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SCOPING STUDY FOR TIDAL STREAM ENERGY DEVELOPMENT IN SCOTTISH WATERS

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Executive Summary

The Scottish Government has set a range of challenging targets for energy and climate change. These recognise the potential to take advantage of the extensive marine energy resources (wind, wave and tidal power) available in Scottish waters and include meeting at least 30% of total energy demand from renewable sources by 2020, incorporating:

- 100% of electricity demand from renewables (31% by 2011)
- 11% of heat demand from renewables
- 10% of transport fuel from renewables

In addition, the Climate Change (Scotland) Act 2009 sets statutory targets of at least 42% emissions cuts by 2020, and at least 80% by 2050.

To assist in meeting these targets, the Scottish Government has adopted an iterative approach to marine planning for the renewable energy sectors. A Sectoral Marine Plan for Offshore Wind Energy in Scottish Territorial Waters (Blue Seas - Green Energy) sets out the Government's vision for developing offshore wind energy up to 2020 and beyond and has identified short term development sites for offshore wind up to 2020, with a potential to deliver almost five Gigawatts (GW) of electricity generation capacity. A new Scoping Study extends the potential development area out to 200 nm.

A sensitivity analysis of the process used to develop the offshore wind Plan concluded that, as additional data and monitoring information and improved data handling procedures become available, these should be incorporated into the emerging iterative marine planning process.

A process was therefore put in place by Marine Scotland to develop a Scoping Report for the potential for tidal stream energy development in Scottish waters out to 200 nautical miles, building on the Scoping Study undertaken for the Saltire Prize (Harrald and Davies, 2010). This report describes the process employed by Marine Scotland in collaboration with The

Crown Estate to develop a series of new offshore tidal stream energy plan options within Scottish marine waters.

The Crown Estate spatial modelling tool MaRS was used to create multi-factorial expressions of the technical opportunities and constraints on tidal stream energy development in Scottish waters, and of the constraints on consenting presented by themed groups of factors. These themes reflect current commercial (industrial) activities such as fishing, aquaculture and offshore oil and gas, environmental factors such as designated Natura sites and the distributions of certain sensitive species and a broad field of socio-cultural interests including recreational uses, archaeological potential, visual and landscape factors. These models have been combined and used to develop overall expressions of the relative degrees of constraint. The sensitivity of the process was investigated through the creation of a series of combined models altering the relative influence of each the themes. Considerable similarities were found between the combined models, and the model that weights the three themes equally was taken forward and used to develop areas of search for plan options for tidal stream energy developments within Scottish Territorial Waters (STW).

The options identified are shown in Figure S1 and listed below.

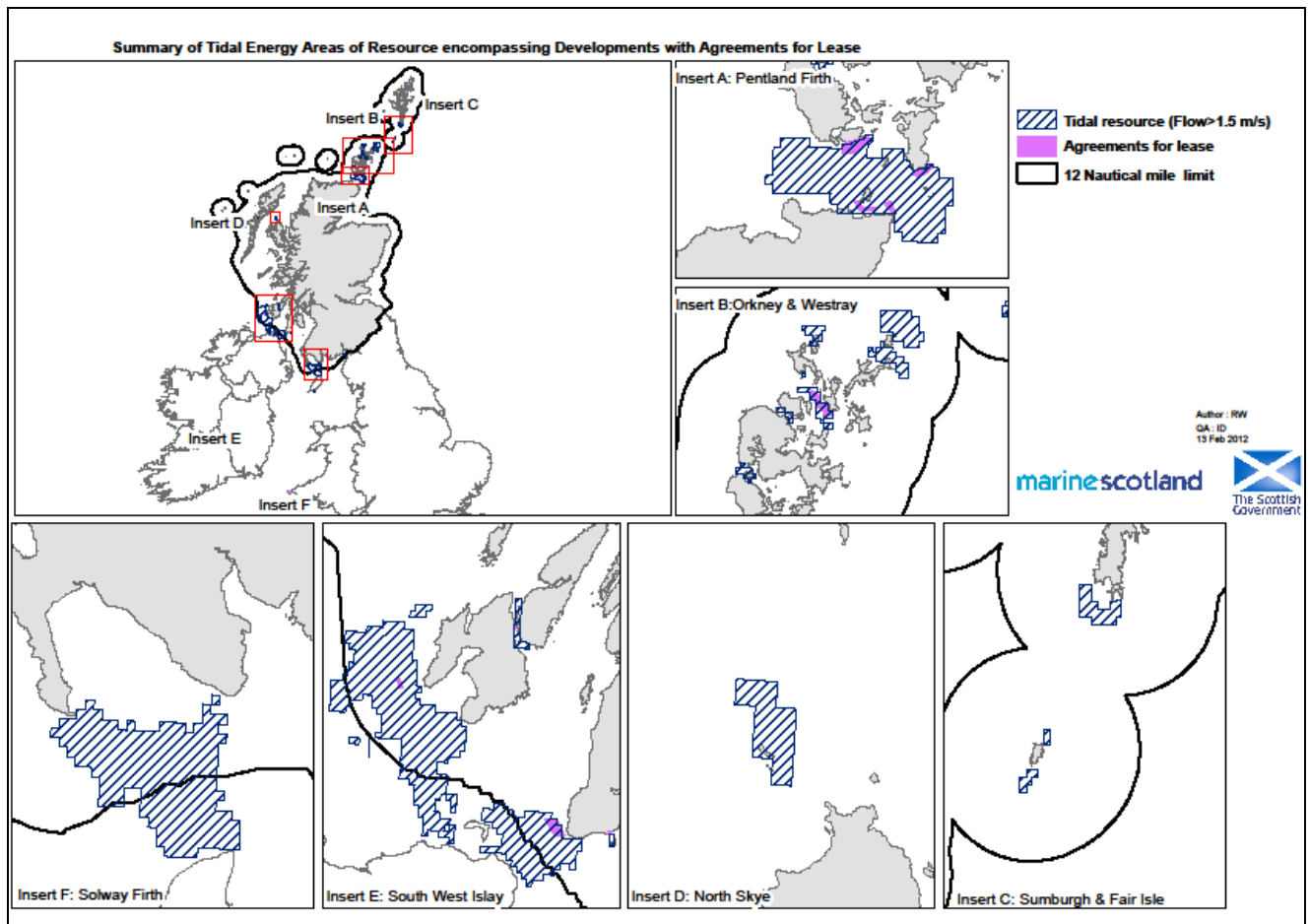


Figure S1 Areas of search for tidal stream plan option areas identified within Scottish marine waters.

The potential locations for tidal stream energy developments are strongly limited to the locations where sufficiently strong tidal currents occur. These areas are confined to coastal and near shore waters where the large volumes of water involved in tidal fluxes are constrained to pass through firths and sounds (such as the Pentland Firth), or round headlands (such as off the south west of Islay).

The tidal stream energy resource areas in Scotland are:

- A. Pentland Firth
- B. Orkney and Westray
- C. Sumburgh and Fair Isle
- D. North Skye
- E. South west Islay and Kintyre
- F. Solway Firth

The identification of resource areas has been based upon tidal stream information on a grid scale of 1.8 km (DECC, 2008). Resource areas smaller than this may well not be represented, and areas up to the scale of a few cells may be poorly represented. It is well known that there are a large number of small areas around Scotland where tidal streams are at times powerful. These include areas at headlands, areas around sills at the entrances to sea lochs (and separating basins within sea lochs), and in channels and sounds between islands and between islands and large land masses. Such areas will not have been captured by this scoping study, but in favourable locations may offer considerable potential for small (and perhaps medium) scale developments for testing or commercial purposes.

There are currently no areas of Scottish marine waters outside STW where tidal streams are sufficiently fast to generate commercial interest based on current tidal stream technologies.

The outputs from this study will inform the marine planning process by leading to the development of Regional Locational Guidelines (RLG) for tidal stream energy development, which in turn will be the basis for the Sustainability Appraisal to cover tidal stream energy development in Scottish waters. This process involves Strategic Environmental Assessment (SEA), Habitats Regulations Appraisal, Socio-economic Assessment, as well as statutory consultation with key sectors, stakeholders and the wider public.

1 Background

The Scottish Government has set a range of challenging targets for energy and climate change. These recognise the potential to take advantage of the extensive marine energy resources (wind, wave and tidal power) available in Scottish waters and include meeting at least 30% of total energy demand from renewable sources by 2020, incorporating:

- 100% of electricity demand from renewables (31% by 2011)
- 11% of heat demand from renewables
- 10% of transport fuel from renewables

In addition, the Climate Change (Scotland) Act 2009 sets statutory targets of at least 42% emissions cuts by 2020, and at least 80% by 2050.

It was clear from the Strategic Environmental Assessment for wave and tidal energy in territorial waters west and north of Scotland (Scottish Government, 2007) that Scotland had

considerable potential for tidal stream energy developments. A particularly notable resource area is the strong tidal currents in the Pentland Firth, arising from the differences in the phase of the tidal wave on the east and west of Scotland. Other potential development areas included tidal streams around some headlands (for example south west of Islay) and in sounds between islands (for example the Sound of Islay and sounds in Orkney and Shetland). The Strategic Environmental Assessment of the potential for wave and tidal power developments in Scottish Territorial Waters (STW) to the north and west of Scotland (Scottish Government, 2007) reviewed this potential, and identified the need to ensure that environmental interactions, and interactions with other users of the sea were taken into account when creating development plans and considering individual projects in the licensing process.

Subsequently, renewable energy, including marine renewables, has become a key aspect of the Scottish Government's economic strategy. The need to encourage technological development and install early projects in the sea, led to the creation of the Saltire Prize (<http://www.sdi.co.uk/sectors/saltire-prize.aspx>). Smooth development of potential Saltire Prize projects was assisted by the adoption of a marine planning approach to the identification of areas with the necessary wave or tidal stream resource, and in which interactions with other uses and sensitivities of the sea were minimised. This was achieved through a Scoping Study for wave and tidal power (Harrald and Davies, 2010), and supporting Regional Locational Guidance (RLG, Harrald *et al.*, 2010). The result is that there are now more than 10 projects with exclusivity agreements for lease for wave and tidal power in Scottish waters, together with a further 11 commercial scale projects (a total of 1.6 GW) in the Pentland Firth and Orkney Waters Strategic Area.

The Saltire Prize Scoping Study was developed from a brief that emphasised the need to avoid sensitive areas. The report (Harrald and Davies, 2010) noted that these conditions were more restrictive than might be applied in wider development contexts. Since the Saltire Prize Scoping Study was completed, new information on interactions with the environment and other users has become available, together with new ways to handle the underlying data. Furthermore, the Scottish Government is now responsible for marine planning out to the 200 mile limit. These, and other factors, have come together to indicate a need to undertake a new Scoping Study for tidal stream power, covering all Scottish waters, together with new Regional Locational Guidance, to form the basis for a development plan and supporting Sustainability Appraisal.

