Changes in direction for sailing chart resolution

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Maritime Surveys

The role of the maritime survey has typically been to acquire bathymetric data to assure the safety of shipping in the sailing channels and passages around the world. Commercial and military shipping traffic pushes the limit of the accuracy of navigational charts as ships become larger and faster with increased draft requiring more room to manoeuvre. Submariners however place different demands on navigational charts which can be created to suit their needs based upon the same base material that the maritime survey has collected.

Background - Data Collection

The Royal Danish Administration of Navigation and Hydrography (RDANH) is the statutory body in Denmark concerning all aspects of hydrography and oceanography under the auspices of the International Hydrographic Organisation (IHO). RDANH conducts the administration of sea surveying, encompassing the post processing function that comprises validation, quality control, storage and distribution of the collected hydrographic data together with the collection of oceanographic data in relation to compensation for tidal variation and water column variation. RDANH's hydrographic data are used by the Danish National Survey and Cadastre (DNSC) for the production of charts, within Danish territorial waters.

Data is collected by the Royal Danish Navy who makes equipment and personnel available to RDANH for the practical planning and execution of surveying after the agreement of November 6, 1990 between the Department of Defence and RDANH.

Surveying in the Danish Territorial waters is undertaken with 5 vessels equipped with multibeam echosounders. For surveying along Greenland's West Coast there are 2 more vessels equipped with singlebeam and multibeam echosounders.

Figure 1 Standard Flex class vessel

Figure 2 SKA class vessel

The data acquired by traditional survey vessels using traditional equipment, such as singlebeam echo sounders and positioning systems, can best be described as giving only a general indication of the seabed. With the advent of multibeam echosounders, the achieving of 100% bottom coverage is within reach. Wrecks and underwater obstacles are easily detected and the sailing time of the survey vessel can be optimised with the simultaneous collection of other forms of data.

There is an economic advantage to a multibeam system in that the number of survey lines is reduced to achieve 100% bottom coverage, thereby saving fuel and time. For example when surveying an area of 10 x 12 kilometres with an average water depth of around 20 meters, a standard singlebeam echo sounder survey made with line spacing of 25 meters will require 400 survey lines to cover the area whereas a multibeam survey requires only 150 lines to give 100% coverage.

However, the amount of data acquired during a multibeam survey can present problems in terms of quality control, data storage and distribution. In the example area given above, a singlebeam survey will give 300,000 depths. A multibeam echosounder survey however, will give in excess of 78 million depths.

Data Management

The in house working data format used at RDANH for hydrographic data is a combination of the geometric depth (being calculated based on the ships position, ships motion, sound velocity and the calibration factors unique to each ship) plus the information/metadata associated with the calculation of every depth.

The working data format contains the following information stored in a binary form,

- Position North,
- Position East,
- Depth,
- Beam number,
- Time,
- Amplitude (signal backscatter),
- Quality,
- Vessel heave,
- Vessel pitch,
- Vessel roll (at time of measurement)

Only after the completion of the post processing process, is data stored in a depth database at RDANH.

Due to the already large and increasing data volume and the limitations of the existing database system it was clear to RDANH that a new system was needed to give greater flexibility for storage, retrieval, manipulation and presentation of data.

Establishment of the depth database

In 1998, ESRI’s representative in Denmark, InformiGIS was contracted by RDANH to develop a new depth database based on SDE technology.

There were a number of questions which needed to be answered before the system was designed;

> **How much data is to be stored?**
> *All multibeam data, including flagged erroneous data will be stored.*
>
> **What type of data is to be stored?**
> *Only fully post processed data will be stored in the database*
>
> **Is the data to be stored on-line at all times or will near-line be acceptable?**
> *All data is to be stored on-line.*
>
> **Is there a life to the data?**
> *All data will be stored indefinitely.*
>
> **Will there be updates made to an existing data set?**
> *The dataset will be continually updated and replaced*
>
> **What attributes will be given to the data in addition to depth and position?**
> *All attributes available in working data format will be stored in the database for each depth item together with survey_id for data tracing purposes and tidal correction values.*
>
> **What will be the requirements to retrieve data from the database in terms of speed and flexibility?**
> *Based upon the "average" size of a survey and that the system must function online for all user requests, a performance requirement of 1 million depth items to be loaded into or retrieved from the database within 2 minutes was set. The "average" survey was defined at 20 million data items. The performance requirement is to be achievable regardless of the total database size.*
> *It must be possible to retrieve data from the database based on a combination of search criteria.*
>
> **What will be the format / datum of the database?**
> *For ease of transformation, all data is to be stored in geographic units under WGS84 in the database.*

