New Zealand Bathymetry Investigation

October 2015

ISBN 978-0-478-10766-1

Executive Summary

Land Information New Zealand (LINZ) is working to grow the value created by location information. Decisions using this information already add $1.2 billion to New Zealand's economy and LINZ has a 10 Year Vision to grow this value.

To achieve this it has taken on a stewardship role for some of New Zealand's most important fundamental data such as topographic data and aerial imagery. This stewardship approach has led to this data being made more accessible and in common formats that allow it to be reused and modified.

LINZ is now looking to carry this approach across to bathymetric data, which is information about underwater terrain. This information is vital to New Zealand's marine economy. It is used for developing the nautical charts that support maritime safety; conserving our shorelines and waters; managing fisheries; and identifying undersea resources such as minerals.

But, despite its importance, New Zealand has lacked a full picture of the extent and location of the bathymetric data held by government and the private sector. This investigation aims to create a better understanding of this data so it can be managed to create even greater value.

It includes market research carried out through a mixture of quantitative and qualitative methods to understand and describe the current state of bathymetry in New Zealand. The economic review uses international literature to describe the likely value to be realised from having better bathymetric data.

The investigation found there is real potential for leadership and coordination of bathymetric data to bring significant benefits for New Zealand. There are currently significant gaps in the availability of bathymetric data and little or no coordination of bathymetry across New Zealand. These issues prevent this data from meeting its potential to contribute to New Zealand both socially and economically.

While there is substantial investment in bathymetric data in New Zealand, collecting it remains expensive and time consuming. Areas of New Zealand's waters remain unmapped to a high resolution.

There is also duplication of collection and dissemination, poor collection standards, and a lack of discoverability or easy access. In addition, the metadata or description of the data is often poor, and the data cannot be easily shared between organisations and systems.

An extensive review of international cost-benefit literature shows that better coordination of bathymetry and the production of a national bathymetry model would produce economic benefits of between 1:2 and 1:6. These benefits would come from reducing duplication and administration, improving survey prioritisation, and better availability of usable, quality data that is fit for purpose. All would lead to more effective decision-making.

This investigation recommends greater coordination of bathymetry acquisition and dissemination in New Zealand and that at all Crown funded data collected should be made public.

Key Findings

- The marine environment is an important asset that provides extensive benefits for New Zealand.
- In 2002 the marine economy contributed $3.3 billion (3% of total GDP) to the total economy ($115 billion).
- Bathymetric data is information about the morphology of underwater terrain and is derived from measurements of the depth of lakes and oceans. It is a key asset that supports New Zealand's marine economy.
- The need for, and the use of, bathymetric data in New Zealand is widespread. Sixty-six of the 71 stakeholders that responded to LINZ's bathymetry questionnaire use bathymetry in their business.
- At least $20 million per annum is spent on collecting bathymetric data through hydrographic and bathymetric surveys.
- There are noticeable gaps in the coverage of bathymetric data (even in priority areas) – up to 70% of New Zealand's waters are not mapped to a high resolution.
- There is a range of sectors in the New Zealand economy where marine spatial data is vital to decision-making. for example:
    - *shipping*
    - *fishing and aquaculture*
    - *offshore minerals, and*
    - *government and defence.*
- A review of international literature shows:
    - return on investment for hydrographic services is between 1:3 and 1:9, and
    - return on investment for good bathymetric data provision is between 1:2 and 1:6.
- There is little coordination of effort in New Zealand to streamline the acquisition and dissemination of bathymetric data.
- Better coordination of bathymetric data in terms of acquisition and dissemination could have a considerable impact on New Zealand's marine economy

Recommendations

1. It is recommended that there is greater coordination of bathymetry acquisition and dissemination in New Zealand.

A number of 'quick wins' have been identified that could be implemented to improve coordination and quality of bathymetric data.

Initially, work should be carried out to distinguish where coordination would most benefit the sector.

Initiatives to improve coordination would build on where coordination already exists and involve stakeholders working together to decide the best course of action.

2. It is recommended that all Crown funded data collected should be made public.

Public agencies need to work together to identify all the data that can be made publicly available and how to make it easily discoverable and available.

3. It is recommended that the long term goal for bathymetry in New Zealand should be to develop a freely available national bathymetry model

Bathymetry stakeholders should agree on the specifications for a national bathymetry model and work together to develop and deliver a suitable product that can be used across the sector.

Figures

1 Introduction

1.1 Context

Location information – information that shows where things are, and how they relate to one another and change over time – is crucial to New Zealand's growth. It can support navigation and travel, give certainty to property rights and improve understanding for better decision-making.

In 2008, the Cooperative Research Centre for Spatial Information (CRCSI) estimated that this information contributed $1.2 billion to the New Zealand economy. LINZ is working to grow this benefit, and has set a 10 Year Vision to drive a tenfold increase in the value created through the use of location information.

As part of its work to support this, LINZ has taken a stewardship approach to some of New Zealand's fundamental spatial data, working to improve understanding and accessibility. Bathymetry is among this data, and this investigation is a first step in looking at how it can be managed for greater benefit to all of New Zealand.

1.2 The purpose of this report

The New Zealand Bathymetry Investigation was commissioned as foundational work to support LINZ's 10 Year Vision.

AIMS AND OUTPUTS

The primary aim of the New Zealand Bathymetry Investigation is to identify how to manage New Zealand's bathymetric data to maximise its contribution to New Zealand's economy.

Three main outputs of the investigation were identified:

- market research to understand current and future requirements of New Zealand bathymetry,
- a review of economic value to assess the benefits to New Zealand of better management of bathymetric data, and
- high-level recommendations for the next steps in the development and coordination of bathymetric data in New Zealand.

1.3 The structure of this report

To meet these aims and outputs three basic approaches have been used: a literature review, a market survey based on a widely circulated questionnaire, and individual meetings/interviews.

This report presents the results of the New Zealand Bathymetry Investigation in the following structure:

- Section 1 provides background information on New Zealand's marine environment and economy.
- Section 2 provides an analysis of the responses from the LINZ bathymetry questionnaire and the information gathered from individual discussions and interviews with stakeholders.
- Section 3 identifies the economic value of better management of bathymetric data in New Zealand, using existing international literature.

2 Methodology for the investigation

2.1 Market Research

A mixture of quantitative and qualitative methods was used to understand the current landscape of bathymetry in New Zealand. As part of the quantitative research, a questionnaire was sent to stakeholders to find out about issues relating to the collection and use of bathymetric data. The questionnaire was also available as a link on the LINZ website and was advertised by the New Zealand Coastal Society and the New Zealand Institute of Surveyors.

To initiate more in-depth discussions, interviews and meetings were held with some key stakeholders. Lastly, additional information on the collection, use and provision of bathymetric data internationally and within New Zealand was obtained by internet searches.

2.1.1 Identification of bathymetry stakeholders

Stakeholders were identified in four ways:

- relevant contacts were selected from the existing stakeholders of the NZHA,
- contacts who had used or downloaded bathymetric data from LINZ Data Service were identified,
- contacts identified themselves through the LINZ internet site which provided details of the investigation and how to get involved, and
- contacts identified themselves through responses to the questionnaire provide to the New Zealand Coastal Society and New Zealand Institute of Surveyors.

Although the aim was to identify all stakeholders, it is acknowledged that there were limits to coverage. For example, not all bathymetry stakeholders are known and took part in the questionnaire. This is further explored in the Limitations section (5.2.5)

2.1.2 Questionnaire

2.1.2.1 DESIGN

The questionnaire was developed in consultation with LINZ colleagues and other major bathymetry stakeholders and comprised three sections:

- data use,
- data requirements, and
- data acquisition.

It was designed and deployed using Survey Monkey and utilised question logic to direct respondents through different paths in the questionnaire, depending on the respondent's answers.

Depending on their organisation's situation, respondents answered a minimum of four questions and a maximum of thirty. Apart from two questions on spend, all other relevant questions were compulsory.

Respondents were asked in an email sent in early September 2014 for their input into the questionnaire. A follow-up email was sent out two weeks later with a link to the online survey (21 September 2014). Respondents were given three weeks to complete the survey (14 November 2014), which was then extended by a further week (1 December 2014) to allow for late responses. We accepted either a single response from the whole organisation or separate responses from different groups/units within the same organisation.[1]

[1] All questions from the questionnaire are available in the Appendices, here.

2.1.2.2 RESPONSES

Seventy-four organisations from across New Zealand were invited to complete the questionnaire. We received 73 responses from 58 different organisations. Fifty-nine responses were complete and 14 responses were incomplete (i.e. the respondent had not finished the questionnaire). Fifty-five complete responses were from individual organisations, representing a response rate of 73%.

Respondents represented a wide range of industries, the majority (70%) coming from professional, scientific and technical services (e.g. consultancies), public administration and safety (e.g. government) and transport, postal and warehousing (e.g. Port Authorities).

2.1.3 Stakeholder meetings and interviews

To gain a more in-depth understanding of the use of bathymetric data in New Zealand a number of stakeholders were interviewed by telephone and in face-to-face meetings. These were semi-structured but informal discussions about issues related to the collection, use and management of bathymetry data in New Zealand.[2]

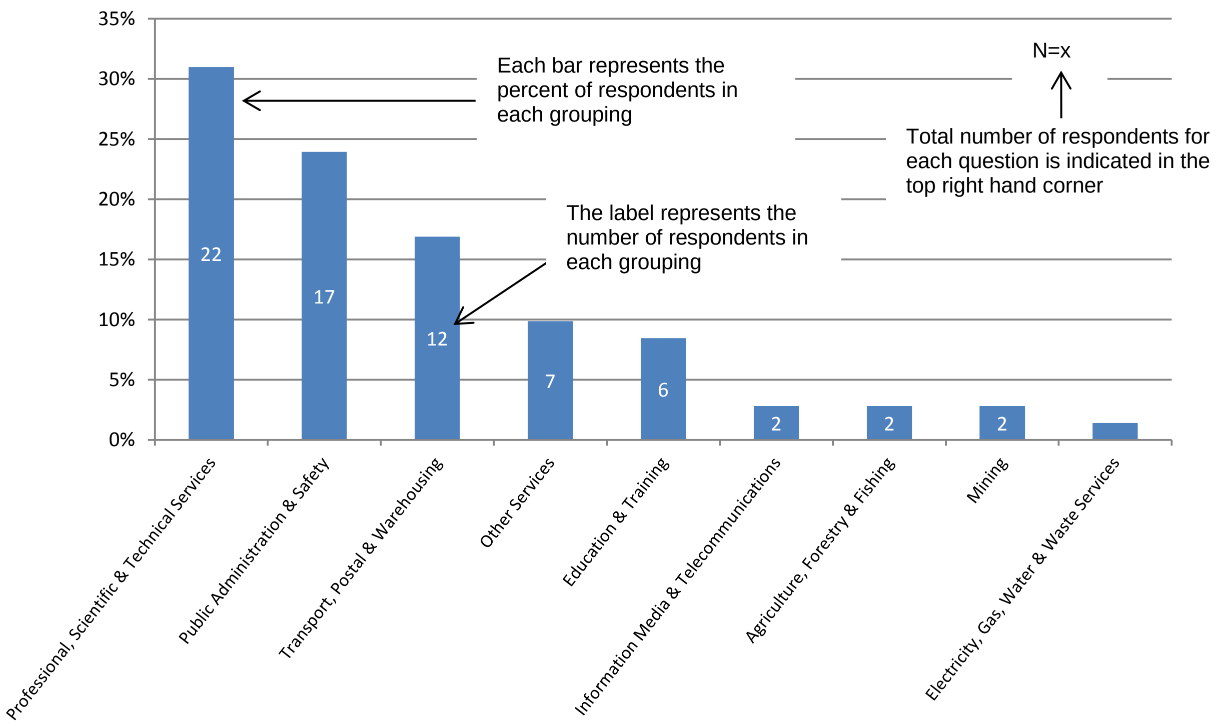
2.1.4 Internet research

To focus the contact with stakeholders on important issues, internet research was used to gather relevant background information. Google and Google Scholar were used as the primary search engines.

2.1.5 Interpreting graphs

Throughout this document, graphs illustrate the responses from the questionnaire. The following figure explains how to interpret the graphs in this report. Refer to the questionnaire outline for more information on each question.

Figure 4: Industry sectors from respondents' results ← This caption describes what the figure is about



[2] A full list of organisations that responded can be found in the Appendices, here.

2.2 Economic literature review

The economic assessment presented in this report is based on:

- a review of available international literature, which details business cases for national hydrographic services,
- a review of literature on the provision of bathymetry data, and
- identifying benefits of bathymetry in New Zealand.

It was decided that a formal cost-benefit analysis was beyond the scope of this investigation.

However, there is a considerable amount of robust international literature examining the economic benefits of bathymetry and data provision (including the provision of bathymetric data).

Much of this work takes the form of traditional cost-benefit analysis, the aim of which is to evaluate the additional value that is created under a reference case when compared to the value that is created under the counterfactual (i.e. with or without scenarios).

3 Background

3.1 Key Points

- The marine environment is an important asset that provides extensive benefits to New Zealand.
- In 2002 the marine economy contributed $3.3 billion (3% of total GDP) to the total economy ($115 billion).
- Bathymetric data is information about the morphology of underwater terrain and is derived from measurements of the depth of lakes and oceans. It is a key asset that supports New Zealand's marine economy.
- There is much wider use of bathymetric data in New Zealand than just for charting.
- There is a heavy reliance on older, traditional bathymetric data, for example single beam, shoal biased data.
- Considerable international efforts are already underway to improve discoverability and sharing of bathymetric data.
- New Zealand is a submerged continent that starts from the highest mountains and finishes in the deepest trenches.
- The science and technology to bring the land and the sea together is emerging.
- Responsibility for the marine environment is split across multiple sectors.

3.2 Bathymetric data in the marine environment

The marine environment is an important asset to New Zealand, providing extensive benefits. The sea is a place for gathering fish and other seafood, a place for energy production, transport and services, and a place for recreational and cultural uses.

In 2002 the marine economy contributed $3.3 billion (3% of total GDP) to the total economy ($115 billion). Shipping (27%), fisheries and aquaculture (26%), and offshore minerals (23%) were the largest contributors. For example 99.7% (60 billion tonnes per annum) of New Zealand's imported and exported cargo/goods are transported by sea – equating to an export value of $5 billion per month and $50 billion for the year in March 2014. Presently 90% of fish caught in New Zealand waters are exported, and the value of fishing quota is estimated to be worth $1.2 to $1.5 billion per annum. Lastly, in 2015 oil was New Zealand's fourth largest export revenue with an estimated value of $2.2 billion per annum, generating around $400 million per annum in royalties and $300 million in taxes for the Government.

Bathymetric data is a key asset that supports New Zealand's marine economy. It populates charts used by vessels to navigate through our waters efficiently and safely; it creates hydrodynamic models used in scientific research to protect and conserve our shorelines and waters; and it helps to identify, manage and exploit the valuable resources in our seas, such as fish and minerals.

BATHYMETRY AND BATHYMETRIC (DEPTH) DATA

Bathymetric (depth) data is information about the morphology of underwater terrain and is derived from measurements of the depth of lakes and oceans.

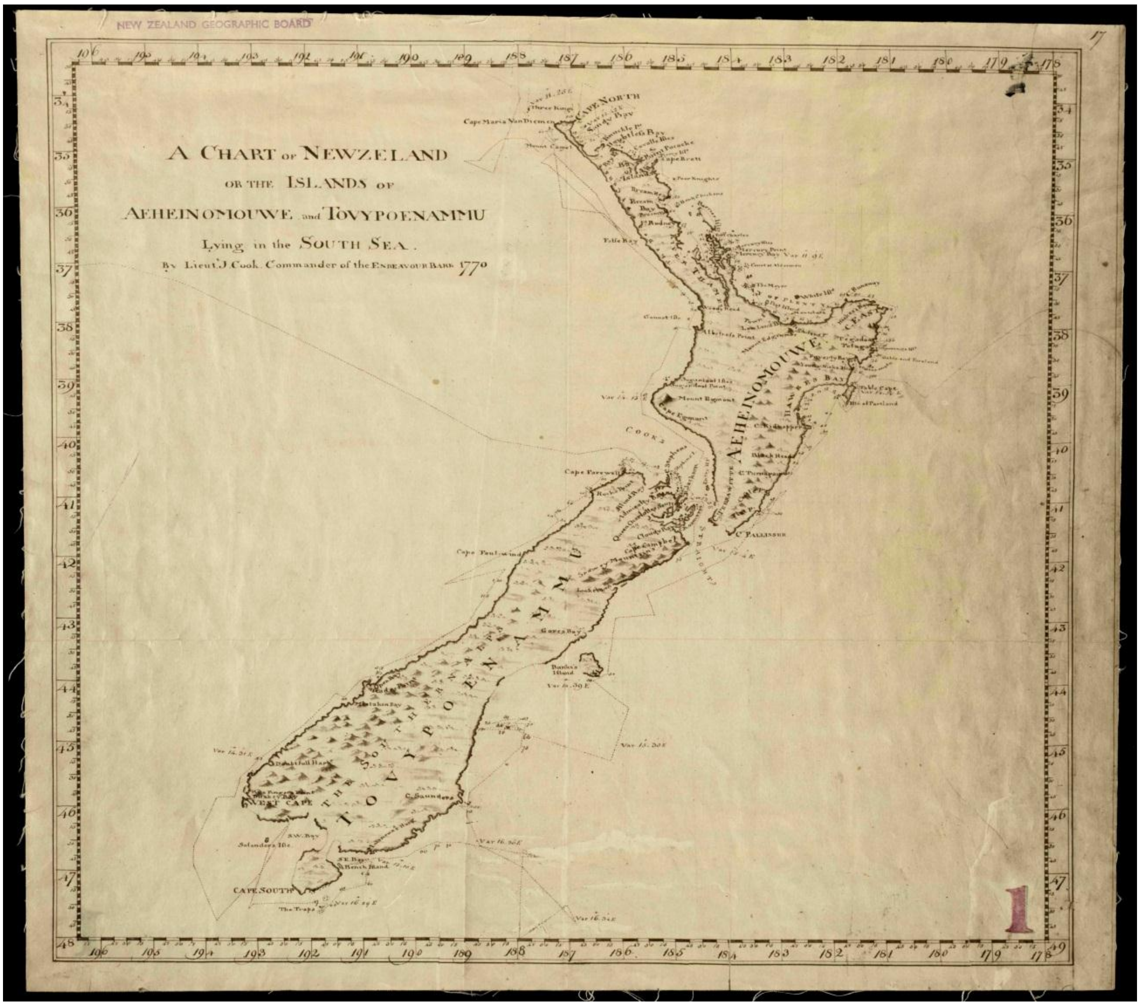
Bathymetry can be defined as: the determination of ocean depths; the general configuration of the sea floor as determined by profile analysis of depth data; and submarine topography

3.3 Early bathymetric data

Historically, bathymetric data was primarily collected and used by hydrographers to produce nautical charts. Hydrographic surveys have been carried out in New Zealand ever since its settlement by Europeans. However, even before European settlement, Māori, who were already experienced navigators of the sea, would have had bathymetric knowledge, such as the location of local water hazards and the best places to fish and land their boats. This knowledge was passed down through generations orally and place names that detailed monsters (taniwha) that lived in the sea in places of danger, navigable routes and historic maritime events or disasters.

The first European survey of New Zealand waters was by Captain Cook who published charts of coastal regions and ports after his exploratory voyages. These surveys were far from complete but it is remarkable that some of Cook's soundings remain on charts to this day, testament to the comprehensiveness and accuracy of his work (figure 1). Even so, considerable numbers of early European ships were wrecked on uncharted hazards such as submerged rocks and shoals.

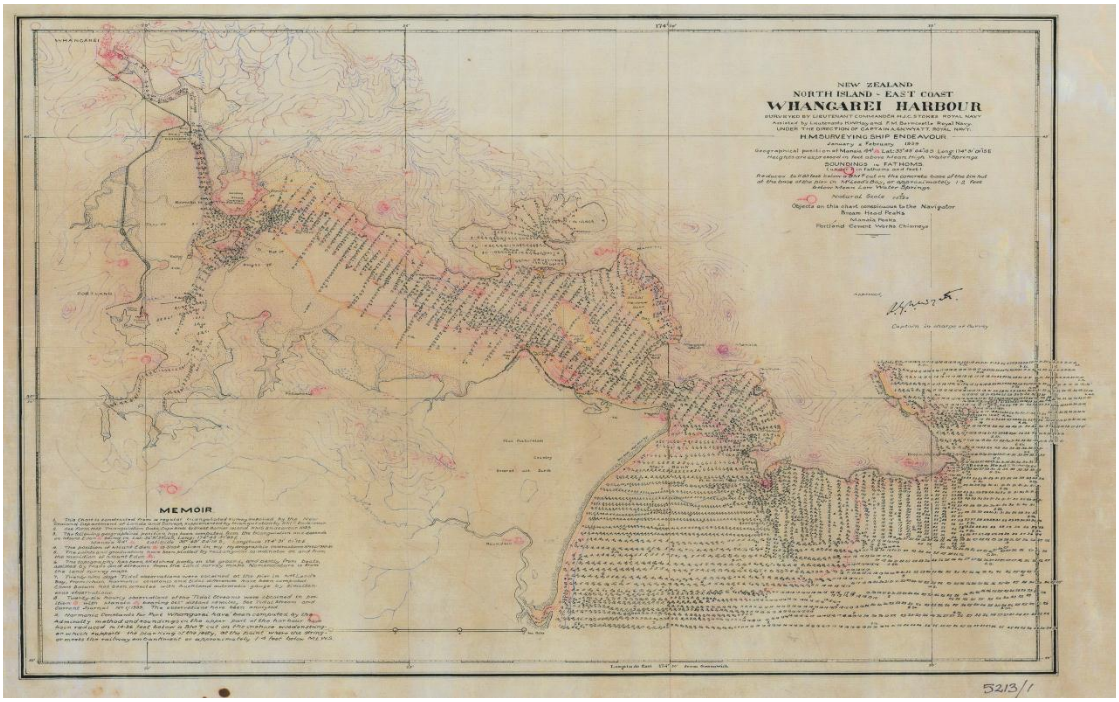
Figure 1 Captain Cook's first survey of New Zealand



Early shipwrecks and the resulting disruptions to trade led to the first determined effort to survey the coastline of New Zealand in 1848 by Captain J Stokes in command of the *HMS Acheron*.

