Cyfoeth Naturiol Cymru
Natural Resources Wales

Newborough Warren Phase 1 Dune Rejuvenation Works Topographic Survey Report

Kenneth Pye & Simon J. Blott

Kenneth Pye Associates Ltd

Report No: 101

Date: March 2015

About Natural Resources Wales

Natural Resources Wales is the organisation responsible for the work carried out by the three former organisations, the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales. It is also responsible for some functions previously undertaken by Welsh Government.

Our purpose is to ensure that the natural resources of Wales are sustainably maintained, used and enhanced, now and in the future.

We work for the communities of Wales to protect people and their homes as much as possible from environmental incidents like flooding and pollution. We provide opportunities for people to learn, use and benefit from Wales' natural resources.

We work to support Wales' economy by enabling the sustainable use of natural resources to support jobs and enterprise. We help businesses and developers to understand and consider environmental limits when they make important decisions.

We work to maintain and improve the quality of the environment for everyone and we work towards making the environment and our natural resources more resilient to climate change and other pressures.

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We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

This Evidence Report series serves as a record of work carried out or commissioned by Natural Resources Wales. It also helps us to share and promote use of our evidence by others and develop future collaborations. However, the views and recommendations presented in this report are not necessarily those of NRW and should, therefore, not be attributed to NRW.

Newborough Phase l Dune Rejuvenation Works Topographic Survey March 2015

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1. Job Summary

KPAL Job No:	270315
Report Date:	24/08/2015
Client:	Natural Resources Wales
Client Job Title:	Newborough Warren Dune Rejuvenation Works: Phase 1
Survey conducted:	27th March 2015
Instruments used:	Leica Viva NetRover controller and GS08 SmartAntenna mounted on GLS30 pole (2 m) Leica RX900 controller and ATX900 antenna mounted on GLS30 pole (2 m) Leica GX1230 RTK base station mounted on GST20-9 tripod Leica RX1210T Field Controller
No. of data points:	1838
RTK Control Station:	Wooden post surveyed-in using Leica Smartnet GPRS on 16 May 2013 (BM1). The post was found to be firm in the ground and no movement was considered likely since 2013. The post was resurveyed using Leica Smartnet GPRS, and the new positions (which were 6 to 24 mm different from 2013) were used as the benchmark for the survey: Easting: 242096.660 m Northing: 363312.431 m Height: 21.499 m OD
RTK Backup Station:	Wooden post surveyed-in using Leica Smartnet GPRS on 16 May 2013 (BM2), 25 m NNE of Control Station above (see Table 2).
Fixed profiles:	Thirty existing profile lines (1-30, previously surveyed on 16-17 May 2013 and 13 March 2014) were resurveyed, and the three ground surveys compared with data surveyed before the restoration works using airborne LiDAR in May 2009. Chainages along profile lines were interpolated at positions on a theoretical straight-line between the zero and end points of the profile.
Survey undertaken by:	S.J. Blott, A. Pye and K. Pye

2. Scope and purpose

The requirements for dune rejuvenation trials at Newborough Warren were identified in a report by Pye & Blott (2012). Three areas (referred to as Areas 2, 3 and 4) were subsequently selected for Phase 1 trials which commenced in January 2013 and involved (a) stripping of vegetation from the windward dune slopes, crests and parts of the arms and deflation corridors, (b) excavation of sand to deepen parts of the deflation corridors to encourage the development of wet slack habitat, (c) placement of stripped turf blocks in areas on and behind the dune arms, and (d) in the case of Area 3 the placement of excavated sand to create a bare sand mound. No works have been undertaken in Area 1 identified by Pye & Blott (2012) which serves as a control.

An aerial LiDAR survey of Newborough Warren east of Newborough Forest was conducted on 12 May 2009 (Figure 1), and the entire Newborough area was flown on 9 April 2014 (Figure 2). A first topographic monitoring survey of the Phase I area was carried out in May 2013 (KPAL, 2013) and was followed by a drone aerial photography survey by ExeGesis Ltd in June 2013 (Figure 3). A second ground topographic monitoring survey carried out on 13th March 2014. This report provides a summary of the results of a third ground topographic monitoring survey carried out on 27th March 2015 and comparisons made with previous surveys.

3. Survey methods and error checking

In the March 2015 survey ground surface elevations were determined at 1838 points using Leica RTK GPS SmartRover equipment listed in the Job Summary (Section 1.0) above. The distribution of survey points in relation to the three rejuvenation trial areas is shown in Figures 1 and 2. Many of the survey points were located on profile lines which were also surveyed in May 2013 and March 2014. The limits of defined features, including areas of windblown sand deposition, the main dune crest, and areas of standing water, were also mapped by survey points.

Average vertical and horizontal errors reported by the instrument during the March 2015 survey were well within the expected range (Table 1).

The benchmark posts 1 and 2, which were established in May 2013, were still present in March 2015 and were found to be firm with no sign of movement over the intervening period. Re-checking of the position and elevation of the benchmarks using Leica SmartNet corrections showed a vertical differences of 24 mm and 31 mm, which are within the errors expected for RTK GPS technique, due largely to atmospheric effects (Tables 2 and 3).

Ground photographs were taken at a number of locations around the site; a selection is reproduced in Appendix 1.

4. Results - profile comparisons

4.1 Area 2

The locations of survey profile lines within Area 2 are shown in Figures 4 and 5. A summary of the changes between the LiDAR surveys in May 2009 and April 2014 is shown in Figure 6. The main features (base and crests of dune ridges, standing water, and areas of blown sand) mapped in the field are shown in Figure 7. Topographic profiles recorded during the March 2015 survey are compared with those of the May 2013 and March 2014 surveys in Figure 8.

The changes in elevation along most of the profiles were relatively small, amounting to less than 10 cm on the margins of the deflation troughs and the greater part of the side walls. Greater lowering was evident on the raised dune ridge on the western arm, where it is crossed by Profile 6, and on the dune crest in the NE corner of the site, where it is crossed by Profile 11. Further windblown sand has accumulated in the NW margin of the trial area, transported from the adjoining upwind area by southwesterly and southerly winds. This area remains largely free from vegetation, and the unconsolidated sand is deep enough to be become mobile during periods of high wind activity to form megaripples and small barchan features.

The total area of substantially bare sand area surveyed in March 2015 was 1.95 ha, an increase of 0.16 ha since the restoration works in 2013 (Table 4), caused by the increase in blown sand area to the north of the site.

4.2 Area 3

The locations of survey profile lines within Area 3 are shown in Figures 9 and 10. A summary of the changes between the LiDAR surveys in May 2009 and April 2014 is shown in Figure 11. The main features (base and crests of dune ridges, standing water, and areas of blown sand) mapped in the field are shown in Figure 12. Topographic profiles recorded during the March 2015 survey are compared with those of the May 2013 and March 2014 surveys in Figure 13.

Changes in elevation since March 2014 were again small (generally less than 10 cm), depending on location. The main areas of lowering due to deflation were in the NE part of the site (i.e. most exposed to southwesterly winds), on profiles 19 and 20. A substantial portion of this sand appears to have accumulated in the northern corner of the site where Profile 18 has exhibited up to 1 metre of accretion along most of the profile from the base to the crest. A thick layer (generally 1-15 cm) of largely unvegetated sand was evident on the downwind side of the dune crest, having been transported there by southwesterly winds, with a thinner spread of sand extending some 50 metres NE of the de-vegetated dune crest.
The total substantially bare sand area surveyed in March 2015 was 1.29 ha, an increase of 0.21 ha since the restoration works in 2013 (Table 4), caused by the increase in blown sand area to the north of the site.

4.3 Area 4

The locations of survey profile lines within Area 4 are shown in Figures 14 and 15. A summary of the changes between the LiDAR surveys in May 2009 and April 2014 is shown in Figure 16. The main features (base and crests of dune ridges, standing water, and areas of blown sand) mapped in the field are shown in Figure 17. Topographic profiles recorded during the March 2015 survey are compared with those of the May 2013 and March 2014 surveys in Figure 18.

Only very small elevation differences are evident on the vegetation-stripped areas around Area 4, including the new ridge in the SW part of the site which has exhibited remarkably little change. Sand continues to spread northwards on the downwind side of the trial area, forming a largely unvegetated 0-10cm thick layer, probably sourced from a former artificial sand mound and very little sand deflation is evident anywhere else in Area 4.

The winter of 2014-15 was relatively dry, with the result that groundwater levels were low at the time of survey and little standing water in all three areas. The large lake covering much of Area 4 in March 2014 has, by March 2015, reduced to a very small puddle, much used by the resident ponies, surrounded by a 5 metre wide wet mud patch.

The total substantially bare sand area surveyed in March 2015 was 1.22 ha, an increase of 0.12 ha since the restoration works in 2013 (Table 4), due mainly to an increase in blown sand extent to the north of the site.

Within all three areas some vegetation regrowth and development of surface algal crusts was evident between the 2014 and 2015 surveys, but significant areas of actively moving sand remain, particularly near the crests and on the upper parts of the dune ‘arms’, and a thin layer of windblown sand continues to form in the vegetated areas downwind (see photographs in Appendix 1).

5. References

Pye, K. & Blott, S.J. (2012) *A Geomorphological Survey of Welsh Dune Systems to Determine Best Methods of Rejuvenation. Appendix 3, Newborough Warren.* CCW Contract Science Report 1002.CCW, Bangor.

KPAL (2013) *Newborough Warren Dune Topographic Monitoring Survey, May 2013*. Kenneth Pye Associates Ltd., Solihull.

KPAL (2014) *Newborough Warren Dune Topographic Monitoring Survey, March 2014*. Kenneth Pye Associates Ltd., Solihull.

6. Tables

Table 1. Average error reported by the instrument for all 1838 data points

	1-D quality control (height)	**2-D quality control (position)**	**3-D quality control (position and height)**
Average	9.0 mm	5.7 mm	10.7 mm
StDev	1.1 mm	0.7 mm	1.2 mm

Table 2. Measured location and height of Benchmark 1 (wooden post) in May 2013 and March 2015

	Easting (m)	**Northing (m)**	**Height (m OD)**
Surveyed with Smartnet corrections (16 May 2013)	242096.666	363312.415	21.475
Surveyed with Smartnet corrections (27 March 2015)	242096.660	363312.431	21.499
Difference:	-6 mm	+16 mm	+24 mm

Table 3. Measured location and height of Benchmark 2 (wooden post) in May 2013 and March 2015

	Easting (m)	**Northing (m)**	**Height (m OD)**
Surveyed with Smartnet corrections (16 May 2013)	242104.105	363335.967	14.099
Surveyed with Smartnet corrections (27 March 2015)	242104.118	363335.965	14.130
Difference:	+13 mm	-2 mm	+31 mm
Surveyed 27 March 2015 with base & rover start of survey Error:	242104.124 +6 mm	363335.966 +1 mm	14.116 -14 mm
Surveyed 27 March 2015 with base & rover end of survey Error:	242104.127 +9 mm	363335.956 -9 mm	14.120 -10 mm
Closing Error for Survey:	+3 mm	-10 mm	+4 mm

Table 4. Areas of bare sand in Areas 2, 3 and 4 of the Phase 1 site, for this survey and the two previous surveys. Note that standing water covered some of the site to varying extents in each of the surveys, but at times has dried out completely, and in the table below has been included in the vegetation-stripped area. Some vegetation re-growth has occurred since the initial restoration works, although in most cases it does not constitute a continuous sward, and these areas are included as 'bare sand' in the table below.

Bare sand type in Area 2	Area (ha)			
	May 2013	March 2014	March 2015	Change 2013-2015
Vegetation-stripped	1.36	1.36	1.36	0.00
Significant sand deposition in heaps	0.35	0.35	0.35	0.00
Blown sand	0.08	0.25	0.25	0.16
Total	1.79	1.96	1.95	0.16

Bare sand type in Area 3	Area (ha)			
	May 2013	March 2014	March 2015	Change 2013-2015
Vegetation-stripped	0.82	0.82	0.82	0.00
Significant sand deposition in heaps	0.17	0.17	0.17	0.00
Blown sand	0.11	0.30	0.32	0.21
Total	1.10	1.29	1.31	0.21

Bare sand type in Area 4	Area (ha)			
	May 2013	March 2014	March 2015	Change 2013-2015
Vegetation-stripped	0.96	0.96	0.96	0.00
Significant sand deposition in heaps	0.00	0.00	0.00	0.00
Blown sand	0.10	0.25	0.23	0.12
Total	1.07	1.22	1.19	0.12

Bare sand type in Areas 2, 3 and 4	Area (ha)			
	May 2013	March 2014	March 2015	Change 2013-2015
Vegetation-stripped	3.14	3.14	3.14	0.00
Significant sand deposition in heaps	0.52	0.52	0.52	0.00
Blown sand	0.30	0.80	0.79	0.49
Total	3.96	4.46	4.45	0.49

7. Figures

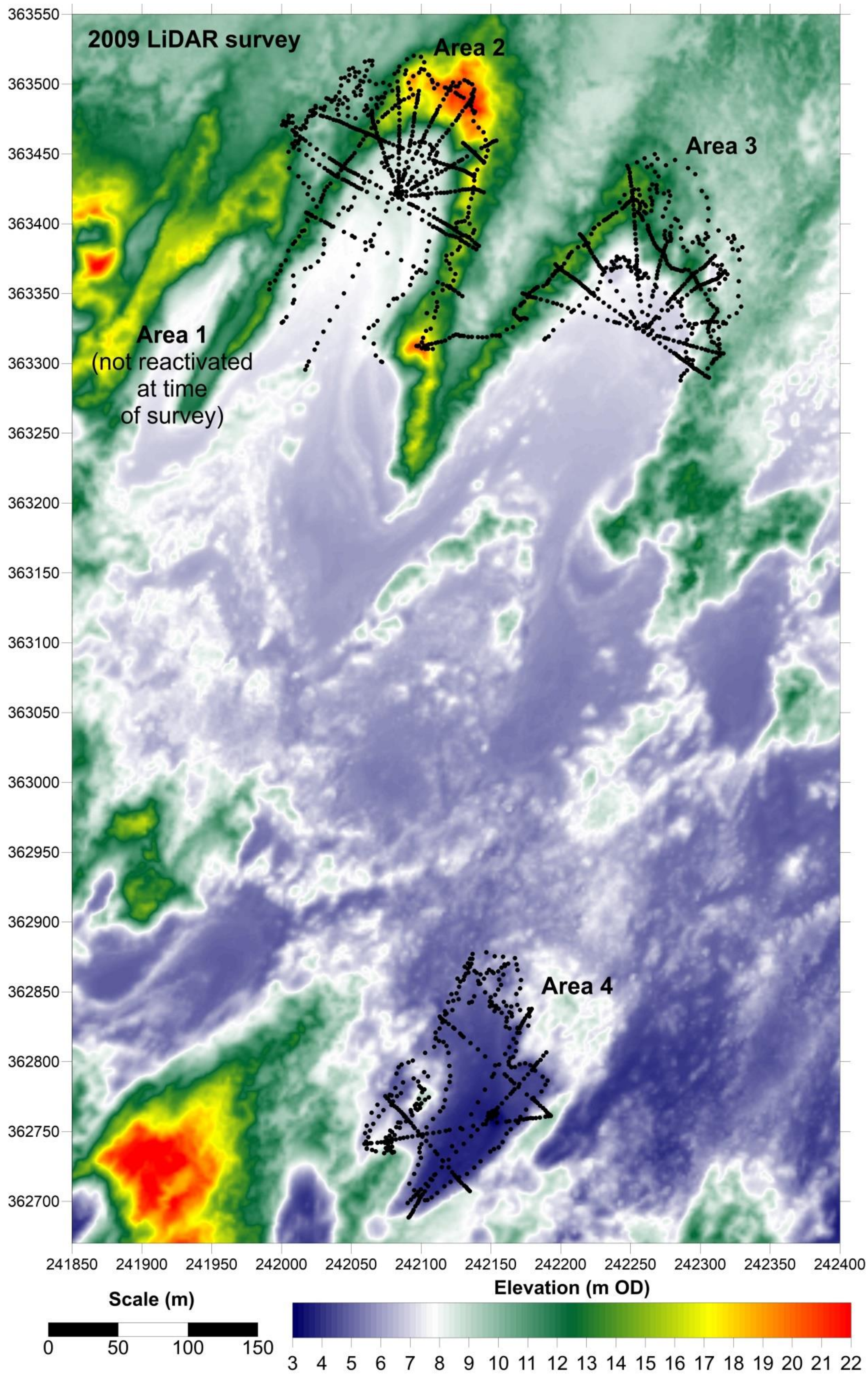


Figure 1. Locations of March 2015 survey data points (black dots) within the three rejuvenation trial areas 2,3 and 4, overlaid on a LiDAR DEM, flown May 2009.

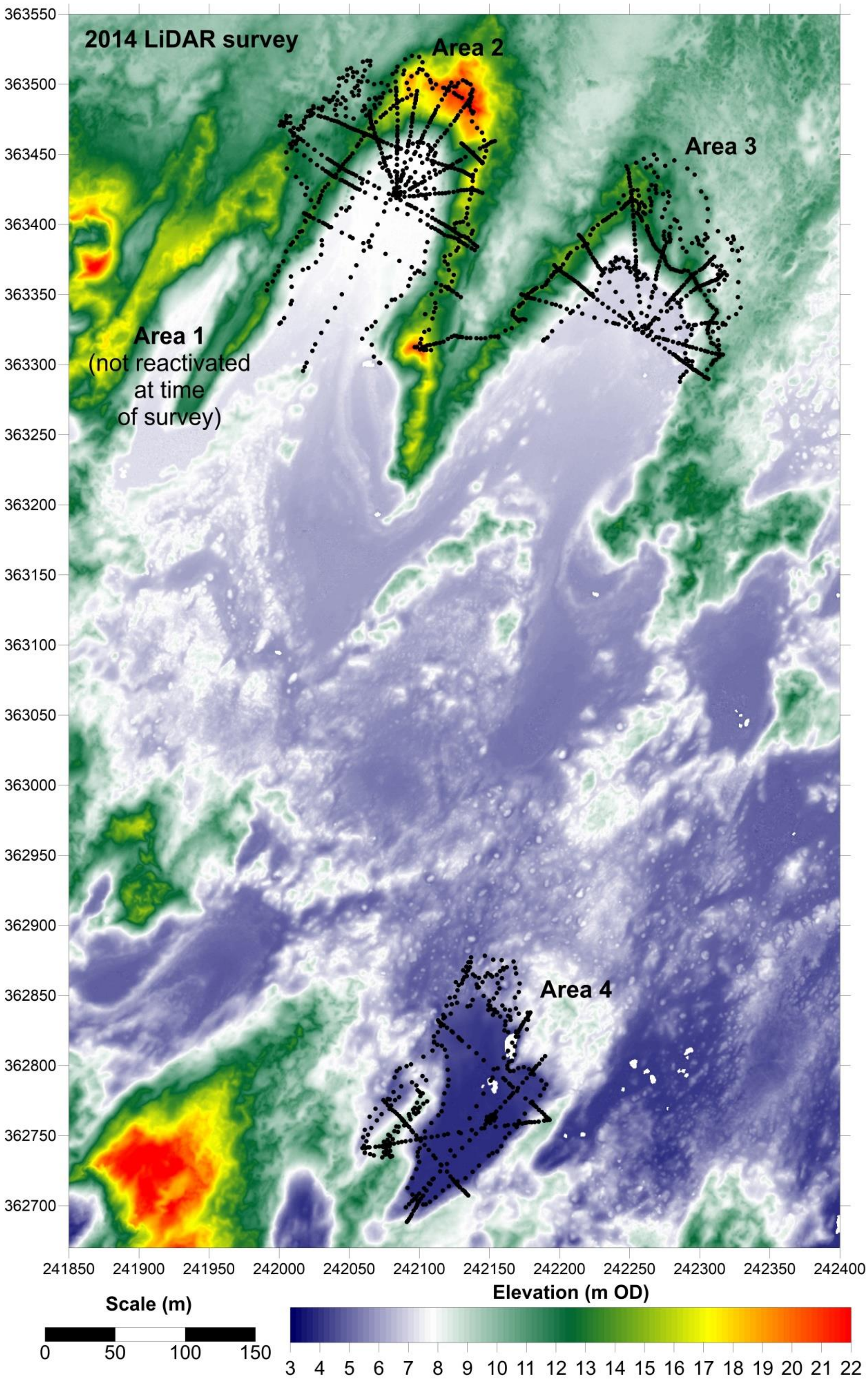


Figure 2. Locations of March 2015 survey data points (black dots) within the three rejuvenation trial areas 2,3 and 4, overlaid on a LiDAR DEM, flown March to April 2014.

