July 2019

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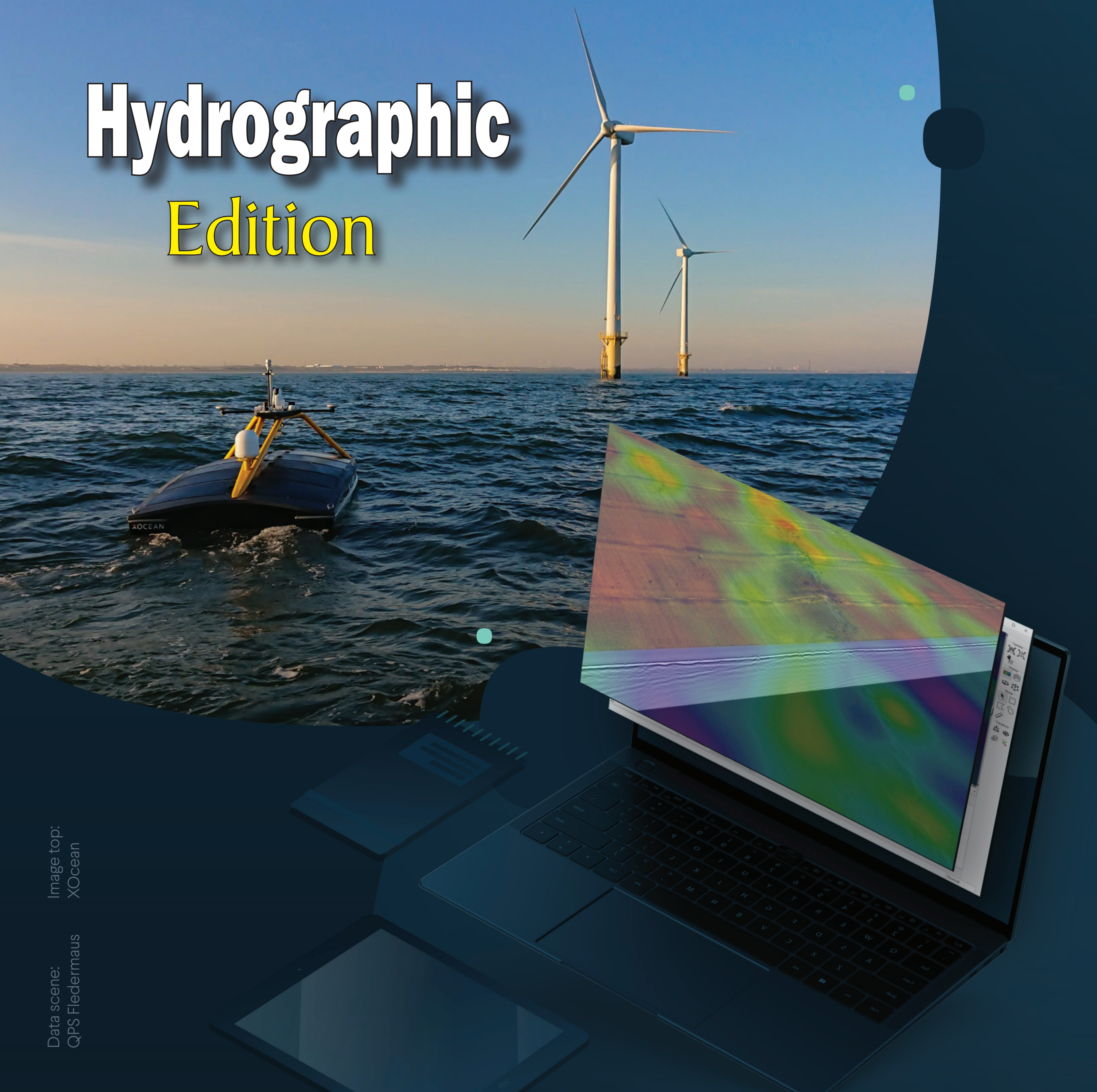

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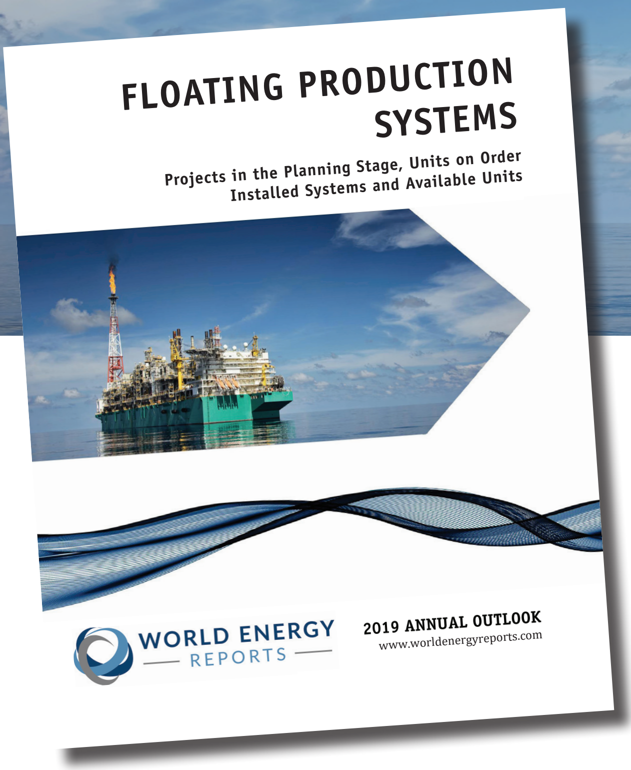

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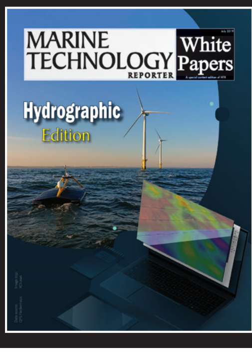

