The Norse Waterways of West Mainland Orkney, Scotland

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Summary

This purpose of the study was to investigate the existence of navigable waterways in the West Mainland of Orkney, Scotland, in the Norse period (790—1350). In the parish of Harray, a Norse farm named Houseby is found. Farms with this name are known from Scandinavia and Orkney and are usually situated by major water routes. An inspection of the oldest geographically referenced maps for the parish suggests that in the past significant waterways across wetlands may have extended north from the loch of Harray towards Houseby in an area close to the power centre of the earldom at Birsay. The main aim of this project was to test this hypothesis using palaeo-geographic reconstructions and further study of place-names. Specific objectives included geophysical analysis of abandoned river channels due to water course re-alignments and core sampling of silted-up lochs. Comparison of the palaeo-reconstructions with place names of significance allowed interpretation of possible routeways along navigable waters by shallow-draught Viking-age vessels and provided the potential for re-drawing the map of Norse Orkney and postulating transfer of produce from estates in the parishes of Harray and Sandwick through the waterways to the power centre at Birsay. Finally, the methodology applied here could be useful to other parts of Orkney, and elsewhere, in understanding more about communication via navigable lochs and waterways through the Norse period.

Introduction

Climate change and natural processes of siltation have inevitably changed the landscape of Orkney since the Norse period (Viking Age and Late Norse Period, c. 790—1350). One aspect of a changed landscape will be that of loss of navigable waterways. The potential existence of a line of these in the West Mainland of Orkney was an idea originally developed by Barbara Crawford (Crawford 2006 a, b). This has been further examined in recent research (Sanmark 2017; Crawford and Sanmark 2016) to highlight an important gap in our knowledge of the past landscape of Orkney.

After the initial Norse settlement, the Orkney Earldom was created in the late 9th century AD and gradually integrated into the kingdom of Norway, where it remained until the islands were mortgaged to the Scottish kingdom in 1468. The fertile West Mainland of Orkney was a key area of power for the Norse Earls, and this is where many of the Earls' seats of power were located, such as the residence at the Brough of Birsay, as well as a large number of other estates linked to the Earls. One of the most interesting estates is Houseby, in the parish of Harray, now located next to Sabiston Loch. Houseby is derived from Old Norse 'húsabær' and translates as 'farms with many houses/buildings'. Estates bearing the modern name huseby/husaby are found across the Viking homelands of Sweden, Norway and Denmark. Outside Scandinavia, Orkney is the only area where these farms have been identified.

Published research into the Huseby farms dates from the 1950s (e.g. Steinnes 1955), and in 2016 an edited volume containing the Stand der Forschung was published (Christensen et al 2016). According to the current scholarly consensus, the Huseby farms formed part of a royal system that was introduced across all three Scandinavian kingdoms, with the growth of kingship in the 11th century. At this time, existing farms were renamed Huseby to signal their special function, most likely as royal farms for the collection of taxes in kind

[1] The order of names is purely alphabetical.

(Christensen et al 2016). These farms shared many traits and characteristics, which varied slightly between geographical areas. The most relevant characteristic for this project is the location of the Huseby estates in the landscape. In this respect, researchers have shown that the Huseby farms were frequently situated at the convergence of different communication routes, often where land and major water routes met (see e.g. chapters in Christensen, Lemm and Pedersen 2016). Above all, a location by significant water routes seems to have been common, which fits with the idea of these farms as collection points for renders and rents in kind. This is indeed the case in Orkney too, as five of the six identified Huseby farms are located on the coast, by important sea routes. The one exception is Houseby on the West Mainland, which is currently found c. 3 km from the Loch of Harray and thus not directly accessible by boat today. In view of the evidence already presented, this is rather surprising.

It is therefore interesting that there is a striking body of evidence suggesting that Houseby was most likely situated by a waterway of some kind. This is strongly implied by the place-names. Houseby is located by the small Sabiston Loch (the former Loch of Houseby), southwest of which is the township of Sabiston. This is documented as 'Sebustar' in 1492 and translates as 'Sea Farm'. The first element is used in Norwegian place-names to refer to an inland 'sea' or 'arm of the sea'. Greenay, the township to the northwest of Sabiston Loch, is another significant name which may be translated as 'shallow waters'. There is also Swartland farm ('Black Land'), 1 km west of Sabiston, which is said to refer to the dark, mossy nature of the soil. Another significant place-name, also a potential indicator of water routes, is Knarston (Old Norse 'knarrar staðir'). This name is derived from the word for a transport vessel (Old Norse 'knörr') and denotes a farm where these vessels were moored. These names, and their topographical situation, have been examined in Norway and are known to be significant for transport routes and connections with the sea or rivers. This is indeed the case with the other Knarston place-names in Orkney which are found on the island of Rousay and on the Bay of Scapa near Kirkwall on Mainland. The Rousay Knarston is located c. 4 km south of the Huseby farm (named Husabae) which replicates the close proximity of Knarston and Huseby farms in Harray (Crawford 2006 a).

The topography around the West Mainland Houseby supports the idea that the water levels were more conducive for navigation during the Norse period. This is particularly clearly seen in the area west and southwest of Sabiston Loch. This is an area of low-lying marshy terrain, which on late 19th-century Ordnance Survey (OS) map is marked as 'liable to floods'. The watercourses in these areas have been heavily modified with drainage channels marked on all current OS maps (Crawford 2006 a). In the Norse period the loch of Stenness was connected to the loch of Harray via a narrow channel to the south of Brodgar marked today by the large standing stone, 'the Watch Stone'. If navigable routeways through connected shallow lochs and gently flowing streams extended north from Harray then Houseby, which is located far inland on modern maps, could instead be shown to have been situated by a major water route through Orkney's West Mainland. In this way, the role of Houseby and other Earldom farms in this area can be shown to have formed an integral part of the Earls' administrative arrangements. It is further possible that the connections through the landscape north of Harray may even have been modified during the Norse period in order to make navigation more practical. Such undertakings are known, for example with the massive Kanhave canal on the island of Samsø in Denmark, which seems to have been constructed in the 8th century. These waterways, including modified streams connecting shallow lochs were easily traversed using the typical, shallow draft (often less than 0.5m) 'snekkja' type vessels used to navigate inland waters (Crumlin Pedersen 2010, 90—1, 141).

The place-name Warth (HY 226218) may also be of significance in this context. This farm lies to the south and west of the Loch of Sabiston and the Loch of Banks, in a low-lying locality which is riddled with drainage ditches, one of which is called the Burn of Warth. West of it is the small Loch of Rosemire. Warth is derived from ON *varða* ('a beacon'), but the origin of the name has been

seen as 'obscure' as it is in a low-lying location. It has the same origin as the Ward Hills in Orkney, where the beacon meaning is well understood (Marwick 1970; Clouston, 1931—2). However, there is plenty of evidence from Denmark, in particular, that the same name (Danish *warth*) was used for a *vagttarne* ('watchtower') in low-lying locations on routes through the waterways, such as the Roskilde fjord. Ole Crumlin Pedersen has studied all such watchtowers in the different branches of the fjord waterways leading to Roskilde as a *varslingsystemer* ('defence system') and shows the interconnecting viewpoints (viewsheds) (Crumlin Pedersen 1978, 52, Fig. 28). This was part of a wide-ranging signal system established in many fjords in the 11th century (Crumlin Pedersen 2010, 129—31).

