

2.3 Geomorphology – landforms and processes

Norfolk has diverse physical landscapes, ranging from the sandy hills of the Cromer Ridge to the peaty levels of the Fens, from the waterways of Broadland to the chalk uplands of West Norfolk, from the till (boulder clay) plateau of central Norfolk to the sand flats of the North Norfolk coast. These landscapes are the result of thousands of years of natural and human processes working on a varied inheritance of geology, soils and landforms.

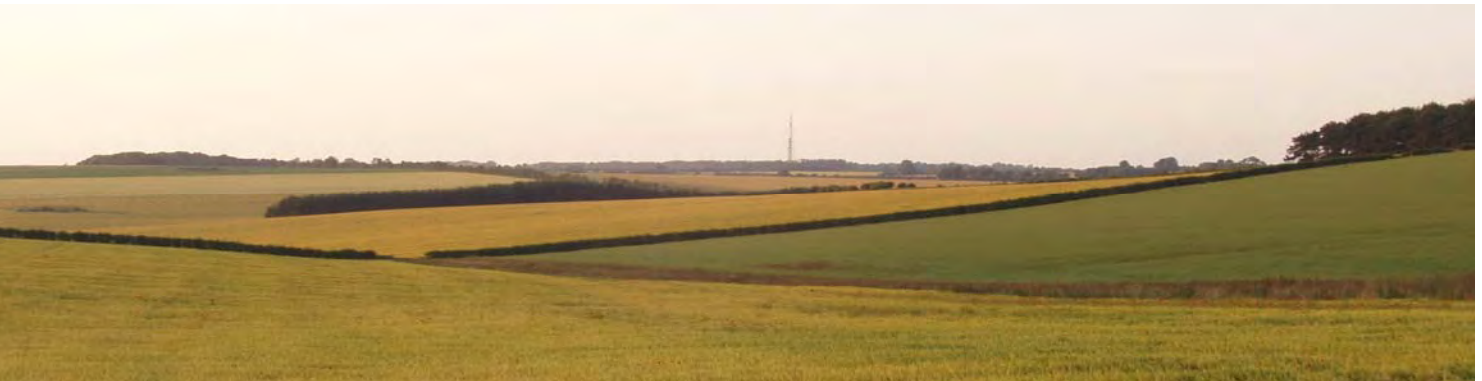


Photo © Tim Holt-Wilson

Massingham Heath in North West Norfolk. This open, rolling landscape is developed on Chalk. Before the Ice Age it would have been as hilly as the Chilterns, but the contours were flattened by the advancing Anglian ice sheet c.450,000 years ago. Glacial deposits cap the wooded hill-tops in the distance.



Photo © Tim Holt-Wilson

A coastal landscape at Salthouse. A shingle barrier beach backed by reclaimed saltmarsh can be seen in the distance. The low hill on the right is a remnant of glacial moraine or esker, probably of Anglian age.



Photo © Tom Barrett

The flat, open landscape of the Potter Heigham marshes. Eight hundred years ago this was part of an estuary; an interdigitating sequence of marine clays and freshwater peats underlies the present floodplain.

Landforms

The physical landscapes of Norfolk are made up of many landform elements. Some are relict features, developed under a different climate during the Ice Age. Others are being shaped today by active, natural processes, and, in many instances, by human activity such as river management and coastal defence work. The result is a dynamic blend of ancient and modern features.

Relict landforms in Norfolk include:

- river terraces, the remnants of former floodplains isolated by later erosion, as in the Nar valley;
- dry valleys, formed during the Ice Age when permeable ground (e.g. chalk or sand) was frozen and could be eroded by water action, as at Tumbley Hill, West Acre;
- meanders, where rivers occupy meandering channels that were formed during periods of higher discharge in the past, as in the Tas valley at Swainsthorpe;
- floodplains, formed by rivers during periods of higher discharge, for example in a glacial meltwater regime, as in the Waveney valley at Earsham;
- floodplains, formed in the lower reaches of rivers where rises in sea level have forced them to deposit their sediment and aggrade, as at Geldeston;
- dolines, circular depressions caused by solution and collapse of chalk bedrock in cold climatic periods, as at the Devil's Punchbowl, Croxton;
- patterned ground, areas of contrasting sandy and chalky subsoil sorted by Ice Age frost action into a pattern of stripes and polygons, as at Brettenham Heath;
- palsas or pingos, hollows with earth ramparts left by collapsed blisters of ground ice, as at Thompson Common;



Photo © Tim Holt-Wilson

Salthouse Heath is a relict glacial outwash plain. A similar plain around Kelling Heath can be seen in the distance.



Photo © Tim Holt-Wilson

The Devil's Punchbowl, Croxton, is a spectacular example of a doline. Its water-level fluctuates according to the height of the local water table.



Photo © Robin Stevenson

A kame feature in the Glaven valley near Letheringsett. This area has many conical-shaped hills made of glaciofluvial sand and gravel thought to have been deposited by a wasting ice sheet.



Photo © Tim Holt-Wilson

Great Hulver Hill (left) and Scrib Hill (right) near Salthouse. The hills are outliers (erosional remnants) of the Salthouse Heath glacial outwash plain.

- glacial outwash plain, formed where many sub-glacial streams emerge from an ice sheet and deposit their bedload in a spreading apron of sand and gravel, as at Kelling Heath;
- glacial till plateaux, extensive areas of till (boulder clay) with interbedded glaciofluvial deposits laid down under an ice sheet, as at Tacolneston;
- terminal moraines, ridges of sand and gravel deposited at the limit of advance of an ice sheet, as at Garrett Hill, Stiffkey;
- kame terraces, irregular mounds of sand and gravel deposited by glacial meltwater along an ice-filled valley side, as in the Heacham River valley at Sedgeford;
- eskers, sinuous ridges of sands and gravels formed by the bed-load of streams flowing in tunnels under an ice sheet, as at Wiveton Downs;
- relict cliff-lines, formed along coasts and estuaries during periods of higher relatively sea level, as at Dersingham;
- raised beaches, where relative movements of land and sea have raised beach deposits above modern sea level, as at Morston;
- relict sand dunes now stabilised by vegetation, as the coastal dunes at Holkham.



Photo © Tim Holt-Wilson

Relict palsas or pingos at East Walton Common, dating from the last glacial period. Earth ramparts surround ponds in depressions where ice mounds once grew.



Photo © British Geological Survey P253934

A raised beach at Morston, photographed in 1934. Recent analysis of the sediments suggests it was deposited about 185,000 years ago; relative movements of land and sea have since raised it above modern sea level.

Photo © Tim Holt-Wilson



River terraces along the River Whitewater at Hoe: the current floodplain (left) and rising ground (right) mark the eroded edge of Terrace 3, dated to about 40,000 years ago.

