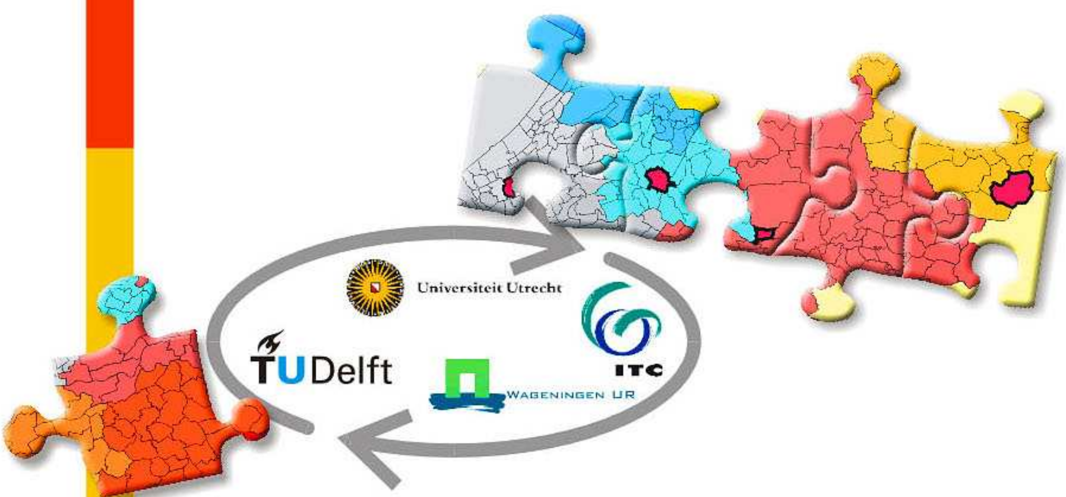
GIMA

Geographical Information Management and Applications

SPECIFYING REQUIREMENTS FOR AUTOMATIC GENERALISATION OF ELECTRONIC NAVIGATIONAL CHARTS

MSc Research by Weronika Socha



I decided to cook a lamb roast. This was a special dish my mother always used to prepare for special occasions. So I called my mother and asked:

- Mum, do you remember the recipe for that delicious lamb roast?

- Certainly, dear. Take a pen a write: take a lamb leg and cut off the end piece, about 10cm and throw it away. Then…

- OK mum… just one question. Why should I cut the end of the leg?

- Hmm… that's a good question. I got this recipe from my mother and she got it from hers. Why should I have questioned their wisdom? Let's call your grandmother to find out.

So we called my grandmother and asked:

- Granny, in our long family history we have shared the lamb roast recipe down through the generations. I wanted to prepare it tonight, and so I called mum to get the recipe, but I don't understand one thing - why do you cut the end of the leg of lamb.

My grandmother thought for a moment and replied:

- I'm not quite sure. You see, me as well, I got this recipe from my mother.

- Oh, dear… the poor old grand-grandmother is barely alive. We need to call her fast!

So we called my grand-grandmother:

- Dear old granny, do you remember the famous lamb roast recipe that has been cooked in our family for generations? Why is it so important to cut the end of the leg?

The grand-grandmother, although very weak, started to giggle. After a moment she replied:

- My mother taught me and it was during the war. We only had a very small home and a very small kitchen. The leg of lamb wouldn't fit, the oven was too small, and so we had to cut it off."

Never do something only because this is the way it has always been done.

Specifying requirements for Automatic Generalisation of Electronic Navigational Charts

MASTER THESIS

RESEARCH IN COOPERATION WITH:

- *LAND INFORMATION NEW ZEALAND*
- *DIENST DER HYDROGRAFIE VAN KONINKLIJKE MARINE*
- *SERVICE HYDROGRAPHIQUE ET OCEANOGRAPHIQUE DE LA MARINE*
- *DIRECTORIA DE HIDROGRAFIA E NAVEGAÇÃO*

Date:

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Author:

Weronika Socha

Geographical Information Management & Applications (GIMA)

Supervisor:

Dr. Jantien Stoter

OTB Research Institute

Technical University, Delft

Professor:

Prof. Dr. Ir. Peter van Oosterom

Section GIS-Technology

Technical University, Delft

Reviewer:

Dr. Richard Knippers

Faculty of Geo-Information Science and Earth Observation

University of Tweente

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SUMMARY

This short summary helps to grasp the motive behind the research, its objectives and to find out what is presented on the following pages of the report. It offers a condensed, one page recapitulation of its contents and intentions and suggests who might be interested to read it.

CONTEXT

Map generalisation is a tedious task, requiring skilled cartographers to work for long periods of time. Experience shows that compiling a map can take several months. It is the common wisdom that such labour-intensive tasks should be consigned to computers and thus be accomplished more uniformly, more precisely, more rapidly, and at much reduced cost (Buttenfield & McMaster, 1991). The benefits of automatic generalisation could aid hydrographic offices (HOs) in their ENC creation.

OBJECTIVES

The aim of the project is to create 'hard knowledge' specifications that could be subsequently used to create/use with tools for automatic generalisation of ENCs. The research compiles requirements of various HOs with the recommendations of S-4 and knowledge in model and cartographic generalisation of topographic charts to create computer translatable rules that allow creating a smaller scale/usage ENCs from a higher scale/usage ENC / S-57 data without or with minimum human interference.

DELIVERABLES AND THEIR IMPACT

The final report presents a set of specifications, rules and tools that allow going from one compilation scale (Approach) to another (Coastal) without or with minimum human interference. It also discusses shortcomings and rate of success of such approach. The study mainly bases on the existing generalisation operators available in the literature, but where it is just- points out scarceness of the choice and proposes new solutions. As a result, an IHO standard could be created for the generalisation of charts (ENCs) and tools implemented in the software used for chart creation.

WHO SHOULD READ THIS REPORT?

This report might be found interesting by the GIS community, especially when interested in advancements in digital cartography and ENCs. The main recipients, however, are the hydrographic community, mainly Hydrographic Offices, and hydrographic software vendors. They may find ideas for potential implementations that could aid their business. The secondary recipients could be other parties linked to Electronic Navigational Charts, namely ECDIS producers and chart users. The author hopes that this research could also inspire other projects on automatic chart generalisation and complement projects on bathymetric generalisation.

ACKNOWLEDGEMENTS

Although it is my name that bears the responsibility for this report, there are several individuals who made the journey possible, bearable and even enjoyable. This report would have never been created if it was not for the guidance, help and support of many people. I would like to take this opportunity to express how thankful I am to them.

First, my utmost gratitude to my supervisor – Dr Jantien Stoter who kept her hope in me even in times, when I did not give her many reasons to ☺. Her devotion to the subject and her availability to always guide and support me were truly motivating.

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A very warm thank you to my ex-colleagues at CARIS BV, especially to my ex-manager, Mr Geerten Blessing and Mr Peter Schwarzberg. I could always count on their help, advice and CARIS license loans. ☺

Mamo, Tato, bez Was ta praca nigdy by nie powstała. Ze wszystkich, to Wam najbardziej dziękuję. Zawsze mogłam się Wam wygadać, pożalić i zawsze mogłam liczyć na pomoc, motywacyjnego kopa i coś w lodówce żebym mogła się skoncentrować tylko i wyłącznie na pisaniu. Kocham Was najmocniej na świecie i dziękuję.

Żabko, Je sais que j'ai été parfois très difficile à supporter pendant ma thèse. Je n'arrive pas à trouver les mots pour exprimer toute ma gratitude pour ce que tu as fait pour moi, cependant j'ai besoin de te remercier. Ton soutien m'a vraiment aidé et j'espère que cela renforcera encore plus notre relation. KC.

I dedicate this report to L. and C.

You will always stay in my heart.

TABLE OF CONTENTS

1 INTRODUCTION

This chapter presents the context in which this research is set, describes the research problem tackled by it and the research questions that are answered in the following chapters. It also explains what is not part of the research. Next case study is introduced through methodology, description of the data providers, tools and data used. Structure of the report concludes the chapter.

1.1 CONTEXT AND BACKGROUND

From this chapter readers can learn what drives map creation and how it had evolved. Then Nautical charts are introduced and technical details about ENCs and S-57 – the standard used to produce them are presented.

For many centuries it was the water transport and explorations that were the main motor in the development of more accurate, sophisticated and functional charts. Containing many details and precise drawings charts had become pieces of art, very precious and hard to get. However, once the exploration ended, land mapping became inherently crucial and was powered by the economic benefits coming from the better understanding of the location. Soon land mapping dominated the interest of cartographers.

Even though cartography is as old as maps themselves, or perhaps older, the rebirth of this science is happening now. This is because, while basic elements of topography and theme existed in cartography before, the concept of not only depicting but also analysing clusters of geographically-dependent phenomena, hence the advent of GIS, revolutionized our views on geo-data. The society becomes more location aware and new applications appear constantly. The GIS accelerated the transition from the paper to digital environment. The necessity to perform complicated analyses called for computer readable maps. This brought geographic data storing and cartography to a new level.

Also the navigation has changed. Vessels become bigger, more specialised and follow very high pressured deadlines which requires them to sail on the smallest possible tide margins.

Ocean exploration and shallow waters exploration require constant monitoring of the changing environment. If one adds up to this fisheries and recreational boating, the need for accurate and tailored information becomes apparent.

The present time world seems to favour digital maps over the paper ones. Computers and hand-held devices became a common part of the landscape. Today's society wants information that is up-to-date and tailored to provide exactly what is needed. National Mapping Agencies try to follow-up with the demand and have changed their approach towards map making.

One of the most important techniques used in compiling maps is generalisation. Generalisation is applied for two main reasons- firstly, because while a map is a model or reality, due to miniaturization of the world it depicts it cannot effectively present all the real-life objects. Selection and simplification of the detail assure that the best of the overall picture is conveyed.

The second reason for generalisation is theming of maps. Maps serve different purposes and it would be inefficient to have one map for different applications. Different elements of our reality interest a tourist, a driver and a utilities company officer. Generalising a map based on a theme of interest assures that everyone gets a tailored product that assists their task.

When generalising a map a decision has to be made which elements should appear and which ones should be left out, simplified, displaced, enlarged etc. The output should be aesthetically pleasant, and must enable users to succeed in a given task (Mackaness & Ruas, 2007). According to The International Cartographic Association (ICA), generalisation is the selection and simplified representation of detail appropriate to the scale and / or the purpose of the map… (ICA, 1973).

In the historical perspective generalisation has always been the property of cartographers. It was seen as a high skilled profession, in which both scientific as well as artistic skills were required.

Map generalisation is a tedious task, requiring skilled cartographers to work for long periods of time. Experience shows that compiling a map can take several months. It is the common wisdom that such labour-intensive tasks should be consigned to computers and thus be accomplished more uniformly, more precisely, more rapidly, and at much reduced cost (Buttenfield & McMaster, 1991).

The idea of automated generalisation is not new but the execution is difficult. National Mapping Agencies (NMAs) have rule sets for cartographers that describe which decisions they need to take when generalising. Generalisation is complex and often requires interpretation by an experienced cartographer. The current conventional method of map generalisation is that cartographers can add their own interpretation during the process. It is called interactive generalisation.

Automation of cartographic processes such as generalisation would be a significant step towards highly efficient and flexible map production (Stoter et al. 2009). This has been acknowledged by the NMAs and research aiming at evaluating possibilities and developing necessary rule sets and tools is in progress. Several researches, by Stoter (2010) and others aimed at firstly assessing the current state of generalisation, and secondly creating rules and procedures for topographic map generalisation. Software vendors follow the developments and new more and more sophisticated tools are created.

The results are promising and some NMAs were even able to switch parts of their production to an automatic mode. Examples include Baden-Württemberg province in Germany and Ordnance Survey UK, in cooperation with 1Spatial[1].

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[1] http://www.geoconnexion.com/news/1spatial-mapping-on-demand-for-baden-wuerttemberg Accessed on 9th of September 2012

1.1.1 SITUATION OF NAUTICAL CHARTS

Hydrographic Offices (HOs) producing nautical charts would also benefit from new developments but it is not always possible. National (Land) Mapping Agencies have developed their own domestic rules for generalisation and are not constrained in terms of content and/or level of generalisation by any international communities. This gives them freedom in production, but also imposes to the software vendors creating tailored solutions. Those are always more time consuming and more difficult to manage and update than off the shelf solutions. An attempt to provide this type of solution is offered by ESRI in the aim to satisfy most of the community, most of the time. Still, neither solution is perfect, neither answers all the needs.

Hydrographic Offices follow similar rules for generalisation. The International Hydrographic Organisation (IHO) dictates these rules. They have been formulated in one of the standards of IHO: Special Publication no. 4 Regulations of the IHO for International (INT) charts and chart specifications of the IHO (S-4). S-4 provides a set of regulations of the IHO for international (INT) paper charts, but as section A-102.8 of S-4 states the generation of such charts can provide a basis on which to build Electronic Navigational Chart (ENC) cover. De facto, the content of ENCs is usually limited to the content of corresponding paper charts, hence the relevance of S-4 to ENC production. What this means is that generalisation rules or at least guidelines for hydrographic offices are centrally created by the IHO.

This opens possibilities to create a uniform generalisation workflow for charts around the World. The work on standardisation of INT charts started together with the idea of their creation in 1967 and got formalized for the first time in 1970 (with corrections in 2003). Unfortunately, the abovementioned publication does not force any hard rules but only indicates best practice and most of the recommendations are descriptive and advisory. From the beginning, the intention was to permit some variations between charting practices of IHO member states as their “existing cartographic practice may be of unusual significance” (S-4, section B-110). This, in return, causes the Hydrographic Offices to interpret the standard and deviate from the original text. They tighten the specifications and tailor them to suit their workflows, characteristics of their areas of charting responsibility and often to match the old ways of producing charts at their premises. In the end, a cartographer is still the one who makes the final decision.

1.1.2 ENCS

One of the major tasks of the Hydrographic Offices is to produce ENCs to be used on board of yachts, merchant vessels and other craft for navigation purposes.

> **Electronic Navigational Charts** (ENCs) are file based vector datasets based on the IHO S-57 Standard. Those charts are similar to regular - paper charts, have a similar purpose but offer a lot more possibilities, and can carry a lot more information. They can be displayed on Electronic Chart Display and Infromation Systems (ECDIS) to combine data from multiple sources: ENC, Radar, Automatic Identification Systems (AIS).

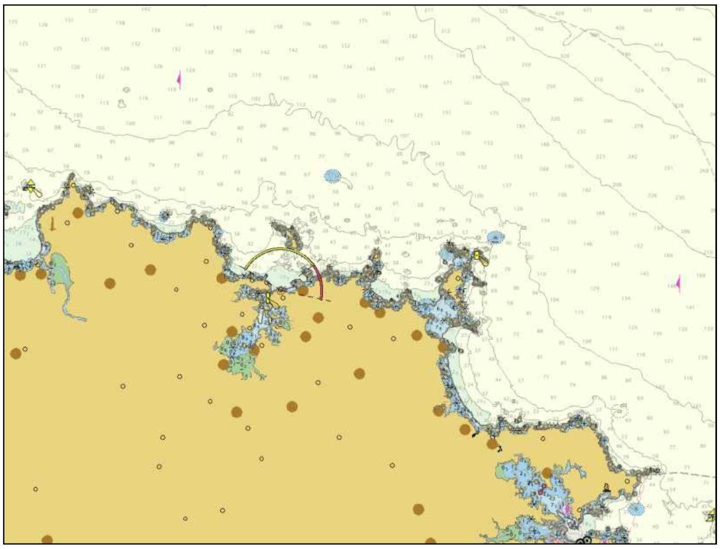

Figure 1Example of an ENC excerpt (coastal usage band, approx. scale 1:90k - 1:350k)

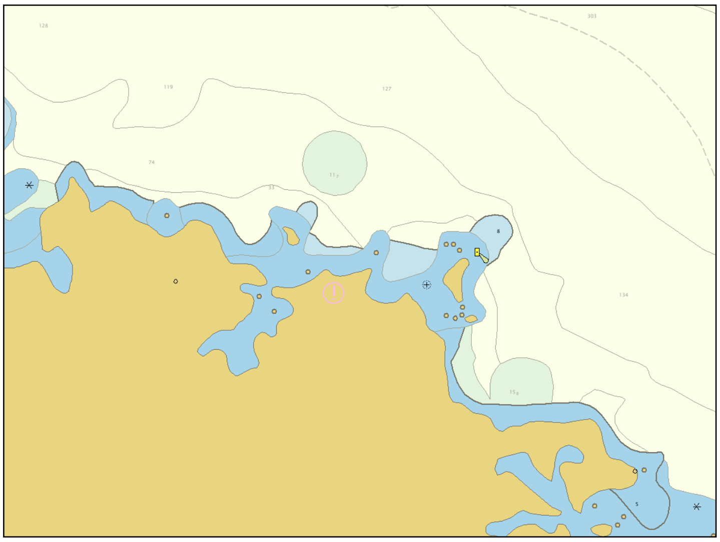

Figure 2 Identical extent of the same area (overview usage band, scale < 1:1.500k)

It can be said that an ENC is de facto a paper chart or elements of such chart converted into a digital form. This vector repository can then be used to generate an interactive image on the computer / ECDIS[2] machine screen. An ENC, once loaded into a computer is used as a system database of objects. Each object is selectable and its attributes can be visualized providing additional information. This information can also be used to create filters and constrains, such as a safety depth limit which, once exceeded triggers an alarm. The chart can be coupled with a

[2] Electronic Chart Display and Information System is the only officially approved Electronic Chart System for non-recreational vessels.

signal from other devices, such as GPS for position information, AIS[3] for the display and information about other crafts in vicinity, ARPA[4] for the display of the radar readings.

Electronic Navigational Charts like all nautical charts differ from the topographic maps. The obvious difference is in the area of focus: water versus land. Nautical charts are dominated by water areas and topographic maps only use them as a background where land masses do not reach the map frame. The other major difference is in accuracy. Most of the objects on land are fixed, can be measured in detail and verified, if needed. Water is a very dynamic environment that changes constantly. Reference points are more difficult to find, as depths and the shape of a coastline change with coming and going tides, that are never 100% predictable. Underwater features cannot be carefully examined and remote sensing is most of the time the only way to find them. Remote sensing techniques are, in turn, subject to numerous measurement errors, as the medium through which the signal travels is not uniform. Salinity, temperature, density change constantly. Also the measuring platform – the hydrographic survey ship is affected by waves and wind, which affects its ability to maintain its position. Wrecks and underwater dunes can be shifted in severe weather conditions by strong waves and floating aids to navigation rotate on anchors that are used to attach them to a seabed. It is very difficult to create a static chart that would take all these dynamics into account. At the same time the mariner has no choice but to trust the information on the chart, as most of the depicted objects are under water, outside the area of visual inspection.

Providing navigational aid is the main purpose of a chart. “Aesthetically pleasant” factor plays a far lesser role than in the case of topographic maps. All these makes it impossible to apply topographic cartography solutions directly into nautical charting workflows.

ENCs can be divided into usage bands based on their purpose/scale. As much as for all the ENCs the main purpose is to provide the safety to navigation, the level of detail that can assure this during various periods of the passage differs.

There are 6 usage bands (or in other words scales) that are used for the ENCs:

1) Overview. Scale Range < 1:1499999

This type of charts is not used for navigation, but for planning purposes. They cover areas of entire oceans or continents and the level of detail is very low.

2) General. Scale range 1:350000 – 1:1499999

These charts can be used for navigating in open waters and during ocean passages when a vessel is by no means restricted (depths, land masses, heavy traffic, obstructions). They cover large areas, for example entire sea basins. Level of detail is low, but sufficient for the purpose.

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[3] Automatic Identification System

[4] Automatic Radar Plotting Aid

3) Coastal. Scale range 1:90000 – 1:349999

As the name indicates those charts are used when a vessels is in vicinity of land and open water passage is finished. Obstructions play a higher role and first Aids to Navigation (buoys, beacons, lighthouses, etc) need to be identified to assist navigation. Land objects can be identified by light they emit by night or by radar response visible. Also traffic intensifies.

4) Approach. Scale range 1:22000 – 1:89999

In this phase of navigation vessels are exposed to depth limitations, obstructions and restrictions such as land masses, marine reserves, etc. Land is within sight and land features can be identified by their shapes, colour, height, etc.

5) Harbour. 1:4000 – 1:21999

Vessels navigate in a highly restricted environment (by depths, width and traffic congestion, in a channel or harbour basin). Usually, a pilot (an external person from the harbour with an extensive knowledge of the area) is on board to assist the navigator.

6) Berthing. Scale range >1:4000

Highly detailed and precise charts used for mooring and berthing vessels in a harbour. Level of detail is very high, indicating individual berthing places and utilities.

The usage bands can be associated with radar signal ranges, but the values are only indicative. The actual compilation scales may be different based on the available data sources.

International Maritime Organisation (IMO) suggests ENCs to be used on board of all the merchant vessels: "All ships, irrespective of size, shall have nautical charts and nautical publications to plan and display the ship's route for the intended voyage and to plot and monitor positions throughout the voyage. An electronic chart display and information system (ECDIS) is also accepted as meeting the chart carriage requirements of this subparagraph." (SOLAS Chapter V Regulation 19/2.1.4)

IMO designated a mandatory carriage requirement of ECDIS being implemented according to a phased-in timetable with effect from 1 July 2012 on all the new tankers an passenger ship. This requirement will be extended in the coming years to all existing merchant vessels and by July 2018 there will be an ECDIS on every operating merchant vessel's bridge in the world (figure 3). It is of importance for hydrographic organisations to have a practical understanding of Electronic Navigational Charts, the transition from paper chart to ENC, and international standards relating to the production of ENCs. Hydrographic Offices will need to increase their portfolio of ENCs to meet the growing demand.

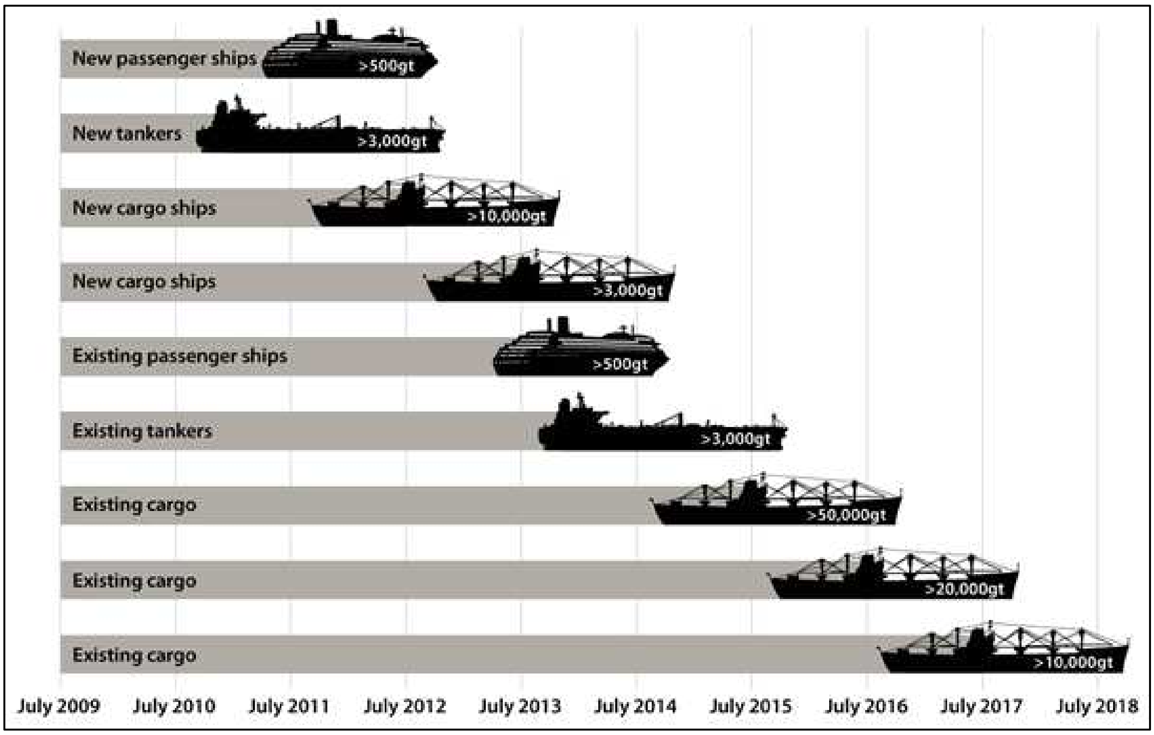


Figure 3 ECDIS carriage requirement implementation dates (Source http://www.ecdisfit.com/regulations/)

If automatic generalisation of ENCs was possible, the goal of improving efficiency of the Hydrographic Offices could be eased and also the emerging hydrographic services e.g. of the Pacific Islands could build their production capacity faster.

1.1.3 S-57

As mentioned above, production of ENCs is based on the S-57 Standard.

S-57 is a standard for the exchange of digital hydrographic data between hydrographic offices (and others) and for its distribution to users. It provides a vector, file-based mechanism for the transfer of data from one computer system to another, independent of the make as well as medium used to establish the transfer. It is a computer and operating system independent format and it permits a very accurate and detailed method for mapping navigation data.

The use of a single standard and data model is another advantage in the creation of automatic generalisation solutions. It was created by the nautical data producers and is designed to meet all the hydrographic data expectations. The standard offers a standardised way to structure both survey and chart data and permits a very accurate and detailed method for mapping navigation data.

Even though the works on a common data exchange standard were in progress before, there was one event in the history of navigation that accelerated the process. On 23rd March, 1989, the Exxon Valdez oil tanker ran aground on Bligh Reef, Prince William Sound, Alaska. It became the worst spill in terms of damage to the environment worldwide. The Exxon Valdez spill was the largest ever in U.S. waters until the 2010 Deepwater Horizon oil spill and its effects in Alaska are visible to this day. This, partially, influenced the hydrographic society to create an electronic chart display system allowing vessels to increase their safety of navigation. In 1990 the first version of the standard was published. The current version, Edition 3.1 is to remain valid indefinitely to allow hydrographic offices to fully implement it. The next generation S-100 standard is now ready and enables to broaden the use of the standard in new fields, like fisheries, underwater exploration etc, but the implementation for the ENC production will take years. S-57 and S-100 datasets are compatible.

S-57 data model is based on objects and consists of the two main components: non-positional (feature object) and positional (spatial object). There are three types of spatial objects: points, lines and areas. As for the feature objects, there are around 170 object classes that share around 190 attribute classes. A feature object contains descriptive information about a real world object, eg. a buoy. It will use attributes like colour, shape etc… to describe it. A real world object may be divided into multiple S-57 objects. An aid to navigation will be composed of a support structure, light and/or topmark and all of them will be individual feature objects. All of them will relate to one spatial object - will share a point geometry. They will also be assigned a Master-Slave relationship. This connection between objects is made to facilitate their management and avoid curious situations when a topmark or a light exists without any support structure. The supporting structure is by default considered a master, but this relationship can be assigned manually between any objects that form such relation. Apart from the Geo type of feature objects, that relate to the tangible objects, there are three other feature object class types: Meta (quality, coverage, etc), Collection (describe relations, do not have any spatial) and Cartographic (forbidden on an ENC, but used on paper chart, like compass roses etc).

Both, the feature object classes and attributes are defined by a six capital letters acronym. The attribute values can be of the following types:

‘E’: Enumerated - 1 value selected from a list of values

‘L’: List - 1 or more values selected from a list of values

‘F’: Floating point number - range, resolution, units, format given

‘I’: Integer value - range, units and format is given

‘A’: Coded string - format is given

‘S’: Free format string

For certain object classes populating some attributes may be mandatory, or mandatory under certain conditions (e.g. when another attribute is populated). Some object classes may exist in all geometrical forms, but some are allowed only in one or two. A sounding can only be a point, whereas a land can be a point, line or an area, depending on the generalisation.

While most of the spatial objects are two dimensional (latitude and longitude) soundings are the only feature objects to use x,y,z geometry, with "z" depicting depth. For other underwater objects, such as wrecks and obstructions, depth is encoded as one of the feature object's attributes. Such an approach allows to group soundings with identical attributes into one feature object with various spatial positions and depths.

The standard contains no display definitions. They are included in the S-52 standard that defines ENC presentation for display in ECDIS. This assures that the standard can be used for the creation of other products, not only ENCs.

ENCs are split into user defined "cells", also known as "dataset files", with a unique file name, indicating, among other, the producing agency and the intended purpose. Those datasets need to be rectangular, although the actual data coverage within the cell can be of any shape, e.g. the shape of a corresponding paper chart. One of the most important rules is that data intended for a single purpose cannot overlap (as this could cause ECDIS not to display it properly), although the cell extents can. There is no predefined cell tilling scheme and hydrographic services use different practices in that matter. Some try to keep the cells adjacent with a full coverage within a cell, some make the cells overlap and data is distributed within a cell based on the paper chart extents.

The contents of an ENC can be divided into two groups. Group 1 is called the "Skin of the Earth" and is composed of non-overlapping area objects that cover the entire available coverage. The object classes that form Group 1 objects are:

LNDARE - land areas, DEPARE - depth areas, DRGARE - dredged areas, FLODOC - floating docks, PONTON – pontoons, UNSARE - unsurveyed areas and HULKES - moored ship.

Group 2 consists of all the remaining Geo objects that reside on top of the Group 1.

When compiling an ENC or populating a database, two approaches can be used: either base datasets are combined on the best scale and other usage bands are generalised from the base dataset or usage bands are created independently, based on the existing paper chart coverage. A mixed approach is to have some objects digitized from the paper charts and parts populated from a base dataset.

Regardless of the approach the processes are still (semi-) manual. Different features come from different sources and are processed separately, for example – bathymetry (soundings, depth contours, depth areas), aids to navigation (beacons, buoys and lighthouses), topographic features (conspicuous land information), coastline. The compilation of a single chart can take from weeks to even months, with the datasets being imported, processed, controlled, eventually corrected, approved, cut into products and sent to the reseller for verification and distribution. At the same time datasets need to be up to date, so when new information arrives, sets of products need to be updated and the entire cycle repeated. This is a very time and efforts exhausting process.

From the conversations the author had with members of hydrographic services it can be stated that the hydrographic community looks at the achievements in the automatic generalisation of topographic maps by the National Land Mapping Agencies with curiosity and enthusiasm. They would like to see similar changes being introduced in the nautical chart production. CARIS – the nautical solutions provider confirms to have been approached by numerous hydrographic offices with questions about possible developments in this field. However, before any encoding can take place, requirements and rules need to be formulated that will translate user requirements into computer applicable commends.

1.2 RESEARCH FORMULATION

In this section the research problem is elaborated on. Scope and research questions and objectives complement it.

Given the advancements in automatic generalisation of topographic data it is disappointing not to see it used for creation of ENCs. Although, in many cases, it has to be customized and it is still case by case applied, automatic generalisation is used to a certain extent by land mapping agencies. Efforts are clearly visible to assist the research in this field.

Hydrographic community is interested in the outputs of these researches, but they cannot be fully utilized due to differences in approach and purposes maps and charts serve. Generalisation operators designed for land applications do not give fully satisfactory results, but give confidence that it would be possible to treat hydrographic data in a similar manner (Socha et al. 2011).

Generalisation cannot be separated from standardisation. If hydrographic offices of the world could standardise the contents and the specifications for production of their ENCs, charts could be more consistent across the area, but also across the scales. There would not be problems with phantom objects left out or omitted on different scales. Automatic generalisation of Electronic Navigational Charts would make charts more correct and uniform.

Unfortunately, at the present time hydrographic offices compromise seamlessness of their datasets to meet production deadlines. Charts do not match on the edges as they have been processed as discrete entities by different cartographers. The content varies between scales and neighbouring cells. The process is prone to human errors and since each cell is processed separately, the effects on each chart vary. The requirement of keeping the charts up to date adds on to the obligations and the resources are often cut. Hydrographic Offices, once required to produce paper charts for navigation, now have to cope with a growing demands of the community. Not only they have to create a portfolio of the Electronic Navigational Charts and keep it up to date, but also the emerging trend of MSDIs and tailored products pulls out their resources. These resources often cannot be enlarged, either because the efforts may be temporary, or because of the internal/external restrictions. The teams need to be kept compact and highly efficient.

Hydrographic Offices seek help at their hydrographic production software vendors to develop tools that could speed up their production. This took place, for example, during the HPD and

BDB CARIS User Group Conferences in 2011. HOs are partially aware of the advancements on the land side and would like to be able to achieve the same and even more on the bathymetric side. They also see that their time consuming and routine workflows in chart production could be handed over to machines. Software vendors, like CARIS, need to know what the offices actually expect. Furthermore, they need to find a business case in these new developments. It is costly and time consuming to customize the software for individual clients. Software vendors would like to hear hydrographic offices speak with a single voice and express clearly the improvements they expect to see.

The cooperation between hydrographic offices is not always easy as they are spread around the world and often do not have resources to spare and dedicate to this enterprise. At the same time, no country should impose their solutions to others. International Hydrographic Organisation, the body that normally governs all decisions that affect the whole community does not intend to interfere in the production methods of the hydrographic offices motivating it by the fact that these institutions know best their areas of operation and their subtleties and special needs in charting. It is also not considered safety critical for the IHO to take the lead. In this situation of hopes and expectations there is no trigger and no link between the stakeholders.

There are several problems that emerge from this situation. First of all production of Electronic Navigational Charts is inefficient and often ineffective. The time between the data availability and product distribution is long. In spite of the best efforts from the Hydrographic Offices the data on the charts that mariners use may not be the most recent they possess. A lot of effort goes into production and those efforts could also be spent elsewhere. The quality of charts is also not optimal. There are mistakes and inconsistencies resulting from human errors. This is mostly visible at the borders of the data. In the past, when mariners used different scale paper charts, those inconsistencies remained undiscovered, but once the navigator could load and overlay all the charts at once they became clearly visible and cause confusion and reduced confidence in nautical products. These inconsistencies can also affect the performance of ECDIS using the data for analyses of the safety of the vessel underway.

Secondly, the hydrographic offices do not cooperate and harmonise their efforts. The discretion in charts production is the privilege of every hydrographic office, but this situation does not foster cooperation. Often hydrographic offices experience similar problems but communication and seeking common solutions is rare. This is also due to the resources limitations. User group meetings and conferences are often the only occasions to share problems and ideas. There are also new hydrographic offices emerging in the areas insufficiently charted. These new administration units need to catch-up on production with an imperfect know-how and limited staff.

Software vendors do not want to take the responsibility and deliver solutions that will either fail to satisfy user needs or need costly customizations. They do not have access to chart production specifications and workflows of the offices and only advise when asked.

In the recent times hydrographic offices experience an outburst of interest in the hydrographic products and a rise in expectations from the clients. Same, scarce resources are faced with multiplication of new tasks. They need to seek efficiencies to manage their services.

Automatic chart creation is the future of cartography. It provides the necessary efficiencies and savings. It can provide high quality state-of-art robust production.

This study aims to approach the problems and create a link between the software vendors and nautical chart producers. This link is to collate and translate chart production specifications into clear requirements. This thesis project aims to create business rules with specific criteria that could be used to create tools for the automatic generalisation of ENCs. At present, there are no efficient specifications or tools for the automatic generalisation of S-57 data. Direct translation of topographic data generalisation principles does not provide satisfactory results as imperatives associated with ENC are different. The "aesthetically pleasant" component included in ICA's definition of generalisation is of the lesser value and the "success in the given task" has usually a much more profound meaning than going from point A to B.

1.2.1 PROBLEM DEFINITION

The goal of the research is to collate the requirements of HOs in conjunction with the guidance already contained in S-4 and knowledge in model and cartographic generalisation of topographic maps to create computer translatable rules that would allow the creation of smaller scale ENCs from a higher scale ENC / S-57 database with minimal human intervention.

The problem of the lack of clear requirements is narrowed down to two usage bands. Automatic generalisation of dataset of the Approach purpose (1:22000 – 1:89999 scale) is performed to transform data into the destination usage band – Coastal (1:90000 – 1:349999 scale).

This research is important in the light of the IHO's mandate to build sufficient ENC coverage for the vessels moving into ECDIS based navigation. The implemented solutions could also help emerging hydrographic authorities to fulfil their charting obligations faster. This can lead to an increase in an overall safety of navigation by increasing the charting capacity and quality. The project is in line with WEND[5] principles by one of the IHO working groups WENDWG (Worldwide Electronic Navigational Chart Database Working Group, 2011) aimed at creating a common database of charts covering the entire globe.

Hydrographic Offices put their efforts also into creation of Marine or Hydrographic Spatial Data Infrastructures. Automatic generalisation is a key to on-the-fly data rendering if the data is to be shared online. The world of nautical products is changing and authorities are faced with a growing demand of specific products. To efficiently answer those needs with the same resources

[5] Principles of the Worldwide Electronic Navigational Chart Database to ensure a world-wide consistent level of high-quality, updated official ENCs through integrated services that support chart carriage requirements of SOLAS Chapter V, and the requirements of the IMO Performance Standards for ECDIS.

available they would need to employ automatic generalisation. This research can be considered a milestone in meeting all the above mentioned requirements.

1.2.2 SCOPE

For feasibility reasons the project needed to be limited to two usage bands. Approach and Coastal are selected. Lower scale datasets: General and Overview are considered not sufficiently detailed for efficient rules creation and also of a lower significance to navigation. Higher scale datasets: Berthing do not represent the majority of the workload for hydrographic offices as they only cover small areas of major ports. It is also considered that they are often part of the pilot navigation, and pilots are likely to have better knowledge and resources than an ENC can have, therefore improvements to these datasets would not have high impact on the overall safety of navigation.

Harbour – Approach pair was considered but until 2011 there were slightly more Approach cells than Harbour in the chart availability percentages. IHO reports that as per November 2011 there were 184 out of 238 (77%) charts of usage band 5 (Harbour) available for the Atlantic region and 20 out of 26 (77%) for the Pacific region. At the same time there were 137/174 (79%) and 20/22 (91%) available respectfully for the Approach usage band. Finally, only 62/102 (61%) and 7/9 (78%) available for usage band 3 (Coastal) (MACHC, 2011). In the data providers structure from 2012, these numbers are different, perhaps because ECDIS carriage mandate comes into power in July 2012. In the Netherlands there are 43 Harbour ENCs, 19 Approach and 6 Coastal. In New Zealand 123 Harbour, 115 Approach and 46 Coastal. France reports 202 Harbour ENCs, 160 Approach ones, and 90 Coastal. New Zealand reported that there were still some ENCs in production, out of which 51 were Harbour charts, 68 Approach charts and 20 Coastal ENCs. (Appendix 3-6)

Coastline and Approach datasets are considered important since they are utilized in the coastal traffic by transiting vessels. These datasets are also interesting in terms of their content. They contain sufficient detail to draw satisfactory conclusions and yet not overwhelmingly lot of detail as with the higher scales. Good balance of land and water features makes the analysis balanced and tackle all important aspects of ENCs.

The scope of the project is limited to Geo type of feature objects. Generalisation of Meta objects is not considered. This is due to the fact that Meta objects either cover the entire area or large portions of the chart and are related to Geo objects. Performing generalisation without a link to Geo objects would not make sense. Collection objects do not have spatial component and are relations between Geo type of objects.

Also generalisation of bathymetry is not tackled. Bathymetry plays an important role on a chart, but it is a mathematical model of a bottom depth approximations managed separately before the final depth areas, contours and sounding selection can be used for production. This requires special safety considerations and developments of complicated mathematical algorithms. Other researchers examine the problem (e.g. Peters, 2012). The efforts to obtain the highest level of safety should not be spoilt by performing hasty generalisation transformations. At the present time, it is assumed that every usage should have bathymetric features available from the external source where this pre-products were created according to the safety restrictions and intended use.

The expected outputs, apart from a set of generalised charts are expected to constitute of specifications and generalisation rules. The project focusses on similarities in the datasets and investigates only the bulk of the ENC content. Feature objects that are in minority or appear occasionally on the charts are rejected. Those are therefore still subject to interactive generalisation, which does not mean that automatic generalisation of them could not be performed. Consequently feature objects that are not used on the sample datasets cannot be analysed. The sample is broad and covers areas spatially and topologically different but it cannot be expected that it will exhaust all ~170 feature object classes and especially in all spatial types.

The study bases on the provided datasets (see table 1). It is assumed that datasets provided are not different in the production approach or methods used from standard datasets produced by an organisation. It is therefore considered that the conclusions drawn from analysing them could be applied with a similar rate of success to the remaining datasets produced by the organisation. It is also considered that the chosen hydrographic offices do not differ in their production methods or product quality from other producing agencies.

Table 1 Overview of the available datasets.

Country	Coastal ENCs provided	Approach ENCs provided
Brazil	BR323000 BR323100	BR401501 BR401506 BR401508 BR401622 – not used
France	FR332010	FR432010
New Zealand	NZ305322	NZ405321 NZ405324
The Netherlands	NL301630	NL400110 NL400122

1.2.3 RESEARCH QUESTIONS AND OBJECTIVES

This project is practice-oriented. The outputs support hydrographic offices to progress in the creation of the Electronic Nautical Charts by means of automatic generalisation. They also support hydrographic production software vendors to create efficient tools for automatic handling of hydrographic data. This project paves the way to further investigation and creation of new generalisation solutions. **The main research objective is to tackle and solve the problem of the lack of hard knowledge values and rules to be used for automatic generalisation of electronic navigational charts.** Soft cartographic knowledge and subjective interpretation cannot be used to create computer-readable commands and tools for automatic charts creation. The final report present a set of rules that allow going from one compilation scale to the other without or with minimum human interference. It also discusses the shortcomings of this approach and the rate of success of such approach. The study is mainly based on the existing generalisation operators available in the literature, but points out scarceness of the choice and proposes new solutions.

It was assumed that it is possible to create an Electronic Navigational Chart by means of the automatic generalisation operators or other tools that reduce human interaction in the chart creation process. Earlier study by Socha et al. (2011) on generalisation of different theme maps gave promising results in terms of the possibilities to automatically derive a smaller scale nautical chart from a greater scale one, but also discussed shortcomings of the approach used. The problem of the methodology used is that it was to general and land oriented to give satisfactory results in products "safety of navigation" oriented. These shortcomings are tackled in this research.

The research answers the following questions:

1) Which universal computer translatable rules can be created to allow the creation of smaller scale ENCs from a higher scale ENC / S-57 database with none to minimal human intervention?

The strength of this question lies in the word "universal". The success of the project is measured by the evaluation of a degree of adaptation needed to achieve the goal by different organisations. The rules created need to uniform so that the software vendors can create satisfactory solution to please the majority of the clients. Based on the sample used for this project, it is expected that the rule satisfies a requirement on all the charts.

a) What patterns of change in the data can be derived by comparing lower and higher scale charts?

When the datasets are compared similarities and regular behaviours can be found. Situations where a feature or an interactive generalisation process varies from the overall rules cannot be tackled and will be pointed out. Regular behaviours in the interactive generalisation process are those that can be translated into hard knowledge rules.

b) How the content of higher scale charts can be transformed to reflect the content of the lower scale charts? How can this transformation be automatized?

This question focusses on the approach taken to generalise charts. At the present time there are two possible methods of generalisation of any geographic data. One is to use generalisation operators that transform data from one state to another. The second method is to use multiscale databases that create representations of objects on scale-based usages. Both approaches are considered and evaluated.

c) How to standardise the chart content so that tools and parameters used fit many organisations' needs?

Since generalisation cannot be separated from standardisation the research checks how charts could be standardised in their contents so that the automatic generalisation solutions can be implemented in an off-the-shelf software product without any customization needed on the client's site.

d) When can these rules be considered successful?

This question can be partially answered upfront. The project can only be considered successful when there are uniform rules created that allow minimizing time and human effort needed in the chart creation process. Two factors are important: the rules need to be uniform and they have to minimize or eliminate human interaction in the process hence triggering time savings without compromising quality of the product. The quality of the product can be measured in two ways. Firstly, the product needs to be able to serve its purpose. Secondary, it should not vary greatly from the existing products, as those are considered valid and fit for purpose. The research answers the question in detail.

The successful study gives a possibility to develop and implement solutions in a chart production software that allow time and efforts savings by the hydrographic offices. The indirect result would be to trigger greater cooperation between hydrographic bodies who want to continue research on automatic generalisation of Electronic Navigational Charts. A positive conclusion would be that the academic world and the hydrographic community work closer together to bring the nautical cartography to the next level. The successful completion of this project has also the potential to provide benefits to the ENC producer community and flow-on benefits to the users of ENCs. Benefits include:

- **Consistency between HO's**

At the present time charts vary in content from country to country. This can be best seen among countries that share a coastline. One hydrographic service may use a lot of detail on land or use additional, non-safety critical information, while the other may depict only the basic safety related elements. Uniform rule sets and populating the product databases in an automatic way would assure a similar content of ENCs in different organisations. This, in turn would result in the seamless ENC coverage even on the boundaries between countries.

One other issue that could be solved with the automatic generalisation is the matching of the data on the boundaries. At the present time all the efforts of the hydrographic offices goes into their own production and meeting deadlines. Time savings gained thanks to automation could go into the effort of harmonizing data on the boundaries between the countries to make sure that there are no dangling edges, differently interpreted or duplicate information. This behaviour is expected of the member states as advised in the WEND principles of the Worldwide Electronic Navigational Chart Database Working Group.

- **Faultlessness between usage bands, as data could be easily tracked back to source**

At the present time each chart, even of the same area consists of elements that are not related. If a general, coastal, approach, harbour and berthing chart show a symbol of an island, then for the database these are 5 different land area islands. The cartographer needs to update at least 5 different products (paper charts excluded). If, by accident only 3 usage bands are updated: firstly the mariner gets disoriented and loses confidence in the product and secondly the staff needs to investigate case by case the mismatch. It may lead to so-called phantom features residing in the database. Those objects cannot be track down, no information can be found about their background, but with safety of navigation precautions in mind the hydrographic office needs to put a lot of effort in finding evidence of either inexistence of this object in reality or contrary. With the automatic generalisation being employed - existence of every object in the database would be justified by its origin in the base dataset. Also in case of updates, consistency would be preserved eliminating the risk that some products would get updated and some would be missed out. This results in the increase of the safety of navigation.

- **Acceleration of population of the database**

Hydrographic offices use two sources for their nautical products. Either they digitize/vectorize the contents of paper charts or use external datasets provided by other authorities (like Land Mapping Agencies) to extract different elements of the chart. In both scenarios manual processing is required. In case of the use of external sources of data, the processing could take place once per usage band and then the products could be cut regardless of their location. In case of digitizing or vectorizing digital forms of paper charts, the work is even more time consuming as each dataset is processed and QCd separately.

Nevertheless, both solutions allow processing on one usage band at a time. If data usage bands could be automatically derived from one base dataset then the processing could only take place at the basic level, leaving the derived usage bands to only by controlled. An automated solution in comparison with human work translates itself into time efficiencies. This also means that the elapsed time from acquiring data to the date of publication would decrease making charts more reliable and up-to-date.

- **Transparency**

It is often the case that charts of neighbouring areas differ in content. This happens because data can be subject to interpretation and there are multiple ways to encode a certain feature. For example rocks can be either encoded as a seabed type, obstruction or an underwater rock.

Interactive generalisation is based on the cartographer's knowledge, experience and also sense of aesthetics. The same dataset can be generalised into as many products as there are different cartographers. Hard knowledge rules executed by a computer discriminate subjectivism and leave no ambiguity in respect to why certain decisions were made resulting in populating or not of certain features.

- **Flexibility – in adjusting parameters, also in choosing data to populate.**

Although this research does not focus on other products than Electronic Navigational Charts, the idea of tailored products meeting the needs of particular audience has already reached the hydrographic community. With the advent of tailor made products automatic generalisation would allow hydrographic services to answer new demands almost on-the-fly. Base dataset can contain huge amounts of objects but the decision to populate them to lower scale usage band could be made as required. Changing specifications has at the present time a long time of execution. This sometimes blocks the HOs from making innovative decisions, as the work to implement them seems overwhelming. With the automatic solution any changes could be made more efficiently.

- **Cost reduction**

Cost reduction manifests itself mainly in the time savings achieved by reducing the time needed for the interaction with data. It is also possible that with the possibility to quickly derive datasets from greater scale ones, the storage of such derived products will become redundant. That could result in storage and maintenance cost reductions. Data could be acquired and stored once, which could cut cost of gaining and warehousing it. In addition to the time savings, efforts of the work force could be put elsewhere to create additional profit.

- **Integrity of data**

In case of a full implementation of automatic generalisation approach, there would be only one, base dataset and data would not be imported from various discrete sources. If all the data came from one source, there would not be any dangling contours nor not matching border data.

Success measures for this project can be created in two ways. Firstly, if the research objectives are met and rules are created that allow implementation of tools allowing the creation of ENCs in a time shorter than during the manual work, then the project can be considered successful. Those rules also have to satisfy the needs of all the stakeholders. The second measure is outside of the academic realm of the research. As the project is practice-oriented the success of the entire enterprise can be considered if business case is found by both software vendors and hydrographic offices and solutions here presented are implemented. This means that the proposed solution needs to be not only effective but also easy to encode, implement and execute. In both cases, the success of the report provokes further research.

1.3 METHODOLOGY

Methodology executed in this project is listed below. Next the division of the project into phases is presented and main milestones summarised. Methods are described at the end of the section.

Used methodology is mainly linear, but iterations may occur in points 5-7. It is based on Stoter et al. (2009).

1) Theoretical study and problem formulation

This part consists of the literature study, as described in the next chapter and analysing chart production environment to find flaws and space for potential improvement.

2) Acquisition of pairs of comparable datasets and workflows

This point comprises e-mail correspondence and meetings with the potential and final stakeholders. After the datasets sre acquired it also covers data preparation- choosing analysis areas, where more than one were available and cropping the boundaries.

3) Comparative analysis of the dataset pairs and between pairs in order to identify similarities and outstanding differences.

Visual inspection of charts focused on generalisation processes is the first step in this phase. Safety requirements of the ENCs from various sources are analysed and finally rule sets formulated. These can be divided into standardisation requirements and generalisation requirements.

4) Automatic generalisation of datasets based on the rule sets.

Automatic generalisation operators are matched with the requirements. Complex structures are built in ArcGIS to meet the chart generalisation criteria.

5) Evaluation of the results.

The initial evaluation of the results is carried after each component is generalised. The generalised and original component are overlaid and compared visually (including the verification of attributes). Where needed – point 6 is executed. The final, refined results are sent to the corresponding Hydrographic Offices for the closing evaluation.

6) If needed, refinement of specifications.

Where the results differed greatly from the original datasets or where a solution could not find application to all the datasets, refinements or amendments need to take place.

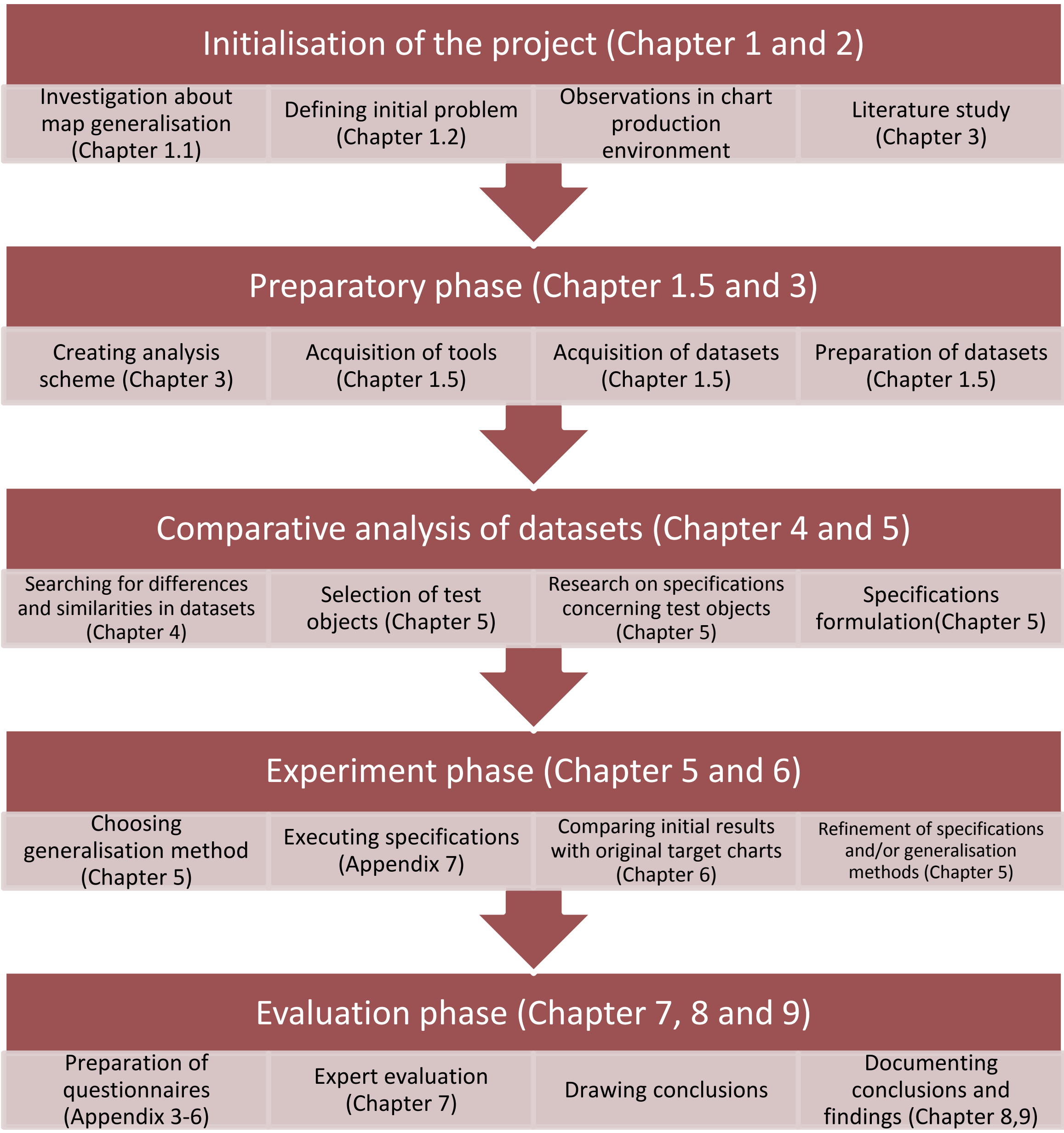
7) Documentation of conclusions.

The physical output of this phase can be found in the following chapters.

This methodology assures consistent and objective assessment of the hypothesis and accurate documentation of the outcomes. The methodology is generic and could be used for datasets of various content and scales producing always-uniform results. Outside of the scope of this study a similar methodology could be used for all object-oriented datasets.

1.3.1 PHASES

The project was divided into 5 phases, presented below:



1.3.2 MILESTONES

The completion of the is marked by the following milestones:

- A base of stakeholders (HOs) willing to cooperate secured and data obtained.
- Analysis scheme finished and working. Data is prepared for analysis.

- A set of rules for generalisation created based on the analysis scheme. The set allows to create a smaller scale ENC from a greater scale one with minimum to none human intervention. The process lasts less than the conventional ENC creation.
- Evaluation from nautical charts experts is received.

1.3.3 METHODS

These are the methods used to execute the methodology.

Data collection

The initial stakeholders base was approached via an e-mail and in person during one of the IHO user group meetings. An e-mail was also sent via IHO's web contact form, but this method was unsuccessful. Collaboration has been established with four hydrographic offices (see section 1.4). Initial message called out for assistance in an ENC generalisation project (Appendix 1). Once the stakeholders confirmed their participation e-mail request was sent to provide one or more Coastal scale ENC produced by the organisation and one or more Approach ENC covering the same area. Datasets were sent either by regular mail, e-mail or downloaded directly from one of the computers connected to the hydrographic database.

Data specifications were downloaded from the official IHO webpage[6]. Other materials consist of manuals, textbooks published on the internet, navigation, hydrography and GIS course materials and private professional library.

Visual Inspection

Datasets were loaded into a S-57 compliant software and overlaid. Transparency and thematic layers were used to facilitate the inspection. Statistical information available in the software was used (feature count) to select classes of interest. Open mapping services were visually examined and encyclopaedic knowledge in geography used to understand chart content. Visual inspection was complemented with the study of technical documentation indicating safety relevant objects.

Survey no. 1 Qualitative Research

A questionnaire was created and sent out to the stakeholders to summarise visual inspection, clarify ambiguous elements and assess current production methods. The questionnaire was divided into four parts. General part contained questions about the producing agency (human-ware, software, charting responsibility). This section was important to verify at what scale automatic generalisation could be useful. Chart Production section asked about current data production methods, data sources and production times. This section helped to identify areas of possible improvements and benchmarks for efficiency and effectiveness of automatic generalisation tools needed. Questions in Data related section were derived from the previous step analyses of the data the organisations provided and were customized for each participant

[6] http://www.iho.int/iho_pubs/IHO_Download.htm

separately. The answers to these questions helped to verify if observations discovered flaws in the data that could be improved with the introduction of automatic generalisation or if there was an intention in creating the chart as it is. Last part – Automatic Generalisation was designed to confirm the current state of AG in the offices and examine if they were interested in pursuing its implementation.

With the questionnaires a request to provide chart production specifications was sent by e-mail. Responses returned after around a month, also be means of e-mail. Only some stakeholders attached digital versions of their specifications.

Synthesis of available information

In creation of specifications reverse engineering was used. They were created by analysing charts' structure and function. Function of charts was derived from literature, their structure from the datasets themselves and technical documentation. All this was collated with the findings from literature and returned questionnaires. Missing specifications were created by deduction. It was used based on ancillary documentation about navigation, radars, hydrography, cartography etc.

Experiments – Multiple trials

Inspection of available generalisation methods and functions helped to match what needs to be done with how it can be done. Methods were tested on the datasets with the use of parameters contained in the specifications. Generalisation methods were cross-validated (if a method used worked on one dataset, remaining datasets were used to validate, calibrate the method). Effectiveness of a method was measured by visual and content comparison with the benchmark-original dataset. Where parameters in the specifications were derived from external official, documentation, results were accepted "as is", unless they greatly differed from the original dataset. Where hard values were deduced or results varied greatly, a sensitivity analysis aided to find settings best fitting the results to the original chart. Ocassionally refinements in specifications were needed. Whenever possible – standard parameters were used for all charts.

Survey no. 2 Evaluation

Resulting maps were visually inspected and initial evaluation performed by the author focusing mainly on similarities and differences between the resulting and original charts. The main differences or problems with generalisation were extracted with examples. They were put into the final evaluation questionnaire. The questionnaire consisted of three parts. Introduction part explained and justified the results. It provided a summary of generalisation methods and specifications used. This was done to help the experts understand the reasoning behind the results of the automatic generalisation process which affected evaluation, especially when results differed from the original dataset. Evaluation part started with an explanation of evaluation expected from the experts and rules of grading the results. Each theme/class's evaluation was divided into four components: Safety of Navigation, Aesthetics, Usability and Efficiency versus effects. The three first categories are related to the objectives of a chart, the fourth one describes implementation value for the production. General comments concluded the questionnaire. Questionnaires were sent along with the maps by e-mail and received back the same way one month later.

1.4 DATA PROVIDERS

In this section one can find descriptions of the data providers, their profile and responsibilities. This aids to understand how the charts are made and why.

- Directoria De Hidrografia e Navegação (DHN) – The Brazian Hydrographic Office

is a military organisation of the Navy of Brazil. It is responsible for projects related to navigation, maritime and inland waters of Brazil. It is located in Niterói, state of Rio de Janeiro. DHN provides services such as oceanographic data models, weather forecast, nautical charts of the areas under their jurisdiction and navwarnings. It coordinates and conducts hydrographic and meteorological surveys autonomously or in partnership with public and private institutions.

There are 12 persons responsible for paper chart production and 3 for ENC production. They are responsible of the production of more than 200 national marine and more than 400 national river charts. The organisation is responsible for 38 international paper charts and 166 ENCs. It also shares the responsibility over Antarctica, producing 6 charts. A compilation of a simple ENC takes around 20 days.

