



**Environmental Impact and Mitigation Desk Study for the Galway  
Bay Marine and Renewable Energy Test Site**

**Produced by**

**AQUAFACT International Services Ltd**

**On behalf of  
SmartBay Ireland**

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## Table of Contents

<b>1. Introduction</b>	<b>1</b>
<b>2. Review of Potential Sensors, Equipment and Devices</b>	<b>1</b>
2.1. Long Term Infrastructure .....	1
2.1.1. Cardinal Marks.....	1
2.1.2. Subsea Observatory (Cable End Equipment [CEE] and Frame).....	2
2.1.3. Waverider Data Buoy.....	3
2.1.4. SeaStation Platform.....	4
2.1.5. Gravity Base .....	5
2.2. Recurring / Short Term Infrastructure.....	6
2.2.1. SmartBay Data Buoy.....	6
2.2.2. Acoustic Array.....	7
2.2.3. ADCP .....	8
2.2.4. Cables and Cabling.....	9
2.3. Test and Demonstration Devices.....	10
2.3.1. Oscillating Water Column Wave Energy Converter (WEC) .....	10
2.3.2. Point Absorber WECs .....	11
2.3.3. Attenuator WECs.....	12
2.3.4. Oscillating Wave Surge Converters WEC .....	13
2.3.5. Overtopping / Terminator Devices.....	14
2.3.6. Pressure Differential WEC.....	15
2.3.7. Water Pressure / Bulge System WEC.....	15
2.3.8. Rotating Mass Point Absorber .....	16
2.3.9. Rotational Tidal Turbine .....	17
2.3.10. Other Floating Devices.....	18
2.3.11. Innovation Projects .....	18
<b>3. Potential Impacts</b>	<b>19</b>
3.1. Potential Impacts associated with Installation .....	20
3.1.1. Direct Physical Disturbance to the Seafloor.....	20
3.1.2. Contamination during Installation Works.....	20
3.1.3. Suspended Sediments .....	21
3.1.4. Noise .....	21
3.1.5. Installation Vessels and Equipment .....	23
3.1.6. Accidental Events.....	24
3.2. Potential Impacts associated with the Operation of the Test Site.....	24
3.2.1. Physical Presence .....	24
3.2.2. Energy Extraction.....	27
3.2.3. Noise .....	29
3.2.4. Electro-Magnetic Fields (EMF) .....	29
3.2.5. Maintenance Vessels .....	30
3.2.6. Accidental Events.....	30

<b>4.</b>	<b>Impact Assessment</b>	<b>31</b>
4.1.	Impact Analysis .....	31
4.1.1.	<i>Loss of Habitat and Species</i> .....	32
4.1.2.	<i>Disturbance to Seabed</i> .....	34
4.1.3.	<i>Addition of New Substrata/Structures</i> .....	35
4.1.4.	<i>Collision Risk</i> .....	37
4.1.5.	<i>Barrier to Movement</i> .....	39
4.1.6.	<i>Energy Removal</i> .....	40
4.1.7.	<i>Noise</i> .....	40
4.1.8.	<i>Electro-Magnetic Fields</i> .....	45
4.1.9.	<i>Accidental Events / Contamination</i> .....	46
4.2.	Impact Assessment Tables .....	47
<b>5.</b>	<b>Mitigation / Best Practice</b>	<b>47</b>
5.1.	Proposed Measures .....	47
5.2.	Mitigated Impact Assessment Table.....	49
<b>6.</b>	<b>Summary</b>	<b>50</b>
<b>7.</b>	<b>Reference</b>	<b>53</b>

#### List of Tables

Table 4.1:	Impact Classification Table - Likelihood .....	31
Table 4.2:	Impact Classification Table – Consequence .....	32
Table 4.3:	Risk matrix .....	32
Table 4:	Maximum estimated seafloor footprint .....	34
Table 5:	Risk matrix for the Galway Bay Marine & Renewable Energy Test Site.....	47
Table 6:	Risk matrix for the Galway Bay Marine & Renewable Energy Test Site.....	49
Table 7:	Summary table of installation activities showing impact scores .....	51
Table 8:	Summary table of operational activities showing impact scores .....	52

## 1. Introduction

AQUAFAC International Services Ltd. was commissioned by SmartBay Ireland Ltd. to carry out an environmental assessment and mitigation desk study for an extensive list of ocean energy devices that have the potential to be deployed in the Galway Bay Marine and Renewable Energy Test Site. This document will form part of an application by the Marine Institute (MI) for a 35 year Foreshore Lease. The purpose of the lease application is to allow for the upgrade of the current site infrastructure and the deployment of a wider range of renewable energy devices and novel marine sensors and technologies. The broad scope of devices covered in this document is to ensure that over the lifetime of the lease as many future (as yet unknown) types of devices as possible are covered.

## 2. Review of Potential Sensors, Equipment and Devices

### 2.1. Long Term Infrastructure

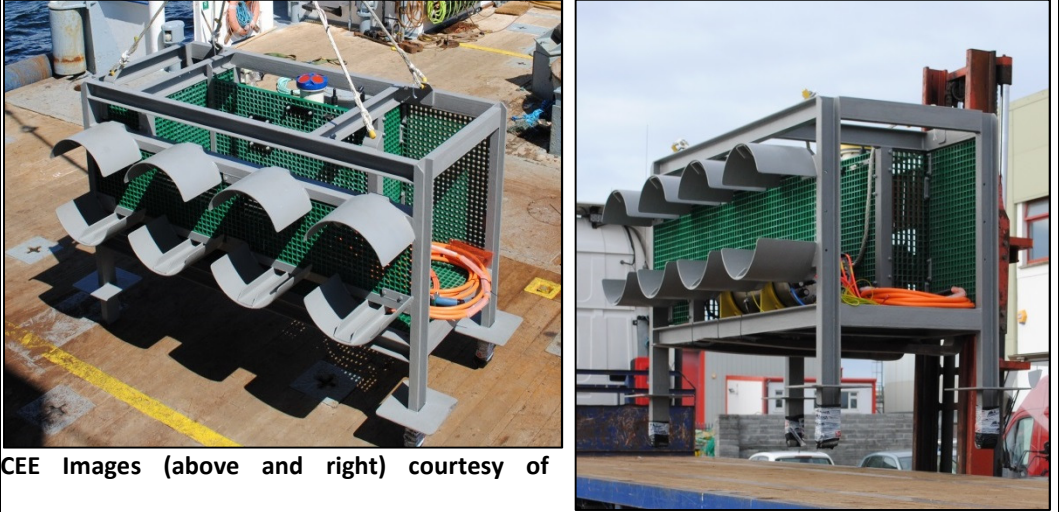

#### 2.1.1. Cardinal Marks

Description	Anchored floating markers used to delimit extent of proposed Galway Bay Marine & Renewable Test Site and ensure safe navigation around the site. Two north and two south cardinal marks onsite.
Location	Four corners of the site
Duration	Permanent
Dimensions	3m diameter x 7m high (2m draught).
Position	Floating at the surface
Mooring	Single point chain/rope affixed to 2 tonne clump weight (2m wide x 2m long)
Footprint	Sea surface: $7.07\text{m}^2 \times 4 = 28.28\text{m}^2$ Seabed: $4\text{m}^2 \times 4 = 16\text{m}^2$
Installation	From service vessel (either towed to site or craned into position) and clump weight dropped.
Lighting	Follow IALA Guidelines. North cardinals have a continuous white flashing light and the south cardinals have 6 short flashes and one long. The western markers (VQ) have a different sequence to the eastern (Q).

Visualisation		These images are for visualisation purposes and are not the actual cardinals onsite.
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### 2.1.2. Subsea Observatory (Cable End Equipment [CEE] and Frame)

Description	<p>The subsea observatory consists of Cable End Equipment (CEE), frame and connected equipment. It is a stationary device with ports into which sensors, SeaStation, WECs and HDTV cameras are plugged to receive power (max. 400V DC [3.5kW]). The CEE frame is deployed on the seabed and anchored under its own weight. All equipment will be deployed within or attached to the frame.</p> <p>Associated Equipment:</p> <p><u>CEE Frame</u> – see imagery below</p> <p><u>Cable End Canister</u> – deployed within the CEE frame</p> <p><u>CTD (Conductivity, Temperature and Depth [Pressure]) Sensor</u> - attached to CEE frame</p> <p><u>DO (Dissolved Oxygen) Sensor</u> – attached to CTD</p> <p><u>Turbidity and fluorescence sensor</u> – attached to CEE frame</p> <p><u>Hydrophone</u> – measure underwater noise, attached to CEE frame</p> <p><u>ADCP (Acoustic Doppler Current profiler)</u> – attached to the CEE frame</p> <p><u>Acoustic receiver</u> – monitor tagged fish, attached to CEE frame</p> <p><u>HD Television Camera</u> – Record underwater video footage, attached to CEE frame or free-standing frame/mount</p> <p><u>Underwater light</u> – 1600Lux@1m intermittent use during video capture, attached to CEE frame.</p> <p>Light and camera maybe moved to separate self-contained stand away from CEE in the future, to a maximum distance of 20m</p>
Location	Southwest corner of test site
Duration	Permanent
Dimensions	Frame: 3m length x 1.5m width x 1.7m high, 1.5 tonne
Position	On the seabed
Mooring	Self-mooring

Footprint	Seabed: CEE 4.5m <sup>2</sup> and it should be noted that the Cable Termination Equipment (CTE), which is located c. 10m from the CEE has a footprint of 2m <sup>2</sup>
Installation	Craned into position from service vessel
Lighting	Will be an intermittent 1600Lux@1m underwater light which will be on during video capture. CEE and CTE are subsea and will not be marked on the surface
Visualisation	<div>  <p>CEE Images (above and right) courtesy of SmartBay Ireland Ltd. © Diarmuid Ó Conchubhair</p> </div> <div>  <p>CTE (to foreground) (left) courtesy of Marine Institute © Andrew Downes</p> </div>

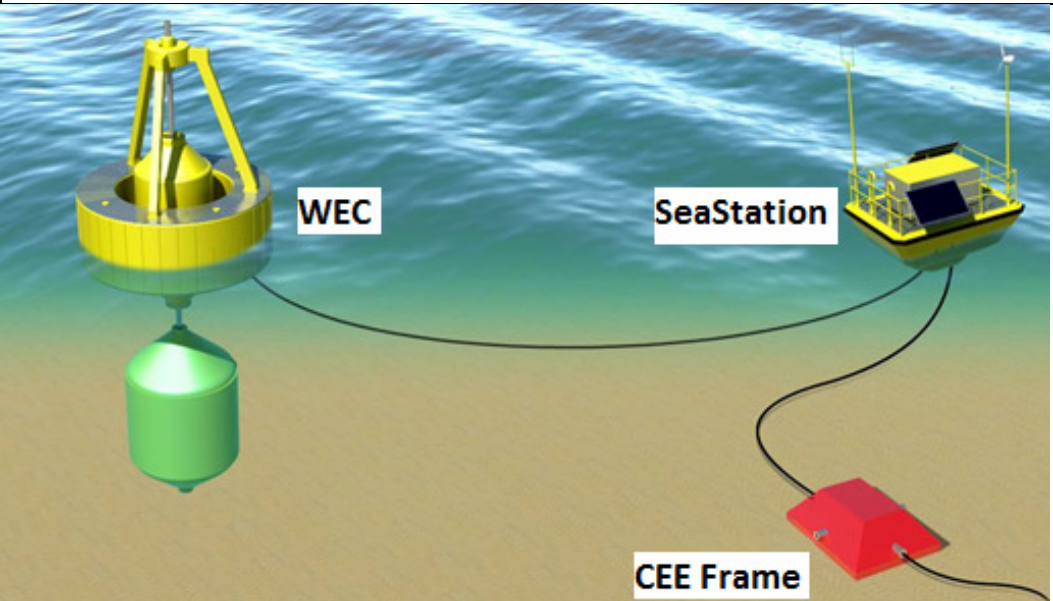
### 2.1.3. Waverider Data Buoy

Description	Stationary floating device which records wave climate continually
Location	Western edge of test site
Duration	Permanent
Dimensions	0.9m diameter
Position	Floating at the surface
Mooring	Anchored via single point rope mooring affixed to a 0.5 tonne clump weight / sinker (1m wide x 1m long)
Footprint	Sea surface: 2.54m <sup>2</sup>

	Seabed: 1m <sup>2</sup>	
Installation	Craned into position from service vessel	
Lighting	Short range navigational light. Special mark, yellow, 5 flashes	
Visualisation		Wave Rider Image Courtesy of SmartBay Ireland Ltd. ©Mark Wemyss

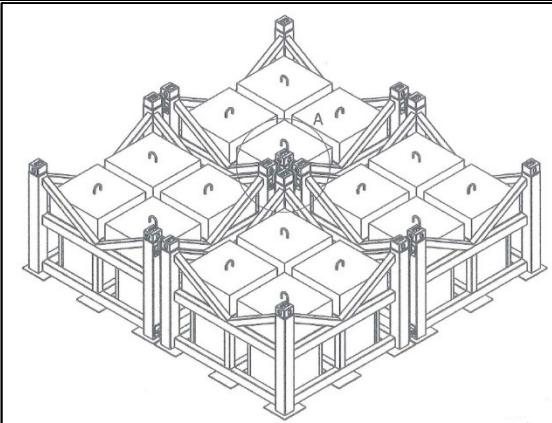
#### 2.1.4. SeaStation Platform

Description	Floating platform connected to the shore via the CEE and can power up to 3 energy converters which can be connected via separate umbilical cables. The SeaStation will have a permanent hydrophone attached to measure underwater noise.
Location	Within 100m of the CEE
Duration	Permanent, annual recovery for scheduled maintenance. Additional recoveries/deployments, although unlikely maybe required for unplanned O&M.
Dimensions	25m x 8m or 12m x 12m.
Position	Floating at the surface
Mooring	Mooring will most certainly be at least 4 point. It may be 8 point with 8 anchors and 8 lines coming to 4 points on the SeaStation. The lines would most likely be chain and anchors would be in the region of 2 to 3 tonne high hold Danforth. Three tonne dimension are around 2m wide, 3.5m long and 2m high.
Footprint	Sea surface: Worst case scenario 200m <sup>2</sup> footprint Seabed: 7m <sup>2</sup> footprint (56m <sup>2</sup> for 8 anchors)
Installation	Towed to site by service vessel. Anchors lowered into position by service vessel.

