Frank Stikkel and Dieuwertje Klazinga

Eemszinker: Safely Trench Dredging a Live Gas Line

Abstract

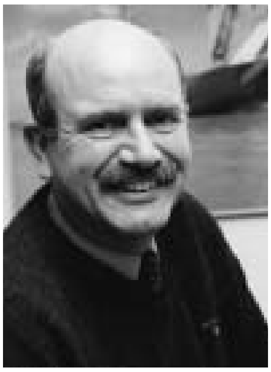
The original installation of the "Eemszinker" pipeline took place in the mid-1970s but over the past 30 years the river's strong currents have exerted a powerful scouring effect along the edge of the sandbank. This resulted in the recurring exposure of a 500 m section of the pipeline. A project to deepen a section of the strategic, 42 inch pipeline bringing gas from Norway to The Netherlands, where it crosses the river Eems was undertaken by four consortium partners, Boskalis BV, Visser & Smit Hanab BV (V&SH), Van Splunder Funderingstechniek and Rederij Waterweg.

In order to protect Eemszinker, it was decided to lower the live Eemszinker into a new and deeper trench. This is believed to be the first deepening project involving mechanical excavation with a major gas line remaining live throughout the operation. The success of the operation was largely possible as a result of the extreme accuracy and reliability of the dredging equipment's positioning systems. The ability to perform the deepening task with the gas line remaining live meant no disruption of supplies to Eemshaven's gas-fired power stations and the Dutch gas grid.

After receiving her degree in 2000 in Civil Engineering from the Delft Technical University, Dieuwertje Klazinga joined Boskalis' in-house engineering company Hydronamic bv. As a project engineer, she is involved in engineering activities during the design, preparatory, and execution phases of a project. At the Eemszinker project she acted as site engineering manager.

Dieuwertje Klazinga

After receiving his degree from the International Agricultural College/Land & Water Management, Frank Stikkel joined Royal Boskalis Westminster Group as assistant superintendent in 1980. Since then he has worked on numerous dredging projects worldwide and is presently a senior Project manager. On the Eemszinker project he was responsible for all the dredging and backfilling works. Presently he is working at a Boskalis project in Kazakhstan.



Frank Stikkel

Introduction

Norwegian gas from the Ekofisk Field lands at Delfzijl, in the north of The Netherlands. The Eems crossing links Phillips Petroleum's gas cleaning and drying plant at Rysumer Nacken, on the German bank, to Delfzijl and the Dutch national gas grid. The ability to perform the deepening task with the gasline remaining live meant no disruption of supplies to Eemshaven's gas-fired power stations and the Dutch gas grid.

During the original installation of the "Eemszinker" pipeline in the mid-1970s, Boskalis played a major role. This pipeline traverses the morphologically active Eems estuary over a distance of 4 km. The pipeline crosses both the Oostfriesche Gaatje shipping channel and the shallows of the Paap sandbank.

Over the past 30 years the river's strong currents have exerted a powerful scouring effect along the edge of the sandbank. This has resulted in the recurring exposure of a 500 m section of the pipeline. In order to protect Eemszinker and prevent the development of free spans, a succession of protective layers — stone, sandbags and screens — have been laid over three decades. This material has accumulated to the point that, in effect, a 560 m long "dam" has been created. This is a significant navigational obstruction in an area where the

Figure 1. Location map of the Eemszinker gas line in the north of the The Netherlands.

surrounding seabed has eroded to a level some 10 m deeper. The solution adopted involved lowering the live Eemszinker into a new and deeper trench, 900 m in length and dredged to a level below the calculated future scour level (Figure 1).

Project Preparation

During the first quarter of 2003 Gas Transport Services (a subsidiary of Gasunie) awarded the Eemszinker deepening contract to main contractor Visser & Smit Hanab BV (V&SH). The works, completed in late September of 2003, were undertaken by a consortium involving V&SH, Boskalis BV, Van Splunder Funderingstechniek and Rederij Waterweg. Prior to the execution of this project, the navigational clearance over the pipeline was between 5 m and 9 m. With the deepening works successfully completed, largely possible as a result of the extreme accuracy and reliability of the dredging equipment's positioning systems, the navigational clearance over Eemszinker is now 20 m.

