## 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.*

# OOSTENDE & IJSER VALLEY SEISMIC CAMPAIGN
# 12-16 MAY 2014

## WP 1.2.3_B


Responsible partners: UG-RCMG, Deltares, VLIZ

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# 1. Framework and objectives

## 1.1. Framework

In May 2014 more than 350 kilometres of 2D high resolution seismic reflection data were acquired offshore Ostend and the eastern 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 and these techniques are often 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.

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 PhD research wants 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 Simon Stevin (VLIZ), is a continuation of a survey performed in the area October 2013. It has similar objectives as the previous survey, but this time with a few new goals added:

- Test different seismic sources and receiver configurations in different geological settings of the Belgian Continental Shelf, i.c. the Ostend and IJser Valley.
- 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 detailed information on the complex geological layering of the Ostend and Yser Valley as well the offshore continuation of the latter.
- Identify archaeological potential of geological layers and the seafloor (shipwrecks).
- Define locations for further, more detailed, surveys in the area.

# 2. Study area

The complete study area is composed of two different palaeovalley systems that are now buried beneath the seafloor. The first comprises the Ostend Valley. This valley is located roughly 10 km offshore the city of Ostend and the seismic grid covers a cross-section of the valley (figure 1). This funnel-shaped valley structure in the top-Palaeogene morphology started out as a river valley during the Saalian ice age when sea level was low. With the rise of sea level during the Eemian interglacial the river valley evolved into a more open estuary, where coastal and tidal forces shaped the funnel-shaped valley, as we know it today (see figure 1). During the subsequent sea level drop (Weichsel ice age) fluvial incision occurred again, only this time not as strong as during the Saalian. Eventually the valley got cut off at the end of the Pleistocene when a large aeolian dune blocked the river more inland redirecting it to the north, where it still resides today.

The second valley system is called the Yser Valley. This is a smaller valley west of the Ostend Valley, near the Belgian-French border (figure 1). The onshore Holocene geological history of this valley has been well studied in the past few decades (for more information see related works of Baeteman, 2008). However very little is known about its offshore continuation. Most likely the first river incisions occurred during the Late Pleistocene but further details are lacking. Both the Ostend and IJser valley systems seem to have a different catchment area, separated by a local high in the top-Paleogene surface.

