Sediment Input from Coastal Cliff Erosion

Operational Investigation 577

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Sediment Input from Coastal Cliff Erosion

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The project was undertaken to provide information on the composition of the Region's cliffs to aid Flood Defence personnel in the execution of their responsibilities.

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GLOSSARY

Diamict/Diamicton	Poorly sorted sediment of varying grain size. In this area associated with glacial deposition. The term is interchangable with *till.*
Glauconitic sand	Green clay mineral which forms granule aggregates up to 1 mm in diameter. Produced on continental shelves.
Littoral	Intertidal
Mud	Sediment grain size <0.063 mm (63 μ)
Sand	Sediment grain size 0.063 mm - 2 mm
Gravel	Sediment grain size >2 mm
PSD	Particle size determination
Pleistocene	One of two epochs of the Quaternary which lasted from approximately 2 million years (Ma) to about 10,000 years ago. The Holocene is the other epoch which began about 10,000 years ago.
Quaternary	The period of geological time which covers approximately the last 2 Ma.
Tertiary	The period of geological time which began about 65 Ma ago and lasted approximately 63 Ma.
Till	Sediments deposited by the direct action of glacial ice; normally poorly sorted. The term is interchangable with *diamict/diamicton.*

EXECUTIVE SUMMARY

The successful implementation of soft engineering schemes for coastal and flood defence requires realistic long-term forecasts for the demand and supply of replenishment materials. The coastline of Eastern England from the north shore of the Thames Estuary to the north east corner of the Wash is an area which includes extensive cliffs of relatively soft sediments which, under wave attack, provide or have the potential to provide sediment to the littoral and nearshore environment.

This report provides a quantitative basis for estimating the volume and proportion of mud, sand and gravel input from cliffs in this area. Although no account has been taken of the state of cliffs in terms of coastal defence and current erosion conditions, the data presented is available for integration into models of coastal recession and littoral and nearshore budget calculations.

The cliffs in gross sediment character terms can be broken into three primary and one subordinate sector. These are, a southern sector, dominated by muds, from Mersea to Harwich characterised by cliffs of London Clay with some Pleistocene sand and gravel and Red Crag. A central sector, from Felixstowe to Caister predominantly distinguished by Plio-Pleistocene Crag sequences, mainly of sand. A northern sector, comprising a virtually continuous line of cliffs from Happisburgh to Weybourne dominated by a heterogeneous mixture of mainly glacial sediments, principally mud and sand. A subordinate sector at Hunstanton, on the Wash, where a rock cliff of Chalk and Carstone provides mainly sandy sediment. The Chalk, because of its solubility, is not the principal contributor of sediment.

For the sectors identified above, the southern sector's total potential of eroded sediment is estimated at 181,000 m^3 per m recession, the central sector, 309,000 m^3 per m recession, and the northern sector, with the highest cliffs, 692,000 m^3 per m recession. The cliffs at Hunstanton are a minor component of the system with potential volumes of only 16,000 m^3 per m recession.

In terms of future sediment inputs from cliff erosion in the areas covered by this study, it appears that the stratigraphy indicated by the present cliffs, and the volume and character of the sediments identified by this study are likely to be applicable to any recession scenario invoked for the next hundred years.

The volume and sediment character data has been incorporated into the Environment Agency Shoreline Management System as graphical and database elements

The methods adopted for this study are readily applicable to other areas of potential cliff erosion. The system of cliff section surveys at intervals based on cliff morphology and geology provides a method which is rigorous and cost effective and can be updated at any time, increasing the precision and value of the original survey.

Keywords. *Cliffs, Coastal defence, East Anglia, Essex, Erosion, Sediment, Sediment budget.*

1. INTRODUCTION

The successful implementation of soft engineering schemes for coastal and flood defence requires realistic long-term forecasts for the demand and supply of replenishment materials. Such forecasting can only be made from an understanding of the nature and rate that materials are introduced naturally to littoral and nearshore sedimentary budgets.

Sediment is introduced to the nearshore and littoral budgets from four main sources:

- Inland catchments *via* streams and rivers.
- Sea cliffs.
- Scoured shore and nearshore substrate.
- Offshore sea bed sediments.

In addition sand may be reintroduced to the littoral budget from coastal sand dunes, or from further afield as windborne fines. For grain and clast sizes larger than medium sand sea cliffs are the most important source of sediment. The volume and nature of material from cliff erosion need to be identified to assist in understanding coastal processes and also to evaluate the impact of coastal protection schemes.

The coastline of Eastern England from the north shore of the Thames Estuary to the north east corner of the Wash is an area which includes extensive cliffs of relatively soft Quaternary and Tertiary sediments which, under wave attack, provide or have the potential to provide sediment to littoral and nearshore budgets. This study characterises the sediments within these cliffs at the present day (Figure 1).

2. OBJECTIVES

The study aims to provide systematic information on sediments that will enhance understanding of the littoral and nearshore budgets along this stretch of coast, and, in particular, allow the forecasting of the demand for beach replenishment material in this area to be improved.

A prime objective is to provide a quantitative basis for estimating the volume and character of sediment input from cliffs and their contribution to the littoral and nearshore sediment budgets of the area. The data acquired may be integrated with models of coastal recession to determine sediment input, classified by grade, to the littoral budget.

Explicitly the objectives of the study are:-

- Identify the volume of sediment input from geological sources to the coastal system in different grain size classes.
- Identify what future potential sediment inputs may be.
- Identify the amount of material remaining as beach building material and the amount diffusing away from the coast.
- Evaluate the importance of cliff sediment input to sediment budgets.
- Provide a methodology for adoption in similar studies in other areas.

The data on volumes and grain size of sediment available from cliffs in the area should be available in a form which can be entered into the Environment Agency, Anglian Region shoreline management system. This is a comprehensive geographical information system based on Intergraph software and is an important tool in modelling systems and understanding their behaviour in the coastal zone.

2.1 Data Review

The relatively long length of coastline under investigation, approximately 90 kilometres of cliff, and the variable nature of the sediments in the area meant that a systematic method of investigation had to be adopted.

The initial task undertaken was a review of existing literature, geological and topographical maps and borehole records. The cliffs of this part of Eastern England have been studied by geologists since the middle of the last century. The erosion of many cliffs prior to the erection of defences gave excellent exposure of the geology and this provides a valuable store of historical data. Coverage of modern geological maps is not comprehensive, apart from the area south of Great Yarmouth. This review identified the cliffed coastlines for field inspection and assessment.

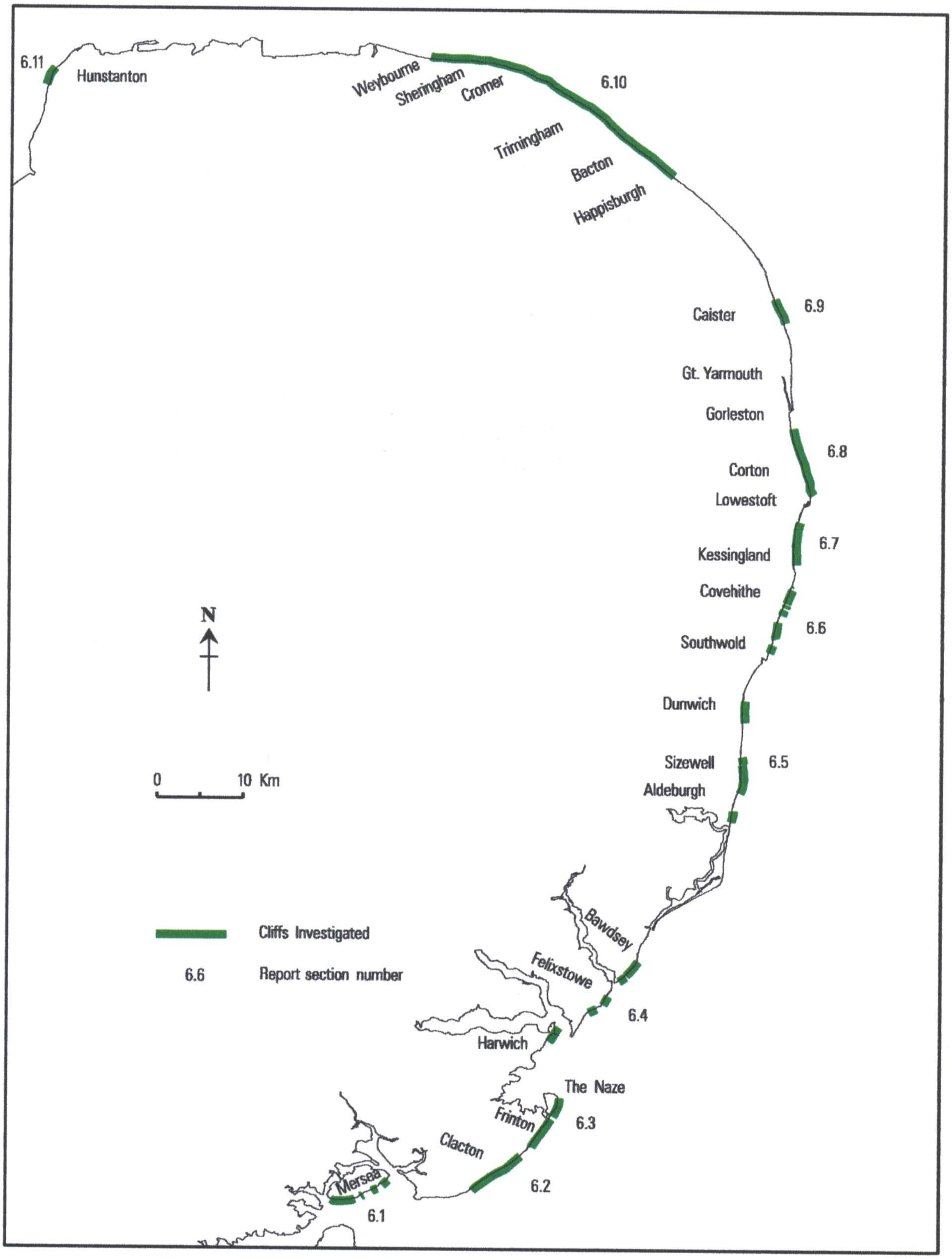


Figure 1 Location of cliffs under investigation

The study is not restricted to undefended cliffs or those with well exposed sediments. Cliffs which are covered by defences, urban development, promenades or vegetation have also been assessed. In these cases the evaluation of sediment character has relied on the review of existing data.

3. FIELD INVESTIGATION

The Environment Agency, have an existing marker system along the coastline within the area. Each marker, normally a metal disc set in the ground, marks the location of beach profile surveys undertaken on a regular basis by the Agency. The markers are located approximately one kilometre apart along the open coastline. The numbering system used by the Agency to designate their markers has been adopted as the primary numbering system for the cliff sections recorded in the sediment study. This has the added advantage of allowing the Agency to associate beach profile surveys with the cliff surveys within their shoreline management system.

During field work the entire length of the cliffs under investigation were walked and assessed. Basic data were collected on a pro-forma for individual cliff sections. The sections for description were chosen on a number of criteria which included :-

- Start and end points of cliff sections
- High and low points in cliff sections
- Environment Agency marker positions
- Quality of sediment exposure in cliff sections
- Changes in lithology and stratigraphy

The frequency of sections was therefore not uniform along the coast, but separation was rarely more than a kilometre and could be less than 100 metres.

3.1 Recording cliff sections

The cliff section pro-forma was designed to provide information for direct entry into a computerised database. The data gathered was designed not only to cover the requirements of this study but also to provide a record for future comparative studies.

The height of the cliff at each section was recorded. Each section was subdivided into vertical intervals based on lithological character with the percentage of mud, sand and gravel recorded for each interval. The percentage recorded was either an estimation based on visual inspection or the result of particle size analysis undertaken on representative samples (see Appendix B). For areas and lithologies where no visual estimation was possible, particle size data was extrapolated from adjacent exposures or data available from reviewed sources. For example, much of the London Clay cliffs in Essex are not exposed and particle size data has been taken from extensive BGS data on the London Clay in south Essex (Grainger, 1972).

Other criteria recorded for the section include, area defended, extent of vegetation cover, areas of mass movement and slope angle. The nature of the cliff top inland for 50 m may also be recorded. This enables future volume calculations to be made on cliff recession up to 50 m from the present cliff line. A short description of the foreshore is also included, this is to complement each photograph of the foreshore taken at each section. It is also valuable in comparing the material in the cliff and the material exposed on the beach.

4. DATA COMPUTATION AND ANALYSIS

The data from each cliff section was entered and manipulated within an ORACLE database on BGS computers. The individual cliff sections are the primary data source. Each cliff section may be sub-divided vertically into intervals based on changes in stratigraphy and lithology. The interval heights and percentage of mud, sand and gravel in each interval are recorded. Each cliff section has been chosen to represent the lithology of the cliff in its locality. The basic information for each recorded cliff section is given in Appendix C and this information is also available in the Environment Agency Shoreline Management System (Figure 1 and 3).

The data required to provide material volume and grain size character for a stretch of cliff are :-

- Length of cliff
- Height of cliff
- Percentage of mud, sand and gravel in cliff material

The depth of the cliff also has to be factored into the volume equation. Because the study is only investigating cliff sediment character and not sediment yield allied to a recession rate for any given cliff, volume estimates are computed on a nominal one metre uniform recession of the whole cliff.

To gain the volume of sediment for a stretch of cliff the following calculations and assumptions are made:-

- The height and percentage of mud, sand and gravel at each cliff section is the primary source of data.

- The distance between cliff sections is calculated within the database and treated as a straight line.

- The geology and lithology of each cliff section is assumed to represent the cliff area for a distance midway to the nearest cliff section. This area is the cliff section zone (Figure 2). Because the distance between cliff sections is variable, a cliff section zone may be split into two unequal sub-zones on either side of a central cliff section. Where cliff sections lie at the end of cliffs, a cliff section zone will only extend along the cliffed side of the section.

- The cliff height at the midway point between cliff sections is calculated within the database. This midway point is also a sub-zone boundary.

- The area of each cliff section's sub-zone is calculated within the database.

- The volume of sediment within each sub-zone reflects the calculated sub-zone area multiplied by a nominal one metre of recession. The volume proportion of mud, sand and gravel within each sub-zone corresponds to the logged proportion of mud, sand and gravel at each central cliff section.

- Sediment volumes for each stretch of cliff between Agency markers are compiled from the sub-zone data within each stretch of cliff.

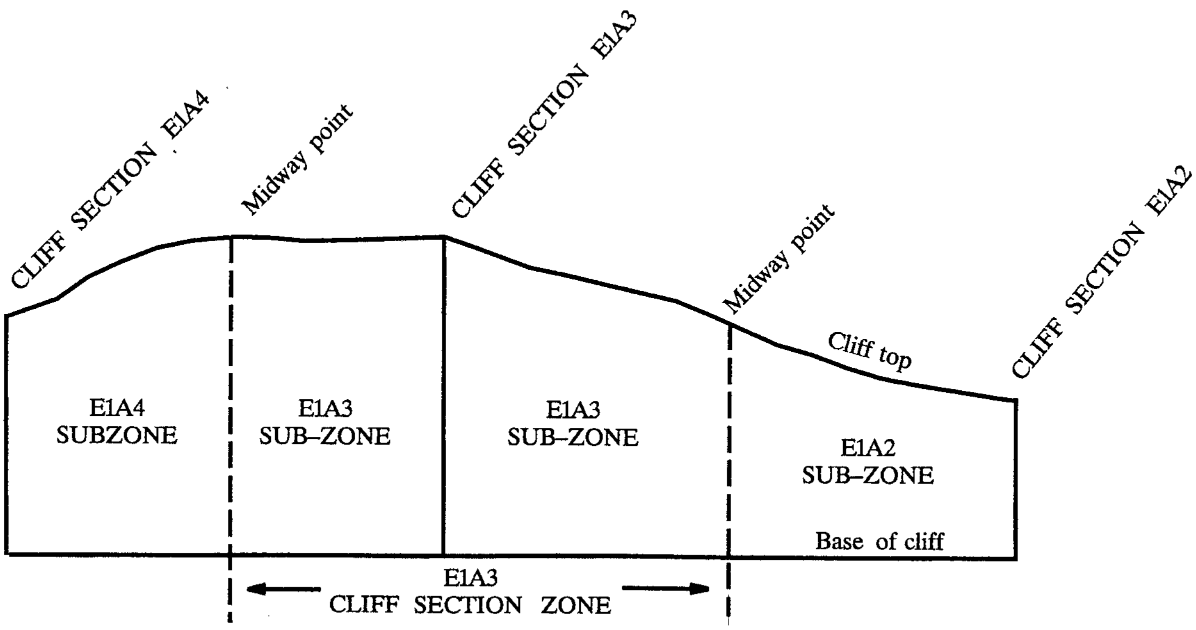


Figure 2 Cliff section zones and sub-zones

5. DATA OUTPUT

The Environment Agency specified that output on volumes and sediment type should cover cliffed areas between Agency markers. The volumes for the cliff section sub-zones within each stretch of cliff are therefore added to give total sediment volume and mud, sand and gravel volume between markers.

The results are presented in two forms, analogue and digital.

5.1 Analogue Data

The analogue data are the graphs and tables which comprise Figures 4 - 18 and also Appendix A. The tables includes volume data which refers to the cliff between the two markers listed on each line. Exceptions occur where :-

a) the same marker number appears twice on the same line. This happens at the end of cliff sections where there is no adjacent marker e.g E2A8 at West Mersea (Figure 4).

b) a marker number may be repositioned in the database at the end of a cliff section rather than at its true position on the ground. This can occur where there is no cliff at the marker number's true position or there is no adjacent marker which can be used e.g. E1D1A at Harwich (Figure 7).

c) in some areas, cliffs may not occupy the whole coastline between markers e.g. Mersea Island and Covehithe.

The XY graphs indicate by histogram the percentage of mud, sand and gravel between each marker, and the line on the graphs denotes the total volume of sediment. The marker numbers on the X axis refer to the first marker number column in the accompanying table.

5.2 Digital Data

The digital data are the graphical elements loaded as an Intergraph design file into the Environment Agency Shoreline Management System and attached database files.

Figure 1 shows in reduced form the loaded graphical elements for the whole study area. Figure 3 is an example of the graphical elements from the Shoreline Management System for the North Norfolk cliffs. The cliffed sections of coast are indicated by lines which vary in colour and thickness according to the volume of sediment computed in the database between the markers displayed. The pie charts indicate the percentage of mud, sand and gravel between each marker, this is the same data as the histograms in Figures 4 - 18.

The limitations on marker position described in b) in the section on analogue data are also applicable to the digital data. Where a stretch of coastline between markers comprises a number of cliff sections separated by flat coast the data shown is the average/total of all the cliff sections between the relevant markers, the individual cliff sections are not distinguished in the computation.

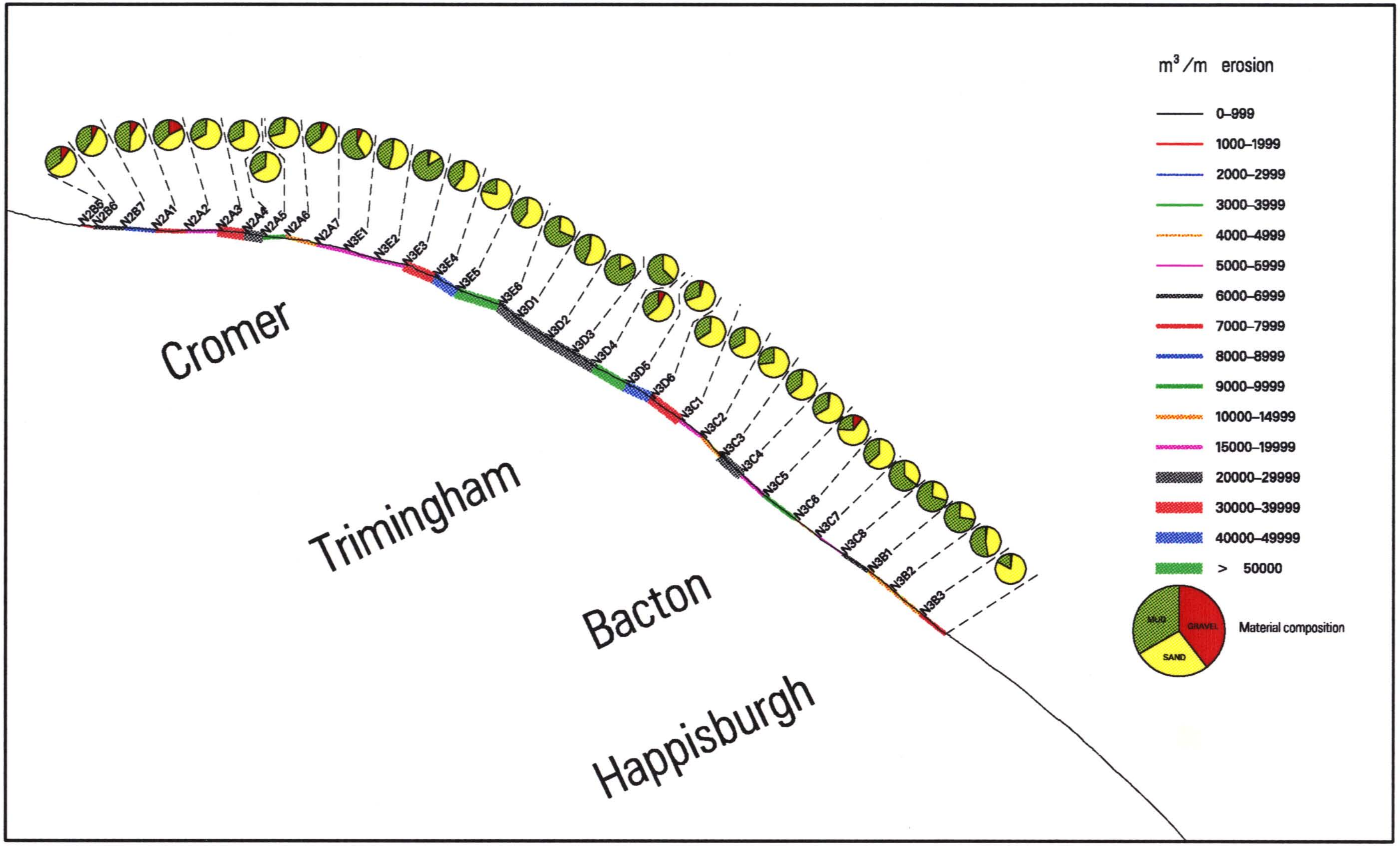


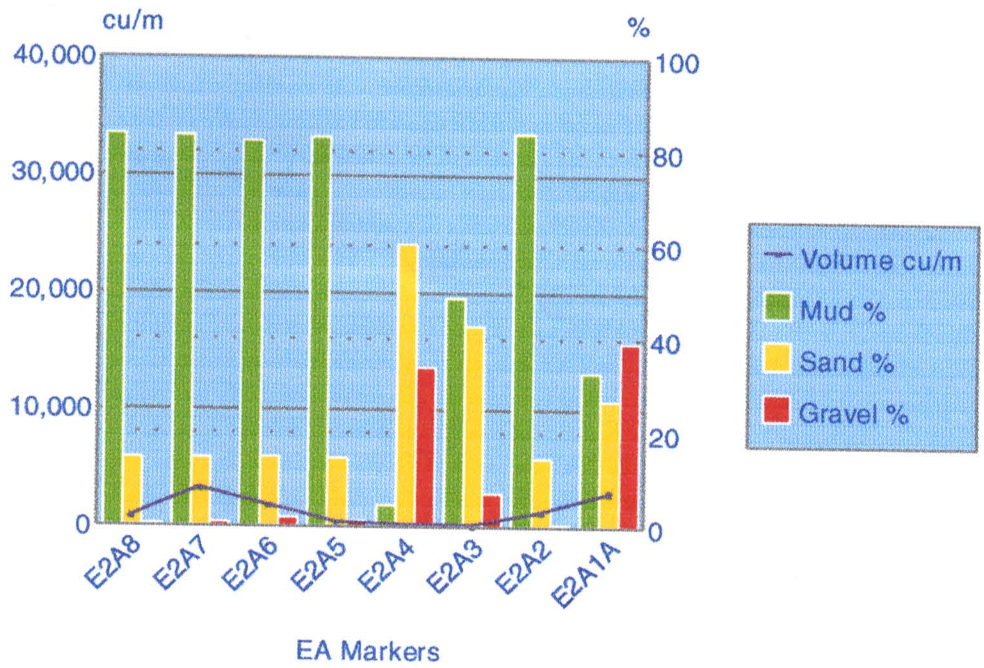
Figure 3. Example of graphical elements entered in the Environment Agency Shoreline Management System

Two database tables are attached to the graphical elements within the Environment Agency Shoreline Management System.

