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Shore Approach Feasibility Study

Strait of Belle Isle (SOBI) cable crossing

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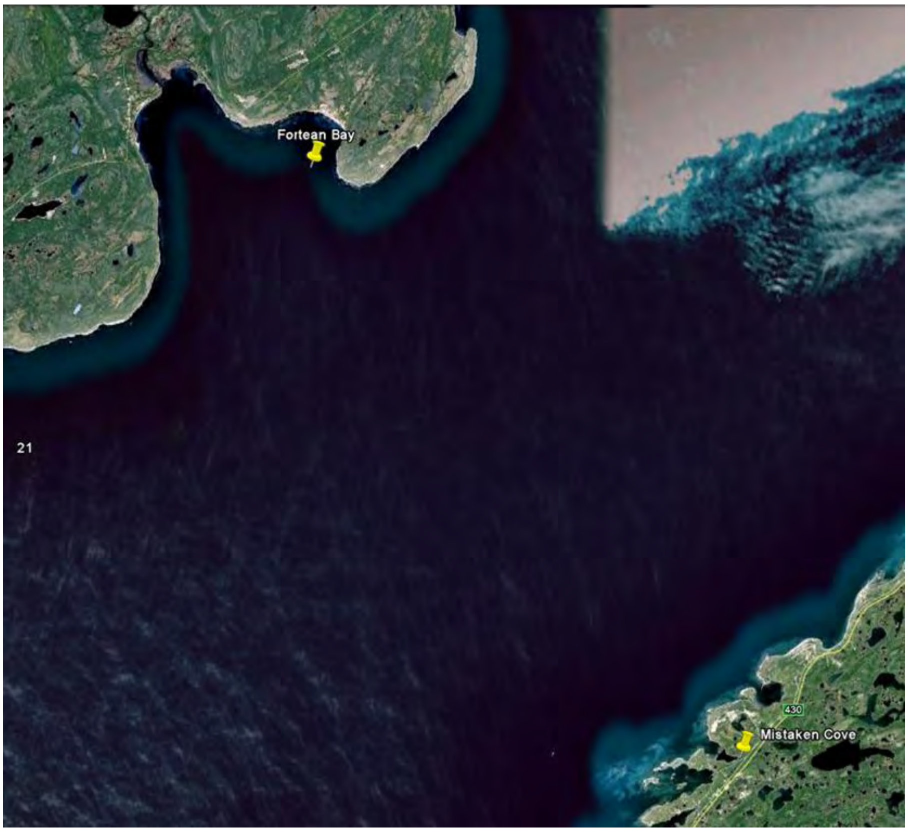

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Document Control Sheet

Client:	Nalcor Energy Lower Churchill Project
Title:	**Shore Approach Feasibility Study** **Strait of Belle Isle (SOBI) cable crossing**
Summary:	This report discusses the technical feasibility of dredging and backfilling shore approach trenches for a cable crossing at L'Anse Amour (Forteau Bay, Labrador) and Mistaken Cove (Newfoundland). Based on review of the boundary conditions, suitable equipment is selected. Based on estimated volumes the duration of dredging and backfilling the trenches is reviewed for various options and scenarios. The cost impact of the soil-scenarios is discussed, and finally recommendations are made for establishing the critical soil characteristics.

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Appendices

1 Introduction

To further develop their Lower Churchill Transmission Project, Nalcor is in the process of conducting studies for a potential seabed submarine cable crossing across the Strait of Belle Isle, between Labrador and Newfoundland.

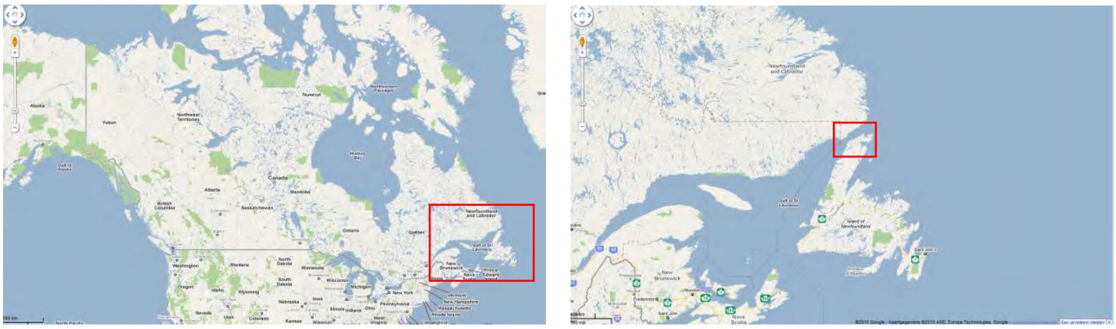

Figure 1: Strait of Belle Isle, between Labrador and Newfoundland (Canada) (Source: Google)

This report specifically reviews the technical feasibility and the cost implications of dredging and backfilling a shore approach trench at both sides of the Strait of Belle Isle.

2 Project description

2.1 Project location

The exact cable route across the Strait of Belle Isle has not yet been finalized, but it is assumed that the cable will have a shore approach on the Labrador coast with a landing site in the area L'Anse Amour beach in Forteau Bay and on the Newfoundland side in the area of Mistaken Cove, see Figure 2 below.

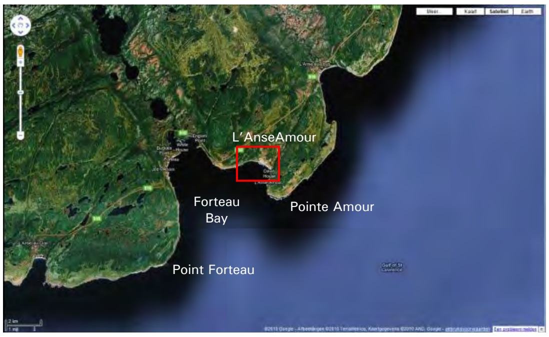

Figure 2: Image of intended shore approach location Labrador (left) and Newfoundland (right) (Source: Google)

2.2 Cable details

Installation of three (3) parallel cables is being considered. The cables are anticipated to be placed together in one trench at the shore approaches. Nominal distance between cables is proposed to be in the order of 0.5 m. The cable is anticipated to be a 320kV cable (450 MW per cable) with an outside diameter of approx. 110 mm, as per the design data provided in ref. [1].

2.3 General methodology

This study assumes that the shore approach area is the nearshore area which is too shallow for access with a cable-laying and/or trenching (support) vessel. The cable will be floated out and pulled to shore along the shore approach section.

In general, a seabed submarine cable should be protected from hydraulic and mechanical influences in the nearshore shallow areas, which is why cables are trenched and/or covered in this area. Various methods are available, including rock-covering, trenching by means of cofferdams or sheetpiles, sheave constructions, etc. This study will focus on the relatively simple method of constructing a temporary trench to allow installation of the cables, and subsequent refilling of the trench to provide protective cover.

The goal is to detail a work method through which these tasks can be completed at both shore approaches within one workable (ice-free) season.

2.3.1 Shore approach dimensions

The following parameters will be assumed when reviewing the shore approach sections:

- Trench depth : 2 m, 3 m or 4 m
- Length of shore approach: shore to -10 m or -15 m depth contour
- Number of cables: 3
- Distance between adjacent cables: 0.5 m

3 Boundary conditions and assumptions

3.1 Bathymetry of Strait of Belle Isle

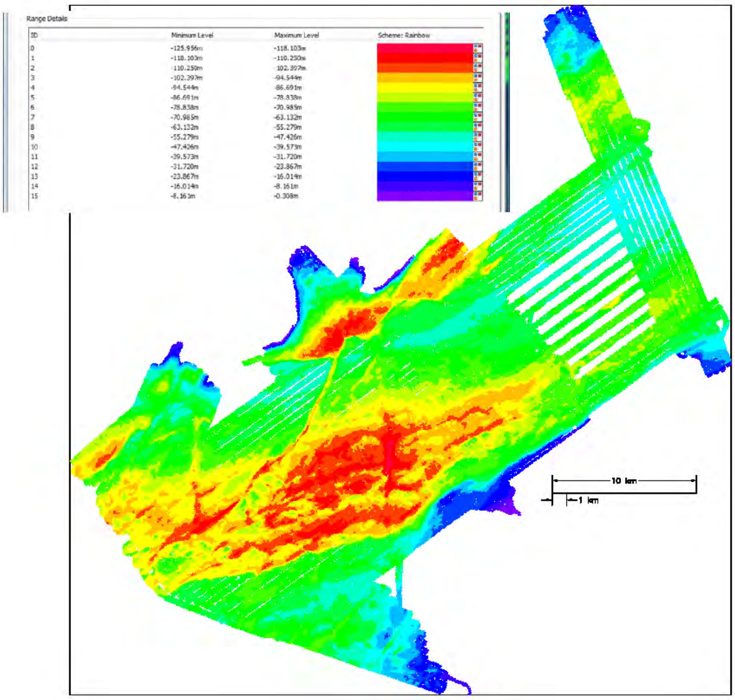

Figure 3: Bathymetry plot (provided by Nalcor, source not defined)

Figure 3 shows a plot of the bathymetry in the Strait of Belle Isle. Furthermore, the bathymetry in the Strait is described in Ref. [2] as follows:

On the Labrador side of the Strait the seafloor deepens rapidly from the coastline across a narrow coastal zone (0-25 m water depth) that is mostly less than 500 m wide, reaching up to 1 km width in Forteau Bay and L'Anse au Clair Bay (Figure 4). Depths increase in a nearshore zone that extends from the 25 m isobath to between 80 and 100 m southwest of L'Anse au Clair and to 115 m off Forteau Bay.

In the Labrador nearshore zone are two prominent seafloor channels. A shore-parallel, coastal channel separates the nearshore zone from two bank areas. The channel is typically 65-75 m deep and as narrow as 0.5 km; widening to about 4 km at the entrance to Forteau Bay, with the deepest region (115 m) occurring offshore from Forteau Bay. Channel A extends southwest from the mouth of L'Anse au Clair where it is about 1 km wide, widening to about 3 km and deepening to 100 m between Isle au Bois (Quebec) and the northwestern slope of Bank A.

Immediately seaward of the nearshore zone, the seabed shoals onto two banks where water depths decrease to less than 75 m. Bank A, offshore from L'Anse au Clair and Forteau Point, is bisected by channel B, a narrow north-south oriented trough. The Channel is between approximately 0.5 and 1 km in width and ranges in depth from 55 m on Bank A to 100 m in deeper water to the south. Immediately east of Channel B, Bank A shallows to as little as 15 m water depth.
Bank B, seaward of Forteau Bay and Pinware River, is separated from bank A by channel C, a pronounced northeast-southwest oriented trough that is 80 – 100 m deep and about 1 km wide. Bank B widens progressively to the northeast,

occupying the central portion of the Strait. Local relief on both banks is between 5 and 10 m.

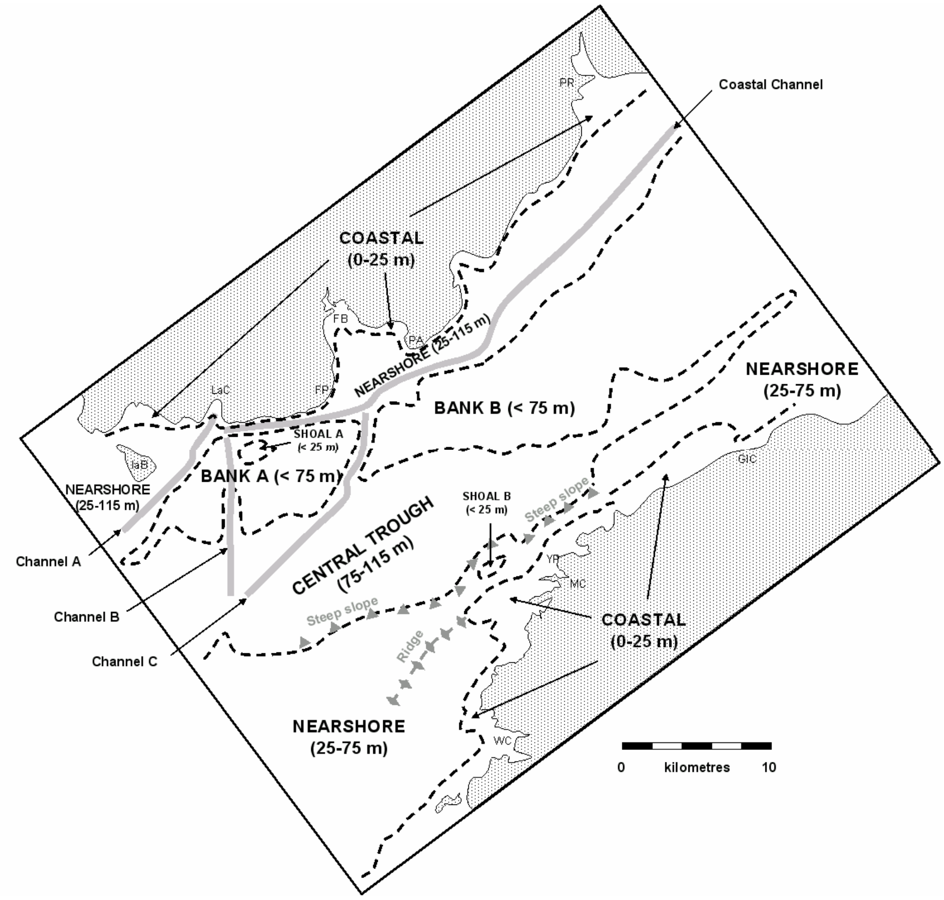

Figure 4: Regional seafloor physiography of the Strait of Belle Isle (FB = Forteau Bay, MC = Mistaken Cove). (Source: Ref. [2], figure 2.2)

3.2 Soil conditions

3.2.1 Regional setting

As described in Ref. [2], the Strait of Belle Isle is a 120 m-deep marine channel separating the northwest coast of the Great Northern Peninsula of the Island of Newfoundland from the southeast coast of Labrador. The Strait is underlain by Precambrian gneisses that form a platform overlain by layered sedimentary rocks of Lower to Upper Cambrian age. It is the Lower Cambrian rocks of the Labrador Group (clastic rocks above and below a middle limestone unit) and Middle to Upper Cambrian limestones of the Port au Port Group, that form the actual substrate and which shape the morphology of the seabed in the Strait. Regionally, the layered rocks on both sides of the Strait dip gently towards the southeast at 2-4°. As a result, older rocks of the Labrador Group occur on the northwest side of the Strait and beneath much of the seabed, and these are progressively overlain by younger limestones of the Port au Port Group beneath the seabed on the Island of Newfoundland side of the Strait and onshore.

The Strait has been occupied by grounded ice masses during Pleistocene glacial episodes, producing an eroded, irregular bedrock topography with a veneer of glacial and post-glacial unconsolidated sediment deposits. The deposits are predominantly coarse-grained, and have an extensive gravel lag surface formed by wave and current action during post-glacial marine flooding of the Strait. Water depths were higher than present at the end of the last glaciation due to glacial isostatic depression of the land surface. Post-glacial isostatic rebound resulted in a relative sea level fall during the Holocene, marked by a series of raised beaches above the present shore line.

3.2.2 Bedrock geology

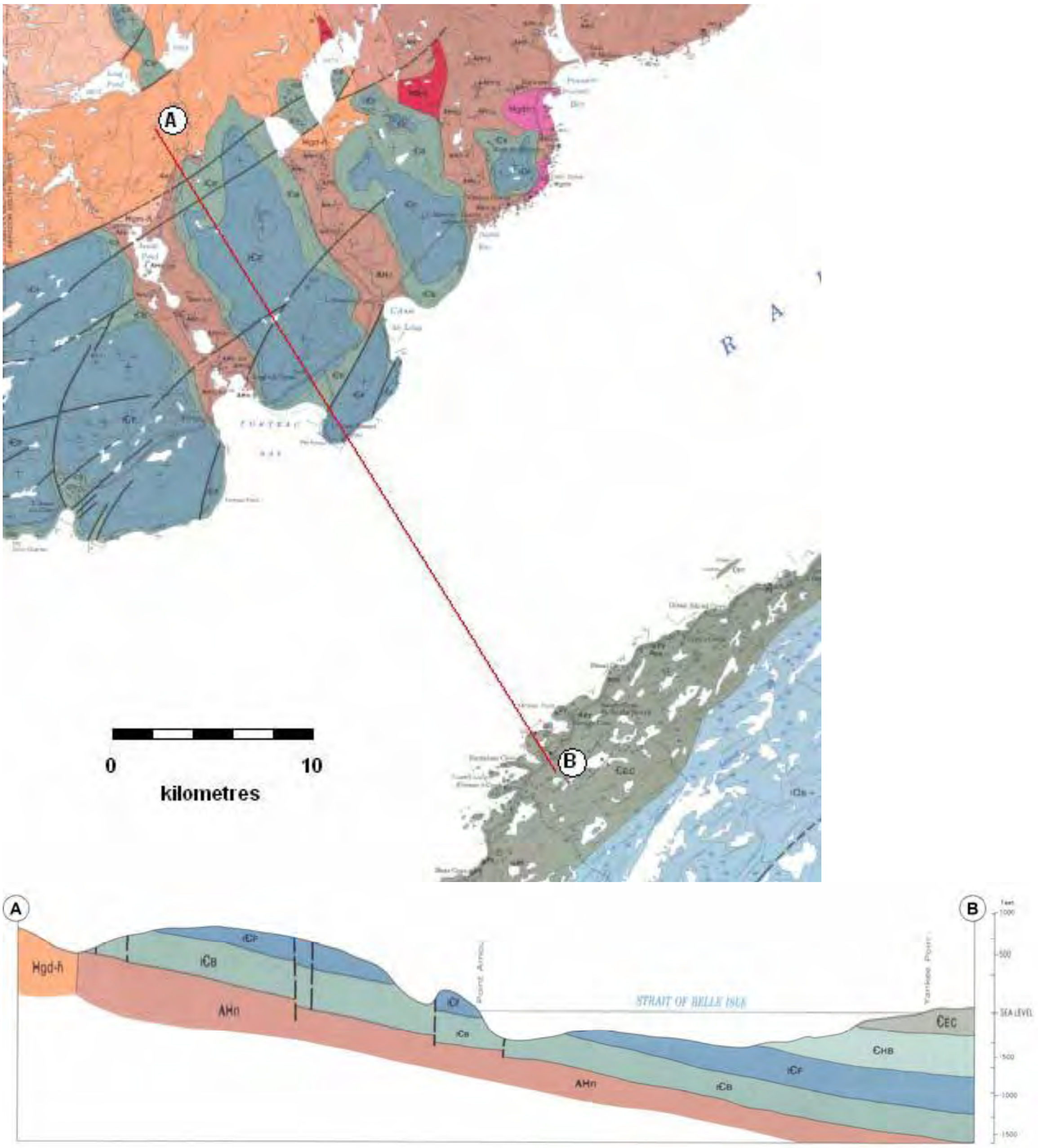

Figure 5: Strait of Belle Isle on-land bedrock geology and geological cross-section between Point Amour to Yankee Point showing interpreted bedrock stratigraphy from Precambrian gneiss (pink) up through the gently east- to southeast-dipping rocks of the overlying Labrador and Port au Port Groups (Source: Ref [2], figures 2.3 and 2.4)

Rocks of Precambrian and Palaeozoic age outcrop on land extensively on both side of the Strait. Ref [2] describes a geological cross-section of the Strait between Point Amour (eastern head of Forteau Bay) and Yankee Point (north of Mistaken Cove, see Figure 5, that shows an essentially tectonically undisturbed stratigraphic sequence below the seabed, with beds dipping very gently (generally $<3^\circ$) to the east and southeast. This cross-section, though general, is considered the most valid interpretation of bedrock distribution beneath the Strait.

3.2.3 Surficial geology

Ref. [2] describes the surficial geology as follows:

The regional distribution of unconsolidated seafloor surficial sediments was first described by Drapeau (1968). The surficial geology map showed for the first time the presence of sand, gravel and a sand-gravel mixture. The Nova Scotia Research Foundation investigations (1973) interpreted a relatively continuous layer of undifferentiated sediments across the Strait with estimates of overburden thickness up to 5 m. Where overburden does not cover bedrock, ponded deposits were shown to be separated by long parallel sediment ridges, interpreted by Woodworth-Lynas et al. (1992) as Ribbed Moraines related to glaciation.

The Nova Scotia Research Foundation (carried out further surveys 1974a,b) and identified sand and gravel waves: bedforms indicative of strong bottom currents. Extensive offshore surveys by Kenting Exploration Services Ltd. (1979) confirmed the coarse nature of surficial sediments (pebbles, cobbles and boulders) and interpreted the median thickness of all sediments to be 1.5 m with isolated pockets up to 4 m thick. Further extensive surveys by Geonautics Ltd. (1981b,c, 1984) identified nearshore bedrock channels filled with sediment, which form the approaches to both landing sites.

In essence the seafloor comprises a wide variety of glacial and post-glacial to recent sediments that rest on bedrock.

1. Glaciomarine – Marine: This unit stratigraphically overlies the Glacial Drift deposits and generally occurs as small isolated pockets of ponded sediment, notably between Ribbed Moraines. Geophysical data indicate that the unit is thickest in the southern part of the region where internal stratification, parallel to the smooth upper surface, suggests that here at least the unit consists of fine-grained sediment. Like the older Glacial Drift, the unit is generally overlain by modern gravel lag deposits and sand and shell ribbons. Lithologically, this is the most variable of all the mapped units. In the offshore boreholes, sediments range from medium to dense, poorly sorted sand and pebbles (with cobbles, boulders and minor silt) to soft or loose finer sediment (silty sand and gravel to silt and clay with minor sand) in deeper water.

2. Gravel Lag: This is the dominant unit covering most of the modern seabed surface. As the name suggests the unit has been formed by the winnowing and removal of fine-grained sediment from the underlying Glacial Drift and Glaciomarine – Marine units by strong ocean currents. The resulting lag is a relatively thin veneer (<1 m thick) of coarse gravel, pebbles and boulders, particularly on the crests of ridges.
   Sediment classification of single-beam sonar transects (RoxAnn sediment classification system; Appendix C) indicates that approximately 90% of the seabed comprises pebbles, cobbles and boulders in interpreted size ranges from 5 cm to more than 1 m (2″ to 40″) in diameter, the majority of which (65% of the seabed) comprises cobbles and boulders in the size range 5 to 75 cm (2″ to 30″). The remaining 10% consists of approximately 9% of coarse-grained sand and shells with pebbles and 1% fine sand

3. Sand-Shells: This unit comprises lithic sand, broken shell fragments or a mixture of both. Numerous sand patches characterize the Newfoundland nearshore zone but the most extensive deposits occur in the bays of the Labrador coast.

4. Bedrock: Bedrock of the underlying layered Labrador Group and Port au Port Group is exposed at the seafloor in places throughout the Strait, usually in the form of flat surfaces and bedrock steps.
   On the Newfoundland side, at Yankee Point (north of Mistaken Cove), the exposed bedrock along the shoreline and for some distance offshore (approximately 2000 m) is Petit Jardin Formation dolomite with interbedded shale. At the Borehole 074-B-D1 location, this formation extends to a depth of approximately 42 m below ground surface (or 33 m below sea level). The RQD for this formation ranges from 60% to 90%, which indicates that the rock is fractured to moderately jointed, i.e. in fair to good condition.
   The massive limestones of the Forteau Formation were encountered below 219 m below ground surface (or 210 m below sea level) at Yankee Point, but are exposed onshore at Forteau Point (western head of Forteau Bay) on the Labrador side. (Interbedded Limestone and Shale 40% , log 74-B-D2 up to 27.4 m).
   There is very limited information available to use for an assessment of the strength of the offshore bedrock types. Information about core strength of the formation, in terms of RQD (Rock Quality Designation), has been extrapolated from the deep onshore boreholes 74-B-D1 and 74-B-D2, and based on an inferred bedrock stratigraphy.
   Based on observations from the Point Amour and Yankee Point, onshore boreholes and on visual observations from the shallow offshore boreholes, it would appear that sound to very sound bedrock formations may be present along most of the seafloor of the Strait, at least below a water depth of 20 m. On the Newfoundland side, the March Point dolomite and Forteau limestones intersect the seafloor from a water depth of 20 m, and extend to banks A and B (south and north). On the Labrador side, the Bradore Formation sandstones are exposed within the Labrador coastal trough from approximately sea level to a water depth of 80 m.

The surficial geology on land is presented in Figure 6. The shoreline on both sides of the Strait comprises mostly raised beaches and terraces of gravel (pale blue) or gravelly veneer < 4m thick on rocky terrain (dark blue). Inland most of the region comprises essentially exposed bedrock either with small patches of thin till (pale pink) or obscured by forest (dark pink).

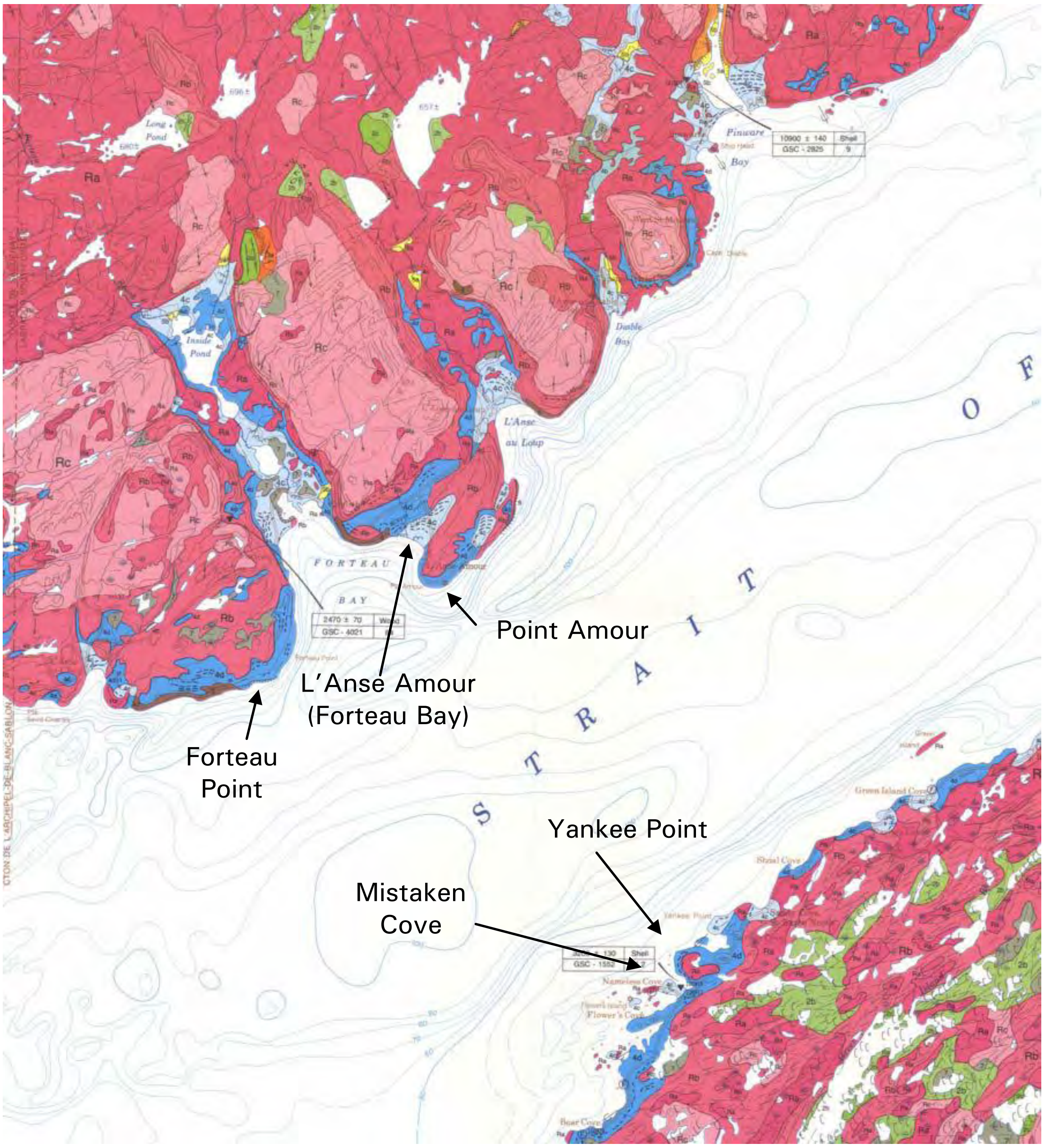

Figure 6: Strait of Belle Isle onland surficial geology. (Source: Ref. [2], figure 2.17)

3.3 Description of landing sites

Ref [2] provides the following description of the shore approach areas at either side of the Strait:

3.3.1 Mistaken Cove, Newfoundland

As can be seen from Figure 6, the onland surficial geology on the north and east side of Mistaken Cove is characterized as gravelly veneer < 4m thick on rocky terrain (dark blue), while the south shore of the cove is characterised as raised beaches and terraces of gravel (pale blue). In Figure 7, a barrier (barachois) is visible across Mistaken Cove. This pebbly barachois is discussed in Ref. [2] as follows:

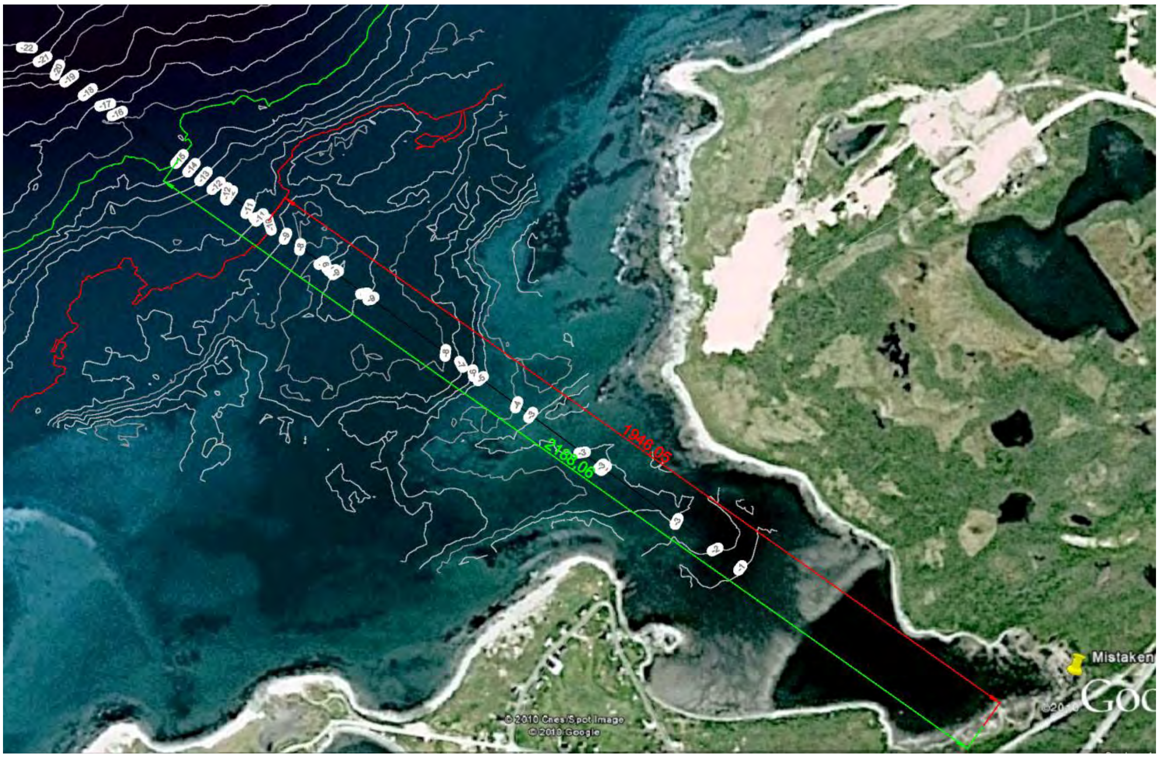

Figure 7: Mistaken Cove, Newfoundland

The shorelines on both sides of Mistaken Cove comprise very gently southeast-dipping (1-3˚) dolomitic limestones of the Petit Jardin Formation (Lower Dolostone Member). The barachois extends across the cove with a 20-25 m wide tidal gap in the centre. The barachois surface comprises a rounded pebbly and sandy gravel (2-5 cm diameter) lag deposit over a sandier substrate (Figure 8). In places, large sub-rounded boulders (1- 3 m diameter) rest on the barachois surface and elsewhere on the pebbly tidal flats behind.

