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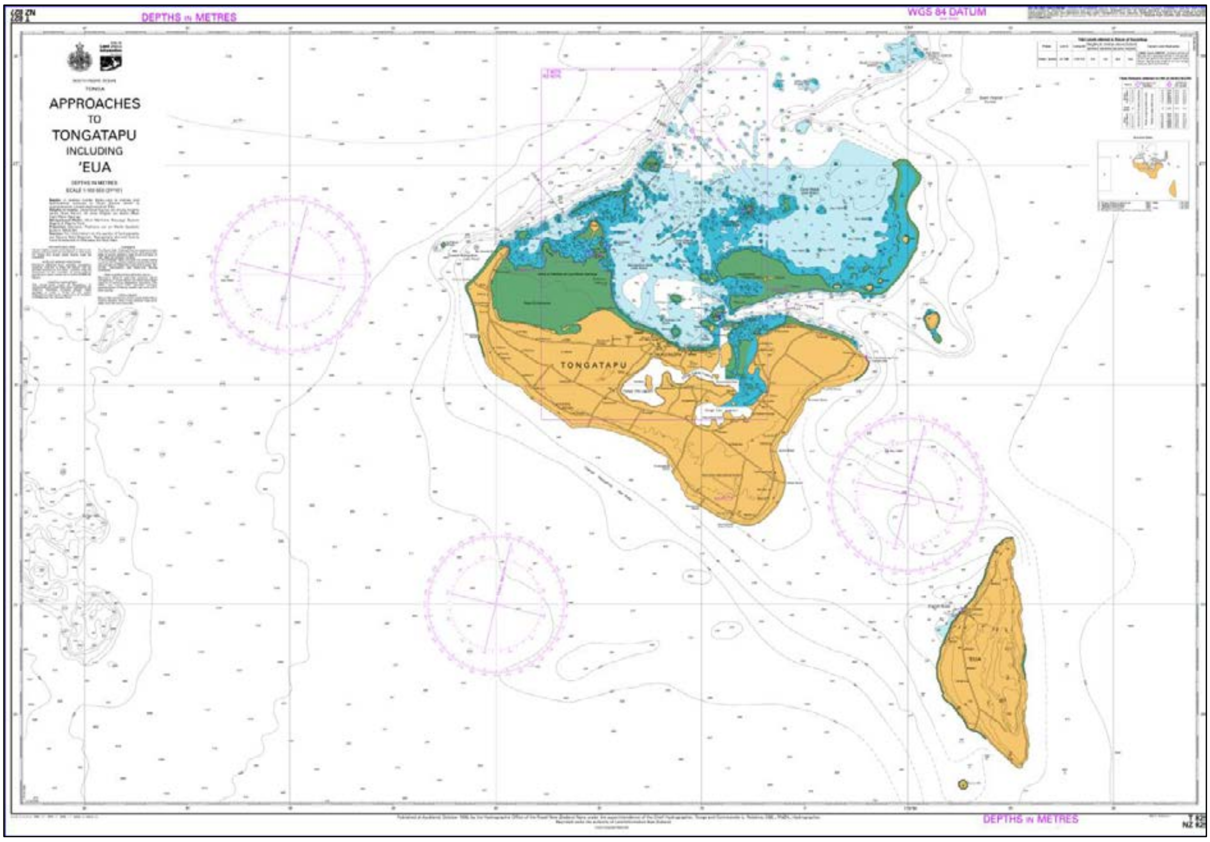
SOUTH WEST PACIFIC REGIONAL HYDROGRAPHY PROGRAMME

TONGA RISK ASSESSMENT



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SOUTH WEST PACIFIC REGIONAL HYDROGRAPHY PROGRAMME

TONGA RISK ASSESSMENT

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PROLOGUE

This report covers the detail of a hydrographic risk assessment of Tongan waters. It is divided into two independent documents, a synopsis and the main report, which is this document. This provides a detailed record of the work together with explanatory text and detail as appropriate. More importantly, it gives objective and useful information that allows the Tongan Government to consider what action to take in light of the results. The study uses spatial data, using a risk comparative technique to define where official nautical charts should be upgraded to modern standards. The risk report contains ten main sections, briefly described below.

Section 1 introduces the scope of the hydrographic risk assessment and presents methodology. Section 2 gives an overview of Tonga's nation profile and its economy. Section 3 provides a description of the key items of relevance to the risk assessment that partially influence the risk results. Section 4 draws a more detailed picture for each island group with focus in geographical characteristics, tourism, port infrastructure, domestic vessel trade, key sites of environmental and cultural significance, and local economy. This information was taken into account in the GIS risk model.

Section 5 presents an analysis of shipping from local port records, showing trends for all types of SOLAS (international) vessels for the Port of Nuku'alofa. It also interprets domestic coastal vessel shipping based on records supplied by the Port of Nuku'alofa. Further marine traffic analysis for internationally trading (SOLAS) vessels, using S-AIS data is presented in Section 6. This analysis provides the base layer of the GIS risk model in order to evaluate cumulative risk from 31 criteria layers. The risk results are shown in Section 7.

In section 8, the economic analysis identifies and estimates the economic value (or if not a value the cost) that would be generated through charting upgrades where needed. It also takes account of the risk reduction available from charting improvements, using economic data from Tonga. Section 9 provides a traffic prediction assessment for Ha'apai waters, where charts remain in Fathoms and traffic is low, to explore risk as well as cost effectiveness of charting upgrades, against an anticipated increase in cruise vessel operations.

Section 10 presents conclusions and recommendations for hydrographic survey, economics and risk to allow further insights for the decision makers. Section 11 provides information about the data confidence of the risk model.

There are seven Annexes of supporting material of importance to this risk assessment.

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GLOSSARY

Abbreviation or name	Explanation
AIS	Automatic Identification System. A ship transponder based system where ship-identify and positional information are transmitted and received. Vessels over 300 gross tons trading internationally are required to carry AIS transponders (Radio Regulations).
S-AIS	Satellite (received) Automatic Identification System
ALARP	As Low as Reasonably Practicable
AToN	A shore based light or mark that may be lit, that assists a passing vessel in its positional awareness. Equipment fitted on a vessel to aid positional or situational awareness are known as Navigational Aids. It is an important differentiation.
CATZOC	Category of Zone of Confidence CATZOC is a system used by many (but not all) hydrographic authorities to advise mariners of the confidence a hydrographic authority has in chart quality, as well as the standard of survey that different areas of the same chart are based on. Hydrographic data is encoded against five categories (ZOC A1, A2, B, C, D), with a sixth category (U) for data which has not been assessed. The categorisation of hydrographic data is based on three factors (position accuracy, depth accuracy, and sea floor coverage). It is attached to the electronic chart metadata as an attribute of the M_QUAL object.
CBA	Cost Benefit Analysis
Consequence	Positive (particularly in a planned event) or negative (particularly in the case of an accident). Consequences can be expressed in terms of "most likely" and "worst credible" and a combination of the two gives a balanced overview of the risk. Note that "worst credible" is quite different from "worst possible". For example, in the case of a passenger ship grounding on a reef at high speed the "worst credible" result might involve the death of 20% of the complement. The "worst possible" result would be the death of 100% of the complement. The latter is so unlikely to occur that it would not be helpful to consider it.
ECDIS	Electronic Chart Display Information System
EEZ	Exclusive Economic Zone
ENC	Electronic Navigational Chart
Event	Unwanted or unplanned occurrence with consequential harm (i.e. accidents).

Abbreviation or name	Explanation
Frequency	The measure of the actuality or probability of an adverse event occurring. It can be expressed descriptively (e.g. frequent, possible, rare) or in terms of the number of events occurring in a unit of time (e.g. more than one a year, once in every 10 years, once in every 100 years). Frequency can be absolute, i.e. derived entirely from statistics, or subjective, i.e. an informed estimation of the likelihood of an event occurring, or a combination of the two.
GIS	Geographic Information System
GT	Gross Tons: A measure of a ship's cargo carrying capacity. It is a volumetric measurement based system and not one of mass. The unit is therefore Tons and not Tonnes. GT is universally used for regulatory management of vessels.
Ha	Hectare
HW	High Water
IMO	International Maritime Organisation
Kt	Knot (unit of speed equal to nautical mile per hour, approximately 1.85km/hr or 1.15 mph)
Km	Kilometres
LINZ	Land Information New Zealand
LW	Low Water
M	Metre
MOI/MPD	Ministry of Infrastructure/Marine and Ports Division
NPV	Net Present Value
NM	International Nautical Mile
TOP	Tongan Pa'anga – Currency T$
VHF	Very High Frequency (radio communication)
WC	Worst Credible
ML	Most Likely
SMA	Special Management Area (a Tongan equivalent of a formal Marine Reserve)
Risk	A function of the combination of Frequency and Consequence of adverse events. The value of the function is unknown, in exactly the same way that a monetary currency has an unknown value. Risk is therefore a form of currency, used to measure the importance of adverse events proactively before they happen. Risk is often quantified as frequency x consequence to keep arithmetic simple.

Abbreviation or name	Explanation
Forms of Risk Assessment	**Quantified Risk Assessment (QRA):** Undertaken for a safety case approach when measuring specifics. Totally numerical: For shipping this would be ship miles transited divided by the number of incidents of, say, collision, contact, grounding, or just expressed as the probability (or chance) of an incident occurring overall (e.g. aircraft passenger miles). **Comparative Risk Assessment (CRA):** This is the type used for Hydrographic risk work. It is a form of risk assessment, where the true quantum of the risk is actually unknown, so the risk numbers are used comparatively to identify and separate out high risks from low risks. This is done because the true number of incidents in each of the areas is unknown, as is the true number of sea miles, but there is an approximation. In this form of risk assessment, the risk is truly being used as a currency.
Hydrographic Risk	This form of risk assessment has recently been developed. Hydrographic risk, by its nature, must rely on shipping traffic volume as a driver for the risk level; no traffic; no risk. In this risk concept, Risk is Traffic (*with inherent potential loss of life, potential pollution (volume, Type and Size)*) x Likelihood Criteria (*Ocean conditions; Navigational Complexity, Aids to Navigation, Navigational Hazards*) x Consequence Criteria *(Environmental importance, Cultural importance, Economic importance*). These are combined in a GIS using Risk Terrain Modelling (RTM) to output a spatial result.
Inherent Risk	The probability of loss arising out of circumstances or existing in an environment, in the absence of any action to control or modify the circumstances. In this case, consider the Niuas entrance. The circumstance is the single ship transit, but part of that is what is existing in the entrance (it is narrow, shallow, the leads are too close together and the vessel transits at the capacity of this channel).
Risk management	Decision making on the implementation of measures stemming from risk assessment, then monitoring the efficacy of the controls.
SPREP	Secretariat of the Pacific Regional Environment Programme. This is an intergovernmental organisation co-ordinating environmental projects across the whole Pacific region.

1 INTRODUCTION

The SW Pacific Islands have experienced increases in commercial vessel traffic operating through their waters. Much of this growth is related to the numbers of large cruise ships operating in the SW Pacific. This trend of growth is projected to continue. This is coupled by a slow but steady growth in coastal trade within the various SW Pacific nations; small vessels in international terms, but these are domestic vessels that can be licenced to carry a significant number of passengers.

A disparity now exists between the size of SOLAS vessels, the growing volume of domestic coastal traffic and the quality of nautical charting used for navigation. Many of the charts date to the 1800s, some to the mid-1900s, and are in need of updating to modern standards.

This study uses a top-down approach to risk assessment, recently developed in New Zealand, to prioritise areas for chart improvement surveys in Tongan waters, based on a combination of vessel transit risk and economic growth. The risk-based result is designed to aid decision-making by the Tongan Government, with the assistance of the hydrographic professionals with regard to updating nautical charts.

It is important to understand there are two different types of risk that need to be considered when reading this report, Inherent Risk and Hydrographic Risk.

Inherent risk is easy to understand, in that a harbour may present a difficult entrance (e.g. narrow, shallow, cross currents and poor aids to navigation). This provides an inherent heightened risk for a vessel wishing to transit the entrance. Hydrographic risk, on the other hand measures traffic by volume, type and size, as well as a range of other factors assessing consequence impacts.

Thus the inherent risk of a single transit into a harbour can be high for a vessel individually, but a hydrographic risk result may be lower, simply because the numbers of transits per annum are low and/or the vessels involved are small.

1.1 AIMS AND OBJECTIVES

The aims of this document are to describe:

- An application of a robust and previously developed, risk based methodology for the prioritisation of hydrographic surveys in Tongan waters;
- To investigate the comparative risk of a shipping incident in the Kingdom of Tonga; and
- To produce GIS derived output plots clearly showing the spatial distribution of shipping risk that enables the Government of Tonga to identify priority areas for chart improvement surveys.

1.2 METHODOLOGY

The method deployed uses risk assessment in a comparative way, to identify areas of Tonga that are more susceptible to an incident involving either a large SOLAS vessel or a smaller domestic coastal trader. This is in terms of the range of most likely and worst credible potential for loss of life, damage to the environment, damage to economic development and impact to areas that are culturally important to the Tongan people.

The types of accident that can occur to vessels are related to the type of vessel transiting Tongan waters, as well as their size and cargo/passenger capacity. Details of vessel transit information is thus key to the methodology, and was supplied from satellite AIS data (S-AIS), together with port pilotage records, obtained during a data gathering visit to Tonga. Further information was obtained from cruise vessel operators and agents about cruise-calls, including future aspirations throughout the Tongan archipelago. Details of the fleet of coastal domestic vessels were obtained and rough schedules. Ship traffic was analysed in a Geographic Information System (GIS) and domestic shipping routes and associated volume added to this. Event Trees were used to derive the realistic types of grounding or foundering incident that could occur, and their outcomes related to the vessel types and the size of those vessels. The event trees were translated into consequence criteria for a risk matrix to be used in the GIS analysis. Event Trees are attached at Annex A and Annex B presents the results of traffic analysis plots from both AIS transmissions and data gathering (for domestic vessels).

With both analysis of vessel traffic volume and information known about the more vulnerable locations of Tonga, the traffic analysis was linked to location, and thus the risk criteria being used in a matrix from for any layer of information in the GIS.

The use of a GIS technology allowed a large number of factors (all of which were geospatial in nature) to each be considered in terms of their risk contribution and linked to the most dense traffic areas, taken from the traffic analysis. The resulting risk levels, comparative in nature, could be displayed in the GIS as a coloured overlay "heatmap". This made the end result visual and easy to interpret. A detailed description of the GIS Analysis and Hydrographic risk assessment methodologies has been published by LINZ[1].

Use of a GIS was vital to accommodate the multitude of datasets, undertake the analysis and present the results. This approach was used after determining the large amount of environmental research undertaken in relation to climate change, and datasets obtained, (e.g. corals or mangrove datasets) could be verified for Tonga by using the information obtained during in-country data gathering visits.

The method used is advantageous as it is data driven (i.e. reducing opinion-based input), using expert judgement only where necessary (e.g. event tree outcomes and risk criteria), and identification of the relevant risk factors.

In summary, vessel traffic analysis was undertaken on satellite derived AIS data for a six month period of 2013, including December and January 2014 (summer) to build a model of shipping movements through Tongan Waters. A number of factors related to maritime risk were then identified and scored on a five point scale (i.e. Risk Matrix) across the study area. Each risk factor was then weighted in terms of its relative importance to the final model and combined with the traffic analysis to produce a final cumulative plot of hydrographic maritime risk in Tonga, which took account of the accuracy of the current charting quality. Against this a cost effective hydrographic and charting upgrade programme could be developed for Tonga, solidly based on risk and data analysis.

The risk results are presented in Section 7 , with geographic risk plots presented at **Annex D**. Risk Criteria used throughout the main analysis is common with similar work undertaken in the Cook Islands and Vanuatu.

[1] http://www.linz.govt.nz/hydro/projects-programmes/improving-maritime-safety-in-the-pacific (Marico Report Number 12NZ246)

A Cost Benefit Analysis of the risk result was then added, Section 8, taking account of the risk in each cell and using other referenced work to establish the risk reduction available from chart improvements. Other costs, such as pollution clean-up, economic impact out of accidents, Tongan GDP, etc., were also used to determine a Net Present Value of charting improvements (+Ve or –Ve) throughout the EEZ study area. This is presented at section 8 and **Annex F** presents the criteria used in the CBA model.

2 TONGA – INFORMATION AND ECONOMIC OVERVIEW

2.1 TONGA HISTORIC OVERVIEW

The Kingdom of Tonga is Polynesian in origin, positioned between 18^0 00S and 21^0 30S, and 173 30W and 175 30W[2]. The Tongan archipelago comprises 176 islands, many of which are small atolls; 36 of the islands are inhabited. The Tongan archipelago has a recorded land area of 749km^2, much of which is limestone and volcanic in origin. The islands are divided into four main groups, or provinces: Tongatapu (including ‘Eua Island), Ha'apai, Vava’u, and Niuas. According to the latest census, 2011, the population of Tonga's is about 103,250 and is approximately stable. About two-thirds of the population reside on the main island Tongatapu, on which the capital city Nuku'alofa is located.

In many Polynesian languages, Tongan included; the word “Tonga” means "south". Its name is such, because this archipelago is the southernmost group of islands of central Polynesia. The name of Tonga is also related to the Hawaiian region of Kona.

By the 12th century, Tongans and the Tongan paramount chief, the Tu‘i Tonga, earned a reputation across the central Pacific, known as the Tu’i Tongan Empire. The first European explorers arrived in 1616, with the Dutch explorers Willem Schouten and Jacob Le Maire. Abel Tasman visited in 1643. European visitors followed, such as Alessandro Malaspina[3] in 1793, the first missionaries in 1797, and the Wesleyan Methodist Rev. Walter Lawry. Tonga originally became known as the Friendly Islands due to the congenial reception granted to Captain James Cook in 1773[4].

A young strategist warrior king, Tāufa‘āhau, united Tonga into a kingdom in 1875, when it became a constitutional monarchy. The constitution was influenced by the British system. The benefits of this to the people of Tonga include a modern code of law, freedom of the press, an efficient land tenure system, and a limitation on the power of chiefs.

During the period 1900 -1970, Tonga was a protected state under a Treaty of Friendship with Britain. The Treaty of Friendship ended in 1970 under arrangements established by Queen

[2] NP 61 Pacific Islands Pilot Volume II.
[3] This was part of the Spanish Navy mission.
[4] This was a British Navy mission.

Salote Tupou III. In the same year, Tonga joined the Commonwealth of Nations, becoming a member of the United Nations in 1999. Throughout its existence, Tonga is rightly proud to have retained its indigenous governance and its unique monarchical system.

2.2 SEISMIC AND VOLCANO ACTIVITY

The Tongan archipelago lies on the convergent boundary of the Indo-Australian and Pacific plates. These tectonic plates are converging obliquely resulting in seismic activity in a number of areas. Changes in seabed bathymetry are quite common, meaning the hydrographic system needs regular update/feedback. Tonga has recorded groups of reported volcanic activity where high seismic activity occurs; Hunga, Tofua, Fonua, Metis Shoal and Home Reef[5]. In March 2009, an underwater volcano, 62km northwest of Nuku'alofa, Hunga Tonga-Hunga Ha'apai, created a new island[6]. There are thought to be a cluster of 36 undersea volcanoes in this area alone, providing considerable uncertainty of sea bottom profile.

Submarine Volcano No.	Geographic Location
1.	24° 26'S 175° 29'W
2.	21° 28'S 175° 49'W
3.	20° 51'S 175° 33'W
4.	20° 34'S 175° 24'W
5.	20° 20'S 175° 24'W
6.	19° 11'S 174° 51'W
7.	19° 02'S 174° 41'W
8.	19° 01'S 174° 44'W
9.	18° 19S 174° 21'W
10.	15° 31S 173° 40'W

Table 1: Locations of Submarine Volcanos Recorded by the NP61 SW Pacific Pilot Publication.

5 Reported volcanic activity is indicated on nautical chart NZ 82.
6 The volcano is called Hunga Tonga-Hunga Ha'apai

Table 1, above, shows the submarine volcano activity[7] recorded by the NP61 Pilotage Sailing Directions, which clearly advise mariners of the caution required when navigating these areas.

Tonga is vulnerable to tsunamis, due to its seismic activity. Tongan islands are also vulnerable because many are low lying, and flat; the exception is the Vava'u Group. The most recent tsunami affected the Niuas, especially Niuatoputapu, September 2009. Waves more than 17 metres high were reported, resulting in damage to coastal villages. The harbour entrance at Niuatoputapu was also filled with tsunami debris, which prevented any vessel entry for delivery of relief aid. The NZ Government provided assistance, with a visit by NZ Navy, who cleared the harbour entrance of Tsunami debris and then removed coral heads that were encroaching on the entrance channel. This facilitated entry for emergency relief supplies and provided added benefit in assisting the use of this harbour by the new (deeper draught) Japanese aid funded ferry, 'OTU ANGA'OFA.

2.3 NATIONAL ECONOMIC OVERVIEW

The Tongan archipelago has a recorded land area of 749km^2, much of which is limestone with volcanic origin. A total of 22% of the land (approximately 31,000 Ha) is arable, with 15% farmed[8] or planted with permanent crops. The Government Statistics Department record the country's population at 103,252 in 2011 (with 70% residing on Tongatapu).

The GDP for 2011-12 was recorded at TOP $799.3 million with a capita income of TOP $7,738. Table 2, below, shows the important industries and environmental factors of the Tongan economy that generate this country's GDP.

[7] Pacific Islands Pilot NP 61

[8] Food and Agriculture Organization of the United Nations Statistics

Drivers of GDP[9]	
Exclusive Economic Zone	676,401 km^2
Key Employment Industry	Agriculture (67% of population)
Key GDP generating industry	Agriculture & Fisheries
Major Ports	Port of Nuku'alofa and Neiafu Harbour
Climate	Tropical/Subtropical, SE trade winds during winter, NW winds with regular rainfall during summer

Table 2: Key Drivers Creating Tongan GDP

The Tongan economy is further supported by remittances from Tongans employed overseas. During 2009, overseas remittances[10] were reported to account for 28% of GDP; thus Tongans working abroad also provide a cornerstone of economic success. The US is the main source of remittances, followed by New Zealand and Australia.

Foreign aid assists with economic development and its contribution can be measured as a component of the Tongan economy. Aid assists mostly with infrastructure and construction projects.

2.3.1 Commodities

Agricultural produce is the leading contributor to GDP, followed by tourism. Manufacturing is present, but on a small scale. Tonga's main trading partners are New Zealand, Australia, Fiji, Japan and the USA. The majority of Tongan exports are agricultural in nature, while imports include a variety of consumer and industrial goods.

Table 3, below, presents the recorded values of the main exports for the period 2008-2010[11].

[9] World Trade Organization – Trade Policy Review 2014
[10] The World Bank; Migrations and Remittances Factbook 2011.
[11] WTO Trade Analysis Tonga, 2014

Exports $M	2008	2009	2010
Total agriculture	4,063	2,581	2,219
Squash and pumpkins	1,898	802	340
Manioc, dried	257	188	191
Yams	43	54	0
Taro(cocoyam)	48	82	166
Roots and tubers .	4	4	127
Watermelons	23	23	53
Other melons (inc. cantaloup)	0	0	25
Vanilla	97	61	113
Sugarbeet	0	0	40
Coffee, green	47	47	0
Coconuts	398	425	383
Cigarettes	23	23	0
Cigars	0	0	58
Cabbages and other brassicas	26	26	11
Citrus juice, concentrated	0	0	20
Vegetable products	79	26	500

Table 3: Exports of Main Agricultural Products (in millions $)

Although this data is somewhat dated, it still represents the range of exports in 2013, although export growth appears unpredictable. For example, squash has been Tonga's major export historically, but its production has declined according to domestic cargo volume records for the period 2008-2013. It appears that taro exports have been rising in contribution to value.

2.3.2 Tourism

Tourism provides significant foreign exchange and has a growth potential for recreational activities (yacht, whale watching and diving). Most Tongan islands are regarded as pristine; many are premier destinations for scuba divers and whale watchers wishing to explore the marine life in the South West Pacific.

Table 4 shows the contribution tourism made to GDP and employment in 2011, compared with 2002 [12]. This is a respectable time to consider long term trends. The figures show that the direct contribution by tourism to GDP has increased by 1.2% for the period 2002-2011.

[12] Figures are based on the Travel and Tourism Economic Impact 2012 for Tonga - World Travel and Tourism Council

Given that the Tongan economy has itself expanded in that time, this marginal increase is important.

The data is an accrual of the total expenditure of business and leisure on tourism services, together with government expenditure on services (cultural or recreational) directly linked to visitors. Government employment costs are also included.

	2002	2011
Tourism as % of GDP	3.2%	4.4%
Tourism Contribution to Total Employment	3.6%	4.1%

Table 4: Tonga's Tourism GDP and Employment Contributions - 2002 and 2011

An increased percentage share of overall employment was also achieved over this period by the Tourism Industry. For 2011, tourism generated 1,500 jobs. The World Travel and Tourism Council analysis suggests that tourism related jobs are expected to double by 2022[13].

In summary, although tourism has grown marginally in terms of GDP in 9 years, the industry has become more important in terms of employment for Tongans. Figure 1 shows that there has been growth in visitor arrivals for all transport modes, including air, cruise and yachts.

[13] Travel and Tourism Economic Impact 2012 Tonga Report - World Travel and Tourism Council

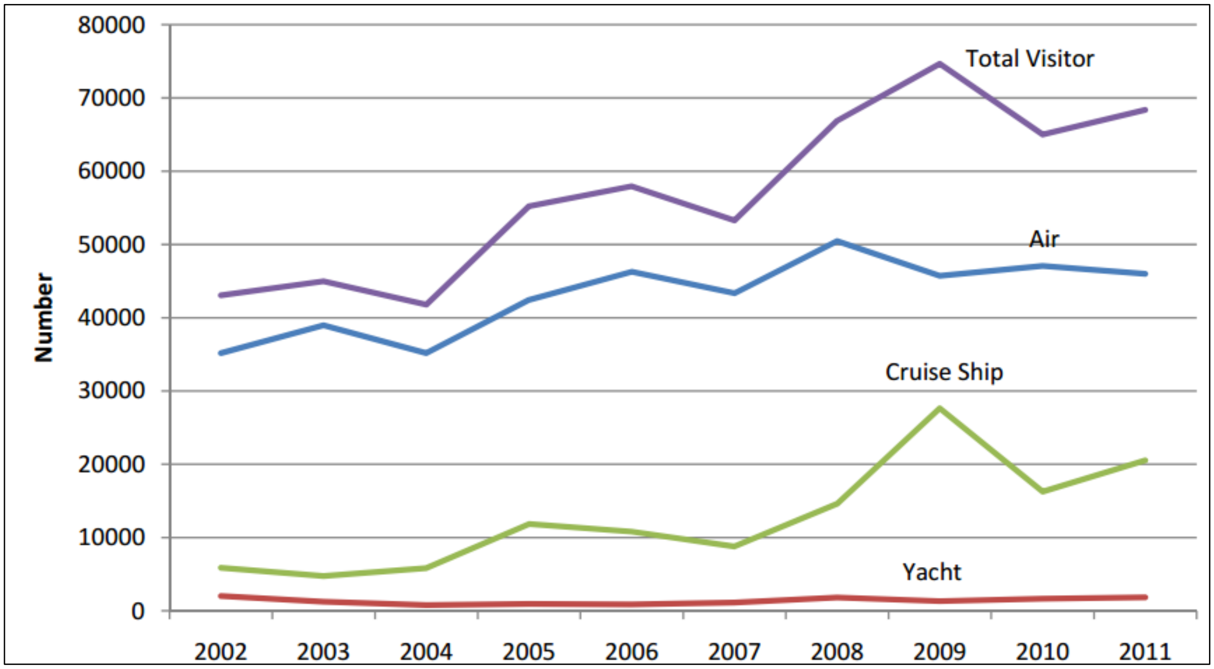

Figure 1: Visitor Arrivals by Transport Mode 2002-2011

Figure 1 is a graphical representation of the number of visit arrivals in Tonga by transport mode for the period 2002-2011[14].

Over 94,000 arrivals by air have been recorded during 2011 compared to 2002, this data taken from the Tongan Government statistical figures. Approximately 70% of air arrivals are from either Australia or New Zealand. The total number of visitor arrivals has significantly increased from 2002 onwards. The number of yachts into Tonga is dominated by arrivals to Vava'u and remained steady. The biggest contributor in terms of change is the cruise sector.

Cruise passenger arrivals showed strong growth in 2007 to 2009[15] where a 22% increase is recorded. However, 2011[16] shows a fall in arrivals of 60%, compared with 2010. The cruise passenger market has considerable uncertainty of vessel numbers. This has led to the development of a new wharf in Tongatapu in 2012 (see Section 4.3.4 for more information), which has provided a certainty of berthing in Tongatapu. One aspect of this is Tongan culture and strong adherence to the Sabbath being a day of worship and rest. Practically this

[14] Government of Tonga, Statistics Department, Statistical Bulletin on International Arrivals, Departures and Migration 2011.
[15] Domestic Records provided by the Tonga Tourism Authority.
[16] Data is incomplete from January to November.

means a cruise operation needs to plan to either be at sea for a Sunday, or berth and depart either side.

Although not shown in the overview data above, the Vava'u group has suffered a quite dramatic fall in visitors arriving by air since the global recession, but arrivals by sea remain constant. This it seems is being addressed by the introduction of new aircraft domestically and the possibility of direct international flight via either Fiji or Niue. The fact that visitors overall to Tonga have risen, shows that other Island Groups of Tonga have experienced a visitor increase.

2.3.3 Conclusions- National Economic Overview

1) Although tourism has grown marginally in terms of GDP in 9 years, the industry has become more important in terms of employment for Tongans.
2) Figures show there is growth in visitor arrivals for all transport modes, including air, cruise and yachts.

3 CULTURAL AREAS OF RELEVANCE

3.1 CULTURAL INFLUENCES

Tonga has very strong cultural identity, societal structure and knowledge systems. Although the nation is small, it is one formed centuries ago[17]. Even if today it embraces the opportunities and developments of modern life, it never forgets its basic traditions or the individuality of its culture. The most principal characteristic that drives all aspects of life in Tonga is identified as ‘ofa[18] (love). It is recognised as an ideal for relationships among Tongans. This comes in contrast with the tribal customs and habits such as in other Pacific countries like Vanuatu.[19] Religious association is strong amongst all Tongans, which seems linked in no small way to the strong underlying cultural values of this nation.

Although there appears endless patience in the Tongan nation, the importance of culture and thus the cultural damage that may ensue from a serious ship casualty is a key part of this risk assessment.

The following sections provide insight into Tongan traditional principles. It is of relevance to the hydrographic risk assessment and the societal harm that may arise in the aftermath of a serious vessel grounding.

3.2 FAMILY STATUS

There are four drivers that guide Tongan society and family today and these are the Fefaka’apa’apa’aki (mutual respect), Feveitokai’aki (sharing, cooperating and fulfilment of mutual obligations), Lototoo (humility and generosity), and Tauhi vaha’a (loyalty and commitment). Family has very significant structure with strong links. Among Tongans there is a flexible equilibrium between the role of a man and a woman in the society, led by their contribution in the working field as well as sharing tasks in the family daily routine. The responsibility for raising a child lies not only with both parents, but close relatives or elder siblings participate (kinship). There are cases where a family which does not own a

[17] The probable first settlement of Tongatapu is by the Lapita people during 900BC.
[18] A former deputy prime minister has characterised ‘ofa which means love as the principal feature of Tongan society.
[19] The Hydrographic Risk Assessment study for Vanuatu pointed out the rich cultural heritage related to the cultural spirits and tabu as part of a clan system which is opposed to the communal system of Tongan society

household and access to land; can join with another family that does. Everything is almost communal, from food to sleeping arrangements. Thus it would be expected that a shared response to any shipping accident would be expected, including significant cultural impact.

3.3 RELIGIOUS INFLUENCES

Christianity has an important and vital impact on Tongan society. Tongans are very religious and feverant attendants at church. The majority of the population, including the king and the royal family, are members of the Free Wesleyan Church of Tonga, but other faiths also thrive. Attending church is as much a religious behaviour as a social event, with robust competition producing church choirs of international standing. Christian celebrations, such as Christmas, are times when Tongan families interact and meet family members normally separated by distance.

Sunday is very important in this religious environment and it is celebrated as a strict Sabbath which is highlighted in the state constitution. No business activity is allowed on Sunday, with the exception of some essential services that are approved by the Minister of Police.

This affects shipping movements and activity, such as ship berthing ceases. Port and freight operations also suspend operations. This therefore impacts on port movements for most Tongan ports and harbours. The coastal shipping service schedule is also affected, where domestic ferry vessels remain berthed for the Sabbath.

Of relevance to the risk assessment is Sunday cancellation[20] of cruise ship arrivals. This has affected cruise vessel calls in the past, where an operator has aborted a call after misunderstanding that Sunday arrival is especially difficult for the Tongans to service.

There are regular church conferences in Tonga, and Vava'u hosts a significant international church conference annually (June). When conference events occur, the number of passengers wishing to travel by sea (or air) rises, sometimes quite considerably. Private charters (both air and sea) are often required to meet demand.

20 Based on published schedule data, two cruise vessel visits were cancelled.

3.4 MONARCHY AND LAND OWNERSHIP

Tonga is a constitutional monarchy, with the king retaining the highest authority. In this way, society is traditionally divided into three categories. Ranked hierarchically from highest to lowest, they are:

1) Tuʽi (monarch);
2) houʽeiki (nobility); and
3) kakai (commoners).

The king represents the executive power of the government. The Crown, together with the nobles as second in rank and the government, possess all the lands of Tonga. As part of the constitution a system of land tenure is implemented in Tonga which is unique among Pacific counties. Landholding in Tonga is given by a grant while the sale of land is prohibited. However, "owners" have the ability to further lease their holding under certain restrictions. These include a limitation of any estate holder to lease only his 5% of their total estate holding. Property rights are only passed on through generations, making family birth-right an extremely important part of Tongan culture.

3.5 CONCLUSIONS - CULTURAL INFLUENCES AND RISK ASSESSMENT

1) The cultural, religious and family statuses of Tongans have a profound effect on the economy of Tonga. The need to interact across the island groups, especially at times of Christian celebration, explains a tolerance of shipping risk.
2) Due to the Tongan Sabbath legislation, Sunday business operations are either limited or suspended.
3) This includes shipping movements or cargo handling. Coastal vessels also remain in port for the Sabbath and Cruise Operators in the past have found the need to abort calls due to misunderstanding the adherence to the Sabbath.

4 THE ISLAND GROUPS OF TONGA

As introduced earlier the Kingdom of Tonga is divided into four autonomous groups, shown geographically in Figure 2, below.

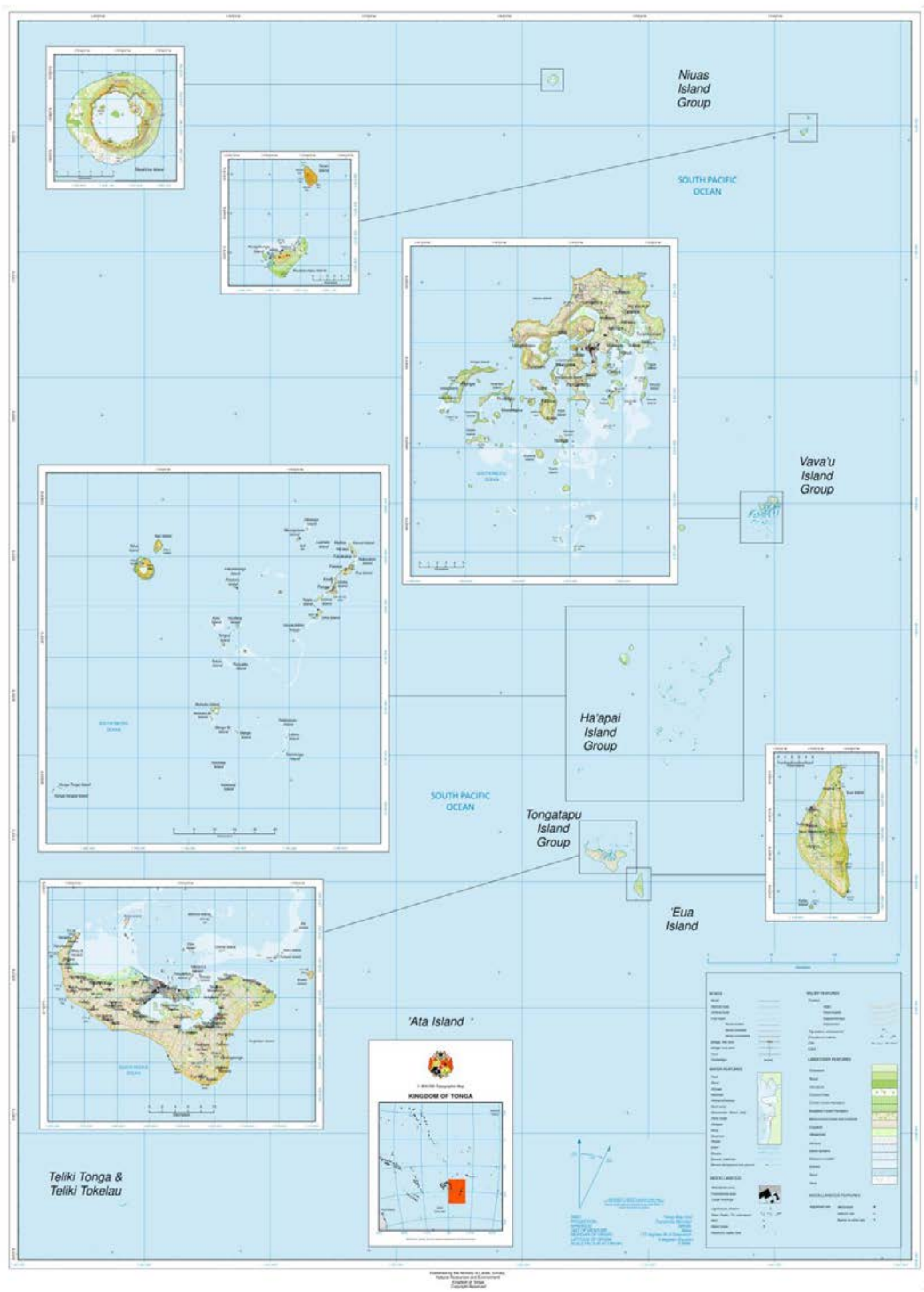

Figure 2: Kingdom of Tonga Island Groups

The 2011 population census[21] divided the archipelago into five autonomous areas, with Tongatapu Group separated into Tongatapu and 'Eua. It helps if this hydrographic risk assessment also adopts this approach. Thus the five areas are:-

1) Tongatapu
2) 'Eua
3) Ha'apai
4) Vava'u
5) Niuas

This next section provides information of relevance to the risk assessment about each region, commencing with Tongatapu.

4.1 TONGATAPU

Tongatapu comprises a large number of islands, which are dominated in size by the main island of Tongatapu[22]. Nuku'alofa is both the provincial capital of Tongatapu province and the capital of Tonga. A population of 75,416 was recorded by the 2011 census.

About 25% of the population is engaged in fishing and agriculture activities, whilst another 25% is involved in craft and related trade (handicraft, building etc.). The principal exports are root crops, squash, coconuts and fish products. Tourism also makes a major contribution to the Tongatapu economy which accounts for 12% of the Tongan GDP. The island group has many low lying islands and atolls, vulnerable to the effects of a large spill.

4.1.1 The Port of Nuku'alofa

The Port of Nuku'alofa is the main port of Tonga and it has been delivering its own infrastructure development for a number of years. It has upgraded its international container terminal and a new cruise facility (AID funded) entered into service recently. It has a developing logistics infrastructure, including wharves and storage sheds, in a relatively competitive environment. Freight is mostly containerised with over 75%[23] being moved by container ships with regular destination links. The port also has a busy domestic coastal

[21] Tonga 2011 Population and Housing Census, Statistics Department Tonga.
[22] It is translated as 'Sacred Island' in Tongan Language.
[23] Ports Authority Tonga Annual Report 2013.

passenger and cargo service facility, that link with destinations throughout the Island Groups of Tonga. Recently, the domestic coastal fleet has expanded, but with the new vessels providing most of the cargo and passenger transport capacity.

The port of Nuku'alofa has its own Port Act, which clearly defines its harbour waters and jurisdiction to its harbour limits. Within harbour limits the port is responsible for Aids to Navigation, pilotage and conservancy. Outside of Port Waters, the Ministry of Infrastructure, Marine and Ports Division (MOI/MPD) has responsibility for those functions.

4.1.2 Terminals and Harbours in Tongatapu

Table 5, below, records the ports and harbours in Tongatapu, these are all in the Port of Nuku'alofa. The chart CATZOC[24] ratings shown are utilised in the Hydrographic GIS Risk Assessment analysis and CATZOC ratings with a value of 'U' ratings are assumed to be a D category[25].

Location	Island	Chart	Year	Scale	CATZOC	Facilities	Shipping
Queen Salote Wharf	Tongatapu Island	NZ 827/T 827	1998	1:100K	A1	Main Wharf	International and Domestic Visits
Vuna Wharf	Tongatapu Island	NZ 827/T 827	1998	1:100K	A1	Main Cruise Berthing Facility	Cruise and Naval vessels visits
Faua Harbour	Tongatapu Island	NZ 8277/T 8277	2010	1:100K	B	Fishing Fish market	Domestic, Fishing vessels and Yachts (local or visiting). Laid up vessels.

Table 5: Terminals and Harbours in Tongatapu Province

The Tonga Naval base lies within the Nuku'alofa port limits, which is not referenced further in this risk assessment. This is because naval vessels are small in terms of environmental risk

[24] CATZOC - Zone of Confidence, an M_QUAL attribute advising the mariner of the charting quality.
[25] D category is the lowest zone of confidence.

impacts, but equally provide mitigation because they have the potential to assist with or conduct hydrographic survey.

4.1.3 Tourism Attractions in Tongatapu

The main tourist attractions are:

- Sacred city of Mu'a and the Ha'amonga'a Maui Trilithon;
- Mapu'a Vaca Blowholes and the Abel Tasman Landing Site;
- Reef and cave diving;
- Whale watching;
- Scenic islands such as the Royal Sunset Island Resort in Atata Island.

4.1.4 Domestic Coastal Vessel Trade

The Port of Nuku'alofa is a terminus for most coastal trading vessels and provides a hub to the Ha'apai, Vava'u, and Niuas groups. It is also provides the link to the Island of 'Eua, which is a surprisingly busy passenger route (see section on 'Eua). The route to 'Eua in particular has tankers, cargo vessels, and ferry traffic transits, all using Piha Passage, an alternative entry which is entered via an area of narrows, surrounded by the Pangaimotu marine reserve.

There is also a considerable coastal passenger trade to/from Nuku'alofa, which is served by domestic cargo ships. At the time of data gathering, five domestic vessels were recorded in frequent coastal shipping service, ALAIMOANA, 'ONEMATO, 'OTUANGA'OFA, PULUPAKI[26] and SITKA (See section 5.2.4 for further details). Domestic freight is unloaded and discharged at Faua Harbour and No.3 and No.4 Berths of the Queen Salote Wharf. Figure 3 illustrates the No.3 berth of Queen Salote Wharf, which is mainly used by the new (aid funded) interisland ferry 'OTUANGA'OFA, both for passengers and freight transportation.

[26] PULUPAKI can be provided with a trading licence in the busy summer period, but is mostly laid-up.

Figure 3: Berthing at No.3 of the Queen Salote Wharf, showing RoRo Ramp

4.1.5 Cruise Vessels Visits

In recent years, cruise vessel calls increased with larger vessels calling at the new Vuna Wharf cruise facility (see sub-section 5.2.1). Vuna wharf is a superb solution for Tongatapu calls and is within walking distance to downtown for passengers. Bearing in mind the cruise market growth in South Pacific, the Port of Nuku'alofa is successfully attracting cruise operators with large cruise vessels, such as P&O and Cunard making calls during 2014. Feedback from shipping agencies reported cruise stakeholder desire for further development of the Tongan cruise sector.

Along with other developments, there is an infrastructure proposal to enhance the waterfront in Nuku'alofa for tourism purposes[27].

[27] The Tonga Chamber of Commerce and Industry has proposed the waterfront development between the Vuna Wharf and the commercial port to attract international visitors.

4.1.6 Nukualofa Seafarer Training College

As was the case with Vanuatu, Tonga has for many years had a Seafarer training centre. The training and qualification of domestic seafarers to standards that are considered best practice internationally, allows vessel owners to properly use the approved nautical charts that are produced by the charting authority for the area (in this case LINZ).

Effective training and standards make a real difference to mitigation of offshore transit risk for both SOLAS and domestic commercial vessels, but more importantly it provides marine insurers with the knowledge that personnel capable of safely operating the vessels they insure are qualified to an appropriate standard.

The seafarer training establishment in Tongatapu was visited as part of data gathering. It is extensive and well kept.

Figure 4 : The Seafarer Training Centre at Nukualofa

Training operations at seafarer training centre had been suspended after an Audit by Singapore in 2011, which found problems of training and examination standards at the college[28]. This resulted in the withdrawal of recognition internationally. Tongans, serving on a number of vessels not registered in Tonga found themselves with qualifications that were not recognised and had to address this by retraining else-where (at additional cost). The Ministry of Infrastructure, Marine and Ports Division (MOI/MPD) also acted promptly and withdrew recognition of the qualifications issued by the centre, pending its reactivation.

Although it is possible for any Government to recognise the standards provided by local training establishments, for domestic use, MPD did take a correct decision. This is because it would be difficult in practice for owners to obtain cover from marine underwriters or P&I Clubs. Ship insurance is delivered to the standards provided by the international maritime conventions. As some forms of insurance are mandatory by international convention, it follows that those who may cause the need to call on the insurance are certified to a recognised international standard (i.e. it's at the core of a vessel owner's Due Diligence). Some Tongan stakeholders referenced problems of obtaining insurance for their vessels.

The NZ Aid programme is assisting in the return of the college to its training function. This is an important development. At time of the data gathering visit, a Technical Advisor with a long history of seafarer training had been appointed to the Ministry of Education and Training and was assisting with a reactivation of this training establishment. This report recognises the importance of marine training and the involvement of assisted funding to achieve this. The reopening of the Training College will be a key part of a national package of maritime risk mitigation, as well as the provision of employment opportunities for Tongan seafarers.

4.1.6.1 Conclusion – Nuku'alofa Seafarer Training College

1) The training of Tongan seafarers to recognised qualifications was suspended in 2011. The Training College at Nuku'alofa is being reactivated with Aid support, including NZ Aid. The efforts to re-establish the maritime training college at Tongatapu go hand in hand with improvements to Navigational Safety provided by nautical chart Improvements. A successful Seafarer Training programme should be a long term objective delivered in parallel with charting improvements where necessary.

[28] The Implementation of the STCW Convention was accompanied by an IMO system of FSI (Flag State Implementation), under which marine regulators party to the SOLAS convention audit each other, to ensure seafarer standards are adequate for employment in any vessel operating under any registry.

4.1.7 Key Sites of Environmental Significance

Tongatapu has a large number of coral reefs, mangroves and breeding sites which are of high environmental significance. A number of these have formal protection status. Several pristine islands and inlets lie on these reefs in the close approaches to the Port of Nuku'alofa. In the case of an accidental oil spill, the environmental pollution will be devastating to the broader area. There are two important concentrations of mangroves in Tongatapu, one lies in the harbour and the other in the main lagoons of Fanga'uta and Fanga Kakau. A total of 10 species of Mangroves are recorded, with the two most common species being *Rhizophora samoensis* and *Rhizophora stylosa*. Mangroves are vulnerable to contamination by any type of fuel or lubricating oil.

Fanga'uta and Fanga Kakau Lagoons are the first official marine reserves in Tonga, implemented in 1974. Their established status leaves them in generally pristine condition and has assisted in halting the decline of mangrove coverage.

Environmental research in Tonga was originally centred on Tongatapu, and a number of other areas have been developed into official marine reserves of note. Those of Tongatapu Island which have been designated during the 1970's are listed below [29]:

- Ha'atafu Beach – 8ha (western lip of Tongatapu);
- Hakaumama' o Reef – 126ha (Breeding site);
- Malinoa island and it surrounding reef – 73ha (mangroves and breeding sites);
- Monu'afe Island and beach -32 ha;
- Pangaimotu western sand flats and reef into Piha Channel - 48ha (mangroves and breeding sites);

Other sites of environmental significance with formal designation are:

- Ha'atafu Beach Reserve (breeding and coral);

In recent years, due to concern over declining coastal fish stocks, Tonga has introduced formalised coastal community management committees and designated Special Management Areas (SMAs). Under the Fisheries Management Act 2002, there are restrictions in fishing methods and only authorised persons and fishing vessels are allowed to use designated SMAs. Restrictions exist for the Fisheries Habitat Reserves (FHR), as part

[29] 'The Environment of Tonga – Geography Resource', published by Wendy Crane Books.

of the SMAs, where no fishing of any nature can occur. For Tongatapu, there are three SMA's, taken account of in the risk assessment.

- 'Eueiki Island with an area of 119 ha[30] (harvesting any octopus species less than one foot in length is not allowed as a special condition for this protected area),
- 'Atata, an area of and 745 ha[31],
- Fafa Island, an area of 485 ha[32].

4.1.8 Key Sites of Cultural Significance

A key cultural site is the sacred city of Mu'a, which was the megalithic capital for hundreds of years and the maritime trade centre of ancient Tonga. Located within the Fanga'uta and Fanga Kakau Lagoons marine reserve, it was strategically built in the east lagoon side of the protected area. The central area of Mu'a was surrounded by a "canal" that offered a sheltered berthing place for canoes and some protection from invaders. Another culturally important area is the Mapu'a Vaca Blowholes which are associated with the legend of Houma, located in the Houma village, South of Tongatapu Island.

4.1.9 Summary of Economic Information

4.1.10 Cargo Exports

The local economy of Tongatapu is linked to subsistence farming and fishing. The majority of the households in Tonga comprise self-sustainable farms on a small scale. The main exports for Tongatapu are squash, cassava, watermelon, coconut and taro and the export countries are New Zealand, Australia and Japan. During 2012, the Ministry of Finance and National Planning launched a $1 million Pa'anga funding for agricultural produce exporters, in an effort to boost food exports to New Zealand. New Zealand is a close trading partner and direct shipping links are mostly to New Zealand.

Faua Harbour is the base for both coastal and deep sea fishing. It remains the country's top export fishing facility for both domestic and overseas consumption. Broadbill swordfish,

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[30] Community Special Management Areas in Tonga brochure – Fisheries Division.
[31] Community Special Management Areas in Tonga brochure – Fisheries Division.
[32] The Tonga's Minister of Minister of Agriculture, Food, Forests and Fisheries declared the Fafa Island SMA, to come under the management of the Coastal Community Management Committee, on 4 December 2013.

snapper, mahi mahi and yellow fin tuna are mainly exported to Hawaii, Australia and Japan. Such exports are fresh and high value, transported by air. One expanding company catches, prepares, flies and then sells the tuna fresh on an electronic fish auction in Tokyo, thus earning the best price return possible, but not without exposure to significant commercial risk.

4.1.10.1 Energy

Tonga Power supplies electricity to all parts of Tonga, but is headquartered in Nuku'lofa. There has been significant and well planned investment in power generation and distribution infrastructure in Tonga, including investment in alternative forms of renewable energy. Much of this has been aid funded. Since 2012, a new 1MW solar plant, built on Tongatapu and funded by the New Zealand government, supports 5% of the household electricity needs. The objective of this project is to reduce the dependence of Tongatapu province on imported fossil fuels and reduce carbon emissions. Tonga Power is a major user of domestic shipping capacity. As well as shipping wood pylons (from 'Eua) on which cables are mounted, it moves much of its fuel used for generation from Tongatapu to other island groups within the bunker[33] tanks of domestic vessels. The remainder is transported in drums.

This increases the volume of fuel oil (bunkers) carried by some of the domestic coastal trading fleet, above that needed for propulsion to their destination. This fuel transport was accommodated in the risk assessment by adding in an equivalent "tanker shipment" at the same frequency and parcel size as the shipment made to 'Eua, by ANATOLIA PACIFIC.

4.1.11 Tourism

Tongatapu has a total room-capacity of about 630 in hotels, guest houses, home-stays and bungalows. Data suggests room occupancy rate averages 45%, leaving capacity for expansion. Most visitors using hotel accommodation are business related, accounting for 56%. Visitor arrivals by air (who all enter the country via Tongatapu) have remained static during the last 10 years, while the holiday market has shown a decline[34]. It is worth noting

[33] Bunkers = ships own fuel, stored in either double bottom or wing tanks.
[34] This is compared to 16,000 holiday arrivals in 2012 instead 17,500 during 2000.

even in this section that the onward travel decline is acute to the Northern Vava'u Province (from which Tongatapu airport infrastructure is in part funded). For the year 2012/2013, 55% of the tourist arrivals visited Tongatapu while the remaining 45% travelled on to other provinces.

4.2 'EUA ISLAND

'Eua comprises the main island of 'Eua (population of approximately 5,000 in 2014), and Kalau Island, which is small and unpopulated. The east side of 'Eua Island mainly consists of cliff-tops, while the west has remote sandy beaches and fringing reefs.

'Eua is of fundamental importance to the Tongan economy. It has quality volcanic soils that produce a significant contribution of the food used on Tonga. It has a managed forest area, which provides just about all of the timber used for construction in Tonga. All cargo (grown product and timber) is carried by sea, together with a surprising passenger volume. The trade link between 'Eua and Tongatapu is one of the most important in Tonga.

The population of 'Eua, determined during the 2011 census is relatively small at 5,016, but this is constantly changing as people take their produce across to Tongatapu for sale in the main market. The majority of employment is in the agriculture, fishing and forestry industries. Historically, the northeast territory of the island belongs to the King, but 'Eua residents are allowed "leases" for community farming on this land[35]. The southwest area is owned and formed by the Crown/Government.

4.2.1 Ports and Harbours

There is one main harbour on 'Eua, Nafanua, which was reportedly improved by Aid funding in the 1980s. Its entrance transits the fringing coral reef and is limited in size. It provides a ramp for the 'Eua to Tongatapu ferry and has a wharf area in need of maintenance upgrade (photographs below).

Table 6, below, records the ports and harbours of 'Eua Island. Where there is an anchorage only, the facilities column is left blank, apart from any comments affecting charting. The

[35] Farming in the Kings lands is said to be free and the King has opened access to any Tongan to grow food.

CATZOC ratings are utilised in the Hydrographic Risk Assessment, and all U ratings are assumed to be a D category (lower quality).

Location	Island	Chart	Year	Scale	CATZOC	Facilities	Shipping
Nafanua Harbour	‘Eua Island	NZ 287/T 297	1998	1:100K	D	Main Wharf	Domestic Ferry visits / Fishing
Ohuna	‘Eua Island	NZ 287/T 297	1998	1:100K	D	Uncharted Coastal Fuel Manifold with Mediterranean mooring	International Liquid Vessel visits

Table 6: Ports and Harbours in ‘Eua Province

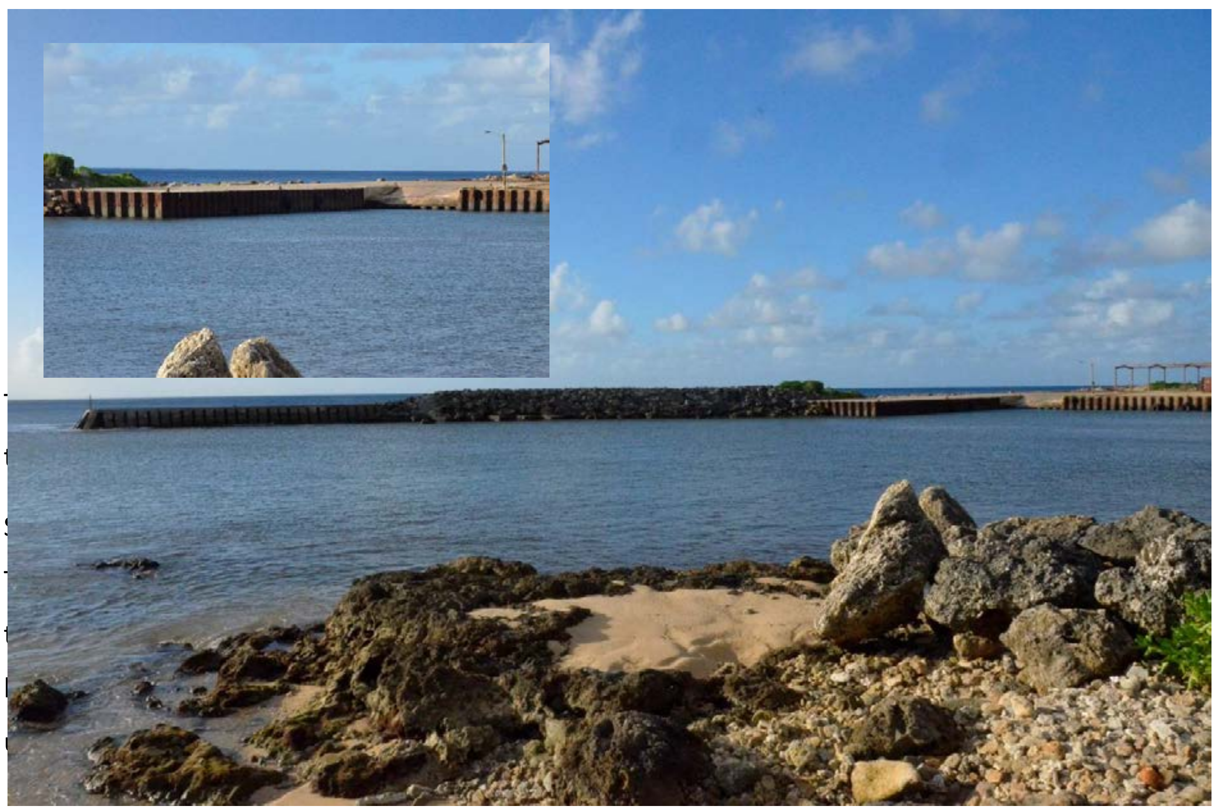


Figure 5 : Nafauna Harbour Showing Ramp and Wharf Shuttering (in need of upgrade)

4.2.1.1 Fuel Supplies to 'Eua

Figure 6 : The Coastal Fuel Manifold Installed in the Surf at 'Eua

The fuel supply for 'Eua is delivered by a small tanker, **ANATOLIA PACIFIC** originating from Fiji, which part discharges first in Vava'u, then Nuku'alofa and/or finally at 'Eua into a manifold in the surf at Ohonua on the northwest coastline (Figure 6). The pipeline is directly linked to storage tanks ashore in that location. This mooring/discharge arrangement was uncharted at time of the data gathering visit, no aids to navigation were apparent. The tanker calls every two or three months, sometimes directly after calling at Vava'u.

There are mooring bits in the sea to which the vessel will attach stern moorings, after first anchoring. This provides the vessel with a triangular mooring layout, bow to sea, for the discharge (termed a Mediterranean mooring). The possibility of pollution from such a cargo transfer arrangement is considered significant, as is pipeline failure. However the option to transit the fuel by road taker would require a larger ferry in service between Nuku'alofa and 'Eua. A third option would be to install a fuel receiving manifold in Nafauna harbour and ship the fuel by a domestic cargo vessel (e.g. SITKA) in the vessel's bunker tanks[36]. The third option would require a road tanker on 'Eua, installation of a transit pipeline or relocation of the fuel depot to the Harbour area.

4.2.2 Tourism Attractions in 'Eua Island

'Eua Island is a popular destination for whale watching when in season, although numbers are relatively small it is an activity with expansion potential. It is reportedly common for humpback whales to approach close to the cliffs of the eastern shore, which lie close to the Tongan trench underwater canyon. Whales are attracted by the deep water. Cave trekking and hiking are popular, with locations such as the Fangatave Cliffs and Maui's Archway providing attractions.

The tourism potential of 'Eua is mostly untapped, as the King's reserve has provided for an unspoilt east coast.

4.2.3 Domestic Coastal Vessel Trade

There are a number of vessel types on the route between Nuku'alofa and 'Eua. The greatest volume is passenger ferries, represented by two vessels, tankers and domestic general cargo vessels (SITKA). Annex B, presents the results of traffic analysis plots from both AIS transmissions and data gathering (for domestic vessels).

Passenger movements between Tongatapu and 'Eua have increased dramatically in recent years, according to records provided by Ports of Tonga Authority, possibly as a result of a low cost service. It is surprising to note that this ferry, dedicated to the 'Eua route, carries an average passenger volume of over 3100 people per month, reaching over 5000 per month in the Christmas season. Given the island's population of about 5000, the underlying economics of this route need exploring.

A dramatic increase in passengers on the route occurred after the 'Eua community council commissioned a domestic ferry, 'ONEMATO, in 2013. This provides a once daily return voyage between Nuku'alofa and Nafauna Harbour, 'Eua and has a passenger capacity

[36] This assumes that the harbour could be accessed by vessels of the draught

(licenced) of 150. Another ferry, ALAIMOANA, visits ‘Eua Island three times per week, is privately owned and has a licenced passenger capacity of 88.

It appears from local advice that workers commute from ‘Eua to Nuku’alofa, but a considerable volume of fresh produce is transported to Nuku’alofa. The ticket price to/from ‘Eua averages $21 Tongan pa’anga for one way. This is considered the most affordable choice for local residents.

Vessel	Total Passengers 2013	Route
ALAIMOANA	5,180	Tongatapu to ‘Eua three times weekly
‘OTU ANGA'OFA	31,397	Tongatapu to Northern Groups
SITKA	3,68	Tongatapu to Northern Groups
ONEMATO	34,576	Tongatapu to ‘Eua return daily.
PULUPAKI	5,154	Tongatapu to Northern Groups (intermittent - December to February)

Table 7 : Passenger Totals for Vessels in Passenger Service in Tongan Waters

Many passengers are reportedly involved in some form with the production and shipment of grown produce from ‘Eua to the market at Nuku’alofa (where 75% of the nation’s population resides). The ‘ONEMATO is community owned, offering a much reduced transit cost, which may have improved the passenger throughput significantly, but the underlying commercial need to produce and transport produce grown in the rich soils of ‘Eua to market is real.

In simple terms this means that the route to ‘Eua carries significantly more people than all the passenger routes to the northern islands of Tonga. Furthermore, an equivalent of 33% of the total population of Tonga travels to or from ‘Eua each year! Yet the ferry involved is much smaller than others working in Tonga (including the interisland ferry ‘OTU ANGA’OFA).

The two ships are serving the Nuku’alofa to ‘Eua route transported a total of 39,756 passengers in 2013. The community ferry, Figure 7, is a Korean designed open decked ferry, introduced into service in January, 2013. It is a landing craft design, reportedly built in 1996 for cargo service, then converted in Korea to also carry passengers in 2002. Passenger capacity has been added by the addition of an enclosed passenger cabin at the rear, accessed from the deck by a single stairway. The passenger cabin leads to a further open deck passenger area above, which is accessed from the enclosed passenger cabin below by a single stairway. The cabin size is small for the vessel's licenced capacity.

Table 7, above confirms that the annual total volume of passengers carried by ONEMATO at 34,576 is greater than that of the larger ferry 'OTU ANGA'OFA, serving the Tongan northern archipelago (which carried a total of 31,379 passengers in 2013).

Figure 7 : A General View of the Nuku'alofa to 'Eua Ferry. 'ONEMATO

Given that 'Eua also produces all the timber used for building in Tonga, this ferry can carry significant cargo payloads, in addition to people[37]. The sawmill on 'Eua advised shipping about 15,000m^3 of timber per annum, with a maximum of about 500 m^3 in a week. This is in the form of posts (or poles for electrical distribution). It is not known what portion of this cargo is carried by 'ONEMATO.

The passage to 'Eua transits through shallow into deep water. A sudden change of bottom profile is where a mariner would expect the steepest seas to appear in any conditions of wind over tide.

[37] The vessel SITKA also transports logs.

4.2.3.1 Professional Observations – ‘Eua

An observation of this study is that safety benefit would accrue out of a review of this short route, given the rapid expansion of passengers using the service in relation to the design of the vessel. The need to facilitate future deployment of a marginally larger ferry design, with enclosed decks and improved passenger accommodation facilities may already be apparent.

This may lead to a need to review the design of Nafanua harbour and its entrance/access arrangements. It should be noted that any change to the harbour layout/entrance would be a significant infrastructure project.

4.2.4 Cruising Yacht Activity

Up to 40 yachts per annum are said to visit ‘Eua.

4.2.4.1 Key Sites of Environmental Significance

‘Eua is an unspoilt destination, in some areas pristine and abundant. The following key sites are of environmental significance, which are designated Special Management Areas (SMA’s):

- ‘Eua National Park, which contains the largest tract of pristine native forest in Tonga.
- Kalau Island, an important nesting area with a population of 10,000 seabirds.

Neither of these sites is likely to be adversely affected directly by pollution from a shipping accident as both the forestry areas and bird nesting is not at the land water interface. However oil damage to seabird colonies could be significant. These factors were used for the environmental score used in the hydrographic risk assessment. Locals report turtle breeding does occur in ‘Eua and Green Turtles are known to have foraging grounds. Four more SMAs were proposed in 2014 for inshore waters, out to 50 metres. In these areas, the community manages the stock of marine life.

4.2.4.2 Key Sites of Cultural Significance

A particular area of cultural significance is located in the south-east of ‘Eua Island. A natural stone bridge, called Li’angahuo ‘a Maui, is said to be connected to the God Maui. The legend refers to how Li'angahuo 'a Maui on 'Eua was formed when the God Maui threw his spear across the island.

Much of the island land area is directly owned by the King of Tonga, underpinning the cultural significance of 'Eua in general. Tongans are allowed to farm freely in parts of this area, and it is a factor in the success and sustainability of the forestry.

4.2.4.3 Summary of Economic Information

4.2.4.4 Cargo Exports

A large percentage of the 'Eua Island workforce[38] is occupied with forestry, farming and fishing activities. 'Eua mainly exports squash and forestry products domestically, throughout Tonga. The local timber is of high quality from a variety of pine trees, managed sustainably. A visit to the 'Eua sawmill confirmed that log shipments occur almost on a daily basis, mostly utilising the vessel engaged on the ferry service to Nuku'alofa, or for a larger shipment, a domestic cargo vessel (SITKA). Domestic demand for 'Eua timber is high and the volumes produced are enough to sustainably supply all of the Tongan building and infrastructure needs (e.g. Telegraph/Power poles). About 15,000 m^3 are shipped to the mainland annually, with a maximum of 500m^3 being shipped in a week.

Local residents are also involved with the food trade to Nuku'alofa market by taking advantage of the daily ferry connection. Almost all food grown is exported to Nuku'alofa, because 'Eua does not have a Government licenced market, required for such trade in produce. It should be noted that if the ferry or other vessels trading to 'Eua are out of service, locals reportedly travel with their produce to the Nuku'alofa market by small craft.

4.2.4.5 Tourism

The contribution of tourism to the economy of 'Eua is embryonic and at first view, not significant. However, the impact of a significant vessel loss involving oil release would affect the viability of most businesses associated with tourism. Tourism is key to the Tongan economy overall and the risk assessment needed to take account of a difference between damage to a tourism industry and cessation overall.

[38] According to last published census during 2011, 40% of the population in Tonga is involved with agriculture activities

On average there are approximately 50-60 tourist arrivals per month into ‘Eua (about 1000 annually). There has been an upgrade of Kaufana Airport, which may in future impact positively on tourist numbers. The daily ferry service also improves accessibility, although it is not known how many passengers are tourists. The flight between Tongatapu and ‘Eua takes about 8 minutes. A scheduled aircraft was lost (without injury) on landing at ‘Eua in 2014.

There are five guesthouses, all located in the west side of the ‘Eua Island. Only one of them offers cultural and scenic tours around ‘Eua. ‘Eua offers a variety of activities which include:

- Whale watching,
- Diving and snorkelling in caves,
- Trekking in rainforest and tropical forests.

Two licensed whale watching boats mainly operate during the high season June – September and there is only one diving operator with links to Tongatapu.

4.2.5 Conclusions – ‘Eua

1) The arrangements for tanker discharge and the shore cargo connections at 'Eua Island would benefit from review, as present arrangements comprise discharge via a manifold in the surf, on an exposed shoreline. A review of charting scale could be beneficial.
2) Safety benefit would accrue out of a review of the short passenger route between Nuku’alofa and ‘Eua, given the rapid expansion of passengers using the service in relation to the design of the vessel. This may lead to a need to review the design of Nafanua harbour and its entrance/access arrangements. It should be noted that any change to the harbour layout/entrance would be a significant infrastructure project.

4.3 HA’APAI

At the time of data collection, Ha’apai was recovering from the effects of cyclone Ian, which passed directly over the centre of the island of Lifuka. Damage was widespread and an subjective assessment of the areas such as economy and influences on hydrographic risk was made for the risk assessment.

The population of Ha’apai is about 6000, with the largest island, Lifuka providing the Government administration.

Much of the Ha'apai Group overall is charted in fathoms on an undetermined datum, with charts for the ports and anchorages only having been updated. Thus there is an uncertainty of transit into and across Ha'apai in general, making the broad introduction of ENC's across the area problematic. The low CATZOC status of charts is made clear to mariners.

