AIRTRICITY
GREATER GABBARD

REVIEW OF BANK MORPHOLOGY, PHYSICAL PROCESSES POST-CONSTRUCTION AT ARKLOW BANK, AND SIMILARITIES WITH THE FORMATION OF, AND POTENTIAL IMPLICATIONS OF PLACING FOUNDATIONS AT, INNER GABBARD AND THE GALLOPER

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1.0 Introduction

As required by the statutory consents for operational Arklow Bank Offshore Wind Farm, Arklow Energy Limited (AEL) has commissioned four hydrographic surveys during Spring 2004, Autumn 2004, Spring 2005 and Autumn 2005. The reports feature results of hydrographic surveys around the cable route and turbine foundations. This short note summarises the results of the Spring 2004 and Autumn 2004 surveys.

It is hoped that the reports will provide information on the interaction of the sand bank with the foundations and cables, for background information on the impact assessment for the Inner Gabbard and Galloper sand banks for the proposed Greater Gabbard project.

This note summarises the investigations undertaken during the Arklow EIA and bathymetric surveys around the wind turbines, to ascertain the characteristics of the Arklow bank and cross referencing the attributes to those of The Inner Gabbard and The Galloper banks. This will subsequently allow an insight into the potential impacts from placing turbine foundations and cables at Greater Gabbard.

2.0 Assessment of the effects of cable and foundation installation at Arklow Bank

The Arklow Hydrographic surveys for Spring 2004 and Autumn 2004 have been compared and assessed, set against the context of the Arklow ES (plus relevant supporting Appendices – 10 – Murphy-Dollard Report and 13 – Geophysical Report).

2.1 Baseline

The Arklow bank comprises loose to medium dense fine to coarse sands with coarser sands towards the periphery of the bank (especially the east) grading to very dense gravel and gravelly sand and some clay which is interpreted to represent the glacial morainic core of Quaternary Age (Arklow ES, 2001). The underlying Till is interpreted to crop out at the seabed in isolated places E and N of the Bank.

Material comprising the bank is 35-40m thick at the southern end and 10-15m thick at the northern end (Geophysical report, App 13, 2001).

The bank crest varies from 0.4 to 4m LAT (Chart Datum) from North to South, although there is historical evidence that the bank dried out in the past (Admiralty Chart 1873-1914). Extensive areas of the bank lie in less than 2m of water. Away from the crest, the bank slopes steeply from 20 to 30m. This is more apparent on the east flank.. This gives the southern half of the bank an asymmetrical cross section, where as the north end is more symmetrical. Bathymetry data from a Spring 2000 survey showed that the bank had apparently moved slightly north and east (particularly the south end) of the Admiralty Chart plotted position. Although consistent with the dominant forces acting on sediment transport, it could equally be explained by improvements in more accurate mapping techniques (Arklow ES, 2001). Sea depths at Arklow bank are quoted in Admiralty Charts to be continually changing (Murphy & Dollard, 2001).

Evidence that liquifaction occurs at the bank caused by mass movement processes which cause wrecks, for example, to move, subside or become partially covered is quoted in the Arklow ES:

> "*Anecdotal evidence from local fishermen suggests that a degree of liquefaction is prevalent in sediments along the bank. This ascertion is supported to a degree by the fact that a number of wrecks were not at their charted location*"
> (Arklow ES, 2001)

Sand waves exist along the flanks of the bank with crest oriented perpendicular to the bank crest, and up to 30m wavelength with amplitudes of a few metres. Smaller assymetrical sand waves form locally along parts of the bank crest. Away from the bank the seabed is mostly smooth with migrating sand ribbons (crests perpendicular to the direction of sand transport).

Seas around the Arklow Bank have a low tidal range even during springs (calculated in the bathymetry surveys at 2m during springs and 1m during neaps). This range has apparently increased since the Admiralty Chart indicates springs range of 1m and neaps tide range at 0.6m (Arklow ES, 2001). There is evidence of sand transport from tidal currents (which can be up to 5 knots or 2.5 m/s) northwards on the Western flank and southwards on the Eastern flank. Regionally, the dominant current direction is North and therefore net sediment transport is in this direction (Arklow ES, 2001).

