Archaeology South-East

ASE

Household Waste and Recycling Site, Willowbrook Road, Worthing West Sussex

An Environmental Characterisation and Interpretation

Planning Ref: WB/548/06

NGR: TQ 16179 03886
ASE Project no. 3595
Site Code: WWR 08

ASE Report No. 2009008
OASIS id: 54053

by Dr Matt Pope and Liane Peyre
With contributions by
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Abstract

A single borehole was sited ahead of proposed development at Viridor's Willowbrook Road property. The aim of this work was to characterise the palaeoenvironmental potential of sediments associated with the Teville Stream, a misfit stream which occupies a large alluvium filled inlet formerly known as Broadwater.

The core determined a sequence truncated by the excavation of a pit ahead of landfill emplacement. Beneath the landfill deposits and disturbed alluvial sediments associated with this development, a sequence of undisturbed alluvium was recorded preserving micropalaeontological evidence suggesting phased periods of estuarine conditions perhaps controlled by the formation of gravel bars across the mouth of the estuary. The sequence shows the formation of an intertidal inlet, with rising sea levels (possibly in the Bronze Age) open the lower reaches of a freshwater channel to intertidal conditions. Evidence for associated development of saltmarsh persists through much of the sequence while terrestrial pollen indicates deforestation in the Middle Bronze Age. A single AMS date (Cal BP 3690 to 3470) was obtained for this phase.

The site offers the first opportunity to study environmental history of drainage within the Worthing area and will repay more detailed study in future research.

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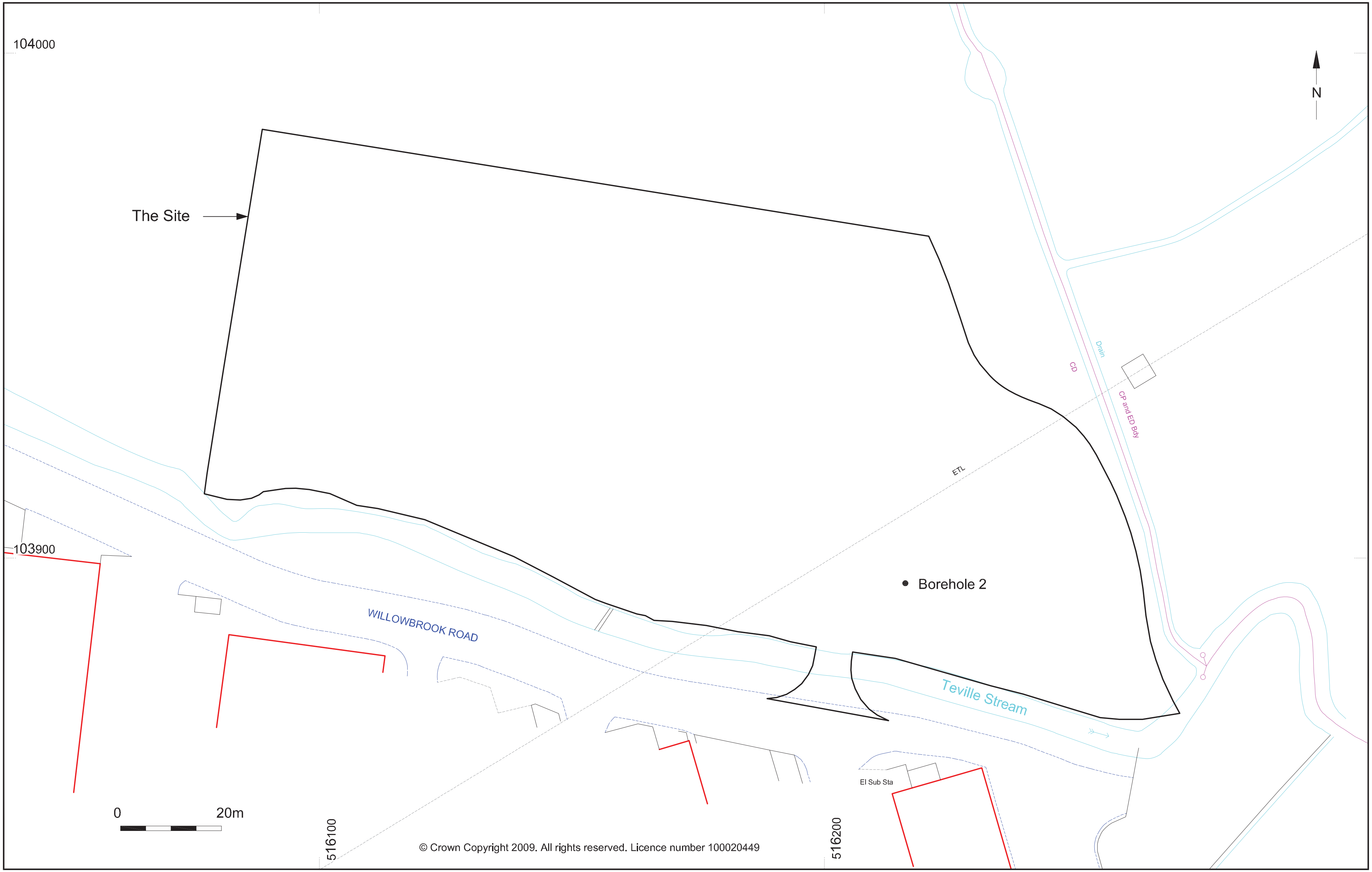
© **Archaeology South-East**		HWRS Willowbrook Road, Worthing	Fig. 1
Project Ref: 3595	Jan 2009	Site Location Plan	
Report Ref: 2009008	Drawn by: DH		



© Archaeology South-East		HWRS Willowbrook Road, Worthing	Fig. 2
Project Ref: 3595	Jan 2009	Location of borehole	
Report Ref: 2009008	Drawn by: JLR		

1.0 INTRODUCTION

1.1 Site Background

1.1.1 Archaeology South-East (ASE), the contracting division of the Centre for Applied Archaeology at the UCL Institute of Archaeology, were commissioned by Peter Brett Associates LLP on behalf of their client Viridor Waste Management to undertake an geoarchaeological borehole at the site of a new household waste and recycling site at Willowbrook Road, Worthing, West Sussex, (centred NGR: 516179, 103886; Planning Ref: WB/548/06), (Figs 1 and 2).

1.1.2 After discussion with John Mills, Senior Archaeologist, West Sussex County Council (WSCC) and under condition 16 of the planning condition, It was recommended to undertake a geoarchaeological investigation in advance of the proposed piling of the bridge foundations over the Teville Stream. The rest of the proposed ground works were not considered to have any impact on potential archaeological deposits.

1.1.3 The current document represents an Enhanced Assessment Report prepared with reference to the communication with WSCC, and their *Recommended Standard Archaeological Conditions* (version 2b), henceforth "the Standard Conditions". All work was carried out in accordance with these documents (unless otherwise specified below), and the relevant *Standards and Guidance* of the Institute of Field Archaeologists (IFA). It provides an updated version of an earlier assessment report incorporating pollen and AMS dating results.