Prototype test

RDANH commissioned InformiGIS to produce a prototype system to demonstrate the capabilities of SDE working with an Oracle database. The specification of the prototype was;

> Oracle database version 7.3.3.
> SDE version 3.0.2.
> Digital Alpha 600 333 Mhz 256 MB RAM

InformiGIS designed bespoke software to communicate directly with SDE under all operations to the database. This included the packing of data into multipoints and encoding of certain data fields in the *measure* field of a 2000 point multipoint to optimise storage space.

With a test data set of approximately 500 million depth items supplied by RDANH, the results of the prototype test were as follows;

Data indexes created simultaneously during loading
500 million data occupied approximately 18 GB of disc space
Loaded in blocks of 10 million depths.

Each block required approximately 25 minutes to load
46 seconds to retrieve 1 million depths.

Hardware recommendations

Based on the prototype test, the final configuration of the production system was defined and implemented as follows;

Digital AlphaServer 8400 with 625 Mhz CPU and 8 GB RAM.
Multiple array RAID disks of 9.1 GB capacity.
Backup using DAT tape cartridges 64 GB unattended 12 minutes to backup 1 GB.

Storage time, 40 seconds per million depth items.
Retrieval time, 6 seconds per million depth items.

With the subsequent population of the database, RDANH has an online system which can be accessed by other utilities within the ESRI program suite.

Database Integration

As part of RDANH's result contract for 2003, a goal was set to"Investigate and describe the possibilities for the increased use of Geographic Information Systems (GIS) within the Royal Danish Administration of Navigation and Hydrography". A prototype, based around ArcIMS, was developed in house to show the possibilities available.

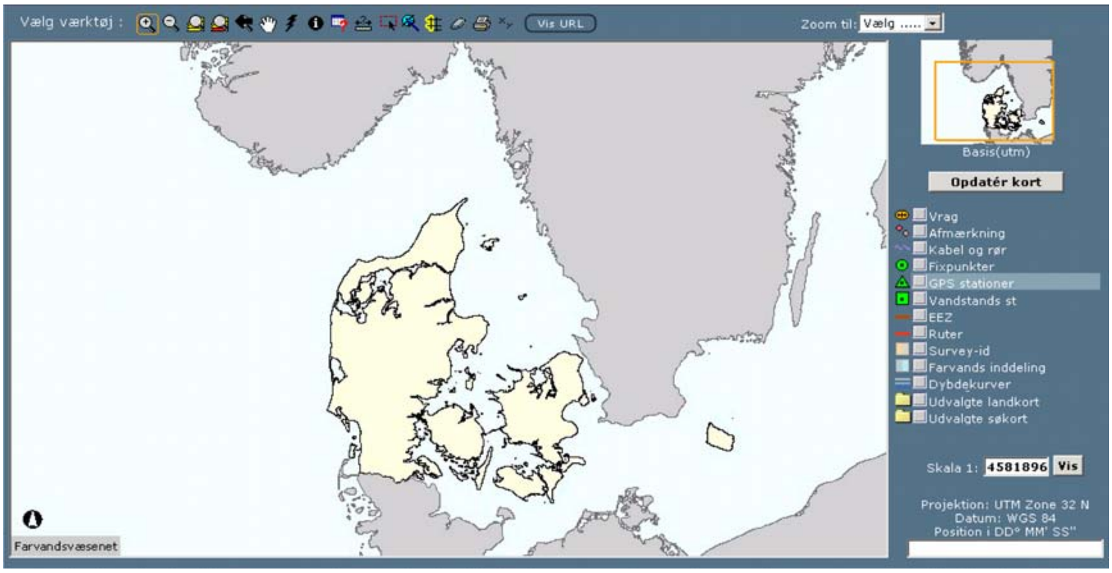

Figure 3 ArcIMS service page

System data

The prototype was to show the possibilities in combining different data systems and was limited to include the following systems currently in use at RDANH;

Wreck register
Cable and pipe register
Aids to Navigation register
Survey source information overview
Depth database coverage

Plus 5 reference data systems

EEZ limits
International Sailing routes
Territorial water limits
Nautical and Land charts

When combined, these data give a very good indication of the potential to compare and utilise existing data from existing systems within RDANH.