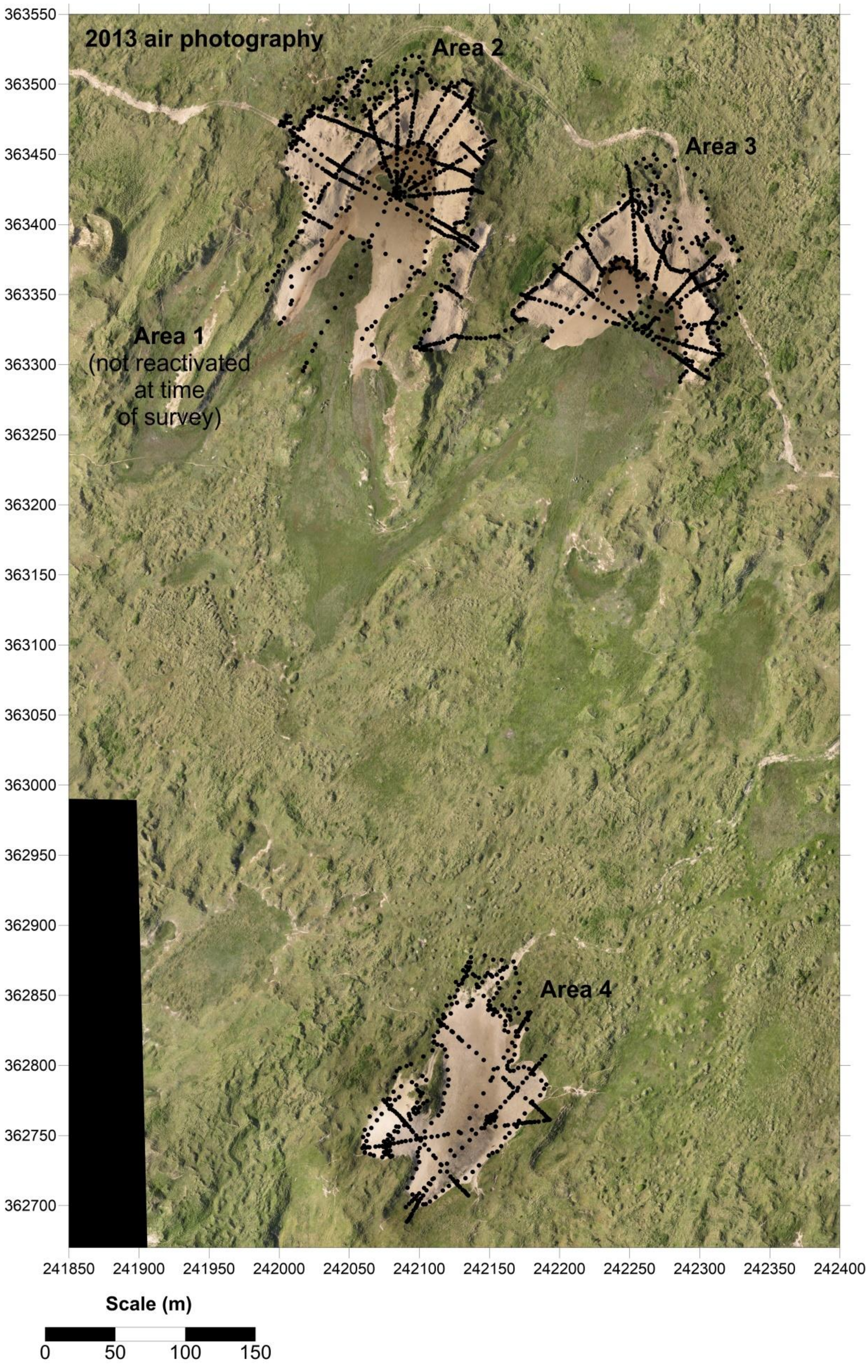


Figure 3. Locations of March 2015 survey data points (black dots) overlaid on June 2013 aerial photographs (flown by exeGesIS).

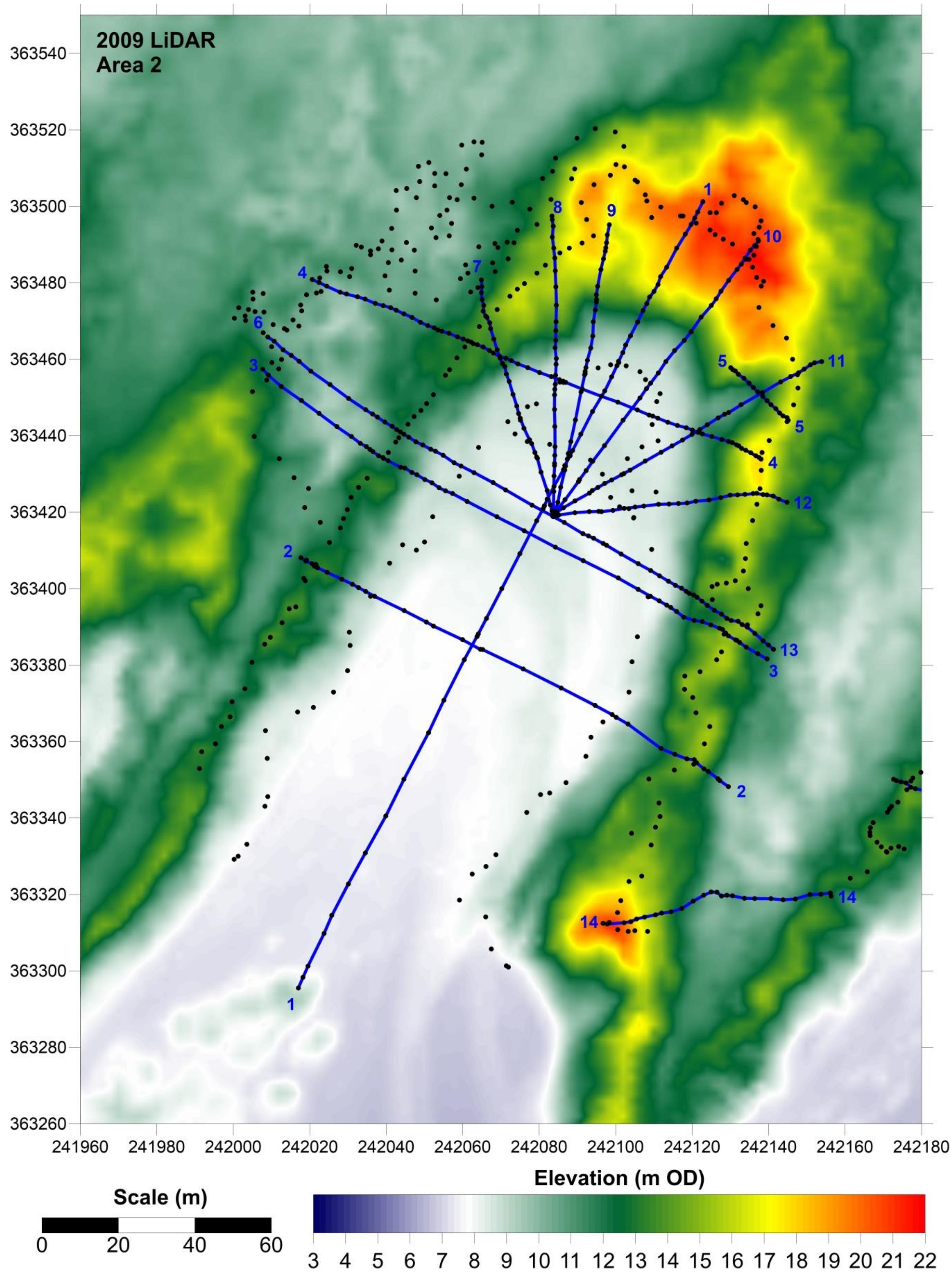


Figure 4. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) in Area 2, overlaid on 2009 LiDAR.

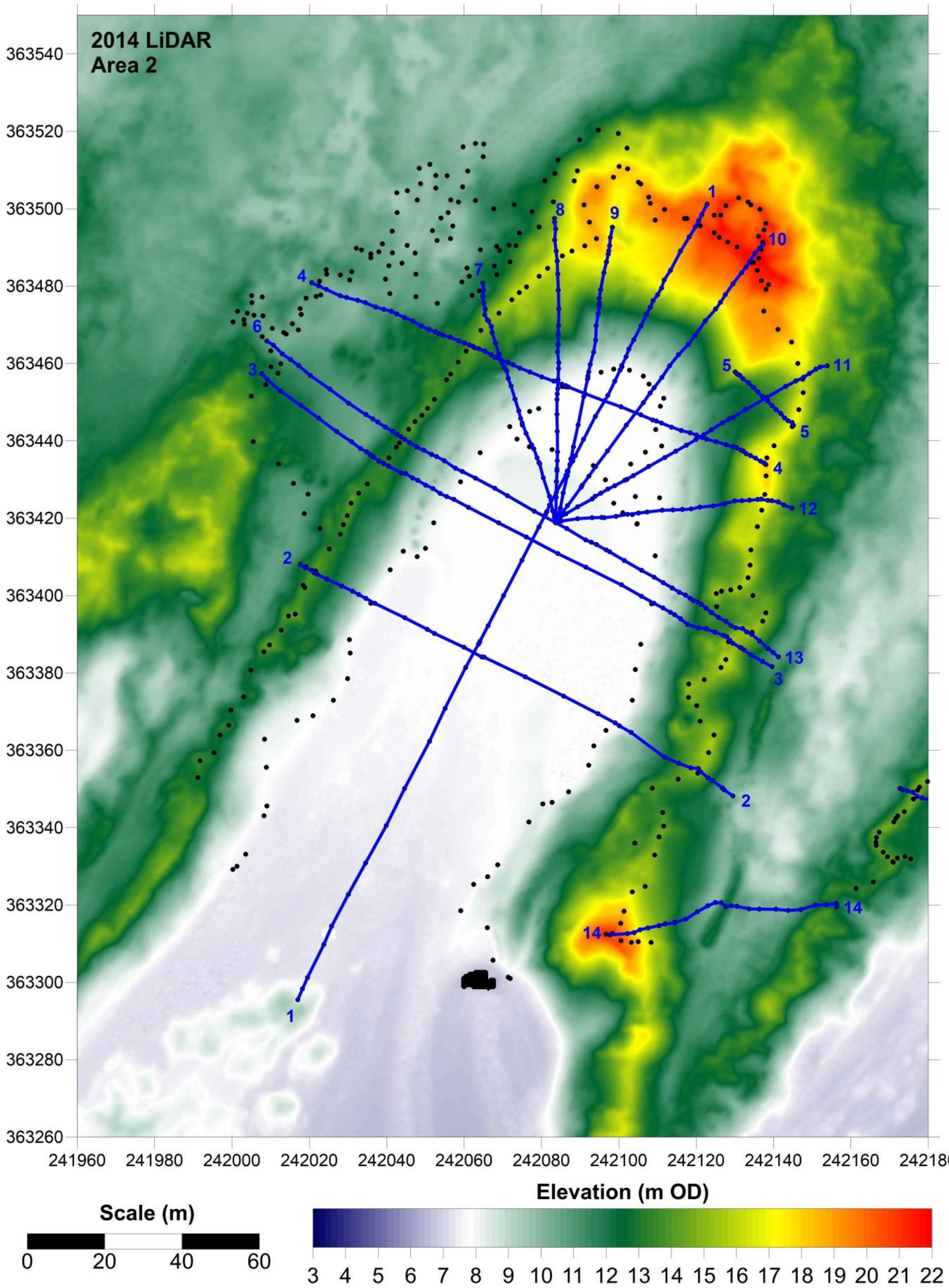


Figure 5. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) in Area 2, overlaid on 2014 LiDAR.

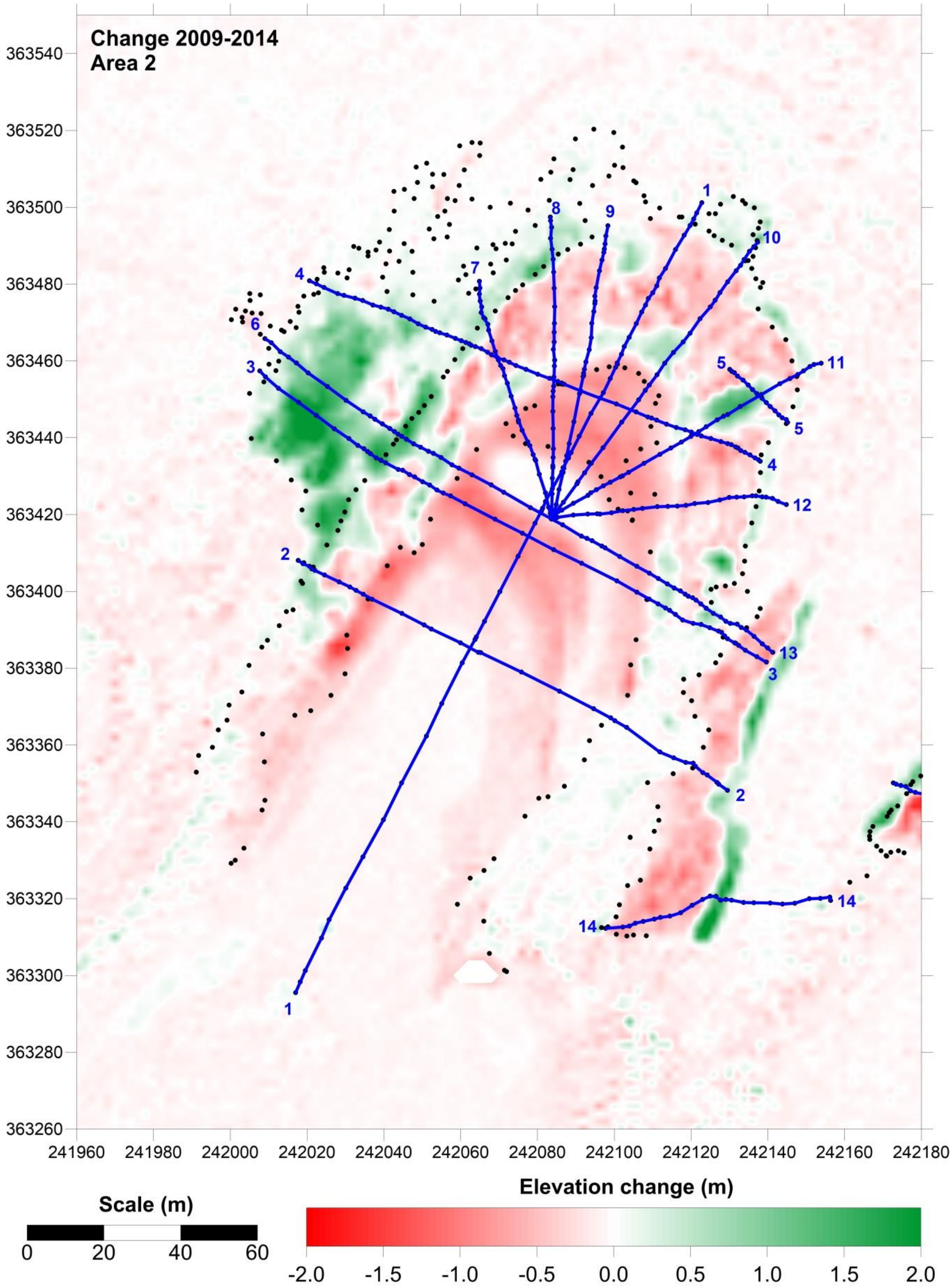


Figure 6. Change in elevation in Area 2 between the LiDAR surveys on 12 May 2009 and 9 April 2014. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) are also shown.

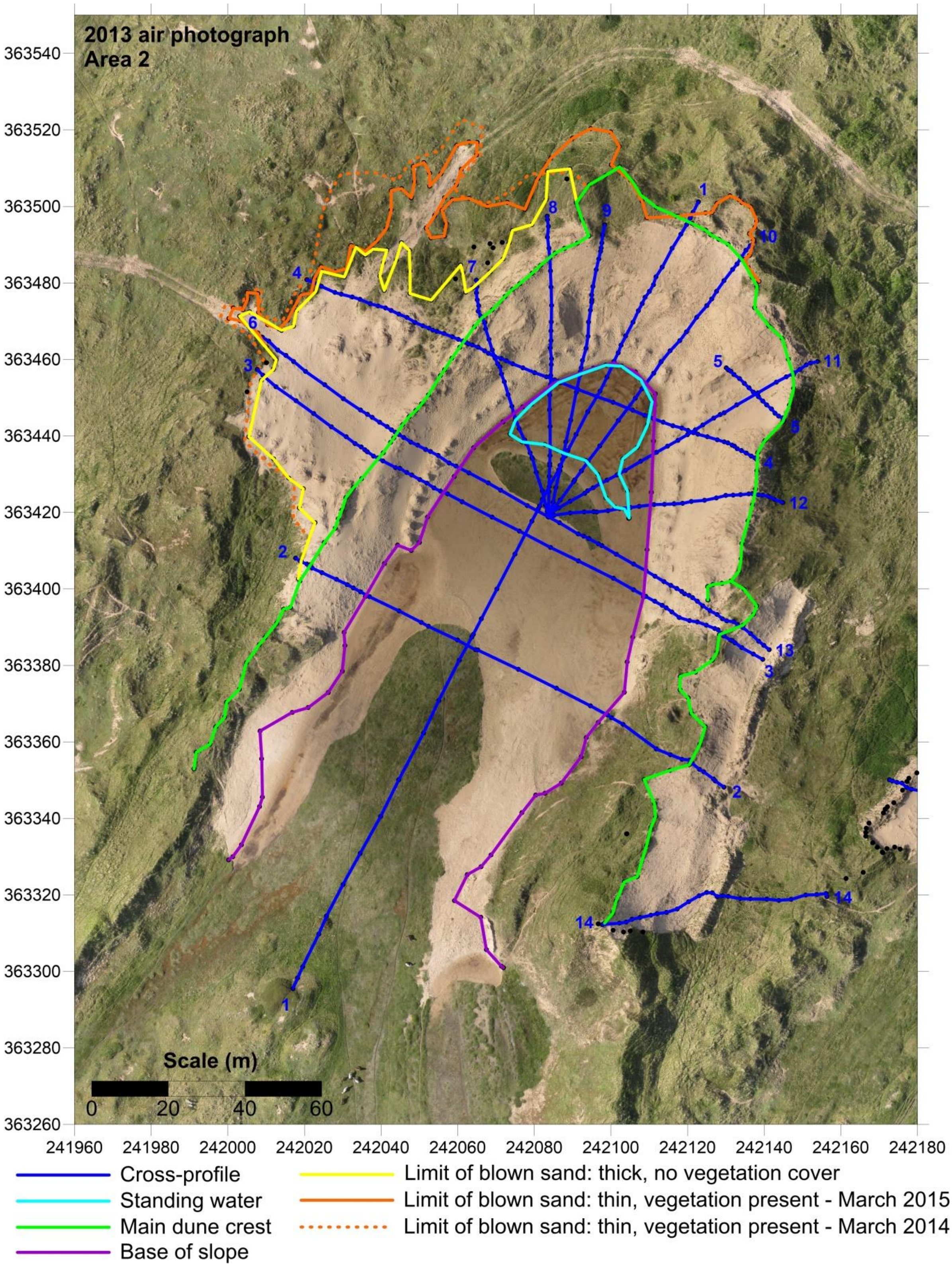
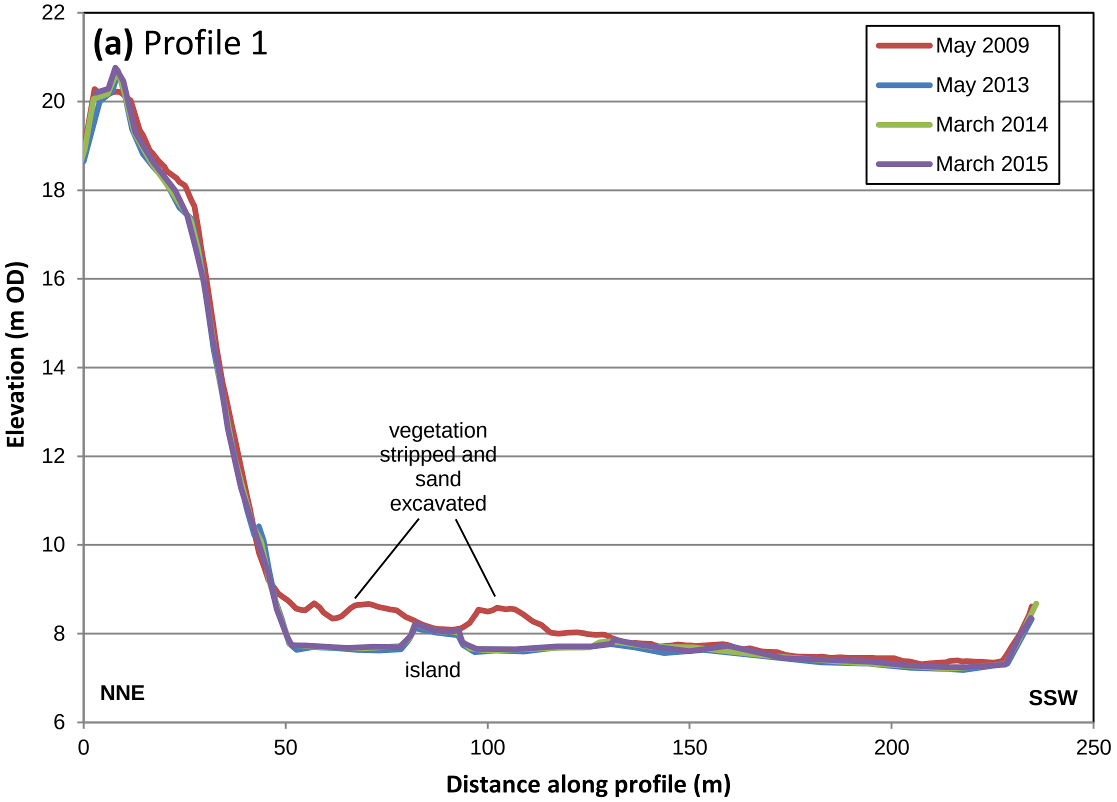


Figure 7. Locations of March 2015 data points (black dots) and cross-profiles (dark blue lines) in Area 2, overlaid on June 2013 aerial photographs (flown by exeGesIS). The limit of blown sand, standing water, and the main dune crest and base of slope surveyed in March 2015 are also shown.



