# Deployment of Seatricity's wave energy converter at EMEC's wave test site at Billia Croo in Orkney

# Navigational Risk Assessment Summary

Report to Seatricity

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# Contents

# 1 Introduction

## 1.1 Introduction

Seatricity is planning to install a demonstration array of its wave energy converter technology at the European Marine Energy Centre (EMEC) Wave Test Site Facility at Billia Croo in Orkney during early summer 2012. It is planned to install 30 ‘Oceanus’ wave energy converters with a combined total installed capacity of not more than 800kW. It is planned to decommission the project in 2017.

The Seatricity WEC consists of three main components, a foundation, a pump and an actuating float. The actuating float moves relatively to the pump due to movement of the waves. This activates the pump causing it to pump seawater which is then conveyed to shore, via seabed flexible rubber and steel pipelines, where the high pressure water is used to power a conventional Pelton Wheel hydro turbine (housed onshore) to generate electricity.

A generic Navigational Risk Assessment (NRA) for the wave test site at Billia Croo was initially completed in 2009 (ARC, 2009). This NRA was revised in 2010 to incorporate a new berth and associated cable that was installed at the test site during 2010 (ARC, 2010). In addition to this site wide assessment, a regulatory requirement still remains for a device-specific addendum to be completed for each device or array of devices using the site. The device-specific information required covers the installation and operation and decommissioning of the project at the EMEC site and importantly other offsite maritime activities between the deployment port and the EMEC site.

Aquatera Ltd has been commissioned by Seatricity to assist in securing the necessary permits and licenses for the proposals. This Navigational Risk Assessment Summary forms a device-specific addendum to the test site NRA (ARC, 2009) and it is intended that the test site NRA along with this addendum fulfil the requirements as set out in MGN 371[1].

This addendum will accompany the license applications required for project consents and form an integral part of the project’s Health and Safety Management System. The process of completing the risk assessment has also been used to develop and test the operational plans for the project through an iterative evaluation process, ensuring that all risks have been considered throughout the development and design of the project. This also helps ensure that the project complies with the CDM Regulations[2] by showing that safety considerations have been integral to the design and planning process.

The methodologies used in completing the various elements of this Navigational Risk Assessment Summary follow the requirements and guidance outlined below:

- Marine and Coastguard Agency’s (MCA) Marine General Notice 275 (MCA 2008/2) “Proposed UK Offshore Renewable Energy Installations – Guidance on Navigational Safety Issues”.
- Marine and Coastguard Agency’s (MCA) Marine General Notice 371 (MCA 2008/1) “Offshore Renewable Energy Installations – Guidance on UK Navigational Practice, Safety and Emergency Response Issues”.
- DTI/BERR– Guidance on the Assessment of the Impact of Offshore Wind Farms (DTI/BERR 2005).

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[1] MGN 371 - Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response Issues (MCA, 2008)

[2] The Construction (Design and Management) Regulations 2007

- Health & Safety Executive Offshore Technology Report on Marine Risk Assessment (H&SE 2001).
- DNV RP-H101- Risk Management in Marine and Subsea Operations (DNV 2003).

As a precursor to completing this risk assessment an environmental scoping document (Aquatera, 2011) was circulated to key stakeholders that included a preliminary assessment of key marine safety issues. Feedback to this document has been used to define the scope of this risk assessment.

This current report covers all stages of the proposed project including installation, operation, planned and unplanned maintenance, decommissioning and possible emergency situations. The geographical and operational boundaries of the study are the load out area in Stromness harbour, the test site at Billia Croo and the tow routes proposed between the two sites.

The key objective of this addendum is to demonstrate that all appropriate navigational safety risks have been identified, assessed and mitigated to a level that is at least 'As Low As Reasonably Practicable' (ALARP) and that best practice has been applied throughout project design and operational planning.

This addendum contains the following:

- Risk Claim – including a Navigational Safety Claim specific to the proposals
- Project description – an overview only; please refer to the Environmental Report (Aquatera, 2012a) for more details.
- Status of the Hazard Log – summary of all risks and risk matrices
- Search and rescue (SAR) overview
- Navigation risk assessment/Major hazards summary – summary of major hazards indentified and relevant controls
- Status of the risk control log
- Through life safety management
- Hazard Log – complete hazard log with mitigation and prevention measures associated with all identified risks

**This document should be read as an addendum to the following reports:**

- **Navigational Safety Risk Assessment for the wave test site at the European Marine Energy Centre (ARC, 2009)**
- **Navigational Safety Risk Assessment for the extensions to the wave test site at the European Marine Energy Centre, Orkney (ARC, 2010)**

# 2 Risk claim

## 2.1 Navigational safety claim

The NRA for Billia Croo (ARC, 2009) concluded that the residual risks from the deep water site were 'tolerable with monitoring'. With the extension of the test site boundaries and the addition of the fifth cable the revised NRA (ARC, 2010) concluded that the risks were still 'tolerable with monitoring'. These conclusions were based on the review of the existing and new hazards, the test site's operational history, stakeholder feedback and recently available AIS traffic data.

As a result of this assessment undertaken for Seatricity, the risk from the proposed deployment of the Oceanus array and associated equipment at the test site, including all transit to and from the support facility at Stromness is assessed as **‘tolerable with monitoring’**. The term “tolerable with monitoring” assumes that there is “a commitment to risk monitoring and reduction during operation” and with the further explanation that: “risks must be mitigated with engineering and/or administrative controls and must verify that the procedures and controls cited are in place and periodically checked” (DTI, 2005).

This assessment assumes that all safety requirements outlined in the test site NRA (ARC, 2010 – page 11) will remain in place. All risks that have been systematically identified and recorded in the Hazard Log (refer to Appendix B). Special attention will be paid to the control of risks that are assessed as ‘intolerable’ before the implementation of additional mitigation measures.

## 2.2 Supporting reasoned argument

The supporting arguments for this assessment are contained within the Hazard Log (Appendix B) and the summary of major hazards provided in Section 7.

## 2.3 Overview of the evidence obtained

The risk assessment has been carried out using a structured process of risk identification, assessment and management that takes account of local conditions and relevant data sources, the Hazard Identification and Risk Assessment (HIRA) process. The main sources of data and information for this process are:

- Consultation responses to the scoping process undertaken in late 2011 (Aquatera, 2011)
- Navigational safety risk assessments undertaken for the wave test site (ARC, 2009 and 2010)
- Marine environment and metocean data & traffic patterns analysed within the EMEC site NRA (ARC 2010)
- Project Execution Plan
- Operational experience of seafarers working in the waters planned for deployment

## 2.4 Tools and techniques used

Hazards were identified by professional environmental risk consultants and mariners systematically applying a ‘structured what if technique’ (SWIfT) technique to the Project Execution Plan. A ‘bowtie’ methodology (refer to Figure 2.1) was used as a basis for building the project Hazard Log which is presented in full in Appendix B.

The risk assessment was carried out using definitions for frequency and consequence and a tolerability matrix that are based on ISO 17776:2000 ‘Petroleum and natural gas industries - Offshore production installations - Guidelines on Tools and Techniques for Hazard Identification and Risk Assessment’ (ISO, 2000). A mainly qualitative approach was taken to assess the frequency of an event for a defined consequence, using the Marine Accident Annual Reports (MAIB, 2010) as a guide for accident statistics.

DTI Guidelines (DTI, 2005) recommend that an NRA should consider quantitative risk analyses of current and future scenarios. Given the small scale of this project and the fact that shipping activity is unlikely to change significantly over the lifetime of the project, the use of quantitative risk assessments with different future scenarios does not seem proportionate to the level of risk. Therefore, a structured qualitative approach has been used which is consistent with the level of detail that has been used for the previous NRAs for the EMEC Tidal Site in 2005 (ARC, 2005) and 2010 (Anatec, 2010) and for the Wave Site in 2009 (ARC, 2009) and 2010 (ARC, 2010).

The risk assessment was carried out in two parts:

1. Initial risk assessment - assuming that mandatory mitigation measures were in place
2. Residual risk assessment – This was undertaken where the risk level was initially classified as either intolerable or required further reduction to a level that was 'As Low As Reasonably Practicable' (ALARP). In these cases further prevention and control measures were introduced until the risk was considered to be ALARP.

The bowtie methodology was originally pioneered for use in the offshore oil industry. Components of the HIRA process can be linked together in an arrangement resembling a 'bow-tie' pattern.

A hazard is released by carrying out an activity (threat) that has the potential to cause an accident (top event) with associated potential consequences. For example, a hazard could be working at the top of a ladder. The threat would be a difference in height. This hazard would be released by a 'top event', in this case the top event would be falling or slippage of the ladder. The consequence of the fall (the top event) would be injury.

Preventative and recovery controls can then be added to illustrate the fundamental components of the safety management system. For example, preventative controls could be wearing a fall arrestor, or tie-back of the ladder to prevent slippage. Recovery controls could be the use of soft flooring to soften a fall, or protective clothing to prevent against injury.

This method is suitable for the management of risk rather than the detailed quantitative assessment of risk. It is particularly useful in proactive accident prevention, and the management of safety within a system. Understanding can be gained by examining the routes by which controls can fail and identifying the critical components of the system that prevent these failures.

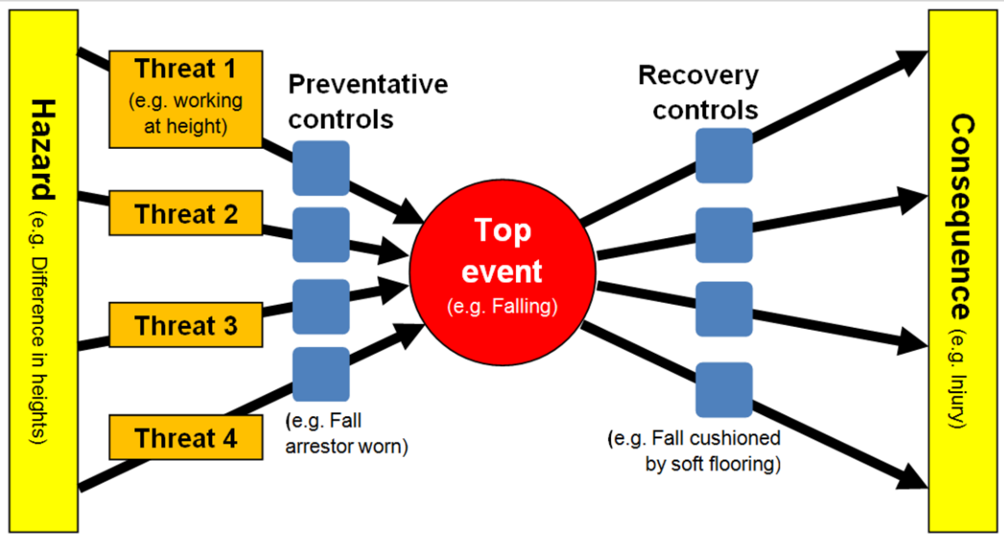


**Figure 2.1 The bowtie method**

# 3 Project description

## 3.1 Project details and proposed location

It is planned to install 30 Seatricity WEC's with a combined total installed capacity of not more than 800kW at the wave test site. The WECs will be installed at a depth of approximately 33-38m below LAT[3]. The devices will be grouped into three 100 m diameter rings with each ring comprised of 10 devices (refer to Figure 3.1). The actuating floats will be interconnected by catenary chains hanging to a depth of approximately 5m between actuating floats. Auxiliary moorings (clump weights or chain) will also be installed. These will be connected by catenary chain and nylon rope to each actuating float.

