



6.4 User Manual

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Section 1 Introduction

RhinoHyd is a hydrostatic and stability analysis program integrated within Rhinoceros as a plug-in module. Its purpose is to provide an aid to solving some of the basic ship stability and hydrostatic problems confronted by marine architects and designers.

Capabilities

RhinoHyd runs fully within the Rhino environment, allowing the user to select the ship to be analyzed directly from the current Rhino document.

Once a ship has been selected, the user has a choice of analysis types:

1. Statical Stability Analysis.

After a statical stability analysis has been performed, any of the following may be plotted:

- Righting arm.
- Righting moment.
- User defined heeling curves.
- Area under or between any curves.
- Trim.
- Points of interest.

2. Hydrostatic Curves of Form Analysis.

The curves of form analysis allows the following to be plotted:

- Displacement.
- Waterline length.
- Beam.
- Longitudinal center of force.
- Longitudinal metacentric height.
- Transverse metacentric height.
- Vertical center of buoyancy.
- Waterplane area.
- Wetted surface area.
- Midship area.
- Block coefficient.
- Prismatic coefficient.
- Waterplane coefficient.
- Midship coefficient.
- Vertical prismatic coefficient.
- Immersion.
- Moment to change trim.

3. Cross Curves of Stability Analysis.

The output from a cross curve analysis may be plotted to show the heeling arm at up to 10 heeling angles and draft levels.

4. Equilibrium Analysis.

5. Section Area Curve.

The user may select a number of hull sections to be created. The area of these sections will be plotted in a graph window or directly in the Rhino document.

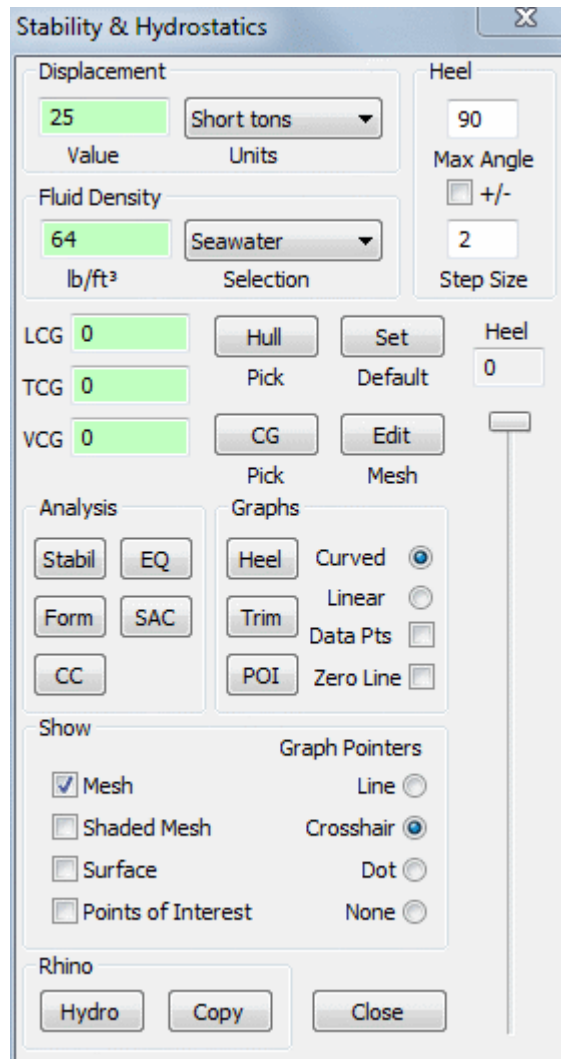
After a statical stability, curves of form, or equilibrium analysis has been calculated, RhinoHyd can animate the ship with the slider control located on the main dialog window. For example, if a stability analysis has been performed, the slider will rotate the ship to each heeling angle and also adjust the trim and sink. The ship can be displayed as either a mesh, shaded mesh, or surface object, along with points of interest in the Rhino document. The user may also display any of the available plots while the animation is running and a plot pointer will move in real-time with the animation. The user may right mouse click on any plot to either copy the plot graphic or the raw data to the clipboard. The raw data can then be pasted into a spreadsheet for further analysis. At any point of the animation, a button on the main dialog may be pressed to launch Rhino's hydrostatic calculation command. Rhino will analyze the ship in the current animated position and display its usual output window. This is a good way to spot check the accuracy of RhinoHyd.

