AISM Association Internationale de Signalisation Maritime **IALA** International Association of Marfine Aids to Navigation and Lighthouse Authorities

IALA Recommendation O - 134

on the

IALA Risk Management Tool

For

Ports and Restricted Waterways

Edition 1

May 2006

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IALA Recommendation on the IALA Risk Management Tool for Ports and Restricted Waterways

Recommendation O – 134

THE COUNCIL

RECALLING that one of the aims of the Association is to foster safe, economic and efficient movement of vessels and the protection of the environment through the improvement and harmonisation of aids to navigation and vessel traffic services world-wide.

RECALLING ALSO that Regulation 13 of Chapter V of the 1974 SOLAS Convention (as amended) requires:

1 Each Contracting Governments undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires.

2 In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines [Reference is made by footnote to IALA] when establishing such aids.

NOTING that the responsibility of National Members for the safety of navigation and protection of the environment in waterways under their jurisdiction and that a number of National Members have requested guidance on means of assessing the risk of collisions and groundings address these issues;

NOTING ALSO that risk management studies have been carried out in various areas using different standards;

RECOGNISING that the safety and efficiency of vessel traffic and the protection of the environment would be improved if a risk management tool employing harmonised standards and criteria was used to assist National Members during the assessment of risks in waterways under their jurisdiction;

HAVING CONSIDERED the proposals by the Working Group on the development of a Generic Port and Waterway Risk Model;

ADOPTS the IALA Risk Management Tool for Ports and Restricted Waterways as set out in the annex to the present recommendation;

RECOMMENDS National Members to use the IALA Risk Management Tool for Ports and Restricted Waterways when assessing the risk of collisions and groundings in waterways under their jurisdiction, as part of their decision making process.

IALA Risk Management Tool
For Ports and Restricted Waterways

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PART 1: POLICY AND PRINCIPLES

1.1 Introduction

The IALA Risk Management Tool comprises of two models that are capable of:

- Assessing the risk in ports or restricted waterways, compared with the risk level considered by Authorities and stakeholders to be acceptable. The elements that can be taken into consideration include those relating to vessel conditions, traffic conditions, navigational conditions, waterway conditions, immediate consequences and subsequent consequences;
- Identifying appropriate risk control options to decrease the risk to the level considered to be acceptable. The risk control options available include improved co-ordination and planning; training; rules and procedures including enforcement; navigational, meteorological and hydrographical information; radio communications; active traffic management and waterway changes.
- Quantifying the effect on the risk level of an existing port or waterway that may result from a change or reduction of any of the risk control options in use.

The Risk Management Tool can also assist in assessing the risk level of existing ports and restricted waterways as well as determining the probable risk level of proposed new ports and waterways or if substantial changes to existing ports and waterways are being planned. The two models, one of which conducts a Qualitative Risk Assessment and the other conducts a Quantitative Risk Assessment, can be used individually, sequentially or in parallel. A flow diagram of the procedure is given in Figure 1.

1.2. Qualitative Risk Assessment

The Qualitative Risk Assessment model has been developed by the US Coast Guard as the “Port and Waterway Safety Assessment model” (PAWSA).

Overview

The PAWSA risk assessment process identifies major waterway safety hazards, estimates risk levels and consequences, evaluates potential mitigation measures, and sets the stage for implementation of selected measures to reduce risk.

PAWSA can provide an accurate risk assessment of an existing port or waterway in a short time frame and with limited expenditure. It is undertaken by carrying out a subjective assessment of the probability of risk in a waterway, based on the experience and expert opinion of stakeholders.

The assessment by this model indicates whether the existing risk level in the waterway is:

- **Acceptable** and no further work is needed unless changes occur in important criteria, such as the traffic pattern or the types of ships using the waterway;
- **Not Acceptable** but the risk control options necessary to make the risk level of the waterway acceptable have been identified adequately;
- **Not Acceptable** and more detailed study is necessary to enable the risk control options that will make the risk level of the waterway acceptable to be identified adequately.

The PAWSA process has been completed in many ports/waterways in the US. The process has generally been well received by local maritime communities and resulted in some resounding successes. PAWSA is an effective process for evaluating risk and enabling local authorities and waterway communities to work toward long term solutions tailored to suit local circumstances. The aim of the process is to find solutions that are both cost effective and meet the needs of waterway users and stakeholders.

1.3 Quantitative Risk Assessment

The Quantitative Risk Assessment model has been developed by the Canadian Coast Guard in conjunction with the Danish Technical University and the Maritime Simulator Centre Warnemünde as the "IALA Waterway Risk Assessment Programme" (IWRAP).

Overview

The IWRAP risk assessment process identifies major waterway safety hazards; estimates risk levels, evaluates potential mitigation measures, and sets the stage for implementation of selected measures to reduce risk to the required level. The model does not consider the consequences of any collision or grounding.

IWRAP can provide information on the appropriate risk control options to be:

Used in an existing port or waterway where the qualitative risk assessment has shown that the risk level is not acceptable and that more detailed study is needed to identify the risk control options;

Incorporated in the planning for substantial changes to existing ports and waterways;

Incorporated in the planning of new ports and waterways.

The algorithms of IWRAP are quite complex. The key features of the programme being:

- Vessel positional accuracy - determined from a set of rules developed by a study of marine aids by Canadian Coast Guard;
- Safety margin, drift angles and bank affect - calculated using formulae developed by PIANC;
- Probabilities of grounding and collision - derived from formulae developed by Prof. Pedersen of the Technical University of Denmark (DTU) and in conjunction with Prof. K Benedict of the University of Wismar and Prof. E. Topuz of the Istanbul Technical University

As part of the ongoing validation process, IWRAP has been applied to the Straits of Bosporus, Tampa Bay, and parts of the St. Lawrence River with results indicating a strong correlation between theoretical and actual incident data.

1.4 Applications to use the IALA Risk Management Tool

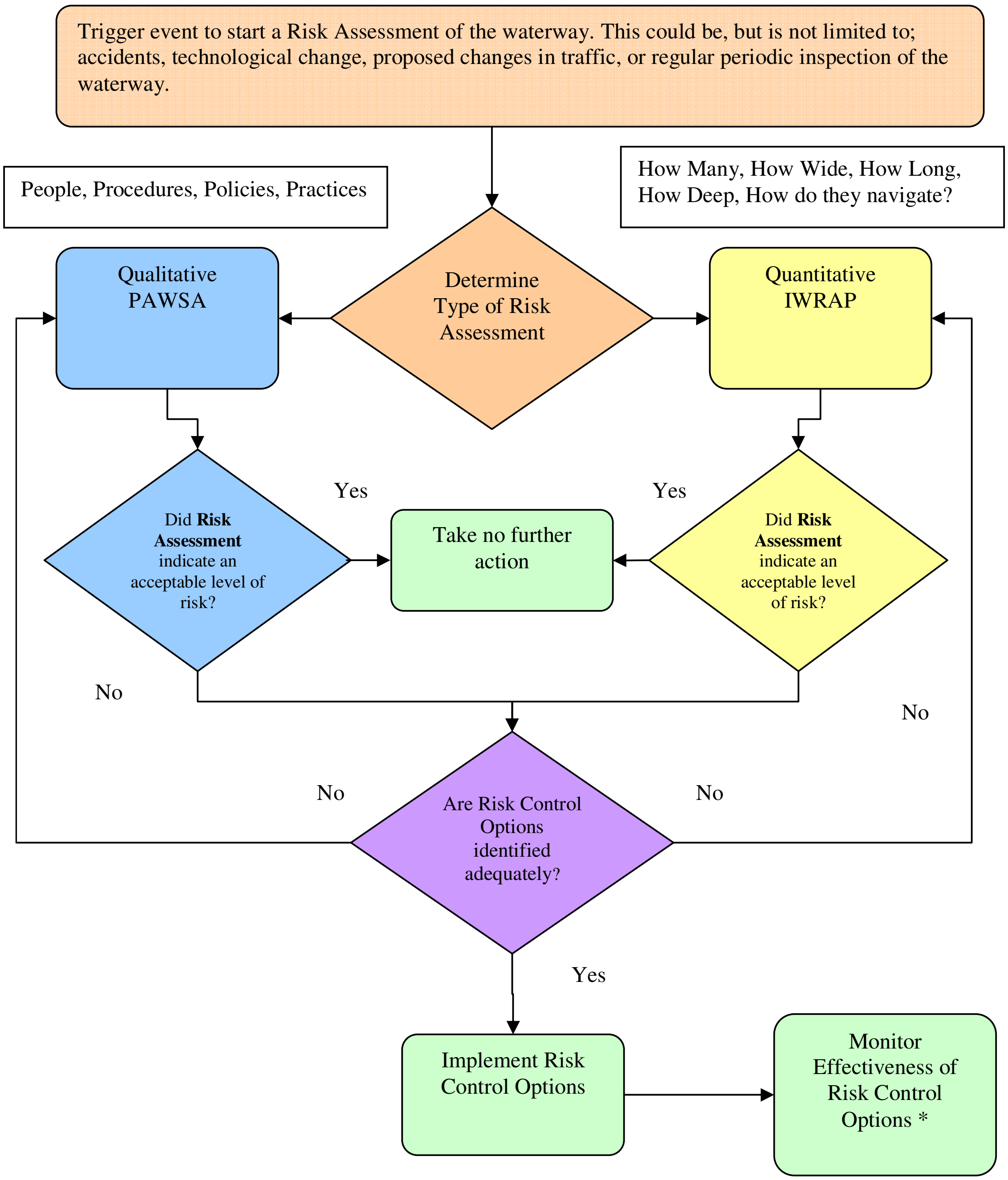
Applications to use the IALA Risk Management Tool should be made by the Authority concerned to the IALA Secretariat. This will enable records to be maintained on the use of the Tool and, as the Tool is under constant review and upgrading, ensure that Registered Users are provided with the latest versions of the both the PAWSA and the IWRAP CD's as and when they are revised.