Active landforms in Norfolk include:

- sand-dunes, formed where wind-blown sand accumulates and may become bound by marram grass and other plants, as at Holkham;
- spring-lines, where downward percolating ground-water flushes out of a slope where it meets an underlying layer of impermeable rock, as at Dersingham Bog;
- estuarine mud-flats, where organic-rich silts and clays build up in sheltered areas of the coast, as at Wells;
- spits, curved promontories of beach material shaped by tidal currents and longshore drift, as at Scolt Head;
- saltmarshes, where sheltered areas of mud-flats become stabilised by a succession of plant species, as at Burnham Overy;
- floodplains, flat areas of alluvium deposited by rivers in their overbank phase, as at the Ouse Washes, Welney;
- land-slides, where unconsolidated sediment slumps on steep slopes or cliffs above a water-lubricated slide zone, as at Sidestrand cliffs;
- tufa mounds, where upwelling springs of chalk-rich water deposit their lime to produce mounds of calcareous tufa, notably at Badley Moor, East Dereham;
- cliffs, steep rock exposures created by processes of erosion and weathering, as at Happisburgh;
- wave-cut platforms, where waves erode a bench in resistant rocks, as at West Runton beach;



Photo © British Geological Survey P210717

Ringstead Downs, near Hunstanton, is a dry valley developed in Chalk bedrock. It is thought to have been carved by glacial meltwaters during the last glaciation, over 14,000 years ago.



Photo © The Landscape Partnership

Winterton Dunes displays a well developed system of stabilised dunes interspersed with ponds known as dune slacks; heathland has developed here on acidic sandy soils. The site is a National Nature Reserve.

- bournes or intermittent Chalk streams, as the River Burn at North and South Creake;
- terracettes, stepped micro-relief features caused by soil creep, as at Thetford Castle;
- valley-floor springs, where valleys have been incised and intercept current ground-water levels, as at St Helens Well, Santon;
- gullies, where runoff water collects and erodes channels, as at Roman Camp, West Runton.



Photo © Tim Holt-Wilson

A tidal creek in mature saltmarshes at Stiffkey. Such upper marsh environments on the North Norfolk coast are stable features, and may be at least 1000 years old.



Photo © Tim Holt-Wilson

Winter flooding by the River Waveney at Billingford. Clays and silts are deposited on the floodplain as thin layers of alluvium.



Photo © Tim Holt-Wilson

Holocene coversands at Ling Common, Castle Rising. Luminescence dating has shown that sand was actively deposited here in the first millennium AD, possibly as a result of a sand invasion event.

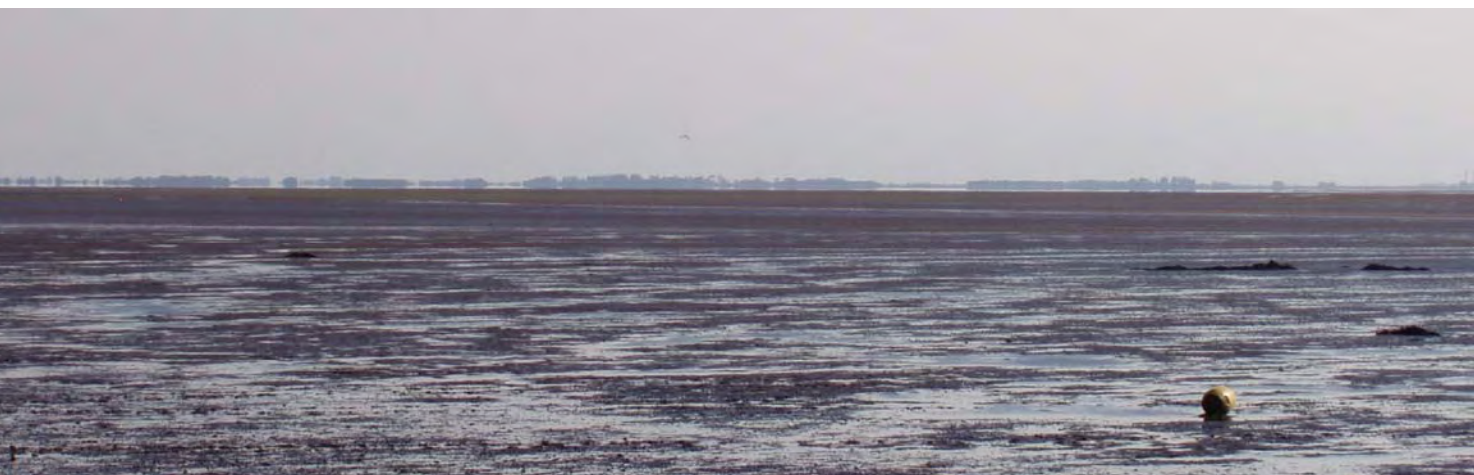


Photo © Tim Holt-Wilson

A view over intertidal sandflats and mudflats in The Wash, Snettisham. The land in the distance at Terrington St Clement was once saltmarsh, reclaimed from the sea in the 1950s and 1970s.

Geomorphological processes

Norfolk's physical landscape has been, and continues to be, shaped by natural as well as human processes.

The Norfolk coastline has been affected by changing sea-levels throughout the Holocene. After the end of the last glacial period, sea levels were over 50m lower than today and Norfolk was part of the land area known as Doggerland, now submerged by the North Sea. There was an initial fast rise in sea level caused by global ice melt, and the line of the present coastline was more or less established by 8,500BC. This was followed by a slower, steadier rise caused by isostatic adjustments². The rate of sea-level rise has been episodic, with locally varied effects. The sediments in parts of the north Norfolk coast demonstrate subsidence of about 10cm per century over the last three millennia. Sediments at West Winch and Wiggshall St Germans contain alternating marine and freshwater beds, and have been analysed to tell a story of successive sea level changes in Fenland, with marine advances into the basin about 4800, 2500 and 2000 years ago. The courses of former tidal creeks may be seen in Fenland as roddons, meandering deposits of silty soil surrounded by fen peat. A similar story of fluctuating sea levels can be told in eastern Norfolk, where borehole samples from Great Yarmouth and nearby marshland have been used to reconstruct varying details of coastal geography through the Roman, Saxon and Mediaeval periods. Climate change is likely to accelerate sea-level rise; estimates of future relative rise in eastern England vary between 22cm and 80cm according to different climatic scenarios for the year 2080³.

Norfolk has a long history of coastal erosion. Estimates suggest that the coast has retreated landward by between 1 and 2km over the last 900 years, with several villages lost to the sea. Current losses at Happisburgh average over 8m per year⁴.

²Norfolk is estimated to be sinking at a rate of about 0.5mm per year.

³Hulme et al. (2002): *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report* (Tyndall Centre for Climate Change Research, University of East Anglia)

⁴See <http://www.bgs.ac.uk/landslides/Happisburgh.html>



Photo © Tim Holt-Wilson

The lower reaches of Stiffkey River valley, once an estuary earlier in the Holocene. The present day floodplain is developed on marine silts and clays characteristic of a saltmarsh environment.