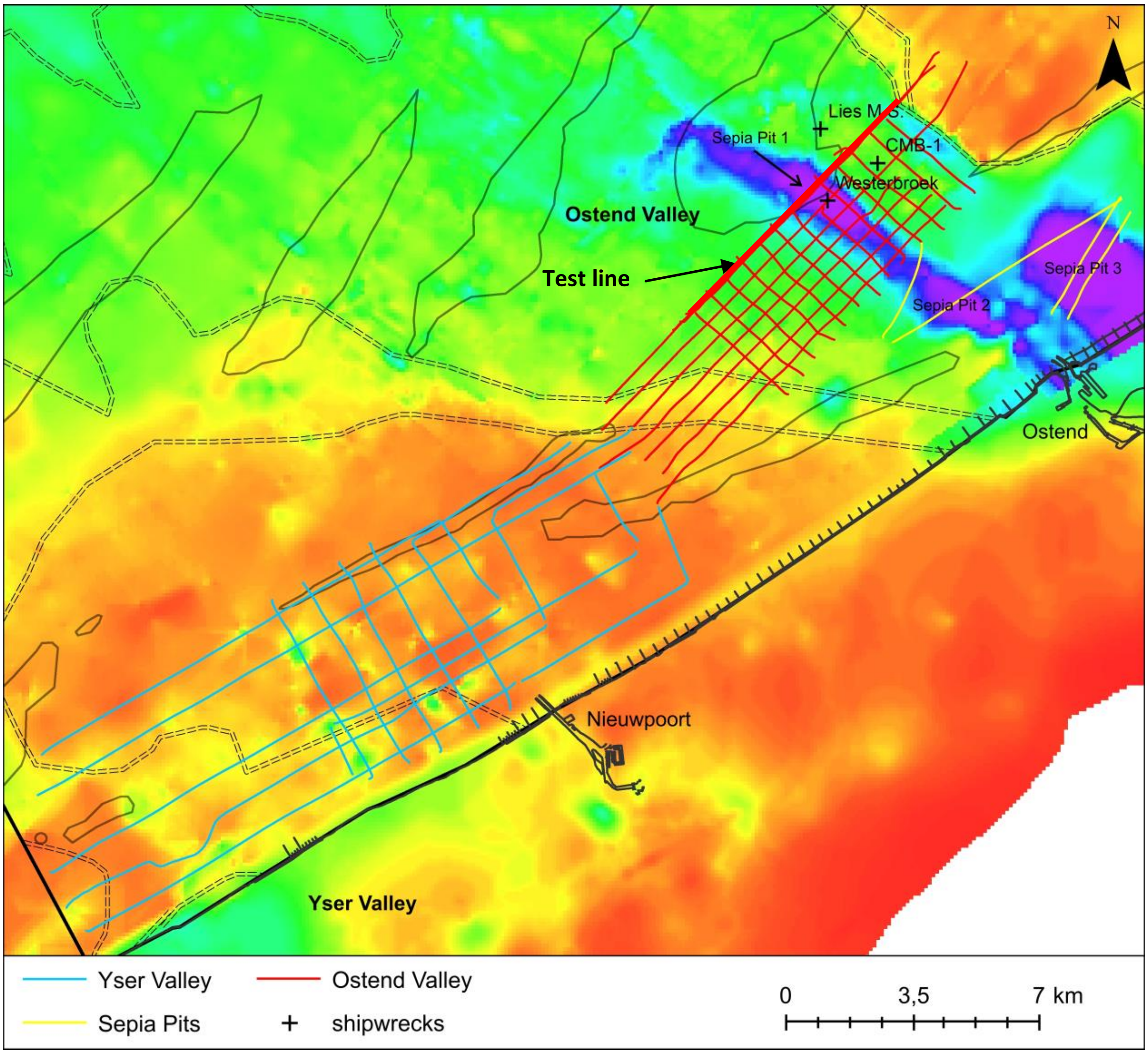


*Figure 1 The survey area in May 2014 visualized on top of the Palaeogene surface. Recorded seismic networks in the Ostend and Yser Valley are shown (blue and red lines) as well as the so-called Sepia Pits (yellow lines). Black crosses mark the shipwrecks ('Lies' and 'Westerbroek').*

# 3. List of participants

| Name | Organisation | Function | 12/05 | 13/05 | 14/05 | 15/05 | 16/05 |
|---|---|---|---|---|---|---|---|
| **Tine Missiaen** | RCMG | Chief Scientist | x | x | x | x | x |
| **Koen De Rycker** | RCMG | Engineer | x | x | x | x | x |
| **Oscar Zurita Hurtado** | RCMG | Geophysicist | x | x | x | x | x |
| **Maikel De Clercq** | RCMG | Geologist | x | x | x | x | x |
| **Vasileius Chademeinos** | RCMG | Geophysicist | x | x | x | x | x |
| **Annelies Incoul** | Geography | Geographer | | x | x | x | |
| **Chris Mesdag** | Deltares | Geophysicist | x | x | x | x | x |

# 4. Data acquisition

## 4.1. Equipment and seismic characteristics

The following seismic sources were used during the campaign: (1) Centipede sparker, (2) SIG sparker, (3) high-frequency (HF) boomer (Deltares), (5) Geopulse and (6) 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 different sources were used simultaneously (e.g. PES and HF boomer; PES and sparker). In addition to the seismic equipment a Hydrochart was used. This device is a combination of multibeam and side-scanner sonar to image the seafloor and exposed objects.

| Equipment | Frequency range | Resolution | Penetration |
|---|---|---|---|
| **Centipede sparker** | 1.1 – 1.2 kHz | vertical: > 35 cm | in a sandy sea bottom, up to 50 m |
| **SIG sparker 1200** | 800 - 900 Hz | vertical: > 50 cm | In a sandy sea bottom, up to 100 m |
| **HF boomer** | 2 - 6 kHz | vertical: > 35 cm | up to 50 m (depending on sediment) |
| **Geopulse** | 3,5 kHz | vertical: 25 cm | up to 50 m (depending on sediment) |
| **Parametric Echosounder** | 6 - 12 kHz / 100 kHz | vertical: 15 cm | up to 30 m (in soft sediments) |
| **Hydrochart** | 500 kHz | horizontal: 10 – 50 cm | N.A. |

*Table 1 Characteristics of the equipment used during the survey. For information about the geometrical set-up see figure 2.*

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; 24 channels). Both streamers were towed behind the vessel and were laterally spaced by four metres. The single channel streamer was towed at port side while the multichannel streamer was positioned one meter to the starboard side compared to the middle of the stern (figure 2).

