## 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 VALLEY SEISMIC CAMPAIGN
# 7-9 OCTOBER 2013

## WP 1.2.3. A

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Oct 2013

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# 1. Framework and objectives

## 1.1. Framework

In October 2013 more than 120 kilometres of 2D high resolution seismic reflection data were acquired offshore Oostende 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.

## 1.2. Survey Objectives

This seismic campaign, carried out on board of the RV Simon Stevin (VLIZ), has multiple objectives:

- Test different seismic sources and receiver configurations in different geological settings of the Belgian Continental Shelf.
- Produce a preliminary survey methodology that takes into account the depth of investigation and the expected vertical resolution needed for the layers/objects to be found.
- Obtain more precise information on the complex geological layering of the Ostend Valley.
- Identify archaeological potential of layers.
- Define locations for further, more detailed, surveys in the area.

# 2. Study area

The survey area is located 10 km offshore the city of Ostend and mainly covers a section of the Belgian Continental Shelf known as the Ostend Valley. This funnel-shaped valley structure in the top-Palaeogene morphology started out as a fairly small 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. 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 redirecting it to the north.
Throughout the late Quaternary history the Ostend valley has likely provided an attractive environment for human habitation.

The study area can be defined by the following UTM coordinates (see figure 1):

1. 482215,44 E ; 5675288,99 N
2. 484279,19 E ; 5673653,87 N
3. 490486,33 E ; 5685306,14 N
4. 492565,96 E ; 5683607,51 N

In view of the limited time available (only 3 working days instead of 5 due to predicted storm weather) the survey area was divided into 4 smaller focus areas (figure 1): Test Line (TL), Eastern Flank (EF), Central Valley (CV) and Western Flank (WF). Each area represents a different geomorphology and lithology.

Figure 1 also shows the relative location of each seismic line with respect to the shoreline and the interpreted limits of the Ostend Valley.

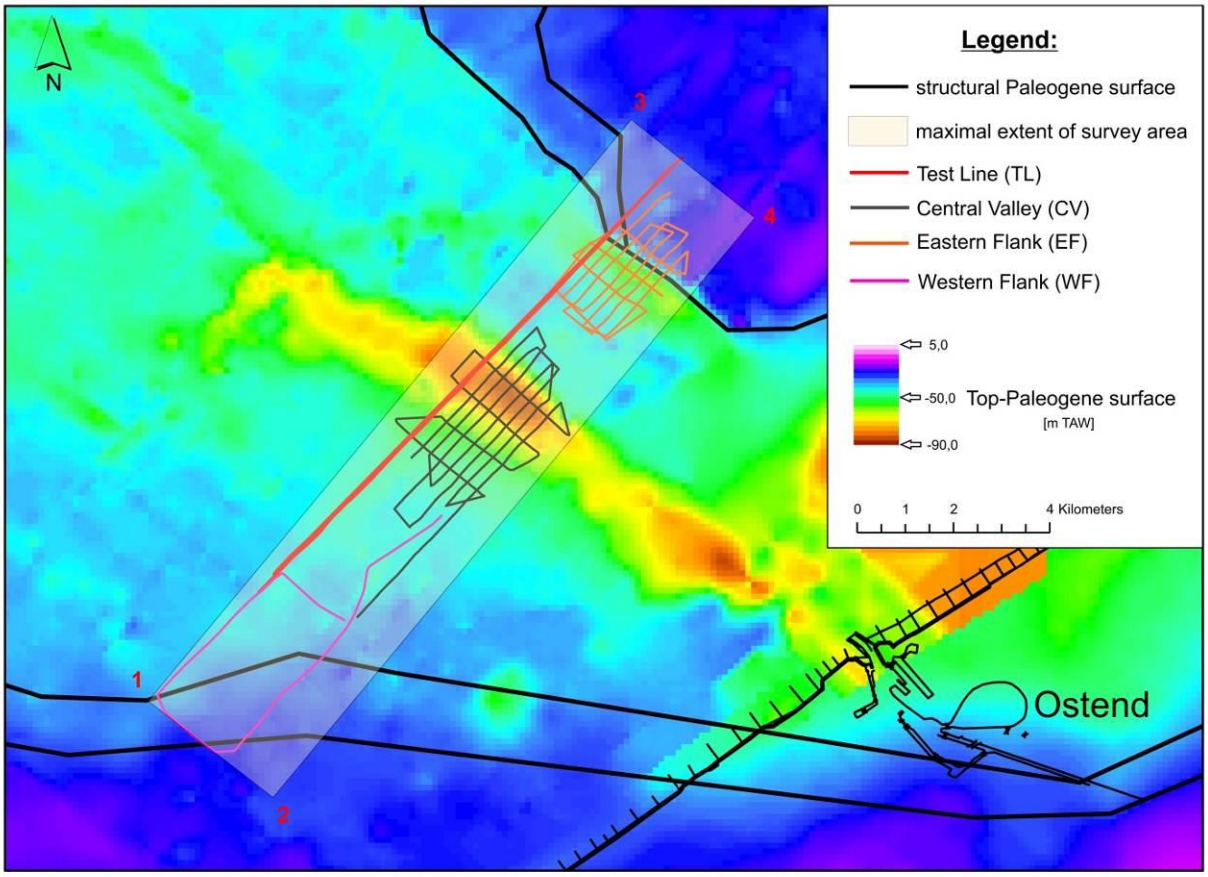


*Figure 1 Representation of the maximal extent of the survey area and the recorded seismic networks in the Ostend Valley visualized on top of the Palaeogene surface.*

