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Overview of the SOLAS probabilistic damage stability regulations

GHS is able to perform the calculations required by resolution MSC.216(82) which adopted the regulations on subdivision and damage stability as contained in SOLAS chapter II-1. These regulations are based on the probabilistic concept, using the probability of survival after collision as a measure of ships' safety in a damaged condition.

To perform probabilistic damage calculations with GHS, the Advanced Features (AF) module is required. Use the Modules Wizard to determine if your license includes the use of this module. Simply enter the command, "RUN MODULES.WIZ" or run MODULES from the drop-down menu, Wizard\All. After the wizard is run, a window will appear containing a list of initials for GHS Optional Modules with Yes or No indicating whether each module is included in the license. If AF is not listed as present, then you need to contact Creative Systems to determine availability and costs.

Two commands in the GHS command dictionary, DAMSTAB and DIVISION, with the proper parameters, are used to perform the probabilistic damage calculations. It is recommended that the DAMSTAB2 wizard be used as it simplifies the input of parameters for probabilistic damage stability calculations. Some requirements that apply to passenger vessels (wind heel, passenger moments, etc.) are not implemented in the GHS program, so those calculations must be performed using the wizard. This booklet will only cover performing probabilistic damage calculations using the wizard.

Excerpt from ANNEX 22 of RESOLUTION MSC.281(85) Explanatory Notes to the SOLAS Chapter II-1 Subdivision and Damage Stability Regulations (Not a direct quote)

The harmonized SOLAS regulations on subdivision and damage stability, as contained in SOLAS chapter II-1, are based on a probabilistic concept which uses the probability of survival after collision as a measure of ships safety in a damaged condition. This probability is referred to as the "attained subdivision index *A*" in the regulations.

The probability that a ship will remain afloat without sinking or capsizing as a result of an arbitrary collision in a given longitudinal position can be broken down to:

- The probability that the longitudinal centre of damage occurs in just the region of the ship under consideration;
- The probability that this damage has a longitudinal extent that only includes spaces between the transverse watertight bulkheads found in this region;
- The probability that the damage has a vertical extent that will flood only the spaces below a given horizontal boundary, such as a watertight deck;
- The probability that the damage has a transverse penetration not greater than the distance to a given longitudinal boundary; and
- The probability that the watertight integrity and the stability throughout the flooding sequence is sufficient to avoid capsizing or sinking.

The first three of these factors are solely dependent on the watertight arrangement of the ship, while the last two depend on the ship's shape. The last factor also depends on the actual loading condition. By grouping these probabilities, calculations of the probability of survival, or attained index *A*, have been formulated to include the following probabilities:

- The probability of flooding each single compartment and each possible group of two or more adjacent compartments; and
- The probability that the stability after flooding a compartment or a group of two or more adjacent compartments will be sufficient to prevent capsizing or dangerous heeling due to loss of stability or to heeling moments in intermediate or final stages of flooding.

This concept allows a rule requirement to be applied by requiring a minimum value of *A* for a particular ship. This minimum value is referred to as the "required subdivision index *R"* in the present regulations and can be made dependent on ship size, number of passengers or other factors legislators might consider important.

Evidence of compliance with the rules then simply becomes: $A \geq R$

It is the responsibility of the GHS user to know and understand the regulations concerning probabilistic damage stability before using the probabilistic damage ability of GHS and the DAMSTAB2 wizard.

Before using the Wizard

Before using the wizard, the vessel's geometry file should be reviewed to be sure it is suitable for probabilistic damage calculations. All internal volume should be modeled as a compartment, or in GHS lingo, as tank class parts. A geometry file intended for intact or deterministic damage stability analysis may not be suitable for a damage stability analysis.

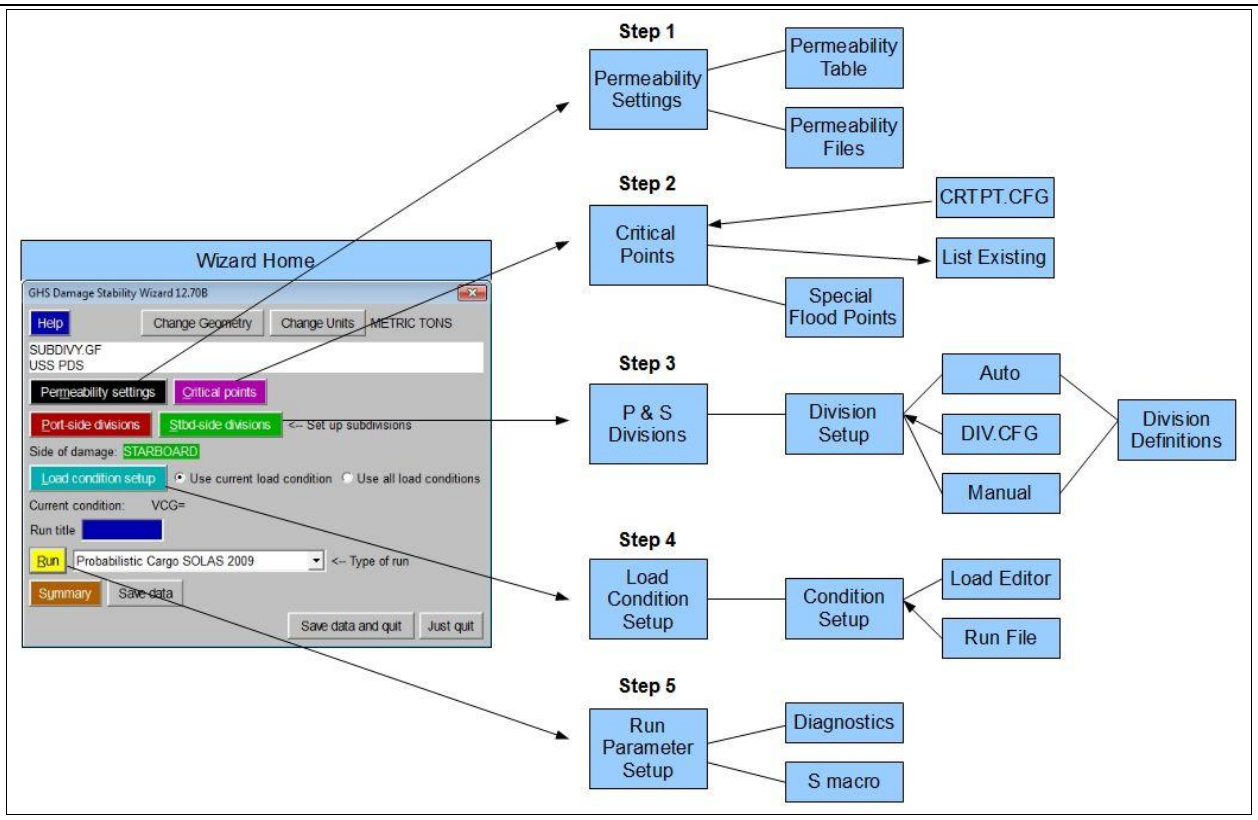
The specific gravity of the water should also be set in the geometry file as the wizard doesn't provide the option to change the specific gravity of the environment. (The specific gravity of the environment is stored in the saved condition files, so simply changing the SG in the GF file will not be sufficient to change an existing set of wizard files.)

In addition to the GF file verification, some basic information should be collected prior to entering the wizard. At a minimum, vessels load drafts, critical points, tanks subject to crossflooding or progressive flooding should be determined.

It is strongly suggested that a new folder be created for each probabilistic evaluation of a ship. The wizard creates numerous files. These are for storing the division definitions, load conditions, parameters for the selected regulation, report files, summary files, notes and trace files. For this tutorial, create a folder in a location and with a name of your choosing. Copy the geometry file into this folder. It is helpful to have a shortcut for GHS in this folder too.

Overview of the DAMSTAB2 Wizard

The procedure for completing a first run through the Damstab2 wizard consists of six main steps. The diagram below illustrates the main options for each step.



The wizard provides two convenient methods to specify the permeability for tanks according to Regulation 7-3 Permeability. The user can choose between entering the permeability of each group of compartments into a wizard template or read in a run file containing GHS permeability commands.

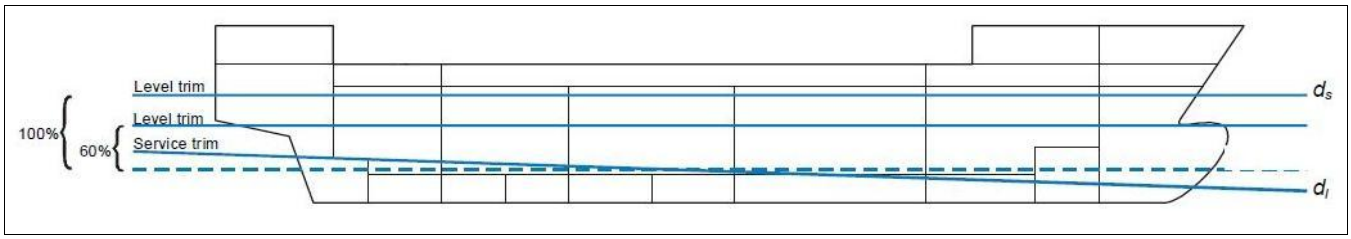
The downflooding and weathertight points are required to evaluate the probabilistic regulations. Like permeability, the critical point input can be given directly or through a run file containing GHS commands. There are some special features such as progressive flooding if a tight point is immersed as equilibrium that are only available if the critical points are entered into the wizard interface.

If progressive flooding to tanks or compartments outside the division is to be considered, the affected tanks can be specified for each division.

The geometry of the watertight subdivision will have some influence on the Attained Index, *A*. The wizard can automatically define the divisions or groups of compartments. These divisions can also be set by the user. Doing so will likely change the computed Attained Index. It is up to the user to understand the regulations when specifying the divisions.

The location of longitudinal bulkheads forming wing tanks and horizontal bulkheads (decks) will also effect the computed results. When wing tanks are fitted, the probability factor for damage is reduced taking into account that inboard tanks will be flooded only a small percentage of the time. Likewise, for spaces between decks. The locations of the longitudinal and horizontal subdivisions are measured from the side shell and baseline respectively.

The regulations require at least three load conditions be investigated. The results of these three conditions are combined in a weighted formula based on the expected time in service at each load condition. The 3 minimum drafts to be considered are the light load (d_l), the subdivision draft (d_s) and a partial load draft (d_p). The partial load draft is defined as the light load draft plus 60% of the difference between the light load and subdivision drafts. The service trim is used at the light load draft, while level trim is used with subdivision and partial load drafts.

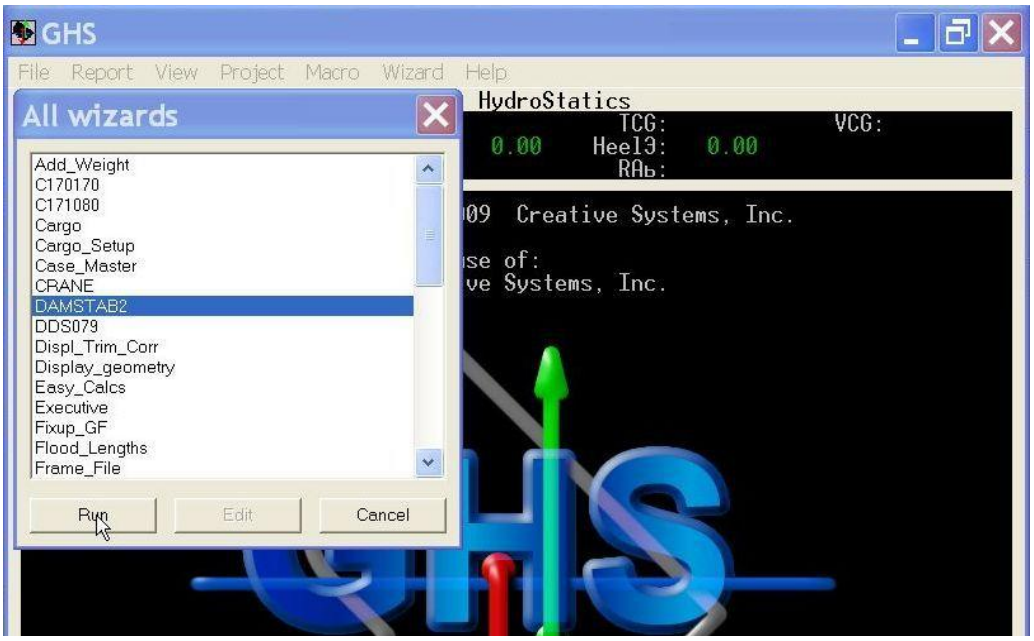


These conditions can be specified for either the loaded condition or the light ship by entering a weight and center or a draft and trim. In both cases, the wizard permits the evaluation of load cases with tank loads even though the SOLAS regulations seem to be intended for generalized rather than specific load conditions. Any tank loads can be defined using either Load Editor or a run file containing LOAD and ADD commands.

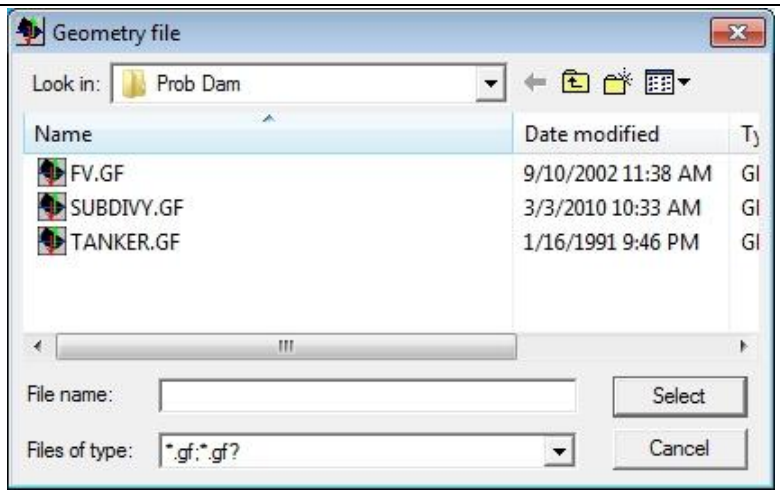
Again, it is the responsibility of the user to understand the regulations when selecting the locations of divisions, wings and decks.

Getting started

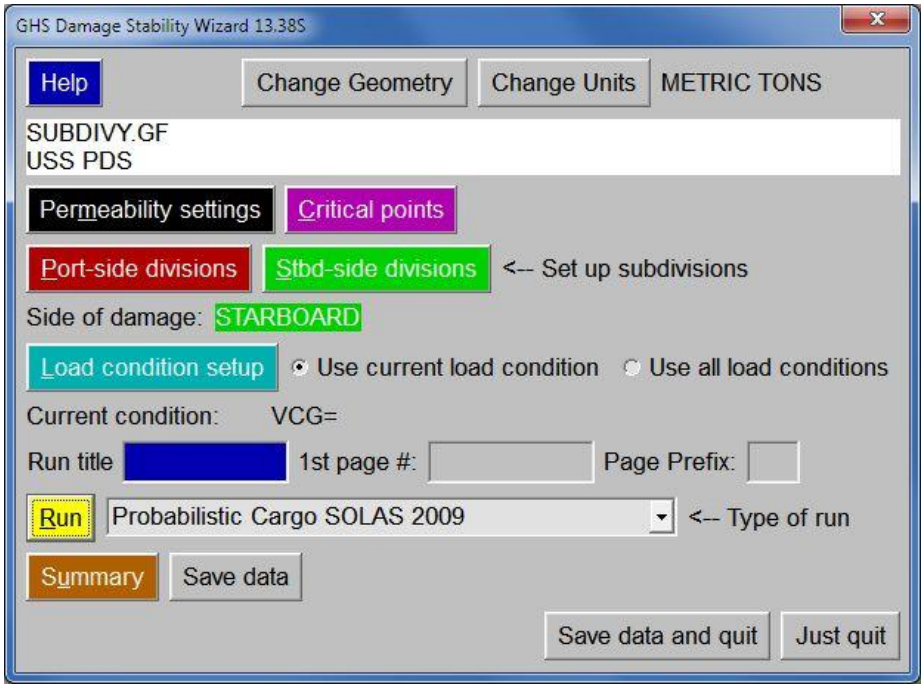
To access the wizard, use the pull down menu at the top of the GHS window. Click Wizard, then the sub menu All…, select DAMSTAB2 and click RUN. The DAMSTAB2 wizard also appears in the Conditions … sub menu.



