since the last reported case, so a prolonged tailing off would delay any recovery accordingly. The virus can survive for months, particularly in cold, damp conditions. Sunlight kills the virus but it can survive in dung and can be carried on the wheels of lorries moving from farm to farm. In the 1967 epidemic many farms which were restocked too early had a second outbreak. Much tighter restrictions were imposed in the 2001 outbreak.

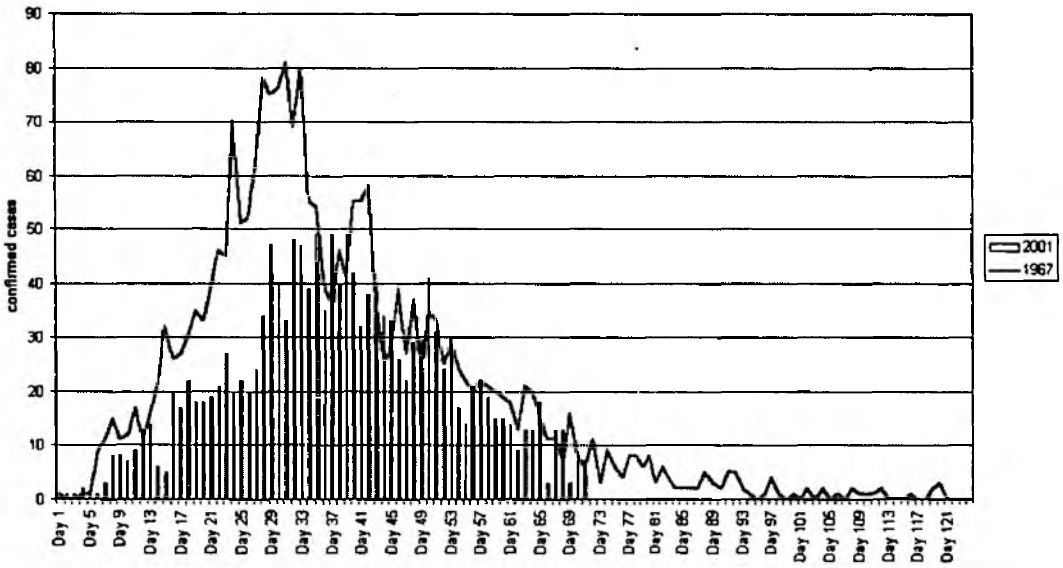

Figure 2.2: Timelines for the 1967 and 2001 FMD epidemics. Source: DEFRA

2.3.3. The Outbreak in Cumbria

The first Foot and Mouth case in Cumbria was confirmed on 28th February 2001. Within Cumbria there were a total of 893 infected premises out of the nation wide total of 2030, some 43%. 32% of the total slaughtered animals were in Cumbria amounting to 1.3 million, of which just over 1 million were sheep (see table 2.2).

Animal	Infected Premises	After Direct Contact	Adjacent farms	Suspicious	**Total**
Cattle	164119	29949	18373	2459	**214900**
Sheep	398121	171699	499938	8236	**1077994**
Pigs	1731	16208	21743	164	**39846**
Goats	139	188	177	6	**510**
Deer	20	24	407	0	**451**
Other	37	8	0	0	**45**
Total	**564167**	**218076**	**540638**	**10865**	**1333746**

Table 2.2: Number of animals slaughtered in Cumbria and reason for slaughter. Source: DEFRA

The geographical spread of the disease is shown in Figure 2.3. This map locates the farm premises where the case was recorded, so does not show the extent of the landscape that was to be affected by the outbreak.

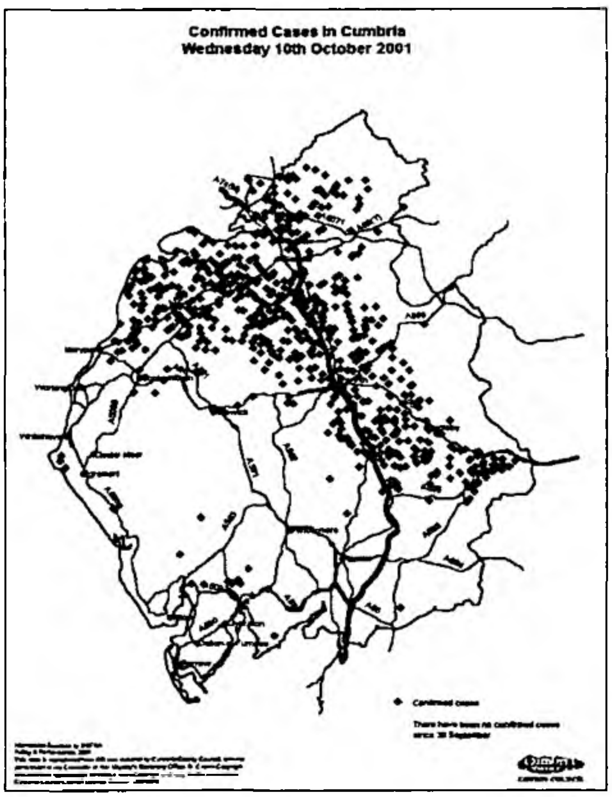

Figure 2.3 – The geographical spread of cases in Cumbria
Source – Cumbria County Council.

To understand the effect of foot and mouth in upland Cumbria the unique husbandry system that has developed over hundreds of years must be considered. The flocks on the upland fells of Cumbria comprise of breeds like the native Herdwick, the Swaledale and some cross breeds. Farmers believe they would be almost impossible to replace because of special qualities honed over hundreds of years. Farmers say they are so important because:

- They have been bred for hundreds of years to be "territorial". This is known as being "hefted" to the fell. This means they can be safely left on unfenced terrain and will not wander off their traditional patch. Ewes teach this behaviour to their lambs.

- They have special resistance to diseases, and parasites like ticks - a characteristic taken advantage of by other sectors of the sheep farming industry to breed into their own sheep.

- They are bred to be tough enough to withstand appalling weather, allowing the marginal felltops to be farmed.

- They are in balance with the environment, grazing heather and grass evenly, and keeping bracken and scrub under control. This keeps the world-famous "Lake District look" to the scenery.

Farmer's representatives for Cumbria do not know how many hefted sheep are on the fells, but it is in the order of hundreds of thousands, belonging to hundreds of farmers. They are only seen once a year when they are brought down to lamb.

At the height of the outbreak, it was feared that the entire Herdwick flock would have to be culled. This would have removed the "hefted" memory from the flocks, with unknown consequences on the farming practices and shape of the landscape. The chief executive of the Lake District Park Authority claimed that:

"If we lost the whole flock, it would be catastrophic. It would take 10 years to re-establish sheep on the high fells. We would have to fence off the fells, and the public would go berserk, or we would need hundreds of shepherds, and where are the people? Many of our farmers are quite old, and they would not want to spend 10 years rebuilding the flock. The beauty of the area is the wide-open fell land. In two or three years, the short grass, which is grazed by the sheep, would be gone, and would be replaced by scrubland. The views would be gone, and the Wordsworth landscape could die." [6]

There are no easily available definitive figures for the proportion of the hefted sheep that were culled. Estimates range from one quarter to one half of the Herdwick flock. What effect this will have on the landscape remains to be seen.

[6] BBC online 26th March 2001 – "Lake District faces disease D-day"

2.3.4. Likely changes in farming practice

This study, as previously discussed, it not concerned with the short term effects of culling and disposal. It is concerned with those changes in farming practice that may have an effect on the landscape.

This study was initiated by the concern of Environment Agency staff in Penrith that the stocking levels in the Lake District were noticeably lower. At the time of writing (March 2002), it is impossible to predict whether the levels of stocking will increase. Flocks recovered after a few years of the 1967 outbreak, which did not affect Cumbria, and involved a smaller cull, centred on cattle.

Re-stocking of the fells cannot commence in earnest until the end of the lambing season. Because of DEFRA restrictions, livestock slaughter markets could not re-open until 11th February 2002. At the time of writing (March 2002) movements are allowed under licence, and it is hoped that auction markets for sheep will be able to re-open later in the year, if veterinary advice to Government argues it is safe to do so.[7]

Farmers in the Lake District are making individual decisions as to whether to re-establish their business, and if so, on what basis. One factor in this decision making is the compensation payments that farmers have received for their culled stock. The total compensation paid to farmers in the UK is £1050 Million. These payments could represent a significant opportunity for farmers to re-focus their lives, in farming or other enterprises. Four options are available to them:

1. Rebuild their business as it was.
2. Diversify into other forms of farming or business.
3. Move from farming and abandon the land.
4. Intensify their business

There is no easy way of determining which option the Cumbrian farmer is going to favour. A survey of 1000 farmers by ADAS carried out in November was publicised by the Government on 19th Feb 2002, with the following key points[8]:

Most farmers will restock, only 6% wanted to move out of farming.
78% want to restock and continue farming as soon as possible.
25% are "definitely" or "possibly" planning to diversify into non-farming activities.
The longer term reduction in the numbers employed in agriculture is likely to continue.

[7] Lord Whitty, 5th February 2002 – DEFRA News Release 50/02
[8] "Number 10" website, 19th Feb 2002.

The same survey was reported in the farming press on 22nd February[9], with a different slant:

"Hundreds of farmers will be forced out of the industry. Most that do restock will not return to pre FMD levels.
"Sheep population may reduce significantly in the short-term, but recover in the longer term"
"The NFU predicts that 10% of the farmers whose animals were culled will leave the industry".
"Separate DEFRA figures show that 30 culled out farms have chosen not to complete the cleansing and disinfection as they are moving out of livestock production. A further 2000 farms have yet to complete the process, while 8000 farms have the green light to restock. DEFRA does not know how many are restocking"

It would seem from the above that the farming industry is very resilient, and without any further pressures it will not collapse. A survey by the Scottish Agricultural College[10] showed that no farmers who had been affected by the outbreak intended to quit farming, though this may be due to a shortage of employment options. The survey shows that there farming systems will emerge simpler, with fewer workers and lower fixed costs.

The effects of the removal of stock from moorland areas have been studied[11]. On Stanton Moor, in the peak district, the removal of stock for 3 years led to a firm establishment of silver birch saplings. In general it is suggested that three years is required for vegetation to establish a "toe hold" that could change the character of the environment.

2.3.5. Changes in farming policy after FMD.

It has been suggested that Government policies in farming and environment are converging. The merging of the environmental parts of DETR and MAFF into DEFRA in May 2001 was a significant step in this regard.

Margaret Beckett, the Secretary of State for DEFRA, specifically noted the ability of "hard hit" Cumbria to embrace change where it is clearly needed to build a better future[12]. The government's flagship policy formation report is "Farming and Food: A Sustainable Future"[13]. This report recommends a sea change in the way that agricultural subsidies are dispensed by redirecting them from food production to protecting the

[9] Farmers Guardian Feb 22nd 2002, P1.
[10] Farmers weekly, 22nd February 2002, P20.
[11] Institute of field archaeologists: "Archaeological issues in a post Foot & Mouth environment", 20/12/2001
[12] Speech to the NFU AGM, 7th February 2002
[13] Report of the "Curry" policy commission on the future of farming and food, January 2002.

countryside. This report, warmly received by DEFRA, is being used as the basis for "modulation" of the CAP payments to the UK, a process whereby up to 20% of the subsidies can be redirected to agri-environment schemes and rural development. The UK is planning to modulate 3% immediately, rising to 4.5% by 2006. The Curry Report recommends raising this to 10% by 2004. This could provide £200 Million, with the UK to provide a matching amount.

The methods of deploying this money have yet to be fully determined, and the decision has attracted a wide range of opinion:

"With the industry in its current dire state, it is hardly surprising that we oppose suggestions of taking money from farmers in this way"- Ben Gill NFU President.

" I would encourage farmers to really look at this report closely and recognise that to some extent we have seen signs over the past couple of years of British agriculture drinking in the last chance saloon" – Barbara Young, Chief Executive, Environment Agency.

Those involved are convinced that any changes will be slow, with little chance of anything other than marginal change over the next four years. DEFRA plan to launch the machinery to drive the recommendations of the report forward in the autumn.

The future of the landscape in the Lake District lies in the hands of the farmers. It remains to be seen whether the hard-hit resilient industry will recover in a form that will retain the unique character of the Lake District. Whilst the connections between farming practices and the landscape seem clear, it is not known how quickly changes may occur, and whether they would be irreversible.