A final way to get data is through scripting. RhinoHyd exposes its statical stability and hydrostatic functions for RhinoScript writers. Example scripts are shown in Appendix B.

Section 2. Using RhinoHyd

Getting Started

RhinoHyd is a Rhino plug-in and not a stand-alone application. You must have a working copy of 64 bit Rhino V6 in order to install RhinoHyd. RhinoHyd does not support 32 bit versions of Rhino. Once installed you may launch the main dialog by mouse clicking the RhinoHyd menu item at the top of Rhino. A screen capture of this dialog is shown below.



The remainder of this section will explain each of the items on this dialog.

Displacement and fluid density.

In the upper left corner of the dialog are two user input edit boxes for the ship's displacement value and displacement units. If you don't know the displacement, use Rhino's hydrostatic command to help you. As you type the displacement value into the edit box, the box background will change colors. If it turns red, you are typing values that are not going to work. For example if you first type a negative sign, nothing you type after will correct it. When the background turns green, the value is acceptable. This is just a way to provide a quick visual feedback to show that your input data is acceptable. The units box has a drop-down list of acceptable displacement units. When RhinoHyd is first launched, it checks your current Rhino document settings to determine, among other things, your modeling units. If you are using English units, the listed displacement units options will be: short tons, long tons, kips, or pounds. If you are using metric units your choices will be: tonnes, kilograms, or newtons.

Just below the displacement boxes are the fluid density boxes. Again, a colored background is used and the required units value is shown below the value. English units will be lb/ft^3 and metric units will be kg/m^3 . A drop-down list of default values is provided for seawater and freshwater. There is also a user input option that allows for a user defined value.

Heel.

In the upper right corner of the dialog are a group of three boxes titled "Heel". These values will be used during stability or cross curve analysis. The upper edit box is where the user inputs the maximum heeling angle that will be calculated. Below this box is a check box labeled "+/-". When this is checked, the analysis will be calculated with a range that includes the negative maximum heel value. In other words, the heeling range will be from negative maximum angle to positive maximum angle. The maximum angle will be limited to 180 degrees when this box is checked and 360 degrees when it is not. The bottom edit box allows the input of the heel angle step size. This is the increment the solver uses as it steps through the heeling range. There is no color coded background for these controls. They will only accept an integer value and any number input greater than the allowable maximum will automatically be reset to the allowed value. The user should look at these boxes after performing an analysis because the values may automatically change. RhinoHyd will require a minimum of six heel angles and may adjust the maximum heel or step size to get them.

Moving down the dialog, the user will find a button labeled "Set". This button will save the current state of the dialog as the default state each time the dialog is launched in the future.

Model.

Next to this button is the "Hull" pick button. This allows the user to input the model geometry. When this button is clicked, the user will be prompted to select the ship surface. The only acceptable geometry is one valid surface or one valid polysurface, closed below the waterline, and all surfaces must have their face normals pointing outward toward the water because inward facing surfaces will be calculated as negative volume. Only valid surfaces are acceptable. If you try to select a surface that Rhino has flagged as invalid, it will be rejected and the user will be given a warning. Rhino has tools to diagnose invalid objects using the menu item: Analyze/Diagnostics/... .