2.0 GEOARCHAEOLOGICAL BACKGROUND

2.1 The site is located at NGR 516179, 103886), immediately to the north of the Brighton to Worthing Railway line and the Teville Stream (Figure 1). The ground level of the site stretches from 3m O.D. at the southern extent of the site to over 5m O.D. at the site's northern limit. The local Topography forms part of the Sussex Coastal Plain, which is some 4km wide at this point and bounded to the north by the South Downs and to the South by the modern coastline. The site is situated some 2km to the south of the inferred cliffline of the Brighton-Norton Raised Beach. Given the altitude of the site it is was considered possible that deposits forming part of the terrestrial and marine facies of the Norton Formation (Bates *et al* 1998) could be present at the site.

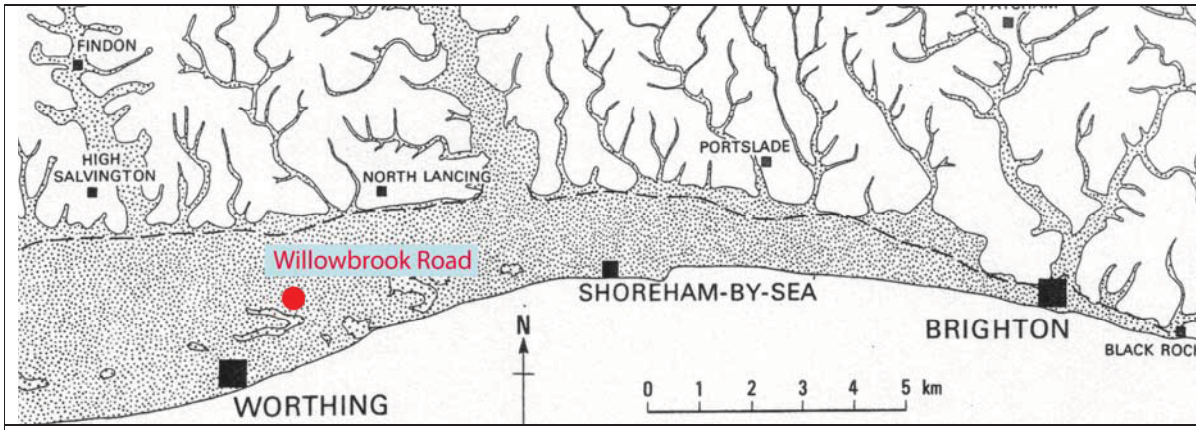


Figure 1: Location Map

2.2 The BGS Sheet 318 (1984) shows the site to be underlain by Storm Beach and Alluvial deposits although some Quaternary sedimentation is shown as also being present. The latter can be readily seen in the Black Rock raised beach section, 10.5 km to the east, and form a series of bedded colluvial deposits comprising red to pinkish silts supporting consolidated beds of sub-angular chalk and flint gravel. Some of these beds are orientated in relation to the remnant chalk cliff of the Brighton Raised Beach and will have bedding angles of up to 45 degrees orientated on a NE-SW axis. Others are of dry valley origin and will have generally horizontal bedding angles and form the fill of north-south oriented valley profiles (Young and Lake 1998; Gallois 1969).

2.3 It was thought, on the basis of inspection of geotechnical logs, that potential existed for palaeoenvironmental remains to be preserved at depth at the proposed development's location. The logs appeared to indicate that, underlying the Made Ground (landfill) and superficial Head Gravels, alluvial and marine deposits might be preserved. These were considered likely to contain important palaeoenvironmental material and to possibly preserve prehistoric archaeology. Basal marine sequences and the associated wave-cut platforms were also thought to be present.

2.4 While the environmental history of the major Sussex Rivers has been studied to an effective degree during the past 50 years (Thorley 1971; Kirkaldy and Bull 1940; Burrin 1988). The study of the in-filled rifes of the Sussex Coastal plain is very much in its infancy, their full potential to deliver long seqeunces having been recognised recently. Through both research and commercial projects being undertaken currently by Martin Bates (Lampeter) and Mark Roberts (UCL), the formation of rifes and their relationship to the drowned harbours of the coastal plain is starting to be understood as a process controlled in part by variation in sub-surface solid geology (Calcareous Chalk or Tertiary) and relating to the drowning and subsequent infilling of melt water channels. These melt water channels can be traced directly back across the coastal plain to both minor Downland river valleys (Ems, Lavant) and major dry valleys (eg. Slindon, Findon, Avisford Dell)

2.5 It was also thought possible that the work could help to determine the possibility that the Broadwater inlet could have served as a Harbour for Worthing during the Medieval period. Two Medieval accounts suggest a Harbour present on the Teville Stream in 1324 and 1493 and that this Harbour was considered a member of Shoreham Port (Hudson *et al*. 1980). With the gradual silting up of the inland Harbour at Steyning and Bramber by this time, estuarine Harbours on the coast at Shoreham and Worthing may have become more important as anchorages for shipping and for trade. Originally the inlet of the Teville Stream separated the hamlet of Broadwater and Worthing, the former presumably taking its name from the flooded estuary.

2.6 Accounts are given in the 16^{th} Century for off-shore bars forming along the Worthing coast leading to the formation of lagoons both east and west of Worthing (Hudson *et al.* 1980). One of these lagoons is likely to be the Broadwater inlet. Eventually large areas of dry land began to form behind these gravel bars, including the salt common at Worthing, until some of these areas became again subject to removal through marine erosion in the 18^{th} century. Undoubtedly the main controlling factor in the development of the coast line around Worthing is the distribution and changing morphology of off-shore gravel bars and beach gravel. Fluctuating fluvial and tidal regimes affecting the Teville inlet may well have been a feature of its early past too.

Figure 2: The Rig at Willowbrook Road

3.0 AIMS

3.1 The objective of the geoarchaeological work was to provide an assessment of palaeoenvironmental potential at the site. The work, when integrated alongside results of earlier geotechnical investigation at the site, could then be utilised to provide a first order stratigraphic model for the site.

3.2 Research Aims for this area:

- To investigate the geological formation processes at work on the site.

- To understand the historic development of the settlement and land use of the East Worthing area.

- To understand the use and development of landscape structure and sedimentation within the Broadwater/Teville Stream drainage area.

3.3 Specific Research Objectives for this area:

- To investigate evidence of the changing geological processes/topography of the area and ascertain its' potential for preserving archaeological artefacts/eco-facts.

- To recover palaeoenvironmental evidence and create a first order stratigraphic model of sedimentation.

- To investigate evidence of the changing geological processes/topography that may have covered earlier periods of archaeological activity through processes such as the formation of alluvium and marine inlet infill.

- To investigate and compare prehistoric activity on the site in relation to local findspots and monuments.

- To investigate evidence relating to the later development of the area during the Anglo-Saxon, medieval and post-medieval periods.

4.0 METHODOLOGY

4.1 Two boreholes, excavated using a standard Dando percussion rig (Figure 2), were undertaken close to the footprint of the proposed. Exact siting within the footprint was not possible due to a) proximity of power lines and b) steep slope gradients. Both boreholes were however sunk within 8m of the footprint area. While Borehole 1 (BH1) foundered in made ground hitting an obstruction, Borehole 2 (BH2) was sunk to a full 10m depth. The boreholes were recorded and sampled by Dr Matt Pope with the assistance of Liane Peyre, ASE.