The application should indicate the waterway on which the risk assessment is to be made and the dates on which the work is scheduled. On receipt of the application the IALA Secretariat will Register the Authority as a User and provide copies of the CD's containing the latest version of both the PAWSA and IWRAP models free of charge to the Authority.

The PAWSA and IWRAP CD's contain all the information necessary to prepare and conduct a risk assessment. However, if guidance is required the IALA Secretariat will arrange this in coordination with the United States Coast Guard and/or the Canadian Coastguard as appropriate.

Authorities are requested to provide copies of the results of risk assessments made by the IALA Risk Management Tool to the Secretariat.

Figure 1
Risk Management Tool - Flow Diagram



* Monitoring the effectiveness of the risk control options should be an ongoing process that is revisited periodically. The monitoring should also indicate where to rejoin the process if unsatisfactory results are shown.

PART 2 – THE PAWSA MODEL

2.1 Objective of the PAWSA Risk Assessment

The purpose of PAWSA is to provide Authorities and waterway communities with an effective tool to evaluate risk and work toward long term solutions tailored to local circumstances. The assessment should identify solutions that are cost effective and meet the needs of waterway users and stakeholders.

2.2 PAWSA Background

The PAWSA process grew out of the tremendous changes that took place during the 1990s in the United States Coast Guard (USCG) Vessel Traffic Service (VTS) Acquisition programme. As a result of this the USCG established the Ports and Waterways Safety System (PAWSS) to address waterway user needs and place a greater emphasis on partnerships with industry to reduce risk in the marine environment.

As part of PAWSS, the USCG immediately convened a national dialogue group (NDG) comprised of maritime and waterway community stakeholders to identify the needs of waterway users with respect to Vessel Traffic Management (VTM) and VTS systems

From the NDG came the development of the PAWSA process, this opens a dialogue with waterway users and stakeholders to identify needed VTM improvements and to determine candidate VTS waterways. PAWSA provides a formal structure for identifying risk factors and evaluating potential mitigation measures through expert inputs. The process requires the participation of professional waterway users with local expertise in navigation, waterway conditions, and port safety. In addition, stakeholders are included in the process to ensure that important environmental, public safety, and economic consequences are given appropriate attention as risk interventions are selected.

2.3 Risk Assessment Methodology Overview

2.3.1 General

The PAWSA risk assessment process is a disciplined approach to identify major waterway safety hazards, estimate risk levels, evaluate potential mitigation measures, and set the stage for implementation of selected measures to reduce risk. The process involves convening a select group of waterway users/stakeholders and conducting a two-day structured workshop to meet these objectives. An appropriate Authority is required to initiate and manage the workshop. However, the process must be a joint effort involving waterway users, stakeholders, and the agencies/entities responsible for implementing selected risk mitigation measures. The risk assessment process represents a significant part of joint public-private sector planning for mitigating risk in waterways.

The methodology uses a generic model of waterway risks. The only “safety” related issues that are deliberately excluded from the model are those that relate to port, facility, and vessel security. Those security-related issues are not covered during a PAWSA because the workshop is unclassified and usually open to the public whereas discussions of security issues may delve into sensitive topics that should be treated as classified information.

2.3.2 The Ports and Waterways Safety Assessment Workshop Guide

The Ports and Waterways Safety Assessment Workshop Guide (the PAWSA Workshop Guide) provides the guidance and procedures required for conducting a Ports and Waterways Safety Assessment. The PAWSA Workshop Guide is organized into seven sequential chapters that introduce the PAWSA process and then describe methodology, pre-workshop logistics requirements, participant selection, workshop preparation, session facilitation, and post-workshop reporting. Using this Guide as the primary reference, the appropriate Authority arranges for a meeting location and selects a group of waterway users and stakeholders from the local community to participate in the workshop. During the workshop, participants discuss safety-related issues relating to the waterway and then provide numerical inputs to quantify those discussions.

2.3.3 Waterway Risk Model

Since risk is defined as the product of the probability of a casualty and its consequences, the Waterway Risk Model includes variables dealing with both the causes of waterway casualties and their effects. The six risk categories determined were:

1. **Vessel Conditions** – the quality of vessels and their crews that operate on a waterway.
2. **Traffic Conditions** – the number of vessels that use a waterway and their interactions.
3. **Navigational Conditions** – the environmental conditions that vessels must deal with in a waterway relating to wind, water movements (i.e., currents), and weather.
4. **Waterway Conditions** – the physical properties of the waterway that affect how easy it is to manoeuvre a vessel.
5. **Immediate Consequences** – the immediate impacts of a waterway casualty: people can be injured or killed, petroleum and hazardous materials can be spilled and require response resources, and the marine transportation system can be disrupted.
6. **Subsequent Consequences** – the subsequent effects of waterway casualties that are felt hours, days, months, and even years afterwards, such as shoreside facility shut-downs, loss of employment, destruction of fishing areas, decrease or extinction of species, degradation of subsistence living uses, and contamination of drinking or cooling water supplies.

The diagram below shows six risk categories and corresponding risk factors that are considered in the Model.

Waterway Risk Model					
Vessel Conditions	**Traffic Conditions**	**Navigational Conditions**	**Waterway Conditions**	**Immediate Consequences**	**Subsequent Consequences**
Deep Draft Vessel Quality	Volume of Commercial Traffic	Winds	Visibility Impediments	Personnel Injuries	Health and Safety
Shallow Draft Vessel Quality	Volume of Small Craft Traffic	Water Movement	Dimensions	Petroleum Discharge	Environmental
Commercial Fishing Vessel Quality	Traffic Mix	Visibility Restrictions	Bottom Type	Hazardous Material Release	Aquatic Resources
Small Craft Quality	Congestion	Obstructions	Configuration	Mobility	Economic

2.4 Numerical Methodology

2.4.1 Theory

The theoretical concept underlying the PAWSA process is the proven Delphi method of converting the opinions of local subject matter experts into quantified results. This method is used so that the quantified results can be compared internally (i.e., the results for one risk factor can be compared to those for other risk factors and the results from one stage (e.g., Book 3) can be compared to the results from other stages (e.g., Book 4) during the workshop) and externally (i.e., the results from one waterway can be compared to the results from other waterways).

Proof that the PAWSA process produces valid results comes from the internal consistency checks that are built into the results spreadsheets within the Excel™ workbook (PAWSA software) used to capture and analyze the participants' quantified inputs. Those consistency checks have shown repeatedly that workshop participants develop strong consensus about the levels of risk in the waterway and the effectiveness of various risk mitigation strategies. This consensus emerges although the participants typically represent widely different interests within the overall maritime community and the 1 to 9 measurement scale used is correlated only loosely with qualitative descriptors for each value on that scale.

The rest of this paper describes the mathematics used to produce results from the quantitative assessments data (Books 1 – 5) the participants provide during a PAWSA workshop.

Book 1: Team Expertise

There is no expectation that every participant in a PAWSA workshop will be equally knowledgeable with respect to all 24 of the risk factors included in the Waterway Risk Model. Consequently, *Book 1: Team Expertise* is used to weigh the relative strengths of each team with respect to the six risk categories. After being presented with the concepts underlying the model, each participant team is asked to discuss (among themselves) how their background and experience aligns with the model. They then verbally present their conclusions to the larger group. These presentations give all teams a sense of where everyone thinks they are strong – or perhaps not so strong. After all teams have spoken, each team evaluates whether they think they are in the top, middle, or lower third of all teams present in knowledge about the six risk category areas. Throughout the workshop, these initial expertise evaluations are used to produce preliminary results for all other Books. Towards the end of the workshop, when each team has a much more in-depth feel for how all the teams compare to everyone else present, the team expertise evaluations are returned to each team for them to evaluate all of the other teams' level of expertise as well as to review and revise their own scores as necessary. The completed expertise evaluations are used to determine the final workshop results.