Figure 8 Cyclone Damage in Ha'apai was Extensive

4.3.1 Ha'apai Charting

Charting in Ha'apai needs special reference as its effect in the risk assessment is important. Charts remain published in Fathoms and cannot be updated without new surveys. This is because the datum is unknown and survey in some cases goes back to the time of Capt. Cook. Given this, the production of electronic charts is not possible (which ship's ECDIS systems use for electronic navigation) as new surveys on the WGS 84 datum are required. Although poor charting such as this does mean high risk for navigation, the true quantum of that risk will be directly related to the nature of the traffic, in terms of vessel type and number of transits per month.

4.3.2 Ports and Harbours in Ha'apai

Table 8, below, records the ports and harbours of Ha'apai Group. The CATZOC ratings are utilised in the Hydrographic Risk Assessment, and all U ratings are assumed to be a D category – the lowest. The Group is covered at large scale by NZ 8247 and 8248.

Location	Island	Chart	Year	Scale	CATZOC	Facilities	Shipping
Pangai Harbour – Taufa'ahau Wharf	Lifuka	NZ 8238	2005	1:800	A2, B	Main wharf	Domestic and international shipping
Ha'afeva Harbour	Ha'afeva	NZ 8248	1993	1:72 600	D	Wharf	Domestic shipping and fishing
Ha'afeva Anchorage	Ha'afeva	NZ 8248	1993	1:72 600	D	Anchorage	Domestic
Nomuka Anchorage	Nomuka	NZ 8259	1993	1:72 600	D	Anchorage	Domestic

Table 8: Ports and Harbours in Ha'apai Province

Figure 9 : Pangai Wharf, Ha'apai Showing RoRo Landing

4.3.3 Domestic Coastal Vessel Trade in Ha'apai

There are two main wharfs accessible by domestic coastal vessels, one on Lifuka Island (Pangai Harbour) and one on Ha'aefeva Island. The regular domestic ferry, 'OTUANGA 'OFA, also calls at an alternative anchorage approach, east of Ha'afeva Island, which aligns well for economic transit if the vessel is en-route to the Port of Nuku'alofa.

Prior to the Ha'apai visit, Lifuka Island had suffered extensive damage from Cyclone Ian, with a large number of fishing and inshore service boats destroyed. For this reason, domestic coastal ships can be expected to call frequently at Pangai Harbour with relief and rebuilding supplies in forthcoming years.

The 2014 ferry schedule includes a weekly call in Ha'apai for the RoRo ferry (OTUANGA'OFA) with the cargo ship SITKA making a fortnightly call.

It should be noted that Tonga Power uses the bunker capacity of both the ferry and the cargo vessel (SITKA) to carry and deliver diesel fuel to Ha'apai for power generation. Thus there is an increase in the true volume of oil being transported, over that of cargo.

4.3.4 Cruise Vessels Visits

During 2013 (before the cyclone), there were three smaller cruise vessel visits in Ha'apai province, one visit to Foa Island, one visit to Tofua Island, and one to the main harbour, Pangai. The average appears to be two visits per cruise season to the Ha'apai Group.

Three (uncertain) "anchorage" areas[39] are reportedly used by both smaller cruise vessels and yachts, although the Sandy Beach "anchorage" on Foa Island is known to be in deep water. In most cruise vessel cases, deep water exists and these either drift offshore or stooge after launching passenger tenders.

Cruise operators cite the need for a further port call in Tonga to improve commercial success of new cruise calls. Ha'apai has many old charts, which negate the ability of large cruise vessels to access the province navigating using ECDIS.

[39] These are the Foa Island, Sandy Beach Resort, Uoleva Island, and Tofua Island

4.3.4.1 Key Cruise Visit Attractions in Ha'apai

All of the Islands of Ha'apai present an area of pristine and abundant Pacific coastline, although minimal infrastructure exists to support a large influx. Tofua Island needs reference in this risk assessment as cruise vessels already visit this island, but do not land passengers. Tofua Island lies on the periphery of the Ha'apai Group and is an oval, steep-sided volcano which forms a caldera, which last erupted in 2009. Some activity was also recorded in 2012[40]. The island is known for the stranding of Captain Bligh during the famous mutiny on HMS BOUNTY in 1789. The Tofua Island volcano has been active for many years, with the first recorded eruption observed by Captain Cook in 1774. Its historic notoriety already attracts vessels and it has potential for further visits, which if coupled with a landing on one of the main islands of Ha'apai, increases cruise viability. Landing on Tofua with passengers is unlikely due to the terrain.

About 6Km north of Tofua Island is Kao Island, the highest volcano of the Tonga Islands, rising to 1030 m.

There are two scheduled visits to Tofua for the 2014/2015 summer season according to agents.

Foa Island, part of the main Ha'apai Group has a luxury resort offering a variety of sport and other activities, which visiting cruise vessels take advantage of for cruise passengers (mostly German cruises). In 2013/4, most of the cruise vessels visiting this area are boutique.

[40] The volcano eruption in Tofua is reported by the Volcanic Ash Advisory in Wellington

Figure 10 : Islands of Tofua and Kao – Cruise Visit Location

4.3.5 Cruising Yacht Activity

111 yachts are recorded as visiting in both 2011 and 2012. 177 yachts are recorded as visiting the Ha'apai islands group in 2013, an apparent increase. However, local advice suggests that visiting yacht numbers are approximately constant overall. Uoleva Island is popular for yacht visits. The 2014 cyclone has dramatically affected the number of visits in 2014.

4.3.6 Key Sites of Environmental Significance

There are a number of reserves, or Special Management Areas (SMAs) designated by the Fisheries Division on Ha'apai. These are recent additions and were taken account of in the risk assessment.

- Felemea SMA – Uiha District – 1,633 ha;
- Ha'efeva SMA – Lulunga District - 972 ha;
- O'ua SMA – Lulunga District – 4,606 ha.

In addition, three turtle breeding sites[41] are reported in Ha'apai; one in Luanamo Island, the second in Nukulei Island, the third in Uihi Island. Advice from the data gathering visit suggested a further three "unofficial" turtle nesting grounds are located south of Nomuka Island, Fonuamaka Island, and Fonunika island.

A further SMA is in place at Nomuka Iki Island where fishing, even by the local community is prohibited. Further SMAs are planned, subject to funding.

4.3.6.1 Key Sites of Cultural Significance

In relation to the hydrographic risk assessment, these are the most significant cultural sites taken into account:

- Makahokovalu - Site of eight slabs of rock forming a square which is associated with history and legends;
- Royal tombs at ‛Uiha. Burial grounds of high-ranking chiefs;
- Kao and Tofua volcanoes are associated with legends related to Gods of Maui.

[41] Confirmatory data provided by the State of the World's Sea Turtles Online Database

4.3.7 Summary of Economic Information

4.3.7.1 Cargo Imports and Exports

Agriculture and fisheries are predominantly subsistence activities, but they employ more than 85% of the population of Ha'apai. However, there is a growing trade in produce with Nuku'alofa, this being facilitated by a reliable ferry service. The main agriculture products are cassava, yam, sweet potato, plantain, banana and bluggoe. Fruit trees include coconut, mango, breadfruit, chestnut and polynesian-lychee. Fruit such as mangoes are exported in the local markets of Tongatapu when in season and occasionally in Vava'u, however it is not the main source of income. Fisheries play a critical role in the local economy of the smaller islands of Ha'apai, such in Nomuka Island where lobster is harvested. Apart from the fishing community usage, a considerable volume is exported in Tongatapu. An important source of income is coming from pandanus and paper-mulberry tree products. Ha'apai women weave mats from pandanus which are distributed throughout Tonga.

Fuel for transport is mostly transported and delivered in drums. Tonga Power additionally takes deliveries in bulk direct from the fuel bunker tanks of both the ferry and the cargo vessel SITKA.

4.3.7.2 Tourism

About 500 tourists per annum arrive, predominately by air. Some backpackers reportedly use the ferry service from Nuku'alofa. Ha'apai is a pristine and abundant area for the marine environment. Whale watching and diving are the main outdoor tourism activities. There were three licenced whale watching boats operating out of Lifuka Island, with all operations affected by the cyclone. Horse riding and kayaking are also available. The main provider for whale watching is the operators of Sandy Beach Resort, which also attracts cruise operators.

The latest cyclone, January 2014, was devastating for Ha'apai, which suffered a focussed pass of the eye. Tourism decreased dramatically, as six out of the seven homestays in the islands of Lifuka and Foa were seriously damaged. These included Matafonua Lodge, Billy's Place, Fifita's Guest House, Lincy's Guest House, 'Evaloni's Guest House, Tiulipe Guest House. Sandy Beach Resort suffered more minor damage, but the delivery of foodstuff and hotel supplies were disrupted. An estimated value of the damages to tourist accommodation was $1.6 Million Tongan Pa'anga. In addition to this, dive operations and other attractions serving tourists mostly lost their boats and equipment.

4.3.8 Key Conclusions - Ha'apai

1) Ha'apai is still charted in Fathoms on an undetermined datum. This provides the lowest quality of charting in a large area.
2) Charting improvements to a known datum are necessary for the introduction of electronic charting.
3) Visits by International shipping are low in number, but regular domestic services operate throughout the Islands.
4) There is considerable interest from the cruise sector to visit Ha'apai, which has a number of attractions of relevance. Indeed, there are already some small, but regular callers (annual), both to outer and the main islands of the group. It is likely to attract cruise vessels once a charting upgrade has occurred. Transit risk levels already support the need for charting review
5) The Ha'apai Group has been hit by Cyclone Ian and infrastructure recovery, including those supporting navigational safety, will take a number of years.

4.4 VAVA'U

Vava'u is the second most populous island group of Tonga, with a population of about 15,000. Historically, it has had a strong tourist industry and enjoys one of the most sheltered deep water harbours in the SW Pacific. Vava'u has a large number of pristine reefs in its island group.

4.4.1 Ports and Harbours in Vava'u

Table 9, below, records the terminals and anchorages of Vava'u. TheCATZOC ratings are utilised in the Hydrographic Risk Assessment. Vava'u was the subject of extensive survey and charting upgrade in 2010, with existing charting coverage being reissued to modern standards. Neiafu Harbour has a safe anchorage in its outer area that is used by large cruise vessels.

Location	Island	Chart	Year	Scale	CATZOC	Facilities	Shipping
Neiafu Harbour/Halaevalu Wharf	Vava'u	NZ 8225	2010	1: 10K	A1/A2	Main Wharf	Domestic and International Shipping
Pacific Energy Vava'u Terminal	Vava'u	NZ 8225	2010	1: 10K	A1/A2	Uncharted Gas Terminal Mediterranean Mooring	International liquid bulk vessel visits
Eunga'onatale Beach	Vava'u	NZ 822	2011	1:50K	A1/A2	Port of Refuge	Yachts

Table 9: Ports and Harbours in Vava'u Province

The Helaevalu wharf, Neiafu was noted to be of solid construction and in good condition, with both RoRo ramps and berthing for any type of general cargo vessel or RoRo. The arrangements for the domestic ferry allowed for efficient berthing and cargo transfer.

Figure 11: The Domestic Ferry alongside the RoRo berth at Halaevalu Wharf, Neiafu

4.4.1.1 The Vava'u Oil Terminal

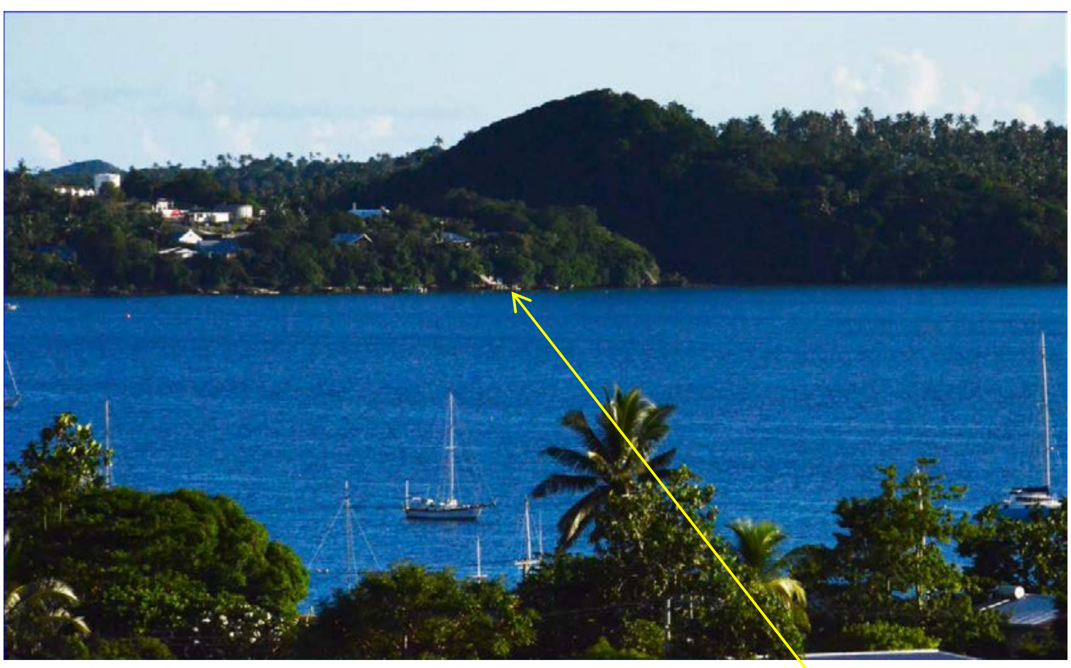


Figure 12 : Location of the Pacific Fuels Terminal

The Pacific Energy terminal at Vava'u is located in the sheltered waters of Neiafu Harbour. It is supplied by both domestic coastal vessels as well as SOLAS tankers originating from Fiji. LPG Gas, Diesel, Gasoline and Avgas are all handled by this terminal.

This terminal has a similar open discharge arrangement for the transfer of liquids ashore to the arrangements in place at 'Eua. However, the discharge connection to the shore tanks is located on a plinth at the harbour water/land interface. There is thus not such a pressing need to review this arrangement as there is at 'Eua, although any spill would contaminate the waters of what is an exceptional natural harbour.

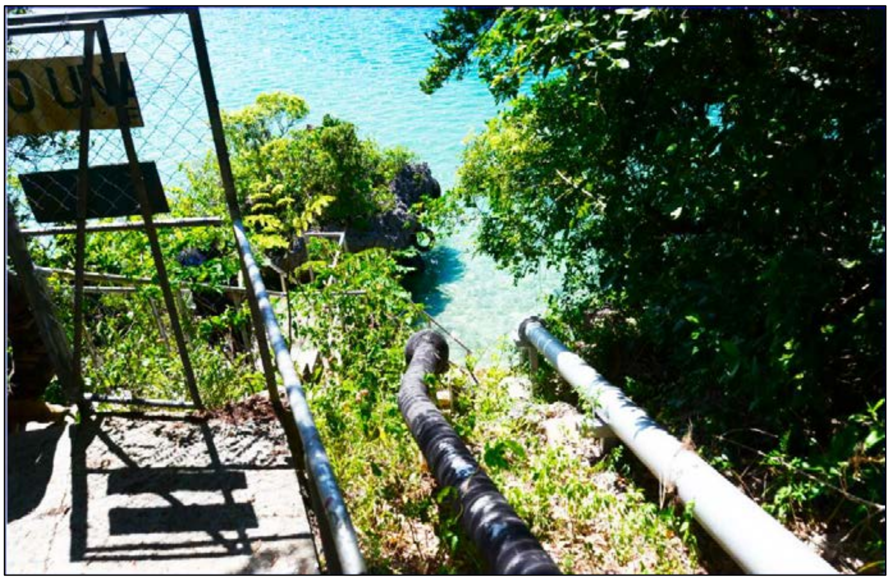


Figure 13 : Bulk Liquid Discharge Arrangements at Vava'u Terminal

4.4.2 Tourist Attractions in Vava'u

In Vava'u, few attractions are accessible by road, with the main tourist industry being concentrated in water activities. Whale watching and diving experiences are popular, mostly being booked in advance for cruise passengers and other travellers. At the time of the visit, there were eight licensed whale watching operators, five diving centres, two game fishing charters, two kayaking outriggers, a surfing and a snorkelling hire and seven boat transfer operators. There are a total of 35 homestays. In some areas, homestays reported bookings being down by 90% of 5 years ago; air travel caution was referenced. Some homestays have closed in recent years.

Vava'u is a popular stopover for international yachts (some 500 per annum), with tourist attractions tailored to this market. The harbour is a safe, sheltered haven for international yachts, many of which wait out the cyclone season there.

There are a number of venues providing a variety of tours including local cultural demonstrations and traditional feasts. The Botanical Gardens, En'eio, grow native plants, including vanilla, and also provide guided bird watching and a feast on Sundays (when most other venues close).

Neiafu Harbour frontage boasts both hotels and restaurants/bars.

4.4.3 Domestic Coastal Vessel Trade in Vava'u

The domestic coastal shipping trade in Vava'u appears vibrant and has potential to grow. Neiafu Harbour is a major coastal hub for Northern Tonga. There is a weekly coastal passenger service (OTU'ANGA OFA) and a fortnightly freight service (SITKA) with strong links between Ha'apai and Tongatapu Provinces.

Neiafu Harbour is also an international arrivals port, with some container and small bulk liquid (tanker) vessels visiting.

4.4.4 Cruise Vessels Visits

Small and large cruise vessels (e.g. PACIFIC PEARL, HANSEATIC, EUROPA) currently visit Neiafu Harbour. These are annual arrivals, with EUROPA and HANSEATIC the most regular. The majority of larger vessels anchor in the entrance of the harbour, with smaller vessels berthing at Halaevalu Wharf. The number of port calls to Vava'u by cruise ships has declined since 2011, although there is recent evidence that some large cruise vessels are beginning to visit. The latter is likely to be related to the improvements to charting already achieved in Vava'u.

One of the attractions of Neiafu Harbour is the variety of shore excursions available to cruise visitors.

4.4.5 Recreational Activity - Yachts

The volume of yachts using Neiafu Harbour is not surprising, given that it is one of the finest natural harbours in the SW Pacific, sheltered by high land on all sides. There are also safe anchoring grounds for yachts as well as dedicated moorings.

The Vava'u Group is, therefore, a popular destination for international yachts, with the harbour lying on a line of logical transit across the SW Pacific. The period May – October is the busiest time, with some yachts remaining in the harbour for the cyclone season to pass. In the last decade there has been on average 455 yachts annually, with the highest number of visits being 573 for 2010.

There are five yacht charter providers located in Neiafu Harbour; one has strong links with New Zealand. Additionally, there are 43 anchorages suitable for yachts.

There are shops, chandlery and tourist businesses servicing the international yachting community.

4.4.6 Key Sites of Environmental Significance

The data gathering visit determined there were two SMAs established while four SMAs were planned. These are:-

Established SMAs:

- Ovaka Island – The SMA has Fishing Habitat Reserve of 215 ha and giant clam and protective zone of 86 ha;
- Taunga Island - The SMA has a Fishing Habitat Reserve;

Planned SMAs (three are referenced)

- Hunga Island;
- Lapa Island;
- Falevai, Kapa Island.

Vava'u has a considerable number of mangroves and turtle breeding sites, which influence the GIS risk analysis model. A SPREP survey undertaken in 2012[42] determined there were 380 hectares of mangroves in Vava'u, about 30% of the Tongan total.

4.4.7 Key Sites of Cultural Significance

Cultural sites that are exposed to coastal areas that could be directly affected by a shipping accident are included in the risk assessment criteria. Although sacred sites were referenced, there were no sites reported that met the risk inclusion criteria in Vava'u.

4.4.8 Summary of Economic Information

4.4.8.1 Cargo Exports

Vava'u mainly produces root crops, yam, taro, coconut, kava, vanilla. It exports locally to other provinces in Tonga, and occasionally offshore. Vanilla, one of its main exports, is of high value and niche food manufacturers from both Australia and New Zealand are investing in further cultivation expansion. The Tongan Government Agriculture Division also runs a pilot biogas project at a piggeries farm, which is aid funded by China.

Vava'u also has extensive aquaculture activities. At the time of the visit, ten aquaculture installations were reported, associated with pearl, mullet and clam farming. A management plan and licensing plans are the subject of implementation by the Fisheries Division.

Sea cucumber is being cultivated as a potential export to Fiji and Asian countries.

4.4.8.2 Energy

A solar energy power project (5MW) was completed on October 2013, funded by Aid from the UAE. The solar plant will reduce dependency on imported oil.

[42] http://www.sprep.org/biodiversity-ecosystems-management/vavau-mangrove-survey-successfully-completed-using-gis

4.4.8.3 Tourism

The Vava'u tourist data obtained suggests 8,600 visitor arrivals per annum, with about 1300 arriving by sea (mostly yachts). The tourist numbers have been steady as far as the arrivals by sea are concerned, although arrivals by air have fallen dramatically, due to uncertainty of aircraft travel.

A planned international flight connection direct between Vava'u and Fiji may, in future, provide an alternative international gateway.

4.4.9 Key Conclusions – Vava'u

1) Neiafu Harbour is an exceptional natural harbour, offering shelter and sustainable future expansion in support of the tourist and cruise industries.
2) It offers a range of attractions from Whale watching and diving to religious conferences.
3) Vava'u is a premier destination for international yachts. A number of yacht charter providers also operate, together with a range of marine businesses that are supported by the yacht visitors.
4) Large Cruise vessels are already accessing Vava'u, albeit in limited numbers. Coastal infrastructure at Neiafu can readily cater for moderate visitor numbers.
5) Vava'u is an international point of entry for shipping to Tongan waters and has direct calls from both container vessels and tankers. However, the bulk of the shipping trade is from domestic coastal vessels.

4.5 THE NIUAS

Figure 14 : Niuatoputapu and Adjacent Tafahi Volcano

The Niuas group comprises two main neighbouring islands, Niuatoputapu and Niuafo'ou. Niuatoputapu is located 155NM north of the Vava'u Group, whist Niuafo'ou lies 106 NM west of its neighbour. In 2011, the population of the Niuas group was recorded at 1283, a 23% decrease since the 2006 census. A reason for this was the migration of local residents to the main island of Tongatapu for economic reasons.

Only Niuatoputapu Island was visited for the in-country data gathering, because of landing strip preparation being incomplete in Niuafo'ou. During the visit to Niuatoputapu, local representatives advised the population was approximately 800 (with 30-40 living on the adjacent island of Tafahi), but was stable. This suggests that about 480 people live on the island of Niuaf'ou.

4.5.1 Ports and Harbours in the Niuas

Table 10 below, records the harbours of the Niuas. There is one per island. Where there is an anchorage only, the facilities column is left blank. The CATZOC ratings are utilised in the Hydrographic Risk Assessment, and all U ratings are assumed to be a D category - lowest.

Location	Island	Chart	Year	Scale	CATZOC	Facilities	Shipping
Niuafo'ou Harbour	Niuafo'ou	NZ 8215	1996	1:100K	C	Concrete Main wharf and ferry ramp	Domestic Shipping
Niuatoputapu Harbour Pasivulangi Wharf	Niuatoputapu	NZ 8215	1996	1:9K	C	Landing open to Sea	Domestic Shipping

Table 10: Ports and Harbours in Niuas Province

Niuafo'ou has a very small jetty open to sea swells and landing cargo there is difficult (Figure 15). Cargo is offloaded into small craft, with the vessel at anchor. The domestic vessels can only berth during high tide. Figure 15 shows a panoramic view of the landing stage, taken from the ramp of the regular ferry.

Niuatoputapu Harbour is situated in a lagoon within the barrier reef on the north west of the island. A narrow entrance channel, located on the northern tip of Niuatoputapu Island, leads to Pasivulangi wharf. Figure 16 shows an overview of the wharf. The wharf is able to accommodate domestic coastal vessels with a maximum recommended draught of 3 metres[43].

4.5.1.1 Niuatoputapu Harbour – 2009 Tsunami

In 2009 offshore seismic activity produced a tsunami that affected both Samoa and Northern Tonga. The Niuas suffered coastal damage affecting homes and the Niuatoputapu Harbour entrance was left full of debris from the tsunami. The NZ Navy cleared the entrance, allowing delivery of aid. Some coral heads in the harbour entrance channel were removed using explosives and this was followed by a sketch hydrographic survey.

[43] According to the Admiralty Sailing Directions NP61, the maximum recommended draught for vessels calling at Niuatoputapu is 3 metres.

Figure 15: The Harbour Arrangements at Niuafo'ou (Landing Stage Open to Sea)

Figure 16: Pasivulangi Wharf, Niuatoputapu Harbour

4.5.2 Aids to Navigation - Niuatoputapu

In Niuatoputapu Harbour some of the AToNs have been upgraded or replaced and many were lit[44]. At the time of the data gathering visit a number of Aids to Navigation were in need of maintenance or were missing when compared with the current chart records (see Figure 17). The domestic ferry later grounded adjacent to one of these in 2014, reportedly suffering minor hull damage (see Figure 18).

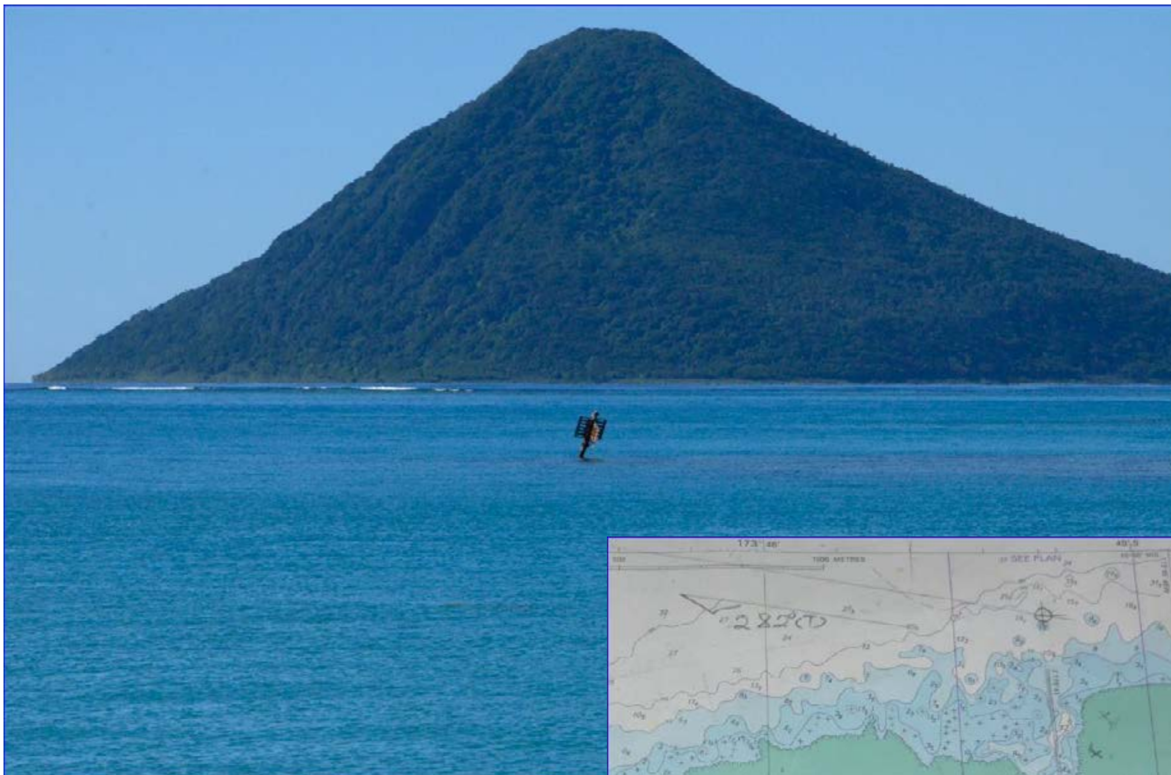


Figure 17 : Some AtoNs in Niuatoputapu were in need of Attention

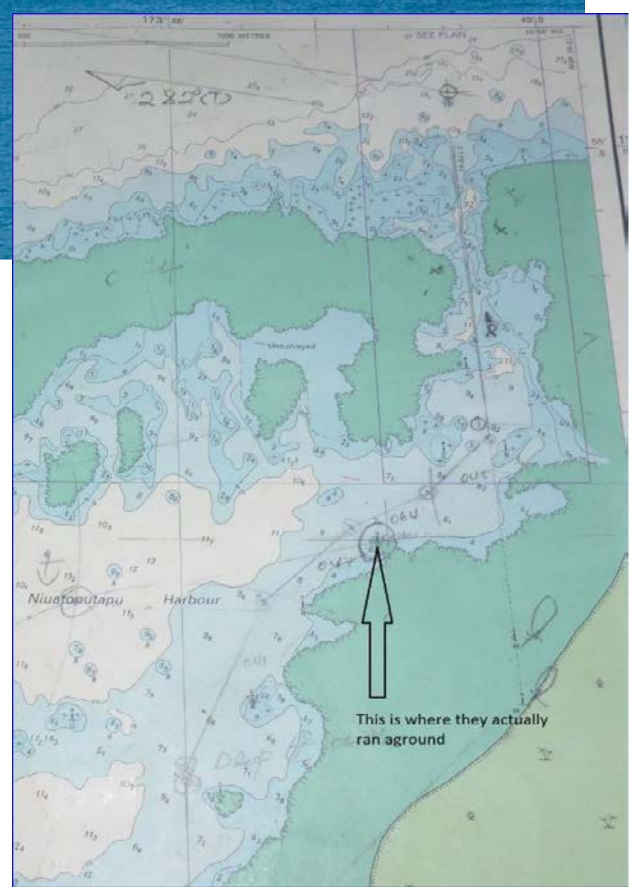


Figure 18: Location of a (minor) Grounding 'OTUANGA'OFA in Niuatoputapu

[44] There was a Marine and Ports Division Replacement programme in 2013.

4.5.2.1 Niuatoputapu Harbour Entrance Leads

Even though traffic levels to the Niuas are low, there are some features of this harbour that make discussion in this report important. The narrow and shallow nature of this harbour entrance is such that accurate and sensitive leads are important for safe transit. Channel leads, when aligned one behind the other, provide an alignment for a vessel approaching this narrow entrance, such that the vessel will remain in the deepest water available. The sensitivity of a set of leads is directly proportional to the distance between them. Leads with a greater distance apart will open more rapidly if a vessel aligned on them begins to vector and move off the correct course. Sensitive leads allow for early corrective action.

From the in country data gathering, it was apparent that new leads, lit with solar powered LEDs, had recently been installed at Niuatoputapu harbour entrance (see Figure 19).

Figure 19: The Channel Entrance leading marks at Niuatoputapu Harbour (solar powered)

However, given the narrow nature of Niuatoputapu Harbour entrance and the distance from the leads to the entrance transit, the leads were noted to be too close together. If a vessel was having difficulty in either cross currents or swells at the entrance approach, the leads would be insensitive to any vectoring off the correct harbour approach course. This is a factor in raising transit risk levels for an individual transit.

Figure 20: The Harbour Entrance Leads are too close together for sensitivity.

4.5.3 Niuatoputapu Harbour Entrance and the Regular Ferry

The narrow nature of the Niuatoputapu harbour entrance is referenced already. It also has a draught limit of close to 3m. The design of the ferry 'OTUANGA'OFA reaches the channel's maximum size, both in terms of channel width as well as depth. The seaward approach to the entrance channel may be dangerous at times with strong swell or cross currents at low tide. The ferry operators are aware of this and the ferry does anchor adjacent to the entrance approach to await an improvement in conditions for transit into the harbour and Pasivulangi Wharf.

Figure 21 : The Ferry 'OTUANGA'OFA is a Maximum Size for the Niuas harbours

There is an important inherent risk to consider in relation to this vessel and its importance to Tonga. Since its introduction into service, this vessel has replaced quite a number of older domestic vessels that were plying Tongan waters. This hydrographic risk assessment correctly measures charting risk as a function of traffic volume, but it does not directly measure an inherent risk that has a high consequence impact if vessel loss did occur.

The combination of insensitive vessel leads, a narrow harbour entrance and a regular vessel transit, which is at the maximum capacity of the entrance channel, does raise the likelihood of a grounding event at Niuatoputapu. If this did occur and the ferry was severely damaged or even lost, the economic effect would be immediate throughout Tonga. Since introduction into service, the 'OTUANGA'OFA has provided a safe and efficient service, transporting both passengers and the majority of freight moving domestically. It is not true to say that alternatives could not be found[45], but it is true that there would be significant economic impact, such that risk mitigation in prevention is worthwhile.

[45] There are a number of laid-up Domestic Coastal Vessels in Tongatapu Harbour, but these would provide an inferior safety margin to that which is delivered by "OUTUANGA"OFA

4.5.4 Domestic Coastal Vessel Trade

Two domestic vessels regularly call at the Niuas; 'OTUANGA'OFA and SITKA, calling at a maximum of once per month to both islands, Niutatoputapu and Niuafo'ou. The call frequency appears to be driven by cargo needs and can be up to six weeks. For example, electricity generation depends on the transportation of fuel drums and about 80 per month are delivered. Both diesel and aviation fuel are delivered in drums; aviation fuel is needed for a return journey by air, due to the distance from Vava'u.

4.5.5 Cruise Vessels Visits

There has been a cruise visit about once per year by a small cruise vessel (e.g. BREMEN, ORION, CALEDONIA SKY). Cruise operators making these calls also visit Vava'u and Ha'apai, as part of a world cruise schedule. German operators appear to be the most regular callers. However, the Niuas are reported to be excluded from 2013 onwards, with difficulties in landing passengers cited as a reason. For 2014, two cruise vessels were scheduled (ORION, CALEDONIA SKY).

4.5.6 Cruising Activity

On average, there are approximately 30 yacht visits per year to Niuatoputapu, staying a maximum of 2 days. Yachts use the commercial wharf; there is a small fee and coastal clearance is required by Customs.

4.5.7 Key Sites of Environmental Significance

Niuatoputapu Island is a remote, pristine and diverse environmental area with a plethora of corals which cover the entire island. Mangroves grow in the harbour entrance and a large bird breeding ground dominates the South East. Because of the relatively low population and remoteness of the Niuas, there are no formally recorded SMAs or reserves.

4.5.8 Key Sites of Cultural Significance

Legends and volcano activity is an integral part of culture for Tonga. It is suggested that this is driven from factual events through the Tongan oral tradition. The volcano of Tafahi Island is a key area of cultural significance that has been considered in the risk assessment.

4.5.9 Summary of Economic Information

The Niuas is a self-sustaining island group, with domestic shipping visits at best monthly or more commonly at six week intervals. The economy is mostly around subsistence agriculture, fishing and traditional crafts. The supporting of remote family members (in both directions) is in focus.

4.5.9.1 Cargo Imports and Exports

Using the domestic ferry, Niuatoputapu exports yellow fin and mahi mahi to Vava'u and yams, although this is in small quantities. Families in the Niuas also send food provisions to their members working in Nuku'alofa. Same as in Ha'apai, Niuas women weave mats from pandanus which are also distributed throughout Tonga. Exports are thus limited in commercial terms.

Imports are mainly fuel and lubricants, approximately 80 drums per month (diesel and aviation fuel are delivered in drums).

4.5.10 Tourism

Tourism numbers to the Niuas are limited, due to the distance from other island groups, but they do occur. However, there have been small cruise vessel calls in the past 5 years, although offshore swells dictate their ability to land passengers safely. On average, there are 50 visitors to Niuatoputapu each year and the community maintains a guesthouse for government officials and tourists.

4.5.11 Conclusions - Niuatoputapu Harbour Entrance

1) It appears that risk mitigation benefit, on an individual ship-transit basis, would accrue out of a review of both the available depth and Aids to Navigation, including entrance leads, of Niuatoputapu Harbour and its entrance.

5 ANALYSIS OF SHIPPING IN TONGA FROM LOCAL RECORDS

This section of the report analyses the marine traffic throughout the waters of Tonga, based on records from the Port of Nuku'alofa, which is the main logistics and passenger hub for Tonga. The Ports Authority Tonga, kindly provided high quality and detailed port movement records for international and domestic coastal vessels, both in hard copy and digital format. This information was later utilised to cross check with the S-AIS data received from international trading ships, which made a key contribution to the quality of this particular hydrographic risk assessment[46]. Data for Vava'u and Ha'apai was collected locally.

5.1 TRAFFIC ANALYSIS – PORT MOVEMENT DATA FROM PORT OF NUKU'ALOFA

The Ports Authority Tonga movement data set included cargo volumes and gross tonnage information for all types of vessels. This was provided in a number of databases, which were merged into a common one, so that statistical analysis could be achieved.

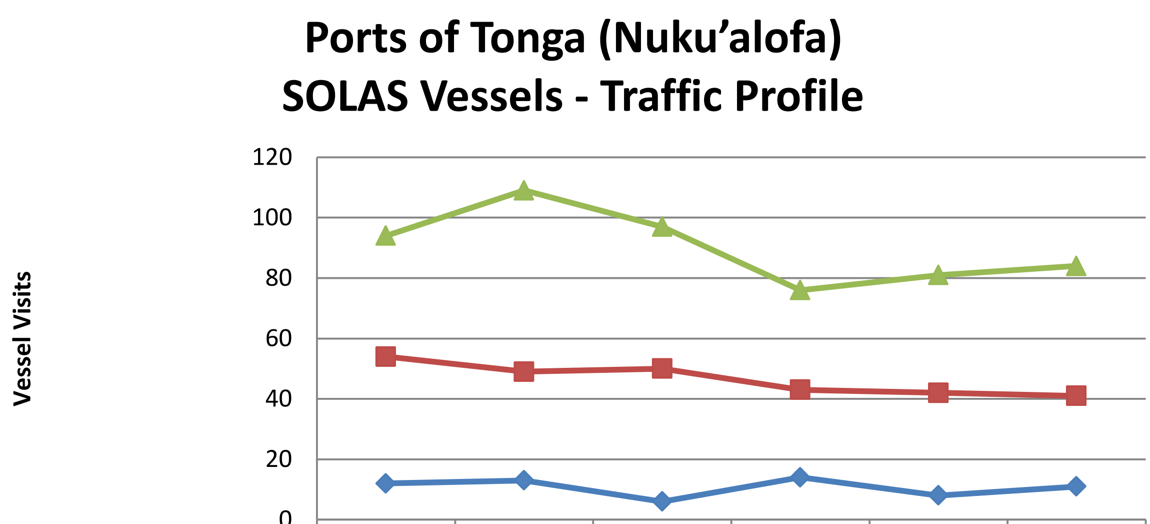
Analysis of movement trends, seasonality and size for SOLAS vessels was undertaken. The overall data of vessel movements covered the period from 2006 to 2012, which included considerable details about vessels and cargoes offloaded. For domestic cargo and passenger vessels, details of movements, passenger numbers and cargo types/volumes were provided. Records of last port and next port calls for 2012 and 2013 have also significantly allowed a cross-reference against S-AIS data modifications. This quality of this information is acknowledged and allows an accurate risk assessment and economic analysis to follow.

For the purpose of the international traffic analysis, three core vessel types were used, allowing for direct comparison with SW pacific hydrographic risk assessments in other EEZ jurisdictions. Vessel types of passenger vessels (cruise); dry cargo vessels and bulk liquid vessels (tankers) were used. "Dry cargo" vessels include general cargo, bulk carriers, containers and Ro/Ro vessels. The "bulk liquid" category includes tankers and gas ships.

[46] S-AIS data is message information from AIS-equipped vessels that are received by a satellite.

5.2 PORT OF NUKU'ALOFA TRAFFIC ANALYSIS – OVERVIEW

This section provides an overview of the traffic analysis, followed by more detailed information based on vessel type. A graphical representation of the shipping traffic profile for international vessels visiting Tonga is shown below at Figure 22 .



	2008	2009	2010	2011	2012	2013
PASSENGER Tonnage	12	13	6	14	8	11
LIQUID Tonnage	54	49	50	43	42	41
DRY Tonnage	94	109	97	76	81	84

Figure 22 : International Vessel Movement Profile for Port of Nuku'alofa

The traffic analysis takes 2008 as a baseline year; as it represents a low in the economic cycle and thus a useful reference from which to measure trends to 2013. The overall data shows a slow decline for dry and liquid vessel visits, whilst cruise vessel numbers have fluctuated from 2008 to 2013. It also suggests that both dry cargo and liquid vessel movements are slowly declining. However, the underlying cargo records show something of interest in that cargo volumes inbound and outbound at Nuku'alofa show a steady increase in cargo volume associated with fewer ship calls. The cargo volumes do suggest the Tongan economy has been slowly expanding since 2009. Cruise tonnage shows an approximately steady trend, but 2010 and 2012 were both years in which a decline in cruise movement numbers is apparent. However, the cruise facility at Vuna Wharf, together with improvements made to port infrastructure handling container and general cargo vessels, are expected to result in increased vessel-calls in future years.

Although it is not shown in the data period above, Tonga's economy was affected by the global recession. In particular, vessel-visit numbers declined by 46% between 2006-2008, which reflects the global crisis in port operations and shipping industry. However, vessel gross tonnage *increased* by 11% for the same period, showing a trend to larger ships also occurred during the recession. Thus the Port of Nuku'alofa has been making some quite impressive efficiency gains since the mid 2000's.

5.2.1 Cruise Vessels Visits

The port of Nuku'alofa has been the key Tongan destination for cruise vessels for a number of years. The majority of cruise vessels visit Nuku'alofa, with some large cruise vessels calling also at Vava'u.

Table 11 presents a detail of recorded cruise vessel visit statistics from 2008 to 2013 (reflecting the trend line in Figure 22). Overall and considering the recession, cruise visits for 2008, 2009 and 2011 remained steady and could be considered even as prosperous years for the economic benefit they bring. There are however quite large swings in the numbers of vessel visiting year on year.

Cruise Vessel Visits 2008 – 2013													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	2	5	0	1	0	2	0	0	1	1	0	0	12
2009	0	6	1	2	0	1	0	0	1	0	2	0	13
2010	0	0	0	1	1	0	0	0	1	0	3	0	6
2011	0	6	2	2	0	0	1	0	0	1	0	2	14
2012	0	1	1	3	0	0	0	0	0	2	0	1	8
2013	2	2	1	2	0	0	0	0	0	1	3	0	11

Table 11: Cruise Vessel Visit Data for Port of Nuku'alofa

In future years, cruise ship visits to Tonga may benefit from a number of nationwide infrastructure projects, including the tourism sector, delivered in part by the various Aid Donors in conjunction with the Tongan Government. An important development for the cruise industry was the construction of Vuna wharf in 2012, which is a dedicated berthing facility for cruise vessels, with a design that facilitates good mooring security; modern passenger facilities; ISPS Code security and easy access to Nuku'alofa itself. This modern berth can readily accommodate cruise vessels of 300 metres in length and maximum draught 10.0m, and provides scope for even larger vessels to berth safely.

Interestingly, the initial schedule for 2013 included 17 cruise vessels visits to Nuku'alofa but in the event, only 11 ended up calling. There appear to be various reasons for this, including weather cancellations. One factor of relevance is the deep respect the Tongans have for religion. In Tonga Sunday is a day of rest and worship, which is widely adhered to. Port and other business activities are thus closed during Sunday, and unable to offer berthing services. It appears a number of planned weekend cruise calls were aborted before the industry developed scheduling plans in response.

The schedule predictions for 2014 suggested that cruise stakeholders across most operators are keen to extend visits in Tongan waters into the Ha'apai and Vava'u Islands Group.

The cruise vessel visit forecast for 2014[47] showed a sustainment of the 2013 visit plans. There was a trend towards larger vessels, with the obvious increase in passenger capacity. Two examples are the visits of the QUEEN ELIZABETH and QUEEN VICTORIA. This growth in gross tonnage is also likely to be a direct impact of the Vuna wharf development.

5.2.1.1 Cruise Stakeholder Feedback

There is more than one cruise stakeholder making regular visits into Tongan waters, via either New Zealand or Australia, with almost Nuku'alofa always a destination. Feedback strongly suggests that the ability to make further calls into other Tongan destinations would assist cruise operators in marketing, itinerary planning and passenger numbers growth. One operator has already based a cruise vessel at Auckland for the summer cruising season and advised it is viable to operate an 8 day cruise out of Auckland, with the first port of call being

[47] This is based on domestic records at the time of the data-gathering visit.

Nuku'alofa. This would be followed by calls to a Ha'apai (providing charting was improved) and Vava'u destination. This would balance passenger time at sea with port calls.

5.2.2 Dry Cargo Vessels Visits

The port of Nuku'alofa, with its centre of Tongan population and geographic location, functions as the Tongan trade hub for both dry cargo exports and imports. This includes container, ro/ro, bulk carriers and general cargo vessels.

During 2008, a total of 94 dry cargo vessel-calls were made, fluctuating to 109 vessels in 2009. Table 12 shows that overall there is a slow drift to a reduced number of calls, with 2012 and 2013 suggesting a stability of trade. 2008 to 2013 suggests a decline of about 11% in ship-calls to the port. Dry cargo vessels generally call at set intervals during a given year, hence the data does not show any seasonal trend.

Dry Cargo Vessel Visits 2008 - 2013													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	8	8	7	7	8	7	7	10	7	8	6	11	94
2009	8	7	8	9	10	10	8	8	7	10	10	14	109
2010	10	7	9	8	8	6	10	8	6	8	9	8	97
2011	9	6	7	4	6	6	6	3	4	9	7	9	76
2012	7	5	6	9	6	5	8	8	7	8	7	5	81
2013	5	8	4	7	7	6	7	8	9	8	7	8	84

Table 12: Dry Cargo Vessel Visit Data for Port of Nuku'alofa

The GT of vessels ranges from 2,000GT to 18,000GT. The majority of dry cargo vessel visits involve two container vessels, TROPICAL ISLANDER and PACIFIC ISLANDER II (18,174GT and 17,134GT, respectively). These vessels also dominate the cargo volume of the trade. Both vessels carry containers and Ro/Ro cargo (trucks and cars). Analysis of cargo throughput for dry cargo is shown in section 5.3.

It is noteworthy that Tonga exports considerable volumes of squash when in season; a vessel is normally charted for this. Squash was a significant export that in recent years appears to have been in decline by volume.

5.2.3 Bulk Liquid Vessels Visits

Oil and gas tankers have also shown a steady reduction in calls since 2008; from 54 calls in 2008 to 41 calls in 2013. Table 13 shows this reduction in traffic. The port of Nuku'alofa is mainly served by small oil tankers, averaging 2000GT from 2008 to 2013. Gas vessels are of size varying between 3000GT to 4500GT.

The data suggest that the cargo volumes of petroleum product and gas imports have grown overall between 2008 and 2013. Analysis in section 5.3 shows this trend. Greater volume is being delivered by fewer ship calls.

There is a large NZ funded solar energy generator complex, which may reduce the Tonga's dependence on fossil fuels or limit the volume being transported in an expanding economy.

Bulk Liquid Vessel Visits 2008 - 2013													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	4	6	4	5	5	5	4	6	3	5	3	4	54
2009	6	3	3	5	4	3	5	4	3	5	5	3	49
2010	5	3	5	3	4	5	4	3	3	4	6	5	50
2011	3	3	4	4	3	4	3	4	4	4	4	3	43
2012	3	4	3	5	3	3	5	5	3	3	3	2	42
2013	5	3	4	2	3	3	2	3	4	3	4	5	41

Table 13: Bulk Liquid Vessel Visit Data for Port of Nuku'alofa

5.2.4 Domestic Coastal Shipping

The data provided by the Ports Authority of Tonga for the domestic shipping sector contained detailed records. It included timetables and cargo volumes. Passenger numbers were provided overall as well as individually for each vessel. Table 14, presents the schedule of domestic vessels that operated at the time of the data gathering visit.

Domestic Coastal Services Operating - Ports of Tonga (Nuku'alofa)					
Vessel	**GRT**	**Type**	**Route**	**Frequency**	**Status**
ALAIMOANA	160	Cargo/Pass (88)	Nuku'alofa -'Eua	Weekly	Operating
'OTUANGA'OFA	1534	Cargo/Pass (400)	Nuku'alofa – Nomuka - Ha'afeva – Pangai - Neiafu – Niuatoputapu – Niuafo'ou - Pangai - Ha'afeva – Nomuka - Nuku'alofa	Weekly (Bi-monthly to Niuas)	Operating
SITKA	289	Cargo/Pass (Dec-Feb)	Nuku'alofa - Ha'apai – Vavau - Niuas	Weekly	Operating
'ONEMATO	111	Cargo/Pass (150)	Nuku'alofa -'Eua	Weekly	Operating
PULUPAKI	420	Cargo/Pass (210)	Port Nuku'alofa - Ha'afeva	Intermittent	Laid up

Table 14: Domestic Coastal Services for Ports of Tonga

The Port of Nuku'alofa has separate terminals for domestic vessels and is also the economic centre for all such domestic operations. Cargo transferred from international vessels as well as import and export cargoes are all handled at these terminals. Freight volumes are transported by domestic coastal vessels to the Ha'apai and Vava'u island groups, as well as 'Eua. Like other Pacific Island Groups, local residents mainly use the domestic fleet for interisland travel.

Until December 2013, there were approximately five vessels operating in Tongan waters. A new passenger vessel, OTUANGA'OFA, entered service in 2011 to serve Tonga nationwide. Two vessels operate the Nuku'alofa – 'Eua ferry route. One, 'ONEMATO is community owned, entering service in 2013; the second, ALAIMOANA is privately operated. The one remaining ferry is dedicated to the same route as OTUANGA'OFA.

During the peak season (December to February), 'OTUANGA'OFA is allowed to increase the licenced passenger capacity of 400, to 600 persons. It appears regulators elect to increase this vessel's capacity as a better option to meet demand than allowing another laid up vessel into passenger service. The passenger vessel PULUPAKI, mostly laid up, is also occasionally allowed back into peak season service, with a passenger capacity of 210. SITKA also occasionally carries passengers.

Interestingly, 'OTUANGA'OFA has carried 32% of the total passengers journeying in Tonga since its introduction into service in 2010. 'ONEMATO, in service to 'EUA, discussed earlier in sections 4.1.4 and 4.2.3, also carries a large volume of passengers - more per annum in 2012/13 than the much larger 'OTUANGA'OFA.

A significant number of domestic cargo and passenger ships have been laid-up the last five years. Table 15 shows a brief list of these.

Domestic Coastal Services Laid-up – Ports of Tonga				
Vessel	**GRT**	**Type**	**Route**	**Status**
AJANG SUBUH	415	Cargo	N/A	Temporary (2010-11)
KAIWAI	188	Cargo	N/A	Temporary (2011)
KUSIMA	N/A	Cargo	N/A	Temporary (2011)
OLOVAHA	707	Cargo/Pass (350)	N/A	Temporary (2008-09)
MAAMAKAMO II	440	Cargo	N/A	2011-12
ALO'OFA	78	Cargo/Pass	Port Nuku'alofa -'Eua	Laid up
IKALE	210	Cargo/Pass (120)	Port Nuku'alofa -'Eua	Laid up
MAAMAKAMO I	50	Cargo	Port Nuku'alofa -'Eua	Laid up
SIUPELI KOULA	69	Cargo/Pass (25)	Port Nuku'alofa - Nomuka	Laid up
TAUTAHI	270	Cargo/Pass(380)	Nuku'alofa - Ha'apai-Vavau	Laid up
MELIE MEI LANGI	78	Cargo	Port Nuku'alofa - Nomuka	Laid up

Table 15: Domestic Coastal Services Laid-up for Ports of Tonga

The routes and schedules of the non-operating local ships have significantly varied with freight availability.

5.3 PORT EFFICIENCY – NUKU'ALOFA

The port data suggests that Port of Nuku'alofa has improved its efficiency since the beginning of 2010. This is evidenced by the increasing cargo volumes but the decreasing ship visits and sizes which are proportionally[48] compared using 2008 as the baseline.

Figure 23 shows a comparison between vessel numbers, size of ships (GT) and cargo volume. The trend is expressed in percentages, again using 2008 as a baseline.

The figure shows that between 2011 and 2012 both the Gross Tonnage and number of port calls declined on average by 20% and 10%. Cargo volumes, on other hand, had an average growth of 3% for the same period. Thus there is a trend towards more cargo being carried by fewer ships. The port of Nuku'alofa is showing efficiency gains in the dry cargo sector, an important factor in its potential for growth.

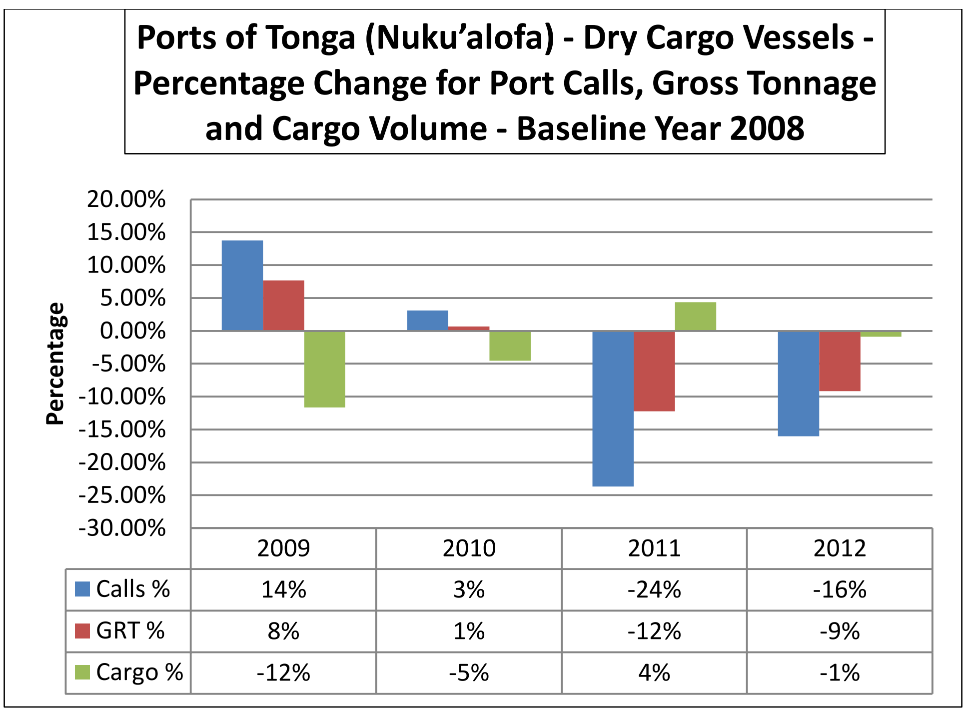


Figure 23: Percentage Change Trends for Port Calls, GT and Cargo for Dry Cargo Vessels

[48] The data are proportionally compared using the percentage change which is a simple way to draw statistical conclusions in comparison with multiple variables.

Figure 24 shows cargo volume and ship call trends for bulk liquid vessels. Cargo volume through the port has increased by 12% on average, from 2010 to 2012. The number of port calls has reduced overall by 21%, with a corresponding fall of 17% in gross tonnage through the port associated with liquid bulk vessels. This is accompanied by a modest increase in bulk liquid cargo through the port.

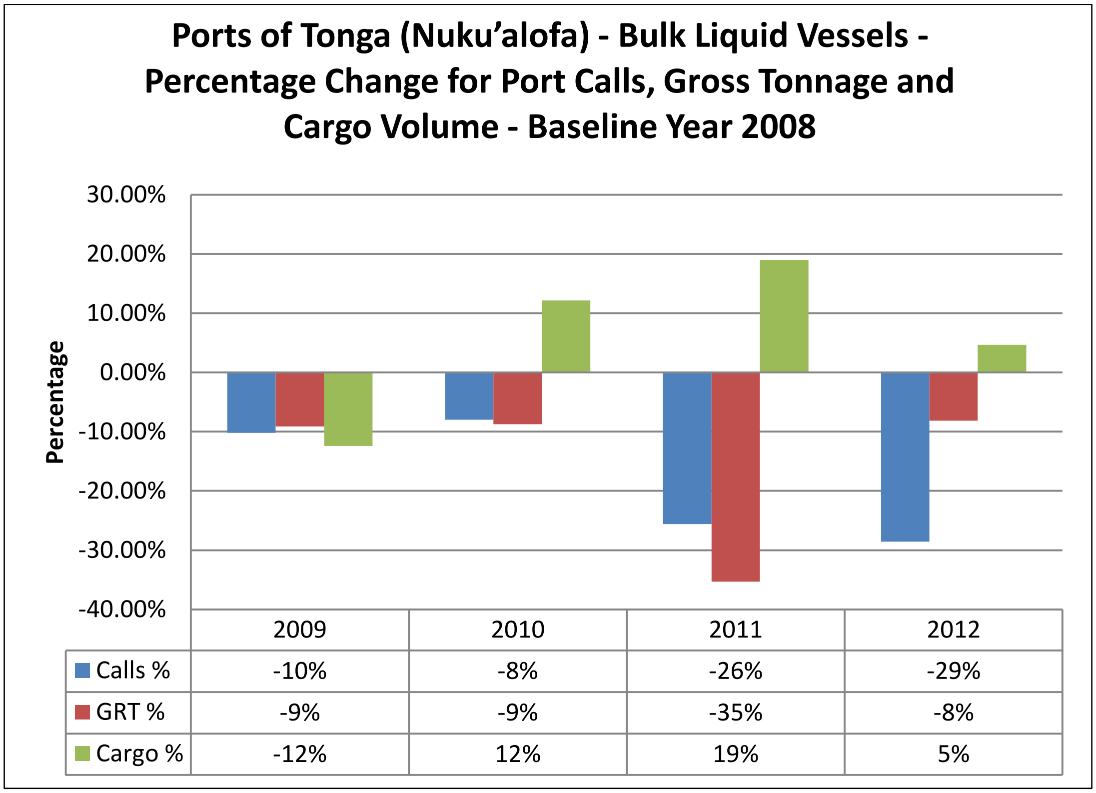


Figure 24: Percentage Change Trends for Port Calls, GT and Cargo for Bulk Liquid Vessels

It is therefore a clear conclusion that the Port of Nuku'alofa has made efficiency gains in all of its cargo handling segments. Bulk liquid has shown the most gain in terms of cargo volumes handled by fewer ships. The trend towards cheaper unit costs, because the port can handle larger volumes is important. This port has the potential to develop into a "cargo transhipment hub" for the area if the trend can be maintained.

A Port Master Plan would be of benefit to this port, with development objectives that include:-

- Review of the ports approach channels and capacities;
- Review of its Aids to Navigation, and their disposition and reliability;

- Review of its systems in support of Navigational Safety, including passenger services;
- Planning of the use of its land bank for sustainable port development;
- Evaluation of the market opportunities it can service;
- A review of the further efficiency gains available to it.

5.4 CONCLUSIONS – ANALYSIS FROM PORT CALL RECORDS

5.4.1 Conclusions – Analysis of Nuku'alofa Port Data

1) The Port of Nuku'alofa is the most significant Tongan port by ship-traffic volume and therefore, the marine trade hub for Tonga. The Port has made efficiency gains in all of its cargo handling segments. Bulk liquid has shown the most gain in terms of cargo volumes handled by fewer ships. The trend towards cheaper unit costs, because the port can handle larger volumes is important. This port has the potential to develop into a "cargo transhipment hub" for the area if the trend can be maintained.
2) The Port of Nuku'alofa efficiency gains are supported by its landside developments, such as cargo/container area paving and new wharf facilities. Its business model needs to develop into a Port Master Plan, supporting review of its approach channel capacities, Aids to Navigation and planning its development into a "hub port" for the area.

   In 2013, two renewable power projects (solar plants) were completed in Vava'u and Tongatapu group. Given this significant development the forecast demand for fuel transport may either decrease, or in an expanding economy, be maintained at current levels.
3) The Port of Nuku'alofa shows there is a fluctuation in cruise vessel visits, year on year. The gross tonnage of these vessels is marginally increasing, based on 2013 and 2014 data. The forecast suggests suggest that this increase will be sustained in the years to come, underpinned by the new cruise facility at Vuna wharf.
4) Although cruise vessel numbers have fluctuated from 2008 onwards, there is a clear trend to larger ships. The new cruise terminal at Vuna Wharf, Nuku'alofa, has facilitated this growth in vessel size, with visits from some of the largest cruise vessels occurring in 2014. However, central and northern parts of Tonga would have difficulty in handling large cruise vessels. The exception to this is Vava'u, where large cruise vessels anchor in shelter at the harbour entrance.

5) The number of the liquid bulk vessel visits has been slowly reducing, although freight statistics show that these vessels now carry more cargo. Thus, increasing efficiency in this industry also is apparent. There will be some fuel consumption savings realised from newly installed solar power facilities.

5.4.2 Conclusions - Domestic Coastal Vessel Information

6) There are two key passenger routes in Tonga: Nuku'alofa to the central and northern islands, and Nuku'alofa to ‘Eua. The latter route carries a surprising volume of passengers (34,500 annually), this being a passenger volume greater than the sum of all seagoing passenger routes in Tonga. The vessel ‘ONEMATO is smaller than the main ferry 'OTUANGA'OFA. A wider review of the Tongatapu-‘Eua route, including harbour facilities, would be beneficial, given a rapid expansion of passenger numbers in recent years and the size of the vessel involved.

6 INTERNATIONAL SHIPPING – AIS TRANSPONDER DATA

6.1 INTRODUCTION

This section analyses the traffic movements of SOLAS vessels carrying AIS transponders and domestic vessel movements, geocoded by the project team. It also includes yachts and fishing vessels fitted with AIS transponders. There are some plots of the traffic in this section, which are supplemented by all of the traffic plots, which are presented at **Annex B**.

6.2 DATASETS SOURCES

The principal input for the identification of shipping routes is data from the Automatic Identification System (AIS). Satellite derived AIS provided by ExactEarth for the entirety of the South Pacific has been used to complete this project. Data was analysed for the following periods:

- 1st January 2012 to 31st March 2012;
- 14th July 2013 to 30th September 2013; and
- 1st December 2013 to the 31st January 2014.

It should be noted that the 2013-2014 datasets is additional to that obtained and analysed in the Vanuatu pilot project.[49] Therefore, in total seven and a half months of AIS data was analysed that was representative of the seasonality over a number of recent years. Later data periods contained a much larger pool of Class B transponders, representing the transmissions from yachts, recreational craft and some fishing vessels.

Satellite AIS data requires frequent satellite sweeps and so there can be an interval between received reports of up to 6 hours. To overcome this limitation, it was necessary to undertake post-processing to augment the AIS data, with port visit records taken from in country data gathering. Marico Marine report for the Vanuatu risk hydrographic assessment (12NZ246, 2013) detailed the full methodology, and its inherent limitations, that were

[49] It should also be noted that the exactEarth algorithms were updated to "EV1" in late 2012. This significantly increased the amount of data that could be collected by the satellite constellation as well as increasing the proportion of Class B AIS messages. There was therefore a noticeable improvement in both the amount and quality of supplementary data that was used in this study.

employed to process the AIS data into useful vessel tracks. The methodology has been published in full by LINZ.

6.3 ANALYSIS BY VESSELTYPE

Figure 25 shows all vessel tracks recorded during the study periods and a density plot is created in Figure 26 that highlights the dominant routes. Track density highlights areas where traffic is the greatest by number, as well as showing routes.

Tonga consists of two main ports located on Tongatapu and Vava'u, with a considerable movement of mainly domestic traffic moving between them. International trade that calls in Tonga also focuses on these two traffic centres. In Tongatapu, the larger of the two ports, traffic is shown to spread in all directions including to New Zealand, Vanuatu, Fiji, Southern Cooks and Samoa. Vava'u has far fewer destinations for international traffic but a number of vessels are shown transiting to Fiji, Niue and further afield.

Ha'apai has lower traffic levels, with its main port, Pangai (Island of Lifuka) being visited overwhelmingly by domestic coastal vessels only. However, Ha'apai Group would benefit most from charting upgrades, which would bring international vessels into these waters.

The greatest proportion of international traffic (SOLAS) is traffic transiting straight through Tongan waters and several routes are immediately evident. In the northern section of the Tongan EEZ are two traffic routes between Fiji and Samoa, and Fiji and Tahiti. In the central and southern sections of Tonga, traffic passes to the north of Vava'u and to the south of Tongatapu whilst transiting from west to east across the EEZ.

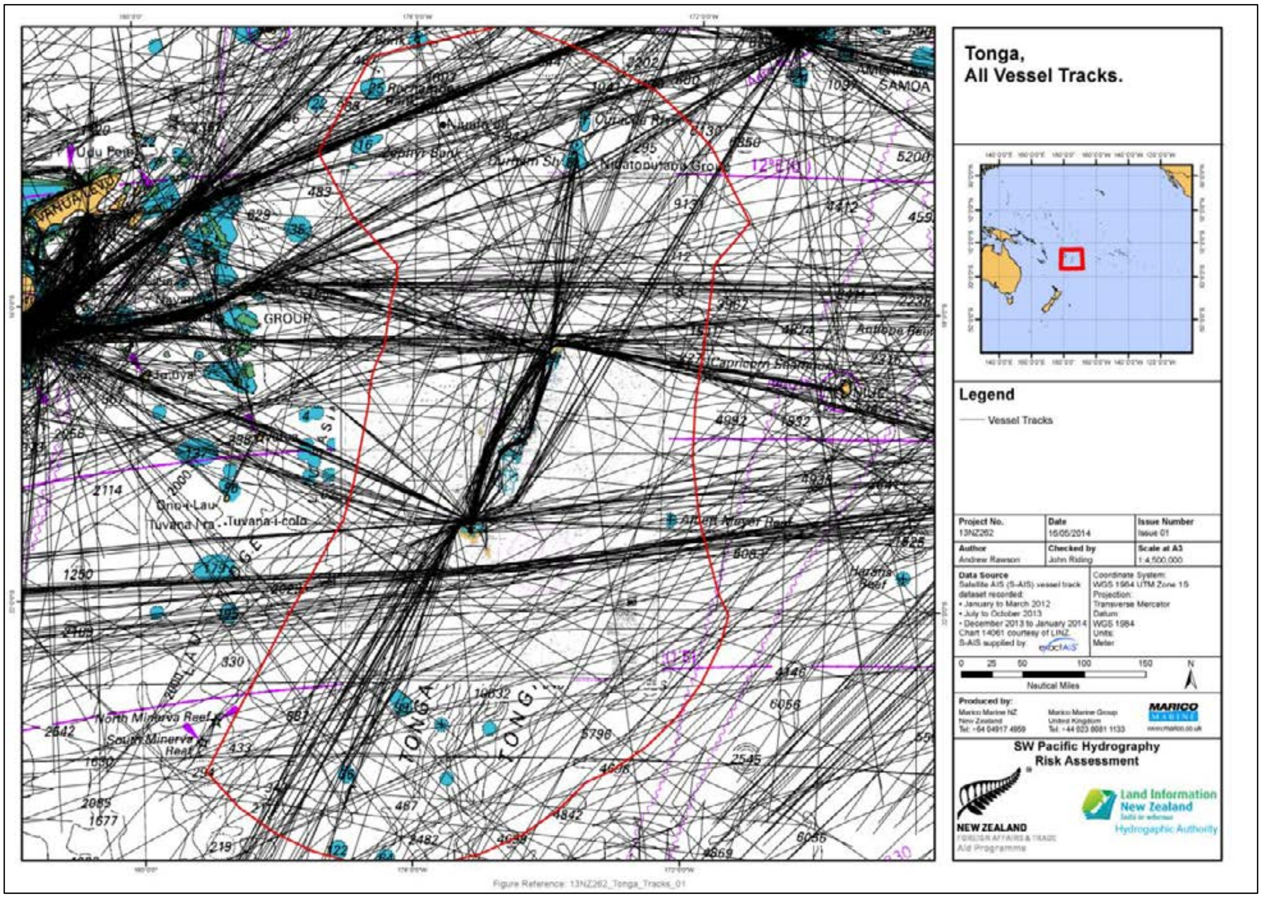


Figure 25: All Vessel Tracks

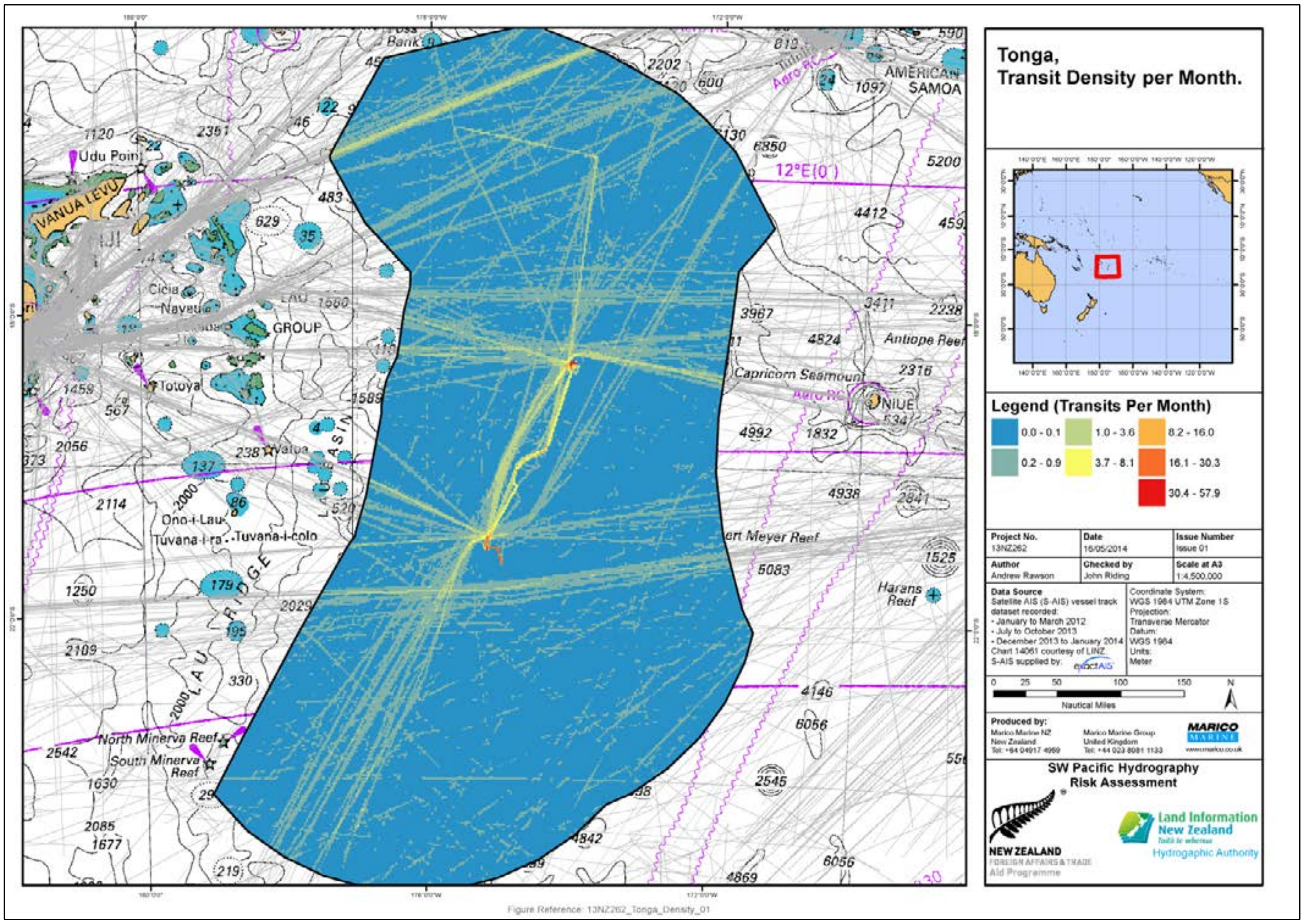


Figure 26: Transit Density Per Month

Figure 26 shows the routes where the traffic density levels are high.