The geology of Orkney is typified by bedrock consisting of mid-Devonian flagstones that for the most part occur as flat-lying units with minor structural deformation and no acute folding. Grain size within the flagstone varies from coarse basal units to fine mudstones which fracture into blocks ranging from a metre to a centimetre in size. These beds are occasionally intruded by late Permian dolerite dykes typically trending NE-SW across the islands. The bedrock surface is typically highly weathered (fractured and broken) and is commonly overlain by glacial till, the result of ice retreat following last glacial maximum. Unconsolidated sedimentary sequences above the till depend on geographic position with hollows in the glacial landscape filling up with lake deposits consisting of fine grey silty sands and surrounding landscapes with windblown sand a common feature of coastal locations. Where water-logging has occurred peat deposits have built up over the last 5kyrs. Ancient and modern streams have eroded this landscape cutting down to bedrock and also infilling the landscape with siltation.

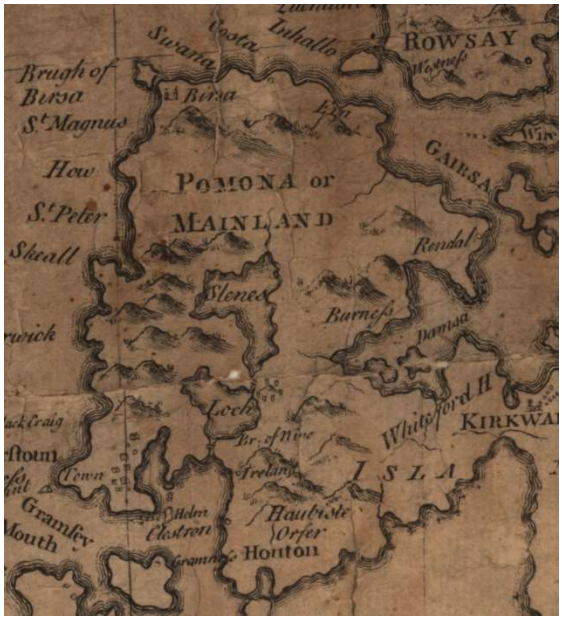
In summary, this project investigated new information on the potential waterways of Orkney and attempts to redraw the map of Norse Orkney thereby leading to a complete revaluation, not only of the Houseby estate, but other Norse sites across the West Mainland.

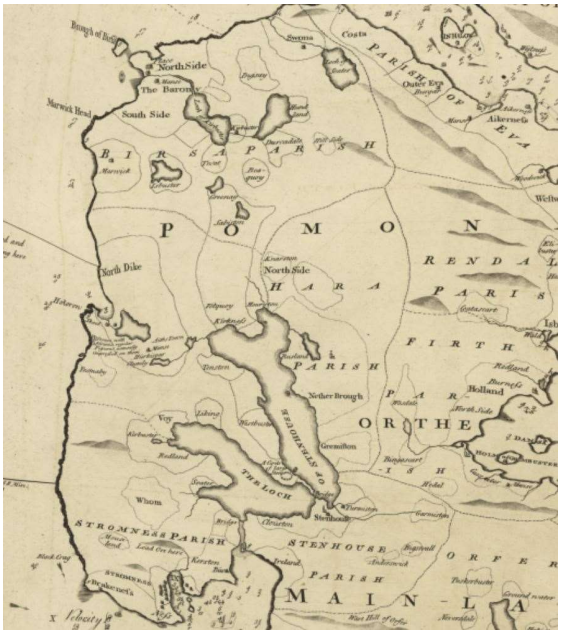
Methodology

Prior to field investigation of the site a background mapping exercise was conducted of all available georeferenced maps from the National Map Library of Scotland. These included Mckenzie's coastal charts of 1750, James Dorret's 1750 land maps and the series of OS maps from the 1830s. Together with recent aerial photography surveys these allowed a targeting of potential infilled stream and lochs for further investigation.

Field work consisted of both remote geophysical sensing and collecting ground truth information using targeted coring. The geophysical methods adopted was direct current electrical resistivity tomography (ERT) as this has proven successful in identifying similar palaeo-channels in other landscapes (Bates and Bates, 2016). Ground truth coring was conducted using a hand auger with sampling in the soft sediments down to over 2m depth. The core material was recorded in the field and sub-samples preserved at key intervals in the sections for further laboratory analysis. Location information and high-resolution topographic details of each field site were recorded using ground-based GNSS and also with airborne imagery and topographic mapping using drones.

Laboratory study included the assessment of selected samples for their contained microfossils. Samples for assessment were broken up by hand into small pieces, placed in ceramic bowls and dried in an oven. After drying a small quantity of sodium carbonate was added (to facilitate the removal of the clay fraction). The sediment mix was immersed in hot water and left to soak overnight. The sediment was then washed through a 75 micron sieve with hand-hot water, the resulting residue being returned to the bowl for drying. Once thoroughly dry the residue was transferred to plastic labelled bags for storage and further examination that included sieving using a nest of >500µ, >250µ and >150µ sieves. Microfossils from each grade were then picked by sprinkling a small amount of residue onto a tray and examining it under a binocular microscope. A detailed recording of the microfossil species was finally undertaken and is presented as semi-quantitative indications.



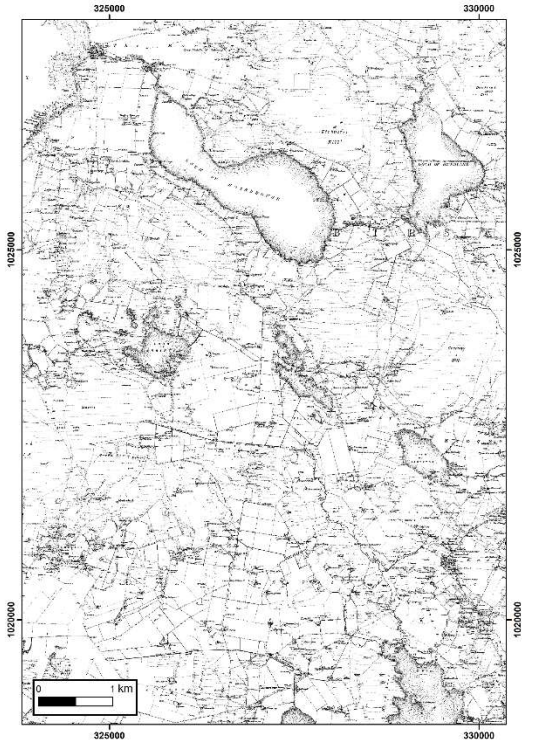


Figures 1 a) b) c).

Results

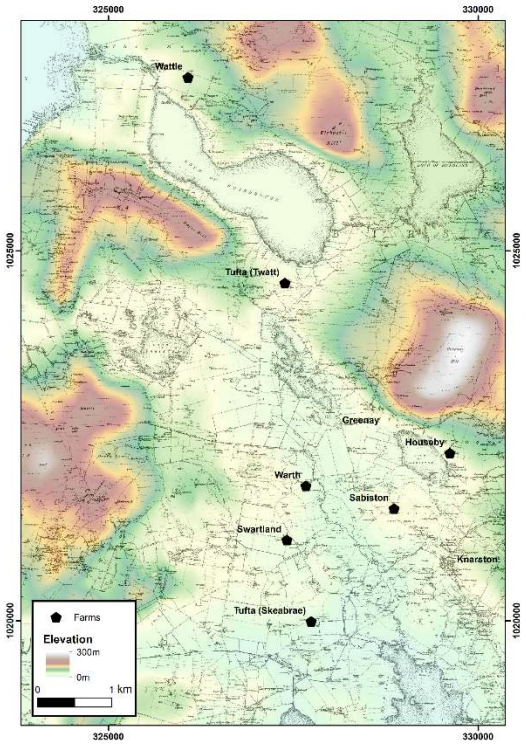
Figure 1 shows the 1750 maps by James Dorret and McKenzie together with the 1830 OS map for West Mainland Orkney. Figure 2 shows the OS map overlain by present day topography derived from the OS 5 m digital terrain model (Digimap). Highlighted on this map are farms and areas discussed in the text with names of Norse significance. The terrain model was manipulated using ArcGIS (v. 10.4, ESRI) with methodology for producing stream flow analysis following the work of Tarboton et al. (1991) and a final stream network using an ordering proposed by Strahler (1952).