If no geometry file was in memory and if file DAMSTAB2.SAV doesn't exist, the following dialog box will appear. If the file DAMSTAB2.SAV exists, the front dialog box will open with the parameters from that file already loaded. If a geometry file was already loaded, the wizard will open ready to use that geometry file. For the exercise below, select SUBDIVY.GF.



The main menu window will appear. The “Help” button will open a window with an overview of the Probabilistic Damage Stability wizard.

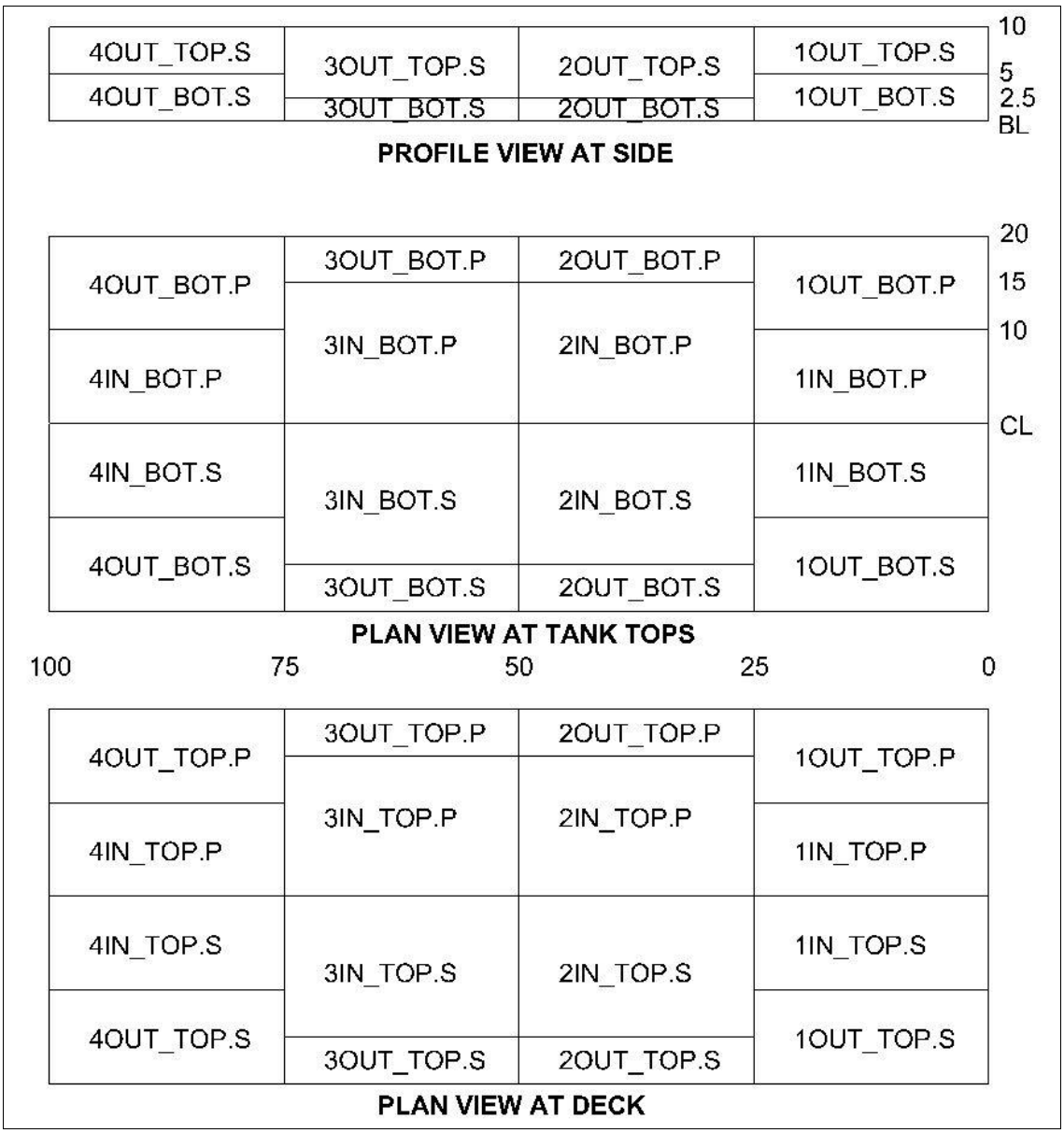


The geometry file and units can be changed with the corresponding buttons. Many of the buttons have hot keys, which are indicated by the underlined letter in their labels. The “Permeability settings” and “Critical points” buttons allow you to edit the values in the wizard model. Regulation 7-3, Permeability, specifies permeabilities for cargo compartments at ds, dp, and dl. The wizard provides a table format to set the required values without having to make changes to the geometry file or have multiple files. Special critical points can be added when said points are connected to or protected by a tank or compartment. Critical points which are defined in the geometry file or a CRTPT.CFG file can not be assigned to specific tanks or given special effects.

Your first run with the Damstab2 wizard

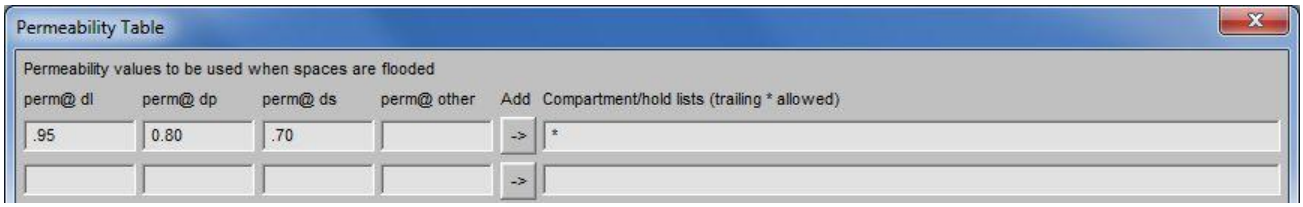
In this exercise, we will step through the minimum inputs needed to complete a probabilistic damage stability run for the light ship load condition. In later exercises, we will learn how to set up additional load conditions and then explore the various optional parameters needed when the vessel characteristics warrant a more complete analysis.

For this simple demonstration, the simple rectangular barge with 32 total tanks as shown will be used. It is in the SUBDIVY.GF geometry file.



The first run will be for the light ship condition. The vessel has the following properties: Light ship weight = 8200 tonnes at a draft of 2.0 m, LCG = 50 m, VCG = 6.0 m. The Subdivision Loadline draft is required. We will use 8.5 meters.

Click the Permeability settings button to bring up a window to select if you wish to use your own file or the table provided by the wizard. If you choose to use your file, instructions are given as to what file names to use and what parameters to include.



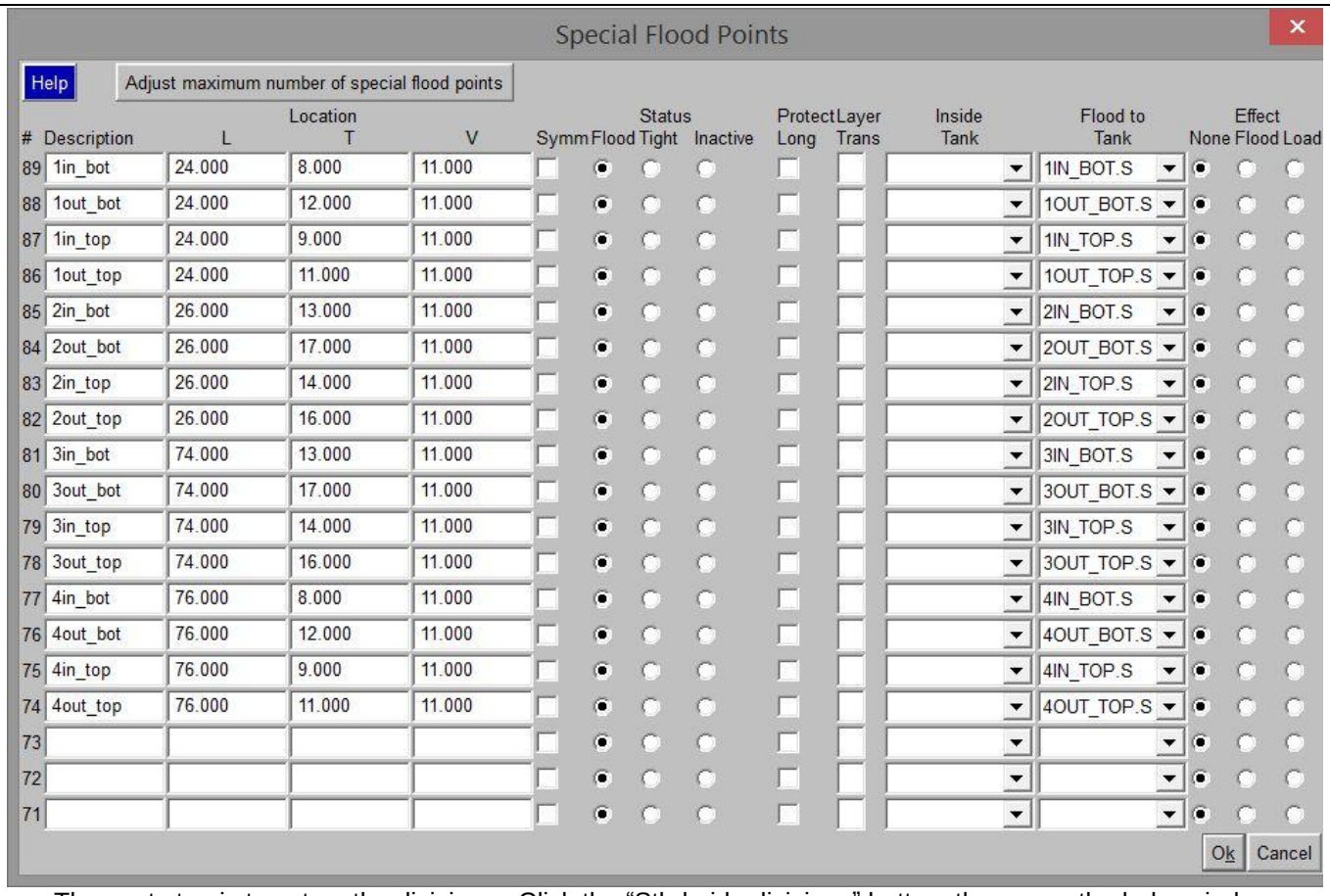
For liquid cargo compartments, the permeabilities at the respective load conditions are 0.95 at dl, 0.80 at dp and 0.70 at ds. The “perm@other” column corresponds to the “other” label in the load condition setup dialog. For this analysis, we can set them easily in the table using a single asterisk since all the tanks in this model are for liquid cargo. The table should look like the figure above. Be sure the “Use table” button is selected when you are finished entering the permeabilities.

Critical points can be assigned in the geometry file, in a CRTPT.CFG file or by using the Special Flood Points table. If the critical points are defined within the geometry file or in the CRTPT.CFG file, they may have any or all of the attributes available in GHS. By using the Special Flood Points table above, additional properties are available. Note the critical point numbers in the table start at 89 and decrease. This is so any existing critical points will not be overwritten. If there is no description given, any data on that line is ignored. The columns labeled Symm, Flood, Tight and Inactive (Noflood) set parameters recognized by GHS. Similarly, the “Flood to Tank” column sets the /TANK:*tankname* parameter. The “Inside Tank” dropdown box sets the /Inside: *tankname* parameter which allows a critical point to be considered protected due to its location inside another tank until the protecting tank is damaged.

Many of the columns display tool tips if the mouse hovers over the input field, for example:

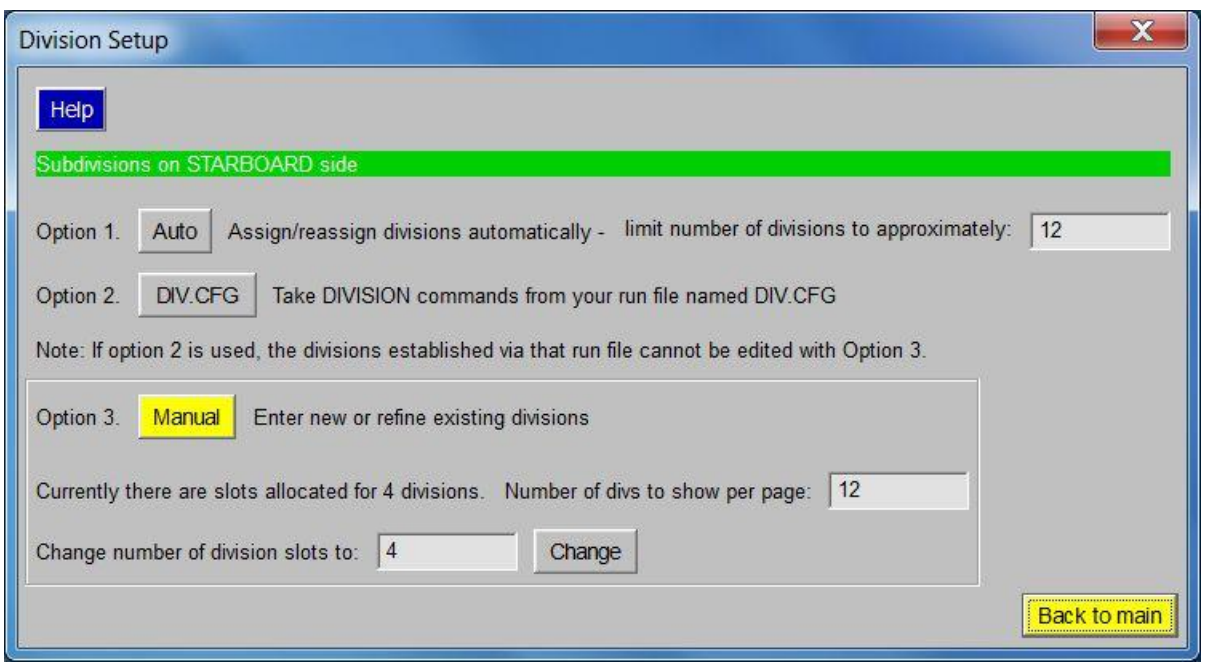
Protect Long - Ignore point if outside damaged division range
Layer Trans - Ignore point if penetration inboard layer (B) is less than this (0-3)
Inside Tank - name of tank/compartment which protects this flooding point
Effect, None - no change to tanktype (standard)
Flood - change flood to tank to type fld if tight point and immersed at equilibrium
Load - similar to Flood but capture flooding water as intact