Boskalis was responsible for the positioning, survey and dredging works, whilst V&SH's main task was to position and lower the pipeline into the deepened trench. Van Splunder Funderingstechniek carried out the pile-driving for a series of pipeline support/lowering stations, whilst Rederij Waterweg provided the waterborne logistics, performed local dredging works associated with the piling, and otherwise prepared the pile locations.

Work on deepening the 42 inch gas line began in March, immediately following the contract award. Conditions on site were difficult, with the river's 4 kt current increasing to 6 kts over the Eemszinker obstruction. Prior to the commencement of works, a number of engineering solutions were explored. They included the installation of a new Eemszinker, tied into the existing line on both banks. For this event, however, a fully developed and convincing safety case was instrumental in the client's decision in favour of the positioning and lowering of the existing gas line, in the live condition, into a deeper trench.

The main works began with the removal of scour protection at several locations, so as to locate the pipeline with precision. Over 20 support frames were then constructed at 40 m intervals, so Eemszinker could be attached both horizontally and vertically (Figure 2).

The remaining scour protection was then removed and the new trench dredged. In the final phase, the pipeline was lowered in a safe, controlled manner. The project was completed with part-backfilling of the deep section of the trench with stones and the removal of the support stations. This solution's safety case relied heavily on high precision working with a cutter suction dredger, a large backhoe and other heavy equipment (Table I).

Site Safety Strategies

The client had two primary requirements: guaranteed continuity of gas supply and, in addition, a controlled and safe working method. This was a challenging operational environment and the selection of the work method was influenced by the exceptionally high current velocities over the top of the "dam" and, secondly, the presence of very stiff to hard clays beneath the pipeline.

The Eemszinker work method had eight distinct phases:
- Local removal of scour protection, using an airlift. By this means, the pipeline was located without the risk of damage associated with mechanical intervention.
- The construction of the pipeline support stations.
- The attachment of the pipeline to the support stations.
- Removal of all remaining scour protection.
- Dredging the trench beneath the suspended pipeline.
- Lowering the pipeline.
- Backfilling the trench (partly).
- Removal of the support stations.

Hydronamic, Boskalis' in-house technical consultancy, undertook the dredging-related engineering during both the project preparation and execution phases. Its work

Figure 2. Support frames for holding the pipeline during dredging works as well as for during the lowering of the pipeline.

was related to soil data interpretation, velocity measurements and the calculation of sedimentation and erosion rates. The results allowed V&SH to calculate critical strength values for the live gas line and, in turn, the strength requirements for the support stations to be established along the trench line. Another important task was the qualitative risk assessment, which set out all risks and associated mitigating measures.

This provided the essential data required by Gasunie to make successful applications for the necessary permits and licences to proceed with Eemszinker in the live condition.

All project activities were subject to the provisions of a detailed Health, Safety and Environmental Plan.

Physical arrangements included the red Gas Alarm button on the bridge of every vessel. If pressed, this immediately activated acoustic and light signals on board all other vessels. Other safety provisions, for example, related to methods for the repositioning of the large backhoe dredger deployed. The HSE Plan specified repositioning only during low current velocities. The plan also required the daily calibration of all positioning systems installed on the dredge vessels. A clear set of circumstances was defined under which dredging must stop. A Hydronamic site engineer was responsible for compliance with the HSE Plan. Hydronamic also carried out regular measurements, to verify estimated sedimentation rates, and developed the safety contours for all equipment deployed for the various dredging tasks.

Removing the "Dam"

Consortium partner Waterweg used an airlift system for local removal of the protective layer, to reveal the gas line. Mattresses laid at some locations were recovered with diver assistance. Additional work was carried out at the piling locations for the pipeline support stations, which also carried the lowering system.

The large backhoe *Rocky* from Boskalis Sweden dealt with much of the 35,000 m^3 of bottom protection removed. The dredged material was dumped into split barges, for transport to the site's underwater temporary storage area. The removal of bottom protection material from kp 1.250 to kp 2.060 allowed the progressive natural erosion of the "dam". *Rocky* was positioned on three spuds (a toppling spud at the stern and two fixed spuds amidships) and was manoeuvred into position by a Multicat support vessel.

