

## Linking hydrodynamic research to the maritime industry

### Based on marine traffic streams in the Dutch Caribbean

## Final Report

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## **QUALITATIVE NAUTICAL RISK ASSESSMENT FOR THE DUTCH CARIBBEAN**

**Based on marine traffic streams in the Dutch Caribbean**

### **Final Report**

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## MANAGEMENT SAMENVATTING

### Inleiding

Sinds 10 oktober 2012 is Nederland uitgebreid met drie gebieden: Bonaire, St. Eustatius en Saba. Door deze bestuurlijke aanpassingen is het ministerie van Infrastructuur en Milieu verantwoordelijk voor de Exclusieve Economische zone rond de eilanden.

In dit kader is Dienst Noordzee van Rijkswaterstaat een advies aan het voorbereiden voor de implementatie van het "International Convention on Oil Pollution Preparedness, Response and Co-operation". Als onderdeel van dit advies heeft MARIN in opdracht van RWS een nautische risico analyse uitgevoerd.

De studie bestond uit twee delen, ten eerste de inventarisatie van het verkeer rond de eilanden Bonaire, Saba en St. Eustatius. Het tweede deel is de werkelijke analyse van het risico in het gebied. Het initiële idee was om op basis van de verkregen verkeersdatabase een kwantitatieve risico analyse uit te voeren met behulp van het SAMSON-model. Echter op basis van de beschikbare informatie, met name over de exacte routes die schepen gevaren hebben, kon geen betrouwbaar verkeersbeeld rond de eilanden gemaakt worden. In overleg met RWS is besloten een kwalitatieve risico analyse uit te voeren in plaats van een kwantitatieve. In de analyse is voornamelijk gekeken naar het risico voor mensen (met name cruise schepen) en het risico op olie uitstroom.

### Doelstelling

De doelstelling van de studie is tweeledig:

1. Het aanmaken van twee verkeersdatabases voor het maritieme verkeer in het Nederlandse deel van de Caribische Zee:
  - a. Een verkeersdatabase voor de territoriale wateren rond Bonaire
  - b. Een verkeersdatabase voor de territoriale wateren rond Saba and St. Eustatius
2. Het uitvoeren van een nautische risico analyse gebaseerd op de verkregen verkeerssituatie, waarbij de zogenaamde "hot-spots" wat betreft het risico voor personen aan boord en olie uitstroom aangegeven worden.

De territoriale wateren omvatten de 12 mijlszone rond de eilanden.

### Belangrijke verkeersstromen in het Nederlandse Caribische gebied

Gezien de geografische ligging van de eilanden is er voor twee gebieden is een maritieme verkeersdatabase is aangemaakt:

- De territoriale zee (12 mijlszone) rond Bonaire
- De territoriale zee (12 mijlszone) rond Saba and St. Eustatius

Voor het creëren van de databases is gebruik gemaakt van algemeen beschikbare gegevens over scheepvaart activiteiten in het Caribische gebied en "live AIS". Als basisjaar voor de meeste statistische gegevens is 2010 gebruikt.

Oorspronkelijk was het studiegebied beperkt tot alleen de territoriale wateren en niet de complete EEZ van de eilanden. Dit was voorgesteld omdat aangenomen was dat in de territoriale wateren voornamelijk de schepen die de eilanden zelf bezoeken, zouden varen. De studie naar de verkeerstromen heeft echter aangetoond dat ook veel passerende schepen dit gebied doorkruisen, met name bij Bonaire. Gegeven de beschikbare informatie is het erg lastig gebleken een goede schatting te geven over de gevaren routes, de intensiteit en de types van de schepen op de routes. Echter deze

verkeersstromen zijn wel van belang bij het uitvoeren van een goede, betrouwbare kwantitatieve risico analyse naar de uitstroom van olie. Een aanbeveling is dan ook deze verkeersstromen in de toekomst beter te bestuderen, bijvoorkeur met behulp van AIS-gegevens. Als deze data beschikbaar is kan de studie ook uitgebreid worden naar de hele EEZ.

Door het gebrek aan voldoende gedetailleerde data en de vele aannames die gedaan zijn, dienen de resultaten van de studie naar de verkeersstromen niet te worden geïnterpreteerd als accuraat en compleet. De resultaten leveren een goede eerste stap in het beschrijven van de verkeersbeelden rond de eilanden.

Hieronder worden de belangrijkste resultaten betreffende het verkeer voor de beide gebieden samengevat.

- **Verkeersstromen rond Bonaire**

Op Bonaire is een olieterminal gevestigd (BOPEC) die regelmatig bezocht wordt grotere olietankers; in 2010 bezochten 229 tanker de terminal. Deze schepen driften eerst gedurende geruime tijd in een gebied tussen Curaçao en Bonaire voordat ze aanmeren. De verkeersdatabase (betreffende het olie transport) bestaat daarom uit twee belangrijke delen:

- een deel driftende tankers
- een deel varende tankers, vertrekkend vanaf de terminal richting de volgende bestemming.

De cruise-industrie is de andere belangrijke intensieve scheepvaartactiviteit rond Bonaire. In 2010 deden 143 cruise schepen Bonaire aan. De overige scheepvaart activiteit bestaat uit lokale bevoorradingschepen, de CARGILL zoutterminal en brandstofaanvoer naar het vliegveld van Bonaire.

De territoriale wateren van Bonaire worden niet alleen bezocht door schepen van en naar Bonaire, maar ook door passerende schepen. Met name de schepen varende tussen het Panamakanaal en de bestemmingen oostelijk van Bonaire. Gebaseerd op de gegevens van het Panamakanaal wordt geschat dat er vier keer per dag een schip op relatief kort afstand passeert, zodanig dat 50% van deze schepen daadwerkelijk de territoriale wateren kruist. Deze passerende schepen zijn meegenomen in de verkeersdatabase

Daarnaast wordt de 12 mijlszone ook regelmatig doorkruis door schepen op de route van en naar Curaçao en Venezuela. Echter door het ontbreken van gegevens over deze schepen is deze verkeersstroom (nog) niet mee genomen in de verkeersdatabase. Door gebruik te maken van AIS-gegevens over een langere periode kan meer informatie over deze schepen verzameld worden en kunnen ze in de toekomst wel toegevoegd worden.



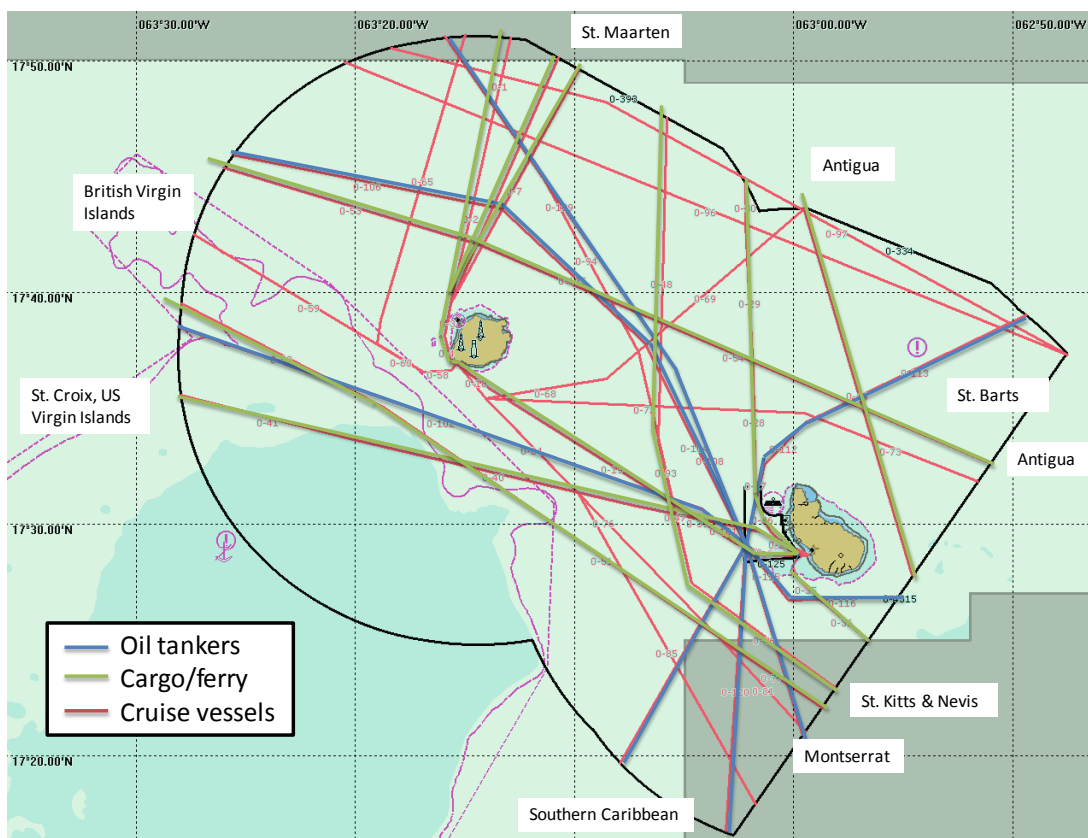
**Figuur 1** Overzicht van alle verkeersstromen rond Bonaire

- **Verkeersstromen rond Saba and St. Eustatius**

De belangrijkste scheepvaartactiviteiten rond Saba en St. Eustatius bestaan uit het vervoer van olie naar de NUSTAR terminal en de bunkeractiviteiten rond deze terminal. Jaarlijks wordt de terminal door 1100 schepen bezocht. De algemene procedure is dat schepen voor anker gaan op aangewezen locaties voor de terminal. Vervolgens komen kleinere bunkerschepen langs de geankerde schepen liggen om te bunkeren. Tenslotte vervolgen de schepen hun reis op zee. De olietankers die de bunkerolie aanvoeren moeten soms enkele dagen wachten alvorens ze kunnen afmeren bij de steiger of de "Single Point Mooring".

De overige scheepvaartactiviteiten rond de eilanden Saba en St. Eustatius bestaan voornamelijk uit kleinere bevoorradingsschepen, RoRo-schepen en er zijn twee ferry services tussen Saba en St. Maarten. Daarnaast wordt Saba bezocht door enkele cruise lines.

Ook de territoriale wateren rond Saba en St. Eustatius worden veelvuldig doorkruist door passerende schepen: schepen die niet een van de eilanden aandoen, mede doordat nabijgelegen eilanden een grotere scheepvaartactiviteit vertonen. Cruiseschepen en vrachtschepen vormen hierbij de belangrijkste groep. Een ruwe schatting van het aantal schepen in deze groep is 215 cruiseschepen (waaronder de grootste ter wereld) en ruim 1000 vrachtschepen.



Figuur 2 Overzicht van de verkeersstromen rond Saba en St. Eustatius

### Kwalitatieve risico analyse

Er is een analyse gedaan van de ongevalstatistieken voor het gehele Caribische gebied, over de periode 2008-2010. Gedurende deze periode waren 123 schepen betrokken bij ongevallen in de regio, waarvan er 47 betrokken waren bij ongevallen op open zee. Vier van de schepen waren betrokken bij ongevallen die vervolgens hebben geleid tot vervuiling en twee van de schepen waren betrokken bij ongevallen die hebben geleid tot fataliteiten. Onder deze schepen waren drie tankers en vier passagiersschepen.

Algemeen gezien wordt het risico op olie uitstroom groter geacht voor de regio rond Saba en St. Eustatius dan voor de regio rond Bonaire, vanwege de hogere verkeersintensiteit en het veel grotere aantal tankers.

#### • Bonaire

De belangrijkste risico's met betrekking tot de uitstroom van (lading)olie zijn de volgende:

- Aanvaring met driftende schepen in de "waiting area" ten westen van Bonaire
- Aanvaringen van kleinere tankers op de route tussen Curaçao en Bonaire en ander verkeer op deze route;
- Het aan de grond lopen van grotere tankers op de route richting het noorden en aanvaringen tussen deze tankers en ander verkeer op deze route, en in het bijzonder de driftende tankers die wachten voor de BOPEC terminal.

Uitstroom van bunkerolie kan voorkomen op de route richting het noorden en ook op het punt waar deze route de verkeersroute richting het Panamakanaal ontmoet. Geconstateerd kan worden dat het risico voor de uitstroom van olie het grootst is in de gebieden ten westen, noordwesten en noorden van Bonaire.

De kleinere tankers hebben een totale ladingscapaciteit van 144,000m<sup>3</sup>. De totale lading zal alleen in zee terecht komen als een schip zinkt of breekt na een ongeval. Als gevolg van een ernstig ongeval met een gat in de ladingtank zal veelal maximaal de inhoud van 1 zijtank in zee stromen. Dit betekent voor de kleinere tankers een maximale uitstroom van 12,000m<sup>3</sup>. De maximale capaciteit van een zijtank van de grotere tankers is 16,500 m<sup>3</sup>, dus voor deze tankers is dit het maximaal te verwachte volume van een uitstroom. De totale capaciteit van deze grotere tankers is 372.500 m<sup>3</sup>. Ongeveer 85% van de tankers die een bezoek brengen aan de BOPEC terminal zijn kleinere tankers. Deze aantallen zijn gebaseerd op de gegevens nu beschikbaar en geven slechts een indicatie van de mogelijk hoeveelheid olie aanboord van de tankers.

De belangrijkste risico's met betrekking tot mensenlevens betreffen aanvaringen tussen een cruiseschip en een ander schip op de plek waar de cruiseroutes naar het noorden en de verkeersroute naar het Panamakanaal elkaar ontmoeten en tevens aanvaringen van cruiseschepen op de route Bonaire - Curaçao met andere schepen op deze route.

Er kan worden geconcludeerd dat het risico voor zowel olie uitstroom als mensenlevens zeer laag is voor het gebied ten oosten en ten zuiden van Bonaire, aangezien hier nauwelijks scheepvaartverkeer aanwezig is.

- **Saba en St. Eustatius**

Hoewel het netwerk van scheepvaartverkeersroutes rondom Saba en St. Eustatius complex is, is het toch mogelijk een aantal regio's aan te wijzen waar een verhoogd risico op olie uitstroom is. Een specifiek risico is het aan de grond lopen van tankers op het rif Saba Bank en op Saba zelf. Daarnaast is het risico van aanvaringen van belang in de gehele regio, maar met name ten westen van St. Eustatius, waar een concentratie van tankers aanwezig is. De gebieden ten oosten en noorden van St. Eustatius en het gebied ten westen van Saba hebben een verlaagd risico, omdat de verkeersintensiteit hier laag is.

De grootte van de tankers die een bezoek brengen aan de NUSTAR-terminal variëren tussen kleine tankers met een totale capaciteit van 13,000 m<sup>3</sup> en de grootste tankers met een capaciteit van 375,200 m<sup>3</sup>. De capaciteit van de zijtanks, de maximaal verwachte uitstroom als gevolg van een ernstig ongeval, varieert tussen de 700 m<sup>3</sup> en de 16.600 m<sup>3</sup>. Waarbij gezegd kan worden dat ongeveer 70% van de tankers die de NUSTAR-terminal bezoeken een zijtank capaciteit hebben van minder dan 6,000 m<sup>3</sup> en slechts 1% van de tankers een capaciteit boven de 13,000 m<sup>3</sup>. Deze aantallen zijn gebaseerd op de gegevens nu beschikbaar en geven slechts een indicatie van de mogelijk hoeveelheid olie aanboord van de tankers.

Met betrekking tot het risico voor mensenlevens, zijn de belangrijkste risico's aanvaringen tussen cruiseschepen en andere grote zeeschepen ten zuiden van St. Eustatius en het aan de grond lopen van passerende cruiseschepen bij Saba en Saba Bank.

### **Mogelijke risico reducerend maatregelen**

Om het nautische risico in de gebieden te verlagen bestaan een aantal “standaard” maatregelen waarvan enkele ook al bestaan in het gebied:

- Gebruik van sleepboten;
- Aanwezigheid van reddingscapaciteit;
- Aanwezigheid van oliebestrijdingscapaciteit
- Aanwezigheid van nood sleephulp (Emergency Towing Vessel)
- “Vessel Traffic Service”

Naast de standaard maatregelen enkele locatie specifieke maatregelen worden voorgesteld voor het gebied rond Bonaire. Dit betreft maatregelen voor het “wachtergebied” voor schepen naar de BOPEC terminal. In dit gebied gaan schepen niet voor anker, maar wachten al driftend tot ze naar de terminal kunnen. Het risico in het gebied zou gereduceerd kunnen worden door een ankergebied of afmeer faciliteiten. Echter door de aanwezigheid van koraal en door de relatief grote diepte in het gebied is het niet mogelijk een ankergebied in te stellen. Een alternatief is een “officieel” wachtergebied te introduceren in het gebied, dat ook als zodanig zichtbaar is op de nautische kaarten. Hierdoor wordt de situatie duidelijke voor passerende schepen, hetgeen het risico zal verlagen.

Tenslotte moet het voor de passerende schepen duidelijk zijn dat de wachtende tanker “beperkt manoeuvreerbaar” zijn op het moment dat ze daar driftend aan het wachten zijn. Een schip kan dit duidelijk maken door middel van zijn navigatie status in het AIS-bericht. Deze status moet echter handmatig worden aan gepast, dus niet alle schepen doen dit. Een aanbeveling is dat de betreffende monitorende autoriteit deze status goed in de gaten houdt en zo nodig een schip adviseert de status te wijzigen.

### **Aanbevelingen betreffende risico analyse in de toekomst**

Om met behulp van het SAMSON-model, een kwantitatieve risico analyse uit te voeren moet extra aanvullende informatie verzameld worden. De huidige studie heeft aangetoond dat alleen de informatie van de terminals op de eilanden niet toereikend is om een volledige beschrijving van het verkeer rond de eilanden te creëren. Er is namelijk een groot aantal schepen dat het gebied rond de eilanden alleen passeert. Om in de toekomst wel een kwantitatieve risico analyse uit te voeren is het noodzakelijk AIS-gegevens van het gebied te verzamelen en dan specifiek van het gebied dat beschouwd moet worden in de analyse; de EEZ. AIS-gegevens bevat alle informatie die nodig is om een betrouwbare verkeersdatabase op te bouwen, waarin de (exacte) routes van de schepen, de samenstelling van het verkeer wat betreft type en grootte en het aantal schepen is samengevoegd.

Naast de AIS-gegevens is ook extra meer gedetailleerde informatie over de import en export van olie van zowel de NUSTAR als de BOPEC terminal nodig. Naast de hoeveelheid olie is het ook van belang te weten wat de belangrijkste routes zijn van schepen die de terminals bezoeken. Deze informatie is nodig om een realistische aannames te doen wat betreft de hoeveelheid vervoerde olie in bepaalde gebieden rond de eilanden.

## MANAGEMENT SUMMARY

### Introduction

The Dutch ministry for Infrastructure and Environment is since the statutory change of the Kingdom of The Netherlands responsible for the quantity and quality within the Exclusive Economic Zone (EEZ) of the Dutch Caribbean. The execution of this task lays at Rijkswaterstaat (RWS).

Rijkswaterstaat Noordzee is preparing an advice regarding the implementation of the "International Convention on Oil Pollution Preparedness, Response and Co-operation". As part of this advice a maritime risk assessment has been performed by MARIN.

The study exists of two main parts, first an inventory of all traffic in the area around the islands of Bonaire, Saba and St. Eustatius. And second the actual risk assessment. The initial idea was to use this traffic database within the SAMSON-model and determine the expected number of nautical accidents per year and the expected risk for people and oil spills. However the available information about the traffic, and most important the "actual" route of the ships, was not sufficient to create a reliable traffic image around the islands. Therefore it was decided to perform a qualitative risk assessment instead of a quantitative one. This risk assessment was concentrated on the risk for people (cruise ships) and the risk of oil spills.

### Objective

The objective if this study consists of two parts:

1. To construct two traffic databases for marine traffic in the Dutch Caribbean:
  - a. A traffic database for the territorial waters of Bonaire
  - b. A traffic database for the territorial waters of Saba and St. Eustatius
2. To perform a nautical risk assessment based on the traffic situation and indicate "high risk areas" with respect to outflow of oil and loss of life on board cruise ships

The territorial waters comprise the zone of 12 nautical miles around the islands.

### Main traffic streams in the Dutch Caribbean

Because of the geographical layout a marine traffic database was composed for two separate sea areas:

- The territorial waters (12 nm zone) of Bonaire
- The territorial waters (12 nm zone) of Saba and St. Eustatius

The database was created based on general available information on shipping activities in the Dutch Caribbean and by using live AIS. For the traffic intensity mostly the statistics for 2010 were used.

The area of research was initially limited to the territorial waters and not the entire EEZ because of the limited amount of available information. The assumption was that the territorial waters would only be entered by vessels which actually visit the islands. However, this study showed that this is not the case. Especially near Bonaire, very intense traffic including large vessels can be observed. It is very difficult to estimate the

numbers and composition of ships involved in these traffic streams, but it is clear that they are relevant for a proper estimation of risk on oil spills. Therefore, it is recommended to further study these traffic streams, preferably using AIS data. When this data will be available the study area can also be widened to the whole EEZ-area.

Because of the large amount of assumptions which had to be done, and the lack of detailed data, the results of this study should not be interpreted as a factual and complete representation of the situation. They should rather be seen as a first step in the description of marine traffic in this area.

The main characteristics for each of the two areas will now be summarized:

- **Traffic streams near Bonaire**

Bonaire has an oil terminal (BOPEC) which is frequently visited by tankers: in 2010 229 ships visited the terminal. These ships spend a large amount of time drifting in the area between Curacao and Bonaire.

Therefore the traffic database, concerning oil transport, consists of two parts:

- one part representing the drifting ships and
- one part representing the ships departing from the terminal towards their next destination.

Another intense shipping activity at Bonaire is the cruise industry, accounting for 143 calls in 2010. Other, smaller, shipping activities at Bonaire are local cargo and supplies, the CARGILL salt terminal and fuel trans-shipment for the airport.

It was also found that the territorial waters are not only accessed by ships that visit Bonaire, but also by passing traffic. Especially traffic to and from the Panama Canal and surrounding region account for many passing ships. It was estimated that about four times a day such a ship passes at a close distance to the island and that maximum 50% of these ships actually access the territorial waters. This element was taken into account in the traffic database. However, it was also found that ships on route to/from Curacao and Venezuela access the 12 nm zone frequently. However, because of a lack of data about these vessels, it was found not appropriate to include these ships in the traffic database. AIS data over a longer period of time could provide further knowledge on those ships.



**Figure 1 Overview of the traffic routes around Bonaire**

- **Traffic streams near Saba and St. Eustatius**

The main shipping activity around Saba and St. Eustatius is oil trans-shipment and bunkering at the NUSTAR terminal at St. Eustatius. Annually about 1100 vessels call at this terminal. The general procedure is to anchor in the dedicated anchorage area in front of the terminal. Bunker barges moor alongside the anchored ships which require bunkers. These vessels then proceed to sea.

The vessels which come for oil trans-shipment wait for several days and then moor at the jetty or single point mooring for loading/ discharging.

Other shipping activities on these islands are small scale: supplies are provided by small Ro-Ro vessels, there are two ferry services connecting Saba to St. Maarten and some cruise lines visit Saba.

However, with many nearby islands - some of which have much more active shipping activities – also these territorial waters are frequently accessed by other shipping traffic. The main groups are cruise ships and cargo ships connecting the surrounding islands. An estimation of the routes and numbers of ships was made, although very roughly. It was estimated that 215 cruise ships (amongst which the largest in the world) and well over 1000 cargo ships access the area.

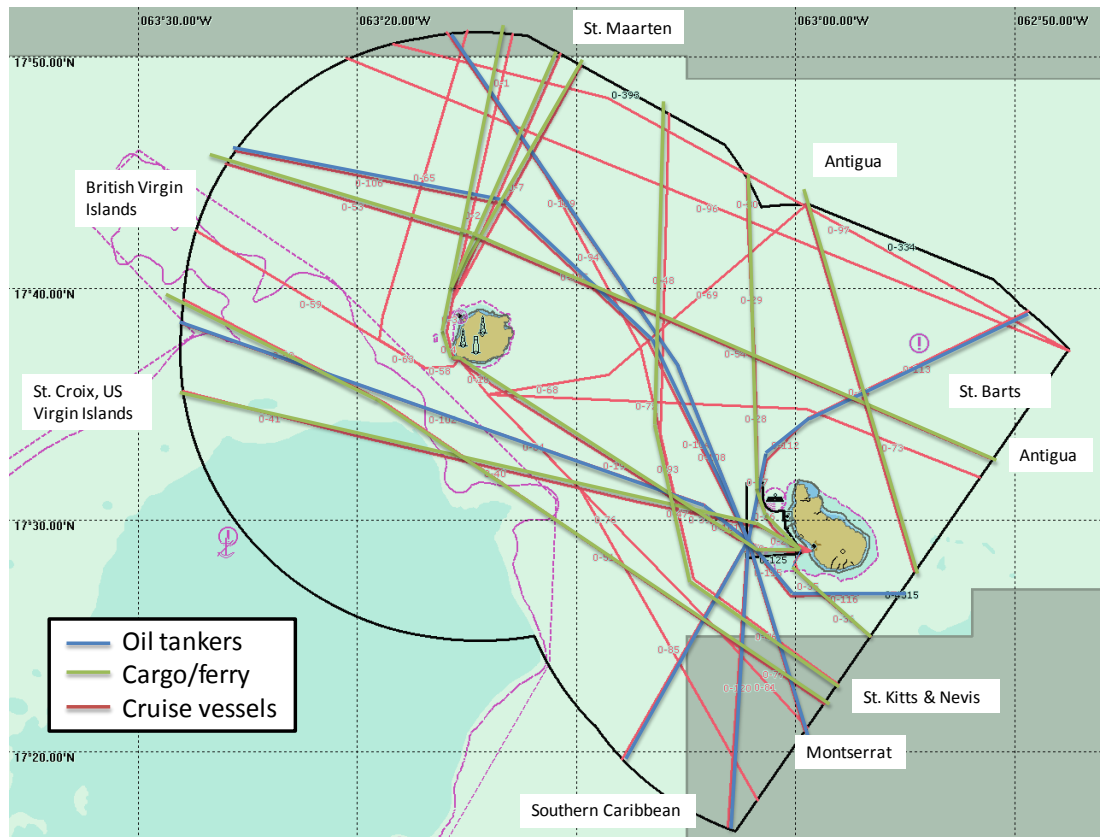


Figure 2 Overview of the traffic routes around Saba and St. Eustatius

### Qualitative Risk Assessment

An analysis was done of accident statistics for the entire Caribbean region for the period 2008-2010. In this period 123 vessels were involved in accidents in this region, of which 47 at open sea. Four vessels were involved in accidents at open sea resulting in pollution and two vessels were involved in accidents resulting in a loss of life. Three tankers and four passenger vessels were involved in accidents.

In general, the risk of outflow of oil is regarded to be higher in the area around Saba and St. Eustatius than for the region around Bonaire because of the higher traffic intensity and much higher number of tankers.

- **Bonaire**

The main risks in the area around Bonaire with respect to outflow of cargo oil are:

- collision with drifting vessel in the “waiting” area west of Bonaire;
- collisions of smaller tankers on the route between Curacao and Bonaire and other traffic on this route;
- groundings and collisions of larger tankers on the route to the north with other traffic on this route and in particular collisions with tankers which are adrift while waiting for BOPEC terminal.

Outflow of bunker oil could occur on the route to the north and also at the position where ship traffic from Bonaire to the north meets the traffic route to the Panama Canal. Therefore, it can be safely stated that the area inducing the highest risk for the outflow of oil in this region is the area west, north-west and north of Bonaire.

The smaller tankers have a total capacity of 144,000 m<sup>3</sup>. This total amount of oil will only be spilled when the ship sinks or breaks after an accident. After a serious collision with a rupture or hole in the cargo tank the maximum expected outflow of oil will be the capacity of one wing tank, so about 12,000 m<sup>3</sup>.