- Service Hydrographique et Océanographique de la Marine (SHOM) – Naval Hydrographic aand Oceanographic Service of France

is a French administrative public body administered by the Ministry of Defence. SHOM's main task is to provide a public service in hydrography and maritime cartography, including the collection, elaboration, confirmation and spread of nautical information useful to civil or naval navigators and to all who sail for professional or pleasure, as well as those responsible for care of the coast. Other responsibilities include the provision of support for the navy's hydrographers, oceanographers and meteorologists concerning specific information on maritime matters to ensure the optimal running of the navy's weapons systems (radar, sonar, infra-red sensors, carrier-borne aircraft etc.).

28 persons are engaged in the paper chart production and 15 in the ENC production. Among 1081 charts produced by the agency, there are 126 INT charts. The office manages 356 ENCs. The area of charting responsibility is presented on figure 4:

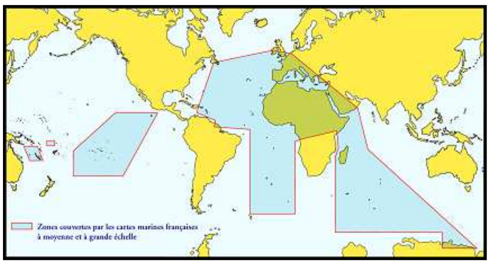


Figure 4 SHOM marine charts coverage (medium and big scale) zones (Soure: SHOM questionnaire on ENC production)

About 6 months (including all the administrative tasks) are required for a new ENC publication.

- New Zealand Hydrographic Authority under Land Information New Zealand (NHA LINZ)

Land Information New Zealand (LINZ) is a New Zealand government department responsible for land titles, geodetic and cadastral survey systems, topographic information, hydrographic information, managing Crown property and a variety of other functions. The NHA sits in the Customer services group. The New Zealand Hydrographic Authority provides data collection, management, maintenance and distribution functions for LINZ Hydrographic services, including the provision of Notices to Mariners, nautical charts, tidal information and other publications, including their warehousing and distribution. Other activities include hydrographic surveying and the positioning of New Zealand's international boundaries.

Currently the group consists of 16 people, including the national hydrographer, the manager, senior hydrographer, senior tides specialist, the paper chart team and the Electronic Navigational Chart team. 4 persons are involved in the paper chart production but there are also 8 external contractors employed. 6 persons are part the ENC team (2 of them dedicated to SW pacific ENCs).

The production team is responsible for 165 national and 29 international paper charts. There are 123 ENC already managed and further 179 in production. Those charts cover New Zealand, South West Pacific and Ross Sea Region. Approximately 2 months are needed to produce an ENC.

- Dienst der Hydrografie van Koninklijke Marine – Hydrographic Service of the Royal Dutch Navy (Ministry of Defence) in The Netherlands

provides nautical charts and publications concerning the maritime region belonging to the Kingdom of the Netherlands and in the context of international treaties. In addition, the Hydrographic Service produces military hydrographic and meteorological products in accordance with NATO standards. The area of responsibility for civil and military products primarily includes the Netherlands Continental Shelf and the waters surrounding the Netherlands Antilles and Aruba. The main tasks of the Netherlands Hydrographic Service are to chart the sea, to publish the nautical charts and the related hydrographic publications. The area of responsibility concerns the Netherlands Continental Shelf and the waters around Curaçao, Sint Maarten and Aruba.

4 persons are engaged in the paper chart production and 2 in the ENC production. 16 national and 20 INT charts are produced in the premises of the Dutch HO. The organisation produces also 8 small craft series for recreational sailors. 74 ENCs are produced. The charts cover the areas of the North Sea, Antilles and Suriname. It takes between 4 and 8 weeks to complete the workflow and produce a single ENC.

The offices share their documentation, including specifications for ENC generalisation and sets of ENC data. Two or more ENCs of the same area but of two navigational purposes - Approach and Coastal are used. One serves as a source dataset and one is the initial benchmark and also source for analysis of the data content change between the usages. The ENCs are compared and then automatic generalisation is performed to obtain results as similar as possible to original coastal map from the provided approach map. Automatically generalised map is compared with the original and sent to the contributing HO for evaluation. Author's own observations along with the expert's opinion form the results of the thesis. Any difficulties encountered are documented and recommendations drawn.

The participation of four so geographically different and widely spread countries is greatly valued and expected to give the required variation in both topographic/ bathymetric scenery and methods of chart making. Hopefully the flow-on result will be that created specifications will cater for a wider spectrum of possible cartographic practices and will suit the needs of the majority of prospective users.

1.5 TOOLS AND DATA USED

This section describes implements and resources used to carry out the analysis. First three software types are presented, followed by three data formats those programs use and finally datasets received from the producing agencies are shown and briefly described.

1.5.1 DESCRIPTION OF THE SOFTWARE

Three different software packages were used in this project. Initially CARIS HPD Source Editor and ESRI ArcGIS were considered, but afterwards CARIS HPD became unavailable and CARIS S-57 Composer was used instead. There were no differences in performance or available operations useful for this project between these two software packages. More about the software packages can be found below.

- HPD (after www.caris.com)

A seamless database solution to eliminate data redundancy. Using Oracle® data processing, HPD offers an integrated suite of products that can manage all data in a seamless database, providing for simultaneous data processing and workflow by multiple users. Efficiency is maximized for data storage with features being stored only once, with the ability to create multiple representations for different products. One Feature One Time.

The HPD suite of products provides efficiency in maintaining source data and the production of multiple marine products from a single database.

The HPD suite of products can be used for production of S-57 ENCs, S-57 AMLs, Paper Charts to IHO standards and Generic Products based on user-defined sets of features. The HPD Product Editor derives its products from the source data in the same database. Updates to source are carried automatically to multiple products. Product-specific features and customizations can be made without affecting the source features.

- S-57 Composer

CARIS's stand-alone solution for ENC and other S-57 products creation. The software resembles HPD, but does not connect to an external database. The data and the products are stored locally.

- ArcGIS 10

ArcGIS is a geographic Information System software produce by ESRI. It is a suite containing programs forming a solution for an organisation having to import, process, store and retrieve geo-data. It is used to visualize and analyse geographic data and it can be used to create value-added products from various datasets. In version 10.0, released in September 2010, the company has introduced operators that are being part of the cartographic Tools set. Those operators are designed to assist automatic generalisation of geo-data.

1.5.2 DESCRIPTION OF THE DATA FORMATS

Three data formats are used for the analysis in three software suits:

- .000 unencrypted S-57 data. It is a vector data format created by the IHO along with S-57 hydrographic data transfer standard to facilitate data exchange for marine applications. It stores a hierarchical collection of spatial and feature objects with detailed attribute and relationship data.

- .hob stands for Hydrographic Object Binary and is a binary file format developed by CARIS to store S-57 data.

- .shp (and related) shape format from ESRI. Data from CARIS HPD will be exported to this format to be further analysed in ArcGIS - a geographic Information System software produce by ESRI. It is a format of vector and associated data. The .shp shapefile stores feature geometry, and the .shx shapefile stores the file lookup index.

1.5.3 DATASETS PER PRODUCING AGENCIES

Below one can find figures presenting the received charts and their short description. Charts are categorised by the providing country.

The datasets come from areas of a great topological and hydrographical variety. They show from the western coasts of the Atlantic (Brazil), via relatively closed and busy waters of the North Sea (The Netherlands), then an island on the Indian Ocean (France) and finally the gates of the Pacific (New Zealand). All datasets were delivered in S-57 format. Further description can be found below.

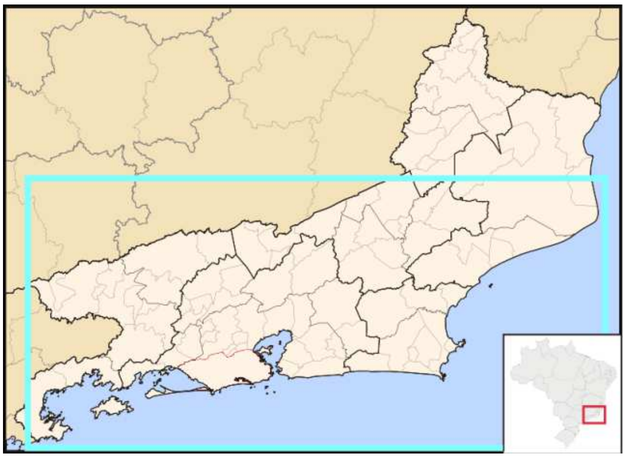


Figure 5 Location of areas covered by the charts provided by the Brazilian Hydrographic Office (Source: Wikipedia)

Coastal

- BR323000 Do Cabo São Tomé a Ilhas Maricás

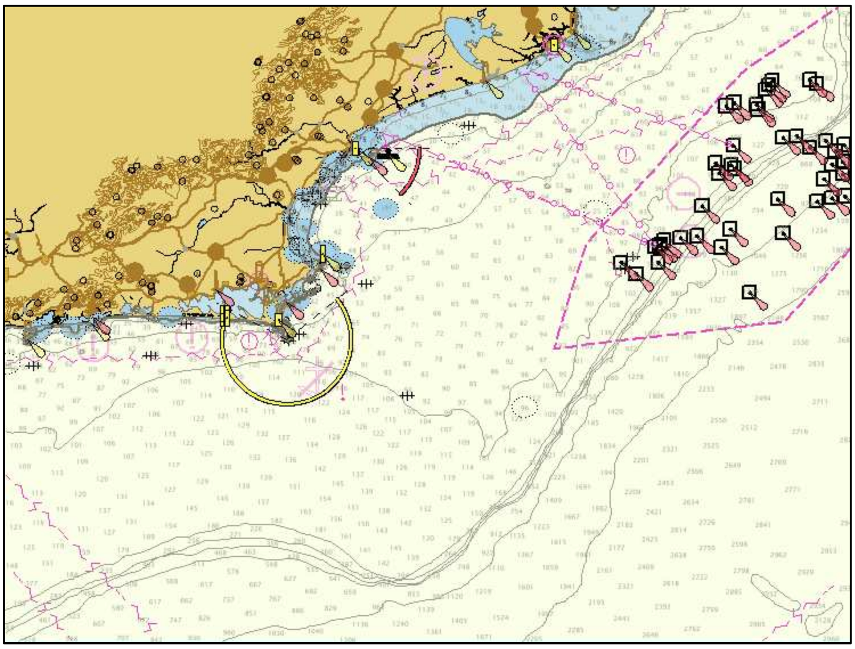


Figure 6 ENC BR323000 Do Cabo São Tomé a Ilhas Maricás

- Area

Lat. 24-00.00S, Long. 043-21.00W – Lat. 21-55.00S, Long. 040-00.00W

The first, out of two, coastal scale datasets provided by the Brazilian Hydrographic Office covers the waters around an important for the world trade harbour – Rio De Janeiro. The harbour itself surrounds a bay Baía de Guanabara and is depicted on the next chart.

- BR323100 Do Rio de Janeiro a São Sebastião

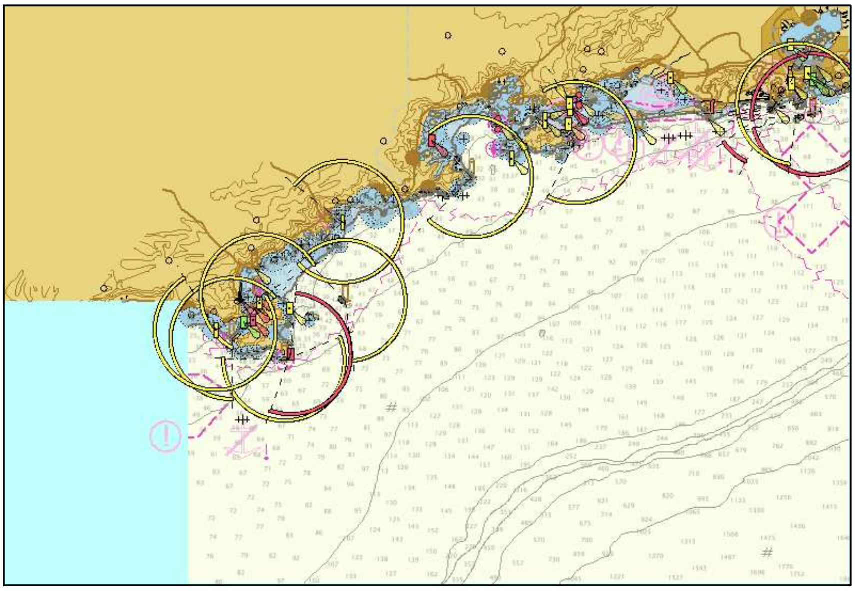


Figure 7 ENC BR323100 Do Rio de Janeiro a São Sebastião

  - Area

Lat. 24-47.00S, Long. 046-22.00W – Lat. 22-40.00S, Long. 043-00.00W

The second coastal chart covers Rio De Janeiro itself and then the coast down to São Sebastião. Regrettably again only a small area has been used for analysis, only the upper right corner with Rio de Janeiro and surroundings.

Approach

- BR401501 Baía de Guanabara – Parte Norte

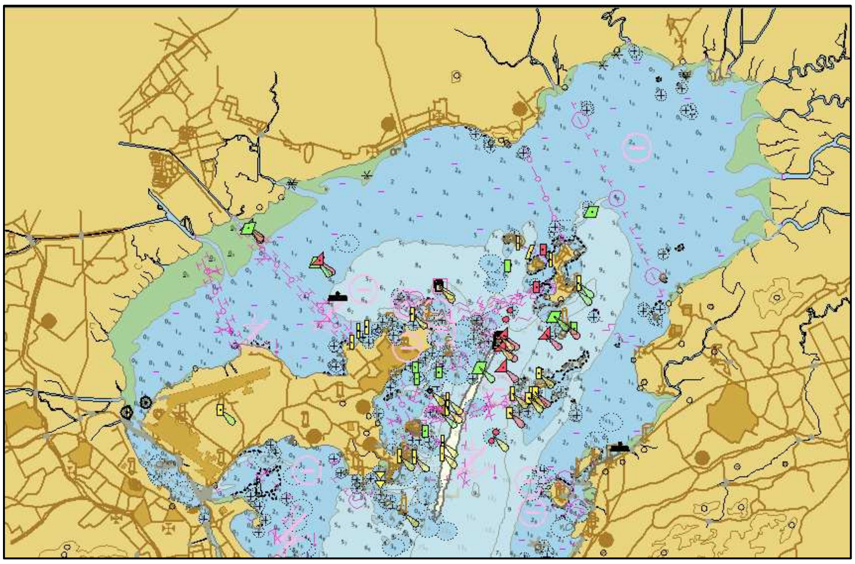


Figure 8 ENC BR401501 Baía de Guanabara - Parte Norte

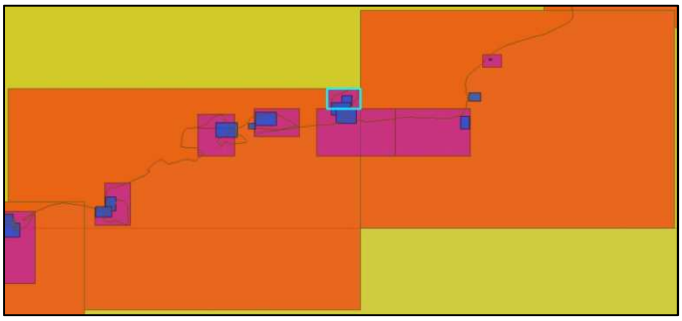


Figure 9 BR401501 location on the ENC coverage of the coast of Brazil (Red - Coastal, Magenta - Approach, Turquoise frame - available Approach cell, Blue - Harbour) (Source: IC-ENC/IHPT ENC World Catalogue, http://www.ic-enc.org)

- Area

Lat. 23-05.50S, Long. 043-19.00W – Lat. 22-40.00S, Long. 043-00.00W

As one can see the area presented here covers the northern part of Baía de Guanabara.

- BR401506 Proximidades da Baía de Guanabara

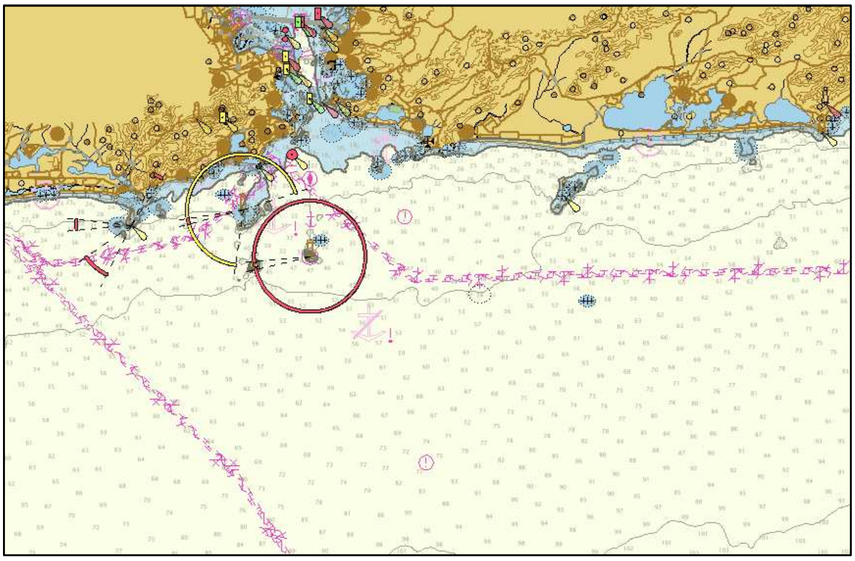


Figure 10 BR401506 Proximidades da Baía de Guanabara

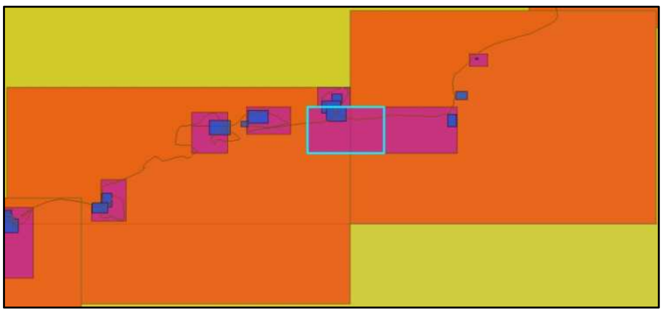


Figure 11 BR401506 location on the ENC coverage of the coast of Brazil (Red - Coastal, Magenta - Approach, Turquoise frame - available Approach cell, Blue - Harbour) (Source: IC-ENC/IHPT ENC World Catalogue, http://www.ic-enc.org)

- o Area

Lat. 23-18.50S, Long. 043-25.00W – Lat. 22-51.50S, Long. 042-40.00W

This chart presents the south side of the bay and the coast.

- BR401508 Do Cabo Frio a Ponta Negra

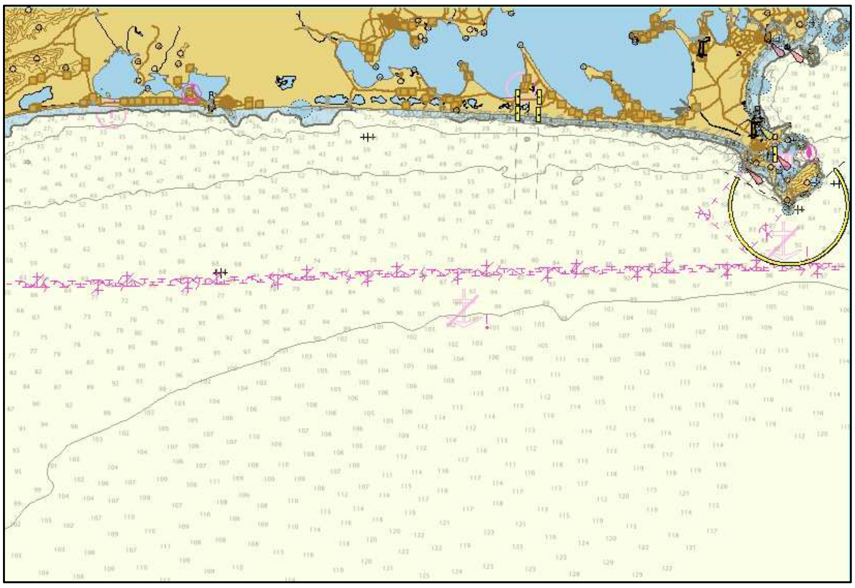


Figure 12 ENC BR401508 Do Cabo Frio a Ponta Negra

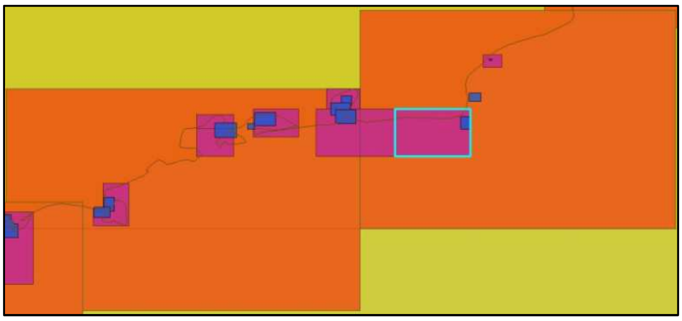


Figure 13 BR401508 location on the ENC coverage of the coast of Brazil (Red - Coastal, Magenta - Approach, Turquoise frame - available Approach cell, Blue - Harbour) (Source: IC-ENC/IHPT ENC World Catalogue, http://www.ic-enc.org)

- o Area

Lat. 23-18.50S, Long. 042-40.00W– Lat. 22-51.50S, Long. 041-57.00W

Finally, the last chart goes further east and depicts the coast.

Figure 14 Location of La Réunion (Source: Wikipedia)

Coastal

- FR332010 La Réunion

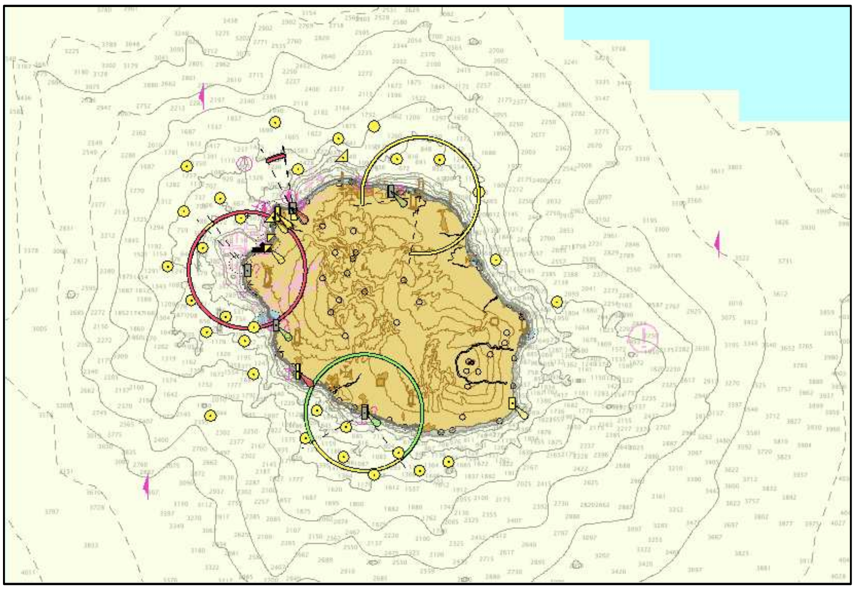


Figure 15 ENC FR332010 La Réunion

  - Area

Lat. 21.6967S, Long. 054.6933E – Lat. 20.5133S, Long. 056.5433E

This chart maps Île de La Réunion (Réunion Island), one of the French overseas departments and the surrounding waters. Réunion is located on the Indian Ocean, east of Madagascar. It is a volcanic island with two active volcanoes Piton de la Fournaise (2,631m above the sea level) and Piton des Neiges (3,070m above the sea level). Both volcanoes gave the island interesting mountainous topography that is depicted on the chart by means of land elevation (LNDELV) lines and points.

Réunion is not an important merchant hub, but a relatively important ocean route from South Africa to the South East Asia goes this way (see Appendix 2). Tourism is promoted and fishing is of importance, as fish & seafood (Tuna, Swordfish and Patagonian toothfish) are one of the main export products.

Approach

- FR432010 La Réunion - Northern part

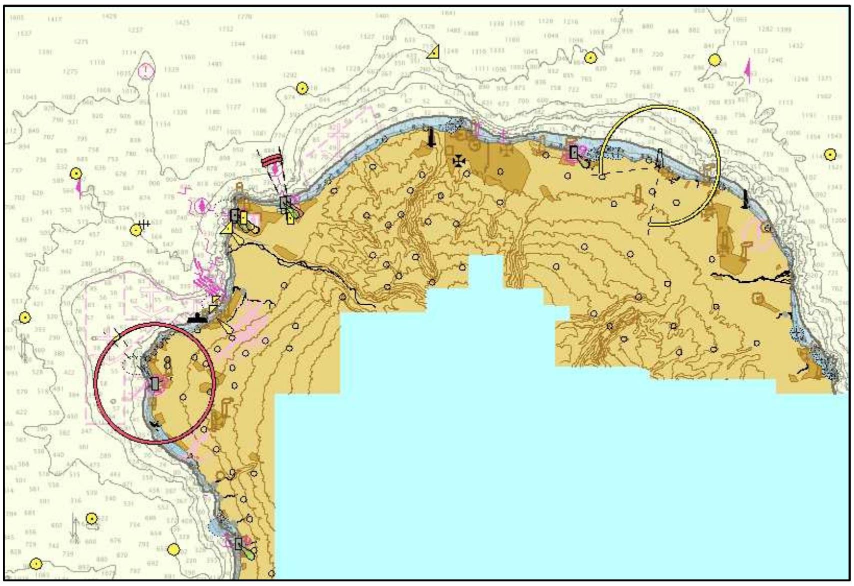


Figure 16 ENC FR432010 La Réunion - Northern part

- o Area

Lat. 21.1950S, Long. 055.1100E – Lat. 20.7900S, Long. 055.74333E

This chart depicts the north side of the Réunion Island without the centre of the land, which is irrelevant to the mariners. The entire Approach usage band coverage for this island is composed of 3 cells: FR432010 (provided) and FR473280, FR472220 (not provided) (figure 17)

Figure 17 ENC coverage of the Réunion Island (Red - Coastal, Magenta - Approach, Turquoise frame - available Approach cell, Blue - Harbour) (Source: IC-ENC/IHPT ENC World Catalogue, http://www.ic-enc.org)

Figure 18 Location of the area covered by the chart provided by the Dutch Hydrographic Office (Source: Wikipedia)

Coastal

- NL301630 North Hinder / Eurogeul / Westerschelde

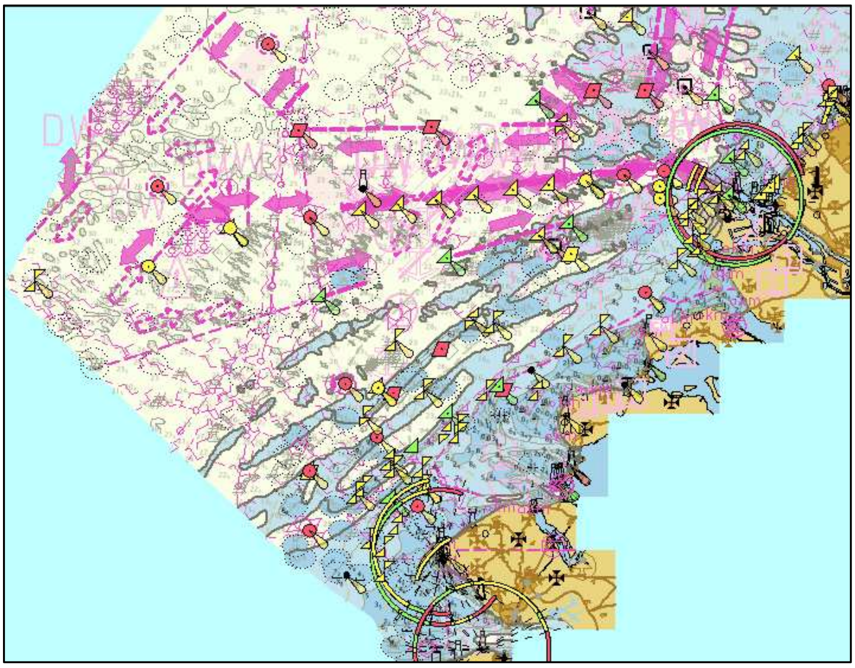


Figure 19 NL301630 North Hinder / Eurogeul / Westerschelde

- Area

Lat. 51-22.22N, Long. 002-32.28E – Lat. 52-13.75N, Long. 004-16.92E

The chart covers a very important for sea trade channel called Eurogeul with the final part Maasgeul leading to the port of Rotterdam – the largest port in Europe. Eurogeul is a dredged to 23m deep water route allowing vessels with a draft of more than 20m to enter the harbour. Traffic Separation Schemes on the chart are marked in magenta. One can rightly expect that the density of traffic in these waters is enormous. Hence the chart is packed with information – the most densely populated with objects chart of the analysed datasets.

The chart actually spans from the less significant harbour of Scheveningen (The Hague) to a popular touristic destination Zeeland and the boundary with Belgium, close to the city of Cadzand Bad. The boundary is the reason for a tilted shape of the chart.

Approach

- NL400110 Westkapelle to Stellendam

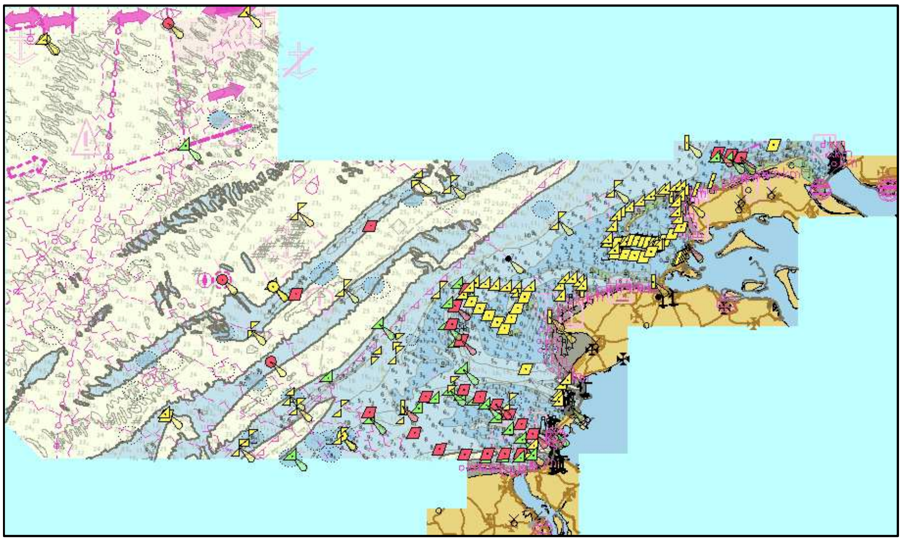


Figure 20 NL400110 Westkapelle to Stellendam

- Area

Lat. 51-32.15N, Long. 002-56.92E – Lat. 51-58.45N, Long. 004-08.62E

The approach equivalent of the Southern part of the chart covers Zeeland.

- NL400122 Approaches to Europoort

Figure 21 NL400122 Approaches to Europoort

  - o Area

Lat. 51-22.22N, Long. 002-32.28E – Lat. 52-13.75N, Long. 004-16.92E

As the name indicates the chart maps approaches to Europort.

1.5.3.4 NEW ZEALAND'S DATASETS:

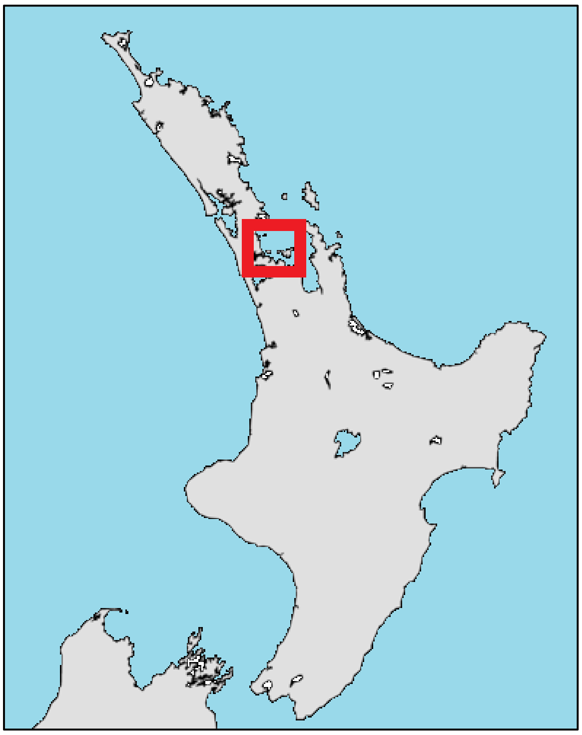


Figure 22 Location of the area covered by the chart provided by the New Zealand Hydrographic Authority (Source: Wikipedia)

Coastal

- NZ305322 North Island – East Coast – Approaches to Auckland - West

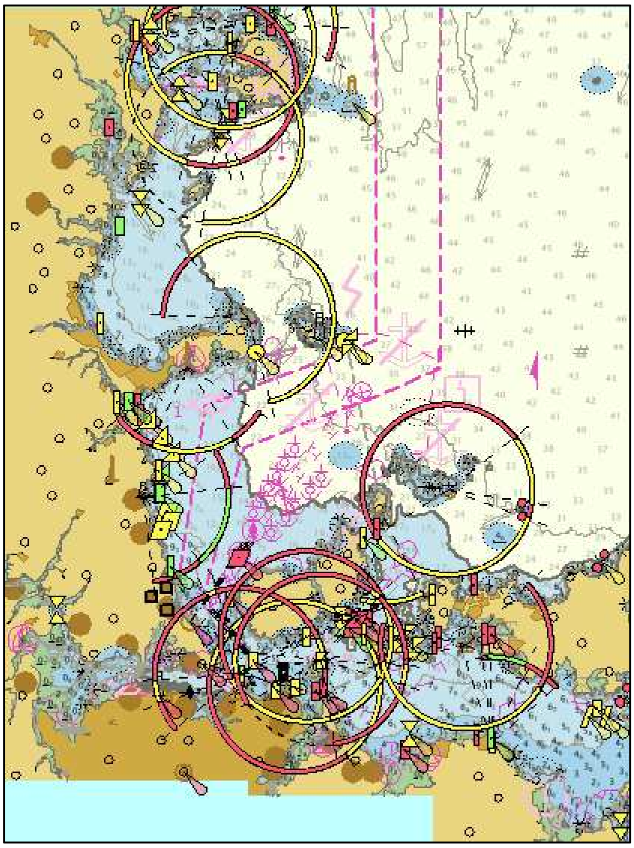


Figure 23 NZ305322 North Island – East Coast – Approaches to Auckland - West

- Area

Lat. 36-56.90S, Long. 174-38.00E – Lat. 36-22.90S, Long. 175-09.53E

Auckland – the biggest city in New Zealand lies on and around an isthmus, less than two kilometres wide at its narrowest point, between Mangere Inlet and the Tamaki River. There are actually two harbours in the area – Waitemata Harbour (visible on the chart) and Manukau Harbour (not visible, located to the South of Auckland and open to the Tasman Sea).

The chart presents the approaches to Auckland via Hauraki Gulf with its islands: Rangitoto Island, Motutapu Island, Waiheke Island and others up to Kawau Island. The ports around Auckland are visited by around 1,600 commercial vessels a year and handle the movement of 60% of New Zealand's imports and 40% of its exports. This makes Auckland one of, if not the most important port in New Zealand (comparable only with the Port of Tauranga).

Approach

- NZ405321 North Island - East Coast - Mahurangi Harbour to Rangitoto Island

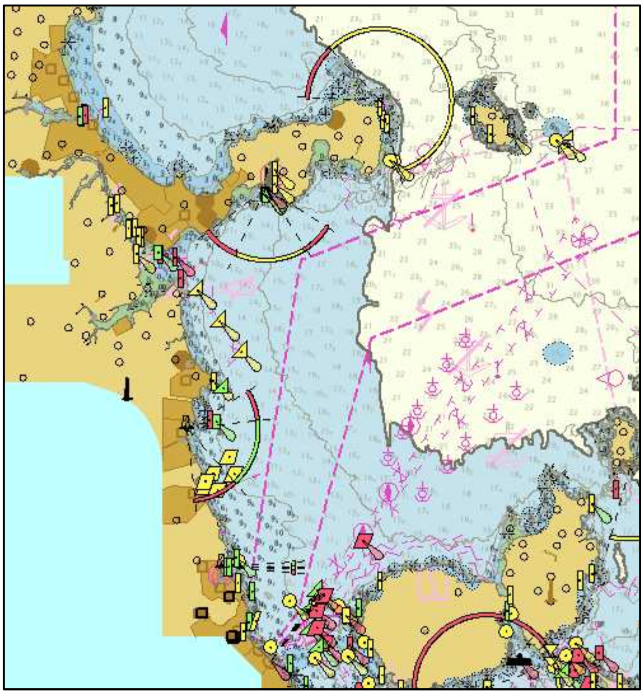


Figure 24 NZ405321 North Island - East Coast - Mahurangi Harbour to Rangitoto Island

- Area

Lat. 36-48.60S, Long. 174-40.00E – Lat. 36-27.40S, Long. 174-57.40E

This approach chart covers waters north of Auckland.

- NZ405324 North Island - East Coast - Mahurangi Harbour to Rangitoto Island

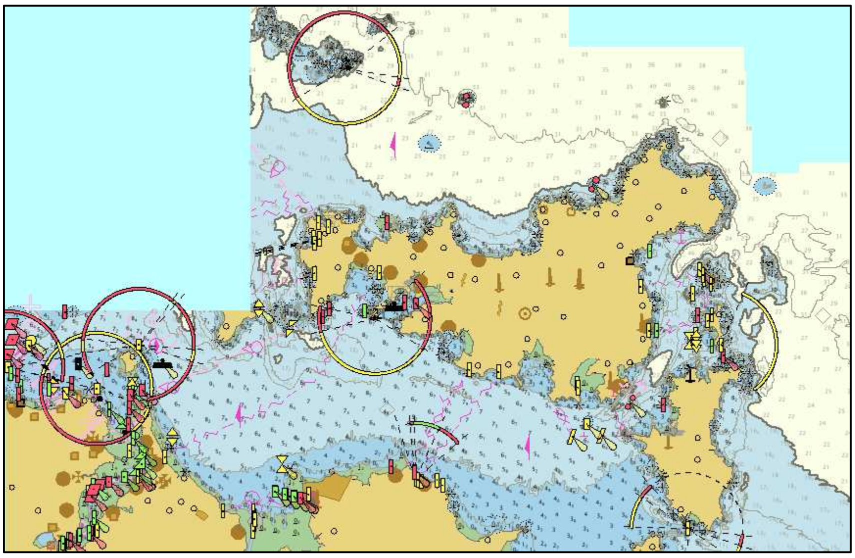


Figure 25 NZ405324 North Island - East Coast - Mahurangi Harbour to Rangitoto Island

- Area

Lat. 36-48.60S, Long. 174-40.00E – Lat. 36-27.40S, Long. 174-57.40E

This chart shows the southern part of the Coastal chart with waters of Tamaki Strait.

1.6 STRUCTURE OF THIS REPORT

This report is divided into eleven chapters, including appendices. Chapters one and two are introductory chapters, introducing project settings and background literature study. Chapters three to seven present the results. Conclusions can be found in chapter nine. Chapter ten and eleven are the bibliography and appendices.

The introduction acquaints the reader with Electronic Navigational Charts and current practices of production. It explains how chart production differs from map production and which standards are in use. The awareness of this aids to place the project correctly in the current GIS research scene. The chapter announces what the problems are and where more study and development could be of use. Next the chapter presents the research problem and poses questions that this report aims to answer. Methodology, Data providers and Tools and data used in the project introduce the case study.

The literature review in three core disciplines relating to this study: maps and map making, generalisation and finally navigation, navigational safety and the role of ENCs is presented. The study of the literature in those fields is recommended when dealing with chart production and was needed to draw proper conclusions from this project. This chapter is concluded with a short comment on how this research contributes research to the overall picture.

The first of the results chapters is a description of the analysis scheme that was created. It shows how data was pre-processed and what routine was used to obtain the results.

Next the differences between Coastal and Approach datasets are shown. The author compares datasets of the same area between the scales to shed some light on one of the research questions.

Specifications chapter is divided into specifications, standardization, conditions and proposed generalisation method created for each analysed object group. Explanation follows to justify the choices made.

Resulting maps are shown in the Outputs of Generalisation Effort and their evaluation. As the title indicates each set of charts is briefly evaluated by the author.

Expert Evaluation by the Hydrographic Offices is the last of the results oriented chapters. Comments to all generalised object groups are combined with a mark given.

The final chapters – Conclusions, Recommendations and Further Research close the research. Conclusions answer the research questions. Recommendations are addressed to Hydrographic

Offices, Software Vendors and Hydrographic Community. Further research shows what still needs to be done in this field.

The Literature and Appendices are listed at the end. The appendices include questionnaires, figures, generalisation models and maps that due to practical reasons could not be incorporated into the body of this report.

2 LITERATURE REVIEW

To undertake the research in ENC generalisation one needs to understand how maps are created and used, which information they should convey and for which purpose. It is also important to be aware of contemporary and historical generalisation, its methods and approaches. One must be aware of models that are used and had proven to be worthy. It is necessary to know about ENCs, transfer standard and data model, but also about hydrography and specific objects that dominate this sort of thematic map. A basic knowledge of navigation and safety of navigation is useful, as some of its aspects affect strongly the way nautical charts are made.

For this reason literature about maps and cartography, generalisation, navigation and ENCs is discussed below.

2.1 LITERATURE ABOUT MAPS AND MAP MAKING

To start with a clarification, Oxford Dictionary of English gives a definition of a map (as understood in the context of this study) as a diagrammatic representation of an area of land or sea showing physical features, cities, roads, etc. In other words, as soon as a question contains a phrase like "where?" a map can be the most suitable tool to solve the question and provide the answer. (…)It would put the answers in a spatial perspective (de By, 2004). The laconic definition of a map does not treat about the aim of the map and it is this aspect of a map that deepens the perception of a map from a simple graphic representation of the spacial content.

An intelligible briefing of the history and evolution of maps can be found in a presentation of Rodrigue[7]. Maps originated from the times of Herodotus (circa 450 BC) from the urge to explore and travel and therefore for the technologically unarmed people they were supposed to be rather easy to read than geometrically correct. In the times of Aristotle (ca. 350 BC)-- considered one of the first physical geographers - map became a way to display other phenomena, such as temperature or winds. But it was Eratosthenes (ca. 250 BC) who gave the beginning to the modern cartography by introducing the idea of roundness of the Earth, calculating its circumference and developing the concepts of a parallel and a meridian which introduced the concept of geographical location. Map projections were introduced by Ptolemy (ca. 150 AD) and his maps (figure 26) remained the most accurate for many centuries as during the Middle Ages, the period of decline, cartographic approach was lost in Europe.

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[7] World Map Evolution.ppt http://people.hofstra.edu/jean-paul_rodrigue/course_worldregional.html Accessed on 5th of February 2012

Figure 26 Ptolemy's (150AD) Ulm edition world map, 1482 (sourced from Geog 001 World Map Evolution.ppt)

Renaissance, as in all fields of science gave cartography a new life. It is interesting to point out that the drive for innovation came from the side of the nautical charts that were required and created by the maritime explorers in the 15th and 16th centuries. It was also the invention of compass that boosted the quality of graphical representations of Earth. It wasn't however until the modern times that we acquired the complete and accurate view of the world. The use of remote sensing and the use of computer databases as a storage brought cartography onto a completely new level (figure 27).

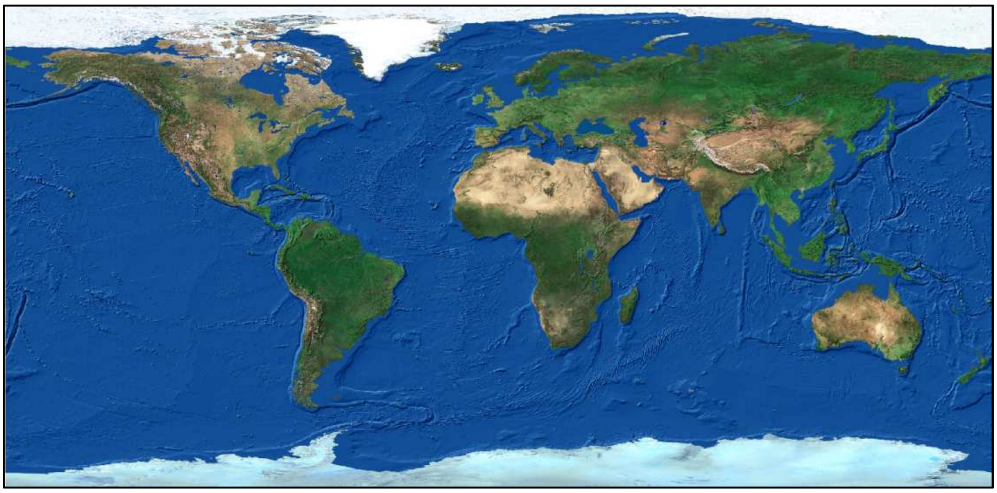

Figure 27 Satellite Composite Image (sourced from Geog 001 World Map Evolution.ppt)

Nowadays map conception and design has developed into a science with a high degree of sophistication. Maps have proven to be extremely useful for many applications in various domains (de By, 2004). Three very popular map types on the market are, for example, the ones used for tourism, navigation and topography. From this superficial division various sub-themes can be derived. One can think of navigation maps for sailors that will comprise both: the characteristics of a navigational map and the ones dedicated for tourism. End users, or simply, users of those maps have different intentions and goals in mind, but inevitably when they reach for a map it is to find themselves or other objects in the spacial environment. The primary goal for the maps is to serve as a tool to display spatial information in a compact, clear and easy to use way that will aid users in achieving their goals. The circle of retrieving spatial information by means of a map is illustrated on figure 28:

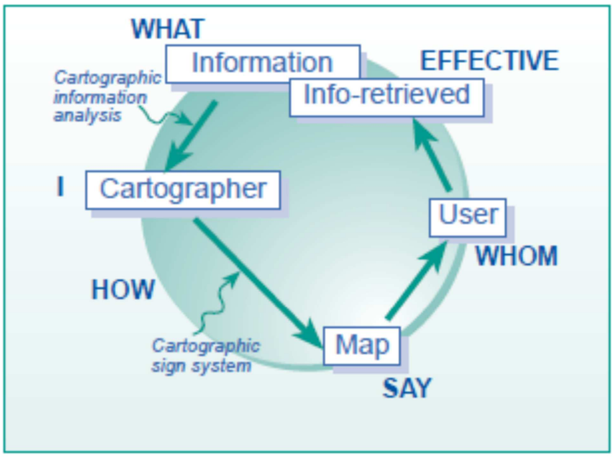

Figure 28 The cartographic communication process (from de By, 2004)

De By (2004), however, points out several disadvantages of maps:

- Traditional paper maps are generally restricted to two-dimensional static representations.
- It is always displayed in a fixed scale. The smaller the scale, the less detail a map can show.
- A map is always a graphic representation at a certain level of detail.
- Features spanning two map sheets have to be cut into pieces.

Can these disadvantages be overcome? Buckley and Frye (2011) put on paper what is very likely the opinion of the society that the introduction of mass printing capabilities led to what might arguably be called the last major revolution in cartography but we are now in the midst of another shift related to the production and dissemination of maps – the movement from print to online maps. For this study not the online aspect of maps matters as much as the idea of presenting a map on a screen with the capability of zooming, panning and querying the context. As with printing, the Web has allowed maps to be created, disseminated, and used in ways that are vastly different than in the past, and the implications of this shift are yet to be fully realized (Fu and Sun, 2010 from Buckley and Frye, 2011).

One realization of the abovementioned implications is on-demand-mapping. On-demand mapping is concerned with the generalisation of maps based on user request and according to user requirements This is the first time when generalisation is mentioned as being critical to an achievement of a mapping goal, even though, as it is explained in the next chapter the idea is not new. In on-demand mapping users are able to produce their own maps and customize the process of generation (Cecconi et. al., 2002). The idea is to dynamically create digital products, mainly on a display without actually compiling a separate dataset. Cecconi's idea is to combine multi-scale databases and map generalisation.

As to the way maps are made in general one should consider the steps in the map making process as presented by Kimerling et al, 2009:

- Thinking of ourselves as separate from the environment,
- Deconstructing the environment into constituent parts that can be classified and named,
- Gathering data about the features, attributes and phenomena that are the constituent parts,
- Processing the data to draw out the essential characteristics, and
- Manipulating and displaying the results graphically in a way that reveals something meaningful or interesting or useful about the mapped environment.

This is merely a conceptual model of map creation, but given the variety of detailed specifications of NMAs it makes a common denominator.

Going deeper into the theme of maps a distinction can be made for nautical charts. These are maps as well and therefore fall under Oxford Dictionary's definition. NOAA (US National Oceanic and Atmospheric Administration) defines the principal purpose of the nautical chart that makes them stand out from other maps. In brief, it is to provide information necessary to promote safe and efficient marine navigation. The time-honoured application of a chart is to provide data that can be used by the navigator to fix the vessel's position, for example by taking visual bearings on charted natural and artificial features or ATONs[8] (NOAA, 1997)

The nautical chart differs considerably from the topographic map in its treatment of the coastline. The topographic map emphasizes the land forms and the representation of relief, with shoreline as an approximate delineation of the waterline at mean sea level. In contrast, the nautical chart has such a unique requirement for detailed and accurate representation of the coastline and water forms that it must be considered an a separate category from topographic maps in any discussion of coastal geography (Nautical Chart Manual from NOAA, 1997). Other differences focus around the main assumption that it is irrelevant to chart a feature that could not be seen from the water. Nautical charts would therefore chart conspicuous topography and some valuable to mariners' eyes landmarks which could serve to repair course of the vessel. Features that clearly do not belong to the nautical chart are town, county and state boundaries, although outlines may be indicated of the cities to give an idea, during the night time where glows from the city lights may be expected. One should also not encounter inland buildings,

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8 Aids To Navigation

street names, highway network or land use. Lakes may be depicted where considered conspicuous.

Nautical charts do not escape the principles of the maps mentioned above, neither they overcome the defaults, but carry additional particularities. Calder (2008) attempts to summarize necessary knowledge about it, however his work is rather superficial and addressed to non-expert readers. Nevertheless, he tackles several serious issues, for example with accuracy which is, for a paper chart on a level of about 1mm x the chart scale. He confronts it with the accuracies achievable by the current GPS receivers to point out the shortcomings and of the first. Additionally 50% of the soundings in use on modern charts were collected before 1939 (Calder, 2008). Contrary to the authors praising the possibilities of electronic/web based maps he notices that they are often only “zoomed in” which gives the false impression that they are of better quality, where, in reality many are compiled from the same source. Apart from this lesson of cautiousness he presents also basic characteristics of nautical charts denoting their scarce yet perfectly standardised colour scheme(only blue, green, white, buff and black) and symbology.

These and many other aspects of the nautical chart have long time been standardised as, contrary to land maps, sea charts often covered international waters and areas under jurisdiction of various countries. Trans-oceanic passage planners expected a uniform navigational aid for every segment of the route.

‘In a time-worn and completely forgotten pamphlet which was published in Washington, in 1884, Mr E R KNORR, the Chief Draughtsman of a Hydrographic surveying expedition of the United States of America, had already proposed the issue of original charts and he gave figures showing the enormous economies which could be effected if all the nations which publish charts of the same coast or port were to come to an understanding as to the reproduction of these charts on a common basis.’ (Admiral JM Phaff quoted by IHO, 2005). The same was discovered by Renaud[9] in 1918 and an idea of establishing an International Hydrographic Conference gave start to international cooperation between hydrographic agencies of the World. As a result IHO Regulations for International Charts were compiled from various reports and national specifications in 1984. This publication functions today in the collection of publications of IHO under S-4. It gives foundations to producing uniform nautical charts around the World. Its sections cover definitions, regulations and schemes for chart production and parts B and C provide descriptive instructions about the content of medium and small scale charts respectively.

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[9] Ingénieur Hydrographe M J A RENAUD was a founder of the IHB, but died just before the election of Directors in May 1919.

To supplement this publication 3 graphical guides are published:

- INT1 Symbols, Abbreviations, Terms used on Charts

  Provides the chart user with a key to symbols and abbreviations used on charts compiled in accordance with these specifications. Although it may be used by cartographers as a quick reference, the specifications should always be used for detailed guidance.

- INT2 Borders, Graduation, Grids and Linear Scales

  Shows specimens of the various patterns of border graduation and linear scales.

- INT3 Use of Symbols and Abbreviations

  A standard reference chart of a fictitious area with as many examples as possible of the use of these specifications.(IHO, 2005)

One can see the vast amount of effort and enormous possibilities coming from the fact that the World of nautical charts is so homogenous. Why is it then that nautical cartography does not set the technological standards as it was the case in the XV and XVI centuries?

2.2 LITERATURE ABOUT GENERALISATION[10]

Ever since map exists, generalisation is a subject connected to its making. In this research the definition of generalisation by the International Cartographic Association (ICA) is used: Generalisation may be defined as the selection and simplified representation of detail appropriate to the scale and/or purpose of a map (ICA, 1973).

Early 20' scientific research of the German cartographer Max Eckert (Die kartenwissenschaft, 1921) emphasizes this artistic approach. The author argues that 'the dictates of science will prevent any erratic flight of the imagination and impart tot the map a fundamentally objective character in spite of all subjective impulses. In this respect that maps are distinguished from fine products of art. Generalised maps and, in fact, all abstract maps should, therefore be products of art clarified by science (Eckert, 1908, 347 cited from: McMaster, 1992 p.18).

Although mapmaking has evolved during centuries from fine work of arts to a high functional map, mapmaking is still considered to be a skilled craft. The scientific approach of applying requirements and searching for generic requirements can be conflicting with the aesthetic approach of the craft men. The efforts to come to generic specification rules for automated generalisation, replacing the work of cartographers must be seen in this historical context. In research the subject of automated generalisation is treated with great care: how can the soft knowledge of cartographers be translated in hard requirements for automated generalisation models?

[10] Based on Socha et. al (2011)

In literature a number of conceptual generalisation models and classification methods can be found. These three models are found in most relevant literature and will help to structure the generalisation process later on in the application of generalisation rules for the purpose of that study.

Noticeable is that all the three models are from the early nineties. In this period digital generalisation became more usual; this development is visible in all the models by making the distinction between cartographical generalisation and digital generalisation. Despite the age, the three models are still useful to approach digital generalisation. Below, some characteristics of three models:

Model of Grünreich: high over approach on generalisation of topographical maps, applied in Germany by the ATKIS project. It separates the data modelling from the cartographic modelling (Foerster, 2010)

McMaster and Shea model on digital generalisation, presenting a logical framework addressing the issue ***why*** to generalise, assessments on the situation ***when*** to generalise and providing operators ***how*** to generalise (McMaster et al, 1992).

Brassel-Weibel model: process based model of digital generalisation. This is one of the first models which considered the aspect of *automated* generalisation (McMaster et al, 1992).

Grünreich Model:

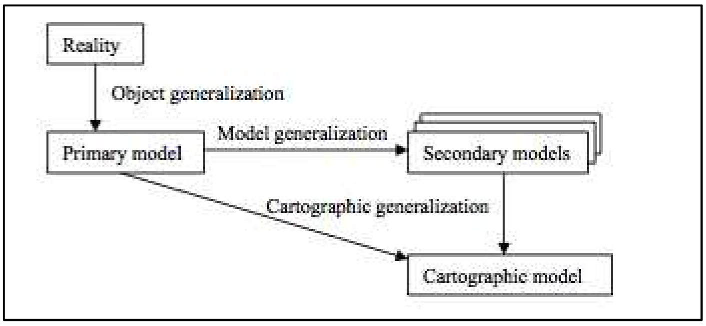

Figure 29 Grünreich model

The Grünreich model has been the fundament for designing new architecture for generalisation of topographical maps in Germany, which is based on separation of data and maps. It 'proposes a multi-stage generalisation approach from reality to a dataset or to a map' (Foerster et al, 2007, p.5). This fundament was implemented in Germany by the ATKIS project, and is still the standard in Germany. All federal surveying authorities have to comply with the ATKIS standard (Amtlichen Topographisch – Kartographischen Informatiossystems or Authoritative Topographic-Cartographic Information System) and it has the character of a geospatial reference data information system.

The most important components of ATKIS are object-based digital landscape models (DLM) encompassing several resolutions and digital topographic maps (DTK) (Busch et al, 2004). On a high level the ‘reality’ is generalised in objects in the primary mode (DLM), forming the basic dataset for all derived object-based data models (DLM) and cartographic models (DTK).

McMaster and Shea model:

The McMaster model is built upon three pillars (figure 30):

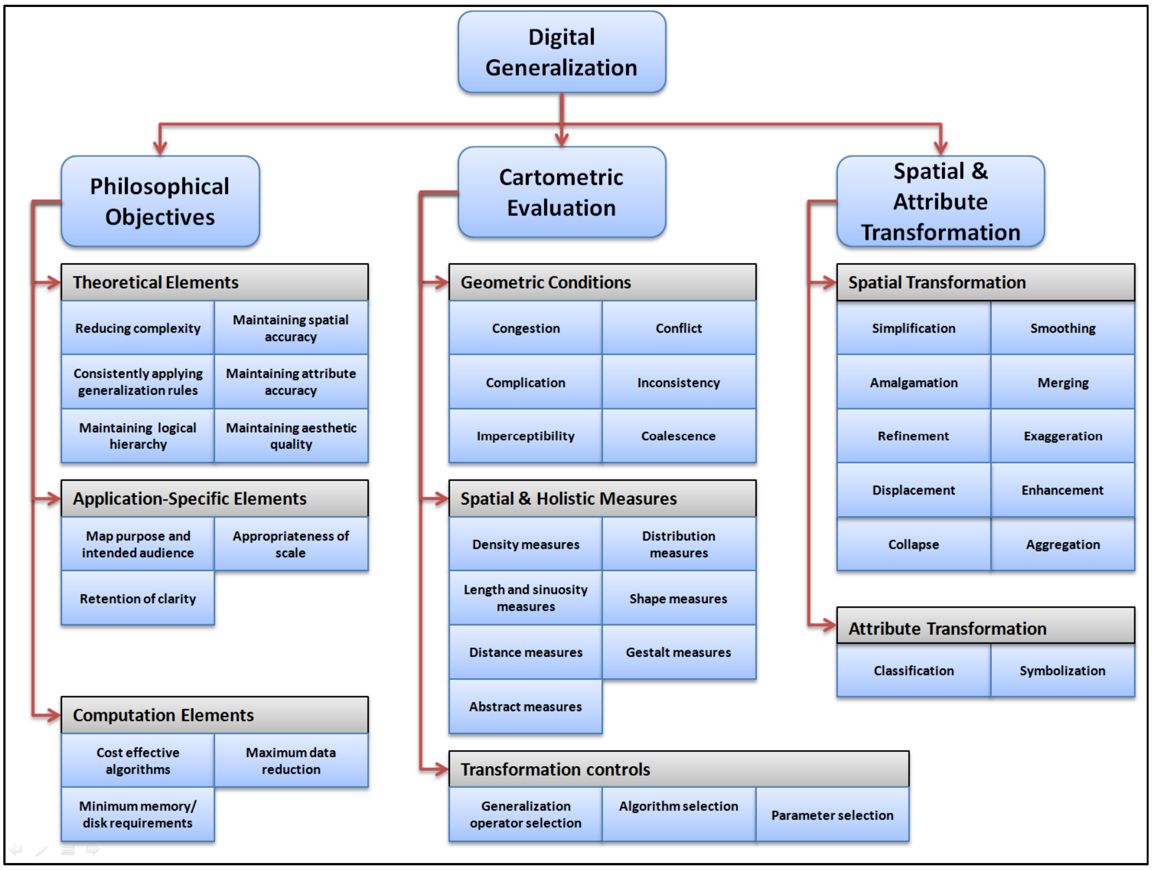

Figure 30 McMaster and Shea Model: conceptual framework of Digital generalisation (McMaster et al., 1992)

The first pillar is the philosophical objectives and can also be seen as the intrinsic objectives to perform generalisation: why do we generalise. Evaluating the three elements in this pillar: (1) theoretical (2) application specific elements and (3) computation elements the why question is extended with the quality considerations of the generalisation process. The why question can be answered by, for example, purpose of the map and reducing complexity etc. and the quality considerations are covered by the use of efficient computation algorithms and maintaining spatial accuracy and aesthetic quality of the map. (McMaster et al, 1992)

The second pillar- cartometric evaluation covers the situation assessment: when to generalise. Decomposing this pillar delivers the conditions, measures and controls of the generalisation process. The consequence of evaluating the generalisation is the required action on the undesirable consequences of scale change, such as congestion, conflicts and inconsistency. This can be defined as the geometric conditions that determine a need for generalisation. The conditional measures can be used to assess spatial relationships between objects. The spatial and holistic measures that are defined are not complete but provide a starting point of conditions within the map which 'does require or might require generalisation' (McMaster et al, 2002). The transformation control of the generalisation techniques emphasises the need for an evaluation of the use of operators, algorithms and parameters. 'To obtain unbiased generalisations successfully, the order in which operators are applied becomes critical (McMaster et al, 2002). Along with the selection of appropriate algorithms and input parameters, these factors play a significant role in the outcome of generalisation transformations. (McMaster et al, 2002)

The last pillar of the McMaster & Shea model is the spatial and attributes transformation operators. They introduced a first classification of generalisation operators, which consists of twelve operators and two categories. This classification is limited regarding the Grunlich approach, but also regarding current GI research, where visualization and data are separated to reduce complexity and avoid redundancy (Foerster, 2007)

Still this method can be seen as a useful attempt to categorise the relevant generalisation operators. The next paragraph the Shea and McMaster classification will be extended with other views on the classification and typology of generalisation operators.

