IWT SBO PROJECT 120003 “SEARCH”

Archaeological heritage in the North Sea

Development of an efficient assessment methodology and approach towards a sustainable management policy and legal framework in Belgium.

Archeologisch erfgoed in de Noordzee

Ontwikkeling van een efficiënte evaluatiemethodologie en voorstellen tot een duurzaam beheer in België.

THORNTON VALLEY SEISMIC CAMPAIGN
22-25 APRIL 2014

WP 1.2.3. C

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April 2014

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1. Framework and objectives

1.1. Framework

In April 2014 more than 300 kilometres of 2D high resolution seismic reflection data were acquired offshore the Belgian coast as part of the IWT-SBO project SeArch ("Archaeological heritage in the North Sea: development of an efficient methodology and approach towards a sustainable management policy and legal framework in Belgium"). The purpose of this project is to assess the archaeological potential of the Quaternary deposits in the Belgian part of the North Sea. To this date no efficient survey methodology exists that is particularly aimed at archaeological assessment studies. Standard geophysical and remote sensing techniques are mainly used on an ad hoc basis (if at all), and often these techniques are not well adapted for archaeological investigations. Moreover they are ineffective in large parts of the nearshore zone due to the presence of biogenic gas in the sediments, and generally cannot be applied appropriately in intertidal areas. What does the project aim at with regard to survey technology?

One of the main goals of the SeArch project is to supply a flexible, generic survey methodology through the development and improvement of marine geophysical and remote sensing techniques for seafloor and sub-seafloor imaging, with major focus on acquisition (sources/receivers), data processing and interpretation of high-quality data. This should allow a cost-efficient and accurate assessment of the archaeological potential of the seafloor and sub-seafloor environment.

The acquired data will also be applied in a post-track doctoral research of the SeArch project. This project aims to develop an 'archaeological potential map' of the Belgian part of the North Sea (BCP) indicating the sensitivity of marine areas to human settlements and their remnants. Such a map will contribute to an increase in cost-efficiency and accurate assessment of marine works at sea regarding the archaeological potential of that working area.

1.2. Survey objectives

This seismic campaign, carried out on board of the RV Belgica (Belgian Navy), has multiple objectives:

- Test different seismic sources and receiver configurations in a geologically complex area of the BCP, i.e. the Thornon Bank area. This region is composed of a network of ancient river valleys filled with fluvial (fine sands to gravel) and marine deposits topped by a vast tidal sandbank (used for sand extraction).
- Produce a preliminary survey methodology that takes into account the depth of investigation and the expected vertical resolution needed for the layers/objects/buried landscapes to be found.
- Obtain more precise information on the complex geological layering of the Thornton Valley and the Northern Valley as well as the connection between these two valleys (see figure 1).
- Identify archaeological potential of layers.
- Define locations for further, more detailed, surveys in the area.

2. Study area

The survey area is located between roughly 30-50 km offshore Zeebrugge and mainly covers a section of the BCP marked by two prominent valley systems in the top-Paleogene surface, known as the Northern Valley and the Thornton Valley. Both valleys cut through the surrounding top-Paleogene surface, respectively Offshore Platform and Scarp which were formed during emptying of the Late-Saalian lake. Both valleys are filled with marine Eemian deposits and the Thornton Valley is also filled with fluvial deposits (Kreftenheye) which are positioned below and above these marine Eemian deposits. This implies a Late-Saalian to Early Eemian age for the formation of these structures. Because of the lack of data no connection between the two valleys has been established yet (figure 1).

