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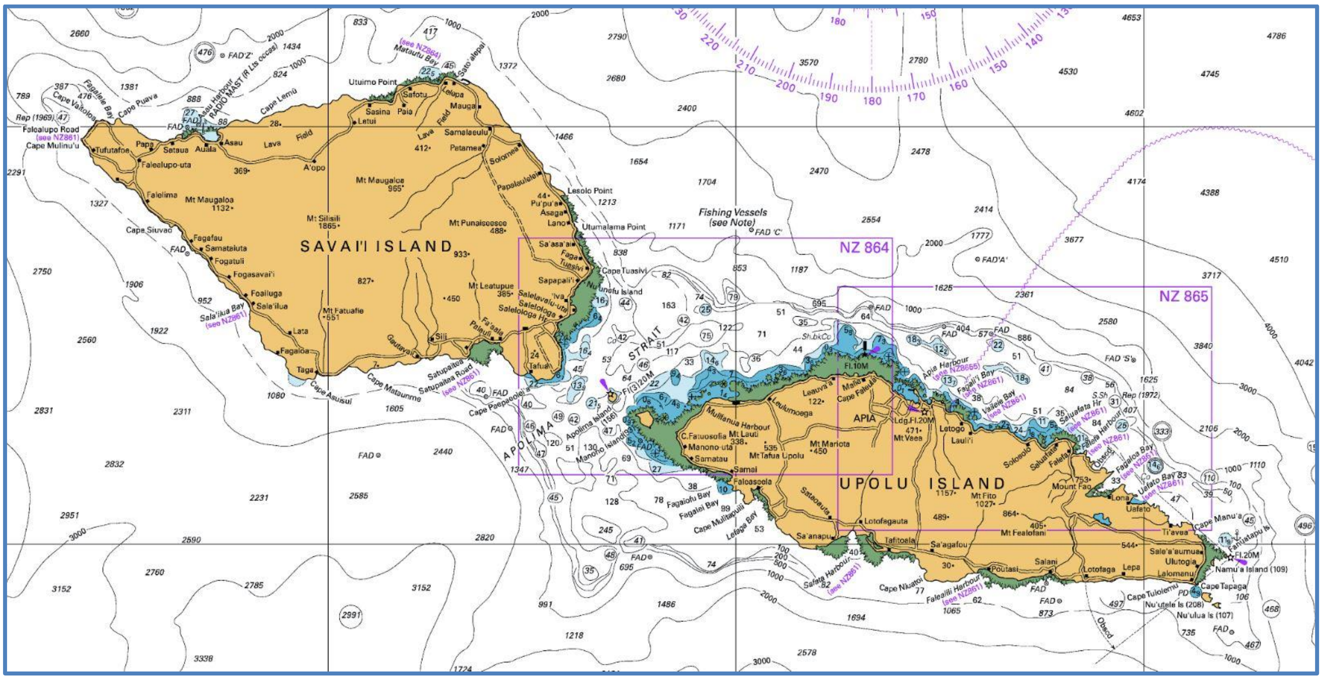
PACIFIC REGIONAL NAVIGATION INITIATIVE

SAMOA Hydrographic Risk Assessment

Annexes



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PACIFIC REGIONAL NAVIGATION INITIATIVE

SAMOA Hydrographic Risk Assessment

Annexes

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SAMOA Hydrographic Risk Assessment

Annexes

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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[1] and those used in the Cook Islands[2] and Tonga[3] and Niue[4].

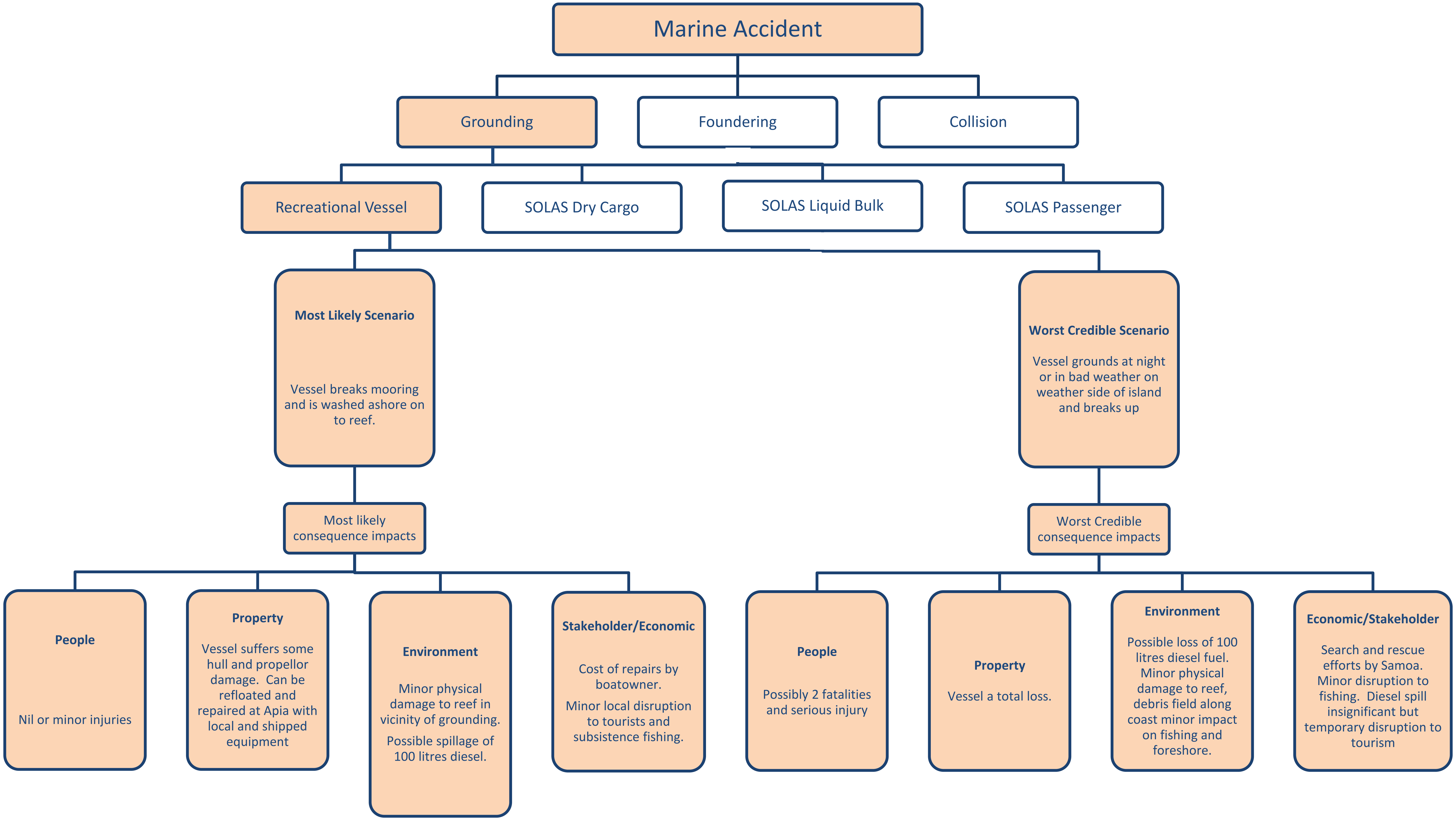
2. Samoa has substantial domestic traffic due to the frequent inter-island passenger/vehicle ferry service from Mulifanua to Salelologa and regular cargo/fuel journeys from Apia to Salelologa. This category represents the highest likelihood of incident due to the frequency of passages and the constrained navigation at the terminal ports.

3. Recreational vessels present a different type of risk in that this class of vessel is more likely to navigate into poorly charted waters in remote areas and therefore do present a risk, though consequence is limited to personnel casualties. Accordingly, an event tree that covers the grounding of recreational vessels has been included.

3. The event trees were used to confirm the veracity of the weightings of the risk consequence factors employed in the overall risk calculations and to estimate consequential costs of incidents in the cost benefit analysis (described in Section 8 of the main report).

[1] (Marico Marine Report No. 15NZ322 Issue 03, 5 August 2015)
[2] (Marico Marine Report No. 14NZ262MR Issue 02, 20 January 2015)
[3] (Marico Marine Report No. 14NZ262 – TM, Issue 1, 27 November 2014)
[4] (RNAPL16002 - NIUE Hydrographic Risk Assessment, 2016, p. Annex A)

ANNEX A - Event Trees



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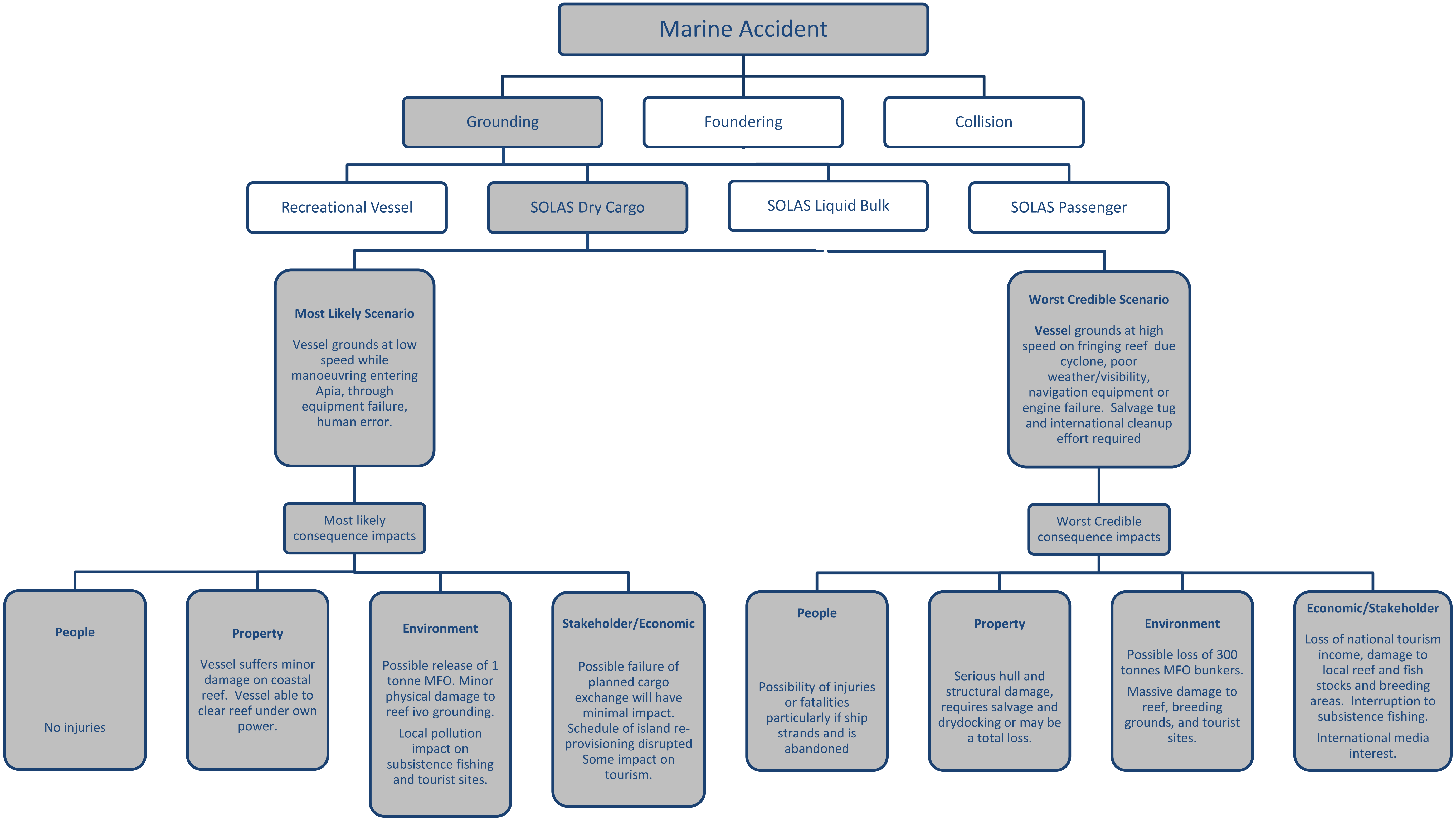

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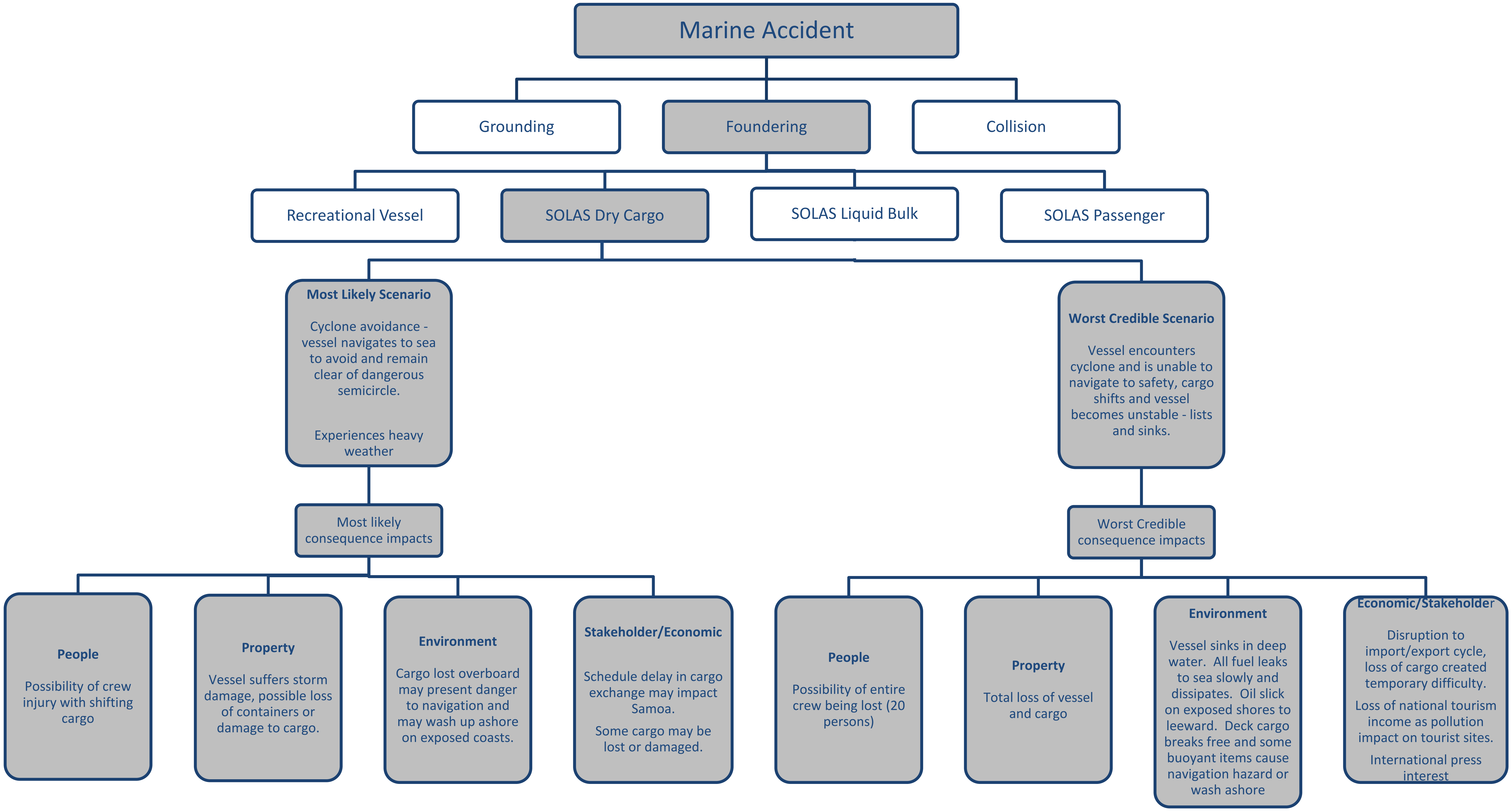

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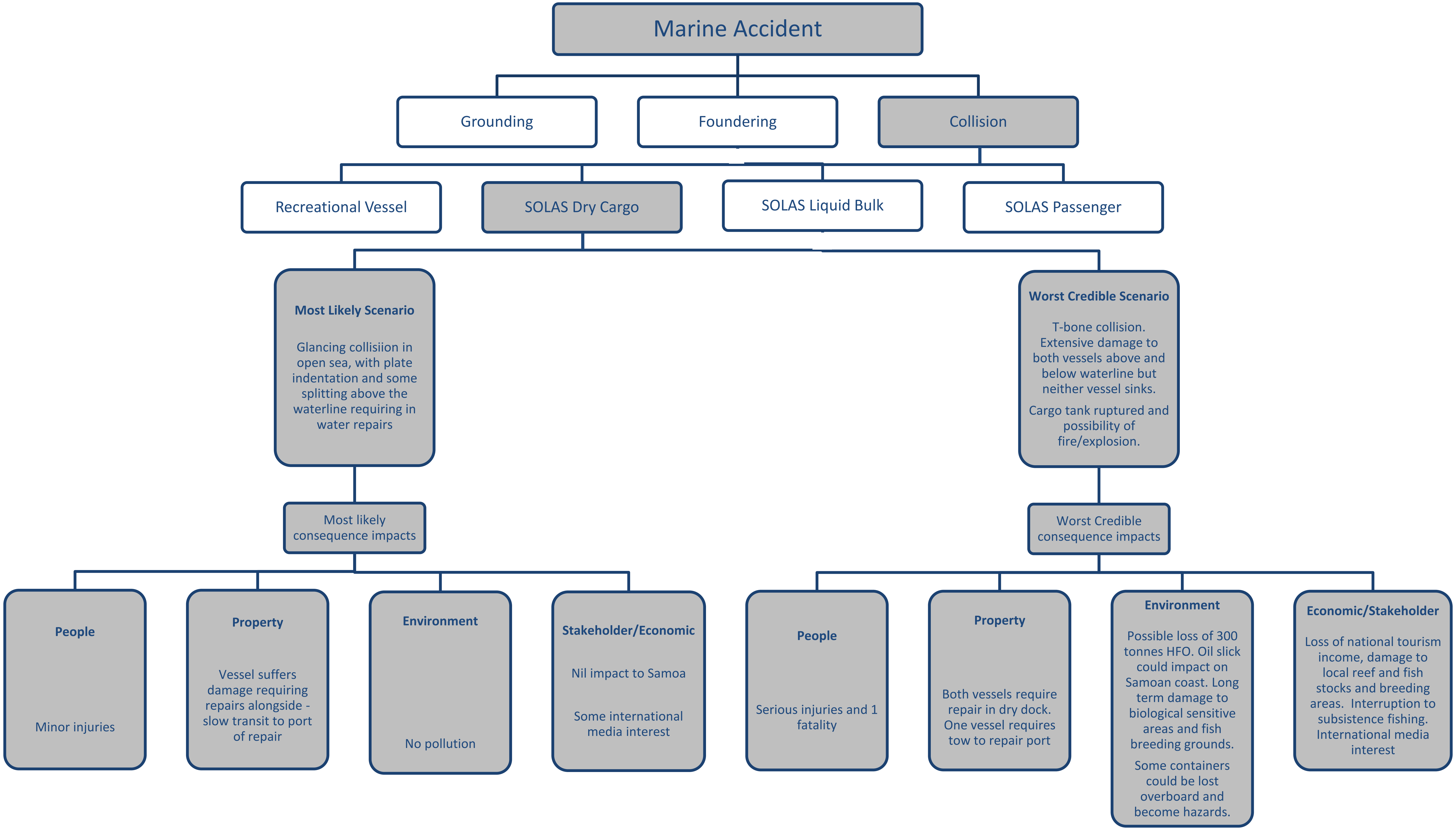

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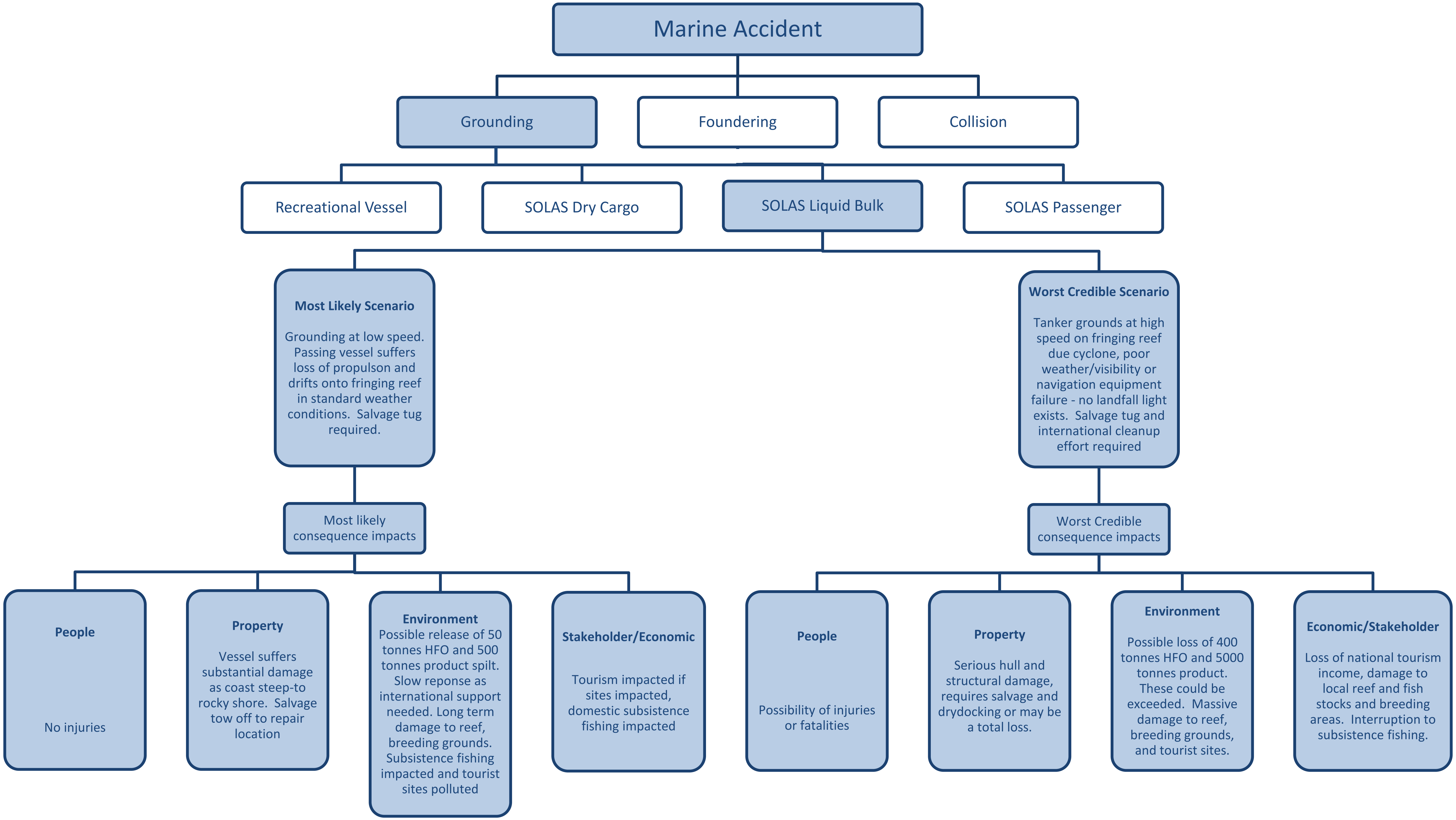
ANNEX A - Event Trees