2.4. The Environment Agency's interest

2.4.4. Statutory responsibilities

Throughout the Foot and Mouth disease outbreak the Environment Agency role was to ensure that carcass disposal was carried out in line with appropriate regulation so as to minimise the environmental impact. A report produced by the Agency (The Environmental Impact of the Foot and Mouth Outbreak: An Interim Assessment) identified changes in stocking and grazing patterns as an impact on the appearance of the countryside due to changes in the type and growth of vegetation. This was considered to be a medium to long term impact, the nature of which would depend on the response of farming industry and changes in agricultural policy. It also concluded that there was a need for further research into sustainable land use and agriculture.

The Agency has legislative responsibility for administering the EC Groundwater Directive through the Groundwater Regulations 1998. The Agency also advises on the implementation of the Code of Good Practices for the Protection of Water. The Agency's primary concern following the outbreak will be in monitoring the disposal sites to ensure the protection of ground and surface waters. But both ground and surface waters may potentially be affected by any changes in agricultural practices, and land use in general, that result from the socio-economic impacts of the Foot and Mouth Outbreak.

Whilst the Agency has no direct responsibility for land use and landscape quality, understanding of the changes in the wider countryside may act as indicator of potential impacts on areas over which the Agency does have direct legislative responsibility.

2.4.5. Technical capabilities

The Environment Agency, because it is the competent authority for so much environmental legislation has a wide range of staff and tools at its disposal to assess landscape change. In the context of this study, it has considerable skills and equipment in the field of remote sensing, backed up by staff with intimate local knowledge of the environment.

These skills do not establish the Agency as the lead authority in any assessment of landscape change, but positions it as a key player in delivering any such assessment.

2.5. Establishing a baseline to measure policy efficiency

The 2001 foot and mouth disease outbreak in the UK may well be a trigger that results in a step change or acceleration of the changes in farming practices against a background of worsening economic conditions and policy pressure towards environment. Such changes must have an effect on the landscape. It will be impossible to isolate changes due to foot and mouth from this continuum of change, though any step change or acceleration may be identified.

In order to measure the effectiveness of any policy, a baseline has to be established to measure from. Socio-economic baselines and census results will establish the changes in farming practice, but not the resulting changes in landscape. The ultimate aim of policy, as established by the Curry report, is to establish a sustainable rural economy and safeguard the countryside, indeed return some sections of it to former biodiversity and character.

Measurements, such as of biodiversity, can act as good indicators of the "health" of the countryside, but do not give a holistic view of landscape character.

It is important that a baseline of landscape character is established so that changes can be identified, policy effectiveness established and the character of the countryside protected. In order to achieve this, three time periods must be considered:

- The post war period to 2000, this will establish the rate of change due to non-epidemic related pressures, and establish a baseline.

- The period immediately before the epidemic in 2000, to establish a checkpoint to measure any step changes from. As the epidemic occurred in the early stages of the 2001 growing season, and various short term changes to land use occurred, it is best not to use 2001 as a baseline.

- 2002/3 and successive periods to establish if any significant "step change" has occurred and if the landscape stabilises in the medium term, or continues to change.

3. Using Remote Sensing for Identifying and Quantifying Landscape Change.

3.1. Background

In order to gain an understanding of the extent, nature and rate of landscape change, measurement and monitoring is required. Terrestrial measurements of particular indicators (e.g. biodiversity, length of stone walls) will give valuable information, but are based on a sampling network. These measurements give a patchy view of elements of the landscape rather than the required holistic view.

Remote sensing, that is *the recorded observation and measurement of an object without touching it,* provides an alternative and complimentary data source that can measure across an entire area, often called a "synoptic viewpoint". Remote sensing performed from satellites and aircraft is called Earth Observation (EO), and is integrated with terrestrial data in a Geographic Information System (GIS). As many satellite EO systems continuously record and archive land surface imagery it also has the unique advantage of being able to be used retrospectively.

This section sets out to give a brief introduction to EO, and to then take all available EO systems and apply criteria to them to identify those suitable for this study. These sensors and systems are then presented in more detail. Finally, an inventory of the data availability for these sensors is then presented.

3.2. Overview of Earth Observation methods

Earth observation data are a valuable tool for mapping and monitoring earth surface features and processes. To use EO data effectively it is important to understand the different types of platform and sensor type.

EO sensors can be satellite-borne or airborne. The satellite platforms can be geostationary or polar-orbiting. Geostationary satellites are placed in a high orbit so that the satellite rotates at the same speed and direction as the earth to enable it to observe the same area of the earth at very frequent intervals. These satellites and their sensors are used for meteorological observations. Polar-orbiting satellites are placed in a low orbit to enable more detailed information to be gathered, however they will not be overhead at the same point on the earth's surface for a period of, typically, 16 – 26 days. Some sensors may have a facility to tilt in order to reduce the revisit time to 2 - 3 days. This facility will increase the likelihood of obtaining suitable data for a given location. For airborne data the sensor is mounted in an aircraft. The user can specify the flight path and timing of the data acquisition and the resolution is a function of the sensor and the altitude of the aircraft. However aircraft platforms are not stable platforms and the data will need to be corrected for the roll, pitch and yaw (wobble) of the aircraft. Historic data will not have these corrections, most new data collections will. This section focuses on the polar-orbiting and airborne sources of EO data.

EO instruments measure the amount of reflected and emitted radiation from the earth's surface. Due to atmospheric absorption and the strength of the signal sensors are limited to the optical, thermal and microwave region of the electromagnetic spectrum (see Figure 3.1). Each instrument has a number of characteristics; the number, width and type of wavelength bands; the ground resolution; and swath width.

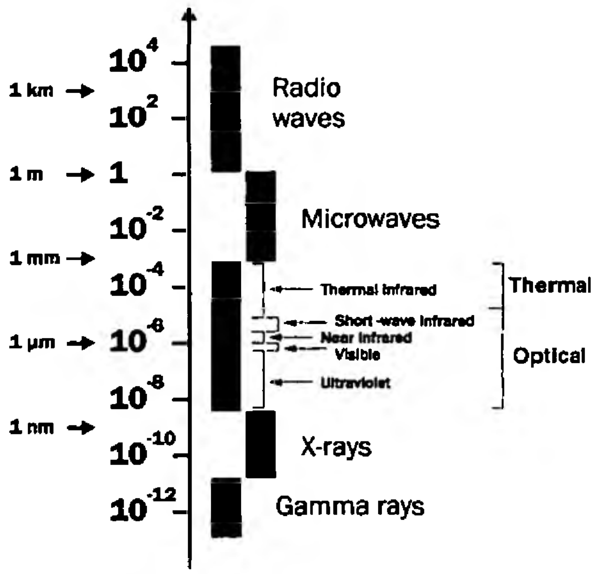

Figure 3.1: The Electromagnetic Spectrum...

Optical instruments such as the Thematic Mapper sensor on the Landsat satellite measure reflectance from the earth's surface in the visible, near-infrared and short-wave infrared parts of the spectrum and emission in the thermal infrared part of the spectrum. Optical wavelengths cannot pass through cloud and therefore require cloud-free conditions to acquire usable imagery. The different wavelengths can used to provide information on different phenomena (see Table 3.1).

For instance, Figure 3.2 shows the typical spectral response of green vegetation. Notice the low reflectance in the visible part of the spectrum. This is mainly due to chlorophyll. The high reflectance in the Near Infrared is caused by strong scattering from cell walls. Finally there are features in the Short-wave Infrared, which are due to absorption by liquid water. The magnitude of these features will vary and can be used to discriminate vegetation species.

The short wave infrared (SWIR) channels on the Landsat Thematic Mapper (TM) are sensitive to changes in leaf-tissue water content (turgidity) and to moisture variation in vegetation and soils. Because reflectance decreases as water content increases, it is possible to

determine plant vigour and, when used in conjunction with other channels, distinguishing a greater range of species than with just the near infrared[14]. The TM is proven and it is frequently used in operational vegetation mapping. The use of the SWIR region of the spectrum will be crucial for discerning changes in the enclosed areas of the Lake District.

Name	Wavelength Range	Main characteristics and applications
Visible	400 - 700 nm	Detect phenomena in the same wavelengths as the human eye – ease of interpretation for mapping; penetrate water to enable some water quality parameters to be measured; cannot penetrate clouds, blue wavelengths are sensitive to contamination from haze
Near-infrared	700 - 1200 nm	Particularly useful for vegetation mapping; cannot penetrate clouds; no reflectance from water bodies - good for mapping land/water boundaries
Short wave infrared	1.2 - 3.0 μm	Estimating foliar moisture, vegetation species determination. Useful for geological and soil mapping.. Cannot penetrate clouds and no reflectance from water
Thermal infrared	3.5 - 100 μm	Measures thermal emission rather than reflectance – useful for mapping surface temperature. Cannot penetrate clouds.
Microwave	100 μm – 1 m	Measures the radiation that is returned from an energy pulse – smooth surfaces reflect energy away from the sensor (therefore small lakes and flooded areas will appear dark); topographic features are clearly depicted

Table 3.1: Characteristics and main applications of wavelength ranges

The width of the wavelength bands being sensed can be important. Different surfaces have diagnostic absorption characteristics at specific wavelengths. If, for example, the user wanted to detect algal blooms, he/she would want to select a narrow wavelength band centred on the chlorophyll absorption feature at 685nm. A broad wavelength band would have less sensitivity to this feature. So-called hyperspectral sensors are the most suitable for this type of application. These have many narrow-wavelength bands

Microwave instruments are either passive or active sensors. Passive instruments measure microwave reflectance in the same way as optical sensors. However because the amount of radiation at these longer wavelengths is reduced the ground resolution is coarse. These sensors are mainly used for continental scale studies. Active sensors are designed to solve this problem and provide more detailed resolution. These send a pulse of microwave energy towards the ground and detect the energy returned (backscatter). These instruments are also known as radar instruments. As a consequence Microwave instruments can detect radiation through clouds and are particularly useful in equatorial and mid-latitude regions of the world.

[14] Townshend, J.R.G., Gayler, J.R., Hardy, J.R., Jackson, M.J. and Baker, J.R. 1983. Preliminary assessment of Landsat 4 Thematic Mapper products. **International Journal of Remote Sensing**, 4, 187-828.

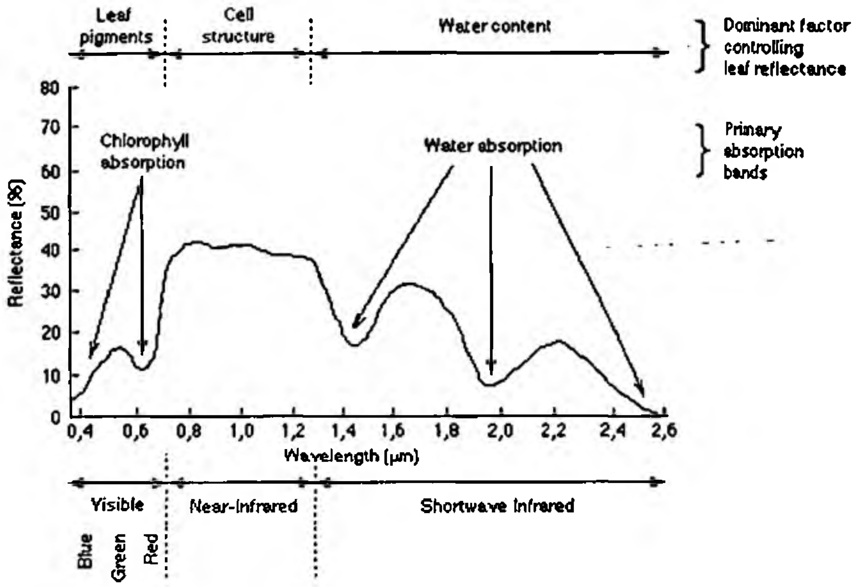

Figure 3.2: Typical spectral response of green vegetation

The main use of microwave instruments is the measurement of topographic features, water bodies and oil spills / leaks. Some work has been done on using radar for vegetation studies (e.g. Crop Type Determination), but it is still widely considered that the spectral characteristics of optical instruments.are better at discriminating surface types, especially vegetation types.