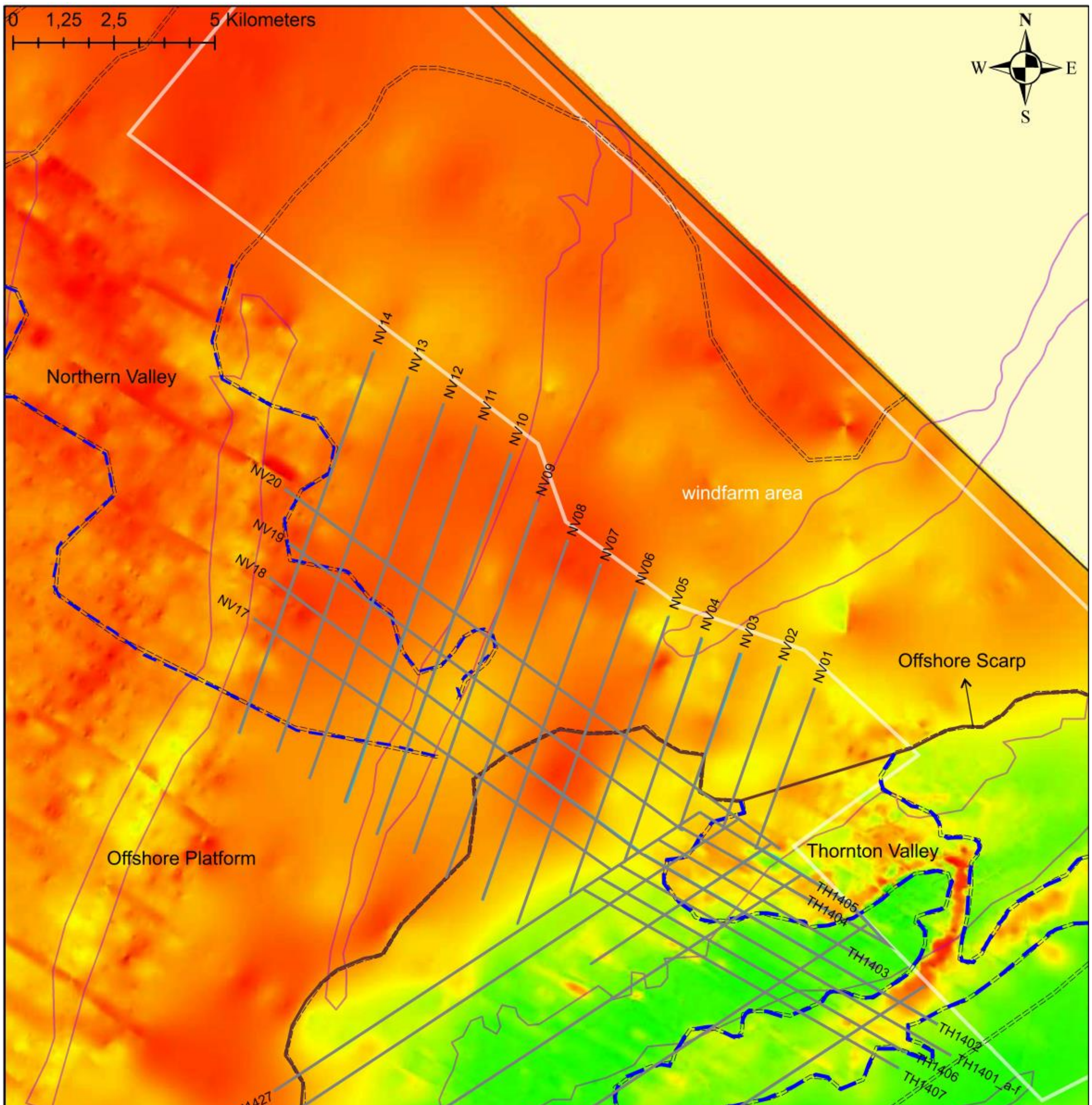

Figure 1 Representation of the seismic lines of the survey area in both the Northern Valley and the Thornton Valley visualized on top of the Top-Palaeogene surface.

3. List of participants

Name	Organisation	Function	22/04/2014	23/04/2014	24/04/2014	25/04/2014
Tine Missiaen	RCMG	Chief Scientist	x	x	x	x
Koen De Rycker	RCMG	Engineer	x	x	x	x
Maikel De Clercq	RCMG	Geologist	x	x	x	x
Vasileios Chademenos	RCMG	Geophysicist	x	x	x	x
Kainan Mao	RCMG	Geologist	x	x	x	x
Cornelis Stal	Department of Geography	Geographer	x	x	x	x

4. Data acquisition

4.1. Equipment and seismic characteristics

Different seismic sources were tested during the campaign: (1) Centipede sparker, (2) SIG sparker 1200, (3) SIG sparker 1270, (4) Seistec boomer and (5) Parametric Echosounder (PES). Each source has a particular frequency range output resulting in high- or low-resolution images with a low or high penetration into the subsurface (see table 1). Where possible the PES was used in combination with the Centipede sparker.