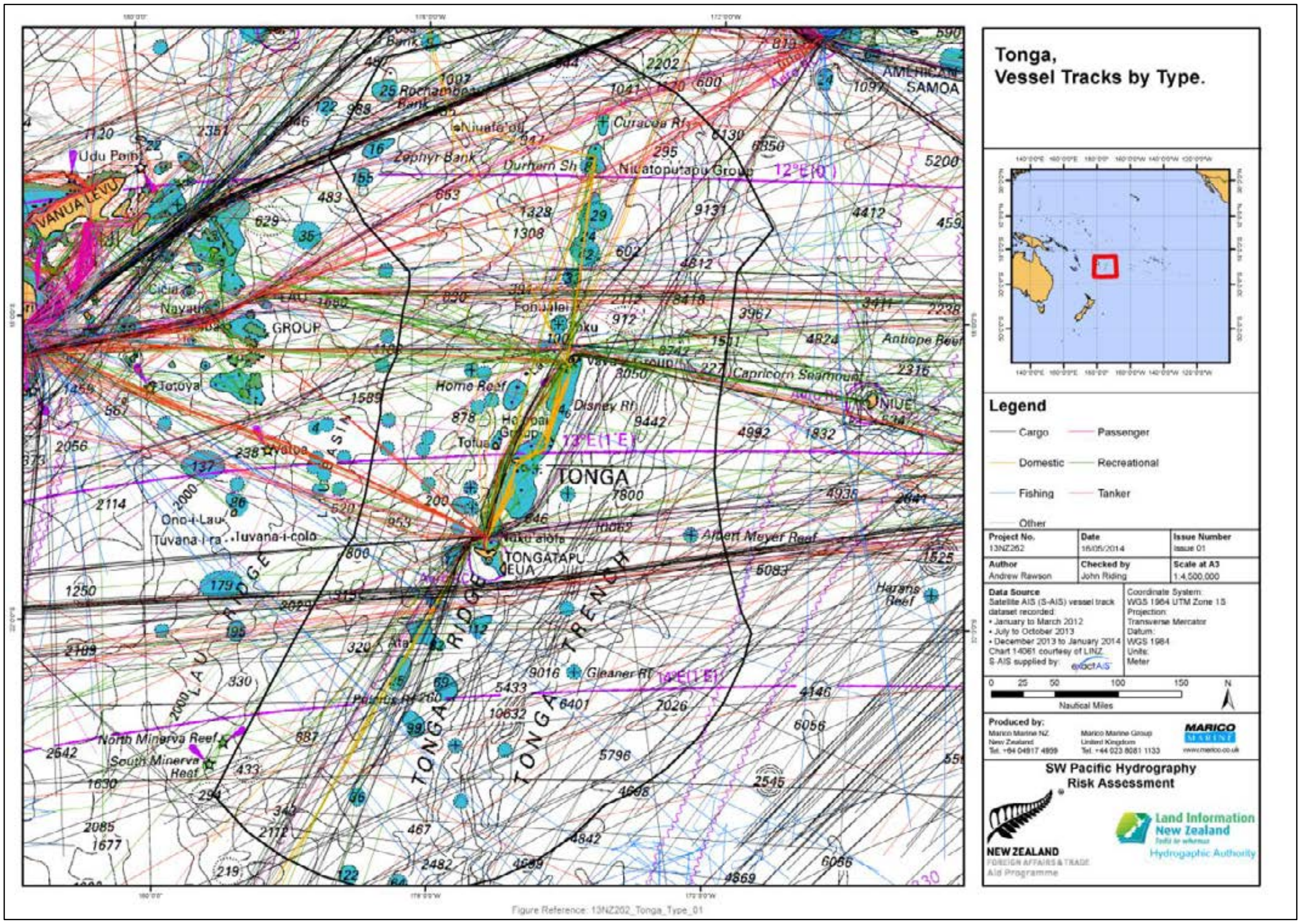


Figure 27: All Vessel Tracks by Type

Figure 27, expanded in Figure 28 to Figure 33, show the tracks of all vessels by vessel type. Each vessel was classified into one of seven categories:

- Dry cargo (bulk, container, reefer, Ro-Ro etc.);
- Liquid tankers (oil, chemical, gas etc.);
- Passenger vessels (cruise vessels);
- Domestic traders (passenger and cargo);
- Recreational craft (sailing yachts, motor yachts and tall ships);
- Fishing vessels (commercial fishing vessels and trawlers); and
- All others.

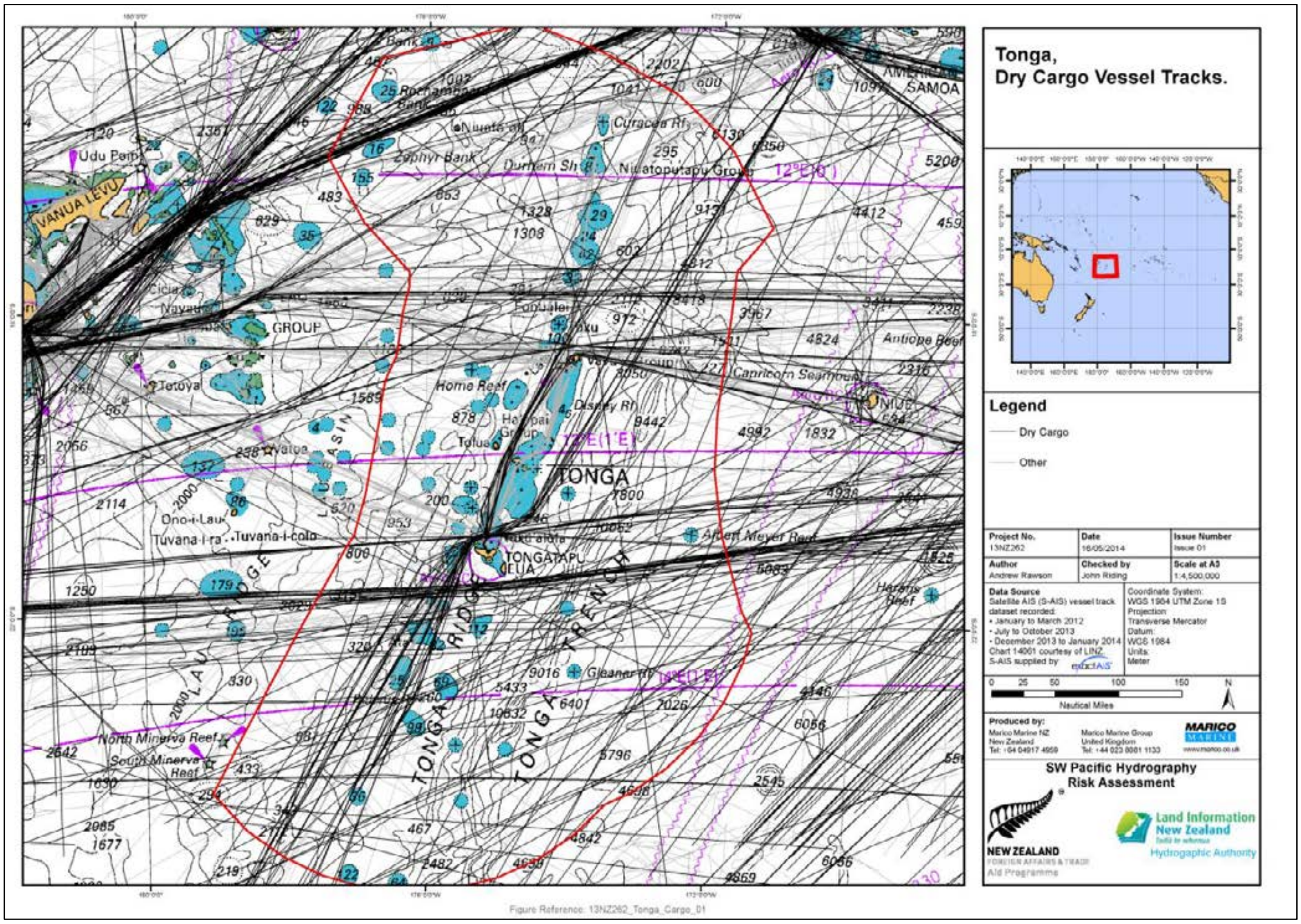


Figure 28: Dry Cargo Vessel Tracks

Figure 28 shows the movements of all dry cargo vessels Tonga. 100 unique cargo vessels were recorded inside the EEZ during the analysis periods. A number of large Panamax sized vessels (<100,000 GT) were recorded transiting the EEZ. However these were transiting well clear of any of the islands. Those cargo vessels that called into Tongan ports are of a smaller size, the largest recorded was the *PACIFIC ISLANDER II*, a ro-ro and cargo vessel of 17,134 GT. This is a regular caller to Nuku'alofa.

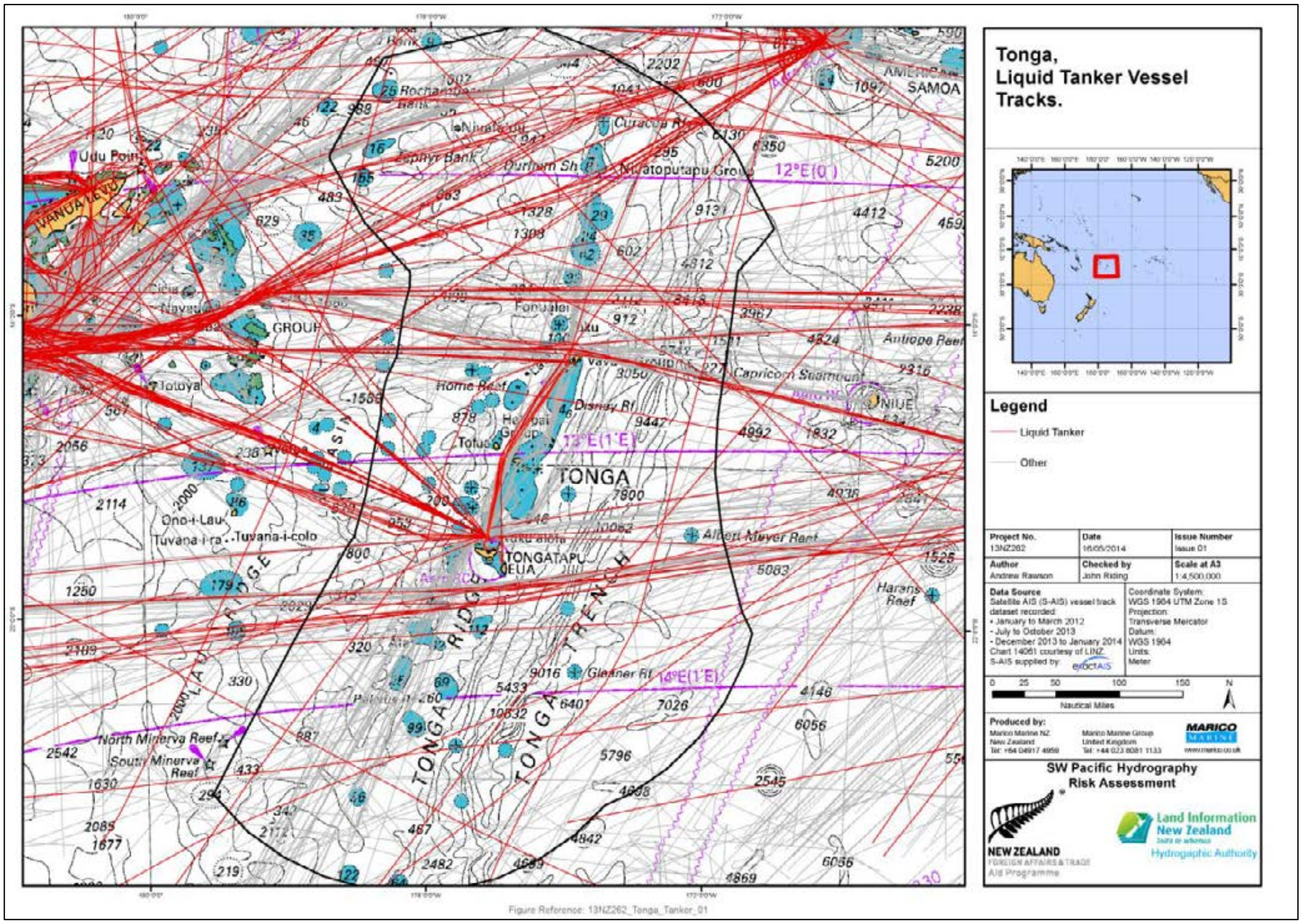


Figure 29: Liquid Bulk Vessel (Tanker) Tracks

The movements of bulk liquid vessels (tankers) are shown in Figure 29. Only a low number of tankers were recorded, with only 35 unique vessels. Whilst two Suezmax size vessels were recorded transiting the EEZ (average 81,000 GT), the RIO CARONI and the SUEZ FUZEYYA, they were well clear of the islands. Only small tankers of less than 3,000 GT are recorded making regular visits to either of the two ports in Tonga. There is, however some interisland tanker traffic, linking Nukualofa to Vava'u and 'Eua. This traffic is regular in nature, with 'Eua receiving a fuel shipment on average once in eight weeks.

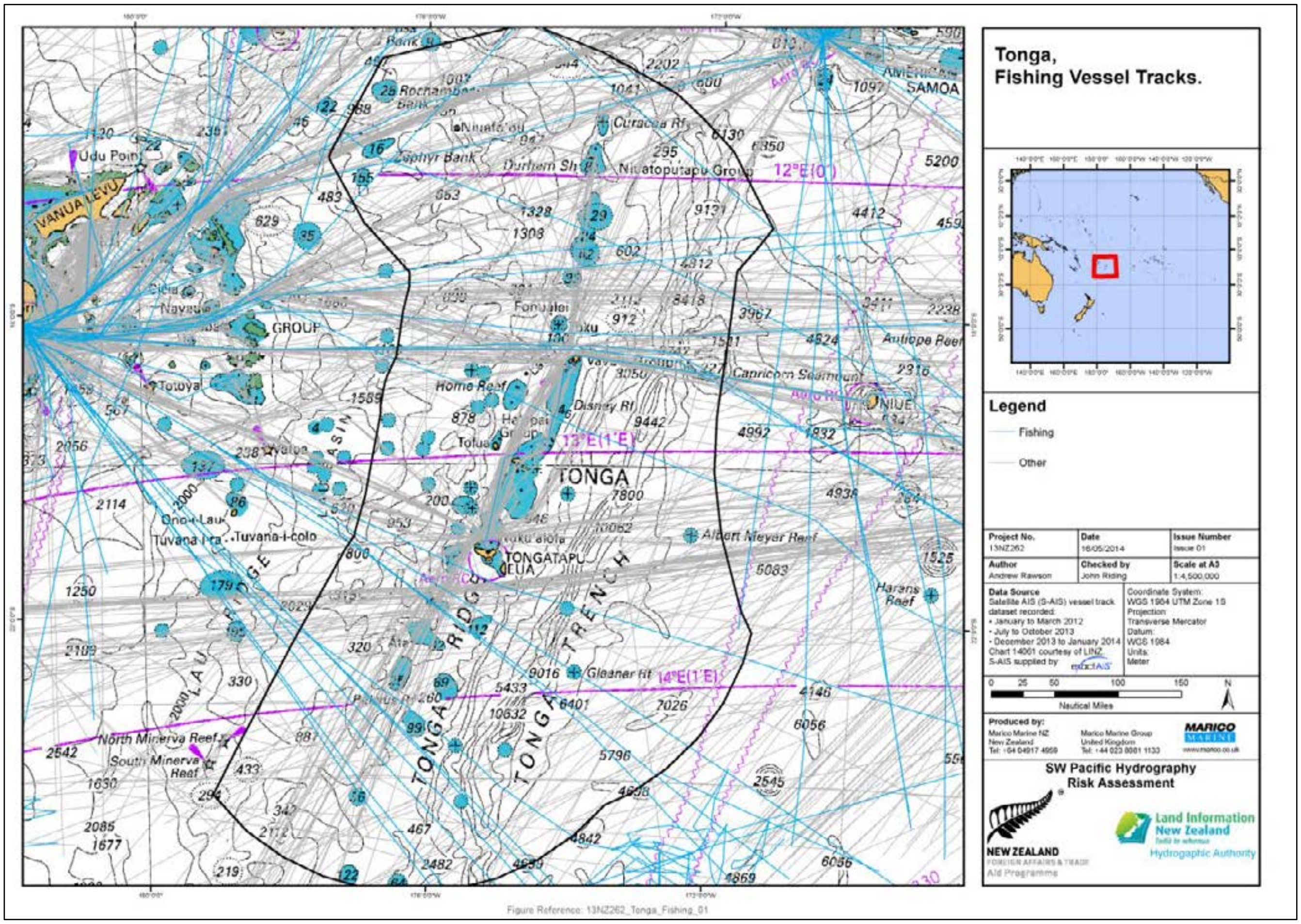


Figure 30: Fishing Vessel Tracks

Figure 30 shows fishing vessel tracks from those vessels fitted with AIS transponders within the Tongan EEZ. Commercial fishing vessels mainly transit straight through to the North and South of Tonga, although a considerable number take the passage between Tongatapu and Vava'u.

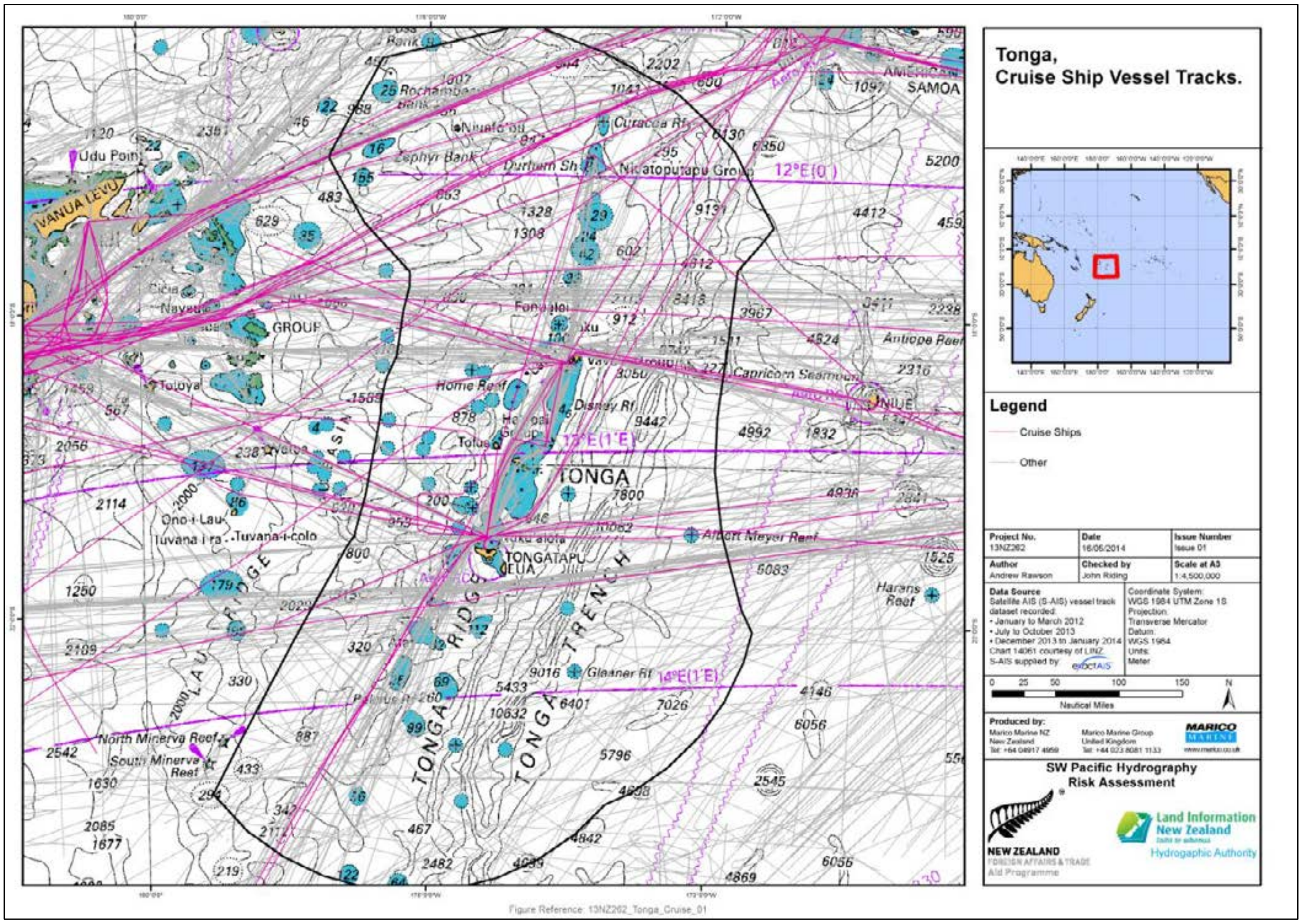


Figure 31: Cruise Vessel Tracks

Figure 31 shows the tracks of all cruise ships recorded within Tonga. The majority of cruise vessels visiting Tonga are transited either from Fiji Islands, eastbound, or Australia and New Zealand, northbound. The Port of Nuku'alofa and Neiafu Harbour are identified as the main locations with the higher cruise traffic density, although Neiafu has lower call numbers than Nuku'alofa. There is evidence that larger cruise vessels are arriving into Tonga. Other occasional destinations include the Niuas, and Ha'apai. In the Ha'apai Group of islands (Tofua and Lifuka Island) transits were augmented based on domestic local records of arrivals[50]. The use of this data in some cases allowed the actual tracks of the visiting vessels taken to be added to the data set, as they were outside of the period of the data supplied.

50 A domestic shipping agency has confirmed the transit of cruise vessel through Tofua and Ha'apai Group.

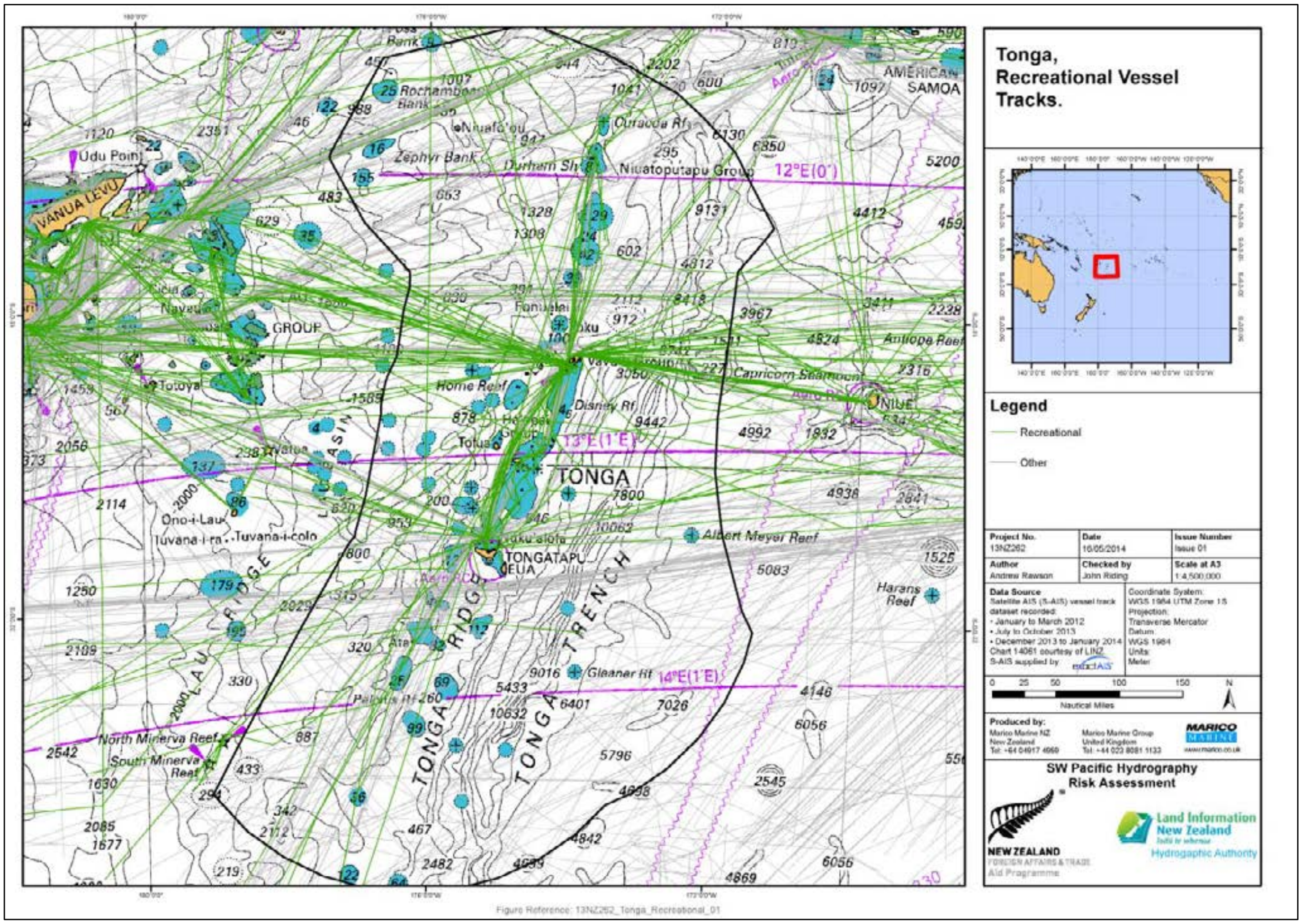


Figure 32: Recreational Vessel Tracks

Recreational vessel tracks are shown in Figure 32. There are a surprising number of recreational vessels (international yachts and cruisers) active in or passing into Tongan waters. A large proportion of these transit into Vava'u harbour, a popular and pristine destination. It appears normal for a recreational vessel to remain in Vava'u for a period of weeks.

Other popular locations for recreational vessels are Lifuka Island, Ha'apai and the Port of Nuku'alofa.

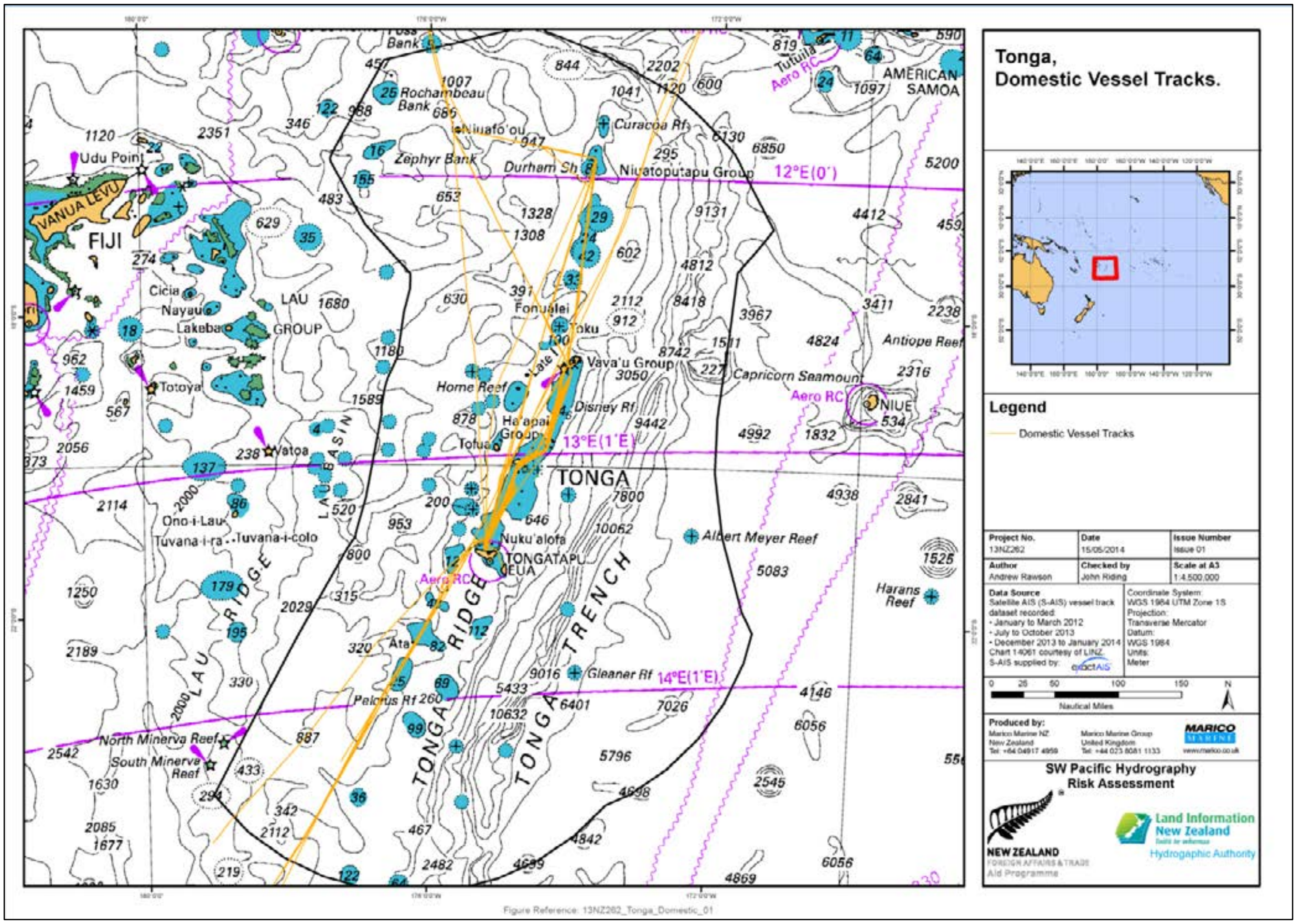


Figure 33: Domestic Vessel Tracks

Figure 33 shows the routes that domestic vessels take in Tonga. Domestic vessels are those vessels that fulfil a regular inter-island passenger or cargo service. These vessels are generally of a smaller size and would not often be equipped with AIS. In the case of Tonga, three vessels are carrying AIS transponders and these are OTU'ONGA OFA, ONEMATO, and ST THERESA, a domestic general cargo ship that has been on a regular service between Nuku'alofa and Auckland. In the aftermath of cyclone Ian this vessel was assigned to transport emergency and relief supplies from Nuku'alofa to Ha'apai. For those which are not carrying AIS, vessel tracks have been augmented on the GIS, from the local records provided by the Port of Nuku'alofa, or in the case of other ports, by the Ministry of Infrastructure, Marine and Ports Division.

6.4 ANALYSIS BY VESSEL CHARACTERISTIC

Further analysis was undertaken based on the characteristics of vessels transiting through Tongan waters. Density grids[51] were produced as to identify the highest characteristic concentrations by area.

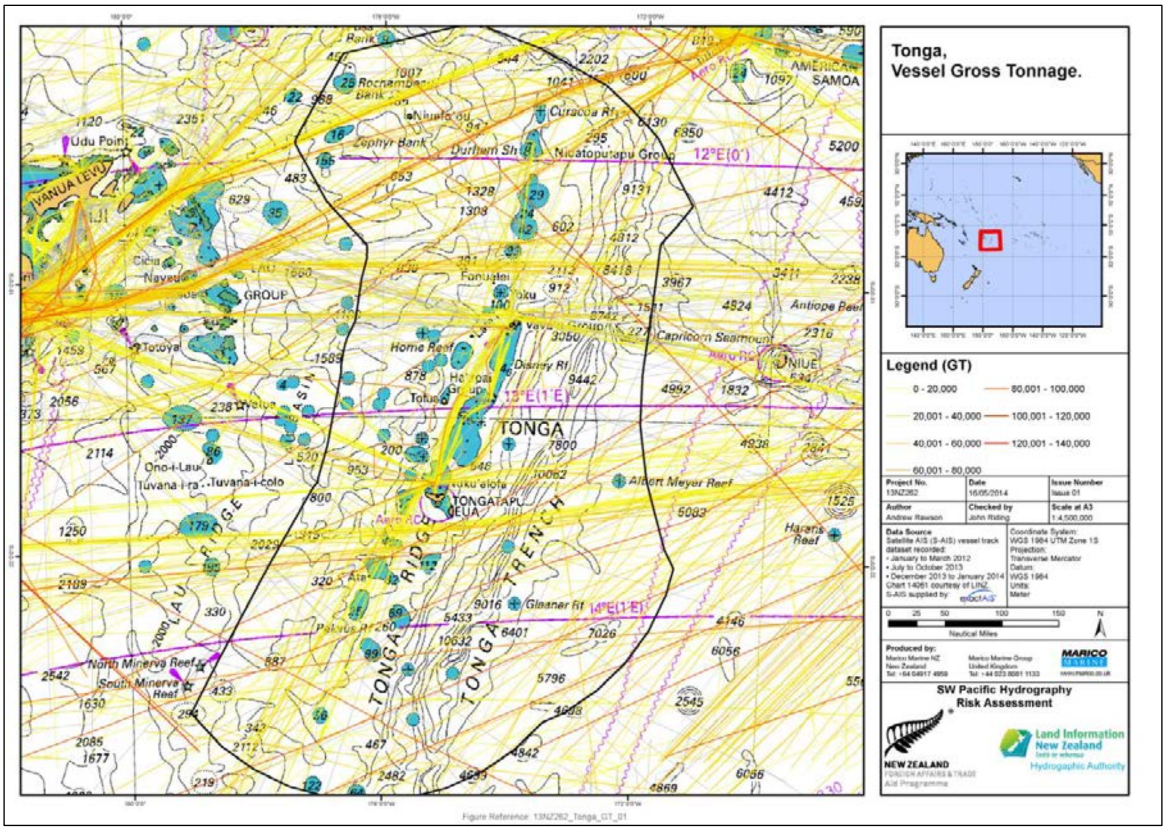


Figure 34: Vessel tracks by Gross Tonnage.

Figure 34 shows the spatial distribution of vessels in terms of Gross Tonnage. It is becoming apparent that Port of Nuku'alofa concentrates the highest cargo and passenger capacity. Interestingly, large cruise vessel transits are identifiable among popular island groups.

[51] Each grid square is a nautical mile.

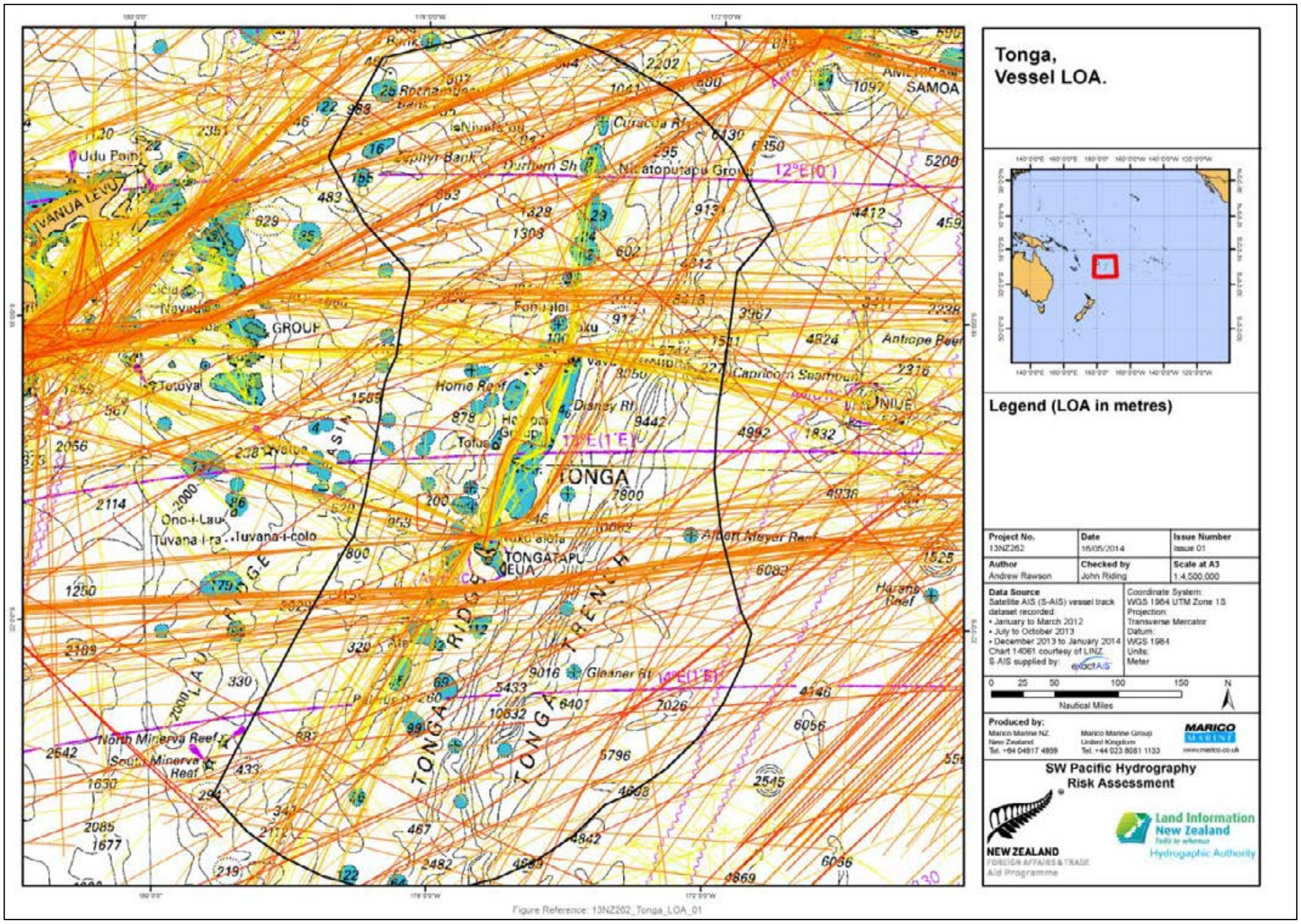


Figure 35: Vessel Tracks by Length

Figure 35 and Figure 36 show the tracks differentiated by their length and draught respectively. It is apparent that the largest vessels transit to the north and south of Tonga.

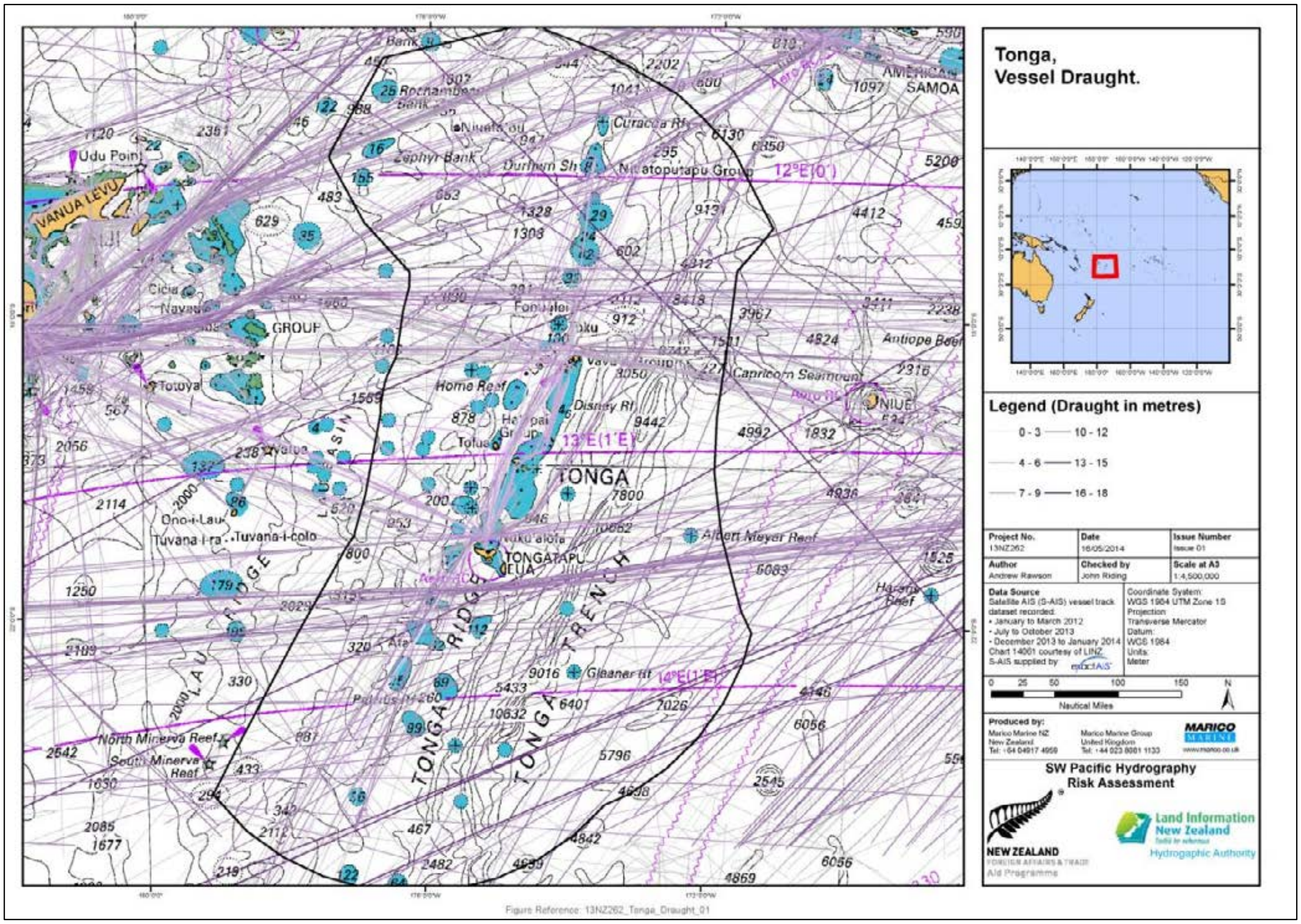


Figure 36: Vessel Tracks by Draught

6.5 CONCLUSIONS – INTERNATIONAL VESSEL TRAFFIC ANALYSIS

1) Nuku'alofa is the most significant port by ship traffic-volume. It has a relatively steady trade in container imports and exports.
2) SOLAS multipurpose vessels visit the Port of Nuku'alofa, whilst smaller feeder container vessels call at Pangai (Ha'apai) and Neiafu (Vava'u) harbours. These vessels represent the Pacific trade route connecting the major Pacific ports with Australia and New Zealand. The multipurpose vessels calling at Nuku'alofa represent the Pacific-Asian trade route with linkages to Singapore and Japan.
3) The Port of Nuku'alofa has potential to take advantage of these trade routes and develop into a transhipment hub in the South West Pacific region. This could offer substantial capital and operating cost advantages for the harbour as well as economic

prosperity. Further maritime safety improvements would allow larger vessels to access the port safely.

4) Vava'u is a premier destination for international yachts. A number of yacht charter providers also operate at Neiafu Harbour, with other waterborne tourism activities supported by such visitors.

5) Although Ha'apai has been affected by a recent cyclone, it is likely to attract cruise vessels once a charting upgrade has occurred. Some are already visiting. Transit risk levels already support the need for charting review.

7 RISK ANALYSIS RESULT

7.1 INTRODUCTION

This section presents the result overlays for every group island of Tonga, as well as for the Tongan EEZ overall. It highlights the areas that decision makers need to consider for charting improvements and other mitigations, from a risk perspective. It should be noted that the risk results should be considered in conjunction with the Cost Benefit Analysis results, as both provide complementary information for decision makers to consider.

The initial risk assessment output needed to be re-iterated for Ha'apai, where vessel traffic volume is low, in order to ensure an accurate result. Details of this are recorded in the Ha'apai results part of this document, Section 7.5.

Conclusions and Recommendations for this part of the report are presented in Section 10.1.

7.2 RISK MATRIX AND TRAFFIC

The derived risk matrix used in the GIS overlay analysis is shown in Figure 37, which is the same as that used for the other studies of this series. The risk derived is a combination of traffic, likelihood criteria and consequence criteria. This is the key feature of the methodology, as the model depends on the presence of shipping traffic for there to be a risk.

In the risk assessment, the traffic type, size and volume are evaluated by a grid of geographic cells in the GIS. The traffic profile (ship type, size and density in relation to the grid) then influences the risk levels associated with each of the 31 criteria. The criteria are each held on a separate layer in the GIS.

The matrix also shows the influence each of the GIS overlays have on the risk results, **Figure 37**. Review of the matrix shows the emphasis placed on chart quality within the risk assessment, measured in the risk assessment by the CATZOC M_QUAL attribute recorded by LINZ as metadata to their charts. The CATZOC system was also used to determine the available risk reduction from chart improvements from a lower ZOC rating to a higher one. The CATZOC system is explained at the beginning of this report. Plots of Tongan Island

Groups, showing the ZOC ratings as interpreted for potential risk contribution, for each of the key sea areas surrounding Tongan Groups, are presented at **Annex C.**

Figure 37: Risk Matrix for Tonga

		Risk Scores 0	1	2	3	4	5	Weightings Factor	Category	TotalModel
			Increasing Risk ----------------->							
Traffic	Vessel Traffic									
	Potential Loss of Life		Insignificant	Low	Moderate	High	Catastrophic			0.5000
	Pollution Potential		Insignificant	Low	Moderate	High	Castastrophic			0.5000
Likelihood Risk Criteria	MetOcean Conditions									
	Prevailing Conditions Exposure		Sheltered at most times	Mainly Sheltered	Moderate Exposure	Mainly Exposed	Exposed on most days	3	0.3	0.1500
	Spring Mean Current Speed	Open Sea (insignificant)	1-2 knots	2-3 knots	3-4 knots	>5 knots	>5 knots	2		0.1000
	Visibility	Unknown	Poor Visibility Very Unlikely	Poor Visibility Unlikely	Occasional Poor Visibility	Often Poor Visibility	Poor Visibility Common	1		0.0500
	Navigational Complexity									
	Type of Navigation Required		Open Sea >10nm	Offshore Navigation (5-10nm)	Coastal Navigation (1-5nm)	Port Approaches	Constrained Navigation (Within 1nm)	3	0.15	0.1500
	Aids to Navigation									
	ChartZoc		A	B	C	D	U	3	0.3	0.1800
	Proximity to Non Working AToNs	No Lights	100% effective range	80% effective range	70% effective range	60% effective range	Within 50% effective range	2		0.1200
	Bathymetry									
	Depth of Water 15m Contour	>10nm	5-10nm	2.5-5nm	1.5 to 2.5nm	1 to 1.5nm	Within 1nm	3	0.1	0.0600
	Bottom Type		Soft				Hard/Rocky	2		0.0400
	Navigational Hazards									
	Proximity to Known Reefs	>10nm	5-10nm	2.5-5nm	1.5 to 2.5nm	1 to 1.5nm	Within 1nm	2	0.15	0.0333
	Proximity to Volcano	>10nm	5-10nm	2.5-5nm	1.5 to 2.5nm	1 to 1.5nm	Within 1nm	2		0.0333
	Proximity to Known SeaMounts	>10nm	5-10nm	2.5-5nm	1.5 to 2.5nm	1 to 1.5nm	Within 1nm	1		0.0167
	Proximity to WW2 Military Sites	>2.5nm	2-2.5nm	1.5-2nm	1-1.5nm	500m-1nm	Within 500m	1		0.0167
	Proximity to Charted Tidal Hazard (Overfalls/Race)	>2.5nm	2-2.5nm	1.5-2nm	1-1.5nm	500m-1nm	Within 500m	3		0.0500
Consequence Risk Criteria	Environmental Impact									
	Proximity to Large Reef (High Quality / or Isolated Shoreline	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3	0.5	0.0789
	Proximity to Key Offshore Reef	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0526
	Proximity to Large Wetlands Resource (Mangroves) (Large Volume or Small Volume)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.0789
	Proximity Small Wetlands Resource (Mangroves) (Large Volume or Small Volume)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0526
	Proximity to Important Breeding Grounds	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.0789
	Proximity to World Biological Protected Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.0789
	Proximity to Regional Biological Protected Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0526
	Proximity to Local Biological Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1		0.0263
	Culturally Sensitive Areas									
	Proximity to World Cultural Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3	0.15	0.0750
	Proximity to Regional Cultural Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0500
	Proximity to Local Cultural Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1		0.0250
	Economically Sensitive Areas									
	Proximity to Sites of High Economic Contribution	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3	0.35	0.1000
	Proximity to Sites of Moderate Economic Contribution	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1		0.0333
	Proximity to Key Infrastructure (Ports)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.1000
	Proximity to Tourist Diving Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1.5		0.0500
	Cruise Ship Stops	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0667

7.3 TONGA HYDROGRAPHIC RISK – OVERALL

The overall comparative risk result is shown in Figure 38, with a plot identifying the key risk areas is shown at Figure 39. The following areas that have significant or heightened risk level are:

- Nuku'alofa Harbour and approaches.
- Piha Passage and coastal transit to 'Eua.
- Nafanua Harbour, 'Eua.
- Lifuka Island and Pangai Harbour, Ha'apai.
- Ha'afeva Island, Ha'apai.
- Ha'ano Island, Ha'apai.
- Foa Island, Ha'apai.
- Vava'u Island and Neiafu Harbour.
- Sea area South of Kapa Island, Vava'u.
- Passage between Fofoa Island and Ovaka Island, Vava'u.
- Sea area between 'Euakafa Island and Richards Patches, Vava'u.

These areas should be reviewed alongside the cost benefit analysis results, because significant risk in some areas will arise from traffic volume, especially passengers. The cost benefit result takes account of the available further risk reduction from charting upgrades. Analogous to the significant risk results of Tongatapu Island, Vava'u also shows an area of significant risk in the sea area South of Kapa Island. In Ha'apai, there is heightened risk at the northern west coast of Foa Island which extends to the south along the coastline of Lifuka Island. Both risk areas in Vava'u and Ha'apai are associated with the domestic ferry transiting past it and environmentally important sites.

Niuatoputapu harbour entrance has provided a low hydrographic risk result, which is related to the low number of domestic vessels visits and the vessel capacity on the trading route. However, it is a significant inherent risk of this entrance that encompasses a ferry grounding or loss, involving significant consequence to Tongan domestic coastal trade.

7.3.1 Decision Making Criteria

If a recommended criterion to review areas that evince moderate risk and act on areas that show heightened or significant risk is accepted, it is possible in broad terms to specify recommended areas for either charting/AToN review or hydrographic survey for chart upgrade.

In a number of areas providing a heightened risk result, charting may have been updated because past expert judgement had recommended this. In such areas it is appropriate to confirm charting is adequate and that aids to navigation and channel use remain appropriate. However, the cost benefit information is critical to this decision. If there is risk, combined with a net present value (as opposed to a net present loss) to upgrade or reorganise charting, decision-making becomes well informed.

This following part of this section presents, in more detail, the hydrographic risk for each region.

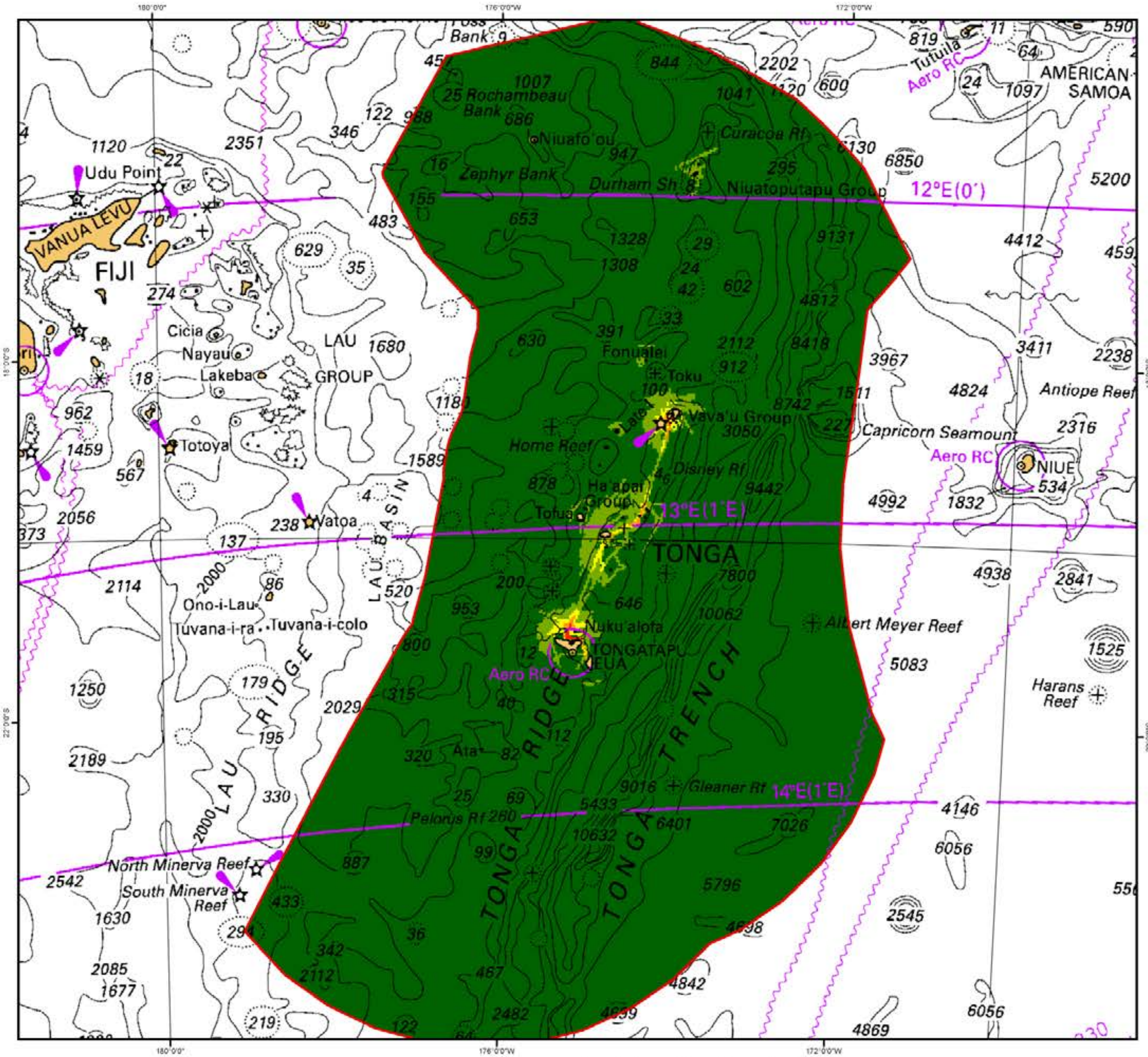
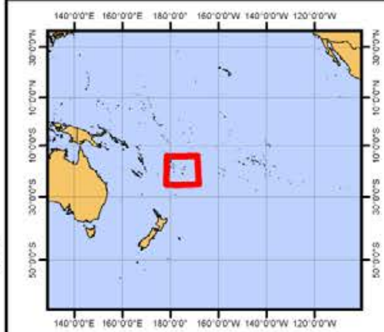


Figure Reference: 13NZ262_Tonga_RiskModel1_02

Figure 38: Tonga Risk Model Results



Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 02
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:4,500,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 25 50 100 150 Nautical Miles N

Produced by:
Marico Marine NZ, New Zealand, Tel: +64 04917 4959
Marico Marine Group, United Kingdom, Tel: +44 023 8081 1133
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Land Information New Zealand Toitū te whenua Hydrographic Authority

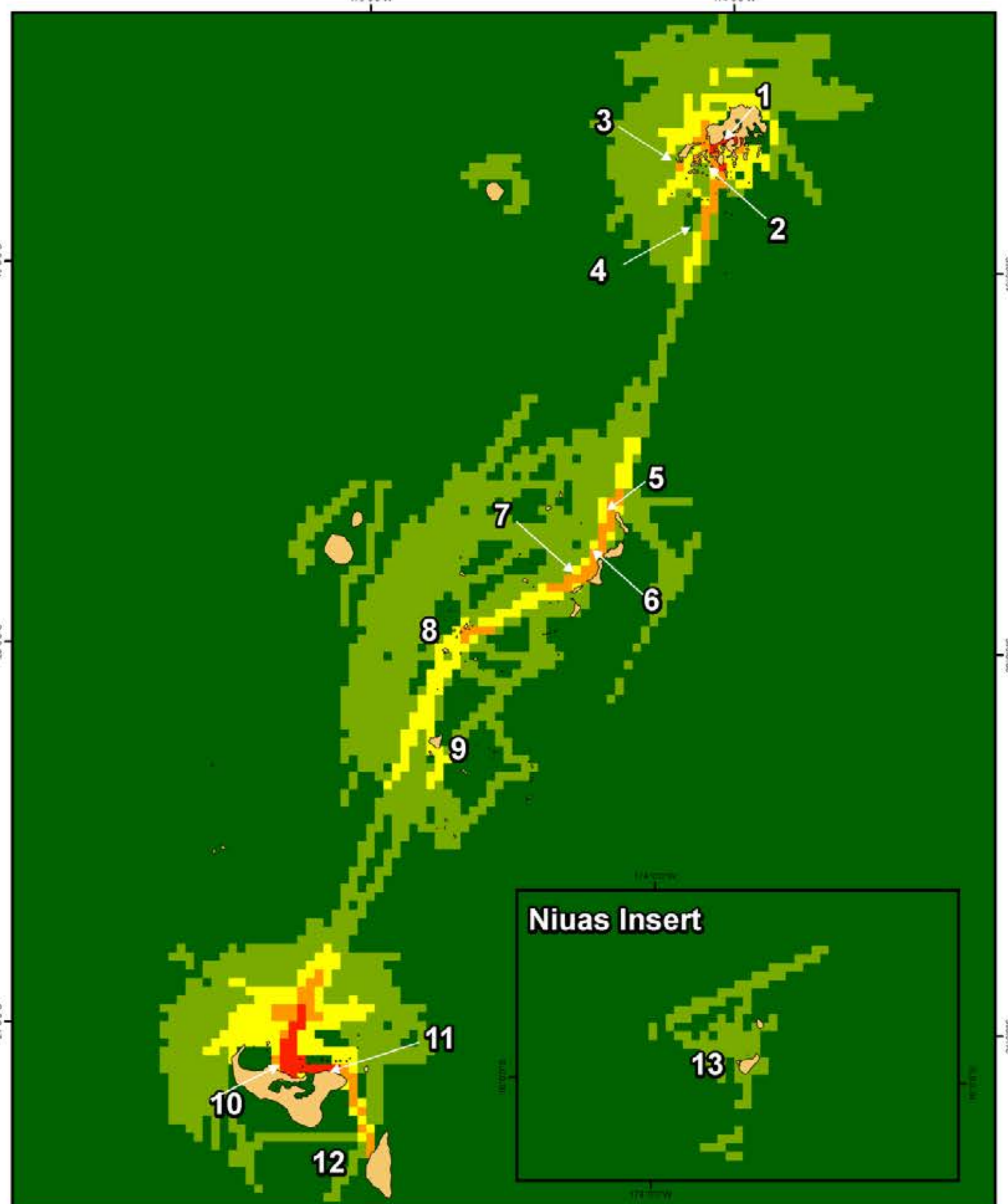
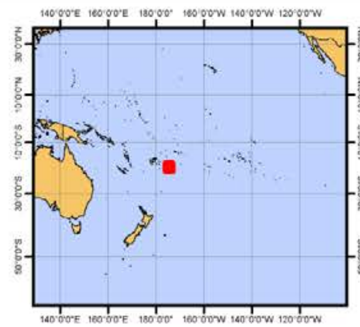


Figure Reference: 13NZ262_Tonga_RiskModel16_01

1	Vava'u Island and Neiafu Harbour
2	Sea area South of Kapa Island
3	Passage between Fofoa Island and Ovaka Island
4	Sea area between 'Euakafa Island and Richards Patches
5	Ha'ano Island
6	Foa Island
7	Lifuka Island and Pangai Harbour
8	Ha'afeva Island
9	Nomuka Island
10	Nuku'alofa Harbour and approaches
11	Piha Passage and coastal transit to 'Eua
12	Nafanua Harbour
13	Niuatoputapu Harbour Entrance

Figure 39: Tonga Risk Results Showing Key Areas of Risk



Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	01/10/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:1,250,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
• January to March 2012
• July to October 2013
• December 2013 to January 2014
Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System:
WGS 1984 UTM Zone 1S
Projection:
Transverse Mercator
Datum:
WGS 1984
Units:
Meter

0 5 10 20 30
Nautical Miles

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Land Information New Zealand
Toitū te whenua
Hydrographic Authority

7.4 TONGA HYDROGRAPHIC RISK - TONGATAPU AND ‘EUA ISLANDS

Tongatapu provides an interesting result, which is driven by the high volume of both international and domestic coastal vessels, combined with key marine reserves and mangroves at the Nuku’alofa harbour approaches and Piha Passage. The harbour approaches provide a widespread area of moderate risk, including marine reserve locations, with heightened levels in the entrance channels. An area of significant risk is located in the central part of the harbour. This risk is partly because the CATZOC A rating (highest) for the harbour is focused around the main entrance channel, surrounded by CATZOC B areas. Yet a considerable portion of the traffic, especially domestic coastal vessels, accesses the harbour by means other than the main surveyed channel. The risk result is also influenced by a relatively large number of marine reserves in the approaches and transits through this important harbour.

Heightened risk levels also extend out intermittently to ‘Eua. These are mainly influenced by the scheduled domestic coastal passenger ferry service, which has a focussed route and is always busy with passengers and cargo. Piha Passage also skirts marine reserves. The risk result is, in part, also the result of the liquid bulk transits. These vessels transit between Nuku’alofa and Nafanua Harbours, also using Phia Passage (which is logical). The tanker discharges fuel into the surf connection on the north western coastline of ‘Eua (see Section 4.2.3).

Risk levels in this area are precise, as both the ferry and the tanker carry AIS transponders and transit routes are therefore accurately known. The 6-8 week frequency of the liquid bulk transits meant that tracks had to be searched for in the wider S-AIS database and added to the risk dataset.

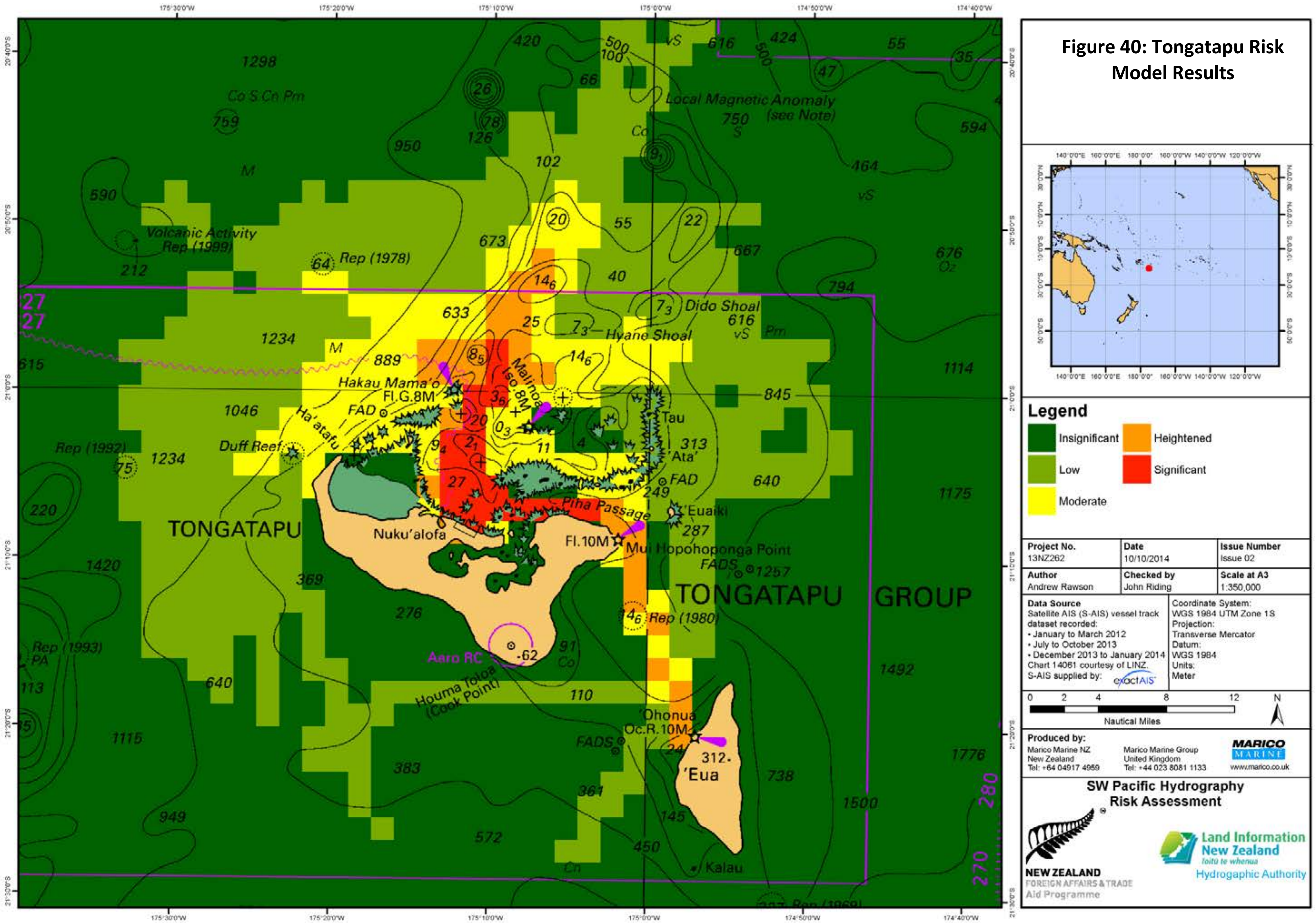


Figure 40: Tongatapu Risk Model Results

Figure Reference: 13NZ262_Tonga_RiskModel7_02

7.5 TONGA HYDROGRAPHIC RISK – HA'APAI

7.5.1 Reviewing Risk Accuracy

The Ha'apai risk result needed careful review, because of its unique charting problem and traffic levels. Apart from occasional visits by specialist "boutique" cruise vessels, the waters of Ha'apai are overwhelmingly used only by domestic coastal vessels. As hydrographic risk is related to vessel traffic, these waters do not show a significant risk level. However it does not mean that the risk to an individual vessel of using these waters is not important; it is. The charts in Fathoms are on an undetermined datum, which means it is not possible to produce ENCs without new surveys. This produces a high inherent risk to a vessel wishing to transit these waters. The only way to explore this risk in a Hydrographic Risk model (where low traffic = low risk) is to add representative traffic tracks in a Traffic Prediction. This is done in **Section 9** of this report. However prior to this, the initial risk result for Ha'apai was reviewed to ensure it was accurate in relation to the traffic presently using Ha'apai.

Two areas were considered further; the fact that the ferry 'OTUANGA'OFA carries an increased passenger complement during high season (November to February); and the fact that fuel oil for use ashore for power generation is reportedly transported in the bunker tanks of the cargo vessel SITKA and the ferry. If this did not occur, other vessel transits would be likely to provide the trade. Thus, equivalent transits were added to the risk model as follows.

1) As the passenger complement increase was 200 persons, an additional equivalent track of a passenger vessel with 200 passenger capacity was added weekly through the normal ferry route in Ha'apai. These tracks were added as complete round voyages between Nuku'alofa and Vava'u.
2) The additional volume of oils in transit was accounted for by adding an equivalent tanker of the size visiting 'Eua through the waters of Ha'apai every eight weeks. That is the same frequency that the tanker visits 'Eua.

