Norfolk Vanguard Offshore Wind Farm

Appendix 20.3

Geomorphological Walkover Survey

Environmental Statement

Volume 3

Applicant: Norfolk Vanguard Limited
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Photo: Kentish Flats Offshore Wind Farm

Environmental Impact Assessment
Environmental Statement

Document Reference: PB4476-005-0203

June 2018

For and on behalf of Norfolk Vanguard Limited

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Signed: [redacted]

Date: 8th June 2018

For and on behalf of Royal HaskoningDHV

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Glossary

HDD	Horizontal Directional Drilling

Terminology

Onshore cable corridor	200m wide onshore corridor within which the onshore cable route would be located as presented in the PEIR.
Onshore cables	The cables which take the electricity from landfall to the onshore project substation.
The Applicant	Norfolk Vanguard Limited.
The project	Norfolk Vanguard Offshore Wind Farm, including the onshore and offshore infrastructure.
Trenchless crossing zone (e.g. HDD)	Temporary areas required for trenchless crossing works.

20 GEOMORPHOLOGICAL WALKOVER SURVEY

20.1 Introduction

1. The Norfolk Vanguard Offshore Wind Farm project (herein 'the project') onshore cable corridor would cross a variety of surface waters, ranging from major watercourses to small drainage ditches. The project includes six crossings of watercourses that are designated as main rivers by the Environment Agency and are also river water bodies under the Water Framework Directive.

2. This report presents the results of a geomorphological walkover survey that was undertaken to identify the main geomorphological characteristics of each of the main river watercourses that would be crossed by the onshore cable corridor.

3. Section 20.2 presents the survey method, and the outputs of the survey are presented in section 20.3.

20.2 Survey Methodology

4. A targeted geomorphological walkover survey was undertaken on 11th April 2017 to characterise the surface water conditions of the following watercourses at the proposed crossing points (Figure 20.1):

- North Walsham and Dilham Canal at Little London.
- King's Beck at Colby Corner.
- River Bure at Abbot's Hall Farm, Drabblegate.
- Blackwater Drain at Salle Park (also known as the Booton Watercourse).
- River Wensum at Old Hall Farm, Mill Street.
- Wendling Beck at Old Brigg, Gressenhall.
- Wendling Beck at the Woodlands, Bushy Common.

5. The surveys considered a variety of factors that are necessary to characterise the baseline geomorphology of each watercourse, including:

- Flow conditions, including dominant flow types and the degree of variability within each reach.
- Channel form, including planform, width and depth variation, bank form and condition, substrate types and the type and presence of bed forms such as pools, riffles and bars.
- Floodplain characteristics, including connectivity to the river channel and the structure of the riparian zone.
- Evidence of channel modification, including enlargement and resectioning, artificial bank protection, embankments and in-channel structures.

6. At the trenchless crossing technique (e.g. HDD) zones, the walkover survey encompassed the onshore cable corridor width and at least 200m upstream and downstream.

20.3 Survey Results

20.3.1 North Walsham and Dilham Canal

20.3.1.1 Overview

7. The North Walsham and Dilham Canal is an extensively modified watercourse with a straight planform and uniformly graded banks. The channel is dominated by low energy glide flows and appears to support very little geomorphological diversity (Plate 20.1). The canal was formerly known as the River Ant.

Plate 20.1 North Walsham and Dilham Canal

20.3.1.2 Channel form

8. The channel has a straight, uniform planform. The banks are steeply graded, approximately 1.5 to 2m high, stable and well vegetated throughout the reach. The channel is approximately 5m wide at the bank base and 7m wide at the bank top.

9. The substrate is dominated by sands and silts. There were no visible bedforms or signs of erosion in the main canal, although siltation was evident in the channel margins and in the lee of emergent vegetation.

10. The main channel is punctuated by an earth dam at the downstream end of the reach (although the channel continues as a reed-filled remnant channel). Flow from the main canal is diverted via a pipe into the drain located immediately to the left, which markedly increases flows in this drain. The discharge from the main channel

enters the side drain perpendicular to the flow, which has resulted in a localised area of scour immediately opposite the outfall.

11. Both sides of the canal are flanked by drains which run parallel to the main channel throughout the reach. These are narrow and well vegetated, with steep, uniform banks. These contained water at the time of the survey, but do not appear to support regular flows (with the exception of the left drain downstream of the earth dam).