This survey remained one of the only sources of bathymetric information until 1937, when Captain Wyatt, in charge of the *HMS Endeavour*, was commissioned by the New Zealand government to re-survey the coast. Some of the data captured by that survey (figure 2) is still used in charts produced by the Zealand Hydrographic Authority (NZHA).

Figure 2: Sounding sheet from Captain Wyatt's survey of Whangarei Harbour, January/February 1939



The survey, due to take 20 years, was not completed due to the outbreak of World War II. In 1949, the Surveying Service of The Royal New Zealand Navy was formed to complete and maintain the work started by Captain Wyatt. The Navy carried out this work using a number of survey vessels until 1996, when responsibility for maintaining New Zealand's official nautical charts was passed over to LINZ, the NZHA.

The NZHA at LINZ produces official hydrographic information such as charts, tide tables and notices to mariners to meet the requirements of the international convention for the Safety Of Life At Sea (SOLAS). As well as providing updates and corrections to official charts and information the NZHA undertakes hydrographic surveys to continually improve our data and provide an accurate description of New Zealand's seabed, coastline and hazards.

3.4 Modern bathymetry applications

Uses for seafloor data have widened considerably from the time it served mainly as a guide for safe navigation. Many organisations (e.g. government, universities, consultancies) now collect and use bathymetric data to support activities such as scientific research, coastal zone management, and seabed exploration and development. These uses have initiated the requirement for increasingly more detailed, sophisticated and accurate data.

Activities beyond chart production date from the 1930s, coinciding with advancements in technology and the availability of large amounts of accurate data. One of the first applications of underwater acoustics (sonar) was to map the morphology of the seabed to understand the sea floor structures such as subduction trenches and spreading ridges that are the product of plate tectonics. These activities led to other geological and oceanographic research. The use of bathymetric data for hydrodynamic modelling did not begin until as late as the 1980s, and is presently still a developing field. Hydrodynamic models are tools able to describe and represent the motion of water. They are used for modelling phenomena such as coastal processes, tsunamis and changes in sea levels.

In 2012 a paper at the XVIII conference of the International Hydrographic Organization (IHO) called for the Regional Coordination Committee (IRCC) to take the necessary actions to improve the collection, quality and availability of hydrographic survey data worldwide for uses outside of hydrography.

At present bathymetric data produced for the purposes of safety of navigation does not always satisfy the needs of the wider bathymetry user community. For example, depth data displayed on nautical charts is selected with a shoal (shallow) bias as the location of shoals is of greater importance for navigational safety than deeps. This data is therefore not the best portrayal of general seabed morphology.

The challenge, as identified by Hell, Broman and Jakobsson (2011), is to determine what bathymetric data is being used far more widely for science and by society; whether there are problems arising from the cross-disciplinary use of this data; and whether there are optimal ways to prepare and distribute bathymetric data so its usefulness is maximised.[3]

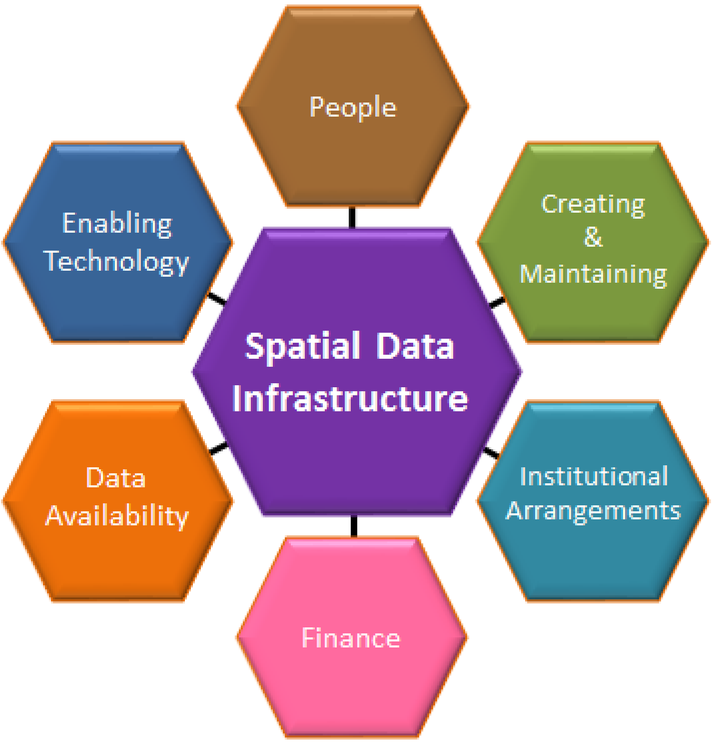
3.5 Marine Spatial Data Infrastructure (MSDI)

An important part of the growing and widening use of bathymetric data is its management. Not only in terms of storage, but how it can most effectively be discovered and shared.

The overarching term used for this set of issues and opportunities is a marine SDI.

A spatial data infrastructure can be defined as the technologies, policies, and people necessary to promote sharing of geospatial data throughout all levels of government, the private and non-profit sectors, and the academic community. Figure 23 shows the key components of a generic SDI. [4]

Figure 3 Key Components of a Spatial Data Infrastructure



The availability of bathymetric data is just one part of a marine SDI. A recent publication by the IHO has asserted that hydrographic offices are 'uniquely placed to play a central role in the development of the marine component of all SDIs', particularly the base reference and core geographic layers. However it is acknowledged that many providers need to have input into a MSDI if it is to be successful. For example, NOAA has been actively developing a MSDI since the late 1990s to support spatial planning in US waters. They have six major components to their MSDI, ranging from data about jurisdictional boundaries to geology and the seafloor (bathymetry).[5]

[3] Hell, Benjamin, et al. "The use of bathymetric data in society and science: A review from the baltic sea." *Ambio* 41.2 (2012): 138-150

[4] SDI definition can be found here: https://www.fgdc.gov/nsdi/nsdi.html

[5] For more information: http://www.msp.noaa.gov/_pdf/Paper_MSP_School_Fowler_Smith_Stein_MSDIv2.pdf

At present, there is no specific MSDI for bathymetric data in New Zealand. Much of the bathymetric data collected by the government is not immediately publicly discoverable and relies on either an existing relationship or discussions with the organisation to access it. Many portals have duplicate datasets with differing information and poor metadata. Where it is available, it is often unclear who owns the dataset and how to access it,.

An example of a regional MSDI in New Zealand is the Hauraki Gulf Marine Spatial Plan. The plan is a partnership between Auckland Council, Waikato Regional Council, the Department of Conservation, Ministry for Primary Industries and Hauraki Gulf Forum.

The plan provides the best available scientific information and mātauranga Māori knowledge of the natural and physical resources of the Gulf, as well as an online spatial planning tool (SeaSketch). More information can be found here.

3.6 Extent of New Zealand's waters

The extent of New Zealand's internal and offshore waters is defined by the United Nations Convention on the Law of the Sea (UNCLOS). The convention is an international agreement that defines the rights and responsibilities of nations with respect to their use of the world's oceans. Specifically the convention sets the extent of areas, with varying rights and responsibilities, measured from a baseline, typically the low water line (i.e. lowest astronomical tide) of a coastal state, as depicted on large-scale charts. The areas, illustrated in figures 4 and 5, are:

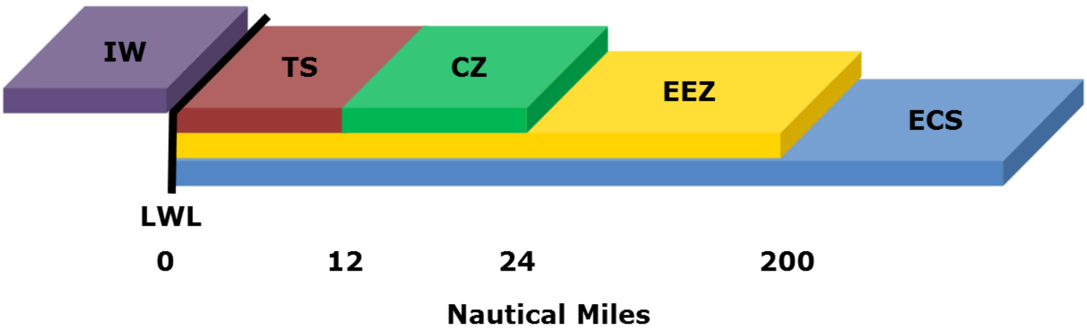
- Internal waters (IW) - waters on the landward side of the baseline of a nation's territorial waters, and
- Offshore waters:
    - Territorial Sea (TS): 0-12 nautical miles (nm) offshore,
    - Contiguous Zone (CZ): 12-24 nm offshore,
    - Exclusive Economic Zone (EEZ): 0-200 nm offshore, and
    - Extended Continental Shelf (ECS): 0->200 nm offshore.

New Zealand's internal waters include nine lakes with a surface area larger than 100km^2, 41 lakes with a surface area larger than 10km^2 and more than 3000 smaller lakes.

New Zealand's offshore waters (also referred to as the marine environment) contain a total area covering almost 6,000,000 (6 million) square kilometres, with one of the largest EEZs in the world.

The total area of our offshore waters is over 20 times the size of New Zealand's landmass.[6]

Figure 4: New Zealand's recognised Maritime Zones.[7]



LWL: Low Water Line[8]

IW: Internal Waters

TS: Territorial Sea

CZ: Contiguous Zone

EEZ: Exclusive Economic Zone

ECS: Extended Continental Shelf

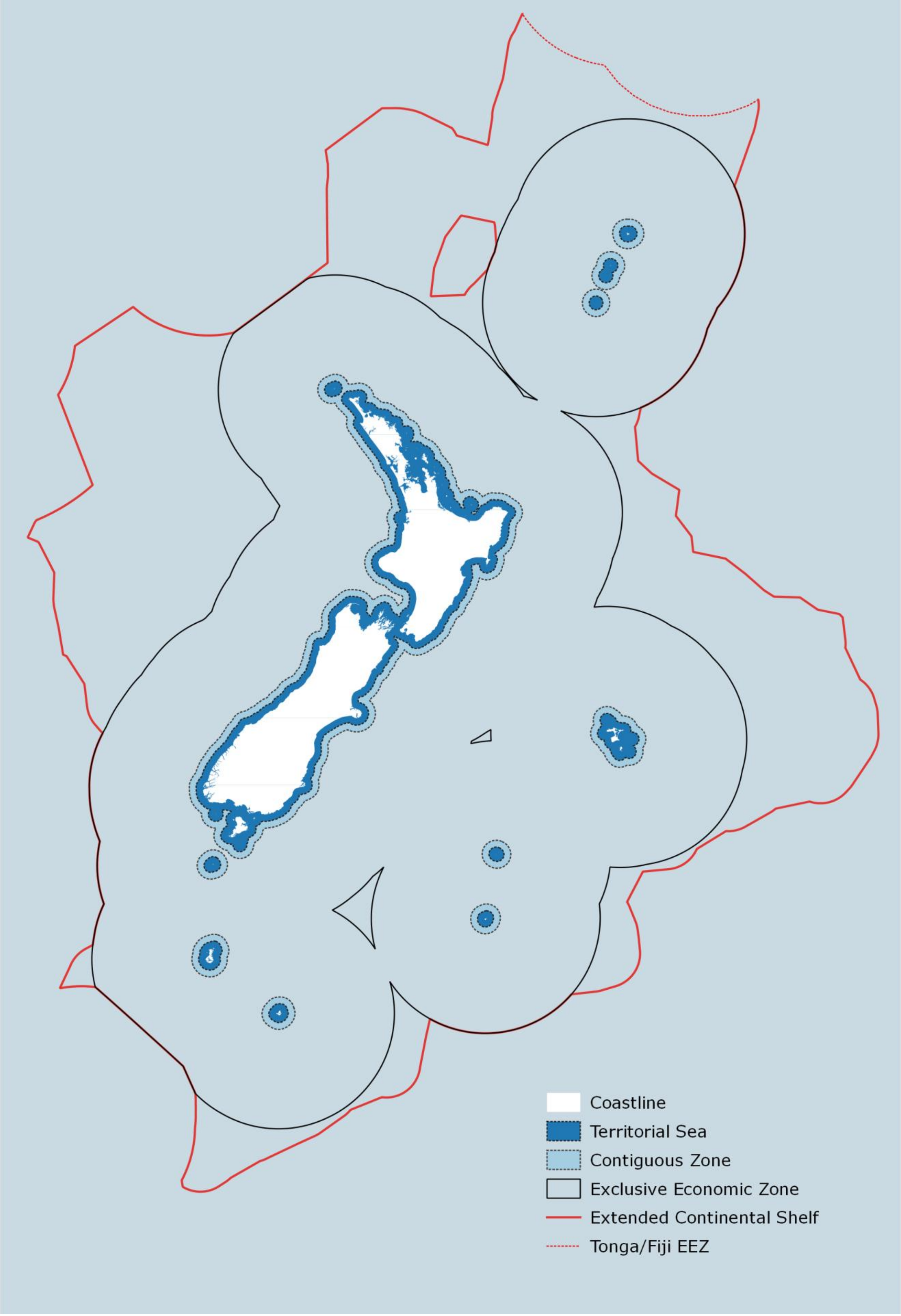
[6] Calculations by LINZ.

[7] Diagram adapted from Geoscience Australia.

[8] Also known as the lowest astronomical tide (LAT).

The definition of the limits of New Zealand's waters is a complex task that is undertaken by GNS Science (GNS), NIWA, LINZ and the Ministry of Foreign Affairs and Trade (MFAT). Under UNCLOS there are a number of maritime zones defined generally by their distance from the land, but more precisely as their distance from the Territorial Sea Baseline (TSB).

Figure 5: New Zealand maritime boundaries



3.7 Joining land and sea

One view of New Zealand is that the seafloor surrounding the exposed land represents the submerged parts of a continent. To represent this continent, land and sea need to be shown as one continuous surface.

Traditionally bathymetric and topographic measurements have been collected independently to serve different purposes. The point of reference for bathymetric measurements is usually the Low Water Line measured from different local datum. Topographic data is measured from the Mean High Water (MHW) mark.

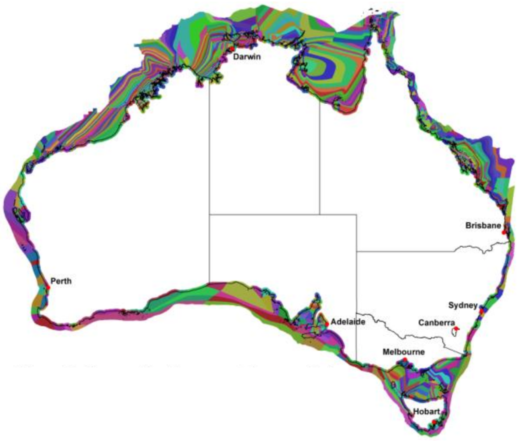
The challenge is to be able to express vertical height/depth data to a consistent reference frame for both bathymetric data and topographic data. This can be achieved using vertical separation models which allow two different height measurements to be rationalised into one.

A number of institutions have developed or are in the process of developing vertical datum separation models. These have either been initiated for hydrographic purposes to enable the use of Global Positioning System (GPS) for referencing depth measurements at sea or to enable the creation of seamless coastal datasets.

For example VDatum is the vertical datum transformation software tool of the US. The tool transforms information between 36 different vertical reference systems.

In Australia the CRCSI has been developing AusCoast VDT, a tool to enable the transformation of ellipsoid height/depth data to other vertical datums of interest. The aim is the creation of seamless elevation datasets across the littoral zone.

Figure 6 AusCoast VDT provides vertical transformations via a vertical separation grid, 20km inland of the coastline to the 500m bathymetric contour



New Zealand is yet to develop a universal vertical separation model, notwithstanding informal models that may exist at an organisation level. However, a joint land and sea project is becoming increasingly important for New Zealand’s development because of the power of seamless vertical data, for example in accurate sea level modelling.

3.8 Jurisdiction over New Zealand's waters

Six central government agencies and 16 regional councils (including unitary authorities) hold legislative jurisdiction for managing activities in New Zealand's internal and offshore waters. Each authority has different roles and jurisdictional boundaries; Table 1 presents an overview of each of these.

Table 1: Role and jurisdiction over New Zealand waters

Name	Agency Type	Role	Jurisdiction (mandate)
New Zealand Hydrographic Authority (NZHA)	Central government	Safety of life at sea (SOLAS) by charting New Zealand's surrounding sea and environs	South West Pacific to the Antarctic, including New Zealand and the Ross Sea
Ministry for the Environment (MfE)	Central government	Responsible for EEZ and CS Act 2012, development of regulations and providing policy advice on legislation[9]	EEZ – CS
Environmental Protection Authority (EPA)	Central government	Managing the effects of specified restricted activities on the environment in the EEZ and CS	EEZ – CS
Ministry for Primary Industries (MPI)	Central government	Principal advisers on, and maintain effective management of, New Zealand's fisheries and aquaculture	TS – EEZ
Department of Conservation (DOC)	Central government	Marine reserves and protecting threatened species	EEZ – TS
Ministry of Transport	Central government	Principal advisers on, and administration of, maritime transport legislation	TS – CS
Maritime NZ	Central government	Ensure that all maritime activities are carried out safely, with minimal impact on the environment and on our nation's security	TS – CS
New Zealand Petroleum & Minerals (NZP&M)	Central government	Managing New Zealand's government-owned oil, gas, mineral and coal resources ("the Crown Mineral Estate")	IW – CS[10]

[9] The Act assists in sustainable management of natural resources in the EEZ and CS.

[10] NZP&M does not consent to applications. These are managed by local government (TS) and EPA (EEZ).

Name	Agency Type	Role	Jurisdiction (mandate)
Regional councils	Regional government	Managing the effects of: coastal waters; flood control; harbour navigation and safety; and oil spills and other marine pollution	TS

The information in the above table is adapted from the report *Ocean Governance: The New Zealand Dimension*. The report examines New Zealand's marine policies and legislation and provides a schematic representation of jurisdictional boundaries of the key statutes for New Zealand waters

4 International bathymetric data sharing

Geoportals play a significant role in a SDI. Portals are websites that act as a door or gateway to a collection of information resources, including datasets, services, cookbooks, news, tutorials, tools and a collection of links to other important data catalogs.[11] The provision of data through geoportals has been rapidly developed in the last 10 years. Now many organisations around the world are working towards making their data widely available The shortcomings of this are that there are now almost too many portals which duplicate information and provide multiple versions of the same data, which will clearly be causing inefficiencies.

The main drivers of the improvement in data provision, through geoportals for example, were recently highlighted by the Australian Cooperative Research Centre for Spatial Information (CRCSI) and the Swedish Maritime Administration, who both carried out extensive surveys of bathymetry stakeholders. The drivers are:

- the wide and growing need for and use of detailed depth data
- the lack of available information
- the lack of coordinated bathymetry collection
- the opportunities to improve collaboration
- the restrictions on access to and use of current data.

Some of these geoportals should be noted in the context of New Zealand's ambitions in this area, as they often include collaboration between organisations and freely available data. For example the New Zealand open government information and data programme aims to make non-personal government-held data and information more widely available and discoverable, and easily usable. In fact, *The 2014/15 Open Data Barometer Global Report* shows that New Zealand continues to be one of the best countries in the world at allowing open access to government data.

4.1 Examples of international data sharing initiatives.

4.1.1 GEBCO

The General Bathymetric Chart of the Oceans (GEBCO) consists of an international group of experts who work on the development of a range of freely available bathymetric datasets and data products, including gridded bathymetric datasets, the GEBCO Digital Atlas, the GEBCO world map and the GEBCO Gazetteer of Undersea Feature Names.

4.1.2 NOAA

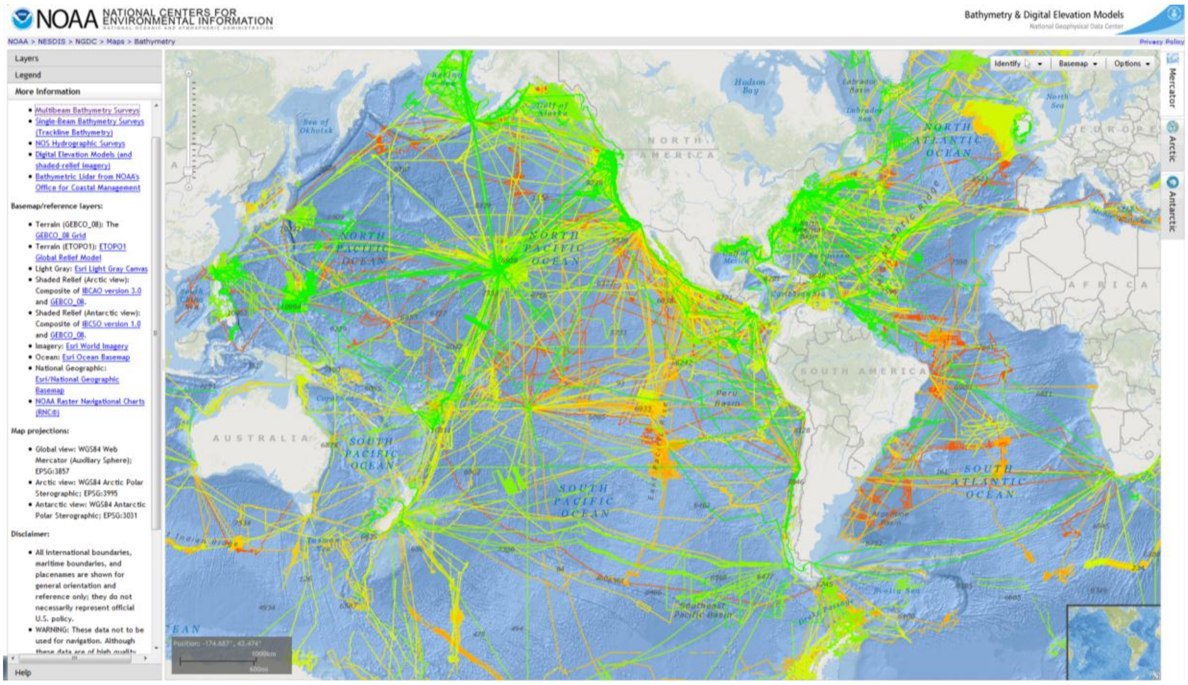
The National Geophysical Data Center (NGDC), part of the National Oceanic and Atmospheric Administration (NOAA) operates a worldwide digital data bank of oceanic soundings on behalf of the Member Countries of the International Hydrographic Organization (IHO).

