NEW ZEALAND
MINISTRY OF FOREIGN AFFAIRS & TRADE
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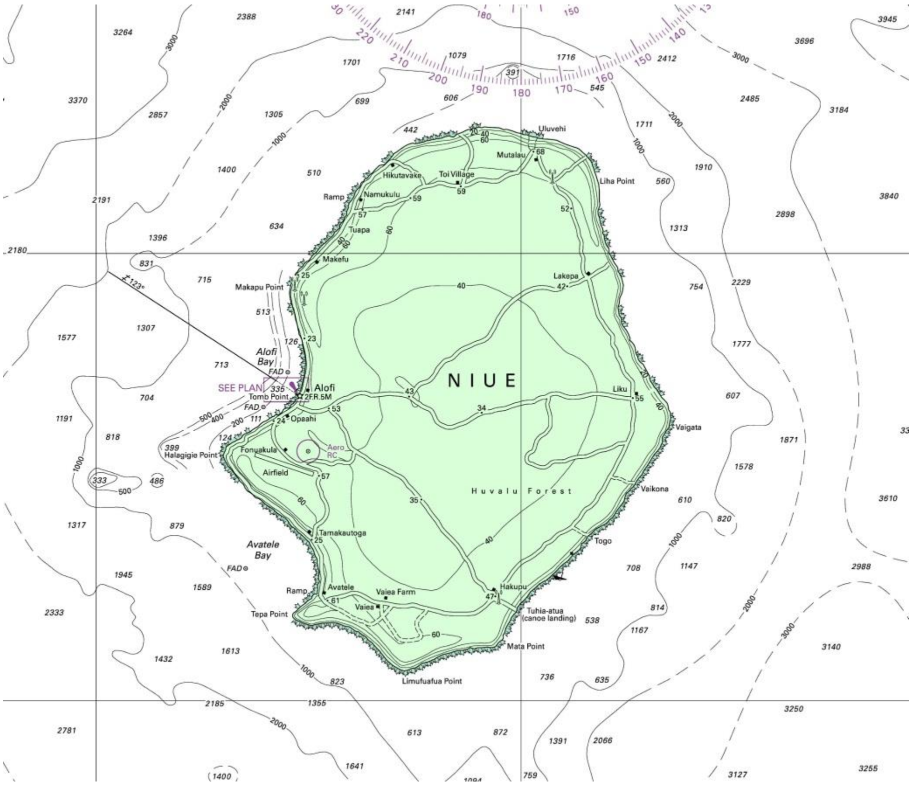
Hydrographic Authority

PACIFIC REGIONAL NAVIGATION INITIATIVE

NIUE Hydrographic Risk Assessment



Report Number: RNALZ16002

Version: 1.0

Date: 31 July 2016

Supported by the New Zealand Aid Programme

PACIFIC REGIONAL NAVIGATION INITIATIVE

NIUE Hydrographic Risk Assessment

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Satellite AIS data under licence from exactEarth

FOREWORD

This report details the hydrographic risk assessment of Niuean waters based on the Land Information New Zealand (LINZ) Hydrographic Risk Assessment Methodology as published in Report Number 15NZ322 Issue 03[1]. This risk assessment is part of the continuing programme of Pacific regional hydrographic risk assessments being conducted by LINZ, supported by the Ministry of Foreign Affairs and Trade (MFAT), which is intended to cover the extent of New Zealand's area of charting responsibility. This assessment follows other published risk assessments of Vanuatu, the Cook Islands and Tonga which are available from the International Hydrographic Organization website at this link.

The intent is that these assessments, conducted using the same methodology, is to provide participating Governments with consistent and comparable information that will assist them and other supporting aid agencies, to make informed decisions in relation to investment in hydrographic work to provide economic benefit and improve safety of navigation.

ACKNOWLEDGEMENTS

A number of Niuean Government officials and citizens provided invaluable advice and information to support this risk assessment. Particular thanks go to Andre Siohane, Director General of the Ministry of Infrastructure for hosting our visit to Niue and coordinating introductions and meetings. A special mention also to the support of Niue Telecom for providing copies of radio logs to enable confirmation of non-AIS vessel traffic. This risk assessment relies heavily on the previous work of MARICO Marine New Zealand Ltd who, under contract to and with the support of LINZ, developed the methodology and conducted earlier risk assessments in the south-west Pacific Islands.

[1] This report utilises and in some aspects updates LINZ Risk Methodology: South West Pacific Regional Hydrography Programme – Marico Marine Report No. 12NZ246, Issue 3 - February 2013.

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EXECUTIVE SUMMARY

0.1 **Niue** is an isolated raised coral island of 269km^2 amid a maritime exclusive economic zone of approximately 390,000km^2.

0.2 There is substantial **maritime traffic** that traverses the Niue EEZ, these vessels include tankers, passenger, general cargo, fishing, research and recreational/superyachts however most of this traffic traverses in deep water and does not pass within 5 km of land or reefs. The only regular ships visiting Niue are: a general cargo re-supply vessel on a monthly cycle, a number of recreational vessels/superyachts (approximately 100 per year between April and October) and a small but potentially increasing number of cruise vessels. Domestic vessels consist of one 10m, locally registered long line fishing boat, numerous outboard powered small craft of less than 6m (some used for commercial fishing, diving or whale watching charter), and traditional canoes.

0.3 The **current nautical charting** consists of one approach scale chart of Niue, chart NZ845 (scale 1:150,000) which is a modern metric chart on WGS 84 datum, compatible with satellite navigation and supported by ENC NZ300845. However this chart shows many areas of broken contour lines indicating that it is based on old or incomplete survey data. This paper chart includes a large scale inset plan of part of Alofi Anchorage (scale 1:6,000), however the extent of this plan does not cover the full area used by for seasonal yacht moorings, and an extreme scale plot of Alofi Wharf (scale 1:1000). The remainder of the Niue EEZ is covered by small scale international charts NZ 14630 (INT 630), at a scale of 1:1,500,000, and NZ14605W at a scale of 1:3,500,000 which are suitable for their intended purpose of ocean navigation.

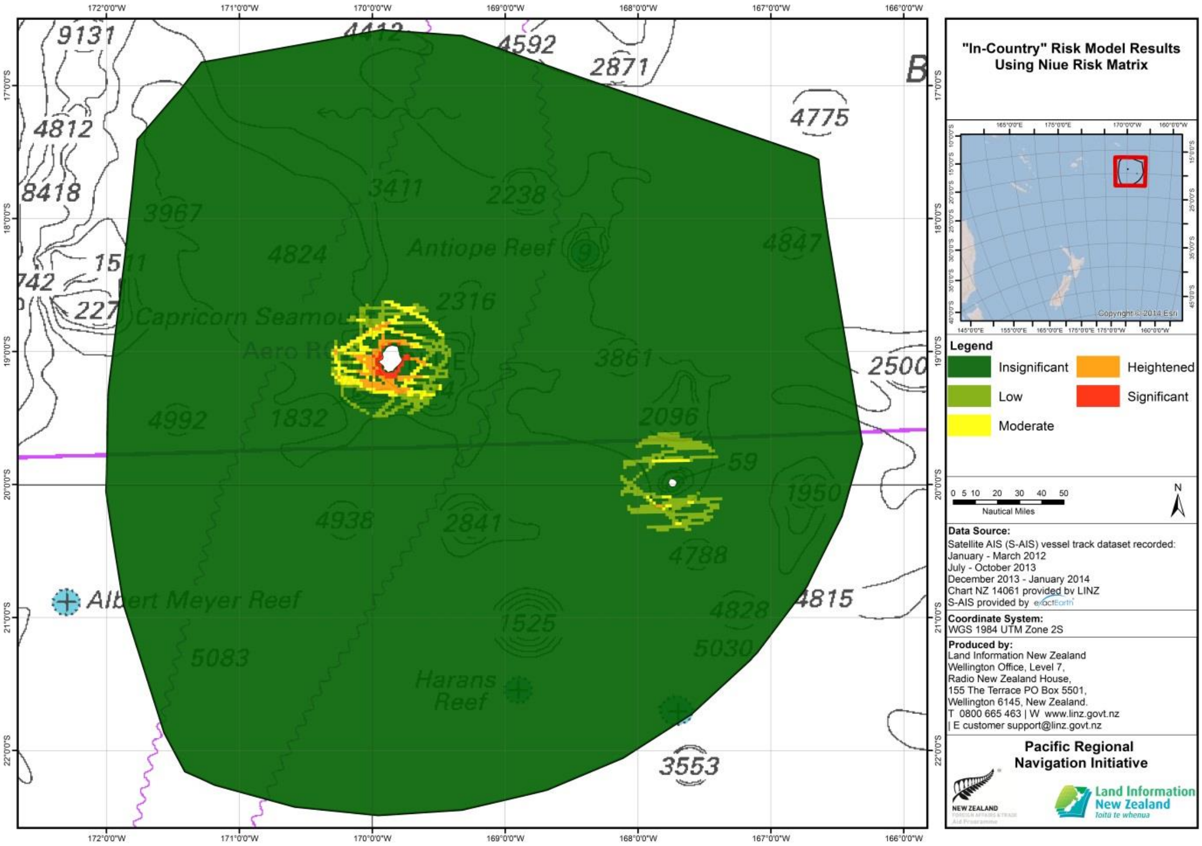
0.4 **Hazards to navigation**. It is concerning that there are no navigation landfall lights to warn vessels of their approach to Niue at night. There are a number of FADs located within the coastal waters of Niue, these are unlit, not all charted and constitute a navigational hazard near the island. If a vessel becomes fouled on these devices and disables its propulsion or steering, then it could contribute to the risk of grounding on the island. The seasonal yacht moorings in Alofi harbour are also unlit and their extent is not fully shown on the navigational chart.

0.5 There is a **modern multibeam bathymetric survey** of the surrounds of Niue which extends from the reef edge to 5km offshore. This survey was conducted by SOPAC (now SPC) in 2005 as part of a SOPAC/European Union project *Reducing Vulnerability of Pacific ACP States*. This information is not currently included on charts as the original survey data and supporting quality metadata has not been made available to LINZ.

0.6 The only offshore reef of significance is **Beveridge Reef** situated approximately 120nm east-south-east of Niue. This reef is considered environmentally significant for the marine biodiversity of Niue and it is protected under Niue regulations, however there has been no hydrographic survey of this reef and there is no large scale chart of the reef to provide a baseline and framework for its management

0.7 **Other charted reefs** within the Niue EEZ are Antiope Reef (95nm east-north-east of Niue) at a depth of 9.5m and dangerous to surface navigation, Harans Reef (130nm south-south-east of Niue) with an unknown depth but reported to break, and a reported, unnamed shoal on the extremity of the EEZ in the far south east the existence of which is considered doubtful. Commercial vessel routes avoid these reefs.

0.8 The "**in country"**[2] **risk assessment** found the highest hydrographic risk in the vicinity of Niue Island particularly around Alofi. This risk is associated with the greatest vessel traffic density near land. The significant risk areas on the west coast are attributable to a relatively high traffic count of small vessels on the approaches to and in the vicinity of the port of Alofi, a visit by a large cruise ship and the consequence risk value of the coastline and areas with 3km to seaward of the west coast which are of cultural and economic value for subsistence fishing, whale watching/tourism, and the proximity to the port which is the main centre of infrastructure and a cruise ship destination.



Executive Summary Fig: 1 - Niue "In Country" Risk Results

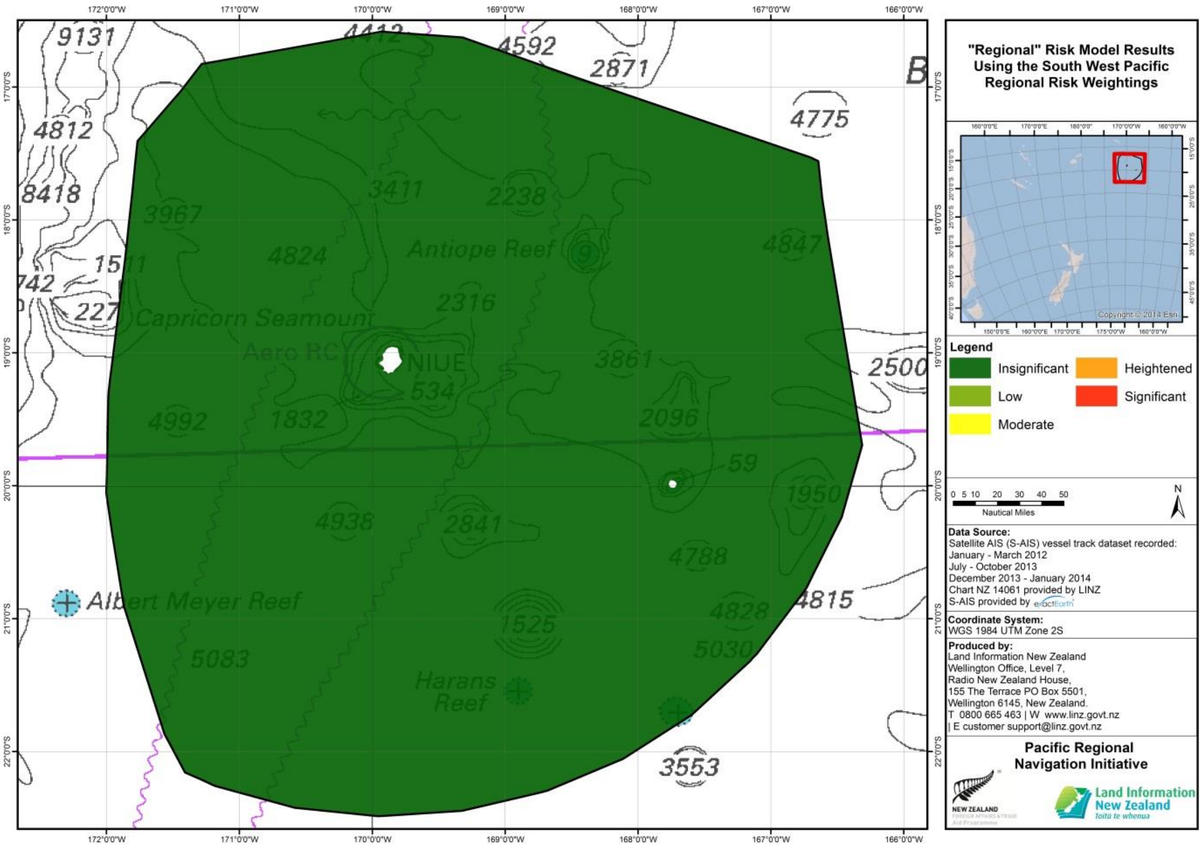
[2] Refer to *Glossary and Definitions*

0.9 On investigation, the significant risk area on the south and south-east coast is found to be attributable to a single transit of a 30,000 GT passenger vessel. This fact evidences the low traffic characteristic of this risk model by highlighting the sensitivity of the model to one ship of moderate GT.

0.10 The risk results for Niue are summarised in the following table:

NIUE **Priority Areas for Safety Improvement** (Based on In Country Risk Level)		
Location	**Area**	**Comparative Risk Level**
Niue Island	Vicinity of Alofi Bay	Significant
	Within the 1000m contour around Niue Island	Heightened / Significant
	Within 15nm of Niue Island	Moderate
Beveridge Reef	Between 3nm and 15nm from Beveridge Reef	Low / Moderate
	Within 3nm of the Beveridge reef	Insignificant
Open ocean	Outside 15nm from Niue Island or Beveridge Reef	Insignificant

0.11 The **regional risk assessment** found that in comparison to other South West Pacific island groups, particularly Tonga and Cook Islands, the entire Niue EEZ, has a much lower absolute maritime risk profile and is assessed as *insignificant*. This is unsurprising given the geography of the seabed and island, the deep water virtually to the shore line, the very limited commercial vessel traffic visiting the island and the lack of complicated navigational routes near reefs or shallow water.



Exec. Summary Fig: 2 - Niue Regional Risk Results

0.12 Despite the *insignificant* risk rating on a regional basis, **charting improvements are recommended** following consideration of the "in country" risk assessment and the potential benefits to Niue. The standard of existing charting does not support current or future planned maritime activities as well as it should. The following navigational safety and charting improvements are recommended:

a. Plan of Alofi Landing - reduce the scale to 1:2,000 and expand the extent of this plan to support safe anchoring and cargo operations for the routine cargo resupply ship. The latest survey data should be included to extend the navigable area into that currently shown as "inadequately surveyed".

b. Plan of Alofi Anchorage - extend the plan of Alofi Anchorage at least one mile to the south to provide sufficient chart coverage to properly manage the safe mooring of vessels and administration of the port waters, the scale could be reduced to 1:10,000 to meet this purpose

c. Chart NZ845 - update to include the latest available multibeam survey data and include the positions of the unlit FADs and the full extent of the seasonal yacht mooring buoys which being unlit, constitute a hazard to navigation,

d. Approaches to Niue – install and chart landfall lights of at least 10nm nominal range near the cardinal extremities of the island so that vessels approaching from any direction are able to see the island at night (these may be combined with telecommunications towers), and

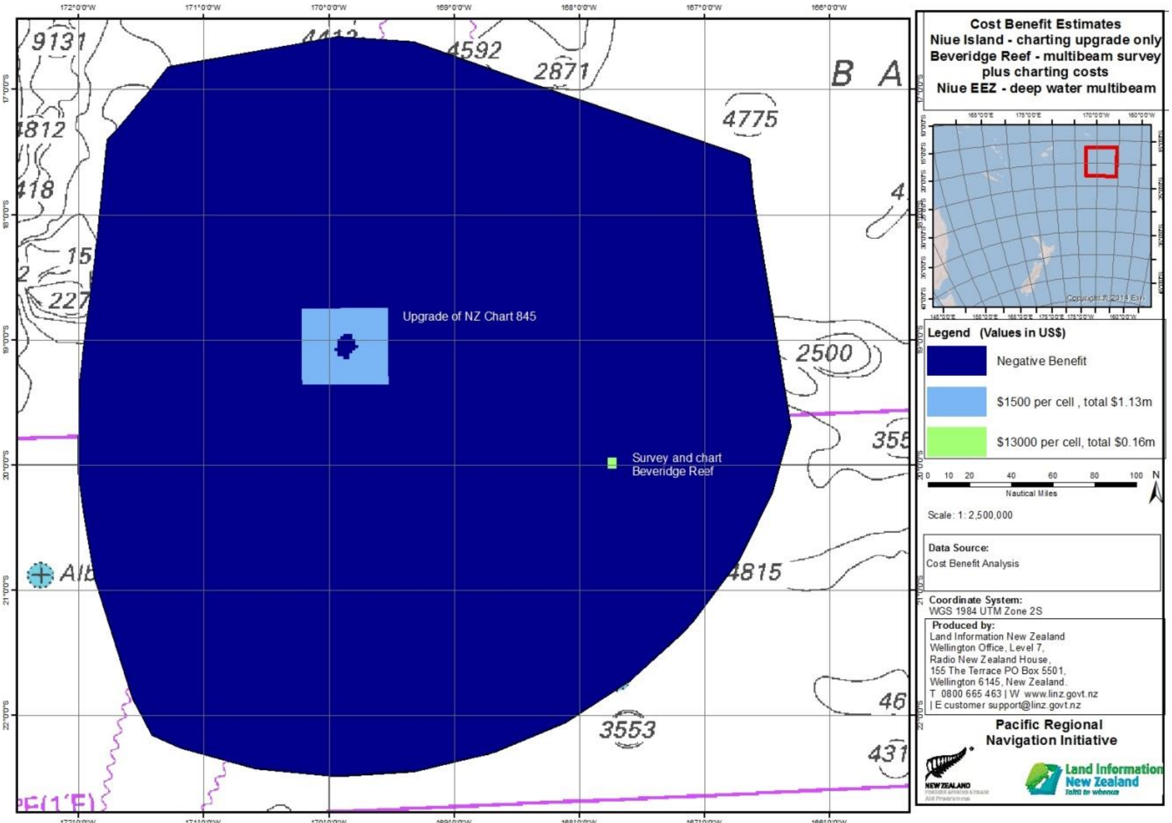
e. Beveridge Reef - survey the reef and surrounds to modern standards and produce a large scale chart of the reef to enable safe navigation by research and patrol vessels. This activity will also provide a baseline map for resource monitoring/management and submissions for international recognition of a marine reserve of protected sea area.

f. On an opportunity basis it would improve the quality of ocean charting to: determine the extent and least depth over Harans Reef, and to prove or disprove the existence and depth of the unnamed shoal referred to at the south eastern extremity of the Niue EEZ.

0.13 The unique geography of Niue as an isolated island within an extensive, deep water EEZ renders it unnecessary to conduct a cost benefit analysis to assess value of investing in hydrographic surveys in the deep ocean areas. In these unobstructed deep waters where the seabed does not place any constraints on safe navigation, the benefit of improved ZOC would only be theoretical. Therefore, whilst the conduct of a systematic deep water multibeam survey of the entire Niue EEZ would produce benefits in terms of mapping ocean resources, it would provide no realistic reduction of hydrographic risk. The cost benefit equation thus provides negative returns for all the deep offshore areas. This assessment is confirmed by the lack of maritime incidents in Niue EEZ in past decades.

0.14 However, there are direct benefits of hydrographic improvements in the vicinity of Niue and Beveridge Reef. A cost benefit analysis was conducted for recommendations 'a'-'c' above (Niue Island) using the costs of re-compilation of Chart NZ 845 (and plans), against a theoretical benefit of increased cruise ship tourism. The result, detailed in the Figure below, shows a positive NPV of US$ 1.13 million over 10 years.

0.15 A second cost benefit analysis of the recommendation 'e' (Beveridge Reef) was conducted using the estimated cost of LIDAR survey plus production of a new chart against the benefits of enabling the use and effective management of this important reef resource. This result showed a small net positive NPV of US$ 0.16 million over 10 years. Additionally and more importantly, is the immeasurable benefit to Niue of having the foundation hydrographic data to enable the management of this significant resource and to support planned applications for international recognition of this reef as a marine reserve.



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GLOSSARY AND DEFINITIONS[3]

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).

ALARP As Low as Reasonably Practical.

AToN Aids to navigation. A floating or shore based light or mark that may be lit, or a virtual (electronically generated and transmitted) representation of such mark, 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.]

CATZOC The S57 attribute of the M-QUAL object that specifies the Zone of Confidence determined by the hydrographic authority for a specified area of a chart. CATZOC is a mandatory attribute in an ENC, intended to give mariners an indication of the confidence they can place on the charted information. It depicts the final charted reliability of that area, which includes an assessment of the quality of survey. Areas are 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).

CBA Cost Benefit Analysis. For consistency with previous reports the CBA is defined in US dollars.

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.

CRA Comparative Risk Assessment. 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.

[3] For consistency, where abbreviations / acronyms are common with previous LINZ Risk Assessment Reports the definitions have been aligned as far as practicable with those in (Marico Marine Report No. 14NZ262 – TM, Issue 1, 27 November 2014).

ECDIS	Electronic Chart Display and Information System – The official IMO recognised bridge navigation system which when used with ENC meets navigational carriage requirements.
EEZ	Exclusive Economic Zone.
ENC	Electronic navigational chart – the official, government authorised navigational information dataset which, when used with a compliant ECDIS, will meet IMO chart carriage requirements for SOLAS class ships.
Event	An unwanted or unplanned occurrence with consequential harm (i.e. accidents).
FAD	Fish Aggregation Device. A man-made object consisting of buoys or floats tethered to the ocean floor used to attract pelagic fish.
Frequency	**(when referred to in relation to risk)** 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.
HFO	Heavy Fuel Oil. A generic term used to refer to heavier grades of marine fuel that are mainly made up of the heaviest fraction of distillation of crude oil with small percentages of distillate added. It requires pre-heating before burning and is only used in large ships. HFO is close to crude oil in its pollution potential.
HR	Hydrographic Risk. This risk assessment methodology has been developed by LINZ. This Hydrographic risk assessment methodology relies 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 components are combined in a GIS using Risk Terrain Modelling to output a spatial result.
HW	High Water.
IHO	International Hydrographic Organization.
IMO	International Maritime Organization.

"In-country" Refers to results displayed using colour band classification break values calculated only from the Niue EEZ study area data, thus ensuring that the full colour range is utilised in the heat map. These are relative results across the Niue EEZ.

IR 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.

Jenks Breaks **(or Natural Breaks)** is an algorithm for classification of statistical results that seeks to partition data into classes based on natural groups in the data distribution. It tries to maximize the similarity of numbers in groups while maximizing the distance between the groups. There are different implementations of the algorithm for different software packages, so results can differ from one application to another. The ESRI ArcMap implementation was used in this analysis.

km Kilometre.

kt Knot – one nautical mile per hour

LINZ Land Information New Zealand - The national hydrographic authority of New Zealand.

LW Low Water.

m Metre.

MFO Marine Fuel Oil. A generic term referring to lighter grades of fuel (such as marine diesel oil (MDO) or marine gas oil MGO)) consisting or mainly distillate oil that is normally used in bunkers of smaller commercial vessels or those that require frequent manoeuvring.

MMSI Maritime Mobile Service Identity – a unique identifier for an AIS installation on a ship, base station, aid to navigation SAR aircraft or handheld VHF radio with digital select call that is allocated by the flag state (national maritime authority).

MNZ Maritime New Zealand – The New Zealand Maritime Safety Authority.

ML Most Likely (referring to an Event).

nm International Nautical Mile, a standard distance of 1852 metres.

NPV Net Present Value.

QRA **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).

"Regional"	Results described as **"regional"** are those displayed using the same colour band classification break values used in the regional risk diagrams of the previous Cook Islands and Tonga hydrographic risk assessments. Regional results are therefore comparable to those previous assessments.
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.
RTM	Risk Terrain Modelling.
S-AIS	Satellite (received) Automatic Identification System.
SOLAS	The United Nations Safety of life at Sea Convention.
SOPAC	Pacific Islands Applied Geoscience Commission. This commission was brought under the administration of SPC Pacific Regional Environment Program in 2010 and became part of the SPC Geoscience Division (GSD) in 2011.
SPC	Secretariat of the Pacific Community.
SPREP	Secretariat of the Pacific Regional Environment Programme. This is an intergovernmental organisation co-ordinating environmental projects across the Pacific region.
SWL	Safe Working Load. The lifting capacity of a crane, derrick or other lifting equipment.
TEU	Twenty-foot Equivalent Units. The standard reference size of a shipping container, though many containers are up to twice the capacity of a container ship is measured in the number of TEU it can carry.
UNCLOS	The United Nations Convention on Law of the Sea.
VHF	Very High Frequency. This refers to a frequency band of radio often used for short range marine voice communications.
WC	Worst Credible (referring to an Event).
ZOC	Zone of Confidence. The charted representation of CATZOC.
$	Dollars. Unless otherwise specified $ refers to New Zealand dollars.

1. INTRODUCTION

1.0.1 In the South West Pacific, island nations have generally seen an increase in SOLAS traffic transiting their waters as the volume of global maritime trade increases and a resurgence of marine tourism has spurred the cruise ship industry to find new destinations. These trends are likely to continue.

1.0.2 Additionally over the last twenty years the development of the UNCLOS and the formal recognition of the 200nm EEZ's (and in some cases extended continental shelves to 350nm) has brought with it additional responsibilities on nations of all sizes to ensure that there are adequate charts to support safe navigation through their waters.

1.0.3 This hydrographic risk assessment uses an established methodology of combining geospatial vessel traffic density information with risk likelihood factors (including chart quality), and risk consequence factors to provide a spatial heat map indicating relative levels of risk.

1.0.4 In reading this report it is important to understand that the distinction between *Inherent Risk* and *Hydrographic Risk*. *Inherent Risk* is easiest to understand; a port may present a difficult circumstance such as constrained waters, close to reefs and exposed to swell. This provides a clear individual risk for vessels visiting that port. *Hydrographic risk*, as defined in this methodology measures traffic in all geographic areas by volume, type and size and then applies a range of consequence factors to provide a standardised risk outcome. Thus the inherent risk of a single transit for an individual vessel may be relatively high, however the overall hydrographic risk result may be low because the number of transits per annum are low or the vessels involved are smaller than in others in the region.

1.1 Aim

1.1.1 The aims of this report are to:

a. describe the analysis of hydrographic risk relating to Niue and Niuean waters based on the same LINZ developed risk based methodology previously used to assess hydrographic risk in Vanuatu, the Cook Islands and Tonga in order to inform prioritisation of hydrographic survey and charting improvements,

b. to produce GIS derived plots showing the spatial distribution of shipping risk that enables the Government of Niue and LINZ to identify priority areas for focussing hydrographic survey and charting improvements , and

c. to provide the Government of Niue with a GIS model that can be used to contribute to the ongoing monitoring and management of hydrographic risk and maritime areas.

1.2 Methodology[4]

1.2.1 The method deployed uses risk assessment in a comparative way, to identify areas within the Niuean EEZ that are more susceptible to an incident involving either a large SOLAS vessel or smaller cargo, fishing or recreational vessels. This risk is determined in terms of the range of most likely and worst credible outcomes for potential for loss of life, damage to the environment, damage to economic development and impact to areas that are culturally important to the Niuean people.

1.2.2 The types of accident that can occur to vessels are related to the type of vessel transiting Niuean 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 Niue Telecom radio logs, obtained during a data gathering visit to Niue. Details of local vessel/boat operations were obtained through discussions.

1.2.3 Ship traffic was analysed in a Geographic Information System (GIS), the details of how the tracks were created and processed to remove anomalies is provided at Annex B. As Niue has no domestic commercial vessels of any significant GT no additional non-AIS data was added to the ship traffic plot. Event Trees (see Annex A) were used to derive the realistic types of navigational incident that could occur (grounding, foundering or collision) and their outcomes related to the vessel types and the size of those vessels. These outcomes confirmed that the risk multipliers and the consequence criteria for a risk matrix (Annex E), were valid for Niue. These values were then used in the GIS risk calculations (see Annex F).

1.2.4 The information known about important tourist destinations, the cultural and resource sensitivities of seamounts, reefs and the coastline of Niue were entered in the GIS and this could then be used to influence the risk consequence criteria to be combined with the locational traffic analysis in the GIS. A plot of each layer of information used as an input to the analysis is included and described at Annex D.

1.2.5 The use of a GIS allowed a large number of geospatially referenced factors to be considered in terms of their risk contribution and linked to the most dense traffic areas. 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[5].

1.2.6 The methodology 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.

1.2.7 In summary, the assessment was conducted as follows:

[4] This report applies the same methodology described in (Marico Marine Report No. 14NZ262 – TM, Issue 1, 27 November 2014), the text is reproduced here with minor adjustments to apply to Niue.
[5] (Marico Marine Report No. 12NZ246, Issue 3, February 2013) (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015)

a. Vessel traffic analysis to build a model of shipping movements through Niuean waters was undertaken using satellite derived AIS data for January – March 2012, July to October 2013 and December 2013 to January 2014,
b. 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; this included the confidence of the current nautical charting,
c. 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 Niue,
d. the risk results are presented in Section 7, and
e. a CBA of recommended charting improvements is described in Section 8.

1.3 Risk calculation and GIS implementation

1.3.1 As described above, and to maintain consistency with previous results, the risk criteria used throughout the analysis is common with similar work undertaken in Vanuatu, the Cook Islands and Tonga. The calculation of hydrographic risk for Niue also uses a similar GIS implementation of a weighted overlay method to that used in the risk assessments of Vanuatu [6], Cook Islands[7] and Tonga[8]. The documents "LINZ Hydrographic Risk Assessment Methodology Update"[9] and the Annexes to the Vanuatu Risk Assessment Report[10] provide a good explanation of the method but additional details of this risk calculation are provided in Annex E.

1.4 Cost benefit analysis

1.4.1 Where recommendations for charting improvements are made these are supported by a cost benefit analysis. The details are provided in Section 8.

[6] (Marico Marine Report No. 12NZ246-1, January 2013)
[7] (Marico Marine Report No. 14NZ262MR Issue 02, 20 January 2015)
[8] (Marico Marine Report No. 14NZ262 – TM, Issue 1, 27 November 2014)
[9] (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015)
[10] (Marico Marine Report No. 12NZ246-1, January 2013)

2. NIUE – GENERAL INFORMATION AND ECONOMIC OVERVIEW

2.1 Niue Island

2.1.1 Niue is a single upraised coral island atop an ancient volcanic seamount located near the centre of a triangle formed by Tonga, Samoa and the Cook Islands at latitude 19° South and longitude 170° West. Its dimensions are approximately 20 km north-south and 18km east-west, an area of approximately 260km^2. Within its EEZ there is one significant reef, Beveridge Reef which is protected by local regulation and considered to be a breeding ground for marine life surrounding Niue. There are a number of significant seamounts indicating past submarine volcanic activity and the proximity of the convergence of the Indo-Australian and Pacific tectonic plates along the Tonga Trench to the west indicate that further volcanic activity is possible.

2.1.2 The island has a coastline comprising shear vertical coral limestone cliffs 20m to 50m high. At the foot of the cliff is a very narrow fringing reef, varying from about 50m to 100m width, this is more prominent on the western side of the island which is protected from the prevailing seas and south easterly trade winds. The oceanic seabed rises steeply from several kilometres depth at a relatively short distance offshore. In severe cyclones, large waves are able to break to the tops of the cliffs, damaging buildings located on the rim of the island[11]. Niue has no natural anchorages or safe harbours but there has been some level of regular maritime trade through the port of Alofi, on the west coast, for nearly 100 years.

2.1.3 Being a single island, Niue has no domestic passenger ferries and no significant maritime capability. It has one government operated search and rescue workboat which is restricted to operating within 3nm of the coast and there is one domestic licenced long line fishing vessel of 10m that operates seasonally to meet local demand. Other maritime activities are limited to local fishing, whale watching and diving charters all operated from trailable runabout type boats of less than 6m length. There are also numerous traditional canoes used for local fishing.

2.1.4 Niue is a self-governing parliamentary democracy in free association with New Zealand. Its population is recorded as 1,611 persons (2011)[12] and is relatively stable after having been generally declining since its reported peak in excess of 5,000 in the late 1960's. The population is divided among 14 villages and village life remains important to Niue's cultural and political organisation.

2.1.5 The island has been inhabited for more than a thousand years and it is believed that the initial inhabitants came from two principal migrations, one from Samoa and one from Tonga with a smaller migration from Pukapuka in the Cook Islands.[13] Until the 18th century there was no central government or leader and local chiefs exercised control over their villages. Contact with Tonga or Samoa introduced the concept of kingship and a succession of kings (Patu Iki) ruled the island, until a central Government was formed in the 20th century. There remains a culture and practice of local control by village councils and Niueans still have a strong sense of loyalty to their local village.

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[11] Niue Port Study, SMEC Australia – February 2011
[12] http://niue.prism.spc.int/ (accessed 14 April 2016)
[13] http://www.niueisland.com/facts/ (accessed 10 March 2016)

2.1.6 In 1774, the English navigator Captain James Cook sighted Niue but was refused landing by the locals on three different attempts. He named Niue 'Savage Island'. Missionaries from the London Missionary Society established Christianity in 1846. Niue chiefs gained British Protectorate status in 1900, and in 1901 Niue was annexed to New Zealand. In 1974 Niue gained self-government in free association with New Zealand and government to this day has followed a Westminster-style rule. The Niue Assembly consists of 20 members, 14 of whom are elected by village constituencies and 6 from the common roll. The 20 members elect a Premier and the Premier selects three cabinet ministers from the 19. Members elect a Speaker from outside their ranks. A general election is held every three years.[14]

2.2 Economic Overview

2.2.1 Niue has a land area of 260km^2 and is mostly limestone and very porous. There are no rivers hence no run off into the sea, helping to maintain the surrounding waters as pristine; a key marketing feature for nature tourism. Approximately 70% of the land is forested and much of this allocated to nature /forestry reserve. The island prides itself on it pure and unpolluted status and is working to become completely insecticide free. The island sits on a large aquafer which is a reliable source of fresh water for agriculture and domestic consumption and absolutely crucial to the survival of Niue and is a high management priority. A "Ridge to Reef" project, supported by the Secretariat of the Pacific Community (SPC) is looking at harmonising land based activities with risks of pollution and management of drinking water.

2.2.2 Niue has initiated financial activities to earn foreign revenue. A company register was opened to provide the benefits of a low taxation environment for foreign countries. An online companies office registry regime and website was implemented in 2006 with assistance from the New Zealand Companies Office. More recently Niue has opened a commercial ship registry which is operated from Singapore.

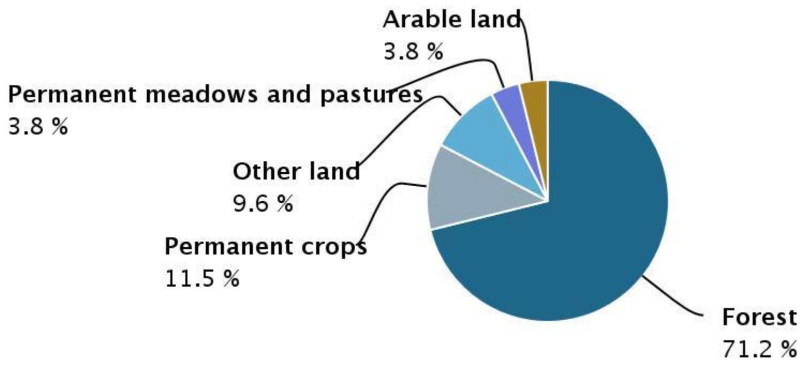

Figure 1: Niue land use (Food and Agriculture Organization)

[14] http://www.gov.nu/wb/pages/parliament.php (accessed 14 March 2016)

2.2.3 Niue is highly dependent on foreign aid. The 2015 GDP of Niue[15] was NZ$24.5 million, about $15,000 per capita. Niue received $14.5 million in foreign aid from New Zealand, around 30% of the national budget. While local fishing is extremely important to the subsistence of Niueans, most food, and all building materials and consumable goods are imported. In 2014, exports totalled $1.345 million, imports $14.064 million giving a negative balance of trade of $12.719 million.[16]

2.2.4 With assistance from the Food and Agriculture Organization of the United Nations (FAO), Niue is working towards increasing their domestic food production to provide better food security and reducing the imports required to support increasing tourist visits to the island[17]. Local farmers grow taro, yams, cassava, sweet potatoes, papaya and bananas. There are also small holdings of pigs, goats and chickens.

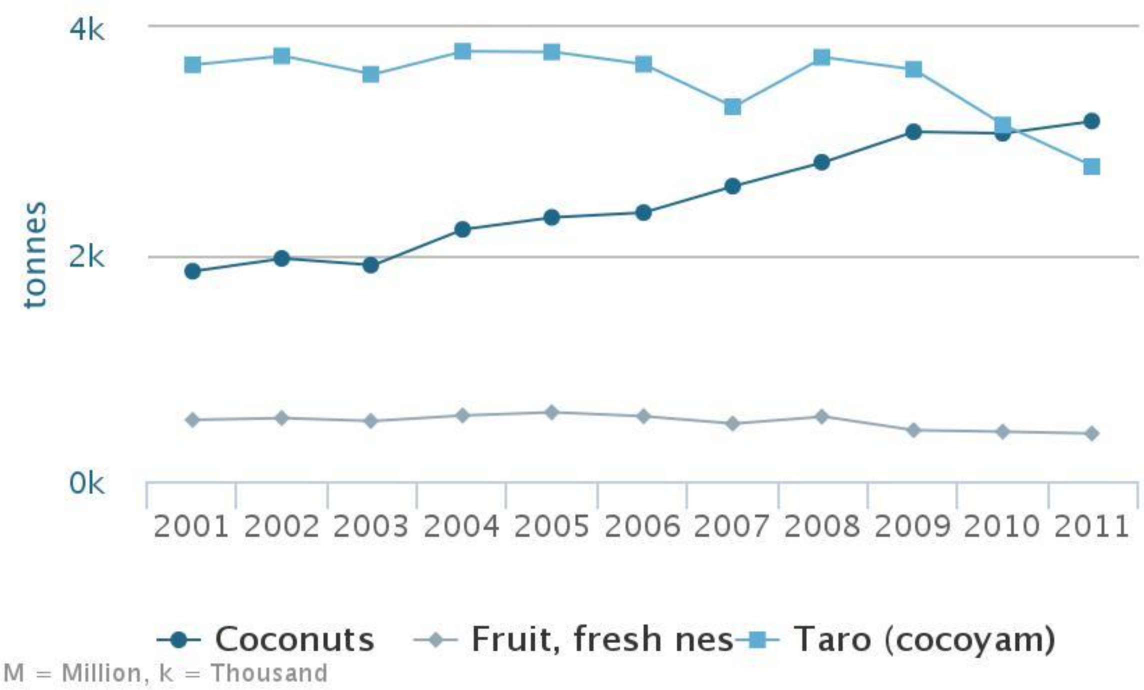

Figure 2: Agricultural production (Food and Agriculture Organization)

2.2.5 The PACER PLUS[18] agreement between Pacific Island Countries and Australia and New Zealand, which is expected to enter full negotiations in July, was seen as an opportunity to increase access to markets and could improve trade.

[15] (Secretariat of the Pacific Community, 2015)
[16] (Secretariat of the Pacific Community, 2015)
[17] (Office of Support to Decentralization, 2015)
[18] Pacific Agreement on Closer Economic Relations (PACER) is an umbrella agreement on trade between Pacific Island Forum counties and Australia and New Zealand. The PACER PLUS element is a proposed free trade agreement which falls under this framework and is approaching the negotiation phase.

2.3 Export Commodities

2.3.1 The main agricultural exports are organic noni fruit juice and coconuts, there is a small quantity of vanilla beans[19] and bee products are a relatively new development and their potential has not yet been proven.