The outcrops of limestone on both sides of the cove suggest that the barachois and associated tidal flat deposits may not be very thick, unless there is a buried channel that runs the length of the cove, as found at Winter Cove further south. Behind the barachois the tidal flat surface comprises a bouldery gravel lag.

Water depth in the vicinity of the barachois at the time of the investigation was estimated at ~ 1-2 m, and in the tidal gap ~ 1 m.

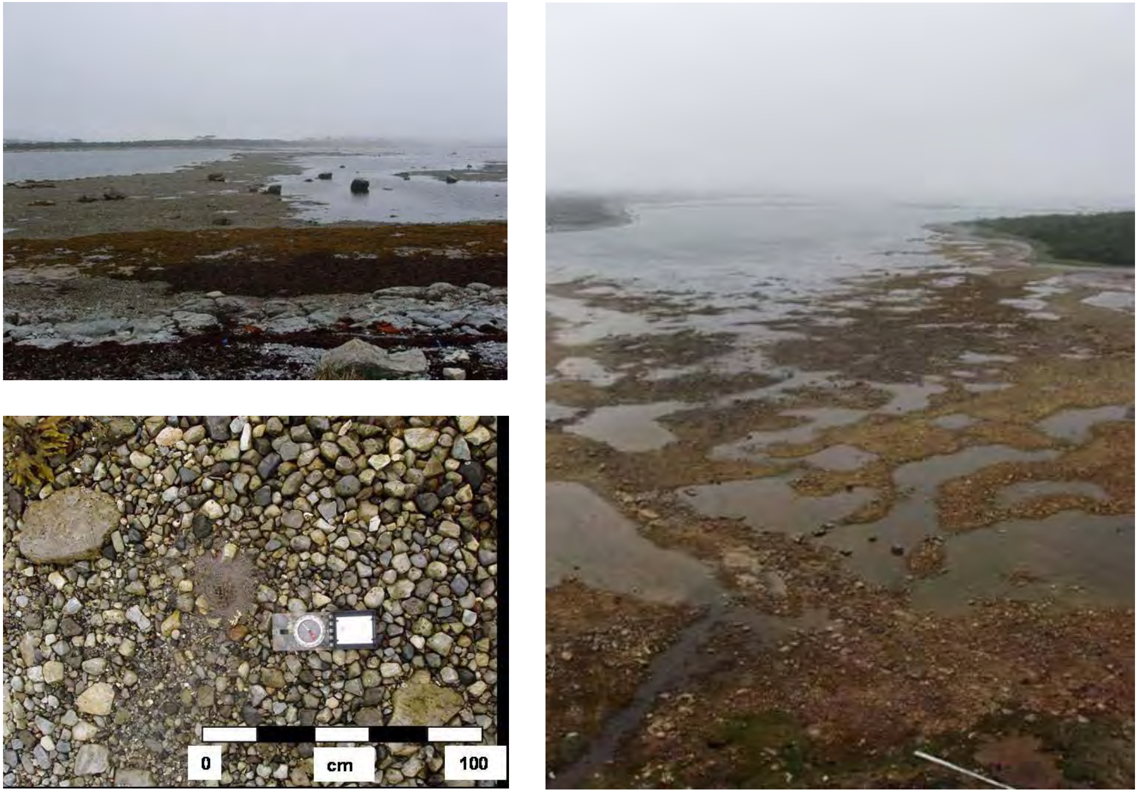

Figure 8: Views of Mistaken Cove (Source: Ref. [2], figures 4.10 to 4.12)
Top left: View looking southwest along the gravelly barachois at Mistaken Cove. A few large boulders (<1m diameter) rest on the barachois surface. Grey dolomitic limestone bedrock of the Petit Jardin Formation forms the upper beach in the foreground.
Bottom left: Pebbly gravel lag surface of the barachois at the narrow tidal gap in Mistaken cove. A worm cast (centre) indicates course sand beneath the gravel lag.
Right: Aerial view of Mistaken Cove looking seawards to the northwest showing the boulder gravel lag that characterizes the tidal flat surface behind the barachois (seen in the middle distance).

3.3.2 Forteau Bay, Labrador

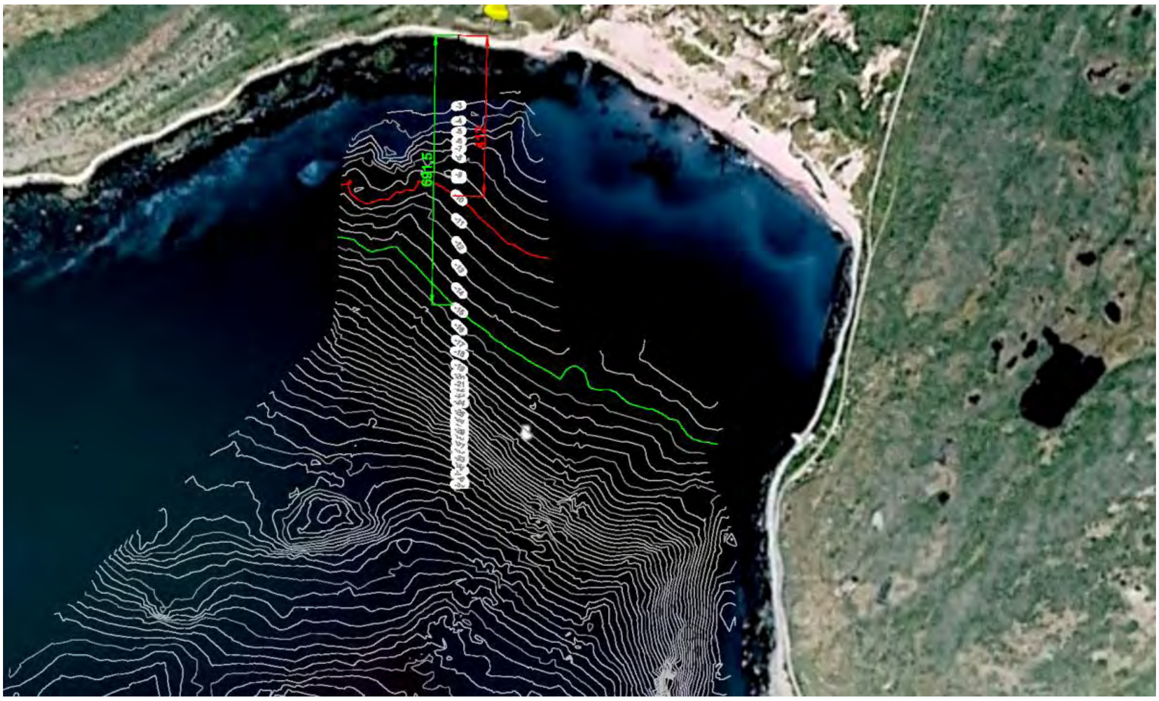

Figure 9: L'Anse Amour (Forteau Bay), Labrador

The beach at L'Anse Amour comprises well-sorted, medium- to coarse-grained sand. The main beach faces towards the southwest and is about 1 km long and 20-30 m wide. It is crossed by three brooks draining through a sequence of raised beaches behind the modern beach (Figure 10).

The upper beach is marked by a grass-stabilized sand bluff, representing the first in a series of raised beaches behind. On the eastern side, sand "blowouts" are common in the raised beach sequence behind the modern beach. The eastern end of the beach is marked by a transition from sand into a region of large, rounded boulders at the shoreline towards Davis House and Point Amour. The boulders probably rest directly on limestone bedrock of the Forteau Formation.

The three brooks form narrow, meandering channels cutting down through the raised beaches and the modern beach sand before draining into the bay. The westernmost brook is characterized by a flat, rocky stream bed. The western end of the beach, at the foot of Bradore Formation sandstone cliffs that form Crow Head, is protected from wave action by a zone of large boulders in the intertidal zone.

Figure 10: Views of L'Anse Amour beach in Forteau Bay (Source: Ref. [2], figures 4.13-4.19)
Top left: Eastern portion of L'Anse Amour beach showing stabilized grassy upper beach, raised beaches behind the modern beach, one of the three brooks that drains across the beach and "blowouts" developed in the raised beach sequence in the distance.
Top right: View 2.5 km westwards towards the Bradore Formation sandstone cliffs of Crow Head from the eastern end of L'Anse Amour beach. The beach is 20-30 m wide and is crossed by three brooks.
Middle left: View towards the Davis House and Point Amour at the eastern end of L'Anse Amour beach showing transition from sand beach to large rounded boulders, resting on bedrock of Forteau Formation limestones.
Middle right: View westwards towards Crow Head showing the first of three brooks that cut through the L'Anse Amour beach.
Bottom left: View west towards Crow Head across the rocky flat streambed of the third of three brooks that cut across the L'Anse Amour beach. The rocks have been washed down from inland bedrock exposures of Bradore and Forteau Formation.
Bottom right: Shallow water lagoon at the western end of the L'Anse Amour beach, view west below Crow Head. Large boulders in the intertidal zone may protect this portion of the beach from wave action and in winter may stabilize nearshore ice.

While the beach at L'Anse Amour gives the impression of a sandy coastline, one should be aware that the sand overlies bedrock of Bradore Formation sandstone (quartzite, orthoquartzite and arkosic sandstone). Thickness of the sandy layer has not been determined in detail.

3.4 Ice coverage

Historical pack ice information in the Strait of Belle Isle is reviewed in Ref. [2], and summarized in Table 1. Pack ice coverage usually diminishes in the month of July, although a favourable year might see pack ice diminish as early as May. The Strait is generally free from pack ice during August through November. Pack ice generally returns during the month of December.

In Ref. [3] the occurrence of pack ice is discussed in relation to passage of ocean-going ships through the Strait of Belle Isle. In late December ice begins to form locally, and generally by mid-January passage of ocean-going vessels because uneconomic. The retreat of pack ice in spring is said to be dependent on the wind; easy navigation through the strait can begin in early May or be delayed by ice congestion until late June. On average, ice coverage closes the Strait for approximately 140 days/year, allowing passage of ocean-going ships for 225 days/year.

NB: It should be noted that occurrence of pack ice and passage of ocean-going vessels in the centre of the Strait cannot be related directly to occurrence of pack ice in the sheltered shallow bays on either side of the Strait.

Date	Years of data	Average Ice Conc.	Standard Deviation	Minimum Ice Conc.	Maximum Ice Conc.
04-Jan	13	4.8	4.6	0	10
18-Jan	37	7.4	3.9	0	10
01-Feb	37	8.0	3.8	0	10
15-Feb	37	9.4	2.3	0	10
01-Mar	36	8.7	3.0	0	10
15-Mar	37	9.2	2.3	0	10
29-Mar	36	7.4	3.8	0	10
12-Apr	37	5.8	4.5	0	10
26-Apr	37	4.6	4.5	0	10
10-May	37	3.1	3.7	0	10
24-May	37	2.0	3.3	0	10
07-Jun	36	0.9	1.5	0	9
21-Jun	25	1.0	1.7	0	9
05-Jul	14	0.6	0.5	0	1
19-Jul	5	0.6	0.5	0	1
02-Aug	1	No data			
16-Aug		No data			
30-Aug		No data			
13-Sep		No data			
27-Sep		No data			
11-Oct		No data			
25-Oct		No data			
08-Nov		No data			
22-Nov	1	No data			
06-Dec	16	0.1	0.3	0	1
20-Dec	31	1.6	3.3	0	10

Note: 0/10ths concentration indicates no ice or open water, and 10/10ths indicates 100% ice coverage.

Table 1: Weekly average pack ice concentrations (10ths) in the Strait of Belle Isle (Source: ref. [2])

3.5 Hydraulic conditions

3.5.1 Currents and tidal streams

According to Ref. [6], tidal streams flow back and forth (twice daily) through Strait of Belle Isle at rates of up to 3 knots in the SW entrance. The stronger streams occur on the N side, and rates diminish towards the S shore where they do not exceed 2 knots. There is considerable inequality in the rates of successive streams, particularly when the moon has high declination.

Additionally, there is considerable variability in the currents occurring in Strait of Belle Isle. The outgoing current (flowing towards NE) may sometimes last for several days, whilst at other times an ingoing current (flowing towards SW) may persist for an equally long period. The variability appears to be linked to difference in air pressure inside and outside the Gulf of St. Lawrence. The current seems to respond almost immediately to changes in the pressure gradient, even before the wind pattern is fully established.

A combination of current and tidal stream normally results in alternating ingoing and outgoing flows during each tidal cycle, although one flow is likely to be appreciably stronger than the other. But since the flow encountered in Strait of Belle Isle is a resultant of currents dependent on meteorological conditions and tidal streams in which there is a degree of inequality, it is not easy to predict flow rates and the times of slack water with any degree of accuracy.

Ref. [7] provides a summary of ocean current statistics for the cable route across the Strait of Belle Isle, focusing on the crossing as a whole. The document discusses measured current speeds (max. speeds of 1.8-2.6 m/s are mentioned for various seasons), and estimated current speeds based on statistics (max. speeds of 3.3-4.3 m/s are mentioned for various seasons). No detailed information is provided about flow velocities within the relatively sheltered bays which will accommodate the shore approaches.

According to Ref. [6], inside Forteau Bay (Labrador) tidal streams are so weak that they are easily influenced both in strength and direction by wind. But outside the bay, off Amour Point and Forteau Point (eastern and western head of Forteau Bay, respectively) the tidal streams are strong and very irregular, occasionally running in one direction at a rate from 4-5 knots (2-2.5 m/s) close to the shore and in an opposite direction a short distance offshore. During the survey three distinct streams were met within a distance of 2 miles, the tide rips were of considerable strength and these irregularities continually changed from unknown causes.

No details of streams and currents are known for the direct vicinity of Mistaken Cove (Newfoundland). But based on the limited water depth and the limited water-storage capacity of the cove, it is assumed that flows inside the cove are minimal.

3.5.2 Tidal levels

The following tidal levels (relative to Chart Datum - CD) are provided for Forteau Bay (51°28'N, 56°56'W) in Chart 4735 (Ref. [8]):

Mean High Water Spring	MHWS	+1.4 m	(+4.6 feet)
Men High Water Neap	MHWN	+1.1 m	(+3.7 feet)
Mean Water Level	MWL	+0.9 m	(+2.8 feet)
Mean Low Water Neap	MLWN	+0.6 m	(+1.9 feet)

Mean Low Water Spring	MLWS	+0.3 m	(+1.0 feet)
Lowest Astronomical Tide	LAT (=CD)	+0.0 m	(+0.0 feet)

3.5.3 Waves

Ref. [2] reviews wave statistics for several 'unsheltered' locations within the Strait of Belle Isle. The point located closest to the middle of the Strait, between Forteau Bay and Mistaken Cove, is Node 18071 (lat 51.4°N, Lon 56.8°W, depth 77.1 m).

As can be seen from Table 2, in the summer months (June-July-August) wave heights are ≥ 1 m for 15% of the time. In the autumn months (September-October-November) wave conditions (wave heights) are substantially less favorable: wave heights are ≥ 1 m for approximately 45% of the time.

However, the majority of the dredging and backfilling operations will take place within the sheltered bays of L'Anse Amour (Forteau Bay) and Mistaken Cove, where wave conditions will be considerably more favorable than in the middle of the Strait.

June-July-August

Hs (m)	N	NE	E	SE	S	SW	W	NW	Total
				Direction (from)					
3.5- 4.0	0	0	0	0	0	0.001	0	0	0.001
3.0- 3.5	0	0	0	0	0	0.003	0	0	0.003
2.5- 3.0	0	0	0	0	0	0.071	0.011	0	0.083
2.0- 2.5	0	0.012	0	0	0	0.531	0.068	0	0.611
1.5- 2.0	0.024	0.179	0.061	0.006	0.003	2.398	0.398	0.064	3.134
1.0- 1.5	0.420	0.941	0.327	0.118	0.109	7.330	1.787	0.339	11.369
0.5- 1.0	1.327	2.264	2.057	0.655	0.500	17.734	5.910	0.658	31.105
0.0- 0.5	1.023	5.655	6.267	1.572	1.925	30.783	5.646	0.821	53.694
Total	2.794	9.051	8.712	2.351	2.537	58.852	13.821	1.882	100.00

September-October-November

Hs (m)	N	NE	E	SE	S	SW	W	NW	Total
				Direction (from)					
5.0- 5.5	0	0	0	0	0	0.002	0	0	0.002
4.5- 5.0	0	0	0	0	0	0.011	0.003	0	0.013
4.0- 4.5	0	0	0	0	0	0.050	0.003	0	0.053
3.5- 4.0	0	0	0	0	0	0.139	0.020	0	0.159
3.0- 3.5	0	0.009	0.003	0	0	0.442	0.110	0	0.564
2.5- 3.0	0.022	0.092	0.012	0	0.001	1.056	0.419	0.038	1.640
2.0- 2.5	0.129	0.302	0.049	0	0.055	2.719	1.338	0.127	4.720
1.5- 2.0	0.665	1.091	0.409	0.160	0.232	5.885	3.747	0.735	12.924
1.0- 1.5	2.473	3.225	1.225	0.802	0.634	8.779	6.910	2.746	26.795
0.5- 1.0	3.260	4.150	2.976	1.225	0.932	11.277	8.966	2.554	35.341
0.0- 0.5	0.598	3.223	2.288	0.634	0.657	6.668	3.143	0.580	17.790
Total	7.147	12.091	6.962	2.821	2.511	37.027	24.658	6.781	100.00

Table 2: Seasonal Sea State Statistics for Node 1871 (Source: Ref. [2])

3.6 Local weather

According to Ref. [6], during summer, dense fogs prevail in the Strait of Belle Isle, sometimes lasting for several days and occurring with either W or E winds. With winds from the W, the fog commences first along the Labrador side, frequently keeping to that coast. With E winds, the fog is general throughout the strait. The Newfoundland side almost always clears first. These fogs cling closely to the water and the shore. From a vessel's masthead the summits of the Labrador hills may sometimes be seen over them. During a period of 40 days observations in July and

August fog occurred on 60% of them on the Labrador side and on 40% on the Newfoundland side.

During the Caribbean hurricane season, mainly between August and October, tropical storms entering the area have usually lost much of their tropical characteristics, but may still give rise to very disturbed weather together with rough seas.

After strong E winds, a heavy swell lasting several days sets through the Strait, making most landing places on the Newfoundland side unusable.

4 Work methods

4.1 Introduction

Work methods are reviewed on the assumption that the shore approach trenches will be dredged, cables will be placed, and the trenches will be backfilled, all within one working season.

4.2 Theoretical volumes

Based on the assumptions discussed in section 2.3.1, the minimum bottom width for the shore approach trench is approx. 1.5 m. The (theoretical) angle of the side slopes of the trench is dependent on the local soil conditions. The resulting total (theoretical) in-situ volume to be removed per meter length of trench is determined in Table 3.

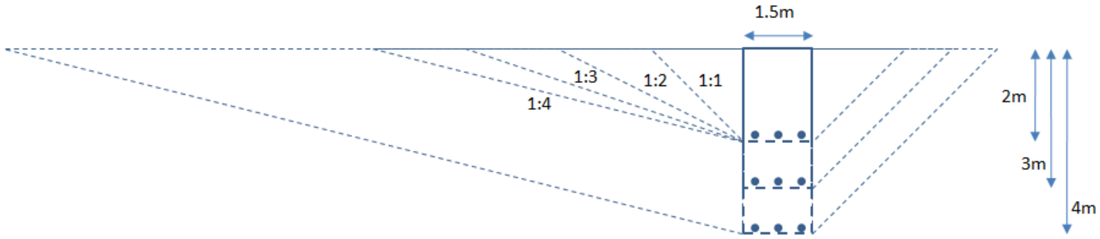

Figure 11: Schematic overview of theoretical trench cross-sections

		Average slope angle (v:h = 1:..)			
		1	2	3	4
Minimum bottom width:		1,5	1,5	1,5	1,5
Trench depth	2	7	11	15	19
	3	13,5	22,5	31,5	40,5
	4	22	38	54	70

Table 3: Volumes per meter length of trench for theoretical trench cross-sections (in m^3/m^1)

Based on the soil data available it is assumed that the material to be dredged consists of a layer of loose material (sand/shells, gravel, boulders) over firm bedrock. Volume calculations will be based on the assumption that slopes will fall to a natural angle of 1:3 (v:h) over the full depth of the trench, i.e. steeper slopes which might be feasible in the bedrock material are disregarded.

As discussed in section 2.3.1, the shore approach section is defined as the section from the shoreline to the -10 m or -15 m depth contour. The corresponding length of the shore approach sections has been determined based on the available bathymetry (see Figure 3). Using the resulting section lengths, the theoretical volume to be dredged is calculated in Table 4.

	section length	trench depth		
		2m	3m	4m
Forteau Bay shore to -10m	415	6.225	13.073	22.410
Forteau Bay from -10m to -15m	285	4.275	8.978	15.390
Total	700	10.500	22.050	37.800
Mistaken Cove shore to -10m	1.950	29.250	61.425	105.300
Mistaken Cove from -10m to -15m	250	3.750	7.875	13.500
Total	2.200	33.000	69.300	118.800
TOTAL		**43.500**	**91.350**	**156.600**

Table 4: Theoretical volumes to be dredged for various options

4.3 Equipment

In general, there are three major types of equipment which might be employed for excavating and backfilling of trenches:

- Trailing Suction Hopper Dredger (TSHD)
- Cutter Suction Dredger (CSD)
- Backhoe Dredger (BHD)

General descriptions for each of these types of equipment are available in Appendix 2.

Project-specific boundary conditions are governing in determining which type of equipment is most suitable. In this case, the following boundary conditions are especially relevant for selecting equipment for dredging and backfilling of the shore approach trenches:

- Soil conditions
- Volumes to be removed
- Water depth available

A TSHD is not considered suitable for dredging the shore approach trenches, because of bedrock and boulders that will most likely need to be removed, but also because of the limited dimensions of the trenches, and the nearshore and shallow conditions restricting manoeuvrability.

A CSD could be very suitable for dredging the shore approach trenches, especially if substantial volumes of rock need to be dredged. However, if the majority of dredging takes place in the loose material on top of the hard rock bed, then the accidental availability of large boulders will pose a serious problem for a CSD. Another downside of using a CSD is the fact that a substantial “access channel” will have to be created for the CSD itself when it reaches the shallow area, which vastly increases the volumes to be dredged.

For the current project, a large BHD (type ‘Nordic Giant’, or similar, see details in Appendix 3) is considered to be the most suitable equipment. A BHD is very suitable for dealing with obstacles such as boulders, and for efficiently handling limited volumes of material in shallow areas. However, there is a limit in rock strength which can still be dredged efficiently by BHD. And in the most shallow regions of the route, a BHD will also have to create an “access channel” for its pontoon. This study assumes an access channel of approx. 15 m wide and 3 m deep – the actual access channel would have to be tailored to the actually used BHD pontoon.

4.4 Scenarios

Due to the limited availability of detailed soil data at the shore approach areas, assumptions have been made as to the specific conditions of the material that has to be dredged.

4.4.1 Scenario 1: 100% loose material

The first scenario assumes the ‘optimal’ situation, where the layer thickness of loose material over the bedrock is sufficiently thick that no bedrock needs to be removed. This means that the BHD can work at ‘optimum’ production capacity, of course still taking into account some downtime due to weather conditions and delays due to obstruction removal.

4.4.2 Scenario 2: 75% loose material, 25% bedrock

The second scenario assumes that 75% of the material which needs to be dredged is loose material, while 25% of the volume to be dredged consists of bedrock. This bedrock is assumed to be sufficiently weathered to allow direct dredging by BHD, without pretreatment (drilling and blasting) of the bedrock. The BHD production capacity in this bedrock will of course be substantially reduced.

4.4.3 Scenario 3: 75% loose material, 25% bedrock to be blasted

The third scenario also assumes that 75% of the material which needs to be dredged is loose material, while 25% of the volume to be dredged consists of bedrock. However, this bedrock is assumed to be so strong, that it cannot be removed (efficiently) by the BHD, but needs to be pretreated (blasted) first. Drilling and blasting of the bedrock is very time-consuming, but the dredging production for the BHD after pretreatment will be much improved in comparison to bedrock dredging in scenario 2.

4.5 Schedule

4.5.1 Working window

In section 3.4 it is discussed that during the months of July through to November the (centre of) the Strait is usually ice-free, allowing passage of ocean-going vessels. It is assumed that during these months, the ice coverage in the sheltered bays of the shore approaches will also allow implementation of the dredging, cable installation, and backfilling operations. This gives an assumed working window of approximately 22 weeks.

Based on input provided by Nalcor, the cable-laying operations will be a stand-alone activity which will take place after dredging of both shore approaches, and before backfilling of both shore approaches. Cable-laying is assumed to take 3 weeks, and dredging equipment is assumed to lay idle during this period. This results in a working window for dredging and backfilling operations of approximately 19 weeks. (Please refer to Appendix 4 for an example cable installation method statement.)

Based on the hydraulic conditions (wave heights, flow velocities) discussed in section 3.5, the conditions within the sheltered bays are assumed to be favourable, causing relatively little delays to the dredging and backfilling operations. But it should be noted that the outer part (approx. 1 km) of the shore approach at Mistaken Cove is actually not quite sheltered, and might be prone to more unfavourable current and wave conditions. Shifting of the dredger between sheltered and unsheltered locations during varying hydraulic conditions could be considered to allow work to continue with limited delay.