7.5.2 Ha'apai Result

The results for Ha'apai, as presented, include the review that added traffic equivalents to the risk model. **Figure 41** shows the hydrographic risk result of Ha'apai Group. There is an extended area of heightened risk along the coastline of the main islands in the Ha'apai Group, surrounded by moderate risk. The heightened level of hydrographic risk result is fundamentally driven by the size and relatively low frequency of the ship traffic using these waters ('OTU ANGA'OFA makes an average once per week transit).

The lack of other traffic through the waters of Ha'apai is likely a result of the uncertain nature of the charting. This is interesting, as the heightened result is driven partly by the pristine and abundant nature of the Ha'apai sea area, with a large number of turtle breeding grounds, together with both formal and informal reserves. The traffic component of the risk is, of course, the other major contributor although the poor charting standard is the final important influence. It is inadequate charting which provides a significant inherent risk for a single vessel transit. The hydrographic risk ranking limited to heightened is because of the relatively low level of traffic.

Ha'ano Island is mainly influenced by domestic coastal vessels navigating close inshore with a number of breaking reefs and tidal hazards. Likewise, Foa Island is a cruise anchorage located close to a holiday resort that is also visited by cruise passengers. Ha'afeva Island is a key area of environmental importance.

Pangai Harbour, Lifuka Island, extends the area of heightened risk due to the relative concentration of traffic (there were an increased number of relief supply vessels after Cyclone Ian). The south west coast of Lifuka Island is a shipping lane with unreliable AtoNs.

Nomuka Island depicts a moderate risk, which is reflecting the importance of the Fish Habitat Reserve, the corals and turtle breeding grounds.

There is considerable interest from cruise stakeholders in opening up further destinations in Tonga and the in-country data gathering exercise determined that small cruise vessels were already visiting at least one of the resort areas in Ha'apai annually and the island of Tofua, has also become a regular location.

It is a clear conclusion of this study that an increase in traffic levels through Ha'apai, or even access by large cruise vessels, would produce a risk result showing a much wider area of heightened risk, as well as potentially significant risk. Decision-makers should be guided accordingly and taken note of the CBA results. This is explained further in Sections 8 and 9.

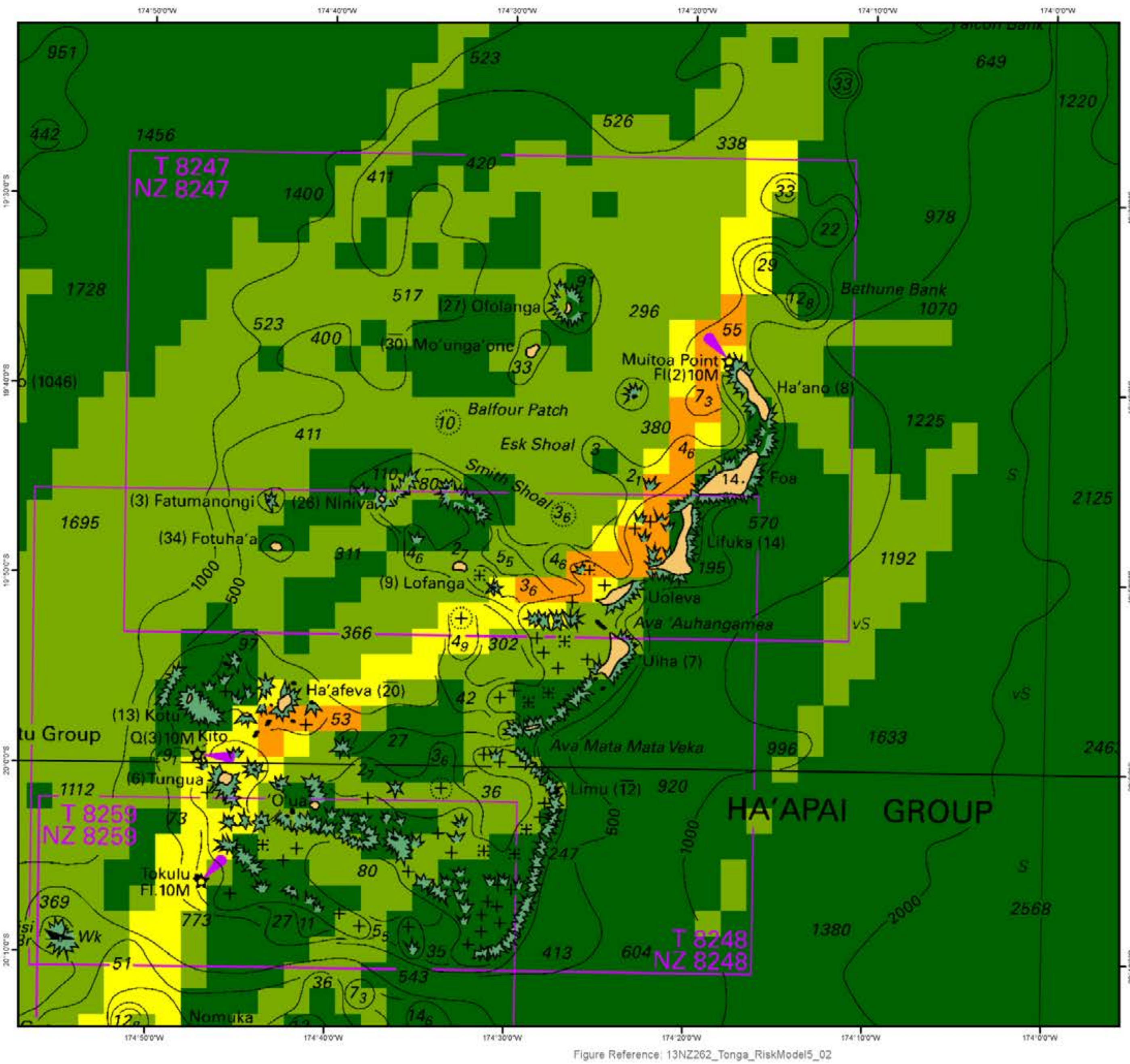
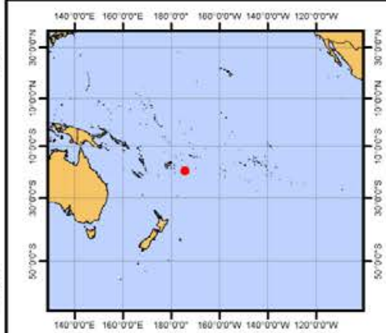


Figure 41: Ha'apai Group Risk Model Results



Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 02
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:350,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 2 4 8 12 Nautical Miles

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Land Information New Zealand Toitū te whenua Hydrographic Authority

7.6 TONGA HYDROGRAPHIC RISK- VAVA'U

The hydrographic risk profile result of Vava'u Group is shown in Figure 42. Three distinctive areas depict heightened risk levels. These results are located on the route taken by the domestic ferry and domestic cargo vessels from Ha'apai to Vava'u. One of the areas of heightened risk is also close to the harbour approach for large SOLAS vessels. All of these risk results are adjacent to marine reserves.

In Vava'u SOLAS international vessels make a lower contribution to risk levels than domestic vessels. This is because of the lower traffic levels associated with such vessels, even though there is clear evidence that the size of cruise vessels visiting Vava'u is increasing. The presence of areas of high environmental significance (corals, Special Management Areas and turtle breeding grounds) provide an underlying influence on the transit risk level result.

Neiafu Harbour and its approaches provide a heightened risk result. The risk results reflect the economic importance of the harbour, with regular port calls for all types of ships combined with presence of aquaculture farms, turtles and a fuel handling operation. In Vava'u, AToN's were noted to be in good condition, although review around the Pacific Fuels terminal would be of benefit.

The passage between Fofoa and Ovoka Islands produced an isolated area of heightened risk surrounded by an area of moderate risk. The newly established Special Management Area influences this result, in combination with liquid bulk and domestic coastal passenger vessel transits.

The sea area between Kapa Island and Richard Patches has both adequately and inadequately surveyed areas which are mainly used by the domestic vessels, including passenger services. Special Management Areas are also of significance in these waters.

The risk result is driven by the existing traffic levels. Data gathering established the potential for significant expansion of Neiafu Harbour as well as the attractions of this pristine area to new cruise visitors and international yacht crews alike. An increase in vessel visits, or vessel size or even ferry capacity would result in an extension of the areas of heightened risk.

This is an area where charting improvements were made in 2010. However, the risk assessment has focussed the areas that need attention for either review or charting upgrade. The Cost Benefit result, which takes into account the risk reduction available from charting upgrades, should be reviewed next (Section 8.10.4).

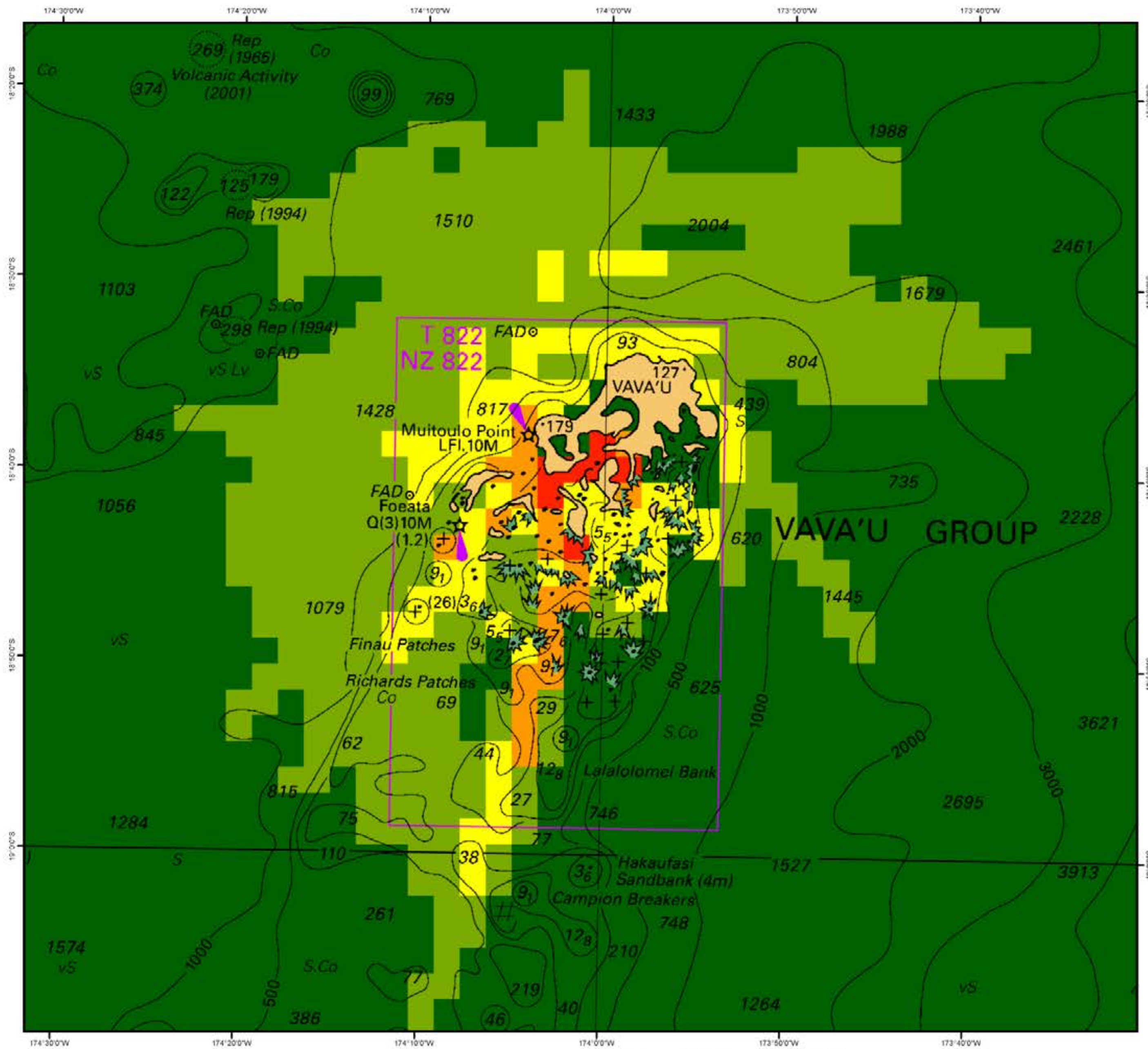
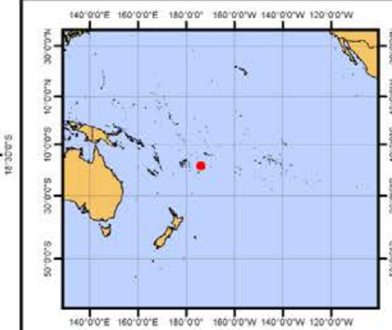


Figure Reference: 13NZ262_Tonga_RiskModel4_02

Figure 42: Vava'u Group Risk Model Results



Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 02
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:350,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 2 4 8 12 Nautical Miles N

Produced by:
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Marico Marine Group, United Kingdom, Tel: +44 023 8081 1133
MARICO MARINE www.marico.co.uk

SW Pacific Hydrography Risk Assessment

NEW ZEALAND FOREIGN AFFAIRS & TRADE Aid Programme
Land Information New Zealand Toitū te whenua Hydrogaphic Authority

7.7 TONGA HYDROGRAPHIC RISK - NIUAS

The Niuas Group provides a low hydrographic risk result overall. Figure 43 shows a low risk model result at the west coastline of Niuafo'ou Island. Similarly, Figure 44 evinces a low risk result in all directions, as well as at the harbour entrance of Niuatoputapu Island. There was one small cruise vessel visiting Niuatoputapu Island during 2014, which did not attempt to enter the harbour entrance. However, there are two more cruise calls scheduled for 2015. This forecast may or may not come to fruition, but it shows there is some potential for cruise calls in the specialist boutique sector of the market.

The risk results are directly related to the low (only occasional) visits to the Niuas by the domestic coastal passenger vessel. The islands are also of relatively low population and the tourist economy is embryonic.

However, there is an important inherent risk associated with the narrow and relatively shallow Niuatoputapu Harbour entrance, discussed earlier in this report (Section 4.5.3). As the hydrographic risk assessment by its nature is driven by vessel transit numbers (both size and frequency), it does not measure the inherent risk associated with this difficult harbour entrance. This is a risk of entry the vessel faces each time it uses the transit. It is the consequences of total loss, or serious damage to 'OTUANGA'OFA that is important in this instance, because of its importance in providing safe passenger and cargo transit throughout the waters of Tonga.

The data gathering also determined a need to review the harbour leading light beacons for their effectiveness (i.e. to increase their sensitivity to show a vessel misalignment with the entrance transit by increasing the distance between them). Some charted AToNs were noted to be missing in Niuatoputapu harbour at the time of data gathering.

The data gathering also determined a need to review the leads for their effectiveness (increase the distance between them) and repair the AToNs in Niuatoputapu harbour, also reported earlier.

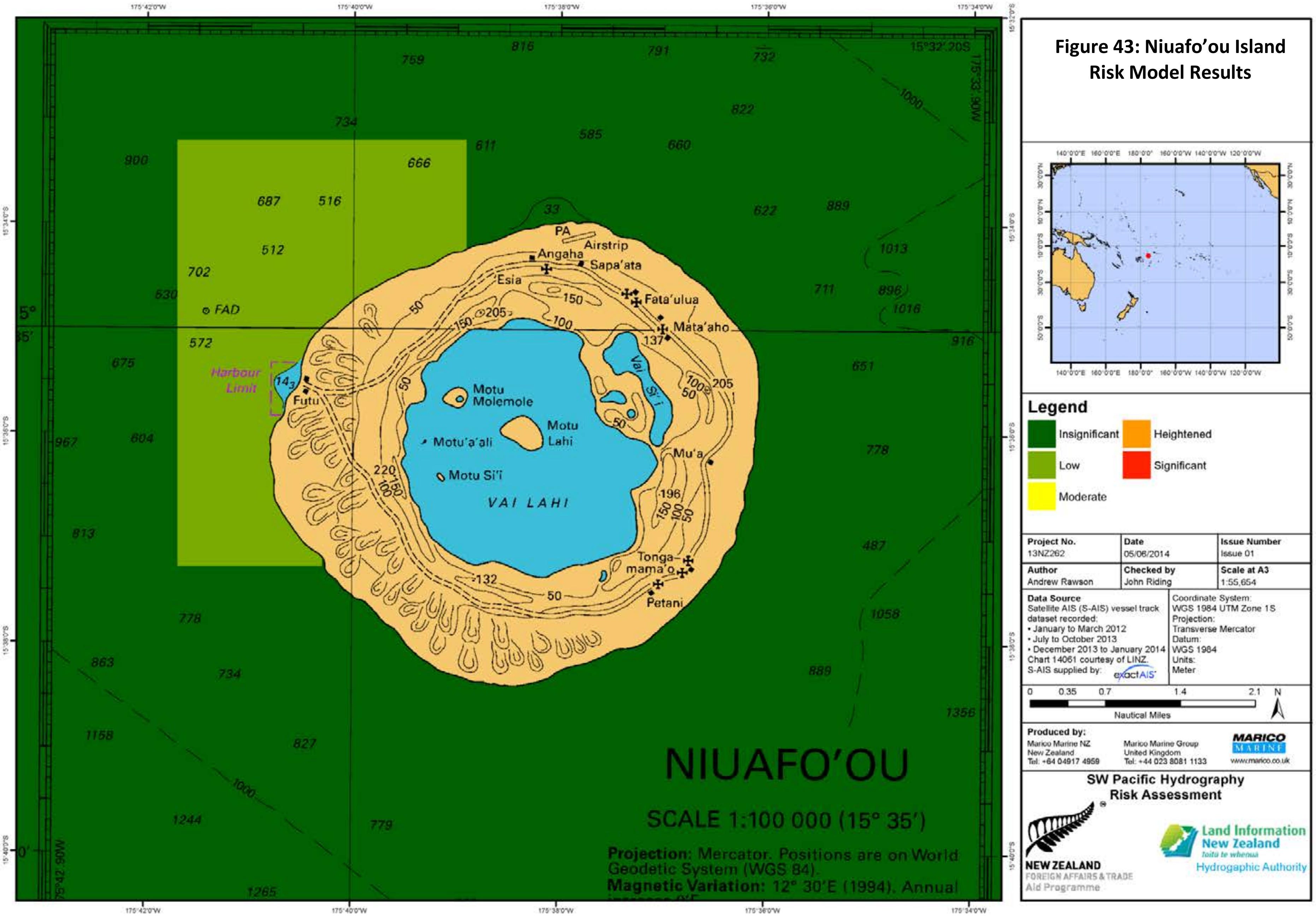


Figure 43: Niuafo'ou Island Risk Model Results

Figure Reference: 13NZ262_Tonga_RiskModel2_01

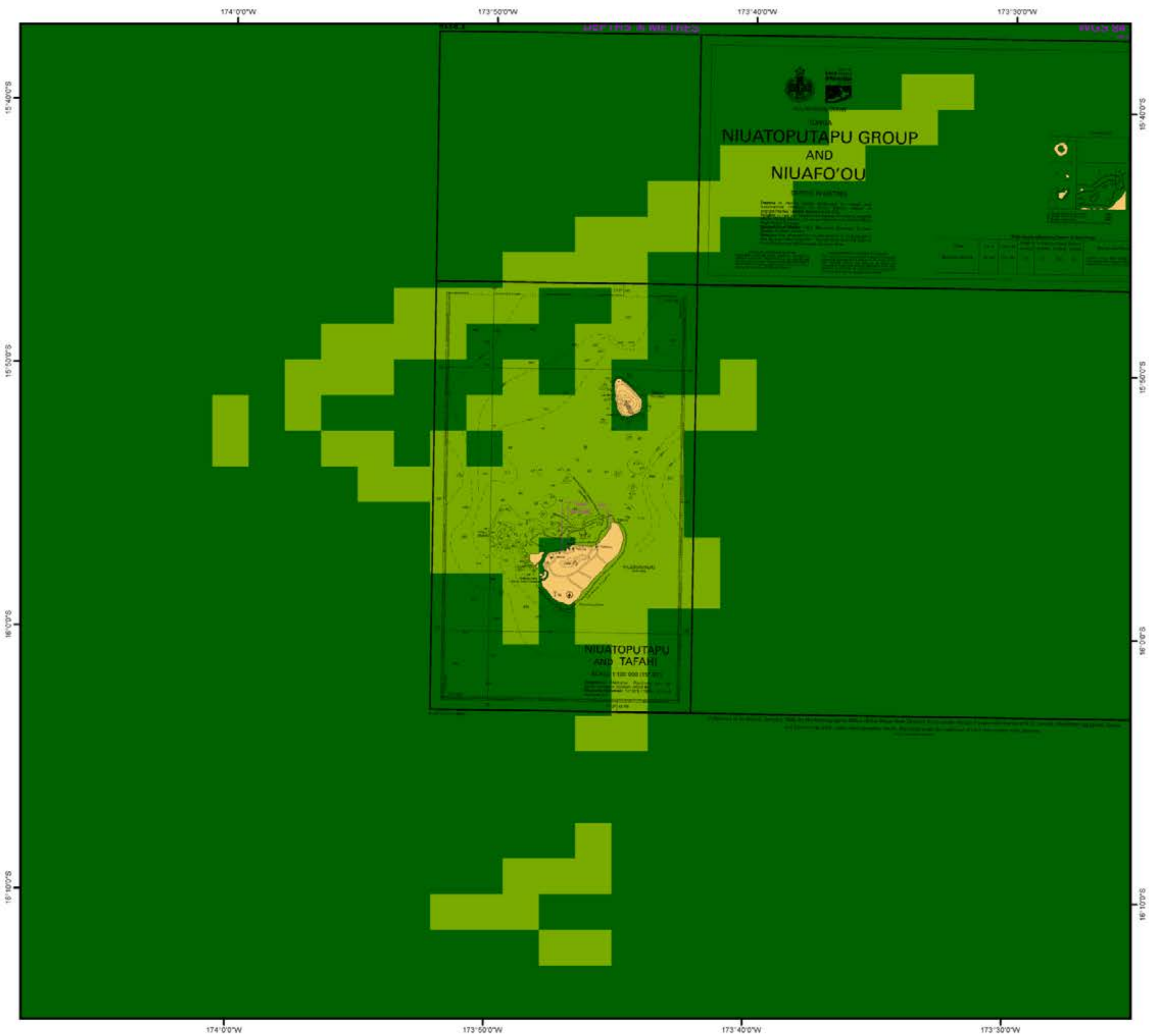
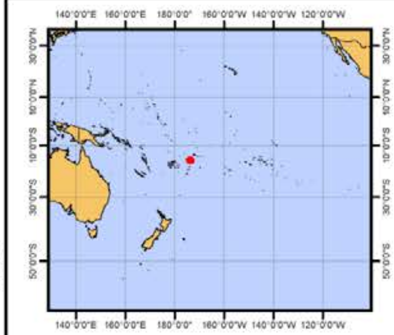


Figure 44: Niuatoputapu Island Risk Model Results



Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	05/06/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:250,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System:
WGS 1984 UTM Zone 1S
Projection:
Transverse Mercator
Datum:
WGS 1984
Units:
Meter

0 1.5 3 6 9 N
Nautical Miles

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Aid Programme

Land Information New Zealand
Toitū te whenua
Hydrogaphic Authority

Figure Reference: 13NZ262_Tonga_RiskModel3_01

7.8 TONGAN HYDROGRAPHIC RISK - DOMESTIC COASTAL VESSELS

Figure 45 shows the risk level associated with domestic coastal vessel transits. As this is a risk associated with just one layer of the GIS against the risk matrix criteria for that level, the scale of risk for this individual layer is not the same as that for the risk assessment. However, what this plot shows is that domestic vessel traffic is a very significant main driver of the overall hydrographic risk profile for Ha'apai as well as a contributor for the significant risk result obtained from Tongatapu. This can be understood from reviewing the risk levels by the colour of individual cells, which are close to the results delivered by the risk assessment overall.

The licensed passenger capacity of the domestic fleet and the regularity of transits, both with respect to the routes always taken and the volume of transits is a driver of domestic vessel risk. The significant risk result risk levels occurs in Tongatapu, when compared to other parts of Tonga, because of the greater volume of traffic overall in Tongatapu. The high traffic volume service to 'Eua is a factor in this result. Hydrographic risk is directly related to the volume of shipping traffic in an area.

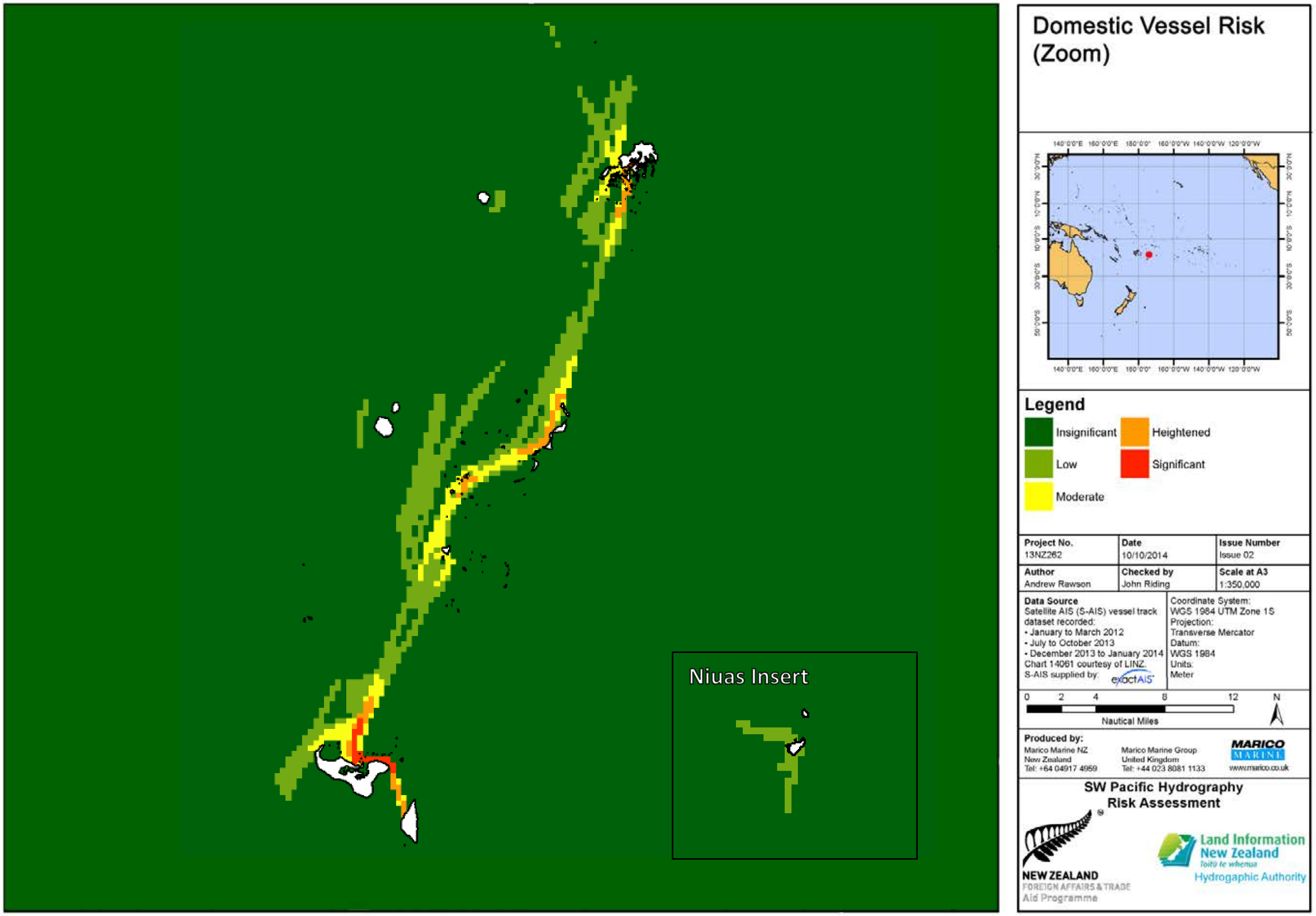


Figure 45: Domestic Vessel Risk

8 ECONOMIC ANALYSIS – COST BENEFIT ANALYSIS (CBA)

8.1 INTRODUCTION

The hydrographic risk methodology relies on evidence of economic growth, combined with ship transit risk (traffic volume, vessel type and size) in order to conclude a need for improved charting. The combination of economic increase and ship activity provides the body of evidence for trade growth on the basis of adequate and accurate charting.

In this section, the economic analysis does two things:

- It identifies and estimates the economic value (if not a benefit, the cost) that would be generated through charting upgrades, where needed.
- It takes account of the risk reduction obtained by charting improvements.

Subsequently, this analysis also determines the potential economic risks of no improvement to these charts. The net result is a measure of the cost benefit payback (or cost) of the surveys to improve charting. The results are presented in the same GIS format as the risk assessment.

8.1.1 CBA Methodology - Overview

To facilitate the above scenarios, the economic analysis delivers a cost benefit analysis (CBA) overlaid, cell by cell, onto the GIS risk model that quantifies the balance between maritime costs and benefits of a hydrographic survey, mathematically linked to the risk reduction achieved. It is based on the passenger and freight data of Tonga, as well as survey costs, taken as an average of the various studies that report such costs.

The methodology identifies the net present values associated with charting upgrades and survey. It evaluates these against the safety benefits for SOLAS international and domestic coastal vessels. The safety benefits translate into a risk reduction, which itself is based on referenceable work from around the globe that has evaluated available risk reduction associated with charting improvements.

The derived cost of survey is calculated in the GIS CBA model and applied to each grid cell. The risk reduction available is then taken from the risk result in each grid cell. The overall benefit (or net costs) is calculated based on the difference between the risk result in Section

7, which assumes no improvements to charts, when compared with a risk reduction available if charts are improved.

Finally, the net present function is employed to give an estimate of monetary return (or overall cost) on the investment needed in each grid cell to bring charting up to modern standards. The investment is based on independent work that established that ECDIS, used with accurate and adequate ENCs reduces grounding likelihood and improves situational awareness by about 36%[52] overall. This figure did not take account of charts where the datum is unknown, as is the case for Ha'apai. The risk reduction benefit available by a charting upgrade from such a standard is higher.

It has to follow that the available risk reduction from charting improvements will vary, depending on the status (quality) of the chart that is to be resurveyed and upgraded (or indeed reorganised. LINZ are one Hydrographic Office employing the CATZOC categorisation of chart and data quality, which is a useful attribute for both the assessment of risk, as well as CBA calculations that need to establish a risk benefit for the CBA calculation.

A varying range of available risk reduction was developed, using the work by DNV as a benchmark. This is shown in **Table 16**, below.

Charting Upgrade Risk Reduction Available	
ZOC A	2.5%
ZOC B	5%
ZOC C	10%
ZOC D	20%
ZOC U	30%
Fathom Charts	45%

Table 16 : CBA Risk Reduction Relationship to ZOC Category

Annex C presents CATZOC plots for each of the island groups of relevance to the CBA.

[52] DNV 2010 – Technical Data Report - Marine Shipping QRA: Enbridge Northern Gateway Project

A 10 year life cycle was assumed for CBA costing purposes. **Annex F** presents assumptions used in support of calculations for the scenarios derived, together with other supporting information.

8.1.2 CBA Data Sources (Key Data)

To successfully undertake a CBA as a GIS layer, linked to the risk result in each cell, required data in new areas that previous hydrographic risk projects had not needed. Some of this data varies considerably and was not readily available. Two key examples are:

- the cost of hydrographic survey; and
- the risk reduction that can be expected from a charting upgrade.

For the former, an internet search was undertaken, which served to emphasise the range of costs that occur, taking into account the fact that different technologies have different costs. One reference from SHOM, the French Hydrographic Office, provided formally referenceable data, suggesting surveys using singlebeam technology cost about 450 Euros per square kilometre. The internet provided data similar to that from SHOM. The following costs were averaged and singlebeam costs chosen for the CBA model.

- Low cost (satellite): 35 dollars per km squared;
- Low Medium Cost (single beam): 500 dollars per km squared;
- Medium cost (Multibeam): 1633.3 dollars per km squared Modelled cost; and
- Highest cost (Lidar): 2381.9 dollars per km squared (although LIDAR cost varied enormously).

Further information is attached as **Annex F**. In order to consider the risk reduction that might be available from any charting upgrade, work undertaken by Det Norske Veritas was reviewed. This was from a study originally undertaken to estimate the benefits of the introduction of ECDIS to SOLAS shipping. This work referenced international casualty frequencies (groundings) and concluded that a risk reduction of up to 36% could occur from accurate charting combined with ECDIS systems on-board vessels. Further work was then completed in 2010 for a Canadian shipping channel, again referencing the same 36% risk reduction value. However, no charting in this area of Canada was representative of the condition of the Charts in Ha'apai, where they remain in fathoms on an undetermined datum. The risk reduction available in this specific case would logically be higher than that found by the DNV work. References for this are also presented at **Annex F**.

8.2 ECONOMIC ANALYSIS

8.2.1 Benefits of Hydrographic Surveys

Hydrographic survey data is a facilitator. Classically the data is integrated into ships' charts as a navigational aid; to provide the wherewithal for the ship to safely plan and undertake a voyage avoiding such hazards as dangerous shoals. The quality of hydrographic data determines the extent to which investors are prepared to undertake 'the shipping adventure', and insurers to underwrite the risk, to supply essential transportation services to nations such as Tonga. If the hydrographic data and, in the modern context, the relevant ENCs are of high quality, there is an increased likelihood the service will be of high quality as well, with competition ensuring no excess freight rates. Conversely, poor quality data brings with it the risk of substandard shipping.

However, particularly with the advent of Geographical Information Systems (GIS) underpinned by powerful computer processing, and integration with satellite and other remote sensing technologies, hydrographic data delivers a wide range of additional benefits to multiple marine stakeholders, notably planning and development. It is now widely accepted that these benefits of hydrographic survey data, which are mostly unquantifiable in financial terms, outweigh those derived from its classic application, hence the common assessment that hydrographic data should be viewed as a public rather than private good.

Across the three shipping sectors hydrographic survey data delivers benefits in different ways. For the international shipping of freight, the principal benefit is assessed to be the maintenance of market stability with the opportunity to lever significant reductions in transportation costs. For domestic shipping, with a poor record historically – and recently – improvements in safety will flow from hydrographic data. Finally, for cruise tourism, hydrographic data provides planners with the information they require to identify suitable sites for future development, to access in particular the burgeoning Australian/New Zealand cruise market[53]. For any or each of the aforementioned applications, for Tonga, the benefits of hydrographic survey are considered to outweigh the costs.

Commercial shipping relies on current hydrographic survey data. A hydrographic survey undertaken to the latest International Hydrographic Organization (IHO) standards[54] provides the following benefits:

- Accurate and reliable full bottom coverage allows for more flexible route planning, more precise navigation and more flexibility to utilise the increased loading of ships, thus increasing the economic efficiency of shipping.
- Critical new shallows or water depth, less than previously charted, may be identified and appropriate action taken.
- Facilitate revisions of fairways or routes, and planning of modified or new Traffic Separation Schemes.
- Enabling changed practices in navigation with new ECDIS[55] functionality (e.g. 3D navigation with real time dynamic water level in formation, precise warnings), with consequential reduction in environmental harm and insurance premiums.
- Provision of quality information for training purposes.

These factors have been identified as causal to shipping companies using less efficient or less capable vessels that are more likely to be involved in a maritime accident in areas with poor hydrographic data (Connon and Nairn, 2011).

Further, the International Convention for the Safety of Life at Sea (SOLAS) requires signatory states to facilitate the production of current electronic navigation charts (ENCs) for ships navigating their coastal waters[56]. Should a member state not fulfil this obligation, insurers may decline to provide cover, or charge an additional premium, to vessels wishing to navigate its coastal waters, including ports.

8.2.2 ENC Charts

All ENC's are based on the World Geodetic System 84 (WGS84 datum) and are organized in so called Cells. The cells are allocated to defined scale ranges with a different degree of generalization or usage bands.

[53] In 2014, New Zealanders are expected to represent approximately 20% of the cruise market after a period of significant growth.
[54] IHO S-44 Standards for Hydrographic Survey
[55] Electronic Chart Display and Information System
[56] Regulation 9 of SOLAS Chapter 5

To comply with IMO requirements, a member state should develop accurate and adequate ENCs for all its waterways, including ports.

Beyond shipping, reflecting its 'public good' nature[57], hydrographic survey data delivers a wide range of additional benefits to maritime stakeholders as illustrated in Table 17.

Indeed, the largest users of hydrographic data are typically developers, notably port developers, and planners. The specific benefits of charting improvements to shipping in Tonga are summarised at **Annex E.** Notable is the support hydrographic survey data provides to the training of Tongan nationals, as valued seafarers, and the wider economic impact benefits this delivers; up to 28% of Tonga's income is generated through remittance from citizens working outside the country.

In summary, hydrographic data is a facilitator and should be considered as vital infrastructure, servicing exactly the same purpose as a mapped highway on land. Like all other types of infrastructure, it is a key to the door most likely to lead to economic prosperity. Put another way, without hydrographic data it would not be possible to efficiently conduct the activities shown in Table 17.

57 'Public goods' are services in the public interest which would not be supplied at optimal levels by market forces alone

Benefiting Activity	Hydrographic Data Type									
	Coastline	Coordinates	Current	Depth	Geo Description	UNCLOS Boundary Definition	Aids to Navigation	Sea Bottom Contours	Tide Levels and Datum	Wrecks
Aquaculture	X	X	X	X		X		X	X	
Cable / Pipe Laying	X	X	X	X	X	X		X	X	X
Coastal Zone Management	X	X	X	X	X	X	X	X	X	
Defence	X	X	X	X	X	X	X	X	X	X
Dumping		X	X	X	X	X			X	
Coastal Engineering	X	X	X	X	X	X		X	X	X
Environment	X	X	X	X	X	X		X	X	
Fisheries, Living Resources	X	X	X	X	X	X	X	X	X	X
Health: 'Red Tides'	X	X	X	X	X	X	X		X	
National Boundaries	X	X		X	X			X	X	
Scientific Research	X	x	X	X	X	X	X	X	X	X
Maritime Transport / Navigation	X	X	X	X	X	X	X	X	X	X
Natural Hazard Modelling	X	X	X	X	X	X	X	X	X	
Deep Sea Mining	X	X	X	X	X	X		X	X	X
Ports	X	X	X	X	X	X	X	X	X	X
Real Estate	X	X	X	X	X	X			X	
SOLAS	X	X	X	X	X	X	X		X	X
Sports	X	X	X	X	X	X	X	X	X	X
Tourism	X	X	X	X	X	X	X		X	X

Table 17: Beneficiaries of Hydrographic Survey Data (Source: FIG 2011)

Nevertheless, as highlighted above, the principal benefit derived from hydrographic surveying is mitigation of navigational risk, particularly vessel grounding, through the effective application of bathymetric (chart) data. There have been numerous studies investigating the risk reduction available from charting upgrade.

Figure 46 below is a bow-tie representation of risk related to the vessel grounding hazard. Two potential causal events are identified: 'Powered Grounding', which includes human error due to poor passage planning and / or loss of awareness – possibly due to deficiencies in the navigational information available; and, 'Unpowered Grounding' typically the result of propulsion and / or steering failure.

The consequence of vessel grounding is determined by a number of factors ranging between a 'most likely' – usually, but not always, a minor incident - and a 'worst credible' outcome. The factors influencing consequence include vessel design, for example damage stability and maintenance; the competence of the crew (to manage an emergency situation); the nature of the seabed; and, environmental conditions.

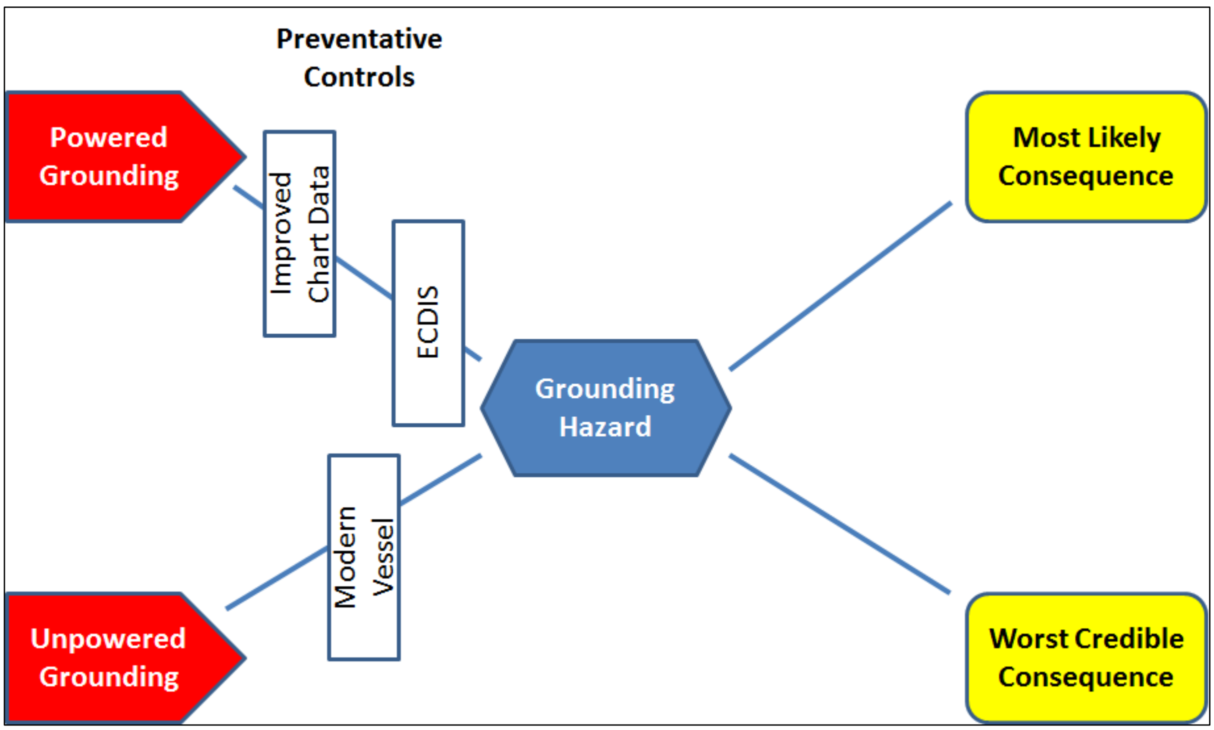


Figure 46: Bow Tie Representation of Grounding Risk

As shown in Figure 46, improved chart data is a risk control that directly mitigates the likelihood of a powered grounding, i.e., through facilitating ships' navigators' access to the most appropriate charts for the area of operation. Further mitigation may be achieved through application of ECDIS; a technology that reduces the probability of grounding related to human error through provision of due warning if the vessel is standing into danger[58]. Carriage and use of ECDIS for ships' navigation is a requirement of SOLAS, as is the obligation on coastal states to deliver ENCs as referenced above. The reduction in grounding likelihood through used of ENCs and ECDIS is estimated by a 2008 DNV study to be a maximum of about 36%[59].

It is important to note that the full benefits of ECDIS can only be realised if ENCs are accurate and adequate. To produce ENCs, best international practice suggests it is often more feasible and productive to completely re-survey sea areas where old survey data exists than try to use old data and estimate where it will be useful. Old datasets are in many cases inhomogeneous and partial re-surveys are inevitable (HELCOM 2013).

There are additional indirect benefits to navigational safety from a hydrographic survey. As previously remarked, areas that are poorly surveyed are assessed to be more likely served by old, unreliable vessels with a higher probability of propulsion failure. Conversely, as shown in Figure 46, modern vessels reduce the likelihood of unpowered grounding incidents.

8.3 TONGA SHIPPING – THE EXISTING SITUATION

8.3.1 Overview

The island countries of the Pacific have much in common. All are essentially archipelagos with far-flung island communities, remote from major markets.

Given that most commodities and manufactured goods are transported by, and that much domestic travel is by sea, the cost and quality of shipping immediately affects the welfare of citizens as consumers and producers (PES 2008).

The impacts of shipping costs on an economy in general and on the volume of trade in particular are well researched. It is estimated that a 10% increase in transport costs reduces trade volume by 20% (Liu Xianghui 2012), with a doubling shipping costs reducing GDP per person growth by one-half to one per cent (PES 2008).

[58] ECDIS will not prevent a human violation, i.e., a deliberate act by an individual, usually the vessel master, to circumvent the safety controls in place to prevent (e.g.) vessel grounding. Further, the ENCs must be of at least Usage Band 4, ideally bands 5 and 6

[59] Det Norske Veritas ECDIC and ENC Coverage Study- Follow Up Study – Report No2008 -0048. This study assessed worldwide grounding in relation to worldwide transits.

The provision of safe, reliable and sustainable maritime transport is essential to the Tongan economy, therefore, and depends upon the creation of an environment that facilitates the safe operation of services in an efficient and commercially viable manner. This, in turn, is determined by numerous factors such as appropriate vessel operation, route profitability and the availability of infrastructure.

8.3.2 Tongan Economy

The Tongan economy has a GDP of less than US$800 million and was severely hit by the global economic crisis, particularly its impact on tourism. GDP growth declined sharply in 2006/07, but subsequent reconstruction led to a modest recovery. The past two years (fiscal years 2011/12-2012/13) are characterised by limited growth (WTO 2014).

As shown in Figure 47, Tonga's merchandise exports are limited and are exceeded by its imports; over half of all imports are fuel and food. Its major trading partner is New Zealand. In terms of volume, about 200,000 tonnes are imported, which equates to around 10,000-12,000 TEU[60]. About 20,000 tonnes of cargo are loaded / exported per year, around 1,000 TEU (WTO 2014).

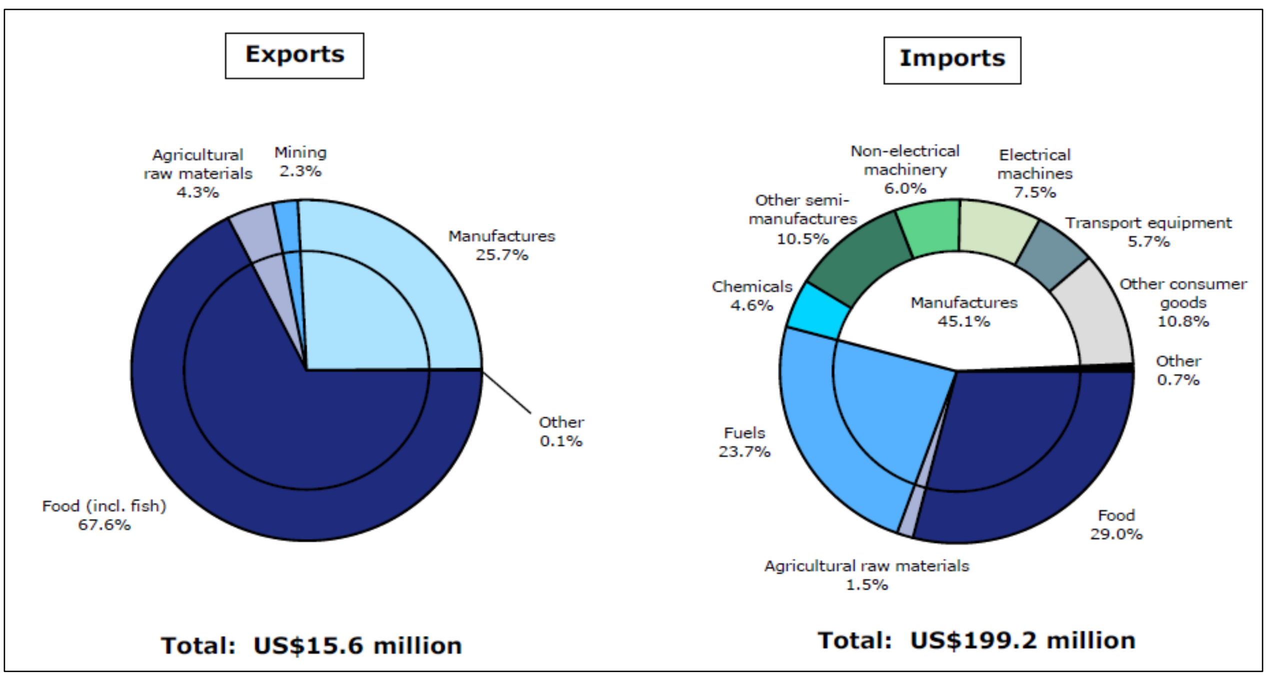


Figure 47: Tongan Product Composition of Merchandise Trade, 2012

[60] Twenty Foot Equivalent Unit – the standard ISO shipping container

In its niche markets for squash (Japan and Korea), Tonga has lost market share. Although fishing in Tongan waters remains important; fishing has been retreating in contribution since 2004, reportedly in part due to a loss of competitiveness. Transport is a significant issue with a level of the catch unloaded in foreign ports with a loss of benefit to Tonga. There is at least one company in Tongatapu now exporting fresh tuna, direct to the Japanese markets to arrest this trend.

8.4 MARITIME TRANSPORT - INTERNATIONAL

8.4.1 General Cargo

For general cargo, i.e., everything but fuel, Tonga's major port, Nuku'alofa, is regularly served by modern, multi-purpose vessels. Designed to carry containers, vehicles and break bulk, these vessels are ideally suited to the trade. Nuku'alofa is served on a rotation through other key ports in the Pacific Islands; see Table 18 below. In addition to the ports shown in Table 18, there are linkages to Asian ports including Busan, Hong Kong, Jakarta, Kaohsiung, and Singapore.

Service	Operator	Frequency	Vessel	Service Type/ Ship Size
Brisbane / Sydney / Melbourne / Lautoka / Suva / Pago Pago / Apia / Nuku'alofa / Suva / Lautoka / Brisbane	Reef Shipping / Neptune Shipping Line PDL / PFL	Two sailings monthly	*Forum Samoa* *Capitaine Tasman*	Multipurpose: 600–650 TEU; 7,000–7,500 GT
Tauranga / Auckland / Lautoka./ Suva / Funafuti /Tauranga	Neptune/PDL	Fortnightly	*Capitaine Wallis*	Container: 520 TEU; 4,500 GT
Auckland-Nuku'alofa-Apia-Pago Pago-Auckland	Reef Shipping, PDL, Sofrana	Fortnightly	*Southern Cross*	Multipurpose: 512 TEU; 4,000 GT
Lyttleton/Napier/Auckland / Lautoka/Suva / Apia / Pago Pago /Nuku'alofa/Lyttleton	PFL	Fortnightly	*Forum Pacific,* *Forum Fiji III*	Multipurpose: 61–512 TEU; up to 7,600 GT
Lyttleton/ Whangarei/ Auckland/ Nuku'alofa/ Papeete	PDL	21 days	*Southern Pearl*	Container: 325 TEU; 4,366 GT

GT = gross tonnage, PDL = Pacific Direct Line, PFL = Pacific Forum Line, TEU = 20-foot equivalent unit.

Source: CI-Online, www.ci-online.co.uk; New Zealand Shipping Gazette; Lloyds List DCN; Fiji Times; Solomon Star; schedules provided by ships agents; shipping line websites.

Table 18: South Pacific Island Services

Taking into account the number of shipping companies operating to Tonga, the market can be judged reasonably contestable. Consequently, freight rates are not considered to be excessive, typically around $2000 per TEU for a shipment from Australia to Tonga (Asian Development Bank, 2009).

Nevertheless, the commercial vessels serving Tonga are small by modern standards. Trading to multiple ports on each voyage, their operators cannot exercise the economies of scale of dedicated container services whose operators secure further economies through use of 'hub-and-spoke' operation[61]. Such developments have seen freight rates for shipping containers from Asia to Europe fall to little more than $1000 per TEU (Lloyds List 2014).

In other words, there is potential for significant reductions in Tongan freight rates should it prove possible to establish dedicated container services to the islands.

8.4.2 Petroleum

The other major import for Tonga is fuel, in the form of refined petroleum. Primarily this is transported by tanker from Australasian refineries, although there are also shipments from Fiji and Tonga. Presently tanker discharge facilities are provided offshore east of Queen Salote Wharf, Nuku'alofa, with the vessels secured to dolphins. The maximum size of vessel that can be accommodated at this facility is relatively small[62], the port handling approximately 40-50 million litres of petroleum products per year. Larger tankers occasionally visit Vava'u, as is the case at 'Eua.

There have been significant developments in the global shipment of refined petroleum in recent years. Few product tankers of size less than medium range are now constructed[63]. These vessels increasingly load at 'super refineries' established in Singapore and the Middle East, with the consequential closure of some smaller refineries in Australasia.

With improved efficiency, the cost of shipping petroleum is generally decreasing. A representative gasoil shipment between Singapore and Australia has fallen from approximately $64 per tonne in 2009 to $36 per tonne in 2013 (Hale and Twomey 2013).

61 Large vessels, typically at least 8,000 TEU, operate long-haul services between regional transhipment ports with vessels of around 2,800 TEU providing feeder services to / from transhipment hubs
62 The largest vessel that can be accommodated is 80m length overall (LOA) with 5m draught
63 Vessels up to 55,000 dwt with LOA 179m, width 29m, draught, 11m

As indicated above, Nuku'alofa cannot handle medium range tankers. The tankers serving Tonga are generally constructed for the specialist chemical trades, where there is an ongoing demand for transporting small mixed product parcels.

With developments such as fracking, demand for chemical tankers is high. Their freight rates have risen to a five-year high and are likely to increase further, a representative voyage from the US Gulf to the East Coast of South America securing $80 per tonne (Arnsdorf 2013).

There is no significant demand for the shipment of dry cargoes in bulk to or from Tonga, although this may change if mining in any form was established within the Tongan EEZ.

Other than irregular services to Halaevalu Wharf on the island of Vava'u[64], there is no direct international trade to Tongan ports other than Nuku'alofa. Port infrastructure, including inadequacies in hydrographic data, is not conducive to the operation of deep-sea vessels. All imports for the outer islands, and any potential exports, must therefore be routed through Nuku'alofa.

8.4.3 Domestic Shipping: Freight and Passenger

Domestic services are essential to the international trade of Pacific island countries. As noted above, the bulk of inbound international cargo is shipped into Nuku'alofa for deconsolidation and distribution around the various islands. Often, cargo is stowed in loose form, traditionally by cranes or manual labour which is inefficient given that virtually all are transported in standard shipping containers. Construction materials make up a large part of this freight, and a significant amount of liquid is moved in drums to service island needs for diesel (transport and power generation), motor gasoline, and two-stroke fuel for outboards.

Tonga's domestic services were enhanced by the introduction, in 2010, of the Ro-Ro passenger vessel 'OTUANGA'OFA. The vessel has a total loading capacity of 520 tones and can accommodate up to 400 passengers, operating on a weekly schedule from Nuku'alofa to the outer islands, with a bi monthly service to the Niuas.

To a greater or lesser degree, depending on the specific port served, the safe navigation of the 'OTUANGA'OFA is dependent upon the local knowledge of its master and bridge team. This knowledge is principally drawn from valued experience. Nevertheless, as exemplified by

[64] Approximately monthly

the (minor) grounding of the vessel on 1 May 2014, departing Pasivulangi Harbour, such knowledge is fallible and lacks the objectivity of modern ENCs. The presence of ECDIS may have improved situational awareness, but only if suitable ENCs were available (see again, Figure 46).

8.4.4 Cruise Ship Tourism

The world's cruise industry has grown 125% and launched 143 new cruise ships, since 2000. Emerging cruise markets of South America, Asia and Australia have contributed to the strong growth (PIFS 2013).

At present there are no signs of this growth slowing down. New ships being built have passenger capacities of over 4,000 with a wide range of facilities and activities on board. This means the industry is able to cater for a diverse range of tourists on a range of budgets, and taking them around the world to visit different ports and cities (Worley & Akehurst 2013).

However, for cruise operators, the South Pacific is a challenging environment due to the great distances between destinations and limited infrastructure. In 2012, only 1% of the total worldwide cruise passengers, or around 200,000 passengers were estimated to have taken a cruise to the South Pacific. Of that, approximately three quarters were forecast to be from Australia although, since 2006, the South Pacific has lost market share due to an increase in New Zealand and round Australia cruises (PIFS 2013). There is recent evidence that this trend may be reversing as larger cruise vessels penetrate the SW pacific.

The new Vuna Wharf at Nuku'alofa is suitable for handling all but the very largest passenger liners and is a regular port of call for Northern-hemisphere based vessels on their winter round-the-world cruises[65]. Smaller 'boutique' vessels may also visit Vava'u and, occasionally, Ha'apai and Tofua[66]. There are less frequent visits to the Niuas.

Total cruise passenger arrivals for Tonga are shown in Figure 48 below. With 14 vessels scheduled to arrive in 2014 compared to 17 in 2013, visitor numbers remain similar to the levels seen in 2009.

[65] Recent visitors include the 292m *Queen Elizabeth* and *Queen Victoria*

[66] Typically vessels with less than 500 passengers catering to a high-end market, for example, the *mv Paul Gauguin*

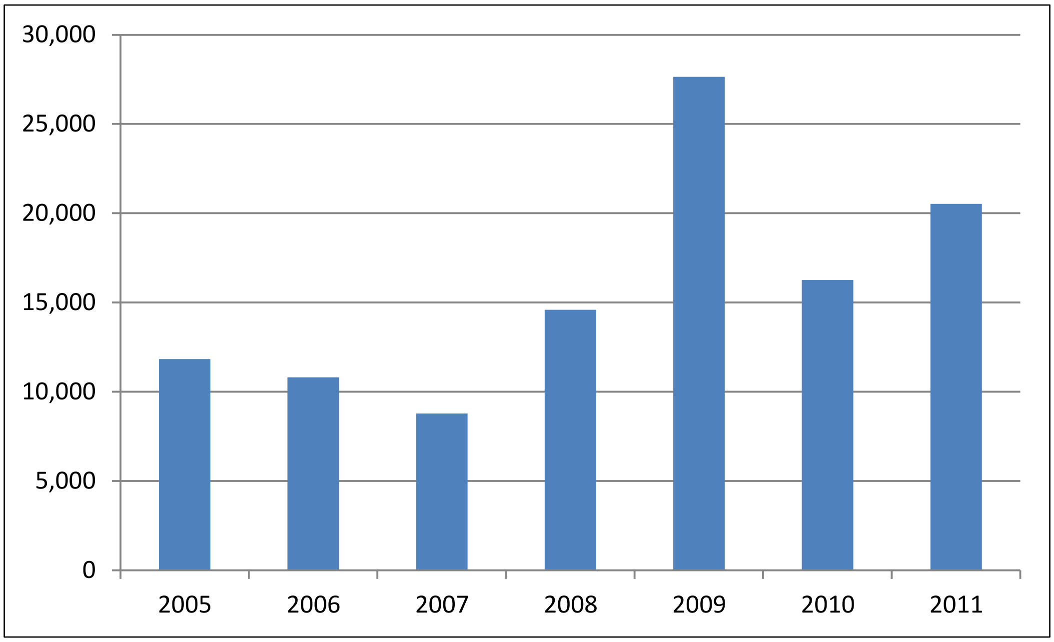


Figure 48: Tonga Passenger Arrivals by Cruise Liner
(Source: Tonga Department of Statistics)

The expenditure of visiting cruise vessel passengers and crew brings economic benefit, albeit this can be over-stressed[67]. There are further direct benefits from port dues[68] and indirect employment benefits. Extrapolating data for Auckland (Worley and Akehurst 2013), the estimated spend for each passenger and crew member, in each port, is US$156 and US$50 respectively. Likewise extrapolating from Auckland, where it is estimated 102 cruise visits generated 1,723 jobs, this is equivalent to 16.9 man years per port call.

8.5 FUTURE DEVELOPMENTS – ECONOMIC IMPACTS

8.5.1 Introduction

The economic drivers shaping the development of international commercial shipping are complex. The market is highly competitive and freight rates notoriously volatile.

[67] The cruise liner business model is based on maximising expenditure on the vessel whilst minimising expenditure in port
[68] These are marginal. With an aggregate of visiting cruise liners of approximately 450,000gt, income for 2013 is estimated to be $17,688

Nonetheless, there are constants. Notably these include further penetration of containerisation into the general cargo trades, the wider adoption of hub-and-spoke operations, and the increase in both tanker size and voyage length.

8.5.2 General Cargo

Should no hydrographic surveys be undertaken and, therefore, the status quo maintained, with Tonga's continued reliance on small multi-purpose vessels, it is feasible – and reasonable – to assume freight rates will increase at rates exceeding those of dedicated container service. Moreover, in the medium to long term, with increasing competition, the financial viability of these services will come under stress escalating freight rate inflation, to cover the cost of increasingly expensive replacement vessels.

Further, if appropriate ENCs are not developed, the costs of ships' insurance may similarly increase and the option exists for it to be withdrawn. Should insurance become difficult to obtain, the scenario exists where owners prepared to accept the risk of operating without insurance, become prevalent in Tongan domestic trade. This would invariably lead to the use of elderly, sub-standard vessels, typically displaced from markets subject to regulatory scrutiny and enforcement.

Stakeholder discussions indicate that a major shipping company is reviewing its South Pacific operations with the aim of establishing a regional transhipment hub. Through hydrographic survey, the dredging required to facilitate the safe operation of suitable vessels is accurately identified offering potential for significant infrastructure enhancement, whilst minimising environmental impact; see 'benefit 4' in the table, **Annex E.**

8.5.3 Petroleum

Given the developments outlined previously, with a continued reliance on specialist chemical tankers, it is reasonable to assume freight rates to ship fuel to the Pacific islands will continue to increase in excess of general inflation, noting also the closure of the remaining Australasian refineries may significantly increase voyage length and costs[69]. Further, as for general cargo, if charts are not updated in accordance with IMO

[69] The former Australasian refineries may be used as storage / transhipment centres

requirements, in due course it is likely that reputable operators will withdraw tankers due to difficulties in securing what for this vessel type is mandatory insurance.

Similarly hydrographic surveying identifies potential options for development. This may include the establishment of terminal facilities in Neiafu Harbour (Vava'u), which offers deep water in sheltered surroundings that may prove suitable as a transhipment hub served by medium range tankers.

8.5.4 Domestic Vessel Operations

The safety benefits of hydrographic surveys to domestic shipping in the Pacific islands were identified above. Should chart data decline in quality, it is reasonable to assume risk to navigation will increase beyond what are already elevated levels, particularly in port approaches. As for other sectors, if charts are not updated, it will be increasingly difficult to secure finance for replacement vessels particularly due to the difficulties securing insurance cover.

8.5.5 Cruise Tourism

In contrast with other markets, as referenced above, cruise tourism to Tonga seems to be growing in visitor numbers, but relatively steady in terms of vessels visit numbers. Should charts not be updated, the consequential difficulties in securing insurance will ultimately lead to the loss of, initially, the larger liners engaged on round-the-world cruises and eventually all passing cruise trade. The Australian/New Zealand cruise market has grown over 130% in the past five years. The market is characterised by relatively short - up to ten days – multi-port cruises; the cruise experience rather more important than the actual localities visited (CLIA 2014).

The typical cruise liner serving the Australasian market has a capacity of around 2,000 passengers[70]. Although a berth alongside is not essential, presently the quality of hydrographic data is inadequate to consider bringing vessels of this size into ports other than Nuku'alofa and Vava'u. Furthermore, with restricted voyage time, unlike Vanuatu and New Caledonia where cruise tourism is booming, Tonga is seen to be out of range of the Australian market and likely to remain so other than for occasional voyages direct from

[70] The mv *Sun Princess* has a LOA of 261m, beam of 32.25m and draught of 8.1m

Australia[71]. To service the Australian market, stakeholder discussions indicate a minimum of three, ideally four ports would be necessary to develop Tonga as a suitable destination for a cruise liner based in the islands or Fiji.

8.6 SCENARIO DEVELOPMENT FOR ECONOMIC ANALYSIS

8.6.1 Overview of Criteria and Assumptions

Based on the discussion above, Table 20 summarises the assumptions adopted for the scenarios subject to the following economic analysis. That is:

- maintain the status quo, with a general degradation in existing charts to the point they are withdrawn, or
- undertake a hydrographic survey to IHO standards, to secure ENCs compliant with IMO requirements.

Given the uncertainties involved, and the impact of other external forces, there is inevitably significant variance in the model; there can be no guarantee the various markets will develop as assumed. Furthermore, although hydrographic survey data would be an enabler to facilitate the investment required to develop Nuku'alofa port as a container transhipment hub, for example, the costs of investing in the likes of the required ship-to-shore cranes have not been accounted for. Nonetheless, taking into account documented experience from elsewhere, the assumptions are viewed to be generally robust. **Annex F** then presents the detail of the assumptions and data used for the Cost Benefit Calculation.

[71] P&O Cruises Australia has scheduled three voyages for 2015 visiting two Tongan ports.

Table 19: Assumptions for Economic Analysis

Sector	Period	Scenario Assumptions	
		Status Quo	Charting Improvements to IHO Standards
International Shipping			
General Cargo	Short Term (0-5 Years)	Freight rate inflation double rate of other markets Accident probability stable, costs of consequence double rate of inflation[72]	Freight rate inflation double rate of other markets Accident probability reduced by 36% within three years[73] Nuku'alofa identified as suitable for development of container terminal. Chart and ENC distribution business provides employment.
	Medium Term (5-10 Years)	Reduced demand for new multi-purpose Lo-Ro vessels Further escalation in freight rates reflecting vessel replacement rates Accident rates increase as vessels age	Nuku'alofa container port development. Dedicated container service established, port regional transhipment hub 20% reduction in freight rate, inflation in line with other markets thereafter, to benefit of GDP. Accident probability improves consequential to use of new vessels
	Long Term (>10 Years)	Insurance declined, multi-purpose vessels withdrawn Replacement small, elderly uninsured vessels outlawed by PSC[74] Erratic high cost service Food shortages degrading economy, loss of export markets Major accident highly likely, one month port closure plus clean-up	Expanding GDP in region increases container throughput. Experience with new technology further reduces accident rates. Tonga develops as regional centre for seafarer training

72 This is a common feature for all areas

73 Estimated benefit secured through use of ECDIS and appropriate ENCs (DNV 2008)

74 Port State Control (PSC). Under the provisions of IMO instruments, port state authorities, such as the Paris Memorandum of Understanding states in Europe, may inspect visiting vessels to determine compliance with IMO safety and environmental regulations and standards. If the vessel is seriously non-compliant, it may be banned from port entry until the deficiencies have been corrected

Sector	Period	Scenario Assumptions	
		Status Quo	**Charting Improvements to IHO Standards**
Fuel	Short Term	Freight rates increase significantly faster than inflation Accident probability stable, costs of consequence (oil spill) double rate of inflation	Freight rates initially increase significantly faster than inflation Accident probability reduces as for general cargo Site suitable for medium range tanker transhipment terminal identified (Vava'u)
	Medium Term	Global demand increases, suitable tankers can only be secured at highly inflated rates, if at all Accident probability stable,	Transhipment terminal developed for medium range tankers loading in Singapore Freight rates, and cost of fuel, reduce to worldscale benchmark
	Long Term	Insurers refuse cover for tanker operations to islands Fuel transported by road tankers as deck cargo on general cargo vessel High cost, chronic fuel shortages High risk of catastrophic damage to environment	Tonga terminal expands with increasing use of ISO containers for fuel shipment Experience with new technology further reduces accident rates
Domestic Shipping			
	Short Term	'OTUANGA'OFA suffers an ECDIS-preventable grounding with more serious consequences. Multiple major injuries, possible fatality, vessel out of service for protracted period	Initially as for short-term until ENCs become available. With ENCs, probability of incident reduces. Increased uptake of electronic charting and improved navigational safety culture. Shorter, more efficient routeing identified
	Medium Term	*'OTUANGA'OFA* operations increasingly unreliable Loss of confidence, escalated decline in outer islands	Vessel fitted with ECDIS Probability of incident involving *'OTUANGA'OFA* reduces by 36%

Sector	Period	Scenario Assumptions	
		Status Quo	Charting Improvements to IHO Standards
	Long Term	Insurance withdrawn, *'OTUANGA'OFA* removed from service Irregular freight and passenger transfer in old, poorly maintained vessels Major disaster with catastrophic loss of life Chronic food and fuel shortages, outer island economies collapse	With increasing demand for freight, to service developments in tourism, investment secured for larger vessel to replace *'OTUANGA'OFA*– With experience, and introduction of new vessel, decline in accident rates
Cruise Tourism	Short Term	Over-reliance on passing northern-hemisphere trade, concentrated Jan/ Feb Ship insurers issue warning not to use Tongan ports due non-compliance with IMO standards	Survey demonstrates 2,000 passenger vessels can safely operate to Vava'u, Ha'apai and Tofua the northern-hemisphere cruise market brings increased visits by the largest vessels, with confidence in IMO compliance
	Medium Term	Tonga removed from itinerary of large cruise liners Only small 'boutique' vessels occasional visitors	Vessel homeports to provide year round, weekly, 'fly cruises' for Australian market Shore resorts develop for stopover Second port identified as suitable for largest vessels on round-the-world cruises
	Long Term	No cruise liner visits	Two or more additional vessels homeport in either NZ or Australia to serve SW Pacific Market and other market (US / Europe)

Table 20: Assumptions for Economic Analysis

8.7 INTERNATIONAL SHIPPING

8.7.1 Safety Benefits

Few vessels exercise the right of innocent passage through Tongan waters; the existing ENCs are broadly adequate to ensure their safety. Consequently only vessels visiting Tongan ports would secure specific utility from larger scale ENCs. For the ports in use - Nuku'alofa and Vava'u – the approach channels are relatively short and relatively well provided with aids to navigation, and pilotage.