Lighting	Single white mast headlight
Visualisation	

#### 2.1.5. Gravity Base

Description	Depending on mooring requirements, individual 9 tonne frames or a series of interlocking 9 tonne frames to a maximum of 54 tonnes. Prefabricated concrete weights placed into the frame(s). Devices are either mounted directly to gravity base or slack moored by means of single/multipoint moorings to the gravity base
Location	Potentially anywhere within the test site
Duration	Permanent in the site once deployed, may require repositioning or reconfiguration for different scaled test devices
Dimensions	2.5m length x 2.5m width x 2m height
Position	On the seabed
Mooring	Self-mooring
Footprint	Sea surface: n/a Seabed: 6.25m <sup>2</sup> , 6 frames side by side = 37.5m <sup>2</sup>
Installation	Craned into position from service vessel

Visualisation		Image showing 4 sections, Courtesy of Marine Technology Ltd.
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## 2.2. *Recurring / Short Term Infrastructure*

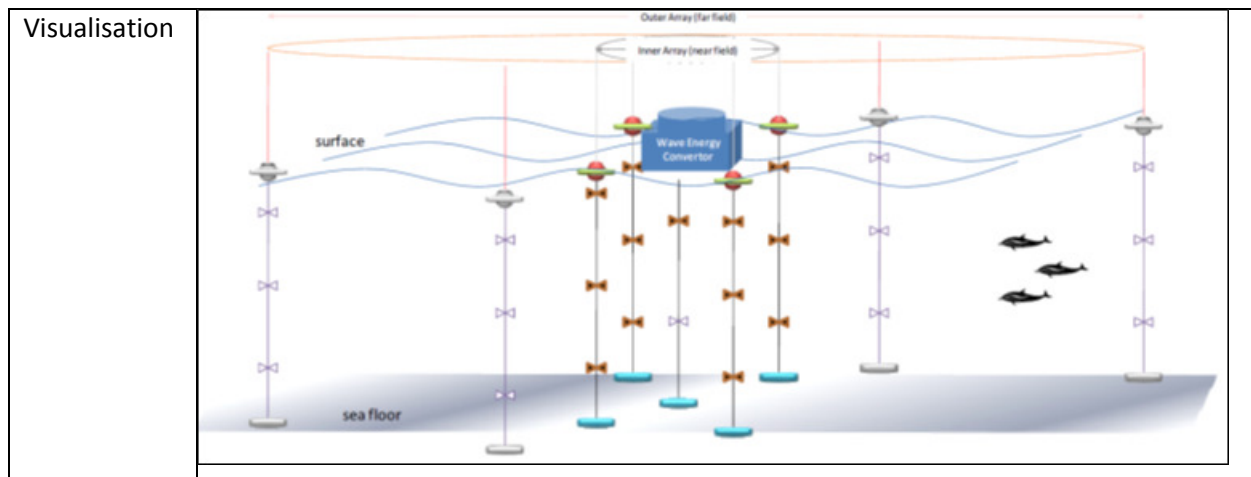
### 2.2.1. **SmartBay Data Buoy**

Description	Floating, moored device which records environmental data continually at the test site. This data buoy will have a hydrophone attached to measure project specific (6-18mths) underwater noise.
Location	Potentially anywhere in the test site
Duration	Regular short to medium-term deployments to support ocean energy devices and research projects
Dimensions	2.5m diameter x 7m height (2m draught)
Position	Floating at surface
Mooring	Single, bridle or multipoint rope, wire or chain moorings affixed to one or two 2 to 3 tonne clump weights (1.5m x 1.5m x 1.5m)
Footprint	Sea surface: 4.91m <sup>2</sup> Seabed: 2.25m <sup>2</sup> , worst case scenario – 2 weights = 4.5m <sup>2</sup>
Installation	Towed into position from service vessel
Lighting	May have 5 yellow flashes

Visualisation		SmartBay buoy image courtesy of SmartBay Ireland Ltd.
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### 2.2.2. Acoustic Array

Description	A system of 6 individual landers will be positioned on the seafloor. The 6 landers will be connected via 17mm diameter cabling to a central hub (containing the associated electronics and ICT components) which in turn is connected via a 25mm diameter cable directly to the CEE. Each lander will have an acoustic monitoring hydrophone affixed to it and one hydrophone floating at mid water by means of an in-line float. A particle velocity sensor will also be attached to the acoustic array. The purpose is to monitor noise levels from ocean energy devices and monitoring the presence of cetaceans and other sea life.
Location	Hub will be within 150m of CEE
Duration	Regular short-term deployments to monitor ocean energy devices
Dimensions	Landers: Triangular base of 1m side x 0.75m height, weight 1 tonne Central Hub: Diameter of 0.5m, height of 1.2m, weight 0.05 tonne Cabling: 400m long x 0.025m diameter
Position	On the seabed with hydrophones floating at mid water
Mooring	Self-mooring
Footprint	Sea Surface: n/a Seabed: Landers $0.5\text{m}^2 \times 6 = 3\text{m}^2$ Central Hub: $0.2\text{m}^2$ Cabling: $10\text{m}^2$
Installation	Craned into position from service vessel



### 2.2.3. ADCP

Description	An Acoustic Doppler Current Profiler (ADCP) will be deployed to measure water current speeds.
Location	Potentially anywhere within the test site
Duration	Project specific (6-12mths)
Dimensions	Trawl resistant frame: 2m x 1m
Position	Midwater, surface or bottom
Mooring	Attached to mooring line weighted to the seafloor or attached to existing onsite infrastructure. Alternatively deployed in trawl resistant frame (2m x 1m x 1m) with or without surface riser
Footprint	Sea surface: n/a Seabed: 2m <sup>2</sup>
Installation	Deployed from service vessel

Visualisation	 <p>Image showing ADCP (with yellow protection cap in place) in anti-trawl frame. Courtesy of SmartBay Ireland Ltd. ©Diarmuid Ó Conchubhair</p>
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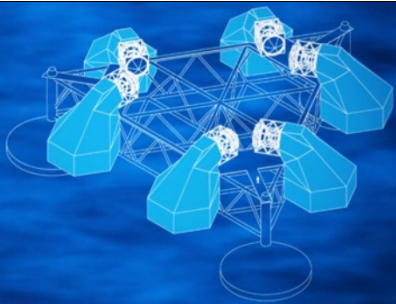
#### 2.2.4. Cables and Cabling

Description	The interconnecting cables will be designed for this specific application with embedded strength members and a protective jacket commensurate with its intended use and performance requirements. The umbilical cables between the SeaStation and a WEC will be designed to float within the water column and not touch the seabed to avoid any interference with the sea bed and to reduce wear and tear on the cable. These lighter umbilical cables will be designed to withstand the majority of sea conditions, but break off and protect the more permanent and expensive connectors/cables at the SeaStation and WEC ends. The riser cable from the CEE to the SeaStation will, for a portion of its length, rest on the seabed before rising to meet the SeaStation floating at the surface. The portion of this riser cable resting on the seabed will have its movement restricted through the use of an anchor point and ballasting of the cable using sand bags or the introduction of a 'Lazy S' or similar bend inducer to lift the cable off the seabed to avoid disturbance to the sea floor and reduce wear and tear on the cable. All cables will be designed with EMF shielding.
Location	Between test devices, SeaStation and CEE
Duration	Project specific 6-18mths (deployment requirements may require a deployment of longer duration but this is uncommon)
Dimensions	400m long x 0.025m diameter (just acoustic array)

Position	Mostly floating with some resting on the seafloor
Footprint	10m <sup>2</sup> (Acoustic array cabling)
Installation	Deployed from vessel


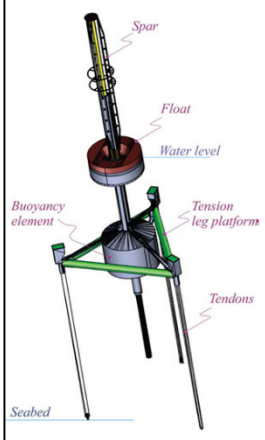
## 2.3. Test and Demonstration Devices


### 2.3.1. Oscillating Water Column Wave Energy Converter (WEC)

Description	These devices are floating, hollow structures. They are open to the sea below the water line so that they enclose a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn compresses and decompresses the air column. This trapped air is allowed to flow to and from the atmosphere via a turbine, which usually has the ability to rotate in the same direction regardless of the direction of the airflow. The rotation of the turbine is used to generate electricity.	
Location	Within reach of SeaStation	
Duration	Project specific 6-18mths (deployment requirements may require a deployment of longer duration but this is uncommon)	
Position	Floating at surface and moored to the seabed	
Installation	Towed into position from service vessel	
Lighting	May have 5 yellow flashes	
Examples	 <p><b>OE Energy Buoy</b> (deployed in Galway Bay 2007-2011). Rectangular shaped device, 6m width x 12m length. Footprint 72m<sup>2</sup>. Usually moored with a multipoint chain mooring affixed to high hold embedded anchors. A piled foundation (which, if required, would be subject to a separate Foreshore Licence application) can be used in addition to or opposed to the anchor system.</p>	
	 <p><b>GRS Power Platform</b> (proposed for Galway Bay 2016 for 6 months). Triangular shaped device with 6 oscillating water column wave generators and a wind turbine (optional). 26m sides x 8m height. Footprint 338m<sup>2</sup>. For a Galway Bay deployment,</p>	

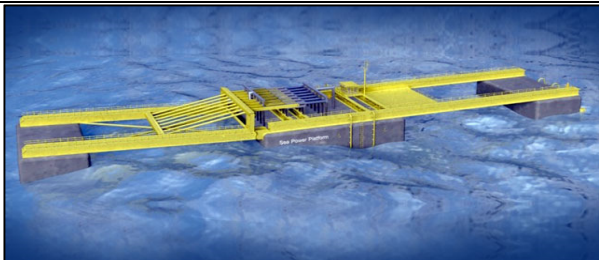
	GRS will seek to test one individual OWC on either a floating platform OR a fixed piled platform (which, if required, would be subject to a separate Foreshore Licence application).
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### 2.3.2. Point Absorber WECs

Description	These devices are floating structures which absorb energy from all directions through their movements at/near the water surface. The movement of the water causes the floating part to move relative to a fixed structure. They convert the motion of the buoyant top relative to the base into electrical power. They have small dimensions compared to the typical wavelength, tending to have diameters of a few meters and have the capacity to absorb energy from the sea area much larger than the device dimensions. This type of device is typically axisymmetric. The power take-off system may take a number of forms, depending on the configuration of displacers/reactors.	
Location	Within test site	
Duration	Project specific 6-18mths (deployment requirements may require a deployment of longer duration but this is uncommon)	
Position	Floating at surface and moored to the seabed	
Installation	Towed into position from service vessel	
Lighting	May have 5 yellow flashes	
Examples	 <p><b>WaveBob</b> (deployed in Galway Bay 2006-2007). Floating cylindrical device, 5m diameter. Surface footprint 19.6m<sup>2</sup>. Usually moored with a two/three point mooring affixed to embedded anchors or clump weights. Seabed footprint 21m<sup>2</sup> for 3 x 3 tonne high hold Danforth.</p>	
	 <p><b>Sigma WEC</b> (proposed to deploy in Galway Bay 2016). This WEC transforms, by an original mechanical PTO system, the wave induced vertical motion of the circular floating buoy into electrical energy. The circular float is designed with an open bottom and a system of unidirectional valves. The float is connected to a spar by a specially constructed and patented spherical joint. The spar is supported by a tension leg platform with 3 tendons of equal length, so it remains vertical throughout the motion. 5m diameter buoy, 2m depth with</p>	

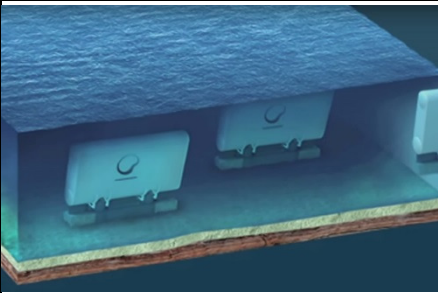
	12m stem below surface and 6m leg platform. Surface Footprint = $18\text{m}^2$ . Patented procedure for deployment. Usually moored with a three point mooring affixed to embedded clump weights or by using gravity base. Mooring footprint: $54.08\text{m}^2$ if using clump weight or max. $37.5\text{m}^2$ if using gravity base.
	<b>WavePump</b> (proposed deployment in Galway Bay 2016). A circular floating buoy moored to the seabed, 4m diameter, 1.25m height. Surface footprint $12.6\text{m}^2$ . Usually moored with a two point taught mooring to a gravity base structure. Seabed footprint max. $37.5\text{m}^2$ if using gravity base.


