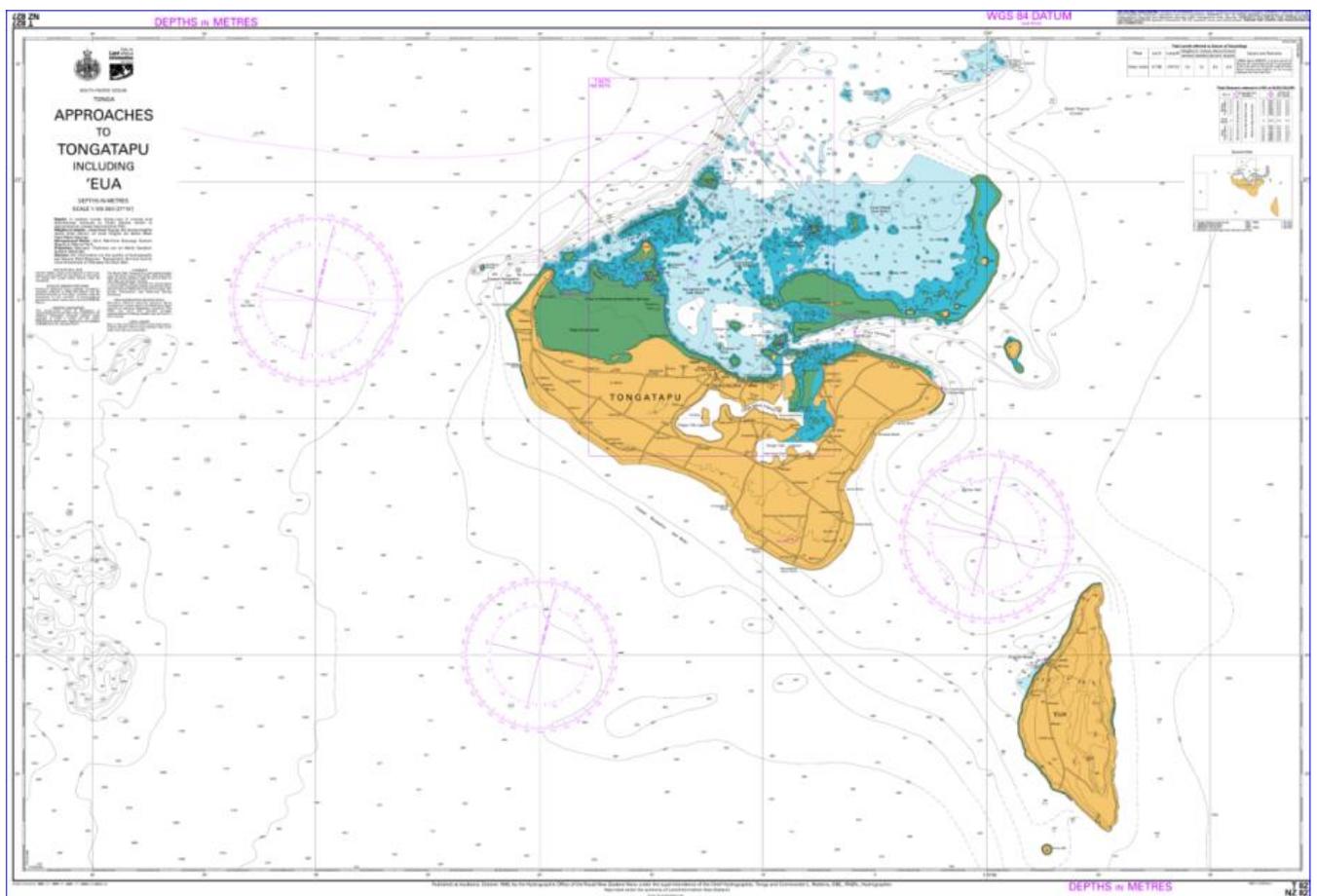


SOUTH-WEST PACIFIC REGIONAL HYDROGRAPHY PROGRAMME

TONGA RISK ASSESSMENT - REPORT SYNOPSIS



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SOUTH-WEST PACIFIC REGIONAL HYDROGRAPHY PROGRAMME

TONGA RISK ASSESSMENT - REPORT SYNOPSIS

Prepared for:	Land Information New Zealand
	Level 7, Radio New Zealand House 155 The Terrace PO Box 5501 Wellington 6145
Author(s):	John Riding / Gianis Priovolos / Andrew Rawson

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Marico Marine NZ Ltd
Level 11
156 Willis Street
Wellington
6011
New Zealand

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CONTENTS

1	INTRODUCTION	3
1.1	SCOPE	3
1.2	DATA SOURCES AND QUALITY	4
1.2.1	Cost Benefit Data.....	4
1.3	VESSEL TRAFFIC OVERVIEW	5
1.4	PORT TRAFFIC ANALYSIS	6
1.5	DOMESTIC COASTAL VESSELS	7
1.6	TRAFFIC FORECAST – HA’APAI	8
2	MAIN REPORT SECTIONS AND CONCLUSIONS.....	8
2.1	ECONOMIC CONCLUSIONS	9
2.2	SOLAS VESSEL TRAFFIC ANALYSIS	9
2.3	DOMESTIC COASTAL VESSELS	10
2.4	OFFICIAL NAUTICAL CHARTS	11
2.5	CONCLUSION BY REGION.....	11
2.6	SUMMARY RISK TABLE	13

FIGURES

Figure 1: Port of Nuku’alofa Traffic Profile.....	7
Figure 2: Prioritised Risk Model Result Summary for Kingdom of Tonga	14
Figure 3: Cost Benefit Results of Charting Improvements for the Kingdom of Tonga.....	14
Figure 4: Cruise Traffic Forecast for Ha’apai Waters, Compared with Original Result.....	14
Figure 5: Map of Kingdom of Tonga	14

Annex A Benefits of Charting Upgrades

1 INTRODUCTION

This hydrographic risk assessment allows the Tongan Government, with the support of regional charting authorities, to come to a conclusion about the nature and scope of chart improvement surveys in Tonga. It provides recommendations and conclusions to assist decision makers to prioritise hydrographic surveys in Tonga. These are based on the needs of contemporary shipping for the provision of accurate and adequate nautical charts.

