

An Innovative Heat Mapping Methodology and GIS Tool to Support Offshore Wind Farm Site Selection Projects

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1. Introduction

Within the offshore renewables industry, heat mapping is becoming an integral part of the constraints and feasibility study process during the early stages of wind farm site selection projects. Targets set for the UK government dictate that 15% of energy for the country is to be sourced from renewable options by 2020, leading to an increase in offshore developers commissioning work involving site selection-type studies. In January 2009, the Crown Estate announced nine Round 3 offshore wind farm zones across UK waters. The successful development partners awarded each of these zones are now undertaking environmental and engineering studies across these regions to identify priority areas suitable for wind farm development (The Crown Estate, 2012). To achieve consent, these studies are required to take into account a number of environmental, social and infrastructural constraints, which in turn feed into the process for optimising zonal design to ensure that other areas of the zone are not sterilised; known in the industry as Zone Appraisal and Planning (ZAP).

Fugro EMU Limited (an offshore survey and consultancy company based in Hampshire, UK) has contributed to a number of site selection and environmental characterisation projects resulting in the development of a Heat Mapping Methodology and GIS Tool (Figure 1) to enhance the decision-making process and aid identification of target areas for development. Fugro EMU Limited's experience of working in this industry sector has prompted the creation of this tool, allowing end-users the flexibility to amend heat mapping outputs based on their changing and evolving understanding of the impact constraints may have on the consenting of an offshore wind farm.

2. Background and Methodology

Traditionally, the phrase "Heat Map" is applied to a raster dataset that shows a concentration of information, from the largest density through to the lowest density. These raster datasets have the purpose of being able to identify areas at a glance. Whilst these heat maps quickly focus attention to areas that may want to be explored further, they do not provide the answers to the questions decision makers and regulators want to know. For example, what features are limiting opportunity in a particular area, or the effect of a constraint on output heat maps?

The devised methodology is based on a suitably scaled ESRI vector grid (a geodatabase feature dataset) as opposed to the traditional raster grid - the benefit being that heat mapping outputs can have multiple attributes behind the data. By vectorizing the heat map, the resulting output has the potential to provide a clear and concise method for identifying suitable wind farm sites, as well as aid the understanding of the constraints and conflicts to development within a zone.

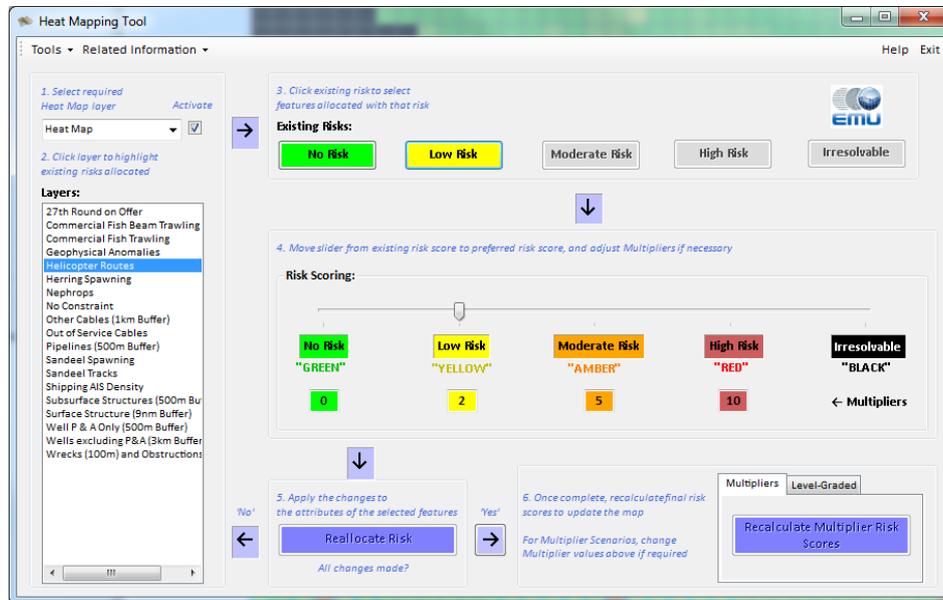


Figure 1: The Heat Mapping Tool

Initially, the grids are populated with various ‘constraint’ columns typically associated with site selection works, and that fall under the following data themes: physical, ecological and socio-economic. Such constraints include marine archaeology, physical features, fish ecology, commercial fisheries and oil and gas infrastructure, and related datasets are obtained from number of sources, including both freely available and licensed data.