### 2.3.3. Attenuator WECs

Description	These devices are floating structures which operate parallel to the wave direction and effectively rides the waves. These devices capture energy from the relative motion of the two arms as the wave passes them.
Location	Within the test site
Duration	Project specific 6-18mths (deployment requirements may require a deployment of longer duration but this is uncommon)
Position	Floating at surface and moored to the seabed
Installation	Towed into position from service vessel
Lighting	May have 5 yellow flashes
Examples	 <p><b>SeaPower Platform</b> (proposed for Galway Bay 2015-2016). This floating platform is made up of 3 large hollow concrete/steel floating pontoons hinged together. The platform, although of large overall displacement (17m length, 5m width, 2m height), has a shallow draught (0.6m) and low visual profile above the waterline. The mechanical/electrical/hydraulic PTO systems are mounted on deck and the stiff concrete hulls ensure that noise will be minimal. Surface Footprint <math>85\text{m}^2</math>. Slack moored by means of 4 point moorings to standard seabed anchors. Seabed footprint <math>28\text{m}^2</math> for 4 x 3 tonne high hold Danforth.</p>

	 <p><b>Perpetuwave Power</b> (proposed for Galway Bay 2015-2016). This floating platform is similar to the SeaPower platform. 15m length, 6m width, 3m height, 0.3m draught. Surface Footprint 90m<sup>2</sup>. Slack moored by means of 4 point moorings to standard seabed anchors. Seabed footprint 28m<sup>2</sup> for 4 x 3 tonne high hold Danforth.</p>
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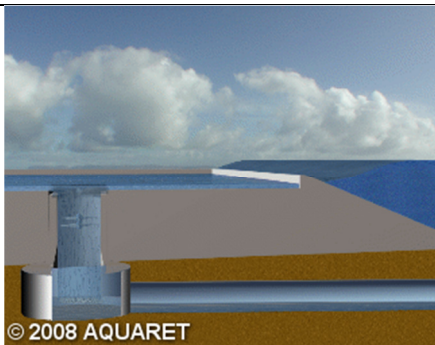
#### 2.3.4. Oscillating Wave Surge Converters WEC

Description	<p>These devices extract energy from the horizontal movement of waves in the nearshore coastal zone in water depths of 10-20m. OWSC predominantly oscillate horizontally in surge as opposed to the majority of wave devices, which oscillate vertically in heave and usually are deployed in deeper water. These devices are mounted to the seabed and the arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves. Most devices are all subsea with some devices having only top of the flap above the waterline. Typical scale devices &lt;10m width, 10m height x 5m length (Max. Footprint 50m<sup>2</sup>)</p>
Location	Within test site
Duration	Project specific 6-18mths (deployment requirements may require a deployment of longer duration but this is uncommon)
Position	Fixed to the seabed and typically fully submerged although some device may break the surface
Installation	Towed into position from service vessel
Lighting	May have 5 yellow flashes on surface elements
Examples	 <p><b>WaveRoller.</b> Prototypes tested prototypes in Peniche, Portugal in 2007 and 2008. Three 100kW WaveRoller units deployed in Natura 2000 site in Peniche in 2012 and connected to the Portuguese grid. This device is installed under water at depths of c. 8 – 20m, where the wave surge is most powerful. The panel spans almost the entire depth of the water column from the sea bed without breaking the surface. As the WaveRoller panel moves and absorbs energy from ocean waves, the hydraulic piston pumps which are attached to the panel pump the hydraulic fluids inside a closed hydraulic circuit. The high-pressure</p>

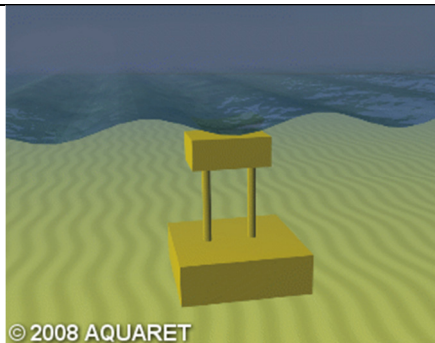
	fluids are fed into a hydraulic motor that drives an electricity generator. Flood ballast tanks with water to submerge the unit and moored to seafloor using a gravity foundation.
Examples	 <p><b>Oyster.</b> First sea trials at the European Marine Energy Centre (EMEC) in Orkney between 2009 and 2011. Second-generation Oyster 800 machine tested in June 2012 and produced electrical power to the grid. The Oyster wave power device is a buoyant, hinged flap which is attached to the seabed at depths of between 10 and 15m. Oysters' hinged flap, which is almost entirely underwater, pitches backwards and forwards in the nearshore waves. The movement of the flap drives two hydraulic pistons which push high pressure water onshore via a subsea pipeline to drive a conventional hydro-electric turbine. Mounted on seabed using piled foundation (which, if required, would be subject to a separate Foreshore Licence application). Unlikely the Oyster device will be deployed in Galway Bay as the water depths are too great but similar devices may be deployed on platforms in the site.</p>

### 2.3.5. Overtopping / Terminator Devices

Description	Overtopping devices capture water as waves break into a storage reservoir. The water is then returned to the sea passing through a conventional low-head turbine which generates power. An overtopping device may use 'collectors' to concentrate the wave energy. Probable dimensions 55m length x 97m width x 4.8m height (Surface Footprint 5,335m <sup>2</sup> ).
Location	Within test site
Duration	Project specific 6-18mths (deployment requirements may require a deployment of longer duration but this is uncommon)
Position	Floating at surface and moored to the seabed
Installation	Towed into position from service vessel
Mooring	Usually moored with a multipoint mooring affixed to embedded anchors or clump weights. Seabed footprint 7m <sup>2</sup> for 1 x 3 tonne high hold Danforth.
Lighting	May have 5 yellow flashes

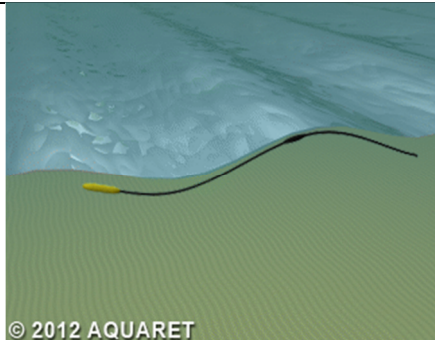
Examples		
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### 2.3.6. Pressure Differential WEC

Description	These devices are typically located near shore and attached to the seabed using gravity bases or piled foundations (which, if required, would be subject to a separate Foreshore Licence application). The motion of the waves causes the sea level to rise and fall above the device, inducing a pressure differential in the device. The alternating pressure pumps fluid through a system to generate electricity. Likely surface footprint 12.6m <sup>2</sup> . Usually moored with a two point taught mooring to a gravity base structure. Seabed footprint max. 37.5m <sup>2</sup> if using gravity base.	
Location	Within test site and may require a floating or piled foundation (which, if required, would be subject to a separate Foreshore Licence application)	
Duration	Project specific 6-18mths (deployment requirements may require a deployment of longer duration but this is uncommon)	
Position	On the seabed	
Installation	Towed into position from service vessel	
Mooring	Fixed to seabed by gravity or piled foundation (which, if required, would be subject to a separate Foreshore Licence application).	
Examples		

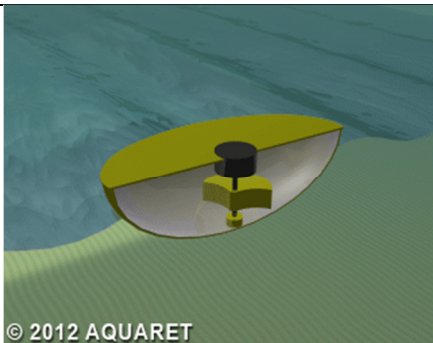
### 2.3.7. Water Pressure / Bulge System WEC

Description	Bulge wave technology consists of a rubber tube filled with water, moored to the seabed heading into the waves. The water enters through the stern and the passing
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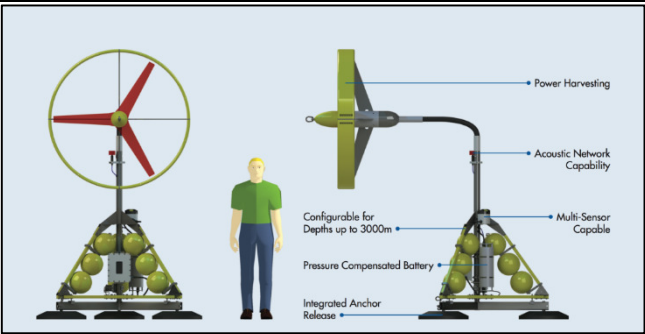
	<p>wave causes pressure variations along the length of the tube, creating a 'bulge'. As the bulge travels through the tube it grows, gathering energy which can be used to drive a standard low-head turbine located at the bow, where the water then returns to the sea. Likely dimensions: 20m L x 4m W x 1m H. Footprint 32m<sup>2</sup>.</p>
Location	Within test site
Duration	Project specific 6-18mths (deployment requirements may require a deployment of longer duration but this is uncommon)
Position	Floating at surface and moored to the seabed
Installation	Towed into position from service vessel
Mooring	Generally moored with a multipoint mooring affixed to embedded anchors or clump weights. Seabed footprint 7m <sup>2</sup> for 1 x 3 tonne high hold Danforth.
Lighting	May have 5 yellow flashes
Examples	

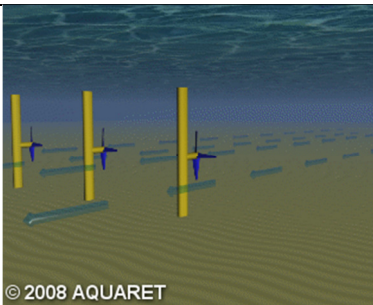
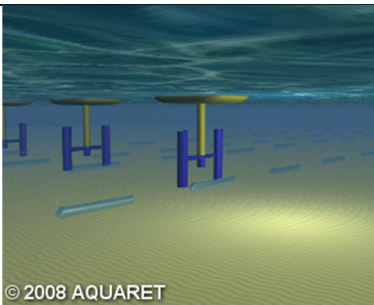
### 2.3.8. Rotating Mass Point Absorber

Description	<p>Large buoy like structure that is on the sea surface, inside a rotating mass is connected to a pump and/or generating system. Two forms of rotation are used to capture energy by the movement of the device heaving and swaying in the waves. This motion drives either an eccentric weight or a gyroscope causes precession. In both cases the movement is attached to an electric generator inside the device. For a ¼ scale device, dimensions would be 7.5m long x 3.8m wide x 2.25m high. Surface footprint = 28.5 m<sup>2</sup>.</p>
Location	Within test site
Duration	Project specific 6-18mths
Position	Floating at surface and moored to the seabed
Installation	Towed into position from service vessel
Mooring	Generally moored with a multipoint mooring affixed to embedded anchors or clump weights. Seabed footprint 7m <sup>2</sup> for 1 x 3 tonne high hold Danforth.
Lighting	May have 5 yellow flashes

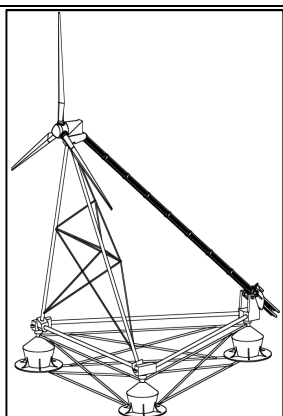
Examples		
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### 2.3.9. Rotational Tidal Turbine

Description	These devices can be either seabed mounted, within the water column or at the surface. Omni-directional turbine that can generate power from ocean currents. Devices may also support multiple sensors for wide area, real-time environmental monitoring.	
Location	Within test site	
Duration	Project specific 6-18mths	
Position	Floating at surface, in the water column or attached to the seabed	
Installation	Towed into position from service vessel	
Mooring	These devices may be deployed on the seabed with a gravity base, tethered within the water column or sea surface, piled into the seabed (which, if required, would be subject to a separate Foreshore Licence application) or attached to another structure on site.	
Examples		<p><b>Seaformatics</b> (proposed for Galway Bay 2016). An omni-directional turbine that can generate power from ocean currents as low as 0.1m/s. The device supports multiple sensors and has been designed for wide area, real-time, environmental monitoring. The device is deployed on seabed without moorings or external anchoring. Triangular 1.8m base, 2.5m height, 1.5m diameter turbine, 0.5 tonne (Footprint 1.62m<sup>2</sup>).</p>

	 <p>© 2008 AQUARET</p> <p>Horizontal Axis</p>	 <p>© 2008 AQUARET</p> <p>Vertical Axis</p>	
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### 2.3.10. Other Floating Devices