The teams, in doing the expertise evaluation, conceptually are dividing up six expertise pies (risk categories) into different sized slices, with the relative size of each slice from each pie equalling the expertise of each team relative to the other teams for that risk category. An example for the Navigational Conditions Risk Category:

Team 1: Circles a 1 indicating they are in the Top 1/3 of all teams present

Team 2: Circles a 3 indicating they are in the Lower 1/3 of all teams present

Team 3: Circles a 1 indicating they, also, are in the Top 1/3 of all teams present

These responses are entered into the data input cells in the *Bk 1 Input* spreadsheet in the Excel™ workbook. The spreadsheet then inverts those inputs, i.e., all inputs are subtracted from 4 so that a 1 becomes a 3 and a 3 becomes a 1. This is done so that the Top 1/3 teams get the biggest slice of the pie. Those inverted scores are added up (showing that, in our example, the total pie size = 3 + 1 + 3 = 7). Then each team's slice is computed by dividing their inverted score by the total pie size. For our example:

Team 1: 3/7 = .429 (≈ 43% of the Navigational Conditions expertise pie)

Team 2: 1/7 = .143 (≈ 14% of the Navigational Conditions expertise pie)

Team 3: 3/7 = .429 (≈ 43% of the Navigational Conditions expertise pie)

Obviously, and mathematically very important, adding all of the slices together equals 100% of each expertise pie. These computations are done independently for each of the six risk categories (expertise pies). Each team's relative expertise in each category (size of their slice) is multiplied by their inputs for the four risk factors <u>in that category</u> during all of the other quantitative evaluations (*Books 2 – 5*). When this multiplication is done, the products that result are the weighted inputs for that team for that book. Because the sum of the expertise for each category equals 100%, the sum of the weighted inputs equals the risk level.

Book 2: Risk Factor Rating Scales

The concepts that define each of the 24 risk factors in the Waterway Risk Model have been described in qualitative terms, such that they range from a very benign, best case risk scenario to a highly dangerous, worst case risk scenario. Two intermediate qualitative risk level descriptors describe risk somewhere between the best and worst cases, with the first intermediate descriptor less risky than the second intermediate descriptor. Those qualitative descriptors have been refined over the course of many PAWSA workshops to remove ambiguities and use of multiple variables, both of which lead to poor consensus.

For uniformity, all risk assessment in the PAWSA workshop is done using a 1 to 9 point scale, where 1 represents the lowest risk and 9 represents the highest risk. The purpose of *Book 2: Risk Factor Rating Scales* is to establish the numerical relationships between the two intermediate qualitative risk descriptors and the best case and worst case end points. This is done with a pair-wise comparison technique, used to break up a complex problem (e.g., defining numerically how risk increases across a range of qualitative descriptions) into manageable component parts.

Participant teams evaluate the increase in risk associated with moving from the lower risk descriptor in the left hand column of *Book 2* to the higher risk descriptor in the right hand column. Three pairs of comparisons are done for each risk factor. When the inputs from all participants for those three comparisons are aggregated, a risk rating curve results. The three comparisons for Wind Conditions are:

Lower risk										Higher risk
Strong winds occur **LESS** than twice a month **AND** well forecast	1	2	3	4	5	6	7	8	9	Strong winds occur **MORE** than twice a month **BUT** well forecast
Strong winds occur **MORE** than twice a month **BUT** well forecast	1	2	3	4	5	6	7	8	9	Strong winds occur **LESS** than twice a month **BUT** without warning
Strong winds occur **LESS** than twice a month **BUT** without warning	1	2	3	4	5	6	7	8	9	Strong winds occur **MORE** than twice a month **AND** without warning

Equally Risky → Somewhat More Risky → Much More Risky → Extremely More Risky

Continuing with the three team example from the previous section, hypothesize the following *Book 2* inputs for the Wind Conditions risk factor:

	Team 1	Team 2	Team 3
First Comparison	4	3	3
Second Comparison	7	5	6
Third Comparison	7	8	8

The inputs from each team for each risk factor in a particular risk category are multiplied by that team's expertise score for that risk category. For the example, that produces the following results:

	Team 1	Team 2	Team 3	Sum
First Comparison	4 x .43 = 1.72	3 x .14 = .42	3 x .43 = 1.29	3.43
Second Comparison	7 x .43 = 3.01	5 x .14 = .70	6 x .43 = 2.58	6.29
Third Comparison	7x .43 = 3.01	8 x .14 = 1.12	8 x .43 = 3.44	7.57
			Grand Total:	17.29

The first comparison is between the descriptor for the best case (which is called the "A" value) and the first intermediate descriptor (which is called the "B" value). The second comparison is between the "B" value and the second intermediate descriptor (which is called the "C" value). The third comparison is between the "C" value and the worst case descriptor (which is called the "D" value). The sums at the end of each row above show how much the risk increases going from the lower risk descriptor to the higher risk descriptor. Obviously the sum of those sums (17.29 in this example) represents the total increase in risk going from the best case to the worst case descriptors. On the 1 to 9 scale used throughout the rest of the PAWSA process (*Books 3*, *4*, and *5*), the best case is always assigned a risk level value of 1.0 and the worst case is always assigned a risk level value of 9.0. Note that the difference between those values is: 9 – 1 = 8 points. From this information, it can be seen that the "B" risk level value equals the best case value (1.0) plus the sum of the first comparison products (3.43) divided by the total increase in risk going from the best to the worst case scenario (17.29) times the total distance along the 1 to 9 scale (8). Doing the math, the "B" value in this example equals:

$$B = 1.0 + (3.43 / 17.29 * 8) = 2.59$$

In like manner, the "C" value equals the "B" value plus the sum of the second comparison products (6.29) divided by 17.29 times 8, or:

$$C = 2.59 + (6.29 / 17.29 * 8) = 5.50$$

Finally, although it is already known that the worst case value always equals 9.0, it can be shown mathematically that that value equals the "C" value plus the sum of the third comparison products (7.57) divided by 17.29 times 8, or:

$$D = 5.50 + (7.57 / 17.29 * 8) = 9.0$$

Typical results are:

A Value (Best Case Descriptor)	1.0
B Value (First Intermediate Descriptor)	2.5 to 3.0
C Value (Second Intermediate Descriptor)	5.0 to 6.0
D Value (Worst Case Descriptor)	9.0

To compare results from one workshop to another, all PAWSA workshops must use the same "aggregate" risk measuring scales. Those scales (one for each of the 24 risk factors in the Waterway Risk Model) are being developed through an iterative process wherein the *Book 2* results from each workshop are combined with the results from all previous workshops. This is done by simply averaging together the "B" values that were calculated during preceding workshops with the "B" values calculated for the current workshop. The same is done for the "C" values. This produces a four-point risk measuring curvilinear scale for each factor. The aggregate risk measuring curves thus defined are used as described in the next section.

Book 3: Baseline Risk Levels

To determine a risk level value for every factor in the Waterway Risk Model, *Book 3: Baseline Risk Levels* uses the same four qualitative descriptors for each risk factor as were used in *Book 2*. In theory those qualitative descriptors are written in absolute terms; that is, the risk level values that are produced by *Book 3* do not take into account any actions already implemented to reduce risk in the waterway. In practice, PAWSA participants sometimes have difficulty thinking in such absolute terms and the effects of existing mitigations tend to creep into the discussion and evaluation of this workshop stage.

Key to achieving strong consensus in the *Book 3* results is the discussion period that immediately precedes filling out this quantitative evaluation. During that discussion the various perspectives concerning each risk factor are voiced and, sometimes, debated. Often participants refer to read-ahead material provided for the workshop (or readily available to them via other means), especially for risk factors amenable to measurement and/or quantification (e.g., volume of traffic, wind conditions, cargo volumes). Once the discussions have run their course, participants simply check the box next to the qualitative descriptor for a particular risk factor that best matches conditions in the waterway being evaluated.

If a team checks the first box (describing the best case), then a 1 is entered into the *Bk 3 Input* spreadsheet, obviously corresponding to a value of 1.0 for that input. If a team checks the second box, then a 2 is entered into the spreadsheet and the computer algorithm assigns the "B" value from the aggregate risk measuring scale for that factor to that input. In like manner, a check in the third box is entered as a 3 and assigned the "C" value; a check in the fourth box (describing the worst case) is entered as a 4 and assigned a value of 9.0.