At starboard, with an offset of two meters from the multichannel streamer, the different types of sparkers were towed while the HF boomer was towed from the middle of the stern connected to the A-frame of the ship. The longitudinal offset of the boomers and sparkers was held at a constant distance of 25m. The Hydrochart, PES and Geopulse were attached to a specifically designed mounting at the port hull of the vessel (see figure 2).

## 4.2. Recorded networks (sub-areas)

### *Shipwreck investigation*

In the area of the Ostend Valley two shipwrecks ('Westerbroek' and 'Lies') were investigated with the Hydrochart. The multibeam of the ship was not used simultaneously because of interference from the Hydrochart. These shipwrecks have previously been investigated with the multibeam of the RV Simon Stevin and can thus be compared. For every wreck a few parallel cross-lines (line separation 30 m) were performed in order to image the ship from several directions. Due to problems with the navigation antenna correct calibration was not possible and only relative coordinates could be recorded.

### *Test Line (TL)*

The same seismic test line was used as during the 2013 campaign (see figure 1). In May 2014 the test line was recorded run five times with three different types of equipment, including a HF boomer from Deltares and the Geopulse from RCMG (table 2). The purpose was to compare the different sources but also to assess the potential differences in data acquisition of changing weather conditions along the same line.

| Line | Source | Orientation | Source Offset | S. Ch Offset | M. Ch Offset |
|---|---|---|---|---|---|
| **OV_14_01_a** | HF boomer | east - west | 25 m | 31 m | 31 m |
| **OV_14_01_b** | HF boomer | west – east | 25 m | 31 m | 31 m |
| **OV_14_01_c** | Centipede sparker | west – east | 25 m | 31 m | 31 m |
| **OV_14_01_d** | HF boomer | east - west | 25 m | 31 m | 31 m |
| **OV_14_01_e** | Geopulse | east-west | N.A. | 40 m | N.A. |

*Table 2 Test Line acquisition configuration.*

Preliminary results obtained on board showed that the Geopulse did not have a high penetration. The HF boomer showed good penetration depth but resolution in the shallow sections was less compared to that of the centipede sparker.

Preliminary comparison of the single channel streamer data and a near offset stack from the multichannel streamer proved that data acquired with the multichannel streamer presented a higher signal to noise ratio. It was therefore decided to acquire all data with the multichannel streamer while keeping the single channel streamer for comparison purposes.

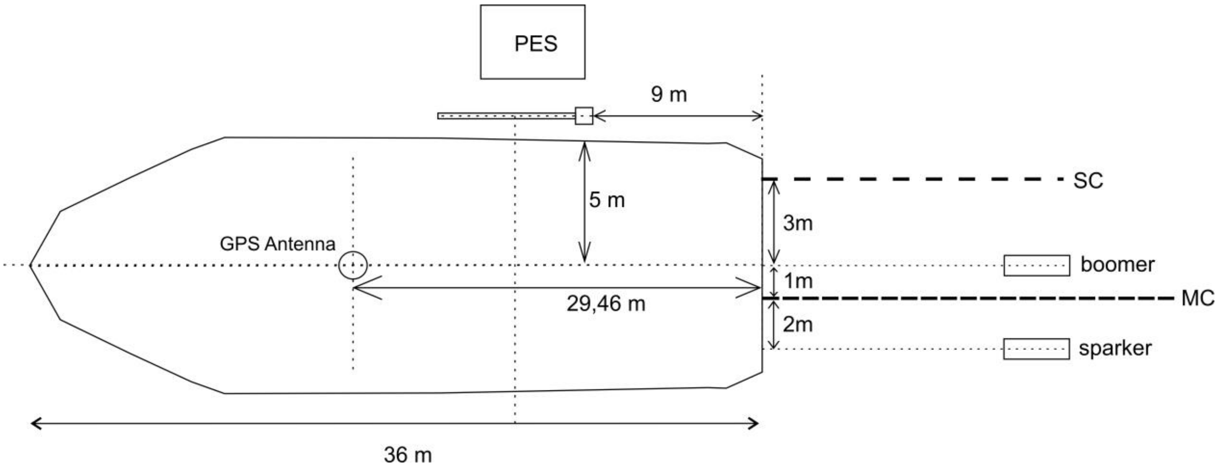


*Figure 2 Sketch of the vessel illustrating the equipment configuration. SC = Single Channel streamer; MC = Multichannel streamer.*

