ET 3 - Site selection

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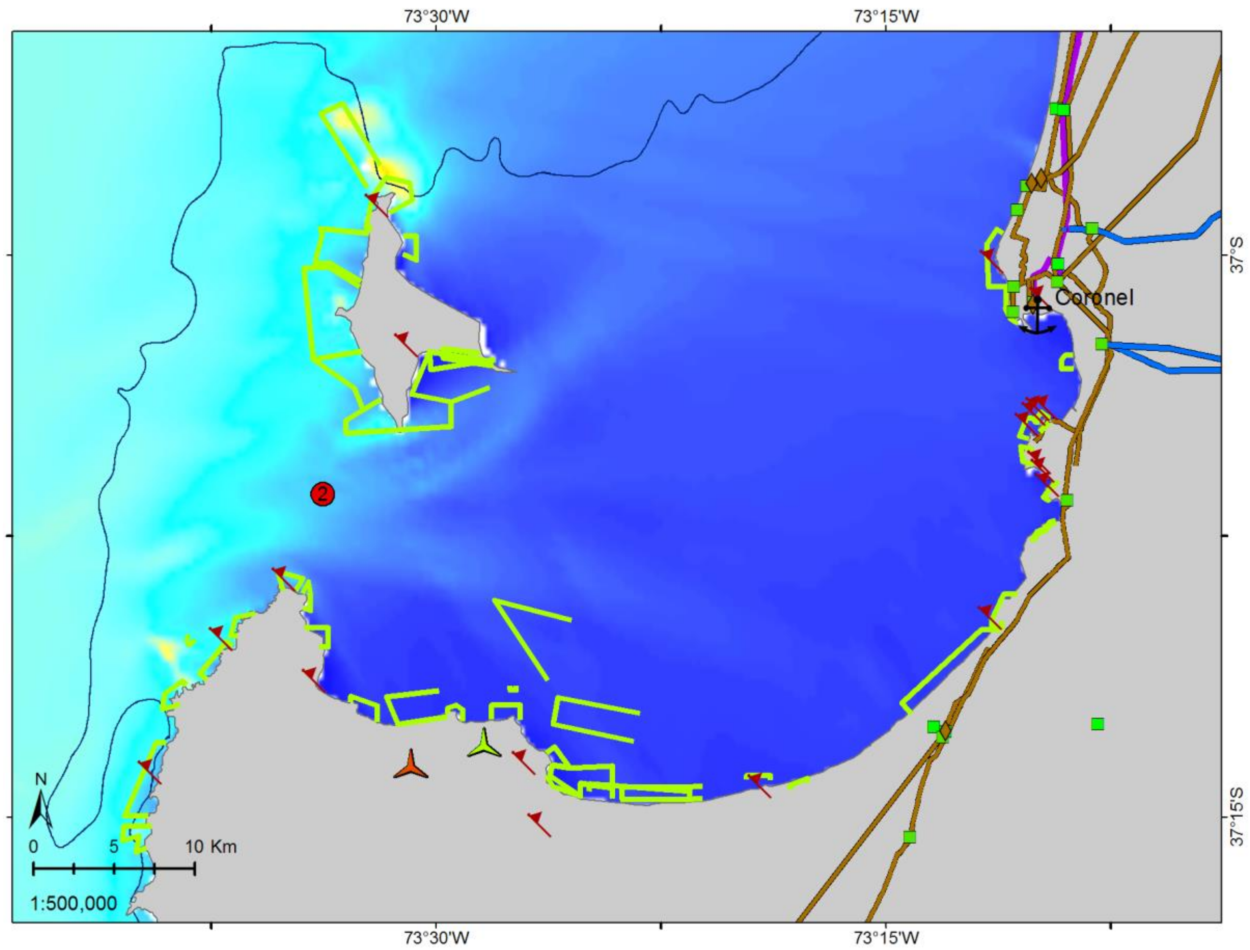
Co-funded by the
Erasmus+ Programme
of the European Union

Overview of module

- Site assessment
  - Why mapping tools
  - Introduction to RADMAPP Tool
  - Site Selection Assessment
  - Case study example

OVERVIEW



Reference: Santa María island Chile analisys. Source: Aquatera Ltd.

Looking at best practices to improve project reliability & profitability by:

- Understanding the challenges involved in site selection
- Outlining the key issues, opportunities, and risks involved in establishing profitable sites
- Introducing the RERA model that has been successfully used to site proposals for 1500 MW of wave and tidal capacity

MAPPING TOOLS

WHY INCLUDING MAPPING TOOLS

- Used to identify and compare possible sites
- Uses unlimited criteria
- Can be tuned to particular technologies
- Used for detailed design of sites
- To determine optimum site boundaries and layouts
- Updateable with latest survey results, technology performance and infrastructure solutions

Why?

Tool for decision making

Quality and accuracy of analysis

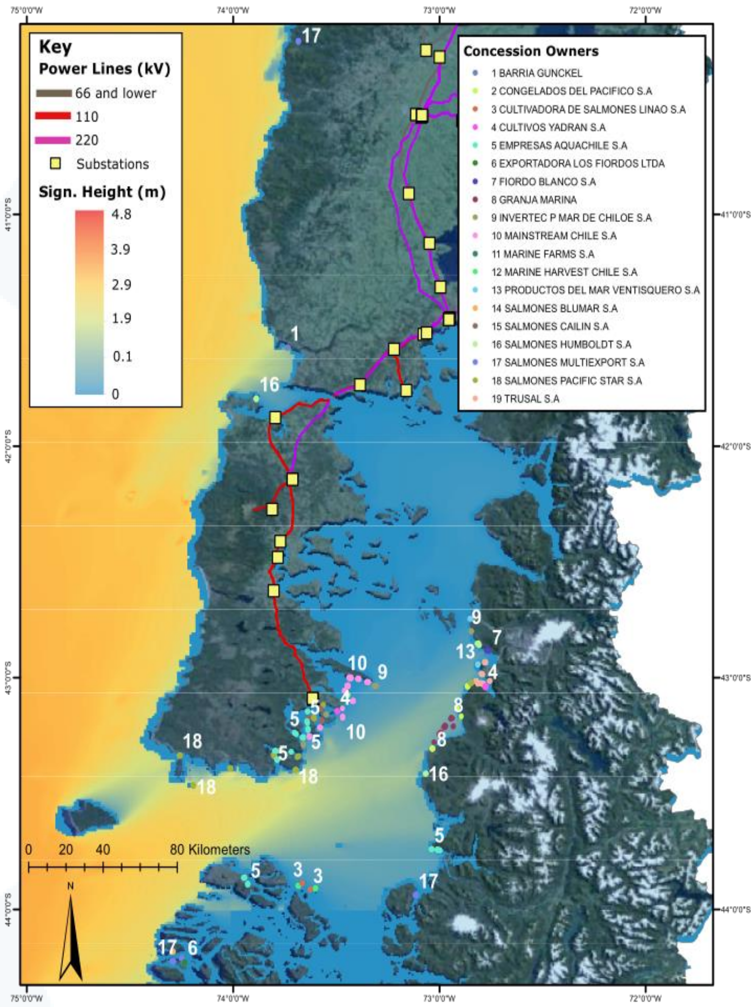
Supply chain development analysis

Synoptic tool for strategic communication and business development

Others: educational, community develop,etc.

MAPPING Analysis

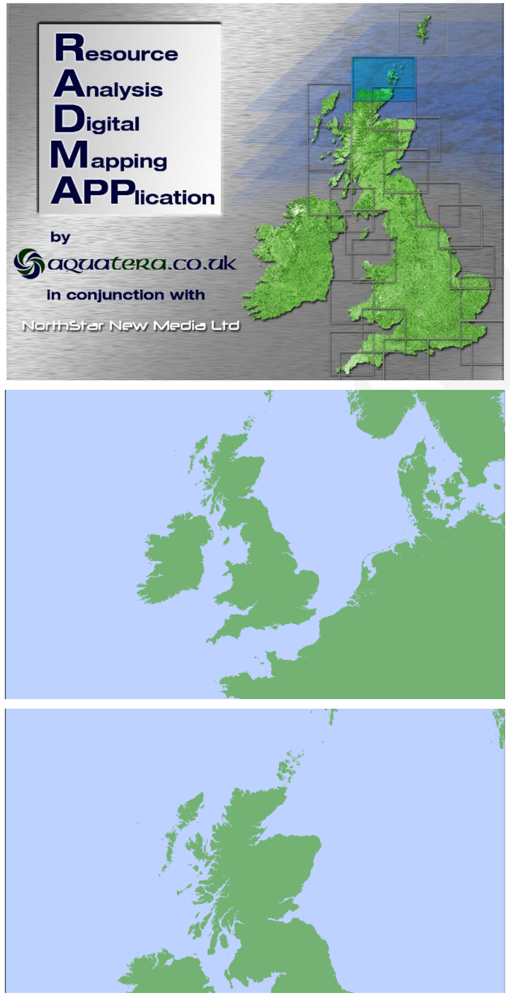
- **Site Development**
- **Project - Technical Assessment**
- **Cost Assessment**



Data Source:
Wave resource information Courtesy of Chilean Ministry of Energy and University of Chile, based on 2010 year simulations through WRF model.
Salmon farms, Servicio Nacional de Pesca y Acuicultura, Concesiones 2013.

Reference: Recommendations for marine energy development in Chile, Los Lagos Region analysis. Source: Aquatera Ltd.

INTRODUCTION TO RADMAPP TOOL

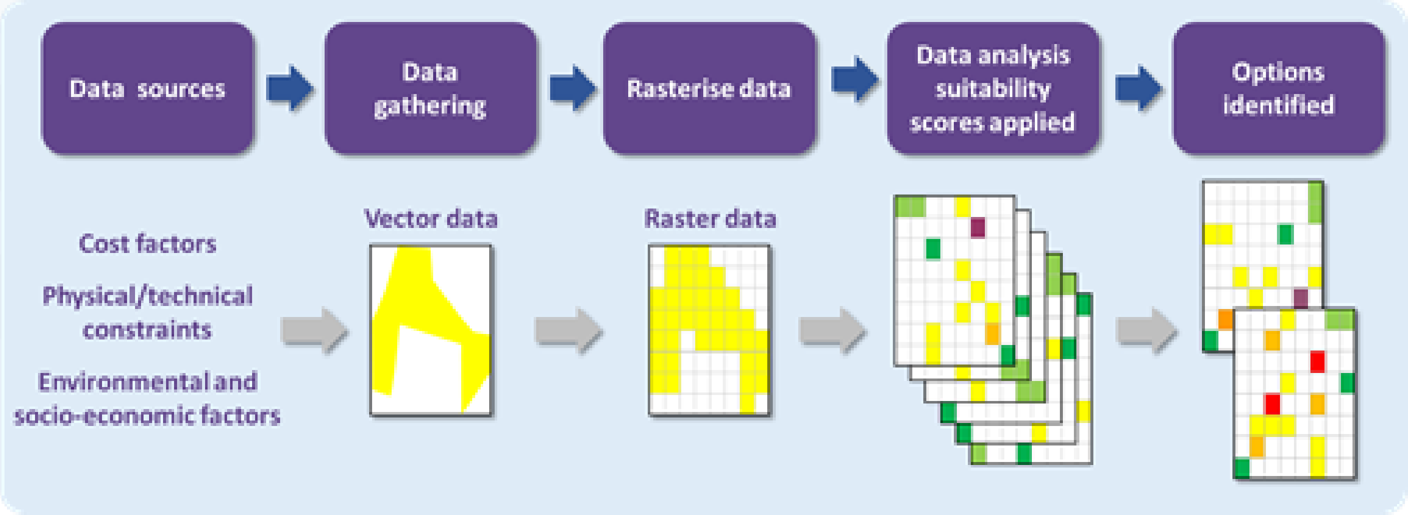


- RADMApp provides a grid cell spatial analysis tool for an infinite number of criteria associated with a development or other spatial activity
- Undertaken at Global, National, Regional, and Community levels, RADMApp provides a detailed, yet adaptable approach to predicting possible development scenarios
- Following a consistent approach in different locations creates the potential for integrating outputs across a wider area and for area comparisons

Reference: RADMAPP display screenshots. Source: Aquatera Ltd.