The first is a Summary Data Table whose structure is the same as the tables in Figures 4 - 18, the only difference is the omission of the Location field from the Summary Data Table. The second is a Cliff Section Table. The data from this table is given in Appendix A. It consists of the data from each logged cliff section, principally the location, cliff height, stratigraphy and percentage of mud, sand and gravel.

6. CLIFFS AND SEDIMENT

6.1 Mersea Island



LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
WEST MERSEA	E2A8	E2A8	84.0	751	15.0	134	1.0	9	894
WEST MERSEA	E2A7	E2A8	83.7	2795	15.0	501	1.3	43	3339
WEST MERSEA	E2A6	E2A7	82.5	1573	15.2	290	2.3	43	1906
WEST MERSEA	E2A5	E2A6	83.4	405	15.0	73	1.6	8	486
EAST MERSEA	E2A4	E2A5	5.0	13	60.7	158	34.3	89	260
EAST MERSEA	E2A3	E2A4	49.2	108	43.2	95	7.6	17	220
EAST MERSEA	E2A2	E2A3	84.1	1148	15.0	205	0.9	12	1364
EAST MERSEA	E2A1A	E2A2	33.3	1003	27.1	816	39.6	1192	3011
AVERAGE/TOTAL			**63.2**	**7797**	**25.8**	**2271**	**11.1**	**1412**	**11480**

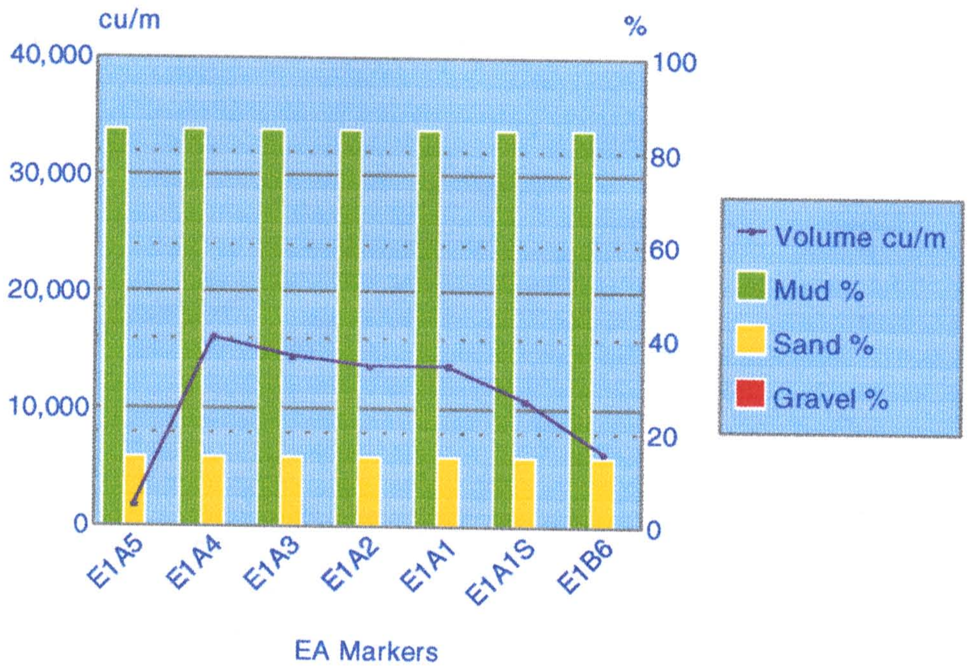
Figure 4. Mersea Island : Cliff sediment and volume data (m^3 per m recession)

Mersea Island (Figure 1) lies in eastern Essex between the mouths of the River Colne and the Blackwater. The island is under 8 kms long and is elongate in a roughly east-west direction. It has a fragmented series of cliffs along its south facing coast with the most prominent forms at either end of the island.

The island is formed of London Clay with sporadic cover of Pleistocene gravels and sands and some Brickearth. The cliffs at West Mersea between E2A5 and E2A8 rise to a maximum height of 6.8 m and comprise London Clay with possibly some thin Brickearth. The London Clay is not well exposed and the particle size distribution of 85% mud and 15% sand given for the London Clay in the database is a default figure averaged from Grainger (1972). This default PSD figure has been used for all London Clay cliffs included in this study.

A few low cliffs of 1 m to 3 m in height occur within the central part of the island. The lower cliffs can include significant Brickearth which accounts for the higher proportions of sand and gravel. The cliffs at East Mersea exposed between E2A1A and E2A2 consist of London Clay at the western end where it reaches a maximum height of 4.8 m. To the east the London Clay dips down beneath the base of the cliff and the whole eastern end of the cliff section comprises up to 5 m of Pleistocene sand and gravel.

6.2 Clacton on Sea - Holland on Sea

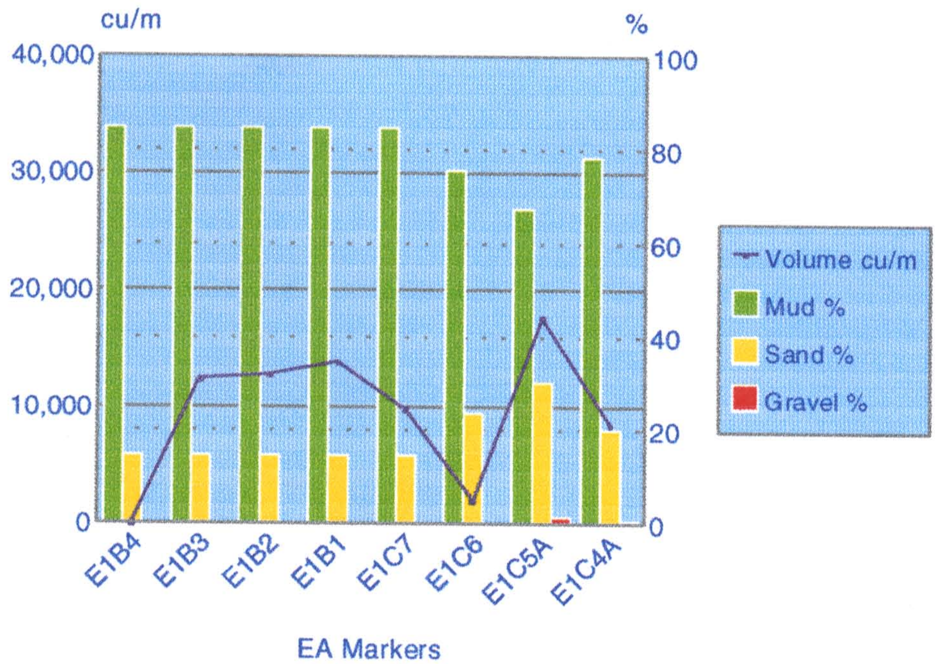


LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
CLACTON ON SEA	E1A5	E1A6	85.0	1551	15.0	274	0.0	0	1825
CLACTON ON SEA	E1A4	E1A5	85.0	13712	15.0	2420	0.0	0	16132
CLACTON ON SEA	E1A3	E1A4	85.0	12353	15.0	2180	0.0	0	14533
CLACTON ON SEA	E1A2	E1A3	85.0	11636	15.0	2053	0.0	0	13689
HOLLAND ON SEA	E1A1	E1A2	85.0	11661	15.0	2058	0.0	0	13718
HOLLAND ON SEA	E1A1S	E1A1	85.0	9144	15.0	1614	0.0	0	10757
HOLLAND ON SEA	E1B6	E1A1S	85.0	5375	15.0	949	0.0	0	6324
AVERAGE/TOTAL			**85.0**	**65431**	**15.0**	**11547**	**0.0**	**0**	**76978**

Figure 5. Clacton on Sea - Holland on Sea : Cliff sediment and volume data (m^3 per m recession)

There is little or no exposure of sediment or rock along the cliffs on this coast (Figure 1). The cliffs are interpreted as consisting of London Clay. There is virtually a continuous cliff section for about 7 kms which, for much of its length, has a planar top at a height of 12 m to 15 m. At the cliff ends, the tops decline at an angle to sea level. A default value has been taken for the particle size determination of the London Clay. The common PSD and the relatively high cliffs have given a consistent value to the volumes of sediment associated with these cliffs, with a very high proportion of mud.

6.3 Frinton on Sea - The Naze



LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
FRINTON ON SEA	E1B4	E1B5A	85.0	64	15.0	11	0.0	0	75
FRINTON ON SEA	E1B3	E1B4	85.0	10596	15.0	1870	0.0	0	12466
FRINTON ON SEA	E1B2	E1B3	85.0	10871	15.0	1918	0.0	0	12789
WALTON ON THE NAZE	E1B1	E1B2	85.0	11813	15.0	2085	0.0	0	13898
WALTON ON THE NAZE	E1C7	E1B1	85.0	8368	15.0	1477	0.0	0	9844
WALTON ON THE NAZE	E1C6	E1C7	75.9	1558	24.1	495	0.0	0	2053
THE NAZE	E1C5A	E1C6	67.8	11965	30.5	5379	1.7	307	17651
THE NAZE	E1C4A	E1C5A	78.6	6680	20.5	1740	0.9	81	8501
AVERAGE/TOTAL			**80.9**	**61914**	**18.8**	**14975**	**0.3**	**388**	**77277**

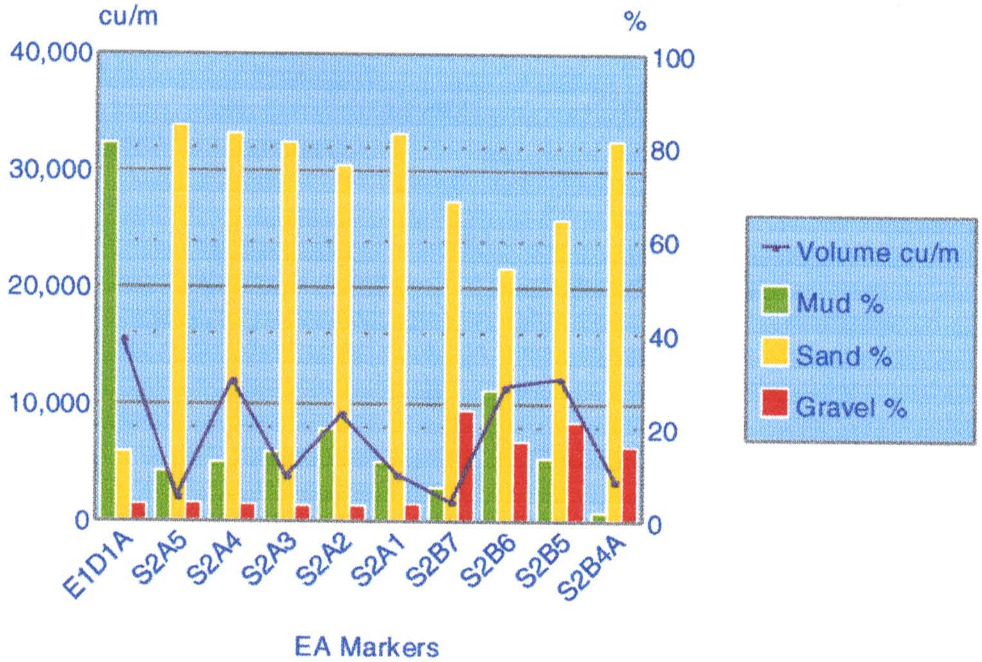
Figure 6. Frinton on Sea - The Naze : Cliff sediment and volume data (m^3 per m recession)

This coastline has two areas of cliff (Figure1). The longest, which stretches for four kilometres in front of Frinton on Sea to the southern part of Walton on the Naze, is underlain by London Clay. It has a maximum height of 20 m and its top varies to about 12 m in height. The cliff stretches from marker E1B4 to E1C6. The low volume of sediment, 75 m^3, at E1B4 is due to the fact that the marker is virtually at the end of the cliff and the stretch to E1B5A is low ground not cliff.

The second area includes the high ground of The Naze, a promontory based on London Clay which is over 2 kms long and backed by extensive salt marsh around Walton Channel and Hamford Water. The Naze is a prominent hill with cliffs up to 23 m high at its maximum. The high point is about 800 m wide and the cliffs descend to sea level on either side.

Although the bulk of the cliffs comprise London Clay there is a significant exposure of Red Crag, Pleistocene sandy gravels and silts, and Brickearth overlying the London Clay. In the highest sections of the cliff these sequences of sand, gravel and silt can be over 5 m thick. The Red Crag, which can contain considerable shelly material, is only exposed in the high cliffs and is pinched out as the cliff descends. However, about a metre of the sandy Brickearth continues to overlie the London Clay across most of the cliff section.

6.4 Harwich - Bawdsey



LOCATION	MARKER NUMBERS		MUD %	m³	SAND %	m³	GRAV %	m³	TOTAL m³
HARWICH	E1D1A	E1D2	81.1	12596	15.0	2330	3.9	606	15531
FELIXSTOWE	S2A5	S2A6	11.0	234	84.8	1808	4.2	89	2131
FELIXSTOWE	S2A4	S2A5	12.8	1543	83.4	10054	3.8	463	12060
FELIXSTOWE	S2A3	S2A4	15.0	576	81.3	3121	3.7	143	3840
FELIXSTOWE	S2A2	S2A3	20.0	1830	76.5	7007	3.5	319	9156
FELIXSTOWE	S2A1	S2A2	12.8	516	83.4	3359	3.8	155	4029
AVERAGE/TOTAL			**14.3**	**4699**	**81.9**	**25349**	**3.8**	**1168**	**31217**
BAWDSEY	S2B7	S2A1	7.5	125	68.6	1146	23.9	398	1669
BAWDSEY	S2B6	S2B7	28.4	3271	54.4	6267	17.2	1980	11517
BAWDSEY	S2B5	S2B6	13.7	1669	64.9	7919	21.4	2614	12202
BAWDSEY	S2B4A	S2B5	2.1	73	81.6	2838	16.3	565	3476
AVERAGE/TOTAL			**12.9**	**5137**	**67.4**	**18170**	**19.7**	**4992**	**28864**

Figure 7. Harwich - Bawdsey : Cliff sediment and volume data (m^3 per m recession)

Three stretches of cliff are aligned along this coastline at Harwich, Felixstowe and Bawdsey (Figure 1). They are separated by the converging estuaries of the Stour and Orwell rivers at Harwich and Felixstowe and the River Deben at Bawdsey.

Harwich marks the northern limit of cliffs which are dominated by the muddy sequences of the London Clay. Although London Clay is exposed in the cliffs further north at Felixstowe and Bawdsey it is a subordinate component of the cliff sequences. A variation in the London Clay at Harwich is the presence of a stoneband, 20 - 30 cms thick, of volcanic ash and this accounts for the minor gravel component in the sediment from these 2 kms of cliff. Red Crag also caps the hill on which Harwich is situated.

The cliff at Felixstowe comprises a two-fold sequence of sandy Red Crag up to 15 m thick on London Clay which is generally less than 3 m in thickness. The cliffs contain over 75% sand. About 4 kms of cliff front the coast with a maximum height of about 17 m, although cliff elevation is variable with heights down to 2.5 m. At its southern end the cliff swings inland away from the coast.

The two-fold succession of Red Crag on London Clay continues at the cliff section at Bawdsey. The stretch of cliff covers over 3 kms of coast with a maximum height of over 16 m in the southern half. The Red Crag is the dominant sequence with over 13 m in some areas, the London Clay is generally less than 3 m thick, although it has been noted to over 6 m. The cliff at Bawdsey is the most northerly exposure of London Clay on the East Anglian coast. The Red Crag has a significant gravel and shell component, varying from 25% - 30%.

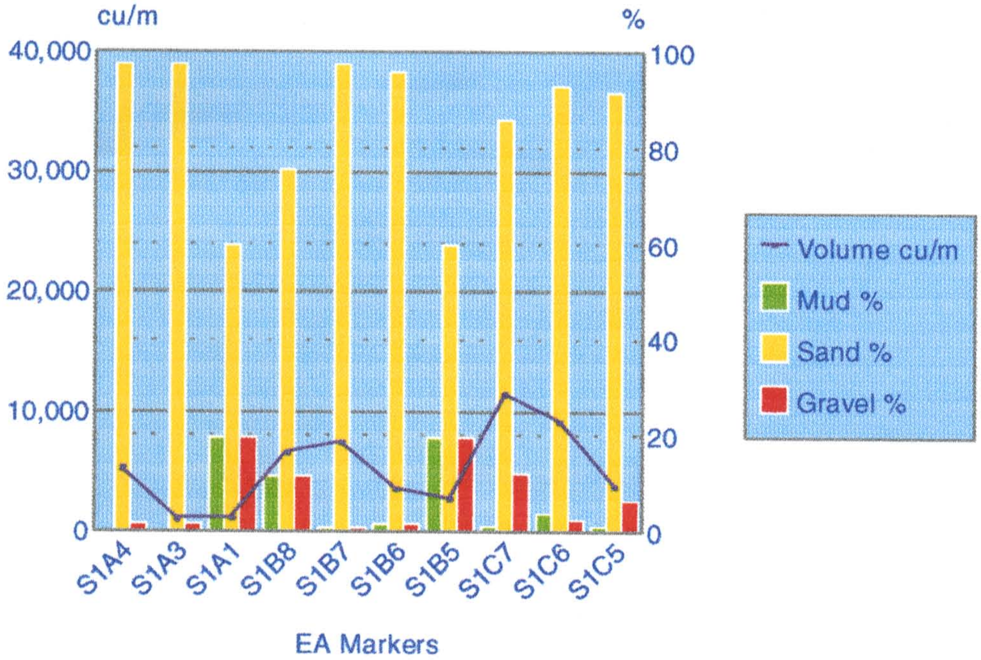
6.5 Aldeburgh - Dunwich

This section of coast which has three cliffed areas at Aldeburgh, Sizewell and Dunwich (Figure 1) is characterised by the onset of younger sediments of the Norwich Crag Formation.

The short cliff, 1250 m long, at Aldeburgh lies at the northern end of Orford Ness where the River Alde reaches the coast. It has a maximum height of about 10 m, and is dominantly a sandy sequence, >97%, commonly shelly, with Norwich Crag overlying Coralline Crag, although the break between the two formations is not visible in the cliff.

The Sizewell section of cliff runs from Thorpeness in the south to Sizewell Power Station along a stretch of coast which is over 4 kms long. The cliffs are variable in height from less than 2 m to over 9 m. At Thorpeness the cliffs are dominated by a sandy glacial Till with a large, 20% each, component of gravel and mud. Sandy Red Crag may also occur in the cliff at Thorpeness beneath the Till. The next 2 kms north to Sizewell are characterised by cliffs of Chillesford Sands, a member of the Norwich Crag, mud and gravel are negligible, around 2% in total.

At Sizewell there is a short gap in the cliff about 150 m long. To the north of this gap in front of Sizewell Power Station, the 750 m stretch of coast is backed by a cliff of presumed made ground up to 5 m high. The composition of the made ground is indeterminate and the figures given for sediment composition are therefore an estimate. This covers the area around markers S1B5 to S1B6.



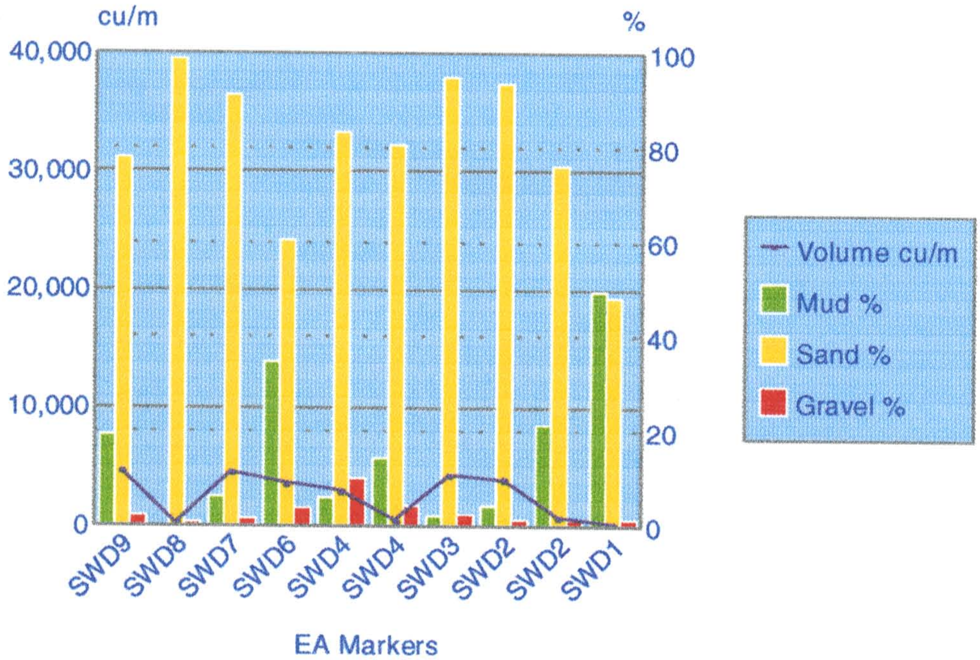
LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
ALDEBURGH	S1A4	S1A5	0.2	11	97.8	5193	2.0	104	5308
ALDEBURGH	S1A3	S1A4	0.2	2	97.8	1156	2.0	23	1182
AVERAGE/TOTAL			**0.2**	**13**	**97.8**	**6349**	**2.0**	**128**	**6490**
SIZEWELL	S1A1	S1A2	20.0	243	60.0	730	20.0	243	1217
SIZEWELL	S1B8	S1A1	12.0	806	75.9	5079	12.0	806	6691
SIZEWELL	S1B7	S1B8	1.1	82	97.8	7355	1.1	85	7522
SIZEWELL	S1B6	S1B7	1.9	69	96.0	3521	2.1	78	3668
SIZEWELL	S1B5	S1B6	20.0	571	60.0	1713	20.0	571	2854
AVERAGE/TOTAL			**11.0**	**1772**	**77.9**	**18398**	**11.1**	**1783**	**21952**
DUNWICH	S1C7	S1B1	1.5	168	86.1	9934	12.4	1425	11527
DUNWICH	S1C6	S1C7	4.1	380	93.1	8583	2.8	259	9222
DUNWICH	S1C5	S1C6	1.4	55	91.7	3563	6.9	267	3885
AVERAGE/TOTAL			**2.3**	**603**	**90.3**	**22080**	**7.3**	**1951**	**24634**

Figure 8. Aldeburgh - Dunwich : Cliff sediment and volume data (m^3 per m recession)

The cliffs at Dunwich are a well exposed sequence of predominantly Norwich Crag sediments. The cliffs are about 3 kms long and are backed by high ground between Minsmere Level to the south and Dingle Marsh to the north.