20.3.1.3 Flow conditions

12. Flows are dominated by shallow, uniform, low energy glides. Very little variation was observed during the walkover survey; the blind end to the channel did not appear to cause impoundment. The water column had a moderately high level of turbidity at the time of the survey.

20.3.1.4 Floodplain characteristics

13. The floodplain on both banks appeared to be well connected to the canal throughout the reach. The narrow strips of land (c. 5m) between the canal and the drains either side are maintained as access routes. Beyond these channels, the land on the left bank is used for arable agriculture, while the land on the right bank consists of a nature reserve supporting grassland, woodland and wetland habitats.

20.3.1.5 In-channel and riparian vegetation

14. The banks were well vegetated, with fringes of reeds and other emergent vegetation along much of the bank toes and extending into the channel in places. Extensive vegetation growth was also observed on the bed in parts of the reach.

20.3.2 King's Beck

20.3.2.1 Overview

15. King's Beck is a uniform, incised channel that has been artificially straightened and resectioned (Plate 20.2). The channel is dominated by glide flows and there is extensive in-channel vegetation growth. In addition to the main channel, there are several connected channels that have similar characteristics (Plate 20.3). These are largely artificial, although some reaches may represent a resectioned historical course of the watercourse.

20.3.2.2 Channel form

16. King's Beck follows a narrow, incised channel with a straight planform. The banks are approximately 1.5 to 2m high, steeply graded, stable and well vegetated, with a vertical or near-vertical toe in places. The channel is approximately 2m wide at the bank base and 5m wide at the bank top.

17. The substrate was largely obscured by in-channel vegetation growth, although where visible appear to be dominated by silts and fine sands. There are extensive deposits of fine sediment at the toe of each bank, supporting thick vegetation growth. The channel has cut through the marginal deposits, maintaining a narrow meandering path free of encroaching sediment and vegetation along the thalweg[1].

Plate 20.2 King's Beck (main channel)

Plate 20.3 Channel adjacent to King's Beck

18. In addition to the main channel, there are several other watercourses that run parallel and are connected with the King's Beck. These channels have similar characteristics to King's Beck, with uniform banks, glide flows and a pronounced thalweg visible within the bank line. The bed of the channel on the right (eastern) side of the beck appears to be slightly lower than the main river and other adjacent channels in this reach (Plate 20.3). This watercourse diverges from King's Beck downstream of Beck Farm, flowing further east along a more sinuous course before re-joining the main river upstream of Aylsham Road. This may represent a historical course of the main King's Beck.

[1] A line connecting the lowest points of successive cross-sections along the course of a valley or river.

20.3.2.3 Flow conditions

19. Flows are dominated by uniform glides throughout this reach.

20.3.2.4 Floodplain characteristics

20. The floodplain on both banks appeared to be well connected to the channel throughout the reach. The land on the left bank appears to be used for pastoral agriculture, while the land on the right bank supports a variety of established and newly-planted woodland habitats.

20.3.2.5 In-channel and riparian vegetation

21. The banks are well vegetated, with occasional small riparian trees. Considerable in-channel vegetation growth was observed during the walkover survey, extending from the bank toe towards the centre of the channel.

20.3.3 River Bure

20.3.3.1 Overview

22. The River Bure is a moderately sinuous watercourse that has been historically resectioned and enlarged (Plate 20.4). The channel has largely uniform banks and flow conditions are dominated by uniform glides. Evidence of lateral accretion (in the form of low berms within the resectioned bank line) suggests that the channel is naturally recovering from historical modifications.

Plate 20.4 River Bure

20.3.3.2 Channel form

23. The River Bure follows a moderately sinuous meandering planform, although individual lengths of channel within the study reach appear to have been historically straightened and resectioned. The channel is approximately 8 to 10m wide.

24. The water was very close to the bank top at the time of the survey; emergent vegetation growth suggests that this is likely to be representative of prevailing conditions in this reach. The banks above 'normal' water level are shallow (<1.5m) and uniformly graded, while the banks below the water are vertical or very steeply graded.