4.2 Sediments were recorded in the following manner. Beneath the made ground, detailed observations will be made of the lithological and sedimentological character of sediments encountered. These comprise detailed sediment descriptions at 0.25m intervals or at the junction of major stratigraphic or lithological boundaries. The descriptions comprise matrix lithology, coarse components, sediment cohesion and well as characterisation of superficial structures and likelihood of decalcification. Where deposits suitable for environmental sampling were encountered (such as dated excavated contexts of buried soils, well-sealed slowly silting features, sealed hearths, sealed features containing evident carbonised remains, peats, water-logged or cess deposits), bulk soil samples (40 litres or 100% of smaller features) were taken for environmental analysis.

4.3 Where possible samples were recovered as continuous U100 samples. In each case the basal 0.2m of each U100 sample, which always sits outside of the sleeve, was retained as a bulk sample. In this way continuous profiles could be recovered.

4.3 Bulk samples and U100 cores are stored in secure, environment controlled facilities at ASE until it is decided that the p[programme of analysis is complete.

5.0 RESULTS

5.1 The following sedimentary sequence was recorded at the site for Borehole 2.

Depth	Stratigraphy	Lithology	Colour	Coarse Component	Sample	Notes
0	Made Ground					
2.5	Made Ground/Disturbed Alluvium	Firm Clay	5Y 5/2 Olive Grey with red mottles	None	None	Fleck of brick noted indicating disturbed nature of sediments.
2.7	Disturbed Alluvium	Firm Clay	5Y 5/2 Olive Grey with red mottles	None	U100i Complete Sample	
3.2	Disturbed Alluvium	Firm Clay	5Y 5/2 Olive Grey with red mottles	None	Bulk Sample Si	U100i shoe
3.5	Organic Alluvium	Stiff Clay	Gley 1 7/1 BG with 10% reddish mottles and Mn staining	None	Bulk Sample Sii	
3.7	Organic Alluvium	Stiff Clay	Gley 1 7/1 4BG with 10% reddish mottles and Mn staining	None	U100ii Complete Sample	
4.2	Organic Alluvium	Stiff Clay	Gley 1 7/1 5BG with 10% reddish mottles and Mn staining	None	Bulk Sample Siii	U100ii shoe
4.4	Organic Alluvium	Stiff Clay	Gley 1 7/1 5BG with 10% reddish mottles and Mn staining	None		Cleaning
4.6	Organic Alluvium	Cohesive Silty Clay	Gley 1 7/1 5BG with 10% reddish mottles and Mn staining	None	U100iii Complete Sample with macroscopic plant remains	Change to below within sealed U100 sample. AMS date at 4.62m (see below)
5.1	Marine Sand	Silty Sand	Gley 5/1 10 Greenish Grey	10% Rounded flint cobbles 10-40mm	Bulk Sample Siv	
5.3	Marine Sand	Silty Sand	Gley 5/1 10 Greenish Grey	10% Rounded flint cobbles 10-40mm	SV Organics Noted	
5.7	Weathered Reading Beds					
5.8	Reading Beds					Proved to 10m Depth

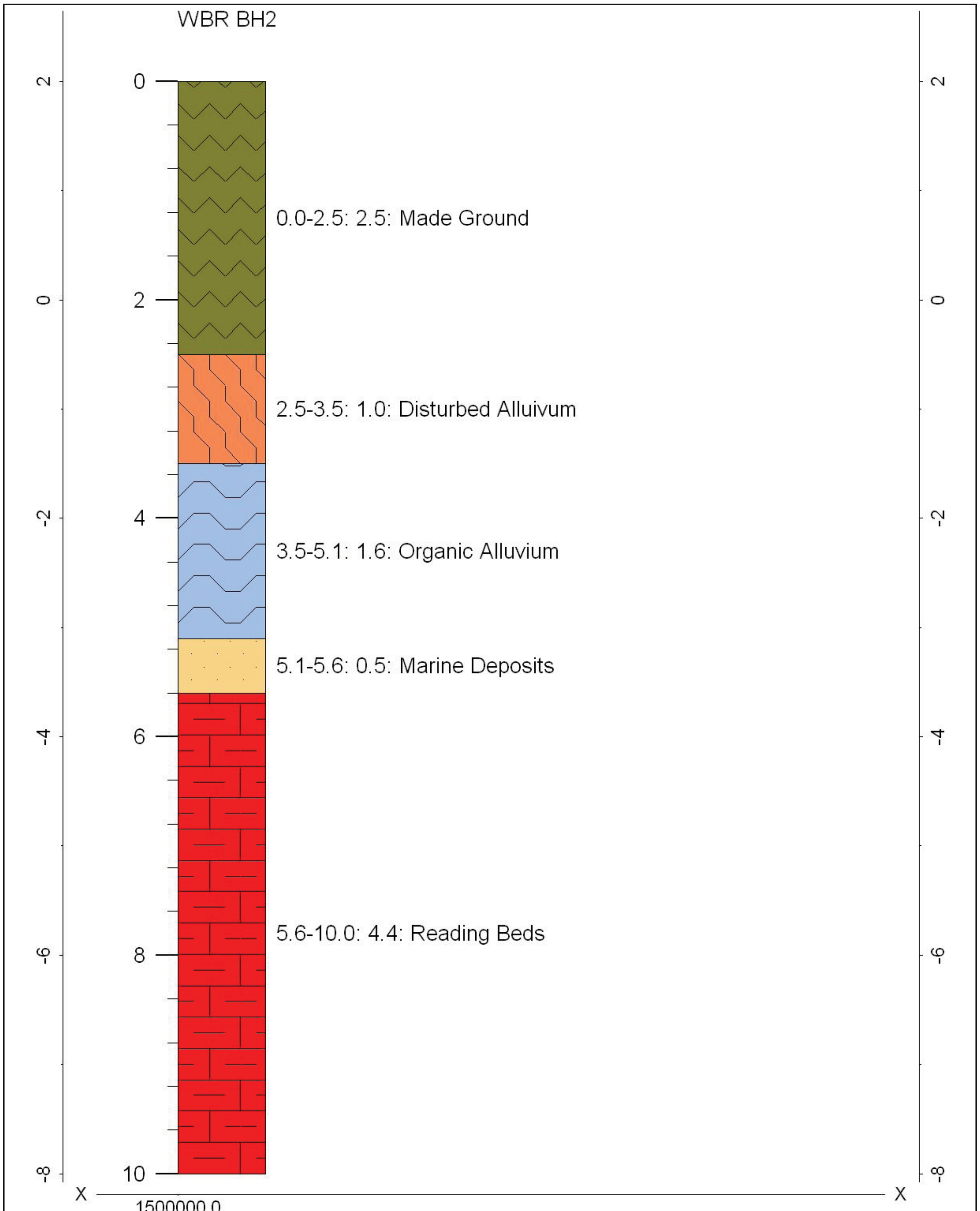


Figure 3: Strip log for Borehole Two at Willowbrook Road

5.2 The recorded sequence shows the emplacement of marine deposits on the solid geology of the Tertiary Reading Beds (Figure 3); these are currently thought on the basis of altitude to be related to Holocene marine deposition and not part of suites of Raised Beach deposits from the earlier Pleistocene.