Figure 3.1 also shows the proposed layout of pressurised 1.5" pipes within each ring of devices. At the centre of the ring the pipes from each pump connect into a valve manifold on a 5" pipeline which will in turn connect into a 10" main pipeline to be conveyed to the connection point onshore. Absent from Figure 3.1 are tethers for deployment/retrieval of the devices. Each tether is connected to the base of the pump and the central manifold so that each device can be attached and unattached by lifting the manifold and pulling the relevant tether.

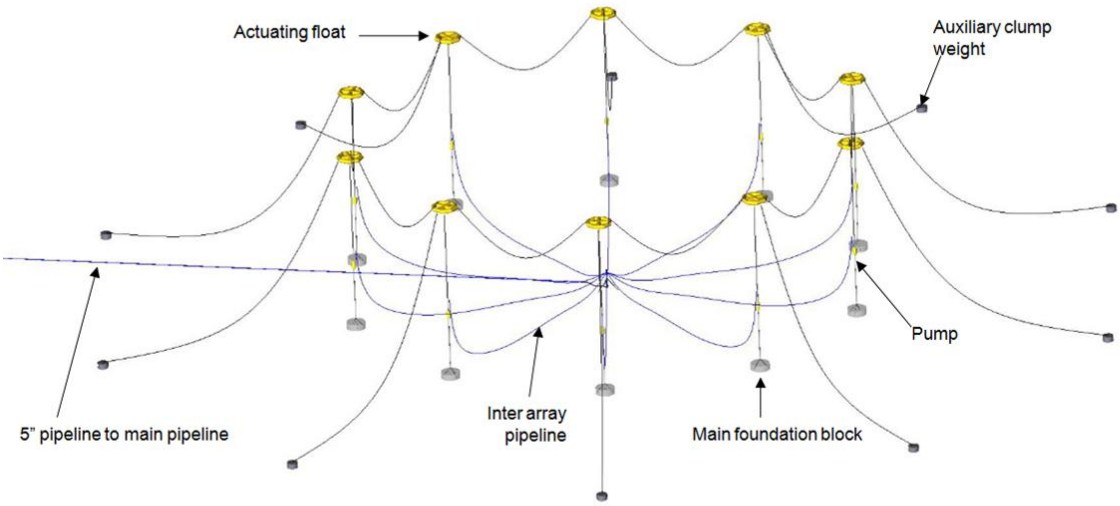


**Figure 3.1 Design for each ring of devices**

Figure 3.2 shows the proposed layout for the rings of devices (turquoise circles), the pipeline route from the rings to the turbine house onshore, and the location of EMEC's existing 10" diameter low pressure PE pipe which will be used for seawater return.

The main pipeline is approximately 1.8 km in length with interconnects (flexible jumpers) into each ring of devices ranging from 150 - 300 m. Figure 3.3 shows the location of the proposals in relation to the EMEC Billia Croo wave test site.

Figure 3.4 provides a visualisation of a ring of devices in the water.

[3] Lowest Astronomical Tide

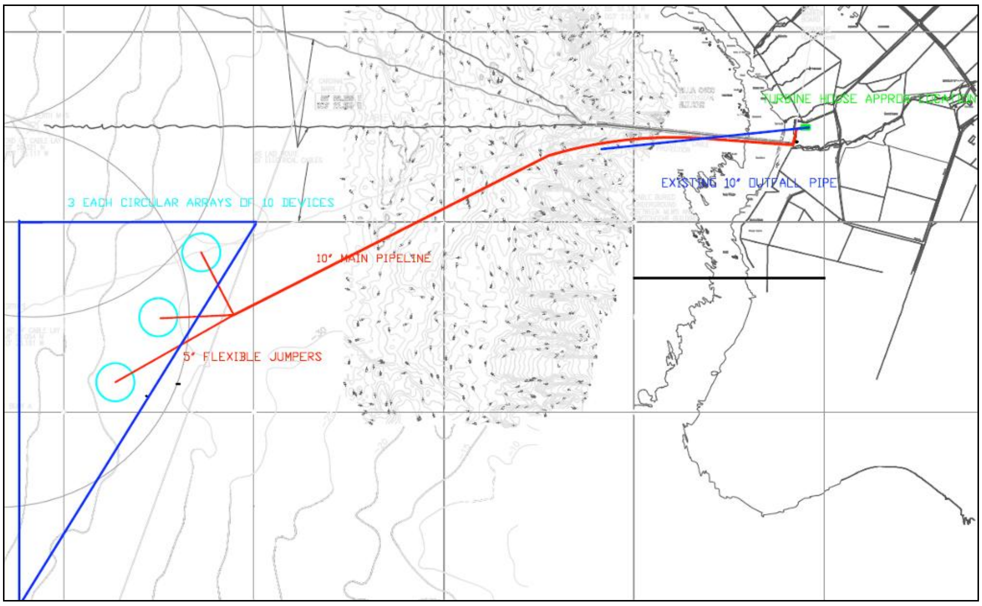


**Figure 3.2 Proposed location of the Seatricity WEC's at EMEC's wave test site at Billia Croo**

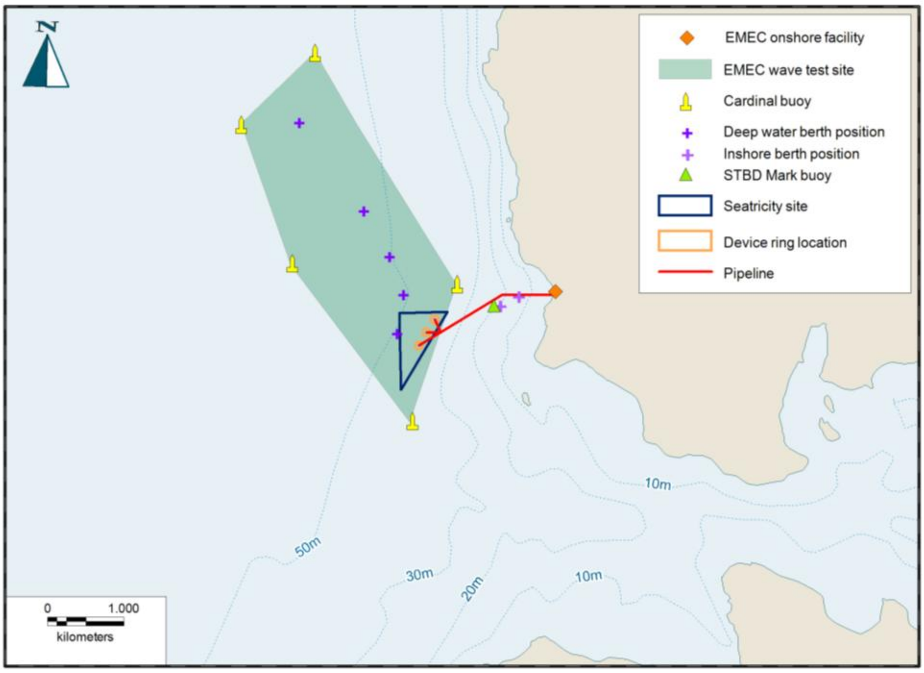


**Figure 3.3 Location of the Seatricity deployment within the EMEC wave test site**

**Figure 3.4 Visualisation of an area in the water**

The actuating floats will be fabricated from aluminium alloy. The actuating floats will be 4.8 m in diameter and made from 0.8 m diameter, 8 mm thick tube with each float weighing 1100 kg. Freeboard will be approximately 0.6 m. A synthetic rope (Aramid Twaron) will be attached to a universal joint assembly on the flange on the lower side of the substructure. The rope then further connects to the top of the pump unit. This rope connection is the primary, actuating, taut mooring for the actuating float. Further fittings will be added to the actuating floats for connection of the additional mooring lines and the chains connecting the actuating floats together.

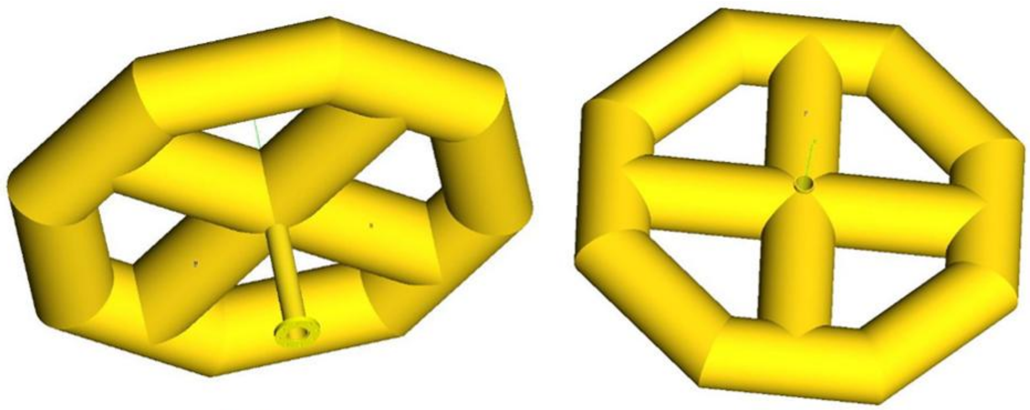


**Figure 3.5 Actuating float design**

## 3.2 Proposed timeline

An outline schedule of works is provided in Table 3.1 (note that the timeline skips years 2013 to 2016 where operation and monitoring will continue):

**Table 3.1 Proposed timeline for the Seatricity WEC deployment at Billia Croo**

| Task | 2012 | | | | | | | | 2017 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A |
| **Installation** | | | | | | | | | | | | | | | | |
| Mobilisation | | | | | | | | | | | | | | | | |
| Foundations | | | | | | | | | | | | | | | | |
| Device | | | | | | | | | | | | | | | | |
| Pipeline | | | | | | | | | | | | | | | | |
| **Operation** | | | | | | | | | | | | | | | | |
| Connection | | | | | | | | | | | | | | | | |
| Operation and monitoring | | | | | | | | | | | | | | | | |
| **Decommissioning** | | | | | | | | | | | | | | | | |
| Disconnection | | | | | | | | | | | | | | | | |
| Decommissioning | | | | | | | | | | | | | | | | |
| Demobilisation | | | | | | | | | | | | | | | | |

| | |
|---|---|
| | Planned timings |
| | Contingency |

## 3.3 Vessel requirements

The detailed methodologies associated with the installation of the devices and the associated structures are currently under development. This fact, and the difficulties in confirming availability of local vessels, means it is difficult to explicitly define the specific vessels that will be used during installation. The same is true for maintenance and decommissioning activities, where inability to predict which vessels will be available in the future makes predicting specific vessel use unrealistic. Current planning, however, suggests that the vessels and vessel types outlined in Table 3.2 could be used. Note that no large construction or DP (dynamically positioned) vessels will be required at any stage of the project.