They range in height from less than 5 m to over 11 m. Sands dominate the sequence but there are significant areas where gravels can be up to 60% of the sediment. Although muds are generally a very minor component there are some areas of glauconitic sand within the Norwich Crag with up to 15% mud.

6.6 Southwold - Covehithe



LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
SOUTHWOLD	SWD9	SWD10	19.6	912	78.0	3635	2.4	113	4661
SOUTHWOLD	SWD8	SWD9	0.0	0	99.0	227	1.0	2	229
SOUTHWOLD	SWD7	SWD8	6.5	297	91.5	4174	2.0	89	4559
SOUTHWOLD	SWD6	SWD7	35.1	1278	60.9	2221	4.0	146	3646
AVERAGE/TOTAL			**15.3**	**2487**	**82.4**	**10257**	**2.3**	**351**	**13095**
COVEHITHE	SWD4	SWD5	6.1	308	83.5	2486	10.4	183	2977
COVEHITHE	SWD4	SWD4	14.6	74	80.9	407	4.5	23	503
COVEHITHE	SWD3	SWD4	2.3	99	95.1	4142	2.6	114	4355
COVEHITHE	SWD2	SWD3	4.7	185	93.8	3695	1.5	58	3938
COVEHITHE	SWD2	SWD2	21.8	165	76.5	582	1.7	13	760
COVEHITHE	SWD1	SWD2	49.8	113	48.6	111	1.6	4	227
AVERAGE/TOTAL			**16.6**	**945**	**80.9**	**11422**	**3.1**	**394**	**12760**

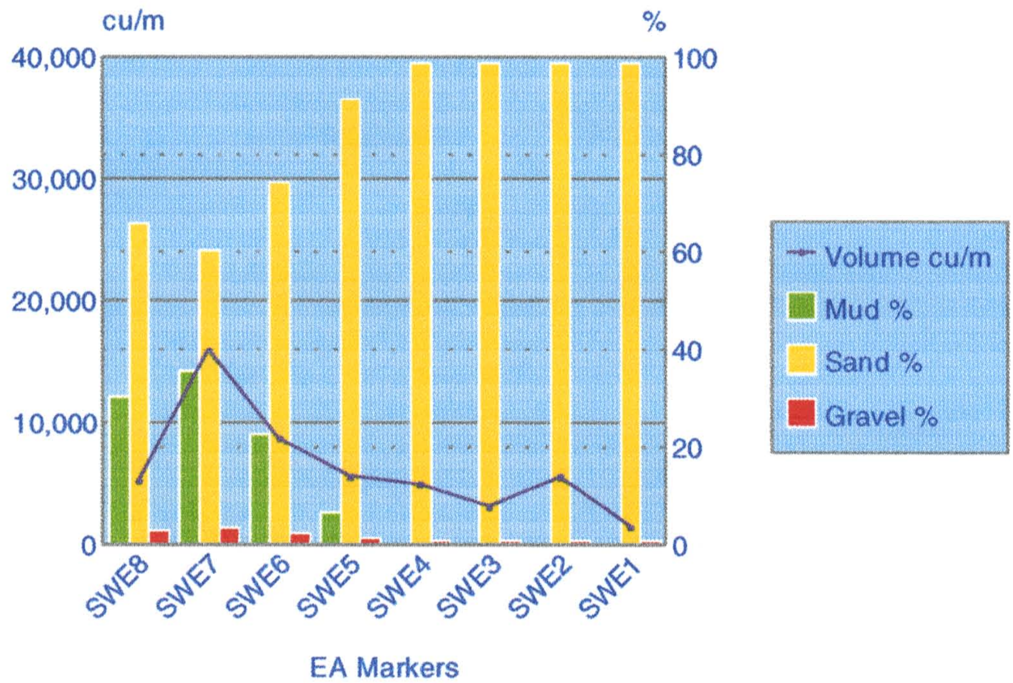
Figure 9. Southwold - Covehithe : Cliff sediment and volume data (m^3 per m recession)

This area of Suffolk includes three stretches of cliff at Southwold, Easton Bavents and Covehithe (Figure 1). The cliff at Southwold lies to the north of the River Blyth and is about a kilometre long and includes the area between the SWD8 and SWD10 markers. It ranges in height from 3 m to over 8 m. It appears to be lithologically variable with both very sandy sequences of Norwich Crag and very muddy sediments of Lowestoft Till with over 80% mud dominating various parts of a relatively short cliff. It should be noted the exposure of sediment at the cliff is poor.

North of the cliff at Southwold there is a short gap of low ground, 700 m wide, across Easton Marshes to the cliffs at Easton Bavents. These cliffs are about 2 kms long and contain a varied sequence of Norwich Crag sediments including Westleton Beds sand and gravel, clay with sand laminae of the Easton Bavents Clay underlain by sand and silt. These give a distinctive proportion of mud in the sediments exposed between markers SWD6 and SWD8 where the cliff range in height from 4 m to greater than 6 m.

The cliffs at Covehithe start a kilometre north of the cliffs at Easton Bavents. They stretch for almost 4 kms in a linear north-easterly direction. There are three sections of cliff with the central section about 2 kms long and the other end sections, 600 m and 250 m in length. The cliffs range in height from 3 m to over 6 m. As at Easton Bavents the cliffs consist of a varied sequence of Norwich Crag sediments which, although dominantly sandy in the long central section cliff, do show a notable gravel component, 10%, in the southern cliff around SWD4 to SWD5 and significant mud, up to 50%, in the northern cliff at SWD1 to SWD2.

6.7 Kessingland - Lowestoft

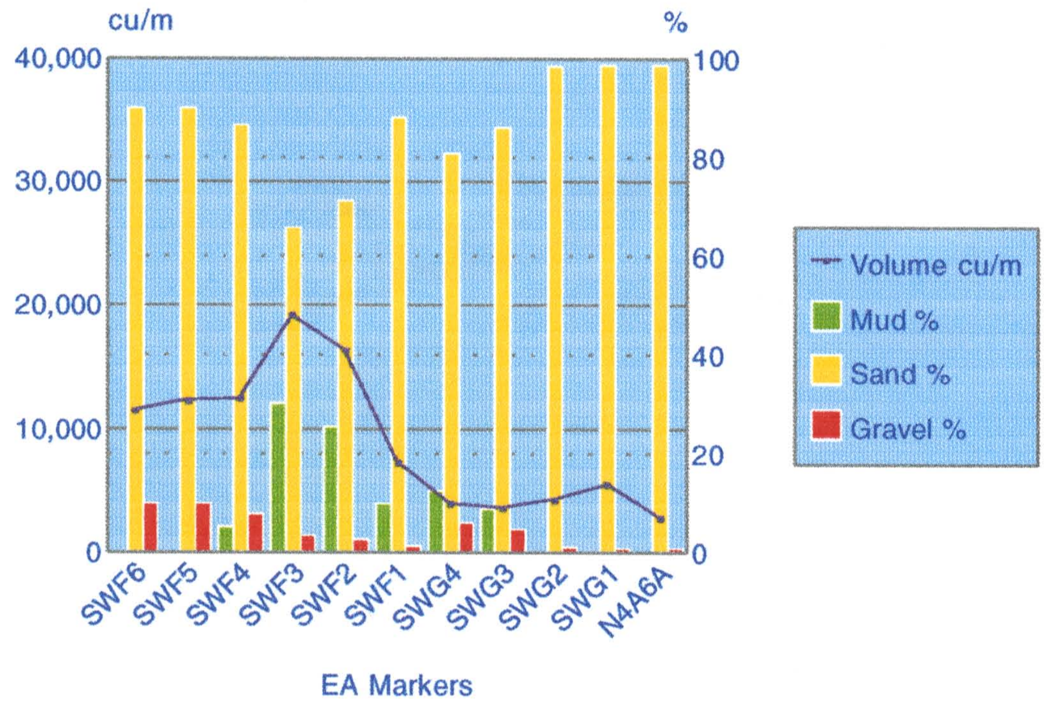


LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
KESSINGLAND	SWE8	SWE9	30.5	1611	66.2	3503	3.3	172	5286
KESSINGLAND	SWE7	SWE8	35.8	5738	60.6	9687	3.6	581	16006
KESSINGLAND	SWE6	SWE7	22.8	1995	74.6	6510	2.6	231	8735
LOWESTOFT	SWE5	SWE6	6.9	387	91.7	5166	1.5	82	5635
LOWESTOFT	SWE4	SWE5	0.0	0	99.0	4951	1.0	50	5001
LOWESTOFT	SWE3	SWE4	0.0	0	99.0	3087	1.0	31	3119
LOWESTOFT	SWE2	SWE3	0.0	0	99.0	5557	1.0	56	5613
LOWESTOFT	SWE1	SWE2	0.0	0	99.0	1478	1.0	15	1493
AVERAGE/TOTAL			**12.0**	**9730**	**86.1**	**39939**	**1.9**	**1218**	**50887**

Figure 10. Kessingland - Lowestoft : Cliff sediment and volume data (m^3 per m recession)

The 6 kms of cliff between Kessingland and Lowestoft (Figure 1) become dominantly sandy northwards. The southern half of cliff up to marker SWE6 has a significant thickness of Lowestoft Till lying on Corton Formation sands. The till has over 80% mud and also some subordinate gravel and this accounts for the significant proportion of mud in this southern area. The Lowestoft Till is missing from the cliff north of SWE6 and Corton Formation sands dominate to the end of the cliff near SWE1 at Lowestoft. However, about 2 to 3 m of silty sand within the Cromer Forest Bed Formation underlies the Corton Formation sands around SWE5. Along the whole section from Kessingland to Lowestoft cliff height varies from less than 4 m to a maximum of approximately 14 m.

6.8 Corton - Gorleston on Sea



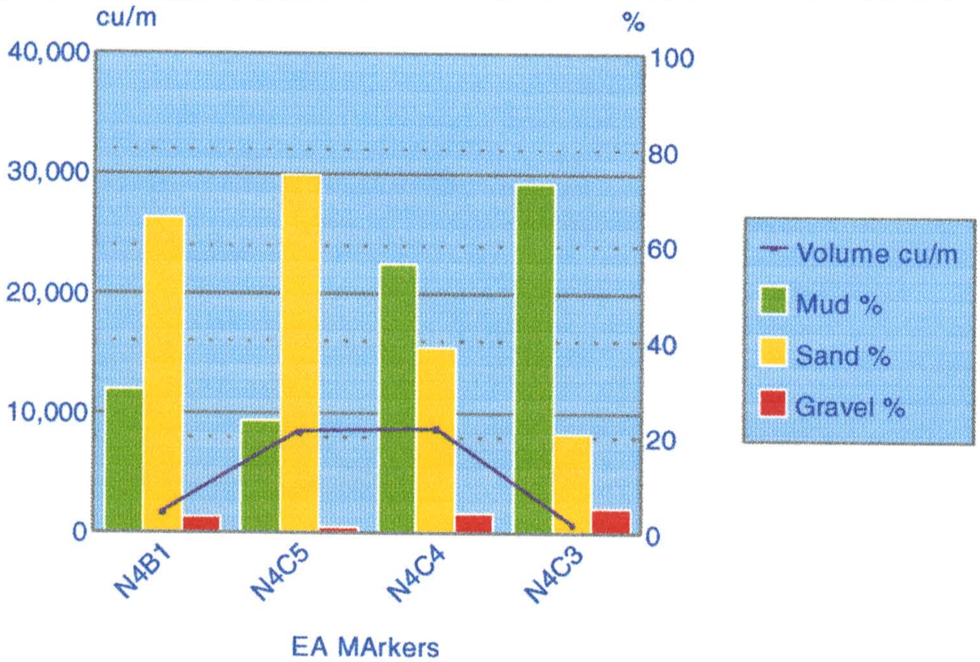
LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
CORTON-GORLESTON	SWF6	SWF7	0.0	0	90.0	10362	10.0	1151	11514
CORTON-GORLESTON	SWF5	SWF6	0.0	0	90.0	11083	10.0	1231	12315
CORTON-GORLESTON	SWF4	SWF5	5.3	657	86.8	10849	7.9	983	12490
CORTON-GORLESTON	SWF3	SWF4	30.4	5847	66.0	12710	3.6	689	19246
CORTON-GORLESTON	SWF2	SWF3	25.8	4235	71.3	11687	2.9	475	16397
CORTON-GORLESTON	SWF1	SWF2	10.2	753	88.2	6479	1.6	115	7346
CORTON-GORLESTON	SWG4	SWF1	12.7	502	81.1	3209	6.2	246	3957
CORTON-GORLESTON	SWG3	SWG4	9.0	326	86.2	3119	4.8	175	3620
CORTON-GORLESTON	SWG2	SWG3	0.0	0	98.8	4260	1.2	52	4312
CORTON-GORLESTON	SWG1	SWG2	0.0	0	99.0	5461	1.0	55	5516
CORTON-GORLESTON	N4A6A	SWG1	0.0	0	99.0	2789	1.0	28	2817
AVERAGE/TOTAL			**8.5**	**12320**	**86.9**	**82009**	**4.6**	**5201**	**99530**

Figure 11. Corton - Gorleston on Sea : Cliff sediment and volume data (m^3 per m recession)

The Corton to Gorleston section begins within the northern part of Lowestoft near Ness Point, the most easterly point of the British Isles (Figure 1). The total length of the section is over 10 kms from south of marker SWF7 to the Suffolk side of the river mouth at Gorleston below marker N4A6A. The highest cliffs are in the southern half of the section between Corton and Lowestoft, here they reach a maximum of over 22 m and generally exceed 15 m with few areas below 10 m in height. North of Corton the cliffs are less than 8 m high, some sections reach just over 3 m. The difference in total volume of sediment along the cliff mirrors the gross changes in cliff height.

Corton Formation and Corton Woods Formation sediments dominate the whole cliff sequence. The higher proportion of gravel, up to 10%, in the Lowestoft area between SWF4 and SWF7 is due to the slightly gravelly facies within the sand of the Corton Woods Formation. The cliffs at Corton and to the north as far as SWG3 include sequences of Lowestoft Till and Pleasure Gardens Till between the Corton Woods Formation and the underlying Corton Formation. These tills contain over 80% mud and account for the relatively high fraction, up to 30%, of mud within this stretch of cliff. North of marker SWG3 the cliff reverts to Corton Formation sands.

6.9 Caister on Sea



LOCATION	MARKER NUMBERS		MUD %	m³	SAND %	m³	GRAV %	m³	TOTAL m³
CAISTER	N4B1	N4B2	30.1	531	66.2	1166	3.7	65	1762
CAISTER	N4C5	N4B1	23.6	2004	75.0	6364	1.4	118	8486
CAISTER	N4C4	N4C5	56.5	4949	39.0	3419	4.5	392	8760
CAISTER	N4C3	N4C4	73.4	591	21.0	169	5.6	45	805
AVERAGE/TOTAL			**45.9**	**8075**	**50.3**	**11117**	**3.8**	**620**	**19813**

Figure 12. Caister on Sea : Cliff sediment and volume data (m^3 per m recession)

Caister on Sea lies north of Great Yarmouth (Figure 1) and the cliff section runs from the northern end of the village, near marker N4B2, for 3 kms to the village of Scratby just north of marker N4C4. Cliff height is generally 8 to 9 m, although it is below 5 m at the southern end.

Sands dominate the cliff at and south of N4C5 at California, although up to 30% of the sediment is mud. The sequence in this southern area comprises Corton Sands interbedded with a sandy Corton Till, which contains a high proportion of mud. North of California, the Lowestoft Till, which contains over 80% mud, overlies the Corton Formation sands with increasing thickness, producing a mud dominated cliff in the northern half of this section.

6.10 North Norfolk : Happisburgh - Weybourne

The North Norfolk cliffs stretch for about 34 kms from Happisburgh (marker N3B3) in the northeast around to Weybourne (marker N2B5) in the centre of the north coast (Figure 1 & 3). The sediment and volume data for the cliffs are illustrated in Figures 13 to 17. It should be noted that the large volume of material in the high cliffs at Trimingham and Cromer, necessitated a change in maximum value for the Y volume axis in Figures 14 and 15 to 80,000 m^3 from the standard maximum of 40,000 m^3 used for all the other XY graphs in the report.

This coast contains the highest stretches of cliff in the report area reaching over 60 m in height around Trimingham and Cromer. The cliffs commonly exceed 15 m in height for considerable lengths, with many long stretches over 25 m. Areas of less than 10 m in height are concentrated at either end of the section around Happisburgh, Ostend and Weybourne. This collection of high cliffs produces the largest sediment volume figures in the report area, for example, >72,000 m^3 between N3D4 and N3D5 at Trimingham.

The sediments are predominantly Pleistocene glacial sediments. They are a complex sequence of till, diamict, silt, sand and gravel. Their mode of formation is a matter of debate with evidence invoked for terrestrial, lacustrine and marine sedimentation within a glacial environment. Stratigraphically this has lead to a heterogeneous mixture of sediments with lateral and vertical discontinuities common. Included in some stretches of cliff are peat and organic deposits of the Cromer Forest Beds and significant exposures of chalk, either as rafted blocks emplaced by moving ice or in-situ outcrops.

Because of the complexity of the whole cliff section no attempt has been made to sub-divide the section on a stratigraphical basis. The section has therefore been broken into five sections for convenience of display in Figures 13 to 17. Sand and mud are the dominant sediment with with gravel very subordinate over large areas.

Happisburgh at the southern end of the section has a high proportion, 80%, of sand in the cliffs around N3B3 associated with Mundesley Sands and a sandy Happisburgh Diamicton. North of N3B3 to N3C7 very muddy Happisburgh Diamicton and Happisburgh Clay become dominant and the amount of mud in the Mundesley Sands increases. The percentage of mud between these markers increases to over 70%.

From marker N3C6 at Bacton, where the cliffs are relatively low at about 5m in height, sand becomes dominant northwards to the very high cliffs around N3D4 at Trimingham. Along this section sand is almost consistently over 60%, not only because of the preponderance of sands but also the sandy nature of the diamictons in the cliffs. The slight increase in gravel at N3D4 and N3D5 is due to the occurrence of gravelly Maycroft Sands. Chalk was noted in the cliffs around N3D6.

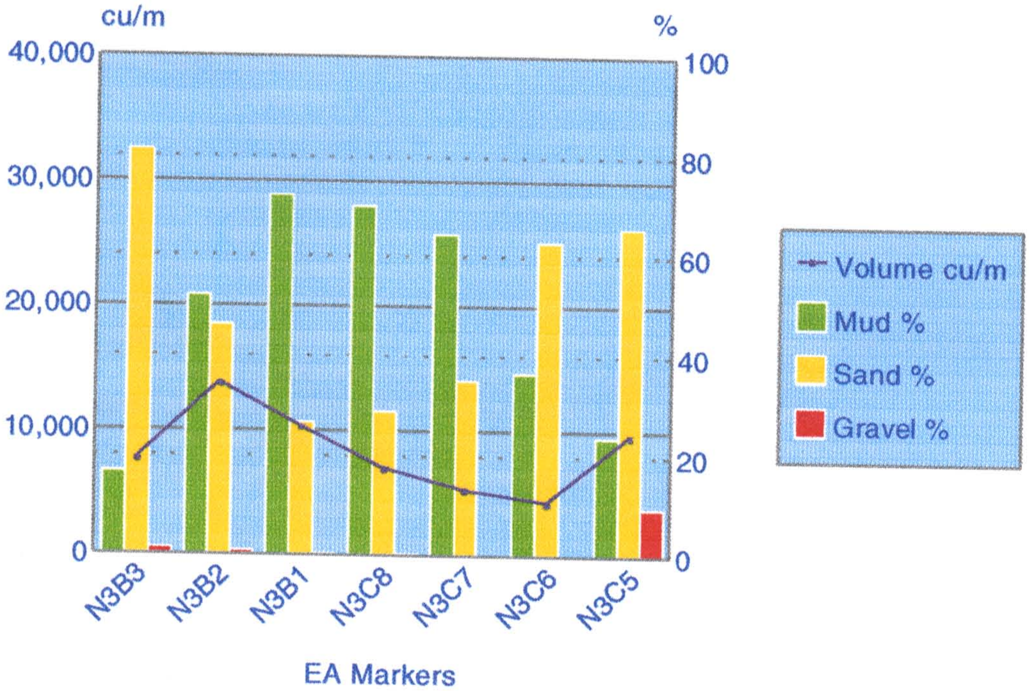
Continuing north to N3E6 at Overstrand the cliffs revert to mud domination mainly because of the occurrence of thick sequences of Happisburgh Clay and Trimingham Clays, although the mud influence is broken around N3D1 because of the occurrence of sandy Laminated Fines.

The high cliffs at Cromer from N3E5 to N3E3 contain 60% to 80% sand. The diamictons in the area are generally sandy in nature and there are thick sequences of Trimingham Sands. To the north of Cromer at N3E2 the diamictons become very clayey with over 80% of the succession comprised of mud.

Diamictons continue within the cliffs at Runton, some of which are particularly sandy, also sand and gravel becomes more common. Thin occurrences of Cromer Forest Bed organics up to 1.2 m thick occur around N2A7 and N2A6. These are likely to provide very little inorganic material as eroded sediment.

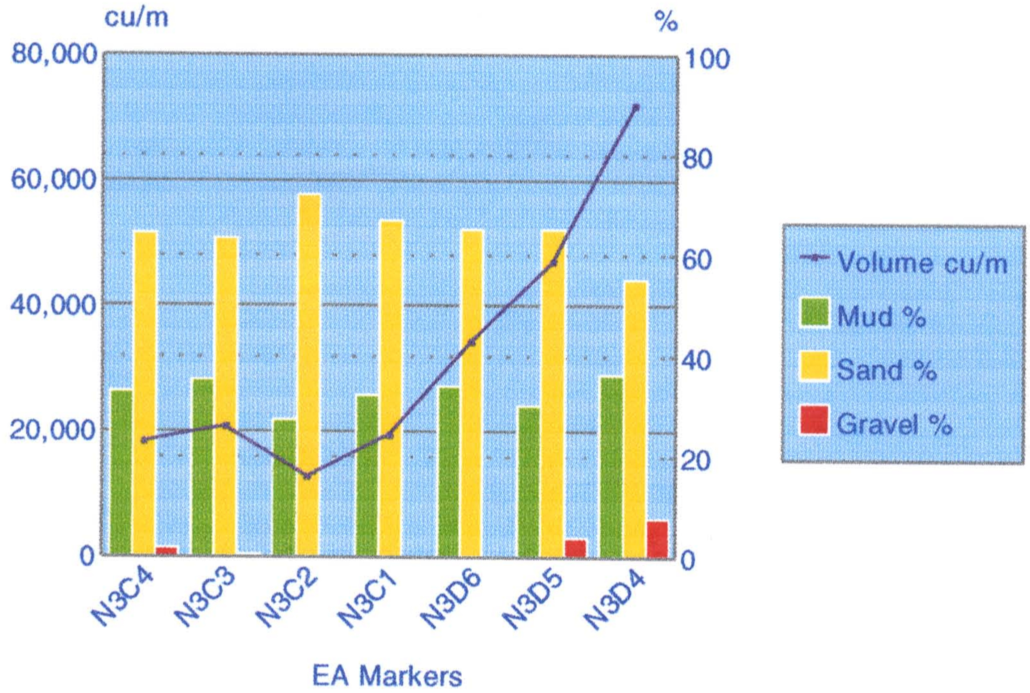
The Runton to Sherringham section, N2A6 to N2A2, is dominated by sandy diamictons with over 60% of the cliffs consisting of sand. Chalk up to 6 m thick was noted around N2A5.