Nevertheless, there is synergy: it is the restrictions in port infrastructure including hydrographic survey data that largely determines the type of vessels that can serve Tonga. Notwithstanding the present shipping market serving Tonga is well balanced for general cargo, it is less so for the petroleum trades. The vessels serving the islands are non-standard with consequentially higher freight rates compared to dedicated container vessels. Furthermore, in due course, these vessels will require replacement. At such time owners have the option of building further specialist vessels, at heightened cost compared to 'standard' container ship designs – which inevitably further escalates freight rates, or withdrawing from the market.

The availability or otherwise of appropriate ENCs will not, in itself, determine ship owners' business strategy. Nonetheless, the lack of ENCs is likely to be a significant disincentive to future investment, particularly as difficulties may be encountered securing adequate insurance[75]. Should quality operators withdraw from the Tongan market, there would be little alternative but to secure the services of vessels similar to the *TYCOON*, which was involved in a serious incident at Christmas Island in January 2012, blocking the port – and effectively all trade to the island – for three months. In short, sub-standard ships whose use, in addition to presenting a greater risk, could ultimately destabilise the Tongan Economy

[75] Most vessels are owned by one entity and chartered (hired) by another. It is a standard condition of charter that the charterer warrants the safety of ports the vessel is directed to serve. If the port does not fulfil international standards, including provision of ENCs, charterers may find insurance is unforthcoming.

8.7.2 Economic Benefits

For international shipping the principal economic benefit derived from hydrographic survey data is market stability. In other words, more certainty that Tonga will continue to be served by quality operators. However, for the reasons outlined above, adequate ENCs of larger scale will also open up the potential for new port development, bringing with it the opportunity to secure access to modern, efficient ship management techniques, notably containerisation and larger petroleum tankers.

With the previously observed caveat regarding the unpredictability of shipping markets, if ENCs of appropriate Usage Bands are not developed, the underlying assumptions are:

- the volume of containers (TEU) will increase in line with assumed GDP growth (2.4% per annum);
- freight rates for specialist multi-purpose vessels will initially increase at twice the rate of general inflation in the market, i.e., compared to dedicated container vessels;
- from 2020 specialist vessel operators increasingly lose market share to dedicated container operators and must increase rates accordingly;
- from 2025 specialist vessel operators are forced to withdraw from Tonga due to difficulties securing insurance, sub-standard – but high cost – shipping only source for transport.

Conversely, if ENCs are published, it is assumed that, by 2020, dedicated container operators will serve Nuku'alofa bringing an immediate 20% reduction in freight rates, the inflation thereafter in line with worldscale.

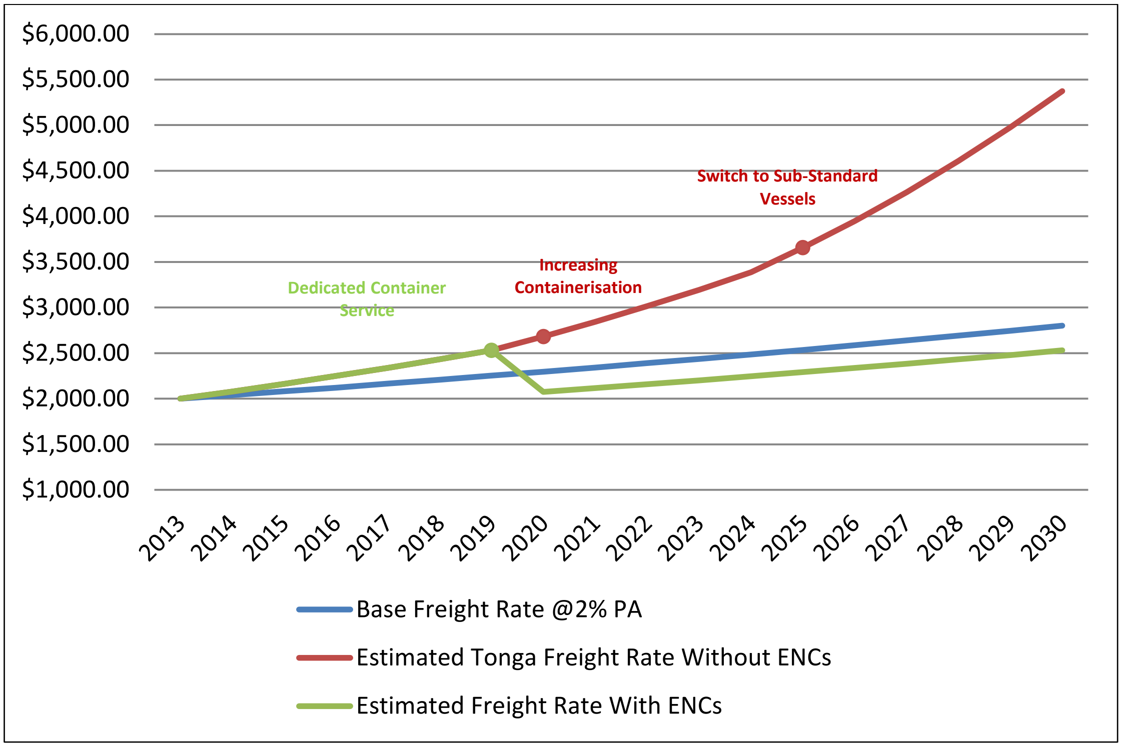


Figure 49: Predicted Container Freight Rate Without / With ENC (TEU Tonga / Australia)

Figure 49 shows the estimated impact on general cargo (container) freight rates of not undertaking hydrographic surveys to IHO standards throughout Tongan Waters, with a comparison to the predicted rates assuming ENCs are developed.

The transport of petroleum shows a similar trend with the exception that freight rate inflation is anticipated to be greater than that of general cargo due to the shortage of suitable small chemical tankers (which are prevalent in the SW Pacific Island trades for fuel transport because of their smaller package capability). Table 21 shows the estimated additional annual costs for transporting freight through Tongan waters without ENCs. Freight costs are gradually increasing throughout the period 2013 -2030. Therefore, there is no additional benefit if ENCs are not updated to the highest standard for liquid bulk shipping.

Year	Annualised Additional Freight Costs (General)	Annualised Additional Freight Costs (Petroleum)	Total Increase in Freight Costs Per Annum
2013	0.00E+00	0.00E+00	0.00E+00
2014	4.92E+05	1.64E+05	6.55E+05
2015	1.04E+06	3.49E+05	1.39E+06
2016	1.64E+06	5.58E+05	2.20E+06
2017	2.31E+06	7.92E+05	3.10E+06
2018	3.04E+06	1.05E+06	4.10E+06
2019	3.85E+06	1.35E+06	5.20E+06
2020	5.46E+06	1.81E+06	7.27E+06
2021	7.26E+06	2.34E+06	9.59E+06
2022	9.27E+06	2.93E+06	1.22E+07
2023	1.15E+07	3.60E+06	1.51E+07
2024	1.40E+07	4.37E+06	1.84E+07
2025	1.79E+07	5.45E+06	2.33E+07
2026	2.23E+07	6.69E+06	2.89E+07
2027	2.72E+07	8.11E+06	3.53E+07
2028	3.28E+07	9.74E+06	4.25E+07
2029	3.91E+07	1.16E+07	5.07E+07
2030	4.62E+07	1.37E+07	5.99E+07

Table 21: Change of Freight Benefit for Tonga without ENCs

Table 22 shows the estimated additional annual costs (or savings) for freight costs Tonga respectively, assuming ENCs are introduced through the waters. An increase in freight costs occurs at a decreasing rate until 2020. From 2021 onwards, the benefit accumulation suggests savings would then accrue if ENCs are introduced.

Year	Annualised Additional Freight Costs (General)	Annualised Additional Freight Costs (Petroleum)	Total Increase (Decrease) in Freight Costs Per Annum
2013	0.00E+00	0.00E+00	0.00E+00
2014	4.92E+05	1.64E+05	6.55E+05
2015	1.04E+06	3.49E+05	1.39E+06
2016	1.64E+06	5.58E+05	2.20E+06
2017	2.31E+06	7.92E+05	3.10E+06
2018	3.04E+06	1.05E+06	4.10E+06
2019	3.85E+06	1.35E+06	5.20E+06
2020	-3.15E+06	-2.98E+06	-6.13E+06
2021	-3.29E+06	-3.12E+06	-6.40E+06
2022	-3.43E+06	-3.25E+06	-6.69E+06
2023	-3.59E+06	-3.40E+06	-6.99E+06
2024	-3.75E+06	-3.55E+06	-7.30E+06
2025	-3.91E+06	-3.71E+06	-7.62E+06
2026	-4.09E+06	-3.87E+06	-7.96E+06
2027	-4.27E+06	-4.05E+06	-8.32E+06
2028	-4.46E+06	-4.23E+06	-8.69E+06
2029	-4.66E+06	-4.41E+06	-9.07E+06
2030	-4.87E+06	-4.61E+06	-9.48E+06

Table 22: Change of Freight Benefit for Tonga with full Introduction of ENCs

To summarise, in 2013 prices, through to 2030 it is estimated the total excess freight charges if there is no publication of adequate larger scale ENCs is of the order of US$244.7M, whereas with adequate ENCs it is estimated there is a potential saving over the same time period of US66.7M.

8.7.3 Domestic Shipping

In the short to medium term, Hydrographic data (ENCs) is envisaged to deliver little direct economic benefit for Tongan domestic shipping, both passenger and freight. The existing vessels, particularly the *'OTUANGA'OFA*, are assumed to fulfil foreseeable requirements.

Domestic shipping will, however, secure significant safety benefits from larger scale ENCs.

As previously described, inadequacies in charts and related human error would appear to have been causal in the grounding of the *'OTUANGA'OFA* in port approaches. With the caveat of a potential gamblers' fallacy[76], without ENCs and the application of ECDIS, or similar, it is reasonable to assume the probability of further grounding remains high. As always, with high density passenger vessel operation, the worst credible consequence will similarly be high, hence this reflects the highest risk maritime activity within the Tongan islands.

For quantification purposes, a risk model was developed based on published research data. The detail of the assumptions used in the model is included as **Annex F**. From the model the risk, in financial terms, without ENCs has been estimated for each 1km^2 within the Tongan Extended Economic Zone (EEZ) and compared with the estimated (reduced) risk with ENCs; to an approximation, ENCs are estimated to reduce grounding probability by about 36%. With knowledge of the likely cost of developing larger scale ENCs, the Net Present Value (NPV) of the investment in hydrographic survey may be determined. Where the NPV is positive, the survey is assessed to deliver a financial return on investment; where negative the survey costs outweigh the benefit.

The results of the economic analysis are shown in the diagrams [below] [annexed]. As would be expected, the areas benefiting from the development of ENCs are those primarily used by domestic shipping.

This is not to suggest there is no benefit from conducting wider hydrographic surveys, beyond the areas indicated. However, a full bathymetric survey, to the IHO standards required for ENCs, would provide little additional utility suggesting the use of satellite derived bathymetry as an alternative.

76 Gamblers who lose often continue to wager on an outcome in the belief that a losing streak cannot continue whereas, all things being equal, the probability of the outcome – winning or losing – never changes from one wager to the next.

8.8 CRUISE TOURISM

Notwithstanding the increase in cruise tourism worldwide, the number of cruise passengers visiting Tonga has decreased in recent years. There are a number of factors underpinning this situation, notably the lack of suitable facilities to host cruise liners outside of Nuku'alofa and Vava'u. There would appear to be little likelihood of the situation improving in the short to medium term. In the longer term, without suitable ENCs, and lack of insurance cover, it is reasonable to assume all cruise liners will withdraw from the Tongan market.

Taking into account the above, the safety benefits of hydrographic survey are minimal. With few ships visiting, the existing risk is low and likely to decrease to zero with the loss of the remaining trade.

As previously highlighted, whilst not ensuring the future of cruise tourism in Tonga, hydrographic surveys – and the resulting larger scale ENCs – are a key, if not the key facilitator of such development. As outlined in **Annex E**, the benefits of hydrographic survey data extend beyond providing an accurate bathymetric profile; as does the data itself. Planners may objectively seek to develop new port opportunities for cruise liners in the knowledge that suitable channels previously only suspected as existing can be proven and appropriately provided with aids to navigation (buoys and beacons), optimally located through access to the necessary data[77].

In summary: ENCs address the paradigm of servicing the Australian/New Zealand cruise market, which seeks a minimum of three ports of call in the Tongan islands. On the basis of that assumption, noting the expenditure of both passengers and crew in each port, and the estimate of employment generated (Worley and Akehurst 2013), Figure 50 shows the estimated revenue generated by cruise liners for 'low growth' and 'high growth' scenarios[78].

[77] For a given length and breadth, the draught of a cruise liner is far less than that of a cargo ship or tanker. Further, cruise liners are far more manoeuvrable and may therefore safely enter restricted areas unsuitable for cargo ships. Finally, as noted above, cruise liners are provided with suitable launches and do not require a berth alongside, thus, full port facilities are not required.

[78] Low growth assumes, from 2018, Australian cruises visit bi-weekly visit between December and March, with their expansion in 2023 to a weekly visit. High growth assumes similar call pattern with season extended from October to March.

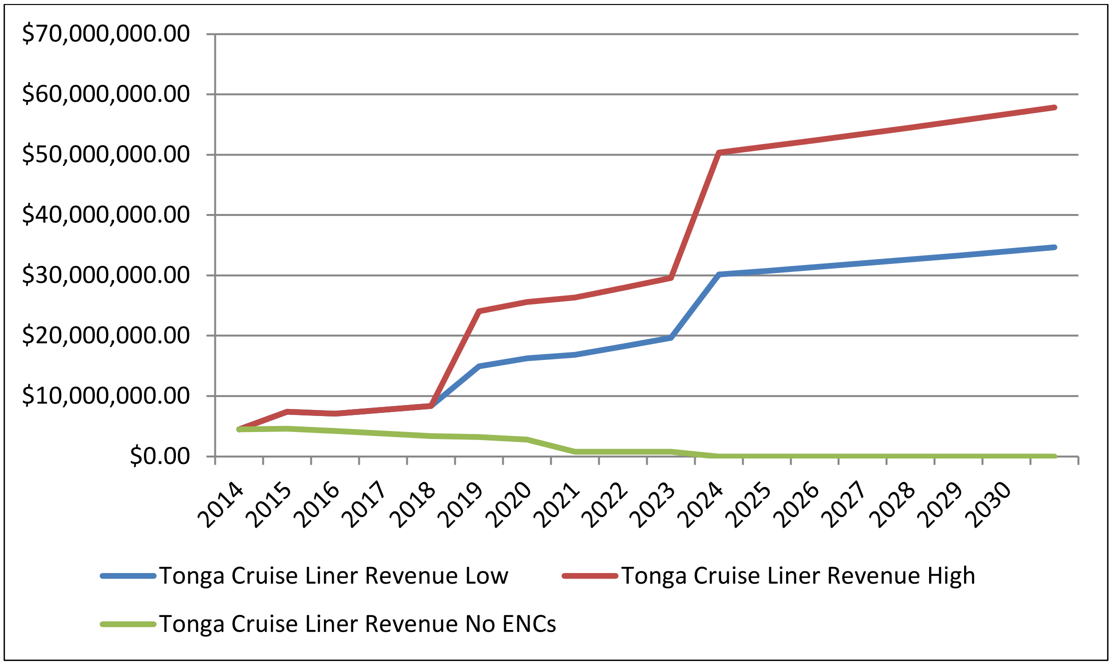


Figure 50: Tonga Projected Cruise Tourism Revenue

8.9 OTHER BENEFITS OF CHARTING IMPROVEMENTS

There are a number of other areas where charting improvements are in the wider public interest. The first is Aid Relief after a significant natural event. Accurate charting allows planning for cargo delivery into areas other than designated ports, which may be inaccessible following a natural event. Aid can also be delivered directly to where it is needed by e.g. landing craft, if charting is accurate throughout a coastline. The second area is sea level inundation from climate change. Accurate high quality hydrographic survey data is of significant value in measuring sea level change over a considerable period of time.

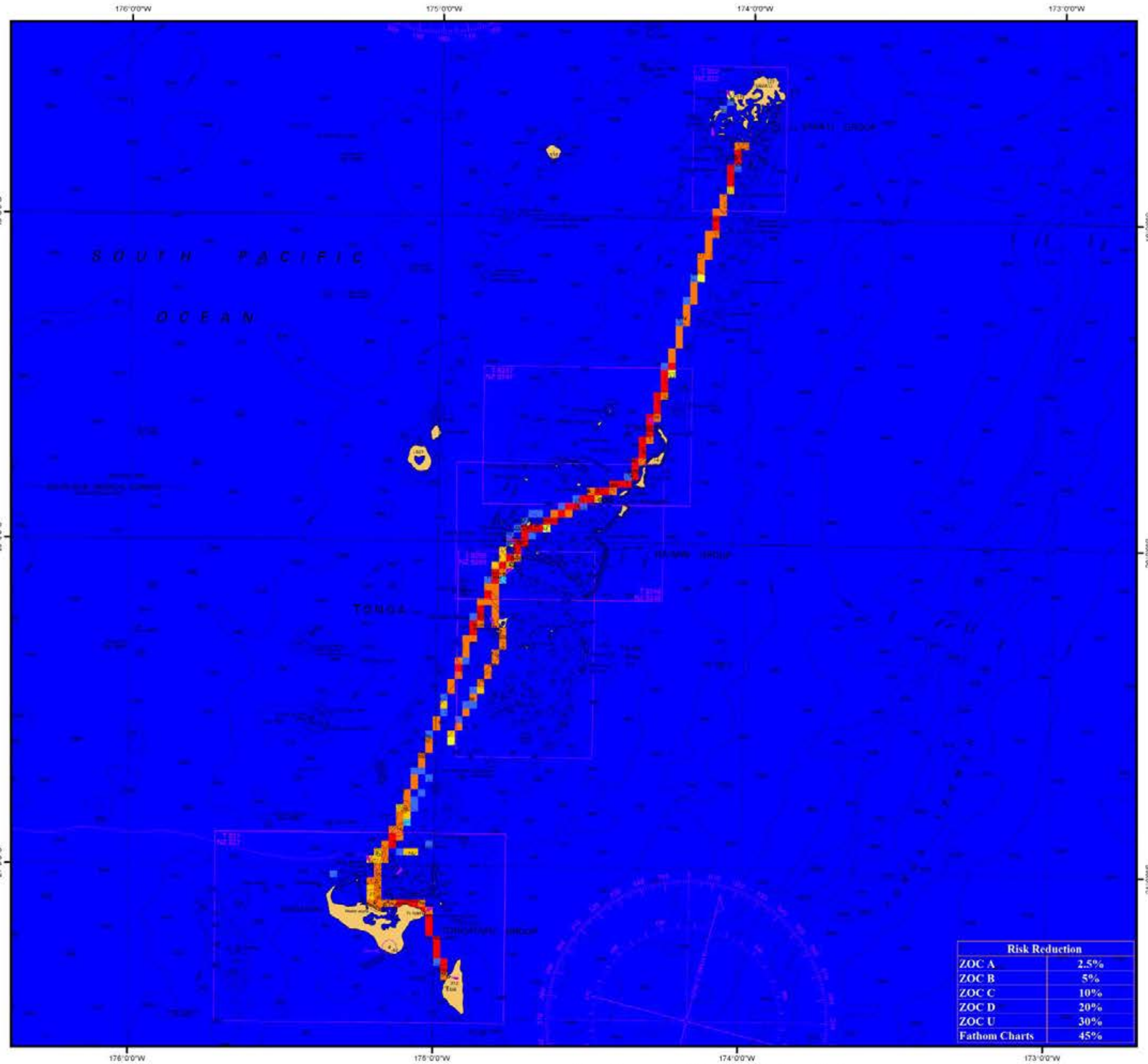
8.10 COST BENEFIT ANALYSIS RESULTS

8.10.1 Tonga Cost Benefits Results

Figure 51 presents the maritime cost benefit result for Tonga, overall, which is followed by further plots to detail the result. The model assumes singlebeam hydrographic survey costs and a percentage grounding risk reduction in related to the CATZOC rating of the chart. The period of benefit assessment was a ten years. Each grid cell in the GIS outputs a net present value NPV. The following areas with high NVP return are:

- Port of Nuku'alofa and it's approaches;
- The Piha Passage;
- Nafanua Harbour, 'Eua Island;
- Ha'ano, Lifuka and Uoleva Islands;
- Sea area between Kapa Island and Richard Patches, Vava'u.
- Ha'apai and especially the shipping lane between Ha'afeva Island and into Foa.

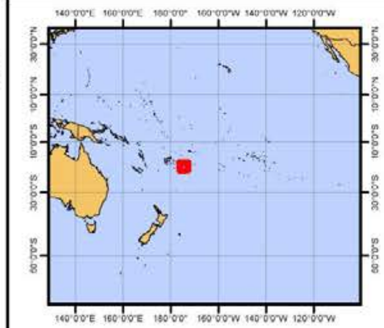
It should be noted that for clarity, the Nuias are not included in Figure 51 because it also has a negative cost benefit result throughout its waters.



Risk Reduction	
ZOC A	2.5%
ZOC B	5%
ZOC C	10%
ZOC D	20%
ZOC U	30%
Fathom Charts	45%

Figure Reference: 13NZ262_Tonga_CostBenefit2_02

Figure 51: Cost Benefits Results for Tonga – Costed as Singlebeam Survey ($500)



Legend (Net Present Value US$/10 Years)

- -3,087 - -1,000
- -999 - -100
- -99 - -10
- -9 - 0
- 1 - 10
- 11 - 100
- 101 - 1,000
- 1,001 - 10,000
- 10,001 - 100,000

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 02
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:1,250,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014
Chart 14061 courtesy of LINZ
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 5 10 20 30
Nautical Miles
N

Produced by:
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8.10.2 Tongatapu and ‘Eua Islands Cost Benefits Results

Figure 52 shows the cost benefits results for Tongatapu and ‘Eua Islands. The most positive cost benefit result is located at the Port of Nuku’alofa and Piha Passage.

They show a positive range NVP between $10,001 and $100,000. The highest in benefit is concentrated on the eastern side of Tongatapu harbour. Charting is already to a high standard in Tongatapu and the reason for this positive NPV result (overall) is the fact that the main entrance channel has a zone of CATZOC A, surrounded by CATZOC B. There is a significant portion of harbour traffic, including domestic passenger ferries that transit into the harbour using more direct means than the main channel entrance. This is through an area of CATZOC B and thus the available risk reduction, combined with the level of ship traffic, as well as the presence of a number of adjacent marine reserves.

The high NPV on the eastern side of the harbour is explained by the fact that Piha passage is surveyed to a CATZOC D standard, but has a large volume of passengers transiting down it annually, together with the occasional tanker shipment to ‘EUA. It appears that a chart reorganisation is worthwhile considering for the harbour, together with survey of Piha channel.

To lesser extent, Nafanua Harbour has also a high NVP that emphasizes the significance of the risk reduction available from charting improvements. The underlying factor driving this result is the increasing volume of domestic ferry transits and passengers between Nuku’alofa and ‘Eua.

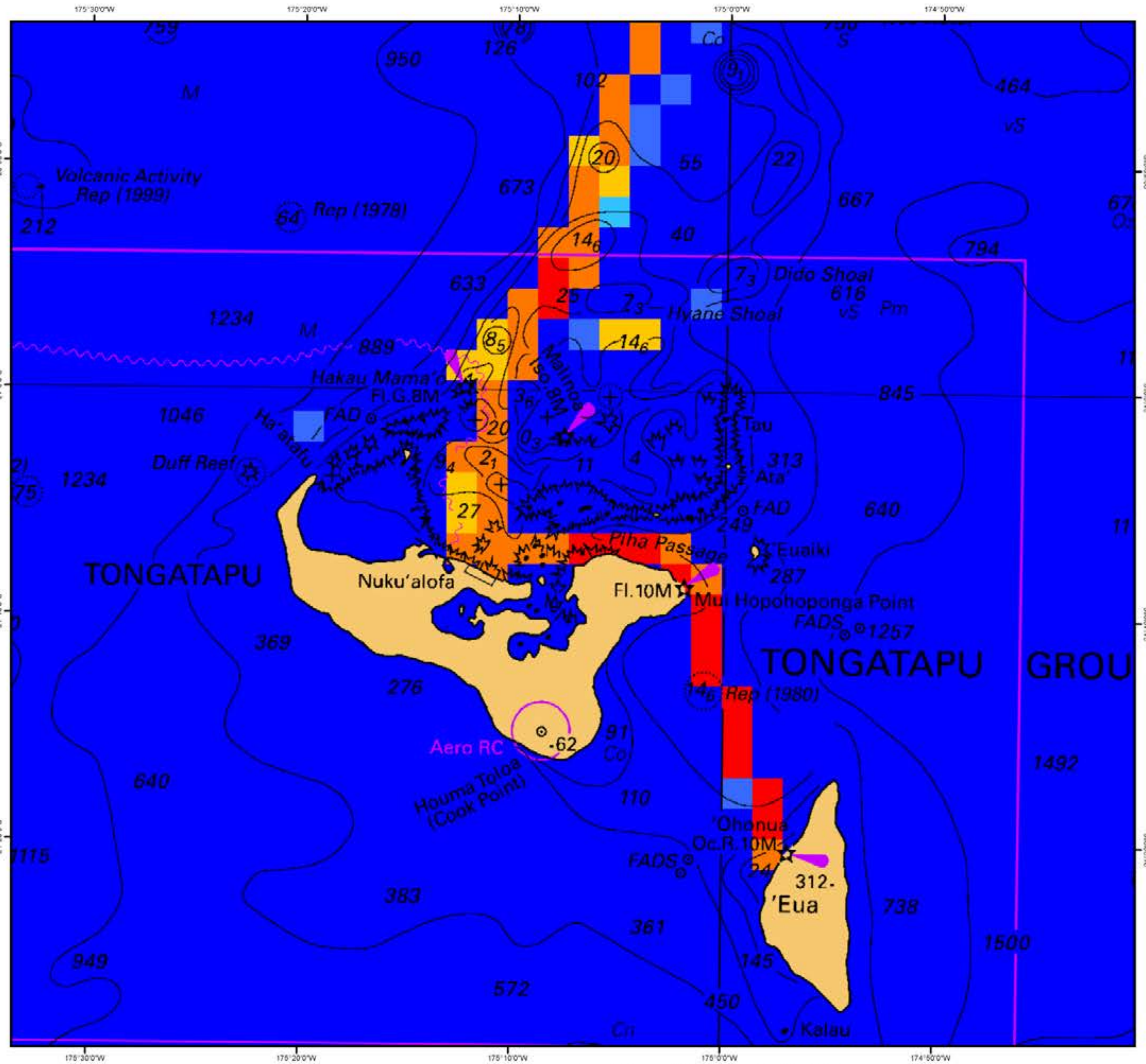
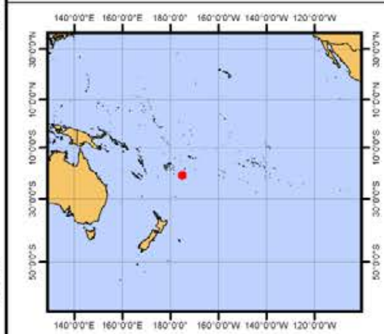


Figure 52: Tongatapu Group – Cost Benefit Analysis



Legend (Net Present Value US$/10 Years)

- -3,087 - -1,000
- -999 - -100
- -99 - -10
- -9 - 0
- 1 - 10
- 11 - 100
- 101 - 1,000
- 1,001 - 10,000
- 10,001 - 100,000

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 02
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:300,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System:
WGS 1984 UTM Zone 1S
Projection:
Transverse Mercator
Datum:
WGS 1984
Units:
Meter

0 1.75 3.5 7 10.5 Nautical Miles N

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Figure Reference: 13NZ262_Tonga_CostBenefit5_02

8.10.3 Ha'apai Group Cost Benefit Results

Figure 53 presents the cost benefit results for Ha'apai Group. There is a strong Net Present Value throughout Ha'apai. Given that traffic levels through the waters of Ha'apai are relatively low, this very clear result is influenced most by the risk reduction available out of updating charts that are presently unusable in a ship's ECDIS.

The result does suggest though that with current traffic levels, it is more cost effective to survey in the north of the province than in the south, yet the charting is of the same standard almost throughout the waters of Ha'apai. This is partly because shipping takes two routes through Ha'apai waters in the south (lower vessel transit numbers = lower risk, and therefore lower risk reduction for the CBA). The results of the traffic forecast are thus of be of interest (section 9).

Although the result is positive in most areas around the natural shipping channels of the area, it is possible to consider specific areas as well. These are suggested as follows:-

- The shipping lane between the Ha'afeva Island and Tokulu Island,
- The northwest reefs of Ha'ano Island
- The west coastlines of Lifuka Island and Pangai Harbour
- Uoleva Island
- Foa Island.

Charts NZ 8235,8247,8248,8259 and 8266 are all non-metric (i.e. in Fathoms), surveyed on an undetermined datum. The CBA benefits from improvements to charting are positive and significant, especially in the north at the interface with the waters of Vav'au.

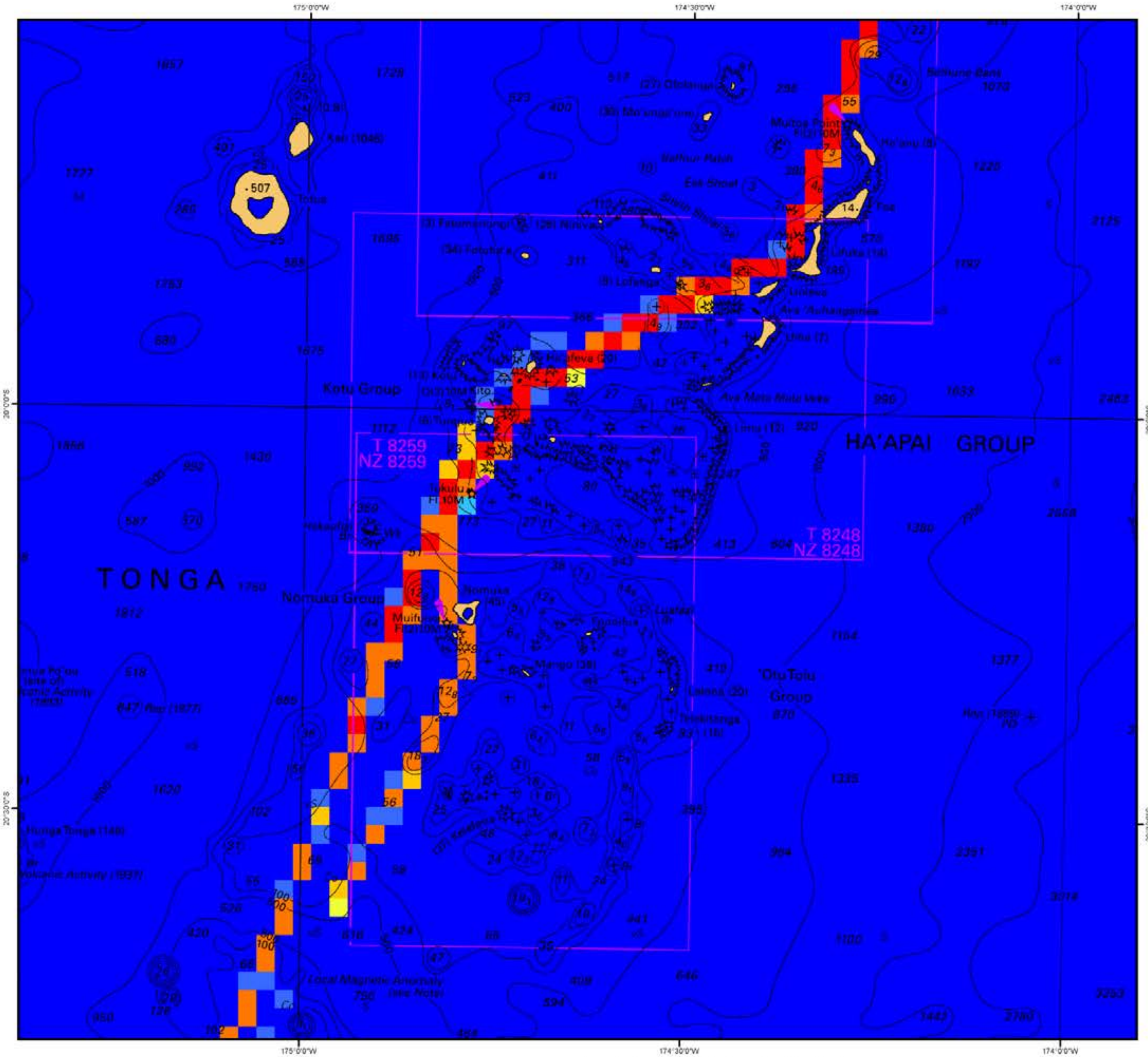
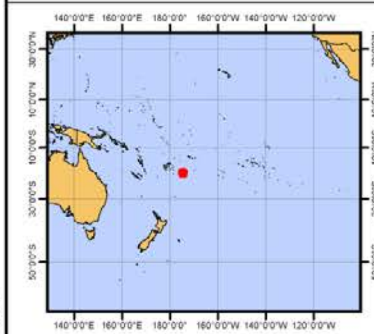


Figure Reference: 13NZ262_Tonga_CostBenefit4_02

Figure 53: Ha'apai Group – Cost Benefit Results



Legend (Net Present Value US$/10 Years)

- -3,087 - -1,000
- -999 - -100
- -99 - -10
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Project No.	Date	Issue Number
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Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
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Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 3 6 12 18 Nautical Miles

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8.10.4 Vava'u Group Cost Benefit Results

Figure 54 depicts the cost benefits for Vava'u Group, which is a very interesting result. Despite the high hydrographic risk result for Neiafu Harbour and Vava'u Island approaches, the charts are of high quality, based on recent surveys. Much of the Vava'u area is a CATZOC A rating (see **Annex C**). This shows the strength of the CBA segment of this report, as high hydrographic risk can be generated in an area of relatively frequent traffic volume, which has high environmental and economic utility, despite the charts being in good order. The CBA result clarifies that updating the charting further in Vava'u would achieve nothing economically. In short, charting is already adequate.

However the southern waters of Vava'u shows a nigh NPV, making it advisable to review again the charting in the southeast of this province. This commences in the sea area between Kapa Island and Richard Patches. The reason for this is the CATZOC rating of the charting in the seas south of the province, which is of CATZOC D rating, i.e. much lower than the expected approach route to Neiafu Harbour. Domestic coastal vessels, including the passenger ferries, route through these CATZOC D waters to Neiafu Harbour, thus transiting a different area to that advised at the time of the most recent surveys for charting upgrades for Vava'u. There is thus significant benefit to the domestic passenger vessels used in service between Tongatapu and Vava'u for a further charting upgrade. A chart reorganisation is suggested, which may include new surveys in the south west and into the interface with the waters of Ha'apai.

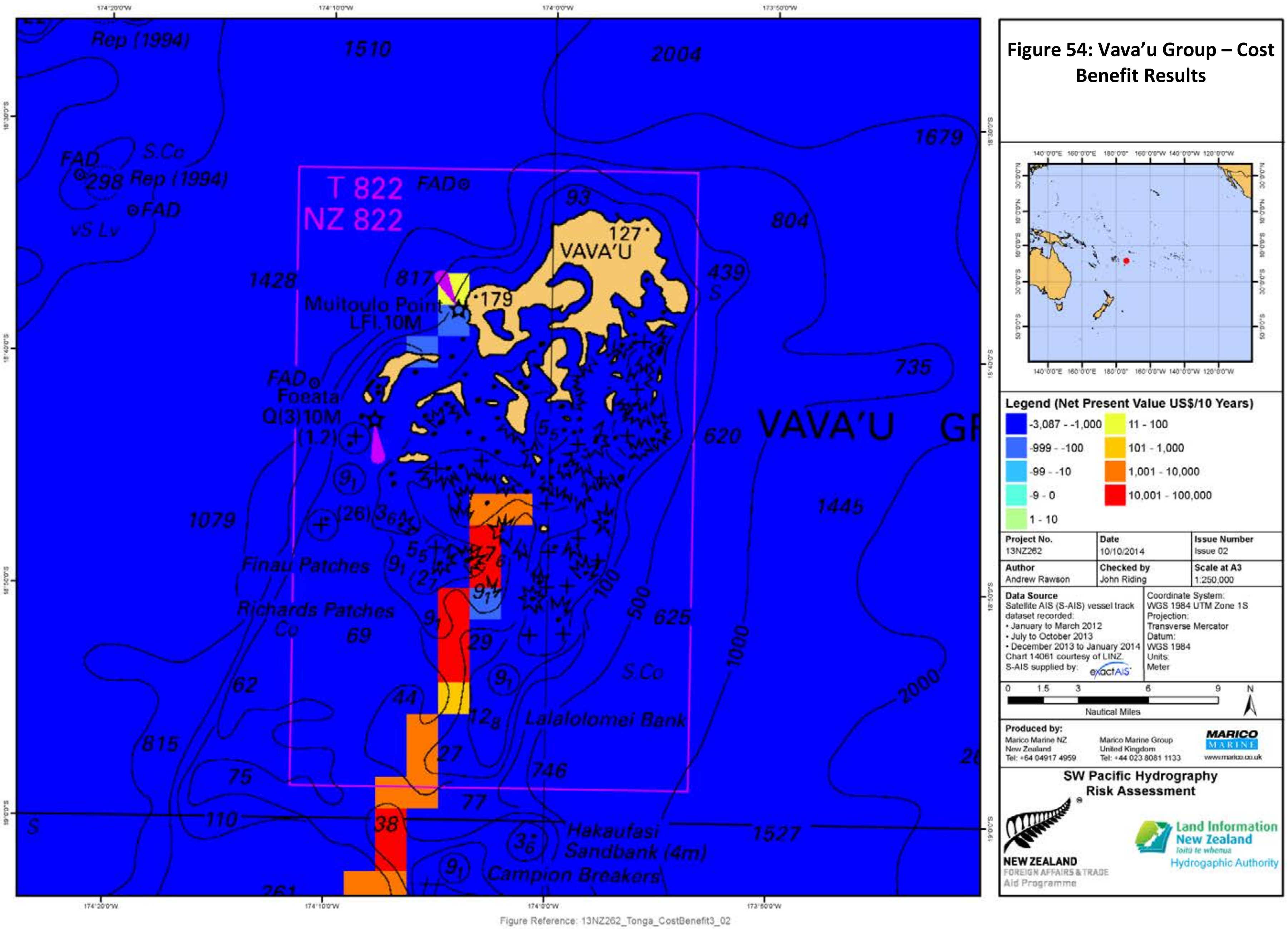

Figure 54: Vava'u Group – Cost Benefit Results

8.10.5 Sensitivity Analysis

Testing of the cost benefit result was undertaken. The result was found to be highly sensitive to the type of hydrographic survey system used for survey, which is, of course, a function of survey cost. The result is also sensitive to the cost of oil pollution clean-up, but more to the actual value of the risk reduction delivered by the introduction of improved charting. The latter result has been fixed at a maximum risk reduction of 36%. However, it is true that the assessment of risk reduction, which is based on research work undertaken by Det Norske Veritas (a well-known classification society), is at best an estimation and at worse un-defendable. This is because this work assumes that the sum of all the grounding events in the world divided by the sum of all the shipping routes in the world and the traffic volume on them, is a result that can be applied to any particular maritime location in the world. Clearly it cannot, but this is the best estimate there is of the risk reduction value available.

Of importance though is that the risk reduction estimate is linked to chart data that were already capable of delivering an ENC. In the case of Ha'apai the charts remain in Fathoms, but on an undetermined datum. Thus, any charting improvement in this Island Group in particular is going to produce a step change in charting quality, but also arguably a much greater reduction in transit risk.

Figure 55 shows the change in the NPV result across Tongan waters as the cost of survey changes. The case assessed in the CBA model is that of singlebeam survey, which a relatively low cost of survey. A sensitivity analysis was also undertaken which compares the differing survey options and shows how sensitive the CBA result is to survey cost. The sensitivity analysis clearly shows that even if multibeam technology was selected for survey, the whole of Ha'apai waters still shows a strong new benefit. The use of single beam technology increases the survey area that delivers a result with a positive cost-benefit.

The sensitivity analysis also clearly shows the cost effectiveness of updating the charts of the Ha'apai waters. Ha'apai remains the most cost effective area for charting upgrade, irrespective of survey cost.

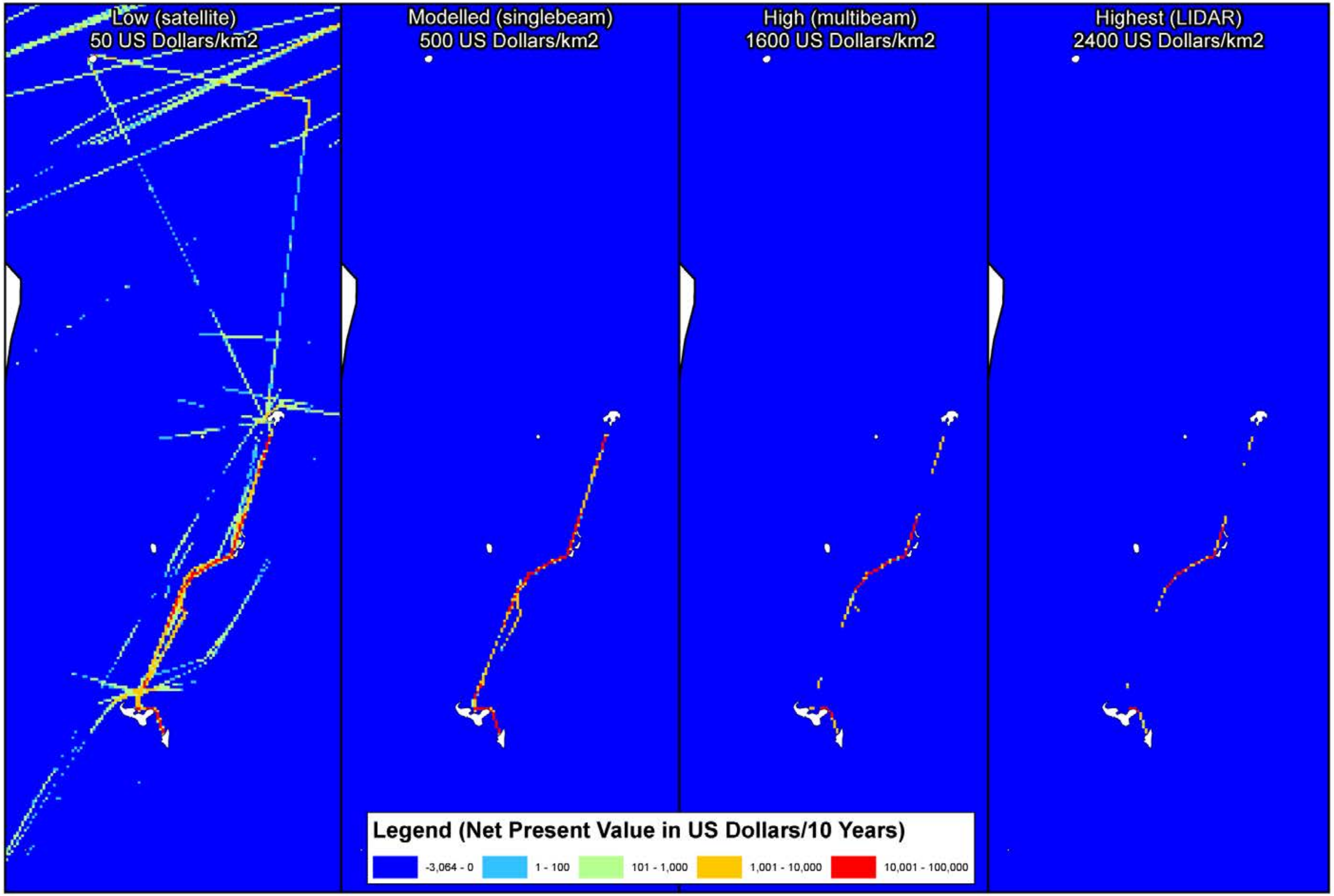

Figure 55 : CBA Sensitivity Analysis – Results Show Survey Cost Dramatically Affects NPV

9 TRAFFIC FORECAST – HA'APAI

9.1 INTRODUCTION

Ha'apai has charts that remain in Fathoms on an undetermined datum. Apart from occasional visits by specialist and small "boutique" cruise vessels, the waters are overwhelmingly used only by domestic coastal vessels. This explains the hydrographic risk result of heightened risk. The problem of charting remaining in Fathoms on an undetermined datum, is that conversion to modern charting (ENC) cannot be undertaken, without new surveys. It is thus inadequate for modern navigation. There is considerable interest in Cruise Stakeholders gaining access to the waters of Ha'apai, which they cannot in practice implement, until charts that are suitable for their electronic navigation systems can be produced. The waters of Ha'apai present a high inherent risk to each planned transit, until chart improvement occurs. The main hydrographic risk result can therefore be puzzling at first, as a judgemental belief will conclude it represents high risk; it does, but this is inherent risk, not hydrographic.

Hydrographic risk is a function of traffic frequency and the consequence impacts of a shipping accident in a sea area. It is necessary for a hydrographic risk assessment to take account of traffic levels, as updating charts where there is no ship traffic is by definition uneconomic, but equally if there is no shipping traffic, there can be no risk arising from a hydrographic problem. This section of the report covers an exercise that provides a Traffic Forecast for Cruise Vessel access, together with a CBA update.

9.1.1 The Concept of a Traffic Forecast

A Traffic Forecast is important for a Hydrographic Risk Assessment, not so much to understand risk levels, but more to understand the status of the costs and benefits of upgrading charting in an area. The Traffic Forecast has to be both realistic, as well as practical. For the forecast, a known ship, representative of the envisaged traffic is provided with a route, destinations, as well as a frequency of visits. Tracks are added to the GIS risk model, with data attached to the tracks from a vessel of size, displacement and in this case passenger capacity that is representative of future expectations.

9.2 DEVELOPMENT OF A TRAFFIC FORECAST

Cruise interests were consulted about potential future plans, with Carnival advising the viability of an eight day cruise to Tonga, with a vessel based in Auckland for the summer season to provide the service. There has been significant increase in cruise passengers from New Zealand in recent years, and a vessel is already based out of Auckland for the peak season. The types of cruise vessel visiting this area of the SW Pacific were reviewed and a representative vessel selected. This was PACIFIC PEARL, which already makes regular visits to Vanuatu, Tonga, Fiji, New Zealand and Australia. At 63,000GT, it is in the middle of the range of cruise vessel size that trades in this area. Criteria for the Chosen Vessel, together with the risk update are presented in **Table 23.**

Vessel Criteria			Risk Consequence Data			
Vessel	Gross Tons (GT)	Passenger Capacity	People (ML)[79]	People (WC)[80]	Pollution (ML)	Pollution (WC)
PACIFIC PEARL	63,785	2500	25	625	15	375

Table 23: Vessel Criteria For Ha'apai Traffic Forecast

Passage plans were developed for the Traffic Forecast, which are presented at **Annex G**. These routed the vessel into Nuku'alofa, with two optional destinations in Ha'apai, in destinations where cruise vessels have previously visited this island group, followed by Vava'u. This was to the main islands of the group, with an eight day frequency for the months of November through to February. A second cruise option was added to the GIS risk model at the beginning and the end of the season, in which the vessel transited out west to visit the Island of Tofua. This followed the track of two previous cruises to this island, already recorded in the vessel track database.

All cruise vessels visits were also routed as originating from and returning to New Zealand as part of an eight day cruise. The Traffic prediction is thus realistic, considering only the addition of cruise vessels through Ha'apai waters, and assumed that cargo shipments would continue to be met by the existing ferry and domestic cargo vessel schedule.

[79] Based on the Most likely (ML) consequence scenario.
[80] Based on the Most Credible (WC) consequence Scenario

9.3 TRAFFIC FORECAST RESULTS

The traffic forecast risk results are shown in Figure 56. The effect of a moderate number of cruise vessels commencing operations in the waters of Ha'apai is to extend the area of heightened risk quite considerably. The sea area south of Nomuka Island also produces a heightened risk, which has the potential to be a useful cruise destination.

The reasons for risk not reaching higher levels are twofold:

- Firstly, the traffic forecast reflects a modest, but realistic increase in the number of cruise vessel penetrating into the waters of Ha'apai, once charting is upgraded. This increase is based on feedback of plans from one cruise operator, but including calls to one of the popular resorts at Foa Island. Any decision by other operators to commence Ha'apai calls, or if larger vessels than the one used as a basis for the forecast, will increase the risk result. The waters of Ha'apai, even with an increase in vessel numbers that is significant in percentage terms, will still though experience only a low vessel-traffic level overall.
- Secondly, the passage plan for cruise vessels through Ha'apai needed to route these more conservatively than the (smaller) domestic vessel routeing. The passage plans are presented at **Annex G.** Because the traffic forecast does not directly follow the domestic route, risk calculations using traffic concentration as a factor have produced the result overleaf. It shows that the risk result is only one part of the story, and that the cost benefit assessment result provides the other side for decision makers to use.

The CBA result is shown at Figure 57, which is important. It shows that cruise vessel penetration into Ha'apai results in a dramatic increase in the extent of the area of high Net Present Value (i.e. there is a positive monetary benefit to economy/environment/safety over the 10 year period of assessment). It also shows this high positive benefit extends into the waters south of Ha'apai, improving the result for Ha'apai in the main CBA result. In simple terms it means that upgrading charting in Ha'apai waters is cost effective in the extreme.

Decision makers should be guided accordingly.

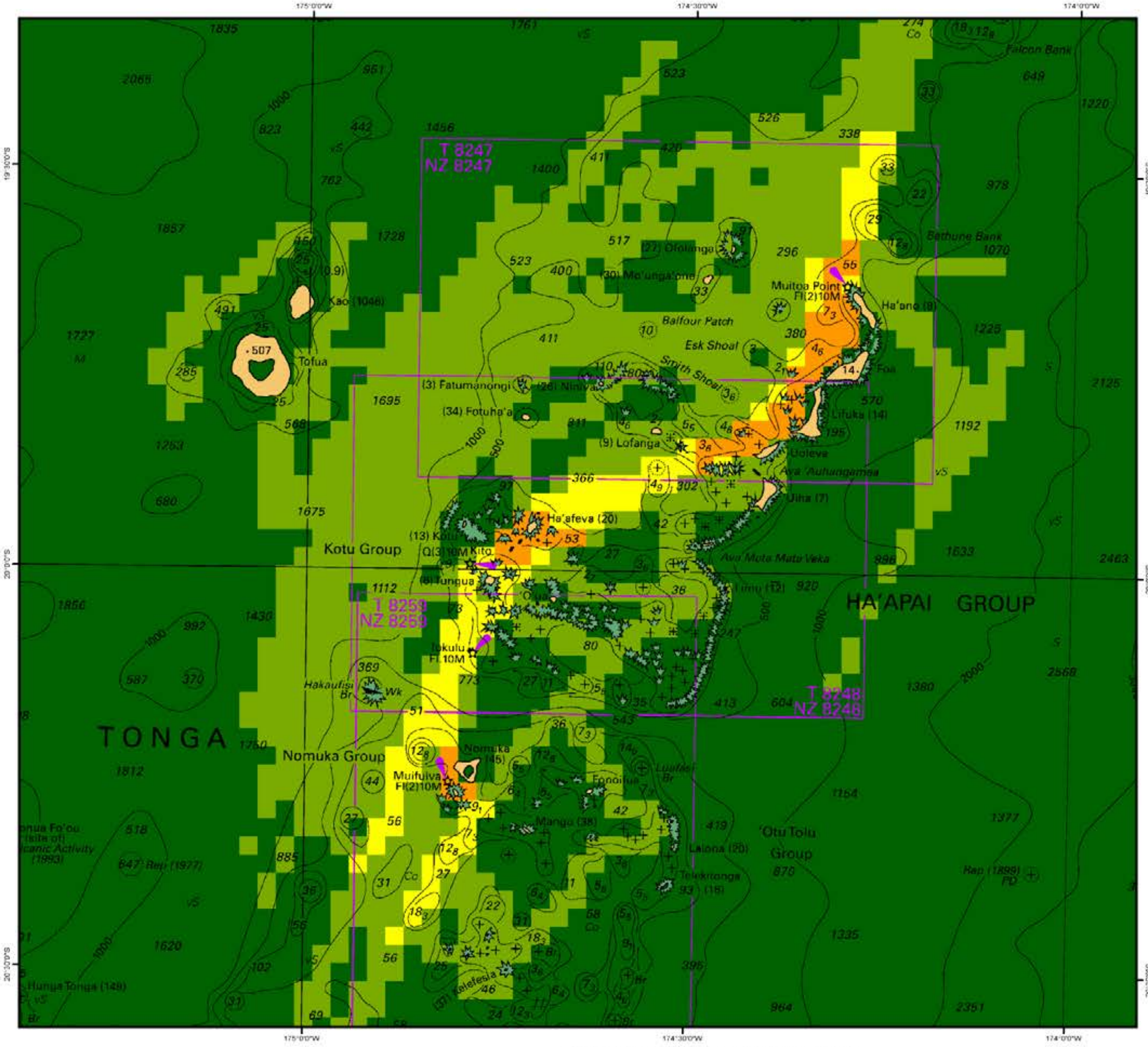

Figure 56 : Traffic Forecast Risk Result for Ha'apai

Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 01
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Andrew Rawson	John Riding	1:500,000

Data Source
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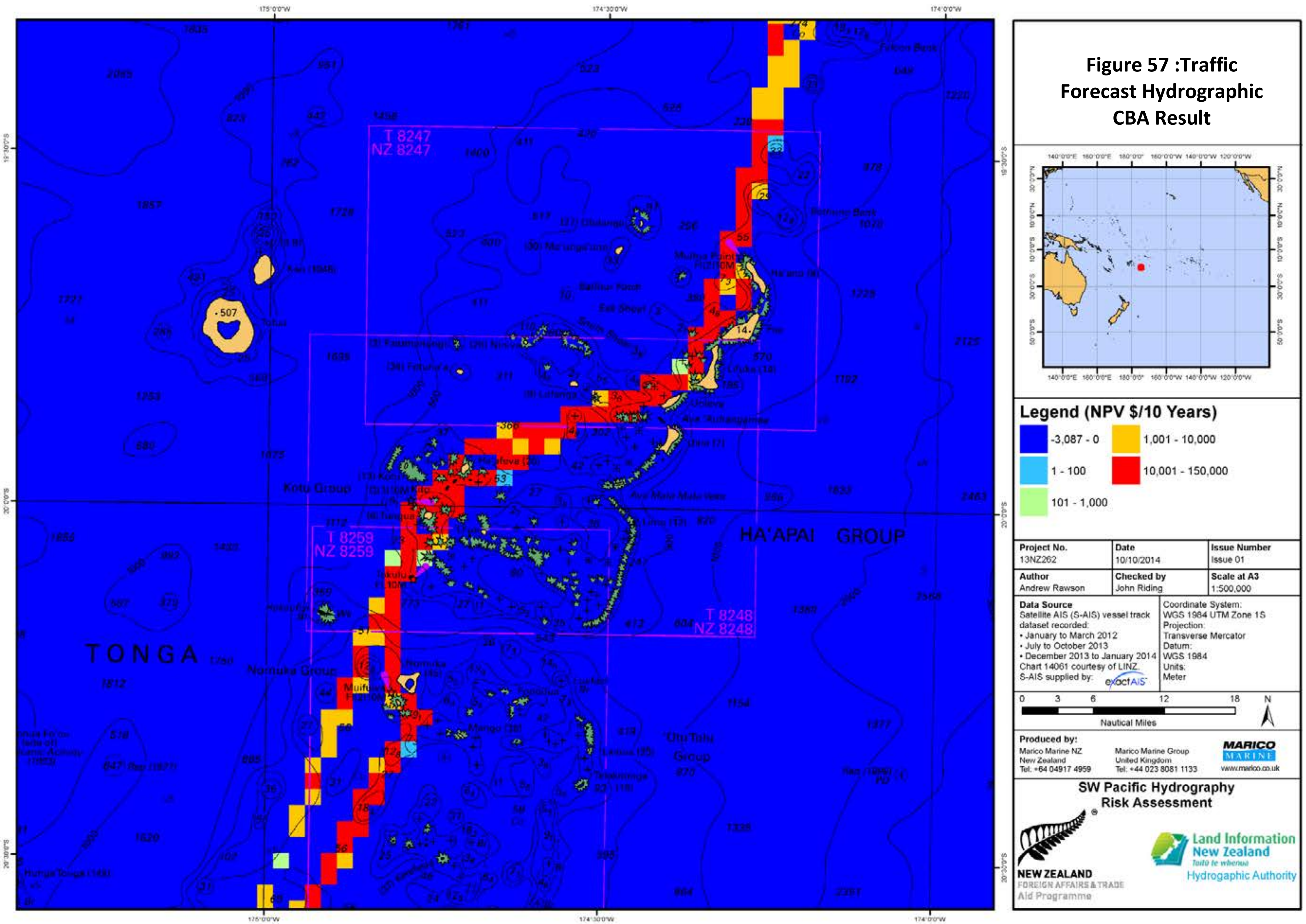

Figure Reference: 13NZ262_Tonga_CostBenefit_Step4_01

9.4 COMPARISON BETWEEN TRAFFIC FORECAST AND MAIN CBA

A final plot is included in this report, which shows a comparison of the main CBA result, against the Traffic Forecast CBA result this time extended to show the majority of the waters of Tonga. Figure 58 shows this net effect of the additional cruise vessels, which were routed from Tongatapu, through to Vava'u. This CBA comparison is included as it shows there is benefit in a review of charting standards in the waters between Tongatapu and Ha'apai, but importantly also in the approaches to the main shipping channel for Neiafu Harbour, Vava'u.

The comparison provides a useful clarity for decision-makers to consider.

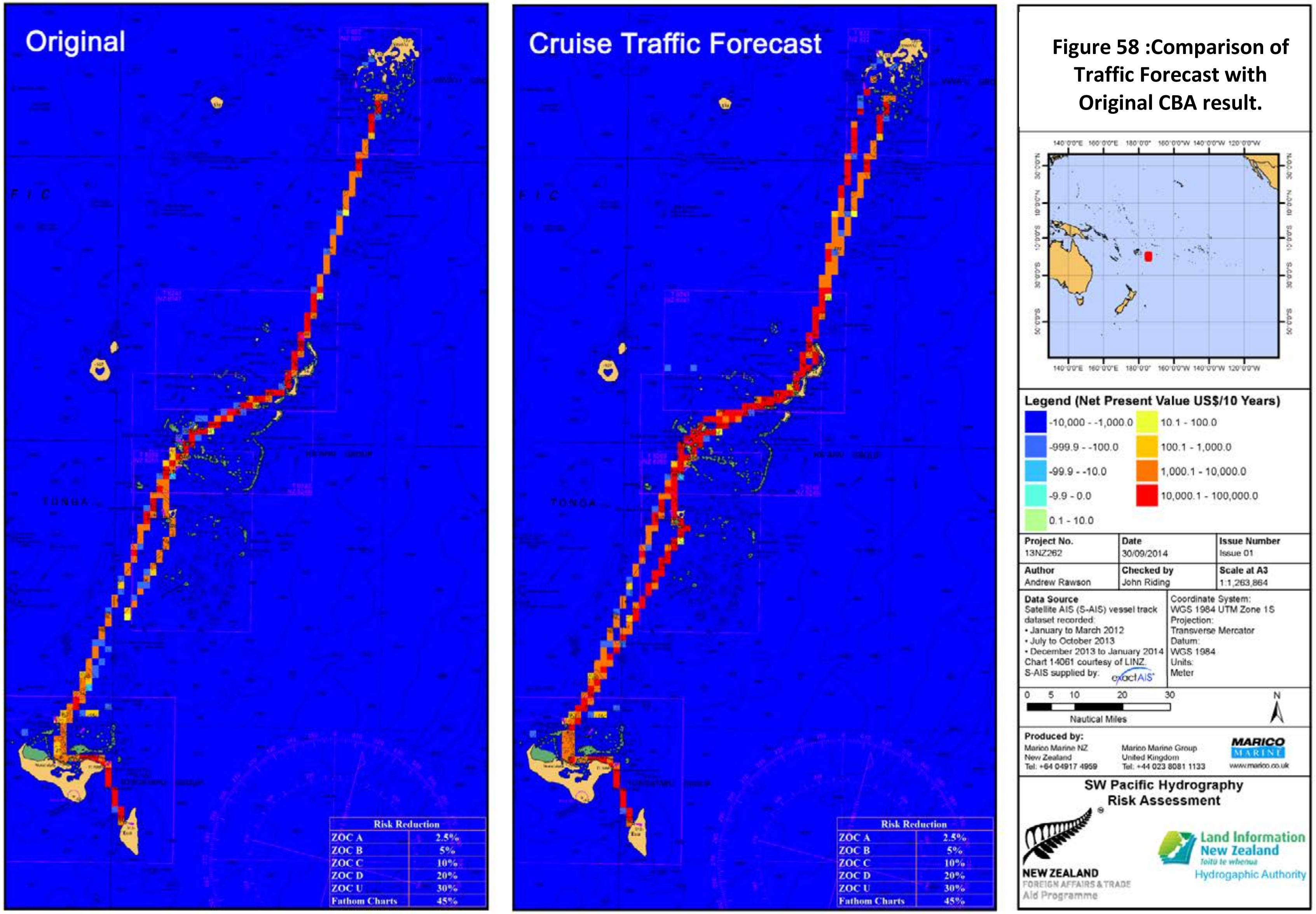

Figure 58 :Comparison of Traffic Forecast with Original CBA result.

Figure Reference: 13NZ262_Tonga_CostBenefit_Step4_03

10 CONCLUSIONS AND RECOMMENDATIONS

10.1 OFFICIAL NAUTICAL CHARTS

1 The risk assessment, combined with the cost benefit assessment has clearly determined areas where the accuracy and adequacy of charting should be reviewed against modern standards and updated. In some areas this includes the number and disposition of Aids to Navigation.

2 Official nautical charts for Ha'apai Group are in fathoms on an undetermined datum. Electronic chart production (RNC or ENC) cannot proceed without new hydrographic surveys to modern standards. Many SOLAS vessels are required to carry ECDIS, which in turn require official RNC/ENC and are presently excluded from operating in this island group.

10.2 CONCLUSIONS - CULTURAL INFLUENCES AND RISK ASSESSMENT

3 The cultural, religious and family statuses of Tongans have a profound effect on the economy of Tonga. The need to interact across the island groups, especially at times of Christian celebration, explains a tolerance of shipping risk.

4 Due to the Tongan Sabbath legislation, Sunday business operations are either limited or suspended. This includes shipping movements or cargo handling. Coastal vessels also remain in port for the Sabbath and Cruise Operators in the past have found the need to abort calls due to misunderstanding the adherence to the Sabbath.

10.3 CONCLUSIONS - ANALYSIS OF SHIPPING FROM PORT RECORDS

5 The Port of Nuku'alofa is the most significant Tongan port by ship-traffic volume and therefore, the marine trade hub for Tonga. The Port has made efficiency gains in all of its cargo handling segments. Bulk liquid has shown the most gain in terms of cargo volumes handled by fewer ships. The trend towards cheaper unit costs, because the port can handle larger volumes is important. This port has the potential to develop into a "cargo transhipment hub" for the area if the trend can be maintained.

6 The Port of Nuku'alofa efficiency gains are supported by its landside developments, such as cargo/container area paving and new wharf facilities. Its business model needs to develop into a Port Master Plan, supporting review of its approach channel capacities, Aids to Navigation and planning its development into a "hub port" for the area.

7 In 2013, two renewable power projects (solar plants) were completed in Vava'u and Tongatapu group. Given this significant development the forecast demand for fuel transport may either decrease, or in an expanding economy, be maintained at current levels.

8 The Port of Nuku'alofa shows there is a fluctuation in cruise vessel visits, year on year. The gross tonnage of these vessels is marginally increasing, based on 2013 and 2014 data. The forecast suggests that this increase will be sustained in the years to come, underpinned by the new cruise facility at Vuna wharf.

9 Although cruise vessel numbers have fluctuated from 2008 onwards, there is a clear trend to larger ships. The new cruise terminal at Vuna Wharf, Nuku'alofa, has facilitated this growth in vessel size, with visits from some of the largest cruise vessels occurring in 2014. However, central and northern parts of Tonga would have difficulty in handling large cruise vessels. The exception to this is Vava'u, where large cruise vessels anchor in shelter at the harbour entrance.

10 The number of liquid bulk vessel visits has been slowly reducing, although freight statistics show that these vessels also now carry more cargo. Thus, increasing efficiency in this industry also is apparent. There will be some fuel consumption savings realised from newly installed solar power facilities.

10.3.1 Conclusions – 'Eua

11 The arrangements for tanker discharge and the shore cargo connections at 'Eua Island would benefit from review, as present arrangements comprise discharge via a manifold in the surf, on an exposed shoreline. A review of charting scale could be beneficial.

12 Safety benefit would accrue out of a review of the short passenger route between Nuku'alofa and 'Eua, given the rapid expansion of passengers using the service in relation to the design of the vessel. This may lead to a need to review the design of Nafanua Harbour and its entrance/access arrangements. It should be noted that any change to the harbour layout/entrance would be a significant infrastructure project.

10.4 CONCLUSIONS FROM SOLAS TRAFFIC ANALYSIS

13 As is the case, for domestic vessels, Nuku'alofa is also the most significant port for SOLAS vessel traffic-volume. It has a relatively steady trade in container imports and exports.

14 SOLAS multipurpose vessels visit the Port of Nuku'alofa, whilst smaller feeder container vessels call at Pangai (Ha'apai) and Neiafu (Vava'u) harbours. These vessels represent the Pacific trade

route connecting the major Pacific ports with Australia and New Zealand. The multipurpose vessels calling at Nuku'alofa represent the Pacific-Asian trade route with linkages to Singapore and Japan.

15 The Port of Nuku'alofa has potential to take advantage of these trade routes and develop into a transhipment hub in the South West Pacific region. This could offer substantial capital and operating cost advantages for the harbour as well as economic prosperity. Further charting improvements would allow larger vessels to access the port safely.

16 Vava'u is a premier destination for international yachts. A number of yacht charter providers also operate at Neiafu Harbour, with other waterborne tourism activities supported by such visitors.

17 Although Ha'apai has been affected by a recent cyclone, it is likely to attract cruise vessels once a charting upgrade has occurred. Some are already visiting. Transit risk levels already support the need for charting review.

10.5 CONCLUSIONS - DOMESTIC COASTAL VESSEL ANALYSIS

18 There are two key passenger routes in Tonga: Nuku'alofa to the Central and Northern Islands, and Nuku'alofa to 'Eua. The latter route carries a surprising volume of passengers (34,500 annually), this being a passenger volume greater than the sum of all seagoing passenger routes in Tonga. The vessel 'ONEMATO is smaller than the main ferry 'OTUANGA'OFA. A wider review of the Tongatapu-'Eua route, including harbour facilities, would be beneficial, given a rapid expansion of passenger numbers in recent years and the size of the vessel involved.

19 The training of Tongan seafarers to recognised qualifications was suspended in 2011. The Training College at Nuku'alofa is being reactivated with Aid support, including NZ Aid. The efforts to re-establish the maritime training college at Tongatapu go hand in hand with improvements to Navigational Safety provided by nautical chart Improvements. A successful Seafarer Training programme should be a long term objective delivered in parallel with charting improvements where necessary.

10.6 CONCLUSIONS GIS RISK ANALYSIS

20 Vava'u presents heightened risk in three important locations, surrounded by areas of moderate risk. These are at Vava'u Island, the sea area between Kapa Island and Richard Patches and the passage between Fofoa and Ovaka Island. An underlying risk influence is the density of yachts together with a moderate volume of SOLAS vessels and coastal traders. This is combined with

the presence of Special Management Areas (SMAs) and turtle breeding grounds. Specifically, risk levels south of Kapa Island and Richard Patches are of significance, because domestic vessels transit a charted area of low CATZOC rating, together with an abundance of corals, reefs and SMA's. A liquid bulk terminal is located in Neiafu Harbour.

21 In **Ha'apai**, Ha'ano Island presents a large area of heightened risk surrounded by moderate risk. This risk is influenced by regular domestic vessel transits in waters adjacent to coral and turtle breeding sites. The risk profile extends significantly along the west cost of the main islands of the Ha'apai Group, including Pangai Harbour, Lifuka, with heightened risk reflecting both economic and environmental importance. A combination of yachts and domestic coastal vessels with adjacent SMAs produce heightened risk at Ha'afeva Island and Nomuka Group. Most charts in Ha'apai Island Group are in fathoms on an undetermined datum, which provide priority for charting upgrade. This is supported by the risk result, but more powerfully by the CBA result.

22 In **Tongatapu**, the Port of Nuku'alofa and its approaches show an area of significant risk. Nuku'alofa is the largest port and the premier tourist destination, therefore of high economic value. The port is busy, with modern facilities and attracts all types of SOLAS vessels, including large cruise ships. It has the potential for further development, thus being an important candidate for charting review, including the disposition and reliability of Aids to Navigation. A chart reorganisation to extend the coverage area of CATZOC A rating can be considered.

23 Piha Passage, presents a significant local risk. This arises from a high volume of ferry transits carrying a relatively high volume of passengers. The same route is used by a liquid bulk ship. The channel is narrow, with known high currents and surrounded by reserves, as well as mangroves and important cultural sites. A review of charting and Aids to Navigation is justified by the risk result for mitigation effectiveness.