## 3. List of participants

| Name | Organisation | Function | 07/10/2013 | 08/10/2013 | 09/10/2013 |
|---|---|---|---|---|---|
| Tine Missiaen | RCMG | Chief Scientist | x | x | x |
| Koen De Rycker | RCMG | Engineer | x | x | x |
| Oscar Zurita Hurtado | RCMG | Geophysicist | x | x | x |
| Maikel De Clercq | RCMG | Geologist | x | x | x |
| Mike van der Werf | Deltares | Engineer | x | | |
| Marco de Kleine | Deltares | Geologist | x | | |
| Giovanni Diaferia | Deltares | Geophysicist | x | x | x |
| Peter Frantsen | Deltares | Geophysicist | x | x | x |
| Wim Versteeg | VLIZ | Geophysicist | x | x | |

## 4. Operations and weather conditions

| Date | Time | Operations | Recording track |
|---|---|---|---|
| Friday 04/10/2013 | 09:00 – 19:00 | installation and set-up of all equipment on board | |
| Monday 07/10/2013 | 10:00<br>11:45<br>18:30<br>19:15 | departure Ostend harbour<br>start measurements end measurements<br>arrival Ostend harbour | TL_01-04 |
| Tuesday 08/10/2013 | 08:55<br>09:30<br>19:45<br>20:00 | departure Ostend harbour<br>first measurements end measurements<br>arrival Ostend harbour | TL_05-06<br>EF_01-10 |
| Wednesday 09/10/2013 | 07:30<br>08:30<br>16:30<br>16:50 | departure Ostend harbour<br>first measurements end measurements<br>arrival Ostend harbour | CV_01-11<br>WF_01-05 |
| Thursday 10/10/2013 | 08:15 – 14:15 | demobilisation of all equipment | |
| Friday 11/10/2013 | 09:00 – 13:00 | pick-up of RCMG equipment and transport to UGent | |

*All times represented are in local time (GMT + 2h).

During the survey weather conditions ranged from very good on Monday 7th October to poor on Wednesday 9th October in the afternoon. Due to the arrival of a storm on Wednesday night the survey scheduled for Tuesday and Friday had to be cancelled.

Specific weather conditions during the survey:

- **Monday 07/10/2013:**

Sunny weather conditions with a maximum temperature of 16°C, average wind speeds up to 5-6 m/s and a maximum wave height of 50 cm.

- **Tuesday 08/10/2013:**

Clouded weather conditions with a maximum temperature of 15°C, average wind speeds up to 5 m/s in the morning and up to 9 m/s in the afternoon. Maximum wave height of 55 cm.

- **Wednesday 09/10/2013:**

Clouded weather conditions with showers. Maximum temperature of 15°C, average wind speeds up to 7 m/s in the morning and up to more than 10 m/s in the afternoon with maximum wave height of 60 cm in the morning and higher than 100 cm after 14:00. In the course of the afternoon a storm approached the area.

- **Thursday 10/10/2013**

Stormy weather conditions with heavy rain showers and even hale accompanied with high wind speeds and wave heights. Conditions prohibit any continuation of the survey campaign.

- **Friday 11/10/2013**

Weather conditions are still bad because of high wind speeds and wave heights. Conditions prohibit any continuation of the survey campaign.

# 5. Data acquisition

## 5.1. Equipment and seismic characteristics

Different seismic sources were tested during the campaign: (1) Centipede sparker, (2) SIG sparker, (3) "Seistec" boomer, (4) AA300 boomer, (5) X-Star chirp, (6) Geopulse and (7) 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 Boomer; X-Star and 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** | 800 - 900 Hz | > 50 cm | In a sandy sea bottom, up to 100 m |
| **'Seistec' boomer** | 1 - 5 kHz (main frequency of 2.5 kHz) | > 25 cm | up to 100 m |
| **AA300 boomer** | 2 - 6 kHz | > 35 cm | up to 50 m |
| **X-Star chirp** | 500 Hz – 12 kHz | 30 cm or better | in a sandy sea bottom a penetration of 10-20 m |
| **Geopulse** | 3,5 kHz | 25 cm | up to 50 m (depending on sediment) |
| **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 and (2) a multichannel streamer (24 channels). Both streamers were towed behind the vessel and were laterally spaced by three metres. The single channel streamer was towed at port side while the multichannel streamer was always positioned in the middle of the stern.