5.3 The Upper facies of the Marine Sands contain finer silts and organic remains representing what appears to be the alluvial infilling of an open Estuarine inlet. The sand then give way to alluvial sedimentation with a series of organic silty clays containing macroscopic plant remains.

5.4 The upper facies of the alluvium appears to be significantly disturbed by activities associated with Landfill. The sequence is capped by in excess of 2.5m of domestic and industrial landfill.

6.0 THE ENVIRONMENTAL SAMPLES: CHARACTERISATION AND DATING

6.1 Micropalaeontology

6.1.1 Twelve samples were submitted in early December 2008 for microfaunal analysis, it was hoped the microfaunal assessment, using primarily the foraminifera and ostracods, would greatly assist in the reconstruction of the palaeoenvironment of the site through time.

61.2 After weighing, each sample was put in a ceramic bowl. The sediment was first broken by hand into very small pieces and then thoroughly dried in the oven. Boiling water was then poured on the sample and a little sodium carbonate added to help remove the clay fraction on washing. It was then left to soak overnight. The sample was then washed with hot water through a 75 micron sieve. Breakdown was not achieved initially, however, in some cases due to the high organic and clay content, and the procedure had to be repeated, whereupon a satisfactory breakdown was reached. The resulting residue was finally decanted back into the bowl for drying in the oven. When dry the sample was stored in a labelled plastic bag. Examination of the residue was undertaken under a binocular microscope. First the residue was put through a nest of dry sieves (>500, >250 and >150 microns) and then sprinkled out a fraction and a little at a time onto a tray. Any organic remains or items of interest were noted and the data incorporated, on a presence (x)/absence basis, into Figures 1 and 2, accompanying this report. The ostracods and foraminifera on the other hand, if they occurred, were picked out and placed on 3x1" faunal slides for archive purposes, the species being listed semi-quantitatively on the accompanying figures attached to this report.

6.1.3 The results of the microfaunal analysis are shown in Table 1. The uppermost columns show the total "Organic remains". Plant remains, seeds, etc. were found in all twelve samples, insect remains in six, molluscs in five, earthworm granules in four, and *Bithynia* opercula in two. The present study concentrates on the foraminifera and ostracods. Luckily, eight samples contained brackish foraminifera, two brackish ostracods and a further three, freshwater species. Finally, it is thought the mollusc fauna, albeit limited to only a few samples, would be useful in reconstructing the ecology especially of the uppermost sediments.

ORGANIC REMAINS

Depth in borehole	2.90-3.0m	3.00-3.10m	3.10-3.15m	3.15-3.80m	3.80-3.90m	3.90-4.00m	4.00-4.60m	4.60-4.70m	4.70-4.80m	4.80-4.90m	4.90-5.0m	5.00-5.05m
plant debris + seeds	x	x	x	x	x	x	x	x	x	x	x	x
molluscs	x	x	x						x			x
insect remains	x							x	x	x	x	x
earthworm granules	x	x	x	x								
freshwater ostracods	x	x	x									
***Bithynia* opercula**		x	x									
brackish foraminifera			x	x	x			x	x	x	x	x
iron tubes (rootlets)				x	x		x					
brackish ostracods									x	x		

Ecology	*freshwater/terrestrial habitat*		*intertidal flats, regressive; latterly with onset of freshwater habitat*			*?inlet blocked or dried up*		*estuarine; mid-high saltmarsh*				
	freshwater		brackish, tidal			?		brackish, tidal				
			▲ **end of marine access**					▲ **AMS Date**				

Table 1: Summary of organic remains

BRACKISH FORAMINIFERA Depth in borehole	2.90-3.0m	3.00-3.10m	3.10-3.15m	3.15-3.80m	3.80-3.90m	3.90-4.00m	4.00-4.60m	4.60-4.70m	4.70-4.80m	4.80-4.90m	4.90-5.0m	5.00-5.05m
Elphidium williamsoni			xx		o			x	xx	xx	x	x
Haynesina germanica			x	x	x			xxx	xxx	xx	x	xx
Ammonia sp.				x	x			xxx	xxx	xx	xx	xxx
Trochammina inflata								xxx	xxx	xxx	xx	xx
Jadammina macrescens								xxx	xxx	xxx	xx	x
Arenoparrella mexicana										x		
BRACKISH OSTRACODS Depth in borehole	2.90-3.0m	3.00-3.10m	3.10-3.15m	3.15-3.80m	3.80-3.90m	3.90-4.00m	4.00-4.60m	4.60-4.70m	4.70-4.80m	4.80-4.90m	4.90-5.0m	5.00-5.05m
Cyprideis torosa									x	x		
Leptocythere lacertosa									x	x		
Leptocythere castanea										x		
Leptocythere porcellanea										x		
FRESHWATER OSTRACODS Depth in borehole	2.90-3.0m	3.00-3.10m	3.10-3.15m	3.15-3.80m	3.80-3.90m	3.90-4.00m	4.00-4.60m	4.60-4.70m	4.70-4.80m	4.80-4.90m	4.90-5.0m	5.00-5.05m
Ilyocypris bradyi	o	o	xx									
Candona neglecta		o	x									
Prionocypris zenkeri			x									
Herpetocypris sp.			x									

Organic remains are recorded on a presence (x)/absence basis only
Foraminifera and ostracods are recorded: o - one specimen; x - several specimens; xx - common; xxx - abundant/superabundant

Calcareous foraminifera of low-mid saltmarsh and tidal flats
Agglutinating foraminifera of mid-high saltmarsh
Brackish ostracods of tidal flats and creeks