### ***Ostend Valley (OV)***

The seismic network of the Ostend Valley is an extension of the network performed in 2013. At that time the weather conditions resulted in fast deteriorating data quality, especially for the lines in the western flank of the valley. The 2014 network was therefore extended to the west, but also the south. The latter lies beyond the Ostend sandbank thus creating a different geological setting.

| Line | Source | Source Offset | SC Offset | MC Offset |
|---|---|---|---|---|
| **OV_14_05** | SIG sparker | 25 m | 31 m | 31 m |
| **OV_14_06** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_07** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_03** | SIG sparker | 25 m | 31 m | 31 m |
| **OV_14_04** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_08** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_10** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_11** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_02** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_18** | HF boomer | 25 m | 31 m | 31 m |
| **OV_14_17** | HF boomer | 25 m | 31 m | 31 m |
| **OV_14_16** | HF boomer | 25 m | 31 m | 31 m |
| **OV_14_15** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_14** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_13** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_12** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_25** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_26** | Centipede sparker | 25 m | 31 m | 31 m |
| **OV_14_08** | Centipede sparker | 25 m | 31 m | 31 m |

*Table 3 Ostend Valley acquisition configuration.*

### *Yser Valley (YV)*

The seismic network in the Yser Valley focuses on the offshore extension of this river valley. Running the seismic lines in this area proved challenging due to the combination of shallow bathymetry, the presence of many sandbanks and high tidal ranges which often lead to a deviation from the planned course.

| Line | Source | Source Offset | SC Offset | MC Offset |
|---|---|---|---|---|
| **YV_14_04** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_03** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_25** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_06** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_05** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_01t** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_01_a** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_01_b** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_02** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_26** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_5-6** | SIG sparker | 25 m | 31 m | 31 m |
| **YV_14_06_ex** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_24** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_23** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_22** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_21** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_20** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_2-3** | Centipede sparker | 25 m | 31 m | 31 m |
| **YV_14_29** | Centipede sparker | 25 m | 31 m | 31 m |

*Table 4 Yser Valley acquisition configuration.*

### *Sepia Pits (SP)*

The so-called Sepia Pits are three scour pits that are part of the deeper tidal channel in the Ostend Valley. The most northern pit (#1) is located within the Ostend Valley recorded network and was therefore well covered. The two southern pits (#2 and #3) are less well known. Old seismic data (often analogue) covering the pits are marked by a low data quality, partly due to the presence of shallow gas. Therefore several seismic lines were run over the pits in 2014 to allow a more detailed study. This will also give new information about the more landward part of the Ostend Valley.

| Line | Source | Source Offset | SC Offset | MC Offset |
|---|---|---|---|---|
| **SP_14_01_t** | centipede sparker | 25 m | 31 m | 31 m |
| **SP_14_01** | centipede sparker | 25 m | 31 m | 31 m |
| **SP_14_02** | centipede sparker | 25 m | 31 m | 31 m |
| **SP_14_03** | centipede sparker | 25 m | 31 m | 31 m |