25. Low level floodplain units (berms or inset benches) were apparent throughout the reach, most notably (but not exclusively) on the right bank. These features have formed inside the wider bank line, and are likely to be representative of channel narrowing by lateral accretion. This suggests that channel has been historically enlarged but is now readjusting naturally. This is supported by the uniformly graded banks and localised straightening within the larger-scale meandering planform.

26. Although there was no evidence of erosion at the time of the survey, evidence of cattle poaching was observed in parts of the left bank that lacked the low-level berms.

20.3.3.3 Flow conditions

27. Low energy glide flows are predominant throughout the study reach. The water was very deep and highly turbid at the time of the survey.

20.3.3.4 Floodplain characteristics

28. The floodplain appears to be well connected to the river channel throughout the survey reach. The floodplain on the left bank is dominated by woodland, while the land on the right bank is used for grazing livestock. There are several drains on the floodplain on the left bank, which run parallel to the river. However, these features are not directly connected to the main river channel (although they may have been connected in the past). This area of floodplain also contains several damp depressions that could contain standing water during wetter periods.

20.3.3.5 In-channel and riparian vegetation

29. The bed was obscured by turbid water at the time of the survey, so it was not possible to determine whether there was significant growth of submerged in-channel vegetation. However, the dominant low-energy flow conditions suggest that a degree of vegetation growth is likely. The majority of the channel is fringed by reeds and other emergent plant species. A large proportion of the left bank is lined by mature trees, which are largely (but not exclusively) set back from the edge of the channel by several metres.

20.3.4 Blackwater Drain

20.3.4.1 Overview

30. The Blackwater Drain (also known as the Booton Watercourse at this point) is a narrow, meandering channel that supports a range of different flow types and geomorphological habitat niches (Plate 20.5). Exposed tree roots in the bed indicate that the channel has recently incised.

20.3.4.2 Channel form

31. The channel is approximately 3m wide and follows a gently meandering course. The banks are steep, stable and well vegetated. The channel supports a range of habitat niches, including exposed gravel bars, shallow riffles and deeper pools. The substrate is dominated by gravels with occasional cobbles, with silt deposition occurring in the margins and slower flowing areas.

32. Exposed tree roots in the survey reach, particularly downstream of the proposed cable crossing, suggest that the watercourse is currently incising or has done so recently.