Table 2: Micropalaeontology

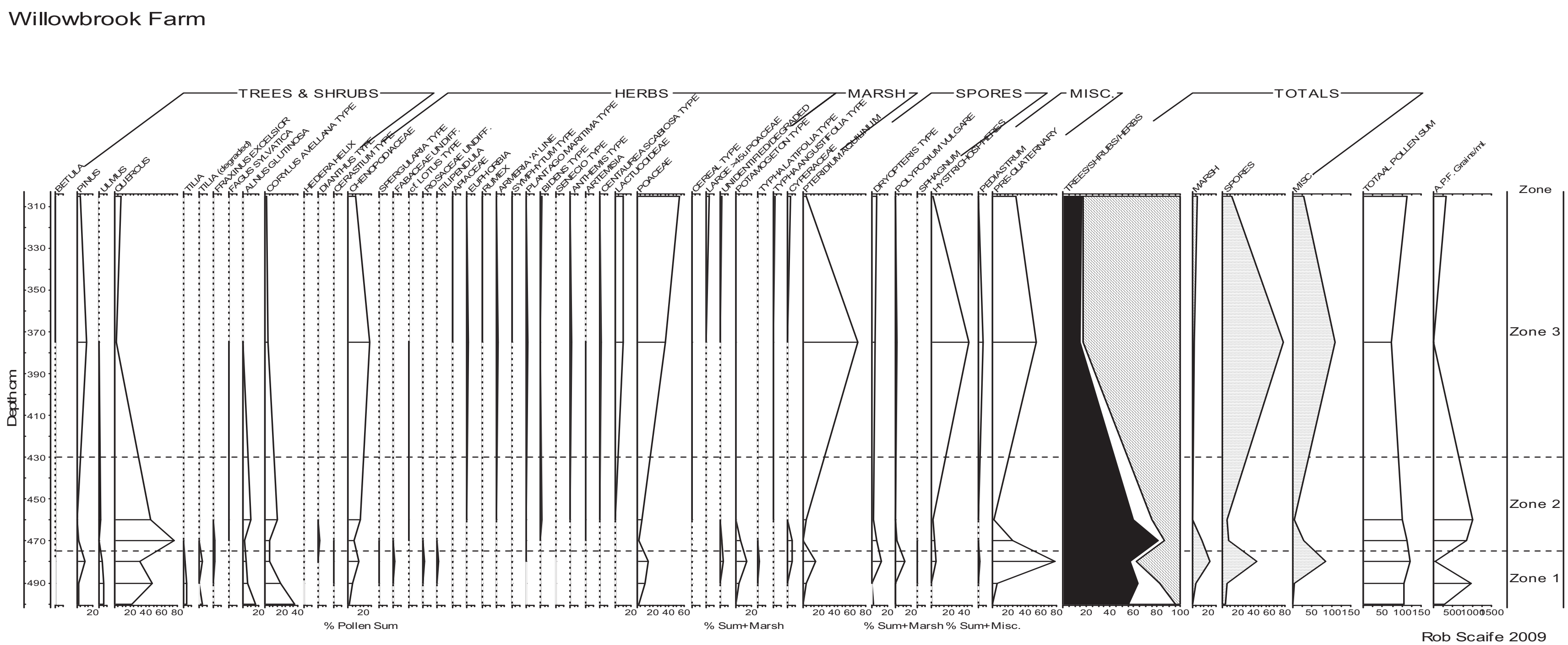


Table 3: Palynology: AMS Date at 4.62m

6.1.4 The lowermost sediments in BH 2, some 45cm of organic clay (interval 4.60-5.05m), contain a low-diversity, but extremely rich, foraminiferal fauna which is shown in the second set of columns in Figure 2. The foraminifera are colour-coded to show their ecological preferences: grey indicating the calcareous foraminifera of saltmarsh and tidal flats, and blue-green for the specialised agglutinating foraminifera of mid-high saltmarsh. The Appendix at the end of this report lists these species and gives more detailed information about their preferred habitats (after Murray, 2006). So, right from the onset, there is mid-high saltmarsh developed at the site, which must therefore have been situated on the fringes of the marine inlet that soon developed, possibly after a catastrophic breach of the coastal barrier during Holocene sea-level rise. It will be interesting to obtain the radiocarbon dating for this event. The dearth of ostracods in the same samples (third set of columns in Figure 1) – brackish species (colour coded lime-green) found only within the interval 4.70-4.85m – probably indicates that tidal mudflats were at a premium during this time, either due to the peripheral location of the site, and/or a relatively small tidal range.

6.1.5 The next two samples, covering the interval 3.95-4.10m, are completely barren of either foraminifera or ostracods. The colour of the facies changes, the brown clays wash down to next-to-nothing during processing, and all that remains in the residue is sparse plant remains and some iron tubes formed around rootlets. It is suggested that the inlet became cut off from the sea and possibly dried up completely. Future sampling of this interval would shed some light on this conundrum. At 3.90m in the core marine access was clearly restored, however, and the interval 3.10-3.90m contains a low diversity fauna of brackish foraminifera (colour-coded grey) indicative of intertidal flats, albeit in a regressive regime. Above 3.10m the foraminifera have gone completely and we must assume marine access, at least at the Willowbrook Road site, had ended. Whether the whole rife ceased to have tidal access through the closing of the coastal barrier - either through natural or man-made agencies - remains to be determined.

6.1.6 Before marine access was lost, however, a freshwater/terrestrial regime had become established. A study of the molluscs and a palynological analysis of the sediments above *c.*3.80m are necessary and will both add greatly to the environmental detail at this time. Significantly, earthworm granules also occur in the top four samples, reinforcing the terrestrial component here. The sample from 3.10-3.15m at least contains a reasonable fauna of four freshwater species of ostracods (lowermost column in Figure 1) typifying weedy pools and/or very slow-flowing water.

6.1.7 Some 2.15m of core (BH2) was analysed (interval 2.90 – 5.05m) in this Assessment Survey. The twelve samples (each of a 5cm slice) come from quite close intervals, with only 5cm gaps between samples for the most part, that is except for a gap of 60cm between 3.15m and 3.75m and a 50cm gap between 4.10m and 4.60m. It is recommended that these gaps are targeted in future to give the complete picture. Moreover, as we have seen, the nature of the actual onset of the inlet is unknown. The lowest sample analysed (5.00-5.05m) indicates that mid-high saltmarsh was already fully developed in the vicinity of the Willowbrook Road site. It would be hoped that a sample taken just above bedrock at the base of the core might be illuminating, that is if it had not been removed immediately by the erosion that must have taken place at the very moment the initial breaching of the then coastal barrier occurred. This was probably in itself a catastrophic event during a period of active sea-level rise. Preserved wood from this level was identified by L.Allott (ASE) as oak.

6.2 Pollen Analysis

6.2.1 A pollen assessment analysis has been carried out on sediments sub-samples obtained from between 3.05m and 5.0 metres. These comprise grey and grey brown (oxidised) silts and clays which appear to be of marine or brackish water origin. The study was undertaken primarily to determine presence or absence of sub-fossil pollen and spores and if present, to provide preliminary data on the habitat of deposition, local and regional vegetation. Pollen and spores were recovered from the 7 samples examined in varying quantities and degrees of preservation. The pollen assemblages confirm the saline origin of the sediments with evidence of halophytic plants and also provides date on other local and regional vegetation. This report details the results of this investigation.

6.2.2 *Pollen Method*

Standard pollen extraction techniques were used on samples of 2ml volume (Moore and Webb 1978; Moore *et al.* 1992). Total pollen (assessment) counts of 100 to 150 pollen grains per level, plus extant spores were identified and counted. Absolute pollen numbers were calculated using Stockmarr *Lycopodium* tablets (Stockmarr 1971). A pollen diagram (figure 1) was plotted using Tilia and Tilia Graph. Percentages used in this diagram were calculated as follows:

Sum =	% total dry land pollen (tdlp).
Marsh/aquatic =	% tdlp + sum of marsh/aquatics.
Spores =	% tdlp + sum of spores.
Misc. =	% tdlp + sum of misc. taxa.