RADMApp TOOL

- Initially we establish a grid cell model of the area
- We then gather information about the distribution of factors associated with the development
- Each parameter of each factor is scored in terms of it's "suitability" in relation to the development
- A model is then used to generate a result for a given set of conditions
- Can be used to examine "what if" scenarios

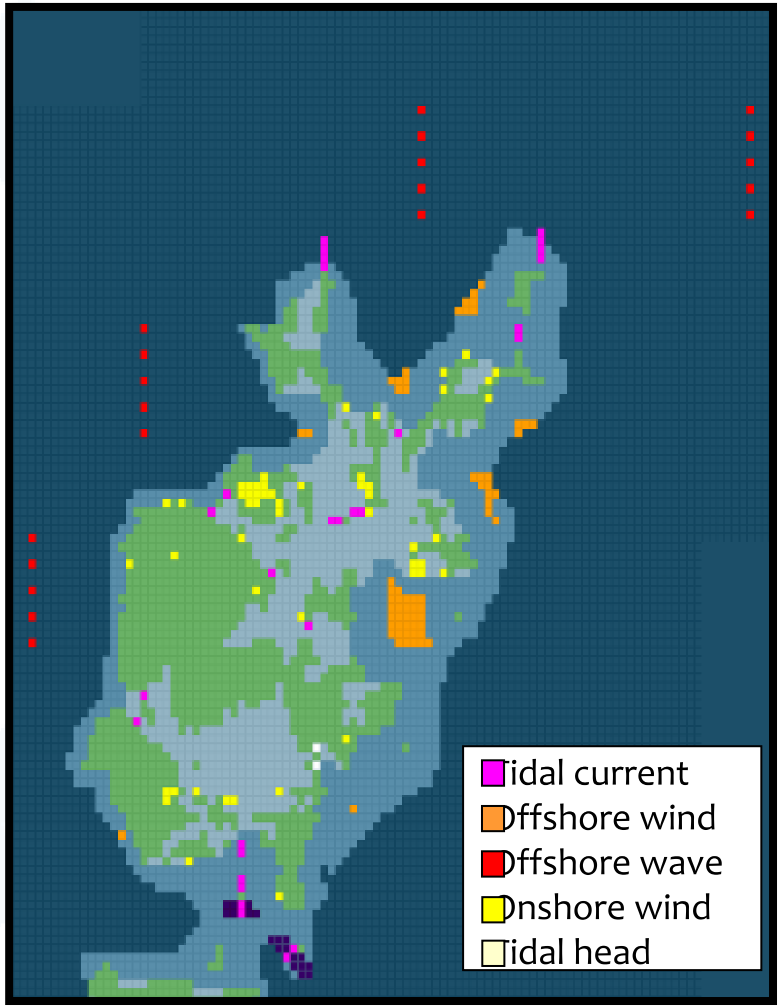


Reference: RADMAPP layer method analysis. Source: Aquatera Ltd.

Mapping tools history - RERA model

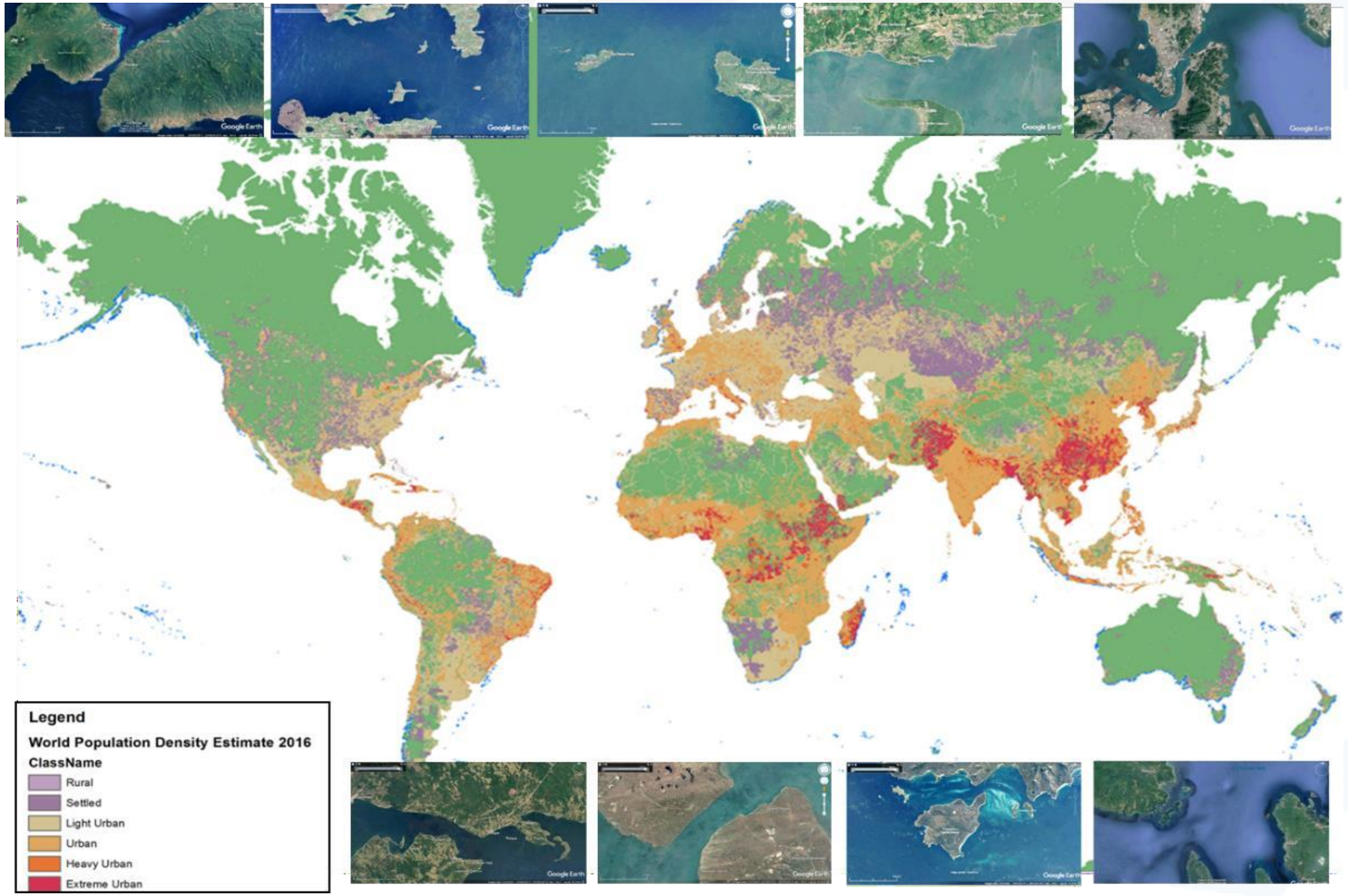
Energy category	Acceptability scenario		
	High	Medium	Low
	Installed generation capacity (MW)		
Current energy use	201	201	201
R & D	8	11	17
Existing/approved wind	23	23	23
Total installed capacity (MW)	**1603**	**3177**	**5158**
Annual power production (GWh)	**5580.1**	**11057.6**	**17951.3**
Energy income (£M@1.2p/kWh)	**67.0**	**132.7**	**215.4**
ROC income (£M@4.6p/kWh)	**256.7**	**508.6**	**825.8**

Energy category	Acceptability scenario		
	High	Medium	Low
	Installed generation capacity (MW)		
Tidal current	**1462**	**2443**	**3571**
Offshore wind	**0**	**385**	**986**
Offshore wave	**101**	**226**	**226**
Onshore wind (1 MW units)	**0**	**46**	**256**
Tidal head	**1**	**6**	**7**
Coastal wave	**0**	**0**	**0**
Energy efficiency	19	33	47
Micro-renewables	16	29	47
Biomass crops	3	7	14
Biomass harvest	2	3	3
Bio-digestion	0.1	0.4	0.7
Energy from waste	0	0	0



Reference: RERA tool previous to RADMAPP. Source: Aquatera Ltd.

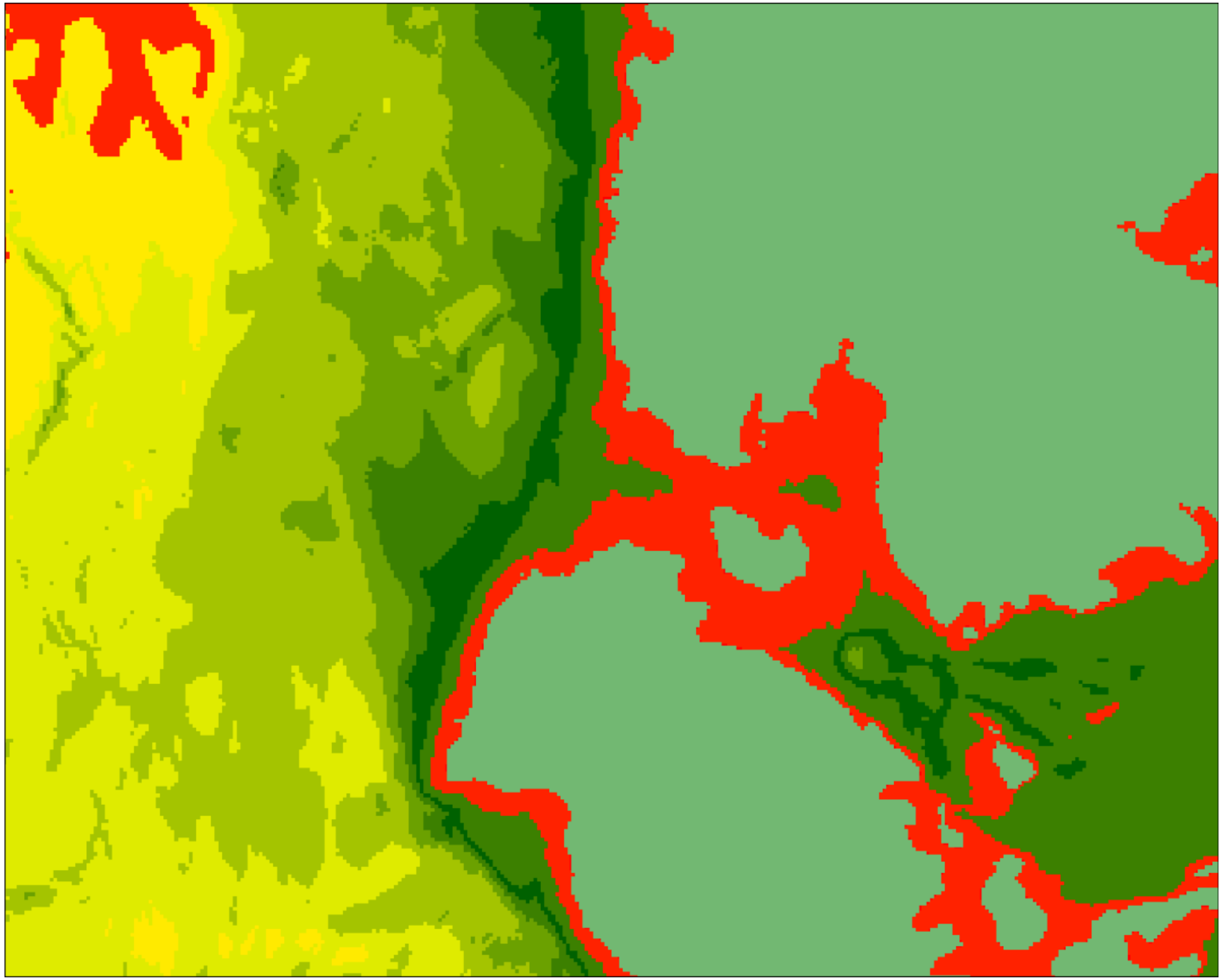
RADMApp TOOL



- RADMApp tool sets the world in a grid of 500 million 1 km2 square information cells and 1.6 million coastal km.
- The first step is to determine the study area
- A grid cell based study area is then created, for example 100m x 100m as shown in the World Population density map in the left.