Description	Floating wind platforms which are designed to accommodate wind turbines (and associated turbine tower)
Location	Within the test site, may require SeaStation connectivity and may also require the use of a piled foundation (which, if required, would be subject to a separate Foreshore Licence application)
Duration	Project specific 2 weeks to 12 mths
Position	Floating at surface and moored to the seabed
Installation	Towed into position from service vessel
Mooring	Generally slack moored by means of a single or multipoint point moorings to standard seabed anchors, piles (which, if required, would be subject to a separate Foreshore Licence application) or gravity weights
Lighting	Turbine will require aviation lighting as specified by Irish Aviation Authority and navigational lighting as specified by Commissioner of Irish Lights
Examples	 <p><b>TetraFloat</b> (previously proposed for Galway Bay 2016). A floating triangular structure designed to house a conventional wind turbine. The device designed for Galway Bay will be 1:5 scale. 25m height x 20 length x 17m width (12m blade tip diameter, 37m height in total). Surface Footprint = 170m<sup>2</sup>. Seabed footprint: max. 37.5m<sup>2</sup> if using gravity bases.</p>

### 2.3.11. Innovation Projects

Description	Innovation projects that may require the deployment and testing of innovative sensors and marine equipment. These may be mounted to the CEE frame, be self-deployed
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	with a gravity base or utilise other existing infrastructure on site (i.e. SeaStation, data buoy etc.).
Location	Potentially anywhere within the test site
Duration	Project specific 6-12mths/Permanent
Position	On the seabed, attached to CEE frame or other infrastructure
Installation	Lifted/towed into position from service vessel
Examples	Deployment and testing of novel moorings. These maybe in conjunction with standard sinkers or a gravity base
	Artificial reef material tested on site to analyse biological and chemical effects in the marine environment
	Generator – the SeaStation will be equipped with a permanent generator. Various WECs may want to include a self-contained generator on their devices (device and project specific) for the duration of their deployment

### 3. Potential Impacts

The impacts associated with the Galway Bay Marine and Renewable Energy Test Site can arise in 2 ways:

1. Installation of foundations to support the devices and the actual installation of the devices, sensors and equipment; and
2. Operational impacts arising from the working devices, sensors or equipment interacting with the environment.

There are a number of receptors that can be impacted by the above and they are:

- Geology, Geomorphology and Sediment Processes
- Seabed Contamination and Water Quality
- Protected Sites and Species
- Benthic Ecology
- Fish & Shellfish
- Birds
- Marine Mammals & reptiles

The test site has been in operation for the past 10 years and is marked on Admiralty Charts, and as such is avoided by all recreational users, commercial fishermen and navigation routes in the area.

The continued use of the area as a renewable energy test site will not impact these receptors. As a result, these receptors are not discussed further.

### **3.1. *Potential Impacts associated with Installation***

The vast majority of devices will require anchorage to the seafloor. Some will be anchored under their own weight (CEE Frame), some will require a gravity base (e.g. oscillating wave surge and pressure differential devices) and some will simply require clump weights or anchors (e.g. SeaStation, SmartBay data buoy). Devices that will be anchored under their own weight, clump weights and anchors will be lowered to the seafloor from a service vessel. The gravity foundation will consist of either individual 9 tonne frames or a series of interlocking 9 tonne frames which will be lowered to the seabed from a support vessel.

#### **3.1.1. Direct Physical Disturbance to the Seafloor**

The lowering of objects to the seafloor will result in:

- the **disturbance of natural sediments** on the seafloor and temporarily resuspend them; and
- a **loss of substratum and disturbance to species** in the installation area.

When sediments get resuspended, the coarser fraction of the disturbed sediment tends to settle out close to the works but can remain mobile. The fine material tends to disperse widely at high energy sites and eventually settle out over wide areas.

The direct impacts from the loss of substratum and disturbance to species will include localised mortality or displacement of species where objects come into direct contact with the sediment. Any potential damage to the benthos and disruption of sediment locally could lead to changes in invertebrate fauna and fish stocks which may reduce food availability for birds at least in the short term (BirdLife International, 2003).

#### **3.1.2. Contamination during Installation Works**

Installation works have the potential to release contaminants into the water column if the sediments in the installation area are historically contaminated. Sediments can build up contaminants over time from industrial or domestic waste, radionuclides, munitions etc. While impacts on water quality would most likely be temporary, depending on the type and amount of material released, potential contaminants could be dispersed over a much wider area and persist within the environment .

### 3.1.3. Suspended Sediments

The lowering of any object (clump weight, anchor, CEE frame, gravity base, mooring chains/ropes, jack-up rig etc.) on to the fine muddy sand seafloor of the test site will result in:

- The temporary resuspension of particulate materials

Indirect impacts include **smothering and increased suspended sediment and turbidity**. The smothering of sensitive benthic species, fish spawning habitat and shellfish habitat can occur due to the subsequent settlement of the resuspended sediments. Increased suspended sediment and turbidity levels can impact on sensitive filter feeding organisms such as king and queen scallop, cockles and mussels. Fine particles can travel great distances from the disturbed area due to tidal currents and depending on the quantities of remobilised sediments this impact could be widespread. Increased turbidity could affect the foraging and predator/prey interactions of birds due to reduced visibility. In addition, herring, sprat, grey and common seals are sensitive to reduced visibility.

### 3.1.4. Noise

Noise sources during the installation works will be confined to that generated by the installation vessels. Vessel noise is a combination of tonal sounds at specific frequencies (e.g. propeller blade rotational frequency and its harmonics) and broadband noise (Vella *et al.*, 2001). Propeller cavitation noise is the primary source of sound from underway vessels, whilst noise from propulsion machinery originates inside a vessel and reaches the water via the vessel hull. Noise from shipping is roughly related to vessel size, larger ships have larger, slower rotating propellers, which produce louder, lower frequency sounds (SMRU, 2001). Overall, vessel noise covers a wide range of frequencies from 10Hz to 10kHz. Source levels and dominant frequencies range from 152 dB re 1  $\mu$ Pa@1m at 6300Hz for a 5m Zodiac with offboard motor, through 162dB re 1  $\mu$ Pa@1m at 630Hz for a tug/barge traveling at 18km/hr, through to a large tanker with source level around 177dB re 1  $\mu$ Pa@1m in the 100Hz third octave band (Richardson *et al.*, 1995). The use of bow thrusters increases broadband sound levels.

#### 3.1.4.1. Fish

There is a high level of diversity in hearing structures among fish, resulting in different auditory capabilities across species. Many fish species hear in the range of about 30Hz to 1kHz (1000Hz); however, some investigations have demonstrated species-specific hearing capabilities in the infrasonic range of less than 20Hz (Karlsen, 1992; Knudsen *et al.*, 1997; Sand & Karlsen, 2000) and in the ultrasonic range of over 20kHz (Mann *et al.* 1998, 2001; Popper *et al.*, 2004). Shipping exhibits

major energy below 1,000Hz and is therefore within the frequency range of hearing of most fish species (Richardson *et al.*, 1995; Popper *et al.*, 2003). Fish and shellfish species may be disturbed by the noise from the maintenance vessels.

#### 3.1.4.2. *Birds*

Diving birds could also be affected by shipping noise causing them to become disorientated and affecting their foraging success (AECOM Ltd., 2010). Effects on surface feeding birds are likely to take the form of disturbance effects. This could cause birds to temporarily avoid the immediate area which may have implications for foraging and breeding success, stress on individuals and energy budgets.

#### 3.1.4.3. *Cetaceans & Pinnipeds*

Marine mammals use acoustics to navigate, locate prey and maintain social contact and as a result they are very sensitive to anthropogenic noise. Underwater hearing sensitivity in harbour seals indicates a fairly flat frequency response between 1kHz and about 50 kHz, with hearing threshold between 60 and 85 dB re 1  $\mu$ Pa (Richardson *et al.*, 1995). Toothed whales are most sensitive to sounds above about 10 kHz and below this sensitivity deteriorates. Harbour porpoises exhibit a very wide hearing range with relatively high hearing thresholds of 92 – 115 dBrms re 1  $\mu$ Pa below 1 kHz, good hearing with thresholds of 60 – 80 dBrms re 1  $\mu$ Pa between 1 and 8 kHz, and excellent hearing abilities with thresholds of 32 – 46 dBrms re 1  $\mu$ Pa from 16 – 140 kHz (Kastelein *et al.*, 2002). Behavioural audiograms for the bottlenose dolphin (Johnson, 1967; Ljungblad *et al.*, 1982; Au, 1993) indicate that hearing ranges from approximately 75Hz to 150kHz with the best sensitivity between 10kHz to 60kHz. It is assumed that baleen whales are sensitive to sound of low and medium frequencies because they predominantly emit low frequency sounds, primarily at frequencies below 1 kHz and in many cases predominantly infrasonic sounds (Richardson *et al.*, 1995).

In essence, cetaceans and pinnipeds have the ability to detect ship noise and it may elicit a temporary avoidance behaviour for some of the more sensitive species (larger baleen whales) whereas many toothed whales appeared to be tolerant of vessel noise and are regularly observed in areas where there is heavy traffic (Thomsen *et al.*, 2006). Seals hauled out on land may also be disturbed by the presence of installation vessels. In general, ships more than 1,500m away from hauled out grey or common seals are unlikely to evoke any reactions from seals, between 900 and 1,500m seals could be expected to detect the presence of vessels and at closer than 900m a flight reaction could be expected (Brasseur & Reijnders, 1994). These impacts would be most significant if they occurred during the sensitive breeding and moulting seasons. Breeding seals if disturbed could

exhibit flight reactions and temporarily abandon their young and moulting seals maybe scared into the water and may lose condition as a result of additional energetic costs (AECOM Ltd., 2010). Disturbance of otters could also occur should maintenance works occur close to the coastal areas where they are present (AECOM Ltd., 2010).

### **3.1.5. Installation Vessels and Equipment**

There is a risk of marine birds, seals, cetaceans and turtles colliding with construction machinery and vessels during the installation phase.

#### **3.1.5.1. Birds**

While birds are generally more manoeuvrable than marine mammals they are at **risk of colliding** with vessels especially at night (AECOM Ltd., 2010). Birds can typically collide with surface structures of ships or the ships can collide with birds rafting on the surface. The physical presence of vessels and installation equipment can have a temporary **disturbance effect** on birds due to physical and visual intrusion. This could cause birds to avoid the immediate area which may have implications for foraging and breeding success, stress on individuals and energy budgets.

#### **3.1.5.2. Mammals**

Shipping **collision** is a recognised cause of marine mammal mortality worldwide and the major factors influencing injury or mortality are vessel size and speed. In addition there is always a risk of corkscrew injuries to marine mammals from vessel propellers.

Seals hauled out on land may be **disturbed** by the presence of installation vessels and equipment. In general, ships more than 1,500m away from hauled out grey or common seals are unlikely to evoke any reactions from seals, between 900 and 1,500m seals could be expected to detect the presence of vessels and at closer than 900m a flight reaction could be expected (Brasseur & Reijnders, 1994). These impacts would be most significant if they occurred during the sensitive breeding and moulting seasons. Common seals moult from August to September and breed from May to July and grey seals moult from November to April and breed from late August to December. Breeding seals if disturbed could exhibit flight reactions and temporarily abandon their young and moulting seals maybe scared into the water and may lose condition as a result of additional energetic costs (AECOM Ltd., 2010). Physical disturbance of otters could also occur should disturbing works occur close to the coastal areas where they are present (AECOM Ltd., 2010).

### 3.1.5.3. *Fish & Shellfish*

Fish and shellfish species may also be disturbed by the physical presence of the installation vessels and equipment.

### 3.1.6. **Accidental Events**

There is the potential of accidental pollution events from service and support vessels required during the installation works. These vessels will have fuel tanks and hydraulic systems for cranes and winches. These pollution events could include the release of fuel and lubricating oil, cleaning fluids, paints, specialised chemicals and litter. Any potential spillages could impact water quality and contaminate seabed sediments.

## 3.2. ***Potential Impacts associated with the Operation of the Test Site***

The impacts of the operational phase of the test site are confined to the physical presence of the devices, equipment, infrastructure and cables within the site, either on the seabed, in the water column or at the surface. The operation of the devices and associated equipment may generate noise, EMF fields and heat and may impact on hydrodynamics and sediment processes.

In addition to the permanent equipment that will be deployed in the site (4 cardinal markers, waverider, SeaStation and CEE frame with associated sensors, hydrophone, acoustic receiver, HDTV camera and underwater light), the site has a capacity to hold 3 energy converters which will be connected to the SeaStation.

### 3.2.1. **Physical Presence**

The physical presence of devices or foundations on the seabed could impact **water depth/availability of water column** above the device. This could have implications for navigation and other sea users.

Sediment transport pathways could also be impacted in the immediate vicinity of devices or foundations and **sediment accretion or erosion (scour) of the sediment** could occur. ABPmer (2002) have estimated the extent of scour to be between 6-10 times the tower diameter. The scouring of sediments could have impacts on the existing benthic communities at the site as the fine sediments will be transported away leaving behind coarser sediments which can be recolonised by a different group of species not found in the fine sedimentary communities. The recolonisation can modify and consolidate the sediment making it suitable for further recolonisation success.