The overall conclusion, based on evidence of economic growth, as well as vessel transit risk, is a need for improved charting in some areas of Tongan waters. The findings are supported on grounds of traffic risk and economic growth. The Cost Benefit Analysis (CBA) of the hydrographic survey provides analysis of the economic and safety advantages both for international and domestic coastal shipping in Tonga.

1.1 SCOPE

The hydrographic risk model identifies shipping routes at risk, in relation to traffic type, size and density as well as volume of passengers, against the consequence impact criteria. This study uses the same risk criteria as used in the Vanuatu hydrographic risk assessment, 2011. The model combines AIS datasets and non-AIS local trading routes, with navigational hazards and areas of cultural/environmental/economic value to produce a cumulative risk model. Potential environmental damage impacts feature strongly, such as the presence of corals or mangroves, turtle breeding grounds, culturally important areas and the Tongan reserve system of Special Management areas.

The Exclusive Economic Zone (EEZ) of Tonga was divided into cells of 20 kilometre squares in order to compare risk levels. For there to be hydrographic risk there must be a combination of traffic, likelihood criteria and consequence criteria. The traffic type, size and volume thus influences the risk levels in each cell associated with each of the criteria. Domestic coastal vessel trades and volumes were added as an overlay, by using Gross Tonnage (GT) as a measure of capacity on a route. The resulting risk matrix is shown in the main report. The risk result was followed by a simple Cost Benefit Analysis, which complements the risk result and confirms areas where charting upgrades provide risk and cost benefit. The CBA is based on costs of singlebeam hydrographic survey and the consequence impacts of ship groundings (including cruise).

The traffic analysis and risk model output are attached in full in the Annexes of the main report. The Cost Benefit Analysis result is presented in a spatial format within this synopsis (Figure 3).

A further task of traffic prediction was undertaken to explore the use of the waters of Ha'apai by cruise vessels. This was needed because cruise vessels only rarely visit these waters, which pose high inherent risk, because charting remains in Fathoms on an undetermined datum.

1.2 DATA SOURCES AND QUALITY

The risk approach is dependent on the quality of the input datasets. The satellite derived (S-AIS) data were augmented prior to use in the GIS modelling process. This was necessary because the S-AIS data are recorded at intervals when the satellite passes over the study area. The time period for Tonga is currently every 8 hours.

The Port of Nuku'alofa provided both digital copies of port records for international vessels calling at the port, together with detailed information on cargo figures and domestic vessel services. The datasets allowed an in-depth analysis of shipping trends, seasonality and size of vessels in comparison with freight volumes. Importantly, they were used to link S-AIS data to factual port calls. The identifiable vessels from port movements that were not in the AIS dataset could be manually routed-in, using known navigation patterns. The new database contained incorporated factual port data with S-AIS records.

Worldwide studies evaluating grounding incident rates and available risk reduction from charting improvements were used and referenced, to derive a best estimate of the cost effectiveness of charting upgrades in the different areas of Tongan waters.

1.2.1 Cost Benefit Data

For the Cost Benefit Analysis, hydrographic survey cost data as published by different sources was found to vary significantly. An average figure was used, with an additional task undertaken to test sensitivity by running the CBA model for different survey scenarios (the cost of single beam technology was used). The CBA methodology was developed around other work suggesting a maximum benefit of 36% reduction in Grounding accrues from charting upgrades (source: Det Norske Veritas). This work was developed further to link a variable risk reduction percentage, to

the ZOC¹ category (or chart quality). Table 1, below, shows the result of this development and the values used for the cost benefit work.

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 1 : CBA Risk Reduction Relationship to ZOC Category

The CBA work also makes an assumption that singlebeam technology is deployed for costing purposes. See Figure 3.

1.3 VESSEL TRAFFIC OVERVIEW

Dry cargo ships and domestic ferries provide by far the greatest transit numbers in Tongan waters. Their contribution to the transit risk is significant. However, cruise vessels are also increasing in number and some cruise interests are lobbying for a third port of call in the Kingdom of Tonga to improve viability for the 1-2 week cruise market.

The Port of Nuku’alofa is capable of becoming a key node, not only for the Tongan archipelago but also for international dry shipping trades. The North East Asian-Pacific and the Oceania-Pacific trade routes use this port. It is the major port in Tonga and capable of berthing the largest cruise vessels at a dedicated facility. The small ferry to ‘Eua, ‘ONEMATO, carries almost 35,000 passengers a year, making this by far the busiest route in Tonga. This means that the route to ‘Eua carries significantly more people than all the passenger routes to the northern islands of Tonga and an equivalent of 33% of the 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

¹ The ZOC category (Zone Of Confidence) is a charting standard based on depth accuracy and survey seafloor coverage. Technically, it is an MQUAL attribute available to the user to advise of charting standard.

'OTUANGA'OFA). Risk is also influenced by large vessels transiting through Tongan waters, south of Tongatapu Group.

The Ha'apai Group is centrally located between Tongatapu and Vava'u Groups. Pangai Harbour traffic volume and risk is dominated by the domestic ferry, 'OTUANGA'OFA. With official charts still published in fathoms, few SOLAS vessels access the Ha'apai Group. However, small cruise vessels are accessing both Foa and Tofua already. There is confirmed demand from cruise industry stakeholders to access these waters to improve cruise destination options, including a cruise vessel having a summer base at the Port of Auckland.