A Murphy-Dollard Report, 2001 report (ES, Appendix 10) states that:

> "*due to differential flood (stronger) and ebb (weaker) currents the channels either side of the Bank create a steeper slope to the west and their dip slopes toward the east.*"

(Murphy & Dollard, 2001)

This is entirely contrary to what the ES text states (summarised above). Appendix 13 of the Arklow ES states that the western flank of the Bank is also steeper than the eastern, so there is an apparent disparity.. Flood and ebb tides are quoted at ranging from 1.5-4 knots (0.75 to 2 m/s) (Arklow ES, 2001)

Wave roses indicate a dominance of southerly waves from Atlantic swells, but large waves of >2m height have been recorded from all directions. The dominant wind direction is westerly, although the roughest sea states tend to be when prevailing winds are from the NE, E or SE. Due to the energetic environment, turbidity and suspended sediment levels are generally high limiting marine biological growth (Arklow ES, 2001).

2.2 Predictions at Arklow

A 50 year return period storm surge event was calculated to create a highest water level of 3.51m above LAT, or 3.57m for a 100 year storm surge. Significant wave heights have been calculated ranging from 5.6 m for a 1 year event, through 8.3m for a 50 year event and 8.7m for a 100 year event (Murphy-Dollard Report, 2001).

Localised scour had been predicted from simulations (computer and manual calculation) due to:

- the nature of seabed sediment
- high tidal flows, and
- churning of water caused by shallow depth and breaking waves.

In computer models the net direction of sediment transport at Arklow was E or NE in simulation for the effects current alone, but when wave action effects were also applied this changed to W. The top 2m of the banks are thought to be 'mobile' (Murphy & Dollard, 2001).

Predicted localised scour from the wind farm was identified as being greatest where water depth was between 1 and 2.5m. Adequate scour protection was, therefore, recommended.

> *"Whilst this scour will have consequences on design and protection of the base structures, it is unlikely to have any noticeable effect on the overall stability of the bank. This is because of its local nature and the distance between the turbine structures."*

(Murphy & Dollard, 2001)
It is further quoted that:

> *" the effects of global warming (sea level rise, increase in storminess, changes in wind climate) may play a much more significant role in altering the Bank and its interaction with the coastline than the placement of wind turbines*".

(Murphy & Dollard, 2001)

Manual calculations indicated that critical shear stress is exceeded in all scenarios (all loading types and grain size) up to D_{50} = 0.7mm. The turbines in the north of the site are predicted to have the least scour due to a less severe wave climate (Murphy & Dollard, 2001).

2.3 Spring and Autumn 2004 Post-Construction Surveys

The Spring survey was undertaken in June 2004. The Autumn survey was undertaken in September 2004.

The Spring 2004 survey was compared against the pre-construction survey undertaken in August 2002. The report indicates localised increases in sediment volume, however, it should be noted that comparison of sediment volumes may be inaccurate due to placement of scour protection material..

Bathymetry contours were recorded generally run NE-SW in both surveys. Small sand wave features are present in the survey areas in the June 2004 report. No sand wave activity was reported in the Autumn

2004 report, but ridges and hollows are – it is not clear if reference to these equates to reference to sand waves.

The first post construction report in Spring 2004 identified radiating contours and therefore evidence of scour at turbines 4, 5 and 6.

There are references in the Spring 04 report to some potential residual construction impacts, these were possible spud leg depressions adjacent to Turbines 5 and 6 but these had subsequently infilled by Autumn 2004.

Turbine 5 was recorded as the shallowest turbine in both surveys. In Autumn there is reference to a 3m rise in seabed in the first 10m from the pile suggesting a scour pit. .

Localised scour is noted at all 7 turbines in the spring report either from radial contour evidence or actual depressions identified within 15m of the turbine bases to depths of between 0.5 and 2.5 m. Most scour evidence occurs between 3 and 10m distance from the pile and tends to be on the N or E quadrants. In Autumn 2004, scour hollows are noted to have filled either wholly or partially at turbines 1, 2, 3, 6 and 7 (Hydroserv, Autumn 2004).