At starboard, with an offset of 3 m from the multichannel streamer, the different types of boomers and sparkers were towed. The longitudinal offset of the boomers and sparkers varied and the particular configuration for each line is specified in the tables below.The parametric Echosounder and the Geopulse were attached to a specifically designed mounting at the port hull of the vessel, while the X-star chirp was towed along the starboard of the ship (see Figure 2).

## 5.2. Recorded networks (sub-areas)

***Test Line (TL)***

This consisted of 6 seismic lines that almost crossed the entire width of the valley (figure 1). The lines all follow the exact same trajectory in order to allow correct comparison of the different data. 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 | Direction | Source | Source Offset | S. Ch Offset | M. Ch Offset |
|---|---|---|---|---|---|
| **TL_01** | NE-SW | PES | N.A. | N.A. | N.A. |
| | | Seistec boomer | 25 m | 29 m | 29 m |
| **TL_02** | SW-NE | PES | N.A. | N.A. | N.A. |
| | | Centipede sparker | 26.5 m | 29 m | 29 m |
| **TL_03** | NE-SW | PES | N.A. | N.A. | N.A. |
| | | AA300 boomer | 29 m | 29 m | 29 m |
| **TL_04** | SW-NE | PES | N.A. | N.A. | N.A. |
| | | X-Star chirp | N.A. | N.A. | N.A. |
| **TL_05** | NE-SW | X-Star chirp | N.A. | N.A. | N.A. |
| | | SIG Sparker | 30 m | 29 m | 32 m |
| **TL_06** | SW-NE | X-Star chirp | N.A. | N.A. | N.A. |
| | | Geopulse | As diagram | 15 m | 22 m |

*Table 2 Test Line acquisition configuration.*

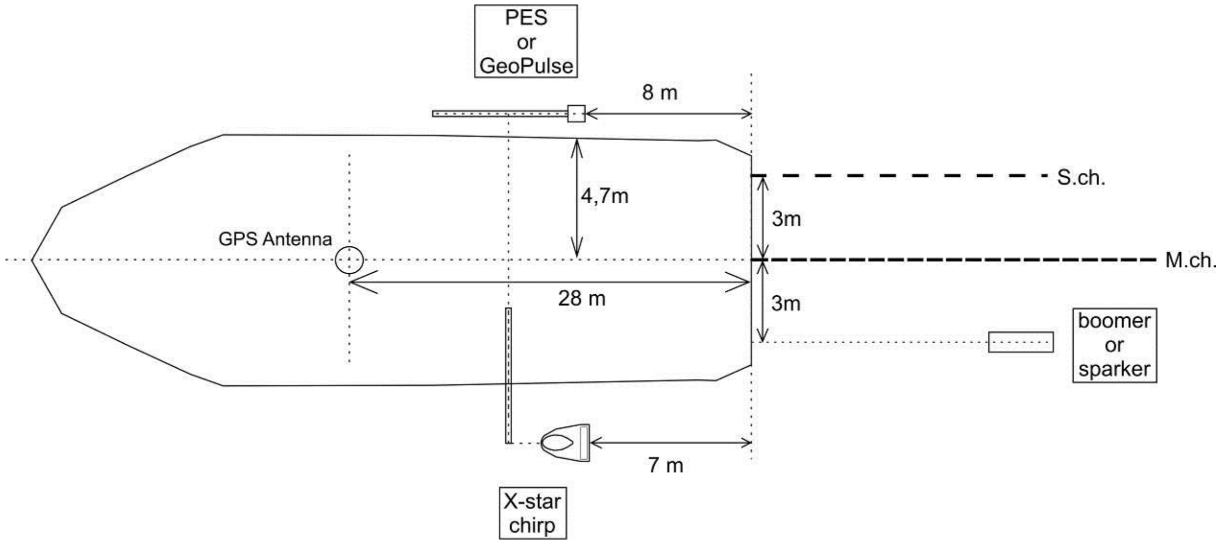


*Figure 2 Sketch of the vessel illustrating the equipment configuration.*
*SC = Single Channel streamer; MC = Multichannel streamer.*

Preliminary results obtained on board showed that the sparker sources produced the deepest penetration, while maintaining a relatively good resolution. Centipede sparker showed a sharp wavelet, producing a higher resolution image than the SIG sparker. Boomer sources (especially the AA300) showed good resolution but lower penetration depth.

For the parametric echosounder different types of frequency outputs were used ranging from 4 to 14 kHz using 1, 2 or 3 pulses. The results of this device were poor and the acoustic signals were not able to penetrate the thick sand layers. It was therefore not used for the other sub-areas.

The Geopulse introduced some strong periodical noise that obscured most of the data. Most likely this was due to an electronic problem in the acquisition unit. Particular data processing is needed in order to try to attenuate the effect of this noise.

Different frequency ranges (sweeps) were also tested for the X-Star Chirp, producing very good results, almost comparable to the sparker source (Centipede).

Therefore, both the X-Star Chirp and the Centipede sparker were used for subsequent recording of the different sub-areas (flanks and central valley).

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. We therefore decided to acquire all our data with the multichannel streamer while keeping the single channel streamer for comparison purposes.