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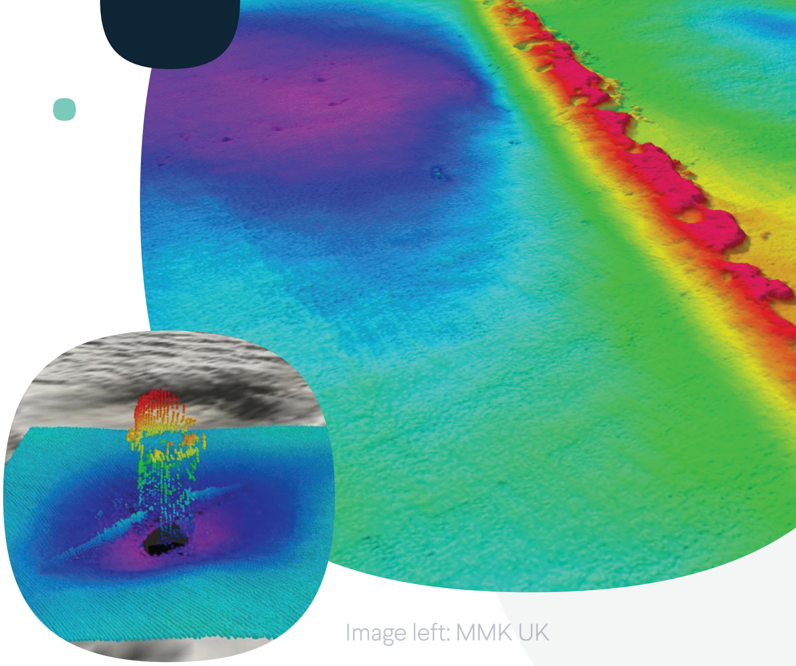

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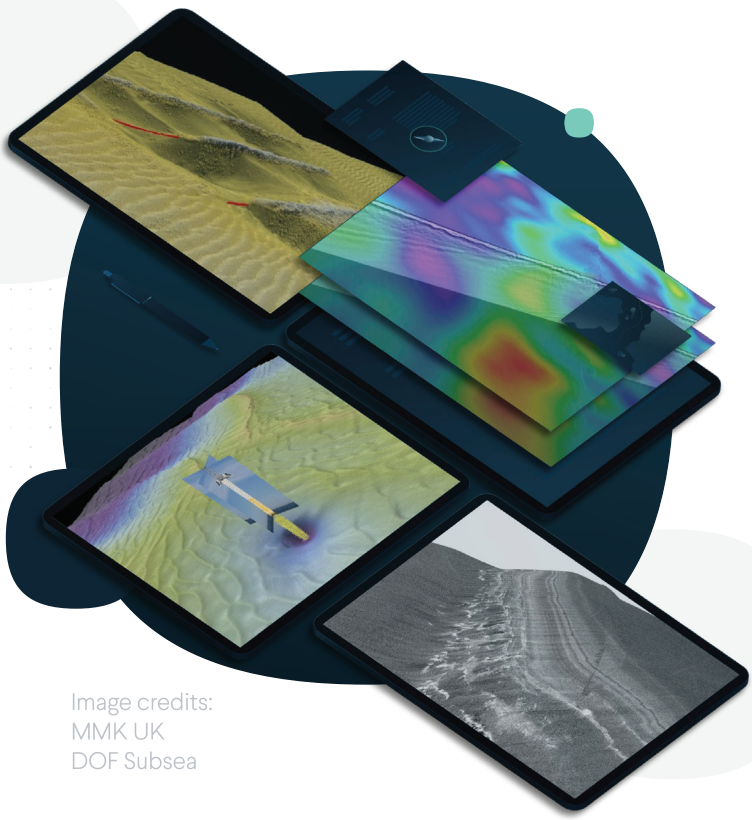

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Qimera offers fast and easy hydrographic data processing. Intelligent state management ensures that any processing changes in the data supporting OWF are accomplished automatically.

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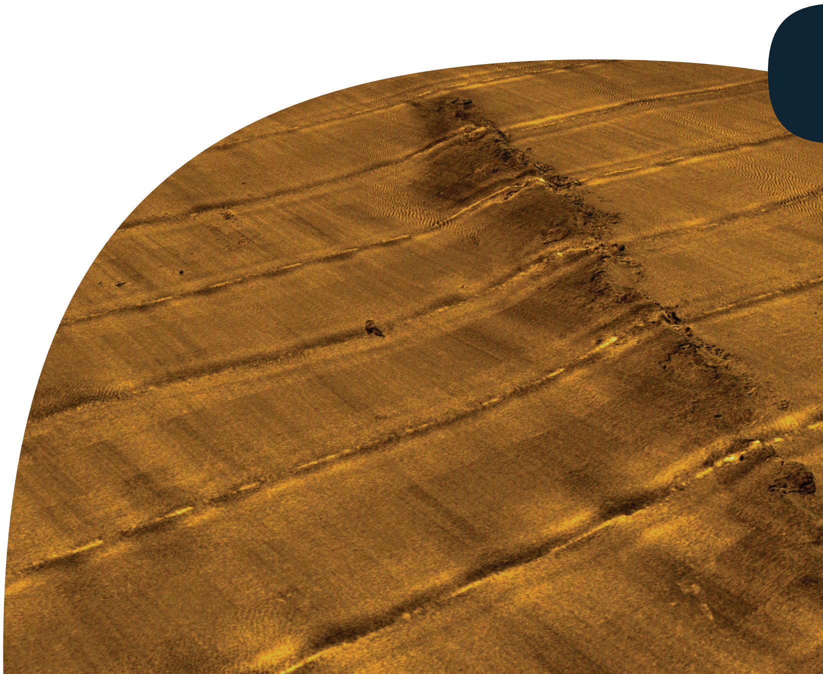

Catching the winds of change through automation, quality and comprehension

Deborah Febres Urdaneta,
Support Manager QPS at Fredericton, Canada

Now starting her 6th year at QPS, Deborah is leading the Support Team of QPS west. Prior to joining QPS, she worked as a GIS consultant for Tamarack Geographic, and altogether she has 15 years of experience with geospatial and geomatics solutions. Deborah holds a MSc in Marine Resource Management from the University of Rimouski and a BSc in Marine Biology and Oceanography from Universidad Simón Bolívar.

Rian Brak,
Support Manager QPS at Zeist, Netherlands

After 5 years working for QPS, Rian leads the Support Team of QPS East. Rian has 14 years of surveying experience starting as an Assistant Operator for the Royal Dutch Navy Submarine Division, and then as a Senior Hydrographic Surveyor for Deep BV. Rian has a Category B certificate as Hydrographic Surveyor from STC – Rotterdam.