Equipment	Frequency range	Vertical resolution	Penetration
Centipede sparker	1.1 – 1.2 kHz	> 35 cm	in a sandy sea bottom, up to 50 m
SIG sparker 1200	800 - 900 Hz	> 50 cm	In a sandy sea bottom, up to 100 m
SIG sparker 1270	1000 – 1400 Hz	N.A.	N.A.
'Seistec' boomer	1 - 5 kHz (main frequency of 2.5 kHz)	> 25 cm	up to 100 m
Parametric Echosounder	6 - 12 kHz / 100 kHz	15 cm	up to 30 m (in soft sediments)

Table 1 Characteristics of the equipment used during the survey.

When applicable, two different types of receivers were used to register the data; (1) a single channel streamer (SC) and (2) a multichannel streamer (MC; 12 channels). In this case two single channel streamers of the same type were tested. This was to assess the result of the new oil fill of one of the streamers. After preliminary data processing on the field there seemed to be no difference between the two streamers so only one was used from that moment. Both streamers (SC and MC) were towed behind the vessel and were laterally spaced by three metres. The single channel streamer (offset 31m) was towed at port side while the multichannel streamer was always positioned in the middle of the stern (see figure 3 Appendix A). After testing of the multichannel streamer it was decided not to use it because half of the channels were not registering a signal.

At starboard, with an offset of 3m from MC, the Seistec boomer and different types of sparkers (SIG 1200, SIG 1270 and Centipede) were towed. The longitudinal offset of all the devices was fixed during the survey. For the Seistec boomer the offset was 25m, the SIG sparkers had an offset of 30m while the Centipede had an offset of 26,5m. The parametric Echosounder (PES) was attached to a specifically designed mounting at the port hull of the vessel (see figure 2 Appendix A).

4.2. Recorded networks

Test Line (TH1401_a-f)

The test line consists of 6 seismic lines that crossed the entire width of the sandbank and its subsurface structures (figure 1). The lines all follow the exact same trajectory in order to allow correct comparison of the different data (variable orientation!). The two first test lines (TH1401_a and b) with the Centipede sparker had to be rerun because of technical difficulties (see appendix). As explained in table 2, different types of seismic sources were combined for each line. This helped to determine what type of equipment was most appropriate in each particular geological setting.

Line	Source
TH_14_01_a	PES
	Centipede sparker
TH_14_01_b	PES
	Centipede sparker
TH_14_01_c	PES
	Centipede sparker
TH_14_01_d	PES
	Seistec boomer
TH_14_01_e	PES
	SIG Sparker 1
TH_14_01_f	PES
	SIG Sparker 2

Table 2 Test Line acquisition configuration.

Preliminary results obtained on board showed that the sparker sources produced the deepest penetration, while maintaining a relatively good resolution. The Centipede sparker showed a sharp wavelet, producing a higher resolution image than both SIG sparkers. The Seistec boomer source showed a good resolution but a little less detail than the Centipede sparker. The internal receiver of the Seistec boomer showed technical difficulties and could not be used for future measurements.