Another active instrument, which uses an optical laser, is called a LiDAR. This type of instrument is usually used to measure surface heights rather than information on the type of surface. Currently this type of sensor is mounted on airborne platforms.

Figure 3.3: Diagram of a satellite sensor's swath.

Instruments have different ground resolutions (also called spatial resolution) and swath widths (See figure 3.3). A narrow swath width is usually found on instruments with a high ground resolution and conversely a sensor with a broad swath will have a coarse ground resolution. The ground resolution is a function of the 'instantaneous field of view' (IFOV) of the sensor. The IFOV is usually equivalent to one pixel (picture element) in the image.

The revisit time of a satellite is usually related to swath width. A broad swath will ensure that the same point on the earth's surface is imaged more frequently than a narrow swath. Higher spatial resolution sensors on board satellites have narrower swaths that would usually result in long revisit times. In order to obtain more frequent coverage these satellites usually have a tilting capability. In the case of the SPOT satellite the HRV-IR sensor (see Appendix A) can tilt 22.6 degrees to the left or right of the swath. This reduces the revisit time from 26 to 2-3 days. This feature is particularly valuable for optical satellites since a shorter revisit time increases the likelihood of obtaining suitable cloud-free data, particularly in mid-latitude temperate areas.

Significant improvements in surface discrimination can be obtained by combining complementary data sources. This applies to the use of terrestrial data to give context to the EO data, as well as the use of multiple EO sensors. The use of laser mapping (LiDAR) and optical imagery in conjunction has been proven by the Environment Agency, and was used operationally to aid the production of the UK Countryside 2000 land use map[15].

Remote sensing technology has emerged as a potentially powerful tool for providing information on natural resources at various spatial and temporal resolutions. This potential can only be achieved if the data are sufficiently reliable and error-free for the purpose for which it is required. When using remotely sensed data, the sources of errors may result from geometric or radiometric errors. For accurate calibration and classification, terrestrial data must be used. Similarly, changes and trends that appear in remotely sensed data can only be fully appreciated and understood when there is a good knowledge of what has occurred on the ground. In summary, remote sensing does not replace terrestrial measurements, but rather complements them allowing sparse sampling networks to be expanded to cover wider areas, giving the holistic view that is needed to identify and measure landscape change.

3.3. Overview of remote sensing data sources.

Table 3.2 gives an overview of all available remote sensing data sources, both operational and planned. It forms the starting point for the selection of candidate systems.

[15] Classification of airborne CASI and LiDAR data from selected CS2000 sample squares Module 8 final report R.A. Hill, R.M. Fuller, G.M. Smith & N. Veitch. http://www.cs2000.org.uk/Final_reports/M08_final_report.htm.

Spatial Resolution	Satellite	Instrument	Resolution	Status
Coarse-resolution satellite imagery (>300 m)	NOAA	AVHRR	1.1km	Operational
	Feng Yun 1C	Multispectral	1.1km	Operational
	OrbView 2	SeaWifs	1.1km	Operational
	ERS-1/ERS-2/Envisat	ATSR/AATSR	1km	Operational
	Kompsat-1	OSMI	1km	Operational
	EOS Terra / *Aqua*	MODIS (Bands 3-7/8-36)	500m/1km	Operational / *Launch April 2002*
	Spot 4	Vegetation	1km	Operational
	IRS-P4 (Oceansat)	OCM	360m	Operational
Medium-resolution satellite imagery (300 - 10m)	Landsat 5	MSS	120 / 30m	Operational
	Landsat 5	Thematic Mapper	120 / 30m	Operational
	Landsat 7	Enhanced Thematic Mapper	60 / 30 / 15m	Operational
	Spot 1,2,3	HRV	20 / 10m	Operational
	Spot 4	HRV-IR	20 / 10m	Operational
	Spot 5	*HRG (Multi.)*	*20 / 10m*	*Launch April 2002*
	IRS 1C, 1D	LISS-3(Multi./Pan.)	70 / 23.5 / 6m	Operational
	EOS Terra */Aqua*	ASTER	15-90m	Operational / *Launch April 2002*
	EOS Terra */Aqua*	MODIS (Bands 1-2)	250	Operational / *Launch April 2002*
	EO-1	ALI (Multi./Pan.)	30 / 10m	Operational
	EO-1	Hyperion (Hyperspectral)	30m	Operational
	Envisat	MERIS(Multi.)	300m	Operational
	CBERS-1	Multispectral	20-260m	Operational
	ADEOS-II	*GLI*	*250m*	*Launch Nov 2002*
	IRS-P6	*LISS-3 (Multi./Pan.)*	*23.5m*	*Launch late 2002*
	ERS-1/ERS-2	SAR	30m	Operational
	Envisat	ASAR	30m	Operational
	Radarsat-1	SAR	10-30m	Operational
	Radarsat-2	*SAR*	*28m*	*Launch 2003*
	Shuttle Radar Topography Mission (SRTM)	SAR	30m	Complete
High-resolution satellite imagery (<10m)	IKONOS	Multi./Pan.	4 / 1m	Operational
	EROS-A1	Pan.	1.8m	Operational
	KOSMOS	KVR-1000 (Pan.)	2 / 3m	Operational
	KOMPSAT-1	EOC (Pan.)	6.6m	Operational
	Quickbird	Multi./Pan.	2.5 / 0.61m	Operational
	Eros-B Series	*Multi./Pan.*	*3.3 / 0.8m*	*Launch 2003*
	Orbview-3	*Multi./Pan.*	*4 /1m*	*Launch 2003*
	IRS-P5 (Cartosat)	*Pan.*	*2.5m*	*Launch 2003*
	IRS-P6 (Resourcesat)	*LISS-4 (Multi./Pan.)*	*6m*	*Launch late 2002*
	Spot 5	*HRS (Pan.)*	*2.5m*	*Launch April 2002*
	Radarsat-2	*SAR (Ultrafine mode)*	*3m*	*Launch 2003*
High-resolution airborne imagery (<10m)	n/a	CASI	2m +	Operational
	n/a	ATM	2m +	Operational
	n/a	Hymap	2m +	Operational
	n/a	Talytherm	2m +	Operational
	n/a	LIDAR	2m +	Operational
	n/a	Intermap IRSAR	1.25 / 2.5 m	Available 2002
	n/a	Aerial Photos	1m +	Operational

Table 3.2: Current and near-future EO instruments. Instruments yet to be launched are shown in italics.

3.4. Remote Sensing for Landscape Change

The selection of suitable remote sensing systems for landscape change has been approached in a logical stepwise fashion. The first set of criteria are related to **Technical suitability.** The second set are related to **Study Suitability**.

3.4.1. Technical Suitability:

These criteria relate to the three types of landscape change as identified in section 2.1. They are applied to all the available systems in table 3.2, where each system is rated according to its suitability each type of landscape change.

To recap:

Changes in enclosed areas:

The enclosed grasslands are used for lambing, early pasture and winter forage production. They are often "improved" and are typically the result of re-seeding, drainage, artificial fertilisation, and herbicide application either singly or in combination.

Any change in the intensity of agriculture in these areas will result in a change in the species composition and seasonal length of sward. If remote monitoring techniques are to be used to identify change, these are the characteristics that must be identified.

CRITERIA: Changes in enclosed areas

- Sensor must be able to differentiate land parcels – **spatial resolution must be better than 100m**
- Sensor must have sufficient spectral sensitivity in the correct parts of the spectrum to be able to discern changes in biomass, vigour and species composition to the community level. – **must record information in the red, green, near infra-red and reflected middle infrared bands**

Changes in "open" areas:

The land over 600 metres is broadly classified as "Mountain" and comprises rugged and steep land, crag, scree, fell or other bare rock and associated rough vegetation, including semi-natural upland vegetation. May include areas of bracken, scattered trees, open water, rivers, streams, bogs, mires, bare peat, or a mosaic of these.

Any remote monitoring systems to identify and monitor changes in the mosaic must have a resolution sufficient to detect changes in the mosaic structure.

CRITERIA: Changes in "open" areas

- Sensor must be able to differentiate changes in mosaic – **spatial resolution must be better than 100m**
- Sensor must have sufficient spectral sensitivity in the correct parts of the spectrum to be able to discern changes in mosaic – **must record information in the red, green and near infra-red** as a minimum, but short wave infrared would be advantageous.

Changes to landscape structure.

Both the managed and open areas in the Lake District have a distinctly unique character. "Character" is a subjective term that is often based on aesthetics and notoriously difficult to quantify. However, some features of the landscape such as hedgerows, copses or walls contribute to the character and can be quantified.

Any remote monitoring method of identifying landscape structure change must be able to resolve small-scale features such as walls and hedgerows.

CRITERIA: Changes in landscape structure

- Sensor must be able to identify landscape structure elements such as hedgerows, trees and walls. **Spatial resolution must be at least 2.5 metres, preferably 1m.**

These criteria were applied to all the available systems as defined in table 3.2. Table 3.3 shows the results of this application, with each system being rated according to its suitability for each type of landscape change. Three classes of rating result: inappropriate, possibly suitable and suitable.

Satellite / Instrument	Spatial Resolution (M)	Number of Bands / M-IR	Case 1 Enclosed Landscape	Case 2 Open Landscape	Case 3 Landscape Structure
Coarse Resolution Sensors					
NOAA - AVHRR	1100	5 / No	Not Suitable	Not Suitable	Not Suitable
Feng Yun 1C - Multispectral	1100	10 / Yes	Not Suitable	Not Suitable	Not Suitable
OrbView 2 - SeaWifs	1100	8 / No	Not Suitable	Not Suitable	Not Suitable
ERS-1/ERS-2 - ATSR	1000	7 / Yes	Not Suitable	Not Suitable	Not Suitable
Envisat - AATSR	1000	7 / Yes	Not Suitable	Not Suitable	Not Suitable
Kompsat-1 - OSMI	1000	6 / No	Not Suitable	Not Suitable	Not Suitable
EOS Terra/*Aqua* - MODIS (Bands 3-7)	500	5 / Yes	Not Suitable	Not Suitable	Not Suitable
EOS Terra/*Aqua* - MODIS (Bands 8-36)	1000	29 / No	Not Suitable	Not Suitable	Not Suitable
Spot 4 - Vegetation	1000	4 / No	Not Suitable	Not Suitable	Not Suitable
IRS-P4 (Oceansat) - OCM	360	8 / No	Not Suitable	Not Suitable	Not Suitable
Medium Resolution Sensors					
Landsat 5 - MSS	120 / 30	5 / No	Not Suitable	Not Suitable	Not Suitable
Landsat 5 - Thematic Mapper	120 / 30	7 / Yes	Suitable	Suitable	Not Suitable
Landsat 7 - Enhanced Thematic Mapper	30 / 15	7 / Yes	Suitable	Suitable	Possible
Spot 1,2,3 - HRV (Multi./Pan.)	20 / 10	3 / No	Not Suitable	Suitable	Possible
Spot 4 - HRVIR (Multi./Pan.)	20 / 10	4 / Yes	Suitable	Suitable	Possible
Spot 5 - HRG (Multi.)	*20 / 10*	*4 / Yes*	Suitable	Suitable	Possible
IRS 1C, 1D - LISS-3 (Multi./Pan.)	23.5 - 70 / 6	4 / Yes	Suitable	Suitable	Possible
EOS Terra/*Aqua* - ASTER	15-90	14 / Yes	Possible	Possible	Not Suitable
EOS Terra/*Aqua* - MODIS (Bands 1-2)	250	2 / No	Not Suitable	Possible	Not Suitable
EO-1 - ALI (Multi./Pan.)	30 / 10	9 / Yes	Suitable	Suitable	Possible
EO-1 - Hyperion (Hyperspectral)	30	220 / Yes	Suitable	Suitable	Possible
Envisat - MERIS (Multi.)	300	15 / No	Not Suitable	Not Suitable	Not Suitable
CBERS-1 - Pan.	20-260	7 No	Not Suitable	Not Suitable	Not Suitable
CBERS-1 - IR-MSS	80	4 / Yes	Possible	Possible	Not Suitable
ADEOS-II - GLI	*250*	*36 /*	Not Suitable	Not Suitable	Not Suitable
IRS-P6 (ResourceSat) - LISS-3 (Multi./Pan.)	*23.5*	*4 / Yes*	Suitable	Suitable	Possible
ERS-1/ERS-2 - SAR	30	N/A	Not Suitable	Possible	Not Suitable
Envisat - ASAR	30	N/A	Not Suitable	Possible	Not Suitable
Radarsat-1 - SAR	10 / 30	N/A	Not Suitable	Possible	Not Suitable
Radarsat-2 - SAR	*28*	*N/A*	Not Suitable	Possible	Not Suitable
SRTM	30	N/A	Not Suitable	Possible	Not Suitable
High Resolution Sensors					
IKONOS - Multi./Pan.	4 / 1	4 / No	Not Suitable	Possible	Suitable
EROS-A1 - Pan.	1.8	N/A	Not Suitable	Possible	Suitable
KOSMOS - KVR-1000 (Pan.)	2 / 3	N/A	Not Suitable	Possible	Suitable
KOMPSAT-1 - EOC (Pan.)	6.6	N/A	Not Suitable	Possible	Suitable
Quickbird - Multi./Pan.	2.5 / 0.61	4 / No	Not Suitable	Possible	Suitable
IRS-P5 (Cartosat) - Pan.	*2.5*	*N/A*	Not Suitable	Possible	Suitable
IRS-P6 (Resourcesat) - LISS-4 (Multi./Pan.)	*6*	*N/A*	Not Suitable	Suitable	Suitable
Spot 5 - HRS (Pan.)	*2.5*	*N/A*	Not Suitable	Possible	Suitable
CASI	1-10m	15 / No	Possible	Possible	Suitable
ATM	2m +	11 / Yes	Suitable	Suitable	Suitable
Hymap	2m +	128 / Yes	Suitable	Suitable	Suitable
Talytherm	2m +	2 / No	Not Suitable	Not Suitable	Not Suitable
LIDAR	2m +	N/A	Possible	Possible	Suitable
Intermap IRSAR	1.25 / 2.5m	N/A	Not Suitable	Possible	Suitable
Aerial Photos	1m or less	N/A	Possible	Suitable	Suitable