Building on the same three team Wind Conditions example from previous sections, hypothesize the following *Book 3* inputs:

	Team 1	Team 2	Team 3
Box Checked	Third	Second	Third
Spreadsheet Entry	3	2	3
Risk Value	C	B	C
Value Assigned	5.50	2.59	5.50

The inputs for each team for each factor are multiplied by their team expertise scores and then added together to produce the baseline risk value for that factor. Continuing our example:

	Team 1	Team 2	Team 3	Sum
Value Assigned	5.50	2.59	5.50	
Expertise Score	.43	.14	.43	
Product	2.36	.36	2.36	5.08

Thus, for the example, the baseline risk value for the Wind Conditions factor is 5.1. (Note: All results are displayed rounded to one decimal place because the qualitative descriptors that underlie these quantitative results are not precise enough for greater numerical precision.) The results from *Book 3* for each risk factor in the Waterway Risk Model become the baseline from which the effectiveness of existing mitigation strategies are evaluated in *Book 4*. Those baseline numbers are marked on the *Book 4* assessment forms using a highlighter pen.

Book 4: Mitigation Effectiveness

Again, the key to good consistency in results from the *Book 4: Mitigation Effectiveness* stage is the discussion that immediately precedes filling out the quantitative evaluations. Those discussions focus on three issues: (1) the specifics of what has been done to reduce the risk associated with a particular factor; (2) the effectiveness of those mitigation actions; and (3) whether existing mitigations are well balanced with the baseline risk value.

Once the discussions are complete, the participants do two things: (1) circle a number on the 1 to 9 scale that shows the effectiveness of existing mitigations in reducing risk below the absolute levels determined via *Book 3* and (2) circle Yes (or No) depending on whether they think existing mitigations adequately balance the risks for each factor (or not).

The vast majority of the time, participants will circle a number on the 1 to 9 scale to the left of (smaller than) the highlighter mark denoting the *Book 3* result. However, if they conclude that actions taken previously are having no effect on reducing the baseline risk, they will circle the *Book 3* result mark. Though unusual, participants might state (and then evaluate) that existing mitigations actually increase the risk for some factor(s). For example, while discussing the Dimensions risk factor, participants cite as an existing risk mitigation strategy that leading lights have been established to help waterway users keep from running aground in a narrow channel, but state that the leading lights are out of alignment with the channel, thereby increasing the risk of groundings. They then could evaluate the effect of that mitigation by circling a higher number (i.e., to the right) of the *Book 3* result mark.

The numbers that are circled by the participants are entered exactly as indicated into the *Bk 4 Scores* spreadsheet with two exceptions: (1) if the participants circle the space between two whole numbers, the entry is invalid and the team is required to reassess providing a whole number entry; and (2) if the participants circle the *Book 3* result mark, a lower case "e" is entered and the computer algorithms convert that entry into the *Book 3* results value.

As with *Books 2* and *3*, the *Book 4* numerical entries are multiplied by the *Book 1* expertise scores and then those products are added together to produce the present risk level, which takes into account the effectiveness of existing mitigations.

Continuing the example from previous sections:

	Team 1	Team 2	Team 3	Sum
Number Circled	3	Highlighter mark	4	
Spreadsheet Entry	3	e	4	
Value Assigned	3	5.08	4	
Expertise Score	.43	.14	.43	
Product	1.29	.71	1.72	3.72

Rounding this result to one decimal place, it can be seen that the effectiveness of existing mitigations in reducing Wind Conditions risk is judged to be: 5.1 – 3.7 = 1.4 points.

As the final step in *Book 4*, participants make a subjective evaluation, based on the preceding discussions, as to whether they think risks are adequately balanced with existing mitigations for each factor. They do this by circling Yes (they are balanced) or No (they are not balanced) on the line in *Book 4* for each factor. Those Yes / No answers are coded into the *Bk 4 Y-N* spreadsheet as lower case "y" or "n". If two thirds or more of the participant team expertise indicates Yes, then that risk factor is dropped from further discussion / evaluation in *Book 5: Additional Mitigations*. This condition is denoted by a green *Balanced* on the *Book 4* results display spreadsheet (*Bk 4 Disp*). If two thirds or more of the participant team expertise indicates No, then that risk factor should definitely be discussed / evaluated in *Book 5*. That condition is denoted by a red *NO* on the *Book 4* results display. If there is less than two thirds consensus about the efficacy of existing mitigations then a yellow *Maybe* is displayed. Those "Maybe" risk factors also should be discussed / evaluated in *Book 5*. Finally, if the present risk level is evaluated as being HIGHER than the risk level from *Book 3* or, when appropriate, is higher than the risk level determined during a previous PAWSA held for the same waterway, then a red *RISING* is shown on the *Book 4* results display.

Book 5: Additional Mitigations

In the final quantitative evaluation stage of the PAWSA process, discussion is focused on those risk factors where the present risk level is not *Balanced*. For each risk factor displaying a *NO*, *RISING*, or *Maybe* flag, the *Book 4* results are marked using a highlighter on blank copies of the *Book 5: Additional Mitigations* evaluation forms. This serves as a starting point for evaluating the possible effectiveness of new mitigation strategies. For each risk factor so marked, the workshop participants are asked to offer ideas about what should be done to reduce the present risk level. Again, the quality of the discussion directly affects consistency of results obtained.

Analysis of risk mitigation ideas offered to date showed that those ideas usually fall into nine major implementation categories. Those categories are:

Coordination / Planning

Voluntary Training

Rules & Procedures

Enforcement

Navigation / Hydrologic Information

Radio Communications

Active Traffic Management

Waterway Changes

Other Actions

Those categories are fully described on a handout given to participant and also are defined on the first page of *Book 5*.

After the participants have presented / discussed their risk mitigation ideas, they are asked to write short phrases (3 to 5 words each) describing the ideas they think have merit. Those short phrases are written on the lines next to the categories into which the ideas best fit. For example, if the risk factor being discussed is Wind Conditions and the idea being considered is "Install wind sensor at Long Point", then the participants would write those words on the line next to the Nav / Hydro Info intervention category under that risk factor. After recording an idea, the participants indicate what risk level would result from implementing that idea. This is done by circling a number to the left of (lower than) the *Book 4* risk level mark on the 1 to 9 scale next to the implementation category where the idea was written. As in *Book 4*, only whole numbers are used; therefore, if the participants circle the space between two whole numbers, the entry is invalid and the team is required to reassess providing a whole number entry. The closer that circle is to 1, the more effective the participant team feels the idea to be. Those evaluations are again multiplied by the team's expertise scores and then those products are added together to get the possible risk level resulting from implementing the ideas written down for a particular category.

Again using the Wind Conditions example:

	Team 1	Team 2	Team 3	Sum
Number Circled	2	3	2	
Spreadsheet Entry	2	3	2	
Expertise Score	.43	.14	.43	
Product	.86	.42	.86	2.14

The algorithms for the *Book 5* display spreadsheet (*Bk 5 Disp*) determine which implementation category most teams have chosen and then how much risk improvement would result from the ideas written down for that category. Those *Book 5* display algorithms also determine which implementation category was judged to be most effective (i.e., had the biggest delta between the *Book 5* and *Book 4* results). A yellow *Caution* flag is displayed if the most chosen implementation category is NOT the same as the most effective category AND either fewer than 50% of the teams chose the most chosen category OR more than 50% of the teams chose the most effective category. The presence of the yellow *Caution* flag for any risk factor indicates the possibility that there is more than one "best" mitigation measure that potentially will achieve further risk reduction for that factor.

Workshop Outputs

Workshop outputs should include electronic and paper copies of a participant contact list, workshop critique comments, and the *PAWSA Workshop Report*. The *PAWSA Workshop Report* should include the quantitative results from *Books 1 – 5*, discussion comments made during the workshop, and an in-depth analysis providing specific recommendations as to the mitigation strategies that should be implemented and the organizations that should take the lead in implementing them.

PART 3 – THE IWRAP MODEL

3.1 Purpose

The IALA Waterway Risk Assessment Program (IWRAP) has been developed to provide a standardized method of assessing the risks within most waterways. The outputs from IWRAP can be used to assess the risk in each the section of a waterway and in turn determine the degree of risk to navigation throughout the entire waterway.

IWRAP also allows different scenarios to be developed so that proposed changes to a section of waterway may be tested and analyzed before their implementation.

