Article

Zones of Confidence (ZOC) for New Zealand

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Abstract

In July 2004 HSA Systems Ltd commenced a project for Land Information New Zealand to assess and assign Zones of Confidence to all hydrographic surveys incorporated within 138 hydrographic charts of New Zealand. This article provides an overview of the process to create a detailed picture of the quality and extent of New Zealand's hydrographic survey resource. Each hydrographic survey was assessed in relation to the data quality aspects of the International Hydrographic Organisation (IHO) S-57 Standard. The project team assessed in excess of 1,792 survey fair sheets and allocated 1,465 Zones of Confidence to survey areas.

Résumé

En juillet 2004, HSA Systems Ltd a démarré un projet pour « Land Information New Zealand » en vue d'évaluer et d'attribuer des zones de fiabilité à tous les levés hydrographiques incorporés dans les 138 cartes hydrographiques de la Nouvelle-Zélande. Cet article donne une vue d'ensemble de processus de création d'une image détaillée de la qualité et de l'étendue des ressources en levés hydrographiques de la Nouvelle-Zélande. Chaque levé hydrographique a été évalué par rapport aux aspects de la qualité des données de l'Organisation hydrographique internationale de la norme S-57 de l'OHI. L'équipe du projet a estimé qu'il y avait plus de 1 792 minutes de rédaction hydrographiques et a attribué 1465 zones de fiabilité à des zones de levés.

Resumen

En Julio del 2004, HAS Systems Ltd. comenzó un proyecto para que el Departamento de Información Territorial de Nueva Zelanda evaluase y asignase Zonas de Confianza a todos los levantamientos hidrográficos incluidos en las 138 cartas náuticas de Nueva Zelanda. Este artículo proporciona una visión general del proceso de creación de una descripción detallada de la calidad y extensión de los recursos de los levantamientos hidrográficos de Nueva Zelanda. Cada levantamiento hidrográfico fue evaluado en relación con los aspectos de la calidad de los datos de la Norma S-57 de la Organización Hidrográfica Internacional (OHI). El equipo del proyecto evaluó una cantidad superior a 1.792 parcelarios y atribuyó 1.465 Zonas de Confianza a las áreas levantadas.

Introduction

To date, New Zealand has provided quality indicators on all of its hydrographic charts by way of Source Data Diagrams and Diagrams of Sounding Line Density. To address the current hydrographic data quality requirements, LINZ required the capture of ZOC information for their hydrographic surveys. LINZ (2004) contracted HSA to undertake this project with the project outcomes being:

- Provide a detailed understanding of the quality of all hydrographic surveys used in the compilation of New Zealand's larger scale nautical charts;
- Improve the survey prioritisation process; and
- Allow for the future depiction of ZOC diagrams on LINZ's paper charts and Electronic Navigational Charts (ENCs).

The purpose of this paper is to provide an overview of how the ZOC information was acquired including a discussion on the data sources, assessment and encoding approach.

ZOC	Position Accuracy (m)	Depth Accuracy (m)	Seafloor Coverage
A1	± 5.0	= 0.5 + 1% depth	full area search undertaken; all significant seafloor features detected have had depths measured.
	Typical Survey Characteristics (see Note): controlled, systematic, high accuracy survey on WGS 84; using DGPS or a minimum 3 lines of position with multibeam, channel or mechanical sweep system.		
A2	± 20	= 1.0 + 2% depth	full area search undertaken; all significant seafloor features detected have had depths measured.
	controlled, systematic survey; using modern survey echosounder with sonar or mechanical sweep.		
B	± 50	= 1.0 + 2% depth	full area search not achieved; uncharted features, hazardous to navigation, may exist.
	controlled, systematic survey.		
C	± 500	= 2.0 + 5% depth	full area search not achieved; depth anomalies may be expected.
	low accuracy survey or data collected on an opportunity basis such as soundings on passage.		
D	worse than ZOC C	worse than ZOC C	full area search not achieved; large depth anomalies may be expected.
	poor quality or data that cannot be assessed due to lack of information.		
U	quality of bathymetric data yet to be assessed.		

Figure 1. Zone of Confidence (ZOC) Assessment Criteria

Zones of Confidence (ZOC's)

A concise history of the development of ZOCs and their adoption by the International Hydrographic Organisation (IHO) is described by Johnson (2004). Aspects of Johnson's paper are briefly restated here in order to provide an overview of ZOCs. During the 1990's the concept of ZOCs was developed by the Australian Hydrographic Office (AHO). The IHO Data Quality Working Group (DQWG) developed ZOCs as a technically feasible solution for the assessment and display of hydrographic data quality to support safe and efficient navigation.