Key: Not Suitable | Possible | Suitable

Table 3.3: Technnical Suitability for Landscape Change Detection

3.4.2. Study Suitability:

Once a system has been deemed technically suitable using one or more of the above criteria, a further set of criteria related to the availability and cost of the systems are applied to provide the candidate systems for the study. These criteria are then considered for providing information prior to the outbreak, during the outbreak year and for future monitoring. Satellite data that are recorded and archived continuously and aerial surveys are the only available sources for pre-2001 and 2001 records.

CRITERIA: Suitable for study baseline (pre-2002)

- **Data must be available for a minimum of 15 years prior to 2001**
- **Data must continue to be available for the foreseeable future**
- **Data must be available at reasonable cost**

CRITERIA: Suitable for 2000 record

- **Data must be available for 2000**
- **Data must be available at reasonable cost**

CRITERIA: Suitable for future monitoring

- **Data must be available for 2002 onwards.**
- **Data must be available at reasonable cost**

Ideally, a system will be able to satisfy all criteria, though given the wide variability in technical criteria and the need to have a long record of data, this is unlikely. Due to high levels of cloud cover over the Lake District it may be necessary to look at integrating data from multiple passes or systems.

Table 3.4 shows the application of the study suitability criteria to provide candidate systems to be detailed and considered in the methodology for identifying and quantifying landscape change. Again they are categorised into three levels of suitability. Candidate systems are identified in the detailed description of selected systems.

Satellite / Instrument	Length of Archive (Years)	Cost per KM	Likely to Continue	Baseline Suitability	2000/1 Record Suitability	Future Monitoring Suitability	Consider for Study	Detailed Information Ref
Medium Resolution Sensors								
Landsat 5 - TM	16	$0.079	Yes	Suitable	Possible	Possible	Suitable	A
Landsat 7 - ETM	3	$0.019	Yes	Suitable	Possible	Possible	Suitable	B
Spot 4 - HRVIR (Multi./Pan.)	4	0.72 / 0.35€	Yes	Not Suitable	Possible	Possible	Suitable	C
IRS 1C, 1D - LISS-3 (Multi./Pan.)	4	$0.51	Yes	Not Suitable	Possible	Possible	Suitable	D
EO-1 - ALI (Multi./Pan.)	2	$0.32	No	Not Suitable	Possible	Not Suitable	Possible	
EO-1 - Hyperion (Hyperspectral)	2	$1.55	No	Not Suitable	Possible	Not Suitable	Possible	
High Resolution Sensors								
IKONOS - Multi./Pan.	2	$18 / 20	Yes	Not Suitable	Possible	Suitable	Suitable	E
EROS-A1 - Pan.	2	$9.6	Yes	Not Suitable	Possible	Suitable	Suitable	F
KVR-1000 - Pan.	13	$0.35	Yes	Not Suitable	Possible	Suitable	Suitable	G
KOMPSAT-1 - EOC (Pan.)	2	?	No	Not Suitable	Possible	Not Suitable	Not Suitable	
Quickbird - Multi./Pan.	1	$30	Yes	Not Suitable	Not Suitable	Suitable	Suitable	H
Airborne Sensors								
CASI	N/A	See Note 1	See Note 2	Not Suitable	Not Suitable	Possible	Suitable – [redacted] note 3	I
ATM	N/A	See Note 1	See Note 2	Not Suitable	Not Suitable	Suitable	Possible – See note 4	
Hymap	N/A	See Note 1	See Note 2	Not Suitable	Not Suitable	Suitable	Possible – See note 4	
LIDAR	N/A	See Note 1	See Note 2	Not Suitable	Not Suitable	Suitable	Suitable – See note 3	J
Aerial Photos	50	Varies	See Note 2	Suitable	Possible	Suitable	Suitable	K

Key: Not Suitable | Possible | Suitable

1 - The cost for acquisition depends on the area being flown and the number of acquisitions requires
2 - The CASI and Lidar systems are available to the Agency, so can be deployed. Hymap and Air Photos would require survey commisioning or equipment change
3 - CASI is included as it is available to the Agency.
4 - HYMAP and ATM are not included as the costs of commissioning surveys are preclusive, even if they are more suitable than CASI

Table 3.4: System suitability for Lake District Landscape Change Study

3.5. Selection of systems for use in this study:

Detailed descriptions of each of the systems that have been deemed suitable for the study (as laid out in table 3.4 can be found at Annex A, identified by the letters A-K as found in table 3.4.

A catalogue of image availability and cloud cover has been produced. Two periods were considered: from the start of the satellite archive to 2001, where the best cloud free images are listed, and the 2000/2001 period, where all images with moderate cloud coverage are listed.

The catalogue can be found at Annex B.

Using the criteria in section 3.4, the most suitable satellite imagery for this study is the Landsat TM and ETM. This sensor provides continuity of coverage since 1984, and sufficient cloud free imagery is available for 2000. Table 3.5 shows the dates of completely cloud free or very low cloud for the area shown in figure 3.4.

Landsat	Date	Clear	Low cloud
5	3-May-84		X
5	26-Apr-87		X
5	14-May-88	X	
5	10-Feb-89		X
4	9-May-89		X
5	4-Jul-89		X
5	25-Nov-89		X
5	15-Jan-91		X
5	6-Aug-95		X
5	22-Aug-95		X
5	10-Jul-97		X
5	1-Dec-97		X
5	1-Aug-99		X
7	15-Dec-99		X
7	5-Apr-00		X
5	7-May-00		X
5	5-Jul-01	X	
5	12-Dec-01	X	
5	10-Mar-02	X	
7	26-Mar-02	X	

Table 3.4 Low cloud cover Landsat scenes for the Cumbria Area

Figure 3.4: Landsat frame 204,22 covering the Lake District

Figure 3.4 shows the acquisition footprint of the Landsat Satellite over the study area, it is sufficiently large to not place any constraints on the detailed survey. Figure 3.5 shows a very low resolution "quick look" of Landsat data taken on the 7th May 2000. It represents the most cloud free image in the immediate Pre-FMD period. Other images exist that have sufficient cloud free areas to cover the focussed study areas (see 5.2) or to enable them to be stitched together to form an additional seamless mosaic.

It is advantageous to have more than one image in a growing season. For instance, improved grassland has a similar spectral response to cereals in spring, whereas they look very different in autumn and winter. This study must consider the requirements for such multi-season imagery carefully, as it will increase costs and levels of effort and de crease the chances of finding suitable imagery.

Figure 3.5: Low resolution Landsat TM quick-look, frame 204,22, 7th May 2000

If the available budget allows, it may be useful to purchase SPOT data or investigate the one cloud free IKONOS scene for the area (more details can be found in Annex B).

A seamless mosaic of air photos of the Cumbria area are available as part of the "Millennium Map", from Getmapping limited. These will also prove useful in establishing landscape structure elements for the period preceding the epidemic.

4. Terrestrial data sources for identifying and quantifying landscape change

It is possible to use remote sensing to measure changes in the gross species composition and structure of the Lake District Landscape. This will define the state term of a pressure-state-response environmental model. Any changes identified in the landscape over time identify the "response" stage of the model. In order to put the changes in context and to further appreciate the linkages between the stages in the model, socio-economic data are required.

Additionally, there will be ground based measurements that are useful as they will be more detailed (for example detailed species composition), or measure key items (e.g. livestock numbers) that cannot be extracted from remote sensing data. Detailed measurements often have a sparse sampling basis, but can be very useful in putting remote sensing measurements in context, so called "ground truth". These measurements are best taken in a similar time frame to the remote sensing imagery.

Whilst this study was not directed to provide a complete list of all data sources and sets, it is important to identify types of data that are important in establishing a framework for identifying and quantifying landscape change.

4.1. Types of terrestrial data

A number of data types of data were identified:

FMD outbreak. (e.g. Case locations, cull statistics)
These data will set the scene of the outbreak. It is important to identify areas that will not have been so badly affected by the FMD outbreak so that "control" areas can be established to attempt to identify changes that are due to the changing economic pressures rather than the FMD cull.

Socio-Economic Data (e.g. Census).
The local economy of the Lake District must be sustainable for the landscape to be maintained. Statistics as to the recovery of the tourist industry, local employment and so on can provide useful input into the "pressure" element of the model.

Farming Practice. (e.g. fertiliser sales)
Changes in farming practice will lead to changes in the landscape. The yearly agricultural census will provide useful information, as will a number of secondary data sets.

Environmental Audits (e.g. Land use mapping)
A number of assessments of elements of the landscape have been undertaken in the UK that will act as a useful benchmark and give valuable ground truth to any remote sensing based measurements, particularly those with a long time frame.

Environmental Indicators (e.g. Bird populations)
High level indicators can serve as a "barometer" for the stability of the elements that go to make up the landscape. They can be used to provide "State of the Environment" assessments and are frequently used by central government as performance indicators.

Environmental Monitoring (e.g. River chemistry)
Regular monitoring schemes frequently have a long time base and are scientifically rigorous. Whilst they may not directly relate to landscape change, they are good at showing changes in the pressures put on the landscape, for example, a reduction in the amount of sediment in the rivers would indicate a change in land cover that has reduced soil erosion.

Contextual data (e.g. Ordnance Survey Mapping)
These data provide the grounding for any environmental assessments. The boundaries of catchments and topography are good examples of physical measurements that are often used in predictive models. Additionally, data sets such as administrative boundaries are important for reporting and applying other data sets that are reported using them. A good example is the agricultural census that is reported on a parish basis.

Ad-hoc Data
There are many "amateur" data sets that are collected on a voluntary basis that can provide useful information. Local wildlife trusts and conservation societies often hold unique data sets that have a long time base.

A number of specific data sets were identified in each category during the short duration of this study. Some of these data sets are owned by the Agency. The Agency has data access, exchange and sharing arrangements with many of the owners of these data sets. A preliminary list of these data can be found at Annex C.

5. A framework for identifying and quantifying landscape change

5.1. Requirements for identification and quantification of landscape change

The preceding sections have set the scene for establishing a methodology for identifying and quantifying landscape change in the Lake District. The requirements for information on landscape change can be broken down to establish the framework within such a methodology can be applied. This section considers each type of requirement in turn.

5.1.1. Changes over time

Landscape change is continuous. Major changes in agriculture have occurred since the Second World War, with a closer linkage between economic pressures and farming practices towards the end of the twentieth century. The FMD outbreak may well effect a "step change" in farming practices, due either to the results of the cull or changes in the economic background brought in by the government as a result of FMD. In order to successfully characterise landscape change over time, the continuum of change must be considered, as far back as World War II (WWII), with a focus around the FMD "trigger" event. In order to establish if a step change has occurred, then surveys must be established in the future.

