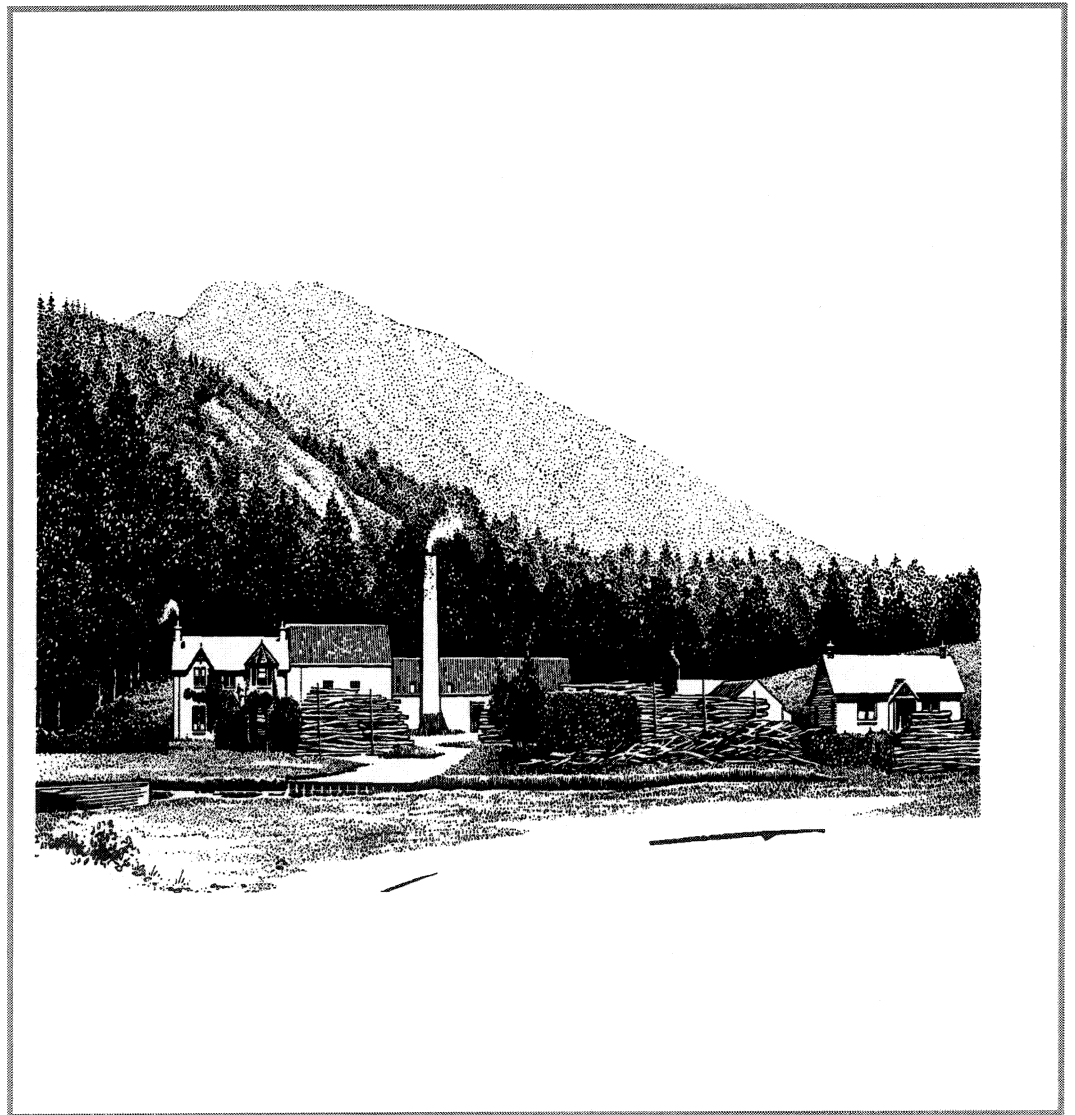




# Excess sulphur and nitrogen deposition in England's Natural Areas

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**Excess sulphur and nitrogen deposition  
in England's Natural Areas**

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## 1 Summary

- 1.1 This report examines the geographical distribution of critical loads exceedence to English Nature's natural areas resulting from current and future deposition of sulphur and nitrogen. The results show that current sulphur deposition causes a number of natural areas to be at high risk, especially in the English uplands. However, future deposition indicates that this problem is much reduced, although a number of areas do remain at risk. However, exceedence of nitrogen critical loads is a severe problem for many upland and lowland natural areas. These results are discussed in the context of possible future controls on pollutant emissions and indicate that significant additional control measures would need to be implemented in order to protect many of England's natural areas.