Table I. Utilised dredging plant.

Backhoe dredger *Rocky*	removal scour protection and dredging around the supports
	Cutter dredger *Jokra* bulk dredging of the new trench
Suction dredger *Nordland*	dredging final trench profile
Crane barges *Strekker* and *Kreeft*	trench backfill

Figure 3. The large backhoe Rocky working very near to the gas line.

The project team performed exhaustive site surveys, locating the position of the gas line with great precision. The principal survey work platform was the shallow draught Coastal Surveyor 2. The tasks opened with the pre-dredge survey, followed by the monitoring of progress in removing bottom protection materials, trench dredging and, subsequently, backfilling.
The survey team also verified the proper functioning of positioning systems. An office-based differential GPS monitoring system was established, to activate an alarm should deviation exceed 10 cm in either X, Y or Z modes. The survey tools included the GPS/KART system and an attitude sensor mounted on a jet lance. The latter equipment, used to probe into the river bottom, functioned well at depths exceeding 20 m.

Figure 4. Close up of the bucket of the Rocky.

The GPS/KART system providing horizontal control utilised a permanent base station signal from Rijks-waterstaat's offices at the Eemsmond Building in Delfzijl. This is located just 4 km from the work area. Whilst GPS/KART also provided the vertical positioning of floating equipment, this was supported by a second system based on a radio tidal transmitter, again situated close to the site – at the Landestelle Jetty. The echo-sounders employed consisted of Kongsberg Simrad EM 3000 multibeams and Atlas Deso 17 single beams.

The Dredging Works

Engineering feasibility studies had demonstrated that 22 support/lowering stations were required (most at 40 m centres). The backhoe *Rocky*, with a 7.5 m^3 bucket, removed the bulk of the accumulated scour protection (Figures 3 and 4). This backhoe was selected because of its ability to dredge with extreme accuracy in close proximity to the pipeline. Some 30,000 m^3 of stone had been removed by late June 2003. The recovered material was transported by the split barges to the temporary stockpile, located against the slope of the Paap sandbank, around 1.5 km from the main works. Later, this stone was recycled and re-used in the trench.

The bulk dredging for a new and deeper trench was performed by *Jokra*. This cutter suction dredger repre-sented a high production solution. *Jokra* was equipped

Figure 5. The bulk dredging for a new and deeper trench was performed by the cutter suction dredger Jokra.

with a 1,000 m x 700 mm discharge line running to the spreader pontoon *Vulcanus*. The latter distributed dredged material over two disposal sites, on either side of the trench. *Jokra* was positioned on one spud and two side anchors. The dredger also had a back-up stern anchor in place during dredging and relocation upstream from the pipeline (Figure 5).

Jokra was rigged to work at the specified maximum depth of 24 m. The main dredging of the trench was completed by mid-July 2003, with some 360,000 m^3 of material pumped to the two disposal locations on the sandbank. *Jokra* began by dredging two access channels on either side of the pipeline, in the shallow area of the works. Bulk dredging of the trench then commenced from the deep sections to the shallow area.

Each of the stations for supporting and lowering the gas line consisted of two piles, situated on either side of the trench line. The piles carried a steel deck and hoist system at a position above the river surface. The exposed pipeline was supported by a bracket around the lower circumference, linked to an upper cradle. This assembly was connected to the hoist by a lifting sling. In addition, side slings were connected to the piles, to provide the required stability during dredging and lowering operations. All 22 support/ lowering stations had been installed by late May 2003.

With the main dredging works completed by *Jokra*, a series of other dredging tasks were undertaken. These involved the suction dredger *Nordland*, mobilised by Boskalis' German subsidiary Heinrich Hirdes, for the removal of siltation material from the trench. *Nordland* was equipped with a dustpan head and two jet nozzles. It removed all sandy material remaining under the Eemszinker and achieved the final trench profile. Finally the backhoe *Rocky,* now equipped with a longer boom and stick as well as a smaller bucket (to allow dredging to 24 m), was called in to assist when areas of very stiff clay were encountered. The backhoe's high precision work was particularly valuable in areas difficult to reach, such as between the piles of the support structures.