**Table 3.2 Anticipated project vessel spread**

| Project phase | Task | Vessel type | Vessel options |
|---|---|---|---|
| Installation | Main pipeline installation | Multicat | C-Odyssey<br>Voe Viking |
| | Pipeline protection installation | Dive/support vessel | Uskmoor<br>Ocean Enterprise |
| | Foundation block installation | Multicat | C-Odyssey<br>Voe Viking |
| | Pump and float installation | Support vessel | Ocean Enterprise<br>Uskmoor |
| | Auxilliary mooring installation | Multicat or Support vessel | C-Odyssey<br>Voe Viking<br>Ocean Enterprise<br>Uskmoor |
| | Array interconnection with catenary chains | Multicat or Support vessel | Ocean Enterprise<br>Uskmoor<br>Ocean Enterprise<br>Uskmoor |
| | Inter-array pipeline installation | Support vessel | Ocean Enterprise<br>Uskmoor |
| | Dive support/pipeline inter-connection | Support vessel | Ocean Enterprise<br>Uskmoor |
| | General support | RHIB | TBC |
| Operation and maintenance | Pump/actuating float changeover | Support vessel | Ocean Enterprise |
| | General support | RHIB/ standard workboat | TBC |
| Decommissioning | Dive support/pipeline disconnection | Support vessel | TBC |
| | Inter-array pipeline decommissioning | Support vessel | TBC |
| | Array interconnection with catenary chains detachment and removal | Multicat or Support vessel | TBC |
| | Auxiliary mooring decommissioning | Multicat or Support vessel | TBC |
| | Pump and float decommissioning | Support vessel | TBC |
| | Foundation block decommissioning | Multicat | TBC |
| | Pipeline protection decommissioning | Support vessel | TBC |
| | Main pipeline decommissioning | Multicat | TBC |
| | General support | RHIB | TBC |

The Ocean Enterprise, as listed in Table 3.2 above, is a purpose built vessel, which has been used during much of the prototype testing in Antigua. The vessel will be transported to Orkney for use in operations at the EMEC wave test site. The vessel will be cleaned and painted before shipment to the UK and has no internal ballast tanks. The vessel is shown alongside a prototype WEC during testing in Antigua in Figure 3.6 below.

**Figure 3.6 The Ocean Enterprise alongside a Seatricity prototype WEC**

## 3.4 Mobilisation

All the major components will be manufactured and/or assembled in Orkney:

| | |
|---|---|
| Floats and ancillary equipment | Ness Boatyard |
| Pipeline construction | Billia Croo EMEC land site |
| Reaction and mooring blocks | Finstown Quarry |
| Generator installation and associated works | Billia Croo EMEC land site |

Partially assembled and other components are expected to be delivered to Orkney by road and ferry, including tubulars for pipeline construction, pumps, and rigging.

The reaction and mooring blocks will be manufactured in the quarry at Finstown and delivered individually by road to the load out point in Stromness. Due to weight of the blocks and to avoid handling crane lifts at sea, it is likely they will be hung off the bow of a multi-cat or similar vessel for transport out to the site.

The floats and riser assemblies can be loaded out directly from the Ness boatyard. The floats are relatively small and a workboat can be utilised for the tow out. Pilotage will not be required, provided the combined length of the tow is less than 65 metres. Extreme tides through Hoy sound, even in clam weather will pose difficulty for a tow; wind against tide will exacerbate the situation.

A towing plan and deck plan will be required and approved by the Master of the vessels involved in operations, for the load out of the three different types of clump weight and the buoy and riser arrangement.

## 3.5 Pipeline installation

The main pipeline (11” diameter) will arrive in Orkney in 12 metre sections. Three sections will be assembled into one 36 metre length ready for deployment of the pipeline.

The assembly line at the Billia Croo shore site will assemble two 36 metre lengths during the pipeline pull out process. It is anticipated that each 72 metre section will take approximately 1 hour to prepare.

Nine pipeline stabilisation/guide blocks will be installed at the point of curvature of the pipeline. A temporary mooring 3 point pattern will be installed for the installation of the pipeline stabilisation blocks. Placement of the blocks will be diver assisted to achieve correct positioning and orientation. When all nine blocks are in place and a suitable weather window is identified, the pipe pulling line will be inserted through the stabilisation blocks. One end of the line will be secured on the beach in readiness to attach to the pipeline pulling head and the other end will be buoyed off.

The pull will be achieved by a multi-cat or similar vessel moored on a standard four point mooring at pre-determined locations. Divers will be used to guide through stabilisation blocks.

## 3.6 Device array installation

The main foundation blocks and auxiliary moorings will be installed onto the seabed using a multicat-type vessel. Connection to the auxiliary moorings will be performed by a support vessel or multicat.

The pump will be connected to the float onshore prior to each float being towed to site using a small workboat. Each pump will then be attached to the main foundation by use of a tether operated latch mechanism on the foundation. This will be performed by a support vessel without the need for divers. The interconnector chains will then be installed from a small workboat, completing the ring of devices.

The inter array pipelines will be 5” diameter flexible pipeline installed generally from the surface. Divers may be required for making final connections to the main export pipe.

## 3.7 Operation and maintenance

### 3.7.1 Normal operation

All controls for the plant are located onshore. The offshore pumping units are self-regulating and require no electrical control systems. This eliminates the use of electrical/electronic equipment in the marine environment. The pumping units are designed for a 5 year maintenance programme however a large part of the EMEC testing programme is to confirm this and make modifications if necessary.

### 3.7.2 Maintenance

**Actuating float replacement -** Whilst no maintenance of the WECs is predicted to be necessary during the project, Seatricity plan to stock spare units so that they can be changed out as necessary. Changing a pump/actuating float combination can be carried out by the Ocean Enterprise service vessel without the need for divers and experience has shown that this can be safely achieved in up to 2 m wave height and in less than one hour.

**Pipe cleaning -** It is very difficult to predict the fouling rate of the plant by marine organisms. This varies dramatically from one place to another and is highly dependent on water depth and temperature. The fouling rate of the equipment mounted on the seabed is not expected to affect the plant performance significantly. There is a potential for the fouling of the inside of the main pipeline and for this reason the pipelines will be designed so that they can be cleaned periodically by 'pigging'. To facilitate this process an access tee will be fitted to the high pressure pipeline ashore. A gate or ball valve will be fitted at the offshore end of the pipe and will be either diver or ROV operated. A cleaning pig formed of multiple polyurethane rubber discs mounted on a shaft can then be inserted through the onshore access tee and driven to the offshore end by pressurised water. Note that the flow rate in the smaller diameter pipelines will be such that fouling will not take place.

**Actuating float fouling -** The underside of the actuating floats will attract fouling organisms. Initially, it is not planned to use any antifouling paint on the actuating floats. The operation of the actuating floats will not be affected by moderate amounts of fouling and it is anticipated that annual cleaning may suffice. If it transpires that cleaning the actuating floats becomes too frequent a requirement, then other options may be investigated.

## 3.8 Technical and environmental monitoring

During the operational phase, Seatricity will monitor the device and carry out any necessary maintenance. During this time Seatricity will conduct the full spectrum of demonstration testing and monitoring, including:

- Power output
- Power quality to grid
- Pressures and flow stability in interconnecting pipelines
- Mechanical stresses
- Corrosion, wear and biological fouling

An Environmental Monitoring Plan (EMP) has been developed for the proposed project. Please refer to Aquatera (2012b) Array deployment of Seatricity's Oceanus wave energy converter at EMEC's wave test site in Orkney: Environmental Monitoring Plan.

Proposed monitoring measures are outlined in the project Commitments Register (refer to section 10 of the EA (Aquatera, 2012a)).

## 3.9 Decommissioning

Because the individual units of the Seatricity WEC are small, decommissioning will be a relatively straightforward operation carried out by small vessels within a short timeframe.

During decommissioning, all structures deposited during installation will be removed from the test site except for the rock bolts used to stabilise the cable, which will be cut as close to the seabed as is practical and left in the seabed/grout cement. Floats and pumps will be recovered followed by the pipe system and the mooring system. Seatricity and its marine operations contractor will carry out the decommissioning procedures, which will be outlined within the Initial Decommissioning Programme in line with the relevant guidelines (DECC Decommissioning of Offshore Renewable Energy Installations under the Energy Act 2004) and presented in full within the Decommissioning Programme. In addition, Seatricity will also decommission the onshore infrastructure associated with the deployment.

The existing pipe which will be used for outflow of water from the onshore turbine is owned by EMEC and decommissioning of this pipeline will not be the responsibility of Seatricity.

# 4 Status of hazard log

## 4.1 Summary of all risks identified

The HAZID process leading to the completion of the hazard log identified some 32 hazards and related events. Many of these hazards were classified as medium risks and were therefore considered to be acceptable with ongoing management in place to achieve a risk outcome As Low As Reasonably Possible (ALARP) (see Table 4.1). A number of hazards had associated risks that were considered to be more serious, where further mitigation would be required for them to reach acceptable levels (see also Table 4.1).