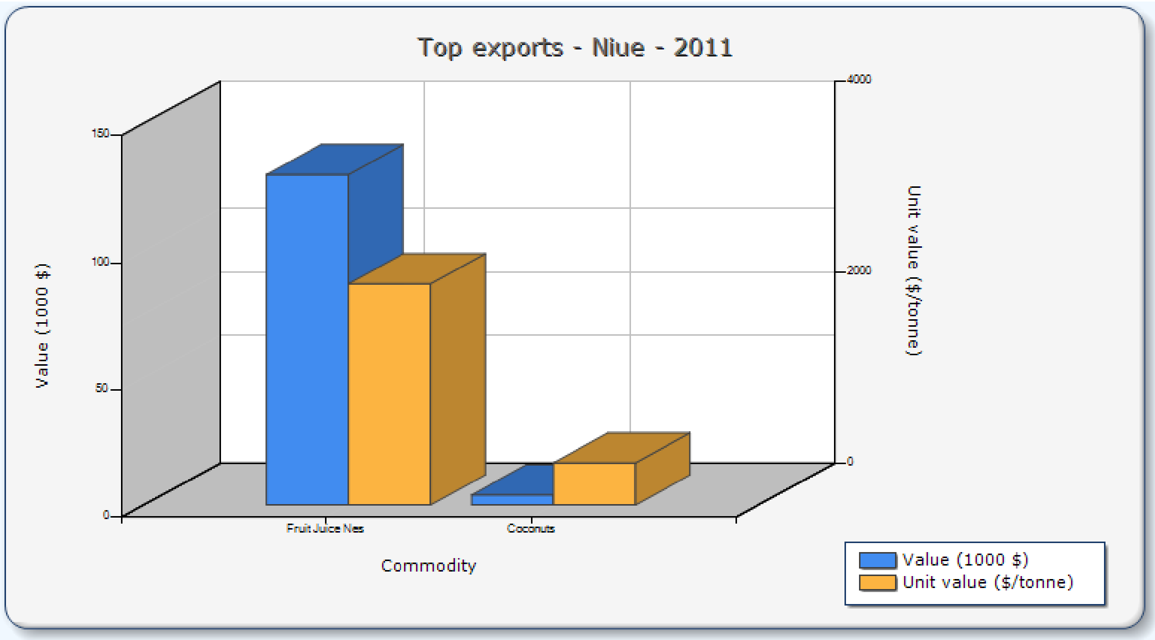

Figure 3: Niue agricultural exports[20]

2.4 Fishing

2.4.1 From 2003 to 2008 the Government of Niue in a joint venture with a New Zealand company operated a fisheries industry comprising of long line fishing trawlers and a processing plant for albacore, yellow fin and big eye tuna. The industry failed primarily because of difficulties in unloading at Alofi Wharf[21]. With trawlers being damaged when alongside and using lighters to land the catch resulting in degradation of the fish. The local commercial operation and processing plant closed down in 2008 and only one small commercial operator remains, operating a 10m longline vessel and catching fish for domestic consumption only. The Department of Fisheries considers that if a safe harbour could be provided the fish processing industry could be re-established. In pursuance of this aim the Forum Fisheries Agency conducted a maritime engineering port study in 2011 and recommended a boat harbour be constructed immediately north of the existing wharf.[22]

2.4.2 Niue now licences foreign fishing vessels to conduct longline commercial fishing. The licence cap is set at 10 vessels and there are currently four licenced operators operating vessels up to 40m. There have been up to 7 licenced vessels from Fiji, the Cook Islands and the United States of America

[19] (Stanley, 2014)
[20] (Food and Agriculture Organization)
[21] (SMEC - A. Patterson, 2011, p. 1)
[22] (SMEC - A. Patterson, 2011, p. 20)

(USA). Niue's only fishing revenue is from licences. These vessels are tracked using VMS and ARGOS and unload their catch at foreign ports. According to the fisheries department approximately 200 tonnes per year is now caught. Niue is keen to increase the revenue from this source. There is a tuna fishing agreement with USA but there is no USA fishing in Niuean waters at present as the waters are too cold for purse seine fishing as the fish are too deep. Niue considers that there is currently illegal unreported fishing that is occurring in their 360,000km^2 of EEZ that they have no method of patrolling.[23]

2.4.3 According to the Asia Development Bank, in 2009 Niue's fishing catch was a total of 790 tonnes made up of: coastal 10 tonnes, coastal offshore 140 tonnes, off-shore commercial 640 tonnes (source: ADB (2009)[24]).

2.5 Tourism

2.5.1 Tourism is the most important resource to the Niuean economy and it is growing rapidly. In 2014 7,661 tourist visited Niue and in 2015 this number climbed to 10,689, already exceeding the Government target of 10,000 tourists by 2020. The vast majority of these tourists came by air as can be seen in the table below.

Mode	Number of Visitors in 2015	Period on Niue (average)	Person days on Niue	Average Spend per visitor[25] ($)	Total spend per mode ($000)	Per cent of GDP
Air	7839	10 days	78390	768	6,020	24.6%
Cruise ship	2483[26]	6 hours (max)	620	n/k	n/k	n/k
Recreational vessel	367	3 days	1101	354	130	0.5%

Figure 4: Visitor numbers by mode and period of stay[27]

2.5.2 The Niue Ocean Wide (NOW) Project[28] supported by the Oceans 5, was launched in 2015 and is aiming to improve Niue's global profile as a pristine eco-tourism destination by promoting conservation and sustainable use of the EEZ through tightly-managed resource use zones and a world-class marine reserve at Beveridge Reef.

[23] (F.Tauafiafi, 2016)
[24] (Gillett, 2011)
[25] Spend data taken from passenger departure cards and not available for recreational or cruise vessel passengers.
[26] This is the total number of cruise ship personnel cleared to visit Niue, however the actual number that stepped ashore is thought to be much lower due to boat transfer challenges and simple logistics in the case of 1834 potential visitors on one ship. Cruise ship passengers are permitted to visit Niue for a maximum of 8 hours.
[27] Figures provide by Niue Government Statistician, 18 March 2016.
[28] (Oceans 5)

2.6 Cruise shipping

2.6.1 The number of cruise ship visits to Niue increased to five in 2015, the highest on record, however the economic impact of those visits was not considered significant. The visits of cruise ships are entirely weather dependent as the island has no secure anchorage and no consistently reliable landing wharf. Even in a small swell, attempting to disembark elderly passengers from cruise ship tenders is dangerous and unsatisfactory. Additionally, at this stage at least, the population is not geared up to entertaining and making revenue from rapid turnaround tourists and are generally not very interested in them. According to Niue Government officers, this area presents an opportunity for economic development and there needs to be a greater effort to develop services to take advantage of potential revenue earnings from increasing cruise ship visits.

2.6.2 Of the 5 cruise ship visits this year, four of those were small adventure cruise ships with total passenger numbers between 150 and 170, the other was the Holland America Cruise line *MS Amsterdam* with 1,834 personnel cleared to go ashore. Local advice is that only 50% of the ships were able to successfully land. A further limitation is that the timing of cruise ship visit appears random and entirely driven by the shipping lines without proper consultation. As an example a ship arrived at Niue at Christmas time which is firmly reserved for family activities.

2.6.3 The opinion as to the value of cruise ship visits varies depending on who you ask and its future economic value is uncertain. If the proposed development of a protected boat harbour at Alofi goes ahead, and the local tour operators amend their offerings to provide for short term tourists, then cruise ship visitors could become a more reliable and viable source of revenue. However there is concern that large numbers of tourists trying to see the highlights of Niue in an 8 hour visit will undermine the beauty of the serenity and isolation of the island. The islanders tend to prefer to develop a more relaxed tourist industry based on tourist who visit by air and stay for between 10 and 14 days rather than the frenetic pace of cruise ship passengers trying to see and do everything in one day.

2.7 Recreational vessel visits

2.7.1 The number of recreational vessels that can visit Niue at any time is limited by the number of moorings available as small vessels cannot anchor safely. The Niue Yacht Club, places 20 moorings off Alofi each April, the risers are fitted with sub surface buoys to keep the lines clear of seabed obstructions. The mooring risers are recovered for servicing in November leaving the ground tackles in place.

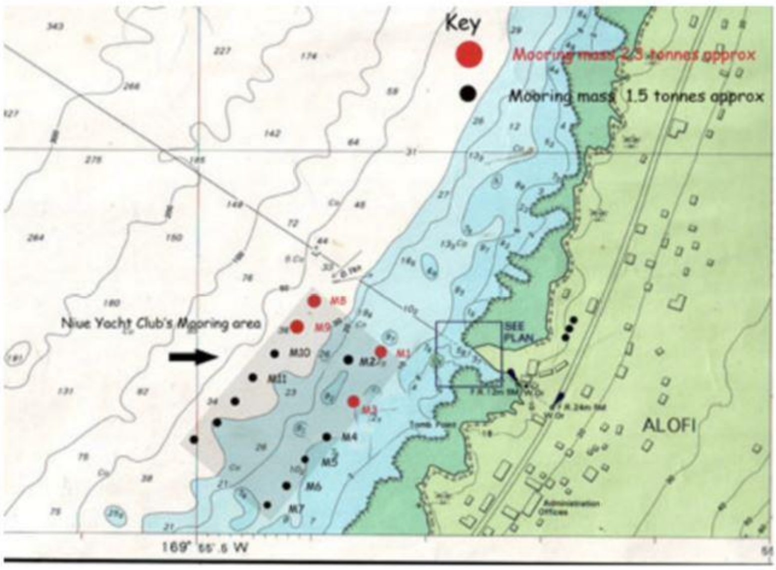

Figure 5: Planned positions of NYC moorings (Source: www.nyc.com)

2.7.2 The yacht club is active in promoting and coordinating yacht visits especially world ARC Tour cruising yacht rally which can bring more than 30 yachts and more than 100 crew. The yacht club coordinates the arrival of the vessels to ensure that sufficient moorings are available. Approximately 100 recreational vessels visit Niue each year ranging in size from 10m to 75m, they generally stay an average of 3 days on the island.

2.7.3 Feedback from recreational mariners is that it is difficult to safely approach Niue at night as there are no visible charted landfall lights when approaching from any direction. Additionally, as the buildings are generally set well back from the coast (except in the vicinity of Alofi) there are no other lights to provide warning of the approaching coast.

2.7.4 There have been 3 recorded incidents involving recreational vessels in recent times. One, a catamaran was washed onto the reef and was successfully pulled off, lifted out for repair and sailed away. A second older mono-hull yacht washed onto the reef north of Alofi and was re-floated with minimal damage and a third mono-hull fouled its propeller, called for help and was prevented from hitting the reef by a cruise ship tender. There were no serious injuries or any pollution damage from any of these incidents.

2.8 Imports

2.8.1 Imports make up the great majority of commodities consumed in Niue. While some fresh and perishable foods and urgent supplies are imported by air the great majority arrives by sea. The quantities of imports for the past 3 years are shown in the following table. The numbers are relatively steady with the exception of break bulk which would be directly related to specific cargo for current projects.

	Reefers (TEU)	Generals (TEU)	Tanktainer (TEU)	Vehicle (TEU)	Total (TEU)	Break bulk (Items)	Total Weight (Tonnes)
2013	24	234	150	159	889	322	6,895
2014	27	269	146	146	866	283	6,916
2015	25	281	155	155	1,026	412	7,431

Figure 6: Sea freight import statistics

2.9 Energy / Fuel Security

2.9.1 Fuel import is crucial to Niue particularly diesel for electricity generation and jet fuel to facilitate the routine air service from Auckland. Currently Niue produces 14% solar power and has set a target of achieving 80% renewable energy generation (including wind) by 2024.[29] However, there is currently no battery storage for solar energy and power generation on the island remains reliant on diesel generators. There are five, 5000 kVA generators with one operating during the day when solar is generating. One challenge faced is having sufficient flexibility in diesel power generation to be able to regulate supply in synergy with the variations in solar energy generation.

[29] A Niue energy roadmap was launched in 2015.

2.9.2 The Niue Bulk Fuels Depot manages the importation and use of fuel. All fuel arrives by tanktainers which are loaded to a maximum weight of 18 tonnes due to limitations of the unloading mobile crane. A two week reserve of all fuel supplies is maintained to account for delays in ship delivery schedules. The average monthly usage of fuel is:

Petrol 38,000 litres	(2 x 19000 litre tanktainers)
Diesel 108,000 litres	(6 x 18,000 litre tanktainers)
Jet Fuel 38,000 litres	(2 x 19,000 tanktainers)

Figure 7: Monthly average fuel use

2.10 Conclusion – Economic Overview

2.10.1 Niue's economy is in a relatively stable state with 30% of the national budget dependent on foreign aid. The population that has been declining since 1969 has now stabilised and with no new industries or activities likely within the next 5 years the maritime cargo demand, and hence commercial traffic, is likely to remain relatively static for the foreseeable future. Current efforts to improve agricultural self-sufficiency are unlikely to substantially reduce the demand for imports. If the new boat harbour is built and landing of passengers becomes more reliable then there may be an earnest effort to cater for single day tourists and there may be a slight increase in cruise ship visits. Air transferred tourism is the main revenue earner for Niue, this form of tourism has developed well over the last 5 years and is expected to continue to grow. Despite some potential fuel savings as a result of increased solar energy generation, fuel imports are also expected to remain steady due to increasing vehicle use to support tourism. Unless additional flights are scheduled to meet increasing tourism demands, the demand for imported fuel is expected to remain stable.

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3 CULTURAL ASPECTS AND TRADITIONAL RESOURSE MANAGEMENT

3.1 Cultural Influences

3.1.1 Niuean culture has been handed down from generation to generation, there was originally no central government and the village chiefs controlled all aspects of village life, many traditions are still observed today. Collectively the term "Taoga Niue" refers to both culture and craft, and has strong meaning to Niueans. Religion has an important position in Niue and is central to its traditions and its expectations. All people are expected to dress modestly and Sunday is observed as a day of worship and rest, and activities such as boating and fishing are not allowed. There remains a culture and practice of local control by village councils and Niueans still have a strong sense of loyalty to their local village.

3.1.2 Information about local cultural sites is not currently publicly available. Much sensitive information has been collected for a previous project about 20 years ago, but this information was lost during Cyclone Heta in 2004 when government buildings were destroyed. Local councils manage their own cultural sites and also to some extent manage their local fishing resources by restricting access to coastal areas during particular seasons. On the coastal reef cultural sensitive areas change depending on seasons and other factors, thus it is recommended that the entire coastal reef of Niue be considered culturally sensitive.

3.2 Subsistence fishing

3.2.1 Subsistence fishing is important to Niueans. Fridays are generally reserved as a day for fishing. The islanders fish from the shore, or use traditional canoes or small outboard powered boats (up to about 6m) to fish within 5km of the Niue coast.

Figure 8: Outboard powered boats enable fishing around the entire coast of Niue

3.3 Traditional fisheries management

3.3.1 The local councils will close areas to fishing for various periods. They do this by hanging a palm leaf upside down on the approach sea path, this means *FONO* or closed. The near-shore seamounts are traditionally important but they try not to overfish these areas and they are only permitted to be fished in times of drought or food shortage.

Figure 9: Traditional fishing by canoe (Photo: K. Vial)

4 MARITIME OVERVIEW

4.1 Niue Island

4.1.1 Niue is an uplifted coral island surrounded by deep water with no off-lying dangers. There is a narrow reef plateau surrounding most of the island. This is more prominent on the west coast, and in some areas particularly on the east and south coasts cliffs descend to the sea. The greatest navigational danger for vessels navigating in the vicinity is to collide with the island itself as it has no landfall navigational lights, the majority of its radio masts are unlit and except in the vicinity of Alofi, houses and infrastructure are set back from the coast and are not visible from sea.

4.2 Port of Alofi

4.2.1 There is a small solid concrete wharf at the port of Alofi, the capital of Niue on the island's mid-west coast. This wharf is completely exposed to the ocean swells from south-west to north-west and is only effectively useable in calm weather. The wharf has been subject to various studies[30] and repairs and was most recently repaired in 2015[31]. Following the FFA report of 2011 a hydrographic survey and technical report was undertaken by SPC[32]. A new tsunami warning and climate change modelling precision tide gauge was also erected on the wharf by the Australian Bureau of Meteorology in 2015.

Figure 10: Alofi Wharf showing lead daymarks, BOM tide gauge and fishing boat preparing to be hoisted on wharf derrick

4.2.2 Alofi wharf is only suitable for use on calm days and generally only suitable for small vessels. Alofi remains the only useable port site in the country. Currently a regular shipping service provided by Matson shipping loops from New Zealand to Niue via Fiji, Samoa, Cook Islands and Tonga on a three to four week cycle. The unloading and loading of cargo normally takes two days in good sea conditions and the vessel normally has a four day window in case of bad weather,

[30] (Shaw, 2006)
[31] (Bay Underwater Services NZ Ltd, 2014)
[32] (Applied Geoscience and Technology Division, SPC, 2014)

if the weather is unsuitable throughout this window then the cargo will not be exchanged and the vessel will depart.

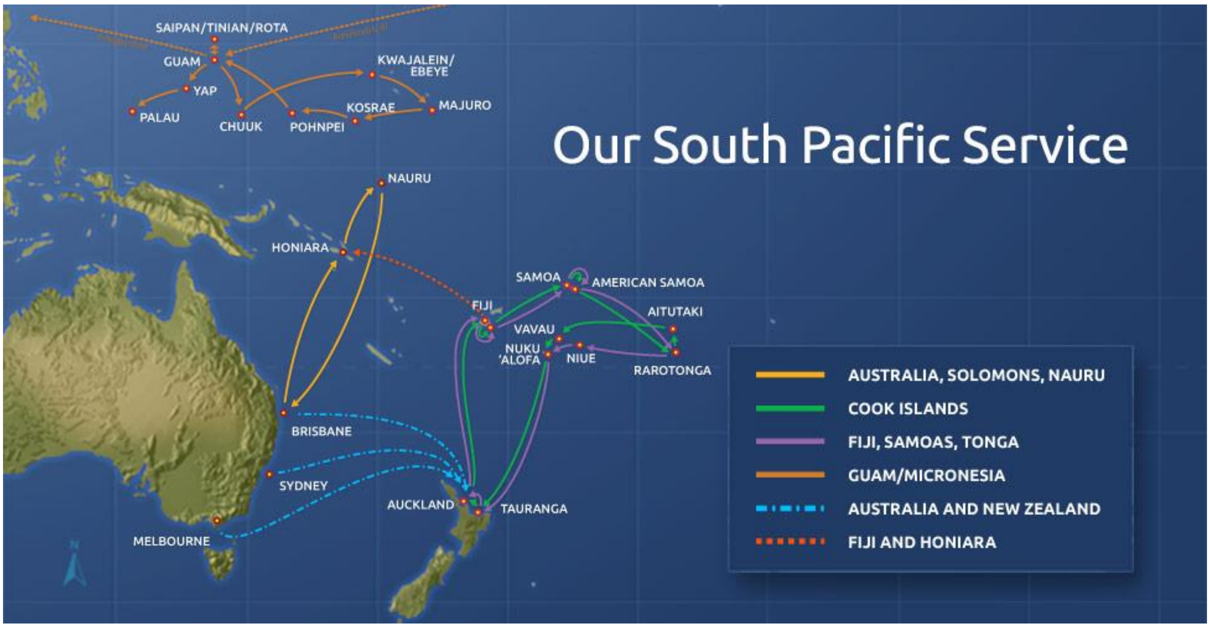

Figure 11: Matson Shipping - South Pacific loops

4.2.3 These commercial vessels do not berth at the wharf but anchor off and Mediterranean moor by long stern lines to the wharf bollards to provide stability when working cargo. Cargo is transferred to the wharf by unpowered barge towed alongside by the Niuean 13.5m search and rescue work boat *Tafehemoana II*. The barge has the capacity to carry two 18 tonne containers in one load. An electric powered derrick is permanently mounted at the wharf but cargo is worked by a 50 tonne SWL (at minimum boom length) mobile crane operated by the Government stevedore. Containers for Niue are limited to 18 tonnes to enable them to be lifted by this crane at the necessary boom reach. Niue is dependent on maritime trade through the port of Alofi. The great majority of frozen, packaged foods and manufactured as well as all building materials, machinery and fuels are imported through this wharf. Fuel supplies, including jet fuel, are imported and stored in *tanktainers* at various locations around the island (the previous storage tank in the vicinity of the wharf having been rendered unusable by storm waves).

Figure 12: *Tafehemoana II* used with 13.5 m barge for cargo transfer

Figure 13: MV *Liloa* moored at Alofi, note mobile crane on wharf preparing to launch barge

4.2.4 A small proportion of imports and exports are air-freighted on jet service to Auckland. This service operates weekly in the off season and twice weekly in the tourist season (from April to September). Its operation is entirely reliant on the fuel imported by sea.

4.2.5 Niue, being a single island has no domestic passenger ferries and no significant maritime capability. It has one government operated search and rescue workboat which is restricted to operating within 3nm of the coast and there is one domestic licenced long line fishing vessel of 10m that operates seasonally to meet local demand. Other maritime activities are limited to local fishing, whale watching and diving charters all operated from trailable runabout type boats of less than 6m length. There are also numerous traditional canoes used for local fishing.

4.3 Avatele

4.3.1 At Avatele, located 8 km south of Alofi, a small protected basin exists within the reef with a narrow channel leading to the ocean. The basin is serviced by a concrete launching ramp and a fixed arm derrick with a SWL of 2 tonnes. No commercial ship operations use this basin, but it was occasionally used in the past for transferring commercial fish catch ashore when swell precluded using Alofi. It is now primarily used by local fishermen from Avatele using both traditional fishing canoes and outboard powered vessels up to 5m. The coast off Avatele is a deep bay facing north-west with excellent protection from the south-west through south-east and east to north. This geography provides the calmest and most protected sea area on the island. However due to its relatively narrow reef a previous report concluded that “the Avatele site does not have the potential to be exploited as a large port site or even small craft harbour that has significant advantages over

Alofi, but has the potential to have some improvements to navigation safety for small runabouts and workboat / lighter when Alofi is otherwise closed".[33]

Figure 14: Avatele basin landing looking north-west

4.4 Namukulu

4.4.1 A concrete launching ramp suitable for trailable boats and traditional canoes exists at Namukulu about 8 km north of Alofi. The ramp accesses a small lagoon, protected by the reef at low water and with a very narrow opening to the sea. The ramp is used primarily for subsistence fishing and local small boat access. Due to the cliff shoreline and narrowness of the fringing reef in this area it has little potential for development.

Figure 15: Namukulu boat ramp and through reef channel

[33] (SMEC - A. Patterson, 2011, p. 19)

4.5 Beveridge Reef

4.5.1 Beveridge Reef is a horse shoe shaped coral atoll located about 120 nm south east of Niue. It is the only drying reef in Niue's EEZ. The reef has an opening on the western side and provides some shelter from the prevailing south easterly trade winds for small vessels. Under Niuean regulations Beveridge Reef is a protected area, a permit is required to visit the reef and no fishing is permitted with 3nm of the outer reef edge.

Figure 16: Beveridge Reef looking north (Source: nyc.org)

4.5.2 Beveridge Reef is considered to be an important breeding ground for the marine life that surrounds Niue and surveys and studies of the reef will be conducted by National Geographic while producing a documentary film in 2016 as part of their "Pristine Seas" programme. This aims to find evidence to support an application for recognition of a Particularly Sensitive Sea Area (PSSA) around the reef and for the reef to be managed as a marine reserve.

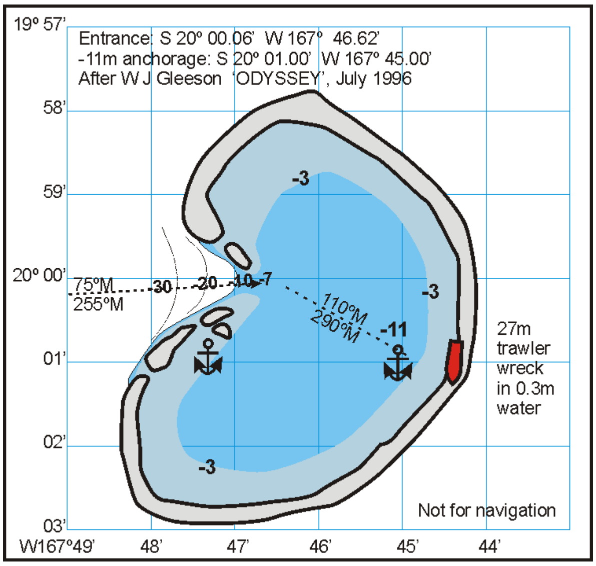

Figure 17: Yachties chartlet of Beveridge Reef (Source: www.seafriends.org.nz/niue/geo.htm

4.5.3 In Niue's national legislation fishing is prohibited with 3 nm of Beveridge Reef and some Niueans would like to see it completely closed to visits by recreational and other vessels. Nevertheless Beveridge Reef is noted as a popular location for recreational vessels. The seafriends NZ website states that "Beveridge Reef only barely extends above water, offering shelter to boats who can negotiate its 7m shallow entrance sill. The reef is rather large, about 5 x 4 nm or 9.5 x 7.5 km, about half the length and width of Niue and one quarter its area. As it is also subjected to the SE trade winds and swells, best anchorage is towards the wreck of a 27m (90ft) trawler on a course of 110º Magnetic. On this course, coral bommies leave about 6m of water above them. This anchorage provides best shelter against the SE trade winds. A good dive spot is reported just south of the entrance at the eye of the anchor symbol. Please note that this is a hand-drawn chart, not suitable for navigation, but its GPS co-ordinates are more reliable than those on present nautical charts… A latest report (2004) mentions that the trawler wreck has become invisible. Shallowest part of entrance: S 20º 00.06' W 167º 46.62'. The anchorage at 11m is at S 20º 01.00' W 167º 45.00'." [34]

[34] (Anthoni, Dr J.F. - Seafriends, 2005)

5. KEY SITES OF SIGNIFICANCE

5.1 Key sites of Environmental Significance

5.1.1 Beveridge Reef as previously noted is considered to be an important breeding ground for the marine life that surrounds Niue. Further studies of the area are planned and a proposal for international recognition as a marine reserve is planned.

5.1.2 There is currently only one official coastal marine conservation area on Niue Island, which is on the reef plateau to the north of Alofi. However it is apparent that the entire Niuean coastline is of the utmost environmental significance from both subsistence and economic perspectives. A sign at Tomb Point refers to Alofi South Marine Protected Area, of which there is no official record.

Figure 18: Signage at Tomb Point, Alofi

5.2 Key sites of Cultural Significance

5.2.1 The entire coastline of Niue and seamounts within 5km of the coastline are recognised as having cultural significance and comes under local councils' traditional management.

6. INTERNATIONAL SHIPPING TRAFFIC DATA (AIS)

6.1 Introduction

6.1.1 This section discusses the results of the traffic data analysis for Niue EEZ. Raw ship S-AIS data for the periods: January – March 2012; July – October 2013; and December 2013 – January 2014 were used for the ship traffic analysis and calculation of hydrographic risk. These are the same periods used for previous assessments of the Cook Islands and Tonga (Vanuatu used only the 2012 dataset) and were chosen to provide consistency and allow a comparative analysis. Full details of the dataset sources, method of track creation and track processing are provided in Annex B. This section provides an overview of the traffic results.

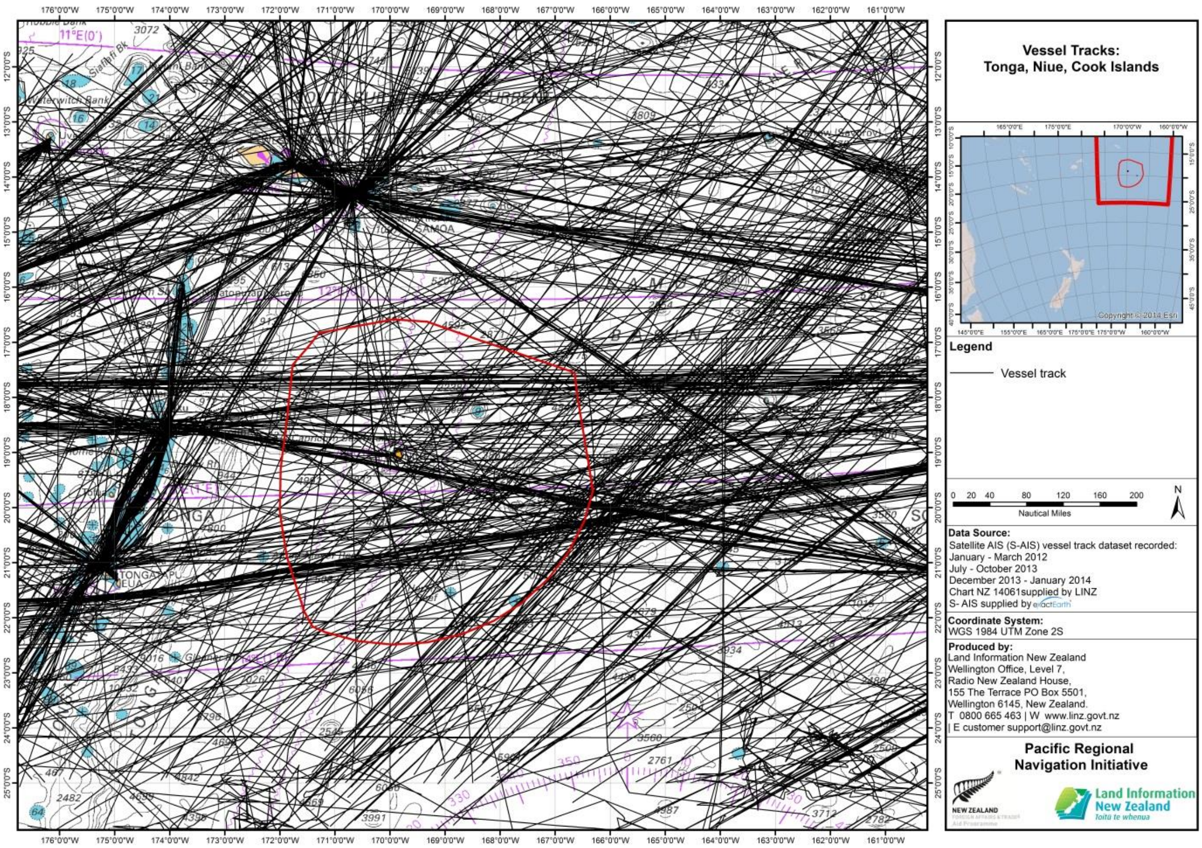

Figure 19: All vessel tracks SW Pacific region for the analysis period

6.1.2 This plot indicates that the density of traffic through Niue EEZ and particularly visiting Niue is generally less than that in the surrounding island groups.

6.2 Traffic Analysis by Vessel Type

6.2.1 While there are very few port calls to Niue itself there are a significant number of transits through the EEZ. Figure 20 depicts the total traffic through Niue EEZ during the assessment period colour coded for vessel type.

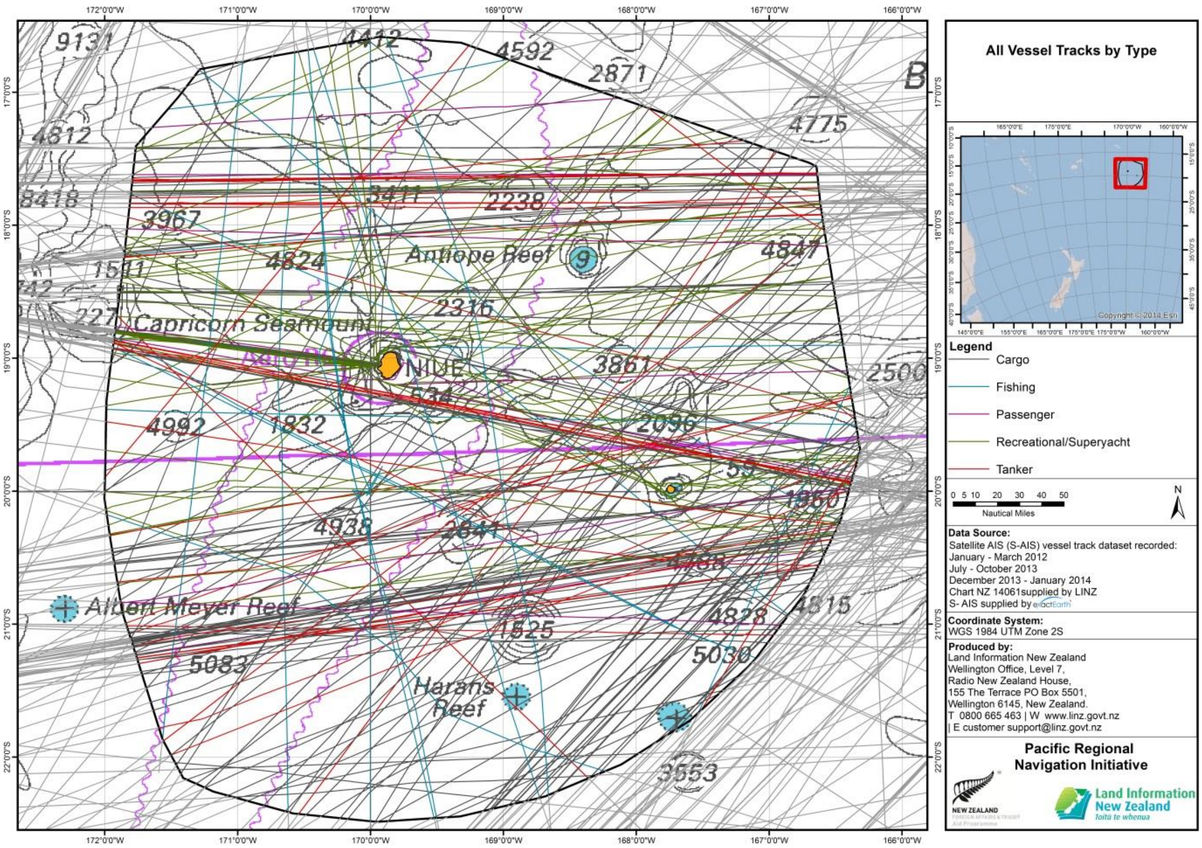

Figure 20: All vessel tracks across Niue EEZ, colour coded by type

6.2.2 As can be seen from the legend in the plot, the vessels are classified in 5 classes

- Dry cargo;
- Fishing/research;
- Passenger;
- Recreational/superyacht; and
- Tankers

Note: there are no AIS fitted domestic vessels in Niue and the only other vessel type was research vessel, which were combined with fishing vessel in this analysis.

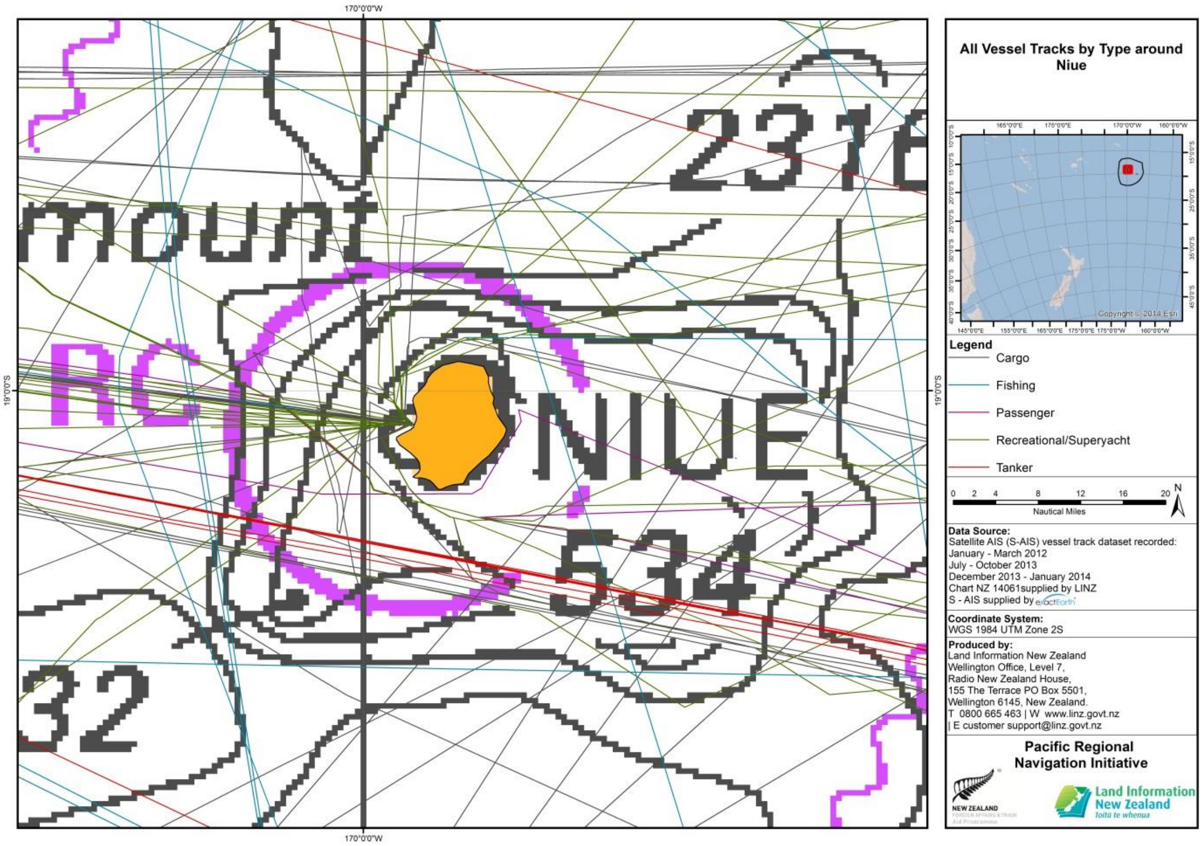

Figure 21: All vessel tracks near Niue, colour coded by type

6.2.3 From Figure 21 it is apparent that AIS fitted recreational vessels present the largest number of calls to Niue while tanker vessels make up a large proportion of the traffic transiting the EEZ on set routes, cargo vessels tend to crisscross the area, and there are occasional fishing vessels and only two passenger vessels visiting Niue during the period (this number increased to five in 2015).

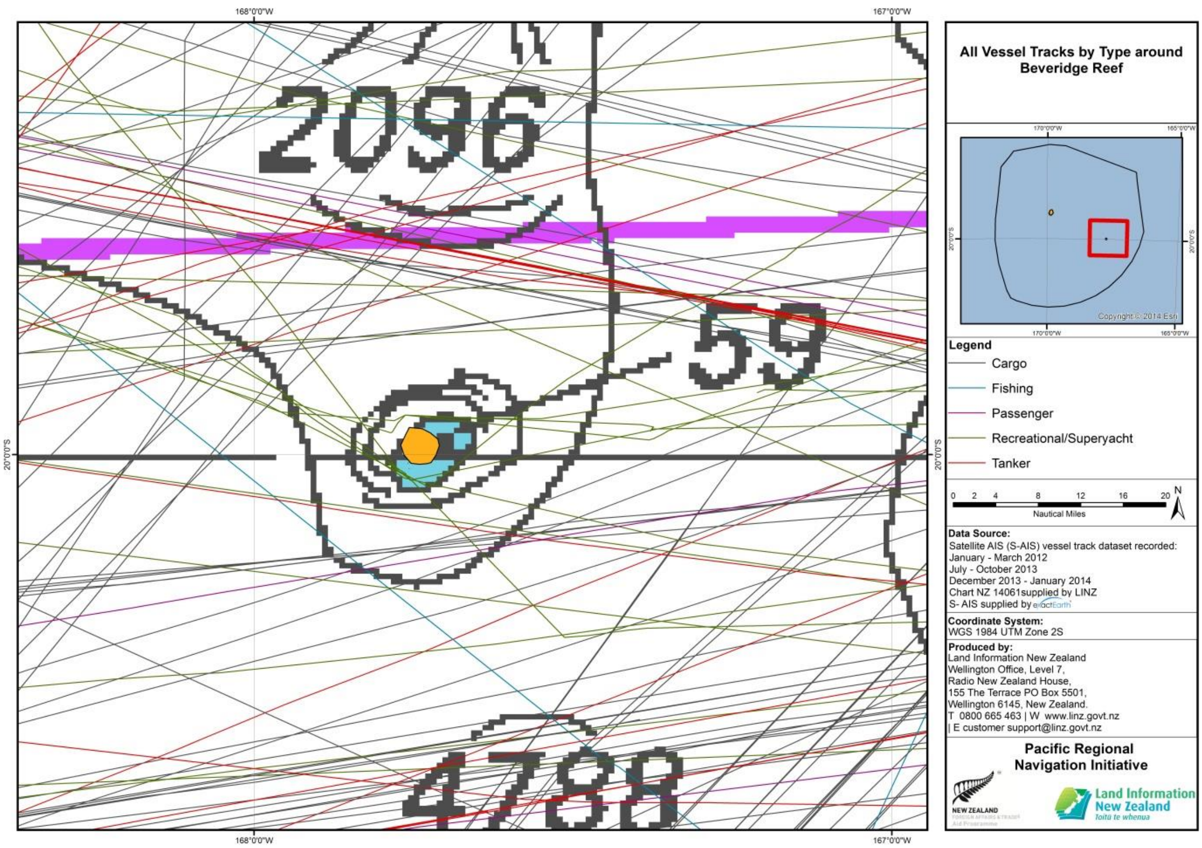

Figure 22: All vessel tracks near Beveridge Reef, colour coded by type

6.2.4 In the vicinity of Beveridge Reef most traffic avoids the reef by at least 5 nm however there are a number of close visits by recreational vessels.