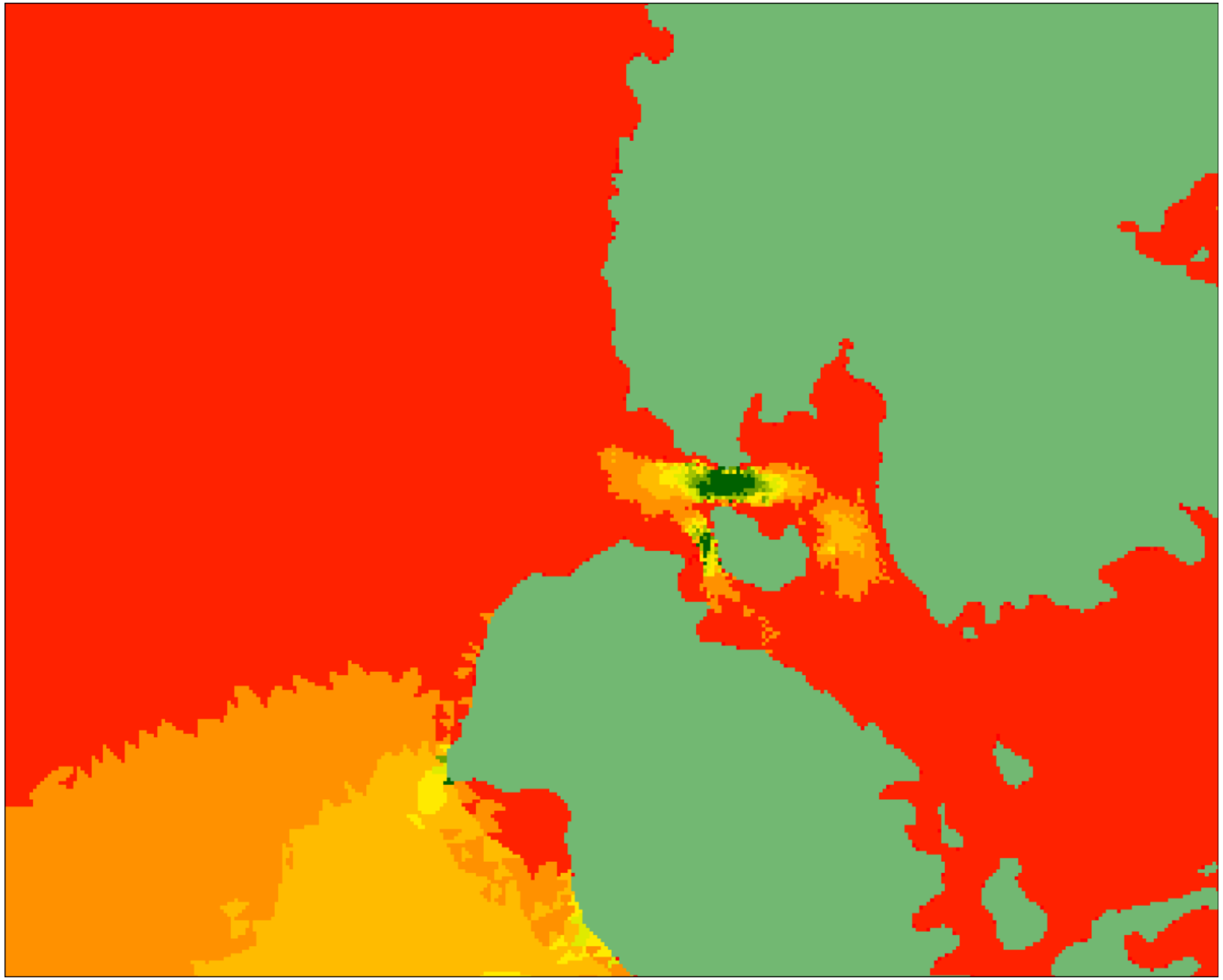
Reference: World map, Aquatera Ltd.

Marine site development Technical Factors - Bathymetry example



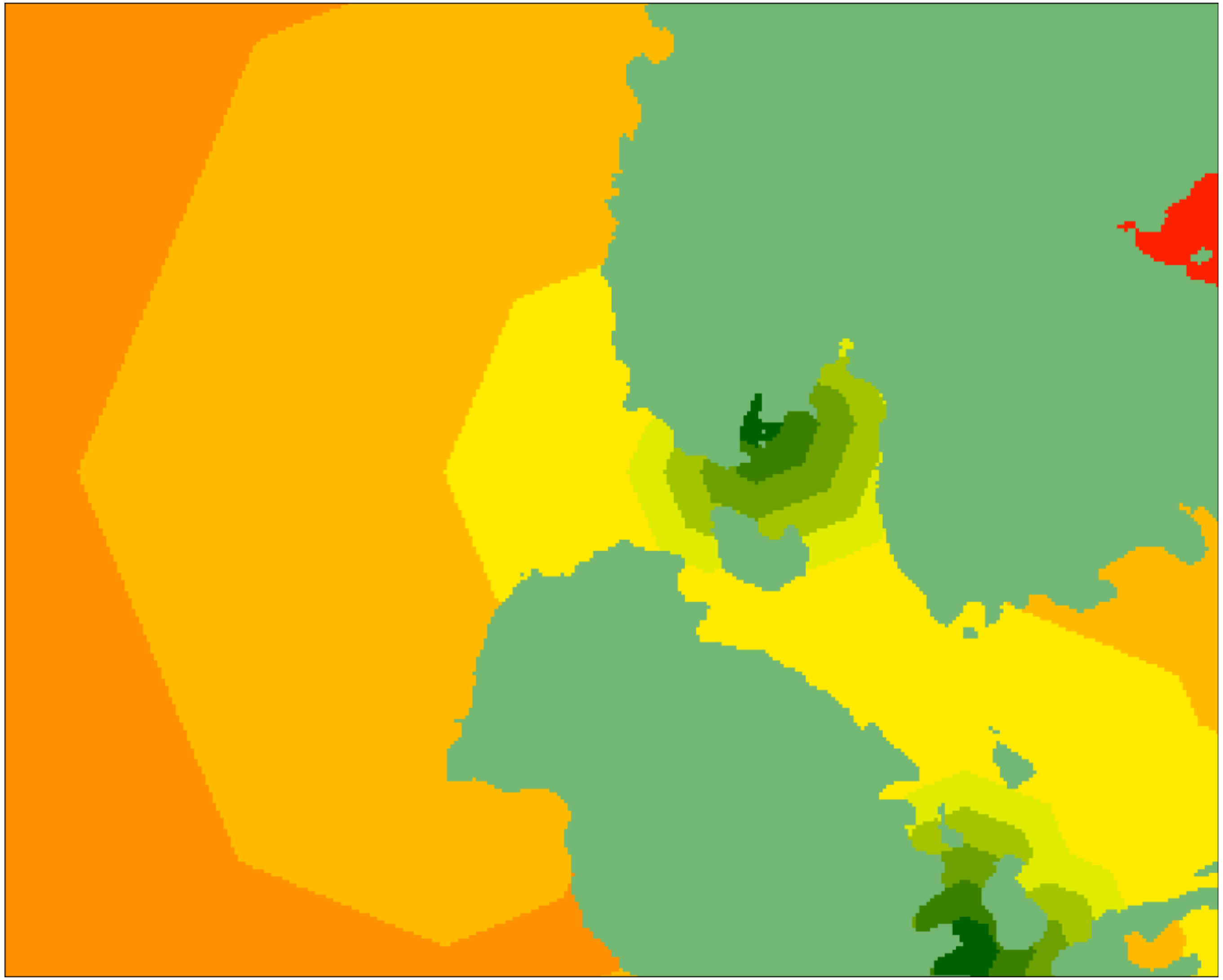
- Each parameter is converted from it's raw format to a rasterised format of the same spatial dimensions as the study area
- As these bathymetry data are already in raster format, they are simply resampled to the correct dimensions and orientation
- Using the scoresheet, each cell in the parameter is re-scored

Marine site development Resource Factors - Tidal example



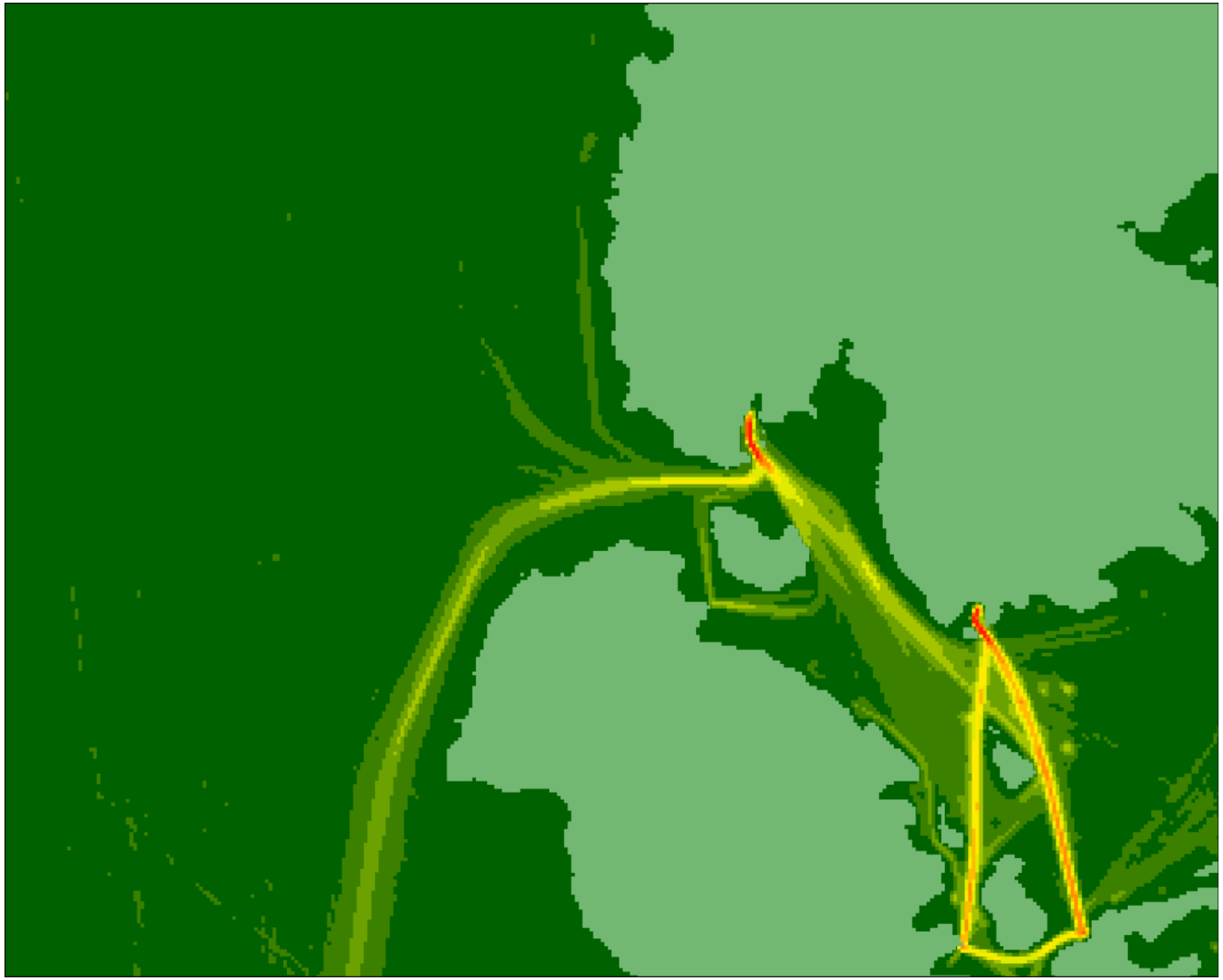
- These raw tidal data are provided as vector polygons of information
- The vector data are rasterised to the same 100m x 100m grid
- Again, using the scoresheet, each cell in the parameter is re-scored