The physical presence of devices, gravity bases, clump weights and anchors on the seabed (or scouring associated with structures fixed to the seabed) will result in a **direct loss of benthic habitat and sessile species** in the footprint of the infrastructure. This can also result in a loss of suitable substratum (particularly for benthic spawners) and feeding grounds for fish and shellfish species, foraging ground for birds and mammals. This infrastructure will also **introduce a hard substrate** to the sedimentary environment of the test site. This hard substrata will be available to benthic algae, invertebrates and fish and could encourage the establishment of a community of rocky reef fish and invertebrates (including biofouling species) that would not normally exist at the site. The impact of this can be seen as positive in that biodiversity, food availability and foraging opportunities for fish, shellfish, birds and mammals is increased, however the introduction of exotic benthic species or fouling communities could have a negative impact in that these communities differ significantly from the surrounding soft bottom community.

The presence of wave and tidal devices have the potential to pose a **collision risk** for almost all species of marine finfish. The groups of fish species at risk depends on the location of the devices. Demersal species would not be impacted by the presence of a device at the sea surface but they may benefit from the habitat structure provided by the foundations and/or mooring of the device. They could however be impacted by the presence of a bottom mounted device and some species that make migrations up the water column using tidal stream transport could be impact by mid-water devices. Pelagic species make diurnal vertical migrations and have the potential to be impacted by all devices.

Birds are also at risk of collision particularly with wind turbine towers and blades. The risk depends on a number of factors including species sensitivity, weather and visibility, location of bird populations adjacent to the devices, bird flight behaviour (height above sea level etc.), migration routes and flight routes to feeding areas. Wave and tidal devices can also pose a collision risk to birds although those devices without rotating blades pose less of a risk than those with blades (e.g. horizontal and vertical axis tidal turbines). Diving species are at greater risk of collision with subsurface turbines and mooring cables than surface feeding species, which are at a lower risk of interaction with floating devices and surface structures as these do not use rotating blades (AECOM Ltd., 2010). As areas of high flow attract birds due to good foraging opportunities (Daunt *et al.*, 2006), the risk of collision can be increased if the renewable devices change the flow characteristics which may affect manoeuvrability and underwater swimming agility of birds.

Birds can also be impacted by the presence of wind turbine structures. Bird collision risk is predominantly confined to the operational phase and is influenced by species sensitivity, weather and visibility, bird flight behaviour, location of bird populations adjacent to the turbines, migration routes and feeding areas etc. The layout of the wind turbines, the spacings between them and the associated lighting can also have an influence on the collision risk to birds.

Marine mammals and reptiles also have the potential to collide with renewable energy devices as they must transit the water column to breath at the surface (AECOM Ltd., 2010). That said, marine mammals are highly mobile and have the ability to both avoid and evade these devices as long as they detect the object, perceive it as a threat and take appropriate action at long or short range. There are a number of factors that can interfere with this and they include detection failure, diving constraints, group effects, attraction, confusion, distraction, illogical behaviour, disease and life stage, size and season.

Mooring equipment will likely act like other natural or artificial seabed structures and pose few novel risks for vertebrates in the water column (AECOM Ltd., 2010). Cables, chains and powerlines extending up through the water column will have smaller cross sectional areas than vertical support structures and so produce reduced flow disruption and fewer sensory cues to approaching diving birds. Instead of being swept around these structures, mammals are more likely to be entangled in them. Areas of high turbidity can pose more of a risk for diving birds and marine mammals due to reduced visibility.

There is the potential for fish to suffer injury or mortality through **pressure changes** occurring with turbines as water is sucked through. This impact is confined to shrouded tidal devices such as venture devices, which use shrouding to constrict the flow leading to a pressure low after the constriction. Impacts can include damage to gills, eyes, gill bladder, decapitation, pulping of body tissues or internal haemorrhages.

The presence of devices may provide a **barrier to movement** which may result in avoidance behaviour by fish and shellfish species, birds and marine mammals which will ultimately result in **habitat exclusion**. While this avoidance behaviour would reduce the collision risk it may result in limiting access to feeding areas which could ultimately affect feeding and breeding success. It may also result in barriers to the usual migration and transit patterns of marine fish and birds. This could result in increased energy expenditure.

Loose lying mooring cables can affect the three dimensional structure of the seabed as they move in the current and this **disturbance to the seabed** could impact juvenile fish and a range of demersal species.

As the test site has been in operation for 10 years, it has become an unofficial fishing exclusion zone as the local commercial fishermen tend to avoid using the area. As a result, there is the potential for the **establishment of spawning or nursery areas** which are undisturbed by commercial fishing activities. This would be beneficial to fish resources as would the development of artificial reefs around the gravity foundations if they are left *in situ* for extended periods of time (i.e. years).

Renewable devices with surface structures have the potential to **provide roosting, nesting and/or breeding sites** for birds (AECOM Ltd., 2010). Man-made structures are regularly used by gulls, terns, cormorants and gannets as perching posts.

Seals have the potential to use horizontal surface structures as **haul out sites**. This may be beneficial by increasing the area upon which seals can haul out on, however it may put seals at risk of injury getting on and off the structures and from exposure to moving or articulating parts.

The metal structures deployed at the site will have sacrificial anodes attached (e.g. chain moorings, metal constructed devices, SeaStation, gravity bases etc.). Sacrificial anodes are designed to corrode in seawater in preference to these metal structures. Zinc and aluminium anodes are the most commonly used and these metals are potentially toxic to marine life if concentrations are high enough.

Some of the devices/equipment installed at the site may contain **anti-fouling compounds**, which may impact on water and/or sediment quality, benthic communities, fish and shellfish species, birds and marine mammals. As top predators seals and cetaceans are more susceptible to various substances building up in their bodies (AECOM Ltd., 2010).

### **3.2.2. Energy Extraction**

Sediment transport pathways and coastal processes could be impacted by localised hydrodynamic changes associated with wave or tidal energy removal by the operating device. This can have impacts in the immediate vicinity of devices or foundations and sediment accretion or erosion (scour) of the sediment could occur. The effects of energy extraction on sediment processes could result in

changes to suspended sediment levels and turbidity and occur up to 50m from the operating device and operating devices could potentially have significant adverse effects on coastal processes particularly in areas with high levels of erosion, accretion and long-shore drift (Scottish Executive, 2007). King scallop, queen scallop, cockle, mussel, herring and sprat are sensitive to this and increased turbidity can affect visibility for diving birds and marine mammals and increase their likelihood of collision. Grey and harbour seals have been identified as having a high sensitivity to reductions in visibility and cetaceans have a moderate sensitivity to it (AECOM Ltd., 2010).

The extraction of tidal energy causes a decrease in water flow and this can potentially impact habitats and species that are sensitive to changes in tidal flow. Water currents typically carry food and nutrients into a community and carry waste material and fine sediments away. Any interruption to this pattern can therefore affect flora and fauna. Changes in tidal flow can affect sediment patterns which have the potential to affect benthic communities. In addition, shellfish have a low to medium sensitivity to changes in tidal flows and herring, which spawn on gravel beds created by high water flow, are likely to be sensitive to this effect. Birds and mammals could be impacted by any changes to the benthic communities and fisheries. Seals use their vibrissae in hunting prey to sense small-scale hydrodynamic vibrations and flow vortices in the water column. Changes to tidal flows could impact their ability to catch prey. Based on limited existing projects and modelling studies, the extent of the potential on tidal energy can extend for up to 0.5km from the tidal device (AECOM Ltd., 2010).

Extraction of wave energy can result in a decrease in wave exposure and this can impact benthic communities that are sensitive to wave exposure levels (e.g. maerl and *Modiolus* beds). In addition cockles are highly sensitive to changes in wave exposure and nearshore juveniles of plaice, cod and saithe have a low to medium sensitivity to changes in wave exposure. Birds and mammals could be impacted by any changes to the benthic communities and fisheries. It is estimated from limited existing projects and modelling studies that the potential effect on wave energy can extend for up to 20km from the wave device (AECOM Ltd., 2010).

The extraction of wave and tidal energy can affect sedimentation pattern and result in increases or decreases in suspended sediments, turbidity and sediment deposition. These impacts can extend for up to 50m from devices (Bryden, 2006). These impacts could affect benthic communities (e.g. maerl beds) and fish and shellfish species (king scallop, queen scallop, cockle, mussel, herring and sprat) depending on the degree of change and the nature of the receiving environment.

### **3.2.3. Noise**

The potential noise sources from operating devices include rotating machinery, flexing joints, structural noise, moving air, moving water, moorings, electrical noise and instrumentation noise (AECOM Ltd., 2010). Noise from these devices could potentially disrupt prey location and underwater navigation in marine birds and prey location, navigation and social interaction in marine mammals or even result in temporary or permanent hearing damage. This noise also has the potential to affect fish, species in the immediate vicinity of the devices. The operational noise generated from these devices will be considerably lower than that generated by vessel noise, however it could result in avoidance behaviour and exclusion from an areas. This could result in limiting access to feeding areas which could ultimately affect feeding and breeding success.

The noise generated by maintenance vessels also has the potential to impact sensitive species in the area and this may elicit a temporary avoidance behaviour by sensitive fish, birds and mammals. This could cause birds to temporarily avoid the immediate area which may have implications for foraging and breeding success, stress on individuals and energy budgets. Seals hauled out on land may also be disturbed by the presence of maintenance vessels. In general, ships more than 1,500m away from hauled out grey or common seals are unlikely to evoke any reactions from seals, between 900 and 1,500m seals could be expected to detect the presence of vessels and at closer than 900m a flight reaction could be expected (Brasseur & Reijnders, 1994). These impacts would be most significant if they occurred during the sensitive breeding and moulting seasons. Breeding seals if disturbed could exhibit flight reactions and temporarily abandon their young and moulting seals maybe scared into the water and may lose condition as a result of additional energetic costs (AECOM Ltd., 2010). Disturbance of otters could also occur should maintenance works occur close to the coastal areas where they are present (AECOM Ltd., 2010). Fish and shellfish species may also be disturbed by the noise from the maintenance vessels.

### **3.2.4. Electro-Magnetic Fields (EMF)**

Electric charge in movement (electricity) results in a magnetic field. Electromagnetic fields (EMF) are only present when an electric current is present. Electricity involves both a voltage and a current. The higher the voltage the stronger the electric field and the higher the current the stronger the magnetic field. The direction of the magnetic field is perpendicular to the direction of the electric current. EMF strength increases proportionally to the current intensity and decreases by the square root of the distance from the cable. The cables connecting the energy converters to the SeaStation, the SeaStation to the CEE and the CEE to shore will produce EMFs as a result of power transmission.

The devices themselves will also have an electrical signature which will be specific to the individual devices e.g. whether the power generator is in the water or on a platform and if there is a riser cable from a device on the seabed. These EMFs can affect migration and prey detection in certain electro-sensitive fish species such as elasmobranchs (sharks, skates and rays), lamprey, some bony fish such as Atlantic salmon and eel and some cetaceans (whales and dolphins).

### **3.2.5. Maintenance Vessels**

There is a risk of marine birds, seals, cetaceans and turtles colliding with maintenance vessels during the operational phase. While birds are generally more manoeuvrable than marine mammals they are at **risk of colliding** with vessels especially at night (AECOM Ltd., 2010). Birds can typically collide with surface structures of ships or the ships can collide with birds rafting on the surface. Shipping collision is a recognised cause of marine mammal mortality worldwide and the major factors influencing injury or mortality are vessel size and speed. In addition there is always a risk of corkscrew injuries to marine mammals from vessel propellers.

The physical presence of maintenance vessels can have a temporary **disturbance effect** on birds due to physical and visual intrusion. This could cause birds to avoid the immediate area which may have implications for foraging and breeding success, stress on individuals and energy budgets. Seals hauled out on land may also be disturbed by the presence of maintenance vessels. In general, ships more than 1,500m away from hauled out grey or common seals are unlikely to evoke any reactions from seals, between 900 and 1,500m seals could be expected to detect the presence of vessels and at closer than 900m a flight reaction could be expected (Brasseur & Reijnders, 1994). These impacts would be most significant if they occurred during the sensitive breeding and moulting seasons. Common seals moult from August to September and breed from May to July and grey seals moult from November to April and breed from late August to December. Breeding seals if disturbed could exhibit flight reactions and temporarily abandon their young and moulting seals maybe scared into the water and may lose condition as a result of additional energetic costs (AECOM Ltd., 2010). Physical disturbance of otters could also occur should maintenance works occur close to the coastal areas where they are present (AECOM Ltd., 2010). Fish and shellfish species may also be disturbed by the physical presence of the maintenance vessels.

### **3.2.6. Accidental Events**

There is the potential of accidental pollution events from service and support vessels required during routine maintenance of the equipment and devices installed at the site. The SeaStation will house a diesel generator and fuel will need to be delivered to the SeaStation when a device is under test.

These pollution events could include the release of fuel and lubricating oil, cleaning fluids, paints, specialised chemicals and litter. Any potential spillages could impact water quality and contaminate seabed sediments.

The renewable energy test devices will have hydraulic fluid in them and there is the possibility of **minor leakages which may contaminate** water, benthic communities and potentially fish and shellfish if the nature and quantity of material lost is sufficient. The SeaStation will also contain an external diesel generator and there is the potential for leakages from this. The SeaStation may also house transformers which can sometimes be filled with oil. Contamination can be in the dissolved phase or in the form of a slick forming low solubility liquids. Marine birds are particularly sensitive to contamination by oil based compounds (AECOM Ltd., 2010).