**Table 4.1 Risk matrix – initial review with no additional mitigations**

| | | Probability | | | | |
|---|---|---|---|---|---|---|
| | | 1-Extremely Unlikely | 2-Very Unlikely | 3- Unlikely | 4- Possible | 5- Likely |
| Severity of impact | 1 Negligible | | | | | |
| | 2 Minor | | 18, 19, 20 | 5 | 8 | |
| | 3 Moderate | 3, 10, 16 | 2, 23, 24, 25 | 9, 17 | | |
| | 4 Major | 1 | 6, 11, 13, 15, 21, 26 | 4, 7, 12, 14 | 22 | |
| | 5 Extreme | | | | | |

| | |
|---|---|
| Low Risk | Broadly acceptable risk |
| Medium Risk | Tolerable only if mitigation measures consistent with ALARP are implemented and the analysis team has found the residual risk tolerable |
| High Risk | Unacceptable risk requires further mitigation to reduce to Tolerable status |

There were also areas which had arisen in the scoping process, where consultees perceived risks to be present. Many of these are already covered in the former classification but a few additional points still arose. Each of the hazards and associated risks classified as being unacceptable or of specific concern to stakeholders are listed below:

Risks classified as unacceptable in their current state of management were:

- Collisions involving the device and vessels from other EMEC site operations

Risks indicated as being of concern by stakeholders were:

- Collision between vessels and devices/moorings
- Devices breaking loose and becoming a navigational hazard at sea
- Diving operations for maintenance, decommissioning

A number of specific mitigation measures are outlined in the hazard log. These will help to reduce the likelihood or severity of the events and therefore reduce the resultant levels of risk to more acceptable levels. These additional mitigation and recovery measures are listed below:

| **Additional prevention measures** |
|---|
| Notice to Mariners will be used during installation operations |
| Appropriate marking will be maintained |
| Charts of site with buoys present will be distributed locally |
| Establish standing procedures for use of Hoy Sound and approach to Ness Shipyard |
| Avoid transit of Hoy Sound when ferry or other EMEC devices are also in transit |
| Discuss possible routings for transit with local creel boat skippers and agree with local creel boats a cessation of fishing in any areas critical to the operations if necessary. |
| Keeping a lookout for creel buoys at all times, potentially with a dedicated lookout used during passage through Hoy Sound. |
| Ensure all vessel crews are aware of creels in area. |
| Use methods for pipeline pull that are less sensitive to prevailing sea conditions |
| Procedures followed in line with COLREGS |
| Detailed pre-planning and constant communications with other vessels through shared VHF channel |
| Control speed of vessels within defined working area |
| Avoid putting vessel at risk from downstream/downwind hazards |
| Identify hazardous areas to be avoided in operational procedures |
| Discuss operational plans with local creel boat skippers |
| Project vessels equipped with standard navigation systems and GPS. Radar watch, for safe navigation in poor visibility |
| Project vessels have to be coded with workboat certificate. |
| Tow vessel will maintain radar and visual watch and plot any targets which may present danger to tow |
| Extensive use of Orkney Marine Services to coordinate vessels in Hoy Mouth. |
| Dive vessel will maintain radar and visual watch for any targets which may present danger |
| EMEC SIMOPs procedures will ensure that all vessels are aware of operations on site |
| Lift equipment which needs diver intervention off seabed if possible |
| Careful control of guide block positioning<br>Ensure pathway created by guide blocks is conservative regards bending radii.<br>Apply suitable lubricants if required to guide mechanisms.<br>Avoid stopping pull once underway if possible |
| Use physical locator guides for positioning such as lengths of rope |
| Minimise period where moorings lines left unattended. |
| Tow vessel responsible for inspection of equipment and adjusting tow parameters during actual tow. |
| The tow vessel will be instructed to restrict the tow line tension to pre-determined limits. |
| Ensure that the forces being applied to the equipment are less than the equipment designed and certified for. |
| Clear as laid layout diagrams for vessel skippers. |
| Chose a designated entrance gap where separation chains are set deeper. |
| Only one operational vessel will be permitted to be inside the array circle at a time. |
| Only one operational vessel will be permitted to be within the range of the mooring line. |
| Vessel will generally be moored on a steady heading with multi anchor spread |
| Site wide NRA already completed covering the interaction of vessels with the test site boundaries (ARC may 2009). |
| Adherence to COLREGS. |
| GPS tracker system fitted to all actuator floats. |
| Close liaison with EMEC and other developers, port authority to ensure SIMOPS are safely coordinated. |

| **Additional recovery measures** |
|---|
| All vessels to be equipped with rope cutting gear. |
| Have a procedure established to deal with loss of propulsion ensuing that the safety of the vessel is not further compromised by actions taken in strong tidal and heavy sea conditions |
| Take account of need for pipe repair or sacrificial length in fabrication plan. |
| Appropriate action based on COLREGS |
| Clear procedures for dealing with grounding/foundering |
| Project vessels to be equipped with cutting gear and means of debris recovery. |
| If vessel begins to take on water, mobilise support vessels from shore to perform rapid recovery back to port. |

| Additional recovery measures |
| --- |
| Provide more pipeline guide blocks. |
| Redesign pipeline guide mechanisms |
| Include potential for shoreline recovery to land as well as recovery to sea, if buoy reaches shore. |
| Replace damaged component and alter procedures to avoid the causative events recurring. |
| Have adaptable repair shop nearby in Stromness |

Applying these addition mitigation measures therefore helped to reduce either the likelihood or the consequence of possible events, or both, changing the anticipated level of risk. The results are shown in Table 4.2. It can be seen that all risks now fall into the medium category, making then acceptable so long as they are managed to be ALARP.

The most serious risks within the Medium Risk category and include:

- Collisions involving the device and vessels from other EMEC site operations
- Collision between project vessels
- Collision on site with 3rd party vessel
- Collision with another developer's vessel
- Collision with 3rd party during tow

Clearly all of these risks are avoidable and it would be hoped that the planned operations could be undertaken without these risks manifesting themselves.

**Table 4.2 Risk matrix – residual risks after applying additional mitigations**

| | | Probability | | | | |
|---|---|---|---|---|---|---|
| | | 1-Extremely Unlikely | 2-Very Unlikely | 3- Unlikely | 4- Possible | 5- Likely |
| Severity of impact | 1 Negligible | | 17 | | | |
| | 2 Minor | | 5, 18, 19, 20, 23 | 8 | | |
| | 3 Moderate | 2, 3, 4, 10, 16 | 9, 24, 25 | | | |
| | 4 Major | 1, 11, 12, 13, 15, 21, 26 | 6, 7, 14 | 22 | | |
| | 5 Extreme | | | | | |

| | |
|---|---|
| Low Risk | Broadly acceptable risk |
| Medium Risk | Tolerable only if mitigation measures consistent with ALARP are implemented and the analysis team has found the residual risk tolerable |
| High Risk | Unacceptable risk requires further mitigation to reduce to Tolerable status |

# 5 Search and rescue overview and assessment

This search and rescue (SAR) overview builds on the SAR section in the EMEC Wave Test Site NRA (ARC, 2010).

## 5.1 Potential impacts and demands on search and rescue services

When the devices are installed they will float on the surface within the boundaries of the test site. This will have no effect on SAR activities that operate around Orkney. The device will be marked (in accordance with NLB and MCA guidance) with yellow reflective material with a yellow flashing beacon; because the buoys are built of aluminium they should be clearly visible on radar, however as they are low in the water with little freeboard, their visibility on radar might be dependent upon sea state. As mentioned above, under normal operation the devices will present no extra hazards than that of a conventional moored buoy or isolated rock.

During the installation and decommissioning phases additional vessels will be located at site and these also should have no adverse effect on SAR activities.

In the event of SAR activity related to the Seatricity devices, the presence of the devices, their moorings and also the high likelihood of other developer's devices and associated subsea structures being present will present a hazard to rescue craft. The locations of all equipment in place on the site will be notified to the local lifeboat and any other SAR resources as needed.

Within the relatively small boundaries of the project there is not thought to be the potential for the project, at any stage, to place significant demands on local or national SAR facilities. Other major hazards, identified by the developer's risk assessment, such as injuries to personnel incidents would present an acute but limited demand on SAR services.

Developer's own contingency plans for its personnel
The evacuation of ill or injured personnel during any phase of the project could be carried out by the project's work and standby vessels.

## 5.2 Search and rescue description

Helicopter support: HMCG operates four SAR helicopter units providing suitably equipped helicopters and facilities at Sumburgh Airport (Shetland), Stornoway (Isle of Lewis). The helicopters provided have a full night/all-weather capability for civil maritime and civil aviation SAR and medical evacuation from ships and offshore installations and a limited night overland capability (MCA, 2008d). Two Sikorsky S92A helicopters are based at both Stornoway and Shetland. Helicopters and crews at Sumburgh and Stornoway maintain a 15 minutes readiness state from 0730 to 2100 and 45 minutes readiness state outside these times all year round. Further to this there are MOD helicopters at RAF Kinloss and Lossiemouth, and Royal Navy helicopters from HMS Gannet at Prestwick, available for additional support.

Coastguard: Operations in the northern area of the North Sea and waters in and beyond the coastal waters of the north of Scotland are coordinated by the Coastguard Marine Coordinating Centre (MRCC) at Aberdeen. The area covered by the MRCC extends from 55° 30'N (Berwick on Tweed) to 62°N and from 2°E (linking with Norwegian CG) to 5°W (Cape Wrath linking with Stornoway CG). There is a Marine Rescue Sub Centre (MRSC) at Lerwick (Shetland) which has operational responsibility for the sea area north of the Pentland Firth and particularly the coastal waters around the Orkney and Shetland Islands.

Lifeboats: There is a Severn Class RNLI lifeboat stationed at both Kirkwall and Stromness and a RNLI Tamar class boat at Long Hope. Other lifeboats are stationed at Wick and Thurso. A pilot boat is stationed at Kirkwall which has a limited towing capability (available 24 hours a day) and there are various other small commercial craft. Tugs at Scapa Flow are manned 24 hours a day and their response time to site would be about 5 hours. The Maritime and Coastguard Agency has an Emergency Towing Vessel (ETV) on station between southern Shetland and northern Orkney.

Medical: In the event of medical assistance the Coastguard will be able to advise on this. Nearest hospitals are Kirkwall (A&E), Inverness and Aberdeen.

# 6 Emergency response overview and assessment

A Project Emergency Response Plan (ERP) will be prepared by the Project Team for each phase of the project. The ERPs will dovetail with local and regional emergency response systems including MCA and RNLI, with EMEC's ERPs and SOPs and with the safety management systems of the developer and main contractors.