Neiafu Harbour is the second largest port in Tonga and provides a sheltered harbour with adequate water for large vessels to access. There are regular coastal domestic vessel visits, with SOLAS dry cargo and bulk liquid trades and occasional visits by large cruise vessels. A large number of international yachts also visit Vava'u. A significant number of vessels transiting through Tongan waters are large and pass these waters between the Niuas and Vava'u Group.

1.4 PORT TRAFFIC ANALYSIS

Overall, vessel visits at the Port of Nuku'alofa are gradually decreasing over time based on port movement records, Figure 1. However, efficiency gains are apparent showing more cargo carried by the reducing port calls. This is evident for both container and liquid bulk vessels. An important factor is recent port developments, which include a new cruise wharf and a container handling area upgrade allowing container stowage (concrete paving).

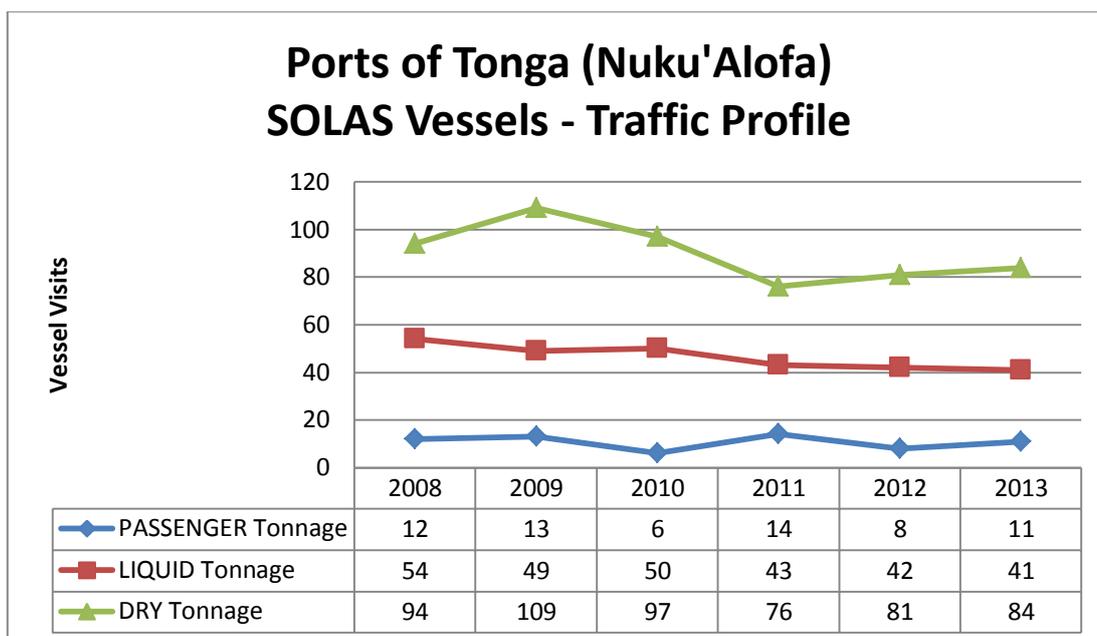


Figure 1: Port of Nuku’alofa Traffic Profile

Development of the Cruise sector has significant potential for Tonga, with one operator considering an 8 day Tongan cruise itinerary using a vessel with its home port being Auckland for the season. Vessels of 90,000 gross tons (GT) have already visited and size is increasing, evidenced by average tonnage of 42,000 GT, for 2013, to 50,000 GT for 2014 (projected in part).

1.5 DOMESTIC COASTAL VESSELS

Inter-island domestic coastal shipping is the economic lifeline of Tonga. Domestic registered vessels tranship export goods from the outer islands to the Port of Nuku’alofa. Similarly, a large volume of imported goods are transported from Tongatapu to the other island groups.

There are two main inter-island routes, Nuku’alofa to the central and northern Islands and Nuku’alofa to ‘Eua Island. Both routes have scheduled services on a weekly and daily basis, respectively. Chartered services occur, but are less frequent, usually during public holiday and religious celebrations. The two dedicated coastal ferries carry more than 90% of the total passenger trips in Tongan waters².

² The new ferry funded by Japanese aid had a dramatic effect on the efficiency of Tongan shipping, transporting cargo and passengers that a fleet of five domestic vessels previously carried.

The Vava'u and Ha'apai Group have good service links for cargo, measured by the overall GT capacity scheduled on the route. In terms of passengers, the Nuku'alofa – 'Eua route is carrying the largest volume, equivalent to 33% of the Tongan population annually.

Data gathering determined that fuel (e.g. for electricity generation by Tonga Power) was regularly being transported in the bunker tanks of domestic coastal vessels (in addition to cargo in drums). To reflect this, a track of an equivalent bulk oil vessel was added into the risk model. It was also determined that the ferry, 'OTUANGA'OFA is granted a passenger licence for 600 people in the summer months³, to meet passenger demand for both religious and/or family oriented events (e.g. Christmas). This 200 passenger increase was included in the risk model by adding in a weekly track of an equivalent ferry, with a 200 passenger capacity⁴, between Tongatapu, Ha'apai and Vava'u.

1.6 TRAFFIC FORECAST – HA'APAI

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 traffic forecast addressed this by applying vessel tracks of a representative cruise vessel to destinations in Ha'apai. This was validated with input provided by a major cruise stakeholder, which involved an 8 day Tongan cruise based out of Auckland.

The traffic forecasting showed that the addition of a seasonally-weekly cruise vessel transit through Ha'apai waters increased risk marginally, but has a dramatic effect on cost benefit (Figure 4).