## 4. Impact Assessment

### 4.1. Impact Analysis

Impact analysis involves the establishment of the impact classification criteria followed by impact analysis based on these criteria. Impact analysis tables evaluate and rank the impacts compared to each other. They form the basis for rating the likelihood (see Table 4.1) of an impact occurring and the consequence of the impact (see Table 4.2). The likelihood and consequence ratings are combined to form a score for impact evaluation. Table 4.3 shows the Impact Matrix based on likelihood and consequence and the impact scores vary between from **Low**, **Medium** and **High**

Table 4.1: Impact Classification Table - Likelihood

Rating	Likelihood	
	Category	Description
1	Remote	1% likelihood of impact occurring
2	Unlikely	1-20% likelihood of impact occurring
3	Possible	20-50% likelihood of impact occurring
4	Probable	50-95% likelihood of impact occurring
5	Highly Likely	>95% likelihood of impact occurring

**Table 4.2: Impact Classification Table – Consequence**

Rating	Consequence	
	Category	Description
0	None	No change due to impact occurring
1	Negligible	Individuals in the population/characterising species in a habitat affected but effect not detectable against background natural variability
2	Minor	Direct or indirect mortality or sub-lethal effects caused to individuals by the activity/up to 15% of habitat disturbed seasonally but population remains self-sustaining. Seasonal change in characterising species and community structure and function
3	Moderate	<i>In situ</i> population depleted by the activity but regularly sub-vented by immigration/over 15% of habitat disturbed seasonally. Seasonal change in characterising species and structure and function. Frequency of disturbance < recovery time. Non-cumulative
4	Major	Population depleted by impact and immigration insufficient to maintain local populations/over 15% of habitat disturbed persistently leading to cumulative impacts. Persistent change in characterising species, structure and function. Frequency of disturbance > recovery time. Cumulative
5	Severe	Population depleted and supporting habitat significantly depleted and unable to support the population. Biodiversity reduction associated with impact on key structural species. Impact is effectively permanent due to severe habitat alteration. No recovery or effectively no recovery.

**Table 4.3: Risk matrix**

Likelihood	Highly Likely	5						
	Probable	4						
	Possible	3						
	Unlikely	2						
	Remote	1						
			0	1	2	3	4	5
			None	Negligible	Minor	Moderate	Major	Severe
			Consequence					

#### 4.1.1. Loss of Habitat and Species

The loss of habitat and species will arise in the footprint of scaled devices, gravity bases, clump weights and anchors on the seabed (or scouring associated with structures on the seabed).

An attempt to quantify the footprint of the infrastructure in the test site estimates that c. 135m<sup>2</sup> will be occupied by the permanent or recurring/short-term devices. The footprints of some scaled test devices (that require moorings other than the gravity foundations already included) can also be seen in Table 4. Assuming worst case scenario, if 3 scaled GRS power platforms were deployed simultaneously the footprint would increase to c. 460m<sup>2</sup>. Taking a conservative approach, this study will assume a maximum footprint of 500m<sup>2</sup>. This footprint accounts for 0.13% of the test site (the test site covers an area of 375,200m<sup>2</sup> [670m x 560m]).

While this loss of habitat cannot be mitigated the actual area lost is so small that the impact on the benthic community will be **negligible**. In addition, following the removal of the infrastructure (if removal is required) the impacted area will immediately begin to recover through recruitment from neighbouring undisturbed areas. The species characteristic of the test site (AQUAFAC, 2010) include opportunistic spionids and cirratulids which are able to recolonise disturbed areas quickly. A follow up survey 24 months later indicated no impact on the seafloor from the operation of the test site (AQUAFAC, 2011). Recovery rates from other types of benthic habitat disturbances range from 40 days following hydraulic dredging for razor clams (Hall *et al.*, 1990) to 6-12 months following trawling (Jennings & Kaiser, 1998). Coates *et al.* (2015) reported rapid recovery within a year following dredging and gravity base installation associated with an offshore wind farm in the North Sea.

In addition the loss of such a small area of seabed is extremely unlikely to cause any reduction in fish stocks or spawning and nursery areas. The only fish species feeding on the benthos are likely to be demersal and as birds are more likely to feed on pelagic species there will be no knock on effect for birds. Marine mammals in the area are extremely unlikely to be impacted upon given the very small area of seabed impacted and the extremely unlikely impact on fish stocks in the area.

**Loss of Habitat and Species: Likelihood = Highly Likely; Consequence = Negligible; Impact = Low**

**Table 4: Maximum estimated seafloor footprint**

Device	Footprint	Total
Cardinal Marker Mooring	4m <sup>2</sup> x 4	16m <sup>2</sup>
Subsea Observatory	4.5m <sup>2</sup> plus 2m <sup>2</sup> CTE	6.5m <sup>2</sup>
Waverider Mooring	1m <sup>2</sup>	1m <sup>2</sup>
SeaStation Mooring	7m <sup>2</sup> x 8	56m <sup>2</sup>
Gravity Base (Max)	6.25m <sup>2</sup> x 6	37.5m <sup>2</sup>
SmartBuoy Mooring	4.5m <sup>2</sup>	4.5m <sup>2</sup>
Acoustic Array	0.5m <sup>2</sup> x 6 landers	3m <sup>2</sup>
	0.2m <sup>2</sup> (central hub)	0.2m <sup>2</sup>
Cabling	10m <sup>2</sup>	10m <sup>2</sup>
GRS Power Platform	36m <sup>2</sup> x 3	108m <sup>2</sup>
Oscillating Wave Surge	50m <sup>2</sup>	50m <sup>2</sup>
Seaformatics	1.62m <sup>2</sup>	1.62m <sup>2</sup>

#### 4.1.2. Disturbance to Seabed

The placement of any infrastructure on the seabed will disturb and remobilise sediments in the immediate footprint of the object. This will result in a short-term (minutes), localised increase in suspended sediment levels and turbidity. Small localised sediment plumes are generated frequently in the marine environment by a variety of activities e.g. remote sampling, fish emerging from and burial in the seabed, dolphin and porpoise foraging and feeding, storm events etc. It is not possible to quantify the volumes of sediment that would be mobilised during the placement of infrastructure on the seabed, however they will be so low as to have no effect on water quality, habitats or species. It is worth noting that naturally high background levels of 65,000mg/l have been recorded in Galway Bay under storm conditions (Galway Harbour Company, 2014a) and these volumes are orders of magnitude greater than what would be generated by the proposed activities.

The subsequent settlement of the remobilised sediment will also have no impact on the habitats and communities in the immediate vicinity of the object as volumes will be so low.

Sediment disturbance during the operational phase could include scour around the gravity bases, however given the relatively low velocities<sup>1</sup> in the area any impact from this is likely to be minimal.

<sup>1</sup> Mean bottom current speeds in the test site are 0.09m/s on a flooding spring tide and 0.06m/s on an ebbing spring tide (Marine Institute, 2013).

Movement of the catenary mooring lines and any other cables which will continuously or periodically rest of the seafloor have the potential to disturb and remobilise sediments. It is estimated that up to 5m either side of the lines/cables could be affected. The sediments disturbed by this activity will be orders of magnitude lower than that generated during storm events. Any short term temporary impacts from this will have a negligible impact on the environment.

In summary, disturbance to sediment and the resultant increases in suspended sediments and turbidity and the subsequent deposition of sediments will be of such a scale that impacts on the benthos, fisheries, birds and mammals will be negligible.

The likelihood of these disturbances occurring are highly likely however the consequences are negligible (i.e. not detected against natural background variability). Monitoring at the commercial scale SeaGen turbine in Strangford Lough reported that the changes observed appeared to be gradual and in line with natural variation (Keenan *et al.*, 2011).

**Disturbance to Seabed: Likelihood = Highly Likely; Consequence = Negligible; Impact = Low**

#### **4.1.3. Addition of New Substrata/Structures**

All new hard surfaces installed in the test site will provide surfaces for colonisation e.g. underside of surface buoys or scaled devices, gravity bases and mooring chains etc. Previous studies at the test site have showed that the mussel *Mytilus edulis* colonised anchor chains and the scaled test devices (AQUAFAC, 2010). The moorings were found to be heavily settled by epifauna such as anemones, mussels, star fish and echinoids.

The types of colonising plants and animals depends on a number of parameters including size, height, shape, profile, scale, morphological complexity, material used and rugosity (roughness of the surface) (Connell & Glasby, 1999; Rilov & Benayahu, 1998; 2000). Of these, complexity is the primary factor determining attractiveness of a structure to fauna and flora (Pickering & Whitmarsh, 1997; Hoffman *et al.*, 2000). Highly complex structures provide a greater surface area for colonisation and more 'nooks and crannies' for shelter from predators and physical conditions. This allows a more diverse and dense assemblage including organisms that are more fragile or light sensitive to colonise an area from which they were previously excluded (Vella *et al.*, 2001).

Recruitment would primarily occur in two ways; through migration from the surrounding substrate or by the settling of larvae, spat, algal spores etc. from currents (Vella *et al.*, 2001). The first species

to colonise would be algae (if depths allow) and invertebrates. Colonisation would often have a characteristic succession with microscopic and filamentous algae initially settling, followed by rapidly settling species and thereafter, a more diverse community would develop. Furthermore, community composition would vary with depth. With an increase in species diversity there may also be an increase in the general productivity of the area (Wickens & Barker, 1996 cited in Hoffman *et al.*, 2000; Grossman *et al.*, 1997). This is probably due to the fact that a greater diversity of fixed colonising species would attract various free-living invertebrates and small fish, which in turn attract larger organisms up to and including marine mammals (Vella *et al.*, 2001). These increases in biodiversity and biomass can enhance crustacean fisheries (e.g. lobster); molluscan fisheries (e.g. scallops) and aquaculture (e.g. mussels) (O’Leary *et al.*, 2001). It is also likely that detritivores living in the local sediments, would migrate to the structures and would feed on the increased organic detritus in the area. Therefore, it is highly likely that the infrastructure at the site would increase the local species diversity, biomass and productivity. Additionally, fish tend to aggregate around objects in the sea (Vella *et al.*, 2001). This phenomenon has been widely used in the development of Fish Aggregating or Attraction Devices (FAD’s). However the attraction of fish to objects such as artificial reefs is poorly understood. It is assumed that fish are attracted to submerged objects because they provide shelter from currents and wave action and safety from predators (Vella *et al.*, 2001).

Growth of marine grass occurred on a commercial scale tidal device in Cobscook Bay after slightly more than two months of submergence (ORPC, 2013). Following 16 months deployment, the main generator had 75% cover of tubularian hydroids, lesser barnacles and filamentous algae (ORPC, 2014). An investigation at the Horns Rev offshore wind farm in Denmark (Bio/consult, 2000 cited in Leonard, 2000) reported fouling by invertebrates on the monopile masts, five months after construction. The fouling species included bryozoans, several species of sea anemone, sea squirts, star fish, polychaete worms and the common mussel. After the establishment of the turbines at the Nysted offshore wind farm, a considerable increase in the number of cod present in the wind turbine area was noted. The increase was explained by the development of a reef fauna, namely a larger density of small crustaceans and fish (Birklund, 2005). The invertebrate fauna was mostly comprised of mussels and barnacles with *Gammarus* associated with the mussel.

The species that will colonise the infrastructure at the test site will be epifaunal species originating from the numerous rocky reef communities within the greater Galway Bay area such as benthic algae and invertebrates. The development of epifaunal communities, while different to the baseline infaunal community within the fine muddy sand habitat, will be consistent with those found

throughout Galway Bay and they will serve to increase species diversity at the site, which in turn will attract larger organisms up to and including marine mammals.

While colonisation of the structures will begin immediately, it is anticipated that at least 12 months will be required before a functional community has been established (i.e. individuals begin reproducing). Up to this point, structures can be removed from the site. Consideration should be given to leaving any long-term structures in place (e.g. interlocking gravity base frames *in situ* for >12 months) if significant functional communities have been established on them, as these communities would function as artificial reefs and serve as shelter, habitat and food source for fish and larger species.

Monitoring at the commercial scale SeaGen tidal turbine in Strangford Lough reported that colonisation of the device since its installation has replaced the community lost at the device foundations during construction.

While the addition of new substrata will provide new surfaces for colonisation, the degree to which equilibrium communities will establish will depend on the level of disturbance at the site (i.e. recovery/ maintenance of structures etc.). While increases in species diversity is a positive impact, it is predicted that this positive impact will balance out the community lost during the construction stage and in reality will have a negligible impact overall.

The installation of surface objects may provide additional roosting, perching, nesting or breeding sites for birds and potentially haul-out sites for seals (if structures are <0.5m above the sea surface). While an increase in habitat is seen as a positive benefit, there is a chance that this may increase their risk of collision and therefore the benefit is cancelled out and in reality will have a negligible impact overall.

**Addition of New Substrata/Structures: Likelihood = Highly Likely; Consequence = Negligible; Impact = Low**

#### **4.1.4. Collision Risk**

Rotating blades are typically associated with wind and tidal devices however some wave energy converters use rotating surfaces that could also pose a collision risk. Tidal devices operate within the range of 5 to 30 RPM (compared to 80-600 RPM for conventional hydroturbines) (Copping *et al.*, 2013a) and slow the flow of water and remove energy.