The maximal expected outflow of oil after an accident with a large oil tanker which lead to a hole in the cargo tank will be 16,500 m<sup>3</sup> (maximum size of a wing tank). The total capacity of these larger oil tankers is about 372,500 m<sup>3</sup>. Almost 85% of all tanker calling at the BOPEC-terminal are smaller tankers. These numbers are based on the information available now and are just an indication of the possible amount of oil on board in the tanks.

The main risks with respect to loss of life are collisions between a cruise ship and another ship at the location where the cruise routes to the north and the traffic route to the Panama Canal meet as well as collisions of cruise ships on the route Bonaire-Curacao and other cruise ships or tankers on the same route.

It can be concluded that for the area east and south of the island has a very low risk both for pollution and loss of life, as almost no traffic is present in this region.

- **Saba and St. Eustatius**

Although the network of shipping routes around Saba and St. Eustatius is quite complex, some areas with increased risk level for oil spills can be indicated. A particular risk is grounding of tankers at Saba Bank (and Saba). And the collision risk in the majority of the region but especially west of St. Eustatius, where a concentration of oil carrying ships can be found. A reduced risk level can be found in the regions east and north of St. Eustatius and west of Saba, as the traffic intensity here is low.

The sizes of the tankers visiting the NUSTAR-terminal vary between small tankers with a total capacity of 13,000 m<sup>3</sup> and large tanker with a total capacity of 375,200m<sup>3</sup>. The wing tank capacity of these tankers on the area varies between 700 m<sup>3</sup> and 16,600 m<sup>3</sup>. Where almost 70% of all trans-shipments vessels at the NUSTAR-terminal have a wing tank capacity below 6,000m<sup>3</sup> and only 1% above 13,000 m<sup>3</sup>. These numbers are based on the information available now and are just an indication of the possible amount of oil on board in the tanks.

With regard to loss of life the main risks are collisions between cruise ships and other large seagoing ships south of St. Eustatius and grounding of cruise ships passing between the two islands at Saba or Saba Bank.

### **Possible risk reducing measures**

To reduce the risk in the areas some standard measures are available, of which some of them are already in place:

- Use of pilots and tugboats;
- Presence of Search and Rescue equipment;
- Presence of Oil Pollution Combat equipment;
- Presence of an Emergency Towing Vessel;
- "Vessel Traffic service" or other monitoring authority.

Also some additional measures are suggested for the specific area around Bonaire, concerning the “waiting” area for ships sailing to the BOPEC terminal. In this area the ships do not anchor, but drift. Ideally, a risk reducing measure is to reduce the number of drifting ships is as low as possible. Therefore, if there is any possibility to create an anchorage or mooring facility for waiting ships, this would eliminate the risk. But since the geographical layout of the area (presence of coral and the water dept) will not allow an anchorage area another possibility is to create a designated waiting area, which is indicated on the nautical charts. This would make the situation more clear for the passing vessels.

Finally, it needs to be clear to all vessels crossing the waiting area, that the waiting tankers are present and have a restricted manoeuvrability. Vessels can indicate their so-called “navigational status” in AIS. By indicating that they are “not under command”, other vessels can adjust their behaviour towards this vessel. The disadvantage of this option is that this status needs to be altered manually. From the monitoring authority it is advisable to monitor whether a ship is drifting and whether the ship has altered her status.

### **Recommendations concerning risk assessment in the future**

To perform a quantitative risk assessment, using the SAMSON-model, additional data has to be collected. The present study showed that it is not sufficient to only have information from the terminals on the islands, since there are also a (large) number of ships just passing the area around the islands. Therefore it is necessary to collect AIS-data of the areas near the islands. Especially of the areas for which the risk assessment needs to be performed, the EEZ. This AIS data contains all necessary information to determine a reliable traffic database containing the locations of the routes, the type and size of the ships and the number of ships.

Another type of data which is required to make a good estimation of the outflow of oil is detailed information on the import and export of oil at both BOPEC and NUSTAR terminal as well as the main trade routes used by the ships visiting these terminals. this information will provide realistic assumptions on the amount of oil transported by ships over the different routes.

## **1 INTRODUCTION**

### **1.1 Risk assessment of marine traffic in the Dutch Caribbean**

The Dutch ministry for Infrastructure and Environment is since the statutory change of the Kingdom of The Netherlands responsible for the quantity and quality within the Exclusive Economic Zone (EEZ) of the Dutch Caribbean. The execution of this task lays at Rijkswaterstaat (RWS).

Rijkswaterstaat Noordzee is now preparing an advice regarding the implementation of the “International Convention on Oil Pollution Preparedness, Response and Co-operation”.

To support the advice, a maritime risk analysis is used. In this analysis a risk assessment is performed on oil spills as a consequence of maritime accidents as well as loss of life as a consequence of accidents involving cruise ships. MARIN has done similar studies for RWS for the North Sea area in the past, using the SAMSON model. Crucial input for such a risk assessment is a detailed description of marine traffic in the area. Collecting information on marine traffic and researching the main traffic streams along the islands therefore is the first step in the risk assessment. In the second part of the study the results of this first step are used as input for the risk assessment.

After the performance of the first part of the analysis, results have been discussed with RWS. This has lead to a change in the objectives of the study: it has been decided that the risk assessment will be done in a qualitative way instead of the initially planned quantitative risk assessment. This report presents the entire analysis: the entire traffic analysis as well as the qualitative risk assessment.

### **1.2 Objective**

The objective if this study consists of two parts:

3. To construct two traffic databases for marine traffic in the Dutch Caribbean:
  - a. A traffic database for the territorial waters of Bonaire
  - b. A traffic database for the territorial waters of Saba and St. Eustatius
4. To perform a nautical risk assessment based on the traffic situation and indicate “high risk areas” with respect to outflow of oil and loss of life on board cruise ships

The territorial waters comprise the zone of 12 nautical miles around the islands.

### **1.3 Report structure**

Chapters 2 to 4 represent the first part of the analysis: the analysis of marine traffic streams. Chapter 2 provides a general introduction to traffic modelling in SAMSON and points out the main assumptions and sources of information used in the study. Chapter 3 and 4 then describe the two areas under consideration and describes the construction of the traffic databases for different groups of ships in the area. At the end of both chapters an overview is given for the route structure for all vessels in the area.

Chapters 5 to 9 cover the second part of the study: the risk assessment. In Chapter 5 a description is given of quantitative risk assessment (QRA) and elaborates why it has been decided to not perform such an analysis (yet) for the Dutch Caribbean. Also some requirements are listed for a future successful QRA. Then, in Chapter 6 a short analysis of accident statistics in the area is presented to indicate the accident frequency and type in the area. Chapters 7 and 8 then describe the qualitative risk assessment for the regions of Bonaire and Saba/St. Eustatius. Chapter 9 summarizes the results of the analyses of the two regions and compares them. Finally, conclusions and recommendations are described in Chapter 10.

## 2 METHODOLOGY

### 2.1 Traffic modelling in SAMSON

An essential part of SAMSON is the traffic database, which describes the maritime traffic in density, composition and behaviour.

The maritime traffic is divided into two main groups; the **route bound ships** and the **non-route bound** (or random) **ships**. The route bound traffic consists of merchant vessels and ferries sailing along the shortest route from one port to another. The non-route bound traffic contains vessels that mainly have a mission at sea, such as fishing vessels, supply vessels, working vessels and pleasure craft. Within the SAMSON-model, route bound and non-route bound traffic are modelled in a different way.

#### 2.1.1 Route bound traffic

The route bound traffic is normally modelled on the dedicated shipping routes. Because of the location of the different ports and the traffic separation schemes, most of the route bound ships sail on a large network of links, comparable with a road network.

The traffic database consists of waypoints and links which connect these waypoints. On each link, the traffic, in number of movements per year, is determined for each of the 36 ship types and 8 size classes (as used in SAMSON), based on the Gross Tonnage (GT) of the vessel. This large number of classes is required for subsequent calculations, such as the calculation of the kinetic energy in case of a collision.

In order to attribute vessels to specific links, required information is the origin (previous port of call) and destination (next port of call) of the ship and the presence of traffic separation schemes. By making assumptions on the chosen route and determining the number of ships that will take this route, a traffic database for route bound traffic can be constructed.

#### 2.1.2 Non-route bound traffic

The non-route bound traffic cannot be modelled in the same manner as the route bound traffic, because the behaviour of these non-route bound ships at sea is different. A non-route bound ship does not sail from one port to the other along a clear route, but rather from port to one or more destinations at sea and then usually back to the port of departure. Fishing vessels mostly form the largest group of non-route bound ships. These ships sail from one fishing ground to another during one journey and they sail different tracks during fishing activities. The behaviour of these ships at sea is therefore not easy to predict. Therefore, the traffic image of the non-route bound traffic is modelled as densities of ships per grid cell.

### 2.2 Ship types to be included

Because the traffic databases will be used as input for a risk assessment for oil spills, some ship types can be left out of consideration. These are the ships which can, under no circumstance, be the cause for a hole in the skin of an oil tanker. The following ship types are assumed to meet this requirement: yachts, pilot and tug boats and small ferries (less than 50 passengers). Also small scale local traffic, like fruit boats and small fishing boats will not be taken into account.

## 2.3 Resources and references

The available information on marine traffic on the Caribbean Sea is limited. There are no large datasets of AIS or radar records available for this study. The characteristics of shipping activities can therefore not be derived by means of data analysis. Instead, the following resources are used:

- Port and terminal statistics for Bonaire, Saba and St. Eustatius, provided by RWS [1]
- Live AIS tracking facilities, through vesseltracker.com and marinetraffic.com [2], [3]
- Online published schedules of cruiselines and local companies
- Information on terminals, provided through RWS and internet research

Through live online AIS tracking facilities it is possible to track shipping movements real-time. This is possible in areas where the providers have installed a local AIS base station. This gives an idea of the type of ships in that area as well as the typical behaviour. It is for instance very well possible to identify areas which are used as anchorage areas. However, it is not possible to obtain data over a longer time period. Therefore it is not possible to track cruise vessels around Bonaire, as at this moment the area is avoided by cruiselines because of the hurricane season. Another limitation of live AIS is the (lack of) coverage in certain areas. For instance, near Bonaire there is only coverage on the western side of the island. Finally, it needs to be mentioned that AIS was only tracked during office hours. Therefore, even within the considered period the traffic image is not complete.

In most cases, the provided port statistics for 2010 are used in order to estimate the traffic intensities. However, for groups of ships where data is lacking, the intensities are based on AIS or more recent port statistics. Therefore, the base year for the traffic database is 2010, complemented with 2011 data.

Because of the limited data resources, it is possible that specific shipping elements are not identified in this analysis. These are ships which do not come forward from the documentation, vessels which have no AIS installation or vessels with a very low traffic intensity.

*The results of this study at no means should be considered as a factual and complete representation of the marine traffic in the territorial waters. Most of the results are strongly dependent on assumptions and limited datasets. Therefore they should be interpreted as a first step in the description of traffic.*

### 3 MARINE TRAFFIC IN THE TERRITORIAL WATERS OF BONAIRE

#### 3.1 Main characteristics

Bonaire currently has four mooring facilities which are used by ships on a regular basis, which are all situated on the western, sheltered, part of the island:

1. The commercial port of Kralendijk, which is used by cruise ships and cargo vessels which supply the island
2. The port of Bonaire Petroleum Corporation (BOPEC), which is used by oil tankers to load or offload cargo
3. The Airport Fuel Pier, biweekly visited by a tanker which supplies the airport with kerosene
4. The CARGILL Salt terminal, used by GDC vessels which load salt for export to the USA and Europe

Each of the mooring facilities attracts specific groups of vessels, for most of which statistics are available.

There are no traffic separation schemes or similar traffic regulatory measures available in the area. This basically means that ships can sail anywhere. The routes that are chosen are therefore mainly dependent on the origin and destination of the vessels. On the western side of Bonaire, the island of Curacao is situated at a distance of about 20 nm. This therefore also is a determining factor for the chosen vessel path. East of Bonaire some atolls are situated. This area is avoided by ship traffic. An overview of the area is given in Figure 3-1.



Figure 3-1 Overview of area around Bonaire

Through live AIS it has been observed that the territorial waters are also crossed by ships that do not visit any of the ports at Bonaire. A specific group of ships with a high traffic intensity are those sailing on a route between the Panama Canal and the Gallion's Passage near Trinidad & Tobago. Also vessels on a route between Venezuela and the USA and some vessels with destination Curacao have been observed to enter the territorial waters. This group of ships is a large uncertainty in the traffic database as there are no available statistics and no extensive AIS data on the used routes.

Although there is AIS coverage in all ports of Bonaire, there have not at all terminals and ports vessels been spotted during the period of observation. In fact, mainly tankers at the BOPEC terminal and also passing vessels have been observed. For the other terminals (practically) no ships have been spotted. This is probably because of the low traffic intensity and possibly because of a lack of AIS systems onboard local cargo

ships. Because of this reason, for this area many alternative data sources needed to be found and some rough assumptions were made.

### **3.2 Methodology and main assumptions**

Starting point for ship numbers and ship types are the statistics for 2010 supplied by RWS. Where possible, live AIS was used to obtain information on the used routes of vessels. By observing the area for about a month, a database of visiting ships could be constructed. Routes and traffic composition could as such be analyzed. Also some traffic intensities are derived from AIS.

Assumptions:

- Vessels sail as much as possible in a straight line towards their destination
- Where possible, sightlines are used, as marked in the nautical chart
- Ships maintain a minimal distance to the shore of about 2 nm

For the different groups of ships, it will be discussed separately how the numbers of ships and the route network have been derived. First this is done for all traffic which visits Bonaire. Then also passing traffic will be discussed.

### **3.3 Destination traffic**

#### **3.3.1 BOPEC terminal**

At this terminal oil products are stored and trans-shipped. On Bonaire no oil is being produced. Therefore all products are both imported and exported at this terminal. The oil is imported from the other ABC islands as well as Venezuela and is being exported especially to Asia. The terminal is capable of receiving the largest tankers in the world, up to 500,000 DWT.

#### **Traffic composition**

The traffic consists of oil tankers. In 2010 the terminal was visited by 229 of those ships according to the terminal statistics, see [1]. The average gross tonnage was about 64,000 tons per ship.

Through live AIS, the visiting tankers have been monitored for a period of about a month. Totally, 14 vessels have been observed. Based on these data it was found that roughly three sizes of tankers called at the terminal:

- 160,000 GT
- 60,000 GT
- 40,000 GT

The tankers were either crude oil tankers or product tankers. All of them had a double hull.

Based on the indicated draught of the vessel in AIS, it could be derived whether the vessels has been loading or offloading at the terminal. For as far as known, all vessels of the largest size class loaded cargo at the terminal. The majority of the smaller vessels offloaded cargo.

If it is assumed that for every visiting vessel of the largest size class, the terminal is visited by three vessels of about 60,000 GT and three vessels of about 40,000 GT, the average GT is about 66,000 GT. This corresponds more or less to the actual average GT in 2010.

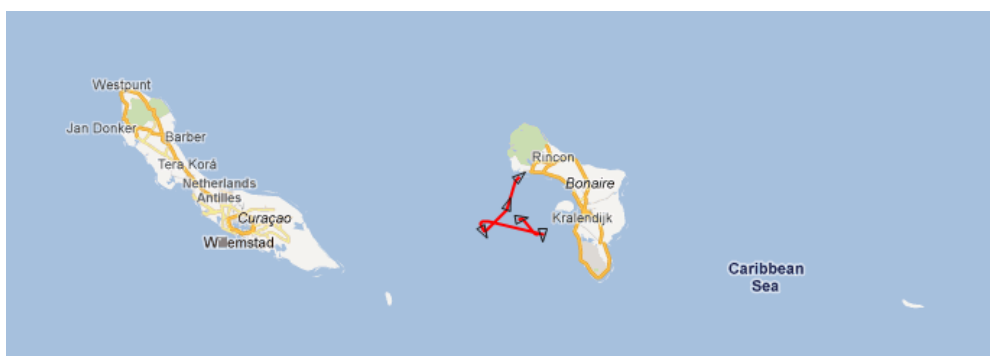
It is assumed that 50% of the vessels are crude oil tankers and 50% are product tankers and that the distribution of vessel sizes is equal for those two groups of ships. When the statistics of 2010 are used, the following shipping matrix can be established:

**Table 3-1 Shipping matrix BOPEC terminal**

| Type/GT   | 30,000-60,000 | 60,000-100,000 | >100,000 | Total |
|-----------|---------------|----------------|----------|-------|
| Crude oil | 49.1          | 49.1           | 16.4     | 114.5 |
| Product   | 49.1          | 49.1           | 16.4     | 114.5 |
| Total     | 98.1          | 98.1           | 32.7     | 229   |

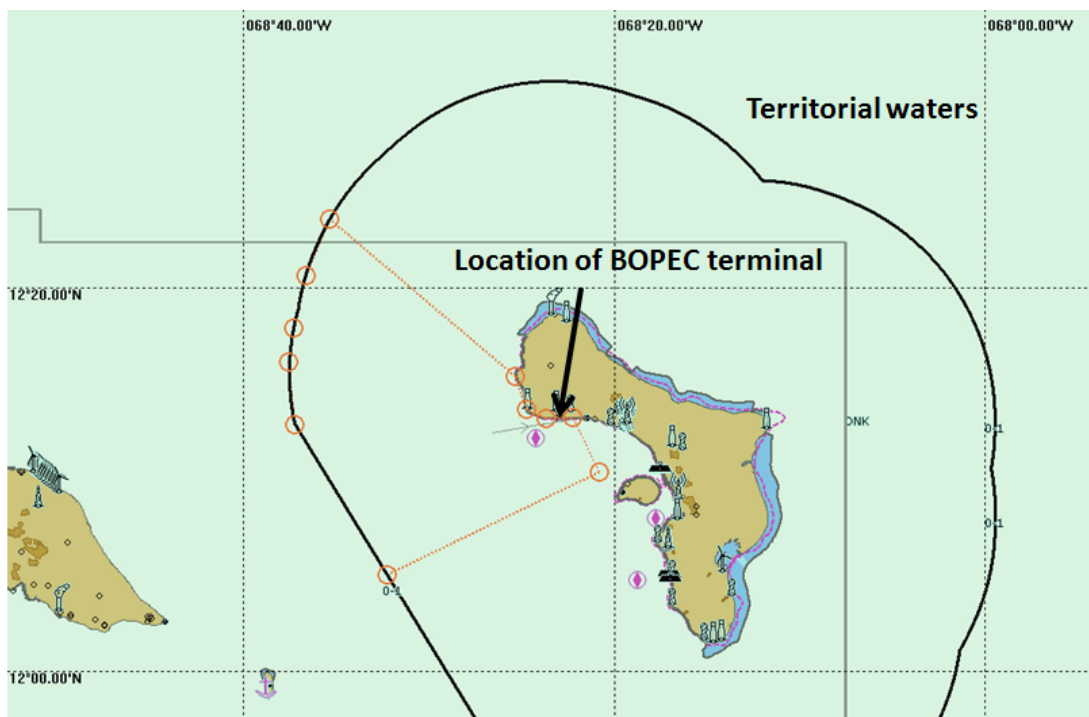
### Route structure

Tankers that visit the terminal mostly have to wait for several days before they can moor at the jetty. As the water depth is too large, anchoring is not possible. Therefore, during the waiting period most vessels drift in the area west of Bonaire. Being adrift means that the ship lays still in the water but is not at anchor. In this state the ship has poor manoeuvrability because of a lack of speed. An example of a drifting ships, just before heading to the terminal is given in Figure 3-1.



**Figure 3-2 Example of a drifting ship near BOPEC terminal**

AIS shows that vessels start drifting already before they enter the territorial waters of Bonaire. This means that the ships behave like non-route bound traffic. Therefore, part of the traffic is modelled as such. However, as soon as the vessels have visited the terminal, they can proceed to their following destination. This means that after unmooring the behaviour of the vessels is like route bound traffic. Therefore this part of the traffic is modelled as such.



**Figure 3-3 Drifting area BOPEC terminal**

Based on the observed vessels, an estimation was made of the area which is used as “drifting area”. The area looks as indicated in orange in Figure 3-3.

The vessels of the largest size class spend considerably more time in the area and at the terminal than the smaller vessels: 11 and 3 days on averages respectively. The difference is both in the terminal and waiting time: the larger ships drifted between 5 and 11 days (9 on average), while for the smaller vessels this was between 2 and 4 days (3 on average).

If it is assumed that these numbers are representative for the actual waiting times, and taking into account the above described shipping matrix, the average number of drifting ships can be calculated:

**Table 3-2 Distribution of drifting ships BOPEC terminal**

| Ship size (tons) | Type    | Number | Av. number of drifting days | Av. number of drifting ships |
|------------------|---------|--------|-----------------------------|------------------------------|
| 40.000           | Crude   | 49.1   | 3                           | 0.403                        |
|                  | Product | 49.1   |                             | 0.403                        |
| 60.000           | Crude   | 49.1   | 3                           | 0.403                        |
|                  | Product | 49.1   |                             | 0.403                        |
| 160.000          | Crude   | 32.7   | 9                           | 0.403                        |
|                  | Product | 32.7   |                             | 0.403                        |
| Total            |         | 229    |                             | 2.418                        |

In total there are about 2.4 drifting vessels in the area. It could now be decided to take a safety margin on this number. On the other hand, it now has been assumed that drifting only happens within the territorial waters. The AIS has shown that the ships also drift outside of this area. It is however difficult to make an estimation for the part of the time that this is the case. Therefore, this element will be taken as the safety margin.

In order to construct a route structure for the leaving vessels, the destinations of the different observed vessels have been studied.

The smaller vessels, with only one exception, sailed in the direction of Curacao. Some visited Curacao, others continued towards Aruba or a more westward destination in Venezuela. However, all of them took a similar route, using the passage between Curacao and the little island Klein Curacao.

The larger ships all continued to more remote destinations, especially in Asia. They were probably fully laden and about to deliver the cargo elsewhere. All of the vessels left in a north-east direction, in the direction of Galleon's Passage in Trinidad & Tobago.

Assumed is that the above distinction of smaller and larger vessels applies in reality as well. Therefore, all large ships will be routed towards Galleon's Passage, while the smaller ones are routed towards Curacao.

#### Moored ship

Tankers moored at the terminal can be collided against by vessel traffic. Therefore the moored ship will be taken into account as well in the risk analysis.

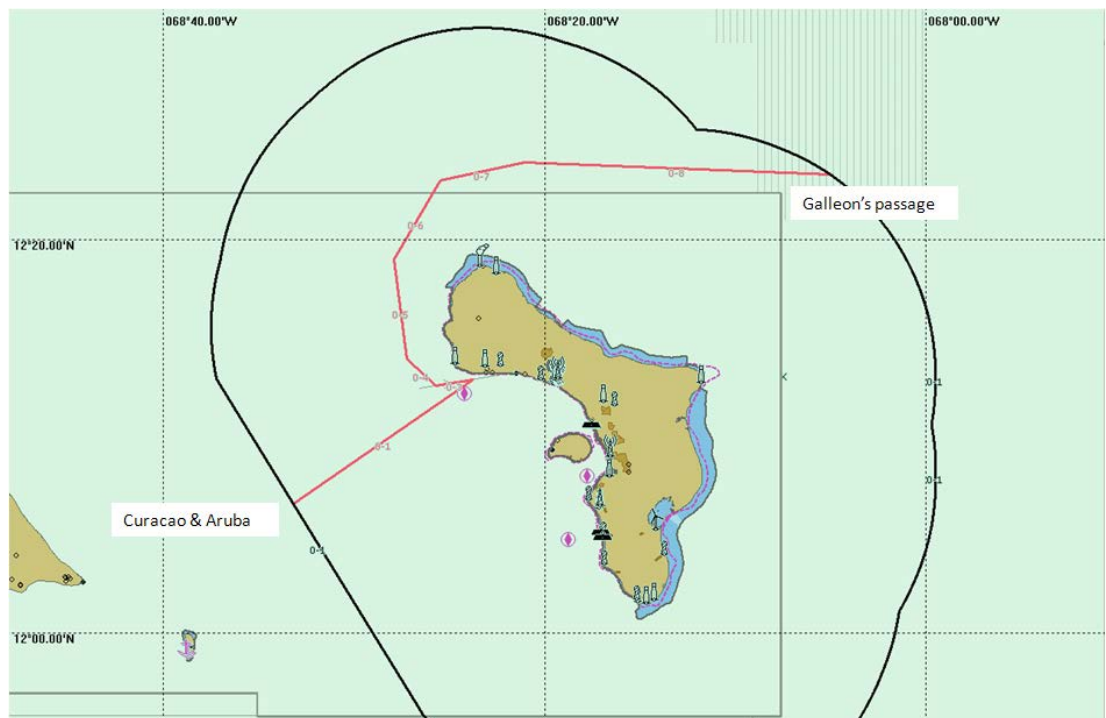


Figure 3-4 Routes from BOPEC towards Curacao and Galleon's Passage

#### 3.3.2 Cruise ships

During the cruise season Bonaire is regularly visited by cruise vessels. These ships moor at the commercial port of Kralendijk. Two jetties are available for cruise vessels. Port statistics are available for the number of cruise vessels, but no further details on the ships are provided. At the time this study is performed, it is hurricane season in the Caribbean which means that no cruise ships are operated near the ABC islands. Therefore, cruise ships could not be observed through AIS. Therefore additional data sources had to be established. This was done through analysis of the already published cruise schedules for 2012 of all cruise lines which are active in the Caribbean, see [4] to [21]. Based on these schedules information could be obtained both on vessel details and route details.

### Traffic composition

In 2010 Kralendijk was visited 143 times by cruise vessels, according to the port statistics. Using the cruise schedules, all cruise vessels have been identified that have Bonaire as a destination for the year 2012. It was found that these ships are all cruise ships or large passenger sailing ships with a gross tonnage between 5000 and 115,000 tons. The ships all fall under the SAMSON ship type "Passenger vessel". When it is assumed that the number of cruise ships calling at the port of Kralendijk is equal to the number in 2010, the vessels can be distributed over the size classes, according to the proportions found for 2012. This results in the following shipping matrix:

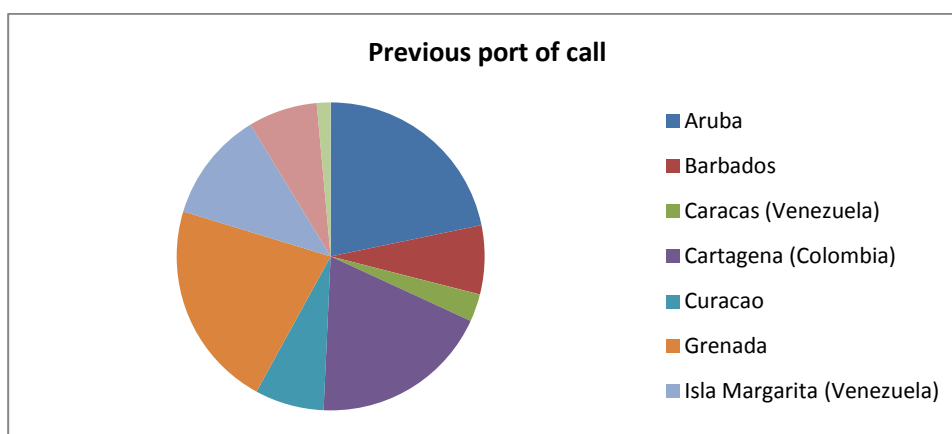
**Table 3-3 Shipping matrix cruise ships Bonaire**

| Type/ GT (tons)  | 5000<br>10,000 | –<br>10,000<br>30,000 | 30,000<br>60,000 | –<br>60,000<br>100,000 | >100,000 | Total |
|------------------|----------------|-----------------------|------------------|------------------------|----------|-------|
| Passenger Vessel | 8              | 16                    | 24               | 169                    | 68       | 286   |

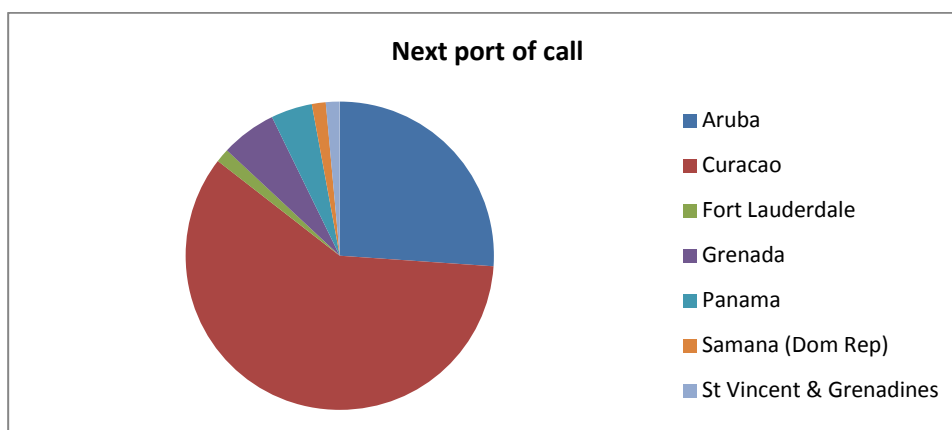
The number of ships is twice the number of ship calls, as both arrival and departure are taken into account.