Cost Factors example



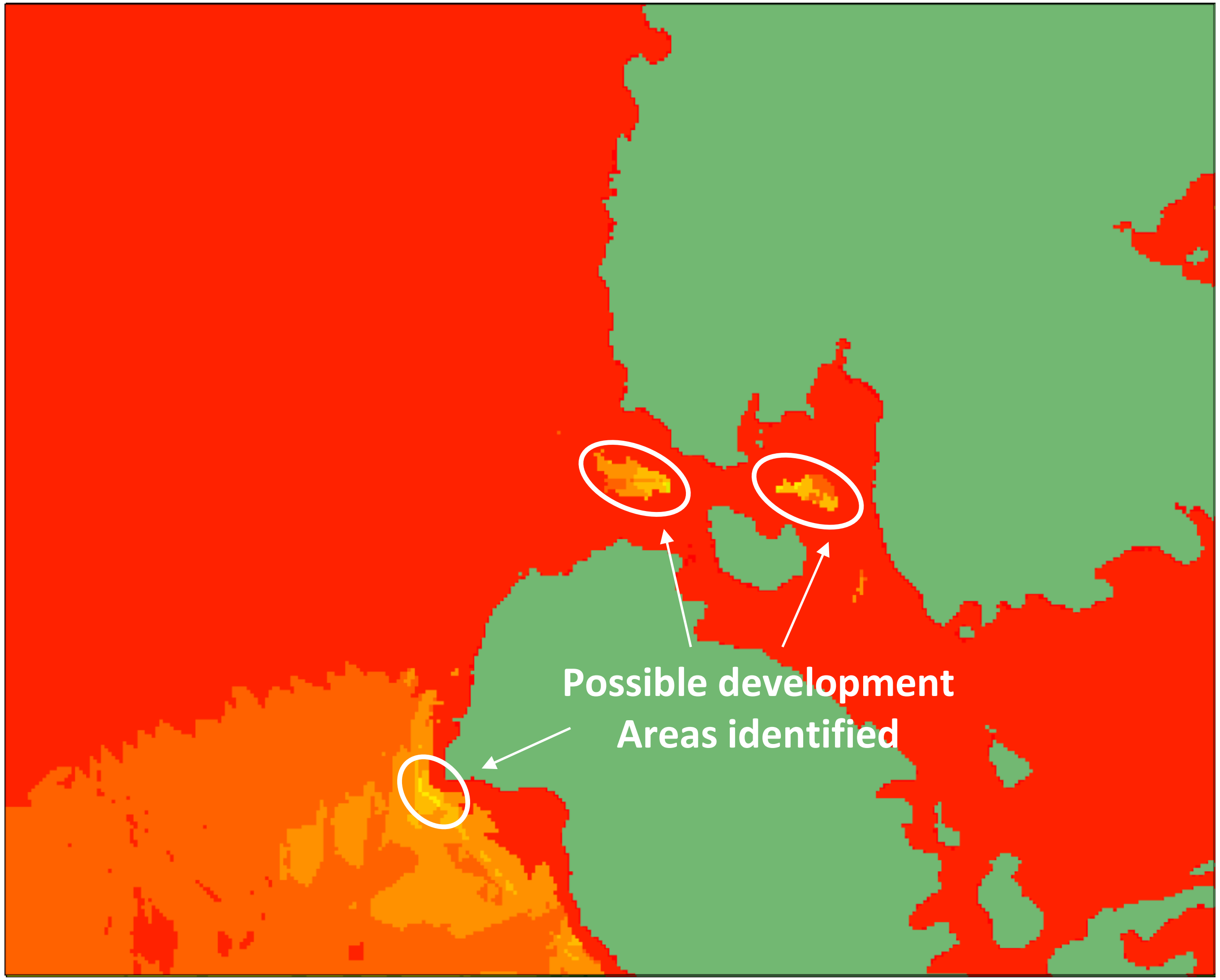
- Port locations are provided as point data
- Again, the vector data are rasterised, but this time, an additional distance calculation is applied providing the distance of each grid cell from the nearest port
- This raster distance map can then be combined with the scoresheet parameters

Socio-Economic and Environmental



- Shipping data are here represented by vector lines
- This time the model converts the lines into the raster grid format
- The data are then re-evaluated by the model to show the density of vessel transits per grid cell
- This density map is then re-scored based on the scoresheet

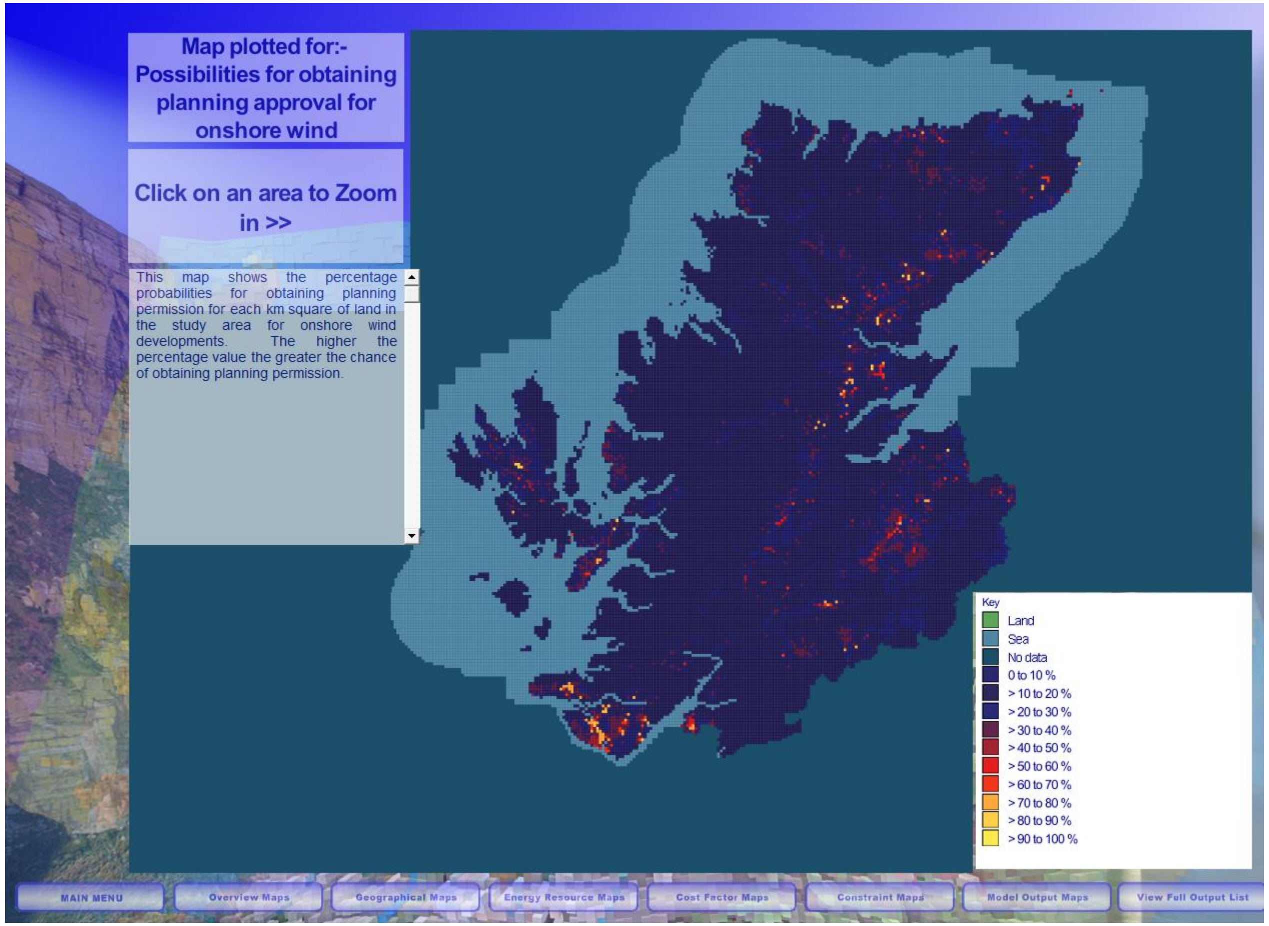
All Scored Data Combined



- Once all the individual parameters have been re-scored, the model combines these layers to produce a final output
- The final map, referred to as a suitability, or heat map, allows the user to determine potential sites for further investigation
- If data are available, a higher resolution RADMApp analysis can be carried out on these sites
- The RADMApp tool also allows the user to alter the scoresheet and quickly produce new outputs to contrast and compare technologies and options

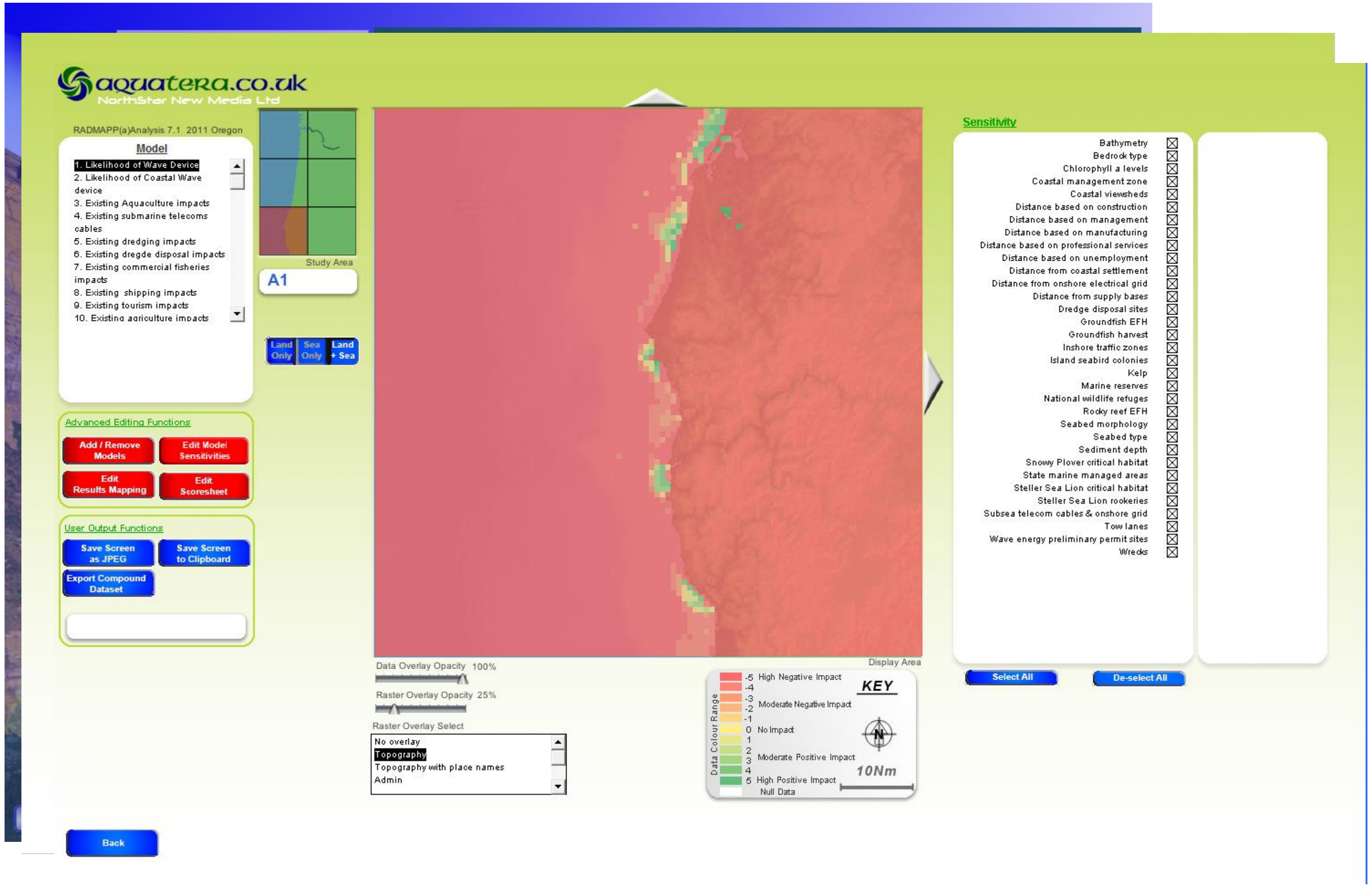
aquatera environmental services and products