The method of encoding data quality information as a Zone of Confidence (ZOC) is contained within the IHO Special Publication No. S-57, Transfer Standard for Digital Hydrographic Data, which includes the Feature Object "M_QUAL" and the attribute "CATZOC" – Category of Zone of Confidence in Data (ZOC).

Areas covered by hydrographic surveys are classified by identifying various levels of confidence with respect to depth accuracy, position accuracy, thoroughness of seafloor search, and the characteristics of the survey.

Six ZOC have been developed - A1, A2, B, C, D and U and these are described in Figure 1. ZOC A1, A2 and B are typically for modern surveys with A1 and A2 requiring a full area sea floor search, C and D reflect low accuracy, low density and/or poor quality data whilst U represents data which is

ZOC	Summary Criteria
A1	all significant seafloor features detected; very high accuracy survey.
A2	all significant seafloor features detected; high accuracy survey.
B	uncharted features dangerous to surface navigation are not expected but may exist; medium accuracy survey.
C	depth anomalies may be expected; low accuracy survey.
D	large depth anomalies may be expected; low accuracy survey.
U	quality of bathymetry yet to be assessed.

Figure 2. Zone of Confidence (ZOC) Summary Criteria

unassessed at the time of publication. ZOC criteria are summarised in Figure 2.

New Zealand's Requirement

Land Information New Zealand (LINZ) is New Zealand's national charting authority. LINZ had a requirement to capture, document and present the ZOC information for surveys used in the compilation of New Zealand's hydrographic charts. ZOC assessments were to be undertaken on a survey basis as opposed to a chart basis i.e. ZOC diagrams for individual charts was not a specific product of this project.

Process Overview

The first step in the project was to undertake a desktop assessment of the number of potential hydrographic surveys used in the compilation of each hydrographic chart. LINZ identified 138 large to medium scale charts requiring assessment, each with its own chart index. The chart index is the key document providing an indication as to which surveys had been used to compile each chart. The chart index is the document from which the Source Data Diagram is compiled and portrayed on the printed paper and raster chart. The desktop assessment indicated approximately 484 surveys consisting of 1,946 fair sheets had been used in the production of these charts.

With the approximate volume of fair sheets identified the process for assessing the survey sheets for ZOC classification was determined and refined - refer to Figure 3.

The process required the largest scale surveys affecting the largest scale charts to be assessed first. In this way smaller scale surveys/ charts and overlapping charts would only need the surveys assessed which fell outside of the larger scale surveys. Each chart index was extracted from the LINZ Hydrographic Data Repository (HDR) along with all of the surveys used in the compilation of that chart. Any ancillary information accompanying each survey i.e. reports of survey, tidal data packs, geodetic data packs etc were also extracted as they are required for full ZOC assessment. In most instances the reports of survey provided sufficient information to complete the ZOC assessment. On occasion, some reports of survey lacked detailed information hence the need for more in depth research into tidal data packs, geodetic data packs etc. Each survey was then evaluated and awarded a ZOC classification. This information was recorded in the project documentation and encoded in an S-57 database. The ZOC polygons were then digitized and tagged with the encoded attribute data.