The new Scoping Study described in this report is one of a series covering offshore wind, wave and tidal stream energy. They form part of a process of regular revisions and updates of sectoral plans for offshore energy. The process to develop the Plan is being supported by using The Crown Estate's Marine Resource System (MaRS) to map zones of broad environmental sensitivity and technical opportunities and constraints.

The MaRS system is a powerful tool for the handling and integration of a wide range of spatial data referring to environmental and technical factors that can influence the development of offshore energy, including tidal stream energy (and other activities). The integrated data are presented as spatial models which map the opportunities and constraints applying in potential development areas. In order to apply the MaRS tool, it is necessary for the user to make a number of decisions regarding the data to be included in the models and the way in which the data are to be handled. A system of scoring and weighting of information held in MaRS is used to produce graduated maps of the least to greatest technical, and subsequently environmental, sensitivity. From these outputs, broad areas of technical opportunity and relatively low constraint on development can be identified and explored in more detail through Regional Locational Guidance.

The first Scoping Study for tidal stream energy in Scottish waters was undertaken in 2010. Experience of both that exercise and subsequent exercises (e.g. Davies and Watret, 2011) has shown that the conclusions are sensitive to technical factors, such as the categorisation of data layers as representing complete (exclusion models) or partial (constraint models) constraints on development, the weighting applied to the layers, and the classification system used to create the scores. However, the degree of sensitivity differs between sea areas.

Furthermore, a sensitivity analysis of the outputs from the Draft Plan for offshore wind (Davies and Aires, 2011) noted that improvements in the available data had occurred since the Draft Plan had been prepared. For example, European Seabird at Sea (ESAS) data were now available in a compiled form suitable for inclusion in spatial modelling. Other data layers are progressively being updated and improved, demonstrating the need to keep sectoral plans under cyclical review to ensure that the outputs are as robust as possible and take account of the best current information and data handling methods. The sensitivity analysis concluded that, as additional data and monitoring information, and improved data handling procedures, become available, these should be incorporated into the emerging iterative marine planning process, as applied to opportunities for development in STW, and to opportunities further offshore.

A process was therefore put in place by Marine Scotland to develop a Scoping Report for the potential for tidal stream energy development in Scottish waters out to 200 nautical miles. It is intended that this will inform the marine planning process by leading to the development of Regional Locational Guidance for tidal stream energy development, which in turn will be the basis for a Sectoral Marine Plan and Sustainability Appraisal to cover tidal stream energy development in Scottish waters.

2 Approach

As was the case in the development of the Scoping Study for the Saltire Prize programme for wave and tidal power development, and parallel documents for wind energy, Marine Scotland has worked with The Crown Estate to use MaRS for the identification of potential areas for offshore tidal stream energy development.

As previously mentioned, in order to apply the MaRS tool, it is necessary for the user to make a number of decisions regarding the data to be included in the models and the way in which the data are to be handled. These decisions include factors such as:

- The factors that require consideration when locating tidal stream energy developments and the availability of spatial data that can be included in the models.
- Whether particular activities or uses should be considered as incompatible with tidal stream energy development, or whether activities or uses should be considered as presenting gradations of limitation to development potential.
- The relative importance (weighting and scoring) that should be applied to the different layers of data in the final integrated model.
- The relative quality and reliability of data layers.

Building on experience of the Scoping Studies for the Saltire Prize, the data layers were grouped into themes (e.g. technical, industrial, environmental, socio-cultural). This procedure minimises the conceptual problems associated with defining appropriate relative weightings for very diverse types of data (e.g. the relative weightings of seabird colonies, fisheries landings, and basking shark sightings). The thematic grouping allows assessment of the sensitivity of the outputs to variation in the overall weighting between themes. This approach had previously been used successfully in the Scoping Study for the Saltire Prize,

and also in the Scoping Study for Offshore Wind in Scottish waters (Davies and Watret, 2011). A similar approach has therefore been adopted in the current study, grouping constraints layers into themes representing constraints arising from industrial activity, environmental factors and socio-cultural interests.

The modelling for this tidal stream energy scoping study built upon the experience gained in the Saltire Prize modelling and subsequently in the Sensitivity Analysis (Davies and Aires, 2011) and updated Scoping Study for offshore wind (Davies and Watret, 2011). The study adopts a similar separation of data layers between constraint and exclusion models, to maintain a balance in the influence that different data layers have on the model outputs. Further efforts were made to ensure that the scoring systems for the various layers followed the statistical advice within the MaRS modelling guidance, and that the scoring system for statistically skewed data sets was appropriate, both in the resultant influence of the layers in the models and the degree of discrimination between areas. Where possible, improved or updated data layers were used in the current Scoping Study, as indicated in Section 3 below.

3 Structures of the Models Used

As described in the documentation supporting The Strategic Environmental Assessment for Offshore Wind (Scottish Government, 2010a), and as is normal in the use of MaRS, the data layers had been classified as either exclusion layers (i.e. indicating areas where development was not appropriate), or constraint layers (i.e. indicating the distribution of factors that acted as partial constraints on development). The constraint layers were each allocated a weighting. Within each constraint layer, the data had been assessed through a scoring scheme. The constraint layers were allocated either to technical resource assessment or to a non-Technical Model. The non-Technical Constraints Model was comprised of the outputs from three thematic Restriction models, covering constraints arising from industrial activity, environmental factors, and socio-cultural interests. The socio-cultural layer is broad in its scope, covering visual and recreational factors as well as historical heritage and archaeological potential. The outputs of these models had been normalised against the Exclusion Model.

The data layers which were included in the various models were as follows:

3.1 Socio-cultural Restriction Model (MaRS ref. 2758)

Data layer	Weight	Maximum score	Potential relative influence
National scenic areas	600	60	36000
Royal Yachting Association cruising routes	300	30	9000
Royal Yachting Association racing areas	300	30	9000
Royal Yachting Association sailing areas	300	30	9000
Scheduled Ancient Monuments	800	80	64000
Surfing beaches	400	40	16000
World Heritage sites	1000	100	100000
Wrecks	700	70	49000
Protected wrecks	700	70	49000
Potential for marine archaeological remains	700	70	49000

3.2 Environmental Restriction Model (MaRS ref. 2751)

Data layer	Weight	Maximum score	Potential relative influence
Bird reserves	800	80	64000
Important Bird Areas	500	50	25000
Local nature reserves	800	80	64000
Special Areas of Conservation	1000	100	100000
Special Protection Areas	1000	100	100000
Sites of Special Scientific Interest	900	100	90000
Offshore candidate SACs and SPAs	1000	100	100000
Offshore draft SACs and SPAs	1000	100	100000
Offshore possible SACs and SPAs	1000	100	100000
RAMSAR sites	1000	100	100000
Possible sea haul out sites	900	90	81000
Areas of importance to basking sharks	700	70	49000
Nursery areas for commercial fish species	300	55	16500
Spawning areas for commercial fish species	300	55	16500
Areas of search for potential Marine Protected areas	600	60	36000
Areas of search for seabird aggregations	400	40	16000
Areas of importance to breeding sea birds	800	145	116000
Areas of importance to sea	500	50	25000

birds in winter Areas of importance to marine mammals	800	145	116000
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3.3 Industry Restriction Model (MaRS ref. 2565)

Data layer	Weight	Maximum score	Potential relative influence
Offshore cables in UK waters (not active)	500	100	50000
Pipelines in UK waters (not active)	500	100	50000
Potential gas and CO2 storage sites	800	80	64000
Carbon capture and gas storage infrastructure	800	80	64000
Current Licensed Areas for Hydrocarbons	700	70	49000
Closed waste disposal sites	700	70	49000
Military Practice and Exercise Areas	1000	180	180000
Shipping density	800	145	116000
Commercial fisheries landings	1000	182	182000
Dredging	1000	100	100000

The commercial fishing layer in the Industry restriction model was created in a separate fishing model using data layers and scores as shown below:

Commercial Fishing Model (MaRS ref. 2565)

Commercial fisheries landings from mobile gear in inshore waters	700	127	88900
Commercial fisheries landings from static gear in inshore waters	700	127	88900
Commercial landings from fishing vessels >15m using mobile gears	700	127	88900
Commercial landings from fishing vessels >15m using static gears	700	127	88900

3.4 Non-technical Exclusion Model (MaRS ref. 2568)

The following features were treated as incompatible with tidal stream farm development, i.e. areas covered were used to create an overall special model of areas from which tidal stream farms should be excluded at this time.

All Offshore Cable inside UK Waters

All Pipeline in UK Waters

Anchorage Areas

Aquaculture Leases – Current

Aquaculture Leases - Pending

Waste disposal sites (open)

IMO Routeing - excluding ABTAs

Munitions Dumps

Offshore Shipping Zones

Operational Anemometers in UK Waters

Protected Wreck Exclusion Buffers

UK offshore wind activity

Shipping Density - Exclusion Areas

Tidal Leases – Live

UK Deal oil and gas Safety Zones

UK Deal oil and gas Surface features

UK Deal oil and gas Subsurface features

UKCS Exclusion Buffer - 500 m

Wave Leases – Live

UK Detailed Coastline - not including Isle of Man (Polygon)

3.5 Tidal Stream Resource Assessment

Tidal stream resource was assessed in terms of the mean spring peak tidal flow, and the mean annual power density. The former provides a screen to ensure that the necessary speed of current is available at a potential development site, while the power density provides an indication of the persistence of suitable currents and therefore the period within tidal cycles that devices may operate satisfactorily.

The outputs from the restriction models, after normalisation against the exclusion model, should be viewed in the context of technical (resource) opportunities of the areas under consideration.