Much of this data is freely available via bathymetric data and products, such as 3D images and grids. For example, NGDC's archive of multibeam echo sounder systems (MBES) bathymetric

[11] Maguire, David J., and Paul A. Longley. "The emergence of geoportals and their role in spatial data infrastructures." *Computers, environment and urban systems* 29.1 (2005): p7.

data holds over 15.7 million nautical miles of ship tracklines (1187 surveys) received from sources worldwide.

Figure 7: MBES bathymetric survey track lines



4.1.3 Europe

The INSPIRE directive is a European directive that came into force in 2007. It requires European Union member states to implement a spatial data infrastructure by 2019. Due to the directive, over the last ten years a number of geoportals hosting bathymetric data have emerged.

4.1.3.1 INFOMAR

The Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR) released a range of integrated mapping products of the physical, chemical and biological features of the seabed in the near-shore area. For example, from their web-mapping viewer bathymetry grids with a resolution of 2-100m can be downloaded for free.

4.1.3.2 EMODNET

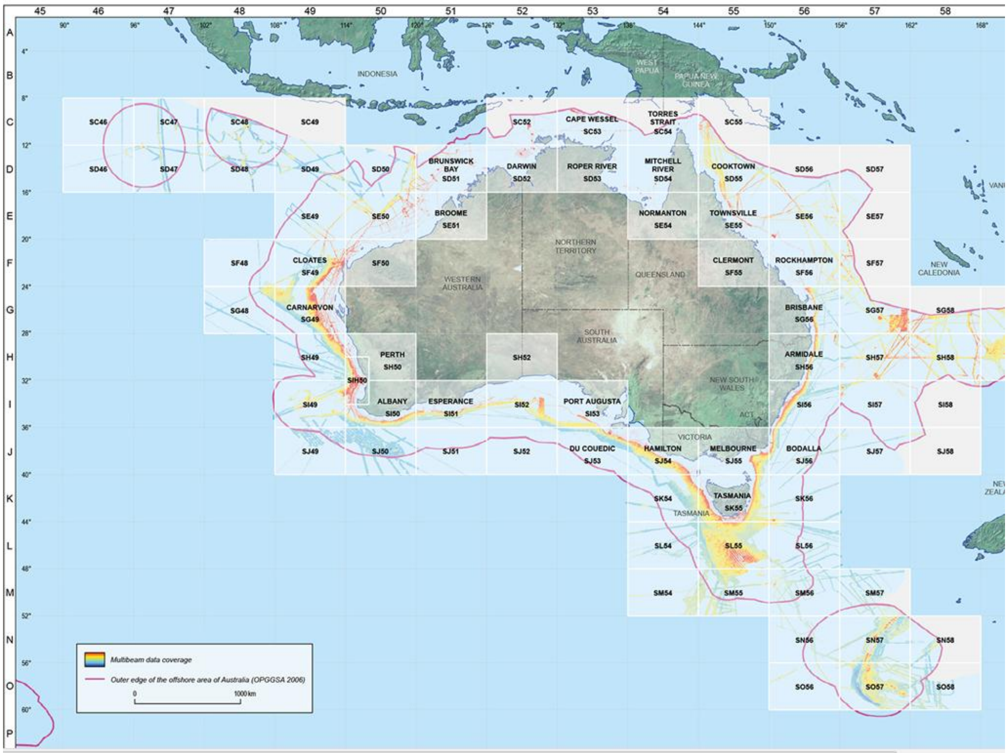
The European Marine Observation and Data Network (EMODnet) is a marine data initiative led by a consortium of organisations across Europe. The EMODnet bathymetry geoportal provides services for discovering and requesting access to bathymetric data from a range of sources. For example, EMODnet produces digital terrain models (DTMs) for European sea regions, available to download for free.

4.1.4 AUSTRALIA

Geoscience Australia is the Australian Government's national geoscience organisation. It is the national custodian of an extensive MBES dataset and holds data collected by the Australian government as well as data submitted from other institutions in the international scientific community and that lie within and around Australian waters.

Geoscience Australia released a 50m grid MBES dataset of Australia in 2012 which is available to download for free as individual tiles or as a complete dataset on a hard drive (at a cost of A$55).

Figure 8: 50m grid MBES dataset of Australia 2012



5 New Zealand's current situation

5.1 Key Points

- High degree of interest in improving the status quo:
    - Strong community of interest in the near-shore and Territorial Sea, and
    - Strong interest in wider EEZ among private sector, government and research organisations.
- Wide range of uses; more than five uses of bathymetry are undertaken by over 30% of the respondents to the questionnaire.
- A disproportionate amount of time is spent on discovery and collation of data rather than interpretation and analysis.
- Lack of coverage/high resolution identified as an area where bathymetry is not fit for purpose.
- Some collaboration already takes place, but there is potential in the community for greater collaboration and cost savings in jointly commissioned projects.
- Compliance with standards, where available, is patchy:
    - Low understanding of survey standards at data capture stage,
    - Little or no universal data schema/definitions to manage data, and
    - Little or no universal dissemination standards.
- Roughly 50% of the data captured is open and freely available; the rest is not available at all.
- Not all the data captured by public funds is made discoverable and is accessible.
- Most organisations who responded acquire third party data, the majority of which is from LINZ Data Service or NIWA.
- Areas in the New Zealand's waters with gaps in data include:
    - the inter-tidal zone, which has little data
    - 70% of EEZ/ECS that is not mapped to high resolution.

  Data from foreign research vessels, exploration surveys and fishing companies could help close these gaps.
- Crowd sourcing from recreational boats offers further opportunities to gather data – perhaps leading to an open street map for the offshore world.
- If development of bathymetric data is successful we would end up with a MSDI equivalent to that created in the terrestrial environment.

This section provides a summary of the current state of bathymetric (depth) data in New Zealand, and is a key output of the New Zealand Bathymetry Investigation. Its purpose is to help inform LINZ and the national bathymetry community of the best strategies for managing this fundamental dataset and to improve its usefulness and value for New Zealand.

The aims of this section are to:

- describe the current state of bathymetric data in New Zealand,
- analyse the results of a New Zealand stakeholder bathymetry questionnaire carried out during November 2014, and
- provide feedback on telephone conversations and one-on-one meetings with stakeholders regarding bathymetry in New Zealand carried out between June and December 2014.

This section of the report is organised into three main parts:

- Part 2.2 details the approach to the market research,
- Part 2.3 provides an analysis of the results of the market research, based on the questionnaire and meetings with stakeholders, and
- Part 2.4 is a summary of the results and main findings of the market research.

5.2 Bathymetric data use

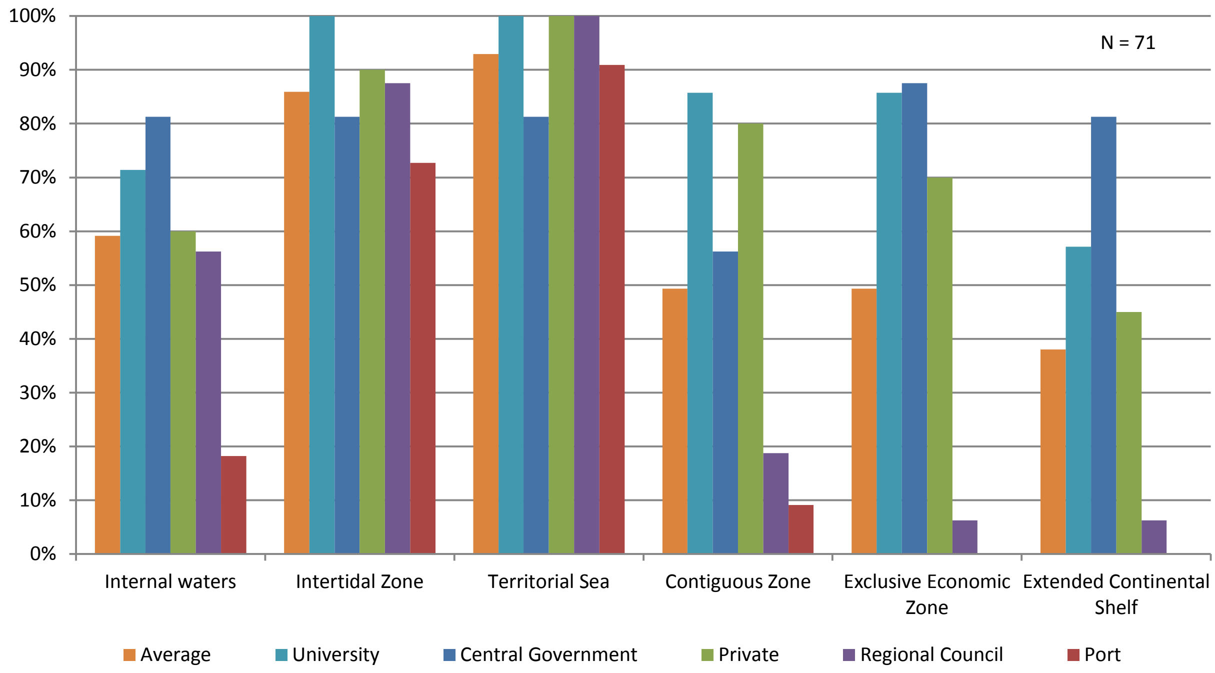
5.2.1 Users' bathymetric data

The majority of organisations that responded to the questionnaire use bathymetry. Four organisations out of 58 (6.9%) did not use bathymetry to carry out their functions. The reasons for this were mixed and inconclusive (e.g. low priority, no resources or lack of expertise). Only in one case was there no business requirement to use bathymetric data.

5.2.2 Geographical extents of interest

Ninety-three percent of respondents' organisations are involved with the Territorial Sea and 86% are involved with the Intertidal Zone. There is less involvement with zones beyond the Territorial Sea i.e. the Contiguous Zone (49%), EEZ (49%) and Extended Continental Shelf (38%). Central government agencies, the private sector and universities have the most involvement in these offshore zones, whilst ports and regional councils have no involvement because their mandates are solely in the Territorial Sea. The results show that across the zones there is a substantial overlap of interest between stakeholders. These shared interests indicate that there could be a number of opportunities for collaboration and data-sharing.

Figure 9: Which geographical extents are your unit/group or organisation involved with?



Key Message

Common interests by multiple organisations in the maritime zones could provide opportunities for collaboration and data sharing

5.2.3 Use of bathymetric data by sector

5.2.3.1 SOVEREIGNTY

Defence

Navies use nautical chart products for surface, submarine, anti-submarine, mine-hunting and air-sea naval operations. Chart coverage must be comprehensive and accurate in order to gain freedom of manoeuvre for warships, to understand where the Navy, and equally importantly, where the enemy can operate, and to control the sea space when necessary. In New Zealand most bathymetry (via charts) is provided by LINZ to support a variety of products used in naval operations.

Search and rescue

Understanding the ocean floor can help improve the response in an emergency. Bathymetric data is used to create high resolution (100 metres per pixel) underwater maps. These enable equipment to search underwater at a distance of 100 metres above the sea floor.

Safety of life at sea (SOLAS)

Charts improve safety of life at sea and need to be highly reliable. They require complete, up-to-date and accurate information on coastline and marine features such as buoys, beacons, rocks, sandbars and water depth. Bathymetric data is a key dataset used to identify these features.

Boundary delineation

Under the United Nations Convention on the Law of the Sea (UNCLOS) the continental shelf is that part of the seabed over which a coastal state exercises sovereign rights with regard to exploration and exploitation. Understanding the morphology of the seafloor can help substantiate the claims of a coastal state to their maritime territory.

5.2.3.2 ENGINEERING/COASTAL INFRASTRUCTURE

Port development

Bathymetric data can be used to assess the condition of navigation channels to quantify and determine dredging requirements, and the condition of navigation structures, such as jetties and breakwaters, and adjacent shoreline.

5.2.3.3 ENVIRONMENT

Fishing zones and Marine Protected Areas (MPAs)

Fishing zones or MPAs are areas of the sea that are protected to allow their habitats and ecosystems to remain at (or recover to) a healthy state. For example, some MPAs may have fishing restrictions.

Seafloor morphology is a key component of marine ecosystems. Research has demonstrated that distributions and diversity of fish species can be predicted using maps of seafloor structure or bathymetry.[12] Bathymetry data can be used not only to understand where marine ecosystems exist, but also to understand the impacts of human and other environmental influence. For example, one study has shown that intense bottom trawling has permanently smoothed the seafloor morphology of the continental slope over large spatial scales.[13]

[12] Fish predict article – is this the full reference?

[13] Missing footnote?

Coastal zone management

Coastal zone management is the process of managing all aspects of the coastal environment to achieve sustainability

Bathymetry is used for a wide range of purposes in coastal zone management, including: modelling coastal hazards, the effects of aquaculture, and other coastal infrastructure e.g. ports; assessing sedimentation and natural defences; and even identifying culturally significant archeological sites.

Archaeology and cultural heritage

The use of MBES and backscatter equipment can produce detailed accounts of underwater archaeological sites such as shipwrecks and the environments they lie in, and also help with recovery of valuable artefacts. Identification and preservation of culturally significant shipwrecks is an important social benefit of bathymetry.

Improved emergency response

Bathymetric data is used to perform oil spill trajectory modelling. This provides accurate, site-specific marine forecasting for salvage operators and clean-up crews, both over the time frame of the initial response and during the subsequent salvage of the vessel. Accurate predictions of oil spill trajectories cannot be made without appropriate forecast data, which relies on suitable wind and current data, which in turn is underpinned and controlled by the effects of local bathymetry.

5.2.3.4 HAZARDS

Bathymetry is essential for modelling and understanding the effects of a range of hazards. Bathymetric surveys can be used to describe the shape of the seabed, understand how it was formed and how it is changing. In particular, bathymetric data has important implications for assessment of offshore hazards (such as earthquakes, tsunami, and landslides), the impacts of deep-water fisheries, exploitation of mineral resources, and understanding coastal change.

5.2.3.5 MARINE TRANSPORT

The use of nautical charts for safe navigation is intrinsically linked to the success of commercial shipping and international trade, which are critical to a country's economic growth. Globally over 90% of international trade is transported by sea. Commercial shipping relies on accurate, up-to-date nautical charts for one important reason; time is money (Connon and Nairn, 2009). Charts provide the most direct routes between ports, allow deeper draft vessels (i.e. greater cargo capacity) to be used, decrease the number of groundings, reduce insurance rates, and reduce the required number of pilots per ship (boats that escort ships into berth). Therefore, hydrographic surveys and navigational charts decrease the risk of loss of life and increase the speed at which ships can get in and out of ports. Larger ships can hold a higher quantity of cargo, which equates to lower cost, ultimately increasing profits.

5.2.3.6 NATURAL RESOURCES

Bathymetric surveys are carried out at almost every stage throughout the lifecycle of an oil field. In the exploration stage understanding the seabed morphology assists in option planning, definition of the area, and positioning for seismic and site surveys. In the development stage it assists in avoiding unstable slopes, gas expulsion features and other seabed geohazards e.g. mud volcanoes, and even in some cases archaeological features.

5.2.3.7 PRIMARY PRODUCTION

Aquaculture

Aquaculture is the practice of sustainably farming shellfish, finfish (e.g. tuna), seaweed and other aquatic and marine organisms. Having good bathymetry plays a role in this industry because it is used for site selection, determining anchor points and modelling the impacts of aquaculture on the surrounding environment.

Commercial fishing

Maps with detailed bathymetry are used for commercial fishing because they identify where fish habitats are most likely to be located: essentially static bathymetric features such as reefs, shelf breaks, seamounts and other irregularities in the sea floor alter the water flow, cause mixing and upwelling of nutrients, which in turn promotes the congregation of sea life. For example, recently LiDAR-derived rugosity, a measure of small-scale variation in the height of a surface can be a predictor of reef-fish abundance in Hawaii. These processes can occur in both coastal and offshore waters and in some cases a few metres may be the difference between an empty net and a full one.

5.2.3.8 RECREATION

Recreational boating/fishing

Nautical charts are used by recreational fishers for safety of navigation but often fishers use enhanced nautical information through their navigation products. For example, crowd sourced data through the Insight Genesis App provides more detailed, up-to-date information about seafloor topology that is not offered on charts.

Tourism

Hydrographic information is critical for the success of cruise ship tourism. For the same reason nautical charts support commercial shipping, charts also support the tourism and cruise-ship industry. Safe navigation of cruise ships into ports is particularly important where tourism forms a large part of the economy.

5.2.3.9 TELECOMMUNICATIONS

Bathymetric data is integral for the laying and the maintenance of telecommunications cables. For example bathymetric information is used to select a safe and economic route for the cable and identify any potential hazards to laying the cable and to avoid sensitive marine environments. Where sufficient data is not available to undertake these activities, detailed surveys will be carried out.

5.2.3.10 SCIENTIFIC RESEARCH

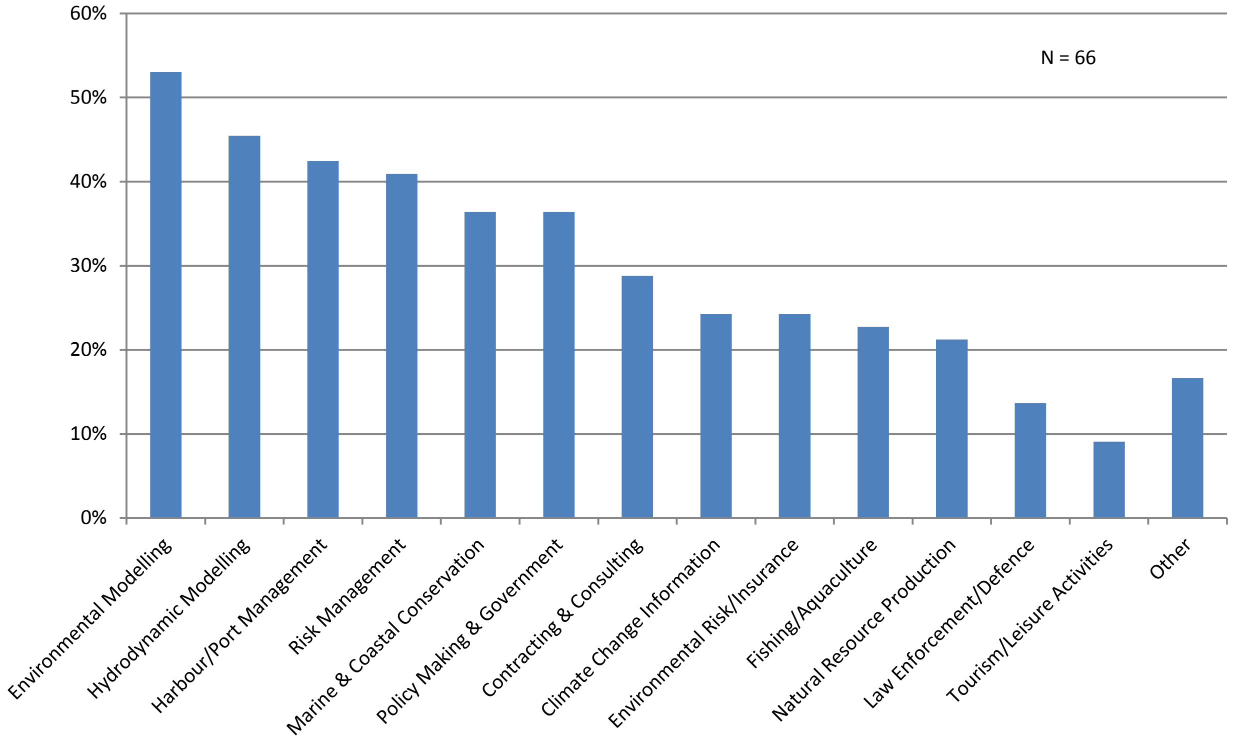
Bathymetric data is used to support a great deal of marine research. There are two main types of marine research that use bathymetry: biological and non-biological. Biological research relates to bathymetry being used to identify and study biological habitats. Non-biological research relates to understanding and planning for natural hazards

5.2.4 Applications of bathymetry

Fifty-three percent of organisations use bathymetry for environmental modelling; the highest use of any identified in the questionnaire. The 2011 bathymetry questionnaire run by CRCSI predicted that environmental mapping and modelling would have the largest increase in future applications, a prediction which is supported by the results seen here. One hypothesis for this is that research scientists are making use of available data from modern sonar equipment, which typically has higher coverage, accuracy and resolution, and is better suited for modelling purposes.

Surveying and mapping, charting and navigation, and scientific interest/research are not included in this graph because they are seen as generalised activities rather than specific uses.

Figure 10: What are the main uses of bathymetry in your unit/group or organisation?