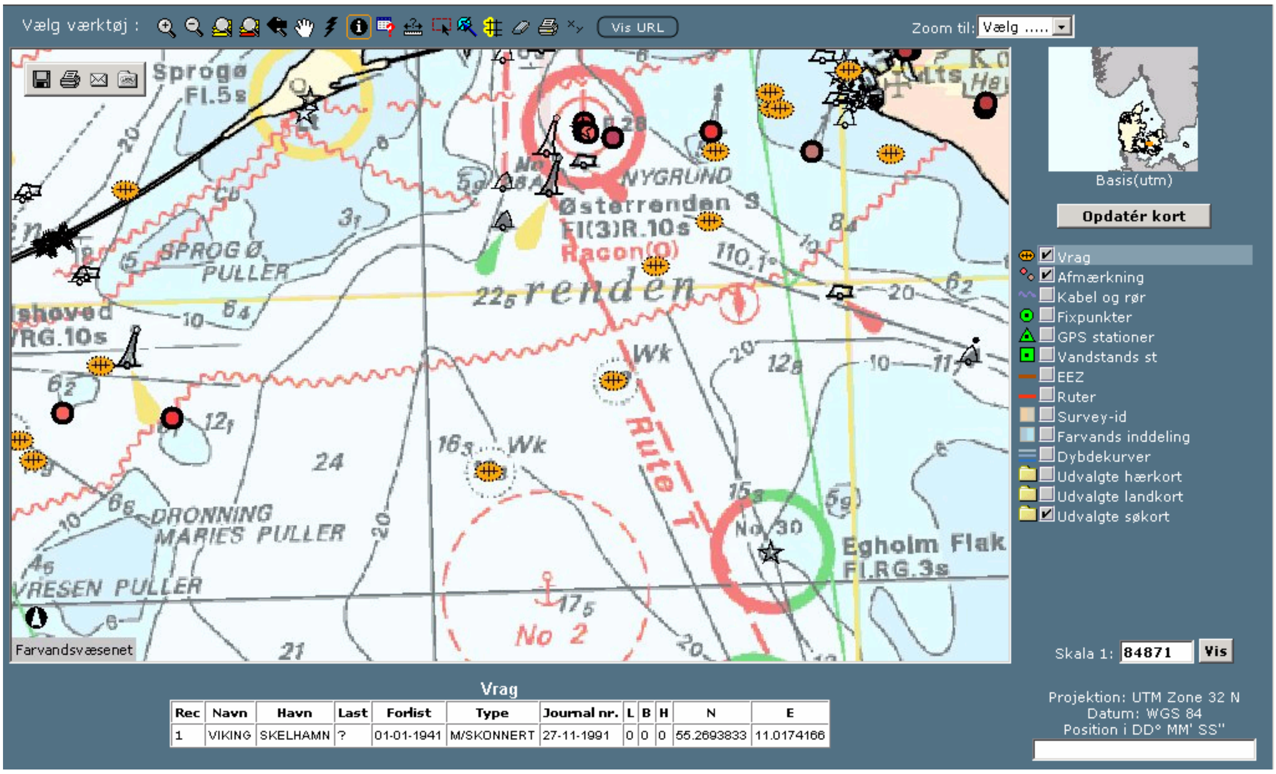

Figure 4 Integration of Charts and data other sources with ArcIMS

The depth database allows the cross referencing of stored data to the survey under which it was collected through the survey source database.