Brassel-Weibel model:

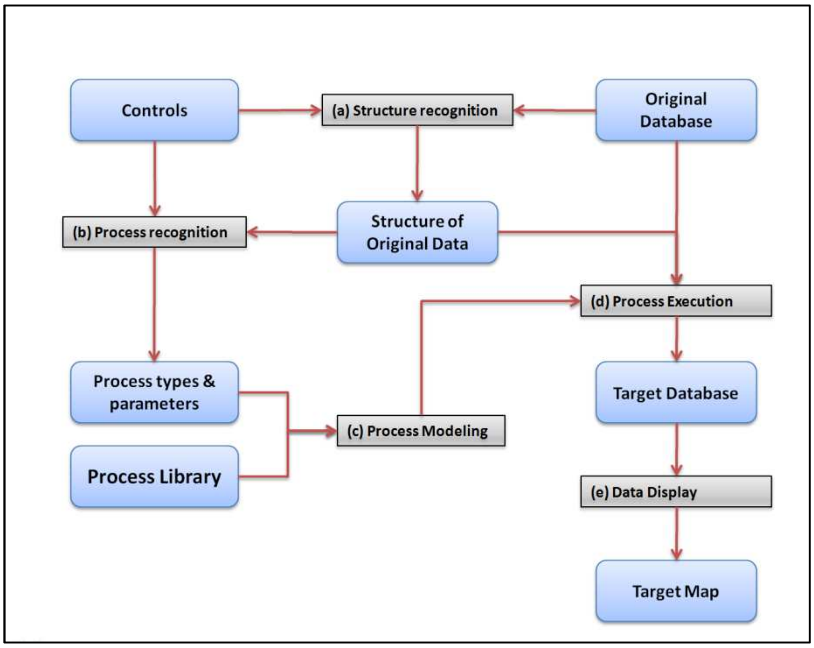

Figure 31 The Brassel-Weibel model of generalisation (McMaster et al, 1992)

The Brassel-Weibel model is a conceptual model on how to structure the generalisation process. The model distinguishes five process steps, all triggered by input and resulting in output. It can be used complementary or as part of the Grünreich model (Foerster, 2010)

The five processes include: (a) structure recognition, (b) process recognition (c) process modelling, (d) process execution and (e) data display.

In the first process, **structure recognition**, the cartographic objects and spatial relations are identified. This process step is controlled (input) by the objectives of generalisation (quality of database, scale target map etc.) and has the original database as input.

The second process is **process recognition**, which identifies the exact generalisation process. Again this process is controlled by the objectives of generalisation. Based on the identified structure of the original data it provides parameters and types of data modification that are necessary.

The third process, **process execution**, sets up the rules and procedures to be followed by the output of the second process (parameters and types of data modification) and rules and procedures from the process library. The fourth process, **process executing**, is actually the generalisation execution in which all the rules and procedures that are identified are applied. It results in the target database, which is the input for producing a final map. (McMaster et al., 2002)

These four steps can be seen as the model generalisation from primary to secondary models in the Grünreich model. The fifth and last process step, **data display**, can be seen as the cartographical modelling from target data base to target map.

In automated, non-automated and manual generalisation the sequence of actions to transform the original map to the target map is done by operators. Operators can be described as 'an abstract description of atomic generalisation functionality' (Foerster, 2010). These functionalities are nothing but computations in a certain sequence, or (a set of) algorithms. It is possible that the same operator can be implemented with different algorithms, giving different results. Basic knowledge of how an operator is implemented is needed to apply an operator in the right way. It is obvious that an operator transforms the source map into a target map and that a performed operator can cause a conflict that has to be solved by another operator. For example, as a road is collapsed from polygon to line, a gap will be created between the new line feature and the old adjacent polygon, which has to be solved.

The McMaster & Shea model presented one of the first extended classifications of digital generalisation operators in 1992. Bader (2001) used this classification partly as a reference set and extended this traditional classification with, as he called it, digital operators (figure 32):

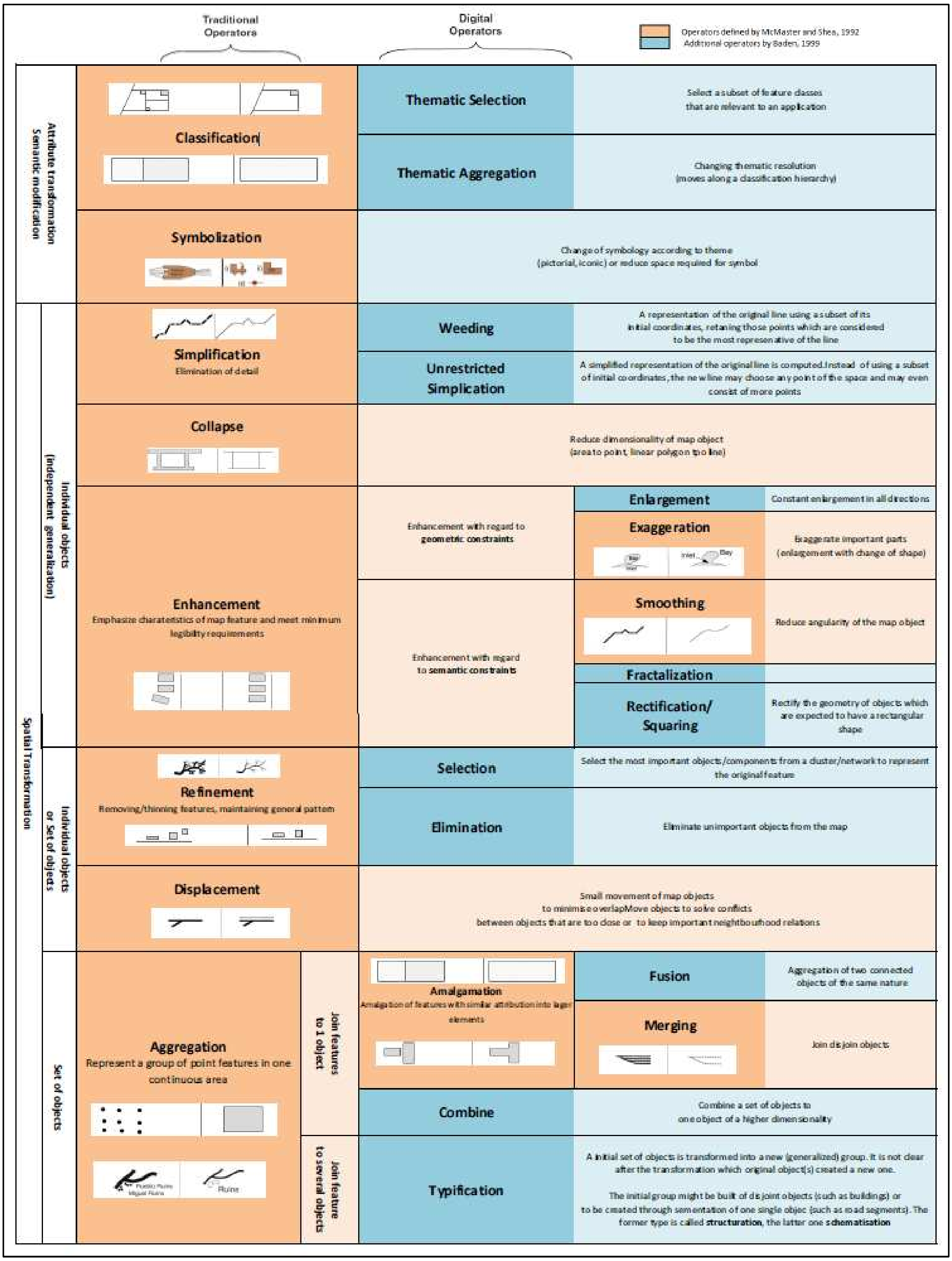

Figure 32 Classification of operators after Bader (2001)

This figure does not contain a complete set of operators but it gives an overview of the complexity of the classification operators. On the other hand, this overview is not fully compatible with the Grünreich model separating model generalisation operators from cartographic generalisation operators.

Foerster (2010) proposed a classification which is in line with the Grünreich model. This classification separates the operators into two categories:

Model generalisation operators: Based on the General Feature Model from ISO 19109 standard, in which specification of the structure of feature types, their properties and interrelations is modelled.

Cartographic generalisation operators: Based on the OGC GO-1 Application Objects model, which specifies an object-oriented view on graphic objects such as cartographic objects. (Foerster, 2010)

The distinction between these two categories of operators is that model operators can be defined and applied for complete feature type (dataset). Cartographic generalisation operators are applied only if a cartographical conflict has to be solved, which only can occur on a local level or on a subset of the feature type (data set). The reflection of this classification can be found in table 2:

Table 2 Classification of generalisation operators by Foerster (2010)

Model Generalisation	Cartographic generalisation
Class selection	Enhancement
Reclassification	Displacement
Collapse	Elimination
Combine	Typification
Simplification	
Amalgamation	

Another approach to generalisation is the idea of Multi-scale Databases. A multi-scale data model is a specific type of a multi-representation data model. The issue of multi-representation was introduced in a research program of the National Center for Geographic Information and Analysis (NCGIA 1989; Buttenfield and Delotto 1989 from Stoter et al. 2008). The idea behind this model is to link or reuse objects on different scales or levels of detail without interfering in their representation at a particular scale. This is a new concept, as historically maps on different scales have been produced independently. Van Oosterom (2009) sees a paradigm shift towards native multi/varioscale support by re-engineering geographic data and providing tools for data providers and end users to apply these data at any desired level of detail. This requires that spatial objects be managed over a range of resolutions, allowing for seamless transition when zooming through data.

Whatever the means of generalisation the research is deemed to continue, as the current methods and implementations leave a wide space for improvement. According to Mackaness and Chaudry (2008) generalisation is or has potential to be applied in five key activities:

- Cartographic Assistant

The existence of many different generalisation techniques means that a 'cartographic toolbox' is available for use by a trained cartographer. In this collaborative environment, such systems have the capacity to improve the quality of cartographic training, ensure quality control in the design process and enable refinement in the adjustment of parameters used to control generalisation techniques.

- Map generalisation service

In the absence of the cartographer, and in the context of GIS, users (with limited cartographic knowledge) require assistance in the rapid design and delivery of cartographic products. The idea of a map generalisation service is that maps can be delivered over the Internet in response to user request – which in turn has led to a focus on the pre-processing of solutions, in which intermediate solutions are stored in a multiple representation database (MRDB).

- Populating Multiple Representation Databases

There currently exist multiple, often disconnected 'silo' databases containing data at different levels of detail. The vision is that model generalisation techniques are applied to data captured at the finest detail in order to create a hierarchical framework of increasingly aggregated geographic phenomena (from house, to suburb, to city to region, to country) – in effect a semantically indexed structure from which different scale linked phenomena can be extracted and queried.

- Spatial Data Integration service

Considerable 'value add' comes from the sharing and integration of data. Integration of geographic data is beset by a host of challenges receiving considerable attention – notably in development of shared data schemas, and addressing ontological issues linked to culture, original purpose and conceptual understandings of place. Model generalisation techniques can play a critical role in aggregating data according to shared partonomic and taxonomic classification methodologies. (Mackaness and Chaudry, 2008)

For the time being, however, there are only few ideas that made its way into practice (Lecordix et al., 2007 and Regnauld and Revell, 2007). Foerster et al. (2010) defines four steps for automated generalisation to be implemented in an organisation:

1) Renewing data models

To be able to successfully introduce automatic generalisation data must be sufficiently attributed. Data model for this study is assumed suitable for the generalisation purposes unless proven otherwise in the research process.

2) Designing the conceptual architecture

Next, decisions have to be made on how to approach the generalisation process. Should each scale/usage step be populated from the previous one (the ladder approach) or should all usages be populated from one, base dataset (the star approach)? Should the model distinguish between model and cartographic generalisation? This research will tackle issues belonging to this phase.

3) Implementing generalisation processes

Generalisation operators need to be used and proven efficient and sufficient for automatic generalisation. At the present time there is no such case in Europe (Foerster et al., 2010)

4) Managing relationships between different scales

At the present time object on different scales/usages representing the same real life objects have little to no links in the database. This links ought to be created and maintained in order to manage data efficiently.

Following this Foerster et al. give reasons for this state. They consider formalizing generalisation requirements are of uttermost importance to automate the process and to unambiguously understand the requirements of NMAs (Foerster et al., 2010). Other reasons are that current studies often focus on particular theme which makes it difficult to find a holistic solution and that generalisation is so subjective that it is hard to encapsulate it in objective forms.

The most important point to automate generalisation – specifying map requirements is tackled by Stoter, Smaalen et al. (2009). In their method they visually analysed maps and corresponding specifications. Knowledge drawn from this experience was then applied during a trial automatic generalisation. Depending on the results specifications were either refined or additional data was added to support decision-making mechanisms. This approach, also known as reverse engineering, assumes that maps generalised by cartographers according to specifications result in satisfying (but not always consistent) maps. Consequently, this research did not assess the quality of specifications for interactive generalisation. Another assumption is that automated processes should result in maps that are comparable to the currently available interactively generalised maps. (Stoter, Smaalen et al., 2009). This research will adopt the same principles. Stoter and Smaalen argue, however, that the current specifications although sufficient for an interactive generalisation are not enough for an automatic generalisation when deep knowledge of cartographer needs to fill the gap not covered by the written text. On one hand it is justifiable to attempt to fill these gaps by hard knowledge rules, on the other, some flexibility should remain to cater for peculiar situations needing alternative approach.

In another study Stoter, Burghardt et al. (2009) propose a methodology framework for evaluating automated map generalisation. Such a framework should balance between human evaluation and machine evaluation to meet the complexity of evaluation; e.g., machine evaluation can direct the user to those parts of the solution that are deemed to be unsatisfactory (Stoter, Burghardt et al., 2009). Such an approach had led them to adopt three methods of evaluating outputs:

- Qualitative evaluation by cartographic experts,
- Automated constraint-based evaluation, and
- Evaluation, which visually compared different outputs for one test case

Similar approach is to be used in this study, however the automated evaluation will use different means and techniques.

2.3 LITERATURE ABOUT NAVIGATION, SAFETY OF NAVIGATION AND THE ROLE OF ENCS

In 1914, two years after the Titanic disaster of 1912, in which 1,503 people lost their lives, maritime nations gathered in London adopted the International Convention for the Safety of Life at Sea, which came to be known as SOLAS convention. SOLAS was a compendium of the lessons learned from the Titanic tragedy. The first version was repeatedly superseded (in 1929, 1948, 1969) and the working version, although with many amendments and corrections comes from 1974. It is owned and maintained by the, founded in 1948, UN agency IMO – International Maritime Organisation. SOLAS Convention covered a wide range of measures designed to improve the safety of shipping. They included subdivision and stability; machinery and electrical installations; fire protection, detection and extinction; life-saving appliances; radiotelegraphy and radiotelephony; safety of navigation; carriage of grain; carriage of dangerous goods; and nuclear ships (IMO, 2009[11]). The most important to charting is Chapter V – Safety of Navigation. This chapter, defines, among others, the minimum requirements for carrying nautical publications on board of vessels. It enforces that vessels conduct navigation only by means of the officially accepted, certified publications of National Hydrographic Offices.

With the era of computerization works began to create a common transfer standard for hydrographic data. The first attempt DX-87 came to life in 1987. These works were disrupted, or rather modulated by an event at Bligh Reef in Prince William Sound, Alaska, where on the 23rd of March 1989 oil tanker Exxon Valdez ran aground spilling 260,000 to 750,000 barrels of crude oil[12], a tragedy to this day considered one of the most devastating human-caused environmental disasters in the World. Voices were risen that if the vessel had an "intelligent" electronic chart display system, the catastrophe could have been avoided. Captain of the vessel was found guilty of the event having been asleep at that time. Third mate, on watch at that time had limited aids to conduct safe navigation as the radar was broken and remained so due to high costs of repair. In result the vessel went of course passing first to the opposite lane of the traffic separation system, then leaving it to be crushed on the rocks of the reef. With chart display systems used today 4 alarms, warnings would have sounded: leaving the outbound lane, entering inbound

[11] http://www.imo.org/About/Documents/IMO%20What-it-is%20web%202009.pdf accessed on 10th of February 2012.

[12] http://en.wikipedia.org/wiki/Exxon_Valdez_oil_spill accessed on 10th of February 2012.

lane, exiting traffic separation scheme, safety depth warning[13]. This event changed the course of actions of the International Hydrographic Organisation and in May of 1992 IHO Transfer Standard for Digital Hydrographic Data was formally adopted. The standard introduced data model (figure 33) and data structure for system and medium independent exchange of hydrographic data. Appendix B.1 of the standard contains Product Specification for creation of Electronic Navigational Charts – ENCs (IHO, 2000).

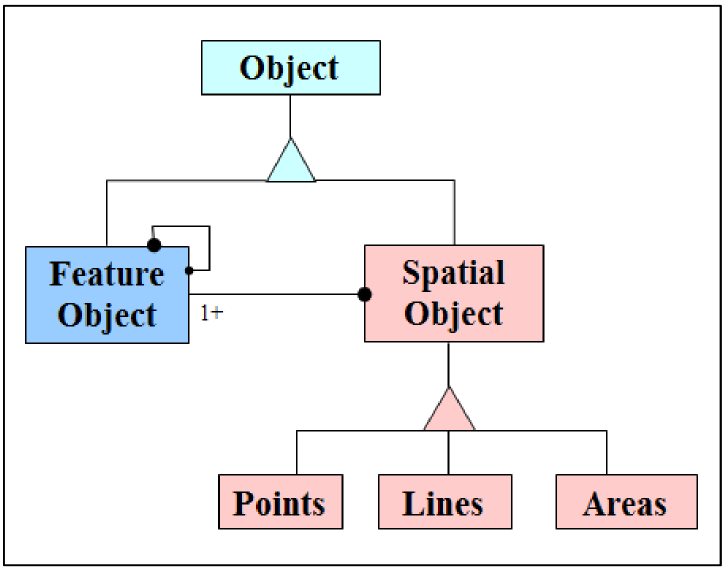

Figure 33 Highly simplified S-57 data model (Source: CARIS B.V.)

Soon after, in November 1996 IMO Resolution A.817(19) as amended by Resolution MSC.64(67) and by Resolution MSC.86(70) formally adopted ECDIS Performance standard, including ENC display. Use of 'Official' ENC data is permitted under the United Nations Law of the Sea, as long as the ENC datasets are updated and maintained using the S-57 specified mechanisms, and an adequate back-up is available (IALA, 2010). In July 2012 all vessels are to be equipped with ECDIS. This implies that heavy capacity building is taking place right now in various HOs to assure sufficient ENC coverage.

Electronic Chart Display and Information System (ECDIS) uses digital vector data in a way that replaces the traditional paper charts with a more versatile electronic product that can draw on a variety of positioning and data inputs, such as GNSS, DGNSS[14], AIS[15], radar, echo sounder, compass, an electronic chart, navigational publications, the chart amendments and tidal and meteorological information (IALA, 2010).

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[13] www.caris.com/exceed/HPD/resource/s57.pps accessed on 10th of February 2012.

[14] (Differential) Global Navigation Satellite System

[15] Automatic Identification System

An electronic chart is a real-time navigation system that integrates a variety of information that is displayed and interpreted by the mariner. It is an automated decision aid capable of continuously determining a vessel's position in relation to land, charted objects, aids-to-navigation, and unseen hazards.

S-57 Transfer Standard is enriched by the so-called satellite standards. These are:

- S-52 Specifications for Chart Content and Display Aspects of ECDIS

As S-57 does not include any presentation schemes, S-52 defines how data should be displayed to assure the maximum recognisability of the features

- S-58 Recommended ENC Validation Checks

Recommended validation checks are supposed to assure faultlessness of topology, population of mandatory – safety critical attributes and general consistency of the data.

- S-62 ENC Producer Codes

Lists the official agencies authorized to produce ENCs that in the light of SOLAS can be used as aids to navigation.

- S-63 IHO Data Protection Scheme

ENCs are protected from the unlicensed use and edits that could hamper its ability to be used in an official way.

- Maintenance Documents, Encoding Bulletins and FAQs

Provide clarifications, updates and corrections.

- S-65 ENC Production Guidance

Describes how production should be set-up in a producing agency.

Less relevant, but also associated with the abovementioned standards are these publications:

- S-64 IHO Test Data Sets for ECDIS
- S-66 Facts about Electronic Charts and Carriage Requirements

The standard has proven to be worthy but implementations soon made it clear that it is not flexible enough. Products such as inland ENCs, Additional Military Layers (AMLs), Marine Information Overlays (MIOs) did not fit in its safety-oriented structure. A new standard was, therefore created S-100 to cater for all the additional requirements (IHO, 2010). S-57 and S-100 are compatible and for a long time will coexist.

ENC cells have a single navigational purpose. There are 6 purposes defined for ENCs:

1) Overview - route planning; ocean crossing

2) General - navigating oceans, approaches to coasts; route planning

3) Coastal - navigating along coastline, inshore or offshore

4) Approach - navigating the approaches to ports/major channels; or through intricate or congested waters

5) Harbour - navigating within ports, harbours, rivers and canals; for anchorages

6) Berthing - detailed aid to berthing (IHO, 2002)

Within the usage data cannot overlap (the extents of the always rectangular cells can). Although usages do not have a defined scale and in relation to ENCs one should use the term "usage" rather than scale" there are recommended and adhered to scales used for data compilation (table 3). These scales match the scale ranges of the radar.

Table 3 Proposed scale ranges for ENC navigational purposes (IHO, 2004)

Navigational Purpose	Name	Scale Range	Available Compilation Scales	Matching Scale Ranges
1	Overview	<1:1499999	3000000 and smaller 1500000	200 NM 96 NM
2	General	1:350000 – 1:1499999	700000 350000	48 NM 24 NM
3	Coastal	1:90000 – 1:349999	180000 90000	12 NM 6 NM
4	Approach	1:22000 – 1:89999	45000 22000	3 NM 1.5 NM
5	Harbour	1:4000 – 1:21999	12000 8000 4000	0.75 NM 0.5 NM 0.25 NM
6	Berthing	> 1:4000	3999 and larger	< 0.25 NM

A stack of ENC exchange sets is loaded into an ECDIS to assist the passage. Depending on the passage segment and zooming ENC of the desired usage is displayed and can be queried.

Hippermann (2012) notices that what is missing in the hydrographic world is the paradigm shift from the way paper charts used to be/ are produced to the way ENCs should be approached. The main difference is that paper charts are discrete entities while multiple ENCs, displayed in ECDIS should form a seamless "chart". While production of individual ENCs is well established, consistent encoding of the same area over usages and even consistent encoding in the bordering areas between cells is still a challenge. Often data used for encoding ENC comes from different sources that have never been compared or set together. Only when the resulting products are displayed together, discrepancies can be observed. Hippermann advices that production environments should be adopted that distinguish between scale dependent and independent data, production specifications dedicated to ENC should be created and that validation checks should be developed and included in the ENC validation software that enable cross cell validation.

Some of the most common types of inconsistencies found in ENC cells are:

- Inconsistent spatial geometry, when encoded edges of the real world feature do not match on multiple ENCs.
- Inconsistent attribute encoding causes the same features to be displayed in a different way as attribute values are the main driver of the S-52 display engine.
- Encoding of SCAMIN either inconsistent or optional results in not seamless display in bordering areas.
- Inconsistent contour interval leads to a disjoint safety contour display.
- Edge Matching, for border areas basic cartographic principles result in topological errors.
- Use of M_CSCL – compilation scale of data when source data is composed of low and high density vertex data (e.g. a paper chart with an inset) leads to inefficient ECDIS displays. Such data should be encoded separately at the different usage.
- Holes in data coverage due to ineffective charting scheme planning.
- Gaps and overlaps although not allowed can occur in neighbouring cells produced by different countries. (Hippermann, 2012)

To this issues Hippermann has some solutions that could be used as constraints in the automatic generalisation specifications. Automatic generalisation would pair with the ideas of Hippermann to allow Hydrographic Offices take the lead in the technological achievements of the modern charting.

It is difficult not to see the potential that automatic generalisation could bring to ENC production. Hydrographic Offices are aware of the technological advances and the profits their colleagues on the land side benefit from. Hydrography, however, is not as popular as topography hence powers and resources are also limited. Main focus of hydrography is to improve precision, efficiencies and accuracy of bathymetric measurements, whereas marine cartography is treated with neglect as being just a step sister of traditional cartography. This is no longer the case and solutions applicable to “traditional” cartography often fail to be of any use for the hydrographic offices. This combination of facts leaves a gap for an interesting research that has potential to make a significant change to the way nautical charts are produced nowadays. The research on generalisation of Electronic Navigational Charts aims to connect two technological novelties that so far have not been truly compatible. The study will explore how automatic generalisation could be used to speed up the production of advanced, vector products for navigation, namely ENCs.

3 DESCRIPTION OF THE ANALYSIS SCHEME

In this chapter first general processes are described, such as pre-processing, selecting data and exporting it. Those are called general, because they operate on the entire dataset. A graph illustrating those processes is presented below (figure 34). Once the data is divided into groups analysis is performed on the selected groups of objects individually. A scheme of this analysis is referred to in the Object class specific section (figure 35).

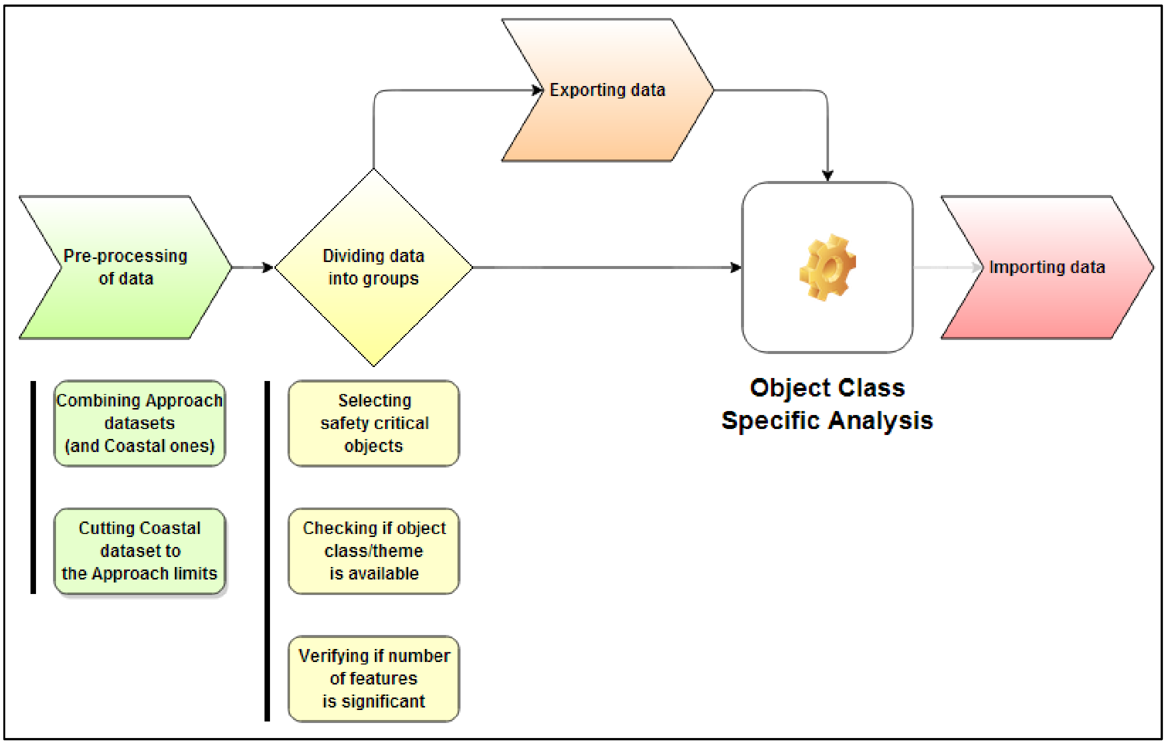

Figure 34 General analysis scheme graph

3.1 PRE-PROCESSING OF DATA

In all the cases the datasets available at the Approach scale covered a smaller area than the destination Coastal dataset. It would be impossible to generalise the entire Coastal ENC with the datasets provided. In all the cases the data covering the entire extent of the Coastal ENC(s) was not available at all in the published Approach ENC format. It is unknown whether the Hydrographic Offices are in possession of the necessary data in 5-57 format, or other. It is impossible to compare datasets of different extent. This would impose errors in the actual feature count and richness of data. For this reason, the Coastal and Approach charts had to be modified.

- Combining Approach datasets

Approach cells are considered isolated entities. This methodology is not ideal for computer rendered images that can be almost endlessly panned and zoomed, but was dictated by the limitations of the producing agencies compiling, in most cases, their ENCs from the paper chart equivalents (refer to Appendix 3-6 Questionnaires). However, to automatically generalise ENCs from the better scale ones, one need to have a seamless coverage.

When more than one Approach dataset is provided, the first step is to combine the ENCs into one set. This is done in HPD/S-57 Composer by ***Select***ing – ***all***[16] the objects from the Approach dataset and ***Edit – Copy***ing it ***– To Scratch Layer***[17]. The same is then done with the other Approach datasets.

Once all the Approach data is on one, editable layer (ENCs are read-only) matching objects spanning over multiple charts (land, depth areas, cables, etc.) need to be connected back into entities. This is done by ***Select by Feature Type– Area*** objects and using the function ***Edit – Areas – Merge Matching***. Analogically, lines need to be selected and merged with the function ***Edit – Lines – Merge Matching***.

Occasionally, it is not possible to merge features with the abovementioned function due to their different attribution, for example on chart 'A' a built-up area is attributed as "city" (a major town inhabited by a large permanent community with all essential services[18]) and on chart 'B' as a "urban area" (an area predominantly occupied by man-made structures used for residential, commercial, and industrial purposes[18]). This might have been due to the fact that charts are compiled by humans and carry the influence of their interpretation where specifications do not suffice. It may also be the case that data on the boundaries of the neighbouring cells does not match geometrically hence the software does not recognise the feature as an entity. In those cases manual edits need to be performed to connect objects.

Where more than one Coastal dataset was provided, the same workflow applies.

- Cutting Coastal dataset to the Approach data limits

The next step is to cut the Coastal datasets that are used as reference data to the limits actually possible to achieve with the automatic generalisation. To achieve this M_COVR, CATCOV:1 of the (merged) Approach dataset is copied ***To Scratch Layer***. The same is done for all Geo objects on the Coastal chart. An area object needs to be created on the Scratch Layer. This is done by selecting M_COVR object and using ***Create – Copy Feature – Class*** tool. An area needs to be created that encompasses the entire Coastal dataset. Two M_COVRs are selected, with the original one superselected in the selection window. ***Edit – Features – Cut*** cuts the original M_COVR size hole in the new object. This object can be superselected while all objects are selected and used to ***Edit – Features – Cut and Remove*** all objects that are inside or cross the

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[16] All relations to commends in the software are marked with ***bold and italic***.

[17] Scratch Layer - is a "scratch pad" where one can digitize new features or edit existing features before importing them into the active file. One can open more than one Scratch Layer. The Scratch Layer is only active while the application is open. (S-57 Composer Help)

[18] S-57 ENC Object Catalogue

superselected area. At the end the extra M_COVR layer can be also deleted and the remaining objects ***File – Export***ed ***– To HOB***.

3.2 DIVIDING DATA INTO GROUPS

A decision was made to focus only on certain objects. Those that constitute the majority of the chart and those that can be considered relevant (IMO resolution display base objects) to the safety of navigation are selected. If this research is considered successful, this could be the beginning of a bigger project to define criteria for all ENC usages and all objects.

Once the data is ready for analysis a decision has to be made – which object shall be analysed. Three criteria were taken into account when selecting objects to analyse:

- Relevance of an object class to the safety of navigation based on IMO (1995)
- Amount of features of an object class on the acquired datasets
- Presence/ Absence of features of an objects class on the acquired datasets.

It happened that an important object class was absent on all/most datasets, hence could not be analysed. In other cases object classes that constitute the majority of a chart and those that can be considered relevant to the safety of navigation are selected. To verify whether an object class is present in the dataset two methods can be used: either a ***Layer*** is created based on the ***Unique Feature Acronym*** (this creates a layer for each object class that is present in the selected dataset) or when a specific object class is sought – ***Select by Feature Acronym*** (this select all objects of an object class or informs that there are none). When all objects of a certain class are selected, one can verify the feature count.

3.3 EXPORTING DATA AND IMPORTING DATA BACK

For some objects it was possible to perform the analysis on the acquired data. This was the case for Aids to Navigation for example. In other cases, or when only part of the analysis could be done in S-57 format, data needed to be exported. This was done by ***Select All*** command executed while on one of the unique Feature Acronym layers or directly by ***Select by Feature Acronym***. When all objects of the desired class are selected ***File – Export – To SHP*** is executed. The user is prompted to give the exported files a name. The name typed in is only the first part of the final name. CARIS adds "_<feature acronym>_<feature geometry type (point, line, area)>" to the three created (.dbf, .shp, .shx) files. If more than one geometry types are included in the selection, data is divided into separate files.

Importing the data back into S_57 format is more complex. The user has to create parser/ importing tool for each feature class and geometry type. ***File – New Scratch Layer*** is needed to enable ***Tools – Object Import Utility***. OIU allows a user to ***Create***, ***Modify*** or choose an existing script and ***Execute*** it. A script is created by Step 1: choosing an external file type (text file, shape file or ODBC) and pointing to it and Step2: mapping existing values to available S-57 feature classes and attributes. When the script is executed a new OIU layer is added to the display.

3.4 OBJECT CLASS SPECIFIC PROCESSING

The following graph (figure 35) shows what happens to a selected object class after pre-processing. The scheme is generic. The actual actions taken are described in a latter chapter.

After the selection of an object class, materials are browsed in the search of any specifications regarding generalisation of such objects. If specifications are found they are selected. There was never a case that specifications would be contradictory.Specifications are collated. If the specifications are sufficient then translation takes place to formalise the syntax. If there are no hard values or there are no specifications, external resources are checked. With safety of navigation objective in mind specifications are completed with hard rules. A possible side output of this are standarisation requirements.

First S-57 software (CARIS) is checked whether or not the specifications and required generalisation can be executed. If so they are. If not or only partially, data is exported into shape format and capabilities of ArcGIS are tested to execute specifications. Successful attempts are imported back into S-57 format. Unsuccessful attempts, if the specifications are strong are executed manually and a description of possible tools replacing the interactive process are described. Unsuccessful attempts without strong specifications or not enough data to test are described.

Where received specifications documents or suplement documentation do not dictate specific parameters there is always sensitivity analysis performed. When hard values find justification in external documentation, results are accepted “as is”, unless they greatly differ from the original dataset. Where hard values are subjective or based on the provided datasets, the sensitivity analysis aids to find settings best fitting the results to the original chart. Whenever possible – standard parameters are used for all charts.

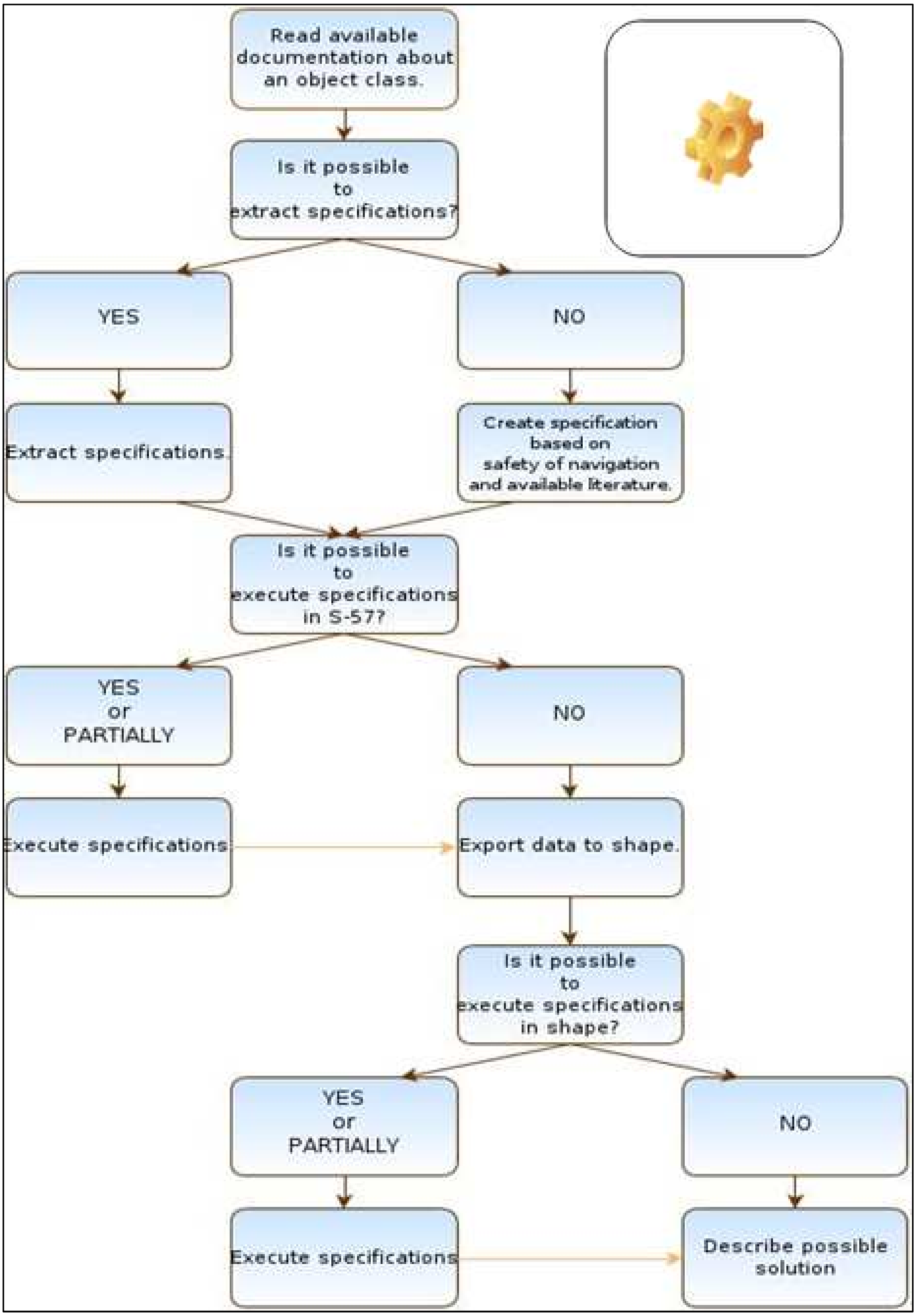

Figure 35 Class/Theme analysis scheme graph

4 DIFFERENCES BETWEEN COASTAL AND APPROACH DATASET OF THE SAME AREA

In this chapter datasets are described in terms of their content. Similarities and differences are found between dataset pairs (coastal-approach).

4.1.1 BRAZILIAN DATASETS:

Coastal

BR323000 Do Cabo São Tomé a Ilhas Maricás

- Compilation scale: 1:180,000
- Features count: 1155

The chart, given its small scale depicts a big area. The most prominent group of features on the chart is the located in the upper-right corner offshore platforms area with multiple underwater cables. This area is actually excluded from processing, as it was not covered by the approach dataset. Only the left part to about 1/3 of charts width is used. It is clear that the area is well developed and populated. The Southeast is the richest part of Brazil and has also the highest population. There is not much relief depicted on the chart, although there seem to be some prominent slopes but the coast is carved by the bays of Guanabara, Sepetiba and Ilha Grande. Deep waters of the Atlantic Ocean washing the shore make the number of wrecks and underwater rocks minimal and present mainly very close to the shore. The depth ranges depicted are:

- 0-5m
- 5-10m
- 10-20m
- 20-30m
- 30-50m
- 50-100m
- 100-500m in 100m intervals
- 1000-3000m in 1000m intervals

BR323100 Do Rio de Janeiro a São Sebastião

- Compilation scale: 1:180,000
- Features count: 1418

The coast is very interesting with multiple bays, islands and rocks. There are many obstruction areas and wrecks present. The shallow areas go farther offshore and the relief starts to be of importance. The area of Rio de Janeiro itself is depicted as one big build-up area, with Baía de Guanabara showing only minimal depiction (there is a caution area informing of that and the entire basin is covered by 0-5m depth area). There are some small islands near the coast. One can also see increased number of Aids to Navigation and some obstruction areas. Cables lay densely on the seabed.

Approach

BR401501 Baía de Guanabara – Parte Norte

- Compilation scale: 1:45,000
- Features count: 2565

There are three things that draw viewer's attention. Firstly, the previously (on nav. purpose 3 chart) minimally depicted bay is now accurately presented with depths and contours. Secondly the agglomeration of Rio de Janeiro is no longer shown as a build-up area but as a network of roads and districts. Finally, the coastline is far more detailed and there are more Aids to Navigation shown. This is natural, as the scale is four times better.

It is worth noticing that most of the chart's area is also covered by the Harbour usage charts.

BR401506 Proximidades da Baía de Guanabara

- Compilation scale: 1:45,000
- Features count: 1861

It's main characteristics are the densely populated coastline and the seabed covered with underwater cables. Similar to the first approach chart, there is more detail in bathymetry and Aids To Navigation. The lagoons are presented as Depth areas with a caution object saying that they only have minimal depiction.

BR401508 Do Cabo Frio a Ponta Negra

- Compilation scale: 1:45,000
- Features count: 1139

Densely populated coastal zone is presented by means of building single objects, but there is no central agglomeration distinguished. The lagoons are presented in the similar matter to the previous chart. The water areas do not show too many features, only a few wrecks and underwater rocks in the upper right corner. This part of the chart has a coverage in Harbour usage ENC for the cape – Cabo Frio. This can be easily perceived on this and on the previous charts, as the areas having its equivalents in better scale charts are actually richer populated than the ones that do not.

4.1.2 FRENCH DATASETS:

Coastal

FR332010 La Réunion

- o Compilation scale: 1:174,877
- o Features count: 639

Fishing importance is confirmed by numerous special purpose buoys (BOYSPP) indicating that "Many fish aggregating devices are present around Ile de la Réunion. They are fitted with a string of orange, red or yellow coloured bowls and a radar reflector. The circular turning area radius is one mile large." There is also one marine farm (MARCUL) depicted.

As in the case of many volcanic islands depths are not critical until very close to shore. Main depth ranges are:

- 0-10m
- 10-20m
- 20-50m
- 50-100m
- 100-200m
- 200-500m etc
- Up to 3500-4000m

Consequently there are not many wreck and obstruction objects. South side of the island contains some unsurveyed areas, but it is the north side that has higher importance to navigation. The south side is not covered by the provided approach chart, therefore has been excluded from processing.

Saint-Denis, Saint-Paul, Port Réunion (Pointe des Galets) and Saint-Gilles les Bains are depicted as build-up areas (BUAARE). There are facilities and caution objects, like anchorages (ACHARE) and submarine cables (CBLSUB) mapped in vicinity.

Approach

FR432010 La Réunion - Northern part

- o Compilation scale: 1:60,000
- o Features count: 778

There are three harbour cells available within the extents of the cell – Saint Gilles Les Bains and Port Réunion West and East side.

Both harbours are presented as BUAAREs. The chart is richer in detail, showing more complete land relief and seabed shape with depth contours. One can see 0-5m and 5-10m contours present. Intertidal areas are marked as such. Rivers, depicted as lines on navigational purpose 3 chart, hence on top of LNDARE are now shown as areas of unsurveyed water (UNSARE) – Group 1 objects. There is also more detail in the deltas.

There are also more landmarks (LNDMRK) on land in the form of towers, masts, churches. Landmarks with CONVIS attribute populated as conspicuous visually are also retained on the Coastal cell.

In terms of Aids to Navigation, more detail can be again observed on land, especially in the harbour areas. On water exactly the same AtoNs are visible.

Aids in the approach navigation include also RECTRC (Recommended tracks), CBLARE (Cable areas) surrounding earlier mentioned submerged cables and various harbour facilities. Better scale allows to depict underwater rocks dangerous in the shallow areas that may be dangerous to a inshore navigation.

4.1.3 DUTCH DATASETS:

Coastal

<u>NL301630 North Hinder / Eurogeul / Westerschelde</u>

- o Compilation scale: 1:90,000
- o Features count: 2594

The chart is characterised with an impressive amount of objects, mainly on the water. It is the only chart that uses OBSRN points and there are close to200 of them. The same can be said about the Aids to Navigation. It is also a very important area for oil production. One can see first platforms situated on the Dutch Continental Shelf. Typically for an industrialised area like this, there are many cables and pipelines laid on the seabed. At a compilation scale, all this looks quite clearly, but when zoomed out, the picture is quite illegible. Surprisingly, no object has SCAMIN assigned.

Waters are quite shallow, with maximum depths around 40m. The depth ranges are:

- 0 – 2m
- 2 – 5m
- 5 – 10m
- 10 – 20m

- 20 – 30m
- 30 – 40m

Approach

NL400110 Westkapelle to Stellendam

- Compilation scale: 1:45,000
- Features count: 2046

There is significantly more Aids to Navigation, soundings and landmarks depicted than on the Coastal chart. The main changes are visible near the coast or on land. The farther from the land mass the less differences. The main difference in the open waters is the generalisation of bathymetry and different levels of detail in contours and depth areas.

NL400122 Approaches to Europoort

- Compilation scale: 1:45,000
- Features count: 2016

Despite having better scale there are not that many differences in the approach area itself. One can see small craft recommended routes and infrastructure on land being added, but the geometrical level of detail remains the same.

On the other hand one can clearly appreciate the differences in bathymetry generalisation, where seabed ripples are clearly depicted on the approach chart and generalised into areas of shallower depth on the Coastal chart.

4.1.4 NEW ZEALAND'S DATASETS:

Coastal

NZ305322 North Island – East Coast – Approaches to Auckland - West

- Compilation scale: 1:90,000
- Features count: 3823

It is visible how densely populated this area is (especially with comparison to the rest of New Zealand). The main characteristics of the chart are an interesting coastline and a vast amount of islands. One should not forget that New Zealand lies between two continental plates and is subject to high volcanic activity. This is also the reason for the presence of many underwater rocks.

The depths are not too big with maximum around 50m. The shallow areas not beyond 20m go far of land. The standard depth ranges are:

- 0 – 2m
- 2 – 5m
- 5 – 10m
- 10 – 20m
- 20 – 30m
- 30 – 50m

Chart NZ5322 (the paper chart equivalent of the ENC) is considered one of the most often used charts in New Zealand.

Approach

NZ405321 North Island - East Coast - Mahurangi Harbour to Rangitoto Island

- Compilation scale: 1:22,000
- Features count: 2289

The area does not differ much from the Coastal chart. The main difference is in the depiction of certain build-up areas being represented as point objects on the Coastal chart and as areas on the Approach one. It may be an example of simplification of representation as the scale gets smaller or a result of using different encoding policies for charts produced over different periods of time.

In this case, both charts have similar edition dates.

NZ405324 North Island - East Coast - Mahurangi Harbour to Rangitoto Island

- Compilation scale: 1:22,000
- Features count: 4112

Here significant differences can be seen. Surprisingly build-up areas that on the Coastal chart are depicted as area type objects, here are shown as points. It is unusual for the simplification to increase with the scale, hence it can be assumed that it is due to differences in production specifications.

The chart comes from 2008 hence differs greatly from the two remaining charts (edition in 2011).

5 SPECIFICATIONS, RULES AND PROPOSED GENERALISATION METHODS

Specifications… chapter describes how the creation of Coastal Charts by means of automatic generalisation of Approach datasets could be achieved. Although it inclines towards the algorithms that have actually been used, its main objective is to extract objective specifications about how such charts should be produced/ should look like. In certain cases, it was possible to create specifications, but not possible to execute it, as there were no tools currently available. In some cases multiple approaches were considered. Each Class/Theme specific contains a comparison of existing and created specifications, standardisation requirements, conditions. Next explanation of those is included and an example generalisation methods (with alternatives) are proposed.

5.1 ATONS & LNDMRK

According to the glossary of terms in the United States Coast Guard Light list Aids to Navigation (AtoNs) are devices specifically intended to assist navigators in determining their position or safe course, or to warn them of dangers or obstructions to navigation (Wikipedia).

Lighted offshore platform, installation buoy or other although fall often under the same principles as AtoNs are not considered here. LNDMRKs, are included here, since very often they serve a similar purpose as AtoNs. The second reason is that there are cases where lighthouses, therefore “devices specifically intended to assist navigators in determining their position” are encoded as landmarks.

Current Specification/ Generalisation Rules

- Full depiction wherever possible (no scale given).
- Generalise to prevent overcrowding.
- AtoNs may be removed in internal basins (no scale given).
- AtoNs may be removed in coastal zones (no scale or distance given).
- Select from those that are selected on better scale charts.
- Prominence and ease of positive identification are the first requisites.

Created Specification/ Generalisation Rules

- Select all beacons on land.
- Select all Landmarks that are lit.
- Select all Landmarks that are conspicuous.
- Select all Cardinal and Isolated Danger AtoNs.
- Select all AtoNs that are ≥2Nm from the shore.
- Select all lit AtoNs not surrounded by land.
- De-clutter selection based on

hierarchy (see Proposed Generalisation Method Step 2).

Standardisation Requirements

- It should be explicit and clear to the hydrographic offices in which cases to encode landmarks (not specifically intended) and in which beacons (specifically intended for navigation). There are cases where e.g. a lighthouse is encoded either as BCNSPP, BCNSHP: 3 (beacon tower) or as LNDMRK, CATLMK: 17 (tower). The later example is considered incorrect, as lighthouses can be considered as specifically intended for navigation. In IALA's Navguide (IALA, 2010) lighthouses fall under the category "Other aids".
- AtoNs are populated with all the information that is available, even if this information doubles content already available in other publications.
- AtoNs are not associated with scales, they are stored on a scale-less layer from which a selection is chosen for a produced chart.
- Master-Slave relations are assigned to all aids that share the same position.
- Aids to navigation on water are not charted in the closed basins (harbours), rivers, canals where safe navigation requires the use of better scale chart (hence, better scale charts exist).
- Outside of the closed basins, rivers and canals, unlit AtoNs are not shown within 2Nm from the shore.
- Outside of the areas mentioned above full depiction of AtoNs is required unless this causes overcrowding.
- Isolated Danger, Cardinal and New Wreck AtoNs are shown at all times regardless of their location.
- Only landmarks that are conspicuous or having a light should be present.

Conditions

- Data is stored on a scale-less layer and populated with required attributes.
- Optionally: Data is already processed for Approach usage and AtoNs used on that usage are designated to be used for further processing.

Proposed Generalisation Method

- Scale independent storage.
- Location and attribute based selection.
- De-cluttering algorithm.

Alternative Generalisation Methods

- Production scale storage with ladder approach (data duplication).
- Selection based on CONVIS attribute (not always available).
- Selection based on VALNMR – value of nominal range (not always available).

5.1.1 EXPLANATION

For 0-dimensional objects the most efficient way to manage them is to store them on a scale-independent layer, as in the vector environment they are not affected by geometrical generalisation. Their representations can be assigned to all required production – scale dependant layers, where management and updating on the base layer would be reflected automatically. Most of the Hydrographic Offices that participated in the research have such a solution employed.

It is required that the scale-less layer, in case of AtoNs is populated with the following objects:

Masters: BCNCAR, BCNISD, BCNLAT, BCNSAW, BCNSPP, BOYCAR, BOYISD, BOYLAT, BOYSAW, BOYSPP, LNDMRK

Slaves: FOGSIG, LIGHTS, LITVES, RADRFL, RTPBCN, TOPMAR

Often on paper charts information about AtoNs changes with the changing scale of the chart. The necessity to cover greater area as the chart's scale decreases and hence concentration of objects lying in vicinity of each other forces cartographers to omit AtoNs details. Those details are presented as a cartographic text next to a depiction of an aid, therefore when space does not permit it, they have to be shortened or removed.

In case of Electronic Navigational Charts this constraint is not valid anymore as a mariner has the choice of turning the text off. All information about an aid may be stored in its attributes and optionally additional facts can be stored in an external text file that gets exported with an ENC and that is referenced in the TXTDSC attribute field of an aid. S-4 advises full depiction of aids to navigation, wherever possible. The only generalisation advised is to prevent overcrowding.

Hydrographic Offices shape their specifications around those general rules in various ways. Following another example of S-4, the hydrographic offices remove AtoNs from internal basins where it is not advised to use Coastal chart for navigation. Some of them remove AtoNs (especially unlit ones) in the coastal zone, a number of nautical miles from the main land mass's shore, where it is considered that the vessels should not be. Other leave only the most important AtoNs – those that have a range of light bigger than a certain limit. Unfortunately, some hydrographic offices do not populate the VALNMR attribute to be able to use this restriction.

S-4 mentions also that, as chart scale decreases the number of AtoNs should be reduced, but those should be the same AtoNs as chosen earlier. This excludes a situation where there is an AtoN on a less detailed scale chart, that is not present on the higher detailed scale one.

This can be achieved in two ways- either using a star approach (all representations from one source) and make sure that all algorithms make the same AtoNs be chosen over various scale, or with a ladder approach (each scale's depiction is sourced from the better scale depiction) and wherever possible choose better scale depictions as an input to the algorithm. For this project, only Approach charts were available, hence the second option was the only possibility.

B-340 Landmarks, conspicuous objects:

A landmark is in this context, any object (natural or artificial) on land which is prominent from seaward and can be used in determining a direction or position. The term excludes objects expressly erected for navigational purposes: these are sometimes referred to as seamarks or daymarks. Prominence is the first requisite for a landmark, but ease of positive identification is almost as important.(...) Prominence varies with the location of the observer and with lighting and atmospheric conditions. A conspicuous object should meet the following conditions: it should be plainly visible over a large area of the sea (...) and it should be easily identifiable. The cartographer has the responsibility of making conspicuous objects stand out from other topographic detail and charting an adequate symbol or legend for positive identification by the navigator.

It was not possible to filter out many rules that were common for the Hydrographic Offices, but there were few that had overlapped.

5.1.2 PROPOSED GENERALISATION METHOD

Step 1:

Input dataset: Approach AtoNs, Coastal usage LNDARE

IF Master {outside} LNDARE

IF {Distance to LNDARE {max area}} ≤ 2Nm

IF Master = BCNCAR, BCNISD, BOYCAR, BOYISD SELECT Master AND Slaves

IF Master {geometry check (not surrounded from at least 3 sides by one LNDARE object)}

IF Slave = LIGHTS SELECT Master AND Slaves

IF {Distance to LNDARE {max area}} > 2Nm SELECT Master AND Slaves

IF Master {inside} LNDARE

IF Master = BCN* SELECT Master AND Slaves

IF Master = LNDMRK

IF Slave = LIGHTS SELECT Master AND Slaves

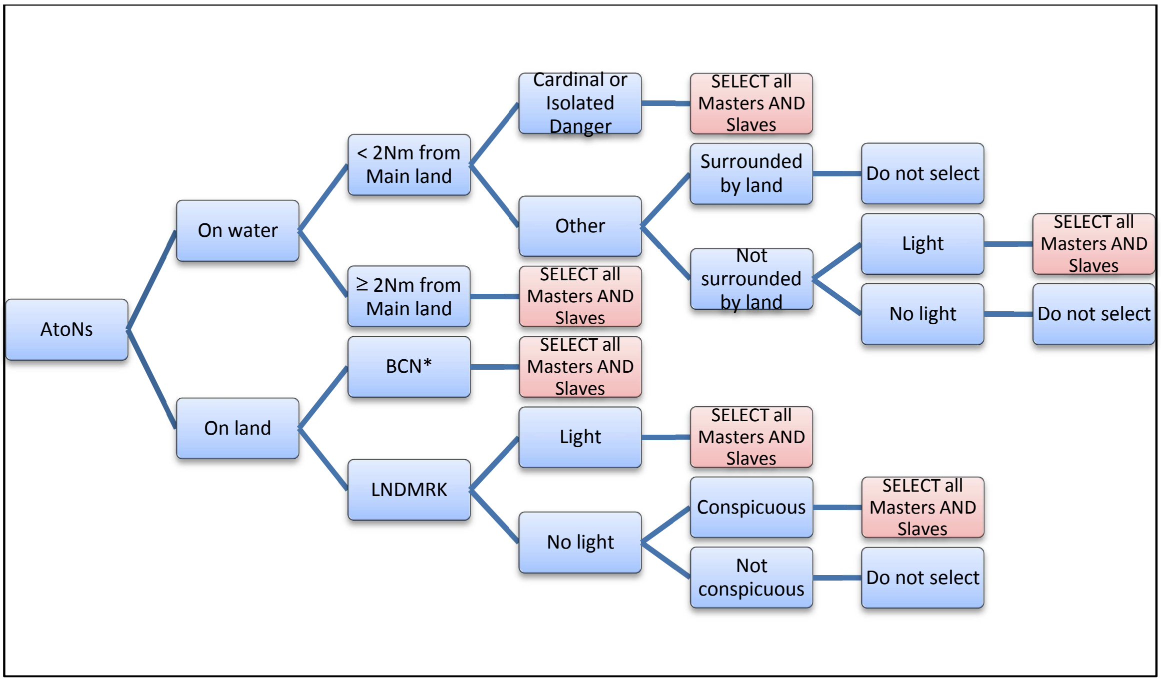

Figure 36 Graph illustrating step 1 of AtoNs generalisation

Step 2:

Input dataset: Selected Masters AND Slaves

IF Buffer{point$_x$(radius 3mm)} {overlaps} Buffer{point$_y$(radius 3mm)} SELECT

a) Based on the presence of RADAR transponder or retroreflector.

b) If they both/all have it, based on structure:

1) Beacons, Landmarks

2) Buoys

c) If the same, based on purpose:

   1) New danger, Cardinal, Isolated danger

   2) Special, Lateral

   3) Safe Water

d) If the same, based on the presence of a LIGHTS:

   1) Light

   2) No light

e) If they both/all have light (if multiple lights per object, then based on the best light):

   1) Bigger range

   2) Bigger height

   3) Colour (based on light colour visibility range)

      a. White

      b. Red

      c. Orange

      d. Yellow

      e. Green

      f. Blue

      g. Violet

f) If still the same or there is no light, based on shape of the structure (CATLMK and BCNSHP):

   1) Towers, masts and other large structures

   2) Rocks, piles, posts etc

g) If still the same, based on a topmark:

   1) Topmark

   2) No topmark

h) If still the same, based colour of the structure (see above)

i) If still the same (consider if it is not a duplicate)

1) Both on water -> remove the one closer to the shore.