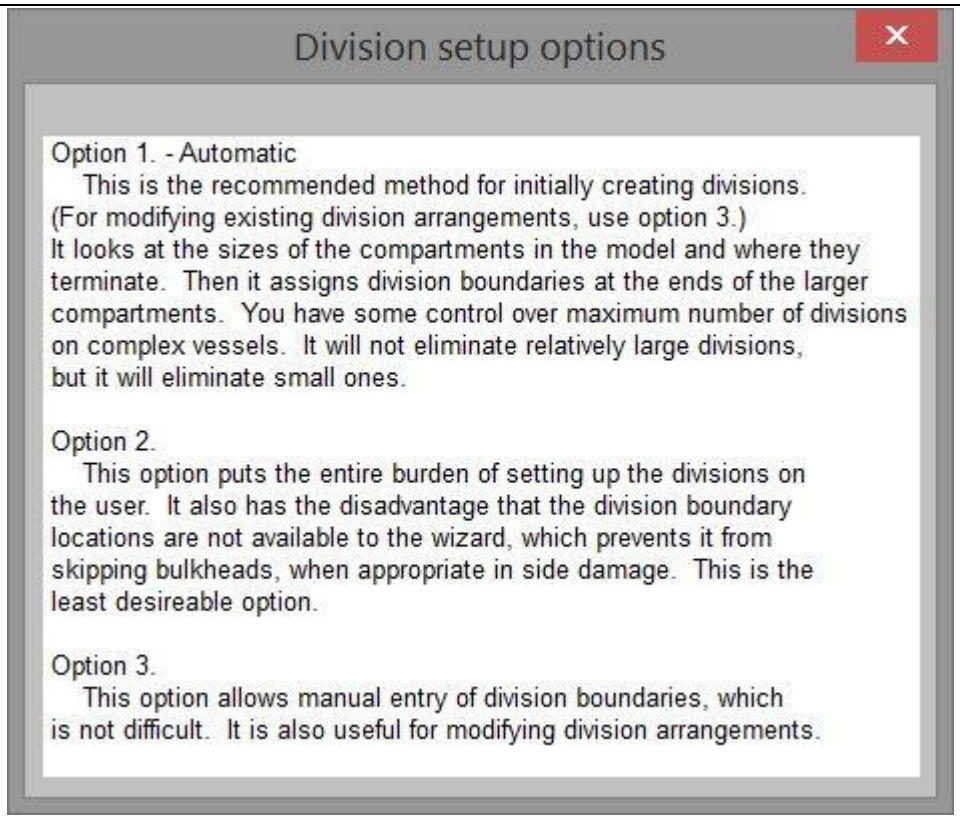
The options Protect Long, and Layer Trans are not meant to be used for typical downflooding points, rather they provide a method to model a pipe or a valve that could cause flooding of a space if it was damaged and immersed.



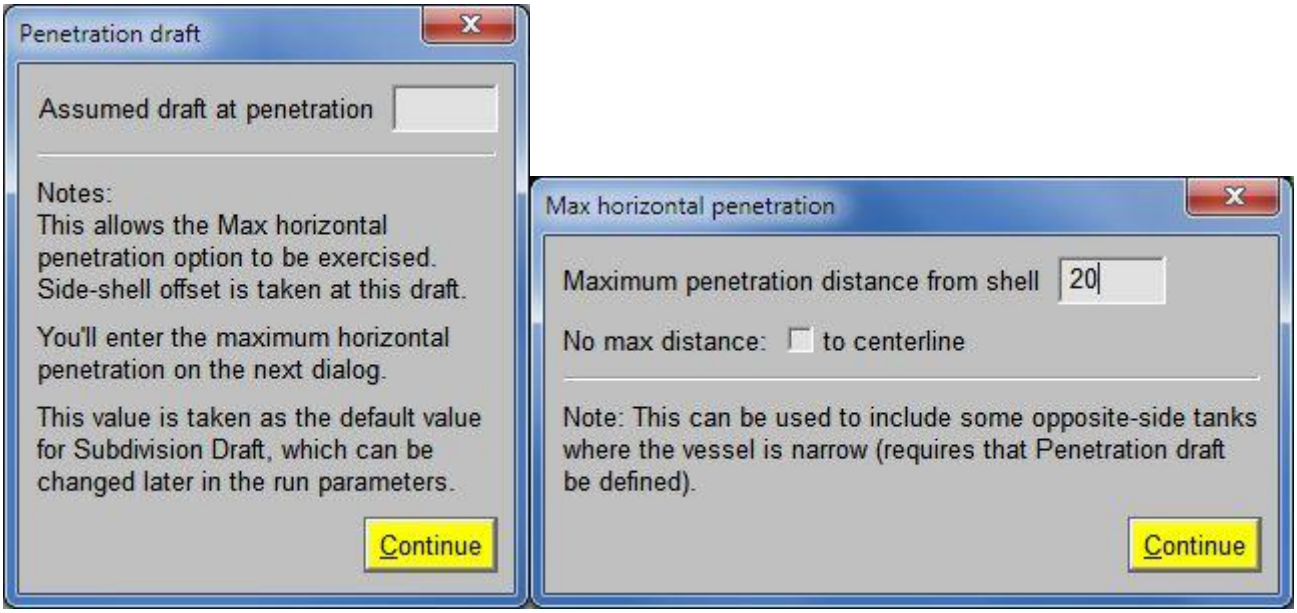
#	Description	Location L	Location T	Location V	Symm	Flood	Status Tight	Status Inactive	Protect Long	Layer Trans	Inside Tank	Flood to Tank	Effect None	Effect Flood	Effect Load
89	1in_bot	24.000	8.000	11.000		●						1IN_BOT.S	●		
88	1out_bot	24.000	12.000	11.000		●						1OUT_BOT.S	●		
87	1in_top	24.000	9.000	11.000		●						1IN_TOP.S	●		
86	1out_top	24.000	11.000	11.000		●						1OUT_TOP.S	●		
85	2in_bot	26.000	13.000	11.000		●						2IN_BOT.S	●		
84	2out_bot	26.000	17.000	11.000		●						2OUT_BOT.S	●		
83	2in_top	26.000	14.000	11.000		●						2IN_TOP.S	●		
82	2out_top	26.000	16.000	11.000		●						2OUT_TOP.S	●		
81	3in_bot	74.000	13.000	11.000		●						3IN_BOT.S	●		
80	3out_bot	74.000	17.000	11.000		●						3OUT_BOT.S	●		
79	3in_top	74.000	14.000	11.000		●						3IN_TOP.S	●		
78	3out_top	74.000	16.000	11.000		●						3OUT_TOP.S	●		
77	4in_bot	76.000	8.000	11.000		●						4IN_BOT.S	●		
76	4out_bot	76.000	12.000	11.000		●						4OUT_BOT.S	●		
75	4in_top	76.000	9.000	11.000		●						4IN_TOP.S	●		
74	4out_top	76.000	11.000	11.000		●						4OUT_TOP.S	●		
73						●							●		
72						●							●		
71						●							●		

The next step is to set up the divisions. Click the “Stbd-side divisions” button, then open the help window. Time should be taken to read and digest this information. If a message appears stating that the number of division slots can't be zero, enter 1 temporarily and click “Help” again.

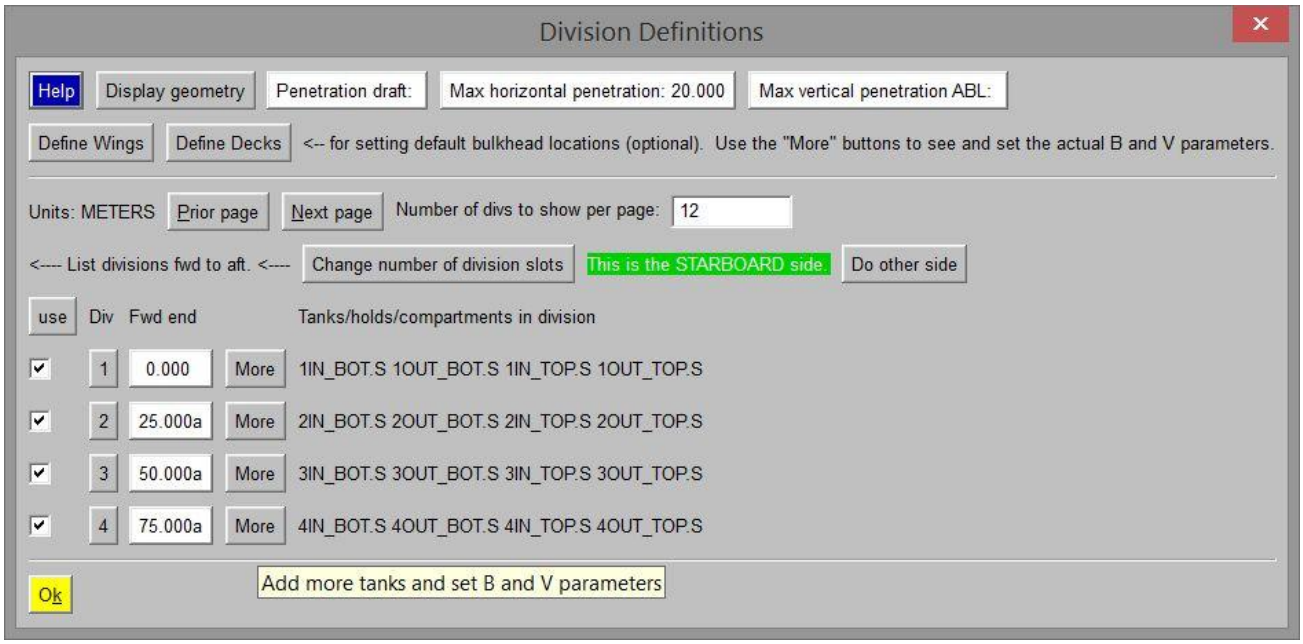




After reading about the three methods for defining divisions, close the help window and click “Auto”. The Penetration draft window will appear, followed by the Max horizontal penetration window. These two windows collect input that GHS uses to determine which tanks belong in a particular division. Clicking Continue starts a new instance of GHS, which will calculate divisions based on the geometry. That session will close, the Division Definition box will then appear, and the generated divisions will be shown.

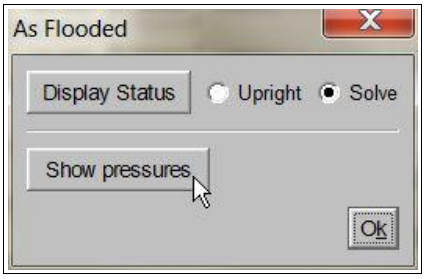


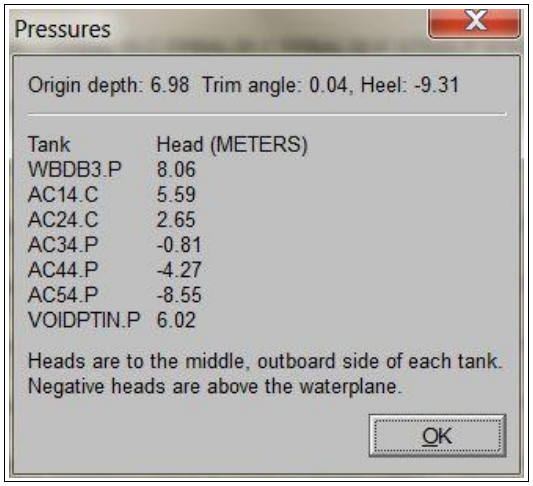
The divisions are at the obvious locations for this vessel. Since there are only 4 divisions, the “Prior page” and “Next page” button have no effect. If you change the “Number of divs to show per page”, use the “Prior page” and “Next page” buttons to update the window rather than clicking “OK”. The “Change number of division slots” button returns to the previous window to allow the user to change the number of divisions. “Do other side” has the same effect as pressing the “Port-side Divisions” button in the previous window and is used when the arrangements are asymmetrical or port heel is expected. The “use” button give options to check a single division or to check all. The check boxes provide a way to speed up the analysis by only considering checked divisions. The tanks in each division are listed to the right of the “More” button which will be discussed later, (Pg 20).



Note that in many cases, hovering the mouse cursor over a button or field will produce a pop up tip similar to the one shown for the bottom “More” button above.

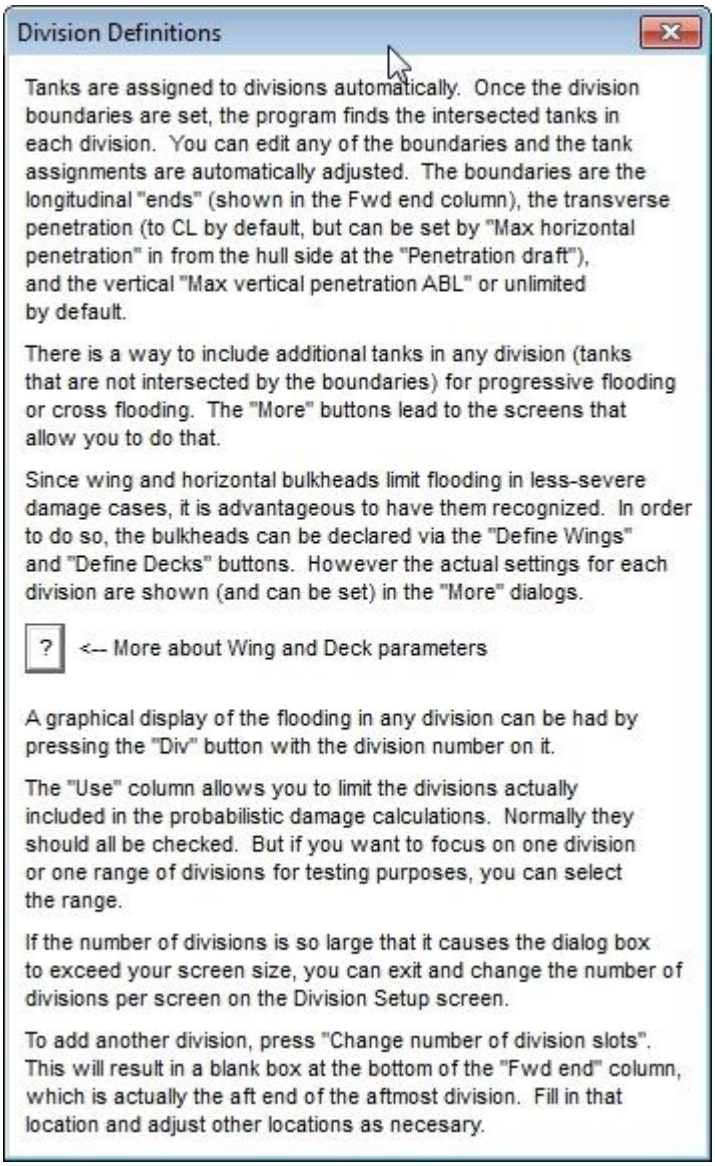
Clicking any of the numbered buttons for the first time will bring up the Load Condition menu to be discussed next. Once a loading is defined, these buttons display the dialog box shown below on the left. “Display Status” opens a Condition Graphic window illustrating the division. “Show pressures” brings up the window shown below on the right indicating the amount of head for each tank in the division. These figures are used in the calculations required to evaluate crossflooding arrangements.





Clicking the yellow “OK” button at the bottom left of the “Division Definitions” window returns to the main menu. From the main menu, click “Load condition setup” to enter the data for one of the load conditions. If one of the “Div” buttons was clicked in the previous window, this window will appear directly.