6.2.5 Individual plots of each vessel type are at Figures 23-27.

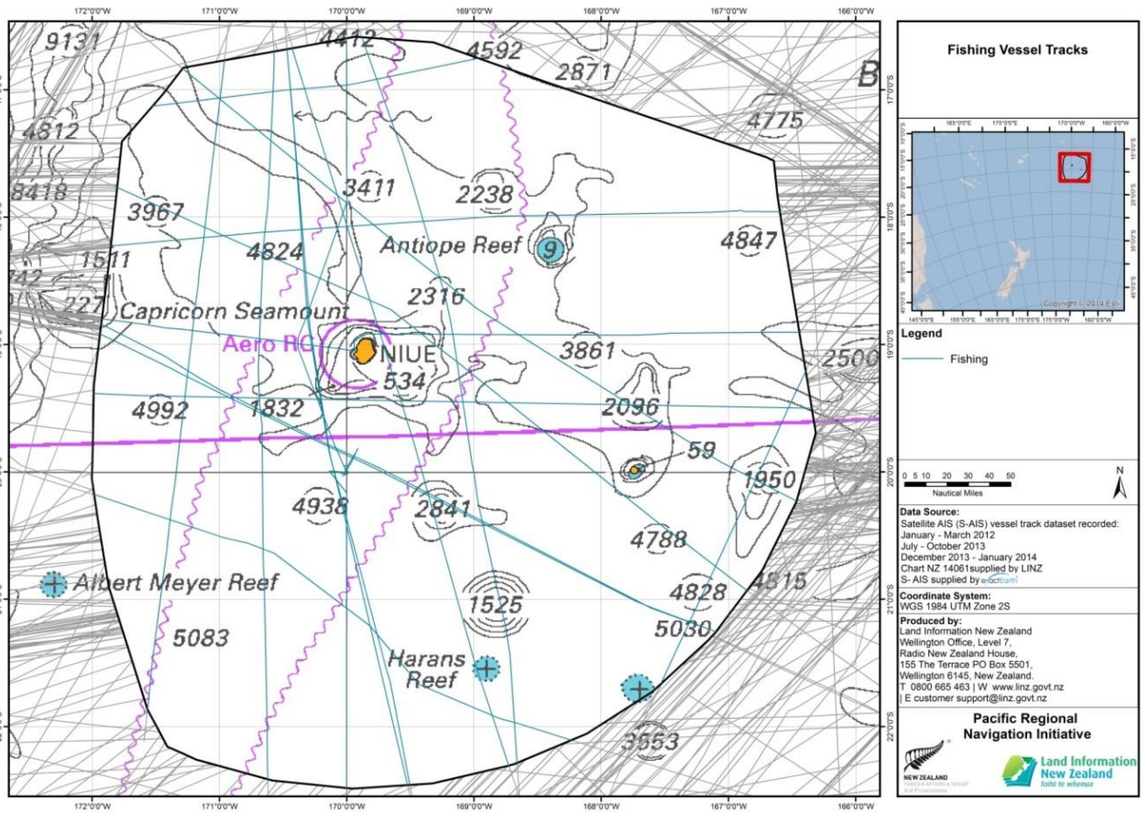

Figure 23: Fishing and research vessel tracks

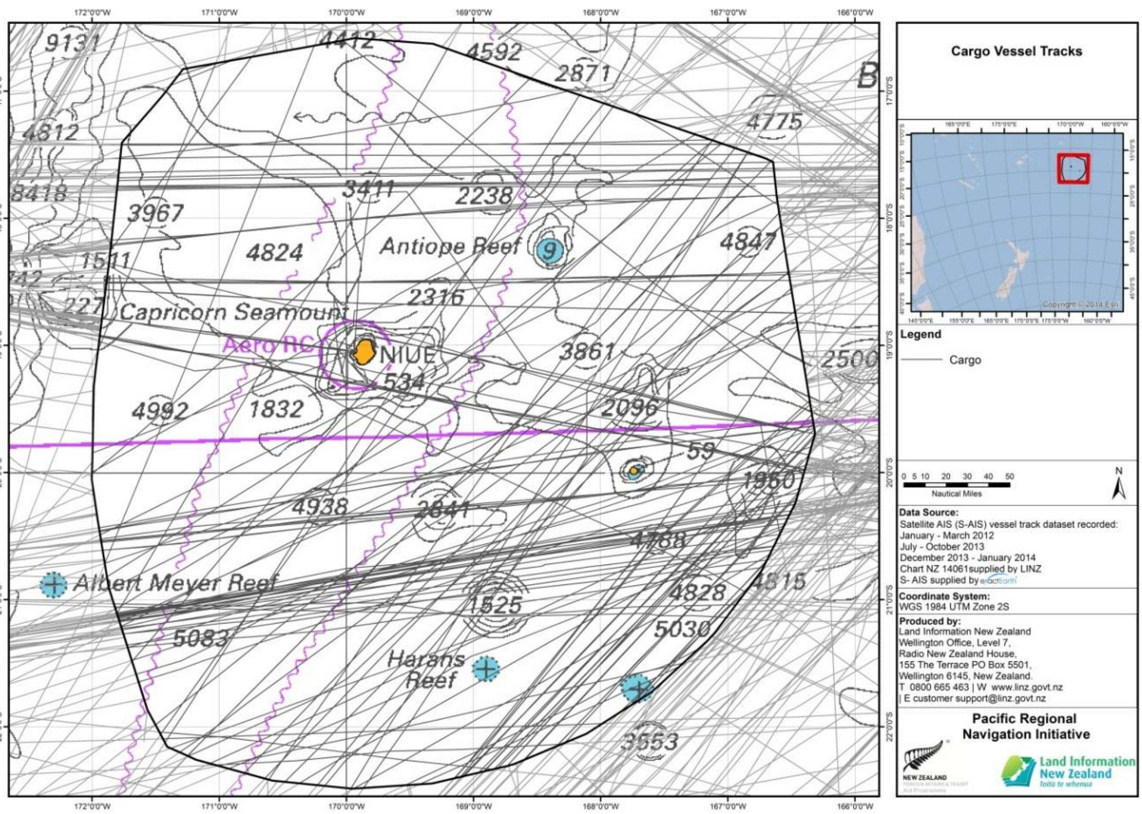

Figure 24: Cargo vessel tracks

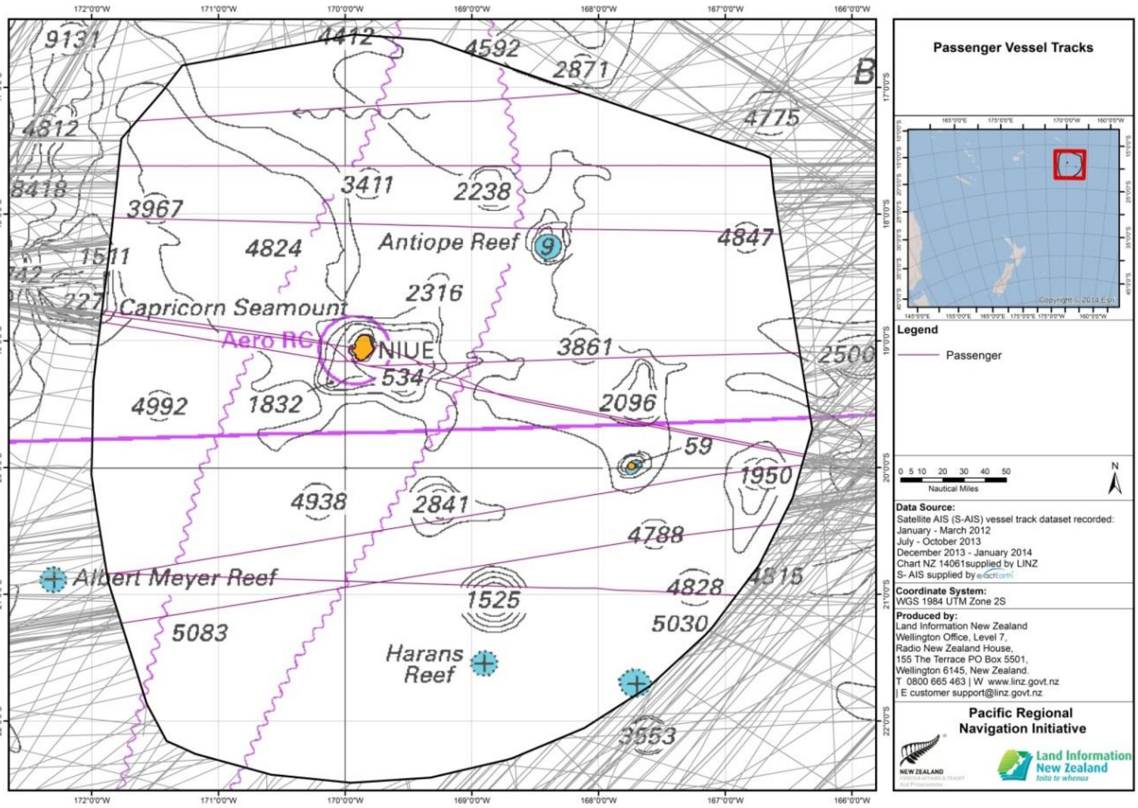

Figure 25: Passenger vessel tracks

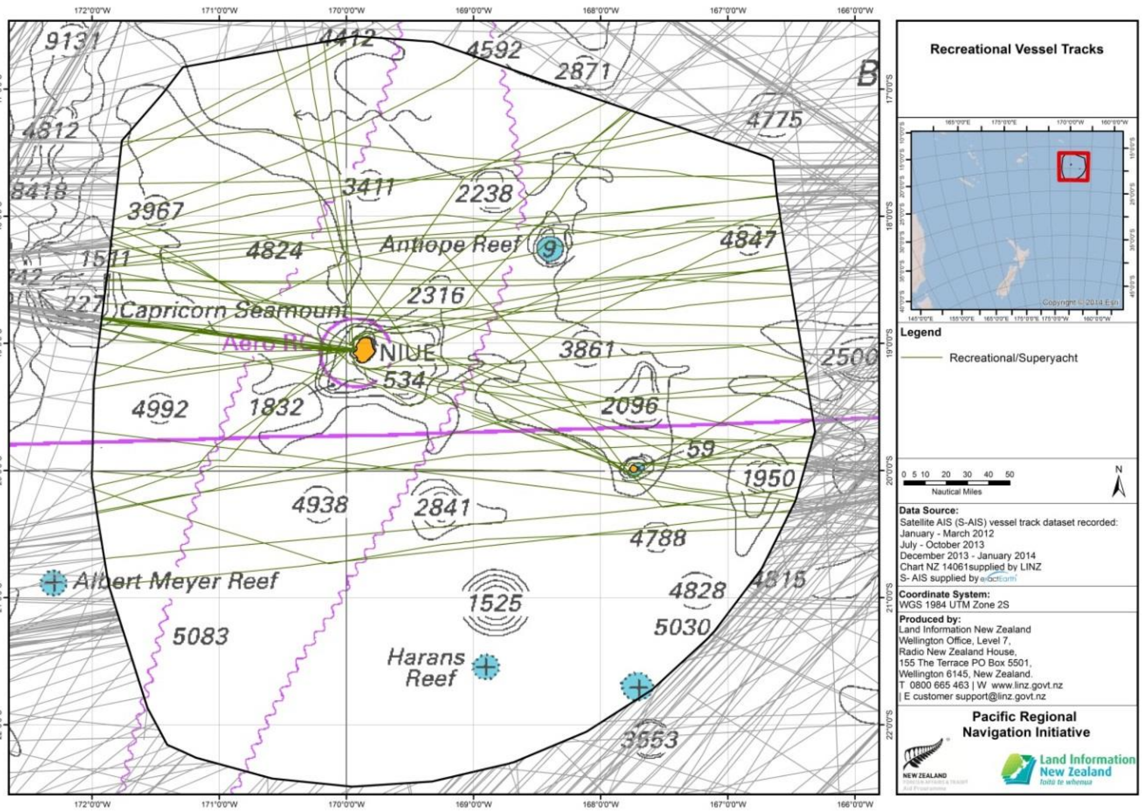

Figure 26: Recreational vessel / Superyacht tracks

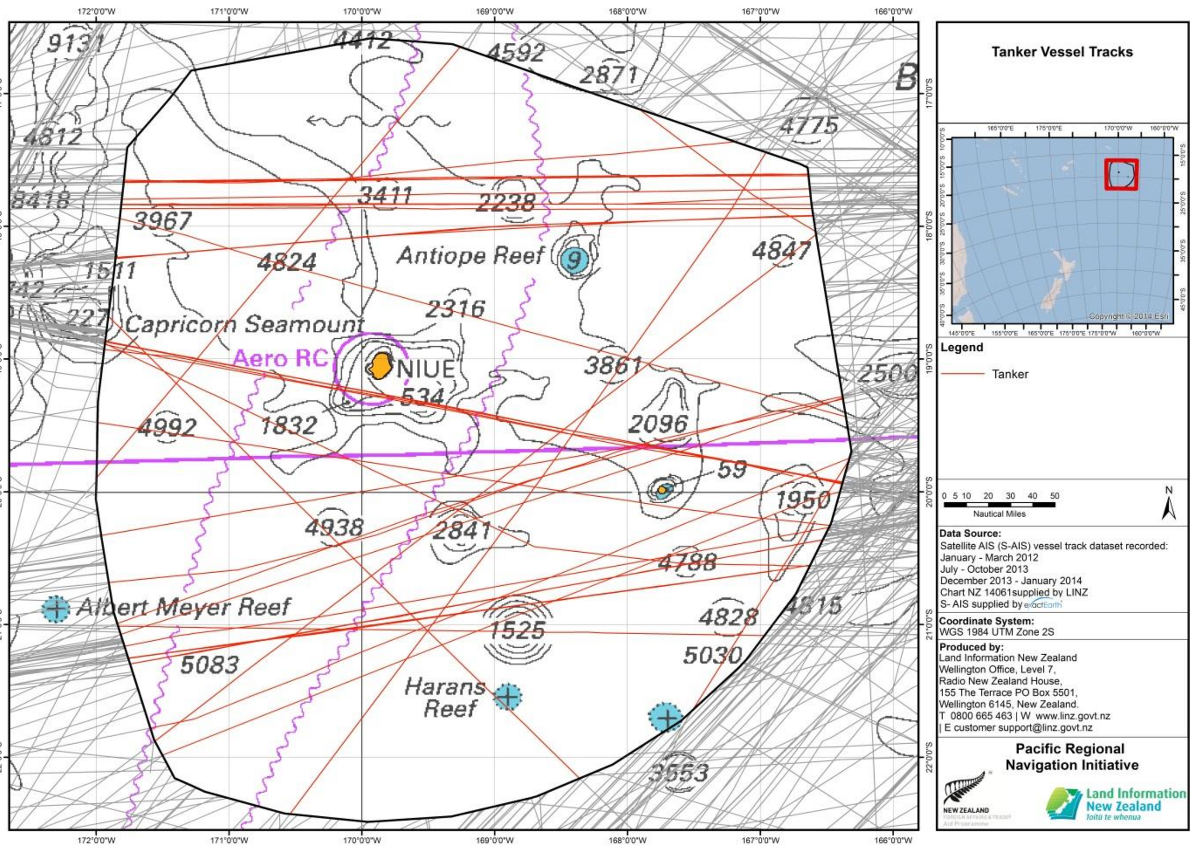

Figure 27: Tanker vessel tracks

6.3 Traffic Analysis by Attribute

6.3.1 In addition to vessel type, from a risk perspective it is informative to consider the draught, length and GT of vessels in particular categories. From the following Figures 28-30 the deepest, longest and largest GT tracks align consistently with the tanker traffic. The larger ships cross the EEZ on predictable and repeated tracks, but none of them call at Niue. Whereas the smaller vessels seem to transit in all directions as they make their way to more numerous and more dispersed ports of call, some calling at Niue. The shallower, shorter and lighter vessels align with the tracks of recreational vessels.

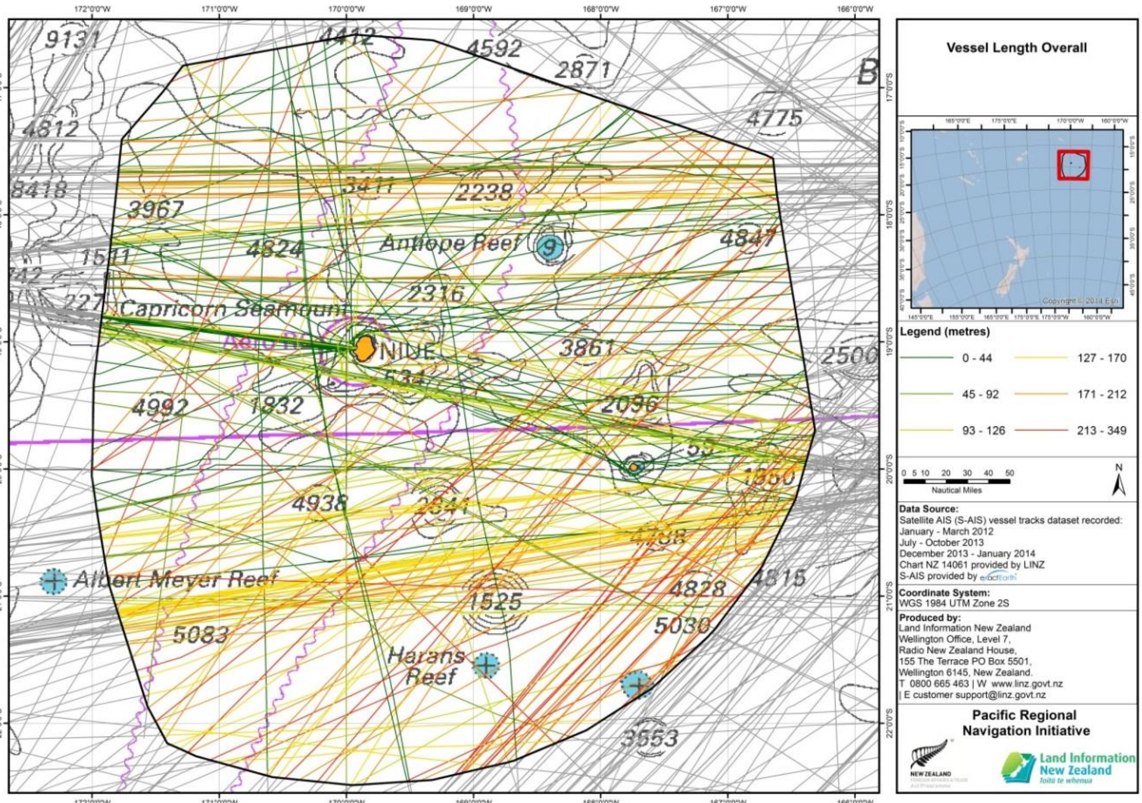

Figure 28: Vessel tracks colour coded by vessel length

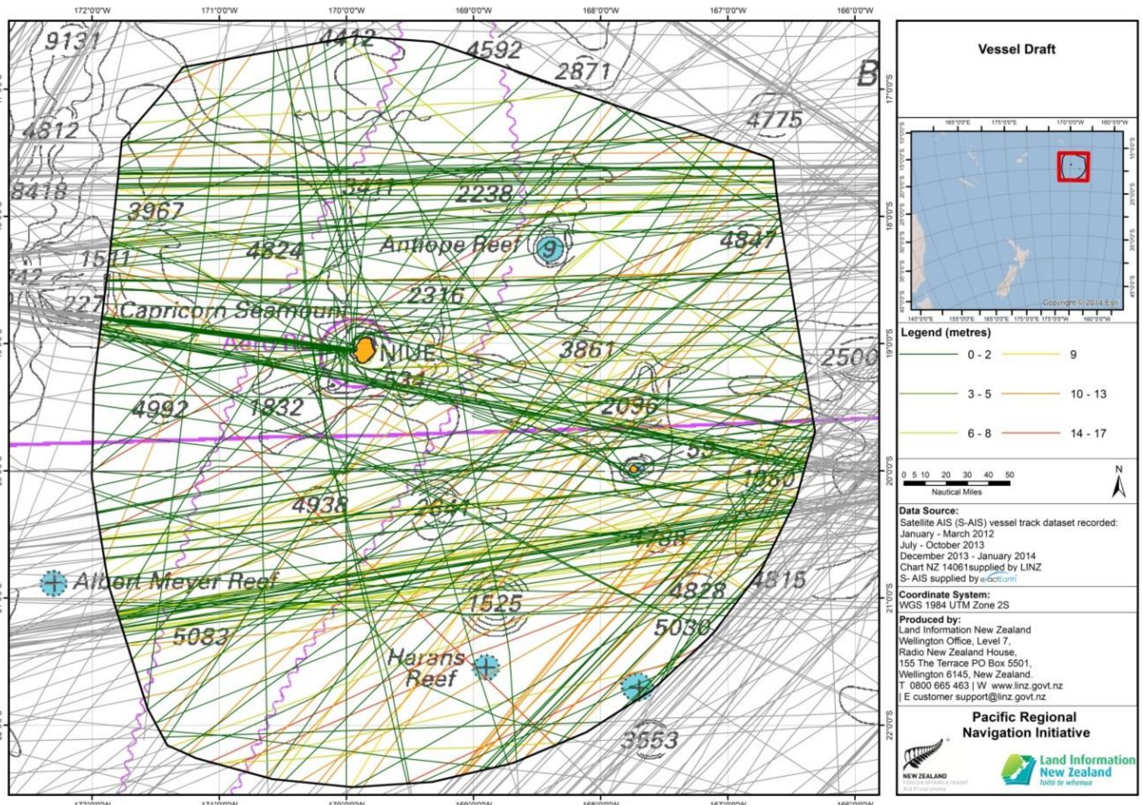

Figure 29: Vessel tracks colour coded by vessel draught

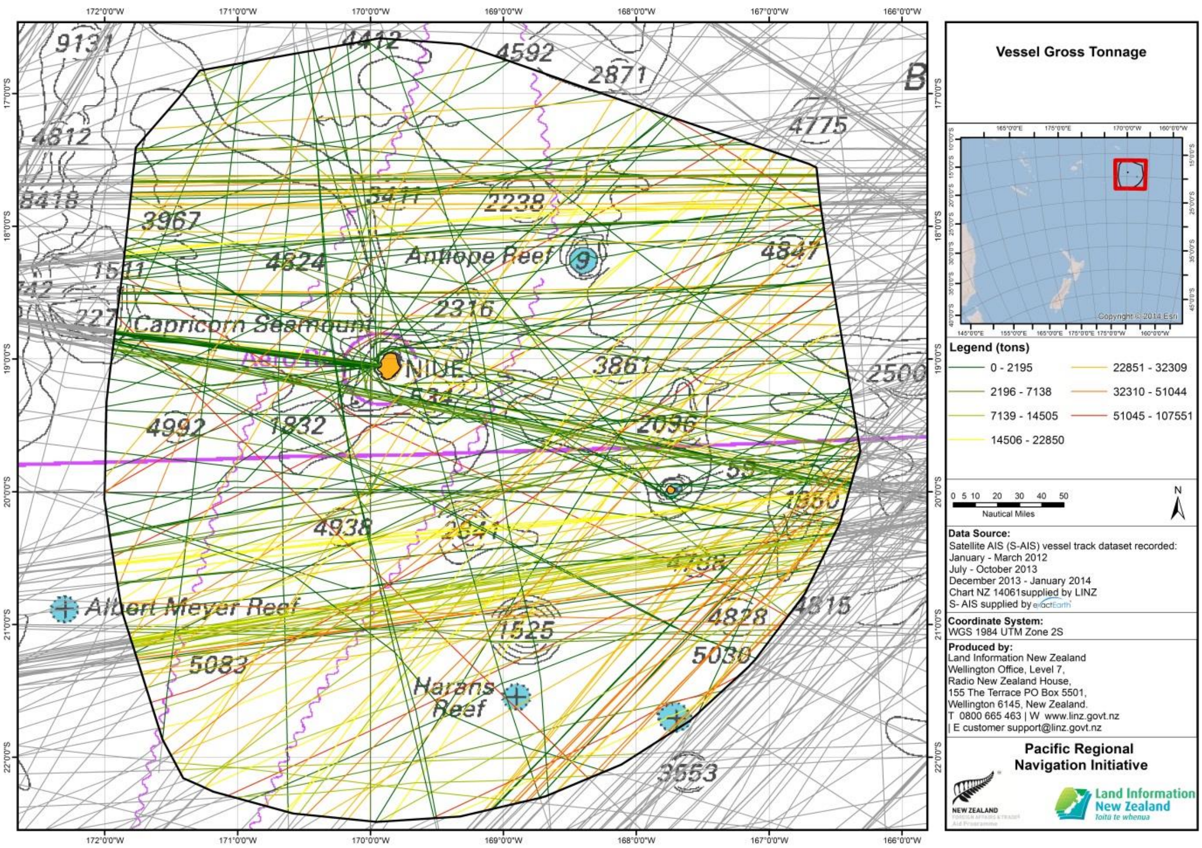

Figure 30: Vessel tracks colour coded by vessel GT

6.4 Conclusion - International Shipping Traffic Data (AIS)

6.4.1 There are only a small number of port calls to Niue despite a substantial amount of shipping traffic passing through Niue EEZ. The largest vessels in the EEZ are tankers and dry cargo vessels exceeding 50,000 GT which transit the area on regular, repeated routes and remain more than 7nm from any charted land or reef. One such east- west tanker route passes about 7nm south of Niue Island.

6.4.2 The majority of vessels calling at Niue and the only vessels calling at Beveridge Reef are classified as recreational or superyachts. In addition, a small cargo vessel calls at Niue regularly for routine island resupply and trade. Occasionally passenger vessels call at Niue (this frequency is reported to be increasing) and on one occasion a very large passenger vessel (30,000 GT approx.) tracked close to the south and east coasts of Niue.

7. RISK ANALYSIS RESULT

7.1 Introduction

7.1.1 This section presents the overall risk results for Niue EEZ, including the two significant areas of Niue Island and Beveridge Reef. Section 7.2 displays the "in country" results, discusses the major contributors to those results and highlights the sensitivity of results to changes in ship traffic and hydrographic charting quality. Section 7.5 then displays and discusses the regional risk results comparative to the previous analyses of Tonga and the Cook Islands.

7.1.2 The details of calculation of the hydrographic risk are provided in Annex F. The visual representation of risk is divided into colour bands ranging through: none, insignificant, low, moderate, heightened and significant.

7.1.3 **Heat map interpretation**. It is reiterated here that the use of Jenks Natural Breaks to allocate the colour mapping for the final "in country" risk plots has the effect of converting the risk results into a relative risk heat map across the Niue study area. This is because this method will represent the lowest risk as *insignificant* (green) and the highest risk as *significant* (red), across the numerical range of calculated risk values. This effect was observed to limit the risk rating in lower traffic areas within the Tonga risk assessment[35]. In that assessment, relative differences in traffic density between the different island groups had the effect of showing less risk in some poorly charted areas that did in fact have regular traffic flows and would substantially benefit from charting improvements. The hydrographic risk in such areas was not as high as in other higher traffic areas where the charting was of a better standard.

7.1.4 Within the Niue EEZ the same distortion occurs when comparing the relative risk near Niue with that near Beveridge Reef (see Figure 31) as the only vessels to visit Beveridge Reef (or even to pass within 5nm of it) are recreational vessels of very low GT.

7.1.5 **Numerical risk results**. The numerical risk results are influenced by the risk factor weightings. These are explained and provided in Annex E. The generic low traffic risk factor weighting matrix was developed by LINZ/Marico Marine[36] for the previous regional South West Pacific risk analyses and is used for the comparative analysis in section 7.5. These risk factor weightings were slightly modified for the Niue "in country" assessment, by removing risk and consequence factors that are not present and redistributing their weights to other factors (see full explanation in Annex E). The "in country" risk results thus obtained are considered to be more representative of the relative hydrographic risk across the Niue EEZ.

[35] (Marico Marine Report No. 14NZ262 – TM, Issue 1, 27 November 2014, pp. 96-98)
[36] (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015, p. D2)

7.2 Niue "In Country" Risk Overview

7.2.1 The overview of the Niue EEZ hydrographic risk colour map, using the Niue local risk factor weightings is shown below. The "in country" colour band classification uses break values calculated only from the study area data, thus ensuring that the full colour range is utilised in the heat map. The majority of the Niue EEZ appears as *insignificant* risk. There are areas of *significant* and *heightened* risk in the vicinity of Niue Island. The risk in the vicinity of Beveridge Reef is *insignificant* to *moderate*. These areas are described in more detail in section 7.3 and 7.4 below.

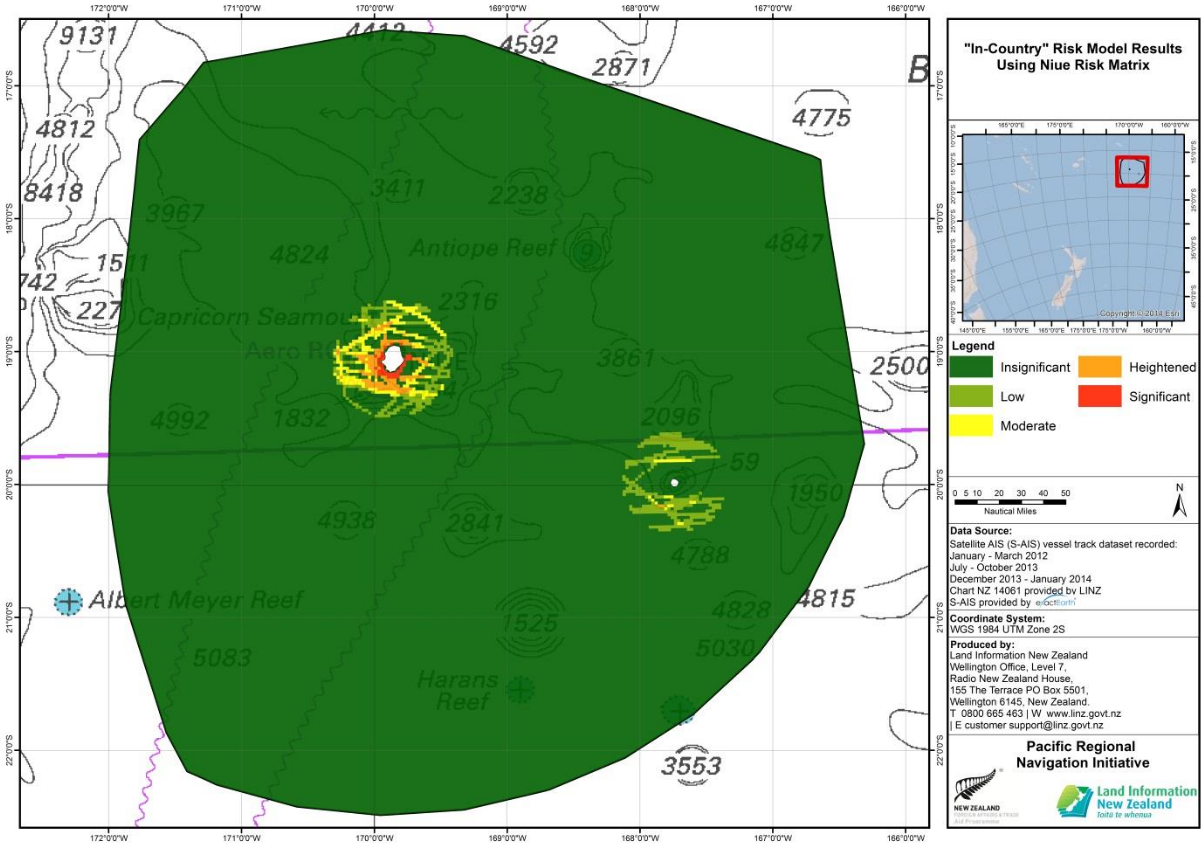

Figure 31: Niue "in country" risk result - Niue risk matrix

7.2.2 To test the impact of using the Niue local risk factor weightings, the heat map below has been produced using the regional SW Pacific low traffic area risk weightings[37].

[37] The SW Pacific low traffic area risk weightings were developed for LINZ as those most relevant to the regional hydrographic risk assessment programme (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015, p. D2)

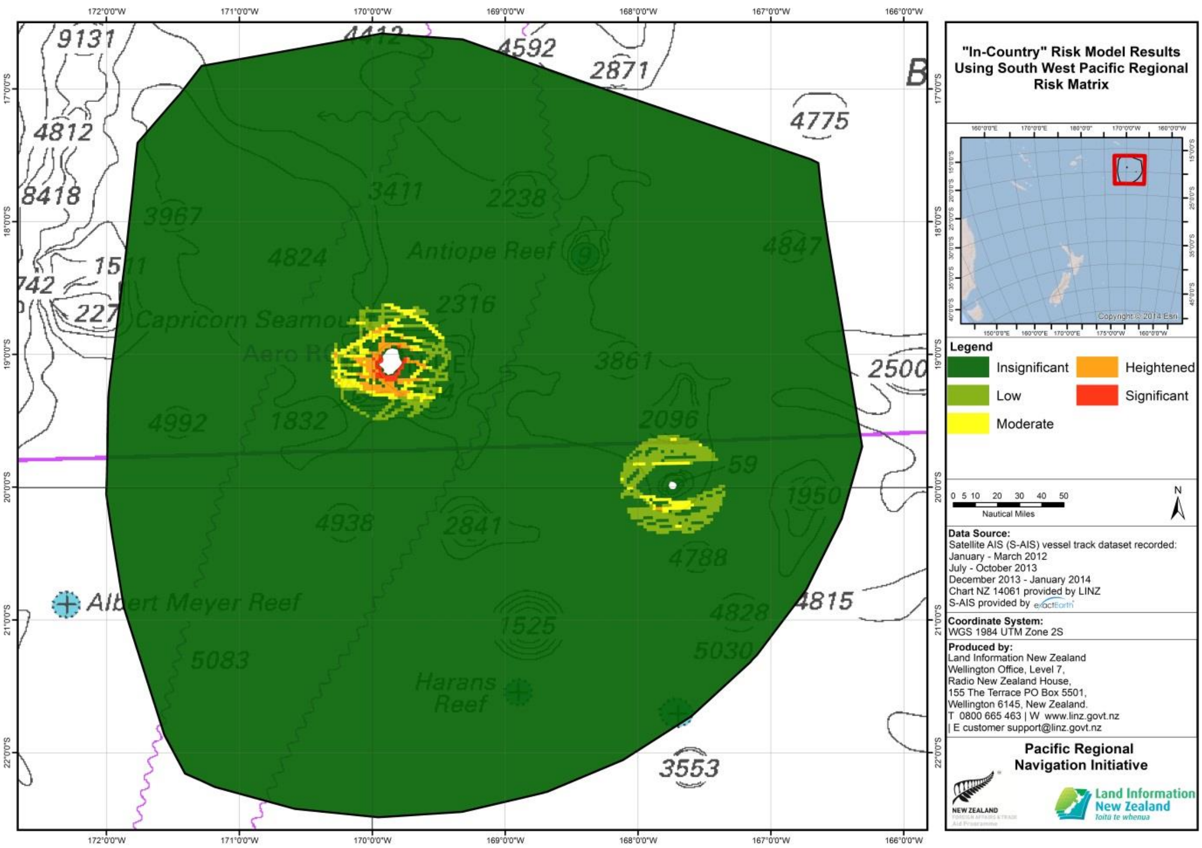

Figure 32: Niue "in country" risk result - Regional SW Pacific risk weightings

7.2.3 While Figure 32 looks identical to Figure 31 (due to the automatic colour banding using the Jenks natural breaks) the absolute risk values have actually more than doubled due to the different risk weighting matrix used. This can be seen in the comparison of the numeric colour band legend values below. Having now highlighted this fact, it can be safely set aside as the results of the "in country" assessment are only meaningful relative to Niue. Additionally, all "in country" heat maps are created using the Niue local risk weightings.

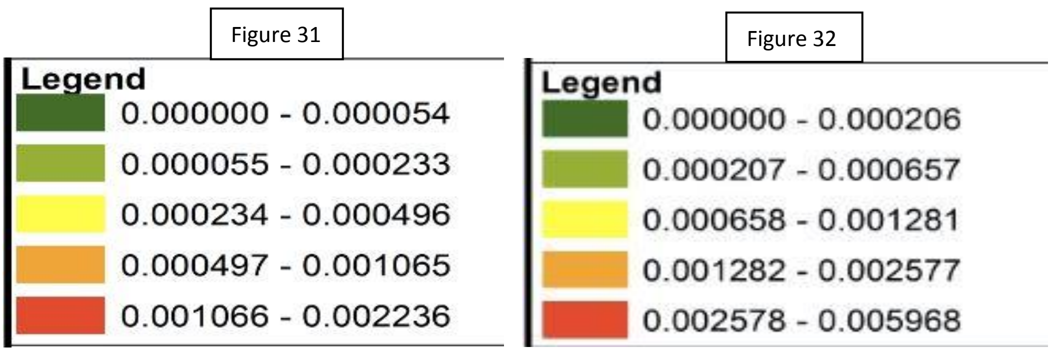

Figure 33: Niue Risk colour bands - regional SW Pacific risk weightings (left), local Niue risk weightings (right)

7.2.4 The clear observation from Figures 31 and 32 is that there is no appreciable hydrographic risk throughout the EEZ except for in the vicinity of Niue Island and Beveridge Reef.

7.3 Niue Island Hydrographic Risk

7.3.1 The hydrographic risk profile of Niue Island is shown in Figure 34. These results look reasonable with generally higher risk on the western side of the island where there is the greatest concentration of vessel traffic and to the south of the Island where large tankers routinely pass 7nm from the island on the weather side, creating some risk to Niue.

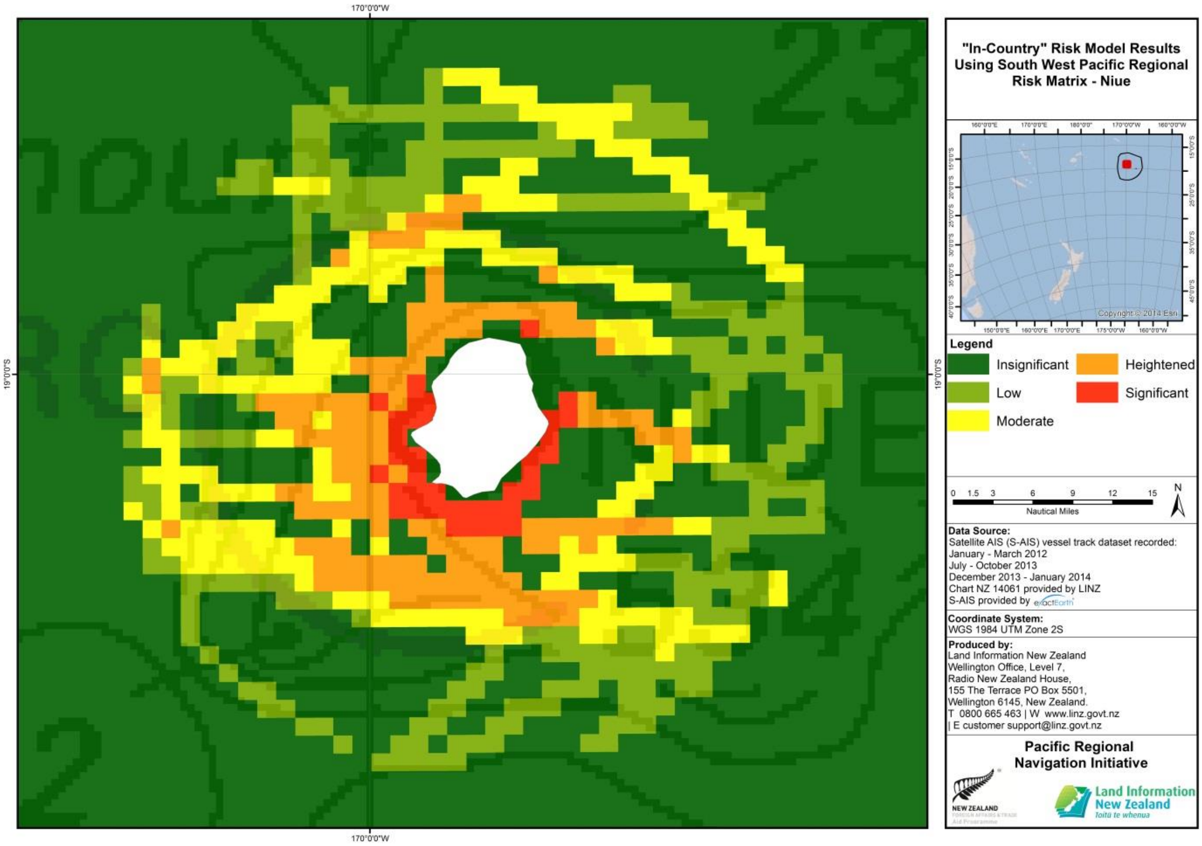

Figure 34: Niue Island risk heat map – regional SW Pacific risk weightings

7.3.2 The *significant* risk areas on the west coast are attributable to a relatively high traffic count of small vessels on the approaches to and in the vicinity of the port of Alofi, a visit by a large cruise ship and the consequence risk value of the coastline and areas with 3 km to seaward of the west coast which are of cultural and economic value for subsistence fishing, whale watching/tourism, and the proximity to the port which is the main centre of infrastructure and a cruise ship destination. On investigation, the significant risk area on the south and south-east coast is found to be attributable a single transit of a 30,000 GT passenger vessel. This fact evidences the low traffic nature of this risk model result by highlighting the sensitivity of the model to one ship of moderate GT.