Each constraint is allocated a risk score which corresponds to a ‘Risk Category’. The ‘heat’ relates to the risk of a grid cell being unable to obtain consent for development, from green for no risk, to red for high risk, with those constraints that cannot be overcome separated out as black (Figure 2). Each constraint is quantified or qualified into one, several or all of the categories based on its spatial extent. The weightings are founded upon “perceived consenting risk” of which there are two sets of criteria – one based on risk levels, the other based on statutory or regulatory consultee opinion (Table 1). Consultee opinion is critical when defining levels of risk as judgements can have far-reaching impacts during the path to consent.

Once this process is complete, the tool (created for use in ArcMap using Visual Studio 2010, vb.NET and ArcObjects) can be used to create the Heat Mapping outputs. Two options of methodology are available to the decision-maker:

1. ‘Multiplier’ format: Incorporates risk-dependent, user-defined multipliers
2. ‘Level-Graded’ format: Based on a count of risk scores found within each grid square

Table 1: Risk Categories and Criteria

Risk Category	Criteria (1)	Criteria (2)*
Irresolvable	Consent can never be achieved	Area should be considered unavailable for development as there is a hard constraint (i.e. on top of a wreck or existing cable or pipeline)
High Risk	Significant risk to consent	Development in this area would almost certainly raise an objection from a type A consultee
Moderate Risk	Environmentally sensitive but can be consented with mitigation management measures	Development in this area would almost certainly raise an objection from a type B consultee
		Development in this area would possibly raise an objection from a type A consultee.
Low Risk	Low sensitivity but consent can be achieved with minimum mitigation and management	Development in this area would possibly raise an objection from a type B or C consultee
No Risk	No risk to consent identified	Development in this area would be unlikely to raise an objection from any consultee

*Consultees classed as follows:

- A – Statutory Consultees - Local Authorities, Natural England, JNCC
- B – Key Non-Statutory Consultees - Those who if they object are likely too a) request very onerous mitigation/consent conditions; b) cause significant delay; or c) prevent consent. These include those that hold a lot of political sway (MOD on aviation, MCA on navigation, RSPB on ornithology, for example)
- C – Other Non-Statutory Consultees - Those who are likely to have an interest in the project but it is unlikely they would a) request very onerous mitigation/consent conditions; b) cause significant delay; or c) prevent consent (Surfers Against Sewage on coastal processes, Individual Representation on seascape and visual grounds, for example)