Additional information about the functions available in the Division Definitions window is available from within the wizard by clicking the blue Help button at the top left of the dialog. The template which appears is shown below.


Division Definitions

Tanks are assigned to divisions automatically. Once the division boundaries are set, the program finds the intersected tanks in each division. You can edit any of the boundaries and the tank assignments are automatically adjusted. The boundaries are the longitudinal "ends" (shown in the Fwd end column), the transverse penetration (to CL by default, but can be set by "Max horizontal penetration" in from the hull side at the "Penetration draft"), and the vertical "Max vertical penetration ABL" or unlimited by default.

There is a way to include additional tanks in any division (tanks that are not intersected by the boundaries) for progressive flooding or cross flooding. The "More" buttons lead to the screens that allow you to do that.

Since wing and horizontal bulkheads limit flooding in less-severe damage cases, it is advantageous to have them recognized. In order to do so, the bulkheads can be declared via the "Define Wings" and "Define Decks" buttons. However the actual settings for each division are shown (and can be set) in the "More" dialogs.

? <-- More about Wing and Deck parameters

A graphical display of the flooding in any division can be had by pressing the "Div" button with the division number on it.

The "Use" column allows you to limit the divisions actually included in the probabilistic damage calculations. Normally they should all be checked. But if you want to focus on one division or one range of divisions for testing purposes, you can select the range.

If the number of divisions is so large that it causes the dialog box to exceed your screen size, you can exit and change the number of divisions per screen on the Division Setup screen.

To add another division, press "Change number of division slots". This will result in a blank box at the bottom of the "Fwd end" column, which is actually the aft end of the aftmost division. Fill in that location and adjust other locations as necesary.

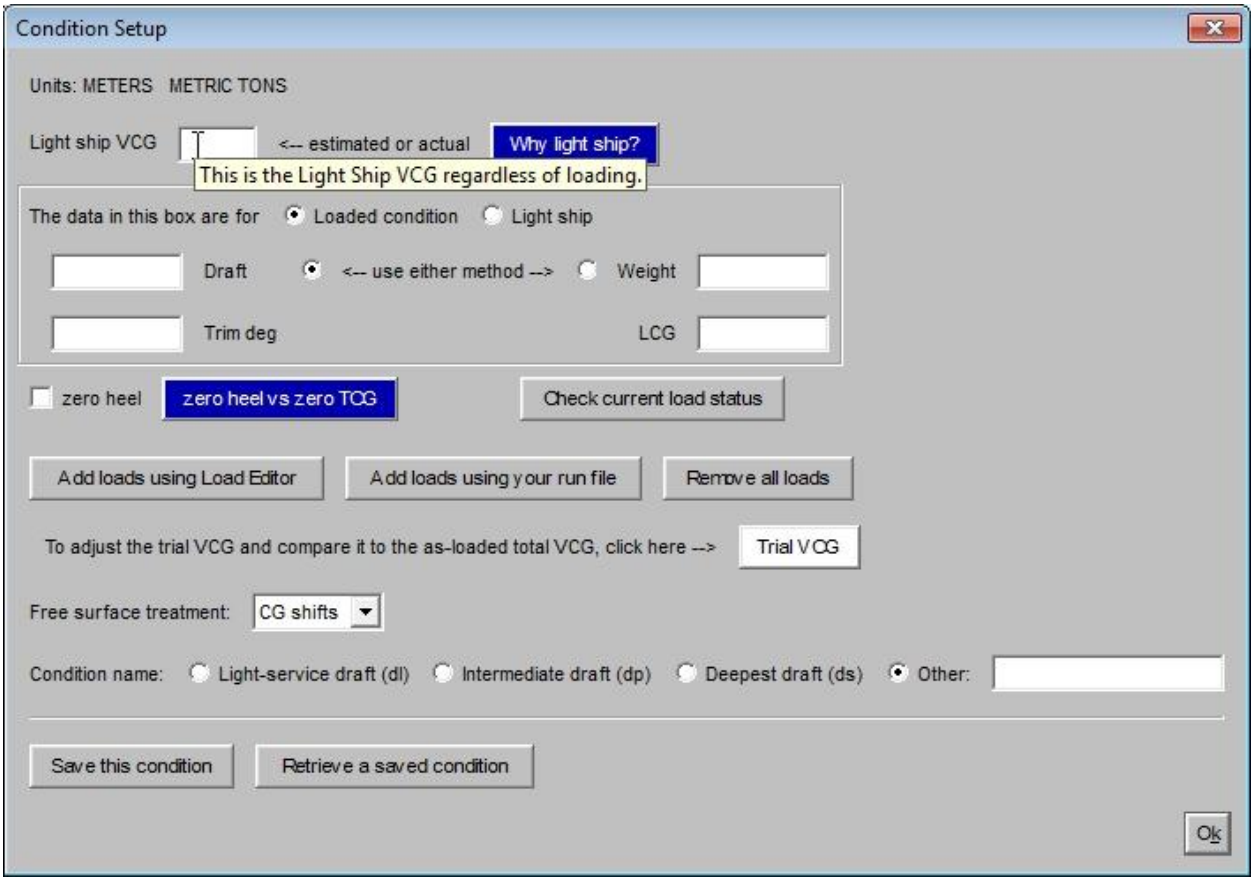
The wizard will locate the divisions based on the ends of the larger tanks. These locations can be edited.

Vertical and horizontal penetration distances can be assigned.

Tanks can be added for progressive or cross flooding.

Wing and horizontal bulkheads can be set. We will ignore them for now.

Once the divisions are defined, the next step is to establish the load condition to be evaluated. Do do that, click on the “Load condition setup” button in the main wizard dialog.

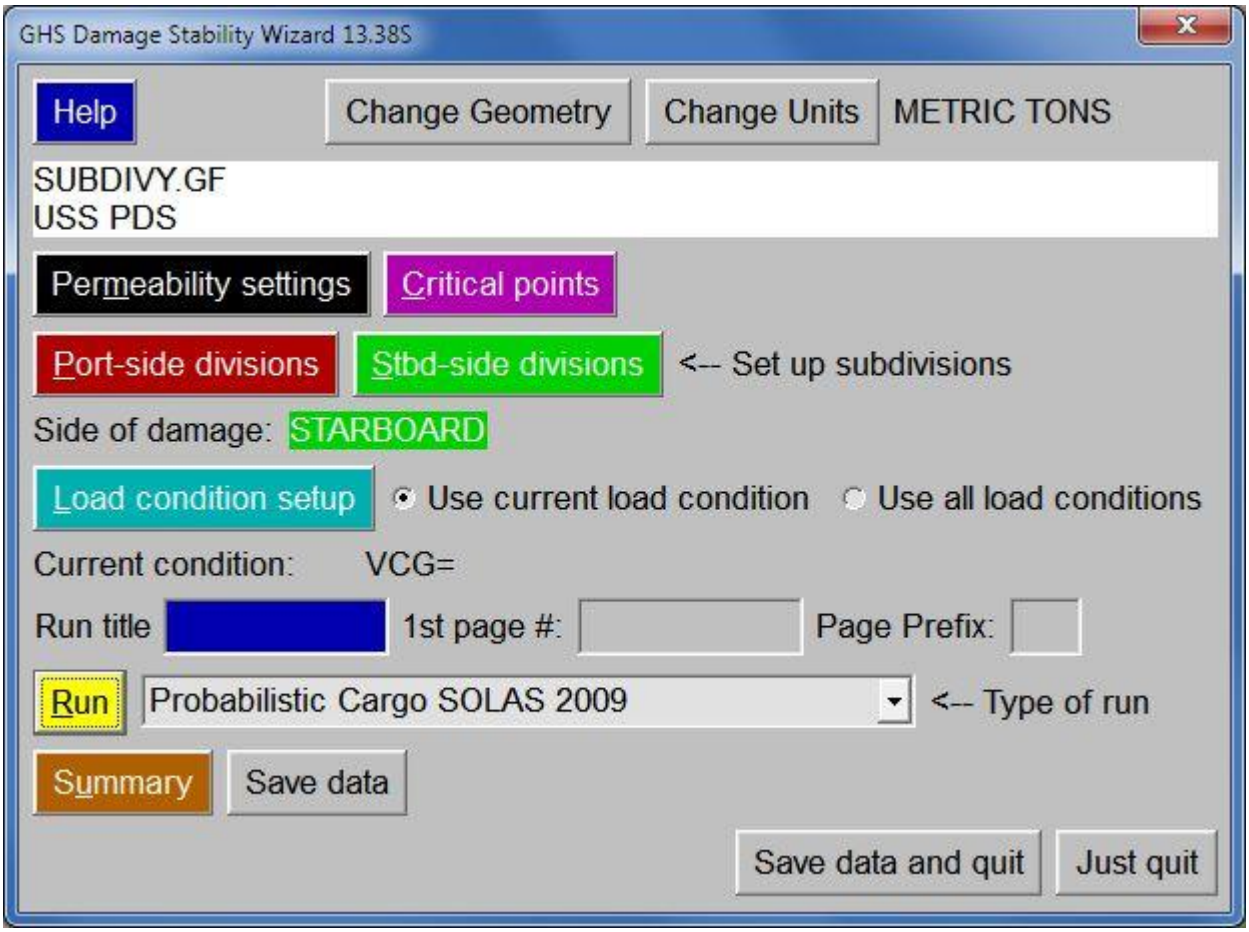


The light ship VCG is required. In fact, none of the other buttons work until a value is entered. Enter 6.0 as a VCG. The information in the box is to establish the water plane. When the draft and trim is known, enter those values in the boxes on the left. If the weight and LCG is known, enter that in the boxes on the right and select the radio button on the right also. Since this the empty load of a barge, we will consider this condition the Light ship condition. Click the radio button for Light ship and enter 2.0 for the draft and 0 degrees for the trim.

If in subsequent runs the loading produces a non-zero total TCG, the intact heel will not be zero. If zero heel is desired, check the zero heel box to adjust the TCG. The “Check current load status” button displays a summary of weight, centers, trim and heel. We will discuss the next three buttons in the next run when we start adding loads.

The Trial VCG is for setting an assumed VCG higher than the load case VCG. This allows the user to find a maximum VCG that still satisfies the regulations. Note that the Trial VCG should be equal to or higher than the Light ship VCG. For this exercise, use the same VCG of 6 m as there are no loads in this condition. We will see how to adjust the Trial VCG in the next run.

Be sure to set the condition name to Light-service draft (dl). Use the “Save this condition” button before continuing. Clicking OK will return to the main menu.



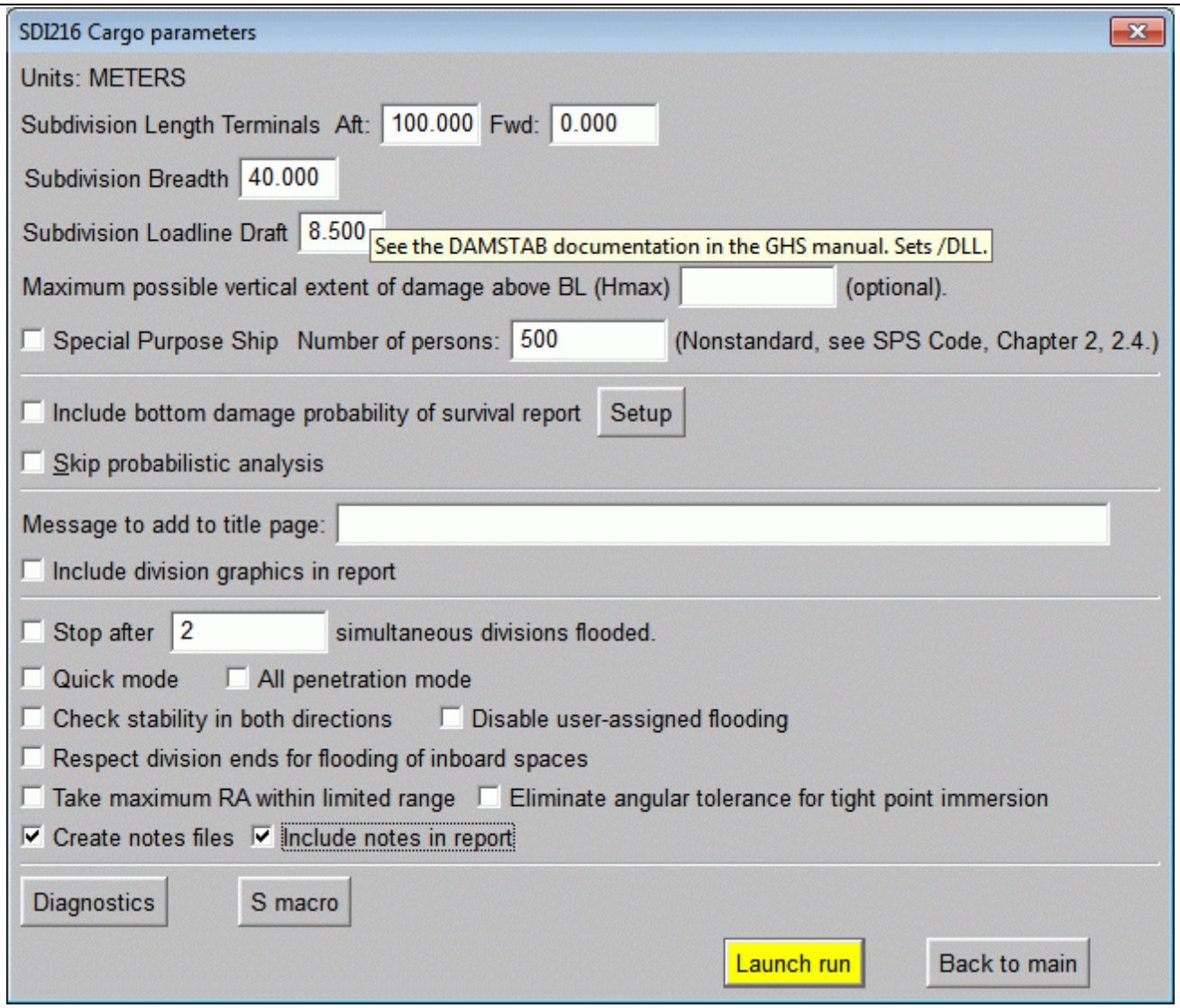
Select the option to Use the current condition. The trim and VCG of the current condition are shown. Enter a run title if desired. The title will appear in the report and the first three letters are used in the report file name. The fields for the starting page number and the page prefix trigger the Page [number] /Prefix: [code] and are also optional (see Help Page for more information).

For this exercise, select the cargo vessel regulations from the Type of run drop-down box. Clicking Run brings up the dialog box on the next page which is used to enter run parameters and select additional options. The dialog changes depending on which regulation is selected.

The Subdivision length is indicated on the top line by showing the locations of the ends of the divisions in geometry file coordinates. If Ls does not equal the length indicated, change the values as needed. In this case, the ends of the barge defines Ls as 100 m. The Subdivision Breadth is taken as the overall breadth of the model as a default. A different value can be entered if the Subdivision Breadth of the vessel is different.

The Subdivision Loadline Draft is required. The pop up tip suggests the GHS manual for more information. We will use the summer load line draft of 8.5 m. A maximum vertical extend of damage can be specified, if omitted, Hmax will be computed according to the regulations. This is only applicable when using the earlier Regulation 25 rules.

A Special Purpose Ship is one that carries people that are part of the ship's crew or passengers. Research ships, cable laying ships and training vessels are examples. Such ships are considered passenger ships and the special personnel are treated as passengers.



