

## SEABED INTERVENTION

### WHY IS SEABED INTERVENTION NECESSARY?

To place a structure on the seabed securely, the seabed should be as flat and regular as possible. If the seabed is irregular or undulating, the structure, for instance, a pipeline or cable or offshore platform, will suffer the risk of spanning and overstressing. To avoid these and other risks, dredging contractors are asked to intervene to make the seabed flatter or to cover the structure that is being placed to protect it. Offshore infrastructure installations are often exposed to high external pressures and cold temperatures. They are subject to tidal movements, currents and scour unless buried or trenched in the seabed. Preparation of the seabed is therefore of crucial importance.

### HOW OFTEN DOES SEABED INTERVENTION TAKE PLACE?

In recent years the need for seabed intervention has been increasing. Since the late 1940s, gas and oil have been mined from offshore sites. Nowadays these resources are being mined at ever greater depths, often in remote areas. These resources have to be brought on shore and this is frequently done through pipelines laid upon the seabed. These pipelines must often traverse long distances over rough seabed terrain to land-based sites.

For instance, at Sakhalin in Russia, the potential recoverable resources are enormous and the challenges equally as great. This offshore project required the installation and post-trenching of 20 km pipeline crossing of Tatar Strait, the narrow fairway between Sakhalin Island and the Russian mainland, a significant distance to be managed in a harsh climate where the short summers mean a limited working

window. Although the main clients for seabed preparation contracts are oil and gas operators for pipe-laying and offshore platforms, the same intervention techniques are applied in other markets, such as cable laying, port construction and in the offshore wind farm industry. Before foundation towers could be sunk at the Thornton Wind Turbine Farm off the Belgian coast, the seabed had to be levelled and a gravel bed for stabilisation had to be laid. Also at the Le Havre's Port 2000, the seabed was levelled to a tolerance of approx. 10 cm before the two massive concrete caissons that close off the breakwaters, could be positioned.

### ARE UNEVEN SEABEDS A COMMON OCCURRENCE?

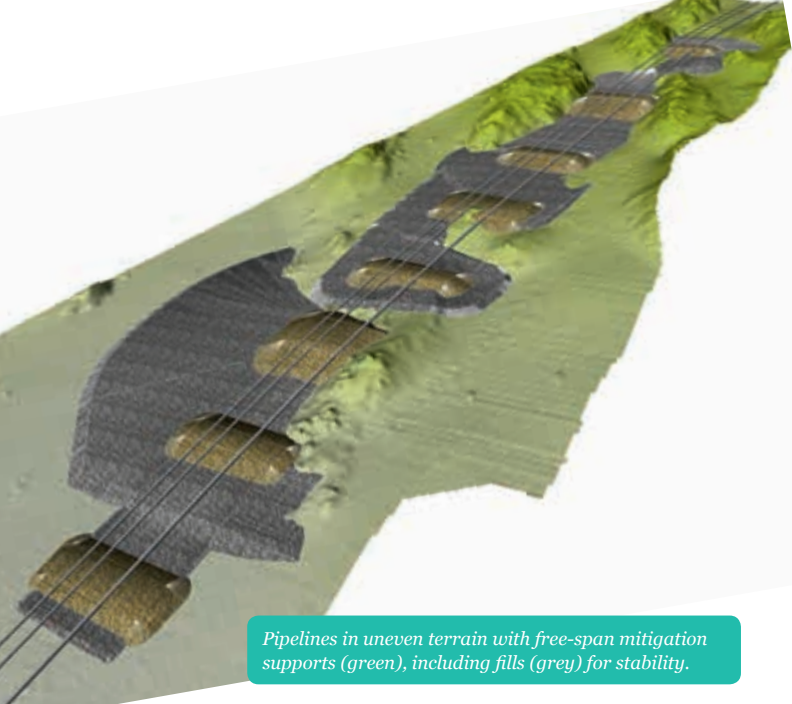
In fact, yes. Uneven or "undulating" seabeds occur rather frequently and can be caused by soft seabed materials which are sensitive to underwater currents. They may also be caused by hard seabed like rocks, boulders and gravel. These conditions can result in unexpected transitions where steep slopes appear resulting in sections of unsupported pipelines or cable called free spans.

### HOW DO FREE SPANS AFFECT PIPELINES?

Free spans – sections of the pipeline that are not touching the seabed – are caused by the irregularity of an uneven seabed created by the turbulence or scouring action of water and sand. They can result in pipeline fatigue when the pipelines in unsupported sections are subject to currents and vibrations.