# 7 Navigational risk assessment

DTI Guidelines (DTI, 2005) recommend that an NRA should consider quantitative risk analyses of current and future scenarios. Given the small scale of this project and the fact that shipping activity is unlikely to change significantly over the lifetime of the project, the use of quantitative risk assessments with different future scenarios does not seem proportionate to the level of risk. Therefore, a structured qualitative approach has been used as described in Section 2.4. This approach is consistent with the level of detail that has been used for the previous NRAs for the Wave Site in 2009 (ARC, 2009) and 2010 (ARC, 2010) and for the EMEC Tidal Site in 2005 (ARC, 2005) and 2010 (Anatec, 2010).

**This NRA is to be read in parallel to the EMEC wave test site NRA (Ref. ARC-039-013-R2) and should be regarded as an addendum to that document.**

The purpose of this chapter is to provide context and description to the key marine safety issues identified during the project scoping process and initial consultation with key stakeholders (Maritime and Coastguard Agency, Northern Lighthouse Board and Orkney Fisheries Association). Please note that the Hazard Log provides details of **all** risks, mitigation measures, contingency plans etc whilst this summary addresses recognised key issues unique to the proposals and the deployment area

The key marine safety issues identified during Scoping were:

- Collision between errant third party vessels and devices/moorings
- Collision between support vessel and devices/moorings
- Collision between permitted third party vessels and devices/moorings
- Device moorings fail resulting in errant/foundering equipment becoming a navigational hazard at sea
- Diving operations for maintenance, decommissioning

The following section provides an overview of the key potential risks along with the control/mitigation measures that will be implemented by the project team and all sub-contractors during all operations.

## 7.1 Collision between errant third party vessels and devices/moorings

(Please refer to risks 1, 2 4, 6, 11, 12, 13, 14, 16, 17, 21, & 24 in the Hazard Log - Appendix B)

The hazards associated with errant vessels passing the test area have been fully addressed within the test site NRA (ARC, 2009). The assessment concluded that the risk of an errant vessel being set into the test area such that it collides with a device "can be considered as extremely remote" (ARC, 2009). A number of risk control measures were identified which will remain in place in the lead up to and for the duration of the proposed project; including EMEC's Emergency Response Procedures which would apply in such an instance.

It is considered that; given the scale of the surface components, the relative footprint of the development (0.4% of the test site) and the risk control measures in place, this risk is addressed sufficiently within the test site NRA and providing that all risk control measures remain in place, no further consideration is required at this time.

## 7.2 Collision between support vessel and devices/moorings

(Please refer to risks 8, 9, 18, 19, & 20 in the Hazard Log - Appendix B)

The installation and removal of the Oceanus array will require extended and precise marine operations. This will involve working in close proximity to devices, mooring lines, interconnector chains, pipework (during installation and removal) whilst negotiating conditions at the site on any given day. There are a number of hazards that have been identified regarding project vessels working on site which may result in collision with project equipment:

- Presence of project equipment poses a collision/snagging/entanglement risk to project vessels working within the test site; particularly when working in close proximity to project equipment
- Unexpected change in weather resulting in reduced manoeuvrability or abandonment of tasks
- Loss of vessel control (human error, steering loss, loss of navigation systems, loss of power) whilst working on site may result in a collision with project equipment.

Therefore, the following mitigation measures are proposed:

- Detailed planning of operations along with the preparation of Safe Working Method Statements
- Use of appropriately trained personnel at all times
- Modern seafaring equipment to be used by skilled operators at all times
- Robust and seaworthy vessels to be used at all times
- Adherence to COLREGS at all times
- Appropriate weather forecasting utilised at all times
- A Project Emergency Response Plan closely linked to the EMEC Site Operating and Emergency Procedures and existing SAR service will be in place and communicated to HM Coastguard and the local Port Authority (OIC Marine Services)
- Timing of works will be carefully selected to take advantage of tidal flows

## 7.3 Collision between permitted[4] third party vessels and devices / moorings / project vessels

(Please refer to risks 7, 22 and 23 in the Hazard Log - Appendix B)

Vessels permitted to work on the site are fully briefed through EMEC's Control of Work procedures on the nature and location of all devices on site. Although the site is managed closely by EMEC's Operations Team, each berth has a defined area of avoidance established and all developers are subject to strict safe operating procedures, there is a potential risk of collision due to the following hazards:

- Presence of project equipment poses a collision/snagging/entanglement risk to other vessels working within the test site
- Unexpected change in weather resulting in reduced manoeuvrability or abandonment of vessels on site
- Loss of vessel control (human error, steering loss, loss of navigation systems, loss of power) whilst working on site may result in a collision with project equipment

All developers will be expected to:

- Prepare detailed Safe Working Method Statements
- Use appropriately trained personnel at all times
- Use modern seafaring equipment and skilled operators at all times
- Use robust and seaworthy vessels at all times
- Adhere to COLREGS at all times
- Use appropriate weather forecasting at all times
- Prepare a Project Emergency Response Plan closely linked to the EMEC Site Operating and Emergency Procedures and existing SAR service

In addition, the following mitigation measures will be implemented:

- Increased visibility of surface structures through the use of high visibility strips on floats
- Appropriate demarcation of the development (as advised by NLB)
- Notice to Mariners issued as and when required plus additional communication with OIC Marine Services (local Port Authority) and Orkney Fisheries Association

## 7.4 Device moorings fail resulting in errant/foundering equipment becoming a navigational hazard at sea

(Please refer to risks 28 and 29 in the Hazard Log - Appendix B)

Device breaks free from mooring (28)
Structural failure in surface buoy (29)

Concern has been raised that structural failure (from design flaws, extreme weather/sea conditions etc) could result in errant equipment becoming a hazard to navigation and other sea users in the local area. This could result in the following events:

- Collision of vessels at sea with errant equipment on or below the surface

[4] Vessels with either a 'Permit to Access' for developers' vessels and works or a 'Permit to Work' for EMEC's own operations under their direct control.

- Entanglement of equipment with vessels and fishing gear
- Equipment becoming a hazard in areas away from the immediate area of the test site

A number of mitigation measures will be implemented by the project team to minimise these risks:

- Auxiliary moorings fitted to prevent WEC drifting  off site
- Threshold of metocean limits is a defining factor in the design of all components including the mooring system[5]
- Inter-connector chains (between floats) will be installed to keep errant floats within the array
- Moorings are designed to withstand severe local conditions
- Device has a protection system to pull the float down below wave motion when severe weather and sea state conditions arise
- Reaction (foundation blocks) are oversized to prevent dragging
- Each float will be fitted with a GPS tracking device which will transmit a warning alarm if a float moves off station and can be used to track any floats in the unlikely event that they break free
- All components (including the mooring
- Main tether to reaction blocks will have third party verification of critical system components. system) will be subject to Third Party Verification (TPV)

## 7.5 Diving operations for installation, maintenance and decommissioning

(Please refer to risk 15 in the Hazard Log - Appendix B)

Procedures for installation, operation and recovery of the devices is designed to minimise the requirement for divers, however there will be some parts of the project where divers will need to be deployed.  The following navigational hazards have been identified with regards to diving:

- Dive support vessel on multipoint moorings will be unable to move away from incoming vessels
- Force of tide/weather leads to dive support vessel dragging/breaking its mooring
- Dive vessel drifting uncontrolled could cause damage to WEC or other vessels
- Local fishing vessels pass the site regularly

The following mitigation measures will be implemented:

- Appropriate weather forecasting
- Task risk assessment and tool box talks
- Vessels nearby for recovery/rescue
- A Project Emergency Response Plan closely linked to the EMEC Site Operating and Emergency Procedures and existing SAR service and will be in place and communicated to HM Coastguard and the Port Authority

[5] The device basic design has taken into account the 50 year max wave height and built in a significant factor of safety.

## 7.6 Entanglement of props with creel lines during transit

(Please refer to risk 5 in the Hazard Log - Appendix B)

One of the more significant navigational hazards for smaller vessel transiting around Orkney is the potential to snag a creel line around the propeller. The strength of these lines can be sufficient that they do not break on contract and the can become entangled with the propeller and prop shaft. This leads to the vessel loosing propulsion power and drifting according to wind and tide. In close proximity to the shore this can lead to grounding, there are hazardous seas associated with tidal overfalls which may not be avoided and there is more potential for collision with other vessels or obstacles at sea such as buoys or devices on the surface. Such incidents happen a number of times each year across the inshore vessel fleet in Orkney. On a number of occasions this can involve calling upon the lifeboat to assist in the recovery of the affected vessel.

The approaches to mitigation are as follows:

- Avoiding areas where creel lines are most prolific
- Discuss possible routings for transit with local creel boat skippers and agree with local creel boats a cessation of fishing in any areas critical to the operations if necessary
- Keeping a lookout for creel buoys at all times, potentially with a dedicated lookout used during passage through Hoy Sound
- Have equipment on board to deal with cutting and freeing creel lines if snagged
- Have a procedure established to deal with loss of propulsion ensuing that the safety of the vessel is not further compromised by actions taken in strong tidal and heavy sea conditions

# 8 Status of the Risk Control Log

A project Risk Control Log will be developed using the Hazard Log (refer to Appendix B). At this stage of the project the Risk Control Log is still being populated but this will be completed as the HIRA process is deepened in conjunction with the contractors executing the works. An audit on key mitigation measures will be carried out before construction starts. This will be combined with a systematic approach to monitoring the implementation and effectiveness of all the proposed mitigation measures throughout the lifecycle of the project.

# 9 Through life safety management

## 9.1 Updating risk assessments

All risk registers will be updated regularly and prior to key stages of the project. The methodology used will follow the pattern of holding workshops with those involved in managing and supervising the activities and where appropriate, with stakeholders and users of the sea in the area affected by the project. Where gaps are present or are discovered within the assessments, appropriate investigation, analysis and additions will be made.

## 9.2 Safety policy

Seatricity and its subcontractors have a strong commitment to achieving the highest standards of safety performance in its own activities and projects in which it participates or leads. Similarly, EMEC has an established Safety Policy embedded in its Integrated Management System which covers the operations at the site.

## 9.3 Safety management system and safety plan

Seatricity has a commitment to active management of safety for its wave energy project. It will engage with its key sub-contractors to ensure that the project has a suitable safety management system (SMS). This will effectively link its own corporate management policies and systems with those of any sub-contractors. The project SMS will be aligned with EMEC's Emergency Response Procedures and Standard Operating Procedures.