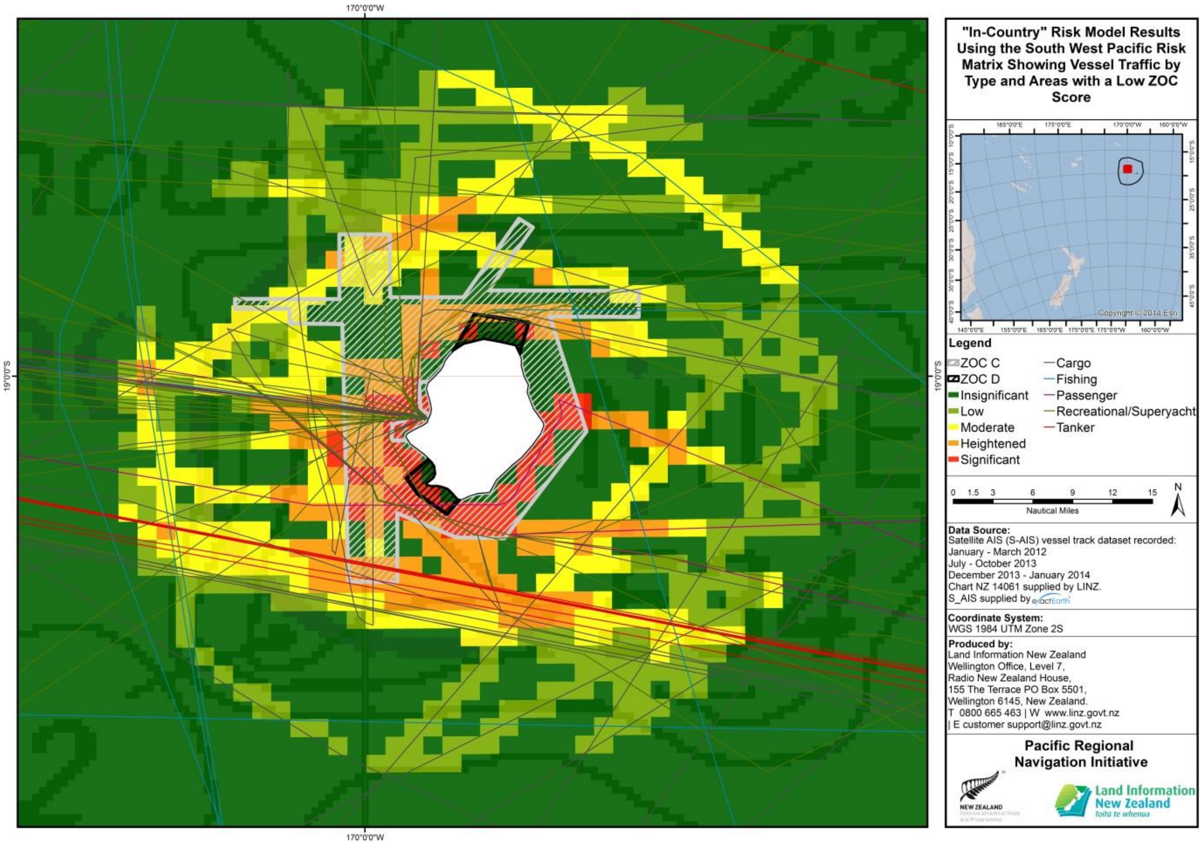

Figure 35: Risk, traffic and Chart ZOC compilation – Niue Island

7.3.3 The details of this traffic are shown in on the above figure, overlaid on both the risk result and shaded areas showing the chart CATZOC category. This plot clearly shows the tanker route passing south of Niue, the concentration of small vessel traffic in the vicinity of Alofi and various other large vessel tracks that have influenced the risk calculation. It can be seen that the *significant* (red) risk areas fall within CATZOC C and D areas, which are generally considered to be inadequately surveyed, particularly if the water is shallow.

7.3.4 To test the model sensitivity and reaction to improved chart CATZOC the risk analysis was repeated changing the CATZOC C areas to the highest quality CATZOC A. The results in Figure 36 should be compared with Figures 34 and 35. The improvement in CATZOC has reduced the extent of red area on the south-west and west of Niue and the isolated red cell to the north has been removed.

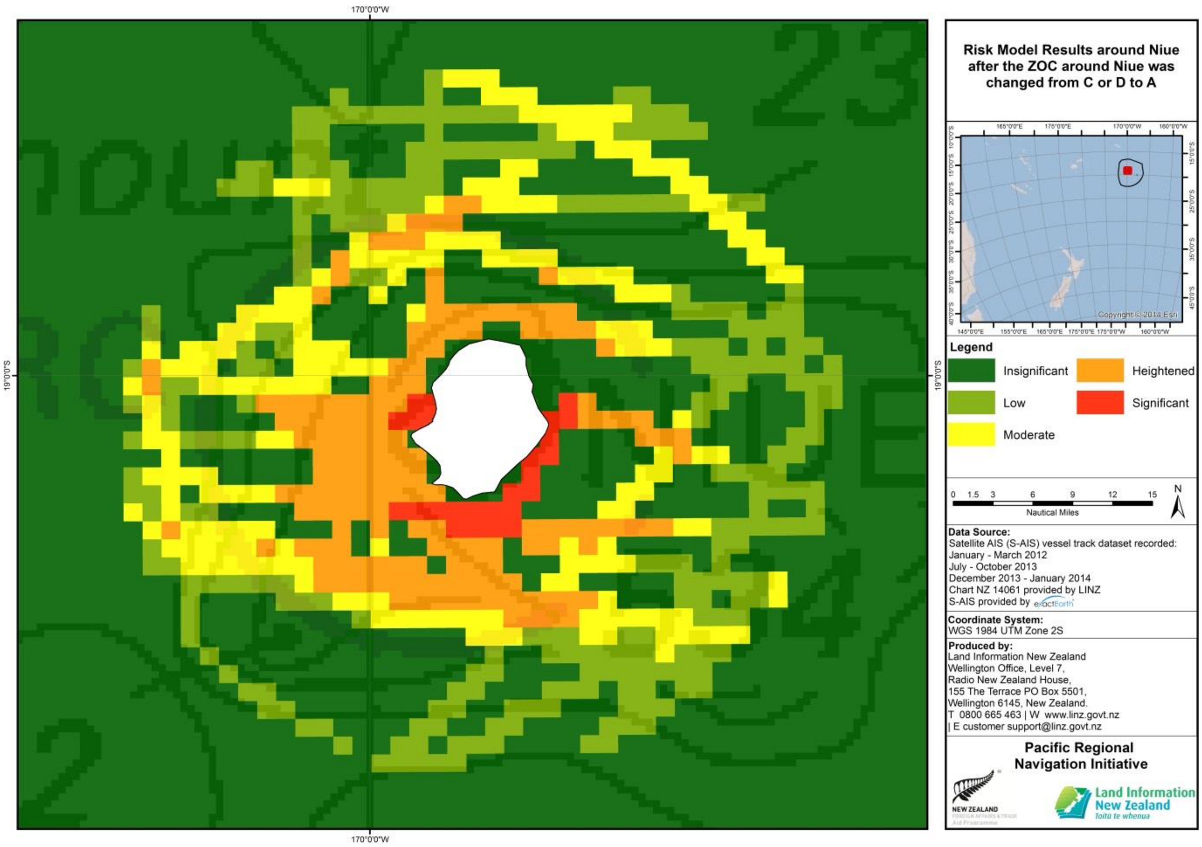

Figure 36: Theoretical risk reduction by upgrading CATZOC C areas to CATZOC A

7.3.5 However, in this case the improvement of CATZOC is a theoretical rather than a practical risk reduction strategy. The seabed topography of Niue is deep up to the coastline and vessels are not draught constrained; they would ground on the coastal reef before they touched the seabed so greater accuracy in depth measurement is not as crucial as the accurate positioning of features.

7.3.6 The large scale chart of Niue (NZ845) suffers from other shortcomings more likely to influence vessel safety, notably: a lack of landfall lights in any direction making approaching or passing the island at night dangerous, and the limited extent of the Alofi port approach plan which is insufficient for managing the regular recreational vessel visits and which limits accurate navigation when approaching Alofi from the north or the south. There are also 13 unlit FADs in the vicinity of Niue only two of which are charted; the remainder constitute a danger to navigation.

7.4 Beveridge Reef Hydrographic Risk

7.4.1 The hydrographic risk profile of Beveridge Reef is shown in Figure 37. The risk in the vicinity of the reef itself is *insignificant*. The moderate risk tracks which show approximately 4-5nm to the north and south of the reef coincide with regular trading routes for large vessels. Despite this low risk profile there is reported to be submerged evidence of previous wrecks on Beveridge reef. The risk outcome in this area is driven by vessel traffic in proximity to a large reef of significant environmental value. The charted CATZOC in this area is D, and there is no large scale chart of Beveridge Reef, however, evidence of vessel tracks confirms that the position of the reef is correctly charted.

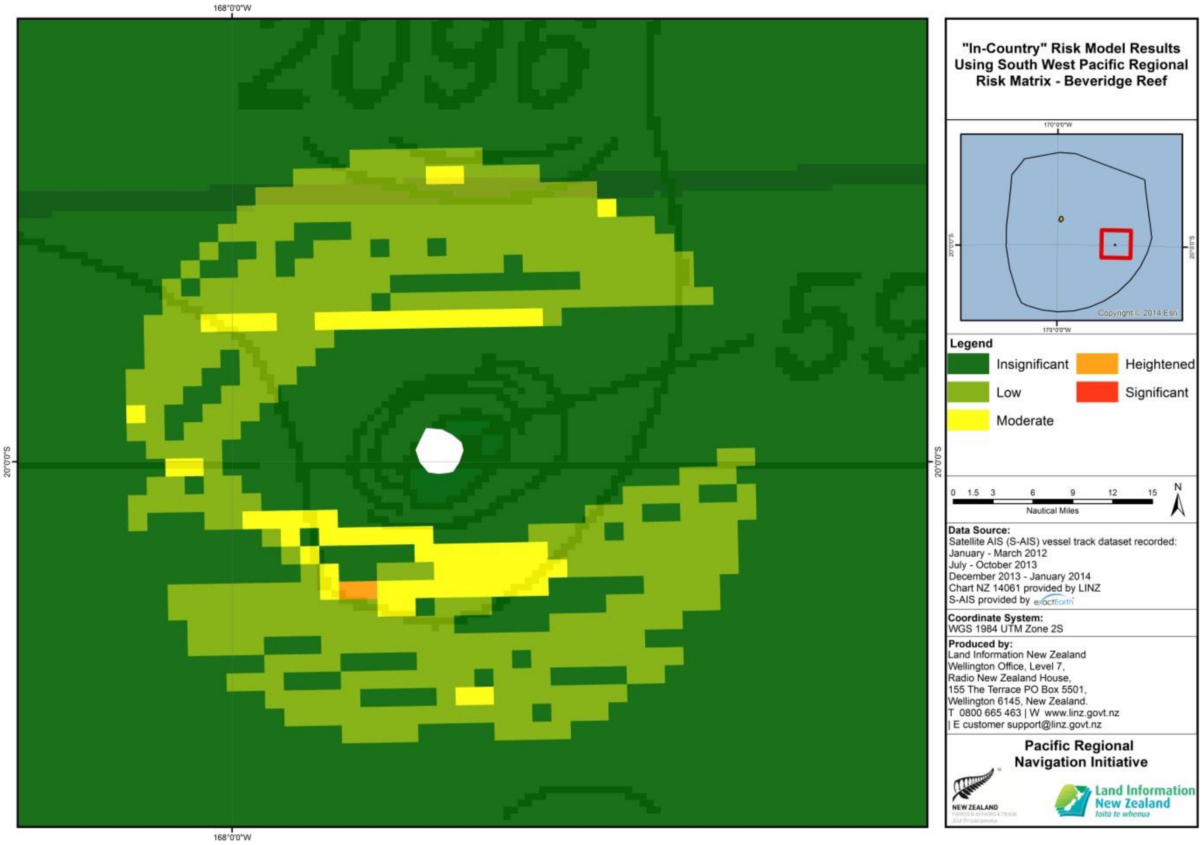

Figure 37: Beveridge Reef risk heat map - SW Pacific risk weightings

7.5 "Regional" Risk Assessment

7.5.1 In order to compare the results of this assessment with those of the other regional South West Pacific hydrographic risk assessments, a further heat map was produced using the regional South West Pacific low traffic risk matrix and the same risk colour band break values as those in the Tonga, Cook Islands and Vanuatu risk assessments. The result seen in the Figure below shows the entire Niue EEZ has comparatively *insignificant* risk – an unsurprising result given the substantially lower traffic levels in the vicinity of land or reefs in the Niue analysis.

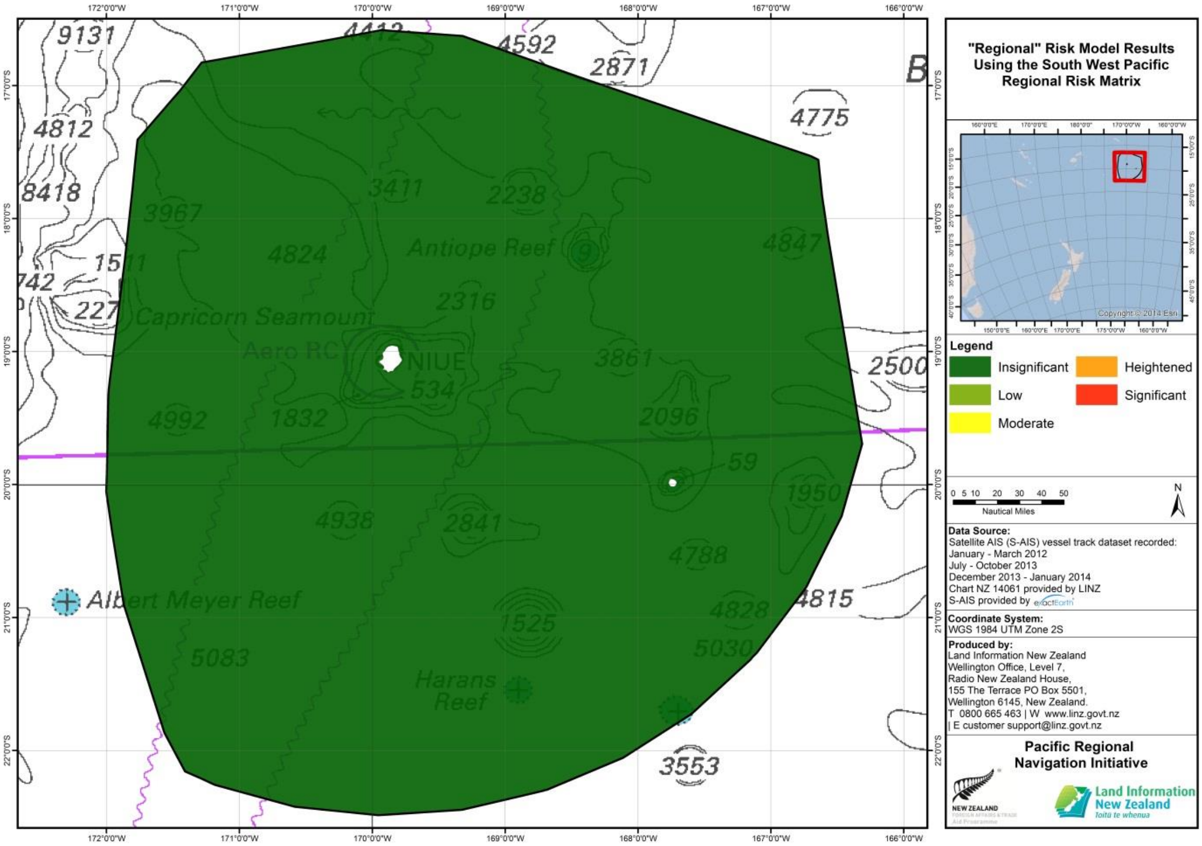

Figure 38: Niue "Regional" Risk Result - calibrated to regional SW pacific risk colour bands

7.6 Chart Improvement Recommendations – Niue Island

7.6.1 In Figure 39 we see the existing nautical chart NZ845 of Niue overlaid with vessel tracks and the specified locations of 13 FADs. These FADs are not lit and only two are currently charted, thus the remainder present a danger to navigation. Local advice is that these FADS are not always in their designated locations as they sometimes break free during storms or cyclones and have to be replaced at a later date. However, it is much safer to have their positions marked on the chart so that vessels will be aware of their locations, and Notices to Mariners can advise when a FAD is temporarily removed.

7.6.2 It is noted that there are no conspicuous fixing marks on the island and the only lights are the leading lights to Alofi Wharf (nominal range 5nm), and one lit Aero beacon at the airport which only has limited visibility because of the height of the island. Additional lights should be considered on communication towers and their positions and characteristics added to the chart.

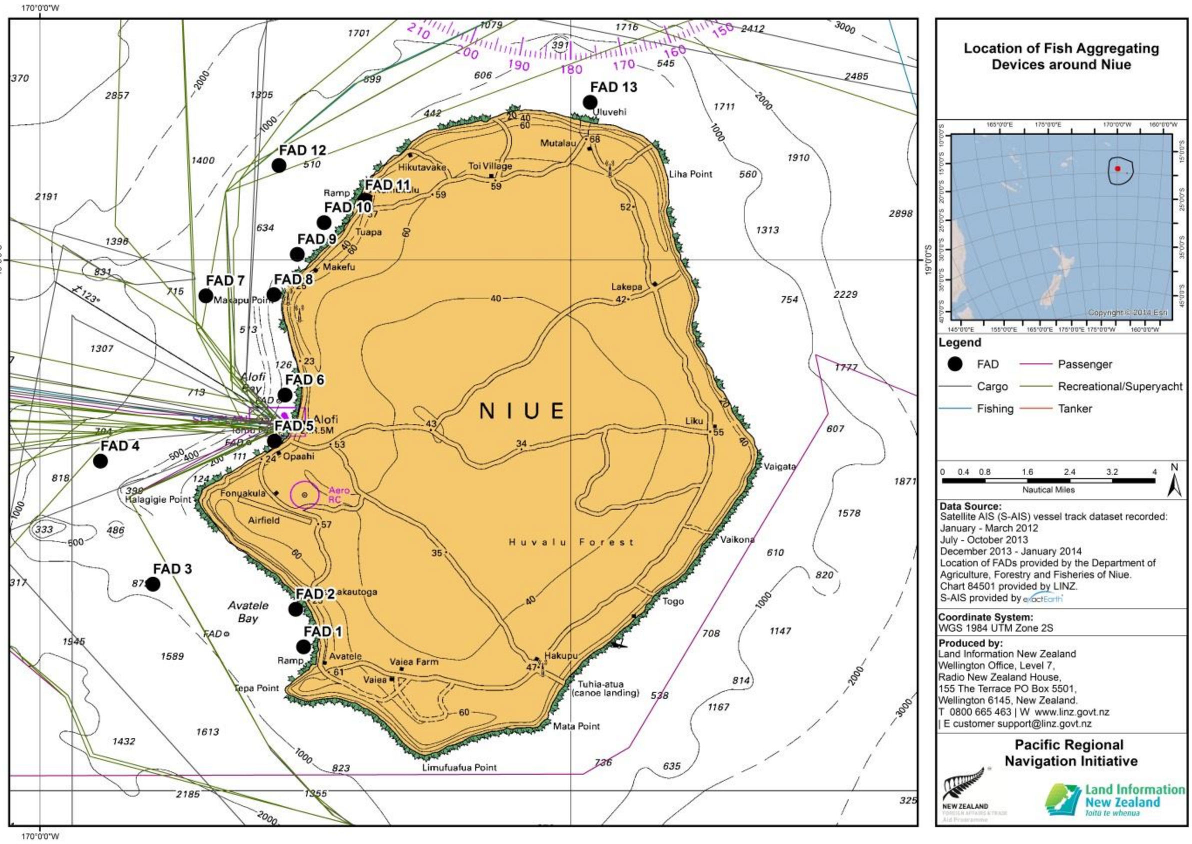

Figure 39: Chart NZ 845 with overlaid vessel tracks and FAD positions

7.6.3 Chart NZ845 also contains two plans. A portion of the Alofi Anchorage plan (scale 1:6,000) is shown below, overlaid with Niue Yacht Club seasonal moorings and vessel tracks. A re-scheme of this plan, extended half a mile to the south, should be considered to encompass the seasonal yacht moorings and enable safe management of the entire anchorage. The scale of the plot could be reduced to 1:10,000 to accommodate the greater extent without adversely impacting the amenity of the plan. The plan of Alofi Landing (scale 1:1,000) is too large a scale and too small an extent to be useful to the regular cargo re-supply ship, so consideration should be given, in consultation with the cargo vessel master, to reducing the scale and increasing the extent of this plan to support safe cargo operations.

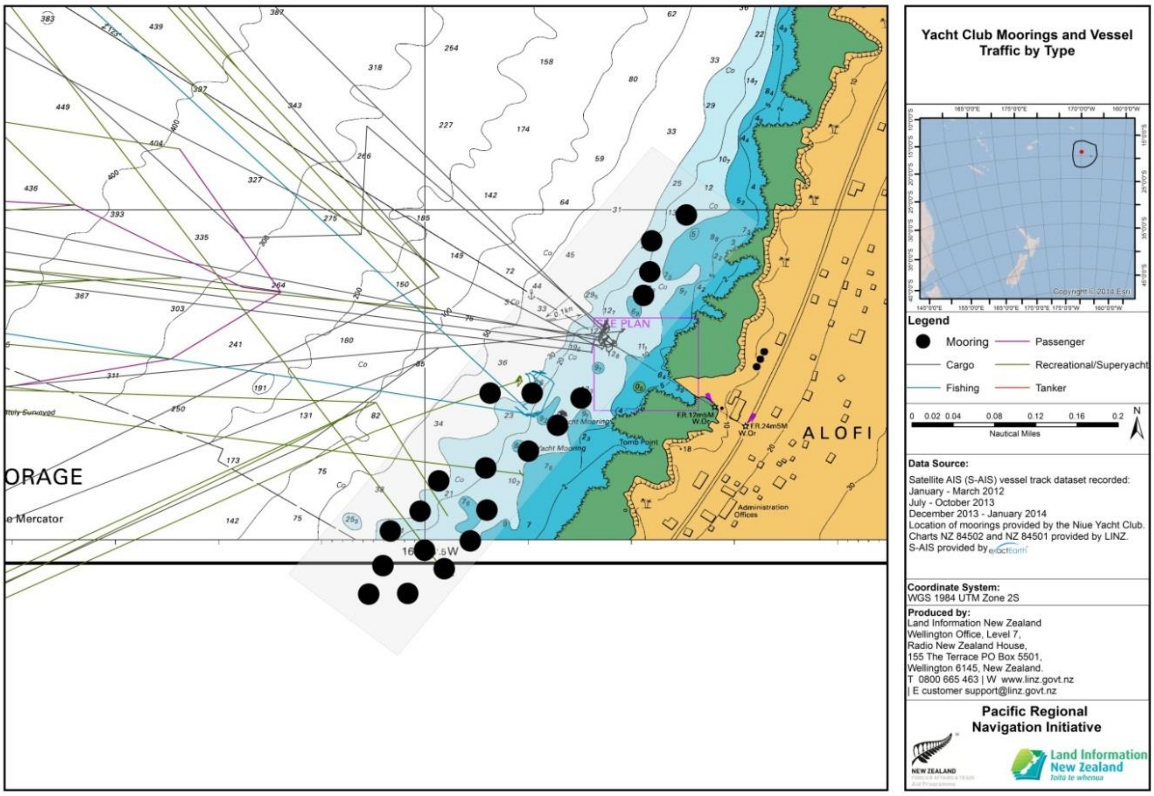

Figure 40: Alofi Anchorage mooring positions

7.6.4 During the course of this hydrographic risk assessment it was discovered that two multi-beam hydrographic surveys have been previously conducted of sea areas surrounding Niue by SPC (formerly SOPAC) and the information has not been incorporated in the nautical chart. Though the additional information is unlikely to substantially improve the functionality of the chart, this new information should be incorporated at the next routine update.

7.7 Chart Improvement Recommendations – Beveridge Reef

7.7.1 Throughout this report Beveridge Reef has been noted as an important and unique coral atoll, protected by Niuean regulation and planned for international recognition as a marine reserve. There is currently no large scale chart of the reef. The largest scale paper chart showing the reef is NZ 14630 (INT 630) at a scale of 1:1,500,000, however, the largest scale Electronic Navigational Chart (ENC) depicting the reef is NZ14605W, at a scale of 1:3,500,000. The risk assessment did not identify any significant hydrographic risk associated with Beveridge Reef. However, due to its importance from a national and biological diversity perspective, it is recommended that the reef be fully surveyed and charted to allow for its effective management and protection.

8. ECONOMIC ANALYSIS – COST BENEFIT ANALYSIS

8.1 Introduction

8.1.1 The CBA methodology of previous work in LINZ SW Pacific hydrographic risk assessment programme is based on comparing the cost of conducting hydrographic survey for each cell with a benefit calculated from reduced personnel loss and oil spill clean-up costs, plus an estimated economic benefit of arising from the availability of better charts. The percentage of reduced risk in each cell is dependent on its current ZOC rating as shown in the following table.

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

Figure 41: Effectiveness of Improved Charting[38]

8.1.2 This method of cost benefit calculation is most valid for those areas where chart quality directly impacts the safety of navigation, such as shallow areas where ships are depth constrained, confined navigational areas where the width of the navigable water will restrict the ability of vessels to manoeuvre to avoid collision, or unsurveyed waters where unknown seabed obstructions dangerous to surface navigation may exist.

8.1.3 The particular geography of Niue, as an isolated island within an extensive, deep water EEZ renders it unnecessary to conduct a cost benefit analysis to assess value of investing in hydrographic surveys in the deep ocean areas. In these unobstructed waters where the seabed does not place any constraints on safe navigation, the benefit of improved ZOC would only be theoretical. Thus, whilst the conduct of a systematic, deep water multibeam survey of the entire Niue EEZ would produce benefits in terms of mapping of ocean resources, it would provide an insignificant direct reduction of hydrographic risk. The cost benefit result thus provides negative NPV for all these deep offshore areas. This assessment is indicatively confirmed by the lack of reported maritime incidents in Niue EEZ in past decades. However there are direct benefits of hydrographic improvements in the vicinity of Niue and Beveridge Reef

8.2 Niue Island chart upgrade

8.2.1 A cost benefit analysis was conducted in the vicinity of Niue Island (area of existing chart coverage NZ845) using the costs of re-compilation that chart, against a theoretical benefit of increased cruise ship tourism. This cost, including the quality assessment and conversion of the data, redesign and production of a new chart and production of ENC cell is estimated at US$55,000. For this area there is an existing multibeam hydrographic survey[39] which has not

[38] (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015, p. 36)
[39] (Secretariat of the Pacific Community, 2007)

been included on the chart. For the purposes of the CBA, this survey is assumed to meet the standard to enable upgrading of most of this region to ZOC B. On the benefit side it is estimated that such action will support an increase in adventure tourism of 1500 visitors per year (5 adventure tourism ships of 300 tourists), each spending an estimated $150 in the local economy[40]. The result, detailed in Figure 42 below, shows a positive NPV of US$1.13 million over 10 years.

8.3 Beveridge Reef surveying and charting

8.3.1 The hydrographic risk identified in the vicinity of Beveridge Reef was *insignificant* due to the very low level of traffic approaching the reef. Nevertheless, our interviews with Niuean Government officials and others confirmed its importance as a unique coral atoll, considered to be a source of Niue's fish stocks and biodiversity, and protected by Niuean regulations. There is also discussion on plans for seeking international recognition as a marine reserve. To provide due consideration to these factors, the cost benefit analysis was extended to consider the impact of surveying and charting Beveridge Reef.

8.3.2 In previous South West Pacific hydrographic risk assessments, singlebeam technology has been was used for costing purposes in the CBA models. While singlebeam is significantly cheaper to deploy than multibeam or LIDAR[41], this technology would not meet the needs of intended marine management, biodiversity monitoring and scientific research of the reef. For Beveridge Reef it is important that either LIDAR or multibeam survey technology be used in order to provide the detailed resolution and feature detection necessary to meet the dual purposes of safety of navigation and effectively managing and monitoring the marine ecology of this reef. High resolution multibeam would provide the greatest underwater resolution and provide coverage into the deeper water, however LIDAR could also offer detailed aerial photography of the drying reef, and depth details of the very shallow areas and lagoons within the reef plateau.

8.3.3 With respect to cost, the area to be surveyed is very small and extremely remote thus mobilisation costs would certainly eclipse the normal average cost of survey on a km^2 basis. Weighing up these factors the CBA has been based on LIDAR (US$2,400/$km^2$), on the basis that given flexibility in survey timing, mobilisation costs could be minimised if the survey were planned to be conducted in conjunction with other surveys in the region. An additional cost of US$55,000 is also allowed for data assessment and chart production.

8.3.4 Benefits are also difficult to quantify due to the current lack of traffic and the stated preference of Niueans interviewed[42] that Beveridge Reef remain protected. This CBA assesses the benefits of developing Beveridge Reef as a controlled adventure tourism destination in full knowledge that this may not be the desired outcome, but in any case, the intrinsic benefit to Niue of being able to effectively manage the reef marine area must then exceed this alternate value as a

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[40] While previous assessments have estimated a per person spend of US$150 per person (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015, p. 34) this is not currently achievable in Niue with ship visits restricted to one day (effectively 6 hours on the island), so a figure of $150 in local currency is used here.

[41] (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015, pp. 33-40)

[42] Josie Tamate (Director General), Ministry of Natural Resources and Coral Pasisi, NOW Project.

tourist destination. This CBA assesses that a reef management charge of $50 per visitor could be made on adventure tourist ships visiting the reef with other conditions that the ship must first call at Niue and potentially carry a Niue observer. A reasonable quantum of revenue is based on the additional 1500 tourists per year estimated at paragraph 8.2.1 above.

8.3.5 This result showed a small net positive NPV of US$ 0.16 million over 10 years. Additionally and more importantly, is the immeasurable benefit to Niue of having the foundation hydrographic data to enable the management of this significant resource and to support planned applications for international recognition of this reef as a marine reserve.

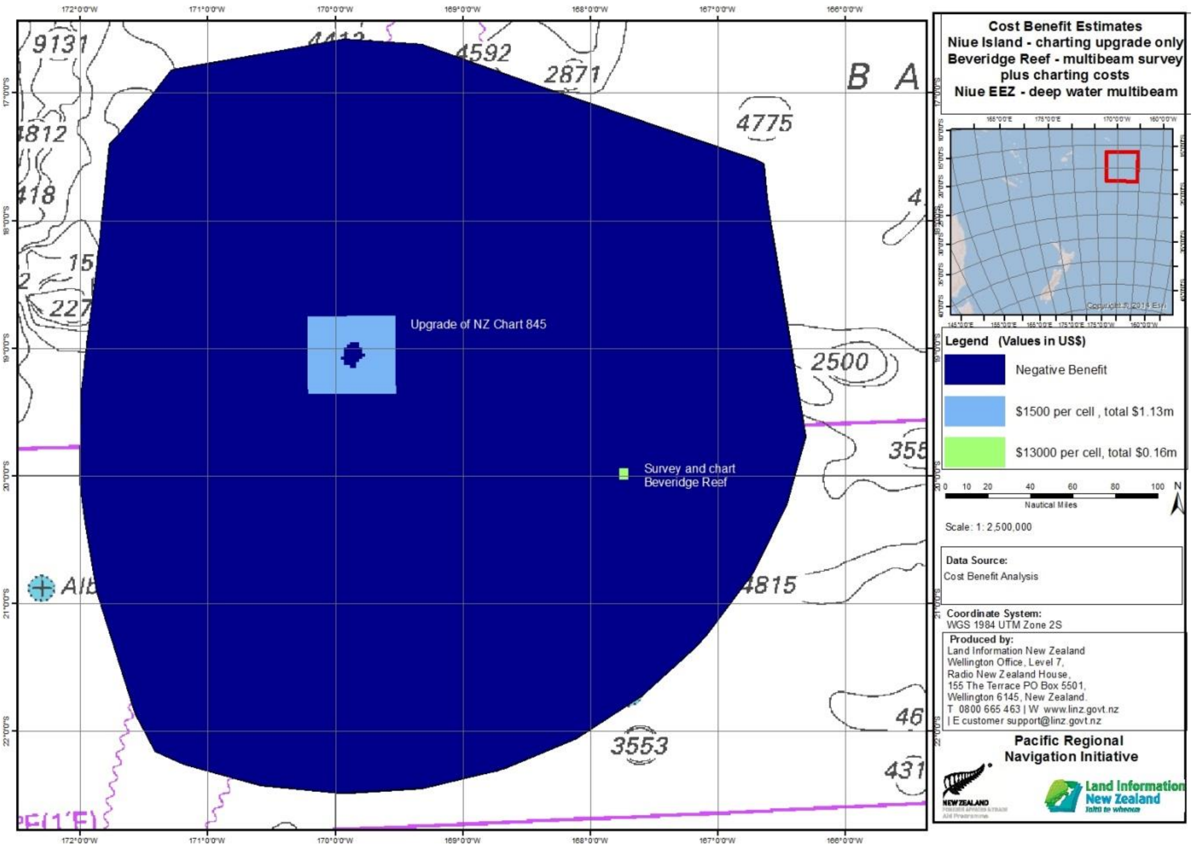

Figure 42: Cost benefit analysis results

9. OBSERVATIONS ON THE NIUE RISK ASSESSMENT

9.1 The formal hydrographic risk analysis of Niue EEZ was conducted using the common vessel traffic AIS dataset and risk analysis parameters as used in earlier assessments of the Cook Islands and Tonga in order to provide as nearly as possible a result that would be consistent across the regions and could be used for comparative purposes. In conducting the assessment it became apparent that, despite standardisation of risk matrices and use of common vessel traffic datasets, the comparative results would be greatly impacted by significant differences in current vessel traffic volumes and differences in the geological characteristics of the seafloor between different regions. For these reasons it is considered that the most useful results are those represented by the "in country" analysis while the regional results still provide a useful benchmark to gauge regional significance. Furthermore the benefits of using all traffic data available would outweigh the perceived benefit of using a common dataset for regional comparative purposes.

10. REFERENCES

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ANNEXES

ANNEX A - Event Trees

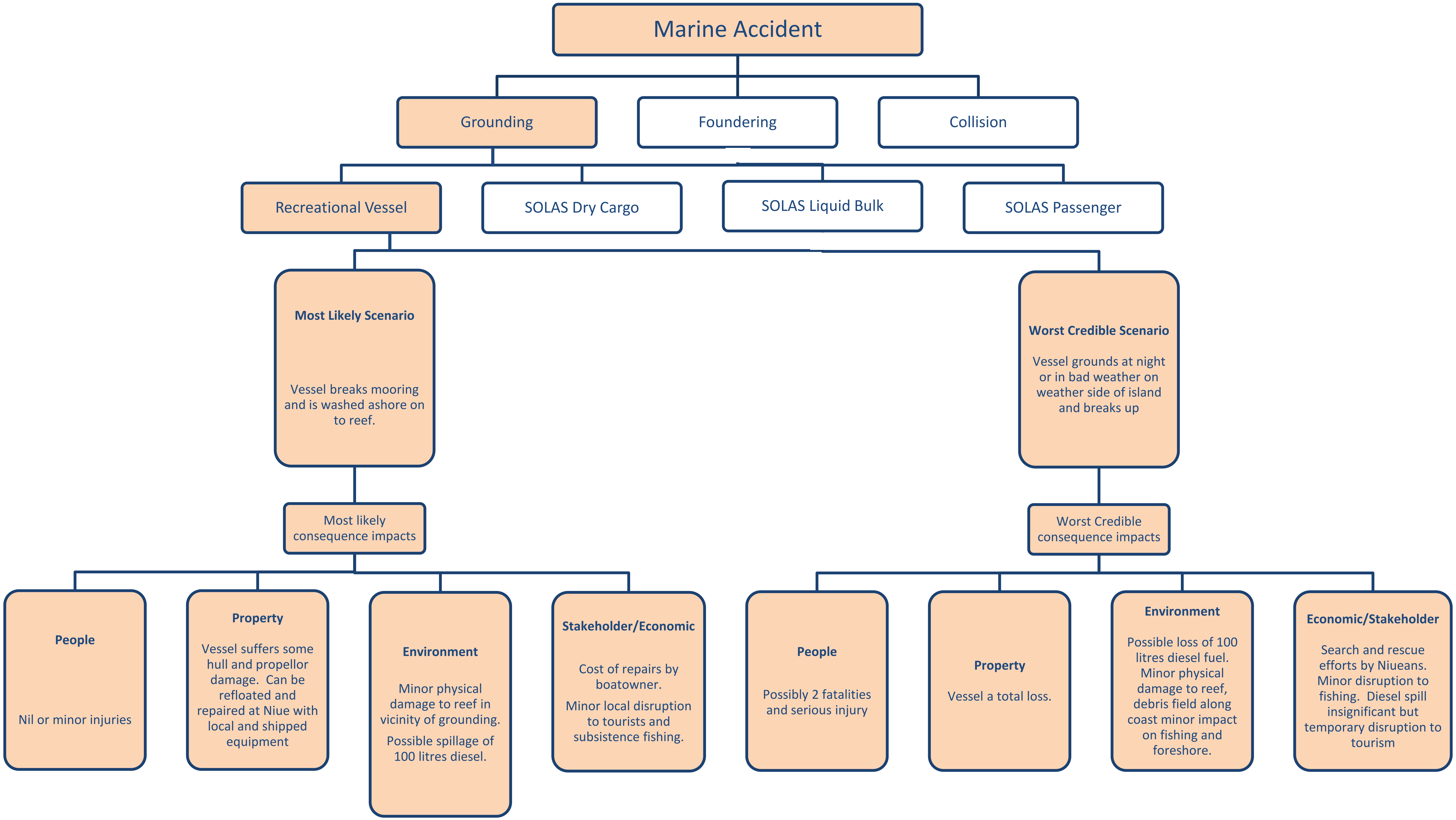
1. Event trees were used to determine the most likely and worst credible impacts of defined unwanted navigation events. For consistency and commonality across the south-west Pacific hydrographic risk assessment area, the event trees in this Annex are based on the generic event trees in the Risk Assessment Methodology[43] and those used in the Cook Islands[44] and Tonga[45] but modified to take account of the far simpler navigational circumstances at Niue.

2. Niue has no domestic cargo or passenger vessels of any recordable GT, therefore the *Domestic Vessel* classification has been changed to *Recreational Vessels* - over 100 of which visit Niue each year. This class of vessel has recorded the greatest number of navigational incidents in Niue in recent history with three groundings on the reef near Alofi during the past decade. Accordingly an event tree that covers the grounding of recreational vessels has been included, however, it was not considered useful to create event trees covering collision or foundering due to the lack of tonnage in this vessel category, their shallow draught and therefore their lack of influence on the risk calculations in areas where they are not concentrated (such as the port of Alofi).

3. The event trees were used to confirm the veracity of the weightings of the risk consequence factors employed in the overall risk calculations.

