FSA STUDY OF LOCAL PASSENGER SHIPS - RISK ASSESSMENT

for

Maritime and Coastguard Agency
FORMAL SAFETY ASSESSMENT
STUDY OF LOCAL PASSENGER
SHIPS -
RISK ASSESSMENT

for

Maritime and Coastguard Agency

Approved by:..............................

Dr T Fowler
Senior Specialist

Job No. C32166800
Revision 2
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# Issue Log

<table>
<thead>
<tr>
<th>Revision</th>
<th>Issue Date</th>
<th>Prepared by</th>
<th>Reviewed by</th>
<th>Approved by</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15th February 2002</td>
<td>S Cox, J Spouge, C Ross</td>
<td>C Ross, J Spouge</td>
<td>T Fowler</td>
<td>Draft report issued for MCA comment</td>
</tr>
<tr>
<td>1</td>
<td>20th May 2002</td>
<td>S Cox, C Vlachos</td>
<td>J Spouge</td>
<td>E Smith</td>
<td>Incorporating comments and supplementary activities</td>
</tr>
<tr>
<td>2</td>
<td>17th July 2002</td>
<td>S Cox</td>
<td>J Spouge</td>
<td>T Fowler</td>
<td>Final report</td>
</tr>
</tbody>
</table>
RESEARCH PROJECT RP 514

FORMAL SAFETY ASSESSMENT OF DOMESTIC PASSENGER SHIPS – RISK ASSESSMENT

SUMMARY OF REPORT INCORPORATING MCA RESPONSE

This summary is compiled by MCA from the Executive Summaries provided for VOLUMES I to VI by the consultants, but with some additional clarification of the background and including MCA’s comments and response.

The original summaries are available in the electronic versions of the reports, available on the MCA website – www.mcga.gov.uk.

Introduction

At the Formal Investigation into the MARCHIONESS/BOWBELLE Collision, the Department for Transport announced that it would carry out a comprehensive Formal Safety Assessment (FSA) of River Thames Class V passenger vessels, to cover every aspect of their safety including their encounter risk with large ships and bridges, fire risk, stability, subdivision, freeboard, visibility, life saving appliances, means of escape, manning, passenger numbers, trading areas and safety management.

Lord Justice Clarke welcomed this. Recommendation 12 of his report reads -

We wholeheartedly support this initiative by the Department to carry out a Formal Safety Assessment (FSA) to cover every aspect of the safety of Class V passenger vessels including their encounter risk with large ships and bridges, fire risk, stability, subdivision, freeboard, visibility, life saving appliances, means of escape, manning, passenger numbers, trading areas and safety management. We recommend that, in the course of what we understand will be a wide-ranging review, the FSA should include an extensive analysis of life-saving appliances and escape means in the light of the concerns expressed in this inquiry. We also recommend that the MCA should afford the highest priority to conducting the FSA on the older vessels.

It was later decided to extend the FSA to all operating environments for domestic passenger ships in the United Kingdom. The five operating environments studied are the tidal Thames, other tidal waters, coastal waters, lakes and lochs and inland (non-

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1 Class V passenger ship - a ship carrying more than 12 passengers, engaged only on voyages in Category A, B and C waters [formerly known as “smooth waters”]; Categories are defined in the Merchant Shipping (Categorisation of Waters) Regulations 1992 (S.I. No. 1992/2356) and waters are listed in Merchant Shipping Notice MSN 1776(M).

2 Published by The Stationery Office 2001: ISBN 0 11 702550 X

3 Domestic Passenger Ships are those of Classes IV, V, VI and VI(A) operating within the United Kingdom, not on international voyages; and ships of EU Classes A to D.
tidal) waters. The study was run by the Maritime and Coastguard Agency (MCA), who conducted the initial Hazard Identification exercise, and then employed Det Norske Veritas Maritime Solutions Limited (DNV) for the risk assessment and cost benefit analysis stages of the FSA (steps 2 and 3 of the “Guidelines for Formal Safety Assessment for use in the IMO Rule Making Process”\(^4\)).

The MCA’s purpose in conducting the study was to provide a base-line for future risk-based regulation of domestic passenger ships by highlighting any areas where the current regulatory framework could be improved to address the identified risks.

RP 514, prepared by DNV, consists of six reports.

The report entitled **Formal Safety Assessment of Local Passenger Ships – Risk Assessment** details the development of a risk model for the analysis of crew and passenger risks from Class IV/V/VI and VIA Passenger Vessels operating in UK waters.

This model will be useful for analysing risk on domestic passenger ships in the different operating environments in the United Kingdom. This will help the MCA to target safety regulations in the areas of greatest risk, and to evaluate the effectiveness of any new safety standards introduced.

The MCA will maintain the risk model by updating it on a regular basis as more data is collected. The interval to the first review is five years.

**Results of RP 514**

The risk model for domestic passenger ships was evaluated for four working environments (tidal waters, lochs and lakes, coastal and non-tidal inland waterways) with the data inputs for each environment based upon a typical vessel.

The original model created in 2002 was updated in 2004 to reflect further data, and the risk model results updated accordingly. These updated results are the ones on which the Cost Benefit Analysis of risk control measures was based. This time the tidal Thames was treated separately from other tidal waters. The risks were calculated per passenger per voyage, and for a passenger commuting regularly on a passenger ship – based on an estimated 400 trips per year.

<table>
<thead>
<tr>
<th>Operating Environment</th>
<th>Individual risk of fatality for passenger per voyage(^5)</th>
<th>Individual risk of fatality – commuter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Thames</td>
<td>(1.3 \times 10^{-7})</td>
<td>(5.3 \times 10^{-5})</td>
</tr>
<tr>
<td>Tidal /estuaries</td>
<td>(1.4 \times 10^{-7})</td>
<td>(5.5 \times 10^{-5})</td>
</tr>
<tr>
<td>Lochs and lakes</td>
<td>(6.4 \times 10^{-8})</td>
<td>(2.6 \times 10^{-6})</td>
</tr>
</tbody>
</table>

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\(^4\) MSC Circular 1023/MEPC Circular 392 5 April 2002

\(^5\) \(1 \times 10^{-5}\) is 1 in one hundred thousand

\(1 \times 10^{-6}\) is 1 in a million

\(1 \times 10^{-7}\) is 1 in 10 million

\(1 \times 10^{-8}\) is 1 in 100 million
Coastal waters 5.43 x 10⁻⁸ 2.17 x 10⁻⁵
Inland waters 4.26 x 10⁻⁸ 1.7 x 10⁻⁵

The risk model indicates that the worst case commuter risk on domestic passenger ships is still within the HSE’s “tolerable” criteria⁶, provided that the risks are made as low as reasonably practicable.

This study highlighted the poor levels of data collection, particularly on minor incidents and “near misses”. If use of the risk model is to bring maximum benefits, more robust data collection is needed across the industry. This issue was endorsed at the risk control measures workshop. The data gathering exercise also indicated a range of threshold levels for the reporting of accidental damage from incidents such as collision – demonstrating a need for clearer definitions of what is meant by “accident”, “incident” and “near miss”, and a better understanding of the reasons for collecting this data.

The MCA is discussing how this can be addressed through the Industry’s national consultative group, the Domestic Passenger Ship Steering Group (DPSSG). The wider question of data about water related incidents is being considered by the Information Advisory Group of the National Water Safety Forum.⁷

Separate reports cover the Cost Benefit Analysis stage of the FSA for the five operating environments – the tidal Thames, other tidal waters, coastal waters, lochs and lakes and (non-tidal) inland waterways.

The Cost Benefit Analysis reports for each operating environment list a range of Risk Control Measures that could be cost effective in reducing incidents. These fall into a range of hazard categories – collision, fire, flooding, evacuation, alcohol, human factors, pier safety, berthing and grounding.

Where relevant, the Risk Control Measures identified as cost effective for each operating environment will be considered in the context of the recommendations from the research reports. Others which fall within MCA’s remit will be considered as part of the review of regulations and guidance applying to domestic passenger ships.

Risk Control Measures which fall outside MCA’s area of responsibility will be passed to relevant organisations, or to District Marine Safety Committees for consideration.

Other measures are identified for which the benefits are shown by the report to be more marginal or not cost effective, but may nevertheless be worth consideration. These will be kept under review as recommended measures are taken forward to see whether they can be incorporated.

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⁶ This is from the Health and Safety Executive (HSE) framework for risk tolerability in “Reducing Risks, Protecting People” (HSE, 2001)
⁷ www.nationalwatersafety.org.uk
Lord Justice Clarke in his Interim Report on the Thames Safety Inquiry in 1999 had concluded that “the regulation of safety for passenger ships on the River Thames has improved almost beyond recognition since 1989”. This study has shown that the safety regime is effective in all operating environments, while demonstrating the differences between them.

While reassured by these findings, the MCA, advised by DNV, took the view that this general conclusion, arrived at by averaging risk across all the vessels operating in each environment, may mask the vulnerability of certain vessels. In particular, there was concern about the survivability of certain vessels in the event of a major incident, and the likelihood in the rare event of an emergency evacuation of evacuating passengers within the available time.

It was therefore agreed that more specific research was required to look at the specific areas of vulnerability - stability (RP 524), fire risk (RP 525), wheelhouse visibility (RP 528A and RP 528B), safety management (RP 527) and evacuation standards (RP 526), with particular emphasis on older vessels.

Six projects were let, covering these areas, which reported between July 2004 and March 2005. Separate executive summaries of these projects and the MCA’s response to their findings are published in Formal Safety Assessment of Domestic Passenger Ships - Follow up to the MARCHIONESS/BOWBELLE Formal Investigation, available on the MCA website. That publication also covers Stage 5 of the Formal Safety Assessment process, “Decisions and Recommendations”.

The MCA acknowledges the valuable assistance with the Formal Safety Assessment provided by passenger ship operators, local navigation authorities and other stakeholders, through attendance at the Hazard Identification and Risk Control Workshops, in providing data and contributing their expert opinion. Using the results of these studies, we look forward to continuing to work with operators and other stakeholders on the further enhancement of a robust, risk-based standards regime for the passenger vessel industry.

SUMMARY OF FSA PROCESS

Stage 1 – Hazard Identification Oct /Nov 2001

For each of the operating environments (tidal rivers including the River Thames, estuaries, lochs and lakes, inland waterways and coastal) meetings were held with operators and regulatory authorities. A typical voyage scenario was used to maintain consistency of response. The five steps considered were:

.1 Passengers on pontoon/pier
.2 Vessel alongside
.3 Vessel on voyage
Vessel returning alongside
Water categories and parameters influencing risk

Risks identified were listed as generic or specific to each operational area. This process is called the Hazard Identification (HAZ-ID) process.