3.6 Improvements to the Previous Spatial Modelling

The use of MaRS to develop Scoping Studies for marine renewable energy has been characterised by progressive improvements in the available data, and the data handling. Some significant differences from, and additions to, previous models have been implemented in the current exercise. The main improvements made were:

- 1 Surfing beaches. There may be some potential for tidal energy devices close to the coast to affect the wave spectrum reaching the coast, and this in turn may affect the suitability of coastal areas for surfing. The locations of surfing beaches were taken from the data in National Marine Plan interactive (NMPi), the data underlying the development of Scotland's Marine Atlas (Scottish Government, 2011a).
- 2 Commercial fishing: The landings from commercial fishing activities were separated to represent mobile and static gears, and VMS and non-VMS (<15m, mostly inshore) vessels. In inshore waters, landings were partitioned between internal waters, 0 – 6 miles, 6 – 12 miles, and landings from greater distances within ICES statistical rectangles that also include areas within STW were identified. Based on current tidal stream project design plans, is likely to be difficult to operate commercial fishing activities, using either mobile or static gear, within the footprint of tidal stream farms. The four combinations of inshore and offshore vessels, mobile and static gear, were therefore given equal weight.
- 3 The offshore wind Scoping Study gave considerable weight to factors related to aviation. These factors are omitted from the current study, as interactions between tidal stream farms and aviation are likely to be insignificant.
- 4 Potential for archaeological heritage remains on the seabed: Maps indicating areas of the current seabed which had been exposed as land at some time since the Ice Age (and had high potential and theoretically high potential for marine archaeology) were combined with maps of seabed sediment type and structure to identify areas of seabed where potential for archaeological remains coincided with favourable seabed

conditions. This layer had initially been used in the Wind Scoping Study (Davies and Watret, 2011), and was carried forward into the current study.

- 5 Sensitivity of areas to seabirds: An initial approach was made to developing indices of the relative sensitivity of sea areas for vulnerable seabirds. Collision of diving seabirds with tidal turbines particularly needs to be taken into account. Mapped data on the distribution of 7 SPA species of sea birds at sea during the breeding and winter seasons (European Seabirds at Sea survey, JNCC) were expressed in terms of the total Scottish population of each species. The distributions of species known to dive to depths where they might encounter tidal turbines were combined to give an overall expression of the relative sensitivity of sea areas in the winter and in the breeding season. The seabird species were chosen using information on diving behaviour (RPS 2011), and were Atlantic puffin, common guillemot, European shag, great cormorant, Manx shearwater, northern gannet, and razorbill.
- 6 Disturbance of seals at sensitive periods in their life cycle may arise from the construction and operation of wave farms in coastal waters. Following from the Marine (Scotland) Act 2010, preliminary work has been carried out to identify important seal haul out and breeding sites around Scotland. A data layer was created showing haul out sites for both grey and harbour seals, and buffers created out to 30 km.
- 7 Sensitivity of areas to marine mammals: Data from the JNCC cetacean atlas of the distribution of marine mammals at sea were scaled to the Scottish populations of each species and then summed to express the overall importance of sea areas to marine mammals.
- 8 Fish spawning and nursery areas: Maps derived from Coull et al, 1998 showing areas of spawning and nursery grounds for 14 commercial fish and shellfish species were gridded and combined to show counts of spawning species or nursery ground species within each grid cell. The resulting layers were scored and weighted.
- 9 Designated areas for the protection of birds: There are a number of different designations for marine or coastal areas for the protection of birds, including RAMSAR sites, SPAs, SSSIs, RSPB reserves, local reserves, IBAs etc. In many cases, areas hold more than one designation, and treating each form of designation independently (as was done in the Saltire Prize Scoping Study) resulted in potentially

multiple counts of the same area for the same environmental sensitivity (birds). The data were therefore processed such that only the most important designation of any particular area was included in the final data layers, for example an area designated at European, national and local levels would be considered as designated at European level, whereas an area designated at local level only would be scored as a local designation.

Of the suggestions made in previous reports, for improvements to underlying data, almost all were achieved and further additions made. Exceptions were:

- a) that SACs were not filtered for sensitivity to tidal stream energy developments.
- b) the distribution of SNH Priority Marine Features (PMF) was not taken into account. A significant amount of work will be necessary to convert the available information on the distributions of PMFs into a form suitable for inclusion in spatial modelling.

4 Results of the MaRS Modelling

4.1 Technical Resource Assessment

The technical resource assessment provides the necessary background against which the range of environmental, socio-cultural and industry factors must be assessed. Unlike offshore wind (and to a degree wave energy), the areas with potential for tidal stream energy developments in Scottish waters are strongly limited by the availability of the power resource. Areas with potential for large commercial developments are found off some headlands, and in some sounds and firths between islands and larger land masses. A mean spring peak tidal current of 1.5 ms^{-1} is an approximation of the minimum speed required by currently available generating devices for economic return. Such strong currents occur only within Scottish Territorial Waters and are not found in Scottish marine waters further offshore. The resource areas identified from the resource assessment are shown in (Figure 1a). The tidal stream energy resource areas in Scotland are:

- A. Pentland Firth
- B. Orkney and Westray
- C. Sumburgh and Fair Isle
- D. North Skye
- E. South west Islay and Kintyre
- F. Solway Firth

The geographical extent of these areas is large enough for there to be opportunities for fully commercial scale development of tidal stream energy projects.

The maximum currents are found in the Pentland Firth area, and in some firths in the Orkney and Westray area. Strong currents are also found South west of Islay. The dominance of the tidal resource in the Pentland Firth is further illustrated by the spatial extent of high mean power density in the area (Figure 1b).

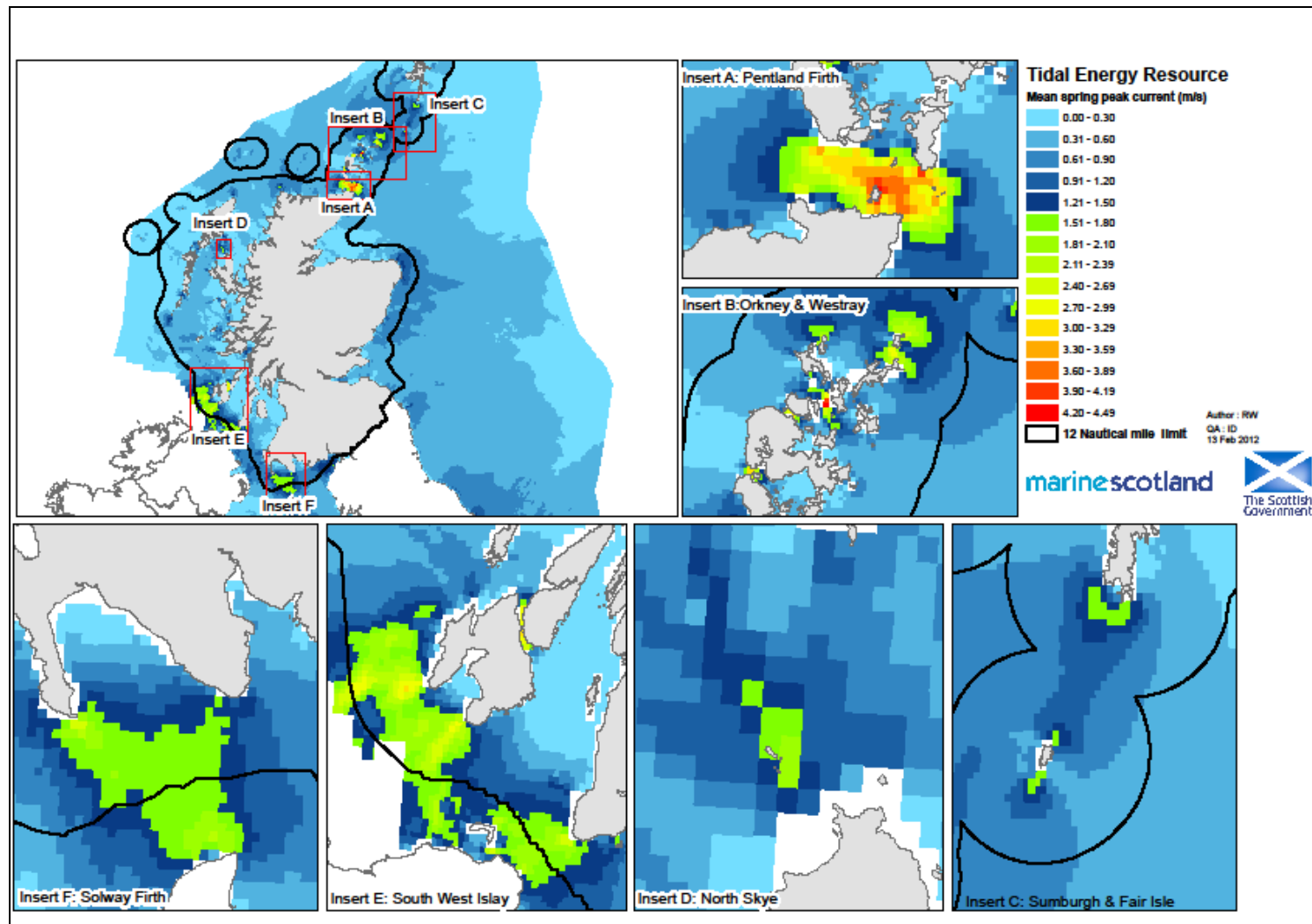


Figure 1a Mean spring peak current (ms^{-1}) in tidal stream energy resource areas in Scottish waters.