## 9.4 Through life review

At each stage of the project a review will be carried out involving the developer, the key contractors, and the Construction, Design and Management (CDM) Coordinator. The review will look at the risks identified in the next phase of the project, and lessons learned from the previous phase. The anticipated duration of the project is 5 years and a final review will be carried out after cessation of operations.

## 9.5 Compliance and assurance

Assurance to Seatricity (and Regulatory organisations) that a proper Project SMS is in place for the project life cycle which complies with Regulatory requirements and Seatricity requirements will be provided by:

- Leadership and engagement of Seatricity management
- Structured audit programme
- CDM Co-ordinator reviews and maintenance of the CDM Safety File
- CDM Co-ordinator ensures competent persons are hires for the project

- Recurring project safety and environment risk reviews with contractors and sub-contractors
- Maintenance and updating of Hazard Logs and Hazard Identification Risk Assessment (HIRA)
- Maintenance and updating of a Risk Control Log based on the Hazard Log but with additional entries to cover development and management of Control Measures
- Development of detailed operating procedures for all key operations and tasks
- Updated Risk Assessments (Hazard Log) and updated Risk Control Logs will be lodged with the Seatricity Project Manager and in the CDM Co-ordinator's Safety File

# 10 References

List of documents and sources that have been used in this report


Aquatera (2011) Deployment of Seatricity's wave energy converter array at EMEC's wave test site at Billia Croo in Orkney; Environmental and Navigational Scoping Information, November 2011

Aquatera (2012a) Array deployment of Seatricity's Oceanus wave energy converter at EMEC's wave test site in Orkney: Environmental Report

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MCA (2008b), Maritime and Coastguard Agency's (MCA) Marine General Notice (MGN 371(M+F)) Offshore Renewable Energy Installations (OREI) - Guidance on UK Navigational Practice, Safety and Emergency Response Issues, 2008

MCA (2008c), Maritime and Coastguard Agency's (MCA) Marine General Notice (MGN 372(M+F)) Offshore Renewable Energy Installations (OREI) - Guidance to mariners operating in the vicinity of UK OREIs, 2008

MCA (2008d), Search and Rescue Framework for the United Kingdom of Great Britain and Northern Ireland, Maritime Coastguard Agency, April 2008

# Appendix A – Risk classification definitions

## Risk Assessment Process

The following risk assessment process (refer to Figure A.1) will be applied throughout the NRA and is outlined within the following section.

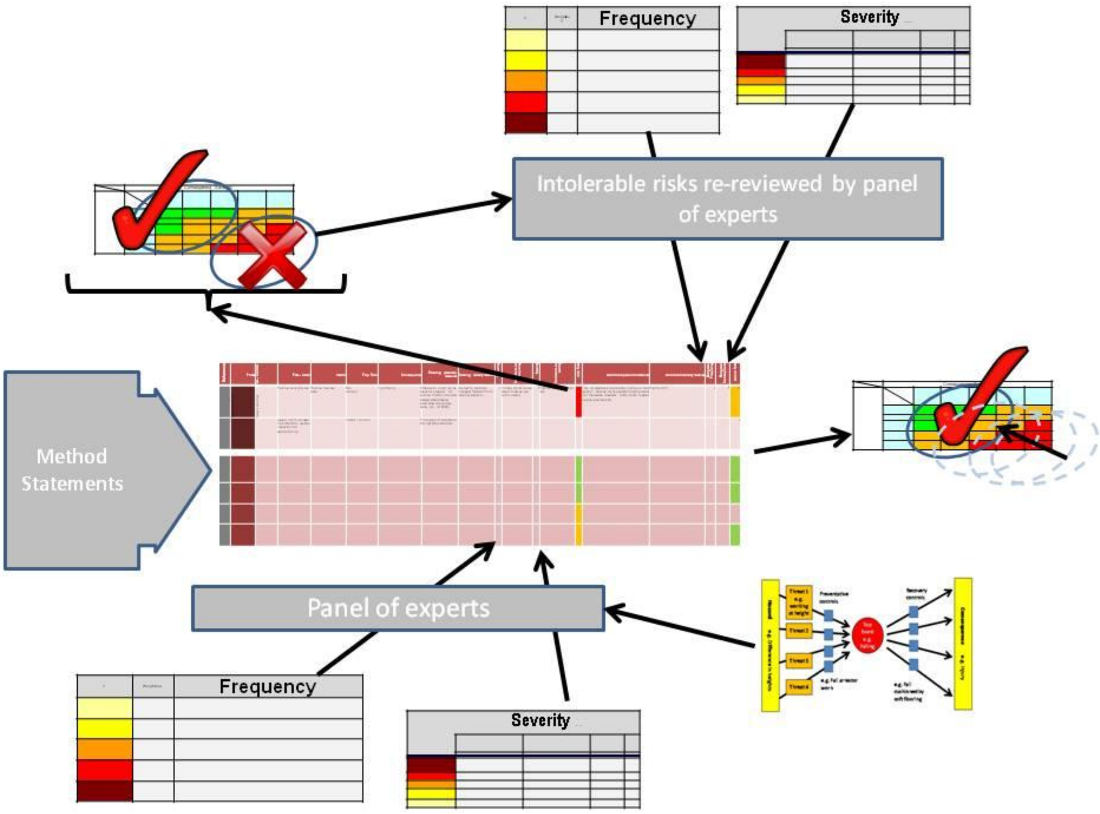


**Figure A.1 – Risk assessment process**

The figure above outlines the process adopted for the creation of the risk assessments. Method statements are provided which provide a detailed series of activities and events for the entire project. An expert panel is then used to review these method statements, identifying ay hazards pertinent to navigation. The SWIfT technique is used to develop the start of the risk matrix with the 'bow tie' methodology used to identify risk consequences. Industry standard severity (Table A.1 and A.2) and frequency table (A.3) are then used to classify each hazard into an initial risk matrix (Table A.4).

Risks that are then identified as 'High Risk' are then re-reviewed by the panel of experts and further mitigation measures are proposed. The risks are then given new frequency and severity scores based on the additional mitigation. Finally an 'Additional Mitigation Risk matrix' is produced where all risks are either acceptable (green boxes) or ALARP (orange boxes) (Table A.5).

Judgments about the severity classification of risks used the following guidance relative to Internal Factors in Table A.1 and relative to External Factors in Table A.2.

**Table A.1 Consequence Severity Categories – Internal factors**

| Category | Health & Safety | Project and Technical | Cost | Reputation |
|---|---|---|---|---|
| | Risks arising from accidents and exposure to chemicals and agents | Operational lost time, reduced flexibility, novel technology | Capital, operating & risk assessed costs from liabilities | Perceptions of external stakeholders |
| 1 Negligible | Elevated risk of minor illness or injury;<br>Managed exposure to nuisance chemicals | Partially disrupts task;<br>Leads to minor delays < 1 day;<br>AMM requires well established technology, but it could affect flexibility | Equipment lost or financial liability of value < £10 K | A minor public awareness and some concerns but minor local news coverage |
| 2 Minor | Risk of short term illness or minor injuries;<br>Uncontrolled exposure to nuisance chemicals | Jeopardises task;<br>Risk of delays > 1 day;<br>AMM requires use of proven technology not tested in this field experience and presents some restricted flexibility | Equipment lost or financial liability of value £10-100 K | Adverse public reaction, possible prosecution, considerable local news with some minor national coverage. |
| 3 Moderate | Associated with serious injury and/or long term illness;<br>Managed exposure to harmful chemicals | Jeopardises activity;<br>Risk of delays > 1 week;<br>AMM relies on not fully proven technologies and/or markedly hinders flexibility | Equipment lost or financial liability of value £100K-£1M | National hostile media coverage, local campaign against developer. |
| 4 Major | Single fatality and/or multiple serious injuries / chronic health problems;<br>Uncontrolled chemical exposure | Jeopardises phase objectives;<br>Leads to serious risk of lost time > 1 month and/or opportunities;<br>AMM uses untested technology | Equipment lost or financial liability of value £1-5 M | International media coverage, national campaign against developer and/or facility |
| 5 Extreme | One incident with multiple fatalities or multiple fatal accidents;<br>Large scale uncontrolled chemical exposure | Jeopardises total project objectives.<br>Risk of delay > 1 year;<br>Acceptable avoidance, mitigation and/or management (AMM) relies upon blue sky research or design from scratch | Equipment lost or financial liability of value > £5 M | Outcry threatens to prevent project |

**Table A.2 Consequence Severity Definitions – External factors**

| Category | Ecological<br>Impacts arising from pollution, land take, access, cultural or archaeological impacts | Economic<br>Impacts from investment, inflation, jobs, interaction with current businesses | Social<br>Impacts from social inequality, cultural influence, skills, third party accidents. | Regulation<br>Compliance with external regulation and internal corporate policy |
|---|---|---|---|---|
| 1<br>Negligible | Within scope of natural variability and/or limited to the vicinity of the operations. | Loss of business <£10,000;<br>Inflation <0.1% | Minor social changes affecting a few individuals negatively;<br>Minor nuisance to individuals | Noted by regulations but not restricted |
| 2<br>Minor | Similar to natural variability, and/or localised to adjacent areas and <1 year recovery potential | Loss of business <£100,000; Inflation <1% | Minor social changes to localised community or limited organisational structures;<br>Serious nuisance/disruption to individuals. | Limited or controlled by spirit of regulations and may lead to regulator challenge |
| 3<br>Moderate | Change beyond natural variability but local geographical effect and/or 1-5 year recovery potential | Loss of business <£1 M;<br>Inflation <10% | Moderate social changes affecting a large section of the local community or minor part of wider population;<br>Localised public safety impact for individuals | Explicitly limited or controlled by regulation, leading to difficulties in gaining approvals |
| 4<br>Major | High toxicity, geographical spread, and/or 5-10 year recovery potential | Loss of business <£10 M; Inflation <100% | Substantial social changes, affecting local population or minor part of the wider community;<br>Public safety impact to local community | Out of line with regulation and unlikely to get approval |
| 5<br>Extreme | Total change to total ecosystems and/or indeterminate recovery period | Loss of business >£10 M; Inflation ≤1000% | Massive social changes, affecting majority of population negatively;<br>Substantial public safety impact to the wider community | In conflict with principles of regulation, leading to regulatory outrage |