Studies carried out to date (although limited) provide no evidence that direct interaction of marine mammals, birds or fish with tidal blades was causing harm to the animals (Copping *et al.*, 2013a). Five short-term deployments provided the information for this assessment by Copping *et al.* (2013a); commercial scale SeaGen in Strangford Lough, ORPC's commercial scale demonstration TGU unit in Cobscook Bay, Verdant 5m diameter full-scale turbines in New York, HGE commercial scale turbine in Minnesota and the OpenHydro prototype turbine in EMEC.

While the data from the SeaGen monitoring is of limited use as the turbines were turned off when seals approached and therefore no interaction could occur, data from the ORPC's turbine documents fish behaviour in and around turbines. This study showed that fish regularly approached the turbine with a higher number interacting with the turbine when it was still rather than when it was rotating and that during these interactions the predominant behaviour was fish entering the turbine (Copping *et al.*, 2013a). No incidences of dead or dying fish were recorded following passage through the turbine. Large fish (older herring, mackerel) appeared to have a greater ability to avoid the turbine than small and medium sized fish (sticklebacks and juvenile herring) (Copping *et al.*, 2013a). Schooling fish also seemed better able to detect and avoid the turbine than individuals. Greater numbers were observed in the wake of the turbine than entering the turbine suggesting that they may have a preference of lower energy regions of the water column. Visibility was also seen as a factor in determining behaviour as at night reaction distances were shorter with more fish entering the turbine than during the day.

Monitoring at the Verdant RITE project showed that resident and migratory fish avoided the turbine area (6 x 3 bladed full scale tidal turbines in 10m of water mounted on the seabed) preferring inshore slower moving water which indicated that behaviour appeared to be primarily influenced by natural tidal currents and secondarily by the presence of operating turbines (Coddling *et al.*, 2013). Blade strike as a potential damage/injury mechanism is still under study at RITE, but no evidence through 9,000 operating hours has been observed (Smith & Adonizio, 2011). Likewise, interaction experiments around the HGE turbine indicated that sizeable fish passing through the turbine were not harmed (Normandeau Associates Inc., 2009). Video footage of fish interacting with the face of the OpenHydro turbine at the EMEC provided no indication that there would be deleterious effects on the fish because they were seen to move away from the turbine when the cut-in speed of the tidal current was reached (Copping *et al.*, 2013a).

The evidence to date indicates that fish would appear to be most at risk from tidal turbine blades because many species may preferentially stay in the vicinity of turbines (Copping *et al.*, 2013a). However, the OpenHydro data support the theory that the bioenergetics of swimming for prolonged periods in strong tidal flows are not advantageous to most marine animals, even though fish and other marine animals are known to use tidal currents as a means of moving through an area (Polagye *et al.* 2011; Forward *et al.* 1999; Arnold *et al.* 1994; McCleave & Kleckner 1982). The risk to marine mammals from turbines could be somewhat increased by their natural curiosity, but this interaction could be mitigated by their intelligence and the habituation that is likely to take place as more devices are deployed (Copping *et al.*, 2013a).

There is also a risk of birds colliding with the single 25m high scaled wind turbine that may be erected at the site. The greatest risk is collision with the rotating blades as opposed to the tower. The species of greatest concern are those which fly at the height of the rotor (14-26m height) e.g. great northern diver, sandwich tern and common tern. Lighting on the turbine may attract birds and increase risk of collision (Winkleman, 1992) however the intermittent nature of the navigational lighting that will be required on the turbine may reduce the risk of bird attraction (Richardson, 2000). It is highly unlikely that a single, temporary, scaled wind turbine will have any impact on bird populations in Galway Bay.

There is also the potential risk that seabirds and marine mammals may collide with installation or service vessels. However the risk is likely to be low for all species (Daunt *et al.*, 2006) and the collision risk during construction is likely to be lower than that posed by commercial shipping traffic (AECOM, 2010).

Given the scaled size of the devices, the slow speed of the turbines blades, the low number of turbines likely to be in operation at any one time and the low number and short-term intermittent nature of the installation/service vessels the likelihood of a collision occurring is unlikely but even if it did the impact would be minor (direct or indirect mortality or sub-lethal effects caused to individuals).

**Collision Risk: Likelihood = Unlikely; Consequence = Minor; Impact = Low**

#### **4.1.5. Barrier to Movement**

The small number of scaled devices that will be deployed in the test site (including a potential 25m high scaled wind turbine) at any one time and the open water extending for c. 1km between the test

site and the northern shore of Galway Bay make the likelihood of any exclusion or barrier effect occurring remote and the consequence would be negligible.

Monitoring at the commercial scale SeaGen device in the Strangford Narrows has not presented a barrier to movement of seals or porpoises in and out of the Lough (Keenan *et al.*, 2011).

**Barrier to Movement: Likelihood = Remote; Consequence = Negligible; Impact = Low**

#### **4.1.6. Energy Removal**

Studies carried out to date on single devices or very small arrays (e.g. Keenan *et al.*, 2011; Smith, & Adonizio, 2011) have shown that due to the small footprint of these devices, entering into large bodies of swiftly moving water, there is little possibility of measurable changes to the physical environment (Copping *et al.*, 2013a). In addition, as waves travel through the water rather than the water itself moving, wave energy extraction will be low and somewhat recoverable as there is a large area of fetch after any device before it comes to the shore, which will see the biggest impact of energy extraction. As a result, given the scale of the proposed test site and the fact that the devices are scaled and not full size, the likelihood of any impact occurring is remote and there would be no change to the physical environment.

**Energy Removal: Likelihood = Remote; Consequence = None; Impact = Low**

#### **4.1.7. Noise**

##### **4.1.7.1. Construction Noise**

Noise from the installation vessel(s) has the potential to impact marine animals in the area. Hearing in marine animals varies between groups. Cetaceans consist of toothed whales (odontocete) and baleen whales (mysticete). The toothed whales are the group most likely to feature in Galway Bay, the dominant species being harbour porpoise and bottlenose dolphin (Marine Institute, 2013). This group communicates at moderate to high frequencies (1-20kHz) and they have highly developed echolocation system operating at high and very high frequencies (20-150kHz). Grey and harbour seals have flat audiograms from 1 to 30-50kHz, with thresholds between 60 and 80 dB re 1μPa. Harbour seals can detect underwater sounds up to 180kHz if it is sufficiently loud but their sensitivity drops off significantly above 60kHz (Richardson *et al.*, 1995). With regards to fish, salmon and eels are limited to the low frequency <600Hz) end of the spectrum.

Underwater noise levels of 185 to >200 dB re 1  $\mu$ Pa with peak frequency between 100 to 1000 Hz will be heard by both fish and marine mammals in Galway Bay.

The study carried out for the Galway Port expansion project (Galway Harbour Company, 2014b) showed that permanent (non-recoverable) and temporary (recoverable) injury do not occur for dolphins and porpoises due to shipping activity. The study also shows that permanent (non-recoverable) injury does not occur for seals and otters and that temporary (recoverable) injury will only occur within <2m of the ship. Disturbance, which may instigate temporary avoidance behaviour will be experienced further afield. The addition of a small number of vessels to the area is not expected to have any significant impact on marine fauna given the levels of ship traffic that currently exist.

Richardson *et al.* (1995) reviewed the published literature on the response of marine mammals to vessel noise. Many toothed whales appeared to be tolerant of vessel noise and were regularly observed in areas where there is heavy traffic. Harbour porpoises are normally considered shy and their reaction to disturbance, is often flight (Flaherty, 1981; Taylor & Dawson, 1984; Barlow, 1988; Parker, 1993). However, they are often observed in areas of intense shipping activity (Hoffman *et al.*, 2000).

Thomsen *et al.* (2006) noted that harbour porpoises (Hearing threshold = 115 dBrms re 1  $\mu$ Pa at 0.25 kHz; Ambient noise = 91 dBrms re 1  $\mu$ Pa at 2 kHz) would detect ship noise around 0.25 kHz at distances of 1km and ship noise around 2 kHz would be detected at a distance of approximately 3km. For harbour seals (ambient noise = 94 and 91 dBrms re 1 $\mu$ Pa at 0.25 and 2 kHz respectively), the zone of audibility would be approximately 20km for the 0.25 content of ship noise and identical to harbour porpoises for the 2 kHz content.

In addition, seal haul out sites are c. 13km from the test site and any airborne noise from the vessel activity will not disturb harbour seals on land.

Bottom living fish in which the swimbladder has degenerated and hearing is not specialised generally have high auditory threshold levels and would probably hardly hear the noise frequencies above 250Hz. At frequencies below 250Hz the sound levels would be approximately 90-110dB for this group of fish to hear the noise. This group of fish includes flounder, plaice, dab, turbot, sea scorpions, eelpout, sandeels and gobies (Engell-Sørensen *et al.*, 2001). Salmon have a swim bladder that is not always completely filled. They can hear frequencies up to 380Hz. In order for salmon to

hear frequencies of 160Hz, the sound level must be approximately 95dB (hearing threshold of 95dB re 1  $\mu$ Pa at 160Hz). Cod, whiting and silver eel have a swimbladder and can probably hear frequencies up to 300-500Hz. At frequencies below 300-500Hz, the sound levels must be approximately 75-100dB for this group of fish to hear the noise (Engell-Sørensen *et al.*, 2001). Herring can hear frequencies between 30Hz and 4000Hz. In order for herring to hear frequencies of 100Hz, the sound level must be approximately 75dB (hearing threshold of 75dB re 1  $\mu$ Pa at 100Hz). According to these calculations, dab, salmon and cod would only hear a large tanker in the area. Herring would hear a zodiac, tug/barge and large tanker. The vessels required for the construction phase would be a tug/barge like vessel, used for transportation and installation of the infrastructure. The increased vessel noise in the area of the test site during the installation and operational phases would be temporary and short-lived. Avoidance reactions by the fish from intermittent or short-term noise sources would be most plausible at short distances (less than 30m) from the sound source.

The likelihood of a noise related impact occurring is possible and the consequence would be negligible (direct or indirect mortality or sub-lethal effects caused to individuals).

**Construction Noise: Likelihood = Possible; Consequence = Negligible; Impact = Low**

#### 4.1.7.2. *Operational Noise*

An important consideration when examining the impacts of the operation noise of an energy device is the existing levels of background ambient noise. Typical ambient noise for shallow coastal waters range from 115 to 125 dB re 1  $\mu$ Pa (average 120 dB re 1  $\mu$ Pa) (Keenan *et al.*, 2013). Depending on the sound level from an operating device it may be masked by ambient noise. Operational noise has been measured for a number of small-scale or single energy conversion devices.

The commercial scale SeaGen tidal energy device consists of two 16m open blade rotors attached to a pile in the seabed in waters 26.2m deep. Throughout normal SeaGen operations, SeaGen is likely to be audible to marine mammals up to about 1.4km (Keenan *et al.*, 2011). Monitoring showed that harbour seals and porpoises swim freely in and out of the Lough while the turbine was operating. In addition, no significant displacement occurred although marine mammals did tend to avoid the centre of the channel when the turbine was operating and harbour seals displayed some small scale redistribution (few hundred meters) during turbine operation (although it is unclear if this was due to noise emanating from the operating device or avoidance due to disturbance of water flow around the device). The operating device did not cause any significant changes in the use of harbour seal haul out sites. While model predictions were made to determine when the SeaGen device would

elicit behavioural responses in porpoises and seals, monitoring showed that that these animals were regularly sighted within the range of predicted behavioural avoidance as a result of noise.

Acoustic monitoring of a demonstration commercial scale tidal turbine in Cobscook Bay in coastal Maine showed that the sound from the barge-mounted turbine was less than 100 dB re  $\mu\text{Pa}^2/\text{Hz}$  at 10m from the turbine (Copping *et al.*, 2013a). At 200 and 500m from the turbine the turbine sound was undetectable above ambient sounds within the bay.

A 1/7<sup>th</sup> scale SeaRay wave buoy in the Puget Sound, Washington was recorded as having a sound pressure level (SPL) of 126 dB, which was the equivalent of a tugboat passing at a range of 1.25km (Copping *et al.*, 2013a). This device could be acoustically identifiable within 500m when there was no ship traffic in the area. When ships were present, the high ambient noise levels masked the wave device sound (ambient levels of 116 dB, peaking at 132dB in a frequency band of 20 Hz to 20 kHz when ship traffic was close by).

Tougaard (2015) recorded underwater noise from the Wavestar wave energy converter; a full-scale hydraulic point absorber, placed on a jack-up rig on the Danish North Sea coast. The noise levels recorded from the operating wave converter were so low that they would barely be audible to marine mammals and the likelihood of negative impact from the noise appears minimal.