2) Both on land -> remove the one farther from the shore.

3) One land and one on water -> remove the one on land.

This method is efficient when there is scale independent source used for AtoNs. Some Hydrographic Offices have the opposite problem. They have AtoNs on scale based usages and would like to transfer them into a scale-less one. In this case a tool to automatically copy AtoNs to a scale-less layer, delete them from scale-based usages and assign representations could be created.

A definable buffer would then check if there are no duplicates on a scale-less layer. This could be based on the attribute value check. It is a good hydrographic practice for services managing AtoNs not to place AtoNs of similar characteristics close to each other to ease positive identification.

The tool would need to not only delete the identified duplicate, but also assign the best scale version to the duplicate's original usage.

5.2 WRECKS

Wrecks are considered one of the most important objects on nautical charts and are certainly those that distinguish them from topographic maps. Along with other dangers, such as rocks and obstructions they are one of the main reasons charts are needed on board of vessels.

It is not important for this particular research into generalisation of ENCs, but it should be mentioned that wrecks are also interesting for recreational users, like scuba-divers. Proper management of wrecks would therefore allow producing agencies to quickly create new products dedicated to a different segment of clients.

Current Specification/ Generalisation Rules	Created Specification/ Generalisation Rules
• Full details of all dangers to navigation are to be charted except in those areas for which the chart is clearly inappropriate for navigation (no scale given). • Wrecks shall be shown to whatever depth they are considered to be of interest, but not generally in water deeper than 2000m. • On medium scale charts, certain	• Select Wrecks that are ≥200m from the shore and lie not deeper than 1200m.

wrecks may be omitted from inshore areas.

Standardisation Requirements

- WRECKS are populated with all the information there is available, even if this information doubles content already available in other publications.
- WRECKS are not associated with scales, they are stored on a scale-less layer from which a selection is chosen for a produced chart.
- Wrecks closer than a certain, standardised distance from the shore are not charted.
- Wrecks deeper than a certain, standardised depth are not selected.
- Wrecks with unknown depth are selected.

Conditions

- Data is stored on a scale-less layer and populated with required attributes.

Proposed Generalisation Method

- Scale independent storage.
- Selection based on location and attribute values.

Alternative Generalisation Methods

- Production scale storage with ladder approach (data duplication).
- Selection based on CATWRK – category of wreck or VALSOU – value of sounding (not always available).
- Selection based on WATLEV – water level (no safety constrain).

5.2.1 EXPLANATION

S-4 in its introduction to dangers in general states that "full details of all dangers to navigation are to be charted except in those areas for which the chart is clearly inappropriate for navigation". The document does not define what the inappropriate distance is but is very specific about the full detail to be depicted. This makes creating the specification much simpler.

The distance was chosen empirically and is a subject of discussion. The decision was made based with safety of navigation in mind and visual inspection of provided datasets. The distance is set very close to the shore – 200m.

The abovementioned specification stresses on the maximum information depiction, such as clearance depths over a mere statement "dangerous" or "non-dangerous". It is the seaman's knowledge of the vessel's characteristics, such as draft to make a decision whether the object is to be avoided.

"Wrecks shall be shown to whatever depth they are considered to be of interest, but not generally in water deeper than 2000m" (S-4). The specification gives a huge safety margin. The deepest trawls go to around 400m and only occasionally to depths as great as 1200m. 1200m was used in the specification, but it could be considered as an open point in the discussion.

There may be cases where wrecks do not have a clearly defined depth clearance. S-4 recommends in such cases estimating safe clearance depth, but this is not always possible, or HOs do not take up the effort. For the safety of navigation, those wrecks should not be omitted.

5.2.2 PROPOSED GENERALISATION METHOD

Input dataset: Scale-less or Approach usage WRECKS (P,A) Approach usage LNDARE (A)

CREATE BUFFER {LNDARE; 200m}

SELECT WRECKS IF {outside buffer}

REMOVE WRECKS IF VALSOU > 1200m

5.3 UWTROC

Rocks can be shown in many ways on charts. Rocks or large boulders which are never covered by water are shown as islets and encoded as LNDARE point or area objects, depending on their size.

Large rock formations that cover and uncover may be shown as intertidal areas with seabed area encoded as rock. Smaller rocks that cover and uncover that are encoded as points and all other remaining rocks (awash, always underwater) are encoded as UWTROC.

For the last two types usually large rocky areas are encoded as seabed areas and only single pinnacles or groups of them are encoded as UWTROC. This object class can only be encoded as point objects.

Rocks do not necessarily need to be considered as obstructions, that is why they have a separate class. Their identification lays usually within raw bathymetric data processing and often it is a processor who decides whether an object should be depicted as a rock or whether it can be presented as a shallower depth area.

Current Specification/ Generalisation Rules	Created Specification/ Generalisation Rules
• Full details of all dangers to navigation are to be charted except in those areas for which the chart is clearly inappropriate for navigation (no scale given).	• Select all UWTROCs unless they are covered by obstruction areas. • Select all UWTROCs with EXPSOU:2.

Standardisation Requirements

- UWTROC are populated with all the information there is available.
- UWTROC are not associated with scales, they are stored on a scale-less layer from which a selection is chosen for a produced chart.

Conditions

- Coastal usage OBSTRN areas are available.

Proposed Generalisation Method

- Scale independent storage.
- Selection based on intersection and attribute values.

Alternative Generalisation Methods

- Production scale storage with ladder approach (data duplication).
- Selection based on VALSOU – value of sounding (not always available).
- Selection based on WATLEV – water level (no safety constrain).

5.3.1 EXPLANATION

Similarly to wrecks, S-4 allows only open water rocks to be mapped. It then focuses on the presentation of rocks depending on their environment. S-57 does not use attribute value awash/ covers and uncovers etc, but describes them with values of two attributes: WATLEV and QUASOU. Those two attributes do not directly state whether the rock is dangerous. No additional information was found in the specifications provided.

In place of other specifications it is considered that the EXPSOU attribute could well describe this characteristic. The exposition of sounding can be either deeper, within or shallower then the range of depth of the surrounding depth area. It is considered that as long as the rock is deeper or within the range of depths it may be omitted as long as there is an obstruction area covering its location. Outside of obstruction areas all rocks are selected, regardless of their attributes.

This does result in clusters of UWTROCs, particularly on one dataset. A further investigation could be made to transform clusters of one object class into another object class. This research did not use such an option.

Given the abovementioned constrains it is considered that generalisation assures maximum safety of navigation, by removing only certain objects within OBSTRN areas and maintaining all the others. This may affect the aesthetics of the chart.

5.3.2 PROPOSED GENERALISATION METHOD

Input dataset: Approach usage UWTROC (P), Coastal usage OBSTRN (A)

IF point {outside} area

SELECT point

IF point {inside} area

SELECT point IF EXPSOU = 2

5.4 LNDARE

The geometry of the land areas is tackled in the Coastline paragraph of the Topography section of S-4 (B-310). It states that coastline should be represented by the high water mark, or in case of non-tidal areas – the mean sea level (MSL).

The participating hydrographic offices do not use the coastline from the topographic datasets, unless, in some cases- the coast is steep and hence not affected by the tide difference. Instead, some extract the coastline from the most recent hydrographic surveys. However, most of them use the corresponding paper chart to digitize the coastline.

It is not clear from this research how the coastlines on the paper charts are created. In some cases, the documentation was not obtained, in others no documentation was available at all. Where available, it was checked that the coastline on paper charts overlapped with the coastline on the archive survey sheets. An assumption can be made that those coastlines are extracted from survey sheets. In other cases- there is no information about the source of the paper charts' coastline. It is assumed that the base dataset is correctly referenced.

When it comes to lower scale charts S-4 is less rigorous and writes (B-310.2) "the coastline shall be generalised (smoothed) as necessary on smaller scale charts but it's essential characteristics shall be preserved.". There is no further constraint to this in the specifications received.

S-57 general constrain for the line features says that lines must not be encoded with a point density greater than 0.3mm at compilation scale. This constraint is used to enable faster drawing on the ECDIS screen and to reduce dataset size. This restriction is not good enough for the cartographic reasons, since it is considered that a simple pen width on paper charts is 0.5mm.

Current Specification/ Generalisation Rules	**Created Specification/ Generalisation Rules**
• The coastline shall be generalised (smoothed) as necessary on smaller scale (no scale given) charts but it's essential characteristics shall be preserved. • An islet too small to be shown in its true (scale) size shall not be reduced to a width less than the width of the coastline symbol (to avoid confusion with pinhole imperfections in chart plates).	• Approach cell's LNDARE points are considered insignificant and are rejected. • Land masses closer than 50m to each other are aggregated into one object (details in explanation). • Land areas are smoothed with the level of smoothing = 242m (details in explanation). • Small islands (1mm on chart scale) are collapsed into points.

Standardisation Requirements

- The coastline of the charted land masses is referenced to the high water mark, or in case of non-tidal areas – the mean sea level.
- There are no land masses closer than 50m from each other.
- Islands that would appear smaller than 1mm are collapsed into points.

Conditions

- Data on the Approach usage covers full extent of the Coastal cell.

Proposed Generalisation Method

- Algorithm with generalisation operators – Bend Analysis.

Alternative Generalisation Methods

- Algorithm with Douglas – Peucker simplification (not aesthetically pleasant, also does not maintain the safety of navigation constrain).

5.4.1 EXPLANATION

The key to formulate this specification starts with the understanding of the ENC use. Coastal navigation starts "in waters contiguous to major land masses or island groups where transoceanic routes tend to converge towards destination areas and where inter-port traffic exists in patterns that are essentially parallel to coastlines" (IALA, 2010). In these circumstances the main purpose of the Coastal ENC is to conduct radar navigation.

There are very specific values, set by IMO, that determine the resolution of a RADAR that can be used for marine navigation (figure 37). There are two types of resolution:

- Bearing resolution is the ability of the radar to display as separate pips the echoes received from two targets which are at the same range and close together. IMO states that bearing resolution should be better than 2.5°.
- Range resolution is the ability to display as separate pips the echoes received from two targets which are on the same bearing and close to each other. IMO states that range resolution should be better than 50m. (Furuno, 2002)[19]

In the light of those constrains the general characteristic of S-4 can be replaced in the following way:

The edge of the LNDARE should be simplified to a level of detail:

$$\sin 2.5° \times \{Radar\ range\ in\ meters\} < \{Level\ of\ detail\ in\ meters\}$$

[19] Those values are dictated for up to 2Nm RADAR range

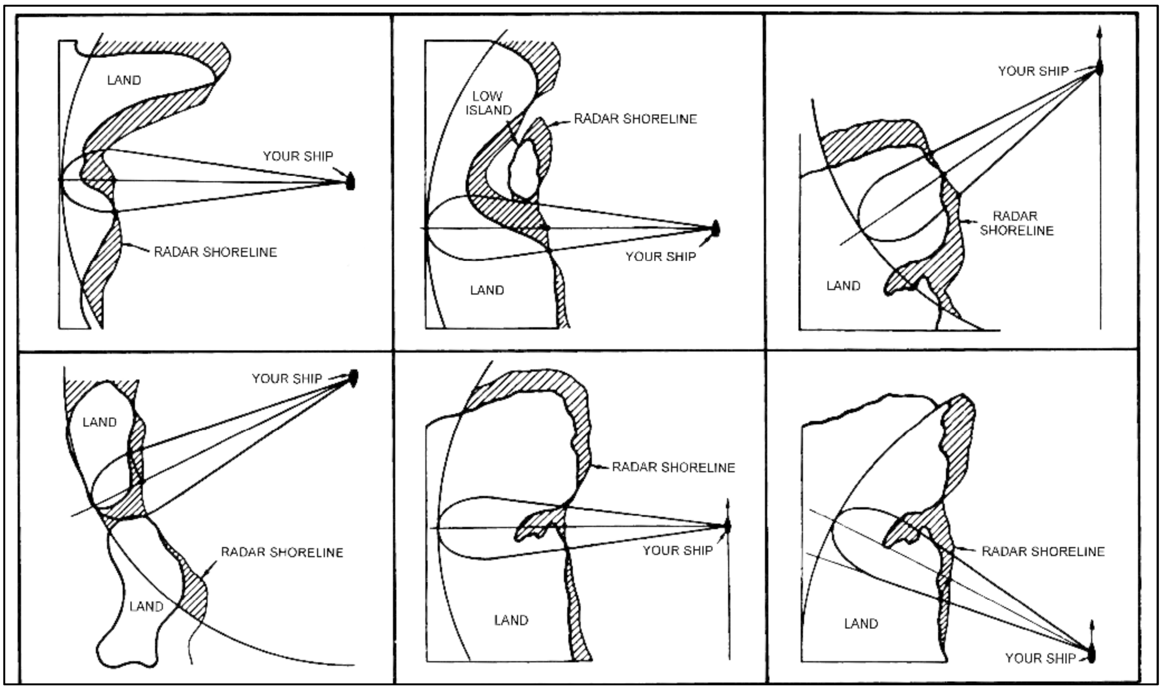

Figure 37 Effects of ship's position, beam width, and pulse length on radar shoreline (Source: http://msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/APN/Chapt-13.pdf)

To obtain the level of detail, one needs to answer what the minimum RADAR range used in Coastal navigation is.

According to the IHO (2004) table of ranges corresponding to chart scales Approach cell should be read into ECDIS display at a 3Nm radar range hence the level of detail calculated for 3NM is 242 m.

One should also consider emergency use of charts. This can take place when a vessel not intending to come closer to land and hence not carrying better scale charts needs to approach the coast due to bad weather conditions or malfunction.

IMO (2002) sets the minimum standards for ship manoeuvrability. A turning diameter of a vessel must be not bigger than five times its length. If we assume that vessels engaged in at most Coastal navigation (not operating close to the shore most of the time) rarely measure less than 50m, then we can consider that they would not look for shelter bays of less than 250m and hence the level of detail = 242 m can still be accepted.

There are different ways to use this value. At the present time there are two simplifying algorithms that are available in the software that was tested:

- Point filtering – Douglas-Peucker tolerance algorithm
- Bend analysis – Wang, 1996

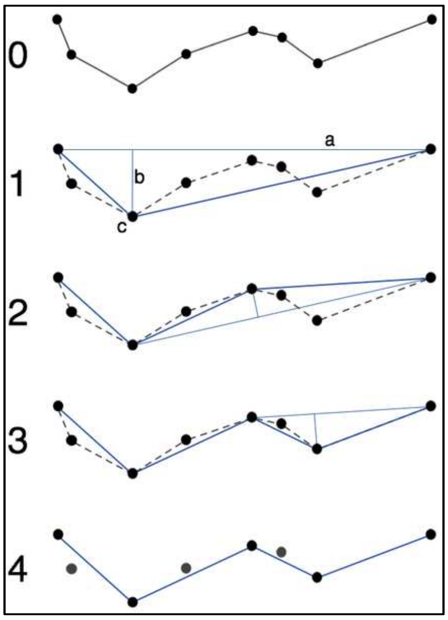

Figure 38 Douglas-Peucker Algorithm example (Source: Wikipedia, 2012)

The Douglas-Peucker method is the faster of the algorithms. Redundant vertices are removed based on the tolerance value (figure 38, segment b). It gives more coarser simplification. The angularity (sharp corners) of the resulting polygon will increase significantly as the tolerance increases, so the polygon may become less aesthetically pleasing (ArcGIS10 Help).

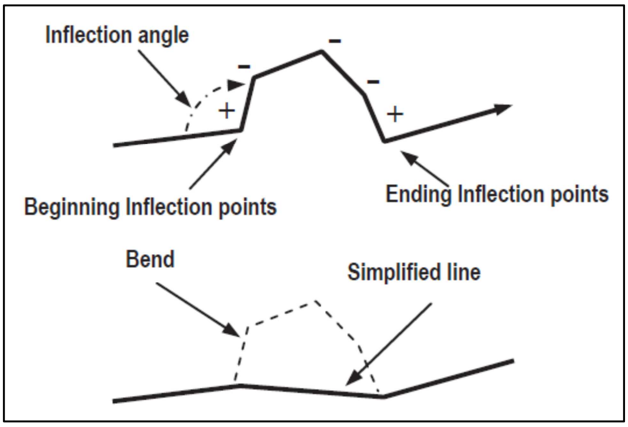

Figure 39 Wang Algorithm bend elimination example (Lee, Hardy, 2005)

The Wang algorithm searches for bend (figure 39), the basic pattern in linear and boundary shapes, by the inflection points; where the inflection angle changes the sign is the beginning or ending of a bend (Wang, 1996)

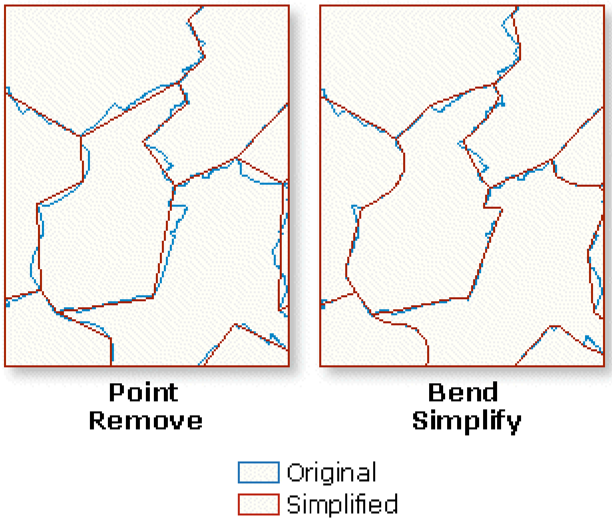

Figure 40 Comparison between Douglas-Peucker algorithm and Wang algorithm as used in ArcGIS10 (Source: ArcGIS10 Help)

Results from the Wang algorithm are more faithful to the original and more aesthetically pleasing (figure 40). One problem found with this algorithm is that small islands due to their nature and inflection angles get removed. This is what S-4 has to say about islands: “An islet too small to be shown in its true (scale) size shall not be reduced to a width less than the width of the coastline symbol (to avoid confusion with pinhole imperfections in chart plates).”

It is possible to eliminate small islands from the initial processing and then add them unchanged to the final map. Ideally, however, small islands close to the shore could be disregarded and those farther from the shore collapsed into LNDARE point objects that are more distinct to human eye.

The safety of navigation consideration in case of small islands close to the shore can be solved thanks to the second RADAR constraint – range resolution of 50m.

Before the simplification takes place, areas that are closer to each other than 50m can be aggregated.

5.4.2 PROPOSED GENERALISATION METHOD

Input dataset: Approach usage LNDARE (A), LNDARE (P)

AGGREGATE area IF {Distance between them measured between x,y pairs} ≤ 50m

SELECT area IF {Area} > 22000 (empirical value, based on the limitations of the algorithms)

SIMPLIFY polygons. {Level of detail} = 242m

DELETE point CONDITION: points do not share geometry with another point object (e.g. a spot height or an Aid to Navigation).

SELECT area IF {Area} < {equivalent of 1mm on the map scale}^{2}

COLLAPSE area TO point

5.5 COALNE

In this research, coastline is directly linked to the created land areas. It is, therefore necessary to sequence the generalisation, so that creation of coastlines starts after land areas are created.

Current Specification/ Generalisation Rules	Created Specification/ Generalisation Rules
• Similar to LNDARE. • It is considered important to show that the coast is artificial.	• Coastline should surround coastal scale LNDARE. • Preserve SLCONS locations from the approach chart. • Preserve attribution from the approach chart.

Standardisation Requirements

- The coastline of the charted land masses is referenced to the high water mark, or in case of non-tidal areas – the mean sea level.
- Coastline follows the geometry of LNDARE.
- Natural coastline is encoded as COALNE.
- Artificial coastline is encoded as SLCONS.
- CATCOA is encoded wherever this information is available.
- Unsurveyed coastline has QUAPOS = 2 (unsurveyed) encoded.
- Coastline is not encoded for edges of LNDARE that share part of geometry with the following objects: LAKARE, RIVERS (A), CANALS(A), SLCONS(A), DOCARE, LOKBSN

Conditions

- Coastal scale LNDARE is available.
- (Optionally) LAKARE, RIVERS (A), CANALS(A), SLCONS (A), DOCARE, LOKBSN are available.

Proposed Generalisation Method

- Creation by means of an operator/ function.
- Selection by intersection to change class and attributes.

Alternative Generalisation Methods

- None.

5.5.1 EXPLANATION

Use of the Object Catalogue (IHO, 2011) 4.5 states that the coastline may be encoded using only two object classes COALNE and SLCONS. These features form the border of the land area (LNDARE) object. COALNE is used to border those elements of land that are considered natural. Those can be beaches, cliffs, lake and river banks etc. Where it is important to show that the coast is artificial (fitted with shoreline constructions) SLCONS should be used. UOC also advises not to encode coastline where rivers, canals etc. are drawn on top of LNDARE (are considered non-navigable at the chart scale)

The same principle as described for the LNDARE can be used: coastline should be represented by the high water mark, or in case of non-tidal areas – the mean sea level (MSL).

It is considered important on the Coastal scale to show that the coast is artificial. One of the reasons is that it is likely to give a different response on the RADAR. The other reason is that harbours are still well outlined on those charts.

It is also considered valuable for the mariner to populate the attribute value for CATCOA. RADAR's echo differs when returning from flat or perpendicular to the signal surfaces[20], so even out of sight, a mariner could make use of an information whether the coast is steep or there is a sandy beach.

5.5.2 PROPOSED GENERALISATION METHOD

Input dataset: Coastline usage LNDARE (A)

Optionally: LAKARE, RIVERS (A), CANALS(A), SLCONS (A), DOCARE, LOKBSN

Approach usage COALNE, SLCONS, LNDARE

[20] http://msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/APN/Chapt-13.pdf accessed on the 20th of August 2012

Approach dataset SLCONS:

SELECT line IF {geometry is shared with} LNDARE (selects only coastline SLCONS, not piers, seawalls etc.)

CREATE buffer {flat, keep attributes}

Approach dataset COALNE:

SELECT line IF CATCOA ≠ UNDEFINED

CREATE buffer {flat, keep attributes}

Coastline dataset:

CREATE line (COALNE) from AREA (LNDARE)

DIVIDE edge IF edge {overlaps with} buffer {SLCONS} AND SELECT

CHANGE feature acronym TO SLCONS

RELATE attributes

DIVIDE edge IF edge {overlaps with} buffer {COALNE}

RELATE attributes

CLIP line IF {geometry is shared with} M_COVR OR LAKARE OR RIVERS (A) OR CANALS(A) OR SLCONS (A)

5.6 BATHYMETRY

This section contains reflections and ideas for automatic generalisation of bathymetry.

Generalising bathymetry is outside of the scope of this research. The author, however, would like to take the privilege of sharing some interesting thoughts, observations and materials that she came across while conducting her own research. Although they cannot be considered as a full research into the topic, they may be a source of inspiration to others who are interested in a subject. A very comprehensive set of specifications/ constrains can be found in the report by Guilbert and Zhang (2012). They identify 4 types of constrains: legibility constraint, position and shape constraints, structural and topological constraints and finally functional constraint. They develop the functional constrains into what can be considered generalisation specifications. Regardless of their method, those specifications can be used as a starting point to any attempt of generalisation.

The author would like to add some thoughts to the abovementioned work:

- Contours and depth areas should not be generalised in the leader approach (each scale from previous), but in the star approach (all scales from one source based on different parameters). The main source is a set of surveyed and processed points.

- A gridded surface of appropriate resolution, taking into consideration safety requirements (e.g. CUBE[21] surface) should be created.

- 3D double buffering is a smoothing operation performed on surfaces (Smith, 2003). Parameters can be adjusted to match the buffer size with the product scale. 3D double buffering preserves shoals, hence adds up to an overall safety. The result is that each product scale has its own surface. This assures that all uncertainty information of surface cells is not lost and can participate in the generalisation process. This also removes the necessity to later aggregate small shoals, remove pits and so on. The aggregation process works on pure geometries, whereas proper surface creation takes into account a whole spectrum of raw data characteristics.

- Another interesting operation that is already available in the software is defocussing. It "inflates" the surface based on the uncertainty value each sounding or surface nod has. This assures that even "the worst case scenario" measurement errors are included. A positive side effect is an aesthetically rounded surface.

- Contours created from such surface are a) suited for the product they were created for and b) do not require too much smoothing.

- Unfortunately, at the present time it seems that smoothing is executed either on contours that are not appropriate to the scale (hence smoothing is expected to act also as generalisation and complex algorithms are created to aggregate shoals and remove pits at the same time) or contours in the commercial software created based on the 3D double buffering and defocussing are smoothed in a very basic way- not able to work on only one, deeper side of a contour. This causes certain, small areas that were previously on the shallower side to end up on the deeper one, hence makes the smoothing be unacceptable for the use on navigational charts. If another double buffering, this time in 2D (or other algorithm that works only on one side of a contour) could be run on contours – the smoothing operation would meet safety constrains.

- Perhaps using hexagons instead of a plain square grid for surface creation would also make the contours smoother.

[21] Combined Uncertainty Bathymetric Estimator (Calder, 2004)

5.7 BUUARE

Build up areas are not the most important features on nautical charts, but, especially up to Coastal level they often take up decant areas of land. Vessels approach land usually to reach a harbour, hence most Coastal charts will have some form of urban areas encoded. One could ask therefore why build-up areas are needed? In the past city auras helped mariners to roughly orient themselves on a map, but nowadays this has lost its significance. On the other side at night the visibility of lights of Aids to Navigation may be affected when in the vicinity of a lit urban area, therefore boundaries of those should be marked on charts. Harbours are obviously needed to plan the passage, but urban areas are also encoded if they do not have access to any water. Usually conspicuous or potentially useful buildings, like churches or hospitals are charted along with some sort of urban area in vicinity, however this is to the discretion of the charting authority.

Current Specification/ Generalisation Rules

- Harbour buildings are of greater importance than inland settlements
- Because the extra detail is not of great importance, it is unnecessary to strive too hard for standardisation.
- The preferred representation is: reasonably full details of roads and buildings in dock areas and adjacent to the coastline generally, to the extent that a mariner unfamiliar with the port gets an indication of the layout of the port and access to shore facilities of general maritime interest.
- Waterfront, landmark and some public buildings are to be charted precisely and individually on the larger scale charts. When representing buildings generally, forming urban and suburban areas, villages and other built-up area the aim of the cartographer must be to create the correct impression of that extent of the built-up area and the density of the buildings.

Created Specification/ Generalisation Rules

- Groups of single buildings are aggregated into build-up areas.
- Single buildings are not shown.
- Build-up areas closer than 3mm per chart scale are aggregated.
- Build-up areas are simplified. Level of detail = 3mm per chart scale.
- Small build-up areas are omitted. Value differs per dataset.
- Approach scale attributes are retained.

Standardisation Requirements

- Level of detail on either all Coastal scale charts or specific scales should be agreed upon.
- Well-lit BUAAREs should be depicted as area objects.
- BUAARE adjacent to the coastline should be mapped as area objects.
- The presence/ absence of roads, railways, single buildings should be agreed upon. If the decision is to map them (as S-4 suggests) they should be included in the generalisation process.
- Airfields should be encoded as aural features will be conspicuous from the sea.

Conditions

- Build-up areas other than villages are depicted as area BUAARE objects.
- Approach usage BUAAREs are mapped according to S-4 principles (B-370)

Proposed Generalisation Method

- Algorithm with generalisation operators.

Alternative Generalisation Methods

- Creation of COALNE from COALNE and SLCONS from SLCONS (data did not match on edges, data did not match LNDARE).

5.7.1 EXPLANATION

Charting of harbours is definitely of greater importance than depicting inland settlements. There is no standardisation about the level of detail needed. “Because the extra detail is not of great importance, it is unnecessary to strive too hard for standardisation.” – reads S-4. However true is the statement about the low importance, some standardisation could aid the development of automatic generalisation tools.

This research proposes to encode only BUAARE objects on coastal maps, as single buildings (BUISGL) are considered insignificant on this scale. BUAAREs are created mainly out of Approach usage BUAARE and BUISGL objects, but in one case also ROADWY was used due to lack of other sources.

S-4 gives some details of what should be depicted by stating "the preferred representation is: reasonably full details of roads and buildings in dock areas and adjacent to the coastline generally, to the extent that a mariner unfamiliar with the port gets an indication of the layout of the port and access to shore facilities of general maritime interest" but it is not clear to which scale this information is useful. A mariner having a certain harbour as a destination has to be equipped with better than Coastal charts of the harbour (where he/she may take the necessary information from) and a mariner whose vessel is not bound for it will have no use of the extra information.

The generalisation is very general and simple assuming that it is better to get 80% of the job done well and allow 20% to be done interactively (adding additional detail, conspicuous buildings) than to fail the entire attempt.

5.7.2 AUTOMATIC GENERALISATION

Input dataset: Approach usage BUISGL (P,A), BUAARE (P,A), Coastal usage: LNDARE (A)

SELECT ALL point

CREATE buffer {flat, envelope}

SELECT ALL area (including newly created buffer)

UNION

DISSOLVE

AGGREGATE area IF {Distance between them measured between x,y pairs} ≤ 3mm/cs

SIMPLIFY area {level of detail 3mm/cs)

SELECT area IF {Area > empirical value}

SPATIAL JOIN area AND area, point {Approach} (this copies attributes of initial objects lost after connecting, dissolving and aggregating)

5.8 OBSTRN

Obstruction objects on ENCs can take all three geometric forms: point, line, area. This specification deals only with areas because line objects were not available in any of the datasets and point objects were only available in one – Dutch dataset, so no comparison could be made to validate the model.

Obstructions are the third, after wrecks and underwater rocks type of danger. Wrecks and rocks may not always be considered as dangerous, but OBSTRN type objects are considered the ones to be avoided. Those can be foul grounds, submerged piles, wellheads etc. Obstruction areas of CATOBS: 6 (foul area) trigger alerts in ECDIS and are therefore very efficient to prevent vessel from entering a certain, dangerous area. Often this type of object is used to surround groups of

UWTROCs to enhance their perception or to depict other uncharted dangers. It has to be remembered that such obstructions require separate DEPARE encoded sharing the same geometry, but this was not in the scope of this study.

Current Specification/ Generalisation Rules	Created Specification/ Generalisation Rules
• Full details of all dangers to navigation are to be charted except in those areas for which the chart is clearly inappropriate for navigation (no scale given).	• All OBSTRN areas from the approach scale are retained • OBSTRN areas are enlarged (1mm per chart scale) • OBSTRN areas closer than 1mm per chart scale are aggregated. • Retain Approach scale attributes

Standardisation Requirements

- An agreement should be reached on when to encode OBSTRN point objects and when the clusters should be changed into areas.

Conditions

- Generalised LNDARE area already exists.

Proposed Generalisation Method

- Enlargement and aggregation.

Alternative Generalisation Methods

- Creation of OBSTRN areas from OBSTRN points by means of buffers and envelopes (algorithms not capable of creating correct areas, not aesthetically pleasant, safety of navigation requirement not met).

5.8.1 EXPLANATION

Obstruction areas were created based on the OBSTRN area objects on the approach chart. The possibility to create OBSTRN areas from clusters of OBSTRN point or UWTROCs is worth considering in the future but was not explored.

All the principles mentioned earlier for dangers to navigation apply to those objects as well.

It was considered important to enlarge the obstruction areas a bit, so that they stand out better. 1mm of chart scale was chosen but this value is arbitrary and discussable.

5.8.2 PROPOSED GENERALISATION METHOD

Input dataset: Approach usage OBSTRN (A), Coastal usage LNDARE (A)

OBSTRN (A)

CREATE buffer {1mm/cs}

AGGREGATE area IF {Distance between them measured between x,y pairs} ≤ 1mm/cs

OBSTRN (A), LNDARE (A)

SELECT area

CUT AND REMOVE

SPATIAL JOIN area AND area {Approach}

5.9 MISCELLANEOUS

After the generalisation of all the other selected object classes was complete a question still remained, what are other object classes that are considered important for the safety of navigation at the Coastal part of passage. Literature study, visual inspection of charts, and author's own practice helped to select several other object classes that, when available, should be presented on Coastal charts.

Current Specification/ Generalisation Rules	**Created Specification/ Generalisation Rules**
• Discrepancy or no specifications.	• Select (differs per object class).

Standardisation Requirements

- Hydrographic Offices should agree upon the ideal content of charts. The selection made above is only an example of how this could look.

Conditions

- Results of generalisation revealed that the main problem with generalisation and thus storing those objects on a scale independent layer is their interaction with LNDARE. The condition could be to store only those objects that do not share geometry with LNDARE, which may be confusing or to develop an “open-end” geometry where object’s shape, once propagated to a certain usage, adjusts its geometry to the generalised LNDARE.

Proposed Generalisation Method

- Scale-independent storage.
- Selection.

Alternative Generalisation Methods

- None.

5.9.1 EXPLANATION

ACHARE ; ACHBRT ; ADMARE ; CBLSUB ; CBLARE ; CTNARE ; EXEZNE ; FERYRT ; ISTZNE ; MARCUL ; MIPARE ; NAVLNE ; PIPARE ; PIPSOL ; PRCARE ; RADRNG ; RECTRC ; RESARE ; TESARE ; TSELNE ; TSEZNE ; TSSBND ; TSSCRS ; TSSLPT ; TSSRON ; PILBOP ; MAGVAR ; RCTLPT ; RDOCAL ; TS_FEB ; TS_PAD ; TS_PNH ; T_PRH were selected for analysis. The selection is not random. Not only those objects may be of mariner’s interest during the coastal period of the passage, but if it could be proved that those objects do not need any geometrical generalisation, they could be stored on a scale independent layer and updating them once would result in the entire affected portfolio to be ready for production. The rate of success varied between datasets, but it is worth mentioning here, so that more consistent approach may be created.

5.9.2 PROPOSED GENERALISATION METHOD

SELECT was the only option used. It was based on similarities between charts and in some cases common sense.

6 OUTPUTS OF GENERALISATION EFFORT AND THEIR EVALUATION

Below readers can find the resulting maps and elements of maps illustrating specific issues. The generalised maps were obtained by applying the generalisation method as introduced in the previous section.

First, one can observe the entire generalisation effort compared to the original chart, and the source chart. In the summary subchapter results are summarized from the perspective of the researcher. Next one can read about the details in specific object classes.

On most of the maps the turquoise tint is the background colour selected to enhance perception. These are not depth areas.

6.1 COMPARISON OF GENERALISED AND ORIGINAL MAPS

For each country the generalised map and the extract of the original map of the same navigational purpose containing the same object classes are presented. A short evaluation by the author of main advantages and disadvantages of automatic generalisation follows each chart pair.

6.1.1 BRAZIL

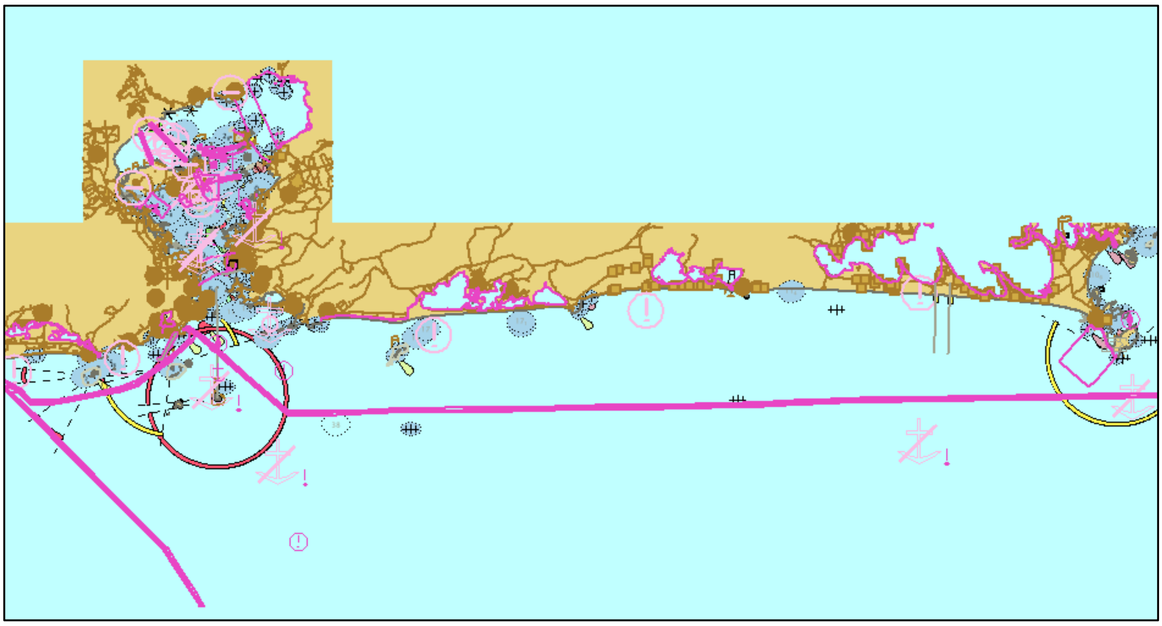

Figure 41 Source data 1:45,000

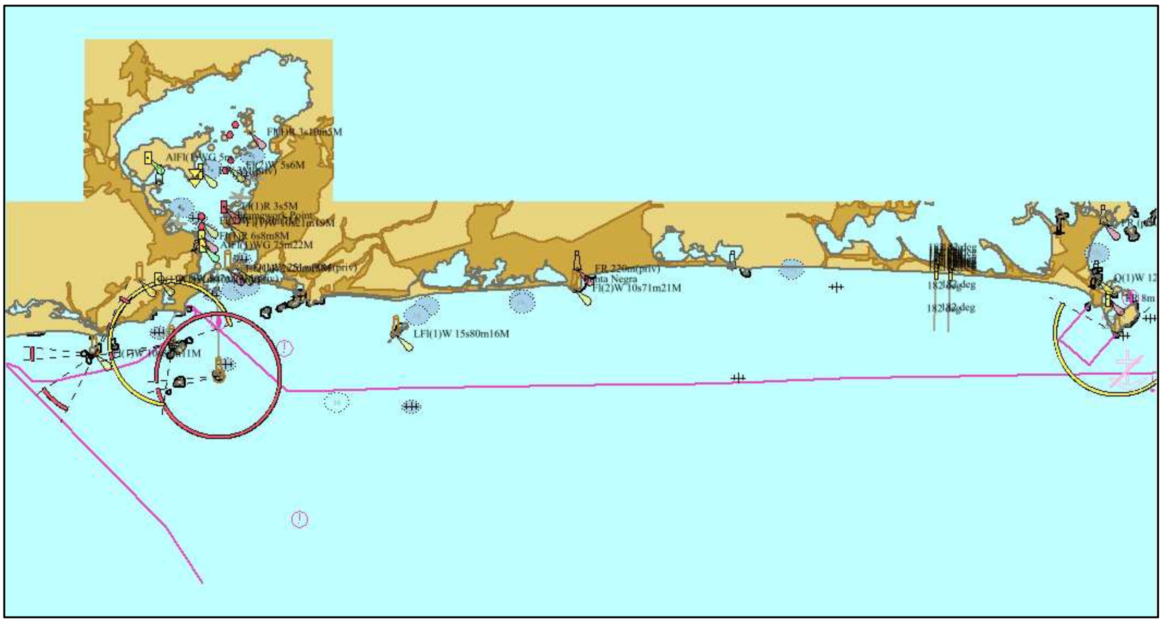

Figure 42 Generalised chart 1:180,000

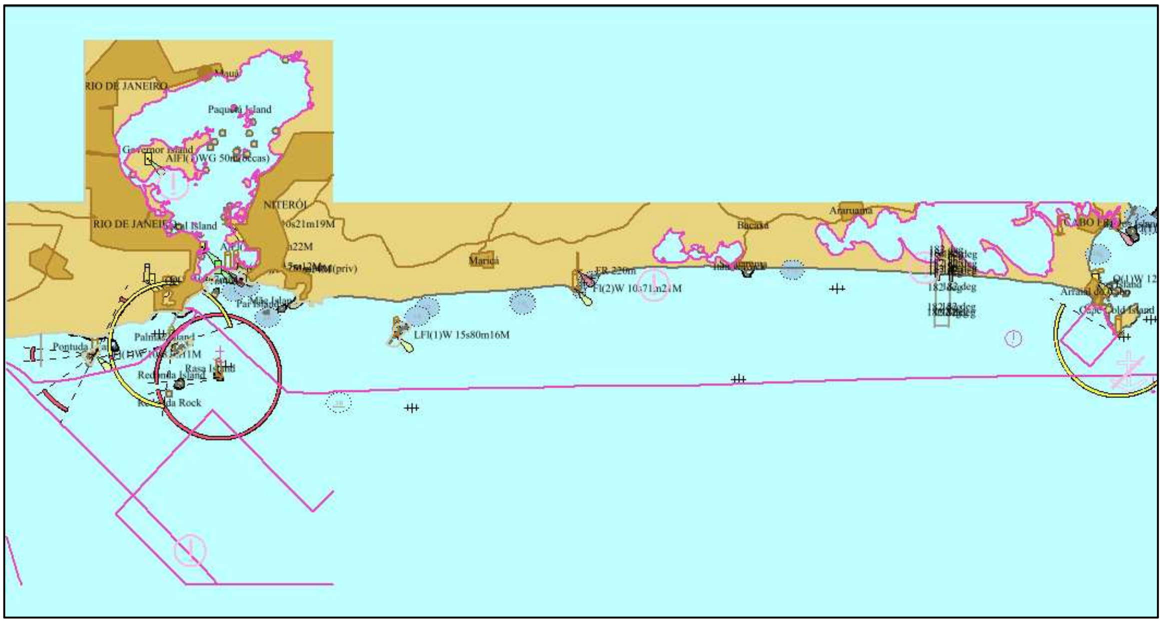

Figure 43 Original chart 1:180,000

Positive:	Negative:
• Shapes preserved. • Attributes preserved. • Consistent and unambiguous selection process.	• BUAAREs very different. • Lagoons preserved on the generalised one. • Selection not always similar in case of UWTROCs.

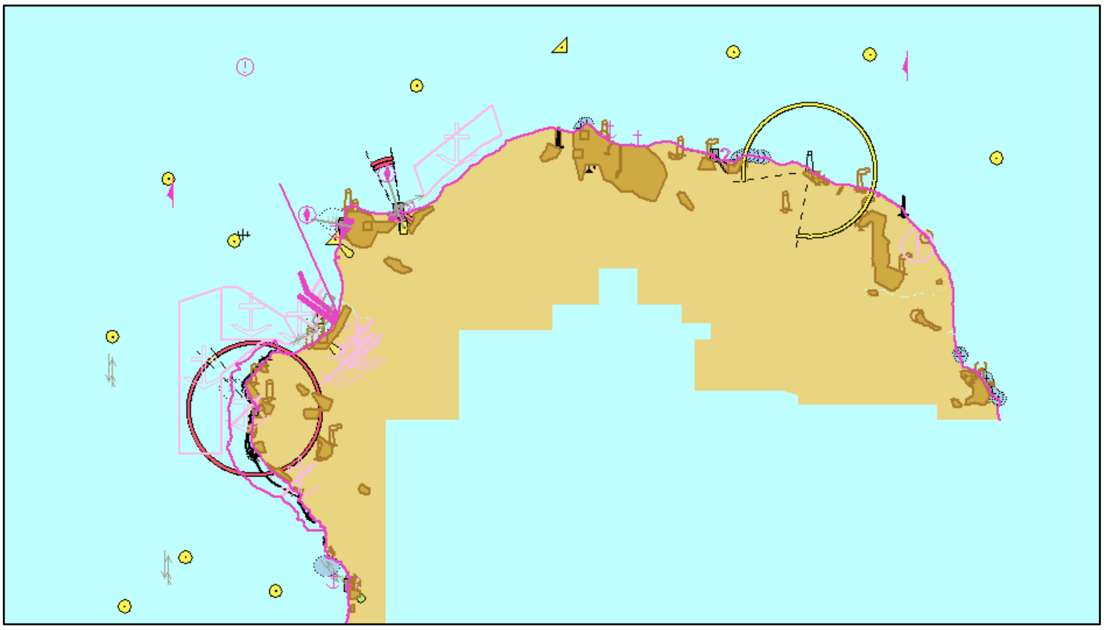

Figure 44 Source data1:60,000

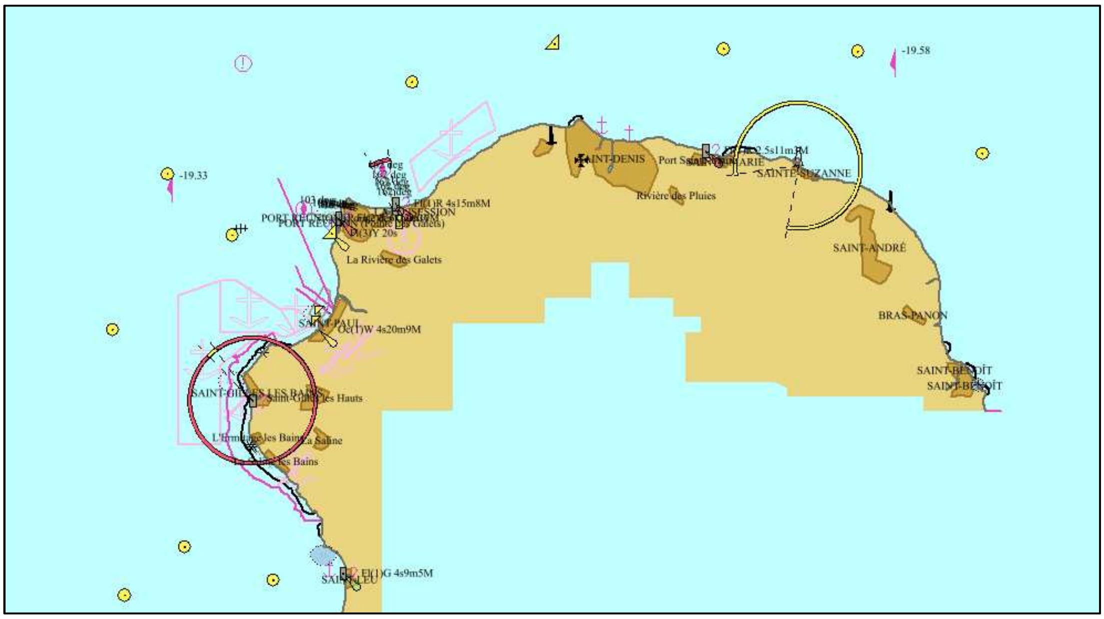

Figure 45 Generalised chart 1:180,000

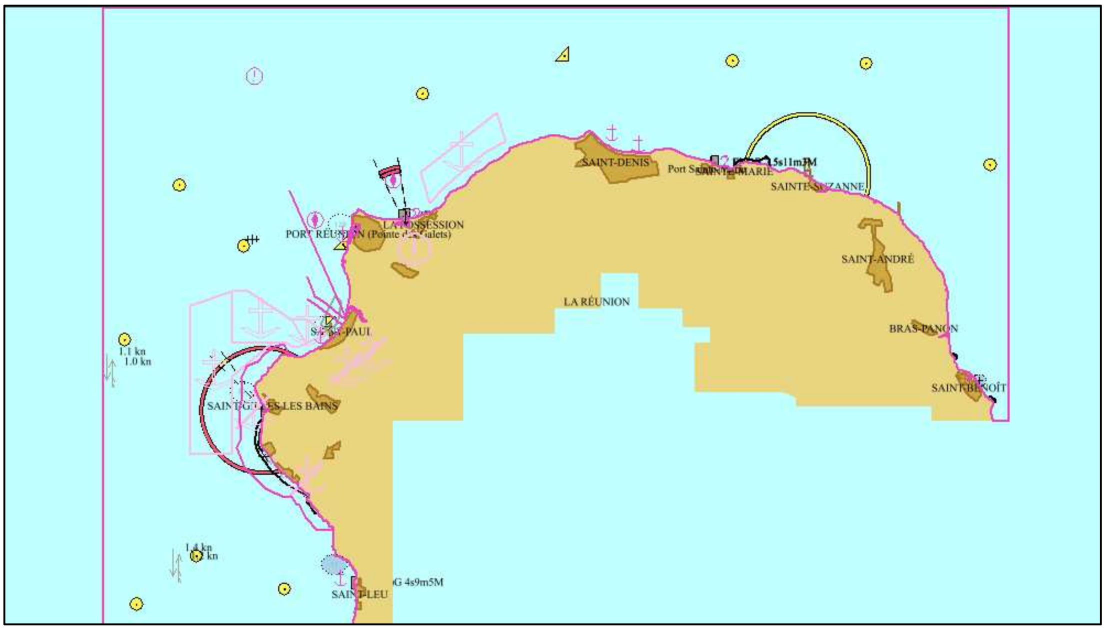

Figure 46 Original chart 1:180,000

Positive:	Negative:
• Effective handling of BUAARE. • More effective depiction of a small island.	• Support structures used by the organisation not used in the algorithm. • Rivers still expected to be encoded as DEPARE (cuts in LNDARE geometry)- not appropriate for this scale.

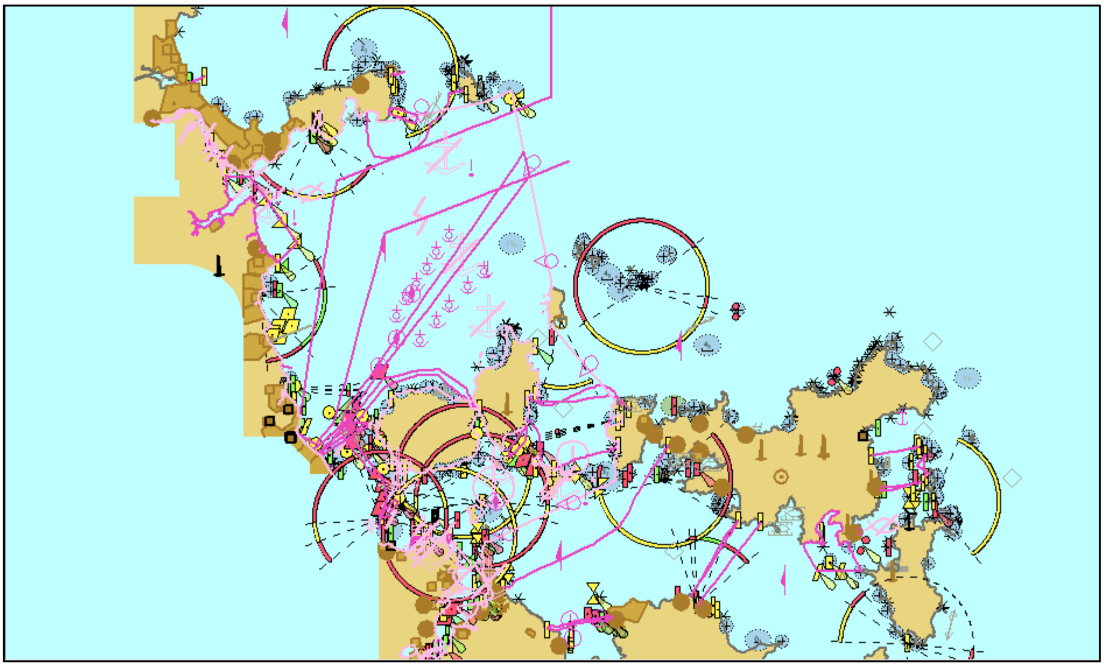

Figure 47 Source data 1:22,000

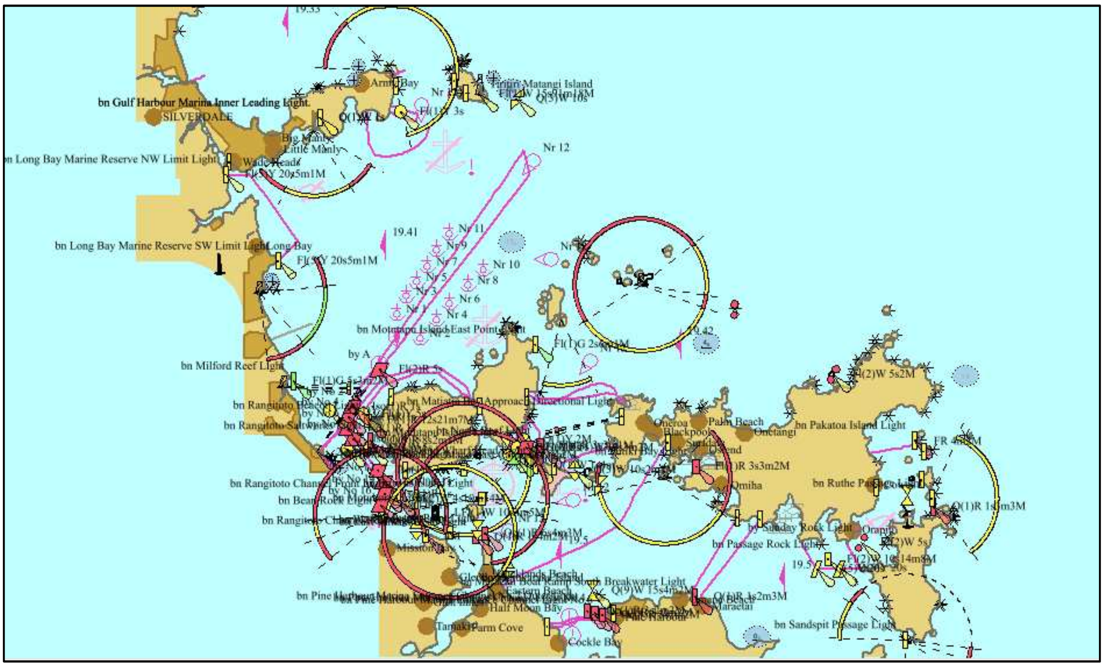

Figure 48 Generalised chart 1:90,000

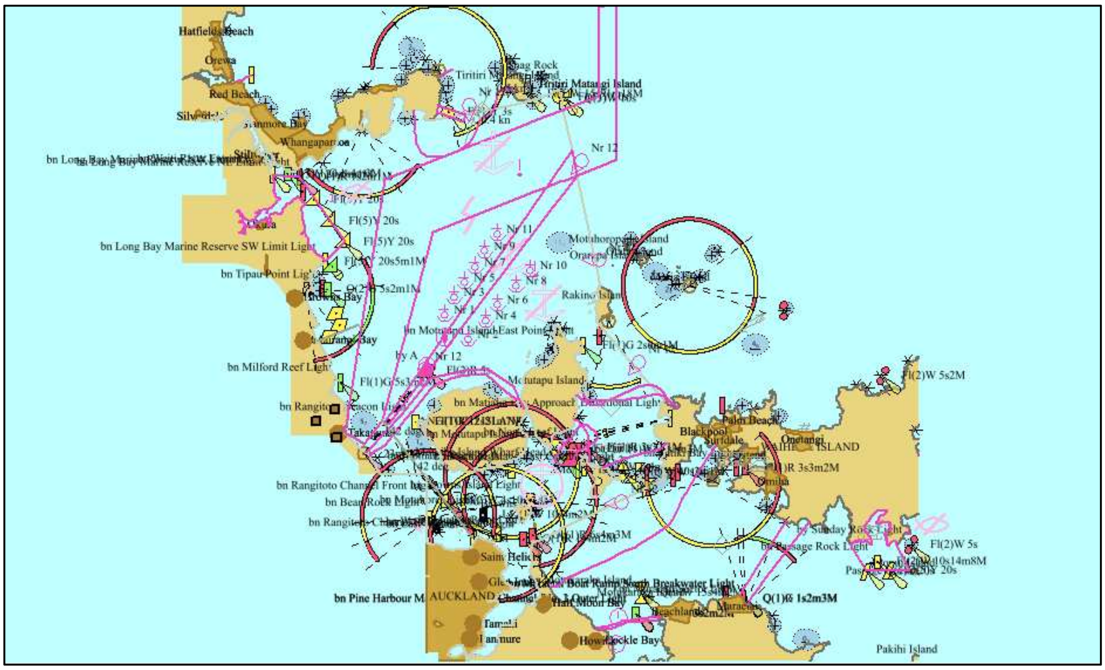

Figure 49 Original chart 1:90,000

Positive:	Negative:
• Better mapping of BUAARE. • Effective depiction of small islands.	• LNDARE: Complex topography overgeneralised. • Clusters of UWTROC.