**Stage 2 – Risk Analysis 2002**

Consultants were engaged to develop a risk model. The aims of the model were:
- to quantify the individual and group risks of fatalities among passengers and crew on local passenger vessels (Class IV, V and VI);
- to show how these risks vary according to vessel type and operational environment;
- to illustrate the risk contributors, influencing factors and potential risk control measures; and
- to provide a means of quantifying the benefits of various risk control options.

The hazards identified within Stage 1 highlighted a range of potential accidents to both crew and passengers. These types of hazards are best suited to qualitative analysis rather than quantitative analysis. The quantitative risk model developed in Stage 2 therefore focussed on the underlying generic hazard categories that lead to loss of life.

The data used to develop the risk model was collected from representatives from each of the operating environments, as well as through a review of both the Marine Accident Investigation Branch (MAIB) accident database and, for the tidal region of the Thames, the Port of London Authority (PLA) accident database. Generic data was used to supplement the local passenger specific data, where data gaps or reliability issues were identified.

The risk model has been formulated in a manner to provide maximum flexibility.

Fault trees and event trees were used to determine the frequency and consequences of possible incidents in the accident categories of collision, grounding, contact, fire/explosion, flooding (for reasons other than collision) and personal accidents. The risk model was evaluated for each of the four working environments, with the data inputs for each environment based upon a typical vessel.

Putting together the results for each accident category, the model was used to calculate the individual risk of fatality for a passenger travelling on every voyage of a typical passenger ship per year\(^8\). For all of the operating environments the risks fell within the

\(^8\) The risks ranged from $1.0 \times 10^{-4}$ to $4.9 \times 10^{-4}$ for the individual risk of fatality for passengers per year, and $2.0 \times 10^{-4}$ to $9.5 \times 10^{-5}$ for the individual risk of fatality for crew per year. These represent the individual risk of fatality for both passengers and crew from travelling on every voyage of a typical passenger ship per year, within each of the operating environments and are useful for calculation purposes only.
“tolerable” safety region HSE Framework for the Tolerability of Risk. Within this region risks are tolerable provided that they are made as low as reasonably practicable.

In addition, influence diagrams were used to show the areas of influence within the risk model. For example, the level of crew competency would affect the actions taken in the event of an emergency, so affecting its outcome. Where possible these effects have been quantified and added to the model, but this is often not possible, because only the most serious incidents are subject to analysis of underlying causes by the authorities. The influence diagrams were also therefore used to provoke discussion in the Risk Control Workshops.

Stage 3 – Risk Control Options: Jan – May 2002

A risk control workshop was held, attended by representatives from industry and the regulator from across all the operating areas who had been involved in the original hazard identification stage. Hazards from both the original HAZ-ID and the developed risk model were considered. Taking account of existing mitigating factors, additional risk control measures were identified for further consideration. The differences between different operating environments were highlighted.

A further workshop (2 sessions) was held specifically for the Thames, involving both operators and regulators, to identify existing measures exceeding regulatory requirements, and further recommendations.

DNV advise that that they would expect the Risk Control Measures (RCMs) identified would affect the risk model, but this cannot be demonstrated because there is very little information available on the underlying causes of reported incidents. It was therefore not possible to update the Risk Model to show the impact of the proposed RCMs.

Instead a judgement approach was used for the Cost Benefit Analysis stage.


At this stage, current MAIB accident records were used to update the risk model, and the risk levels re-calculated – per passenger per voyage, and for a passenger commuting regularly, based on 400 trips per year.

Workshops were used to review the proposed risk control measures (RCMs) against the risk model. To identify the parameters within the model which may be affected by implementation of the RCMs. Expert judgement was used to consider the effects of the proposed measures, using a standard set of questions. This was considered the most

In terms of risk per passenger voyage the figures range from $9.1 \times 10^{-8}$ to $1.5 \times 10^{-7}$.

The upper limit of the “Tolerable” region for passenger risk is $1 \times 10^{-6}$ or one in a million.
appropriate method, because of the limited availability of data relating to the causes of accidents and near misses, and effectiveness of current measures.

Cost data for implementation of the RCMs was gathered from the judgements of operators and regulators. Using the net costs (cost of implementation minus cost of benefits) and the change in the group risk of fatality, an Implied Cost of Averting a Fatality (ICAF) was calculated for each RCM.

An ICAF, is a measure used to compare the cost effectiveness of risk control measures. For the purposes of this study, the MCA has used values for prevented fatalities as £1m per crew member and £2.5m per passenger, based on views taken by the HSE and Department for Transport on this issue.

For each operating environment, a number of measures were identified as cost effective in improving safety (ie with an ICAF value of less than £2.5m). Other measures which are shown to be more marginal or not cost effective are also listed.
Management Summary

This report details the development of a risk model for the analysis of crew and passenger risks from Class IV/V/VI Passenger Vessels operating in UK waters. The risk model has been formulated in a manner to provide maximum flexibility. This report details the evaluated risks of operating in four environments, that is Tidal and Estuaries, Inland Waterways, Lochs and Lakes, and Coastal Waters.

The report documents steps 2 and 3 of the “Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule Making Process”. Step 1 has been completed by the MCA and steps 4 and 5 are outside the scope of this project. Therefore the risk model results are presented for information purposes only and for further consideration with the FSA process.

Data has been collected from representatives from each of the operating environments, as well as through the review of both the MAIB (Marine Accident Investigation Branch) accident database and the Port of London (PLA) accident database for the tidal region of the Thames. Generic data has been used to supplement the local passenger specific data, where data gaps or reliability issues have been identified. The data gathering exercise highlighted the need for more robust data collection across the industry and this issue was endorsed at the risk control measures workshop. Potential areas of under-reporting included the reporting of near misses and minor accidents. The data gathering exercise also indicated a range of threshold levels for the reporting of accidental damage from incidents such as collision.

The risk model has been evaluated for the four working environments, with the data inputs for each environment based upon a typical vessel. The risks evaluated for the environments range from $1.0 \times 10^{-4} - 4.9 \times 10^{-4}$ for the Individual Risk of fatality for passengers per year and $2.0 \times 10^{-4} - 9.5 \times 10^{-4}$ for the Individual Risk of fatality for crew per year. The risk model results are tabulated in Table 1 below.

<table>
<thead>
<tr>
<th>Operating Environment</th>
<th>Individual Risk – Passenger</th>
<th>Individual Risk – Crew</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal /Estuaries</td>
<td>$2.0 \times 10^{-4}$</td>
<td>$3.9 \times 10^{-4}$</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>$1.0 \times 10^{-4}$</td>
<td>$2.0 \times 10^{-4}$</td>
</tr>
<tr>
<td>Lochs and Lakes</td>
<td>$1.8 \times 10^{-4}$</td>
<td>$3.6 \times 10^{-4}$</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>$4.9 \times 10^{-4}$</td>
<td>$9.5 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

The above results represent the individual risk of fatality for both passengers and crew from travelling on every voyage of a typical passenger ship per year within each of the operating environments and are useful for calculation purposes only.

This data is represented below in Table 2 in terms of per passenger voyage which is a more useful basis for comparing with other risks. Table 2 also presents the measured risks of accidental death for rail passengers published for the period 1999/2000 (Railway Safety, 2002).
Table 2: Risk Model Results for the Operating Environments

<table>
<thead>
<tr>
<th>Operating Environment</th>
<th>Individual Risk – Passenger</th>
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<tr>
<td>Tidal /Estuaries</td>
<td>$1.5 \times 10^{-7}$ Fatalities per passenger voyage</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>$9.1 \times 10^{-8}$ Fatalities per passenger voyage</td>
</tr>
<tr>
<td>Lochs and Lakes</td>
<td>$1.4 \times 10^{-7}$ Fatalities per passenger voyage</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>$1.3 \times 10^{-7}$ Fatalities per passenger voyage</td>
</tr>
<tr>
<td>Railway Group (1999/2000 actual)</td>
<td>$4 \times 10^{-8}$ Fatalities per passenger journey</td>
</tr>
<tr>
<td>Railway Group (1999/2000 actual)</td>
<td>$3.3 \times 10^{-7}$ Major injuries per passenger journey</td>
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Table 2 shows that the estimated risks of passenger fatality per passenger voyage are broadly similar to the actual measured risks of passenger fatality per rail journey. Comparing the individual risk of passenger fatality for realistic levels of exposure against the Health and Safety Executive (HSE) framework for risk tolerability indicates that for crew members who are aboard on all voyages or for commuters using the vessel twice per working day, the risks are tolerable provided they are made as low as reasonably practicable. For passengers making less than six voyages per year, the risks for each environment fall into the broadly acceptable region. This region has an upper boundary of $1 \times 10^{-6}$ or 1 in a million individual risk of fatality per year. An individual risk of fatality per year of 1 in a million or less is small compared to background risks and would not normally give rise to concern or result in a change in behaviour.

A Risk Control Measures Workshop was held at DNV's London office, attended by representatives from industry and the regulator. The workshop was used to identify potential risk control measures for further consideration. The workshop highlighted the differences between the four operating environments. Two further half-day workshops were held to identify measures specifically for the Thames, involving both operators and regulators.