Requirement: Landscape change over time

- Methodology must be able to identify "continuum" of change since WWII
- Methodology must be able to identify any "step" changes due to FMD and future changes.

5.1.2. Changes over space

The Lake District landscape has been broken down into two main units, open areas above 600m, and enclosed areas below 600m. The 600m boundary is arbitrary, it indicates the height at which it is economically viable to improve the semi natural. In a similar way that the tin mining industry in Cornwall enjoys a revival if the tin price increases, the extent of "enclosed" actively managed areas will vary. Changes in marginality of areas around 600m should be considered in the methodology – they will affect the make up of the landscape.

Requirement: Landscape change over space

- Methodology must be able to identify changes within the open and enclosed landscape units
- Methodology must be able to identify any changes in the boundary between the two units

5.1.3. Changes in character

Landscape is essentially an aesthetic term. Whilst the species character within an enclosed area may change, to a viewer, the landscape may look the same. However, if walls are removed or golf courses established, the landscape will have changed to the viewer. Changes in land use and structure are therefore important in establishing location and extent of land use change.

Requirement: Landscape character change

- Indicators of land use structure (e.g. wall length / km) must be established
- Methodology must measure changes in these indicators as well as changes in land use.

5.1.4. Scientific Rigour

As far as possible, any methodology should be quantitative, and based on consistent data sources and methods. Sampling strategies for detailed analysis should follow statistical rules such as the stratified random sampling methodology. Data sources should be cross-checked to provide robust measures and estimates of uncertainty. By overlaying the data sets spatially, a "hierarchical" data set can be formed. Control areas should be established where FMD will have had a lesser effect than in the areas that experienced heavy culling.

Requirement: Scientific Rigour

- Methodology must be quantitative
- Methodology must be hierarchical to allow cross checking
- Methodology must be based on statistical rules and include control areas

5.1.5. Data Limitations & Opportunities

Remote sensing archives allow a look back in time that can be compared with current measurements. However, the archive for suitable imagery that can be directly compared with today (Landsat TM sensor) only goes back to 1984. In order to establish a longer time base, monochromatic air photos will have to be used. These will essentially give a qualitative view. It will be impossible to provide a rigorous assessment of all the requirements until surveys are commissioned that are designed to fit the requirements and fit in with the air photo and satellite historic archives.

Advantage must be taken of the pockets of good quality data that have been gathered for other purposes. For example, the location and content of the detailed sampling squares that make up the base data of the Countryside Survey 1990 and 2000 will be a valuable source of ground information. In addition the Environment Agency have flown various segments of Cumbria with CASI and LiDAR in the late 1990s and in 2000/2001. These data afford unique opportunities to establish a quantitative baseline to anchor future, bespoke surveys.

Requirement: Data Limitations and Opportunities

- Methodology must take into account the location of remote sensing and ground data collected before the FMD outbreak.

5.2. Framework Design

When establishing a survey methodology, it is important to define the required outputs as soon as possible. Given the above requirements and the context given by section 2, the following outputs are suggested:

A quantitative baseline and measures of changes in open and enclosed areas based on satellite data running from 1984, cross indexed with ground data, where possible.

A qualitative baseline of landscape structure phasing into quantitative measures based on available air photography, airborne scanner imagery and LiDAR, repeated and extended using bespoke surveys to measure future changes.

A quantitative assessment of the changes in boundary between open and enclosed areas.

A cross comparison of the two baselines and change assessments using bespoke surveys.

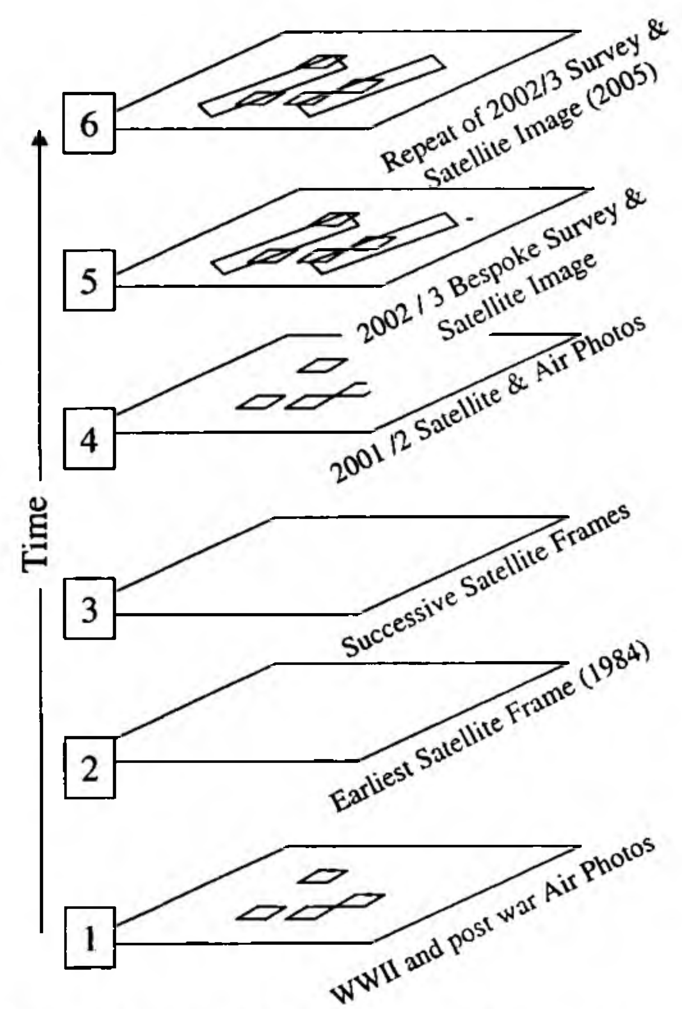

Figure 5.1: Landscape Change Measurement Framework.

A framework that can supply these outputs is illustrated by figure 5.1, where the extent of the possible survey area is defined by the acquisition frame of the earliest suitable satellite for monitoring open and enclosed areas. Numbered layers represent successive time periods.

Layer 1 represents the early air photos. The location of these will limit successive assessments of structure.

Layer 2 represents the earliest satellite image.

Layer 3 represents intermediate satellite imagery needed to establish the rate of landscape change between 2 and 4, this may be more than one image.

Layer 4 represents the same satellite as layer 2 in the immediate pre FMD period, as well as the millennium air photo surveys that were taken in 2000/1.
Layer 5 represents a bespoke survey to join up all the different items and provide a benchmark for future surveys as shown by layer 6, possibly running until 2005.

Layers 2 through 6 use the same satellite frame to provide the first output:

A quantitative baseline and measures of changes in open and enclosed areas based on satellite data running from 1984, cross indexed with ground data, where possible.

It would be a large undertaking to achieve this for the whole of the Lake District, so a representative sample of the open and enclosed areas will need to be chosen. This should be based around the areas where air photos are available, as shown in layer 1. Air photos are not suitable for assessing these changes as they lack the spectral sensitivity and repeatability of satellite imagery.

Layers 1, 4, 5 and 6 use air photos and airborne scanner and LiDAR data to provide the second output:

A qualitative baseline of landscape structure phasing into quantitative measures based on available air photography, airborne scanner imagery and LiDAR, repeated and extended using bespoke surveys to measure future changes.

Layers 5 & 6 introduce transects of imagery to "join up" the areas in open and enclosed areas that are subject to detailed study to provide the third and fourth outputs:

A quantitative assessment of the changes in boundary between open and enclosed areas.

A cross comparison of the two baselines and change assessments using bespoke surveys.

5.3. Framework Implementation

The purpose of this study is to aid the Agency in the establishment of a long term remote sensing monitoring strategy which will be developed in consultation with other parties such as DEFRA and English Nature. If landscape changes do occur as a result of FMD and they are to be identified against the background of landscape change it is important that this strategy is implemented in the 2002 growing season.

A set of steps to establish the framework survey areas and to obtain data is suggested in figure 5.2. It does not include the commissioning of ground surveys to give highly detailed species and structure assessments or photographic records of the landscape from the ground, these are beyond the scope of the study.

The Environment Agency has the necessary staff and assets to carry out the airborne surveys, acquire and interpret the satellite and airborne data. Whilst these systems are not ideal, as they exist and are operational they will provide the timeliness required to capture a quantitative benchmark of the landscape in the Lake District.

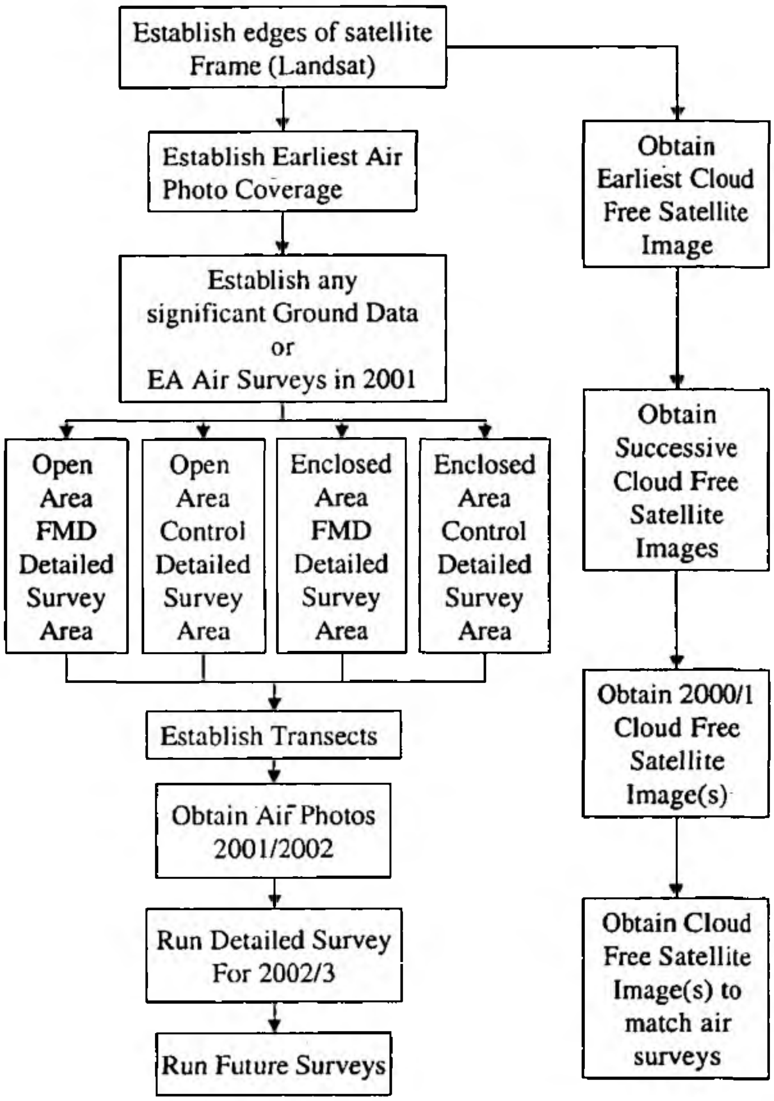

Figure 5.2: Suggested steps for implementing survey framework.

6. Recommendations

A number of urgent recommendations for action can be drawn from this study:

The Environment Agency should proactively seek partners who have a local interest or remit in landscape related issues in the Lake District.

The Environment Agency should take the immediate steps necessary to design a quantitative checkpoint survey in 2002 before any changes take root. These steps include:

1 - Obtaining Landsat imagery from 1984 to 2001.

2 - Sourcing and obtaining post war air photography for the area.

3 - Cataloguing Agency aerial scanner and LiDAR imagery for the Lake District.

4- Delineating the areas to be surveyed using 1-3 above.

5- Obtain 2000/2001 air photos for the areas defined in 4.

These data should be combined into a common map projection with other data sets as necessary (including any high resolution satellite imagery available for 2000/1, if affordable).

The Environment Agency should conduct the aerial survey in 2002, even if a partnership has not been agreed, to ensure that data are collected in the correct time frame. This survey should be conducted alongside ground sampling using Agency and partner ecologists.

Annex A: Detailed description of suitable remote sensing systems.