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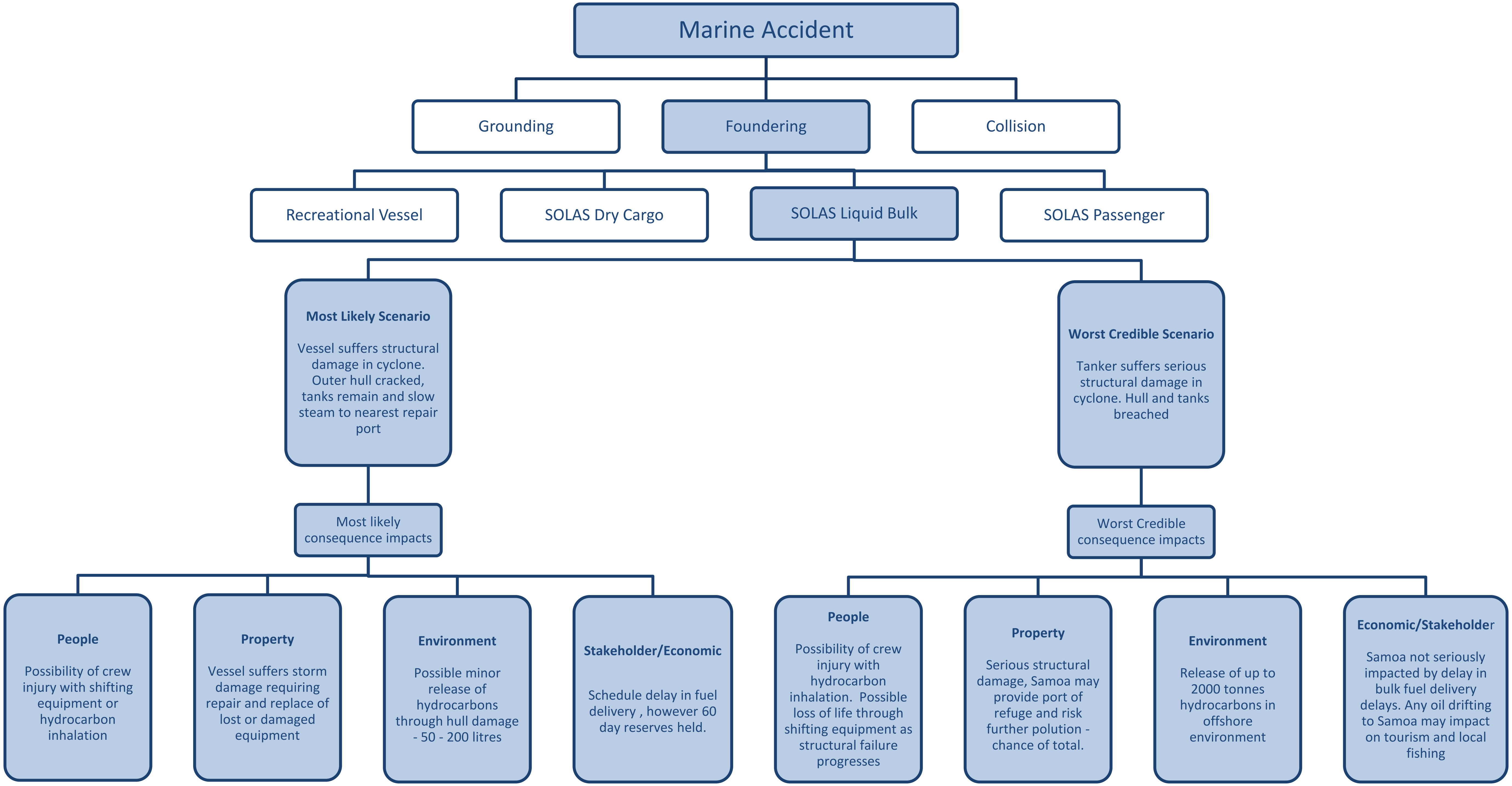
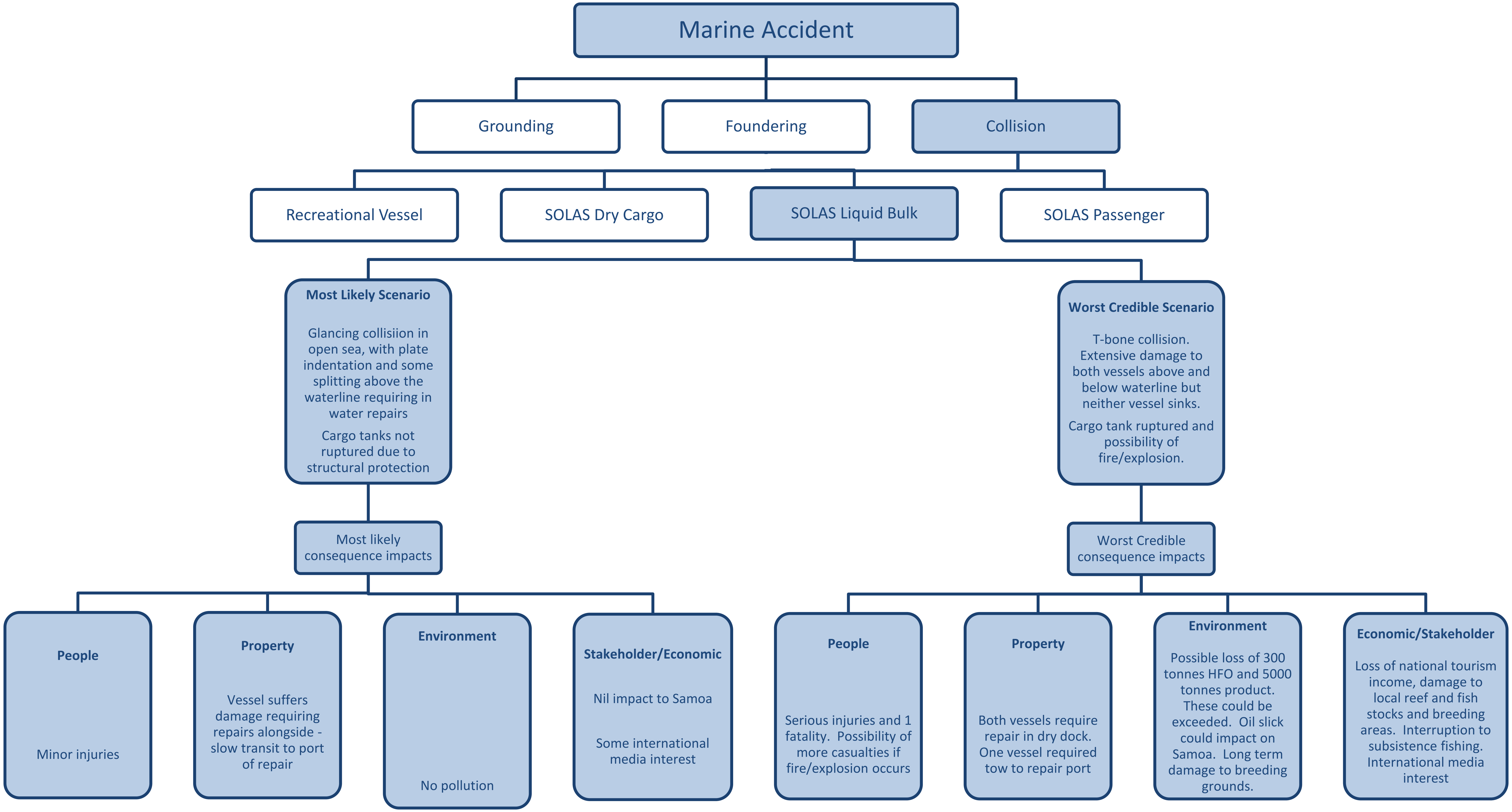
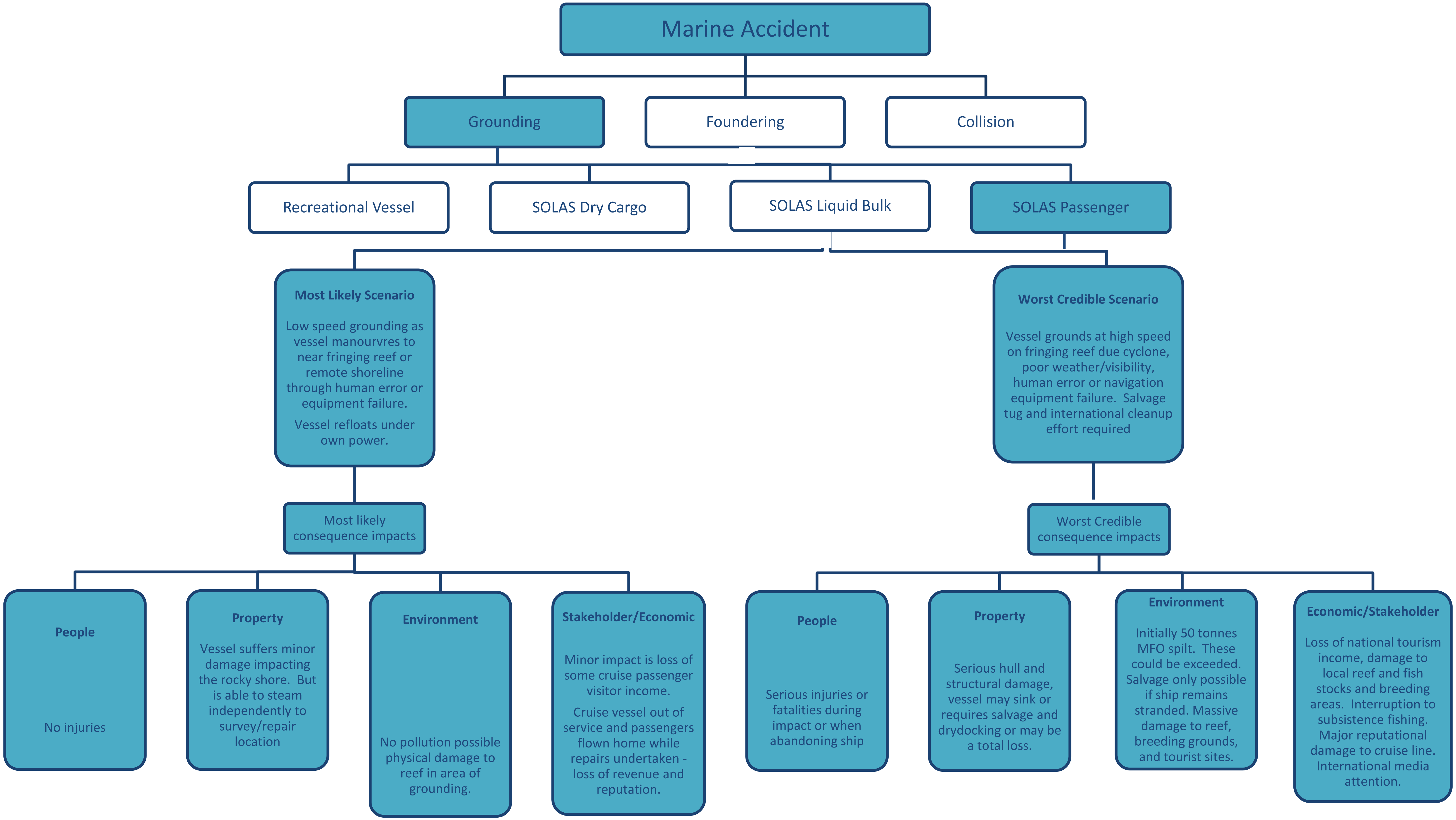



Marine Accident
Grounding
Foundering
Collision
Recreational Vessel
SOLAS Dry Cargo
SOLAS Liquid Bulk
SOLAS Passenger
Most Likely Scenario
Glancing collisiion in open sea, with plate indentation and some splitting above the waterline requiring in water repairs
Cargo tanks not ruptured due to structural protection
Worst Credible Scenario
T-bone collision. Extensive damage to both vessels above and below waterline but neither vessel sinks.
Cargo tank ruptured and possibility of fire/explosion.
Most likely consequence impacts
Worst Credible consequence impacts
People
Minor injuries
Property
Vessel suffers damage requiring repairs alongside - slow transit to port of repair
Environment
No pollution
Stakeholder/Economic
Nil impact to Samoa
Some international media interest
People
Serious injuries and 1 fatality. Possibility of more casualties if fire/explosion occurs
Property
Both vessels require repair in dry dock. One vessel required tow to repair port
Environment
Possible loss of 300 tonnes HFO and 5000 tonnes product. These could be exceeded. Oil slick could impact on Samoa. Long term damage to breeding grounds.
Economic/Stakeholder
Loss of national tourism income, damage to local reef and fish stocks and breeding areas. Interruption to subsistence fishing. International media interest

ANNEX A - Event Trees



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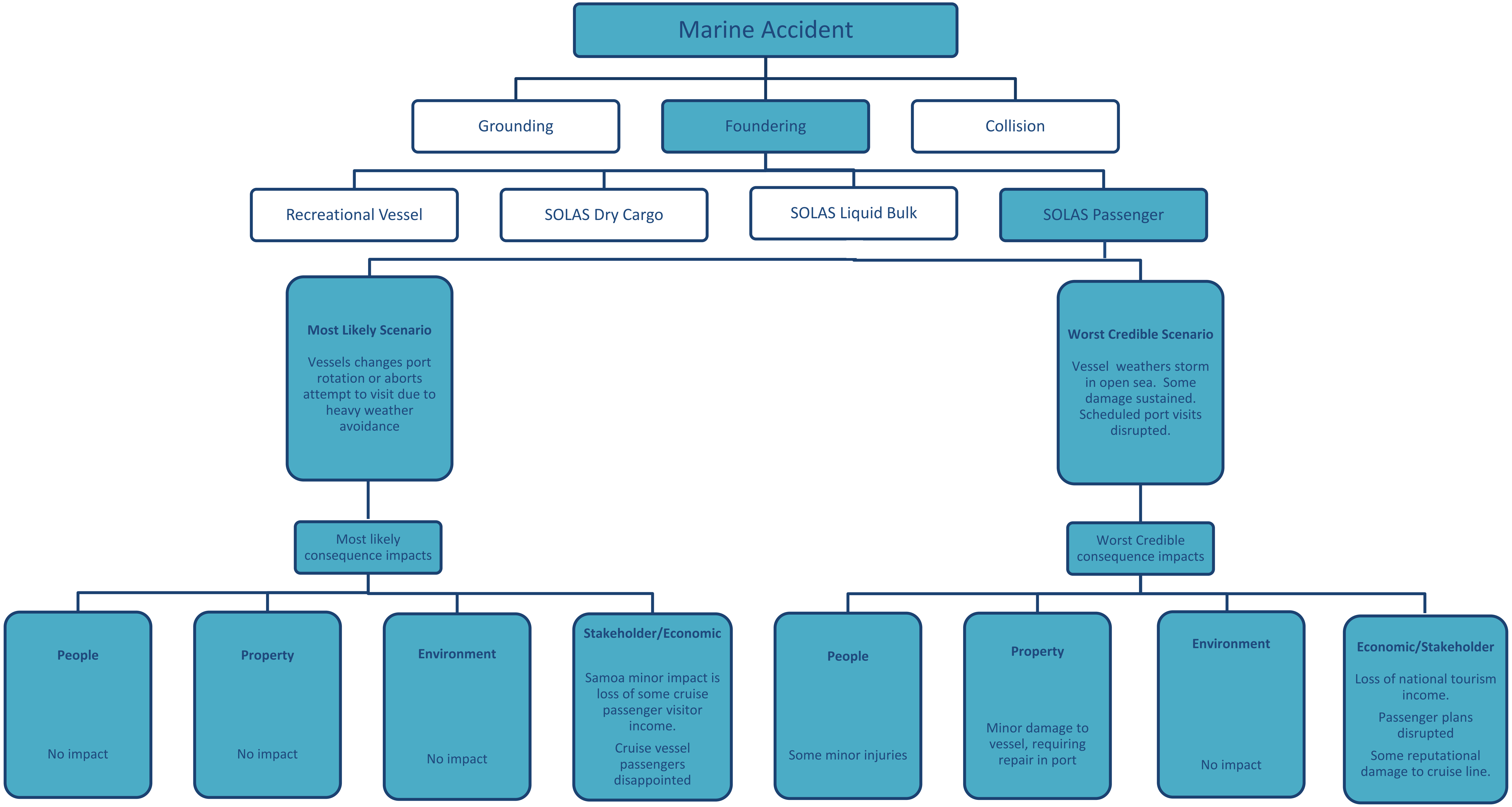

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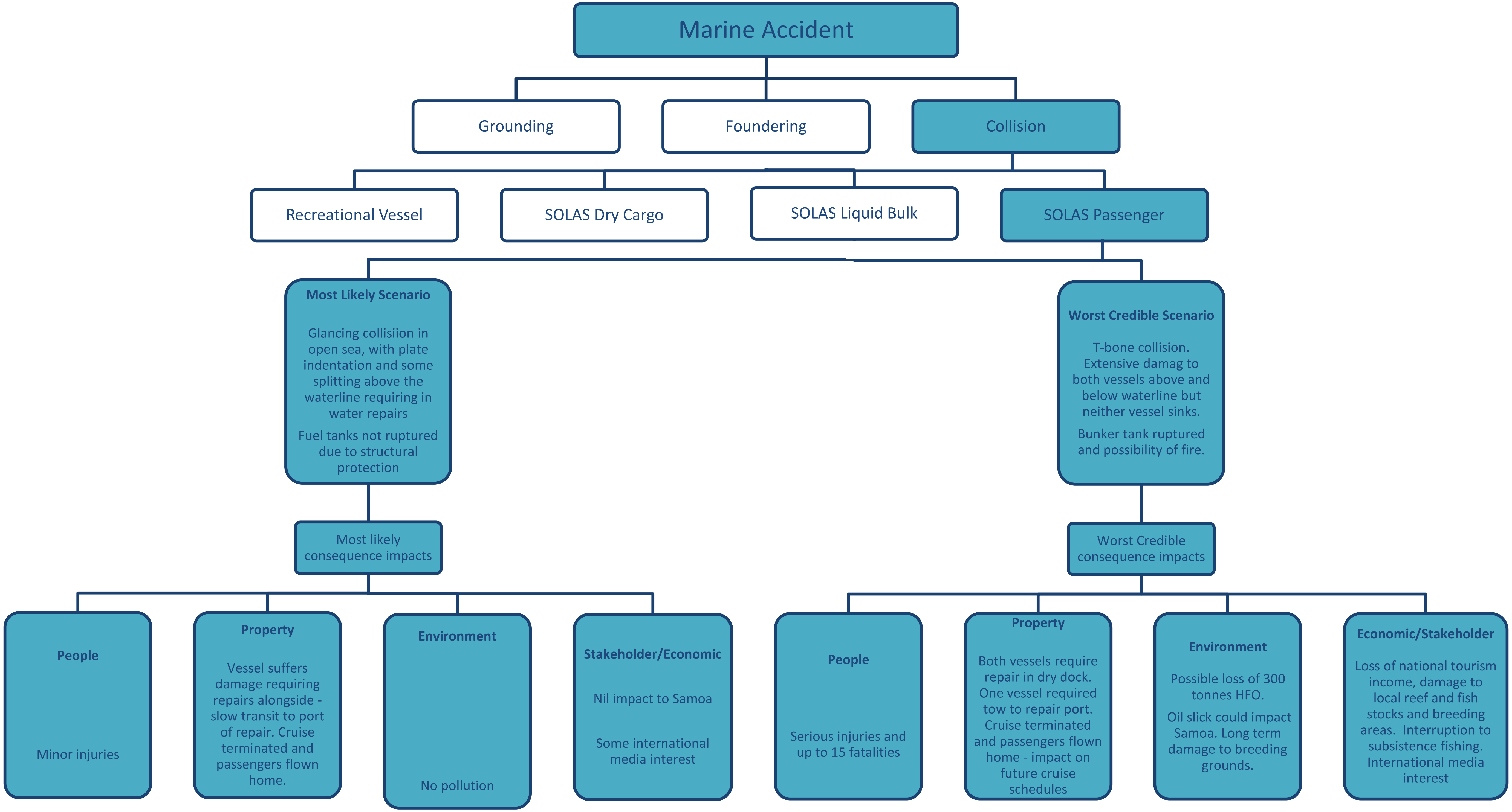

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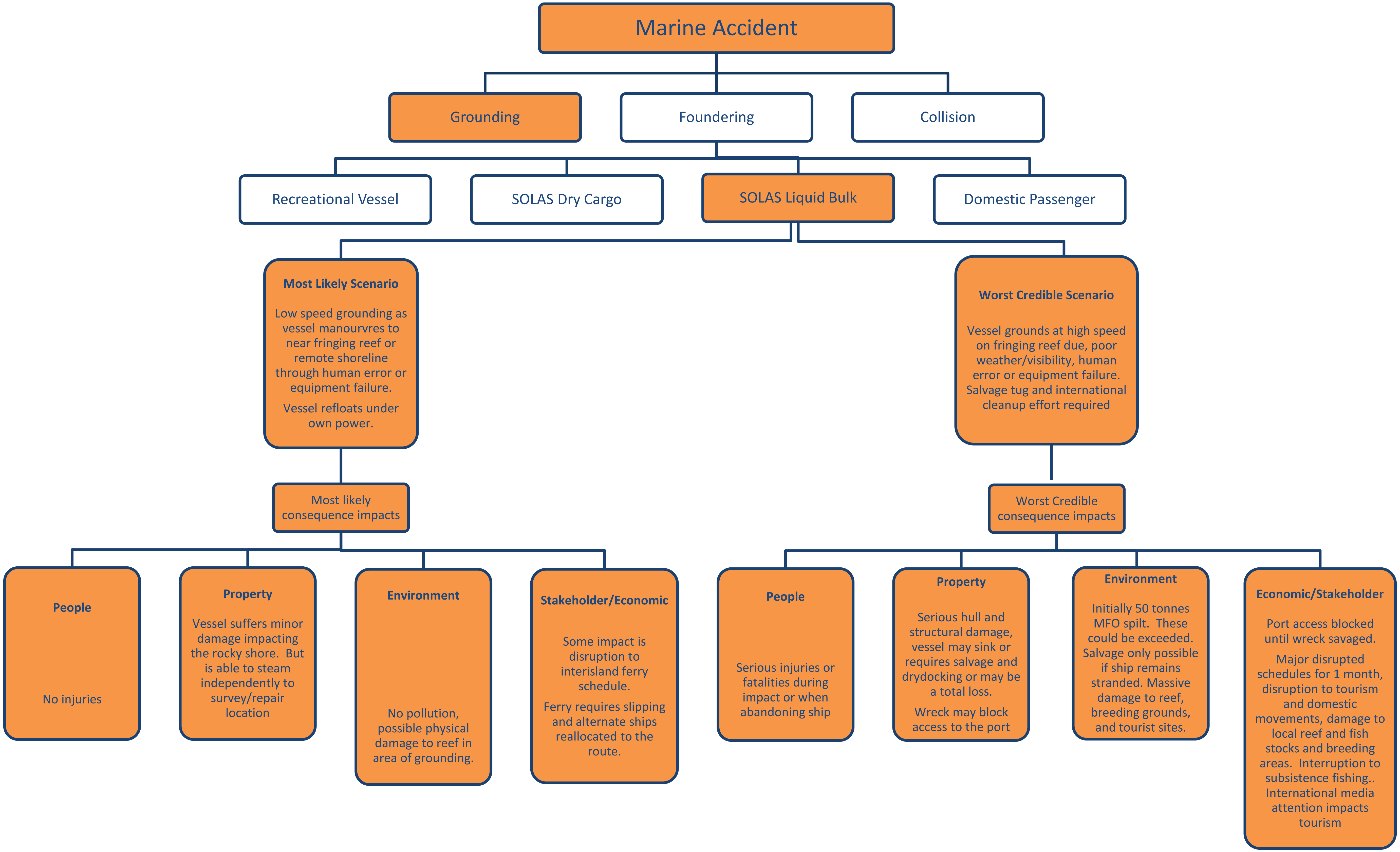