Key Message

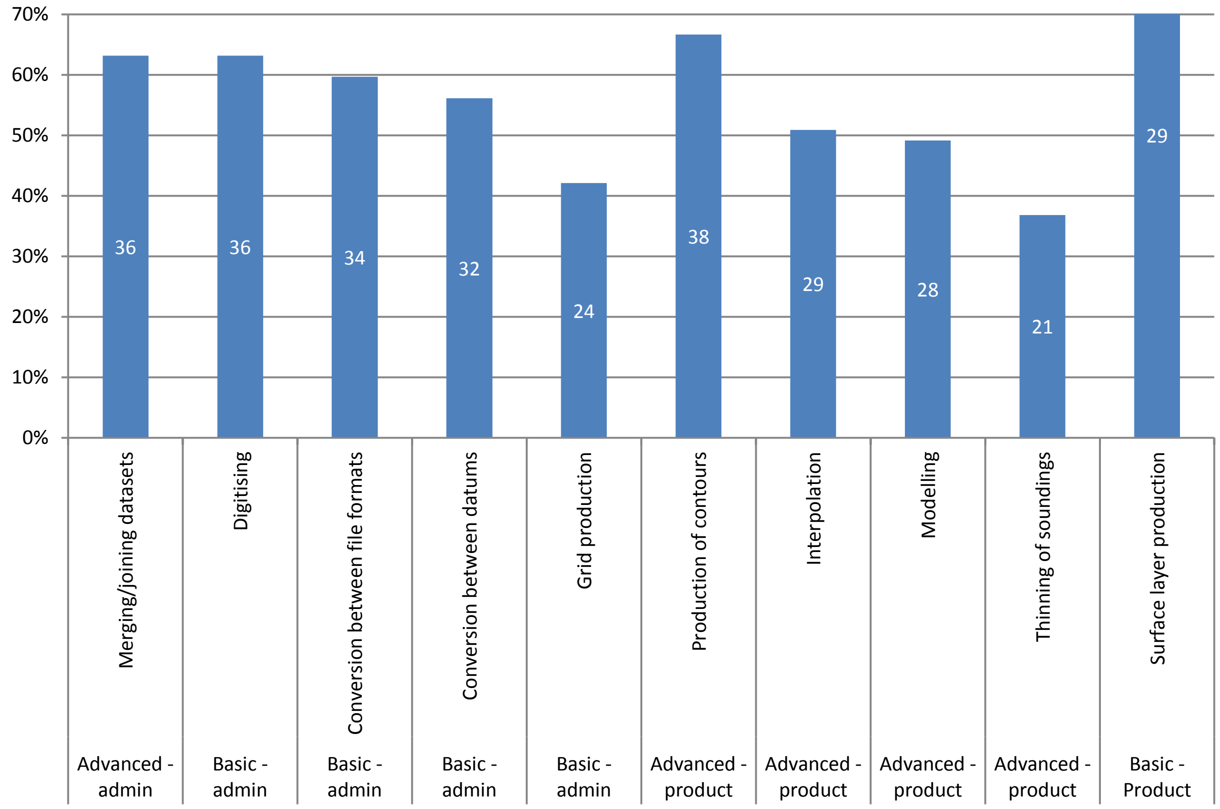
Environmental modelling and scientific research are the two biggest uses of bathymetry, both of which are non-traditional uses of bathymetry.

5.2.5 Processes used to improve bathymetry

The most common processes undertaken by respondents are the production of contours (67%) and digitising of data (63%). Other major processes can be classed as administrative-based tasks, such as merging/joining datasets (63%), conversion between file formats (60%) and conversion between datums (56%). Specialist processes such as interpolation, modelling, and surface layer production, whilst still performed widely, were undertaken less than basic administrative tasks

The responses demonstrate that a considerable effort is spent on administrative tasks. These common tasks suggest that organisations could realise increased efficiencies if datasets were shared and had prescribed standards, such as common metadata fields, file types and datum.

Figure 11: Which processes do you use to improve the bathymetry data you hold?



Key Message

There appear to be common administrative tasks that might be reduced if bathymetric data was shared and processed according to prescribed standards. Improved bathymetric standards might contribute to increased efficiency and therefore either reduced costs or more extensive data analysis.

5.3 Stocktake of bathymetric data

This stocktake has identified the MBES datasets that exist for New Zealand's waters. Three main sources of data were used to compile the view of MBES data:

- MBES data collected by LINZ (which includes some third party data e.g. port data),
- bathymetric data that has been collected by NIWA and GNS, and
- other ad-hoc surveys undertaken by regional councils, government departments and foreign research vessels.

5.3.1 Rationale

The extent of MBES data is just one view of the data that exists in New Zealand. Other datasets collected by SBES for example, which provide partial seafloor coverage, do exist but are not shown.

MBES data is important because it is the latest technology and it usually has the best resolution and most complete seafloor coverage. However, it should be recognised that MBES data is collected with varying resolutions and specifications

5.3.2 Coverage of bathymetric data

Table 2 shows the coverage of MBES for each Zone in New Zealand's waters. It is estimated that MBES data covers approximately 32% of New Zealand's waters. The Territorial Sea, a high marine activity area, has 40% coverage by MBES. This is considerably more than the global coverage of high resolution bathymetric data which is currently estimated at below 10%.

Table 2 Coverage of bathymetric data[14]

Zone	Area (KM^2)	MBES (KM^2)	Coverage (percent)
Territorial Sea	181,000	72,778	40
Contiguous Zone	173,000	75,319	44
Exclusive Economic Zone	4,136,000	1,498,393	36
Extended Continental Shelf	5,793,000	1,879,682	32

Without undertaking full seafloor coverage mapping of all New Zealand's waters there will always be gaps in bathymetric data. However the cost of entirely mapping New Zealand's EEZ using MBES swathe systems has been estimated at $200 million or $50 per square kilometre. This figure is perhaps conservative given that some high spec MBES surveys can cost anywhere between $600 and $10,000 per square kilometre.

5.3.3 Current data collection initiative

Ocean Survey 20/20 (OS20/20) is a 15-year project which aims to complete by 2020 an ocean survey that provides New Zealand with knowledge of its ocean territory. It began as a government-wide initiative with collaboration from Crown research institutes, LINZ and the Royal Navy.

[14] Numbers are rounded to the nearest 1000 KM^2

OS20/20 identified priority areas for data collection which, if completed, would fill in some of the major gaps. For example priority areas focused on maritime safety, areas of potential mineral and hydrocarbon deposits, climate, and fishing and biodiversity.

5.3.4 MBES Swathe (All)

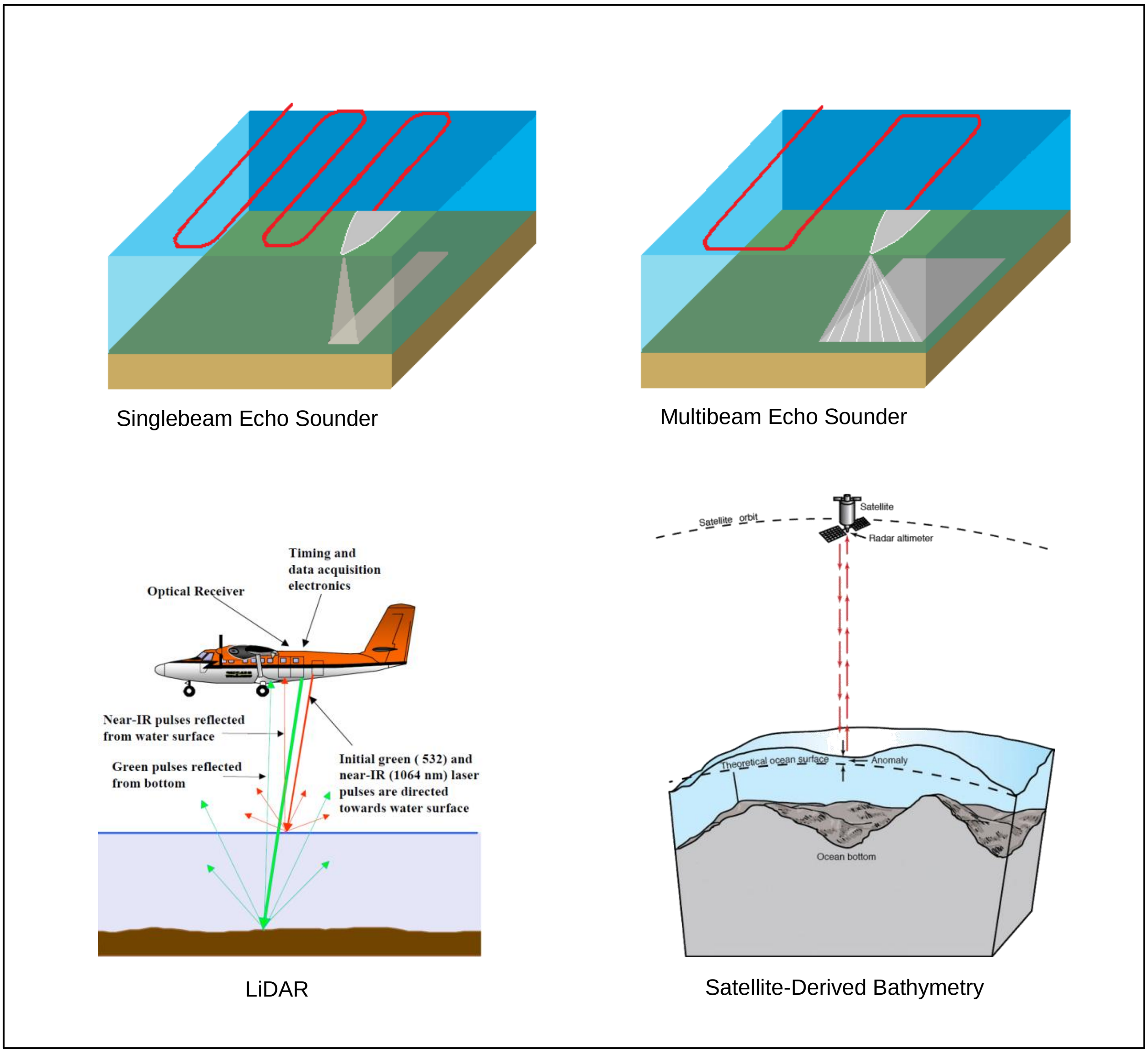
5.4 Bathymetric data collection

This section identifies which organisations collect bathymetry, why they collect it and how it is collected.

Organisations use several methods to undertake bathymetric and hydrographic surveys, each with advantages and disadvantages. Until the 1920s, depth-sounding by lead line was the primary method for collecting water-depth data. Since the development of echo–sounding, this method has largely become redundant.

Currently, the primary method for collecting bathymetric data is to use single beam echo sounder (SBES) or MBES. Light Detection and Ranging (LiDAR) is often used to measure water depths in shallow waters in areas with complex and rugged shorelines. Lastly, recent developments in technology have made satellite-derived bathymetry (SDB) a viable solution for some applications. There are advantages and disadvantages with all the modern bathymetric survey methods and trade-offs always exist with choosing one method over another.[15]

Figure 12 Methods of bathymetric data collection



[15] For a full explanation of these survey methods and the advantages and disadvantages of these see: Kearns, Timothy A., and Joe Breman. "Bathymetry-The art and science of seafloor modeling for modern applications." *Ocean Globe* (2010): 1-36.

5.4.1 Direct acquisition

5.4.1.1 WHO COLLECTS DEPTH DATA VIA BATHYMETRIC OR HYDROGRAPHIC SURVEYS?

Almost 70% of organisations that responded to the questionnaire collect bathymetry data themselves; about half of these use their own vessels and half commission survey companies to collect it on their behalf. Similar results were found in the CRCSI questionnaire of New Zealand and Australian organisations. Bathymetry surveys may be necessary because data doesn’t exist, it is embargoed or not discoverable, it is too expensive, it is out of date, or it is not fit for purpose.

5.4.1.2 JOINT PROJECTS

Half of the organisations that undertake bathymetric or hydrographic surveys have collaborated with other organisations. These projects have involved collaboration among local, regional and central government agencies, New Zealand and overseas research institutions, and private companies.

The cost of data collection is a common driver for collaboration. Another factor is the limited availability of suitable equipment and expertise in New Zealand. Joint commissioning has many benefits and evidence suggests that even coordinating the mobilisation of equipment can result in significant budget savings.

Barriers to collaboration are often administrative, e.g. coordination of survey priorities, resources and budgets.[16]

Key Message

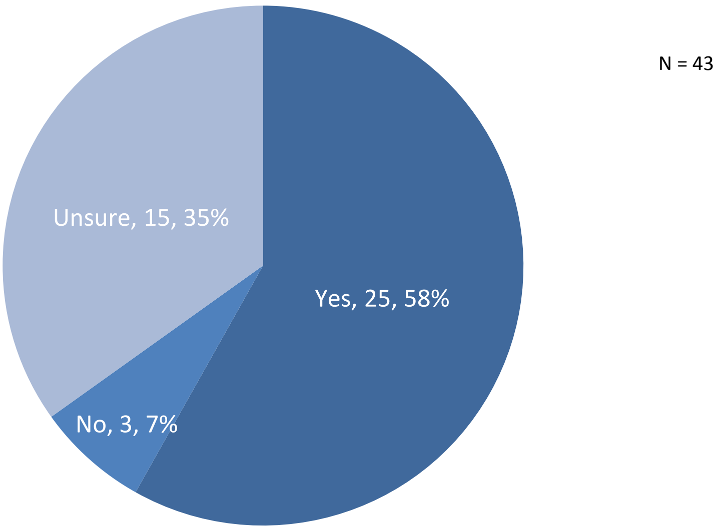
There is a desire in the bathymetry community to work together. Collaboration between organisations could be developed further to reduce duplication and costs of data collection.

[16] Quadros,. “Bathymetry Acquisition - Technologies and Strategies, Investigating shallow water bathymetry acquisition technologies, survey considerations and strategies” CRCSI (2013).

5.4.1.3 COMPLIANCE WITH HYDROGRAPHIC SURVEY STANDARDS AND/OR TECHNICAL SPECIFICATIONS?

Fifty-eight percent of respondents said their survey data complied with some sort of survey standards or technical specifications and 7% said their data did not. Thirty-five percent of respondents were unsure whether it did or not. The level of uncertainty could be due to the lack of expertise of the respondent. Even so it highlights a knowledge gap around data standards that could be improved.

Figure 13: Does the data you collect from surveys comply with any hydrographic survey standards or technical specifications?



5.4.1.4 HYDROGRAPHIC STANDARDS SPECIFICATIONS

Of the 25 organisations that have hydrographic data standards, 65% (15) use LINZ HYSPEC, 57% use S-44 IHO and less than 40% use another unspecified standard. LINZ HYSPEC is the specification for hydrographic surveys undertaken on behalf of LINZ. It is considered to be a more rigorous specification than S-44 IHO. S-44 IHO is the minimum hydrographic specification for hydrographic surveys, recommended by the IHO, if the survey is being used to compile navigational charts.

The standards will not be relevant for all applications of bathymetric data and are not always adopted. However, they provide a benchmark for survey uncertainty (i.e. accuracy or error). Details of standards can be found on GEBCO, IHO and LINZ websites. However, the apparent disconnect in the survey responses between having standards and using them may reflect whether the organisation has the expertise and knowledge to understand their meaning and implications.

Key Message

The feedback on standards from stakeholders indicates a lack of awareness of standards and their importance

5.4.1.5 APPROPRIATE METADATA

Ten respondents (24%) said that their survey data had appropriate metadata, and 22 (53%) said they were not sure. The remaining 10 respondents (24%) said their data did not have appropriate metadata. As with data standards the reason for the uncertainty may be due to the technical ability and knowledge of the respondent rather than the presence or absence of appropriate metadata. Even so, it presents an opportunity to provide more guidance on metadata: what it is, why it should be collected for all datasets, and which standards to follow.

5.4.1.6 WHICH METADATA STANDARDS DOES YOUR SURVEY DATA COMPLY WITH?

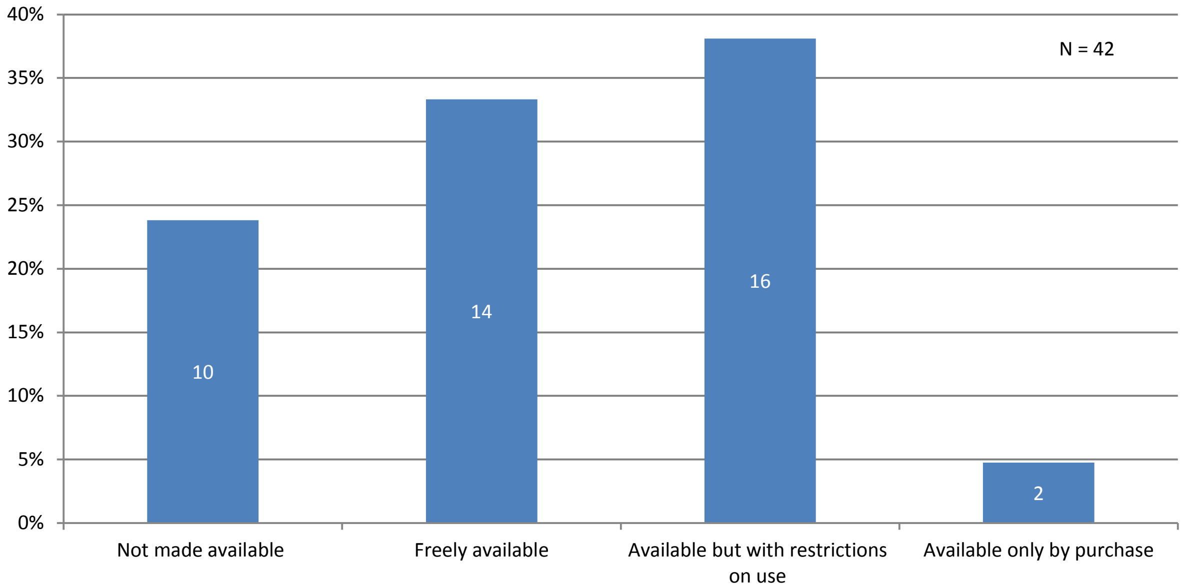
Meta-ISO 19115 ANZLIC was the most commonly used metadata standard (58%). However, only a very small number of respondents (10) answered "Yes" to "Does your survey data have appropriate metadata?" so not much can be taken from this result.

The Australian and New Zealand spatial information council provides guidelines for the ANZLIC metadata profile. The profile adopts established Australian/New Zealand and International Standards. Organisations are encouraged to adopt the profile but it is difficult to force them to use it. It is clear that focused guidance on best practice is needed with respect to the implementation of metadata standards for hydrographic/bathymetric survey data.

5.4.1.7 PUBLICLY AVAILABLE SURVEY DATA

Nearly 35% of the organisations collecting data make it freely available but it is difficult to estimate how much of all bathymetry data is freely available as the amount of data collected by each organisation varies. Using knowledge about the market share of commissioned surveys, it can be roughly estimated that approximately 45% of data collected annually is freely available, 50% is either available with restrictions or available to purchase, and about 5% is not made available i.e. the 25% of organisations that don't make their data available collect only 5% of the data.

Figure 14: Is survey data that you collect made available outside your organisation?



5.4.1.8 SPEND ON COLLECTING BATHYMETRY DATA THROUGH SURVEYS?

At least $20 million (NZD) is being spent every year on bathymetric or hydrographic surveys. This is made up of over 50% from central government spending, 45% from private spending, 2% port spending and the rest (less than 3%) from regional councils and universities.

The overall figure is likely to be an underestimate, since it is likely that the questionnaire did not capture everything that is spent on surveys in New Zealand.

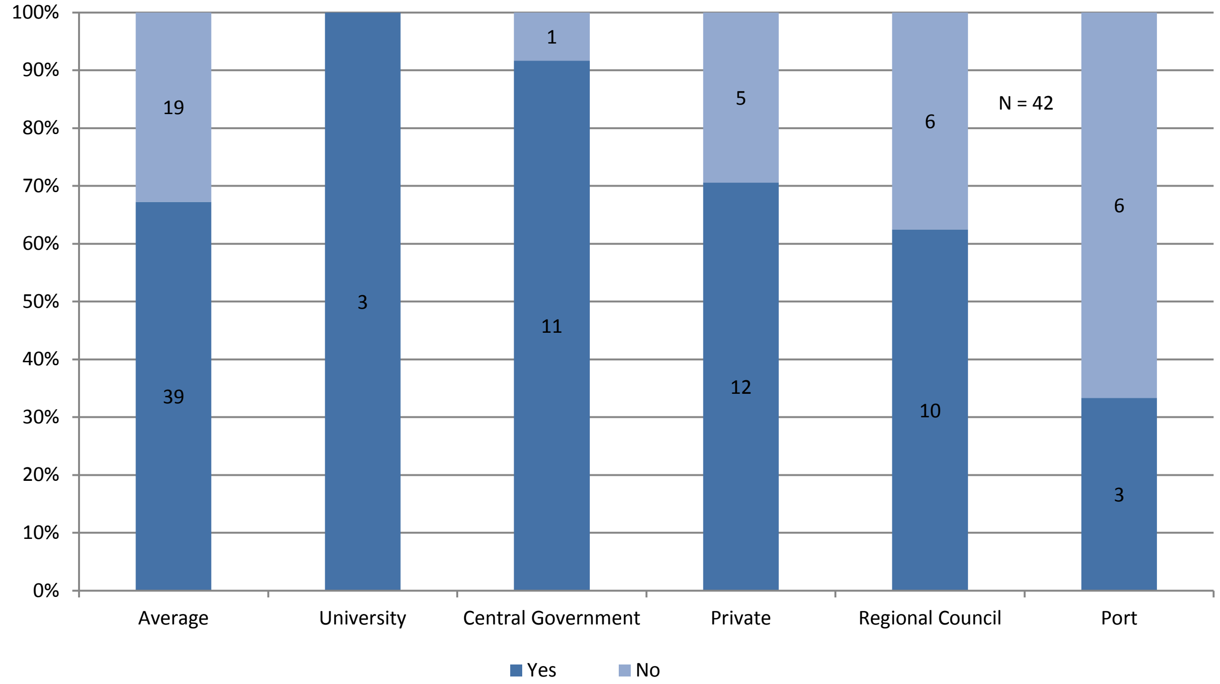
5.4.2 Third party acquisition

Organisations that do not collect bathymetry data themselves can obtain data through third parties. A number of data portals offer bathymetric data, in a variety of forms. For example, internationally the IHO via NOAA provides a database of SBES and MBES ship tracks. GEBCO provides free gridded global bathymetry in a variety of formats e.g. ESRI ASCII raster, GeoTiff. In New Zealand, the LINZ Data Service (LDS) currently provides chart data in the form of vectors, soundings and raster images, while NIWA provides various datasets downloadable from their website. GNS has developed the New Zealand Petroleum Basin Explorer (PBE), an interactive web-based tool that allows users to discover and access bathymetric data collected from a number of different sources. Lastly, NZP&M as previously mentioned has an online exploration database to discover bathymetric data collected by exploration companies. Data can also be sought directly from central government, regional and local councils, ports and many other private organisations.[17]

5.4.2.1 BATHYMETRY DATA COLLECTED FROM THIRD PARTIES

Nearly 70% of organisations obtain bathymetry data from third parties. All the universities that responded collect third party data, whilst only 30% of ports do so. The low use by ports is due to their very specific, geographically focused requirements, which third party data seldom meets.

Figure 15: Do you get bathymetry data from third parties?



