8 The Grid

8.1 Introduction

In this subsection we look in more detail at the specification of the grid which underpins all the geospatial outputs of the ideal system. This grid is a strategic priority for the organisation and an architectural pre-requisite for the system from the initial implementation. The grid is a product-neutral set of coverage features on which the different datasets produced by the organisation are layered. This section explores the concept of the grid in more detail and defines a draft specification which can be used as an initial definition against which testing would be required to arrive at a final, consistent and balanced grid for the future.

8.2 Grid Definition

Existing grids for ENC data coverage (referred to as “scheming”) are reasonably commonplace globally. Numerous countries use a gridded scheming for their ENC series. Norway, Australia, Korea and others have implemented gridded schemes for a variety of reasons and with a wide disparity in parameters and characteristics. NGA’s wish is to implement a global grid for all data products leaving the organisation and, given the difficulties of changing an extant grid it is important to define at the outset something which is practical, consistent and complete.

In this section we define the characteristics of gridded scheming and those factors most relevant to the mission of NGA Maritime as well as providing some rationale for those decisions based on grid schemes of other member states globally.

8.3 Candidate grid specification

A gridded ENC (or other data product predicated on coverage) is a way of splitting data content in a region (or globally) into a series of regular tessellated polygons which together cover the required region.

Gridded schemes in the IHO context were originally introduced in S-57 edition 2 and then dropped in favour of ENC scheming at the discretion of the producer agency. Gridded schemes define a series of (normally rectangular) grids, normally defined by parallels and lines of longitude.

Normally a gridded scheme is used when a data product covers a region partially or completely at a range of different scales and the grid imposes the requirement of common boundaries, so each cell has coincident boundaries with the larger scale with which it overlaps.

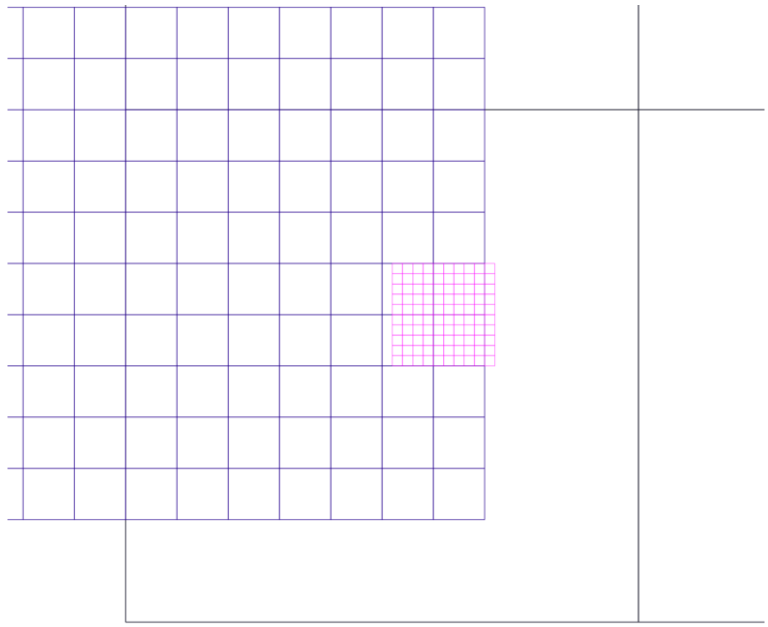

Figure 5: An example of a multi-resolution grid over a region

A grid therefore may be specified by identifying the following pieces of information:

1. The definition of grid size at each chosen scale level (or, in the case of ENC data), usage band. This can also include any scale banding or areas where the grid scheme is not used (some producer agencies only use a gridded scheme for small and medium scales leaving the very largest scales to the discretion of the producer. Additionally grid sizes themselves may be adjusted based on latitude. Some data producers, whose data covers a wide disparity of latitudes will adjust their cell widths at high latitudes to account for the distortion in the "rectangles" these grids define.
2. A point of origin(s) for the grid scheme. Normally a single point of origin is used and popularly the SW corner of the cell identifies its origin. The scheme as a whole can be anchored at one or more point (where the total coverage required is composed of spatially disjoint regions)
3. Any rules for aggregation of grid cells into larger components. Some data producers allow cells to be joined by spatial union to provide a more efficient scheming in some areas.