Bottom damage probability of survival, required by Regulation 9, is available as an option during the initial runs for side damage and when testing certain cases. The probability of survival must not be less than 1.0 for bottom damage. The location and extents of damage are based on vessel dimensions and are the defaults. The run will terminate if the probability of survival falls below the minimum unless the user selects the option to find a lower VCG so the requirement is satisfied.

A message can be entered to be included on the title page in addition to the Run title entered in the main menu. The option to include division graphics will include a Condition Graphic plot of the flooded condition in addition to the default intact condition. The remaining options will be discussed later.

Click “Launch run” to start the calculations.

Discussion of Output

The wizard produces a report that is automatically displayed in the GHS preview window. This report is named DS2-*n*.pf where *n* is the number of the run. The title page includes the usual GHS header, the wizard version used to produce the report, a description of the regulation used, the load condition and a Condition Graphic image of the vessel. The particulars of each division listing the tanks in each division appear the following page(s). The flood point information is next, followed by the load condition, the permeability settings and the result summary. The results of the analysis should look like this.

Executing DAMSTAB /sdi216C /side:STARBOARD /L:0,100 /B:40 /DLL:8.5 /macro:PROBSURV

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 100.000 Terminals: 0.000 , 100.000a
Breadth: 40.000 Draft: 2.001
Subdivision load line draft: 8.500

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	2.002	0.00	0.00	50.19	10.623
1	0.21642	1.000*	0.216	0.216	3.353	1.08f	1.97s	21.51	9.092
2	0.18284	1.000*	0.183	0.399	2.552	0.27f	1.50s	40.70	10.540
3	0.18284	1.000*	0.183	0.582	2.074	0.27a	1.50s	41.08	10.540
4	0.21642	1.000*	0.216	0.799	1.468	1.08a	1.96s	22.05	9.116
		1-division damage:		**0.799**		**Probability of damage:**		**0.799**	
1+2	0.06707	0.999*	0.067	0.865	3.712	1.32f	2.79s	15.91	5.580
2+3	0.06698	1.000*	0.067	0.932	2.845	0.00	4.19s	35.65	8.910
3+4	0.06707	1.000*	0.067	1.000	1.146	2.44a	6.48s	36.20	4.701
		2-division damage:		**0.201**		**Probability of damage:**		**0.201**	
1+2+3	0.00018	0.965*	0.000	1.000	3.930	1.41f	3.60s	13.88	3.503
2+3+4	0.00018	0.970*	0.000	1.000	1.472	1.41a	3.60s	14.19	3.528
		3-division damage:		**0.000**		**Probability of damage:**		**0.000**	

Attained index in this condition: 1.000 **Total probability of damage: 1.000**
Required index: 0.492
Values marked with * computed by macro.

Distances in METERS. Angles in deg.

Under the header, the parameters used in the DAMSTAB command are given. The number of divisions damaged are shown in groups in the table. The first column “P”, is the probability of being damaged. The second column is labeled “Smin” indicating the probability of survival when damaged. The label “Smin” indicates that the search for the minimum S has been performed, otherwise the column would be labeled simply “S”. The “P*S*V” column is the product of P, S, and V. V is the factor for any horizontal bulkhead or deck which may be present. The “A” column reports the cumulative attained index which is a running summation of the P*S*V values with subtotals for each grouping.

On the right hand side are five columns showing the most important characteristics of each damage case. “Depth, Trim and Heel” (the latter two in degrees) represent the waterplane in the damaged equilibrium condition. “Range” is the range of stability beyond equilibrium. “MaxRA” is the greatest righting arm in this range.

The next page is the Summary Data page. Pertinent information is repeated from the title page. At the bottom is the attained index for this load condition and the minimum index needed for this condition. For cargo ships, the required index can be reduced by 50% for the individual load conditions.

```
====== Summary Data ======

Calculation method: SDI216C
Condition name: Light-service draft (dl) (code 0)
Damage side: Starboard

Displacement: 8203.1 METRIC TONS
Trim: -0.00 degrees
VCG: 6.000 METERS
Free surface moment: 0.0 METRIC TONS-METERS
Environment: 1.025


Attained index: 1.000
Minimim index needed for this draft: 0.246
Overall Required index: 0.492
```

The report ends with pages of notes.

```
====== Notes ======


Final flooding is with damaged compartments freely open to the sea
(lost buoyancy).

Max RA taken within full Range.
R1 is the non-dimensional range.  M1 is the non-dimensional maximum RA.
TRACE OFF

Div 1
1IN_BOT.S 1OUT_BOT.S 1IN_TOP.S 1OUT_TOP.S
Damaged between 0.00  and 25.00a
Final equilibrium heel: 1.97    K: 1.000
Min downflooding height is 7.509, point 84
STBD range: 21.51   R1: 1.000   max RA: 9.092   M1: 1.000
   heel at downflood: 23.48  critical pt 84
   S Final = 1.0000

Div 1
1IN_TOP.S 1OUT_TOP.S
Damaged between 0.00  and 25.00a
Final equilibrium heel: 0.00    K: 1.000
Min downflooding height is 8.999, point 82
STBD range: 40.36   R1: 1.000   max RA: 10.814   M1: 1.000
   heel at downflood: 40.36  critical pt 84
   S Final = 1.0000
```

The first section, provides comments and information pertaining to the run. After that, the intermediate results are presented, grouped by the damage cases. The tanks assumed flooded in each damage case are listed. Note that in the two cases for division 1 damage, the first group includes all the tanks and the second only includes two tanks.

The wizard checks for all possible combinations of damage in the division. Since damage to the upper tanks may be more critical due to the higher VCG, this case is included. Only the case giving the lowest attained index is included in the summary table. This feature can be turned off by checking the box for the Quick mode in the “parameters” window. Since the regulation calls for all damage combinations to be checked, this option includes a note on the title page of the report if turned on.

The final equilibrium angle is used to determine K which is in the formula to calculate S-final. The lowest flood point, which determines the range of stability, is given. The range and the maximum RA values are used to find the respective non-dimensional values which are then used to calculate S final.

Second Run – partial load condition

SOLAS probabilistic damage stability regulations don't address liquid loads in tanks, but the wizard goes beyond this particular regulation and permits them. It is the user's responsibility to know the particulars of the regulation to be evaluated and provide input and select options accordingly.

For demonstration purposes, we will add some loads to sink the vessel down to the partial load draft rather than simply specifying the draft and trim. According to Regulation 2 in MSC.216(82), the partial draft exceeds the light-service draft by 60%(d_s – d_l). For the light-service draft of 2.0 m and the subdivision draft of 8.5 m, the partial draft is 5.9 m. The trim is the same as the subdivision draft.

After exiting the preview window, you should be back at the main wizard window. This would be a good time to click the “Save data” button if you haven't already. To start another load case, click the “Load condition setup” button to get to the Condition Setup window. Save the light load condition using the “Save this condition button. This is not the same as the Save wizard data we just did. Now you are ready to start the next load case.

Click “Add loads using Load Editor” and load the inboard tanks, tops and bottoms, in divisions 1 and 4 to 95%. Then add a deck load of 6400 mt at 50 m aft, on CL and at 12 m high. Press “Solve” and the header information should look like this.

Notice the VCG as loaded is 7.141 m. Close Load Editor to return to GHS and the Condition Setup window in the DAMSTAB2 wizard. Enter this value for the Trial VCG. The loaded tanks now will produce free surface effects, which can be treated as a liquid CG shift, or as a free surface correction. The equilibrium waterplane will not be effected, but the range of stability and maximum righting arms will differ slightly. Which one you use is up to you or the classification society. The results below are from a run using the FSM option. Select the Intermediate draft button, save this condition and click “Ok”.

Click “Run”, check the values in the Cargo Parameters box and launch the run. The report preview will open with the changes for the new load condition. In the Status report, page 4, the light ship VCG is 5.999. This is simply a numerical difference, but it demonstrates that the Trial VCG was used as the total VCG and since the VCG of the loads are fixed, GHS adjusted the LIGHT SHIP VCG accordingly. If a higher Trial VCG was entered, then the LIGHT SHIP VCG would have been higher.

Note the permeability of 0.80 should be displayed for all tanks.

Executing DAMSTAB /sdi216C /side:STARBOARD /L:0,100 /B:40 /DLL:8.5 /macro:PROBSURV

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 100.000 Terminals: 0.000 , 100.000a
Breadth: 40.000 Draft: 5.900
Subdivision load line draft: 8.500

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	5.901	0.00	0.00	16.23	4.826
1	0.21642	0.931 *	0.202	0.202	6.079	0.15f	1.92s	12.03	3.531
2	0.18284	0.895 *	0.164	0.365	7.234	0.69f	4.14s	10.26	2.419
3	0.18284	0.897 *	0.164	0.529	6.037	0.69a	4.14s	10.36	2.431
4	0.21642	0.933 *	0.202	0.731	5.823	0.15a	1.92s	12.12	3.548
		1-division damage:		**0.731**		**Probability of damage:**		**0.799**	
1+2	0.06707	0.714 *	0.048	0.779	7.836	1.29f	6.40s	4.15	0.940
2+3	0.06698	0.000 *	0.000	0.779	8.742	0.00	18.83s	0.00	0.000
3+4	0.06707	0.720 *	0.048	0.827	5.584	1.29a	6.40s	4.30	0.968
		2-division damage:		**0.096**		**Probability of damage:**		**0.201**	
1+2+3	0.00018	0.000 *	0.000	0.827	3.011	2.24f	156.46s	0.00	
2+3+4	0.00018	0.000 *	0.000	0.827	-0.903	2.24a	156.46s	0.00	
		3-division damage:		**0.000**		**Probability of damage:**		**0.000**	

Attained index in this condition: 0.827 **Total probability of damage: 1.000**
Required index: 0.492
Values marked with * computed by macro.

Distances in METERS. Angles in deg.

Note: If permeability is left as the default value of 0.985, all the 2-division damage cases have an S value of 0.

The probability of damage is the same since the divisions are the same. The probability of survival has decreased. For the case with divisions 2 and 3 flooded, there is no range of stability due to the flood points, therefore the chance of survival is zero. When 3 divisions are flooded, the vessel capsizes.

```
====== Summary Data ======

Calculation method: SDI216C
Condition name: Intermediate draft (dp) (code 1)
Damage side: Starboard

Displacement: 24191.5 METRIC TONS
Trim: 0.00 degrees
VCG: 7.141 METERS
Free surface moment: 16827.1 METRIC TONS-METERS
Environment: 1.025


Attained index: 0.827
Minimim index needed for this draft: 0.246
Overall Required index: 0.492
```

The Summary Data above is similar to the first run. The free surface moment shown is the intact free surface moment with the intact permeabilities. When the flooded cases are analyzed, flooded tanks do not contribute to the free surface effect even if the tank was loaded before damage.

```
Div 1
1IN_BOT.S 1OUT_BOT.S 1IN_TOP.S 1OUT_TOP.S
Damaged between 0.00  and 25.00a
Final equilibrium heel: 1.92    K: 1.000
Min downflooding height is 4.408, point 84
STBD range: 12.03   R1: 0.752   max RA: 3.531   M1: 1.000
   heel at downflood: 13.95  critical pt 84
   S Final = 0.9312
```

Looking at the results from the flooded first division, we can verify results using GHS without the wizard. Be sure to save the condition and the data and exit the wizard. In GHS, change the permeability of the tanks in that division to 0.80. Then change their type to flooded using the Load Editor or at the command prompt. Once done, solve and view the status and righting arm using free surface moments. The results should look like this:

```
  Baseline draft: 6.082 @ Origin,  Trim: Fwd 0.15 deg.,  Heel: Stbd 1.92 deg.
Part                                Weight(MT)    LCG      TCG      VCG
LIGHT SHIP                           8,200.00  50.000a  0.000    6.000
DECK LOAD 1                          6,400.00  50.000a  0.000   12.000
  Total Fixed                       14,600.00  50.000a  0.000    8.630
                 Load      SpGr      Weight(MT)    LCG      TCG      VCG        FSM
1IN_BOT.P       0.950     1.025      1,198.93  12.472a  4.941p  2.376    2106.93
1IN_TOP.P       0.950     1.025      1,198.93  12.472a  4.941p  7.376    2106.93
4IN_BOT.S       0.950     1.025      1,198.93  87.472a  5.059s  2.376    2106.93
4IN_TOP.S       0.950     1.025      1,198.93  87.472a  5.059s  7.376    2106.93
4IN_BOT.P       0.950     1.025      1,198.93  87.472a  4.941p  2.376    2106.93
4IN_TOP.P       0.950     1.025      1,198.93  87.472a  4.941p  7.376    2106.93
  Total Tanks                        7,193.58  62.472a  1.608p  4.876   12641.56
  Total Weight                      21,793.58  54.117a  0.531p  7.391
                                     Displ(MT)    LCB      TCB      VCB       RefHt
HULL                     1.025      24,411.21  49.643a  0.749s  2.990      -6.078
1IN_BOT.S       Flooded  1.025      -1,025.00  12.500a  5.000s  2.500      -6.078
1OUT_BOT.S      Flooded  1.025      -1,025.00  12.500a 15.000s  2.500      -6.078
1IN_TOP.S       Flooded  1.025        -249.51  12.391a  5.229s  5.612      -6.078
1OUT_TOP.S      Flooded  1.025        -318.12  12.414a 15.180s  5.779      -6.078
  Total Displacement     1.025      21,793.58  54.106a  0.383p  2.965
                Righting Arms:                   0.001    0.000s

  RIGHTING ARMS vs HEEL  Total CG:  LCG = 54.118a  TCG = 0.550p  VCG =  7.971
      Depth    Trim°    Heel°    Displ(MT)      RAθ       RAø     FP Ht
      6.079   0.15f    1.92s    21,793.58     0.000     0.000    4.413(84)
      6.440   0.47f    6.92s    21,793.62     0.000     1.488    2.645(84)
      6.781   0.81f   11.92s    21,793.71     0.000     2.986    0.837(84)
      6.991   0.98f   14.04s    21,793.76     0.000     3.468    0.001(84)
      7.318   1.19f   16.92s    21,796.04     0.000     3.910   -1.200(84)
      7.989   1.62f   21.92s    21,793.57     0.000     4.217   -3.394(84)
      8.147   1.73f   23.07s    21,793.58     0.000     4.224   -3.904(84)
      8.641   2.08f   26.92s    21,789.75     0.000     4.139   -5.587(84)
      9.193   2.49f   31.92s    21,793.58     0.000     3.854   -7.714(84)
      9.665   2.88f   36.92s    21,793.77     0.000     3.446   -9.772(84)
     10.075   3.27f   41.92s    21,793.76     0.000     2.956  -11.759(84)
     10.417   3.64f   46.92s    21,793.76     0.000     2.410  -13.660(84)
     10.684   3.99f   51.92s    21,793.74     0.000     1.826  -15.457(84)
     10.873   4.31f   56.92s    21,793.72     0.000     1.214  -17.137(84)
     10.976   4.59f   61.92s    21,793.70     0.000     0.585  -18.684(84)
                                          True FSM artifice used.
```

The equilibrium heel angles are the same. Only the free surface effects from the loaded tanks are present. The free surface effects of the flooded tanks are not included. The lowest flood point is point #84 at 4.408 from the wizard, 4.413 from GHS. The range is from equilibrium to the point of down flooding, 12.13 from the wizard, 12.12 from GHS. The maximum righting arm is 3.470 from the wizard, 3.468 from GHS.