4.5.2 Duration of activities

Using the theoretical volumes from section 4.2, scenario-specific volumes have been determined, taking into account additional volume for example for the BHD ‘access channel’, and for the BHD bucket-width which determines the minimum width of trench. Using these volumes, and specific BHD production estimates for the various scenarios, the duration of the activities have been calculated, see Table 5 and Table 6.

	Trench depth	Scenario 1			Scenario 2				Scenario 3 *)				
		100% Soil	Backfill	Total	75% Soil	25% Bedrock	Backfill	Total	75% Soil	25% Blasting **)	25% Bedrock	Backfill	Total
Forteau Bay	2m	0,3	0,3	0,6	0,2	0,7	0,3	1,3	0,2	1,9	0,1	0,3	2,6
Mistaken Cove		1,5	1,9	3,4	1,1	4,1	1,9	7,2	1,1	10,8	0,5	1,9	14,3
Total				**4,0**				**8,5**					**16,9**
Forteau Bay	3m	0,4	0,5	0,9	0,3	1,1	0,5	2,0	0,3	3,0	0,1	0,5	3,9
Mistaken Cove		2,1	2,8	4,9	1,6	6,0	2,8	10,4	1,6	15,7	0,7	2,8	20,8
Total				**5,9**				**12,4**					**24,7**
Forteau Bay	4m	0,6	0,8	1,4	0,4	1,7	0,8	2,9	0,4	4,3	0,2	0,8	5,7
Mistaken Cove		3,0	4,0	6,9	2,2	8,4	4,0	14,6	2,2	22,0	0,9	4,0	29,2
Total				**8,3**				**17,5**					**34,9**

Table 5: Duration [wks] of dredging and backfilling shore approaches to depth contour -10m

	Trench depth	Scenario 1			Scenario 2				Scenario 3 *)				
		100% Soil	Backfill	Total	75% Soil	25% Bedrock	Backfill	Total	75% Soil	25% Blasting **)	25% Bedrock	Backfill	Total
Forteau Bay	2m	0,4	0,5	0,9	0,3	1,0	0,5	1,8	0,3	2,7	0,1	0,5	3,6
Mistaken Cove		1,6	2,1	3,6	1,2	4,4	2,1	7,6	1,2	11,5	0,5	2,1	15,2
Total				**4,5**				**9,4**					**18,8**
Forteau Bay	3m	0,6	0,8	1,4	0,5	1,7	0,8	3,0	0,5	4,5	0,2	0,8	5,9
Mistaken Cove		2,3	3,1	5,4	1,7	6,5	3,1	11,3	1,7	17,0	0,7	3,1	22,5
Total				**6,8**				**14,3**					**28,4**
Forteau Bay	4m	0,9	1,2	2,1	0,7	2,6	1,2	4,5	0,7	6,7	0,3	1,2	8,9
Mistaken Cove		3,3	4,3	7,6	2,4	9,3	4,3	16,0	2,4	24,2	1,0	4,3	32,0
Total				**9,7**				**20,5**					**40,9**

Table 6: Duration [wks] of dredging and backfilling shore approaches to depth contour -15m

*Note *) Scenario 3 activities are presented as subsequent activities, while in fact blasting and dredging activities might partially overlap, thereby reducing the overall duration of the activities.*
*Note **) Blasting production based on estimated volumes only (disregarding the surface-area, which can have a significant effect on the estimated duration).*
Note: In the estimate above, the duration of dredging, blasting and backfilling activities is directly linked to the volume to be handled. To gain insight into other possible scenario's (i.e. 50% bedrock, or 75% bedrock), the duration of the activities can simply be adjusted accordingly.

Table 5 and Table 6 show, that if no dredging of bedrock is required (scenario 1), there should be no problem to complete the dredging, cable-laying and backfilling operations within one working season, regardless of whether the trench depth should be 2, 3 or 4 m.

Also scenario 2 could probably be achieved within one working season, except for the option of dredging a 4 m deep trench to the -15 m depth contour, which risks running beyond the limits of the working window.

Finally, if scenario 3 were to occur, then only a 2 m deep trench could be constructed and backfilled within the working window. A deeper trench with 25% bedrock to be pre-treated would take much longer than 19 weeks to be dredged and backfilled, regardless of whether the trench is extended to the -10 m depth contour or to -15 m. This scenario could of course be completed within the required timeframe by mobilising additional equipment (i.e. a second drilling and blasting spread, and if necessary a second BHD).

5 Cost implications

5.1 Assumptions

Beside the assumptions mentioned in previous sections, the cost estimate has been based on the following:

- Equipment: 1 large BHD (type Nordic Giant), 1 tug/survey boat, 1 crew boat
- Accomodation: available nearby on shore
- (De-)mobilisation: from and to Halifax (600 nm distance), including 1 week for preparation (and dismantling).

It can also be noted that the cost of the drilling and blasting have been based on an assumed layer thickness or the bedrock to be treated, where in reality the surface area and layer thickness combined will determine the cost of the drilling and blasting.

5.2 Estimate

To limit the number of alternative estimates, only the option with a 3 m deep trench extending to the -15 m depth contour is presented here, for the 3 separate scenarios.

Cost-estimates for the following options could be provided upon specific request:

- *2 m deep trench to -10 m depth contour (Scenario 1, 2 or 3)*
- *3 m deep trench to -10 m depth contour (Scenario 1, 2 or 3)*
- *4 m deep trench to -10 m depth contour (Scenario 1, 2 or 3)*
- *2 m deep trench to -15 m depth contour (Scenario 1, 2 or 3)*
- *4 m deep trench to -15 m depth contour (Scenario 1, 2 or 3)*

5.2.1 Scenario 1: 100% loose material

Mobilisation & preparation	[redacted]	[redacted]
Dredging	[redacted]	[redacted]
Standby (3 weeks)	[redacted]	[redacted]
Backfilling	[redacted]	[redacted]
Dismantling and demobilisation	[redacted]	[redacted]
TOTAL	[redacted]	

5.2.2 Scenario 2: 75% loose material, 25% bedrock

Mobilisation & preparation	[redacted]	[redacted]
Dredging	[redacted]	[redacted]
Standby (3 weeks)	[redacted]	[redacted]
Backfilling	[redacted]	[redacted]
Dismantling and demobilisation	[redacted]	[redacted]
TOTAL	[redacted]	

5.2.3 Scenario 3: 75% loose material, 25% bedrock to be blasted

Mobilisation & preparation	[redacted]	[redacted]
Drilling & blasting (incl. mob/demob)	[redacted]	[redacted]
Dredging	[redacted]	[redacted]
Standby (3 weeks)	[redacted]	[redacted]
Backfilling	[redacted]	[redacted]
Dismantling and demobilisation	[redacted]	[redacted]
TOTAL	[redacted]	

5.3 Conditions

In the aforementioned estimates, no allowance has been made for the following items:

- Maintenance after dredging and backfill operations.
- Attainment of all necessary licenses, permits and other documentation for all plant and equipment required for Scope of Work, including but not limited to clearance through customs.
- Local taxes, royalties, fees, custom duties, temporary import duties and levies of whatever nature.
- Establishment of a base camp
- Any value added taxes (VAT) or any withholding taxes.
- Delays due to the presence of obstructions, ordered stoppages, excess inclement weather or any other operational delays beyond the control of the contractor
- Normal hydrographic surveys only for the dredging and backfilling work are taken into account. No provision has been made for any special surveys or any visual inspections either by ROV's or by divers.
- Estimate is based on today's price level.

6 Conclusions and Recommendations

6.1 Summary and Conclusions

This report discusses the technical feasibility of dredging and backfilling a shore approach trench at L'Anse Amour (Forteau Bay, Labrador) and Mistaken Cove (Newfoundland).

Based on the local boundary conditions, it has been established that a large Backhoe Dredger would be most suitable for dredging and backfilling the trenches.

Based on the available data, it is not possible to determine with certainty the volume of loose material versus the volume of bedrock that would have to be removed. And if bedrock has to be removed, then the local strength of the bedrock needs further investigation.

If the trenches can be designed in such a way that drilling and blasting of bedrock can be avoided, and bedrock volumes remain below approx. 55,000 m^3, then it is likely that the dredging, cable laying and backfilling operations can be completed by a single BHD within one (ice free) working season. And if drilling and blasting is required, and bedrock volumes are sufficiently small (i.e. less than approx. 20,000 m^3), then it would also be possible to complete the activities with a single set of equipment within one working season. If volumes in excess of these (approximate) numbers are encountered, then mobilisation of a second set of equipment could be considered in order to complete the work within one working season.

The cost estimate (for a trench depth of 3 m extended to the -15m depth contour, constructed with a single set of equipment) shows that if 25% of the material is bedrock that can be dredged without pre-treatment (scenario 2), the total cost of the work goes up by approx. 30% compared to the scenario with no bedrock (scenario 1). However, if 25% of the material is bedrock that requires drilling en blasting (scenario 3), then the total cost of the work goes up in the order of 60% compared to the scenario with no bedrock (scenario 1).

6.2 Recommendations

6.2.1 Soil investigation

The most critical parameters that need further detailing are the near-surface soil conditions. This feasibility study has reviewed scenario's which vary in elevation of bedrock (volume to be removed) as well as strength of bedrock (pre-treatment required or not), and it has been shown that these parameters are essential in establishing the duration and cost of the dredging activities.

The bedrock at Mistaken Cove is assumed to be Petit Jardin Formation dolomites & shales. When encountered during dredging, these rock types will seriously lower production rates of a large Backhoe dredger. Without a more detailed knowledge of the bedrock conditions, it cannot be concluded whether a part of these rocks might have to be fractured by drilling and blasting.

The bedrock at L'Anse Amour (Forteau Bay) is assumed to be predominantly Bradore Formation arkose sandstones & orthoquarzites. When encountered during dredging these rock types will most likely have to be pre-treated for the most part by drilling and blasting.

In order to minimize the risk of encountering unanticipated outcrops of hard bedrock it is recommended to carry out a shallow seismic refraction survey at the landing sites of L'Anse Amour and Mistaken Cove. A shallow seismic refraction survey will show the depth of the bedrock together with the seismic velocities of the bedrock material, which is an important parameter to assess the dredgeability of the material encountered in the shore approach trenches.

A shallow seismic refraction survey can either be executed by trailing a sledge plus streamer along the seabed behind a survey-vessel (if water depths will allow), or by physically placing the streamer-cable on the seabed (in case of very shallow waters, that will not allow access to a survey vessel). The latter option is called a "static" refraction survey. This method is generally much more time-consuming than the trailing method, but due to the very shallow waters within Mistake Cove this method will most likely have to be used at least for part of the survey. Boskalis has positive experience with Fugro France, for example, who have performed such refraction surveys on Boskalis' behalf on several occasions. Refer to Appendix 5 for further information on the Fugro France shallow seismic refraction systems (both Gambas (i.e. trailing) and static).

Further soil investigation in the form of bore holes could be very helpful to assess in detail the bedrock conditions along the shore approaches. However, specific locations, depth and number of boreholes should only be determined after analysis of the results of the seismic refraction survey (which will most likely take weeks or even months to execute and post-process). Also, it is noted that drilling of boreholes into bedrock would require mobilisation of a jack-up rig, which would be very difficult to operate in the shallow near-shore waters.

6.2.2 Landing site selection

Mistaken Cove, Newfoundland

At Mistaken Cove, the landing site is assumed to be at the eastern tip of the cove. Here, the purpose of a semi-static shallow refraction survey would be to locate possible buried paleo-channels in the cove (similar to the sediment-filled channel found at Winter Cove further south, according to Ref. [2]). This could be done by first investigating a few refraction lines across the bay (lines 1a, 1b and 1c in Figure 12). These lines would locate areas with sufficient / maximum sediment coverage in the cross-sections. Connecting these favourable areas in the cross-sections with one additional longitudinal line (line 2 in Figure 12), would finally cover the optimal landing route.

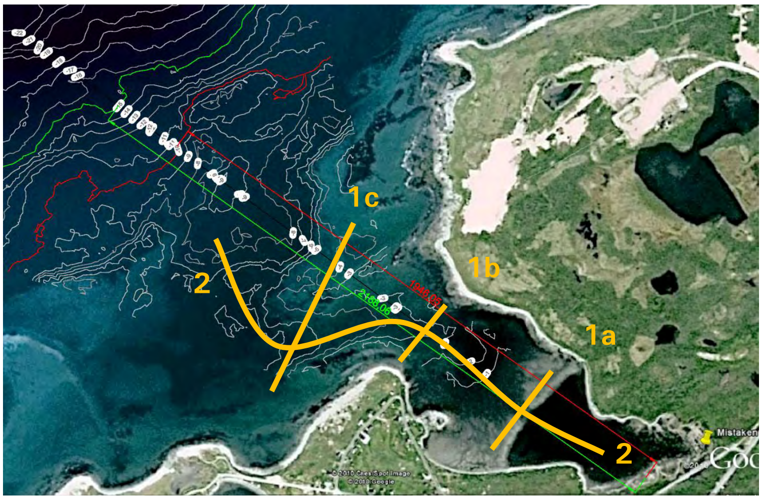

Figure 12: Suggestion for refraction survey lines at Mistaken Cove

If such geotechnical investigation shows that no paleo-channel exists, and/or that significant dredging of bedrock would be required within the cove, then it might be worthwhile to investigate a landing site closer to the mouth of the cove. While it is expected that bedrock levels here will also be close to the surface, it might be worthwhile to reduce the total length of the shore approach, if this also reduces the total amount of bedrock to be blasted and dredged.

<u>L'Anse Amour, Forteau Bay, Labrador</u>
At L'Anse Amour beach, the purpose of a semi-static shallow refraction survey would simply be to establish the level and seismic velocities of the bedrock. One or two relatively short lines parallel to the beach line combined with one line perpendicular to the beach line (along the track of the cables, see Figure 13) will locate the bedrock levels at the landing site and establish the need for pre-treatment or not.

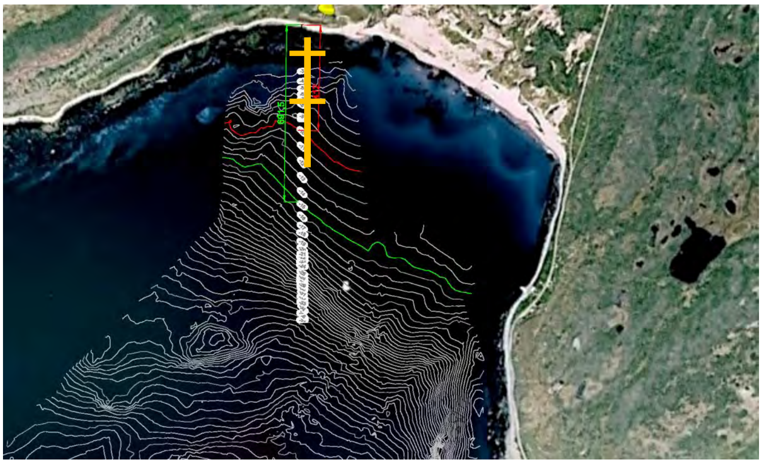

Figure 13: Suggestion for refraction survey lines at L'Anse Amour

The landing site within the L'Anse Amour beach section generally seems to be well selected, to make use of the loose materials overlying the bedrock. Based on available information, it is understood that the location has been selected in the western part of L'Anse Amour beach, possibly to make use of the slightly deeper water in this area. However, from a dredging point of view, it might be preferable to select a landing site further east, in the shallower sections of the L'Anse Amour beach, if loose soil layers on top of bedrock are anticipated to be thicker here. Bedrock levels along the beach could also be established by executing additional refraction survey lines at alternative locations along the beach.

6.2.3 Other recommendations and considerations

- Protection of cables against impact by backfill materials: this feasibility study has assumed that the cables can be laid directly on the dredged trench bottom, and that the dredged material can be backfilled directly on top of the cables, regardless of the type of material that was dredged. Taking into account the likelihood of dredging bedrock, and availability of large rocks/boulders and pieces of bedrock in the backfilling material, it might be prudent to line the trench bottom with sand/gravel prior to installation of the cable, and backfill a layer sand/gravel on top of the cables prior to backfilling with dredged material. This aspect has not been considered here.
- One trench or three trenches: this feasibility study has assumed that the cables can be laid 0.5 m apart in one trench. Whether this is in fact feasible will depend on the type of cable (insulation) and the heat transfer characteristics of the surrounding soil. (Some experience with heat transfer in soils is provided in Appendix 6). If cables have to be placed in separate trenches, the volume to be (drilled, blasted,) dredged and backfilled will increase substantially. Also, it might not be feasible to sidecast dredged material next to the trenches, for later backfilling. This might require temporary (under water) stockpiling of dredged material, with the associated transportation activities (barges).
- Recovery of cables: when looking at which material should be used to backfill the trench, recovery of the cables for maintenance / repair should also be taken into consideration. Using jets would be a logical choice for uncovering the cables, but type (size) of backfill material in combination with cable burial depth might influence feasibility of this method. (Refer to Appendix 7 for an example of Boskalis experience with post-trenching operations. Also refer to www.scanmudring.no for an example of a company offering specialised pipeline and cable intervention equipment).
- Ice coverage in sheltered bays: the ice coverage in the centre of the strait has been investigated thoroughly. The relationship between ice coverage in the centre of the strait versus ice coverage in the bays and coves is not known, and could be investigated by contacting locals. This would give more confidence in the working window used in this study.
- Current velocities and sediment transport: as is mentioned in section 3.5.1, no specific details are known about current velocities in the sheltered bays/coves and nearshore waters. While in general a BHD is well equipped to work in strong currents, such currents might cause sediment transportation (i.e. loss of side-casted material, refilling of the trench prior to and during cable installation). It is recommended to investigate nearshore currents and if possible sediment transportation, so that trench maintenance requirements can be estimated. This aspect has not been included in this feasibility study.
- Drilling and blasting production and cost: as indicated in Table 6 Note **), the blasting production is linked to the volume of bedrock material to be handled. In section 5.1 it is noted that the blasting costs have been estimated based on an assumed layer thickness. In reality, both the production and the cost of blasting will most likely be dependent on both the surface-area as well as the layer thickness to be treated.

In relation to the production assumed in Table 6, one could question whether the duration of blasting would increase so dramatically from a 2m deep trench to a 4m deep trench (both with 25% bedrock), although it might indeed be the case if the surface area where bedrock is encountered increases in line with the increased trench depth.
Blasting production and cost estimates can be reviewed and detailed further when a more clear picture of blasting requirements is available. (Refer to Appendix 8 for details of Boskalis' drilling and blasting department)

- Working in one season or two: this study has assumed that the dredging, cable installation and backfilling operations should take place within one working season. As discussed in section 4.5.2, depending on which trench depth / length and which soil scenario are applicable, this might require mobilisation of a second dredging and/or blasting plant. Another alternative might be to spread the activities over two working seasons. In this case, the most logical split would be to perform the drilling and blasting in one season, and the dredging, cable installation and backfilling in the next. This way, negative impacts on constructed work (such as siltation of trench) can be avoided, and major equipment would not have to be mobilised twice.
- Trench width in relation to side casting: from a dredging and backfilling point of view, no distinction is made in this study between the options with a trench depth of 2 m, 3 m or 4 m. But in reality, a 4 m deep trench with 1:3 side slopes will become so wide (>25 m) that it may become impractical to side-cast all material to one side of the trench. It might become necessary to side-cast material on both sides of the trench, or place material in a temporary (underwater) stockpile, and these activities would be more time-consuming. This detail has not been taken into account in this feasibility study.
- Side slopes of trench: the assessments included in this feasibility study all assume a trench side-slope angle of 1:3 (v:h), based on loose overburden material, regardless of the material to be dredged. In reality, the side-slope angles in bedrock material could be considerably steeper, reducing the volumes to be dredged, and thus reducing the duration and the cost of the work.
- Value engineering: based on additional investigation results (soil, currents, ice coverage, ice gouging depths) and project specifications (cable, insulation, strength), the design of the shore approaches and adjacent cable route sections can be detailed and optimised to ensure that the required cable protection can be realised at minimum cost.

Appendix 1: References

[1] *Scope of Work – Strait of Belle Isle (SOBI) shore Approach Feasibility Study*
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[2] *Lower Churchill Hydro Development - Proposed Subsea HVdc Cable Route*
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[4] *Lower Churchill Hydro Development - Bedrock Tunnel Route Survey*
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[5] *Lower Churchill Hydro Development - Bedrock Tunnel Route Survey*
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[6] *Admiralty Sailing Directions NP 50 – Newfoundland and Labrador Pilot*
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[7] *Summary of Ocean Current Statistics for the Cable Crossing at the Strait of Belle Isle*
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[8] *Chart 4735*
Canada Hydrographic Service, Edition Number 1, Edition Date 7th June 2007

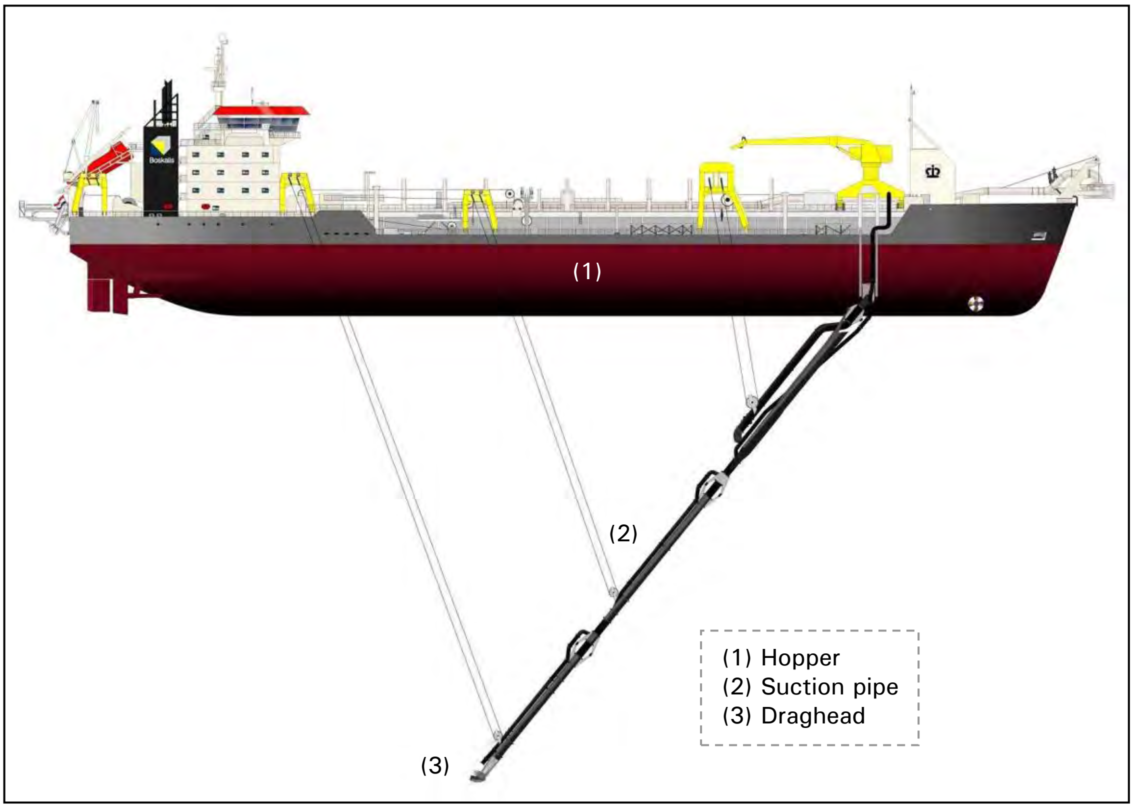
Appendix 2: General description of dredging equipment

- Trailing suction hopper dredger (TSHD)
- Cutter suction dredger (CSD)
- Backhoe dredger (BD)

Trailing Suction Hopper Dredger (TSHD)

General Description TSHD

A TSHD is a sea-going self-propelled vessel equipped with one or two suction pipes, designed to trail along the side of the vessel. At the lower end of the suction pipe a draghead is fixed. Suction is provided by a centrifugal pump, which discharges the mixture of soil and water in the hopper well. A TSHD may be typically equipped with a dynamic positioning and dynamic tracking system.



General layout TSHD

In principle the main parts of the TSHD are:

- the hull, containing the engines, propulsion, pump(s), the crew quarters, the bridge with the navigational control etc;
- the hopper well where, from the pumped mixture of soil and water, the soil settles down and the water is discharged through an overflow system;
- the suction pipe(s) through which the mixture is transported to the pump;
- the draghead(s), connected to the end of the suction pipe.

Work Method Trench Dredging TSHD

Prior to the start of the trenching operations a hydrographic survey of the dredge area will be executed.

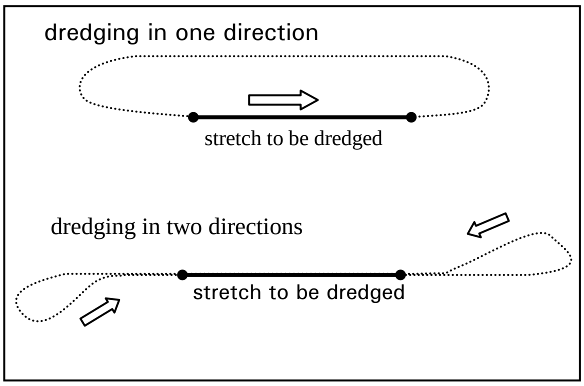
Upon completion of the survey operations the TSHD will sail to the area where the trench shall be excavated. Once in the vicinity of the trenching area the TSHD will position itself along the theoretical centreline of the trench, in accordance with the Contractual Drawings, and lower the suction head (draghead) onto the sea bottom.

The vessel will sail slowly along the centreline at a speed of 1 to 1.5 m/s while removing the soil material by use of centrifugal pumps pumping the dredged materials into the vessel's hopper well. During this process, the draghead will be kept continuously at a controlled position (see section Dredging Control TSHD).

The draghead with the aid of the water jet system cuts and erodes a soil layer. The draghead's height above seabed, thrust and jetting pressure can be adjusted to suit the soil conditions. The centrifugal pump brings up the soil and water mixture through the draghead and suction pipe and pumps the mixture into the hopper well. Most of the solids will settle in the hopper well and the water, together with the suspended fine solids, is discharged through an adjustable overflow system.

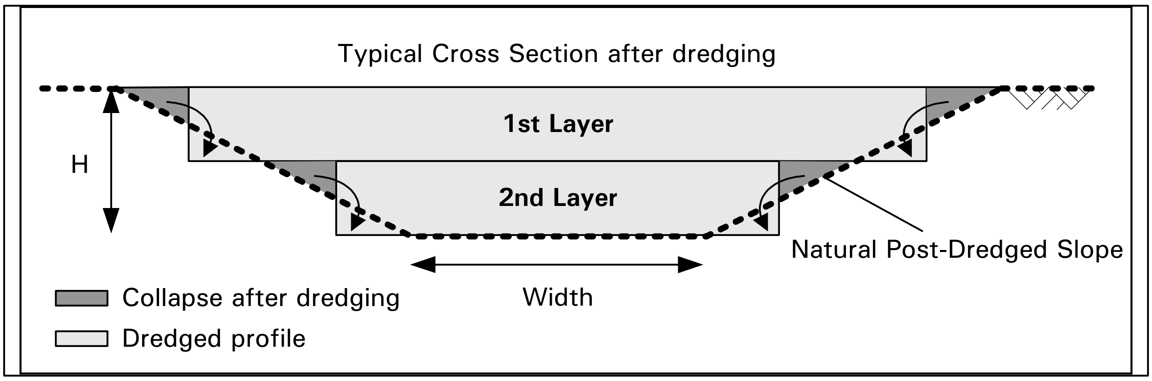
When the draught of the vessel reaches the dredging load mark, dredging will be stopped and the suction pipe is hoisted on deck.
The vessel then sails with the dredged materials to the temporary offshore stockpile, where the load is dumped by controlled opening of the bottom doors.
The distribution of the dumped materials shall be controlled by the speed of the vessel while dumping. Once empty, the bottom doors are closed and the vessel returns to the trenching area.

Using the positioning capabilities of the TSHD, a stretch will be dredged in one or two directions depending on the realised trench depth, weather and current. During each stretch an amount of soil will be removed, depending on the soil characteristics. This scheme will be repeated until the stretch is at the desired depth.



Dredging a trench in stretches

To minimise the number of turns for each load the length of each stretch will be adjusted accordingly. The slope to be dredged and the target dredge levels will be input to the dredging control computer. The trench will be dredged using the Box-cut Method. The number of box-cut layers will depend on the soil type and the total depth of trench to be dredged.



Box-cut Method

If necessary, overdredging may be carried out to create additional buffer for siltation.

Work Method Trench Backfilling TSHD

After completion of the cable installation the trench will be backfilled.