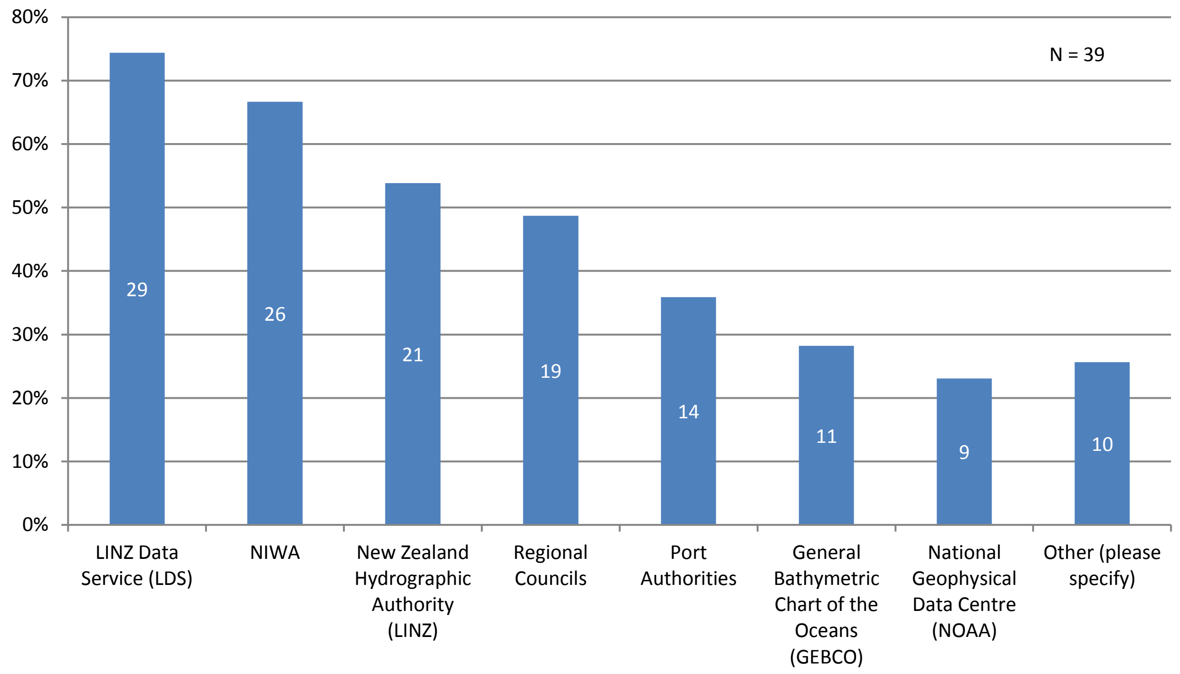
[17] A full list of available data for New Zealand can be found in the Appendices.

5.4.2.2 SOURCES OF THIRD PARTY BATHYMETRIC DATA

Seventy-five percent of respondents obtain third party data from LDS, and 68% obtain third party data from NIWA. Data is also obtained directly from the NZHA, regional councils and port authorities. International databases are the least used source of third party data.

The 'other' category included data supplied by clients and data bought from commercial third parties such as C-Map. C-Map is an electronic chart product for navigational equipment.

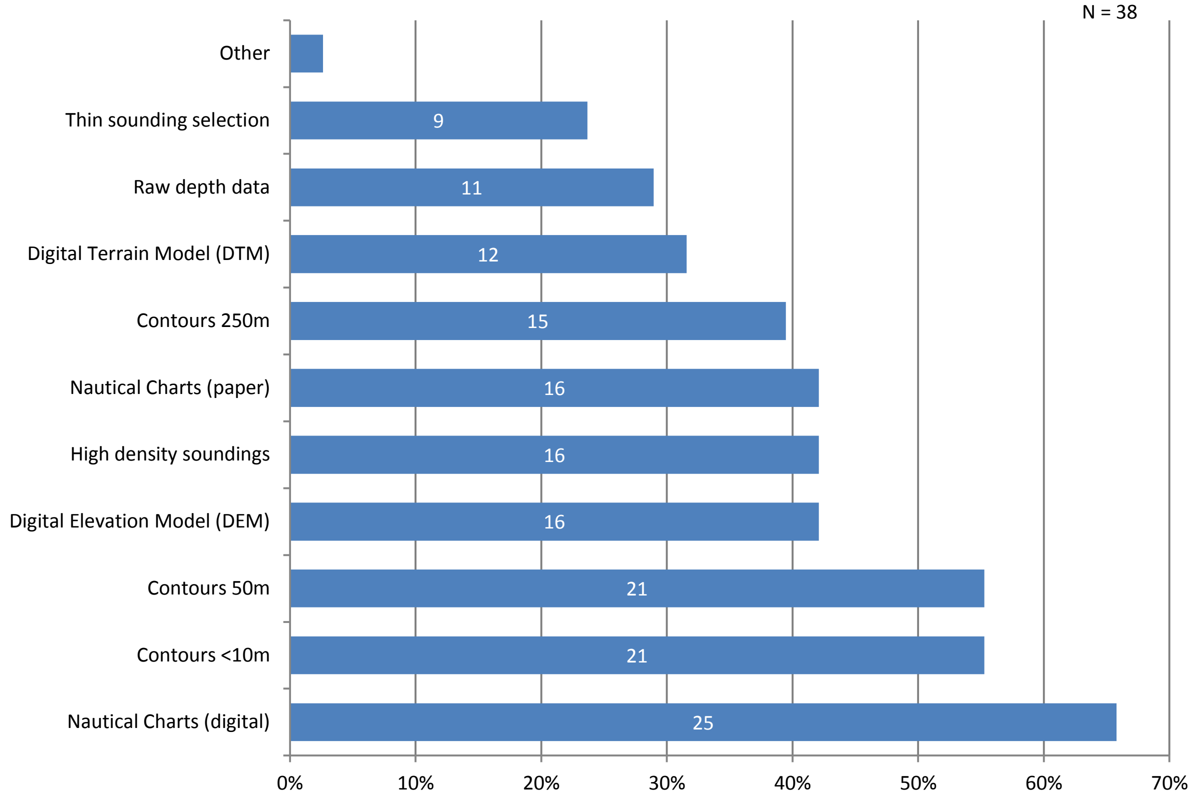
Figure 16: Where do you get third party bathymetry data from?



5.4.2.3 BATHYMETRY DATA/PRODUCTS ACQUIRED FROM THIRD PARTIES

Seventy-five percent of organisations that use third party data use vector versions of LINZ's nautical charts. A considerable number of organisations obtain <10m and 50m resolution contours from third parties. The assumption prior to the questionnaire was that this level of data was not widely available from third parties.

Figure 17 Bathymetry data/products acquired from third parties

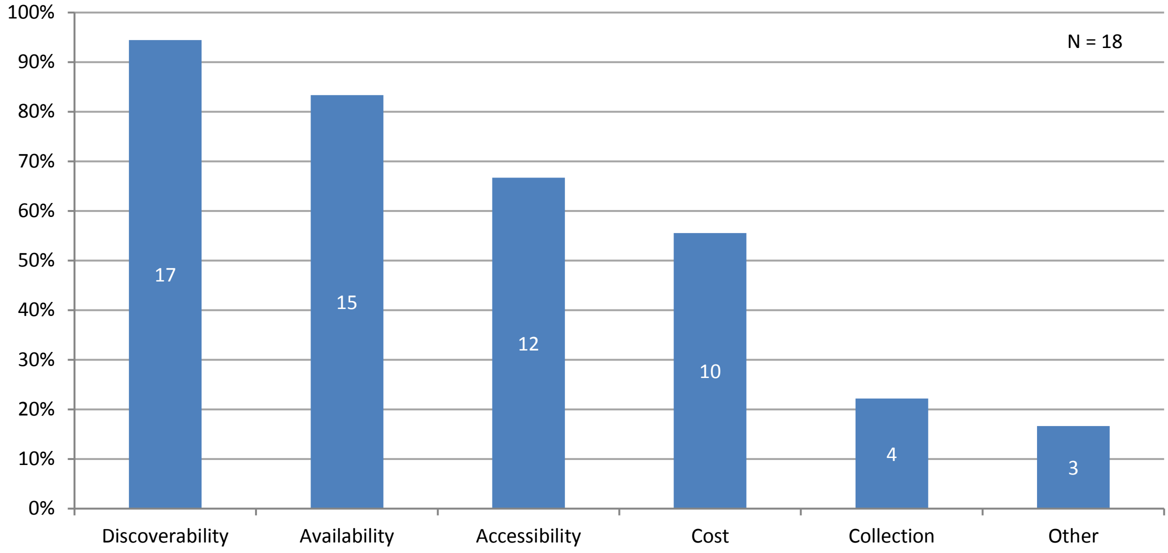


5.4.2.4 ISSUES OBTAINING THIRD PARTY DATA

Approximately half (48%) of those accessing third party data faced issues getting hold of it.

The greatest problem reported was the discoverability of the data (94%), then the availability of the data (83%). The cost was only a problem for about 55% of responding organisations.

Figure 18: What issues do you have getting third party bathymetry data?



5.4.3 Issues and opportunities by sector

5.4.3.1 FOREIGN RESEARCH VESSELS

Background

Foreign research vessels undertake surveys in New Zealand's marine territory, occasionally in collaboration with a New Zealand research institution. These surveys can collect a wide variety of data, often including bathymetry data.

Any foreign vessel conducting research in New Zealand's waters signs an agreement with MFAT that they will provide copies of data they collect. The approval letter to foreign vessels includes the following statement:

Copies of all data collected (including bathymetric data collected in the NZEEZ) and reports prepared based on data collected in areas under New Zealand jurisdiction, or alternatively details of where such data and reports can be obtained, will be submitted to the New Zealand Government, in a form acceptable to New Zealand, as soon as possible, and within a 12 month period, after the conclusion of the cruise… …This information will be treated as public information and may be made available to New Zealanders via the internet unless another arrangement is reached with the New Zealand Government.

The current process is that all foreign research vessels that wish to conduct research in New Zealand waters apply to do so through their foreign commission, which then lodges an application with MFAT. MFAT then consults various agencies (including LINZ) to determine whether the application should be approved. If the research application is successful the applicant is sent an approval letter, which is signed before their arrival in New Zealand waters.

Issues and opportunities

Foreign research surveys have a number of benefits:

- New Zealand institutions usually pay little or none of the survey costs, and
- the vessels can bring technology such as remotely operated underwater vehicles (ROVs) and autonomous underwater vehicles (AUVs) that are not otherwise available in New Zealand.

However, the major negative aspect of these surveys is that their location and timing are not necessarily aligned with New Zealand's national priorities.

Furthermore, at present there is no formal process for receiving any of the data collected by foreign vessels.[18] Nor is the wider bathymetry community being informed about research vessels entering New Zealand waters.

The application process for foreign vessels to undertake research in New Zealand waters and the process to submit data to the New Zealand government is currently being reviewed by MFAT. The bathymetry sector will have an opportunity to contribute to the review.

[18] NIWA and GNS are involved in many foreign research projects and are informally receiving data.

5.4.3.2 ACADEMIA

Background

The Universities of Otago and Canterbury both have small vessels capable of collecting bathymetric data. For example, the University of Otago has had a vessel since before 2003 and mainly uses SBES and side-scan sonar (SSS) and the University of Canterbury has a remote control vessel with MBES capabilities.

The vessels mainly collect data in the shoreline-shelf area to support research topics such as investigating sedimentation of estuaries, paleo shorelines or geology of off-shore islands and fjords.

Issues and opportunities

Investment in universities' surveying capabilities could yield significant cost-benefits. Research vessels collect data at cost and could collaborate with regional councils which may have similar interests in near-shore data. The University of Canterbury has already worked with Canterbury Regional Council (Environment Canterbury).

5.4.3.3 LINZ HYDROGRAPHIC DATA

Background

Bathymetric data collected by LINZ, through hydrographic surveys, accounts for over a quarter of spending on data collection every year i.e. $5.8 million. LINZ has identified ownership of more than 4500 datasets that contain hydrographic information, covering the vast majority of the extent of New Zealand's near-shore waters. Whilst this data has been primarily collected for the purpose of informing chart production (and the SOLAS mandate), it could be an important resource for the New Zealand bathymetry user community.

Issues and opportunities

1. Currently LINZ data is not easily discoverable outside of LINZ as it can only be obtained by the public via direct contact with LINZ. To rectify this situation, LINZ is undertaking a project to catalogue and index all of the data it has, and to make it easily discoverable and accessible by the public.

2. LINZ collects data to satisfy a strict specification that goes beyond that of the IHO S-44 standard. Traditionally the data collected has not encompassed other datasets that may be collected at the same time as bathymetry. These include water column and backscatter data. This data is important to the bathymetry community and could be collected by LINZ on top of their requirements, potentially at a marginal cost.[19]

3. Identifying current or planned surveys that are being undertaken by third parties and that cover areas in the survey programme could potentially have significant economic impacts for LINZ and for the New Zealand government. Where there is data already available, LINZ could save money and concentrate their efforts on other priority areas.

[19] Based on discussions with survey companies.

5.4.3.4 CROWN RESEARCH INSTITUTES

Background

Crown research institutes (CRIs) are Crown-owned companies established to undertake scientific research for the benefit of New Zealand. NIWA (the National Institute of Water and Atmospheric Research) and GNS Science (the Institute of Geological and Nuclear Sciences) both collect and use bathymetric data extensively. NIWA has a number of vessels capable of collecting bathymetric data, water column and backscatter. The *RV Tangaroa* is the only New Zealand based deepwater vessel equipped with a MBES system. Both NIWA and GNS have well established infrastructure for collecting, managing, analysing and delivering bathymetric data.

Issues and opportunities

The dichotomy CRIs face is that they are Crown-funded agencies and also self-funding. The requirement to find funding to pay for the maintenance of bathymetry data has influenced their policies regarding access to this data.

The agencies have a mix of commercial and research activities. Although most data is collected as part of public good research, some data may have been collected for a private company and may therefore have different confidentiality requirements

5.4.3.5 PRIVATE SECTOR

Oil and gas exploration companies

Background

Every year permits are granted to exploration companies, which provide the right to explore and discover minerals in New Zealand waters. The Crown Minerals Act 1991 (section 90) requires any geophysical data collected by exploration companies to be submitted to the New Zealand government. Once commercial embargoes are lifted, normally after five years or when exploration permits expire, it can be released to the public.[20]

At present, the NZP&M online exploration database contains information about bathymetry collected by exploration companies. Data is discoverable and accessible to the public through the database.

Issues and opportunities

The process for recording and describing New Zealand bathymetric data collected is currently not as efficient as it could be. Effort is often focused on collecting seismic data rather than bathymetry.

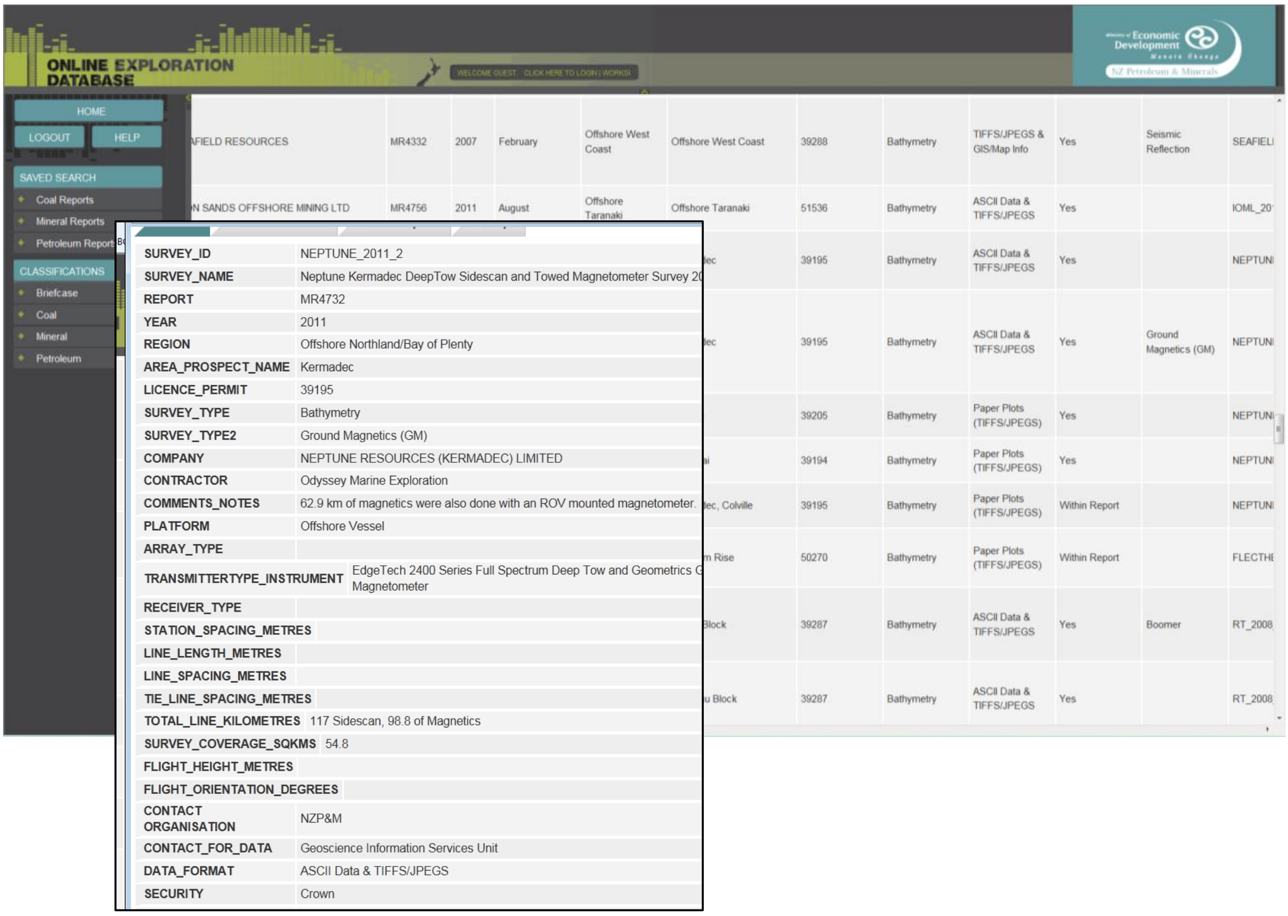
The opportunities for New Zealand are to:

1. strengthen the current processes by which the Crown receives bathymetric data, and

2. strengthen the intermediate information we receive (for example, providing geographical extents of survey areas would help with priority planning for a national programme of hydrographic/bathymetric surveys).

[20] http://www.legislation.co.nz/act/public/1991/0070/latest/DLM5227207.html?search=ts_act_crown+minerals_resel&p=1

Figure 19: NZP&M Online Exploration Database and associated metadata



Fishing Companies

Background

Fishing companies and port authorities are two other industries that routinely collect bathymetric data as part of their core business.

Fishing companies acquire bathymetric data through one-off surveys and via echo sounding equipment on their vessels. Maps with detailed bathymetry are used for commercial fishing because they can identify where fish habitats are most likely to be located.

Issues and opportunities

The vast amount of data that is collected by fishing companies is not accessible to the bathymetric community. The data is often collected at a fine resolution and is deemed commercially sensitive, because it would reveal information about the best places to fish, integral for sustaining the companies' competitive advantage.

The opportunity is to determine whether any of this data could be released at a lower resolution, which does not reveal sensitive information, but is still valuable for the bathymetric community.

Port Authorities

Background

Port Authorities regularly commission bathymetric surveys, albeit in very small restricted areas. The data collected is used to assess the condition of navigation channels, to quantify and determine dredging requirements, and to assess the condition of navigation structures, such as jetties and breakwaters.

Issues and opportunities

The data that port authorities collect is at present largely unavailable to the bathymetric community.

Data is often given to LINZ by ports to enhance the nautical charts that they produce and, some data is also available to purchase by the public. Whilst it is collected for a commercial purpose, after its initial use the historic data is not commercially sensitive. There could be an opportunity to obtain this data for wider use.

Initial discussions suggest that the Harbourmasters community would be open to sharing such information if formally approached.

5.4.3.6 RECREATIONAL BOATING/FISHING

Background

Recreational boats are privately owned vessels ranging from dinghies (under 5m in length) to cruisers (between 8-20m in length). Many larger recreational boats have SBES or MBES equipment on board, used for navigation and for identifying recreational fishing spots.

Issues and opportunities

Electronic Charts

Electronic charts dominate the recreational market and there is a decreasing use of paper charts.

Crowd sourcing

The latest navigation and echo sounding equipment is capable of collecting, storing and re-distributing bathymetric information.

It is unknown to what extent recreational boats use echo sounders, what quality data is collected, or if boaties are willing to share their data. However, there is a clear opportunity to harness and add value to the information collected by recreational boats through crowd sourcing.

There are already private crowd sourcing initiatives available that harness data produced from electronic equipment on boats. For example, Navico's Insight Genesis is cloud-based software that processes bathymetric data from recreational boats and produces customised maps for subscribers.[21]

[21] For more information on Insight Genesis see: http://www.gofreemarine.com/insight-genesis/

5.1 Stakeholder Requirements

This section reports on the needs of bathymetry stakeholders. It provides an insight into the mismatch between the current state of bathymetry and the ideal state. The information will be used to understand what could be done or needs to be done to improve the value of bathymetric data to its users.