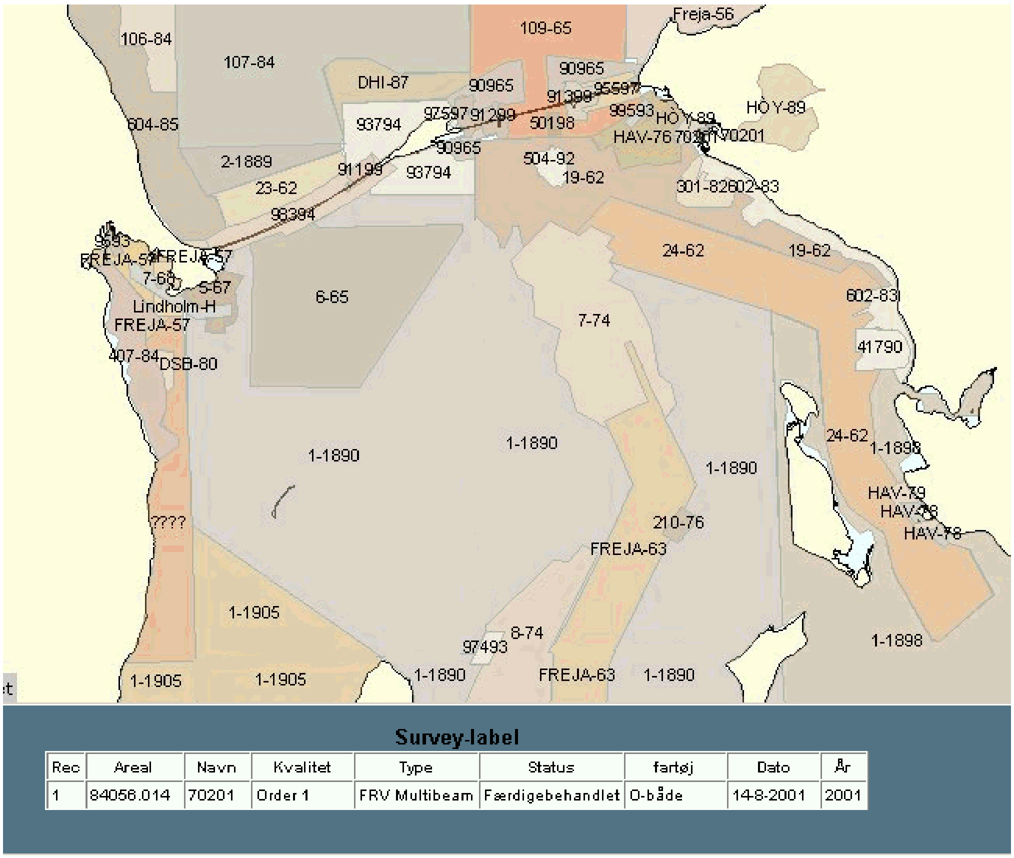

Figure 5 Survey source database

The connection between the SDE depth database and ArcIMS service also allows the comparison of the base data used in chart production to the actual digital information stored in the system.