Third run – subdivision draft condition

Repeat the steps above to add a second fixed weight of 10660 mt at 50 m aft, on CL, and 14 m high. Be sure to reset the Trial VCG. After reviewing the report file, return to the main wizard program and click the "Summary" button. This produces a summary of all three runs.

Summary for SDI216C - Probabilistic Cargo SOLAS 2009 trim:0.00

Run 1-1 Light-service draft (dl)	Starboard	trim:	0.00	att index: 1.000
Run 2-1 Intermediate draft (dp)	Starboard	trim:	0.00	att index: 0.831
Run 3-1 Deepest draft (ds)	Starboard	trim:	0.00	att index: 0.000

Warning: This attained index is less than the minimum 0.5 x 0.492 = 0.246

Draft	@LCF	Attained	Factor	Weighted	VCG	FSM	VCG+
dl	2.00	1.000	0.2	0.200	6.000	0	6.000
dp	5.90	0.831	0.4	0.332	7.141	16827	7.837
ds	8.50	0.000	0.4	0.000	9.239	16827	9.722

Attained index:	0.5324
Required index:	0.4920

The individual attained indexes are present. Since the third one did not meet the requirement that it must be at least 50% of the required, a warning is given. The three attained indexes are then combined in a weighted summation to find the overall attained index. Since it is greater than the required index, no warning is given.

Add Wings and Bulkheads

To see if the wing and horizontal bulkheads offer any benefit, the location and distances must be entered. Return to the Division Definition Window. Opening the help button and clicking on the "?" will display some helpful information.

WING and Deck (HBHD) Parameters

The Wing parameter is the horizontal distance from the side shell to a wing bulkhead in a particular division. In other words, it is the damage penetration distance that would reach the bulkhead.

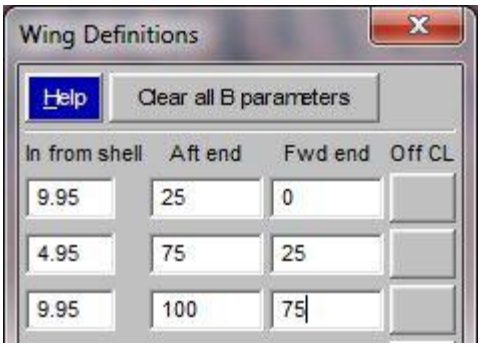
This serves two purposes: 1) The probability of damage outboard of the bulkhead is based on this distance; 2) The program uses this distance to determine whether to flood tanks.

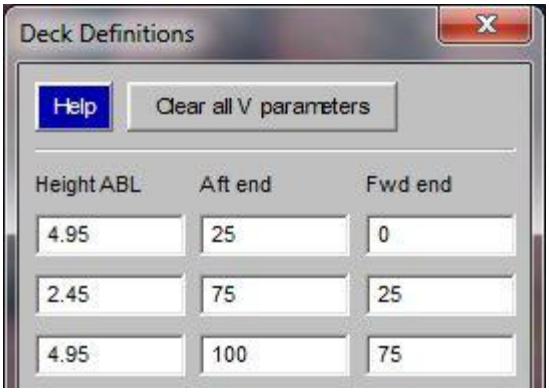
In practice you will want to make the WING parameter slightly less than the distance from shell to the bulkhead to make sure that it doesn't breach the bulkhead. If there is curvature of the side shell and/or sloping or stepped bulkheads, consult the regulations for the proper way to measure this distance. The program will, in most cases, make the correct decision about which tanks to flood. However if you find a case where it is flooding an inboard space when it should not be doing so, you can manually assign that space to a particular wing layer in the More/Division Details dialog.

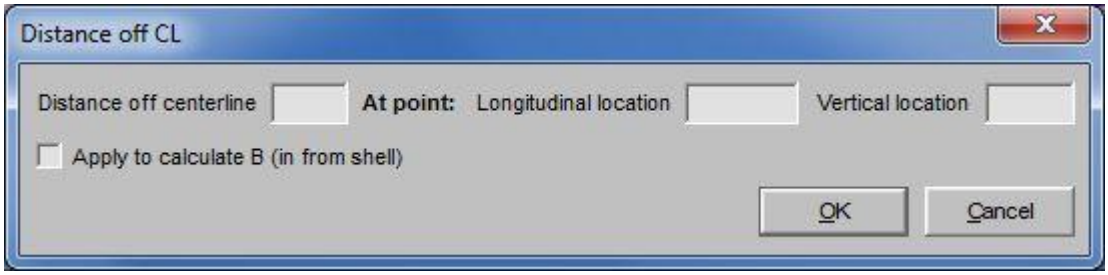
Similarly the Deck or HBHD parameter is the distance from baseline up to a horizontal bulkhead. Again, this number is used both to calculate probability of damage and to determine which tanks to flood. The More/Division Details dialog provides the means of overriding the automatic assignments of tanks to vertical layers as well.

The regulations need to be consulted for sloping and stepped bulkheads.

There are two ways to enter the locations of these bulkheads. Returning to the Port-side or Stbd-side Division windows and selecting option 3, Manual, the Define Wings and Define Decks buttons will display a table for the distances and locations. As recommended above, the distances are slightly less than the actual distances. For our vessel, the entries would be as follows.

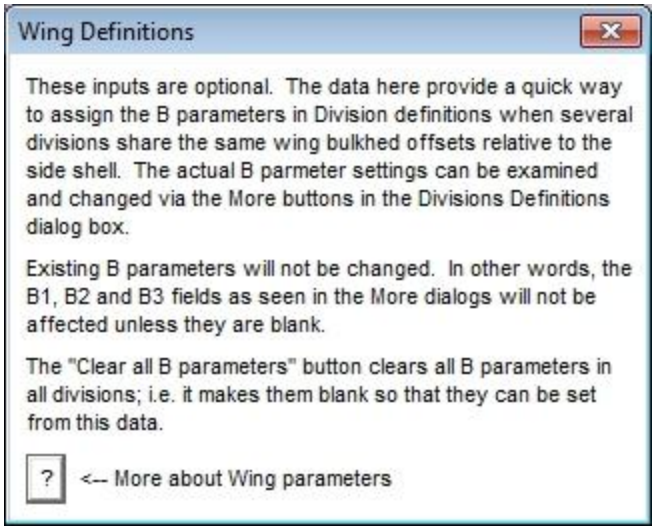




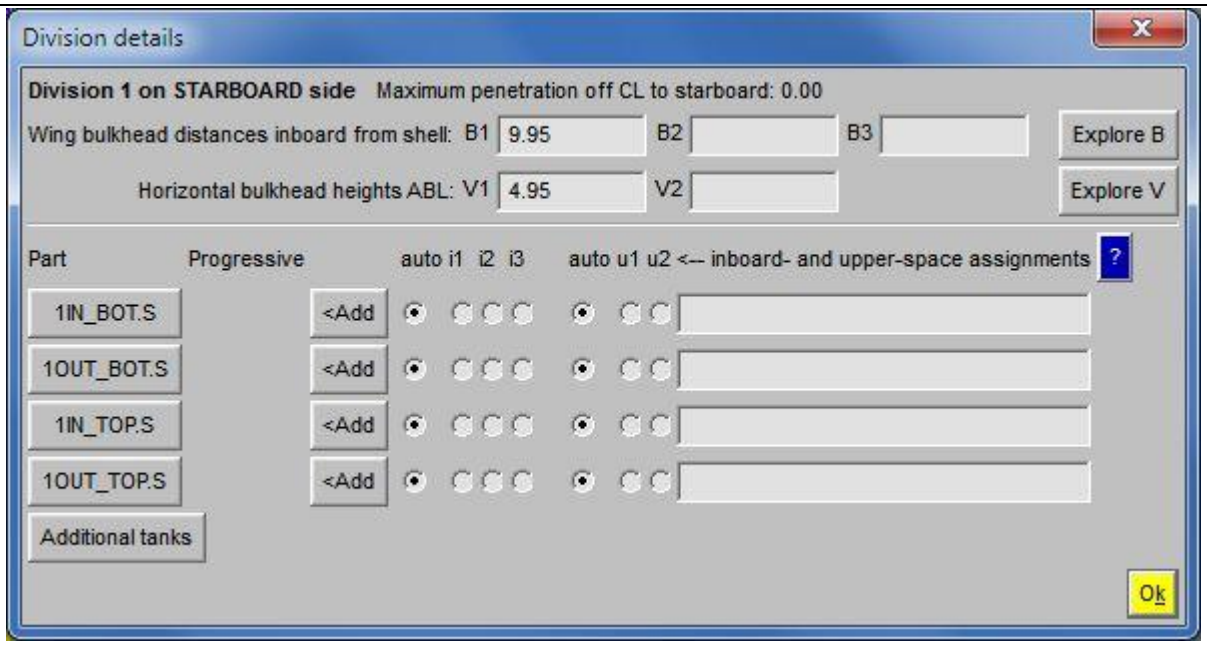


The help window explains how to enter the data into the tables.

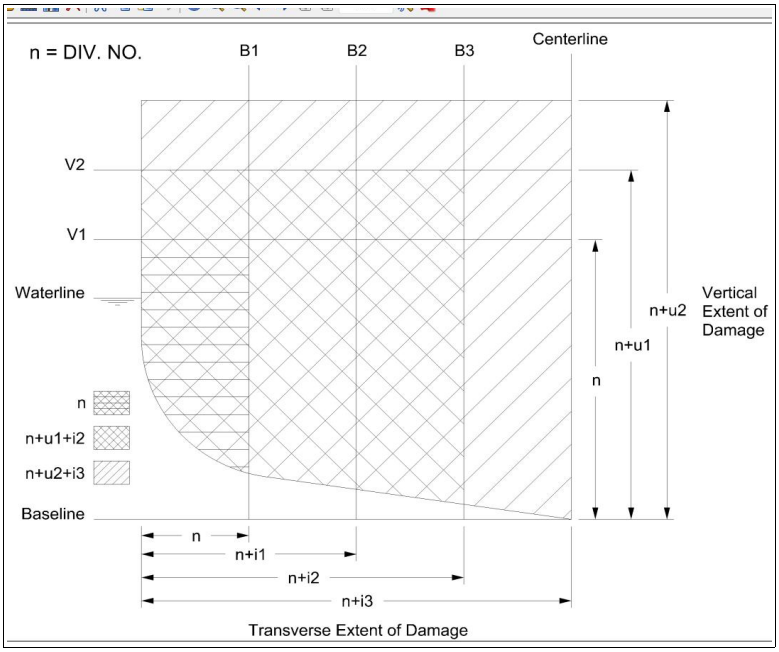
For this vessel, defining the wings and decks using the table above is adequate. Once set, the values entered can be checked by clicking the More button in the Division Definition window.



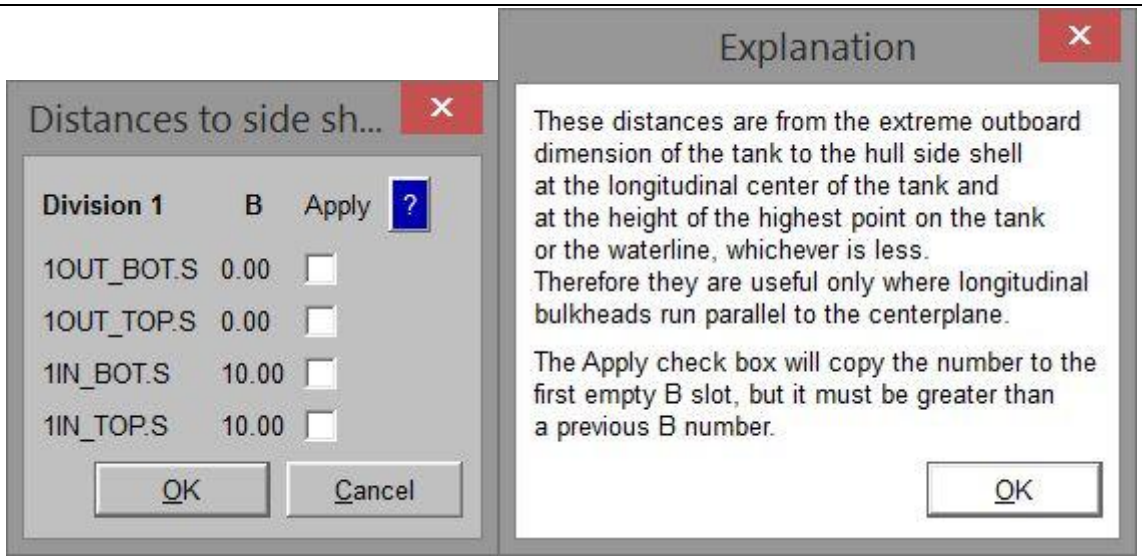
Using the More button for each division allows you to assign these locations on a division by division basis. This is helpful when there are canted bulkheads near the ends of a vessel.

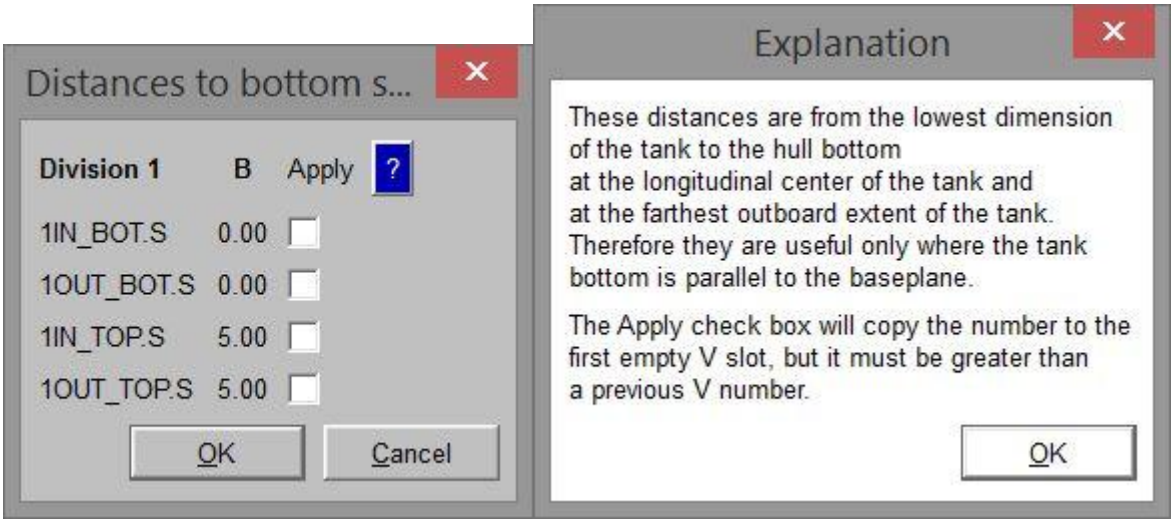


The bulkhead and deck locations for this division are displayed in B1 and V1. Tanks inboard of B1 are automatically assigned to i1, tanks inboard of B2 are assigned to i2, tanks above V1 are assigned to u1 and so on. The automatic assignments can be overridden with the radio buttons. If this is done, a comment can be made in the space provided. The diagram below illustrates the damage extents of the different layers using the terminology that will appear in the reports.



The explore B and V buttons can be used to have the wizard pick out some of the tank border that might make sensible wings or bulkheads. The user has the final choice of which of the boundaries to choose. The dialogs boxes and their respective help windows are shown below.