### Route structure

The basis for the route network are the cruise schedules. Based on the cruise schedules, the previous and consequent port of call were registered for each of the vessels visiting Bonaire. At this moment 71 visits are planned for 2012. The ports of call are distributed as indicated in the figures below.



**Figure 3-5 Previous ports of call for cruise Ships visiting Bonaire**



**Figure 3-6 Next ports of call for cruise Ships visiting Bonaire**

The previous port of call apparently differs per ship. Aruba (15 ships), Cartagena (Colombia, 15 ships) and the island of Grenada (13 ships) are most common. On the other hand, the next port of call is in by far most of the cases Curacao (41 ships) and a significant part of the ships continues to Aruba.

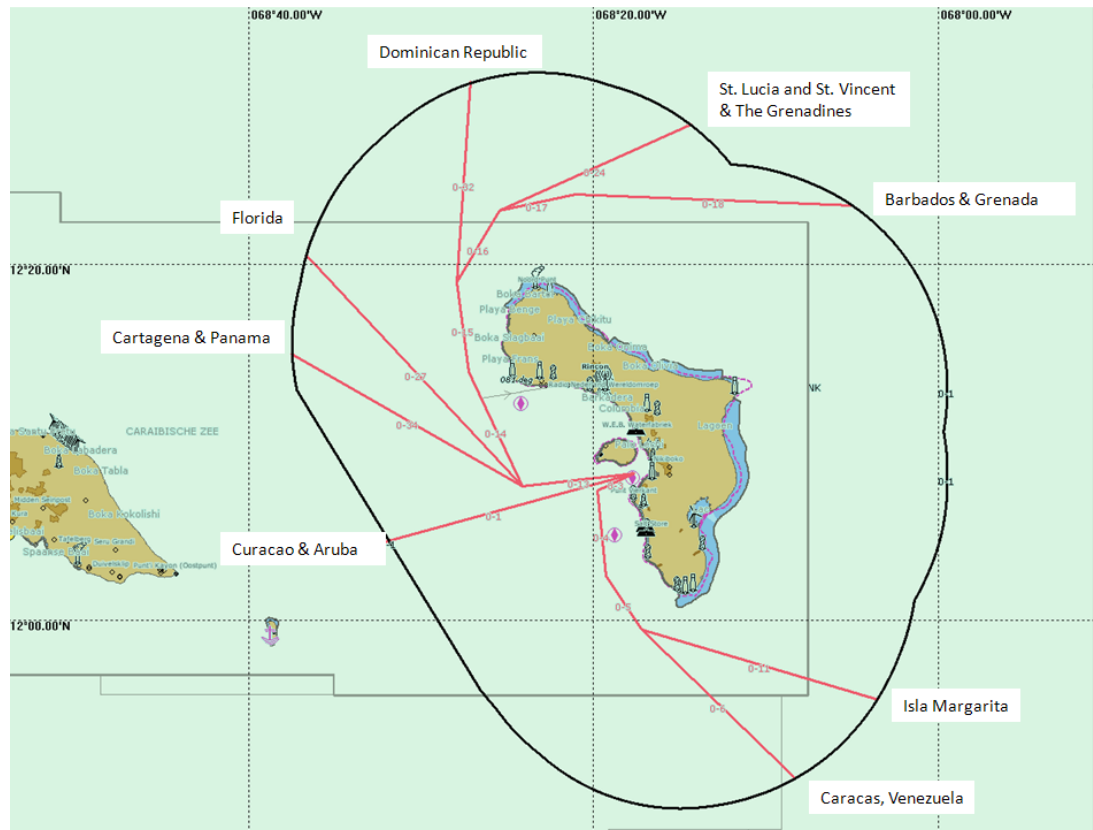
Based on the most likely routes that will be taken, the destinations have been grouped into “main routes”. The routes are defined as follows:

- Aruba/ Curacao
- Caracas (Venezuela)
- Isla Margarita (Venezuela)
- St. Lucia and St. Vincent & The Grenadines
- Barbados, Grenada and Blanquilla (Venezuela)
- Fort Lauderdale (Florida, USA)
- Samana (Dominican Republic)
- Cartagena (Colombia) and Panama Canal

The following assumptions have been made with regard to the most likely routes:

- The route Bonaire – Aruba passes through the passage between Curacao and Klein Curacao
- The route Bonaire – Cartagena/Panama passes north of Curacao and Aruba
- Ships sailing towards Florida use the Windward Passage, in between Cuba and Hispaniola
- Ships sailing towards St. Lucia, St. Vincent & The Grenadines, Barbados and Grenada leave in northerly direction following a similar route as the tankers from the BOPEC terminal to Galleon's Passage. North of Bonaire direction is changed towards the destination.

An overview of the different routes is provided in Figure 3-7.



**Figure 3-7 Overview of the route structure for cruise vessels visiting Bonaire**

Finally, the ships of the different size classes have been distributed over these routes, according to the proportions found for 2012 and taking into account the direction in which the route will be transited.

### 3.3.3 Cargo and local supplies

Bonaire is supplied mainly by small Ro-Ro vessels, which call at the port of Kralendijk. In the port a dedicated jetty is available right next to the piers for the cruise ships. According to the Dutch Caribbean Coast Guard, these ships sail on a fixed route along the ABC islands: Aruba -> Bonaire -> Curacao.

### Traffic composition

The total number of cargo vessels visiting Bonaire in 2010 was 51, according to the port statistics. Because of the low intensity of those ships, only one or two vessels have been observed through AIS. As further information on the details of cargo and supply ships is lacking, assumptions need to be made in order to simplify the traffic composition.

Assumed is that all vessels are Ro-Ro vessels and that they are distributed evenly over the two lowest GT classes in SAMSON: 100-1600 tons and 1600-3000 tons. It is expected that this is an overestimation of the ship sizes: probably more vessels belong to the smallest size class. However, it is considered better to overestimate the risk than underestimate it and therefore this distribution is chosen.

**Table 3-4 Shipping matrix cargo vessels Bonaire**

| Type/ GT (tons) | 100-1600 | 1600-3000 | Total |
|-----------------|----------|-----------|-------|
| Ro-Ro           | 51       | 51        | 102   |

### Route structure

Like for the cruise ships and the BOPEC tankers, it is assumed that the routes towards Aruba and Curacao are the same within the territorial waters of Bonaire. Therefore, only one route is needed in order to model this group of traffic. As the destination at Bonaire is the same as for the cruise vessels, these ships are modelled along the same route as the cruise ships.

#### 3.3.4 CARGILL salt terminal

At this terminal salt is being exported from the local salt pans at Bonaire towards the USA and Europe. The terminal is located a few kilometres south of the port of Kralendijk. There is a mooring facility at a pier. The total capacity of the salt pans is 441,000 tons (400.000 metric tonnes) and all of this is exported by means of shipping.

### Traffic composition

The salt is loaded by general cargo vessels. In 2010 48 of such ships moored at the pier. The smallest vessels had a gross tonnage of 800 tons, while the largest had a gross tonnage of about 35.000 tons. However, the distribution over the different size classes is not known. Also no ships have been observed at the pier during the period of observation by means of AIS. Therefore, some rough assumptions were done regarding the ship sizes.

Assumed is that the ships are distributed evenly over the possible size classes to which they can belong: between 800 and 35,000 GT. This is regarded an overestimation of the size of the average ship: if all of these ship would be fully laden, 640,000 tons would be exported instead of the actual 441,000 tons. As such the following shipping matrix has been derived:

**Table 3-5 Shipping matrix cargo CARGILL terminal Bonaire**

| Type/ GT (tons) | 100-1600 | 1600-3000 | 3000-5000 | 5000-10,000 | 10,000-30,000 | 30,000-60,000 | Total |
|-----------------|----------|-----------|-----------|-------------|---------------|---------------|-------|
| GDC             | 16       | 16        | 16        | 16          | 16            | 16            | 96    |

### Route structure

Also more detailed information on the routes that are taken by these vessels is, at this moment, lacking. Therefore also here some rough assumptions are required. It has been assumed that all vessels come from the direction of either the USA or Europe and also leave again in those directions. Also it is assumed that both routes are used by equal numbers of vessels, in both directions.

The standard route to Europe is assumed to be through the Anegada Passage, between St. Maarten and the British Virgin Islands. The standard route to the USA leads through the Windward Passage (between Cuba and Hispaniola). These routes have some correspondence with the earlier created routes from Kralendijk and BOPEC terminal. The cruise ships to Fort Lauderdale also were assumed to take the Windward passage. Therefore this route can be used, when corrected for the different location of the terminal. The route to Europe was not created yet. This route is partly routed over the structure towards St. Lucia, Barbados etc. which was created for the cruise vessels. In Figure 3-8 the modifications for the different terminal location, as well as the addition of a route to the Anegada Passage, are indicated. They are marked in orange compared to the earlier created network in red.

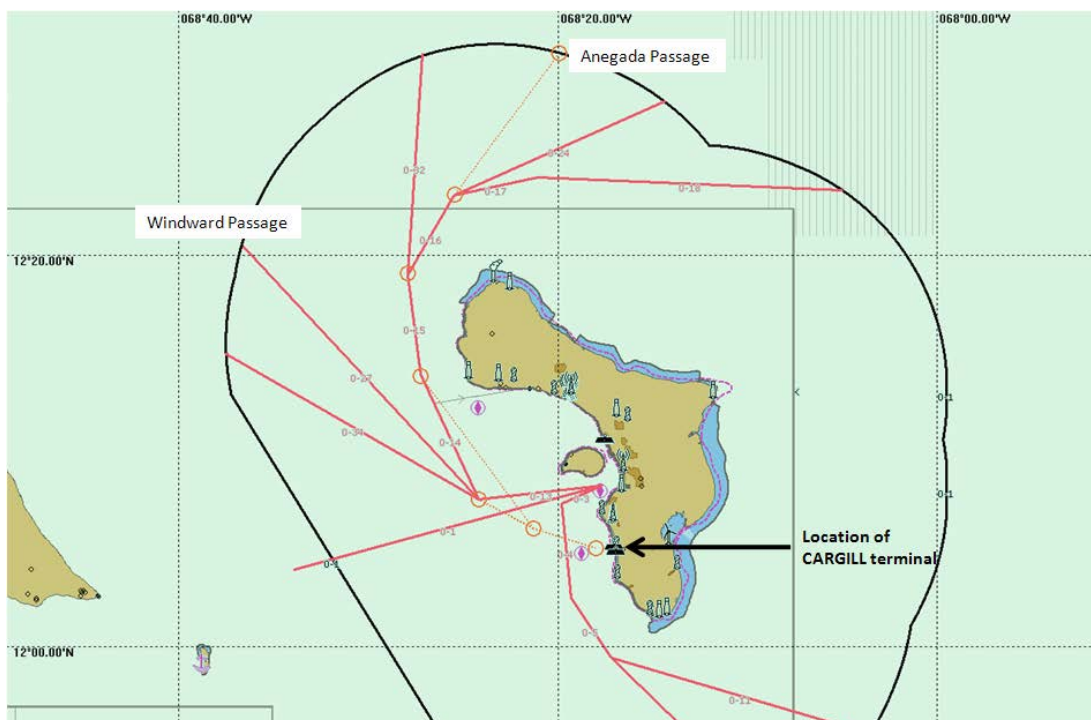


Figure 3-8 Cruise route network adjusted for CARGILL terminal

### 3.3.5 Airport fuel pier

Every 14 days the airport of Bonaire, Flamingo Airport, is supplied with fuel by a tanker which moors at a pier close to the airport. The Fuel Pier is situated just south of Kralendijk. According to the coast guard, the fuel is loaded in Curacao and is transported by a tanker with a double hull. However, in some cases the fuel is trans-shipped by barge instead of the tanker. Also at the Fuel Pier no activity has been observed through AIS. Possibly the transports have been missed or the transport during this month happened by a barge without AIS.

#### Traffic composition

As no ships have been observed at the pier by means of AIS, it is not possible to derive the ship details in such a way. However, it is known that the pier was originally built for a fuel barge with a length of 80 m [23]. This provides some guidance on the type of vessels which can moor at the jetty. Assuming that a ship can have a maximum length of 90 m, it is probable that the ship will not have a GT larger than 3500 tons. This is based on a scan of ship characteristics of tankers in the ship database of Lloyd's List Intelligence. Therefore it will be assumed that the visiting tankers will be of the size class 3000 – 5000 GT. Assumed is that the visiting ship always is of this size and that it is a tanker and not a barge. The ship is assumed to be a product tanker.

#### Route structure

As the Fuel Pier is situated directly next to the commercial port of Kralendijk, it is assumed that the tankers will follow the same route towards and from Curacao as the vessels calling at Kralendijk.

#### Moored ship

Like at the BOPEC terminal, also the Fuel Pier is situated at open sea. Therefore, also these tankers could be struck by passing traffic. This situation will be taken into account in the risk analysis.

### 3.4 Passing traffic

Passing traffic within the territorial waters has been observed through AIS both on the north and west side of Bonaire. By studying the previous and next port of call of those vessels three main groups could be distinguished:

1. Shipping north of Bonaire: this is a main traffic route between the Panama Canal and other destinations in Central America on the one hand, and destinations on the east coast of Latin America and possibly through the Galleon's Passage towards the Cape of Good Hope on the other hand.
2. Shipping west of Bonaire moving in SE/NW direction: these are ships moving between a port in Venezuela and a location in the north or north-western part of the Caribbean.
3. Shipping west of Bonaire and moving in NE/SW direction: these are ships on a route between Curacao and a location in the north-eastern part of the Caribbean.

Especially the first group consists of many vessels, at least several per day. The other two groups are much smaller. For the second group, on most days one vessel was observed and for the third group only one or two vessels have been observed in the entire period. An example of a vessel belonging to the second group is displayed in Figure 3-9.

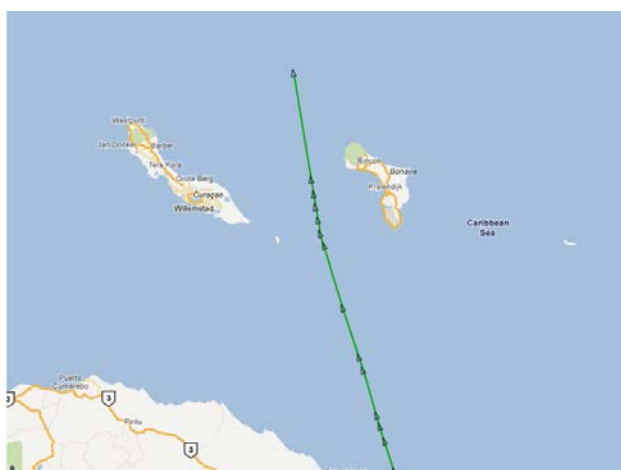


Figure 3-9 Example of a ship sailing from Venezuela in the direction of the Gulf of Mexico

For the first group many examples are available and there are some data resources available, like statistics of the Panama Canal. However, for the two latter groups no statistics are available (yet) and the number of examples from AIS is much smaller. Without additional information a traffic database of those groups will not be usable. Therefore, for now it was decided not to take these ships into account and only include vessels of the first group. However, it should be realized that this is an underestimation of the nautical risk in the area.

#### Traffic composition

In order to make an estimate of the number of ships on the main route from the Panama Canal and Central America in eastward direction, statistics of the Panama Canal are used, see [25] to [27]. It is not possible to do this based on AIS only, as the coverage in the area is poor. Therefore the ships only are present in the area for a very short period.

The statistics show that in 2010 about 1000 passages have been registered which can be attributed to the main trade routes "South America Intercoastal" and "E.C. South

America – West Coast US/ Canada”. Supposedly, this is the main share of the ships passing north of Bonaire. However, also ships which did not pass the canal but did pass near Bonaire (for instance from the Caribbean coast of Central America) need to be taken into account. However, for those ships no statistics are available.

The total number of ships on the route is estimated to be 1500 vessels on annual basis. This corresponds with over 4 passages per day. This is in correspondence with AIS observations: only during office hours every day already 1 to 3 vessels were observed.

With regard to the composition of the passing traffic, it has been assumed that the distribution of ship types is equal to the distribution of ships passing the Panama Canal. Furthermore, as the statistics do not specify the size of the ships, using the Lloyd's List Intelligence ship database, it has been established which are worldwide the most common size classes per ship type. The passing ships are then distributed evenly over these most common size classes, per ship type. As such a rough estimation of the composition was derived, see Table 3-6.

**Table 3-6 Shipping matrix of ships passing north of Bonaire**

| Type/ GT class | 100-1600 | 1600-3000 | 3000-5000 | 5000-10,000 | 10,000-30,000 | 30,000-60,000 | 60,000-100,000 | >100,000 |
|----------------|----------|-----------|-----------|-------------|---------------|---------------|----------------|----------|
| Bulk           |          |           |           |             | 182.6         | 182.6         |                |          |
| Container      |          |           |           |             | 131.9         | 131.9         | 131.9          |          |
| GDC            |          |           | 33.1      | 33.1        | 33.1          |               |                |          |
| LPG            |          |           | 5.3       | 5.3         | 5.3           | 5.3           |                |          |
| Misc           | 1.4      | 1.4       | 1.4       | 1.4         | 1.4           |               |                |          |
| Oil            |          |           |           |             | 61.2          | 61.2          | 61.2           | 61.2     |
| Pass           | 5.4      |           | 5.4       | 5.4         | 5.4           | 5.4           |                |          |
| Reefer         |          |           | 76.4      | 76.4        | 76.4          |               |                |          |
| Ro-Ro          |          |           |           |             | 5.8           | 5.8           |                |          |
| Vehicle        |          |           |           |             | 36.2          | 36.2          |                |          |
| Dredging       |          |           | 26.8      |             |               |               |                |          |

### Route structure

Not all of the ships passing north of Bonaire actually enter the territorial waters. For the ships which have been observed (13 vessels), their tracks have been plotted in the chart in Figure 3-10. It can be noted that many of the ships have entered the territorial waters but that also a significant part did not. Furthermore, it can be noted that the coverage of AIS quickly reduces north of Bonaire. This is indicated by the “broken” tracks. This suggests that further north there could be many tracks, which would not be observed. In total 6 of the 13 vessels entered the territorial waters.

It is likely that, because of AIS coverage, ships which sail closer to the island have a larger probability to be observed by AIS than vessels further away. Therefore it cannot simply be stated that 6/13 share of the vessels enter the territorial waters. It can be stated however that less than 50% of the ships do so.

The route structure is defined as follows: the links are being placed over the most northern tracks in the figure. The density is high in this area and the link is situated just outside the territorial waters. When a normal distribution is assumed, which is standard in SAMSON, and the width of the distribution is sufficient, just less than 50% of the tracks will cross the 12 nm zone.

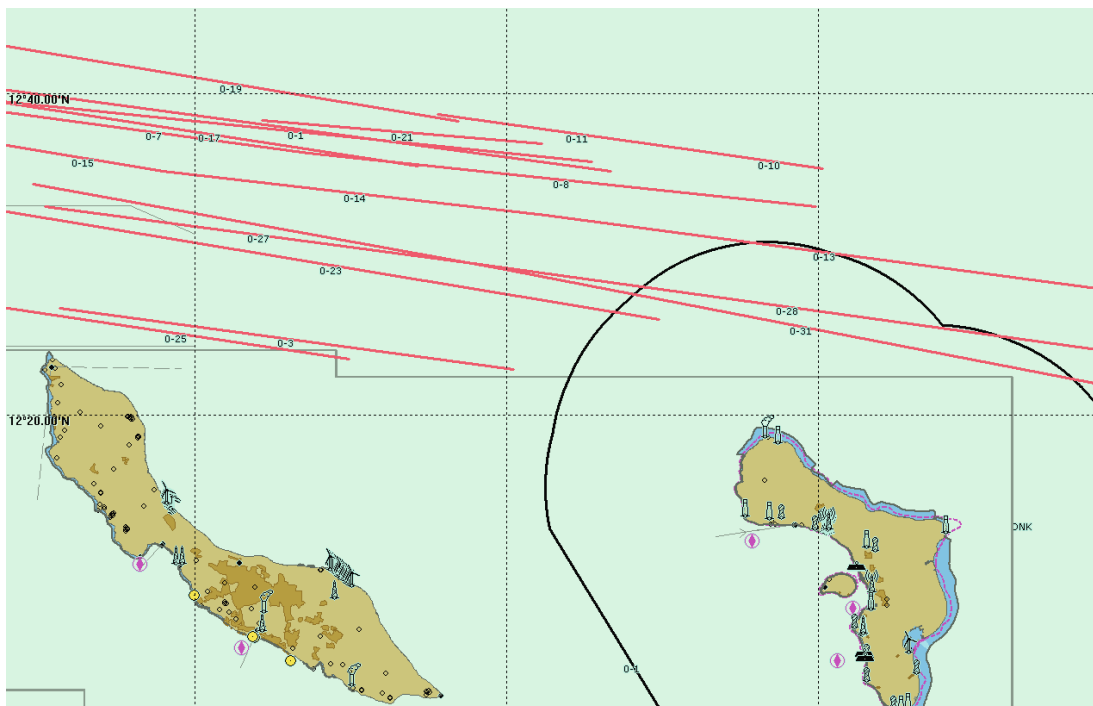


Figure 3-10 Tracks of vessels passing north of Bonaire

### 3.5 Overview route structure

An overview of the routes of all vessel groups as well as the drifting area (in black) is pictured in Figure 3-11.

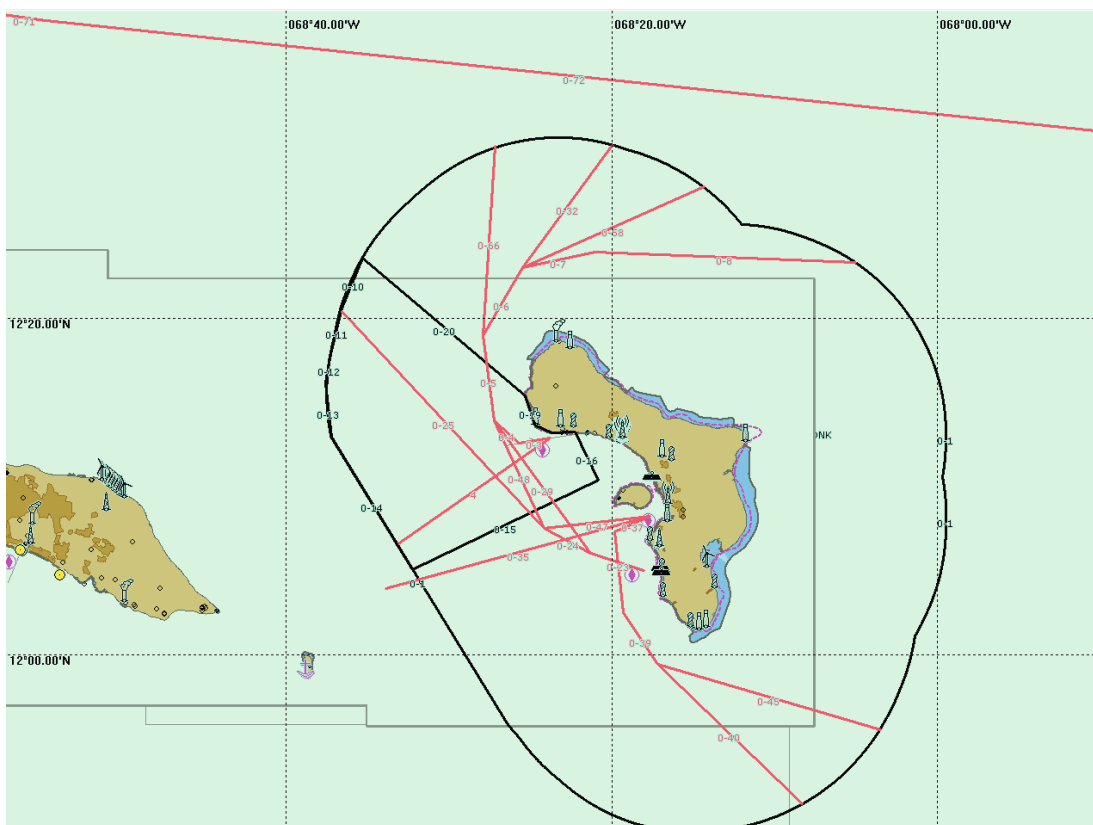


Figure 3-11 Overview of route structure

## 4 MARINE TRAFFIC IN THE TERRITORIAL WATERS OF SABA AND ST. EUSTATIUS

### 4.1 Main characteristics

Saba and St. Eustatius are situated 14 nm apart. The two islands are part of the Windward Islands and surrounded by various other islands, closest of which are the island of St. Kitts, 7 nm south-east of St. Eustatius and St. Maarten, 24 nm to the north from Saba. On the southern side of Saba the nature reserve Saba Bank is situated. This area was recently identified as a “Particularly Sensitive Sea Area” (PSSA) by the IMO, which practically means that the area is to be avoided by ships exceeding 300 GT and that anchoring in this area is not allowed [28].

Like the area around Bonaire, no traffic separation schemes or other types of dedicated channels are available.



Figure 4-1 Overview of the area around Saba and St. Eustatius

Saba is a small island with few shipping activities. There is a port on the southern side of the island, but this harbour is not accessible for deep-water ships. The island is supplied by small Ro-Ro vessels and is linked by means of two ferry services to the island St. Maarten. The island is on the schedule of some exclusive, small scale cruise lines. The cruise ships anchor in front of the harbour and passengers are taken to shore by tenders.

St. Eustatius on the other hand attracts many large seagoing vessels because of its NUSTAR terminal, where petroleum products are stored and trans-shipped and also bunker facilities are available. On the other hand, St. Eustatius is not a cruise destination and there are no ferries which call at the island on a liner service. The harbour is used by cargo ships and pleasure craft.

As the islands are situated in an area with many other small islands, the territorial waters are crossed frequently by cargo and cruise vessels which do not visit any of the two islands.

AIS coverage in this area is much better than in the area around Bonaire. Therefore, the routes that are taken by the different groups of vessels could mostly be identified using this tool.

## **4.2 Methodology and main assumptions**

Again, port statistics for the year 2010 have been used as a guideline for the number of vessels calling at the two islands. For cruise vessels the schedules for 2012 have been used.