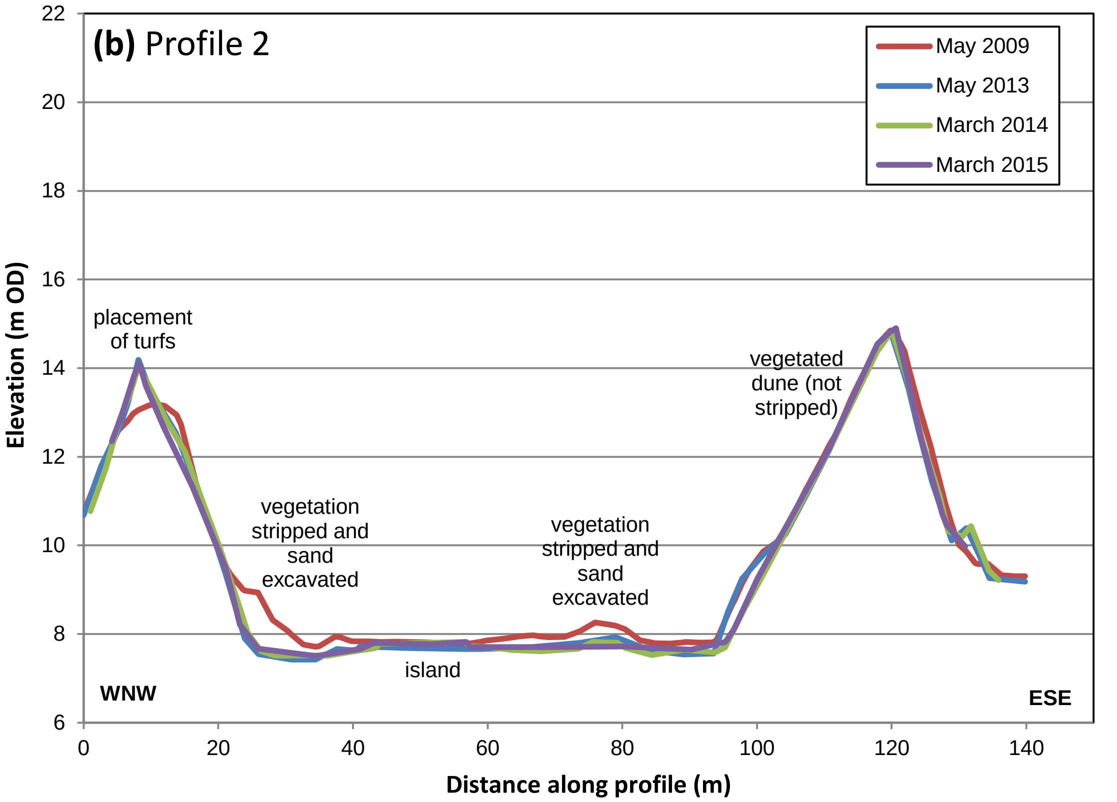
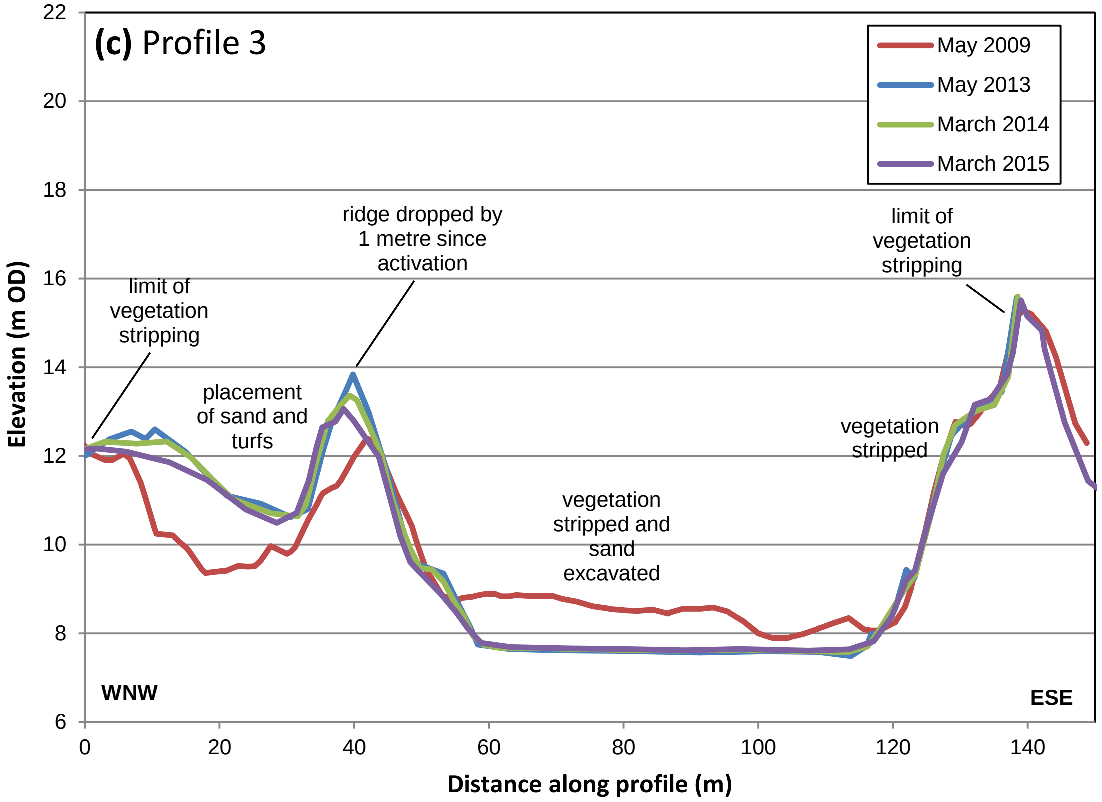


Figure 8. Comparison of surface levels at profiles 1 and 2 in Area 2, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 16 May 2013, 13 March 2014 and 27 March 2015.



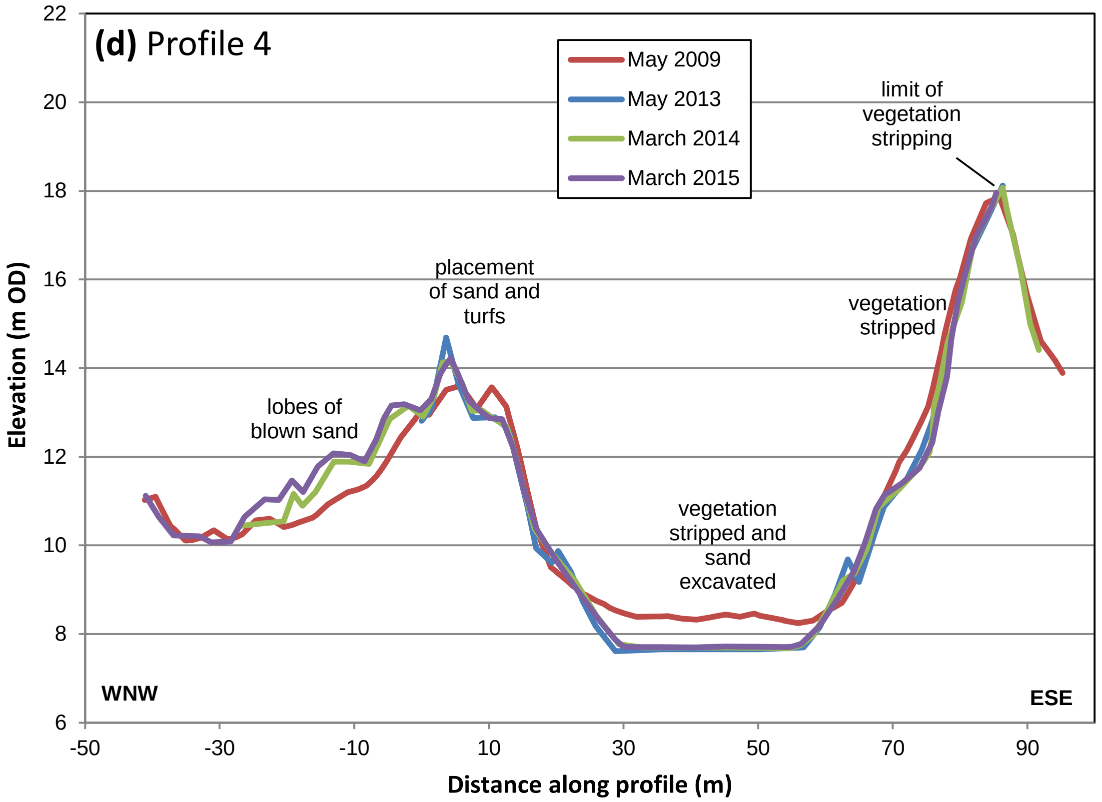
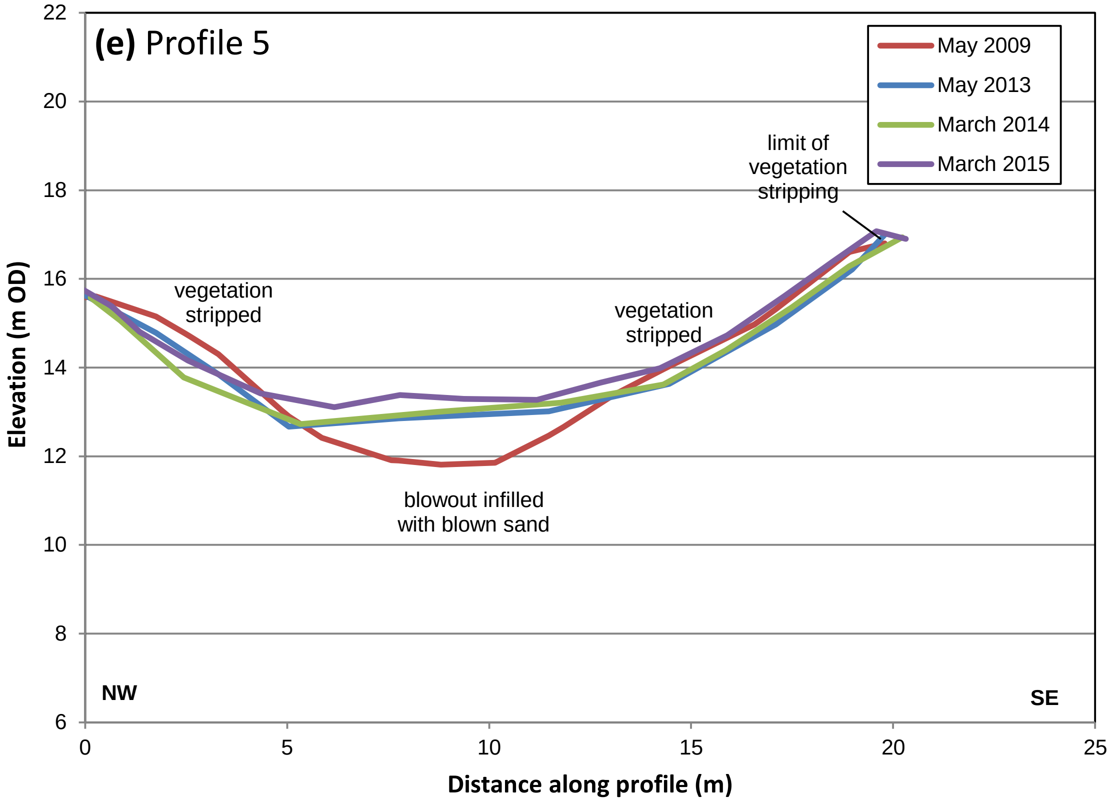


Figure 8 (continued). Comparison of surface levels at profiles 3 and 4 in Area 2, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 16 May 2013, 13 March 2014 and 27 March 2015.



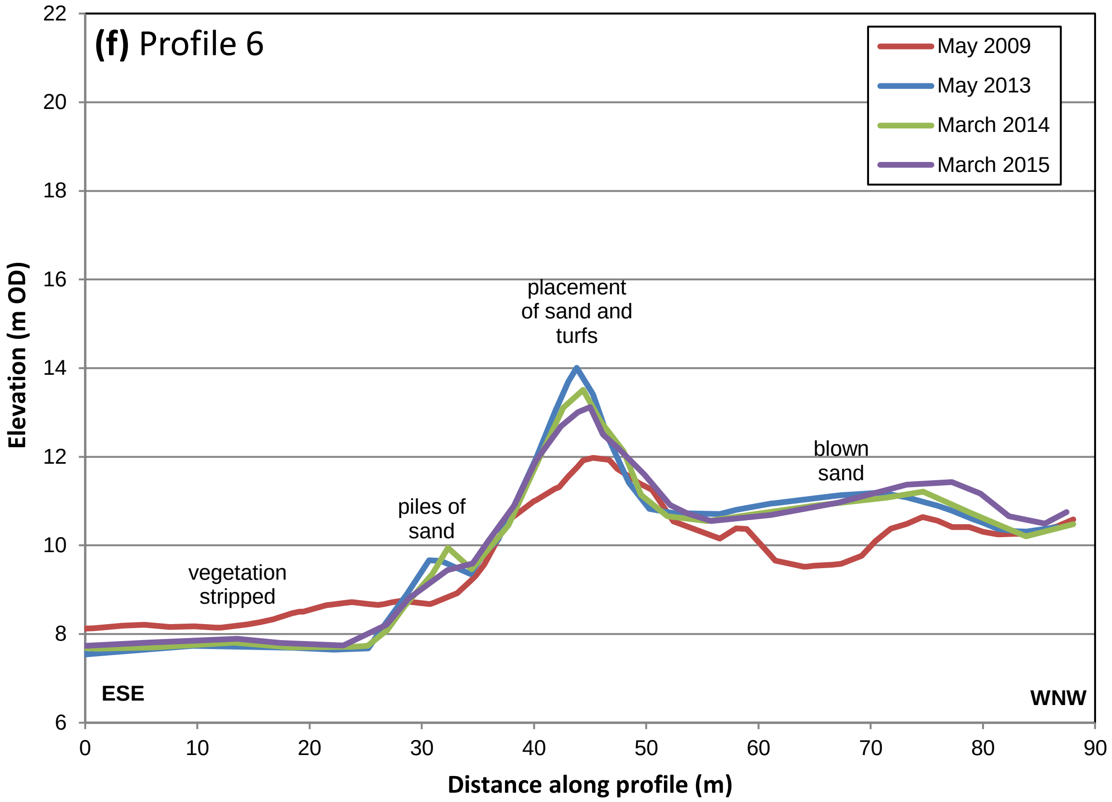
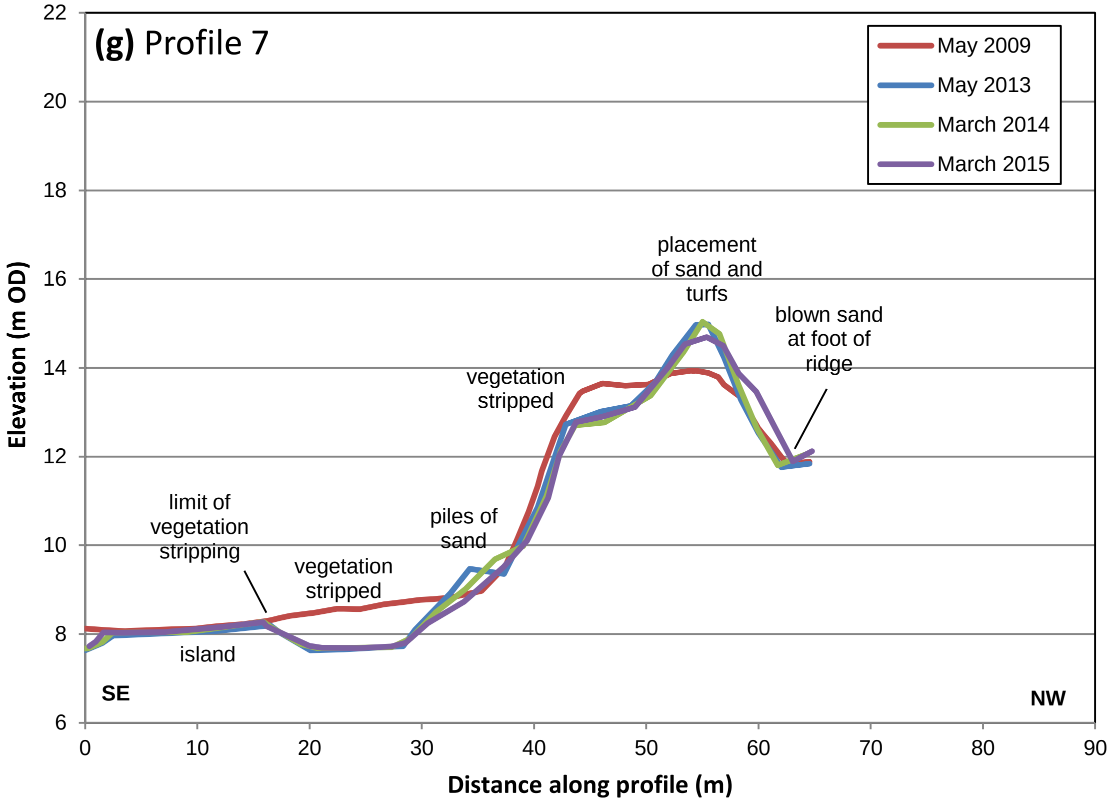


Figure 8 (continued). Comparison of surface levels at profiles 5 and 6 in Area 2, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 16 May 2013, 13 March 2014 and 27 March 2015.



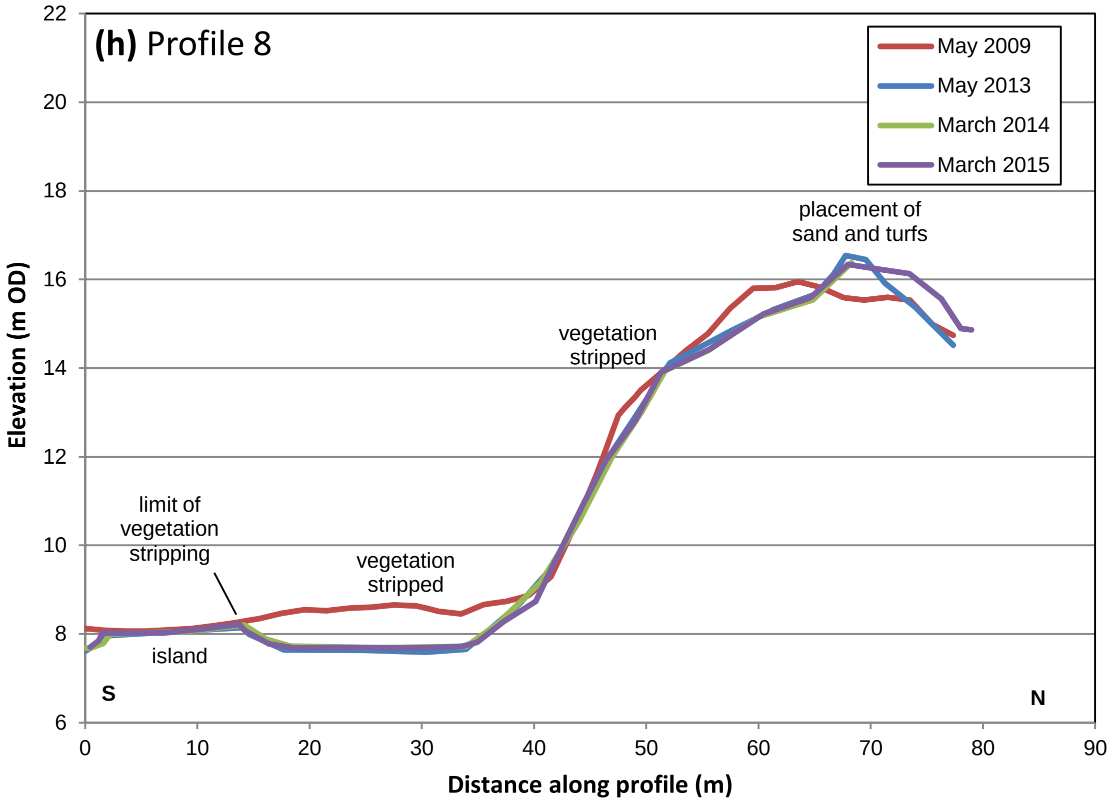
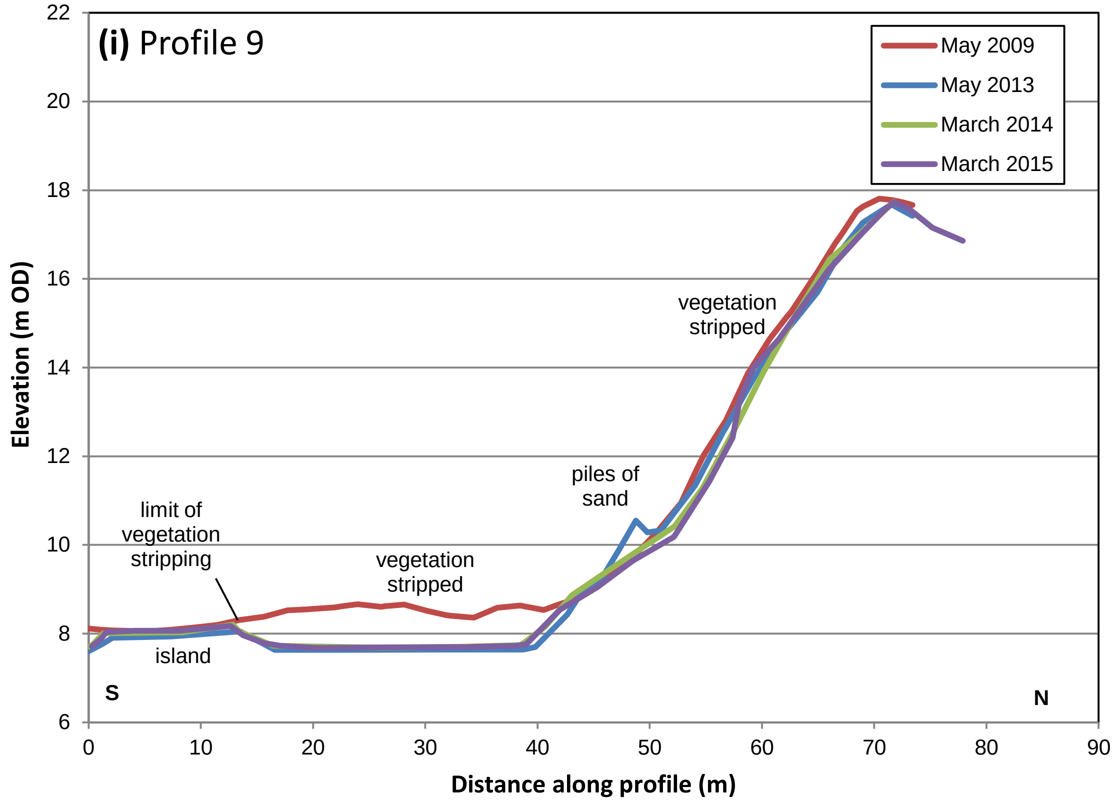


Figure 8 (continued). Comparison of surface levels at profiles 7 and 8 in Area 2, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 16 May 2013, 13 March 2014 and 27 March 2015.