Figure 6. The suction dredger Nordland was mobilised by Boskalis' German subsidiary Heinrich Hirdes for the removal of siltation material from the trench.

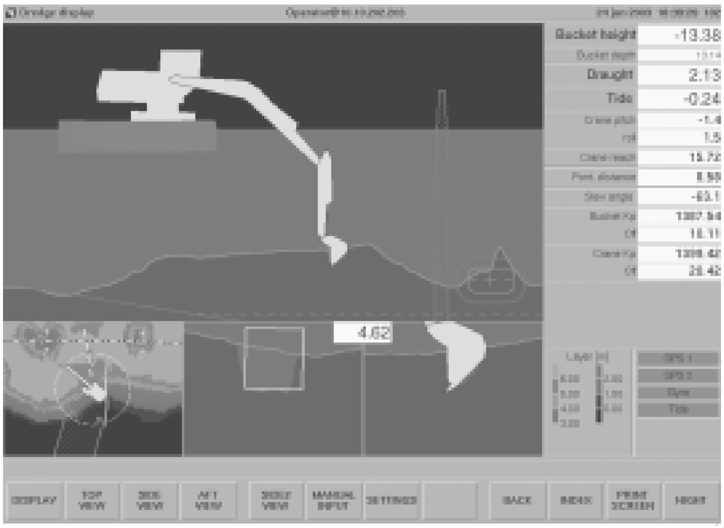


Figure 7. A view from the Rocky of the computer screens showing the crane monitoring system (CMS).

Figure 8. The display screen for monitoring the position of the bucket of the backhoe whilst at work.

The lowering phase was performed over a three-day period by V&SH. This was achieved by a special hydraulic system and the gas line was in the newly deepened trench by early August 2003. The next step was to backfill the deep part of the trench with retained stone (primarily Norwegian granite/basalt). Piles were then pulled and all de-rigging completed. The remaining section of the trench was left to fill naturally.

Enhanced Crane Monitoring System

The continued integrity of the live gas line, together with safe working of heavy equipment in close proximity, were the priorities throughout the project. Extreme care was taken to avoid damage to the pipeline. With this in mind, all vessels were equipped with back-up stern anchor winches, for use when working upstream of the pipeline. The backhoe *Rocky* could work with confidence close to the gas line thanks to an enhanced crane monitoring system (CMS).

The design of a sophisticated electronic positioning and automatic override systems contributed to safe and efficient working around the live gas line.

The control solution had three main components: continuous checking of the quality of the differential GPS/KART position and comparison of the output from two receivers; feedback from an acoustic profiler, for checking the actual position of the pipeline underwater; and the highly accurate positioning control of the equipment when working close to the safety margins. Contact between equipment and pipe was avoided at all times.

Rocky's enhanced crane monitoring system (CMS) can model a 3-D free-hanging object in association with the surrounding safety contour. The display presents bucket position in X, Y and Z relative to pipeline, piles and required trench level. The backhoe's systems included the CMS, a TriTech Superseeker DFS pipetracker (to relate bucket position to actual pipeline position), an Aquarius MK 5002 KART receiver, a NR 203 DGPS receiver and a Van Essen RGC 920 tide receiver. In the event that any part of the backhoe threatened to penetrate the safety contour, the CMS would automatically intervene and alter the movement to preserve the contour, without jamming the backhoe's hydraulic systems. Advanced control systems were also provided for *Jokra* and *Nordland*.

Conclusions

For both the client and the contractors the guaranteed continuity of the gas supply and a controlled and safe working method were of utmost importance. Therefore, throughout the project, everything was done to make certain of the continued integrity of the live gas line and the safe working of heavy equipment in close proximity to it.

The successful execution of the dredging works were primarily made possible by the extreme accuracy and reliability of the dredging equipment's positioning systems including the enhanced Crane Monitoring System (CMS). This ensured that dredging could be executed with great accuracy but contact between equipment and pipeline was avoided at all times.
This ability to perform the deepening task with the gas line remaining live meant that there was no disruption of supplies to Eemshaven's gas-fired power stations and the Dutch gas grid.