2 MAIN REPORT SECTIONS AND CONCLUSIONS

The risk assessment results are shown pictorially in Section 7 of the main report. Section 8 presents the CBA work, establishing the cost effectiveness of charting upgrades throughout Tongan waters. Section 9 reports the traffic forecasting for Ha'apai waters. Key conclusions from the main report are presented below, followed by risk and CBA summaries. **Annex A** presents a summary of benefits of charting improvements and the potential downside of not upgrading charts.

³ 'OTUANGA'OFA has a normal passenger capacity of 400 persons.

⁴ These modifications were needed to accurately reflect hydrographic risk

2.1 ECONOMIC CONCLUSIONS

1. The Cost Benefit Analysis (CBA) for Tonga (Figure 3) is based on singlebeam survey costs. The CBA result is sensitive to survey cost. However, when plotted against a range of such costs by survey type, Tonga still produces a net positive cost benefit result in areas of heightened risk.
2. The CBA result complements the risk result and highlights areas where charts are cost effective to improve. An interesting conclusion in Tongatapu is the need to consider increasing the charted extents covered by the ZOC A category. Given that the ferry transit into Nukualofa does not follow the main channel, instead it routes through ZOC D category waters, this is cost effective.
3. The addition of a seasonal-weekly cruise vessel transit through Ha'apai waters shows a dramatic positive increase in cost effectiveness for the case to modernise charting throughout Ha'apai Group (Figure 4).
4. Cargo export volumes out of Tonga remain approximately constant overall.
5. 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.
6. 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.
7. 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.

2.2 SOLAS VESSEL TRAFFIC ANALYSIS

8. 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 transshipment hub" for the area if the trend can be maintained.
9. SOLAS multipurpose vessels visit 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.

10. 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.
11. 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.
12. The number of 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 is apparent. There will be some fuel consumption savings realised from newly installed solar power facilities.
13. A liquid bulk vessel discharges oil fuel at Vava'u, Tongatapu, and 'Eua. For the transit between 'Eua and Nuku'alofa, the ship navigates the Piha Passage, which has adjacent navigational hazards and marine reserves. A review of charting is supported by risk and has cost benefit.
14. The arrangements for tanker discharge and the shore cargo connections at 'Eua Island would benefit from review, as present arrangements comprise discharge via a single skin pipe and manifold in the surf, on an exposed shoreline. A review of charting scale could be beneficial.
15. Forecasting shows that an increase in SOLAS vessel traffic through Ha'apai (Cruise Vessels) produces a risk result having a much wider area of heightened risk, as well as positive cost benefit for charting upgrades.

2.3 DOMESTIC COASTAL VESSELS

16. 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 and cargo in recent years. An equivalent of 33% of the total population of Tonga travels to or from 'Eua each year. The size and design of 'ONEMATO is relevant to this.

17. 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. Yet 'ONEMATO is much smaller than others working in Tonga, including the interisland ferry 'OTUANGA'OFA.
18. 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.

2.4 OFFICIAL NAUTICAL CHARTS

19. The risk assessment has determined areas where the accuracy and adequacy of charting should be reviewed against modern standards to meet the needs of contemporary shipping.
20. 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/ENCs and are therefore excluded from operating in this island group.

2.5 CONCLUSION BY REGION

21. **Vava'u** presents significant risk in two important locations. These are Vava'u Island (including Neiafu Harbour and approaches) and the sea area South of Kapa Island. Two further areas also produce a heightened risk result: the sea area between 'Euakafa Island; Richard Patches and the passage between Fofoa and Ovaka Island. An underlying risk influence is 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. A liquid bulk terminal is located in Neiafu Harbour.
22. The ferry 'OTUANGA'OFA transits through the sea area between Kapa Islands and Richard Patches (where there is a significant and heightened risk result). Track records show this is through an area where charts report an inadequately surveyed area, which explains the risk result. The CBA analysis also reflects this.
23. In **Ha'apai**, Ha'ano, Foa Lifuka Island presents an area of heightened risk. This risk is influenced by regular domestic vessel transits in waters adjacent to coral and turtle breeding sites. The risk profile extends southwards to Pangai Harbour, Lifuka Island, 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 and the CBA results.
24. It is clear that an increase in traffic levels through Ha'apai, or even access by large cruise vessels, produces risk results with widespread heightened risk. The change in cost effectiveness of charting upgrade is dramatic, because of the available risk reduction to cruise operations (Figure 4 shows a comparison between the original and forecasting results).
 25. In **Tongatapu**, the Port of Nuku'alofa and its approaches shows 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.
 26. The Piha Passage and the coastal transit to 'Eua 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 strong currents and is 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.
 27. 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. In summary, the equivalent of 33% of the Tongan population transits this route annually.
 28. The above review 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.
 29. 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 the 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 would have 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.

30. This is an inherent risk, not measured directly by the hydrographic risk methodology, which uses traffic volume as a basis for risk increment. The high consequence of ferry loss suggests risk benefit would occur from a review of small harbour capacity against the larger ferry now in service. There are cases where consequence impacts would be such that risk mitigation action should still be considered.