As AIS quality is much better in this area, this has been the main source of information with regard to the traffic routes, rather than the assumptions which were defined for Bonaire. AIS has been used to track vessels calling at the NUSTAR terminal and to analyze the routes which have been taken by vessels of different types.

## **4.3 Destination traffic**

### **4.3.1 NUSTAR terminal**

Like the BOPEC terminal, at the NUSTAR terminal oil and oil products are imported from different location in the Caribbean and exported to various destinations. Furthermore, bunker facilities are available. Trans-shipment of oil is done at a jetty at shore as well as at a single point mooring at sea. Bunkering is done by bunkerbarges. A large dedicated anchorage area is situated directly west of the terminal. This is the place where vessels anchor for bunkering as well as for waiting for the terminal.

The traffic database for this group of ships is divided into a part for the moving vessels and a part for the anchored vessels. In the analysis, the group of ships which visit NUSTAR for bunkering only and the group of ships which visit for trans-shipment of cargo are treated separately.

Ship traffic around NUSTAR terminal has been followed through AIS for about three weeks. For each observed vessel the following parameters were registered:

- Ship identity
- Ship type and size
- Previous and next port of call
- Did the vessel moor at the jetty?
- Draught at arrival and departure
- Moment of arrival and departure

From these data it can implicitly be derived whether the vessel came for bunkering or for trans-shipment of cargo. Also the tracks of arrival and departure are mostly available so the chosen routes can be evaluated. In total 41 vessels have been observed.

A ship was identified as a trans-shipment vessel when it complied with at least three of the following requirements:

- The ship is a tanker
- The ship was seen moored at the jetty
- The draught of the vessel changed significantly between arrival and departure
- The period of stay was at least 3 days

A vessel was identified as a bunker-only vessel when it complied with at least three of the following requirements:

- During the presence of the vessel, the vessel was not seen moored at the jetty
- The draught of the vessel did not change significantly during presence
- The period of stay was shorter than 3 days
- The ship is not a tanker

Using these requirements, all ships but one could be attributed to any of the two groups. 15 vessels were identified as “bunker-only” vessels while 25 were identified as trans-shipment vessels.

### **Traffic composition**

As a starting point, the terminal statistics for 2010 have been used for the annual number of calls. In this year 859 visited the terminal for bunkering and 272 for cargo trans-shipment.

#### *Trans-shipment vessels*

Out of 25 observed vessels, 16 were identified as oil tankers, while 9 were tankers capable of transporting both oil and chemical products. As the terminal maintains strict requirements concerning the quality of the vessels, it has been assumed that all tankers have a double hull. Therefore the 16/25 part of the ships are assigned to the SAMSON ship type “Oil product DH” and 9/25 part to the type “Chemical DH”.

The size of the vessels is specified in the statistics of the terminal for 2010: 235 had a DWT of <80,000 ton, 33 a DWT between 80,000 and 160,000 and 4 vessels had a DWT larger than 160,000. These DWT groups have been translated to GT groups based on conversion factors. However, because the categorisation is quite coarse and most vessels fall into one group, also the observation data have been used. Finally, it was assumed that the distribution of size classes over the two ship types was similar. This resulted in the matrix displayed in Table 4-1.

**Table 4-1 Shipping matrix for trans-shipment vessels at NUSTAR terminal**

| Type/ GT | 1600-5000 | 5000-10.000 | 10.000-30.000 | 30.000-60.000 | 60.000-100.000 | >100.000 | Totaal |
|----------|-----------|-------------|---------------|---------------|----------------|----------|--------|
| Oil      | 13.7      | 27.4        | 48.0          | 68.6          | 13.7           | 2.6      | 174.1  |
| Chemical | 7.7       | 15.4        | 27.0          | 38.6          | 7.7            | 1.4      | 97.9   |
| Totaal   | 21.4      | 42.9        | 75.0          | 107.2         | 21.4           | 4        | 272    |

#### *Bunker-only*

For this group of vessels only their number is available from the terminal statistics. For the classification of ship types and sizes therefore only the observations could be used. The observed vessels appeared to be of the following types: bulk carriers, GDC vessels and various types of tankers. However, as the number of observations is only 15, making a very detailed categorisation does not make sense. Therefore it was decided to attribute the vessels to three main types:

- Bulk carriers (including bulk carriers and GDC vessels)
- Oil tankers
- Chemical tankers (including chemical, LNG and LPG tankers)

The distribution of size classes over the different ship types was assumed to be equal to the observed distribution.

Table 4-2 Shipping matrix for bunker-only vessels at NUSTAR terminal

| Type/ GT | 5000-10.000 | 10.000-30.000 | 30.000-60.000 | 60.000-100.000 | >100.000 | Totaal |
|----------|-------------|---------------|---------------|----------------|----------|--------|
| Bulker   | 114.5       | -             | 229.1         | -              | -        | 343.6  |
| Oil      | 114.5       | 57.3          | -             | 57.3           | -        | 229.1  |
| Chemical | -           | 57.3          | 57.3          | 114.5          | 57.3     | 286.3  |
| Totaal   | 229.1       | 114.5         | 286.3         | 171.8          | 57.3     | 859    |

The terminal operates five bunker barges. These are taken into account as well, next to the visiting ships.

### Route structure

The majority of the observed ships sailed directly to the anchorage area. The trans-shipment vessels lifted their anchor just before they could proceed to the jetty and then directly continued their journey. The bunker-only ships mostly directly continued their journey from the anchorage area. Drifting was only observed during bad weather. Therefore, the traffic database could be split into a route network and an anchorage area. Where the anchorage area is defined by a specific area and a vessel density.

### Anchorage area

Based on the anchoring positions of the observed vessels and taking into account the symbols in the chart, the contours of the anchorage area can be roughly defined. This is pictured in orange in Figure 4-2. The black dots indicate the positions where ships were observed anchoring.

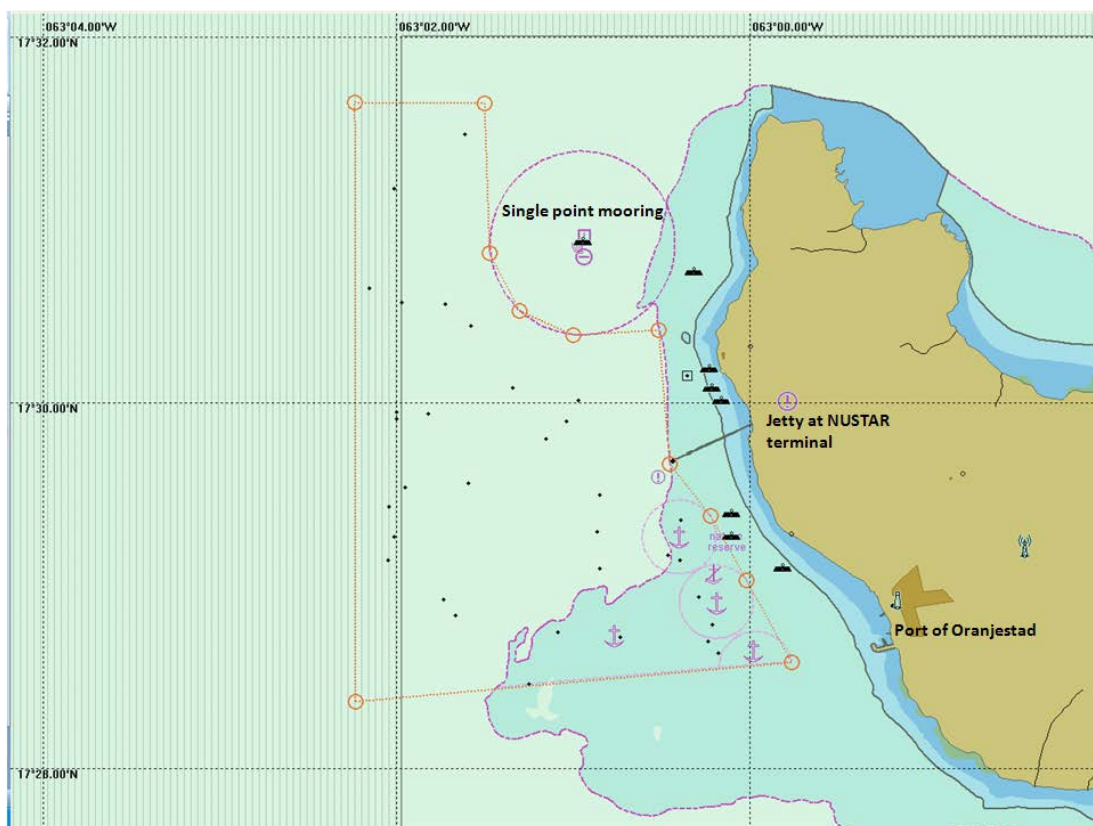


Figure 4-2 Contours of anchorage area near NUSTAR terminal

According to the NUSTAR statistics, there were on average 2.353 anchoring vessels present in 2010. However, in 2010 ships were still allowed to anchor at Saba Bank. It is likely that these ships are now anchoring in the NUSTAR anchorage area. Therefore these ships need to be taken into account as well.

In 2010 it was monitored through AIS how many ships anchored at Saba Bank. These numbers were published in [28]. In 2010, 20 ships were counted with an average stay of three days. This corresponds to an average presence of 0.16 ships. However, the AIS coverage was only 40-60%. Assuming an equal anchoring rate over the entire Saba Bank, this means that on average about 0.33 ships were present in 2010. Therefore it is estimated that on average 2.7 ships are present in the anchorage area near the NUSTAR terminal.

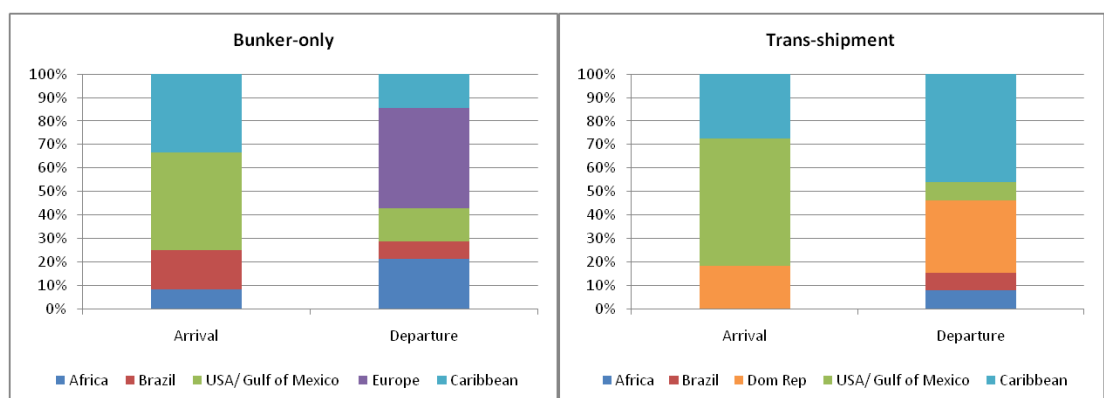
It is assumed that the five bunker barges are always present within the anchorage area.

#### *Route structure for arriving and departing vessels*

In order to derive a route structure, all tracks of the observed vessels have been analyzed. Not for all vessels could both the arriving and departing track be traced back, for instance because of a lack of AIS coverage. The analysis is therefore based on the tracks that could be traced back. Then, the tracks were linked to the origin or destination of the vessel.

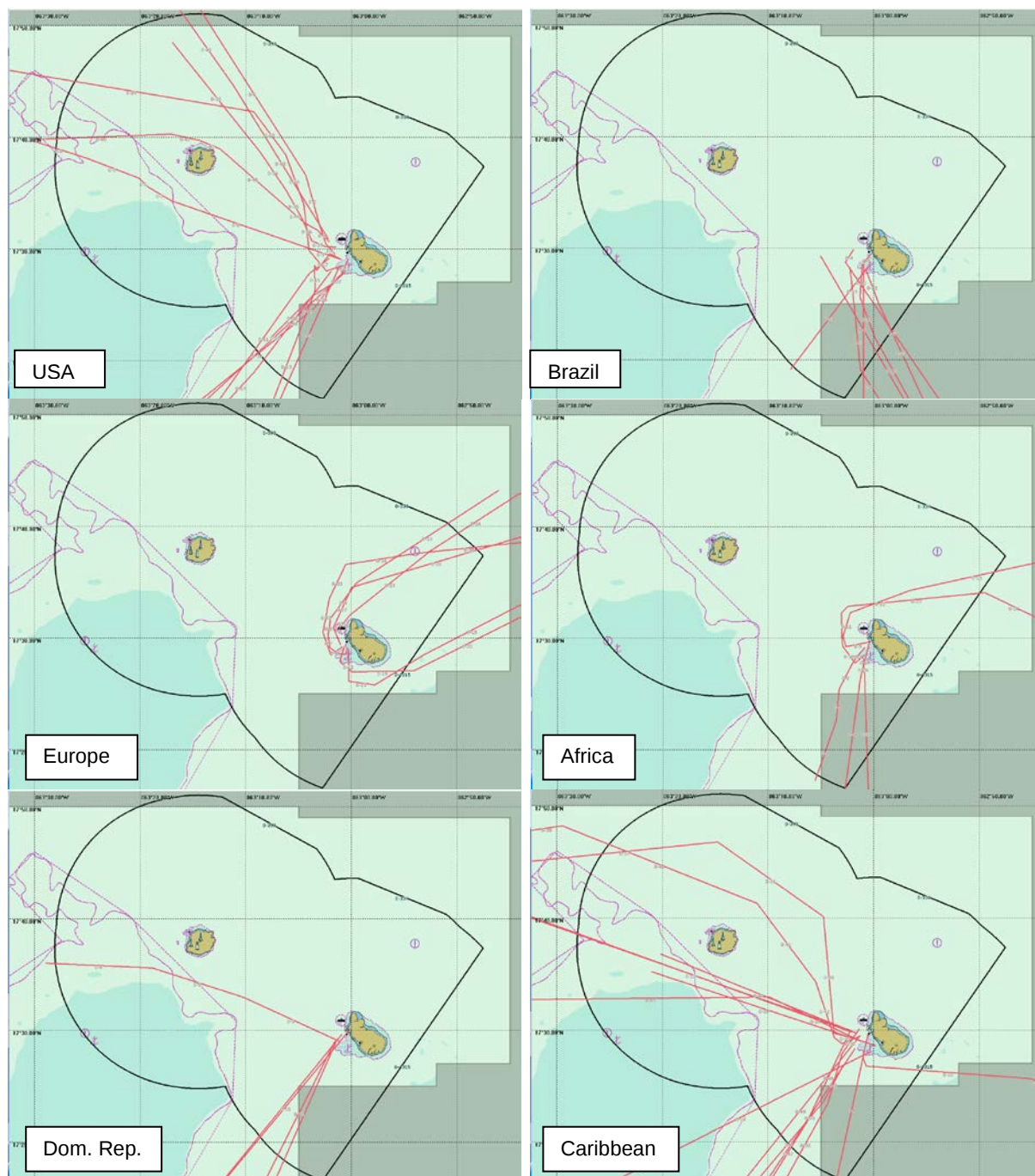
The origins and destinations of the two groups of ships (bunker-only and trans-shipment) are shown in the below figures. For the bunker-only vessels, the majority of the ships came from a location in the Caribbean or the Gulf of Mexico and had a destination on the other side of the Atlantic Ocean. These ships use the terminal apparently as a last stop before the trans-Atlantic voyage.

For the trans-shipment vessels, the majority of the ships started their voyage in the USA. Also a significant part of these ships started and/or continued their voyage in the Caribbean and particularly the Dominican Republic.



**Figure 4-3** Origins and destinations of ships for NUSTAR terminal

Per destination, the chosen routes by the observed ships have been plotted for the part within the territorial waters, see Figure 4-4. It can be noted that for equal destinations different routes are chosen by the vessels. This goes for instance for destinations in the USA, where part of the ships chooses to sail south and the other part north of the islands Puerto Rico, Hispaniola and Cuba. Also close to St. Eustatius different choices are made: of the ships with destination Europe part chooses to sail north and part chooses to sail south of the island.



**Figure 4-4 Chosen routes per origin/destination**

In order to include as much of the diversity as possible, all chosen routes were assembled and 8 main routes were defined, applicable within the territorial waters. The main routes are pictured in Figure 4-5. Because it is known per main route how many ships relatively chose the route, which was their direction and with which purpose they visited the terminal, a traffic database could be created. The starting point at the terminal is a position at the border of the anchorage area.

#### **Moored ship**

The ship moored at the jetty will be taken into account in the risk calculations. In 2010 there was on average 0.745 ship moored at the terminal.

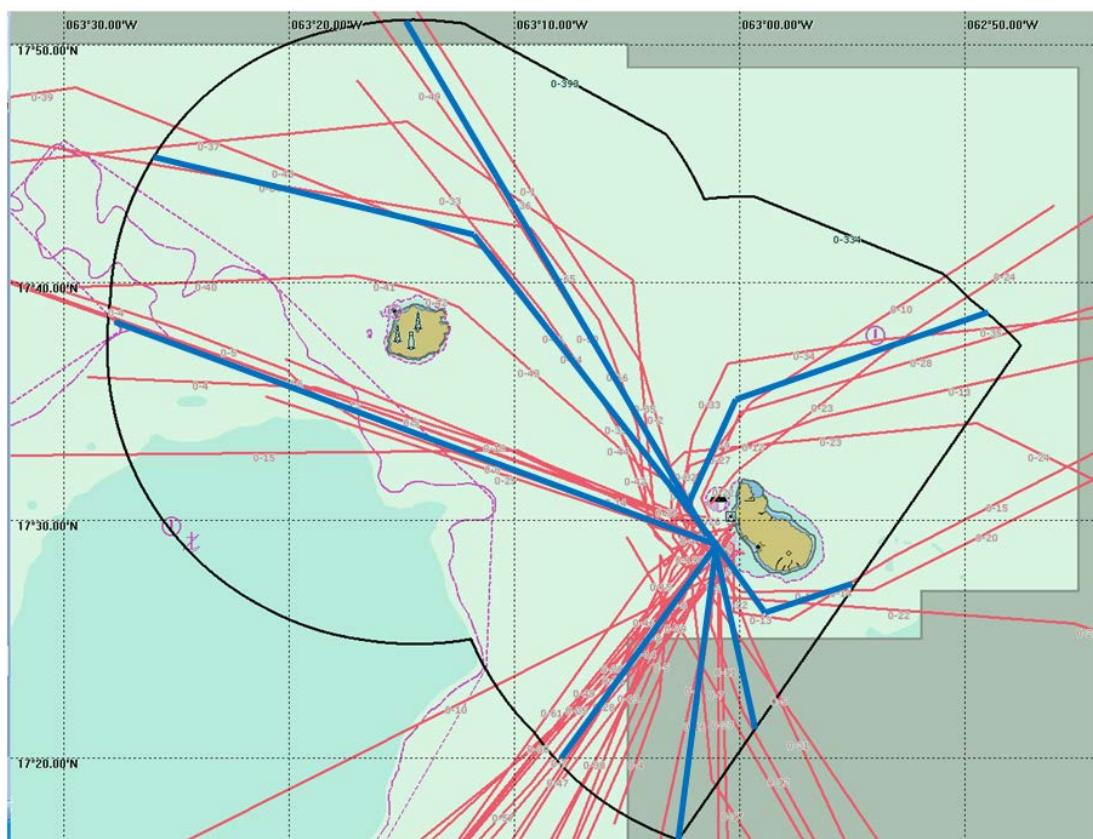


Figure 4-5 Main routes NUSTAR terminal

#### 4.3.2 Cruise

As described earlier, St. Eustatius does not receive cruise ships on a regular basis, but Saba does. Through internet research four cruiselines have been identified which plan voyages to Saba for 2012 with a total of 22 visits. Statistics of the port of Saba are not available for cruise ships as these ships do not actually enter the port. Currently the cruise season is low, and therefore at Saba no cruise ships have been observed through AIS. For this reason, the route structure is primarily based on assumptions based on the cruise schedules, like was done for Bonaire.

#### Traffic composition

At this moment 22 visits are planned for 2012. In order to correct for visits which are not (yet) presented online, or which were not found, 30 annual visits are assumed. Size class distribution has been assumed similar to the one of the vessels in the schedule.

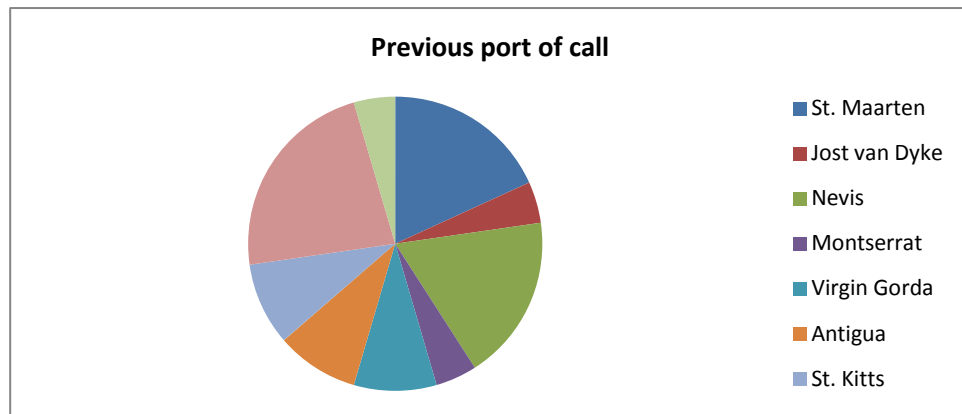
Table 4-3 Shipping matrix cruise vessels Saba

| Type/ GT (tons)  | 3000 - 5000 | 5000 – 10,000 | Total |
|------------------|-------------|---------------|-------|
| Passenger Vessel | 46          | 14            | 60    |

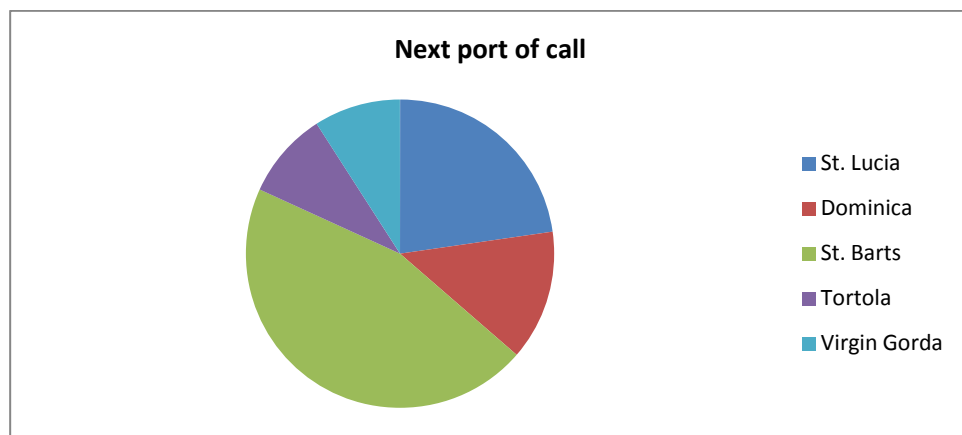
#### Route structure

The definition of the route structure was done in a similar way as for Bonaire: starting point are the previous and next port of call of the vessels which are scheduled to visit Saba in 2012. Then, based on these ports of call and some assumptions the most likely routes were defined.

The previous port of call is not very similar for most vessels. Most vessels come from St. Maarten, Nevis and St. Vincent. The next port of call is in most cases St. Barts.



**Figure 4-6 Previous port of call cruise vessels Saba**



**Figure 4-7 Next port of call cruise vessels Saba**

The ports are grouped into the following categories, regarding the direction and most likely route:

- British Virgin Islands
- St. Maarten
- St. Barts
- Antigua
- St. Kitts & Nevis
- Montserrat
- Islands further south: Dominica, St. Lucia and St. Vincent & The Grenadines

The following assumptions have been done regarding the most likely routes:

- The route between Saba and Antigua passes north of St. Eustatius and St. Kitts
- The route between Saba and St. Maarten passes west of Saba
- The route between Saba and St. Barts passes east of Saba
- Vessels keep a minimal distance of about 2 nm to Saba Bank
- The route structure at Saba starts/ends at the mooring buoy in front of Fort Bay

An overview of the route network is given in Figure 4-8.

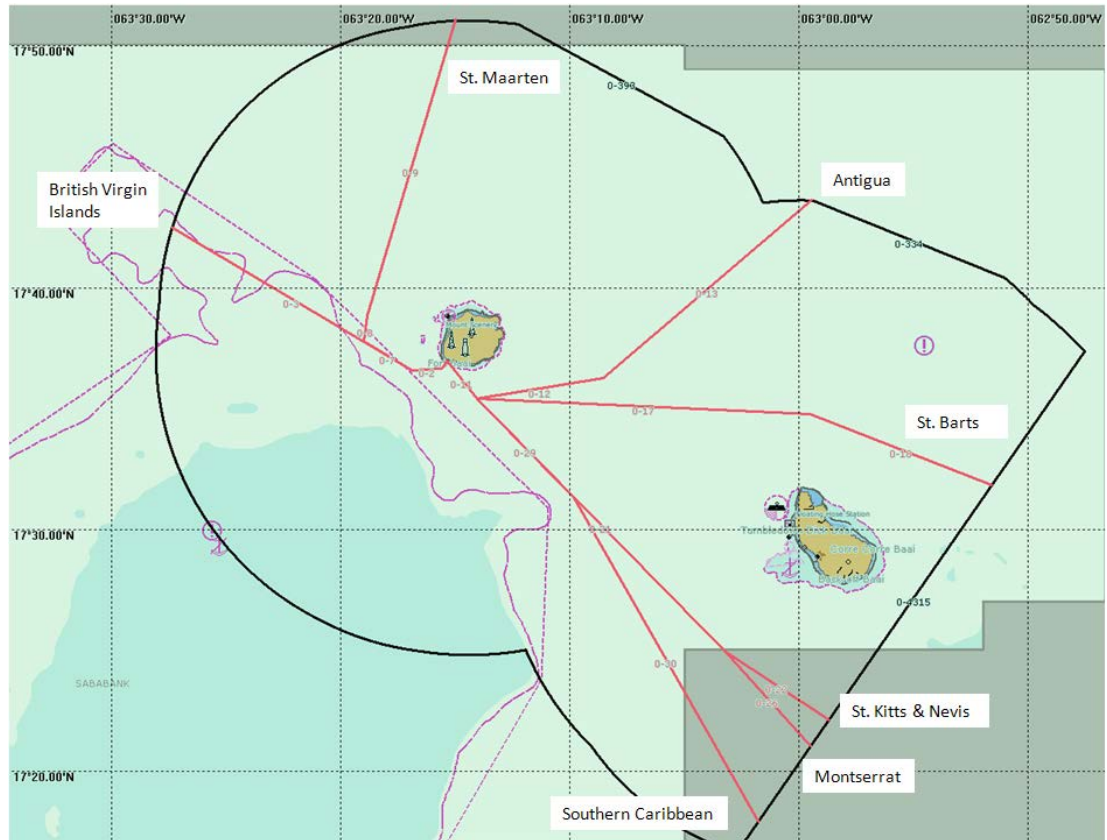


Figure 4-8 Overview cruise routes Saba

#### 4.3.3 Cargo ships and ferries

Supply of both of the islands is done through, mainly, small Ro-Ro vessels. St. Eustatius is in the liner service of several vessels, while Saba mainly is supplied by a single vessel: the Mutty's Pride, which calls at the port every week. Because of this and the fact that Mutty's pride carries AIS, the modelling of cargo ship traffic to Saba is quite straightforward. Furthermore, there are two ferry services calling at Saba. One of the ferries also carries cargo.

For St. Eustatius this is more complicated. However, in [1] it is indicated that the cargo vessels calling at St. Eustatius have a typical trade route: St. Maarten – Puerto Rico – St. Kitts – St. Eustatius – St. Maarten. Their number is in the port statistics.