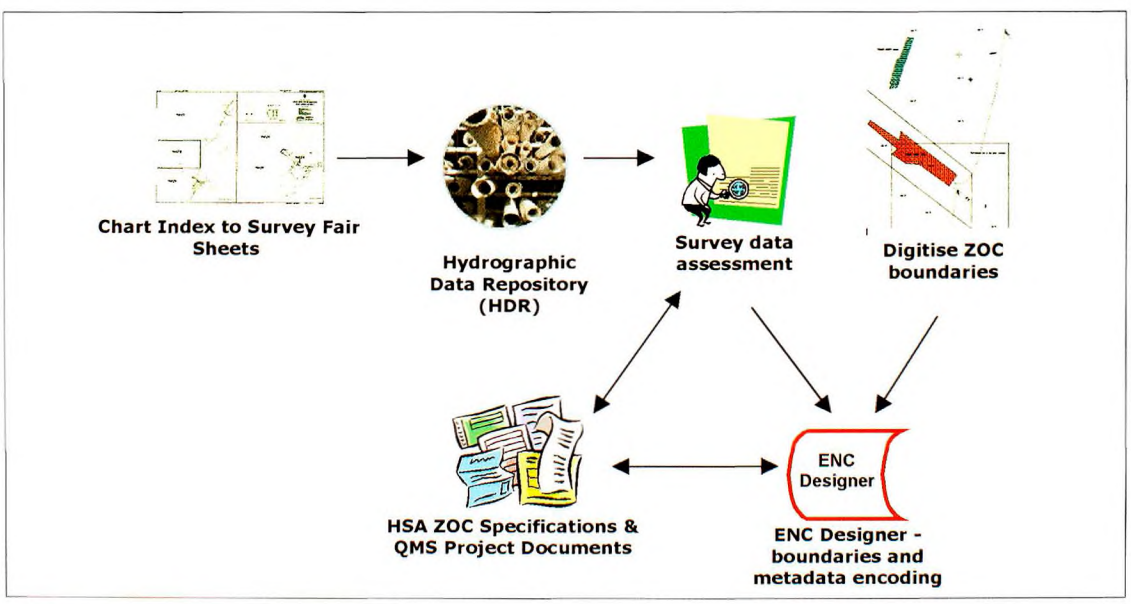

Figure 3. ZOC Assessment Overview

Tools

A key element of the capture, storage, access and dissemination of the ZOC attribute information are the tools with which this information is processed and retained. In New Zealand's case the requirement was for the mass assessment, capture and population of a ZOC attribute database or databases. The databases needed to be populated with ZOC attributes in conjunction with the ZOC/survey polygons. A mechanism by which all of this data could be quickly and readily validated with a high degree of confidence was also required. Two tools were evaluated for the purpose.

ZOCMAN

The Australian Hydrographic Office (AHO) developed the ZOCMAN application in 1999. ZOCMAN was originally developed for the MS Windows 95/NT platform and was compatible with the Borland Database Engine (BDE) 4. ZOCMAN records ZOC attributes, calculates the ZOC rating based on a defined algorithm and enables the operator to encode ZOC/survey coordinates for a single polygon. ZOCMAN allows the operator to manually enter ZOC polygon coordinates. An additional GIS application, such as MapInfo, is required for polygon capture via digitiser. No degree of topological structure is maintained while the spatial aspect of each ZOC polygon must be viewed independently to the attribute data. The ZOC attributes and spatial data is stored in a Borland database format. There is only a limited ability to provide information to other applications without additional processing.

ENC Designer/ AutoZOC Module

ENC Designer is a software tool used in the production of S-57 Electronic Navigation Charts (ENC's). Refer Figure 4. The product was developed by SevenCs AG & Co. KG. ENC Designer operates on the MS Windows XP Pro platform. The application uses topologically structured data at the chain-node topology level which is consistent with IHO S-57. All exported spatial topology will correctly handle islands and holes in ZOC regions. A key aspect of ENC Designer is the ability to export data as an S-57 v. 3.1 ENC data set.. The ZOC ENC cells/databases are therefore easily maintained and disseminated. The ENC cells can be viewed using any of the available ENC viewer applications. With ENC Designer, the user has the benefit of a single software interface to encode both ZOC attribute data

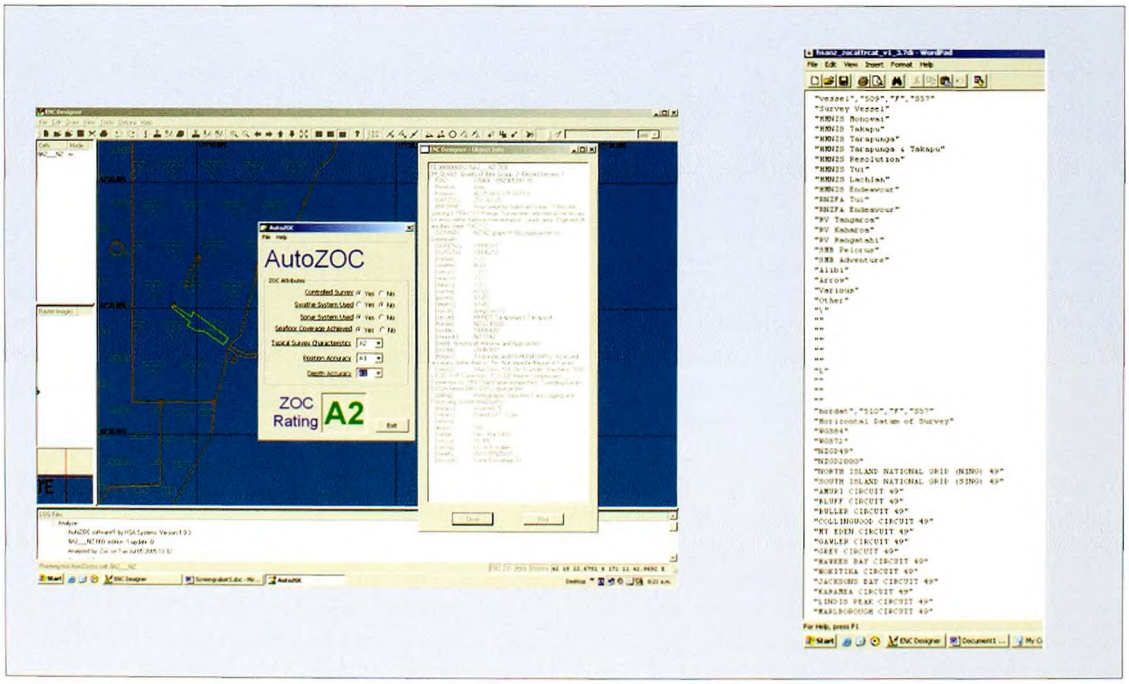

Figure 4. ENC Designer, AutoZOC Module, ZOC Attributes, ZOC polygons and data exported in XML format.

and spatial data. Customised object catalogues can be created to cater for additional attributes. There is also an ability to load TIFF images as a back drop for polygon capture, identifying changes and assisting with quality assurance.

