TECHNICAL MEMORANDUM

Date:	January 9, 2012
To:	Jason Busch, OWET
From:	Paul Manson, Parametrix; Kevin Halsey, Parametrix; Ann Radil, Parametrix
Subject:	Industry Area Mapping for TSP Process
cc:	Gareth Davies, Aquatera, Ltd
Project Number:	283-6309-001 (01/02)
Project Name:	Cumulative Effects Phase II

INTRODUCTION

To support the Oregon Wave Energy Trust's (OWET's) Industry Advisory Group (IAG), Parametrix and Aquatera were asked to develop a series of mapping products to inform the Territorial Sea Plan (TSP) process. To accomplish this, the team combined existing information on wave energy device types, interviews with inventor and developer representatives, and experiences from international development. These inputs informed a database of device suitability parameters used to develop and map spatially explicit device suitability areas. These areas represent a broad set of developer and technology perspectives and a range of device suitability.

In addition to demonstrating where it is technically feasible to site wave energy devices, Parametrix developed a sub-set of device suitability parameters to model the feasibility of siting wave energy devices in an economically-constrained environment. Relative to the parameters used to model technical feasibility for siting wave energy devices, the economically-constrained parameters further limit the feasibility of siting wave energy devices based on proximity to the electrical grid. The goal is to provide the Department of Land Conservation and Development (DLCD) with a final data product that can be integrated into Marine Map for use in the TSP process in 2012. The agency intends to develop a series of management scenarios for the Part 5 amendment, and the suitability areas are needed to encourage the designation of areas in the territorial sea that will have a better chance of meeting tangible device and development requirements. The economically-constrained wave energy device suitability models are currently being used for this process, since these models better represent the current challenges and opportunities facing wave energy project developers.

KEY FINDINGS

The technology types incorporated in the models included attenuators, point absorbers, surge, coastal wave generation, and mid-depth pressure plate-type devices. These devices are seen as representing the core device types anticipated to be commercially viable in Oregon. Suitability criteria were also collected for wind, oscillating water column, and flywheel devices. Device suitability model results are driven entirely by engineering and technical criteria, and therefore reflect practical assumptions of economic viability based on cabling, anchoring, access to deep water and service ports, and proximity to transmission lines and substations. Some results identify areas suitable for wave energy that, if developed, may create conflict with existing uses; this is addressed in a later section of this memo.

Wave energy device suitability was modeled for Oregon's territorial waters, as well as a portion of the outer continental shelf (OCS). The project area is defined as the Region 50 nautical miles (nm) offshore the coast of Oregon, and is 2,131 nm^2. The results of the modeling effort are delineated using "natural breaks". This classification of model results is based upon interpretation of the histogram of data variables and is used to identify the areas that are best suited to coastal, mid-depth, and offshore wave energy devices, given the aforementioned technical and economic parameters.

Coastal, mid-depth, and offshore wave energy device suitability was interpreted by identifying "natural breaks" in the frequency distribution histogram of the model results. Histograms have long been used to evaluate data and patterns. For this evaluation, a histogram was created for each technology class to illustrate the frequency of wave energy device suitability score for each raster grid cell included in the study area. Thus, the histograms for each technology class illustrate the general shape and spread of suitability model results.

There are a number of reasons why categorizing wave energy device suitability using the natural breaks methodology is superior to calculating "hard breaks" in the data, such as the top 1 percent of all model results, the top 2 percent of all model results, etc. These benefits are best understood in light of the goal of this assessment, which is to inform the TSP process. By identifying natural breaks in the datasets, it is possible to consider a suite of alternative development scenarios, without excluding from consideration areas with marginally inferior conditions. Using hard breaks to identify areas suitable for wave energy development would result in distinguishing areas suitable for wave energy development from areas unsuitable for wave energy development based on minor modeling differences that are within the margin of error of the datasets, thus introducing the possibility of making planning decisions using erroneous data.

While it is not recommended that hard breaks are used for planning purposes, it is nonetheless useful to have a context for evaluating the areal extent of the territorial sea and OCS suitable for developing coastal, mid-depth, and offshore wave energy devices. The top 5 percent most suitable coastal wave energy device model results cover an area of 6 nm^2; the top 5 percent most suitable mid-depth wave energy device model results cover an area of 29 nm^2; and the top 5 percent of the most suitable offshore wave energy device model results cover an area of 39 nm^2. Thus, based on the top 5 percent of all suitability model results, in an economically-constrained environment, 74 nm^2 off the coast of Oregon are suitable for wave energy development, and this area is located entirely within the territorial sea.

DESIGNATION OF AREAS SUITABLE FOR WAVE ENERGY DEVELOPMENT

The coastal, mid-depth, and offshore model results indicate that in general, there are discrete areas suitable for multiple wave energy device types along the Oregon coast. These "hot spots" of wave energy development are described in the following section.