24 Safety benefit would accrue out of a review of the short passenger route between Nuku'alofa and 'Eua, given the rapid expansion of passengers using the service in relation to the design of the vessel. This may lead to a need to review the design of Nafanua Harbour, 'Ohonua, and its entrance/access arrangements. It should be noted that any change to the harbour layout/entrance would be a significant infrastructure project.

25 The **Niuas** present a low level risk profile. However, Niuatoputapu Harbour comprises a narrow entrance with rapid coral growth and limited depth. The regular ferry, 'OTUANGA'OFA, is close to or at maximum size that this harbour entrance can accommodate. The entrance approach from sea can be difficult, with significant cross swells. The consequence of a serious incident at the entrance is damage or vessel loss. Loss of the (new) ferry has significant impacts on trade

and passenger transit throughout the Kingdom of Tonga. A recent minor grounding of 'OTUANGA'OFA at Niuatoputapu, adjacent to a (missing) Aid to Navigation, serves only to emphasise this.[81]

10.7 CONCLUSIONS - ECONOMIC ANALAYSIS

26 Cargo export volumes out of Tonga remain approximately constant overall.

27 Although tourism has grown marginally in terms of GDP in 9 years, the industry has become more important in terms of employment for Tongans.

28 Figures show there is growth in visitor arrivals for all transport modes, including air, cruise and yachts.

29 The Cost Benefit Analysis (CBA) for Tonga is based on average singlebeam survey costs. The CBA result is sensitive to survey type, thus cost. However, when plotted against a range of survey types, Tonga still produces a net positive cost benefit result in most areas of heightened risk.

30 CBA Sensitivity Analysis shows that Ha'apai stands out for chart upgrade cost effectiveness, for all types of survey method, even the most expensive.

31 Tonga has a number of relevant infrastructure projects ongoing or completed that could boost tourism, as well as increase the number of cruise port calls from the Australian and New Zealand market.

32 A cruise development strategy encouraging expansion of "boutique" cruise vessels would provide benefit to growth overall. Smaller cruise ships are well suited for central and northern harbours, as well as shore infrastructure. However, large cruise vessels can and do access Vava'u by anchoring in the harbour entrance.

10.8 CONCLUSIONS FROM TRAFFIC FORECASTING

33 Traffic Forecasting of cruise vessel penetration into Ha'apai waters shows a very clear cost benefit result in favour of charting upgrades, where relevant, throughout Ha'apai waters. Risk however remains heightened, because of the lower levels of traffic overall.

[81] It should be clearly noted that this is an indirect risk, not measured by the Hydrographic Risk Assessment, which uses vessel traffic volume to measure risk. The indirect risk is one of the high consequences of loss of the ferry to domestic trade throughout Tongan waters. There are cases where consequence impacts would be such that risk mitigation action would still be considered. This is one such case.

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- Pacific Islands Forum Secretariat (PIFS) *Tourism As A Pillar Of Economic Growth* Document PIFS(13) FEMT.06 Nuku'alofa, Tonga 3–5 July, 2013
- Richard Hale and Ian Twomey *Australia's Maritime Petroleum Supply Chain* Prepared for the Department of Resources, Energy and Tourism, Canberra 27 June 2013
- World Trade Organization (WTO) *Trade Policy Review Report by The Secretariat: Tonga* Document WT/TPR/S/291/Rev.1, 27 February 2014
- Thomas Worley and Greg Akehurst *Economic Impact of the New Zealand Cruise Sector* Prepared for: Cruise New Zealand Document reference: CNZ008.13, August 2013

- Tonga Department of Statistics http://www.spc.int/prism/tonga/
- Kingdom of Tonga Website http://www.thekingdomoftonga.com/

11.1 DATASET CONFIDENCE – RISK MODEL

Dataset	Confidence	Reason
Vessel traffic patterns	Moderate/High	7.5 months of AIS data was analysed, representing traffic patterns over two years, both summer and winter. This was supported by port movement records obtained during the site visits. Domestic traffic routes and frequency were also obtained during the site visit and geocoded into the risk model.
Prevailing conditions	Moderate	Absence of a universal and accurate digital dataset of Tonga's meteorological conditions required approximation using other sources. Modelled conditions are basic without wave propagation or refraction.
Tidal conditions	Low	No dataset available, therefore charted tides and the South Pacific sailing directions were used to identify sites of significant tidal flow. Other potential sites were identified but could not be accurately included I the risk model.
Navigational complexity	N/A	Qualitative judgement.
Chart quality assessment	High	CATZOC ratings extracted from LINZ S-57 charts. In areas such as Ha'apai where ZOC ratings were unavailable, the worst chart quality score was used.
Fixed aids to navigation	Moderate/High	It was not possible for all aids to navigation to be checked by the project team on the site visit.
Depth	Moderate	Depth map created from S-57 data but is therefore inherently limited by the source data of that chart.

Dataset	Confidence	Reason
Bottom Type	Low	Use of a global geological dataset will not accurately reflect localised geological features.
Significant charted reefs	Moderate/High	Most significant reefs are charted and a number of datasets were drawn upon to support this information.
Seamounts	Moderate	Seamount locations drawn from a number of different sources, however it is not possible to model the locations of seamounts which have yet to be identified.
WW2 military sites	High	Considerable literature used to support the assertion that no mined areas exist in Tonga.
Sites of volcanic activity	Low	Few datasets could be found to identify volcanic sites.
Tidal hazards	Moderate	Charted tidal hazards were extracted from the S-57 charts or were geocoded based upon their description in the South Pacific pilot book.
Coral reefs	High	Coral reefs have been widely studied and mapped and so a number of high quality datasets were available on their locations.
Wetlands resource	High	Traditional wetlands resources are based on both literature review and marked during local consultation.
Breeding grounds	Moderate	Multiple studies were provided to the project team regarding the locations of significant breeding grounds. However only those sites for selected species were included.
Environmental protected sites	Moderate	Global protected sites are well marked however local informal sites are only obtainable from consultation with local communities.

Dataset	Confidence	Reason
Culturally protected sites	Moderate	Global protected sites are well marked however local informal sites are only obtainable from consultation with local communities.
Key infrastructure	High	Only Port of Nuku'alofa is a major port.
Tourist sites	Moderate/High	The routes of cruise ships and recreational craft were combined with sites identified during consultation.
Sites of economic contribution	Moderate	Qualitative judgement supported with research and local consultation.
Cruise ship destinations	High	7.5 months of cruise ship movements were analysed and supplemented with consultation during site visits.

ANNEXES

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List of Tables

Annex A
Event Trees

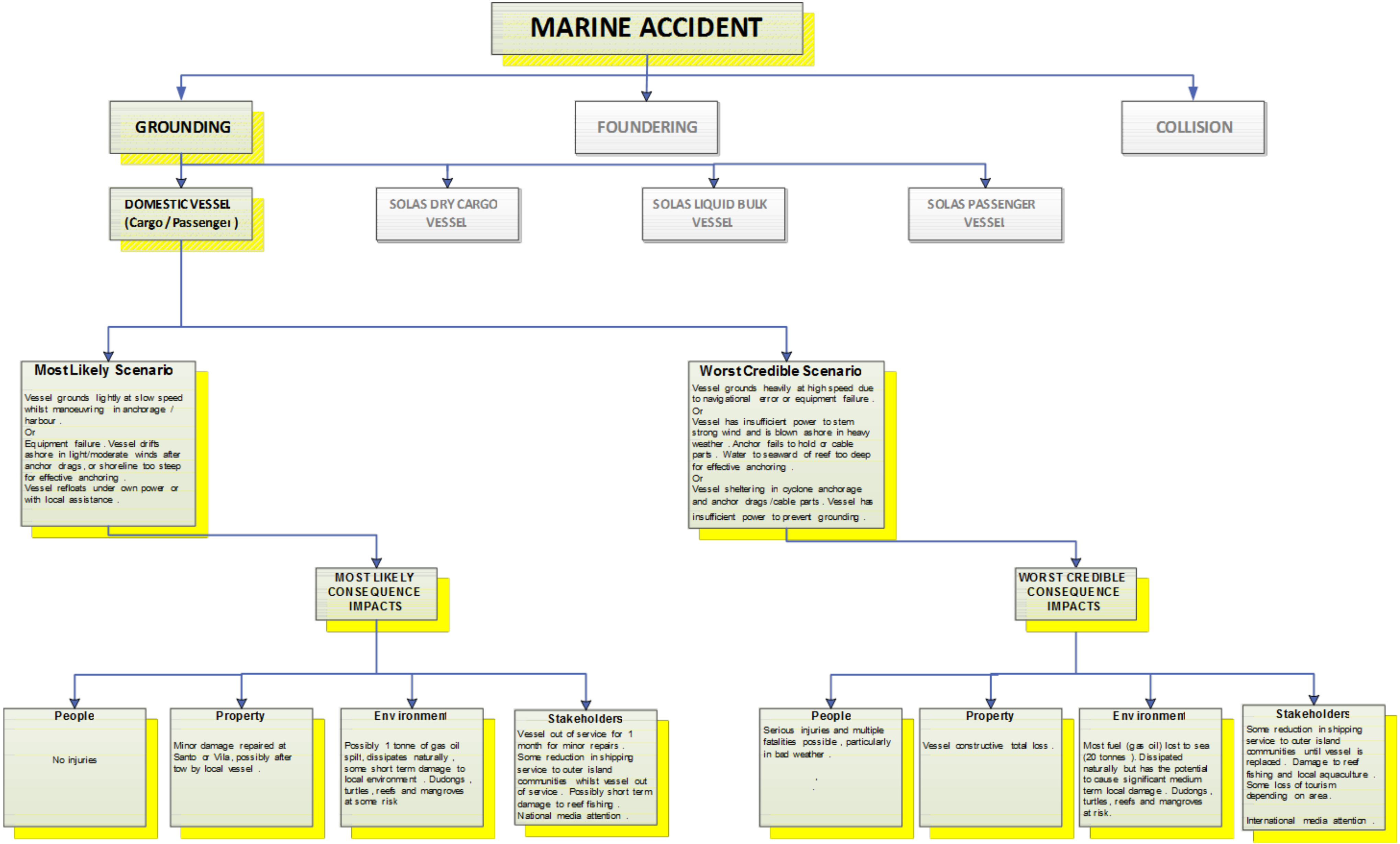

Figure 1: Domestic Vessel Grounding Scenario

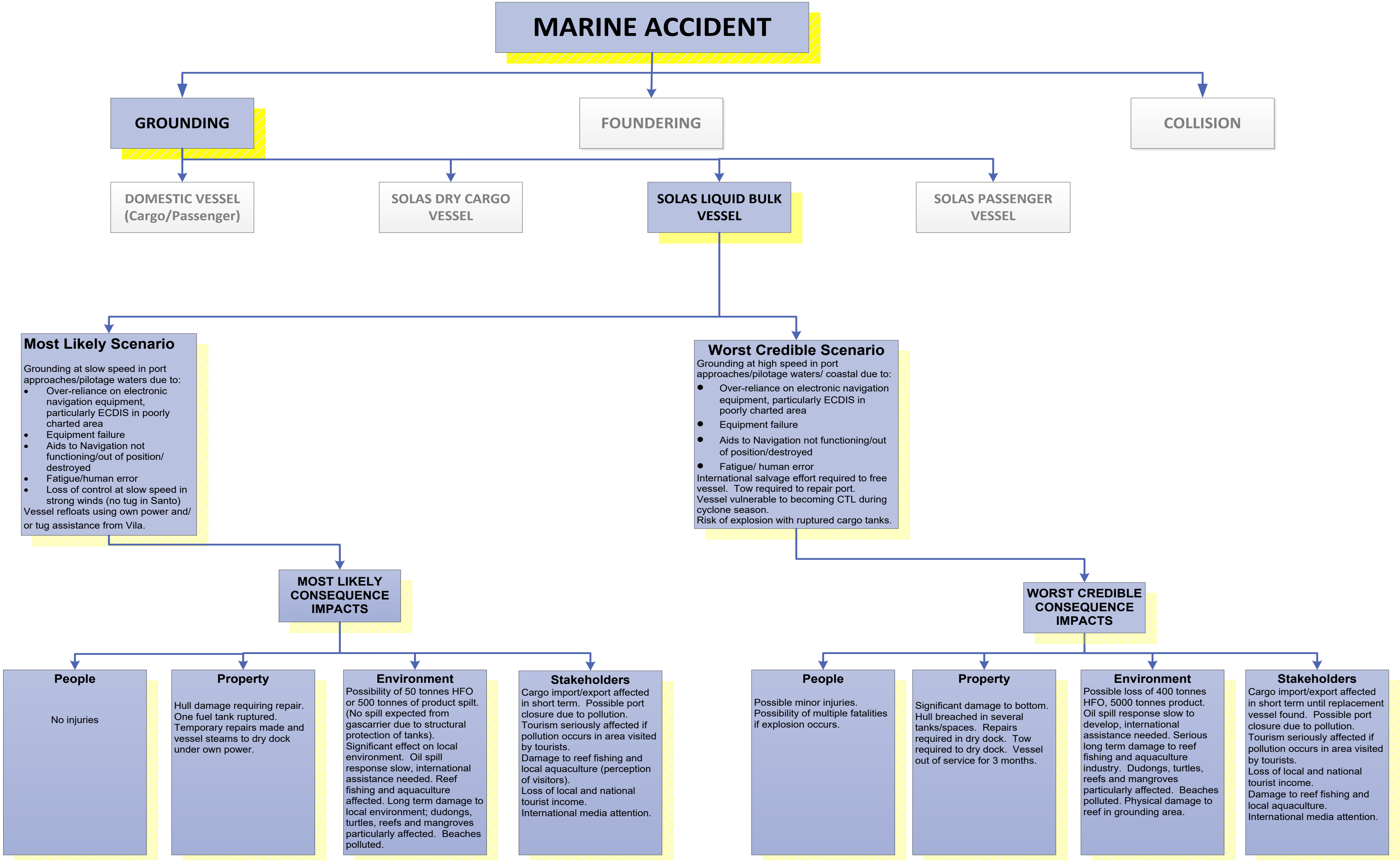

Figure 2: SOLAS Liquid Bulk Vessel Grounding Scenario

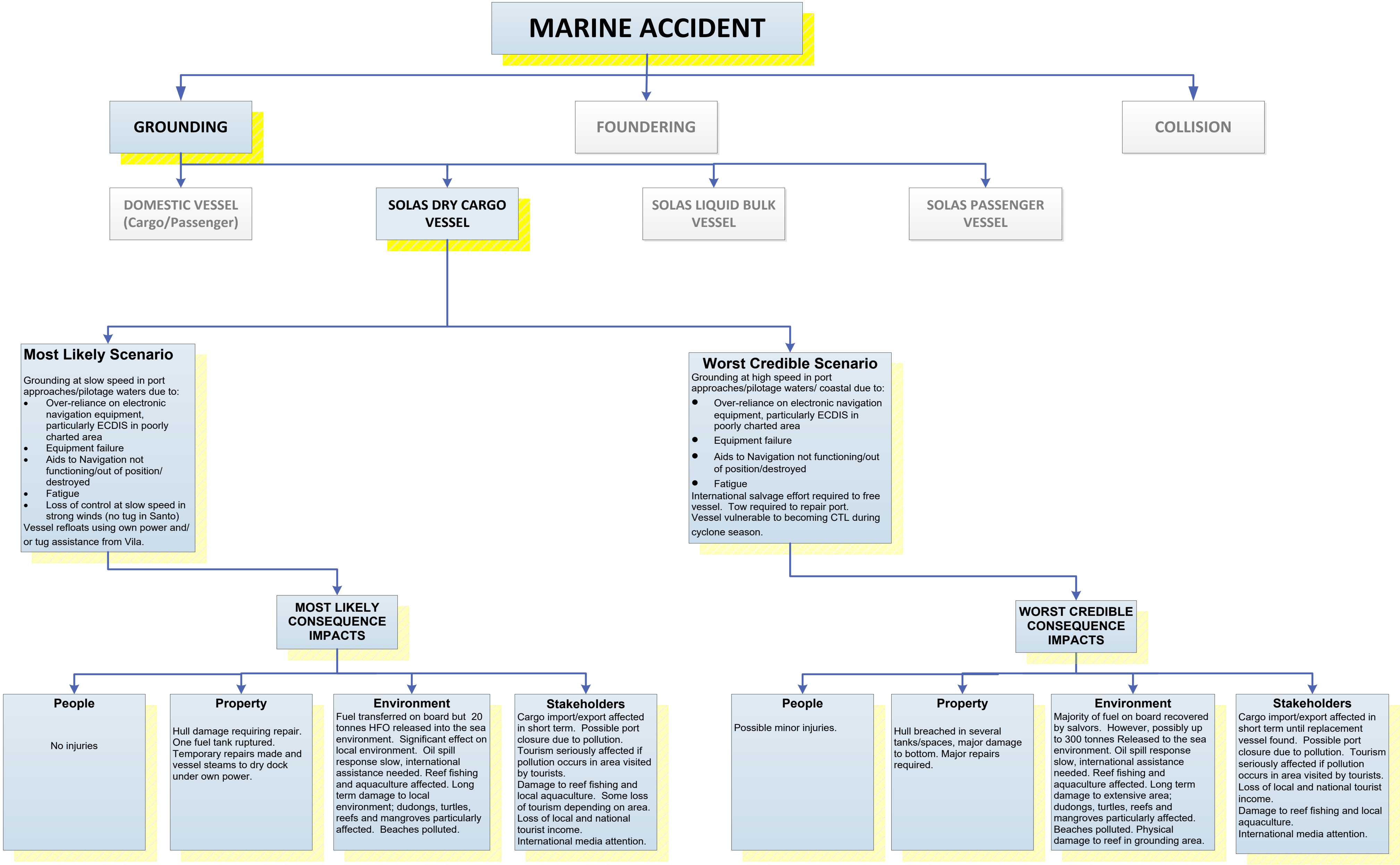

Figure 3: SOLAS Dry Cargo Vessel Grounding Scenario

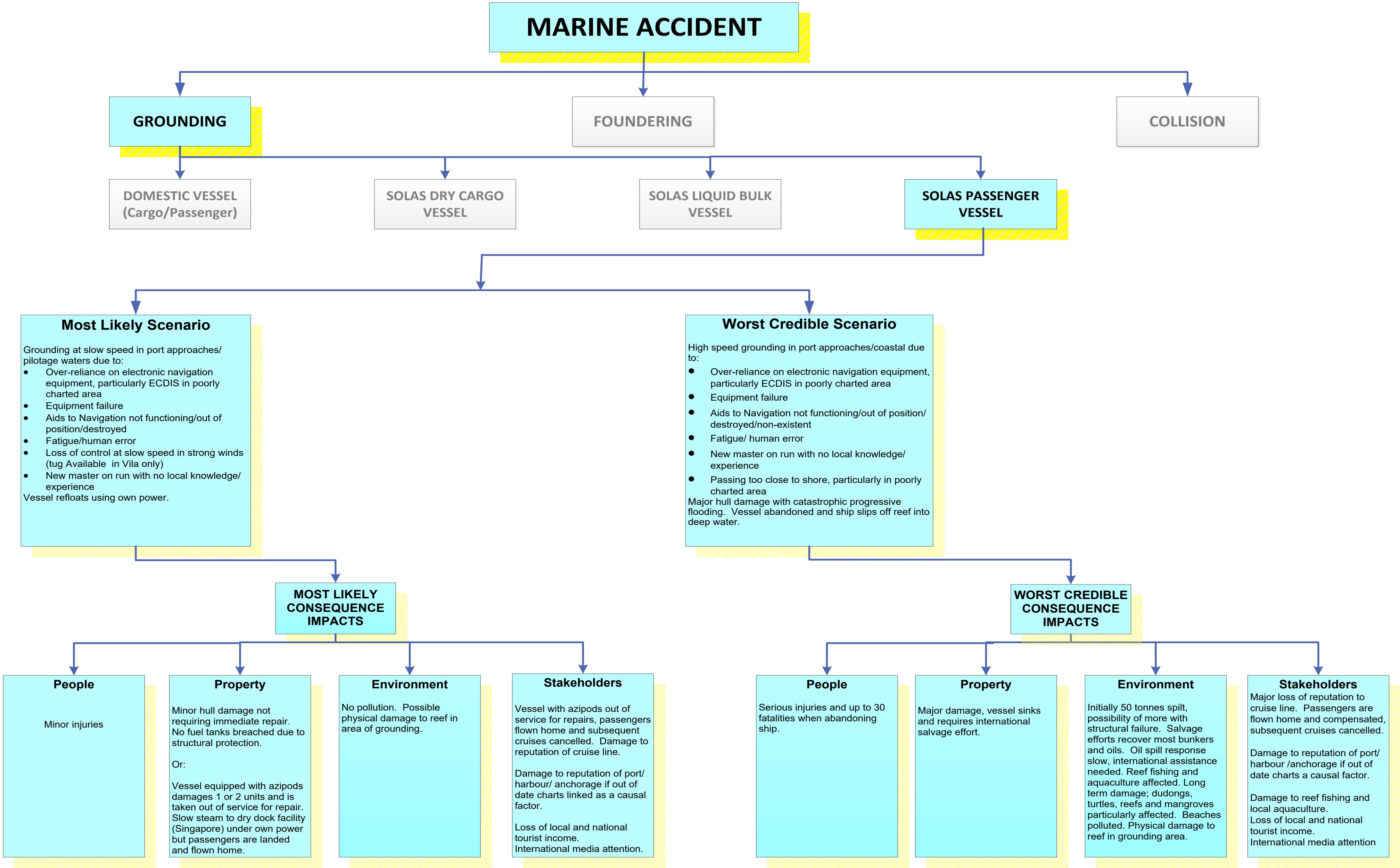

Figure 4: SOLAS Passenger Vessel Grounding Scenario

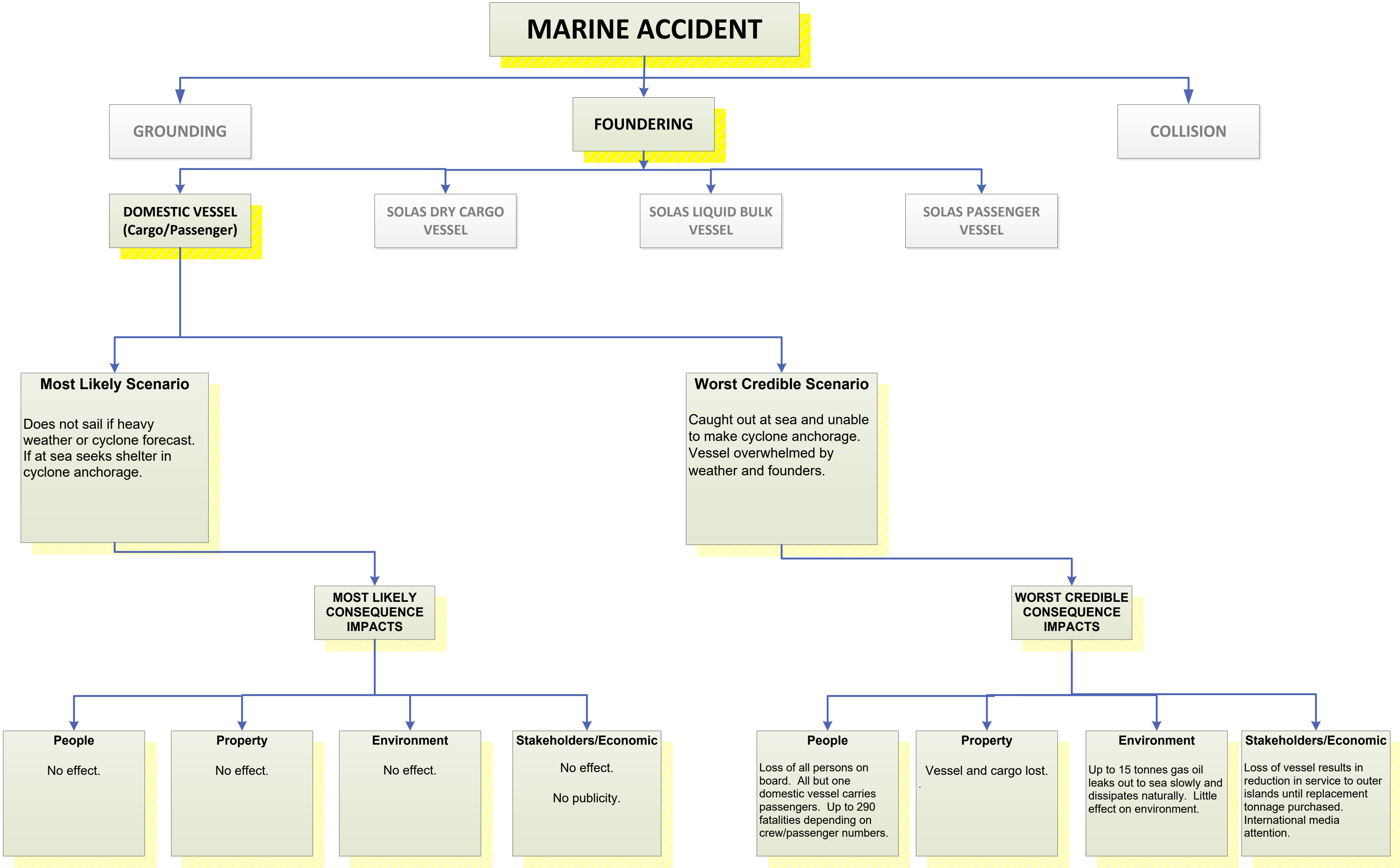

Figure 5: Domestic Vessel Foundering Scenario

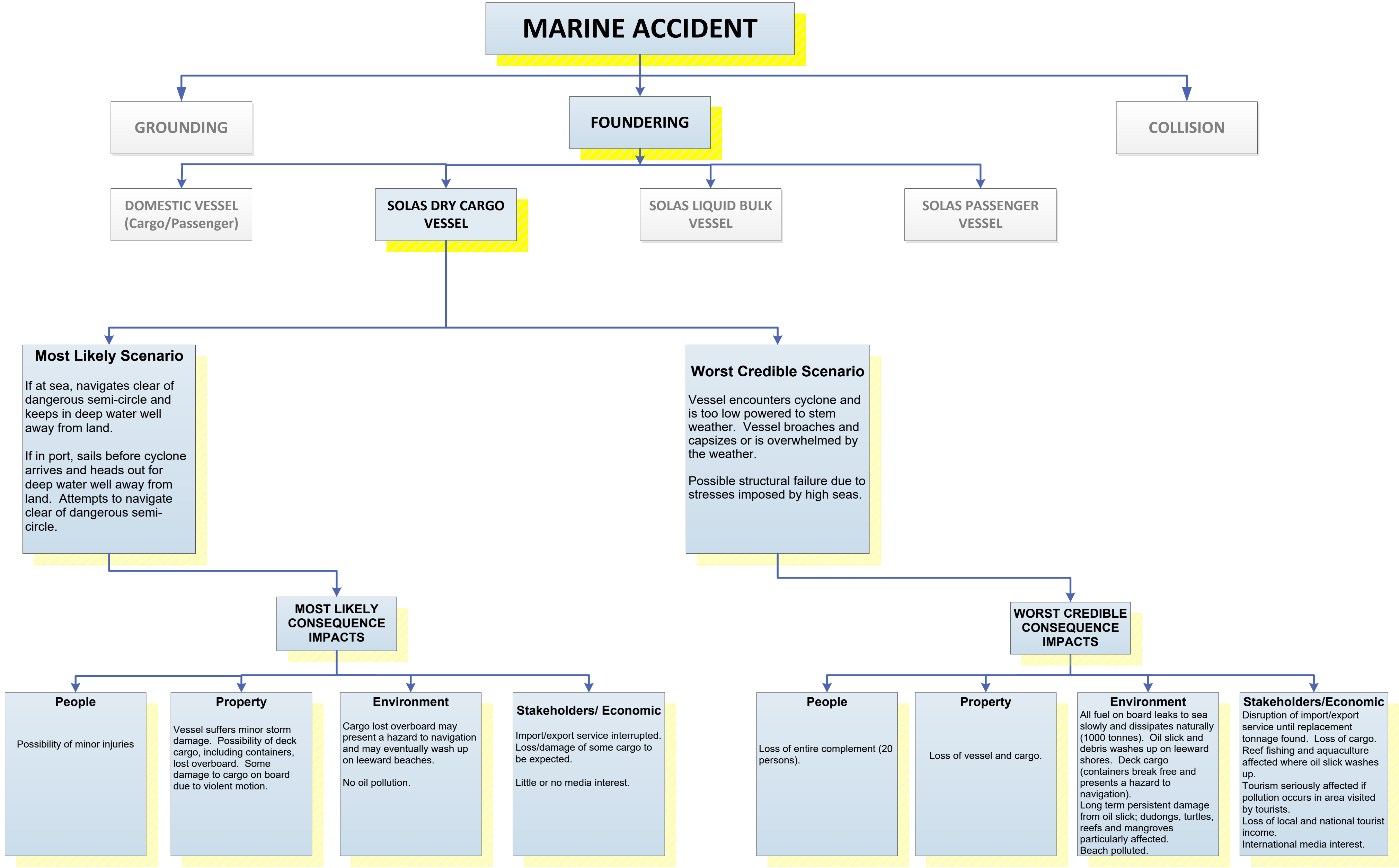

Figure 6: SOLAS Dry Cargo Vessel Foundering Scenario

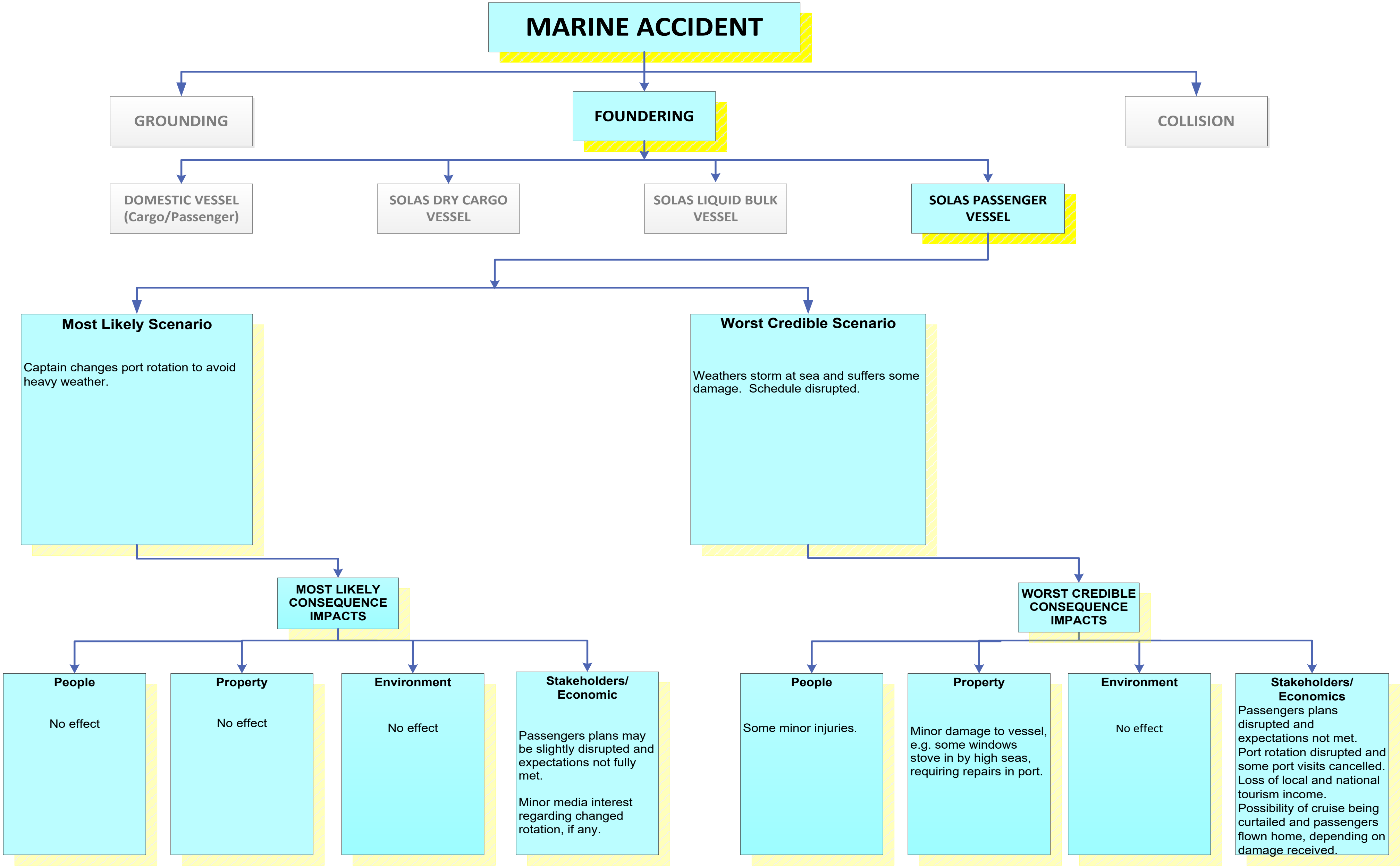

Figure 7: SOLAS Passenger Vessel Foundering Scenario

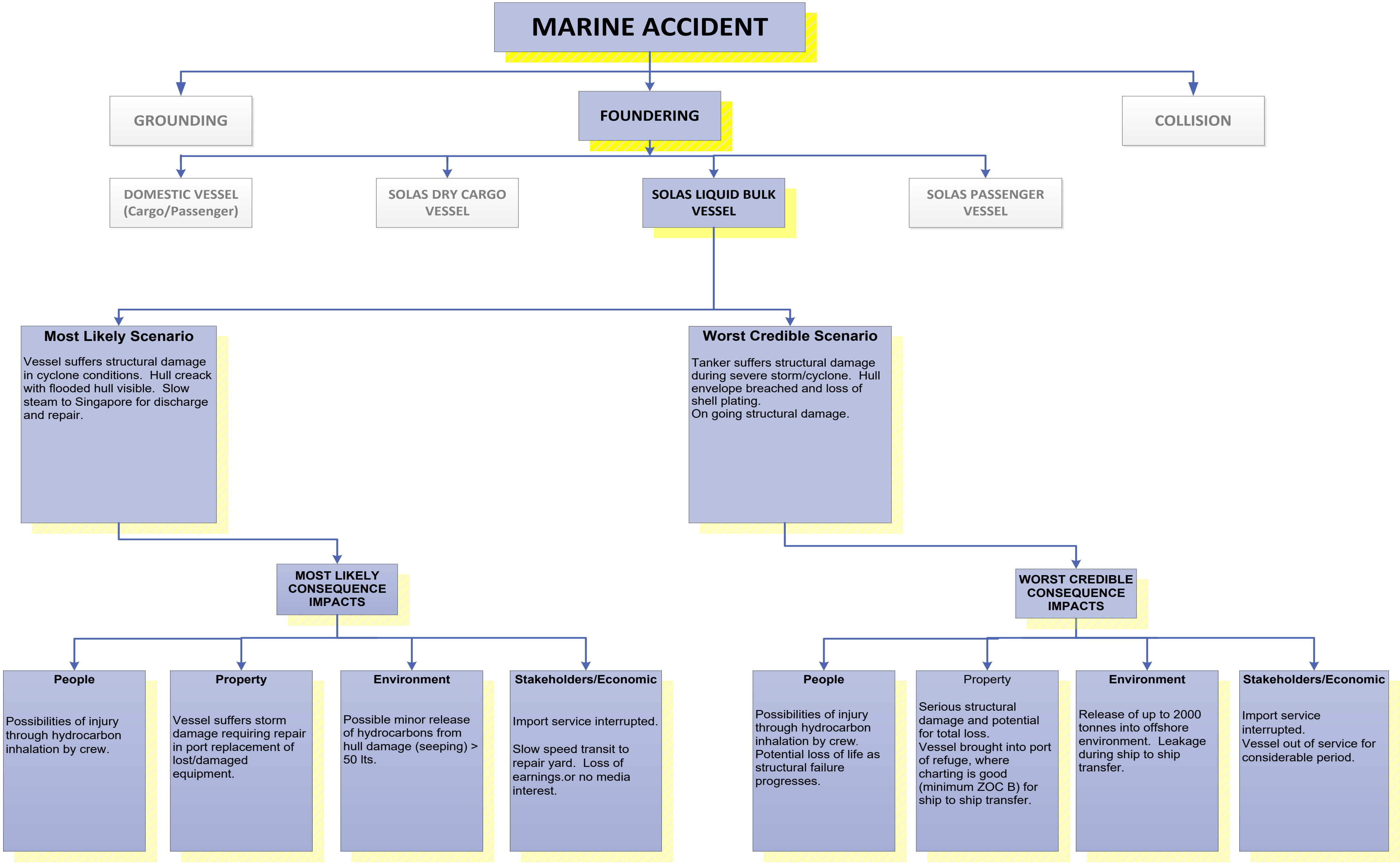

Figure 8: SOLAS Liquid Bulk Vessel Foundering Scenario

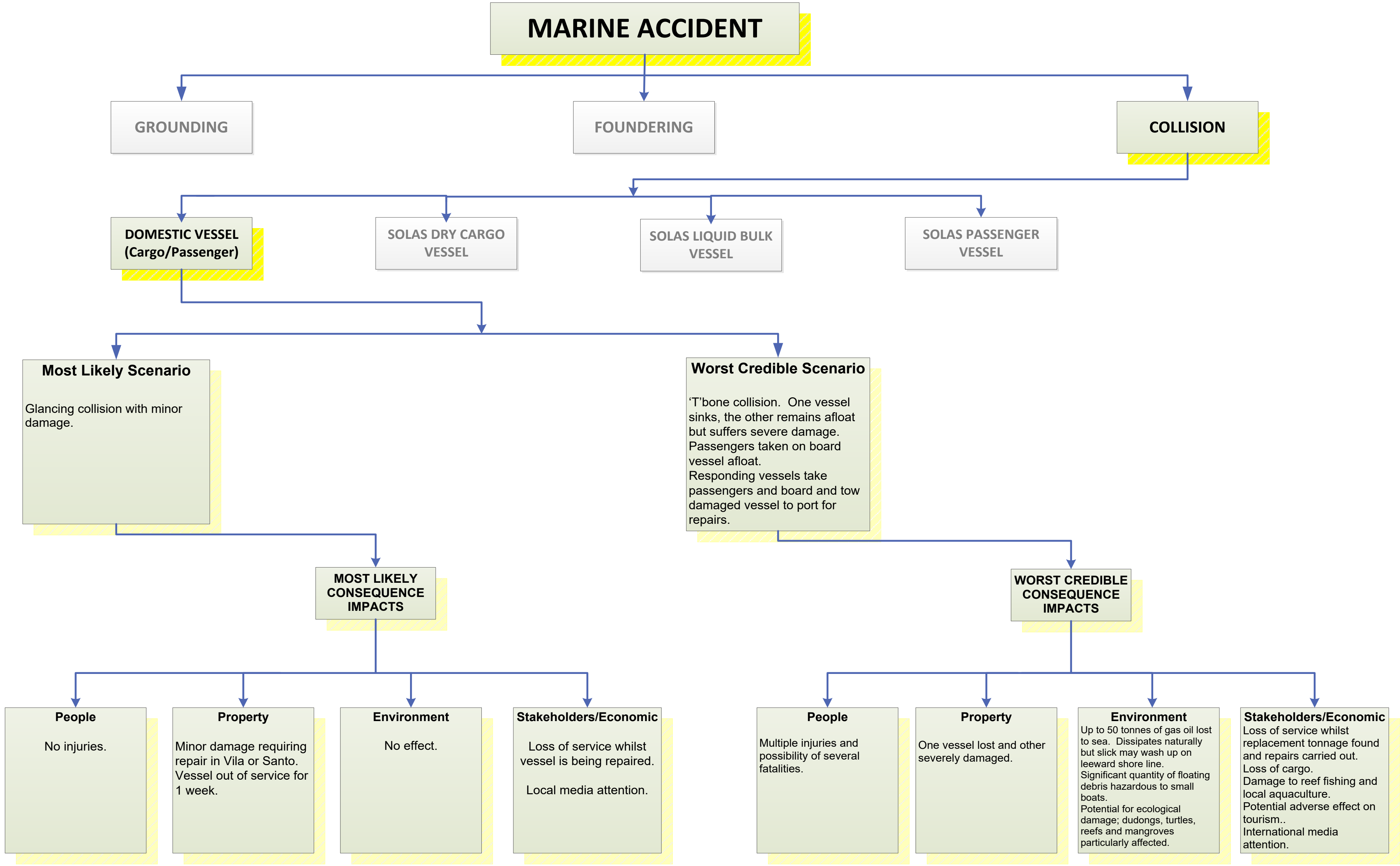

Figure 9: Domestic Vessel Collision Scenario

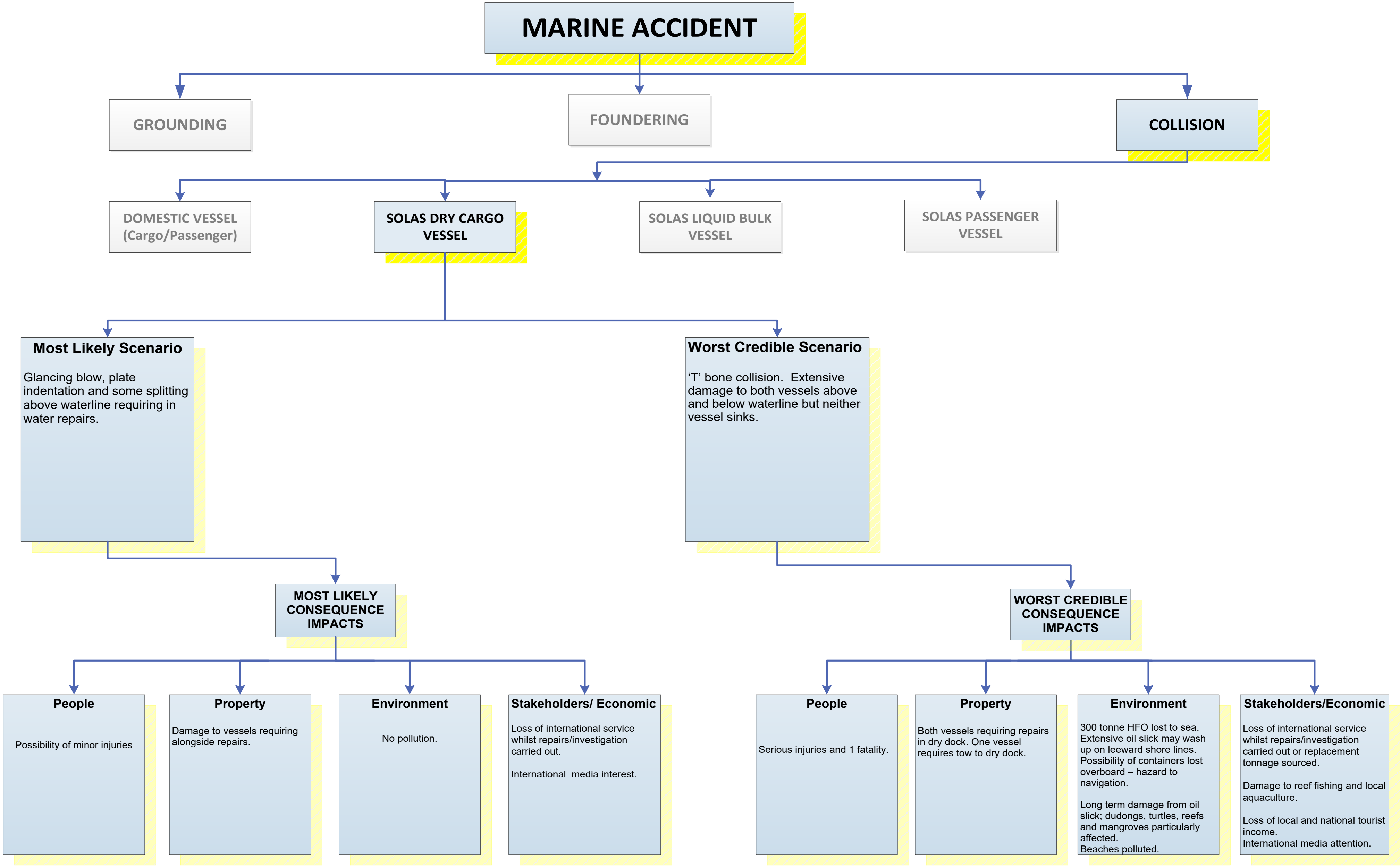

Figure 10: SOLAS Dry Cargo Vessel Collisions Scenario

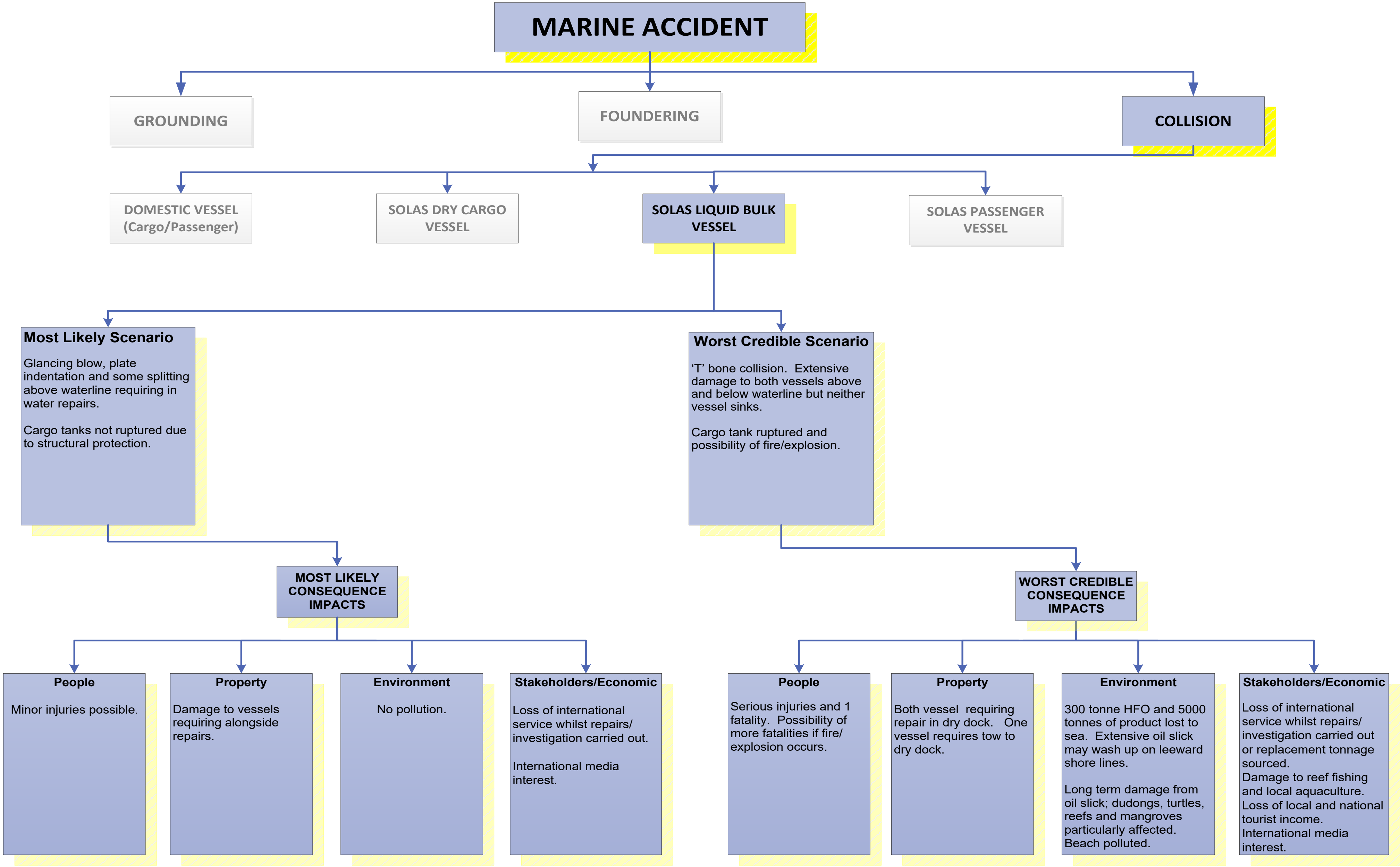

Figure 11: SOLAS Liquid Bulk Vessel Collisions Scenario

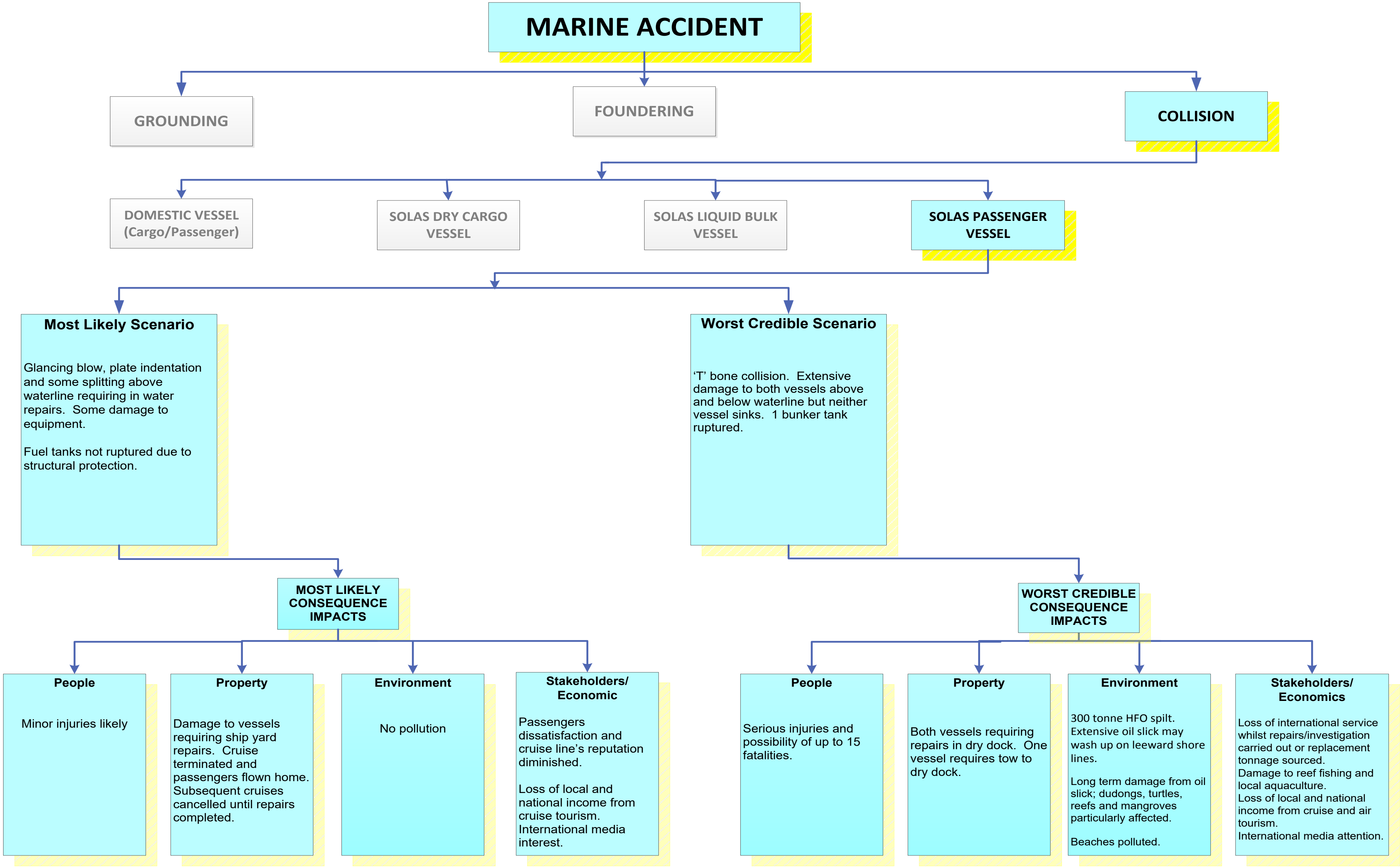

Figure 12: SOLAS Passenger Vessel Collision Scenario

Annex B
Traffic Analysis

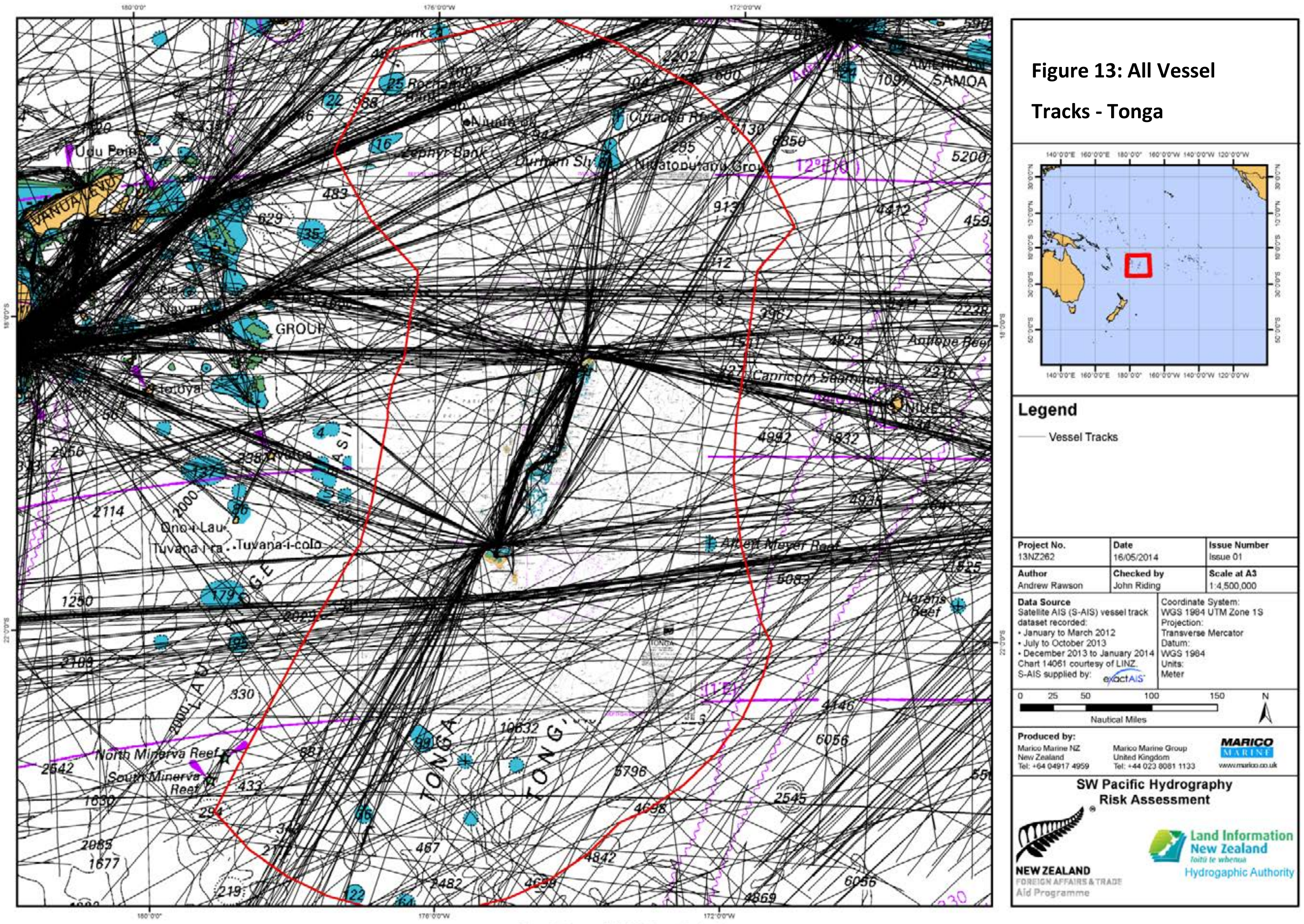

Figure 13: All Vessel Tracks - Tonga

Figure Reference: 13NZ262_Tonga_Tracks_01

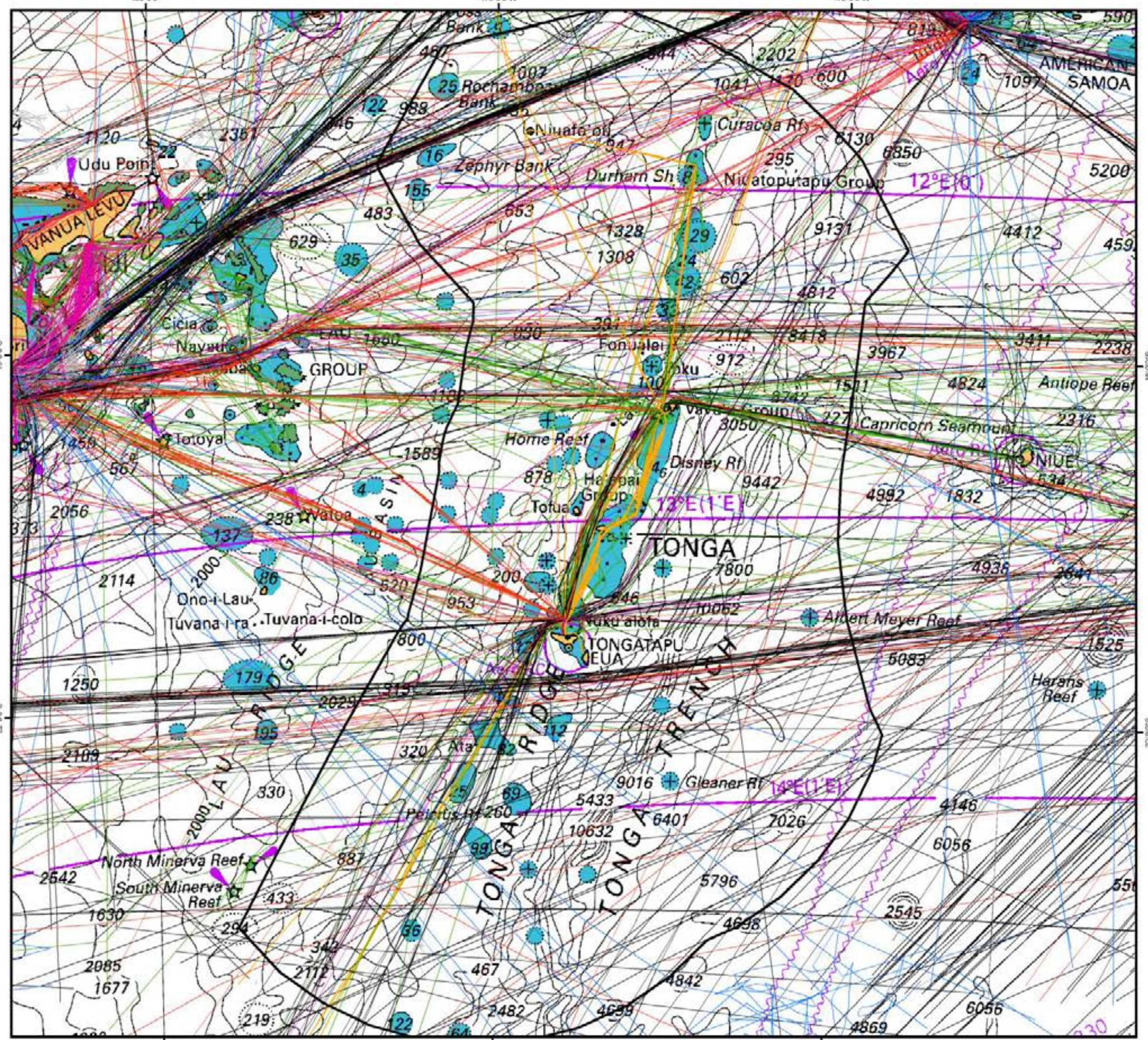

Figure Reference: 13NZ262_Tonga_Type_01

Figure 14: Vessel Tracks by Type – Tonga

Legend

- Cargo
- Passenger
- Domestic
- Recreational
- Fishing
- Tanker
- Other

Project No.	Date	Issue Number
13NZ262	16/05/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:4,500,000

Data Source Satellite AIS (S-AIS) vessel track dataset recorded: • January to March 2012 • July to October 2013 • December 2013 to January 2014 Chart 14061 courtesy of LINZ. S-AIS supplied by: exactAIS	Coordinate System: WGS 1984 UTM Zone 1S Projection: Transverse Mercator Datum: WGS 1984 Units: Meter

0 25 50 100 150 Nautical Miles N

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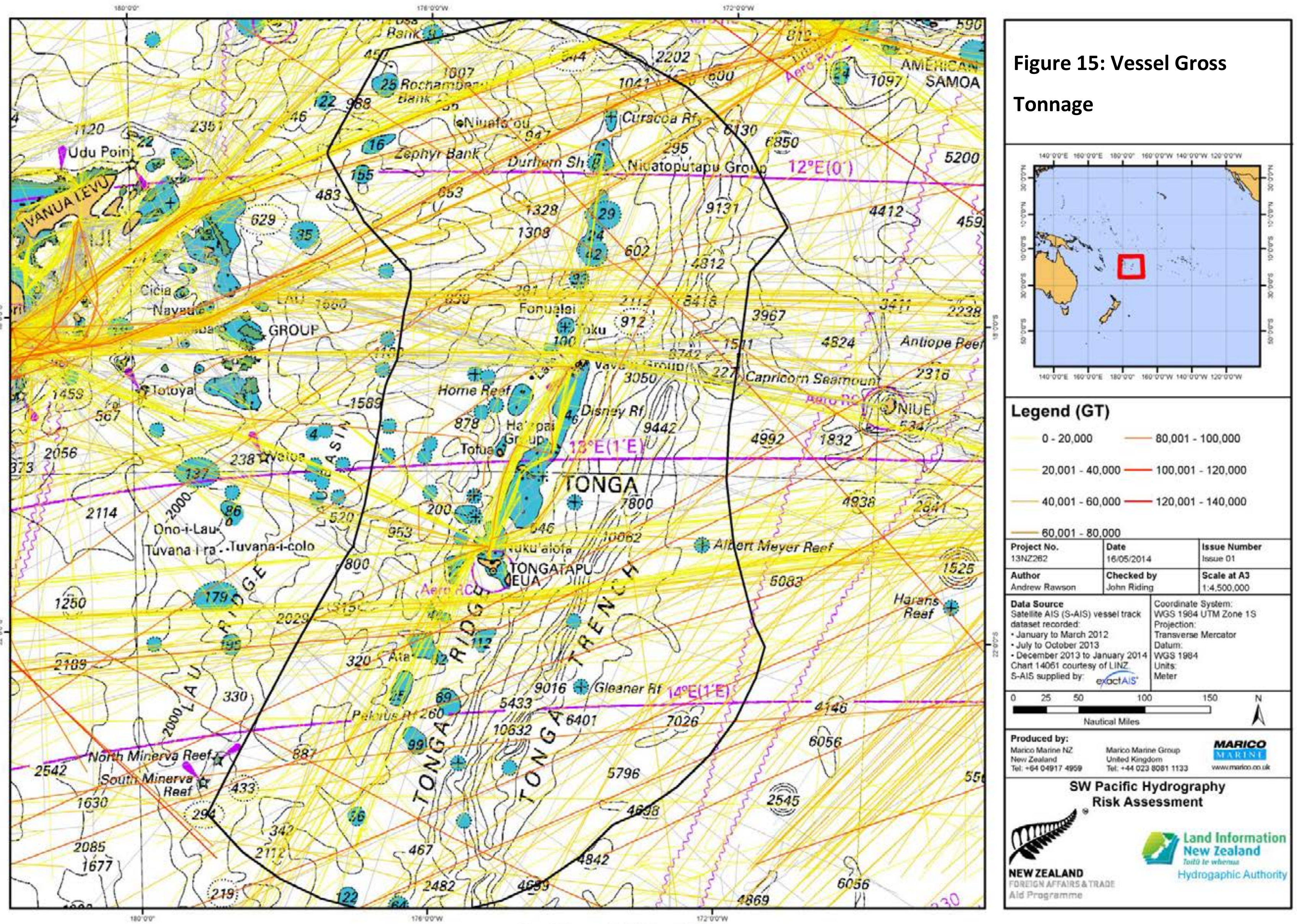

Figure 15: Vessel Gross Tonnage

Figure Reference: 13NZ262_Tonga_GT_01

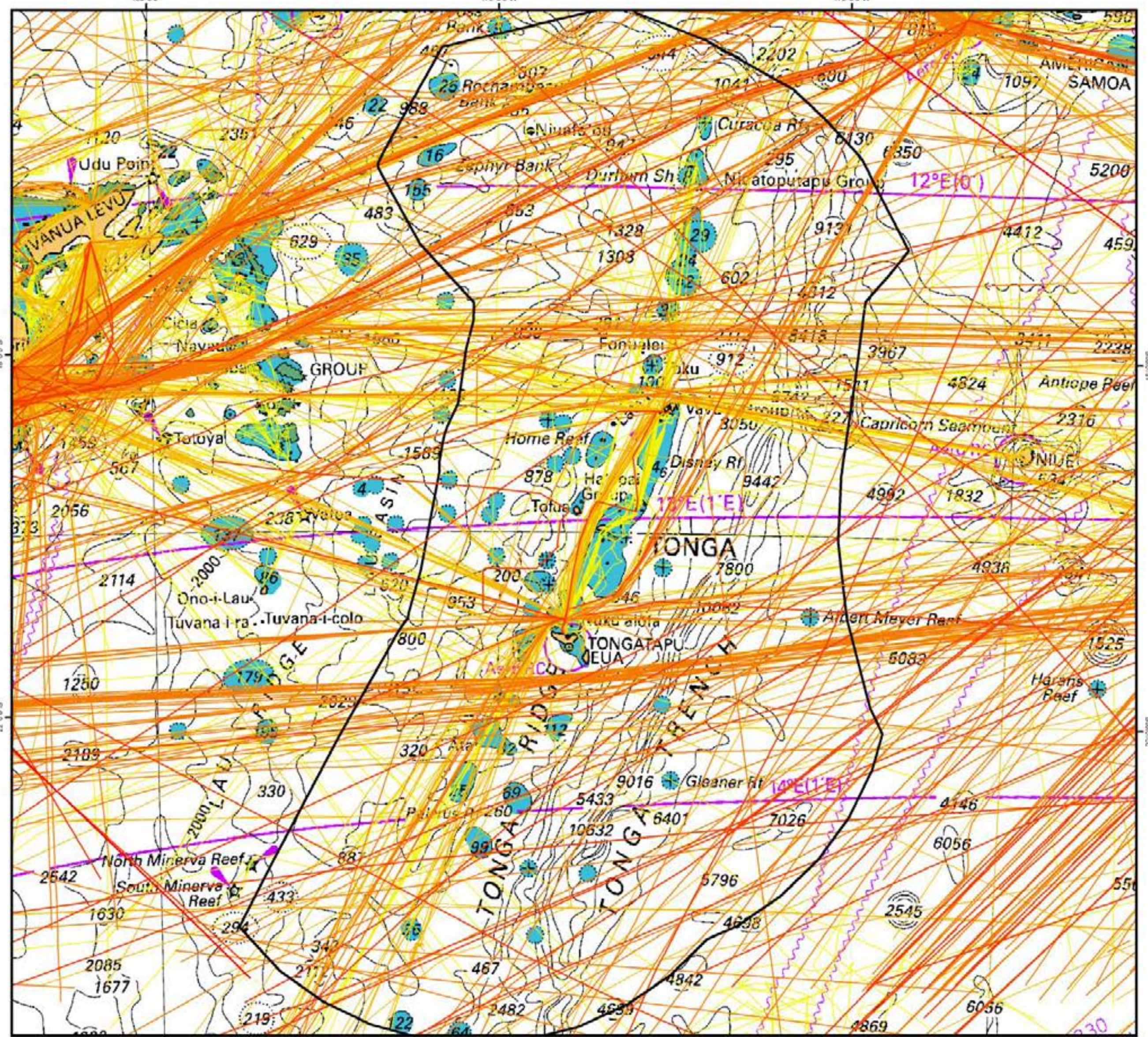

Figure 16: Vessel Length – Tonga

Legend (LOA in metres)

Project No.	Date	Issue Number
13NZ262	16/05/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:4,500,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
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- December 2013 to January 2014

Chart 14061 courtesy of LINZ
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Figure Reference: 13NZ262_Tonga_LOA_01