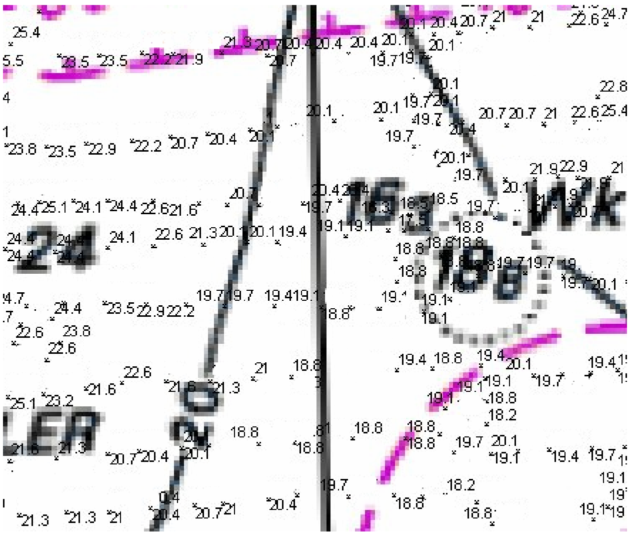

Figure 6 Chart with published depths and SDE database

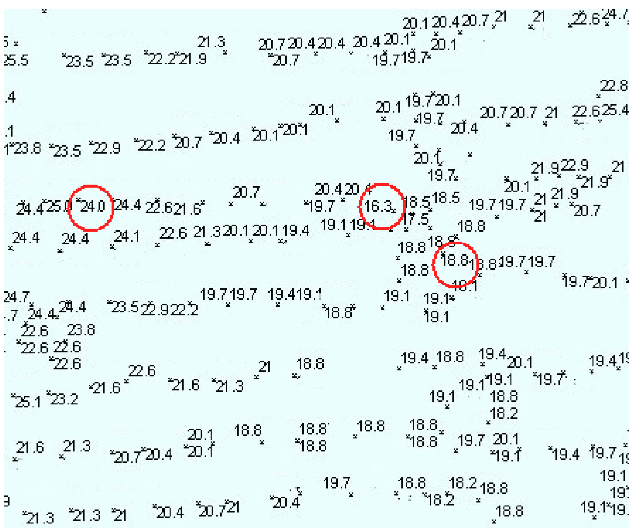

Figure 7 SDE database

Import of S57 data

One of the most important aspects of making a system user friendly is for the appearance of the system to resemble the known or preferred norm, in this case sailing charts. The charts shown on the prototype ArcIMS are raster based charts from the Danish Cadastre and Mapping Agency. As charts are not static in nature, the updating of these charts can be time consuming. One of the major improvements in this area is the potential to import data from electronic navigation charts or ENC in S57 standard. The ENC has a standard format for handling and storing chart information which is described in the standard S57. Through ArcGIS 9 and the S57 to geodatabase converter, the data within an ENC can be imported to ArcIMS.