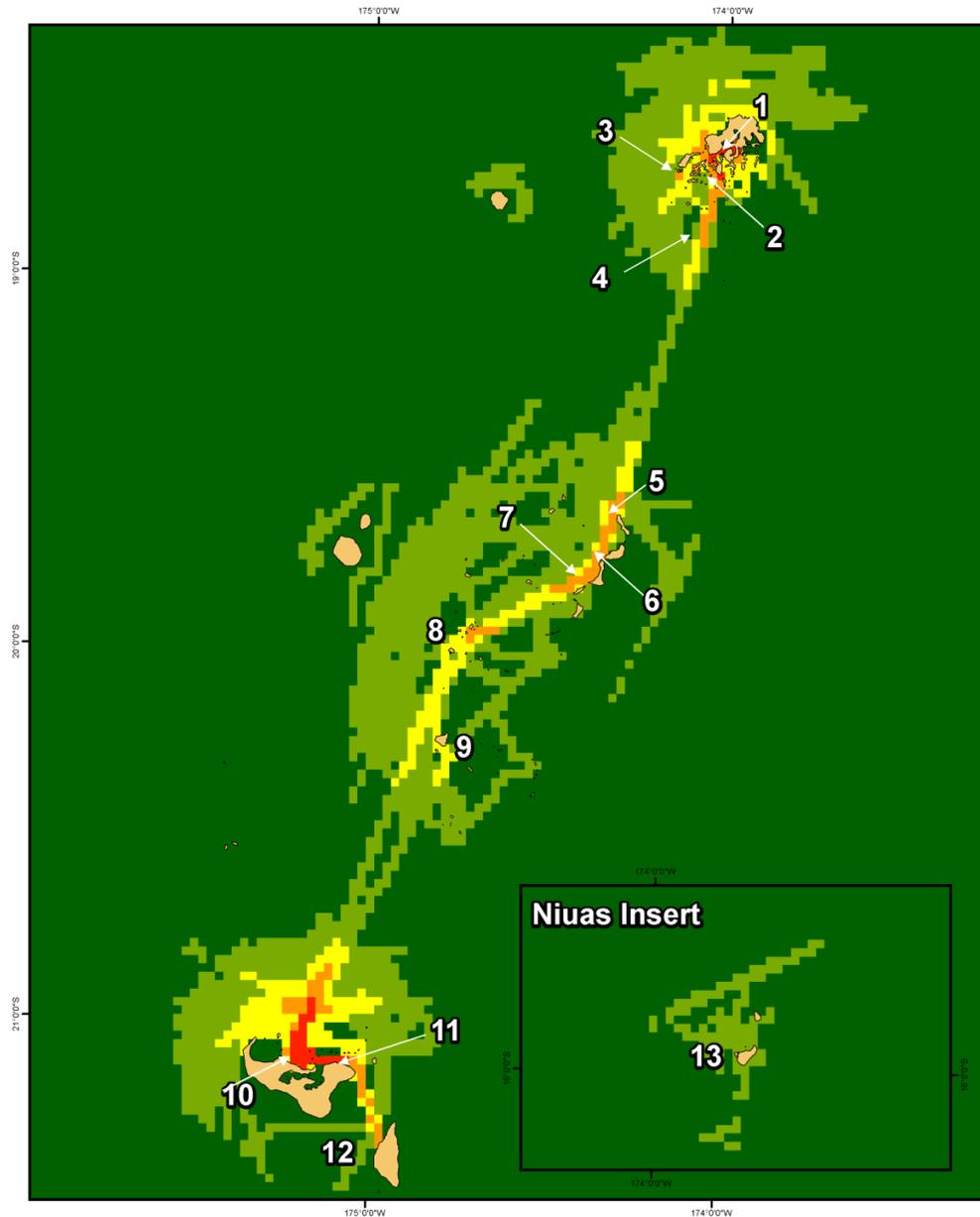
2.6 SUMMARY RISK TABLE

The following tables and risk model mapping provide an overview of the results of the comparative hydrographic risk assessment for the Tongan archipelago. Table 2 presents a high level risk summary, which must be interpreted with care alongside the Cost Benefit result.

KINGDOM OF TONGA Priority Areas for Safety Improvements (Based on Comparative Risk Level)		
Island Group	Area	Comparative Risk Level
TONGATAPU	Nuku'alofa Harbour and approaches.	Significant
TONGATAPU	Piha Passage and coastal transit to 'Eua.	Significant
VAVA'U	Vava'u Island and Neiafu Harbour.	Significant
VAVA'U	Sea area South of Kapa Island.	Significant
HA'APAI	Lifuka Island and Pangai Harbour.	Heightened
HA'APAI	Ha'afeva Island.	Heightened
HA'APAI	Ha'ano Island.	Heightened
HA'APAI	Foa Island.	Heightened
VAVA'U	Passage between Fofoa Island and Ovaka Island.	Heightened
VAVA'U	Sea area between 'Euakafa Island and Richards Patches.	Heightened
'EUA	Nafanua Harbour.	Heightened
HA'APAI	Nomuka Island.	Moderate
NIUAS	Niutoputapu Harbour Entrance (important Inherent Risk).	Low

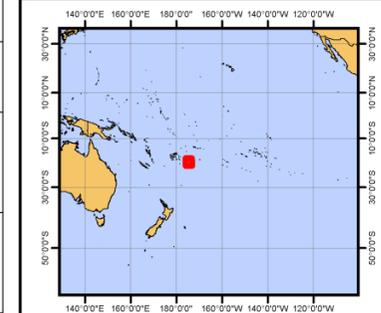
Table 2: Overall Comparative Risk Summary

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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	Niutopotapu Harbour Entrance

Figure 2: Prioritised Risk Model Result Summary for Kingdom of Tonga



Legend

 Insignificant	 Heightened
 Low	 Significant
 Moderate	

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Author Andrew Rawson	Checked by John Riding	Scale at A3 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:		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:
 Marico Marine NZ
 New Zealand
 Tel: +64 04917 4959
 Marico Marine Group
 United Kingdom
 Tel: +44 023 9081 1133

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SW Pacific Hydrography Risk Assessment

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Land Information New Zealand
Toitū te whenua
Hydrographic Authority