When a free span exceeds an allowable distance or threatens to cause a misalignment between connectors, a solution must be found to compensate for the unevenness. The allowable distance for a free span must be determined on a case-by-case basis.

*Pictured above: A post-trenching machine at work in the Tatar Strait. Post-trenching lowers the pipeline from the level at which it was laid to the final pipeline level.*



Pipelines in uneven terrain with free-span mitigation supports (green), including fills (grey) for stability.

Solutions such as levelling the seabed or pre-trenching (a pre-dug trench in which to lay the pipe) or constructing rock beds and berms or crossing support structures can be made to reduce the stress on the free span areas. These supports may include sand-filling. This method will compensate the unevenness by filling in the seabed and reducing stress on the pipeline or cable.

### WHAT OTHER FACTORS INFLUENCE PREPARING THE SEABED?

The length of the pipeline as well as the depth at which it must be placed on the seabed are other factors that can influence the already complex operation of installing pipelines and cables. Appropriate equipment is crucial to meet these challenges. Consequently, in the last decade extensive investments in R&D have been made, resulting in technically advanced equipment for pipe-laying and seabed interventions.

To meet the demands of recent deep-sea oil and gas exploration, equipment has been designed that makes it possible to lay pipelines on a seabed as deep as 2,500 metres (or deeper). Obviously this requires longer cables and hoses with which to reach these depths as well as other equipment especially adapted to these depths. Underwater positioning systems have been improved and precise surveying before, during and after seabed intervention is indispensable. Both positioning and surveying are conducted by remotely operated underwater vehicles (ROVs). By using highly accurate real-time surveying systems, rough terrain and obstacles such as sand waves, outcrops, pockmarks as well as general unevenness can be discovered and addressed.

### WHAT ARE SAND WAVES?

Sand waves are caused by relatively high velocity water currents which form large, ridge-like areas on the surface of the seabed. They look a bit like water waves and occur in general when the seabed is primarily sand or gravel. Where

sand waves predominate they can create a seabed topography that covers many kilometres. Sand waves can be mere ripples – not unlike what one sees on a beach at low tide. Or become veritable hills of some 20 metres high with hundreds of metres in wavelengths extending for many kilometres.

The crests and furrows made by sand waves may remain stationary, but they can also be in motion and change position in both height and width. Although avoiding sand waves altogether as the route for a pipeline is the ideal, this is not always possible. As a result, the seabed will have to be levelled and/or an area may require pre-trenching or sand filling.

### WHAT ARE OUTCROPS?

Similar to sand waves, outcrops of rocks or coral reefs can also pose obstacles to the routing of pipelines. In certain parts of the Gulf of Mexico, such outcrops can be up to 10 metres in diameter and 2 metres in height, whilst outcrops with smaller dimensions can be spread all over the seabed.

Installation of pipelines through areas with outcrops might require pre-lay removal of the outcrops to ensure relatively even seabed conditions. A trailing suction hopper dredger (TSHD) can usually be used to flatten sand wave ridges or outcrops and/or to dredge a trench to allow routing a pipeline through areas with sand waves and outcrops. The newest, largest trailers have been known to work in water depths of between 125 and 150 metres.

### WHAT ARE POCKMARKS?

Pockmarks are craters in the seabed caused by fluids (gasses and liquids) erupting and streaming through the sediments. Sizes of pockmarks can range from a few metres to more than 700 metres in diameter, with depths varying from 10 or 20 centimetres to more than 15 metres. Under normal circumstances the route of a pipeline would try to avoid pockmarks, but sometimes this is not possible. The challenge is then to create a pipeline bed that crosses pockmarks keeping the spans within permissible lengths. A pockmark of a few metres could conceivably be evened out by filling it with gravel or rocks. When larger pockmarks with a broader diameter are encountered, a path or berm is built with rocks and the pipeline is laid upon it. In extremely soft clay, significant settlement is to be expected and the amount of rock and gravel needed to create a stable seabed will need to be calculated and compensated for these subsidences.

To construct such a bed or berm, which demands the accurate placement of rock and gravel in very deep waters, flexible fall pipe vessels (FFPVs) are commonly used and have proven to be cost efficient. Typically FFPVs are used to install large quantities of rock and can reach water depths of some 2,000 metres.

### HOW DOES WEATHER INFLUENCE SEABED INTERVENTION?

Weather plays an important role in all types of infrastructure

projects. This is also the case in offshore operations. Lost time as a result of bad weather can be expensive.