Due to current data limitations and the generic nature of the control measures it has not been possible to re-evaluate the risks within the four environments following implementation of the risk control measures. It is recommended that either a further workshop or alternative means be considered to review the potential impacts of identified measures and to quantify any possible reduction within the model based upon expert judgement.
## Contents

**Summary of report incorporating MCA response**  a

1. **INTRODUCTION** .......................................................................................................... 1.1  
   1.1 Background and Scope ............................................................................................... 1.1  
   1.2 Objectives ................................................................................................................. 1.2  
   1.3 Overview of the FSA Process..................................................................................... 1.2  
   1.4 Project Progression ..................................................................................................... 1.2  

2. **DESCRIPTION OF CLASS IV/V/VI PASSENGER OPERATION IN UK**................. 2.1  
   2.1 Introduction............................................................................................................... 2.1  
   2.2 Classification of Ships and Categorisation of Waters................................................. 2.1  
   2.3 Passenger Vessel Activities ........................................................................................ 2.2  
   2.4 Operational Information.............................................................................................. 2.3  
   2.5 Traffic Density............................................................................................................ 2.3  
   2.6 Vessel Survivability.................................................................................................... 2.3  
   2.7 Measures Implemented post Marchioness Incident.................................................... 2.3  
   2.8 Current Thames Traffic Density and Profile .............................................................. 2.4  

3. **RISK MODEL DEVELOPMENT**............................................................................. 3.1  
   3.1 Introduction............................................................................................................... 3.1  
   3.2 Hazard Identification .................................................................................................. 3.2  
   3.3 Review of HAZ-ID Workshop.................................................................................... 3.2  
   3.4 Data Gathering............................................................................................................ 3.4  
   3.5 Risk Model Development ........................................................................................... 3.4  
      3.5.1 Identification of Failure Cases.......................................................................................... 3.4  
      3.5.2 Cause and Frequency Analysis ............................................................................................. 3.5  
      3.5.3 Consequence Evaluation................................................................................................... 3.5  
      3.5.4 Risk Summation........................................................................................................... 3.5  
   3.6 Use of Influence Diagrams......................................................................................... 3.5  
   3.7 Risk Control Measures................................................................................................ 3.6  
      3.7.1 Risk Control Workshop .................................................................................................... 3.6  
      3.7.2 Impact on Risk Model..................................................................................................... 3.6  
   3.8 Evaluation of Risk Control Measures......................................................................... 3.6  
   3.9 Further Workshops - Tidal Thames ............................................................................ 3.8  

4. **RISK MODEL RESULTS AND DISCUSSION**.................................................... 4.1  
   4.1 Introduction............................................................................................................... 4.1  
   4.2 Risk Model Results ..................................................................................................... 4.1  
   4.3 Evaluation of Results .................................................................................................. 4.5  
   4.4 Model Applicability and Limitations......................................................................... 4.12  
   4.5 Risk Control Measures.............................................................................................. 4.13  
   4.6 Data Availability....................................................................................................... 4.13  
   4.7 Summary................................................................................................................... 4.14  

5. **REFERENCES** ........................................................................................................... 5.1  

---

### Appendices

APPENDIX I  Data Gathering Question Set  
APPENDIX II  Summary of Responses
<table>
<thead>
<tr>
<th>Appendix</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPENDIX III</td>
<td>Risk Model</td>
</tr>
<tr>
<td>APPENDIX IV</td>
<td>Risk Control Workshop and Output</td>
</tr>
<tr>
<td>APPENDIX V</td>
<td>Risk Model Results</td>
</tr>
<tr>
<td>APPENDIX VI</td>
<td>Risk Control Workshop for Tidal Thames</td>
</tr>
<tr>
<td>APPENDIX VII</td>
<td>Thames Specific Review and Discussion</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

The Maritime and Coastguard Agency (MCA) has commissioned DNV to undertake the Risk Assessment phase for the Formal Safety Assessment (FSA) for Local Passenger Ships. This report documents the activities undertaken within the project and the risk model developed.

This report documents the risk assessment activities. A shorter version of this report has also been prepared which does not contain any commercially sensitive issues.

1.1 Background and Scope

A Hazard Identification Workshop was carried out by the MCA and was provided to DNV to support the risk assessment process. DNV has carried out the risk analysis stage, Step 2 of the FSA study, and provided assistance to MCA in the execution of Step 3 of the FSA study, the identification of risk control options. Steps 4 and 5 will be completed by the MCA and are outside the scope of this project.

The Department of Environment Transport and Regions (DETR) announced the commencement of a wide ranging Formal Safety Assessment into the operations of Class V passenger vessels on the River Thames. This announcement was made at the Formal Inquiry into the collision between the passenger vessel Marchioness and the dredger Bowbelle. The risk assessment has addressed the following:

- the encounter risk with large ships and bridges
- stability
- freeboard
- lifesaving appliances (LSA)
- manning
- safety management issues
- fire
- subdivision
- wheelhouse visibility
- means of escape
- trading areas

The scope of the FSA extends to the inclusion of Class IV, V and VI local passenger vessels, with focus on vessels carrying passengers only. The study has excluded Ro-Ros, permanently moored restaurant vessels and similar structures. The study has also considered the following issues in the development of the risk model and risk control measures: -

- vessel design and age;
- human factors;
- operational issues;
- analysis of LSA; and
- means of escape.

Section 3.1 provides further information relating to the development of the risk model and the inclusion of the project scope areas.
1.2 Objectives

The objectives of this project, as stated by the MCA, are: -

1. To establish a quantified risk assessment of local passenger vessels taking into consideration:
   - accident statistics;
   - traffic profiles;
   - exposure to adverse environmental conditions; and
   - availability of emergency response.

2. To develop a risk model based upon the application of data from Step 1 of the FSA Study, Hazard Identification.

1.3 Overview of the FSA Process

DNV has developed a risk model in line with the “Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule Making Process”. Within the staged FSA process, Step 1 was completed by the MCA prior to this project. DNV has used the output from this stage in the execution of this project. DNV has completed step 2 of the formal FSA process and provided assistance in the execution of Step 3. Further detail is provided below.

The “Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule Making Process” states an FSA should comprise of the following steps: -

1. identification of hazards;
2. risk analysis;
3. risk control options;
4. cost benefit assessment, and;
5. recommendations for decision making.

The hazards identified within Step 1 highlighted a range of potential accidents to both crew and passengers. These types of hazards are best suited to qualitative analysis rather than quantitative analysis. The quantitative risk model developed for Step 2, the risk analysis stage, has therefore focussed on generic hazard categories that lead to loss of life.

1.4 Project Progression

The initial focus of the project was to review and evaluate the risks to both crew and passengers from passenger vessel operation on categories A, B, C and D waters, as outlined above. As the project has progressed, the scope has been extended to provide specific focus on the River Thames, and the Thames information has been selected as indicative of a tidal water environment.

The main body of this report therefore covers issues relating to UK waters as a whole, whereas Thames specific information has been collated and presented in Appendix VI and VII.
2. DESCRIPTION OF CLASS IV/V/VI PASSENGER OPERATION IN UK

2.1 Introduction

This section provides an overview of the operations of Class IV/V/VI passenger vessels in UK waters.

2.2 Classification of Ships and Categorisation of Waters

The risk analysis has considered Class IV, V and VI passenger vessels operating in Category A, B, C and D UK waters. Table 2.1 defines the classification categories for the vessels and Table 2.2 defines the categorisation of waters used within this study. Table 2.3 provides a breakdown of the number of passenger vessels by their class and their operating environment.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class IV</td>
<td>Ships engaged on voyages in Category A, B, C and D waters</td>
</tr>
<tr>
<td>Class V</td>
<td>Ships engaged only on voyages in Category A, B and C waters</td>
</tr>
<tr>
<td>Class VI</td>
<td>Ships engaged only on voyages with not more than 250 passengers on board, to sea, or in Category A, B, C and D waters, in all cases in favourable weather and during restricted periods, in the course of which the ships are at no time more than 15 miles, exclusive of any Category A, B, C and D waters, from their point of departure nor more than 3 miles from land</td>
</tr>
<tr>
<td>Class VI(A)</td>
<td>Ships carrying not more than 50 passengers for a distance of not more than 6 miles on voyages to or from isolated communities on the islands or coasts of the United Kingdom and which do not proceed for a distance of more that 3 miles from land.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>River Categorisation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category A</td>
<td>Narrow rivers and canals where the depth of water is generally less that 1.5 metres</td>
</tr>
<tr>
<td>Category B</td>
<td>Wider rivers and canals where the depth of water is generally more than 1.5 metres and where the significant wave height could not be expected to exceed 0.6 metres at any time</td>
</tr>
<tr>
<td>Category C</td>
<td>Tidal rivers and estuaries and large, deep lakes and lochs where the significant wave height could not be expected to exceed 1.2 metres at any time</td>
</tr>
<tr>
<td>Category D</td>
<td>Tidal rivers and estuaries where the significant wave height could not be expected to exceed 2.0 metres at any time</td>
</tr>
</tbody>
</table>
Table 2.3: Number of Vessels by Class and Environment

<table>
<thead>
<tr>
<th>Vessel Class</th>
<th>Operating Environment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tidal Rivers and Estuaries</td>
<td>Lochs and Lakes</td>
</tr>
<tr>
<td>IV</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IV/V</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>IV/V/VI</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>IV/VI</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IV/VI(A)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>V</td>
<td>164</td>
<td>65</td>
</tr>
<tr>
<td>V/VI</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>VI</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>VI(A)</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Total in each operating env.</td>
<td>187</td>
<td>68</td>
</tr>
<tr>
<td>Total number of class IV-VI(A) vessels operating</td>
<td>711</td>
<td></td>
</tr>
</tbody>
</table>

The data in Table 2.3 has been sub-divided to identify those vessels operating on the category B and C waters on the River Thames, see Table 2.4. This table indicates the high proportion of the total Class V vessels in operation on the tidal Thames.

Table 2.4: Class V Vessels operating on the River Thames

<table>
<thead>
<tr>
<th>Vessel Class</th>
<th>River Thames Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>V operating to Teddington Lock</td>
<td>129</td>
</tr>
<tr>
<td>% Class V operating on Thames</td>
<td>18%</td>
</tr>
<tr>
<td>% Class V operating to Teddington Lock</td>
<td>14%</td>
</tr>
</tbody>
</table>

2.3 Passenger Vessel Activities

Class IV/V/VI passenger vessels are in operation throughout the UK. The vessels undertake a range of activities including:

- Commuter services/ferries;
- Sightseeing trips;
- Function venues including dining (day/night);
- Party/Private Charters; and
- Disco Parties.

These services are provided throughout the year, although some organisations operate between April and October only. The number of passengers carried varies from 50 to 500 depending on the vessel size and function. Similarly the age profile of the passengers carried ranges from infants through to the elderly.

The vessel age profile varies from vessels in operation from the 1900's to modern day vessels. Some of the older vessels have been altered from their original design to provide the current operational service; typical modifications include installation of covered decks. Similarly more modern vessels can be a mixture of split decks or open decks depending upon the design and function.
Further information relating to all operating environments can be found in the risk model in Appendix III.