Previous uses of RADMApp



- RADMApp has been used for numerous site selection and spatial data analyses for various industries in multiple locations around the globe
- One of the first projects was to look at development potential for all renewables in the Highland Region of Scotland
- Several year's later, RADMApp was used to assess the cumulative impact of marine renewables off the Oregon Coastline
- More recently Aquatera have worked with the Oil and Gas Technology Centre to use RADMApp to identify how marine renewables can support extraction from marginal pools

Previous uses of RADMApp



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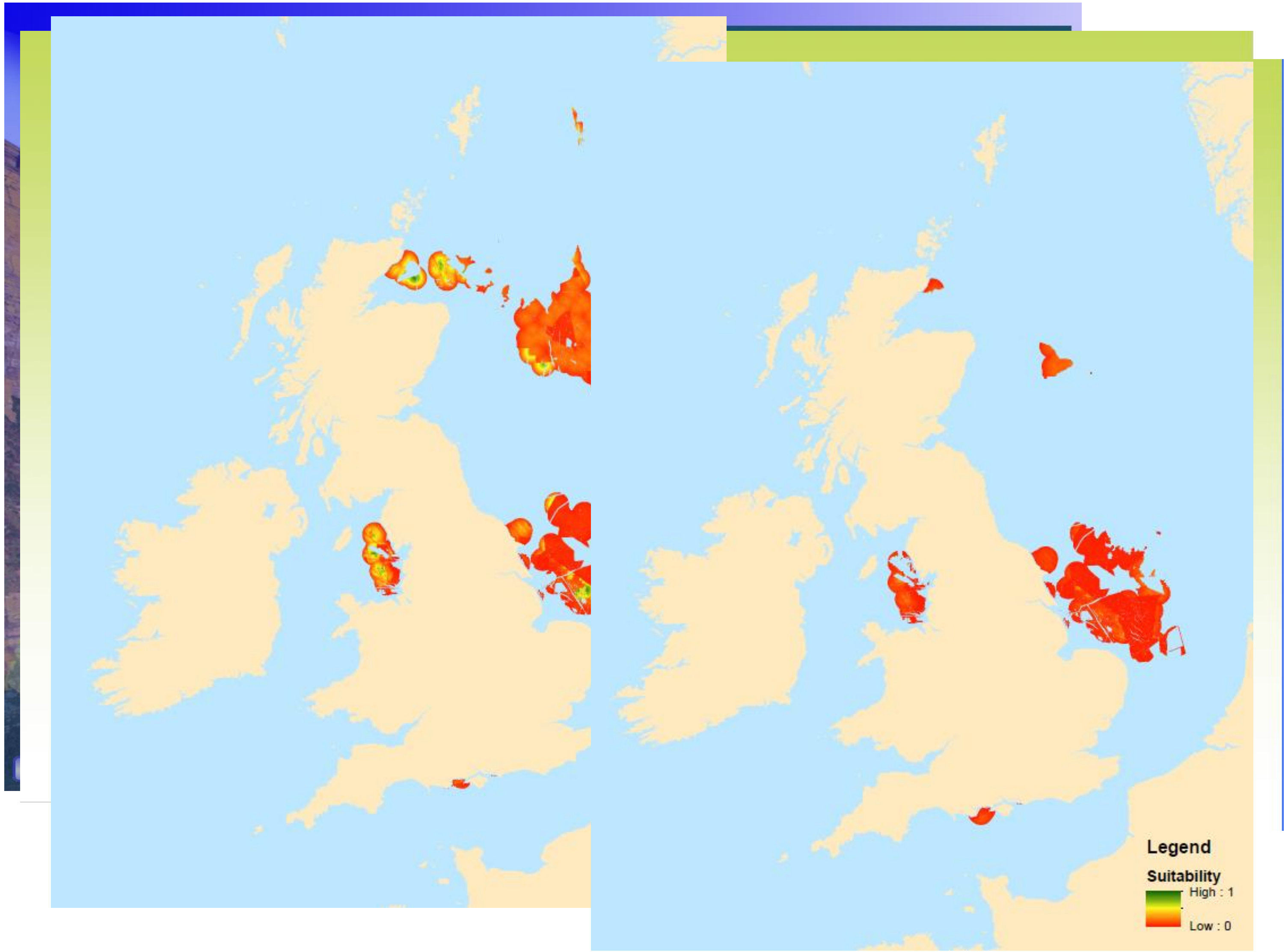

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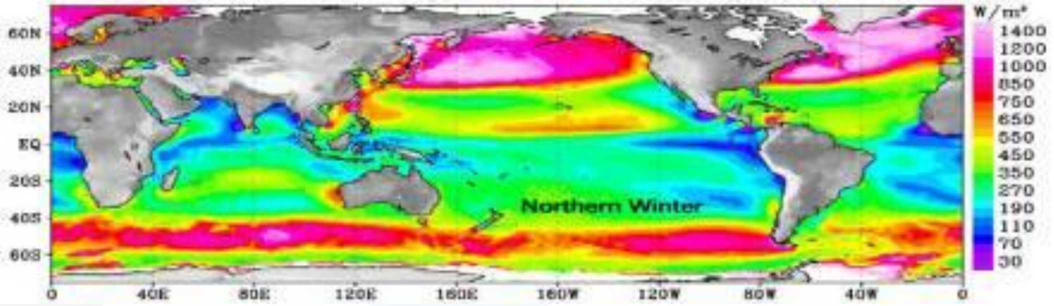
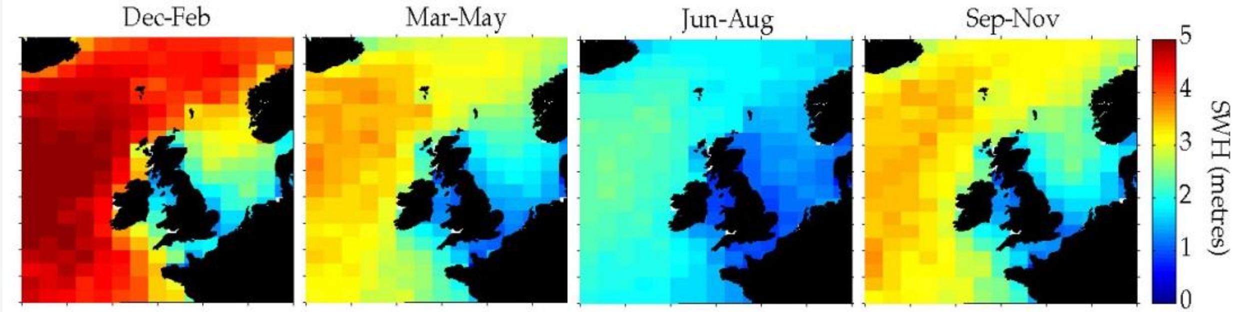
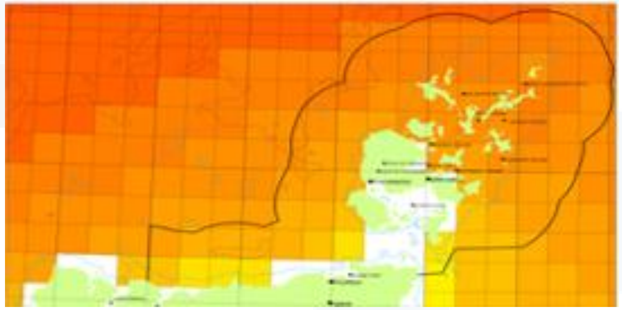
SITE SELECTION ASSESSMENT

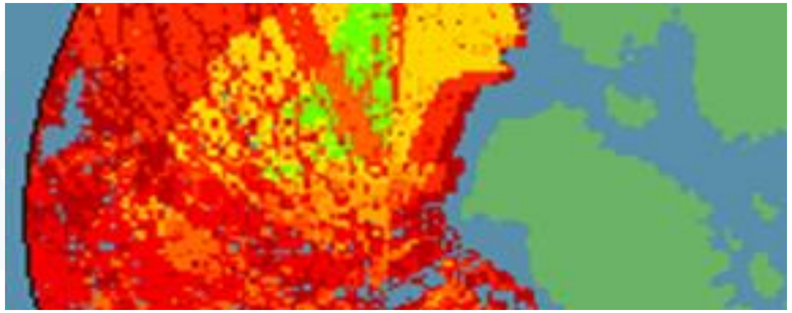
Site Selection Assessment - location

- Right part of the world
- Right country
- Right region
- Right site









Reference: (1) Wave world potential, (2) SWH UK, (3) Radmapp examples, Source: Aquatera Ltd.

Site Selection Assessment - objectives

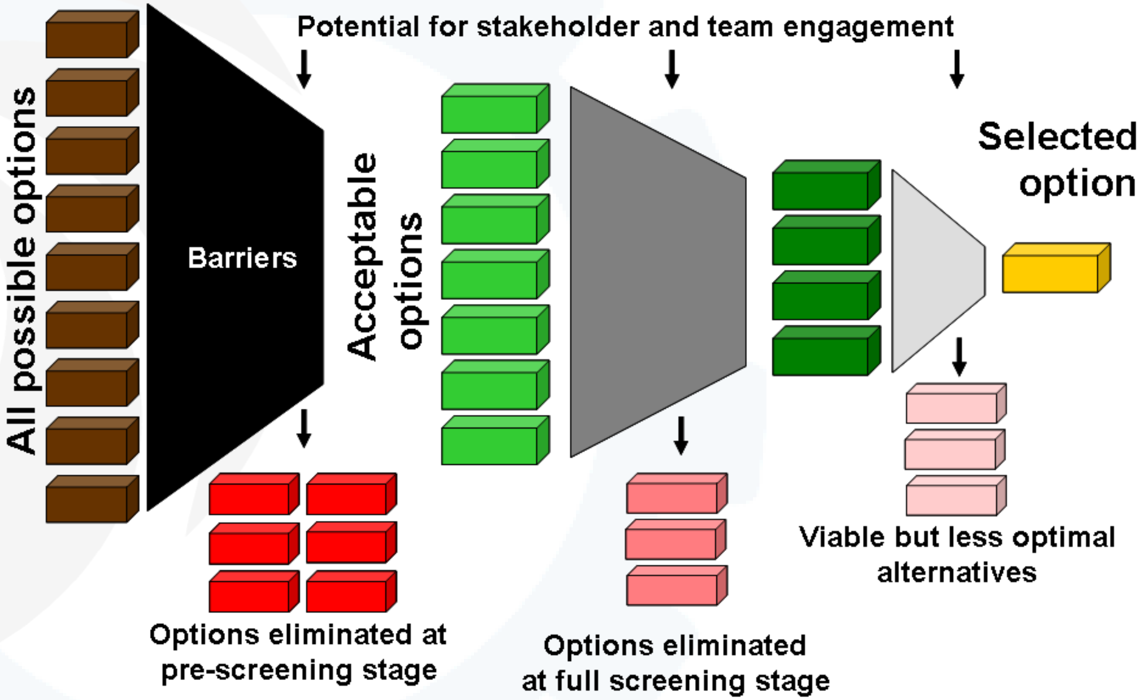
Why, what, how, when?