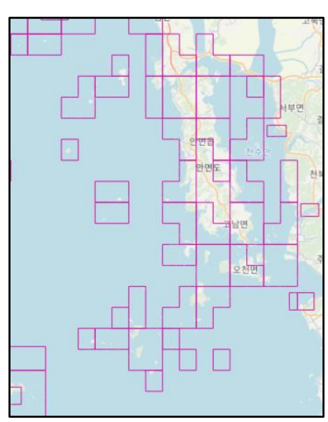

Figure 6: Examples of Aggregated grid squares (Korea)

It is worth noting that for most data producers the issues of distortion at high latitudes are not of overwhelming importance and the choice of grid size, scale and content is largely down to local or regional geography. Because of this there is a large variety of grid schemes worldwide, summarised in the following table (adapted from earlier IIC research work on this topic):

Scale Band	Australia[3]	Korea[4]	Norway[5]	Sweden	Greenland	Russia	Ukraine	Japan[6]	US (Proposed)[7]
1	Irregular, generally 30x30 clipped to marine boundaries	8°x8°	Single cell 1:1.5m Irregular				6	25x25 and 8x8	19.2 and 38.4
2	10°x10°	4°x4° (not all)	Mix of 8°x2° and 2°x2°	4x4 clipped heavily (to boundaries)		Mix of 9x7 and 8x7	4x4	2x2	4.8
3	1°x1°	1°x1°	Majority 2°x2°	mostly 1x1, some 0.5x0.5	0.5x0.5 (irregular)		1x1	0.5x0.5	1.2
4	1°x1° - coastal only. Sometimes irregular	0.5°x0.5°	0.5°x0.5°	mix, 0.5x0.5 and 0.25x0.25			0.5x0.5	mix. ~0.125	0.3
5	Irregular	0.25°x0.25°	Mixed, from 0.25°x0.25° to 0.125°x0.125°	different origin for some cells. Mixture: 0.125x0.125			Irregular	Irregular	0.075
6	Irregular	0.05°x0.05°	Irregular				Irregular	Irregular	

Figure 7: Global grid schemes in current ENCs

[3] Very regular at small scales, less so at larger scales. Clipped.
[4] Includes some irregular. Mainly rectangular but uses L-shaped cells in intermediate scale bands too. Clipped.
[5] Scheme based on S57 2.0. Majority rectangular. Coincident edges between scale bands. Clipped.
[6] 2 small scale grids (SB1) (avoiding overlap).
[7] From US presentation on rescheming.

8.4 Specification of a global grid scheme.

In terms of proposing a global grid scheme it would seem appropriate to take the following elements into account:

1. A global scheme will need to account for distortions of cells based on regular graduations of a degree and therefore some aggregation at high latitudes should be considered.
2. Choosing cell dimensions which of the same order of magnitude as a broad range of other data producers would seem to be sensible. NGA, as a global provider will be capable of reproducing data within grids but, given the disparity globally in schemed data a process of compromise is inevitable. Given that NGA is content with taking on the gridding of existing non-gridded data it lessens the priority to meet exactly the compilation scales within existing data. The main optimisation to make is one which allows a uniform cell size globally and minimises the amount of recompilation required and yet keeps cells to a manageable size (bearing in mind the "5Mb rule" imposed by the existing S-57 regime and the likely continuation of such limits in the future).
3. The creation of SMENC data is known to be bounded by 1° cells and it is thought no SB1 or SB6 data will be produced (discussions with ENC tiger team)
4. The grid should be defined in terms of what is most appropriate for the manageable sizes of cells, the number of created cells and how the grid size affects the management and maintenance of "derived" cells from supplying data producers.
5. The naming convention should then be determined once the optimal grid dimensions and conventions are established. The naming convention is based on geocoding principles so adjacent cells have similar names and the smaller scale cell names can be determined from the larger scale cells (as all cells have the small scale covering cell name embedded in them). Is this based on system considerations or human ones?

