Using the correct planning and smart route engineering to open up more seabed real estate for future offshore wind sites

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Performing in-depth analysis on over 6,000 surface and sub-surface boulders, examined alongside a vast amount of bathymetry data, enabled OceanIQ Route Engineers to safely plan the array cable routes and seabed preparation plans for the 72 turbine Danish Kriegers Flak site.

OceanIQ's parent company, the Global Marine Group (GMG), was appointed by Vattenfall to deliver the route clearance and cable installation campaign at Danish Kriegers Flak, an offshore wind farm located in the Baltic Sea, southeast of Copenhagen. The new development consists of 72 turbines linked to two offshore substations, splitting the site into two areas: Kriegers Flak A and Kriegers Flak B. Together the sites called for a total of 72 inter array cable routes; a large-scale project requiring detailed analytical work in order to determine the most economically viable routes for the entire site.

Developing an asset that was perfect for the job

Wind farms are increasingly located further offshore where seabed environments are more challenging and often consist of boulders, boulder clays and glacial tills, environments that standard ploughs designed to work in mostly sands and clays, find difficult to navigate and effectively work in.

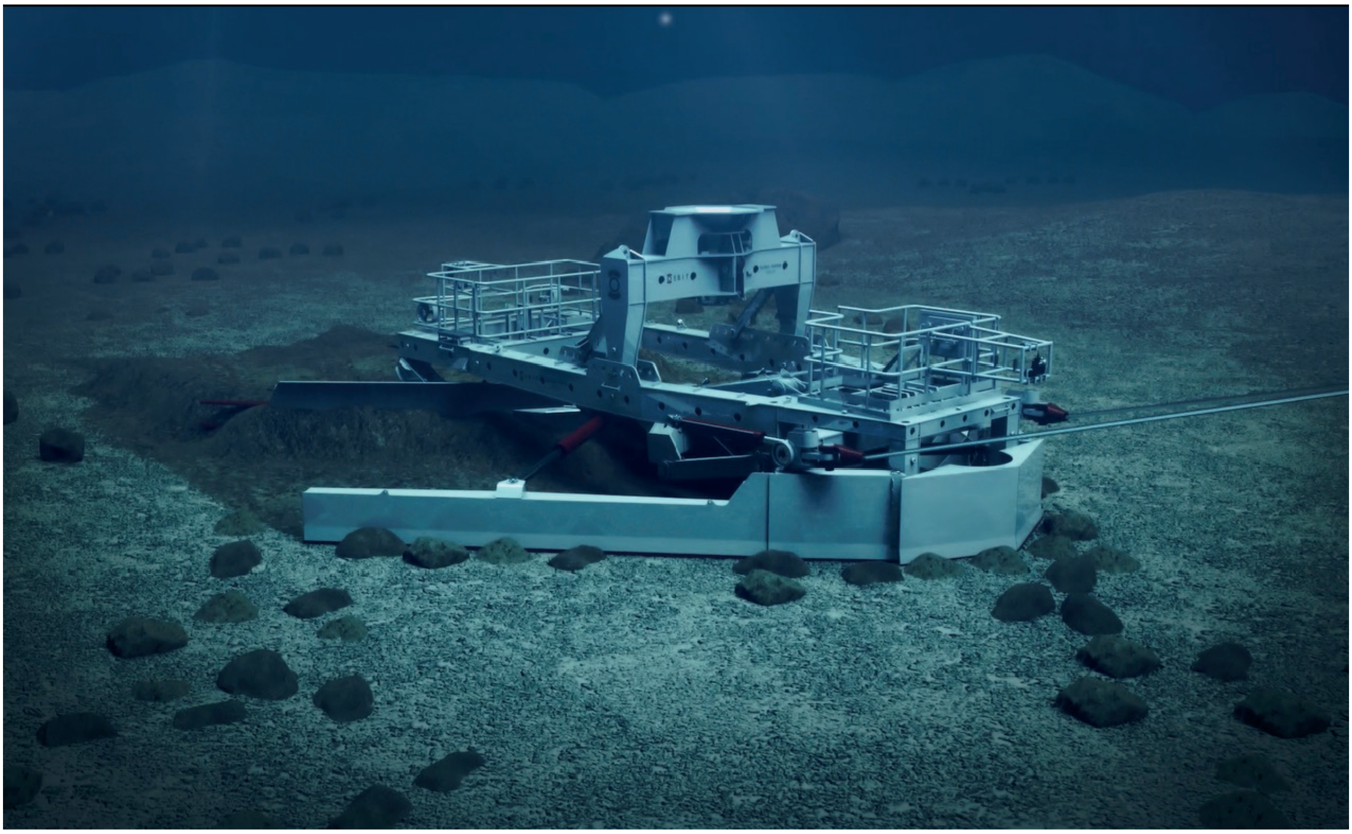
The implication of using existing ploughing approaches with time consuming multi-pass boulder clearing and trenching on the Danish Kriegers Flak project were economic and environmental, taking too long and costing too much, whilst producing large amounts of CO_2 and NOx.