### *Eastern Flank (EF)*

The seismic network in sub-area *EF* consisted of 6 equally spaced parallel lines to the south of the main test line and 4 perpendicular lines, covering the easternmost flank of the Ostend

Valley. Only the Centipede sparker and the X-Star chirp sources were used here (simultaneously). Both single channel and multichannel streamers were deployed.

| Line | Source | Source Offset | SC Offset | MC Offset |
|---|---|---|---|---|
| EF_01-10 | Centipede sparker | 26,5 m | 29 m | 35 m |
| | X-Star chirp | N.A. | N.A. | N.A. |

*Table 3 Eastern Flank acquisition configuration.*

### *Central Valley (CV)*

The seismic network in sub-area *CV* consisted of 7 equally spaced parallel lines to the south of the main test line and 4 perpendicular lines, covering the deepest section of the Oostende Valley. The Centipede sparker was used on the first 6 lines but due to the deteriorating weather conditions (resulting in a marked decrease in the quality of the data) it was replaced by the SIG sparker for the rest of the survey. The X-Star Chirp was used on all lines (simultaneously with the sparker source). Both single channel and multichannel streamers were deployed.

| Line | Source | Source Offset | SC Offset | MC Offset |
|---|---|---|---|---|
| CV_01-06 | Centipede sparker | 30 m | 29 m | 35 m |
| | X-Star chirp | N.A. | N.A. | N.A. |
| CV_07-11 | SIG sparker | 30 m | 29 m | 35 m |
| | X-Star chirp | N.A. | N.A. | N.A. |

*Table 4 Central Valley acquisition configuration.*

### *Western Flank (WF)*

The seismic network in sub-area *WF* consisted of 4 lines: one line extending the main test lines towards the western flank of the Oostende Valley, one parallel line to the south (connecting with the central valley network) and two perpendicular lines. Only the SIG Sparker and the X-Star Chirp sources were used (simultaneously). Both single channel and multichannel streamers were deployed.

| Line | Source | Source Offset | SC Offset | MC Offset |
|---|---|---|---|---|
| WF_01-05 | SIG sparker | 30 m | 29 m | 35 m |
| | X-Star chirp | N.A. | N.A. | N.A. |