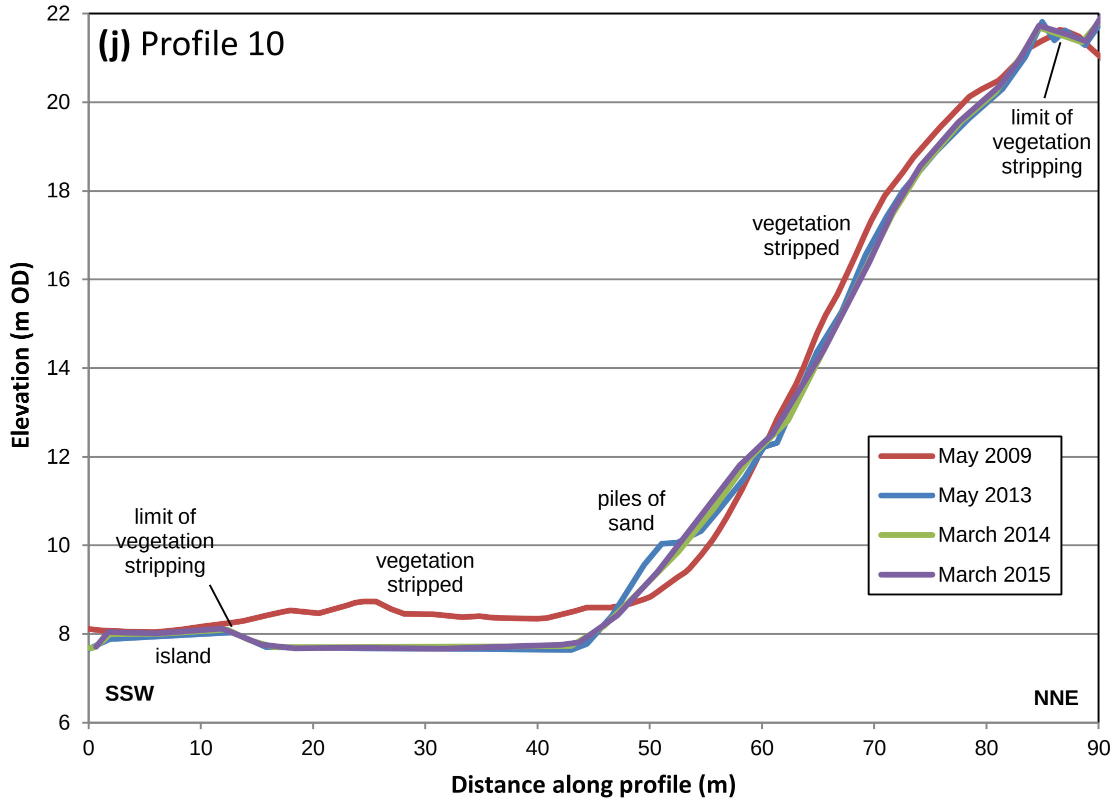
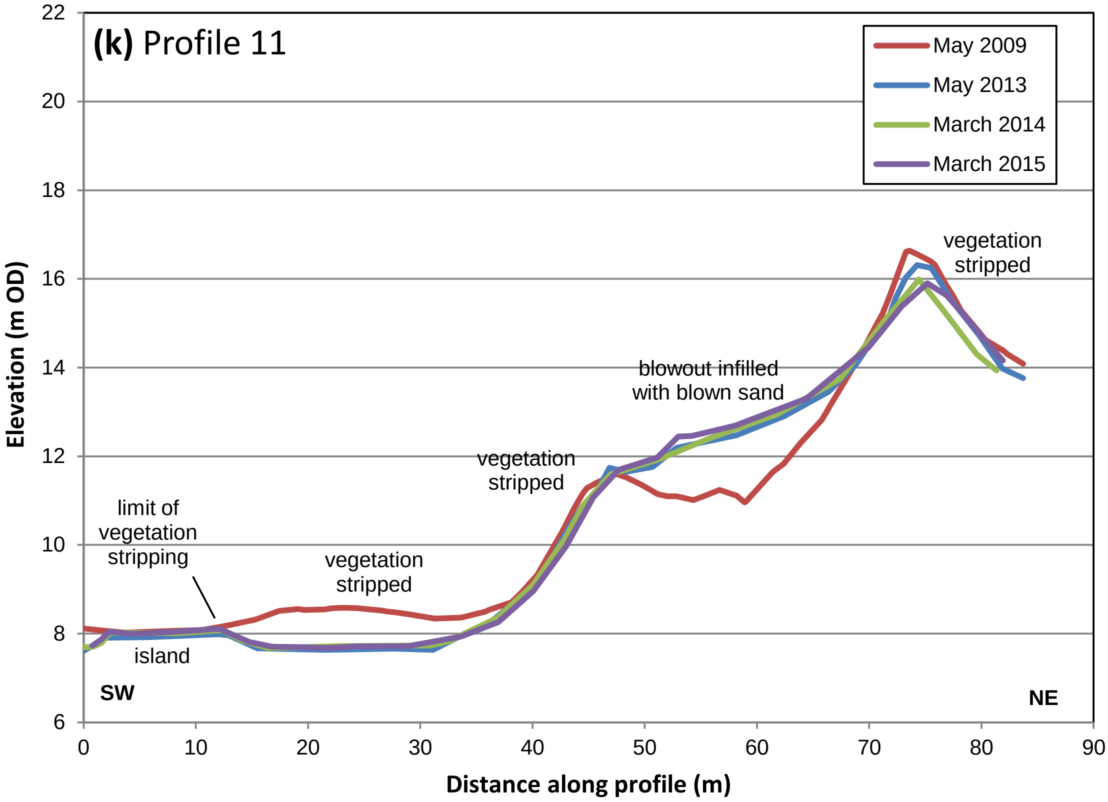


Figure 8 (continued). Comparison of surface levels at profiles 9 and 10 in Area 2, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 16 May 2013, 13 March 2014 and 27 March 2015.



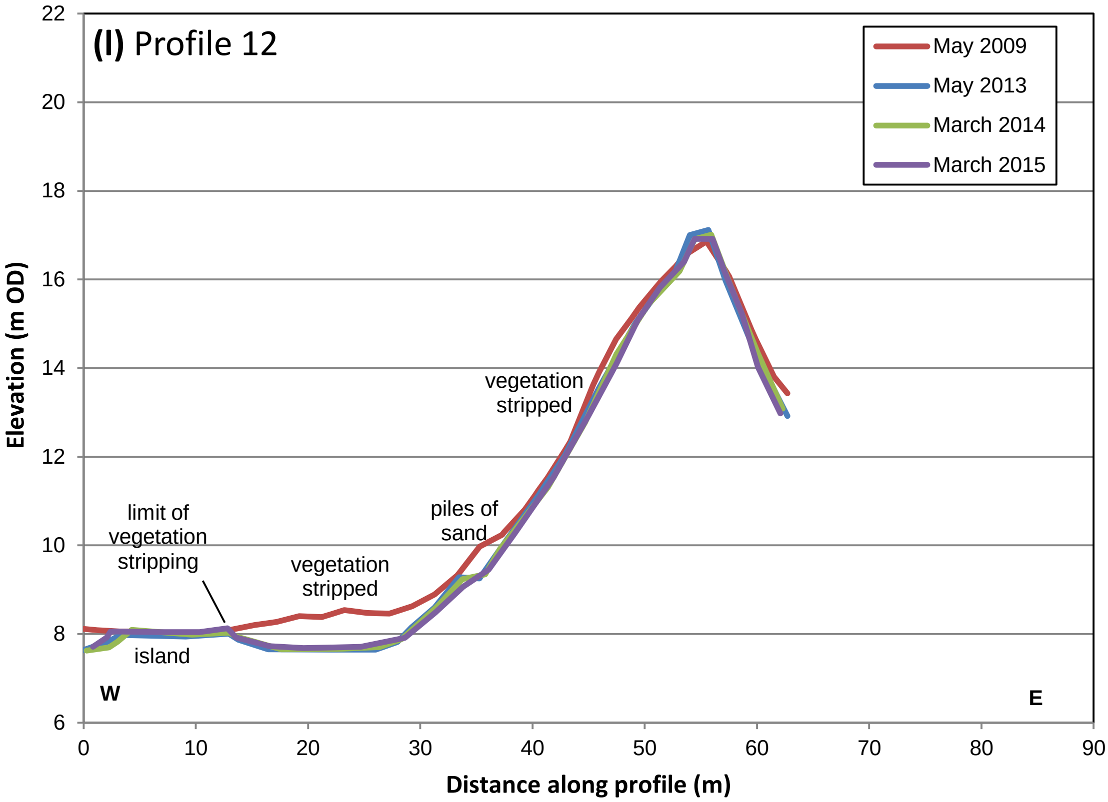
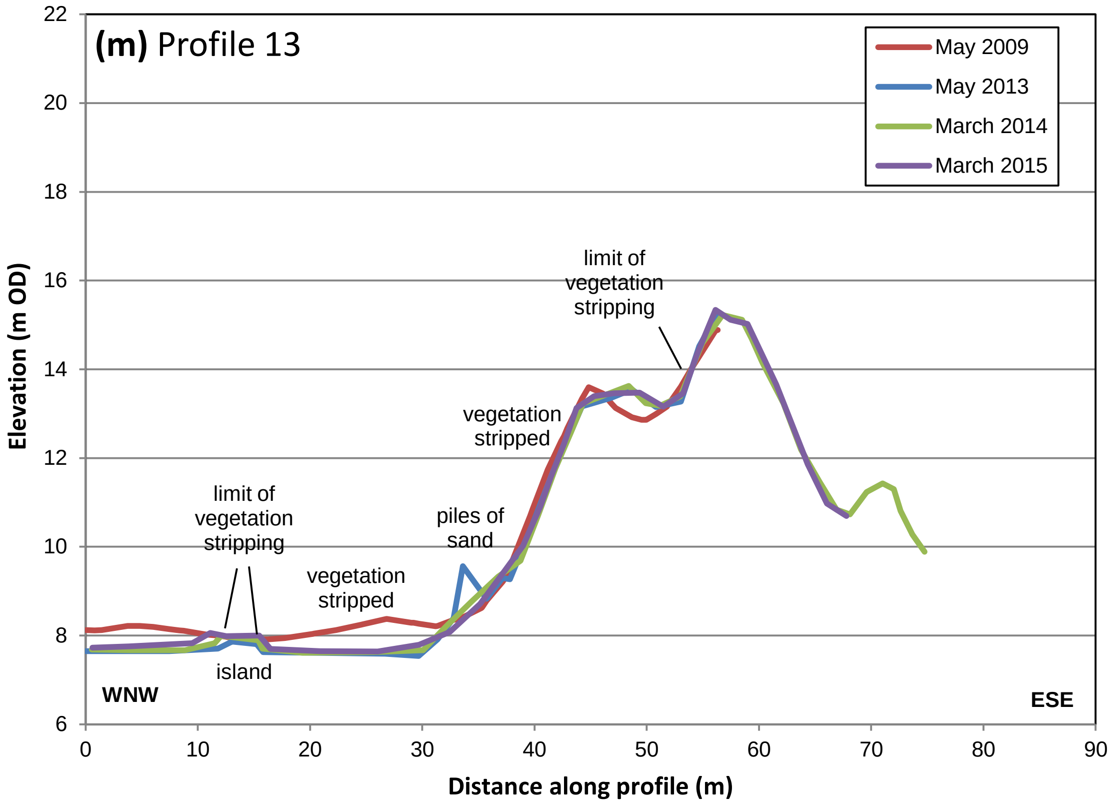


Figure 8 (continued). Comparison of surface levels at profiles 11 and 12 in Area 2, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 16 May 2013, 13 March 2014 and 27 March 2015.



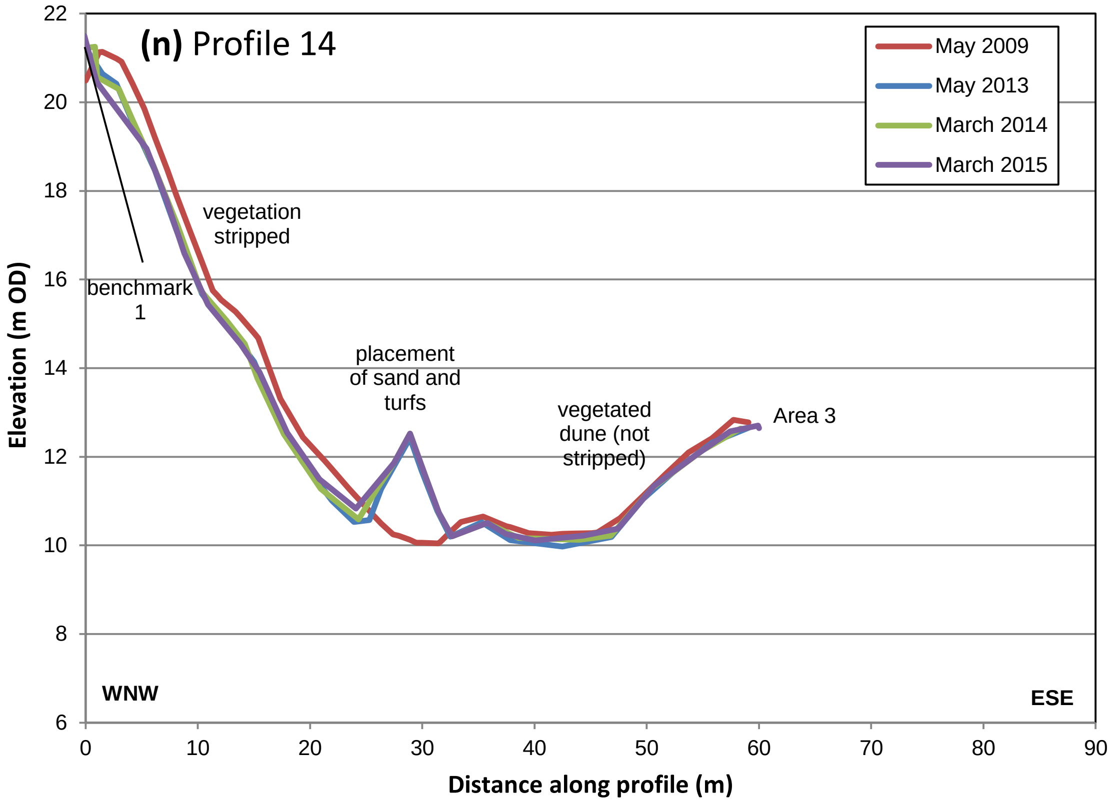


Figure 8 (continued). Comparison of surface levels at profiles 13 and 14 in Area 2, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 16 May 2013, 13 March 2014 and 27 March 2015.

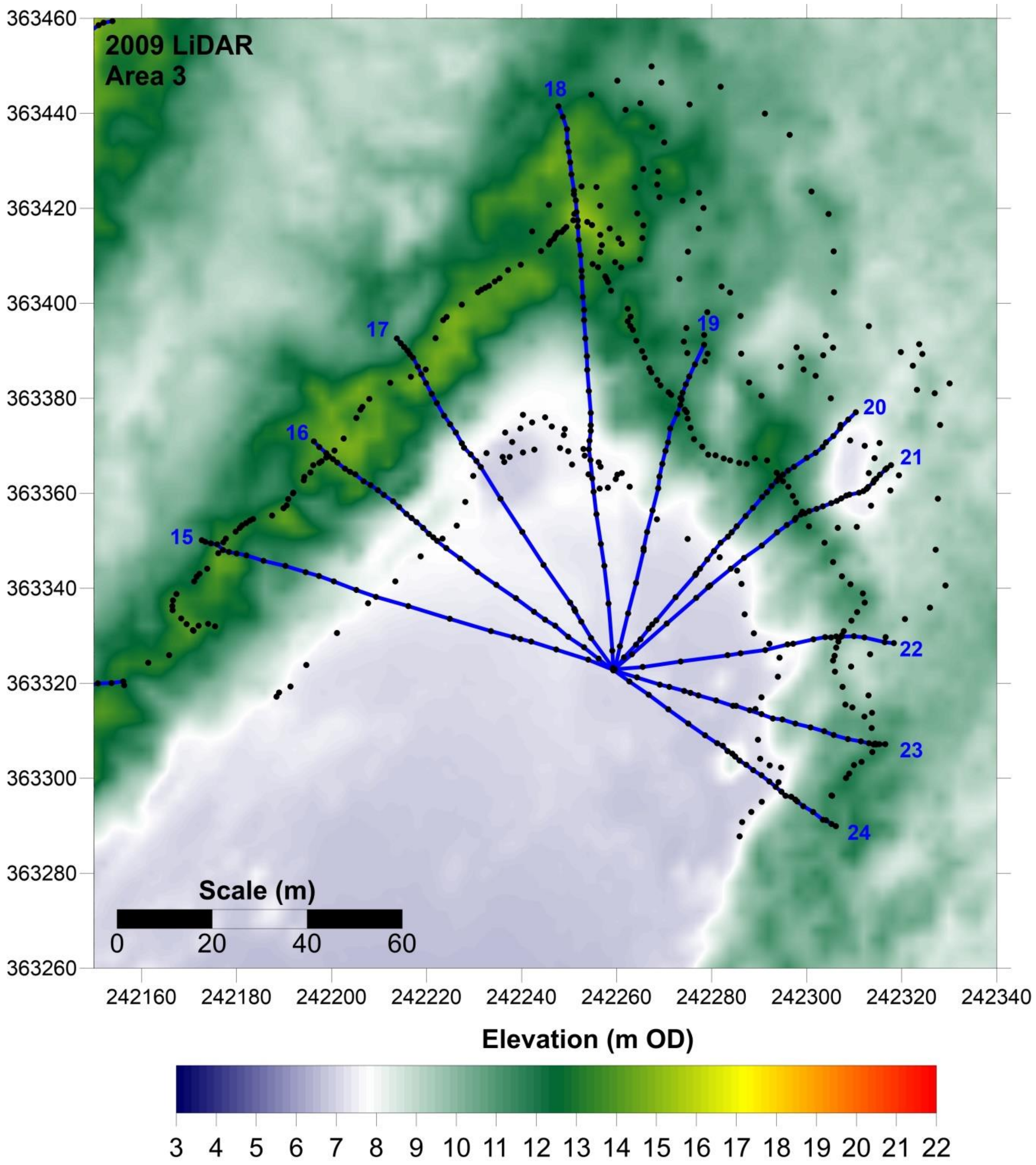


Figure 9. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) in Area 3, overlaid on 2009 LiDAR.

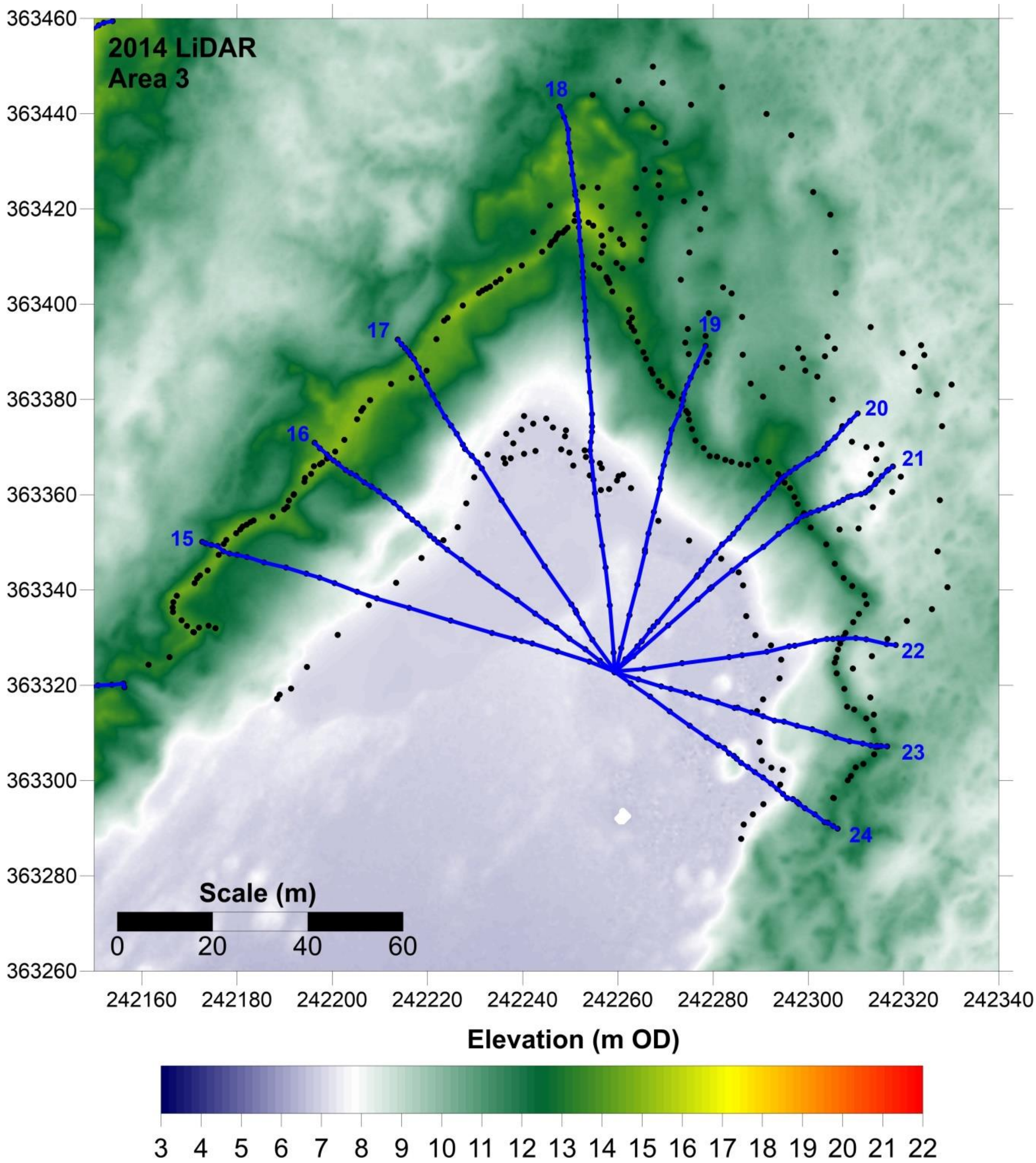


Figure 10. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) in Area 3, overlaid on 2014 LiDAR.