6.1.4 THE NETHERLANDS

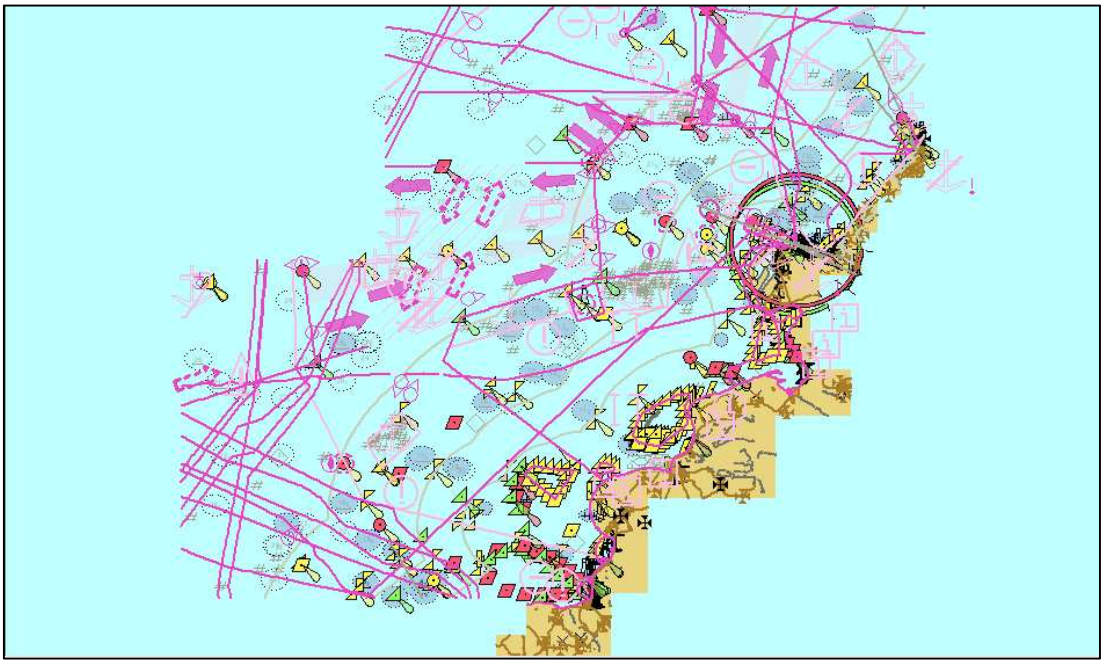

Figure 50 Source data 1:45,000

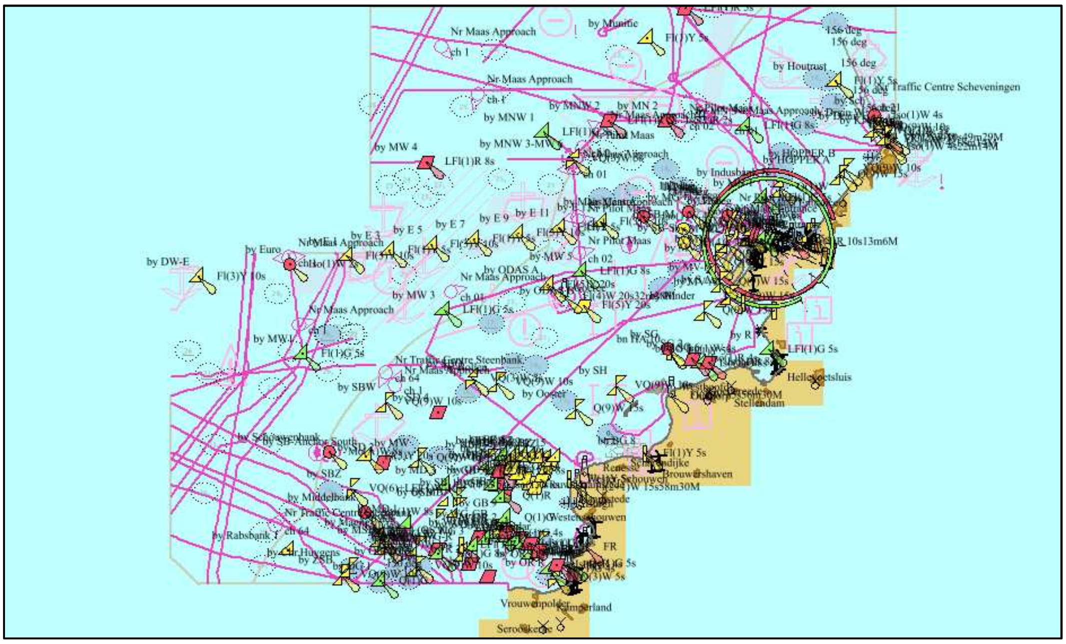

Figure 51 Generalised chart 1:90,000

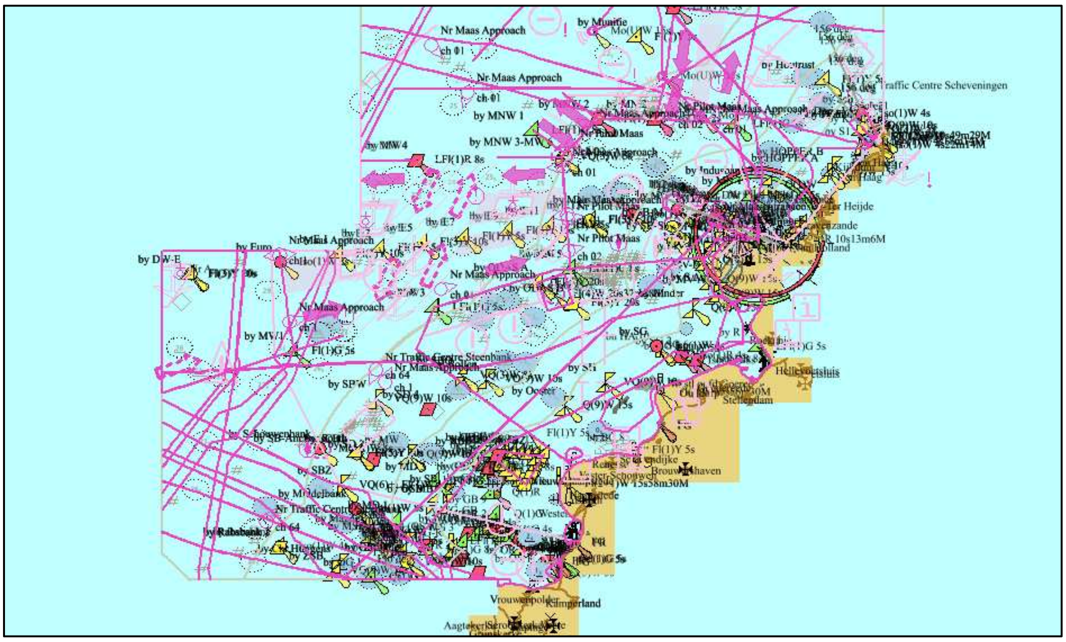

Figure 52 Original chart 1:90,000

Positive:	Negative:
• Effective handling of BUAARE. • LNDARE similar to original. • Efficient handling of huge amounts of AtoNs.	• The only dataset with OBSTRN points, which were not handled. • Caution areas, anchorages etc. could not be matched with the generalised LNDARE.

6.2 SUMMARY OF THE RESULTS

Object group	What was done?	What went well?	What went wrong?
AtoNs and Landmarks	Selection De-clustering	Safe approach Logical selection	Not all support structures chosen Manual effort still needed for special cases
WRECKS	Selection	All selected correctly	Possibly manual deletions involved
UWTROC	Selection Removing redundant	Safe approach	Clusters of objects
LNDARE	Aggregation Simplification Collapsing	Time savings Effective depiction of small islands	Generalisation not on the safe side Oversimplification
COALNE	Create feature based on geometry Buffers Assignation of attributes	Time savings Correct attribution	Short edges
BUAARE	Aggregation Simplification	Correct shape	No differentiation between close to shore and far from shore Need to take more objects into account
OBSTRN	Enlargement	Safe approach Effective depiction Consistent with Approach	No OBSTRN points Clusters of other objects on better scale should be transformed into OBSTRN areas on the target chart
Miscellaneous	Selection	Sometimes time savings	Difficult to find patterns

6.3 DETAILS OF GENERALISATION OUTPUT

For each generalised object there were positive and negative results, as assessed by the author and nautical experts. Below one can find details on what went well and what went wrong with the generalisation of particular object classes. More results can be found in appendices 3-6.

6.3.1 ATONS AND LANDMARKS

At the present time generalisation was semi-manual with the aid of sub-layers and attribute based selections. An automatic tool can replace human interaction.

Positive results:

- Time savings with efficient and effective generalisation.

Mean processing time was 30 minutes (manual) and could be decreased to minutes with an automated solution. The condition is that Approach dataset (or scaleless layer) is populated and fit for purpose.

- Safety of Navigation.

Overall more AtoNs were selected by the algorithm, than by cartographers on the original charts.

- More accurate position.

Since AtoNs come from a less generalised datasets their position is more true to reality. Ideally these would be real-life coordinates not the positions taken from paper charts.

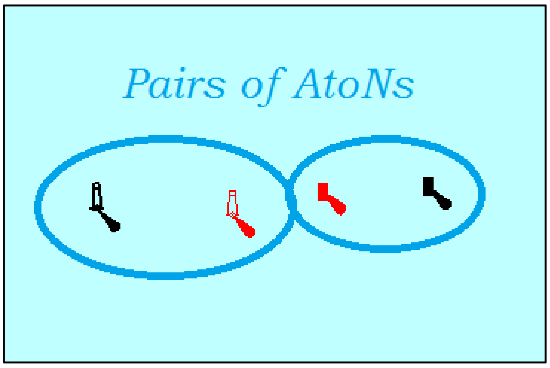

Figure 53 Generalised AtoNs are more accurate

- Prevents clustering.

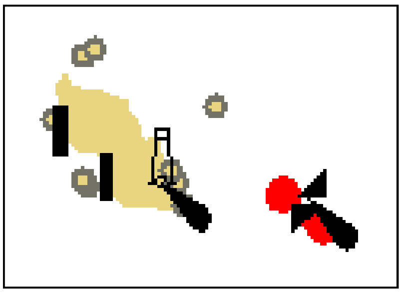

Figure 54 Results of de-clustering algorithm

The second step cleans the chart from the irrelevant detail and the complex selection method follows the rational approach of a mariner who is more likely to notice a stronger light or would be searching for a more conspicuous/ important AtoN.

Negative results:

- PILPNT not considered as a valid AtoNs support.

There are two cases where a very strong light has been omitted from the generalised chart, as its support structure is PILPNT that was not considered during this research.

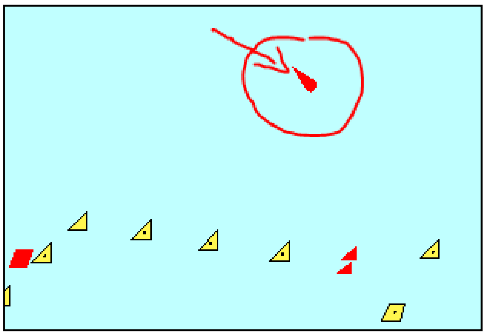

Figure 55 Omitted light due to "incorrect" support structure

This is not serious and PILPNT can be added to the considered support structures.

- Algorithm not able to recognise main land.

As much as it is not a problem to check whether a point is surrounded by a certain object, the algorithm still needs to be calibrated so that AtoNs are not removed from bays that aren't closed basins but surround AtoNs.

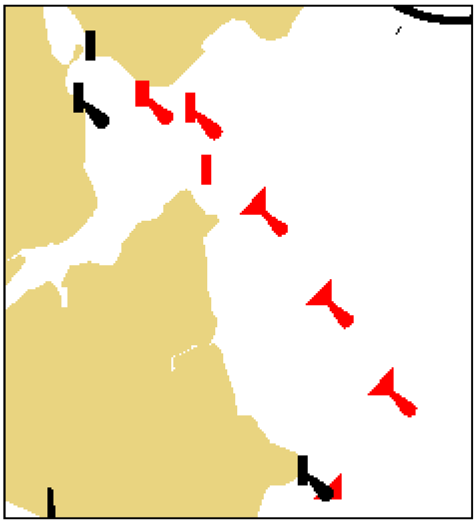

Figure 56 Omitted AtoNs "inside" of a bay

This error is more serious and a method needs to be find to make a distinction between bays and basins.

- Generalisation of land makes AtoNs appear on water.

Where an island has been collapsed into a point that is created in the metacentre of the area, the AtoN that is not positioned in the centre would be located on the water and thus subject to different generalisation rules.

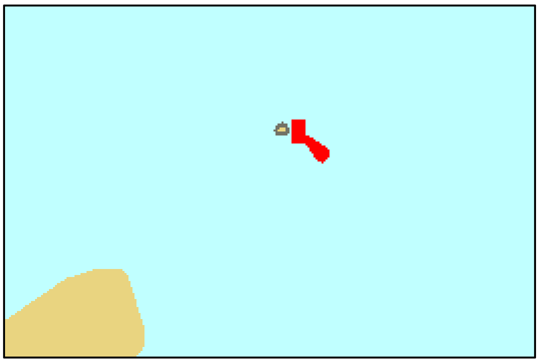

Figure 57 AtoN initially on land, after LNDARE generalisation is located on water and was removed

This could potentially be fixed by using the ungeneralised LNDARE for the selection.

- Irrelevant objects kept.

Stake, pole, perch and post features are small AtoNs and irrelevant at the Coastal scale range to navigation. In favourable conditions (not surrounded by land, on land due to generalisation, without other, more important objects in vicinity) these objects are transferred from the Approach dataset unnecessarily.

There can be an additional condition added that those features should not be populated regardless to conditions.

Open points:

- How to define main land and a closed basin?

6.3.2 WRECKS

At the present time generalisation was semi-automatic with the aid of attribute based selections and buffers created in ArcGIS. An automatic tool can replace human interaction.

Positive results:

- Time savings with efficient and effective generalisation.

Mean processing time was around 10 minutes (semi-manual, two software) and could be decreased to seconds with an automated solution. The condition is that Approach dataset (or scaleless layer) is populated and fit for purpose.

- More accurate position.

Similarly to AtoNs when WRECKS come from a less generalised datasets their position is more true to reality. Ideally these would be real-life coordinates not the positions taken from paper charts.

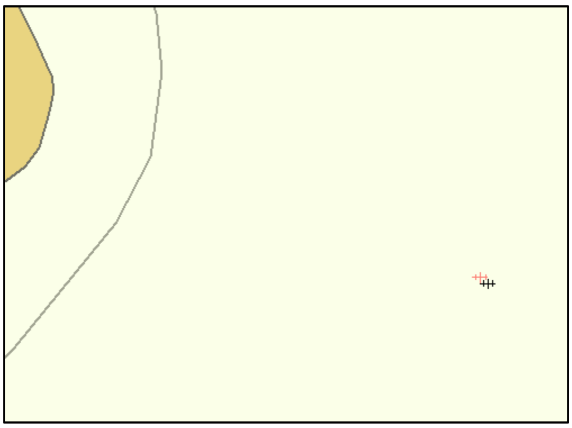

Figure 58 Generalised WRECKS are more accurate

- Consistent attributes

Generalisation of paper charts makes it necessary to omit certain information about objects due to lack of space. Automatic generalisation assures that all attributes are populated even on the smallest scale charts and that they are consistent between usages.

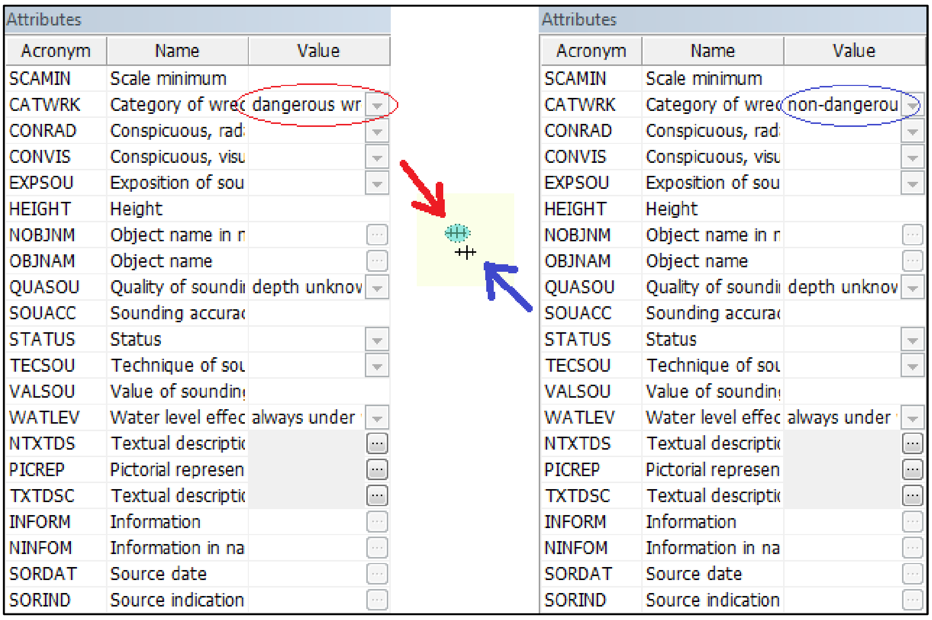

Figure 59 Inconsistent encoding between Approach (red)and Coastal (blue) cells

Negative results:

None, but further testing is required to check the solution in areas with many wrecks (e.g. coast of France and UK at the entrance to the channel).

Open points:

- Is 200m the correct value?
- Is 1200m the correct value?
- Customization of the solution to depict only open water wrecks.

6.3.3 UWTROC

The generalisation of UWTROC was done manually with the aid of filters and selection tools. No human logic was applied, specifications were executed as a computer would execute them, even when it was obvious that the result would not be optimal.

Positive results:

- Time savings.

Mean processing time was 15 minutes (manual) and could be decreased to sub-minutes with an automated solution. The manual processing involved selecting all UWTROC: EXPSOU=2 copying them into a scratch layer and deleting from intermediate layer, then selecting all remaining UWTROC Inside Selected Areas and deleting them. Remaining UWTROC were them copied to the scratch layer and saved.

- Safety of Navigation.

In most of cases more UWTROCs were selected on the generalised chart, especially outside of the OBSTRN areas.

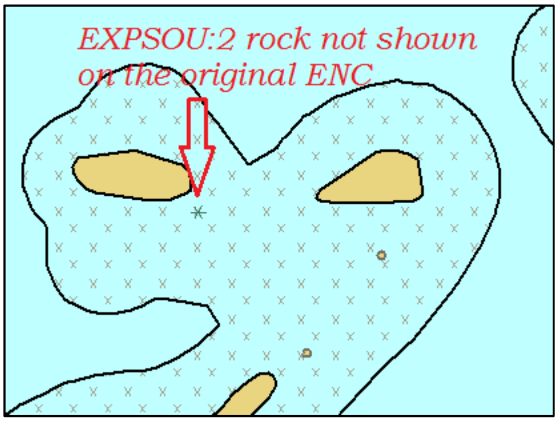

Figure 60 Generalised charts show more safety critical objects

- More accurate position.

Since UWTROCs come from a less generalised datasets their position is more true to reality. Ideally these would be real-life coordinates not the positions taken from paper charts where they would always be subject to digitization error or cartographic displacement.

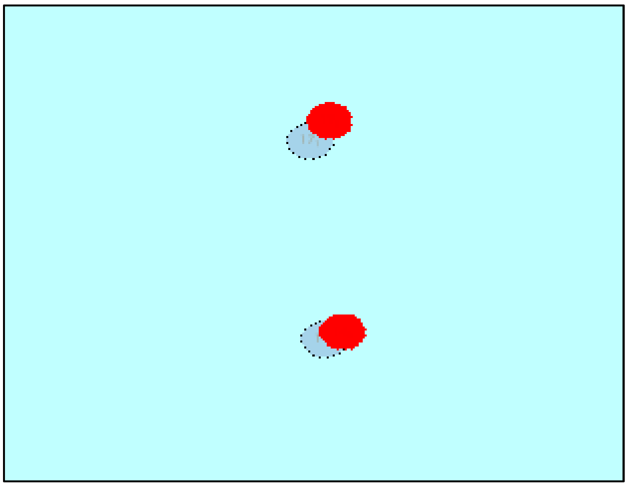

Figure 61 Generalised UWTROC are more accurate

Negative results:

- Clusters of UWTROC.

Since there are no restrictions about the UWTROCs that are not covered by obstruction areas there are cases where many UWTROC from a better scale chart get copied to a smaller scale chart and given the scale difference form clusters of unreadable objects.

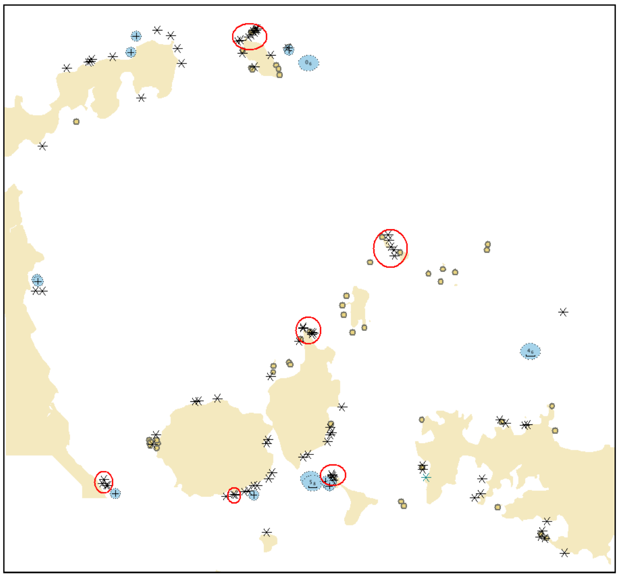

Figure 62 Clusters of UWTROC encircled in red by NHA

This could be resolved by introducing similar de-clustering methods as for AtoNs or by transforming clusters of objects into OBSTRN areas.

- Human judgement is still needed

NHA has indicated that there are rocks that, for various reasons would be better kept even if this is not reflected in the existing specifications.

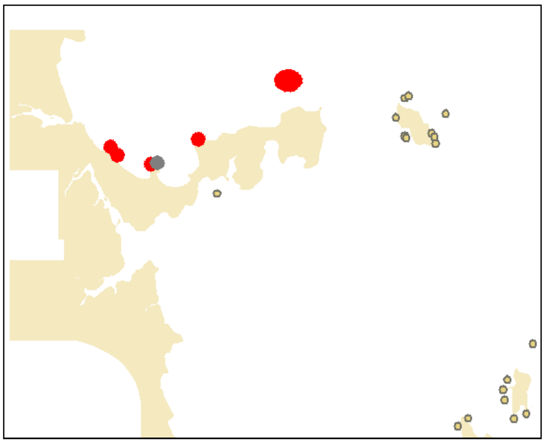

Figure 63 Human judgement not overlapping with the generalisation results

Very likely the specifications should be made more complex to take into account areas of minimal depiction or other attributes. In this case, it is not clear why the UWTROCs were not selected, as they are not covered by OBSTRN areas. This must have been human error of the author.

Open points:

- Minimum depiction areas

6.3.4 LNDARE

LNDARE was entirely generalised in ArcGIS by means of a model created out of various cartographic and not only operators.

Positive results:

- Time savings.

Once the model is created, calibrated and validated generalisation (running the model) takes less than 1 minute.

- Consistent level of detail throughout the data.

The same smoothing is applied not only within the chart, but also between the charts.

- Small islands are more prominent as point objects.

Although some hydrographic offices prefer to enlarge small islands than collapse them, point objects on vector datasets are always shown with the same symbol (the same size), regardless of zooming, whereas area features become less conspicuous as one zooms out, simply because their size is dictated by their geometry.

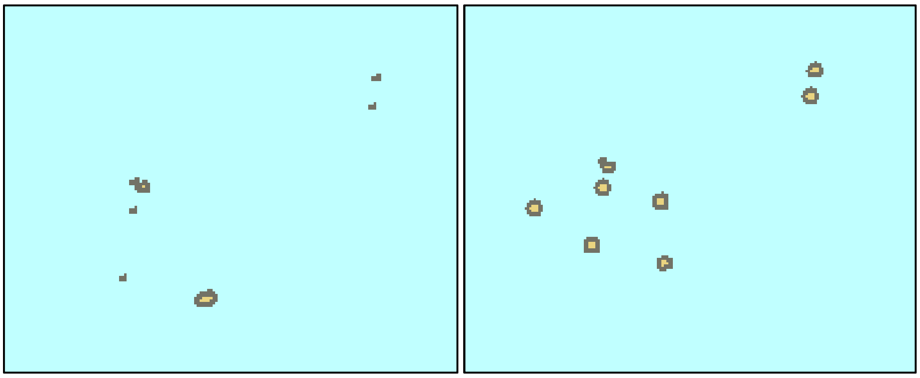

Figure 64 Comparison between original (left) and generalised (right) LNDARE (LNDARE and COALNE shown). View at the compilation scale 1:90,000.

Negative results:

- Unacceptable for safety of navigation!

All producing agencies are unanimous – the generalisation of LNDARE should be only in one direction – seaward.

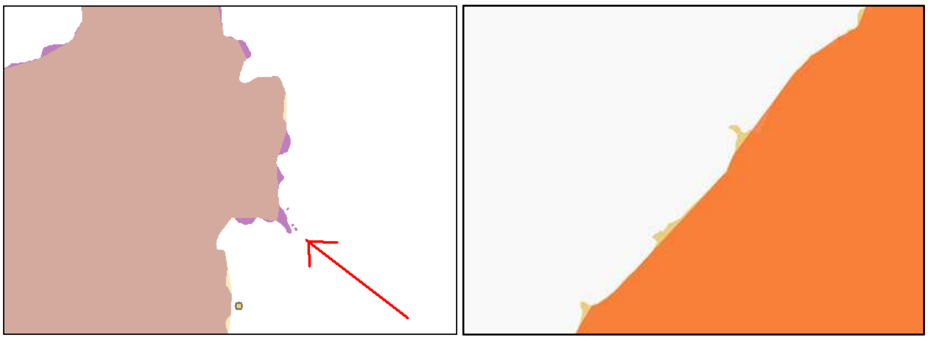

Figure 65 Unacceptable inland generalisation reported by NHA (left) and SHOM(right)

Other agencies notice that after generalisation, some islands are missing.

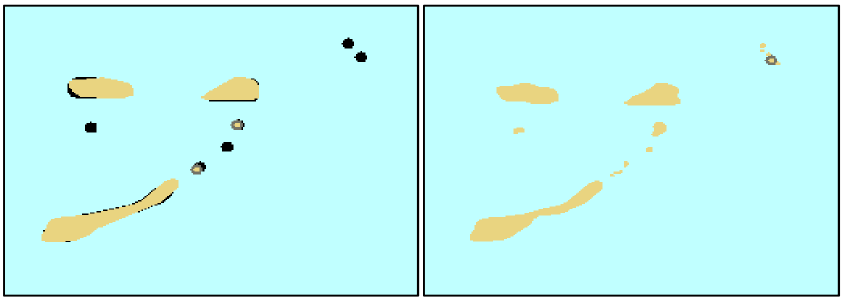

Figure 66 Islands missing on the generalised dataset(buff colour, original in black). The figure on the right shows the original Approach dataset.

It should be added in the specifications that generalisation should only go seaward. None of the algorithms available was capable of this. Double buffering (rolling circle) algorithm would solve this (Smith, 2003).Alternatively other safe approaches could be considered (e.g. Guilbert and Zhang, 2012, Peters, 2012).

- Problems with complex geometries.

In some cases internal rivers or lagoons are kept where they should have been generalised.

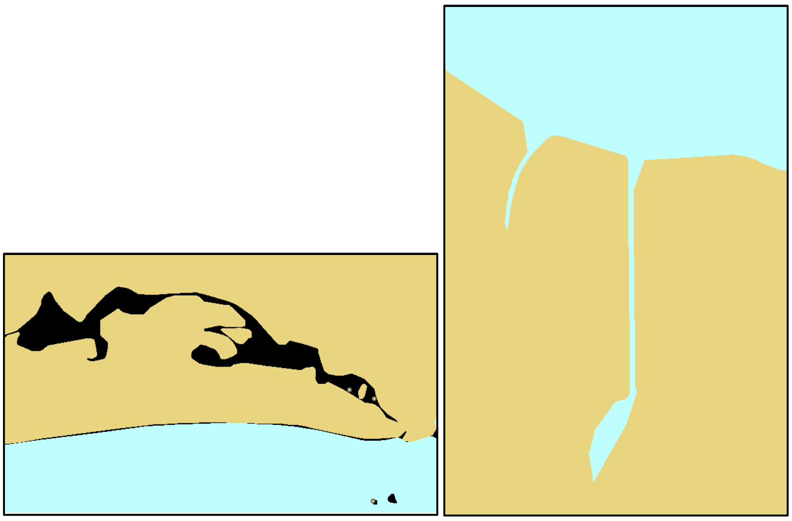

Figure 67 Examples of not generalised detail that is considered redundant

The double buffering algorithm would solve those issues as well.

- Datasets overgeneralised.

Most of the stakeholders point out that the level of generalisation is too big for the scale. In the evaluation they have not been given a full explanation as to the chosen value, but it is also considered that the algorithm chosen does not use it as desirable. On the other hand, it should be reconsidered what the appropriate level of detail is.

Open points:

- Are the specifications incorrect or is the execution erroneous?

6.3.5 COALNE

COALNE was created semi-automatically, in ArcGIS and CARIS S-57 Composer. The only manual operation was to assign attributes based on automatic selection (the software is not capable of doing that automatically).

Positive results:

- Time savings with efficient and effective generalisation.

Mean processing time was around 30 minutes (semi-automatic, but in two software packages, so exporting and importing data was involved) and could be decreased to minutes with an automated solution.

- Coastline matches LNDARE

Overall, the coastline is created correctly. The attributes were transferred properly. SLCONS match the location of shoreline constructions. This solution can be used also for manually created LNDARE, if the generalised one does not meet expectations.

Negative results:

- Short edges.

The only problem is in the presence of very short lines due to inaccuracies in the algorithm. Where the buffers did not cut the coastline in exactly the same point, little segments got excluded from processing. The same might have happened if the original coastline had many bends which were maintained in the buffer.

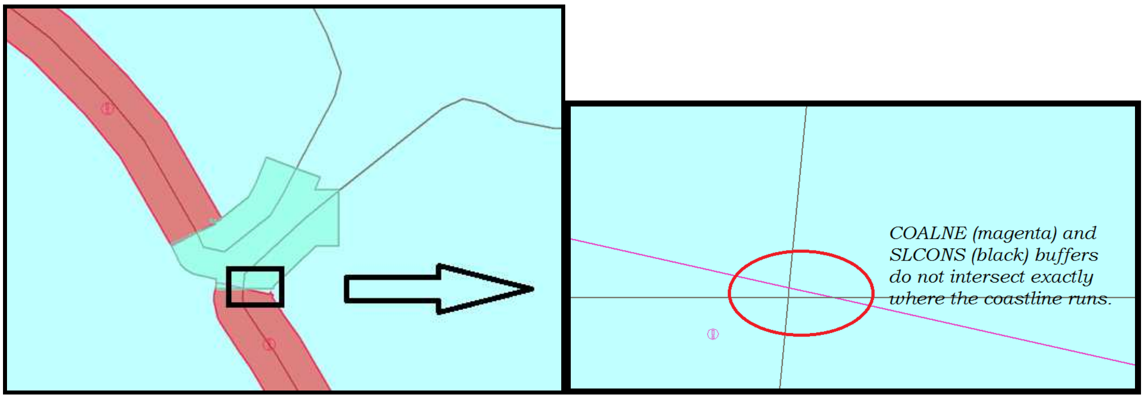

Figure 68 Short edges effect

The problem can be solved with an xml script to QC and correct it. Short edges would be identified and if they were in between edges of the same feature acronym and attribute values they would be assigned those values and merged with the neighbouring objects. If feature class and or attributes would be different, the short segment would be merged with one of them.

Open points:

- SLCONS that are not adjacent to the land were not processed. Further development needs to take place to handle them. The current method was not aimed to include all SLCONS, but only to replace COALNE where SLCONS was needed.

6.3.6 BUAARE

Build-up areas were entirely generalised in ArcGIS by means of a model created out of various cartographic and not only operators.

Positive results:

- Time savings with efficient and effective generalisation.

Once the model is created, calibrated and validated generalisation (running the model) takes less than 1 minute.

- Consistent level of detail throughout the data.

The same smoothing is applied not only within the chart, but also between the charts.

- Results are similar to original charts.

Although this is not a safety critical category, BUAAREs match the original dataset quite well and are more consistent with the shape of the approach ENC ones.

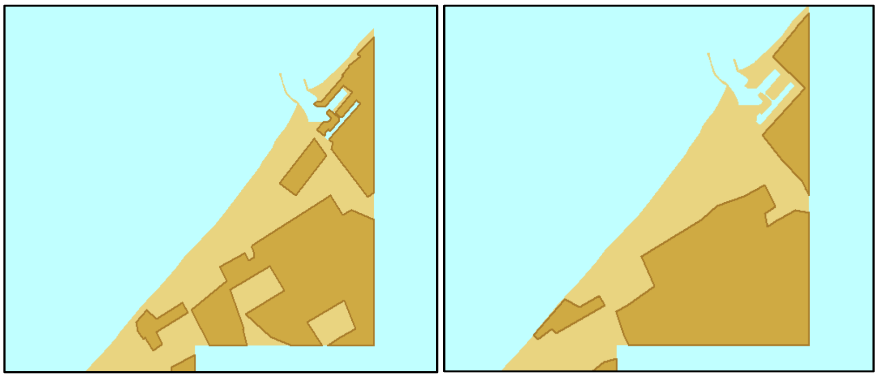

Figure 69 Comparison between the generalised (left) and original (right) BUAARE

Negative results:

- Not possible to generalise or bad results, if settlements are mapped as point objects.

In some cases Approach dataset showed point BUAAREs and Coastline area type objects. Another instance is when Approach dataset shows a network of roads, which is much denser in the urban areas and thus indicates where those are, but there are no areas themselves.

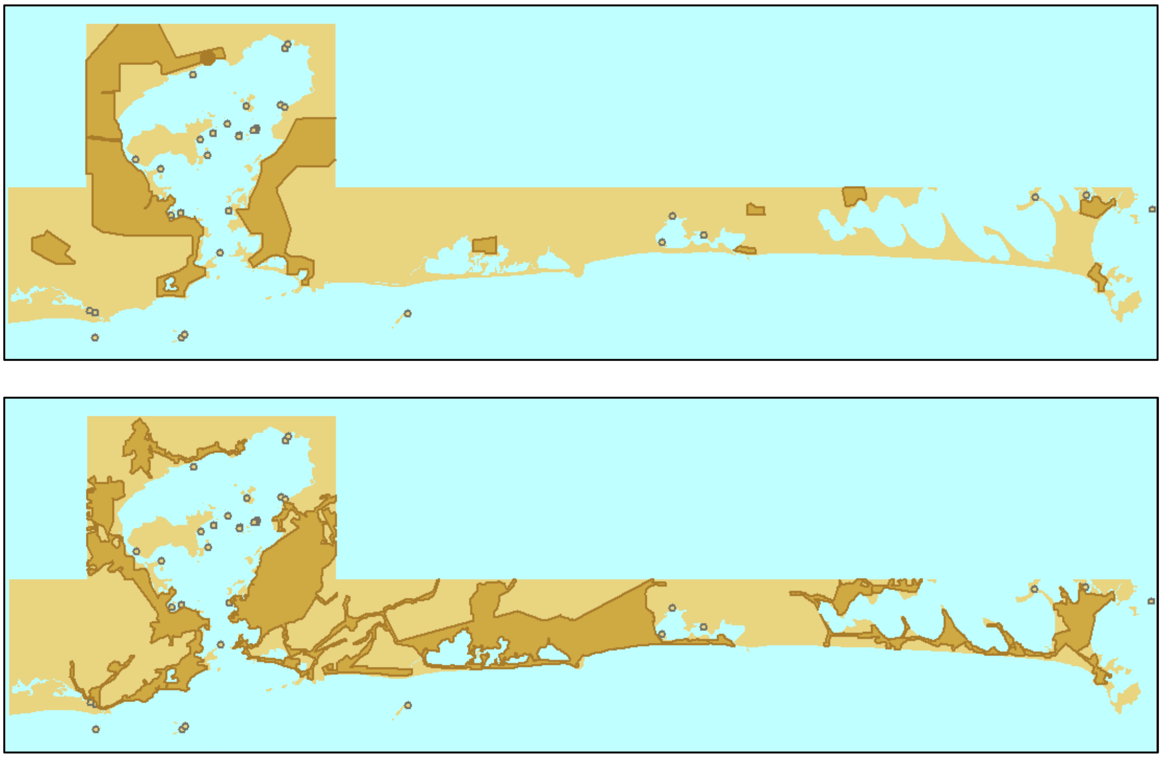

Figure 70 Comparison of the original (above) LNDAREs and those created by means of a road network

This issue cannot be resolved unless there is consistency in depicting urban areas.

- Generalisation does not account for the distance from the shore.

Small settlements close to the shore can be potentially more important than big ones inland.

- No interaction with other objects that might affect the shape of BUAARE.

In most cases roads and certainly not railways, lakes, rivers or channels were not used for generalisation. This is because they have not been considered in the entire generalisation process.

It is possible, however, to easily clip the created BUAAREs with the abovementioned objects.

Open points:

- Are rivers, railways etc. useful on Coastal charts?

6.3.7 OBSTRN

OBSTRN areas were entirely generalised in ArcGIS by means of buffers and clipping with LNDARE.

Positive results:

- Time savings with efficient and effective generalisation.

Mean processing time was less than 5 minutes and could be decreased to sub-minutes if available for S-57 type of data.

- Safety of Navigation.

Overall more OBSTRN areas were selected by the algorithm, than by cartographers on the original charts.

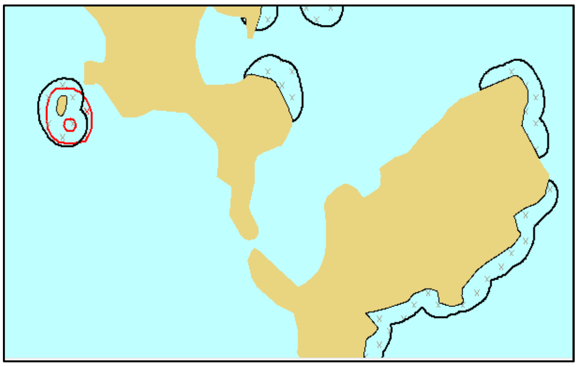

Figure 71 Example of many OBSTRN areas created in place of one on the original chart

- Consistency with Approach datasets

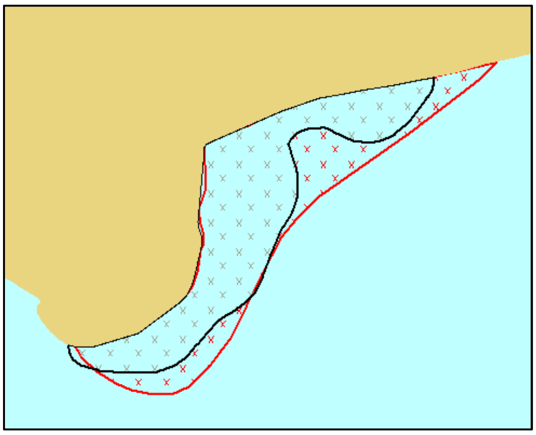

Figure 72 Comparison between generalised (black) and original (red) OBSTRN areas

The shapes of the generalised obstruction areas follow similar geometry as their approach equivalents.

Negative results:

- OBSTRN should not be automatically enlarged, but should follow bathymetry.

It is correct that bathymetric objects should be handled holistically, which was not the case in this research. Surprisingly, however, when one organisation does not want OBSTRN areas to be too enlarged, the other one complains that there is not enough enlargement. There is still a lot of subjective judgement when objects are created. One of the HOs omits detail close to the shore as it is considered that vessels in coastal passage should not navigate in those areas anyway.

- OBSTRN areas are not created as substitute for other objects.

Sometimes information relevant on one scale is no longer important on the other. On a large scale it might be important to indicate that there is a marine farm or a group of rocks but on a smaller scale a simple information that some sort of obstruction exists is enough. Although vector format allows more accurate depiction and the best matching S-57 object should be encoded to describe a feature, in some cases clusters of rocks could be aggregated into an obstruction area (since UWTROC can only be a point object).

Open points:

- How to bypass subjectivity in judgement of OBSTRN areas?
- What about obstruction points?
- How to link generalisation of OBSTRN areas with bathymetry?

6.3.8 MISCELLANEOUS

Miscellaneous object were compared between scales and simply copied to the target dataset where a pattern was found.

This was manual work imitating the use of scale-less layer.

Positive results:

- Possible time savings if patterns can be found.

Details of generalisation can be found in appendices 2-5. Certainly it takes less time to copy feature than to create it manually, but at the present time no fix set of rules could be found.

- Possible efficiencies in data management if objects could be isolated to some sort of scale-independent layer.

All features that are not adjacent to LNDARE could be stored on a scale-less layer and from there maintained and assigned to appropriate usages. This solution is already available – hydrographic offices can create scale-less layers and copy certain objects there, but this is not considered as an automatic generalisation.

Negative results:

- No consistent results could be obtained.

Successful generalisation of an object on one dataset, could be a complete failure on the other.

- No consistency between scales.

Generalisation success was often lowered due to the quality of input. Agencies criticized that not all objects present on the original chart were present on the generalised one or that a piece of object was missing. If an object is not present on the Approach dataset, or if it is wrongly created (with a gap) it is not possible to transfer it into correctly onto the final product.

Open points:

- Why would there be objects missing on the better scale chart that are present on the worse scale?
- Are the objects selected really relevant to coastal navigation?
- What other objects can be transferable?
- How to overcome the problem with objects adjacent to generalised objects (like LNDARE)?

7 EXPERT EVALUATION

This chapter summarizes the evaluation of the resulting maps by the participating agencies. The evaluation was received as a completed questionnaire (Appendix 3-6 b)First general comments are presented, followed by remarks and evaluation about all analysed object classes.

7.1 GENERAL COMMENTS

France

It is very encouraging to finally see results. It is in this area of marine cartography that we lack appropriate tools. Therefore the French office would encourage all initiatives in this direction.

In marine cartography for the generalisation of lines, it is necessary to move the objects "seaward" or to deeper areas. The line generalised is a safe line. This is the most complex criterion to meet, but it is very important.

The generalisation of the bathymetry (COALNE, WRECKS and UWTROC included) should be holistic and not theme by theme. The attempts that were made in these experiments can perhaps give satisfactory and encouraging results, but they would need to be much more complex, taking into account all the issues at once.

For aids to navigation, at SHOM we add an attribute (type of CONVIS) which indicates the importance of objects for navigation. It is this attribute that triggers generalisation during the mapping process. But in the end the cartographer makes the final choice depending on the context.

The generalisation factor (smooth) was perhaps a little too strong for this case (1: 60000 to 1: 170000).

The Netherlands

The results are identified as promising. Although needs to be mentioned that it is a pity that the bathymetry was not generalised, because in every new edition of an ENC the newest bathymetry is included, while changes in the land topography are usually minor. So the generalisation of bathymetry is a recurring event.

New Zealand

The generalisation process produced a land area and coastline which was not completely desirable. However, the auto generalisation routines for de-cluttering of point objects (some rocks and the aids to navigation) were interesting and with perhaps a bit of tweaking could be implemented quite quickly, and generate efficiency improvements.

7.2 ATONS AND LANDMARKS

These are assessments on Safety of Navigation, Aesthetics, Usability and Efficiency versus effects of generalisation provided by the nautical charts experts of the participating organisations. Each category is given a grade from 1 to 10 where 1 means "not acceptable, no chance of using such a solution in this or improved form and 10 means "solution is suitable for immediate use, it meets our production standards, if it got implemented in the chart production software we would incorporate it into our production workflow in a "as is" form." The presented value is the arithmetic mean of individual marks.

Safety of Navigation: 6.5

Comments:

Brazil

Generalisation is considered good, there was only a small displacement of the signals.

France

In the cartographic process of AtoNs, SHOM takes into account not only the structure but also the equipment (LIGHTS, …). Some objects, with a non-important structure, can be selected due to their equipment. In some cases, it is important to select the objects that mark the harbour entrance, even if one of them is not selected. The cartographic process provides to the mariners a selection of the relevant objects according to the navigational purpose.

The Netherlands

A similar approach might be introduced in S-100:

New concept to emulate production database architecture based on two new cell types:

-One containing features without scale e.g. lights, buoys, tracks and some area features.

-The other containing scalable features e.g. coastline and group one features.

Discussion points:

-Will it be more efficient for updates?

-Will distribution be seamless?

-Is this type of data interoperable with data containing both scale dependent and scale independent data?

PILPNT support structures were not included in the algorithm.

New Zealand

The generalisation process has done a reasonable job, and the preventing overcrowding part of the algorithm seems to be a reasonable approach. As mentioned in the questionnaire the algorithm did have issues when it considered a sequence of beacons in an inland water way. If the algorithm could be improved to retain the further most aids to navigation from the coastline could be a way forward.

Aesthetics: 7

Comments:

The Netherlands

First results are considered promising.

New Zealand

The over look and feel appears of high quality. Although overall it seems to have a lot more detail than is required at this scale. Some points to note:

1. There are some areas which manual generalisation might improve the depiction. This seems to be where there is a sequence of aids into port, or harbour – often we would only wish to show the outer most aids. Obviously this may be difficult to achieve through an algorithm.

2. Many stake, pole, perch, post features are shown in NZ3G5322, whereas in a product created by manual generalisation these would be removed for this scale.

Usability (User friendliness): 7.25

Comments:

The Netherlands

The selection process for the AtoNs is considered impressive.

New Zealand

Too much detail at this scale may cause some difficulty reading this chart at this scale.

Efficiency versus effects of generalisation: 6.75

Comments:

Brazil

The position of Aids to Navigation should remain the same after the generalisation.

The Netherlands

The approach still requires a through manual/visual quality control.

New Zealand

The part of the algorithm preventing over-crowding where objects are very close together will save manual effort. However looking at the final result, some manual effort would still be required to de-clutter the aids to navigation for this chart at this scale.

7.3 WRECKS

Safety of Navigation: 9

Comments:

France

It is very important to report all the shoalest objects in an area. The complete process could be an automaticreport completed by a manual deletion of the unwanted objects.

New Zealand

Selection matches existing chart at this scale.

Aesthetics: 9

No comments.

Usability (User friendliness): 9

No comments

Efficiency versus effects of generalisation: 9

No comments.

7.4 UWTROC

Safety of Navigation: 6

Comments:

Brazil

Currently EXPSOU 2 is not used by our organisation, so this error can be disregarded. In some cases the UWTROC did not appear after generalisation. The position of underwater rocks must be maintained.

France

For the points objects the same remarks as for WRECKS can be applied. In some cases UWTROC areas are generalised into points objects.

The Netherlands

The UWTROCs objects on our charts are in an area where most features are omitted. The minimal depiction of detail in this area does not support safe navigation, therefore mariners should use a more appropriate navigational purpose.

New Zealand

Inconsistencies in our existing charting is noted. However, there are (some significant) under water rocks which would better be retained in the generalisation process.

Aesthetics: 6.25

Comments:

New Zealand

There is some quite bad clustering of rocks which covers and uncovers.

Usability (User friendliness): 7.25

Comments:

New Zealand

Not a complete and clear picture of the underwater rocks has been shown by this selection.

Efficiency versus effects of generalisation: 6

Comments:

Brazil

All objects UWTROC should be shown after the generalisation to ensure safety of navigation and the positions should be maintained.

The Netherlands

Since rocks were unnecessarily selected in the areas of minimum depiction, they need to be removed manually.

New Zealand

There would still be quite a bit of manual effort involved in making this selection suitable for charting.

7.5 LNDARE

Safety of Navigation: 2.75

Comments:

Brazil

Much of generalisation was good in shoreline, but had some cases of islands that have disappeared or been displaced.

France

A chart is a thematic map of navigation. Principles cartographic generalisation should be applied, supplemented by the rule of "safety of navigation". It is the application of this rule that is lacking in all current software. It is important to show a mariner that generalisation is correct, it is for him/her a confidence criterion and reliability of nautical document. The results are not acceptable in terms of generalisation. The smoothing factor applied is too high.

The Netherlands

Our policy is to enlarge small islands in the smaller scale, so they remain visible.

Generalisation was not always at the "safe" side. It is our policy to always generalise at the "safe" side.

New Zealand

While the algorithms have in the main done a good job of generalising the LNDARE for representation on a coastal chart, I note the following issues:

1. In some areas the smoothing has 'cut off' land areas, pushing the land area further in land whereas a safer approach to take would be to ensure that the new generalised area only fell to seaward of the land area being generalised.
2. Many significant (possibly named) headlands / points are being omitted. In some cases it has changed the overall shape of the island significantly. As mentioned in case 1, a process to ensure that the new land areas are generalised to the safer (seaward) side may help.
3. A couple areas of small islands which have been omitted, but the one most seaward island should be retained as islets.

Aesthetics: 6.5

Comments:

France

The result does not give a sense of correctly generalised map.

The Netherlands

Generalisation was consistent in the whole ENC.

New Zealand

Apart from some spurious changes to shapes of islands, the overall look and feel of the product appears of good quality. Although it does appears somewhat over-smoothed / generalised when compared to the actual dataset used for this usage.

Usability (User friendliness): 5.75

Comments:

France

There would be too much manual work to recover a cartographically acceptable result.

The Netherlands

There are overlaps and gaps with RESARE, TESARE and ISTZNE. These have to be fixed.

New Zealand

Some ambiguity is present, particular in how some headlands and points are depicted by the land area. Small islets and islands have been omitted where my preference would have been their retention.

Efficiency versus effects of generalisation: 4.75

Comments:

Brazil

Generalisation was efficient in general, but in some cases the spread was not good in the points indicated images.

France

The work of correcting the automatic generalisation would be as significant as the manual generalisation.

The Netherlands

First results are considered promising

New Zealand

The automatic generalisation would save some time during generalisation, although some manual work would still be required to retain some omitted detail. If issue numbers 1 + 2 were fixed above, a much higher score would have been achieved.

7.6 COALNE

Safety of Navigation: 4.25

Comments:

Brazil

In some places it has been found that the attribute is not correct, where the original chart shows COALNE, generalisation shows SLCONS. There were some problems in rivers entries regarding the boundary between Rivers and encounters.

New Zealand

1. As the coastline matches the land area, some safety aspects considered above do apply here too, although these are not scored negative again in this section.
2. The algorithm does a good job of identifying and generating shore line construction elements where they are connected to land area objects, but where they do not abut land areas, they have been omitted. In many cases it is useful to show some sort of generalised version of these in the final product for the mariner.

Aesthetics: 5.5

Comments:

New Zealand

1. Coastline matches the land area, as expected. It has done a reasonable job of generating a generalised version of the mangrove coastline.
2. Algorithms do not appear to take into account shoreline constructions which are not connected to land areas, so these would need to be added manually as mentioned above.
3. The generalised result of some shore line constructions has created some small line segments, which in practice would be better left out. Perhaps a minimum

line length can be used in the algorithm which would omit these and make them part of a continuous coastline instead.

Usability (User friendliness): 6

Comments:

The Netherlands

Many overlapping segments in the lines, and many overlaps/gaps in the area features triggers a lot of edit work.

New Zealand

In general does a good job of depicting the coastline, but the omission of some shore line constructions would be a concern. The removal of some of the short shoreline construction would give a clearer picture.

Efficiency versus effects of generalisation: 4.75

Comments:

Brazil

The attributes must be maintained after the generalisation.

New Zealand

Some manual effort would be required to complete the shore line construction depiction.

7.7 BUAARE

Safety of Navigation: 8.5

Comments:

Brazil

The result was not identical but is similar. This case is not serious because it does not directly affect the safety of navigation.

France

This object class is considered not relevant to the safety of navigation.

The Netherlands

> All important (large, with a harbour or visible from sea) BUAAREs should be charted. A small BUAARE with a harbour can be more important than a large BUAARE far from shore.

Aesthetics: 8.5

Comments:

The Netherlands

> Roads and railways often share geometry with BUAARE. This connection is now gone, and the roads run through the BUAAREs.

New Zealand

> Our depiction of built-up areas is inconsistent. A consistent approach of capture from topography, and some automatic generalisation to smaller scales would make us more consistent.

Usability (User friendliness): 7.66

Comments:

The Netherlands

> BUAAREs now overlap LAKARE, RIVERS and CANALS. This makes edit work necessary. BUAAREs with CATBUA=6 can be removed.

Efficiency versus effects of generalisation: 7.5

Comments:

Brazil

> The result was not identical but are similar. This case is not serious because it does not directly affect the safety of navigation.

New Zealand

> An algorithmic approach to generalisation like this would save quite a lot of manual effort.

Safety of Navigation: 7.25

Comments:

Brazil

> The generalisation of OBSTRN areas was not good in some cases. The original is wider than the final product after generalisation. The OBSTRN should remain unchanged.

New Zealand

> The algorithm has done a reasonable job of simply generalising the obstruction areas, but does not take into account the consideration the context which a cartographer might use.

Aesthetics: 7.75

No comments.

Usability (User friendliness): 6.75

No comments.

Efficiency versus effects of generalisation: 6

Comments:

Brazil

> The generalisation of OBSTRN areas was not good in some cases. The original is wider than the final product after generalisation. The OBSTRN should remain unchanged.

France

> The result object must not be automatically bigger than the source object. The rule by exaggeration to simplistic. The bathymetry objects need to be taken into account as well.

New Zealand

> The algorithm would save a fair amount of manual intervention.

7.9 MISCELLANEOUS

Safety of Navigation: 7.25

Comments:

Brazil

All these objects should be displayed after the generalisation because they are important information for the mariners.

France

NAVLNE and RECTRK are not relevant for this navigation purpose. It makes no sense to report NAVLNE and/or RECTRK without the supporting structures. No remarks on the other objects.

The Netherlands

This part needs to be sorted out better. There are some safety critical features that are missing: OBSTRN (point), OFSPLF, SLCONS and deep water routes.

New Zealand

The algorithm needs to assure that objects which previously abutted land areas, still do so in the generalised dataset

Aesthetics: 8.75

No comments.

Usability (User friendliness): 8.25

Comments:

The Netherlands

The selection process must have been made manually. There is no fixed set of rules.

Efficiency versus effects of generalisation: 7

Comments:

Brazil

All these objects should be displayed after the generalisation because they are important information for mariners.

The Netherlands

Most features are copied, so there is (almost) no generalisation.

8 GENERIC FINDINGS

Many generic findings resulted from this project on automatic generalisation in the nautical domain. To present them in a clearly readable way they are divided into groups: datasets, approach and results oriented.

8.1 FINDINGS ABOUT THE DATASETS

Datasets differed in compilation scales: Brazilian 1:180k – 1:45k, French 1:180k – 1:60k, Dutch 1:90k – 1:45k, New Zealand's 1:90k – 1:22k. Coastal charts of compilation scale 1:90k are closer to Approach charts of 1:60k than to other Coastal charts of 1:180k. Further to that, the spread between a 1:180k (Coastal chart) and 1:45k (Approach chart) is not to be underestimated. For automatic generalisation it is a different leap than to generalise a 1:90k chart from 1:45k datasets.

A difficulty in creating uniform specifications for all charts is in a different importance or character of areas charted. Neuralgic for world trade Europort requires different objects than calm, fisheries and tourism oriented Île de La Réunion. This can be also quoted for charts from different regions. Charts from non-developed areas will differ from those of highly industrialised ones. Charts of such areas also have different number of objects.

The difference in the number of objects or the level of detail can be partially beyond control of Hydrographic Offices. Those who source their data from databases and can allow frequent field inspections or maintain good cooperation with other data collection units are more fortunate than those who source their ENCs from existing paper charts. Those paper charts do not have alternative sources other than survey sheets. The only possibility to verify objects may be in open source satellite or aerial photography. It is clear that all the services do what they can to assure the highest quality of their charts, but cannot do more than what they have.

It is not known what the quality of the datasets used for production is. M_QUAL objects tell only part of the story as CATZOC attribute value often informs only about how the soundings were acquired, not how they were processed and transferred into a chart (although the value should be cumulative). Additionally not all nations provide this information.[22] There is hardly any indication about the quality of the remaining objects. The rarely populated SORDAT and SORIND are not informative enough. For example New Zealand populates the same SORDAT and SORIND for the entire chart and changes SORDAT date with each new edition of the paper chart. In case of late discovery of a ghost object it is very difficult to track down where it got there from. Some HOs do not populate even this attribute.

What is also inconsistent is the use of scale independent databases or layers. Some organisations use scale-less some don't. The next generation hydrographic data transfer

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[22] http://www.iho.int/mtg_docs/com_wg/CSPCWG/CSPCWG6/CSPCWG6-INF1_CATZOC.pdf accessed on the 13th of October 2012

standard and ENC product specification – S-100 and S-101 respectively are likely to promote the use of such layers for point objects. Work on S-101 is in progress. Scale independent layers have many advantages, but the use of scale-less layers within an organisation does not guarantee lack of duplicates. There is still place for improvement.

Nevertheless, the use of scale-less layers should be increased and not only for point objects. At the present time it is not used for limits, routes, cables and restricted areas. This is due to their interaction with other objects, like land areas. Objects adjacent to land should change geometry as the land is generalised. If it would be possible to work around this issue, scale-less layers could bring significant storage and management savings.

8.2 FINDINGS ABOUT THE APPROACH

The project is based on a use case – generalising Coastal chart from the Approach dataset. The choice of those two usages is explained in the introductory chapters, however one needs to realise that the Approach charts only act as a source data, where in reality they are also already generalised. This approach promotes a ladder style of automatic generalisation and it cannot be stated that such an approach is better than the star approach.

There is also a data availability concern when applying a ladder approach. If paper charts are the only source of data, then there are significant data deficiencies as the better the chart's scale the smaller the area covered. Best scale charts cover only harbour areas, which can be considered dots on the ENC world coverage.

One should not assume that the chart would be perfect. It was not possible to achieve the same results as charts were erroneous.

Finally, the project is based on a small sample of datasets and producing agencies. It cannot be taken for granted that other hydrographic authorities follow similar production rules, but it can be considered that the spread of different production techniques covers a vast amount of possibilities.

Other findings about the approach can be divided into three groups: those related to data providers, those about the chosen software and those about the methodology.

8.2.1 FINDINGS ABOUT DATA PROVIDERS

Current chart production methods vary per organisation. This cannot always be overcome, as great costs may be involved. It would be ideal if all hydrographic authorities performed wide-ranging and regular field inspections and sourced their topographic data from up-to-date land mapping agencies' databases. Implementing automatic generalisation tools in such an environment would be almost effortless. In reality, however many hydrographic authorities either do not have the possibility or do not find a business case in using such solution.

The other difficulty for automatic generalisation is the level of flexibility in production that makes charts differ between producing agencies. This, is not only related to specific characteristics of the area, but simply to the fact that hydrographic offices have to supplement the lack of international rules as they see fit. Allowing subgroups of countries mapping areas of similar specific characteristic to develop common production specifications would be more beneficial than giving hydrographic offices free reign over the chart content.

Agency chart specifications, although supplementing international standards, are still loose. Even though many do not realise that and think that specifications are complete, cartographer has a lot of freedom and it could be already seen on the small sample received that two objects representing the same real world feature were encoded differently.

Furthermore, the obtained specifications from responsible authorities were not always clear and consistent. There were not that many specifications received in the first place, but those that were available were rather descriptive and open to interpretation. They emphasised the value of good cartographic practice, rather than giving clear instructions on how features should be encoded. Some of them were also in their maturing state where objects previously encoded with one class, were changed in the next edition.

Generally, the available specifications are often for paper charts and ENCs only follow the same principles. Apart from encouragement to populate quality related attributes, there were no specific rules for ENCs. It is especially disturbing that there was no particular push to benefit from the advantages of ENCs over paper charts.

All those abovementioned constrains could perhaps be lifted with the so called good charting practice. Unfortunately, from author's experience the level of knowledge and experience in chart production teams is not always the same. There are, created by FIG/IHO/ICA Advisory Board on Standards of Competence, profiles for Hydrographic Surveyors and Nautical Cartographers[23] but those are often not met by the HO personnel and there is sometimes a significant gap between cartographers and hydrographers. In some agencies, chart producers are ex-mariners or navy officers, but in others they derive from land applications or fields not related to the sea (Geography, GIS, Land Cartography). They don't understand what the objects signify and what the products will be used for and how. Those persons need more structured and clear international specifications as their own interpretation may lead to erroneous or inefficient encoding of ENC which makes the products either less usable or in the worst case may impede safe navigation.

8.2.2 FINDINGS ABOUT SOFTWARE

The software used in the project is mostly stable and does allow interactive generalisation. Working with the 3 software packages was smooth and intuitive, but prior training is needed to master basic techniques. CARIS is production oriented and there are only few generalisation

[23] http://www.iho.int/iho_pubs/standard/S-5_Ed_11.0.1_06May2011_Standards-Hydro.pdf & http://www.iho.int/iho_pubs/standard/S_8_3rd_Jan_2011.pdf accessed on the 19th of October 2012.

tools, however they involve user on each step. CARIS offers a tailored solution for a very specific production which is the production of ENCs and nautical charts, in general. There was no functionality missing to allow efficient production of charts. Unfortunately, the software crashed several times during the pre-processing of the charts, especially during the ***Cut and Remove*** function. This caused all the preliminary outputs to be lost (as scratch layers are only temporary and active only when the application is open). When repeated, features had to be cut in groups to pick out the one that posed problems and cut it manually. On the automatic generalisation field the software is very limited and offers very basic functionality (for example smoothing with Douglas-Peucker algorithm).

ArcGIS on the other side loses at the starting line for not supporting S-57 data. Nevertheless ArcGIS is not a dedicated chart production software, but rather a multirole tool designed to satisfy most of the users, most of the time. A dedicated generalisation toolbox in the cartography tools contains many generalisation operators, and even adapted to certain, specific tasks (for example Simplify Buildings differs from the Simplify Polygon even though they base on the same generic “simplify” operator). Even with the complex and dedicated tools generalisation in ArcGIS was performed by means of the Model Builder where multiple functions were combined to achieve a satisfactory effect (Appendix 7). However, it needs to be stated that ArcGIS operators returned, in some situations, unexpected and unexplained results (Spatial join not joining the correct fields). Only the final models are included and the unsuccessful attempts are not described as it was not the aim of this research. For some situations an ArcGIS function was not available (or available only on raster data) or additional input variables could not be entered. There is a number of operators that did not work (for example, resolve Building Conflicts) and caused the application to crash.

Although both software packages are considered suitable for this research, it would be worth examining what others have to offer. There is still a lot to improve and implement automatic generalisation tools, especially in the chart production software. There are solutions available on the market, but they are tailored in cooperation with individual clients (1Spatial).