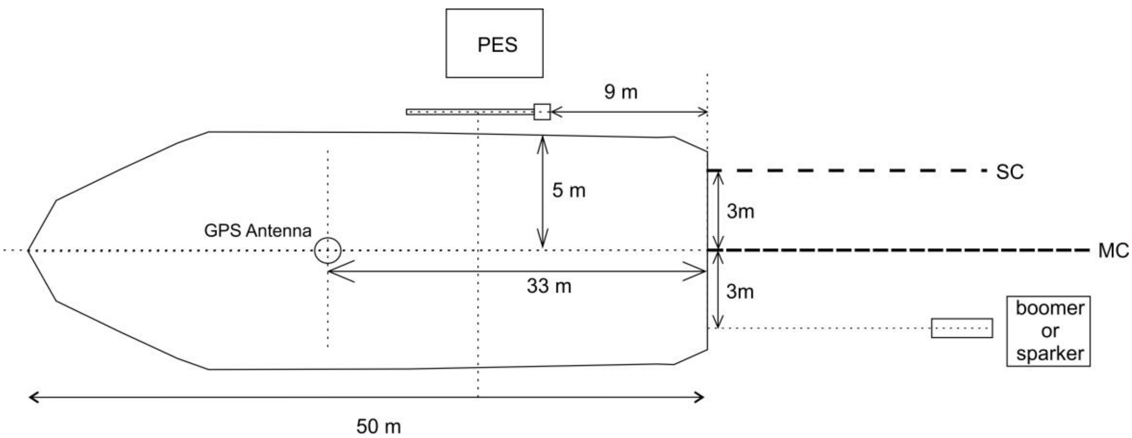

Figure 2 Sketch of the RV Belgica illustrating the equipment configuration.
SC = Single channel streamer; MC = Multichannel streamer.

For the PES different types of frequency outputs were used ranging from 5-8-12 kHz using 1 or 2 pulses. The results of this device varied greatly because acoustic signals were not always able to penetrate the sand layers. Whenever it was able to penetrate the sand layers it gave a detailed image of the Paleogene clays. After a first assessment it was decided to operate the device on a frequency output of 8 kHz with 2 pulses. This gave a good compromise between resolution and penetration.

Thornton Valley (TH)

The seismic network over the Thornton Valley consists of 6 seismic lines east and west of the test line and 6 perpendicular lines parallel to the Thornton sandbank. Only the Centipede sparker, Seistec boomer and the PES sources were used here in combination with the single channel streamer.

Line	Source
TH_14_02	Seistec boomer
	PES
TH_14_03	Centipede sparker
	PES
TH_14_04	Centipede sparker
	PES
TH_14_05	Centipede sparker
	PES
TH_14_06	Centipede sparker
	PES
TH_14_24-26	Centipede sparker
	PES
TH_14_20	Centipede sparker
	PES
TH_14_22	Centipede sparker
	PES
TH_14_24	Centipede sparker
	PES
TH_14_26	Centipede sparker
	PES
TH_14_27	Centipede sparker
	PES

Table 3 Thornton Valley acquisition configuration.

Northern Valley (NV)

The seismic network in the Northern Valley consists of 4 equally spaced parallel lines in a SE-NW orientation and 14 perpendicular lines, covering the profile view of the unknown connection between the Thornton and the Northern Valleys. The Centipede sparker was used on all lines sometimes in combination with the PES.

Line	Source
THNV_14_01	Centipede sparker
THNV_14_02	Centipede sparker
THNV_14_03	Centipede sparker
THNV_14_04	Centipede sparker
THNV_14_05	Centipede sparker

THNV_14_06	Centipede sparker
THNV_14_07	Centipede sparker
THNV_14_08	Centipede sparker
THNV_14_09	Centipede sparker
THNV_14_10	Centipede sparker
THNV_14_11	Centipede sparker
THNV_14_12	Centipede sparker
THNV_14_13	Centipede sparker
THNV_14_14	Centipede sparker
THNV_14_17	Centipede sparker
THNV_14_18	Centipede sparker
THNV_14_19	Centipede sparker
THNV_14_20	Centipede sparker

Table 4 Northern Valley acquisition configuration.