Figure Reference: 13NZ262_Tonga_RiskModel16_01

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Area by Region (N to S)		Comparative Risk Level			Comments
		Moderate	Heightened	Significant	
VAVA'U					
1	Vava'u Island and Neiafu Harbour.			✓	<ul style="list-style-type: none"> • High potential for loss of life and pollution (both domestic ferry and cruise tourism). • Relatively narrow passage into the inner harbour (Neifu) Harbour. • Proximity to a number of sites of environmental importance including coral, breeding grounds and important Special Management Areas. • High density of yacht tourism (planned stop-over for up to one month). • Pristine diving attractions and whale watching. • Moderate volume of traffic including large SOLAS vessels and small coastal traders. • Increasing tanker traffic (laden) part discharging at Utulangivaka fuel terminal (inner harbour) at Toula. • Aquaculture - Cultivated Pearl Farming (Fisheries Department development plans to licence) • Newly established Special Management Areas (SMA)/Fish Habitat Reserves (FHR), Fisheries Management Act 2002.
2	Sea area South of Kapa Island.		✓	✓	<ul style="list-style-type: none"> • Small area of Significant risk south of Kapa Island • Proximity to corals and turtle breeding grounds. • Domestic ferry transit along a narrow surveyed corridor. • Large volume of scattered coral reefs and wetland resources (low lying islets). • Uncharted hazards. • High density of yachts. • Newly established SMAs and FHR under Fisheries Management Act 2002.
3	Passage between Fofoa Island and Ovaka Island.	✓	✓		<ul style="list-style-type: none"> • Isolated heightened risk due Special Management Areas (SMA) at Fofoa and Ovaka Islands. • Moderate volume of traffic including large SOLAS vessels and small coastal traders. • Tanker (liquid bulk) traffic.
4	Sea area between 'Euakafa Island and Richards Patches.		✓		<ul style="list-style-type: none"> • Proximity to corals and turtle breeding grounds. • Domestic ferry and cargo vessel transit along a narrow corridor close to a state inadequately surveyed area. • Large volume of scattered coral reefs and wetland resources (low lying islets). • Uncharted hazards. • Newly established SMAs and FHR under Fisheries Management Act 2002. • Potential 5 star tourist development (lease taken) within established SMA.

Area by Region (N to S)		Comparative Risk Level			Comments
		Moderate	Heightened	Significant	
HA'APAI					
	Ha'apai Overall.				<ul style="list-style-type: none"> Charts NZ 8235, 8247, 8248, 8259, 8266, (surveyed 1898, fathom charts), non metric, undetermined datum. Incompatible with ENCs. Likely future destination for large cruise vessels (presently small cruise destination). Fragile tourist economy.
5	Ha'ano Island.	✓	✓		<ul style="list-style-type: none"> The coastal area East of Ha'ano Island presents heightened risk, surrounded by moderate risk. Vessels (domestic) navigating close inshore with a number of breaking reefs and tidal hazards. Area of dense coral and turtle breeding.
6	Foa Island.		✓		<ul style="list-style-type: none"> Cruise vessels visiting tourist resorts annually, with plans for expansion. Important turtle breeding grounds with considerable wetland resources and corals.
7	Lifuka Island and Pangai Harbour.		✓		<ul style="list-style-type: none"> Shipping lane with moderate density of domestic coastal and small SOLAS vessels. Port of moderate economic value. Vessels navigating close to the shore with breaking reefs and non-functioning AtoNs.
8	Ha'afeva Island.	✓	✓		<ul style="list-style-type: none"> Moderate density of domestic coastal vessel traffic and yachts. Special Management Areas (SMA)/Fish Habitat Reserves (FHR) under Fisheries Management Act 2002. Proximity to pristine corals and breeding grounds.
9	Nomuka Island.	✓			<ul style="list-style-type: none"> Proximity to environmental significant areas, corals and turtle breeding grounds. Moderate density of domestic coastal vessel traffic and yachts. Special Management Areas (SMA)/Fish Habitat Reserves (FHR) under Fisheries Management Act 2002.
TONGATAPU					
10	Nuku'alofa Harbour and approaches.			✓	<ul style="list-style-type: none"> High potential for loss of life and pollution. Density of marine traffic approaching the largest port in Tonga, both international and domestic. Proximity to corals and wetlands, important turtle breeding grounds and SMAs. Port of high economic value and a top cruise destination for Tonga. Proximity to uncharted wrecks. Proximity to unreliable offshore AtoNs.

Area by Region (N to S)		Comparative Risk Level			Comments
		Moderate	Heightened	Significant	
11	Piha Passage and coastal transit to 'Eua.		✓	✓	<ul style="list-style-type: none"> Significant tidal streams and narrow passage (irregular, max 4 knots). Domestic ferry route with annual passenger traffic equal to about 33% of the population of Tonga. Proximity to shallow depths and breaking reefs. Proximity to wetlands, especially mangroves and significant cultural sites. Area of coral growth and tourist resorts.
EUA					
12	Nafanua Harbour.		✓		<ul style="list-style-type: none"> High potential for loss of life and pollution. Density of domestic coastal vessels on a daily basis (domestic produce and high volume of timber). Domestic ferry route with annual passenger traffic about equal to the population of Tonga. Whale watching, diving and coastal homestays. Tanker movements discharging into a manifold in surf. Exposed shoreline.

Area by Region (N to S)		Comparative Risk Level			Comments
		Low	Moderate	Heightened	
NIUAS					
13	Niuatoputapu Harbour Entrance.	✓			<ul style="list-style-type: none"> Inherent risk from ferry grounding/loss, involving significant consequence to Tongan domestic coastal trade. Narrow and shallow entrance into Niuatoputapu harbour with rapid coral growth. Difficult entrance to approach and negotiate (cross swell from sea conditions 3)). Domestic ferry has limited underkeel clearance in the entrance, to Pasivulangi Wharf. Entrance affected by 2009 Tsunami.