### 2.4 Operational Information

Table 2.5 provides further information relating to a typical vessel within each operating environment. The values displayed represent an average vessel with many variations in both passenger numbers, number of trips and operating period.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tidal and Estuaries</th>
<th>Inland Waters</th>
<th>Lochs and lakes</th>
<th>Coastal Waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Passenger numbers per trip</td>
<td>148</td>
<td>50</td>
<td>105</td>
<td>76</td>
</tr>
<tr>
<td>No. of trips per year</td>
<td>1369</td>
<td>1095</td>
<td>1314</td>
<td>3690</td>
</tr>
<tr>
<td>Operating Period</td>
<td>All-year (with reduced traffic in winter period)</td>
<td>March - October</td>
<td>All-year (with reduced traffic in winter period)</td>
<td>All-year (with reduced traffic in winter period)</td>
</tr>
</tbody>
</table>

There are substantial differences in the survivability standards applied to Class IV/V/VI Passenger vessels. Older vessels satisfy a heel or buoyancy test whereas more modern vessels are sub-divided and meet a higher level of survivability.

### 2.5 Traffic Density

The level of traffic density varies widely depending upon the operating environment. Some environments are isolated with only one or two operators whereas others, such as the Thames, are highly populated. The tonnage and speed of the vessels also varies. Traffic density in terms of number of encounters per vessel voyage can be found in Appendix III.

### 2.6 Vessel Survivability

Vessel survivability is classified by four levels of survivability; heel test, buoyancy test, one compartment and two compartment survivability. Heel test vessels satisfy a defined level of heeling moment depending upon the number of passengers carried. Buoyancy test vessels have sufficient buoyancy in watertight compartments or carry additional buoyancy materials to remain afloat following swamping of open compartments in the hull. Vessels satisfying the one compartment standard have sufficient buoyancy to survive the flooding of one compartment. Similarly vessels satisfying the two compartment standard can survive the flooding of two compartments. Older vessels tend to be non-sub-divided, with more modern vessels being subdivided in construction.

### 2.7 Measures Implemented post Marchioness Incident

Various measures have been implemented following the Marchioness Incident. These include measures on crew numbers and visibility. Regulation SI 1993/1213 requires the owner of a Class IV/V/V passenger vessel to notify the MCA of the number of crew, in addition to the master, that he considers necessary to navigate the vessel. The MCA
surveyors review this crew number, typically against a manning matrix to confirm the appropriateness of the crew size. In some instances owners and operators exceed the anticipated number of crew required.

Measures post the Marchioness disaster have been implemented in a number of ways, e.g. wheelhouse visibility. Some vessels have raised the existing wheelhouse, others have fitted CCTV cameras, mirrors or installed walking leads. The most important measure with regard to visibility is the requirement for a dedicated lookout (SI 1992/2357 reg. 4). Vessels less than 45m long do not have to meet the requirements of the 1998 visibility regulations which require the ability to be able to view the side of the vessel from the bridge wings. This requirement is useful if recovering a man overboard or coming alongside. It should be noted though that the 1992 regulations are more onerous with regard to the view astern. The relationship between the Marchioness/Bowbelle accident and subsequent changes to regulations is summarised in a logic diagram, see Figure 2.1.

2.8 Current Thames Traffic Density and Profile

Considering specifically the River Thames, there has been a change in the traffic profile of the river after the Marchioness incident. There has been a marked reduction in the size and frequency of commercial traffic, although commercial traffic of the size of the Bowbelle are still in operation. Therefore a Marchioness type accident still remains a possibility although the likelihood of an incident of this nature has been reduced.

Whilst the commercial traffic size and frequency or operation has reduced, there is a noticeable trend for larger passenger vessels in operation on the Thames. There are also a number of fast catamarans in operation. The resultant consequence of a collision between a passenger ship and a larger Class V passenger ship is unknown, but if the vessel is of the Marchioness type then the outcome is likely to be similar in nature to the Marchioness incident. Further Thames specific information and discussion can be found in Appendix VI.
Figure 2.1 Relationship between the Marchioness/Bowbelle Accident and Regulation Changes

Simplified Fault Tree for the Marchioness/ Bowbelle Accident

51 people died

- Insufficient time for all to escape the sinking vessel
- Insufficient time for “dry” rescue - escape into the water the only option
- Marchioness capsizes and sinks in less than a minute
- Impeded escape
- Marchioness heeled steeply to starboard, flooding the interior through the immersed lower windows
- Lack of emergency exit lighting impedes escape
- Restricted wheelhouse visibility and ineffective lookout on Bowbelle and Marchioness
- Survivability standard of Marchioness

Other contributory factors

AND

Significant Changes to Regulations since 1989

- Merchant Shipping (Emergency Information for Passengers) Regs 1990
- Merchant Shipping (Passenger Ships of Classes IV, V, VI, VI(A)) - Bridge Visibility Regs 1992
- Merchant Shipping (Navigation Bridge Visibility) Regs 1998
3. RISK MODEL DEVELOPMENT

3.1 Introduction

This section provides an overview of the risk model development. The table below provides a cross reference between the areas identified within the project scope, see Section 1.1 and the risk model. Further information regarding the risk model development is provided in the section and the associated appendices.

<table>
<thead>
<tr>
<th>Project Scope</th>
<th>Risk Model Linkage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encounter with large ships</td>
<td>The risk model has considered encounters with ships and bridges directly within the model. Encounters with ships have been addressed within the “collision” accident category. This category has used local passenger ships collision data. The severity of impact associated with the scale of the encountered vessel has been considered within the damage category within the influence model. A detailed analysis considering the scale and resultant damage due to collision has not been possible due to data limitations. Encounters with bridges have been considered within the risk model in the “contact” accident category. This category also includes collisions with berths and other structures. Similarly the resultant severity of damage has been considered within the influence model based upon generic data.</td>
</tr>
<tr>
<td>and bridges</td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>Fire has been considered within the risk model within the “fire” accident category. Consideration has been given to both machinery and superstructure fire. Generic data has been used due to the scarcity of local passenger ship data in all areas apart from Tidal Waters where Thames specific local data has been used.</td>
</tr>
<tr>
<td>Stability</td>
<td>Stability has been considered within the influence diagrams and in terms of survivability within the consequence modelling. Generic data has been used in the consequence modelling.</td>
</tr>
<tr>
<td>Subdivision</td>
<td>Subdivision has been considered within the influence diagrams and in terms of survivability within the consequence modelling. Generic data has been used in the consequence modelling.</td>
</tr>
<tr>
<td>Freeboard</td>
<td>Freeboard has been considered within the influence diagrams and in terms of survivability within the consequence modelling. Generic data has been used in the consequence modelling.</td>
</tr>
<tr>
<td>Wheelhouse Visibility</td>
<td>Wheelhouse visibility has been considered explicitly within the “collision”, “contact” and “grounding” accident categories through the use of local passenger ship data. A detailed analysis of wheelhouse visibility has not been carried out at this stage.</td>
</tr>
<tr>
<td>Life Saving Appliances</td>
<td>LSA has been identified within the Influence Diagrams but not quantified at this stage. The model has used generic data within the consequence modelling.</td>
</tr>
<tr>
<td>Means of Escape</td>
<td>Means of escape has been considered within the risk model in terms of dry and wet rescue. These factors have been identified as a major contributor to the number of fatalities. Detailed modelling of escape routes has not been considered at this stage. It should be noted that this issue has been investigated elsewhere (BMT, 2000 “Thames Safety Inquiry: Emergency Escapes on Domestic Passenger Ships”)</td>
</tr>
</tbody>
</table>

Table 3.1: Risk Model Overview
### 3.2 Project Scope

<table>
<thead>
<tr>
<th>Project Scope</th>
<th>Risk Model Linkage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manning</td>
<td>Manning levels have been considered within the risk model in terms of the number of crew at risk and the corresponding crew fatality risk. A detailed assessment of the effects of crew numbers on the number of fatalities has not been carried out since data does not exist to allow this factor to be modelled.</td>
</tr>
<tr>
<td>Trading Areas</td>
<td>The risk model has considered the risks across four operating environments. The operating environments have been loosely based on the Categorisation of UK waters</td>
</tr>
<tr>
<td>Safety Management Issues</td>
<td>Crew competency and safety management has been identified within the influence diagrams, and partially quantified.</td>
</tr>
<tr>
<td>Vessel Design and Age</td>
<td>Vessel design in terms of basic survivability issues within the operating environment has been considered within the risk model. Vessel age has not been considered. Information is presented on the range of vessel age and survivability for the Tidal Thames</td>
</tr>
<tr>
<td>Human Factors</td>
<td>Human Factors have been identified within the Influence Diagrams and quantified at a high level.</td>
</tr>
<tr>
<td>Operational Issues</td>
<td>Operational issues has been identified and considered for each of the operating environments and used extensively to determine input data for the risk model.</td>
</tr>
<tr>
<td>Analysis of LSA</td>
<td>See above</td>
</tr>
<tr>
<td>Means of Escape</td>
<td>See above</td>
</tr>
</tbody>
</table>

### 3.2 Hazard Identification

Four Hazard Identification (HAZ-ID) meetings were held in October and November 2001 by the MCA, covering the four operating environments. A list of “Hazards and Parameters” was used and developed during the four sessions. Forty-seven hazards were identified in total and this information has been further categorised by DNV and used as a basis for the risk model.

### 3.3 Review of HAZ-ID Workshop

The hazard list prepared within the HAZ-ID workshop sessions was reviewed by DNV and the reported hazards categorised in terms of accident categories given in Table 3.2.

The majority of the identified hazards related to personal accidents. Within the risk model the following accident categories have been considered for quantification in the model and are assigned to the hazards in Table 3.2.