- Resource level & pattern
- Maximum size, average power
- Technical limits
- Seabed type, water depth, current regime
- Political needs
- Jobs, grant sources, home territory
- Planning constraints
- Avoid, reduce or manage constraints
- Accessibility
- Visible from shore, close to port, close to grid
- Cost and revenue
- Low capital, low operational, maximum tariff
- Scale (short and long term)
- Prototype, demonstration, small & large commercial
- Timescale
- Now, 5 years, 10 years +
- Pioneer or follower
- First and only, early (top 3), in the pack

Site Selection Assessment - prioritize

Typical pathway:

- Consider all options
- Identify barriers and imperatives
- Establish levels of acceptability
- Compare options with one another
- Optimise and confirm selection



"Optioneering" process

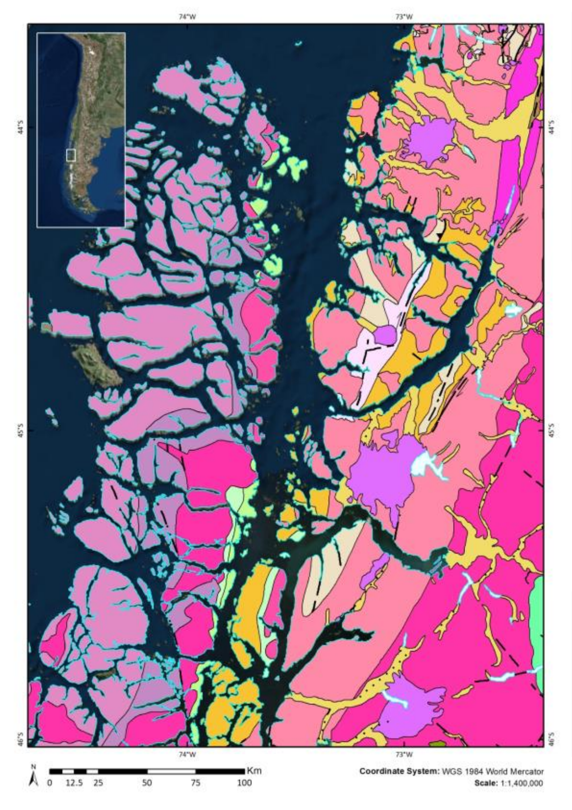
Reference: *Optioneering* method for decision making. Source: Aquatera Ltd.

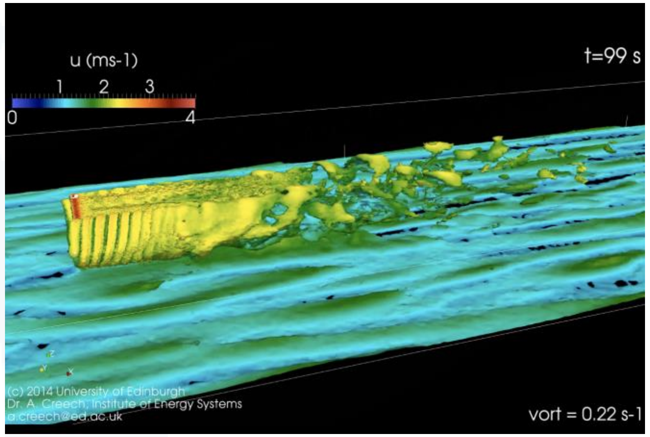
Key issues to consider in site selection

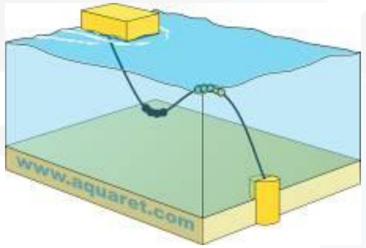
Examples of key parameters:

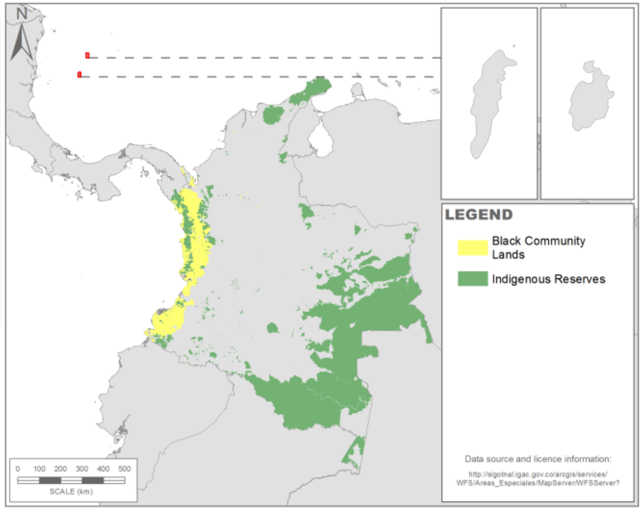
- Resources
- Technical feasibility
- Planning constraints
- Costs and revenue
- Infrastructure
- Social and cultural issues
- Resource patterns
  - Typical conditions
  - Seasonality
  - Extreme conditions

- Data sources
  - Satellite data
  - Buoy data
  - Radar data
  - Modelled data









Reference: (1) Geology Aysen Chile map, Sernagiomin 2009, (2) CFD dual rotor tidal turbine, Institute Energy Systems, University of Edinburgh, (3) AQUARET anchor system, (3) Social protected area in Colombia. Source: Aquatera Ltd.

SITE SELECTION - SCORESHEET EXAMPLE

- A score sheet is then populated for all the parameters to be used in the model

Category	Data Set	Sub Value	Score
Technical	Water Depth	< -80 m	1
		-80 m to -70 m	0.8
		-70 m to -60 m	0.6
		-60 m to -50 m	0.2
		> -50 m	0
	Wave Height (annual mean Hs)	< 2.25 m	1
		2.25 m to 2.5 m	0.9
		2.5 m to 3 m	0.8
		> 3 m	0.7
	Tidal Current Speeds (annual mean spring pe	< 0.5 m/s	1
		0.5 m/s to 1 m/s	0.8
		1 m/s to 1.5 m/s	0.5
		1.5 m/s to 2 m/s	0.3
		> 2 m/s	0.2
	Quaternary Sediment Depths	< 5 m	0.7
		> 5 m	1
	Wind Speeds	< 9 m/s	0.6
		9 m/s to 10 m/s	0.8
		> 10 m/s	1

Cost	Distance to substation	< 50 km	1
		50 km to 100 km	0.8
		100 km to 150 km	0.6
		150 km to 200 km	0.4
		200 km to 250 km	0.2
		> 250 km	0.1
	Distance from port	< 50 km	1
		50 km to 100 km	0.9
		100 km to 150 km	0.8
		150 km to 200 km	0.7
		200 km to 250 km	0.6
		> 250 km	0.5
Environmental	Marine Conservation Zone	Yes	0.8
		No	1
	Marine Protected Area	Yes	0.8
		No	1
	Ramsar	Yes	0
		No	1

Reference: Scoresheet Radmapp example. Source: Aquatera Ltd.

KEY ELEMENTS

Site Development

- Physical
- Environmental
- Human

Project - Technical Assessment

- Technology and project design
- Installation, O&M, Decommissioning
- Other decision making

Cost Assessment

- Offshore equipment & operations
- Construction
- Planning and legal costs

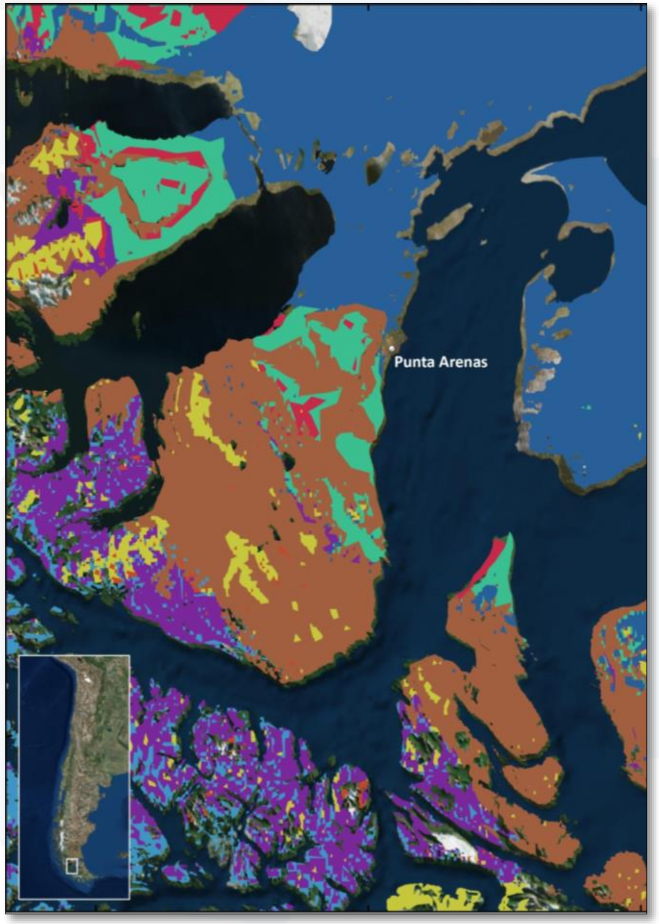
- Restrictions
- Resource potential
- Site definition
- Design data (moorings, cable protection etc.)
- Hazards

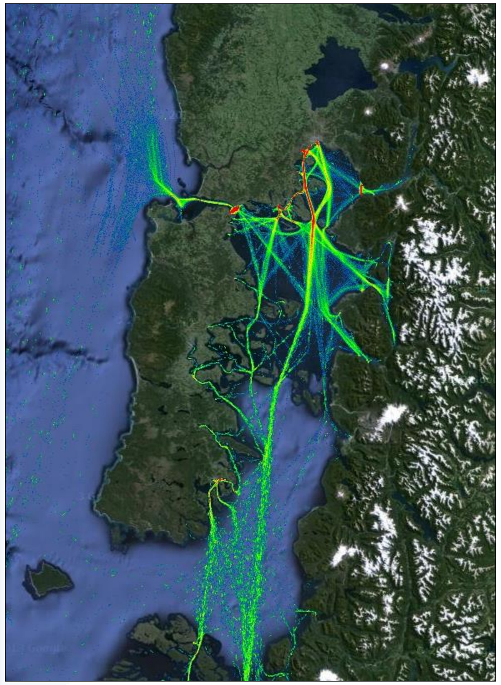
- Project dimensions (cable size, cable length)
- Monitoring
- CAPEX
- OPEX
- LCOE

SITE DEVELOPMENT MAPPING ELEMENTS

- Mapping enables accurate qualitative and quantitative analysis

Factor	Elements
Phisical	• Resource characteristics and patterns • Depth and bathymetry • Seabed type • Geology and seabed conditions (rugosity, morphology) • turbulences and currents
Environmental	• Fauna and flora • Conservation areas • Weather conditions (e.g. El Nino events)
Human	• Other sea users • Navigational risks • Landscape and seascape • Archaeology cultural heritage;