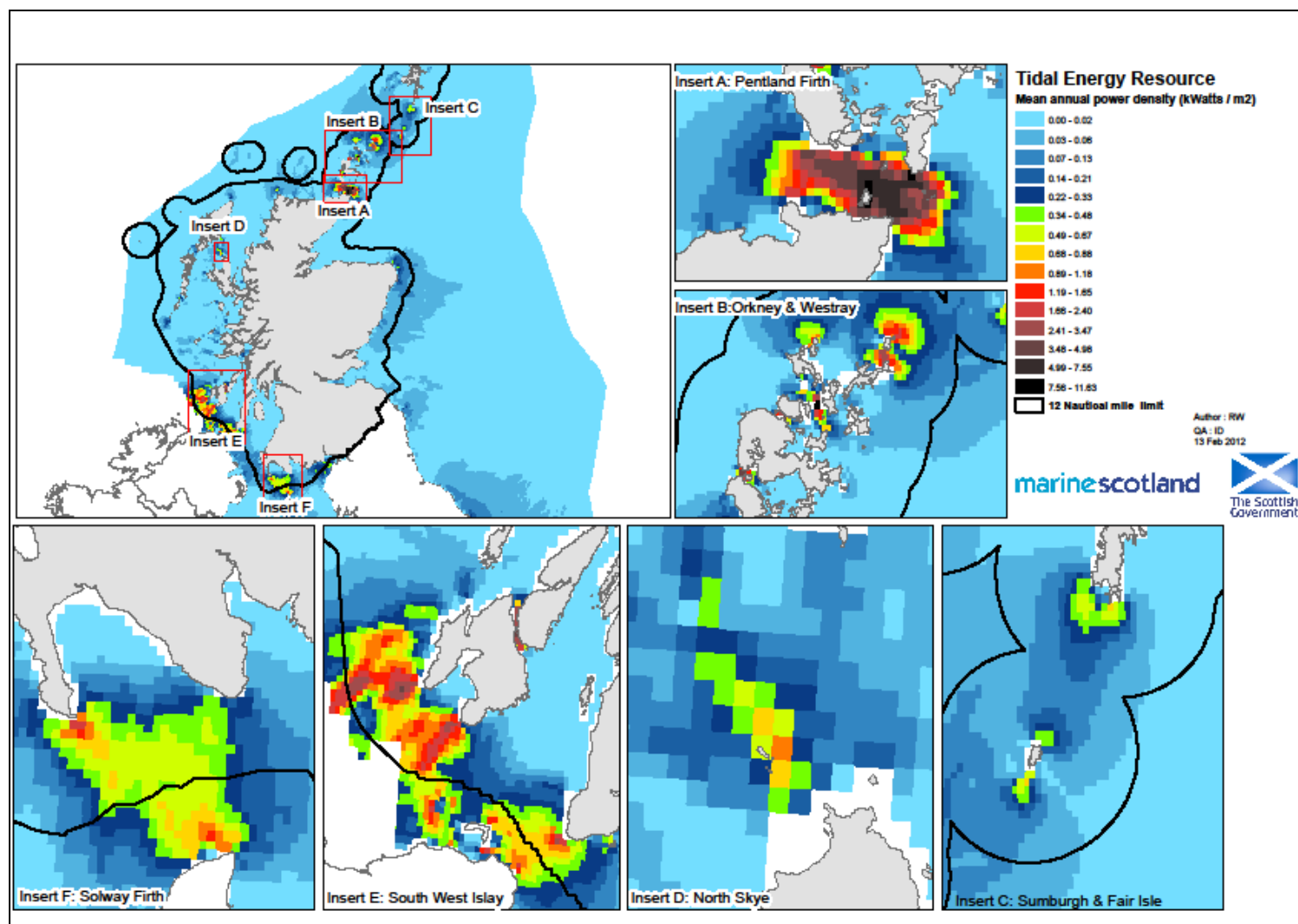


Figure 1b Mean annual tidal power density (kW/m²) at tidal stream energy resource areas in Scottish waters.

4.2 Industry Restriction Model

The output from the Industry restriction model (Figure 2) is dominated by the predominance of current “industrial” activity in the coastal zone, particularly shipping routes, with fishing grounds and military exercise areas extending into more offshore areas.

4.3 Environment Restriction Model

The output from the Environment restriction model (Figure 3) again indicates greater levels of constraint in inshore waters. Relatively high levels of constraint in the North and South Minches are influenced by their importance to seabirds and marine mammals. The designated areas around Rhum and St Kilda, and in the inner Moray Firth are prominent, as is the general importance of waters off the east coast between Peterhead and Berwick to seabirds.

4.4 Socio-cultural Restriction Model

The output from the Socio-cultural restriction model (Figure 4) generally indicates low levels of constraint in most areas of Scottish waters. The areas where greatest constraint is encountered are dominated by areas close to the coast, and particularly areas in and adjacent to National Scenic Areas, where some importance of landscape considerations may be anticipated, particularly for devices that are not wholly submerged. Further contributions to heritage restrictions arise from yachting and sailing activity, surfing beaches and the potential for sub-sea archaeological remains.

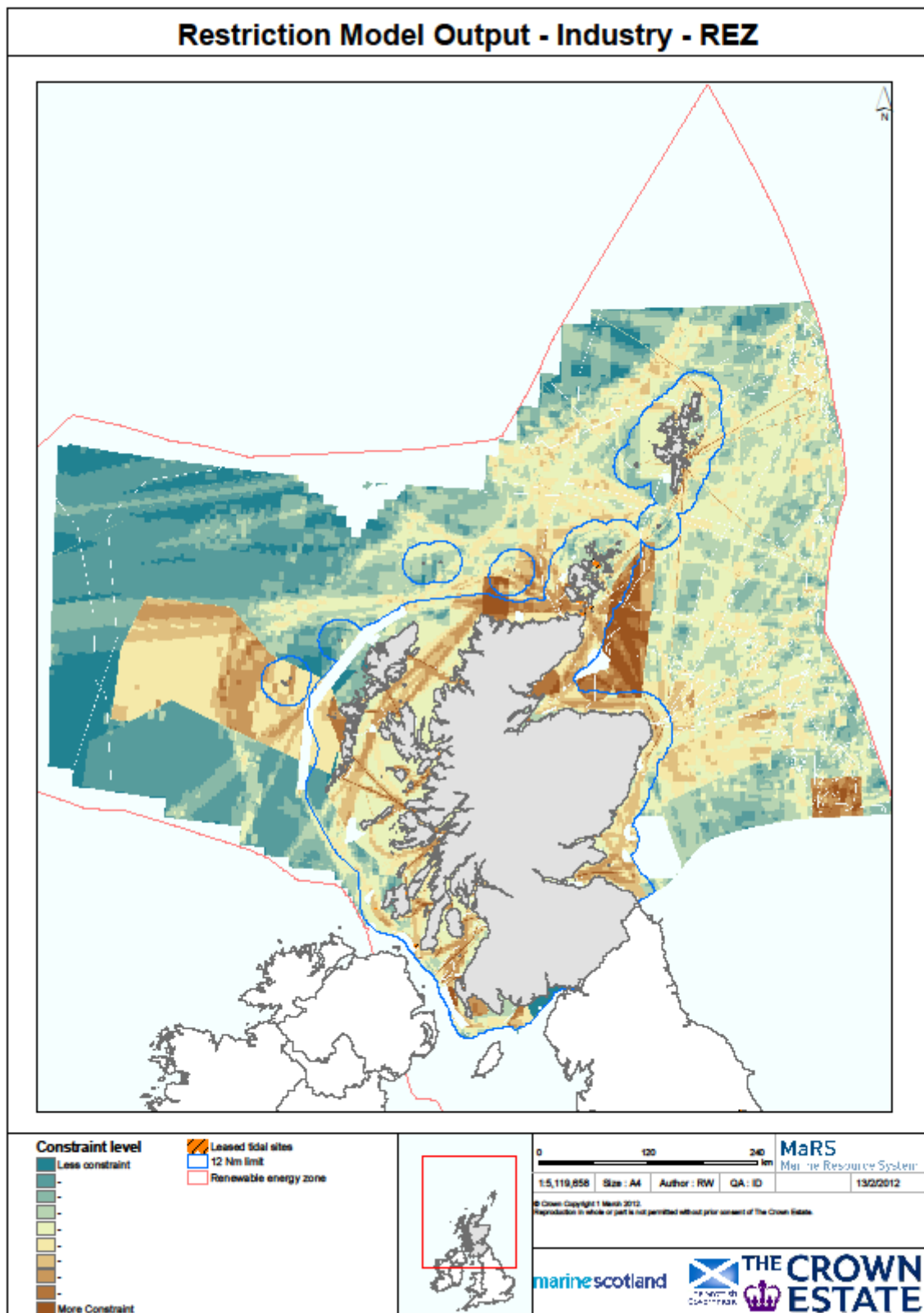


Figure 2 Output from the Industry Restriction model for tidal stream energy development in Scottish waters.

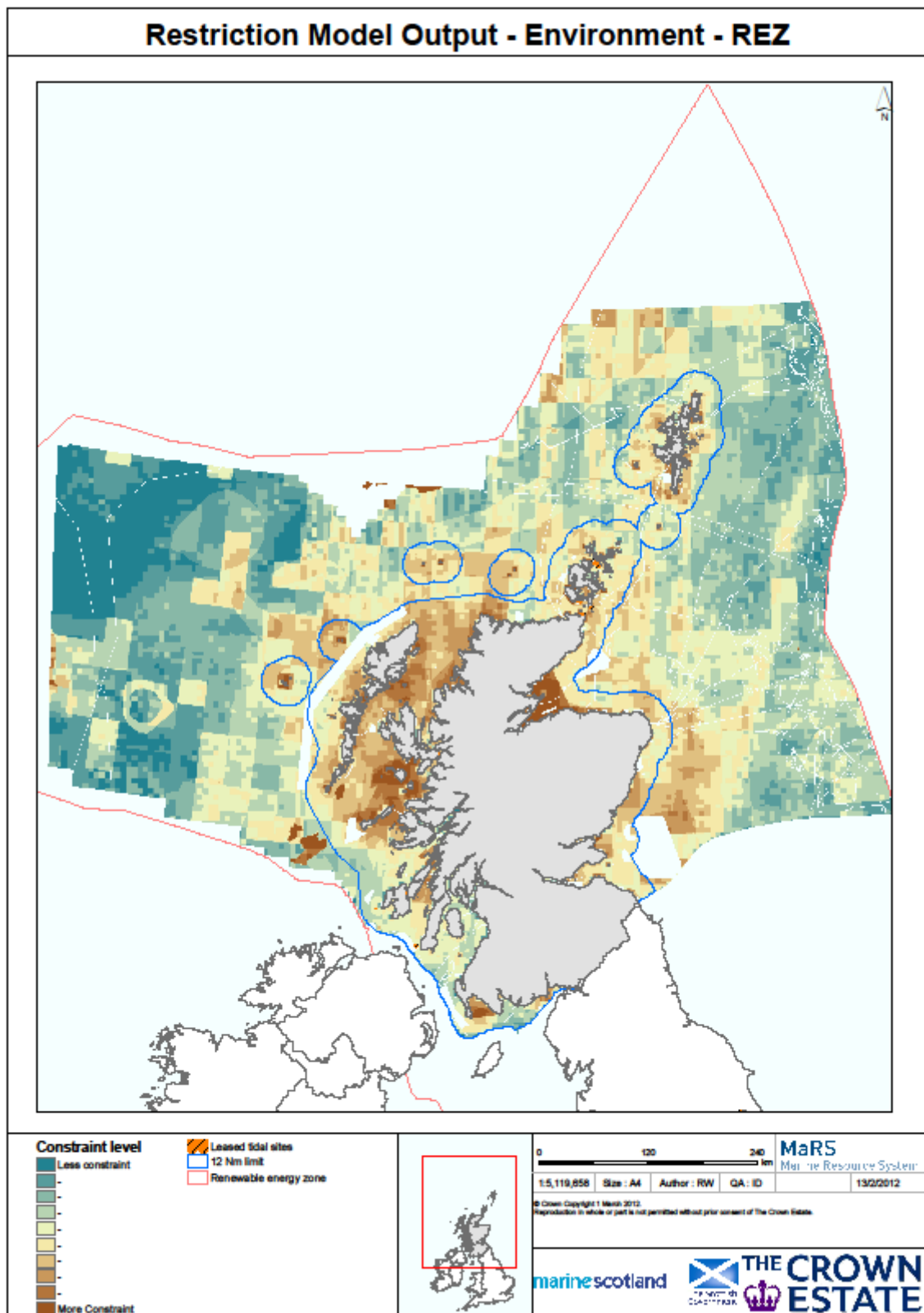


Figure 3 Output from the Environmental Restriction model for tidal stream energy development in Scottish waters.