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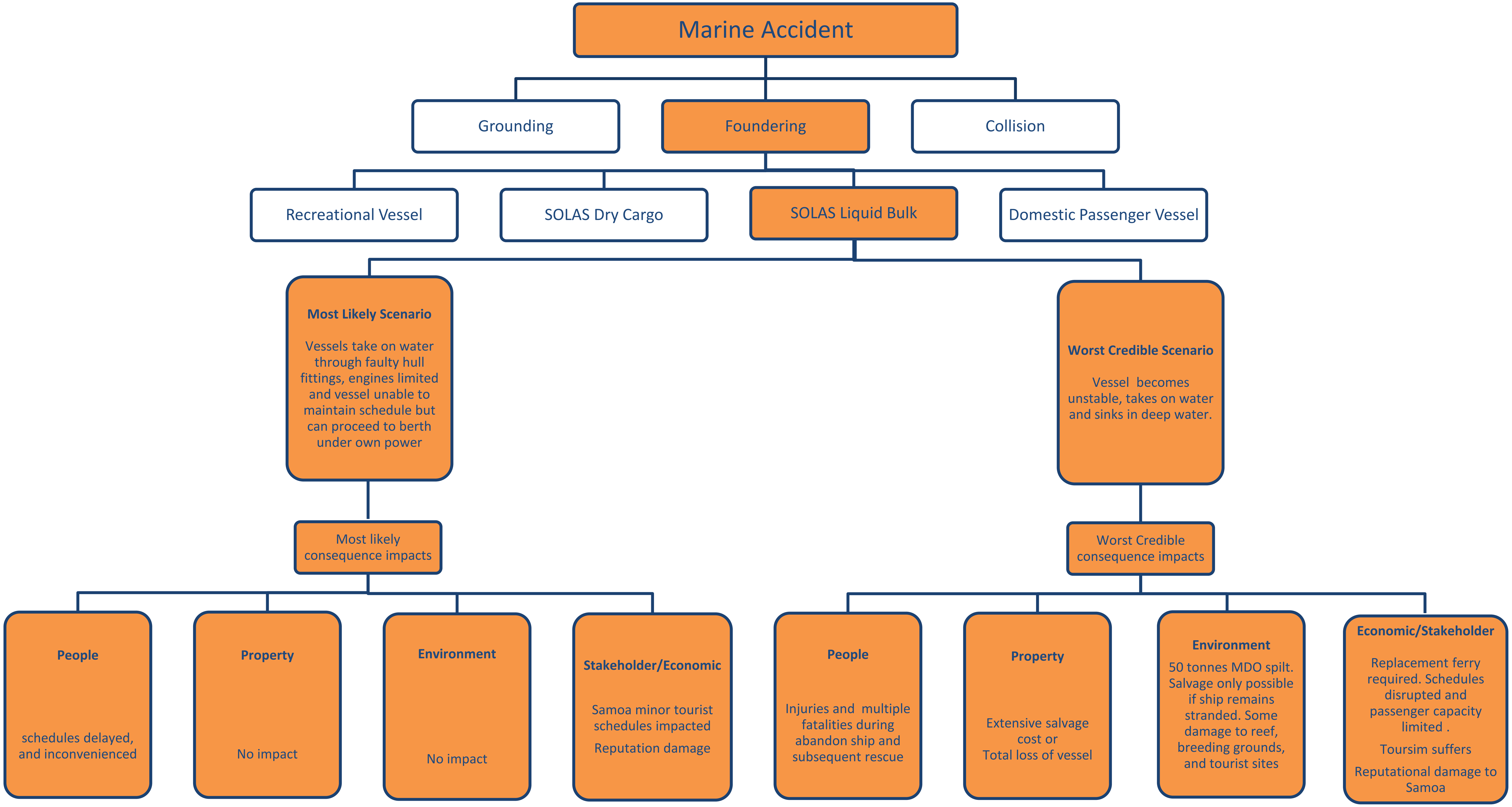
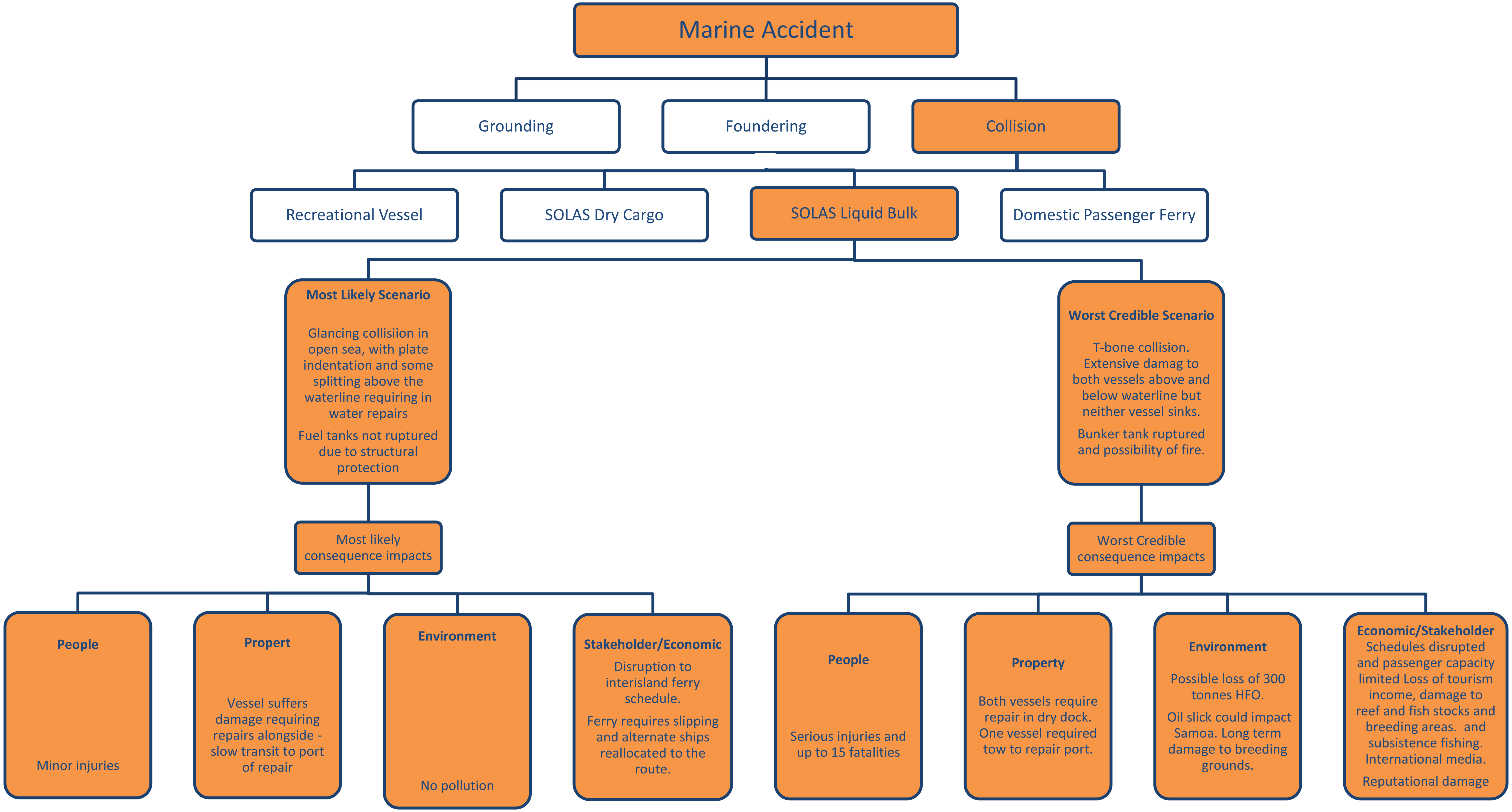
ANNEX A - Event Trees



ANNEX A - Event Trees



ANNEX B - GIS Track Creation and Processing

1 Track Creation[5]

1.1 Raw AIS data was acquired from ORBCOM for the contiguous 12 month period from January–December 2016. While this varies from the periods used for previous assessments of Vanuatu, the Cook Islands, Tonga and Niue, (January – March 2012; July – October 2013; and December 2013 – January 2014), the decision to update the source AIS data was made on the following basis:

a. The AIS data from the previous assessments had become out dated and no longer reflected the current traffic patterns which had changed over recent years, particularly with the increase in cruise shipping activity.

b. The AIS data from the previous assessments had gaps for the months of April – June and November, which may have resulted in the exclusion of certain maritime activities that may have occurred in these periods.

c. ORBCOM has added additional satellites to its AIS network in recent years and was now able to provide a contiguous dataset with a higher update rate and less gaps than previously, thus providing a more comprehensive and reliable dataset.

d. The previous assessments showed that the substantial variations in volume of traffic between national assessments and between differing regions within EEZs caused such a variation of the final risk values that the “regional” risk plot was not a crucial output of the assessment and that the “in-country” risk plot provided the most useful product for hydrographic planning.

1.2 The raw AIS data was received in KML format and was converted to ESRI shape file using QGIS. The full dataset was processed for track information and subsequently, the area for risk assessment was limited to the EEZ boundaries of Samoa and Tokelau as provided by marineregions.org. The geographic boundaries of this dataset acquired for use in the study of Samoa and Tokelau were:

Northern Boundary:	06°05’ S
Eastern Boundary:	176° 30’ W
Western Boundary:	176° 00’ W
Southern Boundary:	16° 15’ S

1.3 Shapefiles were loaded into a PostgreSQL database for processing prior to line generation. The MMSI attribution was converted from string format to integer, and the movement date field

[5] The format of this Annex has been aligned as for Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D14 – D23. The content has been updated for Samoa.

ANNEX B - GIS Track Creation and Processing

was converted to a date time format and transferred to a new field labelled "ping_times." The table was then exported as a FileGeoDatabase.

1.4 NOAA's Marine Cadastre Track Builder[6] was 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 of 1200nm and a time factor of 48 hours between a pair of points. These factors were selected by trial and error to provide the best overall result.

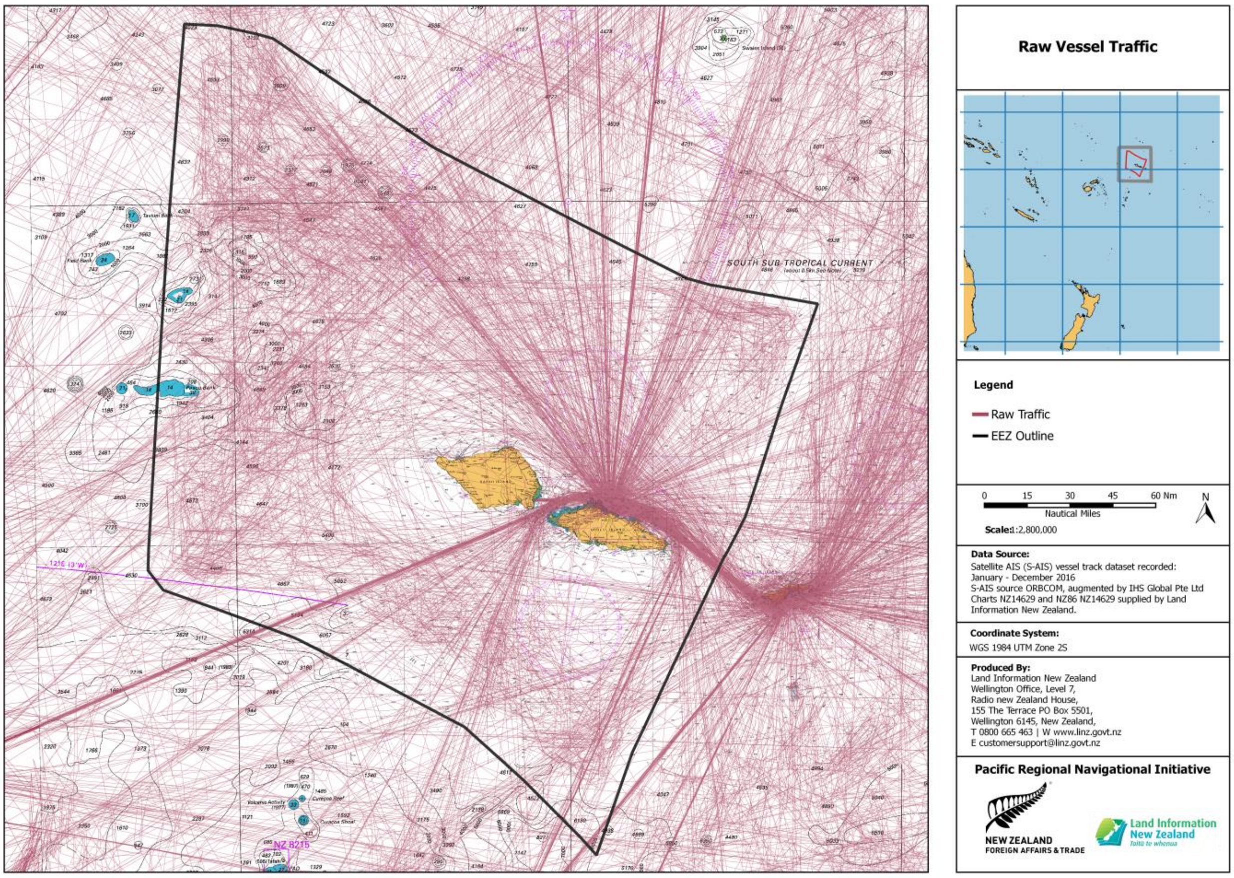
1.5 In QGIS, a non-spatial join was used to associate MMSI with IMO number, using the ancillary xml dataset provided by ORBCOM, containing IMO vessel numbers and ship gross tonnage (GT). To reduce the tracks to a more manageable dataset, PostgreSQL was used to create a new shapefile where only tracks that intersected with the Samoan EEZ were used. Vessel attributes, such as type and GT, were then attached to each vessel track from checking MMSI number against online databases such as Marine Traffic and International Telecommunication Union (ITU).

1.6 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:

- 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 so it was possible that eight hours before a vessel reached the edge of the study area the track would stop;
- There were multiple 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 to adjust the track to its likely route; and
- There were multiple vessels shown as transiting across drying reefs, more clearly shown in Figure 2. These were commonly the result of reefs being between AIS pings, therefore the line generated gave the appearance of vessels transiting drying depths. As with vessels transiting land these could not be discounted, particularly due to the large volume of transits, and so manual track processing was required.

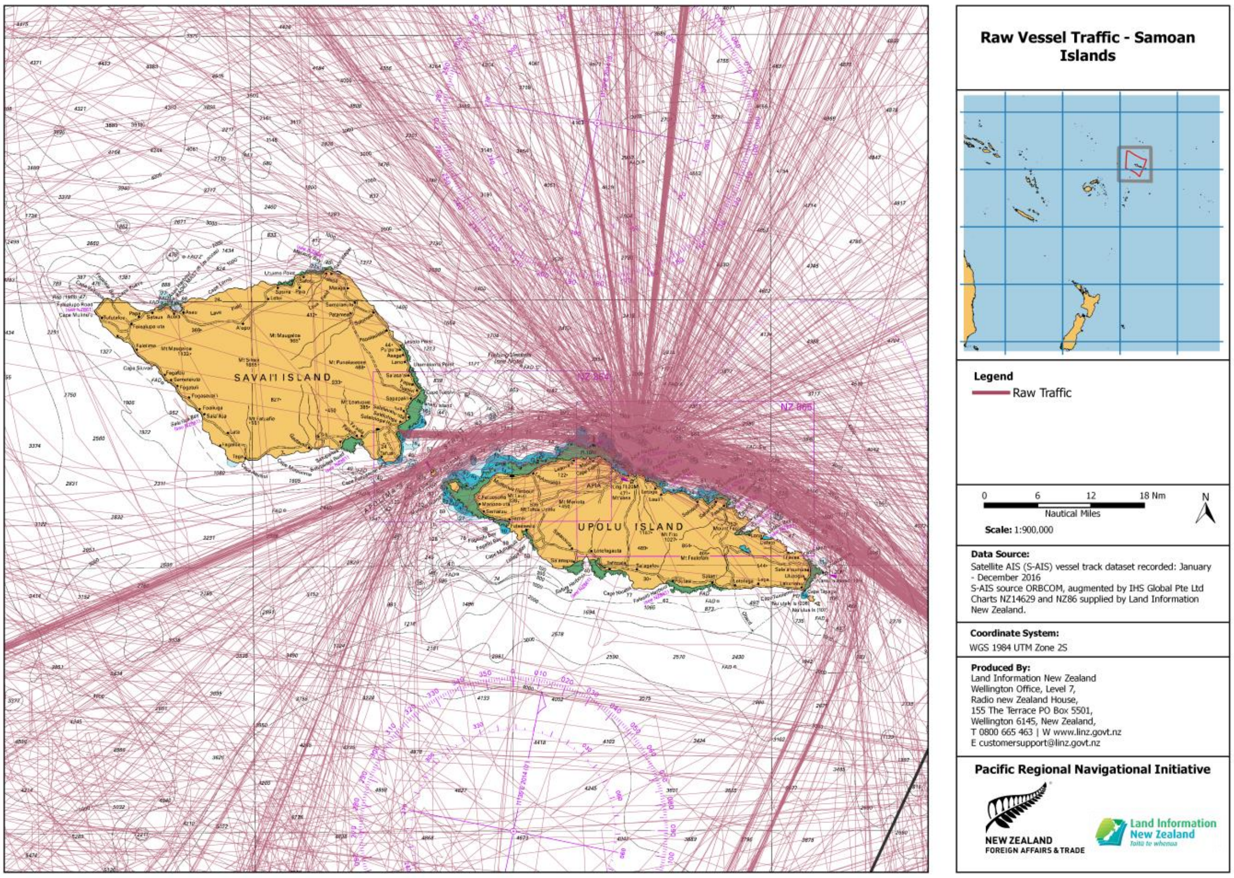
[6] National Oceanic and Atmospheric Administration. "Marine Cadastre Track Builder." Office for Coastal Management - National Oceanic and Atmospheric Administration. 2016. https://coast.noaa.gov/digitalcoast/tools/track-builder (accessed May 13, 2016).

ANNEX B - GIS Track Creation and Processing



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 Samoa

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:

- 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 or drying reefs were manually routed around the coast along their likely course based on:
  - Other vessels' behaviour, in particular the distance vessels of a similar size keep offshore;
  - Adjustments to conform to areas of high traffic density; and
  - Logical pathing corrections, for example where a vessel goes straight through a wharf, it now routes around it.

ANNEX B - GIS Track Creation and Processing

- Using multiple database sources to correct errors in sourced dataset, including incorrectly spelt vessel names, incorrect MMSI numbers, and the addition of GT values where not provided;
- Utilising information from data gathering visit to generate tracks for domestic ferries and fishing vessels not captured via AIS (*alia*'s) and modelled values for GT applied; and
- Assignation of GT to tracks with a GT of 0 to either a value set by other vessels of similar size and type, or on an agreed upon value (typically for recreational vessels).

3 Non AIS Domestic Traffic

3.1 The majority of domestic traffic is not fitted with AIS. It is made up of the inter-island domestic ferry and numerous *alia* vessels of up to 12m in length.

3.2 To account for the ferries their route was tracked by GPS and two tracks were manually entered in the model, one for the *Lady Samoa III* at 40 transits per week and the other for the landing barge which operates in tandem at 36 transits per week. The GT entered for each track was the calculated total GT for each vessel in a year: 2,173,600 GT and 599,040 GT respectively.

3.3 To account for the *alia,* typical tracks for their operational areas were added based on the number licenced to operate as fishing vessels from each port[7]. *Alia* were given a nominal GT of one, and the tracks based on spending 120 days at sea per year in 3 day deployments and travelling at an average speed of 10 knots

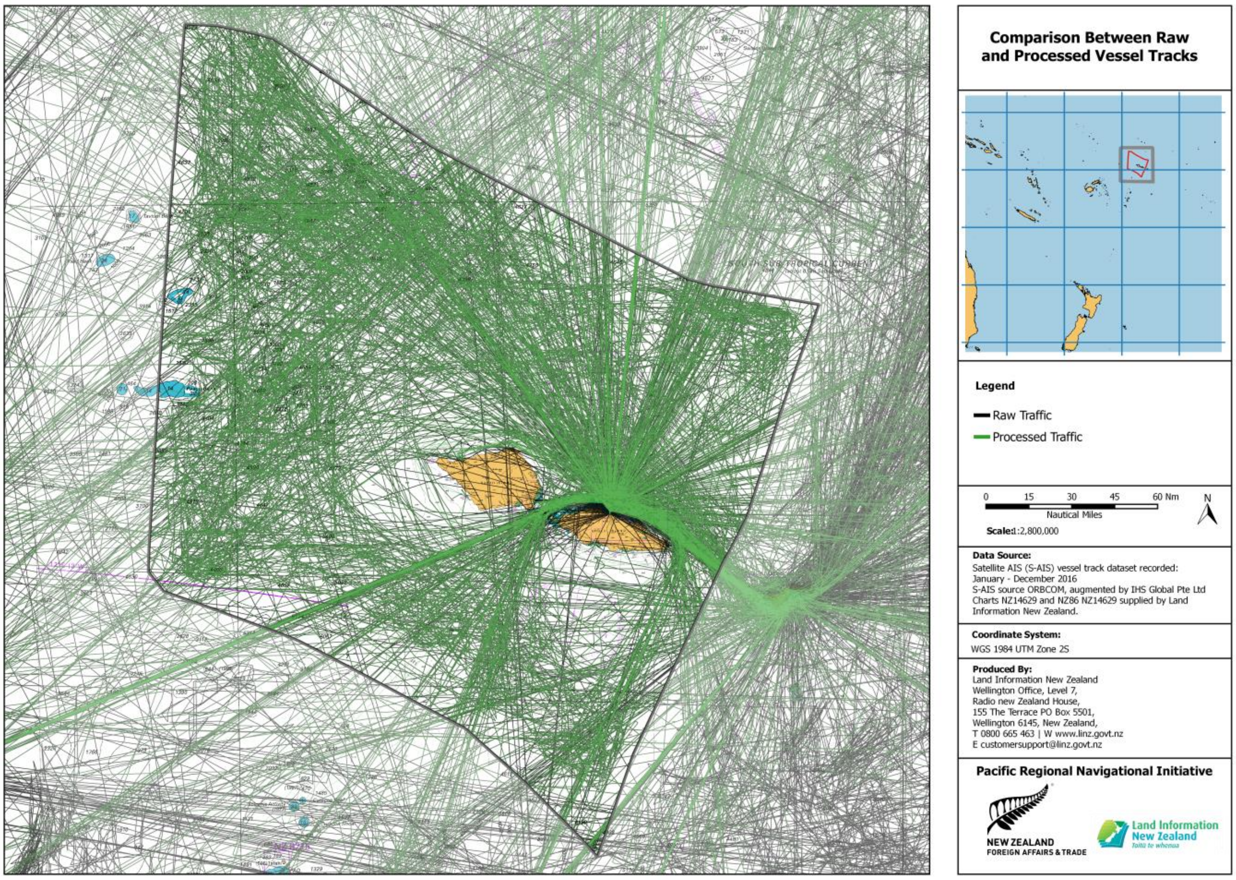
[7] Information from Ministry of Fisheries.

ANNEX B - GIS Track Creation and Processing

4 Final Results

4.1 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 Samoa.