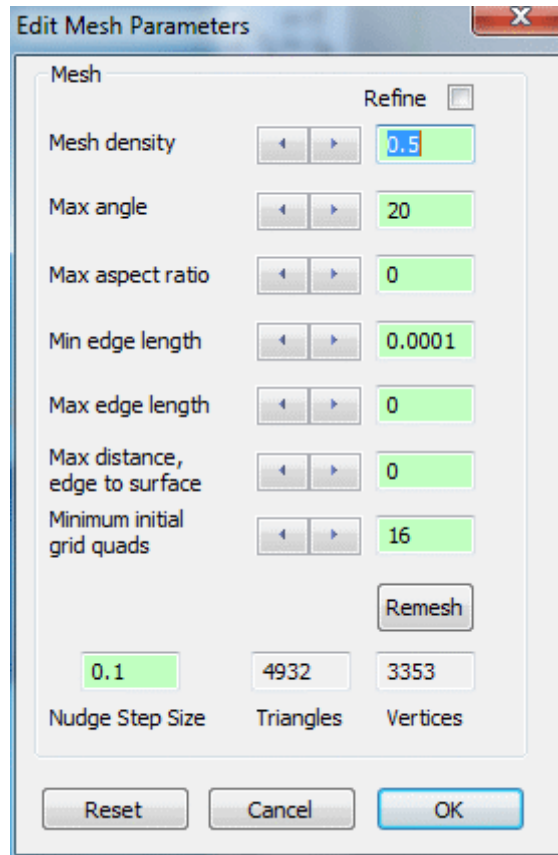
The "CG" pick button allows the user to mouse click on an existing point from the screen which will be used as the center of gravity of the ship. The user may also type the x, y, z coordinates directly into the three edit boxes to the left of the button. All heel and trim rotations will be about this center of gravity point.

After the hull geometry has been input, the ship will automatically be meshed with a set of default mesh parameters using Rhino's mesher. If the resulting mesh is flagged as invalid by Rhino, RhinoHyd will adjust some of the mesh parameters and repeat the meshing operation. If a valid mesh can't be created, the user will be given a warning. The user may diagnose mesh problems by closing RhinoHyd and mesh the surface directly in Rhino. Then use the Rhino menu item: Analyze/Diagnostics/Check. This will generate a report of the problem.

When a hull has successfully been meshed in RhinoHyd, the resulting meshed ship will be displayed in the Rhino views using Rhino's display pipeline. The pipeline allows objects to be displayed without having to add them to the Rhino document. Other display options include a shaded mesh and a copy of the original ship surface. If the meshing operation was successful, RhinoHyd will enable three dialog buttons allowing the user to select the type of analysis to be performed; statical stability, curves of form, cross curves of stability, or sectional area curve. Another option is to edit the mesh before analyzing.

Mesh Edit.

The dialog button labeled “Edit” allows the user to change the mesh parameters. When the Edit button is clicked, the dialog shown below will be launched.



This dialog allows the user to adjust seven different mesh parameters. RhinoHyd uses Rhino’s mesher and these parameters are the same ones that Rhino displays in its mesh dialog box. The user can change the values in the edit boxes by either using the arrow buttons or typing a value directly. If a value is typed, the user must click the button labeled “Remesh” or "OK" before any mesh changes are made. If the arrow buttons are used, the model is automatically remeshed. When an arrow button is clicked, the value is nudged by the amount shown in the edit box labeled “Nudge Step Size”. The arrow buttons may be held down and the mesh will be continually updated with a new value and the meshed ship will be simultaneously displayed in the Rhino views. A description of the mesh parameters is given in Rhino’s help file and will be repeated below.

Mesh density.

Uses a formula to control how close the polygon edges are to the original surface. Values range between 0 and 1. Larger values result in a mesh with a higher polygon count.

Max angle.

The maximum allowable change between the surface normal at any point and the mesh vertex. Two vertices are neighbors if they are at the ends of a facet edge. The default value for this option is 20 degrees and the suggested range is from 5 to 90 degrees. This setting is scale independent. Smaller values result in slower meshing, more accurate meshes, and higher polygon count.