The end section of cliffs from N2A1 at Sheringham to N2B5 at Weybourne has the highest proportion of gravel in the North Norfolk cliffs ranging from 7% to 17% with sand at 40% to 50%. The increase in gravel content is due to the occurrence of PreGlacial Deposits. Chalk outcrops at the base of the cliffs along this section of coast and can be up to 2..5 m thick.



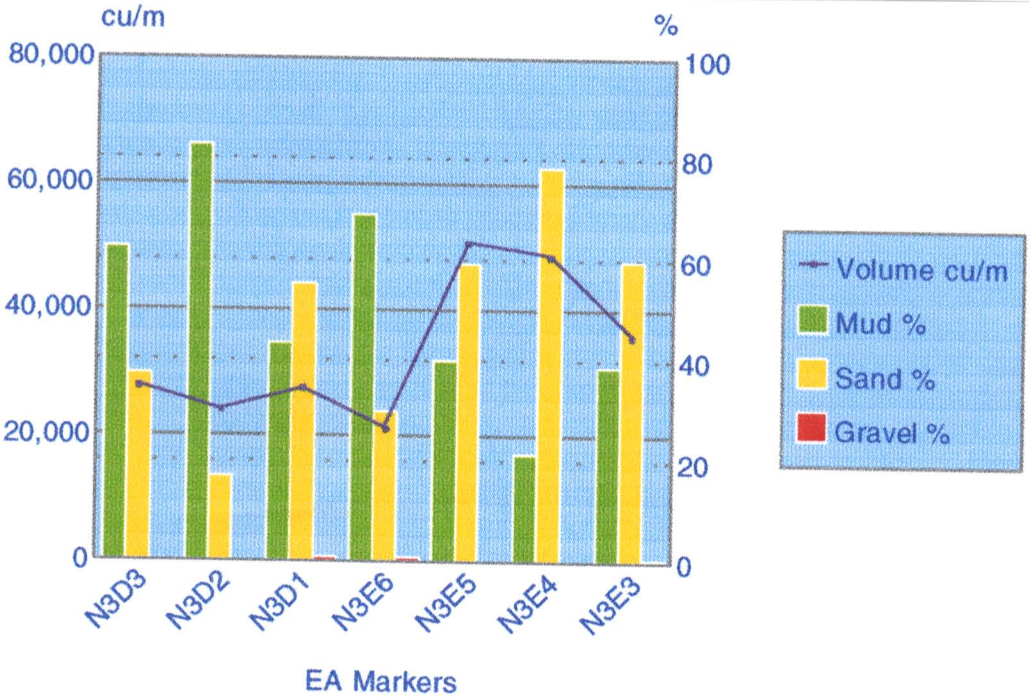
LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
HAPPISBURGH	N3B3	N3B4	16.9	1297	81.4	6242	1.7	127	7666
HAPPISBURGH	N3B2	N3B3	52.4	7251	46.4	6412	1.2	161	13825
HAPPISBURGH	N3B1	N3B2	72.5	7508	26.8	2769	0.7	67	10344
OSTEND	N3C8	N3B1	70.3	4910	29.2	2042	0.5	37	6989
BACTON	N3C7	N3C8	64.7	3439	35.3	1876	0.0	0	5315
BACTON	N3C6	N3C7	36.9	1606	63.1	2747	0.0	0	4353
BACTON	N3C5	N3C6	24.0	2327	66.0	6398	10.0	969	9695
AVERAGE/TOTAL			**48.2**	**28338**	**49.8**	**28488**	**2.0**	**1362**	**58188**

Figure 13. Happisburgh - Bacton : Cliff sediment and volume data (m^3 per m recession)



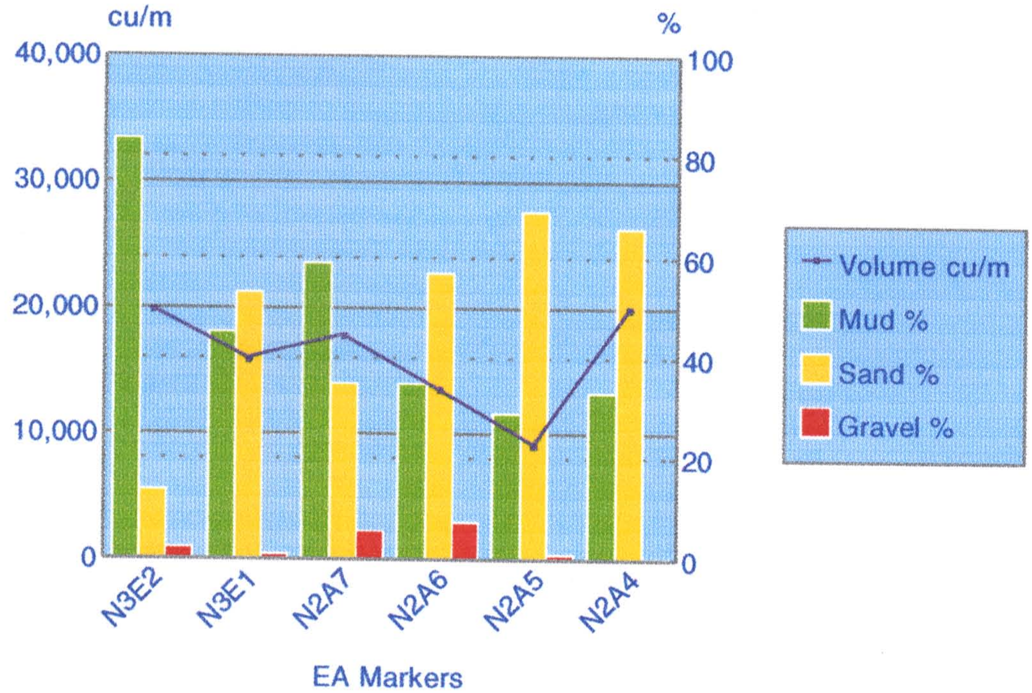
LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
BACTON	N3C4	N3C5	33.2	6131	64.7	11960	2.1	389	18480
MUNDESLEY	N3C3	N3C4	35.6	7453	63.7	13314	0.7	145	20912
MUNDESLEY	N3C2	N3C3	27.5	3556	72.5	9377	0.0	0	12933
MUNDESLEY	N3C1	N3C2	32.5	6365	67.4	13178	0.1	21	19564
TRIMINGHAM	N3D6	N3C1	34.2	11780	65.5	22564	0.3	111	34454
TRIMINGHAM	N3D5	N3D6	30.3	14266	65.6	30934	4.1	1934	47134
TRIMINGHAM	N3D4	N3D5	36.6	26457	55.5	40091	7.9	5689	72236
AVERAGE/TOTAL			**32.8**	**76007**	**65.0**	**141418**	**2.2**	**8289**	**225713**

Figure 14. Bacton - Trimingham : Cliff sediment and volume data (m^3 per m recession)
(Note change of Y axis scale for volume)



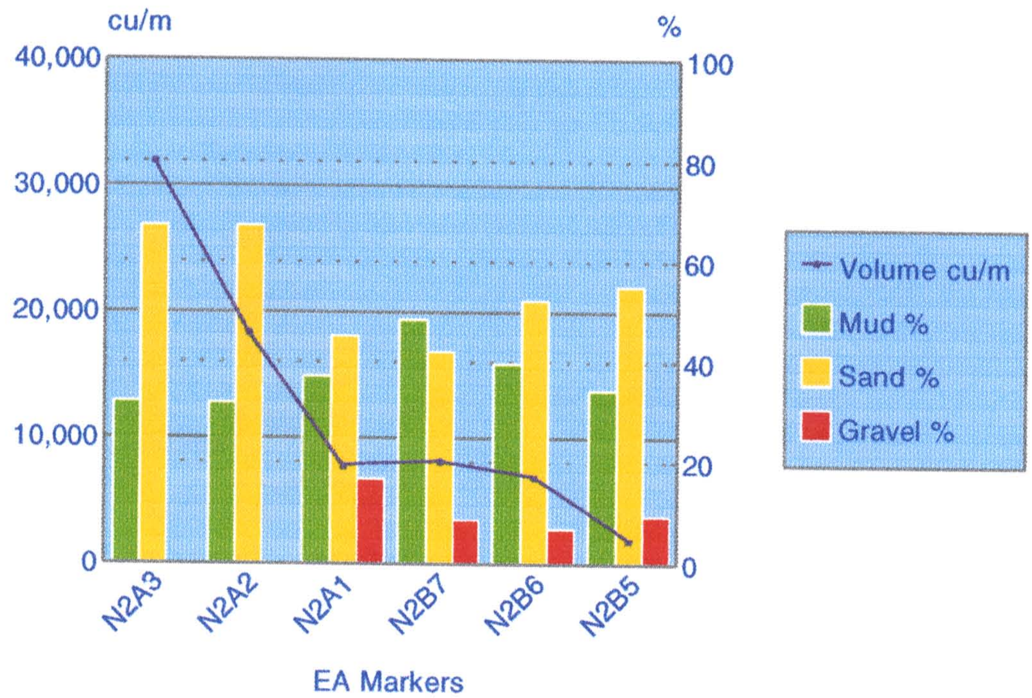
LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
TRIMINGHAM	N3D3	N3D4	62.5	17423	37.5	10454	0.0	0	27876
SIDESTRAND	N3D2	N3D3	82.8	20013	17.1	4122	0.1	20	24155
OVERSTRAND	N3D1	N3D2	43.6	12016	55.4	15286	1.0	275	27577
OVERSTRAND	N3E6	N3D1	69.0	14718	30.0	6399	1.0	213	21330
OVERSTRAND	N3E5	N3E6	40.2	20381	59.5	30220	0.3	148	50748
CROMER	N3E4	N3E5	21.6	10532	78.4	38145	0.0	0	48677
CROMER	N3E3	N3E4	39.1	14095	60.0	21580	0.9	334	36009
AVERAGE/TOTAL			**51.2**	**109177**	**48.3**	**126205**	**0.5**	**990**	**236372**

Figure 15. Trimingham - Cromer : Cliff sediment and volume data (m^3 per m recession)
(Note change of Y axis scale for volume)



LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
CROMER	N3E2	N3E3	83.7	16607	13.9	2769	2.4	479	19854
RUNTON	N3E1	N3E2	45.5	7277	53.4	8543	1.1	177	15997
RUNTON	N2A7	N3E1	59.1	10539	35.2	6277	5.7	1009	17826
RUNTON	N2A6	N2A7	35.3	4792	57.1	7756	7.6	1035	13583
SHERINGHAM	N2A5	N2A6	29.4	2674	69.4	6320	1.2	110	9104
SHERINGHAM	N2A4	N2A5	33.4	6690	66.1	13254	0.5	93	20037
AVERAGE/TOTAL			**47.7**	**48579**	**49.2**	**44918**	**3.1**	**2903**	**96400**

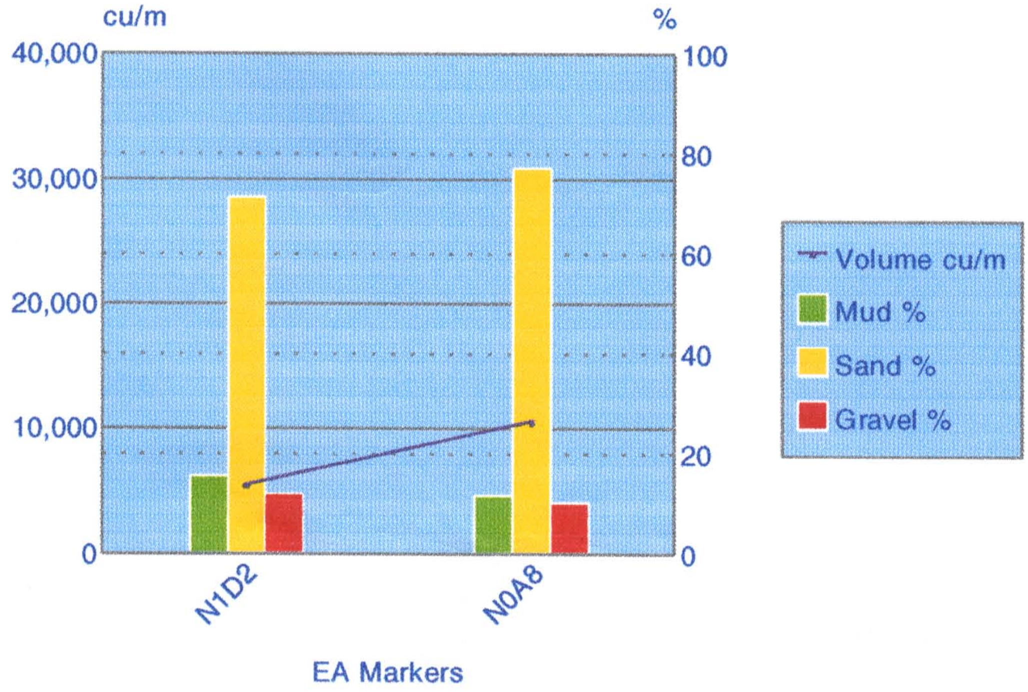
Figure 16. Cromer - Sheringham : Cliff sediment and volume data (m^3 per m recession)



LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
SHERINGHAM	N2A3	N2A4	32.5	10414	67.5	21630	0.0	0	32044
SHERINGHAM	N2A2	N2A3	32.2	5936	67.5	12439	0.3	53	18428
SHERINGHAM	N2A1	N2A2	37.6	2936	45.3	3545	17.1	1338	7818
WEYBOURNE	N2B7	N2A1	48.8	3992	42.3	3462	8.9	728	8182
WEYBOURNE	N2B6	N2B7	40.1	2775	52.7	3638	7.2	498	6911
WEYBOURNE	N2B5	N2B6	34.8	667	55.5	1066	9.7	186	1919
AVERAGE/TOTAL			**37.7**	**26720**	**55.1**	**45779**	**7.2**	**2802**	**75301**

Figure 17. Sheringham - Weybourne : Cliff sediment and volume data (m^3 per m recession)

6.11 Hunstanton



LOCATION	MARKER NUMBERS		MUD %	m^3	SAND %	m^3	GRAV %	m^3	TOTAL m^3
HUNSTANTON	N1D2	N1D3	16.0	886	71.7	3975	12.3	683	5544
HUNSTANTON	N0A8	N1D2	12.1	1286	77.5	8262	10.4	1105	10653
AVERAGE/TOTAL			**14.0**	**2172**	**74.7**	**12237**	**11.3**	**1788**	**16197**

Figure 18. Hunstanton : Cliff sediment and volume data (m^3 per m recession)

The cliffs at Hunstanton lie on the northeast coast of the Wash (Figure 1). They are a distinctive sequence of white Lower Chalk resting on Hunstanton Red Chalk and Carstone. The cliffs are over 2 kms long with a maximum height of 17 m. The cliffs fall to sea level at both ends.

The Carstone, with a thin overlying till, occurs in the southern end of the cliffs with the white Chalk entering the top of the cliffs midway between N1D1 and N1D2. The base of the white Chalk dips gently northwards, so the white chalk becomes thicker to the north with the Carstone thining at the base of the cliff.

The white Chalk comprises limestone and irregular chalk with some gritty beds and shell beds. Chalk and limestone are soluble therefore only insoluble residue will be the product of cliff erosion. A standard figure of 6% mud and 1% sand has been taken for the insoluble material from the white chalk and also the Hunstanton Red Chalk. The Carstone is a brown oolitic sandstone with a pebbly sand at its base.

7. CONCLUSIONS

The study has produced quantitative estimates of the volume and character of potential sediment input from coastal cliff erosion. Although no account has been taken of the state of cliffs in terms of coastal defence and current erosion conditions, the data presented is available for integration into models of coastal recession and littoral and nearshore budget calculations. The cliffs in gross sediment character terms can be broken into three primary and one subordinate sector.

- A southern sector, dominated by muds, from Mersea to Harwich characterised by cliffs of London Clay with some Pleistocene sand and gravel and Red Crag.

- A central sector, from Felixstowe to Caister predominantly distinguished by Plio-Pleistocene Crag sequences, mainly of sand.

- A northern sector, comprising a virtually continuous line of cliffs from Happisburgh to Weybourne dominated by a heterogeneous mixture of mainly glacial sediments, principally mud and sand.

- A subordinate sector at Hunstanton, on the Wash, where a rock cliff of Chalk and Carstone provides mainly sandy sediment. The Chalk, because of its solubility, is not the principal contributor of sediment.

The areas with the greatest potential volume of sediment from cliff erosion are associated with the highest cliffs. In terms of the sectors identified above, the southern sector's total potential is estimated at 181,000 m^3 per m recession, the central sector, 309,000 m^3 per m recession, and the northern sector, with the highest cliffs, 692,000 m^3 per m recession. The cliffs at Hunstanton are a minor component of the system with potential volumes of only 16,000 m^3 per m recession.

Generally most cliffs average less than 20,000 m^3 per m of material between Environment Agency markers, the majority of southern cliffs are less than 10,000 m^3 per m. The only area with cliffs which consistently exceed 20,000 m^3 per m between markers is in North Norfolk from Trimingham to Cromer and the maximum here is over 72,000 m^3 per m.

In terms of future sediment inputs from cliff erosion in the areas covered by this study, it appears that the stratigraphy indicated by the present cliffs, and the volume and character of the sediments identified by this study are likely to be applicable to any recession scenario invoked for the next hundred years.

McCave (1978) and other workers have indicated that winnowing of fine grained material from beaches and dispersal offshore occurs in the East Anglian coastal system. A coarsening of beach sediment in the direction of net wave-driven transport was also noted. This suggests that virtually all the mud liberated from cliffs in this area will escape offshore with only the sand and gravel available for beach building, although with time and progressive reworking the fine sand fractions are also likely to be lost offshore.

If this thesis were applicable to all sectors then the potential volume of sand and gravel available in each sector from one metre of cliff recession would be, for the southern sector, 33,000 m^3 per m, the central sector, 263,000 m^3 per m and the northern sector, 403,000 m^3 per m. These figures take no account of the loss of fine sand because data on the volume of different sand fractions is not available.

It is not within the remit of this study to compare various sources of sediment to littoral and nearshore sediment budgets. However, it is likely that, within this area of the Southern North Sea, cliff erosion has played a major contribution in the supply of sediment to the nearshore and littoral zone. A measure of this contribution would require evaluation of offshore bank systems and changes in wave platform morphology and Ness distribution to compare sediment input and output into the littoral and nearshore system.

8. RECOMMENDATIONS

- The methods adopted for this study are readily applicable to areas of cliff within other Environment Agency regions. The system of cliff section surveys at intervals based on cliff morphology and geology provides a method which is rigorous and cost effective and can be updated at any time, increasing the precision and value of the original survey.

- Although the investigation output in graphical terms has been digital Intergraph design files specifically for loading into the Anglian Region's Shoreline Management System, other methods could be adopted for Agency regions without a similar shoreline management system. These methods could include paper maps or digital files for entry into any proprietry graphical or data system used by other regions. The basic field data can be utilized in virtually any form of analogue or digital output.

- The numbering system used to locate cliffs in this report is based on the Anglian Region marker system. This type of marker system may not be in use in other regions. However, other regions location systems could be adopted or a location system based on the Ordnance Survey National Grid.

- Cliff erosion is an important source of new sediment into littoral and nearshore sediment budgets. To constrain budget models other sources of new sediment need to be evaluated. Shoreface and nearshore platform abrasion of non-mobile sediment such as till, Crag sand and consolidated Holocene sediment are an important source and complimentary to the erosion and retreat of coastal cliffs and the results of this current investigation.

9. REFERENCES

GRAINGER, P. 1972. The Engineering Geology of an area in South Essex. *Institute of Geological Sciences Engineering Geology Report EG/TQ 89/1.*

MCCAVE, I.N. 1978. Grain-size trends and transport along beaches: Example from Eastern England. *Marine Geology,* Vol.28, p.M43-M51.

APPENDIX A: LITERATURE REVIEW

ALLEN, J.R.L. 1989. Evolution of salt marsh cliffs in muddy and sandy systems: A qualitative comparison of British west coast estuaries. *Earth Surface Processes and Landforms,* Vol.14, p.85-92.

ANONYMOUS. 1898. Serious subsidence of the cliff at Walton-on-the-Naze. *The Essex Naturalist,* Vol.10, p.236-237.

ARTHURTON, R.S., BOOTH, S.J., MORIGI, A.N., ABBOTT, M.A.W. AND WOOD, C.J. 1994. Geology of the country around Great Yarmouth. *Memoir of the British Geological Survey,*

BADEN-POWELL, D.F.W. 1948. The chalky boulder clays of Norfolk and Suffolk. *Geological Magazine,* Vol.85, p.279-296.

BALSON, P.S. 1990. The Neogene of East Anglia - a field excursion report. *Tertiary Research,* Vol.11, No.2-4, p.179-189.

BALSON, P.S. AND CAMERON, T.D.J. 1985. Quaternary mapping offshore East Anglia. *Modern Geology,* Vol.9, p.221-239.

BALSON, P.S., HUMPHREYS, B. AND ZALASIEWICZ, J.A. 1990. Coralline and Red Crags of East Anglia. *IAS Field Guide,* No.3, p.48.

BANHAM, P.H. 1962. Glacial Tectonics. *Paramoudra Club Bulletin,* Vol.11, p.1-17.

BANHAM, P.H. 1966. The significance of till pebble lineations and relations to folds in two Pleistocene tills at Mundesley, Norfolk. *Proceedings of the Geologists' Association,* Vol.77, p.469-474.

BANHAM, P.H. 1968. A preliminary note on the Pleistocene stratigraphy of north east Norfolk. *Proceedings of the Geologists' Association,* Vol.79, p.507-512.

BANHAM, P.H. 1971. Pleistocene beds at Corton, Suffolk. *Geological Magazine,* Vol.108, p.281-285.

BANHAM, P.H. 1971. Temporary exposure in the Drift near Cromer. *Bulletin of the Geological Society of Norfolk,* Vol.19, p.35-38.

BANHAM, P.H. 1975. Glacitectonic structures: a general discussion with particular reference to the contorted drift of Norfolk. in *Ice Ages: Ancient and Modern.* WRIGHT, A.E. and MOSELEY, F. (Editors). (Liverpool: Seel House Press.)