#### Traffic composition

According to its schedule and observations through, Mutty's Pride enters the port of Saba once a week (52 times per year) and the port of St. Eustatius 2.5 times a week (130 times a year) on average.

According to port statistics [29], Saba is visited annually by 194 cargo vessels and 192 passenger ships. It was found that there are two ferries which connect Saba to St. Maarten on liner service: "Dawn II" and "The Edge". Dawn II travels three times a week (156 times annually), carries up to 50 passengers and is also capable of carrying cargo. The Edge travels 5 times per week (260 times annually) and carries up to 62 passengers. Together these two ships account for 416 calls annually, which is more than the total number of passenger ships. Therefore, it is reckoned that in the port statistics Dawn II is counted as a cargo ship and The Edge as a passenger ship.

St. Eustatius is visited by 250 cargo vessels annually. Therefore, 120 times a year the port is visited by cargo ships other than Mutty's Pride. There are no ferry services which operate a liner service to this island.

It is assumed that all cargo/supply ships are Ro-Ro vessels with a GT of 1600 tons or less. Both of the ferries are classified as SAMSON type Ferries HSF. Both have a GT lower than 1600 tons.

**Table 4-4 Shipping matrix cargo and ferries Saba and St. Eustatius**

| Island        | Type      | 100 – 1600 GT | Total |
|---------------|-----------|---------------|-------|
| Saba          | Ferry HSF | 832           | 936   |
|               | Ro-Ro     | 104           |       |
| St. Eustatius | Ro-Ro     | 500           | 500   |

#### **Route structure**

Mutty's Pride always sails on a fixed schedule when visiting Saba: St. Maarten (Marigot) -> Saba -> St. Eustatius, always in the same direction. By observing live AIS, tracks of this vessel on this specific route could be obtained. Based on these tracks, a link structure was defined.

The ferries to and from St. Maarten are assumed to follow the same route as Mutty's Pride. However, as The Edge does not go to Marigot at St. Maarten but to Simpson Bay and Dawn II to Philipsburg instead, waypoints for the ferries are situated more to the east.

Mutty's Pride was found to be visiting St. Eustatius on the following routes:

- St. Maarten (Philipsburg) - St. Eustatius - St. Kitts (52x per year)
- Saba - St. Eustatius - St. Maarten (Philipsburg) (52x per year)
- St. Kitts - St. Eustatius - St. Croix (26x per year)

From AIS the exact routes of the vessel on these routes could be obtained. The other cargo vessels that visit St. Eustatius are assumed to sail on the "typical route" as indicated above. This means that they sail from St. Kitts to St. Eustatius and consequently to St. Maarten. It is assumed that those ships follow the same route as Mutty's Pride.

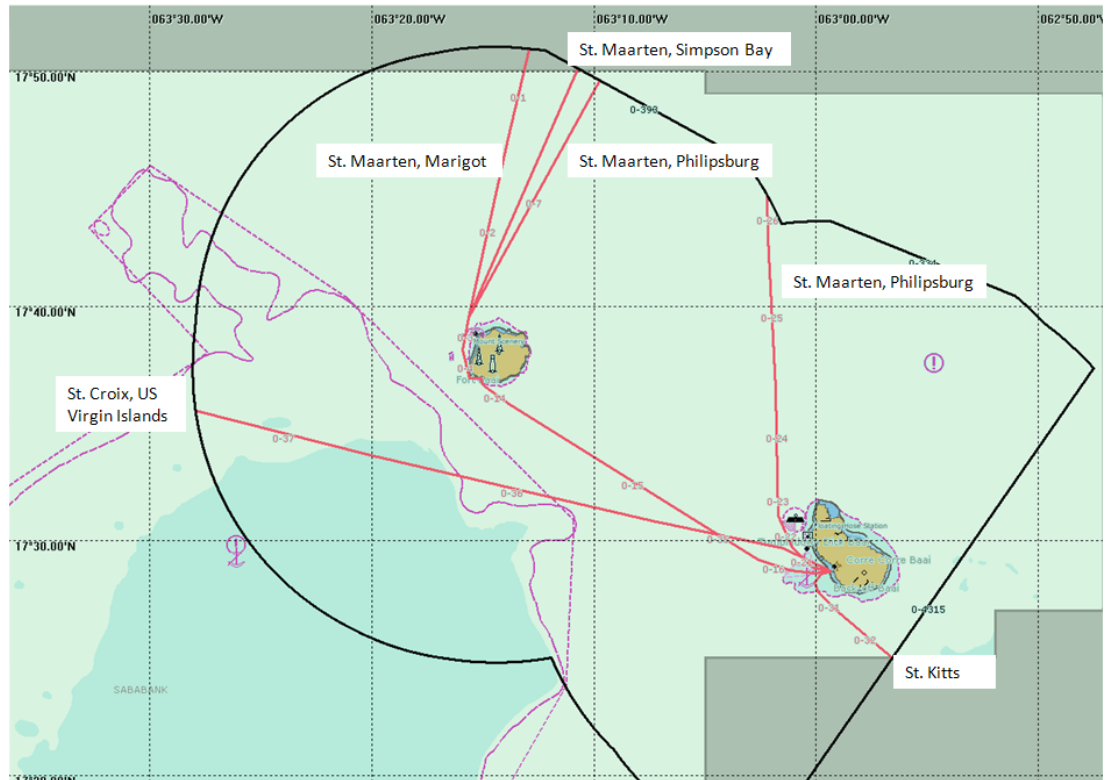


Figure 4-9 Route structure for cargo ships and ferries

#### 4.4 Passing traffic

As the islands are situated in an area with many other small islands, the territorial waters are crossed frequently by cargo and cruise vessels which do not visit any of the two islands. The two groups of ships will now be discussed separately.

##### 4.4.1 Cruise

Based on AIS observations and analyzing the different cruise routes which are indicated in the 2012 schedules, an overview was created of all trajectories for which it is likely that they partly pass through the territorial waters of Saba and St. Eustatius. It was found that there are three main trajectories for which this is the case:

1. Route between St. Kitts/ Nevis and St. Maarten
2. Route between St. Kitts/ Nevis and the British Virgin Islands
3. Route between Antigua and the British Virgin Islands

For other trajectories it is assumed that vessels will maintain a larger distance to the two islands. The trajectories are indicated in Figure 4-10. The pink line indicates the territorial waters. Consequently, the 2012 cruise schedules were matched to the three main routes.



Figure 4-10 Main trajectories for cruise lines accessing territorial waters

#### Traffic composition

Based on the relevant cruise journeys in the 2012 cruise schedules, an estimation could be made of the number of cruise ships on the trajectories as well of the traffic composition.

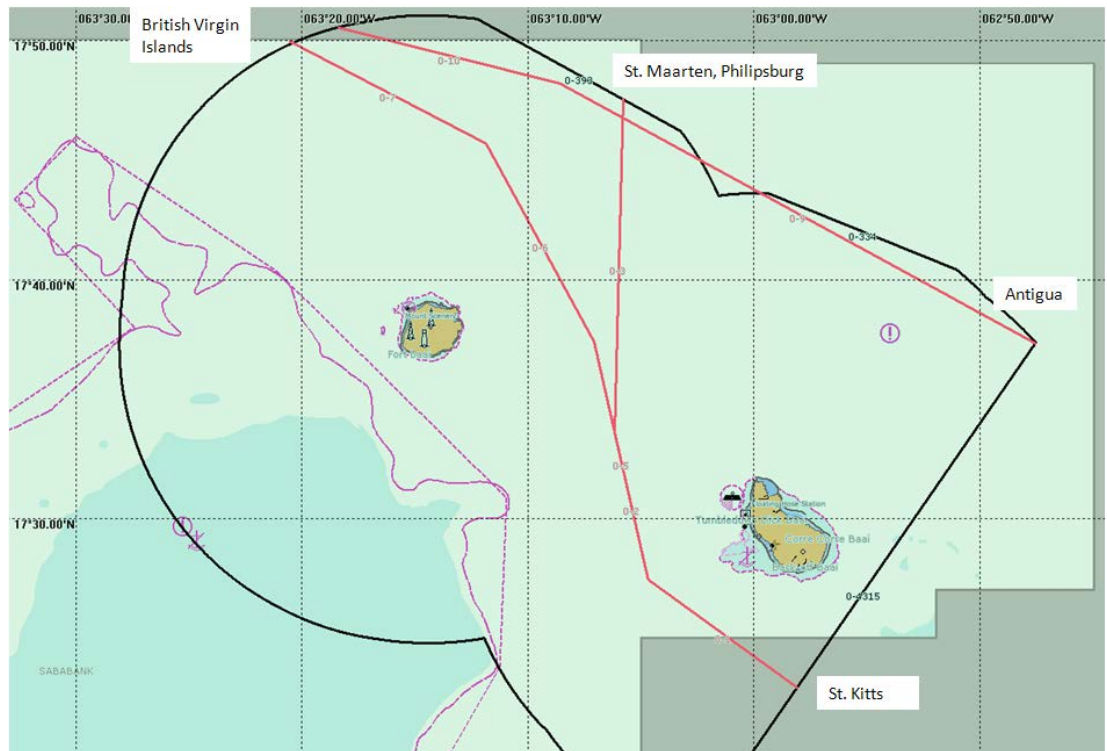
It is difficult to say to which extent the 2012 cruise schedules are complete. Furthermore, the numbers of ships on the three main routes are the result of a manual analyses based on online information. Although this was done with care, it is still very well possible that some cruise journeys are missing. For these reasons a safety margin of 20% will be taken on the numbers of identified ships.

Table 4-5 Shipping matrix passing cruise ships

|                            | 1600-5000 | 5000-10.000 | 10.000-30.000 | 30.000-60.000 | 60.000-100.000 | >100.000 | Total |
|----------------------------|-----------|-------------|---------------|---------------|----------------|----------|-------|
| St. Kitts – St. Maarten    | 6         | 8.4         | 3.6           | 1.2           | 19.2           | 26.4     | 64.8  |
| St. Kitts – Virgin Islands | 3.6       | 3.6         | 18            | 1.2           | 21.6           | 52.8     | 100.8 |
| Antigua – Virgin Islands   | 3.6       | 2.4         | 0             | 25.2          | 18             | 0        | 49.2  |
| Total                      | 13.2      | 14.4        | 21.6          | 27.6          | 58.8           | 79.2     | 214.8 |

#### Route structure

On these routes some cruise vessels have been observed through AIS. Based on these observations the waypoints for the route structure were determined. These are indicated in Figure 4-11.



**Figure 4-11** Route structure for cruise ships around Saba and St. Eustatius

#### 4.4.2 Cargo ships

For cargo vessels on the following trajectories it is observed that they regularly enter the territorial waters:

- St. Maarten - St. Kitts
- St. Maarten - Guadeloupe
- British Virgin Islands/ USA - St. Kitts
- British Virgin Islands/ USA - Antigua

Probably this is also the case for some vessels on other trajectories but this has not been observed. As there is no information on these ships they have been left out of consideration.

It was found that vessels of the first two groups more or less use the same route. Therefore, they will be discussed together.

As for these ships no schedules are publicly available, their numbers have been estimated using other data sources. From the ports of St. Maarten, St. Kitts and Antigua port statistics have been obtained. Then an estimation was done of the proportion of ships which sails on the relevant routes. It is a very rough method of estimation, however more detailed information is currently lacking. In the estimation safety margins are taken in order to be on the safe side.

## Traffic composition

*St. Maarten – St. Kitts/ Guadeloupe*

According to the website of the port of St. Maarten [32], in the months July to September 2011, 266 cargo vessels called at the port. Assuming that these months are representative, this means an annual number of 1064 vessels.

The website marinetraffic.com has a function which displays all ships that called at a specific port in the past week. This function was used to estimate the share of the vessels that either came from or went to the ports of St. Kitts or Guadeloupe. Out of the 21 vessels that called at St. Maarten in the week of 18 September, 9 used the route to/from St. Kitts and Guadeloupe.

Because the available data is limited and to not underestimate the number of vessels, it is assumed that in fact 50% of the ships uses the relevant route either on arrival or at departure. This accounts for 542 vessels annually. It is assumed that the route is used equally often in both directions.

*British Virgin Islands/ USA - St. Kitts*

According to website of the Caribbean Shipping Association [33], annually 1150 ships call at the port of Basseterre, St. Kitts. 203 of those are cruise ships: these should not be included. This leaves 947 ships annually.

During the week of 18 September 2011, 2 out of the 4 ships registered by marinetraffic.com used the route in the direction of the British Virgin islands directly before or after the visit to St. Kitts. If it is assumed that this is in fact 2/3 of the ships, 632 ships use the route either at arrival or departure.

*British Virgin Islands/ USA - Antigua*

In 2010 252 "international vessels", 254 "interisland vessels", 110 tankers and 4 "military vessels" called at the port of St. John's at Antigua [34]. These ships are assumed to correspond to the "cargo vessels" of the other two ports.

In the week of 18 September, 7 ships called at St. John's. Two of those both came from the direction of the British Virgin Islands and also departed in this direction. For one ship the previous and next port of call were not known. Assumed is that 50% of all routes to and from Antigua lead through the territorial waters of Saba and St. Eustatius. Therefore an average of one relevant route per visiting ship is used in the traffic database.

As the definition of ships types is different for the used statistics and not much is known about which ships take which route, it is not straightforward to make assumptions on the distribution. However, some characteristics can be derived based on the data:

- A significant part of all three data sets consist of small Ro-Ro or interisland vessels
- Other relevant ship types are GDC, container ships and tankers

The ships which have been identified as a ship sailing on one of the relevant routes, were all either Ro-Ro or container ships. Therefore, it is assumed that 75% of the ships are Ro-Ro vessels and 25% container ships. The Ro-Ro ships are assumed to have a GT of 100-1600 tons and the container ships have a GT of 5000 – 10,000 tons. All identified vessels fall within these ranges.

**Table 4-6 Shipping matrix passing cargo ships Saba/ St. Eustatius**

| Route                                   | Type/ GT  | 100-1600 | 5000-10,000 | Total |
|-----------------------------------------|-----------|----------|-------------|-------|
| St. Maarten – St. Kitts/ Guadeloupe     | Ro-Ro     | 406.5    |             |       |
|                                         | Container |          | 135.5       | 542   |
| British Virgin Islands/ USA - St. Kitts | Ro-Ro     | 474      |             |       |
|                                         | Container |          | 158         | 632   |
| British Virgin Islands/ USA - Antigua   | Ro-Ro     | 465      |             |       |
|                                         | Container |          | 155         | 620   |
| Total                                   |           | 1346     | 449         | 1795  |

### Route structure

The routes on the different trajectories are different for those ships than for the cruise ships as in the previous section. The main differences are the following:

- On the trajectory between St. Kitts and St. Maarten sometimes St. Eustatius is passed on the east instead of the west
- On the trajectory between the British Virgin Islands and St. Kitts some vessels cross Saba Bank
- For the trajectory between the British Virgin Islands and Antigua different routes are used

Some examples from marinetraffic.com are shown below.



**Figure 4-12** Examples of tracks from marinetraffic.com

Roughly, four main routes can be distinguished:

1. A trajectory between St. Maarten and St Kitts/ Guadeloupe, passing east of St. Eustatius
2. A trajectory between St. Maarten and St Kitts/ Guadeloupe, passing west of St. Eustatius
3. A route south of both islands, crossing Saba Bank
4. A route north of both islands

Analysis of the ships which sailed between St. Maarten and St. Kitts/ Guadeloupe showed that the small Ro-Ro ships typically choose the eastern route, while the somewhat larger container ships choose the western route just like the cruise ships. As this finding makes sense, with respect to the sizes of the ships, it has been assumed that all Ro-Ro ships choose the route east of St. Eustatius and that the containerships choose the route on the west. A similar effect can be noted for the route over Saba Bank: it appears that only the smaller routes pick this route while the larger ships choose the route north of the islands. Therefore this will also be used as an assumption.

Based on the tracks of the different observed vessels, a route structure was defined. See Figure 4-13.

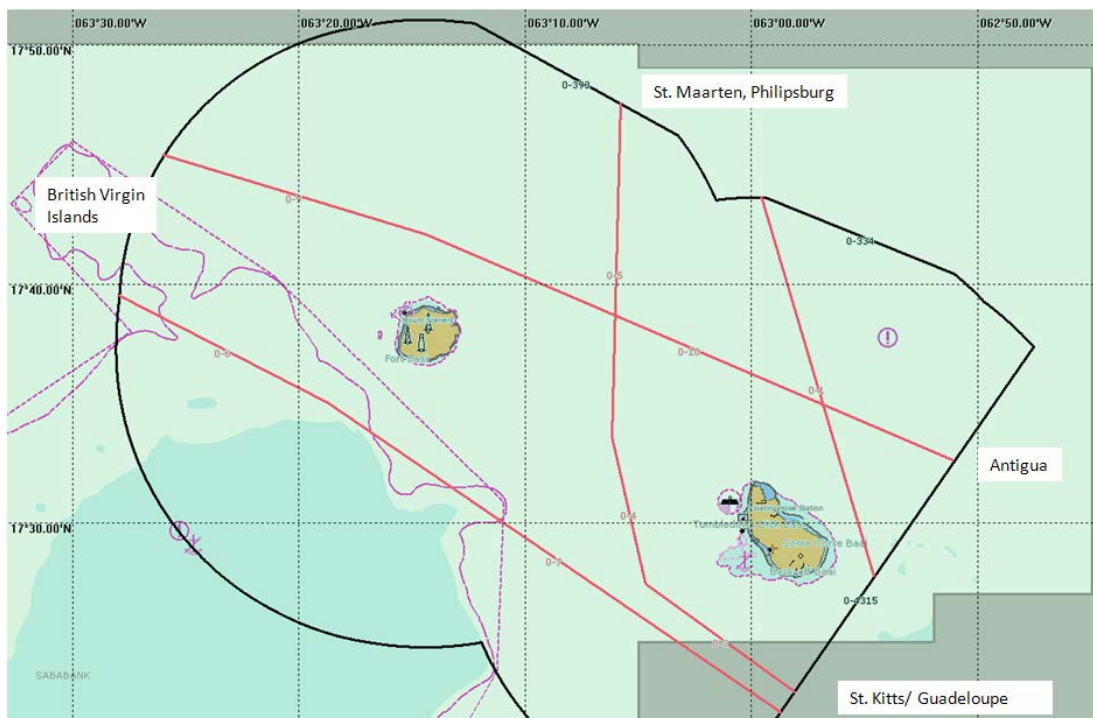


Figure 4-13 Route structure for cargo ships around Saba/ St. Eustatius

#### 4.5 Overview route structure

An overview of all routes in the territorial waters is presented in Figure 4-14. The anchorage area near St. Eustatius is marked black.

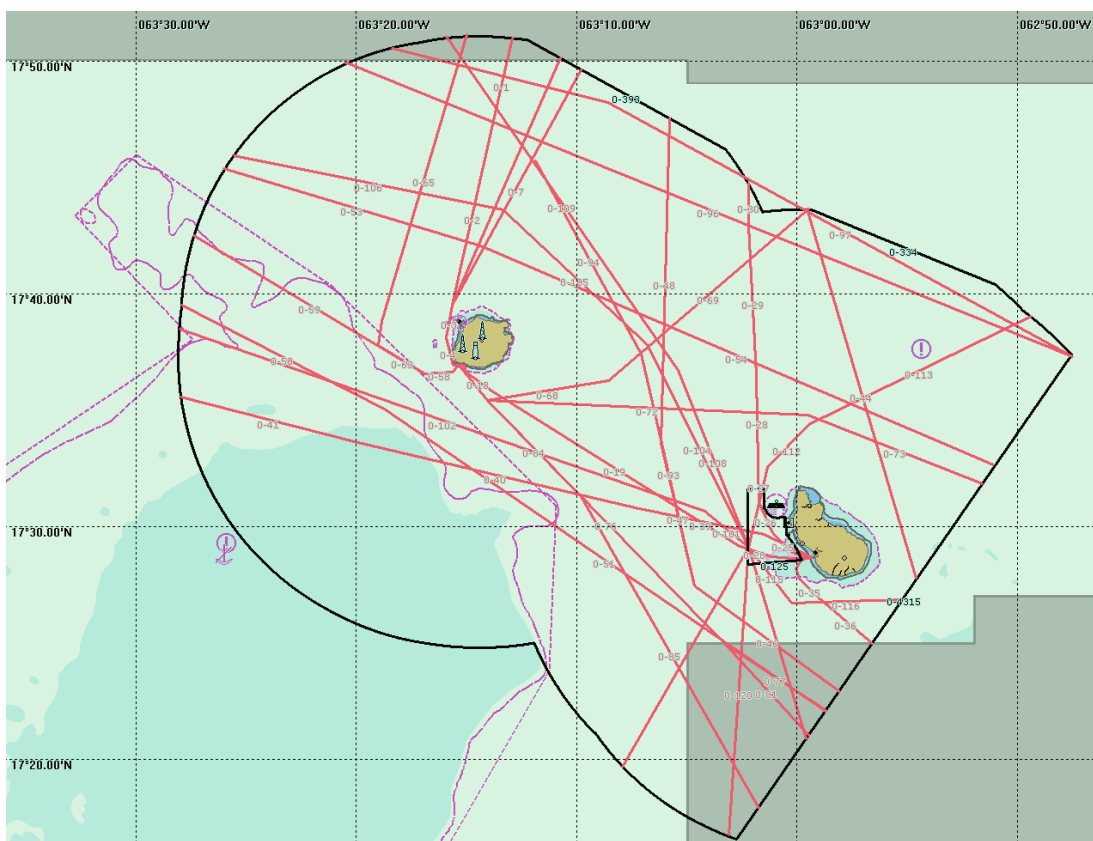


Figure 4-14 Overview route structure Saba and St. Eustatius

## 5 QUANTITATIVE RISK ASSESSMENT

### 5.1 Introduction

Initially, the main purpose of this study was to perform a quantitative risk assessment (QRA) for nautical accidents in the area. In this chapter a short description of such an analysis is given and it is indicated why it has been decided not to perform such an analysis at this stage. The chapter concludes with some requirements for a successful QRA in the future.

The main objective of QRA for the outflow of oil is to calculate the following matters (based on the traffic data):

- The probability of a nautical accident and the probability of outflow of cargo oil as a result of the accident;
- The probability of a nautical accident and the probability of outflow of bunker oil as a result of the accident.

The outflow frequencies can be determined for different outflow classes. The total outflow can be given for some larger areas, but also the outflow probability per grid cell will be determined (standard 8x8 km) for visualisation purposes.

The main approach for the quantitative risk assessment study, to the outflow of oil, consists of two main steps:

1. Determine the main transport routes of oil in the whole area;
2. Calculate the outflow probabilities for the cargo and bunker oil.

### 5.2 SAMSON

MARIN calculates the collision and outflow probabilities using the SAMSON-model: Safety Assessment Models for Shipping and Offshore in the North Sea. The model was developed for the Dutch ministry of Transport, Public Works and Water Management and is used for the calculation of frequencies and consequences of all sorts of accidents at sea. See references [1] – [9].

Most of the blocks of the system diagram of the maritime traffic system, as presented in Figure 5-1, are modelled in the SAMSON-model. The large block “Maritime traffic system” contains four sub-blocks. These blocks describe the traffic situation; the number of movements, the ship characteristics and the lay-out of the sea area. The accident models for collisions, stranding and fire/explosions etc. are used to calculate the frequency of the accidents based on the traffic situation. The large block “Impact” contains the sub-blocks which are used to determine the consequences of the accidents. The model parameters are determined by an analysis of the worldwide accident database 1990-2006 of Lloyds’ Register Fairplay (currently IHS Fairplay).

A detailed description of SAMSON is provided in Appendix B.

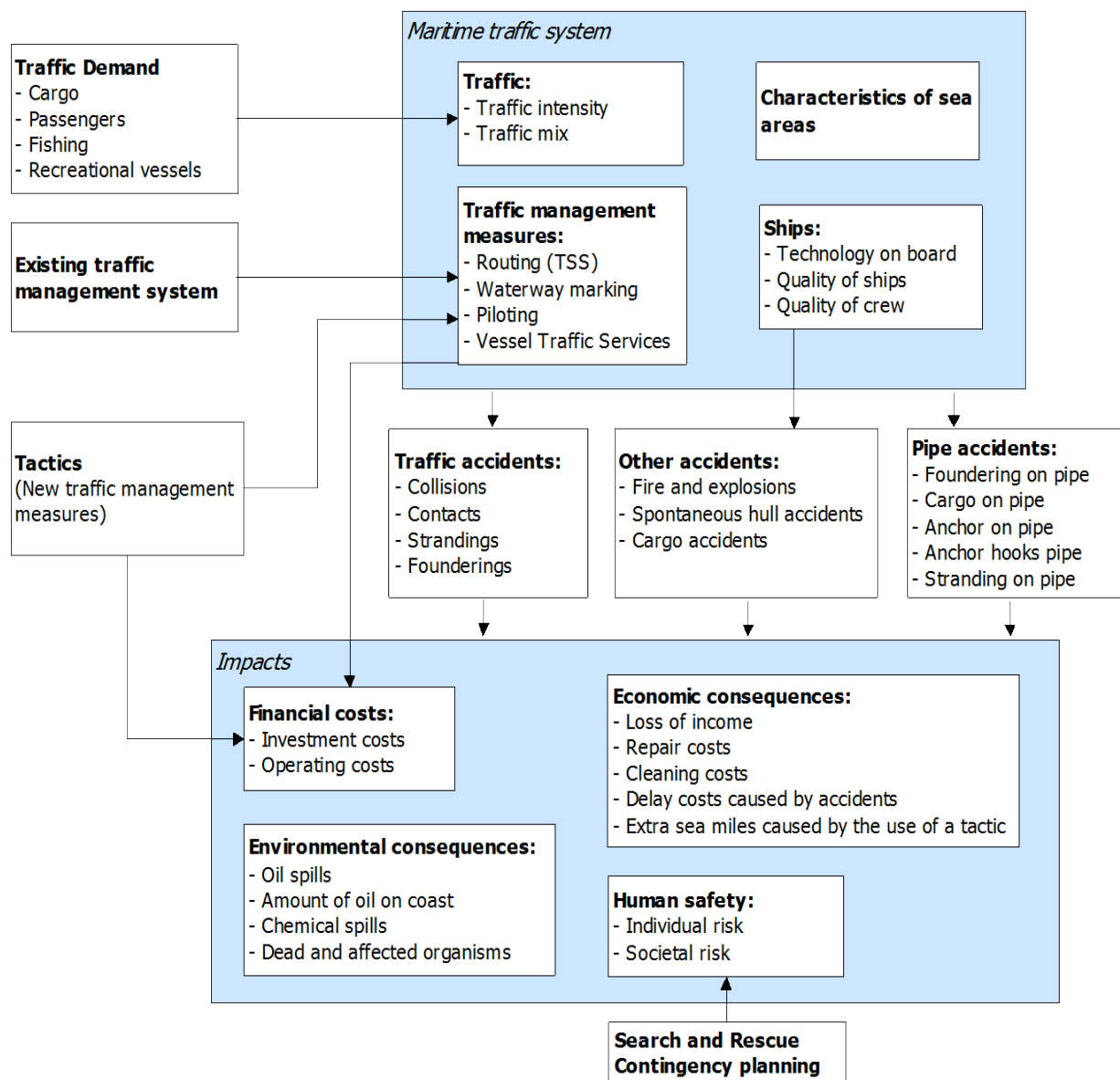


Figure 5-1 System Diagram SAMSON

### 5.3 Application of QRA for the Dutch Caribbean

The analysis of the traffic streams has indicated the following issues:

- Ship traffic in the Caribbean is not committed to Traffic Separation Schemes or other types of traffic lanes. The analysis has shown that there also does not exist any “informal” traffic lanes. Because of the absence of such infrastructure, a proper model of ship traffic therefore requires detailed information on the positions of ships in the area and the routes chosen by ships.
- It was assumed at the start of the study that when the study area would be reduced to the size of the territorial waters of the islands, all “non-destination traffic” would automatically be eliminated from the analysis. Because it was assumed that “non-destination traffic” would not sail in the territorial waters. The analysis has shown that this is not the case. Especially close to Bonaire large numbers of ships pass very close to the island without visiting. Therefore these groups play an important role in the risk assessment.