Photo © Tim Holt-Wilson

Active coastal processes at work at Salthouse: the sea has recently breached the beach barrier and spilled shingle over the reclaimed saltmarshes behind.



Photo © Tim Holt-Wilson

End of the road: the effects of marine erosion and cliff slumping at Loop Road, Trimmingham. The cliffs are retreating here at a rate of over 1.5 m per year.

Coastal defences such as groynes, revetments and beach recharge have significantly slowed the rate, as at Overstrand and Mundesley. As the effects of global warming begin to bite, rises in relative sea level will extend active coastal processes into new parts of Norfolk, and increase rates of erosion in the most vulnerable areas. The lower parts of river valleys will become flooded as estuaries extend further inland, and low-lying areas such as the Fens and Broads may be lost to the sea.

The geomorphology of Norfolk's rivers has significantly changed during the Holocene. Early Holocene rivers typically evolved from a late-glacial braided pattern to a branching and reconnecting (anastomosing) pattern; they later developed single-thread meandering channels within stable floodplains. River and floodplain systems have been greatly altered by human activities during the later Holocene; these include increased alluviation caused by sediment run-off from agriculture and deforestation, the cutting and deepening of artificial channels, peat removal, floodplain drainage, and built development such as weirs, sluices, bridges and buildings. It has been estimated that nearly 90% of the total length of the River Nar, for example, has been modified to some degree⁵. As a result of human activity, rivers have typically lost an active, formative relationship with their floodplains, wildlife habitat has been damaged, and peak river flow regimes have become much 'flashier', with an increased likelihood of flooding events.

In recent centuries, human activity has radically altered many of Norfolk's wetlands. Principal among these are the Fens and the Broads. Drainage of the Fens from the 17th century onwards has resulted in shrinkage of the peat and wind-blow of the soils, and many parts are now at, or below, mean sea level. The low-lying river valleys of the Broads were exploited for peat fuel in the early Middle Ages. Rising sea-levels in the 14th century flooded the peat diggings, leaving an extensive legacy of lakes and fens. The alluvial marshlands of Norfolk have also been drained for agriculture in places such as Halvergate and Terrington St Clement.

⁵ Sear et al. (2005): *Geomorphological Appraisal of the River Nar Site of Special Scientific Interest* (English Nature Research Report 684)



Photo © British Geological Survey P235178

Evidence of coastal retreat at Eccles, near Lessingham, 1896. Other lost villages along this dynamic stretch of coast include Shipden, Waxham Parva and Wimpwell.



Photo © Tim Holt-Wilson

An electric pumping station at Fordham Fen, situated at mean sea level. Peat growth began about 4000 years ago in this part of the Fens, and continued uninterrupted until the drainage work of recent centuries.

2.4 Water

Water is one of Norfolk's vital resources. It is a geological component as well as a geomorphological agent. Studies have shown that Norfolk has a diverse hydrology.

The Chalk is the county's principal aquifer, from which most of the county's water supply is extracted via boreholes. Water is also abstracted from rivers such as the Thet and Bure, and from lakes, as at Ormesby Broad. In eastern parts of the county the Chalk aquifer is confined by overlying deposits. Norfolk's Chalk groundwater has significant variations in hardness, chemistry and age of origin, related to the overlying deposits. For example, carbon-14 dating suggests that in interfluvial areas capped by poorly permeable Lowestoft Till the Chalk groundwater may be up to 18,000 years old, and has high carbonate hardness; it is softer in Breckland where it is overlain by sandy drift.

Other aquifers include Cretaceous and Pleistocene sands and gravels and the Norwich Crag, and their water is often enriched with iron and manganese. Spring water from such 'chalybeate' sources was sometimes exploited in previous centuries for spa purposes, as at North Walsham and Shelfanger. Alongside surface water flows, subterranean groundwater plays a role in coastal areas by supporting a range of transitional habitats between fresh and salt water. However, groundwater near the coast, particularly in the east, is liable to be richer in chloride due to the influence of seawater.

Norfolk's surface waters are predominantly alkaline in character. Over 420km of the county's rivers are classified as chalk rivers⁶ where they flow over the Chalk or chalk-rich superficial deposits. Away from the direct influence of the Chalk, surface waters may be alkaline due to the calcareous influence of the Lowestoft Till. Surface waters are liable to anthropogenic pollution. Pollutants include nitrates, phosphates, pesticide residues and metals such as copper, cadmium and lead from sewage. In 1982



Water lilies on Rockland Broad. Natural hydrological conditions in its catchment produce clear, chalk-rich water which supports a diverse flora. Many other broads suffer from pollution leading to eutrophication and loss of biodiversity.

Photo © Tim Holt-Wilson



Spa House, Shelfanger. A small spa was founded in the 19th century to exploit the supposed health-giving virtues of iron-rich 'chalybeate' springs emerging here from sandy glacial deposits.

Photo © Tim Holt-Wilson

⁶*The State of England's Chalk Rivers* (Environment Agency, 2004).

the River Yare became notably contaminated with mercury from an industrial source near Norwich. Such pollutants become incorporated and stored in river and lake sediments, as well as being transported into the sea.

Photo © Tim Holt-Wilson



The River Glaven at Wiveton. The Glaven is classed as a chalk river for 60% of its length, being directly supplied by springs and groundwater flow from the Chalk aquifer.

Photo © Tim Holt-Wilson



Diss Mere is fed by Chalk springs. Until the mid 19th century it was badly polluted by organic waste from the town, including sewage and effluent from the hemp processing industry.

2.5 Soils

Norfolk's varying landscapes are underlain by an intricate mosaic of different soils, supporting varied wildlife habitats and types of agriculture.

Soils are complex products of physical and biological processes, which include weathering of their underlying geological parent materials, and have reached their present form after at least 10,000 years of development since the last Ice Age. They are a vital economic resource for farmers, and their nature determines the types of agriculture which are feasible.

Photo © Tim Holt-Wilson



Heath Farm, Banham, Deep ditches are essential to drain the stagnogley soils of the till plateau of south and central Norfolk. Waterlogging means early harvesting of sugar beet in wet years and autumn sowing of winter cereals.



Photo © Robin Stevenson

Methwold Fen. Deep peat soils provide an easily-worked and fertile growing medium for root crops and vegetables. Problems include risk of wind erosion, and wastage of the peat, which is causing land sinkage and loss of carbon storage capacity.

Work by the Soil Survey of England and Wales has classified and mapped the soils of Norfolk into various soil associations and their constituent series, some of which are named after sites in the county, such as Methwold and Sustead, where they were first identified.