BANHAM, P.H. 1988. Polyphase glaciotectonic deformation in the Contorted Drift of Norfolk. 27-32 in *Glaciotectonics: Forms and Processes.* CROOT, D.G. (Editor). (Rotterdam: Balkema.)

BANHAM, P.H., DAVIES, H. AND PERRIN, R.M.S. 1975. Short field meeting in North Norfolk.

Proceedings of the Geologists' Association, Vol.86, p.251-258.

BANHAM, P.H. AND RANSON, C.E. 1965. Structural study of the Contorted Drift and disturbed chalk at Weybourne, North Norfolk. *Geological Magazine,* Vol.102, p.164-174.

BERRIDGE, N.G. AND PATTISON, J. 1994. Geology of the country around Grimsby and Patrington. *Memoir of the British Geological Survey.*

BLAKE, J.H. 1884. Explanation of horizontal sections, Sheet 128. Sections of the Suffolk cliffs at Kessingland and Pakefield and at Corton. *Geological Survey of England and Wales.*

BLAKE, J.H. 1890. Geology of the country near Yarmouth and Lowestoft (explanation of Sheet 67). *Memoir of the Geological Survey of England and Wales.*

BOSWELL, P.G.H. 1928. The geology of the country around Woodbridge, Felixstowe and Orford. *Memoir of the Geological Survey of Great Britain.*

BOULTON, G.S., Editor. 1970. *North Norfolk Field Guide.* (Norwich: Quaternary Research Association.)

BOULTON, G.S., COX, F.C., HART, J.K. AND THORNTON, M.H. 1984. The glacial geology of Norfolk. *Bulletin of the Geological Society of Norfolk,* Vol.34, p.103-122.

BRIDGELAND, D.R. 1988. The Pleistocene fluvial stratigraphy and palaeogeography of Essex. *Proceedings of the Geologists' Association,* Vol.99, p.291-314.

BRISTOW, C.R. 1983. The stratigraphy and structure of the Crag of mid Suffolk, England. *Proceedings of the Geologists' Association,* Vol.94, p.1-12.

BRITISH GEOLOGICAL SURVEY. 1977. Woodbridge and Felixstowe. England and Wales Sheet 208/225. Solid and Drift. 1:50,000. (Southampton: Ordnance Survey for British Geological Survey).

BRITISH GEOLOGICAL SURVEY. 1988. East Anglia. Sheet 52N-00°. Sea bed sediments. 1:250,000. (Southampton: Ordnance Survey for British Geological Survey).

BRITISH GEOLOGICAL SURVEY. 1990. Grimsby. England and Wales Sheet 90/91. Solid and Drift. 1:50,000. (Southampton: Ordnance Survey for British Geological Survey).

BRITISH GEOLOGICAL SURVEY. 1990. Great Yarmouth. England and Wales Sheet 162. Solid and Drift. 1:50,000. (Southampton: Ordnance Survey for British Geological Survey).

BRITISH GEOLOGICAL SURVEY. in press. Lowestoft. England and Wales Sheet 176. Solid and Drift. 1:50,000. (Southampton: Ordnance Survey for British Geological Survey).

BROMHEAD, E.N. 1992. *The Stability of Slopes.* 2nd Edition. (London: Blackie.) pp.411

CAMBERS, G. 1973. The retreat of unconsolidated Quaternary cliffs. Ph.D. Thesis. University of East Anglia.

CAMBERS, G. 1975. Sediment transport and coastal changes. *East Anglian Coastal Research Programme Report,* No.3, University of East Anglia,

CAMBERS, G. 1976. Temporal scales in coastal erosion systems. *Transactions of the Institute of British Geographers,* Vol.1, p.246-256.

CAMBERS, G., CRAIG-SMITH, S.J. AND SIMMONDS, A.C. 1975. East Anglian Sea Defence Policy. *East Anglian Coastal Research Programme Report,* No.2, University of East Anglia,

CAMERON, T.D.J., CROSBY, A., BALSON, P.S., JEFFERY, D.H., LOTT, G.K., BULAT, J. AND HARRISON, D.J. 1992. *UK offshore regional report: The geology of the southern North Sea.* (Keyworth: British Geological Survey.)

CARTER, C.H. AND GUY JR, D.E. 1988. Coastal Erosion: Processes, timing and magnitudes at the bluff toe. *Marine Geology,* Vol.84, p.1-17.

CARTER, R.W.G. AND STONE, R.W.G. 1989. Mechanisms associated with the erosion of sand dune cliffs, Magilligan, Northern Ireland. *Earth Surface Processes and Landforms,* Vol.14, p.1-10.

CHANDLER, J.H. AND BRUNSDEN, D. 1995. Steady state behaviour of the Black Ven mudslide: The application of archival analytical photogrammetry to studies of landscape change. *Earth Surface Processes and Landforms,* Vol.20, p.255-275.

CHATWIN, C.P. 1961. *British regional geology: East Anglia and adjoining areas.* 4th Edition. (London: HMSO.)

CLAYTON, K.M. 1977. Beach Profiles: Form and Change. *East Anglian Coastal Research Programme Report,* No.5, University of East Anglia.

CLAYTON, K.M. 1980. Coastal protection along the East Anglian coast, UK. *Zeitschrift fur Geomorphologie,* Vol.34, p.165-172.

CLAYTON, K.M. 1989. Sediment input from the Norfolk cliffs, eastern England - a century of coast protection and its effect. *Journal of Coastal Research,* Vol.5, p.433-442.

CLAYTON, K.M., MCCAVE, I.N. AND VINCENT, C.E. 1983. The establishment of a sand budget for the East Anglian coast and its implications for coastal stability. 91-96 in *Shoreline Protection.* (London: Thomas Telford.)

DHONAU, T.J. AND DHONAU, N.B. 1963. Glacial structures on the North Norfolk coast. *Proceedings of the Geologists' Association,* Vol.74, p.433-439.

EHLERS, J., GIBBARD, P.L. AND WHITEMAN, C.A. 1987. Recent investigations of the Marly Drift of northwest Norfolk, England. 39-54 in *Tills and Glaciotectonics.* VAN DER MEER, J.J.M. (Editor). (Rotterdam: Balkema.)

EHLERS, J., GIBBARD, P.L. AND WHITEMAN, C.A. 1991. The glacial deposits of northwestern Norfolk. 223-232 in *Glacial deposits in Great Britain and Ireland.* EHLERS, J., GIBBARD, P.L. and ROSE, J. (Editors). (Rotterdam: Balkema.)

EVANS, H. 1976. Aspects of the glaciation of west Norfolk. M.Phil. Thesis. University of East Anglia, Norwich. pp.246

EYLES, N., EYLES, C.H. AND MCCABE, A.M. 1989. Sedimentation in an ice-contact subaqueous setting: the Mid-Pleistocene 'North Sea Drifts' of Norfolk, U.K. *Quaternary Science Reviews,* Vol.8, p.57-74.

FISHER, O. 1868. On the denudations of Norfolk. *Geological Magazine (Series 1),* Vol.5, p.544-558.

FUNNELL, B.M. 1961. The Palaeogene and early Pleistocene of Norfolk. *Transactions of the Norfolk and Norwich Naturalists Society,* Vol.19, p.340-364.

FUNNELL, B.M. 1987. Late Pliocene and early Pleistocene stages of East Anglia and the adjacent North Sea. *Quaternary Newsletter,* Vol.52, p.1-11.

GALLOIS, R.W. 1994. Geology of the country around King's Lynn and the Wash. *Memor of the British Geological Survey*, sheet 145 and part of 129 (England and Wales).

FUNNELL, B.M. AND WEST, R.G. 1962. The early Pleistocene of Easton Bavents, Suffolk. *Journal of the Geological Society of London,* Vol.118, No.2, p.125-141.

GEORGE, W. AND VINCENT, S. 1977. Report of field meeting to Walton-on-the-Naze and Wrabness, Essex with notes on the London Clay of Walton. *Tertiary Research,* Vol.1, No.3, p.83-90.

GIBBARD, P.L. AND ZALASIEWICZ, J.A., Editors. 1988. *Pliocene - middle Pleistocene of East Anglia: Field Guide.* (Cambridge: Quaternary Research Association.) pp.195

GRAINGER, P. AND KALAUGHER.PG. 1987. Intermittent surging movements of a coastal landslide. *Earth Surface Processes and Landforms,* Vol.12, p.597-603.

GRAY, J.M. 1988. Coastal cliff retreat at the Naze, Essex since 1874: patterns, rates and processes. *Proceedings of the Geologists' Association,* Vol.99, No.4, p.335-338.

GREEN, C. 1961. East Anglian coastline levels since Roman times. *Antiquity,* Vol.35, p.21-28.

GREEN, C., LARWOOD, G.P. AND MARTIN, A.J. 1953. The coastline of Flegg from Caister Point to Hemsby Gap. *Transactions of the Norfolk and Norwich Naturalists Society,* Vol.17, No.5, p.327-342.

GREEN, C.P. AND MCGREGOR, D.F.M. 1990. Pleistocene gravels of the north Norfolk coast. *Proceedings of the Geologists' Association,* Vol.101, No.3, p.197-202.

GREENSMITH, J.T., BLEZARD, R.G., BRISTOW, C.R., MARKHAM, R. AND TUCKER, E.V. 1973. The Estuarine Region of Suffolk and Essex. *Geologists' Association Guide,* No.12, p.25.

GUNN, J. 1867. The order of succession of the preglacial, glacial and postglacial strata in the coast sections of Norfolk and Suffolk. *Geological Magazine,* Vol.4, p.371-372 and 561.

HAILS, J.R. AND WHITE, P.C.S. 1970. Periglacial features at Walton-on-the Naze,Essex. *Proceedings of the Geologists' Association,* Vol.81, p.205-219.

HARMER, F.W. 1902. A sketch of the later Tertiary history of East Anglia. *Proceedings of the Geologists' Association,* Vol.17, p.416-479.

HARPER, W. 1966. The cliffed coastline of Norfolk. M.A. Thesis. University of Aberdeen.

HART, J.K. 1987. The genesis of north east Norfolk Drift. Ph.D. Thesis. University of East Anglia.

HART, J.K. 1990. Proglacial glaciotectonic deformation and the origin of the Cromer Ridge push moraine complex. *Boreas,* Vol.19, p.165-180.

HART, J.K. AND BOULTON, G.S. 1991. The glacial drifts of Norfolk. 233-243 in *Glacial Deposits in Great Britain and Ireland.* EHLERS, J., GIBBARD, P.L. and ROSE, J. (Editors). (Rotterdam: Balkema.)

HART, J.K., HINDMARSH, R.S.A. AND BOULTON, G.S. 1990. Styles of subglacial glaciotectonic deformation within the context of the Anglian ice-sheet. *Earth Surface Processes and Landforms,* Vol.15, p.227-241.

HARVEY, B.I., LANGSTON, M.J., HUGHES, M.D.A. AND WHALLEY, H.A. 1974. *Records of wells in North Norfolk.* (London: Institute of Geological Sciences - HMSO.) pp.216

HEY, R.W. 1976. Provenance of far-travelled pebbles in the pre-Anglian Pleistocene of East Anglia. *Proceedings of the Geologists' Association,* Vol.87, p.69-81.

HOWORTH, H.H. 1907. North Norfolk Geology: the Chalk and its dislocation. *Geological Magazine,* Vol.44, p.268-277.

HUTCHINSON, J.N. 1965. The stability of cliffs composed of soft rocks with particular reference to the coasts of south east England. Ph.D. Thesis. University of Cambridge.

HUTCHINSON, J.N. 1970. A coastal mudflow on the London Clay cliffs at Beltinge, North Kent. *Geotechnique,* Vol.20, No.4, p.412-438.

HUTCHINSON, J.N. 1975. The response of London Clay cliffs to differing rates of toe erosion. *Building Research Establishment Current Paper,* No.CP27/75, p.1-15.

HUTCHINSON, J.N. 1976. Coastal landslides in cliffs of Pleistocene deposits between Cromer and Overstrand, Norfolk, England. 155-182 in *Contributions to Soil Mechanics.* JANBU, N., JORSTAD, F. and KJAERNSLI, B. (Editors). (Oslo: Norwegian Geotechnical Institute.)

HUTCHINSON, J.N. 1986. Cliffs and shores in cohesive materials: geotechnical and engineering geological aspects. *Proceedings Symposium on Cohesive Shores,* p.1-44.

INSTITUTE OF GEOLOGICAL SCIENCES 1976. Hydrogeological map of northern East Anglia. 1:125,000. (Southampton: Ordnance Survey for Institute of Geological Sciences)

JONES, D.G. AND WILLIAMS, A.T. 1991. Statistical analysis of factors influencing cliff erosion along a section of the west Wales coast, U.K. *Earth Surface Processes and Landforms,* Vol.16, p.95-111.

KAZI, A. 1972. Clay mineralogy of the North Sea Drift. *Nature,* Vol.240, p.61-62.

KAZI, A. AND KNILL, J.L. 1969. The sedimentation and geotechnical properties of the Cromer Till between Happisburgh and Cromer, Norfolk. *Quarterly Journal of Engineering Geology,* Vol.2, p.63-86.

KENDALL, P.F. 1931. The Red Crag of Walton-on-the-Naze. *Geological Magazine,* Vol.68, p.405-420.

KOMAR, P.D., Editor. 1983. *CRC handbook of coastal processes and erosion.* (Boca Raton, Florida: CRC Press.) pp.305

LARWOOD, G.P. AND FUNNELL, B.M., Editors. 1970. *The Geology of Norfolk.* (London: Headley Brothers.)

LUNKKA, J.P. 1988. Sedimentation and deformation of the North Sea Drift Formation in the Happisburgh area, North Norfolk. 109-122 in *Glaciotectonics: Forms and Processes.* CROOT, D.G. (Editor). (Rotterdam: Balkema.)

LUNKKA, J.P. 1991. Sedimentology of the Anglian glacial deposits in northeast Norfolk, England. Ph.D. Thesis. University of Cambridge.

LUNKKA, J.P. 1994. Sedimentation and lithostratigraphy of the North Sea Drift and Lowestoft Till Formations in the coastal cliffs of northeast Norfolk, England. *Journal of Quaternary Science,* Vol.9, No.3, p.209-233.

LYELL, C. 1840. On the Boulder Formation or Drift and associated freshwater deposits comprising the mud cliffs of eastern Norfolk. *The London and Edinburgh Philosophical Magazine and Journal of Science, Third Series,* Vol.16, p.345-380.

MCCAVE, I.N. 1978. Grain-size trends and transport along beaches: Example from Eastern England. *Marine Geology,* Vol.28, p.M43-M51.

MCCAVE, I.N. 1978. Sediments of the East Anglian Coast. *East Anglian Coastal Research Programme Report,* No.6, University of East Anglia, McCave, I.N. 1987. Fine sediment sources and sinks around the East Anglian coast (UK). *Journal of the Geological Society of London,* Vol.144, p.149-152.

McGreal, W.S. 1979. Marine erosion of glacial sediments from a low energy cliffline environment near Kilkeel, Northern Ireland. *Marine Geology,* Vol.32, p.89-103.

McGreal, W.S. 1979. Factors promoting coastal slope instability in southeast County Down, N. Ireland. *Zeitschrift fur Geomorphologie,* Vol.23, p.76-90.

Onyett, D. and Simmonds, A. 1982. Final Report: Beach changes and longshore transport 1974 - 1980. *East Anglian Coastal Research Programme Report,* No.8, University of East Anglia,

Orme, A.R., Prior, D.B., Psuty, N.P. and Walker, H.J., Editors. 1980. *Coasts under stress.* Zeitschrift fur Geomorphologie. Volume 34. pp.255

Owen, H.G. 1995. The upper part of the Carstone and the Hunstanton Red Chalk (Albian) of the Hunstanton Cliff, Norfolk. *Proceedings of the Geologists' Association,* Vol.106, p.171-181.

Peake, N.B. and Hancock, J.M. 1961. The Upper Cretaceous of Norfolk. *Transactions of the Norfolk and Norwich Naturalists Society,* Vol.19, p.293-339.

Perrin, R.M.S., Davies, H. and Fysh, M.D. 1973. Lithology of the Chalky Boulder Clay. *Nature,* Vol.245, p.101-104.

Pointon, W.K. 1978. The Pleistocene succession at Corton, Suffolk. *Bulletin of the Geological Society of Norfolk,* Vol.30, p.55-76.

Prestwich, J. 1849. On some fossiliferous beds overlying the Red Crag at Chillesford near Orford, Suffolk. *Quarterly Journal of the Geological Society of London,* Vol.5, p.343-353.

Prestwich, J. 1871. On the structure of the Crag-beds of Suffolk and Norfolk with some observations on their organic remains. Part 1. The Coralline Crag of Suffolk. *Quarterly Journal of the Geological Society of London,* Vol.27, p.115-146.

Prestwich, J. 1871. On the structure of the Crag-beds of Suffolk and Norfolk with some observations on their organic remains. Part II. The Red Crag of Essex and Suffolk. *Quarterly Journal of the Geological Society of London,* Vol.27, p.325-356.

Prestwich, J. 1871. On the structure of the Crag-beds of Suffolk and Norfolk with some observations on their organic remains. Part III. The Norwich Crag and Westleton Beds. *Quarterly Journal of the Geological Society of London,* Vol.27, p.425-496.

Prior, D.B. and Renwick, W.H. 1980. Landslide morphology and processes on some coastal slopes in Denmark and France. *Zeitschrift fur Geomorphologie,* Vol.34, p.63-86.

Ranson, C.E. 1968. An assessment of the glacial deposits in North Norfolk. *Bulletin of the*

Geological Society of Norfolk, Vol.15, p.1-7.

REDMAN, J.B. 1864. The east coast between the Thames and the Wash estuaries. *Minutes and Proceedings of the Institution of Civil Engineers,* Vol.23, p.186-224.

REID, C. 1882. The geology of the country around Cromer. *Memoir of the Geological Survey of England and Wales.*

REID, C. 1890. The Pliocene deposits of Britain. *Memoir of the Geological Survey of England and Wales,* Vol.27, p.425-496.

ROBINSON, A.H.W. 1966. Residual currents in relation to shoreline evolution of the East Anglian Coast. *Marine Geology,* Vol.4, p.57-84.

ROBINSON, A.H.W. 1980. Erosion and accretion along part of the Suffolk coast of East Anglia, England. *Marine Geology,* Vol.37, p.133-146.

ROSE, J. 1989. Stadial type sections in the British Quaternary. 15-20 in *Quaternary Type Sections.* ROSE, J. and SCHLUCTER, C.H. (Editors). (Rotterdam: Balkema.)

ROSE, J. AND ALLEN, P. 1977. Middle Pleistocene stratigraphy in south-east Suffolk. *Journal of the Geological Society of London,* Vol.133, p.85-102.

ROSE, J. AND HEY, R.W. 1976. Middle Pleistocene stratigraphy in southern East Anglia. *Nature,* Vol.263, p.492-494.

ROSE, J. AND TURNER, C., Editors. 1973. *Clacton Field Meeting Handbook.* (: Quaternary Research Association.)

SAVIN, A.C. 1937. *Cromer in the county of Norfolk. A modern history.* (Norwich: Rounce and Wortley.)

SIMMONDS, A.C. 1976. Recreational value of the beaches. *East Anglian Coastal Research Programme Report,* No.4, University of East Anglia,

SKEMPTON, A.W. 1964. Long term stability of clay slopes. *Geotechnique,* Vol.14, p.77-101.

SOLOMON, J.D. 1932. The glacial succession on the north Norfolk coast. *Proceedings of the Geologists' Association,* Vol.43, No.3, p.241-271.

STRAW, A. 1965. A re-assessment of the Chalky Boulder Clay or Marly Drift of North Norfolk. *Zeitschrift fur Geomorphologie,* Vol.9, p.209-221.

STRAW, A. 1973. The glacial geomorphology of central and north Norfolk. *The East Midland Geographer,* Vol.5, p.333-353.

STRAW, A. 1991. Glacial deposits of Lincolnshire and adjacent areas. 213-221 in *The Glacial deposits in Great Britain and Ireland.* EHLERS, J., GIBBARD, P.L. and ROSE, J. (Editors).

(Rotterdam: Balkema.)

STRIDE, A.H. 1988. Indications of long term episodic suspension transport of sand across the Norfolk Banks, North Sea. *Marine Geology,* Vol.79, p.55-64.

STUART, A. AND WEST, R.G. 1976. Late Cromerian fauna and flora at Ostend, Norfolk. *Geological Magazine,* Vol.113, p.469-473.

TERZAGHI, K. 1950. Mechanics of landslides, application of geology to engineering practice. *Memoir of the Geological Society of America,* Berkeley Volume. p.83-123.

VINCENT, C.E. 1979. Longshore sand transport rates - a simple model for the East Anglian coastline. *Coastal Engineering,* Vol.3, p.113-136.

VINCENT, C.E. 1979. Wave climate and longshore wave power. *East Anglian Coastal Research Programme Report,* No.7, University of East Anglia,

WEST, R.G. 1957. Notes on a preliminary map of some features of the drift topography around Holt and Cromer, Norfolk. *Transactions of the Norfolk and Norwich Naturalists Society,* Vol.18, p.24-29.

WEST, R.G. 1961. The glacial and interglacial deposits of Norfolk. *Transactions of the Norfolk and Norwich Naturalists Society,* Vol.19, p.365-375.

WEST, R.G. 1980. *The pre-glacial Pleistocene of the Norfolk and Suffolk coasts.* (Cambridge: Cambridge University Press.) pp.203

WEST, R.G. AND BANHAM, P.H. 1968. Short field meeting on the North Norfolk coast. *Proceedings of the Geologists' Association,* Vol.79, p.493-507.

WEST, R.G. AND WILSON, D.G. 1968. Plant remains from the Corton Beds at Lowestoft, Suffolk. *Geological Magazine,* Vol.105, p.116-123.

WHITAKER, W. 1877. The geology of the eastern end of Essex (Walton Naze and Harwich). *Memoir of the Geological Survey of England and Wales,* No.48SE,

WILLIAMS, W.W. 1956. An east coast survey: some recent changes in the coast of East Anglia. *Geographical Journal,* Vol.122, p.317-334.

WILLIAMS, W.W. 1960. *Coastal Changes.* (London: Routledge and Kegan Paul.)

WOOD, S.V. 1866. On the structure of the Red Crag. Explanation of the diagram section by Wood, S.V. jnr. *Quarterly Journal of the Geological Society of London,* Vol.22, p.538-552.

WOOD, S.V. 1880. The newer Pliocene period in England. *Quarterly Journal of the Geological Society of London,* Vol.36, p.457-528.

WOODWARD, H.B. 1884. The geology of the country around Fakenham, Wells and Holt.

Memoir of the Geological Survey of England and Wales.

ZALASIEWICZ, J.A., GIBBARD, P.L., PEGLAR, S.M., FUNNELL, B.M., CATT, J.A., HARLAND, R., LONG, P.E. AND AUSTIN, T.J.F. 1991. Age and relationships of the Chillesford Clay (Early Pleistocene: Suffolk, England). *Philosophical Transactions of the Royal Society of London,* Vol.B333, p.81-100.