Backfilling will be performed with dredged soil from the temporary offshore stockpile or surrounding area (indigenous soil). After dredging the backfill material will be placed into the trench either by discharging via bottom doors (dumping), by discharging via the suction pipe or discharging via a floating pipeline connected to a spreader pontoon. Backfilling will be completed when the trench is backfilled till the required level for that particular section.

Dredged/excavated material from the trench will be considered suitable backfill material. It should be confirmed that overdredging in the stockpile areas during backfilling will be acceptable and stockpile areas will be left as is after completion of backfill operations without further rectification.

Dredging Control TSHD

Dredging control for the TSHD is maintained by means of the following systems and equipment:
- Positioning System;
- Suction Tube Position Monitoring System (STPM).

Dredging control is based upon a vessel positioning system. For this purpose, RTK-Differential Global Positioning System (RTK-DGPS) with differential signals transmitted to the vessel via commercial satellite will be used to provide horizontal position data for the vessel.

The positioning computer determines the actual ship and draghead position and presents the results, relative to the area to be dredged, on navigational displays.

These results are derived by calculation from the X, Y, Z inputs from the RTK-Differential Global Positioning System (RTK-DGPS) / STPM System as described below and the ship's bearing provided by the gyrocompass. The positioning computer also determines the actual vertical offset of the draghead as compared to the target dredge depth.

Information outputs from the computer include:

- Plots of dredged / dumped tracks.
- Position of vessel and draghead visualised on screen on a background of bathymetric data, obstacles, buoys and special features such as the presence of existing cables. For example a plan view with a differential colour chart showing the amount still to be dredged, together with a longitudinal and cross profile every 10m of the trench marking seabed level and target level.

The STPM is a system comprising pressure and angle transducers, which determines the drag-head position relative to the ship. This makes relative X, Y and Z co-ordinates of the draghead available to the positioning system and dredging control computers.

Through the dredging control computer all the dredging processes such as the dredging level of the draghead, pump settings and bottom doors are controlled.
The interface between the positioning computer and the dredging control computer enables control of the dredging process to pre-defined levels put into the system from pre-dredge survey information and trench design requirements.

Survey Operations

If the proposed vessel is not equipped for survey operations, other suitable equipment will be deployed. All surveys will be carried out along pre-determined lines. The limits of the corridor width will be established in consultation with the Client.

Pre-dredge/backfill survey
The purpose of this survey is to establish the starting point prior to any dredging / backfilling operations. The pre-survey will consist at least of a longitudinal survey along the centreline of the proposed route.

Intermediate survey
The purpose of intermediate surveys is to monitor progress and ensure that the required alignment, levels and limit adherence is being maintained. The frequency of these surveys is dependent on rate of progress and accuracy levels called for.

Post-dredge/backfill survey
The purpose of the post-dredge/backfill survey is to ascertain that the required alignment, levels and limits have been achieved. This survey is done along the same lines as were used for the pre-dredge/backfill survey.

Cutter Suction Dredger (CSD)

General Description CSD

A CSD is a spud-based dredger equipped with a rotating cutter head and centrifugal pumps.

In principle the main parts of the dredger are:

- the hull, containing the engines, propulsion, pump(s), the crew quarters, the bridge with the navigational control etc.;
- the cutter ladder, containing the cutter head, which cuts the underwater soil and the underwater pump which pumps up the mixture of soil and water;
- the spud poles and spud carrier which provide the forward movement;
- the anchors and side winches which provide the sideward movement.

Different types of cutter heads can be fitted depending on the soil conditions.

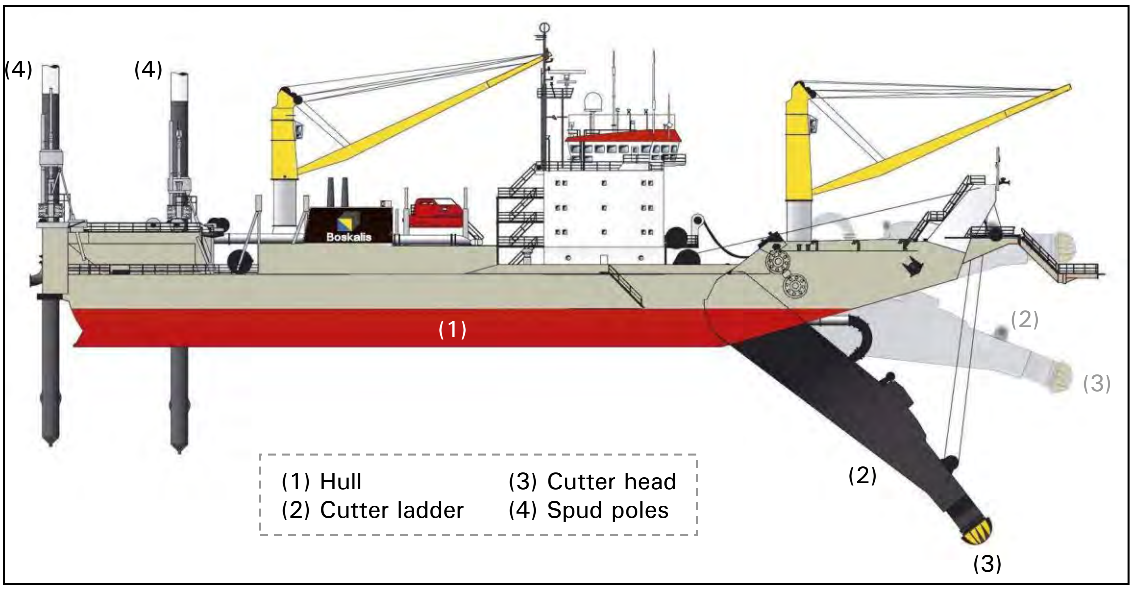


Figure 1 General layout CSD

Work Method Trench Dredging CSD

The CSD will dredge the trench and subsequently pump the dredged material through a floating pipeline into a temporary underwater stockpile. A spreader pontoon equipped with an underwater diffuser will be attached to the end of the floating pipeline in order to control the disposal of the dredged material in the stockpile area. A 4-points mooring anchoring system will control the spreader pontoon position.

To start dredging operations, the CSD will position its working spud in the axis of the trench. The side anchors are placed outside the trench by means of the dredger's anchor booms.

During the dredging activities, the CSD swings around the working spud with the help of its side winches.

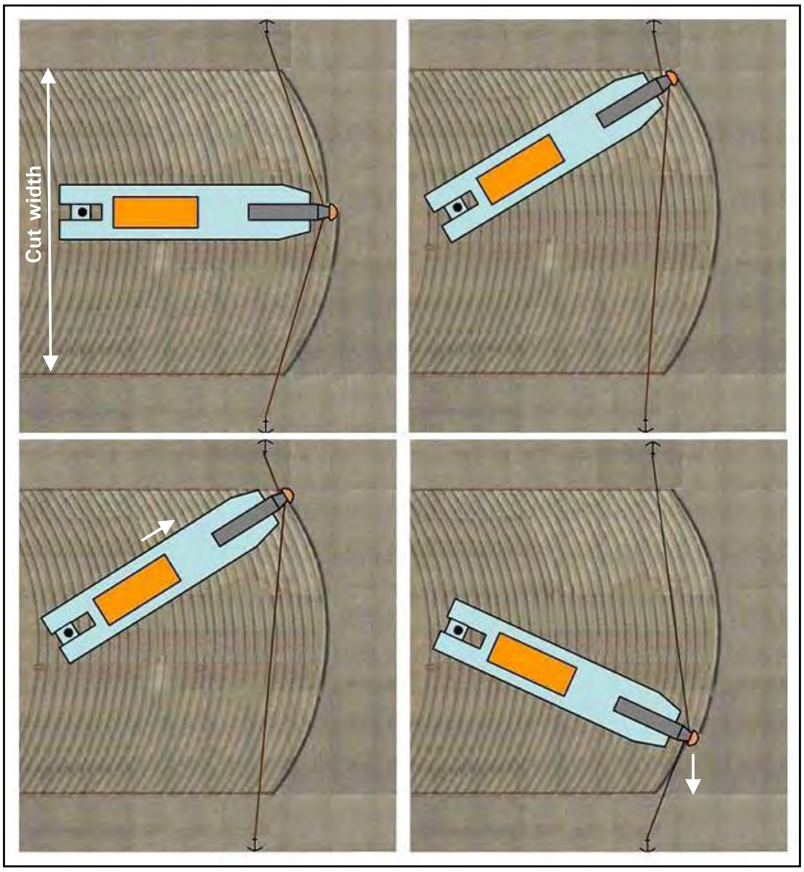


Figure 2 Work Method CSD

In shallow waters, a CSD may have to dredge a so-called "access channel" to provide access for itself to carry out its dredging operations. This "Access channel" should be wide enough to allow the dredger to swing from side to side.

The trench will be dredged using the Box-cut Method. The number of box-cut layers will depend on the soil type and the total depth of trench to be dredged.

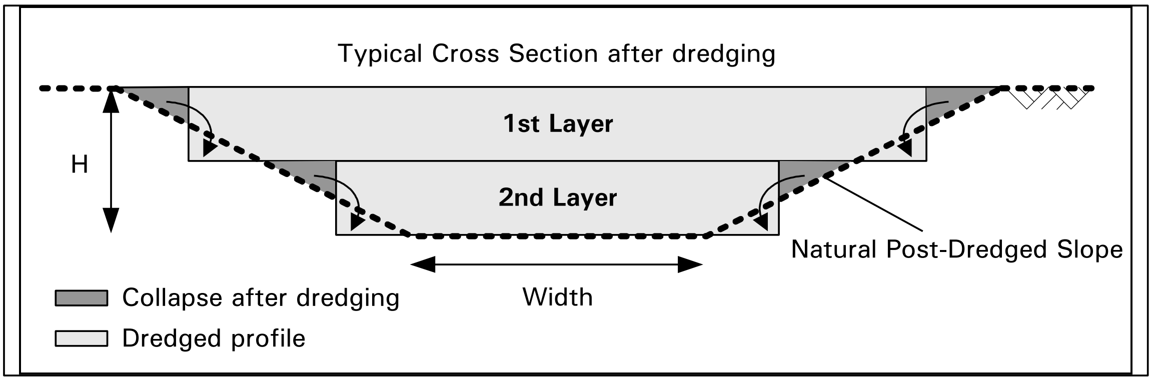


Figure 3 Box-cut Method

If necessary, overdredging may be carried out to create additional buffer for siltation.

During the dredging operations, regular interim surveys will be carried out to verify achieved depth, volumes and alignment of the works.

Work Method Trench Backfilling CSD

After completion of the cable installation the trench will be backfilled. The previously dredged materials that had been stockpiled on the seabed in the vicinity of the pipeline trench will be re-dredged by the CSD.

The CSD will pump the dredged materials back into the trench through the floating pipeline and the spreader pontoon. The spreader pontoon will be equipped with an underwater discharging device to assure an even spreading of the dredged materials into the trench.

Dredged/excavated material from the trench and placed in stockpile areas alongside the trench will be considered suitable backfill material. Overdredging in the stockpile areas during backfilling will be acceptable and stockpile areas will be left as is after completion of backfill operations without further rectification.

Dredging Control CSD

Dredging control for the CSD is maintained by means of the following systems and equipment:

- Positioning System
- Cutter Operating System

Dredging control is based upon a vessel positioning system. For this purpose, a DGPS system with differential signals transmitted to the vessel via commercial satellite will be used to provide horizontal position data for the vessel.

The positioning system determines the actual vessel and cutter head position and presents the results, relative to the area to be dredged, on navigational displays. These results are derived by calculation from the X, Y, Z inputs from the survey system and the vessel's bearing provided by the gyrocompass.

Information provided by the Cutter Operating System includes:

- position of vessel and cutter head visualised on screen;
- bathymetric data;
- differential colour chart showing the amount still to be dredged;
- longitudinal and cross profiles of the trench marking the original seabed level and the design level;
- plots of dredged tracks;
- dredging progress based on assumptions with regards to production.

Survey Operations

If the proposed vessel is not equipped for survey operations, other suitable equipment will be deployed. All surveys will be carried out along pre-determined lines. The limits of the corridor width will be established in consultation with the Client.

<u>Pre-dredge/backfill survey</u>
The purpose of this survey is to establish the starting point prior to any dredging / backfilling operations. The pre-survey will consist at least of a longitudinal survey along the centreline of the proposed route.

Intermediate survey

The purpose of intermediate surveys is to monitor progress and ensure that the required alignment, levels and limit adherence is being maintained. The frequency of these surveys is dependent on rate of progress and accuracy levels called for.

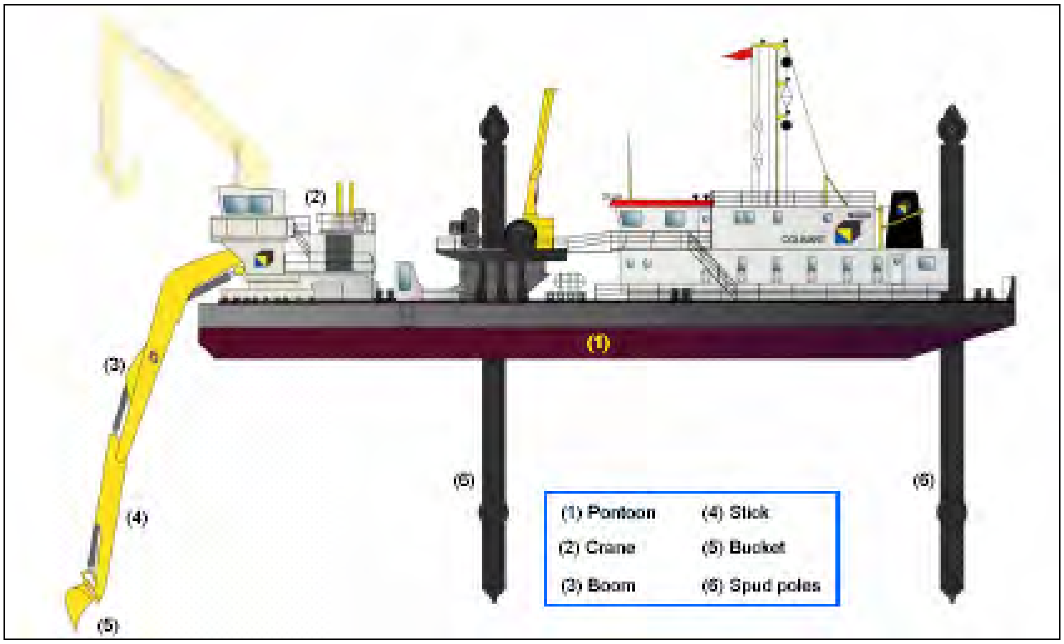
Post-dredge/backfill survey

The purpose of the post-dredge/backfill survey is to ascertain that the required alignment, levels and limits have been achieved. This survey is done along the same lines as were used for the pre-dredge/backfill survey.

Backhoe Dredger (BHD)

General Description BHD

A Backhoe Dredger (BHD) is basically a hydraulic excavator placed on a pontoon. Dredging is executed by the excavator which is mounted on a turntable at the front of the pontoon.



General layout Backhoe dredger

In principle the main parts of a BHD are:

- the pontoon;
- the hydraulic excavator, consisting of a crane, boom, stick and bucket;
- the spud poles and spud carrier. Spud poles provide a stable platform during dredging. The spud carrier enables the pontoon to move forwards and backwards when the front spuds are lifted.

Depending on the soil conditions different buckets can be used. A BHD is suitable for dredging a wide range of materials, from soft material (like soft silt) to hard material (like blasted or weathered rock and stiff boulder clay). Also boulders or debris can be removed. Depths up to 20 meters can be achieved with a BHD. The BHD is mainly used in harbours and other shallow waters.

Although a BHD is a stationary dredger it is a limited obstacle to shipping traffic (no anchor winches). It is especially suitable for working in narrow areas and in the near presence of obstacles (like jetties, quay walls, pipelines, etc.). The backhoe dredger can also be used to create or trim slopes.

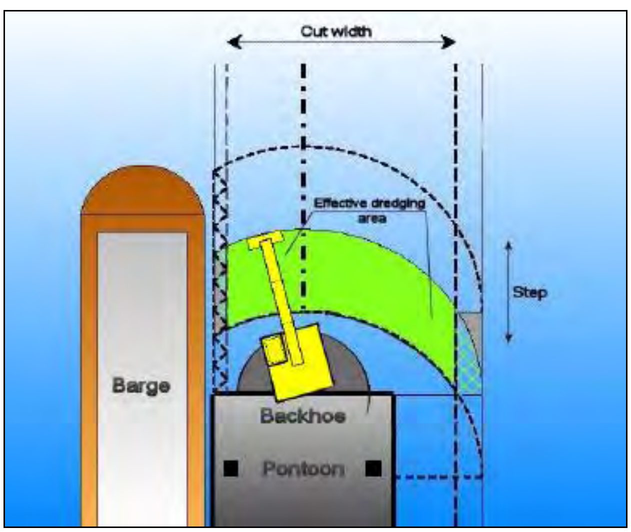
Work Method Trench Dredging BHD

To start dredging operations, the BHD will be towed to the location to be excavated, and will usually be positioned in line with the trench to be excavated. The BHD will position its spuds in the soil.

Dredging with a BHD is not a continuous process, but consists of a cycle of operations:

- Dredging: the bucket excavates soil by a combined back- and upward movement of boom, stick and bucket
- Lifting: when the bucket is filled, a further upward movement of the boom and stick ensures sufficient height above the seabed to start swinging.
- Swinging filled: the bucket will swing sideways above the discharge area by turning the excavator on the turntable. Often discharging will be done into barges (for transportation), but in some cases, such as trench dredging, the material may also be discharged onto the seabed next to the dredger, i.e. side-casting.
- Unloading: positioned above the discharge area the bucket is moved outwards (down) and the soil will then be unloaded.
- Swinging empty: upon completion of discharge the excavator will swing back empty to the dredging area
- Lowering and positioning: the boom will be lowered and the stick and bucket will be moved to their starting position. With aid of a dredge viewer the bucket penetrates the soil on the desired location.

On each position of the pontoon an area as large as practically possible will be dredged (effective dredging area). Upon completion of the dredging within this area, the pontoon will use its spuds to ‘step’ to a new position adjacent to the previous one.



Backhoe Dredger dredging

In very shallow waters, a BHD may have to dredge a so-called "access channel" to provide access for itself to carry out its dredging operations. This "access channel" should be wide enough to allow the width of the pontoon to float freely.

Even though a BHD is very capable of dredging trim side-slopes, a cable trench will be dredged using the Box-cut Method. The number of box-cut layers will depend on the soil type and the total depth of trench to be dredged.

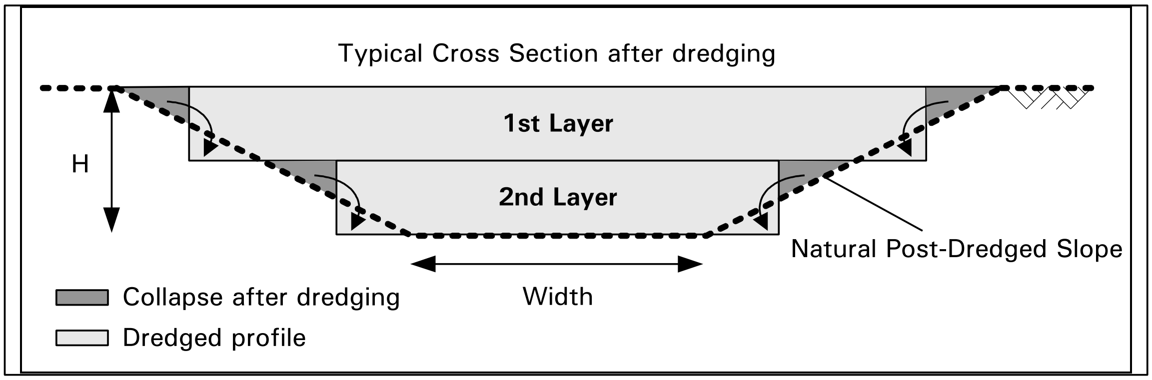


Figure 1 Box-cut Method

If necessary, overdredging may be carried out to create additional buffer for siltation.

During the dredging operations, regular interim surveys will be carried out to verify achieved depth, volumes and alignment of the works.

Work Method Trench Backfilling BHD

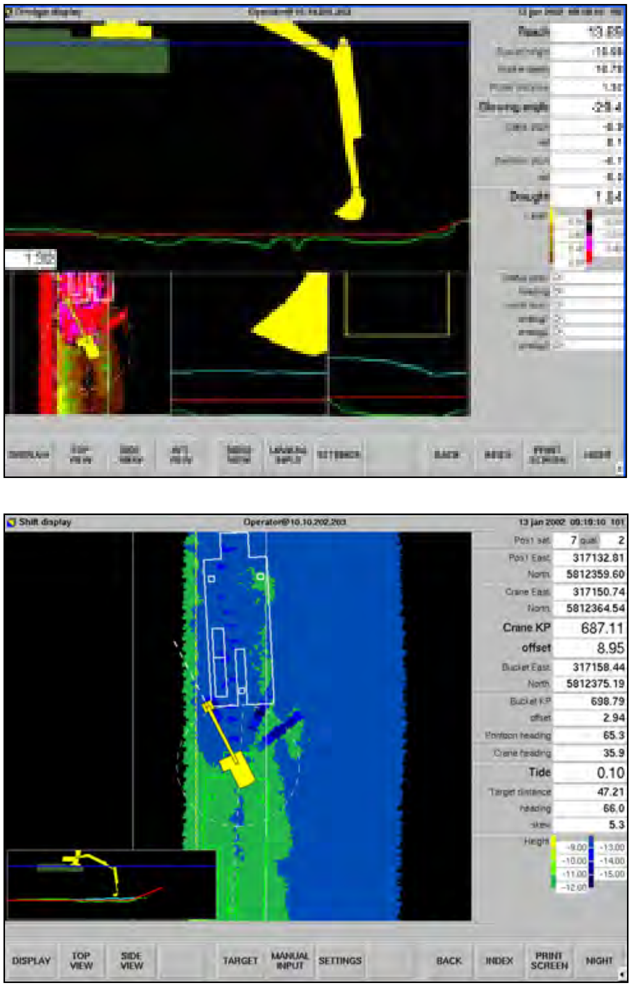
After completion of the cable installation the trench will be backfilled. The previously dredged materials that had been sidecasted on the seabed parallel to the trench will be re-dredged by the BHD and deposited into the trench.

Dredging Control BHD

The data from the pre-survey of the dredge areas will be worked into a dredging scheme and the data is fed into the onboard computer of the BHD.

The control of the dredging process is done by means of the dredging computer and the positioning system. The positioning system will be Differential Global Positioning System, DGPS. The output of this positioning system will be X, and Y co-ordinates of the vessel. With the pontoon's bearing, provided by the gyro-compass, a fully determined position is available.

Crane bucket position is determined relative to the pontoon and dredge layer by a dredge viewer and/or Crane Monitoring System.



Dredging control

Survey Operations

If the proposed vessel is not equipped for survey operations, other suitable equipment will be deployed. All surveys will be carried out along pre-determined lines. The limits of the corridor width will be established in consultation with the Client.

<u>Pre-dredge/backfill survey</u>
The purpose of this survey is to establish the starting point prior to any dredging / backfilling operations. The pre-survey will consist at least of a longitudinal survey along the centreline of the proposed route.

<u>Intermediate survey</u>
The purpose of intermediate surveys is to monitor progress and ensure that the required alignment, levels and limit adherence is being maintained. The frequency of these surveys is dependent on rate of progress and accuracy levels called for.

<u>Post-dredge/backfill survey</u>

The purpose of the post-dredge/backfill survey is to ascertain that the required alignment, levels and limits have been achieved. This survey is done along the same lines as were used for the pre-dredge/backfill survey.

Appendix 3: Typical details of large BHD (Nordic Giant)

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e-mail royal@boskalis.nl, internet www.boskalis.com

Nordic Giant

Backhoe dredger

Main data

Built by	Port Said Engineering Works, Egypt/ Turku Repair Yard, Finland
Year of construction/modification	1999/2002
Classification	B.V. I HULL Dredger no propulsion. Unrestricted navigation.
	Dredging within 15 miles from the shore, or 20 miles from port
Gross tonnage	1,090 Ton
Length overall	55.00 m
Length pontoon	55.00 m
Breadth	17.00 m
Moulded depth	4.00 m
Normal draught	3.00 m
Type of excavator	Liebherr P995
Bucket capacity mud bucket	22.00 m^3
Bucket capacity H.D. bucket	9.00 m^3
Maximum dredging depth	27.00 m
Anchoring system	3 spuds / Tilting spud
Total installed power	2,000 kW
Excavator engine power	1,600 kW

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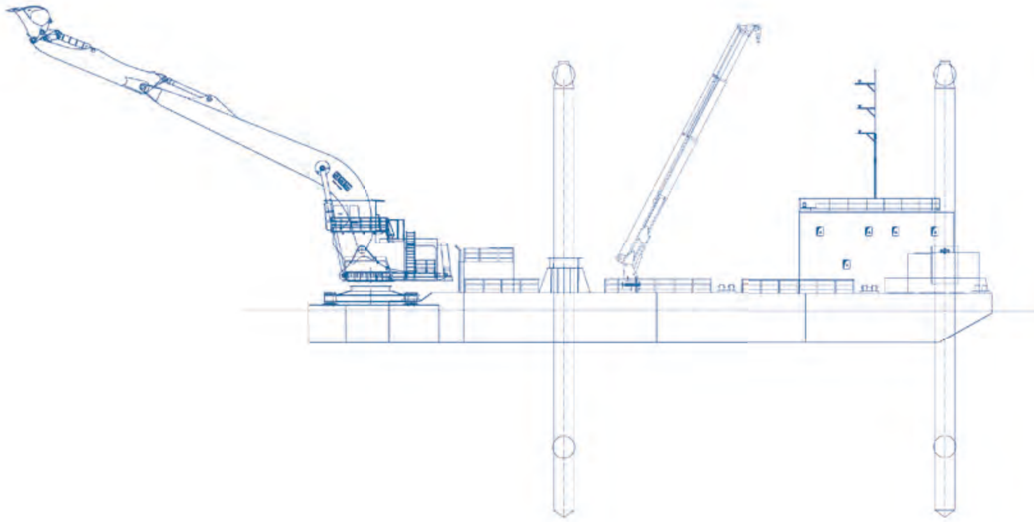
Telephone +31 78 69 69 000, telefax +31 78 69 69 555
e-mail royal@boskalis.nl, internet www.boskalis.com

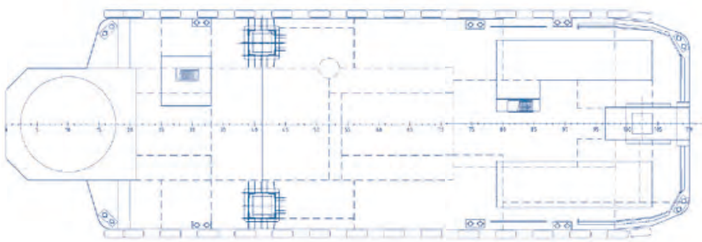
Nordic Giant

Backhoe dredger

Side view



Top view deck level



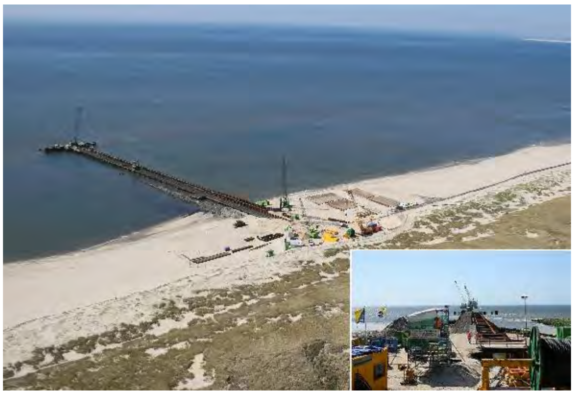
Appendix 4: Example of cable installation method statement

EXAMPLE

METHOD STATEMENT

CABLE INSTALLATION AND SHORE APPROACHES

NALCOR ENERGY



Rev.	Date	Revision Description	Author	Reviewed
0	07-10-10	Example Method Statement	THWE	

Revision Record

Rev. No	Date	Section	Page	Reason

TABLE OF CONTENTS

1. Introduction

Boskalis Offshore and Visser & Smit Marine Contracting have a broad experience in offshore cable installation and all related activities. Both companies also have a wide experience with working under strict SHE-Q requirements of the Oil and Gas Industry.

This method description gives a general overview of typical activities that are executed on Submarine Cable Installation Projects. Together Boskalis Offshore and VSMC have experience in all activities mentioned in this document.