Examples of soil types in Norfolk include

Soil group	Parent material	Landscape element	Example of location
Calcareous Soils	Chalk and chalky superficial deposits	West Norfolk uplands	Massingham Heath
Brown Earths	Glacial, glaciofluvial and aeolian (wind-blown) deposits	North-east Norfolk plateau	North Walsham
Brown Sands	Sandy glaciofluvial deposits	Cromer Ridge	Upper Sheringham
Stagnogley Soils	Chalky glacial deposits	South Norfolk till plateau	Winfarthing
Earthy peat soils	Fen peat	The Broads	Barton Broad
Brown calcareous alluvial soils	Marine alluvium	Marshland	Terrington St John

Peat is an accumulation of partially decayed vegetation, and as such plays an important role in sequestering carbon. Work is being carried out in the Broads area to evaluate the significance of the area's role in carbon capture. Here the total carbon stored in peaty material in deep and shallow peaty soils has been estimated to be 4.825 million tonnes⁷.



Photo © Tim Holt-Wilson

Leached, acidic sandy soils are common in many parts of Norfolk where glaciofluvial sands and gravels are close to the surface. Heathland is commonly developed in such areas, as seen here at Kelling Heath.



Photo © Tim Holt-Wilson

Fine windblown silt (loess) of periglacial origin has made a major contribution to the soils of north-east Norfolk. It has combined with sandy glacial drift to make easily cultivated ploughsoil.



Photo © Robin Stevenson

The distribution of lime-loving and lime-hating plant species reflects variations in soil moisture and chemistry overlying periglacial patterned ground, consisting of alternating chalky and sandy subsoils. Grimes Graves SSSI.

⁷M Shepherd (2009): *Estimating Carbon Storage in Peatlands Within English National Parks* (Unpublished report, Natural England)

2.6 Cultural resources

Norfolk has a geocultural heritage of museum collections and information archives. The county's geology, landforms and archaeology have been the subject of active scientific research for over two centuries, during which many significant collections of specimens and associated photographs and documents have been compiled.

Notable local collectors include R Fitch (19th century), JE Sainty and N Peake (20th century); in many cases their material is archived by the Norfolk Museums and Archaeology Service or regional museums such as the Sedgwick Museum, Cambridge⁸. Such collections are important for scientific study: they may include type and figured material, and may hold specimens and samples from sites that are no longer accessible; sediment samples from the Ludham borehole (1959) are a case in point, as they have been preserved by the British Geological Survey and are still available for study 50 years later. Photographic archives, such as the Hallam Ashley, may provide useful evidence of now-vanished geological exposures and landforms.

Norfolk Landscape Archaeology holds important information relevant to geodiversity, including an archive of archaeological finds and the Norfolk Historic Environment Record, a database of all known archaeological sites and finds in the county, including Palaeolithic. It is backed up by an archive of aerial photographs which show landscape as well as archaeological features.



Alfred Savin's collection of elephant and mammoth teeth from the Cromer Forest-bed, 1896. The collection is now curated by the Norfolk Museums and Archaeology Service.



A Mosasaurus tooth from the Chalk of Norwich, preserved at Ipswich Museum. St James' Pit, Norwich, is designated as a SSSI for its fossils of the marine reptiles Mosasaurus and Leiodon.

Photo © British Geological Survey P234674

Photo © Tim Holt-Wilson with kind permission of Colchester and Ipswich Museums

⁸The Norfolk Museums and Archaeology Service alone curates over 40,000 geological and over 1000 Palaeolithic specimens from Norfolk

3 Conserving Norfolk's Geodiversity

Nature conservation has been defined as:

*'the protection, preservation, management or enhancement and the improvement of understanding and appreciation of flora and fauna and geological and geomorphological features'*⁹.

Nature conservation has great popular appeal. Big advances have been made in the official conservation of biodiversity (fauna and flora) since 1994¹⁰, backed up by a range of national, regional and local Action Plans. However until recently, less attention has been paid to geodiversity; it has not enjoyed such wide understanding and support, even though it forms the physical context for all life on Earth, and the story of the development of our planet and its life forms, including humans, fascinates people of all ages. Norfolk's geodiversity has many special features worthy of conservation.

This section sets out the background to geoconservation in the county, explaining the policies and practices which facilitate this work, and giving a brief summary of the range of threats to the county's Earth heritage. It then goes on to list a set of conservation priorities for the county.

3.1 Geoconservation - the policy background

Statutory geoconservation

The statutory conservation of geodiversity features is part of the remit of National Parks, National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs). These site and area designations are a precious geoconservation resource. The Norfolk and Suffolk Broads has the status of a National Park. There are 20 NNRS in Norfolk, and 39 SSSIs designated primarily for their Earth heritage interest (about 23% of the total). Geological SSSIs in Norfolk were selected as part of the Geological Conservation Review (GCR), a national review undertaken between 1977 and 1990¹¹. SSSIs are administered by Natural England, and there is an ongoing programme of condition monitoring and management. See Appendix 4 for a list of geodiversity SSSIs in the county. The 123 remaining SSSIs are primarily designated for their biodiversity, while geodiversity plays a secondary role as a habitat factor. Seen from a regional perspective, Norfolk has a disproportionately large share of significant geodiversity sites, and is particularly important for its Quaternary and Lower Cretaceous heritage. See Appendix 4 for breakdown of GCR citations in Norfolk compared with regional totals.

⁹Definition from the Glossary of *Planning for Biodiversity and Geological Conservation - A Guide to Good Practice* (ODPM 2006)

¹⁰The UN Convention on Biodiversity, agreed at the Rio Earth Summit in 1992, and ratified in 1994.

¹¹See the Introduction to the GCR at <http://www.jncc.gov.uk/page-2947>.

Water

Water is an important geodiversity resource which receives statutory protection through a range of laws and regulations¹². It is managed by the Environment Agency through its Groundwater Protection Policy and the designation of Source Protection Zones, which are monitored for pollution and contamination. Water abstraction is managed by the Agency through Catchment Abstraction Management Strategies; both pollution and abstraction in Norfolk will be managed under the new Anglian River Basin Management Plan. The risk of flooding is managed through Catchment Flood Management Plans.

Soils

There is no legal framework for directly protecting and conserving soils in the UK. However action for soils is gathering momentum, backed by a Soil Action Plan¹³, an Environment Agency report¹⁴ and a DEFRA strategy document *Safeguarding our Soils – A Strategy for England*¹⁵. The latter addresses the role of peat deposits in storing and potentially capturing carbon. A Soil Framework Directive has been proposed by the European Commission¹⁶ to address the range of threats to soils. The Water Framework Directive influences soil conservation by addressing the issue of pollution in surface water caused by farming activities, e.g. through designation of Nitrate Vulnerable Zones (over 90% of Norfolk is so designated).

Traditionally, soil has been valued in economic and functional terms; however its intrinsic conservation value, its geodiversity and associated archaeological and palaeo-environmental archives, is being increasingly recognised. Soil conservation is an important issue in Norfolk. Although the variety of the county's soils has been mapped, their diversity has not been evaluated and is not monitored for conservation purposes. However good soil management on farms may be included among the objectives of Environmental Stewardship and Catchment Sensitive Farming¹⁷ schemes. Agricultural quality is conserved through Natural England's Agricultural Landscape Classification scheme.