- AIS or radar data is not available for the areas under consideration.
- Other types of data sources, like port statistics, can be used in order to indicate the main traffic streams close to the islands. However, data on the exact positions of ships are lacking so the exact used routes are hard to identify.
- Finally, the AIS data which was used in the analysis was only covering several weeks in a non-representative time of year: hurricane season.

These issues lead to a first estimate of a traffic database, which is based on some very rough assumptions. There is a large extent of uncertainty in especially the routes and also in the number of ships that do not visit the islands.

The traffic model is critical input when calculating nautical risk, as accident frequencies are directly related to the traffic intensity and the number of encounters between ships. It is possible to run a calculation using the first version of the traffic database, however, if this model is not a correct representation of reality, the results will be likewise. It is MARIN's opinion that the current knowledge on traffic streams in the area is insufficient for a proper quantitative risk assessment. Therefore, in agreement with RWS it has been decided to do a qualitative risk assessment instead.

This qualitative risk assessment does not produce numbers of specific risks, but uses the available knowledge of the traffic situation in combination with knowledge on nautical safety in order to pinpoint the main risks in both regions. This can provide some indication on which areas induce the highest risk.

It has also been agreed that the qualitative risk assessment will not only focus on the outflow of oil but also on the risk of loss of life with respect to cruise ships. In order to provide some insight in the actual accident statistics in this area, a short analysis of the IHS Fairplay casualty database for accidents in the Caribbean is performed as well.

#### **5.4 Requirements for future QRA**

In order to perform a representative QRA in the future it is regarded necessary to collect AIS and/or radar data of the area. A substantial dataset will allow the construction of a route network with appropriate indications of the number of ships travelling on each route and an indication of how the distribution of ships over these routes is.

Another type of data which is required to make a good estimation of the outflow of oil is detailed information on the import and export of oil at both BOPEC and NUSTAR terminal as well as the main trade routes used by the ships visiting these terminals. This information will provide realistic assumptions on the amount of oil transported by ships over the different routes.

## 6 ACCIDENT STATISTICS

In order to get some insight in the total number of accidents in the region under consideration, the accidents reported for this region in the IHS Fairplay casualty database 2008-2010 are analysed. The IHS Fairplay database contains all accidents worldwide, which are assigned to a grid. For each accident it is specified whether it has resulted in pollution or fatalities. The focus in the accident analysis is on the main risks considered in this study: outflow of oil as a consequence of nautical accidents and loss of life as a consequence of cruise ship accidents.

First, in section 6.1 the total accident numbers for the region are presented. Then, in section 6.2 the consequences of these accidents with regard to pollution are specified. The same is done with respect to fatalities in section 6.3.

### 6.1 Total accident numbers

The reported accidents are each assigned to a grid cell. The grid cells which are selected for the analysis are indicated in Figure 6-1. As the coordinates of the location of the accidents are not further specified in the database, this is the most specific representation of the location of the accidents.

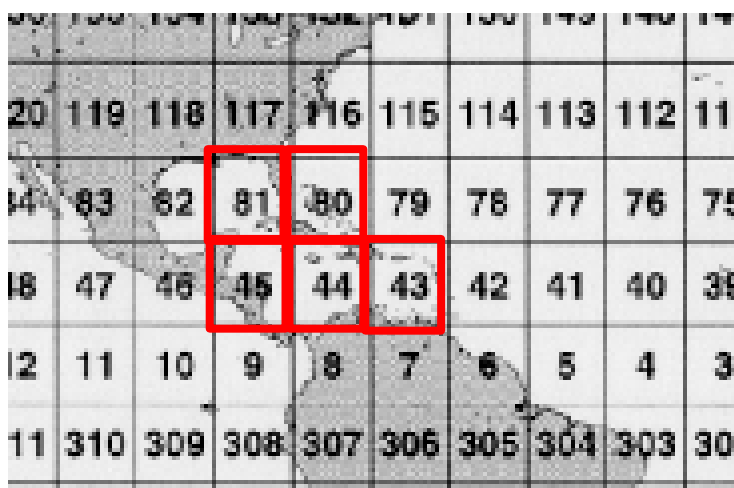


Figure 6-1 Overview of the selected grid numbers

The accidents are divided into groups of accidents which happened at a similar location: at sea, on a river, in port or in constricted waters. This division is presented in Table 6-1. It can be seen that 47 accidents happened at open sea, while 62 were reported to have happened in port. In the remainder of the analysis only the accidents which happened “at sea” are taken into account.

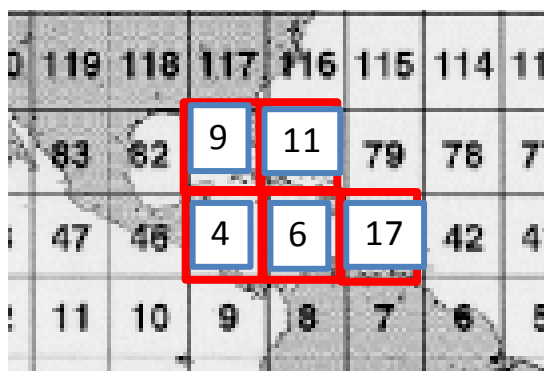
For the grid cells as indicated in Figure 6-1, the numbers of accidents “at sea” in each cell are presented in Table 6-2 and Figure 6-2.

**Table 6-1 All reported ships involved in an accident in the marked grid cells in 2008-2010**

| Accident type        | Type of sea-area where the accident occurred |                 |                                  |                   |            |
|----------------------|----------------------------------------------|-----------------|----------------------------------|-------------------|------------|
|                      | AT SEA                                       | ESTUARY / RIVER | IN PORT / HARBOUR / DOCK / AT... | RESTRICTED WATERS | Total      |
| Collision            | 4                                            | 1               | 16                               | 1                 | 22         |
| Contact              | 2                                            |                 | 6                                |                   | 8          |
| Foundering           | 10                                           |                 | 3                                |                   | 13         |
| Fire/Explosion       | 3                                            |                 | 7                                | 1                 | 11         |
| Hull/Machine failure | 18                                           |                 | 10                               |                   | 28         |
| Wrecked/Stranded     | 10                                           | 9               | 20                               | 2                 | 41         |
| <b>Total</b>         | <b>47</b>                                    | <b>10</b>       | <b>62</b>                        | <b>4</b>          | <b>123</b> |

**Table 6-2 Number of ships involved in an accident "AT SEA", for the different grid-cells**

| Accident type        | Grid cell number |          |          |           |          |           |
|----------------------|------------------|----------|----------|-----------|----------|-----------|
|                      | 043              | 044      | 045      | 080       | 081      | Total     |
| Collision            | 1                | 1        |          |           | 2        | 4         |
| Contact              |                  |          |          | 1         | 1        | 2         |
| Foundering           | 5                | 2        |          | 3         |          | 10        |
| Fire/Explosion       | 1                |          |          |           | 2        | 3         |
| Hull/Machine failure | 7                | 2        | 3        | 4         | 2        | 18        |
| Wrecked/Stranded     | 3                | 1        | 1        | 3         | 2        | 10        |
| <b>Total</b>         | <b>17</b>        | <b>6</b> | <b>4</b> | <b>11</b> | <b>9</b> | <b>47</b> |


**Figure 6-2 Number of ships involved in an accident "AT SEA" in the different grid cells (2008-2010)**

The accidents have been further specified for ship types and accident types. The acronyms of the accident types have the following meaning:

CN: Collision

CT: Contact

FD: Foundering

FX: Fire/Explosion

HM: Hull/Machinery Failure

WS: Wrecked/Stranded

It can be seen that four of the accidents involved a passenger ship of some type and three involved a tanker.

**Table 6-3** Number of ships involved in an accident "AT SEA" per ship type and accident type (2008-2010)

| Ship type                  | Number of ships involved per accident type |          |           |          |           |           |           |
|----------------------------|--------------------------------------------|----------|-----------|----------|-----------|-----------|-----------|
|                            | CN                                         | CT       | FD        | FX       | HM        | WS        | Total     |
| BULK CARRIER               | 1                                          |          |           | 1        | 2         | 1         | 5         |
| CONTAINER SHIP             |                                            |          | 1         |          | 3         |           | 4         |
| CREWBOAT                   |                                            |          |           |          |           | 1         | 1         |
| FERRY                      |                                            |          |           |          |           | 1         | 1         |
| FISHING                    |                                            |          | 2         |          | 1         | 1         | 4         |
| GENERAL CARGO              |                                            |          | 5         |          | 9         | 3         | 17        |
| LIQUEFIED GAS TANKER       | 1                                          |          |           | 1        |           | 1         | 3         |
| OPEN HATCH CARGO SHIP      |                                            | 1        |           |          |           |           | 1         |
| PASSENGER                  |                                            |          |           |          | 2         |           | 2         |
| PASSENGER/RORO CARGO/FERRY |                                            |          |           |          | 1         |           | 1         |
| PLATFORM, SEMI-SUBMERSIBLE |                                            |          |           | 1        |           |           | 1         |
| SUPPLY SHIP (O.R.S.V.)     |                                            | 1        |           |          |           |           | 1         |
| TANKER                     | 1                                          |          |           |          |           | 2         | 3         |
| TUG                        | 1                                          |          | 1         |          |           |           | 2         |
| YACHT                      |                                            |          | 1         |          |           |           | 1         |
| <b>Total</b>               | <b>4</b>                                   | <b>2</b> | <b>10</b> | <b>3</b> | <b>18</b> | <b>10</b> | <b>47</b> |

## 6.2 Pollution

In Table 6-4 it is specified per grid cell for how many accidents pollution was reported. In Table 6-5 these accidents have been specified for accident type and in Table 6-6 this was done for ship types. The fact that no pollution was reported does not necessarily mean that there was no pollution. It can be stated that at least 4 vessels were involved in an accident resulting in pollution. Two of these ships were involved in a contact, one in a case of fire/explosion and one was wrecked/stranded. None of the ships was a tanker.

**Table 6-4** Number of accidents with and without reported pollution

|                       | Total number of ships involved in an accident "AT SEA" per grid cell |          |          |           |          |           |
|-----------------------|----------------------------------------------------------------------|----------|----------|-----------|----------|-----------|
|                       | 043                                                                  | 044      | 045      | 080       | 081      | Total     |
| Pollution reported    |                                                                      |          |          | 1         | 3        | 4         |
| No pollution reported | 17                                                                   | 6        | 4        | 10        | 6        | 43        |
| <b>Total</b>          | <b>17</b>                                                            | <b>6</b> | <b>4</b> | <b>11</b> | <b>9</b> | <b>47</b> |

**Table 6-5** Type of accidents when pollution reported (only AT SEA; 2008-2010)

| Accident type      | Total number of ships reported pollution after accident "AT SEA" |          |          |
|--------------------|------------------------------------------------------------------|----------|----------|
|                    | 080                                                              | 081      | Total    |
| Contact            | 1                                                                | 1        | 2        |
| Fire / Explosion   |                                                                  | 1        | 1        |
| Wrecked / stranded |                                                                  | 1        | 1        |
| <b>Total</b>       | <b>1</b>                                                         | <b>3</b> | <b>4</b> |

**Table 6-6 Type of accidents and ship type when pollution reported (only AT SEA; 2008-2010)**

| Ship type                  | Number of ships reported pollution after accident "AT SEA" |          |          |          |
|----------------------------|------------------------------------------------------------|----------|----------|----------|
|                            | CT                                                         | FX       | WS       | Total    |
| BULK CARRIER               |                                                            |          | 1        | 1        |
| OPEN HATCH CARGO SHIP      | 1                                                          |          |          | 1        |
| PLATFORM, SEMI-SUBMERSIBLE |                                                            | 1        |          | 1        |
| SUPPLY SHIP (O.R.S.V.)     | 1                                                          |          |          | 1        |
| <b>Grand Total</b>         | <b>2</b>                                                   | <b>1</b> | <b>1</b> | <b>4</b> |

### 6.3 Loss of life

Table 6-7 shows that 45 of the ships involved in accidents did not report any loss of life. Two of the ships did, where one of the vessels lost 9 persons and the other 11. Table 6-8 then shows that the first vessel was a bulk carrier and the latter was actually not a ship but a drilling platform.

**Table 6-7 Number of accidents with and without reported fatalities**

|                    | Total number of ships involved in an accident with reported fatalities "AT SEA" per grid cell |          |          |           |          |           |
|--------------------|-----------------------------------------------------------------------------------------------|----------|----------|-----------|----------|-----------|
|                    | 043                                                                                           | 044      | 045      | 080       | 081      | Total     |
| <b>No</b>          | 16                                                                                            | 6        | 4        | 11        | 8        | 45        |
| <b>Yes (Total)</b> | 1                                                                                             |          |          |           | 1        | 2         |
| 9 persons          | 1                                                                                             |          |          |           |          | 1         |
| 11 persons         |                                                                                               |          |          |           | 1        | 1         |
| <b>Total</b>       | <b>17</b>                                                                                     | <b>6</b> | <b>4</b> | <b>11</b> | <b>9</b> | <b>47</b> |

**Table 6-8 Type of accidents and ship type when fatalities reported (only AT SEA; 2008-2010)**

| Ship type                  | Number of persons reported killed in accidents "AT SEA" |          |          |
|----------------------------|---------------------------------------------------------|----------|----------|
|                            | 9                                                       | 11       | Total    |
| BULK CARRIER               | 1                                                       |          | 1        |
| PLATFORM, SEMI-SUBMERSIBLE |                                                         | 1        | 1        |
| <b>Total</b>               | <b>1</b>                                                | <b>1</b> | <b>2</b> |

### 6.4 Conclusions

An analysis was done of accident statistics for the entire Caribbean region for the period 2008-2010. In this period 123 vessels were involved in accidents in this region, of which 47 at open sea. Four vessels were involved in accidents at open sea resulting in pollution and two vessels were involved in accidents resulting in a loss of life. Three tankers and four passenger vessels were involved in accidents.

## 7 QUALITATIVE RISK ASSESSMENT BONAIRE

In this chapter a qualitative risk assessment is performed for the region around Bonaire. The purpose of this assessment is to make an inventory of the risks with regard to oil spills and loss of life as a consequence of accidents with cruise vessels and to identify areas which have an increased risk level.

In the first section an overview is given of the location and traffic situation around the island of Bonaire. In this section the main findings from Chapter 3 are summarized. In section 0 the risk assessment for the outflow of oil is presented and the same is done for loss of life in section 7.3.

### 7.1 Overview location and traffic situation

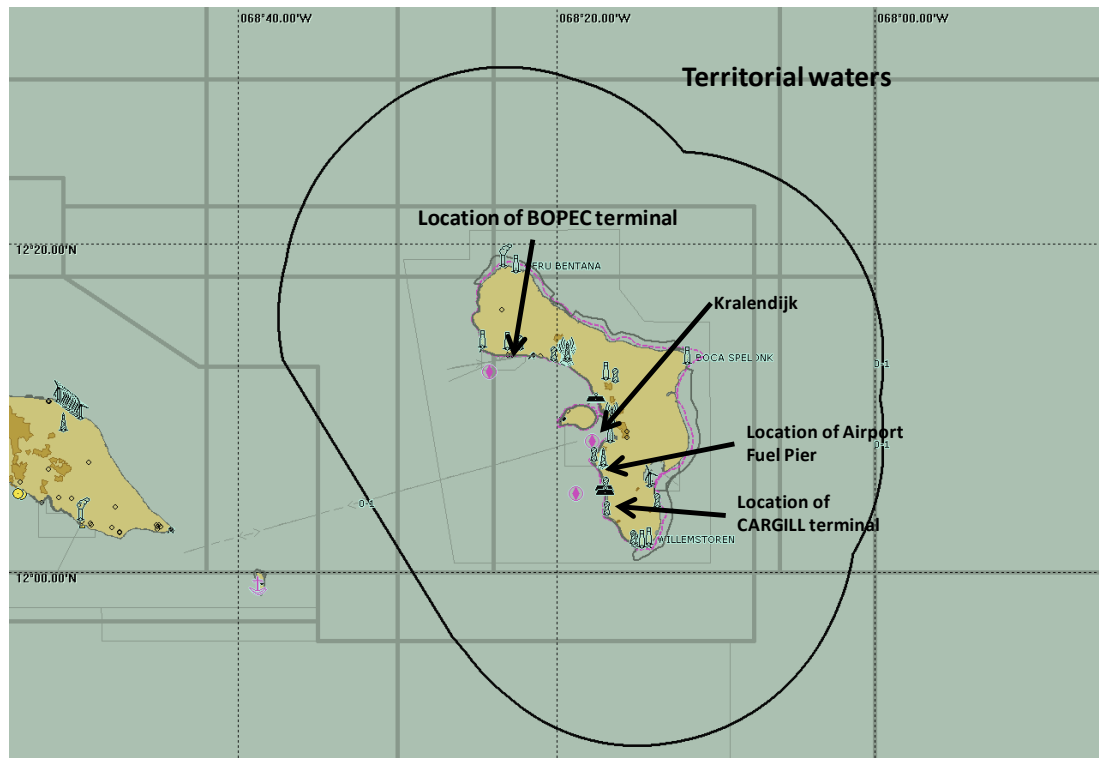
Bonaire is situated north of the coast of Venezuela, east of the island of Curacao, as indicated in Figure 7-1. The island has four “port” areas:

- The commercial port of Kralendijk, used by cruise vessels and cargo ships
- BOPEC terminal, used for loading/offloading and storage of oil products
- The Airport fuel pier, visited every two weeks by a tanker with kerosene supplies for the airport
- CARGILL salt terminal, visited by cargo ships for the export of salt

The port areas are indicated in Figure 7-2.



Figure 7-1 Overview location Bonaire



**Figure 7-2 Overview of the port areas at Bonaire**

In Chapter 3 the total numbers of ship calls per year were determined for each of the port areas for the different types of ships. It was also investigated which are typical routes taken by each group of ships. The findings are summarized below.

**Port of Kralendijk:**

- 143 cruise ships, using a variety of routes
- 51 Ro-Ro cargo vessels to supply the island: these relatively small ships arrive and departure in the direction of Curacao

**BOPEC terminal:**

- 229 oil tankers of which:
  - o 196 smaller tankers importing oil from the direction of Curacao
  - o 32 larger tankers exporting oil typically into the direction of Asia

**Airport fuel pier:**

- 26 kerosene tankers (3500 ton) importing kerosene from the direction of Curacao

**CARGILL salt terminal:**

- 48 GDC ships, both arriving and departing in the direction of Europe

Next to the ships calling at the island of Bonaire there is also a category of ships that do not visit the island but do cross the territorial waters. A main traffic route is the route on the north side of the island, which appears to be mainly used by ships on a route from the Panama Canal in eastward direction. Based on some assumptions the number of ships on this route is estimated to be 1500 ships per year. Not all of these ships do actually enter the territorial waters of Bonaire.

The exact route taken by these vessels is uncertain. In the analysis of AIS-data some of the tracks could be identified. However these tracks are situated on the border of the AIS coverage. Therefore it is not known how many ships were not identified.

There are also some ships pass the waters between Bonaire and Curacao. These ships can be divided into two main groups. One group ships that sail in a SE/NW direction and another group sailing NE/SW direction. From both groups only a few ships were observed in the study period. Therefore there is not enough information available to make an estimation of the type and number of these ships.

Using available AIS-tracks a first route structure has been created. The main routes are indicated in Figure 7-3. The routes indicated in blue are the main routes of oil tankers, the routes in red are the main cruise vessel routes and the green routes are the tracks of the cargo ships to and from the Cargill terminal. The shaded area is the waiting area for the tankers visiting the BOPEC-terminal.



Figure 7-3 Overview of the traffic routes around Bonaire

## 7.2 Risk of oil pollution

Oil pollution accidents can be divided into two groups: accidents involving the outflow of cargo oil and accidents involving the outflow of bunker oil. Outflow can be caused by a variety of accident types. For instance by collisions, groundings and explosions on board. The purpose of the risk assessment is to identify areas in which the probability on any of those different accident types is higher than in other regions. In order to do so, it is necessary to make some assumptions on the factors that increase this probability. These assumptions are similar to the ones used in SAMSON.

In the risk assessment for oil outflow the focus is on collisions and groundings. For collisions, a relevant factor is the number of encounters. This practically means that, if there is a possibility that two vessels will “meet” each other, there is a probability that they will collide. The more encounters are expected, the higher the collision frequency is. Therefore it is relevant to investigate the route structure and see if there are any specific “encounter locations”. For groundings, an important factor is the presence of shoals or coastline. In the case of Bonaire, this is for instance the coastline of Bonaire. The more ships pass such a coastline, the higher the grounding frequency is.

The risk assessment is divided into a section for cargo oil and a section for bunker oil.

### 7.2.1 Cargo oil

The outflow of cargo oil is directly related to the presence of any oil carrying tankers. The study of traffic streams shows that there are three main routes/areas used by oil tankers:

1. The route between Bonaire and Curacao, used by smaller tankers (<100,000 tons) importing oil from the direction of Curacao to Bonaire.
2. The route between Bonaire and Galleon's Passage, used by the larger tankers (>100,000 tons) exporting oil from Bonaire in the direction of Asia and Europe
3. The drifting area between Bonaire and Curacao, used by tankers of all sizes while waiting for the BOPEC terminal
4. The tankers moored at BOPEC terminal

These four aspects will now be discussed separately.

#### **Ad 1. Bonaire-Curacao: Smaller tankers**

About 190 smaller oil tankers per year sail loaded from the direction of Curacao to the BOPEC-terminal. The main route in the territorial area of Bonaire is indicated in Figure 7-3 (blue line). The tankers sail between Curacao and the small island “Klein Curacao”.

##### *Collision risk*

Cruise vessels sailing between Bonaire and Curacao take the same route, so there is a possibility that these two types of vessels meet. The smaller oil tankers also cross some routes that are used by cruise vessels and GDC ships, as well as the waiting area.

##### *Grounding risk*

Depending on the prevailing wind conditions it is possible that a tanker will run aground on the west side of the island just before arriving or just after leaving, in case of an engine failure. Depending on the surface of the bottom (sand or rocks) there is a possibility that the cargo tank of the grounding tanker will rupture and causes an oil spillage.

The prevailing wind direction around the island is east. The wind statistics for the airport are shown in Figure 7-4 [source: [www.windfinder.com](http://www.windfinder.com)]. So based on these statistics the probability that a ship, with engine problems will drift towards the island is very small.

A grounding caused by a navigational error for this type of ships is small as they do not sail along the coast line.

Therefore the grounding probability is considered small. The bottom around the island consist of rock and coral. So this means that when a ship will run aground the probability of a hole in the hull or the cargo tank is relatively large.

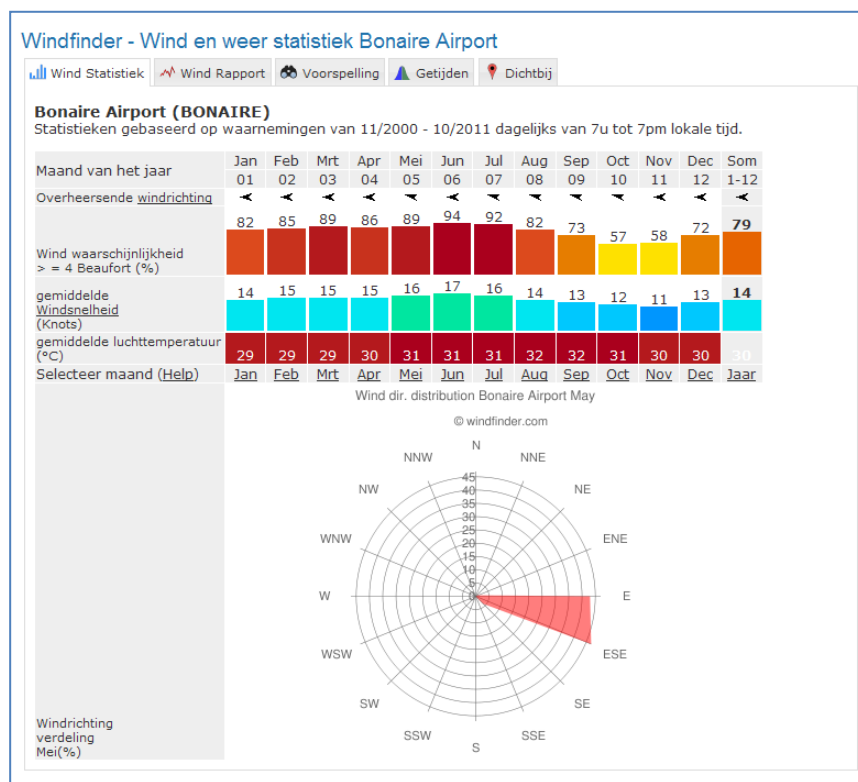


Figure 7-4 Wind statistics for Bonaire [source: windfinder.com]

#### Consequences: outflow of oil

Most of the loaded oil tankers from Curacao will first sail to the waiting area and drift for about 3 days. When the tankers have offloaded their cargo, they will sail “directly” in the direction of Curacao, so for this part of their “journey” the risk of oil pollution after an accident is small, because the ships are “empty”.

In order to determine the volume of the possible outflow of oil, the average capacity of the cargo tank for the oil tankers needs to be determined. This is a standard procedure within SAMSON, where the information is based on the Lloyd's List Intelligence (LLI) vessel characteristics database. As input for the model the average number of tank rows, the capacity of the wing and centre tanks are taken. These numbers are presented in Table 7-1 for a double hull oil crude tanker. These data can be used within this analysis as well.

Table 7-1 Overview of the average capacity of the cargo tanks of a double hull tanker

|                                                 | Gross Tonnage |           |             |               |               |                |          |
|-------------------------------------------------|---------------|-----------|-------------|---------------|---------------|----------------|----------|
|                                                 | 1600-3000     | 3000-5000 | 5000-10,000 | 10,000-30,000 | 30,000-60,000 | 60,000-100,000 | >100,000 |
| Average capacity wing tanks [m <sup>3</sup> ]   | 208           | 767       | 1,307       | 3,359         | 11,198        | 12,987         | 16,672   |
| Average capacity centre tanks [m <sup>3</sup> ] | NA            | NA        | NA          | NA            | NA            | 1,735          | 41,680   |
| Number of tank rows                             | 5             | 4         | 5           | 6             | 6             | 6              | 5        |

Assuming that 50% of the smaller tankers belong to size class 30,000-60,000 tons and 50% belongs to the size class 60,000-100,000 tons (see Chapter 3), this group of ships has wing tanks of an average capacity of about 12,000 m<sup>3</sup>. The total capacity of the tankers is 144,000 m<sup>3</sup> (12,000 \* 6 (rows) \* 2 (sides)). This total amount of oil will only be spilled when the ship sinks or breaks after an accident. After a serious collision with a rupture or hole in the cargo tank the maximum expected outflow of oil will be the capacity of one wing tank, so about 12,000 m<sup>3</sup>.

#### Ad 2. Bonaire-Galleon's Passage: Larger tankers

Most of the oil transported to Bonaire by the smaller tankers is loaded into larger oil tankers that cross the Atlantic Ocean in the direction of Europe and Asia, using Galleon's Passage. These vessels also first wait/drift in the area west of Bonaire before mooring at BOPEC terminal. It is not known to which extent these drifting/waiting vessels are loaded. When these vessels leave Bonaire, they will take the route through the waiting area and then passing the northern side of the island.