Boskalis Offshore (BO) is global market leader in the field of offshore contracting and engineering in general in the field of soil and rock interventions. The company is part of international dredging and marine contractor Royal Boskalis Westminster Group and focuses on upstream oil & gas clients offering them a complete range of services. Uniquely, it functions as a "one-stop-shop" for all matters related to "earth-moving" activities, from feasibility studies and design engineering to dredging, shore approaches and rock placement.

The principal services of Boskalis Offshore comprise pre-sweeping, (deepwater) dredging, pre-trenching, post-trenching, rock dumping and sand placement.

Boskalis Offshore is backed by the dense global network of the Royal Boskalis Westminster group. Including its share in partnerships, Boskalis has approximately 8,000 employees and operates in over fifty countries on five continents.
The company's commitment to safety, health, environment and quality is reflected in the acquired ISO 9001, ISO 14001 and OHSAS 18001 certification.

Visser&Smit Marine Contracting (VSMC), through its mother company Visser & Smit Hanab (V&SH) has secured several decades of experience in the field of engineering and installation of MV and HV power cables.

With the experience of the last few years in offshore renewable projects in Denmark, Germany, Belgium and UK, VSMC has proven to be one of the major European players in the world of installing underground and submarine power cable grid connections.

Through VSMC subsidiary offices in United Kingdom and Germany VSMC is able to serve Clients and support the projects where needed.

VSMC is backed up by the Royal Volker Wessels Group, an international building construction company with more than 17.000 employees and consisting of more than 120 companies with activities in Europe and North America.

Boskalis Offshore bv

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1.1 Contact persons

1.2 Description of the work

1.3 Definitions

CLV	: Cable Lay Vessel
DP	: Dynamic Positioning
PLGR	: Pre-Lay Grapnel Run
ROV	: Remote Operated Vehicle
TOC	: Top Of Cable

2. Project Information

2.1 Cable Data

Cable Specification is as follows:
To be detailed

2.2 Cable Route

The total offshore route length of the connection is approximately 100 km for all three cables. Detailed survey details along the route are provided in below map (to be detailed).

2.3 Burial requirements

To be detailed.

2.4 Survey Work

Surveys required are the ROV pre and post lay surveys, plus other standard surveys. Pre survey will most likely occur in one campaign, as will pre-engineering, for all three cables. The Pre survey will most likely consist of a ROV survey of the route.

Also a bathymetric survey and hazard route survey should be conducted. Post survey will most likely be executed in 3 separate campaigns. To be detailed.

2.5 Cable and Pipeline Crossings

To be detailed (if applicable).

3. Working Method PLGR

3.1 Introduction

Prior to the cable lay operations a pre-lay grapnel run (PLGR) can be performed. For this operation Contractor would use a capable vessel to perform the scope of work.

3.2 Vessel specification

The PLGR vessel will have the following specifications and equipment:

- Capable Winch with sufficient wire and tension measurement;
- 24h / 7 day operations;
- Capable of 15 days offshore;
- Grapnel equipment, including but not limited to rennies, giffords, spear points, flatfish, cutting grapnel and de-trenching grapnel;
- Client office;
- Survey suite;
- Accommodation.

3.3 Mobilisation

Contractor will have performed the following engineering:

- Deck Lay Out;
- Sea-fastening calculations;

At the port of mobilisation all required grapnel equipment and a winch will be mobilised. After the mobilisation the vessel will start PLGR work as close to shore as possible.

3.4 Pre-lay Grapnel Run

Contractor will execute pre-lay grapnel runs along the centreline of the designated cable routes in order to locate any surface debris that could hamper cable-laying operations.

In principle only one pre-lay grapnel run will be executed along the centreline of the designated cable routes. The pre-lay grapnel run will be executed on a reasonable endeavour basis and will only locate surface and shallow buried debris.

Any small debris found during the pre-lay grapnel run will be removed from the seabed and will be stored on the vessels deck. In the event of large-scale debris that cannot be removed or when debris is encountered of a special nature, Contractor will seek instruction from the Client's onboard representative and mutually agree corrective measures, including possible re-routing of the cable. Since it is impossible at this stage to estimate the quantity of debris we may encounter, or the difficulty that may be encountered in removing it and disposing of it, the time it takes to remove it once discovered will be for the Client's account and properly recorded and signed off in daily reports.

The PLGR would be performed up to 250m from any crossing with another cable or pipeline, if applicable.

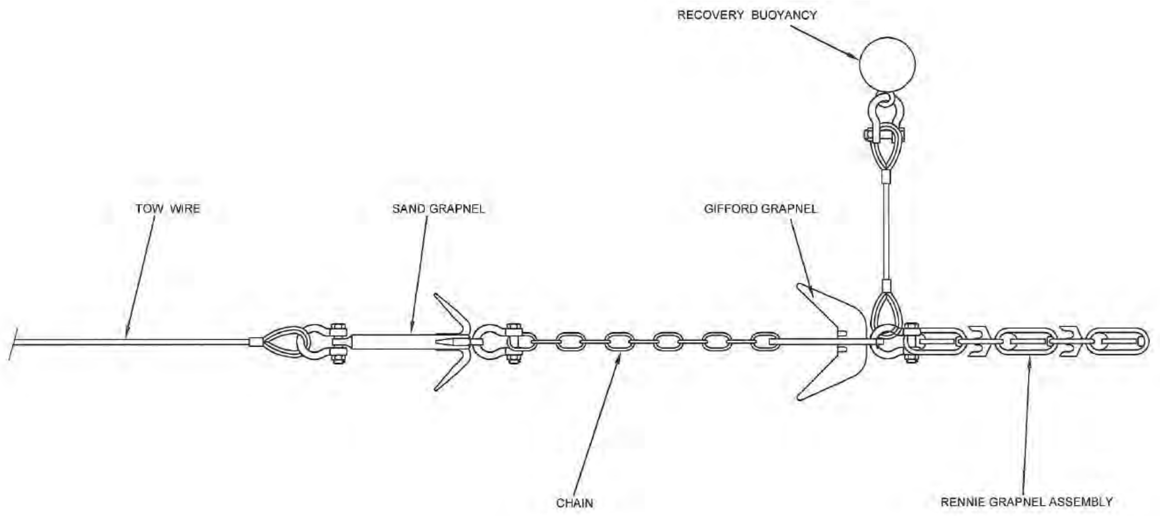


Figure 1 - The towed Grapnel

3.5 Demobilisation

Once PLGR operations are complete, the vessel shall transit to the demobilisation port to unload all nonessential equipment and allow personnel to disembark. Any debris recovered during the PLGR operations will be safely unloaded onto the quay for disposal. The recorded data will be sent to Contractor's main office for final report preparation. The vessel will then sail to its home port for final demobilisation.

3.6 Reporting

The following reports will be produced:

- Mobilisation report;
- Operation log book;
- Daily Progress Report;
- Data log files;
- PLGR Final report;

4. Cable Laying Preparations

4.1 Consents and Agreements

Operational notifications necessary to operate in Canadian waters (eg. Notice to Mariners) will be made to the appropriate authorities. Such notifications will be made in sufficient time prior to operations. Marine operations will only commence once these notifications are made and all other permissions are secured. During such operations, notifications regarding vessel movements will be made to the necessary local Authorities responsible for managing vessel movements in the area.

Excluded are all applications for regulatory licences, permits and wayleaves that may be necessary for this submarine power cable installation project, which are the responsibility of the Client. Contractor will provide the Employer/Client with all reasonable assistance during the permitting process to expedite these regulatory licences, permits and wayleaves.

Any delays resulting from the lack of any permits and/or permissions that are the responsibility of the Client shall be chargeable at a rate that is commensurate with the value of any loss incurred by Contractor because of the delays.

Requirements for any environmental or fisheries reports, marine biological surveys or monitoring studies to be detailed (if applicable).

4.2 Interface with other Works

Contractor will co-operate, liaise with and attend interface meetings with Client and other Contractors engaged on completing the works. In particular, Contractor anticipates interfacing on:

- On-shore cable installation;
- Cable design and supply;

Contractor will provide reasonable facilities to allow Client's representatives to inspect and report on the works carried out by Contractor.

4.3 Facilities

Offshore the following facilities will be made available to the Employer on the various resources proposed: to be detailed.

4.4 Route Engineering

Based on marine survey results, Contractor will check the current route design and together with the Employer will advise on possible cable route changes to avoid obstacles.

4.5 Installation Engineering

On completion of the route engineering Contractor will confirm final cable length specifications to the Client. Contractor will undertake all engineering required to support the safe and efficient load-out, transportation and installation of the cable in accordance with the Employer's requirements. Contractor utilises a specialised modelling program called Orcaflex to simulate the tension loads on the cable during cable lay.

Contractor installation engineering covers the submarine cable installation including, where relevant, but not limited to, the following activities:

- equipment mobilisation and installation onto vessels;
- vessel selection criteria and auditing procedures;
- receipt, handling and storage of components;
- load-out, transportation and sea-fastening;
- subsea cable route design liaison;
- pre lay grapnel run;
- temporary works;
- special equipment.

4.6 Contingency Planning

Contractor will prepare contingency plans to cover unplanned events that may be prudent and can be foreseen as potentially having an adverse effect on the Project. A full Hazard Identification and Risk Assessment (HIRA) will be conducted prior to commencement of the offshore works.

4.7 Selection of Installation Vessels

The Contractor is proposing to use the CLV [to be detailed] for this project.

As an example, we provide a description of CLV Seahorse below. This vessel is exceptionally large in the market, and capable of operating in high seas. It is equipped with a 7,000 ton turntable, in combination with a static coil of a similar capacity. The total loading capacity of the vessel is 16,000 ton. This vessel is one of the few CLVs on the market capable of transporting such loads.

Figure 2 – CLV Seahorse

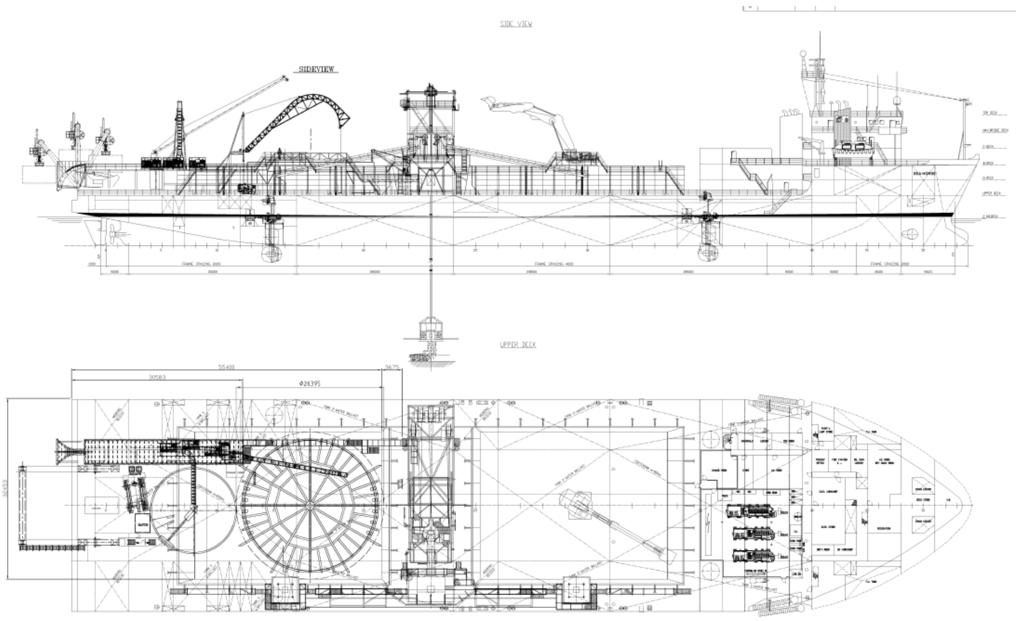


Figure 3 – CLV Seahorse conversion with one turntable and one Static Coil

4.8 Overall Approach

The CLV Seahorse would be mobilised from [to be determined] and travel first to the cable manufacturer's yard to pick up the cable. When the cable has passed its tests and the equipment has been seafastened, the vessel will depart for the shore approach location where the first pull in work will take place.

For laying the cables will be fed through a tensioner and over a cable chute in a controlled catenary to ensure the minimum bending radius is not compromised and minimise the risk of loops forming.

Safety of personnel (both operational and public) is paramount at all times during the cable installation operations where ropes and wires are under tension in public areas. The Contractor will work with the local authorities to ensure the operational area is restricted to operational staff only. Security will, if necessary, be deployed to ensure the general public remain safe and operations carried out in accordance with Boskalis Offshore procedures, Health & Safety Plans and Project Risk Logs. Appropriate barriers, safety walkways and illumination will be provided prior to the commencement of the beach operations.

4.9 Vessel Mobilisation

Contractor will mobilise the CLV complete with Turntable equipment at [to be determined]. The vessel's cable laying equipment will be calibrated and documented prior to load out operations. Cable pathways will be checked for conformity to manufacturer's specifications.

Upon mobilisation the vessel will proceed to the cable manufacturer's factory for loading. The following equipment, or equivalent, will generally be mobilised for the cable installation:

- Main Cable Lay Vessel (CLV) equipped with turntable, tensioner, bundling machine & inspection ROV for touch down monitoring and mooring system for use in performing the shore landing work.
- Shore End pulls: winch & beach team personnel, and float out assist vessels
- Crew transfer vessel:platform access and vessel support (windcat or equivalent)

Naturally, given the distance for cable transport, the support vessels, equipment and personnel will only be mobilized when the cable lay work is about to start.

Prior to the start of cable lay, the following spreads will be mobilised for preparation of the cable route:

- Pre- Lay Crossing Protection Installation Vessel: if required
- Pre Lay Grapnel Run Vessel: if required.

4.10 Cable Loading

At the cable loading facility the CLV will moor such that cable loading can commence. A pre-load meeting will be held prior to commencing load out operations. At this stage the cable test results will be checked to ensure the cable is undamaged.

A cable loading arm and a cable scooter or similar will be used for assistance with the cable loading. The cable factory is assumed to spool the cable out at a speed of 7500 meters over a net 20 hour period per day. The cable will be loaded first into the turntable and then into the static coil.

Contractor will provide the supervision, equipment and consumable items for all onboard cable loading activities. Shore side or barge side provisions are to the Client's account.

Depending on the type of post-lay survey chosen, the cable may be magnetised during loading in order to improve detectability of the cable using passive tracking tools. Whether or not it is magnetised, or a tone must be applied, this shall be arranged by the Client.

Figure 4 – Loading of Cable in a turntable

Upon completion of the loading of the cable, the cable shall be tested. As a minimum the test will involve an OTDR test. Upon the satisfactory completion of testing the Contractor will accept responsibility for the cables.

On completion of testing and acceptance the CLV will depart for the Strait of Belle Isle.

4.11 Logistical Support

Contractor will select, design and provide all marine spreads, including special equipment, required for all operations within this Scope of Work. Contractor will be responsible for all mobilisation and demobilisation of marine spreads and of all necessary equipment.

A local marine base will be established in the vicinity of the cable route, to facilitate the transfer of personnel and essential stores to the site.

5. Cable Laying and Shore Approaches

5.1 Pull in at first shore approach

After loading the cable, the CLV will depart and sail to the first shore approach section. Due to relatively shallow water, it may be necessary to raise the DP assist propellers and to anchor the CLV at 6 points to come close enough to shore to be able to perform a controlled float out.

A winch will be set up on the shore (secured and load tested), and floatation devices will be transported to the CLV using the float out assist vessels (small workboats). The CLV will position itself with a suitable heading above the proposed point to deploy the cable on the floats. At this time the Contractor assumes to carry out a standard beach pull in operation, with personnel positioned onshore for assistance.

Figure 5 – Cable shore pull-in operation

During the pre operation site visit, access to the beach / shore line will be fully identified and initial contact will be made with the local authorities, to ensure the installation procedures meet any local permitting requirements which may effect the landing operation during the period identified.

The Beach Master co-ordinates the pull in operation, giving instructions to the winch operator, CLV and support boats. A messenger wire is passed from the ship to the shore and is connected to the winch.

Figure 6 – Winch arrangement for Cable pull-in

As the cable approaches the shoreline, and ensuring that the cable is positioned above the permitted route, the floats on the first piece of cable intended for onshore installation are removed. When the cable is in position onshore, with all slack taken up, all floats are removed by support vessels and/or divers and the cable is laid on the seabed.

5.2 Cable Laying

After the cable is floated out to shore, the vessel will move off towards the opposite shore of the Strait of Belle Isle. During the initial moving off phase it is critical to monitor the cable lead and tension to ensure that the cable is not pulled too tight.

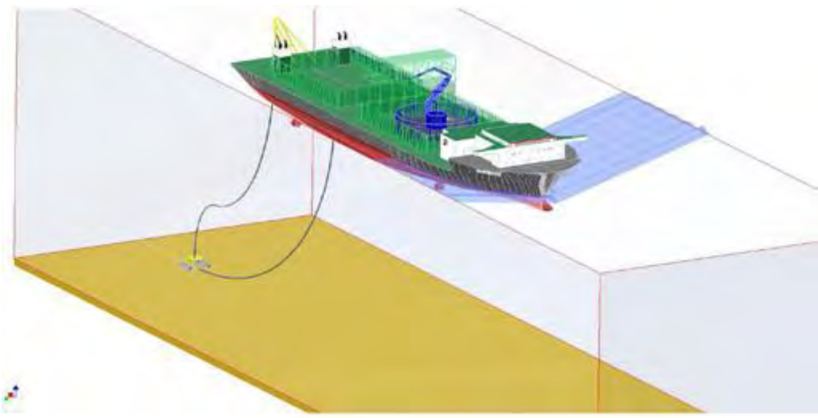


Figure 7 – Cable Laying with CLV Seahorse

For cable lay the ROV is deployed for touch down monitoring. The vessel will move in DP mode along the predetermined route. Progress speed will allow for careful and slower laying at the crossings (if applicable). The ROV will also check that the cable is not laid over large boulders or rock where avoidable, to avoid free-spanning of the cable.

The position of the laid cable will be recorded and as laid data will be presented to the Client on a regular basis during the cable lay operations.

5.3 Second shore - end pull in

At the opposite shore, the cable lay vessel will retract the thrusters of the DP system due to relatively shallow water and anchor the CLV at 6 points to come close enough to shore to be able to perform a controlled float out. Then the cable will be floated out, after attaching the buoyancy and a Chinese finger, in an omega shape.

The cable will then be floated out to shore, using small vessels with shallow draught. When the cable end arrives close to the beach a polyprop messenger wire is attached to the Chinese finger, to pull the cable to further to shore, using a shore based winch.

After pulling the cable ashore a pull wire is attached and the cable is pulled further onshore towards the jointing pit. From the waterline to the jointing pit rollers are installed under the cable.

During the pre operation site visit, access to the beach will be fully identified and initial contact will be made with the local authorities, to ensure the installation procedures meet any local permitting requirements which may effect the landing operation during the period identified.

The Beach Master co-ordinates the pull in operation, giving instructions to the winch operator, CLV and support boats. When the cable is in position onshore, with all slack taken up, all floats are removed by support vessels and/or divers and the cable is laid on the seabed.

6. QA/HSE

Boskalis is committed to achieve the objectives and provide the services in accordance with the Safety, Health, Environment, Quality and Security standards appropriate to the oil & gas industry. Boskalis is ISO 9001, ISO 14001and OHSAS 18001 certified and the vessels meet the strict requirements of the international ISM and ISPS codes.

6.1 HSE Policy Statement

It is the policy of Boskalis that all employees, including those of subcontractors and suppliers, execute their work safely and under healthy conditions, with appropriate concern for the protection of the environment. Boskalis Offshore will strive to reduce the level of accidents, incidents and damages each year of operation. The ultimate Safety, Health and Environmental objectives of Boskalis are:

- Zero accidents or losses
- Zero harm to people and the environment
- Zero damages to equipment and property

6.2 Quality Policy Statement

It is the declared objective of Boskalis to deliver quality services to clients in the most efficient manner and in accordance with the agreed client requirements. To attain this objective Boskalis Offshore employs qualified personnel, utilises up-to-date technology and implements effective procedures.

6.3 Safety improvements

Boskalis is committed to continuously improving its safety performances. An example of a safety initiative that has been implemented recently is the SHOC system:

The Safety Hazard Observation Card (SHOC) system has been implemented for the reporting of hazardous situations on vessels. All crew members are issued with a booklet containing SHOC cards on which they can record their safety observations. The completed cards are collected and acted upon by vessel management. This system has improved the registration of possible hazards, the speed of preventive action and awareness of crew members.

6.4 QA/HSE organisation

Boskalis has a dedicated QA/HSE Manager for the follow-up of all QA/HSE matters. Reporting takes place hierarchically to the Business Unit Manager and functionally to the corporate QA/HSE department of Royal Boskalis Westminster.

On board the vessel the Master is responsible for all QA/HSE matters. Dependent on the vessel the Master might be supported on QA/HSE matters by a Project Safety Engineer. The Master reports to the Project Manager and has an independent functional reporting line to the QA/HSE Manager of the Business Unit.

Appendix 5: Seismic refraction survey

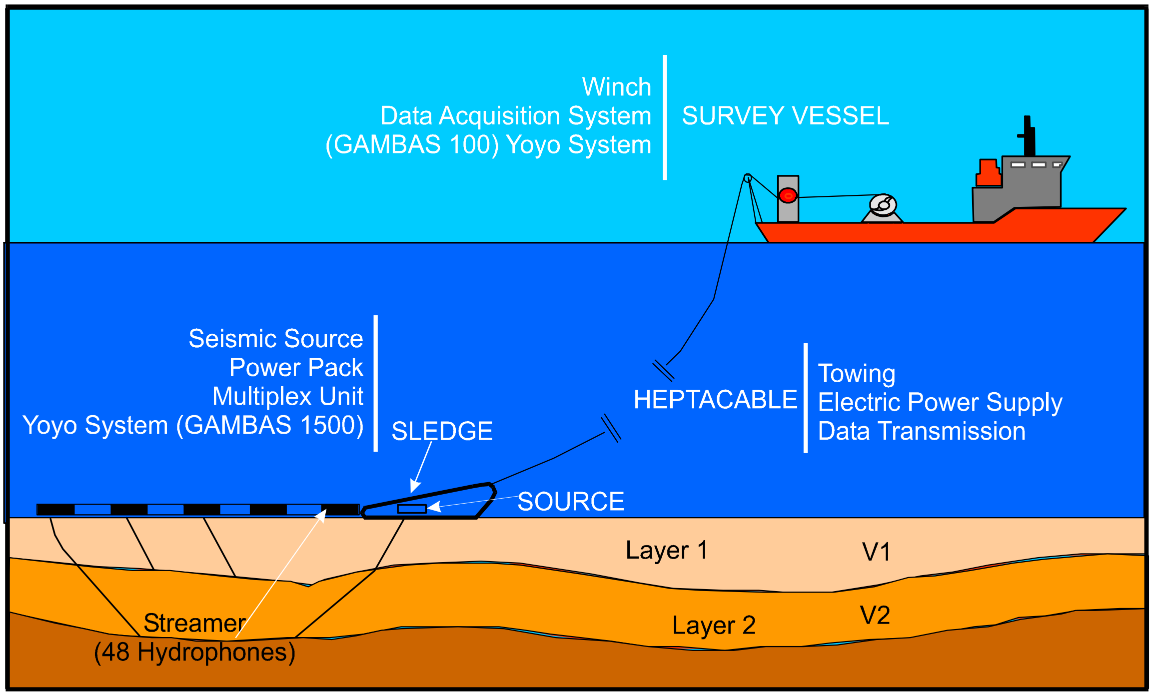
GAMBAS® 50 MARINE REFRACTION SYSTEM

1. GAMBAS® REFRACTION SPECIFICATIONS

The Gambas® 50 system is the shallowest device of the Gambas® family developed by FUGRO FRANCE. A key component of the Gambas® system is the *stop-and-go* motion device which enables the sledge to remain stationary and the streamer to keep in close contact with the seabed during the shooting and recording sequences while the vessel continues sailing. The stop-and-go device is required for maximum system resolution.

The technique is not dependant on the water depth (limitation is the draught of the vessel) and has been operated to 300m water depth with the Gambas®100 deep water system.

For the Gambas® 50 system, the stop-and-go device is integrated to the winch. On the Gambas® 100 system, the stop-and-go motion is performed through a vertical mast. On the deepest version, the Gambas® 1500, the stop-and-go device is housed in the sledge, at sea bottom.



GAMBAS® General Arrangement

The Gambas® 50 system operated by Fugro-France is based on the high resolution seismic refraction technique which is specifically designed to investigate the first metres of sediments below the seabed. The tool towed on the sea bottom by the survey vessel discloses pseudo-continuous profiling of the soil stratigraphy over the target depth and a precise measurement of the compressional wave velocity associated to the various layers.

At each shot point (average spacing between shot is 20-25m), the end processing provides a velocity profile expressed as a file of (hi – Vi) pairs where:

- ✓ hi is the thickness of layer i
- ✓ Vi is the compressional seismic velocity associated with layer i

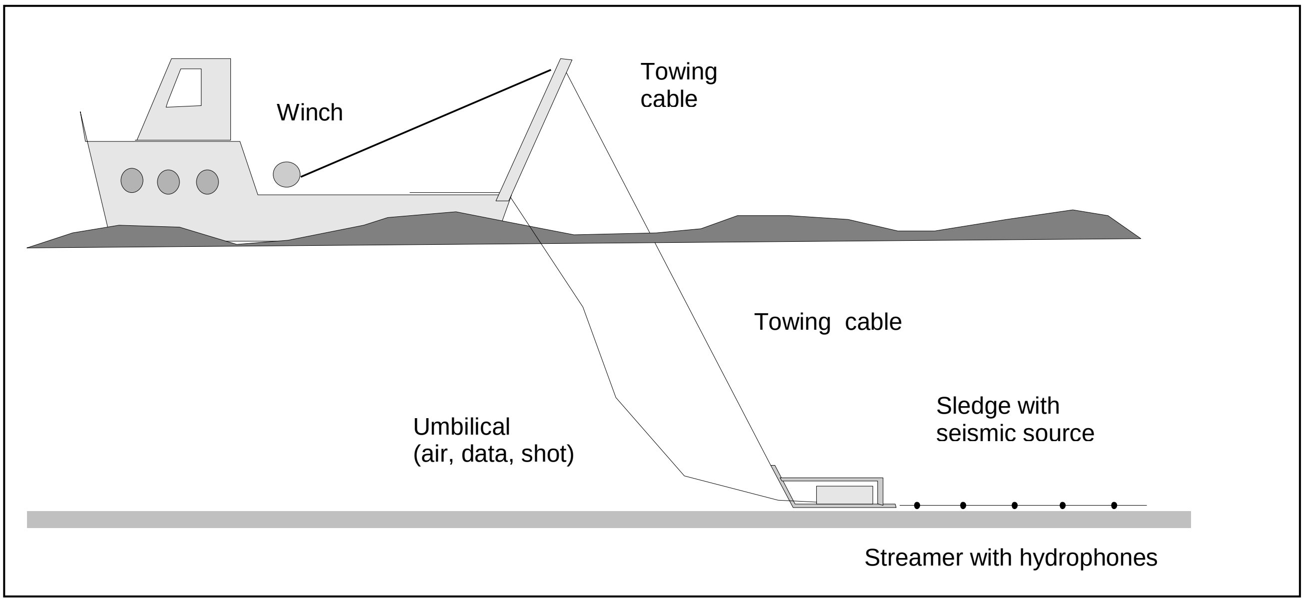
For engineering purposes, the velocity fields are then organised into a coherent representation of the sub-soil stratigraphy, each layer being properly delineated and defined by a characteristic value of its compressional velocity.

This is obtained by selecting velocity classes associated with the different soil types identified along the profile.

Creation of velocity classes requires a statistical analysis of the velocity fields measured along the route. A correlation of the geotechnical results with the velocity fields would normally improve the selection of the velocity classes.