Coastal processes

Norfolk has 98 km of coastline with conservation designations, more than any other county in eastern or southern England. *Planning Policy Guidance 20: Coastal Planning* (PPG20)¹⁸ covers the coastal zone; it provides guidance on managing the impact of development on landscape and the natural environment (including coastal processes), and managing risk (flooding, erosion, landslips). The operation of coastal processes is managed by the Environment Agency through Shoreline Management Plans¹⁹. Flooding and coastal erosion are managed by a combination of planned defences and natural evolution. Coastal erosion is a live political issue in Norfolk, which has one of the fastest eroding coastlines in Britain. There is a need to communicate the scientific realities behind coastal processes, to promote greater public understanding of the long-term inevitability of loss to land and property faced with rising sea levels.

¹²Including the European Nitrates Directive 1991, the Groundwater Regulations 1998, the Water Framework Directive 2000, the Nitrate Pollution Prevention Regulations 2008.

¹³*The First Soil Action Plan for England: 2004-2006* (DEFRA 2004)

¹⁴*The State of Soils in England and Wales*. Environment Agency (2004)

¹⁵See <http://www.defra.gov.uk/environment/quality/land/soil/documents/soil-strategy.pdf>.

¹⁶See http://ec.europa.eu/environment/soil/index_en.htm

¹⁷See <http://www.defra.gov.uk/foodfarm/landmanage/water/csf/index.htm>

¹⁸*Planning Policy guidance 20 - Coastal Planning*. Department of the Environment (1992)

¹⁹See <http://www.environment-agency.gov.uk/research/planning/105014.aspx>

Local sites

The non-statutory conservation of geodiversity sites is principally carried out under Local Sites designation procedures (DEFRA 2006)²⁰, of which Regionally Important Geological / geomorphological Sites (RIGS) are the most widely designated category, although the network is not yet fully extended across the UK²¹. Despite its name, RIGS is a local rather than a regional designation. There are currently five RIGS in Norfolk, and they have the same status in planning as County Wildlife Sites. Local Sites designation is a voluntary agreement between the designating body and the site owner / manager to promote positive conservation management of features of interest, and does not imply any legal obligations nor confer any right of access. Over 280 potential Local Sites / RIGS have been identified in Norfolk through an audit commissioned by the Norfolk Geodiversity Partnership. Its purpose is to provide baseline information for planning purposes as well as suggesting candidate sites for possible designation. The term RIGS is being phased out, and Norfolk's RIGS may in future be renamed Local Geological Sites or County Geodiversity Sites.

Although Local Sites enjoy no legal protection local authorities give them a degree of protection from development through planning policies set out in the Local Development Framework (LDF) and Minerals & Waste Development Framework processes. *Planning Policy Statement 9: Biodiversity and Geological Conservation* (PPS9) was published in 2005 and sets out government policies on conserving geodiversity through the planning system in England²². It views the delivery of geoconservation as one of the objectives for sustainable development, nature conservation and social renewal, and lends important support for local efforts to conserve sites and features. For example, it states that local planning authority policies should attach 'appropriate weight' to designated sites and also 'geological interests in the wider environment'²³. Significantly, PPS9 states that local authority plans and policies should be based on up-to-date information about the environmental characteristics of the areas. It also states that the aim of planning decisions should be to prevent harm to geological conservation interests, and it establishes the principle that where harm is unavoidable adequate mitigation measures should be put in place, or as a last resort planning permission should be refused; Section 106 agreements can be used to deliver such benefits for geodiversity. An opportunity exists to include baseline geodiversity indicators in the Sustainability Appraisal system in the LDF process. Furthermore, as is the case in Norfolk, the condition of RIGS may be adopted by local authorities as an indicator of natural environmental protection under the local authority performance framework target NI 197: Biodiversity²⁴. Also, the planning application validation process (known as 1App) includes a requirement for the consideration of geodiversity interest, which might involve consideration of RIGS or other designated local geodiversity sites by applicants. This requirement tends to be compromised by a lack of awareness of geodiversity on the part of both planners and applicants, and the protection afforded by 1App could be strengthened through the issue of guidance notes for planners and developers in the same way as exists for biodiversity.

²⁰*Local Sites. Guidance on their identification, selection and management.* Department for Food and Rural Affairs (2006)

²¹*UKRIGS Development Strategy 2006-2010.* The Association of UK RIGS Groups (2006)

²²*Planning Policy Statement 9 - Biodiversity and geological conservation.* Office of the Deputy Prime Minister (2005)

²³See PPS9, Key Principles, section 2.

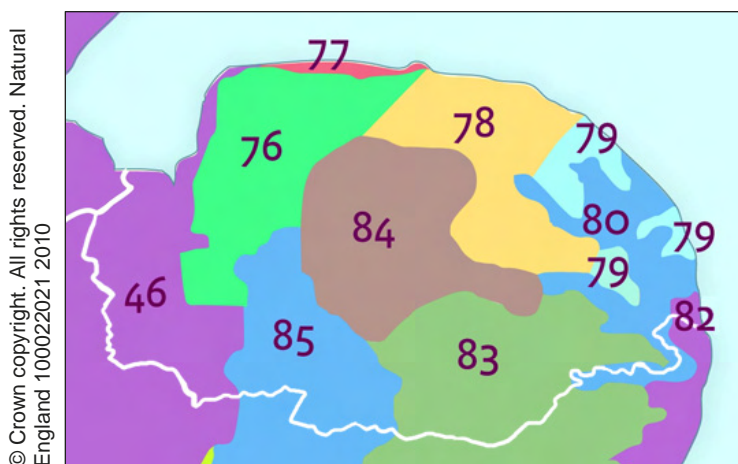
²⁴See <http://www.defra.gov.uk/corporate/about/with/localgov/indicators/ni197.htm>

Archaeology

Archaeological features of national importance may receive statutory protection by English Heritage as Scheduled Monuments, however this designation covers only deliberately created ones. Those that are not deliberately created cannot be scheduled, for example Palaeolithic sites or Holocene peat beds with associated archaeology, as at Titchwell and Holme-next-the-Sea; furthermore there may be difficulties in physically protecting such features, for example in a dynamic coastal environment. Such archaeological remains and associated palaeo-environmental material must be conserved through the local planning process. The conservation of heritage assets takes place under the policy direction of *Planning Policy Statement 5: Planning for the Historic Environment (PPS5)*²⁵. Conditions may be placed on developments to preserve or mitigate damage to archaeological features. Maintenance of archaeological records for planning purposes in Norfolk is the responsibility of Norfolk Landscape Archaeology, and takes place within a strategic research framework which includes a Palaeolithic and Mesolithic agenda²⁶. Buried resources from these periods are the least well known but are most impacted by aggregate extraction. Much important information has doubtless been lost from sand and gravel quarries (e.g. Keswick, Whitlingham) developed in river terrace deposits. Archaeological resource evaluation for these periods is at an early stage in Norfolk, and consequently is only patchily addressed by the development control process.