*Table 5 Western Flank acquisition configuration.*

## 6. Line Summary

| Line | Direction | Date | Start [UTC] | End [UTC] | Position [UTM E] | Position [UTM N] | Equipment | Energy (J) | Frequency (sweep) | Sampling interval (ms) SC/MC* | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **TL_01** | NE-SW | 07/10/2013 | 11:49 | 12:50 | 490077,94<br>484596,78 | 5683348,74<br>5677732,75 | PES | N.A. | 8 – 10 kHz | N.A. | - |
| | | | | | | | Seistec boomer | 300 | N.A. | 0,05/0,25 | |
| **TL_02** | SW-NE | 07/10/2013 | 13:10 | 14:25 | 484888,98<br>490631,78 | 5677987,55<br>5683928,66 | PES | N.A. | 6 kHz. | N.A. | Short termination of data recording due to cooling problems |
| | | | | | | | Centipede sparker | 300 | N.A | 0,1/0,25 | |
| **TL_03** | NE-SW | 07/10/2013 | 14:50 | 16:58 | 491143,76<br>484307,09 | 5684488,69<br>5677487,41 | PES | N.A. | 4 – 6 – 10 kHz | N.A. | - |
| | | | | | | | AA300 boomer | 500 | N.A. | 0,1/0,25 | |
| **TL_04** | SW-NE | 07/10/2013 | 17:20 | 18:30 | 484284,96<br>490938,28 | 5674358,95<br>5684592,61 | PES | N.A. | 5 kHz | N.A. | - |
| | | | | | | | X-Star chirp | N.A. | 0,5 – 8,0 kHz | 0,046 | |
| **TL_05** | NE-SW | 08/10/2013 | 10:47 | 12:11 | 491108,64<br>484049,91 | 5684416,13<br>5677176,60 | X-Star chirp | N.A. | 0,5 – 4,5 kHz | 0,046 | Geopulse signal very weak → no recording |
| | | | | | | | SIG Sparker | 300 | N.A. | 0,1/0,25 | |
| | | | | | | | Geopulse | N.A. | 3,5 kHz | N.A. | |
| **TL_06** | SW-NE | 08/10/2013 | 12:23 | 14:38 | 484205,48<br>491359,02 | 5677308,45<br>5684671,71 | Geopulse | N.A. | 3,5 kHz | N.A. | Geopulse strongly focused on seafloor |
| | | | | | | | X-Star chirp | N.A. | 0,5 – 7,2 kHz | 0,046 | |
| **EF_01** | NE-SW | 08/10/2013 | 12:52 | 13:24 | 491165,63<br>489291,24 | 5684075,62<br>5682256,25 | Centipede sparker | 300 | N.A. | 0,1/0,125 | 13:18 – 13:20 GPS problems |
| | | | | | | | X-Star chirp | N.A. | 0,5 – 7,2 kHz | 0,046 | |
| **EF_02** | SW-NE | 08/10/2013 | 13:34 | 13:48 | 489640,66<br>491085,45 | 5682021,10<br>5683545,18 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | | | X-Star chirp | N.A. | 0,5 – 7,2 kHz | 0,046 | |
| **EF_03** | NE-SW | 08/10/2013 | 13:56 | 14:30 | 491449,18<br>489801,74 | 5683364,73<br>5681632,43 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | | | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | 14:08 bad data due to high speeds |
| **EF_04** | SW-NE | 08/10/2013 | 14:43 | 14:51 | 489312,59<br>490817,45 | 5682030,67<br>5683524,97 | Centipede sparker | 300 | N.A. | 0,1/0,125 | 14:51 – 14:52 GPS problems |
| | | | | | | | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | |
| **EF_05** | NE-SW | 08/10/2013 | 15:10 | 15:39 | 491207,45<br>489642,09 | 5683382,16<br>5681760,09 | Centipede sparker | 300 | N.A. | 0,1/0,125 | no multichannel recording |
| | | | | | | | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | |
| **EF_06** | SW-NE | 08/10/2013 | 15:57 | 16:03 | 490045,81<br>491456,96 | 5681589,47<br>5683053,11 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | | | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **EF_07** | SE-NW | 08/10/2013 | 16:10 | 16:24 | 491414,76 | 5682667,73 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 490120,30 | 5683400,93 | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | |
| **EF_08** | NW-SE | 08/10/2013 | 16:34 | 16:48 | 489485,55 | 5682989,39 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 490741,74 | 5682021,10 | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | |
| **EF_09** | SE-NW | 08/10/2013 | 16:58 | 17:09 | 490049,25 | 5681531,41 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 489139,86 | 5682422,49 | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | |
| **EF_10** | NW-SE | 08/10/2013 | 17:15 | 17:27 | 489773,22 | 5683209,11 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 491013,19 | 5682288,75 | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | |
| **CV_01** | NE-SW | 09/10/2013 | 08:34 | 09:06 | 486689,85 | 5679493,34 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 488854,66 | 5681741,06 | X-Star chirp | N.A. | 0,5 – 2,7 kHz | 0,046 | |
| **CV_02** | SW-NE | 09/10/2013 | 09:12 | 09:40 | 488998,04 | 5681419,79 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 486394,90 | 5678608,22 | X-Star chirp | N.A. | 0,5 – 7,2 kHz | 0,046 | |
| **CV_03** | NE-SW | 09/10/2013 | 09:47 | 10:24 | 486658,05 | 5678295,25 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 489230,14 | 5681022,83 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **CV_04** | SW-NE | 09/10/2013 | 10:33 | 10:52 | 488860,05 | 5681399,63 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 486994,42 | 5679536,37 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **CV_05** | NE-SW | 09/10/2013 | 10:59 | 11:30 | 487024,55 | 5679007,71 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 489129,71 | 5681122,91 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **CV_06** | SW-NE | 09/10/2013 | 11:37 | 11:58 | 489068,01 | 5680515,84 | Centipede sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 487285,90 | 5678664,09 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **CV_07** | SE-NW | 09/10/2013 | 12:14 | 12:30 | 487945,63 | 5678832,76 | SIG sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 486430,70 | 5680164,72 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **CV_08** | NW-SE | 09/10/2013 | 12:39 | 12:49 | 487202,67 | 5680204,44 | SIG sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 488834,39 | 5679611,99 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **CV_09** | SE-NW | 09/10/2013 | 12:57 | 13:13 | 488833,00 | 5679613,10 | SIG sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 487377,33 | 5680908,63 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **CV_10** | NW-SE | 09/10/2013 | 13:23 | 13:41 | 487783,13 | 5681351,26 | SIG sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 489414,08 | 5679885,33 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **CV_11** | NE-SW | 09/10/2013 | 13:49 | 12:43 | 489266,38 | 5680444,36 | SIG sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 485755,99 | 5676745,42 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **WF_01** | NE-SW | 09/10/2013 | 14:47 | 14:59 | 485529,03 | 5676689,67 | SIG sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 484448,81 | 5677501,43 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **WF_02** | SE-NW | 09/10/2013 | 15:01 | 15:31 | 484293,72 | 5677383,36 | SIG sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | 482302,63 | 5675397,64 | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **WF_03** | NE-SW | 09/10/2013 | 15:34 | 15:41 | 482427,06<br>483299,87 | 5675113,29<br>5674416,21 | SIG sparker | 300 | N.A. | 0,1/0,125 | **-** |
| | | | | | | | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **WF_04** | NW-SE | 09/10/2013 | 15:46 | 16:05 | 483629,34<br>485649,24 | 5674433,72<br>5676690,55 | SIG sparker | 300 | N.A. | 0,1/0,125 | - |
| | | | | | | | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |
| **WF_05** | SW-NE | 09/10/2013 | 16:05 | 16:37 | 485659,90<br>487207,75 | 5676709,32<br>5678495,47 | SIG sparker | 300 | N.A. | 0,1/0,125 | Shipwreck encountered |
| | | | | | | | X-Star chirp | N.A. | 0,7 – 12 kHz | 0,046 | |