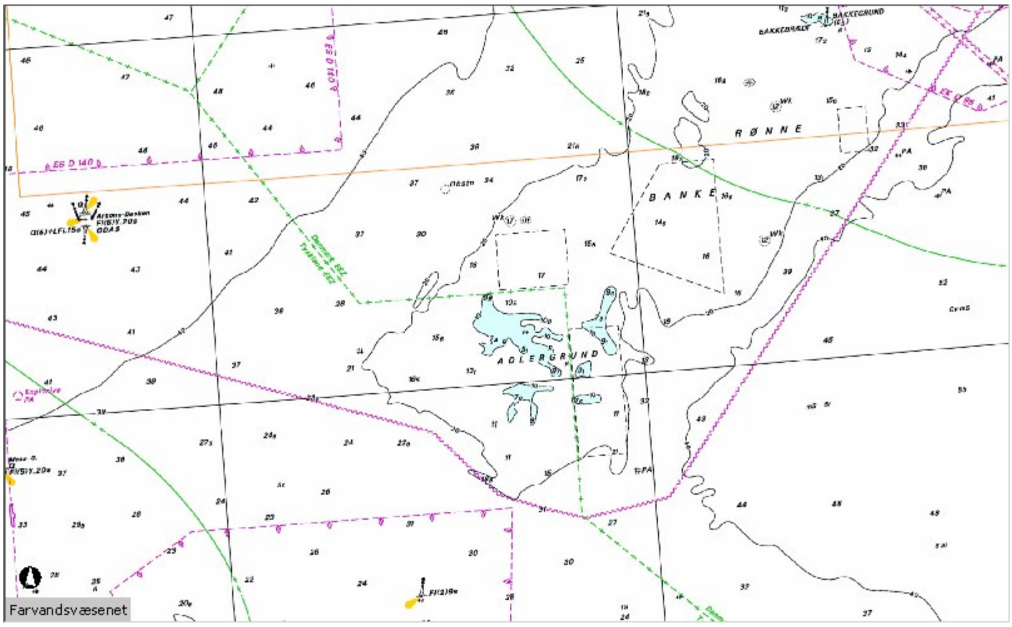

Figure 8 Raster chart

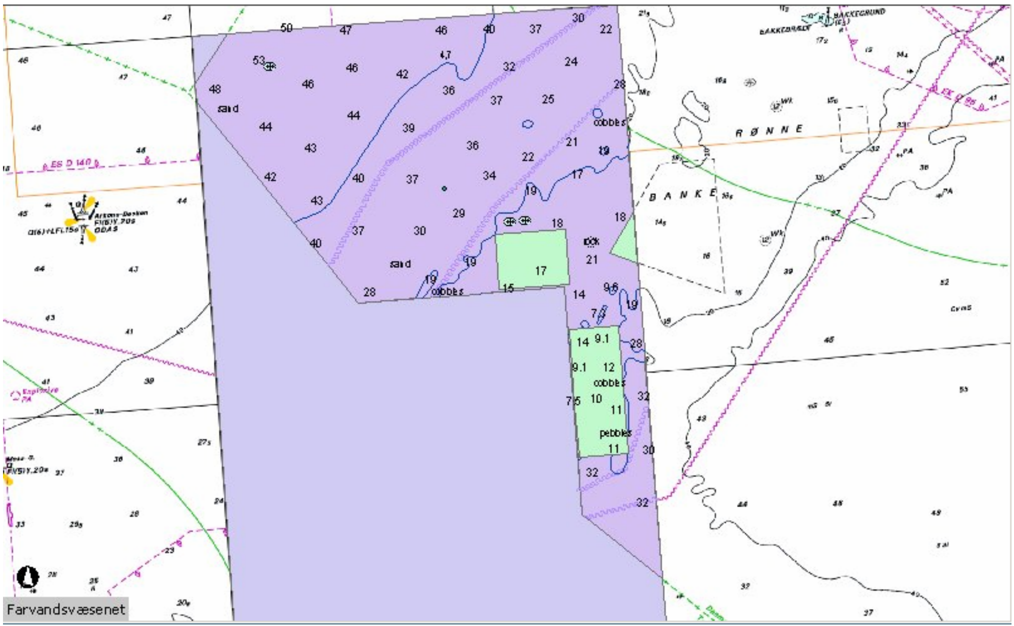

Figure 9 Raster chart with S57 data imported

Production of application specific information

In Danish nautical charts the typical depth contour intervals are 2, 4, 6, 8, 10, 12, 15, 18, 20, 30, 40, 50, 100, 200, 300 meters.

This is adequate for the most vessels within Danish waters, but it is possible to extend the resolution of the deepest intervals by manipulation of the base data material. Within a TIN derived through 3D analyst, extra depth contours can be constructed at more useable intervals than what appear on standard charts.