Landscape

Geodiversity contributes the fundamental elements of landscape directly through geology, geomorphology and soil type, and indirectly through the influence of geology on patterns of land use, settlement, etc. The foundations for landscape conservation were laid in the 1990s through the Natural Areas and Countryside Character Area programmes of English Nature and the Countryside Commission; these characterised variations in natural and cultural heritage at a national scale. In Norfolk, nine terrestrial and three marine Natural Areas were identified for their biodiversity and geodiversity. These schemes have now been replaced by Natural England's National Character Areas (NCA) programme²⁷. NCA and Natural Area documents provide summaries of Norfolk's landscapes, and their varied geodiversity, biodiversity and landuse.



The National Character Area map for Norfolk

- 46. The Fens
- 76. North West Norfolk
- 77. North Norfolk Coast
- 78. Central North Norfolk
- 79. North East Norfolk & Flegg
- 80. The Broads
- 82. Suffolk Coast & Heaths
- 83. South Norfolk & High Suffolk Claylands
- 84. Mid Norfolk
- 85. Breckland

²⁵See <http://www.communities.gov.uk/publications/planningandbuilding/pps5>

²⁶Brown, N, and Glazebrook, J (eds) (2000): *Research and Archaeology: a Framework for the Eastern Counties* (East Anglian Archaeology Occasional Paper No.8). Revised 2008.

²⁷Formerly known as Joint Character Areas.

At a more local scale, Norfolk's variety of landscapes has been mapped and described to varying degrees through procedures of Landscape Character Assessment (LCA) and Landscape Description²⁸. The national policy driver for this is *Planning Policy Statement 7: Sustainable Development in Rural Areas* (PPS7)²⁹. These procedures bring together information about topography, soils, landuse and 'sense of place' to generate qualitative information about the character and appearance of landscape in the county. The resulting datasets may be used to produce maps and policy guidance to inform planning decisions that respect local distinctiveness, including Earth heritage. However, unlike the historic landscape for example³⁰, Norfolk's geomorphological landscape, its natural topographic character and component landforms, has not been mapped and characterised. As a result the contribution of landforms and physical processes to landscape character has been systematically underestimated. Conserving physical landscape will require sympathetic development control policies and a commitment to describing explicitly geodiversity in statements of landscape character.

The European Landscape Convention (ELC) came into force in the UK in 2007, and promotes the protection, management, planning and the wider understanding and appreciation of landscapes. The lead implementing agency in Norfolk is Natural England, and it supports existing work in the county on landscape characterisation and interpretation for public benefit. The ELC defines landscape as 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors'.

Non-statutory geoconservation may also be an important part of landscape designations such as the AONBs and Heritage Coasts in England, and parts of the north Norfolk coast are so designated³¹. Local planning authorities may designate Conservation Areas to include landscape features³²; North Norfolk District Council, for example, has designated the area of the Glaven Valley. Important landowning organisations such as the National Trust, the Norfolk Wildlife Trust and the Royal Society for the Protection of Birds are examples of conservation organisations which routinely protect geodiversity as part of their remit. Many countryside and green infrastructure partnerships and local conservation trusts also do the same. Landowners may conserve geodiversity on their land as part of enhancement of landscape, habitat and historic features. Natural England's Environmental Stewardship Scheme³³ contains measures which may support the conservation of local geodiversity features, for example maintaining and enhancing landscape quality and character, and protecting the historic environment and natural resources.

Links with biodiversity

The Norfolk Biodiversity Partnership is actively promoting the conservation of species and habitats in Norfolk through a range of species and habitat action plans³⁴. The latter may

²⁸Landscape Character Areas (LCAs) and Landscape Description Units (LDUs) have been defined. Historic Landscape Characterisation has also been carried out, to map the landscape in terms of its historic origin.

²⁹*Planning Policy Statement 7: Sustainable Development in Rural Areas* Office of the Deputy Prime Minister (2004).; see sections 24 and 25.

³⁰*Norfolk Historic Landscape Characterisation. Final Report April 2009* (Landscape Archaeology Unit, Norfolk County Council)

³¹See <http://www.norfolkcoastaonb.org.uk/>

³²See Section 69 of the Planning (Listed Buildings and Conservation Areas) Act, 1990.

³³See <http://www.naturalengland.org.uk/ourwork/farming/funding/es/default.aspx>

³⁴See <http://www.norfolkbiodiversity.org/>

directly benefit geodiversity by conserving significant landform elements, for example coastal sand dunes, littoral and sublittoral chalk, maritime cliffs and slopes, and chalk rivers.

New approaches

The strength of a site-based approach is that it draws conservation attention to a designated feature of interest; the weakness is that it implicitly treats features outside the designated area as having lesser importance. Given the policy direction of PPS9 towards conserving 'geological interests in the wider environment', the need for a more holistic approach is indicated. Faced with ongoing, diffuse threats to geodiversity, such as development pressures at a landscape level, the site-based approach may be insufficient adequately to protect geodiversity in the wider landscape. Geographic Information Systems (GIS) and vulnerability mapping techniques offer new possibilities for geoconservation. For example, the Landmap programme in Wales combines geodiversity, biodiversity, historical/archaeological, cultural, visual and sensory datasets to provide an integrated landscape planning tool³⁵. A related approach may involve identification and designation of 'geological landscape assemblages', areas of land with significant concentrations of geodiversity assets, although current government policy favours a shift from landscape designation to 'criteria-based policies' in planning. In 2008 Norfolk County Council began work drafting a vulnerability mapping project for buried Palaeolithic and Mesolithic archaeological resources at risk from aggregate extraction and other processes in the Little Ouse, Waveney and Yare valleys³⁶.

See Appendix 5 for guidance on conserving and enhancing geodiversity through planning in Norfolk.

³⁵See <http://landmap.ccw.gov.uk/>.

³⁶Ward, I (2009): *A Statistical Approach to Vulnerability Mapping of Archaeological Resources along the Waveney, Yare and Ouse River Corridors* (Project Design, Version 2; Norfolk Archaeological Unit)

3.2 Geoconservation – threats to Norfolk's geodiversity

Norfolk's geodiversity comprises a unique range of Earth heritage resources which have been exploited for human benefit for many thousands of years. However the integrity and accessibility of these resources is under constant threat.

The principal threats can be summarised as:

Loss of geological exposures and/or information through

- burial by coastal protection, landfill, landscaping or other planned development;
- burial by dumping and fly-tipping;
- vandalism and graffiti;
- natural processes, such as slumping of unconsolidated sediments and vegetation encroachment;
- non-recording and sampling of temporary exposures, including road cuttings and quarry sections;
- damage to palaeo-environmental archives in peat and alluvium through drainage and excavation.



Photo © Tim Holt-Wilson

A disused gravel pit at Hoe. Poorly consolidated Pleistocene sediments are very prone to slumping and scrub overgrowth, which may make access to geological information more difficult.