The results are shown on figure 3a together with the main present-day lochs. In figure 3b the wetland areas that are prone to flooding as identified on the OS 1830 maps have also been shown. Figure 3 illustrates the change in topography, that is the slope of land across the area. The slope has been divided into four categories, namely, 0—0.1 degree, 0.1 to 1 degree, 1—5 degree, and greater than 5 degree. The majority of the project area is less than 5 degree slope with the main drainage axis showing slopes of less than 1 degree. Two pertinent transects have been drawn across the landscape as identified from the stream network, namely the main stream channel from the Loch of Harray through the Loch of Banks over to the Loch of Boardhouse and down to Birsay and the eastern



branch from the Loch of Harray up to the Loch of Sabiston. The profiles along these transects are shown in Figure 4a and 4b.

Figure 5 shows the results of coring along a transect across the lowest part of the landscape near to the Loch of Harray. Appendix A contains the logs of individual cores. Eighteen cores were acquired through a sequence that showed peat at the surface underlain by silty sands, grey silts and boulder clay. Refusal of the core was typically at the bedrock surface within 1 m of the present-day landscape surface apart from at the centre of the



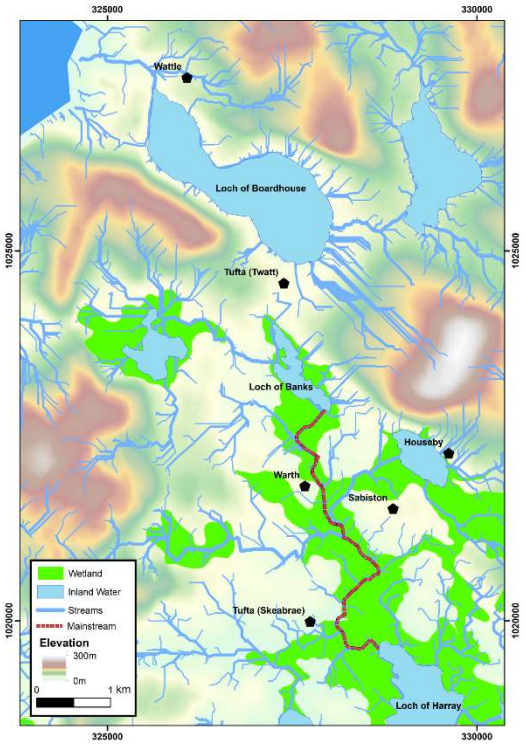
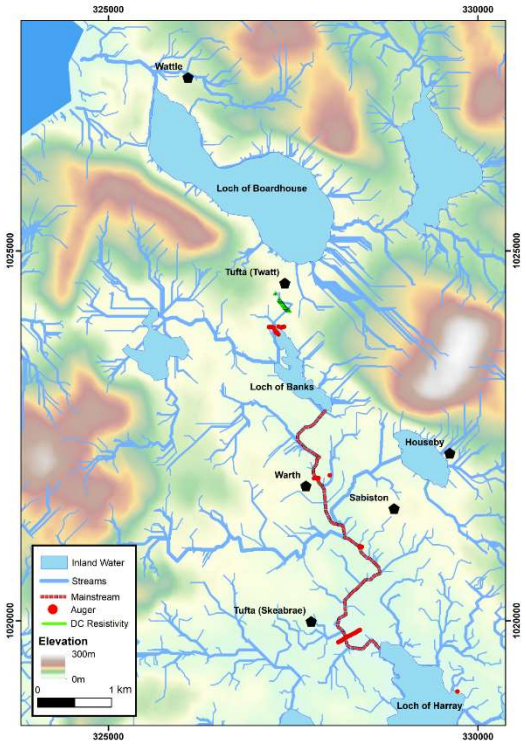
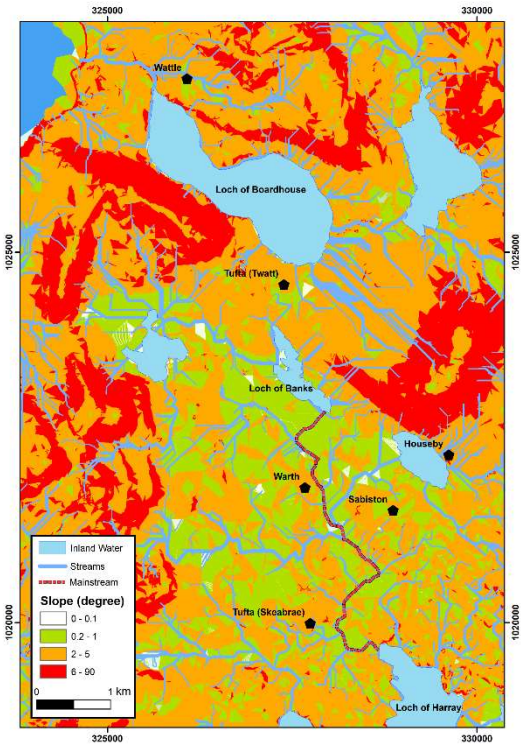


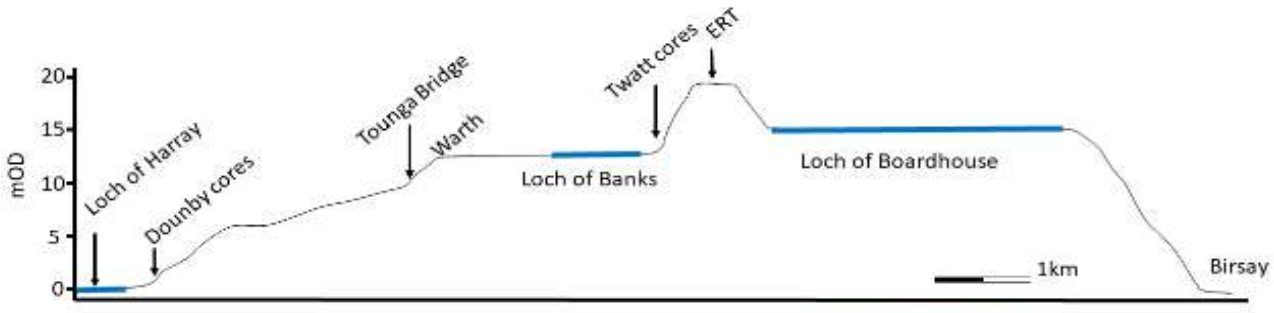
Figure 2. Present day topography overlaid on OS 1830 map of West Mainland Orkney, with farms and areas mentioned in text.