Beginning at the Washington/Oregon border and moving south, the first area suitable for wave energy devices is located south of the Columbia River and north of Tillamook Head. This area is characterized by a gently sloping and sandy seafloor and is suitable for coastal, mid-depth, and offshore wave energy devices. While access to Astoria's port is favorable, transit around the jetties adds substantial traveling distances to and from proximal wave energy devices. This area has been identified by the Northwest National Marine Renewable Energy Center (NNMREC) as a potential location for their test birth facility.

Some coastal and mid-water type devices are well-suited to conditions found in the Tillamook and Netarts Bay area. These areas show potential primarily due to possible access opportunities out of Tillamook/Garibaldi and favorable device depths near shore. Ocean Power Technologies (OPT) has proposed consideration of a 41-square-mile area off Tillamook Head for wave energy development.

The next area suitable for multiple wave energy device classifications is located in an approximately 12-mile-long region located offshore of Newport. Coastal and mid-depth devices are best suited to this site; however, all wave energy device types can be supported here due to favorable port access, close proximity to grid connections, and good anchoring potential. OPT and NNMREC have identified an approximately 35-square-mile area off the coast of Oregon as targeted zones for wave energy development and siting of the test berth facility, respectively.

Moving south, the next hot spot is located off the coast of Florence. This area is approximately 10 miles long and encompasses conditions favorable for the development of coastal and offshore wave energy devices, and to a lesser extent, mid-depth devices. OPT has identified this area as a desirable location for wave energy development.

The next substantial area suitable for wave energy development is located offshore of Reedsport. This location is favorable for the development of coastal, mid-depth, and offshore wave energy device types. Further, this area contains the top 37 percent of all coastal wave energy device suitability model results, the top 12 percent of all mid-depth device suitability model results, and the top 1 percent of all offshore wave energy device suitability model results. While suitability for coastal and mid-depth devices is roughly centered 5 miles north and south of Reedsport, the siting of offshore devices continues to be favorable for approximately 10 miles south of Reedsport, tapering off towards Coos Bay. Both OPT and NNMREC have identified adjacent and overlapping areas in this vicinity as potential sites for siting wave energy devices. The wave suitability models indicate that the offshore environment between Reedsport and Coos Bay is best suited to mid-depth and offshore devices.

Approximately 5 miles south of Coos Bay, offshore of Bandon, there are favorable conditions for coastal, mid-depth and offshore wave energy device types. While depths limit coastal and mid-depth device placement to a narrow band, this area appears to provide extensive opportunity for offshore devices, such as point absorbers and point attenuators. Neither OPT nor NNMREC have proposed this location for wave energy development.

There are extensive, favorable opportunities to develop wave energy devices off the coast of Port Orford. Specifically, a 10-mile band off the coast of Port Orford contains some of the best opportunities for developing all three classifications of marine energy devices, including the top 11 percent and top 1 percent of model results for coastal wave energy devices and offshore wave energy devices, respectively. Neither OPT nor NNMREC have proposed this location for wave energy development. Currently, the data available to populate the wave energy device suitability models does not capture the possible interaction of many offshore islands and rock formations that may alter the wave regime in this region. As a result, this area requires further study.

Last, the area offshore of Brookings also contains favorable conditions for supporting coastal, mid-depth, and offshore wave energy devices. This area appears especially favorable for the siting and operation of offshore wave energy device types. However, as previously stated, the wave regime in this region may be altered by proximal islands and rock formations, and as a result, the suitability of siting and operating wave energy devices in this area requires additional study.

CONSTRAINTS ON DEVELOPING WAVE ENERGY RESOURCES

Designation of areas suitable for wave energy development is a difficult task requiring careful consideration of environmental, socioeconomic, and regulatory constraints. The wave energy suitability models utilized in this analysis focus on the technological and economic constraints associated with developing a wave energy site. Thus, additional consideration of potential interactions with existing marine uses or natural resource values is required, and integrating these constraints will reduce the extent of areas suitable for wave energy development. An analysis is currently being conducted to identify environmentally-sensitive habitats, which will provide greater specificity on Goal 19 resources. Initial results indicate that the areas suitable for wave energy development that create the least conflict with existing uses are located near Reedsport. The area offshore of Newport may have greater conflict with existing uses, including commercial fishing and recreation. Developing wave energy in the opportunity zone located between the Columbia River estuary and Tillamook Head could disrupt existing recreation uses; however, developing this area for wave energy would result in relatively fewer visual, environmental, and fishing impacts.

METHODOLOGY AND ASSUMPTIONS

The modeling uses a spatial multiple criteria decision analysis (MCDA) method. The goal of an MCDA is to identify the key parameters or variables that influence siting decisions for wave energy and combine spatially-explicit criteria to identify desirable areas for wave energy development. A geospatial information system (GIS) and a database with the MCDA parameters compute the spatial solutions based on input from users. The parameters are combined using a weighted product model with all parameters currently weighted equally. The parameters used to model coastal, mid-depth, and offshore wave energy device suitability include:

- Water depth.
- Substrate type.
- Distance from the nearest substation.
- Distance to shore.
- Distance to the nearest transmission cable.
- Distance to service port.
- Distance to deep water port (for device installation).