Abstract

Hydrographic-based projects focusing on Offshore Wind Farms (OWF) pose unique challenges at every stage of the survey workflow. Acquisition requires integration of multiple sensor types, and project requirements often specify concurrent data collection posing installation, timing, and positioning challenges. Post-processing requires users to process, review, and if necessary, correct enormous multi-variant data sets. Surveyors continue to push for increased automation in these and other related processes. Furthermore, data fusion across these temporally and spatially variant data sets is critical for proper analysis in order to aid decision-making. Throughout the process, stakeholders need to communicate to each other, even if they have different backgrounds and/or project objectives. The question then is how can the surveyor best communicate with stakeholders, facilitate decisions, and then feed adjustments back into the survey workflow?

The answers are found within the innovations of the QPS workflow brought about through the merger of complementary technologies both internal and external to the company itself. This working environment was created to be seamless throughout every stage of the project lifecycle. It is powerful enough to handle complex integrations and data acquisition, automated to reduce mistakes and yet simple at critical steps to provide familiarity and clear understanding for stakeholders.

This paper introduces the common survey requirements throughout the various stages of an OWF lifecycle, and derives critical success factors necessary to meet them from real client case studies. Through automation, quality integration/acquisition, reductions in human error, and intuitive comprehension, the QPS workflow is uniquely designed to achieve these success factors. Regardless of a person's background, QPS solutions are aligned to work together to enhance the capacity of all team members involved in a wind farm project by facilitating fluent workflows through all project stages.

The Change

Renewable resources for energy generation have the attention of many nations and markets in search of alternatives to

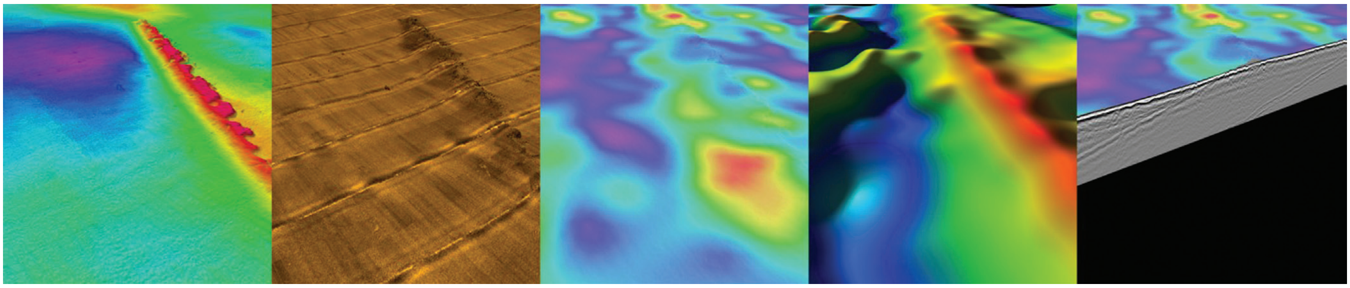

Figure 1. Fledermaus Objects for different deliverables of Desktop Surveys needed for planning OWF. The five images represent bathymetric data, sidescan sonar data, magnetic field surface, geomorphological, and sub-bottom data.

non-renewable hydrocarbon sources. Most notably, OWF have shown significant growth, attributed to high productivity and efficiency for energy capture over time, as well as lower socio-economic and environmental impacts (Azzellino et al, 2013). In Europe alone, it is estimated that over 28% of their energy demand can be provided from wind by 2030, provided primarily through OWF (Halvorsen-Weare et al, 2013). In the U.S., there is very high potential for OWF. Although just one OWF is currently operational in the U.S., there are 12 commercial leases in progress (American Wind Energy Association, 2019). Some of these were auctioned for record-breaking amounts in 2018. The leases encompassed approximately 390,000 acres offshore of Massachusetts. More projects continue to be announced along the Atlantic Coast—most notably, offshore of Rhode Island, New Jersey, and Virginia (Dlouhy, 2018).

The Challenges

OWF pose significant challenges in comparison to land-based projects, and the uncertainties related to offshore work bear a heavy cost. Weather conditions are not as predictable offshore and have a much higher impact compared to those on land. The presence of marine mammals has the ability to stall operations. Periods of good weather present a window of opportunity to maximize productivity but require meticulous planning and coordination. Effective communication cannot be overstated, and the degree to which this is achieved has a direct impact on overall OWF costs. Ultimately, the success of OWF renewable energy projects are tightly linked to marine geomatics surveying, which is critically informing each of the major stages of OWF projects.

Stages of an Offshore Wind Farm

OWF lifecycle stages are defined by the Ulstein Group (2016) below. In each stage, there are considerable requirements for marine geomatics survey work with varying objectives: bathymetric, geophysical, geotechnical, Unexploded Ordnance (UXO) survey, dredging, cable lay, cable depth of burial, precise positioning, seabed characterization, and obstruction surveys being the most common.

•**Planning and Development:** Site investigation surveys of the area for selectivity assessment and suitability. Meteorological survey and area recognition geotechnical surveys also take place.

•**Substructure Installation:** In-depth hydrographic, geotechnical, obstruction reviews and corridor suitability work is done. Dredging and the removal of obstructions are accomplished as needed. After foundations and substructures are installed, there is a post-survey process to ensure adequate positioning of assets.

•**Installation & Commission:** Turbines and other non-substructure installations take place, including the export cable, switch box, and the infield cable lay. Each of these processes require rigorous surveying and high-precision positioning. Environmental impact assessments also require survey information.

•**Operations and Maintenance:** During the operations and maintenance stage, foundation inspections are scheduled and regularly done. Cable installations require continuous inspections as they can be exposed. Scour protection and assessments are part of routine maintenance.

•**Decommission & Repowering:** Tower substructure may be extracted and/or cut. Final surveys and environmental impact assessments are required. If repowering is considered, there will be additional surveys required, and substructure assessments are performed.

In each one of the stages, the survey requirements are generally much higher than a standard hydrographic survey. Rather than just multibeam and/or sidescan data, there are often requirements for co-registered sub-bottom profiles and magnetometer information. Examples of many commonly required data types are shown in Figure 1 via Fledermaus.

The multifaceted data collection requirements support not just bathymetric and geophysical surveys, but are inputs toward archaeological and structural assessments, in addition to UXO surveys. Finally, the data is applied toward meteorological and oceanographic studies associated with site selection. From all the stages, it is clear and understandable how intricately dependent the entire OWF lifecycle is on marine geomatics surveying.