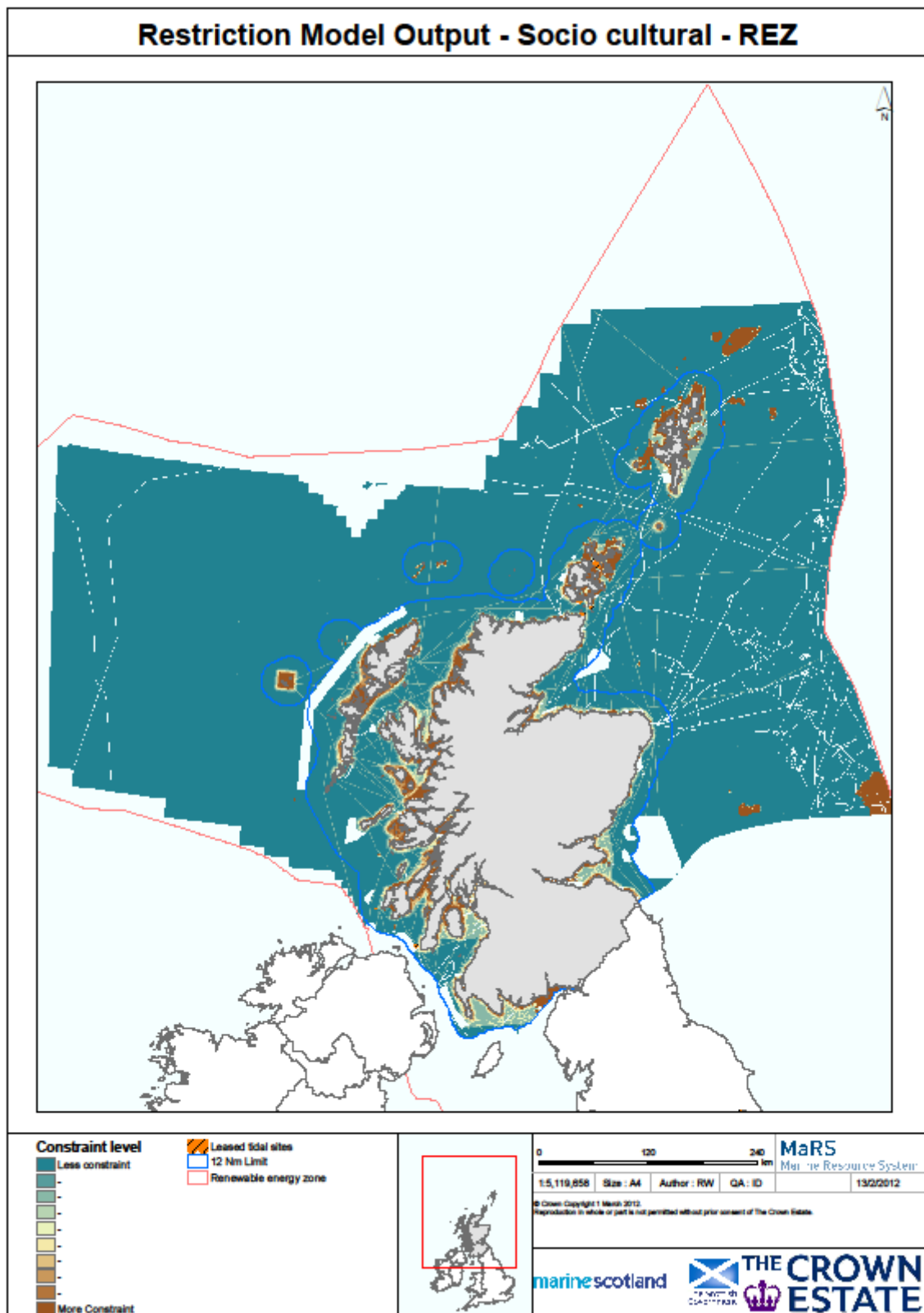


Figure 4 Output from the Socio-cultural Restriction model for tidal stream energy development in Scottish waters.

4.5 Combined Models

An expression of the overall level of constraint on tidal stream energy developments in Scottish waters needs to take account of environmental, industry and socio-cultural restrictions. The presentation of the information by theme has been shown to reduce the difficulties inherent in developing relative weightings for very diverse types of data (e.g. the relative weighting of seabird colonies, wrecks, fish landings, and basking shark sightings). The current Scoping Study has been carried out with the minimisation of consenting risk in mind. Having grouped the data and developed thematic restriction models, it is now possible to combine the models within MaRS and assess the sensitivity of the outputs to variation in the overall weighting between themes. This approach had previously been used successfully in the Scoping Study for the Saltire Prize

Four Combined models were created, in which the relative weightings of the themes were changed. In an Equal Weighting model, the three themes were weighted equally. Three further models were developed, in which each of the themes was assigned a weighting equal to the sum of the weightings for the other two themes, as in Table 1.

Table 1

	Environmental theme	Industry theme	Socio-cultural theme	MaRS model ref.	Figure
Equal weighting constraints model	100	100	100	2581	Figure 5
Environmental focused constraints model	200	100	100	2584	Figure 6
Industry focused constraints model	100	200	100	2583	Figure 7
Socio-cultural focused constraints model	100	100	200	2582	Figure 8

The resultant models covering Scottish waters out to 200 nm are shown in Figures 5, 6, 7 and 8.

There are some broad similarities between the outputs, i.e. features that are not very sensitive to the relative weightings of the three themes:

- 1 Constraint is generally a coastal phenomenon. Most of the activities in the sea, from all three themes, are concentrated in coastal waters. The degree of constraint decreases with distance from the coast. This is particularly clear in the North Minch area, where waters east of the Western Isles are generally highly constrained, while those to the west of the Western Isles show much lower levels of constraint.
- 2 On the east coast, the most constrained areas are in the inner and outer parts of the Moray Firth and some nearshore areas . The degree of constraint generally decreases seawards.
- 3 The North and South Minch are generally moderately to strongly constrained. However, there are areas on the west coast further south, west and south west of the Inner Hebrides, where the degree of constraint is much less. The level of constraint in inshore waters between the Inner Hebrides and the mainland is generally similar to, or greater than that in the Minch.
- 4 The degree of constraint off the east coast of Scotland south of the Moray Firth is less than in the Minch.
- 5 The model emphasising socio-cultural interests is dominated by the distribution of National Scenic Areas landscape issues in the inshore waters west of Scotland in Orkney and Shetland. Landscape is generally considered to be a less significant issue for tidal energy projects than for wind power projects, as several of the tidal stream devices currently being considered for testing or commercial deployment are wholly submerged. It may be anticipated that wholly submerged devices, or those which emerge from the sea to only a small degree would be considered to have less interaction with the landscape.
- 6 The degree of constraint in offshore waters in the Solway Firth is generally low to moderate. However, issues of conservation designation and landscape clearly increase the sensitivity in waters immediately adjacent to the coast, for example in Luce Bay.
- 7 Generally, the levels of constraint outside STW is much less than that within STW. It is also decreases with distance offshore outside STW, such that at 30-40 miles offshore the levels of constraint are generally very low. There will be some sensitive

areas, such as those associated with the oil and gas industry, or actively used for military purposes (training and testing), where development may not be appropriate.

Given the level of similarities in output, the model that weights the three themes equally (output shown in Figure 5) was taken forward and used to develop areas of search for plan options for tidal stream energy developments within STW.

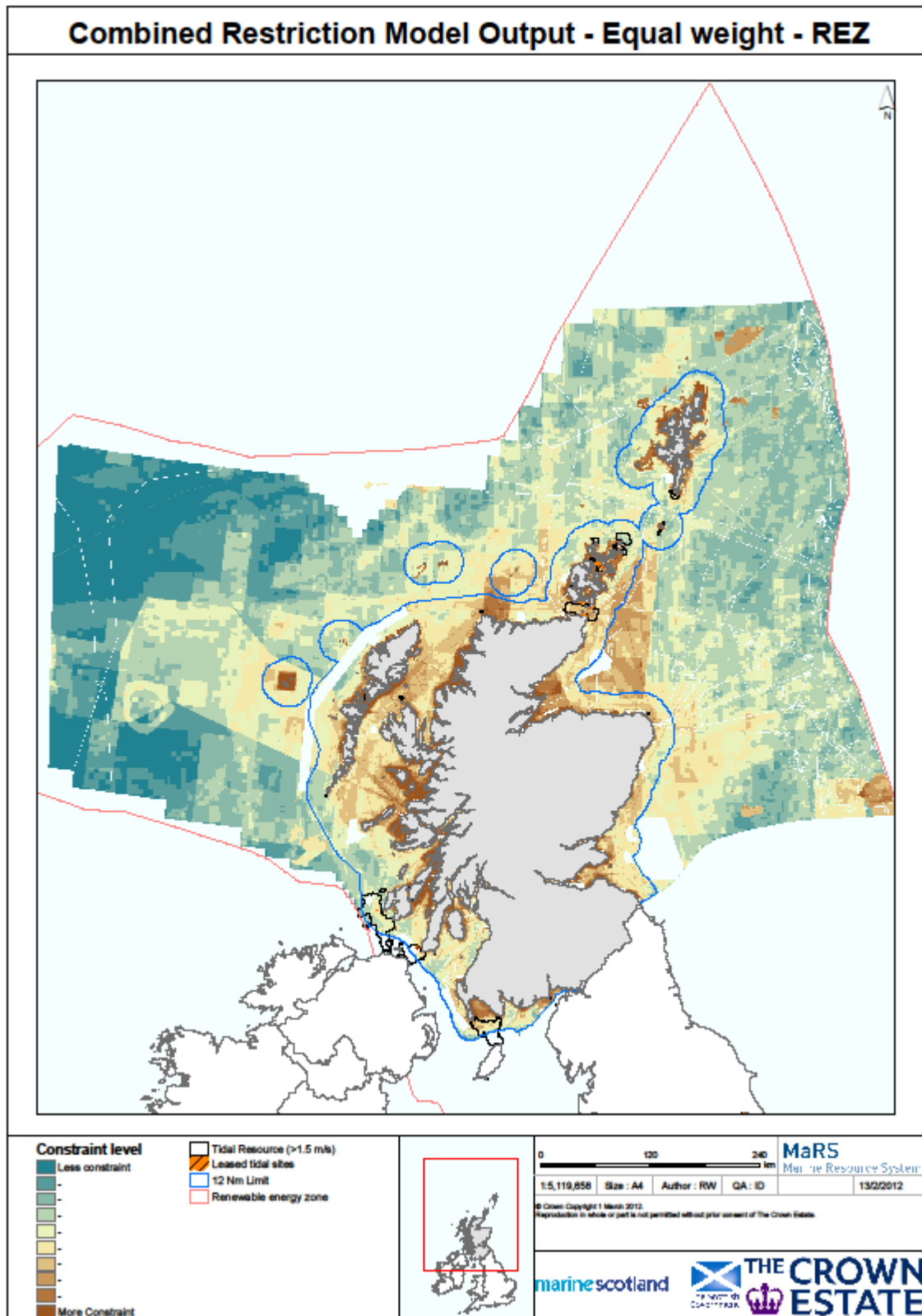


Figure 5 Combined restriction model, giving equal weight to the environmental, industry and socio-cultural themes.