- Collision
- Grounding
- Contact
- Fire/explosion
- Flooding
- Personal accidents
Table 3.2: Summary of HAZID Sessions

<table>
<thead>
<tr>
<th>Hazid Report Hazard</th>
<th>Coverage In Risk Model</th>
<th>Accident Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Risk to passengers - crowd control</td>
<td>Cause of fall into water</td>
<td>Personal accident</td>
</tr>
<tr>
<td>2. Access to vessel - poor jetty condition</td>
<td>Cause of fall into water</td>
<td>Personal accident</td>
</tr>
<tr>
<td>3. Access to vessel - stability of pontoon</td>
<td>Cause of fall on jetty</td>
<td>Personal accident</td>
</tr>
<tr>
<td>4. Weather effect on pontoon</td>
<td>Cause of fall on jetty</td>
<td>Personal accident</td>
</tr>
<tr>
<td>5. Steep angle on access</td>
<td>Cause of fall into water</td>
<td>Personal accident</td>
</tr>
<tr>
<td>6. Gaps between vessel and shore</td>
<td>Delay to operations</td>
<td>N/A</td>
</tr>
<tr>
<td>7. Disabled access</td>
<td>Cause of physical impact</td>
<td>Personal accident</td>
</tr>
<tr>
<td>9. Boarding process and vessel layout</td>
<td>Cause of fall on vessel</td>
<td>Personal accident</td>
</tr>
<tr>
<td>10. Obstruction in gangways</td>
<td>Cause of fall on vessel</td>
<td>Personal accident</td>
</tr>
<tr>
<td>11. Impact with bridges/moorings</td>
<td>Contact category</td>
<td>Contact</td>
</tr>
<tr>
<td>12. Collision with another vessel</td>
<td>Collision category</td>
<td>Collision</td>
</tr>
<tr>
<td>13. Low flying aircraft</td>
<td>Not modelled</td>
<td>N/A</td>
</tr>
<tr>
<td>14. Internal emergencies</td>
<td>Fire/explosion category</td>
<td>Fire/explosion</td>
</tr>
<tr>
<td>15. Skipper incapacity</td>
<td>Cause of illness</td>
<td>Personal accident</td>
</tr>
<tr>
<td>17. Man overboard</td>
<td>Cause of collision, contact</td>
<td>Collision, contact</td>
</tr>
<tr>
<td>18. Loss of propulsion power/steering</td>
<td>Consequence of fall into water</td>
<td>Personal accident</td>
</tr>
<tr>
<td>19. Reduced visibility</td>
<td>Cause of collision, contact</td>
<td>Collision, contact</td>
</tr>
<tr>
<td>20. Act of vandalism</td>
<td>Cause of physical impact</td>
<td>Personal accident</td>
</tr>
<tr>
<td>21. Act of terrorism</td>
<td>Cause of explosion</td>
<td>Fire/explosion</td>
</tr>
<tr>
<td>22. Safety announcement language barrier</td>
<td>Influence on evacuation</td>
<td>All vessel accidents</td>
</tr>
<tr>
<td>23. Navigation lighting</td>
<td>Cause of collision</td>
<td>Collision</td>
</tr>
<tr>
<td>24. Rowing boats, swimmers etc</td>
<td>Cause of collision</td>
<td>Collision</td>
</tr>
<tr>
<td>25. Contact when disembarking</td>
<td>Contact with berth</td>
<td>Contact</td>
</tr>
<tr>
<td>26. Passenger control</td>
<td>Cause of fall on vessel</td>
<td>Personal accident</td>
</tr>
<tr>
<td>27. Risk from mooring lines</td>
<td>Cause of physical impact</td>
<td>Personal accident</td>
</tr>
<tr>
<td>28. Tidal/current effect</td>
<td>Cause of fall into water</td>
<td>Personal accident</td>
</tr>
<tr>
<td>29. Risk to limbs outside vessel</td>
<td>Cause of physical impact</td>
<td>Personal accident</td>
</tr>
<tr>
<td>30. Obstruction of sight lines</td>
<td>Cause of collision</td>
<td>Collision</td>
</tr>
<tr>
<td>31. Incident involving a weir</td>
<td>Cause of flooding</td>
<td>Flooding</td>
</tr>
<tr>
<td>32. Boat rage</td>
<td>Cause of collision</td>
<td>Collision</td>
</tr>
<tr>
<td>33. Grounding</td>
<td>Grounding category</td>
<td>Grounding</td>
</tr>
<tr>
<td>34. Vessel snagging on chamber sides</td>
<td>Cause of flooding</td>
<td>Flooding</td>
</tr>
<tr>
<td>35. Flooding during lock filling</td>
<td>Cause of flooding</td>
<td>Flooding</td>
</tr>
<tr>
<td>36. Debris in lock</td>
<td>Cause of hull damage</td>
<td>Flooding</td>
</tr>
<tr>
<td>37. Collision/contact in tunnels</td>
<td>Cause of collision, contact</td>
<td>Collision, contact</td>
</tr>
<tr>
<td>38. Panic on-board in tunnel</td>
<td>Cause of collision, contact</td>
<td>Collision, contact</td>
</tr>
<tr>
<td>39. Loss of radio/communication link</td>
<td>Consequence of drifting in tunnel</td>
<td>Collision</td>
</tr>
<tr>
<td>40. Operation in flood conditions</td>
<td>Cause of striking submerged object</td>
<td>Contact, grounding</td>
</tr>
<tr>
<td>41. Restrictive locations for evacuation</td>
<td>Influence on evacuation</td>
<td>All vessel accidents</td>
</tr>
<tr>
<td>42. Boarding over other vessels</td>
<td>Cause of fall into water</td>
<td>Personal accident</td>
</tr>
<tr>
<td>43. Wash from large shipping</td>
<td>Cause of fall on vessel, physical impact</td>
<td>Personal accident</td>
</tr>
<tr>
<td>44. Fishing tackle/lines</td>
<td>Cause of drifting</td>
<td>Collision, grounding</td>
</tr>
<tr>
<td>46. Traffic density - public events</td>
<td>Cause of collision</td>
<td>Collision</td>
</tr>
<tr>
<td>47. Mooring process on public quays</td>
<td>Cause of physical impact</td>
<td>Personal accident</td>
</tr>
</tbody>
</table>

Table 3.3 cross-references the accident categories to the four operating environments.
Table 3.3: Applicability of the Accident Categories to the Operating Environments

<table>
<thead>
<tr>
<th>Accident Category</th>
<th>Operating Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tidal/Estuaries</td>
</tr>
<tr>
<td>Collision</td>
<td>Applicable</td>
</tr>
<tr>
<td>Grounding</td>
<td>Applicable</td>
</tr>
<tr>
<td>Contact</td>
<td>Applicable</td>
</tr>
<tr>
<td>Fire/explosion</td>
<td>Applicable</td>
</tr>
<tr>
<td>Flooding</td>
<td>Applicable</td>
</tr>
<tr>
<td>Personal accidents</td>
<td>Applicable</td>
</tr>
</tbody>
</table>

3.4 Data Gathering

The MCA provided a detailed contact list, identifying representatives from all four operating environments, regulatory bodies and authorities, as well as other interested parties.

Following the review of the hazards identified by the MCA workshops a generic question set was developed. The question set, see Appendix I, cover general operational data, as well as specific accident category data.

The question set represents operator and location specific data, which following analysis, has been used to refine or replace generic data used within the risk model.

Representatives from the four operating environments were contacted and data collated. Additionally a site visit was undertaken on the River Thames to view a number of Class V passenger vessels.

Appendix II details the respondents. The data gathering exercise could be extended to include data from operators not contacted within this study.

3.5 Risk Model Development

Appendix III details the risk model developed. The model has been assembled using a series of interlinked Fault Trees and Event Trees. The model has been developed in a manner to achieve maximum flexibility. Risk levels can be evaluated across all operating environments, for a specific category of water or region, or a particular vessel.

3.5.1 Identification of Failure Cases

The HAZ-ID workshops identified a range of hazards with the potential to result in various outcomes. This type of hazard is best suited to qualitative modelling rather than quantitative modelling. Therefore the risk model has been based upon generic failure cases such as collision rather than based solely upon the hazards identified within the workshop. Table 3.2 highlights the linkage between the modelled categories and the hazards identified.

These failure cases have been developed within the model and the causes and consequences evaluated.
3.5.2 Cause and Frequency Analysis

The model has used fault trees as a means of determining Top Event frequencies for various failure cases, such as collision with a berth. Fault trees have been prepared for all six accident categories defined in Section 3.3. The collated operational data has been used to provide judgements on typical operational patterns for the four different environments. This data was supplemented by accident data taken from the MAIB database and accident data reported to the PLA. Where data gaps occurred, generic data has been used. The generic data has also been used to assess the robustness of the operational data.

3.5.3 Consequence Evaluation

Event trees have been prepared to aid evaluation of the consequence of the identified failure cases. The top event frequencies generated from the fault trees have been used as initiating events within the event trees. The event trees have analysed the degree of escalation following the initiating event and considered the impact of current mitigation measures. The outcomes from the various branches of the tree have been used to determine the event paths that lead to loss of life to the passengers and crew.

Limited data was available relating to major accidents with Class IV/V/VI passenger vessels due to the small number of incidents and the absence of a major accident post Marchioness. Therefore, the information from the Marchioness disaster and appropriate generic data has been used in the evaluation of the event trees.

3.5.4 Risk Summation

The calculated number of fatalities per year have been summated to provide an Individual Risk of fatality per year for both the crew and passengers for each operating environment. In addition, an individual risk per year of personal accident to both crew and passengers has also been evaluated.

3.6 Use of Influence Diagrams

Influence diagrams have been prepared to show the areas of influence within the risk model. The diagrams have been quantified where possible and applied to the risk model. Appendix III provides further details of the manner of quantification and the impact upon the risk model.

The diagrams have highlighted a number of influence factors within the risk model. Crew competency and the actions taken within an emergency is one example. Due to the limited data availability it has not been possible to fully quantify within the model the effects of such influences, but it has been recognised that such factors will impact upon the risks to both crew and passengers.

The Influence Diagrams were used to promote discussion within the initial Risk Control Workshop and additional influences identified and incorporated, considering the influences on a qualitative rather than quantitative basis.
3.7 Risk Control Measures

3.7.1 Risk Control Workshop

DNV facilitated a Risk Control Workshop on behalf of the MCA. The workshop was used to identify potential risk control measures for further consideration. The Workshop was held at DNV's London office on 31st January 2002. The workshop delegates were selected by the MCA from the attendees of the initial HAZ-ID. Care was taken to provide a broad representation of all of the operating environments, whilst maintaining a manageable number of delegates.

The workshop was divided into two sessions. Session 1 identifying risk control measures associated with the hazards identified within the HAZ-ID workshops. The second session was used to identify potential risk control measures associated with the developed risk model.

Due to time constraints, it was not possible to consider all of the hazards and parameters identified in the HAZ-ID workshop in Session 1, although selected areas were considered. Additionally there was a degree of overlap between session 1 and 2 ensuring that all aspects of an operational voyage were considered within the workshop.

The sessions were used to identify general issues, current practices, make judgements on best practices and identify further risk control measures for consideration. The output from the workshop can be viewed in Appendix IV.

3.7.2 Impact on Risk Model

The initial risk control workshop identified a number of risk control measures for further consideration. These potential measures, such as a National Competency scheme for boatmen unifying all existing systems may influence many areas in the risk model such as collision frequencies.