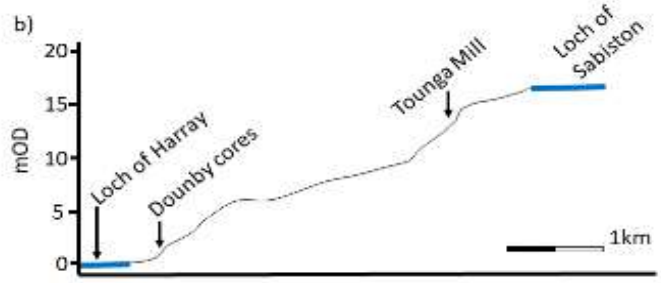


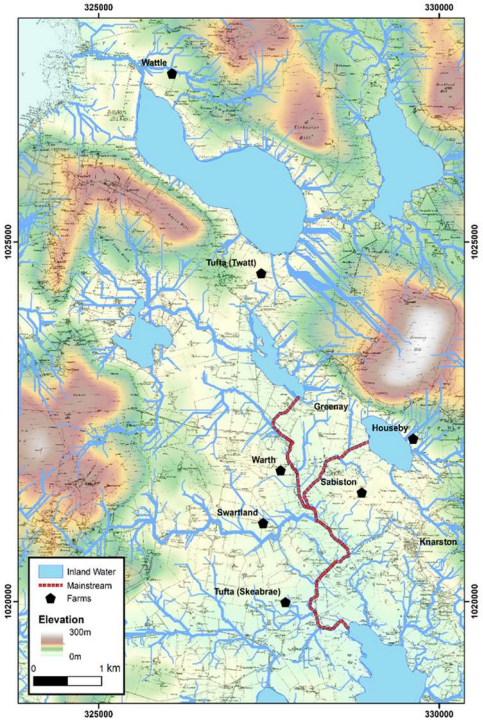


Figur 3 a) present day topography and modelled stream channels with geophysics (DC lines refer to ERT transect) and core (Auger) locations, b) modelled streams and wetlands identified in OS 1830 maps, c) topographic slope with modelled streams

Figure 4 a) transect from Loch of Harray to Birsay along main watercourse, b) profile from Loch of Harray to Loch of Sabiston, c) location map.







transect near to the Burn of Hackland where the river has cut a channel over 2 m deep into the landscape and infilled the sides with sand and soft muds (Figures 6a and 6b).

Further to the north a second investigation of the main channel was made to the west of Tounga and to the east of Warth Farm. At this point the river is crossed by a shallow ford and a small stone footbridge. The river-cut bank sections to the west and east of the burn were logged and elevations measured for the heights of bedrock surface (Figure 7). The section to the west showed almost no glacial till on top of the bedrock surface however the section to the east showed a typical thickness of approximately 1 m of till (see photo, Figure 7c).

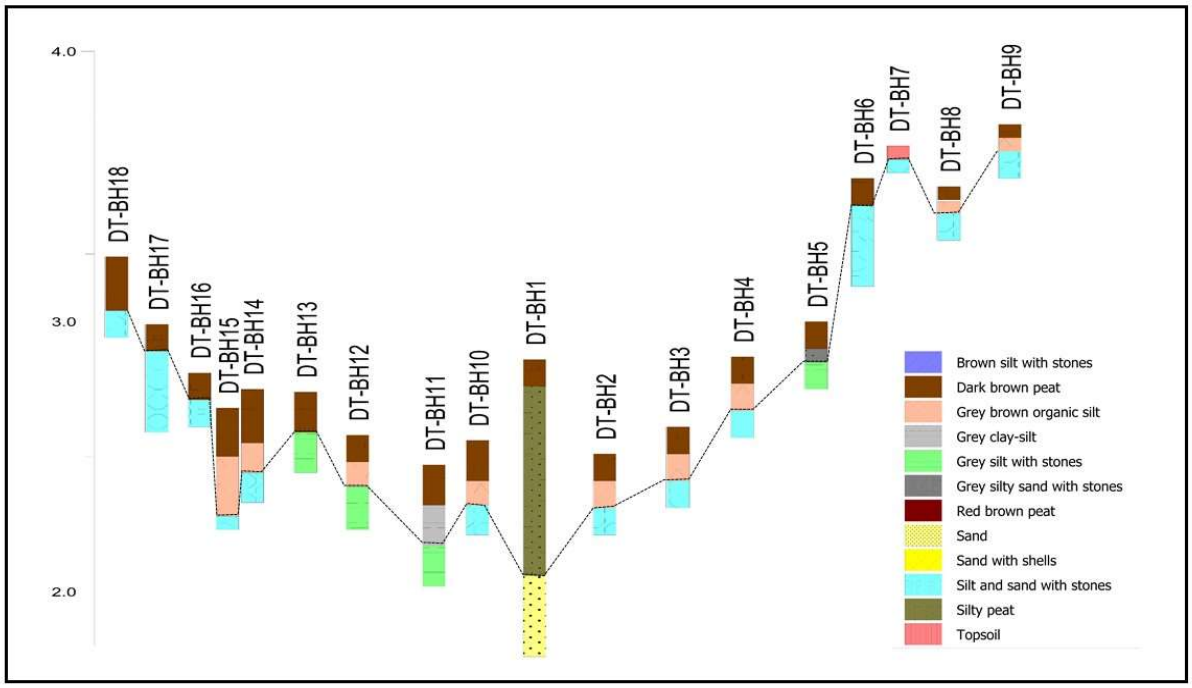
The final core section was taken across the northern end of the Loch of Banks and extended up the gentle hill slope to the east of the loch (Figures 8a and 8b). Again, at this location a deep peat sequence was observed at the surface towards the loch which thinned to the east and eventually was absent up-slope onto the agricultural land. At the centre of the transect the peat was underlain by grey clay with a base of silt and stone typical of the weathered till sequence above the bedrock surface.

The results of the direct current electrical resistivity tomography survey conducted along a line across the low ground (projected low point) between the Loch of Banks and the Loch of Boardhouse is shown in Figure 9. Apparent resistivity variation between less than 10 ohm.m and over 100 ohm.m were recorded. The zones of low resistivity (or its inverse high conductivity) were coincident with modern field drains and no clear channel section could be seen on the cross section.

Interpretation/Discussion

Dounby Transect

This transect (Figure 5) exhibited only a thin sequence of sediments overlying the deposits interpreted as weathered till. Weathered till was located in the base of most boreholes and was overlain by a thin sequence of silts with organic remains in them. The exception to this pattern is found in DT-BH14/15 where dark grey silts were found at the base of the augered sequence. The

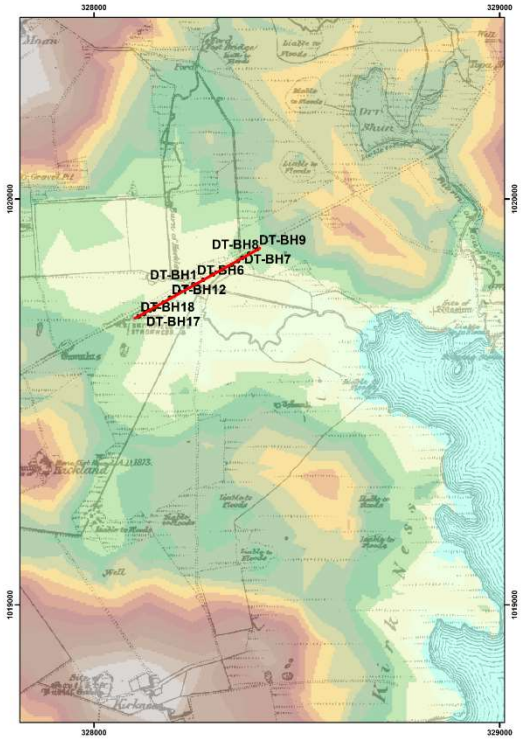


sediments in the base of these boreholes may be sediments trapped in small pockets on the till surface. No sediments interpreted as lake or pond sediments were found in this transect and running water (river) sediments were not found.