[43] (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015)
[44] (Marico Marine Report No. 14NZ262MR Issue 02, 20 January 2015)
[45] (Marico Marine Report No. 14NZ262 – TM, Issue 1, 27 November 2014)

ANNEX A - Event Trees



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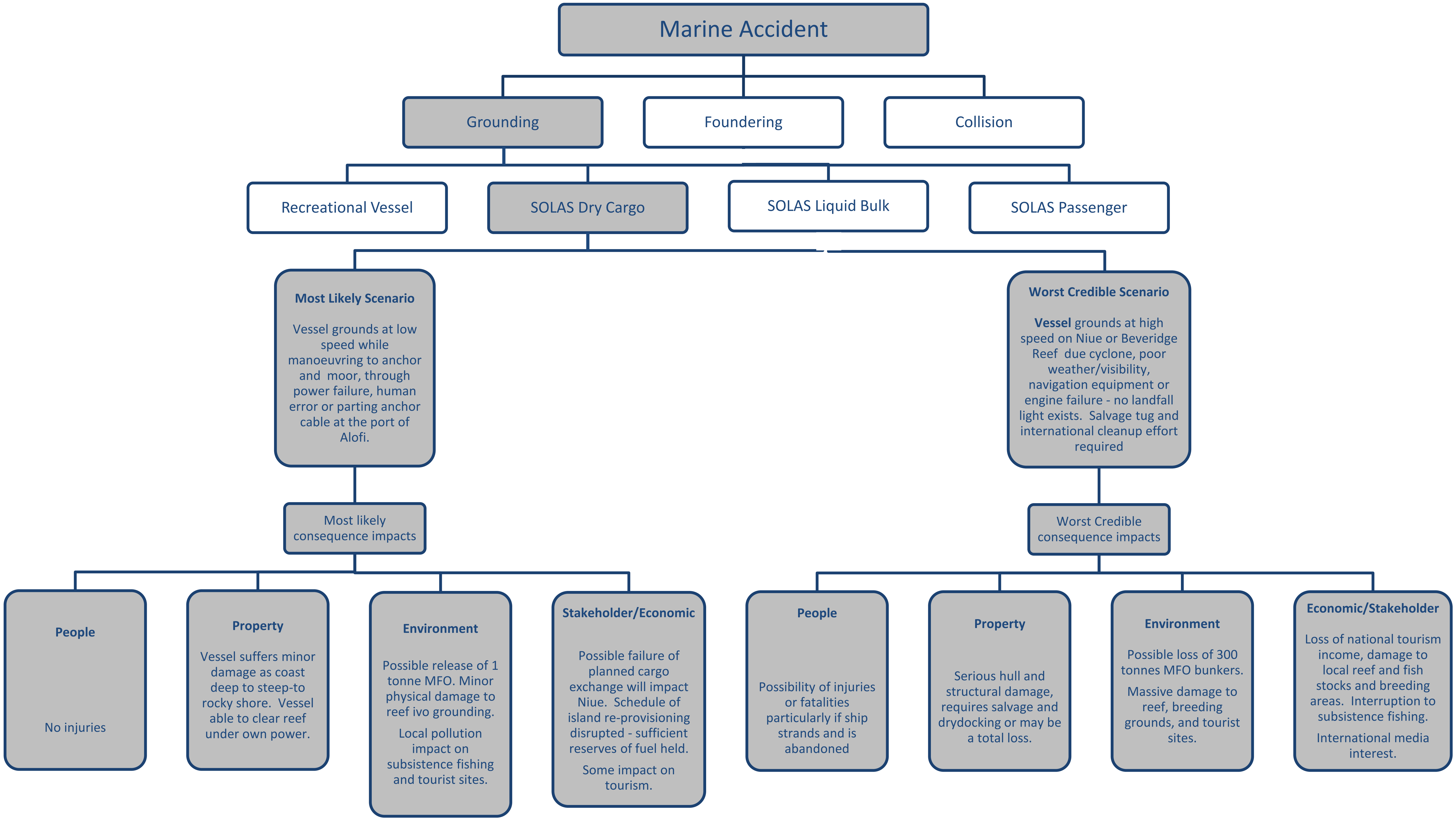

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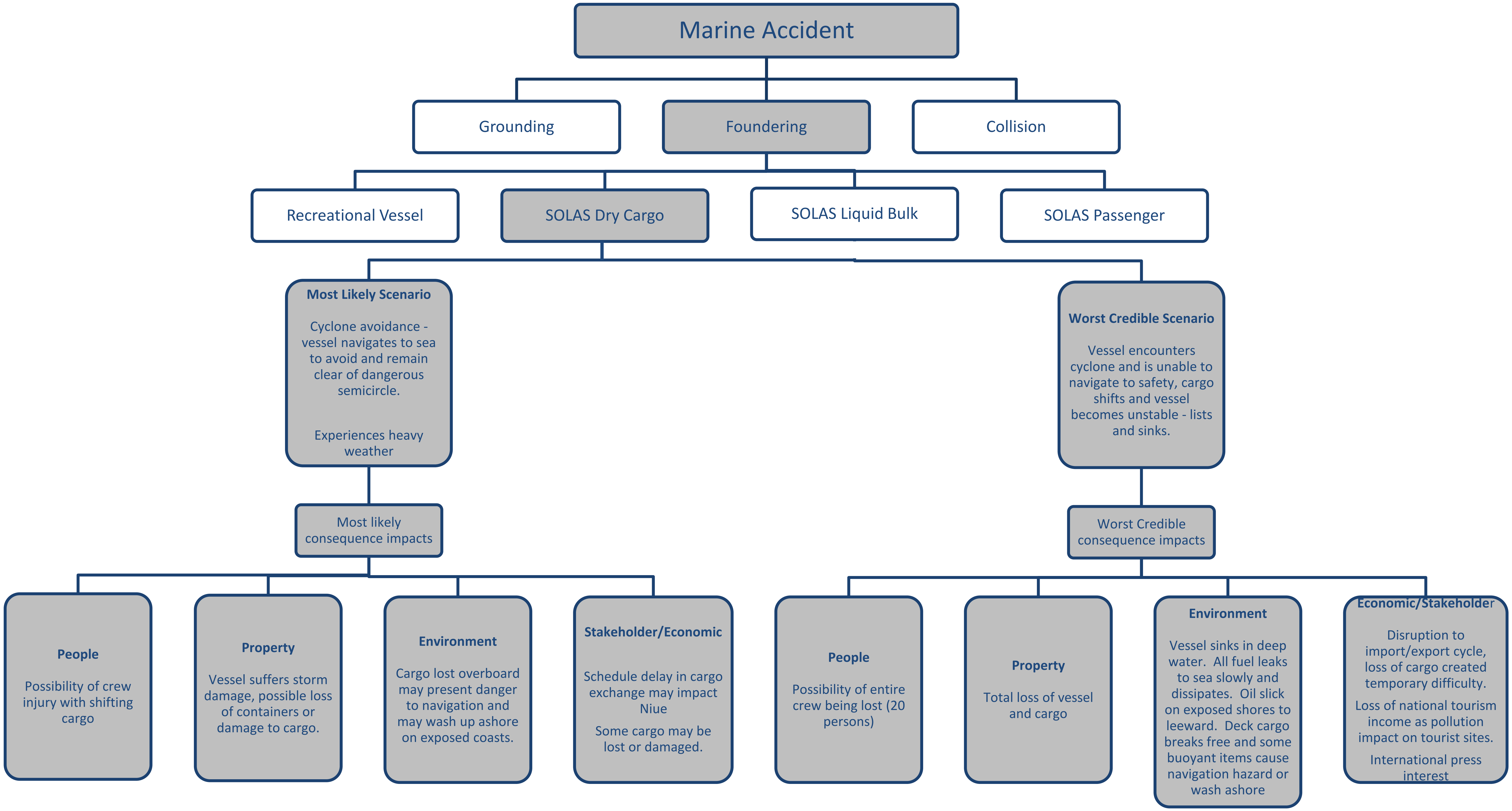

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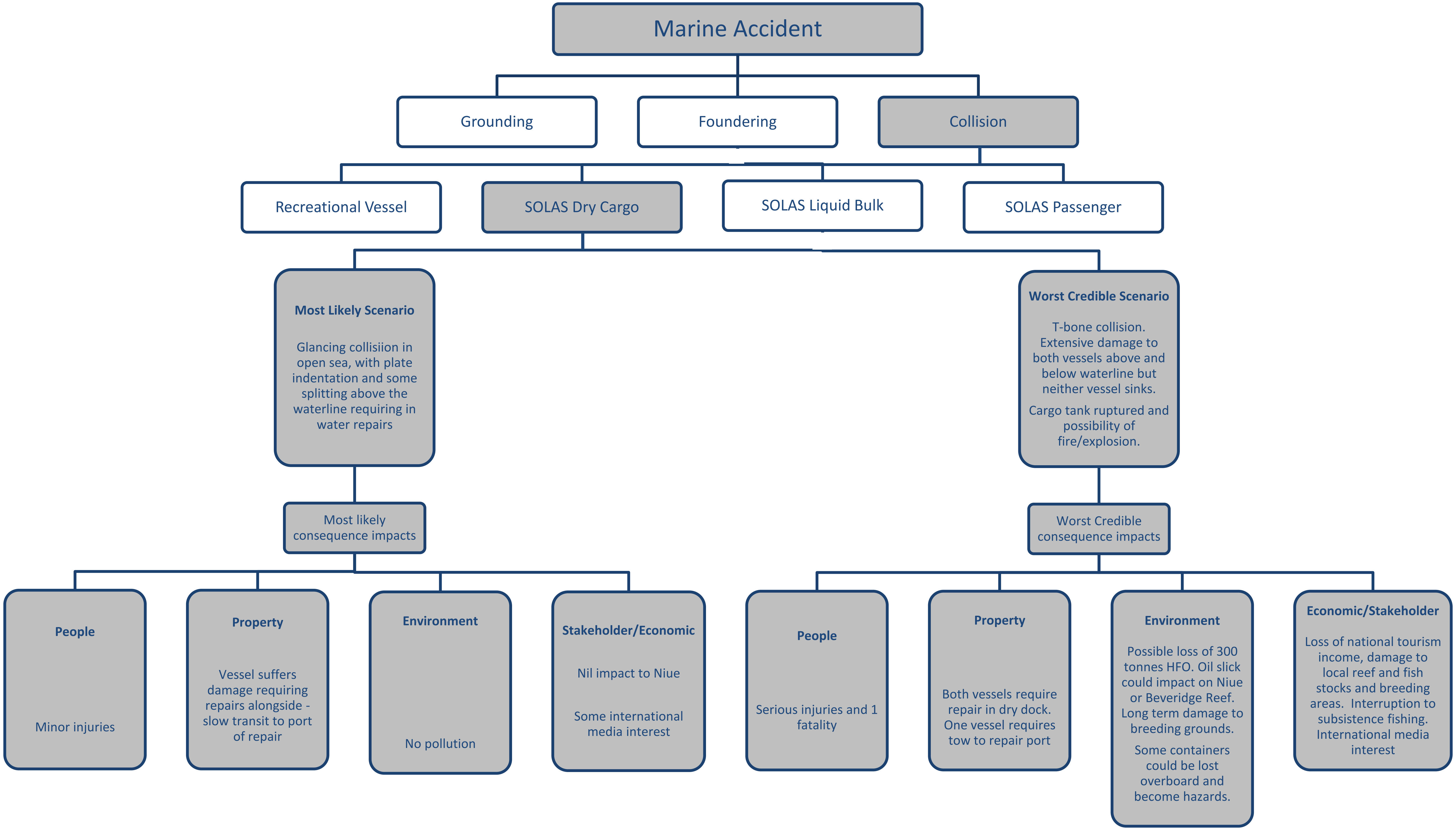

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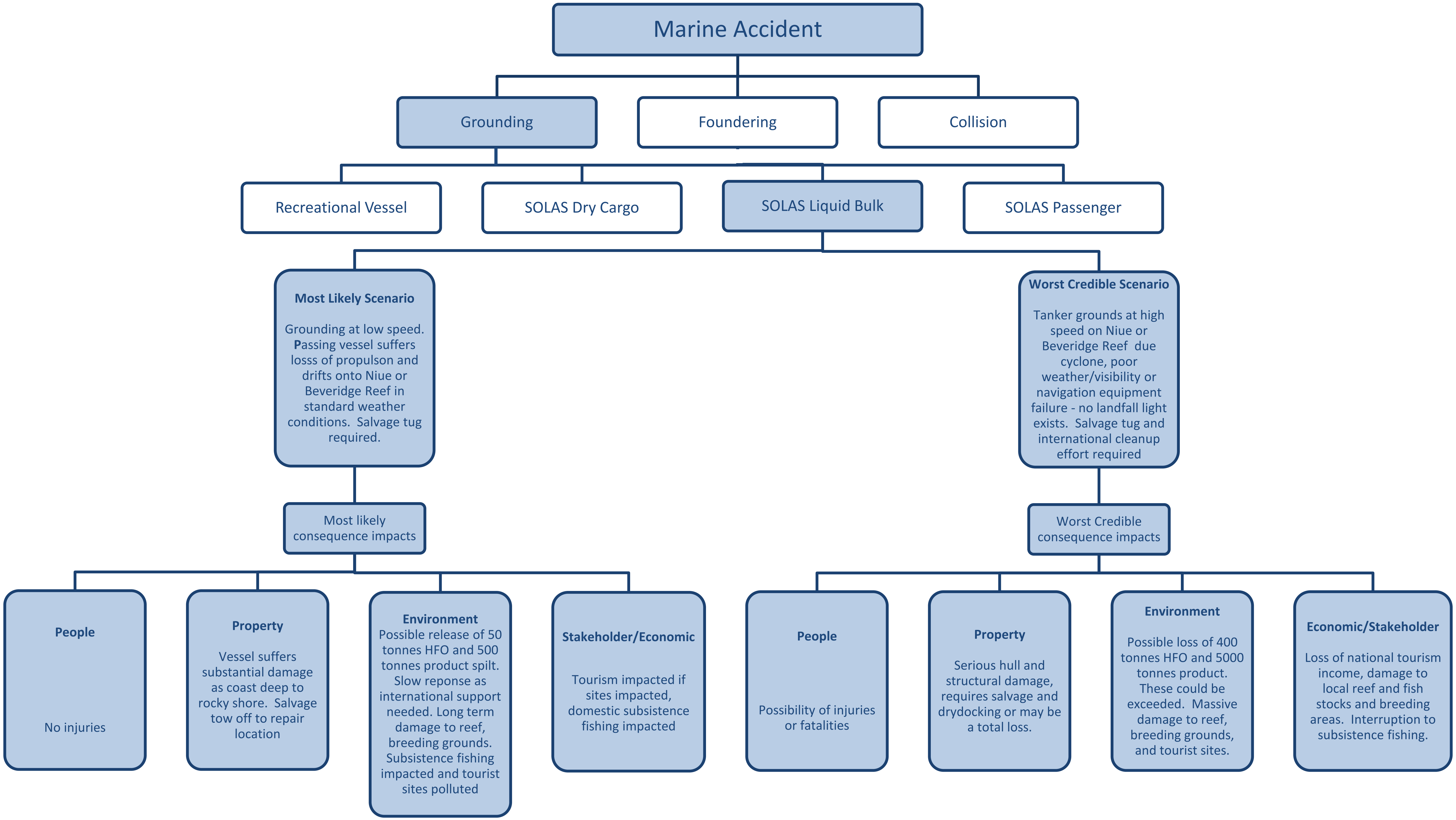

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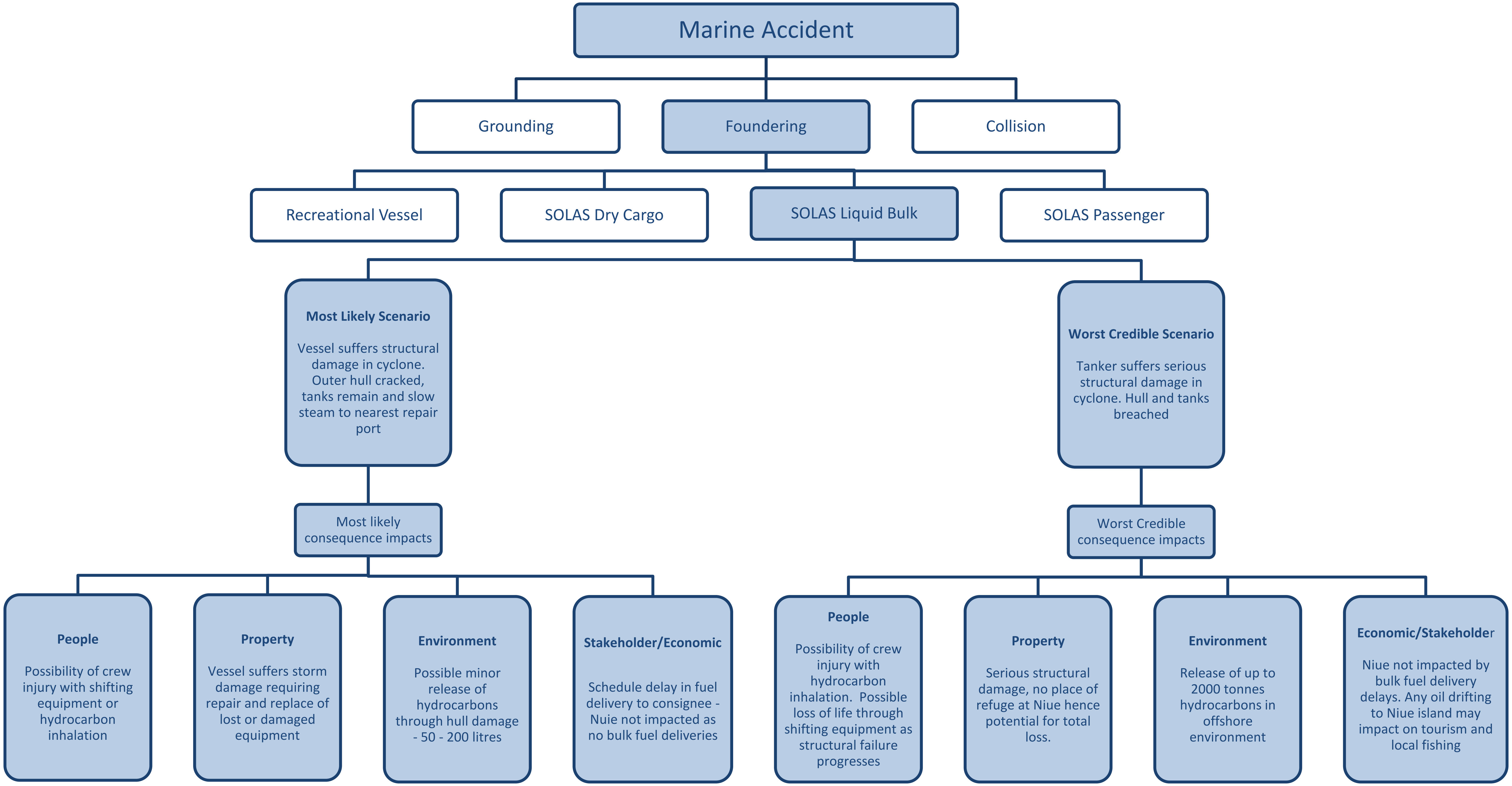
ANNEX A - Event Trees



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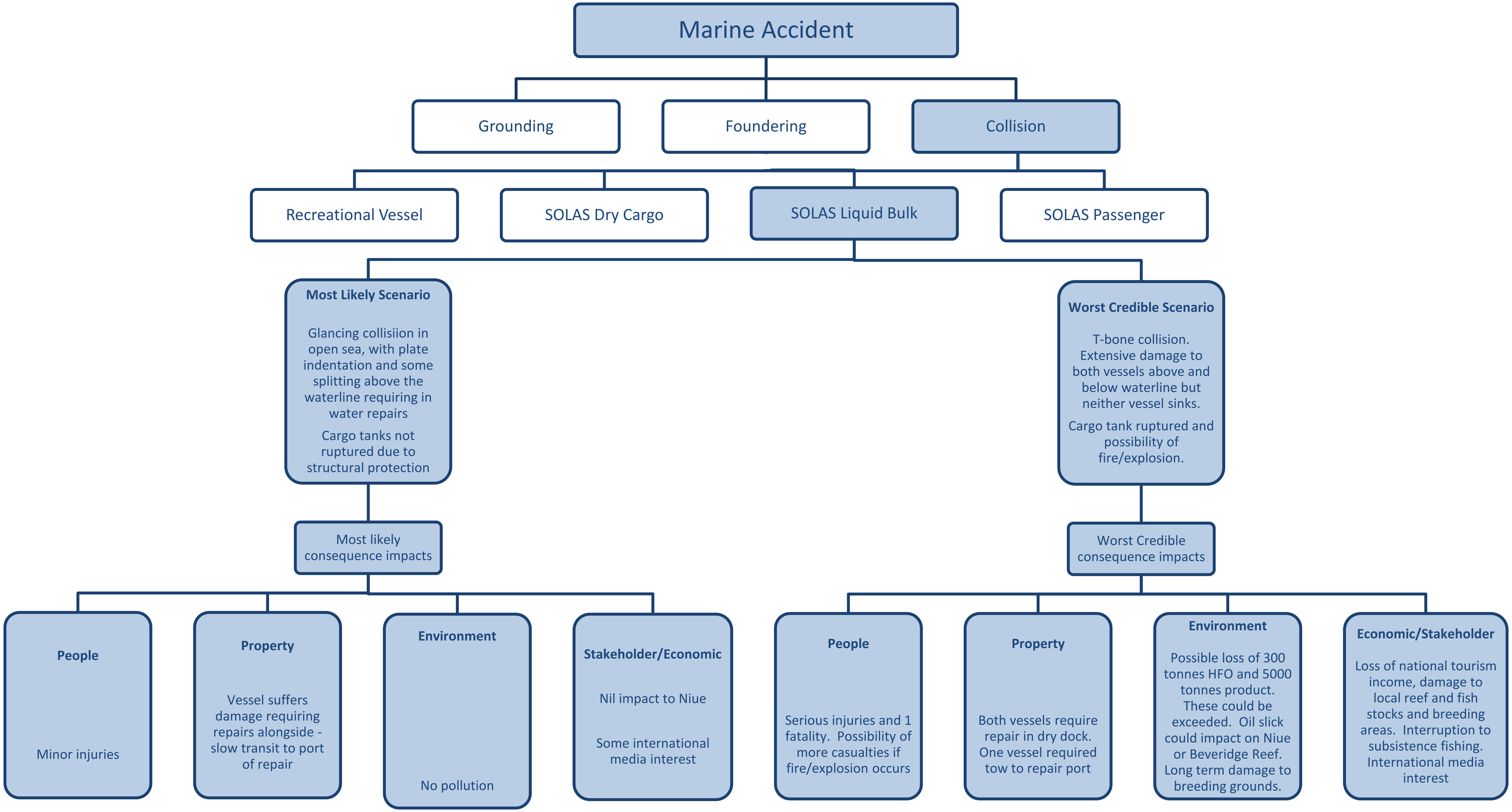

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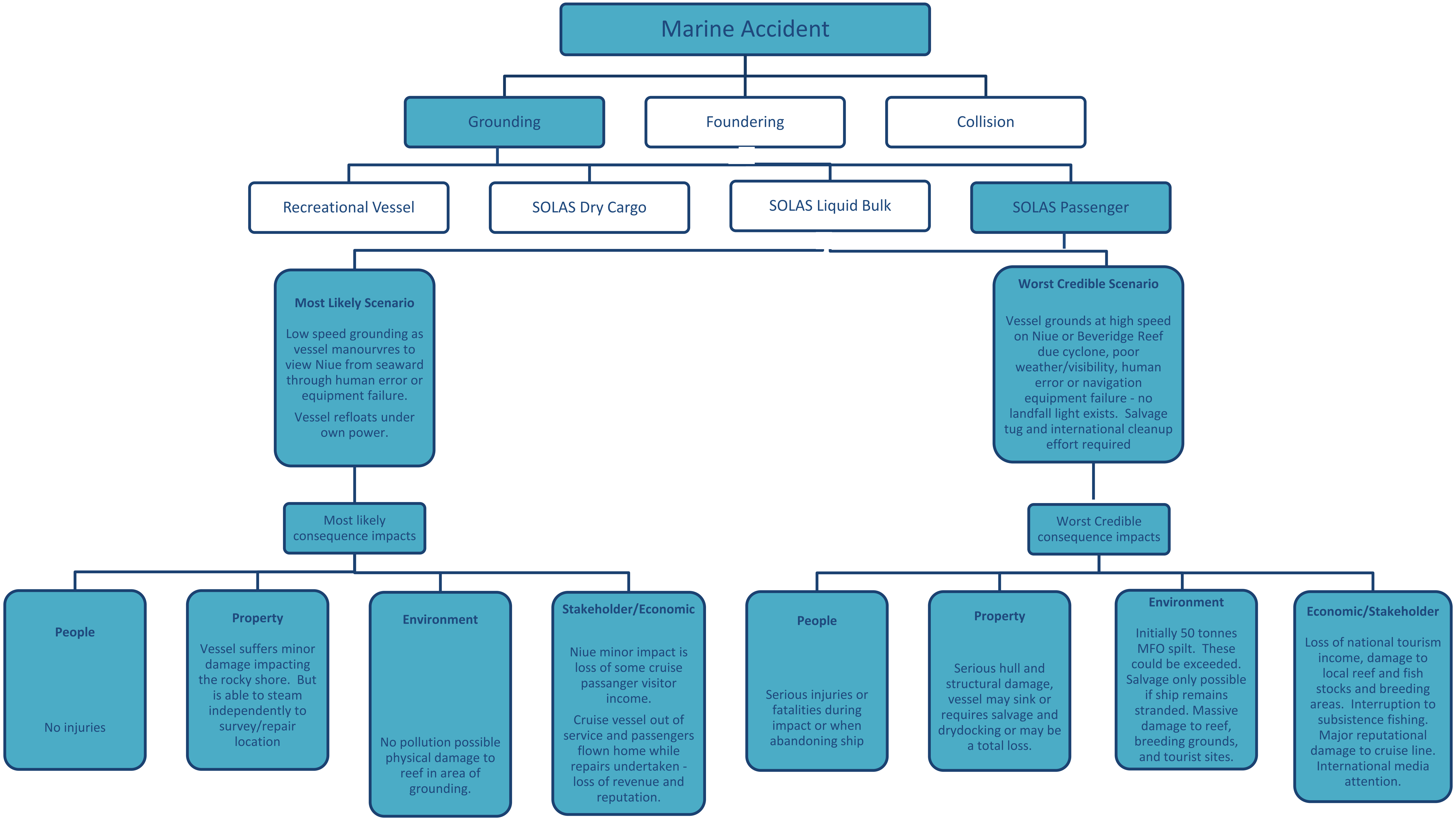

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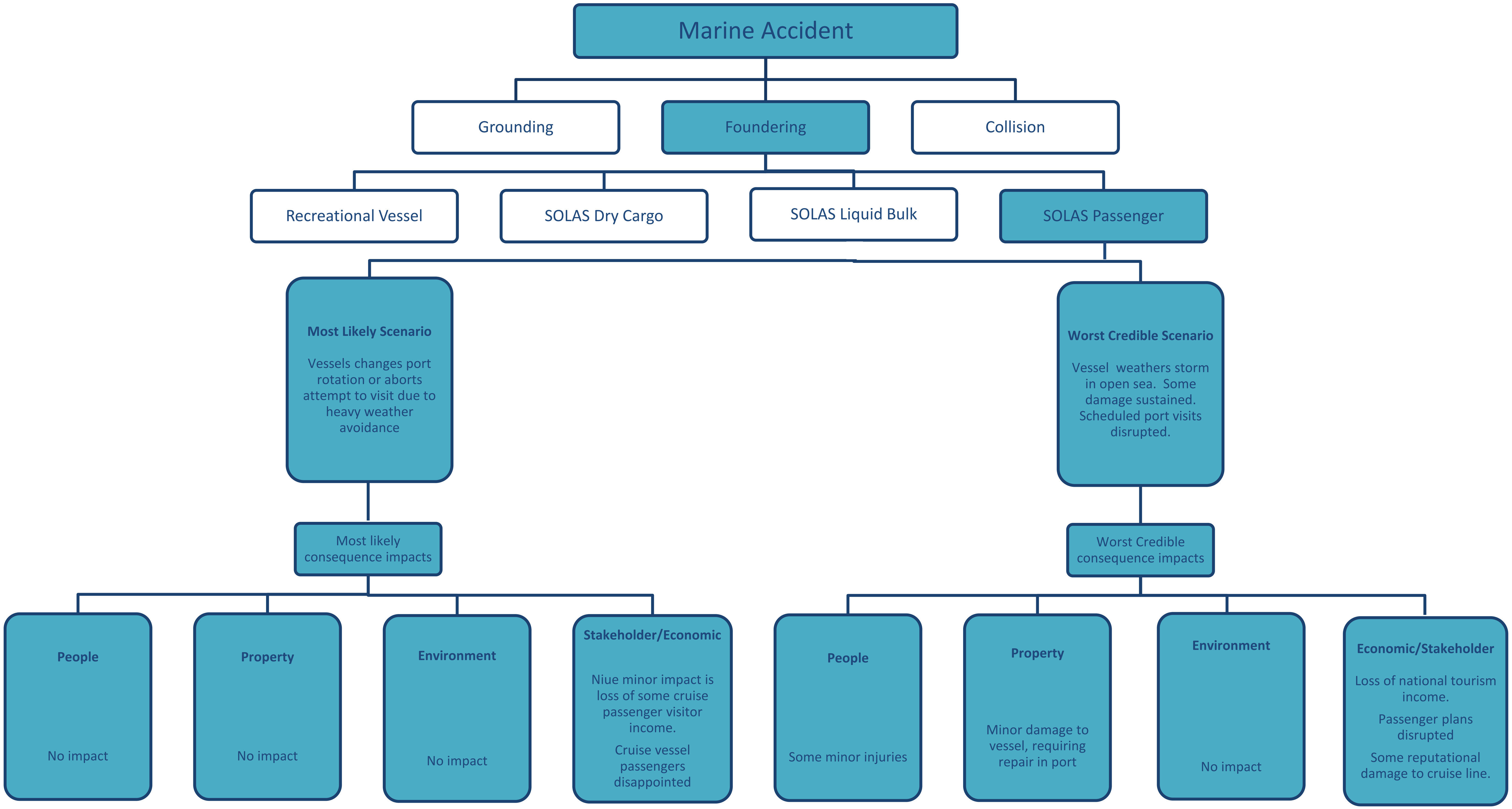
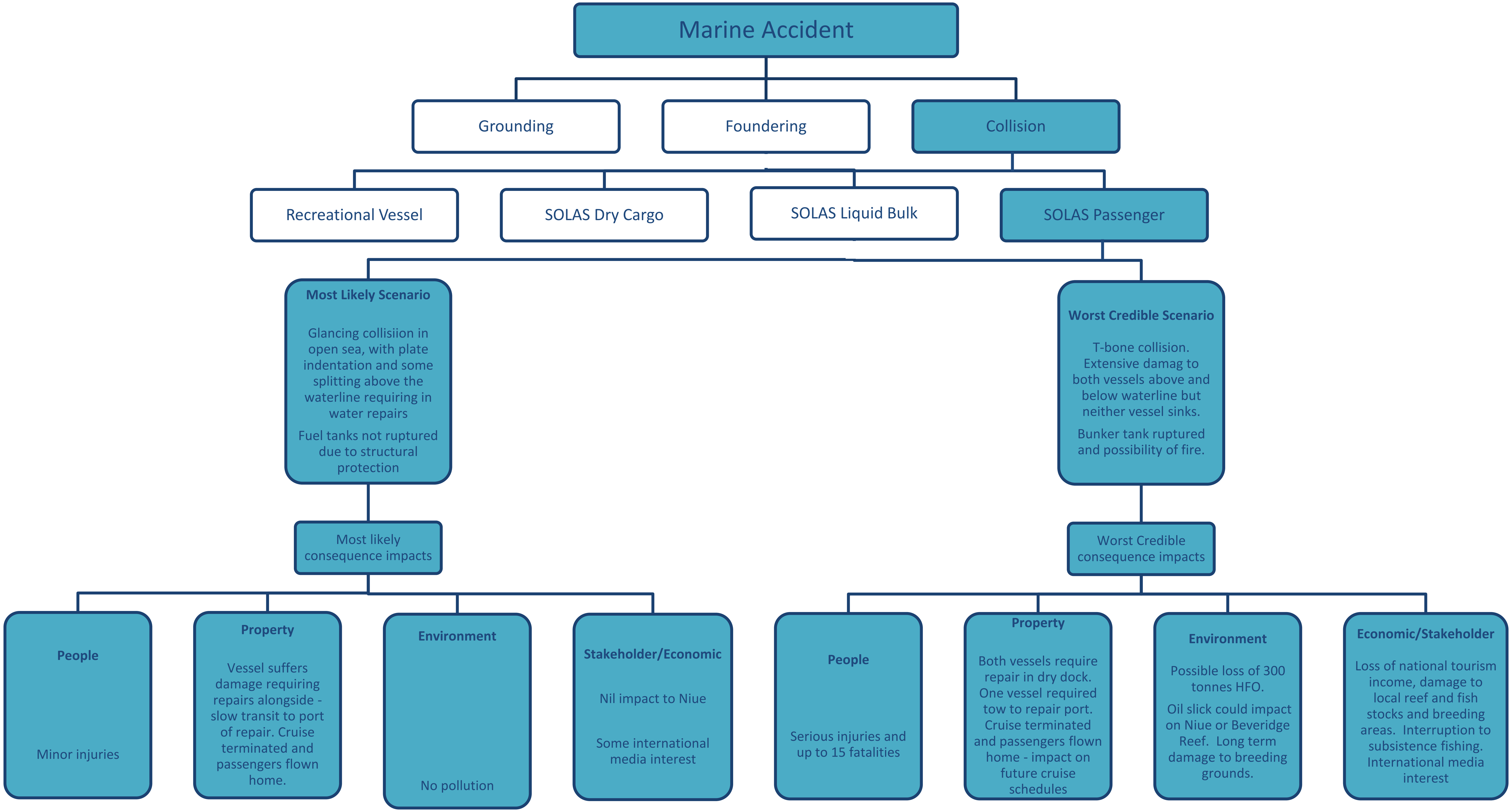


ANNEX A - Event Trees



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ANNEX B - GIS Track Creation and Processing

1 Track Creation[46]

1.1 Raw AIS data was acquired from exactEarth for: January – March 2012; July – October 2013; and December 2013 – January 2014. These are the same periods used for previous assessments of Vanuatu, the Cook Islands and Tonga and were used for consistency and to add integrity to the comparative analysis.

1.2 The geographic boundaries of this dataset used in the study of Niue were:

Northern Boundary: 16° S

Eastern Boundary: 166° W

Western Boundary: 171° W

Southern Boundary: 22° S

The raw AIS data was decoded and converted into ESRI File Geodatabase format using FME software.

1.3 NOAA's Marine Cadastre Track Builder[47] was then used to convert these AIS points into a network representing vessel movements based on the vessel's MMSI number and a user specified threshold of a maximum distance and time between a pair of points. These factors were selected by trial and error to provide the best overall result. Vessel attributes such as length and type, were then attached to each vessel track from checking MMSI number against online databases such as Marine Traffic and International Telecommunication Union (ITU).

1.4 Figure 1, below shows vessel track lines created using NOAA's Marine Cadastre Track Builder, such that each line connects multiple points for an individual vessel. This plot shows the raw nature of tracks and some anomalies that would degrade the analysis. In particular:

- There were gaps in the tracks as a result of the user specified threshold of a maximum distance and time between a pair of points;
- At the extremities of the study area, vessel track lines did not reach the boundary of the EEZ. The cause of this was that the track lines ended when the last transmission was received and

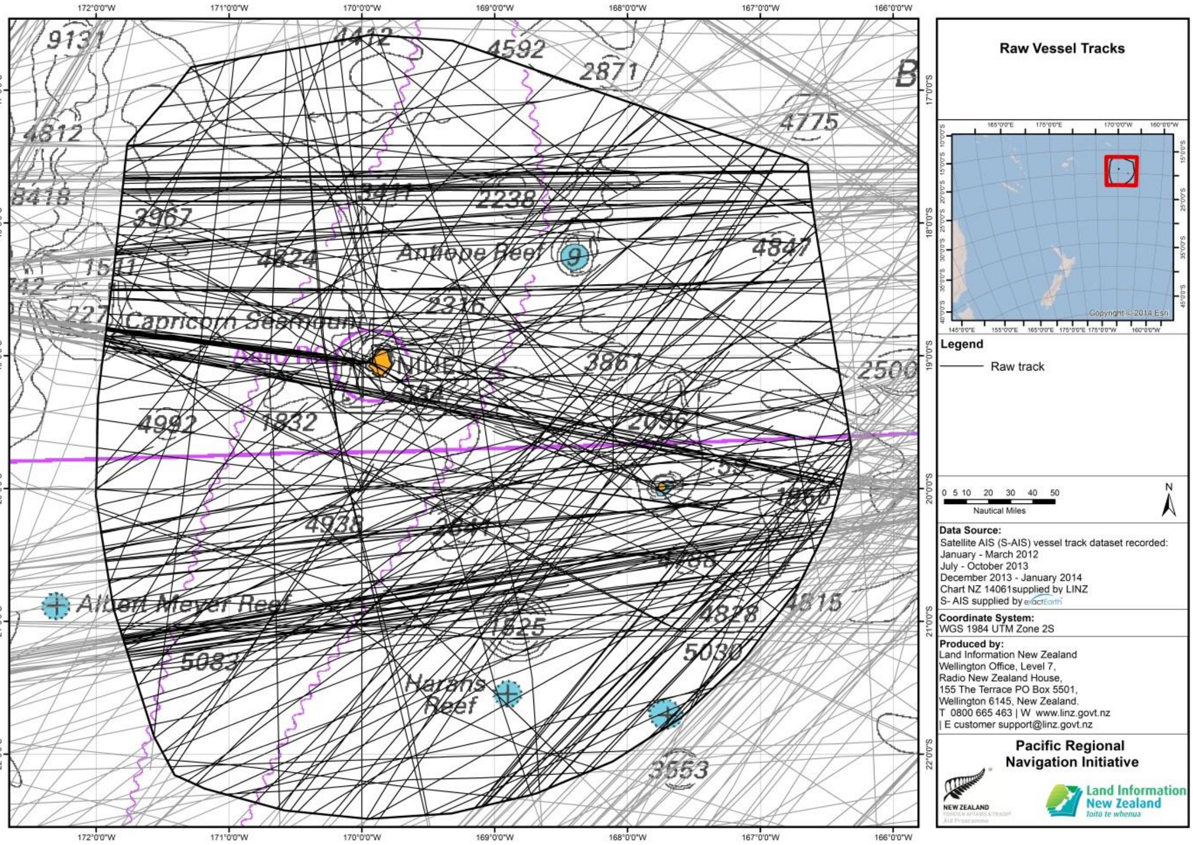
[46] For consistency, the text and format of this Annex is based on Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D14 – D23. Minor adjustments have been made to apply to Niue.

[47] National Oceanic and Atmospheric Administration. "Marine Cadastre Track Builder." Office for Coastal Management - National Oceanic and Atmospheric Administration. 2016. https://coast.noaa.gov/digitalcoast/tools/track-builder (accessed May 13, 2016).

ANNEX B - GIS Track Creation and Processing

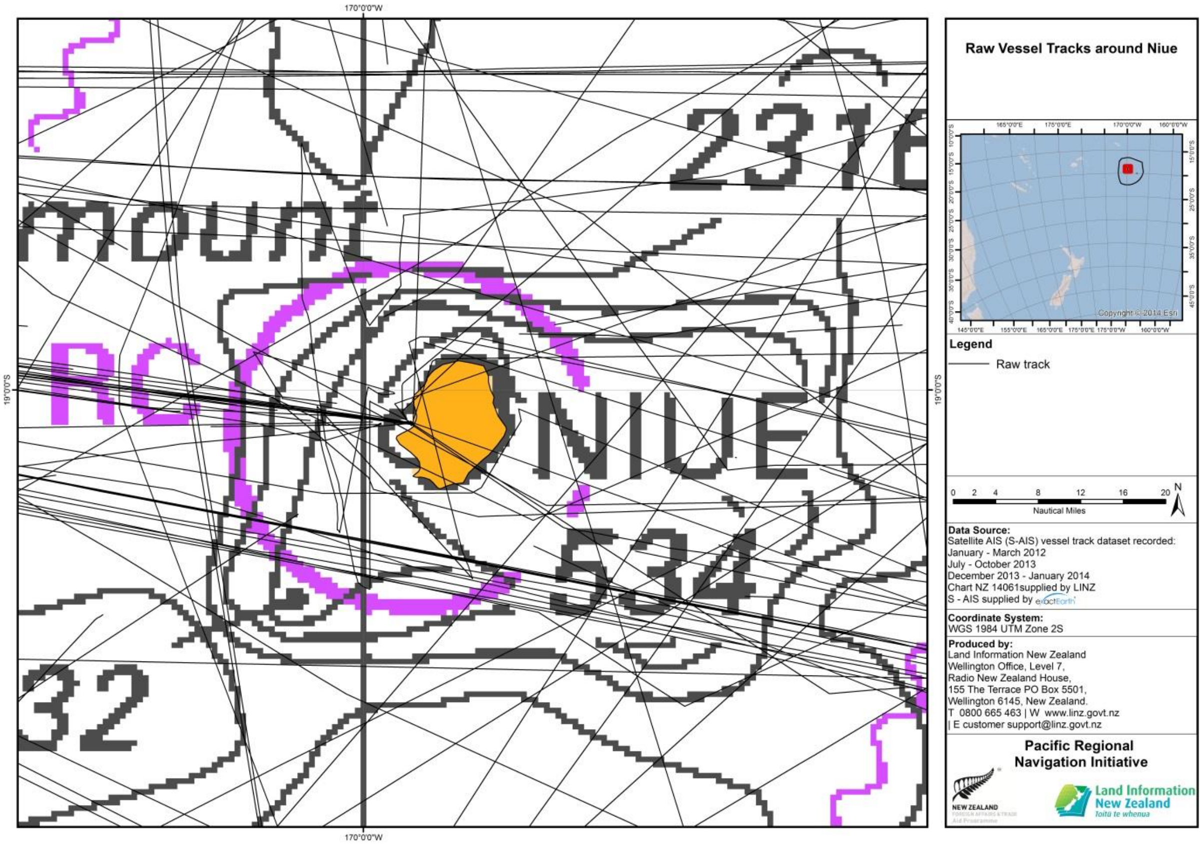
so it was possible that eight hours before a vessel reached the edge of the study area the track would stop; and

- There were 10 vessels shown as transiting across land, these are more clearly shown in Figure 2. These overland vessel tracks could not be simply discounted as this would skew the analysis into suggesting that fewer vessels transited in areas of fine navigation and so manual track processing was required.