Technology Suitability

Different classes of wave energy devices require unique conditions to generate and transmit electricity. The wave energy suitability models contained in this analysis include a range of wave energy device types:

- Coastline Converters: Located on an existing natural or manmade coastline, or where a new coastline is artificially created in near-shore waters.
- Coastal Surge Devices: Where a flap moves laterally in response to wave motion in shallow water (less than 20 meters).
- Offshore Point Absorbers: Where the water moves a float vertically.
- Offshore Oscillating Water Columns: Where the surge generated by waves within a chamber is used to drive air through an above-surface turbine.
- Offshore Surge Devices: Where the pressure differential between two closely situated flaps is used.
- Offshore Attenuator/Pivots: Where the articulation of a joint around a pivot is converted into compressive or rotational energy.
- Offshore Flywheel Devices: Where the motion induced by passing waves is transformed into rotational energy that accelerates a flywheel or gyroscope.
- Offshore Pressure Devices: Seabed-based flexible reservoirs of air which become cyclically compressed and expanded as a wave peak and trough pass over.

To effectively generate and transmit electricity, wave energy devices require the following types of supporting infrastructure:

- Offshore Cable Connection Hub: A seabed-fixed or floating structure, above or subsurface, where multiple cables are connected together, possibly with voltage step-up and/or AC to DC conversion.
- Offshore Transmission Cables: AC or DC cables that transfer electricity over larger distances offshore through cables, or onshore through buried cables or overhead wires.
- Beach Landfall: Section of coast where cables cross from sea to land by being buried into a trench across the shore.
- Directional Drilling Sites: Where a borehole is drilled through and cables can be pulled to make the transition from sea to land.

Suitability Criteria

The suitability of a given area for a particular class of wave energy devices is determined based on the potential site's presence or absence of criteria necessary for wave energy development and operation. The criteria used to model wave energy device suitability in this assessment are listed in the table below.

Criteria	Units	Comments
Water depth (m)	Meters/fathoms	Depth between mean low tide and the seabed.
Distance from shore (nm) technical	Nautical miles	Straight-line distance from coast.
Seabed (type)	Description	Type of sediment on the surface of the seabed.
Sediment depth (m)	Meters	Depth of sediment overburden above bedrock.
Distance of deep-water port (nm)	Nautical miles	Navigable distance from a deep-water port.
Distance from service harbor (nm)	Nautical miles	Navigable distance from a shallow-water harbor.
Water currents (kts)	Knots	The velocity of water currents during mean spring conditions.
Tidal range (m)	Meters	The difference in height between mean low water springs and mean high water springs.
Seabed morphology	Description	Describes the shape of the seabed.
Distance to transmission lines (nm)	Nautical miles	The line-of-sight or Euclidean distance to the nearest transmission line.
Distance to substation (nm)	Nautical miles	The line-of-sight or Euclidean distance to the nearest substation.

An explanation of each of these criteria is provided in the following section.

Suitability Scores

For each of these criteria, a set of suitability scores was developed based on existing information on wave energy device types, interviews with inventor and developer representatives, and experiences from international development. Specifically, scoring reflects known specifications or requirements for anchoring and operating various wave energy devices. Preliminary scores were vetted with technology developers to validate assumptions, confirm existing technology drivers, develop common suitability scores among devices with technological similarities, and ensure that the relative suitability among wave energy devices was logical.

These scores range from zero to ten, with zero representing no potential for wave energy development and ten representing that the conditions observed are favorable for wave energy development in an economically-constrained environment. Ten intervening classifications are then determined in one-unit increments. Zero values are reserved for cases where the parameter overrides all other values, thus eliminating development potential.

It should be emphasized that while every effort has been taken to ensure that the scoring system is logical, credible, and reflective of reality, there may be specific issues associated with particular technologies that take that technology outside the notional class envelope. Given the early stage of technology development and the gradients that apply to most criteria, such deviations are not considered to be critical.

Explanation of Scoring

The following table describes factors used to score the suitability of particular wave energy devices and provides and explanation of the scoring methodology.

Water Depth

Technology	Scoring Explanation
Coastline converter	• The water depth at the coast is considered to be limited to less than 30 m. Therefore, no coastal device can have a water depth greater than 30 m. • Depths of 10 m to 30 m are considered ideal. • Depths of less than 10 m are considered to be less favorable.
Coastal surge	• Given the need for the wave to be creating surge type motion, the water depth range is limited to 10–20 m. • Waters shallower than 10 m will not yield enough exploitable energy. • Waters deeper than 20 m will not generate sufficient surge.
Offshore pressure	• This device works off a pressure differential between wave peaks and troughs; hence, the shallower the water the better. • An upper depth limit is considered to be 50 m. • There is a limit towards the shore in shallow water (less than 10 m) where conditions become less favorable due to sediment concerns.
Offshore point absorber Offshore attenuator/pivot Offshore oscillating water column Offshore surge Offshore flywheel	• The need for floating device clearance from the seabed leads to a minimum depth of approximately 30 m. • The reduction in wave energy due to bottom drag creates a threshold of approximately 50 m. • The cost of moorings makes an upper viability threshold of approximately 80 m. • The absolute limit on depth does not exist beyond cost. • All devices have similar requirements.