HSA developed the AutoZOC plug-in module for ENC Designer. The module incorporated and improved the AHO's ZOCMAN assessment logic flow chart. Refer Figure 5. AutoZOC is invoked from within ENC Designer. The determination/confirmation of a ZOC rating occurs within the AutoZOC module which reads the parameters (made available in the customised object catalogue) and automatically populates the S-57 CATZOC attribute. AutoZOC reads and writes to the S-57 file which ENC Designer generates. The ZOC attributes can then be exported in XML format. XML is supported by most modern Geographic Information Systems (GIS) hence the ability to easily migrate the ZOC data to a platform of choice. In LINZ's case, HSA developed the AutoZOC-DB schema for importing XML data into a MS Access database. AutoZOC-DB contains an AutoZOC calculator. This is purely a validation tool as you cannot actually populate or change a CATZOC value at this stage.

Given LINZ's requirements for the level of attribute data to be recorded, the storage and dissemination of ZOC data, ENC Designer, including the AutoZOC module, was determined to be the appropriate solution for this project.

Methodology

Skill Sets

A key requirement for the project was the need to have qualified and experienced hydrographic survey personnel. A surveyor, qualified to IHO Cat A, was appointed to lead the team. This surveyor's role was to finalise and approve the ZOC classifications assigned to surveys and to ensure that an identical assessment logic was applied to all surveys. An IHO Cat B equivalent hydrographic surveyor was responsible for all of the initial research and assessment of surveys, attribute capture and record keeping. Both surveyors had an extensive knowledge of hydrographic surveying practices within New Zealand. An experienced hydrographic cartographer familiar with New Zealand cartographic practices provided input in terms of how surveys were implemented on New Zealand charts.

Given the familiarity of the surveying staff with a wide variety of software applications for hydrographic data management and processing it was a straight forward task to train staff in the use of the ENC Designer software.

Cell/Database Management

New Zealand's area of charting responsibility is large as it encompasses islands from just south of the equator to Antarctica. It was necessary to create three separate cells or databases based upon geographic regions; Pacific Islands, New Zealand, sub-Antarctic Islands and Antarctica.

It should be noted that at any stage it is possible to integrate any number of cells/databases back into a single master cell/database using ENC Designer. In this way, ZOC data could be managed and quality assured in discrete units. Each cell/database can be loaded, exported and backed up individually.

Digital Index Chart Capture

The next step in the process was to scan and georeference chart indexes in order to provide a raster backdrop for loading into each cell/database. This provided a facility for survey boundary capture and quality assurance. The chart indexes were scanned and output as 300 dpi, black & white Tiff images. Using ENC Designer the Tiff images were individually geo-referenced. The Tiff images were provided to LINZ for internal use and as a digital back up of the paper chart indexes.

Surveys Identified for Assessment from Chart Index

A detailed database of surveys and associated documents was then built from the chart indexes prior to extraction from the LINZ Hydrographic Data Repository (HDR). A team of people was assigned to extract the necessary records from the HDR for assessment. The extraction and return of all records was controlled using HSA's Quality Management System (QMS) as nearly all of the records are originals with some dating back to the 1800's.

ZOC Assessment

The ZOC assessment process was carried out on a survey-by-survey basis commencing with the largest scale surveys. The ZOC assessment teams task was to:

- Examine each survey sheet.
- Examine associated reports for information on survey method used and survey accuracies.
- Determine the surveying method used, ZOC cat-