Annex B - Figure 1: Vessel tracks across the study area

ANNEX B - GIS Track Creation and Processing



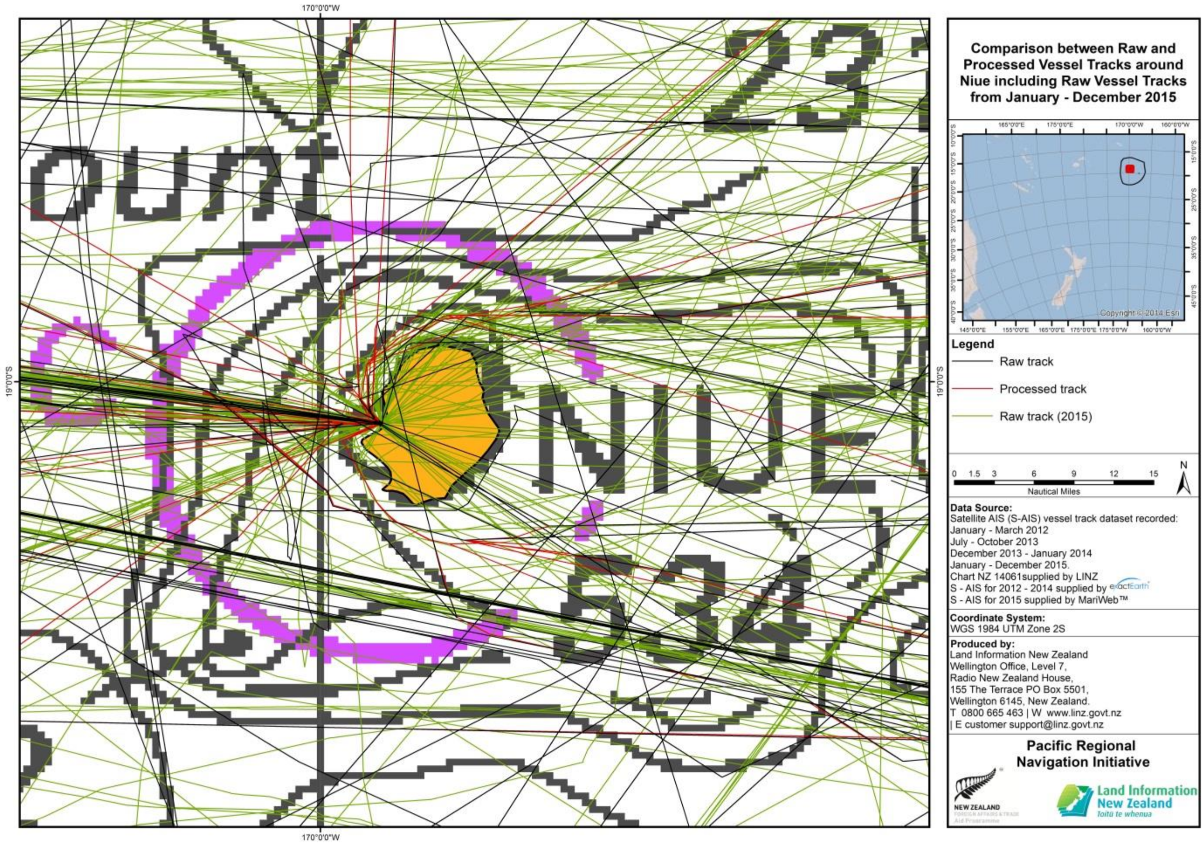
Annex B - Figure 2: Raw vessel tracks around Niue

2 Track Processing

2.1 A number of techniques were used to improve the raw vessel traffic data for use in the analysis of this study, these were:

- Manually connecting points of identical MMSI numbers in a time order to complete gaps along tracks;
- Extrapolating track lines to the edge of the study area. This processing was based on visual assessment assuming that those vessels near the limits of the study area that have a steady track will maintain that track to the boundary of the EEZ;
- All tracks that crossed land were manually routed around the coast along their likely course based on:
    - The vessel's historic activity (including inspection of data held for January – December 2015 as shown in Figure 3) using the assumption that many of the vessels repeat regular course lines; and
    - Reference to Niue Telecom radio logs;
    - Characteristics of the vessels, in particular type and draught to provide appropriate routeing around any significant obstacles; and
    - Other vessels' behaviour, in particular the distance vessels of a similar size keep offshore.

ANNEX B - GIS Track Creation and Processing



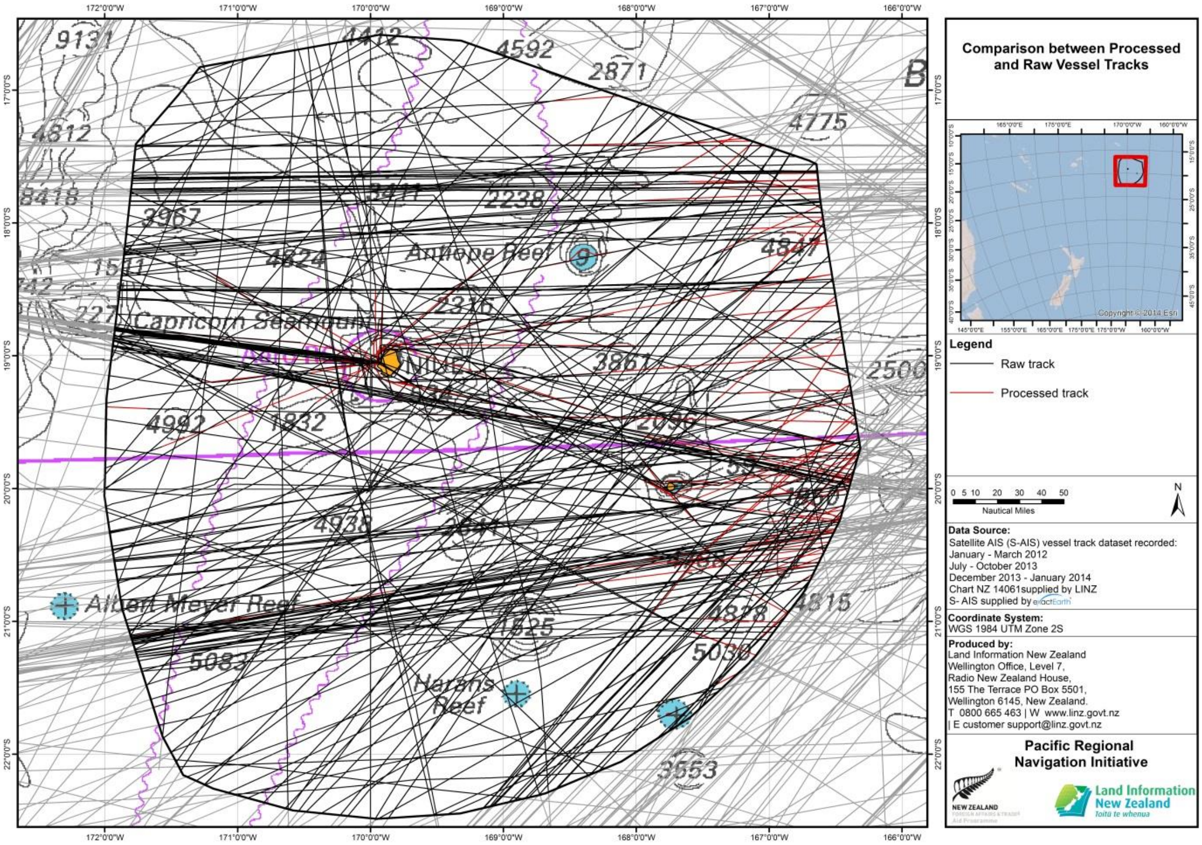
Annex B - Figure 3: Comparison between processed and raw vessel tracks around Niue including raw vessel tracks from January – December 2015

ANNEX B - GIS Track Creation and Processing

3 Final Results

3.1 This Section presents before and after comparison plots of the raw and processed vessel tracks. The plots show an improvement in the consistency and quality of the data post processing that allows a more robust analysis to take place particularly around Niue.

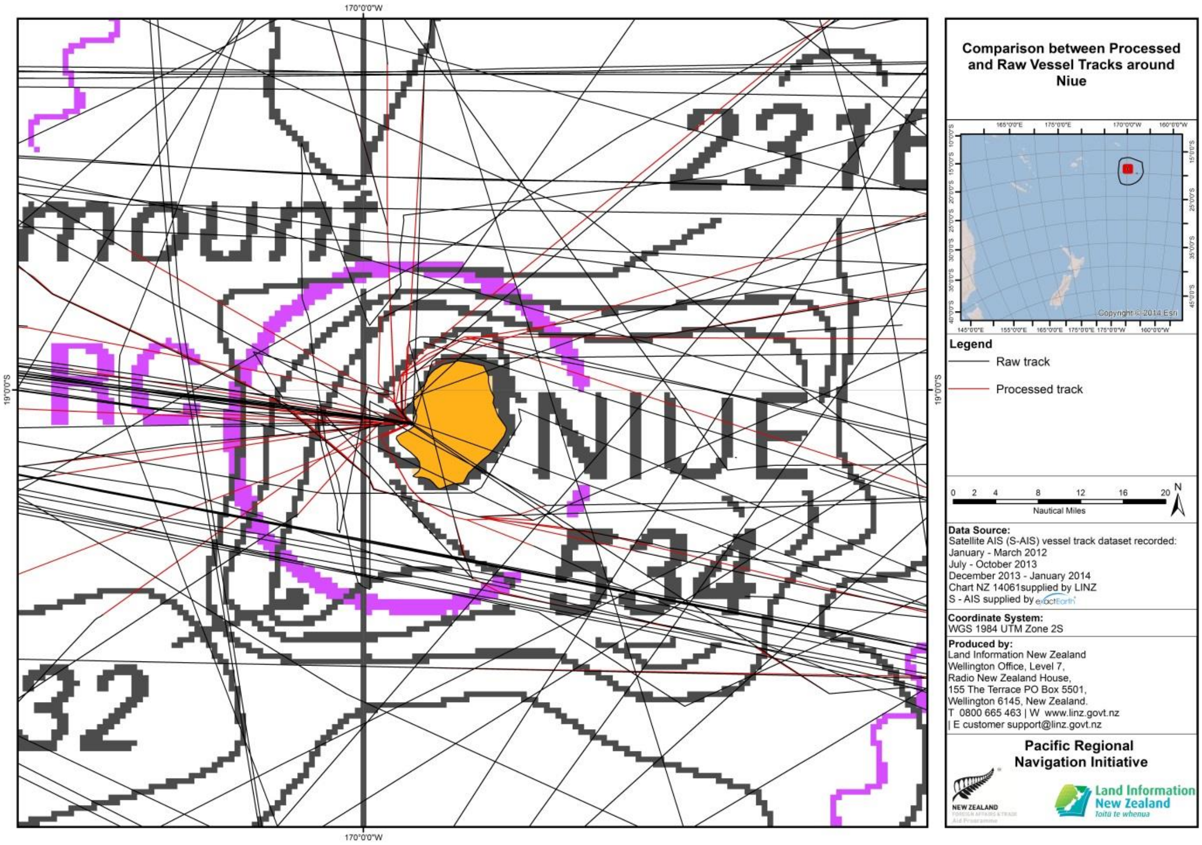
3.2 Figure 4 shows that all vessel tracks have been extended to meet the boundary of the EEZ. Gaps along vessel tracks have been filled and all vessel tracks that crossed land have been manually routed around the coast of Niue.



Annex B - Figure 4: Comparison between raw and processed vessel tracks across the study area

3.3 The difference between the raw and corrected tracks can be more clearly seen in Figure 5, a large scale plot of the raw and processed tracks in the vicinity of Niue.

ANNEX B - GIS Track Creation and Processing

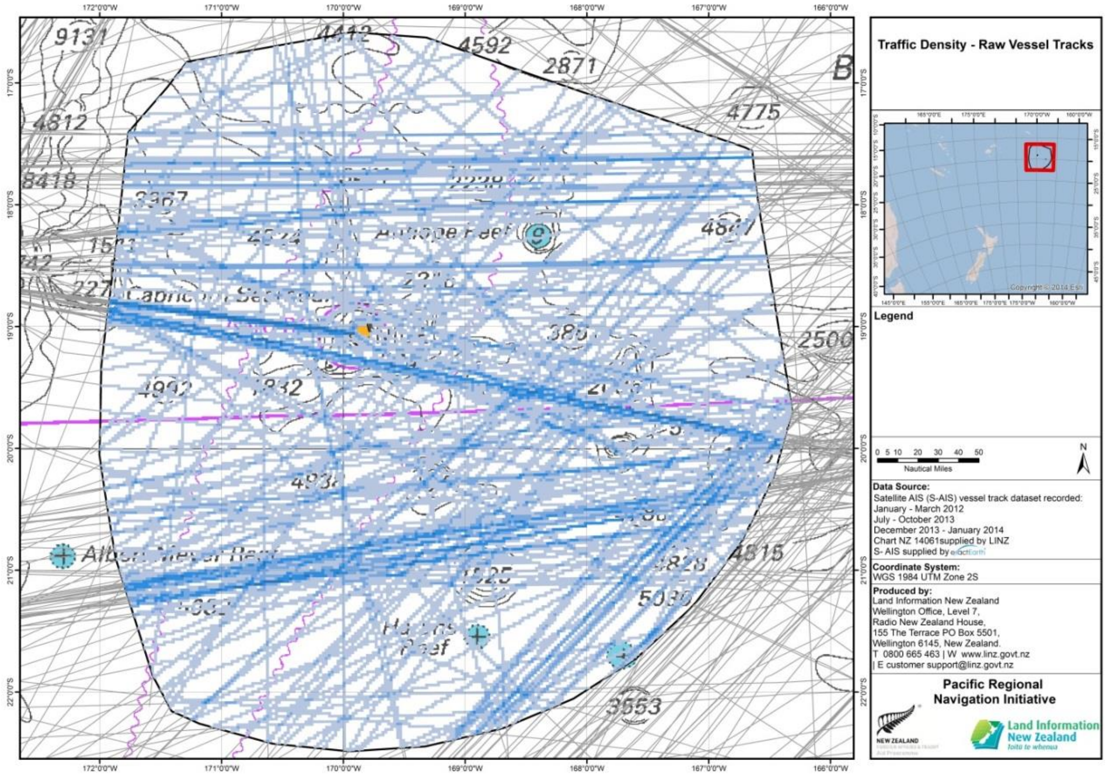


Annex B - Figure 5: Comparison between processed and raw vessel tracks around Niue

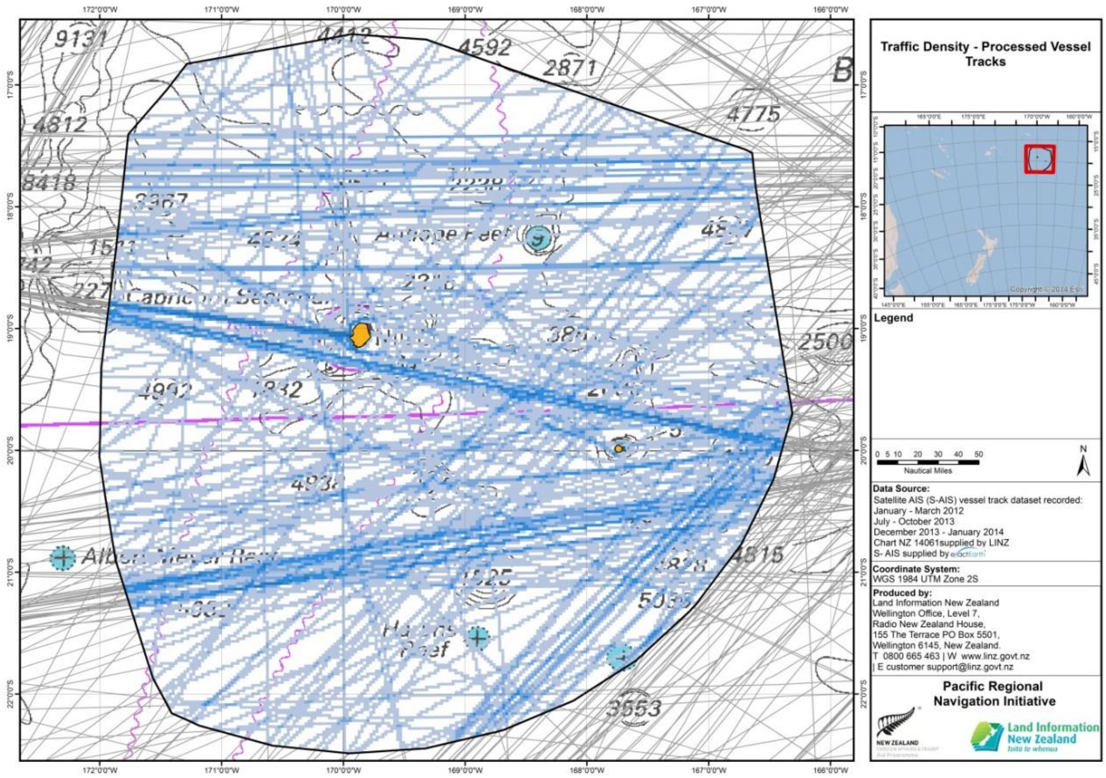
3.4 The impact of the processing on the traffic density across the study area is shown in Figures 6 and 7 on the next page.

3.5 Figure 6 represents the relative traffic density (number of vessels per cell) across the study area before processing. Figure 7 represents the relative traffic density across the study area post processing. There was an increase in the traffic density along the north-west and the south-west coasts of Niue due to the manual correction of overland vessel tracks. The traffic density beyond this coastal region has generally remained comparable to that before the track processing except for near the EEZ boundaries where the extension of incomplete tracks to the boundary has made a noticeable impact.

ANNEX B - GIS Track Creation and Processing



Annex B - Figure 6: Raw traffic density by cell

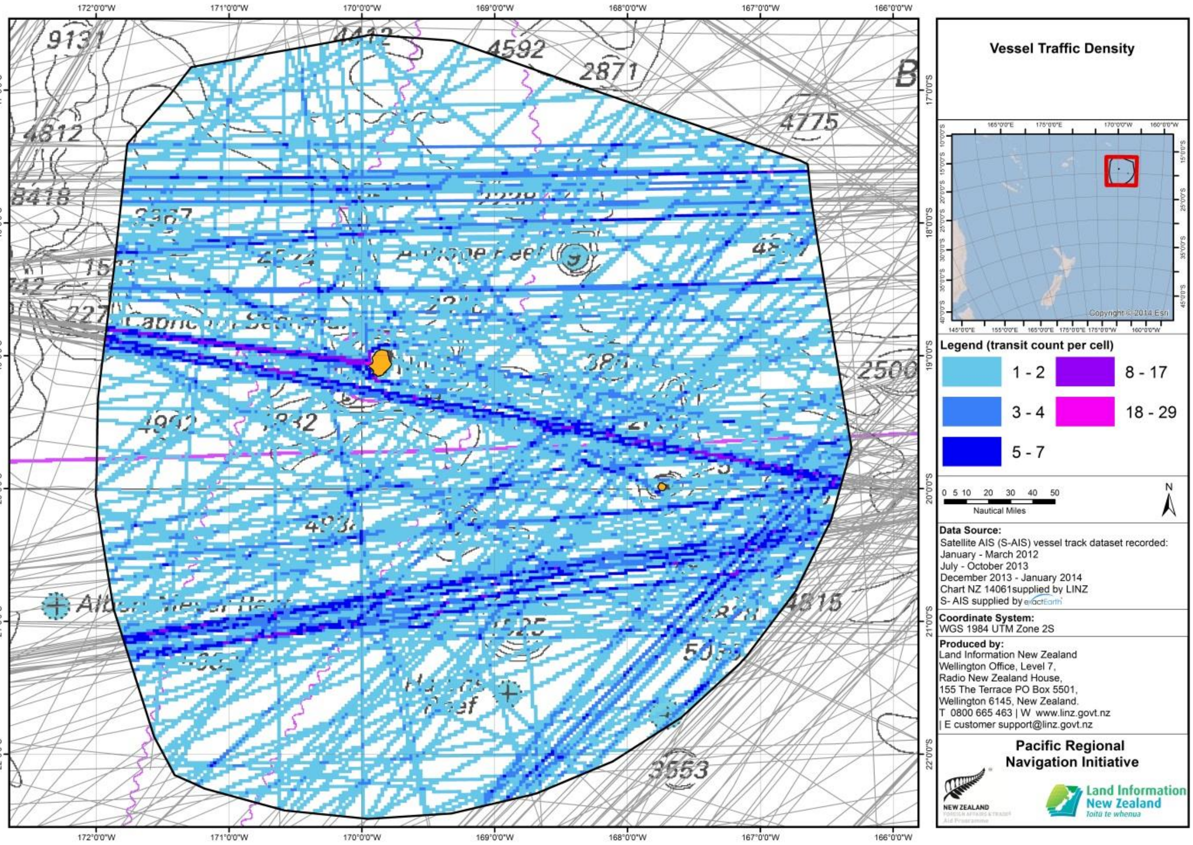


Annex B - Figure 7: Processed traffic density by cell

ANNEX C – Traffic Risk Calculation

1 Traffic Risk Calculation[48]

1.1 After processing the AIS data to produce tracks, a vessel traffic transit density plot was created (see Figure 1). For this purpose the definition of a vessel transit was adopted as "*a sequence of position reports from a particular ship, without significant time gaps, which show some level of purposeful motion*"[49] This overcomes the problem of an anchored vessel biasing the traffic density. A transit starts when a vessel leaves a berth and ends when she leaves the study area. If a vessel stops and starts again then this has been interpreted as two separate transits.



Annex C - Figure 1: Vessel traffic density plot showing number of vessel transits in each cell

1.2 The basis of this risk analysis is that each vessel transit has an inherent potential for loss of life or pollution and that this potential is the product of the size and type of a vessel. For example a large tanker has a higher pollution risk than a smaller one. A large cruise ship may have a smaller pollution risk than a small tanker but a higher potential risk to life. The table at Figure 2 provides GT multipliers for each vessel type in order to calculate the risk inherent in that ship type for pollution or loss of life. This table is taken from *Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, p. D18* and is used to maximise consistency between this risk assessment and the previous LINZ

[48] For consistency with previous LINZ SW Pacific hydrographic risk assessments and convenience of the reader, sections of this Annex have been reproduced by direct copy from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013).
[49] (Calder, 2009)

ANNEX C – Traffic Risk Calculation

hydrographic risk assessments conducted for other South West Pacific States. The referenced report states that the multiplier was "originally created by taking a model ship with a median tonnage that transits through South West Pacific waters and calculating the most likely and worst credible consequences of an incident from *event trees*."[50] For this Niue risk analysis separate *event trees* were created and are provided in Annex A. With the exception of domestic vessels (as no significant domestic vessels exist in Niue), these proved similar to those of previous assessments in Vanuatu, Cook Island and Tonga. This confirmed the validity of adopting the same risk multiplier calculation table as shown in Figure 2 below.

Ship Type	Loss of Life Risk Multiplier		Pollution Risk Multiplier	
	ML	**WC**	**ML**	**WC**
Tankers	$5*10^{-6}$	$7*10^{-5}$	$5*10^{-3}$	0.2
Passenger Ships	$1*10^{-5}$	$1.7*10^{-3}$	$1.6*10^{-5}$	$8.5*10^{-4}$
Cargo Ship	$8*10^{-6}$	$1.7*10^{-4}$	$1.5*10^{-3}$	$7.5*10^{-3}$
Fishing Ships	0.01	0.07	$1*10^{-5}$	0.04
Recreational/ Superyacht	0.01	0.07	$1*10^{-5}$	0.04

Annex C - Figure 2: Table of risk multipliers used to transform GT to a risk potential for the specified vessel types

1.3 This approach is a necessary simplification of reality in a number of ways. Firstly, it is not possible to know the individual crew numbers and cargo volumes of each individual vessel transiting through the study area and so a model ship type will be used. Secondly, the approach is limited in assuming a simplistic linear relationship between GT and consequence potential. This is not always the case and may vary considerably with some vessel types and depending on the employment of the vessel. For example, fishing ships have a relatively high loss of life potential due to their small size and relative instability, dangerous work over the ship's side and their necessity to work is all weather conditions. This risk is likely to be higher for small vessels and in shallow waters where there is a risk of snagging nets on the seabed. However a large fishing vessel working in deeper water is more seaworthy, has more automated equipment and is less likely to snag nets. Additionally, it is exposed to even less risk when not actually engaged in fishing, and when simply on passage is more likely to have the risk profile of a cargo ship. This analysis cannot account for such variations in vessel profile or employment.

[50] (Marico Marine Report No. 12NZ246-1, January 2013, p. D.18)

ANNEX C – Traffic Risk Calculation

1.4 The potential risk of a vessel transit in terms of pollution or loss of life is calculated as the average of the *most likely* and *worst credible* cases and is calculated by the formula below:

$$Potential = ((GT*ML\ Multipler) + (GT*WC\ Multiplier))/2$$

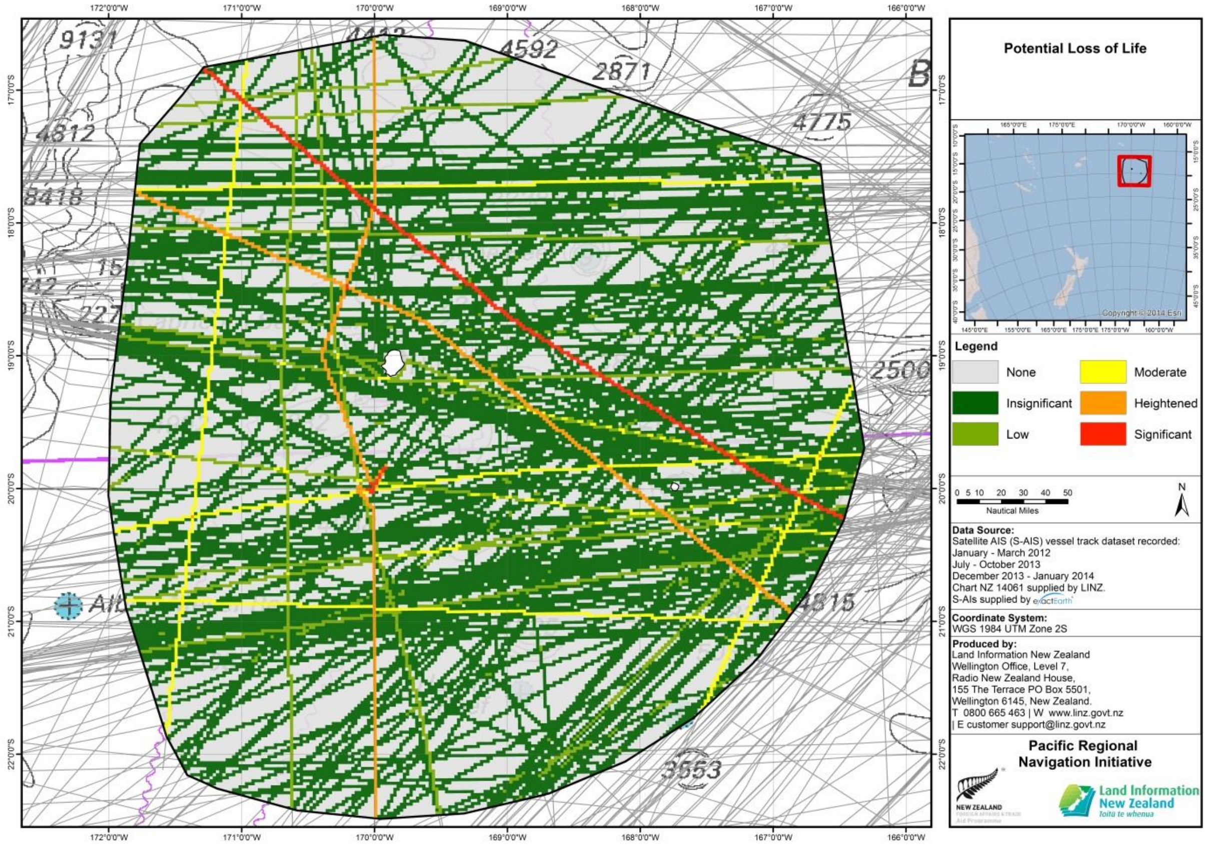
For example the calculation for the pollution potential of a 30,000 GT tanker is:

- Most Likely = 30,000(GT)*0.005(Multiplier) = 150 tonnes spilt.
- Worst Credible = 30,000(GT)*0.2(Multiplier) = 6,000 tonnes spilt.
- Average = (ML+WC)/2 = 3,075 tonnes spilt.

1.5 Using a Jenks Natural Breaks interval method, the distribution of average potential loss of life and average potential pollution were transformed to a 1 to 5 scale. This method of data classification seeks to partition data into classes based on natural groups in the data distribution. Natural breaks occur in the histogram at the low points of valleys. Breaks are assigned in the order of the size of the valleys, with the largest valley being assigned the first natural break[51].

[51]This definition was acquired from esri. “GIS Dictionary.” *esri.* 2016. http://support.esri.com/en/knowledgebase/GISDictionary/term/natural%20breaks%20classification (accessed May 16, 2016).

ANNEX C – Traffic Risk Calculation

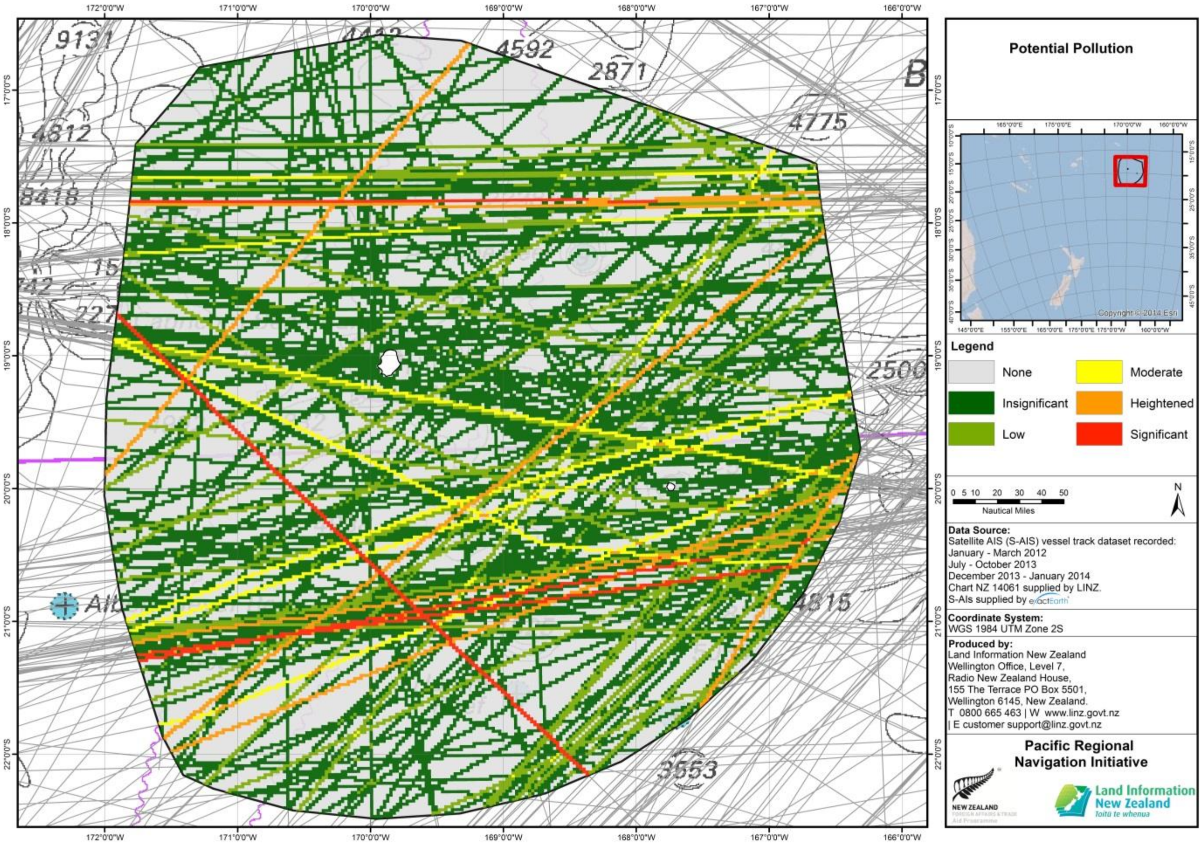


Annex C - Figure 3: Modelled Potential Loss of Life

1.6 Figure 3 shows the modelled potential loss of life across the study area. The areas with a moderate to significant potential loss of life occurred along routes where vessels with a relatively high GT intersected or along the routes travelled by fishing, passenger or superyacht/recreational vessels with a relatively high GT. Note that this is a relative measure using the natural breaks method described above to portray the potential risk variation across the 5 colour bands.

1.7. There are two areas rated as significant loss of life risk on this relative scale. One red line crossing the area in a south easterly direction represents one transit of a 7,800 GT fishing ship (refer discussion at para 1.3 above). The second red area south of Niue is from a 4,000 GT research vessel which operated for a long period in a small area. The fact that these areas are shown as red due to the activities of one ship is indicative of the low amount of traffic and consequently relatively low level of loss of life risk in the Niue EEZ.

ANNEX C – Traffic Risk Calculation



Annex C - Figure 4: Modelled Potential Pollution

1.8 Figure 4 shows the modelled potential pollution across the study area. The waters with a moderate to significant potential pollution occurred along the routes travelled by tankers or where the routes of vessels with a relatively high GT intersected, the majority of this traffic passes in a generally east/west direction across the Niue EEZ. The red line that stands out running in a north westerly direction across the area is attributed to one transit of an 84,000 GT tanker. The fact that this line of cells is shown as red due to the activities of one ship is again indicative of the low amount of traffic and consequently relatively low level of pollution risk in the Niue EEZ.

ANNEX D – Likelihood and Consequence Factors

Overview

1.1 This Annex presents, in GIS form, the likelihood and consequence factors used in the calculation of hydrographic risk and the cost or benefit of addressing areas at risk across the study area. Full details of the level of risk for each factor and its relative importance or influence are shown in the Risk Score Table provided at Annex E. The risk contribution for each element is related to its geographic extent and reduces with distance from the determining feature. This is shown graphically in the Figures of this annex and while the specific measurement scale for each element varies, the relative contribution is generally represented by colour codes as follows:

Grey:	nil
Dark green:	insignificant
Light green:	low
Yellow:	moderate
Orange:	heightened
Red:	significant

1.2 The likelihood factors are those that contribute to the probability of a vessel being involved in a marine accident. These factors are identified as: met-ocean conditions, navigational complexity, aids to navigation, bathymetry and navigational hazards.[52] Figures in section 2 of this Annex shows the level of hydrographic risk due to the proximity of vessel traffic to a feature which is likely to cause or be impacted by a marine accident.

1.3 Consequence factors are used to quantify the effects of an incident.[53] The principal consequence factors are: the environmental impact, damage to culturally sensitive areas and damage to areas that would impact on the Niuean economy

[52]For consistency, this explanation was taken from (Marico Marine Report No. 15NZ322, Issue 3, August 5th, 2015, 29).
[53] For consistency, this explanation was taken from (Marico Marine Report No. 15NZ322, Issue 3, August 5th, 2015, 30).

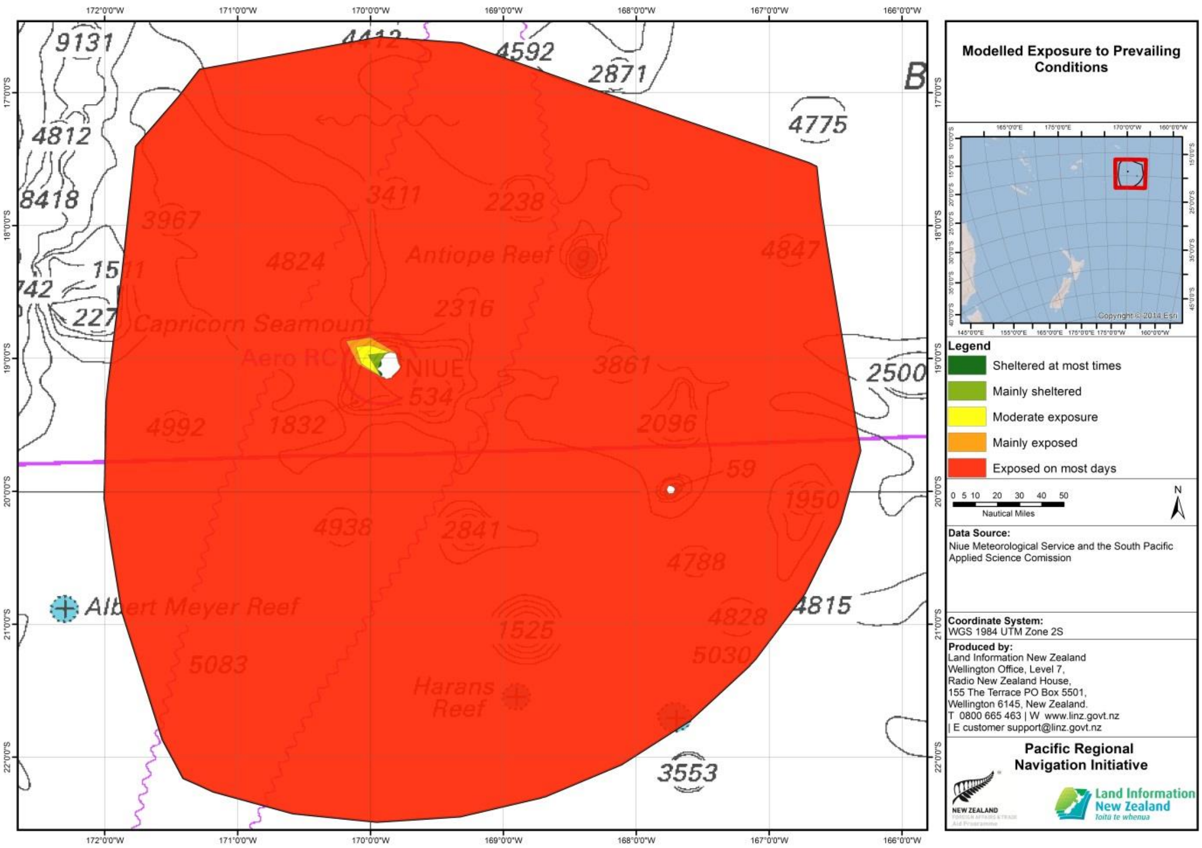
ANNEX D – Likelihood and Consequence Factors

2. Likelihood Factors

2.1 Met-Ocean Conditions

The met-ocean conditions which present a hydrographic risk across the study area are exposure to prevailing conditions, spring mean current speed and visibility.

2.1.1 Exposure to Prevailing Conditions



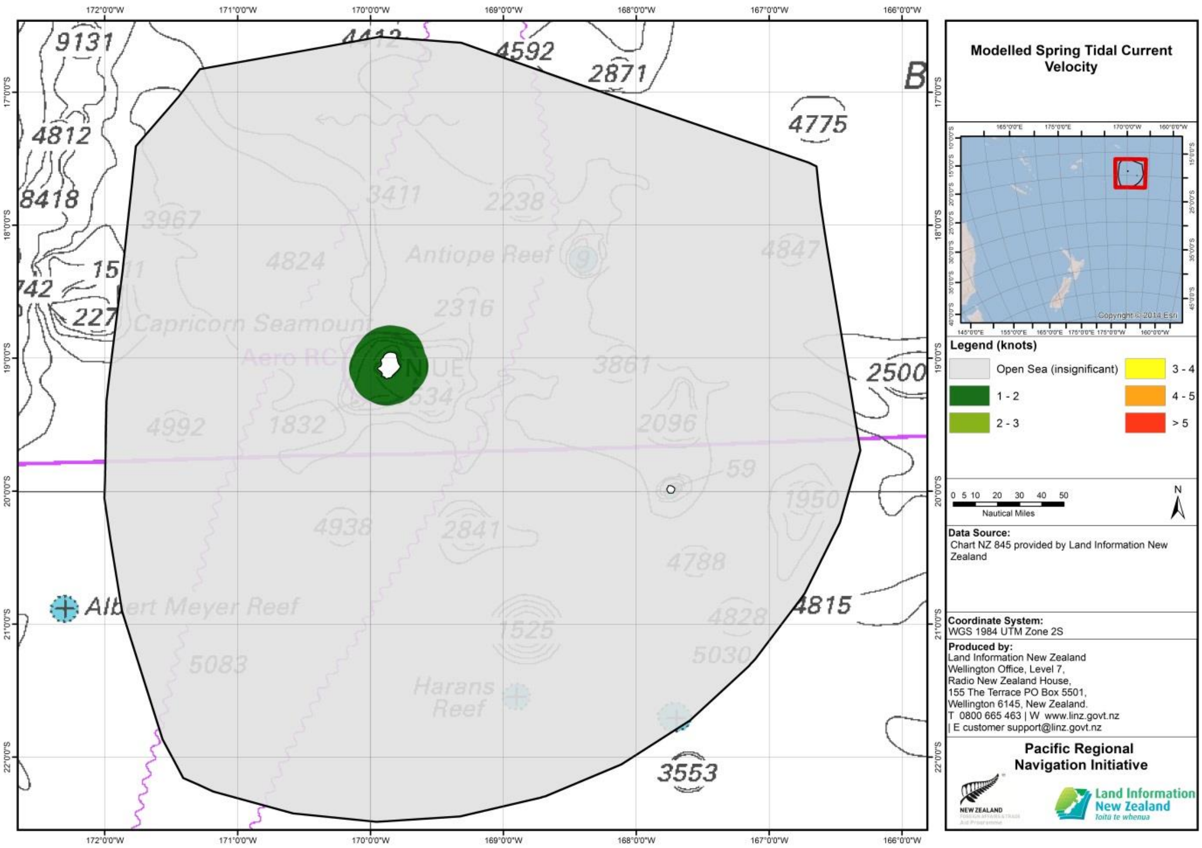
Annex D Figure 1: Modelled Exposure to Prevailing Conditions

Figure 1 represents relative hydrographic risk due to the prevailing conditions across the study area. Information about the wind speed and direction used to create this figure was acquired from the wind rose created for Niue based on 582 observations, taken by the Niue Meteorological Service at the Hanan Airport Observatory during January 1st to June 30th, 2015. The rose showed that there was a predominance of winds from the east and the south east with wind speeds between 0.1 to 40 km/h. Information about the prevailing wave and swell conditions were acquired from the SOPAC Technical Report (PR190)[54]. The report provided a wave climate analysis based on data from 1979 – 2013.

[54] (Applied Geoscience and Technology Division, SPC, 2014, pp. 22-23)

ANNEX D – Likelihood and Consequence Factors

2.1.2 Spring Tidal Current Velocity



Annex D Figure 2: Modelled Spring Tidal Current Velocity

Figure 2 represents relative hydrographic risk due to the spring tidal current velocity across the study area. This figure was created based on tidal currents as marked on chart NZ845. An improvement to this data set could be sought from satellite derived sea surface temperature ocean surface current models which were not available in the timeframe of this study.