Distance from Shoreline

Technology	Scoring Explanation
Coastline converter	• This technology is on the coast already.
Coastal surge	• All suitable water depths lie within 2 nm of the coastline. • The nearer the coastline, the better, due to the need to pump water ashore.
Offshore pressure differential	• Suitable depths lie between 1 nm and 5 nm from shore.
Offshore point absorber Offshore attenuator/pivot Offshore oscillating water column Offshore surge Offshore flywheel	• There are no suitable deployment areas within 1 nm, and reflected waves from any cliff-like coast could be a problem. • Between 1 and 4 nm from the shore is considered optimal. • At greater distances, cabling and service vessel costs will increasingly be a disadvantage. • These types of cost pressures are considered greater during pilot-scale testing.

Seafloor Type

Technology	Scoring Explanation
Coastline converter	• Bedrock is considered to be the best foundation for such devices; increasingly fine sediments create increasing problems due to sediment dispersal in rough seas.
Coastal surge	• Bedrock is considered to be the best foundation for such devices; sand and gravel is a close second, while other materials are less favorable.
Offshore pressure	• Sedimentary seabed types are considered preferable to loose sediment types.
Offshore point absorber	• Sand and mud are considered to have the best anchor holding capacities for all of these technologies. Rock is less favorable but is possible to anchor to.
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance to Deep-Water Port

Technology	Scoring Explanation
Coastline converter	• Developments serviced from land rather than sea.
Coastal surge	• Within 20 nm, but not right on top of the harbor is best for all developments; early schemes will need to be closer to a home port (less than 50 nm) than will be the case for later larger schemes.
Offshore pressure	
Offshore point absorber	
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance from Service Harbor

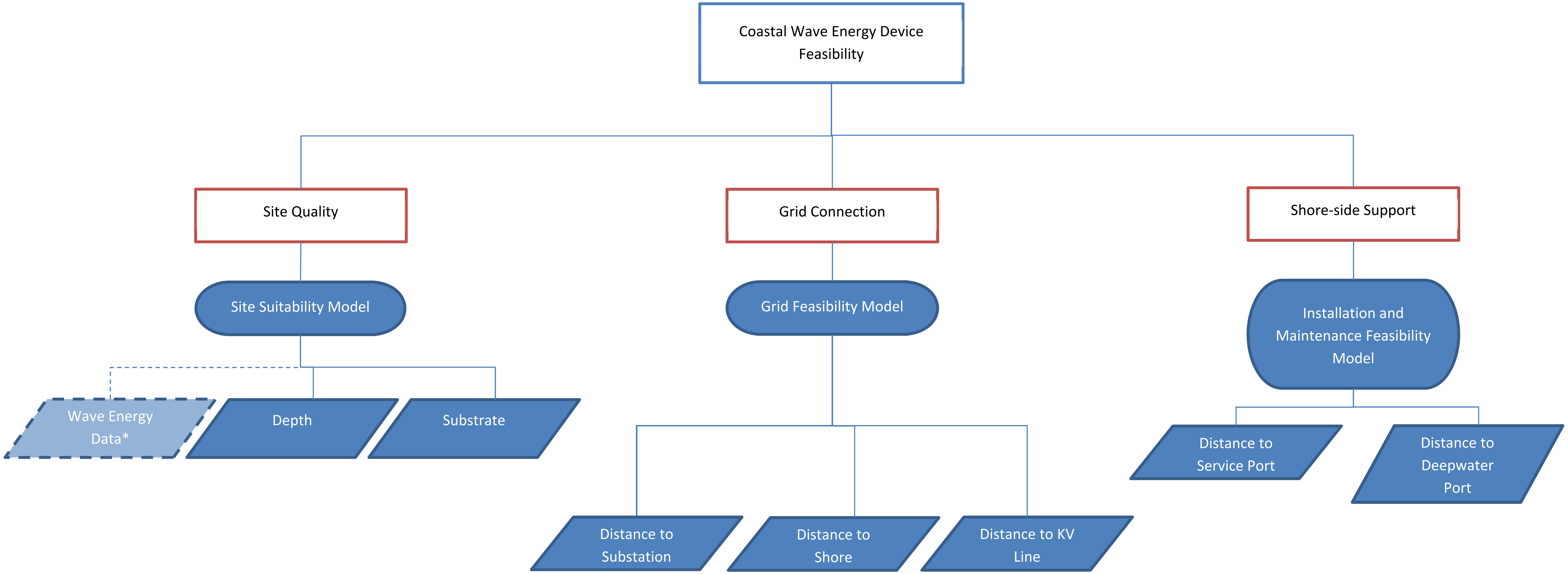
Technology	Scoring Explanation
Coastline converter	• Developments serviced from land rather than sea.
Coastal surge	• Similar to the need for deep-water ports above but without same need for clearance around harbors.
Offshore pressure	
Offshore point absorber	
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance to Transmission Line