8.2.3 FINDINGS ABOUT METHODOLOGY

Methodology used for this research assured good quality of the final outputs, however it has to be noted that the initial methodology had to be changed due to, among other, software availability, time constrains etc. Another reason for changing the methodology was the apparent need for standardisation. The overall approach is correct and can serve to conduct further research in the field, however author’s knowledge and experience is considered beneficial and previous knowledge of the subject is required to use the methodology correctly. Some decisions were made based not on empirical experiments but author’s experience. This is not to say that otherwise such decision could not be made, but that knowledge and experience shortened the process. Knowledge of related disciplines: cartography, navigation, hydrography, GIS is considered very beneficial for the research. The project itself should have been broader and more complex, using different software platforms, datasets and taking into consideration more objects, however considering the scope and time limitations the content is considered optimal and the quality of results high. Two main lessons learned from using the approach are that a research about "ideal" chart content should have been performed first and that it was not worth to strive so hard for standardisation of the specifications itself. It is the initial chart content that should be better defined. Parameters could be left to the discretion of chart producers. In this research they could be simply adjusted so that charts are as similar as possible to the originals.

8.3 FINDINGS ABOUT THE RESULTS

The success of the automatic generalisation is difficult to assess. Here it was measured by the evaluation performed by the hydrographic offices and similarity to the original charts. However the utmost importance is safety of navigation. Evaluation performed by the hydrographic offices is also subjective – a negative mark if the specification follows the already accepted practice in the hydrographic office and positive if it conforms with the current workflow is not enough to consider a method good or bad. Similarly, if the charts are erroneous – then similarities with the generalised chart would mean that the latter one is erroneous too. The measurement of the real safety of navigation is difficult to establish – one cannot experiment with charts and users to expose them to dangers only for the sake of evaluating a method. It has always been a job of a cartographer to evaluate whether a chart is publishable or not and this is how it was done this time. The research could benefit from the evaluation of chart users, especially experienced locals, but it was not possible to reach them.

The results could have been better if time was allowed to spend with each organisation. E-mail correspondence was not the ideal medium and on-site presence and understanding how production really works could be nothing but beneficial for this project. One also has to remember that results are only based on two software platforms.

This project could not produce full charts due to:

- Scope

Bathymetry and "insignificant" objects were not tackled due to lack of time and dedicated researches taking place in parallel.

- Lack of tools

Some possible automatic generalisation solutions were only modelled as automatic, but were in reality interactive due to lack of tools.

- Complicated to model chart transformations

Although only specific objects were generalised often it can be found that other objects should also be taken into account during generalisation. One of the hydrographic offices, for example mentions that the generalisation of BUAARE does not take into account lakes, roads and other objects, which indeed were not taken into account.

It is considered important that generalisation tools maintain links between objects, otherwise the added value may not be sufficient to justify implementation.

The results are not free from issues related to using two software and hence the necessity to export and transform data. One of the flaws is the inconsistency of the area sizes and distances between them. The algorithms need to be executed on the S-57 data and give output in the same format.

9 CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH

This chapter presents conclusions about the research, followed by recommendations to data providers (section 4.2.1), software vendors (4.2.2) and hydrographic community (4.2.3). The chapter is finalised with a suggestion of additional research.

9.1 CONCLUSIONS

The results of the project produced an analysis scheme, specifications, maps, and evaluation by experts. To conclude this project research questions are answered below.

Which universal computer translatable rules can be created to allow the creation of smaller scale ENCs from a higher scale ENC / S-57 database with none to minimal human intervention?

Rules allowing creation of smaller scale (Coastal) ENCs from higher scale ENC / S-57 data (Approach) are presented in section 3.3. It was possible to create generalisation rules for eight out of nine chosen object groups / themes. Rules created for one of the eight groups did not meet the requirements of the nautical experts and need to be revised. Remaining rules were rated positive with various marks.

Created rules are based mainly on conditional selection, de-cluttering, aggregation, simplification/smoothing and enlargement. Created specification are adaptable and can meet the needs of the majority of data providers. The parameters may need to be adjusted.

The assumption that generalisation of topographic and nautical charts is different was correct. This was proven especially when generalising land area and subsequently coastline. Available tools and rules were often not sufficient. The outline of land was made simpler, but this was not performed with safety of navigation in mind and as a result land was converted into water. New ideas needed to be explored and possible solutions to the problems encountered during generalisation are listed in chapter 6.3. However, the goal of the research was met and rules for 8 groups of objects are created.

What patterns of change in the data can be derived by comparing lower and higher scale charts?

All test datasets were characterised by a lower level of detail and lower number of objects (per overlapping area). Not all objects on the Coastal chart had their equivalents, but they should. On the other hand there were objects on the Approach charts that were not shown on the Coastal scale. This was either a result of a human error or an intentional omission of irrelevant information. Line and area objects on the Coastal chart were simplified and smoother than those on the Approach dataset. Some Coastal charts used minimal depiction areas where Approach charts showed full available detail. Minimum depiction areas were located in closed basins and sometimes near the shore. Groups of objects too close to be clearly presented on a smaller scale chart were aggregated and/or collapsed into a different feature class.

Attribution of the objects did not change in most of the cases. There were two exceptions – when a different CONVIS attribute, because an object was no longer considered conspicuous on a smaller scale and when objects were sourced from different paper charts that did not maintain the same attributes. Where paper charts are the only source for chart production and where the content of ENCs is dictated by those paper charts it is not only difficult to introduce automatic generalisation.

How the content of higher scale charts can be transformed to reflect the content of the lower scale charts? How can this transformation be automatized?

Objects that do not require geometric transformations (points, simple lines and areas, like restricted areas, traffic separation schemes etc.) could be stored on a layer that is independent of scale. Conditional selection (based on location, topological relation and/or attribute(s) value) can be used to automatically assign representations to production (scale dependant) layers.

Objects that require geometrical transformations (other lines and areas) need to be aggregated, simplified/smoothed, collapsed etc. This can be achieved by applying generalisation operators to a base dataset. This can be done with either star or ladder approach. This research does not differentiate between the two approaches, because there was only one pair of datasets, where one was considered as a source and the second as a target.

The current methods of generalisation, used in this research, did not prove to be suitable for ENC generalisation. None of them made use of "safety" constrains. Often, safety constrains had to be forced by allowing additional, artificial buffers. The buffers are artificial, simple geometric enlargements that have arbitrary, uniform values. "Safe" methods should make use of more situational constrains. The same can be said about simplifications. They are based on simple approximations, like Bézier interpolation, Douglas-Peucker algorithm or Wang's bend analysis that simplify data "on both sides". The key to the "safe" line and area generalisation in nautical applications is directional generalisation.

New tools need to be developed to promote and facilitate automatic generalisation. It is not clear who should take the initiative – software vendors may not know what their clients need, but hydrographic offices are also not always aware of what is possible. The author hopes that this research would show a common path, both software vendors and their clients could follow.

Without new tools it is not possible to generalise charts without human interference.

How to standardise the chart content so that tools and parameters used fit many organisations' needs?

Proposed standardisation rules are listed in section 3.3. To standardise chart content one should use reverse engineering and focus on the main and emergency purpose of a chart usage. Available objects should be categorised and those that are considered critical for the chart purpose need to be selected.

For these objects rules need to be set-up regarding the way they should be depicted in various situations. Semantics need to be analysed and clear rules of the use of attributes created. Other objects, that are not critical may be let to the discretion of producing agencies, but a maximum level of detail would help to assure that charts do not differ greatly from country to country.

In theory it is possible to achieve consistent charting practice by standardisation but the producing agencies may be reluctant to give up their own procedures and practices.

To make standardisation efficient not only the usage but other aspects should be considered. Scale ranges per usage are too broad to effectively apply the same standardisation. Specifications created in this research suffer shortcomings due to trying to cluster such a broad range of scales to produce uniform specifications. Smaller chart scale steps should be considered to define a chart's purpose.

Standardisation should also differentiate between areas highly industrialised and more natural. Chart producing organisations should create subgroups and share know-how on the type of areas they produce charts for.

When can these rules be considered successful?

Rules can be considered successful if they allowed obtaining results that satisfy the experts. Results in author's opinion and in the evaluation of the Hydrographic Offices are promising, but work still required. The measurement of the success rate by the satisfaction of the stakeholders is not ideals. Their opinion is subjective and sometimes not clear to understand. One of the experts insists that the positions of points should match the existing Coastal scale chart. One of the advantages of using positions from the Approach chart was that point positions are considered more accurate (vectorisation of paper charts places a point in the centre of a paper chart symbol that due to the scale and cartographic aesthetics might have been moved on a smaller scale charts).

It is possible to achieve time savings with generalisation. Evan at this initial stage of research into ENC generalisation results are encouraging. The development of constrains and semi-manual work on 4 charts took less time than what Hydrographic Offices have indicated is required to compile one chart. On one hand, this effort did not result in a full product, was not validated and did not have to await acceptation by the reseller, but on the other hand, time was also used to create, test and implement tools, that in the regular production would be readily available.

One should not assume that the charts created by means of automatic generalisation would be identical as their benchmarks. It was not possible to achieve the same results as the original charts. This is partially due to the shortcomings of the used generalisation methods, partially due to the lack of tools, but also because the original source charts are erroneous.

The quality of datasets affects the success rate of automatic generalisation. For example lack of or inconsistent attribute values make it impossible to make use of them as constrains for generalisation operators. Specifications may read "Important buildings should not be generalised" but it is not clear, how this importance could be measured. Experience in chart creation could hint making use of CONVIS attribute value, but this value is not always available or specifications may omit the necessity of populating it. Also topology is the key issue. If datasets are sourced from discrete paper charts and their corners do not match, it is very difficult to create a continuous smaller scale chart.

Charts produced with automatic generalisation tools will differ from current products, but their quality, if parameters and tools are appropriate will be better. Paper charts should follow the changes in the improved ENCs not to restrict them to their own imperfections. The users should be well informed about these changes and assured that they are made in their best interest and to improve the content.

9.2 RECOMMENDATIONS

From the conclusions it is clear that further effort is needed to successfully implement automatic generalisation of ENCs. Below are the recommendations dedicated to different groups involved into chart production: data producers, software vendors and hydrographic community.

9.2.1 RECOMMENDATIONS FOR DATA PRODUCERS

First and foremost recommendation for the data producers is to evaluate the use of the maps and standardise the content. Perhaps users should be more actively consulted. Often data producers allow users to contact them, by making their contact details available, or even issuing contact forms in their NtMs, but perhaps reaching out to the users, offering questionnaires or approaching them during conferences would be more efficient. However unwavering the position of the HOs is even without this consultation, they should stay on top of what users need.

In order to standardize chart content, share good charting practice and improve chart production efficiency Hydrographic Offices should increase their cooperation, not only regionally. It is recommended to agree upon how to mark what is important. There should not be situations where one producing agency charts only for example UWTROC: EXPSOU:2, as they are considered the most dangerous and the other charts UWTROC: WATLEV:3 because they are not visible above the water surface. Collaboration with software vendors is also encouraged, as often those parties are not aware of possibilities from one side and requirements from the other side.

Sadly, it was noticed that only few producers source their topographic data from the optimal source, which is Land Mapping Agencies. Cooperation in the coastal zone between those agencies is important not only to assure safety of navigation but also since this zone is boosting with new business activities that require accurate and most up-to-data data both on the coast and seaside. It is difficult to understand why given that there are services maintaining Aids to Navigation and storing accurate and updated data Hydrographic Authorities source their Aids to Navigation from existing paper charts, where even with the most accurate data there is digitization error and excessive human labour involved. Cooperation with other stakeholders to obtain accurate and up-to-date data is highly recommended . It is also advised to investigate about the data’s quality.

The most efficient way to assure data quality is to perform field validations. Those field validations start from field inspections by HO personnel, via contracting up to eventually consulting freely available web mapping services. A popular among land GIS users crowd-sourcing could also be an innovative idea in chart production.

Lastly, what also cannot be underestimated is knowledge about how the charts are used. Employees of Hydrographic Offices cannot simply look at them as mere pictures. Hydrographic Offices should invest in good education about navigation and make sure that employees understand the contents of what they are creating and make it be the most usable. Also, however specialised our world becomes there should not be so huge gaps between cartography and hydrography. Nautical cartographers should have some basic knowledge about hydrographic data processing and its limitations and hydrographers should be aware of the purpose of their work and how it is used further.

9.2.2 RECOMMENDATIONS FOR SOFTWARE VENDORS

It seems that cooperation between academics and software vendors interested in land GIS applications is flourishing. Hydrographic software vendors also cooperate with researchers, but often only on the hydrographic side. More cooperation with GIS oriented academics would be beneficial for those software packages that are used in later phases of hydrographic production.

Among solutions that could be implemented is of course automatic generalisation. As can be seen many operators are ready to be implemented, some of them only need calibration to take into account hydrographic priorities. Apart from those, also tools for scale-less population are lacking. In the environment where hydrographic offices source their point objects from paper charts of various scales and need to deconflict them manually to be able to convert them into a single layer scale independent source, tools for de-conflicting and managing scale-less usages could be very useful. Especially given the advent of the S-101 proposed scale independent point layer.

Edge matching is another problem of hydrographic offices that could potentially be tackled by software vendors. Above all software producers should be proactive and not wait for clients to start knocking at their door with ideas.

9.2.3 RECOMMENDATIONS FOR HYDROGRAPHIC COMMUNITY

Hydrographic Community represented by IHO should make sure more attention is given to automatic generalisation benefits, but above all should encourage the community and initiate the process of tightening chart specifications. It is clear that Hydrographic Offices need certain freedom, as they know the area of their charting responsibility best, but there is still a lot of space for constriction before the specifications become too strict. Hydrographic community should act as mentor and leader in automatic generalisation development, supporting implementation of automatic generalisation especially in those organisations that are just starting their production or transiting to modern methods of chart making. The author encourages tighter cooperation between all parties – Hydrographic Offices, ECDIS producers, software vendors and users.

The last recommendation to the hydrographic community is to promote education about navigation and hydrography and to minister to the good and sensible chart making practices.

9.3 FURTHER RESEARCH

This MSc project is the first step to link advancements in contemporary map production with the needs of hydrographic offices. As such it shows clearly that there is great potential in this niche. Further research is needed to continue the exploration. The author takes the privilege to indicate possible paths of future developments.

Only a small percentage of objects that can appear on the Approach and Coastal charts was analysed. Remaining geo objects excluded from this research need to be described and rules for their generalisation formulated. However, it also needs to be clear which objects are safety critical for a chart at a certain scale and which can be omitted. The generalisation performed in this project was not optimal, because there are links between the analysed and not analysed objects, that, due to the scope restrictions had to be disregarded. A more complex approach is needed to generalise charts while all those connections are maintained.

The scope excluded a major component of all charts – Bathymetry. This field is very interesting for hydrographic offices, as they expect great time saving to be possible to achieve. This has been acknowledged by the scientific world and there are researches taking place (e.g. Guilbert and Zhang, 2012, Peters, 2012). What still is needed is the link between the approached by this research underwater rocks & wrecks generalisation and bathymetric generalisation. Bathymetric solution needs to be approached holistically.

The "safe", "seaward" or "deeper" side is mentioned often when results are evaluated. The generalisation of land areas did not score high as this requirement was not met. As mentioned by SHOM – not respecting this rule is the biggest problem of current hydrographic software. A further research into safety restricted generalisation is recommended. Perhaps the use of 2D double buffering could be considered (Smith, 2003) or any other of the bathymetry designed approaches (Guilbert and Zhang, 2012, Peters, 2012).

One of the difficulties of this project was the difference between relatively surrounded bays, that still are considered "open" and closed basins where Aids to Navigation could be removed. It needs to be investigated how to translate this obvious for a human eye difference to a computer. Dutch Hydrographic Office requested the possibility to use "minimum depiction areas" while automatically generalising a chart. This research could not answer this question.

Finally, it is encouraged to validate or verify proposed values for the constrain so that unanimity is reached.

Apart from Geo objects, partially analysed in this research, meta objects remain an important part of every chart. M_QUAL object, for example, describes the quality of bathymetry based on a current survey reports. Every time bathymetry is recreated, those objects need to be updated as well. The facilitation of their creation could also be beneficial for chart producers. It would be worth considering creating meta objects from the actual geo objects.

This research was based on a case study of two, consecutive usage bands. The same amount of work as for the Approach – Coastal pair is also needed for other usage bands.

On the other hand, perhaps some objects could be generalised using the star approach. This research only used generalisation operators or proposed scale independent storage of data. An interesting approach, yet not tested is the use of smooth tGAP structure. It is a space-scale cube where 2D data is transformed by scale in the third dimension. A cut to the structure extracts either data at a specific scale or a smooth multiscale transition of data, depending on the direction of the cut (Van Oosterom 2009, Van Oosterom and Meijers 2011, Meijers et al. 2012).

Paper charts should follow the advancements of Electronic Navigational charts. The platforms used for chart creation should be combined so that two products have data sourced from the same storage, however generalisation methods will slightly differ. Paper charts have a fixed scale, therefore operators belonging to the cartographic generalisation group, like Enhancement, Displacement, Elimination and Typification (Bader 2001, Foerster 2010) should be explored.

A very important research, partially related to automatic chart generalisation is about defining the perfect level of detail for charts and standardizing its content. S-57 does not enforce any rules on the chart content per scale. Nor does any other publication. S-4 makes a distinction between best scale, medium scale and small scale charts. It is clear that an overview chart will not include single buildings, cranes etc and it is clear that Berting chart will include berth numbers, facilities etc. This knowledge, however isn't very well formalised. Approach and Coastal charts that differ only by one scale step are very difficult to specify the proper content. At the present time it's a subjective decision of each hydrographic office to include or not certain, not safety critical objects - rivers, buildings, lakes, roads. It is clear that safety critical objects need to be included, but it is not clear if, for example, a group of rocks should be presented as a group of rocks or an obstruction area. The weakest point of this research was trying to standardise generalisation rules for all charts, regardless how different their original content was.

All those further developments should have the advent of S-100 Geospatial Standard for Marine Data in mind, however the research can go much further and consider the possible future of charting - 3D presentation. How could the current 2D hydrographic data repository be effectively and efficiently transformed into 3D? – is the question that still awaits answering.

10 LITERATURE (QUOTES) AND RECOMMENDED READING

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11 APPENDICES

11.1 APPENDIX 1 – COLLABORATION REQUEST – E-MAIL SENT TO HOS ON 21.11.2011

Weronika Socha
54a Connaught Terrace
Brooklyn - Wellington
New Zealand
weronika.socha@gmail.com

Dear Sir or Madam,

My name is Weronika Socha and I am a hydrographic and GIS specialist currently working as a nautical cartographer for Land Information New Zealand, The New Zealand Hydrographic Authority. My previous employment was as a trainer at CARIS BV and your address came to me via Mr. Charles de Jongh after the HPD UG meeting held in The Hague earlier this year.

I am writing to seek support for a post-graduate MSc thesis that I am undertaking on the automated generalisation of ENC data from larger scales to smaller scales.

At present, there are no efficient specifications or tools for the automatic generalisation of S-57 data. My thesis project aims to create business rules with specific criteria that could be used to create tools for the automatic generalisation of ENCs. The goal of the research is to collate the requirements of HOs in conjunction with the guidance already contained in S-4 and the author's knowledge in model and cartographic generalisation of topographic maps to create computer translatable rules that would allow the creation of smaller scale/usage ENCs from a higher scale/usage ENC / S-57 data base with minimal human intervention.

The successful completion of this project has the potential to provide benefits to the ENC producer community and flow-on benefits to the users of ENCs. Benefits include:

- Improved production consistency between HO's
- Data consistency between ENC cells at different Navigation Purpose Code levels
- Improved efficiency of production
- Cost reduction
- Improved integrity of data

In order to conduct my research, I am seeking the specifications, workflows and any relevant documentation that you use for ENC production, together with two sample unencrypted .000 ENC files (one being larger scale ENC product data, and the other being smaller scale ENC product data that includes the area covered at the larger scale). I will accept whatever terms and conditions are required regarding the use of the data and documentation. Please, be assured that these will never be used for any purpose other than for the completion of this MSc project.

In the first instance, I kindly request that you reply to me to the e-mail provided (weronika.socha@gmail.com) to confirm your interest. This will enable me to determine whether I can proceed with the Project. I will then send you the summary of my Project Proposal together with more details concerning the requirements.

I would be grateful if you could acknowledge receipt of this letter, even if you are unable to assist me, so that I can confirm that you have received it.

Kind regards,

Weronika Socha

11.2 APPENDIX 2 – SHIPPING TRAFFIC

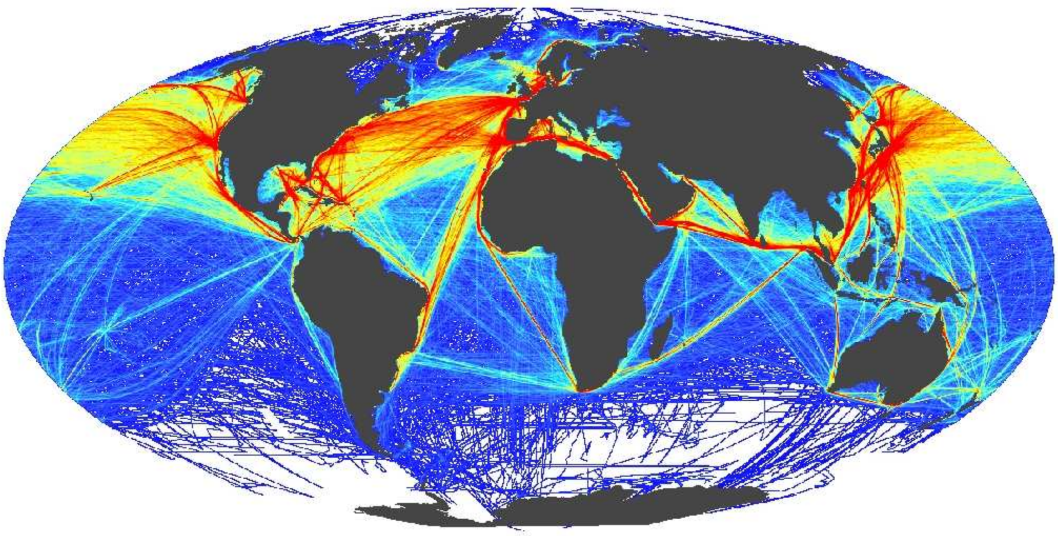


Figure 73 Shipping Traffic http://www.seaweb.org/otherfiles/GlobalShippingImpacts Halpernetal..jpeg accessed on the 16th of October 2012

a) Questionnaire about charts and chart production in your organisation

1. General

In this section I would like to ask about your organisation to get some background about your work.

Resources dedicated to chart production		
Personnel	Paper chart production	***No. of people*** *12*
	ENC production	***No. of people*** *3*
Software		***List types of software used for production and (number of licenses). If an implementation of new software is taking place, please indicate.*** *Microstation V8 (14), CARIS GIS 4.5 (6), CARIS S-57 Composer (3), SevenCs ENC tools (2), Dkart Inspector (2), CARIS HPD Source Editor 2.9 (10), CARIS HPD Paper Chart Editor 2.9 (2), CARIS HPD Product Editor 2.9 (1),*
Portfolio		
Existing charts	National paper charts	***Please indicate how many charts are produced in your premises*** *Maritime: 214 and river: 404*
	INT paper charts	*31*
	ENCs (per usage band)	*2/6 3/21 4/55 5/44 6/1*
	Other (please specify)	*Antarctica: 6*
In or awaiting production	National paper charts	***Please indicate how many charts still await production for a complete coverage*** *Maritime: 8 and river: 30 (2012 / 2013)*
	INT paper charts	*7*
	ENCs (per usage band)	*1/1 2/2 3/6 4/16 5/14*
	Other (please specify)	---
Area of charting		
Charting responsibility over		***Please, provide a brief description of your charting responsibility*** *Coast of Brazil – Brazilian Inland waterways - Antarctica*

2. Chart Production

In this section I would like to ask about the methods and workflows of your chart production. Hopefully this will help me understand better the challenges the office is facing and how those challenges are being dealt with.

This section is marked as confidential and was removed from the final report.

3. Dataset related

Questions in this section were derived from the analyses of the data your organisation provided and are customized for each participant separately.

The answers to these questions will help me verify if my observations discovered flaws in the data that could be improved with the introduction of automatic generalisation or if there was an intention in creating the chart as it is.

Please, if you are aware of other differences between the datasets, let me know.

This section is marked as confidential and was removed from the final report.

4. Automatic Generalisation

Finally in this section I would like to know more about the status of automatic generalisation in your organisation (AG).

Does HO investigate about AG? If so, how?
No. Actually we had this intention some months ago, but people who were about to begin moved to another office.
Are there any attempts of AG in the current workflow?
Only when generating contours from bathymetric database. But we have to create each contour individually, they are not generalised one from another.
What are the main problems with data/production your organisation experiences that could potentially be solved by AG?
Coastlines that need to be smoothed on smaller scales.
What kind of development would you like to see (in terms of automatic generalisation)?
Particularly for coastlines, changing area piers to line ones.

b) Evaluation of the automatically generalised ENCs

1. Introduction

Below you can find a very general description of how each element of the chart was created. Details can be found in the final thesis document that will be available in December. This basic report is expected to help you understand the reasoning behind the results of the automatic generalisation process.

Land Areas

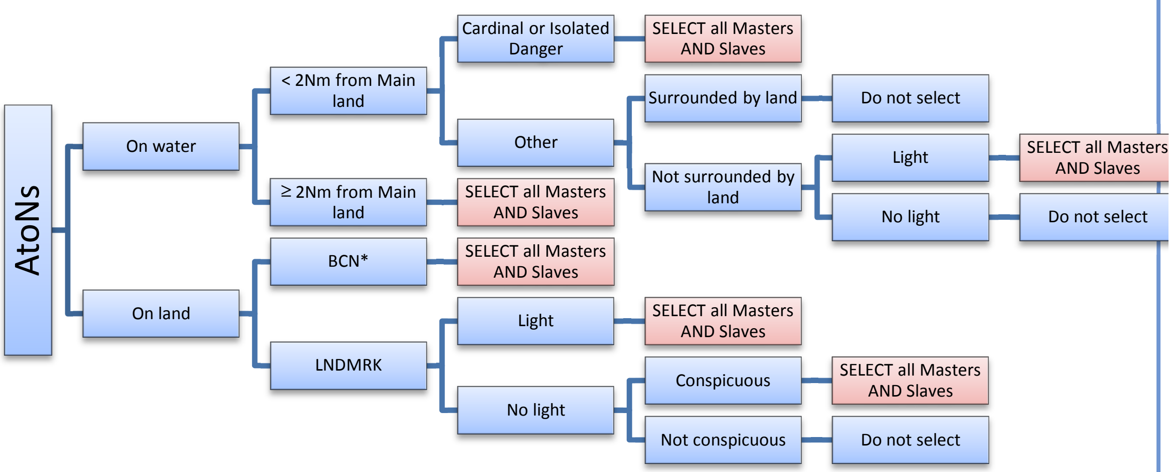
- Land areas were created based on the approach chart LNDARE polygons.
- Approach cell's LNDARE points were considered insignificant and were rejected.
- If land masses were closer than 50m to each other they were aggregated into one object. This is based on the range resolution of marine radars, that do not recognize objects that are closer than 50m as individual features.
- A smoothing algorithm was executed.
- Finally, small islands were collapsed into points.

Coastline - COALNE and SLCONS

- Coastline needs to border LNDARE. It was, therefore, created from the generalised LNDARE polygons and not from the approach cell's coastline.
- To maintain the attributes present in the approach chart, buffers were created around the approach cell's coastline and whenever the generalised coastline intersected the buffer it got assigned all the attributes.
- The coastline was created as COALNE, but for SLCONS coastline buffers were also created, so wherever COALNE intersected a SLCONS buffer, also the feature acronym was changed.

Aids to Navigation and Landmarks

Those objects were selected from the approach dataset, but ideally would be selectable from a scale independent layer. Scale independent usages reduce duplications in the data storage and facilitate data management. They increase the coherence of the products.
Although this was not the subject of this project, it proposes, in the frame of automatic generalisation, an option to detect AtoNs on scale based usages and automatically copy and deconflict them on a scale independent usage. This solution is useful for organisations that already have a scale based storage of AtoNs. This solution was not tested due to the different setting of the project.
The diagram below shows the selection process from the approach AtoNs to those considered relevant for coastal navigation:



To prevent overcrowding the selected AtoNs and Landmarks need to be 6mm[24] (2x3mm buffer around each point) away from each other. If they are closer (if their buffers intersect) deconflictiong and elimination takes place:

a) Based on the presence of RADAR transponder or retroreflector.
b) If they both/all have it, based on structure:
   1. Beacons, Landmarks win over
   2. Buoys
c) If the same, based on purpose:
   1. New danger, Cardinal, Isolated danger
   2. Special, Lateral
   3. Safe Water
d) If the same, based on the presence of a LIGHTS:
   1. Light
   2. No light
e) If they both/all have light (if multiple lights per object, then based on the best light):
   1. Bigger range
   2. Bigger height
   3. Colour (based on light colour visibility range)
      a. White
      b. Red
      c. Orange
      d. Yellow
      e. Green
      f. Blue
      g. Violet
f) If still the same or there is no light, based on shape of the structure (CATLMK and BCNSHP):
   1. Towers, masts and other large structures
   2. Rocks, piles, posts etc

[24] 6mm based on the compilation scale

g) If still the same, based on a topmark:
   1. Topmark
   2. No topmark
h) If still the same, based colour of the structure (see above)
i) If still the same (consider if it is not a duplicate:
   1. Both on water -> remove the one closer to the shore.
   2. Both on land -> remove the one farther from the shore.
   3. One land and one on water -> remove the one on land.

Wrecks

- Wrecks were selected from the approach dataset, but ideally they would be selectable from a scale-independent layer.
- All wrecks that were farther than 200m from the shore were selected.
- Wrecks deeper than 1200m are not selected.

Underwater rocks

- UWTROCs were selected from the approach dataset, but ideally they would be selectable from a scale independent layer.
- Only open water rocks were selected.
- Rocks with EXPSOU:2 (shoaler than the surrounding water) were selected.
- Rocks that were not covered by obstruction areas were selected.

Obstruction Areas

- Obstruction areas were created based on the OBSTRN area objects on the approach chart.
- Obstruction areas were enlarged, aggregated and smoothed.
- Their edges were cut to match the bordering LNDARE.
- Attributes of the approach chart OBSTRN areas were transferred based on the intersection principle.

Build-up areas

- BUAARE were created based on the BUAARE, BUISLG and ROADWAY objects from the approach chart.
- They were enlarged aggregated and simplified. Attributes were transferred.
- Their edges were cut not to go beyond the bordering LNDARE.

Other objects

ACHARE ; ACHBRT ; ADMARE ; CBLSUB ; CBLARE ; CTNARE ; EXEZNE ; FERYRT ; ISTZNE ; MARCUL ; MIPARE ; NAVLNE ; PIPARE ; PIPSOL ; PRCARE ; RADRNG ; RECTRC ; RESARE ; TESARE ; TSELNE ; TSEZNE ; TSSBND ; TSSCRS ; TSSLPT ; TSSRON ; PILBOP ; MAGVAR ; RCTLPT ; RDOCAL were analysed, but not always successfully.

- If similarities were found, objects were copied from the approach chart.
- The only generalisation performed was to eventually adjust the boundary to the current LNDARE for area and line objects.
- Selection differed between the Hydrographic Offices, more details in the results section.
- Ideally, if a pattern can be found between objects on different scales, they could be moved to a scale independent usage and managed from there. This would reduce duplications in the database and increase the coherence in the products. At the present time this component of generalisation is semi-interactive.

2. Evaluation

Now, please open the hob files provided. BR323X00.hob is the combination of the original Coastal usage ENCs that you had sent at the beginning of my research. I have combined them, and cut to the extents of the Approach datasets (to make the datasets comparable). BR323G00.hob is the automatically generalised chart. I would like you to evaluate and comment each component of the generalised dataset. Four main subjects of evaluation I would like you to consider are:

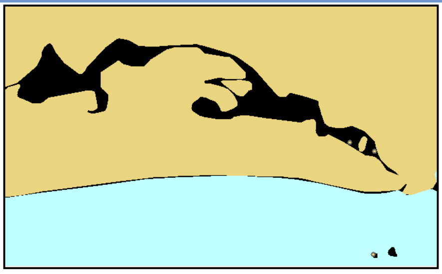
- Safety of Navigation
  Does the depiction meet safety requirements of a nautical chart of that usage? Is the level of detail and accuracy sufficient for the mariner to undertake safe coastal navigation?
- Aesthetics
  Is the component's generalisation aesthetically pleasing giving the final product a feeling of high quality and professionalism?
- Usability (User friendliness)
  Is the chosen depiction clear, does it leave any ambiguity and is it easy to get the desired information from the chart?
- Efficiency versus effects of generalisation
  Does the algorithm provide time and efforts savings in the process of ENC production? Can you see the added value of choosing the automatic solution against the interactive (manual) generalisation? I am aware that most of the proposed solutions are currently not available, but had they been made available, would you consider using them? If a solution is not perfect, do you consider that manual adjustments could take less time that full interactive generalisation?

Please, give to each component a grade form 1 (not acceptable, no chance of using such a solution in this or improved form) to 10 (solution is suitable for immediate use, it meets our production standards, if it got implemented in the chart production software we would incorporate it into our production workflow in a "as is" form).

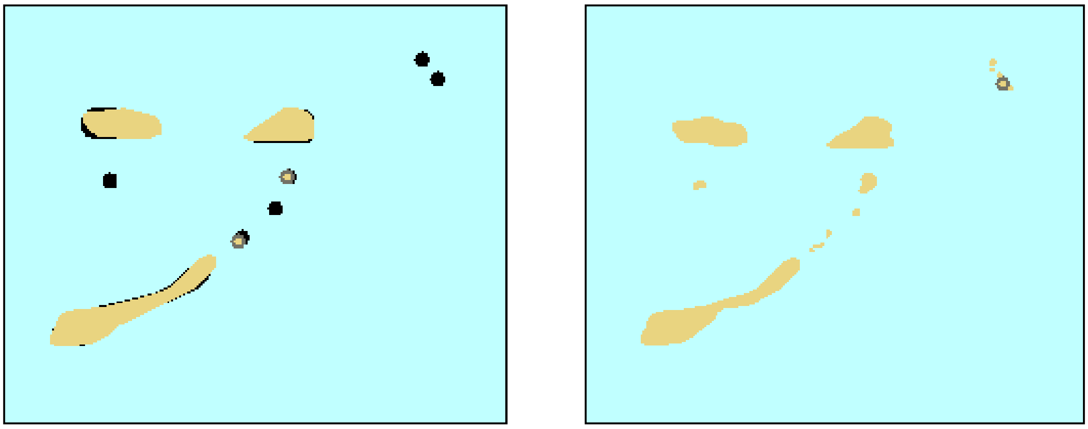
I recommend you to compare the datasets thoroughly, nevertheless I have allowed myself to make some comments about the shortcomings (but also some advantages) that were the most obvious for me.

Please, note that you may find instances where edges minimally do not match. This problem is due to format changes and using two incompatible software. After importing the data into S-57 the edges no longer match perfectly. Had all the operations been performed directly in CARIS, this would not have happened.

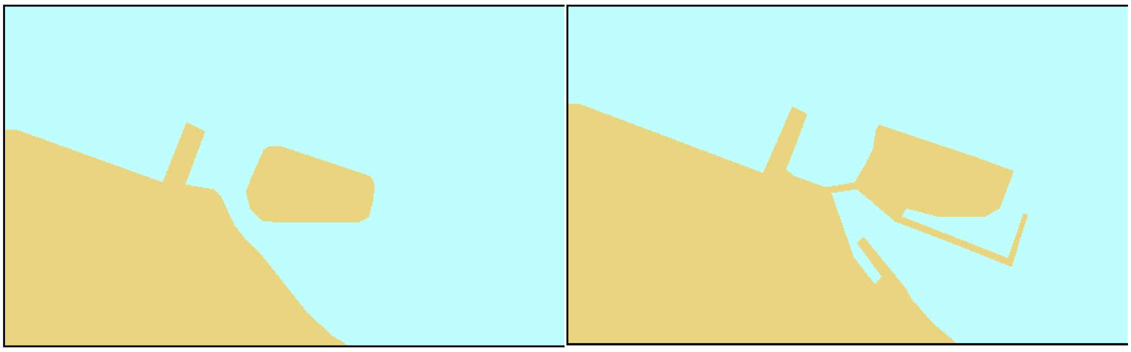
LNDARE
Even the overview between the two charts shows that there are significant differences between the generalised and original LNDARE. The main difference is in the lagoons. Some of them have been removed from the Coastal chart. The algorithm was not able to repeat this. The second difference is in the selection of islands to be charted, mainly in the internal basin. The overall geometry of the remaining areas is very similar to the original coastal chart. Here are the most interesting problems:



Comparison between the generalised (buff colour) and original (black) LNDARE in the depiction of lagoons.



Comparison between the generalised (buff) and original (black) LNDARE in the depiction of islands. The figure on the right is the original approach dataset that had been used for the creation of the generalised one.



Comparison between the original (left) and generalised (right) depiction of detailed long and narrow geometric shapes.

Evaluation

Safety of Navigation: *1-10* - *1*

Comment: Much of generalisation was good in shoreline, but had some cases of islands that have disappeared or been displaced.

Aesthetics: *1-10* - *8*

Comment:

Usability (User friendliness): *1-10* - *10*

Comment:

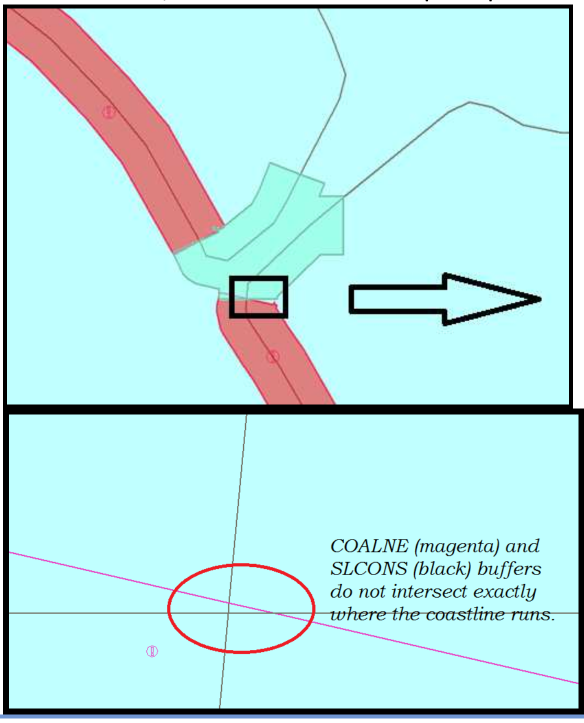
Efficiency versus effects of generalisation: *1-10* - *5*

Comment: was efficient in general, but in some cases the spread was not good in the points indicated images.

Coastline - COALNE and SLCONS

Overall, the coastline is created correctly. The attributes were transferred properly. SLCONS

match the location of shoreline constructions.
The main problem is in the presence of very short lines due to inaccuracies in the algorithm. Where the buffers did not cut the coastline in exactly the same point, little segments got excluded from processing. The same might have happened if the original coastline had many bends which were maintained in the buffer. I am in the process of writing an xml script to QC and correct it, so that it should not pose problems in the future.



Evaluation

Safety of Navigation: *1-10* - *5*

Comment: addition to the issues listed above, in some places the attribute is not correct, where the original was COALNE, changed to the generalisation to SLCONS. In rivers entries were some problems regarding the boundary between Rivers and encounters.

Aesthetics: *1-10* - *5*

Comment:

Usability (User friendliness): *1-10* - *10*

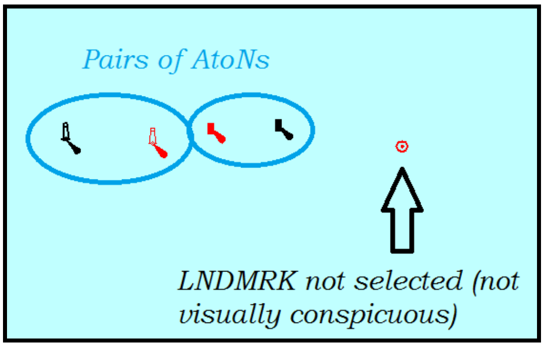
Comment:

Efficiency versus effects of generalisation: *1-10* - *5*

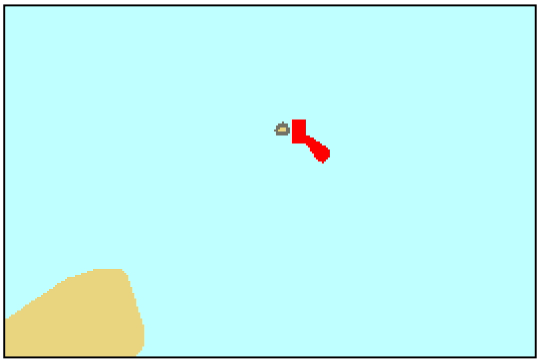
Comment: The attributes must be maintained after the generalisation.

AtoNs and Landmarks

Overall, more objects are present in the automatically generalised dataset. The positions are more accurate and overall selection is more consistent (e.g. only visually conspicuous objects).



Correct selection of AtoNs (black for generalised and red for original). The positions on the generalised chart are more accurate, since they come from a better scale dataset.



Incorrect omission of a beacon due to the generalisation of land. Beacon was not selected by the algorithm (as the beacon is no longer found on land), but is present on the original dataset.

Evaluation

Safety of Navigation: *1-10* - *8*

Comment: In general generalisation was good, there was only a small displacement of the signals.

Aesthetics: *1-10* - *10*

Comment:

Usability (User friendliness): *1-10* - *10*

Comment:

Efficiency versus effects of generalisation: *1-10* - *8*

Comment: the position should remain the same after the generalisation.

Wrecks

All wrecks that are depicted on the original chart are selected also on the automatically generalised one. Generalised one shows more wrecks, in the internal waters that have only a minimal depiction on the original chart.

Evaluation

Safety of Navigation: *1-10* - *10*

Comment:

Aesthetics: *1-10* -*10*

Comment:

Usability (User friendliness): *1-10* -*10*

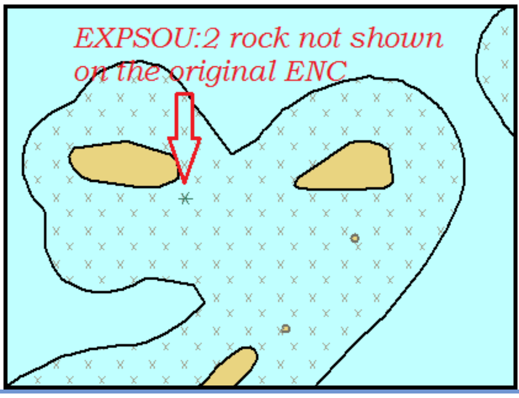
Comment:

Efficiency versus effects of generalisation: *1-10* - *10*

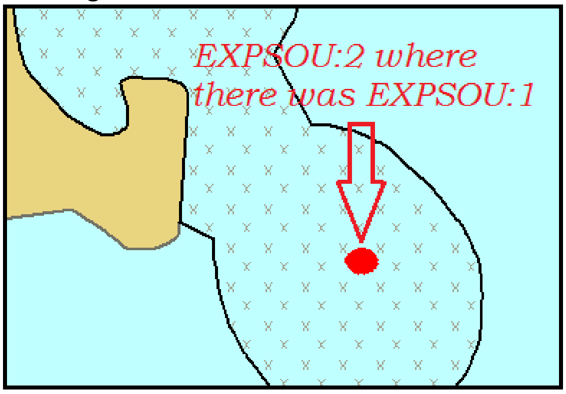
Comment:

Underwater rocks

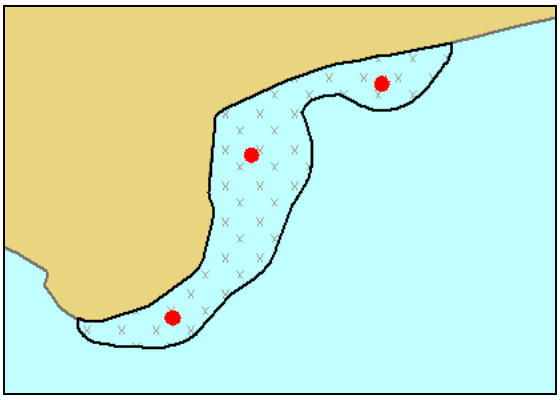
The selection of rocks partially overlaps and partially differs from the selection on the original chart.



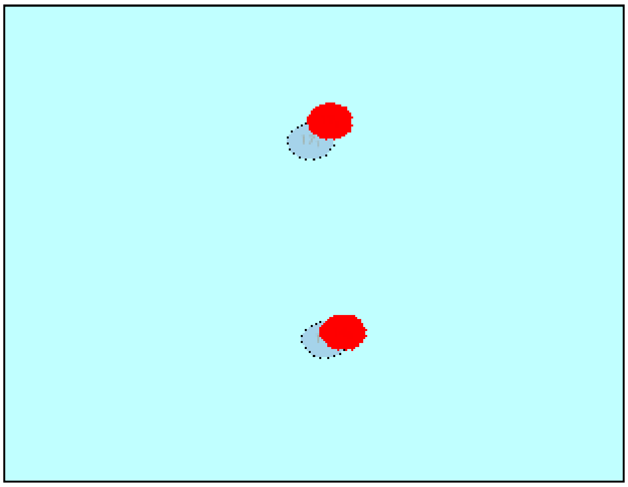
The original chart does not show the rocks that used EXPSOU:2 on the approach chart.



On the other side, it defines some rocks as EXPSOU:2 that were EXPSOU:1 on the approach chart.



The algorithm did not select UWTROCs that did not have EXPSOU:2 and were covered by OBSTRN areas CATOBS: 6 (foul area). The original chart shows them, but does not show OBSTRN area (please, compare with the next component).



In other cases, the same UWTROCs are selected, but the ones sourced from the approach chart are considered to be more accurate in position.

Evaluation

Safety of Navigation: *1-10* - *5*

Comment: Currently EXPSOU 2 is not used, so this error can be disregarded. In some cases the UWTROC not appeared after generalisation. The position must be maintained.

Aesthetics: *1-10* - *10*

Comment:

Usability (User friendliness): *1-10* - *10*

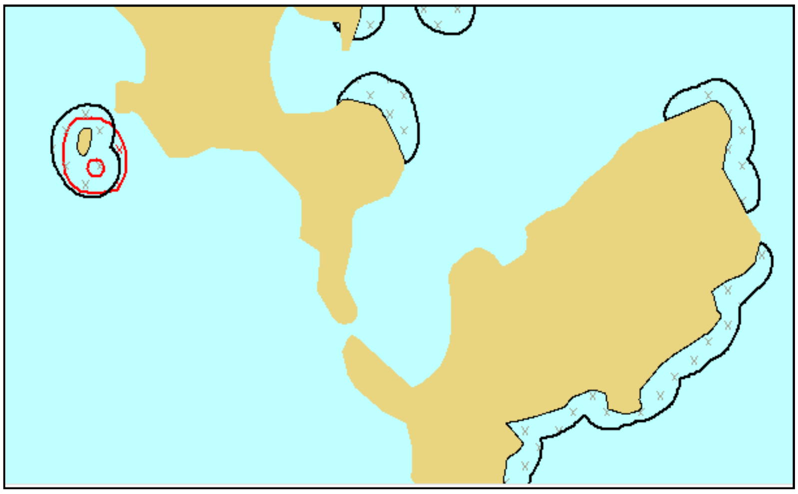
Comment:

Efficiency versus effects of generalisation: *1-10* - *5*

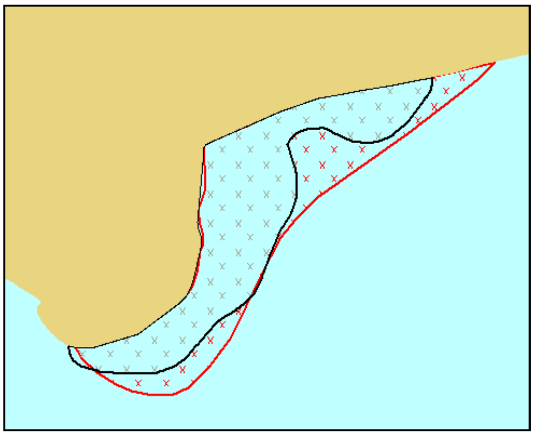
Comment: All objects UWTROC should be shown after the generalisation to ensure safety of navigation, and the positions should be maintained.

Obstruction Areas

Original chart shows much less obstruction areas than the generalised chart. Obstruction areas of CATOBS: 6 trigger alerts in ECDIS and are therefore very efficient to prevent vessel from entering a certain, dangerous area.



Multiple OBSTRN areas are shown on the generalised (black) compared to the original (red) chart.



The original OBSTRN areas are much more generalised than the automatically created ones.

Evaluation

Safety of Navigation: *1-10* - *6*

Comment: OBSTRN areas were not good in some cases the original is wider than the final product after generalisation. The OBSTRN should remain unchanged.

Aesthetics: *1-10* - *10*

Comment:

Usability (User friendliness): *1-10* - *10*

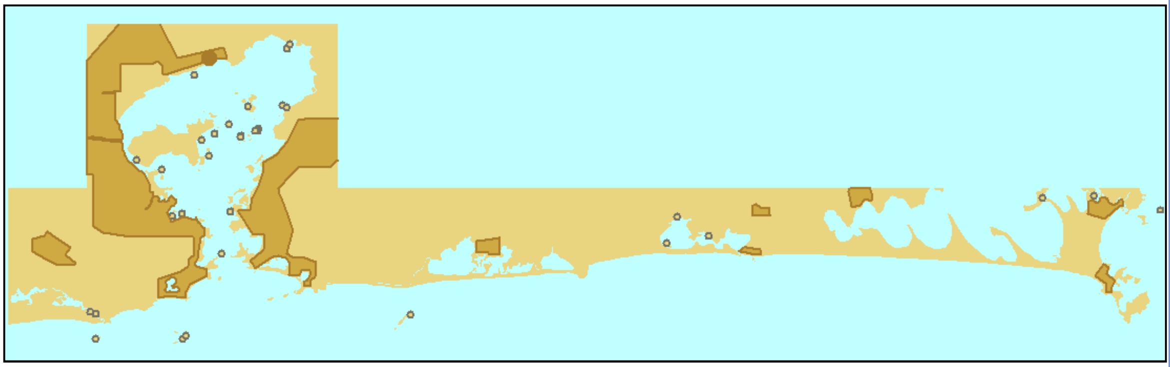
Comment:

Efficiency versus effects of generalisation: *1-10* - *6*

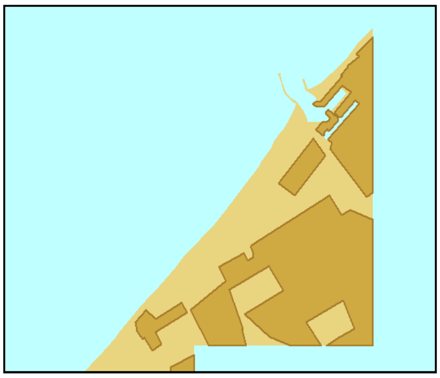
Comment: OBSTRN areas were not good in some cases the original is wider than the final product after generalisation. The OBSTRN should remain unchanged.

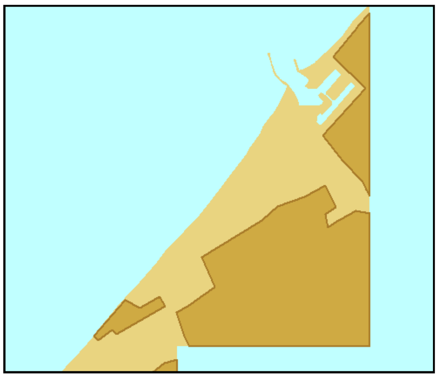
Build-up areas

It was extremely difficult to create build-up areas from the Approach dataset. It did not contain many areas, only point objects, but contained road networks. This was not sufficient to create BUAAREs similar to those on the original chart. Even when the road network was taken into account (in the cases of the other datasets ROADWY were not used) the algorithm was not able to perform well.



For comparison, please see the example of another organisation's chart:





Here, although the results are not identical, they are similar. In case of your organisation's datasets, the results are very much different. Potentially, if parts of the road network could be removed manually(in the central part of the chart), the algorithm would perform better, but no manual adjustments were possible in the scope of this research.

Evaluation

Safety of Navigation: *1-10* - *7*

Comment: The result was not identical but are similar. This case is not serious because it directly affects the safety of navigation.

Aesthetics: *1-10*

Comment:

Usability (User friendliness): *1-10*

Comment:

Efficiency versus effects of generalisation: *1-10* - *7*

Comment: The result was not identical but are similar. This case is not serious because it directly affects the safety of navigation.

Other objects

Out of the mentioned objects only those have been used:
CBLSUB:
There were 23 on the approach chart, but only 4 on the coastal chart. Out of those 4, one was missing on the approach dataset. There was one duplicate on the approach dataset. 3 lines were copied from the approach dataset, the remaining ones were omitted.
CTNARE:
There were 7 on the approach and 4 on the coastal chart, but only two of them overlapped. The rest was subject either to advanced geometry adjustments or incompatible. Two points were copied from the approach dataset.
MARCUL:
There was one on the approach dataset, but none on the coastal. MARCULs have been considered potentially important for coastal chart, therefore one point from the approach dataset was copied.
MIPARE:
Surprisingly there were no MIPARE on the approach charts, but there was one on the coastal. It is assumed that worse scale charts should not have more detail than the better scale ones. Generalisation was not possible.
NAVLNE:
All three objects matched and were copied.
PIPSOL:
There were 19 on the approach and two on the coastal chart. One from those two was missing on the approach chart. Copied the remaining one.
RESARE: 19 on approach, versus 1 on the coastal. Copied the one.

Evaluation

Safety of Navigation: *1-10* - *5*
Comment: All these objects should be displayed after the generalisability because they are important information for the mariners.
Aesthetics: *1-10* - *10*
Comment:
Usability (User friendliness): *1-10* - *10*
Comment:
Efficiency versus effects of generalisation: *1-10* - *5*
Comment: All these objects should be displayed after the generalisability because they are important information for mariners.

3. Other comments

Please, use this space to write any other comments, suggestions or maybe improvements ideas.

Comments

a) Questionnaire about charts and chart production in your organisation

1. General

In this section I would like to ask about your organisation to get some background about your work.

Resources dedicated to chart production		
Personnel	Paper chart production	***28***
	ENC production	***15***
Software	***Currently in use: CARIS GIS, CARIS HOM, LORIK, in-house software*** ***Implementation in progress: CARIS HPD suite (2.9.1), CARIS BDB***	
Portfolio		
Existing charts	National paper charts	***1081(including INT charts) : 607 original + 144 compilation + 330 facsimiles***
	INT paper charts	***126 (included in the 1081 charts)***
	ENCs (per usage band)	***356 : FR1/3 + FR2/20 + FR3/46 + FR4/115 + FR5/123 + FR6/49***
	Other (please specify)	
In or awaiting production	National paper charts	
	INT paper charts	
	ENCs (per usage band)	
	Other (please specify)	
Area of charting		
Charting responsibility over		

2. Chart Production

In this section I would like to ask about the methods and workflows of your chart production. Hopefully this will help me understand better the challenges the office is facing and how those challenges are being dealt with.

How are the ENCs compiled?
ENCs are directly encoded from the existing paper chart : *- by using the digital CARIS file used for paper chart production* *- by using the former digital files (with a brief conversion into CARIS GIS file)* *- by digitizing from the raster file*
Can you describe your workflow for new ENC/new edition compilation

The ENC production workflow starts just after the release of the paper chart.
Three steps :
- *First "the preparation": a study to define how to convert the paper chart objects into S-57 objects, which are the specific rules and/or objects for that ENC… in order to prepare the encoding.*
- *Then "the redaction" : encoding the objects*
  o *The cartographer uses or digitizes the geometry for the future objects. For that, he uses CARIS GIS. The entire geometries are calculated, i.e. the topological relations with GIS.*
  o *Then the S-57 objects are created with CARIS HOM, checked and exported. In the total process, GIS represents 75% of the work and HOM only 25%*
- *Finally, the exported ENC is checked and post-processed by in-house softwares (SCAMIN, custom checks…), by Enc Analyzer (7C's) and by dKart Inspector*
 	
All these steps are checked by different cartographers, managers…
To ensure that paper chart and ENC contain the same objects (eg no sounding is missing), we "draw" the ENC and compare the drawings with the paper chart.

How long does it take to complete the workflow and produce a single ENC?
About 6 months for a new ENC publication, including all the administrative tasks.
What is the production cycle in your organisation?
The cycle depends on the paper chart update: - *all the NtM's for the paper chart are reported on the ENC (by ER if relevant)* - *a new edition of the paper chart is used to update the ENC (by ER or by a new edition)*
Please, describe your data storage and maintenance solution. If you use a database to store vector data on different layers based on usage bands, are objects between scales linked?
Data used for ENC creation are: - *CARIS GIS files* - *Raster files (geotiffs)* - *BDGS: database of wrecks (WRECKS, OBSTRN…) + submarine cables (CBLSUB…) + restricted areas (RESARE, FAIRWY…) + navaids (LNDMRK, LIGHTS, TOWERS, BCNxxx…)*
Is there a scale-less usage employed or is data always associated with the intended product scale? If there is a scale-less usage, how is it populated, what is it used for and which objects are stored on it.
- *The BDGS database is unscaled.* - *The other sources are products, so they have a scale*
ENCs have to be kept up-to-date. When new navigational information is available, how is it handled? How are updates implemented?
First we update the paper chart, then the ENC (see answer regarding the cycle).
What is your data structure? Do you store your data on 6 usage band layers that correspond to the ENC purposes, or do you have in-between layers?
The structure is individuals paper charts, individuals ENC. No layers or usage bands.
When comparing a higher and lower scale chart of the same area, there are obviously differences in content. How are decisions made on which objects should be visible or excluded, generalised, preserved?

We follow the paper chart. Normally, that work is performed during the paper chart publication or edition workflow.
Which international and internal specifications does your organisation follow? What is the level of flexibility for the cartographer to make decisions about the chart content?
For new paper chart publications, we follow the INT/S4 specifications. *But we still have products in former specifications (French specification that is the prototype for the first INT specification and very old specification).*
Are Coastal and Approach usage bands in any way connected?
No.
Does the final user have a say in determining the chart content? Do you survey mariner satisfaction or expectations about your organisation's charts?
Yes. There are 2 users groups representing the users of our documents (one for military purposes and the other for civilian uses). One meeting with SHOM per year.

3. Dataset related

Questions in this section were derived from the analyses of the data your organisation provided and are customized for each participant separately.
The answers to these questions will help me verify if my observations discovered flaws in the data that could be improved with the introduction of automatic generalisation or if there was an intention in creating the chart as it is.
Please, if you are aware of other differences between the datasets, let me know.