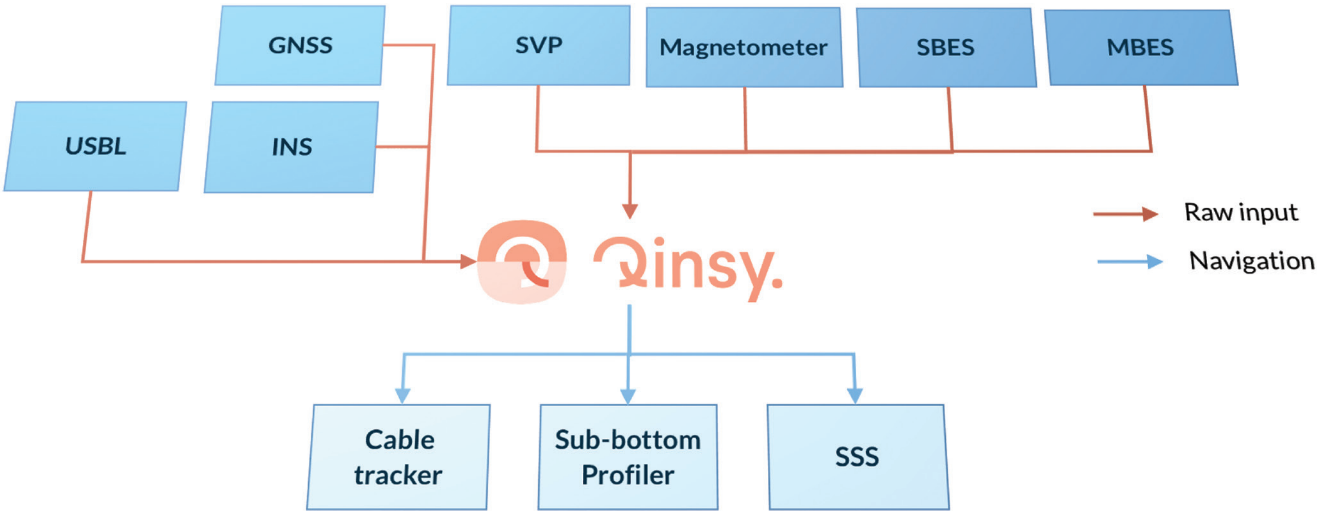

Figure 2. Typical equipment and systems interfaced with Qinsy for Bibby Hydromaps OWF survey workflows.

Case Studies

Bibby HydroMap, https://www.bibbyhydromap.com/

Bibby HydroMap was established in 1997 and is a leading contractor for marine surveys in the United Kingdom and Europe. They are actively involved in many of the OWF-related surveys in the UK. Two examples of these are the geophysical and UXO surveys on the proposed sites to ensure identification of items that could pose a risk to construction operations.

For a different job from the summer of 2018, Innogy Renewables UK Ltd commissioned a depth of burial survey along each of the infield cables on the Galloper Offshore Wind Farm. The objectives supporting the OWF were to determine the depth of burial, assess the level of scour protection, identify any areas of cable exposure or free span, and investigate

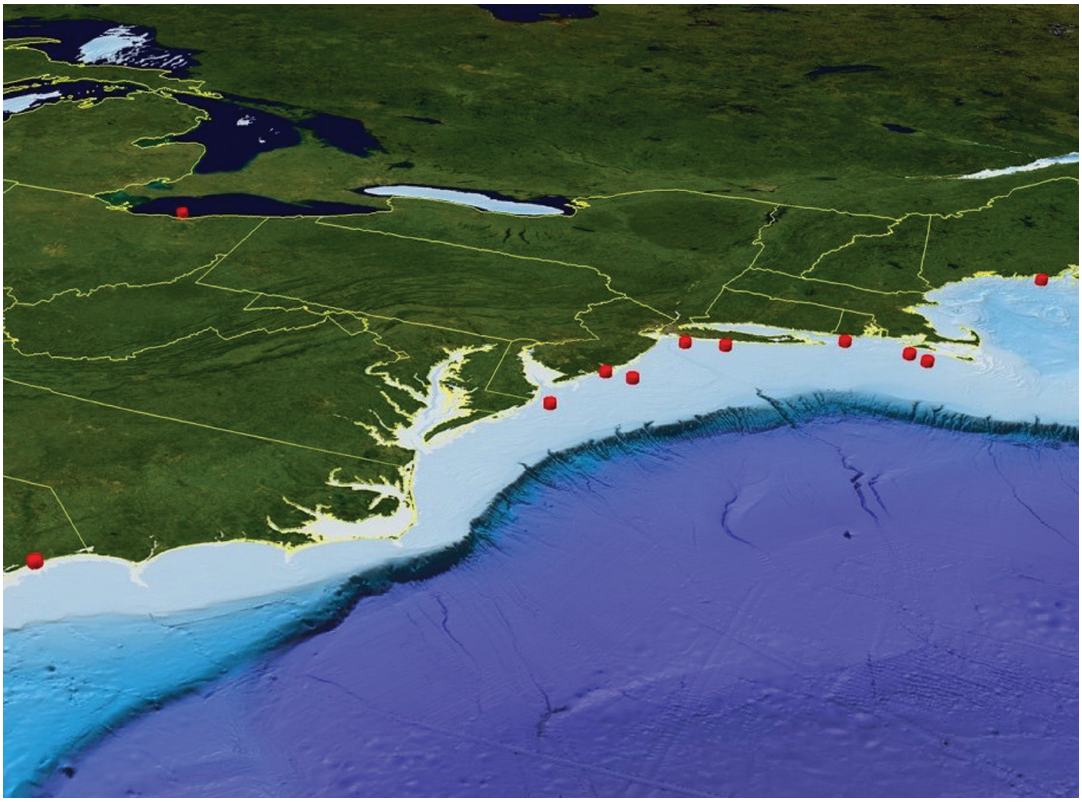

Figure 3. OWF Planning and Development related surveys sites completed by Alpine Ocean Seismic Survey.