ZALASIEWICZ, J.A., HUGHES, M.J., GIBBARD, P.L., PEGLAR, S.M., HARLAND, R., BOULTON, G.S., NICHOLSON, R.A., CAMBRIDGE, P. AND WEALTHALL, G. 1988. Stratigraphy and palaeoenvironments of the Red Crag and Norwich Crag formations between Aldeburgh and Sizewell, Suffolk, England. *Philosophical Transactions of the Royal Society of London,* Vol.B322, p.221-272.

ZALASIEWICZ, J.A. AND MATHERS, S.J. 1985. Lithostratigraphy of Red and Norwich Crags of the Aldeburgh-Orford area, south-east Suffolk. *Geological Magazine,* Vol.122, p.287-296.

APPENDIX B: FIELDWORK AND LABORATORY ANALYSIS

1. FIELDWORK

Prior to commencement of the fieldwork a review was undertaken in consultation with the Environment Agency. The review included the selection of cliffed areas to be investigated, the order in which the cliffs were to be studied in the field and the scope of the fieldwork. The cliffed areas which have been studied are listed in Figure 1. The area covered includes the coastline from Mersea in Essex to Hunstanton on the eastern shore of the Wash.

1.1 Planning

The need to collect quantitative data on cliff height, cliff section length and sediment particle size as well as descriptive data on the geology, all of which had to be entered into a computerised database system, meant a systematic approach had to be adopted to data collection.

The survey was therefore planned on the basis of data collected at representative cliff sections along the coast. For each representative section a two page proforma was designed to standardise data entry and focus on specific points of information required for evaluation and calculation. A copy of the proforma is attached as Figures 2 and 3.

The Agency has an existing marker system along the coastline within the project area. Each marker, normally a metal disc set in the ground, marks the location of beach profile surveys undertaken on a regular basis by the Agency. The markers are located approximately one kilometre apart along the open coastline. The numbering system used by the Agency to designate their markers has been adopted as the primary numbering system for the cliff sections recorded in the sediment study. This has the added advantage of allowing the Agency to associate beach profile surveys with the cliff surveys within their Shoreline Management System as well as other sources of information in the system.

1.2 Criteria

The representative cliff sections for description on the proformas were chosen on a number of criteria, these included :-

- Start and end points of cliff sections
- High and low points in cliff sections
- Environment Agency marker positions
- Quality of sediment exposure in cliff sections
- Changes in lithology and stratigraphy

The frequency of sections was therefore not uniform along the coast, but separation was rarely more than a kilometre and could be less than 100 metres. During the initial fieldwork descriptions were not always made at the Agency marker positions, principally because other criteria listed above may have been close to the marker position and taken precedence. Subsequently, in discussions with the the Agency on output from the survey for the Shoreline Management System, a requirement for data to be computed from the marker positions was identified. Data at the marker stations initially not described, have subsequently been added by extrapolation with adjacent data.

1.3 Recording cliff sections

The cliff section proforma was designed to provide information for direct entry into a computerised database. The data gathered is designed not only to cover the requirements of this study but also to provide a record for future comparative studies.

Photographs were taken of nearly all section localities which were described in the initial field study. The height of the cliff at each section was recorded. Each section was subdivided on its lithological character with the percentage of mud, sand and gravel recorded for each sub-division. The percentage recorded was either an estimation based on visual inspection or the result of particle size analysis undertaken on representative samples. For areas and lithologies where no visual estimation was possible particle size data was extrapolated from adjacent exposures or data available from reviewed sources.

Other criteria recorded for the section include, area defended, extent of vegetation cover, areas of mass movement and slope angle. The nature of the cliff top inland for 50 m is also recorded. This enables future volume calculations to be made on cliff recession up to 50 m from the present cliff line. A short description of the foreshore is also included, this is to complement each photograph of the foreshore taken at sections. It is also valuable in comparing the material in the cliff and the material exposed on the beach. The amount of foreshore visible is obviously dependent on the state of the tide.

It should be noted that not all the fields present on the proforma will contain data.

1.4 Progress

During fieldwork the entire length of the cliffs under investigation were walked and assessed. Fieldwork commenced on the 1st May 1995 at West Mersea and proceeded northwards up the coast through the areas outlined in Figure 1. The bulk of the fieldwork was completed by the middle of June 1995 when the survey reached Weybourne on the North Norfolk coast. The cliff at Hunstanton, on the east coast of the Wash, was surveyed in the spring of 1996, completing the fieldwork for the study.

Progress had to be maintained at a relatively rapid pace to keep within the timescale and costing allowed for the fieldwork. Defended and undefended coastlines were included in the survey. The quality and amount of exposed sediment for description and analysis was therefore very variable. In some areas descriptions were based on extrapolations from adjacent sections or reviews of data from boreholes and publications. Those cliffs which are undefended are not always accessible in their upper reaches due to the dangers of avalanche or stonefall and in some cases their lower parts can be obscured by slipped and slumped material. However, this can have the advantage of bringing material from the higher reaches of cliffs into accessible lower positions for analysis.

Sediment Input from Coastal Cliff Erosion
Area
West Mersea
East Mersea
Clacton on Sea
Frinton on Sea
Walton on the Naze
Harwich
Felixstowe
Bawdsey
Aldeburgh
Sizewell
Dunwich
Southwold
Covehithe
Kessingland-Lowestoft
Corton-Gorleston
Caister
Happisburgh-Weybourne
Hunstanton

Figure 1. Areas of cliffed coastlines under investigation

British Geological Survey - Cliff Survey   Sheet A

LOCATION: DATE: 9 5 TIME:

NRA REF: STATION: GEOLOGIST:

GR: MAP NRA GPS

FEATURE:

STATION LOCATION SKETCH

CROSS SECTION

PHOTOGRAPHS

SECTION: LENS FOCAL LENGTH mm DISTANCE FROM BASE OF CLIFF m

FILM ROLL No. NEGATIVE No.

OBLIQUES: (include sections at edge of photograph)

VIEW *W E N S* FOCAL LENGTH mm DISTANCE FROM BASE OF CLIFF m

FILM ROLL No. NEGATIVE No.

VIEW *W E N S* FOCAL LENGTH mm DISTANCE FROM BASE OF CLIFF m

FILM ROLL No. NEGATIVE No.

FORESHORE: (along line of NRA profile)

VIEW FROM *base of cliff* *top of cliff* (delete) FOCAL LENGTH mm

NRA PROFILE BEARING ° FILM ROLL No. NEGATIVE No.

NOTES

CONTINUATION SECTION FORM OF CLIFF TOP *flat* *sloping* *undulating* AMPLITUDE m

REF STATION LENGTH m REF STATION

m

0m

Coastal Geology Group Nottingham NG125GG 01159363100 c:\dos\bruce\clifrma.cdr

Figure 2. Survey Sheet A

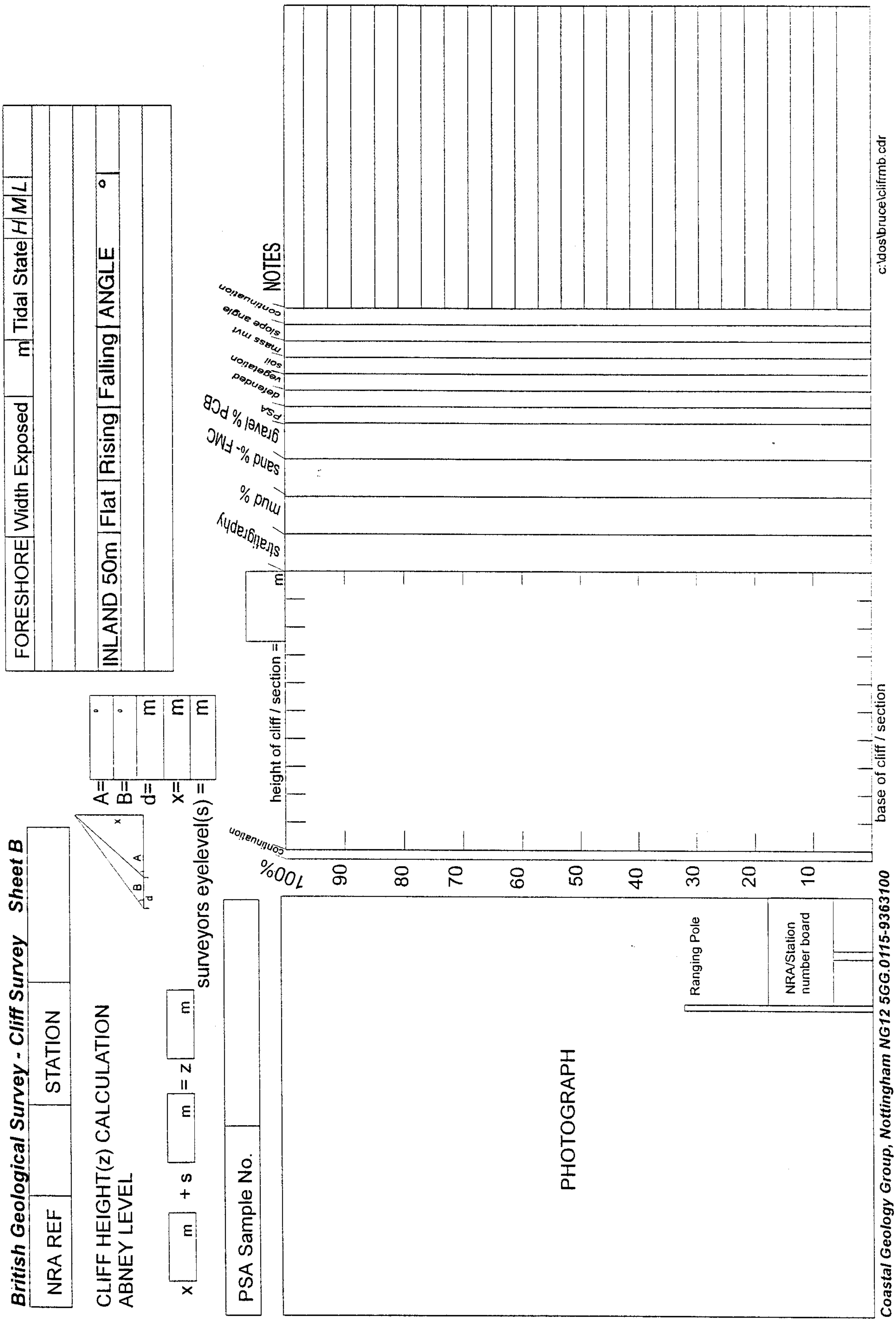


Figure 3. Survey Sheet B

2. LABORATORY ANALYSIS

The analysis of lithological data, particularly the proportions of gravel, sand and mud within the cliff sections is a fundamental requirement of the study. During fieldwork only those cliffs with sediments exposed can be analysed for grain size distribution. A large number of the lithological units found in the cliffs are highly variable in grain size, for example, the Quaternary sediments of the North Norfolk coast. Therefore, a representative grain size determination for these units is not credible. However, for some lithologies a laboratory grain size analysis can be useful as an aid to the estimate of grain size undertaken in the field at representative cross sections for similar lithologies.

Samples from twenty four localities taken during the survey have been analysed for grain size determination. The proportions of gravel, sand and mud were analysed as well as a detailed analysis of the sand fraction in each sample at 0.5 phi intervals.

The samples and results are listed in Figure 4.

Grain size analysis from other studies on cliffs in the area have also been utilised. These include data from the University of East Anglia and a University of Cambridge PhD thesis by J.P. Lunkka.

SEDIMENT INPUT FROM COASTAL CLIFF EROSION

Sample Number	Stratigraphy	Gravel %	Sand %	Mud %	Granulometric analysis of sand fraction in % -0.5 1.41	0.0 1.0	0.5 0.71	1.0 0.5	1.5 0.35	2.0 0.25	2.5 0.177	3.0 0.125	3.5 0.088	4.0 0.063	>phi >mm
E1C5A 3b	Red Crag	7.7	92.1	0.2	4.9	8.3	15.4	19.0	22.3	11.1	11.3	5.6	1.4	0.6	
E1C5A 3a	Red Crag	0.2	94.0	5.8	1.3	2.4	7.2	14.1	11.2	15.7	27.8	16.9	2.5	0.8	
E1C4A +3	Brickearth	0.0	71.6	28.4	0.0	0.1	0.3	0.9	4.9	17.9	27.1	30.9	15.6	2.3	
SWD6 +4	Norwich Crag	4.0	61.6	34.3	1.8	1.8	3.4	6.1	8.1	16.2	37.9	15.9	5.4	3.5	
SWD6 +3	Norwich Crag	0.0	10.3	89.7	0.5	0.2	0.3	0.5	3.6	23.2	42.0	17.4	6.8	5.6	
SWD3 -3b	Norwich Crag	2.6	53.6	43.9	1.2	1.1	1.0	0.7	0.9	2.5	38.2	36.1	14.1	4.3	
SWD3 -3a	Norwich Crag	1.0	90.6	8.3	2.8	3.6	3.4	2.3	2.5	2.9	16.0	35.5	18.9	12.3	
SWD2	Norwich Crag	0.0	1.8	98.2	1.2	2.7	6.4	11.6	17.5	18.0	17.5	11.8	4.1	9.3	
SWF2 +1	Lowestoft Till	6.5	11.4	82.1	4.6	4.5	5.0	5.4	9.5	12.1	12.9	16.3	15.8	14.0	
SWF2 +1	Corton Formation	0.0	60.5	39.5	0.4	0.2	0.3	0.4	1.1	2.3	5.8	24.9	52.9	11.6	
SWF2	Corton Formation - Till	5.4	67.9	26.6	1.4	1.8	3.4	6.6	14.3	17.7	15.0	16.8	14.0	8.9	
N4B1 -1	Corton Till	0.0	46.3	53.7	1.1	0.5	1.1	2.2	5.9	11.3	18.1	23.7	22.2	14.0	
N3B4 -3	Happisburgh Till	1.2	42.5	56.4	0.6	0.7	1.5	2.8	6.5	11.5	17.8	24.2	24.6	9.8	
N3B1 b	Happisburgh Clay	0.0	1.1	98.9	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	
N3B1 a	Happisburgh Diamict	1.3	53.9	44.8	0.0	0.6	3.2	3.0	4.8	9.5	15.8	24.7	19.1	19.3	
N3B1 -1	Happisburgh Clay	0.1	70.3	29.7	0.1	0.1	0.3	0.7	1.7	4.2	11.2	31.1	33.3	17.4	
N3C4	Mundesley Upper Sand	0.3	59.8	39.9	0.0	0.0	0.2	0.1	0.2	0.2	0.8	2.0	24.9	71.7	
N3C3 -1	Mundesley Upper Sand	0.0	79.2	20.8	0.0	0.0	0.1	0.1	0.2	0.2	0.1	4.8	47.1	47.4	
N3C2 -1	Walcott Diamict	0.0	4.0	96.0	0.0	0.0	1.2	1.2	2.4	1.2	3.7	14.6	22.0	53.7	
N3D6	Trimmingham Sand	0.5	78.1	21.5	0.4	0.2	0.7	1.5	4.5	9.7	23.3	32.2	16.0	11.4	
N3D6 -1	Trimmingham Sand	0.6	98.9	0.5	0.1	0.3	1.3	3.6	11.9	33.9	33.4	12.5	2.4	0.7	
N3D3	Trimmingham Clay	0.0	0.0	100.0	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	
N3D2 -2	Contorted Drift	0.0	98.8	1.2	0.0	0.0	0.0	0.0	0.1	7.2	66.3	22.5	3.0	0.9	
N3E6 -1	Contorted Drift	2.1	68.4	29.5	0.3	0.9	1.4	2.5	5.7	10.2	16.2	23.5	21.5	17.9	

Figure 4. Particle size analysis of samples from cliff sections

APPENDIX C: CLIFF SECTION DATA

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
E2A8	1	600779	212380	5.00	1	1.00	SOIL	80	15	5
E2A8	1	600779	212380	5.00	2	4.00	LONDON CLAY	85	15	0
E2A7	3	601430	212396	2.00	1	1.00	SOIL	80	15	5
E2A7	3	601430	212396	2.00	2	1.00	LONDON CLAY	85	15	0
E2A7	1	601842	212397	6.80	1	1.02	SOIL	80	15	5
E2A7	1	601842	212397	6.80	2	5.78	LONDON CLAY	85	15	0
E2A6	3	602202	212409	1.20	1	1.08	HEAD AND SOIL	80	15	5
E2A6	3	602202	212409	1.20	2	0.12	BRICK EARTH?	70	25	5
E2A6	1	602832	212485	1.70	1	1.70	LONDON CLAY AND SOIL	80	15	5
E2A5	2	602975	212540	2.00	1	0.50	SOIL	80	15	5
E2A5	2	602975	212540	2.00	2	1.50	LONDON CLAY	85	15	0
E2A5	1	603140	212580	2.00	1	0.50	SOIL	80	15	5
E2A5	1	603140	212580	2.00	2	1.50	LONDON CLAY	85	15	0
E2A4	2	603994	213020	1.50	1	0.60	FILL	5	70	25
E2A4	2	603994	213020	1.50	2	0.41	SOIL	5	35	60
E2A4	2	603994	213020	1.50	3	0.50	BRICK EARTH	5	70	25
E2A4	1	604100	213080	1.50	1	0.38	SOIL	5	35	60
E2A4	1	604100	213080	1.50	2	1.13	BRICK EARTH	5	70	25
E2A3	2	605280	213610	1.40	1	0.56	BRICK EARTH	10	70	20
E2A3	2	605280	213610	1.40	2	0.84	BRICK EARTH	20	70	10
E2A3	1	605337	213653	3.00	1	0.51	SOIL	80	15	5
E2A3	1	605337	213653	3.00	2	2.49	LONDON CLAY	85	15	0
E2A2	1	605760	213820	3.00	1	0.51	SOIL	80	15	5
E2A2	1	605760	213820	3.00	2	2.49	LONDON CLAY	85	15	0
E2A1A	7	606380	214200	1.20	1	0.83	BRICK EARTH AND SOIL	40	50	10
E2A1A	7	606380	214200	1.20	2	0.37	BRICK EARTH	20	55	25
E2A1A	6	606415	214285	1.25	1	0.86	BRICK EARTH AND SOIL	40	50	10
E2A1A	6	606415	214285	1.25	2	0.39	BRICK EARTH	20	55	25
E2A1A	5	606572	214379	4.60	1	0.46	SOIL	80	15	5
E2A1A	5	606572	214379	4.60	2	4.14	LONDON CLAY	85	15	0
E2A1A	4	606650	214449	4.80	1	1.20	PLEISTOCENE	5	10	85
E2A1A	4	606650	214449	4.80	2	1.20	PLEISTOCENE	5	75	20
E2A1A	4	606650	214449	4.80	3	2.40	LONDON CLAY	85	15	0
E2A1A	3	606754	214575	5.00	1	3.00	PLEISTOCENE	5	10	85

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
E2A1A	3	606754	214575	5.00	2	2.00	PLEISTOCENE	5	75	20
E2A1A	2	606858	214640	4.75	1	4.28	PLEISTOCENE	5	15	80
E2A1A	2	606858	214640	4.75	2	0.48	PLEISTOCENE	10	70	20
E1A5	2	617000	213962	2.80	1	0.56	SOIL	85	15	0
E1A5	2	617000	213962	2.80	2	0.56	LONDON CLAY	85	15	0
E1A5	2	617000	213962	2.80	3	1.68	LONDON CLAY	85	15	0
E1A5	1	617184	214124	9.00	1	9.00	LONDON CLAY	85	15	0
E1A4	3	617407	214278	15.80	1	15.80	LONDON CLAY	85	15	0
E1A4	2	617994	214762	15.00	1	15.00	LONDON CLAY	85	15	0
E1A4	1	618075	214805	15.00	1	15.00	LONDON CLAY	85	15	0
E1A3	2	618614	215174	14.56	1	14.56	LONDON CLAY	85	15	0
E1A3	1	618908	215348	14.00	1	14.00	LONDON CLAY	85	15	0
E1A2	2	619691	215776	13.41	1	13.41	LONDON CLAY	85	15	0
E1A2	1	619773	215847	13.50	1	13.50	LONDON CLAY	85	15	0
E1A1	2	620641	216332	13.56	1	13.56	LONDON CLAY	85	15	0
E1A1	1	620662	216331	11.70	1	11.70	LONDON CLAY	85	15	0
E1A1S	1	621469	216892	10.19	1	10.19	LONDON CLAY	85	15	0
E1B6	2	622073	217485	4.40	1	4.40	LONDON CLAY	85	15	0
E1B4	1	623524	218859	3.00	1	3.00	LONDON CLAY	85	15	0
E1B3	3	623800	219300	12.16	1	12.16	LONDON CLAY	85	15	0
E1B3	2	623900	219460	20.00	1	20.00	LONDON CLAY	85	15	0
E1B3	1	624073	219701	17.00	1	17.00	LONDON CLAY	85	15	0
E1B2	2	624317	220050	12.17	1	12.17	LONDON CLAY	85	15	0
E1B2	1	624651	220475	12.17	1	12.17	LONDON CLAY	85	15	0
E1B1	1	625175	221162	20.00	1	20.00	LONDON CLAY	85	15	0
E1C6	1	626243	222841	7.00	1	1.12	BRICKEARTH & SOIL	28	72	0
E1C6	1	626243	222841	7.00	2	5.88	LONDON CLAY	85	15	0
E1C5A	4	626263	222845	7.21	1	1.15	BRICK EARTH AND SOIL	28	72	0
E1C5A	4	626263	222845	7.21	2	6.06	LONDON CLAY	85	15	0
E1C5A	3	626522	223233	21.00	1	5.46	RED CRAG AND BRICKEARTH	10	85	5
E1C5A	3	626522	223233	21.00	2	15.54	LONDON CLAY	85	15	0
E1C5A	2	626589	223527	21.50	1	0.86	PLEISTOCENE	10	65	25
E1C5A	2	626589	223527	21.50	2	1.29	PLEISTOCENE	25	75	0
E1C5A	2	626589	223527	21.50	3	1.29	RED CRAG	5	95	0