3.8 Evaluation of Risk Control Measures

The MAIB database contains information on all accidents reported to it. However, some minor accidents go unreported. Only the most serious accidents are investigated fully and this is reflected in the recorded data which does not identify the underlying causes in many cases (i.e. where on site investigations have not been carried out). Therefore this data source is not sufficiently robust to make a detailed analysis. At present the risk model has not been updated to reflect the additional measures.

A judgement approach has been used as an alternative means of analysis to indicate the areas in which the risk control measures may impact the overall risks and judgement made whether there will be a change in the current risk levels. Table 3.4 below details the risk control measures and discusses potential outcomes. Further supporting information can be found in Appendix IV. The table provides a linkage between the Risk Control Measures identified, and the subsequent discussion within the workshop, and the risk model.
### Table 3.4: Review of Risk Control Measures

<table>
<thead>
<tr>
<th>Risk Control Measure</th>
<th>Potential Area of Influence</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish range of good practices for pier/pontoon operations taking into consideration the different operating environments</td>
<td>Passenger accidents from boarding</td>
<td>Increased control may result in a reduction minor injuries from boarding as well as the prevention of a serious injury from boarding</td>
</tr>
<tr>
<td>Implementation of regular evacuation drills, including the possible involvement of other operators or regulators where appropriate. The envisaged mock evacuations will involve employees, volunteers or hired help.</td>
<td>Fatalities and injuries from sinking/evacuation</td>
<td>May reduce the number of potential fatalities due to greater crew awareness. Measure will result in swifter evacuation in the event of an emergency with a possible reduction on the number of fatalities and injuries.</td>
</tr>
<tr>
<td>Review and potential implementation of speed controls to reduce wash</td>
<td>Passenger injuries during boarding</td>
<td>Speed controls may reduce the wash effects and therefore have an impact on the number of injuries to passengers upon boarding, although it must be noted that certain vessels generate a greater wash at slower speeds. Speed restrictions may also reduce the number of collisions and impact upon the level of damage sustained, although the size of the striking craft must also be taken into consideration.</td>
</tr>
<tr>
<td>Review current methods of passenger number recording and consider methods and best practices specific to operating environments.</td>
<td>Fatalities and injuries from sinking/evacuation</td>
<td>Through identifying good practices and actions to be taken by the designated Responder there may be a potential for a reduction in the number of fatalities and injuries following a major incident.</td>
</tr>
<tr>
<td>Define a Search and Rescue (SAR) role for all UK waters to aid co-ordination of rescue efforts including equipment and manpower, suggested as the Coastguard.</td>
<td>Fatalities and injuries from sinking/evacuation</td>
<td>A single identified SAR for all UK waters including inland may impact on the simplicity of rescue efforts. The impact on the number of fatalities is unknown.</td>
</tr>
<tr>
<td>Consider implementation of a national competency scheme for boatman, unifying all existing systems providing one license for all operators of passenger vessels</td>
<td>All categories of accidents and fatalities and injuries from sinking/evacuation</td>
<td>An assessment of crew competency against accident data has not been possible due to data limitations. It is recognised though, that an increase in overall competency, not only covering navigational/river competency as currently in place, but also covering areas such as people management will impact upon the number of potential incidents and injuries.</td>
</tr>
<tr>
<td>Review wheelhouse visibility</td>
<td>Collision/Contact frequency, passenger accidents during boarding</td>
<td>Improved wheelhouse visibility may reduce the overall number of collisions. Currently 360° visibility is achieved but this may be only in a very limited horizontal plane or alternative means put in place (such as lookout). This limited visibility may increase passenger accidents through boarding, although data is not available to determine this</td>
</tr>
</tbody>
</table>
### Risk Control Measure & Potential Area of Influence

<table>
<thead>
<tr>
<th>Risk Control Measure</th>
<th>Potential Area of Influence</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control of pleasure craft</td>
<td>Collision/Contact frequency, passenger accidents during boarding</td>
<td>Enforcement of speed controls and bylaws will reduce the number of incidents involving pleasure craft. This will include reduced collisions and accidents during berthing. This measure is unlikely to impact on fatality risks from collision due to the size of the pleasure craft.</td>
</tr>
<tr>
<td>Cultural Change within the Passenger Vessel Industry</td>
<td>Passenger injuries and fatalities</td>
<td>The impact of the current safety culture on accident and incident rates is unknown. Therefore the impact of fundamental shifts in organisational culture will be unknown until a representative profile of current practices can be obtained.</td>
</tr>
<tr>
<td>Development of local procedures to aid swift identification of flooding problems and to initiate plans to minimise the impacts.</td>
<td>Fatalities and injuries as a result of flooding</td>
<td>The improvement of mitigating actions and early warning during a flooding event may minimise the impact of less severe accidents but will be unlikely to minimise the impact of a major accident.</td>
</tr>
<tr>
<td>Review the requirements of life saving appliance (LSA) for the operating environments and compare with the specification of current equipment</td>
<td>Fatalities and injuries following evacuation</td>
<td>The current specification for LSA may not be the most appropriate selection for the operating environment. A more applicable specification may aid swifter recovery of passenger in the event of an emergency, resulting in a possible reduction in injuries. It is unlikely that the specification of such devices will result in a reduction in the number of fatalities following a major accident, which is influenced by a range of factors including the speed of rescue.</td>
</tr>
<tr>
<td>Review of existing fire protection and prevention measures, including evacuation and muster.</td>
<td>Passenger fatalities as a result of fire/explosion</td>
<td>Limited data is available to analyse the current number of fire accidents. Some identified practices have been determined as below good or best practice. Implementation of higher standards may control or reduce the current number of accidents and incidents.</td>
</tr>
</tbody>
</table>

It is recommended that a further workshop be scheduled with a smaller group of delegates representing each environment in turn. The workshop could also be used to consider the impact of the above measures, with respect to the risks to crew and passengers, and to work towards the quantification of this impact.

### 3.9 Further Workshops - Tidal Thames

A further environment specific workshop was held to identify risk control measures associated with the tidal section of the river Thames. Due to the number of delegates the workshop was divided into two sessions. The first session was held on 1\textsuperscript{st} May 2002 and involved a cross section of the Class V Passenger Vessel operators. A second session was held on 2\textsuperscript{nd} May 2002 and involved the regulators and other interested parties. The first session was used to highlight existing practices above regulation and further recommendations. The second session was based upon the output of the previous session and
used to identify further recommendations and to fill any gaps. The output from these sessions can be found in Appendix VI.
4. RISK MODEL RESULTS AND DISCUSSION

4.1 Introduction

This section presents the risk model results. The model has evaluated the risk levels of Class IV/V/VI passenger vessels operating in the four environments listed below, broadly based on the A, B, C and D categorisation of UK waters: -

- Tidal/Estuaries;
- Inland Waters;
- Lochs and Lakes; and
- Coastal Waters

The risk model results are presented in two broad categories: -

- Individual Risk - that is the risk experienced by an individual person; and
- Group Risk - that is the risk experienced by the whole group of people exposed to the hazard, sometimes referred to as societal risk.

These two measures are used to assess both the risk exposure of an individual, in terms of individual risk, and also societal or group concerns raised from major incidents involving multiple fatalities. Typically concerns are raised when 10 or more fatalities occur from a single event.

The individual risk represents the risks experienced by a single individual over the given time period of one year. The results are presented in terms of individual risk of fatality and individual risk of injury.

The individual risks of fatality are presented for both passengers and crew. The risk levels are presented separately since the risk exposure and the benefits differ for passengers and crew. For example a passenger travelling on a day trip will not be exposed to the same range of hazards as a crew member. The crew member will also have received additional training and awareness in those hazards. Similarly the benefits that the passengers and crew gain from travelling onboard are different, for example the crew member receives a wage for their activities, whereas the passenger is paying to be onboard, either for leisure purposes or to commute from one location to another.

The group risk considers the level of exposure to a defined group. The model has considered the group to be the crew and passengers onboard and is presented in terms of per vessel year. This risk parameter estimates the group risk of fatality of the passengers travelling on every voyage over the year.

4.2 Risk Model Results

The risk model results are presented below in a range of formats. Table 4.1 presents the individual risk of fatality to passengers and to crew from travelling on a typical vessel on every voyage in a year.
### Table 4.1: Individual Risk of Fatality Per Year

| Operating Environment | Individual Risk of Fatality per Year | | |
|-----------------------|--------------------------------------|------------------|
|                       | Passenger | Crew | |
| Tidal /Estuaries      | 2.0 x 10⁻⁴ | 3.9 x 10⁻⁴ | |
| Inland Waters         | 1.0 x 10⁻⁴ | 2.0 x 10⁻⁴ | |
| Lochs and Lakes       | 1.8 x 10⁻⁴ | 3.6 x 10⁻⁴ | |
| Coastal Waters        | 4.9 x 10⁻⁴ | 9.5 x 10⁻⁴ | |

Whilst the risk levels presented in Table 4.1 are useful for calculation purposes, the risk values on this basis are not appropriate in considering the tolerability of the calculated risks for passengers. It is incomprehensible that a passenger travelling on a coastal waters passenger vessel will travel on 3690 voyages per year or 70 voyages per week. Therefore the risk results are also presented in Table 4.2 on the basis of per voyage.

### Table 4.2 Individual Risk of Passenger Fatality per Voyage

<table>
<thead>
<tr>
<th>Operating Environment</th>
<th>Individual Risk of Passenger Fatality per voyage</th>
<th>No of Voyages Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal /Estuaries</td>
<td>1.5 x 10⁻⁷</td>
<td>1369</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>9.1 x 10⁻⁸</td>
<td>1095</td>
</tr>
<tr>
<td>Lochs and Lakes</td>
<td>1.4 x 10⁻⁷</td>
<td>1314</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>1.3 x 10⁻⁷</td>
<td>3690</td>
</tr>
</tbody>
</table>

Further inspection of Table 4.2 indicates that the Inland Waters environment carries the lowest individual risk of passenger fatality per voyage. The individual risk of passenger fatality per voyage for Lochs and Lakes, Coastal Waters and Tidal/Estuaries is similar for each of the remaining environments.

Whilst these values are now meaningful in terms of comparison of an annual day-trip on each of the environments, the risk levels presented in Table 4.2 do not take into consideration the travel patterns of those passengers using Class IV/V/VI Passenger Vessels on a regular basis, for example as a commuter service. Table 4.3 presents a range of travel patterns in terms of the individual risk of passenger fatality travelling on Tidal Waters.