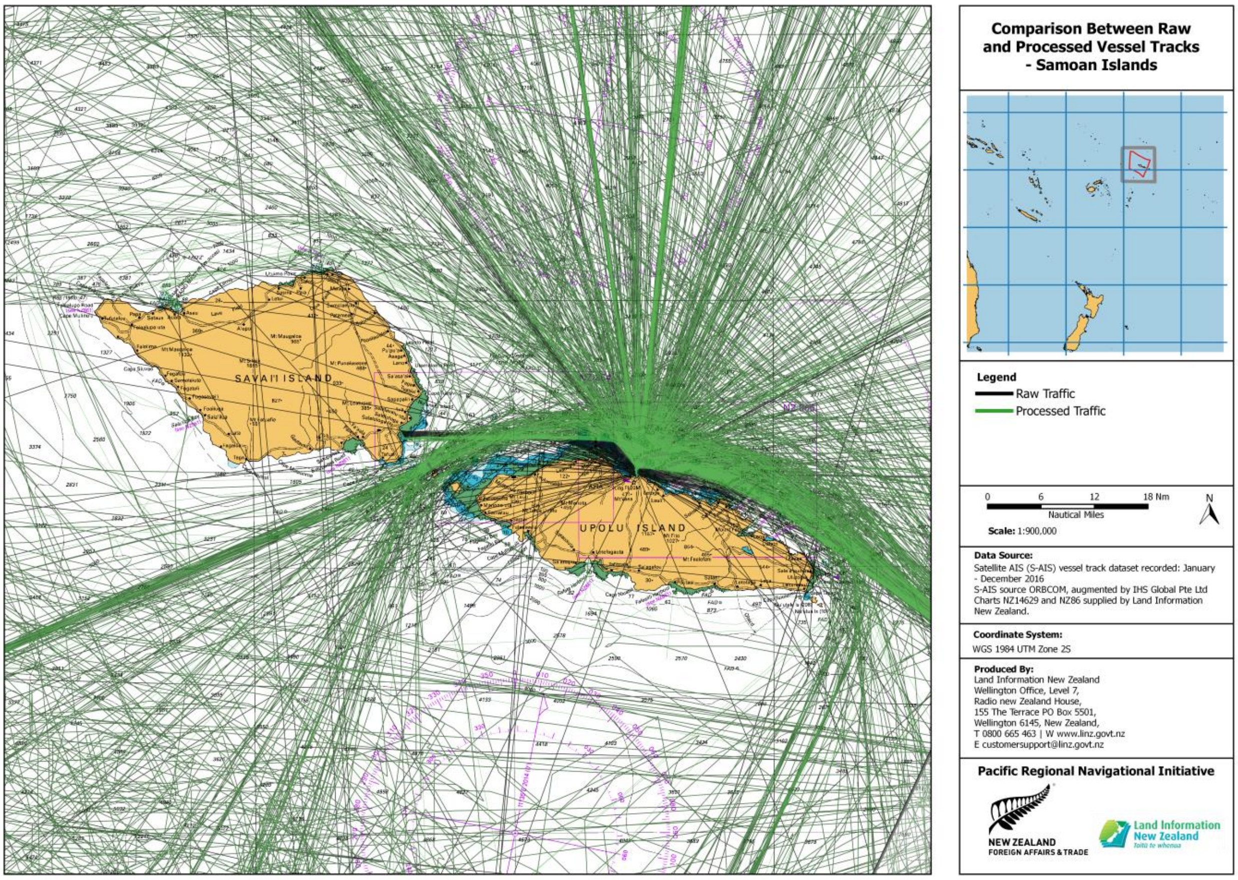
4.2 Figure 3 shows that all vessel tracks in the study area that intersects with the EEZ, with comparison between both raw and processed data. All vessel tracks that crossed land and drying reefs have been manually routed around the coast of Samoa.



Annex B - Figure 3: Comparison between raw and processed vessel tracks across the study area

ANNEX B - GIS Track Creation and Processing

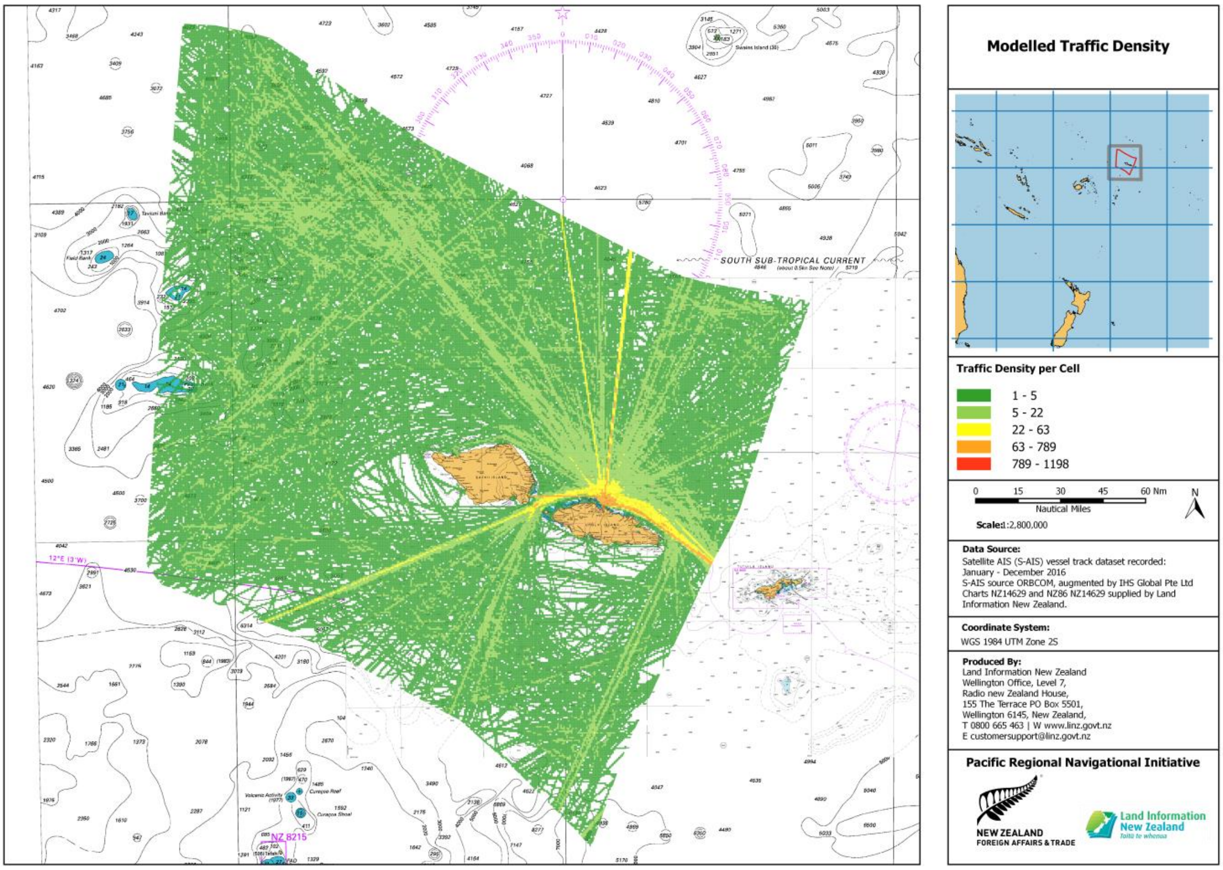
4.3 The difference between the raw and corrected tracks can be more clearly seen in Figure 4, a larger scale plot of the raw and processed tracks in the vicinity of Samoa.



Annex B - Figure 4: Comparison between processed and raw vessel tracks around Samoa

ANNEX B - GIS Track Creation and Processing

4.4 Figure 5 represents the modelled traffic density of all processed vessel tracks across the study area. Traffic density is defined as the number of tracks intersecting a cell. Therefore, you will note that the inter-island ferry route from Mulifanua to Salelologa (which was inserted as only two tracks) does not feature on this plot. A more complete representation of the traffic is given by GT density per cell (the sum of the GT of all the tracks). This is discussed in Annex C.

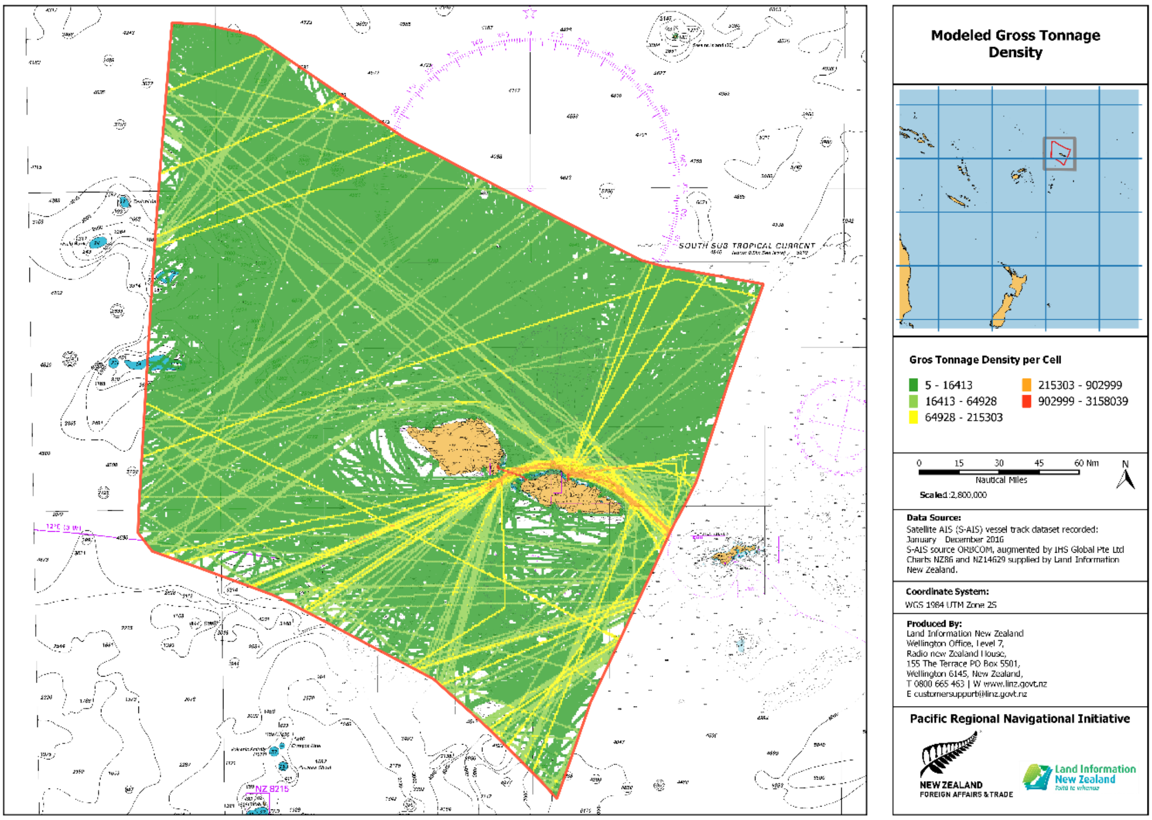


Annex B - Figure 5: Processed traffic density by cell (number of tracks)

ANNEX C – Traffic Risk Calculation

1 Traffic Risk Calculation[8]

1.1 After processing the AIS data to produce tracks, and applying the GT per vessel, a vessel traffic GT 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*".[9] 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 GT per 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

[8] For consistency with previous LINZ SW Pacific hydrographic risk assessments and convenience of the reader, sections of this Annex have been reproduced by copy from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013).
[9] (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*."[10] For this Samoa risk analysis, the event trees previously used in the Vanuatu, Cook Islands and Tonga were considered applicable due to commonality of the general sizes and types of vessels visiting Samoa. The applicability of these accident /incident scenarios 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
Other (Defence, Research & SAR)	$1*10^{-5}$	$1*10^{-5}$	$1*10^{-5}$	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 vessels 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 in all weather conditions. This risk is likely to be higher for small vessels which are more vulnerable to sea and wind conditions, or trawlers working 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.

[10] (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.[11]

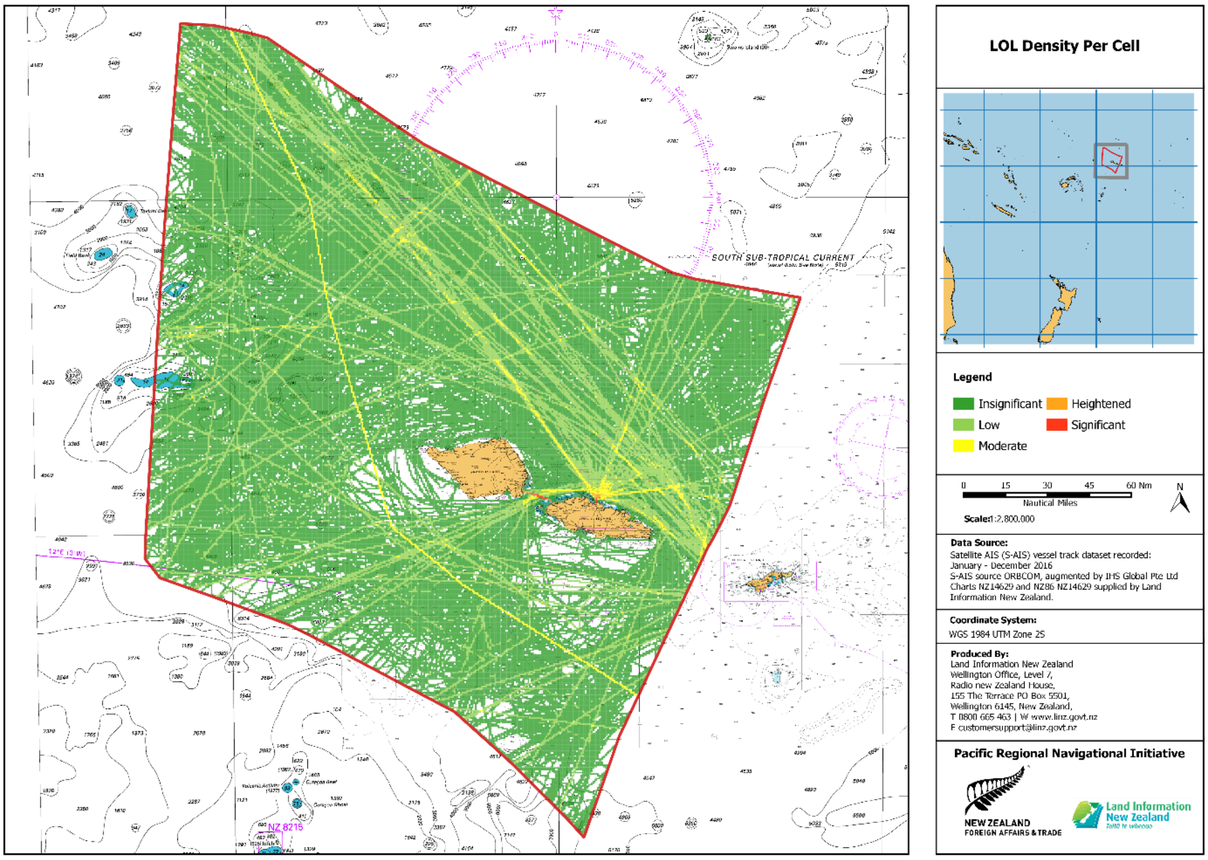
Modelled potential loss of life

1.6 Figure 3 below shows the modelled potential loss of life across the study area. The only areas with significant loss of life potential are: the near approaches to Apia and along the inter-island domestic ferry route where there is a high total GT of passenger vessel traffic. This route also intersects with the major commercial route through Apolima Strait. Note that this is a measure relating to ship type and GT only (not the quality of chart data or potential impact factors) therefore the highest potential will occur where high GT of vessel types with a high risk potential (see Annex C Figure 2 above) exist. It is also a relative measure using the natural breaks method described above to portray the potential risk variation across the 5 colour bands. The values of the colour bands used in these plots are as follows:

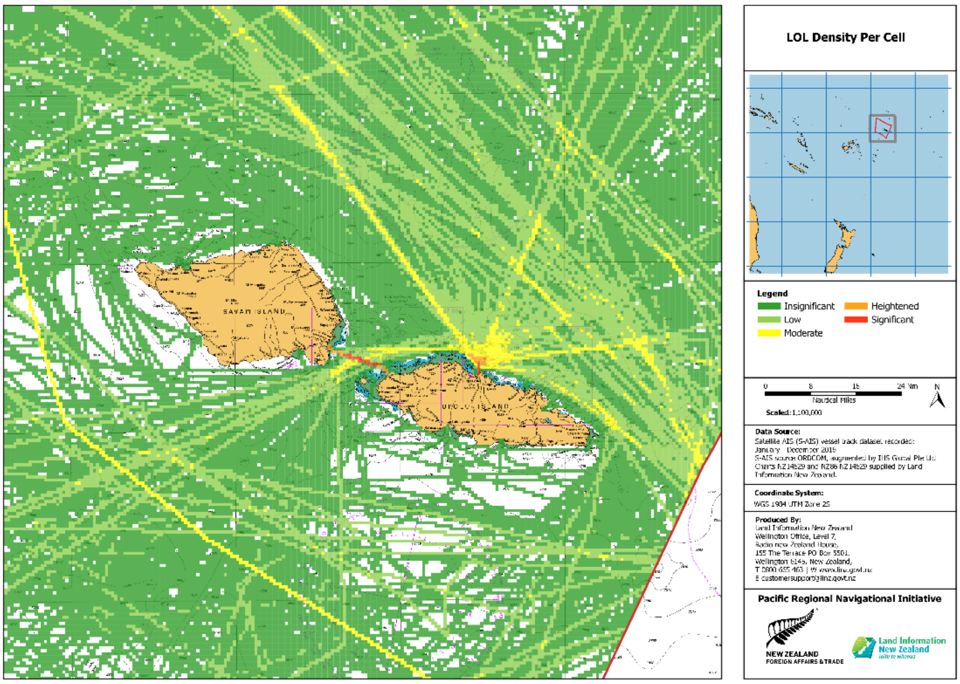
Potential loss of life colour bands	
0-49	insignificant
49-187	low
187-922	moderate
922-2378	heightened
2378 and greater	significant

[11]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



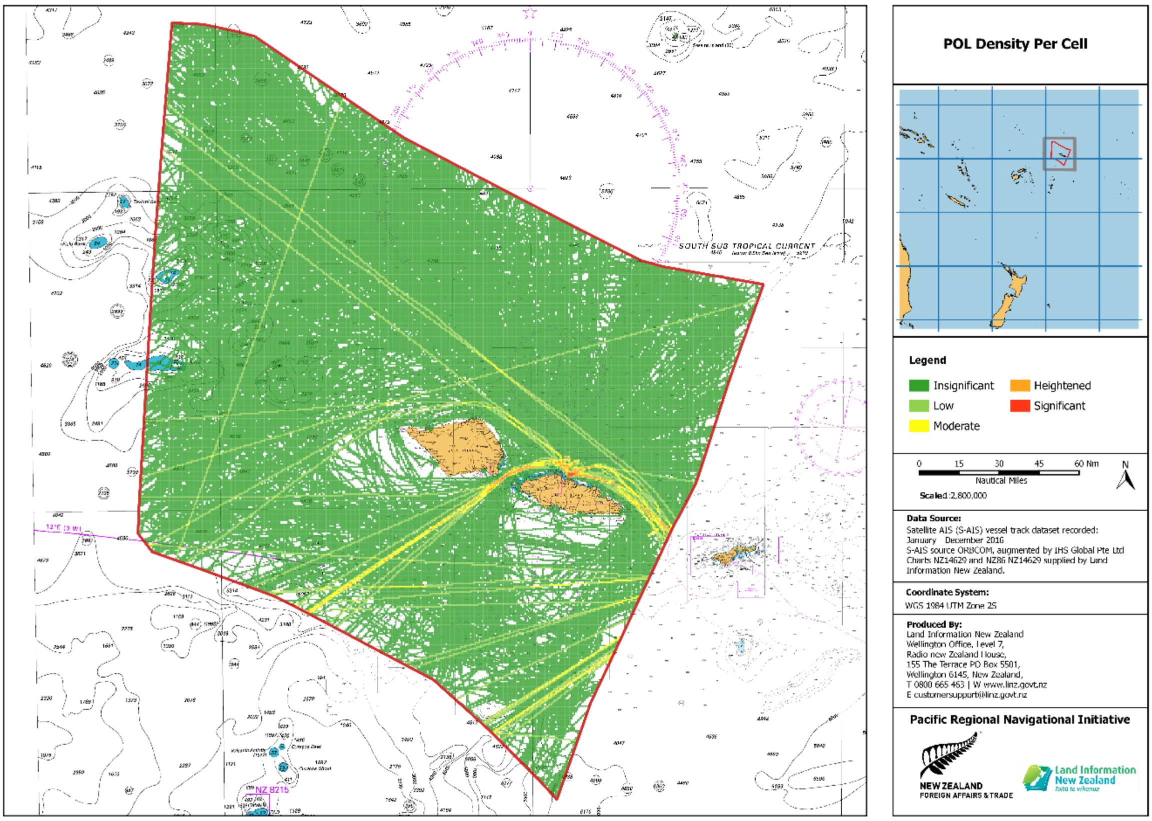
Annex C - Figure 3: Modelled Potential Loss of Life (expanded view below)



1.7. The two areas of *significant* LOL cell density described above both link to small areas of *heightened* LOL density. The remainder of the area is *insignificant* to *low* with some lines of *moderate* LOL density where multiple ship tracks coincide. The fact that a single ship track passing south of Samoa also has a moderate rating indicates that the plot is relatively sensitive.