The PLP240 Pre-lay Plough, was engineered and built for OceanIQ's sister company, Global Offshore, alongside Vattenfall and Osbit, specifically for use on this project. The PLP240 facilitates pre-lay trenching allowing the required pre-cable installation intervention on the seabed to be done in a single pass, saving time, costs, fuel and emissions. The asset is able to clear boulders, surface and subsurface, whilst simultaneously cutting a graduated 'Y' shaped trench and depositing the spoil heap separately to the edges of the trench. The cable is then laid inside the trench, where, depending on conditions and risk profile it may either be left as-is or subject to operations to achieve a required depth of cover by backfilling operations or by using the Q1400 trenching system to jet the cable within the trench itself.

As this marked the PLP240's first project, some trials of the asset were undertaken on similar seabed conditions ahead of the main work beginning. A small amount of each of the tasks involved in the project was completed on separate trial routes that the PLP240 could complete final testing on.

Understanding the design parameters of the specialist assets utilised on the project

Before route engineering could begin, design parameters needed to be established with consideration for the capabilities of the



PLP240 Pre-Lay Plough

equipment intended for boulder clearance and the digging of the cable trenches. The PLP240 in boulder clearance mode is able to achieve a clearance corridor of 16m, remove boulders up to a maximum of 2m in width and make cable turns on a 50m radius.

The Utility ROV Grab to be used for the removal of the larger, heavier boulders that couldn't be ploughed, was confirmed as being able to pick a boulder that was a maximum of 2.5m in length and weighing a maximum of 10 tonnes, as long as two opposing arms could safely close around it. This meant that boulders greater than 2.5m in length but under 2.5m in width, or vice versa, could still be picked if they weighed less than 10 tonnes.