*Table 4 Sepia Pits acquisition configuration.*

## 5. Summary of recorded seismic lines

| Line | Date | Start [UTC] | End [UTC] | Position [UTM E] | Position [UTM N] | Source | Energy (J) | Shot interval | Sampling rate (ms) SC/MC* | Wind (Bft) | Speed (kn) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OV_14_01_a** | 13/05/2014 | 18:11 | 19:18 | 5682885,82 489591,37 | 5677187,19 483928,91 | Deltares boomer | 300 | 0,5s | 0,1s/0,125s | 3-4 | 4 | MC ch. 5 and 6 not working |
| **OV_14_01_b** | 13/05/2014 | 19:28 | 20:25 | 5677621,06 484284,44 | 5682161,20 488885,65 | Deltares boomer | 300 | 0,5s | 0,1s/0,125s | 3 | 4 | MC ch. 5 and 6 intermittent failure, eventually both work |
| **OV_14_05** | 13/05/2014 | 20:45 | 22:11 | 5681297,88 490643,03 | 5673657,96 483169,61 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 4 | - |
| **YV_14_04** | 13/05/2014 | 22:17 | 01: 09 | 5673039,14 483096,28 | 5663157,85 466436,57 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 3-2 | 4 | - |
| **YV_14_03** | 14/05/2014 | 01:16 | 03:14 | 5662488,65 467024,06 | 5669644,19 479236,27 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 3-2 | 4 | - |
| **YV_14_25** | 14/05/2014 | 03:17 | 03:39 | 5669914,48 479187,62 | 5671953,92 477473,74 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | - |
| **YV_14_06** | 14/05/2014 | 03:40 | 05:18 | 5671922,97 477418,80 | 5665674,71 466794,50 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | 04:05-04-15: MC lost power to battery, system reboot |
| **YV_14_05** | 14/05/2014 | 05:30 | 08:09 | 5664574,84 466679,46 | 5673884,83 482776,22 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | line continuation to OV-grid due to low tide |
| **OV_14_06** | 14/05/2014 | 08:43 | 10:28 | 5673305,56 483656,30 | 5680842,62 490942,37 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3 | |
| **OV_14_07** | 14/05/2014 | 10:33 | 12:23 | 5680564,30 491322,14 | 5672492,91 483507,79 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,5 | |
| **YV_14_01t** | 14/05/2014 | 12:24 | 12:43 | 5672388,83 483538,70 | 5670320,57 484290,08 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3-4 | 3,5 | t = transit |
| **YV_14_01a** | 14/05/2014 | 12:43 | 13:30 | 5670312,12 484284,17 | 5667672,34 479826,67 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 4 | 4 | |
| **YV_14_01b** | 14/05/2014 | 13:57 | 15:45 | 5667626,89 479634,19 | 5660905,85 467996,15 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 4 | 4 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **YV_14_02** | 14/05/2014 | 15:52 | 17:57 | 5661521,96<br>467462,15 | 5669188,18<br>480473,26 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 5 | 4,5 | |
| **YV_14_26** | 14/05/2014 | 17:58 | 18:25 | 5669357,52<br>480443,24 | 5672072,64<br>479044,24 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 5 | 4 | |
| **YV_14_5-6** | 14/05/2014 | 18:25 | 19:07 | 5672141,07<br>479065,40 | 5674519,52<br>482818,30 | SIG sparker | 300 | 0,5s | 0,1s/0,125s | 4 | 3,8 | Line between 5 and 6 because of low tide |
| **OV_14_01_c** | 14/05/2014 | 22:40 | 23:03 | 5677150,47<br>483944,22 | 5675211,56<br>482109,44 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 4 | 3,9 | |
| **YV_14_06_ex** | 14/05/2014 | 23:15 | 00:02 | 5674142,29<br>481141,02 | 5671413,33<br>476868,19 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 4-3 | 3,7 | ex = extension of line 6 |
| **YV_14_24** | 15/05/2014 | 00:02 | 00:49 | 5671393,88<br>476870,12 | 5666900,09<br>479508,14 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,5 | |
| **YV_14_23** | 15/05/2014 | 00:58 | 01:45 | 5666411,35<br>478659,11 | 5671411,75<br>475690,85 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,8 | |
| **YV_14_22** | 15/05/2014 | 01:54 | 02:42 | 5670899,50<br>474866,84 | 5665745,80<br>477605,35 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,6 | |
| **YV_14_21** | 15/05/2014 | 02:50 | 03:34 | 5665458,53<br>476777,75 | 5670336,15<br>473878,01 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 4 | |
| **YV_14_20** | 15/05/2014 | 03:44 | 04:30 | 5669870,34<br>473043,99 | 5665016,64<br>475680,63 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | |
| **YV_14_19** | 15/05/2014 | 04:33 | 04: 45 | 5665142,32<br>475229,13 | 5666419,04<br>474650,07 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | deviated from line due to low tide |
| **YV_14_2-3** | 15/05/2014 | 04:46 | 06:06 | 5666516,96<br>474727,44 | 5671178,04<br>482928,45 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | between line 2 and 3 |
| **YV_14_29** | 15/05/2014 | 06:08 | 06:25 | 5671471,61<br>482971,37 | 5673256,50<br>481828,55 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | |
| **OV_14_04** | 15/05/2014 | 06:27 | 08:05 | 5673444,61<br>481937,64 | 5681319,03<br>490073,14 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2-3 | 4 | |
| **OV_14_08** | 15/05/2014 | 08:30 | 09:05 | 5679921,05<br>491287,89 | 5681938,57<br>488310,53 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OV_14_10** | 15/05/2014 | 09:11 | 09:42 | 5681375,46 487778,44 | 5678991,17 490136,93 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | |
| **OV_14_11** | 15/05/2014 | 09:46 | 10:07 | 5678651,29 489795,68 | 5680493,78 488017,06 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | |
| **OV_14_02** | 15/05/2014 | 10:10 | 10:48 | 5681248,21 488722,12 | 5674485,29 482005,55 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | |
| **OV_14_01_d** | 15/05/2014 | 11:04 | 12:30 | 5684349,21 491032,87 | 5677415,96 484122,59 | Deltares boomer | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | With boomer due to good weather conditions |
| **OV_14_18** | 15/05/2014 | 12:38 | 13:08 | 5677646,67 484541,75 | 5675445,73 487055,23 | Deltares boomer | 300 | 0,5s | 0,1s/0,125s | 2 | 4 | |
| **OV_14_17** | 15/05/2014 | 13:15 | 13:44 | 5675951,11 487466,80 | 5678242,32 484832,29 | Deltares boomer | 300 | 0,5s | 0,1s/0,125s | 3 | 4 | |
| **OV_14_16** | 15/05/2014 | 13:53 | 14:20 | 5678624,28 485367,22 | 5676438,24 487775,93 | Deltares boomer | 300 | 0,5s | 0,1s/0,125s | 3 | 4,5 | |
| **OV_14_15** | 15/05/2014 | 14:35 | 15:00 | 5676922,97 488313,18 | 5679172,55 485661,35 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3-4 | 4 | |
| **OV_14_14** | 15/05/2014 | 15:06 | 15:30 | 5679554,44 486254,61 | 5677317,61 488610,58 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3-4 | 4 | |
| **OV_14_13** | 15/05/2014 | 15:36 | 16:03 | 5677840,59 488967,82 | 5680057,77 486587,27 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 4 | 4,5 | |
| **0V_14_12** | 15/05/2014 | 16:09 | 16:37 | 5680420,26 487148,64 | 5678135,22 489549,71 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 4 | 4 | |
| **0V_14_02** | 16/05/2014 | 09:31 | 10:48 | 5681248,21 488722,12 | 5674485,29 482005,55 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2 | 3,75 | |
| **OV_14_01_e** | 16/05/2014 | 10:58 | 12:54 | 5674798,20 481762,38 | 5684535,22 491165,66 | Geopulse | 300 | 0,25s | 0,05s/N.A. | 2 | 3,75 | Line is as long as the parallel lines |
| **OV_14_25** | 16/05/2014 | 13:11 | 13:38 | 5682891,20 489738,64 | 5680907,12 492119,19 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 2-3 | 3,7 | Extra line added to the grid |
| **OV_14_26** | 16/05/2014 | 13:43 | 14:12 | 5680475,11 491740,39 | 5682542,78 489252,65 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,8 | Extra line added to the grid |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OV_14_08** | 16/05/2014 | 14:30 | 14:49 | 5679921,05<br>491287,89 | 5681938,57<br>488310,53 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,8 | |
| **SP_14_01_t** | 16/05/2014 | 14:50 | 15:14 | 5679538,33<br>490677,74 | 5676975,52<br>489634,93 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,8 | SP = Sepia Pits, t=transit |
| **SP_14_01** | 16/05/2014 | 15:16 | 16:16 | 5676855,80<br>489888,35 | 5680730,834<br>96104,42 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,8 | |
| **SP_14_02** | 16/05/2014 | 16:21 | 16:50 | 5680795,12<br>496087,24 | 5677629,45<br>494209,37 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,8 | |
| **SP_14_03** | 16/05/2014 | 16:54 | 17:22 | 5677492,18<br>494651,15 | 5680385,68<br>496347,39 | Centipede sparker | 300 | 0,5s | 0,1s/0,125s | 3 | 3,8 | |