Haikonen (2014) studied the noise generated from 4 different full-scale wave energy converters (point absorbing linear generators) at a site in the Skagerrak on the Swedish west coast as part of the Lysekil Wave Power Project. Harbour seals and harbour porpoises have rather poor hearing in the frequencies where the noises from the WECs have their peak energy  $\leq 400$  Hz (Haikonen *et al.*, 2013a; 2013b). However, the noise levels at 1m from the WEC, are well above the hearing threshold of both harbour seal and harbour porpoise in these frequencies. Generally, marine mammals have shown first signs of being disturbed at noise levels around 120 dB re 1  $\mu\text{Pa}$  for continuous noise (Richardson *et al.*, 1995). Noise level thresholds (SPL<sub>peak</sub>) for minor behavioural disturbance for harbour seal is 160 dB re 1  $\mu\text{Pa}$ , and can be as low as 90 dB re 1  $\mu\text{Pa}$  for harbour porpoise (Bailey *et al.*, 2010). This indicates that harbour seal can express behavioural disturbance if in the immediate vicinity of the WEC, but at a distance of 15m away (in the Lysekil research site) a behavioural response is improbable. However, the harbour porpoise, being much more sensitive, is likely to express disturbance in greater distances. However, no major disturbance is expected at distances >150m from the WECs (Haikonen *et al.*, 2014).

In general for marine mammals, no disturbance is expected at 2km from the WECs (Haikonen, 2014). Masking effects are difficult to predict, however most teleost fishes produce sound that have most of their energy in frequency < 1 kHz (Hastings & Popper, 2005). This indicates that there is a risk of masking effects on fish vocalizations if close enough to the WEC (Haikonen, 2014). The sound production of harbour porpoise ranges in frequency between 120 to 130 kHz with SPL up to 180 dB re 1  $\mu$ Pa (Clausen *et al.*, 2010) and the sound production of harbour seal is in frequency considerably lower than that of the Harbour porpoise. Much of their vocalization is in frequency between c. 15 and 1000Hz, but may range up to 5 kHz. This indicates that the noise from the WECs will not mask the vocalization of harbour porpoise but it may mask the vocalizations of the harbour seal (Haikonen, 2014).

Marine mammal monitoring to assess the effect of a ¼ scale ocean energy device on harbour porpoise presence was carried out at the Galway Bay test site between 2009 and 2010 when an ocean energy scaled device was on site (O'Brien *et al.*, 2012; O'Brien, 2013). Monitoring was also carried out at 2 control sites, one 1km east of the test site and the second was 500m west of the test site. The presence of the wave platform, which was of a substantial size (28t), could have had a positive or negative effect on the occurrence of harbour porpoises in the area:

- The presence of the structure may have deterred animals as they may not be able to sufficiently forage for food as the structure may impact on their echolocation ability. This event is highly unlikely at Spiddal given the high percentage of days with detections (O'Brien, 2013).
- Or the platform itself may act as a cover for many fish species and therefore attract fish to the area and in turn feeding porpoises. International studies have found that wave buoys can serve as artificial reefs and attract fish and other marine life. In fact, in some parts of the world conventional buoys are deployed to serve as 'Fish Attracting Devices' (FADs) (Nelson, 2013).

Results from this short-term deployment and monitoring failed to show a significant difference in detections between sites, suggesting that the OE platform did not influence harbour porpoise presence, either positively or negatively.

Noise impacts from the maintenance vessels will be the same if not lower than that from the installation vessels.

Operational noise from individual devices or small arrays of devices is unlikely to have large-scale effects on the behaviour or survival of marine organisms (Copping *et al.*, 2013a). As a result of the studies carried out to date and the nature and use of the Galway Bay Marine & Renewable test site, the impact of 3 (max) operating scaled energy test devices on marine animals in the area will be negligible.

It should be noted that the CEE hydrophone and acoustic array will facilitate the measurement of sound generated from experimental WEC devices and will facilitate the recording of cetacean vocalisations allowing SmartBay Ireland Ltd. to assess the impact on an ongoing basis. This monitoring will add to current scientific knowledge on noise impacts and it will add to the industries knowledge of potential impacts using scaled prototype devices in the test site.

**Operational Noise: Likelihood = Possible; Consequence = Negligible; Impact = Low**

#### **4.1.8. Electro-Magnetic Fields**

It is anticipated that there could be up to 3 cables connecting scaled test devices to the SeaStation and a 4<sup>th</sup> cable connecting the SeaStation to the CEE. These cables will be free floating between the devices. The CEE will provide 400V DC (3.5kW) power supply to the sensors, SeaStation, test devices and HDTV cameras through a standard 25mm single conductor telecommunications type cable which was laid between the CEE and the shore in April 2015. This cable was fitted with 12 fibres and the single power conductor will require the use of seawater as a return path from the CEE. This cable was double armoured and buried to a depth of 700mm where substrata allowed or laid directly on the seabed and protected with either cast iron protection or concrete bags.

Shielded electric transmission cables do not directly emit electric fields, but are surrounded by magnetic fields that can cause induced electric fields in moving water (Gill *et al.*, 2012). EMF could also disturb fish migration patterns by interfering with their capacity to orientate in relation to the geomagnetic field, as indicated by empirical studies on eel (Westerberg & Begout-Anras, 2000; Westerberg & Lagenfelt 2008; Gill *et al.*, 2012). The extent of EMF can potentially be mitigated by adequate cable design. Only few studies have addressed electroreception in marine mammals (Czech-Damal *et al.*, 2012) or invertebrates (Karlsen & Aristharkhov, 1985; Aristharkhov *et al.*, 1988, Bochert & Zettler 2004) and no significant effects have been shown to date. Probable negative impact from electromagnetic fields (EMF) are generally rated low (Bergstrom *et al.*, 2014).

In addition, Olsen & Larsson (2009) conducted an extensive review of the impacts of electromagnetic fields from sub-sea power cables on marine organisms and concluded that research to date has found that sub-sea power cables pose no threat to the marine environment due to EMF. Additional work commissioned in the UK on behalf of the Collaborative Offshore Wind Energy Research into the Environment (COWRIE) concluded that there was no solid evidence to suggest that EMF associated with high voltage cables have either positive or negative effects on cetaceans, fish or elasmobranchs.

At 3.5kW and 400V the power and voltage of the proposed cables are a fraction of those found in high power undersea cables. For instance the East West interconnector which was recently laid in the Irish Sea connecting the Irish and UK electrical grids can transmit up to 500,000kW at up to 200,000V (Marine Institute, 2013). The low power levels in the proposed cables mean that the magnetic field and induced electric field from the proposed cables will not have any significant impact on marine species in the area. The likelihood of an impact occurring is unlikely and the consequence would be negligible.

**Electro-Magnetic Fields: Likelihood = Unlikely; Consequence = Negligible; Impact = Low**

#### **4.1.9. Accidental Events / Contamination**

Accidental events or spillages from marine vessels and equipment e.g. fuel/oil leaks, cleaning fluids, paint, specialised chemicals, litter etc. have the potential to occur. In addition, fuel spillages could occur when the diesel tank on the SeaStation needs refuelling. In addition, the fuel stored on the SeaStation will be in a secure container and leakages from this will be unlikely.

All vessels employed to carry out any work onsite will have all required certification to ensure sea worthiness. In addition they will employ best practice measures to minimise any possible impacts on the marine environment and in case of an accidental event the ship's Oil Pollution Plan will be implemented and on board oil pollution control measures will be implemented to minimise any impacts on the environment. The quantities of oil/fuel involved in accidental spillages are likely to be very small and the impact on water quality would be minor. The likelihood of a spillage would be unlikely.

There is the potential for contamination from the use of anti-fouling compounds and the erosion of sacrificial anodes. As the quantities and toxicities associated with these are generally expected to be extremely small and therefore the potential effect will be of negligible significance (Aecom, 2010).

There are no sensitive habitats in the vicinity of where these compounds may be used and as a result any impacts will be negligible.

As the test site is located outside of the industrial dock area, outside any of the main shipping routes, there is no historical munitions or spoil disposals at the site, the rivers that discharge into the area are not from industrialised areas and there is a rich diversity of benthic fauna at the site, it is extremely unlikely that the sediments in the test site are contaminated. As a result the remobilisation of contaminated sediments during the installation phase is extremely unlikely.

**Accidental Effects/Contamination: Likelihood = Unlikely; Consequence = Negligible; Impact = Low**

#### 4.2. *Impact Assessment Tables*

Table 5 shows the impact matrix for the various activities associated with the test site. All impacts are considered Low.

**Table 5: Risk matrix for the Galway Bay Marine & Renewable Energy Test Site.**

<b>Likelihood</b>	<b>Highly Likely</b>	<b>5</b>		Loss Habitat & Species Disturbance to Sediment New Substrata				
	<b>Probable</b>	<b>4</b>						
	<b>Possible</b>	<b>3</b>		Noise				
	<b>Unlikely</b>	<b>2</b>		EMF Accident/Contamination	Collision Risk			
	<b>Remote</b>	<b>1</b>	Energy Removal	Barrier to Movement				
			<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
			<b>None</b>	<b>Negligible</b>	<b>Minor</b>	<b>Moderate</b>	<b>Major</b>	<b>Severe</b>
			<b>Consequence</b>					

## 5. Mitigation / Best Practice

### 5.1. *Proposed Measures*

A number of mitigation / best practice measures are recommended to ensure minimal impact from the test site.

- Site specific geophysical and geotechnical surveys to establish a baseline and identify suitable locations for infrastructure

- Carry out pre installation baseline seabed surveys (sediment and faunal) for comparison with post installation surveys to document any changes. Control sites must be included.
- Use installation methods that minimise disturbance of sediments
- Deploy all objects on to the seabed as slowly and controlled as possible to minimise sediment disturbance on the seabed
- Carry out work in appropriate tidal conditions to minimise effect
- Carry out potentially hazardous operations under appropriate weather/tide conditions
- Avoid sensitive time periods for local receptors
- Risk assessment for contingency planning
- Use low toxicity and biodegradable materials
- Use minimum quantities
- Design infrastructure for minimum maintenance
- Design devices to minimise risk of leakage of pollutants
- Risk assessment for contingency planning
- Implementation of Shipboard Oil Pollution Emergency Plan (SOPEP)
- Presence of a trained experienced Marine Mammal Observer (MMO) to implement the NPWS best practice guidelines when all work is taking place and to implement appropriate buffer zones in good sea-state.
- If bow thrusters are required on installation vessels they should be covered to prevent collision with marine mammals
- Target work to take place when porpoise presence is at its lowest e.g. during the spring or early summer
- Only carry out observations (and therefore work) during daylight hours (this will also minimise risk of bird and mammal collision with vessels)
- Carryout SAM at the site during and after installation works to assess if avoidance behaviour is recorded and if so for how long it lasts.
- Design devices for minimal impact of collision risk
- Plan operations efficiently to minimise the number of trips that the service vessel must make.
- Leave any long-term devices, which have become established as functional artificial reefs and are beneficial to the area in place.

## 5.2. Mitigated Impact Assessment Table

Table 6 shows the mitigated impact matrix for the various activities associated with the test site. Again all impacts are considered Low and the likelihood of impact on mammals has decreased to remote.

**Table 6: Risk matrix for the Galway Bay Marine & Renewable Energy Test Site.**

Likelihood	Highly Likely	5		Loss Habitat & Species Disturbance to Sediment New Substrata				
	Probable	4						
	Possible	3						
	Unlikely	2		EMF Accident/Contamination	Collision Risk			
	Remote	1	Energy Removal	Barrier to Movement Noise				
			0	1	2	3	4	5
			None	Negligible	Minor	Moderate	Major	Severe
			Consequence					

## 6. Summary

Summary impact tables can be seen in Tables 7 and 8 below for the installation and operation impacts respectively. Given the scale of the site and the intermittent nature of deployments the impacts on all receptors are of low concern.

- The impacts from the loss of habitats/species, sediment disturbance and addition of new substrata/structures on the benthos, fisheries, protected habitats/species, mammals and birds are all negligible.
- Impacts on mammals, birds, fish and protected species caused by barriers to movement are negligible.
- The impacts from vessel noise on mammals, birds and fish are negligible.
- The collision risk posed to birds, mammals, fish and protected species is minor.
- No impact is expected on any receptor from energy extraction.
- Impacts associated with EMF on mammals and fish are negligible as are impacts from accidental events or contamination.

**Table 7: Summary table of installation activities showing impact scores**

Activity / Receptor		Geology, Geomorphology, Sediment Processes	Seabed Contamination & Water Quality	Protected Sites & Species	Benthos	Fish & Shellfish	Birds	Mammals & Reptiles
Physical Disturbance	Loss Habitat & Species							
	Sediment Disturbance							
Contamination	Drilling/Piling Materials							
Noise	Piling							
	Installation Vessels							
Installation Vessels	Collision Risk							
Accidental Events	Pollution Events / Spillages							

No Concern	Low Concern	Medium Concern	High Concern
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**Table 8: Summary table of operational activities showing impact scores**

Activity / Receptor		Geology, Geomorphology, Sediment Processes	Seabed Contamination & Water Quality	Protected Sites & Species	Benthos	Fish & Shellfish	Birds	Mammals & Reptiles
Physical Presence	Loss Habitat & Species							
	Introduction Hard Substrata/Structures							
	Sediment Disturbance							
	Collision Risk							
	Barrier to Movements / Habitat Exclusion							
	Contamination							
Energy Extraction	Sediment Transport / Hydrodynamic Pathways							
Noise	Devices & Maintenance Vessels							
EMF	Devices & Cables							
Installation Vessels	Collision Risk							
Accidental Events	Pollution Events / Spillages							

No Concern	Low Concern	Medium Concern	High Concern
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