5. Line Summary

Line	Date	Start [UTC+2 hrs]	End [UTC+ 2hrs]	Point A [UTM]	Point B [UTM]	Equipment	Energy (J)	Frequency (sweep)	Sampling rate (ms) SC	Remarks
TH_14_01_a	22/04/2014	17:15	19:00	5705494,35 495402,46	5709989,10 487544,51	PES	N.A.	5 – 12 kHz	N.A.	problems with sparker trigger
						Centipede sparker	300	N.A.	0,125	
TH_14_01_b	22/04/2014	19:04	20:26	5709921,02 487846,37	5705510,99 495333,13	PES	N.A.	5 – 12 kHz	N.A.	navigation fails sometimes
						Centipede sparker	300	N.A	0,125	
TH_14_01_c	22/04/2014	14:50	16:58	5705477,63 495474,24	5709633,04 487592,09	PES	N.A.	5 – 12 kHz	N.A.	good testline with Centipede sparker
						Centipede sparker	300	N.A	0,125	
THNV_14_17	22/04/2014	22:15	23:45	5709725,11 487448,17	5716169,48 478325,32	Centipede sparker	300	N.A	0,125	-
THNV_14_18	22/04/2014	00:02	01:48	5717114,39 478616,31	5710155,08 488168,31	Centipede sparker	300	N.A	0,125	-
THNV_14_19	23/04/2014	02:04	03:50	5710829,03 488992,76	5718012,49 479166,87	Centipede sparker	300	N.A	0,125	
THNV_14_20	23/04/2014	04:00	06:35	5719386,59 479007,43	5710617,68 491165,91	Centipede sparker	300	N.A	0,125	
THNV_14_01	23/04/2014	06:40	07:45	5710123,60 490978,91	5714575,92 492455,18	Centipede sparker	300	N.A	0,125	
THNV_14_02	23/04/2014	07:50	08:35	5714988,21 491565,64	5710877,95 489857,27	Centipede sparker	300	N.A	0,125	
TH_14_01_d	23/04/2014	09:50	10:50	5709979,84 487643,31	5705415,75 495448,88	PES	N.A.	5 – 12 kHz	N.A.	
						Seistec boomer	300	N.A.	0,0625	
TH_14_02	23/04/2014	11:00	12:25	5705822,20 496117,75	5710244,92 488126,58	PES	N.A.	5 – 12 kHz	N.A.	
						Seistec boomer	300	N.A.	0,0625	
TH_14_03	23/04/2014	13:01	14:02	5710744,86 488420,12	5706753,38 495299,03	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	300	N.A	0,125	

TH_14_03-04	23/04/2014	14:06	14:47	5706965,42 495238,24	5708712,51 492849,75	PES	N.A.	5 – 12 kHz	N.A.	transition line 3 to 4
						Centipede sparker	300	N.A	0,125	
TH_14_04	23/04/2014	14:48	15:30	5708746,64 492815,34	5710818,50 489078,32	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	300	N.A	0,125	
TH_14_05	23/04/2014	15:44	16:12	5711066,32 489654,45	5709776,80 491927,73	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	300	N.A	0,125	
TH_14_24	23/04/2014	16:15	18:03	5708666,22 490332,91	5702602,77 481141,63	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	300	N.A	0,125	
TH_14_24-26	23/04/2014	18:05	18:29	5702567,08 480960,32	5703756,32 479325,87	PES	N.A.	5 – 12 kHz	N.A.	transition line 24 to 26
						Centipede sparker	300	N.A	0,125	
TH_14_26	23/04/2014	18:30	21:15	5703867,42 479348,96	5713629,25 493993,28	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	300	N.A	0,125	
THNV_14_03	23/04/2014	21:39	22:35	5715444,53 490667,27	5709654,67 488508,89	Centipede sparker	300	N.A	0,125	-
THNV_14_04	23/04/2014	22:44	23:36	5710187,51 487676,66	5716326,21 489835,52	Centipede sparker	300	N.A	0,125	-
THNV_14_05	23/04/2014	23:53	00:59	5716581,67 488882,93	5709171,55 486174,24	Centipede sparker	300	N.A	0,125	-
THNV_14_06	24/04/2014	01:18	02:47	5708333,29 484939,30	5717258,19 487979,26	Centipede sparker	300	N.A	0,125	-
THNV_14_07	24/04/2014	02:56	04:07	5717458,09 487044,12	5708922,13 483953,72	Centipede sparker	300	N.A	0,125	-
THNV_14_09	24/04/2014	08:42	09:49	5711320,51 482854,01	5719171,58 485632,52	Centipede sparker	300	N.A	0,125	no acquisition between 04:16-18:45. No power.
THNV_14_08	24/04/2014	09:58	11:16	5718590,82 486217,72	5710069.26 483547,83	Centipede sparker	300	N.A	0,125	-
THNV_14_15	24/04/2014	11:16	11:34	5710031,09 483587,95	5708618,35 485368,68	Centipede sparker	300	N.A	0,125	-
TH_14_27	24/04/2014	11:36	11:51	5708636,35 485523,54	5709704,06 487165,87	PES	N.A.	5 – 12 kHz	N.A.	extra line parallel to TH1426
						Centipede sparker	300	N.A	0,125	
TH_14_06	24/04/2014	11:51	13:14	5709678,07 487217,55	5705224,38 494973,64	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	300	N.A	0,125	
TH_14_01_e	24/04/2014	13:33	14:53	5705317,98 495534,06	5709937,60 487617,30	PES	N.A.	5 – 12 kHz	N.A.	
						Sig sparker 1200	N.A.	N.A.	0,125	