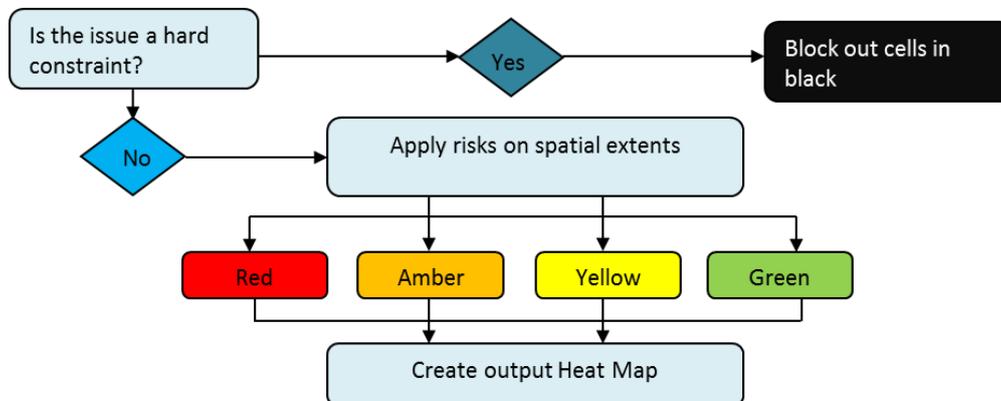


Figure 2: The Heat Mapping Process

The Level-Graded format presents the results in the form of a ‘worse-case’ scenario, and is beneficial in terms of quickly identifying areas to avoid with the highest number of constraints. The counts of each risk score found in a grid cell are concatenated to form a mappable risk value. This option may be attractive to developers who are looking to investigate regions with the minimum number of constraints where there are potentially fewer barriers to obtain consent. However, for a grid cell containing 17 Moderate Risk constraints and only 1 High Risk constraint, an adjacent grid cell with 2 High Risk and 1 Moderate Risk constraints would appear to be ‘less attractive’ than the neighbouring cell due to there being a higher number of High Risk constraints. In reality, it may be that overcoming 17 Moderate Risks is likely to be more time-consuming and expensive than tackling 2 High Risks. The Multiplier format overcomes this problem by multiplying each risk count by a user-defined multiplier, and summing the risk scores calculated for each cell. For both methodologies, ‘Irresolvable’ risk cells are given a value of -1 to exclude them from the value ranges.

The symbologies and classes applied to the grids following the application of either of these methods are predefined by the tool. A quantile classification with 20 classes is used here which ensures there are no empty classes or classes with too few or too many values (ESRI, 2012), although these can be amended by the decision-maker to suit user-specific requirements (i.e. to match the previous grids existing symbology).

3. Example Case Study

The following presents an example case study that applies the described methodology and utilises the functionality of the tool to create output variations based on an end-users prospective requirements.

Table 2: Case Study Constraints and Risk Categories

Constraint	Allocated Risk Category	Constraint	Allocated Risk Category
27 th Round on Offer	Low	Pipelines (500m Buffer)	Irresolvable
Commercial Fish Beam Trawling	High	Sandeel Spawning	High
Commercial Fish Trawling	Moderate	Sandeel Tracks	Low
Geophysical Anomalies	Irresolvable	Shipping AIS Density (Ships/Yr)	< 500 = No Risk
			500 – 1500 = Low
			1500 – 1995 = Moderate
			> 1995 = High
Helicopter Routes	Moderate	Subsurface Structures (500m Buffer)	Irresolvable
Herring Spawning	Low	Surface Structures (9nm Buffer)	High
Nephrops	Low	Wells Plugged and Abandoned (P&A) Only (500m Buffer)	Moderate
Other Cables (1km Buffer)	High	Wells excluding P&A (3km Buffer)	High
Out of Service Cables	Irresolvable	Wrecks (100m Buffer) and Obstructions (50m Buffer)	Irresolvable

A 1km x 1km Grid is created across a fictitious offshore wind farm development zone. For each constraint, grid cells are selected that fall within the extent of that constraint and a defined risk category allocated to each of the selected cells, with risks specified by the offshore developer (Table 2). Cells that fall outside of the selected constraints are categorised as No Risk.

The tool is then used to create both Level-Graded and Multiplier outputs, the latter of which uses the default multiplier values of 0 for No Risk (Green), 2 for Low Risk (Yellow), 5 for Moderate Risk (Orange) and 10 for High Risk (Red). The results are illustrated in Figure 3. Both outputs highlight areas where there is greater risk to consent and enable buildable areas to be defined (dotted outlines). The results appear very similar, confirming that either methodology is suitable for preliminary site selection processes, with the Level-Graded option displaying the worse-case scenario.

At this stage, the grids and tool can be used by the decision-maker to interrogate the grid to provide information about the constraints and risks associated with the output – an approach

not offered with raster datasets. The user selects the required layer from the drop down box which populates the listbox with all of the constraints included in the grid. When a constraint is selected, the 'Existing Risks' buttons are activated and highlighted depending on which risk categories have been allocated to that constraint. Clicking on the available buttons selects the cells that have been allocated that risk. For example, selecting 'Pipelines (500m Buffer)' and clicking 'Irresolvable' displays the cells depicted in Figure 4.