Seasonal factors must be considered and often computer simulation models are used. Seabed and weather conditions therefore need to be determined before operations begin. This is of course easier said than done. To deal with unpredictable meteorology and oceanography (metocean) conditions in regions with uneven, undulating seabeds preparation for interventions – such as pre-lay trenching across rock areas, construction of supporting berms for a pipeline in rough terrain/coral areas, gravel blankets and ramps for PLEMs and PLETs (Pipeline End Manifolds and Pipeline End Terminations), and building pre-lay free-span supports – should be made well in advance. Fortunately the methods for forecasting wind, waves, tides and weather in general have significantly improved.

## HOW IS PIPE-LAYING ACHIEVED IN SUBSEA CIRCUMSTANCES?

Subsea pipe-laying is achieved by specialised vessels that are fitted with a heavy lift crane and equipment to lay pipe. These pipe-laying ships use dynamic positioning systems or anchor spreads to maintain the correct position and speed whilst laying pipe.

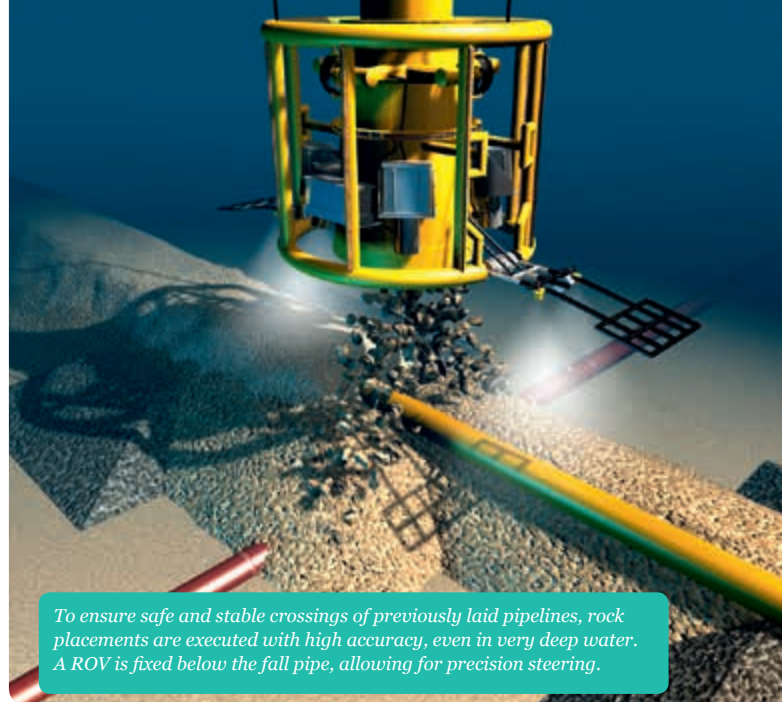
Several pipe-lay methods are commonly used for installation: the S-lay method and J-lay method. The S-lay method is suitable for use both in shallow and deep-water areas depending on the diameter of the pipe. Pipe sections are welded horizontally and these welded sections are continuously fed over the lay barge's so-called "stinger". As the pipeline gradually exits the barge to reach the touchdown spot on the seabed, it forms the shape of an "S". In the J-lay method, pipes are assembled and welded in a vertical tower erected on the lay barge. As the platform moves forward, the jointed pipeline is lowered almost vertically from the launching point down to the seabed, bending only once in a J-shape. In both cases, at the lower end the seabed must be levelled and ready to receive the pipeline.

When using the Reel-lay method long pipe segments are welded, tested and coated onshore and then spooled onto a large vertical pipe reel in one continuous length. Once in position, the Reel-lay vessel moves slowly forward as the pipeline is unspooled.

## WHAT FACTORS INFLUENCE THE CHOICE OF EQUIPMENT?

Water depth is one of the most influential factors in the choice of installation equipment for subsea infrastructure operations. Hydro-dynamic excavation tools have been developed which are able to work in non-cohesive soils and soft clays in extreme environments, from great ocean depths to shallow coastal regions.

If the water depth is shallow, for example, at low tide or nearshore, a very shallow-draught pipe-laying barge, assisted



*To ensure safe and stable crossings of previously laid pipelines, rock placements are executed with high accuracy, even in very deep water. A ROV is fixed below the fall pipe, allowing for precision steering.*

by tugs, anchor handling equipment, crew boats, survey boats and auxiliary equipment, may be required. On the other hand, specialised equipment has been developed to meet the demands of deeper seabeds which are not accessible using conventional hydraulic excavation tools. New positioning systems and surveying systems made possible by the use of remotely operated vehicles (ROVs) provide reliable data at extreme depths and during difficult weather conditions and thus greatly increase the accuracy of pipeline placement and seabed intervention activities.