*Table 6 Representation of the characteristics of the performed seismic lines during the survey.*
**Sampling rate for the X-Star chirp is unrelated to the streamers because source and receiver are located in the device itself.*

# Appendix

### Survey photos

*Figure 3 - AA380 boomer from Deltares.*

*Figure 4 – Purpose designed mounting pole to accommodate the Geopulse and Parametric echosounder.*

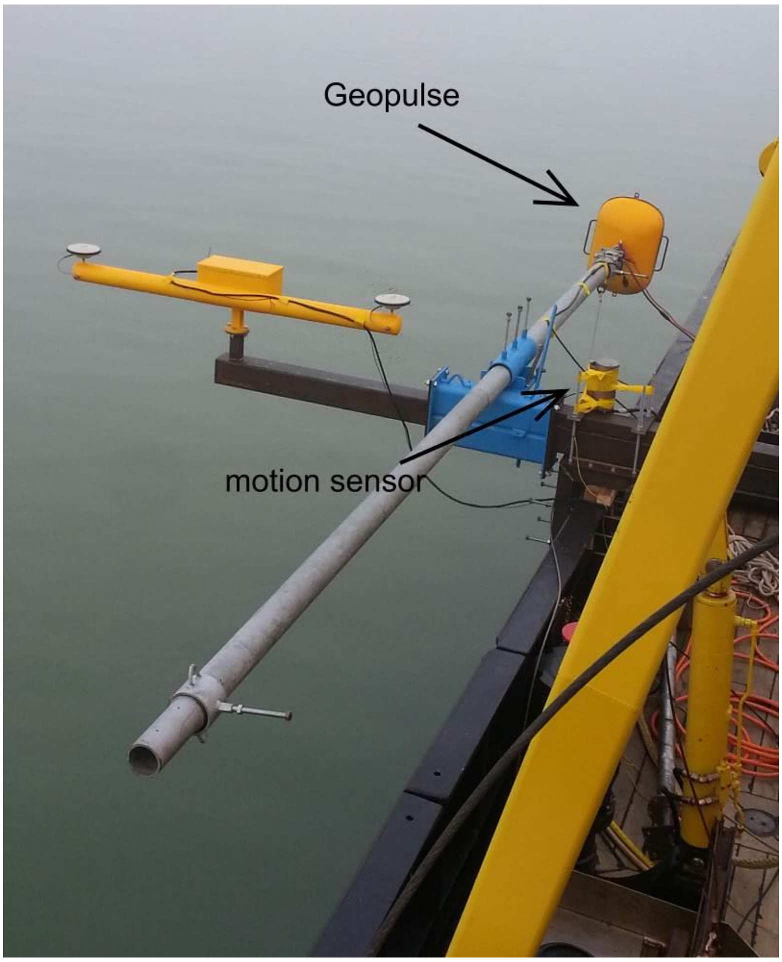