3.2 Background

IWRAP has evolved from a "Minimum Safe Design" (MSD) tool that was developed in Canada. MSD determines the minimum safe channel width based on; types and sizes of vessels, aids to navigation provided, and the geophysical conditions within the channel. The major elements that have been added to the tool are the probabilities of grounding and collision.

Further development has led to the inclusion the effects of the four generic levels of VTS, the value of pilots with their enhanced local knowledge of the waterway, the functionality to analyze crossing situations, and DGPS as a navigation method.

3.3 Programme Overview

IWRAP is a "Windows" based application that is designed to incorporate the complex algorithms of channel design and probability into a simple interface that can be used by a wide audience with minimal training.

To analyze a waterway requires several basic steps including:

1. Divide the waterway into sections for analysis;
2. For each section the analysis will need the following:
    - Enter data into the model about vessels, traffic conditions, navigation aids and waterway layout;
    - Run scenarios for existing and potential circumstances; ,
    - Assess the results with respect to the adequacy of the available channel layout and the number of potential collisions or vessels going outside of the defined channel
    - Create reports.

3.4 Dividing the waterway into sections

The various unique sections of a waterway, with their own inherent risks should be identified by using a large scale chart of the waterway to divide it into straight sections, bends, and crossings.

Straight parts of a waterway may be divided into different sections for analysis purposes. For example, if there is a high concentration of aids to navigation in one part of the waterway, it should be treated as a separate section. Similarly, if the width of the waterway available for navigation narrows at any point the area concerned should also be treated as a separate section.

The length of each section incorporating a bend should include ¼ to ½ nautical miles before and after the bend to allow for extra manoeuvring by ships preparing and exiting the bend. Wherever practicable, a distance at ½ nautical miles should be allowed, especially in waterways used by large vessels.

Areas of the waterway where crossing situations occur should be identified and made into separate sections. Where the limits of a crossing area are not clearly identified, for example, where a ferry crossing is shown by a dotted line, the section should include a distance of between ¼ and ½ nautical miles before and after the indicated ferry crossing line.

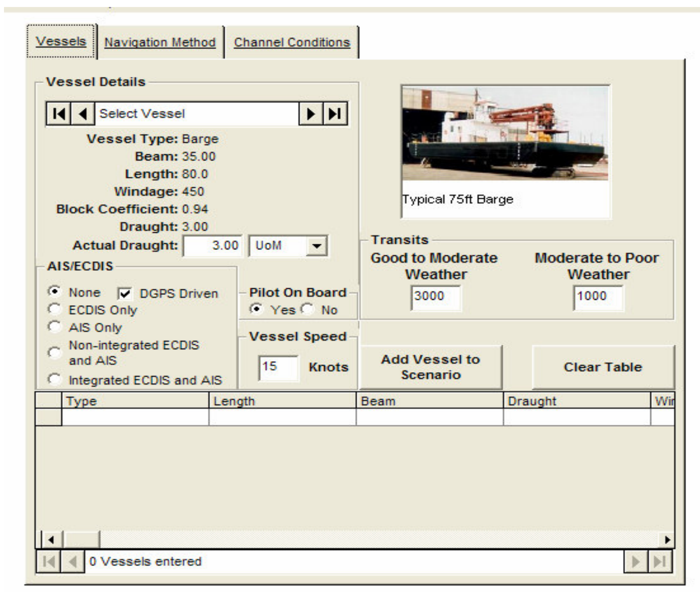
IWRAP has an additional feature for importing and exporting data to/from excel spreadsheets. This allows information to be compiled and shared with others.

3.5 Entering information into the Model

Data entry into IWRAP is carried out by using following the three tabs:

- Vessels
- Navigation Method
- Channel Conditions

3.5.1 Vessels tab

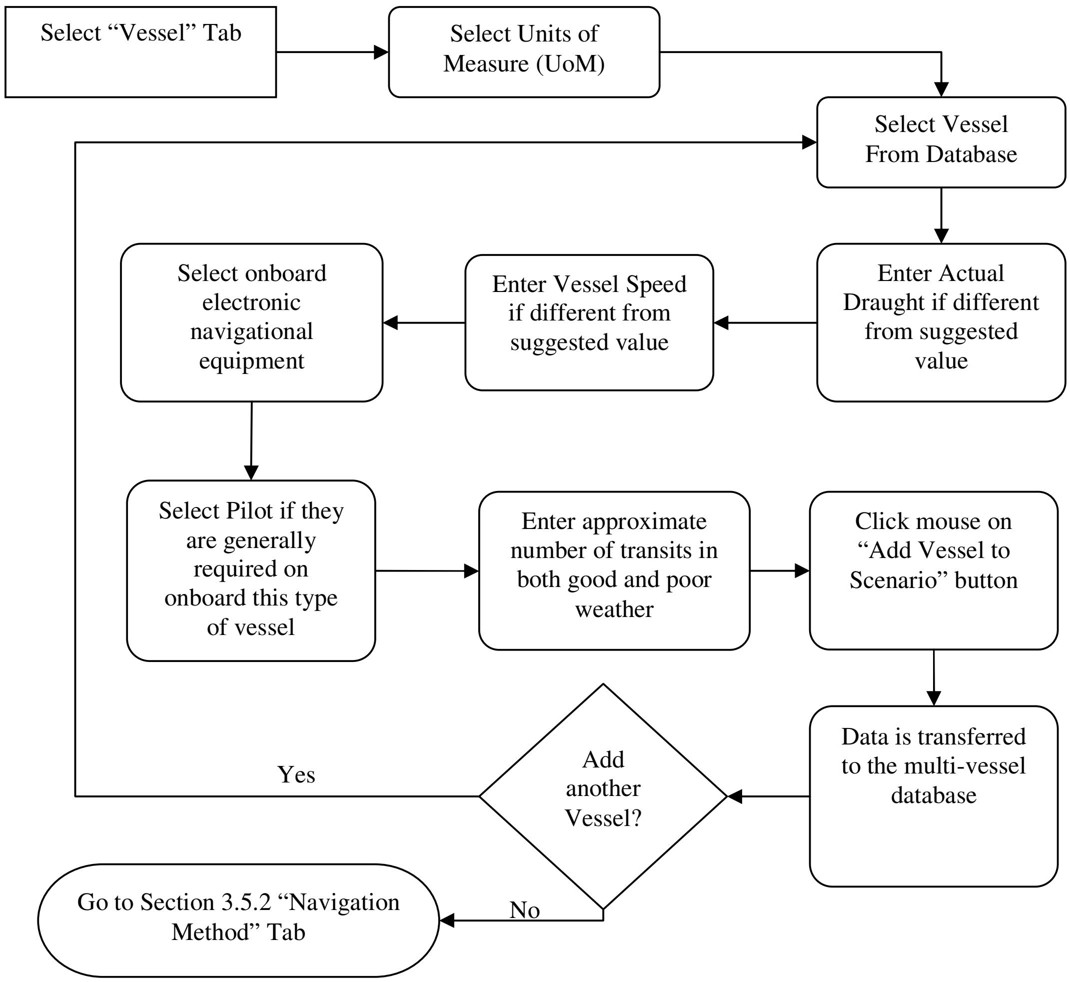


This tab is used to enter information about all types of vessels that use the section of the waterway concerned, including their dimensions, draught and speed through the section. Annual traffic data for the waterway is an important source of this information as it should include the number of transits associated with each vessel category, and the number of those transits that take place in good and in bad weather conditions.

Information about Pilots, AIS, and ECDIS provided on board each vessel is also entered on this tab.

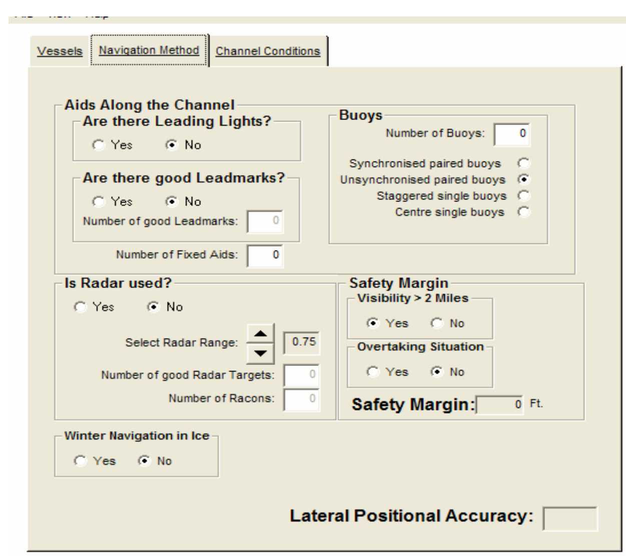
The tab also includes a drop down menu that enables either Imperial or Metric Units of Measurement (UoM) to be used in the model. It is important that all measurements entered in the model should use the same unit.