A Landsat 5 Thematic Mapper

Main use: Provides high-quality mapping information at scales down to 1:100000, 1:25,000 for some themes.

Changes in species composition in "Enclosed Areas" will lead to subtle variations in the spectral response that can be remotely detected. The multi-spectral channels of Landsat 5 Thematic Mapper mean that it is particularly suited to detecting these variations. The spatial resolution of TM allows it to be useful for mapping changes in both "Enclosed" and "Open" areas. Images from Landsat 5 are available for the last sixteen years, so it is a good candidate for use as a baseline.

Data costs and acquisition: Data is readily available from a variety of sources. Costs vary depending upon the age of the data. New and recent data acquisitions cost approximately £1200 for a 185 x 170km scene. Data is available from numerous data vendors, e.g.

Eurimage http://www.eurimage.com/
(users can browse an on-line catalogue and download quick-looks)
Infoterra (NRSC) http://www.infoterra-global.com/
Nigel Press Associates http://www.satmaps.co.uk/

Using the data: Most experienced EO data users will purchase system corrected (Level 1B) data. Unless these data are being used for mere visualisation they will require geometric correction to the map projection being used in the particular project. This task is relatively simple to achieve within all common image-processing systems. Alternatively such a task can be contracted out to a value added reseller (VAR) (typically the VAR will arrange the purchase of data directly from a supplier) or the data supply company itself. The latter option may be particularly attractive if additional processing such as classification is required.

Imaging Mode	Multispectral	Thermal infrared
Spatial Resolution	30 metre	120 metre
Imaging Channels	6 channels	1 channel
	450-515 nm	10.4-12.5 μm
	525-605 nm	
	630-690 nm	
	750-900 nm	
	1550-1750 nm	
	2090-2350 nm	
Swath Width	185km	
Revisit Time	16 days	

B Landsat 7 Enhanced Thematic Mapper

Main use: Landsat 7 provides continuity of data supply from Landsat 5. The addition of a higher resolution panchromatic band allows mapping down to scales of 1:50000. This could be useful for detecting some changes in "Structure".

Data costs and acquisition: Landsat 7 data are distributed by the US Geological Survey. As a result data costs have fallen significantly. A 185-km x 185-km scene costs less than £500. Data can be obtained from

the same data suppliers as for Landsat 5. However the best route is to use the USGS site directly. Here data can be previewed (and quick-looks downloaded) and purchased on-line. Data can then be downloaded a few days later via FTP. The USGS site can be found at
http://earthexplorer.usgs.gov/

Using the data: Landsat 7 data are used in a similar fashion to Landsat 5 data. A merged or 'pan-sharpened' colour composite product can be produced to give added detail.

Imaging Mode	Panchromatic	Multispectral	Thermal infrared
Spatial Resolution	15 metre	30 metre	60 metre
Imaging Channels	1 channel	6 channels	1 channel
	520-900 nm	450-515 nm	10.4-12.5 μm
		525-605 nm	
		630-690 nm	
		750-900 nm	
		1550-1750 nm	
		2090-2350 nm	
Swath Width	185km		
Revisit Time	16 days		

C SPOT 4 HRV-IR

Main use: Provides high quality mapping information at scales down to 1:50000, 1:10,000 for certain themes. The Spot instrument has a higher spatial resolution than Landsat TM so Spot imagery could be used to map changes in "Open" areas and in "Structure". However, the spectral characteristics of the HRV instrument are not as suitable as Landsat's for the discrimination of different vegetation types in "Enclosed Areas".

Data costs and acquisition: Data costs are significantly higher than Landsat (see annex B) and are doubled if the purpose of data acquisition is for the generation of an elevation model. Data can be sourced from:

Infoterra (NRSC) http://www.infoterra-global.com/
Nigel Press Associates http://www.satmaps.co.uk/

Using the data: Data is processed in a similar fashion to Landsat data for single scenes.

Imaging Mode	Panchromatic	Multispectral
Spatial Resolution	10 metre	20 metre
Imaging Channels	1 channel	4 channels
	610-680 nm	500-590 nm
		610-680 nm
		790-890 nm
		1.58-1.75 μm
Swath Width	60km	
Revisit Time	5-10 days	

D IRS LISS-3

Main use: The characteristics and capabilities of the LISS-3 instrument are very similar to the Spot 4 HRV-IR. Although the panchromatic camera has a higher spatial resolution than Spot, the resolution of the multispectral channels is less (especially the fourth SWIR channel).

Data costs and acquisition: Data costs are slightly higher than a single SPOT scene however the scenes are larger, particularly for multispectral data. Data can be sourced from:

Infoterra (NRSC) http://www.infoterra-global.com/
Nigel Press Associates http://www.satmaps.co.uk/

Using the data: see note for SPOT 4

Imaging Mode	Panchromatic	Multispectral
Spatial Resolution	6 metre	23 metre (70m middle IR)
Imaging Channels	1 channel	4 channels
Spectral Range	520-860 nm	520-590 nm
		620-680 nm
		770-860 nm
		1.55-1.75 μm
Swath Width	70 km	142 km
Revisit Time	Less than 3 days	

E IKONOS

Main use: The high-resolution panchromatic camera of IKONOS is particularly suitable for detecting changes in "Structure". Changes in "Open Areas" should also be evident. The lack of a SWIR channel on the multispectral instrument precludes the detection of changes in vegetation in "Enclosed" areas.

Data costs and acquisition: There is a minimum order of 100 sq. km. costing $2000. Data can be obtained from:

Infoterra (NRSC) http://www.infoterra-global.com/
Nigel Press Associates http://www.satmaps.co.uk/

Using the data: These data can be used with standard image processing software tools

Imaging Mode	Panchromatic	Multispectral
Spatial Resolution	1 metre	4 metre
Imaging Channels	1 channel	4 channels
Spectral Range	450-900 nm	450-530 nm
		520-610 nm
		640-720 nm
		770-880 nm
Swath Width	11 km	
Image Area	User Defined	
Revisit Time	Less than 3 days	

F EROS A

Main use: EROS-A, like IKONOS, offers high-resolution panchromatic imagery capable of detecting change in "Structure" and "Open" areas.

Data costs and acquisition: A 12.5km x 12.5km image costs £1500. Images can be ordered and browsed on-line at:

ImageSat International http://www.imagesatintl.com/

Using the data: These data can be used with standard image processing software tools

Imaging Mode	Panchromatic
Spatial Resolution	1.8 metre
Imaging Channels	1 channel
Spectral Range	500-900 nm
Swath Width	12.5km
Image Area	User Defined
Revisit Time	Less than 2 days

G KVR-1000

Main use: High resolution, panchromatic imagery.

Data costs and acquisition: Data costs £2000 for a single (40km x 180km) scene and can be obtained from:

Nigel Press Associates http://www.satmaps.co.uk/

Using the data: Standard image processing software can be used for geometric correction.

Imaging Mode	Panchromatic
Spatial Resolution	2 metre
Imaging Channels	1 channel
Spectral Range	510-760 nm
Swath Width	40 x 180 km
Revisit Time	Less than 3 days

H Quickbird

Main use: Similar capabilities to IKONOS, but with higher spatial resolutions.
Data costs and acquisition: A 12.5km x 12.5km image costs $1500. Images can be ordered and browsed on-line at:

Eurimage http://www.eurimage.com/
Using the data: These data can be used with standard image processing software tools

Imaging Mode	Panchromatic	Multispectral
Spatial Resolution	0.6 metre	3.2 metre
Imaging Channels	1 channel	4 channels
Spectral Range	450-900 nm	490-520 nm
		510-590 nm
		630-690 nm
		760-890 nm
Swath Width	32 km	
Image Area	User Defined	
Revisit Time	Less than 3 days	

I Compact Airborne Spectral Imager (CASI)

Main use: CASI is capable of recording spectral information between 400-900 nm in custom ranges. The CASI can operate in three different modes allowing custom configurations for specific applications. The CASI wavelength range is divided into a maximum of 288 bands with a width of 1.9 nm. Spatial resolution will depend on flying altitude but typical pixel sizes range from 60 cm to 2-5 metres. Swath width will also be dependent on flying height. Because of these characteristics, CASI is useful for monitoring variations in "Open" areas and in "Structure". Its lack of SWIR channels makes it less than optimal for use for monitoring "Enclosed" areas.

Data costs and acquisition: The Environment Agency already possesses an archive of CASI data. Alternatively data can be collected on demand. For geometric accuracy it is essential that the aircraft is equipped with GPS and attitude sensors to remove roll, pitch and yaw effects during pre-processing of the data. The typical accuracy of automatic geocorrection of CASI is 3 Pixels. In the UK data can be acquired by:

Infoterra (NRSC) http://www.infoterra-global.com/
Environment Agency http://www.environment-agency.gov.uk/
NERC http://www.nerc.ac.uk/

Using the data: These data can be used with standard image processing software tools.

Imaging Mode	Multispectral
Spatial Resolution	2.5 / 5 metre
Imaging Channels	15 channel
	Programmable 1.8nm bands between 403-914 nm
Swath Width	1-2.5 km
Image Area	User Defined

LiDAR

Main use: LiDAR is an airborne mapping technique, which uses a laser to measure the distance between the aircraft and the ground. The resulting terrain model has a ground resolution of typically 1-2m, which is sufficient to reveal variations in "Structure".

These data are made up of a number of components – the "first return", that is the top of the surface, the "second return", which is the base of the surface, if it can be penetrated by the optical laser. A third data set is the intensity of the return, which can indicate the difference between vegetated and bare surfaces if the laser is in the near infrared.

Data costs and acquisition: A large and extensive archive of LiDAR data is already available within the Environment Agent. Further data can be acquired by:

Infoterra (NRSC) http://www.infoterra-global.com/
Environment Agency http://www.environment-agency.gov.uk/

Using the data: These data need special tools to produce height surfaces. These tools are commonly available in GIS systems, and can be used to present striking visualisations of the target area.

Imaging Mode	Active laser
Spatial Resolution	1-5 metre
Swath Width	Varies
Vertical accuracy	+/- 15cm relative, +/- 25 cm absolute (80% of data +/- 15cm)
Image Area	User Defined

Annex B: Catalogue of Available Satellite Imagery

LANDSAT

Listings were generated for Landsat 5/7 Path 204 Row 22

Images that are taped aboard the spacecraft are archived by USGS. The European Space Agency (ESA) also receives direct transmissions from Landsat, which increases the number of scenes dramatically. ESA's data policy is more restrictive than USGS, so if the scene is available in both, then it is best to get it from USGS.

ESA's "EOLI "(http://odisseo.esrin.esa.it/eoli/eolinojava.html) is the most comprehensive archive for Landsat European coverage. ESA acquires on average 22 images per satellite per year for each scene. All are logged in the archive regardless of cloud cover. Presentation is by thumbnails and/or meta-data, making it necessary to view all in order to select the most suitable images. There is currently no means of producing a listing or being selective on cloud cover.

The best images are shown in the table below, with likely scenes for this study highlighted:

Landsat	Path-Row	Date	Clear	Low cloud	Medium cloud	High cloud
5	204-22	19-May-84			X	
5	204-22	15-Feb-85	Snowy			
5	204-22	15-Jan-91	Snowy			
5	204-22	06-Aug-95		X		
5	204-22	22-Aug-95		X		
5	204-22	01-Mar-96			X	
5	204-22	12-Nov-96			X	
5	204-22	04-Mar-97			X	
5	204-22	10-Jul-97		X		
5	204-22	01-Dec-97		X		
5	204-22	04-Dec-98			X	
5	204-22	20-Dec-98			X	
5	204-22	22-Feb-99			X	
5	204-22	27-Apr-99			X	
5	204-22	01-Aug-99		X		
5	204-22	04-Oct-99			X	
ETM	204-22	15-Dec-99		X		
ETM	204-22	04-Mar-00	snowy	X		
ETM	204-22	05-Apr-00		X		
ETM	204-22	07-May-00	snowy		X	
5	204-22	16-Jun-00		X		
5	204-22	25-Dec-00			X	
5	204-22	10-May-01			X	
5	204-22	05-Jul-01	X			
5	204-22	22-Aug-01			X	
5	204-22	26-Nov-01	snowy			
5	204-22	12-Dec-01	X			
5	204-22	28-Dec-01			X	
ETM	204-22	26-Mar-02	X			

ESA "Additional Archive" - all low cloud ETM images

A listing of images with less than 50% cloud as shown by the DESCW tool is below, again with likely scenes highlighted.