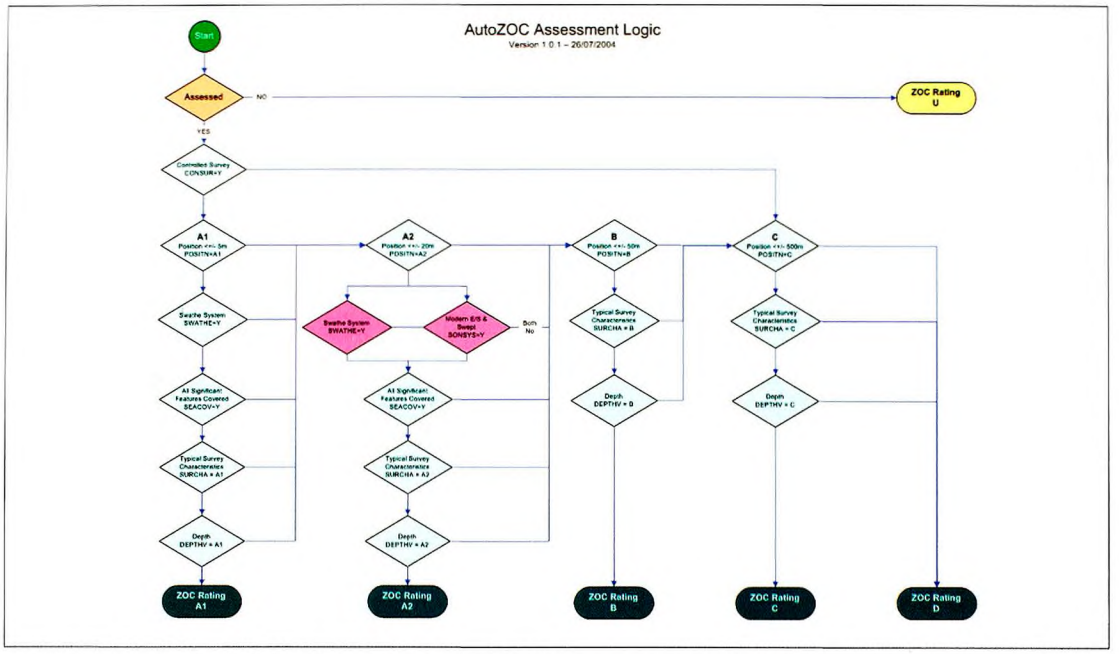

Figure 5. Improved Australian Hydrographic Service ZOCMAN assessment logic flow chart for use in the AutoZOC calculator

egory for position and depth accuracy.
- Determine the ZOC category for seafloor coverage for each survey.
- Where necessary, subdivide the survey into areas of different seafloor coverage and assign appropriate ZOC ratings.
- Seek advise or guidance from LINZ as required
- Record all ZOC assessments using project docu-

Years	Sounding Technology	Depth Accuracy +/-	Positioning Technology	Positioning Accuracy	Broad ZOC Group
Pre 1900	Leadline	0.2 - 5.0??	Sextant	10-1000m	D
1900 - 1967	SBES	0.1 - 2.0	Sextant	10-200m	D,C
1900-1991	SBES	0.1 - 1.0	Terrestrial Fixing (large scale)	3-5m	B
1950's - 1987	SBES	0.1 - 1.0	Hifix6	5 - 30m	B/C
1978 - 1985	SBES	0.1 - 1.0	Trisponder RO3	2 - 8m	B
1985 - 1993	SBES	0.1 - 1.0	Trisponder DDMU	2-8m	B
1980 - 1990	SBES	0.1 - 1.0	SatNav	200m	C/D
1983 - 1993	SBES	0.1 - 1.0	GPS S/A	50-130m	C
1998 - 2004	SBES	0.1 - 1.0	GPS (no S/A)	6-12m	B
1992 - 2004	SBES	0.1 - 1.0	DGPS	1 - 3m	B
1998 - 2004	MBES	0.1 - 1.0	DGPS	1 - 3m	A1 or A2
1995 - 2000	SBES	0.1 - 2.0	GPS (Centurion Coded)	6 - 12m	B
Various	SBES	0.1 - 5	U	Unknown	D
Various	SBES	0.1 - 2.0	Radar/Bearing	0.02 - 0.2 nm	D
Comments:	*Column 1 - Estimates,. needs to be refined from information within ROS's.* *Column 2 & 4 - There are a number of other sounding and positioning combinations that may arise through research of historic data. Each will need to be assigned a ZOC rating based on own merits. MBES is not operated without DGPS as a minimum positioning control.* *Column 3 - Depth Accuracy. This can be extremely variable depending on all factors associated with vertical accuracy - such as tides etc.*				

Figure 6. New Zealand Survey techniques & approximate ZOC rating

Survey Type	Broad ZOC Group	Scale/Accuracy
GEBCO	D	500m
OSS (recent GEBCO)	D	500m
Misc. surveys	C/D	Individual Basis
Pre 1970's	C/D?	Individual Basis
Offshore/RNZN	B/C	As per specs
Inshore	A/B/C	As per specs
Side scan sonar	A2?	As per specs
HMNZS Lachlan 1950's	C	75000/100 200000/200
HMNZS Lachlan 1972/3		As per specs (fitted with metric sounder)
HMNZS Monowai 1980's	B/C	As per specs
GPS 1990's	B+	As per specs

Figure 7. New Zealand Surveys & approximate ZOC rating

mentation controlled by HSA's ISO 9001:2000 Quality Management System.