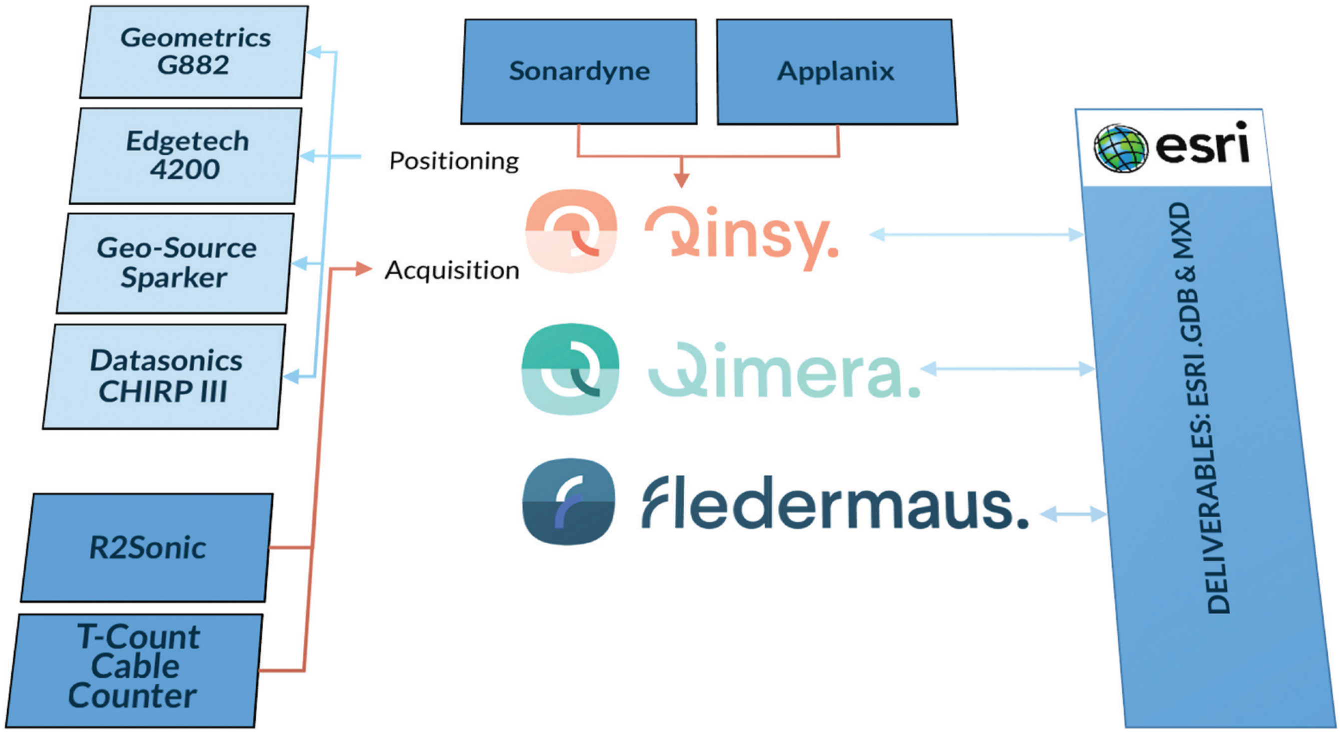

Figure 4. Alpine Seismic survey equipment and systems interfaced with Qinsy and post-survey use of Qimera and Fledermaus for creation of OWF deliverables.

the surrounding seabed to track changes to the environment.

Bibby HydroMap are industry leaders in seabed survey. As shown in Figure 2, their typical workflow for OWF surveys utilizes Qinsy for simultaneous multi-sensor data acquisition, while providing navigation to various other sensors.

Alpine Ocean Seismic Survey, http://www.alpineocean.com/

Alpine Ocean Seismic Survey, established in 1957, has a long history of working with multidisciplinary groups offshore, including geophysical, geotechnical, hydrographic, oceanographic, environmental, marine wildlife and positioning services. Since their founding by a group of Lamont Doherty scientists 62 years ago, Alpine has worked on thousands of marine survey projects worldwide. Alpine maintains its company headquarters in Norwood, New Jersey.

Alpine's project involvement often starts at the planning/permitting stages and depending on the project type, runs through the desktop study, field acquisition, construction monitoring, reporting, and deliverables. Additionally, there are ongoing maintenance and inspection phases, critical to ensure accountability, proper data integration, and cross checking throughout a project's lifecycle. These phases have been employed in all of the site investigation surveys on the East Coast of the U.S. as shown in Figure 3.

Alpine's workflows are supported by QPS software applications. They rely on Qinsy for positioning and surveying, and maintain the critical advantage in the software for the ability to acquire and log data for all systems simultaneously while also ensuring precise geo-referencing. This is shown in Figure 4, along with their ensuing workflow in Qimera and Fledermaus, integrated with Esri, for product generation.

Critical Factors

Reliability

The nature of work for OWF is that there are short notice windows of opportunities to do work. To be effective and efficient, reliability in all aspects of the job is critical, from the team members, to the equipment, and to the software that allows for the systems integration and management. This reliability is important for any kind of surveying, but even more heightened for those in support of OWF, due to their very stringent and multifaceted requirements. Clients often need, at minimum, multibeam bathymetry and backscatter, side scan sonar, magnetometers, and sub-bottom profiling for the types of surveys mentioned above for the various stages of an OWF. From our case studies, and from communicating with other clients, there is an important commonality in their workflow: all instruments are interconnected through Qinsy as a controller package, positioning/timing provision for other sensors, and acquisition package for most (if not all) of the equipment, while also providing the navigation while at sea (see Figure 5). Additionally, while accomplishing those tasks, Qinsy also allows for the processing and gridding of data (including magnetometer) in real-time. Seeing a final product as it is being collected has tremendous benefits in terms of the real-time QA. The surveyor has the ability to ensure data quality and accuracy during collection, which reduces the possibility (and the great expense) of any need to resurvey.