Mission	Track	Frame	Date	nw/q cloud	ne cloud	sw cloud	se cloud
L5	204	22	10/08/1985	50%	50%	30%	50%
L5	204	22	26/04/1987	10%	20%	30%	10%
L5	204	22	13/06/1987	40%	50%	30%	50%
L5	204	22	14/05/1988	0%	0%	0%	0%
L5	204	22	30/05/1988	40%	50%	30%	40%
L5	204	22	06/11/1988	50%	0%	50%	20%
L5	204	22	22/11/1988	10%	30%	30%	10%
L5	204	22	18/06/1989	30%	40%	40%	20%
L5	204	22	04/07/1989	10%	20%	10%	10%
L5	204	22	25/11/1989	10%	10%	20%	10%
L5	204	22	28/01/1990	10%	30%	50%	40%
L5	204	22	04/05/1990	40%	40%	40%	40%
L5	204	22	15/01/1991	0%	10%	10%	10%
L5	204	22	15/11/1991	40%	30%	40%	10%
L5	204	22	25/05/1992	50%	50%	40%	50%
L5	204	22	26/06/1992	50%	50%	40%	40%
L5	204	22	06/08/1995	10%	30%	30%	30%
L5	204	22	22/08/1995	30%	10%	30%	0%
L5	204	22	25/10/1995	50%	40%	40%	50%
L5	204	22	28/12/1995	10%	30%	40%	50%
L5	204	22	10/07/1997	20%	40%	20%	40%
L5	204	22	01/12/1997	10%	0%	40%	40%
L5	204	22	22/02/1999	10%	30%	50%	40%
L5	204	22	16/06/2000	10%	30%	0%	10%
L5	204	22	10/01/2001	50%	50%	40%	50%
L5	204	22	12/12/2001	0%	0%	0%	0%
L7	204	22	15/12/1999	0%	30%	20%	40%
L7	204	22	17/02/2000	30%	40%	30%	40%
L7	204	22	04/03/2000	20%	20%	40%	30%
L7	204	22	05/04/2000	30%	50%	20%	50%
L7	204	22	07/05/2000	10%	0%	20%	10%
L7	204	22	10/03/2002	0%	0%	0%	0%

ESA "Additional Archive" - all low cloud TM images

USGS Archive Listings

Listings for TM and ETM from the central archive are presented below, with likely scenes highlighted:

	Entity Id	Acquisition Date	Path	Row	Aggregate Cloud	LR Cloud	LL Cloud	UR Cloud	UL Cloud
1	7204022009920550	24/07/1999	204	22	40%	10%	50%	30%	90%
2	7204022009925350	10/09/1999	204	22	30%	0%	50%	30%	50%
3	7204022009926950	26/09/1999	204	22	70%	80%	60%	60%	50%
4	7204022009931750	13/11/1999	204	22	80%	80%	60%	90%	80%
5	7204022009934950	15/12/1999	204	22	0%	10%	0%	10%	0%
6	7204022000004850	17/02/2000	204	22	10%	20%	10%	10%	10%
7	7204022000009650	05/04/2000	204	22	30%	40%	20%	50%	10%
8	7204022000012850	07/05/2000	204	22	0%	0%	0%	0%	0%
9	7204022000020850	26/07/2000	204	22	70%	80%	60%	60%	80%
10	7204022000022450	11/08/2000	204	22	80%	80%	80%	60%	90%
11	7204022000024050	27/08/2000	204	22	50%	70%	60%	40%	50%
12	7204022000027250	28/09/2000	204	22	50%	40%	10%	70%	70%
13	7204022000030450	30/10/2000	204	22	70%	90%	60%	90%	60%
14	7204022000032050	15/11/2000	204	22	70%	60%	90%	50%	90%
15	7204022000035250	17/12/2000	204	22	80%	90%	90%	70%	80%
16	7204022000111450	24/04/2001	204	22	90%	90%	90%	80%	90%
17	7204022000113050	10/05/2001	204	22	30%	10%	70%	0%	30%
18	7204022000121050	29/07/2001	204	22	70%	50%	60%	70%	90%
19	7204022000124250	30/08/2001	204	22	70%	90%	40%	90%	60%
20	7204022000125850	15/09/2001	204	22	60%	70%	70%	30%	60%
21	7204022000127450	01/10/2001	204	22	50%	40%	60%	30%	50%
22	7204022000133850	04/12/2001	204	22	40%	50%	20%	50%	40%
23	7204022000135450	20/12/2001	204	22	80%	80%	60%	90%	70%
24	7204022000200550	05/01/2002	204	22	90%	90%	90%	90%	90%
25	7204022000203750	06/02/2002	204	22	80%	80%	70%	80%	70%
26	7204022000205350	22/02/2002	204	22	60%	70%	60%	40%	70%
27	7204022000206950	10/03/2002	204	22	80%	90%	60%	90%	80%

USGS Central Landsat Archive Listing - All ETM data between June 1999 to March 2002

	Acquisition Date	Satellite	Path	Row	OVRL CLD COV	CC Quad 1	CC Quad 2	CC Quad 3	CC Quad 4
1	20/05/1990	5	204	22	70%	20%	90%	90%	40%
2	26/04/1990	4	204	22	90%	50%	50%	90%	90%
3	18/04/1990	5	204	22	50%	60%	30%	60%	30%
4	10/04/1990	4	204	22	90%	90%	90%	90%	90%
5	25/03/1990	4	204	22	40%	10%	30%	20%	20%
6	09/03/1990	4	204	22	70%	30%	20%	90%	90%
7	25/05/1989	4	204	22	80%	60%	50%	90%	90%
8	09/05/1989	4	204	22	30%	10%	0%	20%	20%
9	23/04/1989	4	204	22	70%	60%	70%	90%	60%
10	22/03/1989	4	204	22	40%	10%	10%	50%	50%
11	06/03/1989	4	204	22	90%	90%	90%	90%	90%
12	26/02/1989	5	204	22	70%	60%	40%	70%	40%
13	18/02/1989	4	204	22	90%	90%	60%	90%	90%
14	10/02/1989	5	204	22	30%	0%	0%	20%	0%
15	02/02/1989	4	204	22	70%	70%	40%	30%	50%
16	11/09/1988	4	204	22	60%	40%	50%	80%	60%
17	26/08/1988	4	204	22	50%	80%	40%	70%	20%
18	22/05/1988	4	204	22	40%	70%	30%	40%	20%
19	01/09/1987	5	204	22	90%	90%	90%	90%	90%
20	16/08/1987	5	204	22	90%	90%	90%	90%	90%
21	31/07/1987	5	204	22	90%	90%	80%	90%	80%
22	15/07/1987	5	204	22	90%	90%	90%	90%	90%
23	29/06/1987	5	204	22	90%	90%	90%	90%	90%
24	13/06/1987	5	204	22	50%	50%	40%	50%	30%
25	28/05/1987	5	204	22	90%	90%	90%	90%	80%
26	12/05/1987	5	204	22	90%	90%	90%	90%	90%
27	26/04/1987	5	204	22	20%	0%	10%	20%	30%
28	10/04/1987	5	204	22	80%	70%	50%	60%	60%
29	10/10/1984	5	204	22	70%	30%	40%	20%	10%
30	24/09/1984	5	204	22	70%	50%	90%	70%	30%
31	08/09/1984	5	204	22	90%	90%	90%	90%	90%
32	22/07/1984	5	204	22	70%	90%	90%	70%	30%
33	20/06/1984	5	204	22	80%	90%	80%	70%	90%
34	19/05/1984	5	204	22	40%	50%	40%	30%	50%
35	03/05/1984	5	204	22	20%	10%	30%	20%	10%
36	17/04/1984	5	204	22	50%	50%	50%	70%	30%

USGS Central Landsat Archive TM scenes from 1984 to 1990

Pricing

The Pricing of ESA's Landsat data, available via Eurimage, is wide and varied depending on age and whether a package deal of multiple dates is opted for.

For Landsat 7 ETM they offer their "basic set" which contains all images also acquired and archived by USGS. Dates not appearing in the USGS archive (http://edcsns17.cr.usgs.gov/EarthExplorer/)

can be assumed in the first instance, to be from their Extended Set and at a premium price (around 1500€)

USGS ETM data is available at £430 per scene. It may also be useful to know that ETM supplied by USGS is Public Domain unlike that supplied from ESA.

TM imagery is available as sub-scenes – known as "quarter scenes" and "floating scenes", the use of these should be considered if the boundaries of the sub-scenes do not compromise the desired study areas.

SPOT 4 XI

Searches for scene ID (KJ) 022/238,239,240 and 025/238,239,240, were undertaken

SIRIUS is SPOT's search engine (http://www.spotimage.fr/home/),

A table including likely scenes is below, quick looks are available to aid selection.

Cost

SPOT XI (level 1B) acquired between March 1998 (SPOT 4 launch) and 31 December 1998 is €1250 each. Those acquired since 1 January 1999 are € 2600 each.

SPOT 4 XI KJs 022-238 through to 025-240 Acquired between May 1998 and 31 December 1998 up to 25% cloud

SPOT	KJ	DATE	TIME	HRV	MODE	SCENE CENTRE	Angle	Cloud
4	022240	980425	113815	1	I	+54.1215-003.1414	8.6	DDCCACAC
4	025240	980515	115340	1	I	+54.1205-002.2154	29.3	****AAAA
4	022239	980521	113810	1	I	+54.5854-002.8408	8.6	******CC
4	022239	980612	111513	1	I	+54.5858-003.5699	-22	CCACACAC
4	022240	980827	115415	2	I	+54.1208-003.0245	26.2	DDCDACAD
4	022239	980919	111148	2	I	+54.5854-002.8955	-23.7	CCCCCCBB
4	022240	980919	111156	2	I	+54.1208-003.1820	-23.7	BBBBBBBA
4	022239	980927	115812	2	I	+54.5851-003.7050	26.2	CCBCBCBC
4	022238	981008	114631	1	I	+55.0486-003.3472	14.1	BDBDBDBD
4	025238	981025	111922	1	I	+55.0485-002.0353	-11.7	CCCCCC**
4	025238	981030	112314	1	[illegible]	+55.0488-001.9937	-7	BABACA**
4	025238	981104	112708	1	I	+55.0486-001.9733	-2.2	BBBBBB**
4	025238	990712	111749	[illegible]	[illegible]	+55.0486-002.0033	-11.4	BABAAA**

SPOT 4 XI KJs 022-238 through to 025-240 Acquired between 1 Jan 2001 and 28 March 2002 all cloud