Taxonomy, in general, follows that of Moore and Webb (1978) modified according to Bennett *et al.* (1994) for pollen types and Stace (1992) for plant descriptions. These procedures were carried out in the Palaeoecology Laboratory of the School of Geography, University of Southampton.

6.2.3 *The Pollen Data*

Pollen was present in all (7) of the samples analysed. Absolute pollen frequencies (APF) were calculated and values range from as low as 650 grains/ml at 3.75m to 92,00 grains/ml at 4.9m. Preservation was generally good, although there are some indications that pollen with robust pollen walls (exine) are differentially preserved in some levels. These comprise degrade *Tilia* (lime) in the lower levels and Lactucoideae (dandelion types) in the upper levels. This is clearly due to the minerogenic character of the sediments, the presence of some pollen reworked from earlier sediments or from long distance fluvial transport in sediment laden water. These do not, however, appreciably affect the validity of the data or any interpretation.

Overall, the pollen data show dominance of trees and shrubs in the lower levels and a contrasting dominance of herbs in the upper half of the profile. Three pollen assemblage zones have been defined. These are characterised from the base upwards as follows.

Pollen Zone 1: 5.0m to ca. 4.75m.

Quercus-Ulmus-Tilia-Corylus avellana type: Arboreal and shrub pollen are dominant with *Quercus* (oak; to 50%), *Corylus* (hazel; 37%) at the base of the profile with *Tilia* (5-10%). *Pinus* (pine; peak to 15%), *Alnus* (alder; 17%) and small numbers of *Fraxinus* (ash) are also present. Herb assemblages are less diverse than in overlying zones/levels. Chenopodiaceae (e.g. goosefoots and oraches) and Poaceae (grasses) are most important. Occasional occurrences of *Plantago maritima* (sea plantain) are an important indicator along with Chenopodiaceae, of saline conditions (salt marsh). Freshwater marsh taxa include Cyperaceae (sedges; peak to 6%), *Potamogeton* type (pond weed and/or sea arrow grass) and occasional *Typha latifolia* (greater reed mace). Spores of ferns include small numbers of monolete forms (*Dryopteris* type) and a peak of *Polypodium* (common polypody fern). There is a very substantial peak of derived, pre-Quaternary spores.

Pollen Zone 2: 4.75m to 4.30m.

Quercus: Values of *Pinus, Ulmus,* Tilia and *Corylus avellana* type all decline from the preceding zone. *Quercus* attains its highest percentage values at 4.70m (80%). Herbs remain relatively unimportant and as described for zone 1. There are reduced numbers of spores and a sharp reduction in the pre-Quaternary palynomorphs. Hystrichospheres (dinoflaggellates) start to occur in the profile.

Pollen Zone 3: 4.30m to 3.0m.

Chenopodiaceae-Poaceaea-Lactucoideae-Pteridium aquilinum. Tree and shrub pollen decline to very low levels whilst herbs become dominant. The latter includes increases in Chenopodiaceae (to 30%) and Poaceae (to 76% at the top of the profile). There is also an increase in the diversity of herbs which also includes halophytes – *Armeria* (thrift or sea lavender), *Plantago maritima* type (sea plantain) and the Chenopodiaceae (goosefoots, oraches and glassworts) noted above. Also present are small numbers of cereal type pollen and a range of marsh and aquatic taxa with *Typha angustifolia* type (bur reed and/or reed mace), *T. latifolia* (greater reedmace), *Potamogeton*, Cyperaceae and cysts of algal *Pediastrum.* There are very substantial numbers of *Pteridium* spores Hystrichospheres and secondary pre-Quaternary/geological palynomorphs at 3.75m where pollen preservation is poor and absolute pollen frequencies are low.

6.2.4 *The Palaeovegetation and Environment*

The taphonomy of the pollen in these sediments is complex. The microfossils (pollen, spores, Hystrichospheres and reworked geological palynomorphs) may derive from a number of different sources by both fluvial and airborne transport. Whilst the majority of the pollen is of Holocene age and probably broadly contemporaneous with the sediment deposition, the numbers of reworked palynomorphs present clearly indicates the erosion of bedrock geology or more probably of earlier alluvial sediments. Interpretation of the pollen data can, however, be viewed in terms of the on-site habitat of deposition and associated wetland environment and the non-wetland local and regional vegetation communities.

From the base of the sequence at *ca.* 5.0m, there is increasing evidence of brackish water and/or marine conditions. Chenopodiaceae (goosefoots, oraches and glassworts i.e. halophytes) although sparse in the basal sample increase progressively throughout zone 1 and into zone 2 and 3. Other less well represented halophytes, *Plantago maritima* (sea plantain) and *Spergularia* (sea spurrey), are also present. This probably represents the development of salt marsh associated with rising Holocene relative sea-level during the late prehistoric period. Alder (*Alnus glutinosa*) is present in the lower levels but, however, numbers are not sufficient to indicate any local growth of floodplain, fen carr woodland; it produce very copious numbers of wind transported pollen which would be expected.

At the top of zone 1/base of zone 2, there are minor peaks of sedges (Cyperaceae), pond weed or arrow grass (*Potamogeton/Triglochin* type), greater reed mace (*Typha latifolia*) and algal *Pediastrum* which suggest a short lived phase of freshwater marsh within this increasingly marine/salt marsh habitat. However, substantial numbers of reworked geological pollen and spores with some hystrichospheres and small absolute pollen frequencies at this point in the profile, indicates that there was a strong element of pollen which was transported from elsewhere within the catchment. Chenopodiaceae are also present at this point and as such, brackish/saline conditions probably existed on the site with freshwater marsh elements fluvially transported by rivers from elsewhere. Subsequently, the salt marsh and possibly mud-flat habitat becomes fully developed shown by high values of Chenopodiaceae with thrift/sea-lavender (*Armeria* type), sea plantain (*Plantago maritima*). Hystrichospheres (dinoflaggellates) of marine origin may be of Holocene age but, however, could be associated with the large numbers of reworked pre-Quaternary pollen and spores. Large numbers of the latter are an indication of mud flat.

6.2.6 *The Terrestrial Zone*

The pollen spectra are interesting showing evidence of dominant woodland at the base of the profile (zone 1) and its reduction (zone 2) to very low levels (zone 3).

Initially, Oak (Quercus) and hazel (Corylus) appear to be most important with some lime (*Tilia*) and elm (*Ulmus*). The latter has highest values in the lowest levels and was clearly an important constituent as shrub layer within oak woodland and/or as hazel scrub. Lime is usually considered as being under-represented in pollen spectra (Andersen 1970, 1973) due to its entomophily (insect pollination) and in addition to this is also poorly dispersed due to the fact that it flowers in mid summer at a time when other trees are in full leaf. Consequently it is probable that lime was more important in the landscape at this time than the pollen data here would indicate. There is much evidence from southern and eastern England for such importance during the middle Holocene until its clearance usually during the late Neolithic to early Bronze Age (Greig 1982; Scaife 2000; Waller 1994).