Observations on what is required by a grid scheme:

1. The issue for the "ideal" system is to find a way of creating a usable set of gridded tiles to produce the required coverage within the resource constraints required by updating and practical sizes for their promulgation.
2. The scheming proposed will have three broad groups of scales. Although the current S-57 methodology allows up to six independent scale bands, in time S-101 will remove the scale band concept and it already defines a more practical three band system broadly (Figure 11.5)
3. S-101 will possibly impose a maximum number of discrete coverage areas within a single cell. S-57 has no such limit and each cell is composed of a set of M_COVR objects which either contain data (CATCOV=1) or don't (CATCOV=2). So, a single rectangular cell under S-57 ENC can have a number of coverage areas within it which are spatially disjoint but an S-101 cell may limit the distinct number of them (although this is still very much under development) – so, it is worth noting that a grid scheme defines a broad area of coverage for a cell but the exact areas of that coverage which may have data within them still remains to be defined (and may be dependent on either data supplier data coverage or data NGA may hold or author from existing (e.g. DNC based) data as a source – it also means that the largest scales may be limited in how many spatially disjoint cells they can contain.
4. The 8.3 format file name (and the difficulties of defining naming schemes that fit it) will disappear as S-57 is superseded. A naming scheme for S-101 can be completely different – some producers have intimated they will use the Lat/Lon digits of the SW corner of a cell to

define the S-101 cellname. This would allow the actual requirements (including the geocoding ones) to be isolated and defined better.

8.5 Current proposed grid scheme and naming convention

The naming and schemed concept already received by the project proposes 10°/5°/1° for the main grid dimensions, located with an origin at (0,0) with no aggregation of cells together – there is an additional subdivision of either 0.25° or 1/3° determined by the namespace in the final character of the cell name.

The associated naming scheme defined works within the structures defined by IHO S-57 and defines a namespace for each group of scales. So, the grid scheme proposed is illustrated as per the following diagram

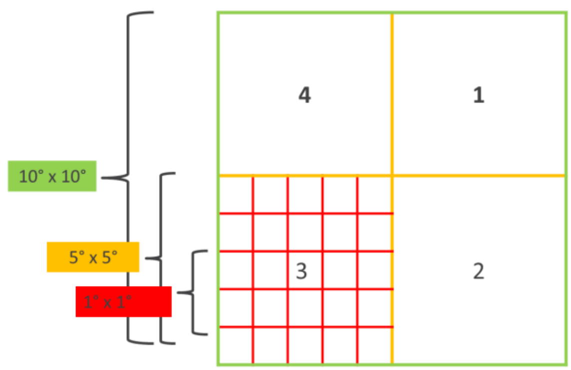

Figure 8: NGA Proposed Grid Scheme (sizes) (source: NGA)

With an associated naming convention of:

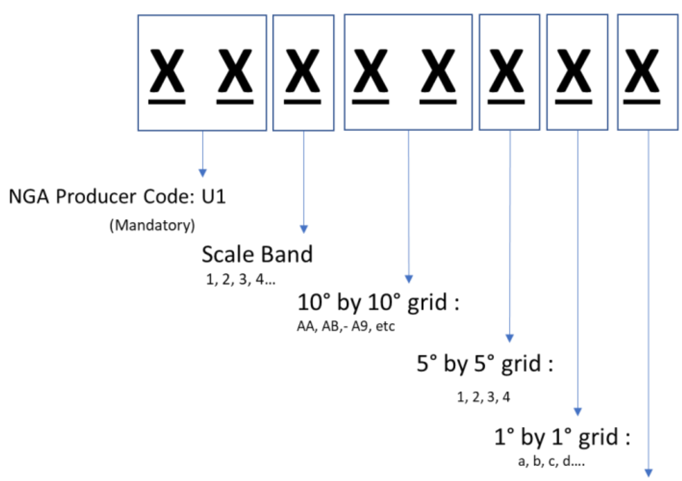

Figure 9: NGA proposed naming convention (source: NGA)

The task with the grid determination is to define for each data producer scale band how they map (broadly) into the defined grid sizes and the U1 cell scale bands within the scheming. Finally, a naming convention defines how each cell is named. The concept of having a namespace for each group of scale bands should be preserved (so, cells adjacent to each other have similar names as in geocoding)

The proposed grid therefore works by mapping supplier data according to the following diagram:

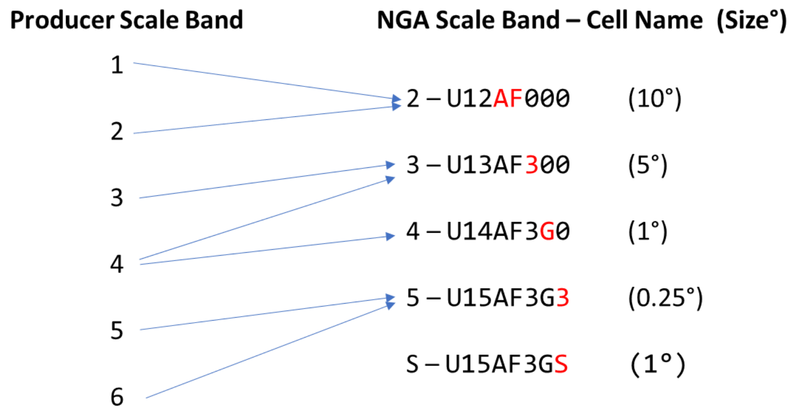

Figure 10: Mapping of Supplier data to NGA Grid and Naming scheme (IIC)

This diagram shows supplier scale bands and how they will map (by output from the central database extraction) to NGA U1 cells, their scale bands and the namespace characters designating which grid cell is selected.

8.5.1 Observations on proposed grid

When defining the grid there is a need to think broadly about scale bands. The aim with the NGA scheming, ultimately, is to map data supplier scale bands to the NGA grid scale bands to a reasonable degree. This is different to scheming for other hydrographic offices because NGA is planning to produce derived data globally and is thus taking on the task of effectively harmonising scales across all global suppliers and finding ways of minimising any manual tasks this entails.

Because data can't overlap within scale bands (as per IHO S-57 product specification) the aim is to define a grid and mapping where the need for NGA to vertically deconflict data is minimised (e.g. because NGA is not planning to scheme any SB6 cells any overlapping SB5 and SB6 cells from data suppliers will need to be vertically deconflicted to become U15 cells in the NGA scheming, similarly for SB1 and SB2 mapped into U12 cells.) Although S-57 will give way to S-101 in time (where the overlapping scale band requirement is dropped) the requirement will be in place for many years simply because of the amount of time that S-57 data is likely to be the prime deliverable from data suppliers.

The mapping of both SB5 and SB6 into U15 at a large scale isn't much of a problem as for most countries SB5 is largest scale produced. About 50% of countries produce SB6 data and they are small in area and detailed in terms of coverage and can be very large scale. Similarly SB5 data can be very small in extent and detailed.

Globally SB1 and SB2 are the smallest scales so it makes sense to map SB1 and SB2 to U12 cells and then SB5 and SB6 to U15. SB3 and SB4 are then mapped to U13 and U14 as appropriate and a 1° division adopted for both (similar to Australia and Canada's proposed scheming).

This also implies a banding into three categories which reflects the S-101 proposals in the current product specification and thus builds in a longer term compatibility with likely scheming from supplier nations in the S-101 timeframe.

Name	Multiplity	Value	Type	Remarks
specificUsage	1	{1} to {3}	CharacterString MD_USAGE>specificUsage (character string) MD_USAGE>userContactInfo (CI_ResponsibleParty)	1. Port Entry – A dataset containing data required: for navigating the approaches to ports for navigating within ports, harbours, bays, rivers and canals for anchorages as an aid to berthing or any combination of the above. 2.Transit – A dataset containing data required: for navigating along the coastline either inshore or offshore for navigating oceans, approaching coasts for route planning or any combination of the above. 3.Overview – A dataset containing data required for: ocean crossing route planning

Figure 11: S-101 planned usages. Banding of scales is discontinued

The 10° division at the smallest scales may be too large in area with some cells being made up of many datasets requiring aggregation from different providers and making for large datasets in bottleneck areas. A 5°at the smallest scale may make this more manageable – it would require a 3 character small scale designation but would make small scale data far more manageable.

e.g.