Technology	Scoring Explanation
Coastline converter	• The closer a wave energy device is to transmission line, the better. • In an economically-constrained environment, it is not feasible to site a wave energy device more than 6 nm from the nearest transmission line. • Distance to transmission is calculated as the line-of-sight or Euclidean distance to the nearest transmission line.
Coastal surge	
Offshore pressure	
Offshore point absorber	
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	

Distance to Substation

Technology	Scoring Explanation
Coastline converter	• While connecting to a substation is not anticipated to be a necessity for most pre-commercial installations, it is a relevant factor for site expansion opportunity. • Thus, even in an economically-constrained environment, closer proximity to a substation is favorable. • The distance to a substation scoring is designed to reflect the less critical nature of the attribute.
Coastal surge	
Offshore pressure	
Offshore point absorber	
Offshore attenuator/pivot	
Offshore oscillating water column	
Offshore surge	
Offshore flywheel	



We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Model:	**Coastal Energy Production – Economically Constrained Environment**
Revision/Date:	**1.8/Feb-2012**
Created By:	**AR**

Function | Analysis | Data | To Be Developed | Model Link | Impact Link

OregonWaveEnergy TRUST

Cumulative Effect Analysis Framework for Marine Renewable Energy

Developed by: Parametrix aquatera.co.uk environmental services and products

Model Specifications

The economically-constrained coastal device feasibility model evaluates the feasibility of siting coastline converter and coastal surge devices in a pre-commercial context. In this context, wave energy devices do not generate significant revenue, and as a result, the suitability scoring reflects the financial importance of proximity to shore and a potential grid connection. The coastal device model combines three sub-models or functions to evaluate the feasibility of siting the device. Coastline converter devices are located on an existing natural or man-made coastline, or where a new coastline is artificially created in near-shore waters. Coastal surge devices harness the energy generated by a flap moving laterally in response to wave motion in shallow water. The three sub-models that determine coastal wave energy device feasibility include site quality, grid connection, and shore-side support.

The site quality sub-model evaluates the suitability of a potential site to provide adequate water depths for coastal device operation, and the presence of a substrate suitable for anchoring a coastal wave energy device. The grid connection sub-model evaluates the suitability of grid access based on the Euclidean distance to a substation, distance to shore, and the Euclidean distance to the closest transmission line, or kilovolt (KV) line. While connecting to a sub-station is not anticipated to be a necessity for most pre-commercial installations, it is a relevant factor for site expansion opportunity. The shore-side support sub-model evaluates the ability of existing shore-side resources to satisfy wave energy developers' needs for access to a deep water port for device installation, and access to a service port for intermittent wave energy device operations and maintenance.

Attribute: Wave Energy Data

* We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Attribute: Depth

Ref.	Classification	Score
1	0m < 10m	0
2	10m < 20m	10
3	20m < 30m	0
4	30m < 40m	0
5	40m < 50 m	0
6	50m < 75m	0
7	75m < 85m	0
8	85m < 100m	0
9	100m < 200m	0
10	>200m	0

Source: 100m DEM Bathymetry

Attribute: Substrate

Ref.	Classification	Score
1	Rock	10
2	Shell	7
3	Gravel	7
4	Sand	8
5	Cobble	5
6	Mud	8

Source: DOGAMI

Attribute: Distance to Substation*

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM > 15 NM	7
4	15 NM > 20 NM	4
5	> 20 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Distance to Shore

Ref.	Classification	Score
1	<1 NM	10
2	1 NM < 2 NM	9
3	2NM < 3 NM	8
4	3 NM < 4 NM	7
5	4 NM < 5 NM	6
6	5 NM < 6 NM	5
7	6 NM < 7 NM	4
8	7 NM < 8 NM	3
9	8 NM < 9 NM	2
10	9 NM < 10 NM	1
11	> 10 NM	0

Source: Buffered distance from shoreline vector data

Attribute: Distance to KV Line*

Ref.	Classification	Score
1	0 <3 NM	10
2	3 NM < 6 NM	10
3	6 NM < 9 NM	8
4	9 NM < 12 NM	4
5	12 NM < 15 NM	2
6	> 15 NM	0

Source: Buffered distance from the wave energy device to KV transmission line data

*Transmission line and substation data was downloaded from Oregon Marine Map (http://www.arcgis.com/home/item.html?id=4c2a32e62b254fb08a33e4a0d1ab75b5).

Land-based distances do not reflect elevation or obstacles. All directions on land are assumed to be line-of-sight or Euclidean distances.