The flow of information entered by this Tab is set out in Flow Chart 1 – Vessels Tab



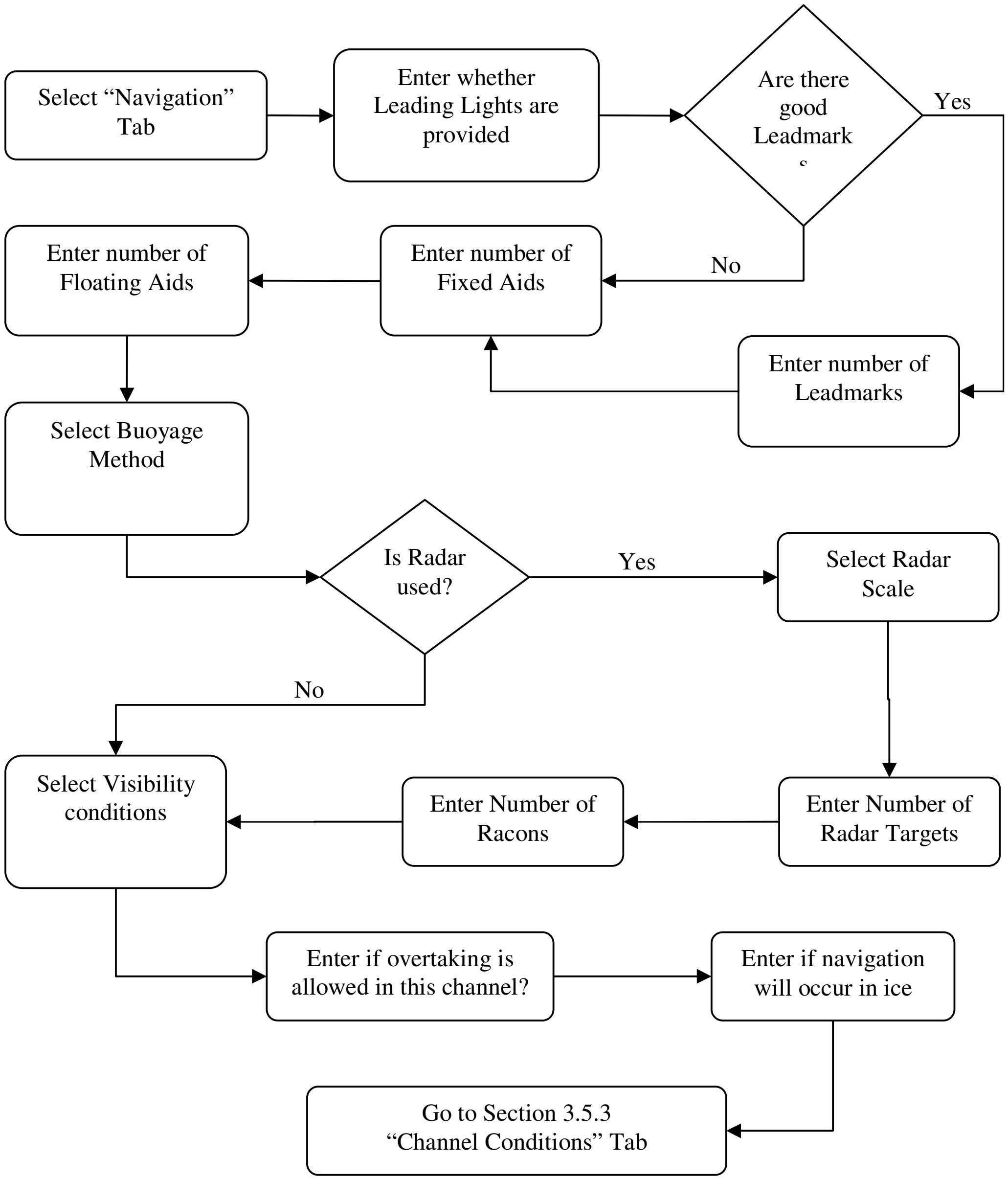
Flow Chart 1 – Vessel Tab

3.5.2 Navigation Method tab



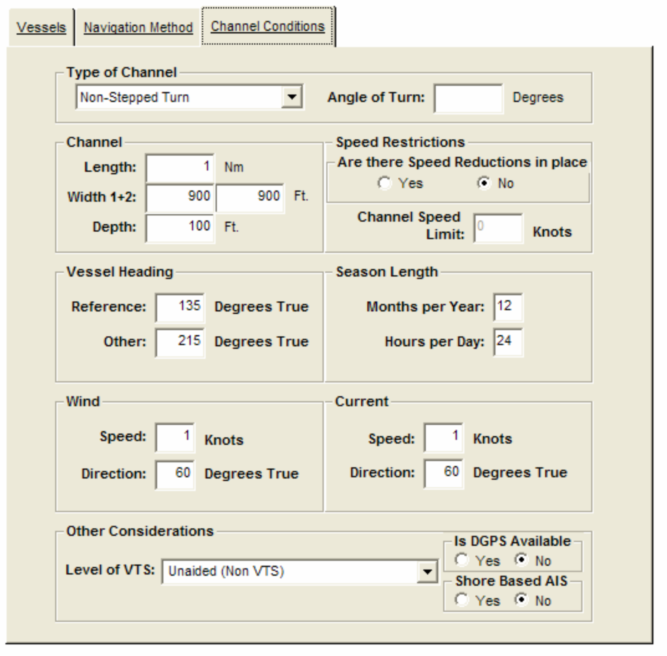
On this tab information on all the aids to navigation for the current section of waterway is entered. This includes the number of Buoys and their arrangement for marking the waterway, Racons, Fixed Aids, Radar Targets, Leading Marks and DGPS.

The flow of information entered by this Tab is set out in Flow Chart 2 – Navigation Method Tab



Flow Chart 2 – Navigation Method Tab

3.5.3 Channel Conditions



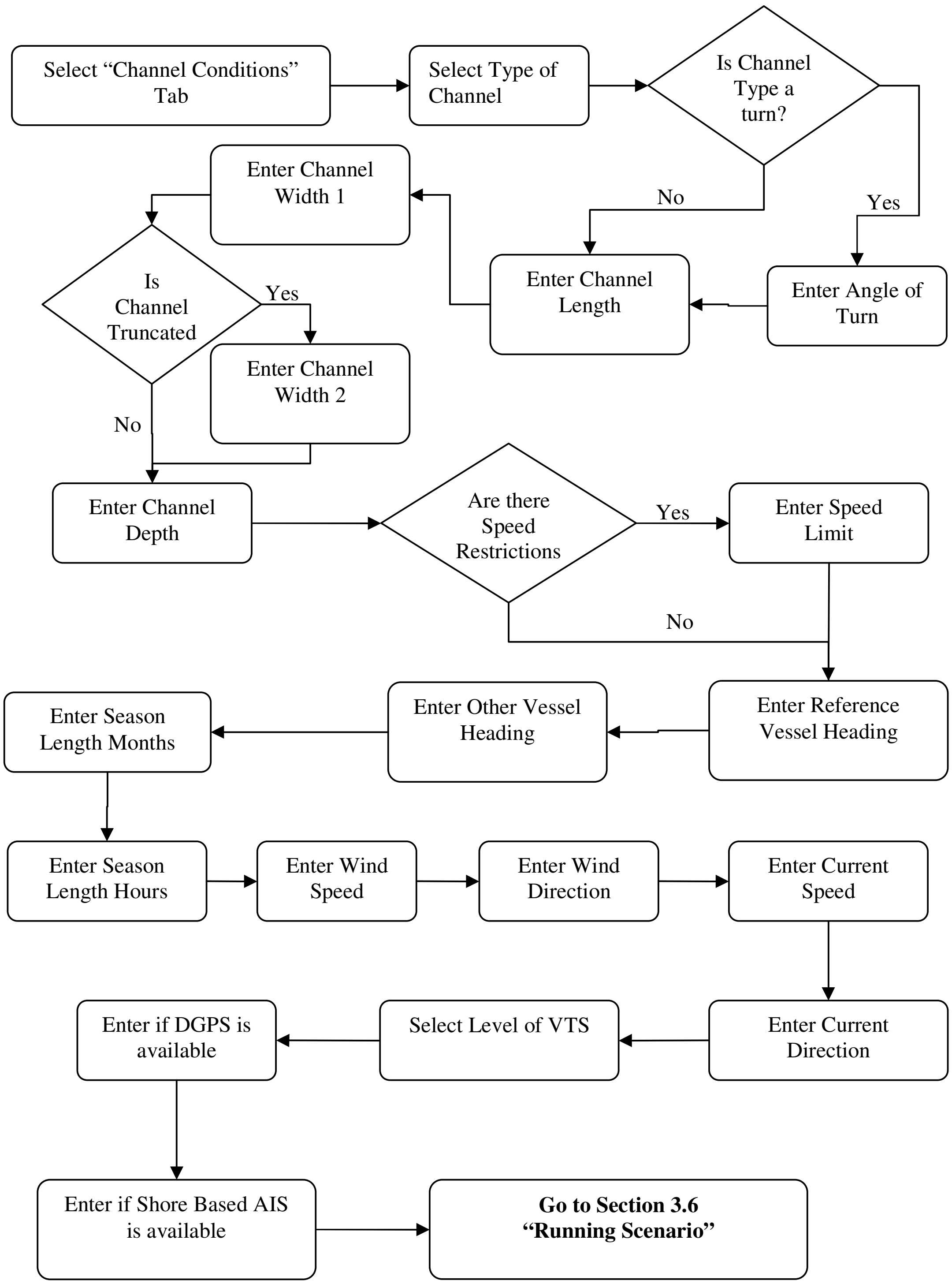
The information entered on this tab relates to primarily the geophysical conditions within the current section of waterway. The information is used to assess the domain of the vessel and effect that the conditions may have on the vessel's ability to maintain a safe course.