##### *Collision risk*

The route of the larger oil tankers around the island is for the major part similar to the route that the cruise vessels and cargo vessel in some cases take. Therefore, there is a possibility of a collision.

##### *Grounding risk*

The distance to the west side of the island is about 3 nautical miles (5.5 km). This is not so much, however as was shown for the smaller tankers, prevailing wind conditions make it unlikely that a drifting ship will hit the shore.

It is however possible that a tanker makes a navigational error and as a consequence grounds on the coast of Bonaire, as these tankers typically sail along the shore of Bonaire. The largest probability on such an incident is at the north-east shore.

##### *Consequences: outflow of oil*

The average capacity of the cargo tanks of the tankers is given in Table 7-1. The average capacity of the wing tanks of the larger oil tankers is 16,500 m<sup>3</sup>. This means that the maximal expected outflow of oil after an accident which lead to a hole in the cargo tank will be 16,500 m<sup>3</sup>. The total capacity of the oil tankers is about 372,500 m<sup>3</sup>.

#### Ad 3. Waiting/drift area

Before mooring at the terminal oil tankers have to wait in some cases for several days. As the water depth is too large, anchoring is not possible. Therefore these ship drift in an area west of Bonaire. This area is indicated in Figure 7-3. It has been determined

that on average 2.4 drifting vessels are present in this area. The smaller vessels, which arrive from the direction of Curacao and plan to offload their cargo wait for 3 days on average. The larger ships, exporting oil for the terminal towards Asia, have an average drifting time of 9 days.

#### *Collision risk*

When these ships are drifting they have a very low speed. This lack of speed increases the response time of the vessel, as it is not fully manoeuvrable. So when an incident occurs, the response time of the vessel will be longer. Also the probability that the engine “fails” is larger when engines need to be “started” again than when a ship is just sailing. The “waiting area” is crossed by all vessels leaving the BOPEC-terminal, including all tug boats assisting the tankers. Also all cruise vessels going to the north side of the island have to cross the waiting area. This means that a large part of the traffic will cross the area, including the large tankers and cruise vessels. Therefore the number of encounters is high. Moreover, these crossing vessels could not be aware that it is a kind of waiting area, because it is not indicated as such on the charts. This can increase the probability that if two vessels meet, the encounter will lead to an accident.

#### *Grounding risk*

As for the sailing tankers in the area, it is unlikely that a drifting tanker will aground at the shore of Bonaire, as the wind has a predominantly opposite direction.

#### *Consequences: outflow of oil*

The smaller tankers are (partly) loaded when they drift, but this is not certain for the larger tankers. It could be that those ships have already loaded cargo at other terminals before arriving at Bonaire, so even though the larger tankers load oil at the BOPEC terminal, this does not mean that they will be “empty” while drifting/waiting before mooring.

Because of the large amount of (larger) ships that cross the area and the fact that most of the drifting oil tankers will be carrying oil, one could mark the waiting area as a “hot-spot” regarding the probability of an outflow of cargo oil.

#### **Possible risk reducing measures**

Ideally, the number of drifting ships is as low as possible. Therefore, if there is any possibility to create an anchorage or mooring facility for waiting ships, this would eliminate the risk.

Another possibility is to create a designated waiting area, which is indicated on the nautical charts. This would make the situation more clear for the passing vessels.

Finally, it needs to be clear to all vessels crossing the waiting area, that the waiting tankers are present and have a restricted manoeuvrability. Vessels can indicate their so-called “navigational status” in AIS. By indicating that they are “not under command”, other vessels can adjust their behaviour towards this vessel. The disadvantage of this option is that this status needs to be altered manually. From the monitoring authority it is advisable to monitor whether a ship is drifting and whether the ship has altered her status.

#### **Ad 4. Tankers moored at BOPEC terminal**

As the terminal is situated directly at open sea, vessels moored at the terminal can be collided against while loading/offloading. As drifting against the tanker is unlikely (considering the wind conditions) and the terminal is situated on the south of the shore the only possibility for such a collision is that a ship moving north, from for instance

Kralendijk, makes a navigational error and hits the moored ship at (almost) full speed. Ships which could get involved are cruise ships moving north from Kralendijk or cargo ships moving north from the CARGILL terminal. As the traffic intensity is quite low (116 vessels annually) the probability on such an accident is regarded low.



Figure 7-5 BOPEC-terminal Bonaire.

### 7.2.2 Bunker oil

As all vessels carry bunker oil, the tankers are not the only threat with respect to outflow of oil. Especially the larger cruise ships in the area can induce a significant risk, because these large ships carry large amounts of bunker oil.

The location of the probability of an outflow of bunker oil is directly related to the location of the major traffic routes. Therefore, near the island the risk will be highest for the sea area north of the island. A second high-risk location is where the route of the passing vessels from and to the Panama Canal is situated. The accidents will occur further from the coast, therefore the probability that oil reaches the coast is smaller, but the frequency of an accident is higher.

## 7.3 Risk of loss of life

With respect to the risk of loss of life as a consequence of an accident involving a cruise ship, a similar approach is followed as for the risk on outflow of oil.

### *Collision risk*

The main routes of the cruise vessels are indicated in red in Figure 7-3. Based on the traffic information which is available at this moment, one of the main risks for the cruise vessel is crossing the east-west traffic route on the north side of the island, ship sailing to and from the Panama canal. The frequency of encounters is high because as much as about 1500 ship per year uses this route (5 ships per day) and about 50 cruise ships per year cross the route. The other risk is collision risk with tankers between Curacao and Bonaire. Annually, about 160 cruise ships and about 200 tankers use this route, inducing a relatively high encounter frequency.

The second part of the risk, next to the probability, involves the consequences of an accident. When an accident occurs north of the island at the location of the route to the Panama Canal, the damaged ship will be situated relatively far away from the island(s), so more time is needed to get rescue equipment etc at the location. However, the distance is still only about 15 nm. Therefore, the difference in consequences is not so large.

*Grounding risk*

Another main risk for the cruise vessel is the probability of a grounding when passing the island on the west side at a relative close distance. The risk for the people on board will be slightly lower in this case.

## 8 QUALITATIVE RISK ASSESSMENT SABA AND ST. EUSTATIUS

In this chapter a qualitative risk assessment is performed for the region around Saba and St. Eustatius. The approach of the assessment and the structure of the chapter are similar to those of the risk assessment for Bonaire. First an assessment is made for the risk of oil outflow and then for the risk of loss of life on board cruise ships.

### 8.1 Overview location and traffic situation

Saba and St. Eustatius are part of the windward islands and situated next to each other.



Figure 8-1 Overview location Saba and St. Eustatius

The following shipping activities at the islands can be recognized:

- NUSTAR terminal at St. Eustatius: this terminal attracts tankers for cargo loading/discharging and other seagoing vessels for bunkering
- Cruise lines visiting Saba: smaller cruise ships which anchor just outside the port of Saba
- Cargo ships and ferries: both islands receive local cargo ships, for supply of the islands, and ferries to other islands. These ships moor in the ports of Saba and Oranjestad (St. Eustatius) respectively.

In Chapter 4 the total numbers of ship calls were determined, as were the main routes used by those ships. The findings are summarized below.

NUSTAR terminal:

- 272 tankers for the trans-shipment of cargo, of which:
  - o 174 oil tankers
  - o 98 chemical tankers
  - o Most ships travel to and from destinations in the USA and the Caribbean
- 859 ships for bunkering, of which:
  - o 344 bulk carriers
  - o 229 oil tankers
  - o 286 chemical tankers
  - o These ships usually come from a port in the USA or Caribbean and consequently proceed to ports on the other side of the Atlantic

- Five bunker barges are present in the anchorage area in front of the NUSTAR terminal

#### Cruise ships Saba:

- 30 cruise vessels (3,000 – 10,000 tons), using a variety of routes

#### Cargo ships and ferries Saba:

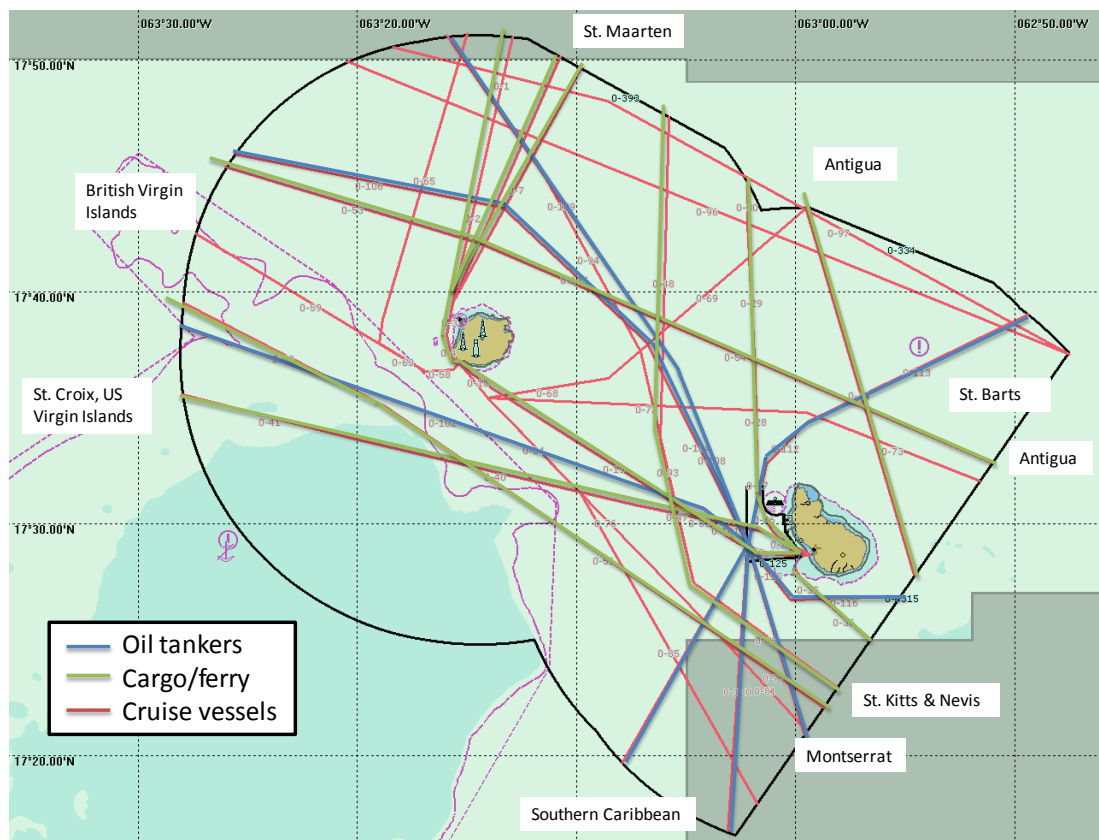
- 416 ferries to St. Maarten
- 52 RoRo cargo ships (100-1600 tons), on route: St. Maarten -> Saba -> St. Eustatius

#### Cargo ships St. Eustatius:

- 250 RoRo cargo ships (100-1600 tons), travelling between St. Eustatius, Saba, St. Maarten, St. Kitts and St. Croix

Next to the ships that actually visit one of the two islands, there is a large category of ships that do not visit the islands but that do cross the territorial waters. These ships can be divided into two groups: cruise ships (214) and cargo ships (1795) on a route between two of the surrounding islands.

The intensity of total shipping traffic in this area is much more dense for the area around Bonaire. This also applies for the tankers. The amount of cruise ships in both areas is similar.



**Figure 8-2 Overview of the traffic routes around Saba and St. Eustatius**

Based on AIS, a route network could be constructed for the described groups. This resulted in the complex network as presented in Figure 8-2. The blue lines indicate the routes which are used by tankers, the green lines are the routes used by cargo ships and ferries and the red lines represent routes used by cruise vessels.

## 8.2 Risk of oil pollution

Like was done for Bonaire, this section is divided in a part covering the risk of outflow of cargo oil as a consequence of an accident involving a tanker, and a part covering the risk of outflow of bunker oil. The focus is both on collisions and grounding of ships and an indication of the size of the oil spill is given.

### 8.2.1 Cargo oil

Four groups of ships can be distinguished which induce a risk of outflow of cargo oil:

1. Tankers visiting NUSTAR
2. Tankers at anchor waiting for NUSTAR terminal
3. Bunker barges present in the anchorage area
4. Moored tanker at the terminal/ SPM

#### Ad. 1 Tankers visiting NUSTAR

Annually, 174 oil tankers and 98 chemical tankers visit NUSTAR terminal for loading/discharging of cargo. The majority of those ships started their voyage in the USA and a significant part started and/or continued their voyage in the Caribbean. No trend could be derived with respect to the relation between the different routes and import/export of oil. Therefore it is assumed that all of these vessels are at least partly loaded with oil (products).

Then there is a group 573 tankers which visits the terminal for bunkering only. Also for these vessels it is not known to which extent they are loaded and therefore it has to be assumed that also those vessels are at least partly loaded.

#### *Collision risk*

As the routes used by ships in the area around both islands cannot be attributed to a few "main routes" it is not effective to identify areas with an increased risk on collisions. Tankers can meet other ships in all parts of the region around both islands and on all the identified routes: the risk is of comparable level in the entire region and high compared to the area around Bonaire as the shipping intensity is higher.

#### *Grounding risk*

Areas which pose a threat with respect to grounding are the islands Saba and St. Eustatius themselves as well as the shallow area Saba Bank. Although the latter is only relevant for ships with a draught exceeding 10 m. It can be assumed that most tankers belong to this category.

Like in the area around Bonaire, the prevailing wind direction is east, see Figure 8-3. Therefore, for this group of ships grounding at St. Eustatius itself can be regarded unlikely. However, grounding at the coastline of Saba for ships using the routes east of Saba and grounding at Saba Bank for the tankers using the most southern routes, is a relevant risk. This involves particularly the group of tankers coming from/ leaving in a southward direction as their number is considerable: about 1250 passages annually. As more routes, with higher intensity, are situated close to Saba Bank than to Saba. The spill is more likely to occur at Saba Bank.

## Windfinder - Wind &amp; weather statistic St. Eustatius

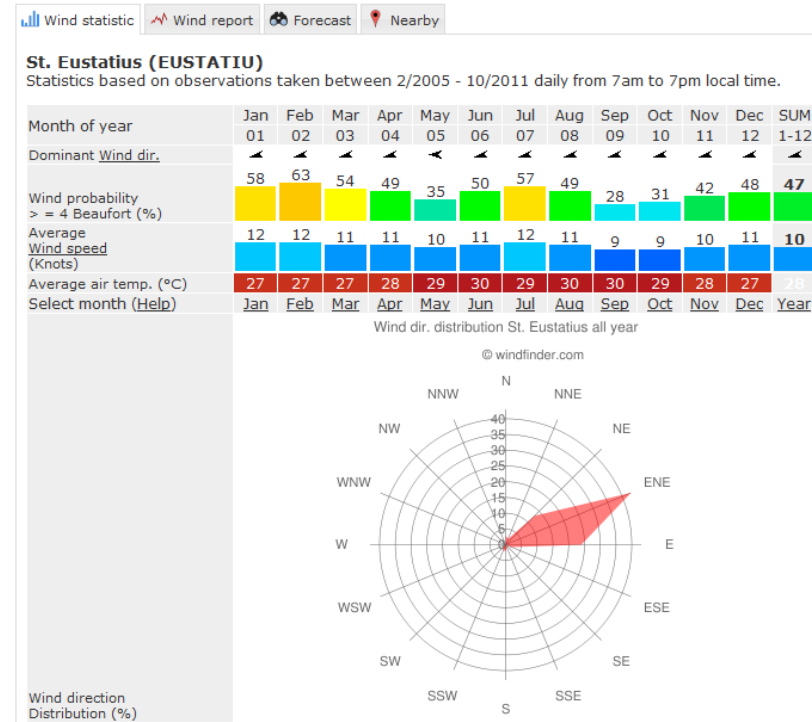


Figure 8-3 Wind statistics for St. Eustatius [source: windfinder.com]

If any oil is spilled in a grounding at Saba or Saba Bank, the consequences will be relatively large as oil will reach shore (or protected area) immediately.

*Consequences: outflow of oil*

For the tankers visiting the NUSTAR terminal for trans-shipment it is not known whether they are fully loaded, partly loaded or empty. In Table 8-1 an overview is given of the number of ships (oil and chemical tankers) that are assumed to have visited the NUSTAR-terminal. Also the capacity of the wing tanks and the average total capacity of the tankers is indicated. The average capacity of the wing tank is the expected maximal amount of oil spilled after an accident in case one cargo tank is damaged.

Table 8-1 Shipping matrix for trans-shipment vessels at NUSTAR terminal

| Type/GT  |                                       | 1600-5000 | 5000-10.000 | 10.000-30.000 | 30.000-60.000 | 60.000-100.000 | >100.000 | Total |
|----------|---------------------------------------|-----------|-------------|---------------|---------------|----------------|----------|-------|
| Oil      | Number of shipments                   | 13.7      | 27.4        | 48.0          | 68.6          | 13.7           | 2.6      | 174.1 |
|          | Capacity wing tanks [m <sup>3</sup> ] | 767       | 1,307       | 3,359         | 11,198        | 12,987         | 16,672   |       |
|          | Total capacity [m <sup>3</sup> ]      | 6,134     | 13,070      | 40,310        | 129,899       | 166,259        | 375,115  |       |
| Chemical | Number of shipments                   | 7.7       | 15.4        | 27.0          | 38.6          | 7.7            | 1.4      | 97.9  |
|          | Capacity wing tanks [m <sup>3</sup> ] | 531       | 1,585       | 6,250         | 3,841         | 5,257          | NA       |       |
|          | Total capacity [m <sup>3</sup> ]      | 4,248     | 12,678      | 62,500        | 86,420        | 141,929        | NA       |       |
| Total    | Number of shipments                   | 21.4      | 42.9        | 75.0          | 107.2         | 21.4           | 4        | 272   |

**Ad 2. Tankers at anchor waiting for NUSTAR terminal**

Both the bunker-only and trans-shipment tankers anchor in the anchorage area in front of NUSTAR terminal, directly after arriving. For the bunker-only vessels, bunker barges come alongside while the ships are at anchor. After bunkering, the vessels continue their journey. The trans-shipment tankers anchor while waiting for mooring at the berth or SPM (Single Point Mooring) at the terminal. As such, these ships arrive in the anchorage area, drop their anchor and lift it as soon as the berth or SPM is available. It was estimated that on average 2.7 ships are present in the area. The majority of those ships are tankers.

*Collision risk*

The tankers in the anchorage area can get struck by passing vessels, by a vessel that broke from its anchor or a vessel at drift for other reasons. However, it can be assumed that drifting vessels do not pose a threat to the integrity of the tanker's hull. Therefore, this type of collision is not relevant when considering the risk of outflow of oil. The relevant case is when these ships get struck by another vessel which is at (full) speed. The main risk in this situation are the cargo vessels visiting St. Eustatius. These ships are large in number and cross the anchorage area when arriving and departing.

*Grounding risk*

Another risk is the situation where a tanker in the anchorage area breaks from its anchor and drifts to shore. This case can be regarded unlikely regarding the wind conditions.

*Consequences: outflow of oil*

For the vessels in the anchor area it is not known whether they are loaded, partly loaded or empty. Therefore it is difficult to indicate the expected amount of oil spilled after a potential accident.

Due to the prevailing wind conditions it can be assumed that a potential oil spill, when it occurs in the anchor area will drift in the direction of the Saba-bank.

**Ad 3. Bunker barges present at the anchorage area**

The bunker barges in the anchorage area carry large amounts of bunker oil and most likely have less structural integrity than a regular tanker. If such a "ship" is collided against, the probability of outflow of oil will be relatively high. Especially because these vessels are relatively small compared to some of the other vessels passing the area. The probability of a collision with such a barge is similar to the probability of a ship at anchor as described above.

**Ad 4. Moored tanker at terminal/ SPM**

The jetty at NUSTAR terminal is positioned perpendicular to the shore and used by tankers on both sides. The SPM is situated at open sea north of the terminal and is used by the larger tankers. Ships moored at the SPM can be regarded as anchoring ships in the anchorage area.

From the AIS it can be concluded that ships with destination Oranjestad do cross the anchorage area but that they stay clear from the SPM and jetty. It is regarded unlikely that passing traffic will hit the moored ship.

With respect to drifting ships, the moored ship is situated "safe" as wind comes from land.

### 8.2.2 Bunker oil

Next to the tankers as described above, also bulk carriers and cargo ships use the anchorage area near St. Eustatius while waiting for and during bunkering. At arrival and before bunkering these ships have a relatively small amount of bunker oil on board, but after bunkering the quantity is much higher. Most of the traffic routes around St. Eustatius pass the area in which the ships are waiting. So there is a probability that a ship at anchor is hit by a passing vessel, although the size of the spill will be relatively small.

Most of the “bunker-only” ships will depart in the direction of the Atlantic Ocean. The routes these vessels take pass the area around St. Eustatius which has a relatively low traffic intensity. It is possible that these ships meet other ships, but the number of encounters will be low. At arrival, there can no particular routes be distinguished. Therefore, this risk cannot be attributed to a specific area within this region.

Other ship types with large quantities of bunkers on board are the passing cruise ships, amongst which are some of the largest cruise vessels in the world. Most of these ships cross the passage between Saba and St. Eustatius, meeting all traffic groups in the area. Especially the part south of St. Eustatius which is used by many of the large seagoing ships visiting the NUSTAR terminal can be marked as an area with increased risk for cruise ships. Furthermore, if a cruise ship runs adrift in the passage between the two islands, it is possible that it will ground either on Saba or Saba Bank. Therefore this should be regarded a risk as well.

The local cargo ships sailing between the islands are small and most likely do not have large amounts of bunkers on board. Therefore, the expected spill size is small. On the other hand, this group of ships is the largest in the area. Therefore the probability that such a ship gets involved in an accident is relatively high. Also, if it gets collided by one of the larger ships in the area, the probability of a spill is large.

### 8.3 Risk of loss of life

In the previous section the probability of an oil spill as a result of a collision with a cruise ship was discussed: the area south and west of St. Eustatius was pinpointed as the area with the highest risk. The same argumentation applies when regarding the risk of loss of life. However, the accident will happen within the vicinity of land. Therefore, the risk can be reduced by the availability of sufficient life saving facilities at St. Eustatius or Saba.

## 9 QUALITATIVE RISK ASSESSMENT RESULTS

### 9.1 Comparison of the two areas

In the below table the total numbers of ship movements for both area are summarized:

**Table 9-1 Summary of ship movements for the two areas**

|                    | Bonaire | Saba/ St. Eustatius |
|--------------------|---------|---------------------|
| Cruise             | 286     | 274                 |
| Local cargo/ ferry | 198     | 3231                |
| Seagoing cargo     |         | 688                 |
| Tankers            | 310     | 1574                |
| Unknown            | 1500    |                     |
| Total              | 2294    | 5767                |

It is clear that the total traffic intensity around Saba and St. Eustatius is significantly higher than around Bonaire. Particularly the total number of tankers is much higher. The number of cruise ships is comparable for both regions.

The total accident probability is therefore higher in the area around Saba and St. Eustatius and particularly for tankers. It can safely be stated that the risk on an oil spill is larger in this area than in the area around Bonaire. However, both areas are very different with respect to geometry and ship traffic. Therefore, each brings their own specific risks which cannot be easily compared. They will be summarized below indicating the high risk areas for both regions.

### 9.2 Main risks Bonaire

For the area around Bonaire the risk of grounding is not so relevant as the wind is predominantly east and there is practically no traffic east of the island. Therefore, collision risk is the main risk with regard to outflow of oil and loss of life.

With regard to outflow of oil, the main risks are:

- Collisions with drifting tankers in the area west of Bonaire
- Collisions of larger tankers leaving by the route north of island and other ships on the routes towards/from the north
- Collisions of smaller tankers sailing between Bonaire and Curacao and other tankers and cruise ships
- Grounding of larger tankers at the north-east shore of Bonaire
- Outflow of bunker oil as a result of collisions between vessels using the route to the north (high traffic intensity)
- Outflow of bunker oil as a result of collisions at the point where routes to the north (cruise and cargo) and the major traffic route to the Panama Canal meet

Based on these main risks, it can be stated that the area west/ north-west/ north of Bonaire can be regarded as the area with the highest oil pollution risk.

The maximum size of an oil spill is estimated to be 375,000 m<sup>3</sup> which corresponds to the entire tank capacity of the largest tankers in the area.

With regard to loss of life the main risks are the following:

- Collisions between a cruise ship and another ship at the location where the cruise routes to the north (about 50 ships annually) and the traffic route to the Panama Canal (about 1500 ships annually) meet
- Collisions of cruise ships on the route Bonaire- Curacao and other cruise ships or tankers on the same route (163 cruise ships, about 200 tankers)

It can be concluded that for the area east and south of the island has a very low risk both for pollution and loss of life, as almost no traffic is present in this region.

### 9.3 Main risks Saba and St. Eustatius

the fact that the two islands are situated close to each other and the fact that the shallow area Saba Bank is near as well, the risk of grounding is an important factor in this area next to the risk of collisions.

With regard to the outflow of oil, the main risks are considered to be the following:

- Collisions between tankers arriving at or departing the NUSTAR terminal and other ships, basically in the entire region around the islands
- Grounding of tankers at Saba Bank or the coastline of Saba, especially for the relative large amount of tankers using the routes to the south, the routes north of Saba Bank and the routes between the islands
- Collisions of tankers at anchor or bunker barges by passing cargo ships in the anchorage area in front of the NUSTAR terminal
- Outflow of bunker oil as a result of collisions between cruise ships and other large seagoing ships south of St. Eustatius
- Outflow of bunker oil as a result of grounding of cruise ships passing between the two islands at Saba or Saba Bank
- Outflow of bunker oil as a result of collisions of bunker-only cargo ships with other ship traffic south, west and north of St. Eustatius
- Outflow of bunker oil as a result of collisions between local cargo ships with each other or other ship traffic. Because of the large number of those ships and their small size it is expected that the frequency of outflow as a consequence of such an accident is high, but that the size of the oil spill is small.

The maximum size of an oil spill is estimated to be 375,000 m<sup>3</sup> which corresponds to the entire tank capacity of the largest tankers in the area. This is an overestimation since only a few of these large tankers are expected in the area. The more realistic average amount of total capacity of an oil tanker is lower, also because there is not sufficient information about the loading condition of the various tankers in the area.

Although the network of shipping routes is quite complex, some areas with increased risk level for oil spills can be indicated:

- Grounding risk of tankers at Saba Bank (and Saba)
- Collision risk in the majority of the region but especially west of St. Eustatius, where a concentration of oil carrying ships can be found
- A reduced risk level can be found in the regions east and north of St. Eustatius and west of Saba, as the traffic intensity here is low

With regard to loss of life the main risks are the following:

- Loss of life as a result of collisions between cruise ships and other large seagoing ships south of St. Eustatius
- Loss of life as a result of grounding of cruise ships passing between the two islands at Saba or Saba Bank

#### **9.4 Possible risk reducing measures**

To reduce the risk in the areas some standard measures are available, of which some of them are already in place:

- Use of pilots and tugboats;
- Presence of Search and Rescue equipment;
- Presence of Oil Pollution Combat equipment;
- Presence of an Emergency Towing Vessel;
- "Vessel Traffic service" or other monitoring authority;

Also some additional measures are suggested for the specific area around Bonaire, concerning the "waiting" area for ships sailing to the BOPEC terminal. In this area the ships do not anchor, but drift. Ideally, a risk reducing measure is to reduce the number of drifting ships is as low as possible. Therefore, if there is any possibility to create an anchorage or mooring facility for waiting ships, this would eliminate the risk. But since the geographical layout of the area (presence of coral and the water dept) will not allow an anchorage area another possibility is to create a designated waiting area, which is indicated on the nautical charts. This would make the situation more clear for the passing vessels.