This woodland, especially lime and elm, decline at 4.80-4.70m (zone 1-2) and there is a sharp increase in oak in response. There are also small numbers of ash (*Fraxinus*) at this horizon and subsequently beech (*Fagus*). Both taxa are markedly under represented in pollen spectra (even more so than lime). The former is diagnostically, a secondary woodland element, often colonising (as here) areas where elm or limes had been cleared. With regard to beech, any opening of the environment allows its large and heavy pollen grains, to be disseminated over greater distances. Thus, presence of these taxa implies some local growth although fluvial transport should also be considered.

Whether this reduction of woodland, and the resulting changes in woodland structure, is due to human activity or other factors is not yet clear. This is because typical/diagnostic indicators of clearance for arable or pastoral agriculture (cereal pollen and ribwort plantain) were not found. However, it seems probable that human clearance was responsible since late-prehistoric deforestation is widely seen in pollen spectra from southern England and especially the Neolithic Elm Decline and the late Neolithic and Bronze Age Lime Decline and subsequent agricultural. However, changing in taphonomy or a hiatus in sedimentation must also be considered. As noted above, the site shows the increasing importance of marine/brackish water conditions. As this progressed, it is possible that the source areas of this woodland pollen became farther removed from the sample site, thus reducing the pollen input from these communities. Waller (1994) has discussed this phenomenon in relation to the Lime Decline. Whilst this is a possible factor here, there was, never the less, clearance of woodland during the late prehistoric period. It is felt that the changes here do, in fact, relate to agricultural changes. Small numbers of cereal pollen and weeds are present in the upper levels. After clearance, occasional oak and hazel pollen are the main constituents of pollen spectra and are typical of late prehistoric and historic pollen assemblages.

Another taphonomic feature is the occurrence of pine (to 15%) of the totals at 4.75m and 3.75m. The former is at a level of poor preservation which may have caused over representation of this robust pollen type. Pine pollen is also, however, over represented in fluvial, freshwater and marine conditions due to its buoyancy. As such, presence here is not regarded as of any significance with the pollen coming from long distance sources (fluvial and/or airborne transport).

6.2.7 *Pollen Summary*

6.2.8 The following main points have been made.

- Sub-fossil pollen and spores were extracted from all of the samples examined. However, the absolute pollen frequencies and preservation was variable. This is typical of alluvial and salt marsh sediments.

- Three pollen assemblage zones have been delimited which show the inherent changes in the pollen spectra.

- The pollen taphonomy is complicated with pollen arriving by airborne and fluvial transport also with the presence of some reworked earlier material (primarily pre-quaternary/geological palynomorphs).

- The on-site conditions appear to have been phases of salt marsh and mud-flat which would have developed as a consequence of rising (relative to land) sea-level. This is evidence by halophytic vegetation types.

- There are indications of freshwater input into the sediments especially towards the base of sequence (zone 1-2 boundary).

- Of importance is the evidence of dominant woodland seen at the base of the profile. This woodland consisted of oak, elm, lime and hazel.

- There was decline in elm and lime and evidence of secondary colonisation by ash (possibly also beech). Oak was, however the dominant woodland type. This change in woodland structure is thought to be due to woodland clearance. However, taphonomic changes caused by salt marsh/mud flat development has also been considered.

- A further reduction in this woodland occurred after which there is some evidence of cereal cultivation.

- Overall, the profile is of interest and use showing the late-prehistoric change from a wooded to a more open landscape and the on site development of salt marsh.

7.0 SYNTHESIS AND CONCLUSIONS

7.1 This work has provided the first comprehensive geoarchaeological study of the depositional history of the Broadwater/Teville Stream inlet. The recovered sedimentary sequence provides a record of environmental change, documenting at least four broad phases of deposition within the inlet. The sequence has unfortunately been truncated towards the top of the sequence, during a period of freshwater deposition, through the excavation of the landfill site. The possibility of later returns to intertidal activity, truncated and therefore unavailable to study cannot be ruled out. Especially in light of known breaches of offshore gravel bars, causing significant coastal erosion, during the Medieval period and in the 18th century.

7.2 Modelling of the channel using existing geotechnical data, while attempted, was not possible given the scope of original recording, however the extent of the inlet is possible to determine through reference to the BGS sheet 318.

7.3 Three phases in broad agreement between the pollen and micro-palaeontological evidence can be determined.

Phase 1: Saltmarsh. From base of hole (5.05m) to 4.75m. Both pollen and micropalaeontology indicate a developing estuarine salt marsh open to the sea at the beginning. Indications from the pollen, although not corroborated from micropal suggest a freshwater component to the regime here, possibly a fully active and incising winterbourne comprising the lower reaches of the Findon Valley drainage. Rising sea levels are indicated throughout this zone with larger number of mid-high saltmarsh forams from the start but becoming more abundant towards the end of the phase. Sea level rise was apparently rapid and may in part have been accelerated by the local breaching of a marine shingle barrier. The inlet was surrounded by mixed oak-hazel-lime-elm forest with sedge and reed mace dominating the channel-edge plant communities.

Phase 2: 4.75m to 4.3m. Decline of lime and elm indicated, probably due to clearance although the effects of rising sea levels on local lime tress may be significant. Continued presence of intertidal, saltmarsh conditions indicated by micropal. A single AMS date from this phase (4.62m) gave a conventional radiocarbon age of 3,340 B.P. (+/- 40 years) which, with 2 Sigma calibration, produced a date Cal BC 1740 to 1520 (Cal BP 3690 to 3470) was obtained, placing it within the Middle Bronze Age. This period covers known decline of *Tilia*, thought to be linked to agricultural land clearance although could possibly result from the effects of rising sea level on local forest cover at the inlet margins.

Phase 3: 3.95 to 4.3m. Indications of at least seasonal drying out of inlet, perhaps due to channel migration of breaching of the marine barrier at another location. Seasonally wet mudflat forms across the locale. In the surrounding environment extensive woodland clearance is indicated by relative rise in non-arboreal pollen. The absence of cereal grains does not directly indicate arable agriculture.

Phase 4: 3.10- 3.95m A return to brackish sedimentation in a Saltmarsh, tidal mud flat environment. Open terrestrial conditions persist in the surrounding landscape.

Phase 5: 2.9m – 3.1m Freshwater fluvial regime and local stabilisation of landsurfaces. Open conditions persist in surrounding landscape. Alluvial sedimentation of relatively permanent water course. Seqeunce then truncated by landfill.

7.4 The conclusions drawn from this study indicate that the Broadwater/Teville stream inlet represents a flooded fluvial channel, similar in character to that of the Aldingbourne Rife investigated recently at North Bersted (Roberts and Pope 2007) but prevalent across both the Sussex Coastal Plain (Allen *et al.* 2004) and within the coastal marshes of East Sussex (Woodcock 2003; Greatorex 2003). As with the Aldingbourne Rife, the Willowbrook Road sequence represents an infilled estuarine channel. The channel is the downstream continuation of large dry valley at Findon which can be traced across the coastal plain from the modern coast to the downs. The size and extent of the Findon Valley and offshore mapping which shows it as a major contributor to the English Channel drainage system during cold stages of the Pleistocene, suggests it was a major melt water drainage channel which then would have continued as an active fluvial channel in the early Holocene especially during periods where ground water levels were high.