The "Other Considerations" frame is used to input information on services that are provided to assist navigation in the waterway section. When DGPS Coverage is provided, vessels that have AIS and/or ECDIS installed will have risk reduction factors applied to the potential number of meetings with other vessels per year.

The Level of VTS drop down box lists four levels of VTS. They are; No VTS; VTS Information Service; VTS navigation Information Service; and, VTS Traffic Management Service. Associated with each level is a pre-scaling factor that is also applied to the potential number of meetings with other vessels per year.

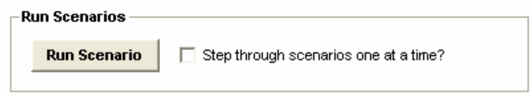
Selecting "Winter Navigation in Ice" will increase the safety margin as a result of manoeuvrability problems associated with transiting in ice.

The flow of information entered by this Tab is set out in Flow Chart 3 – Channel Conditions Tab



Flow Chart 3 – Channel Conditions Tab

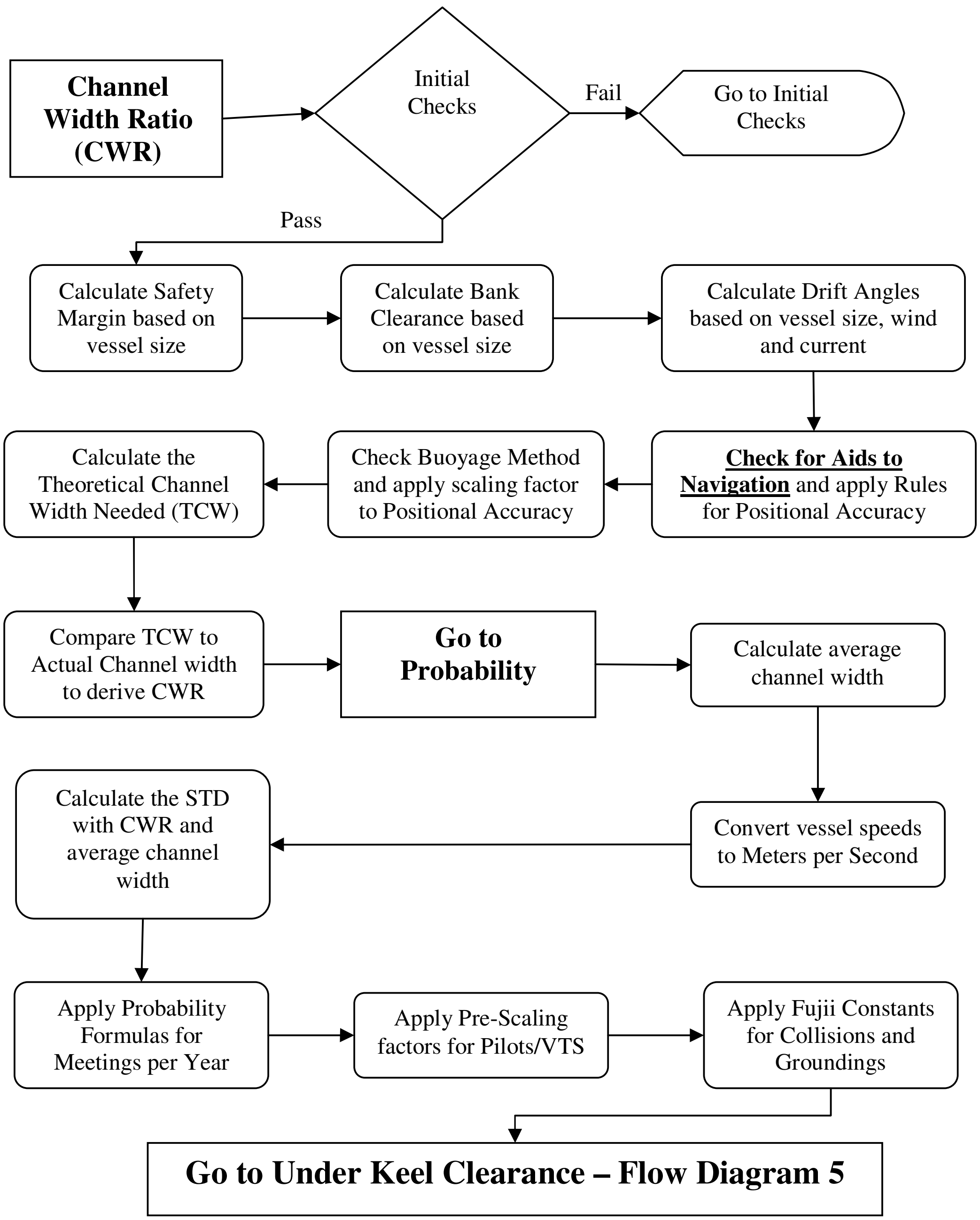
3.6 *Running Scenarios*



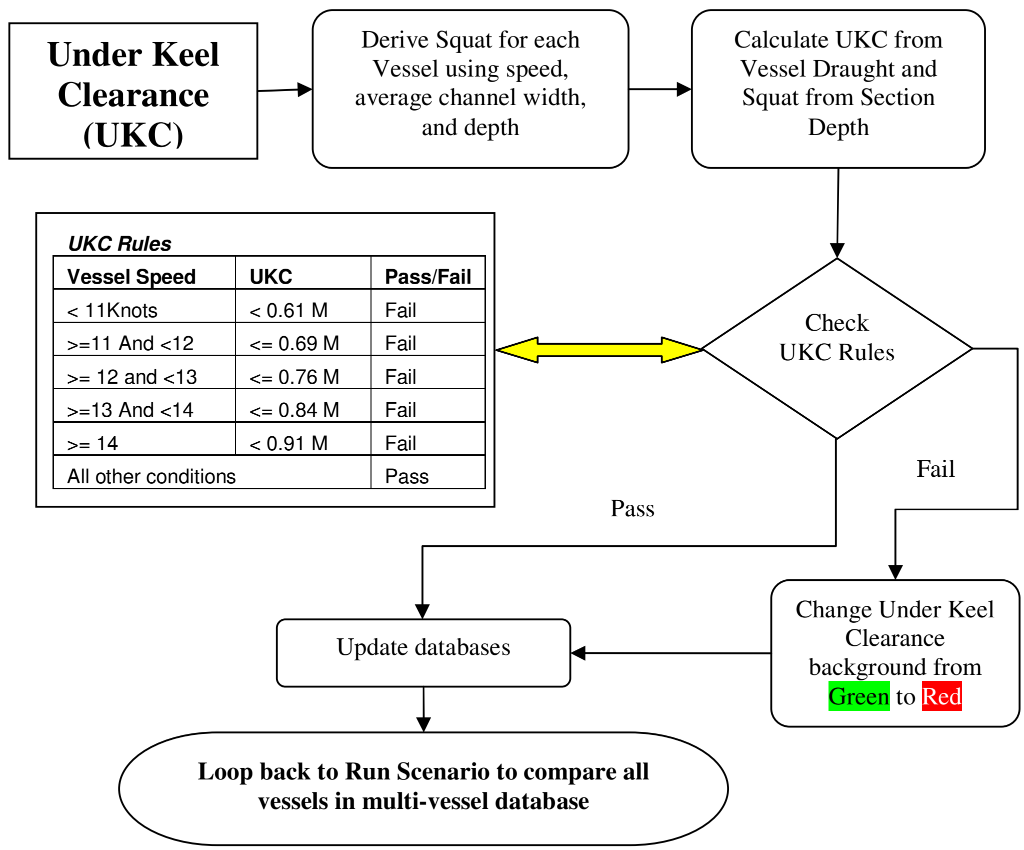
3.6.1 General

After all of the required information has been entered on the three tabs click the "Run Scenario" button and, after checking the validity of the inputs, the model will run through all of the combinations of vessels calculating the results.