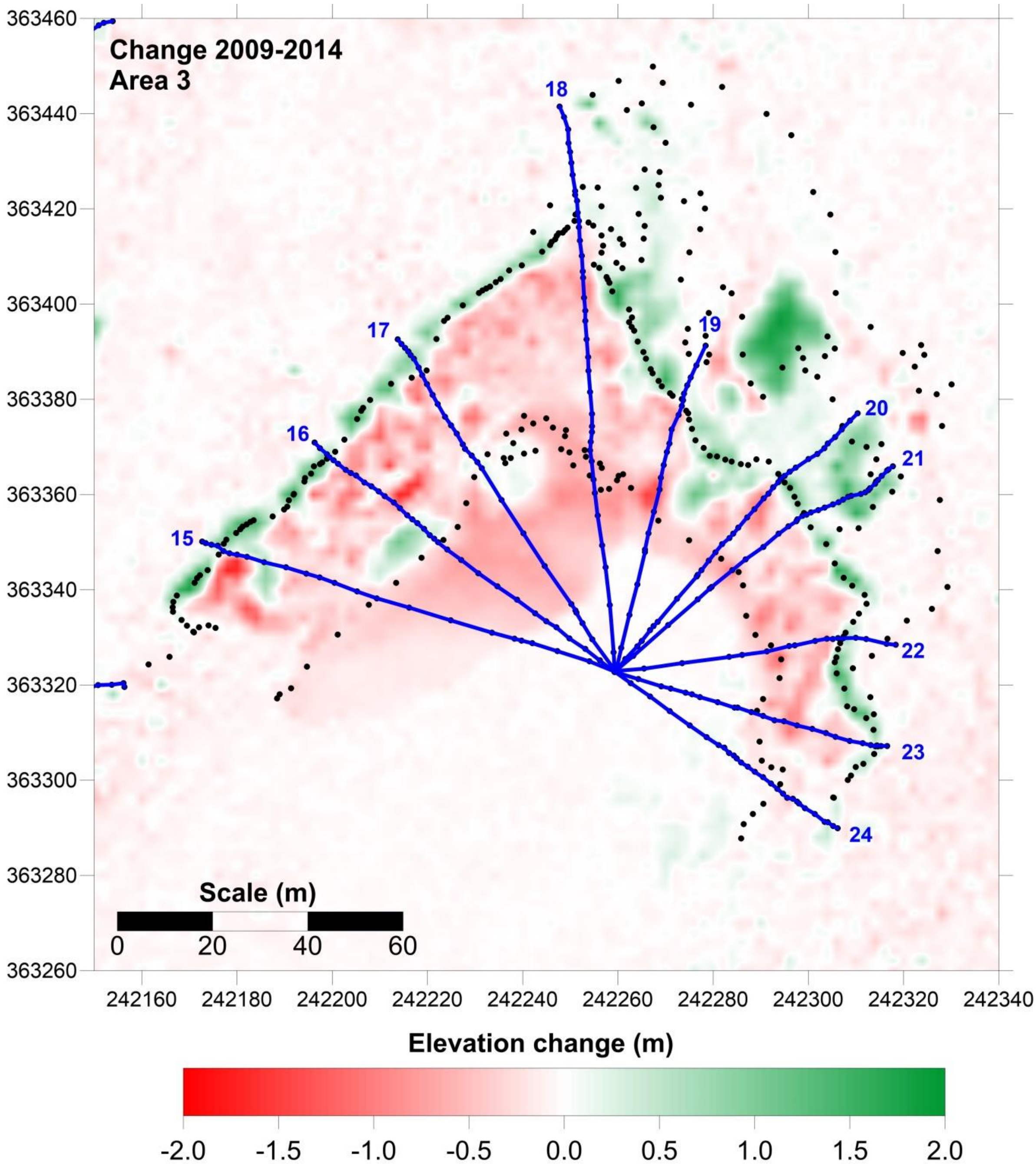


Figure 11. Change in elevation in Area 3 between the LiDAR surveys on 12 May 2009 and 9 April 2014. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) are also shown.

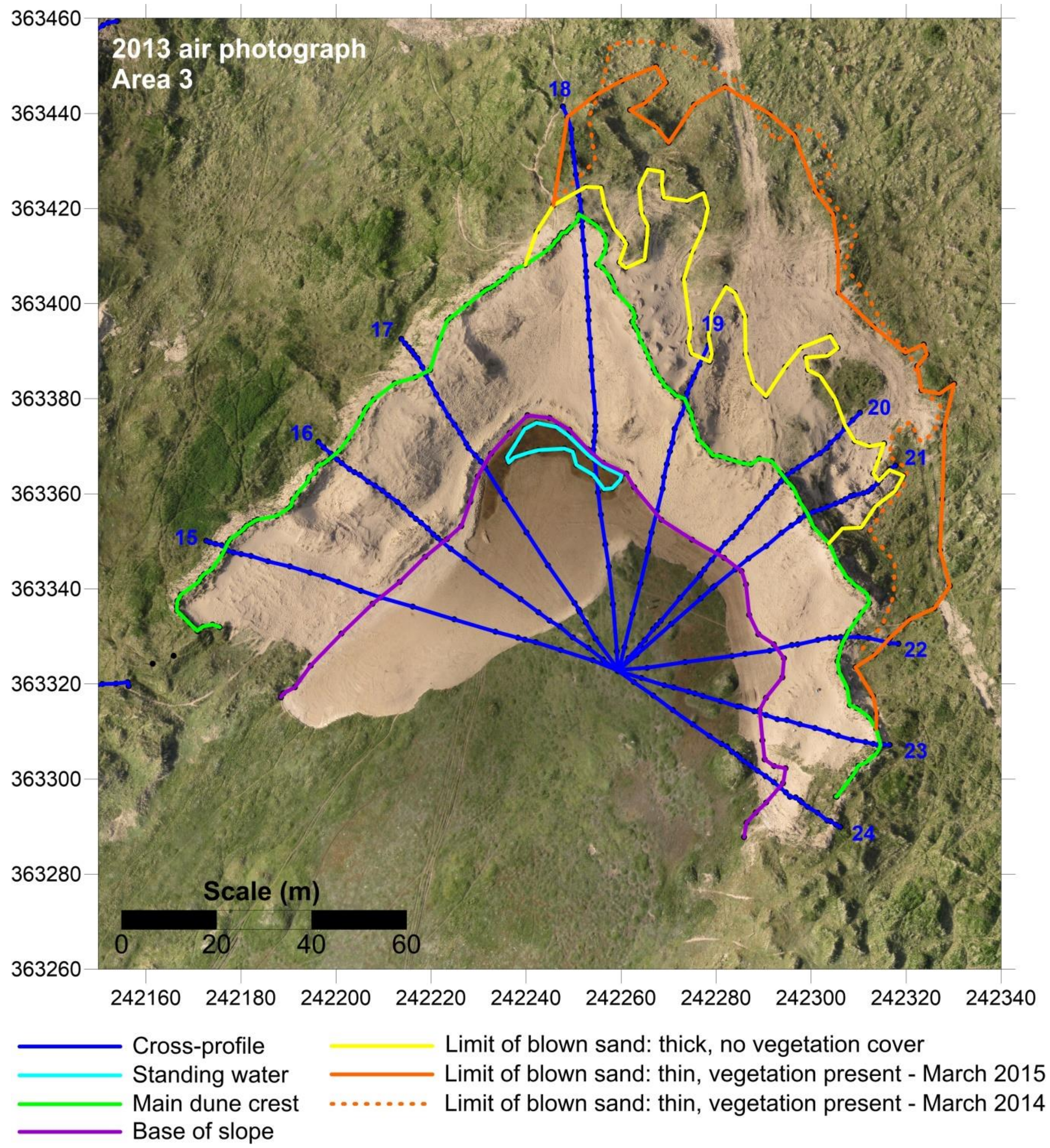


Figure 12. Locations of March 2015 data points (black dots) and cross-profiles (dark blue lines) in Area 3, overlaid on June 2013 aerial photographs (flown by exeGesIS). The limit of blown sand, standing water, and the main dune crest and base of slope surveyed in March 2015 are also shown.

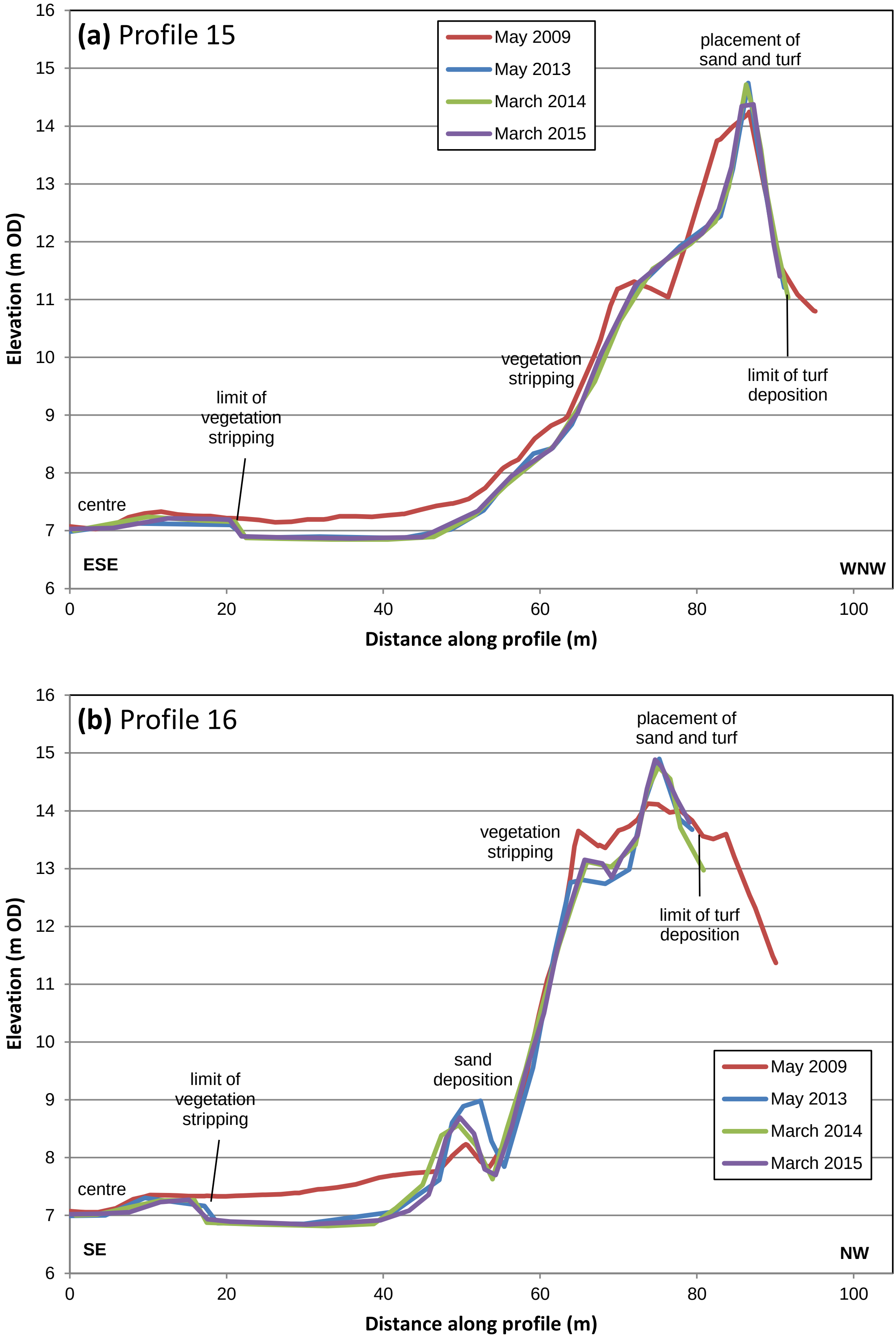
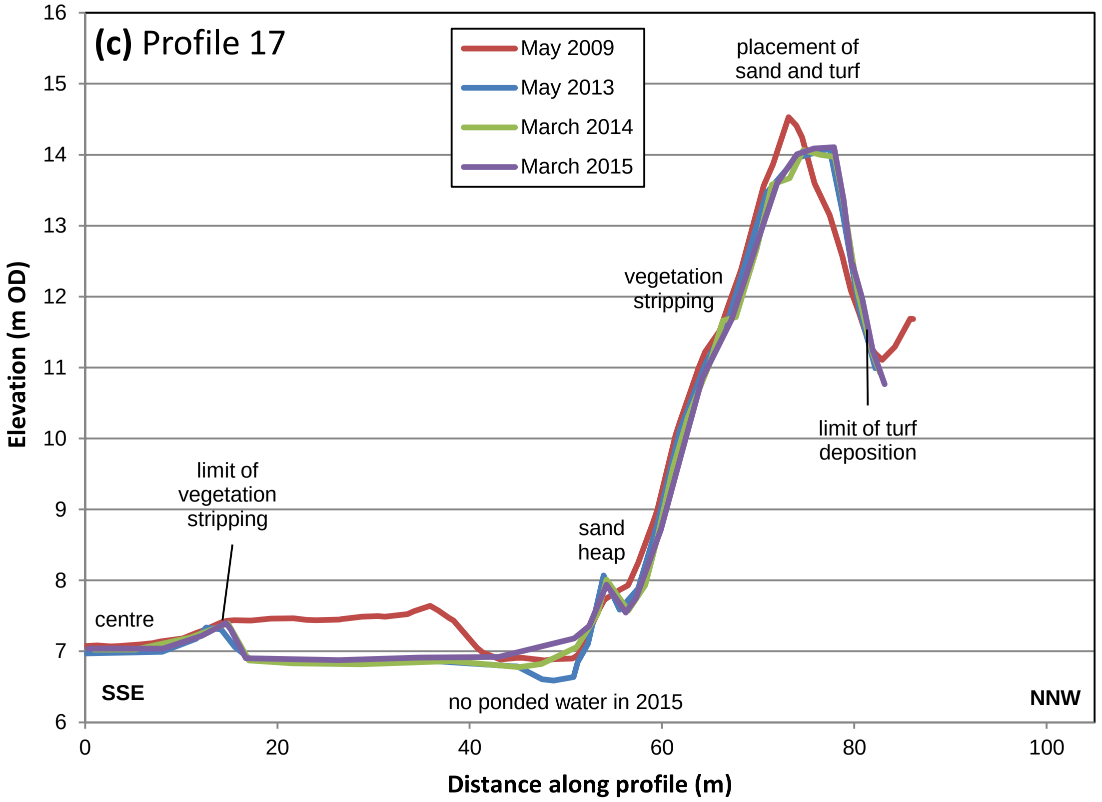


Figure 13. Comparison of surface levels at profiles 15 and 16 in Area 3, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 17 May 2013, 13 March 2014 and 27 March 2015.



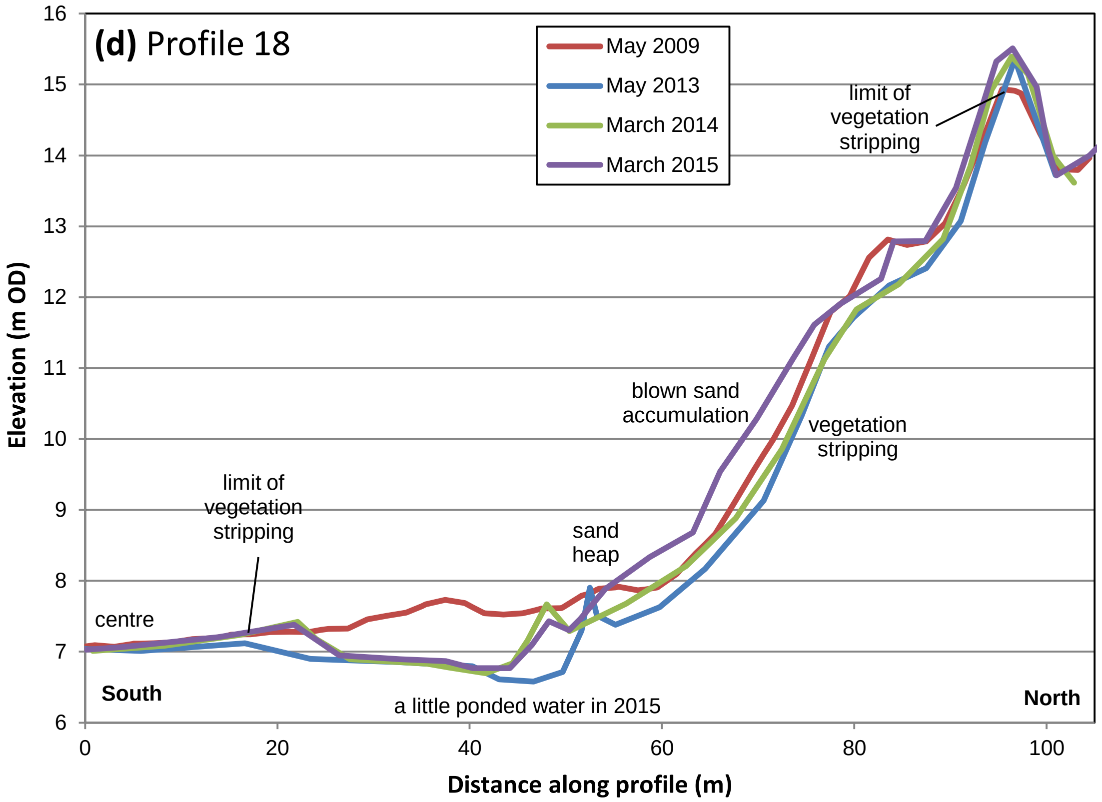
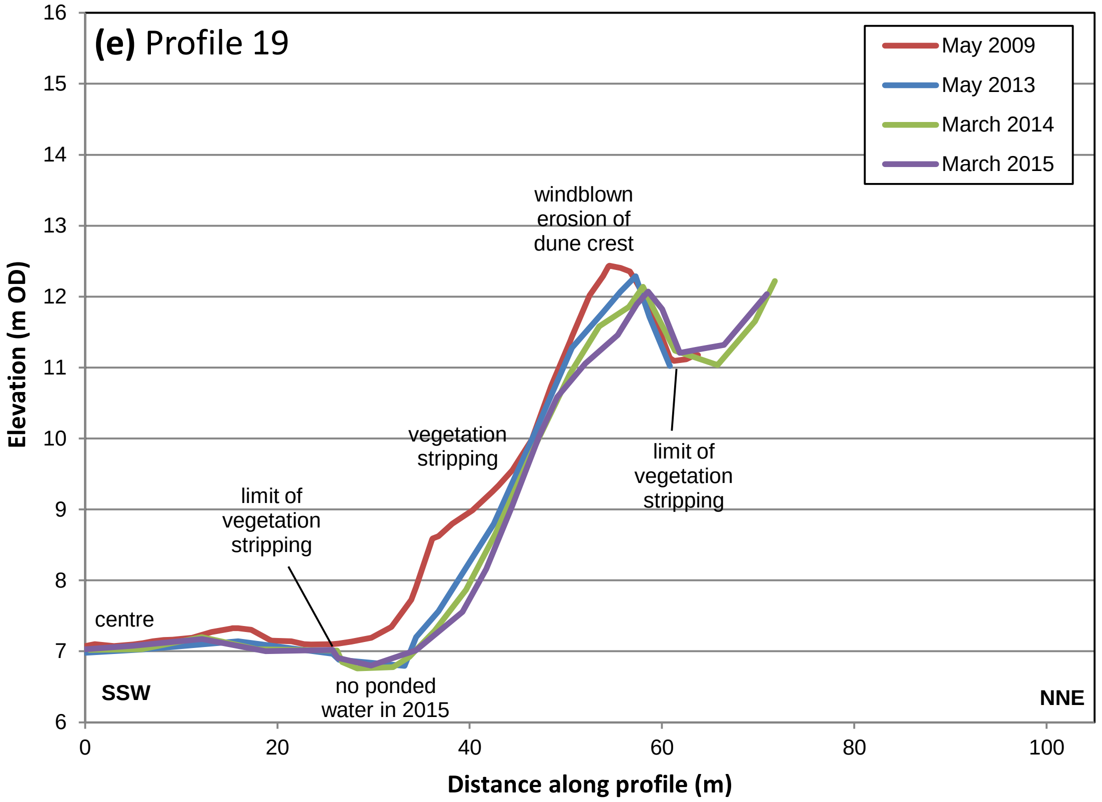


Figure 13 (continued). Comparison of surface levels at profiles 17 and 18 in Area 3, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 17 May 2013, 13 March 2014 and 27 March 2015.