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
E1C5A	2	626589	223527	21.50	4	1.08	RED CRAG	0	83	17
E1C5A	2	626589	223527	21.50	5	1.29	RED CRAG	6	94	0
E1C5A	2	626589	223527	21.50	6	15.70	LONDON CLAY	85	15	0
E1C5A	1	626640	223731	21.45	1	1.07	BRICKEARTH & CRAG	0	20	80
E1C5A	1	626640	223731	21.45	2	1.93	RED CRAG	45	50	5
E1C5A	1	626640	223731	21.45	3	18.45	LONDON CLAY	85	15	0
E1C4A	4	626650	223900	23.00	1	1.15	BRICK EARTH	28	72	0
E1C4A	4	626650	223900	23.00	2	21.85	LONDON CLAY	85	15	0
E1C4A	3	626680	224004	14.41	1	0.86	BRICK EARTH	28	72	0
E1C4A	3	626680	224004	14.41	2	13.55	LONDON CLAY	85	15	0
E1C4A	2	626672	224249	3.70	1	1.48	BRICK EARTH	28	72	0
E1C4A	2	626672	224249	3.70	2	2.22	LONDON CLAY	85	15	0
E1C4A	1	626700	224420	2.00	1	1.00	BRICKEARTH	28	72	0
E1C4A	1	626700	224420	2.00	2	1.00	LONDON CLAY	85	15	0
E1D1A	3	625480	231100	11.31	1	11.31	LONDON CLAY	80	15	5
E1D1A	2	625658	231410	12.00	1	12.00	LONDON CLAY	85	15	0
E1D1A	1	625839	231521	7.50	1	7.50	LONDON CLAY & VOLCANICS	80	15	5
E1D1B	4	625910	231580	6.10	1	6.10	LONDON CLAY	80	15	5
E1D1B	3	626300	231640	7.00	1	7.00	LONDON CLAY	80	15	5
E1D1B	2	626280	232140	5.50	1	5.50	LONDON CLAY	80	15	5
S2A5	2	629960	234180	3.25	1	0.13	SOIL	0	90	10
S2A5	2	629960	234180	3.25	2	2.80	RED CRAG	5	91	4
S2A5	2	629960	234180	3.25	3	0.33	LONDON CLAY	85	15	0
S2A5	1	630223	234274	12.00	1	0.48	SOIL	0	90	10
S2A5	1	630223	234274	12.00	2	10.32	RED GRAG	5	91	4
S2A5	1	630223	234274	12.00	3	1.20	LONDON CLAY	85	15	0
S2A4	3	630600	234500	17.11	1	0.68	SOIL	0	90	10
S2A4	3	630600	234500	17.11	2	14.71	RED CRAG	5	91	4
S2A4	3	630600	234500	17.11	3	1.71	LONDON CLAY	85	15	0
S2A4	2	630770	234560	13.63	1	0.55	SOIL	0	90	10
S2A4	2	630770	234560	13.63	2	11.72	RED CRAG	5	91	4
S2A4	2	630770	234560	13.63	3	1.36	LONDON CLAY	85	15	0
S2A4	1	631040	234650	6.71	1	0.27	SOIL	0	90	10
S2A4	1	631040	234650	6.71	2	5.77	RED GRAG	5	91	4

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
S2A4	1	631040	234650	6.71	3	0.67	LONDON CLAY	85	15	0
S2A3	3	631180	234770	2.50	1	0.10	SOIL	0	90	10
S2A3	3	631180	234770	2.50	2	2.15	RED CRAG	5	91	4
S2A3	3	631180	234770	2.50	3	0.25	LONDON CLAY	85	15	0
S2A3	2	631530	234850	6.00	1	0.24	SOIL	0	90	10
S2A3	2	631530	234850	6.00	2	5.76	RED CRAG	5	91	4
S2A3	1	631660	235030	7.20	1	0.29	SOIL	0	90	10
S2A3	1	631660	235030	7.20	2	3.67	RED GRAG	5	91	4
S2A3	1	631660	235030	7.20	3	3.24	LONDON CLAY	85	15	0
S2A2	2	631960	235610	11.60	1	0.46	SOIL	0	90	10
S2A2	2	631960	235610	11.60	2	9.98	RED CRAG	5	91	4
S2A2	2	631960	235610	11.60	3	1.16	LONDON CLAY	85	15	0
S2A2	1	632150	235920	5.00	1	0.20	SOIL	0	90	10
S2A2	1	632150	235920	5.00	2	4.30	RED CRAG	5	91	4
S2A2	1	632150	235920	5.00	3	0.50	LONDON CLAY	85	15	0
S2A1	3	632410	236250	10.00	1	0.40	SOIL	0	90	10
S2A1	3	632410	236250	10.00	2	8.60	RED CRAG	5	91	4
S2A1	3	632410	236250	10.00	3	1.00	LONDON CLAY	85	15	0
S2A1	2	632440	236300	7.80	1	0.31	SOIL	0	90	10
S2A1	2	632440	236300	7.80	2	6.71	RED CRAG	5	91	4
S2A1	2	632440	236300	7.80	3	0.78	LONDON CLAY	85	15	0
S2B7	3	633500	237730	6.00	1	0.24	SOIL	0	90	10
S2B7	3	633500	237730	6.00	2	5.76	RED CRAG	5	70	25
S2B7	2	633700	237840	5.20	1	0.21	SOIL	0	90	10
S2B7	2	633700	237840	5.20	2	4.99	RED CRAG	5	70	25
S2B7	1	633744	237883	7.50	1	0.30	SOIL	2	90	8
S2B7	1	633744	237883	7.50	2	3.08	UPPER RED CRAG	5	70	25
S2B7	1	633744	237883	7.50	3	2.48	LOWER RED CRAG	10	60	30
S2B7	1	633744	237883	7.50	4	1.65	LONDON CLAY	85	15	0
S2B6	2	633940	238010	14.28	1	0.57	SOIL	0	90	10
S2B6	2	633940	238010	14.28	2	7.57	RED CRAG	5	70	25
S2B6	2	633940	238010	14.28	3	6.14	LONDON CLAY	85	15	0
S2B6	1	634398	238375	16.37	1	0.65	SOIL	0	90	10
S2B6	1	634398	238375	16.37	2	13.42	RED CRAG	5	70	25

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
S2B6	1	634398	238375	16.37	3	2.29	LONDON CLAY	85	15	0
S2B5	2	634520	238520	16.37	1	0.65	SOIL	0	90	10
S2B5	2	634520	238520	16.37	2	13.42	RED CRAG	5	70	25
S2B5	2	634520	238520	16.37	3	2.29	LONDON CLAY	85	15	0
S2B5	1	635081	239107	6.05	1	0.61	SOIL	0	90	10
S2B5	1	635081	239107	6.05	2	5.45	RED CRAG	5	70	25
S2B4A	3	635440	239500	3.50	1	3.50	SOIL/HEAD AND RED CRAG	0	90	10
S2B4A	2	635610	239740	1.75	1	1.75	SOIL/HEAD	0	90	10
S2B4A	1	635660	239880	0.40	1	0.40	SOIL/HEAD	0	90	10
S1A4	2	646440	256590	10.00	1	0.40	SOIL	5	70	25
S1A4	2	646440	256590	10.00	2	9.60	NORWICH CRAG	0	99	1
S1A4	1	646600	256980	4.68	1	0.19	SOIL	5	70	25
S1A4	1	646600	256980	4.68	2	4.49	CORALLINE CRAG	0	99	1
S1A3	2	646560	257120	4.68	1	0.19	SOIL	5	70	25
S1A3	2	646560	257120	4.68	2	4.49	NORWICH CRAG	0	99	1
S1A1	3	647280	259500	1.80	1	1.80	TILL	20	60	20
S1A1	2	647390	259750	3.29	1	3.29	TILL	20	60	20
S1A1	1	647480	259910	2.40	1	2.40	TILL	20	60	20
S1B8	3	647580	260160	4.65	1	4.65	TILL	20	60	20
S1B8	2	647670	260550	8.40	1	4.20	TILL	20	60	20
S1B8	2	647670	260550	8.40	2	4.20	RED CRAG	5	90	5
S1B8	1	647650	260940	7.63	1	7.63	CHILLESFORD SANDS	1	98	1
S1B7	3	647630	261420	7.00	1	0.28	SOIL	5	90	5
S1B7	3	647630	261420	7.00	2	0.28	SUBSOIL	5	93	2
S1B7	3	647630	261420	7.00	3	6.44	CHILLESFORD SANDS	1	98	1
S1B7	2	647610	261560	4.50	1	4.50	CHILLESFORD SANDS	1	98	1
S1B7	1	647590	261940	9.20	1	0.64	SOIL	0	95	5
S1B7	1	647590	261940	9.20	2	8.56	CHILLESFORD SANDS	1	98	1
S1B6	5	647560	262130	6.63	1	0.27	SOIL	0	95	5
S1B6	5	647560	262130	6.63	2	6.36	CHILLESFORD SANDS	1	98	1
S1B6	4	647550	262320	4.59	1	0.18	SOIL	0	95	5
S1B6	4	647550	262320	4.59	2	4.41	CHILLESFORD SANDS	1	98	1
S1B6	1	647590	262930	3.50	1	3.50	MADE GROUND	20	60	20
S1B5	1	647500	263580	5.20	1	5.20	MADE GROUND	20	60	20

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
S1B1	1	647760	267680	7.60	1	0.30	COVER SANDS	1	96	3
S1B1	1	647760	267680	7.60	2	5.02	NORWICH CRAG	0	99	1
S1B1	1	647760	267680	7.60	3	2.28	GRAVEL	0	40	60
S1C7	5	647770	268015	9.80	1	0.39	COVER SANDS	1	95	4
S1C7	5	647770	268015	9.80	2	7.45	NORWICH CRAG	0	99	1
S1C7	5	647770	268015	9.80	3	1.96	GRAVEL	0	40	60
S1C7	4	647750	268240	8.10	1	0.32	COVER SANDS	1	95	4
S1C7	4	647750	268240	8.10	2	5.02	NORWICH CRAG	0	99	1
S1C7	4	647750	268240	8.10	3	2.75	GRAVELS	0	40	60
S1C7	3	647760	268360	11.25	1	0.68	COVER SANDS	5	90	5
S1C7	3	647760	268360	11.25	2	0.90	LOWESTOFT TILL	82	11	7
S1C7	3	647760	268360	11.25	3	4.05	NORWICH CRAG	0	95	5
S1C7	3	647760	268360	11.25	4	3.83	NORWICH CRAG	0	100	0
S1C7	3	647760	268360	11.25	5	1.80	GRAVEL	0	40	60
S1C7	2	647750	268420	10.00	1	0.40	COVER SANDS	5	90	5
S1C7	2	647750	268420	10.00	2	8.60	NORWICH CRAG	0	100	0
S1C7	2	647750	268420	10.00	3	1.00	GRAVEL	0	40	60
S1C7	1	647750	268880	7.20	1	0.29	SOIL AND COVER SANDS	0	95	5
S1C7	1	647750	268880	7.20	2	5.83	NORWICH CRAG	5	95	0
S1C7	1	647750	268880	7.20	3	1.08	GRAVEL	0	40	60
S1C6	3	647760	269520	8.60	1	0.69	SOIL AND COVER SANDS	2	93	5
S1C6	3	647760	269520	8.60	2	7.91	NORWICH CRAG	5	95	0
S1C6	2	647790	269800	7.10	1	0.36	COVER SANDS	5	90	5
S1C6	2	647790	269800	7.10	2	1.78	NORWICH CRAG	15	85	0
S1C6	2	647790	269800	7.10	3	4.97	NORWICH CRAG	1	98	1
S1C6	1	647810	270040	9.10	1	0.46	GRAVELLY SAND	0	95	5
S1C6	1	647810	270040	9.10	2	8.65	NORWICH CRAG	1	98	1
S1C5	6	647830	270090	9.20	1	0.64	COVER SANDS	0	95	5
S1C5	6	647830	270090	9.20	2	7.18	NORWICH CRAG	1	99	0
S1C5	6	647830	270090	9.20	3	1.38	NORWICH CRAG	0	50	50
S1C5	5	647830	270120	10.30	1	0.52	COVER SAND	5	90	5
S1C5	5	647830	270120	10.30	2	2.99	NORWICH CRAG GRAVEL	0	50	50
S1C5	5	647830	270120	10.30	3	6.80	NORWICH CRAG SAND	1	98	1
S1C5	4	647860	270270	8.40	1	0.50	SOIL / HEAD	5	95	5

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
S1C5	4	647860	270270	8.40	2	2.02	WESTLETON SANDS?	0	85	15
S1C5	4	647860	270270	8.40	3	5.88	CHILLESFORD SANDS	2	96	2
S1C5	3	647890	270420	4.60	1	1.10	HEAD / SOIL	5	90	5
S1C5	3	647890	270420	4.60	2	3.50	NORWICH CRAG	2	96	2
S1C5	2	647910	270500	7.20	1	0.36	GRAVELLY SOIL	0	95	5
S1C5	2	647910	270500	7.20	2	6.84	NORWICH CRAG	1	98	1
SWD9	2	651040	276320	8.40	1	0.34	LOWESTOFT TILL	82	11	7
SWD9	2	651040	276320	8.40	2	8.06	NORWICH CRAG	0	99	1
SWD9	1	651110	276480	6.20	1	6.20	LOWESTOFT TILL	82	11	7
SWD8	1	651240	277390	3.00	1	3.00	NORWICH CRAG	0	99	1
SWD7	3	651350	277630	6.10	1	2.01	NORWICH CRAG	0	97	3
SWD7	3	651350	277630	6.10	2	4.09	NORWICH CRAG	0	99	1
SWD7	2	651410	277920	6.00	1	0.36	SOIL	10	70	20
SWD7	2	651410	277920	6.00	2	0.60	NORWICH CRAG	0	99	1
SWD7	2	651410	277920	6.00	3	5.04	NORWICH CRAG	0	99	1
SWD7	1	651370	278180	5.90	1	0.18	SOIL	10	70	20
SWD7	1	651370	278180	5.90	2	0.41	NORWICH CRAG	0	95	5
SWD7	1	651370	278180	5.90	3	0.77	NORWICH CRAG	0	99	1
SWD7	1	651370	278180	5.90	4	2.01	NORWICH CRAG	60	40	0
SWD7	1	651370	278180	5.90	5	0.18	NORWICH CRAG	85	15	0
SWD7	1	651370	278180	5.90	6	2.36	NORWICH CRAG	34	62	4
SWD6	7	651500	278260	5.20	1	0.16	SOIL	10	70	20
SWD6	7	651500	278260	5.20	2	0.21	NORWICH CRAG	0	90	10
SWD6	7	651500	278260	5.20	3	0.62	NORWICH CRAG	0	99	1
SWD6	7	651500	278260	5.20	4	0.36	NORWICH CRAG	60	40	0
SWD6	7	651500	278260	5.20	5	0.99	NORWICH CRAG	85	15	0
SWD6	7	651500	278260	5.20	6	2.86	NORWICH CRAG	34	62	4
SWD6	6	651530	278450	4.97	1	0.15	SOIL	10	70	20
SWD6	6	651530	278450	4.97	2	0.45	NORWICH CRAG	0	95	5
SWD6	6	651530	278450	4.97	3	0.40	NORWICH CRAG	60	40	0
SWD6	6	651530	278450	4.97	4	0.55	NORWICH CRAG	10	90	0
SWD6	6	651530	278450	4.97	5	0.35	NORWICH CRAG	89	11	0
SWD6	6	651530	278450	4.97	6	3.08	NORWICH CRAG	34	62	4
SWD6	3	651620	278790	4.57	1	0.23	SOIL	10	70	20

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
SWD6	3	651620	278790	4.57	2	0.14	NORWICH CRAG	10	40	50
SWD6	3	651620	278790	4.57	3	0.87	NORWICH CRAG	0	99	1
SWD6	3	651620	278790	4.57	4	0.96	NORWICH CRAG	60	40	0
SWD6	3	651620	278790	4.57	5	0.82	NORWICH CRAG	85	15	0
SWD6	3	651620	278790	4.57	6	0.32	NORWICH CRAG	0	85	15
SWD6	3	651620	278790	4.57	7	1.23	NORWICH CRAG	15	80	5
SWD6	2	651670	278940	4.43	1	0.22	SOIL	10	70	20
SWD6	2	651670	278940	4.43	2	0.13	NORWICH CRAG	10	40	50
SWD6	2	651670	278940	4.43	3	0.84	NORWICH CRAG	0	99	1
SWD6	2	651670	278940	4.43	4	0.93	NORWICH CRAG	60	40	0
SWD6	2	651670	278940	4.43	5	0.80	NORWICH CRAG	85	15	0
SWD6	2	651670	278940	4.43	6	0.31	NORWICH CRAG	0	85	15
SWD6	2	651670	278940	4.43	7	1.20	NORWICH CRAG	15	80	5
SWD4	7	652082	279979	2.14	1	0.32	SOIL	5	85	10
SWD4	7	652082	279979	2.14	2	0.41	NORWICH CRAG	85	15	0
SWD4	7	652082	279979	2.14	3	0.71	NORWICH CRAG	0	85	15
SWD4	7	652082	279979	2.14	4	0.71	NORWICH CRAG	15	80	5
SWD4	6	652042	280062	6.70	1	0.27	SOIL	5	85	10
SWD4	6	652042	280062	6.70	2	3.62	NORWICH CRAG	0	98	2
SWD4	6	652042	280062	6.70	3	0.54	NORWICH CRAG	85	15	0
SWD4	6	652042	280062	6.70	4	1.27	NORWICH CRAG	0	85	15
SWD4	6	652042	280062	6.70	5	1.01	NORWICH CRAG	15	80	5
SWD4	5	652158	280263	5.25	1	0.16	SOIL	5	85	10
SWD4	5	652158	280263	5.25	2	2.63	NORWICH CRAG	0	95	5
SWD4	5	652158	280263	5.25	3	0.37	NORWICH CRAG	85	15	0
SWD4	5	652158	280263	5.25	4	1.05	NORWICH CRAG	0	85	15
SWD4	5	652158	280263	5.25	5	1.05	NORWICH CRAG	15	80	5
SWD4	4	652246	280442	3.85	1	0.12	SOIL	5	85	10
SWD4	4	652246	280442	3.85	2	1.81	NORWICH CRAG	0	95	5
SWD4	4	652246	280442	3.85	3	0.42	NORWICH CRAG	85	15	0
SWD4	4	652246	280442	3.85	4	0.73	NORWICH CRAG	0	85	15
SWD4	4	652246	280442	3.85	5	0.77	NORWICH CRAG	15	80	5
SWD4	1	652550	281150	3.00	1	0.09	SOIL	5	85	10
SWD4	1	652550	281150	3.00	2	1.83	NORWICH CRAG	0	95	5

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
SWD4	1	652550	281150	3.00	3	0.39	NORWICH CRAG	85	15	0
SWD4	1	652550	281150	3.00	4	0.69	NORWICH CRAG	15	80	5
SWD3	2	652632	281400	4.50	1	0.14	SOIL	5	85	10
SWD3	2	652632	281400	4.50	2	3.83	NORWICH CRAG	0	98	2
SWD3	2	652632	281400	4.50	3	0.54	NORWICH CRAG	15	80	5
SWD3	1	652900	281956	6.40	1	0.19	SOIL	5	85	10
SWD3	1	652900	281956	6.40	2	6.21	NORWICH CRAG	0	98	2
SWD2	6	653040	282380	5.85	1	0.12	SOIL	5	85	10
SWD2	6	653040	282380	5.85	2	2.22	NORWICH CRAG	1	97	2
SWD2	6	653040	282380	5.85	3	3.10	NORWICH CRAG	5	95	0
SWD2	6	653040	282380	5.85	4	0.41	NORWICH CRAG	80	20	0
SWD2	5	653141	282570	3.90	1	1.29	NORWICH CRAG	0	98	2
SWD2	5	653141	282570	3.90	2	0.47	NORWICH CRAG	1	98	1
SWD2	5	653141	282570	3.90	3	0.39	NORWICH CRAG	0	95	5
SWD2	5	653141	282570	3.90	4	1.79	NORWICH CRAG	5	95	0
SWD2	2	653419	283248	4.00	1	2.00	NORWICH CRAG	0	99	1
SWD2	2	653419	283248	4.00	2	1.72	NORWICH CRAG	43	54	3
SWD2	2	653419	283248	4.00	3	0.28	NORWICH CRAG	8	91	1
SWD2	1	653430	283321	3.20	1	1.76	NORWICH CRAG	0	99	1
SWD2	1	653430	283321	3.20	2	1.18	NORWICH CRAG	98	2	0
SWD2	1	653430	283321	3.20	3	0.26	NORWICH CRAG	5	95	0
SWD1	2	653454	283359	4.60	1	1.98	NORWICH CRAG	0	95	5
SWD1	2	653454	283359	4.60	2	2.39	NORWICH CRAG	98	2	0
SWD1	2	653454	283359	4.60	3	0.23	NORWICH CRAG	98	2	0
SWE8	3	653621	285980	3.70	1	0.74	LOWESTOFT TILL	82	11	7
SWE8	3	653621	285980	3.70	2	2.96	CORTON SANDS	0	99	1
SWE8	2	653603	286419	6.00	1	1.80	LOWESTOFT TILL	82	11	7
SWE8	2	653603	286419	6.00	2	4.20	CORTON FORMATION	0	99	1
SWE8	1	653600	286770	7.30	1	0.37	SOIL	25	70	5
SWE8	1	653600	286770	7.30	2	4.38	LOWESTOFT TILL	82	11	7
SWE8	1	653600	286770	7.30	3	2.56	CORTON FORMATION	0	99	1
SWE7	2	653571	286980	14.00	1	6.30	LOWESTOFT TILL	82	11	7
SWE7	2	653571	286980	14.00	2	7.70	CORTON FORMATION	0	99	1
SWE7	1	653560	287990	13.22	1	5.29	LOWESTOFT TILL	82	11	7

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
SWE7	1	653560	287990	13.22	2	7.93	CORTON FORMATION	0	99	1
SWE6	3	653642	288440	7.00	1	0.98	LOWESTOFT TILL	82	11	7
SWE6	3	653642	288440	7.00	2	3.71	CORTON FORMATION	0	99	1
SWE6	3	653642	288440	7.00	3	2.31	CROMER FOREST BED	16	82	2
SWE6	2	653678	288640	9.80	1	1.47	LOWESTOFT TILL	82	11	7
SWE6	2	653678	288640	9.80	2	6.76	CORTON FORMATION	0	99	1
SWE6	2	653678	288640	9.80	3	1.57	CROMER FOREST BED	16	82	2
SWE6	1	653670	288950	5.70	1	1.43	LOWESTOFT TILL	82	11	7
SWE6	1	653670	288950	5.70	2	1.88	CORTON SANDS	0	99	1
SWE6	1	653670	288950	5.70	3	2.39	FOREST BEDS	16	82	2
SWE5	2	653723	289181	6.00	1	3.36	CORTON FORMATION	0	99	1
SWE5	2	653723	289181	6.00	2	2.64	FOREST BED	16	82	2
SWE5	1	653780	289900	5.78	1	5.78	CORTON FORMATION	0	99	1
SWE4	1	654020	290620	7.40	1	7.40	CORTON FORMATION	0	99	1
SWE3	1	654200	290930	10.00	1	10.00	CORTON FORMATION	0	99	1
SWE2	1	654360	291540	7.80	1	7.80	CORTON FORMATION	0	99	1
SWF7	1	655500	293860	16.00	1	16.00	CORTON WOODS FORMATION	0	90	10
SWF6	2	655280	294020	14.00	1	14.00	CORTON WOODS FORMATION	0	90	10
SWF6	1	655100	294500	15.00	1	15.00	CORTON WOODS FORMATION	0	90	10
SWF5	1	655140	295320	15.00	1	15.00	CORTON WOODS FORMATION	0	90	10
SWF4	3	654820	295870	6.50	1	6.50	CORTON WOODS FORMATION	0	90	10
SWF4	2	654770	296190	8.80	1	8.80	CORTON WOODS FORMATION	0	95	5
SWF4	1	654730	296390	22.30	1	2.45	HEAD	5	93	2
SWF4	1	654730	296390	22.30	2	3.35	CORTON WOODS FORMATION	0	95	5
SWF4	1	654730	296390	22.30	3	3.57	PLEASURE GARDENS TILL	85	10	5
SWF4	1	654730	296390	22.30	4	4.01	LOWESTOFT TILL	82	11	7
SWF4	1	654730	296390	22.30	5	8.92	CORTON FORMATION	0	99	1
SWF3	2	654601	296940	17.70	1	0.89	HEAD	25	74	1
SWF3	2	654601	296940	17.70	2	2.66	CORTON WOODS FORMATION	0	95	5
SWF3	2	654601	296940	17.70	3	3.89	PLEASURE GARDENS TILL AND OULTON BEDS	85	10	5
SWF3	2	654601	296940	17.70	4	1.95	LOWESTOFT TILL	82	11	7
SWF3	2	654601	296940	17.70	5	4.78	CORTON FORMATION	0	99	1
SWF3	2	654601	296940	17.70	6	3.54	CORTON FORMATION TILL	27	68	5
SWF3	1	654479	297366	18.15	1	1.09	HEAD	25	74	1