Microfossil analysis of BH1 showed plant debris, megaspores and insect remains together with the crustacea cladocerans and ephippia. A single freshwater ostracod species was recognised, namely, *Cypria ophtalmica.*

Tounga Bridge

This interesting site exhibits the results of downcutting by the river into the underlying till and bedrock sediments (Figure 7). Till exists overlying bedrock below alluvium to the east while to the west the till is absent and the bedrock is only overlain by alluvium/colluvium. It is noted that the bedrock surface is approximately 1.5 m higher on the west. This evidence implies that the erosion of the cutting in which the modern river lies predates the deposition of the till. In such a low-lying environment the situation of this bluff or cut bank area could be significant as it sits on a wide bend in the palaeo- and present river setting. ArcGIS was used to further analyse the topographic significance of the location by conducting a visibility analysis (line of sight) from the top of the bank near to Warth Farm. The



Figur 5 a) transect near Dounby and the Loch of Harray, b) location map of transect.

results of this are shown in Figure 10. It is interesting to note that down-valley and across the Loch of Harray there is clear line of sight to the Watch Stone located at the necking of the Brodgar peninsula where the Loch of Stennes and Loch of Harray meet. This could perhaps represent something similar to the 'defence system'

Figure 6 a) bridge along Dounby transect showing piers founded on bedrock, b) stream channel cut into bedrock.

identified along the Roskilde Fjord, based on the *warth/vord* and *bavne* (beacon) names (Crumlin Pedersen 2010, 129—31 and fig. 5.12). The Watch Stone is interesting in this context, although the name is likely to be Victorian, it seems plausible that it may have been used for navigation purposes. There are a number of other Neolithic standing stones that seem to have served this function (Tom Muir, pers. comm. 15 May 2019). Even if the Watch Stone is of Neolithic date, it may have served this purpose in the Norse period.

Twatt Transect

This transect exhibits a deeper sequence of sediments than that at Dounby. Up to 1.7 m of sediments are present in places and they exhibit characteristics of a range of different environments of deposition including lake/pond sediments as well as occasional thin bands of sand indicative of moving water. Interestingly boreholes in the wetter parts of the transect (TW-BH7/13) encountered dense sand deposits with stones that were difficult to drill through and may represent moving water fluvial sediments deposited in the deeper parts of the basin.

Core analysis of the plant debris and microfossils in BH4 identified two types of cold/cool ostracod indicator species, namely *Ilyocypris gibba* and *Cytherissa lacustris* within the grey clays at 1.4 to 1.5 m depth. In BH5 a further indicator species was identified that is commonly found in late Pleistocene sequences but known to have become extinct by the Holocene suggesting that the freshwater lake that was present subsequently become silted up. BH9 and BH15 only contained plant material, insect remains, some green algae and crustacea. No ostracods were observed as key identifiers of environment.

ERT

The ERT transect was located at a position designed to intersect any possible enhanced or cut channel through the higher ground between the Loch of Banks and the Loch of Boardhouse. Typically, such channels are infilled following disuse with material that has a different electrical signature to the surrounding soils and bedrock. Along the line decreased resistivity was recorded at both ends in association with modern drainage ditches but no cut feature was noted elsewhere.

Topographic model and stream flows

Analysis of the first OS maps and interpretation of current aerial photographs for the low-lying landscapes north of the Loch of Harray suggest that prior to the improvements in drainage a network of channels interlinked a series of shallow lochs. Over time these lochs have been infilled with silt to leave only the larger Loch of Sabiston and Loch of Banks today. The stream channel gradients throughout the area do not exceed 1 degree which is well within the haulage possibilities for shallow draft vessels. The use of

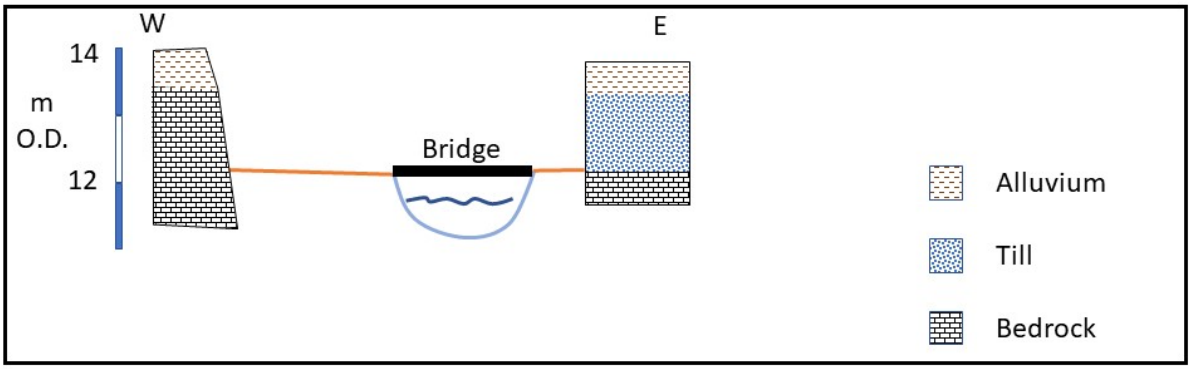


Figure 7 a) cross section of stratigraphy at Tounga (foot) Bridge near Warth, b) photograph of ford and Tounga (foot) Bridge near Warth Farm, c) west bank of Burn of Warth showing bedrock cut section (trowel for scale 20 cm).

portages in Norse society is well established. It is mentioned in many sagas where kings, such as Olaf Haraldsson and Sverre Sigurdsson, are said to have moved their fleets considerable distances and even across mountain passes (Larsson 2007, 163). Gunilla Larsson, who has recreated a number of Viking Age ships with boat builders and also sailed them, has shown how frequent portages were used. She has also demonstrated that the ships were light enough to be pulled on rollers over rather large distances, even up inclines (Larsson 2007, 163; pers. comm. 15/5/19).

The place names in the investigated area are interesting in view of the results as well as existing landscape features. Moving north from the Loch of Stennes:

Tufta in Skaebrae township is located where according to the OS map (Fig. 1c), drainage ditches for watery area of Orr Shun run into Harray Loch. There is also a second Tufta/Tufter, between Twatt and Boardhouse Loch (Marwick 1970, 79).

Marwick derives these names from ON *tupt* pl. *tuptir* 'an old house or building site', i.e. the usual meaning in Orcadian names. In Scandinavia, however, a link has been postulated between the place name and the word *tofte* ('rowers seat' or 'thwart'), so that the farm may have been obliged to provide one rower for the *leidang* ship (the coastal defence levy) (Porsmose 1987 and Ole Crumlin Pedersen in an e-mail of 13/07/08). It is moreover interesting that in Hordaland in western Norway a connection between *tofte* with *snekkja/skipa,* two different names for longships, and Stylegar also cites *skipreidetufti*, in which the term is linked with the *skipreide* district which had to provide a 'fully equipped ship to the levy fleet' (Stylegar 2003, 10, 13). This points to ON *tupt,* pl. *tuptir* being used of boathouse foundations, which could suggest that the 'Tufta' name in these two