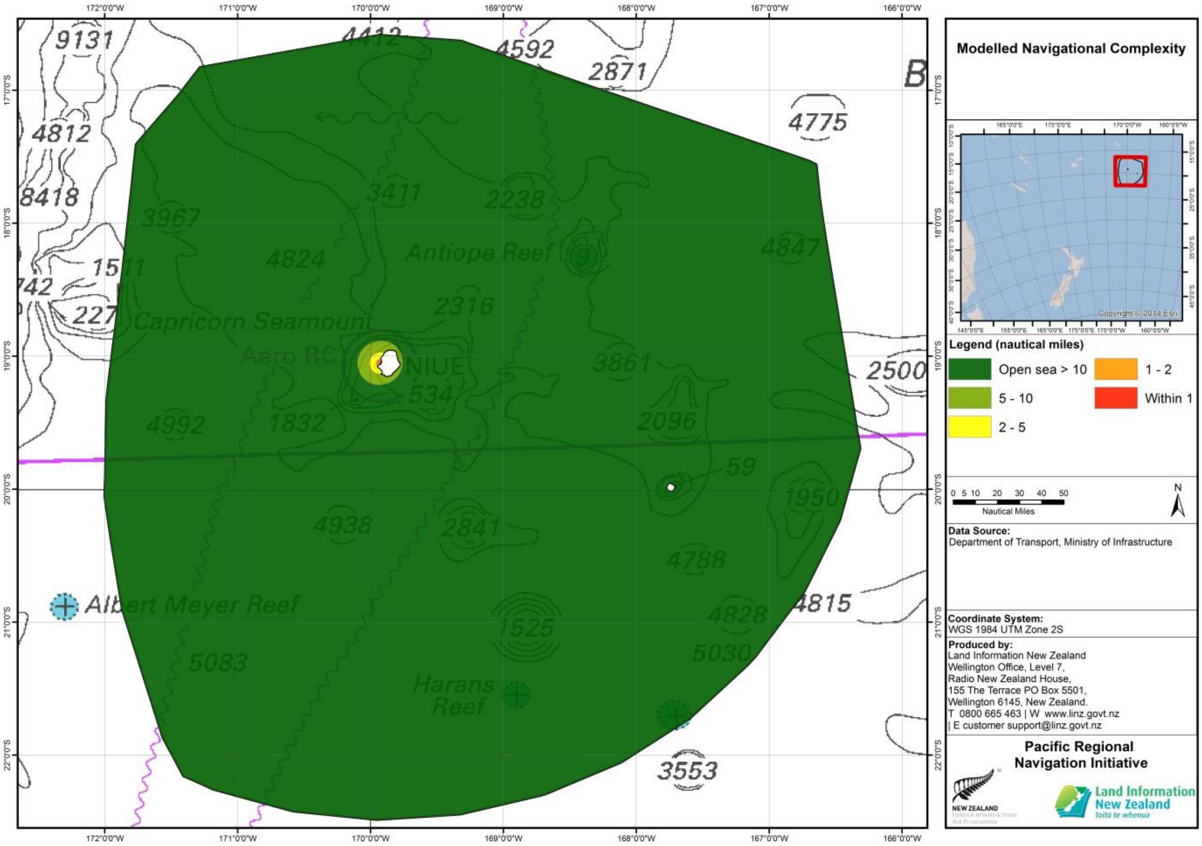
2.1.3 Visibility

While poor visibility can occur across the study area, the occurrence is infrequent and unlikely, and is normally associated with passing rain squalls of short duration. Therefore this factor was assigned a weight of zero in the calculation of hydrographic risk.

ANNEX D – Likelihood and Consequence Factors

2.2 Navigational Complexity

The risk for transiting vessels is greater the more complicated a course is in a given area. In open waters with considerable sea room on either side of the route the risk is significantly reduced in comparison to a constrained navigation channel in a port.[55] In this study, the risk related to navigational complexity was the type of navigation required across the Niue EEZ.



Annex D Figure 3: Modelled Navigational Complexity

Figure 3 represents relative hydrographic risk due to the type of navigation required across the study area. This Figure was created based on a site visit to the Alofi port, as well as an interview with Andre Siohane, the Director General of Infrastructure at the Ministry of Infrastructure. The figure shows that the waters within 1nm of the Niue coastline and the southern side of the port were the waters at significant risk while the waters within 1-2nm of the port were of a heightened risk.

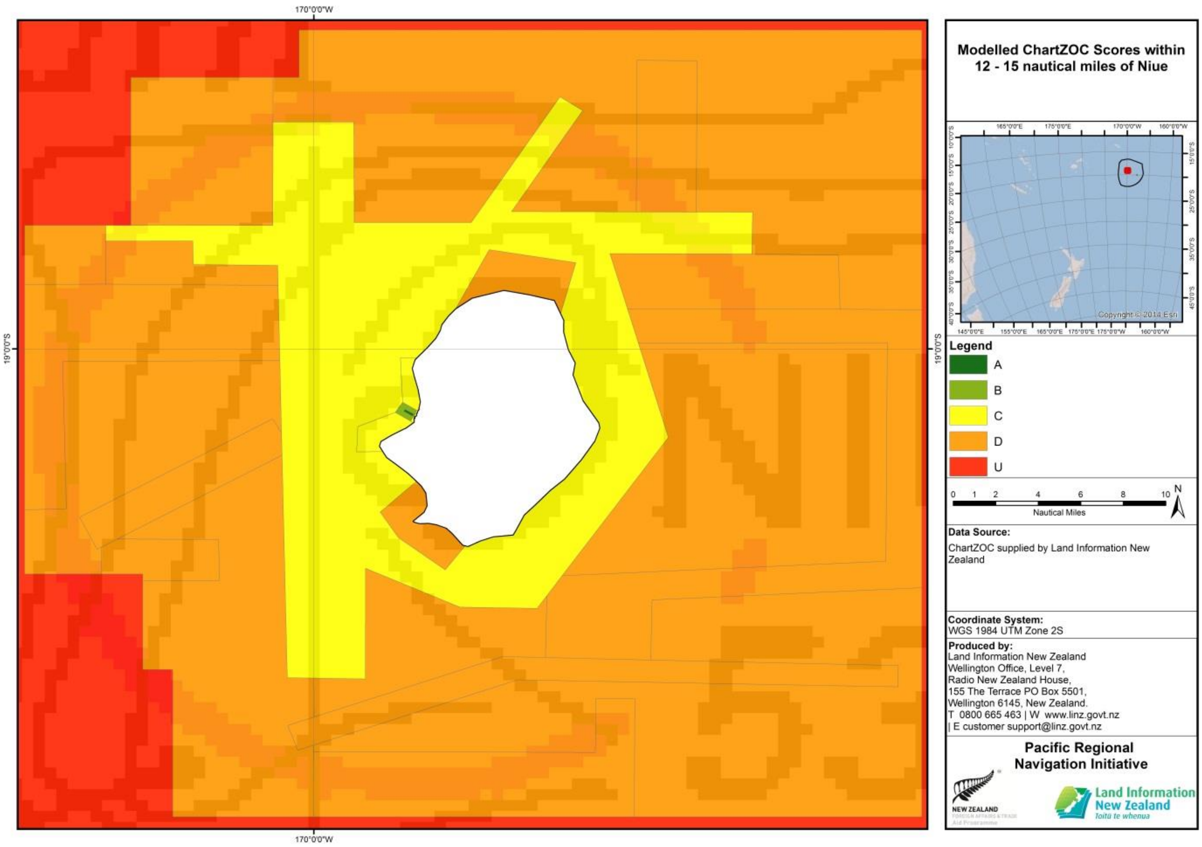
[55] For consistency, this explanation was taken from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D29).

ANNEX D – Likelihood and Consequence Factors

2.3 Aids to Navigation (AtoN) (including Charting)

The risk of a maritime incident is considered to be increased if AtoN are not charted; are incorrectly charted; or are not working. For consistency with previous South- West Pacific risk assessments, the methodology used in this assessment identified two particular hazards; namely, out of date nautical charts and incorrectly marked AtoN such as buoyage or lights.[56] In Niue there are very few formal AtoN, the only lights being the leads to the Alofi landing which were observed to be charted and operating correctly. The real risk factors here are the lack of sufficient AtoN, the presence of unlit FADs and whether the scale of the nautical chart is sufficient for its intended use. Though these factors are not included in the GIS risk calculation they are discussed in the risk results and recommendations.

2.3.1 Charted Zones of Confidence



Annex D Figure 4: Modelled Charted Zones of Confidence Score around Niue

[56] For consistency, this methodology is similar to that used in (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D31).

ANNEX D – Likelihood and Consequence Factors

Figure 4 represents relative hydrographic risk due to the charted zones of confidence; the seafloor of the study area beyond the extents shown in this figure has not been assessed. This Figure was created based on zone of confidence assessment ratings provided by LINZ.

2.3.2 Proximity to Non-Working Aids to Navigation

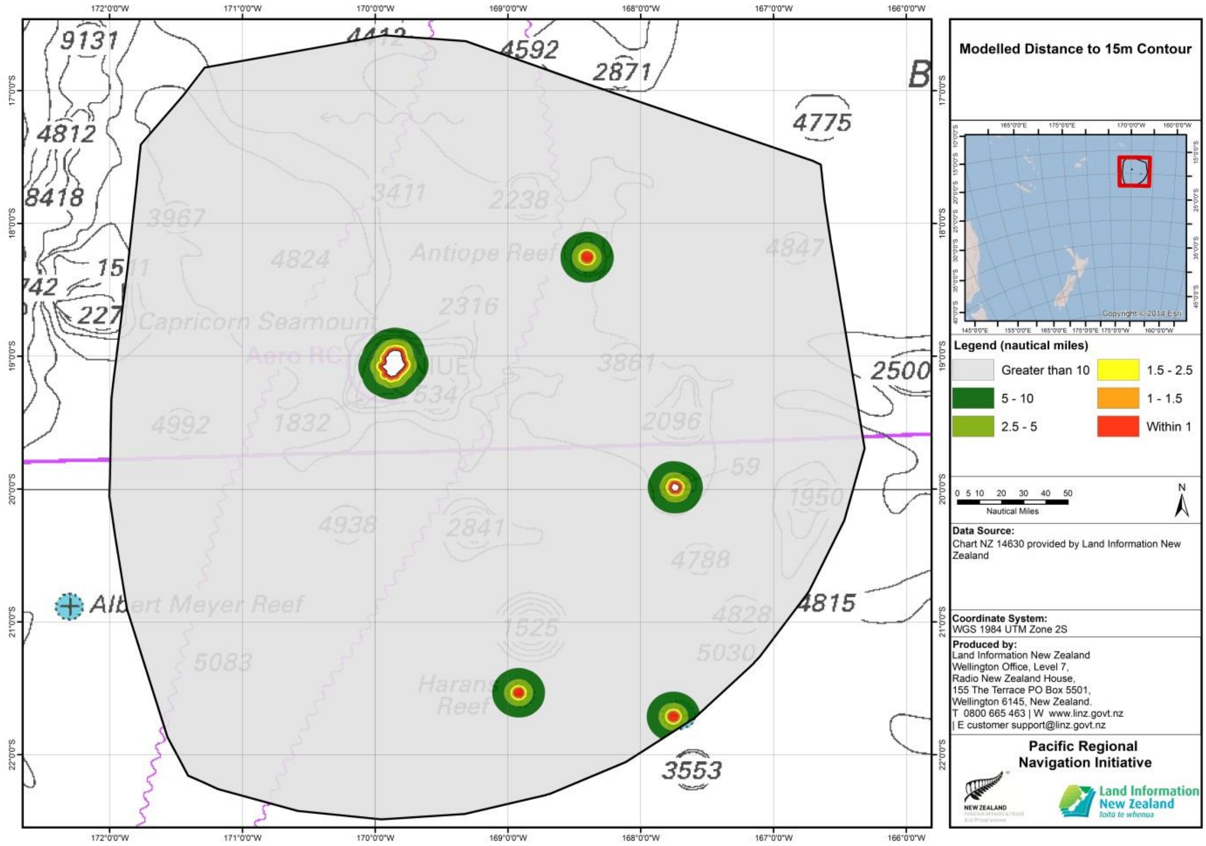
A site visit to the Alofi port showed that the only AtoN on Niue are lit and are correctly marked on LINZ nautical charts. The risk presented by non-working aids to navigation was therefore assigned a weight of 0 in the calculation of hydrographic risk.

ANNEX D – Likelihood and Consequence Factors

2.4 Bathymetry

Depth of available water (or lack thereof), in relation to the draught of vessels navigating in the vicinity, is a considerable hazard to navigation. The hazard is normally considered as the risk of a vessel running aground, however the presence of shallow water also has a secondary effect in limiting the room for vessels to manoeuvre in order to avoid a danger, object or another vessel. Additionally, if a major shipping route is proximate to an area of shallow water then a vessel that becomes disabled has little time to conduct repairs, anchor or obtain assistance before she is aground.[57]

2.4.1 Depth of Water - 15m Contour



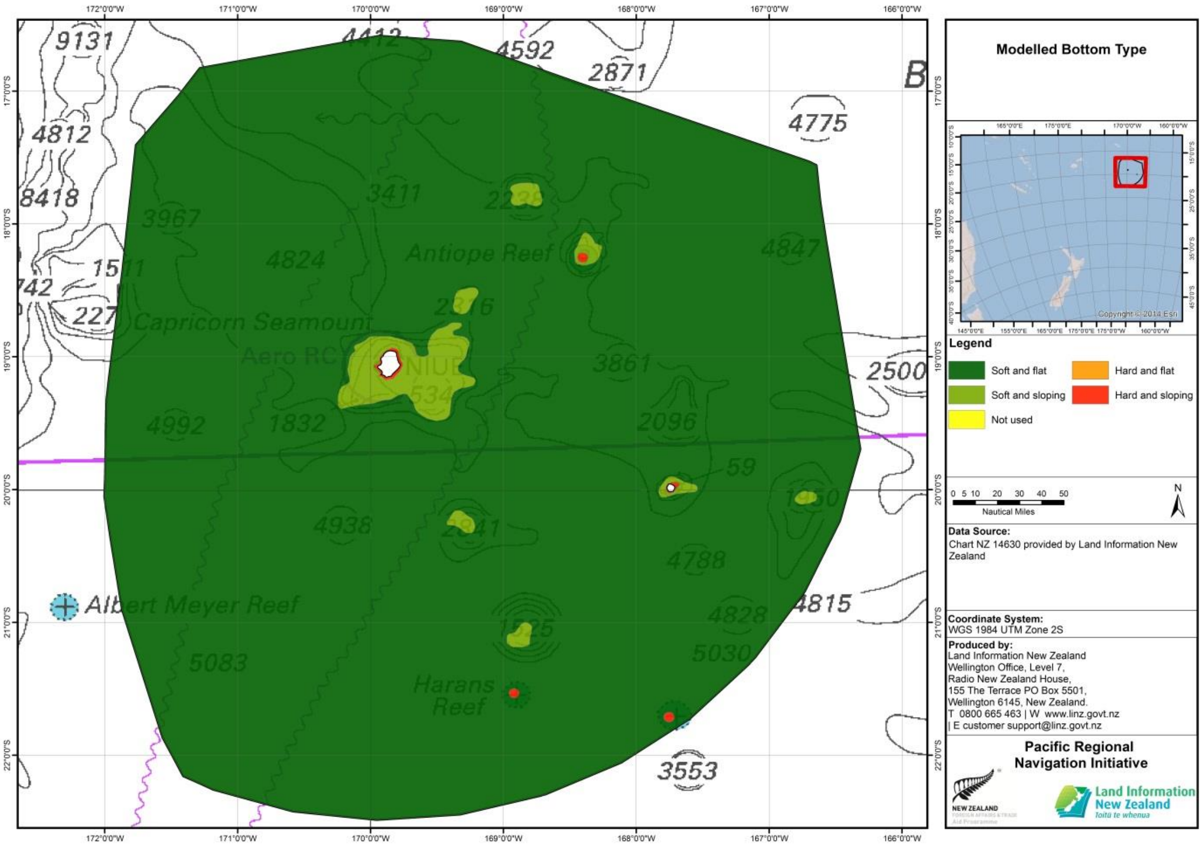
Annex D Figure 5: Modelled Distance to 15m Contour

Figure 5 shows relative hydrographic risk due to the proximity to areas at a minimum depth of 15m. This figure was created based on contour lines as marked on chart NZ 14630 (INT 630).

[57] This explanation has been modified for additional clarity from the original work in (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D36).

ANNEX D – Likelihood and Consequence Factors

2.4.2 Bottom Type



Annex D Figure 6: Modelled Bottom Type

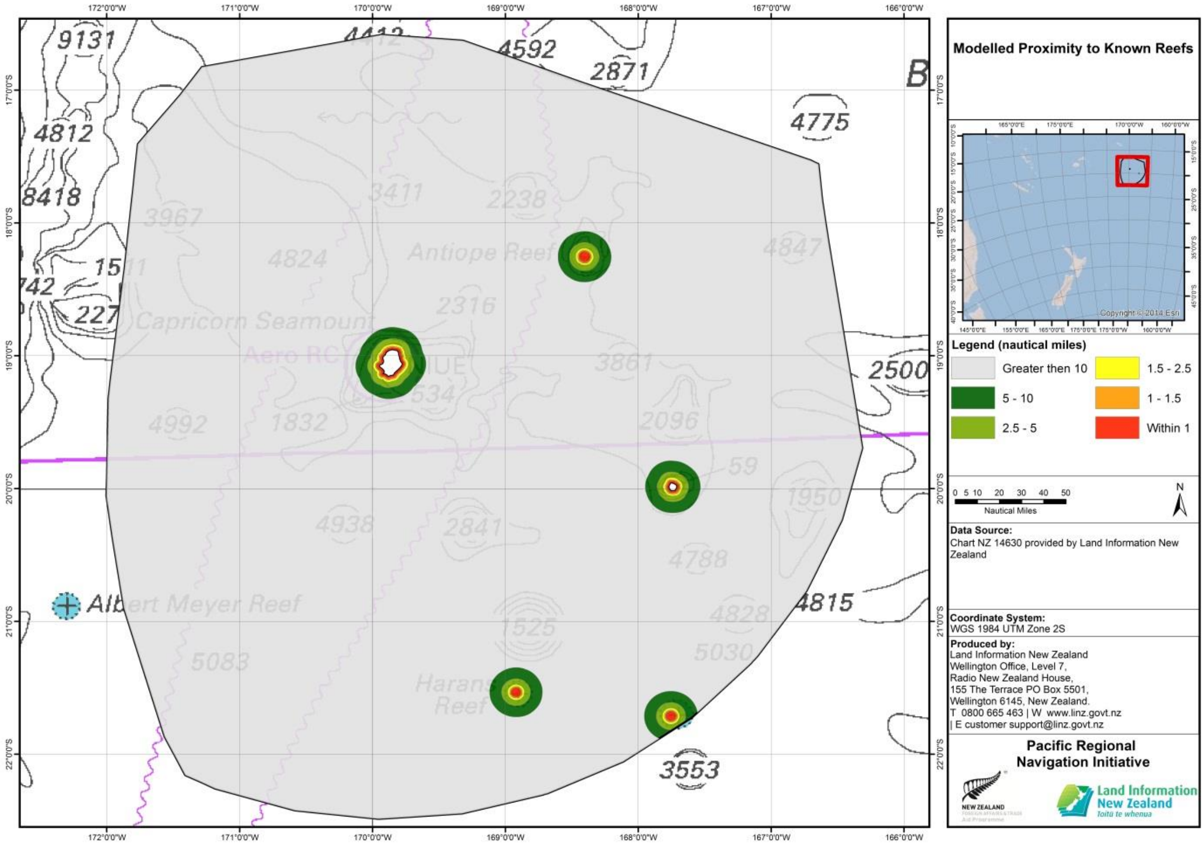
Figure 6 represents relative hydrographic risk due to the nature of the seabed across the study area. This figure was created based on contour lines as marked on chart NZ 14630 (INT 630). While the factors represented here are consistent with the definition in previous risk assessments, in fact the bottom type only becomes significant if there is shallow water and a genuine risk of grounding. Thus only the areas shown in red are relevant to this risk calculation.

ANNEX D – Likelihood and Consequence Factors

2.5 Navigational Hazards

A number of hazards exist that are obstructions to navigating vessels; the risk for a transiting vessel is greater the closer the regular route is to such hazards.[58]

2.5.1 Proximity to Known Reefs



Annex D Figure 7: Modelled Proximity to Known Reefs

Figure 7 represents relative hydrographic risk due to the proximity to charted reefs across the study area. This figure was created based on the location of reefs as marked on chart NZ 14630 (INT 630).

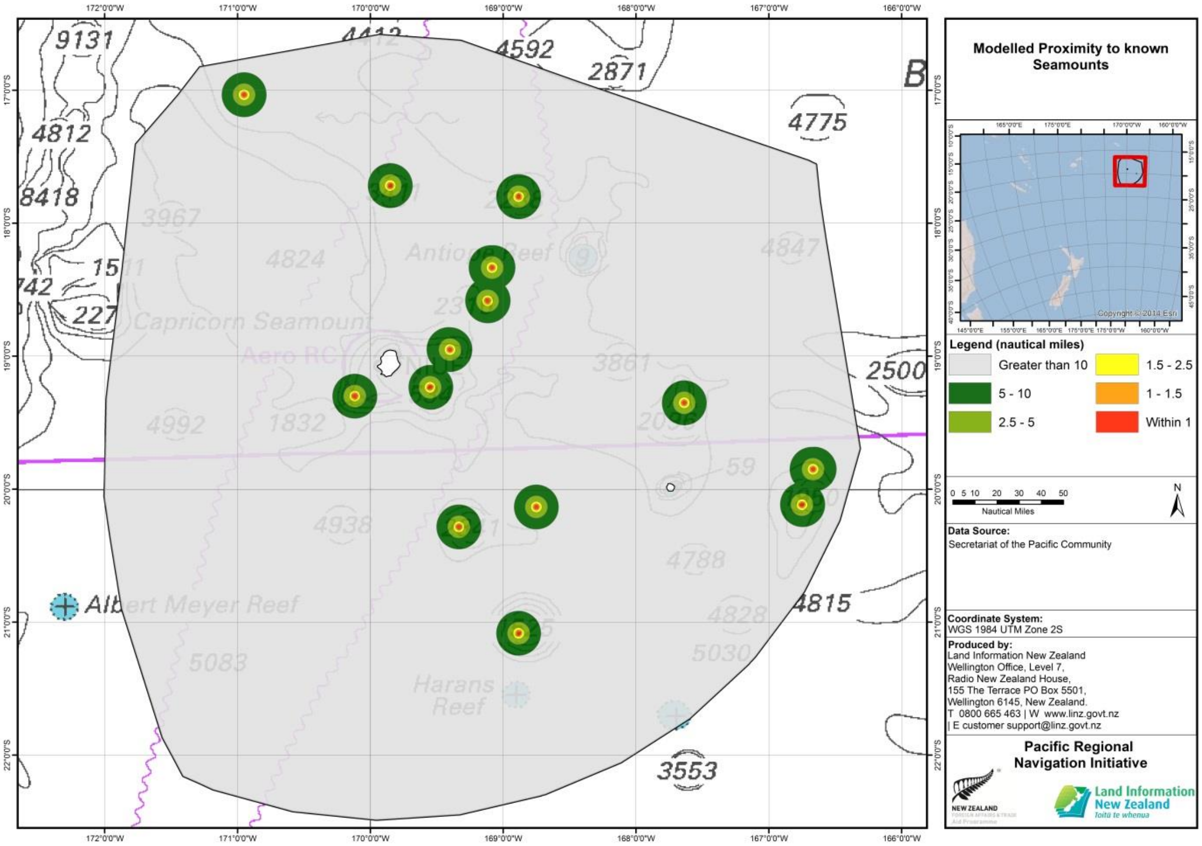
2.5.2 Sub-Sea Volcanic Activity

The study did not find evidence of recent sub-sea volcanic activity across the study area. The level of hydrographic risk due to the proximity to sub-sea volcanic activity was therefore assigned a weight of 0 in the calculation of hydrographic risk and the cost or benefit of addressing these risks.

[58] For consistency, this explanation was taken from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D40).

ANNEX D – Likelihood and Consequence Factors

2.5.3 Proximity to Known Sea-Mounts



Annex D Figure 8: Modelled Proximity to Known Seamounts

Figure 8 represents relative hydrographic risk due to the proximity to known seamounts across the study area. This figure was created based on the Seafloor Imaging (1995) report on Niue's EEZ bathymetry as referenced by in the report by Secretariat of the Pacific Community[59].

2.5.4 Proximity to WW2 Military Sites

The study did not find any WW2 military sites, particularly those of former mined areas or dumping grounds for unexploded ordinance, in the study area. The risk due to the proximity to WW2 military sites was therefore assigned a weight of 0 in the calculation of hydrographic risk and the cost or benefit of addressing these risks.

2.5.5 Proximity to Charted Tidal Hazards (Overfalls/Race)

The study found that charted tidal hazards (overfalls/race) were not present across the study area. The risk due to the proximity to charted tidal hazards (overfalls/race) was therefore assigned a weight of 0 in the calculation of hydrographic risk and the cost or benefit of addressing these risks.

[59] (Secretariat of the Pacific Community, 2007)

ANNEX D – Likelihood and Consequence Factors

3. Consequence Factors

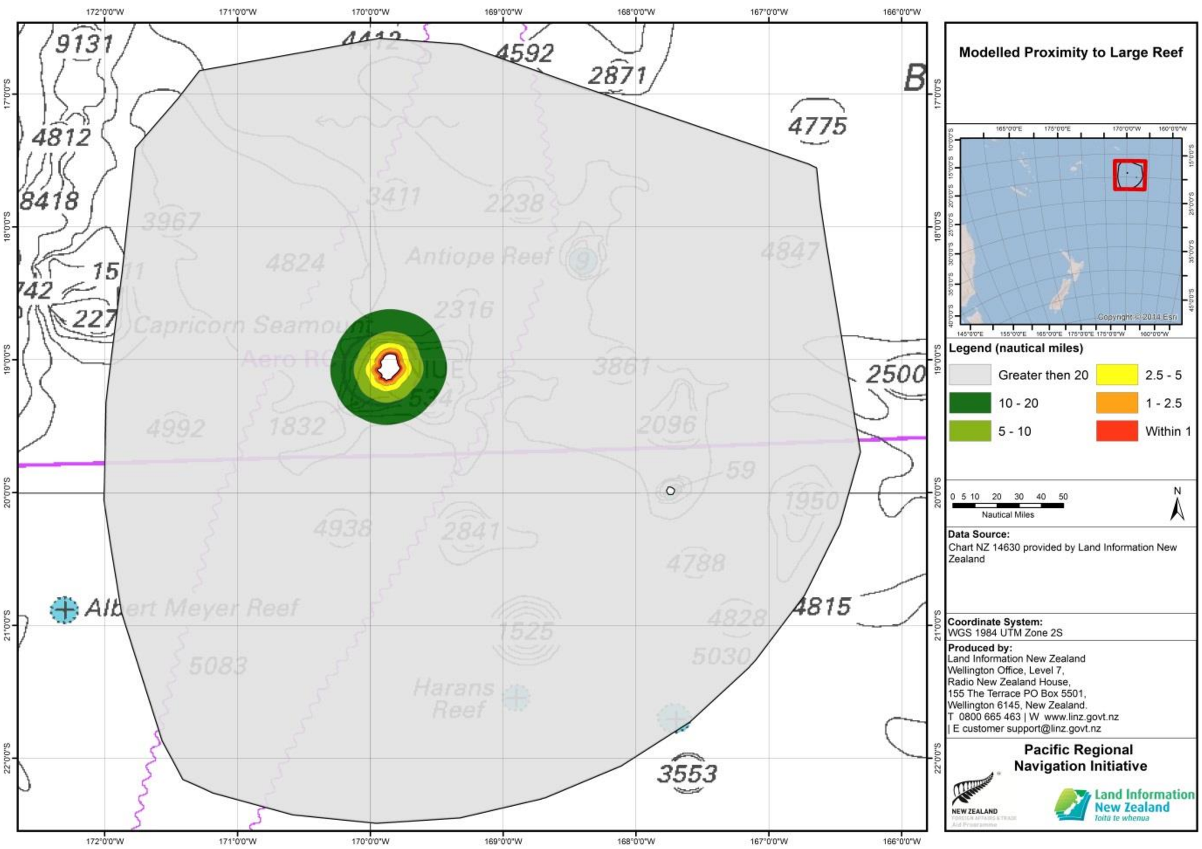
3.1 Environmental Impact

The effect on the marine environment following a major maritime disaster can be devastating. In particular a considerable risk exists in the potential for a fuel tank or a cargo hold to be breached, releasing pollutants. Shoreline habitats can be destroyed by either the primary physical impact of grounding or through the secondary release of a pollutant.[60]

3.1.1 Proximity to Wetland Resources (Mangroves)

Large and small wetland resources can be impacted by a maritime incident within the South West Pacific, however, wetlands are not present within the study area due to Niue being a unique uplifted coral island. The risks to large and small wetland resources were therefore assigned weights of 0 in the calculation of hydrographic risk and the cost or benefit of addressing these risks.

3.1.2 Proximity to Large Reefs



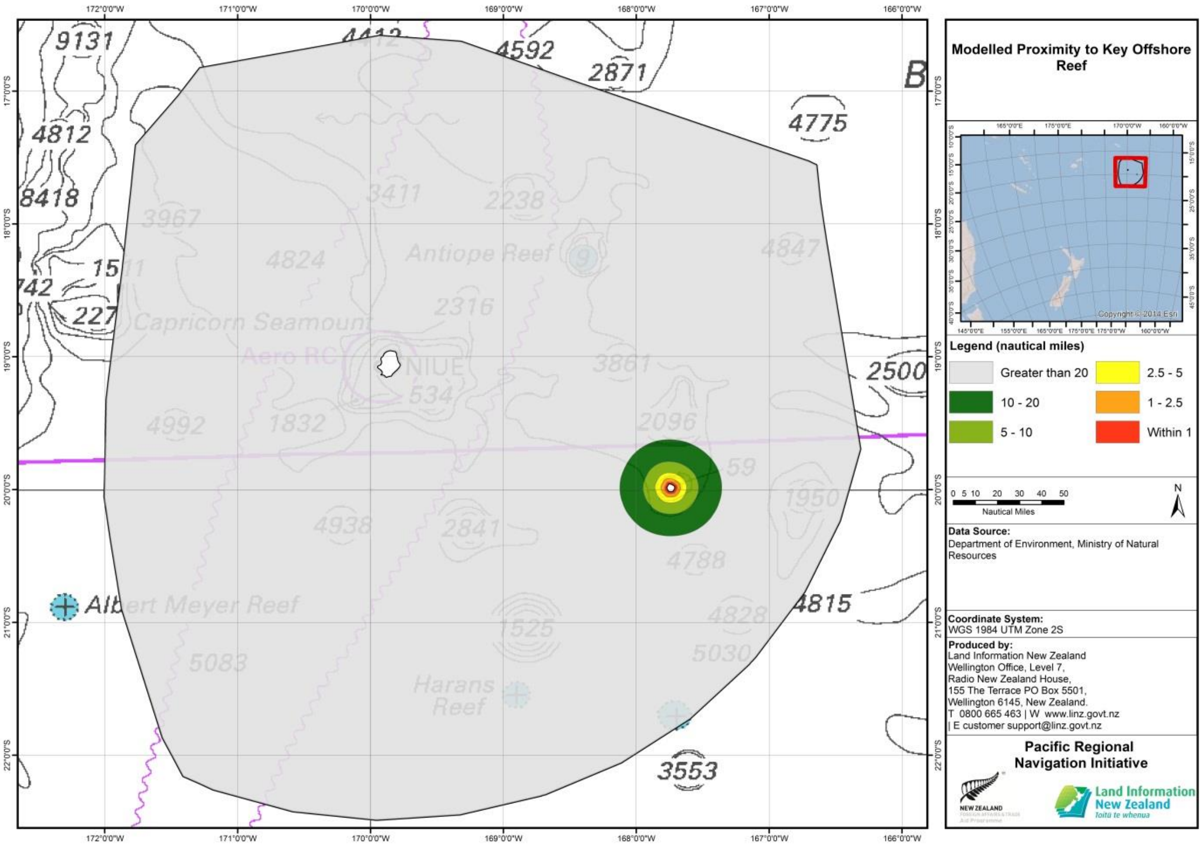
Annex D Figure 9: Modelled Proximity to Large Reefs

[60] For consistency, this explanation was taken from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D51).

ANNEX D – Likelihood and Consequence Factors

Figure 9 represents relative hydrographic risk due to the proximity to large reefs across the study area. This figure was created using chart NZ 14630 (INT 630) which shows that Niue is the only large reef across the area of study. Beveridge Reef was classified as a "Key Offshore Reef" and it was not considered appropriate to include it in two similar consequence criteria.

3.1.3 Proximity to Key Offshore Reef



Annex D Figure 10: Modelled Proximity to Key Offshore Reef

Figure 10 represents relative hydrographic risk due to the proximity to key offshore reefs across the study area. This figure was created based on an interview with Josie Tamate the Director General of Natural Resources at the Ministry of Natural Resources, who identified Beveridge Reef as an important breeding ground, a popular location for recreational vessels; and therefore a site of economic potential for Niue. She also explained that Beveridge Reef is a protected area under Niuean regulations such as the:

i. Whale Sanctuary Regulations 2003;

ii. Territorial Sea and Exclusive Economic Zones Act 1996;

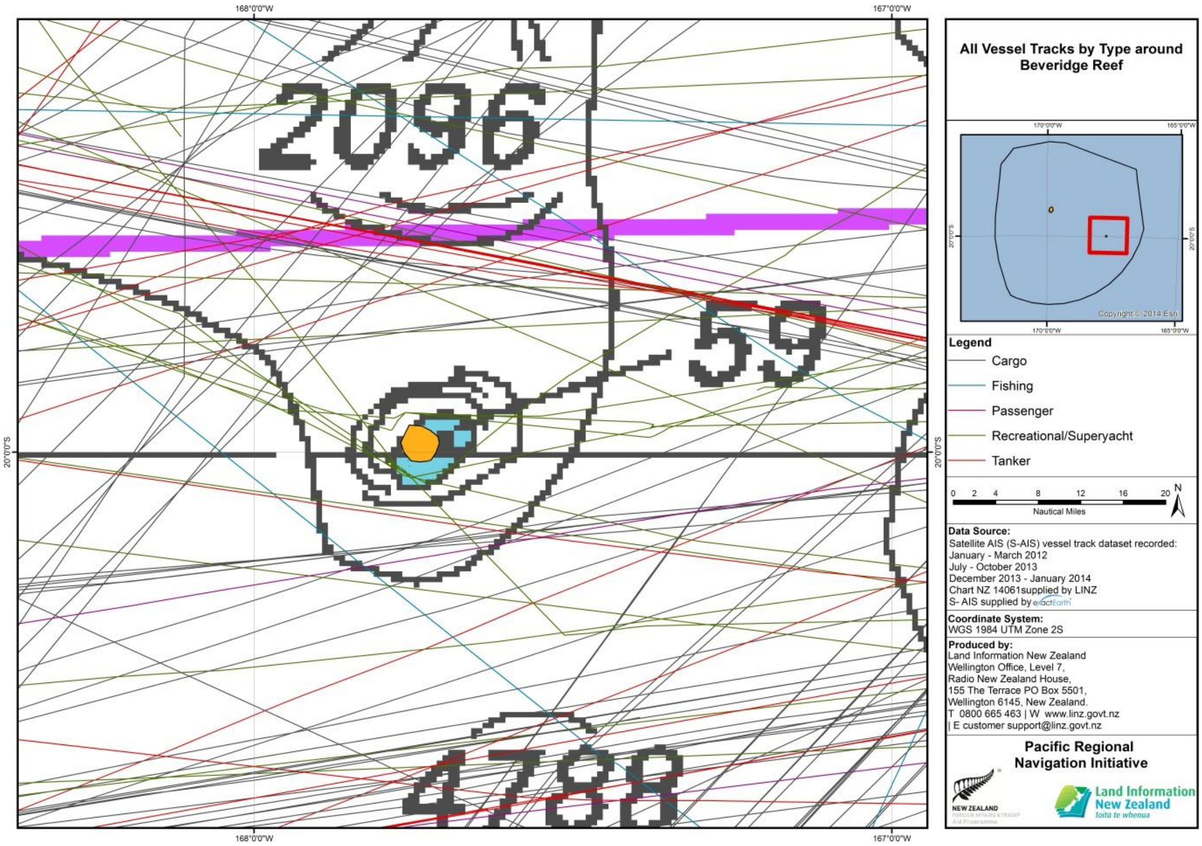
iii. Domestic Fishing Act 1995;

iv. Domestic Fishing Regulations 1996; and

ANNEX D – Likelihood and Consequence Factors

v. Territorial Sea and Exclusive Economic Zone License (Fees) Regulations 2010.

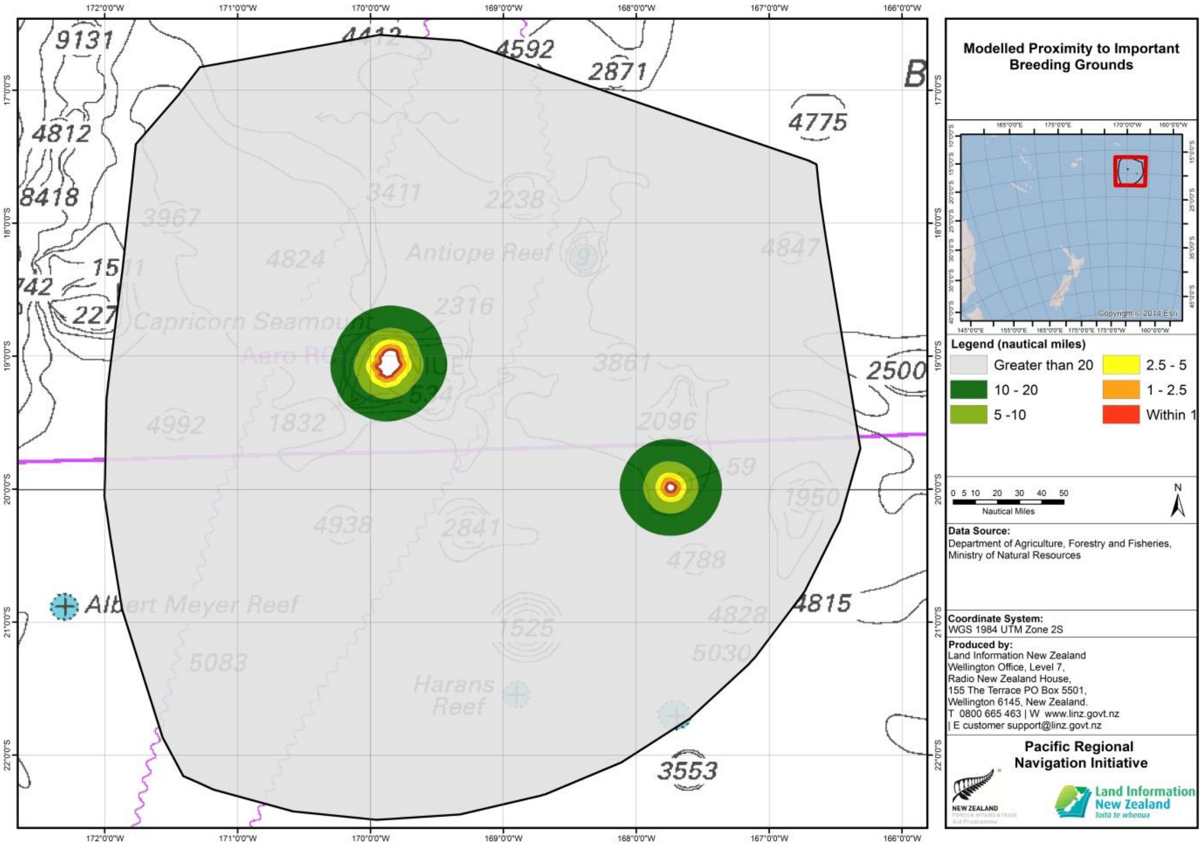
Keith Vial, the Commodore corroborated that Beveridge Reef is a popular location for recreational vessels as shown in Figure 11. The other named offshore reefs Antiope and Harans were not referred to by Niue Government as key offshore reefs and so were not included in this consequence criterion.