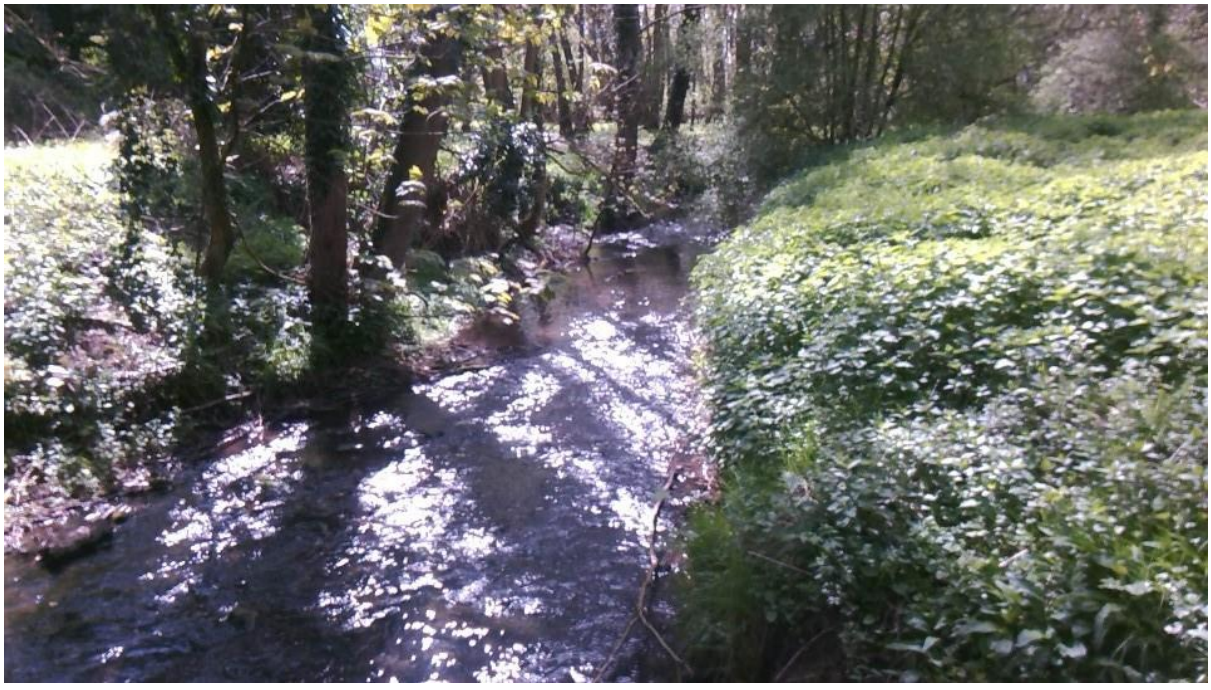

Plate 20.5 Blackwater Drain

20.3.4.3 Flow conditions

33. A range of flow types were observed at the time of the survey, including swift glides in deeper sections (e.g. pools) and riffle flow in shallower sections of the channel.

20.3.4.4 Floodplain characteristics

34. The land on both banks is dominated by pastoral agriculture. There are several areas of woodland in close proximity to the channel.

20.3.4.5 In-channel and riparian vegetation

35. The banks are well vegetated, and there is extensive riparian tree growth. However, very little emergent or in-channel vegetation was observed.

20.3.5 River Wensum

20.3.5.1 Overview

36. The River Wensum is a gently meandering chalk river, with a wide, deep channel and very shallow banks (Plate 20.6 and Plate 20.7). Flows are dominated by uniform, low energy glides, and siltation appears to be the dominant geomorphological process. The channel is fringed by low embankments which may reduce floodplain connectivity but are likely to be frequently overtopped.

Plate 20.6 River Wensum (upstream end of cable corridor)

Plate 20.7 River Wensum (downstream end of onshore cable corridor)

20.3.5.2 Channel form

37. The channel in this reach is gently meandering, with a high meander wavelength and low amplitude. The channel is approximately 20m wide at the bank top.

38. At the time of the survey, the water appeared to be at the natural bank top and close to the level of the floodplain. Emergent vegetation growth suggests that this is likely to be representative of typical low flow conditions in this reach. There is a wide, low (<1m), gently graded embankment along the majority of both banks in this reach.

39. The coarse-grained (gravel) bed that is characteristic of chalk rivers is not visible in this reach. Instead, the substrate is dominated by silts, with extensive accumulations in the channel margins extending across the channel bed.

40. Although deposition is the dominant process in this reach, an area of bank scour and collapse was observed on the right bank at the upstream limit of the proposed cable corridor. This is likely to be a response to the growth of trees and reeds on the opposite side of the channel, which pushes flows towards the right bank.

20.3.5.3 Flow conditions

41. Flows in the reach are dominated by uniform, low energy glides. The channel is very deep, with normal water level apparently close to the top of the bank. The water column was very turbid at the time of the survey.

20.3.5.4 Floodplain characteristics

42. The floodplain on the right bank consists of wet grassland that appears to be used for grazing livestock. The land on the left bank is also used for grazing.

43. The channel is fringed by low embankments that follow the bank line. Although these are likely to reduce floodplain connectivity during lower flows, these features are very low and are likely to be overtopped regularly.

44. Several shallow linear depressions containing wetter ground and wetland plants (*Juncus* spp. and *Carex* spp.) were visible on the floodplain, particularly on the right bank close to the channel. These are likely to be representative of palaeochannels (historical courses of the river).

45. The floodplain on both banks is crossed by an artificial drainage system, with drains running parallel to the main river on both sides of the channel. These are offset by at least 20m from the left bank and 30m from the right bank in the proposed cable corridor. The drains are wide and deep, with uniformly steep graded banks.

20.3.5.5 In-channel and riparian vegetation

46. Extensive growth of emergent vegetation was observed at the time of the survey, particularly on the right bank. A line of reeds was observed along the inside edge of the embankment, which marks the top of the right bank. There are also occasional riparian trees, most notably on the left bank at the upstream end of the proposed cable corridor.

20.3.5.6 Penny Spot Beck

47. The onshore cable corridor also crosses Penny Spot Beck, a tributary of the River Wensum that joins the main river approximately 30m downstream of the outer limit of the corridor (Plate 20.8).