### Table 4.3: Individual Risk of Fatality for Tidal Waters

<table>
<thead>
<tr>
<th>Travel Pattern</th>
<th>Individual Risk of Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Trip</td>
<td>1.5 x 10⁻⁷</td>
</tr>
<tr>
<td>12 trips per year (one trip per month)</td>
<td>1.8 x 10⁻⁶</td>
</tr>
<tr>
<td>Commuter - 400 trips per year (40 weeks per year, 10 trips per week)</td>
<td>5.8 x 10⁻⁵</td>
</tr>
</tbody>
</table>

Table 4.3 shows that a commuter using a passenger vessel as a means of travelling to work each working day has an individual risk of fatality per year of 5.8 x 10⁻⁵. This is likely to be the highest annual risk experienced by any individual passenger.
In addition to the individual risk of fatality for passenger and crew the risk model has also evaluated the individual risk of injury for each environment. These results are presented in Table 4.4.

Table 4.4: Individual Risk of Injury per Year

<table>
<thead>
<tr>
<th>Operating Environment</th>
<th>Individual Risk - Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal / Estuaries</td>
<td>$3.6 \times 10^{-2}$</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>$2.0 \times 10^{-2}$</td>
</tr>
<tr>
<td>Lochs and Lakes</td>
<td>$3.4 \times 10^{-2}$</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>$9.5 \times 10^{-2}$</td>
</tr>
</tbody>
</table>

Table 4.4 shows that the individual risk of injury across the UK waters is between $2.0 \times 10^{-2}$ - $9.5 \times 10^{-2}$ per year. Alternatively this can be expressed as a 1 in 10 to 1 in 50 chance of injury for a passenger travelling on every voyage per year.

As discussed in Section 4.1, as well as evaluating the individual risk of fatality the model has also evaluated the group risk of fatality. These results are presented in Table 4.5 below.

Table 4.5 Group Risk of Fatality

<table>
<thead>
<tr>
<th>Operating Environment</th>
<th>Group Risk of Fatality per Vessel Year</th>
<th>Group Risk of Fatality for each Environment per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal / Estuaries</td>
<td>$3.1 \times 10^{-2}$</td>
<td>5.8</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>$5.5 \times 10^{-2}$</td>
<td>1.2</td>
</tr>
<tr>
<td>Lochs and Lakes</td>
<td>$2.0 \times 10^{-2}$</td>
<td>1.4</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>$4.0 \times 10^{-2}$</td>
<td>9.7</td>
</tr>
<tr>
<td>Total Group Risk for all Class IV/V/VI vessels per year</td>
<td>18.1</td>
<td></td>
</tr>
</tbody>
</table>

Group risk provides a measure of the occurrence of multiple fatalities from a single event and is used as a measure due to societal aversion to multiple deaths. Considering the tidal/estuaries environment the model has evaluated a group risk of fatality of $3.1 \times 10^{-2}$ per vessel year. This value can be expressed as 1 fatality in 32 vessel years. The total group risk for all Class IV/V/VI vessels is evaluated as 18.1 fatalities per year, of which 22% is attributed to personal accidents (see Figure 4.2).

The model has also evaluated which events lead to fatalities. Figure 4.1 shows the spread of initiating events, indicating which events carry the highest frequency. Figure 4.2 shows the corresponding individual risk of passenger fatality for each of the events.
Figure 4.1 shows that 49% of the events relate to contact events defined as the vessel striking a berth, jetty or other fixed object. The remaining events are divided fairly equally between fire, collision grounding and personal accident with a very small number of flooding events.

**Figure 4.2 Individual Risk of Passenger Fatality per Year for each Accident Category**

Figure 4.2 shows that the contact, fire and personal accidents account for 77% of the overall individual risk of fatality. Considering the contact event further, Figure 4.3 shows that the fatalities of a contact event result from the consequence of the event rather than as a direct result of the impact.
Figure 4.3 Fatalities from a Contact Event

Similar charts could be plotted for collision events, showing that 98% of the fatalities result from sinking whereas only 2% of the fatalities can be attributed to the collision impact. Therefore the model confirms that fatalities occur as a result of the consequences of an incident rather than as a direct result of the incident. The full risk results are presented in Appendix V.

4.3 Evaluation of Results

This section compares the risk model results presented in Section 4.2 against historical data and risk tolerability criteria. Table 4.6 presents marine accident casualties data over the period between 1989 and 1999, (Transport Statistics Great Britain, 2000). The table lists the number of deaths and injuries for both crew and passengers on UK passenger vessels, including Class IV/V/VI vessels.
Table 4.6: Marine Accident Casualties

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths from casualties to vessels</td>
<td>53</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Death from casualties on board - other than casualties to vessels</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Other deaths</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing at Sea</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>62</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1989 data includes 50 deaths from Marchioness

Table 4.6 shows that the overall number of fatalities recorded over the period between 1989-1999 is heavily dominated by the Marchioness incident. The data shows a small number of fatalities over the period of 1989-1999, discounting the fatalities associated with the Marchioness. The table shows that most passenger fatalities occurred to passengers whilst onboard rather than as a result of vessel casualties, although the Marchioness data shows that a collision incident has the potential to result in a significant number of fatalities.

Considering trends on the River Thames, the current traffic density in this area is similar to the number of vessels in operation in 1989, although records are very limited. There has been a marked change in the overall profile of the fleet in operation. In 1989 there were a number of large commercial vessels in operation upstream of London Bridge, an area where there was a high density of operation of passenger vessels. Data presented to the Thames Safety Inquiry showed that in 1999, the operation of large commercial vessels upstream of London Bridge had ceased, although vessels of this type are still in operation downstream of London Bridge. This has lowered the overall likelihood of another Marchioness type incident, although the potential still remains.

Summatting the data in Table 4.6 gives actual fatalities of passengers and crew over an 11-year period. This data can be compared against the risk analysis. The total number of fatalities over the 11 years is 109, consisting of 56 vessel casualties, 49 personal and 4 missing at sea. This equates to 9.9 fatalities per year of which 50% are personal. This data includes international voyages on UK passenger ships.

Risk analysis is consistent with actual data for personal accidents but shows a higher risk in vessel casualties than has been experienced in reality since 1989 even including the Marchioness incident. However, major accidents like the Marchioness, are rare but may involve many fatalities, so the absence of such events during the 1990s does not prove that they cannot occur in the next few decades. Although the risk analysis appears pessimistic, this is an appropriate basis for decision making on risks that are very uncertain.

The risk results presented in Section 4.2 can be compared against other risk levels. For example, when considering those passengers using Class IV/V/VI passenger vessels as a
commuting service the risk levels per voyage can be compared to the actual fatalities per passenger journey for the rail sector.

The rail data relates to the operating period 1999/2000 and is the actual number of fatalities and major injuries incurred within the specified operating period. This comparison between the marine sector and the rail sector for individual risk per passenger voyage is illustrated in Table 4.7.

Table 4.7: Summary of Individual Risk per Passenger Journey

<table>
<thead>
<tr>
<th>Operating Environment</th>
<th>Individual Risk – Passenger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal /Estuaries</td>
<td>$1.5 \times 10^{-7}$ Fatalities per passenger voyage</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>$9.1 \times 10^{-8}$ Fatalities per passenger voyage</td>
</tr>
<tr>
<td>Lochs and Lakes</td>
<td>$1.4 \times 10^{-7}$ Fatalities per passenger voyage</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>$1.3 \times 10^{-7}$ Fatalities per passenger voyage</td>
</tr>
<tr>
<td>Railway Group (1999/2000 actual)</td>
<td>$4 \times 10^{-8}$ Fatalities per passenger journey</td>
</tr>
<tr>
<td>Railway Group (1999/2000 actual)</td>
<td>$3.3 \times 10^{-7}$ Major injuries per passenger journey</td>
</tr>
</tbody>
</table>

Table 4.7 shows that the risks in terms of fatalities per passenger voyage on a passenger vessel are broadly comparable with the rail sector.

The Health and Safety Executive (HSE) in "Reducing Risks, Protecting People" (HSE, 2001) lays out a framework for risk tolerability.
The HSE framework above, Figure 4.4, presents three regions. The top region, the dark zone, represents an unacceptable region, where for practical purposes the level of risk is regarded as unacceptable whatever the level of benefits associated with that activity may be. The bottom region, the light zone, represents a broadly acceptable region. Risks falling into this region are generally regarded as insignificant and adequately controlled. The levels of risk characterising this region are comparable with risks regarded as trivial or insignificant in people's everyday lives.

The middle zone, between the unacceptable and broadly acceptable region is the tolerable region. Risks in this region are typical of the risks that people are preferred to tolerate providing the risks are adequately assessed and controlled, the residual risks are kept As Low As Reasonably Practicable (ALARP), and the risks are regularly reviewed.

The HSE advise the following values for the individual risk of fatality for the public; the bands for around the tolerable region set at 1 in 10,000 and 1 in 1,000,000, or 1 x 10^-4 and 1 x 10^-6 fatalities per year.

The MCA does not have specific risk criteria for UK passengers therefore the HSE framework will be used. Considering the individual risk of passenger fatalities per year for Class IV/V/VI Passenger Vessels the following bands apply:

- Individual risk of passenger fatality greater than 1 in 10,000 (or 1 x 10^-4) fall into the Unacceptable region.
- Individual risk of passenger fatality between 1 in 10,000 (or 1 x 10^-4) and 1 in 1,000,000 (or 1 x 10^-6) fall into the Tolerable region.
• Individual risk of passenger fatality less than 1 in 1,000,000 (or 1 x 10^{-6}) fall into the Broadly acceptable region.

The criteria apply to realistic individual exposure, and the most exposed passenger's risk is therefore critical.

Considering a passenger using a daily commuter service. The risk model has estimated that the individual risk of passenger fatality is 5.8 x 10^{-5} for the tidal/estuaries environment. This risk falls into the tolerable region. A risk in the tolerable region is a level of risk that people are preferred to tolerate providing the risks are adequately assessed and controlled, the residual risks are kept As Low As Reasonably Practicable (ALARP), and the risks are regularly reviewed. The demonstration of ALARP will be carried out in the evaluation of the Risk Control Measures identified for the tidal Thames and the associated cost of implementation. This activity will be completed within the Cost Benefit Analysis project.

Figures 4.5 and 4.6 present the individual risk of passenger fatality against other common risks. Figure 4.5 shows the HSE acceptance criteria with the tolerable region shaded. The figure indicates that the range of individual risk of passenger fatality is within the tolerable region for the most exposed passenger (a daily commuter) and within the broadly acceptable region for less frequent passengers. Figure 4.6 shows the individual risk of passenger fatality per voyage for each environment against the passenger fatality rate per journey for the rail sector.