*Table 6 Representation of the characteristics of the recorded seismic lines during the May 2014 survey.*

# Appendix A

## Survey photos


*Figure 1: Data-acquisitioning systems in the wet lab.*

*Figure 2: HF boomer of Deltares attached to the A-frame of the ship.*

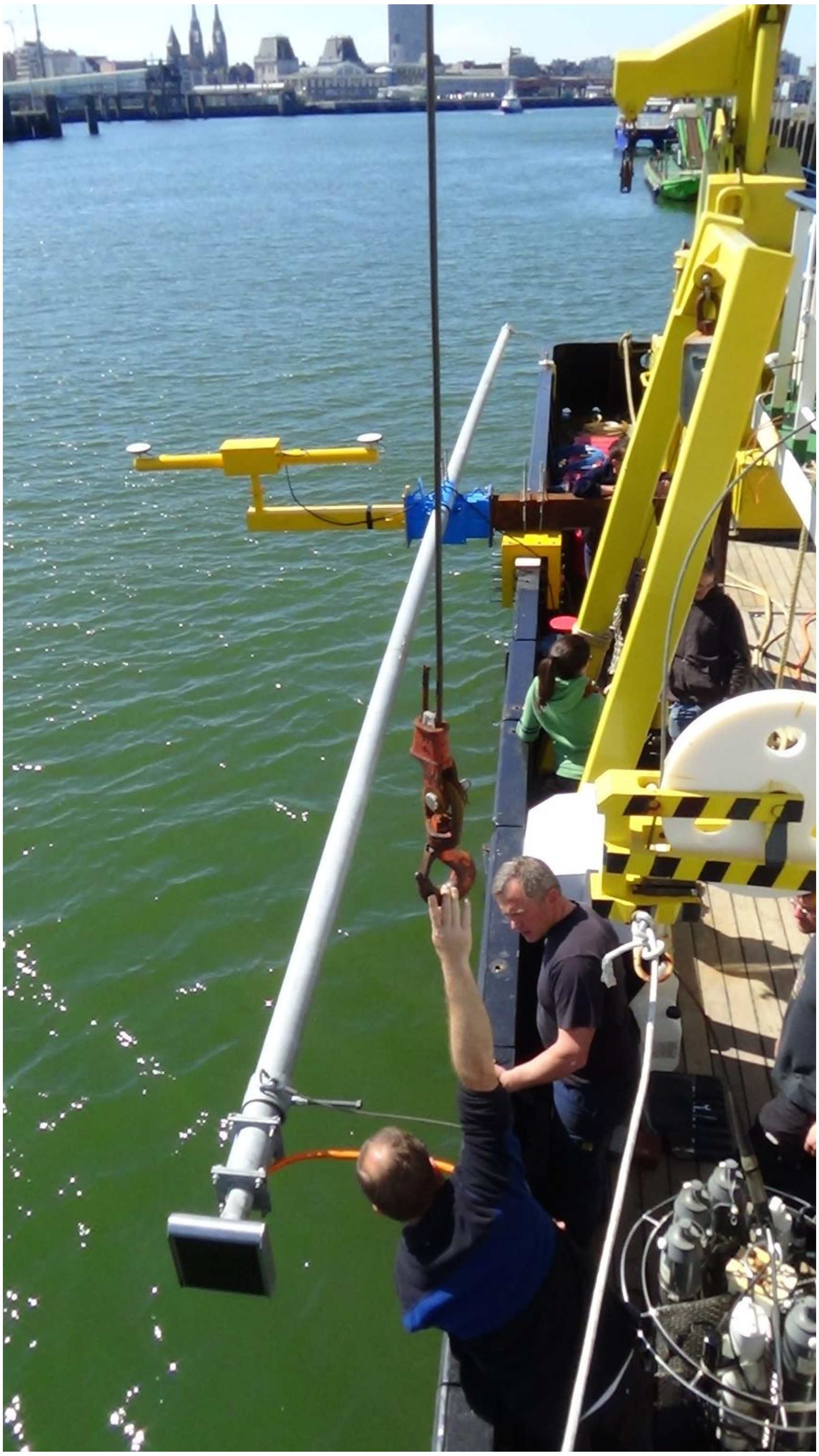

*Figure 3: Fixed mounting for the PES and Geopulse. Here the PES is attached to the mounting pole.*