TH_14_01_f	24/04/2014	15:05	16:31	5710068,32 487417,89	5705411,35 495455,61	PES	N.A.	5 – 12 kHz	N.A.	
						Sig sparker 1270	N.A.	N.A.	0,125	
TH_14_20	24/04/2014	16:54	18:30	5706789,82 494867,95	5700407,91 484991,09	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	300	N.A	0,125	
TH_14_22	24/04/2014	19:13	20:54	5701560,54 483146,93	5708207,97 493236,86	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	300	N.A	0,125	
THNV_14_10	24/04/2014	22:03	23:24	5710902,17 481521,71	5719890,83 484576,93	Centipede sparker	500	N.A	0,125	-
THNV_14_11	24/04/2014	23:46	00:55	5720352,48 483996,51	5711605,95 480715,93	Centipede sparker	500	N.A	0,125	-
THNV_14_12	25/04/2014	01:08	02:40	5712029,20 479808,70	5721579,26 483078,53	Centipede sparker	500	N.A	0,125	-
THNV_14_13	25/04/2014	02:55	04:12	5722130,40 482435,85	5712663,85 478948,92	Centipede sparker	500	N.A	0,125	-
THNV_14_14	25/04/2014	04:23	06:02	5712967,62 478073,29	5722907,68 481444,67	Centipede sparker	500	N.A	0,125	-
THNV_14_14-21	25/04/2014	06:05	06:20	5722899,64 481211,65	5720340,30 479596,85	Centipede sparker	500	N.A	0,125	-
THNV_14_21	25/04/2014	06:22	08:28	5720166,88 479684,99	5711568,23 491767,21	Centipede sparker	500	N.A	0,125	-
TH_14_25	25/04/2014	08:51	09:34	5710163,55 490856,87	5707446,68 486688,61	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	500	N.A	0,125	
TH_14_25-07	25/04/2014	07:34	09:52	5707431,89 486649,59	5709230,56 486386,59	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	500	N.A	0,125	
TH_14_07	25/04/2014	07:55	11:30	?	?	PES	N.A.	5 – 12 kHz	N.A.	-
						Centipede sparker	500	N.A	0,125	

Table 6 Representation of the characteristics of the performed seismic lines during the survey.

Appendix A

Survey photos

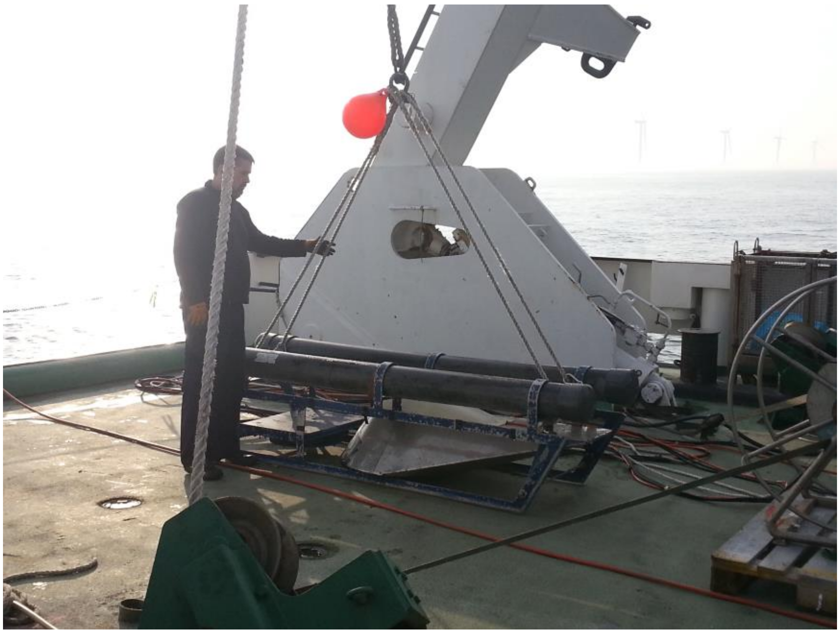

Figure 1: Seistec boomer on board RV Belgica

Figure 2: PES configuration, mounted on the side of the RV Belgica.