## 2 Introduction

- 2.1 This report follows the approach of previous studies (e.g. Brown *et al.* 1996) by using the critical loads concept for the examination of pollutant impacts. The critical loads and levels approach was first developed by Canada in the late 1970s to examine the problems of lake acidification. Since then it has been developed by a number of international co-operative programmes and activities in the UNECE Convention of Long-Range Transboundary Air Pollution. To apply the critical loads concept it is necessary to define a critical load or level in terms of the damage threshold for the response of a receptor (soils, freshwaters, vegetation). The UNECE defines a critical load as:

"a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on sensitive elements of the environment do not occur according to present knowledge."

- 2.2 English Nature has adopted a strategic approach to nature conservation based on the development of natural areas (EN 1993). These areas cover the whole of England and are classified into units using soil, biological and social criteria to act as a focus for the development of conservation action. Currently English Nature is identifying key objectives for each natural area. One of the criterion under these objectives is to identify the threats to nature conservation. One important threat is that of air pollution and this report examines two components of this: sulphur deposition and nitrogen deposition. By combining information on where pollutant deposition is greater than the critical load (or threshold) with information on the distribution of natural areas it is possible to identify which natural areas at risk from the different types of pollution and to quantify those risks.
- 2.3 Sulphur and nitrogen deposition have been identified as having a significant impact on nature conservation throughout Britain (Woodin & Farmer 1993, Farmer 1995, Brown *et al.* 1996). Until now a comprehensive assessment of impacts on nature conservation has focussed on Sites of Special Scientific Interest (SSSIs), which are protected under statute (e.g. Farmer 1993; Farmer & Bareham 1993, Rimes *et al.* 1994, Brown *et al.* 1996). One of the key elements of assigning natural areas is to consider the nature conservation importance (and objectives) of land outside of SSSIs taking account of the

wider countryside. Thus an examination of pollutant deposition impacts should also be set in this context. This report contributes to this analysis.

- 2.4 Acid deposition may result in soil acidification and potential loss of plant and animal species intolerant of low pH conditions. Nitrogen (oxidised and reduced) is also a plant nutrient, therefore excess nitrogen deposition may result in eutrophication causing changes in species composition and biodiversity.

### **3 Methods**

- 3.1 The study was undertaken using a geographical information system (GIS). The analysis in this study was made using the GRID module in ARC/INFO GIS. The following sources of data were used in the study:
  - 3.1.1 measured total non-marine sulphur deposition for the period 1989-1992;
  - 3.1.2 measured total (oxidised and reduced) nitrogen deposition for the period 1989-1992;
  - 3.1.3 modelled sulphur deposition (using HARM 10.4) for an 80% reduction in sulphur deposition from 1980 levels;
  - 3.1.4 an unmodified soils critical loads database for acidity (sulphur) and acidity and eutrophication (nitrogen). These maps are based on a 1 km<sup>2</sup> resolution;
  - 3.1.5 natural area boundaries for England. The boundaries used are those of the second draft of the natural areas map.
- 3.2 The GIS has been used in previous studies (see Brown *et al.* 1996) to attribute the source of sulphur deposition to SSSIs where the critical load for acidity of soils is exceeded.
- 3.3 The pollutants examined allow us to investigate not only the present threat to natural areas, but also future emission scenarios. However, these future controls and trends on nitrogen emissions are difficult to predict (e.g. there is no agreement on reducing ammonia emissions). However, in line with the 1994 UNECE Sulphur Protocol the UK agreed to reduce sulphur emissions to 80% of 1980 levels by 2010. This study has included, therefore, an examination of modelled deposition for this reduction in sulphur emissions.
- 3.4 Each pollutant deposition field was overlaid onto the relevant soils critical loads maps to produce maps of critical loads exceedence. These exceedence maps were then overlaid with the natural area boundaries to estimate the degree of exceedence within each natural area.