**Table A.3 Frequency Category Definitions**

| Consequence Probability | Weighting | Description |
|---|---|---|
| Extremely unlikely | 1 | Has rarely occurred in the industry |
| Very unlikely | 2 | Has occurred a few times per year in the industry |
| Unlikely | 3 | Has occurred several times a year in industry/sector and has occurred in operating companies (Contractors to this Project) |
| Possible | 4 | Has occurred many times per year in the industry and several times a year in operating companies |
| Likely | 5 | Has happened several times per year during operations at this location |

**Table A.4 Risk Matrix**

| | | Probability | | | | |
|---|---|---|---|---|---|---|
| | | 1-Extremely Unlikely | 2-Very Unlikely | 3- Unlikely | 4- Possible | 5- Likely |
| Severity of impact | **1 Negligible** | Broadly acceptable | Broadly acceptable | Broadly acceptable | Tolerable | Tolerable |
| | **2 Minor** | Broadly acceptable | Tolerable | Tolerable | Tolerable | Tolerable |
| | **3 Moderate** | Broadly acceptable | Tolerable | Tolerable | Tolerable | Unacceptable |
| | **4 Major** | Tolerable | Tolerable | Tolerable | Unacceptable | Unacceptable |
| | **5 Severe** | Tolerable | Tolerable | Unacceptable | Unacceptable | Unacceptable |

| | |
|---|---|
| **Low Risk** | Broadly acceptable risk |
| **Medium Risk** | Tolerable only if mitigation measures consistent with ALARP are implemented and the analysis team has found the residual risk tolerable |
| **High Risk** | Unacceptable risk requires further mitigation to reduce to Tolerable status |

## Appendix B – Project Hazard Log

| Reference | Phase | Task - overview | Task - detail | Hazard | Top Event | Consequence | Existing prevention measures | Existing recovery measures | Probability | Comments on probability | Severity | Comments on severity | Initial Risk | Additional prevention measures | Additional recovery measures | Mitigated Probability | Mitigated Severity | Residual Risk |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Generic activities | Marine operations | General risk to mariners from installation, operation, intervention and decommissioning of device at the EMEC site | Project vessels, moorings and surface buoys present collision risk for other vessels. | Contact / collision with 3rd party vessel | Injury/fatality, damage to vessel/device | Activities are located within charted and buoy marked hazardous area.<br>.<br>Plan of site layout available to mariners from EMEC website.<br>Appropriate action based on COLREGS if errant vessel is in vicinity of site | Assistance for errant vessels from Orkney Harbours and Coastguard resources, especially the rescue tug. | 1 | Very unlikely, collision risk area is only a very small sea area | 4 | Possible fatality / damage to vessel and project | 4 | Notice to Mariners will be used during installation operations.<br>Appropriate marking will be maintained.<br>Charts of site with buoys present will be distributed locally. | None | 1 | 4 | 4 |
| 2 | Generic activities | Vessel operations | Transit of vessels and equipment to and from site | Increased traffic density in close proximity with restricted manoeuvring in strong tidal currents | Contact / collision with 3rd party vessel | Damage to project vessel, equipment or 3rd Party vessel and possible injury to people on-board | Use experienced local skippers<br>Communicate with Orkney Marine Services when leaving port and entering harbour area through Hoy Sound.<br>If vessels are in close proximity take appropriate action based on COLREGS | Summon assistance if required from local vessels, Orkney Harbours and Coastguard.<br>Ground vessel if in danger of sinking.<br>Get out of tide race if seaworthiness is compromised | 2 | Very unlikely: However higher than usual traffic density presents an added hazard | 3 | Damage to vessel and or device(s),a delay to project, injury to personnel or 3rd parties | 6 | Establish standing procedures for use of Hoy sound and approach to Ness Shipyard.<br>Avoid transit of Hoy Sound when ferry, or other EMEC devices are also in transit. | Helicopter and emergency tug response from Coastguard | 1 | 3 | 3 |
| 3 | Generic activities | Vessel operations | Transit of vessel to site | Unexpected change in weather or sea conditions | Foundering grounding, shift in deck cargo, difficulty controlling tow, increased transit time, deviation from route | Damage to vessel or equipment. Injury or drowning of personnel | Use local knowledge of sea conditions, part Threshold of metocean limits known. Regular review of weather forecast and weather windows | Identified safe routes and havens with adequate weather windows in forecast.<br>Detailed pre-planning of activities.<br>All personnel to be trained and experienced mariners | 1 | Unlikely that weather forecast is significantly wrong for the short time period in question and modest distances involved | 3 | Damage to vessel and project, injury | 3 | None | None. | 1 | 3 | 3 |
| 4 | Generic activities | Vessel operations | Transit of vessel to site | Loss of control while transit | Foundering grounding, contact or collision | Damage to vessel or 3rd Party vessel | Robust and seaworthy vessel selected for task. Modern seafaring equipment utilised by skilled operators. | Summon assistance from other local vessels, Orkney VTS. | 3 | Unlikely that a suitably equipped and prepared vessel will lose power or navigational integrity | 4 | Damage to vessel and project, injury | 12 | Detailed pre-planning and constant communications. All personnel to be trained and experienced mariners | Possible SAR back-up from coastguard. | 1 | 3 | 3 |
| 5 | Generic activities | Vessel operations | Vessels working on site | Fishing creels along transit route for vessels | Entanglement of creel ropes with propellers | Loss of power and therefore drifting leading to foundering, grounding or collision | Adhere to "safer routes" and lookout procedures detailed in passage plan for route to site. | Clear/cut away creel ropes and mark ends. Inform owner if known. | 3 | Unlikely if passage plan followed. | 2 | Minor damage to vessel and property. | 6 | Discuss possible routings for transit with local creel boat skippers and agree with local creel boats a cessation of fishing in any areas critical to the operations if necessary.<br>Keeping a lookout for creel buoys at all times, potentially with a dedicated lookout used during passage through Hoy Sound.<br>Ensure all vessel crews are aware of creels in area. | All vessels to be equipped with rope cutting gear.<br>Have a procedure established to deal with loss of propulsion ensuring that the safety of the vessel is not further compromised by actions taken in strong tidal and heavy sea conditions | 2 | 2 | 4 |

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| 6 | Generic activities | Vessel operations | Vessels working on site | Project vessels, moorings and arrays present collision risk for other (non EMEC) vessels whilst installing pipeline | Collision with 3rd party vessel | Damage to vessel or 3rd Party vessel | Issue notice to mariners. Direct communication with local vessels. Visual and radar watch maintained. Works performed within defined designated area. Appropriate action based on COLREGS | Have procedures in place to suspend pipe lay if errant vessel is approaching. Re-organise operation to recover from any damage that arises | 2 | Very unlikely - specifically due to low traffic density in vicinity of pipe lay route | 4 | Damage to vessel and project equipment, possible injury | 8 | Procedures followed in line with COLREGS | Appropriate action based on COLREGS | 2 | 4 | 8 |
| 7 | Generic activities | Vessel operations | Vessels working on site | Project vessels, moorings and arrays present collision hazard for other developers vessels whilst installing pipeline | Collision with another developer vessel | Damage to project vessel or developers vessel | Schedule works for periods of low additional site activity. Daylight, good weather working. Maintain good communications with EMEC and other developers. Appropriate action based on COLREGS | Plan for contingency. Re-organise operation to recover from consequence | 3 | Unlikely despite developers having a preference to work at site at the same time in good weather leading to periods of SIMOPS, heightened awareness should avoid most hazards | 4 | Damage to vessel and project equipment, possible injury | 12 | Detailed pre-planning and constant communications with other vessels through shared VHF channel. | Appropriate action based on COLREGS | 2 | 4 | 8 |
| 8 | Generic activities | Vessel operations | Vessels working on site | Multiple vessels working within close proximity to each other on this project | Contact / collision | Damage to project vessels | Develop and adhere to project-specific procedures for operations. Appropriate action based on COLREGS | Re-organise operation to recover from consequence | 4 | Possible: extended period with many SIMOPs and multiple vessels involved | 2 | Limited damage to vessel and project, injury. However, likely to be less severe due to low speeds of vessels engaged in project work. | 8 | Control speed of vessels within defined working area. | Appropriate action based on COLREGS | 3 | 2 | 6 |
| 9 | Generic activities | Vessel operations | Vessels working on site | Loss of control while at test site | Foundering, grounding, | Damage to device or vessel | Robust and seaworthy vessel selected for task. Modern seafaring equipment utilised by skilled operators. | Summon assistance from other local vessels, Orkney VTS. | 3 | Unlikely that a suitably equipped and prepared vessel will lose power navigational control | 3 | Moderate – conditions likely to be favourable given activity is underway. Damage to vessel may jeopardises schedule for project, crew injury possible | 9 | Avoid putting vessel at risk from downstream/ downwind hazards. Identify hazardous areas to be avoided in operational procedures | Clear procedures for dealing with grounding/foundering | 2 | 3 | 6 |
| 10 | Generic activities | Vessel operations | Vessels working on site | Entanglement of project equipment with 3rd party lines while working on site | Snagging of creel lines or other sea debris | Equipment impairment or damage | Ensure site is clear of visible obstacles before work commences. Develop and adhere to project-specific procedures for operations | Cut lines to free entanglement, recover any other observed debris | 1 | Possible: has occurred several times per year | 2 | Minor impact - may damage single or multiple units, repair likely to be achievable | 3 | Discuss operational plans with local creel boat skippers | Project vessels to be equipped with cutting gear and means of debris recovery. | 1 | 2 | 3 |
| 11 | Generic activities | Vessel operations | Vessels working on site | Loss of navigation | Vessel and tow steam into other vessel or object leading to contact / collision | Damage to vessel or 3rd Party vessel | Avoid sensitive operations in poor visibility or darkness | Summon assistance from other local vessels, Orkney VTS. | 2 | Very unlikely that tow vessel will lose navigation. | 4 | Damage to vessels and or equipment | 8 | Project vessels equipped with standard navigation system and GPS. Radar watch, for safe navigation in poor visibility | Coastguard SAR back-up | 1 | 4 | 4 |
| 12 | Generic activities | Vessel operations | Towing equipment to or from site | Lack of power / Loss of control due to unsuitable/ unprepared vessel | Foundering grounding as vessel cannot control tow | Damage to vessel or 3rd Party vessel | Vessel capacity and experience is known and analysed and vetted prior to task. | Summon assistance from other local vessels, Orkney VTS | 3 | Unlikely but has occurred several times in industry | 4 | Major impact - jeopardises this phase of operation | 12 | Project vessels have to be coded with workboat certificate. | Coastguard SAR back-up | 1 | 4 | 4 |