In June 2004, it is not clear whether gravel (which is noted adjacent to Turbines 2, 3, 5, and 6 where sand is noted further away) represents scour protection material or whether scour has occurred removing finer sand and exposing courser material below. Rock armour is specifically cited at turbines 3, 4 and 7, but its presence is also implied at 1, 2, 5 and 6 (i.e. infers all turbines had rock armour placed post construction) (Hydroserv, Spring 2004). In September 2004, rock armour evidence is noted at turbines 1, 2, 3 and 7. There is evidence that some of this material has shifted (as in turbines 1 and 3), eroded or caused subsidiary scour/altered contour pattern (turbine 7). At turbine 2 it is quoted that "*armour material 20m NE of the pile has been absorbed by sediment*" (Hydroserv, Autumn 2004). .

In Autumn 2004, the composition of sediment at the edge sand bank in grab location 16 was noted as coarser material (underlying sand and gravel). Beyond the bank, along the cable route, there are no significant effects identified. Table 2.1 indicates the differences in sediment volume for a 100m by 100m square area around each turbine between Spring and Autumn 2004.

Table 2.1 Changes in Sediment volumes Spring to Autumn 2004

Turbine	Depletion (m^3)	Accretion (m^3)
1	2351	
2	3093	
3	5368	
4	3453	
5	1523	
6		2791
7		3639

No rock dumping occurred between June and September 2004 (Hydroserv, Autumn 2004) .

At turbine 6 a linear sand feature appears to have migrated in a SW direction from 20m NE of the pile in June to 20m SW of the pile in September indicating natural sediment transport patterns (Hydroserv, Autumn 2004).

A shift in material noted following the Autumn survey is part of a natural process that takes place on a seasonal basis as the result of tidal and wave action or periods of calm sea conditions (Hydroserv, Autumn 2004).

Boat skippers have reported an increase in sea depths between the turbines over the six months preceding Sept 04, and yet the report purports there has been no global scour (Hydroserv, Autumn 2004), suggesting another potential disparity.

Scouring has shown negligible change since the previous survey suggesting local scour has reached an equilibrium and in some places e.g. turbine 7 sediment has built up around the pile. The effect of scour has not had any significant effect on movement of surface sands on the bank and the effects seen are confined to shallow scour hollows that change over time (Hydroserv, Autumn 2004).

With the top 2m of sediment being mobile the greatest influence on scour development will be winter storms and the significant wave height (Hydroserv, Autumn 2004).

3.0 The Inner Gabbard, Galloper and Arklow Banks

In terms of regional current velocities, the Inner Gabbard and Galloper banks are generally situated in a more energetic environment and subjected to greater tidal ranges than Arklow. There is no information from the Greater Gabbard geophysical survey summary on bank composition and sediment grain sizes and this will be critical in assessing the critical shear stress and also the long term stability of the banks themselves. Clearly, the Gabbard banks have existed for considerable time based on historical information on ship wrecks. In terms of similarities, the banks are both sub parallel to the dominant tidal flow, the Inner Gabbard and Galloper banks being slightly offset in an anticlockwise direction. Again, with the latter banks, the upstream head of the bank is blunter than the elongate downstream tail (Titan Ltd, 2004). Sand waves frequent the flanks of all banks and sufficient sand supply also covers areas of the seabed away fm the Inner Gabbard and Galloper banks (e.g. SE of the Galloper) (Titan Ltd, 2004). The table below provides a useful summary of the main features (similarities and disparities) between the 3 banks.