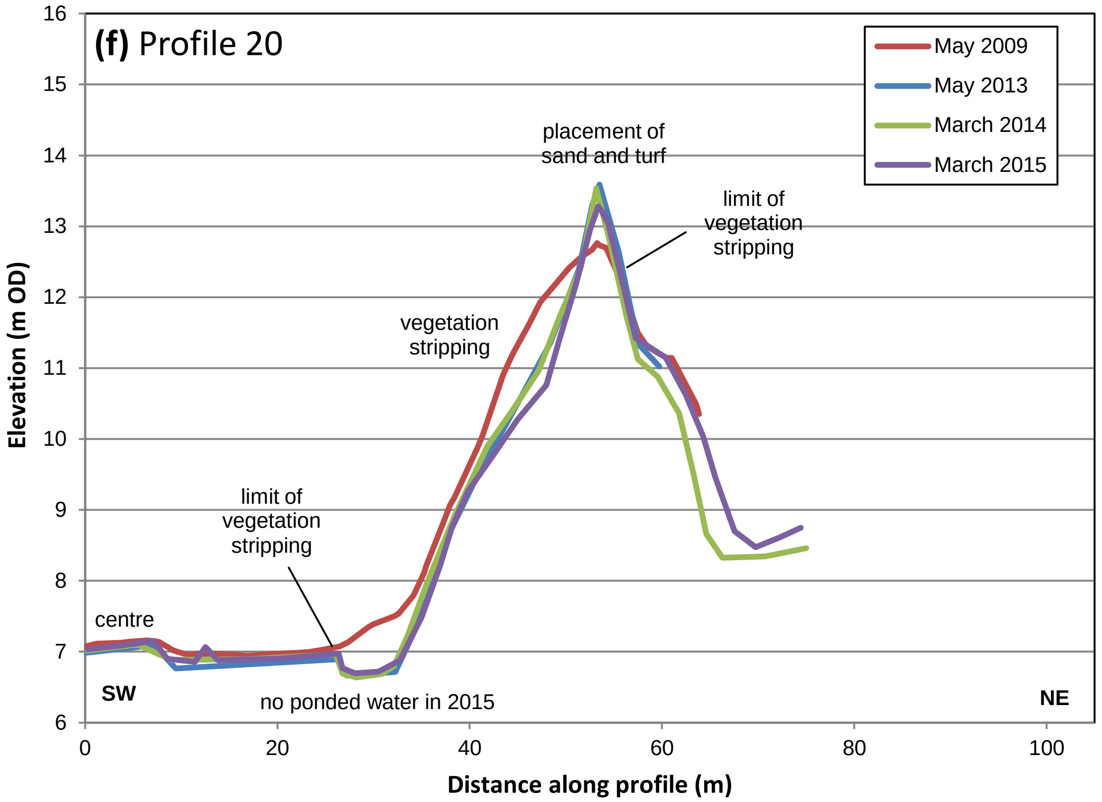
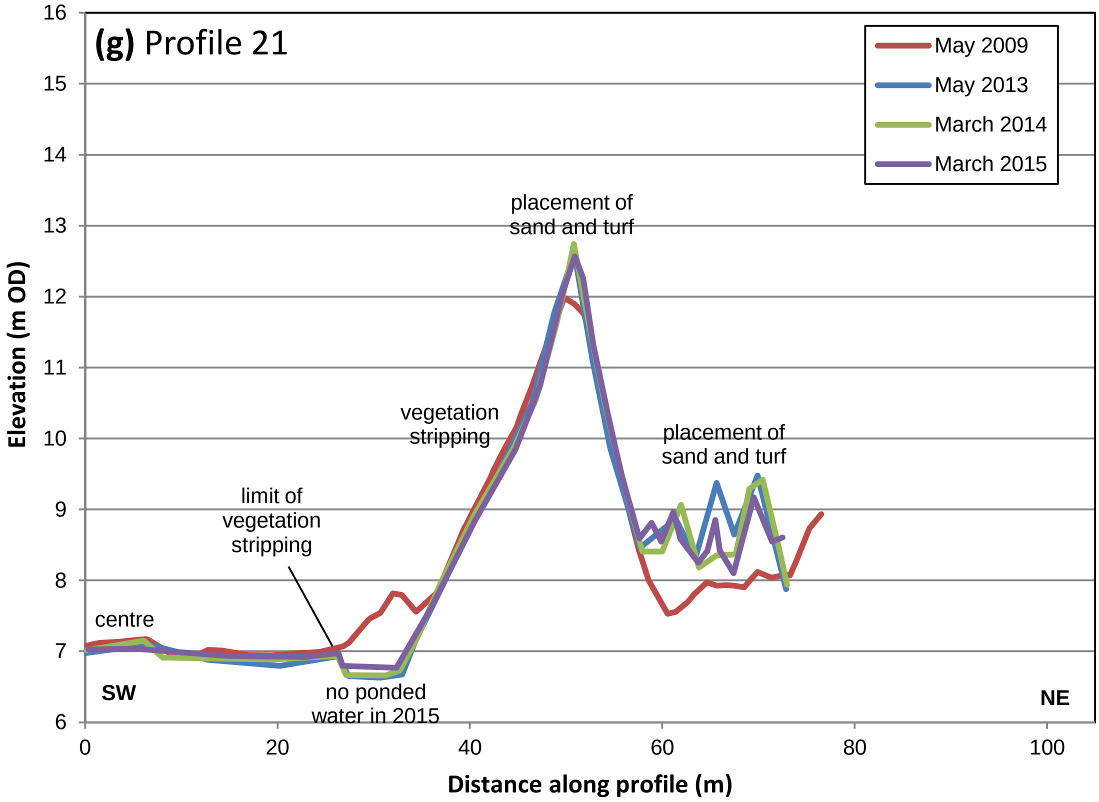


Figure 13 (continued). Comparison of surface levels at profiles 19 and 20 in Area 3, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 17 May 2013, 13 March 2014 and 27 March 2015.



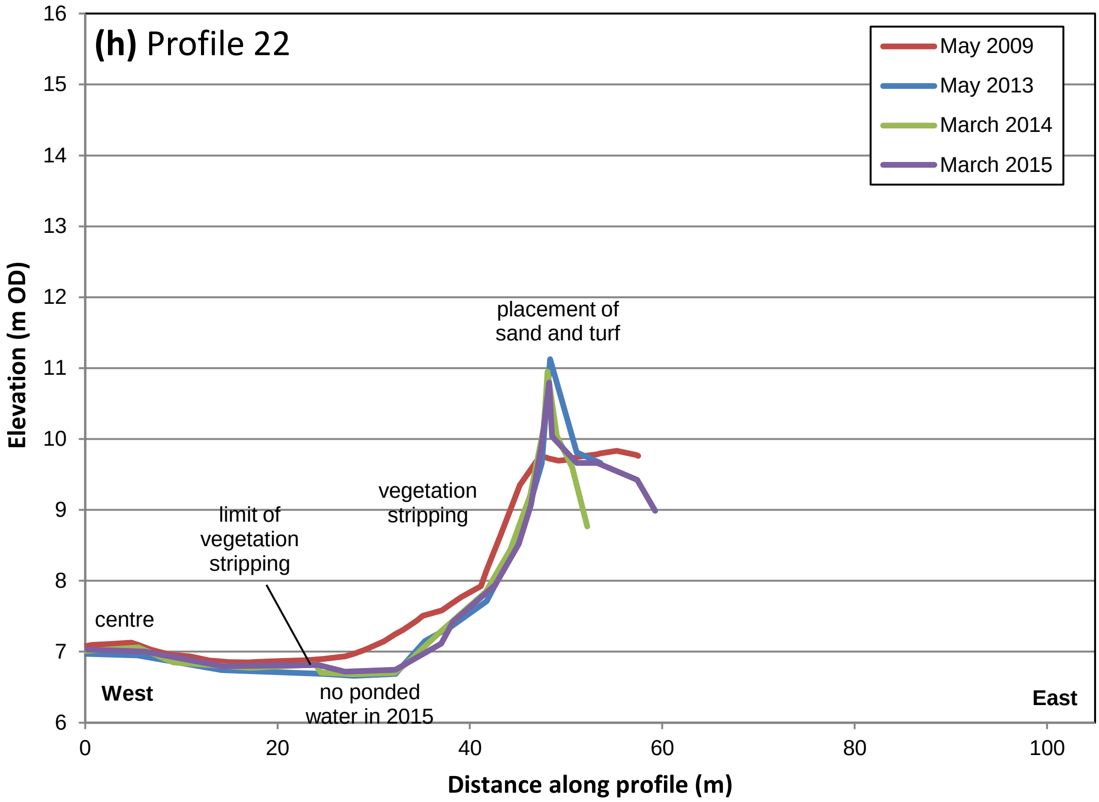
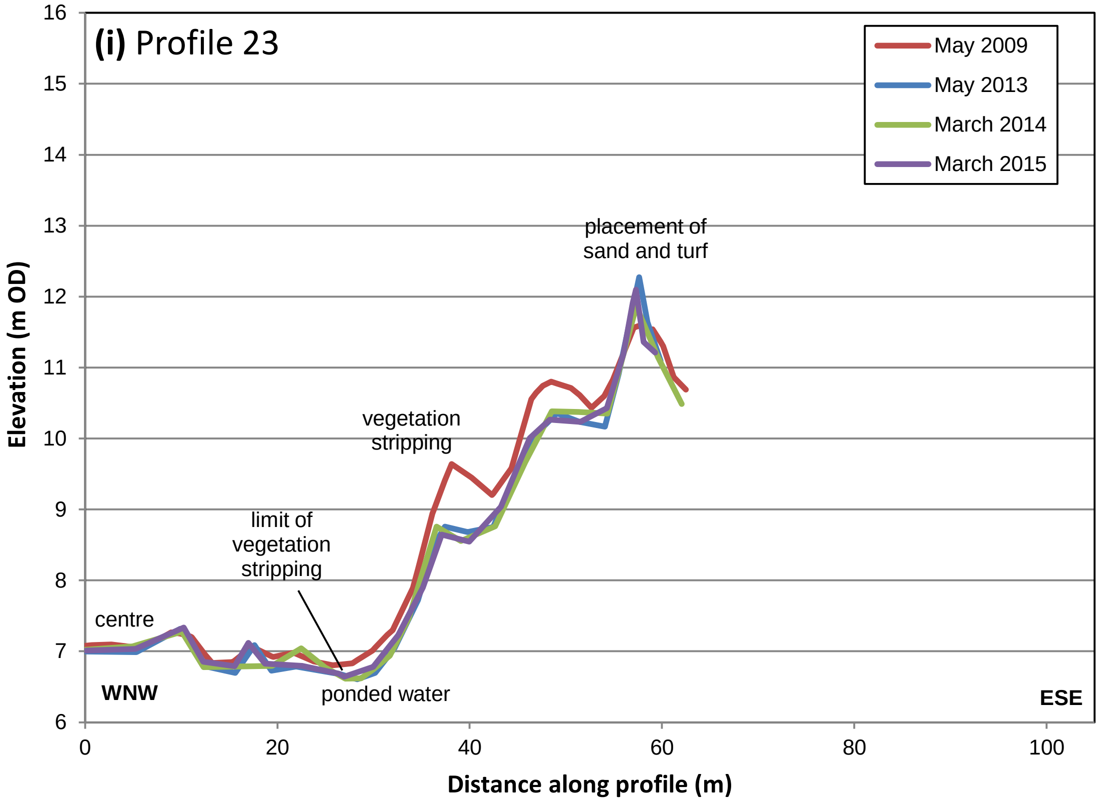


Figure 13 (continued). Comparison of surface levels at profiles 21 and 22 in Area 3, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 17 May 2013, 13 March 2014 and 27 March 2015.



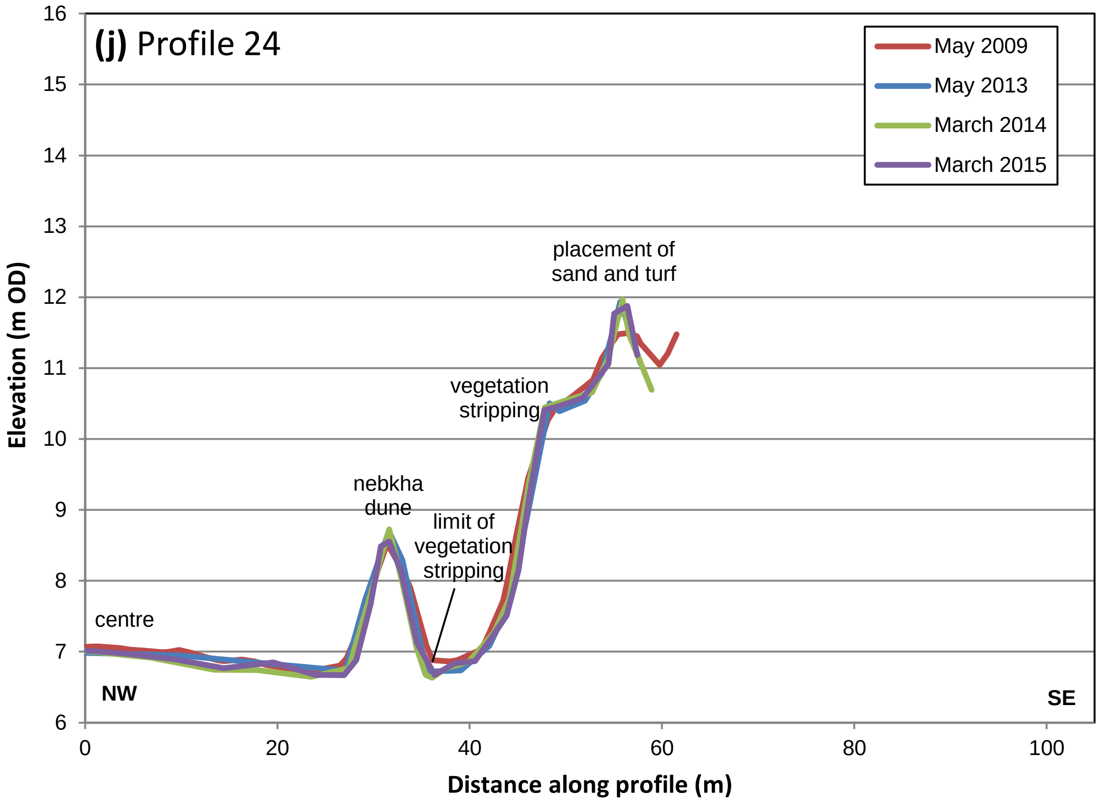


Figure 13 (continued). Comparison of surface levels at profiles 23 and 24 in Area 3, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 17 May 2013, 13 March 2014 and 27 March 2015.

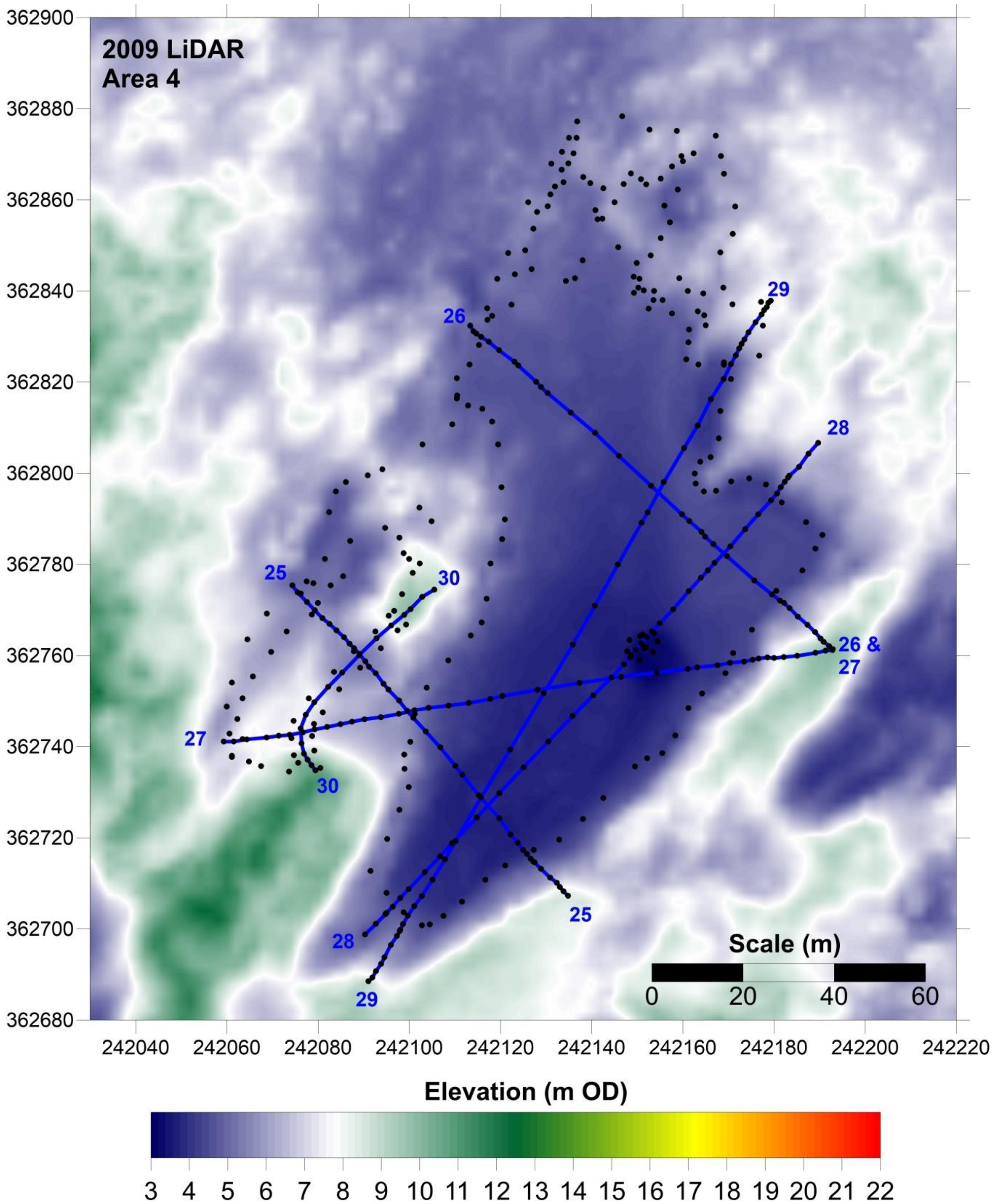


Figure 14. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) in Area 4, overlaid on 2009 LiDAR.

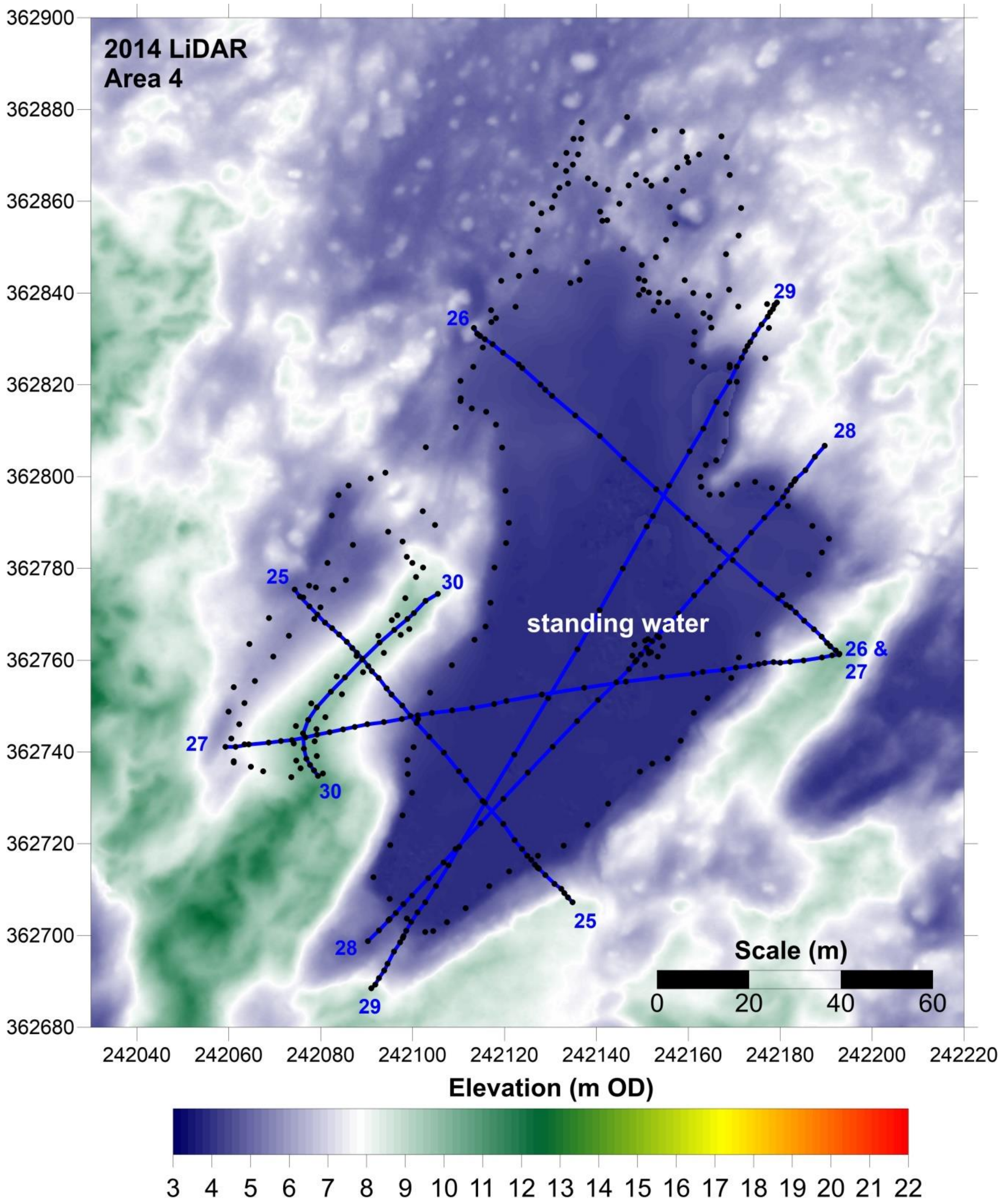


Figure 15. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) in Area 4, overlaid on 2014 LiDAR.