## **4 Results**

- 4.1 Tables 1-3 present the results for each of the three deposition studies. In each table the natural areas are ranked according to the proportion of the land area that is exceeded for that deposition scenario (1.0 equals 100% of the land area exceeded). The table includes information on the area of each natural area and the number of 1 km squares in which the critical load is exceeded for each natural area. Natural areas for which there is no critical load exceedence have not been listed.

## **5 Discussion**

- 5.1 It is clear that current levels of sulphur and nitrogen deposition lead to extensive critical load exceedence in a number of natural areas. Many of the acid sensitive soils in upland areas are experiencing high rates of deposition. Table 3 shows that implementation of the UNECE Sulphur Protocol would cause dramatic improvements in the degree of acidification from sulphur deposition in many natural areas, although some sensitive heathland soils in lowland natural areas remain at risk. It is important to note, however, that in March 1996 HMIP (now the Environment Agency) agreed strict emission reductions with the power generators, National Power and PowerGen which will reduce sulphur emissions to levels even less than those required under the Sulphur Protocol and thus reduce the risk of acidification on sensitive natural areas still further.
- 5.2 Table 2 demonstrates that nitrogen deposition is still as serious problem. The natural areas with highest exceedence are those with acid sensitive soils, responding to the acidifying effects of nitrogen deposition. However, some lowland areas (e.g. chalk-based natural areas) are also potentially sensitive to the effects of excess nitrogen deposition and these are also shown to be at risk. In these areas eutrophication rather than acidification is the impact which is of concern.
- 5.3 Emissions of nitrogen oxides are currently being reduced (e.g. by low NO<sub>x</sub> burners in power station and by the use of catalytic converters in motor vehicles). However, increases in vehicle numbers will partly offset this reduction. At present, there are, however, no targets for control of ammonia emissions (predominantly from agricultural sources). The 1988 NO<sub>x</sub> Protocol of the UNECE Convention on Long-Range Transboundary Air Pollution is currently being revised and discussions are including the excess nutrient effects of nitrogen deposition. The forthcoming EU Directive on Integrated Pollution Prevention and Control will also require regulation of emissions from large animal units. It is hoped that these measures will begin to tackle the problem of nitrogen deposition and reduce the risks to England's natural areas. However, until such controls are in place and have taken effect, nature conservation strategies in natural areas will have to take account of the risks from the effects of sulphur and nitrogen deposition.