The wizard provides two methods to expand the division tanklist: "Additional tanks" and "Progressive Flooding". Both options are accessed from the division details window, click "More" in Division Definitions. Each is described by a note once the button is clicked. No time calculation is performed for either option.

The “Additional tanks” button permanently adds a tank to a division regardless of its location. During the calculation it will be automatically be damaged depending on the longitudinal and vertical extent of damage just like any other tank in the division.

The progressive flooding buttons ("< Add") are more specific. Each button selects an additional tank(s) to be damaged when the tank it is associated with is damaged. Progressive flooding tanks do not have to be located within the division boundary. If the linking tank isn't damaged due to the extent of damage, then the specified tank will likewise not be flooded for that extent. See the discussion of + prefix in the operation section of Help DIVISIONS for more information. An option to perform intermediate flooding only in the progressive flooding tanks is provided as an option before launching the run for passenger vessels.

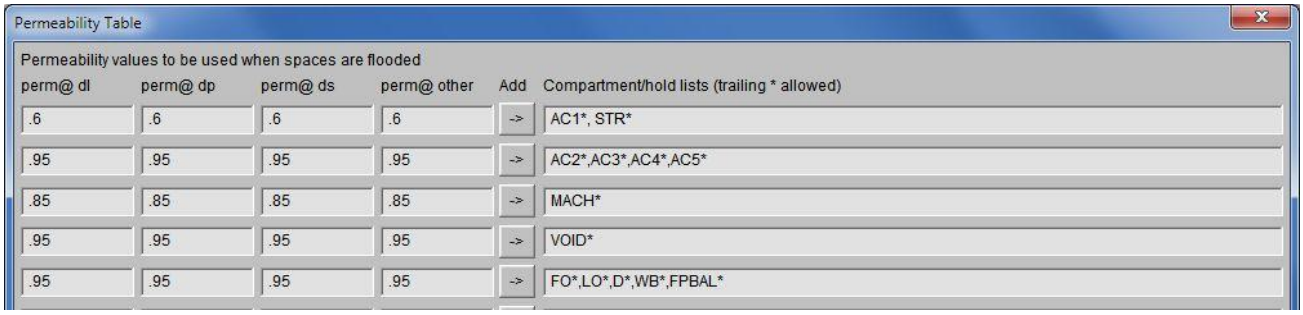
Accepting the input above, click Ok to return to the Division Definition window, click Ok again to return to the main window to rerun the deepest draft case. Looking at the report shows that an attained index of 0.106 was achieved. The previous run produced an attained index of zero. Including the wing and deck locations did improve the attained index, however, the vessel still fails.

Passenger Vessel Exercise

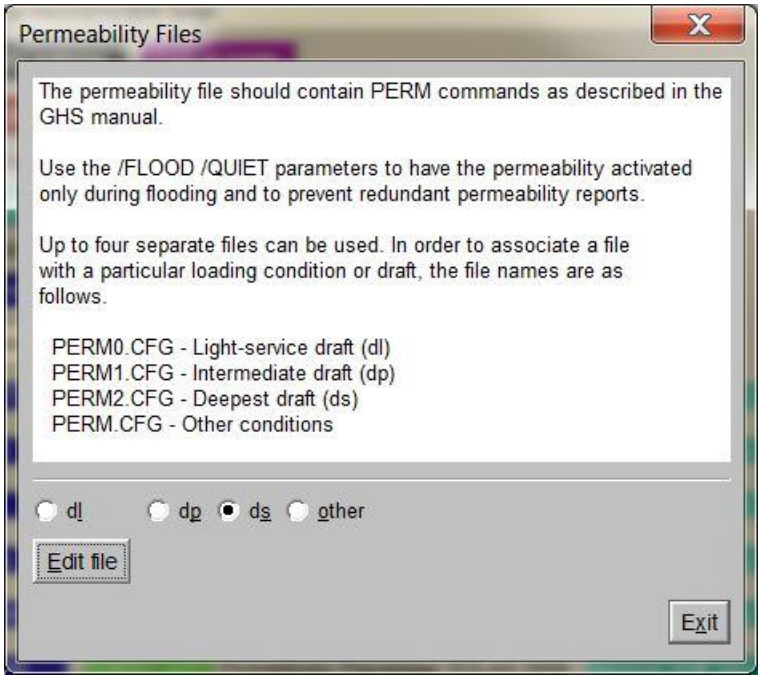
For this demonstration, a simplified passenger vessel with tanks and critical points will be used. It is in the LINER14.GF geometry file. Before starting this new sequence of stability assessments with the DAMSTAB2 wizard, create a new working directory containing the geometry file. It is helpful to have a shortcut for GHS in this folder too.

As is always the case when starting fresh with a new geometry file, we must setup the model in the wizard which includes setting the following: permeability for tanks, critical points, division definitions and vertical and horizontal bulkhead locations (for each division if not continuous). The process below is covered in less detail since this has already been covered with the SubDivy model. A few notes are provided as well as a set of screen shots to use as a guide.

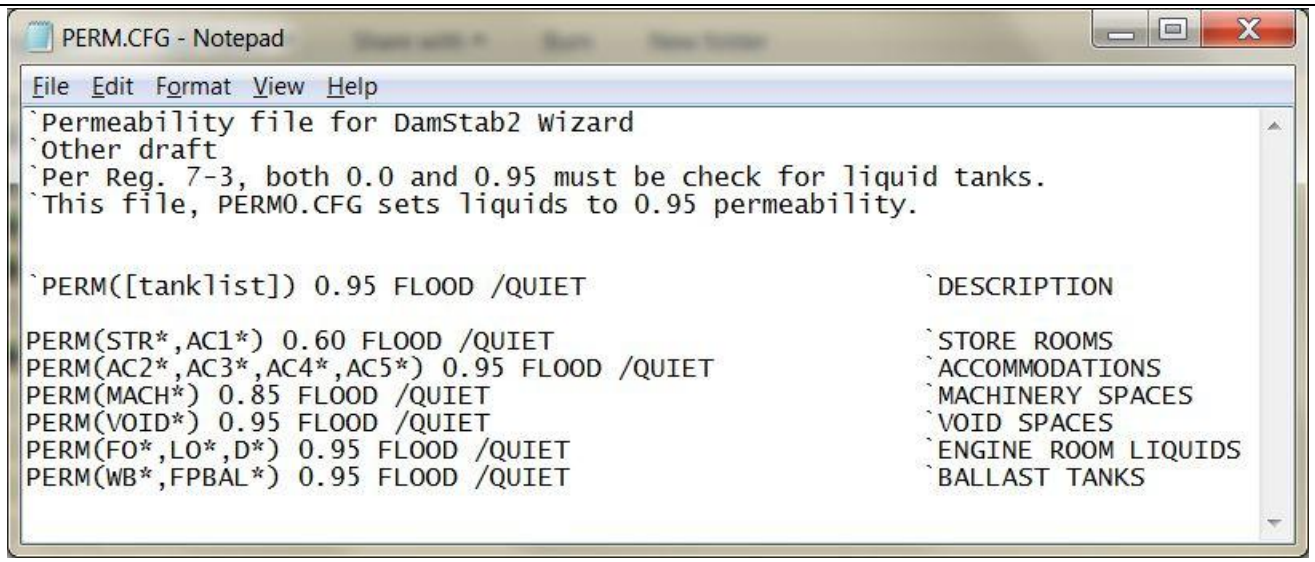
Permeability settings – There are two available methods to set the permeability for the internal compartments. The first is to select the "Use Table" option and copy the permeability settings as follows:



The second option is to select a text file, which lists the permeability for each tank. If this option is used, a file must be generated for each draft and named according to the instructions in the wizard.



An example of a permeability file is shown in the image below:



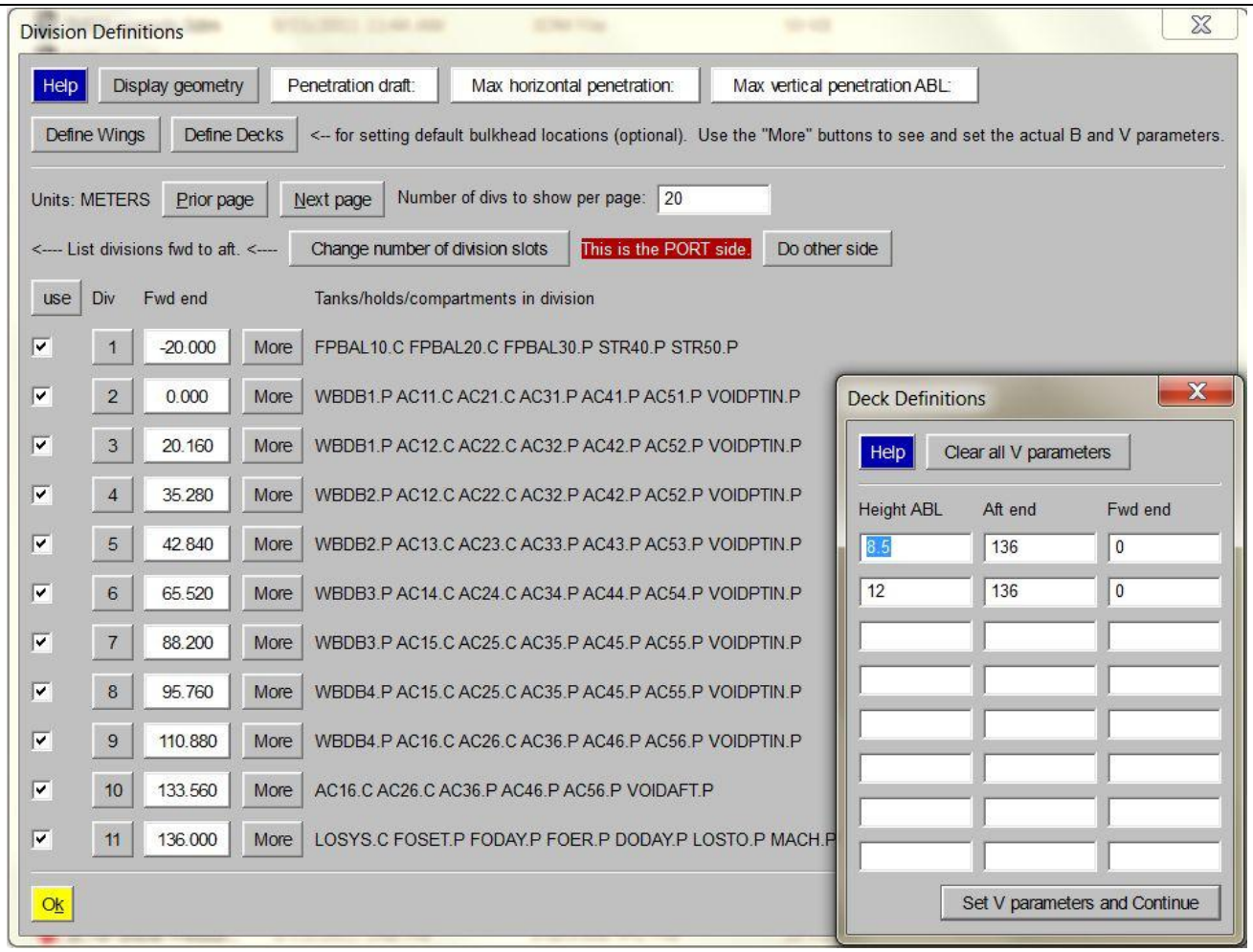

```
`Permeability file for DamStab2 Wizard
`Other draft
`Per Reg. 7-3, both 0.0 and 0.95 must be check for liquid tanks.
`This file, PERM0.CFG sets liquids to 0.95 permeability.


`PERM([tanklist]) 0.95 FLOOD /QUIET                        `DESCRIPTION

PERM(STR*,AC1*) 0.60 FLOOD /QUIET                          `STORE ROOMS
PERM(AC2*,AC3*,AC4*,AC5*) 0.95 FLOOD /QUIET                `ACCOMMODATIONS
PERM(MACH*) 0.85 FLOOD /QUIET                              `MACHINERY SPACES
PERM(VOID*) 0.95 FLOOD /QUIET                              `VOID SPACES
PERM(FO*,LO*,D*) 0.95 FLOOD /QUIET                         `ENGINE ROOM LIQUIDS
PERM(WB*,FPBAL*) 0.95 FLOOD /QUIET                         `BALLAST TANKS
```

Critical points – Since the downflooding points are already set up in the geometry file they do not need to be entered into the Wizard again. The existing points in the GF file can be verified by clicking on “List Existing Critical Points”. Additional critical points and special critical points can be added within the Wizard and both sets of points will be considered.

Port divisions – Use the Auto division maker with 11 divisions. Enter the subdivion draft (6.0 m) when prompted for the penetration draft. After pressing continue, enter the maximum penetration distance from the shell. The regulations state this value should beam/2, which for the LINER14.GF is 14.15 meters.

Next we need to set the deck definitions for the two decks above the subdivision waterline, which is 6.0 m. The first two decks above the waterline are located at 8.5 and 12.0 m above the baseline. Enter these values into the “Define Decks” window along with the longitudinal extent of the decks which is 0 to 136a.

Starboard divisions – select “Do other side” → Stbd → then click “Auto” and “Continue” to generate the division definitions on the Starboard side. Again set the deck definitions.

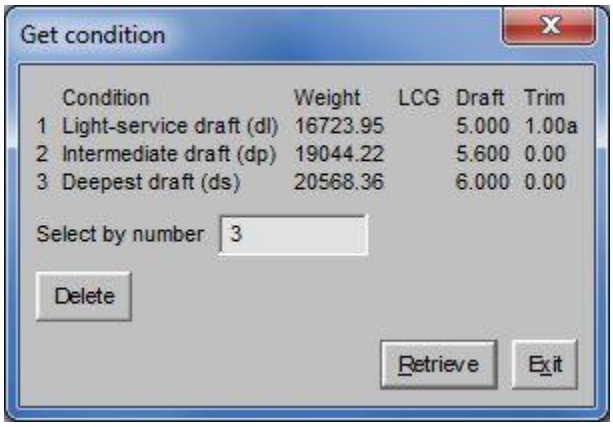


We are almost ready for our first run, the next step is to set up and save the following three load conditions and save all our files thus far.