Plate 20.8 Penny Spot Beck

48. The narrow, straight channel is characterised by steep, uniform banks and shallow, low energy glide flows. There is significant impoundment along parts of the reach, as a result of fallen trees or culverts beneath earth bank crossings.

49. Siltation is the dominant geomorphological process along much of the channel, with the natural coarse gravel bed largely obscured by thick deposits of silt. However, flow is sufficiently swift in several isolated steeper reaches that are also free from impoundment to maintain a clean gravel substrate.

50. A large proportion of the channel within the proposed cable corridor is affected by cattle poaching, resulting in localised bank collapse and an extensive supply of fine sediment. The water is highly turbid along the entire reach.

20.3.6 Wendling Beck at Bushy Common

20.3.6.1 Overview

51. Wendling Beck is a gently meandering chalk river that has been historically straightened (Plate 20.9). The channel is shallow, with steep, low banks and swift flows. These maintain the natural coarse substrate along the majority of the reach, although there is evidence of fine sedimentation along the channel margins and upstream of a twin pipe culvert.

Plate 20.9 Wendling Beck (Bushy Common reach)

20.3.6.2 Channel form

52. The channel is approximately 2m wide, follows a low sinuosity, gently meandering planform through the proposed cable corridor, and is likely to have been historically straightened. The planform is highly sinuous in the unmodified reach immediately downstream.

53. The banks are steep and very low (<0.5m high). Although they are largely well vegetated, there is some evidence of localised toe scour, and exposed tree roots on the right bank indicate that the channel has migrated by at least 0.3m.

54. The channel flows through twin pipe culverts beneath the road at the downstream end of the onshore cable corridor.

55. The substrate is dominated by coarse gravels, although there is evidence of fine sedimentation in the channel margins. The proportion of silts increases upstream of the culverts, which reduce energy sufficiently to promote enhanced deposition.

20.3.6.3 Flow conditions

56. Considerable variation in flow types was observed in this reach. Flows were generally swift and shallow, with alternating runs and riffles. A swift glide was observed upstream of the culverts.

20.3.6.4 Floodplain characteristics

57. The floodplain is wide and flat, and the channel appears to be well connected. The land on both banks through the cable corridor is used for arable agriculture, although grazing land and woodland were observed further upstream and downstream.

20.3.6.5 In-channel and riparian vegetation

58. No in-channel vegetation was observed at the time of the survey, with the exception of an area of young emergent reeds on the left bank at the downstream end of the reach. This narrows the channel and promotes locally swifter flows. The banks are well vegetated throughout the reach. There are several isolated riparian trees on the left bank, and a small copse of woodland on the left bank at the downstream end of the proposed cable corridor.

20.3.7 Wendling Beck at Old Brigg

20.3.7.1 Overview

59. Wendling Beck is a gently meandering channel with low energy glide flows and extensive siltation which obscures the coarse substrate that would typically be associated with chalk rivers (section 20.3.6). The deep, narrow channel has steep banks, and much of the watercourse is likely to have been historically resectioned (Plate 20.10).

20.3.7.2 Channel form

60. The channel is gently meandering, with evidence of straightening in individual sub-reaches. However, it is likely that the channel was considerably more sinuous in the past; for example, a large remnant channel is evident at the downstream (northern) limit of the onshore cable corridor. This channel, which still contains water, is fed by

a field drainage system and re-joins the main channel further downstream. This feature may also be fed by water from Wendling Beck (e.g. through a pipe), although this was not observed during the walkover survey. This channel is likely to have been cut off to increase conveyance in this reach.