ANNEX C – Traffic Risk Calculation

Modelled potential pollution



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 main traffic routes where vessels with a relatively high GT overlap the same cells, most of this traffic passes through Apolima Strait and across the top of Apolu Island, calling at Apia. Again, it is important to note that these values are relative to the total pollution potential across the Samoan EEZ, for reference the actual values of the colour bands are as follows:

Potential pollution colour bands	
0-1612	insignificant
1612-5277	low
5277-10492	moderate
10492-24075	heightened
24075 and greater	significant

ANNEX C – Traffic Risk Calculation

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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: (only included when relevant)	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.[12] Figures in section 2 of this Annex show 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.[13] The principal consequence factors are: the environmental impact, damage to culturally sensitive areas and damage to areas that would impact on the Samoan economy

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

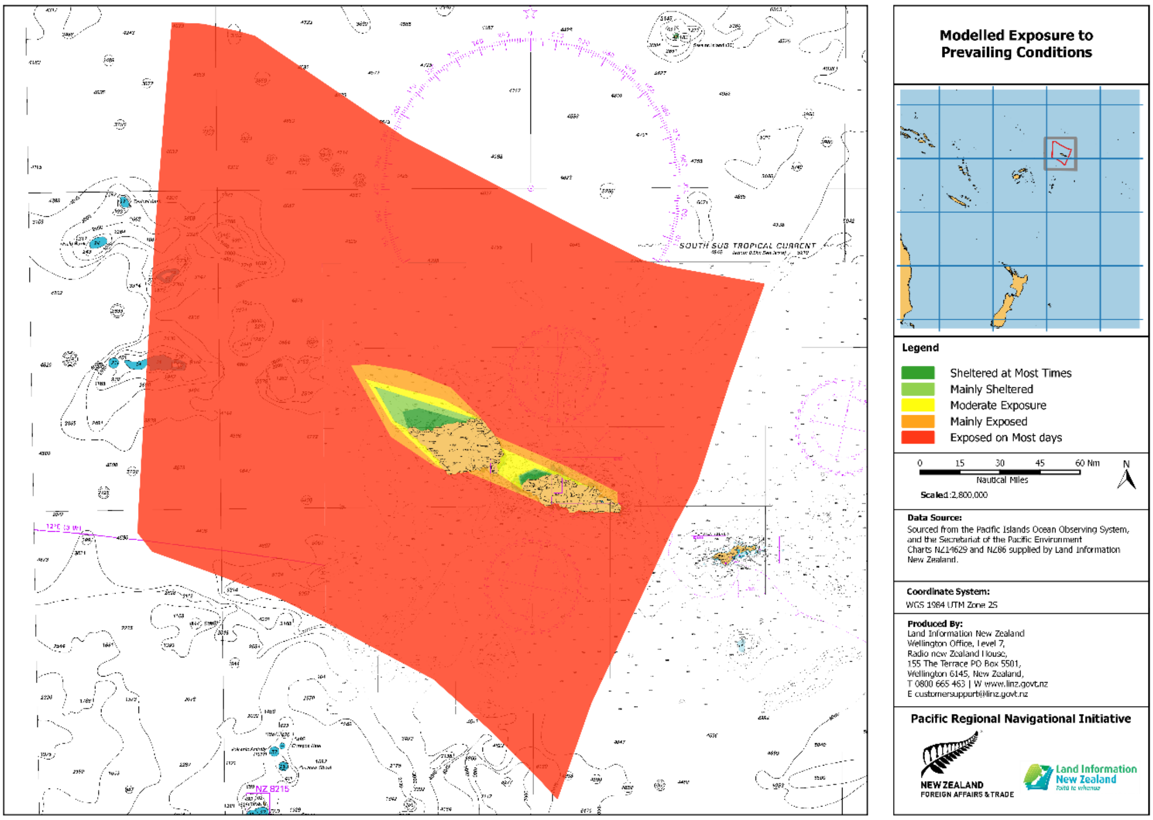
ANNEX D – Likelihood and Consequence Factors

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



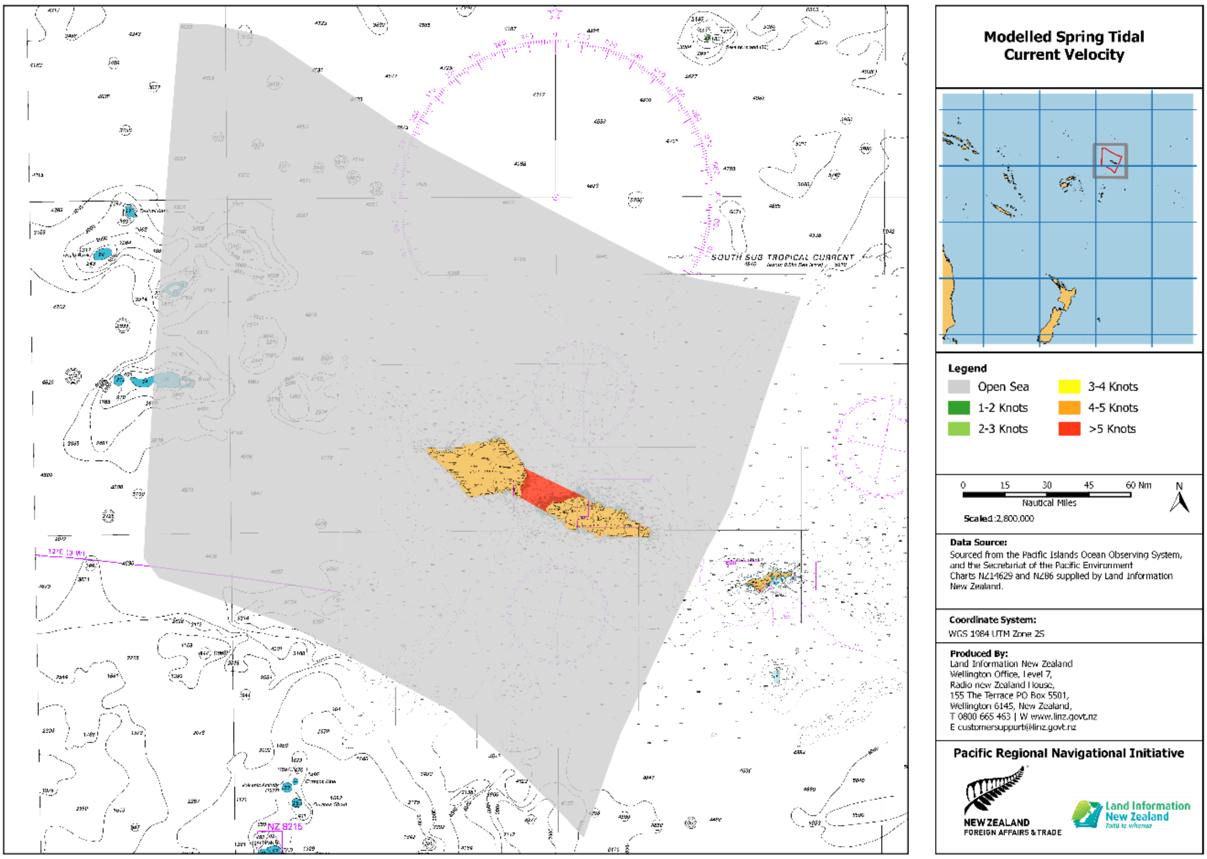
Annex D Figure 1: Modelled Exposure to Prevailing Conditions

Figure 1 represents relative hydrographic risk due to exposure to prevailing conditions across the study area. Information about the wind speed and direction and prevailing wave and swell conditions were taken from the Pacific Islands Ocean Observing System model.[14] This was consistent with but more detailed than information contained in NP61[15] and advice from the Samoa Meteorology Department. There is a predominance of winds and seas from the east and the south east throughout the year. Cyclone events are considered random.

[14] Pacific Islands Ocean Observing System (PacIOOS) http://www.pacioos.hawaii.edu/
[15] (Admiralty Sailing Directions, Pacific Islands Pilot Volume 2 - NP61, 2017) Chapters 1 & 13

ANNEX D – Likelihood and Consequence Factors

2.1.2 Spring Tidal Current Velocity



Annex D Figure 2: Modelled Spring Tidal Current Velocity

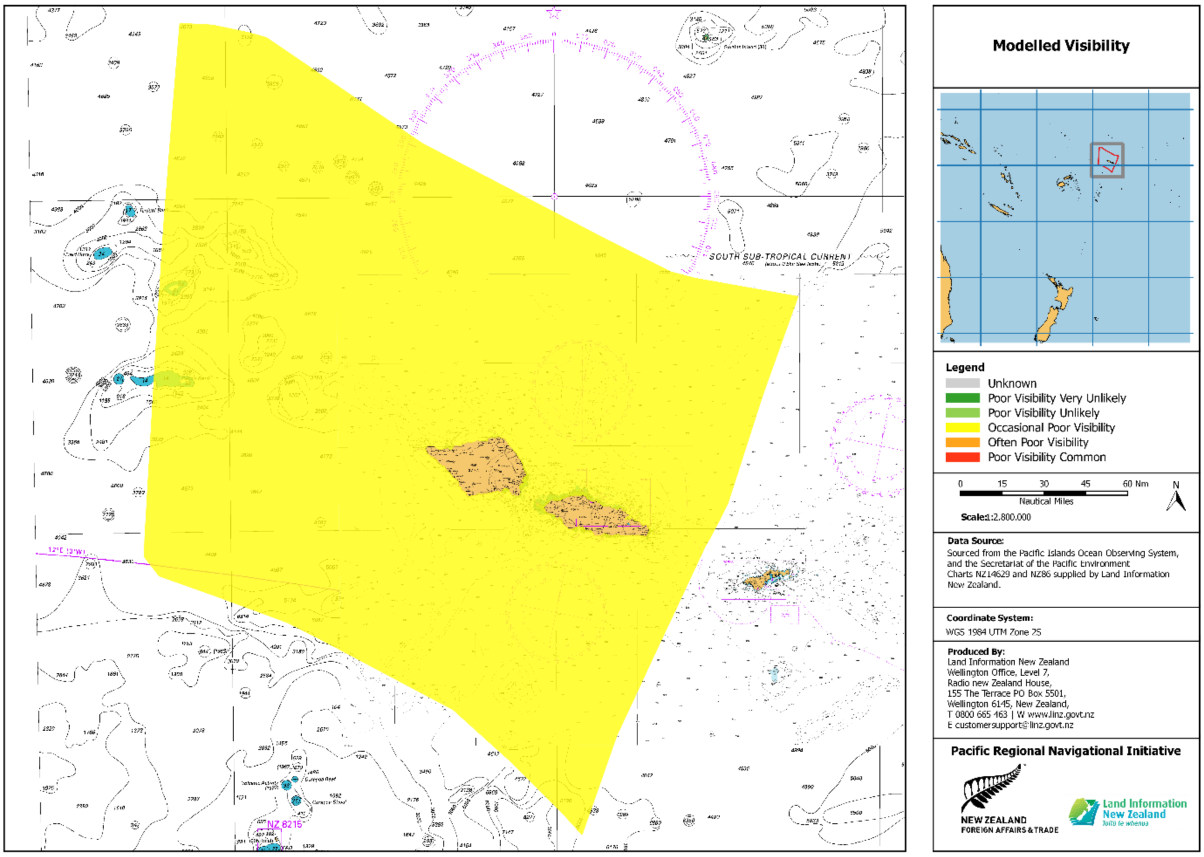
Figure 2 represents relative hydrographic risk due to the spring tidal current velocity across the study area. This figure was created based on data from PacIOOS,[16] currents as described on chart NZ 86 and NP61, and confirmed by discussion with SSC.

[16] Pacific Islands Ocean Observing System at http://www.pacioos.hawaii.edu/currents/model-samoa/

ANNEX D – Likelihood and Consequence Factors

2.1.3 Visibility

Poor visibility can occur across the study area and is normally associated with passing rain squalls of short duration. Nevertheless, it can increase the risk of a navigational incident especially in high traffic areas and close to land. The entire Samoan EEZ has been classified as occasional poor visibility.

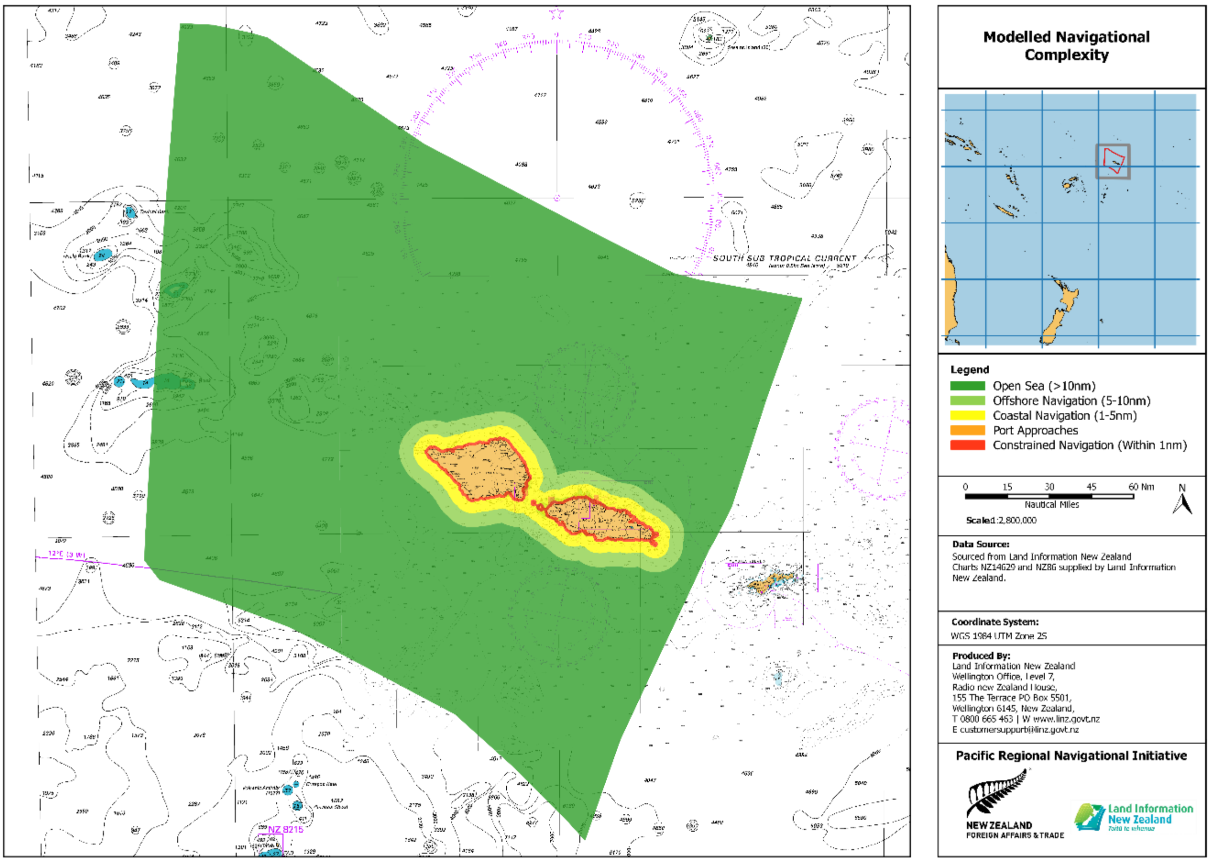


Annex D Figure 3: Visibility

ANNEX D – Likelihood and Consequence Factors

2.2 Navigational Complexity

The risk for transiting vessels is greater the more complicated the navigational track. 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.[17] In this study, the risk related to navigational complexity was defined by the type of navigation required across the Samoa EEZ.



Annex D Figure 4: Modelled Navigational Complexity

Figure 4 represents relative hydrographic risk due to the type of navigation required across the study area. This Figure was created based on site visits to all ports, as well as interviews with relevant harbour masters. The figure shows constrained navigation within 1nm of the coastal reef and within the commercial ports and gradually reducing risk with distance further to seaward as defined in the legend.

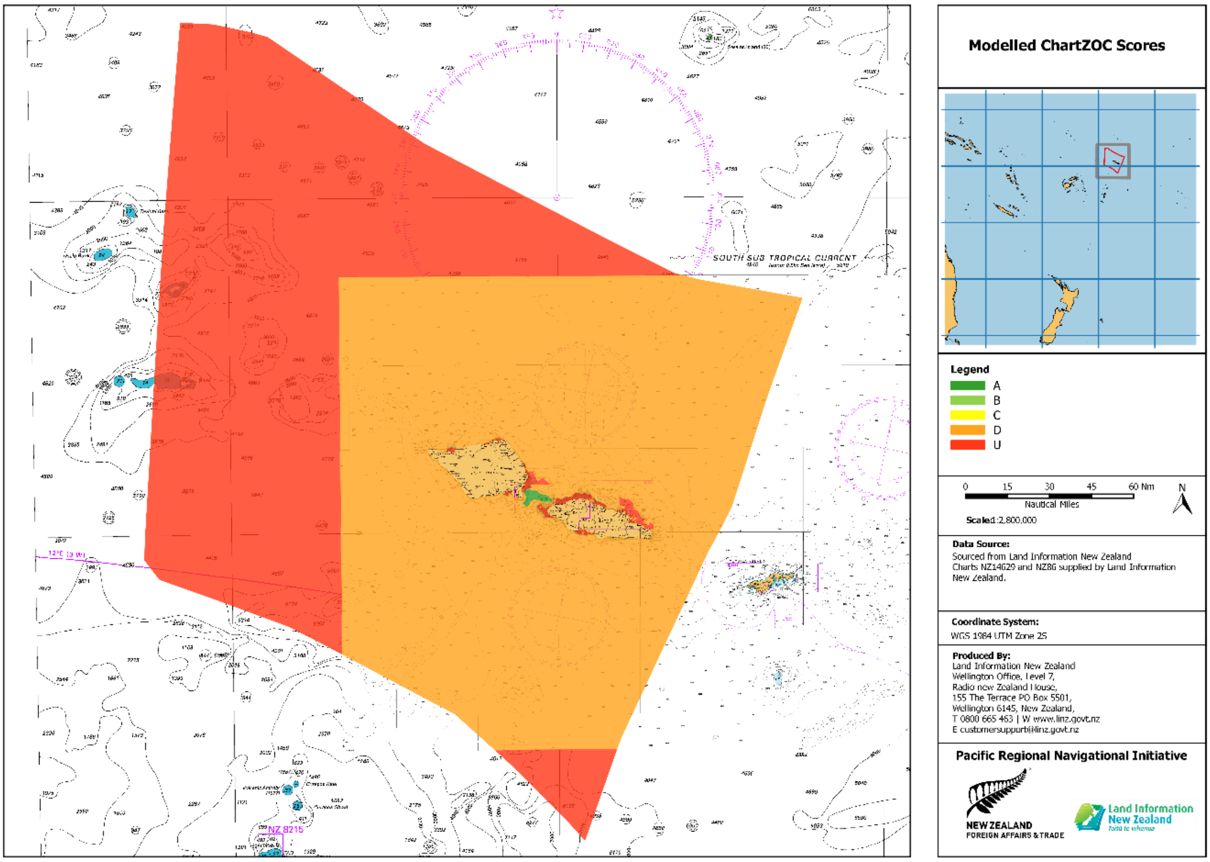
[17]For consistency, this explanation was taken from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D29).

ANNEX D – Likelihood and Consequence Factors

2.3 Aids to Navigation (AtoN) and 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.[18] The other navigational risk factors in Samoa are the possibility that unlit FADs are deployed in positions other than those charted, and whether the scale of the nautical charts in some locations is sufficient for their intended use. These factors are not included in the GIS risk calculation but are discussed in the risk results and recommendations.

2.3.1 Charted Zones of Confidence



Annex D Figure 5: Modelled Charted Zones of Confidence Score

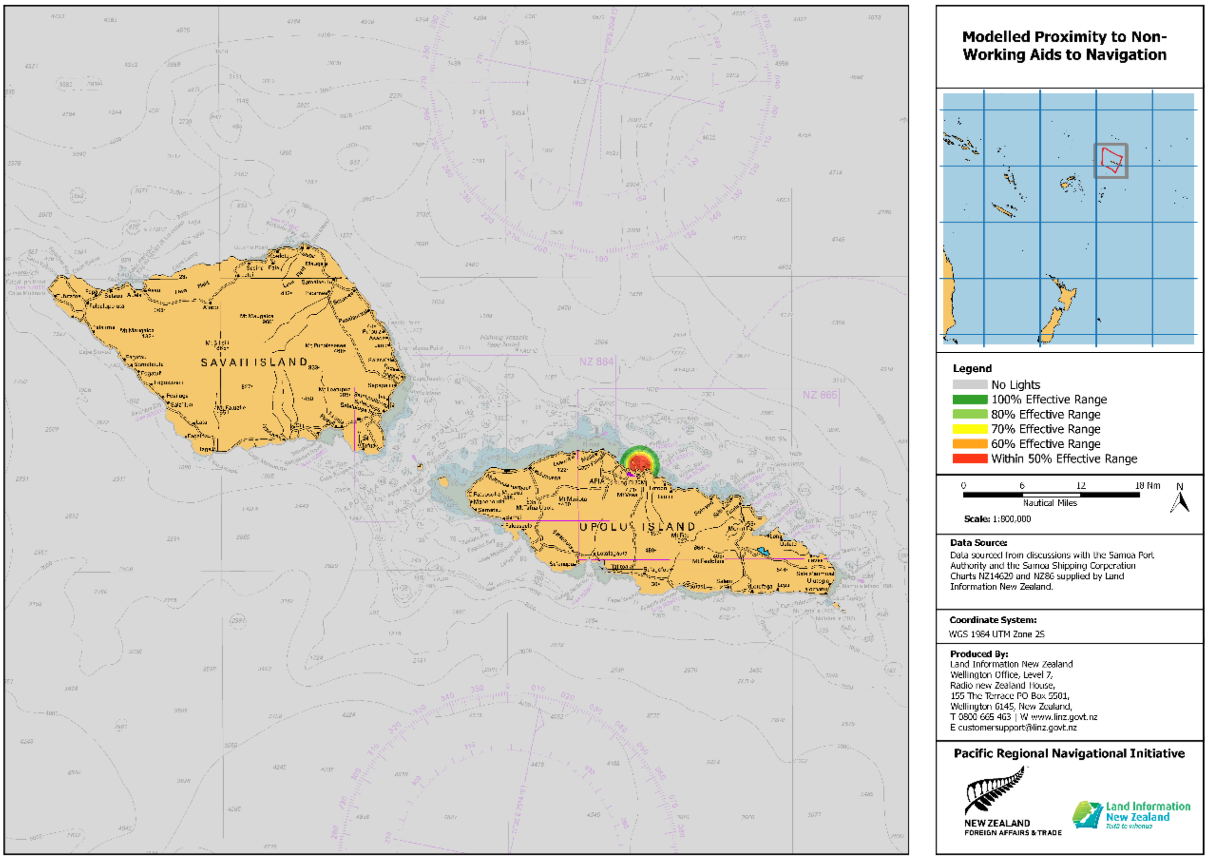
Figure 5 represents relative hydrographic risk due to the charted zones of confidence; the seafloor of the study area beyond the extents shown in this figure has not been assessed. This Figure was created based on zone of confidence assessment ratings provided by LINZ. The larger scale extract of this Figure for the region of Apia to Apolima Strait shows the detail of how CATZOC classifications

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

are divided into specific areas related to the different standard of hydrographic information available.

2.3.2 Proximity to Non-Working Aids to Navigation

In Samoa, there are only a small number of formal AtoN, with two, Apolima Island light and Malua light (west of Apia) being the only navaids outside port limits. Malua light was reported to be charted and operating correctly. Apolima Island light was reported to be operating correctly but the light's intensity had been reduced to 12nm. Within the port of Apia, the beacon (Fl.4s) marking the western entrance reef was noted to be unlit. This is the only item that has been included in the "proximity to non-working aids to navigation" GIS layer. Local advice from Captain Sam Fineas (SSC) is that the charted lit beacons in the vicinity of Manono Island have not existed for a long time. These lights were only useful for local navigation and are not included in this risk layer.



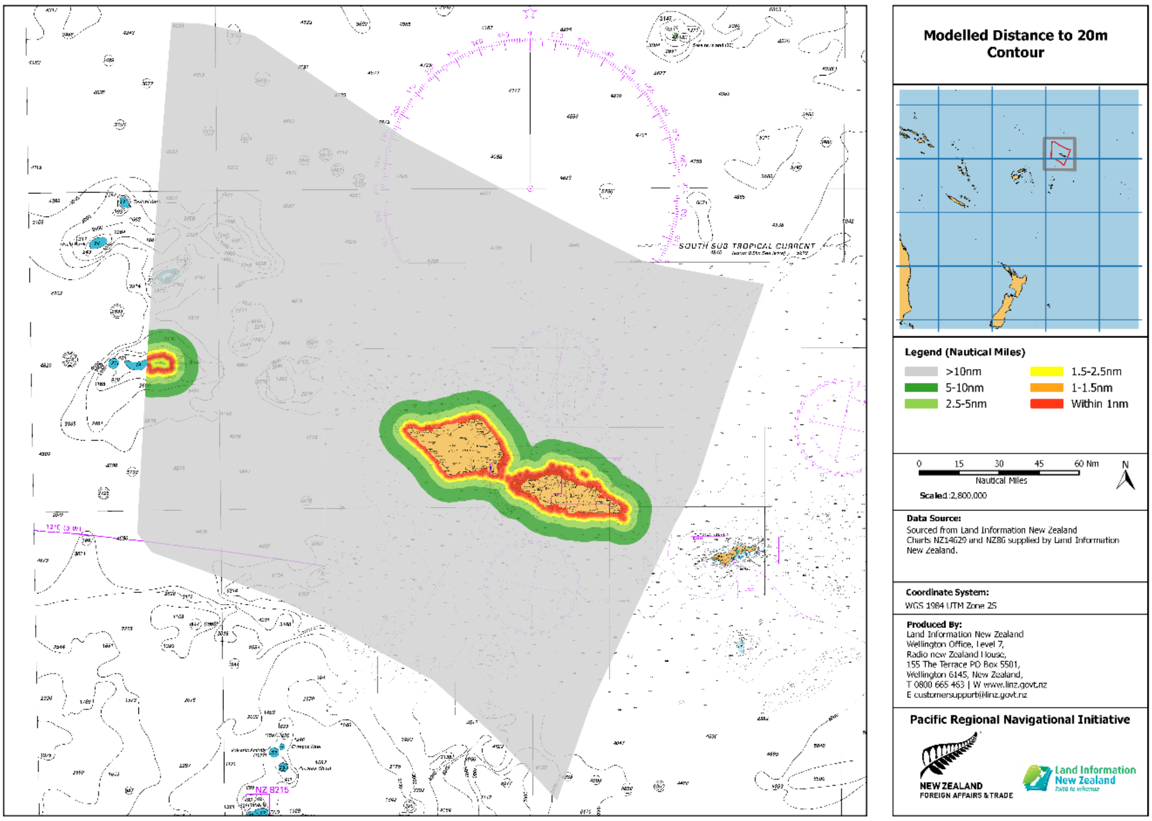
Annex D Figure 6: Proximity to non-working aids to navigation

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.[19] In this assessment the 20m contour was selected for convenience as it could be extracted directly from ENCs. The difference between this and the 15m depth contour used in previous assessment is considered negligible.