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**TABLE 1**

**English Nature Natural Areas exceeded by total non-marine sulphur deposition (1989 - 1992)**

English Nature Natural Area	Area (km <sup>2</sup> )	Number of exceeded squares	Proportion exceeded
Dark Peak	847.79	835	0.985
Charnwood Forest	173.55	153	0.882
Southern Pennines	1300.68	1136	0.873
Sherwood Forest	559.19	480	0.858
Bodmin Moor	279.64	237	0.848
Forest of Bowland	851.74	718	0.843
Black Mountains and Golden Valley	231.04	185	0.801
Dartmoor	901.77	717	0.795
Cumbrian Fells and Dales	3213.35	2502	0.779
Upper Trent Valley	949.07	736	0.775
Yorkshire Dales	2688.72	2019	0.751
South West Peak	434.90	319	0.734
Lancashire Plain and Valleys	1889.77	1347	0.713
Coal Measures	2232.62	1536	0.688
The Derwent Valley	611.80	409	0.669
Dorset Heaths	558.76	345	0.617
North York Moors	1931.86	1143	0.592
Staffordshire Uplands	816.61	478	0.585
Urban Mersey Basin	2197.52	1227	0.558
North Pennines	2634.00	1401	0.532
Midlands Plateau	2957.05	1547	0.523
Exmoor and Quantocks	1364.62	694	0.509
Breckland	1058.36	531	0.502
Coversands	616.85	306	0.496
Suffolk Coast and Heaths	957.29	470	0.491
Dean Plateau and Wye Valley	892.66	434	0.486
Mosses and Meres	3408.35	1644	0.482
North Norfolk	1881.46	891	0.474
Eden Valley	949.30	417	0.439
West Cumbria Coastal Plain	537.48	232	0.432
Greensand	1461.96	611	0.418
The Vales of Yorkshire	3162.00	1255	0.397
Humberhead Levels	936.06	359	0.384
Trent Valley and Levels	4619.84	1681	0.364
Bedfordshire Greensand	239.12	87	0.364
Isle of Wight	382.18	116	0.304
Southern Magnesian Limestone	1426.41	368	0.258
New Forest	808.50	206	0.255
Border Uplands	3544.11	887	0.250
Lincolnshire Clay Vales	471.32	117	0.248
Oxford Heights	383.53	94	0.245
Devon Redland	823.49	201	0.244
Chilterns	1834.82	431	0.235
Lincolnshire Wolds	895.99	187	0.209
Shropshire Hills	811.64	160	0.197
London Basin	4616.62	855	0.185
Broadland	558.96	101	0.181
Blackdowns	891.86	158	0.177
Isles of Portland and Purbeck	182.99	31	0.169
Somerset Levels and Moors	660.18	104	0.158
Vale of Taunton	612.93	84	0.137
Solway Basin	845.21	108	0.128



**TABLE 1 (Continued)**

**English Nature Natural Areas exceeded by total non-marine sulphur deposition (1989 - 1992)**

Durham Magnesian Limestone	462.27	59	0.128
Culm Measures	3159.01	403	0.128
Cornish Killas and Granite	3154.22	360	0.114
Plain of Holderness	1142.35	128	0.112
Severn Valley	2784.92	310	0.111
Northamptonshire Uplands	509.98	56	0.110
Central Marches	670.32	72	0.107
Fenland	3943.92	397	0.101
North Downs	1508.26	149	0.099
Lincolnshire Marsh and Coast	899.53	88	0.098
Malvern Hills and Teme Valley	308.52	29	0.094
Wessex Vales	1843.07	155	0.084
Middle England	5861.61	478	0.082
South Devon	1057.02	84	0.079
Wessex Downs	1129.08	87	0.077
Greater Cotswolds	3579.88	253	0.071
White Peak	458.93	31	0.068
East Anglian Plain	6535.88	383	0.059
Mendips	274.02	16	0.058
Northumbrian Coal Measures	1606.92	89	0.055
Lincolnshire Limestone	1250.63	68	0.054
South Wessex Downs	2495.99	126	0.050
Oswestry Uplands	89.38	4	0.045
Thames Marshes	1274.29	53	0.042
High Weald	1635.24	50	0.031
Avon Ridges and Valleys	726.58	22	0.030
South Coast Plain	953.90	27	0.028
Yorkshire Wolds	973.93	27	0.028
Lower Tees	816.23	21	0.026
Oxford Clay Vales	3254.60	70	0.022
Mid Somerset Hills	530.86	11	0.021
Hereford Plain	1041.03	21	0.020
Low Weald	1936.90	38	0.020
Romney Marsh	412.50	8	0.019
Hampshire Chalk	1591.22	16	0.010
Northumberland Coastal Plain	634.54	6	0.009
South Downs	673.79	4	0.006