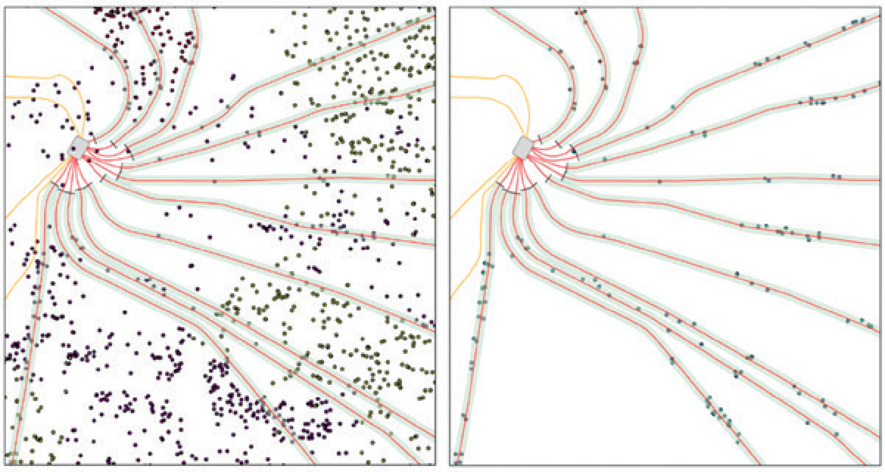
Final project deliverables

The ultimate goal of the boulder analysis work was to identify where on the cable routes the PLP240 would be able to clear boulders, where the UTROV Grab would be able to pick them, and where any remaining boulders too large for either of those activities would be left, requiring an amendment of the cable route itself. The process was iterative, with the cable route designed with all boulder and bathymetry data collated from within the PLP240's 16m cable corridor analysed, and the cable route adjusted based upon the results. This process was repeated until all immovable boulders were avoided and all other boulders could be ploughed or picked, which would then provide the team with the final cable routes.

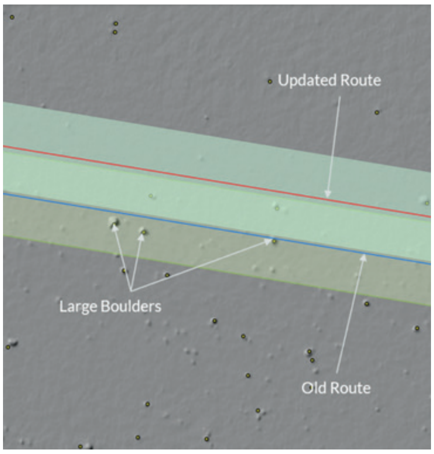
Gaining a full understanding of the seabed, boulder distribution and density

To achieve the final boulder listing, the findings from the route survey, which incorporated side scan sonar and multibeam data, had to be refined in order for OceanIQ Route Engineers to only see those boulders which fell within the parameters of the PLP240's clearance corridor. A 16m buffer was added around the initial cable route position lists (RPLs), in accordance with the width of the PLP240's blade, and spatial intersection was conducted to highlight the auto-picked survey targets (boulders) that fell within the buffer. These boulders were then analysed and categorised by their size and mass to determine the clearance method required.

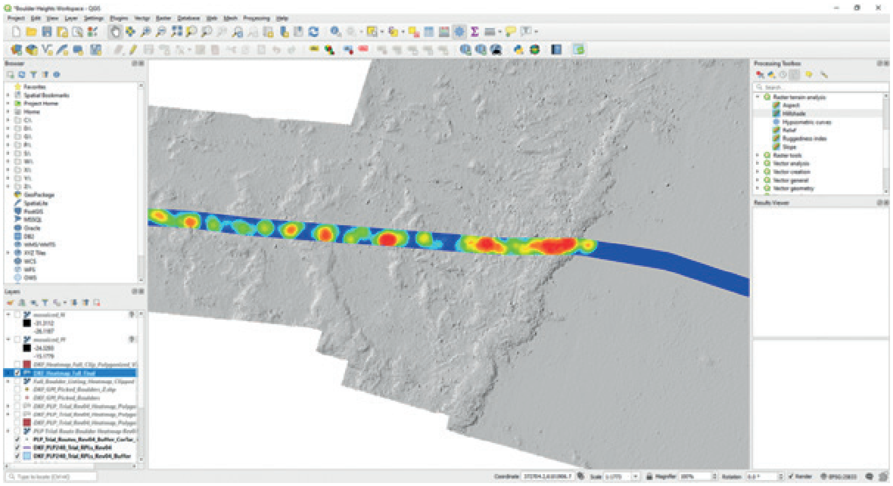
A significant number of boulders in the corridor were deemed too large to be removed by the UTROV Grab, however the auto-picking software that generated the original listing misidentified some clusters of small boulders as large, singular boulders. High-res bathymetry of the site was inspected



The initial route survey shows boulders identified in and around the proposed cable routes, signified by the red lines, and the 16m buffer zone, highlighted in green, surrounding each route: shown left.. Spatial intersection was completed to refine the targets: shown right