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| 13 | Generic activities | Vessel operations | Towing equipment to or from site | Loss of control/power during tow (due to technical problem) | Contact / collision / grounding risk as vessel cannot control tow | Damage to vessel or 3rd Party vessel | Project vessels have coded workboat certificate.<br><br>Vessels inspected before use.<br><br>Engineers on board to effect repairs | Summon assistance from other local vessels, Orkney VTS | 2 | Very unlikely vessel will lose control | 4 | Major impact - jeopardises this phase of operation | 8 | All personnel to be trained and experienced mariners. | Coastguard SAR back-up.<br>If vessel begins to take on water, mobilise support vessels from shore to perform rapid recovery back to port. | 1 | 4 | 4 |
| 14 | Generic activities | Vessel operations | Towing equipment to or from site | Restricted vessel manoeuvrability | Contact/ collision with third party vessels. | Damage/ grounding to project vessel or third party vessel. | Detailed pre-job planning and deployment plan discussed and implemented. | Summon assistance | 3 | Possible higher than usual traffic density presents threat | 4 | Major impact – jeopardises this phase of operation, significant risk to health | 12 | Tow vessel will maintain radar and visual watch and plot any targets which may present danger to tow.<br>Use Orkney VTS to coordinate vessels in Hoy Mouth. | In the event of problems with tow, Stromness will be close enough to be quickly towed back to sheltered waters.<br>If risk of collision deemed, appropriate course of action taken according to COLREGs. | 2 | 4 | 8 |
| 15 | Generic activities | Diving operations | Diving vessel anchored on site | Diving vessel unable to manoeuvre | Contact / collision risk with third party vessel | Damage to vessel or 3rd Party vessel | Diving vessels have coded workboat certificate or MCA certificate | Summon assistance | 2 | Very unlikely as all vessels on site or in the area will be aware of diving ops | 4 | Major impact - jeopardises this phase of operation | 8 | Notice to Mariners will be issued.<br>All personnel to be trained and experienced mariners.<br>Dive vessel will maintain radar and visual watch for any targets which may present danger.<br>EMEC SIMOPs procedures will ensure that all vessels are aware of operations on site | Coastguard SAR back-up.<br>If vessel begins to take on water, mobilise support vessels from shore to perform rapid recovery back to port. | 1 | 4 | 4 |
| 16 | Installation | Foundation installation | Installation of reaction blocks | Periods of time when reaction blocks on the seabed are unmarked, before buoys are installed | Snagging of creel lines, snagging by fishing nets | Equipment damage | Little risk to non EMEC vessel as blocks will generally lie within the test site boundaries. May be more issues with pipeline guide blocks, however other developers vessel may be at risk<br>Notice to mariners issued. | Cut lines to free entanglement | 1 | Very unlikely - block within a marked hazard area | 2 | Moderate impact on this stage of project. Moderate impact on other developers | 3 | Minimise period where moorings lines are left unattended. | None | 1 | 2 | 3 |
| 17 | Installation | Array installation | During tow to site. | Loss of Tow | Floats adrift - contact / collision with other vessels, other objects. floats will eventually ground or founder | Damage to floats or 3rd Party vessel | Use suitable towing gear selected for purpose and inspected regularly.<br>Establish a tow plan with the procedures to be followed, including contingency arrangements.<br>Have a lazy line with pick-up buoy trailing from towed wave buoy.<br>Devices also fitted with tracking beacons which need to be activated in port, before tow.<br>Appropriate action based on COLREGS. | Follow standing procedures, notify Orkney VTS.<br>If situation escalates then summon assistance | 3 | Unlikely although has occurred several times in industry in a year | 3 | Possible collision with vessels, grounding and damage to buoy. | 9 | Tow vessel responsible for inspection of equipment and adjusting tow parameters during actual tow.<br>The tow vessel will be instructed to restrict the tow line tension to pre-determined limits.<br>Ensure that the forces being applied to the equipment are less than the equipment designed and certified for. | Include potential for shoreline recovery to land as well as recovery to sea. | 2 | 1 | 2 |
| 18 | Installation & decomm. | Install pipework | Manoeuvre vessel into centre of array | Working in close proximity to interconnecting chains | Entanglement of interconnecting chains on vessel | Vessel disablement Equipment damage | Ensure that chains are set to maintain good clearance underneath hull, props and rudder of work vessels. | Vessel moved back out of the array system.<br>Cut/release chain from connected buoy. | 2 | Very unlikely as vessel will be relatively shallow draught and chain length can be set accordingly. | 2 | Minor damage to vessel, but could affect schedule.<br>Any contact would likely lead to redesign of such chain connections | 4 | Clear as laid layout diagrams for vessel skippers.<br>Choose a designated entrance gap where chains are set deeper. | None | 2 | 2 | 4 |

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| 19 | Installation & decomm. | Install pipework | Connect 1.5 inch pipelines to centre manifold. | Working within and handling a complex network of pipes | Vessel snagging on pipelines | Vessel disablement Equipment damage | Strict control on pipeline tensions. Vessel to have engines stopped and to be on multi point mooring, possibly using lines from certain wave buoys. | Dive team to investigate snagged pipeline and free it and repair damage or replace damaged component. | 2 | Unlikely that pipelines will snag on a vessel with no turning propellers | 2 | Minor impact but would lengthen task | 4 | Only one operational vessel will be permitted to be inside the array circle at a time. | Replace damaged component and alter procedures to avoid the causative events recurring. | 2 | 2 | 4 |
| 20 | Installation & decomm. | Install auxiliary moorings | Connect auxiliary mooring lines to devices. | Working in close proximity to mooring lines and interconnecting chains | Entanglement with lines and chains Unable to connect mooring lines to devices | Vessel disablement Equipment damage | Strict control on mooring tensions. Vessel to have engines stopped and to be on multi point mooring. | Dive team to investigate snagged pipeline and free it and repair damage or replace damaged component. | 2 | Unlikely that moorings will snag on a vessel with no turning propellers | 2 | Minor impact but would lengthen task | 4 | Only one operational vessel will be permitted to be within the range of the mooring line. Vessel will generally be moored on a steady heading with multi anchor spread. | Replace damaged component and alter procedures to avoid the causative events recurring. | 2 | 2 | 4 |
| 21 | Operation | Normal operation | Device operation | Devices and moorings present collision risk for vessels **not** associated with EMEC test site | Contact / collision | Damage to device(s) or vessel | Area designated as test site and "Area to be avoided", cardinal buoys, area well known within local sea user community - thus vessels should not be entering the test area. Low traffic density area | Re-organise operation to recover from any damage arising. Alert authorities. Alter navigational instructions if deemed part of the problem | 2 | Very unlikely: surface marking in place and array is located inside designated test area off-limits to vessels not associated with EMEC site | 4 | Major impact - could lead to damage to multiple buoys and also damage to the vessel, putting lives in danger. | 8 | Site wide NRA already completed covering the interaction of vessels with the test site boundaries (ARC may 2009). Adherence to COLREGS. GPS tracker system fitted to all floats. | None | 1 | 4 | 4 |
| 22 | Operation | Normal operation | Equipment on station within the test site | Devices and moorings present collision risk for other developers' **vessels** or vessels associated with EMEC test site | Contact / collision | Damage to device(s) or vessel | Floats (with high visibility strips) easily visible to other users. Other EMEC site users will generally not be present in area when conditions are adverse. Each berth has 500m exclusion radius around it | Re-organise operation to recover from any damage arising. Alert authorities. Alter navigational instructions if deemed part of the problem | 4 | Possible given potential high density of devices and vessels in test site area | 4 | Major impact - could lead to damage to multiple buoys and also damage to the vessel, putting lives in danger. | 16 | Close liaison with EMEC and other developers, port authority to ensure SIMOPS are safely coordinated. Adherence to COLREGS. GPS tracker system fitted to all floats. | None | 3 | 4 | 12 |
| 23 | Operation | Normal operation | Equipment on station within the test site | Devices and moorings present snagging risk for other developers' **vessels** or vessels associated with EMEC test site | Entanglement with lines and chains. | Potential increased navigational hazard to other vessels on site | Interconnector chains are rigged to be at a depth of 5 metres at midpoint. | Organise operation to recover from consequence | 2 | Very unlikely that other developer' vessels will be in the Seatricity zone of the EMEC test site. | 3 | Moderate impact on this stage of project. Moderate impact on other developers | 6 | Close liaison with EMEC and other developers to ensure SIMOPs safely coordinated. Adherence to COLREGS. | None | 2 | 2 | 4 |
| 24 | Operation | Normal operation | Equipment on station within the test site | Third party vessel with loss of control drifts into the array. | Contact / collision (See above) | Damage to device or vessel | Area designated as test site and "Area to be avoided", cardinal buoys, area well known within local sea user community. Low traffic density area | Vessel will summon assistance from Coastguard. Emergency plan. | 2 | Very unlikely but vessels operate to the west of this area regularly. | 3 | Moderate impact. Damage to Device or vessel. | 6 | None | Possible SAR Notify authorities. If vessel begins to take on water, mobilise support vessels from shore to perform rapid recovery back to port. | 2 | 3 | 6 |
| 25 | Operation | Normal operation | Structural failure | Moorings unable to hold device due to conditions (tidal currents, waves etc) | Device adrift and uncontrolled in open seas. | Damage to device or vessel - potentially passenger ferry on passage between Stromness and Scrabster | Threshold of metocean limits known for mooring Regular review of weather forecast and weather windows - rapid retrieval of device if weather permits. Inter buoy chains will keep float within the array. | Summon assistance from authorities. Continual monitoring of device will indicate problems ASAP | 2 | Mooring will be designed to withstand severe conditions; however this is the first testing of the device and mooring in this area. Mooring system has a device which will pull the float down and lock it down below the wave motion when severe conditions exist. | 3 | Device has tracker beacon so position will be known, need to notify mariners of presence of obstacle and recover ASAP. | 6 | Stronger, higher capacity components, | Redesign required of mooring systems | 2 | 3 | 6 |

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| 26 | Operation | Normal operation | Structural failure | Initial testing of new device in high energy wave climate | Damage and submergence of floats | Equipment damage | Device designed for heavy seas. Develop and adhere to project-specific procedures for ops. | Re-organise operation to recover from consequence. | 2 | Unlikely given float has been designed, and tested, and includes two separate water tight chambers. However testing in extreme conditions for first time | 4 | Major impact if multiple floats sink. | 8 | Stronger fabrication | Have adaptable repair shop near by | 1 | 4 | 4 |