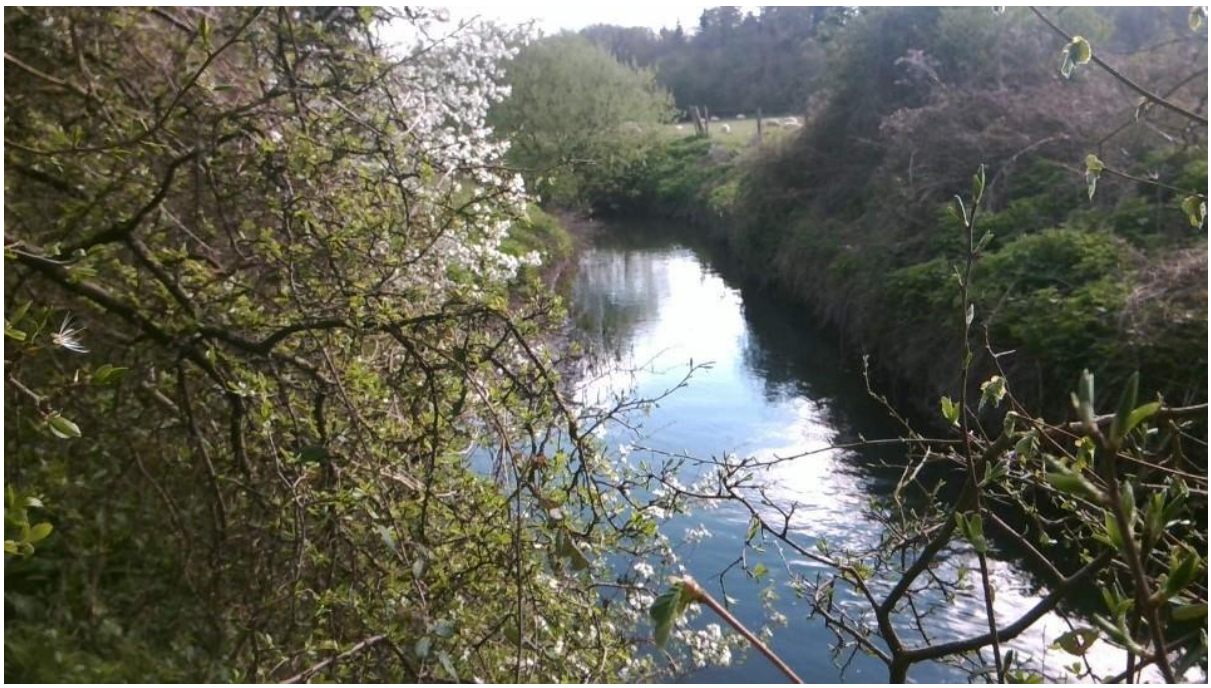

Plate 20.10 Wendling Beck (Old Brigg reach)

61. The channel is narrow (approximately 4m wide) and incised. The banks are vertical or steeply graded, and frequently obscured by extensive vegetation growth. The substrate is dominated by silts, which overlie the natural coarse bed observed further upstream (see section 20.3.6). The steep banks and straightened nature of the channel at sub-reach scale suggest that the beck has been historically resectioned and potentially dredged.

20.3.7.3 Flow conditions

62. Flows are dominated by low energy glides, which were observed throughout the study reach.

20.3.7.4 Floodplain characteristics

63. The floodplain on both banks is used for grazing. The left bank incorporates an area of woodland at the upstream end of the proposed cable corridor, including a pond. Both banks further upstream are wooded.

64. There are no significant barriers to floodplain connectivity, although the incised nature of the channel means that it may be limited

20.3.7.5 In-channel and riparian vegetation

65. Marginal vegetation was observed at some points in this reach, helping to encourage the accumulation of fine grained sediments at the channel margins. The banks are well vegetated. The right bank through the proposed cable corridor is largely tree-lined, and there is also considerable tree growth on the left bank at the upstream end of this reach.