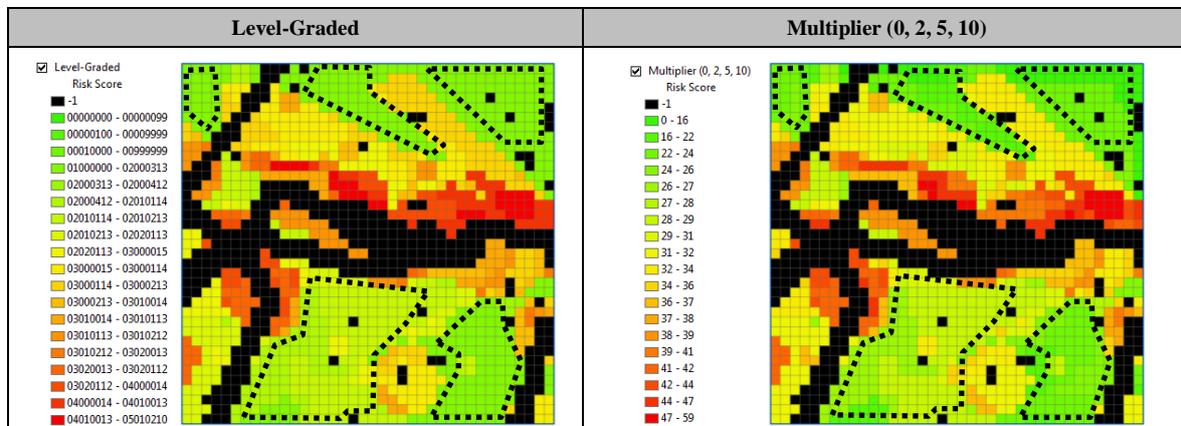


Figure 3: Level-Graded and Multiplier Outputs

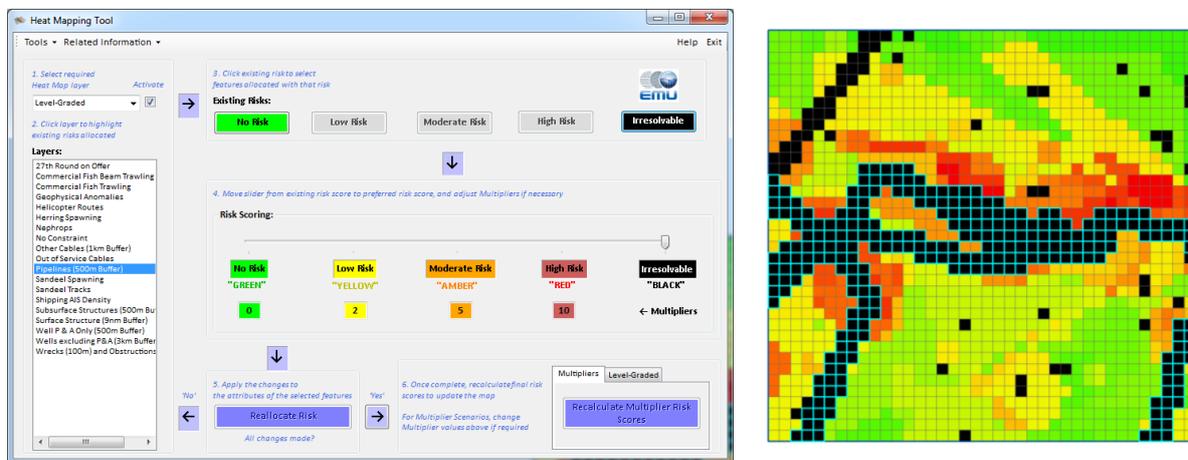


Figure 4: Highlighting Pipeline Grid Cells

As Existing Risks are highlighted, the Risk Scoring sidebar adjusts to match the existing risk allocated to the selected constraint. This sidebar gives the user the ability to change existing risk categories for any given constraint. For example, after consultation with fishing industry, commercial trawling may now be regarded as High Risk and sandeel spawning in the area a Low Risk, while discussions with the oil and gas industry reveal that subsurface structures can be reduced to High Risk as there is a possibility that consent could be granted within the 500m buffer zone. Such changes can be applied and then risk scores recalculated to present updated grid outputs (Figure 5).