I have noticed that the **Coastline** on the Approach cell and Coastal cell differ in geometry. What is the cause of these differences? Was the coastline on the Coastal cell generalised from the Approach cell (or other scale) or are they sourced from different products/datasets?
The good cartographic rules required to generalise the objects from the larger scale (e.g. 1:10 000) to the smaller scale (e.g. 1:25 000). This is the basis of our trainings.
I have noticed that **Aids to Navigation** (point type objects) relating to the same real world feature do not share the same position. Where are they sourced from and how are they attributed? Please, notice the same for other Point type objects, like **Wrecks, Underwater Rocks, Anchorages, Pilot Boarding Places, Land Regions** and **Land Elevation Points.**
To share exactly the same position, the objects must be issued from an unique database. This is the case for the SHOM with the BDGS. But our ENCs have different COMF factor, depending on the scale. This explains the differences on the positions.
I have noticed that **Aids to Navigation** on the Approach cell that are attributed with CONVIS: visually conspicuous are also present on the Coastal cell. On the Coastal cell the same AtoNs are attributed as not visually conspicuous. Please, explain.
This is exact. A LNDMRK can be visually conspicuous at one scale (e.g. 1:10 000) but not visually conspicuous at a smaller scale (e.g. 1:50 000), due to the fact that the two charts (paper or ENC) are not for the same navigational purpose.
I have noticed that all the floating **Aids to Navigation** that are present on the Approach cell, are also maintained on the Coastal one. Those AtoNs do not have any lights. Why is it considered important to maintain all of them on a lower scale chart?
I'm surprised by the question. If the AtoNs objects are present on the Approach or Coastal ENC, their description is complete (i.e. the LIGHTS objects are present if they exists). *Could you please give me an example?*
The issue date of the cells is 2005. I have noticed that there are still some **Depth Areas** line objects present. DEPARE line type objects are no longer considered necessary on ENCs. Do

you agree that they could be removed?

Yes. They are removed on the latest versions of our ENCs, when a new edition is released.

There are **Build-up Areas** on the Coastal cell that do not match the shape of BUAARE referring to the same settlements on the Approach cell. Please, explain.

The objects presents on the ENCs are derived from the corresponding paper chart. The sources used for the paper charts could be different (some are up to date): this explains the possible differences. For example, the topographic source used for the Coastal paper chart could be more recent than the topographic source used for the Approach paper chart.
That is not very important, regarding the safety of navigation.
For bathymetry, we have to be coherent.

I have noticed that **Anchorages, Underwater Cables** and other **Restricted Areas** are preserved on both usage bands, but they do not share the same geometry. The lines run parallel to each other. Is there a reason for such approach, or could these lines share geometry?

I think that this is due to the COMF factor that gives different positions (our ENCs don't have COMF=10 000 000). We are waiting HPD software to solve that issue.

4. Automatic Generalisation

Finally in this section I would like to know more about the status of automatic generalisation in your organisation (AG).

Does HO investigate about AG? If so, how?

Yes but not directly the HO.
Two institutes are currently working on that subject:

- *IRENAV : http://www.ecole-navale.fr/The-Geographical-Information.html*
- *Hong Kong Polytechnic University (Eric Guilbert): some of the results have been presented during the last CARIS conference and he is in contact with CARIS*

Are there any attempts of AG in the current workflow?

No. In our current workflows, we only use routines to remove redundant vertices on lines (based on Douglass-Peucker algorithm) and to decrease the density of soundings.
We don't use any software for soundings selection or generalisation.

What are the main problems with data/production your organisation experiences that could potentially be solved by AG?

Today the cartographers have no efficient automated tools (I prefer semi-automated tools) for generalisation, especially for bathymetry.
To be sure that the "safety of navigation" rules are respected: no software takes that into account today.

What kind of development would you like to see (in terms of automatic generalisation)?

To be short, two kinds of software:

- *To help the cartographer to generalise the bathymetry from the bathymetric database to the products, including "safety of navigation" rules. For example, the filter lines and smoothing tools provided by CARIS BathyDataBase don't take into account the slope to generalise the DEPCNT: in some cases, the 5m DEPCNT could be drawn over 4.5m soundings.*
- *To help the cartographer to generalise the bathymetry from a larger scale to a smaller one.*

b) Evaluation of the automatically generalised ENCs

1. Introduction

Below you can find a very general description of how each element of the chart was created. Details can be found in the final thesis document that will be available in December. This basic report is expected to help you understand the reasoning behind the results of the automatic generalisation process.

Land Areas

- Land areas were created based on the approach chart LNDARE polygons.
- Approach cell's LNDARE points were considered insignificant and were rejected.
- If land masses were closer than 50m to each other they were aggregated into one object. This is based on the range resolution of marine radars, that do not recognize objects that are closer than 50m as individual features.
- A smoothing algorithm was executed.
- Finally, small islands were collapsed into points.

Coastline - COALNE and SLCONS

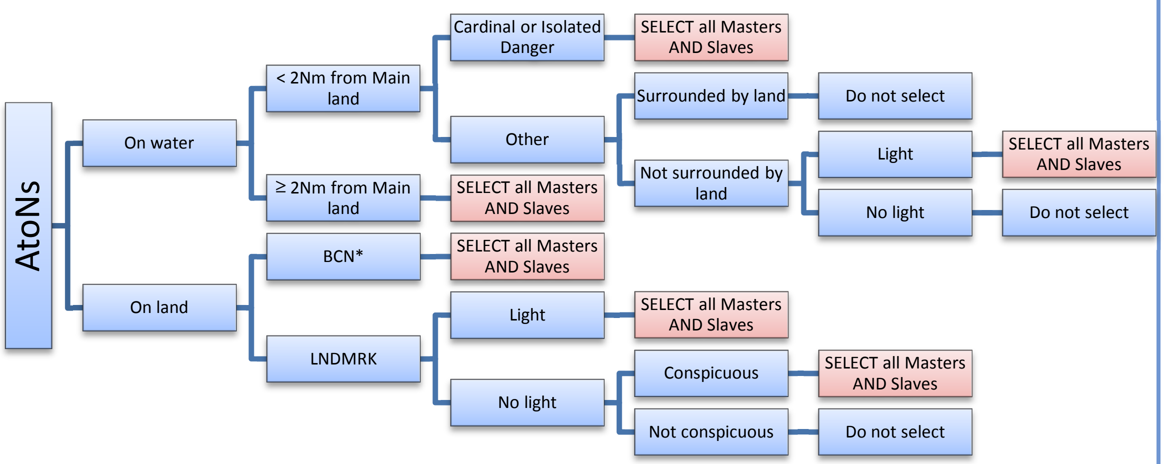
- Coastline needs to border LNDARE. It was, therefore, created from the generalised LNDARE polygons and not from the approach cell's coastline.
- To maintain the attributes present in the approach chart, buffers were created around the approach cell's coastline and whenever the generalised coastline intersected the buffer it got assigned all the attributes.
- The coastline was created as COALNE, but for SLCONS coastline buffers were also created, so wherever COALNE intersected a SLCONS buffer, also the feature acronym was changed.

Aids to Navigation and Landmarks

Those objects were selected from the approach dataset, but ideally would be selectable from a scale independent layer. Scale independent usages reduce duplications in the data storage and facilitate data management. They increase the coherence of the products.

Although this was not the subject of this project, it proposes, in the frame of automatic generalisation, an option to detect AtoNs on scale based usages and automatically copy and deconflict them on a scale independent usage. This solution is useful for organisations that already have a scale based storage of AtoNs. This solution was not tested due to the different setting of the project.

The diagram below shows the selection process from the approach AtoNs to those considered relevant for coastal navigation:



To prevent overcrowding the selected AtoNs and Landmarks need to be 6mm[25] (2x3mm buffer around each point) away from each other. If they are closer (if their buffers intersect) deconflictiong and elimination takes place:

j) Based on the presence of RADAR transponder or retroreflector.
k) If they both/all have it, based on structure:
    3. Beacons, Landmarks win over
    4. Buoys
l) If the same, based on purpose:
    4. New danger, Cardinal, Isolated danger
    5. Special, Lateral
    6. Safe Water
m) If the same, based on the presence of a LIGHTS:
    3. Light
    4. No light
n) If they both/all have light (if multiple lights per object, then based on the best light):
    4. Bigger range
    5. Bigger height
    6. Colour (based on light colour visibility range)
        a. White
        b. Red
        c. Orange
        d. Yellow
        e. Green
        f. Blue
        g. Violet
o) If still the same or there is no light, based on shape of the structure (CATLMK and BCNSHP):
    3. Towers, masts and other large structures
    4. Rocks, piles, posts etc

25 6mm based on the compilation scale

p) If still the same, based on a topmark:
   3. Topmark
   4. No topmark
q) If still the same, based colour of the structure (see above)
r) If still the same (consider if it is not a duplicate:
   4. Both on water -> remove the one closer to the shore.
   5. Both on land -> remove the one farther from the shore.
   6. One land and one on water -> remove the one on land.

Wrecks

- Wrecks were selected from the approach dataset, but ideally they would be selectable from a scale-independent layer.
- All wrecks that were farther than 200m from the shore were selected.
- Wrecks deeper than 1200m are not selected.

Underwater rocks

- UWTROCs were selected from the approach dataset, but ideally they would be selectable from a scale independent layer.
- Only open water rocks were selected.
- Rocks with EXPSOU:2 (shoaler than the surrounding water) were selected.
- Rocks that were not covered by obstruction areas were selected.

Obstruction Areas

- Obstruction areas were created based on the OBSTRN area objects on the approach chart.
- Obstruction areas were enlarged, aggregated and smoothed.
- Their edges were cut to match the bordering LNDARE.
- Attributes of the approach chart OBSTRN areas were transferred based on the intersection principle.

Build-up areas

- BUAARE were created based on the BUAARE and BUISLG objects from the approach chart.
- They were enlarged aggregated and simplified. Attributes were transferred.
- Their edges were cut not to go beyond the bordering LNDARE.

Other objects

ACHARE ; ACHBRT ; ADMARE ; CBLSUB ; CBLARE ; CTNARE ; EXEZNE ; FERYRT ; ISTZNE ; MARCUL ; MIPARE ; NAVLNE ; PIPARE ; PIPSOL ; PRCARE ; RADRNG ; RECTRC ; RESARE ; TESARE ; TSELNE ; TSEZNE ; TSSBND ; TSSCRS ; TSSLPT ; TSSRON ; PILBOP ; MAGVAR ; RCTLPT ; RDOCAL were analysed, but not always successfully.

- If similarities were found, objects were copied from the approach chart.
- The only generalisation performed was to eventually adjust the boundary to the current LNDARE for area and line objects.
- Selection differed between the Hydrographic Offices, more details in the results section.
- Ideally, if a pattern can be found between objects on different scales, they could be moved to a scale independent usage and managed from there. This would reduce duplications in the database and increase the coherence in the products. At the present time this component of generalisation is semi-interactive.

2. Evaluation

Now, please open the hob files provided. FR332010.hob is the original Coastal usage ENC that you had sent at the beginning of my research. I have cut it to the extents of the Approach dataset (to make the datasets comparable). FR33201G.hob is the automatically generalised chart. I would like you to evaluate and comment each component of the generalised dataset. Four main subjects of evaluation I would like you to consider are:

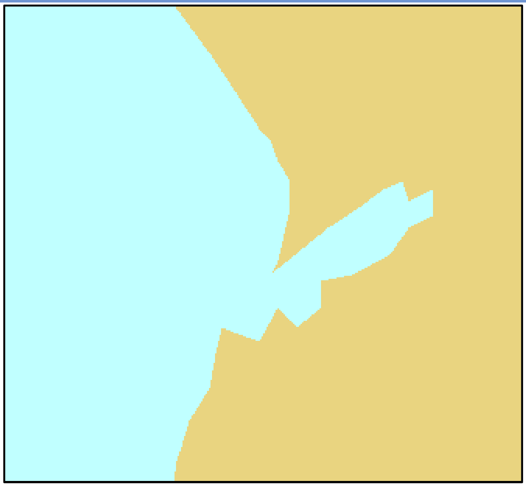
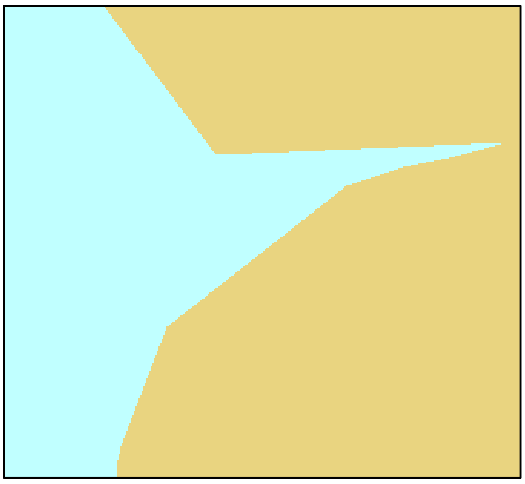
- Safety of Navigation
  Does the depiction meet safety requirements of a nautical chart of that usage? Is the level of detail and accuracy sufficient for the mariner to undertake safe coastal navigation?
- Aesthetics
  Is the component's generalisation aesthetically pleasing giving the final product a feeling of high quality and professionalism?
- Usability (User friendliness)
  Is the chosen depiction clear, does it leave any ambiguity and is it easy to get the desired information from the chart?
- Efficiency versus effects of generalisation
  Does the algorithm provide time and efforts savings in the process of ENC production? Can you see the added value of choosing the automatic solution against the interactive (manual) generalisation? I am aware that most of the proposed solutions are currently not available, but had they been made available, would you consider using them? If a solution is not perfect, do you consider that manual adjustments could take less time that full interactive generalisation?

Please, give to each component a grade from 1 (not acceptable, no chance of using such a solution in this or improved form) to 10 (solution is suitable for immediate use, it meets our production standards, if it got implemented in the chart production software we would incorporate it into our production workflow in a "as is" form).

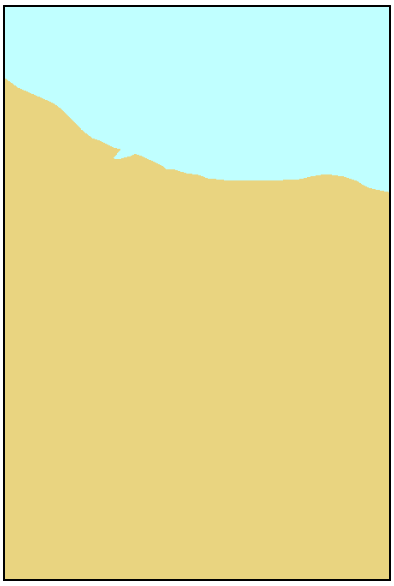
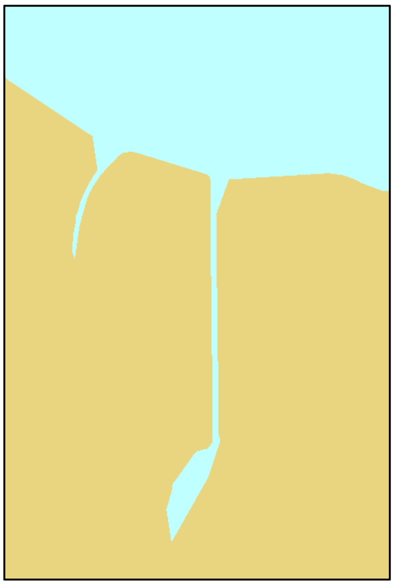
I recommend you to compare the datasets thoroughly, nevertheless I have allowed myself to make some comments about the shortcomings (but also some advantages) that were the most obvious for me.

Please, note that you may find instances where edges minimally do not match. This problem is due to format changes and using two incompatible software. After importing the data into S-57 the edges no longer match perfectly. Had all the operations been performed directly in CARIS, this would not have happened.

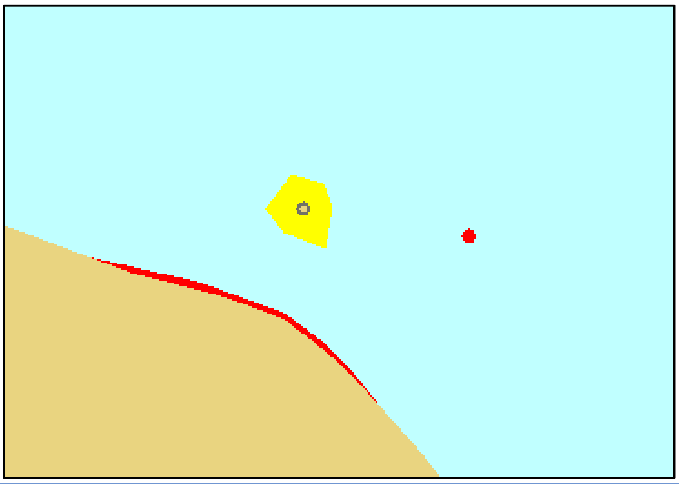
LNDARE
Details show that the coastline of the generalised chart is more smooth than in the original chart. This is considered as an advantage, since the additional detail cannot be appreciated due to a small compilation scale. This smoothnes, however, is not advantageous in all the situations. In the example below a basin became perhaps oversimplified. At the compilation scale the detail is not that easy to appreciate (around leftmost corner of the island), but in the emergency situation a mariner looking for a shelter may want to have a more detailed picture.

The next example shows how the cartographer had considerred the river not to be navigable whereas the algorithm preserved it.

The last detail worth mentioning is the depiction of the only island in the generalised area. The algoritm’s result reflects well the decision taken also by the cartographer to collapse an area feature into a point. The cartographer digitised the island based on the existing scanned paper chart. This led to a positional error (red dot). The island automatically generalised from the better scale chart assures that there is consistency between usages.



Evaluation

<u>Safety of Navigation: *1*</u>

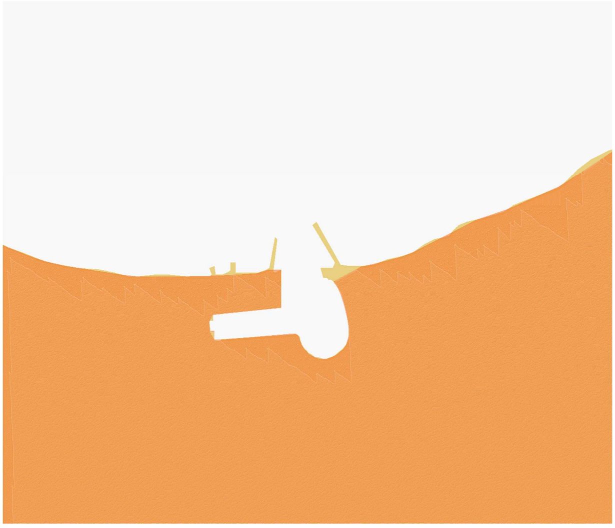
Comment: Une carte marine est une carte thématique de navigation. Les principes de généralisation cartographiques doivent s'appliquer, complétés par la règle « de sécurité de la navigation ». C'est l'application de cette dernière règle que fait défaut dans tous les logiciels actuels.

Il est important de montrer au navigateur que la généralisation est correcte ; c'est pour lui un critère de confiance et de fiabilité du document nautique.

Concernant le résultat (FR33201G .hob en orange), les résultats ne sont pas acceptables en termes de généralisation. Quelques exemples :

– Dans ce cas il ne faut pas généraliser « par suppression », d'autant plus que les détails supprimés le sont « vers la mer » ou le large.

– Dans ce cas des détails importants sont supprimés à l'entrée du port.



– Dans ce dernier cas, l'embouchure de la rivière n'est plus clairement représentée.

J'ai l'impression que le facteur de lissage que tu as appliqué est trop important.

Aesthetics: *3*

Comment: Le résultat ne donne pas le sentiment d'une carte correctement généralisée.

Usability (User friendliness): *1*

Comment: Il y aurait trop de travail de reprise manuelle pour un résultat cartographiquement acceptable.

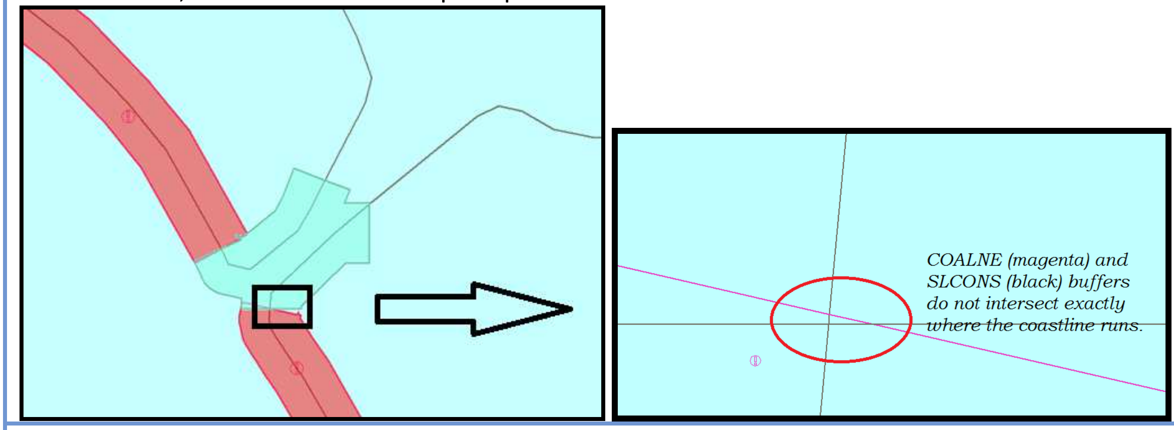
Efficiency versus effects of generalisation: *1*

Comment: Je pense que le travail de correction de la généralisation automatique serait aussi important que la généralisation manuelle.

Coastline - COALNE and SLCONS

Overall, the coastline is created correctly. The attributes were transferred properly. SLCONS match the location of shoreline constructions.

The biggest problem is in the presence of very short lines due to inaccuracies in the algorithm. Where the buffers did not cut the coastline in exactly the same point, little segments got excluded from processing. The same might have happened if the original coastline had many bends which were maintained in the buffer. I am in the process of writing an xml script to QC and correct it, so that it should not pose problems in the future.



Evaluation

Safety of Navigation: 1

Comment: See my comments on LNDARE objects.

Aesthetics: 3

Comment: See my comments on LNDARE objects.

Usability (User friendliness): 1

Comment: See my comments on LNDARE objects.

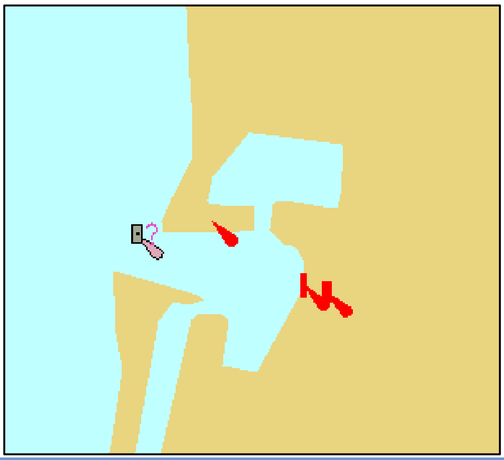
Efficiency versus effects of generalisation: 1

Comment: See my comments on LNDARE objects.

AtoNs and Landmarks

Most of the AtoNs and landmarks selected by the algorithm have their equivalents in the original chart. Apart from the two non-visually conspicuous landmarks that have been omitted in the generalised chart, the main differences are due to the second step of generalisation, which is the removal of the congested objects. Some AtoNs that are present in the original chart have been also preselected but were then removed in favour of "stronger" objects in vicinity on the generalised chart.

There is a case where a very strong light has been omitted from the generalised chart, as its support structure is PILPNT that was not considered during this research.



Evaluation

Safety of Navigation: *5*

Comment: In the cartographic process of AtoNs, we take into account not only the structure but also the equipments (LIGHTS, …). Some objects, with a non important structure, can be selected due to their equipments.

In some cases, it is important to select the objects that mark the harbour entrance, even if one of them is not selected (see La Possession north to Port Reunion).

The cartographic process provides to the mariners a selection of the relevant objects according to the navigational purpose.

Aesthetics: *5*

Comment:

Usability (User friendliness): *5*

Comment:

Efficiency versus effects of generalisation: *5*

Comment: See general comment on §3.

Wrecks

All wrecks that are depicted on the original chart are selected also on the automatically generalised one.

Evaluation

Safety of Navigation: *8*

Comment: It is very important to report all the shoalest objects in an area.

The complete process could be an automatically report completed by a manual deletion of the unwanted objects.

Aesthetics: *8*

Comment: No remarks : the safety is more important than the aesthetics

Usability (User friendliness): *8*

Comment: No remarks.

Efficiency versus effects of generalisation: *8*

Comment: No remarks.

Underwater rocks

The selection of rocks partially overlaps and partially differs from the selection on the original chart.

There is more UWTROCs on the generalised chart, but this is not cluttering the view.

Evaluation

Safety of Navigation: *7*

Comment: For the points objects, see my remarks for WRECKS. Please note that in some cases, UWTROC areas are generalised into points objects.

Aesthetics: *7*

Comment: No remarks : the safety is more important than the aesthetics

Usability (User friendliness): *7*

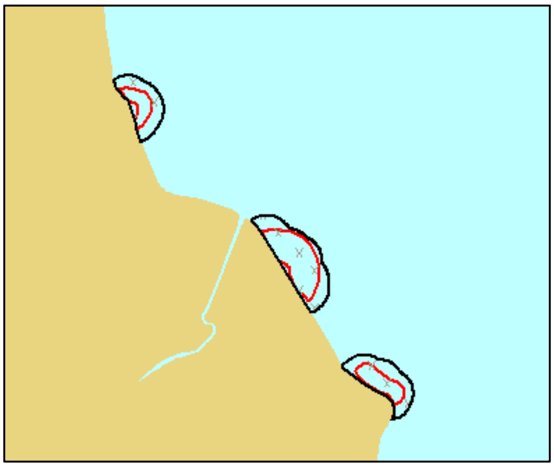
Comment: No remarks.

Efficiency versus effects of generalisation: *7*

Comment: No remarks.

Obstruction Areas

Original chart shows much less obstruction areas than the generalised chart. Obstruction areas of CATOBS: 6 trigger alerts in ECDIS and are therefore very efficient to prevent vessel from entering a certain, dangerous area.



Generalised OBSTRN areas (black) are bigger and match the LNDARE.

Evaluation

Safety of Navigation: *7*

Comment:

Aesthetics: *7*

Comment:

Usability (User friendliness): *2*

Comment:

Efficiency versus effects of generalisation: *2*

Comment: The result object must not be automatically bigger than the source object (see FR332010). The rule by exaggeration is not enough. You have to take into account the bathymetry objects (see my general remark).

In some cases, we delete the object (no representation).

Build-up areas

Although this is not a safety critical category, BUAAREs match the original dataset quite well and are more consistent with the shape of the approach ENC ones.

Evaluation

Safety of Navigation: *10*
Comment: Not relevant.
Aesthetics: *9*
Comment: No remarks.
Usability (User friendliness): *9*
Comment: No remarks.
Efficiency versus effects of generalisation: *7*
Comment: No remarks.

Other objects

Out of the mentioned objects only those have been used:
ACHARE:
All objects from the approach dataset were copied to the generalised one. There is one extra object on the original chart that was not present on the approach chart.
CBLSUBL:
All three objects were copied.
CTNARE:
All two objects were copied.
MARCUL:
One object copied.
NAVLNE:
There were no NAVLNE objects on the original chart, but NAVLNE objects have been considered potentially relevant for Coastal navigation and the ones from the approach chart have been copied. Due to the generalisation of AtoNs however there are no structures that the NAVLNE can refer to.
RECTRC:
Similar to NAVLNE. There were none, but two objects were copied anyway for the consistency between different charts and Hydrographic Offices.
RESARE:
There was one and one was copied. Edges were matched with the existing LNDARE.
PILBOP:
Two objects copied as per original chart.
MAGVAR:
Surprisingly the original chart did not have any MAGVAR points. Two were copied from the approach chart.

Evaluation

Safety of Navigation: *8*
Comment: NAVLNE : if structures are not relevant for the navigational purpose, NAVLNE and RECTRK are not relavant. That makes no sense to report NAVLNE and/or RECTRK without the structures.
No remarks on the other objects : I focussed on the other themes.
Aesthetics: *8*
Comment: No remarks.
Usability (User friendliness): *8*
Comment: No remarks.
Efficiency versus effects of generalisation: *8*
Comment: No remarks.

3. Other comments

Please, use this space to write any other comments, suggestions or maybe improvements ideas.

Comments
J'ai discuté avec mes collègues cartographes et nous arrivons tous aux mêmes conclusions. En cartographie marine, pour la généralisation des lignes, il ne faut déplacer les objets que « vers le large » ou vers les zones les plus profondes. La ligne généralisée est une ligne sécuritaire. C'est le critère le plus complexe à respecter mais il est très important. La généralisation de la bathymétrie (COALNE, WRECKS et UWTROC inclus) doit se faire dans son ensemble et non pas thème par thème. Les essais que tu as réalisés peuvent peut être donner des résultats satisfaisants et encourageants mais cela serait beaucoup plus complexe en prenant en compte tous les thèmes à la fois. Pour les aides à la navigation, au SHOM nous ajoutons un attribut (genre CONVIS) qui indique l'importance des objets pour la navigation. C'est cet attribut que sert de bribe de généralisation lors du processus de cartographie. Mais au final le cartographe reste maitre du choix final en fonction du contexte. J'ai aussi l'impression que le facteur de généralisation (smooth) fut peut être un peu trop fort pour le cas présent (de 1 :60000 à 1 :170000). Mais c'est très encourageant de voir enfin des résultats. C'est dans ce domaine de la cartographie marine que nous manquons cruellement d'outils adaptés. J'encouragerai toutes les initiatives allant dans ce sens.

a) Questionnaire about charts and chart production in your organisation

1. General

In this section I would like to ask about your organisation to get some background about your work.

Resources dedicated to chart production		
Personnel	Paper chart production	***4***
	ENC production	***2***
Software		***Caris S-57 Composer 2.3 (4)*** ***Soon we are going to use Caris HPD.***
Portfolio		
Existing charts	National paper charts	***16***
	INT paper charts	**20**
	ENCs (per usage band)	*1/0, 2/1, 3/6, 4/19, 5/43, 6/5*
	Other (please specify)	**8 small craft charts (1800 series)**
In or awaiting production	National paper charts	***0***
	INT paper charts	**0**
	ENCs (per usage band)	**0**
	Other (please specify)	**0**
Area of charting		
Charting responsibility over		***North Sea, Antilles and Suriname***

2. Chart Production

In this section I would like to ask about the methods and workflows of your chart production. Hopefully this will help me understand better the challenges the office is facing and how those challenges are being dealt with.

How are the ENCs compiled?
Topo and bathy is stored in the TLDB database (Caris GIS-files at scales 1:10000, 50000, 100000, 150000 and 375000). Navigation marks (lights, buoys, wrecks, obstructions, cables, pipelines, nature reserves, etc.) are stored in the HDB database (Oracle with a Caris GIS export function). The ENC is compiled from these two databases.
Can you describe your workflow for new ENC/new edition compilation
Topo is imported from the TLDB-file (conversion Caris GIS to S-57). Area features are created (LNDARE, BUAARE, LAKARE, etc.). Bathy is imported from the TLDB-file (conversion Caris GIS to S-57). Area features are created (DEPARE). HDB-file is imported (conversion Caris GIS to S-57). Include notes from paper chart to ENC. Check for other information in the paper chart that should also be included in the ENC. Run the validation checks. Apply SCAMIN and check the CATZOC. Run external validation checks. Internal verification by people from TLDB and HDB.

Load the ENC into our ECDIS, and upload the ENC to IC-ENC. IC-ENC checks and distributes the ENC.
How long does it take to complete the workflow and produce a single ENC?
Between 4 and 8 weeks (from start to release).
What is the production cycle in your organisation?
A new edition is produced when necessary.
Please, describe your data storage and maintenance solution. If you use a database to store vector data on different layers based on usage bands, are objects between scales linked?
All our data is scale related. Topo and bathy is stored in the TLDB database (Caris GIS-files at scales 1:10000, 50000, 100000, 150000 and 375000). Navigation marks (lights, buoys, wrecks, obstructions, cables, pipelines, nature reserves, etc.) are stored in the HDB database (Oracle with a Caris GIS export function).
Is there a scale-less usage employed or is data always associated with the intended product scale? If there is a scale-less usage, how is it populated, what is it used for and which objects are stored on it.
The data is associated with product scales. An ENC with compilation scale 45000 is made from TLDB data 50000.
ENCs have to be kept up-to-date. When new navigational information is available, how is it handled? How are updates implemented?
Each chart affected is updated separately.
What is your data structure? Do you store your data on 6 usage band layers that correspond to the ENC purposes, or do you have in-between layers?
Our data is stored in the scales 1:10000, 50000, 100000, 150000 and 375000.
When comparing a higher and lower scale chart of the same area, there are obviously differences in content. How are decisions made on which objects should be visible or excluded, generalised, preserved?
See attached file.
Which international and internal specifications does your organisation follow? What is the level of flexibility for the cartographer to make decisions about the chart content?
ENC production is bound to the rules/guidelines made by the IHO (S-65), and has to apply to the S-58 validation checks. Our ENCs are also externally checked by IC-ENC.
Are Coastal and Approach usage bands in any way connected?
Similar source. All data is first compiled at the largest scale in TLDB, and then generalised to the smaller scales.
Does the final user have a say in determining the chart content? Do you survey mariner satisfaction or expectations about your organisation's charts?
We encourage users to come with suggestions/comments. We don't receive many complaints...

3. Dataset related

Questions in this section were derived from the analyses of the data your organisation provided and are customized for each participant separately.

The answers to these questions will help me verify if my observations discovered flaws in the data that could be improved with the introduction of automatic generalisation or if there was an intention in creating the chart as it is.

Please, if you are aware of other differences between the datasets, let me know.

I have noticed that out of a number of **Landmarks** identically attributed on the Approach cell and with approximately the same distance from the coast, only few of them reappear on the Coastal cell. What is the rule behind this selection?
On the ENC with a larger scale appear more details and objects. On the smaller scale ENC only the most important and significant objects appear (to prevent clutter).
I have noticed that AIS station is once captured as a **Landmark** and once as **RADSTA**. Is there a reason for such differentiation?
They should be charted the same. Different interpretation by operators probably...
I am trying to find a pattern in the selection of **Aids to Navigation** on the Coastal chart. I assume that all Cardinal signs are mapped regardless of their position, but other AtoNs seem to be dependent on their distance from the shore. Can you, please, explain how the selection for purpose is executed?
All Cardinal signs are mapped. Other AtoNs are considered case by case by the cartographer.
As much as Aids to Navigation share the same position and attributes on both cells, the same cannot be said about all **WRECKS** and **OBSTRN** points. Are the sources for those different and if so, why?
WRECKS and OBSTRN objects come from one database. So should be encoded the same. I assume one ENC is newer then the other. In the newer ENC the objects are imported from the database (automated process with a lookup table). In the older ENC are many objects placed/changed by NtMs (by hand). All major attributes should be the same though.
Overall, among all my sample datasets, the charts in your organisation seem to be the richest in detail (showing all groynes, for example). Is this level consistent throughout your charting responsibility area? Can you motivate the decision to produce such detailed charts?
We use for the topo 1:10000 digital files from the land registry. They are very detailed, but are generalised in the TLDB. So that is our source. We are in a process to reduce the amount of detail on land.
There are **Build-up Areas** on the Coastal cell that do not match the shape of BUAARE referring to the same settlements on the Approach cell. Please, explain.
We are in a process to reduce the amount of detail on land. So probably one ENC is already generalised, and the other not.
I have noticed that **Anchorages, Underwater Cables** and other **Restricted Areas** are preserved on both usage bands, but that sometimes they do or they do not share the same geometry. The lines run almost parallel to each other. Is there a reason for such approach, or could these lines share geometry?
Underwater cables should not share geometry with anchorages or restricted areas. Anchorages and restricted areas may share geometry.

4. Automatic Generalisation

Finally in this section I would like to know more about the status of automatic generalisation in your organisation (AG).

Does HO investigate about AG? If so, how?
No
Are there any attempts of AG in the current workflow?
No, we already have generalised data in our database. This database will be converted to the different usages in HPD.
What are the main problems with data/production your organisation experiences that could

potentially be solved by AG?
Automatic creation of depth contours and sounding selection. This sounding selection should take into account anchorage areas, entrances to harbours and fairways. Is this possible? We receive topo files with a lot of single buildings and small built-up areas. We have to draw a outline around them now (generalise to a single built-up area). Can this be done automatic?
What kind of development would you like to see (in terms of automatic generalisation)?
?

b) Evaluation of the automatically generalised ENCs

1. Introduction

Below you can find a very general description of how each element of the chart was created. Details can be found in the final thesis document that will be available in December. This basic report is expected to help you understand the reasoning behind the results of the automatic generalisation process.

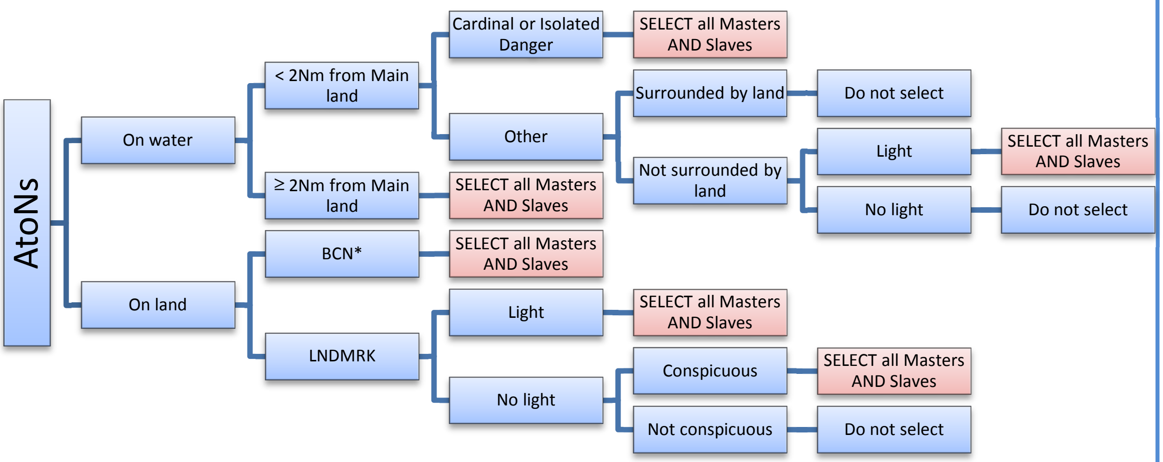
Land Areas
• Land areas were created based on the approach chart LNDARE polygons. • Approach cell's LNDARE points were considered insignificant and were rejected. • If land masses were closer than 50m to each other they were aggregated into one object. This is based on the range resolution of marine radars, that do not recognize objects that are closer than 50m as individual features. • A smoothing algorithm was executed. • Finally, small islands were collapsed into points. Our policy is to enlarge small islands in the smaller scale, so they remain visible.
Coastline - COALNE and SLCONS
• Coastline needs to border LNDARE. It was, therefore, created from the generalised LNDARE polygons and not from the approach cell's coastline. • To maintain the attributes present in the approach chart, buffers were created around the approach cell's coastline and whenever the generalised coastline intersected the buffer it got assigned all the attributes. • The coastline was created as COALNE, but for SLCONS coastline buffers were also created, so wherever COALNE intersected a SLCONS buffer, also the feature acronym was changed.
Aids to Navigation and Landmarks
Those objects were selected from the approach dataset, but ideally would be selectable from a scale independent layer. Scale independent usages reduce duplications in the data storage and facilitate data management. They increase the coherence of the products. This is something that might be introduced in S-100: New concept to emulate production database architecture based on two new cell types: -One containing features without scale e.g. lights, buoys, tracks and some area features. -The other containing scalable features e.g. coastline and group one features. Discussion points: -Prove that it will be more efficient for updates

-Prove that distribution will be seamless

-Prove that this type of data is interoperable with data containing both scale dependent and scale independent data.

Although this was not the subject of this project, it proposes, in the frame of automatic generalisation, an option to detect AtoNs on scale based usages and automatically copy and deconflict them on a scale independent usage. This solution is useful for organisations that already have a scale based storage of AtoNs. This solution was not tested due to the different setting of the project.

The diagram below shows the selection process from the approach AtoNs to those considered relevant for coastal navigation:



How do you determine what main land is? What happens with small islands?
Please include PILPNT as a master for LIGHTS.
Is conspicuous visual, radar or both?

To prevent overcrowding the selected AtoNs and Landmarks need to be 6mm[26] (2x3mm buffer around each point) away from each other. If they are closer (if their buffers intersect) deconflictiong and elimination takes place:

s) Based on the presence of RADAR transponder or retroreflector.
t) If they both/all have it, based on structure:
   5. Beacons, Landmarks win over
   6. Buoys
u) If the same, based on purpose:
   7. New danger, Cardinal, Isolated danger
   8. Special, Lateral
   9. Safe Water
v) If the same, based on the presence of a LIGHTS:
   5. Light
   6. No light
w) If they both/all have light (if multiple lights per object, then based on the best light):

[26] 6mm based on the compilation scale

7. Bigger range
8. Bigger height
9. Colour (based on light colour visibility range)
    a. White
    b. Red
    c. Orange
    d. Yellow
    e. Green
    f. Blue
    g. Violet

x) If still the same or there is no light, based on shape of the structure (CATLMK and BCNSHP):
    5. Towers, masts and other large structures
    6. Rocks, piles, posts etc

y) If still the same, based on a topmark:
    5. Topmark
    6. No topmark

z) If still the same, based colour of the structure (see above)

aa) If still the same (consider if it is not a duplicate:
    7. Both on water -> remove the one closer to the shore.
    8. Both on land -> remove the one farther from the shore.
    9. One land and one on water -> remove the one on land.

Wrecks

- Wrecks were selected from the approach dataset, but ideally they would be selectable from a scale-independent layer.
- All wrecks that were farther than 200m from the shore were selected. Why 200m? Does this also count for small islands?
- Wrecks deeper than 1200m are not selected. Why 1200m? And WRECKS with VALSOU=UNKNOWN?

Underwater rocks

- UWTROCs were selected from the approach dataset, but ideally they would be selectable from a scale independent layer.
- Only open water rocks were selected.
- Rocks with EXPSOU:2 (shoaler than the surrounding water) were selected. And UWTROCs with VALSOU=UNKNOWN?
- Rocks that were not covered by obstruction areas were selected.

Obstruction Areas

- Obstruction areas were created based on the OBSTRN area objects on the approach chart.
- Obstruction areas were enlarged, aggregated and smoothed.
- Their edges were cut to match the bordering LNDARE.
- Attributes of the approach chart OBSTRN areas were transferred based on the intersection principle.

Where are the Obstruction points?

Build-up areas

- BUAARE were created based on the BUAARE and BUISLG objects from the approach chart.
- They were enlarged aggregated and simplified. Attributes were transferred.
- Their edges were cut not to go beyond the bordering LNDARE. Next time include also CANALS, RIVERS and LAKARE.

What are the criteria for removing BUAARE/BUISGL?

Other objects

ACHARE ; ACHBRT ; ADMARE ; CBLSUB ; CBLARE ; CTNARE ; EXEZNE ; FERYRT ; ISTZNE ; MARCUL ; MIPARE ; NAVLNE ; PIPARE ; PIPSOL ; PRCARE ; RADRNG ; RECTRC ; RESARE ; TESARE ; TSELNE ; TSEZNE ; TSSBND ; TSSCRS ; TSSLPT ; TSSRON ; PILBOP ; MAGVAR ; RCTLPT ; RDOCAL were analysed, but not always successfully.

- If similarities were found, objects were copied from the approach chart.
- The only generalisation performed was to eventually adjust the boundary to the current LNDARE for area and line objects.
- Selection differed between the Hydrographic Offices, more details in the results section.
- Ideally, if a pattern can be found between objects on different scales, they could be moved to a scale independent usage and managed from there. This would reduce duplications in the database and increase the coherence in the products. At the present time this component of generalisation is semi-interactive.

2. Evaluation

Now, please open the hob files provided. NL301630.hob is the original Coastal usage ENC that you had sent at the beginning of my research. I have cut it to the extents of the Approach dataset (to make the datasets comparable). NL30163G.hob is the automatically generalised chart. I would like you to evaluate and comment each component of the generalised dataset. Four main subjects of evaluation I would like you to consider are:

- Safety of Navigation
  Does the depiction meet safety requirements of a nautical chart of that usage? Is the level of detail and accuracy sufficient for the mariner to undertake safe coastal navigation?
- Aesthetics
  Is the component's generalisation aesthetically pleasing giving the final product a feeling of high quality and professionalism?
- Usability (User friendliness)
  Is the chosen depiction clear, does it leave any ambiguity and is it easy to get the desired information from the chart?
- Efficiency versus effects of generalisation
  Does the algorithm provide time and efforts savings in the process of ENC production? Can you see the added value of choosing the automatic solution against the interactive (manual) generalisation? I am aware that most of the proposed solutions are currently not available, but had they been made available, would you consider using them? If a solution is not perfect, do you consider that manual adjustments could take less time that full interactive generalisation?

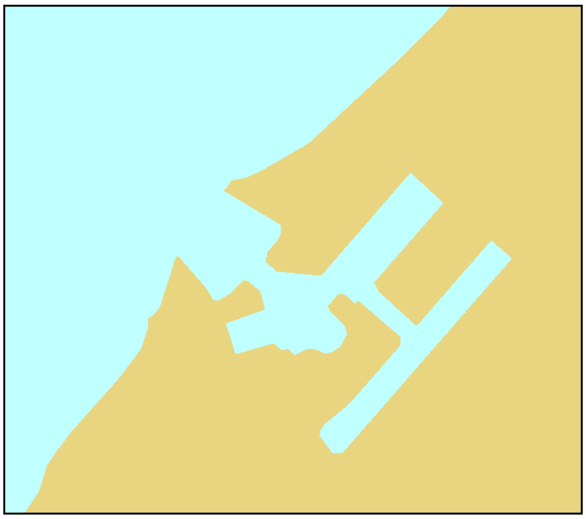
Please, give to each component a grade from 1 (not acceptable, no chance of using such a solution in this or improved form) to 10 (solution is suitable for immediate use, it meets our production standards, if it got implemented in the chart production software we would incorporate it into our production workflow in a "as is" form).

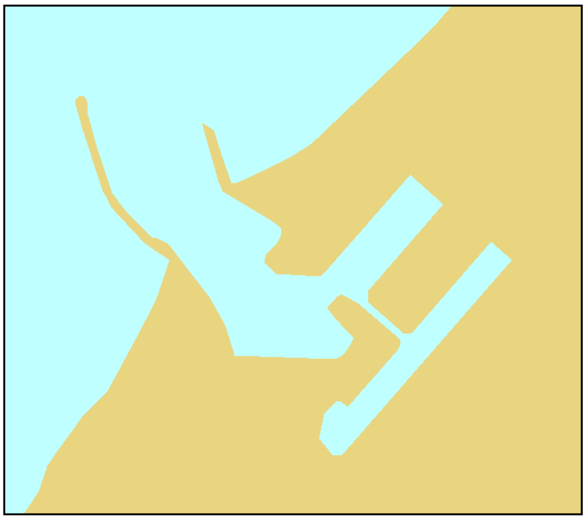
I recommend you to compare the datasets thoroughly, nevertheless I have allowed myself to make some comments about the shortcomings (but also some advantages) that were the most obvious for me.

Please, note that you may find instances where edges minimally do not match. This problem is due to format changes and using two incompatible software. After importing the data into S-57 the edges no longer match perfectly. Had all the operations been performed directly in CARIS, this would not have happened.

LNDARE

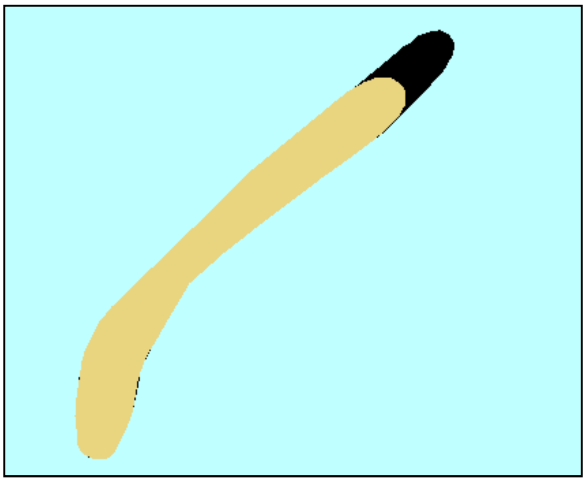
Even zoomed to the compilation scale one can see that the differences are mostly within the digitisation error (both datasets come from the same source and have been subsequently generalised to their respective scales).
One of the dissimilarities is the described before difference in the level of detail when depicting a harbour:





In this case the divergence is double, as less detail is shown on the (left) original chart (compared to the generalised one) in the outside waters than in the inside basin. Although the generalised LNDARE is no reference, the algorithm works the same regardless of the location and thus gives consistent level of detail throughout the data. If so, it makes no sense to give more details about an area that is not of any use in the Coastal phase of the journey. External groins may be helpful as a bearing target for the mariner to establish position(in the original chart the external groins

are charted as SLCONS-line), but basin details could be of interest only if a vessel intends to enter the harbour, in which case she should carry better scale charts of the area. Harbour details are useful for passage planning, so also necessary in smaller scale ENCs.
The next figure shows inconsistence in depiction of an island (one of two islands in the dataset, the other matching the generalised dataset).



The original island is more than 300 meters longer than the generalised one (which is identical to the original Approach sourced one). It is not clear whether there has been a mistake or whether the cartographer intentionally exaggerated the size of an island for safety reasons (the area in the direction of the inconsistency is an intertidal zone) almost joining the main land.
The coastline in NL400110 was newer than the coastline in NL301630. In the new edition of NL301630 this has been fixed. So this was not a generalisation issue (one ENC was newer than the other one).

Evaluation

Safety of Navigation: *5*

Comment: Generalisation was not always at the "safe" side. We always generalise at the "safe" side.

Aesthetics: *7*

Comment: Generalisation was consistent in the whole ENC.

Usability (User friendliness): *6*

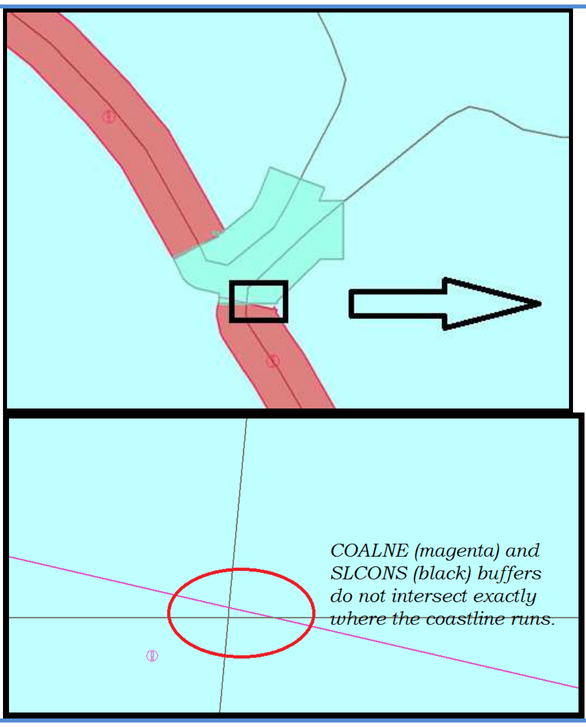
Comment: There are overlaps and gaps with RESARE, TESARE and ISTZNE. These have to be fixed.

Efficiency versus effects of generalisation: *7*

Comment: First results look promising!

Coastline - COALNE and SLCONS

Overall, the coastline is created correctly. The attributes were transferred properly. SLCONS match the location of shoreline constructions.
The biggest problem is in the presence of very short lines due to inaccuracies in the algorithm. Where the buffers did not cut the coastline in exactly the same point, little segments got excluded from processing. The same might have happened if the original coastline had many bends which were maintained in the buffer. I am in the process of writing an xml script to QC and correct it, so that it should not pose problems in the future.



Evaluation

Safety of Navigation: *5*

Comment: See LNDARE

Aesthetics: *7*

Comment: See LNDARE

Usability (User friendliness): *6*

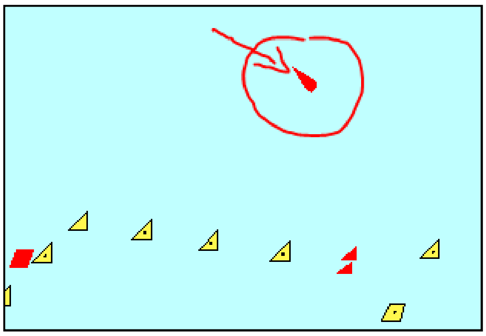
Comment: Many overlapping segments in the lines, and many overlaps/gaps in the area features. This means a lot of edit work.

Efficiency versus effects of generalisation: *7*

Comment: See LNDARE

AtoNs and Landmarks

Generalised chart shows many more AtoNs and LNDMRKs than the original chart. This is due to the fact that the approach dataset defines them as visually conspicuous. In case of AtoNs due to a relatively large compilation scale, the algorithm has found that this amount of objects does not clutter the view.



There is a case where a very strong light has been omitted from the generalised chart, as its support structure is PILPNT that was not considered during this research.

Evaluation

Safety of Navigation: *6*

Comment: Lights on PILPNT were missing.

Aesthetics: *7*

Comment: First results look promising!
Usability (User friendliness): *8*
Comment: Impressive selection process for the AtoNs!
Efficiency versus effects of generalisation: *7*
Comment: You still have to check everything thoroughly visually/manually.

Wrecks

All wrecks that are depicted on the original chart are selected also on the automatically generalised one.

Evaluation

Safety of Navigation: *8*
Comment: Where are the OBSTN points?
Aesthetics: *8*
Comment:
Usability (User friendliness): *8*
Comment:
Efficiency versus effects of generalisation: *8*
Comment: Is it possible to define an area where you can leave out all wrecks and buoys (a minimal depiction area/"blind" area)?

Underwater rocks

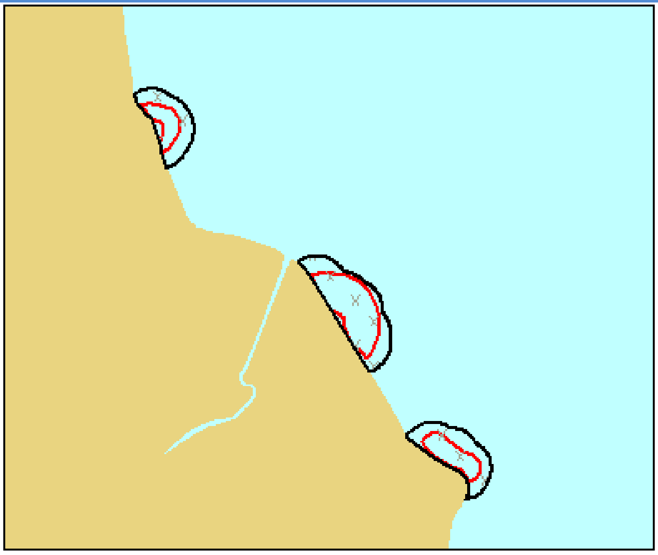
Surprisingly there were no UWTROCs on the original chart. The approach dataset had 4 objects and since there were no OBSTRN areas, they got selected as not covered by OBSTRN area.
The UWTROCs are in an area where most features are omitted.
The minimal depiction of detail in this area does not support safe navigation, therefore mariners should use a more appropriate navigational purpose.

Evaluation

Safety of Navigation: *9*
Comment:
Aesthetics: *5*
Comment: Is it possible to define an area where you can leave out all UWTROCs (a minimal depiction area/"blind" area)?
Usability (User friendliness): *8*
Comment:
Efficiency versus effects of generalisation: *7*
Comment: Now we have to remove the UWTROCs, because they are within a minimal depiction area.

Obstruction Areas

Equally surprising was the fact that there were no OBSTRN areas on the charts. None of the standards enforces the use of this object type, but there are areas of congested OBSTRN point objects that could have been aggregated into areas. This would clean the display a bit, but perhaps the intention was to leave all this detail.
For comparison, please see another dataset with the original (red) and the generalised (black) areas. Here the snapshot is zoomed far beyond the compilation scale, but the generalised OBSTRN areas are enlarged because at a compilation scale they are better visible which increases the safety of navigation.



Generalised OBSTRN areas (black) are bigger and match the LNDARE.

Evaluation

Safety of Navigation: *8*

Comment:

Aesthetics: *8*

Comment:

Usability (User friendliness): *8*

Comment:

Efficiency versus effects of generalisation: *8*

Comment:

Build-up areas

Although this is not a safety critical category, BUAAREs match the original dataset quite well and are more consistent with the shape of the approach ENC ones.

Evaluation

Safety of Navigation: *7*

Comment: All important (large, with a harbour or visible from sea) BUAAREs should be charted. So a small BUAARE with a harbour can be more important than a large BUAARE far from shore.

Aesthetics: *7*

Comment: Roads and railways often share geometry with BUAARE. This connection is now gone, and the roads run through the BUAAREs.

Usability (User friendliness): *6*

Comment: BUAAREs now overlap LAKARE, RIVERS and CANALS. This means edit work. BUAAREs with CATBUA=6 can be removed.

Efficiency versus effects of generalisation: *6*

Comment:

Other objects

None of the remaining datasets was so rich in the "other objects" as this one. For this reason the edge matching was not completed (due to the lack of time and the area and line objects do not border the generalised coastline). Out of the mentioned objects those have been used:

ACHARE:

All objects from the approach dataset were copied to the generalised one.

ACHBRT:

There was only one object on the approach chart and five on the original coastal one. Generalisation was not possible.

CBLSUBL:
Twenty three objects were copied from the approach dataset even though there are only nineteen on the coastal chart. One CBLSUB is divided into five parts on the approach chart.
ISTZNE:
Copied two objects from the approach dataset. They should form one coastal object but could not be merged as the extents do not match between two approach charts.
MARCUL:
Copied only point objects.
MIPARE:
One to one match, so one object copied.
NAVLNE:
There were four NAVLNE objects on the original chart and six on the approach chart. Copied 4.
PIPSOL:
There was one extra object on the approach chart. Copied the ones that overlapped with the original coastal chart.
PRCARE:
Copied all objects.
RECTRC:
Even though there were only four on the original chart, all six were copied.
RESARE:
All objects copied.
PILBOP:
Two objects copied as per original chart.
RDOCAL:
All objects copied.
TSEZNE, TSSBND, TSSCRS:
All copied.

Evaluation

Safety of Navigation: *6*
Comment: Needs to be sorted out better. There are some safety critical features that are missing: OBSTRN (point), OFSPLF, SLCONS and deep water routes.
At position 51-50.856N 3-19.832E there is a piece missing from a CBLSUB.
Aesthetics: *7*
Comment:
Usability (User friendliness): *5*
Comment: I guess this was mainly a manual job?
No fixed set of rules.
Efficiency versus effects of generalisation: *5*
Comment: Most features are copied, so (almost) no generalisation.

3. Other comments

Please, use this space to write any other comments, suggestions or maybe improvements ideas.

Comments
Overall: The results look promising! It is a pity you did not try to generalise the bathymetry. In this area you can gain a lot of time (I think). In every new edition of an ENC we include the newest bathymetry. The changes in the land topography are usually minor. So the generalisation of bathymetry is a recurring event.

a) Questionnaire about charts and chart production in your organisation

1. General

In this section I would like to ask about your organisation to get some background about your work.

Resources dedicated to chart production		
Personnel	Paper chart production	***No. of people*** 4 (some of this resource is also used to support ENC production) 8 external contractors
	ENC production	***No. of people*** 6 (includes 2 people dedicated to SW pacific ENCs)
Software		***List types of software used for production and (number of licenses). If an implementation of new software is taking place, please indicate.*** CARIS HPD Source Editor 2.8.2 (x12) CARIS HPD Product Editor 2.8.2 (x2) CARIS HPD Paper Chart Editor 2.8,2 (x8) L3 Nautronix ENC Analyser 2.9.0 (x1) Endeavour 5 Navigator (x6) CARIS BathyDB 3.2 (currently being implemented) (x1 manager, x2 base) Hypac (x1)
Portfolio		
Existing charts	National paper charts	***Please indicate how many charts are produced in your premises*** 160
	INT paper charts	29
	ENCs (per usage band)	*e.g. 1/23, 2/38, 3/137…* 1: 2 2: 6 3: 38 4: 26 5: 36 6: 15 (Total 123)
	Other (please specify)	-
In or awaiting production	National paper charts	***Please indicate how many charts still await production for a complete coverage*** 5 which include:

		2 Mercury Bay 3 Chatham Island charts
	INT paper charts	0
	ENCs (per usage band)	1: 5 2: 12 3: 20 4: 68 5: 51 6: 13 (Total 179)
	Other (please specify)	-

Area of charting	
Charting responsibility over	***Please, provide a brief description of your charting responsibility*** New Zealand, South West Pacific, Ross Sea Region

2. Chart Production

In this section I would like to ask about the methods and workflows of your chart production. Hopefully this will help me understand better the challenges the office is facing and how those challenges are being dealt with.