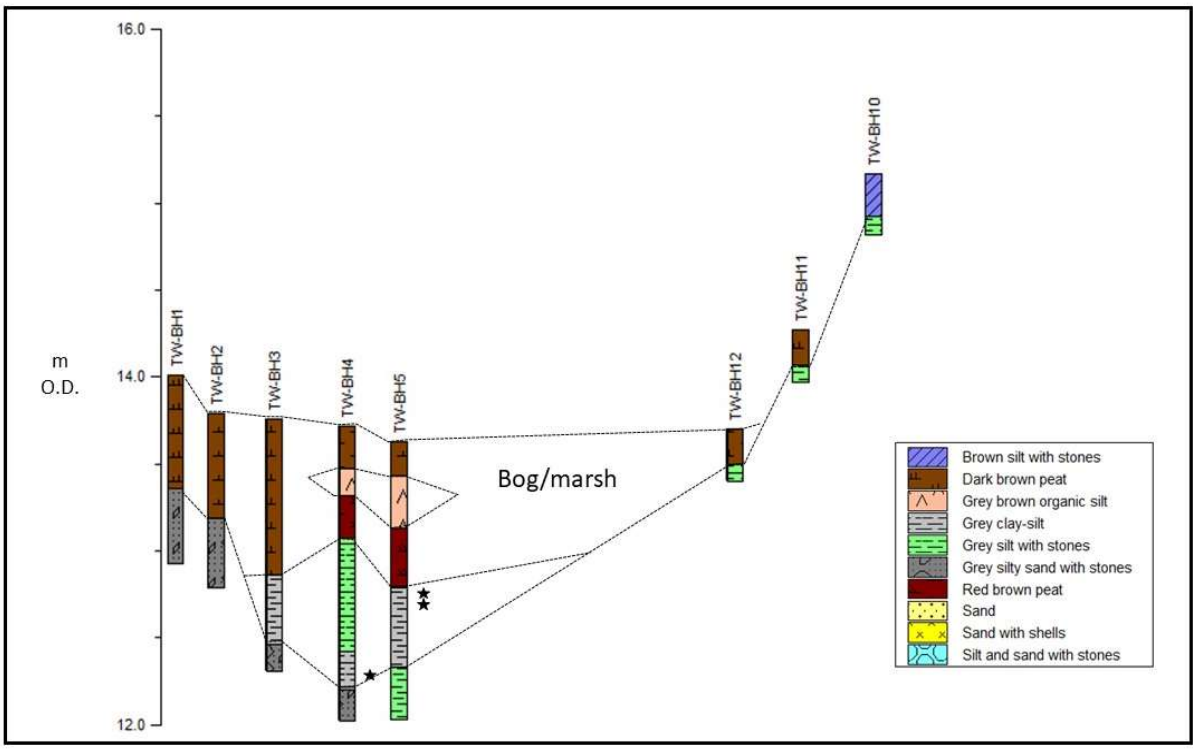
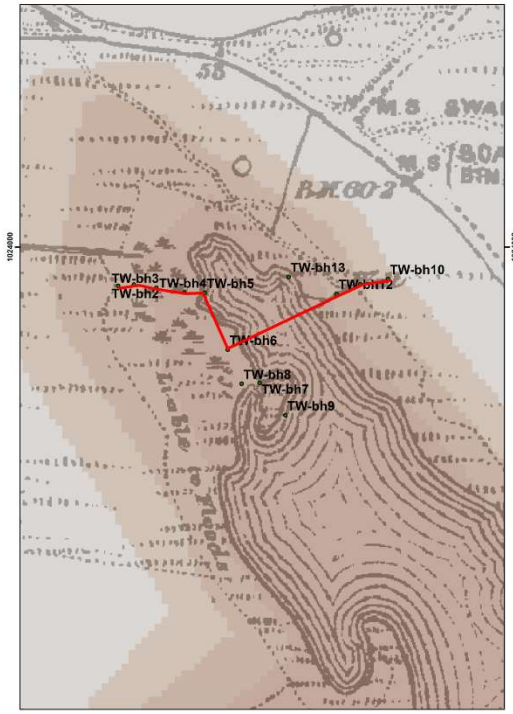
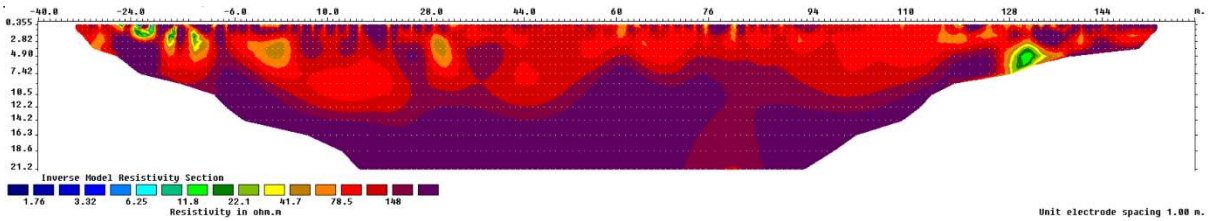


Figure 8 a) Transect through Loch of Banks, b) location map



this name could be derived from ON *skeið* ('fast warship') it would be very significant for the nearby name 'Tufta' already discussed. However, it is usually thought to be derived from ON for a race-track where horse races were held (Marwick 1970, 80).

Warth, to west of the Loch of Sabiston and the Loch of Banks, discussed above: This name is likely to have been part of signal arrangements, (if not defensive) in the postulated waterway system between Dounby and Twatt. It may be very relevant that the Warth farm is located at the narrowing of the channel indicated on Fig. 9, which is where a track goes across the putative waterway to the mill situated at the outflow from Loch of Sabiston. There is a Wart near the Brig of Waith, which is exactly where a warning beacon or signal would prove helpful to seamen navigating the narrow, and shallow channel between the Loch of Stennes and the open waters of the Bay of Ireland. Previous surveys in the Loch of Stennes and Bay of Ireland to the should of the Brig of Waith show that this channel would have been open and navigable from at least 4ka (Bates et al., 2016). According to Clouston, Wart is a 'shore name' and he suggests that it indicates 'an ancient mustering place for the local levies' (Clouston 1933, 15).



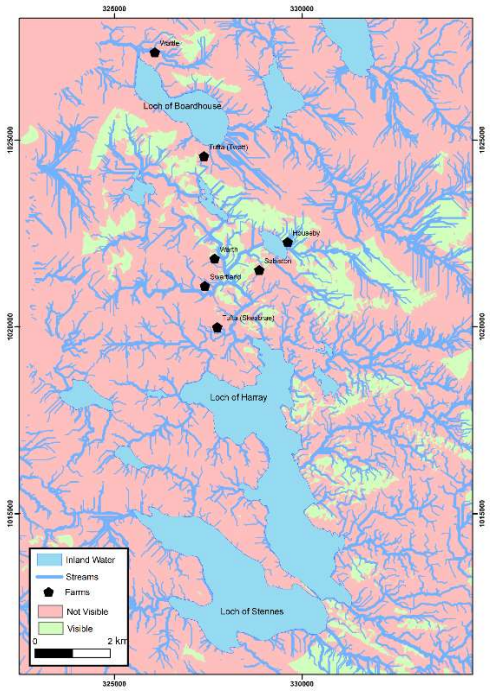


Figure 9 – a) transect showing results of the electrical resistivity tomography inversion to the south of Twatt, b) location map

Wattle is a farm on the north banks of Boardhouse Loch, with a name of great significance: ON *veizla* (a technical term for food renders to a lord, and the name of one of the Orkney scats, i.e. wattle). Marwick notes that this had possibly been a farm 'with the obligation of providing provender for the Norse earls when resident in Birsay' (Marwick 1970, 59) and it may have been located in this position for the collection of food obligations from the surrounding estates in Birsay and Harray for transmission to the earldom seat on the Brough of Birsay (Crawford 2006, 37). If this was indeed the case, the method of transport for the collection of food renders across the watery route from Dounby to Twatt and then across Boardhouse Loch must have been a vitally important part of the earldom organization of food supplies.

In summary, it is possible that in the Norse period there was a network of waterways that crossed the West Mainland making it possible to cut through using a boat. It can be envisaged that boats entered the Loch of Stennes via the Brig of Waith, and then moved into the Loch of Harray across the Ness of Brodgar (and the Watch Stone). From the northern point of Harry Loch, it is possible that boats could continue up to the current lochs of Sabiston and Banks. A short portage can be envisaged from the northern tip of the Loch of Banks to the Loch of Boardhouse. At the northern end of the Loch of Boardhouse, close to Wattle, a stream leads northwest to Birsay. This potential thoroughfare through the West Mainland of Orkney has significance for the interpretation of the farm names in this area and may well explain the location of the *staðir* farms around the lochs, originally Earldom farms granted out to members of the earl's retinue (Crawford, 2006, 31—3 and Fig.3).