2. GAMBAS® 50 EQUIPMENT DESCRIPTION

As presented on the following sketch, the GAMBAS® 50 refraction system comprises:



GAMBAS® 50 Seismic Refraction System

- ✓ Equipment dragged on the sea bottom
- ✓ Stop-and-go control on back deck
- ✓ Surface acquisition recorder in vessel's cabin

2.1 SEA BOTTOM EQUIPMENT

- ✓ A sledge housing the seismic source (air gun Mini G-Gun)
- ✓ A streamer dragged behind the sledge and composed of x GeoSpace MP-25-656 (10Hz) hydrophones (usually by section of 24 hydrophones)
- ✓ A bottom-to-surface link umbilical, providing compressed air to the air gun and serving as trigger line and data link

GAMBAS® 50 Sea Bottom Equipment - Empty sledge

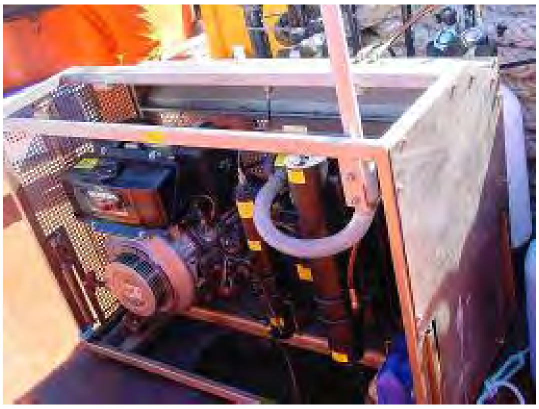
GAMBAS® 50 Sea Bottom Equipment – Air gun

GAMBAS® 50 Sea Bottom Equipment
Instrumented Sledge

GAMBAS® 50 Sea Bottom Equipment – Hydrophone streamer

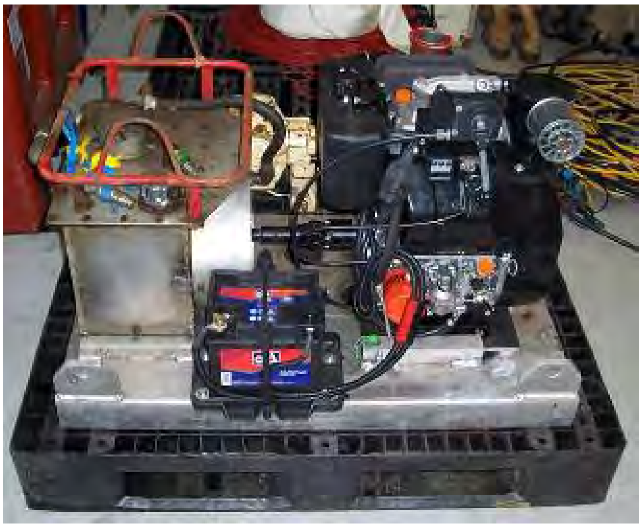
2.2 BACK DECK EQUIPMENT

- ✓ An A-frame or davit to recover and deploy the equipment
- ✓ A winch spooled with up to 300m towing cable
- ✓ An hydraulic power pack and its generator
- ✓ An air compressor, air compressed bottles and air panel (to monitor air flow)

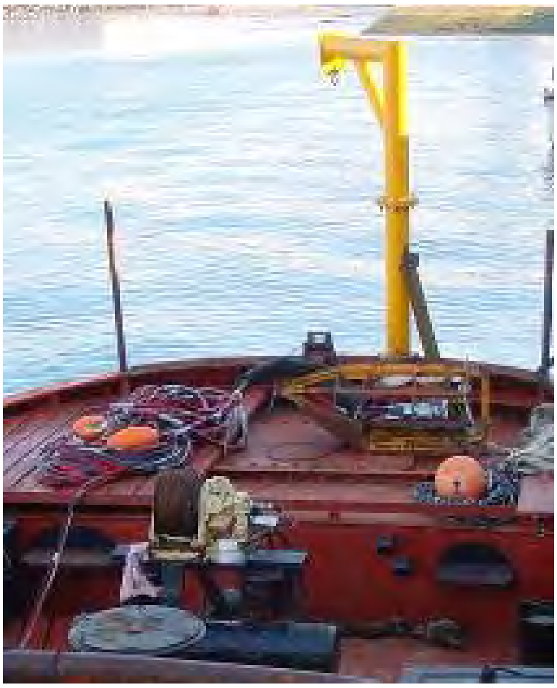


GAMBAS® 50 Back Deck Equipment:
Air Compressed Bottles (left) – Air Compressor (right)

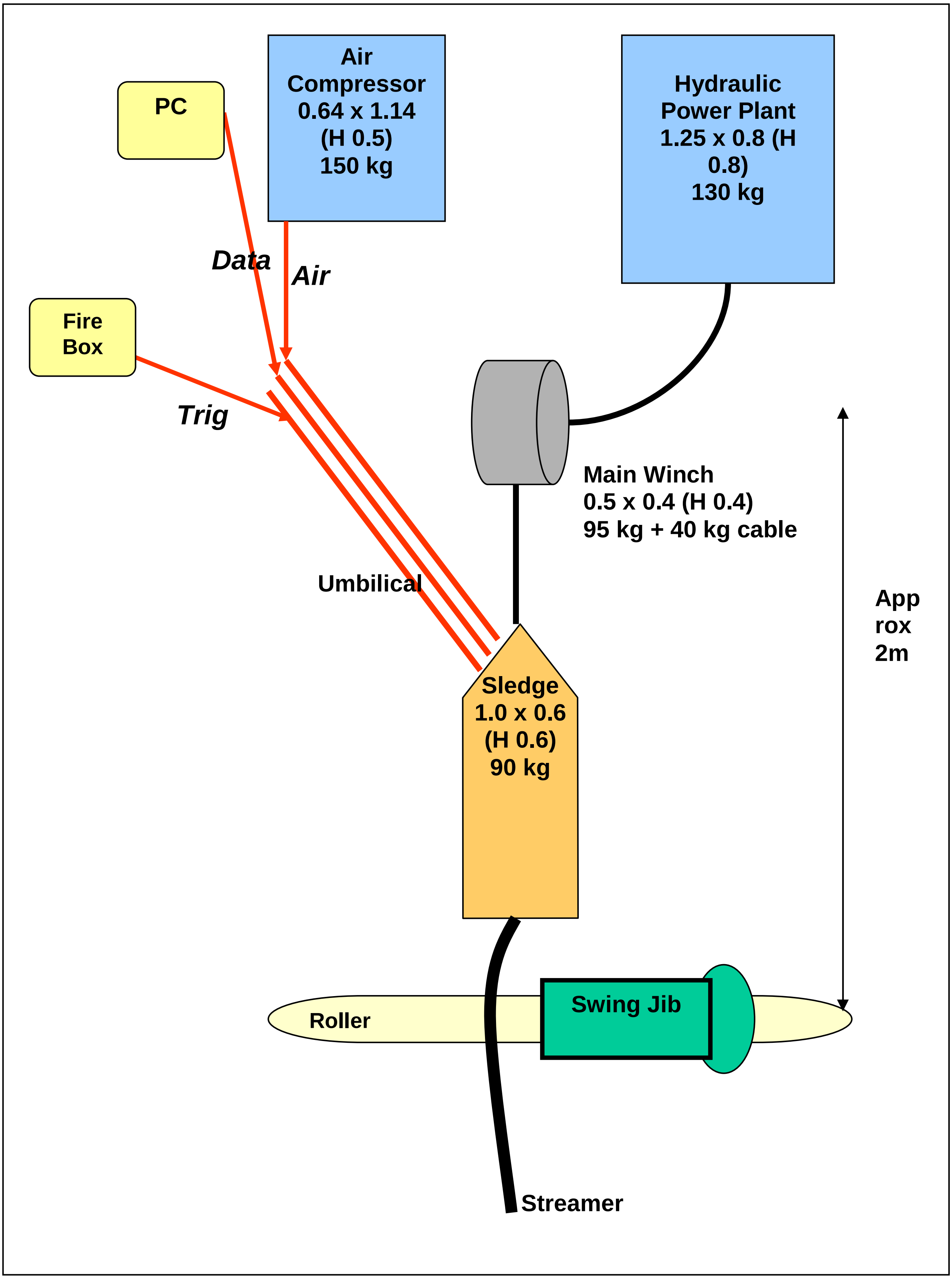
GAMBAS® 50 Back Deck Equipment: Stop-and-go Winch



GAMBAS® 50 Back Deck Equipment – Mini hydraulic plant for the stop-and-go winch



GAMBAS® 50 Back Deck Equipment – Davit for launching and recovery of the equipment



GAMBAS® 50 Standard Deck Lay-out

2.3 SURFACE ACQUISITION SYSTEM

- ✓ A GEOMETRICS 24 channels GEODE recorder
- ✓ A triggering / firing box

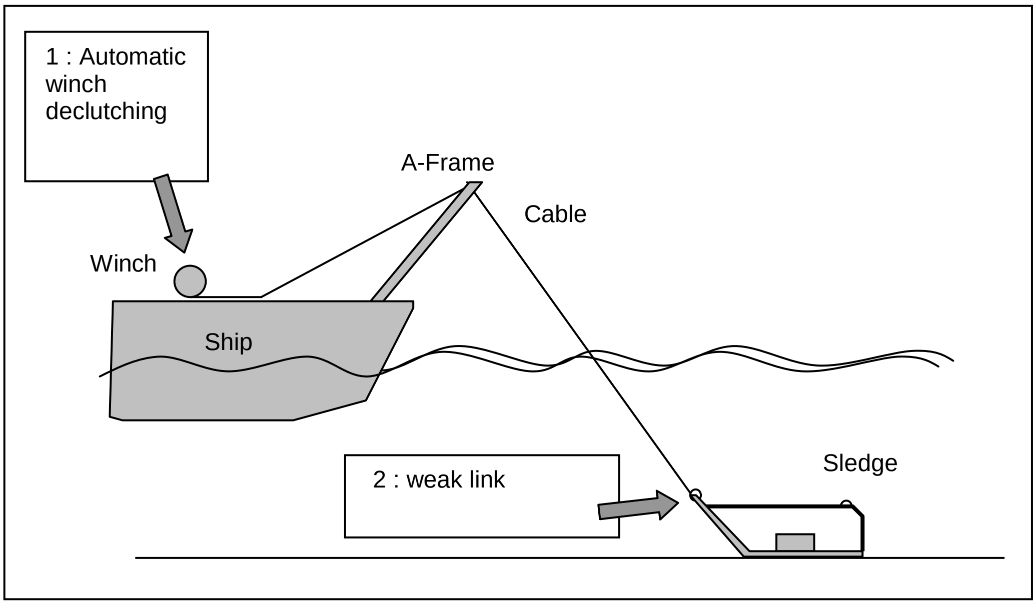
Interfacing between the recorder unit and the positioning / navigation system is undertaken directly using a TTL signal. The signal is triggered from the recorder to the navigation system that, in turn, triggers and logs a navigation fix, later merged in post processing with refraction data.

2.4 SAFETY DEVICES

Safety in operations is ensured by:

1. Automatic winch declutching. The winch is calibrated to release cable automatically should a problem occurs
2. Weak link on the tow line, calibrated to break in case of high traction force

Vessel acquisition speed is about 2 knots.



GAMBAS® 50 Safety Devices

In addition, hydraulic circuit breaker can be engaged by a push button on the deck control panel.

GAMBAS® 50 Safety Devices – Circuit Breaker on the Control Panel

2.5 USUAL SURVEY PARAMETERS

<u>Data acquisition:</u>

	Sampling rate	: 31.25µs (32Khz)
	Record length	: 64 – 100 ms
	Recorder	: GEOMETRICS 24 Channels GEODE system

<u>Energy source:</u>

	Type	: Air gun (Mini G-Gun)
	Volume	: 40 – 60 - 80 cu inch
	Pressure	: 100 - 120 bars
	Shot point interval	: average 20 to 30 metres

<u>Streamer:</u>

	Total length	: Depends on number of sections / hydrophone
	Number of channels	: 24 hydrophones per section
	Geometry	: Variable spacing (0.5 to 4 metres)

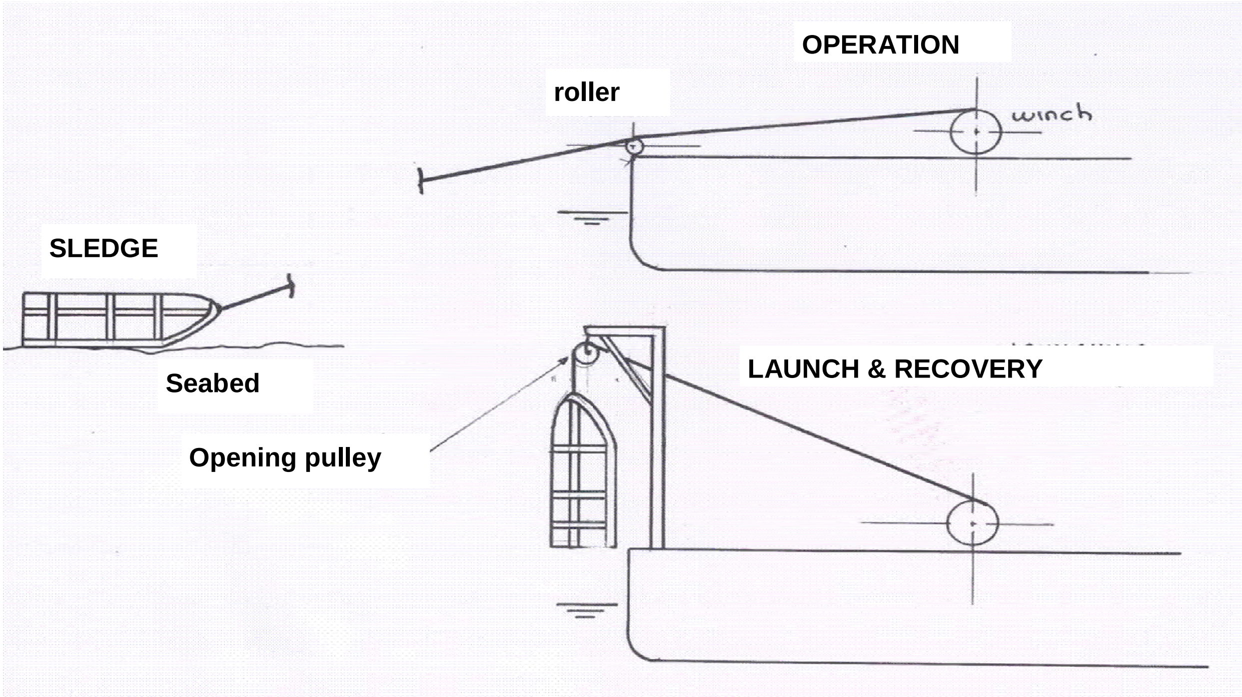
<u>Resolution</u> : Better than 100 m/s in seismic velocity Vp

3. GAMBAS® OPERATIONS

3.1 DEPLOYMENT AND RECOVERY

The sledge is deployed over the stern of the vessel utilising the vessels davit and the lifting / towing winch, through an open pulley.

GAMBAS® 50 Sledge Deployment



GAMBAS® 50 Launch and Recovery Operations

Once the sledge is on the seabed the tow wire is transferred from the open pulley to a 'tow block roller', welded to the stern of the vessel. This roller system allows safe and controllable running of the umbilical / tow wire. The sledge is recovered in a reverse procedure: transferring the tow wire from the roller to the open pulley system and then winding in the sledge through the davit system.

On the vessel deck, the stop-and-go winch rules the motion of the sledge on the seabed without any change in the surface vessel speed. During an initial phase of a few seconds, the system releases a certain length of cable. This enables the sledge to remain stationary and the streamer to stay in close contact with the seabed, during shooting and acquisition periods. It allows for the source to be triggered and for the return signals to be recorded while the sledge is stopped (this, in turn, optimises the signal to noise ratio). As soon as the data acquisition is completed, the stop-and-go system swallows the length of cable paid out in the initial phase. The duration of the reeling phase depends on the vessel speed. For a 20 seconds sequence and a vessel sailing at approximately 2.5 knots, the averaged shooting interval is about 25 metres.

3.2 DATA QUALITY CONTROL

Raw data are recorded in SEG 2 format and displayed in real-time for quality control. During the survey, the geophysicist monitors the records and the shooting frequency. Such close monitoring allows the team to react in any case.

The sledge is continuously towed along the seafloor. In case the noise generated by the friction of the sledge on the seafloor is too strong, the strength of the shot is boosted by increasing the shot pressure of the air gun.

The pressure used for air gun shots is usually around 100 bars, ensuring a good quality of seismic data. This resulted in precise picking of the refracted waves. Resolution on interface position and layer velocity are fully within the specifications of the Gambas® system.

4. GAMBAS® DATA PROCESSING AND INTERPRETATION

4.1 PRELIMINARY PROCESSING AND INTERPRETATION

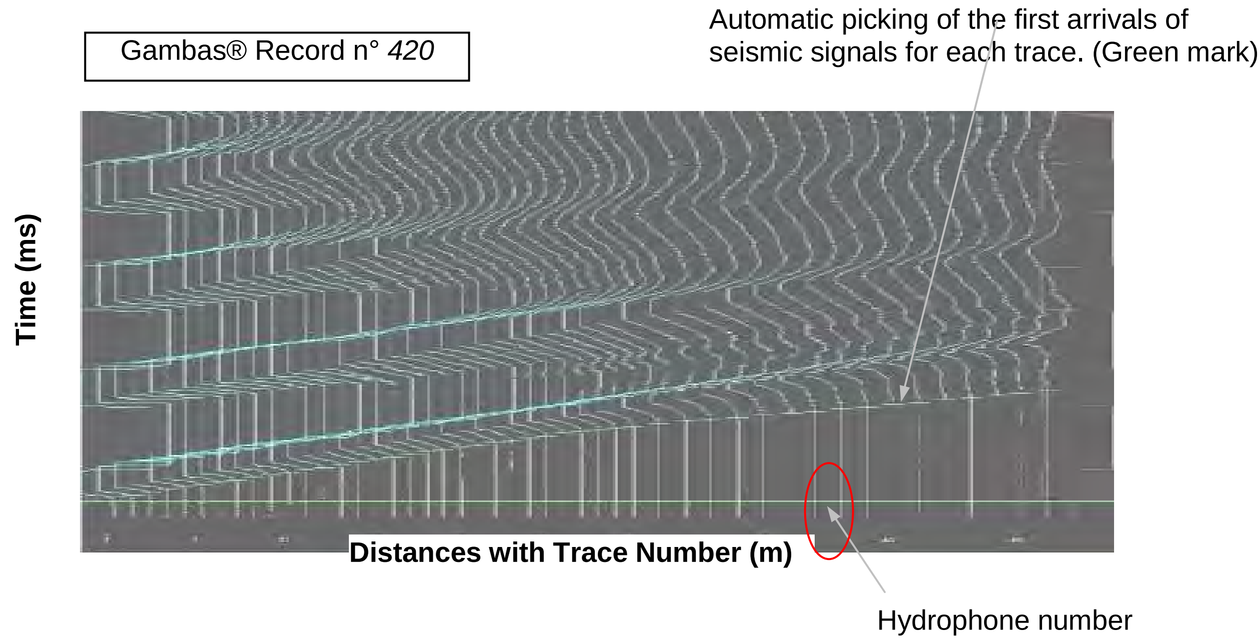
The processing of Gambas® data is carried out using an in-house developed software package – *"Starfix.Gambas"*. This software provides the P-waves seismic velocities and the thickness of the different layers of the sub-seabed at each shot location.

Shot by shot, the 23 channels (the 24th channel monitors the time break) are displayed on the screen of the control PC. This allows the operator to check the quality of the signals and detect any source or hydrophone malfunctions.

When recorded data exhibit a good signal/noise ratio, the program performs an automatic picking of first arrival. However, in case of disturbed signal, manual picking option is available.

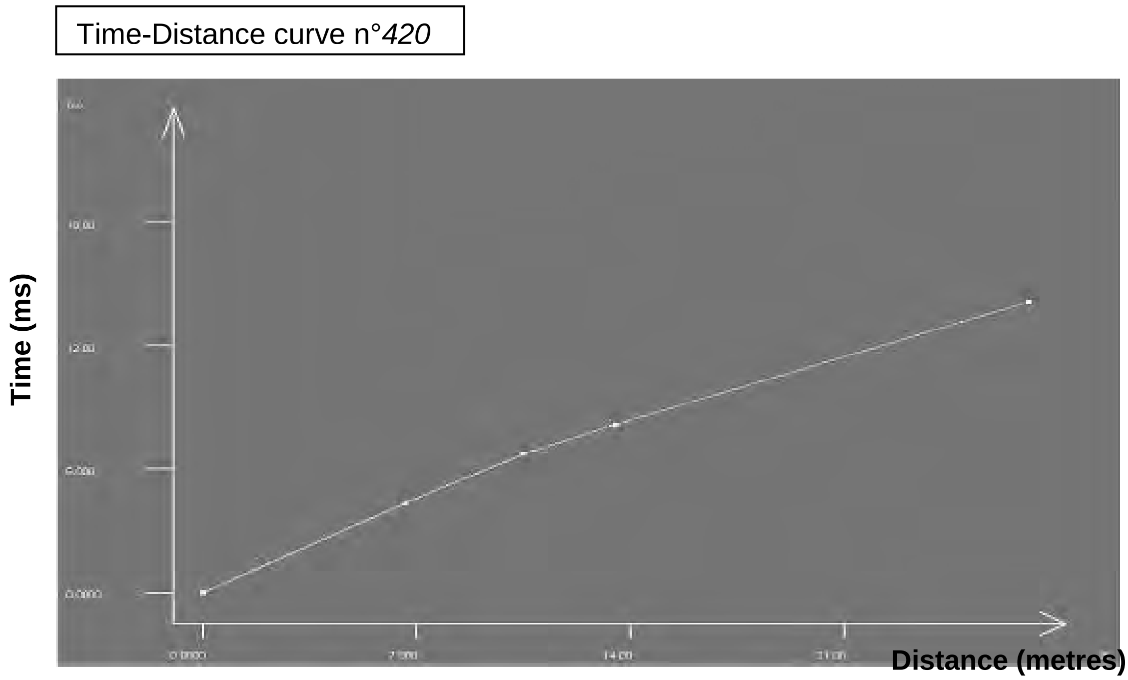
First arrival times are selected, then plotted against the source-hydrophone distances. The software selects automatically the number of layers (up to 5 layers can be identified) and computes the velocity and thickness of each layer.

A processing flow is further explained in the following figures.



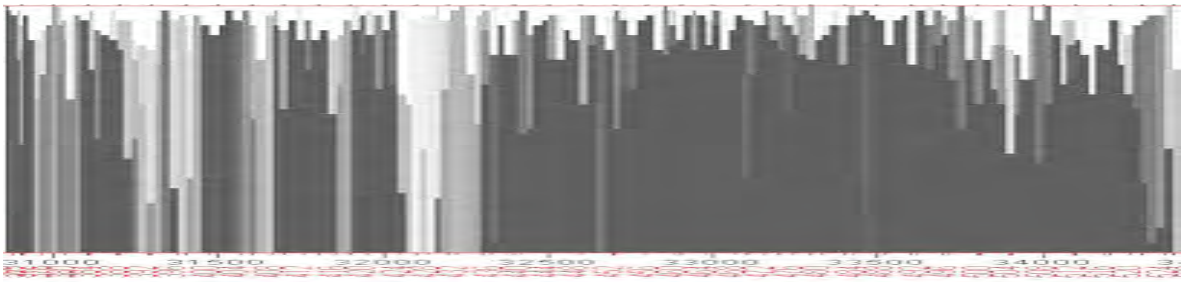
Selection of Seismic Arrivals

Time-distance curves are generated for each shot, and automatic interpretation is performed using the "intercept method".



Automatic Interpretation – Time-Distance curve

Once this process is complete, the raw interpretation is displayed on the monitor as a bar graph giving layer thickness and seismic velocity versus shot number or KP.



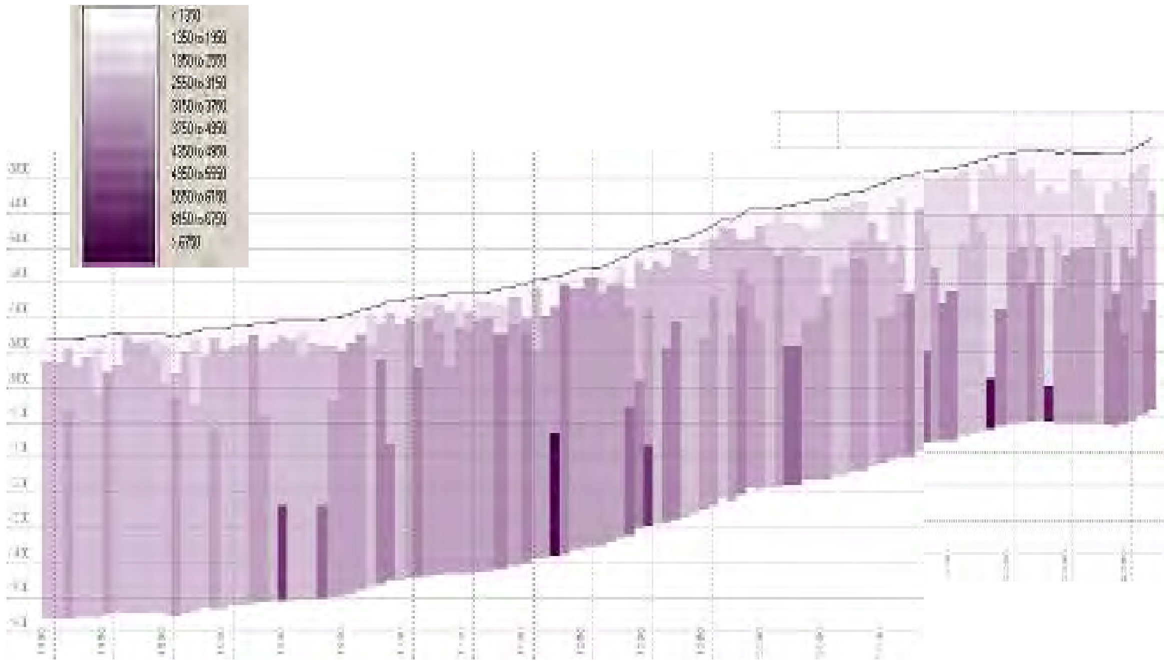
Raw Interpretation Window

The full suite of Gambas® results, including:

- Time
- Shot number
- KP number
- Line number
- Bathymetry
- Raw velocities versus depth

is generated under "Starfix.Gambas®" as a proprietary binary format file. This file can be checked at any time during acquisition or in post processing.

A bar chart showing raw velocities and depths versus KPs, is presented below.



Bar Chart – Raw Velocities and Depths versus KPs

4.2 FINAL PROCESSING

The next stage of the processing consists in identifying and materialising on the bar graph, the areas of homogeneous velocities called *Velocity Classes*. Velocity classes are defined according to several criteria.

Velocity logs are represented using a 35 grey level scale which allows to visually identify zones of equal grey density without being influenced by conventional colour changes.

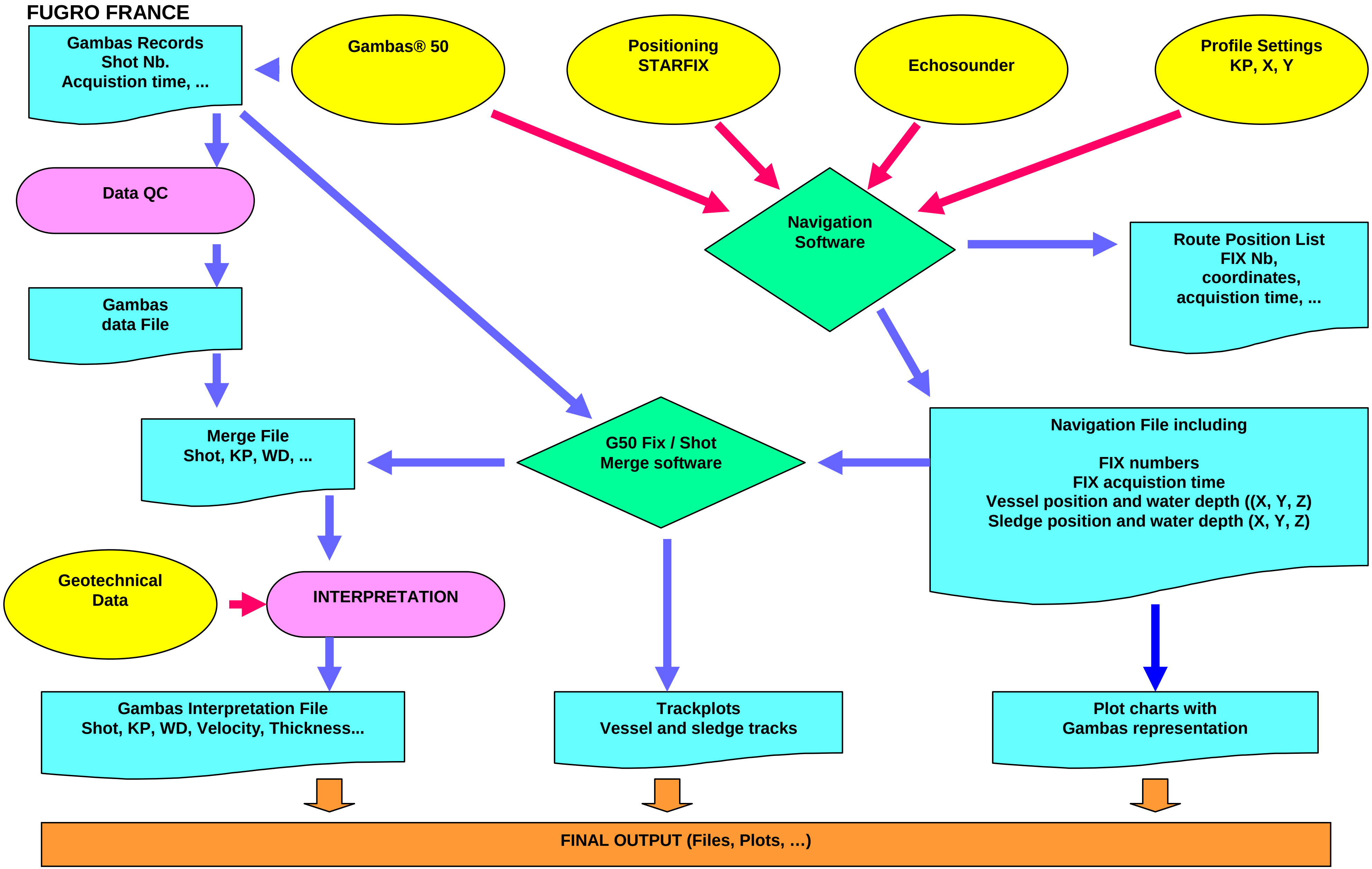
The number of velocity classes should be limited for practical considerations: 5 to 10 classes is generally adequate to describe simple to complex geological conditions.