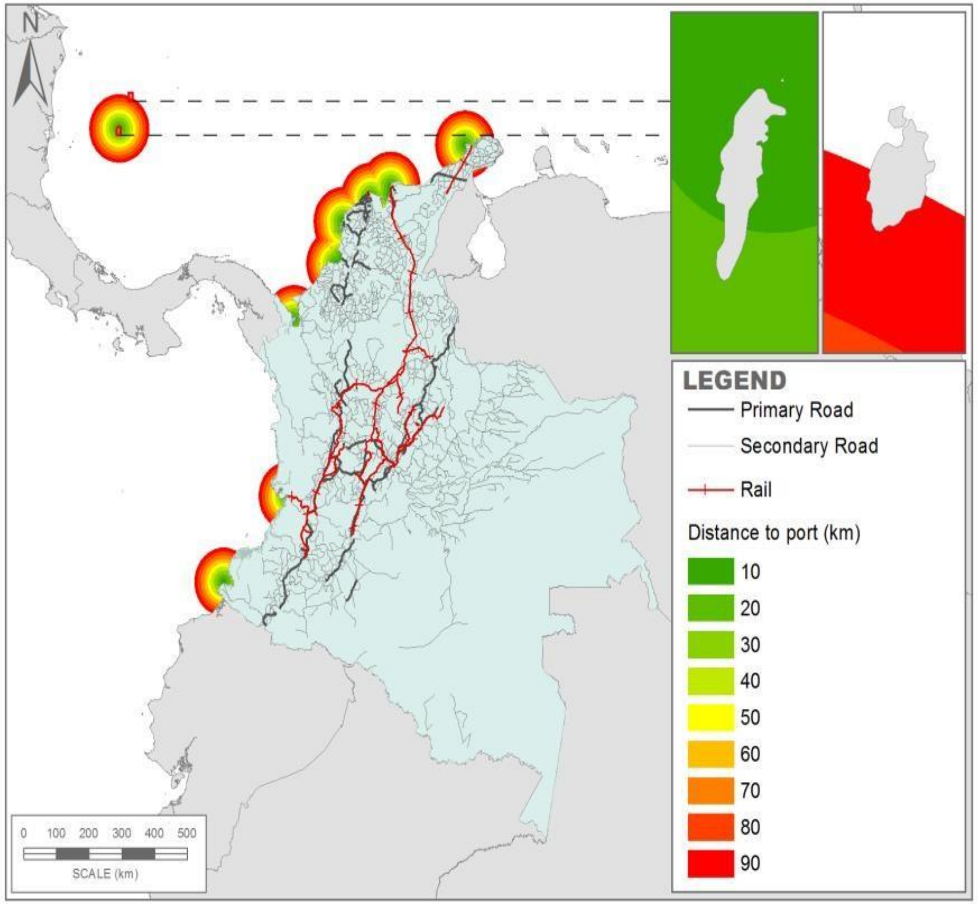




Reference: (1, left) Sernagiomin Chile geology, (2, right- above)Open sea Marine traffic, (3, right below) Aquatera Ltd.Orkney images.

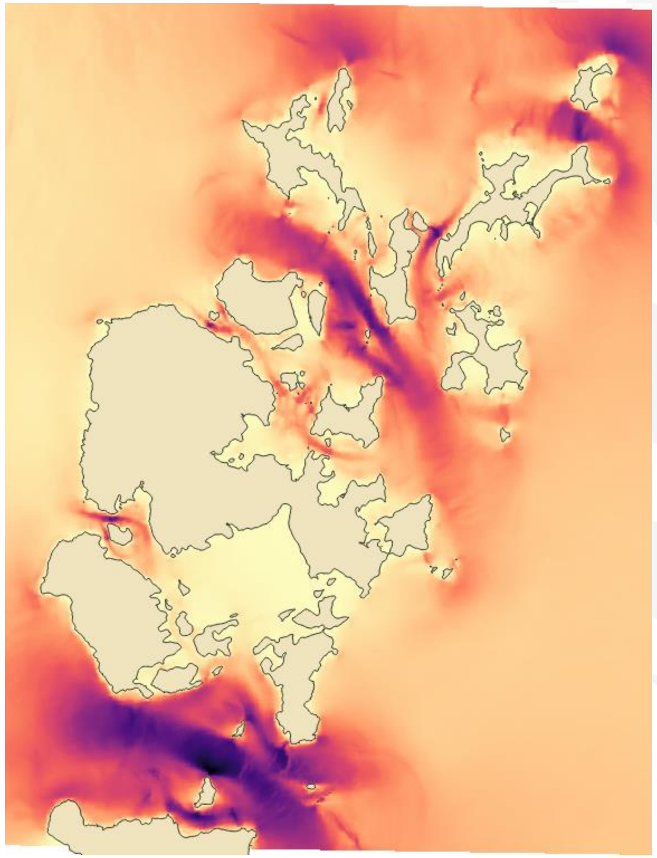
TECHNICAL ASSESMET MAPPING

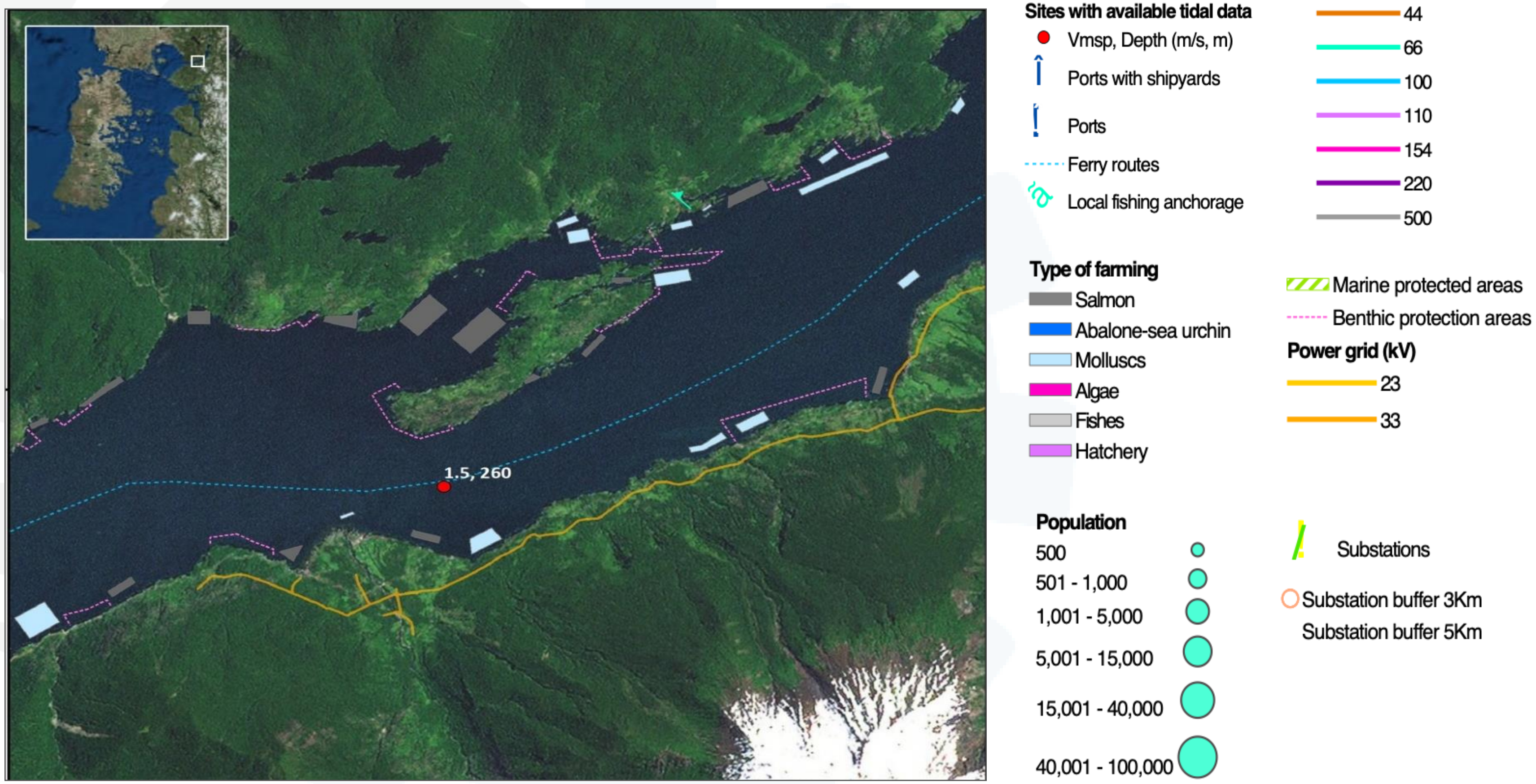
Factor	Elements
Technology and project design	• Technical resource potential • Technology and foundations dimensions • Geotechnical studies • Seabed gradient • Hazards (vessels, collisions, etc.)
Installation Operations, Maintenance Decommissioning	• Distance to port and shore • Substation existence • Site accessibility • Supply chain availability, • Harbours • Decommissioning infrastructure • Weather windows etc. • Dimensions of project (technology, moorings, etc)
Other decision making	• Areas with previous MRE project development, research, experts, etc. • Community acceptance of technology, • Existence of gensets in the locality



Reference: Radmapp example. Source: Aquatera Ltd.

ASSESSMENT EXAMPLES





Reference: (1, left) LCOE radmapp example, source Aquatera.

Reference: (2, right) Radmapp site selection analysis example, source: Aquatera.

SITE ASSESSMENT - PLANNING INFRASTRUCTURE

- Supply chain
  - Materials
  - People
  - Communities
- Manufacture and fabrication
- Assembly and loadout
- Offshore connections
  - Subsea cables
  - Connection platforms

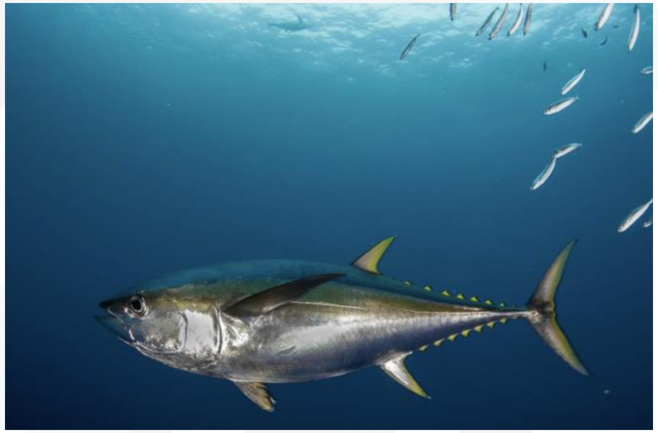
- Specialist vessels and workboats
- Onward energy transport
- Grid
- Other

Reference: Multi category workboats in Orkney and OpenHydro´s Installation Barge, source: OpenHydro.

Reference: Dynamic Positioning (DP) vessels deployed at EMEC’s tidal test site to install tidal turbines and support structures, source: EMEC.

PLANNING CONSTRAINS

- Shipping
- Fishing
- Seabirds
- Sea mammals
- Seabed communities
- Conservation areas



Reference: (1) Yellowfin tuna (2) Atlantic puffin, (3) Atlantic salmon, source: Oceana.