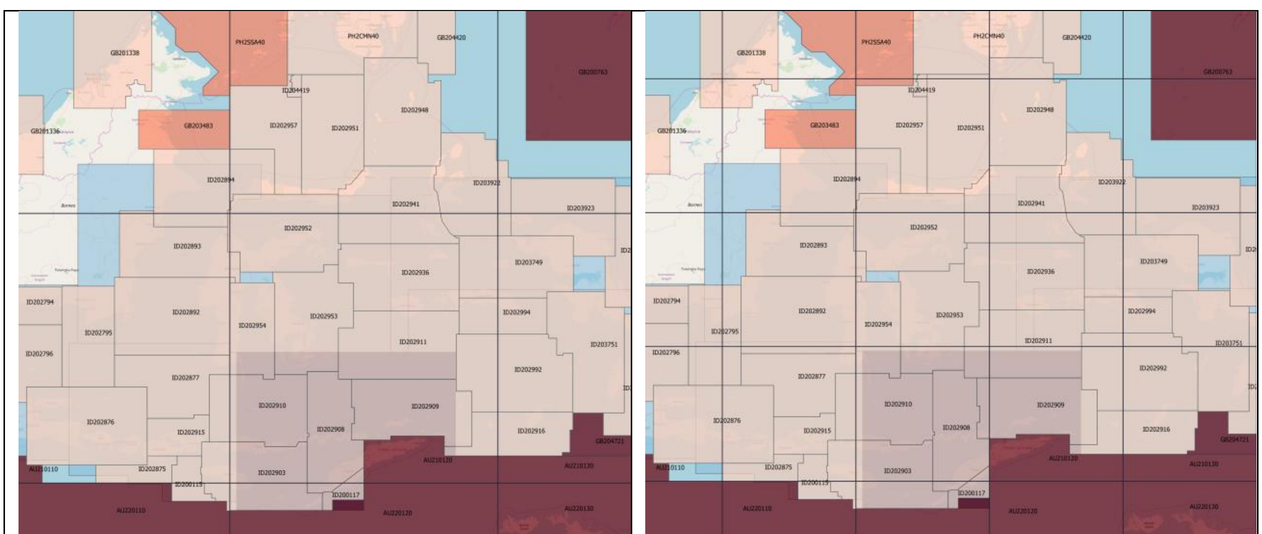

Figure 12: Example Coverage (Indonesia) SB1/SB2 with 10° and 5° grids

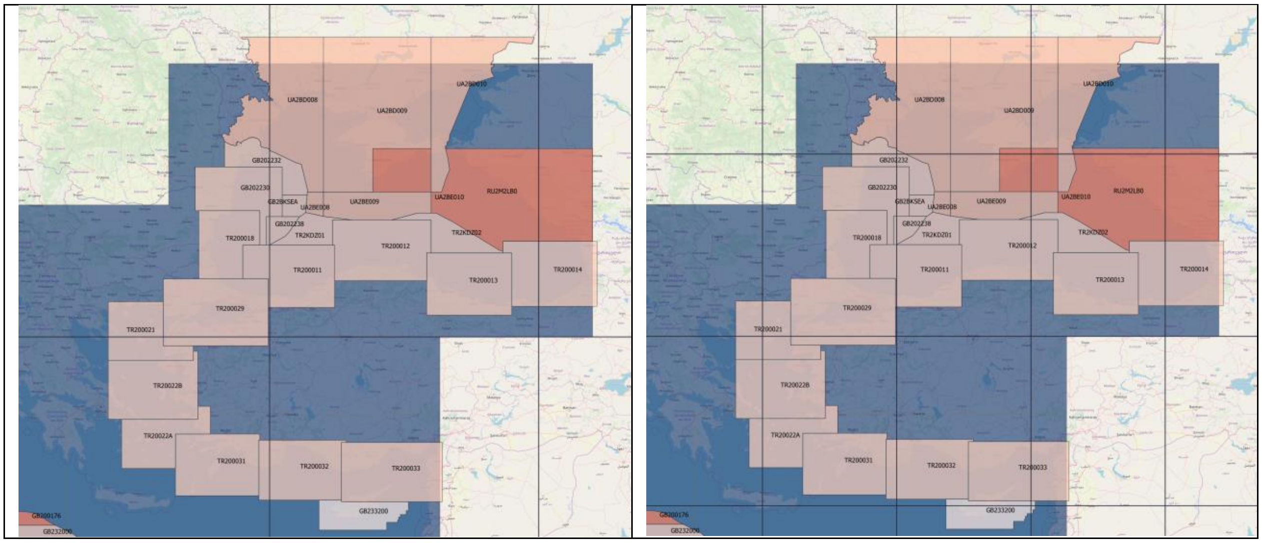

Figure 13: SB1 and SB2 coverage (Black Sea) with 10° and ° grids

In some areas of the world the SB2 cells are very small and these could potentially be defined as U13 cells.