Velocity classes should be (as practicable as possible) valid for representing the totality of the project data. Classes should (as practicable as possible) correspond to well identified soil/rock conditions in connection with engineering considerations.

Ideally the final selection of the velocity classes should be made when all geotechnical data are available and interpreted. This would allow the performance of a full data integration process, and would guaranty that the above criteria are met.

4.3 PROCESSING FLOW CHART WITH STARFIX GAMBAS®

Overleaf is a Gambas® processing and interpretation flow chart.


FUGRO FRANCE
Gambas Records
Shot Nb.
Acquistion time, ...
Gambas® 50
Positioning
STARFIX
Echosounder
Profile Settings
KP, X, Y
Data QC
Navigation
Software
Route Position List
FIX Nb,
coordinates,
acquistion time, ...
Gambas
data File
Merge File
Shot, KP, WD, ...
G50 Fix / Shot
Merge software
Navigation File including
FIX numbers
FIX acquistion time
Vessel position and water depth ((X, Y, Z)
Sledge position and water depth (X, Y, Z)
Geotechnical
Data
INTERPRETATION
Gambas Interpretation File
Shot, KP, WD, Velocity, Thickness...
Trackplots
Vessel and sledge tracks
Plot charts with
Gambas representation
FINAL OUTPUT (Files, Plots, ...)

1. STATIC REFRACTION TECHNIQUE

1.1 STATIC REFRACTION SPECIFICATIONS

From the shoreline to the limit of the Gambas survey (where the Gambas survey is constrained by the draft of the main vessel) , the refraction is performed a bottom-lay method also called here ‘static seismic refraction technique’. This technique is equivalent to the multi-shot arrays usually carried out in land seismic.

To the inverse of the Gambas technique, the streamer is stationary on the sea bottom for several hours, during the time that multiple shots are prepared and fired and data recorded. Then, streamer is removed and laid on a next location.

The static refraction principles follow the seismic refraction basics, also in use for the Gambas technique. Wave propagation, picking of first arrival, time-distance curve and velocity / thickness calculation are described in the following figure.

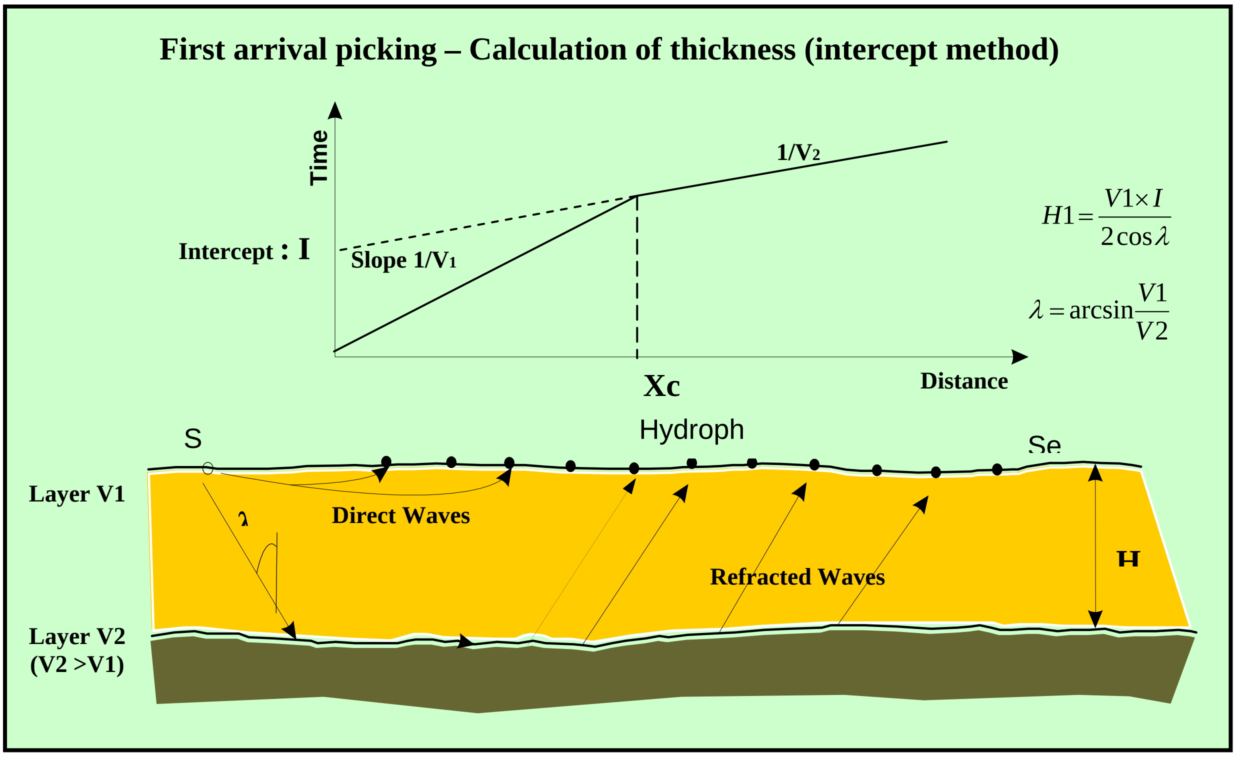


Figure 1: Seismic Refraction Basics

With respect to the Gambas technique, the static refraction gives a lower resolution (horizontal and vertical) due to a larger hydrophone spacing and lesser and more spaced shots. In addition, the operations are more complex and the production is lower. Nevertheless, as the streamer is longer in static refraction than in Gambas, the investigation depth is larger. Furthermore, the multi-shot operation, using forward and reverse shot points, is a benefit to evidence velocity anisotropy (linked to non tabularity of formations) and allows to perform advanced interpretation methods (see further).

1.2 EQUIPMENT DESCRIPTION

1.2.1 SEA BOTTOM EQUIPMENT

- ✓ 2 streamers laid on the seabed, 120-metre long, each of them composed of 24 GeoSpace MP-25-656 (10Hz) hydrophones
- ✓ A bottom-to-surface tether serving as data link

Figure 2: Static Refraction Streamer

1.2.2 BACK DECK EQUIPMENT

On the recording boat:

- ✓ A GEOMETRICS 24 channels GEODE recorder

On the air gun boat:

- ✓ The seismic source (air gun Mini G-Gun)
- ✓ A triggering / firing box
- ✓ Air compressed bottles

1.3 OPERATIONS

The method consists in laying a receiver array (i.e. a streamer) on the seabed and then performing shots with an air gun seismic source at 5 specific locations:

- Central shot, in the centre of the streamer
- Near shots, at both extremities of the streamer, in close position to hydrophones 1 and N
- Offset shots, outside the array, at a notable distance (usually ½ array) of hydrophones 1 and N.

Two small boats are used for system deployment and shooting / recording operations as follows:

- The recording boat carries positioning and navigation systems, streamers, the recording system and a radio link for the source triggering. The recording boat is moored close to the centre of array to ease connections with the seismic recorder.

- The air gun boat (inflatable type) carries air-gun and compressed-air bottle

The streamer is deployed and recovered by hand and its position is recorded at three locations marked with surface buoys. The contact of the streamer with the seabed is ensured through small dead weights. That, in turn, facilitates the deployment of the gun close to seabed. Shots are performed successively at each of the five locations.

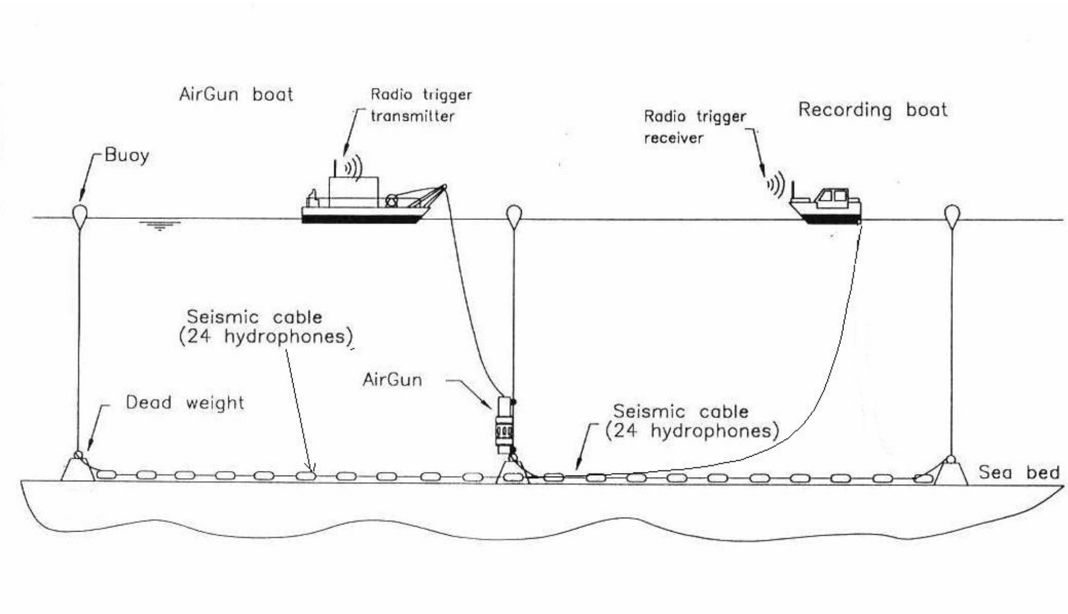


Figure 3: Deployment of Static Refraction System

On the Rayong survey, two 24 hydrophones, 120 metres long arrays, were added up. This 240 metres double array was, then, investigated with 7 shots, as follows, some shots being used for both arrays :

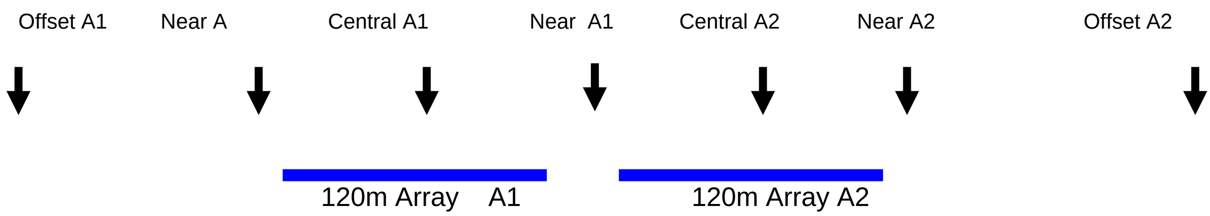


Figure 4 : Double Array and Shot Distribution

On board, each shot is visualized onto a laptop monitor which allows the observer to perform a quick quality control. Digital data are then recorded, one file per shot.

1.4 DATA PROCESSING AND INTERPRETATION

Thanks to the 240 metre long array, 48 channels, 7 shots (each of them being forward and reverse shots), interpretation benefits from the “plus-minus” method of calculation.

The “minus” method permits to take in account the non horizontality of the layers by computing a resulting velocity, in between up-dip and down-dip velocities.

With the “plus” method, a delay is calculated for each hydrophone, allowing to calculate the thickness of the layer overlying the bedrock (assumed to be the deepest layer investigated, with the highest velocity). The major interest of this interpretive technique is the assessment of thickness’, not only at the sole shot points (as with the intercept method) but below each hydrophone.

The principle of the “plus” method is illustrated on the following figure.

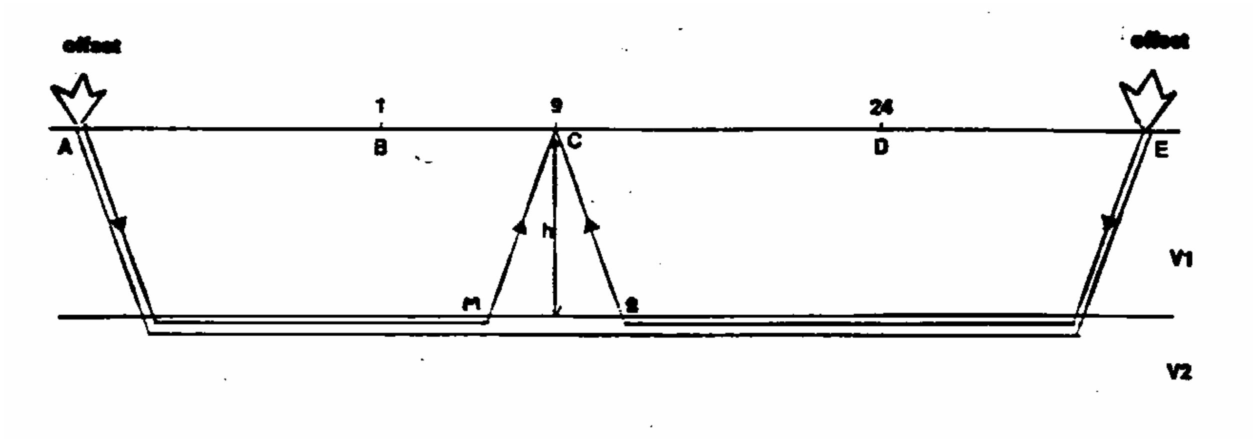


Figure 5: Principle of "Plus" Method

Delay T plus = TAC + TEC –TAE

Where TAC, TEC,TAE are respectively the wave propagation time (in milliseconds) between A and C , E and C, A and E.

As the refraction angle is usually small (10 to 25°), it is generally assumed that the following relation, giving the thickness (h) of V1 layer, could be considered:

T plus = 2 h / V1, then
h = T plus x V1/2

Appendix 6: Heat transfer in soils

The following main heat transfer mechanisms through soil for buried cables (or pipelines) have been identified:

- Conductivity – transport of energy in the groundwater and solid matrix;
- Convection – transport of energy through fluid density-dependent saturated groundwater flow.

The governing parameters in the determination of the overall heat transfer by these two phenomena are:

- Thermal conductivity of backfill soil-water mixture;
- Thermal conductivity of surrounding and sub soil;
- Permeability of backfill soil-water mixture;
- Permeability of surrounding and sub soil;
- Dimensions of cable, trench and backfill profile;
- Temperatures of cable and seawater;
- Other sources of thermal energy in the locality.

For indication, the following thermal conductivity figures are applied:

Material	Thermal conductivity [W/mK]
Seawater (still)	0.65
Clays	1.4
Gneissgranit	1.6
Concrete coating (pipelines)	2.2
Quartz	2.4
Steel	45

Thermal convection has proven to be the needful mechanism to cool down cables, whereas it has been the mechanism to fight in case of pipeline insulation.

The project sheet on the next pages, although for pipeline insulation purpose, illustrates the applicability of cable burial for heat transfer control, i.p. when in combination with other functional requirements (stability, protection).

Port and Waterway Engineering, Project Development

Re-insulation Gannet 'C' Bundles

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Internet: www.hydronamic.nl

Client: Shell UK Exploration and Production Aberdeen
Location: North Sea, United Kingdom
Period: 1996 - 1997

Introduction

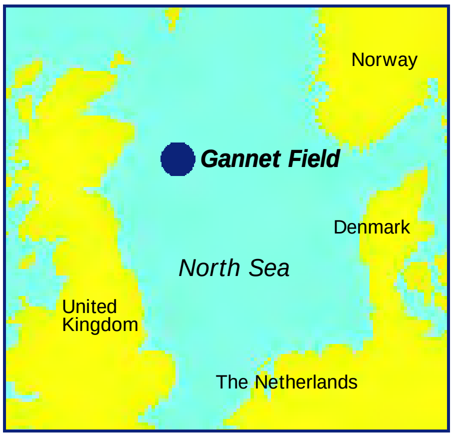
The Gannet 'C' satellite field, which is located in the North Sea at 112 miles East of Aberdeen in 95 m water depth, comprises four drill centres, each having one or more producing wells. The drill centres are connected to the local platform Gannet 'A' by four flowline bundles.

A glycol-based gel, filling the annulus of the Gannet 'C' carrier pipe, insulated the individual flow lines.
Gel was chosen as an insulator because of its insulation properties and its ease of installation.
Concern about the long-term stability, corrosiveness and expansion of the gel initiated a comprehensive test programme that gave discouraging results.
The testing indicated breakdown of the gel, resulting in degrading insulation properties.
The continuing drop in oil and gas arrival temperatures at the platform has confirmed the gel degradation.
From this, Shell's request for the engineering and installation of a re-insulation system for the Gannet 'C' bundles was originated.
The objective of the re-insulation system is that it should provide sufficient insulation to the bundles in order to safeguard production during the total field life of Gannet 'C', being a minimum lifetime of 15 years.

Hydronamic has been involved in the Shell development phase and later on in the design and construct phase.

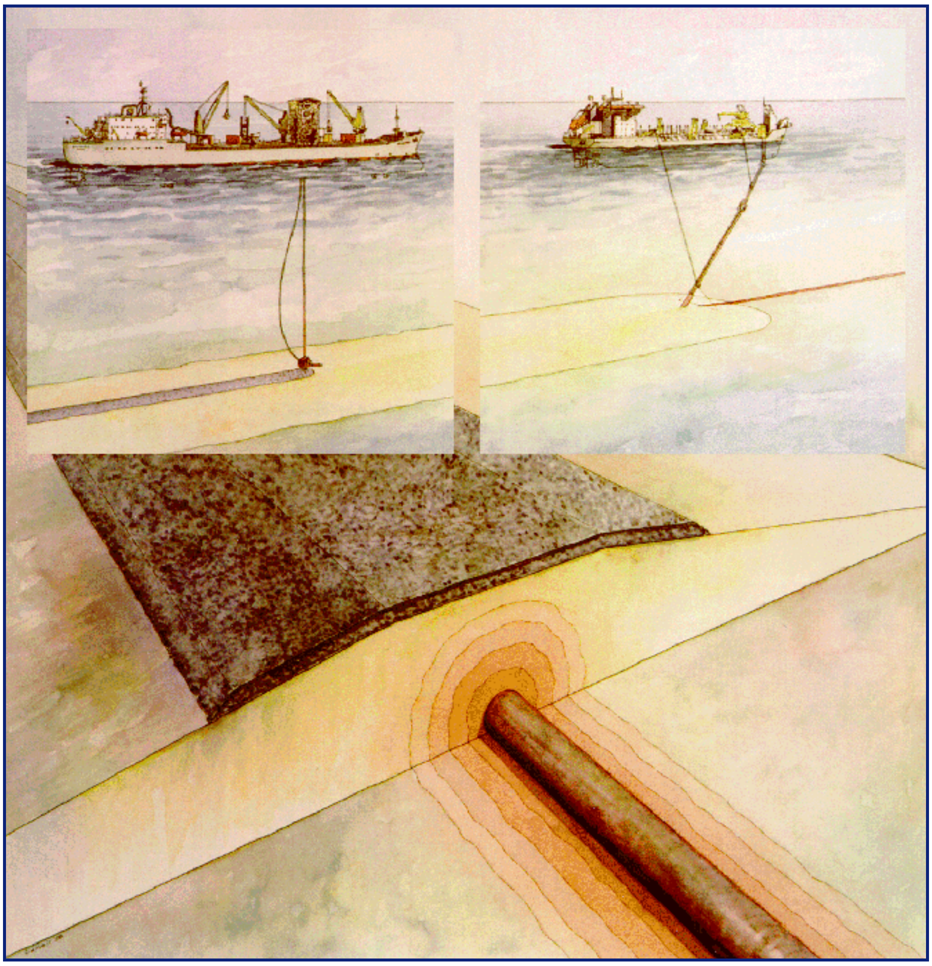
Engineering topics

In Shell's development phase, prior to request for tender, Hydronamic has executed a Minor Service Contract in joint effort with an offshore pipe contractor. In that study the technical and economical feasibility of a re-insulation system on the basis of sand cover has been examined.
The outcome was so promising that a design and construct contract has been awarded to Boskalis, for whom Hydronamic performed the design and project engineering.



Location map.

WD Fairway and Sandpiper near platform Gannet 'A'.



Artist's impression re-insulation Gannet 'C' bundles.

procedures for acceptance to be followed.
The outline of these issues mainly amounted to the definition of a test and check programme for a proper (for Shell) but practical (for Boskalis) verification of the installed berm.
As part thereof contingency measures have been defined.

Publication

Detached from, but certainly prompted by, above engineering results, Hydronamic has prepared a paper for the Offshore Technology Conference 1998 in Houston.
In this paper the technical and economical feasibility of the following two aspects are presented:

- the application of sand and rock as a thermal insulator for offshore pipelines;
- the employment of new generation dredge equipment in offshore areas.

The proposed re-insulation system for the Gannet 'C' flowline bundles comprised a sand berm on top of the bundles with a rock cap protection against erosion.
For final design verification with regard to Shell's functional specifications, an extensive programme of numerical computations and laboratory tests has been set-up.
These functional specifications and consequently the design programme reflected two topics: insulation and stability.

Consultations

On the subject of insulation Hydronamic has consulted Delft Geotechnics. This institute carried out laboratory model tests and developed a mathematical model for the calculation of insulation performance of sand berms.
The objectives of the tests were:

- to investigate and qualify the relevant processes, which occur in the soil as a result of thermal loading;
- to validate the mathematical model for the calculation of the heat transfer of the in-situ Gannet 'C' carrier pipes.

Through the use of the mathematical model, Delft Geotechnics provided a matrix of heat transfer coefficients as function of the following significant parameters:

- conductivity and thermal convection of the berm sand-water mixture;
- temperatures of sea water and bundles;
- dimensions of sand berm and bundles;
- thermal characteristics of the sub soil.

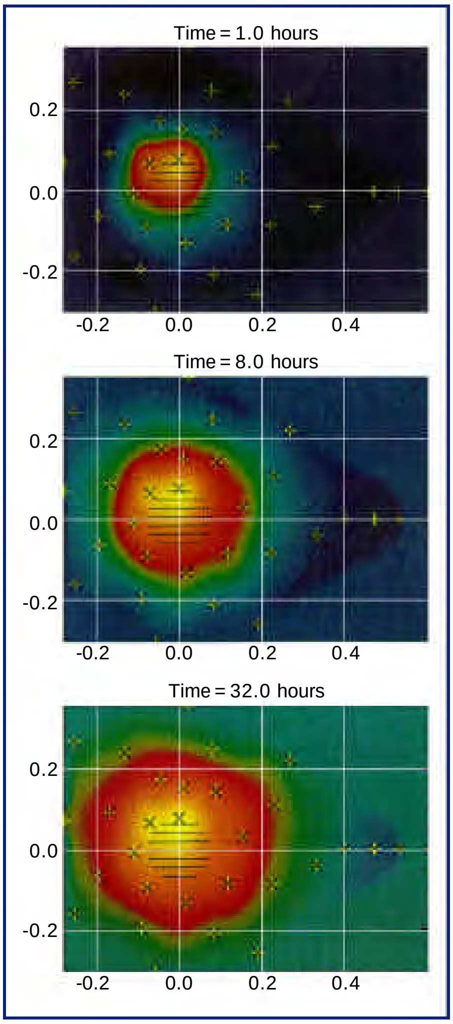
On stability, the second design topic, Alkyon was consulted for evaluation of and complementary works to Hydronamic's stability assessment.
In the design of the gravel cap the following aspects have been incorporated:

- falling apron;
- lifetime erosion;
- insulation properties.

Design

The final design of the sand berm and rock cap was based on the research results and the determination of the optimum work method for berm installation. On the latter subject Hydronamic made use of theoretical and computational in-house models and actual dredge experiences by Boskalis.
In practical terms, Shell's functional specifications have been translated into construction profiles and material specifications of the sand berm and rock cap.
For acceptance by Shell of the Boskalis installation works, Hydronamic has outlined the acceptance criteria and the

Calculated insulation results after 1.0, 8.0 and 32.0 hours.



Appendix 7: Example of post-trenching using jet

Royal Boskalis Westminster nv

Project Data Sheet

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Telephone +31 (0)78 69 69 000, telefax +31 (0)78 69 69 555
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Mumbai High Fields

to Uran Trunkline Project

Client:	ONGC Ltd.
Location:	Mumbai, India
Period:	August 2004 - June 2005
Main contractor:	Hyundai Heavy Industries Co. Ltd.
Contractor:	Boskalis Offshore / Boskalis Westminster Middle East

Boskalis Offshore: skills, resources, experience

Boskalis Offshore brings together the offshore skills, resources and experience of Royal Boskalis Westminster. The group's offshore capabilities include seabed rectification works for pipeline/ cable and platform installation, construction of pipeline shore approaches and landfalls, offshore mineral mining, offshore supply and support services and decommissioning services. Boskalis provides clients with tailored, project-specific solutions for above dredge related offshore services, as illustrated by the following project summary.

Mumbai High Fields to Uran Trunkline Project (MUT)

The Mumbai High Fields to Uran Trunkline Project is situated near Mumbai (Bombay) in India. ONGC Ltd (Oil & Natural Gas Corporation) has constructed two new pipeline connections from the Mumbai High Fields to Uran over a total length of 204 kilometres. These new pipelines have been constructed in order to replace the existing Bombay High Fields to Uran Trunkline, which has already completed more than 25 years of successful operation and has surpassed its design life. The new pipelines are a 30" oil pipeline and a 28" gas pipeline.

a)

b)

a): TSHD "Seaway" during post-trenching works

b): Location map

c): Backhoe Dredger "Colbart" & TSHD "Flevo" in operations

d): Backhoe Dredger "Colbart" equipped with a hydrohammer

The pipe laying has been executed by Hyundai Heavy Industries Co. Ltd (HHI). Boskalis was awarded a subcontract to execute the pre-trenching, backfilling and landfall works from the Landfall Point to 19.5 kilometres offshore (from Port Limits). Project preparations commenced in August 2004 and all operations were completed in May 2005 well before the start of the monsoon season. Upon completion of the operations within the Port Limits Boskalis was requested to use their expertise for the post-trenching of both pipelines until 130 kilometres offshore.

Pre-Trenching Operations

A trench was dredged to a width of 8 metres in the near-shore section (1.6 kilometres) and to a width of 10 metres further offshore. Soil conditions in the area vary between very soft silty clay and weathered basalt. In the case of hard material, a cover of 1 metre on top of the pipeline was


c)


d)

required, in the case of soft material a cover of 3 metres. Three dredging units, each with its own specific features, were mobilized for the operations.
The backhoe dredger “Colbart” dredged the near-shore part of the trench, where the water depth limited the activities of the hopper dredgers, and the sections where hard material was encountered. To pre-handle sections with hard material, the “Colbart” was fitted out with a S35 hydrohammer.

The trailing suction hopper dredgers “Flevo” and “Seaway” were mobilized to dredge the shallow parts of the trench and the offshore section respectively. The dredged material was deposited in a temporary storage area at 1 kilometre distance from the trench to be re-used for backfilling.

To allow HHI’s lay barge to approach the shore close enough an access channel was dredged with a width of 60 metres and a guaranteed sufficient water depth to enable the lay barge to work at all times. At the shore land-based equipment was used for the excavation of the tidal area. To provide the vessels with accurate and up-to-date progress data a multibeam survey launch performed surveys. The constant provision of adequate data enabled the vessels to perform optimally and to adjust their day-to-day planning as per the requirements for achieving the design profile.