For reducing costs related to surveying, simultaneous acquisition of all such sensors is typically the aim on each line of ship data, and this is in addition to the ancillary data collection of navigation, motion, and sound speed. Even in the event of unexpected challenges related to acquisition, it is imperative that at minimum there is still inflow of data collected and positioning provided for the instruments. This is because during the acquisition of the multiple sensors required for OWF surveying, unplanned stoppages in data acquisition typically result in rerunning the entire line with the re-acquisition of data for each sensor—even those that did not experience any problems. This is done for data management and documentation purposes alone, as it is considered imperative to have consistent filenames, and time-tags, and 1:1 ratios of all lines of sensor acquisition, rather than to maintain multiple line segments for reacquired lines not started anew. The simultaneous collection of data from a multitude of sensors further underscores the importance of software stability during acquisition. Software reliability always has had a direct translation to time and money saved through efficient ship operations and not needing to rerun lines. Considering the multi-sensor acquisition required for OWF surveying, the importance is even greater. With industry renowned stability, even while accomplishing the demanding requirements associated with OWF, Qinsy is a proven and well-established industry tool to achieve this success factor.

Quality

High quality data collection is always critical, but again this is heightened ever more so when surveying in support of OWF, because the data collected will be the foundation of work for the next stage of the OWF lifecycle. Poor data quality early on will continue to impose a tax through complications in all downstream processes that rely on that data. For example, if

Figure 5. Monitors of different Qinsy displays and windows showing state of operations for different components and equipment while working online for a survey.

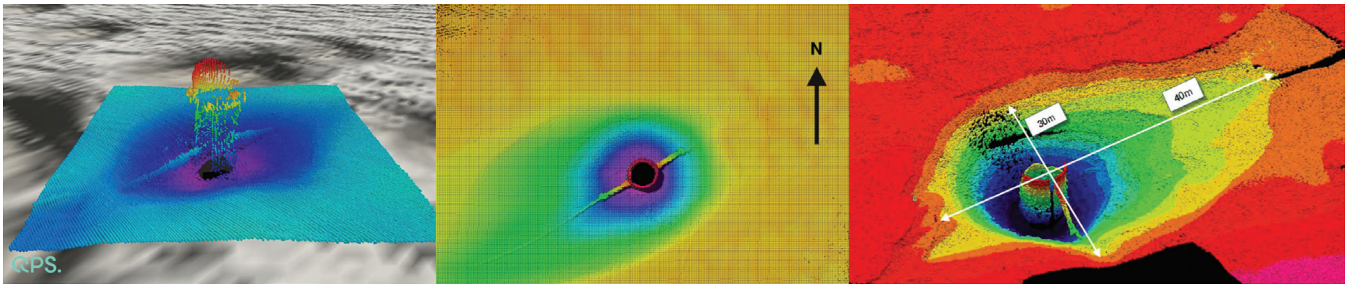

Figure 6. Fledermaus products result from scour analysis to submerged monopile windmill structures. Courtesy of Port of London Authority and MMT UK.

a survey for obstruction assessment does not catch a potential threat, it can cause problems or large delays in the ensuing stages, which can increase costs very quickly. The quality of the process and data are what guarantees cost-efficiency for each of the stages, due to their interdependency in the lifecycle of an OWF. Poor quality data can continue to cost money long after it is collected.

QPS users have made clear that the ability to have one software application doing all multi sensor positioning, navigation, filtering, I/O, sensor data recording, and registering computations for all elements needed, is a tremendous benefit. A specific example from Alpine is their great success in using the real-time filtering solutions in Qinsy to smooth out navigation provided to the connected systems that support their bathymetric surveys, such as the magnetometers and sub-bottom profilers.

High data quality is further enabled in Qimera, which is tightly linked to Qinsy so that projects are opened and managed directly, without any of the lengthy and error-prone data conversion requirements otherwise necessary. Once in Qimera, the core design principle of the program results in a rapid, intuitive workflow for multibeam data processing, while also further removing the opportunity for human error to the extent possible. One way this is achieved is by the intelligent state management of Qimera, which is another core design principle. In particular, Bibby Hydromap expressed the great value in this design element, where they can easily make changes in post-processing settings if necessary. The lines which are affected by any changes in these settings are intelligently tracked, and a user can "queue" the processing for any changes to sound speed applications, motion systems, horizontal or vertical referencing, etc. When it is time to apply all the new settings, it is accomplished with a single click, and by design Qimera guarantees the correct sequence of the post-processing applications. This alleviates the user of the requirement to program and sequence the post-processing actions themselves, thus streamlining the workflow and eliminating any errors that might occur otherwise in the application of correctors.

The QPS workflow has further measures to ensure very high quality deliverables. Qimera has the interactive Wobble Analysis tool, originating from the University of New Brunswick research (Hughes Clarke, 2003), which can quickly diagnose and fix any errors identified in the integration between motion sensor and multibeam echo sounder. Also available in Qimera is the sound speed inversion algorithm from Technical University of Delft (Plaa et al, 2008) that applies a harmonic sound speed value to mitigate refraction error in an automated and repeatable fashion, leading to rapid improvements in data quality. Multibeam backscatter processing and mosaicking is accomplished in Fledermaus Geocoder Toolbox, widely regarded throughout the industry as the top solution for backscatter product quality.

Finally, the quality of OWF deliverables can be examined in a holistic fashion, also via Fledermaus. The visualization, inspection, and analysis of the many data types required can be accomplished in a combined Fledermaus scene. Within such scenes, data can be included in point clouds, surfaces, and the newest technology in Fledermaus, 3D meshes. This technology provides fine detail on the sides and underhanging areas of submerged structures that shoal-biased grids are inherently unable to provide. Imagery in various formats can also be included in such scenes, and can be "draped" atop bathymetric surfaces for further context. The combined scene in Fledermaus has the additional benefit of facilitating easy delivery and sharing among various stakeholders and key decision-makers that are involved, to ensure requirements have been met, on a non-interference basis. Once accepted, the deliverables yield the bathymetric, geophysical, morphological, and archeological context required for subsequent stages. An example of OWF data analysis in Fledermaus is shown in Figure 6.