Attribute: Distance to Service Port

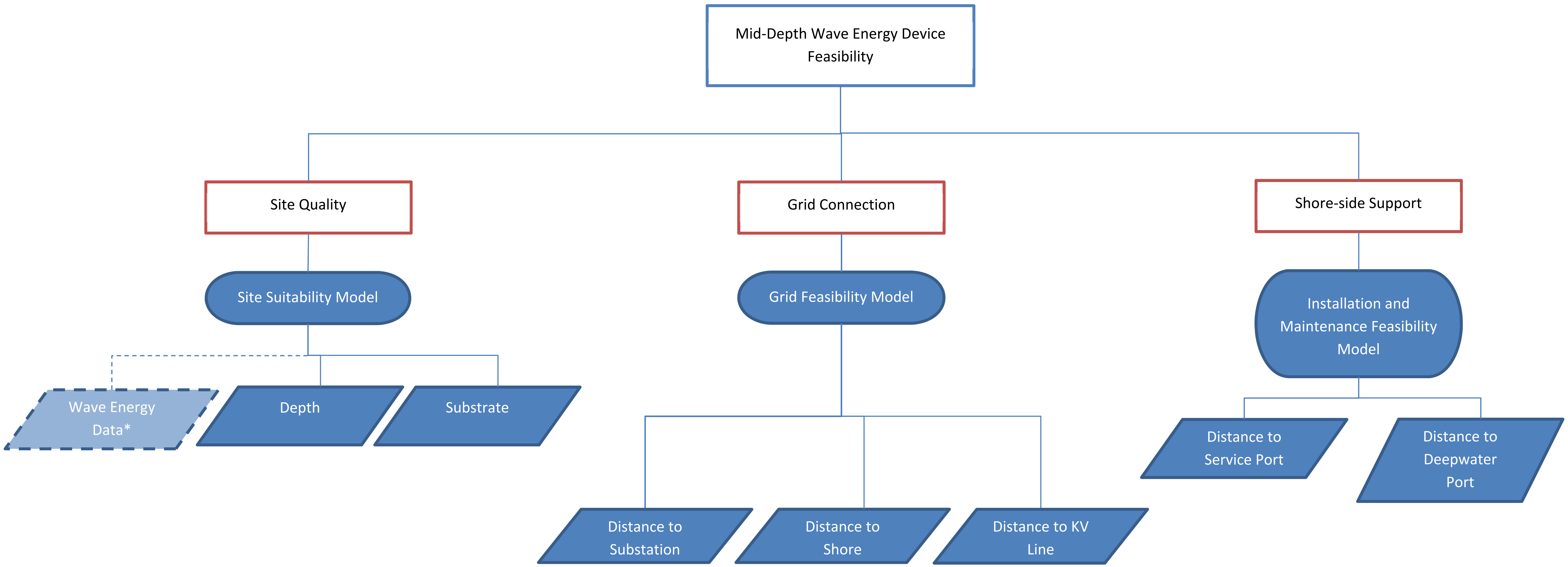
Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM < 15 NM	8
4	15 NM < 20 NM	7
5	20 NM < 25 NM	6
6	25 NM < 30 NM	5
7	30 NM < 50 NM	3
8	>50 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Deepwater Port Distance

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	10
3	10 NM < 20 NM	10
4	20 NM < 30 NM	9
5	30 NM < 40 NM	8
6	40 NM < 50 NM	7
7	50 NM < 100 NM	6
8	100 NM < 150 NM	5
9	150 NM < 200 NM	3
10	>200 NM	1

Source: Buffered distance from shoreline vector data



We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Model: **Mid-Depth Energy Production - Economically Constrained Environment**

Revision/Date: **1.8/Feb-2012**
Created By: **AR**

Function | Analysis | Data | To Be Developed | Model | Impact

Cumulative Effect Analysis Framework for Marine Renewable Energy

OregonWaveEnergy TRUST

Developed by: Parametrix aquatera.co.uk environmental services and products

Model Specifications

The economically-constrained mid-depth wave energy device feasibility model evaluates the feasibility of siting offshore oscillating water column, offshore surge, offshore flywheel, and offshore pressure wave energy devices in a pre-commercial context. In this context, wave energy devices do not generate significant revenue, and as a result, the suitability scoring reflects the financial importance of proximity to shore and a potential grid connection. The mid-depth device model combines three sub-models or functions to evaluate the feasibility of siting the device.

The three sub-models that determine mid-depth wave energy device feasibility include site quality, grid connection, and shore-side support. The site quality sub-model evaluates the suitability of a potential site to provide adequate water depths for mid-depth device operation, and the presence of a substrate suitable for anchoring a mid-depth wave energy device. The grid connection sub-model evaluates the suitability of grid access based on the Euclidean distance to a substation, distance to shore, and the Euclidean distance to the closest transmission line, or kilovolt (KV) line. While connecting to a sub-station is not anticipated to be a necessity for most pre-commercial installations, it is a relevant factor for site expansion opportunity. The shore-side support sub-model evaluates the ability of existing shore-side resources to satisfy wave energy developers' needs for access to a deep water port for device installation, and access to a service port for intermittent wave energy device operations and maintenance.