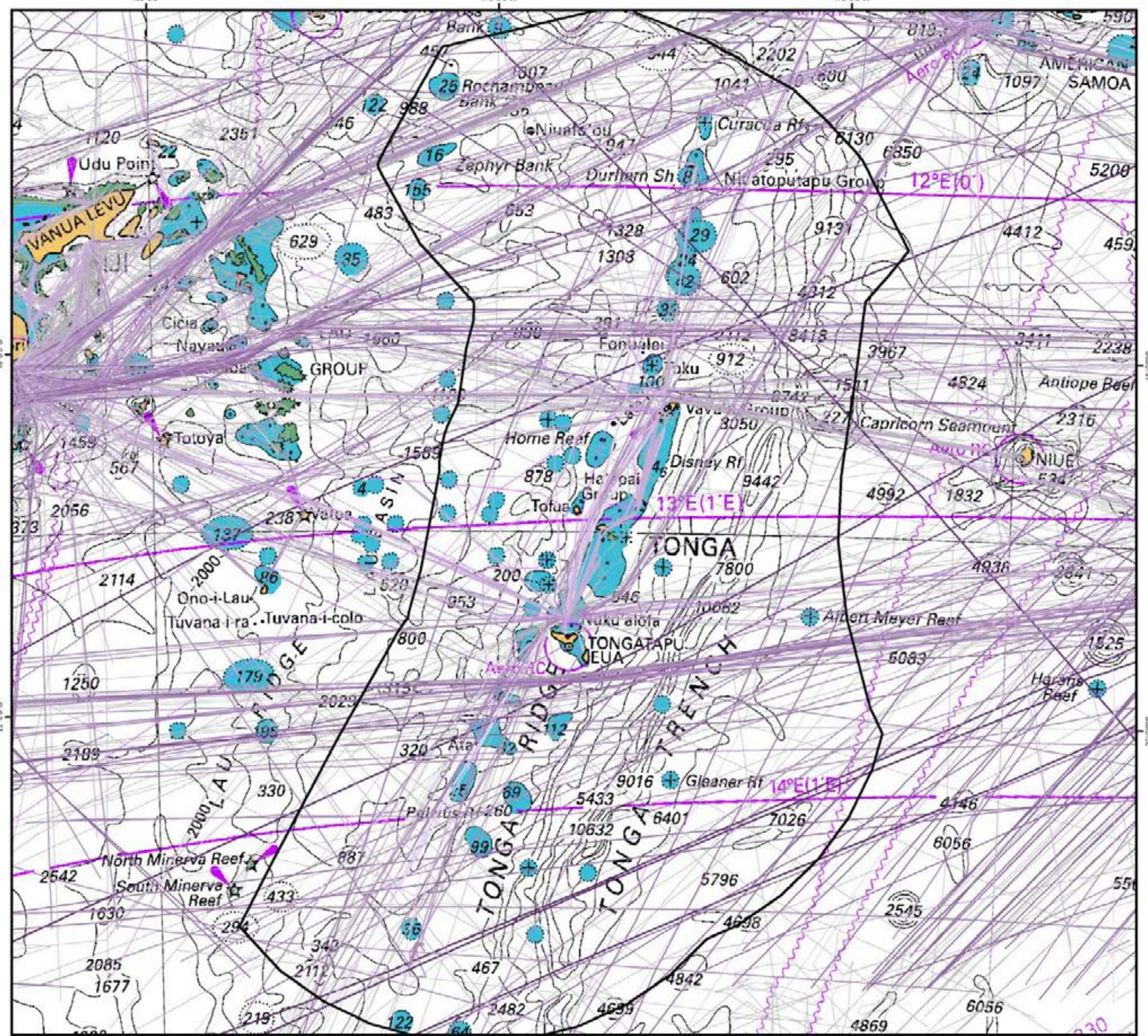

Figure Reference: 13NZ262_Tonga_Draught_01

Figure 17: Vessel Draught – Tonga

Legend (Draught in metres)

0 - 3	10 - 12
4 - 6	13 - 15
7 - 9	16 - 18

Project No.	Date	Issue Number
13NZ262	16/05/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:4,500,000

Data Source
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Projection: Transverse Mercator
Datum: WGS 1984
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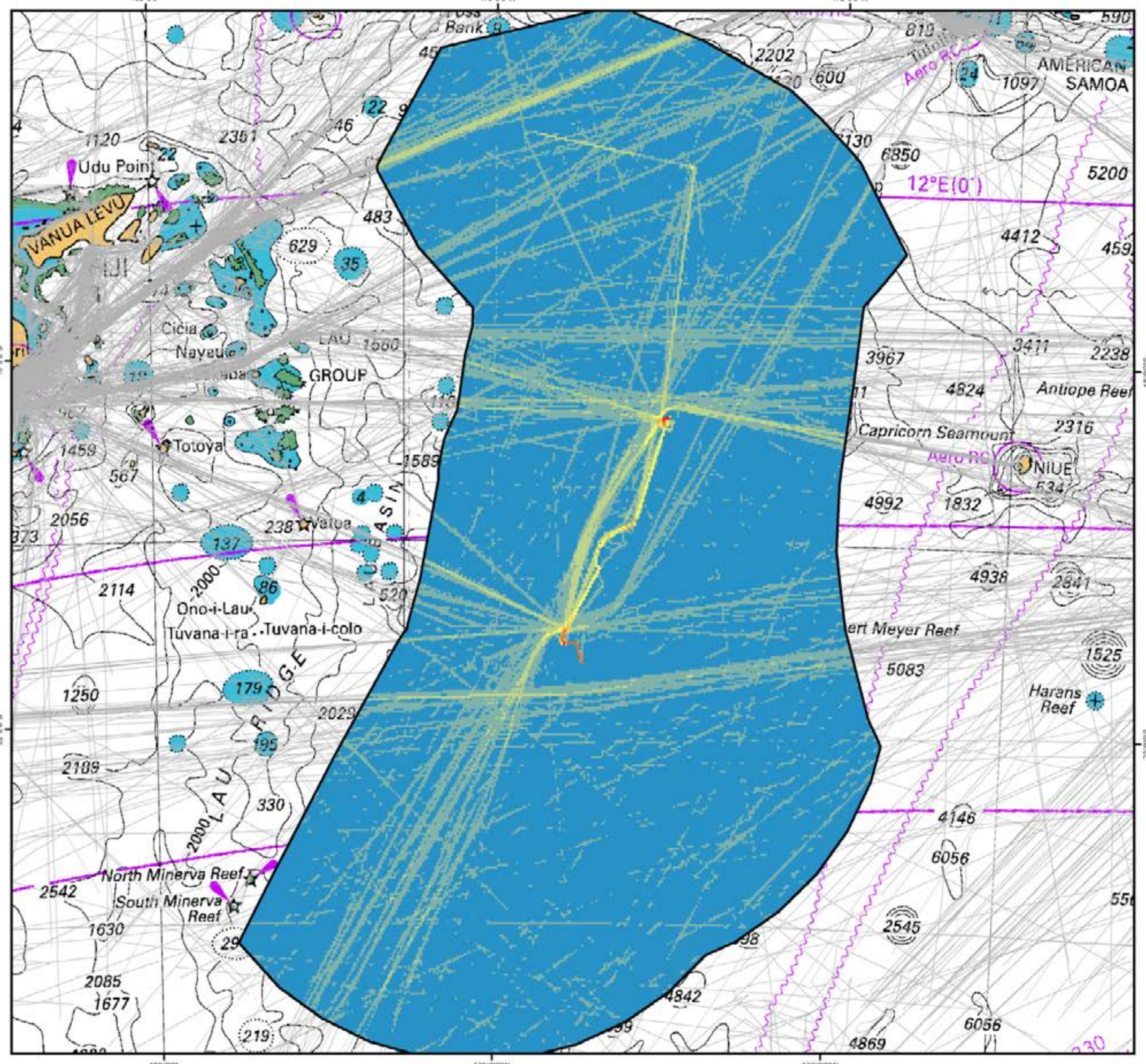

Figure Reference: 13NZ262_Tonga_Density_01

Figure 18: Transit Density per Month – Tonga

Legend (Transits Per Month)

- 0.0 - 0.1
- 0.2 - 0.9
- 1.0 - 3.6
- 3.7 - 8.1
- 8.2 - 16.0
- 16.1 - 30.3
- 30.4 - 57.9

Project No.	Date	Issue Number
13NZ262	16/05/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:4,500,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
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- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
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Projection: Transverse Mercator
Datum: WGS 1984
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0 25 50 100 150 Nautical Miles

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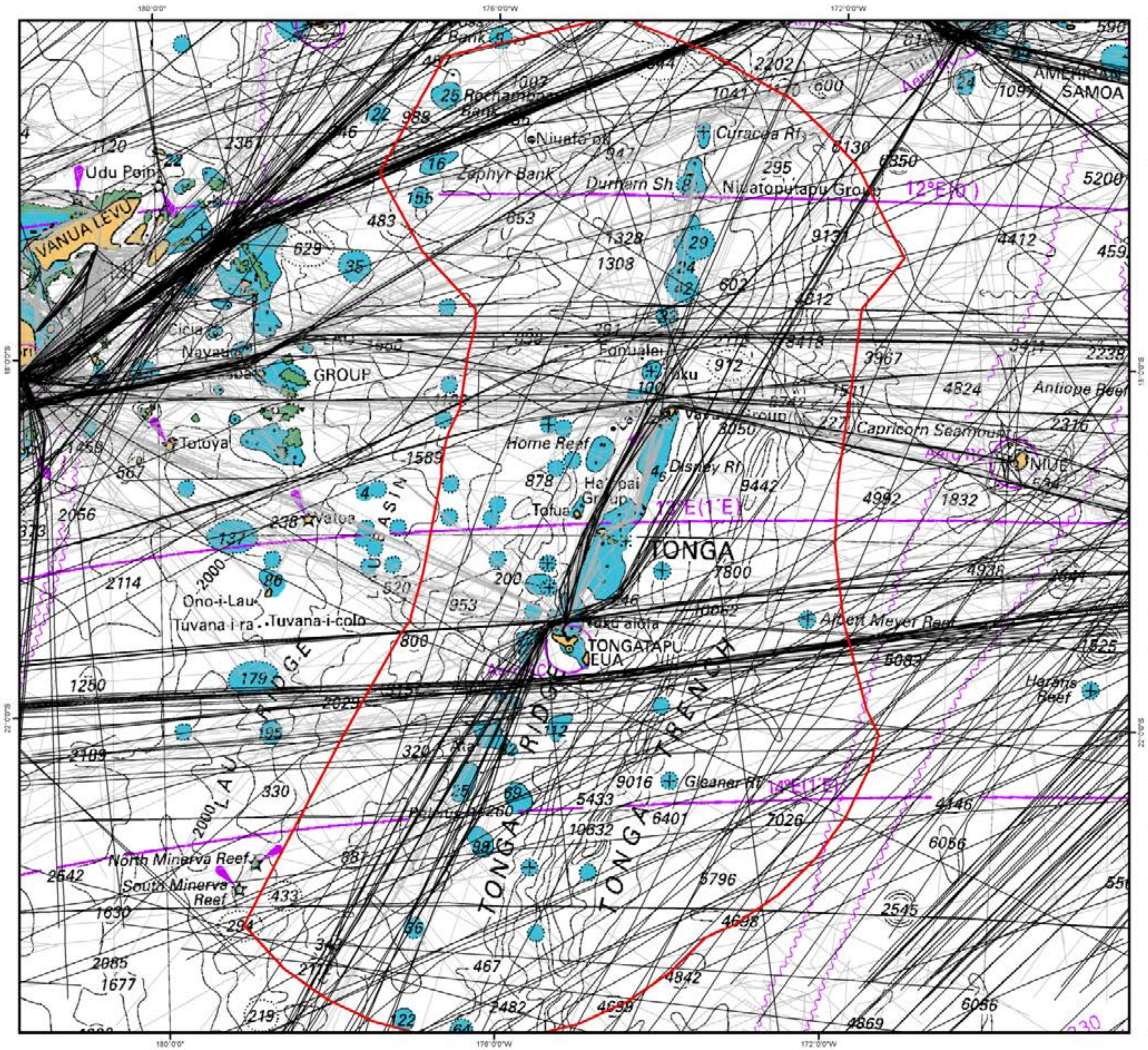

Figure 19: Dry Cargo Vessel Tracks – Tonga

Legend

Dry Cargo

Other

Project No.	Date	Issue Number
13NZ262	16/05/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:4,500,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
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- December 2013 to January 2014

Chart 14061 courtesy of LINZ
S-AIS supplied by: exactAIS

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Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 25 50 100 150 Nautical Miles

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Figure Reference: 13NZ262_Tonga_Cargo_01

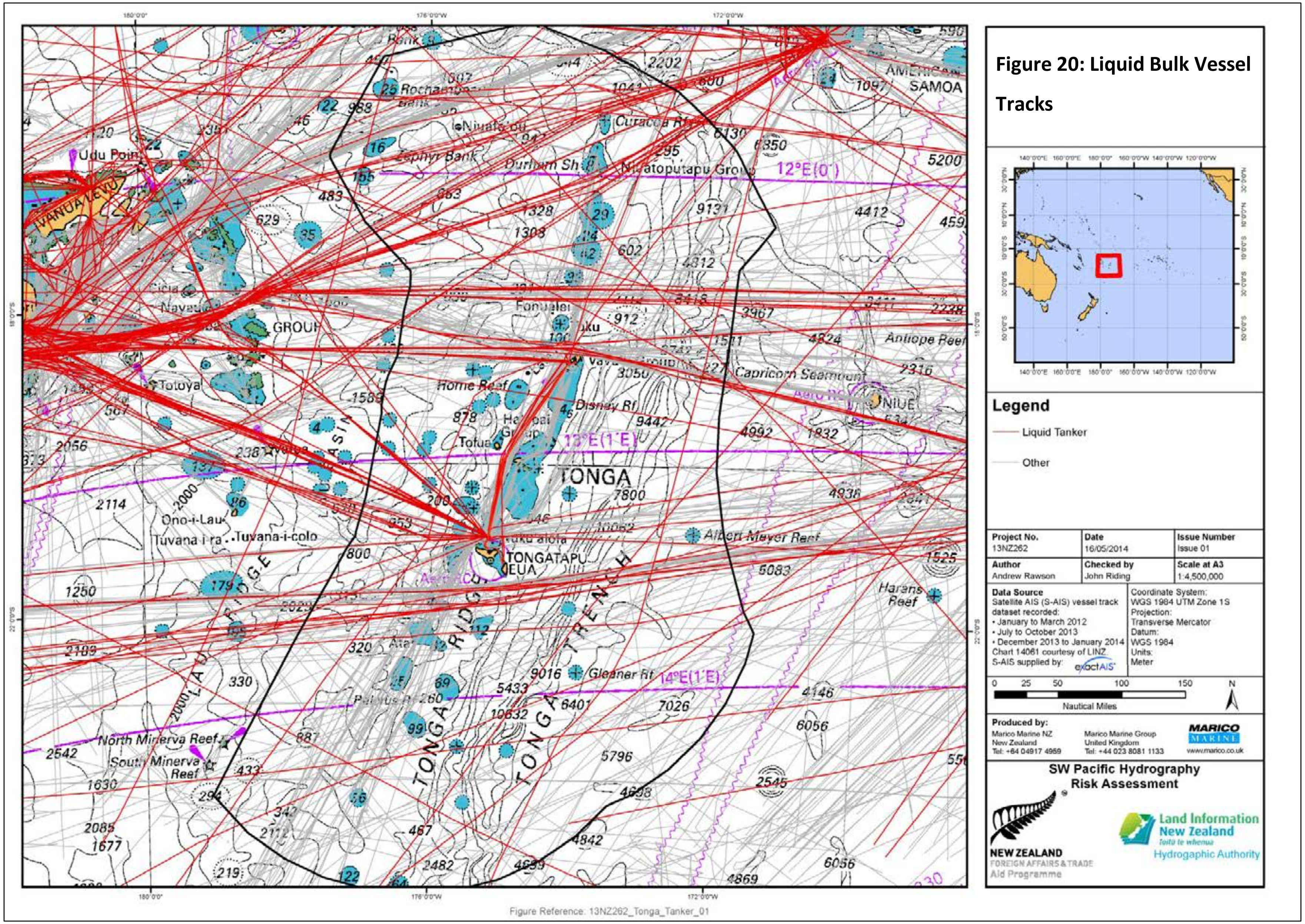

Figure 20: Liquid Bulk Vessel Tracks

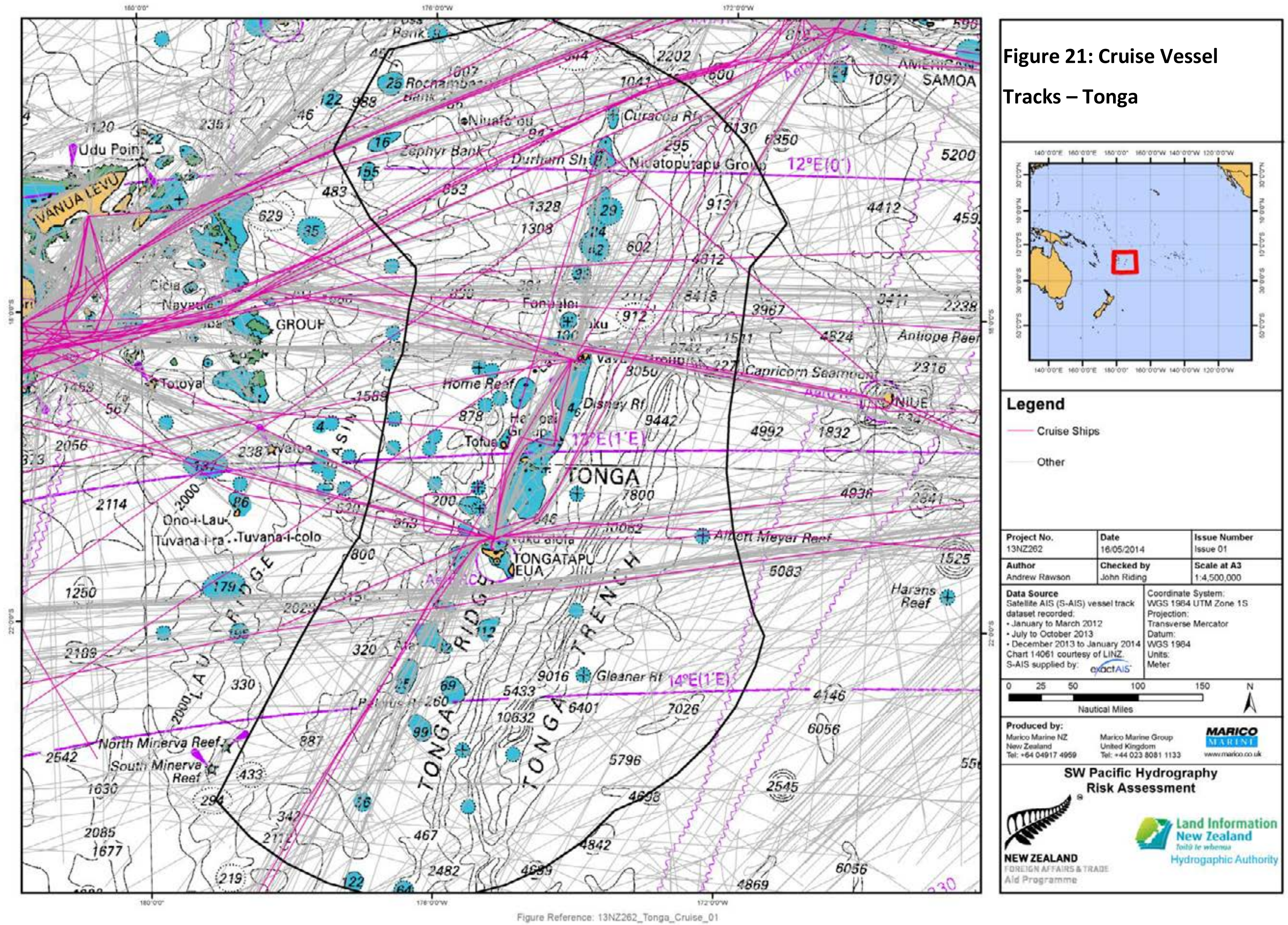

Figure 21: Cruise Vessel Tracks – Tonga

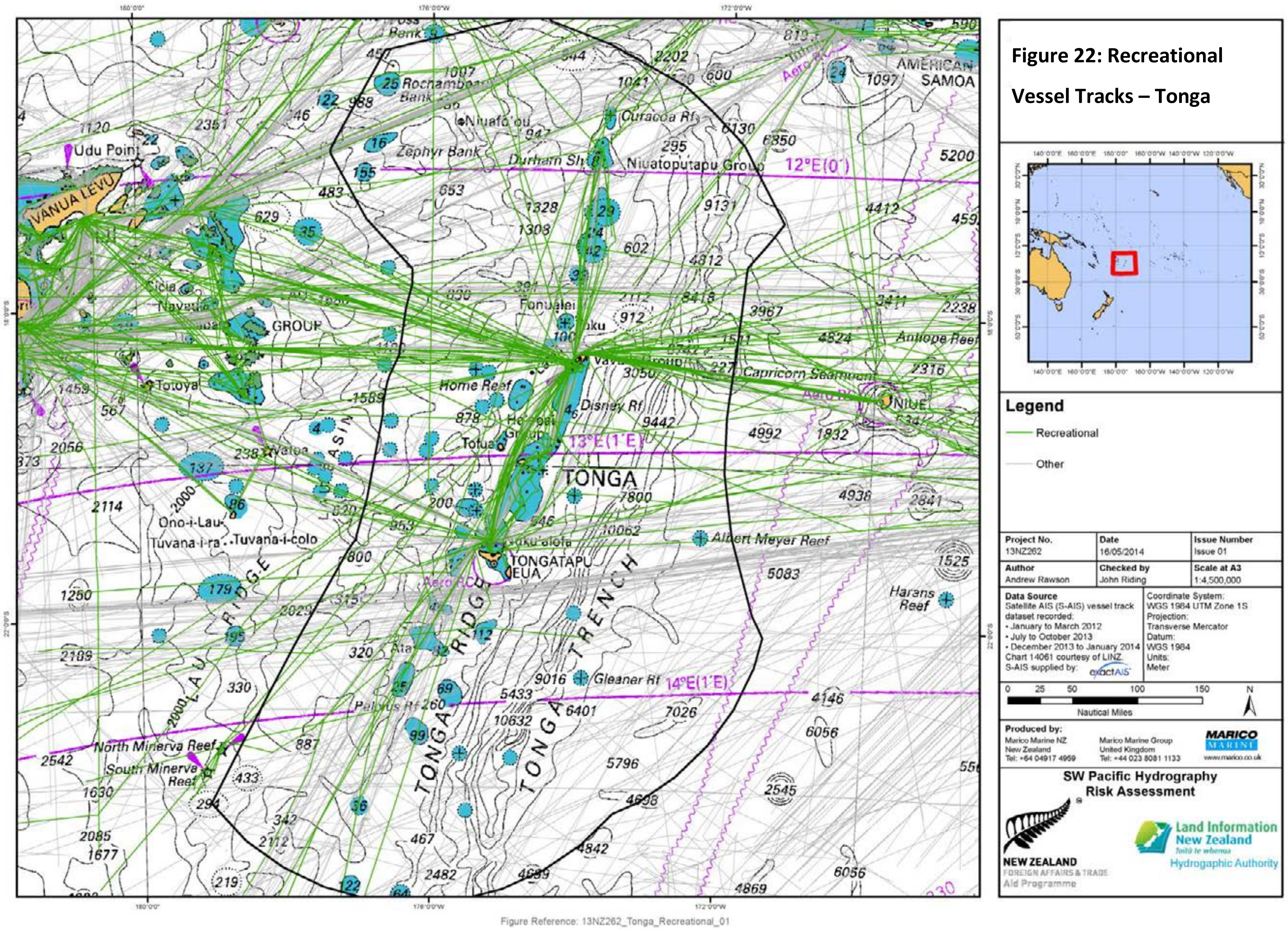

Figure 22: Recreational Vessel Tracks – Tonga

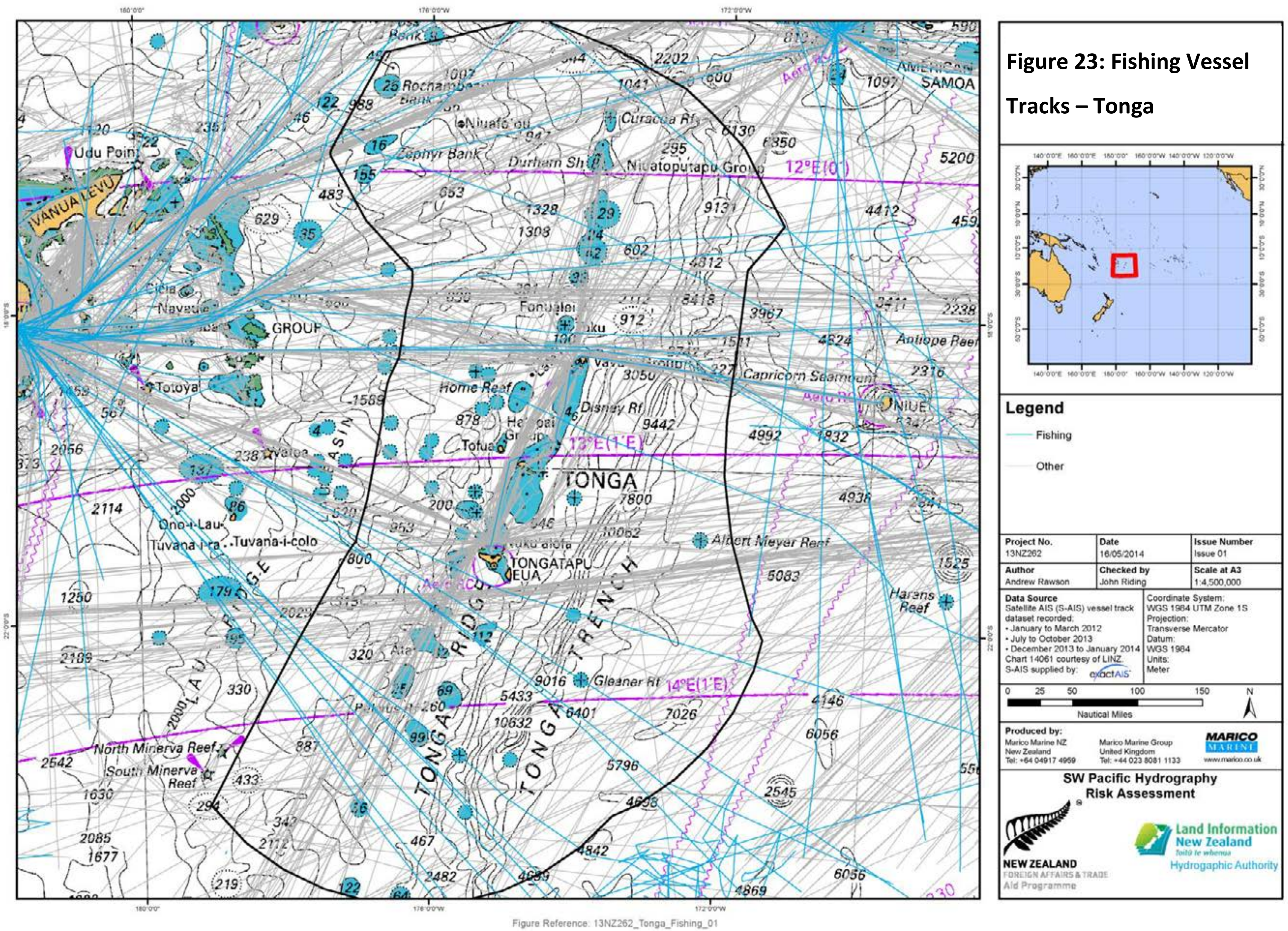

Figure 23: Fishing Vessel Tracks – Tonga

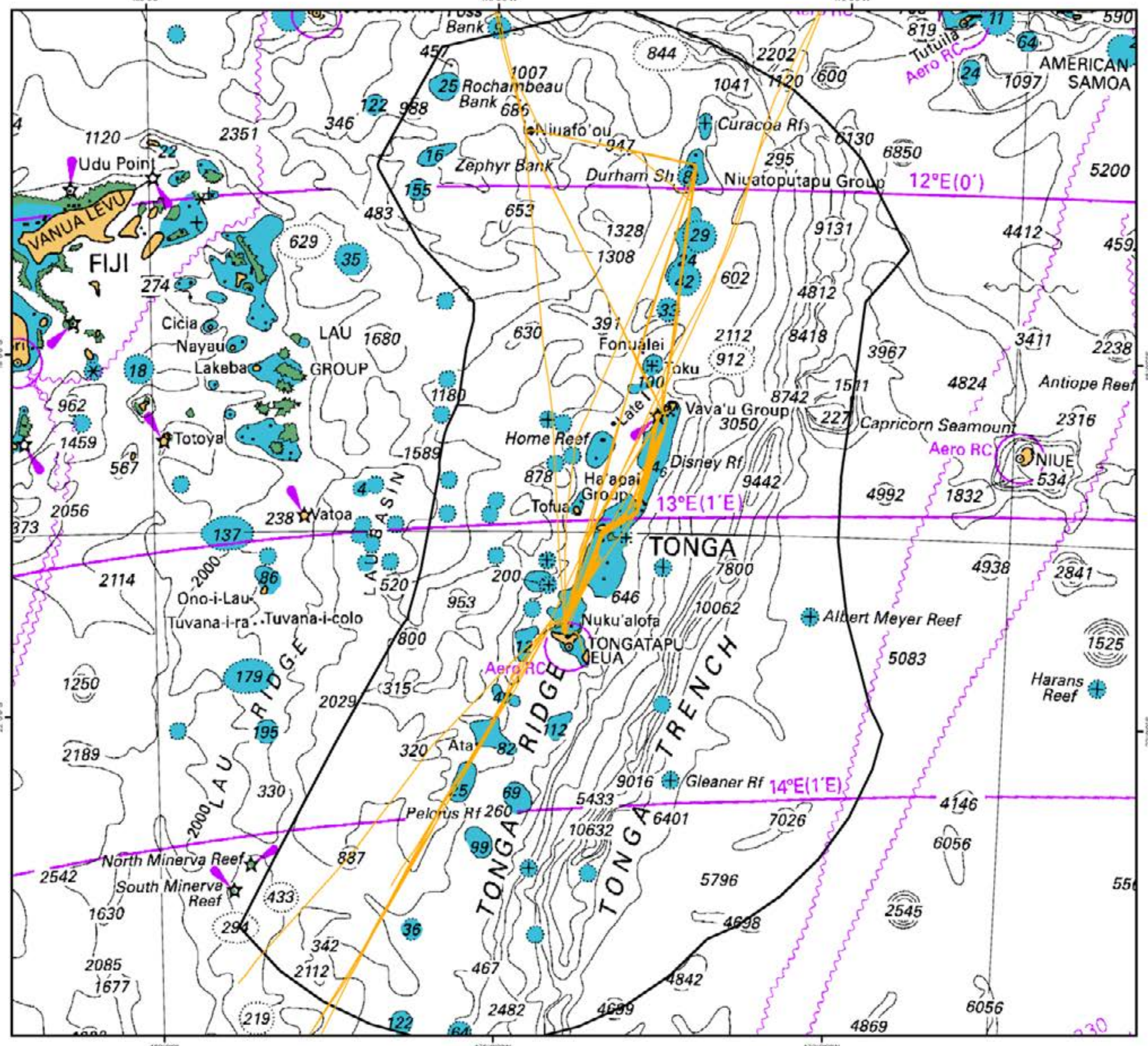

Figure Reference: 13NZ262_Tonga_Domestic_01

Figure 24: Domestic Coastal Vessel Tracks – Tonga

Legend

Domestic Vessel Tracks

Project No.	Date	Issue Number
13NZ262	15/05/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:4,500,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 25 50 100 150 Nautical Miles

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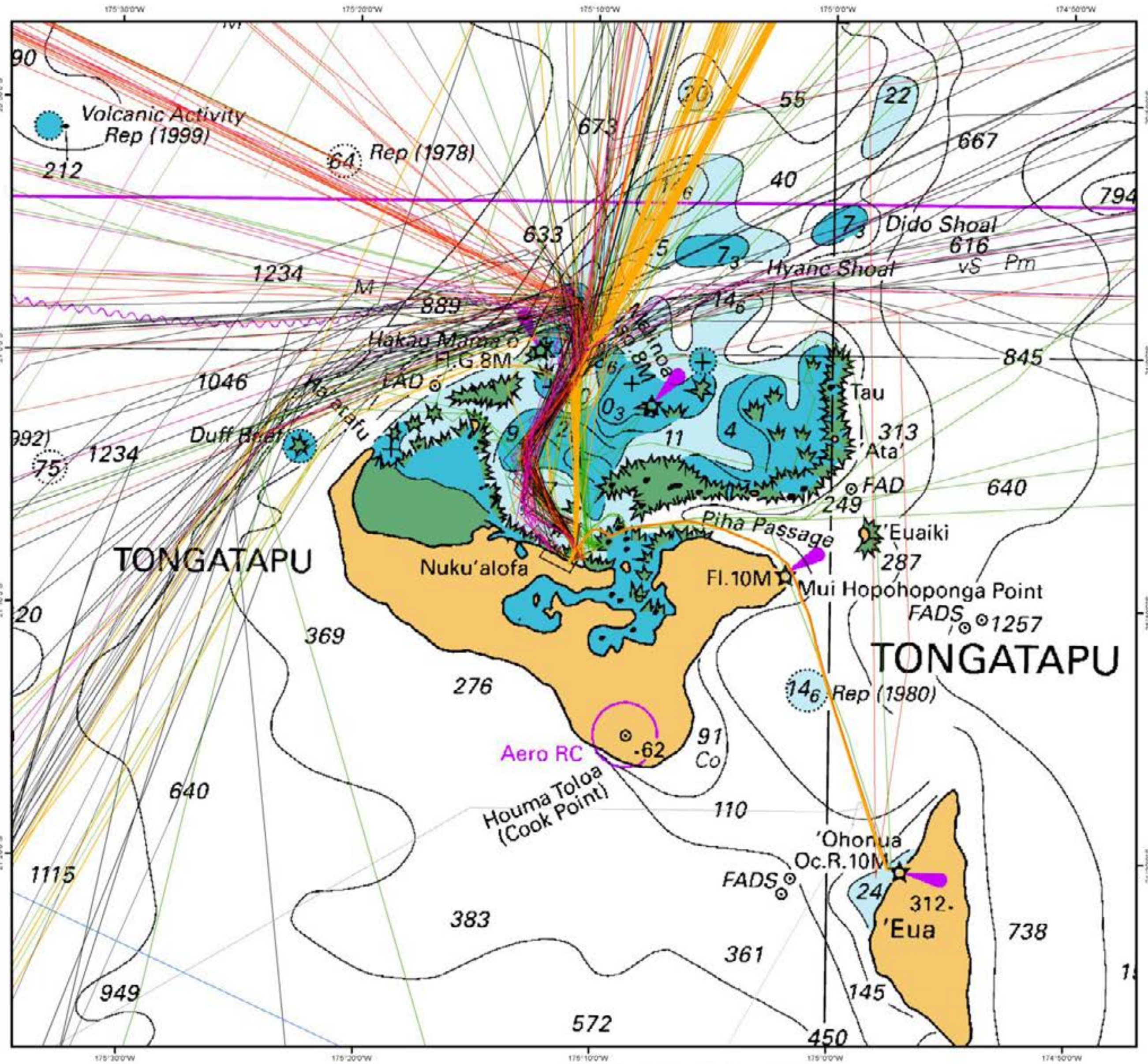
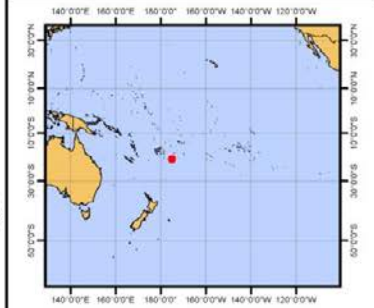


Figure Reference: 13NZ262_Tonga_Tongatapu_01

Figure 25: Tongatapu Group Vessel Tracks



Legend

- Cargo
- Passenger
- Domestic
- Recreational
- Fishing
- Tanker
- Other

Project No.	Date	Issue Number
13NZ262	16/05/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:268,212

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
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- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 1.5 3 6 9 Nautical Miles N

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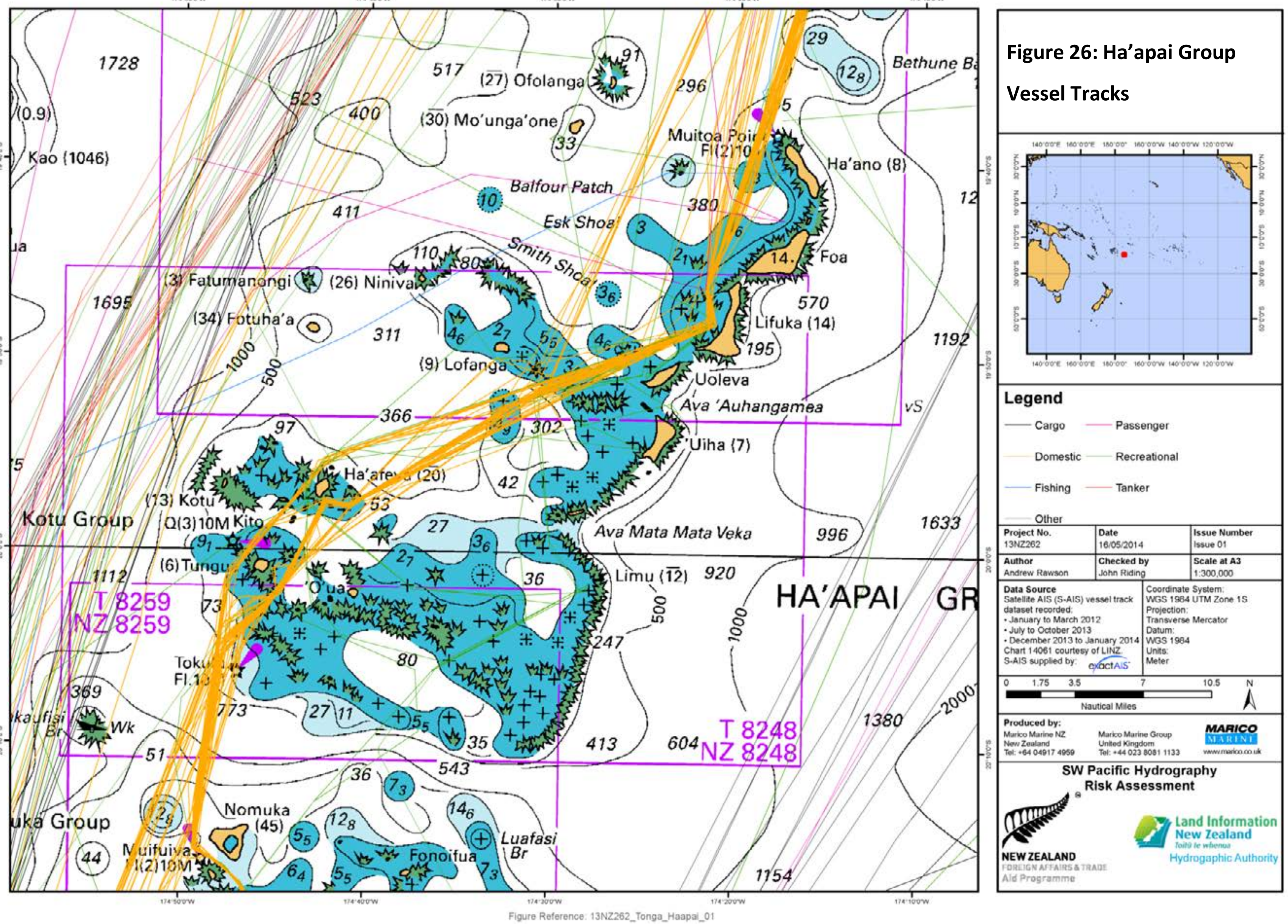


Figure 26: Ha'apai Group Vessel Tracks

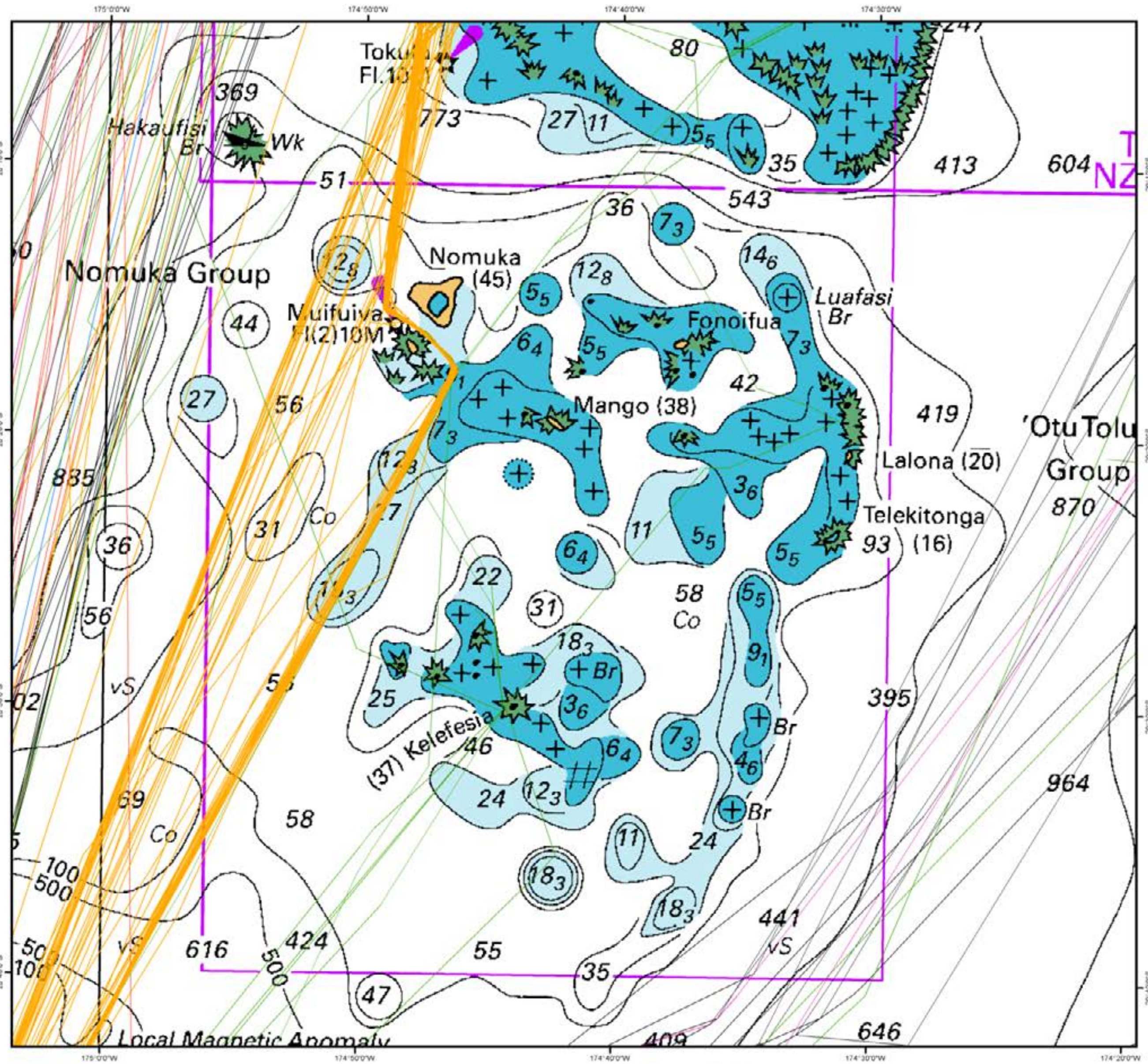
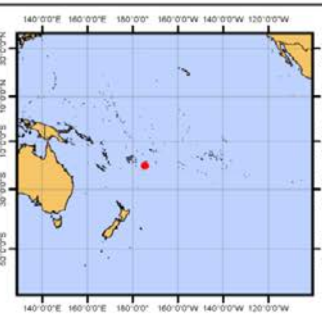


Figure 27: Nomuka Island Vessel Tracks



Legend

Cargo, Passenger, Domestic, Recreational, Fishing, Tanker, Other

Project No.	Date	Issue Number
13NZ262	16/05/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:250,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 1.5 3 6 9 Nautical Miles N

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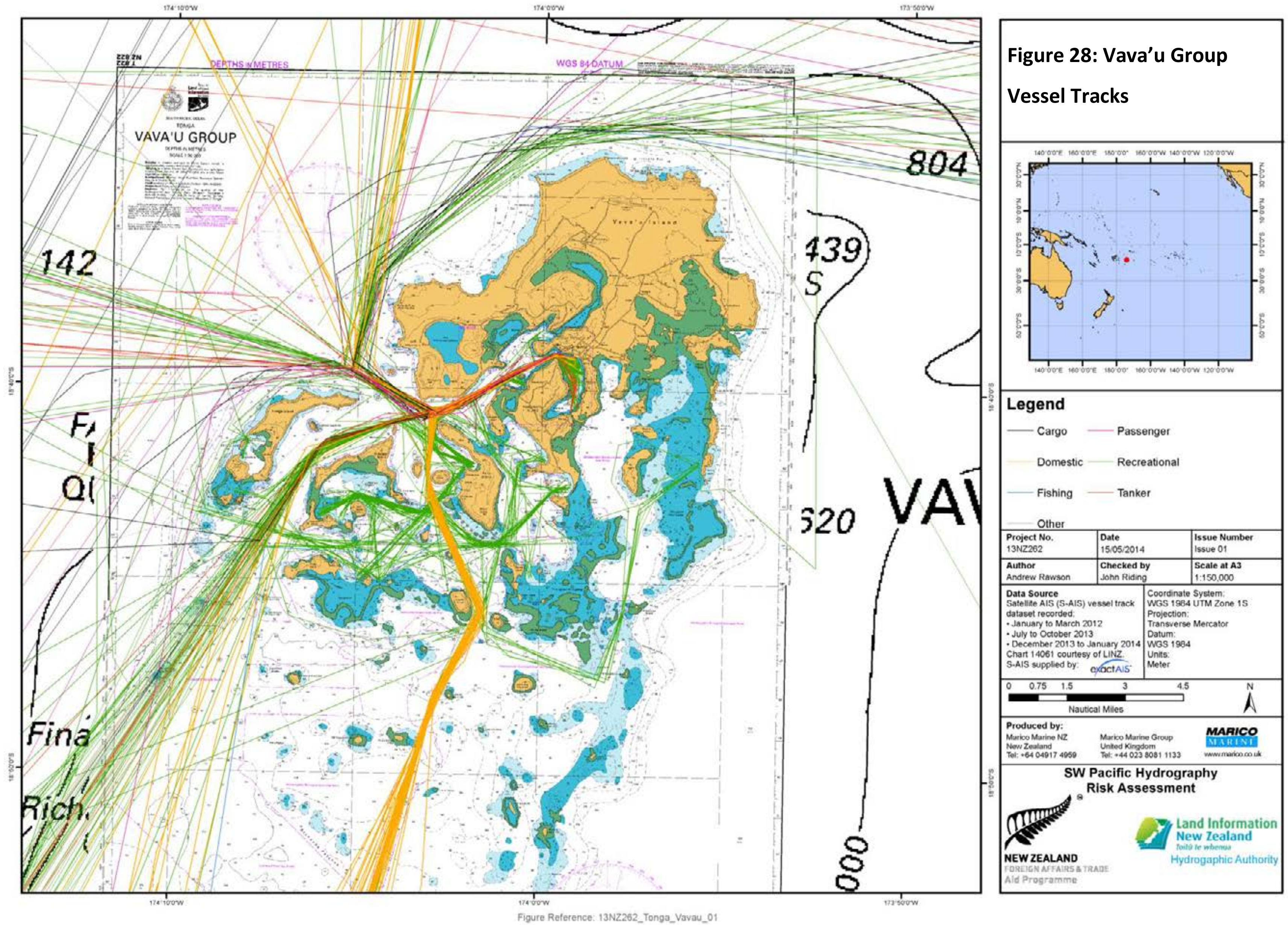


Figure 28: Vava'u Group Vessel Tracks

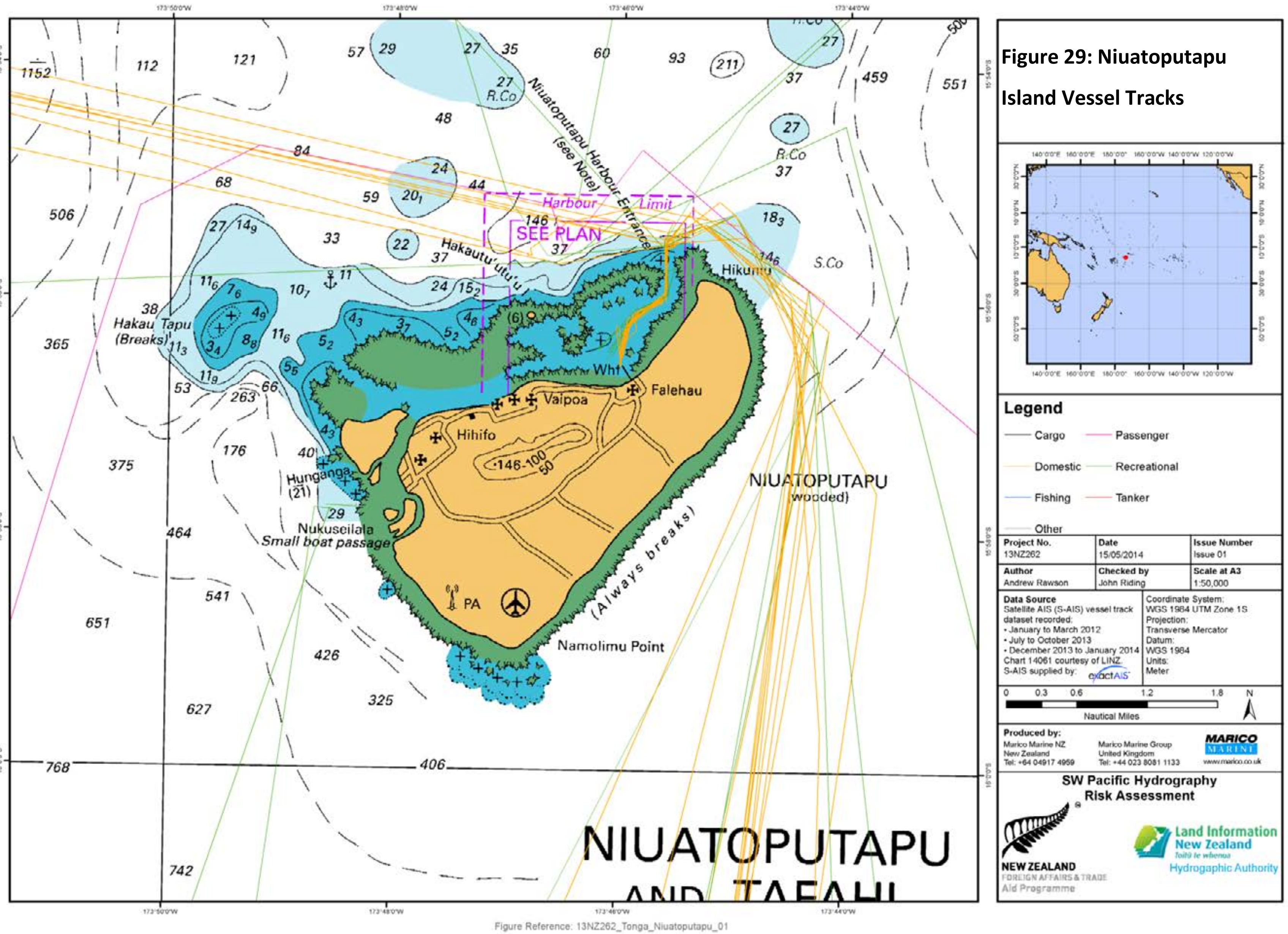
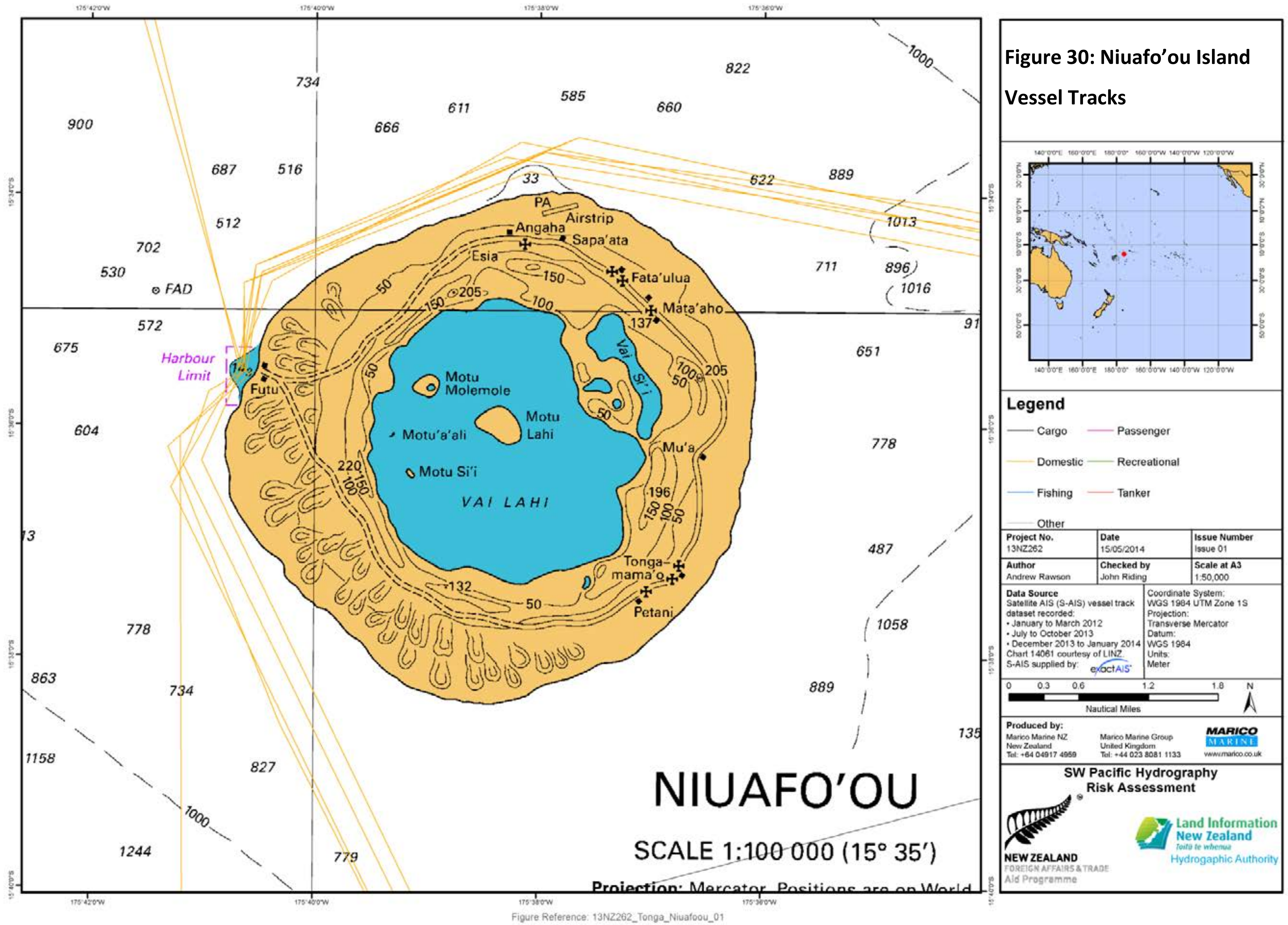


Figure 29: Niuatoputapu Island Vessel Tracks



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Annex C
Chart CATZOC for Each Island Group