Partnering

Partnering elements for better workflows is a critical factor for improved efficiency, particularly in the marine geotechnical surveying aspects related to OWF. Various clients have different configurations of equipment and packages, with the main goal of reaching optimization of cost and efficiency. In some instances, linking technologies together has been forced out of necessity, and even if initially the solutions were not working together efficiently, over time the integration has

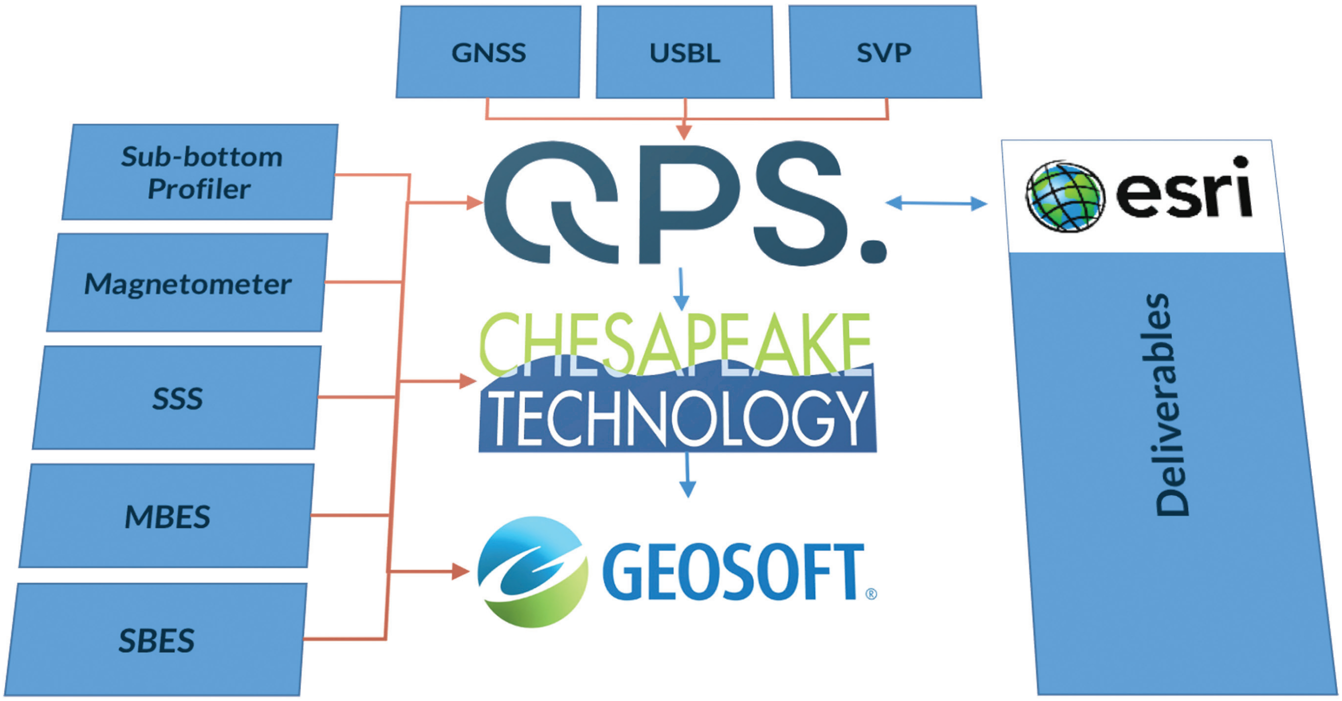

Figure 7. QPS partners with Chesapeake Technologies, Geosoft, and Esri to best facilitate a very streamlined workflow for data and deliverables in support of OWF.

been achieved in response to industry needs. Other times, the integration (and the efficiency gain) was crafted from the outset by way of partnering. The result yields turnkey solutions for particular workflows, even those that extend across different manufacturers. Such seamless workflows have never been more critical, as the requirements for OWF, already stringent, likely will continue to evolve in the future, with increased accuracy, resolution, and sounding density requirements, resulting in heavier overall data volumes. Thus, taking advantage of streamlined, integrated solutions is critical to keep up with ever-evolving industry demands. See Figure 7 for examples of active QPS partnerships formed in order to achieve more seamless workflows supporting OWF.

Common Framework

As mentioned above, each stage has different survey types in order to achieve various objectives. However, our clients have kept the same common framework, using Qinsy, for acquisition from various sensors, positioning, navigation, and cable installations. As such, all of the parties involved are familiar with the solutions and this facilitates communication to achieve greater efficiency. Even when engaged in different mobilization efforts, the common framework of Qinsy as the dashboard control point for the various activities that occur each day is very beneficial. It allows for rapid planning and operations in order to make the best use of time in the window of opportunity given by weather and other elements that are out of the human control.

When drawing upon a common framework, clients get familiar with the way deliverables need to be provided, and from job to job they know how to address such items within a familiar application. Additionally, clients requesting OWF work are now more knowledgeable. These clients are often onboard vessels, to ensure the quality of the deliverables, and they are able to see firsthand the end results. The client has options—they could utilize a 'familiar' remote display from Qinsy to monitor operations in real-time, or they could review a full Fledermaus scene with the freshly acquired data viewed together with that data already collected. Such a combined scene offers opportunity to make observations and connections among different data types not otherwise realized unless viewed in a combined 3D/4D space. This data integration in Fledermaus provides optimal situational awareness, and from it a report utilizing spatial time notes for 3D/4D presentation can be produced and delivered in a matter of minutes, providing project status and rich context to the client representatives both onboard and onshore.

The vision that QPS has to "know the ocean" is shared by most of the hydrographic world. We can take big steps towards achieving this vision through the great value in product integration, which streamlines workflows and eliminates the errors commonly encountered otherwise. The value is achieved