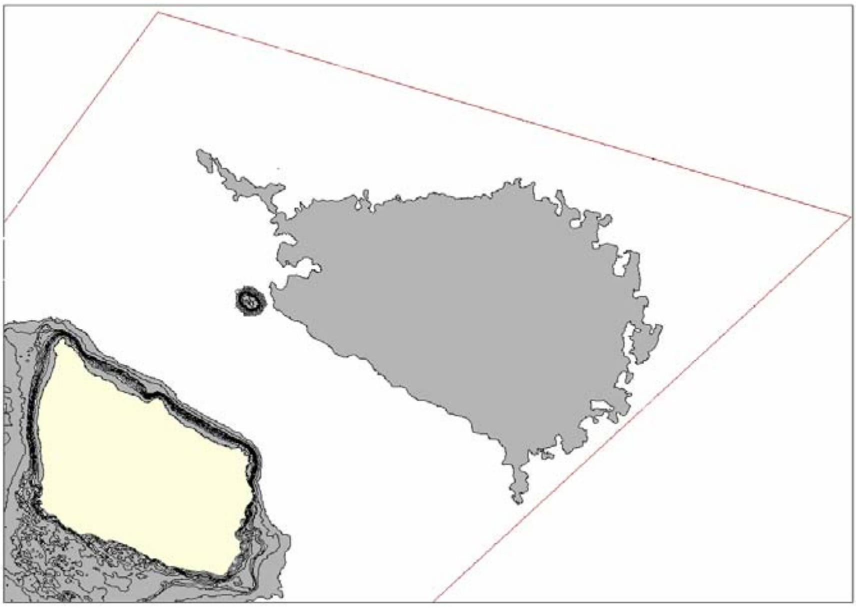

Figure 10 Standard depth curves and areas

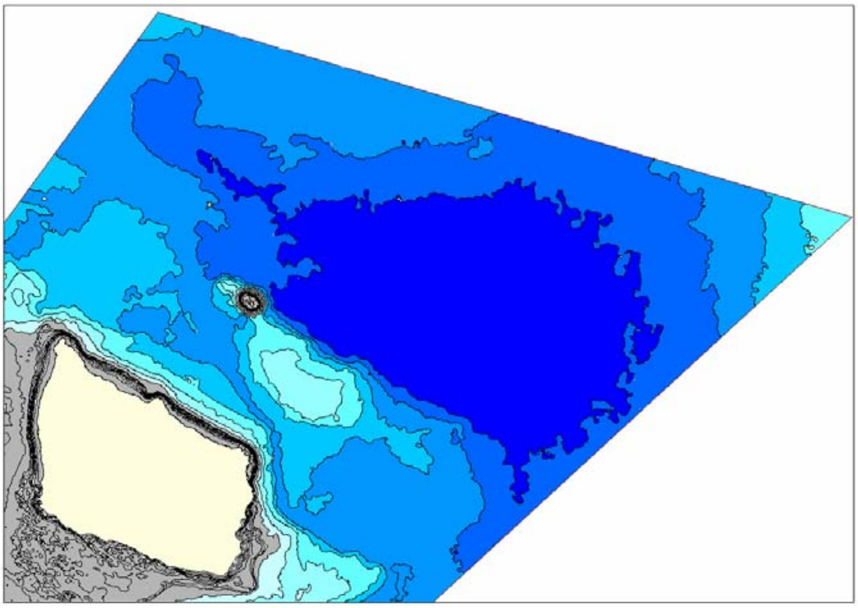

Figure 11 Interpolated depth curves

Application of extra depth intervals

Together with the survey source database an idea of quality and hence accuracy of each survey can be ascertained. Each survey performed by the Royal Danish Navy is in accordance with the IHO recommendation for Hydrographic Surveys SP44.

Submarine navigation

With additional information to the actual form of the seabed, the absolute accuracy of the depth information must also be taken into consideration when evaluating the practical use of the depth information.

A submariner will try to hold a constant height above the seabed. With the accuracy information available through the source database, an operational envelope can be constructed which can help the submariner optimise this.

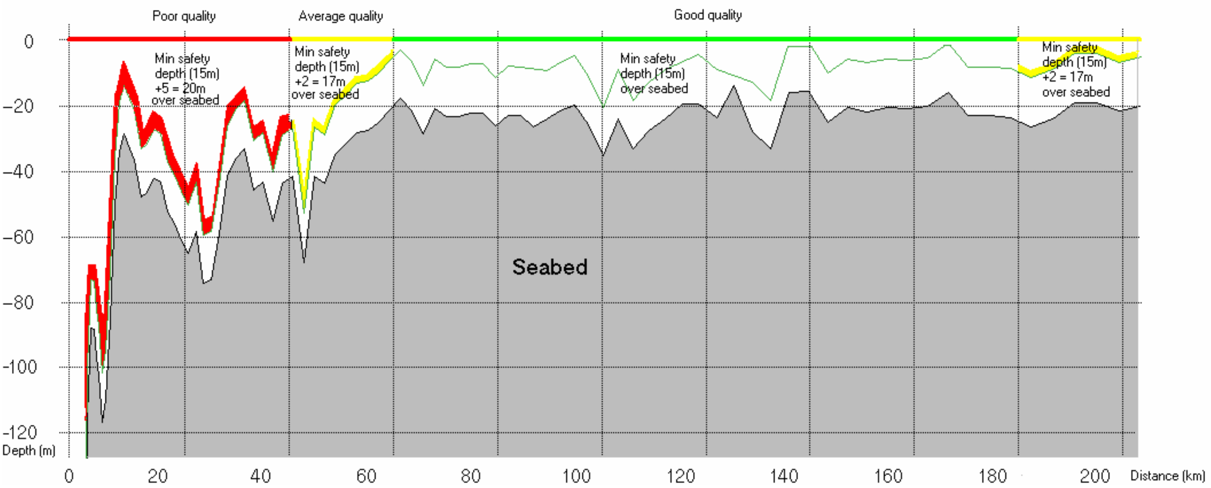

Figure 12 Long section profile showing safety margin with survey accuracy

Pockets of deep water between contours can also be opportune hiding places for submarines.

Future developments

The current ArcIMS runs on RDANH's internal intranet. It is intended that this service is to be ported to cover both the open Internet and the Defence Internal net FIIN.

The replacement of the existing depth database server is due in 2 years and as such a prototype test has been commissioned from InformiGIS to evaluate the porting of the existing system to a Windows environment.

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