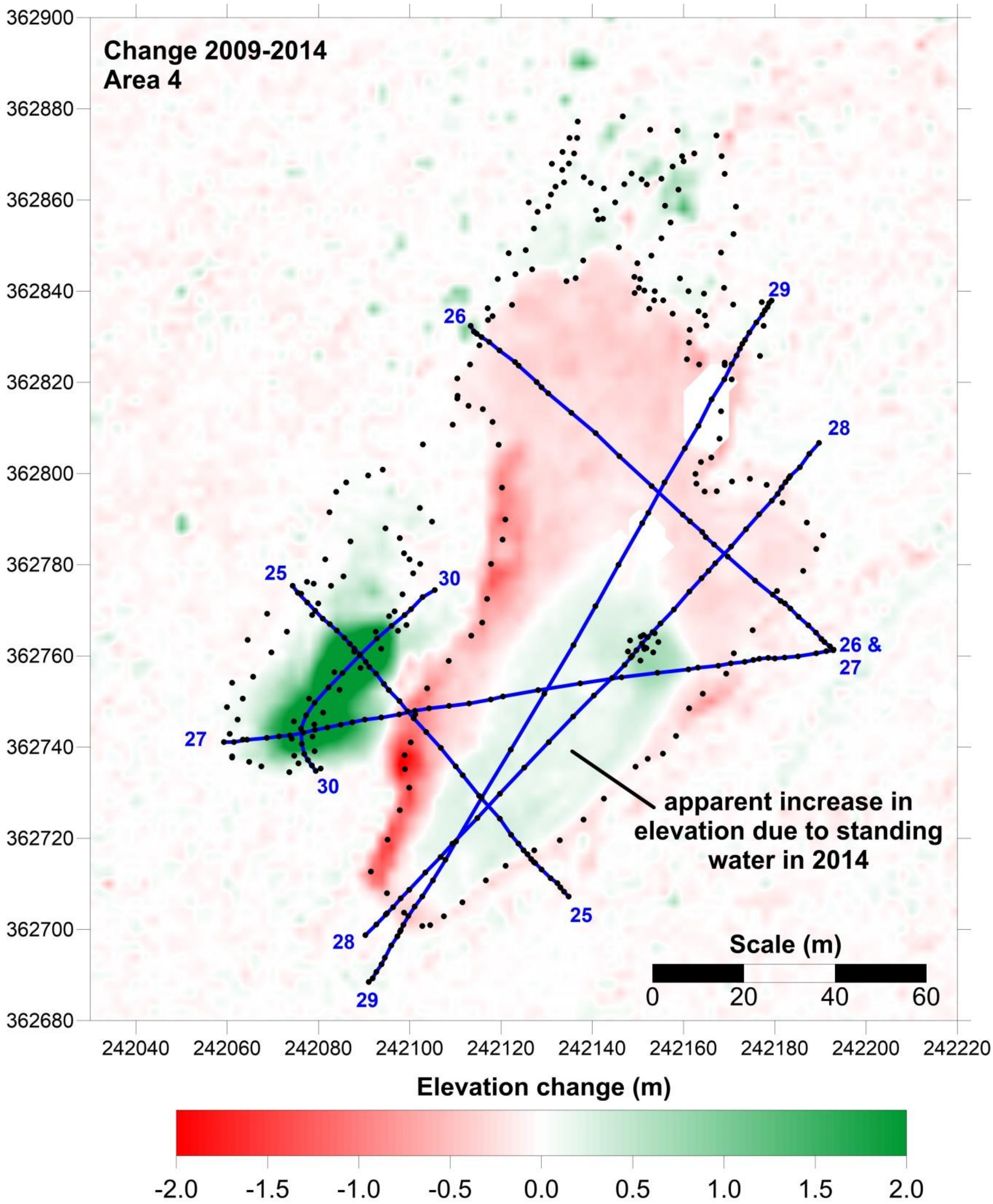


Figure 16. Change in elevation in Area 4 between the LiDAR surveys on 12 May 2009 and 9 April 2014. Locations of March 2015 data points (black dots) and cross-profiles (blue lines) are also shown. Note that the apparent increase in elevation in the deflation trough between 2009-2014 is due to the April 2014 LiDAR survey measuring the surface of standing water (the winter of 2013/14 was particularly wet), and the true land surface in April 2014 would have been lower in elevation than indicated.

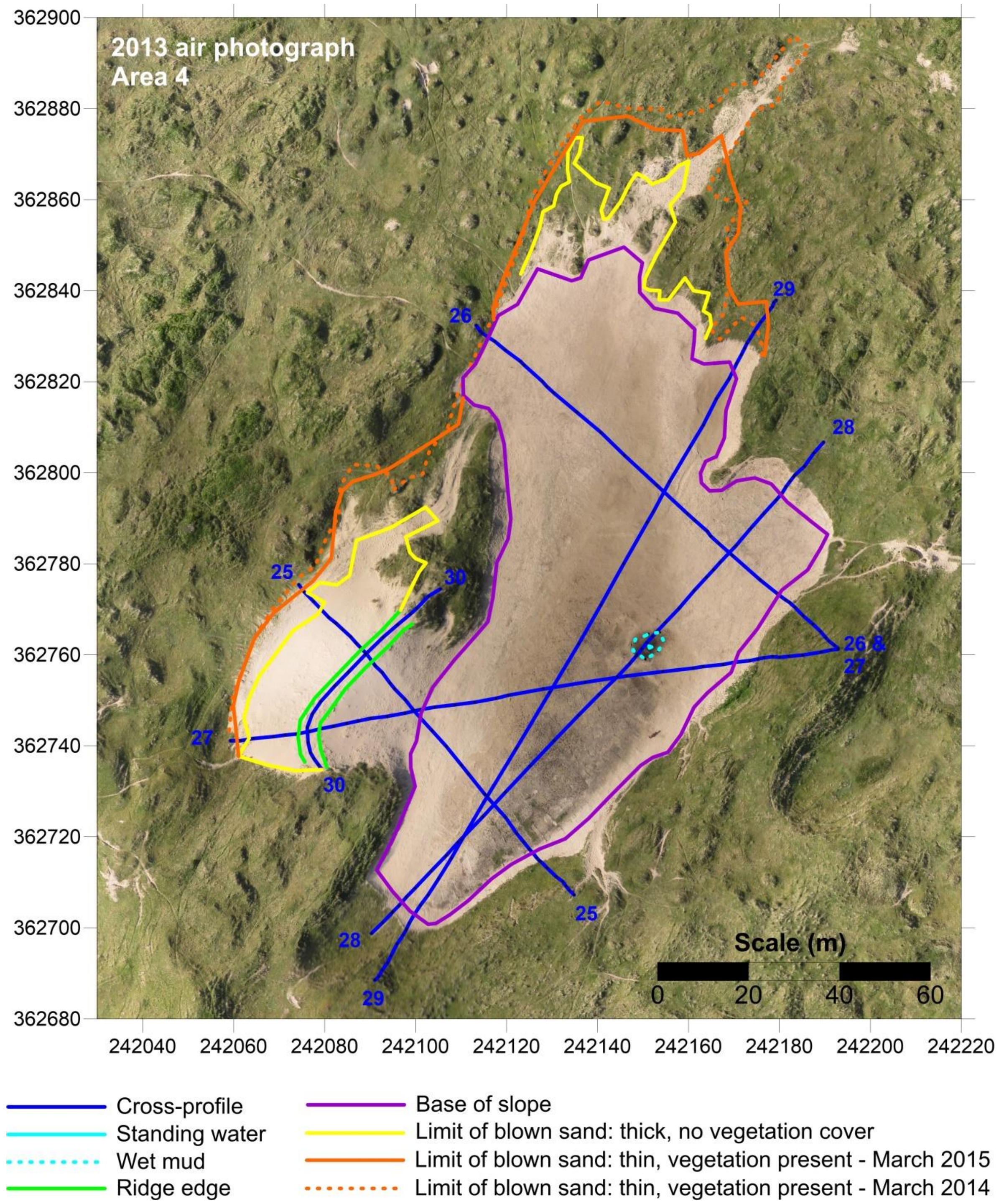
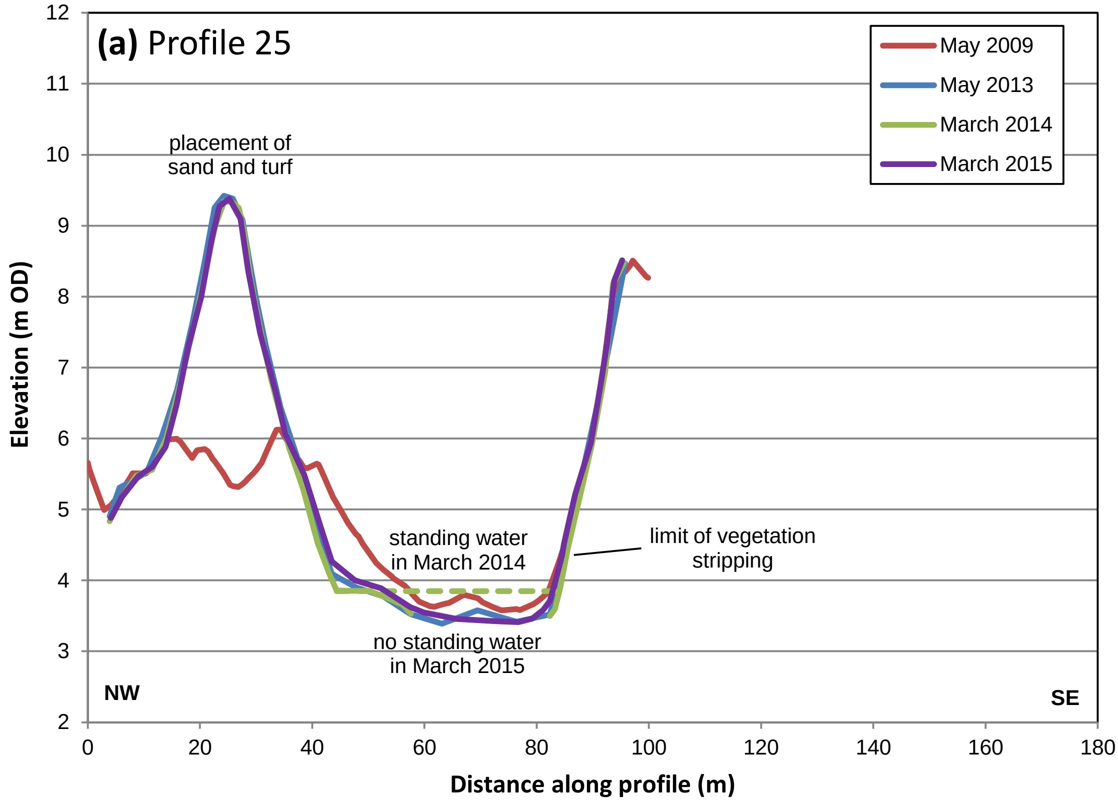


Figure 17. Locations of March 2015 data points (black dots) and cross-profiles (dark blue lines) in Area 4, overlaid on June 2013 aerial photographs (flown by exeGesIS). The limit of blown sand, standing water, and the main dune crest and base of slope surveyed in March 2015 are also shown.



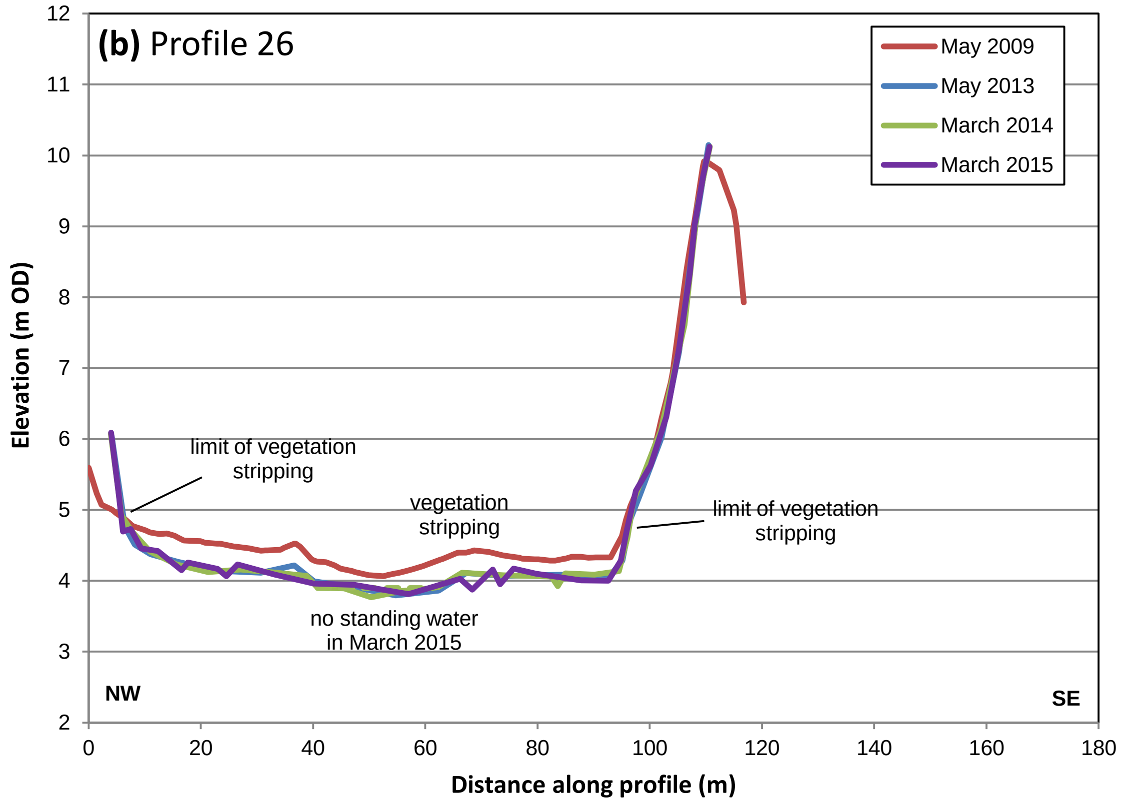
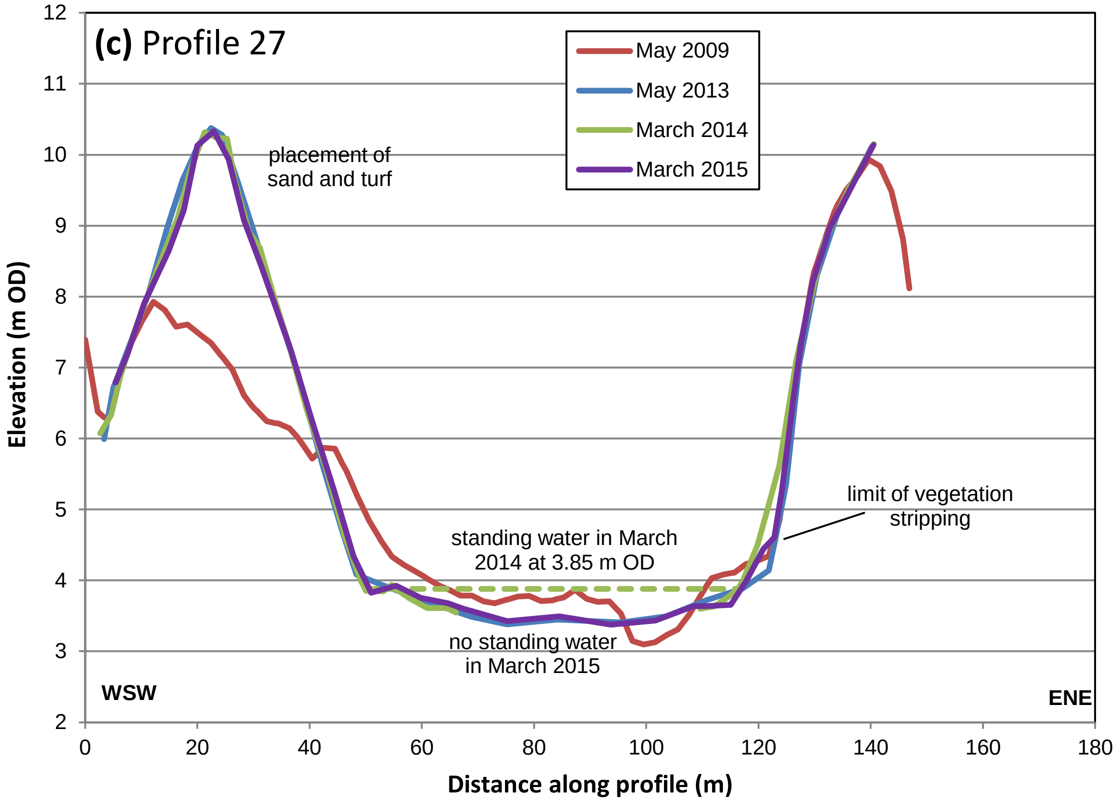


Figure 18. Comparison of surface levels at profiles 25 and 26 in Area 4, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 17 May 2013, 13 March 2014 and 27 March 2015.



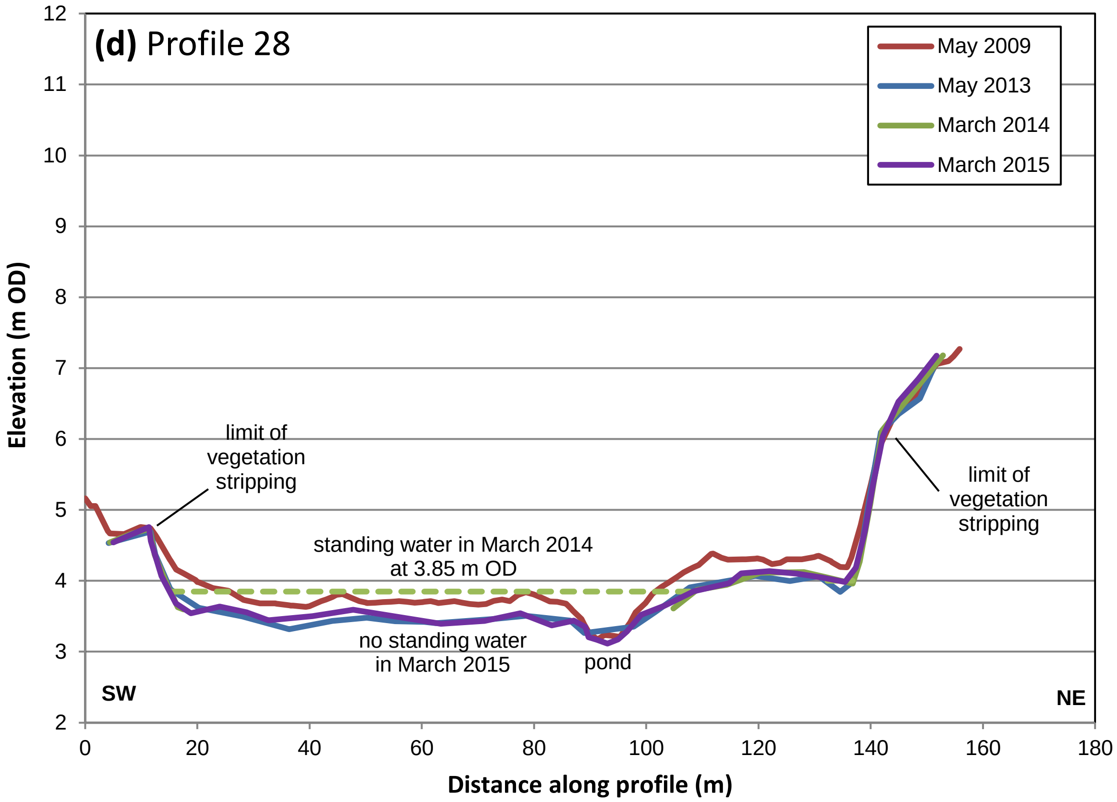
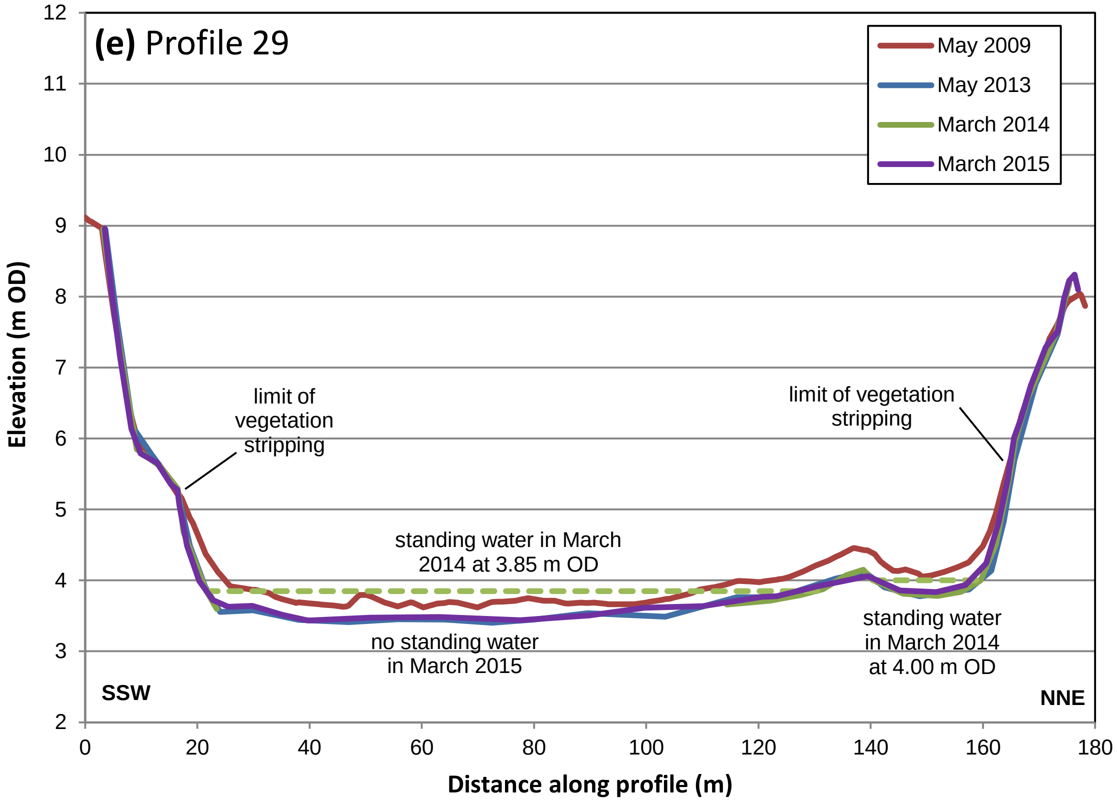


Figure 18 (continued). Comparison of surface levels at profiles 27 and 28 in Area 4, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 17 May 2013, 13 March 2014 and 27 March 2015.