The AutoZOC calculator tool was developed to assist with assigning a ZOC rating. Based upon the IHO ZOC rating criteria, an assessment logic was developed and incorporated into the AutoZOC tool. Refer Figure 5.

As the assessment process progressed a picture was built up of the types of surveys undertaken in New Zealand and their approximate ZOC rating. This is summarised in Figures 6 and 7.

An overview of the process is provided at Figure 9.

The encoding of attribute data required a set of documentation to be created which duplicated the fields to be populated within ENC Designer. This would serve two key purposes:

1. Provides a hard copy record signed by the authorising surveyor. In New Zealand's case this was a senior surveyor qualified to IHO Cat A level.
2. Provides a "paper" back up to the digital equivalent in case of the database becoming corrupted or lost in any way.

The encoding forms were populated from the surveyor's ZOC assessment records. Encoding used the object editor mode within ENC Designer. The AutoZOC calculator was used to confirm the ZOC rating. ENC Designer automatically generated unique object identifiers for each record. The operator populated compulsory fields and other fields where information was known. The INFORM – Notes field was used to document additional information.

Each ZOC attribute record had to be associated with a polygon boundary. The polygon boundary was captured and tagged with the ZOC attribute data. The polygon digitising and editing process within ENC Designer was undertaken in geometry mode. Polygon boundaries were captured with line/node editing undertaken using the features such as snap/split/latch while at the same time maintaining polygon topology. Refer Figure 10.

Desktop Study	Surveys Indexed	484	Sheets Indexed	1,946			**Charts Assessed**	**138**
Reality	**Surveys Actually Assessed**	**731**	**Actual Survey Fair Sheets**	**1,792**	**Other (Gebco, OSS, Sketch, Misc)**	**192**	**Charts Required & Encoded**	**138**
		151.03%		**92.09%**				**100.00%**

Figure 8. Total Surveys Assessed

A key point to note from the statistics in Figure 8 below is the figures in the "Reality" row exceed those from the "Desktop Study" row. This was due to inconsistent chart indexes. It should be noted the chart indexes were never meant to be used as comprehensive source document indicators for a ZOC analysis.

ZOC Encoding Process

The ZOC encoding process involved the following stages:

1. Encoding attribute data
2. Polygon capture
3. ZOC cell XML export

Work Flow

Given the size of the ZOC assessment and projected encoding a small port located on the South Island of New Zealand was selected as a trial area in order to refine the ZOC processing model. This

area incorporated a range of survey types from large scale harbour surveys, sidescan surveys, medium scale approach surveys, smaller scale coastal passage surveys and oceanic GEBCO passage sounding. Once completed and accepted, the ZOC assessment and encoding process began in earnest with the order of priority being the Pacific Islands, Antarctic and finally New Zealand. Refer figures 11 and 12.

The following table provides information on the numbers of ZOCs in each cell/database:

Cell/Database	A1	A2	B	C	D	U	Total Number of ZOCs
Pacific Islands	1	3	27	40	98	19	188
Antarctic	0	4	2	0	0	1	7
New Zealand	2	66	429	302	157	314	1,270
							1,465

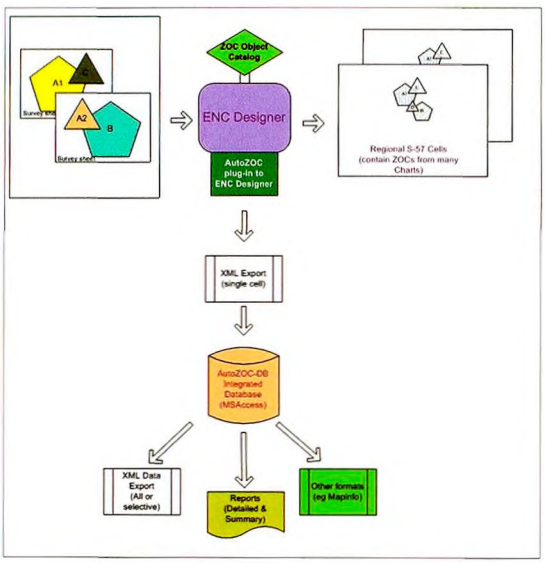

Figure 9. Overview of ZOC encoding and export process

Quality Assurance

The project was undertaken in accordance to HSA's Quality Management System (QMS) which is certified to ISO 9001:2000. LINZ and HSA implemented detailed contract specifications, project plans and quality plans. Each survey was assessed by an experienced hydrographic surveyor then quality controlled and approved by the IHO CAT A qualified surveyor. As well as manual checks of all records ENC Designer provided integrity reports for data captured within ENC Designer. This resulted in a quick and efficient method for correcting data entry errors.