SPOT	KJ	DATE	TIME	HRV	MODE	SCENE CENTRE	Angle	Cloud
4	025238	27/04/2001	112241	2	I	+55.0487-002.3874	-8.6	EEEEEEEE
4	025239	27/04/2001	112249	2	I	+54.5855-002.6167	-8.6	EEEEEEEE
4	025240	27/04/2001	112257	2	I	+54.1209-002.8422	-8.8	EEEEEEEE
4	022238	02/05/2001	112634	2	I	+55.0481-003.2145	-8	****DCCC
4	022239	02/05/2001	112642	2	[illegible]	+54.5851-003.4455	-8	BCBBAAAA
4	025238	02/05/2001	112632	1	[illegible]	+55.0487-002.4279	-4.3	[illegible]BB
4	025239	02/05/2001	112640	1	[illegible]	+54.5849-002.6689	-4.3	BBBBBBAA
4	025240	02/05/2001	112649	1	[illegible]	+54.1207-002.9053	-4.3	ABABABBD
4	025238	07/05/2001	113022	1	I	+55.0485-002.3934	0.5	******BB
4	025239	07/05/2001	113030	1	I	+54.5854-002.6463	0.5	BBBBBBBC
4	025240	07/05/2001	113038	1	I	+54.1208-002.8949	0.5	BCBBBBAB
4	025240	18/05/2001	111854	1	I	+54.1209-002.0483	-9.7	EEEEEEEE
4	025238	23/05/2001	112235	2	I	+55.0485-002.3655	-8.6	CCCBCCCE
4	025239	23/05/2001	112243	2	I	+54.5853-002.5948	-8.6	DEEEDEDE
4	025240	23/05/2001	112250	1	I	+54.1213-002.0502	-4.9	EEEEEDDD
4	025240	23/05/2001	112251	2	I	+54.1207-002.8204	-8.6	DDBDCDCC
4	025240	28/05/2001	112644	1	I	+54.1208-002.0636	-0.2	EEEEEEEE
4	025238	02/06/2001	113023	1	I	+55.0481-002.4033	0.5	EEEEEEEE
4	025239	02/06/2001	113031	1	I	+54.5850-002.6562	0.5	EEEEEEEE
4	025240	02/06/2001	113039	1	I	+54.1214-002.9042	0.5	EEEEEE**
4	025238	07/06/2001	113416	2	I	+55.0490-002.4461	4.9	EEEEEEEE
4	025239	07/06/2001	113424	2	I	+54.5856-002.7109	4.9	EE******
4	025238	18/06/2001	112240	1	I	+55.0489-002.0373	-7	EDEDEEEE
4	025238	23/06/2001	112631	2	I	+55.0485-002.3583	-3.9	EEEEEEEE
4	025239	23/06/2001	112639	2	I	+54.5859-002.5996	-3.9	EEEEEEEE
4	025240	23/06/2001	112647	2	I	+54.1207-002.8373	-3.9	EE******
4	025240	09/07/2001	111852	1	I	+54.1208-002.0521	-9.7	EEEEEE**
4	025238	24/07/2001	113016	2	I	+55.0484-002.3152	0.9	DEDEDDDE
4	025239	24/07/2001	113024	2	I	+54.5855-002.5689	0.9	EE******
4	025240	24/07/2001	113030	1	I	+54.1205-002.0511	4.8	EEEEEEEE
4	025238	29/07/2001	113407	2	I	+55.0490-002.4294	4.9	EEEEEEEE
4	025239	29/07/2001	113416	2	I	+54.5856-002.6941	4.9	EE******
4	025240	29/07/2001	113421	1	I	+54.1215-002.0322	9.3	EEEEEEEE
4	022238	03/08/2001	113801	2	I	+55.0481-003.2619	5.6	EEEEEEEE
4	022239	03/08/2001	113809	2	I	+54.5850-003.5282	5.6	EEEE****
4	028240	04/08/2001	111854	2	I	+54.1213-001.9991	-9.3	DEEEEEDD
4	025238	09/08/2001	112231	1	I	+55.0489-002.4540	-9	******EE
4	025238	09/08/2001	112231	2	I	+55.0484-002.3782	-8.6	EEEEEEEE
4	025239	09/08/2001	112239	1	I	+54.5856-002.6824	-9	DDCDDDDE
4	025239	09/08/2001	112239	2	I	+54.5852-002.6074	-8.6	EE******
4	025240	09/08/2001	112247	1	I	+54.1209-002.9070	-9	EE******
4	025238	24/08/2001	113400	1	I	+55.0489-002.3515	5.2	EEEEEEEE
4	025239	24/08/2001	113408	1	I	+54.5856-002.6169	5.2	EEEEEEEE
4	025240	24/08/2001	113416	1	I	+54.1209-002.8776	5.2	EEEEEE**
4	025238	29/08/2001	113750	2	I	+55.0488-002.3673	9.7	EDEEEEEE
4	025239	29/08/2001	113758	2	I	+54.5864-002.6448	9.7	EEEEEDED
4	025240	29/08/2001	113806	2	I	+54.1205-002.9172	9.7	EDDDDDED
4	025238	04/09/2001	112226	1	I	+55.0481-002.3153	-8.3	DEDEEEEE
4	025239	04/09/2001	112235	1	I	+54.5850-002.5453	-8.3	EE******
4	025240	09/09/2001	112634	1	I	+54.1207-002.0796	-0.2	EEDDDEDE
4	022238	14/09/2001	113014	2	I	+55.0487-003.2009	-3.2	EEEEEEEE
4	022239	14/09/2001	113022	2	I	+54.5852-003.4442	-3.2	EE******
4	025240	14/09/2001	113026	1	I	+54.1209-002.0781	4.6	DBEBEDED
4	022238	19/09/2001	113405	2	I	+55.0491-003.1790	1.5	DECEEEEE
4	022239	19/09/2001	113413	2	I	+54.5853-003.4348	1.5	EE******
4	025240	05/10/2001	112619	1	I	+54.1208-002.0492	-0.2	EEEEEEEE
4	022238	15/10/2001	113358	1	I	+55.0485-002.8348	3.2	**EEEEDE
4	022239	15/10/2001	113406	1	I	+54.5853-003.0948	3.2	EEEE****
4	022238	16/10/2001	111439	2	I	+55.0486-002.8695	-19.8	**DECDCD
4	022239	16/10/2001	111447	2	I	+54.5852-003.0698	-19.8	CDDDDE**
4	026240	30/10/2001	114528	2	I	+54.1212-001.9500	22.7	DBDBDBCB
4	022238	31/10/2001	112557	1	[illegible]	+55.0437-002.8449	-6.3	**CABCCC
4	022239	31/10/2001	112605	1	I	+54.5852-003.0802	-6.3	DCEC****
4	022238	04/11/2001	114908	2	I	+55.0483-002.8276	20.6	**EEDEED
4	022239	04/11/2001	114916	2	I	+54.5854-003.1383	20.6	EDEE****
4	022238	06/11/2001	111031	1	I	+55.0485-002.7628	-23.4	**EEEDDD
4	022239	06/11/2001	111039	1	I	+54.5852-002.9522	-23.4	CDEC****
4	022238	09/11/2001	115258	1	I	+55.0487-002.7017	25.1	**DEDEDE
4	022239	09/11/2001	115308	1	I	+54.5857-003.0250	25.1	DDDDDDDD
4	022240	09/11/2001	115315	1	I	+54.1208-003.3422	25.1	DDDDDD**
4	022238	11/11/2001	111421	2	I	+55.0483-002.8488	-19.8	**EEEEDE
4	022239	11/11/2001	111429	2	I	+54.5850-003.0488	-19.8	DEEE****
4	022238	14/11/2001	115648	2	I	+55.0482-002.8467	28.2	**CDECED
4	022239	14/11/2001	115654	2	I	+54.5853-003.1808	28.2	EEED****
4	022238	15/11/2001	113729	1	I	+55.0488-002.9121	7.3	**EEEEEE
4	022239	15/11/2001	113737	1	I	+54.5853-003.1829	7.3	EEEE****
4	022238	28/02/2002	115545	1	I	+55.0483-002.7959	28.8	**EEEEEE
4	022239	28/02/2002	115554	1	I	+54.5855-003.1305	28.8	EECE****

Spot Satellite listings. All images for FMD period, rest low cloud

IKONOS Imagery coverage map

Cost:

Cost per sq. km for archived Geo data minimum order 100 sq. km

1m Black and White	US$20
1m Colour (Pan sharpened)	US$22
4m multispectral	US$18
1m and 4m bundle	US$30

EROS

One very cloudy image located.

KVR-1000

No scene reference archived by geographical area.

Search requested from Russia but not yet received, will forward.
Example cost US$1600 for an area 160 sq. km.

QuickBird

This new satellite has no archive currently available, data will become generally available later this year (2002).

IRS LISS 111

IRS 1C Paths 10 and 11 Row 29 and IRS 1D Paths 6 and 7 Row 29 were searched.

Imagery from IRS is acquired by DLR and archived both by Space Imaging and DLR (http://isis.dlr.de/services/ISIS/ISIS-query.html). Only a few scenes are available the best ones are::

Sat	Scene	Dates
1C	10/29	4/5/00 and 7/7/97
1C	11/29	26/7/99
1D	6/29	1/5/00 and 6/4/00

Cost
From the USA archive Full scene US$2500, About £100 cheaper from Germany.

IKONOS

No scene reference, archived by geographical area. Search via CARTERRA (http://carterraonline.spaceimaging.com/cgi-bin/Carterra/phtml/login.phtml)

A search table is presented, with useful images highlighted. The coverage map illustrates the position of the two best images.

	Date Acquired	Cloud Cover	Image ID	Elevation Angle
1	22/02/2002	78	2000013107700THC	77.9171
2	22/02/2002	66	2000013107701THC	77.9171
3	22/02/2002	56	2000013107702THC	77.9171
4	08/02/2002	99	2000012894401THC	70.0302
5	06/02/2002	26	2000012874501THC	66.8092
6	06/02/2002	99	2000012887600THC	61.9653
7	03/02/2002	18	2000012821600THC	71.1727
8	03/02/2002	14	2000012821501THC	79.554
9	31/01/2002	99	2000012786000THC	77.2254
10	31/01/2002	99	2000012785800THC	77.9057
11	31/01/2002	99	2000012785901THC	80.9294
12	31/01/2002	99	2000012804200THC	61.6015
13	29/01/2002	99	2000012753200THC	63.4733
14	29/01/2002	99	2000012753101THC	61.3551
15	26/01/2002	99	2000012715300THC	68.8385
16	26/01/2002	99	2000012715401THC	73.6617
17	25/01/2002	99	2000012721700THC	61.3833
18	24/11/2001	89	2000011911400THC	62.1078
19	24/10/2001	1	2000011498600THC	68.2343
20	24/09/2001	60	2000011156500THC	71.9921
21	21/09/2001	99	2000011016300THC	71.2403
22	10/09/2001	91	2000010853300THC	64.3945
23	10/09/2001	79	2000010853400THC	68.0816
24	19/03/2001	4	2000008184600THC	67.4948
25	18/11/2000	99	2000006517402THC	87.636

Annex C: Terrestrial Data Sources.

This listing is not exhaustive. These are example data sets that came to light during the study.

FMD outbreak.
Infected premises: DEFRA
Cull statistics: DEFRA
Authorisations to disinfect: EA
Location of burial sites and pyres: DEFRA / EA
Air Chemistry and longer term leachate monitoring: EA.

Socio-Economic.
2000 Census (among others)– Office National Statistics
Local business information: Local chamber of commerce?
Changes in retail patterns: Supermarkets & other retailers
Changes in tourism: Local tourism offices
Changes in farmers borrowing: Banks

Farming Practice.
Annual farming census: DEFRA
IACS subsidy payments: DEFRA
Changes in farming inputs: Agronomists and farmer's merchants / DEFRA
Countryside Stewardship & Environmentally Sensitive Area grant schemes: DEFRA

Environmental Audits:
1990 and 2000 land use map of UK: CEH / DEFRA
Countryside Survey 1990 / 2000: CEH / DEFRA
1970s monitoring land use change surveys.
1960s Land utilisation map (Alice Coleman)
1930s Land use map (Dudley Stamp)

Environmental Indicators
Environmental Change Network (ECN): NERC
National Biodiversity Network: CEH
Fish populations: Freshwater Biological Association

Environmental Monitoring
Habitat surveys: English Nature
River Chemistry: Environment Agency
River Corridor Surveys: Environment Agency
Hydrological monitoring: Environment Agency

Contextual data
Ordnance survey
Geological: BGS
Soils: Cranfield University
Meteorology: Met office
Location of special areas: ESA, SSSI: English Nature

Ad-hoc Data
Lancaster University vegetation Surveys
Forest Enterprise woodland mapping

Annex D: Potential Stakeholders in Future Work.

This listing is not exhaustive, it includes possible stakeholders who came to light during the study.

English Nature: (National (Richard Wright)and North West staff)

Environment Agency:

National:
Geoff Bateman (FMD Czar)

National Centre for Environmental Data and Surveillance, Bath:
David Palmer, Centre Manager
Neil Veitch, Remote Sensing Scientist.

North West Region:
John Marshall: Area manager, Northern Area,
Steve Garner: Ecologist,
John Pinder: Area EP manager.

Cumbria FMD Steering Group:
Allerdale Borough Council
Carlisle City Council
Copeland Borough Council
Cumbria Chamber of Commerce
Cumbria County Council
Cumbria Crisis Alliance
Cumbria Tourist Board
DEFRA (Both Agricultural and Environment Divisions)
Eden District Council
Government Office North West
Lake District National Park
National Farmers Union
North Cumbria Health Authority
North West Development Agency
South Lakeland District Council
The National Trust

Others
Local Wildlife Trusts
Countryside Agency
Farming Wildlife Advisory Group
NERC Centre for Ecology and Hydrology, Monk's Wood and Merlewood
NERC Institute of Freshwater Ecology, Windermere
RSPB