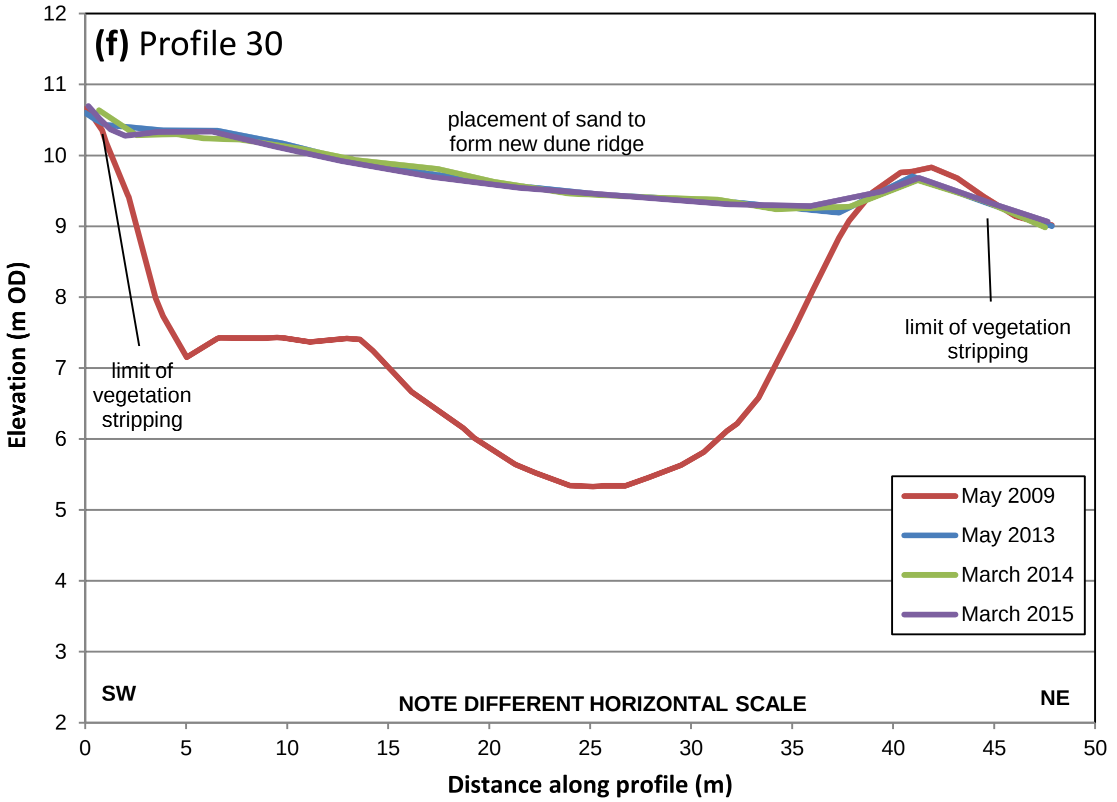


Figure 18 (continued). Comparison of surface levels at profiles 29 and 30 in Area 4, indicated by LiDAR survey on 12 May 2009 (pre-works) and ground surveys on 17 May 2013, 13 March 2014 and 27 March 2015.

Appendix 1

Field photographs taken 27 March 2015

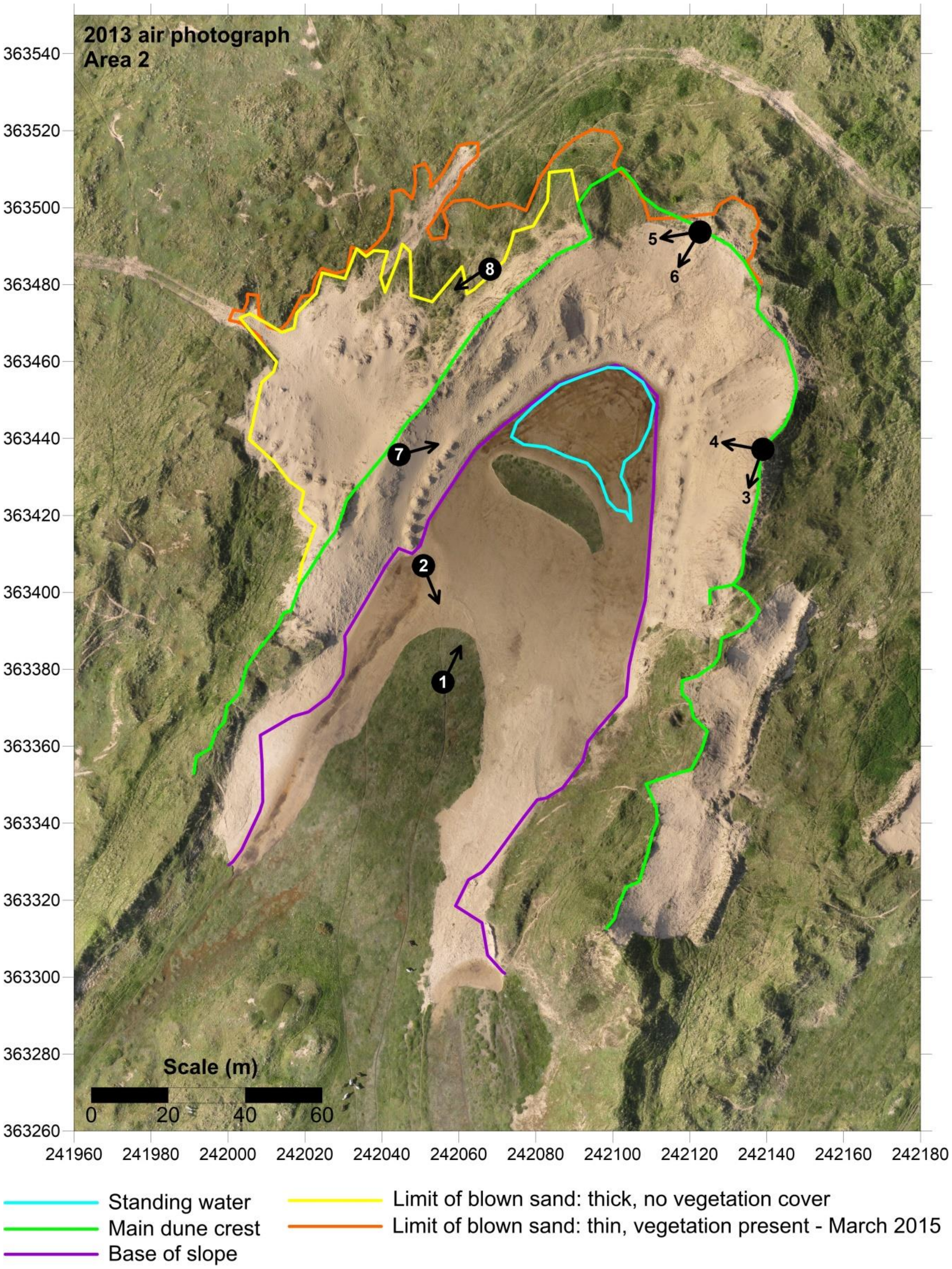


Figure A1.1 Locations of field photographs 1 to 8 in Area 2 reproduced in Appendix 1 to this report. Arrows indicate direction of view; base 2013 aerial photography from Google Earth

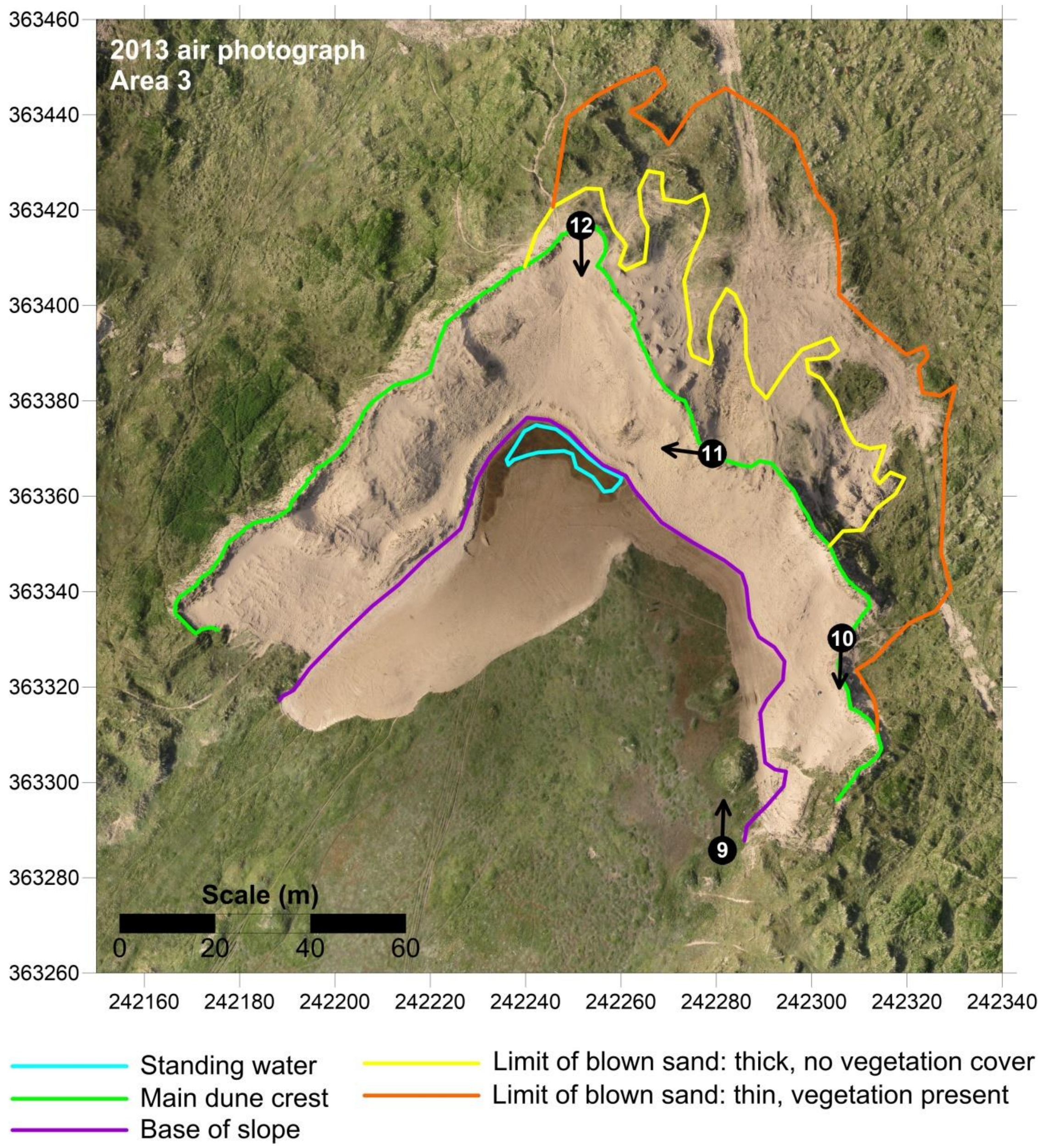


Figure A1.2 Locations of field photographs 9 to 12 in Area 3 reproduced in Appendix 1 to this report. Arrows indicate direction of view; base 2013 aerial photography from Google Earth

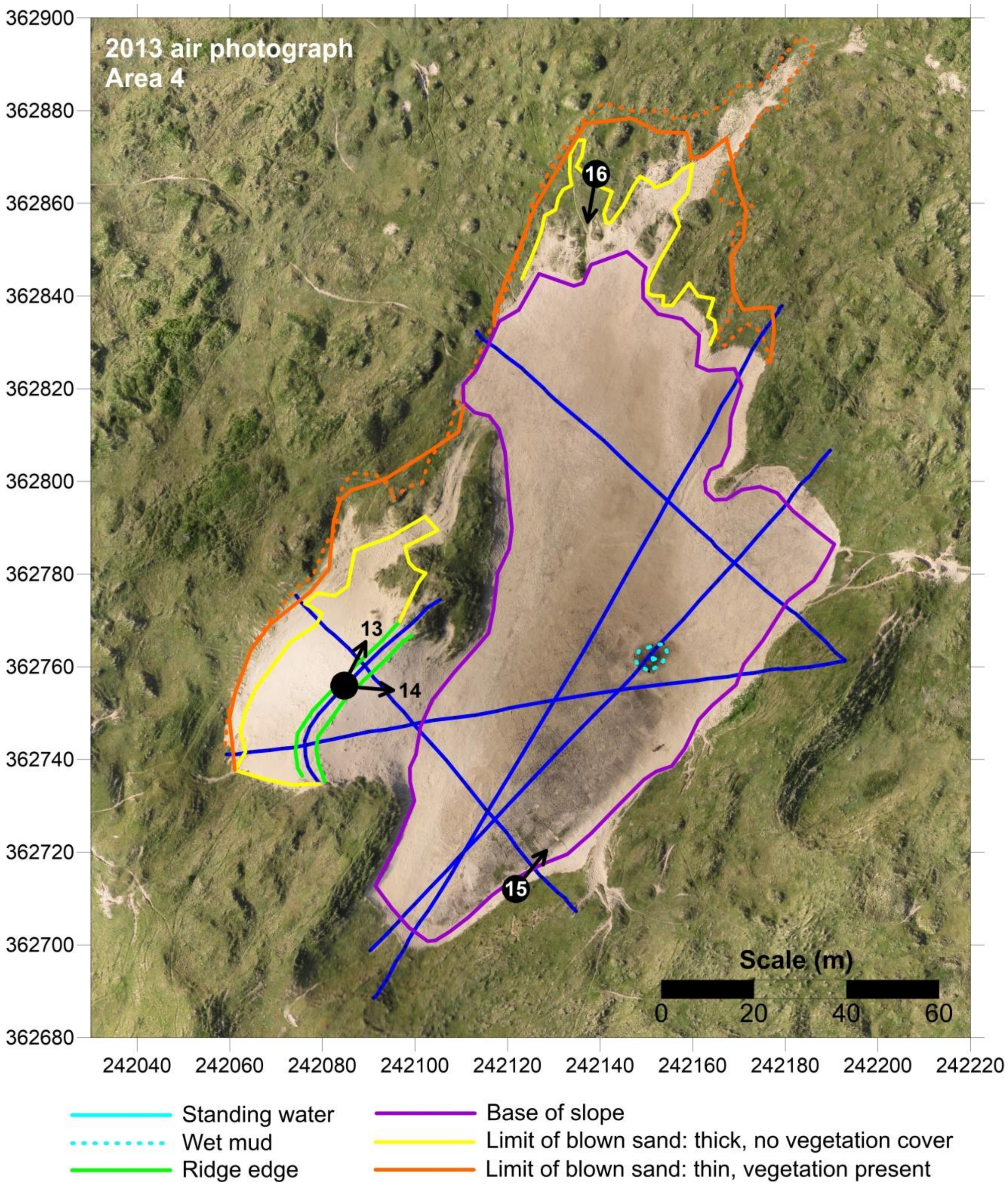
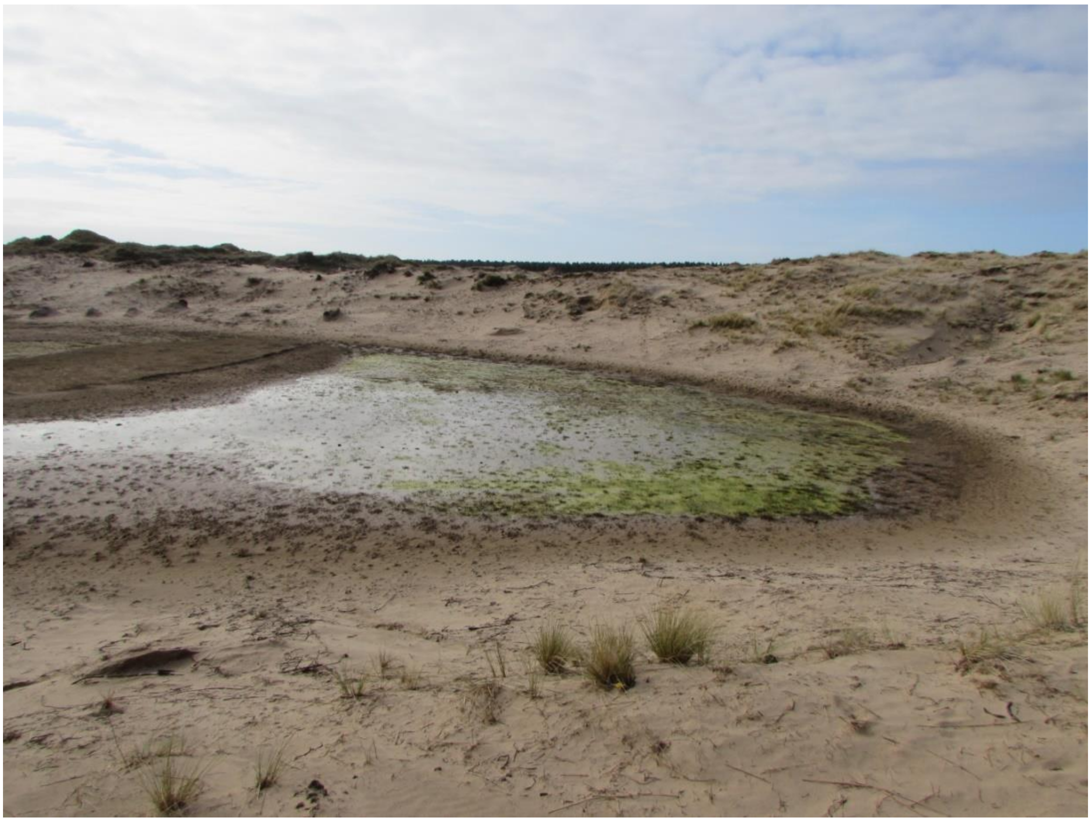


Figure A1.3 Locations of field photographs 13 to 16 in Area 4 reproduced in Appendix 1 to this report. Arrows indicate direction of view; base 2013 aerial photography from Google Earth

Photograph 1. Central axis of the Area 2, looking NE

Photograph 2. View across deflation trough of Area 2, looking SE

Photograph 3. Southern ‘arm’ of Area 2, looking seawards



Photograph 4. Deflation corridor of Area 2, looking W

Photograph 5. Northern 'arm' of Area 2, looking W

Photograph 6. Central axis of the Area 2, looking SW

Photograph 7. Deflation corridor of Area 2, looking NE

Photograph 8. Area of sand blowing on the western side of Area 2

Photograph 9. 'Hedgehog' dune in Area 3, looking N

Photograph 10. SE corner of Area 3, showing vegetation colonisation, looking S

Photograph 11. SE corner of Area 3, showing vegetation colonisation, looking S

Photograph 12. Oblique view across the deflation trough of Area 3, looking S

Photograph 13. View along the constructed ridge on the western side of Area 4, looking NE

Photograph 14. View across the deflation trough of Area 4, looking E

Photograph 15. View along the deflation trough of Area 4, looking NE

Photograph 16. Area of sand blowing to the north of the deflation trough of Area 4, looking S

Data Archive Appendix

Data outputs associated with this project are archived at 'Topographical Survey of Newborough Dune Restoration Work project 421, media 1535' on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] An Excel file named (Newborough Warren Survey Data 25-27 March 2015.xlsx) of data points (x,y,z)

[C] A zip file named (Newborough March 2015 profiles.zip) containing excel files of profile data contained within the report.

[D] A zip file named (Newborough March 2015 Phase 1 shapefiles.zip) containing a series of GIS layers on which the maps in the report are based.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue http://libcat.naturalresources.wales/webview/ (English Version) and http://libcat.naturalresources.wales/cnc/ (Welsh Version) by searching 'Dataset Titles'. The metadata is held as record no [115840]

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