Photo © Tim Holt-Wilson

Castle Drain at Wormegay. Artificial channelisation of water courses destroys wildlife habitat and causes peat to dry out and oxidize, so reducing its carbon storage capacity and damaging palaeo-environmental fossil archives.

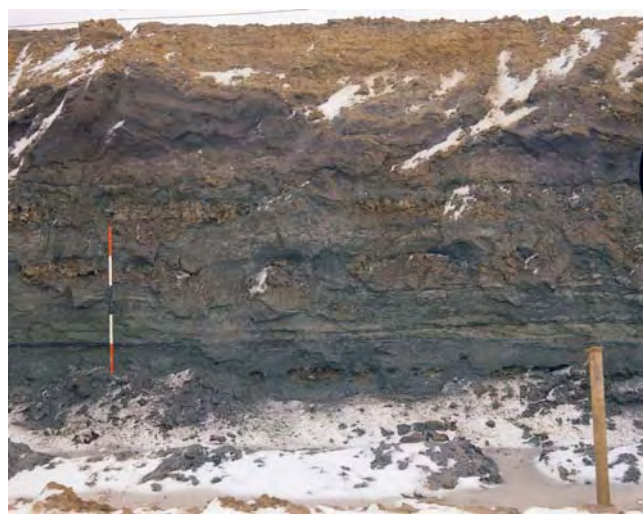


Photo © British Geological Survey P210193

The King's Lynn bypass cutting at Mintlyn Wood, 1965, showing new exposures of sandy clays and ironstones in the Sandringham Sands. Important local geological information may be lost if temporary excavations are not recorded and sampled.

Photo © Gilbert Addison

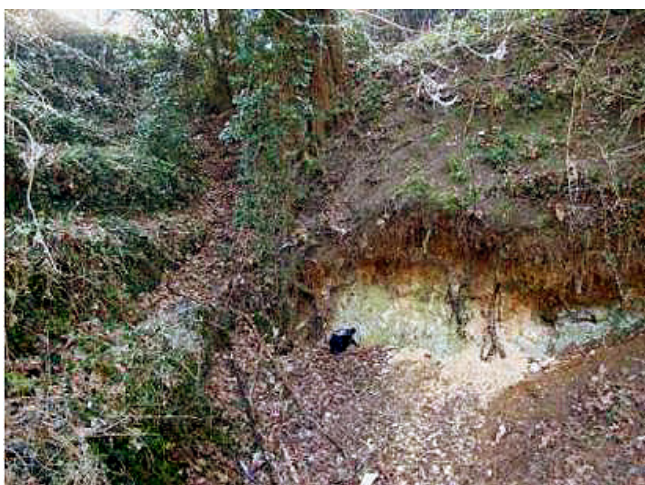


Graffiti damage at Dersingham Sand Pit, part of a SSSI and the type-site of the Lower Cretaceous Dersingham Formation.

Damage to the physical landscape and its geomorphological features and processes through

- coastal protection schemes;
- inshore dredging;
- land drainage and river management schemes, including flood protection;
- anthropogenic landform developments, such as bunds, cuttings, quarries and embankments;
- built development, including infrastructure improvement.

Photo © ADAS



Catton Grove Chalk Pit is a designated SSSI and type-site of the Catton Sponge Bed. The site was partly landfilled in the 1970s, but access to a representative Chalk exposure was safeguarded by constructing a wall of stacked gabions (left).



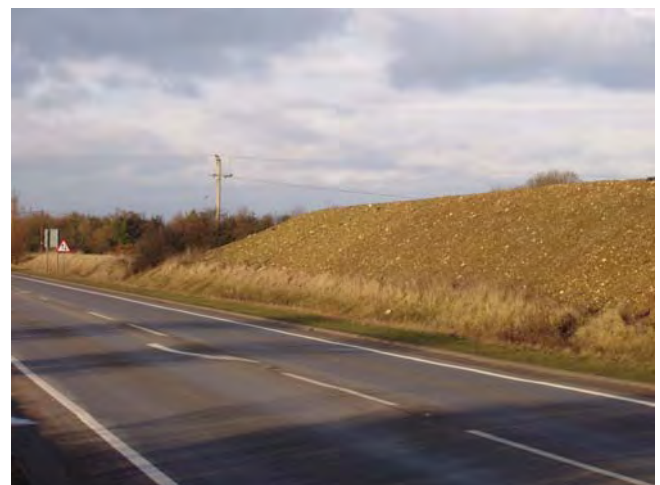
A coastal protection reef at Sea Palling. Such hard sea defences are likely to alter the sediment supply to beaches and sandbanks further along the coast.

Photo © Tim Holt-Wilson



The River Nar at Middleton. The river is artificially embanked and is perched over two metres above its floodplain. It is now prone to siltation and disconnected from a formative relationship with its floodplain.

Photo © Tim Holt-Wilson



A high screening bund beside the Dickleburgh bypass. This artificial landform is at stark variance with the flat landscape of the surrounding South Norfolk glacial till plateau.

Photo © Tim Holt-Wilson

Damage to soil features and processes through

- destruction of soil profiles and structure, including compaction;
- drying out and shrinkage of peat;
- acidification and ochre accumulation;
- soil erosion;
- soil contamination;
- import of materials for filling and ground-raising

Damage to groundwater and surface water through

- pollution and contamination;
- soil acidification;
- over-abstraction.

And lastly, and perhaps most importantly:

Lack of public understanding about geodiversity, and why it is valuable to society for its contribution to economic life, science, wildlife, leisure and recreation.



Photo © Robin Stevenson

A dust storm at Beachamwell, March 2007. The silty soils of Breckland are prone to wind erosion, particularly if they are left bare in spring time.



Photo © Tim Schofield

De-stoning in a field in the Bure catchment. Removal of stones from fields makes cultivation easier. However it leads to progressive damage to soil structure and some archaeological features.

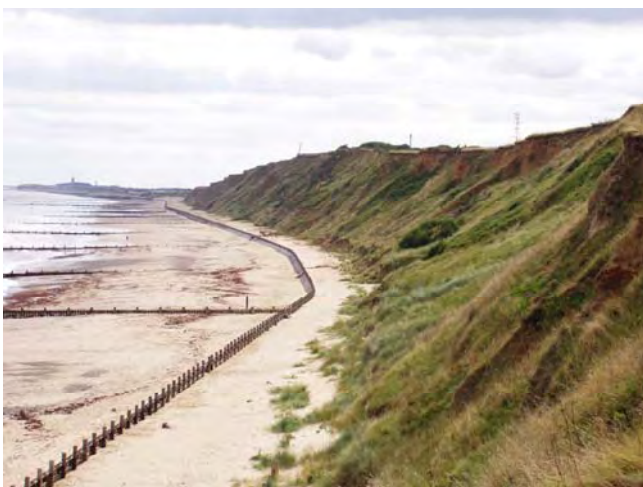


Photo © Tim Holt-Wilson

Mundesley Cliffs SSSI is designated for its exposures of Pleistocene sediments of the Cromer Forest-bed Formation and the Pastonian Stage. Sea defences here have stabilised the cliff, and the geological interest is now obscured by slumping and vegetation.