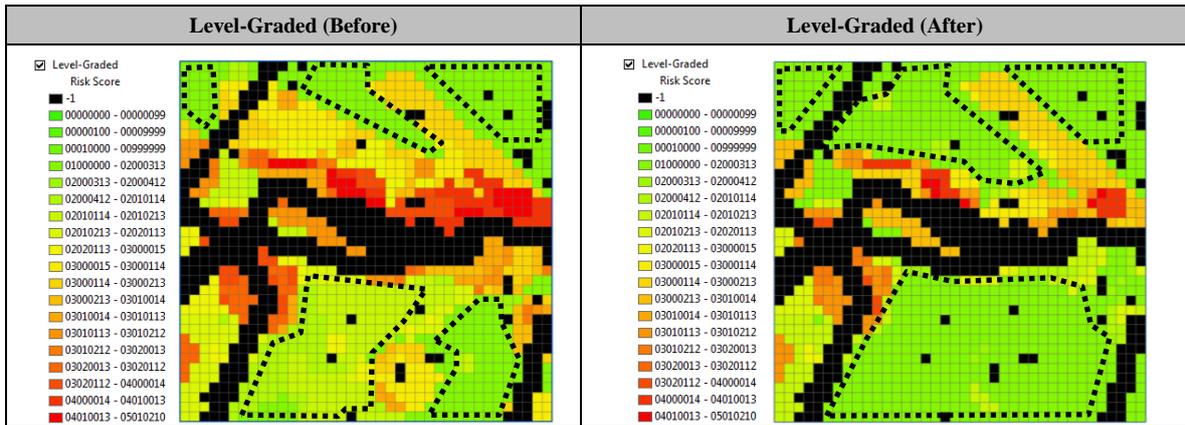


Figure 5: Before and After Level-Graded Outputs

Figure 5 illustrates that on application of these changes, a number of additional areas appear to be potentially suitable for development. While a static map can provide a snapshot of heat-based constraint interactivity, these changes emphasise the importance of being able to modify a grid based on an evolving understanding of the constraints within a development zone.

To supplement the interpretation of a grid, the Identify Tool can also be used to interrogate cells of interest to ascertain which constraints exist that have led to the cell being given a particular score (Figure 7). This is particularly useful for a decision-maker who may need to establish what barriers potentially exist within a selected sub-region.

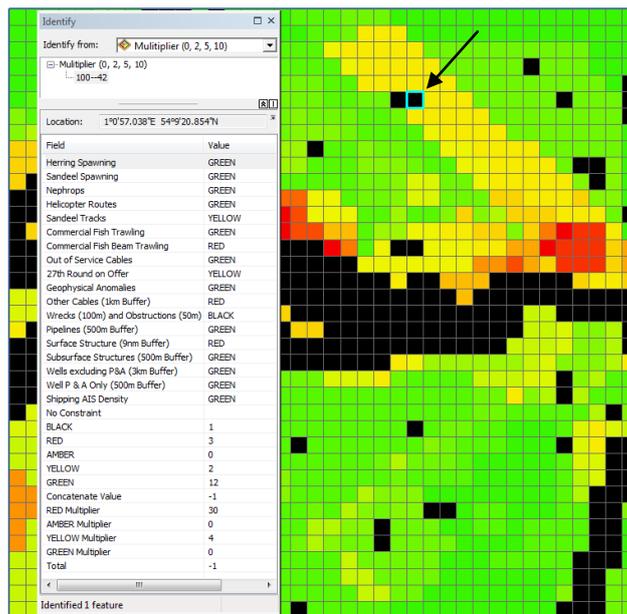


Figure 7: Identifying Grid Cell Attributes

On completion of amendments, the tool has the built-in functionality to export grid variation scenarios to create a geodatabase feature dataset and summary text-file breaking down each of the constraints and the nominated risk category (or categories) allocated to them.

4. Conclusion

Energy generation from offshore renewables is high on the political agenda in the UK and the number of site selection projects has risen significantly. The Crown Estate's offshore wind programme has led to a number of key drivers which have prompted the construction of the innovative approach to constraints mapping presented here, while the Heat Mapping Tool introduces a unique methodology for supporting the consenting process using GIS technology. The ability to interact with GIS output heat map grids combined with the flexibility to run and export various constraint scenarios has generated keen interest in the offshore renewables sector and has been driven by Fugro EMU Limited's experiences in understanding the requirements of the target client-base - the need to maximise buildable area, whilst minimising risk to consent. Moreover, the methodology exists as a means of presenting and integrating large numbers of datasets to help enable developers to make key decisions at the various stages of these subzone-defining phases. As Fugro EMU Limited's experience in this area grows, the Heat Mapping Tool will continue to evolve with the premise of further assisting offshore developers in their site selection efforts.

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