2.4.1 Depth of Water - 20m Contour



Annex D Figure 7: Modelled Distance to 20m Contour

Figure 7 shows relative hydrographic risk due to the proximity to areas at a minimum depth of 20m. This figure was created from the latest Fugro LiDAR bathymetry available.[20]

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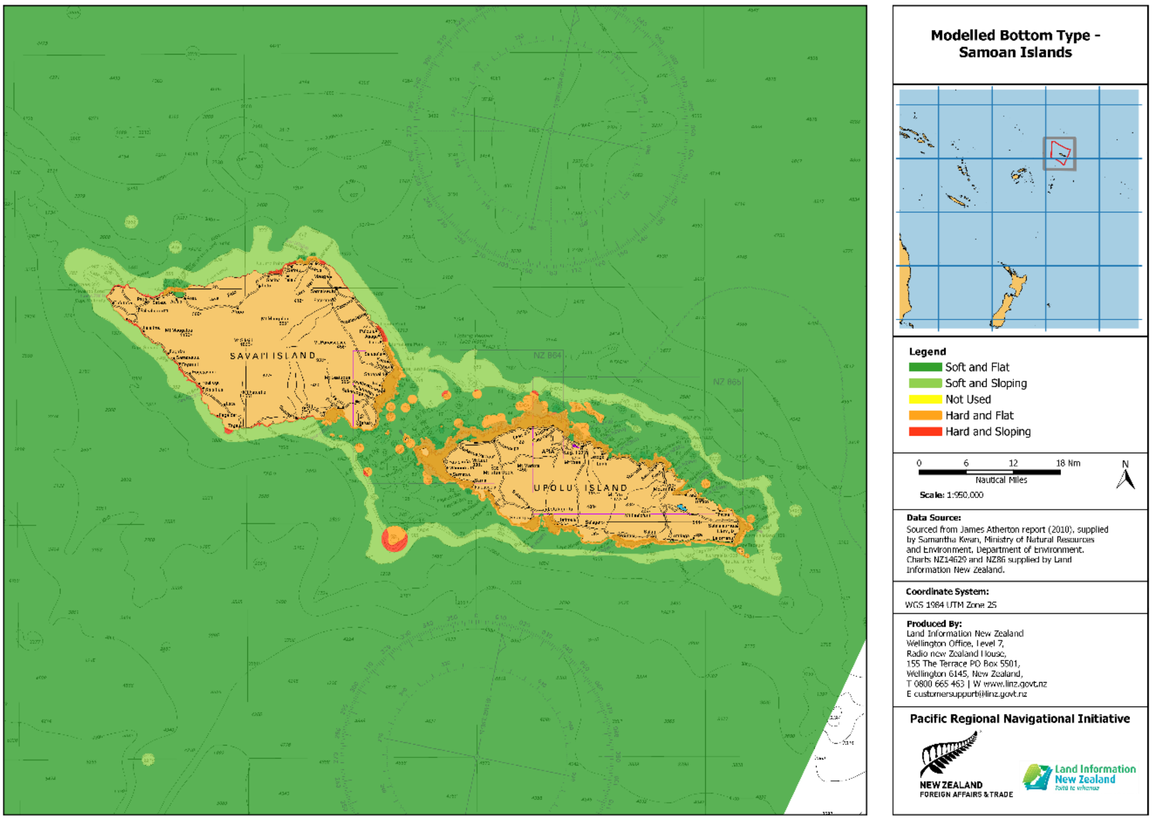
[19] This explanation has been modified for additional clarity from the original work in (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D36).

[20] Bathymetry collected by Fugro LADS under the World Bank project (Enhancing the Climate Resilience of Coastal Resources and Communities Project for Samoa, 2014)

ANNEX D – Likelihood and Consequence Factors

2.4.2 Bottom Type



Annex D Figure 8: Modelled Bottom Type

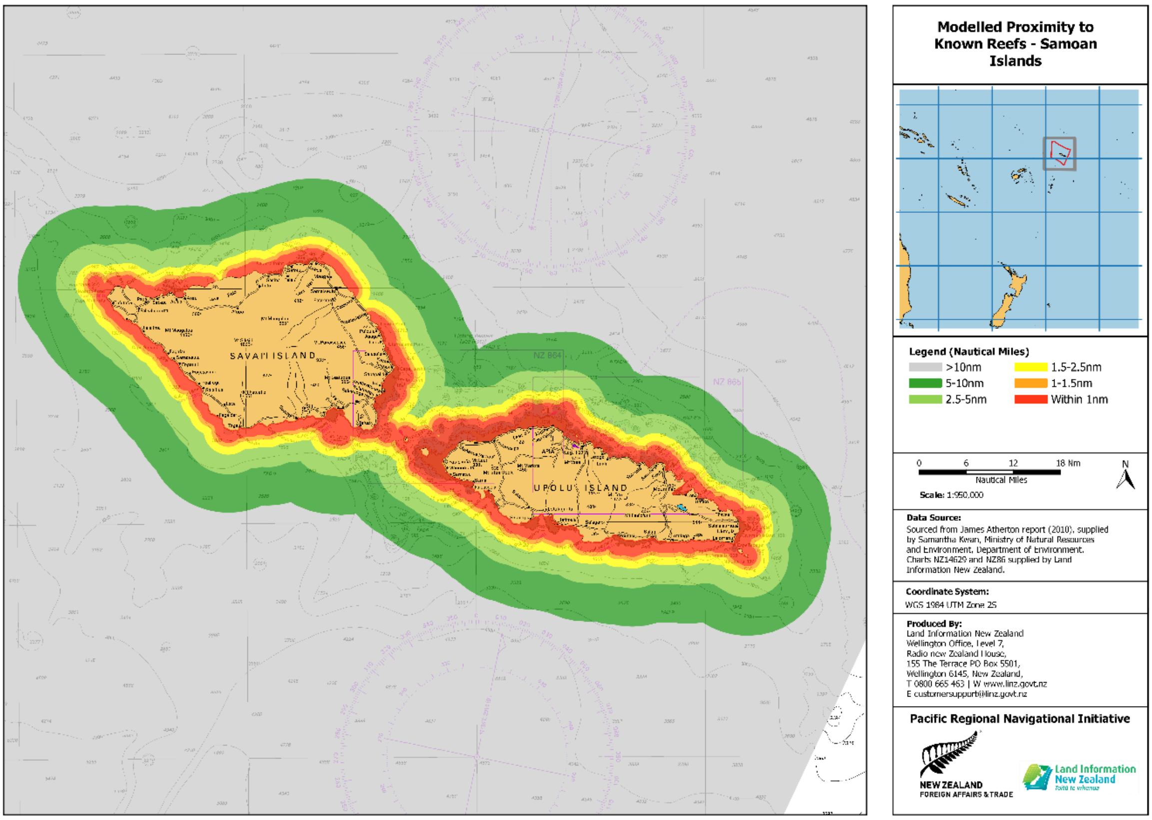
Figure 8 represents relative hydrographic risk due to the nature of the seabed across the study area. This figure was derived from information available on the largest scale chart.

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.[21]

2.5.1 Proximity to Known Reefs



Annex D Figure 9: Modelled Proximity to Known Reefs

Figure 7 represents relative hydrographic risk due to the proximity to known reefs across the study area. This figure was created based on the location of reefs as marked on the largest scale chart with additional information regarding some coastal reefs provided by MNRE.[22]

2.5.2 Sub-Sea Volcanic Activity

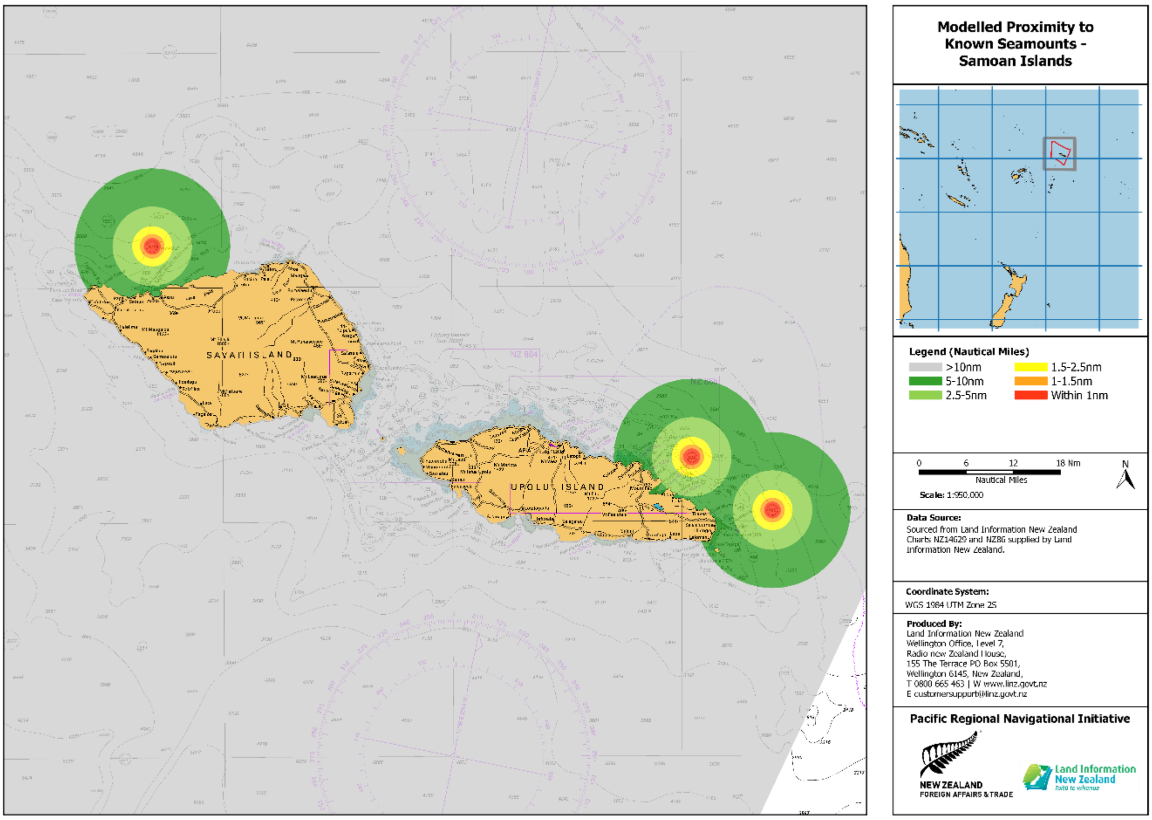
The study did not find evidence of recent sub-sea volcanic activity across the study area. The level of hydrographic risk due to the proximity to sub-sea volcanic activity was therefore assigned a weight of 0 (zero) in the calculation of hydrographic risk.

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

[22] Data sourced from Ministry of Natural Resources and Environment, Department of Environment (Samantha Kwan) with reference to (Atherton, 2010).

ANNEX D – Likelihood and Consequence Factors

2.5.3 Proximity to Known Sea-Mounts



Annex D Figure 10: Modelled Proximity to Known Seamounts

Figure 10 represents relative hydrographic risk due to the proximity to known seamounts across the study area. This figure was created based on existing charts and information provided by SPREP,[23] but only seamounts rising 1000m above the surrounding seabed and to within 500m of the surface were included.

2.5.4 Proximity to WW2 Military Sites

The study did not find any WW2 military sites, 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 (zero) in the calculation of hydrographic risk.

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 (zero) in the calculation of hydrographic risk.

[23] Interview with Ryan Wright, Spatial Planning Officer, Secretariat of the Pacific Regional Environment Program.

ANNEX D – Likelihood and Consequence Factors

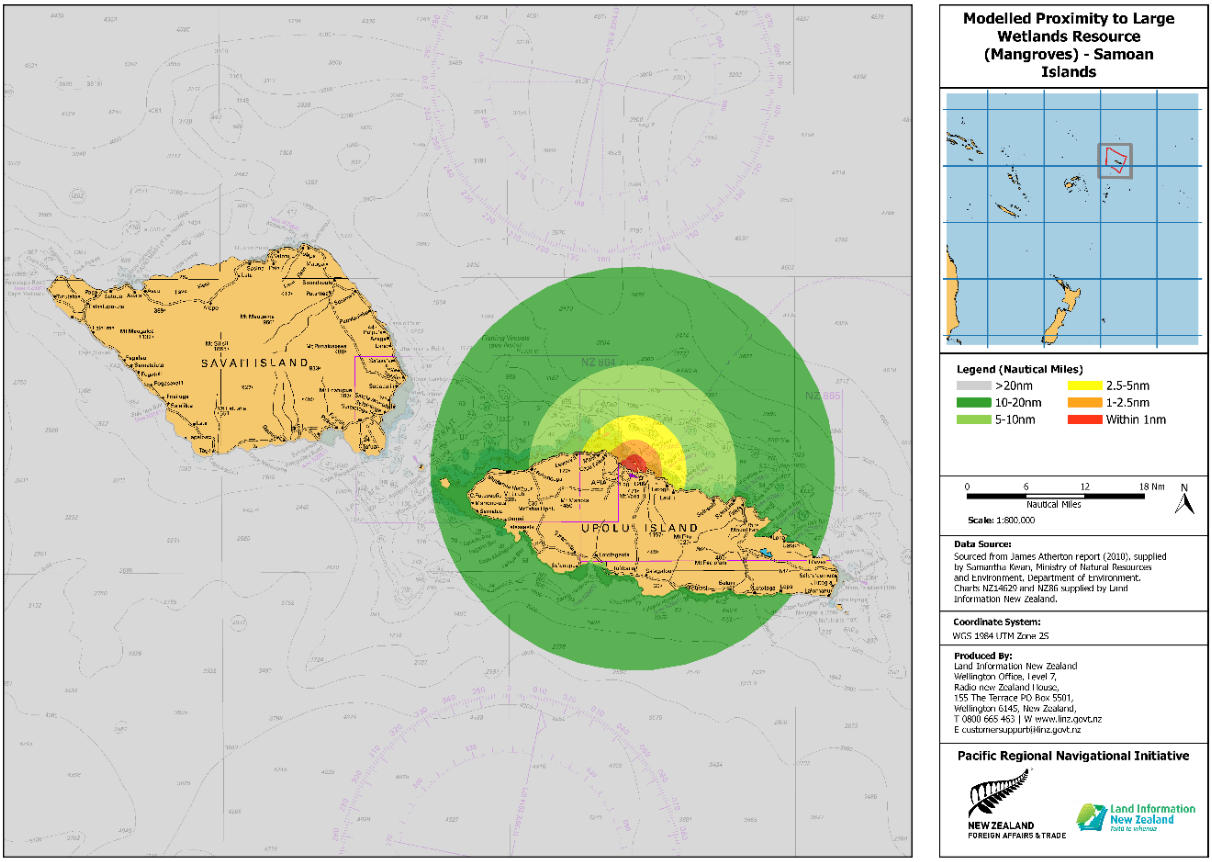
3. Consequence Factors

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.[24]

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. Samoa has a number of significant wetlands including the largest mangrove area in the South-West Pacific at Vaiusu Bay. These figures were compiled from information provided by MNRE.[25]

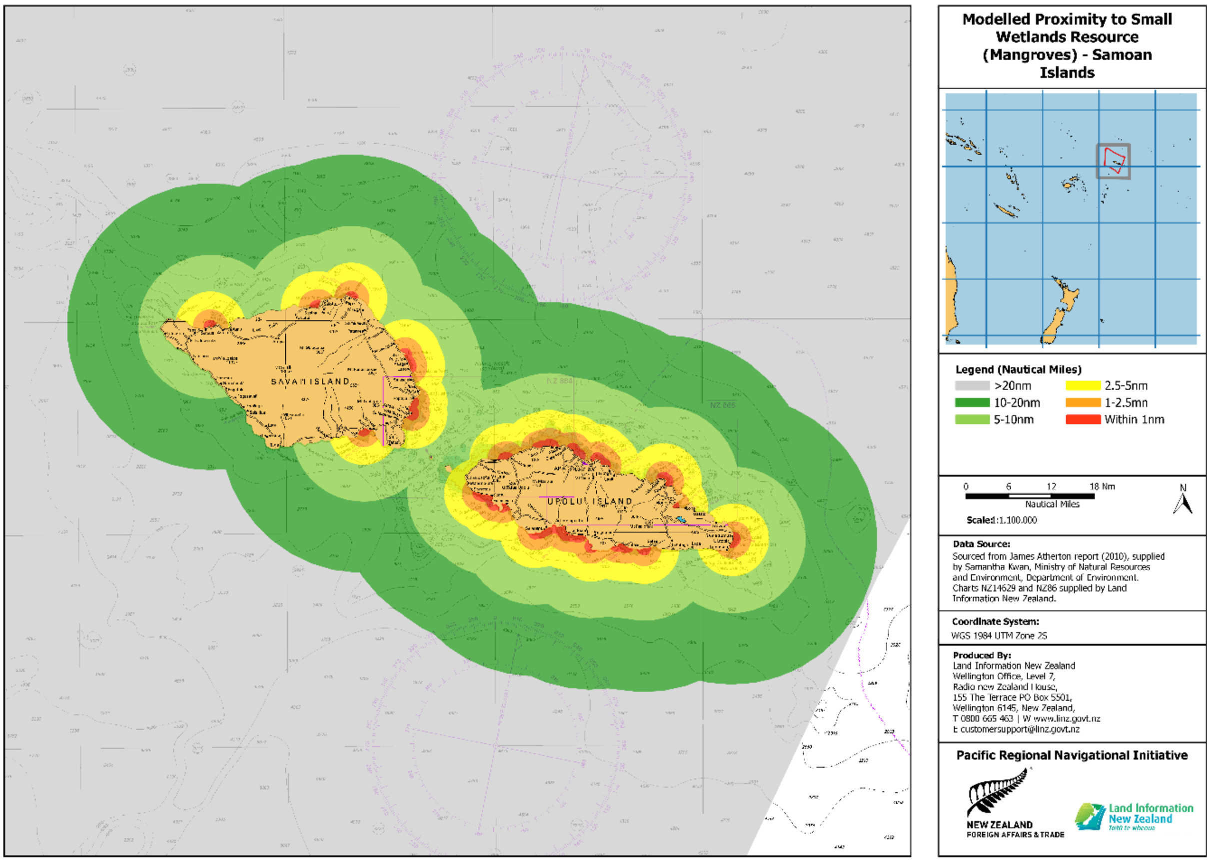


Annex D Figure 11: Proximity to large wetland resource

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

[25] Data sourced from Ministry of Natural Resources and Environment, Department of Environment with reference to (Atherton, 2010)

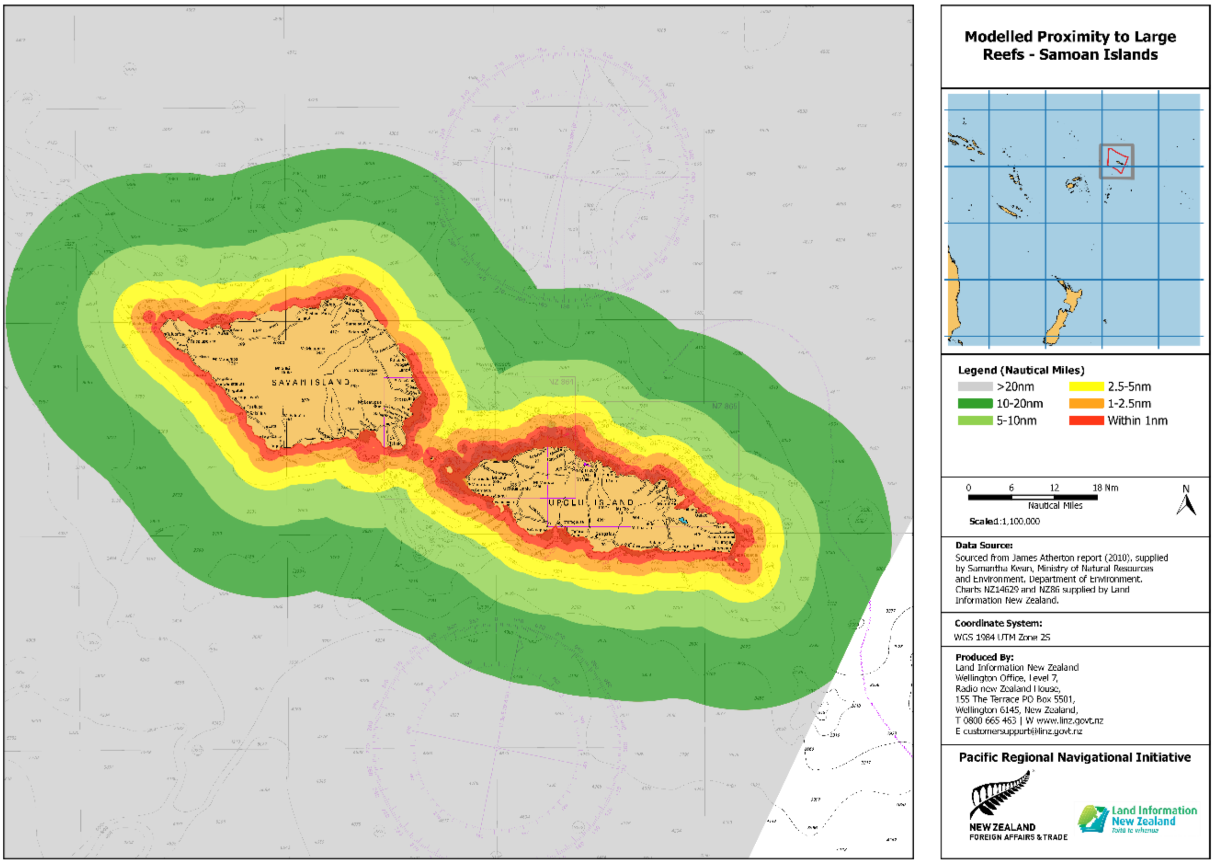
ANNEX D – Likelihood and Consequence Factors