**TABLE 2**

**English Nature Natural Areas exceeded by total (oxidised and reduced) nitrogen deposition  
(1989 - 1992)**

English Nature Natural Area	Area (km <sup>2</sup> )	Number of exceeded squares	Proportion exceeded
Black Mountains and Golden Valley	231.04	230	0.996
Dartmoor	901.77	841	0.933
Dark Peak	847.79	761	0.898
Charnwood Forest	173.55	153	0.882
Central Marches	670.32	588	0.877
Bodmin Moor	279.64	237	0.848
Forest of Bowland	851.74	718	0.843
Sherwood Forest	559.19	468	0.837
Southern Pennines	1300.68	1084	0.833
Yorkshire Dales	2688.72	2136	0.794
Dean Plateau and Wye Valley	892.66	704	0.789
Cumbrian Fells and Dales	3213.35	2520	0.784
Upper Trent Valley	949.07	743	0.783
Malvern Hills and Teme Valley	308.52	237	0.768
Shropshire Hills	811.64	621	0.765
Exmoor and Quantocks	1364.62	1019	0.747
South West Peak	434.90	318	0.731
Mosses and Meres	3408.35	2397	0.703
Dorset Heaths	558.76	385	0.689
New Forest	808.50	552	0.683
Midlands Plateau	2957.05	2010	0.680
Lancashire Plain and Valleys	1889.77	1254	0.664
Eden Valley	949.30	614	0.647
North Pennines	2634.00	1698	0.645
High Weald	1635.24	1034	0.632
Oswestry Uplands	89.38	56	0.627
North Norfolk	1881.46	1161	0.617
Greensand	1461.96	889	0.608
Staffordshire Uplands	816.61	478	0.585
North York Moors	1931.86	1126	0.583
Hereford Plain	1041.03	605	0.581
Broadland	558.96	317	0.567
The Derwent Valley	611.80	339	0.554
Chilterns	1834.82	976	0.532
Breckland	1058.36	544	0.514
Coversands	616.85	306	0.496
Suffolk Coast and Heaths	957.29	474	0.495
South Coast Plain	953.90	469	0.492
Devon Redland	823.49	400	0.486
Urban Mersey Basin	2197.52	1063	0.484
Border Uplands	3544.11	1680	0.474
The Vales of Yorkshire	3162.00	1464	0.463
North Downs	1508.26	649	0.430
Isle of Wight	382.18	154	0.403
Hampshire Chalk	1591.22	634	0.398
Blackdowns	891.86	355	0.398
Bedfordshire Greensand	239.12	95	0.397
Humberhead Levels	936.06	359	0.384
Trent Valley and Levels	4619.84	1681	0.364
Severn Valley	2784.92	1010	0.363
West Cumbria Coastal Plain	537.48	193	0.359
Wessex Downs	1129.08	401	0.355

**TABLE 2 (Continued)**

**English Nature Natural Areas exceeded by total (oxidised and reduced) nitrogen deposition  
(1989 - 1992)**

Coal Measures	2232.62	772	0.346
London Basin	4616.62	1535	0.332
Oxford Heights	383.53	123	0.321
South Devon	1057.02	333	0.315
Cornish Killas and Granite	3154.22	992	0.314
Avon Ridges and Valleys	726.58	190	0.262
Wessex Vales	1843.07	474	0.257
Lincolnshire Clay Vales	471.32	117	0.248
Southern Magnesian Limestone	1426.41	346	0.243
Low Weald	1936.90	449	0.232
Lincolnshire Wolds	895.99	187	0.209
Culm Measures	3159.01	659	0.209
Mendips	274.02	54	0.197
Somerset Levels and Moors	660.18	126	0.191
Isles of Portland and Purbeck	182.99	32	0.175
East Anglian Plain	6535.88	1120	0.171
South Wessex Downs	2495.99	412	0.165
Vale of Taunton	612.93	86	0.140
South Downs	673.79	94	0.140
Solway Basin	845.21	108	0.128
Plain of Holderness	1142.35	128	0.112
Northamptonshire Uplands	509.98	56	0.110
Oxford Clay Vales	3254.60	351	0.108
Mid Somerset Hills	530.86	57	0.107
Thames Marshes	1274.29	135	0.106
Middle England	5861.61	615	0.105
Greater Cotswolds	3579.88	369	0.103
Lincolnshire Marsh and Coast	899.53	88	0.098
Fenland	3943.92	380	0.096
Northumbrian Coal Measures	1606.92	95	0.059
White Peak	458.93	27	0.059
Lincolnshire Limestone	1250.63	68	0.054
Durham Magnesian Limestone	462.27	16	0.035
Yorkshire Wolds	973.93	27	0.028
North Kent Plain	396.82	8	0.020
Romney Marsh	412.50	8	0.019
Northumberland Coastal Plain	634.54	12	0.019
The Lizard	166.73	2	0.012
Lower Tees	816.23	5	0.006
East Anglian Southern Chalk	834.29	4	0.005