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
SWF3	1	654479	297366	18.15	2	2.54	CORTON WOODS FORMATION	0	95	5
SWF3	1	654479	297366	18.15	3	1.45	PLEASURE GARDENS TILL	85	10	5
SWF3	1	654479	297366	18.15	4	3.45	LOWESTOFT TILL	82	11	7
SWF3	1	654479	297366	18.15	5	9.62	CORTON FORMATION	0	99	1
SWF2	3	654221	298020	13.50	1	0.95	HEAD	25	74	1
SWF2	3	654221	298020	13.50	2	4.05	LOWESTOFT TILL	82	11	7
SWF2	3	654221	298020	13.50	3	7.56	CORTON FORMATION	0	99	1
SWF2	3	654221	298020	13.50	4	0.95	CORTON TILL	27	68	5
SWF2	2	654117	298321	6.20	1	0.50	HEAD	25	74	1
SWF2	2	654117	298321	6.20	4	1.55	LOWESTOFT TILL	82	11	7
SWF2	2	654117	298321	6.20	3	1.36	CORTON FORMATION	39	61	0
SWF2	2	654117	298321	6.20	2	2.79	CORTON FORMATION	0	99	1
SWF2	1	653991	298613	7.20	1	0.50	SOIL/HEAD	25	74	1
SWF2	1	653991	298613	7.20	2	3.67	CORTON FORMATION	0	100	0
SWF2	1	653991	298613	7.20	3	3.02	CORTON FORMATION	27	68	5
SWF1	2	653661	299479	5.40	1	1.62	HEAD	25	74	1
SWF1	2	653661	299479	5.40	2	3.78	CORTON FORMATION	0	100	0
SWF1	1	653571	299788	4.00	1	4.00	CORTON FORMATION	10	85	5
SWG4	1	653334	300615	5.20	1	0.78	SOIL	49	50	1
SWG4	1	653334	300615	5.20	2	0.57	CORTON WOODS FORMATION	0	70	30
SWG4	1	653334	300615	5.20	3	3.85	CORTON WOODS FORMATION	10	85	5
SWG3	1	653156	301447	3.30	1	0.17	CORTON WOODS FORMATION	0	95	5
SWG3	1	653156	301447	3.30	2	3.14	CORTON FORMATION	0	99	1
SWG2	2	653142	301739	5.50	1	0.44	CORTON WOODS FORMATION	0	95	5
SWG2	2	653142	301739	5.50	2	5.06	CORTON FORMATION	0	99	1
SWG2	1	653050	302294	5.25	1	5.25	CORTON FORMATION	0	99	1
SWG1	1	652950	303140	7.70	1	7.70	CORTON FORMATION	0	99	1
N4A6A	1	653000	303500	7.80	1	7.80	CORTON FORMATION	0	99	1
N4B1	1	652098	314338	4.60	1	1.20	CORTON SANDS	39	61	0
N4B1	1	652098	314338	4.60	2	3.40	CORTON TILL	27	68	5
N4C5	3	651958	314550	8.75	1	0.53	SOIL	40	55	5
N4C5	3	651958	314550	8.75	2	1.05	CORTON SANDS	39	61	0
N4C5	3	651958	314550	8.75	3	2.98	CORTON TILL	54	46	0
N4C5	3	651958	314550	8.75	4	2.36	CORTON SANDS	38	61	1

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
N4C5	3	651958	314550	8.75	5	1.84	CORTON TILL	27	68	5
N4C5	2	651780	314880	9.10	1	9.10	CORTON FORMATION	15	84	1
N4C5	1	651597	315223	8.60	1	8.60	CORTON FORMATION	10	89	1
N4C4	2	651540	315350	8.90	1	4.45	LOWESTOFT TILL	82	11	7
N4C4	2	651540	315350	8.90	2	4.45	CORTON FORMATION	15	84	1
N4C4	1	651193	316131	8.75	1	7.00	LOWESTOFT TILL	82	11	7
N4C4	1	651193	316131	8.75	2	1.75	CORTON SANDS	39	61	0
N3B4	1	639400	330230	5.90	1	0.94	SOIL	5	90	5
N3B4	1	639400	330230	5.90	2	4.96	MUNDESLEY SANDS	0	99	1
N3B3	4	639140	330400	5.80	1	0.87	SOIL	0	98	2
N3B3	4	639140	330400	5.80	2	4.93	MUNDESLEY SANDS	2	96	2
N3B3	3	639040	330520	6.80	1	0.34	SOIL	5	90	5
N3B3	3	639040	330520	6.80	2	4.15	MUNDESLEY SANDS	2	96	2
N3B3	3	639040	330520	6.80	3	2.31	HAPPISBURGH DIAMICTON	44	54	2
N3B3	2	638880	330640	8.00	1	1.20	SOIL/HEAD	5	90	5
N3B3	2	638880	330640	8.00	2	3.76	MUNDESLEY SANDS	2	96	2
N3B3	2	638880	330640	8.00	3	0.64	LAMINATED SANDS	30	70	0
N3B3	2	638880	330640	8.00	4	1.92	HAPPISBURGH CLAY	99	1	0
N3B3	2	638880	330640	8.00	5	0.48	TILL	44	54	2
N3B3	1	638570	330890	9.00	1	1.26	SOIL/COVER SAND	5	94	1
N3B3	1	638570	330890	9.00	2	5.58	MUNDESLEY SANDS	1	98	1
N3B3	1	638570	330890	9.00	3	0.45	HAPPISBURGH CLAY	30	70	0
N3B3	1	638570	330890	9.00	4	1.26	HAPPISBURGH CLAY	99	1	0
N3B3	1	638570	330890	9.00	5	0.45	HAPPISBURGH DIAMICTON	44	54	2
N3B2	2	637990	331360	11.00	1	0.88	SOIL	5	90	5
N3B2	2	637990	331360	11.00	2	0.55	MUNDESLEY SANDS	0	100	0
N3B2	2	637990	331360	11.00	3	3.19	WALCOTT DIAMICTON	95	4	1
N3B2	2	637990	331360	11.00	4	2.31	HAPPISBURGH CLAY	99	1	0
N3B2	2	637990	331360	11.00	5	4.07	HAPPISBURGH DIAMICTON	44	54	2
N3B2	1	637620	331680	15.00	1	0.75	SOIL	5	90	5
N3B2	1	637620	331680	15.00	2	3.00	MUNDESLEY SANDS	0	100	0
N3B2	1	637620	331680	15.00	3	3.15	WALCOTT DIAMICTON	95	4	1
N3B2	1	637620	331680	15.00	4	4.35	HAPPISBURGH CLAY	99	1	0
N3B2	1	637620	331680	15.00	5	3.75	HAPPISBURGH DIAMICTON	44	54	2

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
N3B1	2	637390	331890	10.00	1	2.00	MUNDESLEY SANDS	20	80	0
N3B1	2	637390	331890	10.00	2	2.00	WALCOTT DIAMICTON	100	0	0
N3B1	2	637390	331890	10.00	3	4.30	HAPPISBURGH CLAY	100	0	0
N3B1	2	637390	331890	10.00	4	1.70	HAPPISBURGH DIAMICTON	100	0	0
N3B1	1	636854	332307	9.00	1	1.35	MUNDESLEY SANDS	0	100	0
N3B1	1	636854	332307	9.00	2	1.35	WALCOTT DIAMICTON	95	0	5
N3B1	1	636854	332307	9.00	3	3.06	HAPPISBURGH CLAY	99	1	0
N3B1	1	636854	332307	9.00	4	3.24	HAPPISBURGH DIAMICTON	44	54	2
N3C8	2	636480	332570	7.00	1	1.40	WALCOTT DIAMICTON	80	19	1
N3C8	2	636480	332570	7.00	2	2.80	HAPPISBURGH CLAY	30	70	0
N3C8	2	636480	332570	7.00	3	2.80	HAPPISBURGH DIAMICTON	100	0	0
N3C8	1	636016	332875	5.00	1	1.00	MUNDESLEY SANDS	30	70	0
N3C8	1	636016	332875	5.00	2	2.00	HAPPISBURGH CLAY	99	1	0
N3C8	1	636016	332875	5.00	3	2.00	HAPPISBURGH DIAMICTON	100	0	0
N3C7	1	635151	333493	5.00	1	4.00	MUNDESLEY SANDS	30	70	0
N3C7	1	635151	333493	5.00	2	1.00	HAPPISBURGH CLAY	99	1	0
N3C6	1	634461	334024	5.00	1	5.00	MUNDESLEY SANDS	30	70	0
N3C5	1	633431	334805	10.00	1	3.00	VALLEY GRAVELS & SANDS	0	50	50
N3C5	1	633431	334805	10.00	2	7.00	MUNDESLEY SANDS	30	70	0
N3C4	2	633151	335080	18.00	1	5.40	STOW HILL SANDS	0	100	0
N3C4	2	633151	335080	18.00	2	3.60	MUNDESLEY DIAMICTON	50	50	0
N3C4	2	633151	335080	18.00	3	7.20	MUNDESLEY UPPER SANDS	30	70	0
N3C4	2	633151	335080	18.00	4	1.80	WALCOTT DIAMICTON	100	0	0
N3C4	1	632693	335473	25.00	1	5.00	STOW HILL SANDS	5	90	5
N3C4	1	632693	335473	25.00	2	5.00	MUNDESLEY DIAMICTON	50	50	0
N3C4	1	632693	335473	25.00	3	13.75	MUNDESLEY UPPER SANDS	40	60	0
N3C4	1	632693	335473	25.00	4	1.25	WALCOTT DIAMICTON	95	0	5
N3C3	1	631997	336089	20.00	1	4.00	STOW HILL SANDS	0	100	0
N3C3	1	631997	336089	20.00	2	6.00	MUNDESLEY DIAMICTON	50	50	0
N3C3	1	631997	336089	20.00	3	6.40	MUNDESLEY UPPER SANDS	0	100	0
N3C3	1	631997	336089	20.00	4	3.60	WALCOTT DIAMICTON	100	0	0
N3C2	2	631700	336460	7.00	1	1.75	MUNDESLEY UPPER SANDS	20	80	0
N3C2	2	631700	336460	7.00	2	5.25	MUNDESLEY UPPER SANDS	20	80	0
N3C2	1	631412	336748	25.00	1	6.25	STOW HILL SANDS	0	100	0

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
N3C2	1	631412	336748	25.00	2	6.25	MUNDESLEY DIAMICTON	50	50	0
N3C2	1	631412	336748	25.00	3	8.75	MUNDESLEY UPPER SANDS	0	100	0
N3C2	1	631412	336748	25.00	4	3.75	WALCOTT DIAMICTON	96	4	0
N3C1	2	631220	336900	18.00	1	3.60	STOW HILL SANDS	0	100	0
N3C1	2	631220	336900	18.00	2	3.60	MUNDESLEY DIAMICTON	50	50	0
N3C1	2	631220	336900	18.00	3	2.70	MUNDESLEY UPPER SANDS	0	100	0
N3C1	2	631220	336900	18.00	4	8.10	WALCOTT DIAMICTON	96	4	0
N3C1	1	630682	337291	25.00	1	10.00	STOW HILL SANDS	0	100	0
N3C1	1	630682	337291	25.00	2	2.50	MUNDESLEY DIAMICTON	50	50	0
N3C1	1	630682	337291	25.00	3	11.25	MUNDESLEY UPPER SANDS	10	90	0
N3C1	1	630682	337291	25.00	4	1.25	WALCOTT DIAMICTON	95	0	5
N3D6	2	630420	337480	17.00	1	5.10	STOW HILL SANDS	0	100	0
N3D6	2	630420	337480	17.00	2	5.10	MUNDESLEY DIAMICTON	50	50	0
N3D6	2	630420	337480	17.00	3	4.76	MUNDESLEY SANDS	0	100	0
N3D6	2	630420	337480	17.00	4	2.04	WALCOTT DIAMICTON	100	0	0
N3D6	1	629717	338030	45.00	1	9.00	TRIMINGHAM SANDS	22	78	0
N3D6	1	629717	338030	45.00	2	31.50	CROMER DIAMICTON	40	60	0
N3D6	1	629717	338030	45.00	3	4.50	CHALK	6	1	0
N3D5	2	629160	338260	55.00	1	35.75	TRIMINGHAM SANDS	1	98	1
N3D5	2	629160	338260	55.00	2	5.50	MUNDESLEY DIAMICTON	95	0	5
N3D5	2	629160	338260	55.00	3	5.50	MUNDESLEY UPPER SANDS	20	80	0
N3D5	2	629160	338260	55.00	4	8.25	WALCOTT DIAMICTON	95	0	5
N3D5	1	628899	338399	60.00	1	18.00	MAYCROFT SANDS	0	50	50
N3D5	1	628899	338399	60.00	2	21.00	TRIMINGHAM SANDS	20	80	0
N3D5	1	628899	338399	60.00	3	12.00	MUNDESLEY SANDS	10	90	0
N3D5	1	628899	338399	60.00	4	9.00	WALCOTT DIAMICTON	95	0	5
N3D4	1	627870	339024	60.00	1	60.00	TRIMINGHAM SANDS/CLAYS	50	50	0
N3D3	1	627260	339361	20.00	1	20.00	TRIMINGHAM CLAYS	100	0	0
N3D2	2	627000	339540	25.00	1	6.25	TRIMINGHAM SANDS	20	80	0
N3D2	2	627000	339540	25.00	2	16.25	TRIMINGHAM CLAYS	100	0	0
N3D2	2	627000	339540	25.00	3	2.50	HAPPISBURGH DIAMICTON	50	50	0
N3D2	1	626310	339910	20.00	1	2.00	TRIMINGHAM SANDS	20	8	0
N3D2	1	626310	339910	20.00	2	16.00	SLUMP	90	10	0
N3D2	1	626310	339910	20.00	3	1.00	HAPPISBURGH CLAY	100	0	0

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
N3D2	1	626310	339910	20.00	4	1.00	HAPPISBURGH DIAMICTON	95	0	5
N3D1	3	625890	340180	30.00	1	9.00	TRIMINGHAM SANDS	20	80	0
N3D1	3	625890	340180	30.00	2	21.00	LAMINATED FINES	50	50	0
N3D1	2	625590	340400	30.00	1	18.00	LAMINATED FINES	1	99	0
N3D1	2	625590	340400	30.00	2	12.00	CHALK RAFT	6	1	5
N3D1	1	625316	340560	20.00	1	2.00	TILL	95	0	5
N3D1	1	625316	340560	20.00	2	3.00	SAND	0	100	0
N3D1	1	625316	340560	20.00	3	5.00	TILL	95	0	5
N3D1	1	625316	340560	20.00	4	10.00	SLUMP TILL AND SAND	70	30	0
N3E6	1	624751	341064	15.00	1	9.00	TILL AND SAND	50	50	0
N3E6	1	624751	341064	15.00	2	6.00	HAPPISBURGH CLAY	100	0	0
N3E5	3	624440	341170	20.00	1	6.00	CONTORTED DRIFT	0	100	0
N3E5	3	624440	341170	20.00	2	6.00	LAMINATED FINES	29	68	3
N3E5	3	624440	341170	20.00	3	8.00	SLUMP	29	68	3
N3E5	2	624080	341280	35.00	1	3.50	TRIMINGHAM SANDS	0	100	0
N3E5	2	624080	341280	35.00	2	14.00	CROMER DIAMICTON	100	0	0
N3E5	2	624080	341280	35.00	3	15.75	CROMER DIAMICTON	40	60	0
N3E5	2	624080	341280	35.00	4	1.75	HAPPISBURGH DIAMICTON	100	0	0
N3E5	1	623380	341485	60.00	1	30.00	TRIMINGHAM SANDS	0	100	0
N3E5	1	623380	341485	60.00	2	27.00	CROMER DIAMICTON	40	60	0
N3E5	1	623380	341485	60.00	3	3.00	HAPPISBURGH DIAMICTON	100	0	0
N3E4	1	622641	341972	50.00	1	25.00	TRIMINGHAM SANDS	0	100	0
N3E4	1	622641	341972	50.00	2	25.00	CROMER DIAMICTON	40	60	0
N3E3	1	621691	342367	20.00	1	13.00	DIAMICTON	80	15	5
N3E3	1	621691	342367	20.00	2	7.00	DIAMICTON	100	0	0
N3E2	2	621220	342460	20.00	1	13.00	DIAMICTON	80	15	5
N3E2	2	621220	342460	20.00	2	7.00	DIAMICTON	100	0	0
N3E2	1	620720	342573	20.00	1	12.00	DIAMICTON	70	30	0
N3E2	1	620720	342573	20.00	2	8.00	DIAMICTON	80	20	0
N3E1	2	620390	342670	15.00	1	15.00	DIAMICTON	5	94	1
N3E1	1	619746	342860	20.00	1	7.00	DIAMICTON	80	20	0
N3E1	1	619746	342860	20.00	2	6.00	CHALK RAFT	6	1	5
N3E1	1	619746	342860	20.00	3	7.00	DIAMICTON	100	0	0
N2A7	3	619280	343000	25.00	1	8.75	DIAMICTON	100	0	0

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
N2A7	3	619280	343000	25.00	2	3.75	SAND & GRAVEL	0	50	50
N2A7	3	619280	343000	25.00	3	7.50	CHALK RAFT	6	1	5
N2A7	3	619280	343000	25.00	4	5.00	SLUMP	100	0	0
N2A7	2	619070	343040	28.00	1	18.20	SAND	0	100	0
N2A7	2	619070	343040	28.00	2	9.80	DIAMICTON	100	0	0
N2A7	1	618824	343063	12.00	1	2.40	SAND & GRAVEL	0	50	50
N2A7	1	618824	343063	12.00	2	7.20	DIAMICTON	0	100	0
N2A7	1	618824	343063	12.00	3	1.20	CLAYEY SILT	100	0	0
N2A7	1	618824	343063	12.00	4	1.20	CROMER FOREST BED - PEAT	5	5	0
N2A6	3	618300	343170	15.00	1	3.75		100	0	0
N2A6	3	618300	343170	15.00	2	0.75		0	50	50
N2A6	3	618300	343170	15.00	3	5.25	DIAMICTON	60	40	0
N2A6	3	618300	343170	15.00	4	4.50	DIAMICTON	100	0	0
N2A6	3	618300	343170	15.00	5	0.75	CROMER FOREST BED - PEAT	5	5	0
N2A6	2	618200	343200	15.00	1	15.00	FINE SAND BED	10	75	15
N2A6	1	617796	343329	10.00	1	9.00	DIAMICTON	10	90	0
N2A6	1	617796	343329	10.00	2	1.00	DIAMICTON	100	0	0
N2A5	1	617060	343300	20.00	1	10.00	DIAMICTON	10	90	0
N2A5	1	617060	343300	20.00	2	4.00	DIAMICTON	100	0	0
N2A5	1	617060	343300	20.00	3	6.00	CHALK	6	1	5
N2A4	1	616448	343394	50.00	1	30.00	DIAMICTON	10	90	0
N2A4	1	616448	343394	50.00	2	12.50	DIAMICTON	100	0	0
N2A4	1	616448	343394	50.00	3	7.50	SAND	10	90	0
N2A3	1	615601	343507	25.00	1	15.00	DIAMICTON	10	90	0
N2A3	1	615601	343507	25.00	2	6.25	DIAMICTON	100	0	0
N2A3	1	615601	343507	25.00	3	3.75	SAND	10	90	0
N2A2	1	614548	343501	10.00	1	6.50	DIAMICTON	10	90	0
N2A2	1	614548	343501	10.00	2	2.00	DIAMICTON	95	0	5
N2A2	1	614548	343501	10.00	3	0.50	DIAMICTON	100	0	0
N2A2	1	614548	343501	10.00	4	1.00	DIAMICTON	10	90	0
N2A1	3	614180	343490	4.00	1	0.80	RUNTON SAND & GRAVEL	60	10	30
N2A1	3	614180	343490	4.00	2	3.20	RUNTON SAND & GRAVEL	0	50	50
N2A1	2	613750	343510	12.00	1	2.40	SAND & GRAVEL	0	50	50
N2A1	2	613750	343510	12.00	2	4.80	DIAMICTON	100	0	0

Agency Marker	Cliff Section	Easting	Northing	Cliff Height	Interval Number	Interval Height	Stratigraphy	Mud %	Sand %	Gravel %
N2A1	2	613750	343510	12.00	3	3.60	PREGLACIAL DEPOSITS	10	80	10
N2A1	2	613750	343510	12.00	4	1.20	CHALK	6	1	0
N2A1	1	613546	343520	10.00	1	5.00	DIAMICTON	50	50	0
N2A1	1	613546	343520	10.00	2	2.50	DIAMICTON	95	0	5
N2A1	1	613546	343520	10.00	3	1.50	PREGLACIAL DEPOSITS	0	50	50
N2A1	1	613546	343520	10.00	4	1.00	CHALK	6	1	0
N2B7	2	613100	343590	9.00	1	5.40	DIAMICTON	70	30	0
N2B7	2	613100	343590	9.00	2	2.25	PREGLACIAL	0	60	40
N2B7	2	613100	343590	9.00	3	1.35	CHALK	6	1	0
N2B7	1	612518	343598	9.00	1	4.95	DIAMICTON	50	50	0
N2B7	1	612518	343598	9.00	2	2.25	PREGLACIAL DEPOSITS	20	70	10
N2B7	1	612518	343598	9.00	3	1.80	CHALK	6	1	0
N2B6	1	611546	343634	8.00	1	4.80	DIAMICTON	50	50	0
N2B6	1	611546	343634	8.00	2	2.00	PREGLACIAL DEPOSITS	10	50	40
N2B6	1	611546	343634	8.00	3	1.20	CHALK	6	1	0
N2B5	1	611150	343700	5.00	1	2.50	DIAMICTON	20	75	5
N2B5	1	611150	343700	5.00	2	2.50	CHALK	6	1	0
N1D2	2	567720	342270	14.00	1	8.68	LOWER CHALK	6	1	0
N1D2	2	567720	342270	14.00	2	1.12	HUNSTANTON RED CHALK	6	1	0
N1D2	2	567720	342270	14.00	3	2.94	CARSTONE	10	80	10
N1D2	2	567720	342270	14.00	4	1.26	CARSTONE	5	55	40
N1D2	1	567379	341743	17.10	1	5.99	LOWER CHALK	6	1	0
N1D2	1	567379	341743	17.10	2	1.20	HUNSTANTON RED CHALK	6	1	0
N1D2	1	567379	341743	17.10	3	9.92	CARSTONE	10	80	10
N1D1	2	567250	341320	12.50	1	12.50	CARSTONE	10	80	10
N1D1	1	567156	340985	8.50	1	0.85	TILL	50	25	25
N1D1	1	567156	340985	8.50	2	7.65	CARSTONE	10	80	10