Annex D Figure 11: Recreational Vessels visiting Beveridge Reef (in green)

ANNEX D – Likelihood and Consequence Factors

3.1.4 Proximity to Important Breeding Grounds



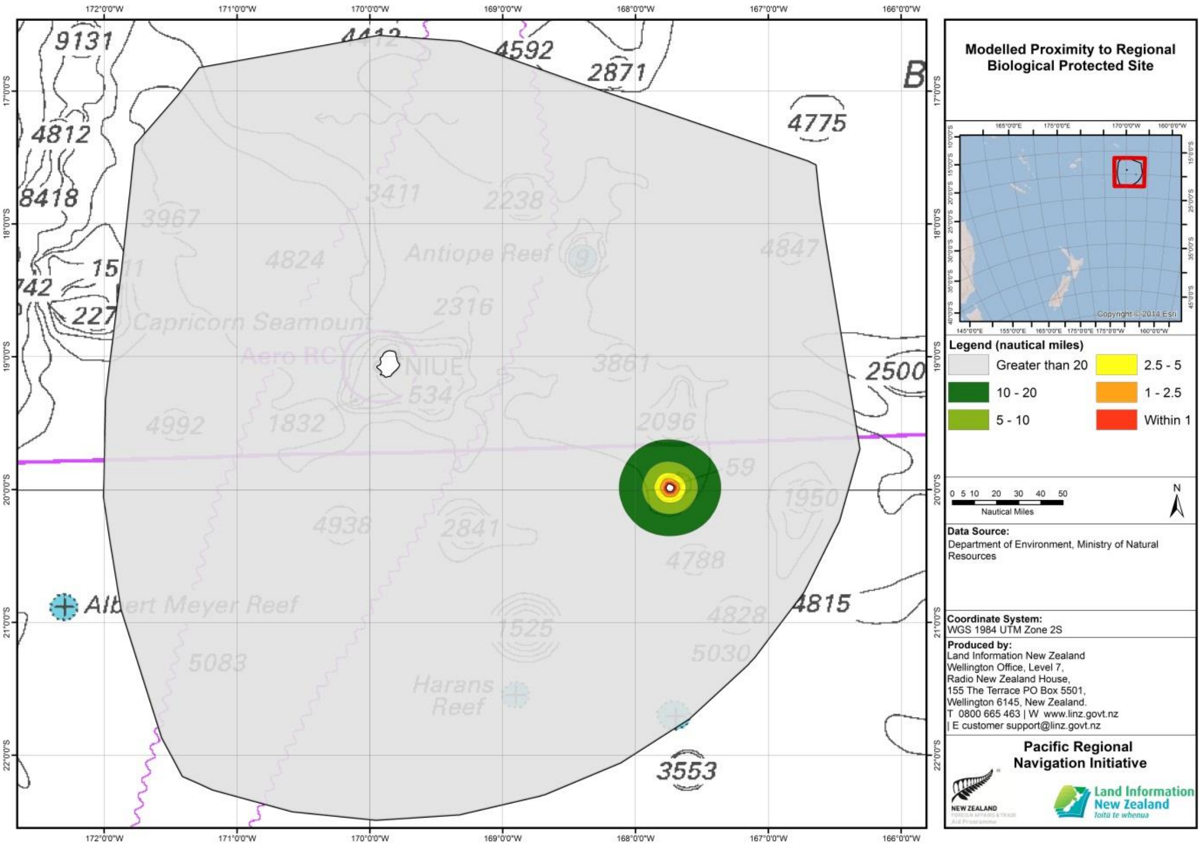
Annex D Figure 12: Modelled Proximity to Important Breeding Grounds

Figure 12 represents relative hydrographic risk due to the proximity to important breeding grounds across the study area. This figure was created based on an interview with Josie Tamate, the Director General of Natural Resources at the Ministry of Natural Resources who explained that Fisheries is recognised within the Niue National Strategic Plan (NNSP) as a key sector and natural resource that offers significant economic development opportunities for Niue. She also explained that fisheries development and management is currently governed under Niuean regulations listed under Figure 11 and that there are future plans to classify Beveridge Reef as a marine reserve.

James Tafatu, the Principal Fisheries Officer at the Department of Agriculture, Forestry and Fisheries of Niue (DAFF) corroborated this information by explaining that the area within 3nm of Niue and Beveridge Reef are important breeding grounds therefore fishing is allowed along the coastline of Niue but is prohibited within 3nm of the external perimeter of Beveridge Reef. He also explained that studies are underway to determine whether Niuean fish stock and marine animal diversity originate from Beveridge Reef.

ANNEX D – Likelihood and Consequence Factors

3.1.5 Proximity to Regional Biological Protected Sites



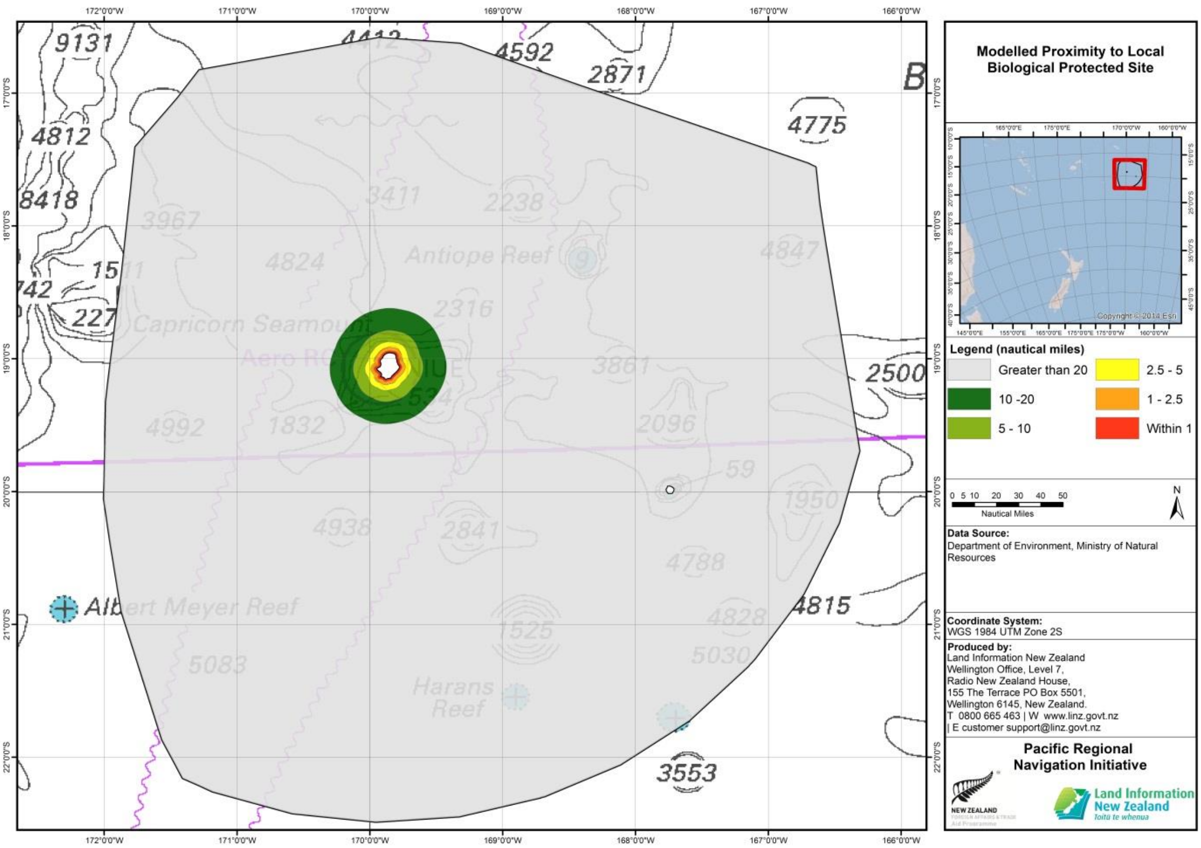
Annex D Figure 13; Modelled Proximity to Regional Biological Protected Sites

Figure 13 represents relative hydrographic risk due to the proximity to regional biological protected sites across the study area. In this figure Beveridge Reef is given the significance of a regional biological protected site due to the stated intention of creating a PSSA or marine reserve discussed under Figures 11 – 13, and an interview with Coral Pasisi[61]. Pasisi explained that the marine spatial planning system being created under this project would be used to conserve and sustainably manage Niue's waters and maintain Niue's global profile as a pristine eco-tourism destination.

[61] Coral Pasisi is a Niuean national who is currently working as a consultant working for the Niue Ocean Wide (NOW) Project and the Green Climate Fund.

ANNEX D – Likelihood and Consequence Factors

3.1.6 Proximity to Local Biological Protected Site



Annex D Figure 14: Modelled Proximity to Local Biological Protected Site

This Figure represents relative hydrographic risk due to the proximity to local biological protected sites across the area of study. This figure was created based on the information explained under Figures 11 – 13. As noted above, while Beveridge Reef is already locally protected by Niue regulation, it is given the greater weighting of being considered as a regional protected site shown in Figure 14 so is not shown here.

ANNEX D – Likelihood and Consequence Factors

3.2 Culturally Sensitive Areas

The consequences of a shipping incident may cause damage beyond the environment. Areas of high cultural significance need to be allocated appropriate consequence weightings. As with environmentally significant sites the relative importance of these sites can range from sites of global significance such as World Heritage Sites to local tabus.

As in previous South West Pacific risk assessments, three designations were created relating to the relative significance of a cultural site. Cultural sites can be globally, regionally or locally significant depending on the importance of a protection designation, such as World Heritage Site, or the size of the group for whom the site is important.[62]

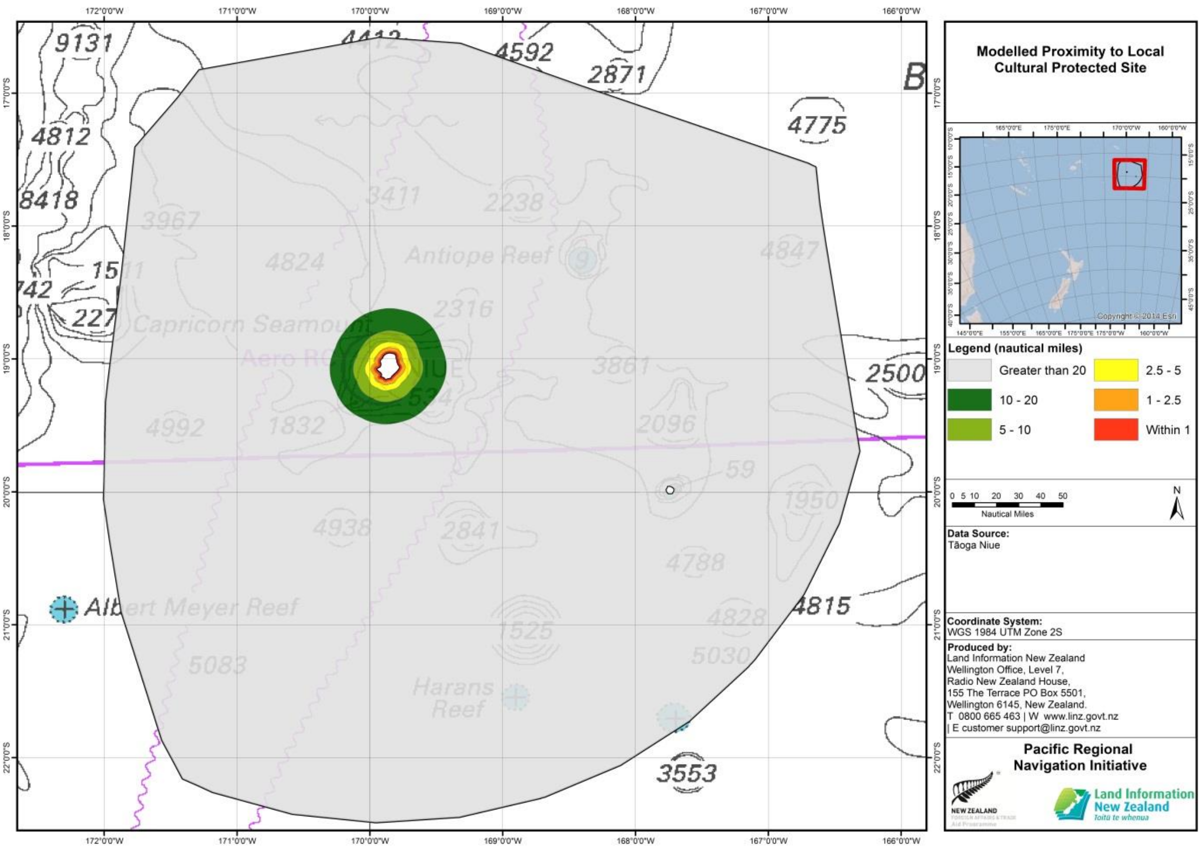
3.2.1 Proximity to World/Regionally Cultural Protected/Important Sites

The study found that there were no world recognised or regionally protected cultural heritage sites across the study area, these factors were therefore both given a weight of 0 in the calculation of hydrographic risk and the cost or benefit of addressing the identified risk.

[62] For consistency, this explanation was taken from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D65).

ANNEX D – Likelihood and Consequence Factors

3.2.2 Proximity to Local Cultural Protected/Important Sites



Annex D Figure 15: Modelled Proximity to Local Cultural Protected Site

Figure 15 represents relative hydrographic risk due to the proximity to local cultural protected sites. This figure identifies the entire coastline of Niue as local culturally protected was created based on discussion with local people and opinion given by Coral Pasisi[63]. There is little documented evidence on local cultural sites as the information is held by village chiefs and passed down through generations. Pasisi explained that Niue's coastline has significant value to the local people and the local village councils manage and protect their respective cultural areas many of which exist along the coastlines. For example, the local councils would close areas to fishing for various periods and limit access to section of their coast on a seasonal basis. She noted that an earlier project had collected information on culturally significant areas from the villages of Niue but was lost in the destruction of Government buildings during Cyclone Heta in 2004.

63 Coral Pasisi is a Niuean national who is currently working as a consultant working for the Niue Ocean Wide (NOW) Project and the Green Climate Fund.

ANNEX D – Likelihood and Consequence Factors

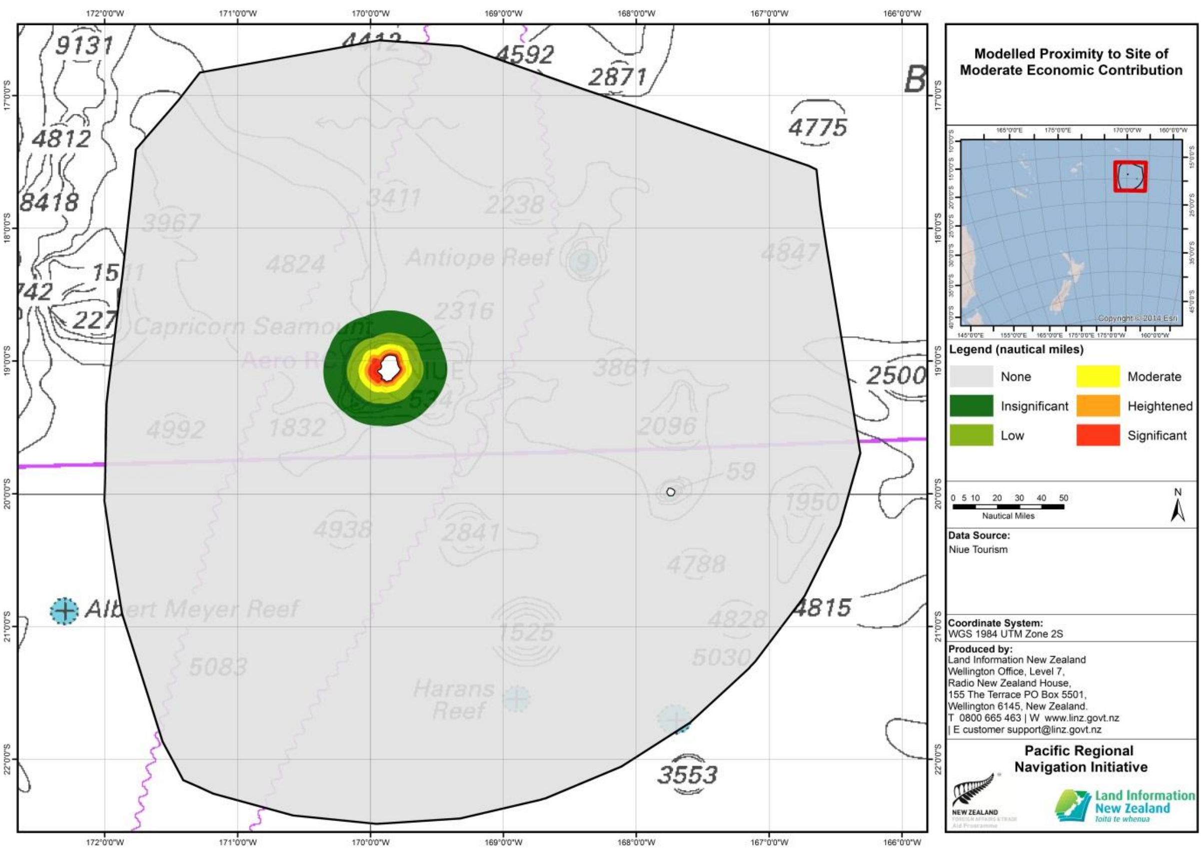
3.3 Economically Sensitive Areas

The economic consequence of a shipping incident refers to the impact upon the local economy and not to the ship operator. The economic consequence is in most cases a denial of access problem with the loss of a resource, tourist potential or in the extreme a closure of a business.[64]

3.3.1 Proximity to Site of High Economic Contribution

The study found that there were no sites of high economic contribution to Niue. The risk to sites of high economic contribution was therefore given a weight of 0 in the calculation of hydrographic risk and the cost or benefit of addressing the identified risk.

3.3.2 Proximity to Site of Moderate Economic Contribution



Annex D Figure 16: Modelled Proximity to Site of Moderate Economic Contribution

Figure 16 shows relative hydrographic risk due to the proximity to sites of moderate economic contribution. This figure was created based on information provided by Olah Jacobsen.[65] During the interview Jacobsen outlined the extents of game fishing and whale watching tours on chart NZ 845,

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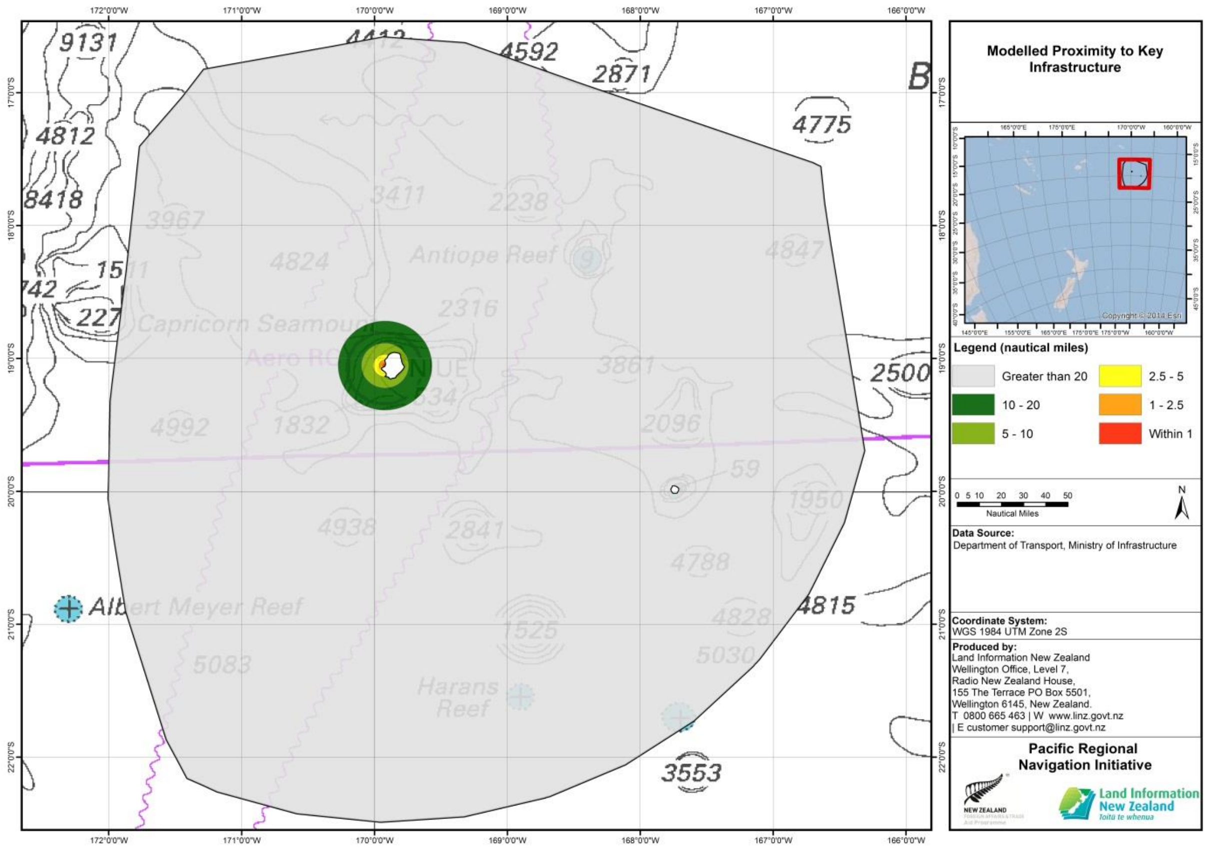
[64] For consistency, this explanation was taken from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D70).
[65] Event Manager at Niue Tourism

ANNEX D – Likelihood and Consequence Factors

which was used to create this figure. This area also encompasses the FADs established around Niue and the area of surface swimming and shallow diving.

3.3.3 Proximity to Key Infrastructure



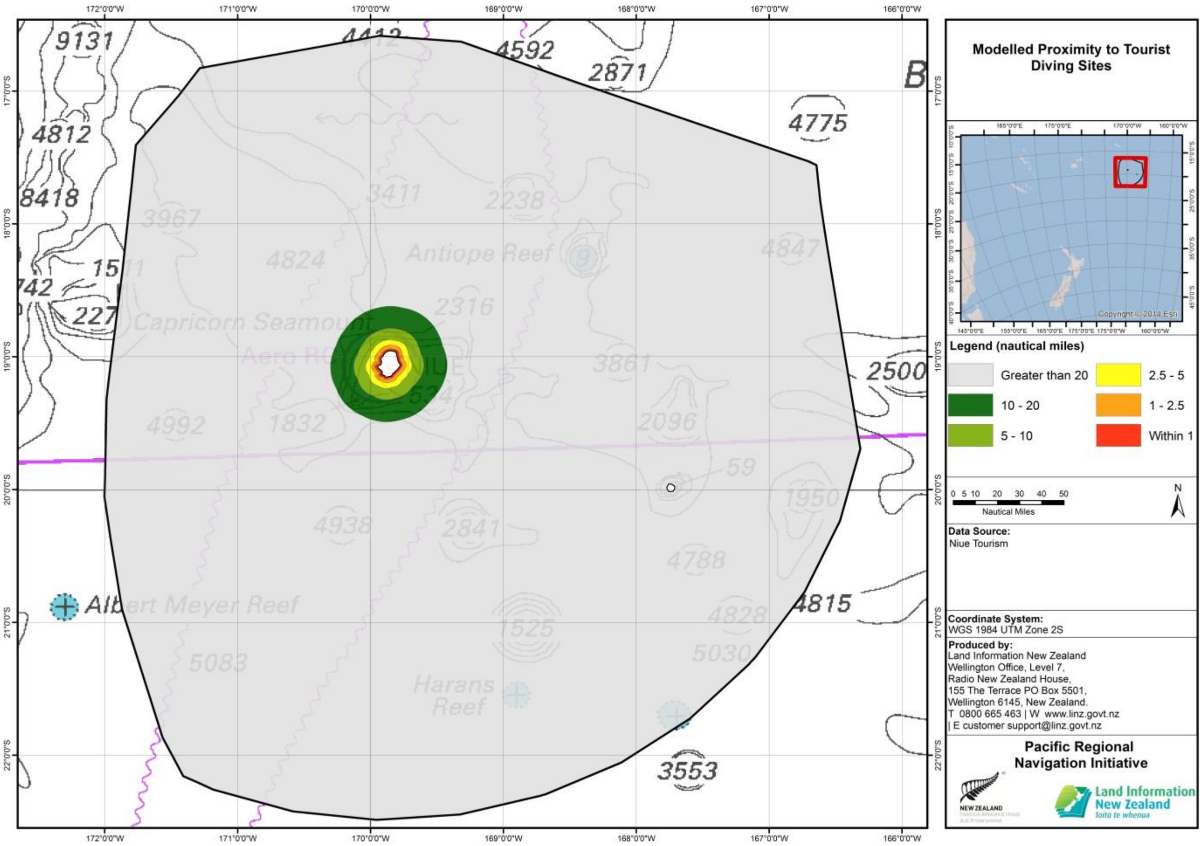
Annex D Figure 17: Modelled Proximity to Key Infrastructure

Figure 17 represents relative hydrographic risk due to the proximity to key infrastructure across the study area. This figure was created based on an interview with Andre Siohane[66] who identified the Alofi port at Niue as the key infrastructure across the study area.

[66] Director General of Infrastructure, Ministry of Infrastructure

ANNEX D – Likelihood and Consequence Factors

3.3.4 Proximity to Tourist Diving Site



Annex D Figure 18: Modelled Proximity to Tourist Diving Site

Figure 18 shows relative hydrographic risk due to the proximity to tourist diving sites across the study area. This figure was created based on an interview with Olah Jacobsen.[67] During the interview Jacobsen outlined the extents of tourist diving sites on chart NZ845, which included the entire coastline of Niue and also sea areas out to 3 km along much of the west coast. It was concluded that the coastline is the area best defined as tourist diving site and is depicted in this figure. The sea area out to 3 km is used for swimming with whales and has been defined as an area of significant economic activity depicted in Figure 16.

[67] Event Manager at Niue Tourism

ANNEX D – Likelihood and Consequence Factors

3.3.5 Proximity to Cruise Ship Stop

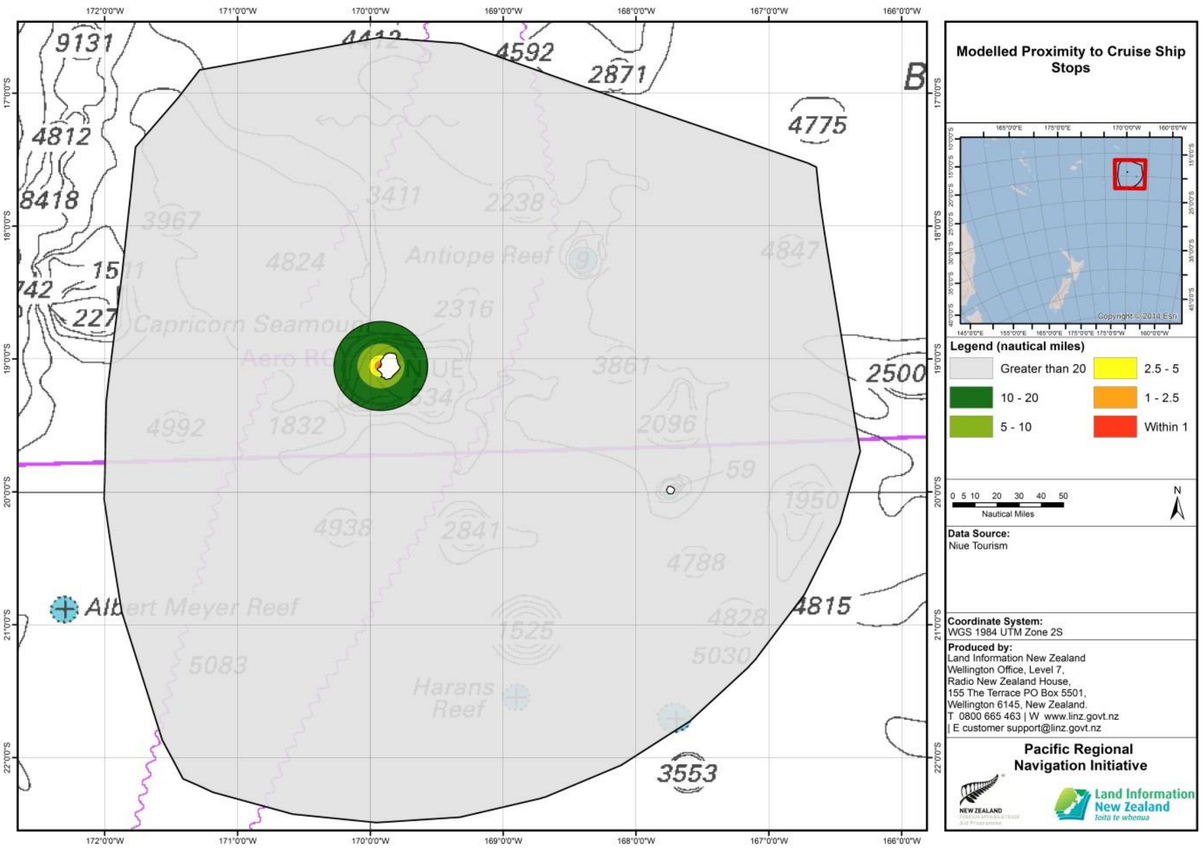


Figure 20: Modelled Proximity to Cruise Ship Stop

Figure 20 represents relative hydrographic risk due to the location of cruise ship stops across the study area. This figure was created based on AIS data and an interview with Olah Jacobsen[68] who confirmed that the Alofi port at Niue was the only cruise ship stop in Niue.

[68] Event Manager at Niue Tourism

ANNEX E – Hydrographic Risk Factor Weighting Matrices

Overview

1. The risk matrix shown on page E-2 below provides both:

   a. the generic low traffic risk matrix developed by LINZ/Marico Marine[69] used in previous regional South West Pacific risk analyses, and

   b. a slightly modified "in country" weighting factor adopted for this Niue risk assessment (last three columns).

2. While the overall aim of this risk assessment is to provide results comparable with those conducted in the Cook Islands and Tonga, the specific circumstances of Niue are such that a number of the likelihood and consequence criteria do not exist in Niue or there was no data available on these items. The implication of these geophysical and metaphysical differences between island groups being that if no compensating adjustments were made, then certain risk categories would be unfairly discounted in the Niue analysis.

3. To test this thesis an amended "in country" Niue risk matrix was created by setting irrelevant likelihood criteria to zero so that other criteria within the category received higher weighting and the overall category retained its relative importance. Those set to zero were: visibility, proximity to non-working AtoN, proximity to sub-sea volcanic activity, proximity to WW2 military sites, and proximity to charted tidal hazards.

4. Additionally, the following consequence criteria were set to zero and other criteria within the category received higher weighting so that the overall category retained its relative importance: proximity to large wetland resource, proximity to small wetland resource, proximity to world biologically protected sites, proximity of world culturally protected sites and proximity to regional culturally protected sites.

5. While it could be argued that the redistribution of these criteria results in biasing the overall risk towards the remaining criteria, it is considered that the overall result is more representative of the absolute hydrographic risk for the Niue "in country" region than that calculated from the South West Pacific regional risk matrix.

6. Risk results were calculated using both of these sets of weightings and a discussion of the differences is include in Section 7 of the main report (Risk Results).

[69] (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015, p. D2)

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ANNEX E – Hydrographic Risk Factor Weighting Matrices

Risk Matrix showing - SW Pacific Regional Risk Weightings (fixed Scales) & Amended Niue "in country" weightings (right 3 columns)

		Risk Scores						Weightings of Regional Risk Assessment			Weightings of Local Risk Assessment		
		0	1	2	3	4	5	Factor	Category	Total Model	Factor	Category	Total Model
		Increasing Risk ----------------->											
Traffic	Vessel Traffic												
	Potential Loss of Life (Vessel Type + GT		Insignificant	Low	Moderate	High	Catastrophic			0.5000			0.5000
	Pollution Potential (Vessel Type + GT Weighted)		Insignificant	Low	Moderate	High	Castastrophic			0.5000			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		0.1500	3		0.1800
	Spring Mean Current Speed	Open Sea (Current insignificant)	1-2 knots	2-3 knots	3-4 knots	>5 knots	>5 knots	2	0.3	0.1000	2	0.3	0.1200
	Visibility	Unknown	Poor Visibility Very Unlikely	Poor Visibility Unlikely	Occasional Poor Visibility	Often Poor Visibility	Poor Visibility Common	1		0.0500	0		0.0000
	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	3	0.15	0.1500
	Aids to Navigation												
	ChartZoc		A	B	C	D	U	3		0.1800	3		0.3000
	Proximity to Non Working ATONs (Nav Lights)	No Lights	100% effective range	80% effective range	70% effective range	60% effective range	Within 50% effective range	2	0.3	0.1200	0	0.3	0.0000
	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	3	0.1	0.0600
	Bottom Type		Soft				Hard/Rocky	2		0.0400	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		0.0333	2		0.1000
	Proximity to Sub-Sea Volcanic Activity	>10nm	5-10nm	2.5-5nm	1.5 to 2.5nm	1 to 1.5nm	Within 1nm	2		0.0333	0		0.0000
	Proximity to Known SeaMounts	>10nm	5-10nm	2.5-5nm	1.5 to 2.5nm	1 to 1.5nm	Within 1nm	1		0.0167	1		0.0500
	Proximity to WW2 Military Sites	>2.5nm	2-2.5nm	1.5-2nm	1-1.5nm	500m-1nm	Within 500m	1	0.15	0.0167	0	0.15	0.0000
	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	0		0.0000
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		0.0789	3		0.1364
	Proximity to Key Offshore Reef	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0526	2		0.0909
	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	0		0.0000
	Proximity Small Wetlands Resource (Mangroves) (Large Volume or Small Volume)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2	0.5	0.0526	0	0.5	0.0000
	Proximity to Important Breeding Grounds	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.0789	3		0.1364
	Proximity to World Biological Protected Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.0789	0		0.0000
	Proximity to Regional Biological Protected Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0526	2		0.0909
	Proximity to Local Biological Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1		0.0263	1		0.0455
	Culturally Sensitive Areas												
	Proximity to World Cultural Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.0750	0		0.0000
	Proximity to Regional Cultural Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2	0.15	0.0500	0	0.15	0.0000
	Proximity to Local Cultural Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1		0.0250	1		0.1500
	Economically Sensitive Areas												
	Proximity to Sites of High Economic Contribution	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.1000	0		0.0000
	Proximity to Sites of Moderate Economic Contribution	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1		0.0333	1		0.0467
	Proximity to Key Infrastructure (Ports)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3	0.35	0.1000	3	0.35	0.1400
	Proximity to Tourist Diving Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1.5		0.0500	1.5		0.0700
	Cruise Ship Stops	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0667	2		0.0933

ANNEX F – Hydrographic Risk Calculations

Overview

1. Risk can be calculated as the product of probability of an undesirable event happening and the expected consequences, i.e. Risk = Probability x Consequence. However, when assessing hydrographic risk the shipping traffic comprises the predominant factor. Previous risk assessments note that "Risk requires the co-existence of three variables. Traffic must transit through an area, there must be a likelihood of that traffic to have an incident and there must be a consequence of that incident."[70] Clearly, if any one of these three factors is not present there is no risk.

2. Each of these factors is calculated from a number of different input variables which are all listed in the risk matrix.[71] The risk matrix is the core document upon which the implementation of the risk model depends. Due to each island group having slightly different risks there is some variance between the risk models used in each of the separate assessments.

3. The hydrographic risk model has three main components:

(1) Spatial definitions of the input data showing vessel traffic and the distribution of likelihood and consequence factors.

a. In the case of likelihood and consequence inputs these are areas defined in the GIS attributed with scores of 1-5 representing relative risk. For example, CATZOC areas can be represented in the GIS as polygons with a 1 to 5 score assigned to each. The definition of each input variable's 1 to 5 scoring is in the risk matrix. For CATZOC, a rating of "A" gets a score of 1 (low risk), "B" gets a score of 2, and so on to "Unassessed" which has the maximum score of 5.

b. Traffic inputs are either satellite AIS tracks from vessels, and if needed, estimated tracks for non-AIS vessels which have been manually digitised in the GIS. Each track has vessel type and gross tonnage (GT) attributes from which a relative score representing potential loss of life and pollution for "most likely" or "worst case" accidents. Section 4.1.4 of the Vanuatu Risk Assessment Annexes explains the detail of how this is done. The end result is a raw but representative score for each vessel track indicating how much potential risk is associated with that particular vessel. All the 'raw' scores are then translated to a 1-5 score using the Jenks Natural Breaks statistical method.

(2) Grid of the study area.

a. The study area (Niue EEZ) is covered by a grid comprising cells 2.5 km by 2.5 km. This grid is the common framework that combines all the inputs and is used to map the computed risk scores.

[70] (Marico Marine Report No. 12NZ246-1, January 2013, p. D.10)
[71] See Annex E

ANNEX F – Hydrographic Risk Calculations

b. Inputs are combined by assigning each cell the input scores for those inputs that spatially intersect each particular cell. This allows all traffic, likelihood and consequence scores to be combined in one layer where the model calculations can be made.

(3) Model calculation and synthesis

a. Each input variable has a weighting applied to it so the relative importance of inputs can be factored in. A final weighting number for each input is calculated from its relative importance to other inputs in its sub-category, then that category's weighting in the overall category and finally the weighting for traffic vs likelihood vs consequence. All these weightings are documented in the risk matrix.

b. The risk is calculated by multiplying the weighted scores for traffic (T), likelihood (L) and consequence (C) together taking into account the following:

- Risk =T x L x C

- All T, L and C scores are divided by 5 to normalise the scores to the commonly used probability range of 0-1 rather than the 0-5 range the input variables were initially classified as.

So the calculation becomes **Risk = T/5 x L/5 x C/5**

- Although risk is equal to T x L x C, consequence is also a product of likelihood and traffic: C = T x L.

Adding in this consideration we get **Risk = T/5 x L/5 x C/25** (because if C =T/5 x L/5 then C becomes C/25.

Refactoring the equation we get Hydrographic **Risk = ((L x T)/5) x C/25**

c. Using this formula hydrographic risk is computed for each cell in the grid and the results are classified using Jenks Natural Breaks into five risk categories of insignificant, low, moderate, heightened and significant for display as a heat map.

4. A Word of Caution – Interpreting Heat Map Results

4.1 The use of Jenks Natural Breaks to allocate the colour mapping for the final "in country" risk plots has the effect of converting the risk results into a relative risk heat map across the Niue study area. This is because this method will represent the lowest risk as insignificant (green) and the highest risk as significant (red), across the numerical range of calculated risk values.

ANNEX F – Hydrographic Risk Calculations

4.2 To normalise the results and thus allow a comparison with the heat map results of other South West Pacific hydrographic risk assessments, a further heat map was produced using the same colour mapping to risk scores as the final heat map colour groups of the Tonga and Cook Islands assessments. The result produced a completely dark green heat map for the Niue EEZ indicating *insignificant risk* throughout. This is an unsurprising result given the substantially lower traffic levels in the vicinity of land or reefs in the Niue analysis.

ANNEX G – Benefits of Hydrographic Surveys to NIUE

Benefits of Hydrographic Surveys[72]

1. Hydrographic survey data is an enabler that underpins all maritime activities. Classically, the data is integrated into ships' charts to enable the safe planning and execution of a voyage. The quality of hydrographic charts is an important factor in determining the risk of undertaking voyages and the cost of insurance to underwrite that risk. It influences decisions on the cost effectiveness of providing essential transportation services. 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 higher costs or substandard shipping.

2. 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, management and development in the maritime domain. It is widely accepted that these benefits of hydrographic survey data, difficult to quantify in financial terms, outweigh those derived from its classic application, hence the common assessment that hydrographic data should be viewed as a public good[73]. It is relatively expensive to acquire because it requires ships or aircraft to transit the ocean and cannot be properly obtained by satellite remote sensing, but the overall benefits of hydrographic survey from a national perspective are considered to outweigh the costs.

3. Hydrographic survey data delivers benefits to different sectors in different ways. For the international shipping of freight, the principal benefit is to enable safe and efficient navigation to minimise risk and provide reductions in transportation costs. For Niue island economy it enables the safe access to the growing cruise tourism market, and for good governance it provides the underpinning data and framework for the effective management of marine resources and environmental monitoring.

4. Commercial shipping relies on current hydrographic survey data. A hydrographic survey undertaken to the latest International Hydrographic Organization (IHO) standards[74] provides the following benefits:

   a. 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.

   b. Critical new shallows or water depth, less than previously charted, may be identified and appropriate action taken.

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[72] This Annex is a modified reproduction of previous published work (Marico Marine Report No 14NZ262CS Issue 02, January 2015, pp. A1-A3)

[73] Public good – a good or service in the public interest which would not be supplied at optimal levels by market forces alone.

[74] IHO S-44 Standards for Hydrographic Survey

ANNEX G – Benefits of Hydrographic Surveys to NIUE

c. Facilitate revisions of fairways or routes, and planning of modified or new Traffic Separation Schemes or sea management areas (which could be applicable to Beveridge Reef).

d. Enabling modern 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 potential environmental harm and insurance premiums.

e. Provision of quality information for training purposes.

5. 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.

6. Further, the International Convention for the Safety of Life at Sea[75] requires signatory states to facilitate the production of ENCs for ships navigating their coastal waters, including ports. 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 waters.

7. Beyond shipping, hydrographic survey data delivers a wide range of additional benefits to maritime stakeholders. Indeed, the largest users of hydrographic data are typically port developers, planners and environment managers. Hydrographic data is an essential enabler for everything that takes place on, under or near the sea, it should be considered as vital infrastructure, servicing similar purposes as three dimensional land mapping.

[75] SOLAS Chapter 5, Regulation 9

ANNEX H – List of Consultations

Niue

1. His Excellency Ross Arden (High Commissioner) and Jenna Priore (First Secretary), NZ High Commission
2. Andre Siohane (Director General), Ministry of Infrastructure
3. Olah Hacobsen (Event Manager), Niue Tourism
4. Hubert Kalauni, (Secretary of Justice), Richard Siataga (LIS/GIS Tech. Officer), Department of Justice, Lands and Survey
5. Avi Rubin, Professional Fisherman, Restaurateur
6. Keith Vial "The Commodore", Niue Yacht Club and Tour Operator
7. James Tafatu (Fisheries Officer), Department of Fisheries
8. Josie Tamate (Director General), Ministry of Natural Resources
9. Kimray Vaha, (Government Statistician/Chief Immigration Officer) Customs, Immigration and Statistics
10. Jules Maher (Establishing Manager, Acting CEO), Foufou Talagi (Acting Director of Telecom) and Farm Tukumulia (Billing Manager), Niue Telecom
11. Coral Pasisi, NOW Project
12. Rosslyn Mitiepo (Acting Director), Niue Meteorological Service
13. Robin Hekau (National Coordinator), Niue Disaster Council
14. Brent Ioane, Acting Chief of Police
15. Sidney Ikiua (Acting Director of Transport), Ministry of Infrastructure
16. Frank Sioneholo, Economic Development
17. Poi Kapaga (Financial Secretary)
18. George Valiana, Bulk Fuels Depot