*Figure 5 – Geopulse attached to the mounting pole on the side of the ship.*

*Figure 6 – Parametric echosounder attached on the same mounting pole.*


*Figure 7 – Seistec boomer from RCMG.*


*Figure 8 – X-star chirp from Deltares*

*Figure 9 – Deployment of the X-star chirp with the deck crane.*

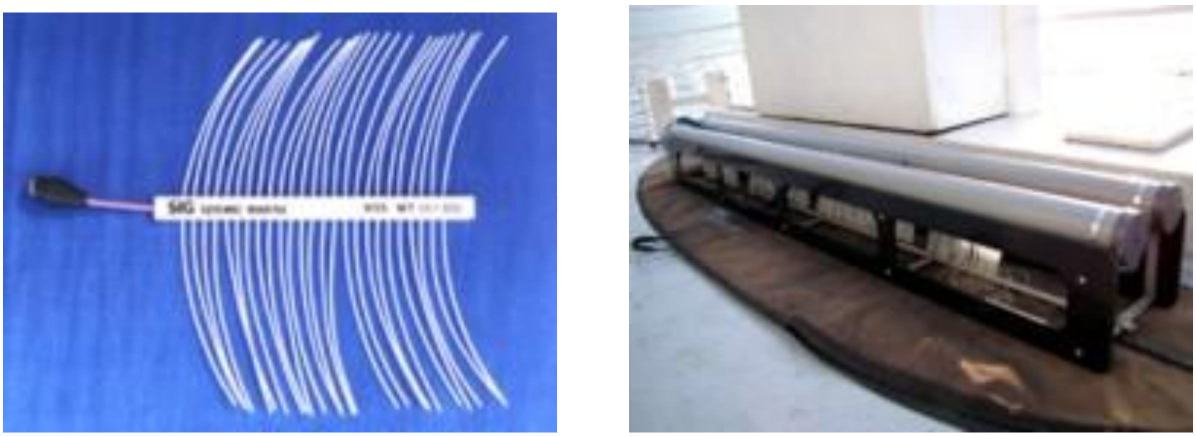

*Figure 10 – Left: Centipede sparker (RCMG). Right: SIG sparker (RCMG).*