Attribute: Wave Energy Data

* We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Attribute: Depth

Ref.	Classification	Score
1	0m < 10m	1
2	10m < 20m	10
3	20m < 30m	9
4	30m < 40m	8
5	40m < 50 m	7
6	50m < 75m	4
7	75m < 85m	2
8	85m < 100m	1
9	100m < 200m	0
10	>200m	0

Source: 100m DEM Bathymetry

Attribute: Substrate

Ref.	Classification	Score
1	Rock	8
2	Shell	2
3	Gravel	10
4	Sand	2
5	Cobble	8
6	Mud	0

Source: DOGAMI

Attribute: Distance to Substation*

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM > 15 NM	7
4	15 NM > 20 NM	4
5	> 20 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Distance to Shore

Ref.	Classification	Score
1	<1 NM	10
2	1 NM < 2 NM	9
3	2NM < 3 NM	8
4	3 NM < 4 NM	7
5	4 NM < 5 NM	6
6	5 NM < 6 NM	5
7	6 NM < 7 NM	4
8	7 NM < 8 NM	3
9	8 NM < 9 NM	2
10	9 NM < 10 NM	1
11	> 10 NM	0

Source: Buffered distance from shoreline vector data

Attribute: Distance to KV Line*

Ref.	Classification	Score
1	0 <3 NM	10
2	3 NM < 6 NM	10
3	6 NM < 9 NM	8
4	9 NM < 12 NM	4
5	12 NM < 15 NM	2
6	> 15 NM	0

Source: Buffered distance from the wave energy device to KV transmission line data

*Transmission line and substation data was downloaded from Oregon Marine Map (http://www.arcgis.com/home/item.html?id=4c2a32e62b254fb08a33e4a0d1ab75b5).

Land-based distances do not reflect elevation or obstacles. All directions on land are assumed to be line-of-sight or Euclidean distances.

Attribute: Distance to Service Port

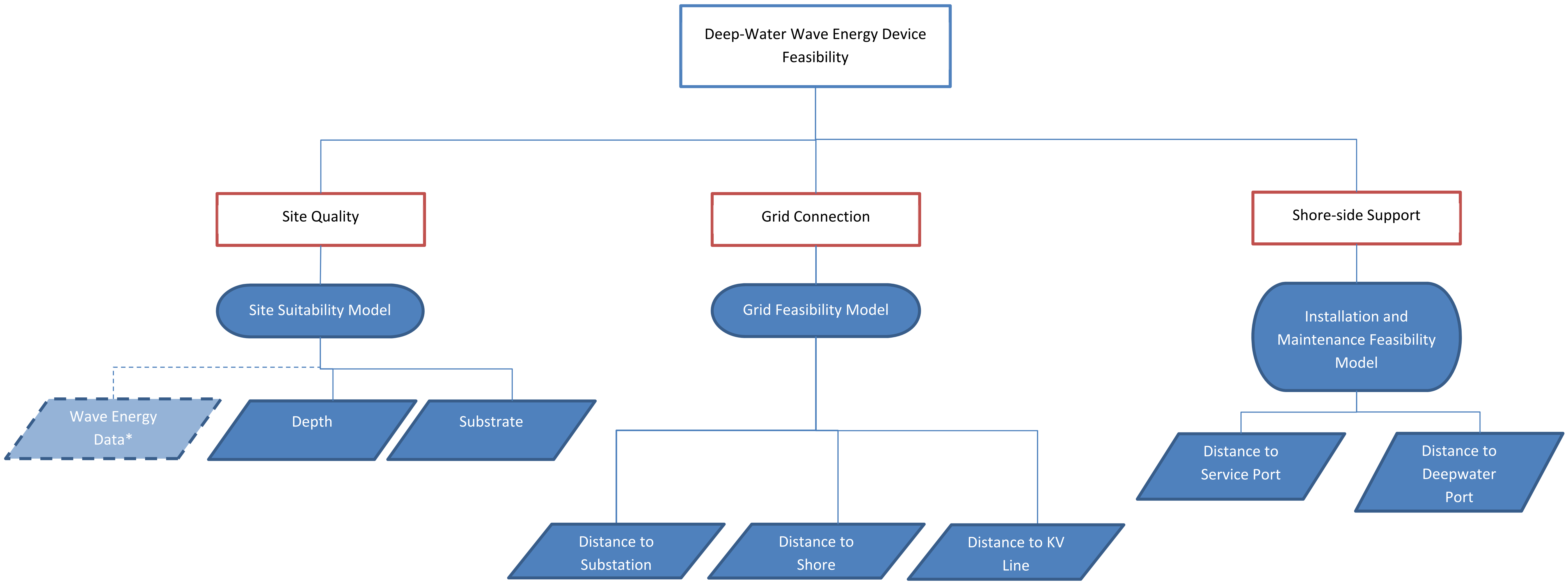
Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM < 15 NM	8
4	15 NM < 20 NM	7
5	20 NM < 25 NM	6
6	25 NM < 30 NM	5
7	30 NM < 50 NM	3
8	>50 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Deepwater Port Distance