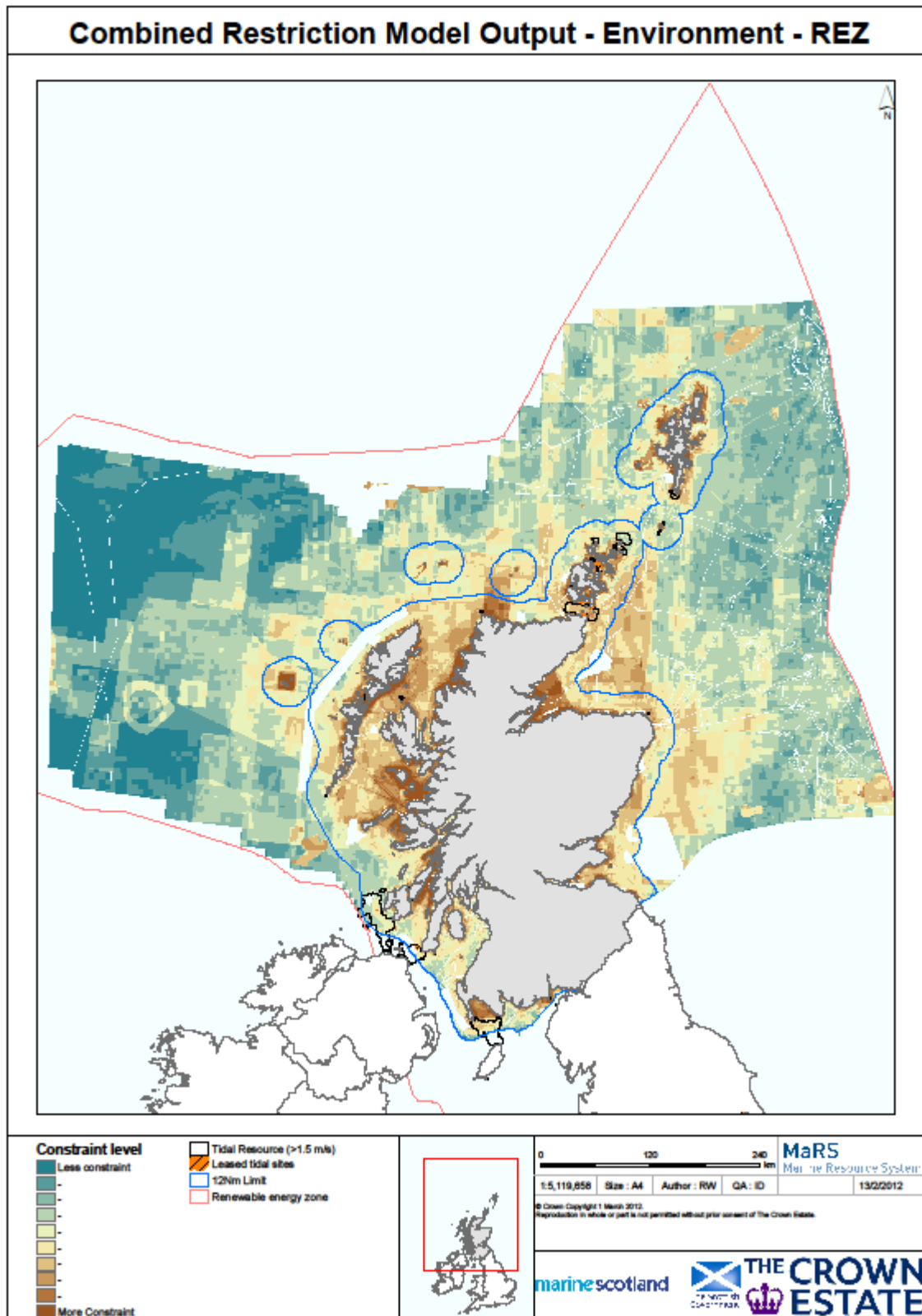


Figure 6 Combined restriction model, emphasising the environmental theme.

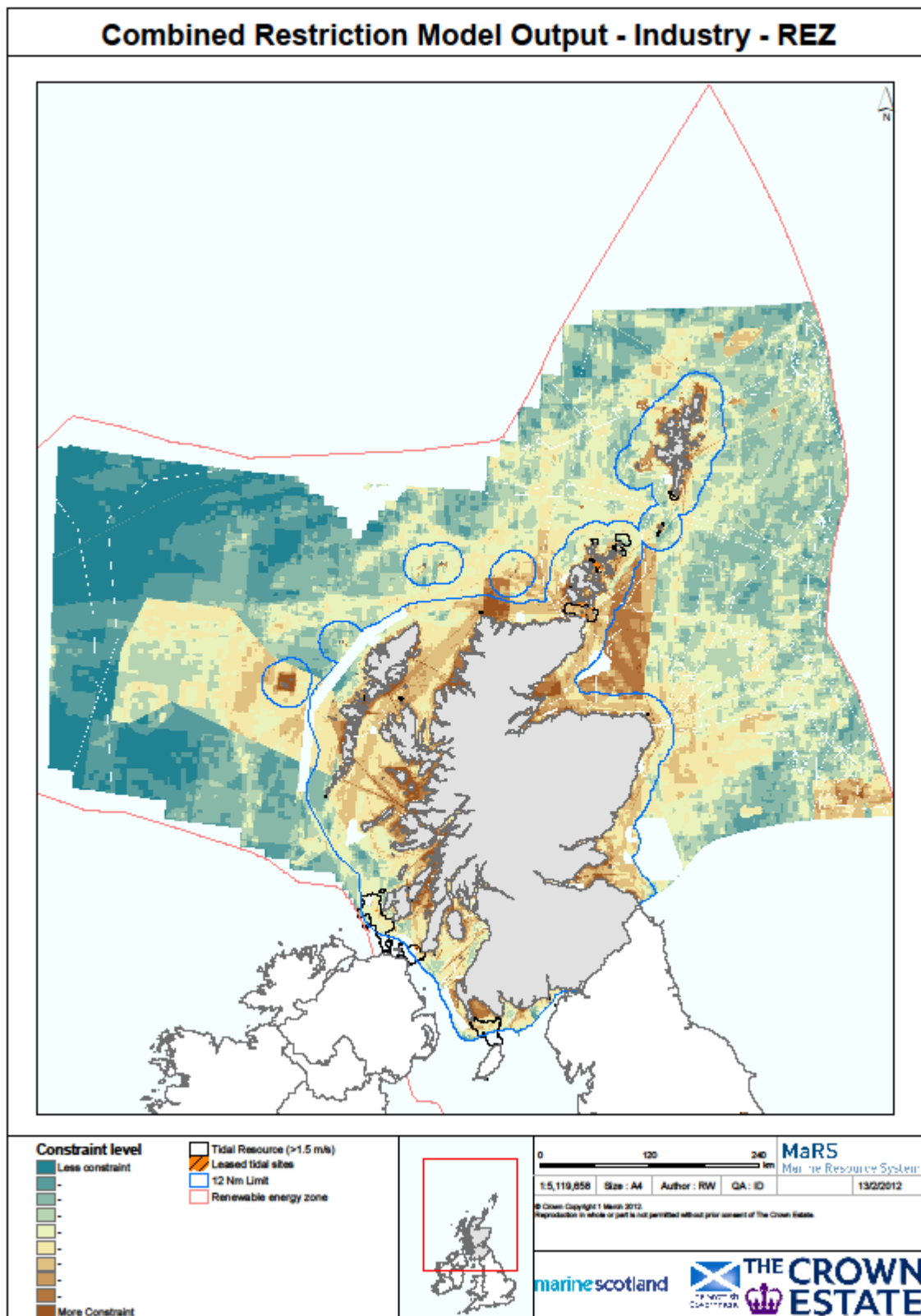


Figure 7 Combined restriction model, emphasising the industry theme.