## WHAT IS PRE-SWEEPING?

Before installation of a pipeline, pre-sweeping of sand waves is usually required in order to level the seabed. One or more dredgers may do the pre-sweeping with pipe-laying vessels following behind. The pre-sweeping operation prepares a smooth enough seabed upon which to lay the pipeline.

The pipeline can then be installed within permissible limits with regard to span lengths, pipe stresses and off-bottom clearances. The newest, largest trailers have very wide pre-sweep dragheads and will use dynamic tracking and multi-beam sonar surveying techniques. These yield better horizontal and vertical tolerances. In soft soils a Mass Flow Excavation (MFE) principle might be applied.

## WHAT IS A MASS FLOW EXCAVATOR (MFE)?

A Mass Flow Excavation method can be used to disperse loose coverings and soft clays. An MFE jet-frame has very powerful water jets which penetrate the seabed and bring the soil in suspension. The water flow removes the suspended sediment and a trench is created into which the pipeline is sunk. The water for the MFE is supplied from high pressure jets and dredge pumps. Amongst other tasks, MFEs are used for trenching and route preparation for subsea pipelines as well as for seabed levelling and sand wave clearance when conventional equipment may not be applicable.

## WHAT IF PIPELINE PROTECTION IS NECESSARY?

Sometimes pre-sweeping for seabed levelling is not the only intervention required for pipeline installation. In some cases, to ensure pipeline stability or protection, trenching is needed. That is, a trench may be excavated to lay the pipeline below the original seabed. After the pipe installation in the trench, if necessary, gravel and/or rock or concrete mattresses can be placed on top of the pipeline.

A similar procedure takes place as the pipeline approaches the shore and landfall section. To protect the pipeline against wave impact at shore approaches, and from damage caused by anchoring in land fall areas and shipping channels, the pipeline will be covered with gravel and/or rock or mattresses.

## WHAT IS HIGH PRESSURE JETTING?

When the seabed is particularly uneven, for example, at Ormen Lange in Norway, trenching was not always the answer and MFE jet stream was not strong enough. To meet the challenge a new high pressure jetting system was developed. The machine contained cylinders equipped with jets and additional high-volume cannons. In this system, surface water is pumped through the drill pipes to the jets at a high pressure that literally cuts through the peaks of the irregular seabed.

## WHAT ABOUT POST-TRENCHING?

In some cases, post-trenching will be chosen as the method by which to lower the pipeline from the level at which it was laid to the final pipeline level. In such a case, an ROV that is designed to bury pipelines will be called into service. This remotely operated trenching machine is operated by a technician on board and moves along the pipeline jetting away the sand or cutting clay or rock from under the pipeline and thus lowering the pipeline to the required depth.

## HOW CAN ROCK INSTALLATION SUPPORT OFFSHORE PIPELINES?

Subsea Rock Installation (SRI) is used to provide physical protection from external objects like anchors and fishing nets; to restrain upheaval buckling that can occur when, as a result of temperature changes, a pipeline starts to expand and move upwards; to mitigate free-spans of pipelines in uneven terrain; and to ensure safe and stable crossings of previously laid pipelines.

## WHAT ENVIRONMENTAL AND SAFETY ISSUES MAY ARISE?

As with all dredging projects, seabed interventions for gas and oil pipelines and cable installations are subject to close scrutiny concerning environmental impacts. Safety issues

such as vessels colliding with a pipeline or anchors dropping are of concern. Interference with marine flora and fauna are also issues. A good design will take these things into consideration and provide safeguards.

Currently the issue of energy efficiency and reducing CO<sub>2</sub> emissions into the air and sea are also being discussed. Equipment for seabed intervention is being developed to comply with these demands.

The interaction of the seabed with pipelines and cables remains complex. Nowadays extensive studies are done to establish a detailed description of the actual characteristics of the seabed prior to any maritime infrastructure operations.

The ultimate concern is to ensure the integrity of subsea structures over time as these are constantly exposed to waves, currents or loads. Thorough stability, stress and protection analyses are continually conducted. Should the integrity of a pipeline or cable fail, for whatever reason, the consequences can be dramatic. Seabed intervention is an important part of the process to prevent this from happening.

## FOR FURTHER READING AND INFORMATION

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