The 1° division works well for SB3 and 4 although some areas may require the SB4 to be pushed into the largest scale category at 0.3° dimensions.

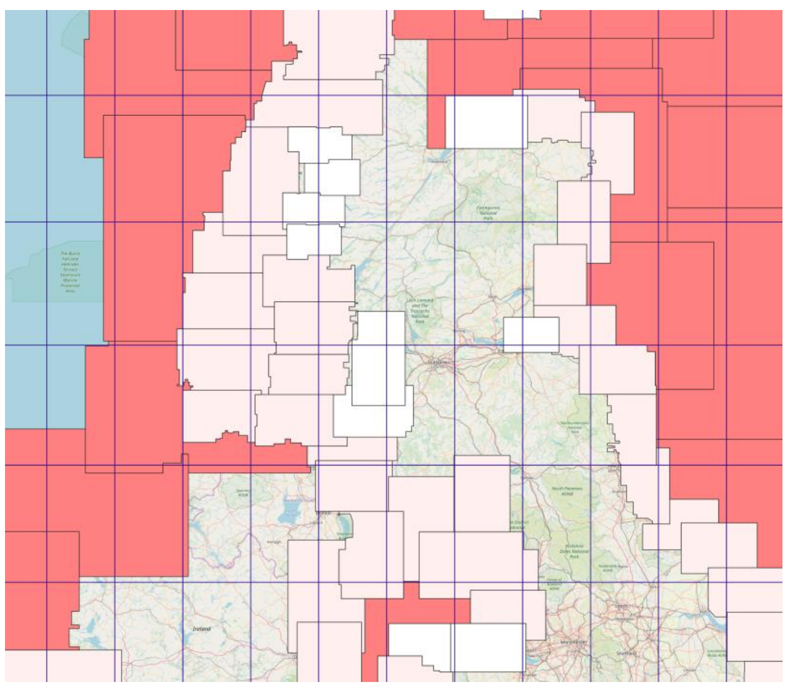

Figure 14: UK Scale Band 3 against 1° grid

The largest scale division should probably be 0.3° or 0.2° splitting each 1° cell into 9 or 25 individual cells at the largest scale, 0.25° is still large in extent and potentially U15 cells would need to contain many areas of spatially disjoint supplier data in order to be viable. Although this is feasible there is an overhead in management of many disjoint areas in cells and the 0.3° 0.2° division does not affect the naming convention (1-9+S as opposed to 1-4+S in the final character) even with the extra character used for the smallest scale.

The move of SB4 into the U15 scale band may cause some overlaps to be processed but these can be accommodated by adopting M_CSCL features within the U15 to accommodate them, subject to good horizontal and vertical consistency in the source cells.

The 0.3° grid is still problematic in that many SB5 and SB6 are very small in extent by comparison with the 0.3° grid size. This would lead to some grid squares having many spatially disjoint areas of coverage.