Table 3: Comparative Hydrographic Risk Level by Region for the Kingdom of Tonga

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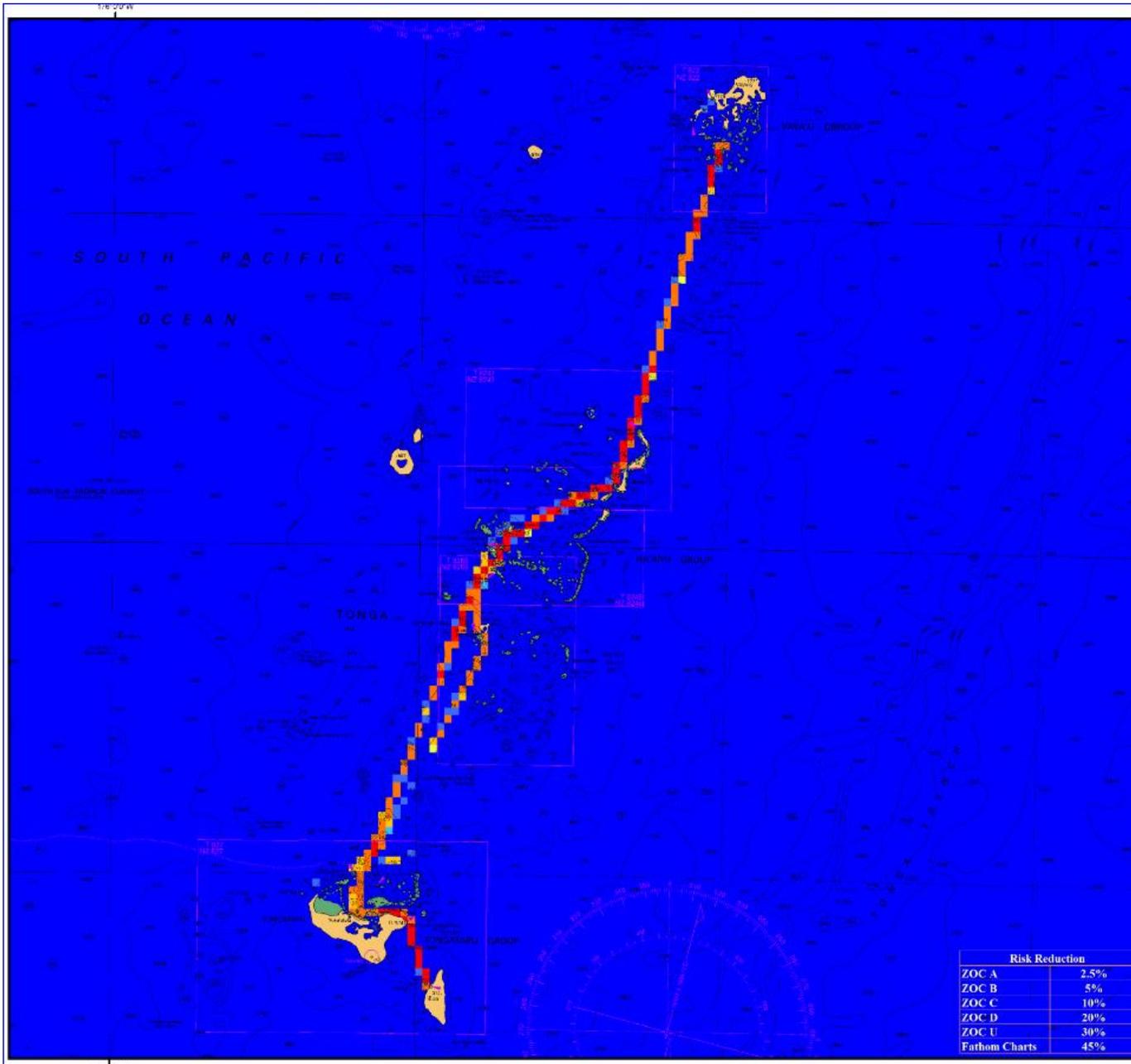
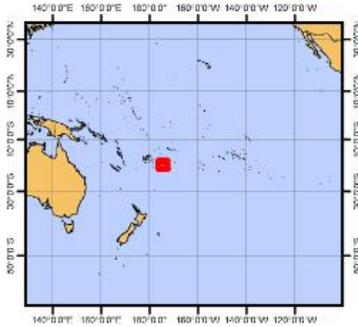
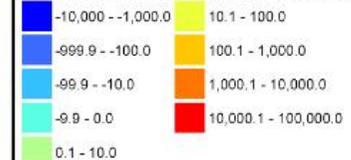


Figure 3: Cost Benefit Results of Charting Improvements for the Kingdom of Tonga.



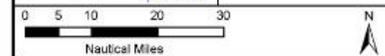
Legend (Net Present Value US\$/10 Years)