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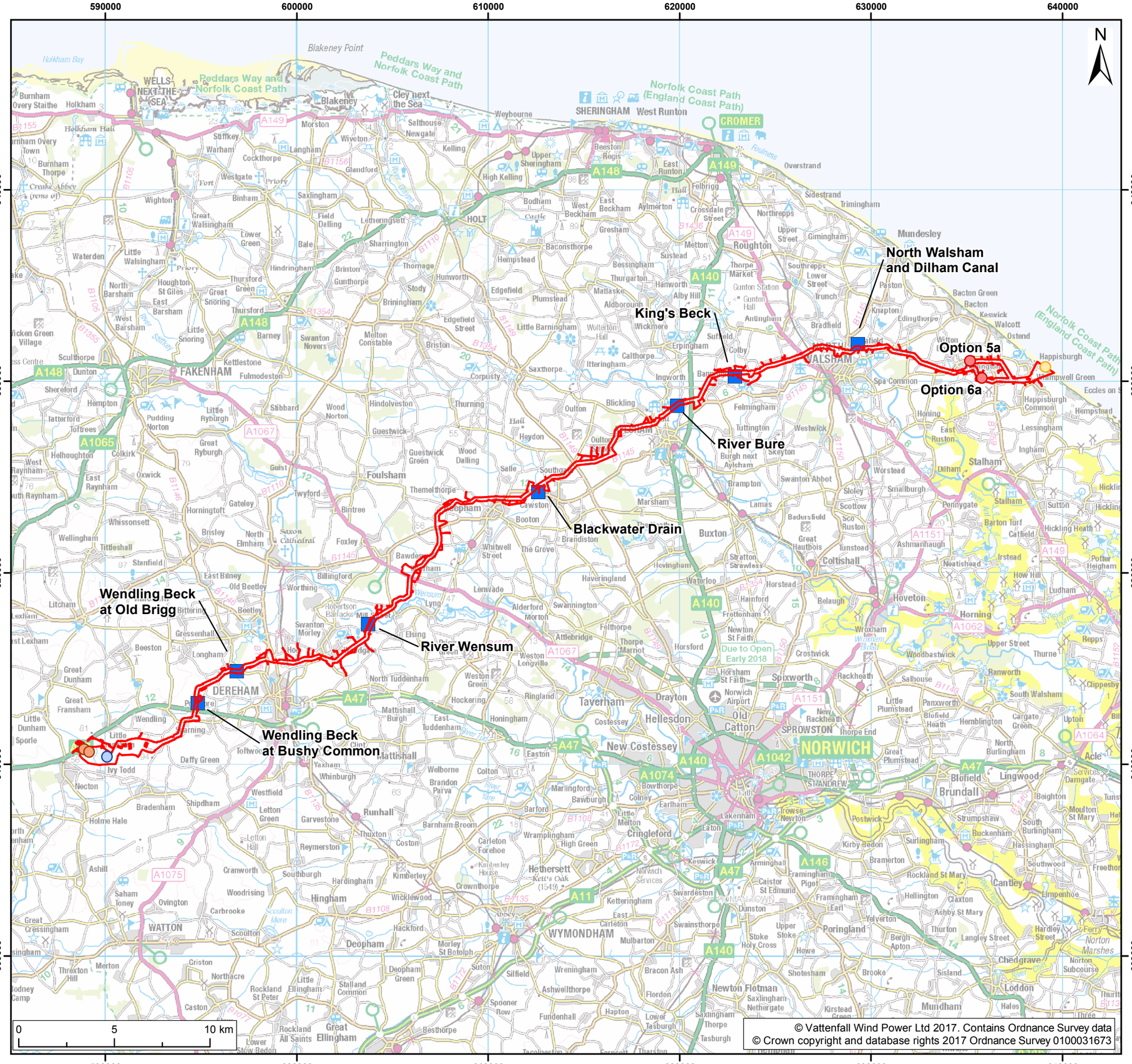
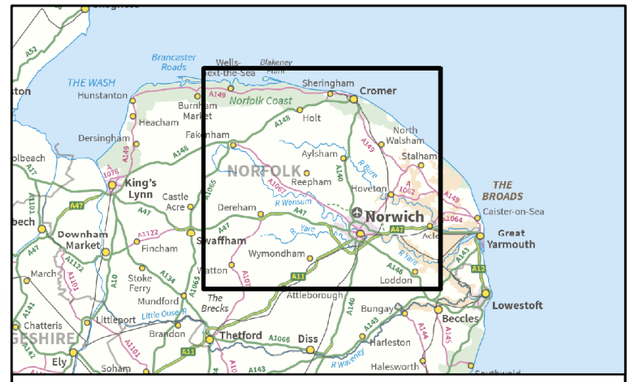
20.4 Appendix 20.3 Figures





Legend:

- Norfolk Vanguard onshore project area
- Landfall zone location
- Cable relay station location option
- Onshore project substation location
- National Grid substation extension location
- River Survey Location

Project: Norfolk Vanguard	Report: Geomorphological Walkover Survey

Title: Location of Field Survey Sites

Figure: 20.1 | Drawing No: PB4476-004-0203-001

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
01	04/09/2017	NJ	ID	A3	1:200,000
02	06/09/2017	NJ	ID	A3	1:200,000

Co-ordinate system: British National Grid **EPSG:** 27700

VATTENFALL

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