7.5 As sea levels rose through the Holocene, the lower reaches of this valley appears to have become a flooded, inter-tidal inlet, which continued to be a body of relatively open intertidal water within the Middle Bronze Age. However sea level alone cannot explain the exact timing of inter-tidal conditions. Across Sussex the sea level inundates river valleys at varying times through the Early to Late Bronze Age (Woodcock 2003). It is likely that it is breaching of coastal shingle barriers, and their changing distribution along the coast, which is controlling the specific time tidal influences appear. The evidence for subsequent phases of mudflat formation, brackish inundation and freshwater regimes would most likely have continued into the upper, now truncated part of the sequence. The limited dating evidence has not allowed us to determine if the channel was open in the Medieval period, providing the Worthing/Broadwater Harbour. However it seems likely that the deposits recorded here for the Teville Stream, relate to the earlier sedimentary history of the same inlet.

8.0 PUBLICATION PROJECT

8.1 Revised Research Agenda: Aims and Objectives

8.1.1 In light of assessment and analysis of the site, it is now possible to revise the research aims towards the final objective of producing a publishable report on the fieldwork. Given that the sequence is now thought to predominantly cover pre-medieval periods and specifically give indication of changes in channel development during the Bronze Age, the research aims have been recast as follows:

8.1.2 RRA 1: To what extent can changes in the sedimentary regime at Willowbrook Road be correlated with similar processes already documented for the Aldingbourne Rife and other contexts on the West Sussex Coastal Plain?

8.1.3 RRA2: Can correlations with changes in fluvial/tidal regime be established more widely with sites elsewhere on the south coast?

8.1.4 RRA3: To what extent is sea level rise playing in the changing sedimentary regime? Can differences in the timings of marine transgression from site to site be related to local characteristics of topography and channel morphology?

8.1.5 RRA4: What evidence can be found to support the role of human agency in vegetation change, specifically elm and lime decline?

8.2 Preliminary Publication Synopsis:

8.2.1 It is suggested that the results of the excavation should be published in an article of around 3- 5,000 words, in a relevant archaeological journal such as Sussex Archaeological Collections. This should present a summary of fieldwork, a chronological reconstruction of environmental and sedimentary change and synthesis of earlier work on similar marine channel contexts within the region and attempt to address the questions posed in the revised research agenda.

8.2.2 The article would follow this proposed structure:

- Introduction
- Circumstances and methodology of fieldwork
- Sedimentary sequence
- Environmental change through the sequence
- Comparison with other recorded inlet sequences in terms of chronological distribution and evidence for anthropogenic involvement.
- Discussion on controlling factors in channel development.
- Bibliography

8.3 Publication Project: Task Sequence:

8.3.1 The publication will be undertaken by one principle author (MIP) with support from the two supporting specialists (JEW and RS). As analysis has been undertaken and results are ready for publication the task sequence reflects only time required to research the wider context on the site, to frame the discussion in light of previous work and to produce publication quality figures for the report. These tasks are shown in Table 4:

Publication Report Writing (MIP	**Person Days**
Liaise with illustrator	0.5 days
Documentary research.	1 days
Prepare integrated publication report. This task comprises the combination of the stratigraphic descriptions, environmental reports, synthesis of previous work and discussion.	4 days
Total	5.5 days
Specialist Analysis	
Micropaleontology: Meeting, redraft of contribution and edit	1 day
Pollen: Meeting, redraft of contribution and edit	1 day
Illustration	
There will be two maps, one section log and one channel cross section	2 days
Production	
Editing (pre-submission & post-ref)	1 days
Project Management	1 days
Sussex Arch Coll publication	Fee

Table 4: Resource for completion of publication report

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APPENDIX 1

Ecological preferences of key foraminifera (after Murray, 2006)

Arenoparrella mexicana
Epifaunal, and infaunal down to 60cm. Originally found on Gulf of Mexico marshes and mangrove swamps; also present in European marshes.

Jadammina macrescens
Epifaunal on decaying vegetation, and infaunal down to 60cm. An herbivore and detrivore. Widespread on **high to mid saltmarsh**, throughout mid to high latitudes worldwide.

Trochammina inflata
Epifaunal, and infaunal down to 60cm. An herbivore and detrivore. Almost universally present on **high to mid saltmarshes,** worldwide.

Ammonia spp.
Infaunal and an herbivore; common in sediments with highly variable mud and TOC contents; **marsh to subtidal**, in salinities not usually below 10‰; also able to tolerate low oxygen.

Elphidium williamsoni
Infaunal and an herbivore; common in sediments with highly variable mud and TOC contents; **low marsh, intertidal to subtidal**; euryhaline.
Haynesina germanica
Infaunal, an herbivore on diatoms and cyanobacteria; common in sediments with highly variable mud and TOC contents; **low marsh, intertidal to subtidal**; euryhaline.

APPENDIX 2

Radiocarbon Lab Report

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.9:lab. mult=1)

Laboratory number: **Beta-254420**

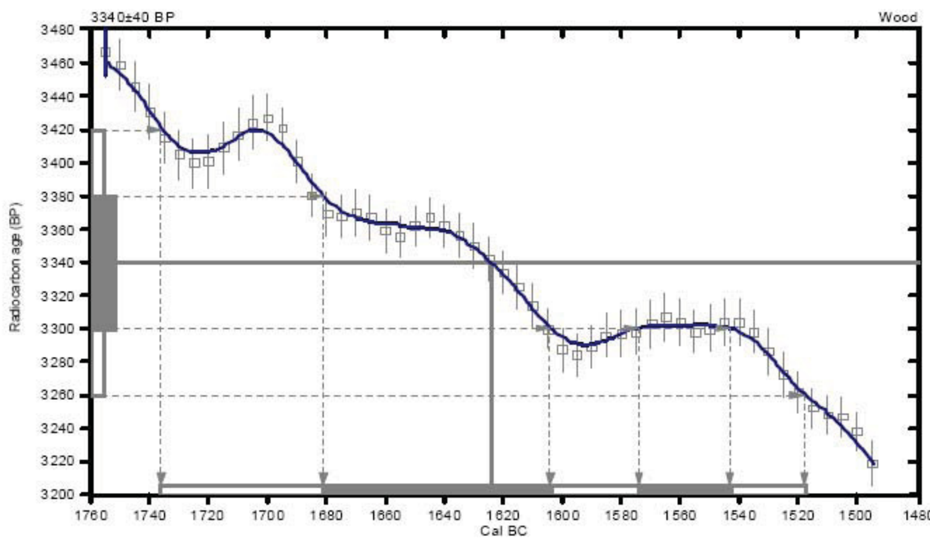
Conventional radiocarbon age: **3340±40 BP**

2 Sigma calibrated result: (95% probability) **Cal BC 1740 to 1520 (Cal BP 3690 to 3470)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 1620 (Cal BP 3570)

1 Sigma calibrated results: (68% probability) Cal BC 1680 to 1600 (Cal BP 3630 to 3550) and Cal BC 1570 to 1540 (Cal BP 3520 to 3490)



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