Project Deliverables

At the completion of the project the following deliv-

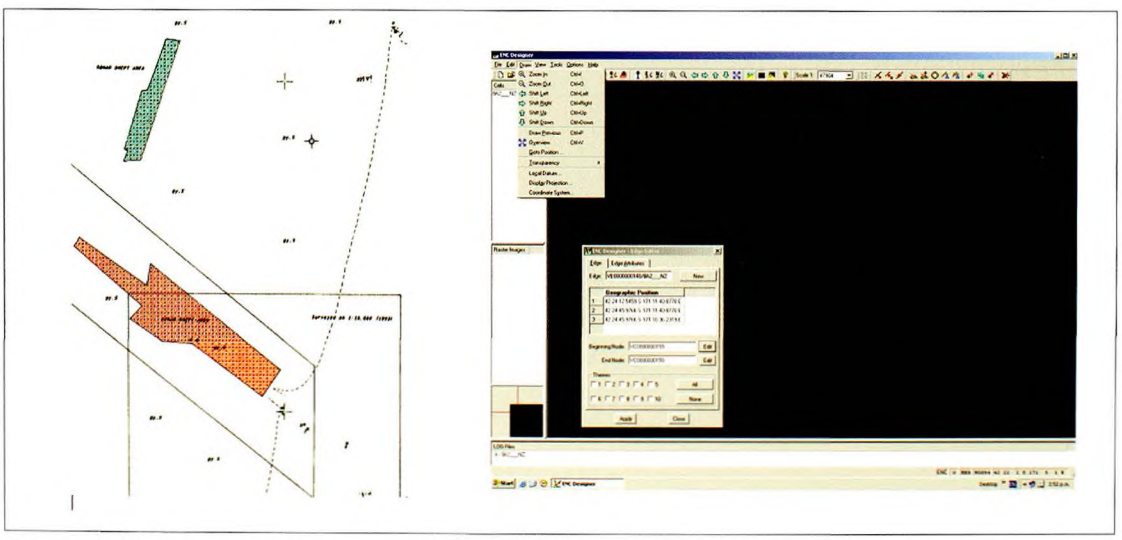

Figure 10. ZOC polygon capture

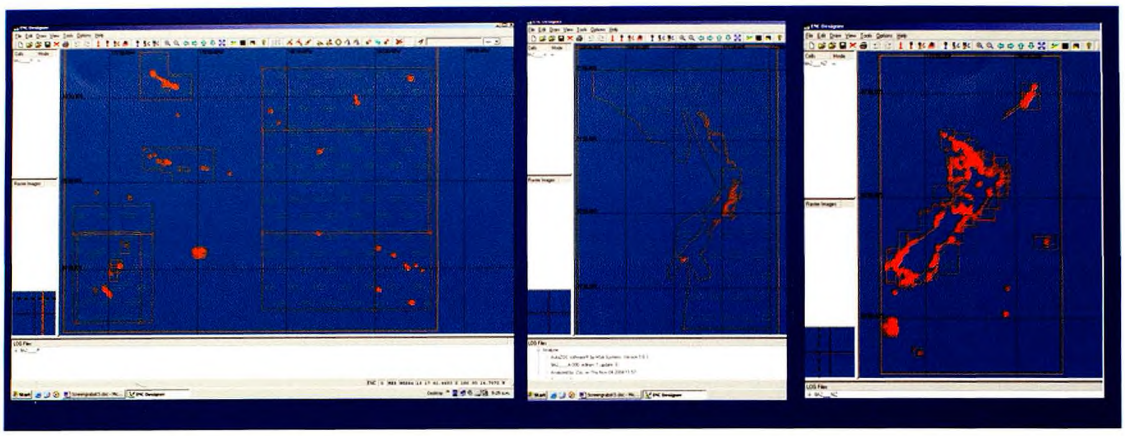

Figure 11. Pacific Islands, Antarctic and New Zealand cells/databases

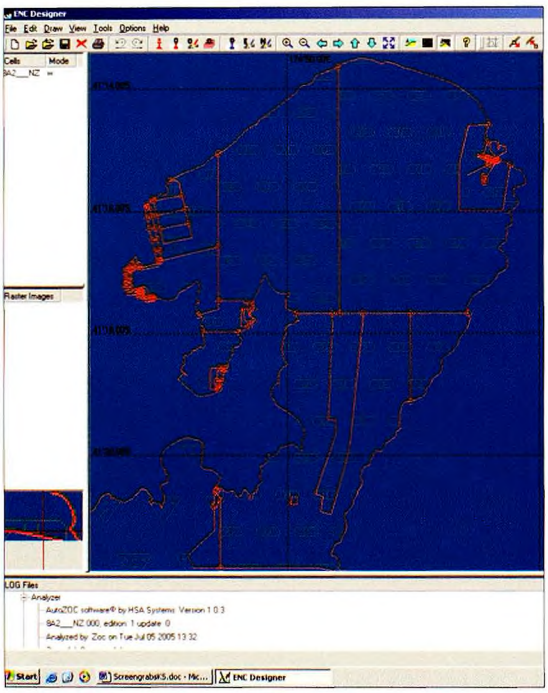

Figure 12. Wellington Harbour, detailed view, New Zealand cell/database

erables were supplied to LINZ:

1. 1 x TIFF file of each index chart (138)
2. 1 x ZOC assessment folder for each chart
3. 1 x XML file for each cell/database
4. Populated AutoZOC database (MS Access)
5. 1 x S-57 v 3.1 ENC cell for each cell/database
6. Summary Report

A key aspect of the data supplied to LINZ was the portability of the digital data in XML format. This permits LINZ to readily migrate the ZOC data to its platform/s of choice for future data capture, maintenance and distribution purposes. This is demonstrated in the following views whereby the ZOC boundary data and attribute data has been migrated into the freely available Google Earth web browser.

Conclusion

The project was commenced in June 2004 and was principally completed by late June 2005 approximately 5 months ahead of schedule. The gain in timing can be attributed to:

- The use of experienced hydrographic surveyors with extensive knowledge of New Zealand surveying practices.
- The use of the ENCDesigner software which enabled both the spatial and attribute data to be captured and managed within the one application.
- A well documented process for ZOC assessment.
- Clear and concise operational and contract documentation.

Given the ZOC assessment process required a review of all hydrographic surveys used in New Zealand's nautical charts, it was clearly evident that there was a diverse range of quality and age in the surveys reviewed. Documentation associated with the surveys, including reports of survey, varied greatly. With modern technologies for hydrographic surveying now readily available, including detailed survey specifications produced by national and international bodies, the quality of attribute data accompanying surveys should be high. Most local and national agencies responsible for under-

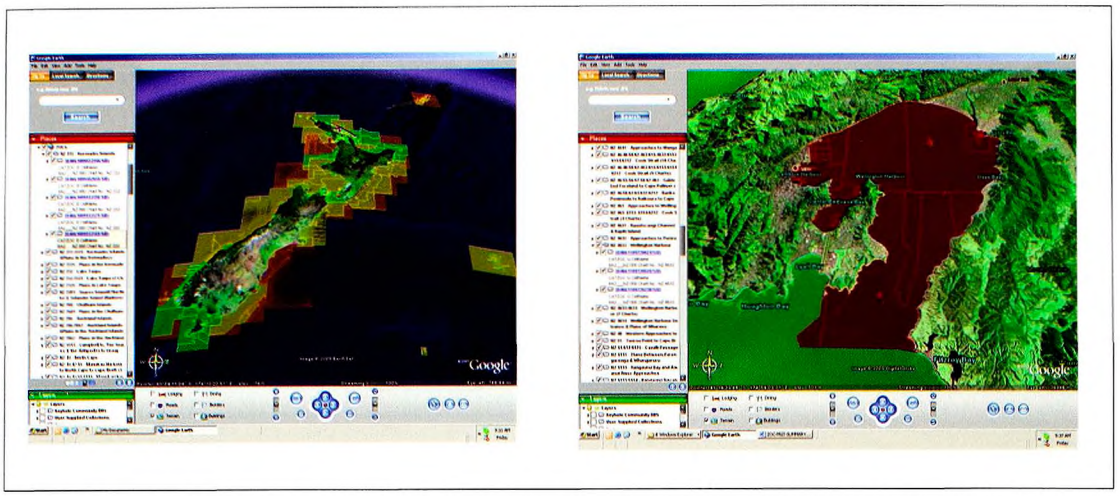

Figure 13. New Zealand cell/database and Wellington Harbour, detailed view with chart backdrop, within Google Earth

taking hydrographic surveys are now required to manage risk. One method for understanding that risk is the assignment of ZOC ratings to hydrographic surveys. This can only be accurately undertaken if a survey is accompanied by supporting information on how the survey was undertaken and to what specifications the data has been gathered.

The information gathered during this project provides LINZ with a detailed view of surveys used in chart production. e.g. their accuracy, age and extent. With this data LINZ can now better identify and prioritize areas which require surveying and programme the release of ZOC information in its products.

Acknowledgements

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DML provides a specialized range of hydrographic and marine services for coastal projects. The company's skills in the hydrographic survey industry are based upon key personnel with many years experience in planning, conducting and producing accurate hydrographic surveys for national and international charting requirements.

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