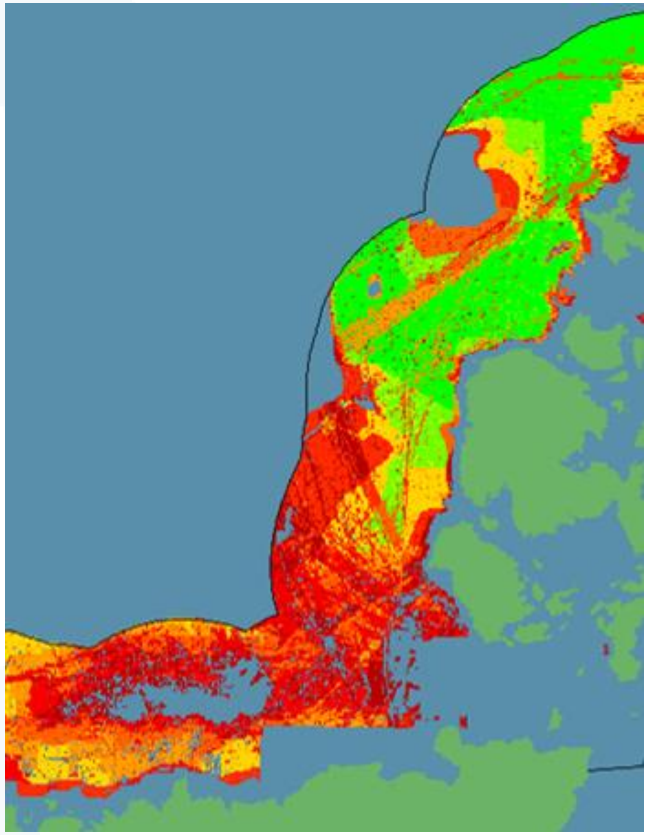
PLANNING - Costs and revenue

COSTS

- Technology development
- Permitting
- Capital
- Installation
- Operating
- Decommissioning

REVENUE

- Selling technology
- Selling know-how
- Selling energy
- Selling or renting out site permits
- Sharing costs

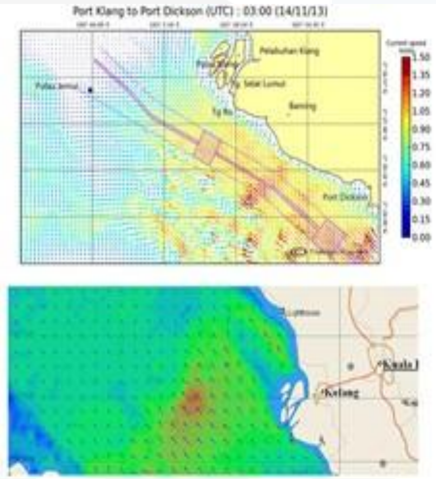


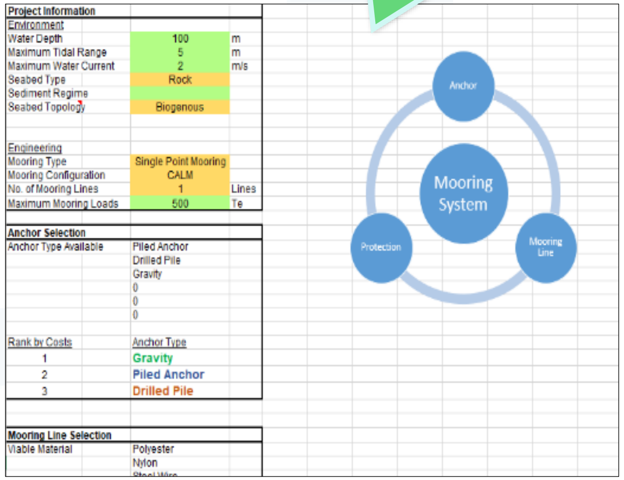
Reference: Site assessment Radmapp example, Aquatera Ltd.

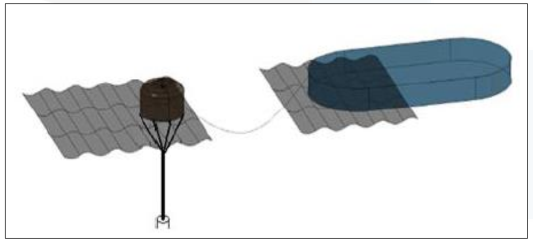
CASE STUDY - MOORINGS

Low cost model Case Study - WEC mooring

1. The mooring model takes in environmental information to decipher what mooring system is the most optimal.
2. Integrating the model into a scripting language (Python, ArcPy) allows to call the model within a GIS client and use the layers to feed the parameters.
3. Creating a map layer with mooring design suggestions for large geographical extents with little fuss.

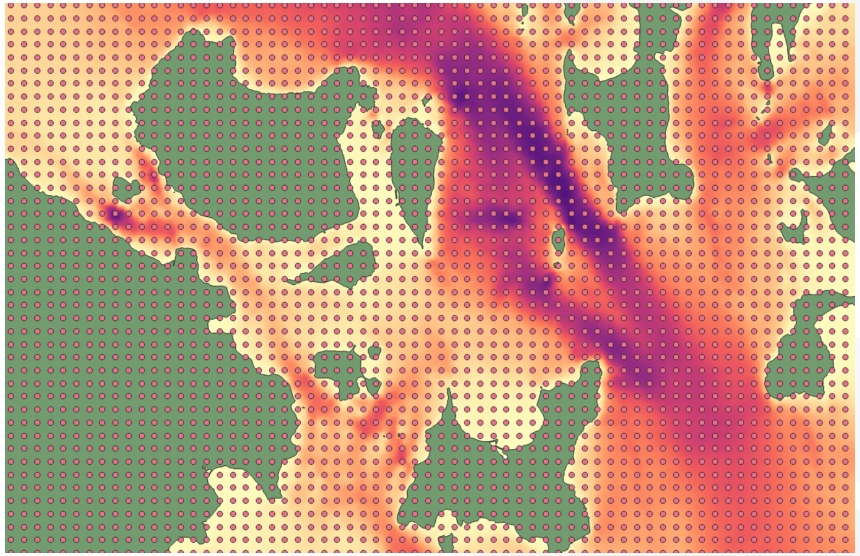






Reference: Low cost model method, Aquatera Ltd.

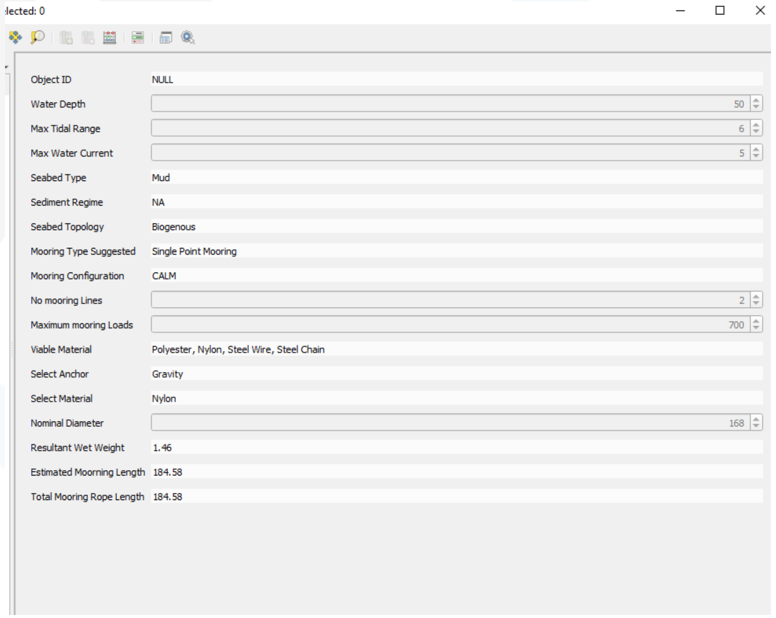
Grid, model outputs



- The resultant output is a grid with each point containing all of the mooring advice information.

Reference: Low cost model LCOE Radmapp example, Aquatera Ltd.

- The mooring model takes in environmental information to decipher what mooring system is the most optimal.
- A grid is created with a specified resolution by the user and each point samples environmental information to be used in the model.



Object ID	NULL
Water Depth	50
Max Tidal Range	6
Max Water Current	5
Seabed Type	Mud
Sediment Regime	NA
Seabed Topology	Biogenous
Mooring Type Suggested	Single Point Mooring
Mooring Configuration	CALM
No mooring Lines	2
Maximum mooring Loads	700
Viable Material	Polyester, Nylon, Steel Wire, Steel Chain
Select Anchor	Gravity
Select Material	Nylon
Nominal Diameter	168
Resultant Wet Weight	1.46
Estimated Moorning Length	184.58
Total Mooring Rope Length	184.58

Low cost model Case Study - WEC mooring

- Basic input parameters that affect mainly the engineering specification of the system.
- These are mainly environmental and load requirements
- The green boxes numerical inputs to be keyed in by the user
- Orange boxes are drop-down lists where the users are restricted to existing selections
- Estimation of mooring system cost

Project Information		
Environment		
Water Depth	50	m
Maximum Tidal Range	4	m
Maximum Water Current	2	m/s
Seabed Type	Mud	
Sediment Regime		
Seabed Topology	Biogenous	
Engineering		
Mooring Type	Single Point Mooring	
Mooring Configuration	CALM	
No. of Mooring Lines	1	Lines
Maximum Mooring Loads	500	Te

Anchor Selection	
Anchor Type Available	Suction Pile
	Embedment
	Gravity
	0
	0
	0
Rank by Costs	Anchor Type
1	Gravity
2	Embedment
3	Suction Pile

Mooring Line Selection		
Viable Material	Polyester	
	Nylon	
	Steel Wire	
	Steel Chain	
Select Anchor	Gravity	
Select Material	Nylon	
Nominal Diameter	168	mm
Resultant Wet Weight	1.46	kg/m
Estimated Mooring Length (pe	184.58	m
Total Mooring Rope Length	184.58	m

Anchor Unit Cost	10,250.00	€/Te
Estimated Anchor Cost	4,322.54	€
Mooring Line Unit Cost	2.75	€/kg
Estimated Total Mooring Line Cost	608,298.28	€
Estimated Total Mooring System C	**612,620.82**	**€**

Reference: Low cost model LCOE example, Aquatera Ltd.

Low cost model Case Study - WEC mooring

Project Information		
Environment		
Water Depth	50	m
Maximum Tidal Range	5	m
Maximum Water Current	2	m/s
Seabed Type	Clay	
Sediment Regime Depth	10	m
Sediment Grain Size		mm
Unit Weight of Soil		kN/m^3
Seabed Topology	Biogenous	
General Seabed Slope Angle		degrees
Engineering		
Device Rated Power	200	kW
Mooring Configuration	Spread Mooring	
Mooring Type	Catenary	
Height of fairlead from sea level	10	m
No. of Mooring Lines	3	Lines
Maximum Mooring Loads	120	Te
Maximum Fz	72	Te
Maximum Fx	72	Te
Deployment Radius + Excursion	150	m

Anchor Unit Cost	10,250.00	€/Te
Estimated Anchor Cost	4,322.54	€
Mooring Line Unit Cost	2.75	€/kg
Estimated Total Mooring Line Cost	608,298.28	€
Estimated Total Mooring System C	**612,620.82**	**€**

Anchor Unit Cost	10,250.00	€/Te
Estimated Anchor Cost	4,322.54	€
Mooring Line Unit Cost	2.75	€/kg
Estimated Total Mooring Line Cost	500,506.97	€
Estimated Total Mooring System C	**504,829.51**	**€**

Project Information		
Environment		
Water Depth	30	m
Maximum Tidal Range	5	m
Maximum Water Current	2	m/s
Seabed Type	Silt	
Sediment Regime Depth	10	m
Sediment Grain Size		mm
Unit Weight of Soil		kN/m^3
Seabed Topology	Biogenous	
General Seabed Slope Angle		degrees
Engineering		
Device Rated Power	200	kW
Mooring Configuration	Spread Mooring	
Mooring Type	Catenary	
Height of fairlead from sea level	10	m
No. of Mooring Lines	3	Lines
Maximum Mooring Loads	120	Te
Maximum Fz	72	Te
Maximum Fx	72	Te
Deployment Radius + Excursion	150	m

Reference: Low cost model LCOE example, Aquatera Ltd.

ET 3 - Site selection

Isa Walker - Aquatera Consultant

Co-funded by the
Erasmus+ Programme
of the European Union

Questions ET 3

10 minutes for Qs