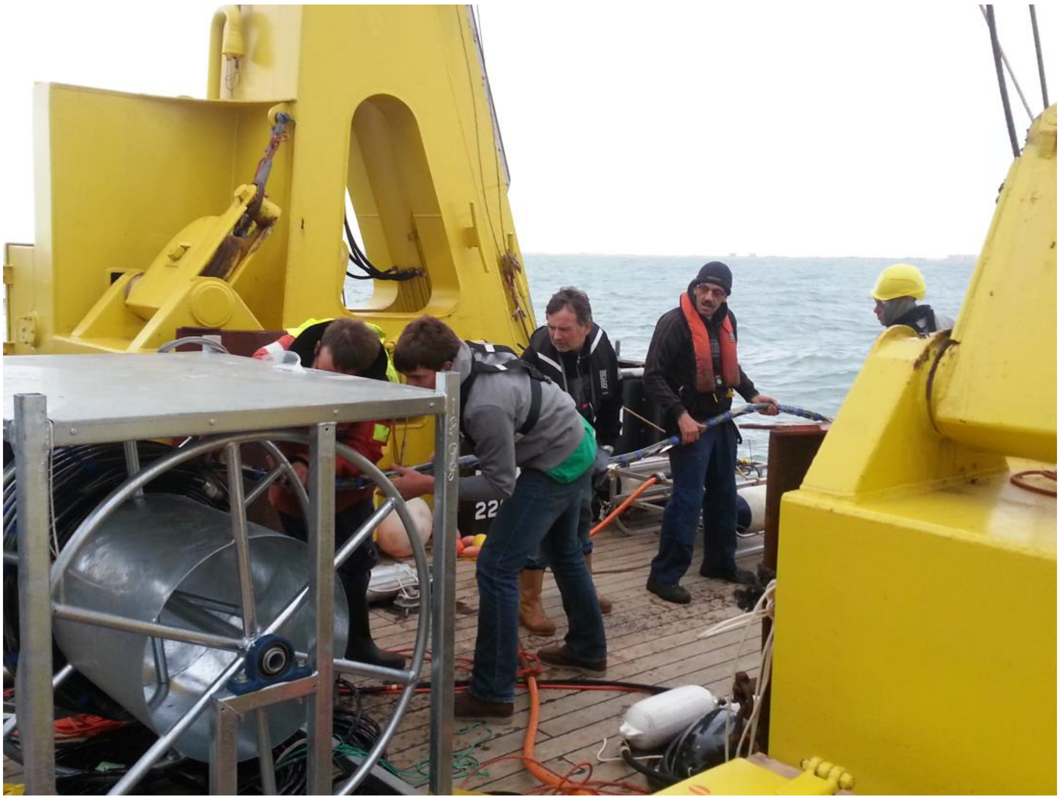

*Figure 11 –Deploying the multichannel streamer from Deltares*

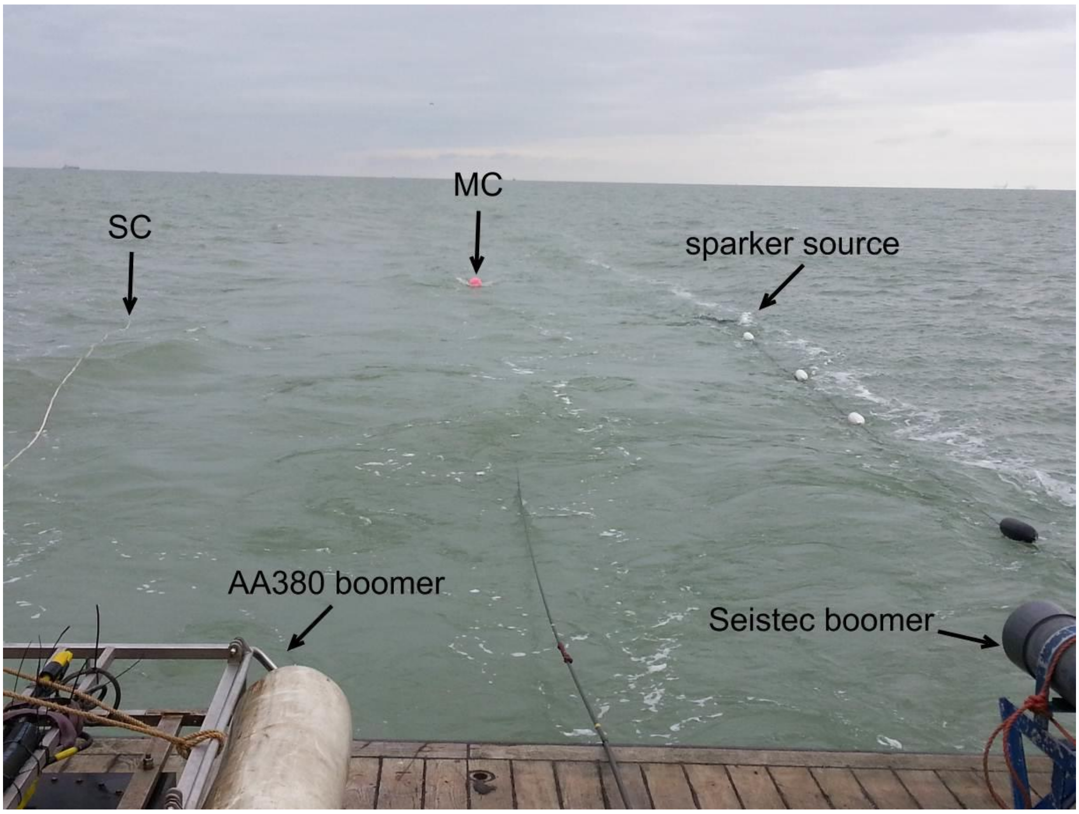


*Figure 12 – Data acquisition using two different streamers (SC = Single channel;MC = Multichannel) and a sparker source towed behind the ship.*

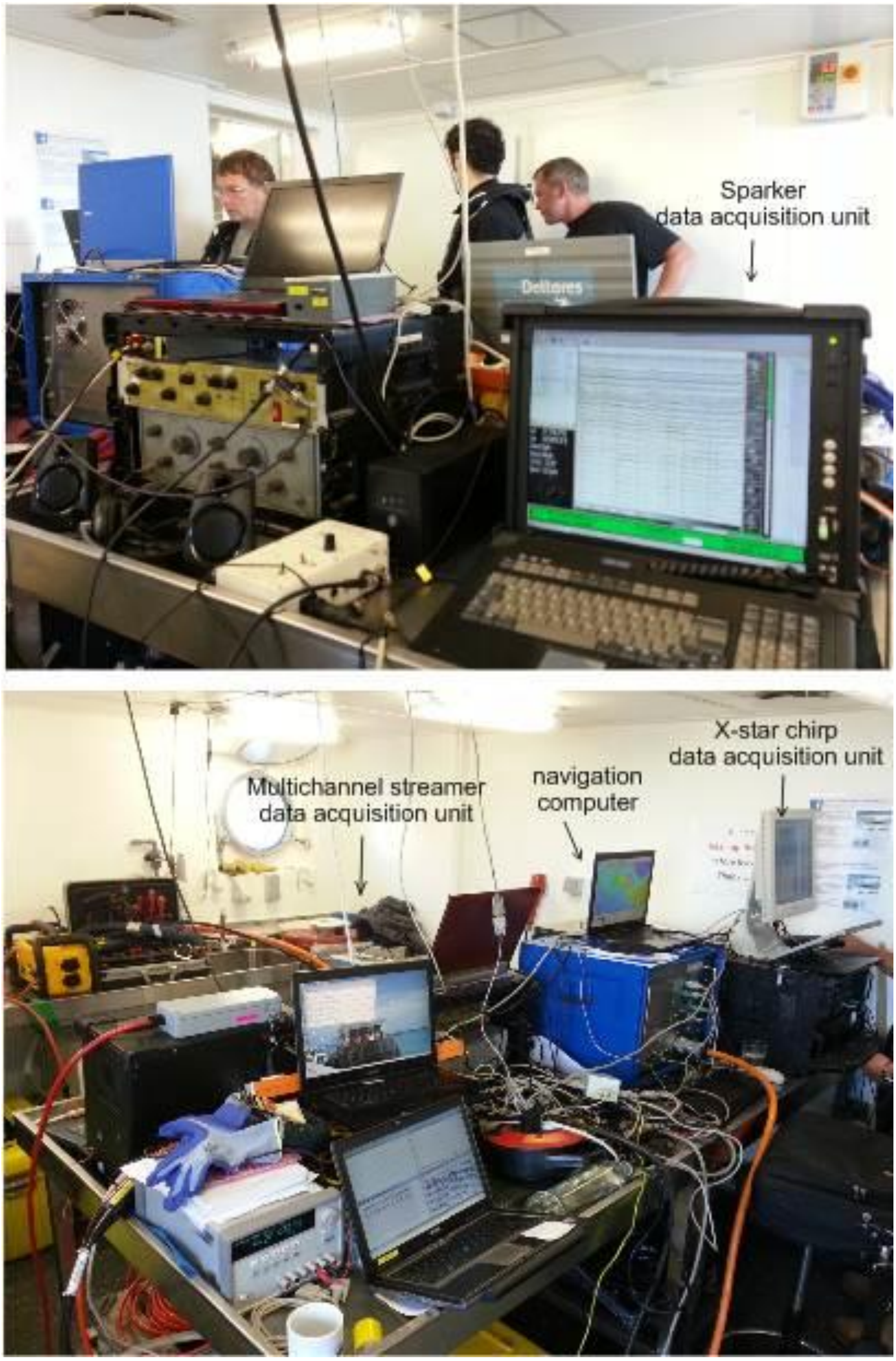

*Figure 13 – Installation of the different acquisition and navigation recording units in the lab.*