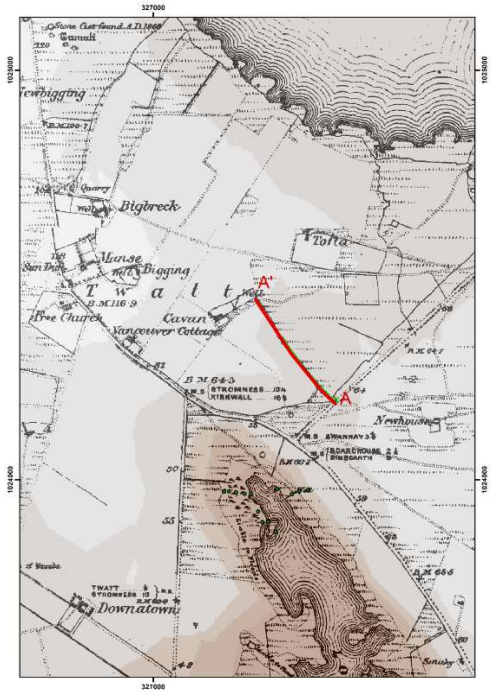


Figure 10 – visibility analysis (line of sight) from Warth.

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Appendix A – Core Logs

Borehole	DT-BH1	**Date drilled**	27/2/19
Grid Reference	328245	1019790	
Elevation	2.86	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Brown peat with living fibres.	
	---diffuse contact---	
0.10 – 0.80	Mid brown silty peat grading downwards into a pale brown silt with organic material	Wetland marsh
	---diffuse contact---	
0.80 -	Grey silty fine sand with rock fragments. Dense and compact.	Weathered till
	---base of borehole 1.10m---	

Microfossil Analysis

depth	**0.90-1.00m**
plant debris + megapores	x
insect remains	x
cladocerans + ephippia	x
freshwater ostracods	x
Cypria ophtalmica	x

Borehole	DT-BH 2	**Date drilled**	27/2/19
Grid Reference	328269.1	1019801	
Elevation	2.51	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peat.	
	---diffuse contact---	
0.10 – 0.20	Brown organic silt, soft and structureless.	Wetland marsh
	---sharp contact---	
0.20 -	Grey silt and sand with many rock fragments.	Weathered till
	---base of borehole 0.30m---	

Borehole	DT-BH 3	**Date drilled**	27/2/19
Grid Reference	328293.6	1019814	
Elevation	2.61	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peat.	
	---diffuse contact---	
0.10 – 0.20	Brown organic silt.	Wetland marsh
	---sharp contact---	
0.20 -	Grey silty and sand with common stones.	Weathered till
	---base of borehole 0.30m---	

Borehole	DT-BH 4	**Date drilled**	27/2/19
Grid Reference	328314.7	**1019826**	
Elevation	2.87	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peat.	
	---diffuse contact---	
0.10 – 0.20	Brown organic silt.	Wetland marsh
	---sharp contact---	
0.20 -	Grey silty and sand with common stones.	Weathered till
	---base of borehole 0.30m---	

Borehole	DT-BH5	**Date drilled**	27/2/19
Grid Reference	328339.8	**1019838**	
Elevation	3.00	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peat.	
	---abrupt contact---	
0.10 – 0.15	Grey silt and sand.	Wetland marsh
	---abrupt contact---	
0.15	Yellow/grey silt and sand with common stones.	Weathered till
	---base of borehole 0.25m---	

Borehole	DT-BH6	**Date drilled**	27/2/19
Grid Reference	328354.8	**1019847**	
Elevation	3.53	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peat.	
	---diffuse contact---	
0.10 -	Grey brown silt with common stones.	Weathered till
	---base of borehole 0.40m---	

Borehole	DT-BH7	**Date drilled**	27/2/19
Grid Reference	328365.6	**1019855**	
Elevation	3.65	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.05	Topsoil.	
	---abrupt contact---	
0.05 -	Grey silt with common stones. Firm and compact.	Weathered till
	---base of borehole 0.10m---	

Borehole	DT-BH8	**Date drilled**	27/2/19
Grid Reference	328382	**1019865**	
Elevation	3.50	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.05	Peat.	
	---abrupt contact---	
0.05 – 0.10	Grey silt with organics.	Wetland
	---abrupt contact---	
0.10 -	Grey silt and sand with common stones. Dense and compact.	Weathered till
	---base of borehole 0.20m---	

Borehole	DT-BH9	**Date drilled**	27/2/19
Grid Reference	328402.1	1019876	
Elevation	3.73	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.05	Peat.	
	---abrupt contact---	
0.05 – 0.10	Grey silt with organics.	Wetland
	---abrupt contact---	
0.10 -	Grey silt and sand with common stones. Dense and compact.	Weathered till
	---base of borehole 0.20m---	

Borehole	DT-BH10	**Date drilled**	27/2/19
Grid Reference	328226	1019780	
Elevation	2.56	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.15	Peat.	
	---diffuse contact---	
0.15 – 0.24	Grey brown organic silt.	Wetland marsh
	---diffuse contact---	
0.24 -	Grey silt with sand and common stones.	Weathered till
	---base of borehole 0.35m---	

Borehole	DT-BH11	**Date drilled**	27/2/19
Grid Reference	328211.6	1019772	
Elevation	2.47	**Driller**	MRB?CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.15	Peat.	
	---abrupt contact---	
0.15 – 0.30	Grey silt with modern roots.	Wetland marsh
	---abrupt contact---	
0.30 -	Yellow brown to grey silt with common stones. Firm and compact.	Weathered till
	---base of borehole 0.45m---	

Borehole	DT-BH12	**Date drilled**	27/2/19
Grid Reference	328187	1019757	
Elevation	2.58	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peat.	
	---abrupt contact---	
0.10 – 0.19	Grey brown silt with organic fragments.	Wetland marsh
	---abrupt contact---	
0.19 -	Grey silt with stones.	Weathered till
	---base of borehole 0.35m---	

Borehole	DT-BH13	**Date drilled**	27/2/19
Grid Reference	328171.5	1019745	
Elevation	2.74	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.15	Peat.	
	---abrupt contact---	
0.15 -	Grey silt with common stones.	Weathered till
	---base of borehole 0.30m---	

Borehole	DT-BH14	**Date drilled**	27/2/19
Grid Reference	328154.1	1019735	
Elevation	2.75	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.20	Peat.	
	---abrupt contact---	
0.20 – 0.31	Grey clay silt with organics.	Wetland marsh
	---sharp contact---	
0.31 -	Dark grey silt with organic material.	?Weathered till
	---base of borehole 0.42m---	

Borehole	DT-BH 15	**Date drilled**	27/3/19
Grid Reference	328147.8	1019728	
Elevation	2.68	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.18	Peat.	
	---abrupt contact---	
0.18 – 0.40	Grey silt with plant remains.	Wetland pond?
	---abrupt contact---	
0.40 -	Grey sandy silt the stones.	?Weathered till
	---base of borehole 0.40m---	

Microfossil Analysis

depth	**0.40-0.50m**
plant debris + megaspores	**x**
insect remains	**x**

Borehole	DT-BH16	**Date drilled**	27/2/19
Grid Reference	328137.7	1019725	
Elevation	2.81	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peat.	
	---abrupt contact---	
0.10 -	Greyish yellow silt with stones.	Weathered till
	---base of borehole 0.20m---	

Borehole	DT-BH17	**Date drilled**	27/2/19
Grid Reference	328123.9	1019717	
Elevation	2.99	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peat.	
	---abrupt contact---	
0.10 -	Yellowish grey silt with stones.	Weathered till
	---base of borehole 0.40m---	

Borehole	DT-BH18	**Date drilled**	27/2/19
Grid Reference	328109.9	1019711	
Elevation	3.24	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.20	Peat.	
	---abrupt contact---	
0.20 -	Grey silt with stones.	Weathered till
	---base of borehole 0.30m---	

Borehole	DT-BH19	**Date drilled**	27/2/19
Grid Reference	328428.906	1020998.842	
Elevation	9.12	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peaty topsoil.	
	---abrupt contact---	
0.10 -	Brown silt with common stones.	Weathered till
	---base of borehole 0.25m---	