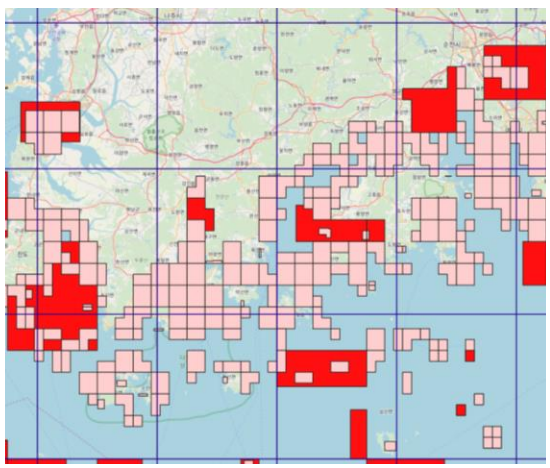

Figure 15: Korean SB5 and SB6 against 0.3° grid

The naming convention, unfortunately, prohibits a more efficient grid scheme but potentially a non-gridded SB5 and SB6 (possibly under U16) could be considered where up to 35 individually schemed SB6 cells could be located in a single coverage of a U15 grid and designated by a single letter each. This namespace could even be split up to allow for either a gridded 5x5 array with up to 10 individual non-gridded cells. This mirrors designs in other countries where the largest scales are ungridded as well as having SB3 and SB4 the same size (e.g. Australia). There is certainly scope for SB5 being smaller in extent (by using a subdivision by splitting the 7th character) – this should be investigated further against existing chart schemes.

This aspect of fitting the grid scheme to current global usages is an area for further consideration in the next phase of the project.

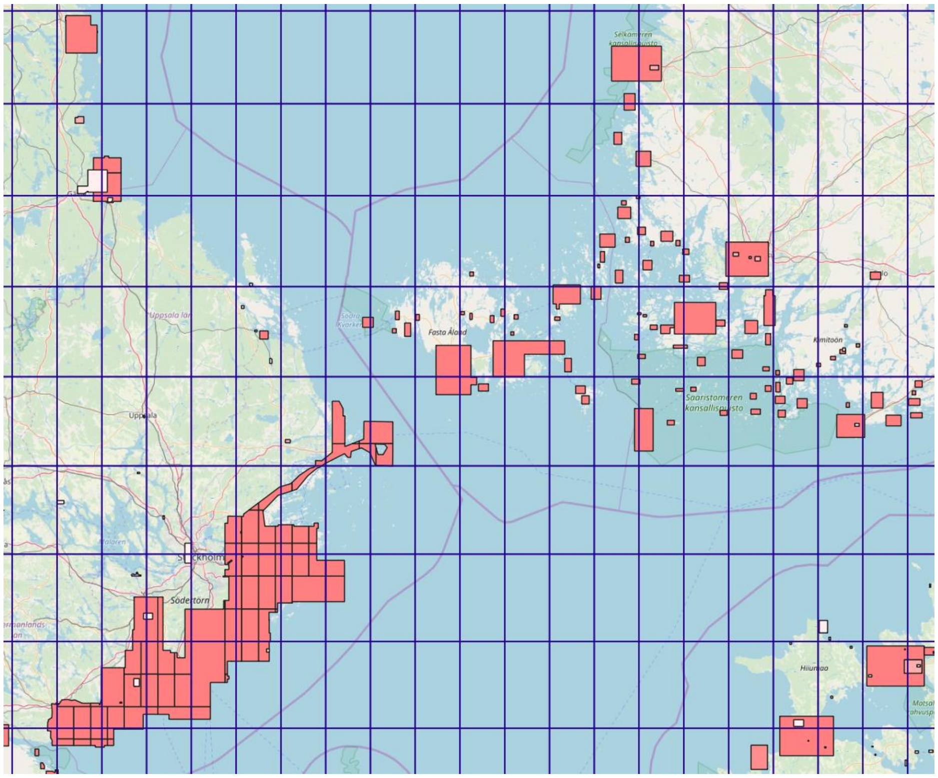

Figure 16: SB5 and SB6 data with 0.3° grid (Baltic)

The 0.3° grid should be sufficient to deal with all SB5/6 areas and production of SMENC data.

8.6 Summary

A suggested alternative scheme and naming convention could therefore be summarised as follows (this shows, again, supplier scale band, its mapping to NGA U1 cells and their scale bands and the proposed grid sizes):