The process by which the calculations are made is shown in the following Flow Diagrams:



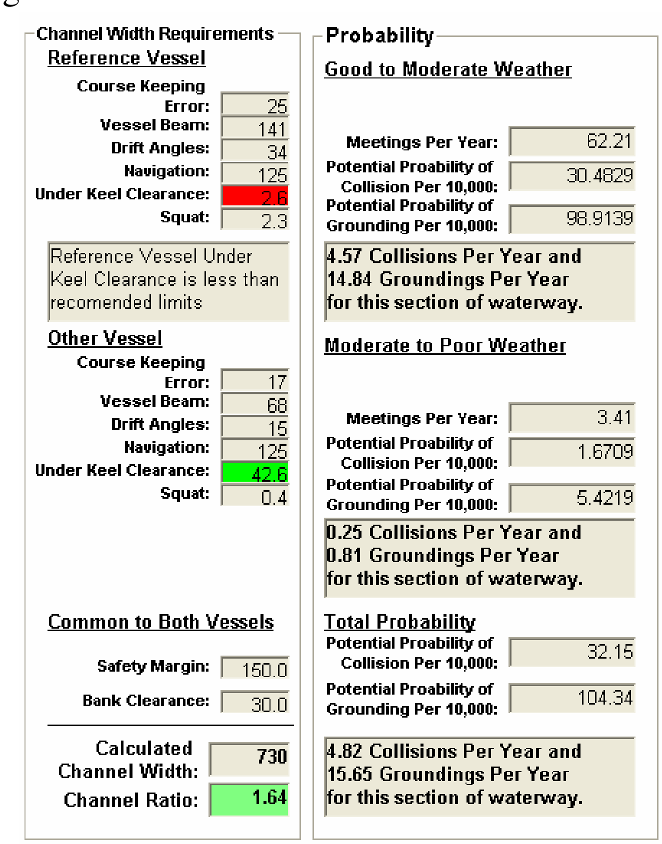
Flow Diagram 4 – Processing of Channel Width Ratio and Probability data



Flow Diagram 5 – Processing of Under Keel Clearance data

3.6.3 Results

The Results from a scenario are shown in two frames; normally the information displayed represents the last pairing of vessels. However, it is possible to step through the results of each pair of vessels individually by ticking the "Step through scenarios one at a time" check box before clicking the "Run Scenario" button. When the "Run Scenario" button is clicked, a pop-up box will appear asking for the name of the waterway section. If more than one scenario is run per waterway section, it is important that they have the same name with a different number.



3.6.3.1 The Channel Width Requirements frame.

This frame contains all of the elements that combine to make up the theoretical Calculated Channel Width (CCW) of the channel for the vessel(s) selected. The CCW is then compared to the actual width resulting in the Channel Ratio. If the Channel Ratio => 1.0 then there is adequate room for the vessel(s) selected and the boxes background colour is green. However if the Channel Ratio =< 1.0 then the Mariner should proceed with a heighten degree of awareness as the channel width is below international standards, and the background of the box will become red.

Other indicators include Squat and Under Keel Clearance. Should the combined effects of Vessel Speed, Squat, Under Keel Clearance, and Channel Depth produce an unsafe situation then the background colour for the Under Keel Clearance box will turn red, and a message will appear on the Safety Margin frame.

3.6.3.2 The Probability frame

This frame contains the following elements that describe the degree of risk to navigation:

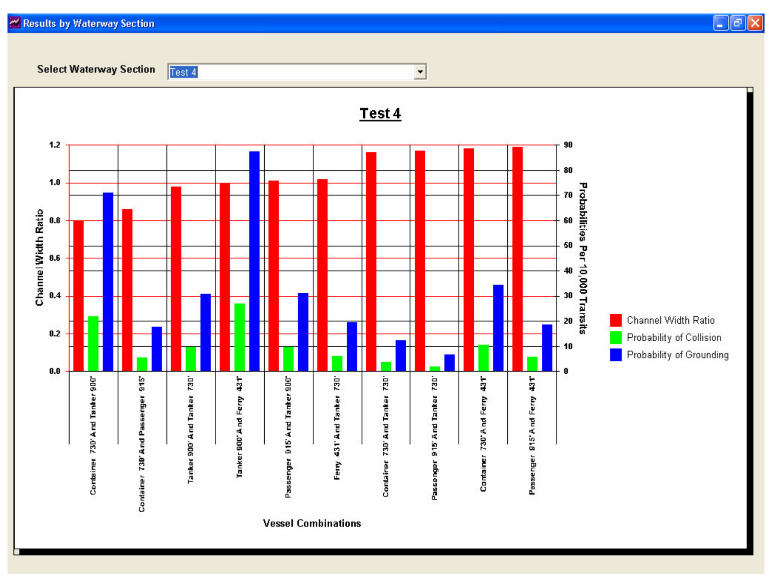
Meetings per Year: the theoretical number of domains that may interact without human intervention. IWRAP averages the transits over a year and then calculates how many vessels could be within the current section of waterway at one time. It also creates a safety perimeter around each of the vessels where the length is controlled by the speed of the vessel, and the width of the perimeter is controlled by the combined effects of wind and current. These are referred to as domains. Not all of the domains within the waterway will experience interactions.

Probability of Collision per 10,000 Transits: the potential number of collisions per 10,000 transits that may happen in this section of waterway. For the purposes of this tool a collision simply means that there is interaction between domains. It does not necessarily mean that the vessels will actually collide.

Probability of Grounding per 10,000 Transits: the potential number of groundings per 10,000 transits that may happen in this section of waterway. For the purposes of this tool grounding simply means that the vessel could inadvertently leave the shipping lane. If the water depth adjacent to the lane is sufficient for the vessel then grounding probably will not happen.

3.7 Assessing Results

Clicking on the Results menu item on the main window, and then selecting the required waterway section will then display a graph showing all of the vessel pairings that were entered into the database for that section of the waterway.



Shown on the graph will be the Channel Width Ratio Probability of Collision per 10,000 transits and the Probability of Grounding per 10,000 transits for each pairing of vessels. The graph has two sets of scales on the "y" axis. One scale relates to the Channel Width Ratio (in red) and the other to the probabilities of collision and grounding (in black).

3.8 Importing and Exporting information

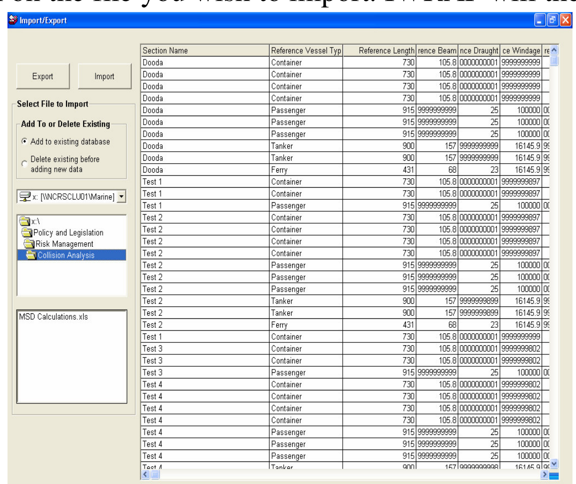
IWRAP has the capability to import details of previous studies and export results and information in the data base. This allows the analyst to revisit a previous assessment or to compile smaller studies into one larger report. The current version of IWRAP requires Excel to be installed on the same computer in order for this function to work.

Exporting Information

To export information, open the Import/Export window, and click on the Export button. Excel will open, data will be copied to the spreadsheet, and you will be asked to save the spreadsheet.

Importing Information

To import a file, click on the Import button. This opens a frame where you then have to choose between “Add to existing database” or “Delete existing before adding new”. After you make your choice, a directory box and file list box will open for you to tell IWRAP where the stored file is located. Double click on the file you wish to import. IWRAP will then open the Excel file and transfer data into the database and close this window when completed.



3.9 Creating Reports

IWRAP produces three reports in HTML format.

A Summary report that lists all of the vessel pairings by waterway section.

A Detailed report that displays all of the information for each scenario.

An Under Keel Clearance report that identifies all occasions where under keel clearance was a problem.

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