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	10
3	10 NM < 20 NM	10
4	20 NM < 30 NM	9
5	30 NM < 40 NM	8
6	40 NM < 50 NM	7
7	50 NM < 100 NM	6
8	100 NM < 150 NM	5
9	150 NM < 200 NM	3
10	>200 NM	1

Source: Buffered distance from shoreline vector data



We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Model: **Deep-Water Energy Production – Economically Constrained Environment**

Revision/Date: **1.8/Feb-2012**
Created By: **AR**

Function | Analysis | Data | To Be Developed | Model | Impact

OregonWaveEnergy TRUST

Cumulative Effect Analysis Framework for Marine Renewable Energy

Developed by: Parametrix | aquatera.co.uk environmental services and products

Model Specifications

The economically-constrained deep-water wave energy device feasibility model evaluates the feasibility of siting offshore wave energy devices, such as point absorber and offshore attenuator/pivot devices, in a pre-commercial context. In this context, wave energy devices do not generate significant revenue, and as a result, the suitability scoring reflects the financial importance of proximity to shore and a potential grid connection.

The three sub-models that determine deep-water wave energy device feasibility include site quality, grid connection, and shore-side support.

The site quality sub-model evaluates the suitability of a potential site to provide adequate water depths for device operation, and the presence of a substrate suitable for anchoring deep-water wave energy devices. The grid connection sub-model evaluates the suitability of access based on the Euclidean distance to a substation, distance to shore, and the Euclidean distance to the closest transmission line, or kilovolt (KV) line. While connecting to a sub-station is not anticipated to be a necessity for most pre-commercial installations, it is a relevant factor for site expansion opportunity. The shore-side support sub-model evaluates the ability of existing shore-side resources to satisfy wave energy developers' needs for access to a deep water port for device installation, and access to a service port for intermittent wave energy device operations and maintenance.

Attribute: Wave Energy Data
* We have assumed all wave energy to be equal regimes along the Oregon coast and, as a result, valued as one within the model.

Attribute: Depth

Ref.	Classification	Score
1	0m < 10m	0
2	10m < 20m	0
3	20m < 30m	0
4	30m < 40m	2
5	40m < 50 m	5
6	50m < 75m	10
7	75m < 85m	8
8	85m < 100m	4
9	100m < 200m	3
10	>200m	1

Source: 100m DEM Bathymetry

Attribute: Substrate

Ref.	Classification	Score
1	Rock	2
2	Shell	5
3	Gravel	5
4	Sand	10
5	Cobble	0
6	Mud	10

Source: DOGAMI

Attribute: Distance to Substation*

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM > 15 NM	7
4	15 NM > 20 NM	4
5	> 20 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Distance to Shore

Ref.	Classification	Score
1	<1 NM	10
2	1 NM < 2 NM	9
3	2NM < 3 NM	8
4	3 NM < 4 NM	7
5	4 NM < 5 NM	6
6	5 NM < 6 NM	5
7	6 NM < 7 NM	4
8	7 NM < 8 NM	3
9	8 NM < 9 NM	2
10	9 NM < 10 NM	1
11	> 10 NM	0

Source: Buffered distance from shoreline vector data

Attribute: Distance to KV Line*

Ref.	Classification	Score
1	0 <3 NM	10
2	3 NM < 6 NM	10
3	6 NM < 9 NM	8
4	9 NM < 12 NM	4
5	12 NM < 15 NM	2
6	> 15 NM	0

Source: Buffered distance from the wave energy device to KV transmission line data

*Transmission line and substation data was downloaded from Oregon Marine Map (http://www.arcgis.com/home/item.html?id=4c2a32e62b254fb08a33e4a0d1ab75b5).
Land-based distances do not reflect elevation or obstacles. All directions on land are assumed to be line-of-sight or Euclidean distances.

Attribute: Distance to Service Port

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	9
3	10 NM < 15 NM	8
4	15 NM < 20 NM	7
5	20 NM < 25 NM	6
6	25 NM < 30 NM	5
7	30 NM < 50 NM	3
8	>50 NM	1

Source: Buffered distance from shoreline vector data

Attribute: Deepwater Port Distance

Ref.	Classification	Score
1	<5 NM	10
2	5 NM < 10 NM	10
3	10 NM < 20 NM	10
4	20 NM < 30 NM	9
5	30 NM < 40 NM	8
6	40 NM < 50 NM	7
7	50 NM < 100 NM	6
8	100 NM < 150 NM	5
9	150 NM < 200 NM	3
10	>200 NM	1

Source: Buffered distance from shoreline vector data