**TABLE 3****English Nature Natural Areas exceeded by 80% sulphur reduction as modelled by HARM 10.4**

English Nature Natural Area	Area (km <sup>2</sup> )	Number of exceeded squares	Proportion exceeded
Dorset Heaths	558.76	302	0.540
Breckland	1058.36	372	0.351
Greensand	1461.96	484	0.331
Dark Peak	847.79	279	0.329
North Pennines	2634.00	859	0.326
Cumbrian Fells and Dales	3213.35	813	0.253
Yorkshire Dales	2688.72	659	0.245
Coversands	616.85	133	0.216
New Forest	808.50	160	0.198
Southern Pennines	1300.68	231	0.178
North York Moors	1931.86	291	0.151
Forest of Bowland	851.74	128	0.150
Border Uplands	3544.11	491	0.139
Dartmoor	901.77	124	0.138
Exmoor and Quantocks	1364.62	161	0.118
Humberhead Levels	936.06	102	0.109
Lancashire Plain and Valleys	1889.77	203	0.107
Oxford Heights	383.53	41	0.107
South West Peak	434.90	43	0.099
Broadland	558.96	51	0.091
North Norfolk	1881.46	162	0.086
Blackdowns	891.86	75	0.084
Urban Mersey Basin	2197.52	184	0.084
London Basin	4616.62	378	0.082
The Vales of Yorkshire	3162.00	254	0.080
Devon Redland	823.49	56	0.068
Somerset Levels and Moors	660.18	41	0.062
Plain of Holderness	1142.35	63	0.055
Isles of Portland and Purbeck	182.99	10	0.055
Staffordshire Uplands	816.61	40	0.049
Solway Basin	845.21	40	0.047
Dean Plateau and Wye Valley	892.66	40	0.045
Midlands Plateau	2957.05	108	0.037
Bodmin Moor	279.64	10	0.036
Eden Valley	949.30	32	0.034
Sherwood Forest	559.19	18	0.032
Lincolnshire Clay Vales	471.32	15	0.032
Mosses and Meres	3408.35	107	0.031
The Derwent Valley	611.80	19	0.031
High Weald	1635.24	50	0.031
Suffolk Coast and Heaths	957.29	28	0.029
North Downs	1508.26	43	0.029
South Coast Plain	953.90	24	0.025
Trent Valley and Levels	4619.84	113	0.024
East Anglian Plain	6535.88	142	0.022
Fenland	3943.92	80	0.020
Romney Marsh	412.50	8	0.019
Mendips	274.02	4	0.015
Low Weald	1936.90	23	0.012
West Cumbria Coastal Plain	537.48	6	0.011
Cornish Killas and Granite	3154.22	27	0.009
South Devon	1057.02	8	0.008

**TABLE 3 (Continued)****English Nature Natural Areas exceeded by 80% sulphur reduction as modelled by HARM 10.4**

South Wessex Downs	2495.99	18	0.007
Culm Measures	3159.01	19	0.006
Lincolnshire Limestone	1250.63	6	0.005
Lincolnshire Wolds	895.99	4	0.004
Black Mountains and Golden Valley	231.04	1	0.004
Bedfordshire Greensand	239.12	1	0.004
Middle England	5861.61	19	0.003
Upper Trent Valley	949.07	3	0.003
Thames Marshes	1274.29	3	0.002
White Peak	458.93	1	0.002
Wessex Vales	1843.07	4	0.002
Mid Somerset Hills	530.86	1	0.002
Northumberland Coastal Plain	634.54	1	0.002
Shropshire Hills	811.64	1	0.001
Yorkshire Wolds	973.93	1	0.001
Wessex Downs	1129.08	1	0.001
Hampshire Chalk	1591.22	1	0.001