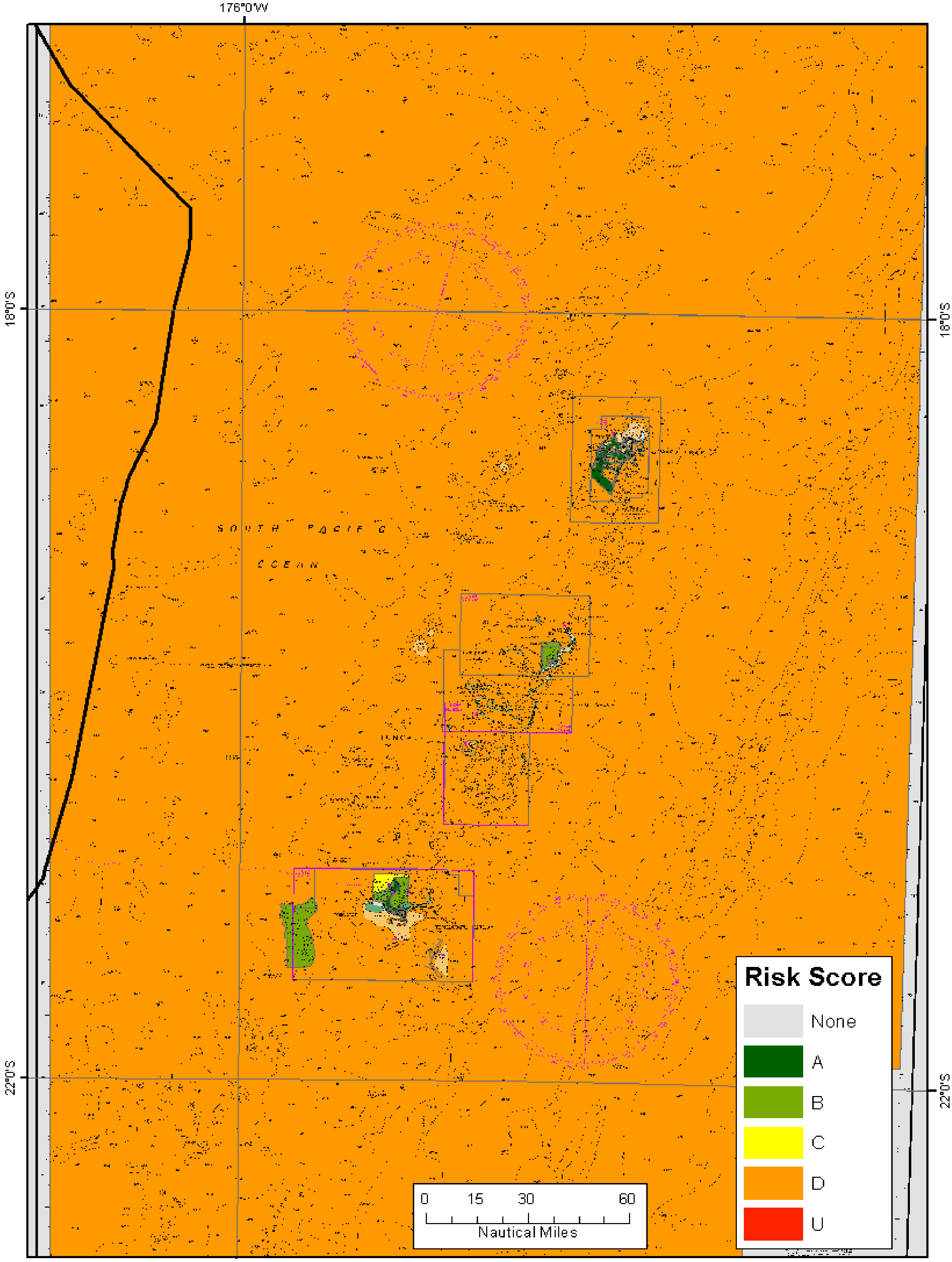


Figure 31: CATZOC Categories for Tonga

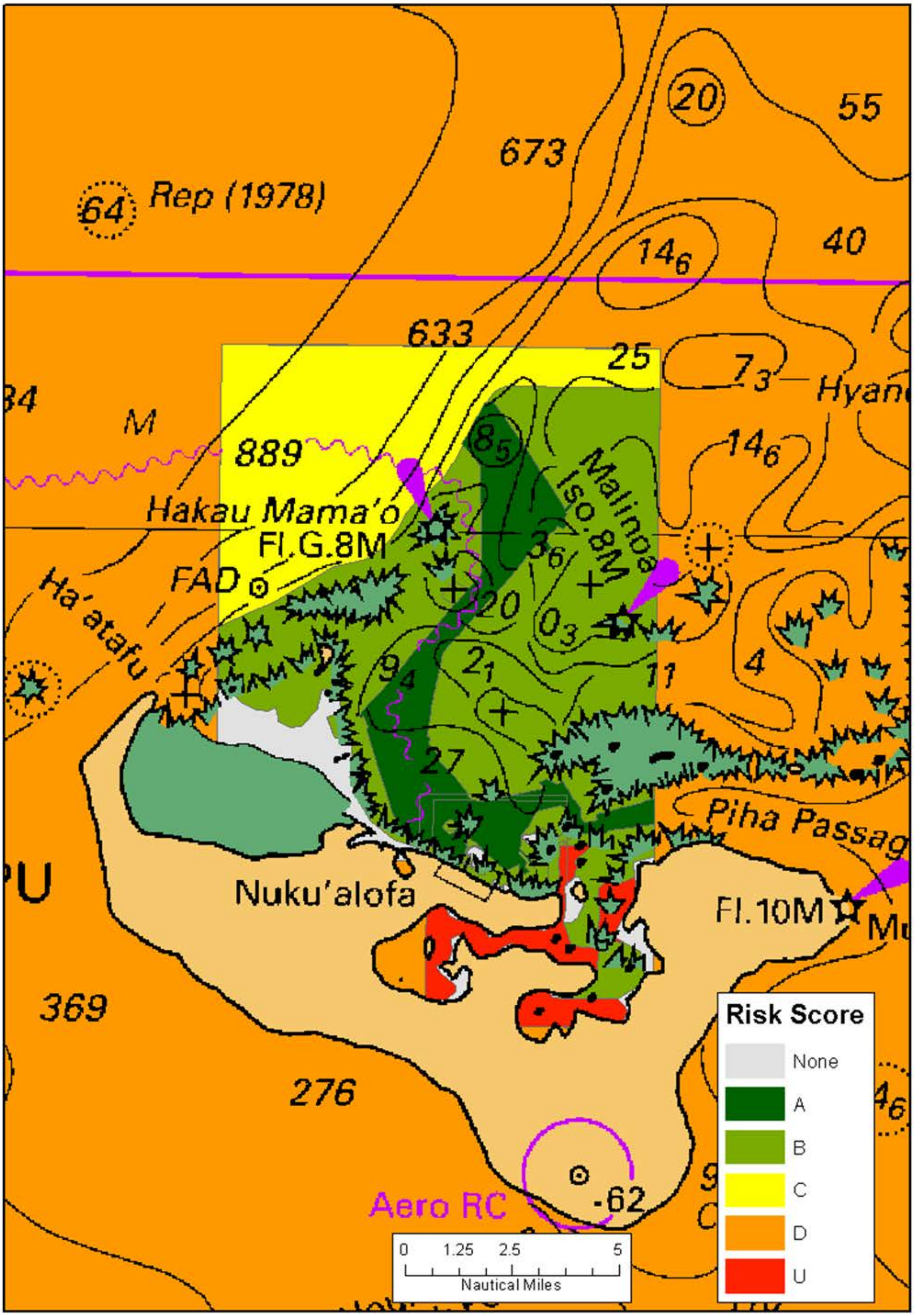


Figure 32: CATZOC Categories for Tongatapu Island Group

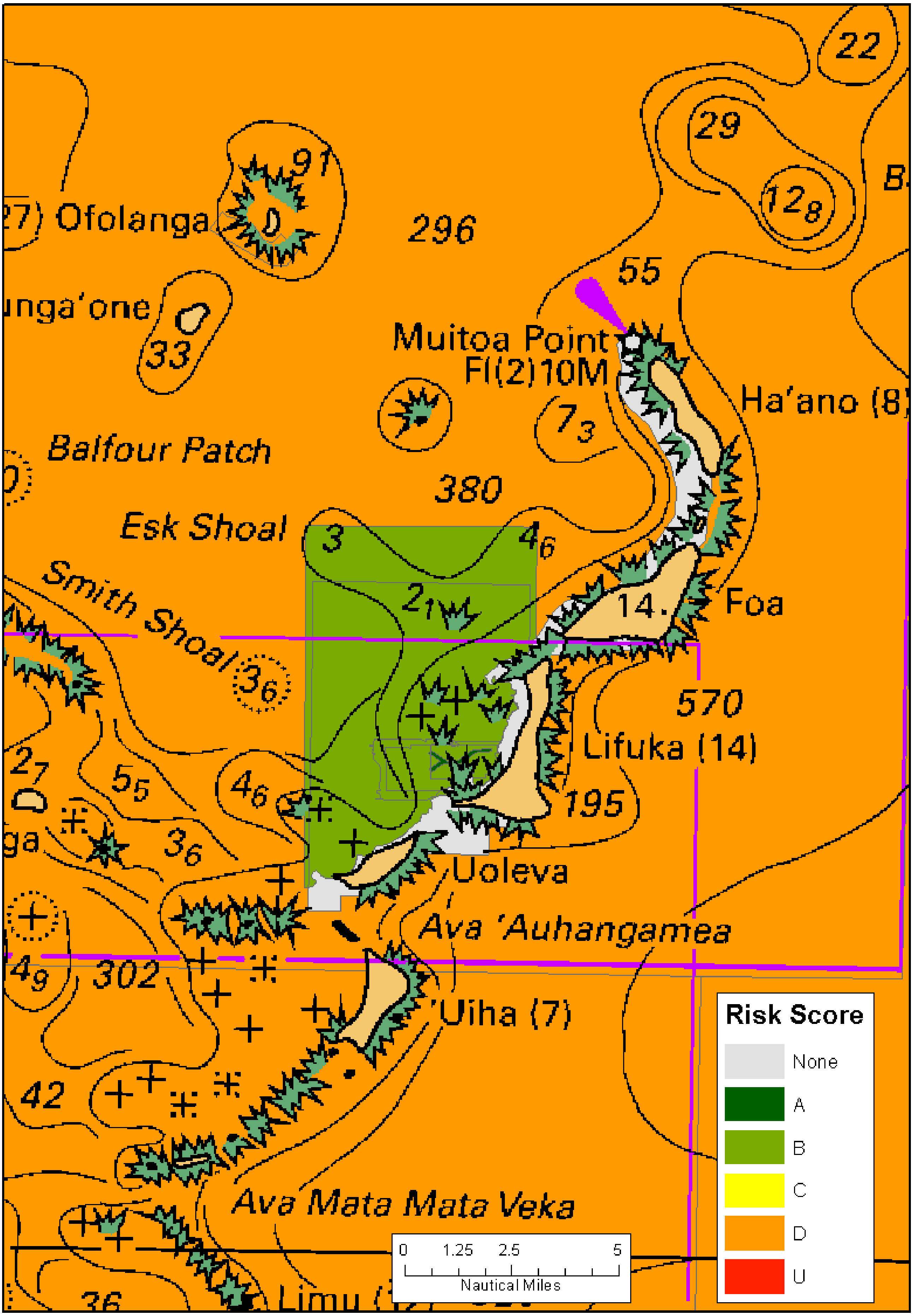


Figure 33: CATZOC Categories for Ha'apai Island Group

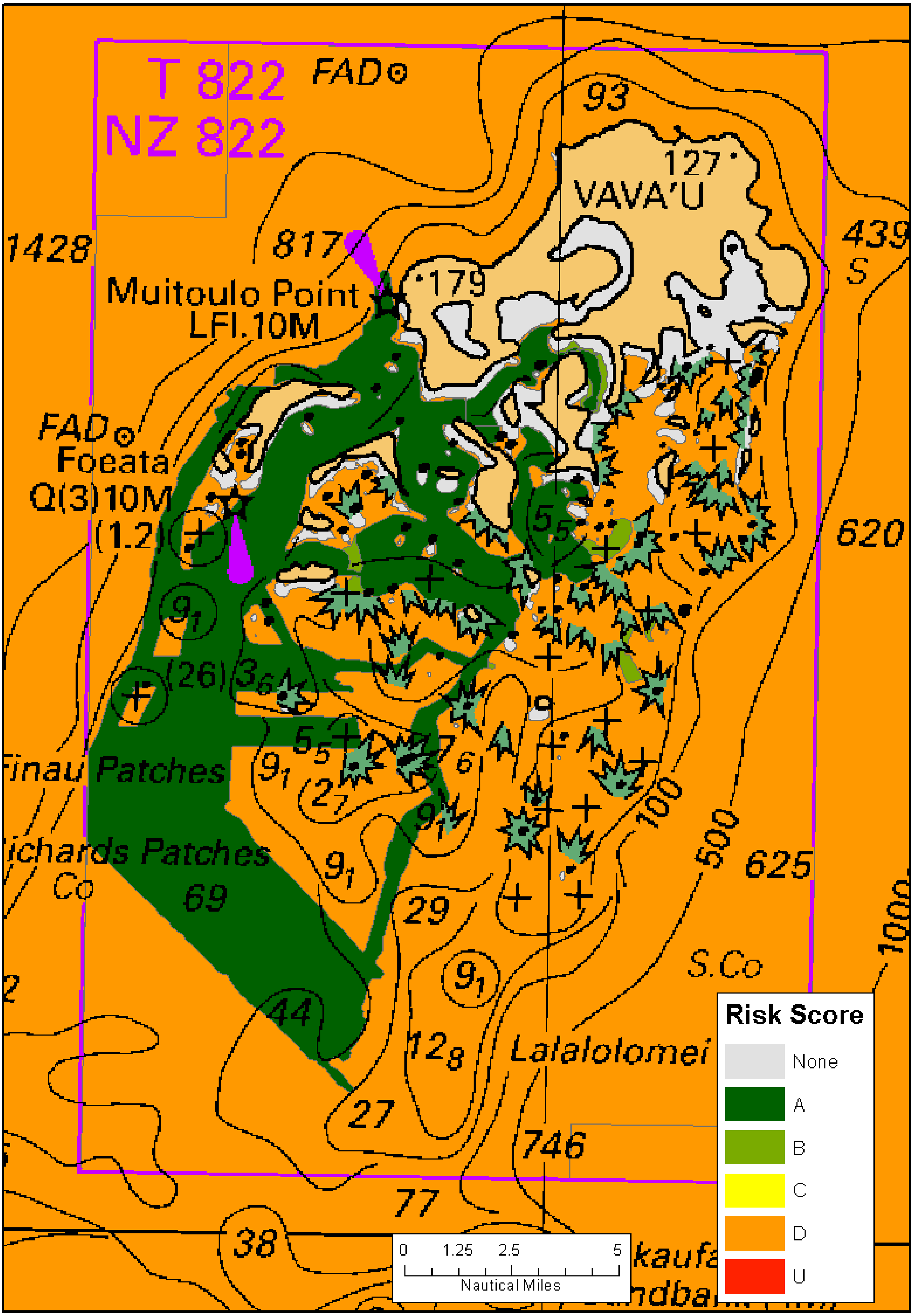


Figure 34: CATZOC Categories for Vava'u Island Group

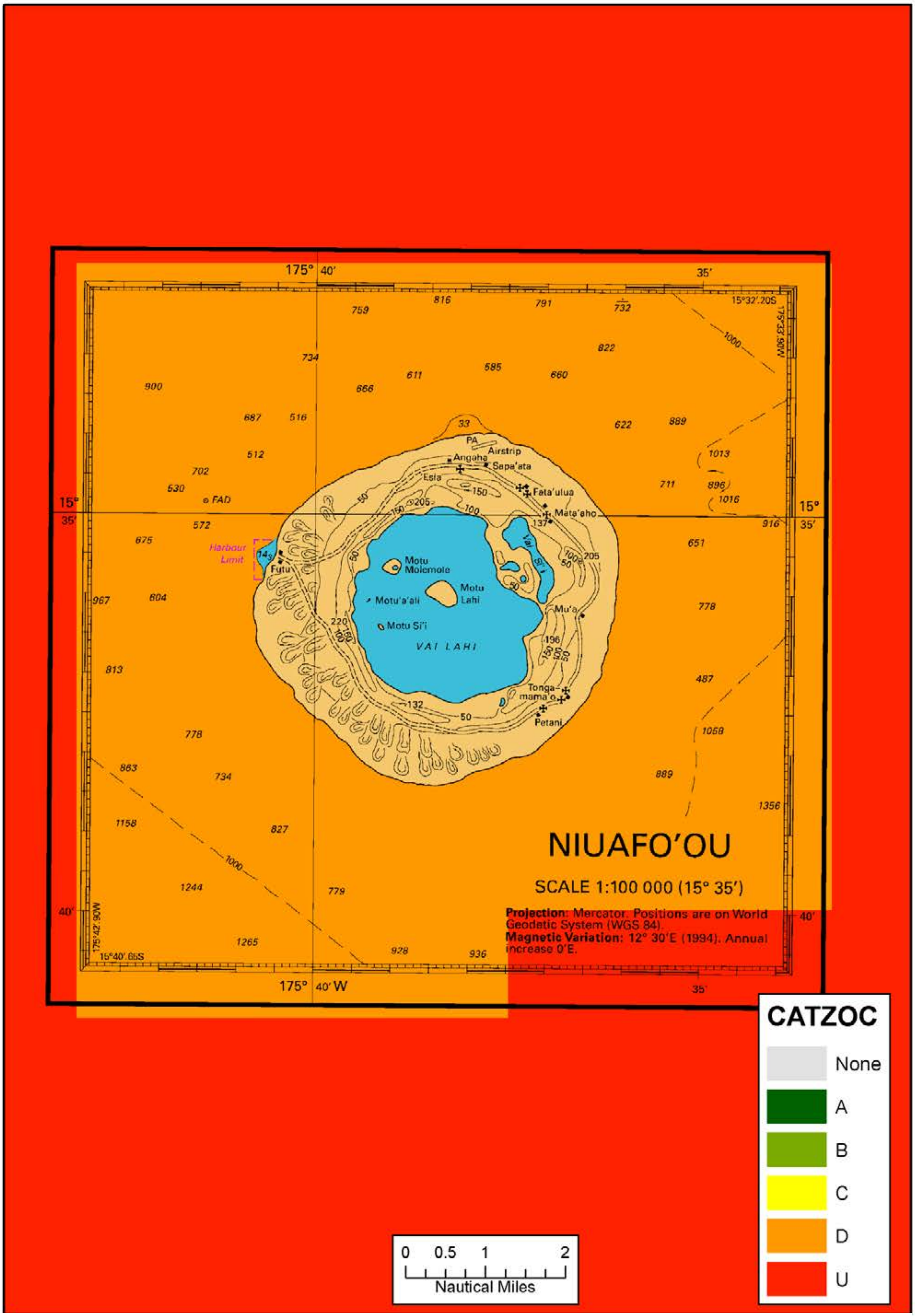


Figure 35: CATZOC Categories for Niuafo'ou Island

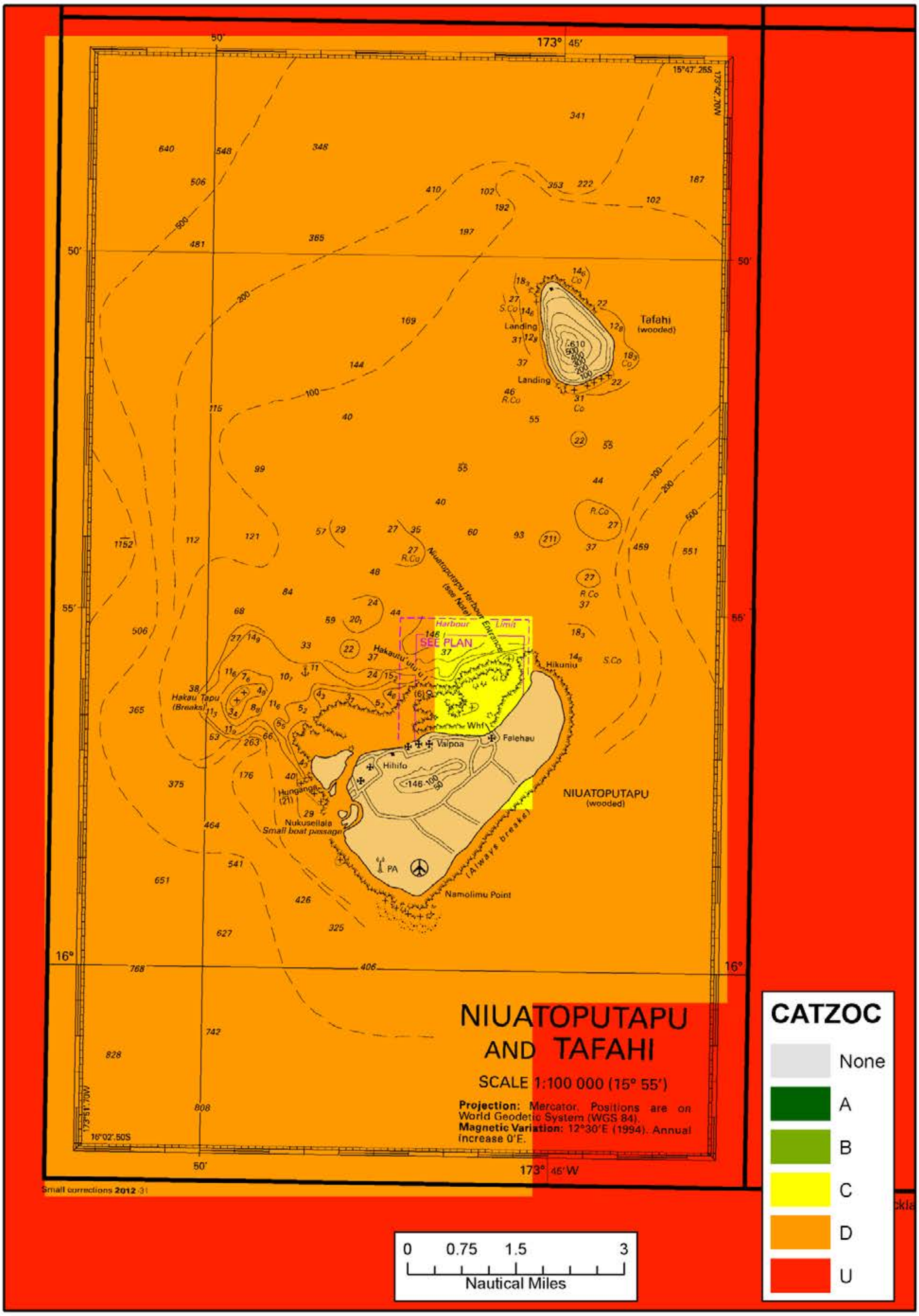
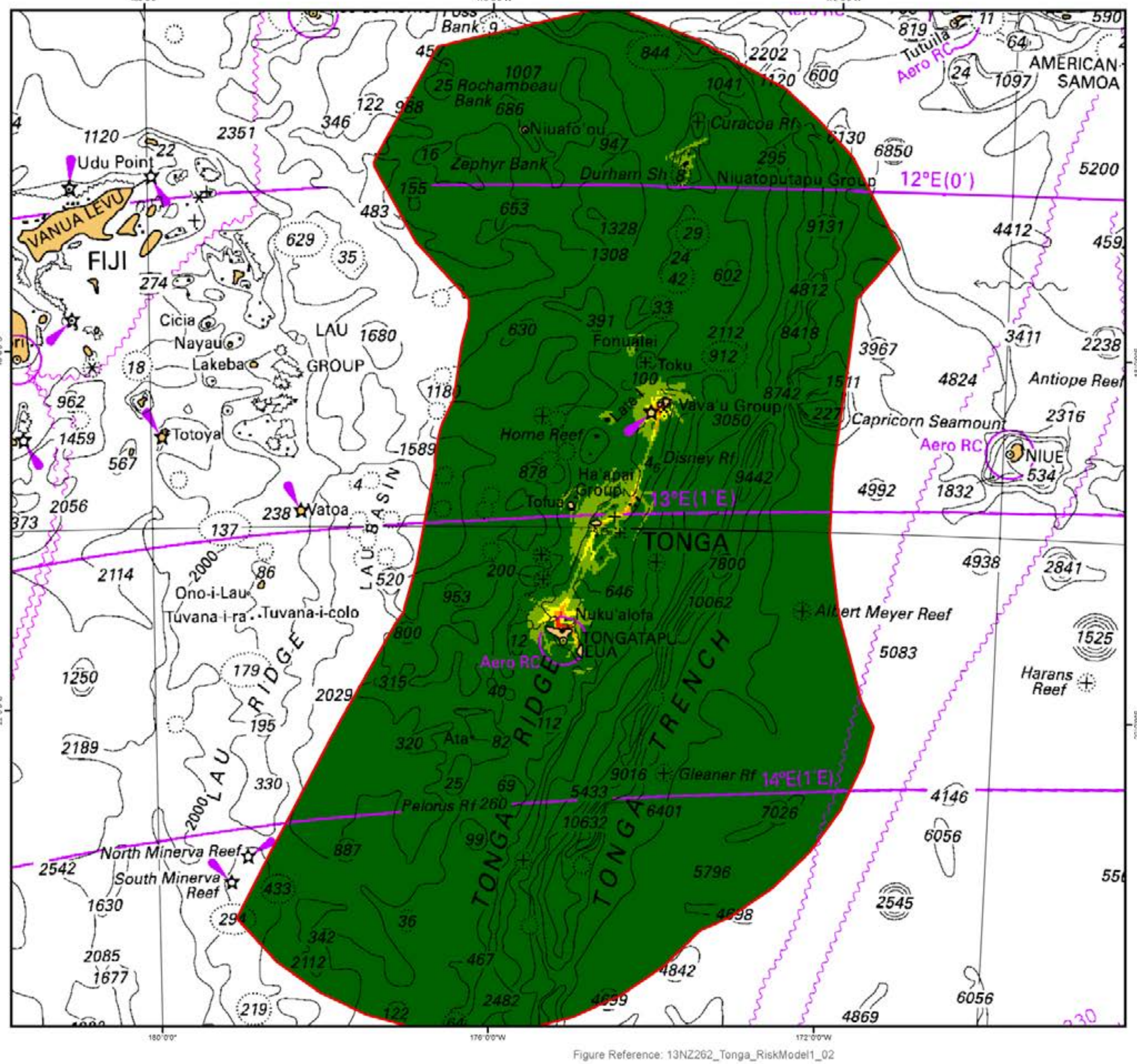


Figure 36: CATZOC Categories for Niuatoputapu Island

Annex D
Risk Model Results

Figure 37: Tonga Risk Model Results



Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 02
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:4,500,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 25 50 100 150 Nautical Miles N

Produced by:
Marico Marine NZ, New Zealand, Tel: +64 04917 4959
Marico Marine Group, United Kingdom, Tel: +44 023 8081 1133
www.marico.co.uk

SW Pacific Hydrography Risk Assessment

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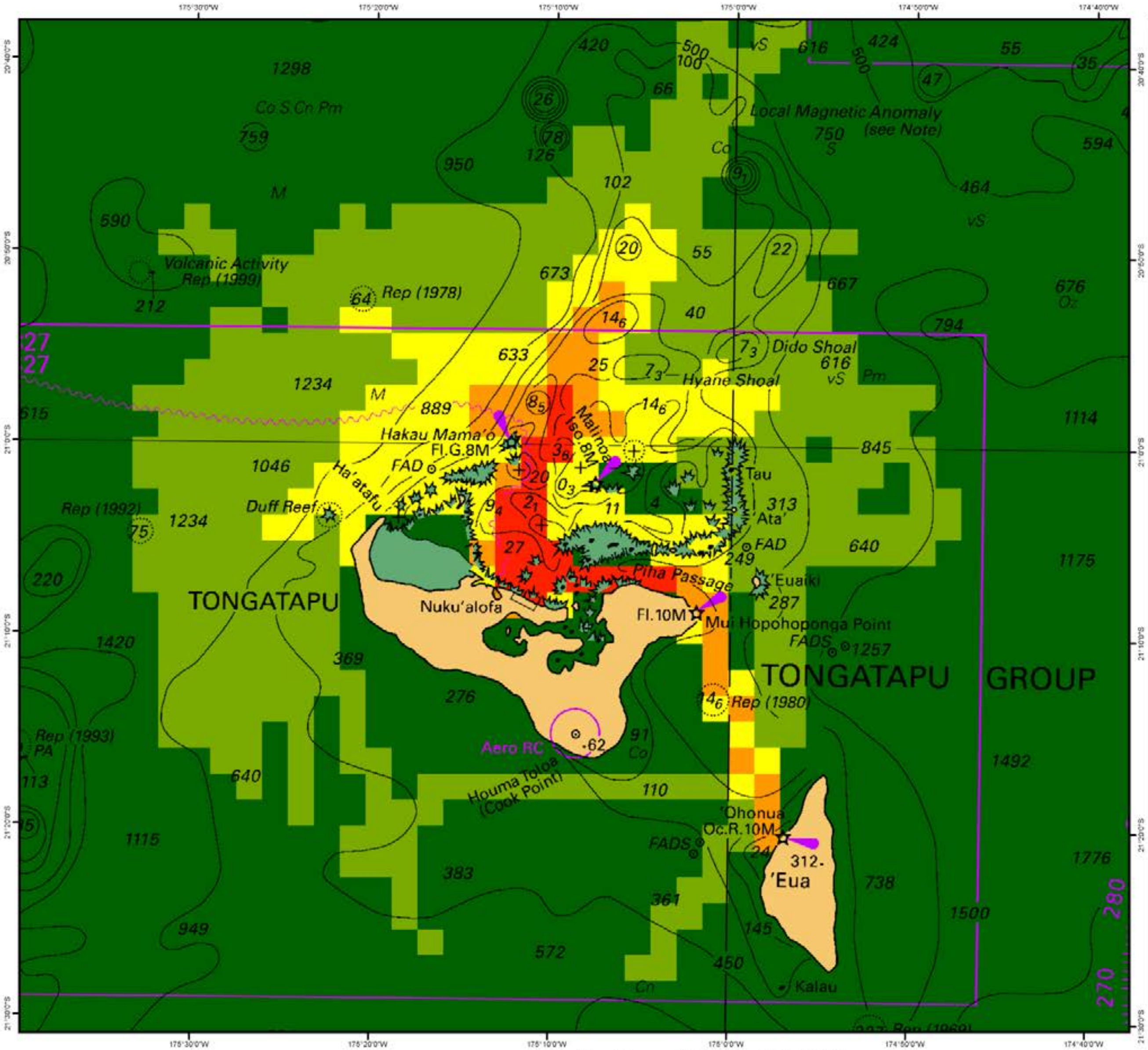
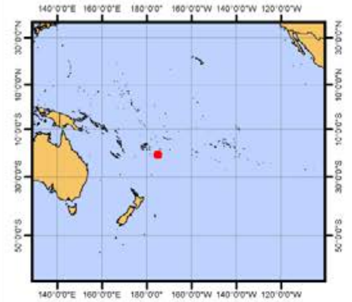


Figure 38: Tongatapu Risk Model Results



Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 02
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:350,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
• January to March 2012
• July to October 2013
• December 2013 to January 2014
Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System:
WGS 1984 UTM Zone 1S
Projection:
Transverse Mercator
Datum:
WGS 1984
Units:
Meter

0 2 4 8 12 Nautical Miles N

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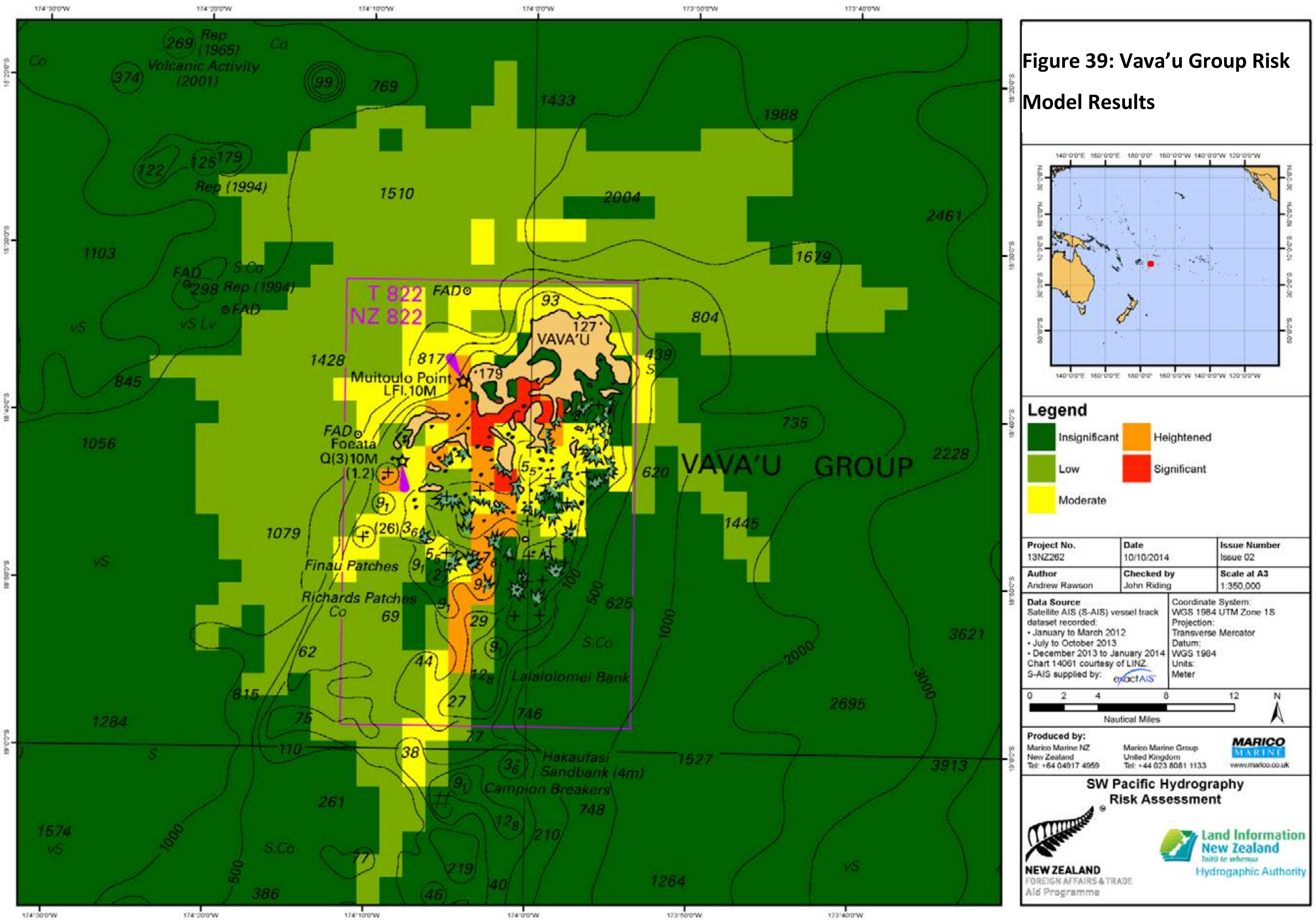


Figure 39: Vava'u Group Risk Model Results

Figure Reference: 13NZ262_Tonga_RiskModel4_02

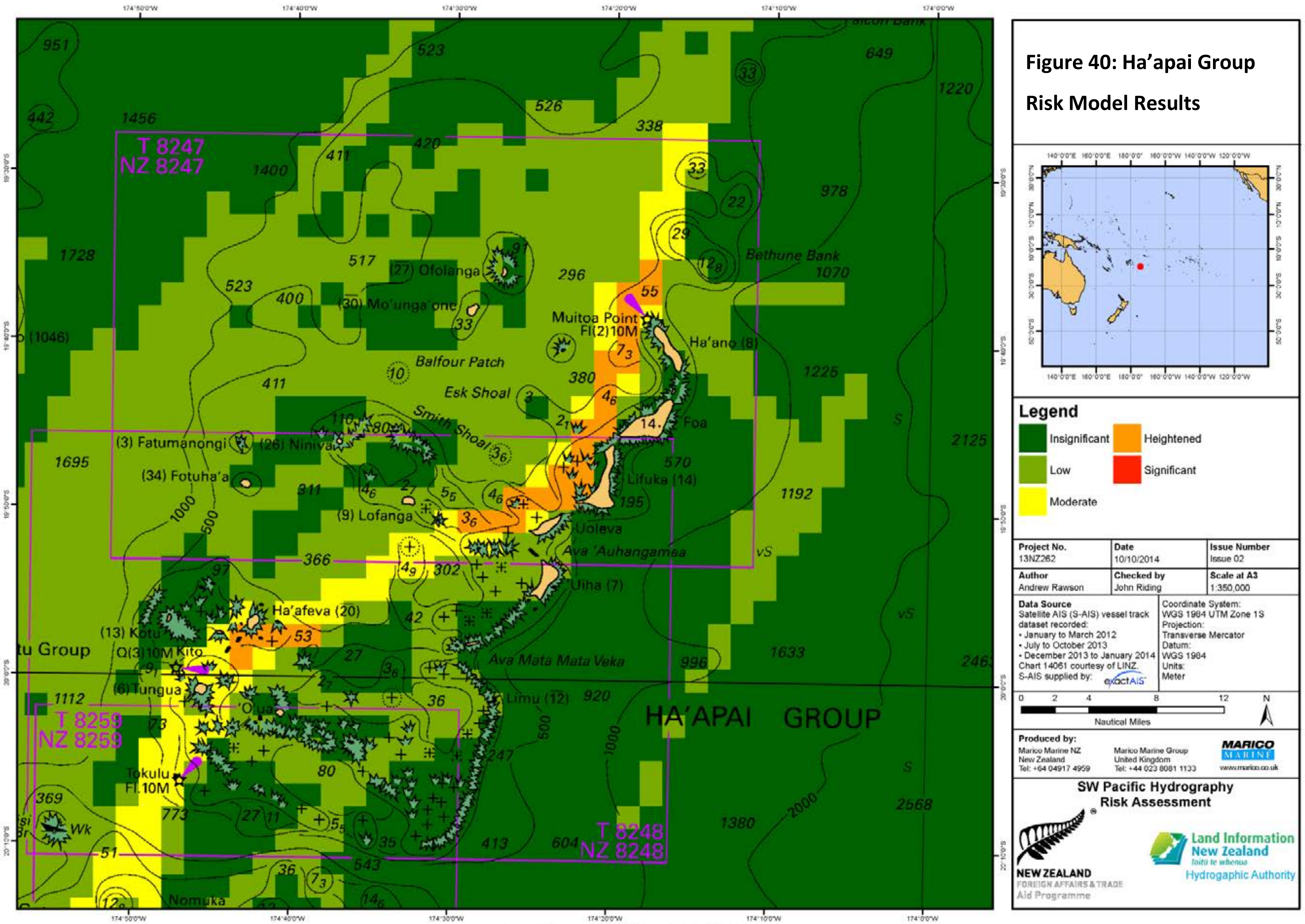


Figure 40: Ha'apai Group Risk Model Results

Figure Reference: 13NZ262_Tonga_RiskModel5_02

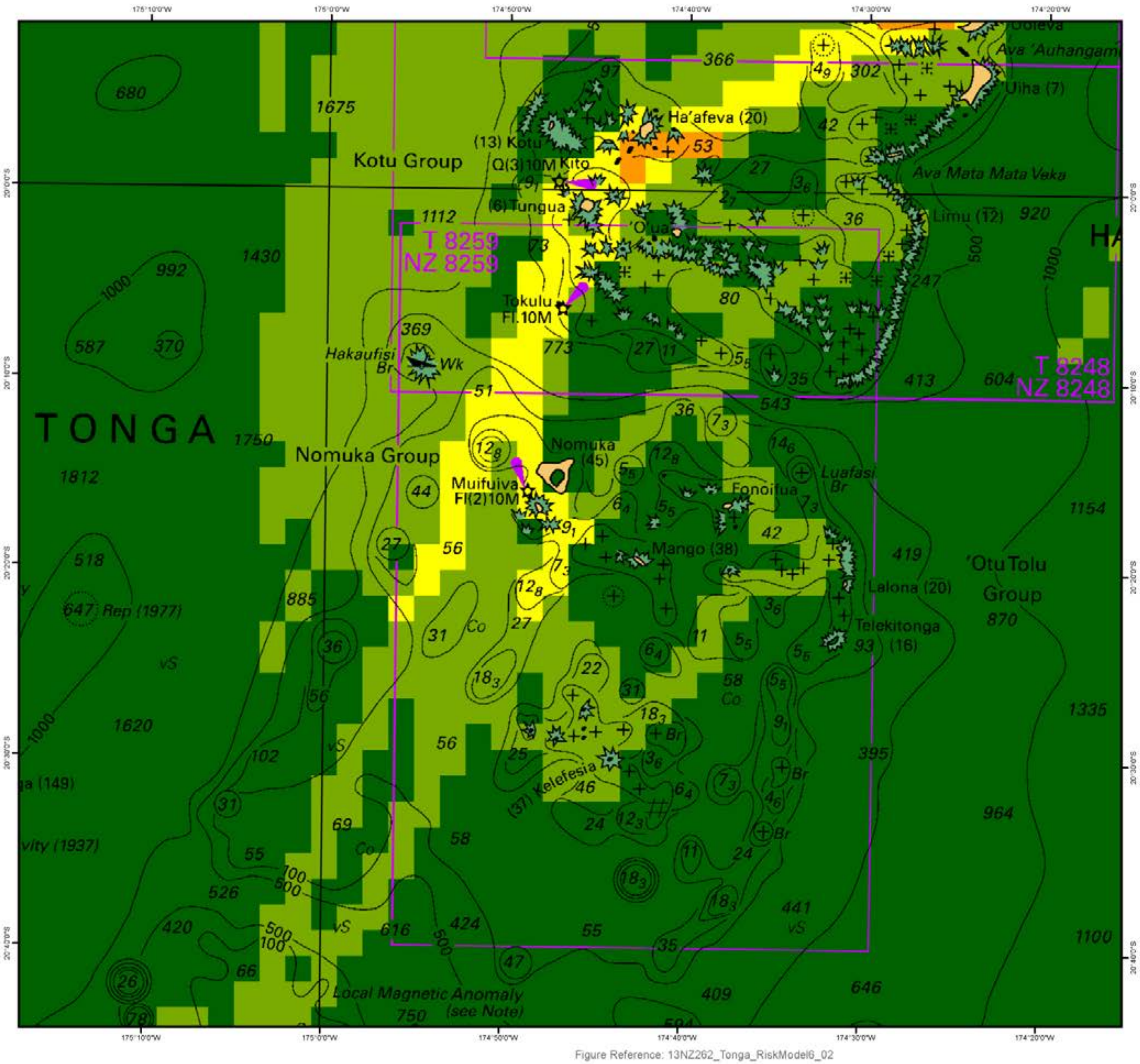
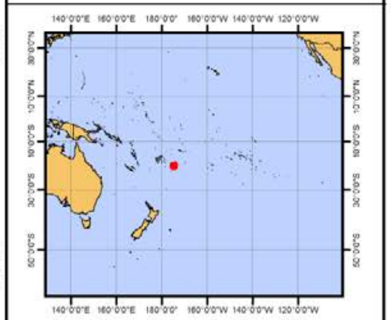


Figure 41: Nomuka Group Risk Model Results



Legend

- Insignificant
- Heightened
- Low
- Significant
- Moderate

Project No.	Date	Issue Number
13NZ262	10/10/2014	Issue 02
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:350,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 2 4 8 12 Nautical Miles

Produced by:
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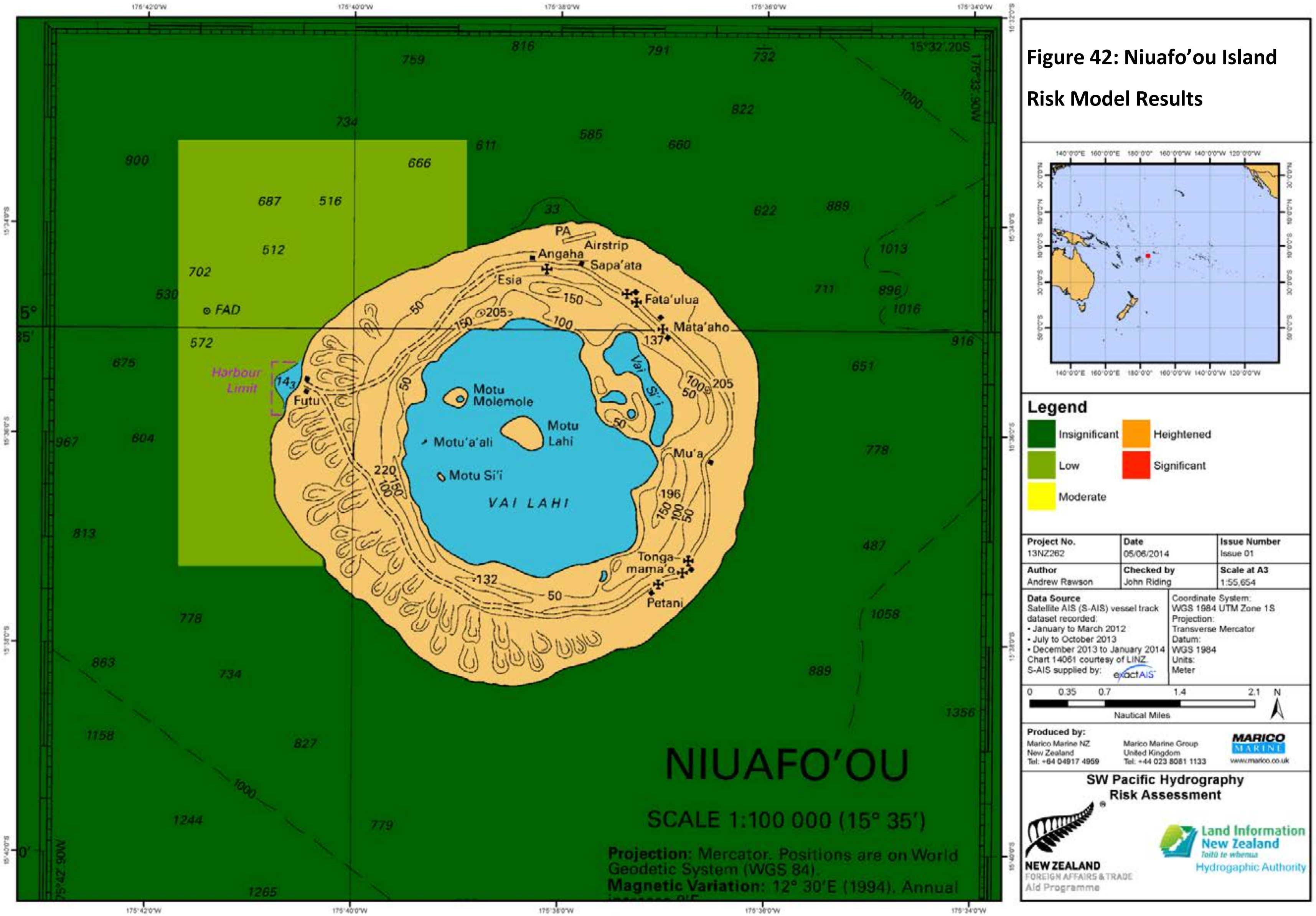

Figure 42: Niuafo'ou Island Risk Model Results

Figure Reference: 13NZ262_Tonga_RiskModel2_01

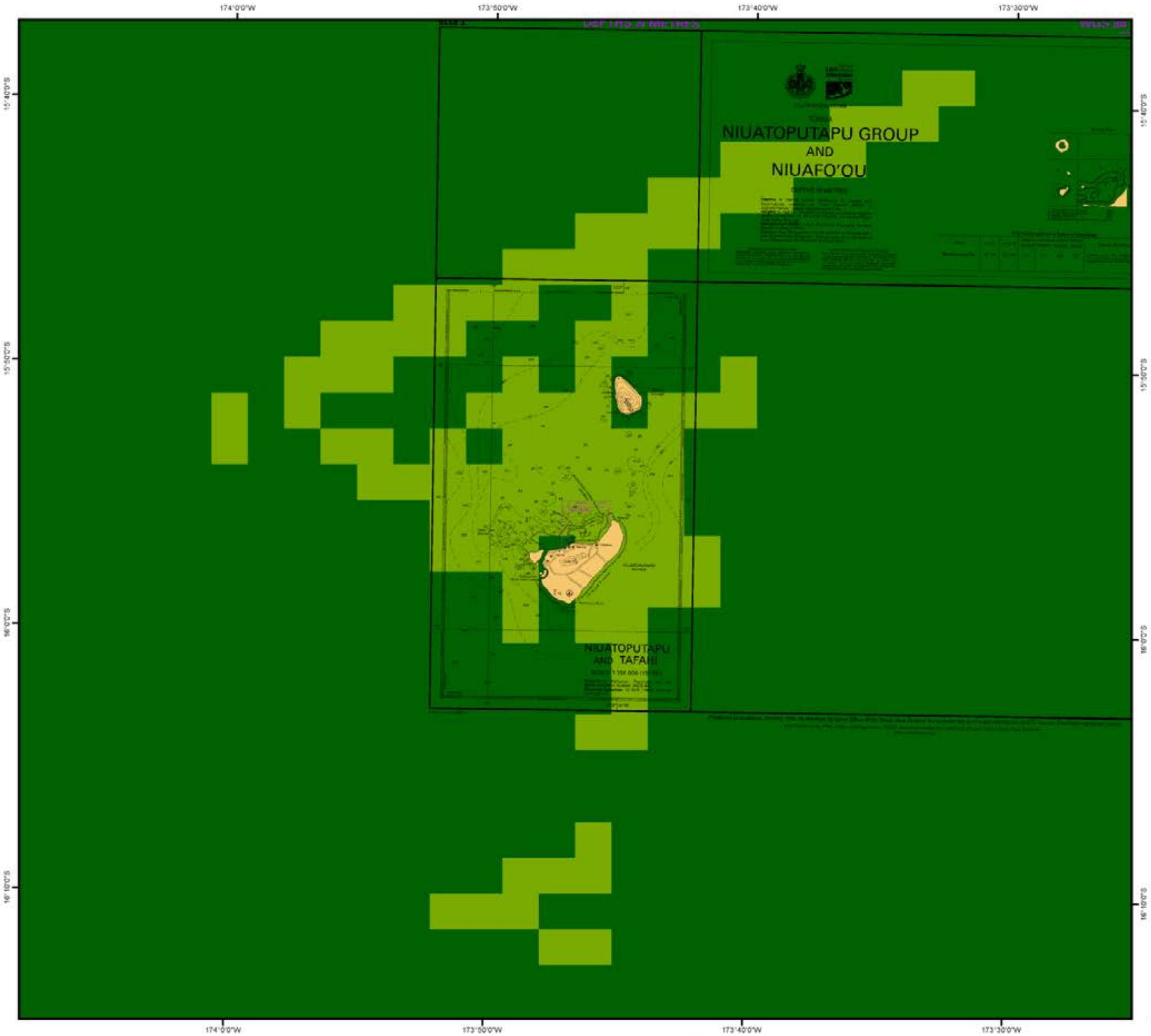

Figure 43: Niuatoputapu Island Risk Model Results

Legend

- Insignificant
- Low
- Moderate
- Heightened
- Significant

Project No.	Date	Issue Number
13NZ262	05/06/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:250,000

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 1.5 3 6 9 Nautical Miles N

Produced by:
Marico Marine NZ, New Zealand, Tel: +64 04917 4959
Marico Marine Group, United Kingdom, Tel: +44 023 8081 1133
www.marico.co.uk

SW Pacific Hydrography Risk Assessment

NEW ZEALAND FOREIGN AFFAIRS & TRADE Aid Programme
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Figure Reference: 13NZ262_Tonga_RiskModel3_01

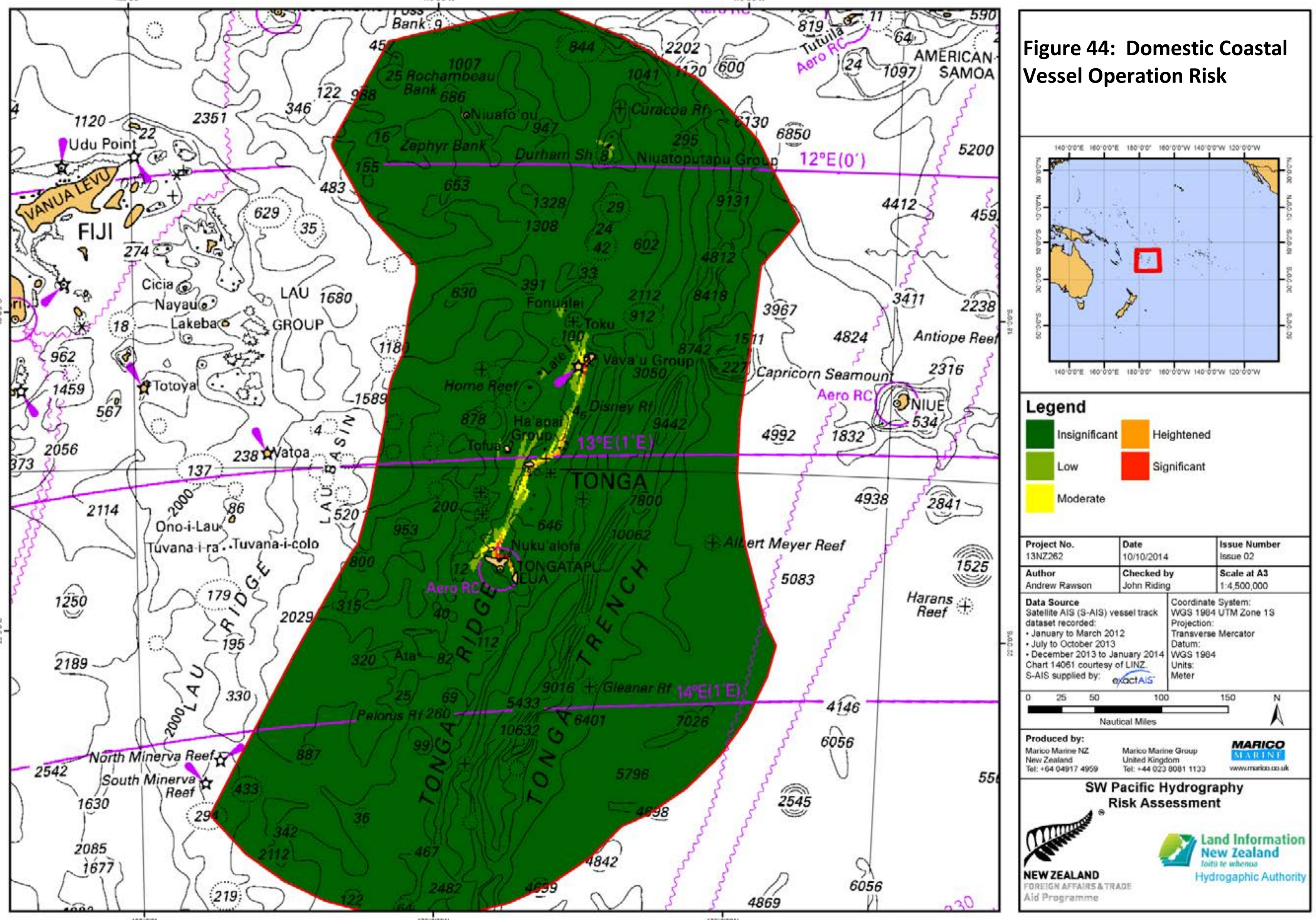

Figure 44: Domestic Coastal Vessel Operation Risk

Figure Reference: 13NZ262_Tonga_DomesticRisk_02

Annex E
Summary of Benefits of Charting and Hydrographic Services Upgrades of Tonga

Tonga				
Table of Benefits Associated with Charting and Hydrographic Services Upgrades				
Economic Analysis Sector	**No.**	**Status Quo**	**Benefits of Hydrographic Service Improvements**	**No Improvements to Hydrographic Services**
Port Infrastructure	1	Port of Nuku'alofa has an infrastructure plan to upgrade its container terminal in Queen Salote Wharf. This may take time as growth prospects are uncertain.	The improved charting standards already enjoyed by the Port of Nuku'alofa provide recognition that the port has remaining capacity in its approach channels for larger ships. Cargo and vessel operators understand their options better and plan efficiency gains. The port's development plan subsequently provides opportunity to develop as an efficient transhipment hub for cargoes to other South West Pacific island nations - Deployment of medium size container vessels becomes a possibility and cargo unit transport costs lower. Cheaper transport costs encourage growth of Tongan exporting companies. A Chart distribution service with ENC updates for ECDIS systems using Nuku'alofa is established as part of port infrastructure development. Income and employment benefits accrue.	Port maintenance and dredging discontinues and international shipping agencies withdraw from their service at Port of Nuku'alofa. There is no viable option to increase productivity as port movements decline. Transportation costs and port/customs charges increase disproportionately over time as traffic volume decays at the port. Unreliable charting is used less and less on domestic vessels; standards fall and ship casualties increase.
	2	The status of the Niuas harbour depths and status of AToNs is uncertain. Some harbours are of uncertain depth and experience rapid coral growth.	Clarity of approaches to the remote harbours of the Niuas reduces risk of grounding for domestic operations. Changing harbour infrastructure status information is circulated more rapidly. Further improvements to entrance channel capacity become more likely. The risk of grounding reduces.	The risk of grounding is heightened even with low vessel visit numbers and any resulting oil spill has disastrous consequences to the marine environment and the local economy. Uncertainty exists for the current depth data, and the regular ferry transiting the entrance of Niuatoputapu Harbour remains with little safety margin.

Tonga

Table of Benefits Associated with Charting and Hydrographic Services Upgrades

Economic Analysis Sector	No.	Status Quo	Benefits of Hydrographic Service Improvements	No Improvements to Hydrographic Services
	3	Charting in Vava'u has already improved, but updating of charts by chart corrections is limited. Neiafu Harbour (Vava'u) is an international port with deep water in sheltered surroundings. It has a schedule of monthly visits from containerships and LO/ROs. Small tankers deliver vehicle fuel and LPG.	Improvements in chart correction for Vava'u create confidence for Neiafu Harbour visitors. New development to accommodate larger size vessels, especially takers increasingly making a two port call in Tongan ports. Potential for other trade opportunities.	Charts are no longer updated and navigational safety becomes a meaningful issue. Neiafu Harbour loses its identity as an international port and solely depends on domestic shipping transportation. Liquid bulk freight volumes decrease and the oil terminal in Vava'u suspends its operations.
	4	Although there has been a clearance operation (blasting of coral formations) after the 2009 tsunami in the harbour entrance of Niuatoputapu by the NZ navy. Surveys are anticipated to show need for further channel deepening.	Dredging for domestic harbours is accurately identified as depth restrictions are accurately measured. Scoping and planning of ongoing hydrographic work improves. Safety benefits accrue to ensure vessels can access ports. Port infrastructure on Island groups other than Tongatapu has potential to grow. Local employment options improve in the long term and population declines reduce.	Deep draught vessels navigate in shallow waters with difficulty as manoeuvring is restricted. Safety and environmental concerns increase. Interisland freight distribution is deprived from ineffective port operations. Unwillingness to invest in an agile supply chain system due to poor port maintenance.

Tonga				
Table of Benefits Associated with Charting and Hydrographic Services Upgrades				
Economic Analysis Sector	**No.**	**Status Quo**	**Benefits of Hydrographic Service Improvements**	**No Improvements to Hydrographic Services**
	5	The majority of Aids to Navigation are either not marked or their status is incorrectly promulgated on charts, or by Notices to Mariners.	The status of leads and other Aids of Navigation (AToN's) improves as information flows for chart corrections from the improving Tongan Hydrographic committee. These are regularly added to charts. A working system with regular Notice to Mariners improves confidence of shipping interests in Tonga as a trading destination. Its location and the lowered risk as a destination lends support for development of a transhipment hub for cargoes from the South and West.	During cyclone season the majority of AToN's becomes defective and there is no proper maintenance. The probability of a grounding accident rises. The recent 'OTUANGA'OFA grounding in Niuatoputapu is a strong example. The accident occurred in the vicinity of an uncharted destroyed AToN.
International Cargo Shipping Sector	6	International trade to Tongan waters is presently focussed around the port of Nuku'alofa. With the exception in part of fuel transhipments, only occasional calls occur to Vava'u, which deliveries relying on transhipment.	Charting improvements allow shipping operators to reduce grounding risk of vessels on existing services. Options for discharge at other international port destinations in Tonga become viable, flexibility improves with potential for cost efficiencies from direct calls. Economic benefits of reducing freight costs influence an increase in cargo shipments in and out of Tonga overall.	No further charting improvements lead to higher risk of maritime accidents. There are no alternative trade routes for vessels on existing services in Tonga. It is difficult to achieve economies of scale. Freight rates remains high as the transportation costs increase for the South Pacific container services n Tonga.
	7	The Tongan hydrographic committee is established, but development progress has stalled.	Confidence in charting system sees navigational safety information flows improve from operators into the Tongan Hydrographic Committee.	The charting system becomes inefficient because it fails to respond to the maritime safety standards and hydrographic best practices.
Domestic Shipping Service and Training.	8	Charting remains unreliable.	Chart reorganisation produces charts of the right scale for domestic vessels on coastal voyages, and port approaches. Accurate depth and AtoN identification reduces risk of grounding. Areas of Tongan waters subject to visits by only domestic vessels begin to open up for trade.	In areas with inadequate charting, shipping companies deploy a fleet that is older, less efficient and capable, and more likely to be involved in a maritime accident due to the age of the equipment and calibre of the crew.

Tonga				
Table of Benefits Associated with Charting and Hydrographic Services Upgrades				
Economic Analysis Sector	**No.**	**Status Quo**	**Benefits of Hydrographic Service Improvements**	**No Improvements to Hydrographic Services**
	9	Demand for cargo transportation – Timber products in 'Eua Island - Farming products Vava'u.	Charting improvements facilitate growth of domestic trade to export ports (including airports). Fishing and farming produce.	Export and domestic trade remains static or declines. An aged fleet transports local products in order to cut additional costs.
	10	The Maritime Polytechnic College in Tongatapu has ceased its operation after losing recognition. Plans are being funded to re-establish the IMO recognised training facility for seafarers. Tongan crew members, presently qualified in other Schools at additional expense have been both sought after and valued by shipping employers.	Charting reorganisation provides efficient material for the training of navigating officers and ratings. Up to date charts show how corrections work; the Tongan Hydrographic Committee provides further material and navigational courses become interesting and relevant. The Maritime Polytechnic College in Tongatapu receives IMO approval to train and examine candidates for STCW certification. The pool for Tongan qualified seafarers both improves in quality as well as numbers. Growth in overseas income being repatriated to Tongan families.	There is no assurance on the training quality of the navigation officers and ratings with inaccurate and withdrawn charts. The Maritime Polytechnic College does not receive accreditation from IMO to conduct maritime training and examinations. A larger number of prospective cadets move overseas for their nautical studies.
	11	There are cases where fishing vessels and domestic ferries are not accepted for marine insurance.	Insurance interests have confidence in Tongan flag vessels with Tongan crews. Tongan crews are trained with better charting services as educational material and navigators are valued in the industry as employable seafarers.	Marine insurance companies become more reserved towards Tongan flag vessels and other IMO member states cease to recognise certificates awarded from an uncertified domestic maritime school.

Tonga				
Table of Benefits Associated with Charting and Hydrographic Services Upgrades				
Economic Analysis Sector	**No.**	**Status Quo**	**Benefits of Hydrographic Service Improvements**	**No Improvements to Hydrographic Services**
	12	Coastal navigation depends on captain's local knowledge rather than on nautical charts.	An ongoing improvement in awareness and confidence in navigational safety together with improvements in chart related practices, such as passage planning and positional monitoring, reduce risk of grounding and other marine accidents in Tongan waters. The standard of the domestic fleet improves as safety awareness grows and owners are influenced by their seafaring.	Charts do not serve as a preventive measure during an accidental oil spill because they are inaccurate. The same applies to emergency response or search and rescue operations in due course of grounding. Tonga has a total of 176 islands with plethora of corals and shallow depths that increases the accident risk.
Cruise Tourism	13	There is pressure from Cruise interests to achieve three port destinations in Tonga to make Island and Ha'apai group of Islands which will increase the cruise visits in Tonga.	The development of accurate and appropriate scale charts into the Northern Tongan Groups and isolated Islands results in increased cruise vessel penetration into the Ha'apai and Vava'u Groups, Niuas and isolated islands. Tonga as a cruise destination develops because port calls in addition to Nuku'alofa become viable. Increasing numbers of Passenger visits bring income into the local economy.	The cruise sector shrinks because nautical charts are not reliable. Cruise shipping operators are reluctant to send their vessels to remote or isolated islands. Cruise port calls decrease and economic development is unsuccessful. An example, MS World Discoverer struck an uncharted reef at Sandfy Passage, Solomon Islands. This depicts the urgent need for proper and reliable scale charts.
	14	Presently the Tongan visitor profile is relatively static, with a significant fall off of visitors to Ha'apai and Vava'u.	An increase in cruise passengers results in more electing to return to Tonga for longer holidays by air, increasing the demand for hotel and homestay accommodation. Tourist activity companies, such as diving and whale watching increase.	Currently, tourism contributes almost 12% of gross domestic product for Tonga and this figure drops for the following years to come. Cruise passenger capacity decreases as well as the holiday market rates. The international tourism revenues decline and unemployment rises.

Tonga				
Table of Benefits Associated with Charting and Hydrographic Services Upgrades				
Economic Analysis Sector	**No.**	**Status Quo**	**Benefits of Hydrographic Service Improvements**	**No Improvements to Hydrographic Services**
	15	The past two years (2012-2013), the GRT of cruise vessels visiting the Port of Nuku'alofa has increased. This may be a direct result of the Vuna wharf berthing facility.	Improved charting provides confidence for the increasing size of cruise vessels to visit Tongan destinations other than Nuku'alofa. Infrastructure and economic development is driven by a need to accommodate larger vessels and trade with an increasing passenger volume.	There is no return on investment from cruise vessels visits because the charts do not provide accurate and updated navigational danger information. Although aid donors provide substantial funding, this is not targeted and infrastructure projects are abandoned in long-terms prospects.
Tongan Hydrographic Committee	16	National Hydrographic Consultative Committee is present and IHO membership is secured. Committee exists, but has been inactive.	The existing Tongan hydrographic committee becomes more effective and Tongan interests are better represented in the work of the International Hydrographic Organisation (IHO). New options for further grant funding accrue.	The Tongan Hydrographic committee fails to follow the IHO standards as a result of lack of momentum.
	17	Although the Tongan Navy has hydrographic unit, this has not conducted surveys for some years and requires technical updating.	His Majesty's Armed Forces Navy has reason to improve its present hydrographic survey capabilities, with the Tongan Hydrographic Authority providing an ongoing recommended programme of work.	His Majesty's Armed Forces Navy hydrographic capability remains inactive, and updating and training cease. Capability decays and loses priority.
	18	Most charts for Tonga are in need of correction in some form.	The Tongan Hydrographic committee gains in importance create a flow of information about Aids to Navigation and chart changes, occurs to the Charting Authority, resulting in regular updating of charts. Confidence grows in the charting system in place for Tongan waters. The Tongan hydrographic committee information flows to the Charting Authority.	The Tongan Hydrographic Committee becomes an inefficient organization with high uncertainty in decision making.

Tonga				
Table of Benefits Associated with Charting and Hydrographic Services Upgrades				
Economic Analysis Sector	**No.**	**Status Quo**	**Benefits of Hydrographic Service Improvements**	**No Improvements to Hydrographic Services**
Chart and ENC Distribution Services	19	The distribution of new or replacement charts in Tonga is fragmented. Published ENCs difficult to obtain within Tonga.	An effective Chart distribution service with ENC updates for ECDIS/ECS systems using Tongan waters is established as part of port infrastructure development. Tongan agents are established outside of Nuku'alofa, in Ha'apai and Vava'u improving usage and promulgation to users. Improved charting extends into the recreational and visiting yacht markets. Employment and benefits accrue.	The fragmented replacement chart system in Tonga remains fragmented. Interest in charting by navigational stakeholders and usage declines.

Table 1 Summary of Benefits of Charting and Hydrographic Services Upgrades of Tonga

Annex F
Assumptions for Hydrographic Cost Benefit Methodology

Model Assumptions	Data Value Used	Detail
Survey Cost/km^2	US$500 – Singlebeam Hydrographic Survey	There are a wide range of Hydrographic Survey Costs worldwide, even for the same technology. An average value was used, based on the cost of the popular technology, Singlebeam Technology.
		Internet Derived Costs: Queensland Govt: Baythymetric LIDAR: $500-1000 per km^2 Single Beam at 50x50m resolution is $1500 per km^2 Canadian Hydrographic Service Bathymetric survey $1700 per sq km Marine Electronic Highway Working Group Multibeam survey - 120km2 (60 survey days) – request for US$1.2million (1mill for survey and processing and 200k for ENC production) - $10k/km^2 Fugro Norway survey in Offshore Magazine $4.95 million for 13,200 km2 – 375$ per km^2 (this record appears unlikely)
		Costs per Square km - Published by Hydrographic Office - SHOM – Laporte 26/9/2012 Based on 2011 values): Bathymetric Lidar: from 1,500 to 2,000€ - Greatly variable and depends on survey and quality of post-processing. MBES (Multibeam Echo Sounders) Survey: from 1,000 to 1,400 – Up to 10 times the figures in the worst cases Satellite Survey: from 25 to 45€ - Depends on the quality of product

Model Assumptions	Data Value Used	Detail
Risk Reduction	Charting Upgrade Risk Reduction: • ZOC A 2.5% • ZOC B 5% • ZOC C 10% • ZOC D 20% • ZOC U 30% • Fathom Chart 45% Probability of Grounding/nm is taken to be 5.98E-07 (DNV)	The Net Present Value is based on independent work that established that ECDIS, used with accurate and adequate ENC reduces grounding likelihood and improves situational awareness by about 36% overall (DNV 2008 – Technical Report – DNV Research & Innovation, ECDIS and ENC Coverage – Follow up study). A varying range of available risk reduction was developed (Charting Upgrade Risk Reduction), using the work by DNV as a benchmark. DNV undertook a study to determine a global probability, using shipping volume and Grounding Incident data. The study provided values of both Grounding Probability and available risk reduction from Charting Improvements. This probability is modified by a factor dependent upon the complexity of navigation from 0.00001 to 1.94. To calculate this conversion factor, the highest and lowest likelihood scores are used from the Marico risk model; DNV score = (0.9358*Marico)-1.3028
Base Inflation	2%	Based on the Asian Development Bank inflation rate for Tonga
A generic or representative SOLAS "ship"	700 TEU	Based on the size of a containership/general cargo vessel applicable to calling at Tongan waters
GDP of Tonga	US$ 815,286,000	Estimated 2013 value based on a 2.4% growth

Model Assumptions	Data Value Used	Detail
Average GDP Increase	2.4% per annum	Real GDP growth has averaged 2.4% per annum since 2006/2007
Most Likely and Worst Credible Relationship	For every 10 accidents, 9 are most likely and 1 is worst credible.	Calculation: Weight ML/WC – SUMPRODUCT (ML:WC,Weight1:Weight2). Average cost of grounding in range between most likely and worst credible outcomes: 80:20 weighting applied. This is a financial figure based on damage to vessel, value of preventing fatality, pollution clean-up etc
Commercial Vessel Accident Consequences – Clean Up cost and GDP Impacts	ML is 2277895 WC is 17964786	Benchmark clean-up costs $6900 per tonne for Oceania – SKEMA Consolidation Studies – 2010 - Evaluation of methods to estimate the consequence costs of an oil spill.
	ML is 1 day of GDP lost WC is 28 days of GDP lost	GDP Impact (blocking port channel).
Clean up costs Annual Rise	4%	Clean up coasts assumed to rise at twice the rate of inflation
Commercial Vessel Accident Consequences - Damage to People and loss of life	Damage to vessel	
	People damage (days lost/fatalities)	
Tongan Median Wage	US$82.4	
ICAF ()	US$ 3,282,000 (EU/HSE figures of 2.4 million Euros)	Implied Cost of Averting a Fatality (ICAF) is expressed in terms of $ per statistical fatality averted
Survey Benefit.	Calculation Policy	Surveys undertaken in Year 1 assumed to provide no benefit until Year 3

Table 2: Model Assumptions Used for ArcGIS Hydrographic Cost Benefit Methodology

CBA METHODOLOGY CALCULATIONS FOR COMMERCIAL (SOLAS) VESSELS	
Description	**Detail**
Distance for each grid	Calculate the distance travelled in each grid cell using the GME sumlinelengthspoly tool, and convert to nm
Period /Time	Scale up the distance from 7.5 months to a year (multiply by 1.6)
Probability per year	The probability per year is base probability * derived factor * distance travelled per year
Total Cost	Total cost is the Consequence of clean up added to the consequence of GDP
Cost Per Year	The cost per year is the probability per year multiplied by the cost per accident
The cost without a survey over 10 years	Year 1 is the cost/year
	Year 2 is cost/year *1.02 (inflation)
	Year 3 is Year 2*1.02
	Etc.
The cost with a survey over 10 years	Year 1 is cost/year
	Year 2 is cost/year*1.02
	Year 3 is Year 2*1.02* ZOC (Charting Upgrade by ZOC Category)
	Etc.
The delta (without survey vs survey)	Year 1 (No Hydro) – Year 1 (Hydro)
	Etc
Economic Benefit	Net Present Value function of the GIS model

Table 3: CBA Methodology Calculations for Commercial (Cargo/Tanker) Vessels

CBA METHODOLOGY CALCULATIONS FOR COMMERCIAL (DOMESTIC) VESSELS	
Description	**Detail**
Distance for each grid	Calculate the distance travelled in each grid cell using the GME sumlinelengthspoly tool, and convert to nm
Period /Time	Scale up the distance from 7.5 months to a year (multiply by 1.6)
Probability per year	The probability per year is base probability * derived factor * distance travelled per year
Total Cost	Total cost is the Consequence of clean up added to the consequence of GDP
Cost Per Year	The cost per year is the probability per year multiplied by the cost per accident
The cost without a survey over 10 years	Year 1 is the cost/year
	Year 2 is cost/year *1.02 (inflation)
	Year 3 is Year 2*1.02
	Etc.
The cost with a survey over 10 years	Year 1 is cost/year
	Year 2 is cost/year*1.02
	Year 3 is Year 2*1.02*ZOC (Charting Upgrade by ZOC Category)
	Etc.
The delta (without survey vs survey)	Year 1 (No Hydro) – Year 1 (Hydro)
	Etc
Economic Benefit	Net Present Value function

Table 4: CBA Methodology Calculations for Commercial (Domestic) Vessels

Annex G
Traffic Forecast – Transit Route Passage Plan

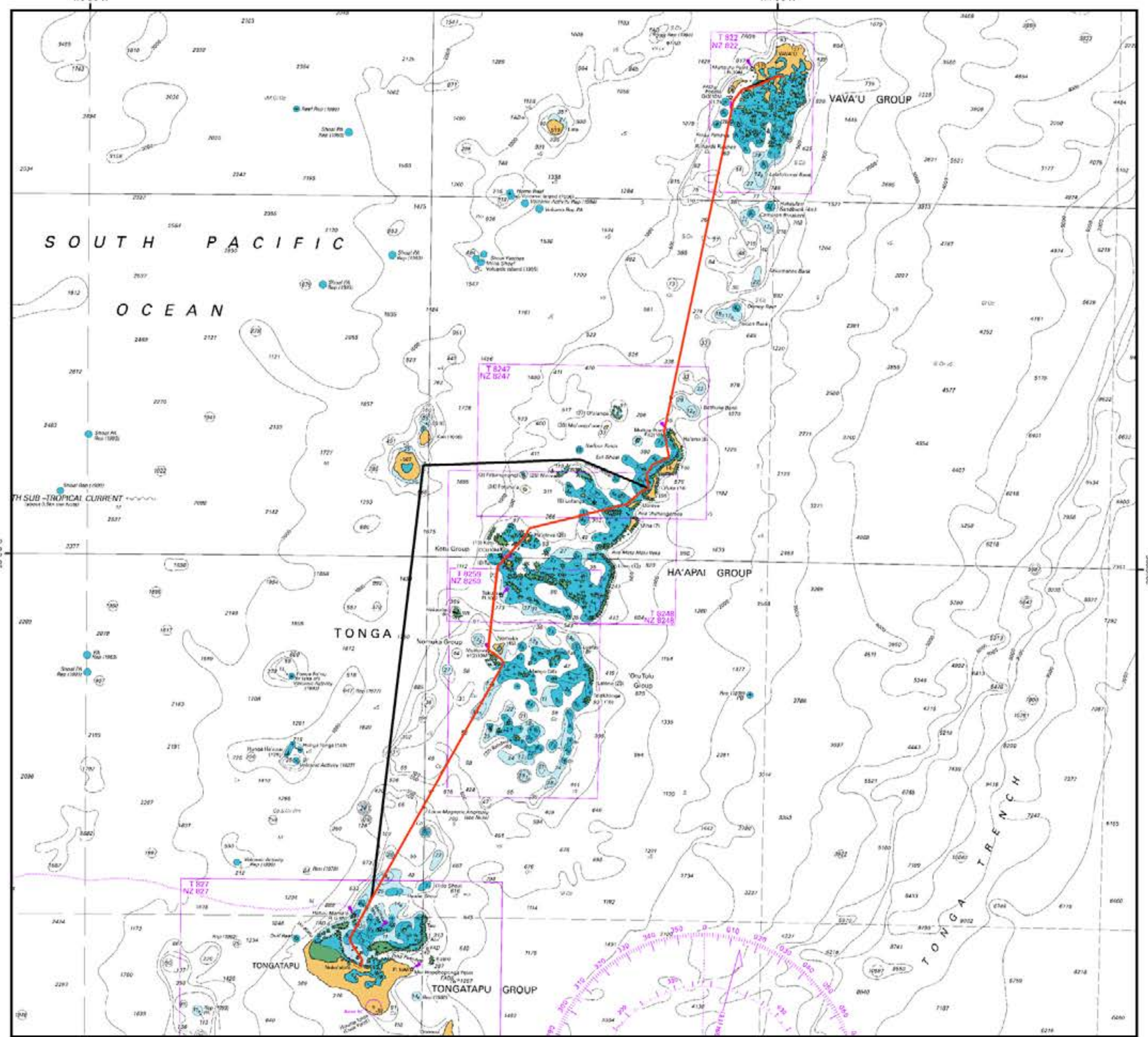

Figure 45: Cruise Vessel Route Passage Planning

Legend

- Route 1
- Route 2

Project No.	Date	Issue Number
13NZ262	24/09/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:1,127,986

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 5 10 20 30
Nautical Miles
N

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Figure Reference: 13NZ262_Tonga_AdditionalTracks_Step4_01

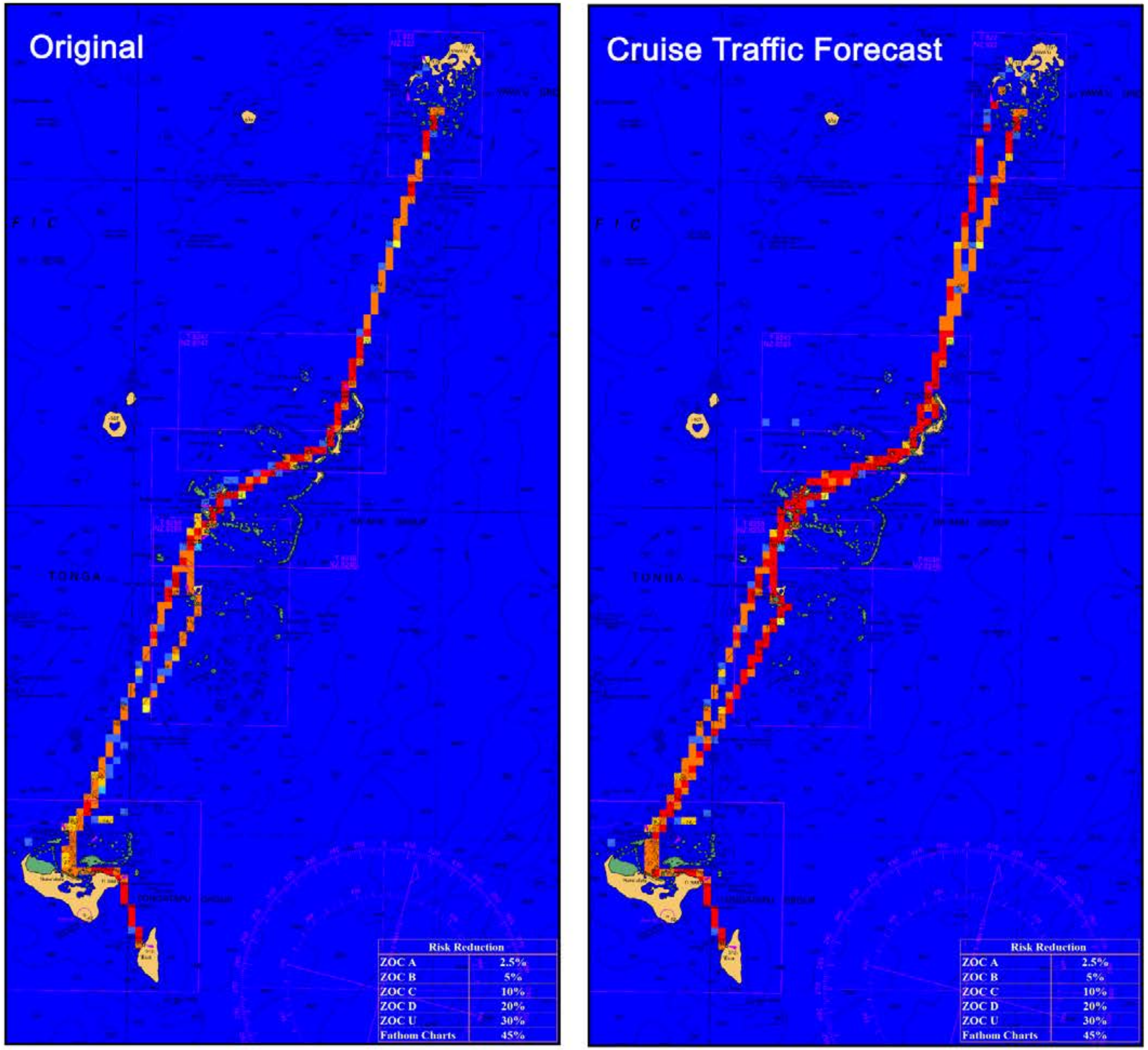

Figure 46: Comparison between Original and Forecast Cost Benefit Results

Legend (Net Present Value US$/10 Years)

- -10,000 - -1,000.0
- -999.9 - -100.0
- -99.9 - -10.0
- -9.9 - 0.0
- 0.1 - 10.0
- 10.1 - 100.0
- 100.1 - 1,000.0
- 1,000.1 - 10,000.0
- 10,000.1 - 100,000.0

Project No.	Date	Issue Number
13NZ262	30/09/2014	Issue 01
Author	**Checked by**	**Scale at A3**
Andrew Rawson	John Riding	1:1,263,864

Data Source
Satellite AIS (S-AIS) vessel track dataset recorded:
- January to March 2012
- July to October 2013
- December 2013 to January 2014

Chart 14061 courtesy of LINZ.
S-AIS supplied by: exactAIS

Coordinate System: WGS 1984 UTM Zone 1S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

0 5 10 20 30
Nautical Miles

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SW Pacific Hydrography Risk Assessment

NEW ZEALAND
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Land Information New Zealand
Toitū te whenua
Hydrogaphic Authority

Figure Reference: 13NZ262_Tonga_CostBenefit_Step4_03