Annex D Figure 12: Proximity to small wetland resource

ANNEX D – Likelihood and Consequence Factors

3.1.2 Proximity to Large Reefs

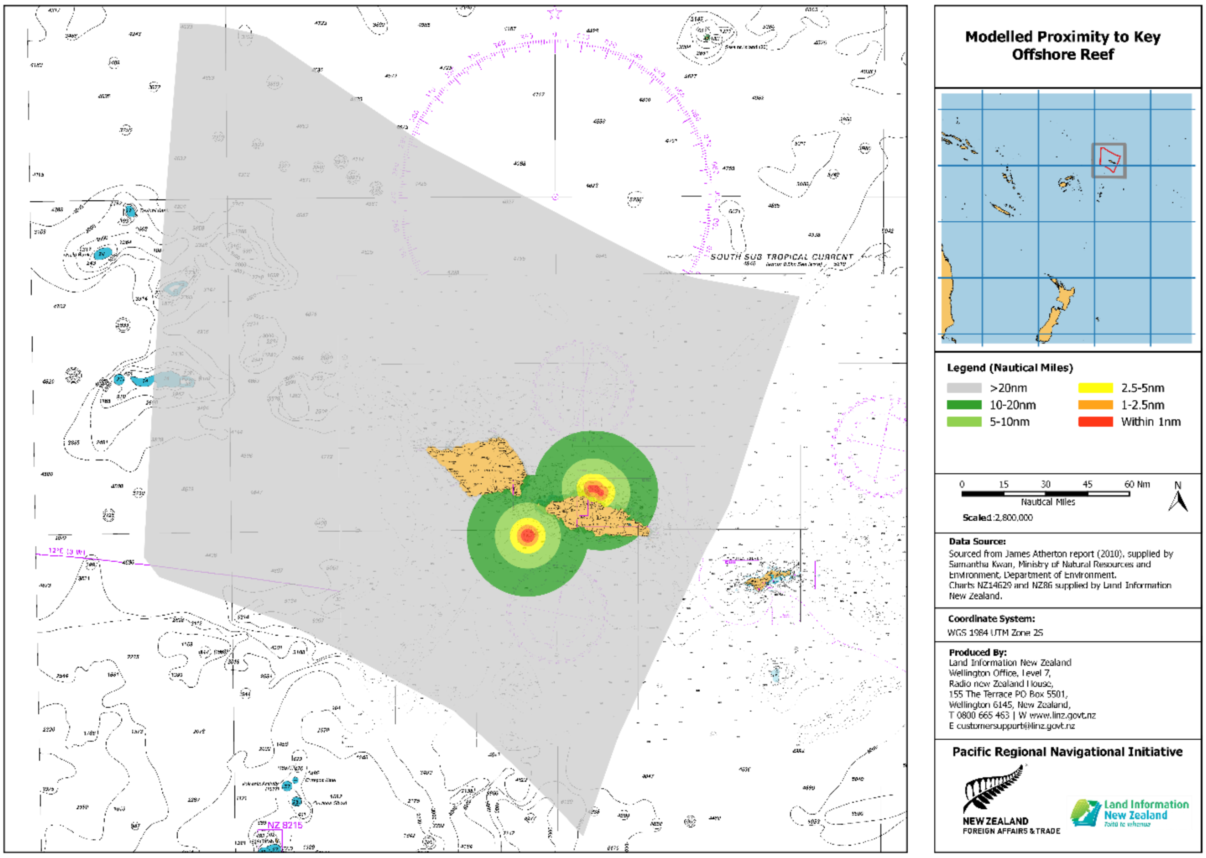


Annex D Figure 13: Modelled proximity to large reefs

Figure 13 represents relative hydrographic risk due to the proximity to large reefs across the study area. Virtually the whole coastline of Samoa is surrounded by fringing reef, though on the southern coast this is narrower and there are some areas where the sea breaks onto coastal cliffs. For this analysis, the entire coastline of Samoa is defined as a large reef. There are no other large reefs throughout the Samoan EEZ

ANNEX D – Likelihood and Consequence Factors

3.1.3 Proximity to Key Offshore Reef

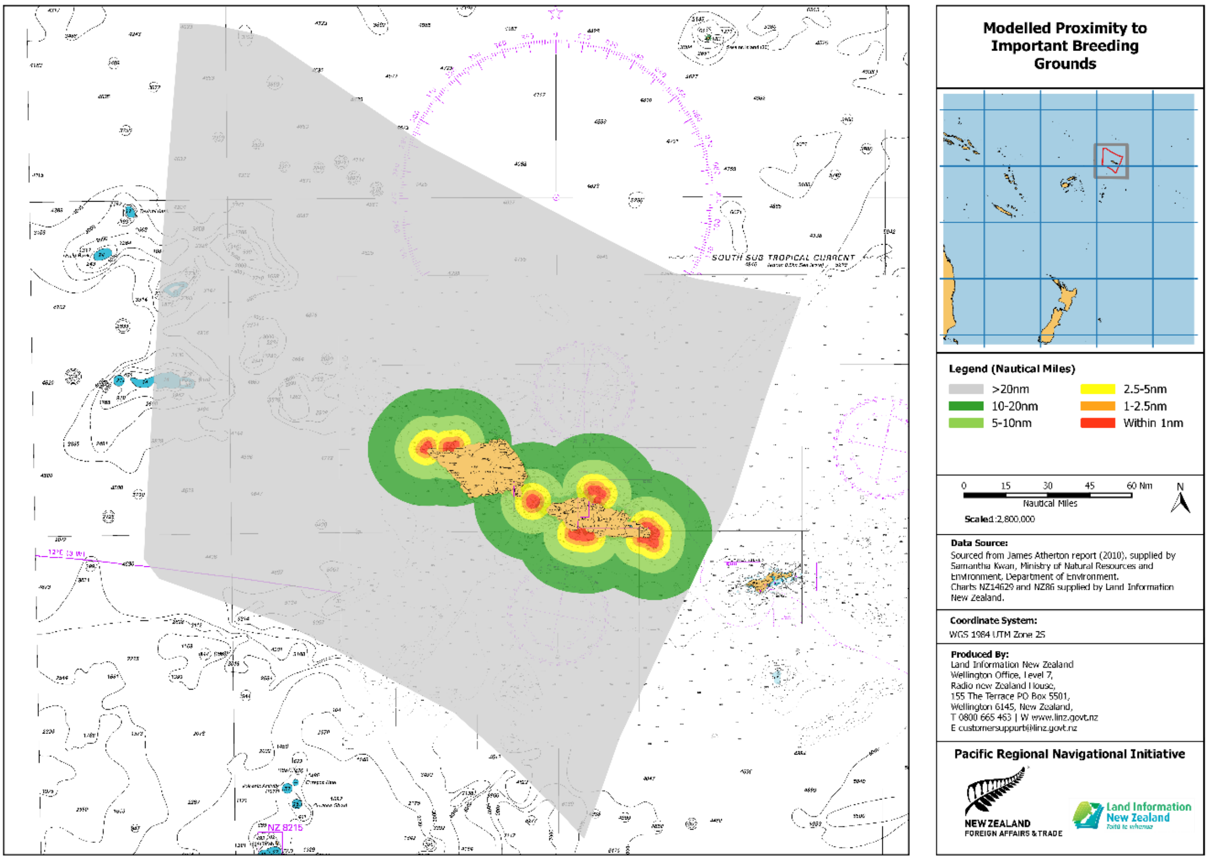


Annex D Figure 14: Modelled Proximity to Key Offshore Reef

Figure 14 represents relative hydrographic risk due to the proximity to key offshore reefs across the study area. This figure was created based on information provided by Ministry of Natural Resources and independently corroborated by SPREP. There were two, key offshore (but submerged) reefs identified, these were "Five Mile Reef," north of Apia and "15 Mile Reef," south-west of Faleaseela.

ANNEX D – Likelihood and Consequence Factors

3.1.4 Proximity to Important Breeding Grounds



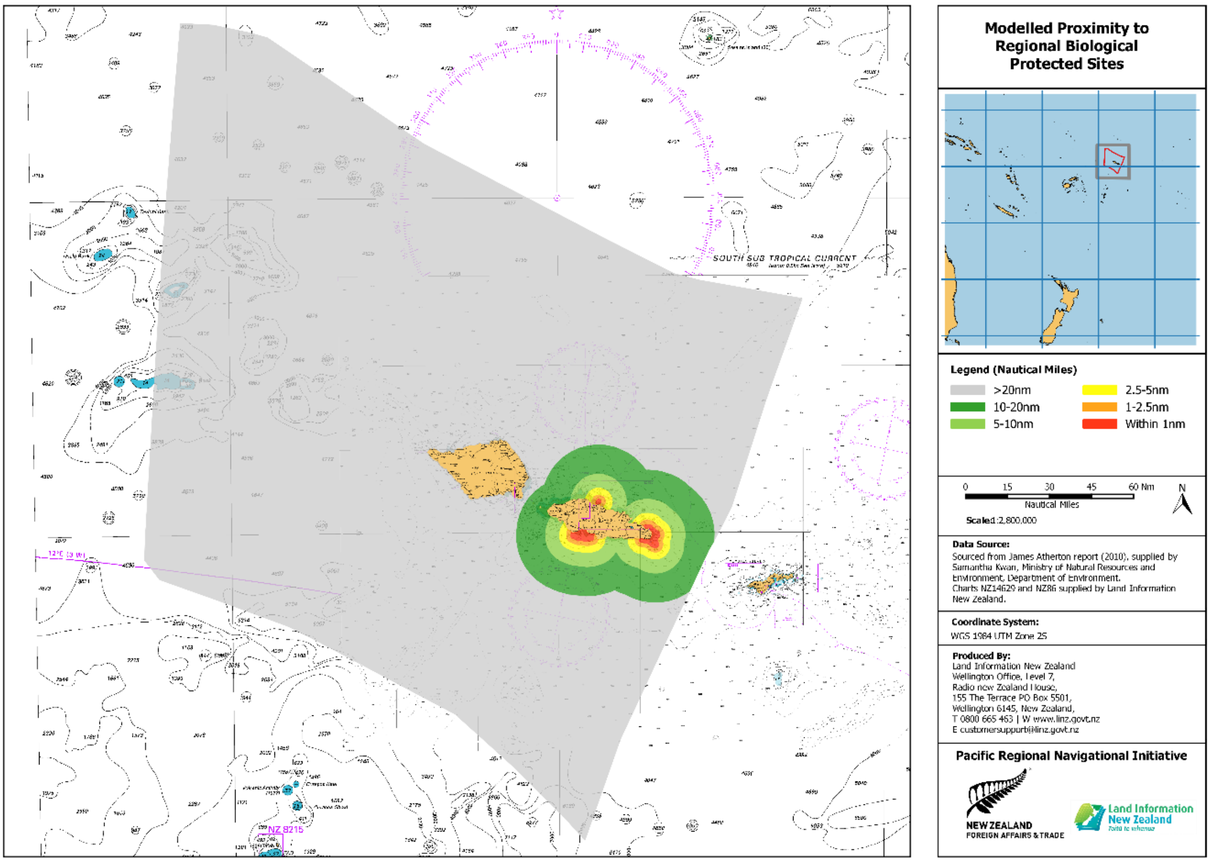
Annex D Figure 15: Modelled Proximity to Important Breeding Grounds

Figure 15 represents relative hydrographic risk due to the proximity to important breeding grounds across the study area. This figure was created based on information provided by MNRE[26] and SPREP.[27]

[26] (Atherton, 2010)
[27] (United Nations Environment Program (UNEP), 2015)

ANNEX D – Likelihood and Consequence Factors

3.1.5 Proximity Regional Biological Protected Sites



Annex D Figure 16; Modelled Proximity to Regional Biological Protected Sites

There were no world biological protected sites in the study area. Consequently, the risk weighting for this criterion was distributed across regional and local biological protected sites. Figure 16 represents relative hydrographic risk due to the proximity to regional biological protected sites across the study area. The sites shown in this figure were given the significance of a regional biological protected site from information provided by MNRE[28] and corroborated by SPREP[29].

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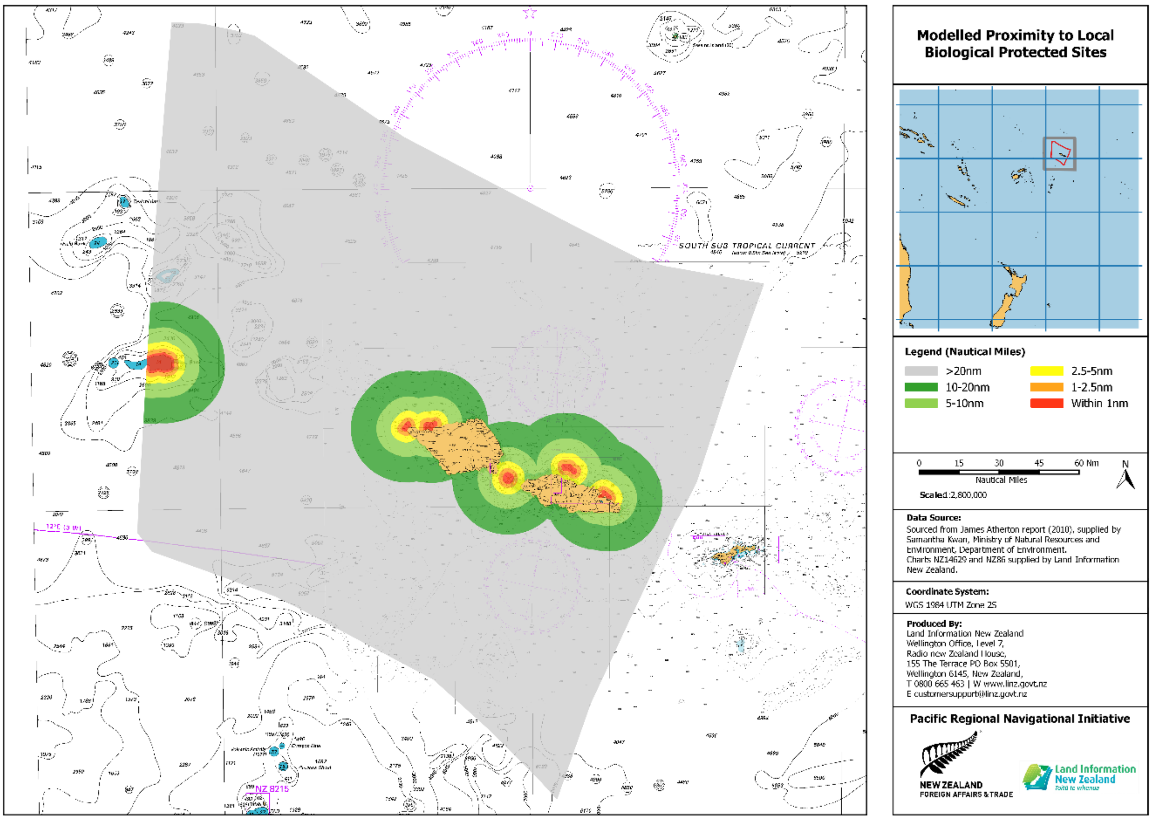
[28] (Atherton, 2010)

[29] (United Nations Environment Program (UNEP), 2015)

ANNEX D – Likelihood and Consequence Factors

3.1.6 Proximity to Local Biological Protected Site



Annex D Figure 17: 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 provided by MNRE[30] and SPREP.[31] Pasco Bank was additionally included due to its potential as a fish breeding area and to ensure that the consequence value would be non-zero.

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 village taboo.

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

[30] (Atherton, 2010)
[31] (United Nations Environment Program (UNEP), 2015)

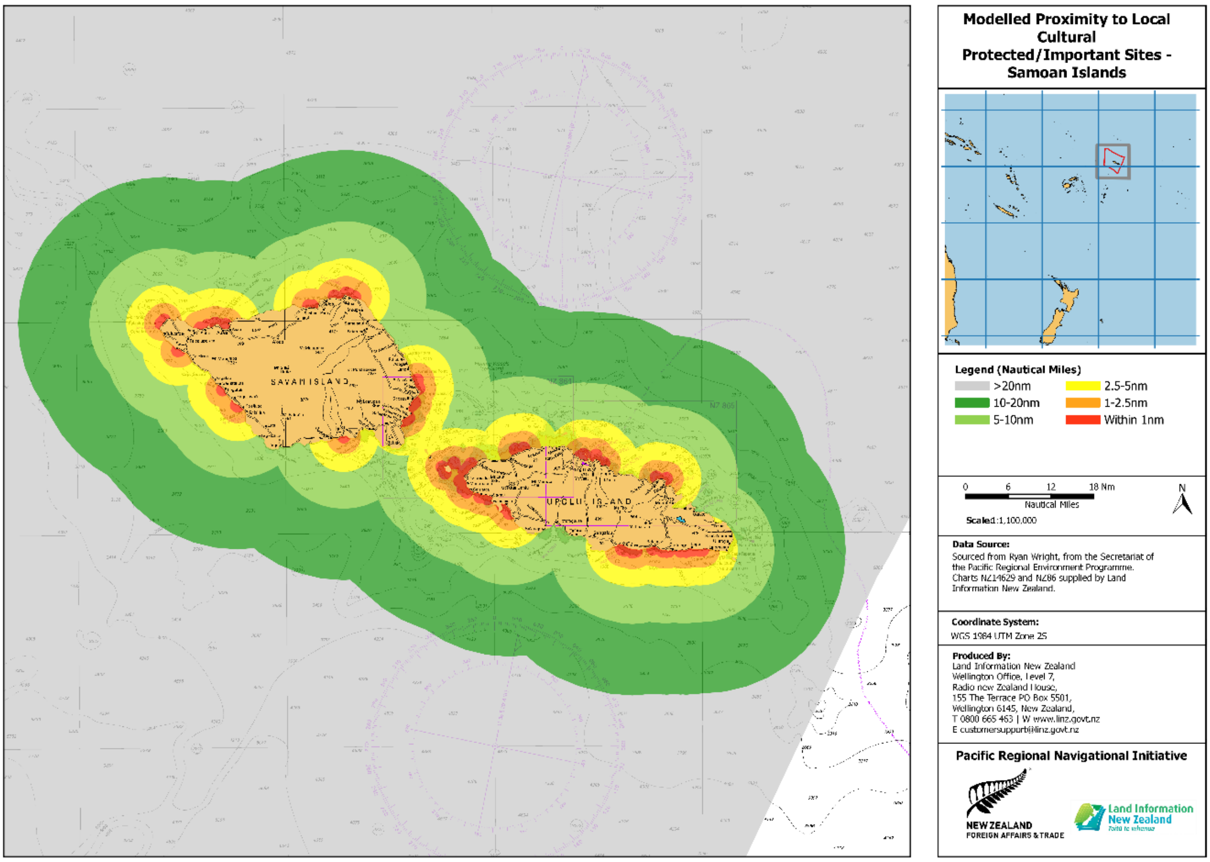
ANNEX D – Likelihood and Consequence Factors

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.[32]

3.2.1 Proximity to World/Regionally Cultural Protected/Important Sites

The study found that there were no formally recognised world 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.

3.2.2 Proximity to Local Cultural Protected/Important Sites



Annex D Figure 18: Modelled Proximity to Local Cultural Protected Site

Figure 18 represents relative hydrographic risk due to the proximity to local cultural protected sites. This figure identifies the cultural sites linked to local villages and was compiled from data provided by SPREP.[33]

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

[33] (United Nations Environment Program (UNEP), 2015) and interview with Ryan Wright.

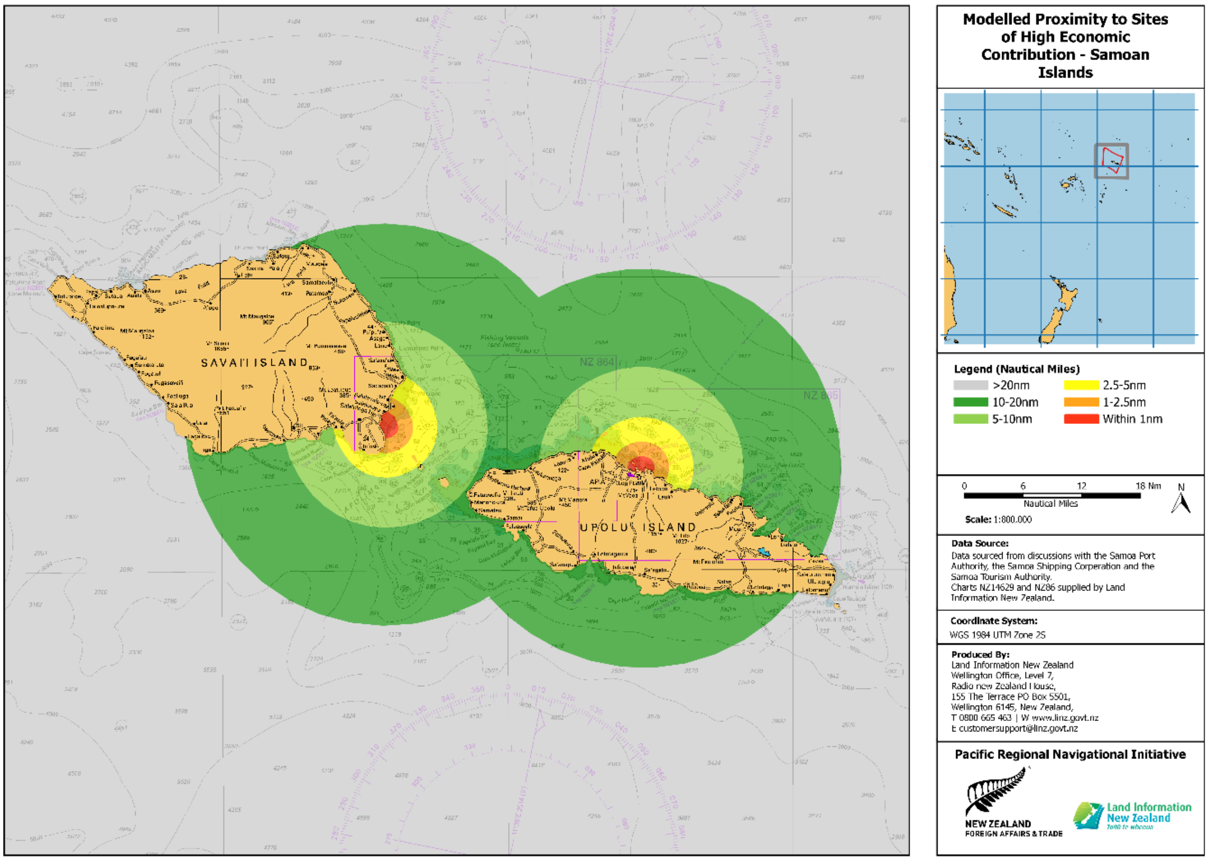
ANNEX D – Likelihood and Consequence Factors

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.[34]

3.3.1 Proximity to Site of High Economic Contribution

The study found that Samoa's international trade was completely dependent on the operation of the port of Apia and rated Apia as a site of high economic contribution. Similarly, the port of Salelologa is the only commercial port on the island of Savai'i and the island's economic survival is completely dependent on the port for imports (including all fuel) and exports. The majority of tourist also transit through here, thus this port is identified as a site of high economic contribution.