# Appendix B

**Survey log and weather conditions**[1]

**Friday 09 May**
12:00 – 18:00 Installation equipment on board Simon Stevin

**Monday 12 May (4-5 bft)**
10:00 Embarking on board Simon Sevin. Further completion of the installation of equipment
14:30 Installation completed. Test Hydrochart in the harbour
15:30 Transit to test area of shallow wreck sites in the OV
16:30 Arrival at first wreck site ("Westerbroek"); navigation antenna Hydrochart (so-called 'coda') was mounted in the opposite direction. No correct navigation data are therefore possible; a preliminary testline (without navigation data) is recorded over the first wreck before going back
16:30 Transit to Ostend
17:15 Arrival at Ostend

**Tuesday 13 May (4 bft and later to 3 bft)**
08:00 Arrival on board.
08:15 Navigation antenna was taken off and mounted correctly; new calibration is necessary but turned out to be problematic
09:30 Transit to wreck sites OV
10:00 Arrival at first wreck; Hydrochart in water; calibration is still ongoing
12:30 Still navigation calibration problems; course set two other nearvy wreck sites ("Lies" and "Westerbroek"); still no correct navigation calibration; 6 lines were recorded, 3 lines per wreck, one over the middle and two lines at 30m on each side of the wreck
13:30 Transit back to Ostend
14:00 Hydrochart replaced by PES on the pole
17:00 Transit to OV
17:30 Arrival at survey area. HF boomer and SC+MC in water; start seismic measurements on testline 1 (in two directions)
20:30 End of measurements over testline 1; boomer is taken out due to deteriorating weather conditions (4 bft); SIG sparker in water, as well as PES.
20:45 Start seismic line OV_14_05 of OV network (W-E)
22:00 End of line in OV, transit to YV and start of seismic line (YV_14_04), with SIG, PES and both streamers

**Wednesday 14 May (3bft)**
00:00-08:00 Seismic network in YV (lines YV_14_03, 25t, 06, 05) .
08:00 Stop network in YV, transit to OV; SIG sparker changed for Centipede sparker due to better weather conditions (3bft)
08:30-12:00 Seismic profiles in Ostend Valley (OV_14_07, 06); change Centipede for SIG sparker because wind has picked up (4 bft)
12:10 High tide and start long profiles in YV close to the shore (YV_14_01, 02, 26, 05t)

[1] Time in GMT+2hr

19:00  End YV; transit profile to OV (starting point of test line 1); SIG replaced by Centipede sparker
20:00 Start of test line 1 in OV (comparison with 2013 data); PES recording stopped
22:10 End of test line 1; continuation of measurements  towards YV
23:00 Start of N-S network in YV with Centipede sparker and both streamers

**Thursday 15 May (2-3 bft)**
00:00-06:00 Continuation of seismic network YV (lines YV_14_24, 23, 22, 21, 20); due to low tide transit to OV (lines YV_14_02,5 & YV_14_29)
06:30  Start measurements OV (EW line OV_14_04)
08:30  Start network of N-S lines in OV (centipede + both streamers). Lines OV_14_08, 10, 11).
10:00 Continuation along line OV_14_02 (W-E) towards start of test line.
10:50  Sparker changed for boomer; an additional test line was run with the boomer in view of good weather (2 bft and calm sea) to compare with data obtained at 4 bft
12:30  End of test line with boomer; return to N-S network of OV (lines OV_14_18, 17, 16)
14:25 Boomer changed for centipede sparker; continuation with lines OV_14_15, 14, 13, 12
16:45  End of seismic measurements.; sparker and streamers hauled in; transit to Ostend
17:15 Arrival at the quay in Ostend; dismounting PES; installation of Geopulse

**Friday 16 May (2 bft)**
07:45  Arrival on board.
08:45  Transit to survey area OV
09:15  Arrival at startpoint of test line 1; Geopulse in water; problems with trigger; Cetipede and both streamers in water; deviation to line OV_14_02
09:30  Start of line OV_14_02 (E-W)
10:50  End of line; centipede changed for Geopulse; both streamers towed closer to the ship.
11:00  Start of test line 1 (W-E) with Geopulse
12:50  End of test line
13:10  Continuation N-S lines eastern flank OV
14:50  End of N-S lines; transit to the Sepia Pits (SP) 2 & 3
15:15  Start long lines over SP with Centipede and both streamers
17:30  End seismic measurements; transit to Ostend
18:00  Arrival at the quay in Ostend.

**Monday 19 May**
12:00 – 18:00 Demobilization equipment on board Simon Stevin