5.1.1 Current data does not meet stakeholder requirements

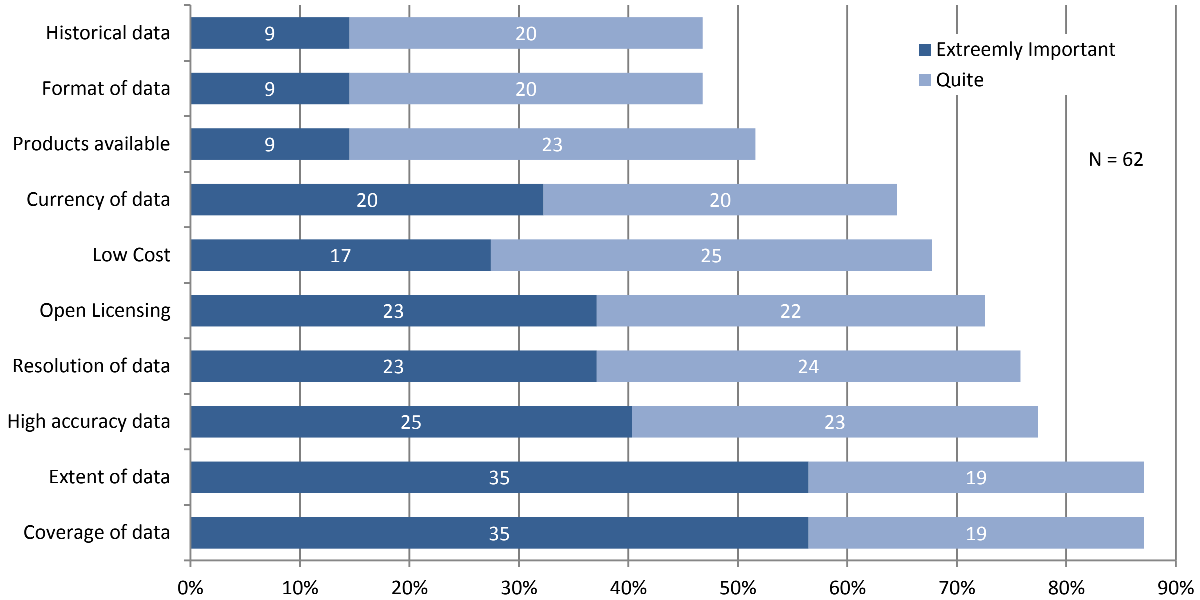
Sixty percent of all respondents said that their current bathymetric data does not meet their business requirements. One hundred percent of respondents from Port Authorities said their data met their requirements, but 100% of respondents from universities, 80% of respondents from government and 50% of respondents from private companies said it didn't.

The likely reason for this contrast is that data collected by ports is used for a single, specific purpose and is likely to have been specified appropriately. Whereas the needs of universities, government and private sector organisations are more diverse and the data they use is often the 'best available' rather than data collected specifically for their use.

5.1.2 Important features of bathymetric data

Respondents were asked to rate the importance of a number of specified factors in terms of the bathymetry they require for their businesses. Fifty-six percent of respondents said that the complete seafloor coverage and geographical extent of data was extremely important and 31% said that it was quite important.[22] Open licensing and low cost of data, whilst less important than factors relating to data quality, were still quite or extremely important to 73% and 68% of respondents respectively. Factors relating to how the data is presented i.e. format or products were much less important than basic non-changeable factors, accuracy or coverage.

Figure 20: Identify the importance of factors for bathymetric data that you require for your business



Key Message

Having data with good coverage and extent is important to nearly all stakeholders

[22] Seafloor coverage is a measurement of the percent of seafloor that has bathymetric information returned in a survey. MBES provides full 100% coverage. Extent is the geographical area that the survey covers. For example a survey could cover a specific inlet or port.

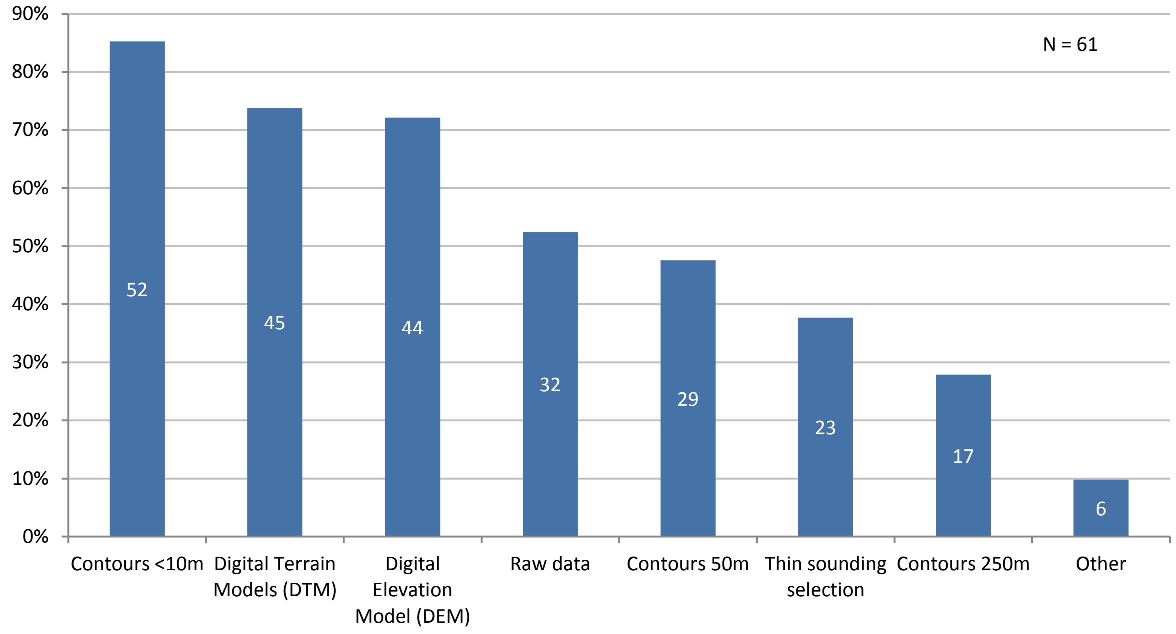
5.1.3 Demand for bathymetry products

Bathymetry products are the outputs of processing the raw bathymetry data. Most commonly these products extrapolate the raw data to allow the visualisaton and analysis of a continuous sea floor surface (usually with contours or a DTM).

There is an overwhelming desire for high resolution bathymetry products to be available in New Zealand. Eighty-five percent of respondents said that they would use contours at <10m intervals if they were available, and 74% said they would use a digital terrain model (DTM).

This is in contrast to what is currently publicly available. High resolution data is publicly available for some geographic areas in New Zealand but not as a product such as a contour layer or DTM. Products currently available for the entirety of New Zealand are soundings and contours (derived from charts) from LINZ and 250m contours from NIWA.

Figure 21: Which bathymetry products would you use if they were available?



5.2 Summary of current situation

This section describes the current situation for bathymetric data in New Zealand, using evidence from a national stakeholder questionnaire and in-depth discussions, interviews and meetings. The research has identified that, whilst there is wide use of bathymetric data across New Zealand, there are noticeable gaps in the data (even in priority areas) and little coordination of effort to streamline acquisition and dissemination of data.

5.2.1 Wide use of bathymetric data in New Zealand

The need for, and the use of, bathymetric data in New Zealand is widespread. Sixty-six of the 71 stakeholders that responded to LINZ's bathymetry questionnaire used bathymetry in their business. At least $20 million per annum is spent on collecting bathymetric data through hydrographic and bathymetric surveys and a further amount is spent on acquiring third party data.

Central and local government, professional, scientific and technical services and the transport industry are among the sectors using bathymetric data. Bathymetric data is used for activities ranging from highly technical environmental modelling and scientific research, to applied navigation and leisure activities.

Bathymetric data is collected and used in all areas of New Zealand's waters. However, the near shore has the most common interest. The near-shore or Intertidal Zone is significant for a number of reasons, but most importantly it represents the region where two very different types of environment meet. The Intertidal Zone is ecologically diverse, but also has significant human exploitation. Furthermore, many aspects of climate change and natural hazards are observed in this zone e.g. sea level rises, tsunamis. It is perhaps for this reason that joining up these two environments, land and sea, into a continuous surface has become so critical.

5.2.2 Gaps in data coverage

The stocktake found that high resolution data has only been collected in approximately 30% of New Zealand's waters and 40% of the Territorial Sea. This is considerably more than the estimate for global coverage (5-10%). Whilst this is good news, a number of organisations highlighted that the data available to them is not fit for purpose, with lack of full seafloor coverage or poor resolution being the biggest issues. Although New Zealand has better coverage than the global average there are still significant areas with gaps in data.

The results of the questionnaire showed that these gaps are often not because the data hasn't been collected but because it is unavailable and not accessible to everyone who needs it. This is especially true for the research community and policy makers. For example, a recent report looking at marine planning and decision-making observed that several interviewees remarked on the limited national scale scientific information and that this information was not available or accessible.[23]

There are a number of opportunities to close these gaps, firstly through better coordination of collection (e.g. joint commissioning of surveys) and secondly through better data provision (e.g. ensuring all data collected is discoverable and available for use).

5.2.3 Coordination of bathymetry acquisition and dissemination

5.2.3.1 EXISTING ARRANGEMENTS

There are a number of existing coordination arrangements in New Zealand for bathymetry, albeit on a local or informal level rather than a national level. For example:

1. Joint commissioning of data collection. Surveys are often jointly commissioned by a consortium of local councils and ports. Private companies will often commission surveys

[23] McGinnis, M. V. "Ocean governance: the New Zealand dimension." (2012) p 31.

for NIWA to carry out. Councils will often work collaboratively with other universities and private businesses.

2. Informal data sharing. Ports may share their data with LINZ to enhance the navigational chart products.

3. Procurement of data services. GNS has been funded by NZP&M to develop and deliver the New Zealand Petroleum Basin Explorer (PBE).

5.2.3.2 COORDINATION ISSUES

A number of factors have exposed the lack of national coordination of bathymetry acquisition and dissemination in New Zealand. For example:

- there are occurrences of duplication of data collection in New Zealand,
- there is no formal process to collect foreign research vessel information,
- there is no 'one place' to get bathymetric data in New Zealand,
- data portals offering bathymetric data often have contradictory information, and
- it is difficult to obtain real, useable data from portals.

The bathymetry questionnaire has also highlighted that many datasets do not have common or agreed collection standards and often they have poor metadata as well. Furthermore, the questionnaire highlighted that many organisations did not routinely release their data, even though it was collected by the Crown.

5.2.4 National Bathymetry Model

There is a desire among stakeholders to have bathymetry products available for them to use.

At present more often than not raw bathymetric data is the only option available to stakeholders. Whilst in certain cases this may be desired, many activities that use bathymetric data require products such as contours or DTMs. A lot of effort is being put into cleaning and processing data and developing products locally and on an ad hoc basis.

The development of a national bathymetry model may fill this gap. A set of products with the best available data could be available for anyone to use. This would decrease the number of transactions with large raw datasets and reduce the amount of time stakeholders spent cleaning and developing models themselves.

5.2.5 Limitations

The data presented in this market research and the stocktake has limitations. In particular, there can be limitations to data gathered from questionnaires. Many common issues can be mitigated with good questionnaire design, for example using multiple choice to limit ambiguous answers. However, some issues cannot be mitigated, specifically for this questionnaire:

1. The questionnaire will not have been completed by all the bathymetry stakeholders in New Zealand. The implications of this are that the results of the questionnaire may not capture an accurate representation of the bathymetry community. Even so, the number of organisations not captured is likely to be small because there was considerable due-diligence to identify the major stakeholders in New Zealand. Furthermore we received a 73% response rate from the organisations we contacted.

2. The correct people may not have answered the questionnaire. The questionnaire required technical knowledge to understand and answer many of the questions. Some of the questions could have been misinterpreted or answered wrongly due to a lack of knowledge.

3. Stakeholders may not be willing to answer some of the questions, because the information is deemed to be commercially sensitive. For example, some stakeholders did not answer the question on their annual spend on surveys. Even so, for spend, we were able to gather

enough information from stakeholders who did answer the question and estimated spend for those who didn't.

4. The organisations responding to the questionnaire reflect the types of industries and the number of organisations that use bathymetry in New Zealand, rather than the amount of use.

6 Economic Review

6.1 Key Messages

- Marine sector accounts for approximately 3% of GDP per annum
- Range of sectors in the economy where marine spatial data is vital to decision-making
- *Shipping:*
    - 99.7%, by gross weight in tonnes, of New Zealand's imported and exported cargo/goods are transported by sea
    - Hydrographic surveys and navigational charts decrease the risk of loss of life and increase the speed at which ships can get in and out of ports
- *Fishing and aquaculture*
    - In 2008, the commercial fishing industry had an estimated value of $3.97 billion
    - Use of bathymetry helps maximise profits by locating fish habitats and reducing damage/loss of fishing gear (NZ$18 million to $89 million per annum)
- *Offshore minerals*
    - Crude oil is New Zealand's 4th largest export, with an estimated value of $2.2 billion per annum
    - Bathymetry assists in locating minerals and securing mining licences
- *Government and defence*
    - New Zealand has jurisdiction over a large marine environment
    - Bathymetry benefits activities used to manage and protect this environment
- Review of international literature shows:
    - ROI for hydrographic services between 1:3 and 1:9
    - ROI for bathymetric data provision between 1:2 and 1:6

This section discusses the social and economic benefits of establishing a coordinated, nationally managed bathymetry programme for New Zealand.

The aims of this section are to provide evidence that bathymetry plays a central part in the marine economy and that better bathymetric data provision will lead to economic benefits for New Zealand.

The section:

- provides background to New Zealand's marine economy and describes where bathymetric data fits in, and
- uses existing literature and case studies to examine the potential economic benefits of developing better data provision i.e. a coordinated approach to data acquisition and distribution.

6.2 The value of New Zealand's marine economy

New Zealand's waters are both socially and economically important, contributing $3.3 billion (3% of total GDP) towards the total economy in 2002. By international comparison this is more than USA (1.2%) and Canada (1.5%) but less than Australia (3.6%) and UK (4.9%).

The islands of New Zealand extend from the sub-tropics to the sub-Antarctic regions, and because there is little overlap with the maritime zones of other countries New Zealand has one of the largest Exclusive Economic Zones (EEZ) in the world (over 4 million km^2), more than 15 times the area of New Zealand's land mass.[24]

New Zealand's marine territory is an important part of the country's economy and culture. It is a source of seafood, fish, and energy production, and a site for transport, recreation and cultural uses.

Shipping (25%), fishing and aquaculture (26%), offshore minerals (20%) and government and defence (20%) make up the largest contributions to the marine economy. Marine tourism and recreation, marine services, research and education, manufacturing and marine construction form the other sectors of the marine economy.

Bathymetry plays a central role in all the activities that make up the marine economy. It provides valuable information on which to base decisions. Examples of the use of bathymetry for shipping, fishing and aquaculture, offshore minerals, and government and defence are highlighted below.

6.2.1 Examples of the benefits of bathymetry in the NZ marine economy

6.2.1.1 SHIPPING

In New Zealand, 99.7%, by gross weight in tonnes, of New Zealand's imported and exported cargo/goods are transported by sea, equating to 60 billion tonnes per annum. In March 2014, the value of goods exported exceeded $5 billion for the month and $50 billion for the year.

Bathymetry is used in nautical charts and by ports to assess the condition of navigation channels to quantify and determine dredging requirements, and the condition of navigation structures. Charts provide the most direct routes between ports, allow deeper draft vessels (i.e. greater cargo capacity) to be used, decrease the number of groundings, reduce insurance rates, and reduce the required number of pilots per ship (boats that escort ships into berth). Therefore, hydrographic surveys and navigational charts decrease the risk of loss of life and increase the speed at which ships can get in and out of ports. Larger ships can hold a higher quantity of cargo, which equates to lower cost, ultimately increasing profits. In one study

[24] Figures based on New Zealand's land mass being approximately 270,000 KM^2 and the EEZ being approximately 4,100,000 KM^2.

carried out by NOAA, one foot of draft may equate to between $36,000 and $288,000 in increased profit, per transit.

For example, at a total cost of $65 million Port Otago is planning a dredging project that intends to increase the depth of the port to 14 metres (in line with commercial demands) and extend its wharves and berths. The reason for the development is to secure visits to the port by bigger ships. It is estimated that the investment will have an overall benefit of over $200 million over 20 years, or a 1:3 return on investment (ROI).

6.2.1.2 FISHING AND AQUACULTURE

Commercial fishing

New Zealand has a strong fishing industry, especially since the adaptation of the 200 nautical mile Exclusive Economic Zone in 1977. New Zealand's unique seafloor topography has given rise to a huge variety of marine habitats and life forms. Presently, 90% of fish caught in New Zealand waters are exported, and in 2008, the commercial fishing industry had an estimated value of $3.97 billion.

The use of bathymetry helps to maximise profits for fishing companies. For example, bathymetry can help identify the best places for trawl fishing which in turn maximises catch and fuel efficiency and reduces the chance of damaging or losing expensive equipment on unidentified features. Loss or damage to fishing equipment has been estimated at between £6000 and £30,000 per annum for one boat.[25] New Zealand has 1,278 commercial fishing vessels, so this equates to between £7.7 million and £38 million (NZ$18 million to $89 million).[26]

Aquaculture

Currently in New Zealand over 23,000 hectares of water space have been allocated to marine based aquaculture, 56% near shore, 36% open space (offshore sites) and 4% undeveloped space in Aquaculture Management Areas (AMAs). In 2011 total aquaculture exports equated to NZ$298 million, however the industry has a target of $1 billion in sales by 2025.

Bathymetry used in multi-criteria site selection is critical to avoid possible negative environmental impacts of an aquaculture development. Good site selection results in a better chance of obtaining resource consent for the development and, once it is developed, a reduction in negative environmental impacts (and the cost of remediation). Also, optimal siting in an aquaculture development maximises yields and thus profits.

6.2.1.3 OFFSHORE MINERALS

Petroleum and mineral resources exploration, primarily oil and gas, is still an emerging industry in New Zealand, but is being actively developed by the Government. Presently, the Taranaki basin is New Zealand's only commercially producing offshore oil and gas source and in 2010 contributed to just over two thirds (69%) of crude oil produced by New Zealand. Despite this, crude oil is New Zealand's fourth largest export, with an estimated value of $2.2 billion per annum which generates around $400 million per annum in royalties and $300 million in taxes for the Government.

Due to the vast size of New Zealand's waters, it is likely there are more areas with significant oil and gas reserves and other commercially valuable minerals. Based on 17 basins which have been identified, The 2012 NZIER report, *Value of oil and gas exploration* concluded that the development of oil and gas in New Zealand could generate an additional $1.5 billion in export revenue in an average year of production over 30 years and an additional $300 million in taxes.

[25] http://www.kimointernational.org/Economic-Impacts.aspx

[26] http://www.fish.govt.nz/en-nz/Fisheries+at+a+glance/default.htm

Bathymetry can assist in understanding the morphology of the seabed, which provides a picture of where minerals might be located, helps identify areas to conduct more focused studies, and enables the use of high resolution AUVs to carry out detailed sampling and mapping. Furthermore, bathymetry provides vital information when compiling an environmental impact assessment, required should a mining licence application be submitted.

6.2.1.4 GOVERNMENT AND DEFENCE

New Zealand has jurisdiction over a large marine environment, 20 times the size of its land mass. Government and defence organisations are responsible for managing and protecting this environment. A huge range of activities contribute to this sector, from regional councils managing their coastal zones to central government managing the effects of activities in the EEZ and Extended Continental Shelf.

Bathymetry plays a central role in many of these activities. For example, bathymetry has been used for substantiating the claims of coastal states to maritime territory, and thus unlocking the potential resources it provides access to – such as petroleum (oil, gas, gas hydrates), locked on and under the seabed. These resources could potentially produce millions or billions of dollars in revenue for a country and it is for this reason that there is an inherent interest for coastal states in knowing and declaring to others the extent of their sovereign rights in the ocean.

In New Zealand between 1998 and 2002 GNS, NIWA, LINZ and MFAT undertook the continental shelf project and a number of bathymetric surveys to gather data to establish the limits of New Zealand's extended continental shelf. The results formed the basis for the submission to the Commission on the Limits of the Continental Shelf (CLCS). At the cost of $44 million to the New Zealand government, the CLCS confirmed the rights of over approximately 1.7 million square kilometres of seabed outside the existing EEZ. This translates to a cost of $26 per square kilometre gained for New Zealand.

6.3 International examples of the benefits of bathymetry

This part of the economic review evaluates existing business cases for national hydrographic services and the provision of bathymetry data. It is intended to provide a commentary on the main themes emanating from international literature.

The literature reviewed is extensive, but not exhaustive; there are many examples of the cost-benefits of bathymetry portals and even more on the cost-benefits of general portals for spatial data (geoportals), which are not covered here.

The review starts off looking at national hydrographic services, because these are typically the largest collectors of bathymetry information and they provide a sound basis for the collection of bathymetry. The review goes on to look at the literature on provision of bathymetry, bathymetry geoportals and geoportals in general.[27]

6.3.1 National and regional hydrographic services

Hydrographic surveys are primarily carried out to produce and maintain nautical charts, and information to aid navigation, improve safety at sea and to satisfy the obligations under the International Convention for the Safety of Life at Sea (SOLAS), 1974 which, in terms of safety of navigation, 'identifies certain navigational safety services that should be provided by contracting governments'. Nautical charts (paper and electronic) are essential for safe navigation and assisting mariners in avoiding dangers and arriving safely at their destination. Without charts mariners would not know about or be able to avoid subsurface dangers that threaten their safety. Under the SOLAS convention, governments (or their authoritative offices – i.e. hydrographic offices) are required to collect, compile, publish and disseminate hydrographic data in the interest of keeping up to date all nautical information necessary for safe navigation.

Much of the literature studied here focuses on reviewing the cost-benefits of having national and regional hydrographic services or mapping programmes for navigation and other associated activities, for example, tourism, commercial shipping, fishing, scientific research, and coastal zone management. Some reviews do not include any cost-benefit analysis, relying instead on a qualitative description of the main benefits using evidence from current literature, such as Australia's review of the RAN Programme.

Spend on hydrographic services varies considerably depending on the size of national waters, the importance given to having good charts, the size of the economy and the age of the review (some results being more than 20 years old). From the studies reviewed in this paper, spend on hydrographic services can be anything from $240,000 to $10 million per annum.

Where country-specific cost-benefit analysis is included, the outcome varies considerably. However, all show hydrographic programmes to be cost-effective in terms of the economic benefits. For example the cost-benefit assessment of the Canadian Hydrographic Services reported a ROI of 1:9 over 15 years whilst a review on hydrographic services in the APEC regions reported a ROI of 1:3 over 25 years. The difference in ROI is mostly due to variations in cost-benefit frameworks applied and differences in scope, for example the inclusion of additional benefits of hydrographic data to activities such as tourism, mineral exploration, commercial fishing etc. One outlier to these examples is the Vanuatu case study which reports a ROI of up to 1:91 over six years. Vanuatu has a very unusual set of circumstances which could support this figure. The country, like many other Pacific nations, has little or no hydrographic services. Therefore the net gains of a hydrographic service are huge.

[27] A full list of literature considered is available in the Appendices, here.