How are the ENCs compiled?
e.g. from existing paper charts that are scanned and digitized *or* *external digital datasets (like AutoCAD, Shape files, etc.) that are converted into S-57 format* *or* *base dataset of detailed data is used and generalisation performed* *or other (please, specify)* *In case of external datasets used, please, specify the source, contents, format and resolution.*
Can you describe your workflow for new ENC/new edition compilation
Please, note that the example is very general. Provide as much detail as possible (e.g. At which stage is SCAMIN applied and soundings grouped). If there are any internal documents describing the workflow, please attach it with your reply. *e.g. data pre-processed in software x – data loaded into software y – data edited – QC loop phase one – product creation – QC loop phase two – product sent to reseller.*
How long does it take to complete the workflow and produce a single ENC?
Approximately 2 months.
What is the production cycle in your organisation?
e.g. a two year cycle for all the charts to be updated as New Editions *or* *the entire portfolio is released as New Editions in March of each year* Cycle is dependent on: - survey data to be included & safety aspects - number of NtM corrections and blocks included on the chart - significant changes to buoyage or beacons - importance of the charted area to shipping - resourcing in the team to apply changes However, for paper chart production, yearly production target is 12 New Editions or New Charts

in the Financial Year. This will change next year, where targets will be based more on timeliness to include new survey data onto charts.
New Editions of ENCs are published either when an ENC update size is greater than the allowable limit, or when the equivalent Paper Chart is published as a New Edition.

Please, describe your data storage and maintenance solution. If you use a database to store vector data on different layers based on usage bands, are objects between scales linked?

e.g. data is stored in a single database in S-57 format
or
data is stored and maintained in separate databases
or
data is not stored in a database (please, describe how data is stored)

Is there a scale-less usage employed or is data always associated with the intended product scale? If there is a scale-less usage, how is it populated, what is it used for and which objects are stored on it.

ENCs have to be kept up-to-date. When new navigational information is available, how is it handled? How are updates implemented?

e.g. each chart affected is updated separately.

What is your data structure? Do you store your data on 6 usage band layers that correspond to the ENC purposes, or do you have in-between layers?

When comparing a higher and lower scale chart of the same area, there are obviously differences in content. How are decisions made on which objects should be visible or excluded, generalised, preserved?

If explanation is too broad, please focus on Coastal and Approach charts or attach any internal specifications used.

e.g. Approach charts depict full topography as imported from the topographic charts 1:50k, while Coastal preserve only details relevant to the safety of navigation (explain which) and omit the remaining detail. Aids to Navigation are preserved based on their significance to the navigation which can be measured by the nominal range of light they display.

Decisions are made based on:

- cartographers training & experience
- adequate depiction for a mariner with regards to safety and aids to navigation
- relevant international specifications and standards
- internal policies
- generalisation policies with regard to the specific area / series of chart being worked on.

Internal policies on LINZ Topographic Detail and LINZ Paper Chart Specification are attached for your reference.

Which international and internal specifications does your organisation follow? What is the level of flexibility for the cartographer to make decisions about the chart content?

All relevant IHO specifications and standards for ENC, Paper Chart, NTMs, and Raster Chart Production plus:
LINZ Paper Chart Specification (internal)
LINZ Paper Chart Specification for Paper Chart Masters (for contractor)
LINZ Policy on Topographic Detail to be shown on Paper Charts (internal and for contractor)
LINZ Source Data Specification (internal)

Are Coastal and Approach usage bands in any way connected?

this can be by either using similar source for production, deriving one from another, etc.

Does the final user have a say in determining the chart content? Do you survey mariner

satisfaction or expectations about your organisation's charts?

3. Dataset related

Questions in this section were derived from the analyses of the data your organisation provided and are customized for each participant separately.

The answers to these questions will help me verify if my observations discovered flaws in the data that could be improved with the introduction of automatic generalisation or if there was an intention in creating the chart as it is.

Please, if you are aware of other differences between the datasets, let me know.

- Our ENCs are Paper Chart Equivalents.
- Little or no generalisation work is required when an area of ENCs are published as the generalisation is already present on the source data from which the ENC was created from
- Generalisation occurs when new source data is incorporated into a series of charts covering a particular area (ie. New Edition) or when a new chart is produces (New Chart)
- Some vertical and horizontal consistency issues exist where these have been translated to source data when the ENC was created.
- Encoding policies and chart specifications change over time, which can result in apparent differences in encoding or appearance of a paper chart: and example of this is the change in LINZs policy to now reduce the amount of topographic detail shown on Paper Charts as they come up for New Edition

4. Automatic Generalisation

Finally in this section I would like to know more about the status of automatic generalisation in your organisation (AG).

Does HO investigate about AG? If so, how?
Hypac has been used to generate a sounding sort and contours at a rendered scale. These were then used as the basis of incorporating an area of new survey data onto a chart. Significant cartographic edits and a final manually selected thinned sounding data is made for the final chart product. Sounding sorts have been also done in CARIS HPD Source Editor on survey data to assist and confirm a cartographers sounding selection.

We are beginning to work with BathyDB now, and will begin to see how well generation of contours and sounding sorts will be for inclusion into new chart editions.
Are there any attempts of AG in the current workflow?
Yes, when new survey data is being included onto charts.
What are the main problems with data/production your organisation experiences that could potentially be solved by AG?
Some cartographic work now done could be reduced by AG, allowing us to incorporate new survey data onto charts more quickly.
What kind of development would you like to see (in terms of automatic generalisation)?
Incorporation of more recently developed / published algorithms to improve the results of AG. AG which can also generate skin of the earth features at the same time as line features.

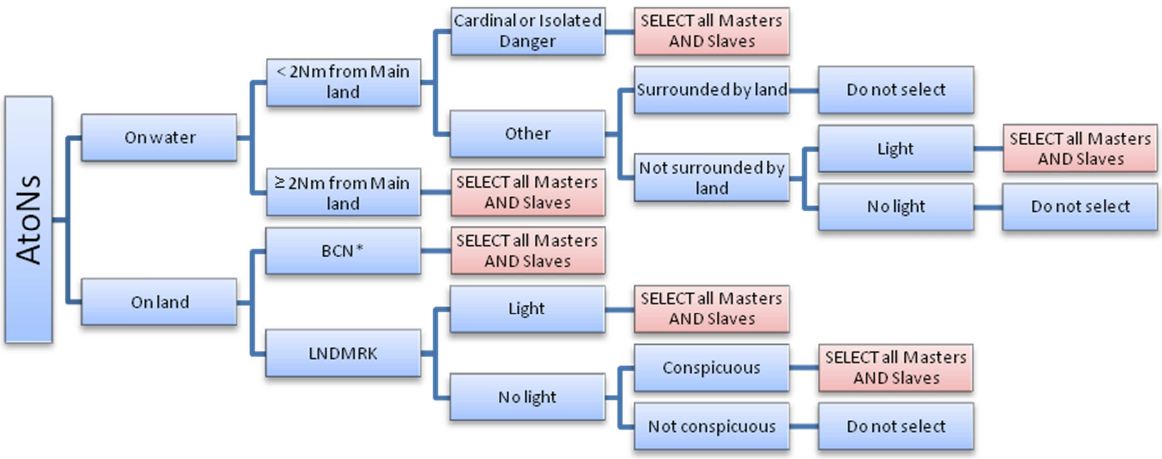
b) Evaluation of the automatically generalised ENCs

1. Introduction

Below you can find a very general description of how each element of the chart was created. Details can be found in the final thesis document that will be available in December. This basic report is expected to help you understand the reasoning behind the results of the automatic generalisation process.

Land Areas
• Land areas were created based on the approach chart LNDARE polygons. • Approach cell's LNDARE points were considered insignificant and were rejected. • If land masses were closer than 50m to each other they were aggregated into one object. This is based on the range resolution of marine radars, that do not recognize objects that are closerthan 50m as individual features. • A smoothing algorithm was executed. • Finally, small islands were collapsed into points.
Coastline - COALNE and SLCONS
• Coastline needs to border LNDARE. It was, therefore, created from the generalised LNDARE polygons and not from the approach cell's coastline. • To maintain the attributes present in the approach chart, buffers were created around the approach cell's coastline and whenever the generalised coastline intersected the buffer it got assigned all the attributes. • The coastline was created as COALNE, but for SLCONS coastline buffers were also created, so wherever COALNE intersected a SLCONS buffer, also the feature acronym was changed.
Aids to Navigation and Landmarks
Those objects were selected from the approach dataset, but ideally would be selectable from a scale independent layer.Scale independent usages reduce duplications in the data storage and facilitate data management. They increase the coherence of the products. Although this was not the subject of this project, it proposes, in the frame of automatic generalisation, an option to detect AtoNs on scale based usages and automatically copy and deconflict them on a scale independent usage. This solution is useful for organisations that already have a scale based storage of AtoNs. This solution was not tested due to the different

setting of the project.
The diagram below shows the selection process from the approach AtoNs to those considered relevant for coastal navigation:



To prevent overcrowding the selected AtoNs and Landmarks need to be 6mm[27] (2x3mm buffer around each point) away from each other. If they are closer (if their buffers intersect) deconflictiong and elimination takes place:

bb) Based on the presence of RADAR transponder or retroreflector.
cc) If they both/all have it, based on structure:
   7. Beacons, Landmarks win over
   8. Buoys
dd) If the same, based on purpose:
   10. New danger, Cardinal, Isolated danger
   11. Special, Lateral
   12. Safe Water
ee) If the same, based on the presence of a LIGHTS:
   7. Light
   8. No light
ff) If they both/all have light (if multiple lights per object, then based on the best light):
   10. Bigger range
   11. Bigger height
   12. Colour (based on light colour visibility range)
      a. White
      b. Red
      c. Orange
      d. Yellow
      e. Green
      f. Blue
      g. Violet

[27] 6mm based on the compilation scale

gg) If still the same or there is no light, based on shape of the structure (CATLMK and BCNSHP):
    7. Towers, masts and other large structures
    8. Rocks, piles, posts etc
hh) If still the same, based on a topmark:
    7. Topmark
    8. No topmark
ii) If still the same, based colour of the structure (see above)
jj) If still the same (consider if it is not a duplicate:
    10. Both on water -> remove the one closer to the shore.
    11. Both on land -> remove the one farther from the shore.
    12. One land and one on water -> remove the one on land.

Wrecks

- Wrecks were selected from the approach dataset, but ideally they would be selectable from a scale-independent layer.
- All wrecks that were farther than 200m from the shore were selected.
- Wrecks deeper than 1200m are not selected.

Underwater rocks

- UWTROCs were selected from the approach dataset, but ideally they would be selectable from a scale independent layer.
- Only open water rocks were selected.
- Rocks with EXPSOU:2 (shoaler than the surrounding water) were selected.
- Rocks that were not covered by obstruction areas were selected.

Obstruction Areas

- Obstruction areas were created based on the OBSTRN area objects on the approach chart.
- Obstruction areas were enlarged, aggregated and smoothed.
- Their edges were cut to match the bordering LNDARE.
- Attributes of the approach chart OBSTRN areas were transferred based on the intersection principle.

Build-up areas

- BUAARE were created based on the BUAARE and BUISLG objects from the approach chart.
- They were enlarged aggregated and simplified. Attributes were transferred.
- Their edges were cut not to go beyond the bordering LNDARE.

Other objects

ACHARE ; ACHBRT ; ADMARE ; CBLSUB ; CBLARE ; CTNARE ; EXEZNE ; FERYRT ; ISTZNE ; MARCUL ; MIPARE ; NAVLNE ; PIPARE ; PIPSOL ; PRCARE ; RADRNG ; RECTRC ; RESARE ; TESARE ; TSELNE ; TSEZNE ; TSSBND ; TSSCRS ; TSSLPT ; TSSRON ; PILBOP ; MAGVAR ; RCTLPT ; RDOCAL were analysed, but not always successfully.

- If similarities were found, objects were copied from the approach chart.
- The only generalisation performed was to eventually adjust the boundary to the current LNDARE for area and line objects.
- Selection differed between the Hydrographic Offices, more details in the results section.
- Ideally, if a pattern can be found between objects on different scales, they could be moved to a scale independent usage and managed from there. This would reduce duplications in the database and increase the coherence in the products. At the present time this component of generalisation is semi-interactive.

2. Evaluation

Now, please open the hob files provided. NL301630.hob is the original Coastal usage ENC that you had sent at the beginning of my research. I have cut it to the extents of the Approach dataset (to make the datasets comparable). NL30163G.hob is the automatically generalised chart. I would like you to evaluate and comment each component of the generalised dataset. Four main subjects of evaluation I would like you to consider are:

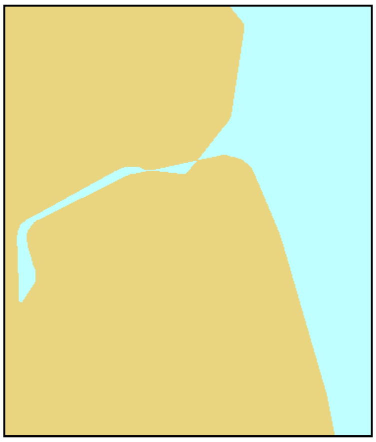
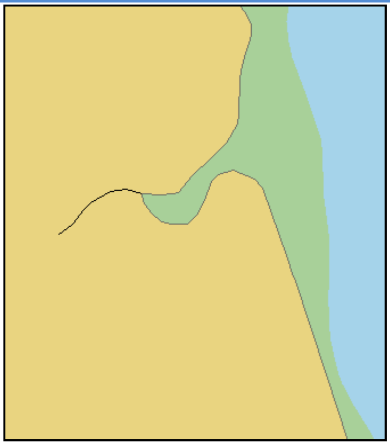
- Safety of Navigation
  Does the depiction meet safety requirements of a nautical chart of that usage? Is the level of detail and accuracy sufficient for the mariner to undertake safe coastal navigation?
- Aesthetics
  Is the component's generalisation aesthetically pleasing giving the final product a feeling of high quality and professionalism?
- Usability (User friendliness)
  Is the chosen depiction clear, does it leave any ambiguity and is it easy to get the desired information from the chart?
- Efficiency versus effects of generalisation
  Does the algorithm provide time and efforts savings in the process of ENC production? Can you see the added value of choosing the automatic solution against the interactive (manual) generalisation? I am aware that most of the proposed solutions are currently not available, but had they been made available, would you consider using them? If a solution is not perfect, do you consider that manual adjustments could take less time that full interactive generalisation?

Please, give to each component a grade from 1 (not acceptable, no chance of using such a solution in this or improved form) to 10 (solution is suitable for immediate use, it meets our production standards, if it got implemented in the chart production software we would incorporate it into our production workflow in a "as is" form).

I recommend you to compare the datasets thoroughly, nevertheless I have allowed myself to make some comments about the shortcomings (but also some advantages) that were the most obvious for me.

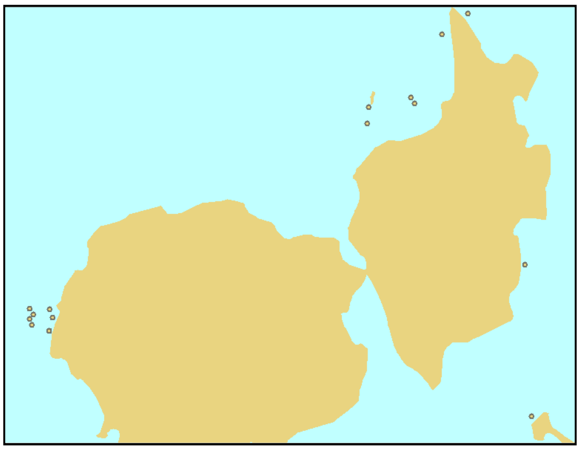
Please, note that you may find instances where edges minimally do not match. This problem is due to format changes and using two incompatible software. After importing the data into S-57 the edges no longer match perfectly. Had all the operations been performed directly in CARIS, this would not have happened.

LNDARE
As can be seen, the main difference between the generalised chart and the original one is in the depiction of small islands as point objects. As area objects they get lost when overvied. Showing small islands as point objects also considerably reduces the amount of nodes that need to be stored in a chart cell. Otherwise the images look similar. The generalised chart's LNDARE looks a little smoother than the original one. The main shortcoming of the algorithm is in the generalisation of rivers.

The algorithm is not complex enough to be able to collapse inland waters into line type rivers. This has to be performed manually.

The other problem is the connection of two main islands (the distance between them is smaller than 50m). Although it is not an issue of navigational safety, it affects the aesthetics of the final product.



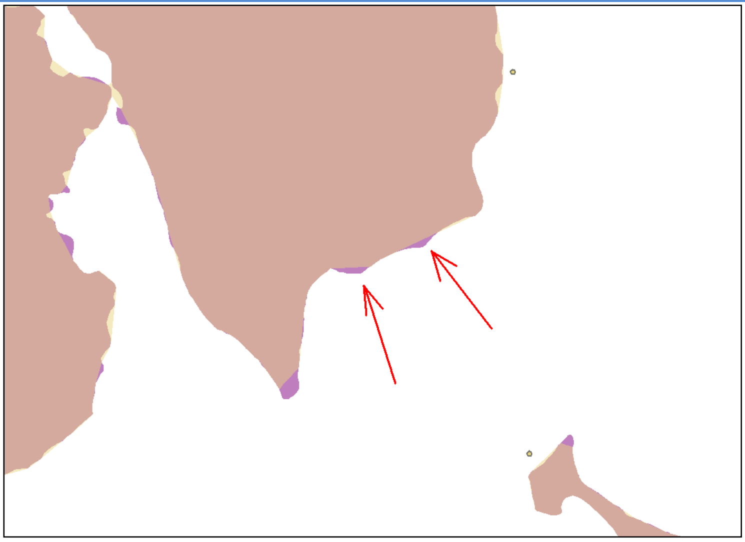
Otherwise LNDARE looks similar on both charts.

Evaluation

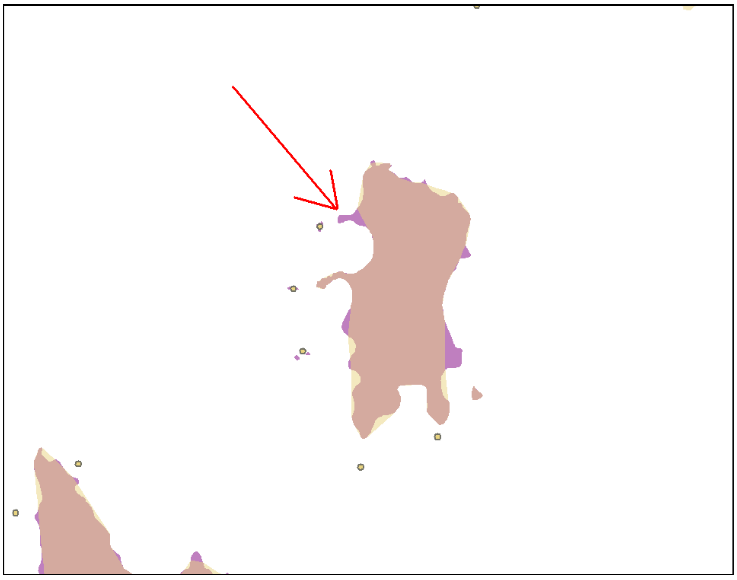
Safety of Navigation: *1-10 4*

Comment: While the algorithms have in the main done a good job of generalising the LNDARE for representation on a coastal chart, I note the following issues:

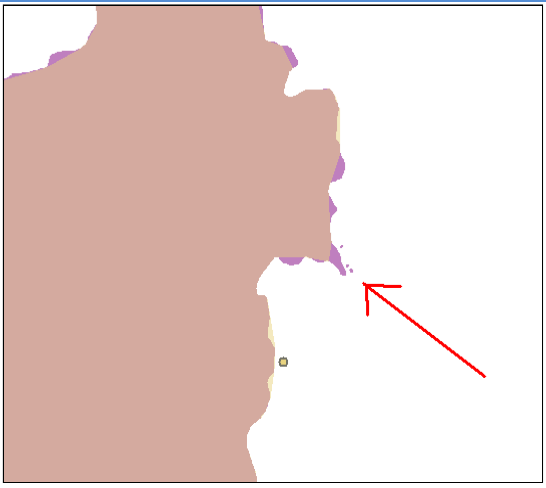
1. *In some areas the smoothing has 'cut off' land areas, pushing the land area further in land whereas a safer approach to take would be to ensure that the new generalised area only fell to seaward of the land area being generalised. Land area from NZ405321 (purple) and NZ3G5322 (buff) compared:*

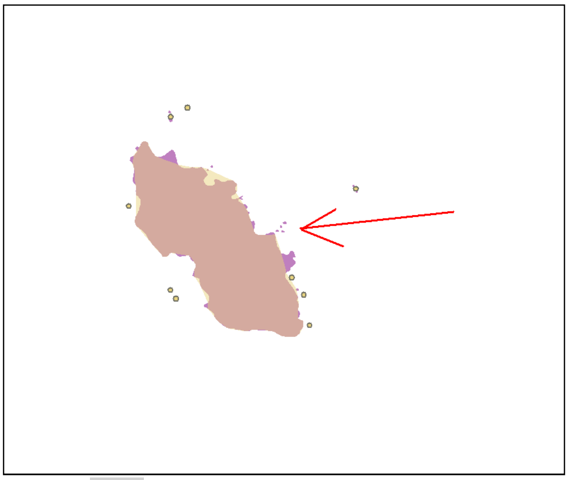


2. Similar to case 1 above, but a more significant issue. Many significant (possibly named) headlands / points are being omitted. In the case indicated below it has changed the overall shape of the island significantly. As mentioned in case 1, a process to ensure that the new land areas are generalised to the safer (seaward) side may help.



1. *A couple areas of small islands which have been omitted, but I would prefer to see the one most seaward island retained as islets:*





Aesthetics: *1-10 8*

Comment: A part from some spurious changes to shapes of islands (see image in item 2 above), the overall look and feel of the product appears of good quality. Although it does appears somewhat over-smoothed / generalised when compared to the actual dataset used for this usage.

Usability (User friendliness): *1-10 6*

Comment: Some ambiguity is present, particular in how some headlands and points are depicted by the land area. Small islets and islands have been omitted where my preference would have been their retention.

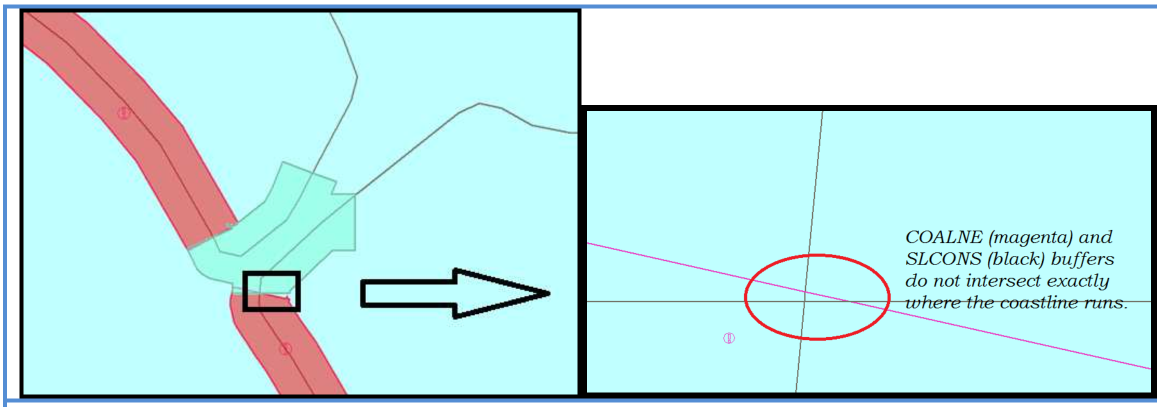
Efficiency versus effects of generalisation: *1-10 6*

Comment: Yes this would save some time during generalisation, although some manual work would still be required to retain some omitted detail. If issue numbers 1 + 2 were fixed above, a much higher score would have been achieved.

Coastline - COALNE and SLCONS

Overall, the coastline is created correctly. The attributes were transferred properly. SLCONS match the location of shoreline constructions.

The biggest problem is in the presence of very short lines due to inaccuracies in the algorithm. Where the buffers did not cut the coastline in exactly the same point, little segments got excluded from processing. The same might have happened if the original coastline had many bends which were maintained in the buffer. I am in the process of writing an xml script to QC and correct it, so that it should not pose problems in the future.

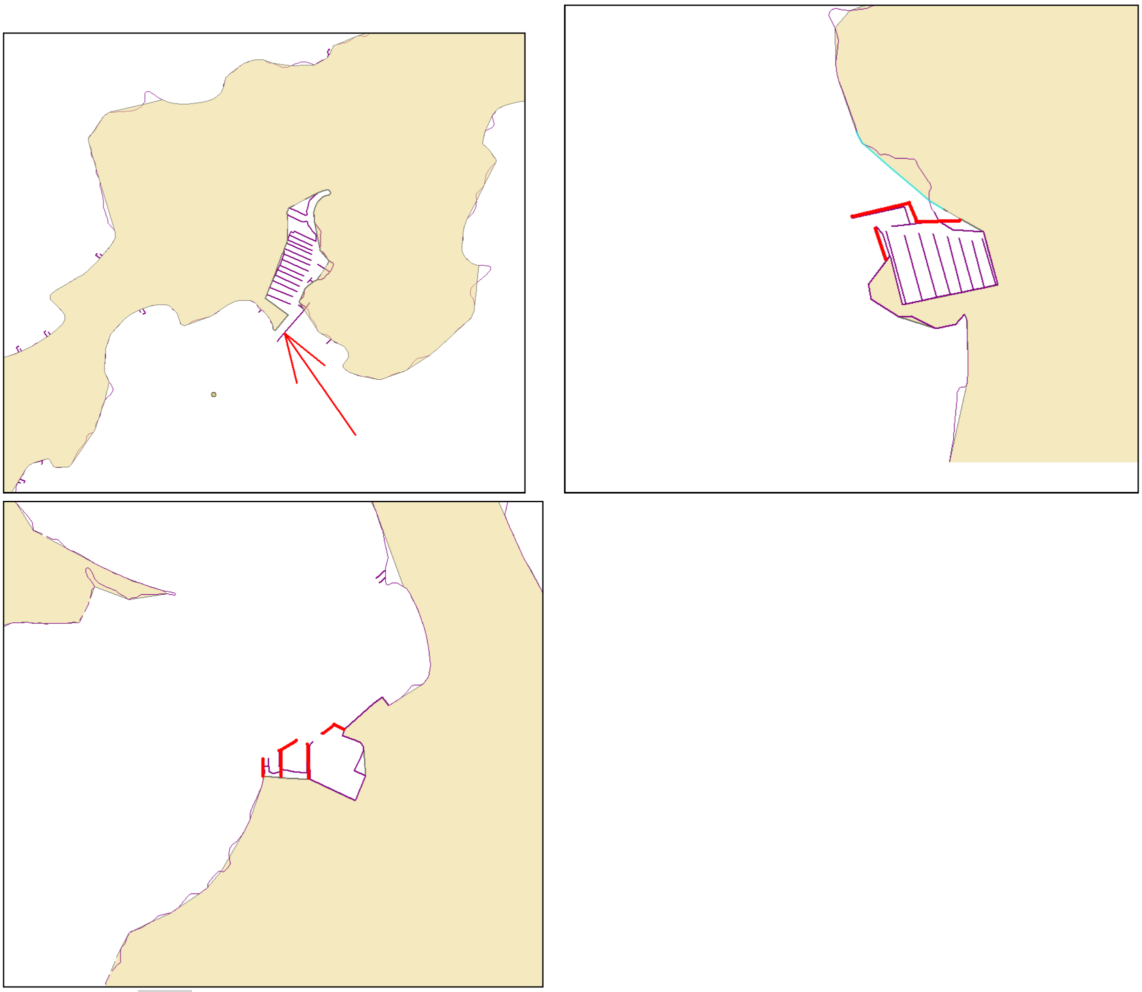


Evaluation

Safety of Navigation: *1-10 6*

Comment:

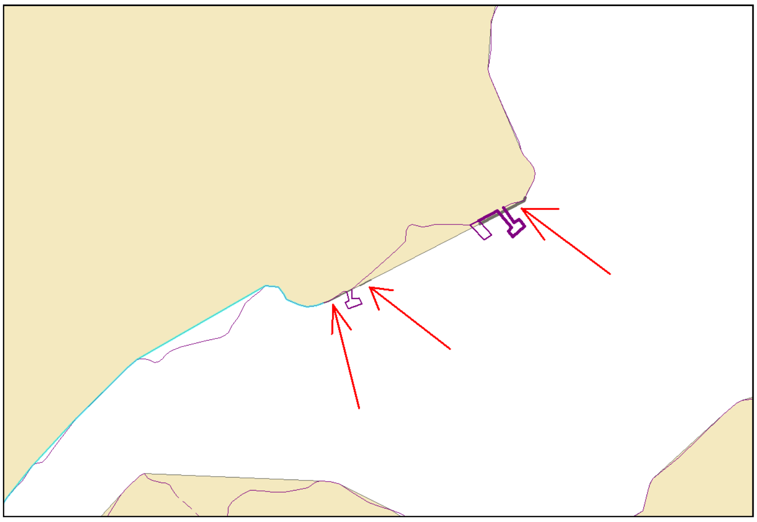
1. *As the coastline matches the land area, some safety aspects considered above do apply here too, although I have not scored these negative again in this section.*
2. *The algorithm does a good job of identifying and generating shore line construction elements where they are connected to land area objects, but where they do not abut land areas, they have been omitted. In many cases we may want to show some sort of generalised version of these in the final product for the mariner. Example below NZ405324 (purple), NZ3G5322 (grey) compared:*

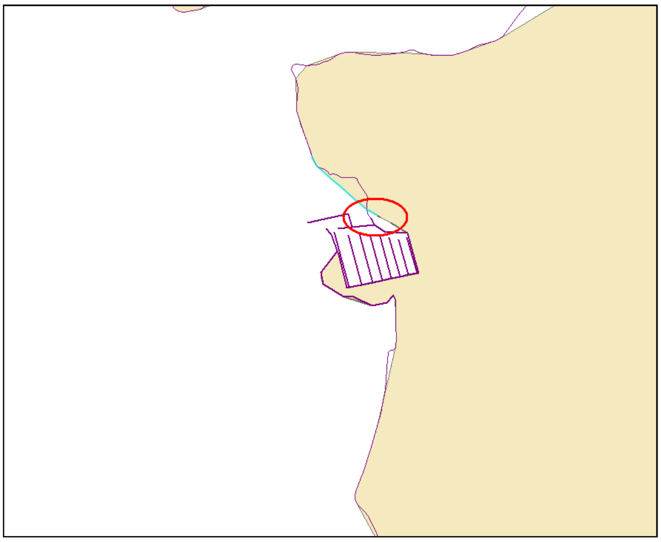


Aesthetics: *1-10 7*

Comment:

1. *Coastline matches the land area, as expected. It has done a reasonable job of generating a generalised version of the mangrove coastline.*
2. *Algorithms do not appear to take into account shoreline constructions which are not connected to land areas, so these would need to be added manually as mentioned above.*
3. *The generalised result of some shore line constructions has created some small line segments, which in practice would be better left out. Perhaps a minimum line length can be used in the algorithm which would omit these and make them part of a continuous coastline instead. Example below compared:*





Usability (User friendliness): *1-10 7*

Comment: In general does a good job of depicting the coastline, but the omission of some shore line constructions would be a concern. The removal of some of the short shoreline construction would give a clearer picture.

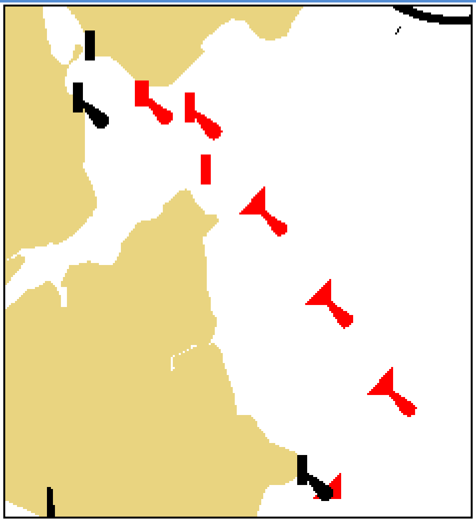
Efficiency versus effects of generalisation: *1-10 6*

Comment: Some manual effort would be required to complete the shore line construction depiction.

AtoNs and Landmarks

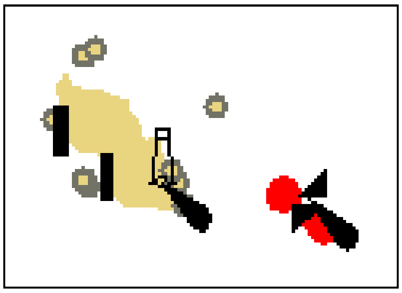
Most of the AtoNs selected on the original chart are also present on the generalised one. In fact the generalised chart shows more AtoNs.

In certain cases, there are AtoNs missing on the generalised chart (figure below):



This is because the algorithm considers those AtoNs as surrounded by LNDARE and hence "internal basins" AtoNs. Those are omitted in the generalisation process, as internal basins should be covered by better scale charts. In this case, AtoNs are obviously not in the internal basin or a harbour, yet the algorithm was not able to recognise that. Perhaps calibrating this setting would work better for your chart. The scope of this project did not assume any modifications between charts.

Below, another example of an omitted AtoN. Here, a BOYSPP was removed in favour of the cardinal one (more important) as it is considered that they are too close and keeping both would deteriorate the perception.



This decision of the algorithm (step two of generalisation- preventing overcrowding) is considered positive. The screen capture is zoomed far beyond the compilation scale and still the objects intersect. A mariner may not appreciate this additional detail.

Evaluation

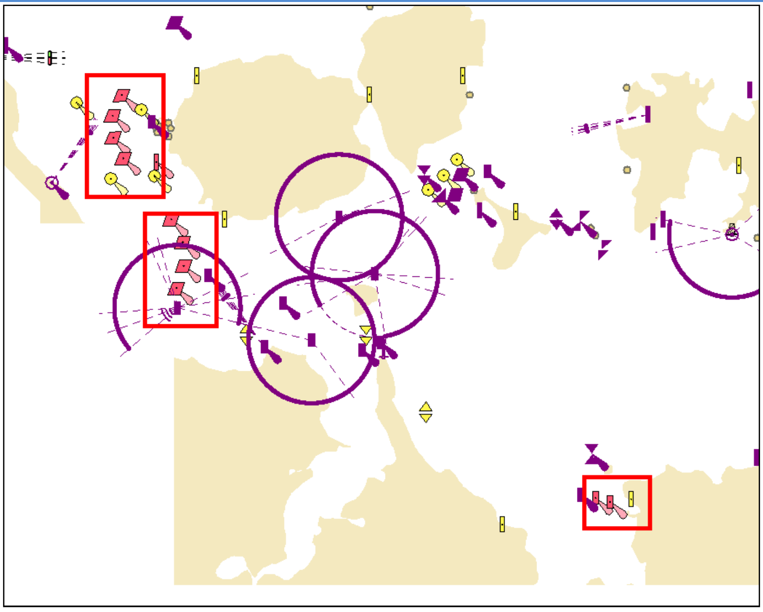
Safety of Navigation: *1-10 7*

Comment: The generalisation process has done a reasonable job, and the preventing overcrowding part of the algorithm seems to be a reasonable approach. As you mentioned the algorithm did have issues when it considered a sequence of beacons in an inland water way. If the algorithm could be improved to retain the further most aids to navigation from the coastline could be a way forward.

Aesthetics: *1-10 6*

Comment: A part from the issue above, the over look and feel appears of high quality. Although overall it seems to have a lot more detail than is required at this scale. Some points to note:

1. *There are some areas which manual generalisation might improve the depiction. This seems to be where there is a sequence of aids into port, or harbour – often we would only wish to show the outer most aids. Obviously this may be difficult to achieve through an algorithm. Example shown below NZ3G5322 (normal colour), NZ305322 (purple):*



2. *Many stake, pole, perch, post features are shown in NZ3G5322, whereas in a product created by manual generalisation these would be removed for this scale.*

Usability (User friendliness): *1-10 6*

Comment: Too much detail at this scale may cause some difficulty reading this chart at this scale.

Efficiency versus effects of generalisation: *1-10 7*

Comment: The part of the algorithm preventing over-crowding where objects are very close together will save manual effort. However looking at the final result, some manual effort would still be required to de-clutter the aids to navigation for this chart at this scale.

Wrecks

All (two) wrecks that are depicted on the original chart are selected also on the automatically generalised one.

Evaluation

Safety of Navigation: *1-10 10*

Comment: Selection matches existing chart at this scale.

Aesthetics: *1-10 10*

Comment:

Usability (User friendliness): *1-10 10*

Comment:

Efficiency versus effects of generalisation: *1-10 10*

Comment:

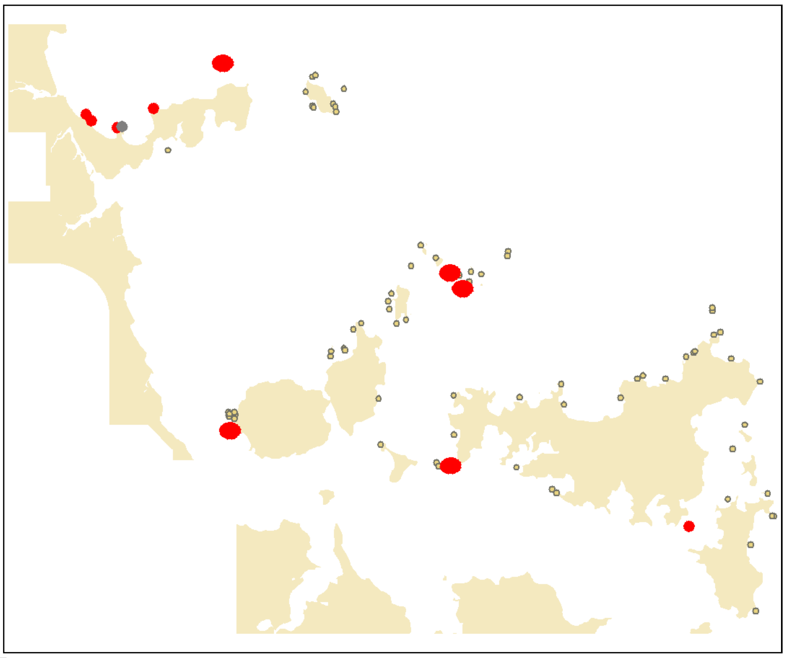
Underwater rocks

There is a huge amount of UWTROCs in the area, which is understandable given the topography. However, some of these rocks could be replaced by OBSTRN areas of CATOBS:6. Areas of that type in ECDIS are considered as dangerous for navigation and trigger an alarm if a vessel crosses their limit. They convey the same information as an area full of UWTROC point objects. At the same time, they give a cleaner view of the area. The methodology used for the selection of UWTROCs was modified in this case to ONLY include EXPSOU:2 UWTROCs, even outside OBSTRN areas. All UWTROCs inside OBSTRN areas have been removed. Even with these restrictions, there are still clusters of UWTROCs. Moreover, EXPSOU:2 UWTROCs can be found on coastal chart where there are either no UWTROCs at all on the approach chart, or where approach chart UWTROCs have a different value of EXPSOU. There is very little consistency between the original coastal and approach charts, therefore there is also not so many similarities between the generalised and the original chart.

Evaluation

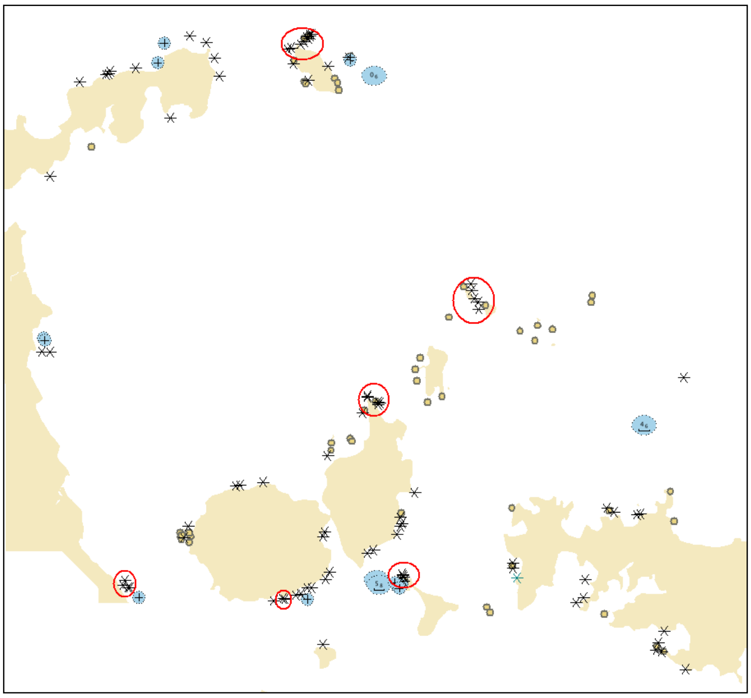
Safety of Navigation: *1-10 3*

Comment: Inconsistencies in our existing charting is noted. However, there are (some significant) under water rocks which I would have like to have seen retained in the generalisation process. I have not examined this thoroughly, but have indicated at least some I would want to retain below (rocks in red, taken from NZ305322). I have also highlighted some underwater rocks to the NE of unknown depth I'd like to see included.



Aesthetics: *1-10 3*

Comment: There is some quite bad clustering of rocks which covers and uncovers. I have highlighted these areas below. Reference to the existing ENC NZ3005322 shows that at chart scale (paper and ENC) all of these rocks cannot be retained.



Usability (User friendliness): *1-10 4*

Comment: Not a complete and clear picture of the underwater rocks has been shown by this selection.
Efficiency versus effects of generalisation: *1-10 5*
Comment: There would still be quite a bit of manual effort involved in making this selection suitable for charting.

Obstruction Areas

In the north of the chart OBSTRN areas created from the approach dataset overlap with the ones from the original coastal ENC.

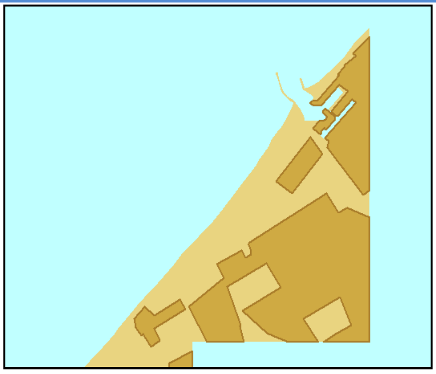
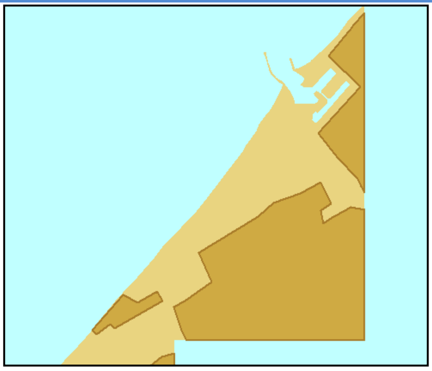
Surprisingly, OBSTRN areas on the original chart go beyond the ones on the generalised chart, even though they had been enlarged with a buffer. The red elements in the figure above have no justification in the better scale approach dataset.
In all other cases the results are very different. There are OBSTRN areas depicted both on the generalised and original chart, but not a single one overlaps. Where there were OBSTRN area in the approach dataset, there aren't any in the coastal one and where the approach chart shows no OBSTRN areas, coastal chart does.

Evaluation

Safety of Navigation: *1-10 8*
Comment: In the example mentioned in your comment above, on the existing generalised chart, the obstruction area has been enlarged to enclose nearby underwater rocks, most probably to better highlight the danger to the mariner on the smaller scale chart. The algorithm has done a reasonable job of simply generalising the obstruction areas, but does not take into account the consideration mentioned above which a cartographer might use.
Aesthetics: *1-10 6*
Comment:
Usability (User friendliness): *1-10 7*
Comment:
Efficiency versus effects of generalisation: *1-10 8*
Comment: The algorithm would save a fair amount of manual intervention.

Build-up areas

There are big differences in the depiction of BUAAREs because surprisingly the level of detail on the approach dataset is lower than on the coastal one. The coastal dataset shows BUAARE area objects whereas approach chart that should be more detailed shows only points. Approach chart does not even store a BUAARE point object with OBJNAM: Auckland. BUAARE representing Auckland on the coastal chart covers the entire area.
For comparison, please see the example of another organisation's chart:

Here, although the results are not identical, they are similar. In case of your organisation's datasets, the results are very different. A good idea could be to source BUAARE objects from topographic datasets and generalise them from the best to the smallest scale.

Evaluation

Safety of Navigation: *1-10 10*

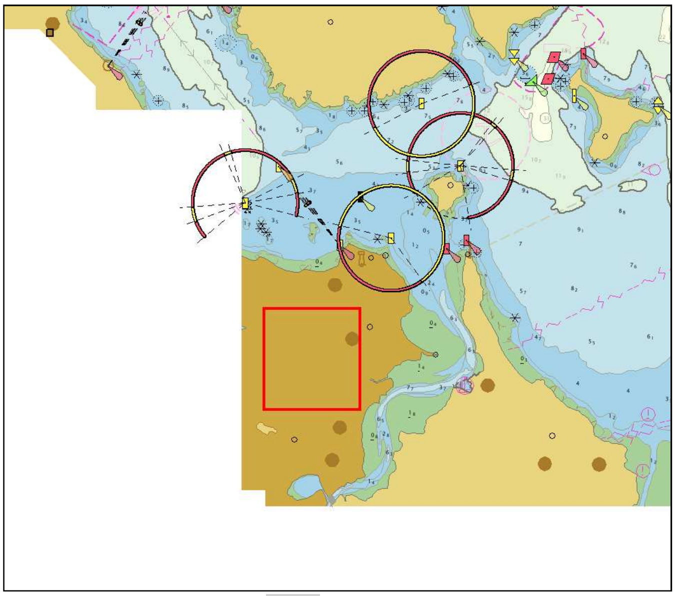
Comment:

Aesthetics: *1-10 8*

Comment: Our depiction of built-up areas is inconsistent. But as you have suggested, a consistent approach of capture from topography, and some automatic generalisation to smaller scales would make us more consistent.

Usability (User friendliness): *1-10 8*

Comment: Some inconsistencies in our source data has caused some issues in the result as you have indicated. For example, the following built up area shown on NZ305322 is not shown on NZ405324 and has there not been created in NZ3G5322:



Efficiency versus effects of generalisation: *1-10 10*

Comment: An algorithmic approach to generalisation like this would save quite a lot of manual effort.

Other objects

Out of the mentioned objects those have been used:

ACHARE:

Only two objects copied. The rest is a small craft mooring area.

ACHBRT:

All objects match. Copied all.

CBLSUB:
Copied all. There are two lines more.
CTNARE:
Copied three points.
FERYRT:
This object is present on the coastal cell, but not on a better scale approach. Generalisation was not possible.
MAGVAR:
There were no MAGVAR objects on the coastal chart. Decided to copy all four from the approach chart.
MARCUL:
Copied 5 points.
NAVLNE:
This object is present on the coastal cell, but not on a better scale approach. Generalisation was not possible.
PILBOP:
Copied two points.
PIPSOL:
Copied 3 objects.
RDOCAL:
All objects match. Copied all.
RECTRC:
This object is present on the coastal cell, but not on a better scale approach. Generalisation was not possible.
RESARE:
There were four objects on the coastal cell and six on the approach. Copied all six objects.

Evaluation

Safety of Navigation: *1-10 10*
Comment:
Aesthetics: *1-10 10*
Comment: Need to make sure objects which previously abutted land areas, still do so in the generalised dataset
Usability (User friendliness): *1-10 10*
Comment:
Efficiency versus effects of generalisation: *1-10 10*
Comment:

3. Other comments

Please, use this space to write any other comments, suggestions or maybe improvements ideas.

Comments
The generalisation process produced a land area and coastline which was not completely desirable. However, the auto generalisation routines for de-cluttering of point objects (some rocks and the aids to navigation) was interesting and with perhaps a bit of tweaking could be implemented quite quickly, and generate efficiency improvements.

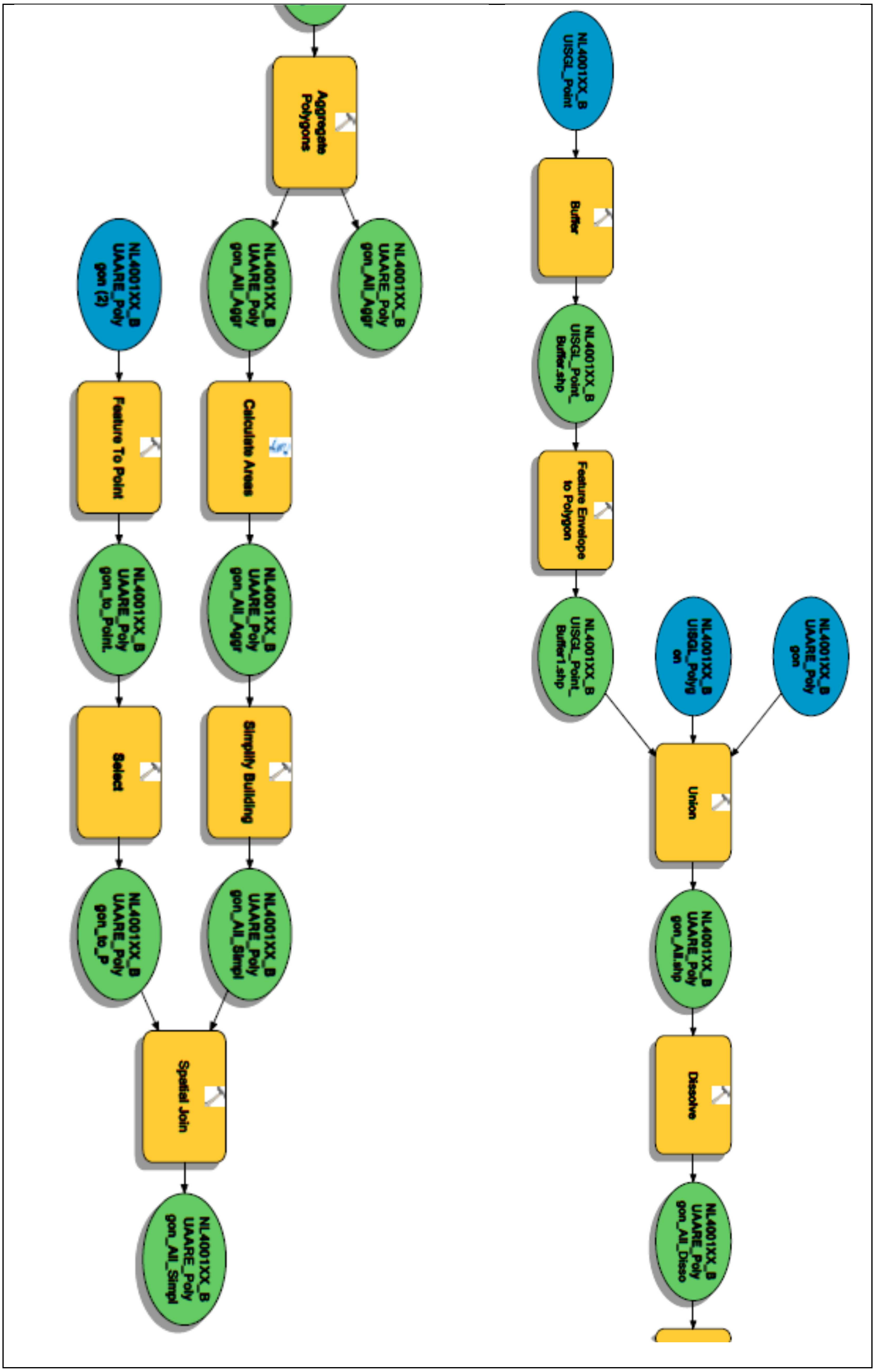


Figure 74 BUAARE NL

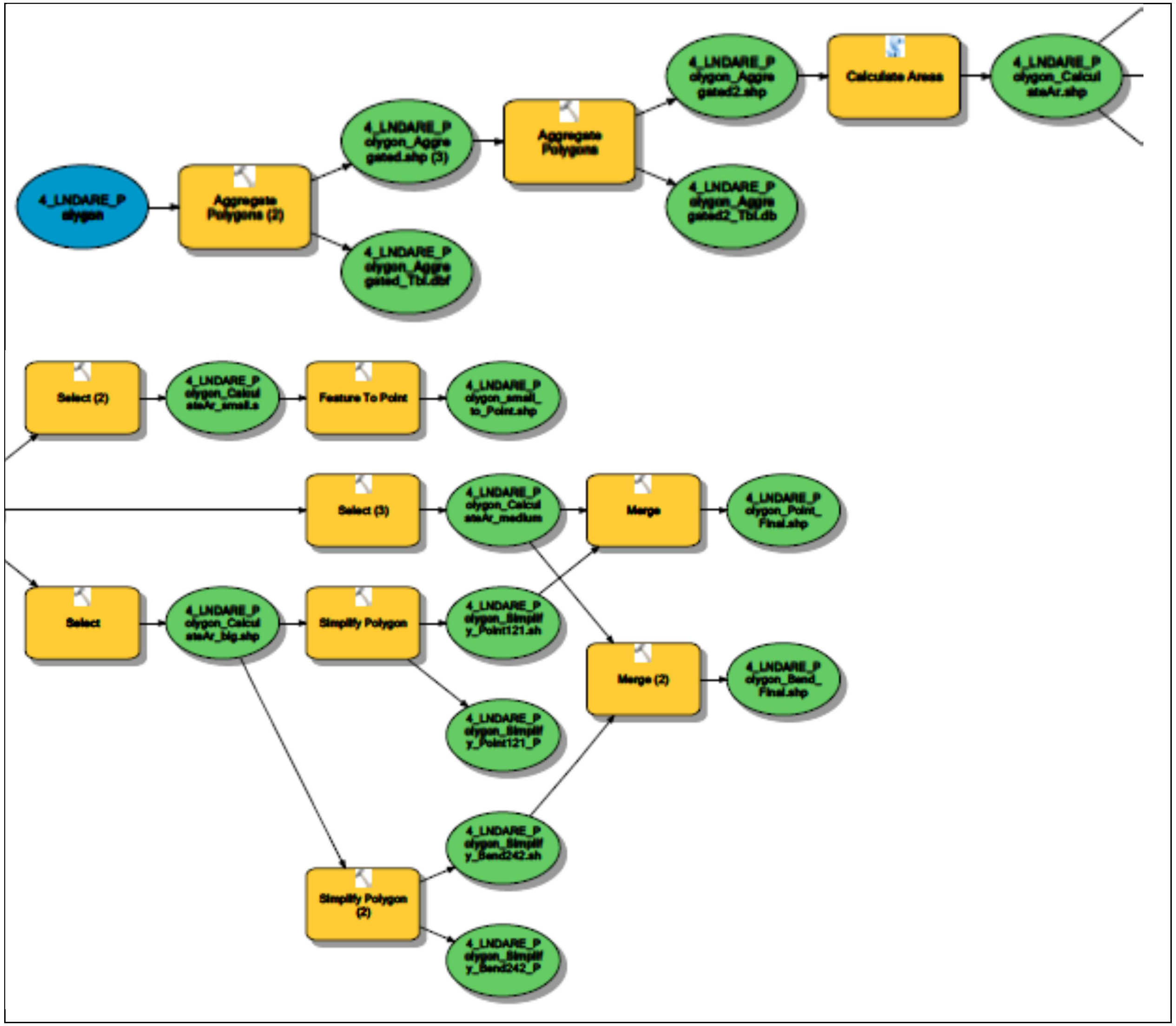


Figure 75 LNDARE NZ

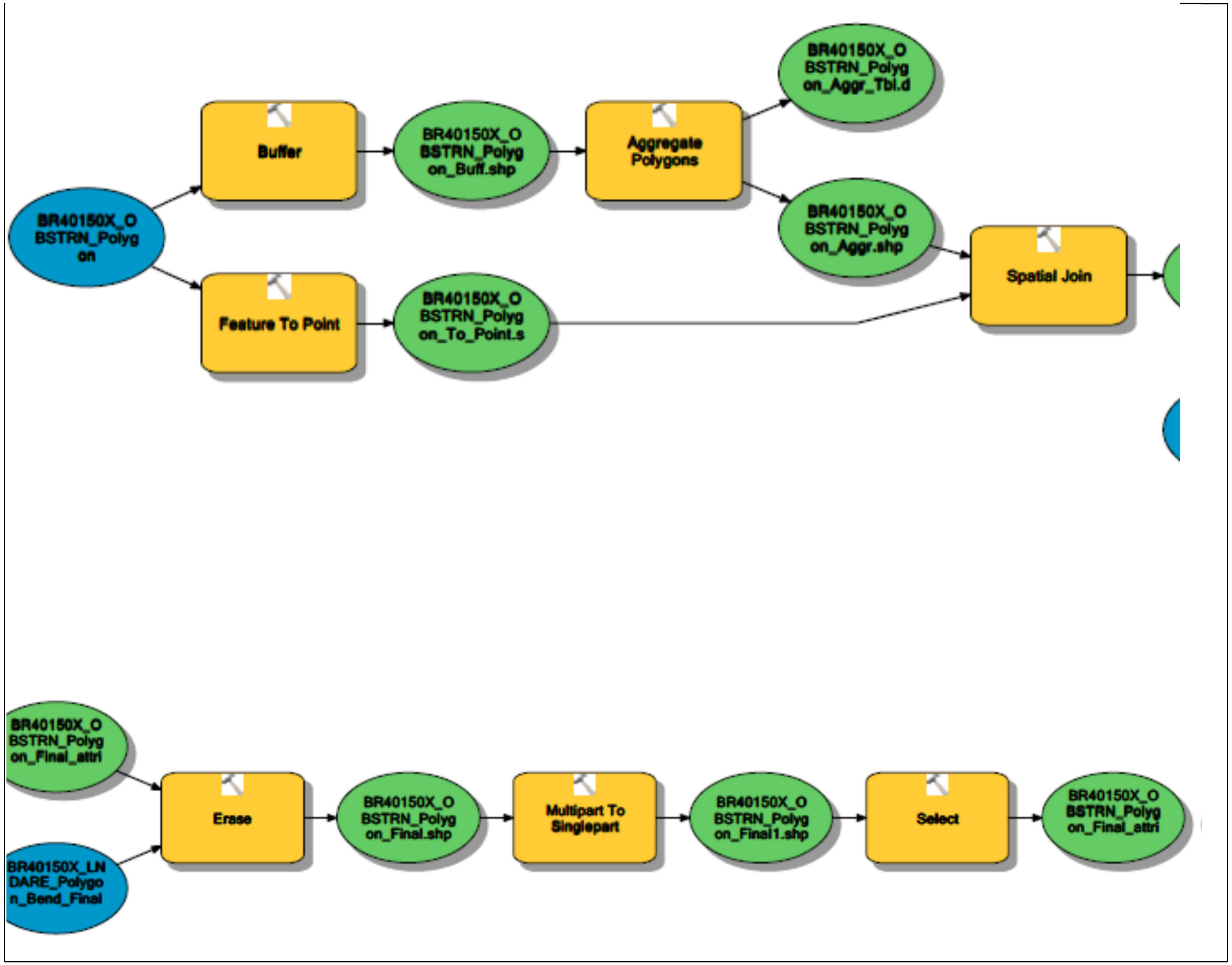


Figure 76 OBSTRN BR