Finally, it needs to be clear to all vessels crossing the waiting area, that the waiting tankers are present and have a restricted manoeuvrability. Vessels can indicate their so-called "navigational status" in AIS. By indicating that they are "not under command", other vessels can adjust their behaviour towards this vessel. The disadvantage of this option is that this status needs to be altered manually. From the monitoring authority it is advisable to monitor whether a ship is drifting and whether the ship has altered her status.

## 10 CONCLUSIONS AND RECOMMENDATIONS

As this study was performed in two stages: the analysis of the traffic streams and the qualitative risk assessment, the conclusions are presented in two sections as well.

### 10.1 Main traffic streams in the Dutch Caribbean

Because of the geographical layout a marine traffic database was composed for two separate sea areas:

- The territorial waters (12 nm zone) of Bonaire
- The territorial waters (12 nm zone) of Saba and St. Eustatius

The database was created based on general available information on shipping activities in the Dutch Caribbean and by using live AIS. For the traffic intensity mostly the statistics for 2010 were used.

The area of research was initially limited to the territorial waters and not the entire EEZ because of the limited amount of available information. The assumption was that the territorial waters would only be entered by vessels which actually visit the islands. However, this study showed that this is not the case. Especially near Bonaire, very intense traffic including large vessels can be observed. It is very difficult to estimate the numbers and composition of ships involved in these traffic streams, but it is clear that they are relevant for a proper estimation of risk on oil spills. Therefore, it is recommended to further study these traffic streams, preferably using AIS data. When this data will be available the study area can also be widened to the whole EEZ-area.

Because of the large amount of assumptions which had to be done, and the lack of detailed data, the results of this study should not be interpreted as a factual and complete representation of the situation. They should rather be seen as a first step in the description of marine traffic in this area.

The main characteristics for each of the two areas will now be summarized:

- **Traffic streams near Bonaire**

Bonaire has an oil terminal (BOPEC) which is frequently visited by tankers: in 2010 229 ships visited the terminal. These ships spend a large amount of time drifting in the area between Curacao and Bonaire.

Therefore the traffic database, concerning oil transport, consists of two parts:

- one part representing the drifting ships and
- one part representing the ships departing from the terminal towards their next destination.

Another intense shipping activity at Bonaire is the cruise industry, accounting for 143 calls in 2010. Other, smaller, shipping activities at Bonaire are local cargo and supplies, the CARGILL salt terminal and fuel trans-shipment for the airport.

It was also found that the territorial waters are not only accessed by ships that visit Bonaire, but also by passing traffic. Especially traffic to and from the Panama Canal and surrounding region account for many passing ships. It was estimated that about four times a day such a ship passes at a close distance to the island and that maximum 50% of these ships actually access the territorial waters. This element was taken into account in the traffic database. However, it was also found that ships on route to/from Curacao

and Venezuela access the 12 nm zone frequently. However, because of a lack of data about these vessels, it was found not appropriate to include these ships in the traffic database. AIS data over a longer period of time could provide further knowledge on those ships.

- **Traffic streams near Saba and St. Eustatius**

The main shipping activity around Saba and St. Eustatius is oil trans-shipment and bunkering at the NUSTAR terminal at St. Eustatius. Annually about 1100 vessels call at this terminal. The general procedure is to anchor in the dedicated anchorage area in front of the terminal. Bunker barges moor alongside the anchored ships which require bunkers. These vessels then proceed to sea.

The vessels which come for oil trans-shipment wait for several days and then moor at the jetty or single point mooring for loading/ discharging.

Other shipping activities on these islands are small scale: supplies are provided by small Ro-Ro vessels, there are two ferry services connecting Saba to St. Maarten and some cruise lines visit Saba.

However, with many nearby islands - some of which have much more active shipping activities – also these territorial waters are frequently accessed by other shipping traffic. The main groups are cruise ships and cargo ships connecting the surrounding islands. An estimation of the routes and numbers of ships was made, although very roughly. It was estimated that 215 cruise ships (amongst which the largest in the world) and well over 1000 cargo ships access the area.

## **10.2 Qualitative Risk Assessment**

An analysis was done of accident statistics for the entire Caribbean region for the period 2008-2010. In this period 123 vessels were involved in accidents in this region, of which 47 at open sea. Four vessels were involved in accidents at open sea resulting in pollution and two vessels were involved in accidents resulting in a loss of life. Three tankers and four passenger vessels were involved in accidents.

In general, the risk of outflow of oil is regarded to be higher in the area around Saba and St. Eustatius than for the region around Bonaire because of the higher traffic intensity and much higher number of tankers.

- **Bonaire**

The main risks in the area around Bonaire with respect to outflow of cargo oil are:

- collision with drifting vessel in the “waiting” area west of Bonaire;
- collisions of smaller tankers on the route between Curacao and Bonaire and other traffic on this route;
- groundings and collisions of larger tankers on the route to the north with other traffic on this route and in particular collisions with tankers which are adrift while waiting for BOPEC terminal.

Outflow of bunker oil could occur on the route to the north and also at the position where ship traffic from Bonaire to the north meets the traffic route to the Panama Canal. Therefore, it can be safely stated that the area inducing the highest risk for the outflow of oil in this region is the area west, north-west and north of Bonaire.

The smaller tankers have a total capacity of 144,000 m<sup>3</sup>. This total amount of oil will only be spilled when the ship sinks or breaks after an accident. After a serious

collision with a rupture or hole in the cargo tank the maximum expected outflow of oil will be the capacity of one wing tank, so about 12,000 m<sup>3</sup>.

The maximal expected outflow of oil after an accident with a large oil tanker which lead to a hole in the cargo tank will be 16,500 m<sup>3</sup> (maximum size of a wing tank).

The total capacity of these larger oil tankers is about 372,500 m<sup>3</sup>. Almost 85% of all tanker calling at the BOPEC-terminal are smaller tankers. These numbers are based on the information available now and are just an indication of the possible amount of oil on board in the tanks.

The main risks with respect to loss of life are collisions between a cruise ship and another ship at the location where the cruise routes to the north and the traffic route to the Panama Canal meet as well as collisions of cruise ships on the route Bonaire-Curacao and other cruise ships or tankers on the same route.

It can be concluded that for the area east and south of the island has a very low risk both for pollution and loss of life, as almost no traffic is present in this region.

- **Saba and St. Eustatius**

Although the network of shipping routes around Saba and St. Eustatius is quite complex, some areas with increased risk level for oil spills can be indicated. A particular risk is grounding of tankers at Saba Bank (and Saba). And the collision risk in the majority of the region but especially west of St. Eustatius, where a concentration of oil carrying ships can be found. A reduced risk level can be found in the regions east and north of St. Eustatius and west of Saba, as the traffic intensity here is low.

The sizes of the tankers visiting the NUSTAR-terminal vary between small tankers with a total capacity of 13,000 m<sup>3</sup> and large tanker with a total capacity of 375,200m<sup>3</sup>. The wing tank capacity of these tankers on the area varies between 700 m<sup>3</sup> and 16,600 m<sup>3</sup>. Where almost 70% of all trans-shipments vessels at the NUSTAR-terminal have a wing tank capacity below 6,000m<sup>3</sup> and only 1% above 13,000 m<sup>3</sup>. These numbers are based on the information available now and are just an indication of the possible amount of oil on board in the tanks.

With regard to loss of life the main risks are collisions between cruise ships and other large seagoing ships south of St. Eustatius and grounding of cruise ships passing between the two islands at Saba or Saba Bank.

### **10.3 Recommendations**

#### **Possible risk reducing measures**

To reduce the risk in the areas some standard measures are available, of which some of them are already in place:

- Use of pilots and tugboats;
- Presence of Search and Rescue equipment;
- Presence of Oil Pollution Combat equipment;
- Presence of an Emergency Towing Vessel;
- "Vessel Traffic service" or other monitoring authority;

Also some additional measures are suggested for the specific area around Bonaire, concerning the “waiting” area for ships sailing to the BOPEC terminal. In this area the ships do not anchor, but drift. Ideally, a risk reducing measure is to reduce the number of drifting ships is as low as possible. Therefore, if there is any possibility to create an anchorage or mooring facility for waiting ships, this would eliminate the risk. But since the geographical layout of the area (presence of coral and the water dept) will not allow an anchorage area another possibility is to create a designated waiting area, which is indicated on the nautical charts. This would make the situation more clear for the passing vessels.

Finally, it needs to be clear to all vessels crossing the waiting area, that the waiting tankers are present and have a restricted manoeuvrability. Vessels can indicate their so-called “navigational status” in AIS. By indicating that they are “not under command”, other vessels can adjust their behaviour towards this vessel. The disadvantage of this option is that this status needs to be altered manually. From the monitoring authority it is advisable to monitor whether a ship is drifting and whether the ship has altered her status.

### **Recommendations concerning risk assessment in the future**

To perform a quantitative risk assessment, using the SAMSON-model, additional data has to be collected. The present study showed that it is not sufficient to only have information from the terminals on the islands, since there are also a (large) number of ships just passing the area around the islands. Therefore it is necessary to collect AIS-data of the areas near the islands. Especially of the areas for which the risk assessment needs to be performed, the EEZ. This AIS data contains all necessary information to determine a reliable traffic database containing the locations of the routes, the type and size of the ships and the number of ships.

Another type of data which is required to make a good estimation of the outflow of oil is detailed information on the import and export of oil at both BOPEC and NUSTAR terminal as well as the main trade routes used by the ships visiting these terminals. This information will provide realistic assumptions on the amount of oil transported by ships over the different routes.

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## **APPENDIX A: ABBREVIATIONS**

## List of abbreviations

|       |                                 |
|-------|---------------------------------|
| ABC   | Aruba – Bonaire – Curacao       |
| AIS   | Automatic Identification System |
| BOPEC | Bonaire Petroleum Corporation   |
| CN    | Collision                       |
| CT    | Contact                         |
| DWT   | Deadweight Tonnage              |
| EEZ   | Exclusive Economic Zone         |
| FD    | Foundering                      |
| FX    | Fire/ Explosion                 |
| GDC   | General Dry Cargo               |
| GT    | Gross Tonnage                   |
| HM    | Hull/ Machinery failure         |
| Nm    | Nautical Mile                   |
| NE    | North-east                      |
| NW    | North-west                      |
| PSSA  | Particularly Sensitive Sea Area |
| QRA   | Quantitative Risk Assessment    |
| RWS   | Rijkswaterstaat                 |
| SE    | South-east                      |
| SPM   | Single Point Mooring            |
| SW    | South-west                      |
| WS    | Wrecked/ Stranded               |

## **APPENDIX B: SAMSON**

## Background

During the last 25 years the SAMSON<sup>1</sup>-model has been developed, extended, validated and improved continuously in different studies for the Dutch Authorities and within different European projects see [1] – [12]. Most of the blocks of the system diagram from in Figure B- 1.**Error! Reference source not found.** are modelled in the SAMSON-model.

The kernel of the SAMSON-model is the traffic database, which describes the maritime traffic in density, composition and behaviour. The maritime traffic is divided into two main groups; the *route bound ships* and the *non-route bound ships*. The route bound traffic consists of merchant vessels and ferries sailing along the shortest route from one port to another. The non-route bound traffic contains vessels that mainly have a mission at sea, such as fishing vessels, supply vessels, working vessels and pleasure crafts. Both groups, route bound and non-route bound, are modelled in a different way.

The route bound traffic is modelled on the shipping routes on the North Sea. Because of the location of the different ports and the traffic separation schemes in the Dutch Economical Exclusive Zone, most of the route bound ships sail on a large network of links, comparable to the road network. It is assumed that ships sail along the shortest possible route to reach their destination. Ships have to comply with rules and regulations such as Traffic Separation schemes.

The shipping intensity on the different links is determined based on all ship movements on the North Sea for one year. Lloyd's Marine Intelligence Unit (LMIU) collects all shipping movements. At MARIN, the traffic database based on the LMIU data for 2004 and 2008 is already available. The ferry movements were obtained from timetables and are added separately because the LMIU-database does not contain this data.

The traffic database contains waypoints and links connecting these waypoints. On each link the traffic, in number of movements per year, is known for each of the 36 ship types and eight ship size classes. This large number of classes is required for subsequent calculations, as for example the calculation of the kinetic energy when a ship strikes an offshore platform.

The non-route bound traffic cannot be modelled in the same manner as the route bound traffic, because the information about the journeys of those ships is not included in the Lloyd's database. Moreover, the behaviour of these non-route bound ships at sea is different. A non-route bound ship does not sail from port A to port B along a clear route, but from port A to one or more destinations at sea and then usually back to the port of departure A. The behaviour of these ships at sea is mostly unpredictable. Fishing vessels also sail from one fishing ground to another during one journey and they sail different tracks during fishing activities. Therefore, the traffic image of the non-route bound traffic is modelled as densities of ships per grid cell (8 x 8 km). The average number of non-route bound ships in an area of 8 x 8 km is assessed by data from IMARES<sup>2</sup> for the fishing vessels in the Dutch part of the North Sea and from AIS<sup>3</sup> data for traffic of supply and work vessels to and from the platforms.

Before AIS-data or the data from IMARES was available the average number of non-route bound ships in an area of 8 by 8 km were assessed from the VONOV<sup>4</sup>-flights.

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<sup>1</sup> Safety Assessment Model for Shipping and Offshore on the North Sea

<sup>2</sup> Institute for Marine Resources and Ecosystem Studies

<sup>3</sup> Automatic Identification System

<sup>4</sup> Verkeers Onderzoek NOordzee Visuele Identificatie.

During a VONOFI-flight all ships within a certain area on the North Sea were observed and described; ships name, position, speed and direction. Afterwards all other ship data was added and a database was built up.

The results of the VONOFI-flights together with the recorded AIS-data received from the Netherlands Coast guard are also used to validate the traffic image of the route bound traffic.

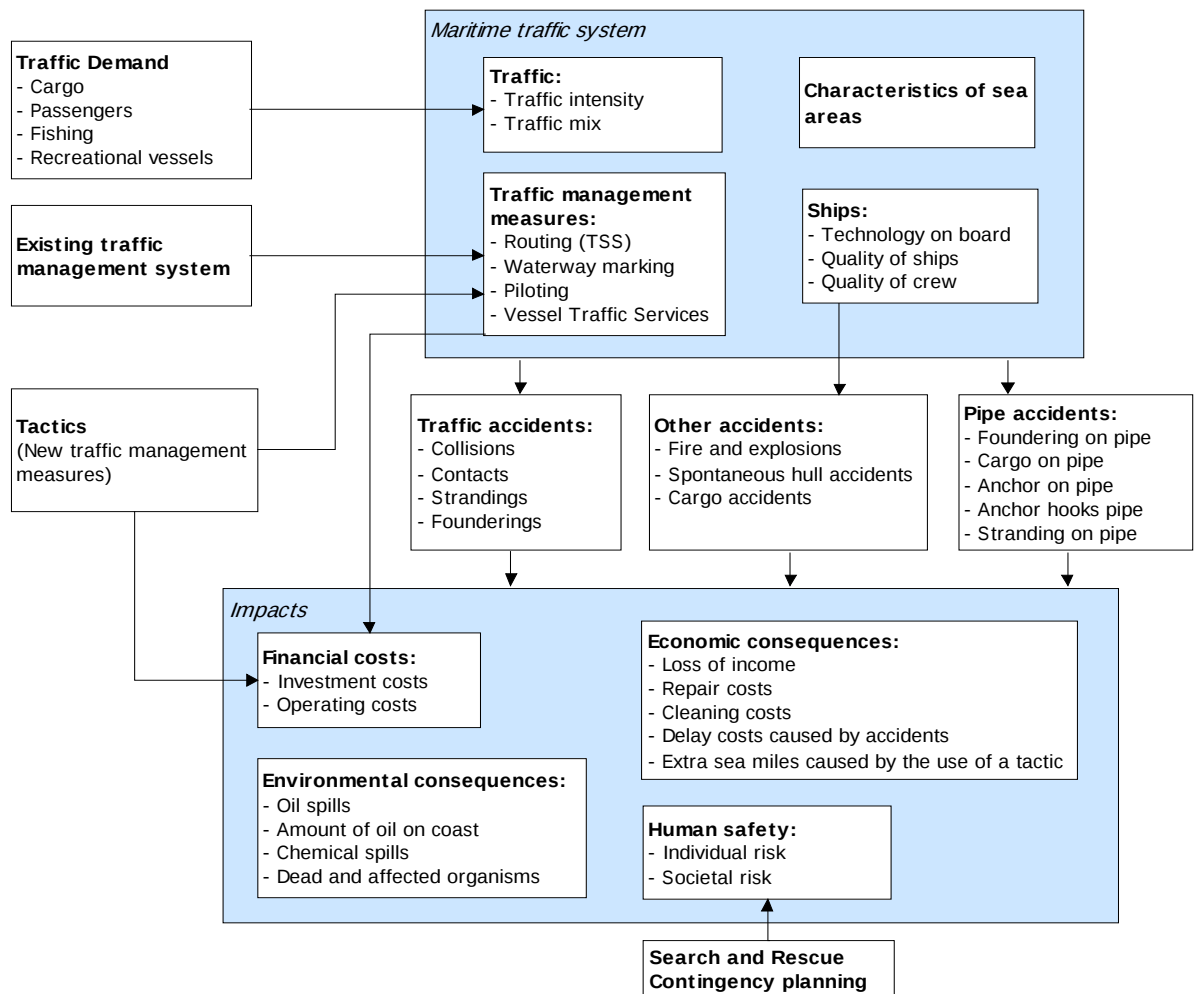


Figure B- 1 System diagram of the maritime traffic system

### Models of SAMSON used for the study

The frequency of outflow of oil is calculated in the following steps:

1. Calculation of the different exposures (possible dangerous situations) for the different type of accidents
2. Calculation of the frequencies of the different accident types, by multiplying the exposures with the associated casualty rate
3. Calculation of the number of ships that are damaged in such a way that the cargo/bunker oil flows out because the cargo tanks are penetrated.
4. Calculation of the frequency of outflow of oil by multiplying the probability of a penetration of a cargo tank with the probability that the cargo tank is loaded with oil.

5. Calculation of the amount of oil that can flow out based on the size of the cargo tanks and the location of the hole in the tank.

#### Ad. 1: Exposures

Within the SAMSON-model different type of exposures are used for different type of accidents. Exposures can be described as possible dangerous situations that could lead to an accident.

An overview of the different accidents types and their exposures are given in Table 0-1

| Accident type          | Exposure                              |
|------------------------|---------------------------------------|
| Collision              | Encounters                            |
| Stranding              | Stranding Opportunity<br>Danger miles |
| Contact                | Stranding Opportunity<br>Danger miles |
| Foundering             | Nautical miles (ship miles)           |
| Fire/Explosion         | Nautical miles (ship miles)           |
| Hull/Machinery failure | Nautical miles (ship miles)           |

Table 0-1 Overview of the different accident types and their exposure

The exposure for a *collision* between two ships is an encounter. Ships can only collide when they are within a certain range of each other. An encounter occurs when a ship penetrates the domain of another ship. This domain is defined as a circle with a radius of 0.5 nautical mile around a ship. Only a small part of all encounters (about  $10^{-4}$ ) will actually result in a collision. The casualty rate, the relation between the number of exposures and the number of accidents, depends on the type and size of the ship.

The two main causes for the accident types *stranding* and *contact* are navigational error and a technical failure, which causes the ship to be uncontrollable.

The exposure measure for a stranding or contact caused by a navigational error is called the stranding opportunity. A stranding or contact caused by a navigational error can only occur when the error is made when the ship is located close enough to the stranding line or fixed object. Only then, a navigational error can be fatal. The stranding opportunity is based on the location, sailing direction, speed and length of the ship and the location of the stranding line or fixed object.

A stranding or contact caused by a technical failure will only take place when the failure occurs near the stranding line or fixed object and when the ship drifts in the direction of the stranding line or object. In addition, the repair time and the probability of successful anchoring are important factors. The exposure for this type of accident is called "danger mile".

#### Ad 2: Accident probability

The relation between the exposures of a certain accident type and the actual accident frequency is called the casualty rate. This casualty rate is determined using different accident databases e.g. the Lloyds casualty database of 1990-2009. The casualty rate is different for the different accident types, ship types and ship sizes.

**Ad 3: Probability of the penetration of the cargo tank**

The probability of damage to the cargo tanks as a result of the different accident types is based on the damage distribution determined by the IMO [16].

**Ad 4: Probability of an outflow**

The probability of an oil spill can be determined by multiplying the probability of penetration of the cargo tanks with the probability that the cargo tanks are loaded.

The average amount of oil on board of certain ship types and ship sizes is determined in different studies for different years [15], [17] and [19].

**Ad 5: The amount of outflow**

The amount of oil that flows out depends on the location of the hole in the cargo tank. When a hole is located above the waterline it is assumed that only the oil above the hole will flow out. When a hole is located below the water line it is assumed that all oil from the tank flows out.

The outflow frequency and the amount of oil can be described by the following simplified formulas:

$$\begin{aligned} N_{\text{accidents}} &= N_{\text{exposures}} \text{CasRat} \\ N_{\text{outflow}} &= N_{\text{accidents}} P_{\text{hole\_in\_tank}} P_{\text{oil\_in\_tank}} \\ V_{\text{outflow}} &= N_{\text{outflow}} V_{\text{tank}} \end{aligned}$$

Where:

|                             |                                         |
|-----------------------------|-----------------------------------------|
| $N_{\text{accidents}}$      | Number of accidents per year            |
| $N_{\text{exposures}}$      | Number of exposures                     |
| $\text{CasRat}$             | Casualty Rate                           |
| $N_{\text{outflow}}$        | Number of outflows per year             |
| $P_{\text{hole\_in\_tank}}$ | Probability of a hole in the cargo tank |
| $P_{\text{oil\_in\_tank}}$  | Probability of oil the cargo tank       |
| $V_{\text{outflow}}$        | Volume of the oil spill                 |
| $V_{\text{tank}}$           | Volume of the damaged cargo tank        |

The described formulas are applied for all accident types.

**Outflow models**

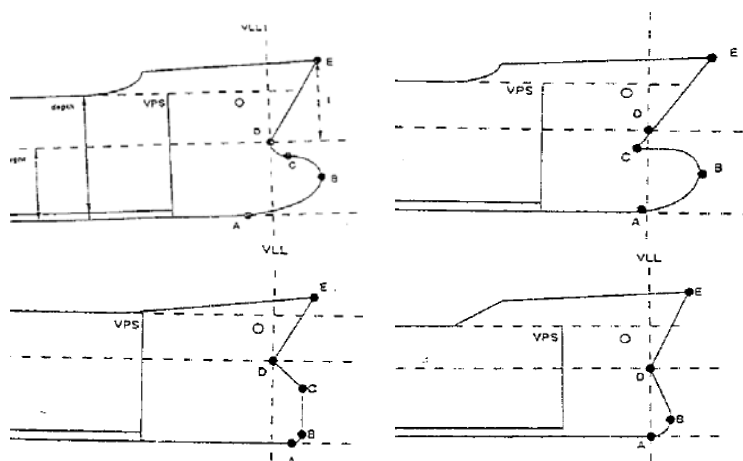
This chapter briefly describes the assumptions in the outflow models.

A useful publication [16] about the outflow of oil as a result of a collision was found in the literature. The assumptions made for the outflow models for the other accident types the outflow models cannot be validated using data from the casualty databases.

**Collisions**

The horizontal probability distribution of the position of the outflow of oil is based on the distribution of the position of a collision from the IMO. The vertical distribution of the position of the hole in the tank is based on the shape of the bow of the ships that collide (see Figure 0-1). When a hole is located above the water line it is assumed that only the oil above the bottom of the hole will flow out. It is assumed that all oil will flow out of the tank when a hole in a cargo tank is located below the waterline.

A small percentage (3%) of the ships involved in a collision will be total-loss. All the cargo and bunker oil will flow out (based on [13] and [14]) as a result of these collisions.



**Figure 0-1 Examples of different bow shapes used in the calculation of the probability of a hole in the cargo tank.**

#### **Contact with platform (ramming)**

When a contact with an object e.g. a platform takes place as a result of a navigational error, the speed of the vessel when she hits the object, will be relatively high. Therefore, this contact is called a ramming contact. Because of the higher speed of the vessel, it is assumed that the outflow distribution is equal to the outflow distribution of the ship that is collided during a collision. In this study, only the outflow of oil from the ship is taken into account. In addition, oil from the platform could flow out and end up in the water as a result of the impact. This type of outflow falls outside the scope of the project.

#### **Contact with platform (drifting)**

When a contact with an object e.g. a platform is the result of an engine failure, the ship will hit the object with the maximal drifting speed (3 knots) of the vessel. The vessel will strike the platform sideways with a relatively low speed. Only the outer cargo tanks will be damaged because of the lower speed. Two outside cargo tanks will only be penetrated in a worst-case scenario.

#### **Contact between ship and ship at anchor (ramming)**

The same outflow model as for a collision between two ships is used for the calculation of the outflow of oil when a ship rams a ship at anchor.

#### **Contact between ship and ship at anchor (drifting)**

No real damage to the cargo tanks is expected when a ship will drift against another ship that is at anchor. Therefore, no outflow is expected.

#### **Contact with a coastal structure (ramming)**

When a ship rams a coastal structure, e.g. breakwater, pier or a sea defence structure, it is assumed that the damage will be at the bottom of the ship. This implies that an expected hole in a tank occurs below the waterline, meaning that all oil contained in the tank will flow out.

#### **Contact with a coastal structure (drifting)**

The outflow of oil as a result of drifting against a coastal structure is modelled in the same way as the outflow of oil as a result of a ship drifting against a platform is used.

**Contact with buoy (ramming, drifting)**

When a vessel strikes a buoy, it will not cause much damage to the vessels. Therefore, this type of accident does not result in an outflow of oil.

**Stranding (ramming, drifting)**

A ship could be stuck after she strands at the coastline, since the Dutch coastline mainly consists of sand, but not much damage will be done to the tanks. Therefore, it is assumed this type of accident will not result in an oil spill for the Dutch Coast. Another type of coastline, such as rocks, can cause major damage to the bottom (and side) of the ship and the tanks.

**Fire/explosion**

No outflow model for the casualty type Fire/Explosion has been found in literature. It is expected that the contribution of this type of casualty is very small.

**Foundering**

For foundering a worst case scenario is used; all oil in the ship will flow out into the sea. Often it is possible to pump the oil out of the ship before or after the ship sinks. The outflow as a result of foundering is not taken into account in the further calculations.

A worst-case scenario is applied for all models, since it is assumed that all oil will flow out immediately from a damaged tank. Normally this is not the case, especially when a hole is located under the waterline. A part of the oil will stay in the tank or will leak out of the tank more slowly because of the hydrostatic pressure.

The total amount of oil that flows out can also be limited by the action of clean-up vessels. The hole can be closed and/or the oil from the leaking tank can be pumped into another ship, which limits the total volume that ends up in the sea.

Not much detailed information is available about the amount of oil spilled after an accident. Therefore, not all models can be verified to the same extent. For some accident models, such as collision, the outflow of oil is modelled as “realistic” as possible. A worst-case scenario is used for other models, such as foundering. This is not a problem for most studies, since the model is used to “compare” different scenarios. For the current study, in which the total expected outflow of oil is determined, it is important to recognize these differences. Because of this importance, the results are expanded for the different casualty types.

**Double hull**

Originally, oil tankers were single hull ships and the traffic database contained only the ship type oil tankers. Nowadays most oil tankers are double hull. For this reason, the ship types used in the SAMSON model are revised. In the traffic database the movements of single and double hull tankers are distinguished.