Three themes are fairly consistent throughout the national and regional reviews:

- First, considering the counterfactual argument (i.e. with or without scenarios) appears to be a common approach to cost-benefit analysis for hydrographic services and mapping programmes. The counterfactual argument is usually: what would be the result of not having a hydrographic service? Whilst in reality this is not strictly the counterfactual argument (it doesn't pertain to a particular event that happened in the past), the conclusion is often that not having a hydrographic service would be catastrophic and the economic implications would be enormous.[28]

- Second, data collected by hydrographic services can be used for many more purposes than just producing and maintaining nautical charts. This is incredibly important in terms of opportunities to reuse data collected for charting purposes.

- Third, an important aspect of hydrographic services and mapping programmes in the context of economic benefits is recognising that parts of them are public goods, i.e. they are non-excludable and non-rivalrous. The public good argument has important implications for bathymetric data in New Zealand in terms of the ability to use data generated by public organisations for multiple purposes without inhibiting its original intended use.

- Lastly, collective action is an important concept for the collection of bathymetric data. Collective action is the term used to describe an action taken together by a group of people to achieve a common goal. In terms of bathymetric data collection it means that for New Zealand it is cheaper and more efficient to collect data once, rather than multiple times by different organisations.

Pertinent to this study, only two national hydrographic reviews directly measure the cost-benefit of coordinating the collection and delivery of hydrographic data. A review of Ireland's national marine mapping programme (INFOMAR), and England's review of the Strategic Regional Coastal Monitoring Programme both include aspects of delivering data through geo-portals and their studies include benefits associated with this activity.

The focus for INFOMAR is to completely map Ireland's offshore waters and to create a range of integrated mapping products of the physical, chemical and biological features of the seabed. Part of this includes data acquisition, data management and interpretation (e.g. the production of a range of information products such as bathymetric/water depth maps) and data exchange (providing improved dissemination of information to policy makers, shared cost approaches, and reduction of duplication of effort).

The total cost of the project is estimated to be €70 million (over seven years), with €3.8 million allocated to data management. In terms of data management, it is expected that establishing a spatial data infrastructure and a national marine data discovery and exchange service could yield benefits over a ten year period of between €2 million and €16 million to the research community. The 2008 INFOMAR options appraisal report points out that the database had already leveraged earnings of €5 million for leading edge Irish research institutions and organisations associated with integrated seabed mapping and geosciences. Furthermore, the database had been utilised in a number of other areas such as the national wrecks database, for habitat mapping, hydrographic charting, and selecting sites of conservation.

In contrast England's Strategic Regional Coastal Monitoring Programme aims to coordinate and integrate coastal monitoring to maximise use of data and to provide the best value. Included within the programme is the monitoring and analysis of bathymetric data and its provision to the public. With an investment of £6.3 million over five years and a proportion of that going towards building and maintaining a geoportal, the programme is expected to deliver benefits in the range of between £4.3 and £19.3 million. Specific short term benefits (Year 1) come from time savings in data collection, preservation of data, efficiency of data collection, and procurement efficiency.

[28] For example see: International Hydrographic Organization (IHO) The Need for National Hydrographic Services *IHO Publication* M-2 (2011) p17.

In addition to the national and regional reviews, the IHO conducted a review of the benefits of hydrography and there are also a small number of published papers that explore the economic impact of hydrographic surveys (for example see Connon and Nairn, 2010). These papers provide an excellent overview of the use and potential benefits of hydrographic services, whilst not performing any cost-benefit analyses of their own. In particular the IHO review, 'The need for national hydrographic services', quantifies the benefits, based on other studies, at 1:10 for major nations with a significant dependence on maritime trades or interests.

The study acknowledges that the users of hydrographic information now go beyond the traditional mariner group to include government agencies, coastal managers, engineers, scientists and others. Furthermore, the study acknowledges that a national hydrographic service plays an important part in any national SDI, because well-managed data is an essential ingredient for economic and commercial development and hydrographic information should be accessible for the widest possible community of users.

6.3.2 Bathymetry data provision

In Europe current spending on collecting and processing marine data is upwards of €1 billion for public bodies and €3 billion for private entities. For this reason marine data has been identified as an important asset in Europe. A number of geoportals are specifically funded to manage and distribute bathymetric data. However, many of these are not supported by cost-benefit analyses. Cost-benefit information does not exist for all European geoportals because under the Infrastructure for Spatial Information in the European Community (INSPIRE) directive, European legislation lays down a framework for a spatial data infrastructure, and has compelled European countries to develop geoportals to serve their bathymetry datasets. An evaluation of the cost-benefits of the wider INSPIRE programme found the benefits to outweigh the costs by a ratio of between 1:5.5 and 1:12. Associated benefits are the reduction of the duplication of data collection, improved decision-making and more cost-effective expenditure.

More specifically the United Kingdom Hydrographic Office (UKHO) carried out an economic review of their Marine Environmental Data and Information Network (MEDIN).

Established in 2008, MEDIN is a partnership of UK organisations committed to improving access to marine data and adheres to the INSPIRE directive. The 2014-2019 business plan shows annual costs of MEDIN are £500K (NZ$1 million) with approximately £90K (NZ$180K) spent on the geoportal infrastructure and staff. It also briefly considers benefits, albeit using previously published sources. The report concludes that previous cost-benefit literature on provision of bathymetry data shows significant efficiency gains from improved data and information management access.

Lastly, The European Marine Observation and Data Network (EMODNet) also considers the economic impact of bathymetric data provision. EMODNet aims to provide free access to, and use of, European marine data across seven disciplines, one of which is bathymetry. The 2009 EMODNet impact assessment identifies that the reduction of operational costs and delays for those who use marine data will help the private industry compete in the global economy, improve the quality of public decision-making at all levels, and strengthen marine scientific research.

Furthermore, the assessment reports that a reduction in the uncertainty of knowledge of the oceans and the seas will provide a basis for managing inevitable future changes, for example sea level rises.

It is also argued that a fragmented, as opposed to an integrated, observing system adds at least 25% to the costs of those who deliver products and services.[29] As an example of this, EMODNet estimates that a reduction of uncertainty in future sea level rise could save as much as €100 million per year in sea defences.

[29] Willis, Zdenka, and N. O. A. A. Director. "The business case for improving NOAA's management and integration of ocean and coastal data." Integrated Ocean Observing System (IOOS) of National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce, Washington, DC (2009).

6.3.3 Spatial data provision

Also relevant to the provision of bathymetric data is literature that deals with spatial data provision more generally. This is because there are similar benefits from coordinating access to any spatial data. For example, the 2008 ACIL Tasman paper describes how spatial information is used across sectors in New Zealand, quantifies the value of spatial data and estimates the potential gains available by removing barriers. The paper estimates that in 2008, as a result of productivity improvements due to increasing adoption of modern spatial information technologies, the use and reuse of spatial information added $1.2 billion (0.6% of GDP) in productivity-related benefits to the New Zealand economy.

The paper, which models with and without scenarios and their contribution to the economy, asserts that examples of the use of modern spatial information technology can be found in all sectors of New Zealand's economy and that there is tremendous potential for further benefits to be realised.

A specific case study in this paper relevant to the bathymetry investigation is NIWA's seabed habitat mapping programme, where advances in GPS technology have helped transform spatial data into meaningful information that can be used to catch fish as well as manage stocks. For example, by creating 3D maps of the seafloor, fishers are pinpointing hills on the sea floor on which to set trawls.

More broadly, Victoria University in Melbourne, Australia has presented case studies exploring the costs and benefits that public sector information (PSI) producing agencies and their users experience in making information freely available. The University concludes that even the subset of benefits that can be measured outweigh the costs of making PSI more freely and openly available. The study highlights that there are costs involved in making data freely available (e.g. set-up costs), but these are outweighed by the long term efficiencies achieved. The study concludes that making information freely available will ultimately lead to an increase in level of use per funding dollar for agencies, allow the use of better, more detailed data, and reduce the amount they have to spend on purchasing their own data. This view is further backed by a 2003 survey of main marine data providers in the UK, which showed that very little income was generated from the sale of data, approximately £70,000 (NZ$140,000) compared to the total public funding of these bodies of £1 billion (NZ$2 billion).

Finally, the U.S. Geological Survey (USGS) completed a detailed cost-benefit analysis of their National Map, an initiative to provide the nation with a mechanism to access current and digital topographic data. The study estimates that at a cost of US$25 million a year for 10 years and US$5 million for 20 years, the programme could provide a net present value (NPV) of benefits of US$2.05 billion in 2001 dollars over its 30-year life span. Benefits would come from the value of information as its data is used to permit, facilitate or improve public or private decisions or processes.

6.4 Summary of economic review

The marine economy represents 3% of New Zealand's total economy. By international comparison this is more than USA (1.2%) and Canada (1.5%) but less than Australia (3.6%) and UK (4.9%). However, over the next 10-30 years there will be substantial development and growth in New Zealand's marine economy. Bathymetry plays an important role in supporting this development and growth, as important information that can support decision-making.

Bathymetric data already benefits a wide range of activities in New Zealand; however, there is an opportunity for bathymetry to make a bigger impact on the marine sector. The opportunity lies in better bathymetric data provision for sectors contributing to the marine economy.

International evidence demonstrates the economic benefits of bathymetry for a wide range of purposes and also the economic benefits of good provision of bathymetric data to those who need and use it. For example:

- the provision of hydrographic services and nautical charts for navigation is widely reported to have profound economic impacts on a nation, for example, the cost-benefit ratios of hydrographic services range between 1:3 and 1:91
- business cases for national hydrographic services also show that hydrographic data can be used for a wide range of purposes other than just charting
- re-sale of data is often not profitable and it is more valuable to the whole economy to make it freely available
- cost-benefit ratios for improving the provision of data range between 1:2 and 1:6.
- improving the provision of bathymetric data (i.e. making data discoverable and available) leads to a number of significant benefits. These include time savings in data collection, preservation of data, efficiency of data collection and procurement efficiency, which all can lead to more cost-effective expenditure and improved decision-making (through the reduction in the uncertainty of knowledge).

7 Conclusions and recommendations

7.1 Conclusions

New Zealand's waters are both socially and economically important, contributing $3.3 billion (3% of total GDP) towards the total economy in 2002.

Bathymetric data is important information which is used to benefit many of the activities that contribute to the marine economy.

This investigation has shown that there is widespread use of bathymetric data across many different sectors, both public and private. Even so, for a dataset with widespread demand and use two issues have been identified that inhibit New Zealand's bathymetry from reaching its full social and economic value.

1. Gaps in data, where data does not exist because it hasn't been collected, or it is not fit for purpose, and

2. A lack of national coordination of bathymetry acquisition and dissemination.

Both issues have implications for many of the stakeholders who need and use bathymetric data in New Zealand. However, it is appreciated that these issues do not affect all stakeholders.

Better coordination of bathymetric data in terms of acquisition and dissemination would improve the availability of bathymetric data and have a considerable impact on New Zealand's marine economy.

Better coordination would:

- unlock existing data currently unavailable, making it available for wider groups of people
- improve the marine spatial data infrastructure
- identify opportunities to combine survey operations
    - improving prioritisation for collection, and
    - reducing spend for amount of data collected (or more data collected for spend), and
- improve overall certainty of outcomes.

7.2 Recommendations

From the results of this investigation the authors have several recommendations to advance the bathymetry sector in New Zealand. Essentially the recommendations will take the sector towards the ideal target state for any fundamental data theme, bathymetric data:

1. which is open for public access,
2. which is discoverable and accessible,
3. which has consistent standards,
4. which is actively reused,
5. which is protected and preserved, and
6. where public investments are optimised.

To achieve this this target state:

1. It is recommended that there is greater coordination of bathymetry acquisition and dissemination in New Zealand.

A number of 'quick wins' have been identified that could be implemented to improve coordination and quality of bathymetric data.

Initially, work should be carried out to distinguish where coordination would most benefit the sector.

Initiatives to improve coordination would build on where coordination already exists and involve stakeholders working together to decide the best course of action.

2. It is recommended that at a minimum all Crown funded data collected should be made public.

Public agencies need to work together to identify all the data that can be made publicly available and how to make it easily discoverable and available.

3. It is recommended that the long term goal for bathymetry in New Zealand should be to develop a freely available national bathymetry model.

Bathymetry stakeholders should agree on the specifications for a national bathymetry model and work together to develop and deliver a suitable product that can be used across the sector.

8 Glossary

Where available the definitions in this glossary have been taken from the IHO dictionary, which is available here: http://www.iho.int/iho_pubs/standard/S-32/S-32-eng.pdf.

Accessibility (of data)	The degree to which data is readily obtainable.
Availability (of data)	The degree to which data is suitable or ready for use.
ANZLIC meta data standards	The Australia New Zealand Land Information Council (ANZLIC) Metadata Profile (version 1.1) is the recommended e-GIF geospatial metadata standard for use by New Zealand government agencies. The Profile was endorsed by the State Services Commission in July 2010, following a consultation period which showed support for the Profile from the geospatial community. Local government and Crown research institutes are also encouraged to use the Profile and private industry is free to use it as well.
ASCII XYZ files	A raster GIS file format in the form of a grid which contain the X and Y coordinate of the center of each cell in a grid and the Z value of that grid (i.e. the depth/height).
Baseline	The line from which the seaward limits of a state's territorial sea and certain other maritime zones of jurisdiction are measured. Normally, a sea baseline follows the low-water line of a coastal state. When the coastline is deeply indented, has fringing islands or is highly unstable, straight baselines may be used.
Bathymetry	The determination of ocean depths. The general configuration of SEA FLOOR as determined by profile analysis of depth data.
Bathymetric Survey	Surveys not designed specifically for charting purposes, e.g. coastal mapping, oil companies, cable laying companies, construction, etc.
Contiguous Zone	A zone contiguous to a coastal state's territorial sea, which may not extend beyond 24 nautical miles from the baselines from which the breadth of the territorial sea is measured. The coastal state may exercise certain control in this zone subject to the provisions of International Law.
Contour (or contour line)	A line connecting points of equal elevation or equal depth.
Coverage	Relates to the proportion of the seafloor that is surveyed in a bathymetric or hydrographic survey. For example, Multi-beam echo sounders can provide a complete and continuous coverage of the seafloor.
Data Currency	Data currency generally refers to whether a dataset is current or up-to-date.
Data Custodian	There are two types of data custodian: Leadership and Delivery. The Leadership Custodian ensures that appropriate management policies and standards are developed and maintained on behalf of the Crown. The Delivery Custodian has responsibility for the continued existence, availability, and integrity of the dataset for as long as required.
Data Steward	The Steward (an agency) considers a holistic and aspirational view in the national interest across a fundamental data theme. The agency promotes good practice, and coordinates activities to ensure best outcomes, overseeing data architecture, quality, maintenance, metadata, pricing, licensing, access and release. The Steward brings the views of users to the table. Stewards are accountable for maintaining the quality, integrity, availability and security of the data so that it meets the needs of users.
Depth	The vertical distance from a given water level to the bottom the water body.
Digital Elevation Model (DEM)	A digital model or 3D representation of a terrain's surface, and includes all objects on it e.g. plants and buildings.
Digital Terrain Model (DTM)	A digital model or 3D representation of a terrain's surface that represents the bare ground surface without any objects like plants and buildings.
Discoverability	The use of any piece of information relates to how discoverable it is, hence discoverable data is data which can be physically found easily. Metadata or information about data can help make data become more discoverable.
Exclusive Economic Zone (EEZ)	The exclusive economic zone is an area, not exceeding 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, subject to a specific legal regime established in the United Nations Convention on the Law of the Sea under which the coastal state has certain rights and jurisdiction.

Extended Continental Shelf	The sea zone that, defined by UNCLOS, extends to the limit of the continental margin, but no less than 200 nautical miles from the baseline.
Extent	The geographic domain of a data collection i.e. the geographic area covered by a survey or dataset.
General Bathymetric Chart of the Oceans (GEBCO)	GEBCO consists of an international group of experts who work on the development of a range of bathymetric data sets and data products, including gridded bathymetric data sets, the GEBCO Digital Atlas, the GEBCO world map and the GEBCO Gazetteer of Undersea Feature Names. See http://www.gebco.net/
Highest Astronomical Tide (HAT)	The highest tidal level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions.
Hydrographic data	Hydrographic data is information about the features of the seabed, and is often used for navigation.
Hydrographic Survey	Surveys prepared specifically for nautical charting.
Hydrography	The branch of applied science which deals with the measurement and description of the physical features of the navigable portion of the EARTH's surface and adjoining coastal areas, with special reference to their use for the purpose of navigation.
Internal Waters	Waters on the landward side of the baseline of a nation's territorial waters. It includes waterways such as rivers and canals, and the water within small bays.
Interoperability	The ability of making systems and organisations work together (inter-operate).
Intertidal Zone	The intertidal zone (also known as the littoral zone) is generally considered to be between mean high water and mean low water.
Littoral zone	See Intertidal Zone.
Lowest Astronomical Tide (LAT)	The lowest tide level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions.
Marine Economy	Economic activities that take place in, or use, the marine environment, or produce goods and services necessary for those activities, and make a direct contribution to the national economy.
Marine Spatial Data Infrastructure (MSDI)	A range of activities, processes, relationships and physical entities that, taken together, provide for integrated management of spatial data, information and services.
Mean high water	The average height of all high waters at a place over a 19-year period.
Mean low water	The average height of all low waters at a place over a 19-year period.
National Oceanic and Atmospheric Administration (NOAA)	NOAA is a scientific agency within the United States Department of Commerce focused on the conditions of the oceans and the atmosphere. In relation to bathymetry and global relief NOAA provides scientific stewardship, products, and services for ocean depth data and derived digital elevation models.
Nautical Chart	A chart specifically designed to meet the requirements of marine navigation, showing [depth/depths]] of water, nature of bottom, elevations, configuration and characteristics of coast, dangers and aids to navigation. May be a paper chart, electronic navigational chart (ENC) or a raster navigational chart (RNC). Also called marine chart, hydrographic chart, or simply chart.
Nautical Mile	A unit of distance that is approximately one minute of arc measured along any meridian, equal to 1,852 metres exactly.
Satellite Derived Bathymetry (SDB)	Bathymetry data derived from satellites, mainly through the use of high resolution imagery and altimeters.
Spatial Data Infrastructure (SDI)	A data infrastructure implementing a framework of geographic data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way.
Territorial Sea	A belt of water of a defined breadth but not exceeding 12 nautical miles measured seaward from the territorial sea baseline.
Third Party Data	Data which is not collected directly by your organisation but which is obtained from existing sources.
Usable data	The extent to which a product (such as a device, service, or environment) can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.
United Nations Convention on the Law of the Sea (UNCLOS)	UNCLOS is an international agreement that defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources.

9 References

Adams, Ruth., et al. "Joining up Land and Sea." GIM International 10.10 (2006). http://www.hydro-international.com/issues/articles/id696-Joining_Up_Land_and_Sea.html

Assessing The Costs And Benefits Of Hydrographic Survey And Charting A Case Study Of Vanuatu (2014)

Brinkman, George L., and S. L. Caverley. "Benefit-Cost Assessment of the Canadian Hydrographic Service." *Intercambio Limited, as yet unpublished consultancy* (1992).

Broman, Barry, et al. "A harmonized depth model of the Baltic Sea."

Commission Staff Working Document European Marine Observation and Data Network IMPACT Assessment *SEC* (2010) 998 final

Connon, Brian., and R. Nairn. "Economic Impact of Hydrographic Surveys", *Report on the Economic Benefits of Hydrography* FIG Publication No 57 (2011) 10-22.

Craglia, M. "Contribution to the extended impact assessment of INSPIRE." Creator INSPIRE Framework definition support (FDS) working group Max Craglia–Sheffield University (contractor), Publisher Environment Agency for England and Wales (2003): 1-65.

Dufourmont, Hans. "Extended Impact Assessment of INSPIRE based on revised scope." *European Commission*, DG Eurostat, Luxemburg (2004).

ECORYS, "Costs-benefits analysis INSPIRE", Final report *ECORYS* (2009).

"Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012", http://www.legislation.govt.nz/act/public/2012/0072/latest/DLM3955428.html

Fowler, Cindy, Brian Smith, and David Stein. "Building a marine spatial data infrastructure to support marine spatial planning in US waters." GISLANDS at: http://www.Gislands.org (2010).

Halsing, David, Kevin Theissen, and Richard Lewis Bernknopf. A cost-benefit analysis of The National Map. Vol. 1271. US Department of the Interior, US Geological Survey, 2004.

Hell, Benjamin, et al. "The use of bathymetric data in society and science: A review from the baltic sea." Ambio 41.2 (2012): 138-150.

Houghton, John. "Costs and Benefits of Data Provision: Report to the Australian Nafional Data Service, Centre for Strategic Economic Studies." Victoria University, September (2011).

"INFOMAR Marine mapping study options appraisal report: final report" PricewaterhouseCoopers (2008).

International Hydrographic Organization (IHO) "The Need for National Hydrographic Services". *IHO Publication M-2* (2011)

Kearns, Timothy A., and Joe Breman. "Bathymetry-The art and science of seafloor modeling for modern applications." *Ocean Globe* (2010): 1-36.

Leveson, Irv. "Socio-Economic Study: Scoping the Value of NOAA's Coastal Mapping Program." *cell* 609 (2012): 462-3112.

Maguire, David J., and Paul A. Longley. "The emergence of geoportals and their role in spatial data infrastructures." *Computers, environment and urban systems* 29.1 (2005): 3-14.

MACHC and Industry, "Maximising the use of Hydrographic survey Data", IRCC6-11B, (2014) retrieved June 2015, http://www.iho.int/mtg_docs/com_wg/IRCC/IRCC6/IRCC6-12B-MaximizeHydroData-MACHC.pdf

McGinnis, M. V. "Ocean governance: the New Zealand dimension." (2012): 4. http://igps.victoria.ac.nz/publications/files/e2e7421271e.pdf

Quadros, N. D. “What Users Want in Their Bathymetry, Bathymetry user needs and Challenges in Australia and New Zealand.” *Hydro International* (2012): 18-23.

Quadros, N. D. “Bathymetry Acquisition - Technologies and Strategies, Investigating shallow water bathymetry acquisition technologies, survey considerations and strategies” *CRCSI* (2013).