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Author Andrew Rawson	Checked by John Riding	Scale at A3 1:1,250,649
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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:	Coordinate System: WGS 1984 UTM Zone 1S Projection: Transverse Mercator Datum: WGS 1984 Units: Meter
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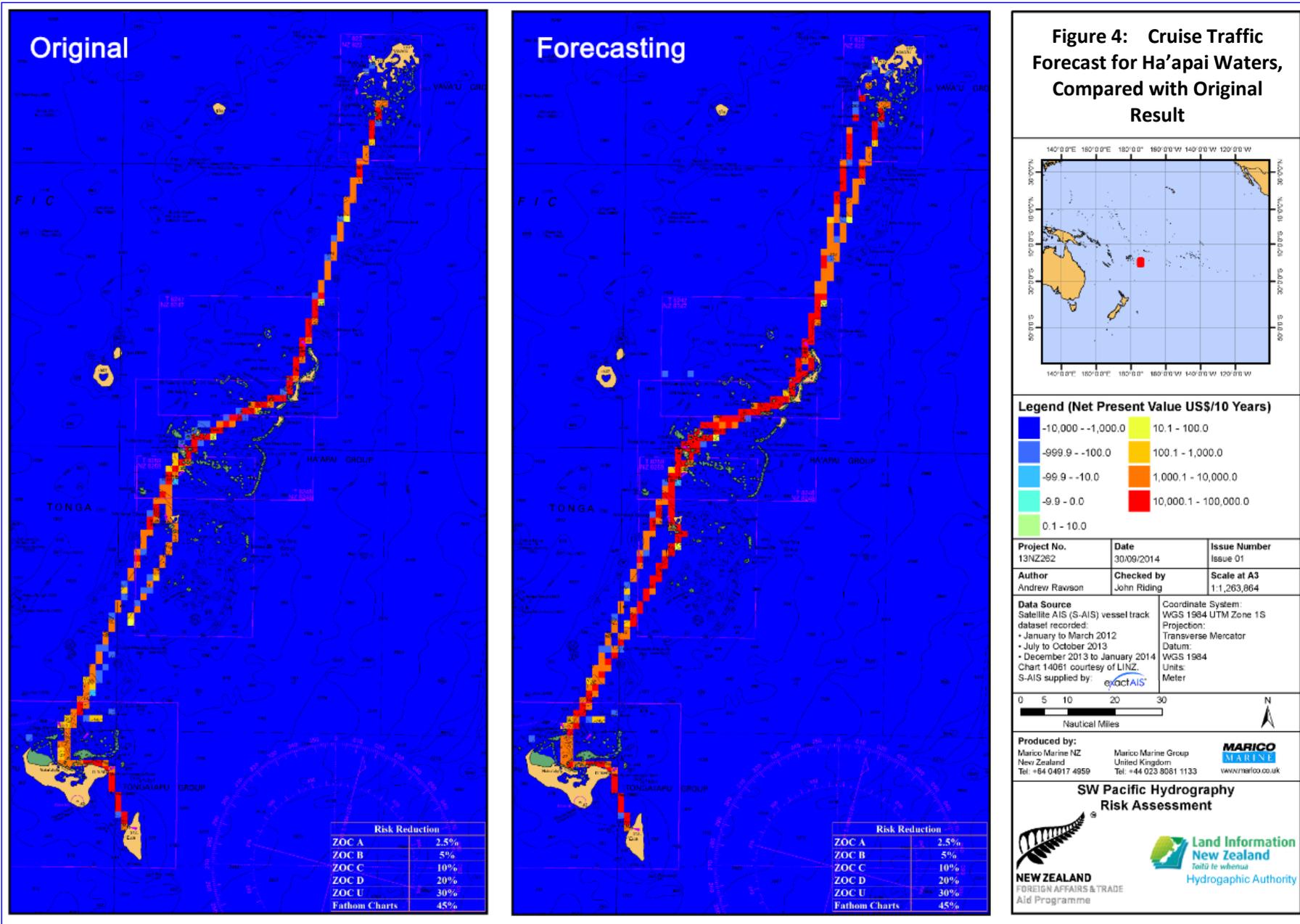
Produced by: Marico Marine NZ New Zealand Tel: +64 04917 4959	Marico Marine Group United Kingdom Tel: +44 023 9081 1133	 www.marico.co.uk
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SW Pacific Hydrography Risk Assessment



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

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Annex A

Benefits of Charting Upgrades

Benefits of Hydrographic Surveys for the Kingdom of Tonga

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 ENC's 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 market⁵. 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) standards⁶ 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.

⁵ In 2014, New Zealanders are expected to represent approximately 20% of the cruise market after a period of significant growth.

⁶ IHO S-44 Standards for Hydrographic Survey

- 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 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. 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 waters⁷. Should a member state not fulfil this obligation, insurers have the option to decline cover, or charge an additional risk premium, to vessels wishing to navigate its coastal waters, including ports.

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. 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' nature⁸, hydrographic survey data delivers a wide range of additional benefits to maritime stakeholders.

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 below in the table within this Annex. 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.

⁷ Regulation 9 of SOLAS Chapter 5

⁸ 'Public good' are services in the public interest which would not be supplied at optimal levels by market forces alone

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.	<p>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 transshipment 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.</p> <p>Cheaper transport costs encourage growth of Tongan exporting companies.</p> <p>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.</p>	<p>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.</p> <p>Transportation costs and port/customs charges increase disproportionately over time as traffic volume decays at the port.</p> <p>Unreliable charting is used less and less on domestic vessels; standards fall and ship casualties increase.</p>
	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.	<p>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.</p> <p>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 transshipment hub for cargoes from the South and West.</p>	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 Niuaotupapu 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 transshipments, only occasional calls occur to Vava'u, which deliveries relying on transshipment.	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.	<p>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.</p> <p>The standard of the domestic fleet improves as safety awareness grows and owners are influenced by their seafaring.</p>	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, Niua 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.	<p>Improved charting provides confidence for the increasing size of cruise vessels to visit Tongan destinations other than Nuku'alofa.</p> <p>Infrastructure and economic development is driven by a need to accommodate larger vessels and trade with an increasing passenger volume.</p>	<p>There is no return on investment from cruise vessels visits because the charts do not provide accurate and updated navigational danger information.</p> <p>Although aid donors provide substantial funding, this is not targeted and infrastructure projects are abandoned in long-terms prospects.</p>
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.	<p>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.</p> <p>The Tongan hydrographic committee information flows to the Charting Authority.</p>	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 ENC's 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 4 – Benefits of Charting Upgrades