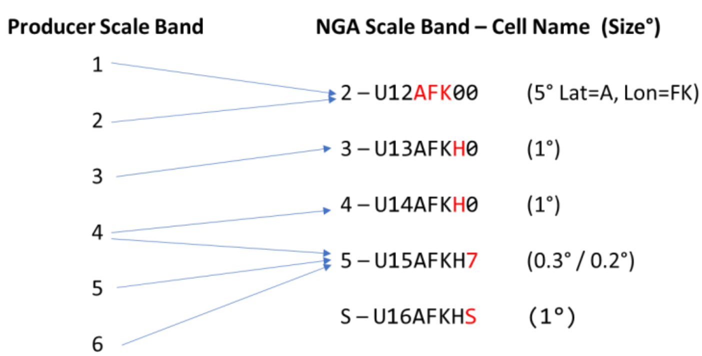

Figure 17: Optional Scheming of grid and mapping to supplier scale bands

i.e. a cell name would become: U1 [SB] [Lat] [Lon] [1°] [0.3/0.2°]

1. 5° Latitude [A-Z0-9] 1 char
2. 5° Longitude [AA – ZZ] 2 chars [SB1&2]

3. 1°division [A-Y] 1 char [SB3 + SB4]
4. 0.3° (or 0.2°) subdivision [S,1-9 or 0-9A-Z] (SMENC) 1 char [SB4 (larger scales) + SB5 and 6]

Characters unfilled because of SB are defined as "0" otherwise. SMENC cells are designated SB6 so that where they overlap with supplier SB5 and SB6 data no overlap is created at the (W)ECDIS at the same usage band. This may not be required depending on the SMENC product specification adopted though.

The grid should be orientated at (0,0) to preserve whole degree dimensions where possible.

Consideration should definitely be given to the aggregation of grid cells at extreme latitudes. This would aggregate longitudinally adjacent cells to avoid cells which are skewed in dimension at high latitude. A further consideration could be polar datasets for regions of the arctic which aggregate many grid cells together to make the management of the charts and their extraction simpler.

8.7 Conclusions.

The choice of dimensions is crucial for the grid to be adopted in the NGA global ENC series as it balances resources, maintainability, update efficiency and size of ENC cell as distributed to NGAs end users. Additionally, whatever grid is adopted potentially has long term implications and will outlive S-57 into the S-101 regime of electronic charts. Naming scheme considerations, although important, may be a lesser priority than adopting grid dimensions which strike the best balance for both NGA and its end users.

The grid dimensions have implications on chart production effort because data has to be extracted and cut against a relevant grid square. In a truly product neutral and seamless database this process of extraction is 100% automated but practical considerations in the interim mean there will be an overhead in the COTS definition and management of the grid so a quantifiable resource cost exists until the required automation is in place.

In terms of defining the grid scheme, consideration should be given to how supplier data is mapped, broadly, into the U1 cell scheming from the supplier usage bands as this is a major determinant of the effort required for its ingest into the database.

Although NGA has a free reign on rescheming cells into other usage bands because it is, in effect, defining its own global series, there is a requirement (at least within S-57) to adhere to the "no overlapping cells within the same usage boundaries" rule on which much W(ECDIS) portrayal is predicated and which has a major impact on usability of cells. There is also the existence of brokered and non-brokered data at fixed compilation scales which will be ingested and a high cost of recompilation of this data if necessary. Given the large disparity of scales globally it is likely NGA will need to spend significant resources in performing harmonisation across the entire data holdings and the grid scheme adopted should be seeking to optimise and minimise this resource cost.

NGA is also planning to create its own content alongside (and instead of) supplier nations' data. This means the grid scheme adopted needs to balance the requirements of optimising resource for ingest of data suppliers' charts as well as providing a good environment for NGA to create its own charts from the sources it is likely to have available.

The best way to define, refine and adopt an optimised grid scheme, therefore, is to look in detail at existing scheming and known plans globally for other member states, examine closely the relationships and disparity in scale bands, compilation scales and spatial extents of current schemes and come up with a balanced scheme which can be adapted for S-101 use in the future and for which an appropriate naming scheme can be defined.

The alternative proposal contained in this section is a first pass at balancing these items, having been arrived at through an examination of the global grids (as documented in table Figure 7) and current known global ENC coverage (as shown in the examples in this section). It is proposed that this initial study is continued in the next phase of the project to refine (or reinforce) the grid scheming against other factors such as the resources required for ingest, cutting data to the grid globally and the requirements of NGAs own cartographic input into the global series.

NGA is also recommended to investigate the OGC's Discrete Global Grid System as another possible future method for global scheming of ENC data. This is noted in the Annex report already supplied and possibly is another thread for the trial.