Statistics New Zealand., "New Zealand’s marine economy 1997–2002." Statistics New Zealand Environmental Series. *Statistics New Zealand*, Wellington (2006) retrieved July 2015 http://www.stats.govt.nz/browse_for_stats/environment/environmental-economic-accounts/marine.aspx

Tasman, A. C. I. L. "The value of spatial information." *Cooperative Research Centre for Spatial Information*. (2008).

Transportation Working Group., “Analysis of the Economic Benefits of the Provision of Hydrographic Services in the APEC Region” *Transportation Working Group* (2012)

Willis, Zdenka, and N. O. A. A. Director. "The business case for improving NOAA’s management and integration of ocean and coastal data." *Integrated Ocean Observing System (IOOS) of National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce, Washington, DC* (2009).

10 Appendices

10.1.1 International data portals

Name Organisation Type	Description	Country	Date Started	Interaction type	Products
Integrated Mapping for the sustainable development of Irelands marine resource (INFOMAR)	The focus of the programme is to create a range of integrated mapping products of the physical, chemical and biological features of the seabed in the near-shore or Zone 1 (0m to 50m) and Zone 2 (50m to 200m). http://www.infomar.ie/ http://maps.ngdc.noaa.gov/viewers/multibeam/	Ireland	2008	Viewer and download	Raw MBES data
North American Atlas	A cooperative project involving the Atlas of Canada, which is part of Natural Resources Canada; Mexico's National Institute of Statistics and Geography (Instituto Nacional de Estadística Geografía e Informática – INEGI); and the National Atlas of the United States. http://nationalatlas.gov/mld/bathy0m.html	Canada	July 2004	Data download only	
Canadian Hydrographic Service (CHS) Fisheries and Oceans Canada	CHS offers 500-metre bathymetric gridded data for users interested in the topography of the seafloor. Collection covers surveys they have conducted. http://www.chs.gc.ca/data-gestion/bathy/bathymetri-eng.asp http://www.chs.gc.ca/data-gestion/bathy/map-eng.asp	Canada		Interactive map and download	
The National Marine Sanctuary of American Samoa	Provides GIS data from shallow-water MBES bathymetric surveys, submersible dives, and workshops conducted in 2001-2005. Recent compilation of deepwater bathymetry for the entire Eastern Samoan region, as well as terrestrial GIS data layers obtained from the American Samoa GIS User Group. http://dusk.geo.orst.edu/djl/samoa/	American Samoa	2001	Data download only	
Geoscience Australia	Geoscience releases a MBES dataset gridded at 50m resolution. They also release an Australian Bathymetry and Topography Grid, June 2009 at a spatial resolution of 250m. http://www.ga.gov.au/scientific-topics/marine/bathymetry	Australia		Interactive map and download	
MAREANO	Uses various sources 2005-2011 to compile a WMS map service for bathymetry data.	Norway	2011		

Name Organisation Type	Description	Country	Date Started	Interaction type	Products
	http://www.mareano.no/en/topics/bathymetric_mapping				
UKHO MEDIN bathymetry data archive centre	The bathymetry DAC is operated by the UK Hydrographic Office and stores bathymetric data gathered around the British Isles. All UK Government sponsored survey data gathered in support of charting (Civil Hydrography Programme data). Datasets supplied by other government survey organisations (e.g. Cefas) are also held as are datasets gathered by some Port Authorities, environmental organisations and academic institutes. https://www.ukho.gov.uk/inspire/Pages/home.aspx	United Kingdom	Various	Geospatial viewer and data download	Lat/long CSV file with depth Metadata XML
SHOM (Service hydrographique et océanographique de la marine)	SHOMs database contains recent SHOM surveys as well as older surveys whose logs were digitised and corrected before being integrated into their database; runs of CARIS bathy database. http://www.shom.fr/en/onlines-services/	France		Viewer and data download	
National Oceanic and Atmospheric Administration (NOAA)	NOAA, US Department of Commerce, provide long-term scientific data stewardship for the Nation's geophysical data, ensuring quality, integrity, and accessibility. One of the areas that NOAA provides stewardship for is bathymetry and global relief. There are various outlets for bathymetry information and data is supplied from various organisations, for example National Ocean Service (NOS). http://www.ngdc.noaa.gov/mgg/bathymetry/relief.html http://coast.noaa.gov/digitalcoast/dataregistry/#/	United States		Data viewers and data download	
European Marine Observation and Data Network (EMODnet) - Bathymetry portal	Developed in the framework of the European Marine Observation and Data Network (EMODnet) as initiated by the European Commission. It provides services for discovery and requesting access to bathymetric data (survey datasets and composite DTMs) as managed by an increasing number of data providers from government and research. http://www.emodnet-hydrography.eu/	Partners across Europe	Various	Like a shop for bathymetry data	Survey data and composite DTMs
Channel Coastal Observatory	Data management centre for the Regional Coastal Monitoring Programmes Hosted by New Forest District Council, in partnership with the University of Southampton and the National Oceanography Centre, Southampton. MBES 2007-2013; SBES 2003-2012. http://www.channelcoast.org/	South England		Like a shop for bathymetry data; free downloads	ASCII text/grid file; Raw data; SD file

Name Organisation Type	Description	Country	Date Started	Interaction type	Products
Marine Datum Infrastruktur Deutschland (MDI-DE)	Provides a variety of Marine data and information https://www.mdi-de.org/mdi-portal/ui	Germany			Various marine datasets
AMSIS : Australian Marine Spatial Information System	A web based interactive mapping and decision support system that improves access to integrated government and non-government information in the Australian Marine Jurisdiction http://www.ga.gov.au/scientific-topics/marine/jurisdiction/amsis	Australia			Various marine datasets
Marine Geoscience Data System	The Marine Geoscience Data System (MGDS) provides a suite of tools and services for free public access to marine geoscience research data acquired throughout the global oceans and adjoining continental margins. Various data across the world from the 1960s through to present: including some New Zealand data. http://www.marine-geo.org/portals/margins/	Mainly US but world data		Free to download	Various formats
UNEP Shelf Programme, Grid Arendal	One stop data shop for use by coastal states preparing a submission delineating the outer limits of their continental shelf http://www.continentalshelf.org/onestopdatashop.aspx			Free to download	

10.1.2 Questionnaire outline

	Contact Information	
	First Name	
	Last Name	
	Organisation	
	Unit/Group	
	Industry [Select One]	Agriculture, Forestry & Fishing Mining Manufacturing Electricity, Gas, Water & Waste Services Construction Wholesale Trade Retail Trade Accommodation & Food Services Transport, Postal & Warehousing Information Media & Telecommunications Financial & Insurance Services Rental, Hiring & Real Estate Services Professional, Scientific & Technical Services Administrative & Support Services Public Administration & Safety Education & Training Health Care & Social Assistance Arts & Recreation Services Other Services
	Email	
	Contact Number	
	I am filling this questionnaire out on behalf of my:	Organisation Unit/Group
Section 1: Data Use		
The purpose of this section is to find out how your unit/group or organisation uses bathymetry data now.		
Q1	Which geographical extents is your unit/group or organisation involved with? [Select all that apply]	Internal waters (lakes/rivers) Intertidal Zone Territorial Sea (12 Nautical Miles Contiguous Zone (24 Nautical Miles Exclusive Economic Zone (200 Nautical Miles) Extended continental shelf Other [please state]
Q2	Does your unit/group or organisation use bathymetry data to carry out its functions?	Yes No
If yes please go to question 3		
Q2.1	What are the main reasons why your unit/group or organisation does not use bathymetry data? [Select all that apply]	Data availability Funding/resources Lack of expertise Low Priority No business requirement Other (please specify)
If you have answered question 2.1 now go to question 8, requirements section OR if no business requirement go to question 24		
Q3	What are the main uses of bathymetry in your unit/group or organisation? [Select all that apply]	Climate Change Information Contracting & Consulting Environmental Modelling Environmental Risk/Insurance Fishing/Aquaculture Harbour/Port Management Hydrodynamic Modelling Law Enforcement/Defence Marine & Coastal Conservation Natural Resource Production Navigation & Charting Policy Making & Government Risk Management Scientific Interest/Research Surveying & Mapping Tourism/Leisure Activities Other (please specify)
Q4	Does the bathymetry data that you use now meet your requirements?	Yes No
If yes please go to question 6		
Q5	What are the main reasons why the data is not fit for purpose?	Poor quality Incorrect extent

	[Select all that apply]	Low resolution Not current Incorrect format High cost Not current enough No/little metadata Other reason 3 Other [please state]
Q6	Which processes do you use to improve the bathymetry data you hold? [Select all that apply]	Conversion between datums Conversion between file formats Digitising Grid production Interpolation Merging/joining datasets Modelling Production of contours Surface layer production (Digital Terrain Models (DTMs)) Thinning of soundings Other (please specify)
Q7	Which software packages do you use to handle bathymetry data? [Select all that apply]	CARIS Bathy Database CARIS HIPS & SIPS CARIS HPD Utilities ESRI ArcGIS ESRI ArcGIS for Maritime ESRI ArcGIS Server ESRI ArcScene Fledermaus GeoMapApp Quantum GIS Other (please specify)
Section 2: Requirements		
The purpose of this section is to find out what your unit/group or organisation's bathymetry needs are.		
Q8	Which bathymetry products would you use if they were available to your unit/group or organisation? [Select all that apply]	Contours <10m Contours 250m Contours 50m Digital Elevation Models (DEM) Digital Terrain Models (DTM) Raw survey data Thin sounding selection Other (please specify)
Q9	What formats would you use if they were available? [Select all that apply]	ASCII xyz BAG (Bathymetry Attributed Grid) CARIS CSAR File ESRI ASCII grid ESRI binary grid ESRI Shapefile GeoTIF KML MapInfo Interchange format Other (please specify)
Q10	How important are the following in terms of the bathymetry that you require for your business?	

	Not Important	Slightly Important	Moderately Important	Quite Important	Extremely Important
Coverage of data					
Currency of data					
Extent of data					
Format of data					
High accuracy data					
Historical data					
Low cost					
Open licensing					
Products available (e.g. DEM, DTM)					
Resolution of data					

Section 3: Data Acquisition		
The purpose of this section is to find out how your unit/group or organisation receives bathymetry data.		
Bathymetry Surveys		
Q11	Does your unit/group or organisation	Yes - we undertake these directly (using our own

	collect depth data via bathymetric or hydrographic surveys?	vessels) Yes - we commission a survey company to carry these out No - we don't undertake bathymetric or hydrographic surveys
If no please go to question 19		
Q12	Are any of the surveys you undertake or commission joint projects with other organisations? [if yes, please explain]	Yes No
Q13	Which type of survey method do you use to acquire bathymetry? [Select all that apply]	Lead Line LiDAR Multibeam Echo Sounder Satellite Derived Bathymetry (SDB) Single beam Echo Sounder Other (please specify)
Q14	Does the data you collect from surveys comply with any hydrographic survey standards or technical specifications? This can include your own organisation's specifications or standards.	Yes No Unsure
If no please go to question 15		
Q14.1	Which hydrographic standards do your surveys comply with? [Select all that apply]	LINZ HYSPEC S-44 IHO Other [please state]
Q15	Does your survey data have appropriate metadata?	Yes No Unsure
Q15.1	Which metadata standards does your survey data comply with? [Select all that apply]	FGDC ISO 19115 - ANZLIC ISO 19115 - MCP ISO 19115 - MCP ISO 19139 - Other Other (please specify)
Q16	Is the survey data that you collect made available outside your organisation?	Not made available Freely available Available but with restrictions on use Available only by purchase
If no please go to question 17		
Q16.1	If you make your survey data available how is it found by people outside your organisation? [Select all that apply]	Data catalogue Data not discoverable Internet Search On application Online database Organisation website Other (please specify)
Q16.2	How is your survey data accessed? [Select all that apply]	Disk FTP Hard Drive Web Portal Web Service (e.g. WMS/WFS) Other (please specify)
Q17	Does your unit/group or organisation have a geographical extent and/or an index of your survey data holdings?	Yes No
If no then 17.1 if yes 17.2		
17.1	Are you able to provide LINZ with a copy of your survey data? If this is possible we will contact you separately to arrange the details	Yes - Survey data No not at this time
17.2	Are you able to provide LINZ either a copy of the geographical extent, index and/or the survey data? If this is possible we will contact you separately to arrange the details	Yes – Index Yes – Extent Yes – Extent/Index Yes – Survey Data & Extent Yes – Survey Data & Index Yes – Survey Data & Extent/Index Yes – Survey Data Not at this time
Q18	Approximately how much in NZD is spent per annum by your unit/group or organisation collecting bathymetry data through surveys?	
Third party data		
Q19	Does your unit/group or organisation get	Yes

	bathymetry data from third parties? i.e. data which has been obtained under licence from third party organisations and not collected directly by bathymetric surveys	No
If no then please go to question 24		
Q20	Where do you get third party bathymetry data from? [Select all that apply]	LINZ Data Service (LDS) New Zealand Hydrographic Authority (LINZ) NIWA Regional Councils National Geophysical Data Centre (NOAA) General Bathymetric Chart of the Oceans GEBCO Petroleum Basins Explorer (PBE) Port Authorities Other (please specify)
Q21	Which type of bathymetry data/products do you get from third parties? [Select all that apply]	Contours <10m Contours 250m Contours 50m Digital Elevation Model (DEM) Digital Terrain Model (DTM) High density soundings Nautical Charts (digital) Nautical Charts (paper) Raw unprocessed depth data Thin sounding selection Other (please specify)
Q22	Do you face any issues getting third party data?	Yes No
If no then please go to question 23		
Q22.1	What issues do you have getting third party bathymetry data? [select all that apply]	Cost Discoverability Availability Accessibility Collection Other (please specify)
Q23	Approximately how much in NZD is spent per annum by your unit/group or organisation getting third party bathymetry data?	
Q24	Thank you for completing this questionnaire. Please use the following section to provide any feedback you may have or mention anything else that you feel wasn't covered in the questionnaire.	

10.1.3 List of stakeholders who completed a questionnaire

Auckland Council	Museum of New Zealand Te Papa Tongarewa
Bay of Plenty Regional Council	Napier Port
Beca	Nelson City Council
Cawthron Institute	NIWA
CentrePort Limited	Northland Regional Council
Chorus NZ	Northport ltd
Department of Conservation (DOC)	New Zealand Defence Force (NZDF)
Discovery Marine ltd	OMV
eCoast	Otago Regional Council
Environment Canterbury	Porirua City Council
Environmental Protection Agency (EPA)	Port Nelson ltd
Fugro BTW ltd	Port Otago ltd
GNS Science	Port Taranaki ltd
Greater Wellington Regional Council	Ports of Auckland ltd
Hawkes Bay Regional Council	Ports of Auckland ltd
Horizons Regional Council	Royal New Zealand Navy
IT Rescue Solutions	Sealord Group
IX Survey Australia pty ltd	Seaworks Ltd
Land Information New Zealand (LINZ)	Transpower
Lat 37	Trimble
Lyttelton, Port of Christchurch	University of Auckland
Marlborough District Council	University of Canterbury
Massey University	University of Otago
MetOcean Solutions	Waikato Regional Council
Ministry for the Environment (MfE)	Waikato Regional Council
Ministry of Business Innovation & Employment (MBIE)	West Coast Regional Council
Ministry for Primary Industries (MPI)	Wriggle Coastal Management

10.1.4 Bathymetric datasets available for New Zealand[30]

Organisation Owner	Date Update Pattern	Dataset Description	Coverage	Fields	Access Cost	File type	Datum	Origin Collection	Accuracy	Base Scale
Land Information New Zealand (LINZ)	Oct 1992 – Sept 2013 (Dec 2013 updated on LDS)	Sounding *points*	New Zealand's Exclusive Economic Zone	Depth (metres?) Source date Source chart	LINZ Data Service Public Free (CCL 3.0 NZ)	Vector ESRI Shapefile	Any	S-57 data Hydrographic survey?	See scale	1:22k – 1:90k 1:90k – 1:350k 1:350k – 1:1,500k
LINZ	Oct 1992 – Sept 2013 (Dec 2013 updated on LDS)	Depth contour *polyline* hydro	New Zealand's Exclusive Economic Zone	Depth (metres?) Source date Source chart	LINZ Data Service Public Free (CCL 3.0 NZ)	Vector ESRI Shapefile	Any	S-57 data Hydrographic survey?	See scale	1:22k – 1:90k 1:90k – 1:350k 1:350k – 1:1,500k
LINZ	Oct 2008 (Dec 2013 updated on LDS)	Raster chart image	New Zealand's Exclusive Economic Zone	Chart number Width Height	LINZ Data Service Public Free (CCL 3.0 NZ)	Raster GeoTIFF (image)	Any	Paper Navigational Charts	See scale	1:25K – 1:100K
National Institute of Water and Atmospheric Research (NIWA)	Produced 2008 (data may well be older than this)	NZ 250m gridded bathymetric data	New Zealand's Exclusive Economic Zone	Depth	NIWA website Public Free (CCL 3.0 NZ)	Vector ESRI Shape file Mapinfo Raster ESRI ASCII grid ESRI binary grid Tiff (image) JPG (image)	D WGS 1984	SBES/ MBES ship tracks CANZ (2008)	250m gridded	1:4 million
Koordinates **NIWA**	Produced 2008 (data may well be older than this)	NZ 250m gridded bathymetric data (contours)	New Zealand's Exclusive Economic Zone	Depth	Koordinates website Public Free (CCL 3.0 NZ)	Vector ESRI Shape file	D WGS 1984	SBES/ MBES ship tracks CANZ (2008)	250m gridded	1:4 million

[30] Some fields in this table are incomplete due to being unable to locate the information from the datasets, this does not necessarily indicate that the information is not there at all.

Organisation Owner	*Date Update Pattern*	*Dataset Description*	*Coverage*	*Fields*	*Access Cost*	*File type*	*Datum*	*Origin Collection*	*Accuracy*	*Base Scale*
NIWA	Produced 2008 (data may well be older than this)	Annotated New Zealand Region Bathymetry	New Zealand's Exclusive Economic Zone	N/A	NIWA website Public Free (CCL 3.0 NZ)	Raster Tiff (image) JPG (image)	D WGS 1984	SBES/ MBES ship tracks CANZ (2008))	250m gridded	1:4 million
NIWA	Produced 2008/2003 (data may well be older than this)	Southwest Pacific Region Bathymetry	New Zealand's Exclusive Economic Zone	N/A	NIWA website Public Free (CCL 3.0 NZ)	Raster GeoTIFF (image) JPG (image)	D WGS 1984	CANZ (2008) and The Centenary Edition of the GEBCO Digital Atlas, 2003	250m gridded	1:4 million
NIWA	Produced 2012	Hauraki Gulf Bathymetry	Hauraki Gulf	N/A	NIWA website Public Free (CCL 3.0 NZ)	Raster ESRI binary grid Tiff (image)	D WGS 1984		20m gridded?	
GNS Science	Various	Petroleum Basin Explorer http://data.gns.cri.nz/pbe/index.html#HTML:Content/PBE_Home.html	New Zealand	Various	Free after registration	Shapefile			Various	
GEBCO	2003/updated 2008	A global one arc-minute grid	Global	N/A	Free after registration	NetCDF ESRI ASCII GeoTiff		Various	One minute grid	
GEBCO	2008/updated 2014	A global 30 arc-second interval grid	Global	N/A	Free after registration	NetCDF ESRI ASCII GeoTiff		Various	30 sec arc	

Organisation Owner	*Date Update Pattern*	*Dataset Description*	*Coverage*	*Fields*	*Access Cost*	*File type*	*Datum*	*Origin Collection*	*Accuracy*	*Base Scale*
World Ocean Circulation Experiment (WOCE)	1990 onwards	http://www.nodc.noaa.gov/woce/woce_v3/wocedata_2/bathymetry/default.htm	Global	Unknown	Free	MGD77 ASCII format		Various	Unknown	Unknown
NOAA ship tracks	Various	Ship tracks across the globe – downloadable	Global		Free	X,Y, Z		Various	Various	Various

10.1.5 Applications and benefits of bathymetry in New Zealand

Sector	Area	Zone	Beneficial activities
Sovereignty	Defence: naval operations, homeland and port security	All	Chart production, navigation, mine counter-measures
	Search and rescue		Chart production, navigation, hydrodynamic modelling
	Biosecurity		Habitat mapping
	Customs	Coastal	Chart production
	Illegal fishing	All	Habitat mapping
	Boundary delineation, law of the sea (UNCLOS)	EEZ + NZCS	Surface modelling
	SOLAS	Coastal and shipping lanes (under 30m water depths)	Chart production, navigation
Engineering and coastal infrastructure	Port development, dredging, pipelines, dumping	Inshore, Coastal, 12NM	Surface modelling
Environment	Fishing zones and marine conservation areas	All	Habitat mapping
	Coastal zone management (pollution, erosion, accretion)	12NM	Marine spatial planning
	Archaeology and cultural heritage		Site identification
	Improved emergency response	All	Impact modelling
	Territorial and EEZ planning		
	Biosecurity, biodiversity		
Hazards	Tsunamis	12NM	Scientific research, hydrodynamic modelling, tidal prediction, public safety zones, building zones
	Crustal definition	12NM	
	Volcanic		

Sector	Area	Zone	Beneficial activities
	Submarine landslides	12NM-24NM	
	Sedimentation Change	12NM	
Marine transport	International trade and commercial shipping	12NM	Chart production, navigation
Natural resources	Seabed exploration - petroleum and mineral extraction	All	Seabed geology, impact modelling, habitat mapping
	Manganese crust and nodules		
	Energy production (tidal/wind)	12NM	Surface modelling
Primary production	Aquaculture	12NM	Habitat mapping, impact modelling
	Bioprospecting		
	Commercial fishing, fish stocks, depths limits for fishing/species	All	Chart production, navigation, habitat mapping
Recreation	Fishing including customary take	12NM	Chart production, navigation, habitat mapping
	Tourism		Chart production, navigation
Telecommunications	Laying and maintenance of submarine cables	All	Surface modelling
Scientific research	Biological	All	Modelling
	Non-biological		

Acknowledgements

Ray Wood (Chatham Rock Phosphate Limited)

Andy Coote (ConsultingWhere)

Jenny Black (GNS Science)

Julia Hodge, Rachel Gabara, Adam Greenland and John Summers (Land Information New Zealand)

Neville Ching and Kevin Mackay (NIWA)