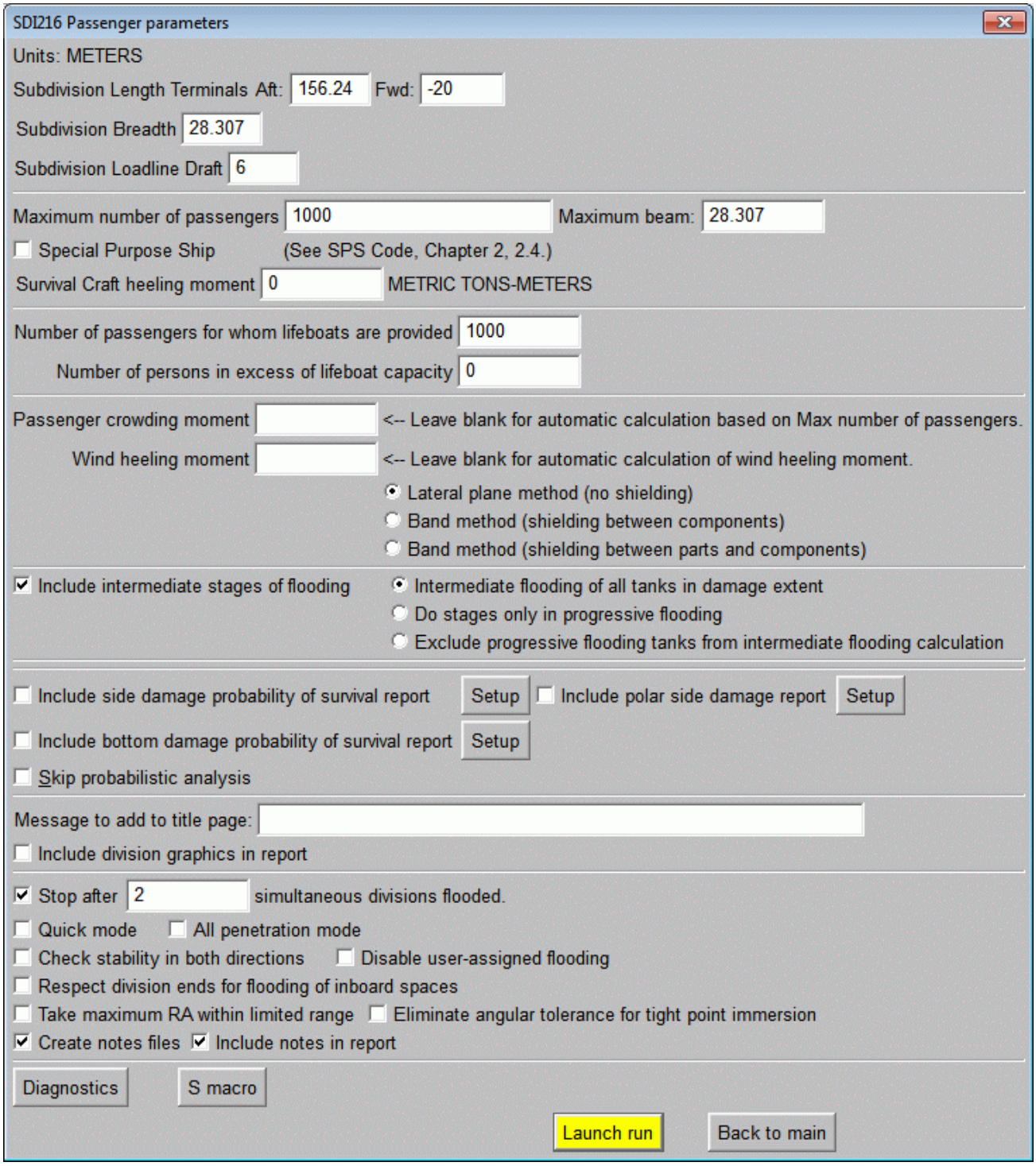
The draft and trim values for the Light-service (dl), Intermediate draft (dp), and Deepest draft (ds) follow:

1. Light-service (dl) 5.0 m 1.0 degrees aft trim
2. Intermediate draft (dp) 5.6 m 0.0 degrees aft trim
3. Deepest draft (ds) 6.0 m 0.0 degrees aft trim

Both the Lightship VCG and the Trial VCG should be set to 9.0 meters.



Set up the “SDI216 Passenger parameters” window with the values as shown. For a vessel this size, 1000 passengers is a good estimate. Be sure to click, “Includes notes in report”. This prints the Survival Probabilities for each set of damages tanks for each division.



The information needed and options available for a cargo vessel run are the same for a passenger vessel. There are additional parameters needed for a passenger vessel run. The prompts for, “Maximum number of

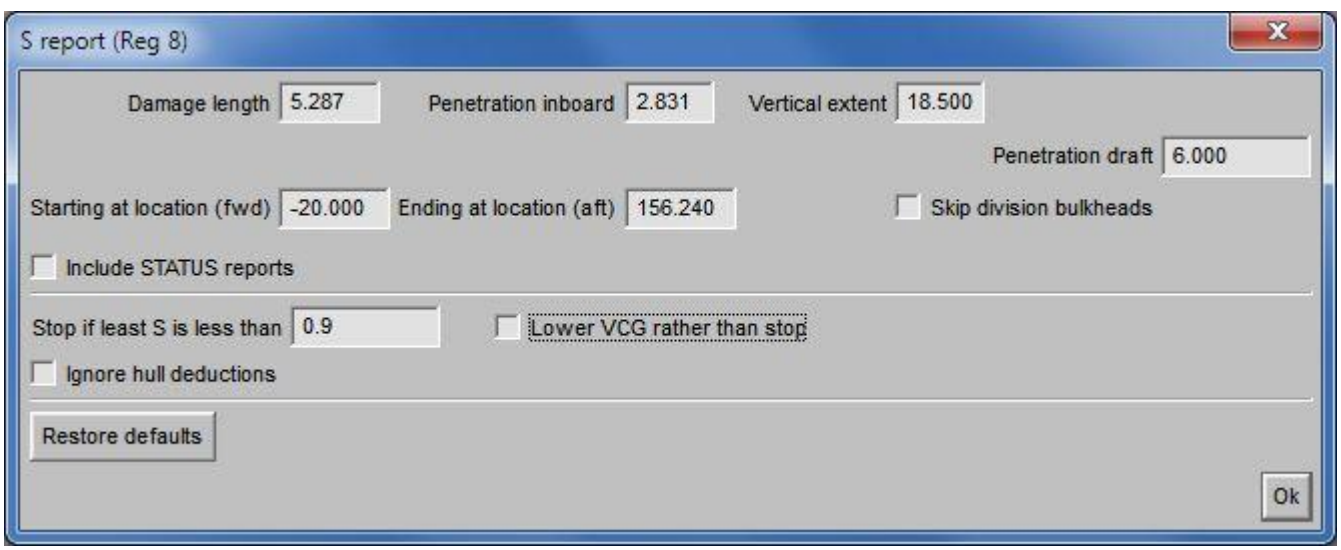
passengers", "Survival Craft heeling moment", the "Number of passengers for whom lifeboats are provided" for and the "Number of persons in excess of lifeboat capacity" are self explanatory.

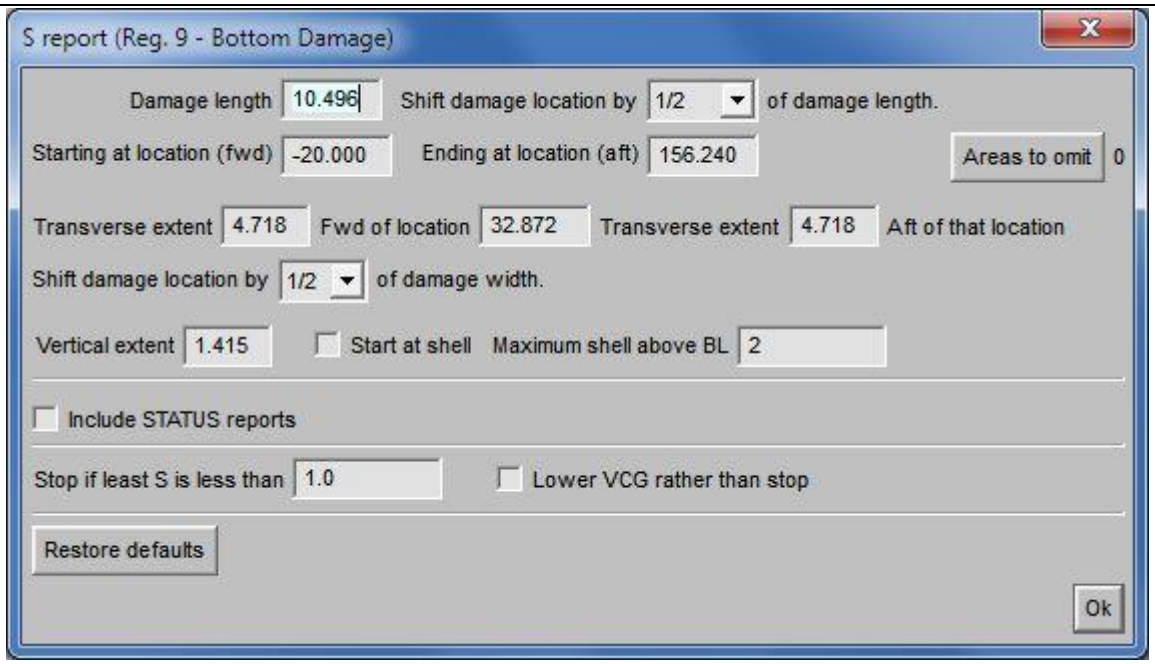
The option to include intermediate stages of flooding as required by SOLAS for passenger ships is located in the middle of the window. Three methods are available which govern how intermediate stages are applied to the tanks in the division.

1. **Intermediate flooding of all tanks in damage extent** – One stage of flooding with intermediate phases of flooding applied to all tanks in the current damage extent. Includes tanks added to a division as progressive flooding tanks or additional tanks.
2. **Do stages only in progressive flooding tanks** - "Flooding stage is any discreate step during the flooding process, including the stage before equalization (if any) until final equilibrium has been reached." This method assumes instantaneous flooding of all tanks within the extent of damage that are not designated as progressive flooding tanks.
3. **Exclude progressive flooding tanks from intermediate flooding calculation** – regulations state that s-intermediate should be calculated for all flooding stages including the stage prior to equalization via cross-flooding. If cross-flooding tanks are assigned using the <Add button (or + prefix in div.cfg) then this provides a way to calculate Si for all non-progressive tanks. Any progressive flooding tanks which are omitted from intermediate phases of flooding are reported in the notes section.

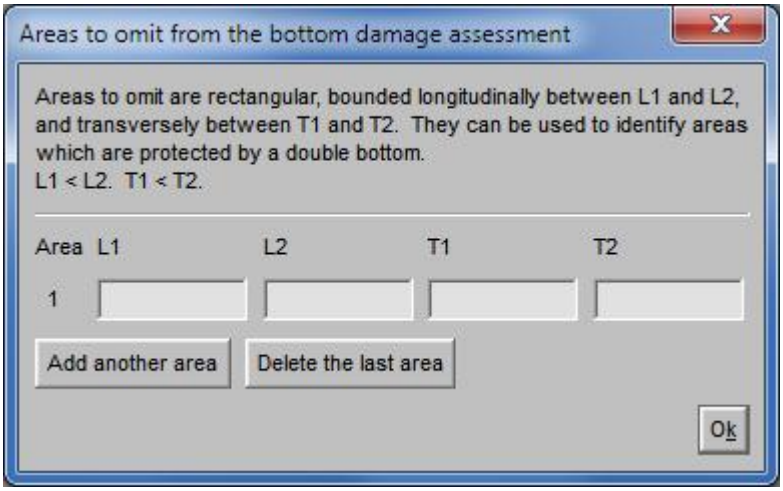
Passenger crowding moment can be given to override the moment computed from the number of passengers and maximum beam. Wind heeling moment can be specified if the superstructure is not included in the model or determined by other means.

Like the bottom damage probability of survival for cargo vessels, passenger vessel are also subject to side damage probability of survival. The side and bottom damage calculations for passenger vessels are required per Regulations 8 and 9. The probability of survival must not be less than 0.9 or 1.0 for side or bottom damage respectively. The location and extents of damage are based on vessel dimensions and are the defaults. The run will terminate if the probability of survival falls below the minimum unless the user selects the option to find a lower VCG so the requirement is satisfied.





For areas of the vessel that are covered by a double bottom, assign areas to omit using the template below. These areas will not be included in the deterministic bottom damage assessment.



Run Options

The bottom area of the window covers the following options. They are the same for both cargo vessels and passenger vessels.

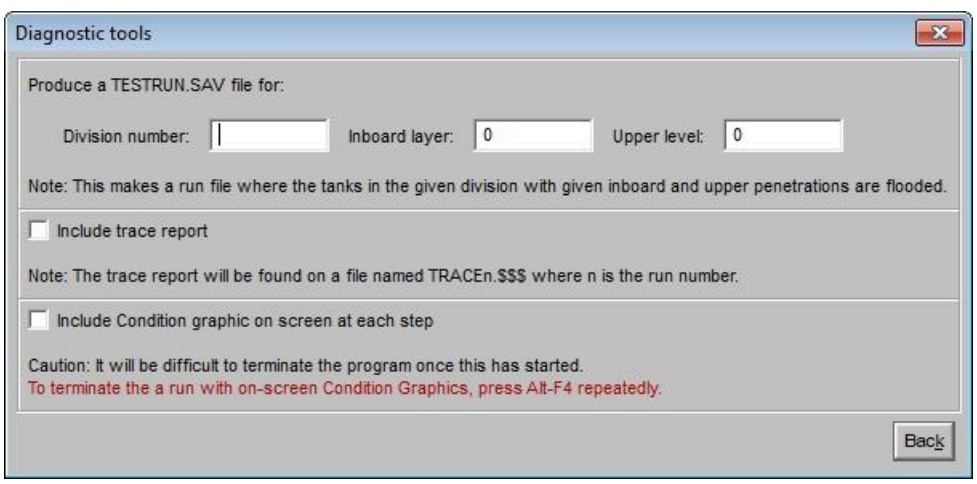
- Stop after *n* simultaneous divisions flooded
  Forces the run to end after the specified number of adjacent divisions are flooded. Also, the run will end when there is no contribution to the attained index for a given set of divisions.
- Quick mode
  Turns off checking for worst case combinations of flooding to shorten the time of runs. For example, in the case of horizontal bulkheads, the wizard will check the case with only the upper compartments flooded as the higher VCG may be more critical.
- All penetration mode
  Considers all penetration combinations under multi-division damage.

- Check stability in both directions, for asymmetrical vessels or loadings
- Disable user-assigned flooding
  Overrides the layer assignments in the Division Details window.
- Respect division ends for flooding of inboard spaces
  Uses the division ends when accounting for the tanks most outboard extent.
- Take the maximum RA within the limited range
  - If unchecked, the maximum right arm within the entire range of stability will be used to determine the s factor.
  - If checked, the maximum righting arm will be taken within the limited ranges specified in Regulations 7-2 (16 degrees for Sfinal, 7 for Sint). This is a conservative interpretation.
- Eliminate angular tolerance for tight point immersion
  Useful if tight point height is limiting stability. The default evaluation method includes a slight angle tolerance for tight point immersion, so if a tight point is well off centerline, it must be higher above the waterline then a point closer to centerline. Checking this option removed this conservative tolerance.
- Create notes files
  - The notes files which provide useful information about each case in the evaluation. This information can help determine the reason for failure particularly if it is related to downflooding or tight point immersion.
  - Include notes in the report. Eliminating the notes files reduces the number of files in the DAMSTAB2 wizard directory.
  - Sometimes it is preferable to eliminate the notes pages (which can be numerous) from reports and keep them as separate files.

Note: Some of the options above deviate from the regulations in order to reduce calculation time. These can be useful in the early stages of an analysis.

Diagnostic & S macro

The Diagnostic button provides several ways to obtain or view intermediate results for checking and troubleshooting.



Specifying a division and the desired layer and level, a run file is produced and executed at the end of the Probabilistic Damage run. The results show the equilibrium condition and the tanks that are flooded. A righting arm calculation and graph is included. Of particular usefulness, a trace file provides output which shows intermediate values calculated during the run with additional explanatory notes. The last option will enable the display, on the screen only, of a Condition Graphics window for all cases with a non zero Smin.

Terminating the run by pressing the Alt-F4 key is not recommended as it may cause the program to behave erratically. It may be better practice to select the division(s) of concern in the Division Definition window to shorten the run time and reducing the output.

The “S macro” button displays information if a user wants to use their own macro to calculate the S factor. The contents of such a macro will not be discussed here as it is beyond the scope of this manual.