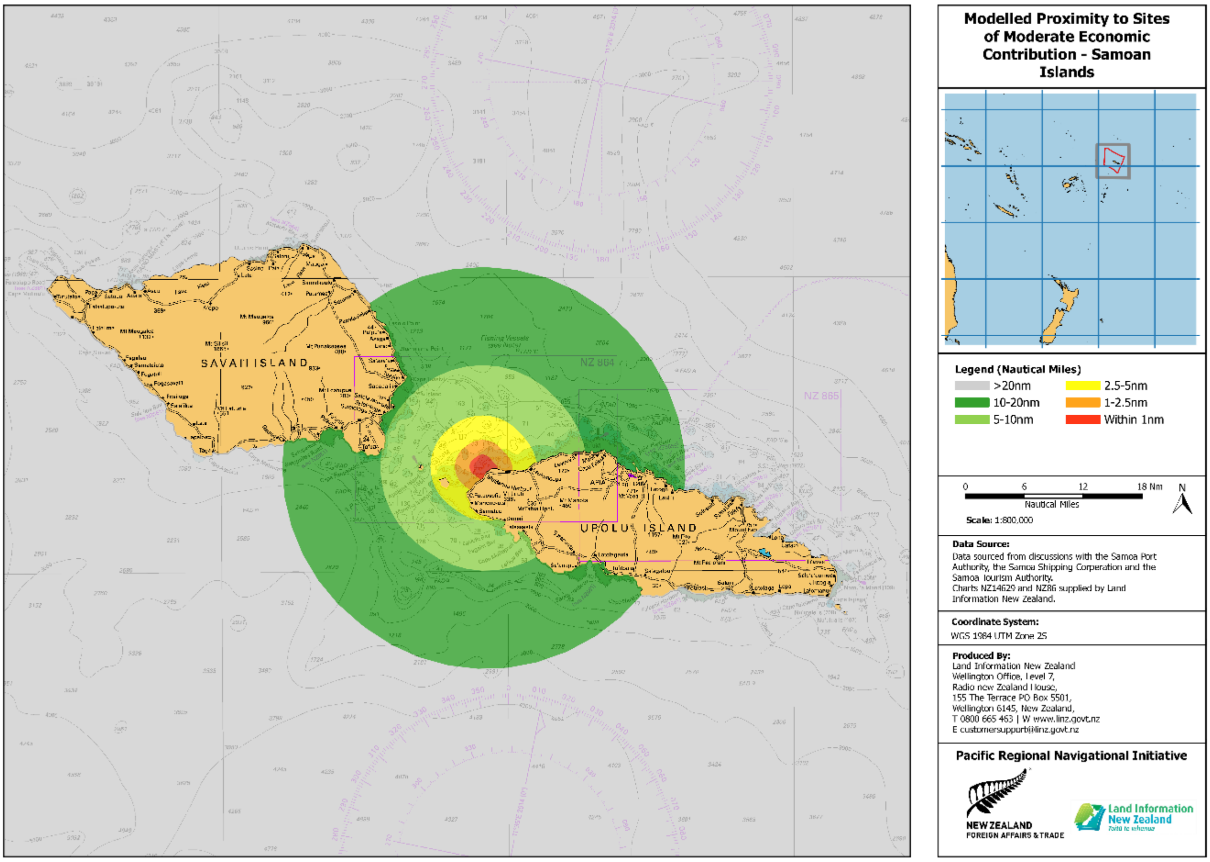


Annex D Figure 19: Proximity to Site of High Economic Contribution

[34] For consistency, this explanation was taken from (Marico Marine Report No. 12NZ246-1, Issue 1, January 2013, D70).

ANNEX D – Likelihood and Consequence Factors

3.3.2 Proximity to Site of Moderate Economic Contribution

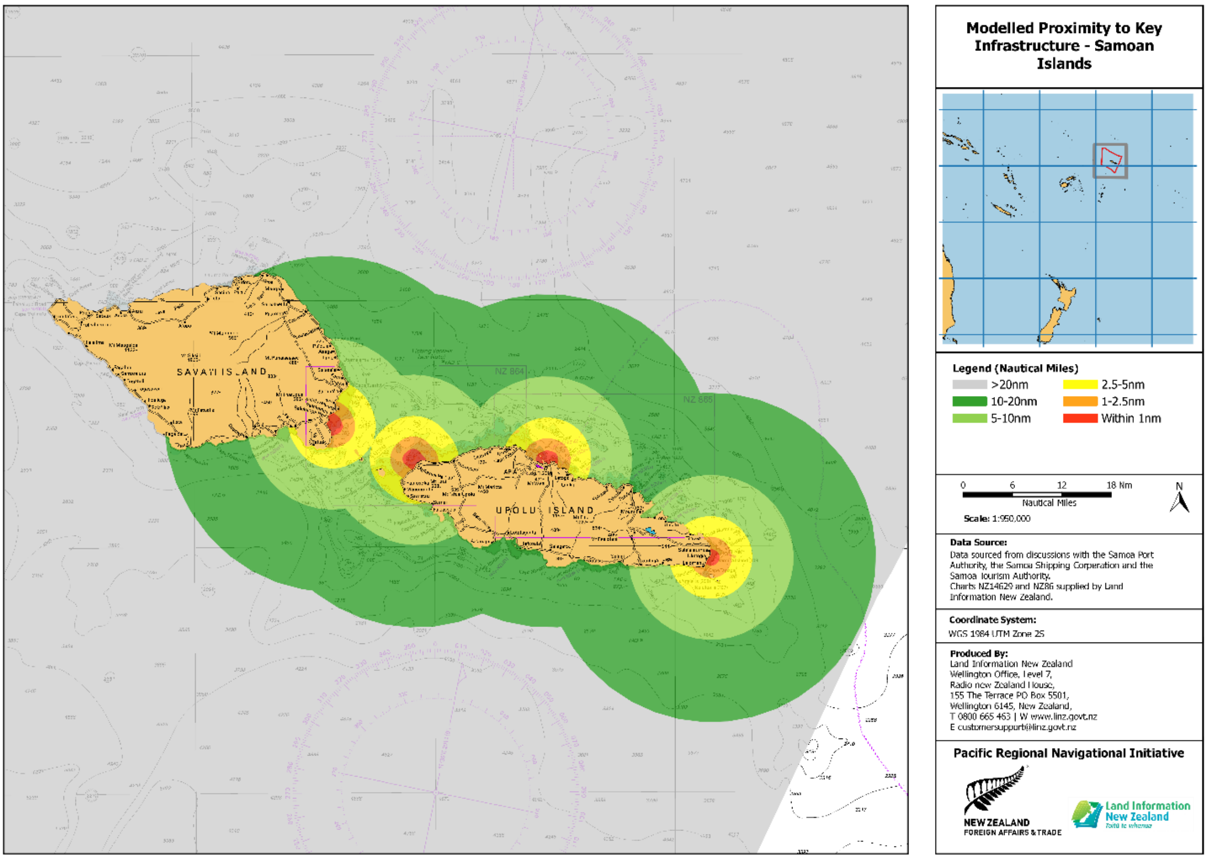


Annex D Figure 20: Modelled Proximity to Site of Moderate Economic Contribution

Figure 20 shows relative hydrographic risk due to the proximity to sites of moderate economic contribution. The port of Mulifanua provides the main connection to the island of Savai'i for inter-island trade and movement of passengers. Apia provides an alternative port and some fuel supplies and other cargo are routed from there directly to Salelologa, thus Mulifanua is classified as a site of moderate economic contribution.

ANNEX D – Likelihood and Consequence Factors

3.3.3 Proximity to Key Infrastructure

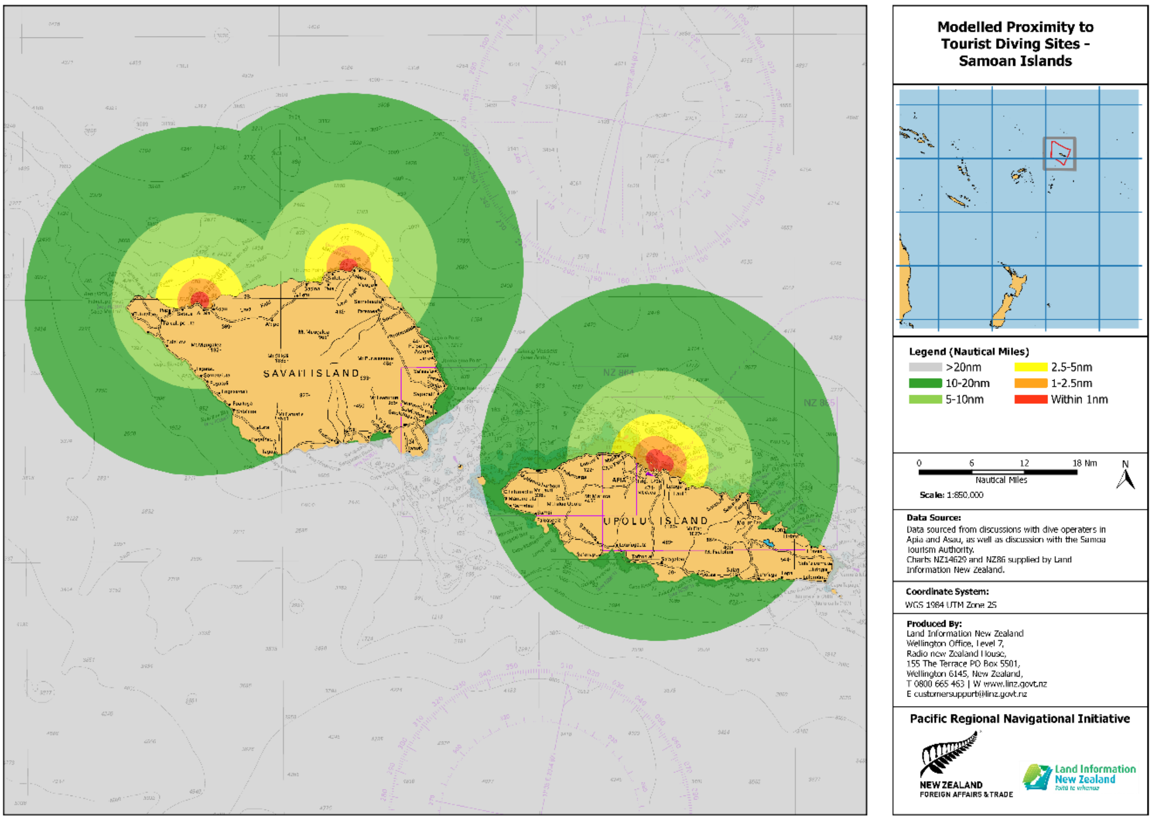


Annex D Figure 21: Modelled Proximity to Key Infrastructure

Figure 21 represents relative hydrographic risk due to the proximity to key infrastructure across the study area. This figure was created based on information gathered during the in-country visit. The port of Apia provides all the infrastructure enabling international maritime trade, the ports of Mulifanua and Salelologa provide the as the key infrastructure for domestic inter-island trade and the port of Aliepata (Satitoa) provides the only slipway in Samoa.

ANNEX D – Likelihood and Consequence Factors

3.3.4 Proximity to Tourist Diving Site



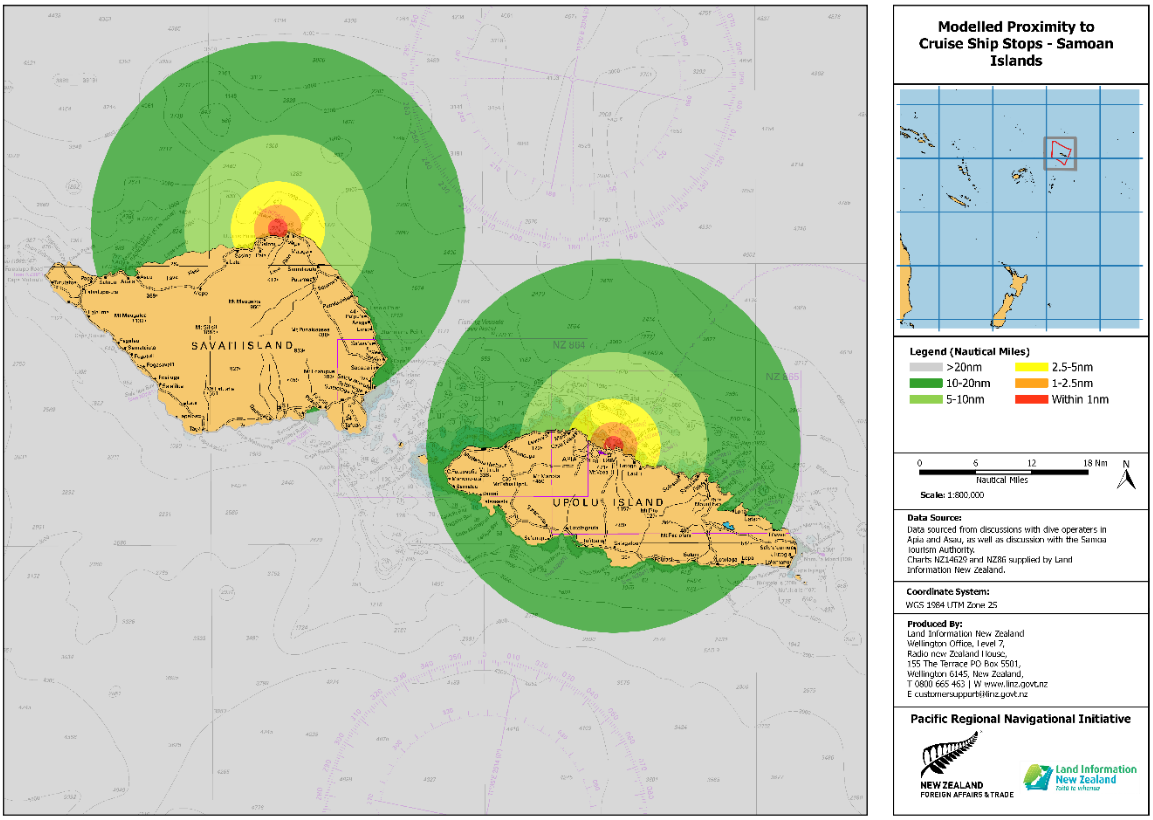
Annex D Figure 22: Modelled Proximity to Tourist Diving Site

Figure 22 shows relative hydrographic risk due to the proximity to tourist diving sites across the study area. This figure was created based on interviews with the operators of "AquaSamoa" and "Dive Savai'i" and corroborated by Samoa Tourism Authority.[35]

[35] Interview with Sonja Hunter, CEO.

ANNEX D – Likelihood and Consequence Factors

3.3.5 Proximity to Cruise Ship Stop



Annex D Figure 23: Modelled Proximity to Cruise Ship Stop

Figure 23 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 confirmed by interviews with Captain Lotomau Tomane,[36] Sonja Hunter[37] and Feagaima'alii Nanai M. Sua[38]

[36] Samoa Port Authority
[37] Samoa Tourist Authority
[38] Ministry of Revenue - Customs

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[39] used in previous regional South West Pacific risk analyses, and

   b. a slightly modified "in-country" weighting factor adopted for this Samoa 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, Tonga and Niue, the specific circumstances of Samoa are such that some of the likelihood and consequence criteria do not exist in Samoa. Thus, an adjustment was made to provide the best risk discrimination between local.

3. An amended "in-country" Samoa 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: 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 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 included in Section 7 of the main report (Risk Results).

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

ANNEX E – Hydrographic Risk Factor Weighting Matrices

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

		Risk Scores						Weightings of Regional Risk Assessment			Weightings of Samoa In-country 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 Weighed)		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	0.3	0.1500	3	0.3	0.1500
	Spring Mean Current Speed	Open Sea (Current insignificant)	1-2 knots	2-3 knots	3-4 knots	>5 knots	>5 knots	2		0.1000	2		0.1000
	Visibility	Unknown	Poor Visibility Very Unlikely	Poor Visibility Unlikely	Occasional Poor Visibility	Often Poor Visibility	Poor Visibility Common	1		0.0500	1		0.0500
	Navigational Complexity												
	Type of Navigation Required		Open Sea >10nm	Offshore Navigation (5-10nm)	Coastal Navigation (1-5nm)	Port Approaches	Constrained Navigation (Within 1nm)	3	0.15	0.1500	3	0.15	0.1500
	Aids to Navigation												
	ChartZoc		A	B	C	D	U	3	0.3	0.1800	3	0.3	0.1800
	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		0.1200	2		0.1200
	Bathymetry												
	Depth of Water 15m Contour	>10nm	5-10nm	2.5-5nm	1.5 to 2.5nm	1 to 1.5nm	Within 1nm	3	0.1	0.0600	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	0.15	0.0333	2	0.15	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		0.0167	0		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	0.5	0.0789	3	0.5	0.0938
	Proximity to Key Offshore Reef (Cooks Reef or Rowe Island)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0526	2		0.0625
	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	3		0.0938
	Proximity Small Wetlands Resource (Mangroves) (Large Volume or Small Volume)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0526	2		0.0625
	Proximity to Important Breeding Grounds	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.0789	3		0.0938
	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		0.0625
	Proximity to Local Biological Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1		0.0263	1		0.0313
	Culturally Sensitive Areas												
	Proximity to World Cultural Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3	0.15	0.0750	0	0.15	0.0000
	Proximity to Regional Cultural Protected/Important Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0500	0		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	0.35	0.1000	3	0.35	0.1000
	Proximity to Sites of Moderate Economic Contribution	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1		0.0333	1		0.0333
	Proximity to Key Infrastructure (Ports)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	3		0.1000	3		0.1000
	Proximity to Tourist Diving Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	1.5		0.0500	1.5		0.0500
	Cruise Ship Stops	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	Within 1nm	2		0.0667	2		0.0667

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.”[40] 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.[41] 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 (Samoa EEZ) is covered by a grid comprising cells 1.0 km by 1.0 km. This grid is the common framework that combines all the inputs and is used to map the computed risk scores. Previous risk South West Pacific risk

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

ANNEX F – Hydrographic Risk Calculations

assessments have used a 2.5 km grid but better processing power has enabled higher resolution to be used in this instance.

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 at Annex E.

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.

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 Samoa study

ANNEX F – Hydrographic Risk Calculations

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.

4.2 To normalise the results and thus allow a level of comparison with the heat map results of other South West Pacific hydrographic risk assessments, a further "regional" 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 and Niue assessments. These values used are shown below.

Regional Risk Colour Map Break Values	
0.00000 – 0.01007	insignificant
0.01007 – 0.03891	low
0.03891 – 0.08772	moderate
0.08772 – 0.17805	heightened
0.17805 – 0.38684	significant

4.3 Due to the Samoa risk assessment utilising a full 12 months of AIS and domestic traffic data whereas the previous assessments have only used 9 months of traffic data, the final cell risk values were multiplied by 0.75 before applying the colour mapping (this is feasible because risk is directly proportional to GT).

4.4 The other difference in this assessment is the cell size. The 1 km square cells used in this assessment are 6.25 times smaller in area than previous 2.5 km square cells. However, as vessels can be assumed to generally travel in straight lines over small distances in open waters (this is not true for pilotage waters), it is the difference in the length of cell sides and diagonals that determine the difference in traffic intersecting the cells. This value is 2.5 times. This would indicate that the total cell traffic risk calculated for Samoa needs to be multiplied by 2.5 times to normalise it with previous assessments.

4.5 A complicating factor is that when traffic is constrained by a narrow channel or by choosing the most efficient (shortest or safest) route, the same amount of traffic may pass through a 1 km cell as would have passed through a 2.5 km cell. This is certainly the case for the narrow entrance channels at Apia, Mulifanua and Salelologa and also in the narrow part of Apolima Strait near Apolima Island. Thus, to avoid overstating the risk in confined areas and accepting that comparative risk may be understated in open ocean areas, **the Samoa risk values have not been adjusted to compensate for the small grid squares.**

4.3 This "regional" heat map shows that Samoa has significantly higher risk around its coastal areas, particularly Apolima Strait and the approaches to Apia, than the "regional" result for Niue, but similar risk levels to those in the higher traffic areas of the Tonga and Cook Islands assessments. These results are consistent with the high level of traffic in these areas, the proximity to navigational dangers and sensitive coastal reef areas, but taking into account the high CATZOC values that result from good quality of hydrographic survey and charting. The quality of charting in these areas is the principal factor that results in the "regional" risk result in these areas being generally lower than in Tonga and Cook Islands.

ANNEX F – Hydrographic Risk Calculations

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ANNEX G – Benefits of Hydrographic Surveys to SAMOA

Benefits of Hydrographic Surveys[42]

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. Good quality hydrographic information is an enabler for all other maritime activities and therefore a pre-requisite for maritime infrastructure development to boost the economy. 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 marine transport 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[43]. 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 the Samoan economy it supports international trade, enables the safe access to the growing cruise tourism market, and for good governance it provides the underpinning data and framework for the effective environmental management of marine resources.

4. Commercial shipping relies on current hydrographic survey data. A hydrographic survey undertaken to the latest International Hydrographic Organization (IHO) standards[44] 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.

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[42] This Annex is a modified development of previous published work and (Land Information New Zealand and Rod Nairn & Associates Pty Ltd, 2016) and (Marico Marine Report No 14NZ262CS Issue 02, January 2015, pp. A1-A3).

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

[44] IHO S-44 Standards for Hydrographic Survey

ANNEX G – Benefits of Hydrographic Surveys to SAMOA

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

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. The absence of good quality hydrographic information (accurate, up to date navigation charts) has 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.

6. Further, the International Convention for the Safety of Life at Sea[45] requires signatory states to facilitate the production of ENCs for ships navigating their coastal waters, including ports. Should an IMO 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. It is therefore beneficial for Samoa to ensure that they establish an effective two-way information flow with the primary charting authority for Samoan waters, Land Information New Zealand.

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.

8. Samoa has recently completed a comprehensive LiDAR mapping project[46] which provides topographic land heights and general bathymetric coverage offshore to depths in the vicinity of 50m. While this information has not been collected to the highest IHO standards, the depth information can be used to make significant improvements to the current quality of Samoa's coastal nautical charting and help to identify specific areas that require further hydrographic survey examination.

[45] SOLAS Chapter 5, Regulation 9

[46] World Bank funded project "Enhancing the Climate Resilience of Coastal Resources and Communities Project for Samoa" (World Bank, 2014)

ANNEX H – List of Consultations

Samoa

	Organisation	Contributor	Position
1.	NZ High Commission	Measina Meredith	Development Programme Coordinator
		Situfu Salesa	Senior Development Programme Coordinator
3.	Ministry of Works, Transport and Infrastructure	Fepulea'i Faleniu Mark Alesana	ACEO Maritime Division
		Etuale Tolo	Senior Maritime Safety Inspector
		Makerita Atonio	Registrar of Vessels
4.	Ministry of Agriculture and Fisheries	Ueta Faasili	Acting ACEO
		Magele Ropeti	Operations Officer
5.	Ministry of Natural Resources and Environment	Safuta Toelau Iulio	ACEO Technical Division
		Petania Tuala	Principal Surveyor, Spatial Information Agency
		Samantha Kwan	Dept. of Environment & Conservation
		James Atherton	Consultant (by phone/email)
6.	Samoa Meteorology Division	Tumau Faasaoina	Acting ACEO, Principal Scientific Officer
7.	Ministry of Revenue – Customs	Feagaima'alii Nanai M. Sua	ACEO Border Operations
8.	Samoa Ports Authority	Capt. Lotomau Tomane	Port Master/ACEO Maritime
	Samoa Ports Authority	Capt. Tafaigata Toilolo	Port Operations Manager
9.	Samoa Shipping Corporation	Capt. Sam Phineas	Operations Manager
10.	Ministry of Police	Manusamoa Christine Saaga	Assistant Police Commissioner
11.	Maritime Police Unit	Sefo Hunt	Team Leader
12.	Maritime Police Unit Samoa Tourism Authority	Anthony Cooper	Australian Technical Advisor to Samoa Maritime Unit
13.	Samoa Tourism Authority	Sonja Hunter	CEO
		Kristian Scanlan	Events Coordinator
14.	Secretariat of the Pacific Region Environment Program (SPREP)	Ryan Wright	Spatial Planning Officer
15.	AquaSamoa	Ted Thompson	Owner
16.	Asau SPA Facility	Nese Tufuga	Caretaker
17.	Dive Savai'i	Olaf & Tina	Owners

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