Photo © Tim Holt-Wilson

The Blakeney Esker is a glacial outwash feature almost unique in southern England, but about 40% of it has been quarried away. Part of its truncated body can be seen here at Blakeney Downs quarry.

3.3 Geoconservation – principles and priorities

Given the importance of Norfolk's geodiversity and the range of threats it faces, we propose a set of priorities to guide a programme of action.

This is based on geoconservation principles set out in the Earth Science Conservation Classification System (ESCC)³⁷, which has established a framework for deciding the conservation management requirements of geodiversity. It is based on the differing vulnerabilities of three kinds of site and feature (Exposure/Extensive, Integrity and Finite), and suggests different strategies for their conservation. See Appendix 6.

Geoconservation priorities

While all Norfolk's geodiversity has value and is worth conserving in its own right, the principles of the ESCC suggests the need to prioritise the conservation of certain features which are more significant or vulnerable. A schedule of geoconservation priorities for Norfolk is presented here.

A. GEOLOGICAL

Geological features from all stratigraphic horizons including

- representative occurrences of all stratigraphic units, including new ones when identified: sites designated as stratotypes are a priority for conservation, also lithostratigraphic type sites designated for their group / formation / member / bed status, also fossil type localities (Norfolk has national and international examples of such sites);
- stratigraphic boundaries and basement beds;
- unconformities;
- sites showing structural features such as faults and folds;
- fossiliferous beds, including those with microfossils which are important geo-archives;
- valuable examples of sedimentary structures, both primary and deformational;
- river terrace stratigraphy;
- occurrences of minerals (*sensu stricto*);
- palaeosols;
- hominid and associated palaeo-environmental evidence;
- interdigitating marine and terrestrial sequences;
- sites having a history of Earth science research.

B. GEOMORPHOLOGICAL

All kinds of relict and active landform and their generative processes are under-researched in Norfolk. Good examples of them all are priority features.

³⁷ Nature Conservancy Council: *Earth science conservation in Britain, a strategy*; Peterborough (1990); and amended: English Nature: *Geological conservation, a guide to good practice*; Peterborough (2006).

Aeolian	Erosional and depositional landforms and their processes (e.g. dunes (inland and coastal) and blow-outs)
Coastal	Erosional and depositional landforms and their processes (e.g. spits, nesses, bars, cliffs, saltmarshes; raised beaches and relict cliffs)
Fluvial	Erosional and depositional landforms and their processes (e.g. gullies, river terraces, meanders, examples of channel migration)
Glacial	Moraines; eskers; kames; erratic boulders; meltwater channels; outwash fans and plains
Groundwater	Springs and spring-lines; spring-sapping hollows; dune slacks;
Karst	Bournes; dolines and solution hollows; swallow-holes; seasonal meres
Lacustrine	Natural lakes
Mass movement	Active and relict landslides; terracettes; solifluction slopes
Tectonic	Fault scarps
Periglacial	Patterned ground; relict pingos, palsas and naleds; 'hummocky ground'; thermokarst hollows;
Impact	Meteorite impact features

The wider landscape

Many parts of the Norfolk landscape may be characterised as gently rolling or undulating plateau areas with intervening slopes and shallow valleys. Although it looks undramatic, this natural physical land form is essential to the county's landscape character, and is under threat from the cumulative, diffuse impact of artificial landforms such as embanking and bunding, infill and other 'landscaping' which alter the natural form of the land surface. What may be appropriate in one topographical context (e.g. a mound of landscaped landfill in a hummocky drumlin landscape) may be entirely inappropriate in flat Fenland or the South Norfolk till plain.

There is a general need to recognise the value of, and to protect, land form outside areas of designated landscape quality such as AONBs. This will mean improving the description of the physical landscape and its components in LCA and LDU work³⁸. Natural, authentic land form is as much a priority for protection as the biological or cultural character of Norfolk's landscape³⁹.

C. SOILS

Soil sections exhibiting clear, undisturbed soil profiles of a particular soil type / association are priority features, as are soils which exhibit response to natural processes and demonstrate natural functions. Examples of palaeosols are a priority, particularly if they are vulnerable by being close to the present surface. Keeping peat soils in a waterlogged state is a priority to retain their carbon storage capacity.

D. WATER

Examples of naturally functioning hydrological systems with natural hydrochemical features are priority features in Norfolk.

³⁸ See page 3.1 (Landscape) above

³⁹ Gray, M. (2006): *Conserving geodiversity in the wider landscape – making it happen* (unpublished research report; English Nature)

E. LINKS WITH BIODIVERSITY

Examples of geodiversity features which contribute to the conservation of priority habitats identified in the UK Biodiversity Action Plan⁴⁰.

F. ECONOMIC AND CULTURAL

Sites and features exhibiting clear associations with economic and cultural value are priorities. Such sites include those which exemplify

- brick-making and mineral working by retaining original buildings (e.g. lime kilns), equipment and worked faces;
- the unique contribution of Norfolk to the history of Earth science;
- use of geological materials for building purposes;
- the role of geodiversity in folk culture.

G. EDUCATION AND RESEARCH

Sites and features with a clear yield for educational and research purposes are a priority. Such sites may include those with potential for demonstrating geology and geomorphology in schools as part of the National Curriculum, and those with a history of published or unpublished scientific research or investigation (including stratotypes), or with likely potential for investigation.

Museum collections and archives relating to the geology of Norfolk, including specimens, photographs and geological records, may be a precious and irreplaceable resource for science and education. Their long-term preservation and the dissemination of the information contained in them is a priority.

⁴⁰ See <http://www.ukbap.org.uk/PriorityHabitats.aspx> for habitats list and descriptions.

3.4 Geoconservation practice

Some of the most important geodiversity sites and features in Norfolk enjoy a measure of statutory protection as SSSIs. Their designation documents include a list of operations likely to damage the site, and a statement about the management needs of the site. Listed operations cannot be carried out by the site owners or managers without the consent of Natural England.

In the case of sites and features outside the network of statutorily protected sites, their geodiversity interest may be conserved by voluntary agreement with the landowner. Non-statutory Local Site designation is one way forward; another is to provide information support at a local level.

Voluntary effort and partnership working are central to conserving Norfolk's geodiversity, through raising popular awareness and developing practical action.

For advice on identifying geodiversity features in your locality and practical guidance on their conservation management, please contact the Norfolk Geodiversity Partnership:

- Jenny Gladstone: tel.: 01603-619387; email: jennygladstone@aol.com
- John Hiskett : tel.: 01603-625540; email: johnh@norfolkwildlifetrust.org.uk
- Tim Holt-Wilson: tel.: 01379-870411; email: timholtwilson@onetel.com

To find out more about practical geoconservation, read the sources listed in Appendix 1.