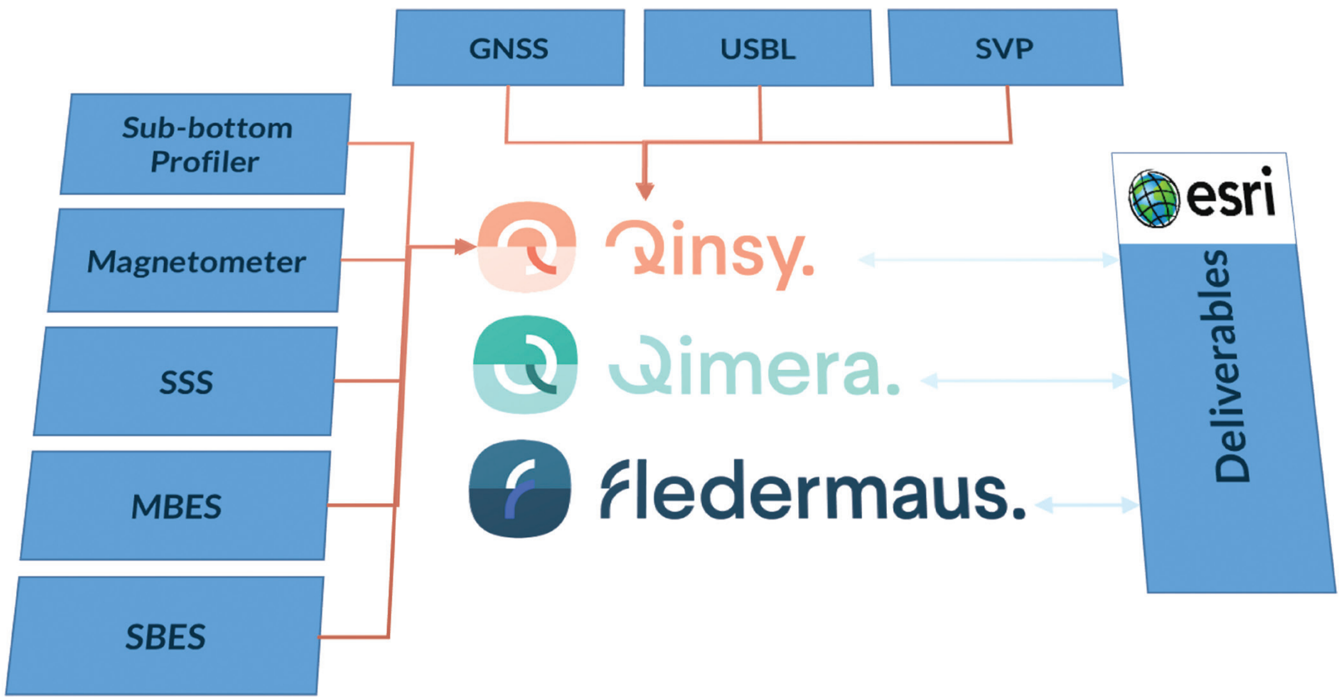

Figure 8. The common framework approach with integrated software applications from QPS yields tremendous benefit to those clients engaged in marine geomatics surveys supporting OWF.

through the preservation of data formats throughout the workflow, removing the problems and inefficiencies experienced during the unnecessary data conversation and accompanying loss in metadata. Because our solutions covers the entire workflow, from data acquisition to processing, analysis, and product generation, the value chain in the integration extends over all these same steps. Figure 8 shows a model of common framework and integration of QPS products as applied toward an OWF workflow.

While we maximize this value in integration, we also ensure modularity in order to support the widely varying workflows of our clients. This is accomplished through compatibility with major industry formats such that any of our modular components can be coupled with solutions from other vendors. Ultimately, QPS strives to support either method, for optimal client flexibility—those wishing to maximize the value in integration, or those wishing to configure their own custom workflow. This could be even extended further to adjoining workflows from other disciplines that do work in the stages related to OWF, such as environmental impact, oceanography and more.

Looking forward

The OWF industry will continue to benefit from advancements in the marine geomatics surveying industry. Such advancements will include the use of autonomous and unmanned vessels. These vessels will continue to become more effective force multipliers during survey operations while they increasingly become more cost efficient and accessible. The remote operation of not just one but entire fleets of vessels has the potential for massive efficiency gains. QPS, already with industry-leading autonomous solutions (**http://whitepapers.marinetechnologynews.com/home/wpdetails/ping-and-done--evolving-qps-technology-for-the-new-era-of-autonomous-hydrography-1dc06**), will continue to lead the way in this regard. Increasing autonomous solutions also means changing roles for surveyors, managing not just a single vessel but a fleet. Artificial intelligence will benefit survey operations, not just through smarter autonomous solutions but also through predictive modeling to better understand optimal survey windows and conversely, when preventative measures should be taken. Data sharing, collaboration, and cloud applications that the industry strives for is only achievable to the extent dictated by connectivity and bandwidth, so related innovations to facilitate these means will have a huge impact in the industry. Continued product integration, both internal to QPS and together with key partners, will continue to facilitate the OWF industry by providing turnkey solutions that are easier to learn, eliminate the opportunity for error, and further streamline the workflow.

Conclusion

With considerable attention placed on renewable energy worldwide, OWFs are very in-focus and will continue to be in the foreseeable future. Companies that wish to pursue OWF work must be well prepared, as each stage of the OWF lifecycle requires considerable effort from several groups that must be well coordinated. In particular, hydrographic survey deliverables required in support of OWF are considerably more complex and with much higher standards than many typical marine surveying jobs. Case studies examined here from Bibby Hydromap and Alpine Ocean Seismic Survey underscore the importance of software reliability and integrated systems in order to optimize operational efficiency, which is further improved by strategic partnering among other software vendors. Quality and capabilities are similarly important in order to meet the myriad requirements of the OWF stages. QPS software tools are utilized in each of these stages, by those groups highlighted in the case studies and many more operating in support of OWF installations, in order to meet the critical factors required for success which were emphasized in this paper. With continued focus on autonomous solutions, remote operations, data sharing and more, QPS strives to continue to lead the way as a software provider in support of OWF installations. We will be pleased to see this valuable form of renewable energy continue to grow worldwide.

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In Summary: Why QPS?

For more than 25 years, QPS have been experts in not only maritime geomatics software solutions, but services, too. For a software company, we certainly spend a lot of time in the field! This is because our products cover the entire workflow, from the surveyor all the way to the pilot. We have a deep understanding of everything from the setup, to the operations, to product generation, and how it is all interconnected—critical for the many stages of the OWF lifecycle.

Qinsy draws from a core strength of stability and systems integration, praised for its ability to drive many systems while also recording data from the multiple sensors required for surveying in support of OWF. Multibeam data opens seamlessly in Qimera, designed for fast and intuitive workflows, and with advanced tools to ensure the highest OWF data quality. Fledermaus offers industry-leading multibeam backscatter processing and mosaicking, while also it has compatibility for the wide array of data types associated with OWF to be combined in a single scene. The scene is a single data file, which greatly facilitates fast and holistic review from the many stakeholders involved in OWF projects, enhancing communication and ensuring requirements are met.

Linking together all of the QPS software solutions yields tremendous value in their integration, in terms of facilitating a seamless workflow and removing the errors that otherwise result from forced linkages and conversions. To further support our clients, QPS partners with manufacturers that provide industry-leading solutions in their respective areas of expertise, resulting in ever-more streamlined and integrated workflows. For more, please visit **https://qps.nl/**.