Large boulders deemed immovable required the cable route to be amended in order to avoid these obstacles and find the most viable route. Once these decisions had been made, the final route position lists (RPLs) could be generated



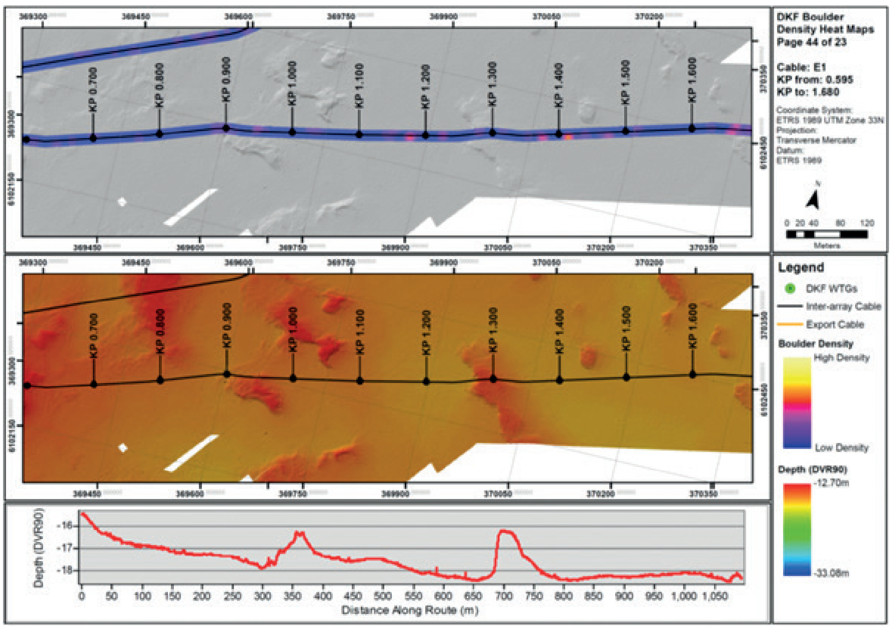
Boulder density heat map

in order to clarify the findings and reclassify those which had been miscategorised.

Once the recategorisation was complete, the few immovable boulders that remained were routed around and avoided by the PLP corridor. With the final routes engineered, the final boulder listing was established resulting in a full boulder pick list for the grab and a list of boulders for the PLP240 to clear.

This detailed analysis led to a boulder risk mitigation strategy based primarily upon avoidance of larger or heavier stones whilst retaining routes which maximised the burial potential and protection for the cables. The inter array cable routes also had to avoid the potential unexploded ordinance (pUXO) targets identified by a thorough UXO survey campaign.

A number of boulders around the offshore substations were not identified by the auto-picking software and needed to be manually identified from the high-res bathymetry. Using calculations taken from the water depth data and the mean depth of the surrounding seabed to determine the boulder heights, the process was automated, and the utilisation of Geographic Information System (GIS) software made the process much quicker.



Boulder density & route profile charts presented in 1 km segments along all cable routes

Building boulder density heat maps to predict asset performance and speed

Boulder density heat maps and route profile charts, which could be used to predict the PLP240's performance and speed across the site, were used to create charts depicting 1km segments of each cable route. The maps, which heavily utilised GIS software to automate the process of creating 234 individual charts covering all cable routes across the entire wind farm, provided a useful source of information that the crew aboard the vessels could refer to during plough operations.

Guaranteeing long-term system viability with proper planning

In total, the route engineering and boulder clearance work on the Danish Kriegers Flak project took almost two years to complete and was hugely beneficial to the final cable installation project which has since been completed by OceanIQ's sister company Global Offshore with support from CWind, also part of the Global Marine Group.

OceanIQ's highly knowledgeable route engineering department provide a wide range of services designed to support subsea cable networks across the lifecycle of each system. Thorough survey and route engineering work, alongside access to the most comprehensive subsea datasets and technical experience able to effectively interpret that data, can ensure the longevity and viability of a system, whether it be in the initial planning phases or in an existing system that is currently operational.

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