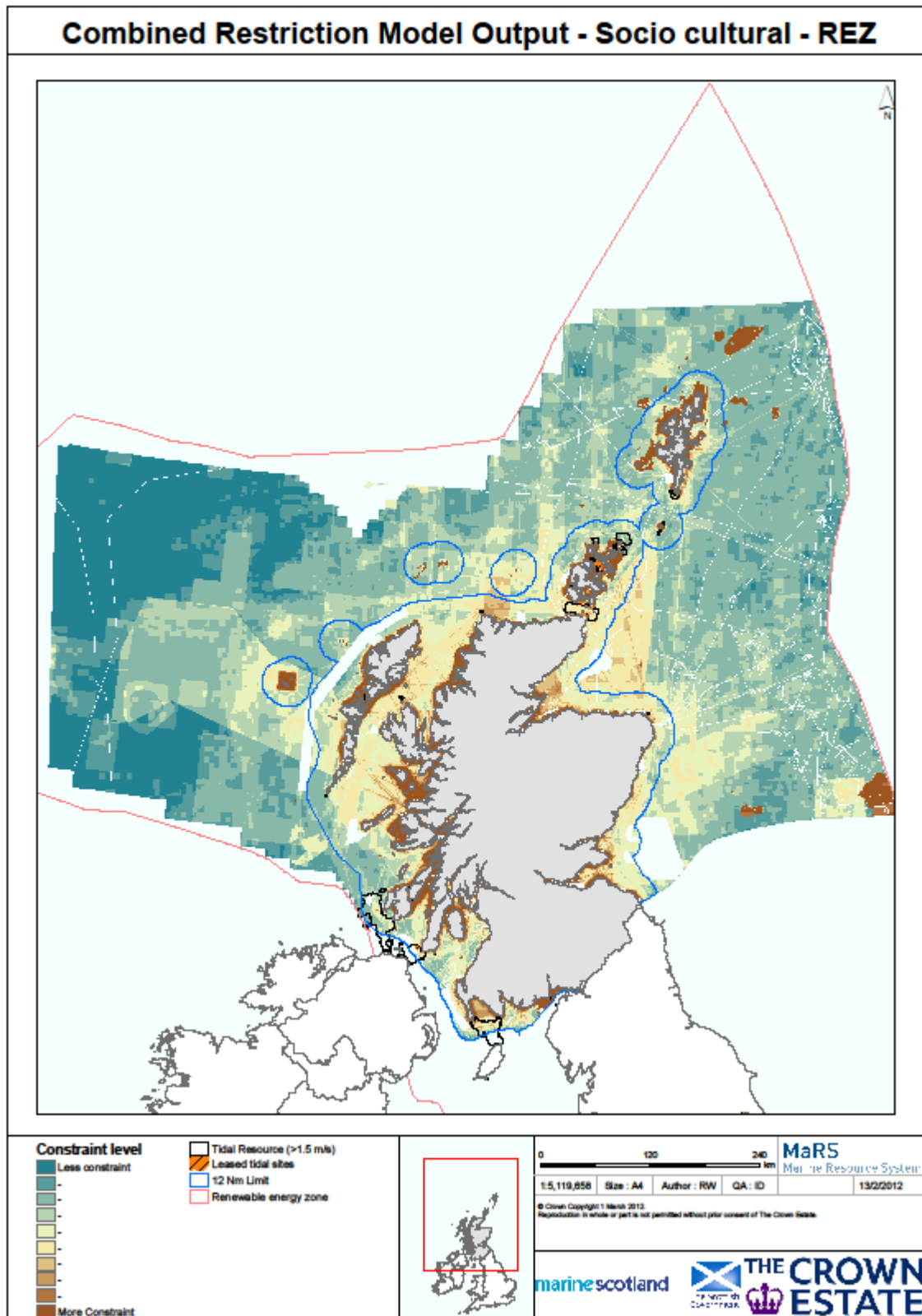


Figure 8 Combined restriction model, emphasising the socio-cultural theme.

5 Opportunities for Tidal Stream Development in Scottish Waters

The potential locations for tidal stream energy developments are strongly limited to the locations where sufficiently strong tidal currents occur. These areas are confined to coastal and near shore waters where the large volumes of water involved in tidal fluxes are constrained to pass through firths and sounds (such as the Pentland Firth), or round headlands (such as off the south west of Islay). Suitable resource areas were identified through the resource assessments.

The tidal stream energy resource areas in Scotland, as identified from the resource assessment, are:

- A. Pentland Firth
- B. Orkney and Westray
- C. Sumburgh and Fair Isle
- D. North Skye
- E. South west Islay and Kintyre
- F. Solway Firth

The geographical extent of these areas is large enough for there to be opportunities for fully commercial scale development of tidal stream energy projects. However, any development will have to take account of the constraints arising from environmental, industry and socio-cultural factors. The relative importance of these factors between areas is shown in more detail in the extracts from the combined models shown in Figures 9, 10, 11 and 12.

All the combined models indicate that the least constrained areas from environmental, industry and socio-economic aspects are South west Islay, northern parts of Orkney and Westray area and in the southern part of the Solway area. The details of the constraints in all the resource areas identified in this report will be presented in greater detail in Regional Locational Guidance.

No resource areas for tidal stream energy developments at this time have been identified outside Scottish Territorial Waters. Technical development has been targeted at situations of high tidal currents, to exploit the associated high power density. There has been some theoretical discussion of the potential to exploit the persistent, but relatively slow ocean currents present in some deep water channels, but no significant commercial interest has been expressed.

This analysis should not be taken to imply that there are no useful tidal stream resource areas elsewhere around Scotland. The identification of resource areas has been based upon tidal stream maps taken from the DECC Renewables Atlas (DECC, 2008). The tidal stream information in that Atlas is presented as a grid of data, with cell size of 1.8 km. Resource areas smaller than this may well not be represented, and areas up to the scale of a few cells or immediately adjacent to the coast may be poorly represented. It is well known that there are a large number of small areas around Scotland where tidal streams are at times powerful. These include areas at headlands, areas around sills at the entrances to sea lochs (and separating basins within sea lochs), and channels and sounds between islands and between islands and large land masses. Such areas will not have been captured by this scoping study, but in favourable locations may offer considerable potential for small (and perhaps medium) scale developments for testing or commercial purposes.

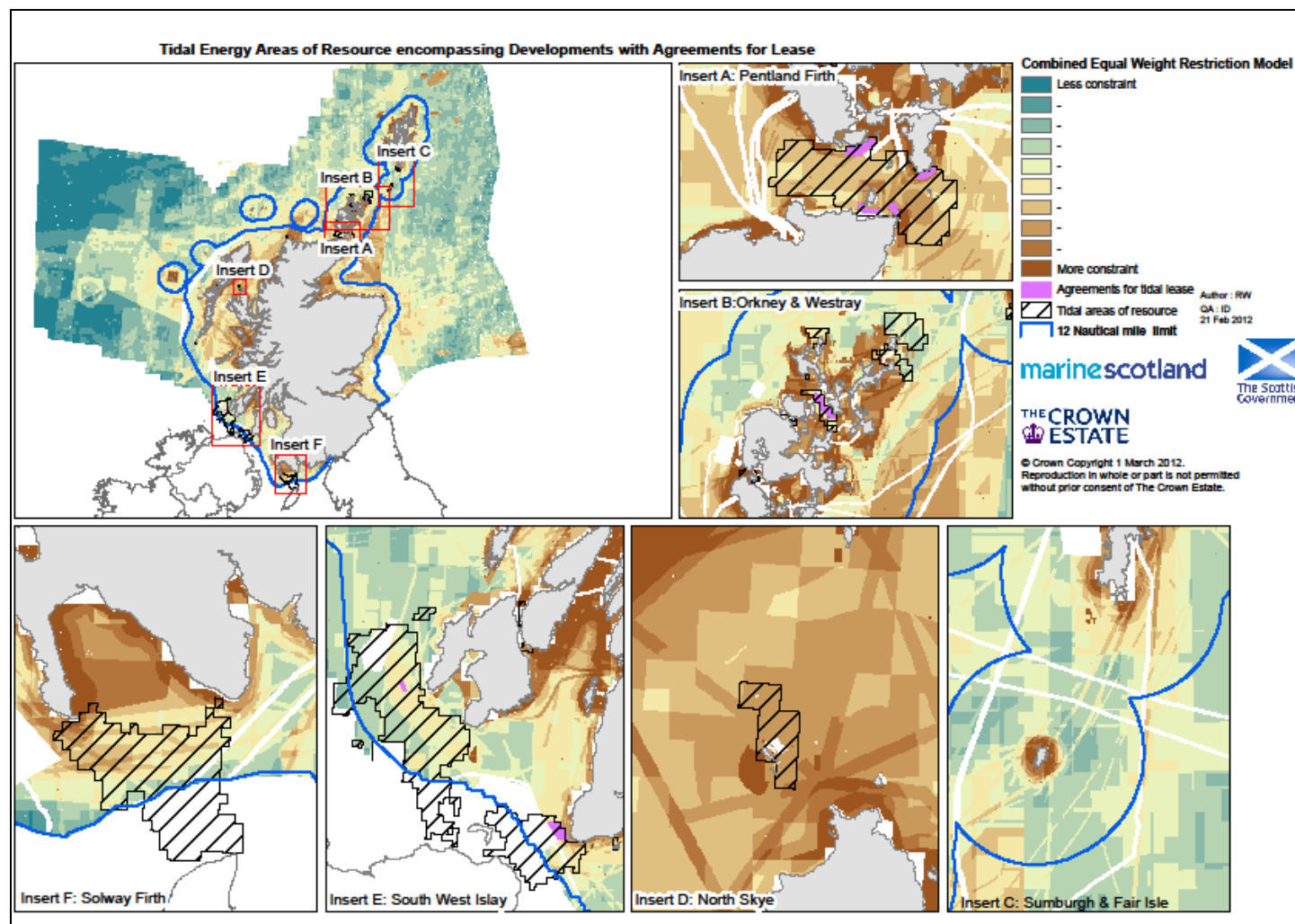


Figure 9 Combined restriction model for tidal stream resource areas, giving equal weight to the environmental, industry and socio-cultural themes.

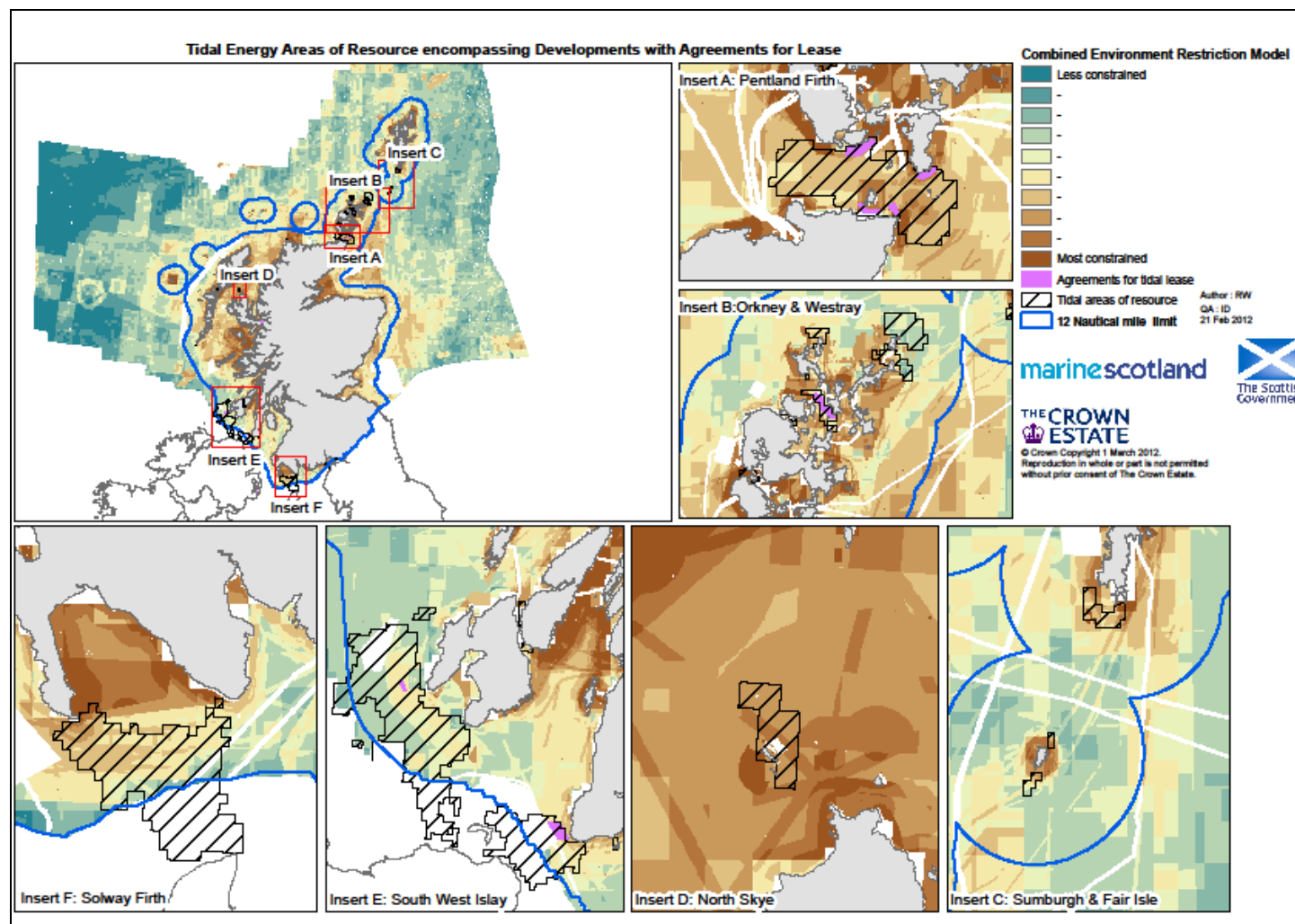


Figure 10 Combined restriction model, emphasising the environment theme.