Considering the crew risks, the crew tolerability criterion for individual risk of fatality is given as 1 x 10^{-3} per year. The individual crew risks presented in Table 4.1 are below this criteria and therefore in the tolerable region, providing the risks are kept as low as reasonable practicable.

It is concluded that the risks on local passenger ships will be tolerable, even for the most exposed passenger, provided that they are kept ALARP (As Low As Reasonably Practicable). The application of FSA (Formal Safety Assessment) will help identify cost-effective risk control options, and hence contribute to making the risks ALARP.
Figure 4.5: Individual Risk per Year Perspective Scale – Comparison with Common Risks

-6 -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5 +6

MINISCULE RISK

- Death from cancer
- All accidents
- Road accidents
- Accidents at home
- Run over by vehicle
- Accidents on railway
- Struck by lightning
- Struck by falling aircraft
- Fatality range for vessel passengers
- Single voyage

HSE: Broadly Acceptable Risk

- One person in world per year
- One person in UK per year

HSE: Maximum Tolerable Risk

- 50% of people per year

RISK MASSIVE

- One in 100,000
- One in 10,000
- One in 1,000
- One in 100
- One in 10
- One in 1

RISK RAPIDLY DECREASING

- One in 10 million
- One in 1 million
- One in 100 million
- One in 10 million
- One in 1 million
- One in 10 million

RISK ACCEPTED

- One in 100,000
- One in 10,000
- One in 1,000
- One in 100
- One in 10
- One in 1

RISK TOLERATED

- One in 10,000
- One in 1,000
- One in 100
- One in 10
- One in 1

RAPIDLY INCREASING RISK

- One in 100,000
- One in 10,000
- One in 1,000
- One in 100
- One in 10
- One in 1

RISK MASSIVE

- One in 100,000
- One in 10,000
- One in 1,000
- One in 100
- One in 10
- One in 1

DEPENDING FROM JOHN PALIN / THE ENVIRONMENTAL INSTITUTE 1992
Figure 4.6: Individual Risk Perspective Scale – Individual Risk per Passenger Journey

-6 -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5 +6

1 in 1,000,000 million
1 in 100,000 million
1 in 10,000 million
1 in 1,000 million
1 in 100 million
1 in 10 million
1 in 1 million
1 in 100,000
1 in 10,000
1 in 1,000
1 in 100
1 in 10
1 in 1

1 x 10^0
1 x 10^{-1}
1 x 10^{-2}
1 x 10^{-3}
1 x 10^{-4}
1 x 10^{-5}
1 x 10^{-6}
1 x 10^{-7}
1 x 10^{-8}
1 x 10^{-9}
1 x 10^{-10}
1 x 10^{-11}
1 x 10^{-12}

Risk Scale:
- MINISCULE RISK
- RISK RAPIDLY DECREASING
- RISK ACCEPTED
- RISK TOLERATED
- RAPIDLY INCREASING RISK
- RISK MASSIVE

- Tidal Estuaries
- Inland Waters
- Lochs and Lakes
- Coastal Waters
- Railway Group Fatalities (1999/2000 actual)

Derived from John Paling/The Environmental Institute 1992
4.4 Model Applicability and Limitations

The model has been developed to evaluate the risks from the operation of Class IV/V/VI passenger vessels operating in UK waters. There is significant variation in the construction, layout, and scale of the passenger vessels as well as the different hazards present in each environment. To account for these variations the model has focussed on the effects of common issues, such as collision, to evaluate the likelihood and consequences of events rather than complex modelling of individual vessel layout. For each environment the model has evaluated the risk from a typical vessel, in terms of passenger numbers and crew, vessel survivability (monohull or sub-divided), ease of escape and number of voyages per year. Therefore the risk levels evaluated for each environment can be used as a baseline. The model can also be used to evaluate the risks for specific vessels, recognising that individual vessels will have risks both greater and less than the baseline evaluated.

In preparing a model that is applicable to all vessel types and all four environments a number of simplifications have been made. For example, in considering evacuation speeds a detailed analysis could be carried out reviewing different vessel layouts, whereas the model currently considers the speed of escape through the windows. Throughout the model additional areas of complexity have been identified for further enhancement. These areas have not been quantified at this stage due to the scarcity of data. Considering the areas of additional complexity, these may be added to the model if this is an area of interest e.g. visibility effects on collision frequency, but further research would be required to populate the model. Similarly the performance of the crew in controlling the vessel during flooding, maintaining the integrity of undamaged spaces, and taking appropriate mitigating actions has been identified as an area which will impact the severity of an accident. At present sufficient data does not exist to allow full quantification of this effect at this stage. Further information can be found in Appendix III.

Rare incidents such as contact with low flying aircraft leading to collision have not been considered within the model. Therefore specific accidents, where there are a number of sequential events leading to a major outcome may not be directly represented in the model.

Areas of uncertainty remain associated with the consequences of an event such as a collision, this issue is particularly relevant for the Thames. Whilst a review of current and historic traffic profiles on the Thames has indicated a reduction in the number of commercial vessels in operation, there is an increase in the number of larger Class V passenger vessels operating on the river. The reduction in frequency of commercial traffic on the Thames reduces the likelihood of another Marchioness incident, although the potential for a collision between a large commercial vessel and a Class V passenger vessel still remains.

Whilst there has been reduction in the frequency of commercial vessels operating in busy passenger areas there has also been a change in the passenger vessel fleet in operation on the Thames. A number of large Class V passenger vessels are now in operation on the river. The outcome of a collision between a small and a large Class V passenger vessel is unknown but if the smaller vessel was of similar construction to the Marchioness then the outcome is likely to be the same.

In discussing the limitations of the risk model, consideration should also be given to the robustness of the data used within the model. Various data sources have been used. Where
possible the data used relates to Class IV/V/VI passenger vessels operating in UK waters, but this data is limited in terms of the detailing the causal factors of minor incidents. Accident investigation of major incidents is robust but few major accidents have occurred. There is also a recognised level of under reporting of both minor accidents and near misses. Therefore there is a degree of uncertainty associated with the risk levels evaluated and the values should be taken as orders of magnitude rather than absolute numbers, e.g. risk level taken as $10^{-5}$ rather than $5.8 \times 10^{-5}$.

### 4.5 Risk Control Measures

Section 3.8 presents the risk control measures identified within the main workshop and indicates on a qualitative basis the potential effects the measures may have. It is recommended that further workshops be held to capture any additional risk control measures for consideration. To improve the focus within the workshops it is suggested that separate workshops be held for each operating environment. The Thames specific workshop has been completed within this project. The output from each workshop will be a refined list of potential risk control measures.

Following evaluation of these measures expert judgement could be used to determine the potential impact these measures may have on the model, in the absence of detailed causal data. It is recommended that a further group representing both the regulators and operators consider these measures further and quantify the areas of risk reduction to aid evaluation of the effectiveness of the risk control measure.

### 4.6 Data Availability

The study has highlighted the need for improved accident and incident reporting across the industry. Whilst major accidents are recorded and there is good consistency across the industry in the reporting of injuries, the reporting of minor damage and near miss incidents is poor. During the data gathering exercise the threshold at which a minor collision would be reported varied depending upon the operating environment. Near miss reporting does occur on the Thames but there is a recognised level of under reporting.

The scarcity of statistical data on accidents and their causes has hindered the detailed evaluation of the impact of crew competency and other influences within the model. Historically, data has been captured in such a way as to limit detailed analysis. For example, issues such as wheelhouse visibility and the impact of their influence on collisions cannot be fully assessed. Accident reports of minor collisions regularly fail to identify the cause of the collision, e.g. poor visibility. Therefore a detailed analysis of the number of collisions occurring as a result of poor wheelhouse visibility cannot be determined. The effect is inherently represented within the current accident data and frequency of occurrence, but detailed investigation and risk estimation cannot be carried out.

It is recommended that measures be taken to improve the level of near miss and minor incident reporting to ensure an accurate nation-wide profile of accidents and incidents. This improved data set could be used to further enhance the risk model and provide a robust baseline from which future risk control measures can be assessed and measured following implementation to confirm their effectiveness.
4.7 Summary

A quantitative risk model has been developed, providing estimates of the breakdown of major accident risk on local passenger ships. This has taken account of the changes in vessel designs and traffic patterns since the Marchioness accident. It has estimated the risks not only of collisions but also of grounding and contacts, which have not occurred in recent years in UK waters. It has covered coastal and inland waters, which have not recent major accident experience. Although the total estimated risks are uncertain and are somewhat higher that recent historical experience, they form an appropriate cautious basis for selecting risk reduction measures and quantifying their benefits.

A number of conclusions can be made as a result of reviewing the model and the model results. These have been summarised below in bullet points:

- The individual risk of fatality of passengers per voyage is less than 1 in a million. This represents a very small level of risk.
- The individual passenger risks per journey are broadly similar to the values measured for the rail sector.
- The individual risk of fatality for a commuter on the tidal/estuaries environment is $5.8 \times 10^{-5}$ per year which lies in the Tolerable Region and will be subject to an ALARP demonstration in the CBA project phase.
- The group risk of fatality for the tidal/estuaries environment has been evaluated as 1 fatality in 32 vessel years.
- In line with the maritime sector as a whole, the model shows that where an incident occurs the consequences can be significant.
- The model shows that the greatest number of fatalities occur as a consequence of an incident rather than from the incident itself, i.e. in the event of a collision incident fatalities occur as a result of passenger escaping into the water and requiring rescue rather than from the direct impact.
- Where possible dry rescue is preferential, wet rescue increases the risk of fatalities. For example the number of fatalities will be significantly less if passengers can be evacuated from a fire through dry rescue rather than from the water. Hence if an incident occurs then vessel survivability becomes the critical factor.
- A number of areas of uncertainty remain, e.g. the effect of a collision between a large Class V passenger vessel and a Marchioness type vessel.
- The study has highlighted the need for improved accident and incident reporting and analysis of minor accidents and near-misses to build up a robust data source for assessment of risk control measures to confirm effectiveness.
- Influences such as vessel layout on evacuation rates, wheelhouse visibility on collision rates, fire protection standards/hazards and subdivision on survivability have not been fully quantified, due to data scarcity. If these influences require further investigation, then additional research should be commissioned to identify supplementary data.
5. REFERENCES


www.railwaysafety.org.uk