Table 3.1 Comparison of Bank Attributes

Attribute	**Sand Bank**		
	Arklow	**Inner Gabbard**	**The Galloper**
Origin/source material	Either: (i) vestige of coastal recession (marine erosion of sand from coast),or, (ii) remnant of gravel barrier from shoreline erosion stranded by rapidly rising sea level, or, (iii) core material is glacial moraine deposit plus mobile post Holocene sand deposits	High currents and tidal range in s. North Sea caused reworking of Holocene marine deposits c.8K years ago. These sediments were then deposited in the outer Thames Estuary as banks and sand wave fields	High currents and tidal range in s. North Sea caused reworking of Holocene marine deposits c.8K years ago. These sediments were then deposited in the outer Thames Estuary as banks and sand wave fields.
Age of sediments	Holocene, with Pleistocene core	Holocene (Analysis of results will determine prescence of any core)	Holocene (Analysis of results will determine prescence of any core)
Composition	Base: v. dense gravel and gravelly sand + some clay	Sand with up to 50% $CaCO_3$ Sand with gravel and clay	Sand with up to 50% $CaCO_3$ Sand with gravel and clay
Tidal current regime around bank	Clockwise (north on western flank, south on eastern flank)	Anticlockwise	Anticlockwise
Surrounding seabed surface geology	Glacial Till	London Clay	London Clay

Min sea depth	<1m (extensive areas <2m)	3.80m	2.48m
Water depth off the bank	20-80m (deepest off to SE)	-10 to -50m CD	-10 to -50m CD
Flood/ebb current speed			
Regional springs	1.25 m/s	1.75 m/s	1.75 m/s
Across Bank	0.75-2 m/s	?	1 m/s
Regional current orientation	NE-SW	NE-SW	NE-SW
Currents across Bank (orientation)	E-W or WSW-ENE	?	?
Tidal range	2m (spring) 1m (neap)	?	?
Dimensions			
Length	23km	16km	12km
Width range	Up to 2000m (at 20m contour)	1100 – 1500m	900-1200m
Depth to surrounding seabed	35-40m at south 10-15m at north	21m	19m
Bank orientation	NNE-SSW	NNE-SSW	NNE-SSW (but turns SSE at S end)
Sand transport			
Regional net sediment transport	N on west side S on east side	?	?
Dominant waves	S from Atlantic swells	?	?
Dominant wind	W	SW	SW
Morphology			
Historical bank morphology	Dried out in early 20th C Potentially shifted east and north of Admiralty chart position	?	?
Sand wave features	yes	yes	yes
W Flank Slope	1-4 degrees	3-4 degrees	3-4 degrees
E Flank Slope	6 degrees	1 degree	1 degree
Wavelength	30m	100-200m	100-200m
Amplitude	<10m	10m	7m
Orientation	Perp. to main bank	NW-SE, but becoming symmetrical at the S end.	NW-SE, more E-W in mid bank, NNW-SSE at S end of bank
Greatest slope angle	6 degrees	W side = facing N E side = facing S 1 in 25	1 in 3
Other associated features			
Other sand accretion	Large feature 60m on to the W side 1-3m high	Significant to the S and SE of bank	Significant sand and gravel to NW up to 6m thick
Bathymetry outside banks	Deepens rapidly to south east	Deepens rapidly to south west	?

4.0 Inferred physical process impacts from the Greater Gabbard OWF

It can be clearly seen that from Section 3 and Table 3.1 that the three sand bank parameters have similarities in their respective dynamic marine environments.

References

Fehily Timoney & Co (June 2001) *Environmental Impact Assessment Arklow Bank Wind Park Final Report*. Sure Partners Ltd.

Hydroserv Hydrogrpahic and Marine Services (Sept 2004) Arklow Bank Wind Farm Project. Hydrogrpaphic and Environmental Monitoring Survey. Interim Report-Autumn 2004. Arklow Energy Ltd.

Hydroserv Hydrogrpahic and Marine Services (June 2004) Arklow Bank Wind Farm Project. Hydrogrpaphic and Environmental Monitoring Survey. Interim Report-Spring 2004. Arklow Energy Ltd.

Murphy, J. & Dollard, B. (May 2001) *Effect of Wind Farm Structures on The Arklow Bank*. Appendix 10 Arklow Environmental Statement. Hydraulics and Maritime Research Centre, University College Cork. Offshore, Marine & Coastal Engineering Unit, Ireland Enterprise.

Unknown (2001) *Arklow Bank Cultural Heritage/ Archaeological Assessment*. Appendix 13 Arklow Environmental Statement.

Titan Environmental Surveys Ltd (2004) *Greater Gabbard Offshore Wind farm Geophysical Survey. Summary.* Airtricity.