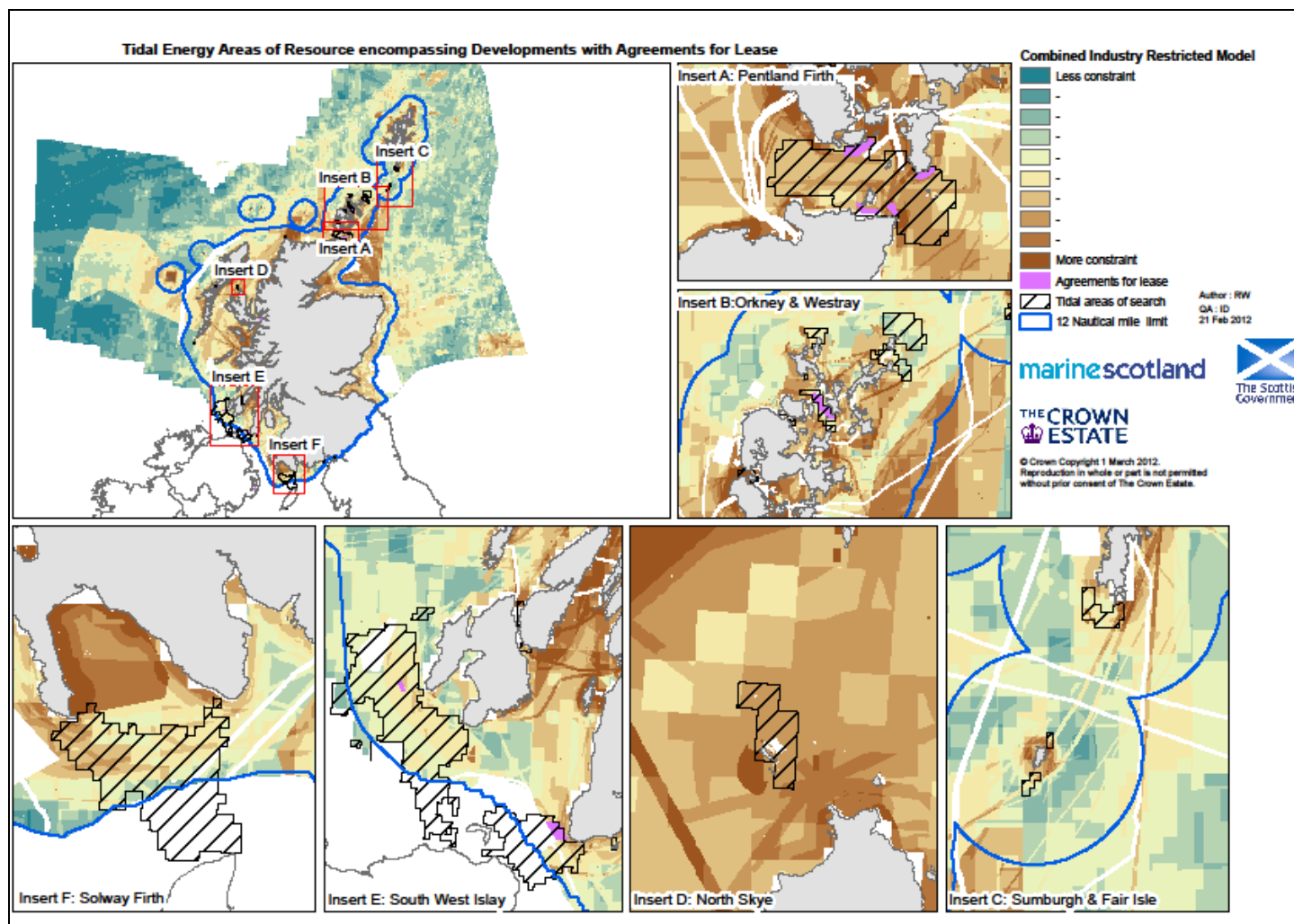


Figure 11 Combined restriction model, emphasising the industry theme.

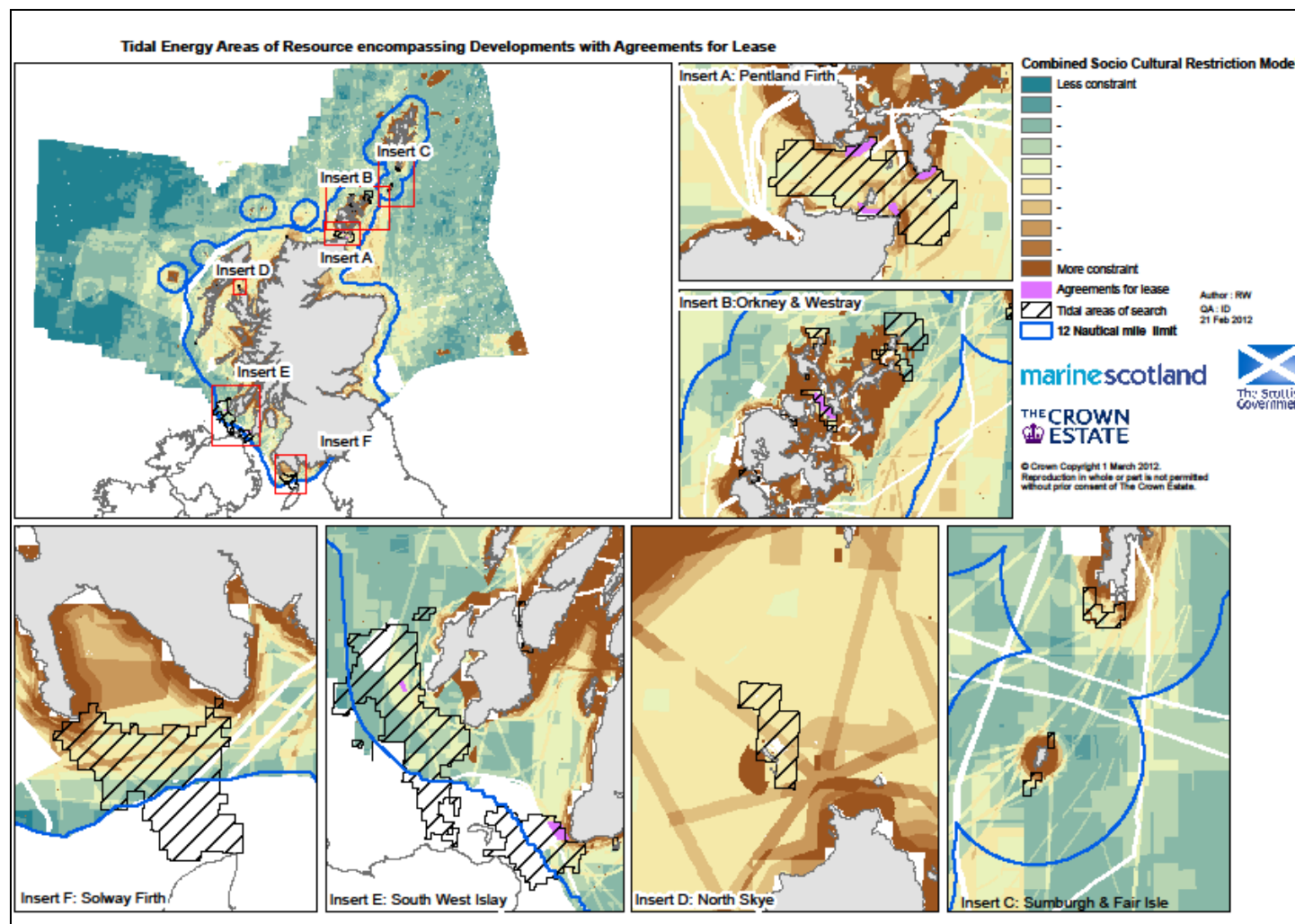


Figure 12 Combined restriction model, emphasising the socio-cultural theme.

6 The Next Steps

The current Scoping Study has used new data and improved data handling methods to develop a new view of the potential of Scottish marine waters for tidal stream energy projects. The Scoping Study utilised the improved data layers and data handling methods that have been developed since the Scoping Study for the Saltire Prize, and building on the experience of the Scoping Study for offshore wind development.

The use of a themed approach to the spatial modelling has allowed the sensitivity of the models to the relative importance given to different spatial factors to be explored, and the general comparability of the outputs from the four Combined Models gives confidence that the outputs from the current exercise are robust. The similarities in the approaches being used for scoping studies for wind, wave and tidal energy will allow a more consistent view to be taken of development opportunities and offer the potential for interactions between opportunities to be taken into account in marine planning across the renewables sectors.

As the potential for wave, wind and tidal stream energy development in Scottish waters is becoming more clear, it will be necessary to take greater account of cumulative effects arising from interactions with other developments, or potential developments. For example, existing Round 3 and STW proposals in the Moray Firth, and off the Firths of Forth and Tay will be the background against which cumulative impacts of wind developments further offshore, or of tidal stream (and wave) energy projects in areas closer to the coast will have to be considered. Similarly, proposals that emerge from the Northern Ireland renewables leasing round may interact with development opportunity proposals in the south and south west of Scotland.

The output maps presented in this report cover the whole of Scottish waters. However, the detail of the information available on tidal streams at the national scale leads to some local detail being difficult to discern. The next stage in the development of a Sectoral Plan for tidal stream energy in Scottish waters is therefore to address each of the potential development areas in more detail through a Regional Locational Guidance process.

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