Figure 3: Data acquisition using two different streamers (SC = Single channel; MC = Multichannel, respectively left and middle) and a source (sparker or boomer; right side) towed behind the ship.

Figure 4: Seistec boomer from RCMG.

Appendix B

Survey log and weather conditions[1]

Tuesday 22/04/2014 (2-3 bft)
8:30: Arrival at Zeebrugge
9:00-10:30: Mobilisation of seismic equipment on board
0:30-15:00: Installation
15:00: Transit to Thornton area
16:30: Arrival southern focus area (TH)
17:00: Equipment in the water (PES), Centipede sparker, 2xSC, MC)
17:30: Start of measurements (TH_14_01), 3 bft:
    Testline a – CS; problems with sparker trigger
    Testline b – CS; navigation fails sometimes
    Testline c – CS; complete line recorded
Strong swell causes the PES sometimes to surface above waterline, this caused "no recording gaps" in the data.
Problems with MC – only the last 6 channels give a signal
17:30-22:00: end of testline measurements, set course to NV
22:15: start measurements NV (CS + 2xSCS + MCS), line 17

Wednesday 23/04/2014 (2-3 bft)
00:00-08:45: Measurements NV
Lines 18 - 19 - 20 - 01 - 02
08:45: End of measurements in NV, set course to TV
09:15: Arrival at TV, CS out of water, Seistec + PES in water
09:30-10:50: testline d; PES on multifrequency mode
11:00-12:30: line 2 with Seistec + PES
Continuing problems with MC. Extensive testing of geode and all connections. No problems to be found; good Seistec data.
Comparison of CS and Seistec data showed that CS had a better resolution and penetration.
12:30: Seistec and MCS out of water, CS in water
13:00: start measurements in TV (CS + PES + 2xSCS)
Lines 3 - 4 - 5 - 24 - 26
Profile 26 continued to the north (line 27)
Comparison of SC data showed that the two streamers have the same quality (new oil in one streamer). It was decided that only one will be used for further measurements.
20:50: stop measurements in TV; course set to NV
PES pole and 1 SC out of water;
21:40: start measurements NV, lines 3 - 4

Thursday 24/04/2014 (2bft daytime, at night-time 3-4 to 5 bft)
00:00-04:20: continuing measurements NV
Lines 5 - 6 - 7
After line 7 failure of sparker power supply
04:30-08:15: repairment of power supply
08:30: continuation of measurements NV (CS + PES + 1xSCS), lines 8 - 9
08:35: short black-out (5min) on the ship, measurements continue

[1] Time in GMT+2hr

11:40: stop measurements NV; transit to TV via line 15
12:00: start measurements TV (CS + PES + 1xSCS), line 6
13:20: CS out of water; SIG1200 sparker in water
Testline e (SIG1200 + PES + SC), at end of line SIG1200 changed for SIG1270
Testline f (SIG1270 + PES + SC)
16:00: end of measurements testline, SIG1270 out of water, CS in water
16:10: continuation TV, lines 20 – 22 (CS + PES + SC)
21:30: stop measurements TV, diesel engine on, equipment out of water and fast transit NV
22:00: equipment in water, start measurements NV, line 10 (CS + SC)
Wind increased to 4-5 bft
Sparker at 500J because of bad penetration at 300J

Friday 25/04/2014 (4 bft)
00:00-08:00: continuation of NV (CS + SC)
Lines 10 – 11 – 12 – 13 – 14 – 21
08:30: start measurements in TV (CS + PES + SC)
Line 25 – short cut to line 7 - line 7
11:30: end of measurements; equipment out of water
11:40: transit to Zeebrugge
13:30: arrival at Zeebrugge