Backfilling Operations

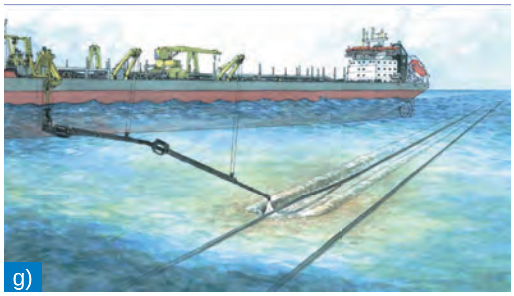
Immediately upon completion of the shore pipe-pull, backfilling operations were started in the available areas. Combining backfilling in the near-shore sections with pipe laying in deeper water resulted in an optimal process, which was required for completion within ten weeks. A part of the backfilling works, by “Seaway” and “Flevo”, was done by discharging through the suction pipe. To enable the “Flevo” to perform this action its pipe layout was converted. The remaining part

e): TSHD “WD Fairway” in the Port of Mumbai

f): Jet nozzle of TSHD “WD Fairway”

g): Post-trenching system as used on TSHD “WD Fairway” and on TSHD “Seaway”

h): Land-based equipment excavating at the Landfall Point at Uran.



was backfilled by means of discharging through the bottom doors, and that by “Flevo” only. The vessel’s small size and ability to position itself exactly above the trench made the “Flevo” very suitable for this kind of operations. This cautious way of discharging resulted in a controlled rising of the backfill level.

Post-Trenching Operations

In addition to the “Seaway” the “WD Fairway” was mobilized to Mumbai for the post-trenching operations. Both vessels were equipped with a purpose-built jet nozzle instead of a draghead. This nozzle created a jet stream which penetrated and eroded the seabed around and underneath the pipelines, which were gradually lowered to the required level. Giving the distance offshore and the water depth in the working area, a multi-beam echosounder was installed on the suction pipe allowing the vessels to perform their own surveys. To ensure the integrity of the pipelines a profiler was fixed on the suction pipe, providing the operator with online information on the position of the jet nozzle with respect to the pipeline. Post-trenching of 420 kilometres was successfully completed in a period of one month.

Appendix 8: Rock Fall brochure

Rock Fall Company Limited

Drilling Contractors & Explosives Engineers

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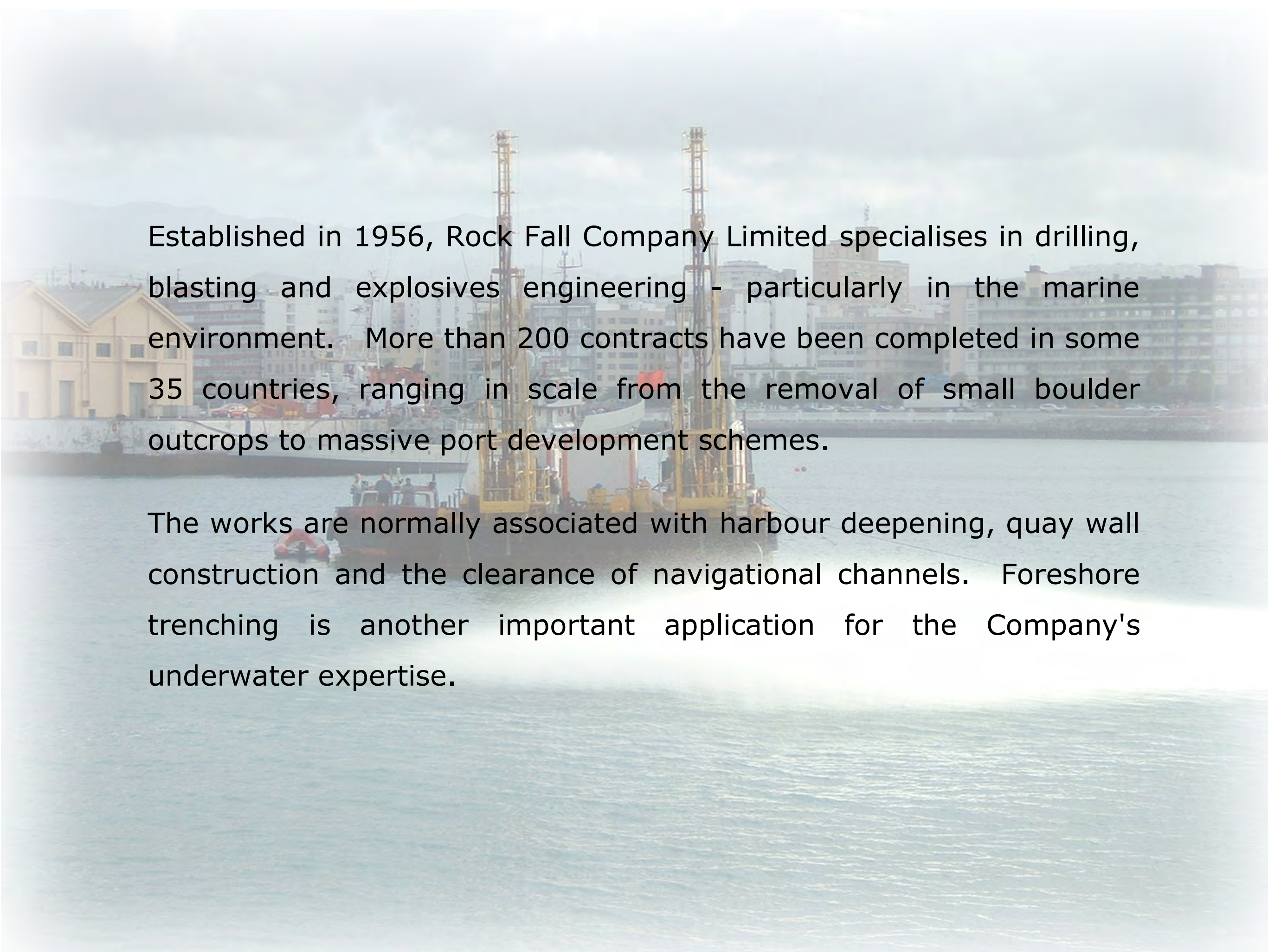
tel: +44 1563 851302
fax: +44 1563 851063
e-mail: info@rock-fall.com
web: www.rock-fall.co.uk

Company Profile

drilling and blasting is our business...



Established in 1956, Rock Fall Company Limited specialises in drilling, blasting and explosives engineering - particularly in the marine environment. More than 200 contracts have been completed in some 35 countries, ranging in scale from the removal of small boulder outcrops to massive port development schemes.

The works are normally associated with harbour deepening, quay wall construction and the clearance of navigational channels. Foreshore trenching is another important application for the Company's underwater expertise.

Precision Work

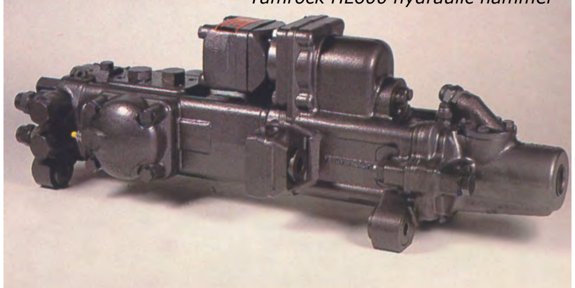
Over the past decades Rock Fall has encountered some of the world's toughest climatic and environmental conditions - from the rough, cold North Sea to the searing heat of the Middle East and the humidity of the Far east, from fast-flowing rivers and estuarial currents to water depths of 45m. Rock conditions have varied widely, from substantial layers of glacial till type overburden to the hardest of Scottish and Swedish granite.


Working close to vessels in Heysham, England, UK, 1996

Rock drilling and blasting work demands strength and tenacity but also precision and skilled engineering. When operating in areas of environmental sensitivity and in confined places, such as alongside quay walls or adjacent to live pipelines, special skills and strict vibration control are necessary.

Extensive Resources

Rock Fall is at the forefront of the rock drilling and blasting industry, continually developing new techniques and perfecting existing methods. Our engineers work closely with leading research organisations.

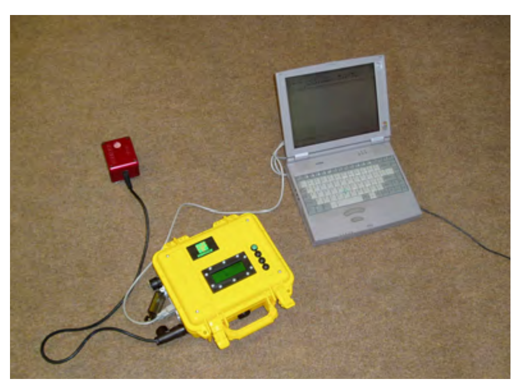

Tamrock HL600 hydraulic hammer

The Company's plant features the latest technology and is designed to be containerised for fast and easy mobilisation to sites throughout the world. Versatility is a feature of the drilling towers and deck equipment which can be placed on virtually any jack up, rigid flat-top or modular pontoon.

A proven track record, skilled and experienced personnel, modern and versatile equipment and the backing of an international organisation - these are the reasons why Rock Fall is the first choice for rock drilling and blasting in support of civil engineering, offshore and maritime engineering projects.

Environmental

Thousands of tonnes of explosives have been used by Rock Fall for marine projects such as the construction of deepwater channels and for the removal of unwanted structures. The explosives engineering industry has an excellent safety record, and attention is also paid to the environmental issues connected with rock blasting. Blasts may effect human swimmers or divers and aquatic animals such as marine mammals and fish.



Rockfall has worked for 20 years in collaboration with Subacoustech Ltd., a specialist underwater acoustics and blast consultancy, to provide environmental impact assessments, measurements, control and mitigation of underwater blasting. The database comprises of several thousand measurements of underwater blasts, which can be used to estimate accurately the expected blast level in a wide range of operations.

Holyhead, North Wales

The construction of a new Ro-Ro terminal in Holyhead Port required drilling and blasting in two phases.

During the first phase in 2002, Rock Fall employed a three-boom barge consisting of two pneumatic drill rigs and one hydraulic drill. The hydraulic rig was recently designed by Rock Fall and was in use for the first time on this Contract.

The top three photographs show phase 1 of the works.

The second phase in 2003, required the use of one pneumatic rig, which can be seen in the bottom two photographs.

Over 7,000m^2 of Mica Schist was blasted prior to dredging.

New York, U.S.A.

A two-year long Contract has been successfully completed in 2003 in the Hudson River of New York, U.S.A. Such a large Contract required the use of three hydraulic drill rigs and a large drilling pattern.

Freezing conditions during the winter months had to be combated, but the equipment held out.

This Contract is part of an ongoing project to deepen the approaches to New York Harbour in order that larger container vessels may dock in the New York and New Jersey areas.

So far, over 230,000m^3 of rock has been pre-treated by drilling and blasting.

Drilling & Blasting under the Bayonne Bridge

Tema, Ghana

Drilling and blasting was carried out during the early months of 2003 in the port of Tema, Ghana, West Africa.

Over 16,500m^3 of Gneiss was blasted within a small creek inside the harbour, very close to pipelines and container ships

Two pneumatic drilling rigs were used to execute the works over a 4-week period.

Las Palmas, Gran Canaria

Drilling and blasting was carried out in the Port of Las Palmas, Gran Canaria, Spain, throughout the summer of 2003. The total area covered was over 17,000m^2.

Strict vibration control was required due to the closeness of structures, quay walls, vessels and public access ways. A two-boom air rig barge was used for the contract.

Appendix 9: Project sheets Boskalis Offshore

The complete landfall contractor

Trenching, pipeline installation and backfilling:
12 pulls in 13 months

Al Khafji, Saudi Arabia (Saudi Aramco)
Balearic Pipeline, Spain (Enagas)
MedGaz Pipeline, Spain (MedGaz)
Dhirubhai, India (Reliance)

Boskalis Offshore bv

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Internet: www.boskalis.com

Introduction

Due to the complexity and multi-disciplinary nature of offshore operations the Energy Sector has very special and specific demands with regards to dredging and related works. In order to provide optimal service Boskalis Offshore has been structured to combine the offshore skills, resources and experiences of the Royal Boskalis Westminster Group while still benefiting from the backup of the group's integrated global network.

The major services Boskalis Offshore provides are related to the shore approach and shallow water sections of offshore projects. These include trenching, cofferdam installation, pipe pulling and installation, backfilling and coastal reinstatement. Boskalis Offshore provides integrated services which complement its customer's activities with project specific criteria thereby providing tailor-made solutions to its customers.

Record year

From November 2007 to December 2008 Boskalis Offshore executed in addition to the normal related dredging services no less than 12 pipe pull operations, a record number of pulls in thirteen months. Current contract commitments include for a further two pipe pulls needing to be performed within the coming six months.

Indian Subcontinent

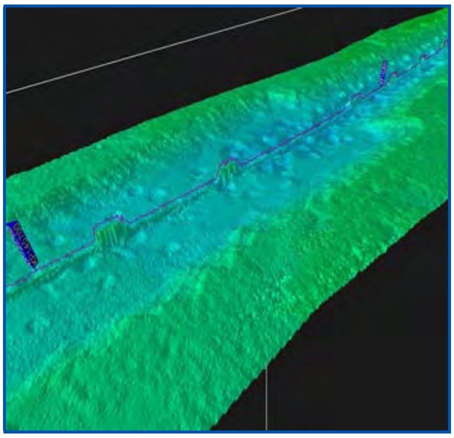
As part of India's ongoing programme toward energy self reliance Boskalis Offshore and a joint venture partner were awarded the dredging and related works associated with the installation of six pipelines connecting the Dhirubhai Fields, part of the Krishna-Godavari Basin, with the onshore facilities. Only a limited narrow area at the landfall point was available for installation operations, this required careful planning and a high degree of precision to work within the permissible constraints. Despite the area being densely populated the landfall site was extremely remote with regards to the provision of services normally required for this type of operation. All accommodation for the 200 strong work force, all all-weather roads and hard standing storage areas, a suitable quay wall facility as well as adequate provision of potable water needed to be constructed.
Boskalis Offshore was also required to perform extensive dredging works within the deltaic coastline area which is subject to heavy sedimentation for the inter connection pipelines. Once the pipelines were installed in excess of 900,000 tonnes of protective rock armour had to be placed over the pipelines. The rock aggregate was locally produced and transported via the all weather access roads previously constructed and loaded onto the side stone dumping vessels mobilised for the task via the quay facilities previously mentioned.

Middle East

The Saudi Arabian coastline in the Persian Gulf is characterised by complex and variable soil types. In order to perform any dredging operations in this region detailed knowledge and experience as well as modern specialised equipment is essential. Having successfully performed several projects in the region Boskalis is perhaps the most experienced dredging contractor in the region; continuously having a large and diverse fleet of equipment working in the region makes Boskalis Offshore the perfect choice of dredging contractor. With the extensive in-house data base and readily accessible fleet of equipment Boskalis Offshore is in a position to provide unique and efficient project specific solutions to suit the customer's requirements.

In the case of a project in Al Khafji Boskalis Offshore were able to provide the customer with exactly the right solutions as well as rapid response with regards to mobilising to site. This meant that the project was completed in the first quarter of 2008 a mere six months after the project was awarded.

The project called for the installation of two pipelines, a 36" and a 42". Local support was effectively non existent, what was available would never have complied with the even most basic of safety audits. In order to expedite the work once the dredging operations were completed the installation of the pull wires was performed using the backhoe dredger, which was able to utilise its DGPS as well as its integrated anchoring systems to accurately lay the twin pull cables in a single operation ensuring that they were parallel to each other.



Precise knowledge of the underwater conditions plays a key role in successful pipeline installation

Above: The first of a series of six pulls in Dhirubhai, India
Below: Dhirubhai after completion of the final pull

To facilitate both pull and wire installation floatation bodies were applied

Both the 42 inch and the 36 inch pipe pull completed

Balearic pipeline ready to be pulled

The GASCO project links the facilities on Das Island to those situated in the Abu Dhabi Industrial Zone in Ras Al Qila. Boskalis Offshore was required to dredge the two shore approach ends in preparation for the pipe pulls. Both trenches were 6km long, in this instance the main contractor undertook the pipe pulling operations however Boskalis Offshore were called upon to provide backup support and assistance throughout the pipe pull operations.

Mediterranean

Two major pipeline projects were performed during 2008 in this region:

- Medgaz which is a pipeline connecting Spain to the gas reserves in Algeria
- Balearic Pipeline which connects the Spanish mainland supply network to the domestic and industrial consumers on the island of Mallorca and Ibiza.

Both projects were situated in or very near to major tourist attractions therefore the pristine and attractive coastline needed to maintain throughout the execution period. For both projects environmental protection constraints were rigidly enforced and adhered to protecting not only the inherent beauty of the area but also protecting the various marine plants and breeding grounds for the abundant marine life in the area.

Ensuring that the tourist season was not hampered in any way as well as performing environmentally sensitive work during periods which can at best be described as not optimal for precise control proved to be challenging and demanding. Both projects were completed on time and to specification.

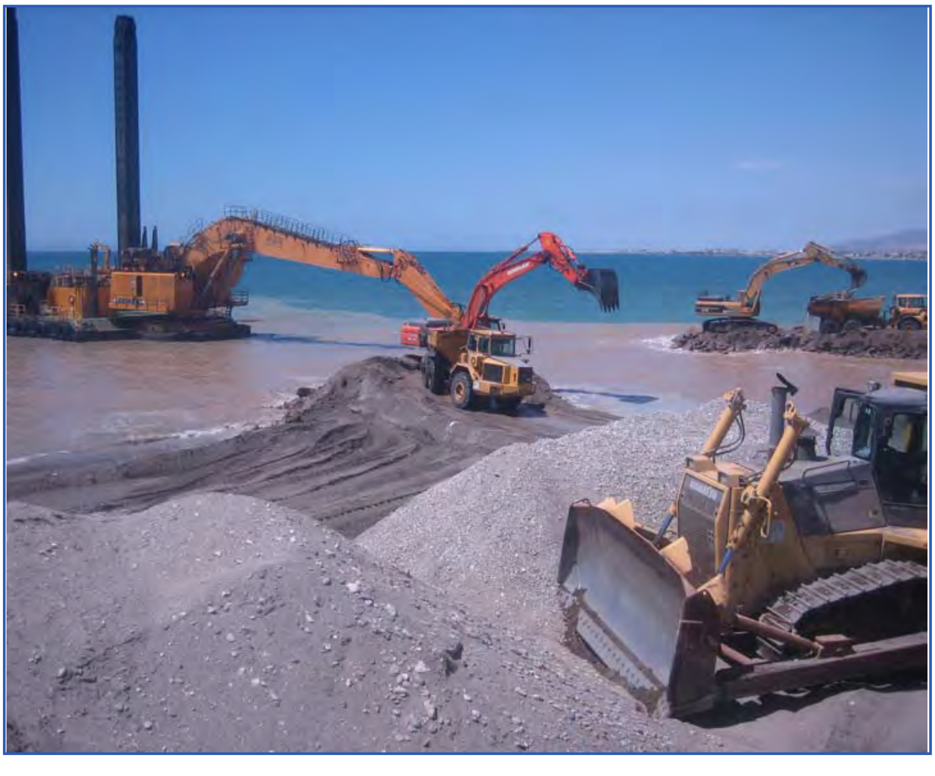
The challenge was met successfully by utilizing the right equipment and the most experienced crew.

Safety, Health & Environment

In every challenge faced in the mentioned projects as well as other activities the main focus is on accomplishing the set targets without compromising the safety and health of those involved. The table below presents at a glance the performance in this field Boskalis Offshore has accomplished in 2007 and 2008 in comparison to average IMCA accomplishments.

Safety Statistic Description	Boskalis Offshore 2008	Boskalis Offshore 2007	IMCA 2007
Fatalities / $1x10^8$ hrs	0	0	1.5
LTI's / $1x10^6$ hrs	0	1.26	1.44
Injuries / $1x10^6$ hrs	4.55	6.29	8.29

Medgaz shore crossing under construction



The complete landfall contractors

Summarizing, Boskalis Offshore is a specialist for pipeline shore approach works. We bring knowledge, engineering, experience and a safe and healthy approach together to deliver the full service on time and according to the strict specification of our clients.

The acknowledgement of this level of expertise is reflected in our ongoing contribution in prestigious projects including the recently awarded German Landfall of the Nord Stream Pipeline and the Safaniya Shore Approach in Saudi Arabia.

Balgzand - Bacton Pipeline (BBL)

A gas pipeline from Balgzand (The Netherlands) to Bacton (UK)

Client: N.V. Nederlandse Gasunie, under auspices of BBL Company
Main Contractor: Saipem UK Ltd.
Contractor: Boskalis Offshore bv
Location: Julianadorp, the Netherlands
Period: March - December 2006

Boskalis Offshore bv

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Boskalis Offshore: skills, resources, experience

Boskalis Offshore brings together the offshore skills, resources and experience of Royal Boskalis Westminster.
The group's offshore capabilities include seabed rectification works for pipeline/cable and platform installation, construction of pipeline shore approaches and landfalls, offshore mineral mining, offshore supply and support services and decommissioning services.
Boskalis provides clients with tailored, project-specific solutions for above dredge related offshore services, as illustrated by the following project summary.

Project description

BBL Company was established to design, construct, operate and exploit the Balgzand - Bacton Pipeline (BBL) for the transmission of natural gas from Balgzand, the Netherlands to Bacton in the United Kingdom.
The overall length of the 36" offshore pipeline is some 230 kilometres.
The capacity is around 42 million cubic metres of gas a day.

As part of the pipeline installation, Saipem UK Ltd awarded Boskalis Offshore the contracts for the shore approaches at Julianadorp, the Netherlands and Bacton in the United Kingdom and the pre-sweeping and rock dumping works along the pipeline route on the North Sea.

Boskalis subcontracted the shore approach at Bacton to the Land & Marine Westminster Joint Venture (comprising Land & Marine Project Engineering Ltd and Boskalis Offshore's sister company Westminster Dredging Co. Ltd).

Shore approach at Julianadorp

The scope started at the tie-in to the HDD dune crossing on the beach.
Planning of activities on the beach required careful consideration with regard to the sensitive dune areas adjacent to the project site and tourists on the beach during the summer season.
From the beach a 300 metres long sheet piled cofferdam was installed to facilitate trench excavation through the surf zone.
From the offshore end of the cofferdam a trench was dredged up to 7 kilometres offshore.

Location map.

Excavation of trench by specially modified excavator; Inset: Pipepull operations.

Installation of sheet piles and trenching by TSHD "Argonaut".

Trenching operations by TSHD "Waterway" and "Argonaut".

This scope also included the supply and operation of a 500 tons capacity linear pull winch and pull wire installation to facilitate the beach pull operations. Upon completion of the pipeline installation, the trench was backfilled, the cofferdam removed and the beach re-instated.

Cofferdam and winch platform

On the beach the activities started with the installation of a 300 metres long and 5 metres wide temporary bridge to be used as access road during the cofferdam installation works. Close to the dunes, a winch platform constructed of sheet piles was installed to protect the equipment at high tides.

The 5 metres wide trench inside the cofferdam was excavated by means of a specially modified excavator driving on the temporary access bridge. Excavated material was temporarily stored adjacent to the cofferdam and later re-used as backfill material.

Pipeline pull-in

The winch was used to pull the pipe from the lay barge to the shore. Boskalis was also responsible for the accurate installation of the 4" steel pull wire from the winch, through the trench, up to the recovery point some 800 metres offshore.

Offshore trench dredging and backfilling

The offshore trench was dredged by Trailing Suction Hopper Dredgers (TSHD). The shallowest part was dredged by TSHD "Sospan Dau"; TSHDs "Argonaut" and "Waterway" dredged the sections in deeper water.
The trench with a bottom width of 5 metres was dredged to ensure a cover on Top of Pipe of 3 metres.
A total volume of approximately 600,000 m^3 of sand and clay was dredged and discharged at a designated temporary storage area for later re-use during the backfill operations.

Upon completion of the pipe lay operations, the offshore trench was backfilled to original seabed level by TSHDs "Coronaut", "Argonaut", "Sospan Dau" and "Sospan".

Tie-in

The final connection between the dune crossing and offshore pipeline was made by means of a tie-in at the beach. This tie-in, including field joint coating and testing of all welds was carried out in an 8 metres deep sheet piled tie-in pit.

Beach re-instatement

Upon completion of the pipe pull, backfilling of the trench was carried out. Finally the cofferdam, winch platform and access bridge were removed and the beach and dunes were re-instated.

Pre-sweeping and Rock Dumping

Pre-sweeping was carried out by TSHD "Oranje", equipped with multibeam survey equipment, enabling the vessel to operate on a stand alone basis. The "Oranje" dredged 381 sand ridges in water depths up to 50 metres.

The Dynamically Positioned Fall Pipe Vessel (DPFV) "Sandpiper" executed rock dumping works at 8 cable crossings and 5 pipeline crossings along the pipeline route. In total 26,654 tonnes of rock was installed. DPFV "Seahorse" performed rock dumping of 33,935 tonnes at a free span section.

The project was completed under typical, unstable, North Sea conditions, but nevertheless to client's complete satisfaction.

Tie-in pit and TSHD "Sospan Dau" backfilling.

Royal Boskalis Westminster nv

Project Data Sheet

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Dhirubhai 1 & 3 Gas Fields Development, India

A large-scale dredging, trenching, pipe pulling and backfilling project

Client:	Reliance Industries Limited
Location:	Krishna Godavari Basin, off the East Coast of India
Period:	August 2007 - November 2008
Main contractor:	Allseas Marine Contractors S.A.
Contractor:	Boskalis Offshore - Tideway JV

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Project description

Reliance Industries develops the offshore gas field known as Block KGDWN-98/3 in the Krishna Godavari Basin, Bay of Bengal off the East Coast of India.
The gas field will be linked to onshore customers and covers an area of approximately 7,500 km^2. The field stretches an area 40 to 60 kilometres southeast of Kakinada.
The scope of works comprised the dredging of a 21 kilometres long and 18 metres wide trench for three 24" gas pipelines, each with a 6" piggyback pipeline, one 12" effluent pipeline and two umbilical cables in water depths ranging from 0 to 50 metres. After pipe laying by the main contractor the pipeline trench was backfilled with partly rock and sand.

Trenching

Two Boskalis cutter suction dredgers (CSD's) were deployed in August 2007. The self-propelled sea-going CSD Cyrus II was utilized to dredge a work channel from the river mouth to offshore to enable access for the trailing suction hopper dredgers (TSHD's). The channel dredging work included dredging of a trench. The medium size CSD Orion was deployed to remove shoals in the river to allow TSHD's to enter the river


a)

b)

a): Landfall cable conduits.

b): Location map.

c): Trenching carried out by TSHD Cornelis Zanen.

d): Pipepull landfall point.

e): Trenching work in the river mouth by CSD's Orion and Cyrus II.

c)


d)


e)

and dredge the trench. Furthermore the Orion dredged the shore approach and an access channel of 1,250 metres plus turning basin for rock loading operations. The dredged spoil from the cutter dredgers was deposited by means of a spreader pontoon or via a shore connection.

The remainder of the trench was dredged with among others the Boskalis TSHD Cornelis Zanen. The total dredged quantity was approximately 8.5 million cubic metres.
The dredged material was temporarily stored in predetermined underwater storage areas close to the dredge areas for later reuse as backfill material.

Landfall

As part of the landfall activities a cofferdam with wing-walls was installed at the transition from the river to the shore as well as a sheet pile anchor wall for the pull-in winch. Following excavation of the cofferdam by excavators and of the approach by CSD Orion and after installation of the 300 tons linear pull-in winch, the four pipelines were pulled ashore. For the shore approach of the umbilical cables two conduit pipes of approximately 170 metres were assembled, installed and pulled into the river prior to the pull-in of the umbilical cables. These cables were pulled around a bend to a total distance of approximately 300 metres each.

Rock logistics

The client supplied the rock for the later rock backfilling to a temporary stockpile in the vicinity of the site. As part of the works a temporary haul road was prepared of around 2 kilometres length connecting the stockpile with the loading point at the river.

Furthermore, in order to load the rock onto the rock dump vessels, a sheet piled rock loading jetty of 160 metres wide was created where the vessels and barges could be moored alongside and loaded.

Approximately 900,000 tonnes of rock were transported to the jetty and loaded with heavy dry earth equipment onto the flattop barges and side stone dumping vessels.
Since part of the public road was used for the rock transport, there was high emphasis on the safety aspects of the job. In the end all works were safely completed.

Backfill

After partial pipe- and cable laying by the main contractor the trench was backfilled. Parts of the pipelines were stabilized and protected by rock berms and where more scour was expected continuous rock dump including falling aprons were installed with a bedding layer of sand.

Two Boskalis vessels were deployed for the installation of rock. The side stone dumping vessel Cetus with dynamic positioning was engaged in the placement of rock berms on both the river and offshore sections.

f)

g)

f): Purpose-built rock loading facility.

g): Backfilling carried out by Side Stone Dumping Vessel Cetus.

h): Fallpipe pontoon Zeepaard.

The fallpipe pontoon Zeepaard with dynamic tracking system on anchors placed the continuous berms and falling apron on the river section. Acoustic doppler current profilers were deployed for accurate prediction of the rock displacement in the actual current. Some 900,000 tonnes of rock were placed in accordance with the main contractor's design.

After installation of the berms, a TSHD backfilled the spaces in between the berms with sand. Parts of the trench not covered by rock were also backfilled with sand. The backfilling works were completed in November 2008.

h)