Borehole	DT-BH20	**Date drilled**	27/2/19
Grid Reference	327994.53	1021966.429	
Elevation	11.12	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.10	Peaty topsoil.	
	---abrupt contact---	
0.10 -	Yellowish grey silt with stones.	Weathered till
	---base of borehole 0.30m---	

Borehole	TW-BH1	**Date drilled**	27/2/19
Grid Reference	327172.175	1023970.697	
Elevation	14.01	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.65	Dark brown peat. Soft and structureless.	
	---sharp contact---	
0.65 -	Grey silty sand with stone fragments.	Weathered till
	---base of borehole 1.08m---	

Borehole	TW-BH2	**Date drilled**	27/2/19
Grid Reference	327184.149	1023971.638	
Elevation	13.79	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.60	Peat.	
	---abrupt contact---	
0.60 -	Grey clay and sand with stones.	Weathered till
	---base of borehole 1.00m---	

Borehole	TW-BH3	**Date drilled**	27/2/19
Grid Reference	327201.227	1023969.188	
Elevation	13.76	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.90	Peat.	
	---abrupt contact---	
0.90 – 1.30	Grey clay silt, soft and unconsolidated.	Low energy water lain pond
	---diffuse contact---	
1.30 -	Grey clay with stone fragments. Dense and compact.	Weathered till
	---base of borehole 1.45m---	

Borehole	TW-BH4	Date drilled	27/2/19
Grid Reference	327222.448	1023965.529	
Elevation	13.72	Driller	MRB/CRB

Depth below ground surface (m)	Description	Interpretation
0.00 – 0.25	Peat.	Marsh (reeds)
	---abrupt contact---	
0.25 – 0.40	Pale greyish brown silt with organics.	Low energy pond
	---abrupt contact---	
0.40 – 0.65	Red brown peat with unhumified plant remains.	Marsh (reeds)
	---abrupt contact---	
0.65 – 1.30	Grey silt with common stones.	Pond or lake with inwash of gravels
	---diffuse contact---	
1.30 – 1.52	Pale grey clay silt. Soft and unconsolidated.	Low energy pond/lake deposit
	---diffuse contact---	
1.52 -	Grey clay silt with common stones.	Weathered till
	---base of borehole 1.70m---	

Microfossil Analysis

depth	1.40-1.50m	
plant debris + seeds	**x**	
mollusc fragments	**x**	
charophyte oogonia	**x**	
freshwater ostracods	**x**	
Ilyocypris gibba	xx	Cold/cool indicator
Cytherissa lacustris	x	Cold/cool indicator

Borehole	TW-BH5	**Date drilled**	27/2/19
Grid Reference	327237.773	1023965.416	
Elevation	13.63	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.20	Peat.	Marsh (reeds)
	---abrupt contact---	
0.20 – 0.50	Pale grey organic silt. Soft and unconsolidated.	Low energy pond
	---abrupt contact---	
0.50 – 0.83	Brown unhumified peat with occasional grey clay silt patches. Soft and unconsolidated.	Marsh (reeds)
	---abrupt contact---	
0.83 – 0.84	Pale brown sand with shell fragments.	High energy flood event
	---sharp contact---	
0.84 – 1.30	Grey clay silt with shell fragments. Soft and structureless.	Low energy pond/lake deposit
	---abrupt contact---	
1.30 – 1.52	Grey clay silt with stones.	Weathered till
	---base of borehole 1.60m---	

Microfossil Analysis

depth	**0.83-0.84m**	**0.90-0.95m**	
plant debris + seeds	**x**	**x**	
molluscs	**x**	**x**	
charophyte oogonia	**x**	**x**	
freshwater ostracods	**x**	**x**	
Candona candida	**xx**	**xxx**	**Cold/cool indicators**
Limnocythere inopinata	**xx**	**xxx**	
Ilyocypris gibba	**x**	**xxx**	
Limnocythere suessenbornensis	**x**	**x**	**Extinct, pre-Holocene**
Potamocypris fulva	**x**	**xx**	
Darwinula stevensoni	**x**		
Cyclocypris laevis/ovum	**x**	**x**	
Cytherissa lacustris		**xxx**	**Cold/cool indicators**

Borehole	TW-BH6	**Date drilled**	27/2/19
Grid Reference	327255.216	1023922.385	
Elevation	13.72	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.40	Peat.	
	---abrupt contact---	
0.40 – 0.72	Pale brownish grey silt with organics.	Low energy pond/lake
	---abrupt contact---	
0.72 – 0.77	Brown peat.	Marsh (reeds)
	---abrupt contact---	
0.77 -	Grey silt with stones.	Weathered bedrock
	---base of borehole 1.20m---	

Borehole	TW-BH7	**Date drilled**	27/2/19
Grid Reference	327279.239	1023897.255	
Elevation	13.51	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.20	Peat.	
	---abrupt contact---	
0.20 -	Pale greyish brown silt and sand with many stones.	?Fluvial moving water
	---base of borehole 0.50m---	

Borehole	TW-BH8	**Date drilled**	27/2/19
Grid Reference	327265.718	1023896.598	
Elevation	13.70	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 - 0.20	Peat.	
	---abrupt contact---	
0.20 – 0.63	Greyish brown organic silt with reeds and root fragments.	Low energy pond/lake
	---diffuse contact---	
0.63 – 0.64	Grey mid to fine sand.	Moving water, fluvial
	---abrupt contact---	
0.64 – 0.73	Unhumified peat.	Marsh (reed)
	---abrupt contact---	
0.73 – 1.00	Grey clay silt with stones.	Low energy pond/lake with occasional inwash of gravel
	---not seen---	
1.00 – 1.20	Pale grey clay-silt.	Low energy pond/lake
	---abrupt contact---	
1.20 -	Grey silt with stones.	Weathered till
	---base of borehole 1.25m---	

Borehole	TW-BH9	Date drilled	27/2/19
Grid Reference	327298.894	1023872.767	
Elevation	13.64	Driller	MRB/CRB

Depth below ground surface (m)	Description	Interpretation
0.00 – 0.20	Peat.	
	---abrupt contact---	
0.20 -	Grey organic fine sand. Some stones. Very dense and compact.	Fluvial moving water
	---base of borehole 0.50m---	

Microfossil Analysis

depth	0.40-0.50m
plant debris + seeds	x
insect remains	x
charophyte oogonia (less cortex)	x
cladocerans	x

Borehole	TW-BH10	Date drilled	27/2/19
Grid Reference	327376.465	1023975.759	
Elevation	15.17	Driller	MRB/CRB

Depth below ground surface (m)	Description	Interpretation
0.00 – 0.10	Topsoil.	
	---diffuse contact---	
0.10 – 0.25	Brown silt with stones.	Slopewash colluvium
	---diffuse contact---	
0.25 -	Yellowish-brown clay silt with stones.	Weathered till
	---base of borehole 0.35m---	

Borehole	TW-BH11	**Date drilled**	27/2/19
Grid Reference	327355.536	1023971.707	
Elevation	14.27	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.20	Peaty topsoil.	
	---abrupt contact---	
0.20 -	Grey brown silt with stones.	Weathered till
	---base of borehole 0.30m---	

Borehole	TW-BH12	**Date drilled**	27/2/19
Grid Reference	327337.382	1023964.596	
Elevation	13.70	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.20	Peaty topsoil.	
	---abrupt contact---	
0.20 -	Grey brown silt with stones.	Weathered till
	---base of borehole 0.30m---	

Borehole	TW-BH13	**Date drilled**	27/2/19
Grid Reference	327301.262	1023977.399	
Elevation	13.53	**Driller**	MRB/CRB

Depth below ground surface (m)	**Description**	**Interpretation**
0.00 – 0.40	Peat.	
	---abrupt contact---	
0.40 -	Stone – could not penetrate.	
	---base of borehole 0.50m---	