Max aspect ratio.

Surfaces are initially tessellated with a regular quadrangle mesh and then that mesh is refined. The initial quad mesh is constructed so that on average, the maximum aspect ratio of the quads is less than or equal to Maximum aspect ratio. Smaller values result in slower meshing and a higher polygon count with more equilateral and nicely shaped polygons. This is approximately the maximum aspect ratio of the quads in the initial mesh grid. Setting Maximum aspect ratio to zero turns off the option. Zero means no limit. The default value for this option is zero and the suggested range, when not zero, is from 1 to 100. This setting is scale independent.

Min edge length.

If any edge is shorter than the Min edge length, no further division of the mesh faces occurs. This is also, approximately, the minimum edge length of the quads in the initial mesh grid. The default value for this option is 0.0001 units and the usable range depends on the size of the model. Bigger values result in faster meshing, less accurate meshes and a lower polygon count. Setting this value to zero turns off the minimum edge length option. This option is scale dependent and the value is always in the current unit system.

Max edge length.

Polygons are further divided until all polygon edges are shorter than this value. This is also, approximately, the maximum edge length of the quads in the initial mesh grid. Smaller values result in slower meshing and a higher polygon count with more equally sized polygons. Setting this value to zero turns off the option. The default value is zero and the usable range depends on the size of the model. This option is scale dependent. When this value is at zero and the RhinoHyd arrow button is used to nudge the value, an initial nudge value that is ten times higher than normal will be used. This is done to jump over tiny values resulting in an extremely dense mesh. If smaller values are required, the user may use the back arrow to back down slowly into smaller edge length values.

Max distance edge to surface.

Polygons divide until the distance from a polygon edge midpoint to the NURBS surface is smaller than this value. This distance is also the approximate maximum distance from polygon edge midpoints to the NURBS surface in the initial mesh grid. Smaller values result in slower meshing, more accurate meshes, and a higher polygon count. Setting this value to zero turns off the option. The default value is zero and the usable range depends on the size of the model.

Minimum initial grid quads.

The number of quadrangles per surface in the initial mesh grid. In practice, Rhino will use at least this many polygons on each surface. Bigger values result in slower meshing, more accurate meshes and a higher polygon count with more evenly distributed polygons. Setting this value to zero turns off the option. The default value is 16. The suggested range is from 0 to 10000. This option is scale independent.

At the top of the dialog, directly above the mesh parameter edit boxes, is a check box labeled “Refine”. After its initial meshing, Rhino uses a recursive process to refine the mesh until it meets the criteria defined by **Max angle**, **Min edge length**, **Max edge length**, and **Max distance, edge to surface** options. The mesh is refined until the angle between surface normals along a polygon edge is smaller than the **Max angle** value. Unchecking this box results in faster meshing, less accurate meshes, and lower polygon count. Also, untrimmed individual surfaces and surface areas away from trim edges and joined edges are meshed with evenly sized quadrangles.

The end purpose of meshing is to provide a discrete representation of the hull for integration of the volume. Any naked edges in the mesh below the waterline may reduce accuracy. It is a good practice to eliminate naked edges in the original model before meshing begins. Only valid meshes will be acceptable. Invalid meshed will result in a warning message being displayed. The user may get a report of a bad mesh using Rhino's menu item: Analyze/Diagnostics/Check.

Reset, Cancel, & OK Buttons

At the bottom left of the mesh dialog is a button labeled “Reset”. This will set all controls back to their default state. The “Cancel” button will ignore all changes made and revert all controls to the state they had when the dialog was launched and close the dialog. The “OK” button accepts all changes and closes the dialog. All changes will persist as long as the main dialog is displayed, even if a new ship geometry is picked. Each time the main dialog is launched, the controls will be set to the default state.

This concludes the discussion of the mesh editing dialog and the main dialog discussion will now continue.

Analysis.

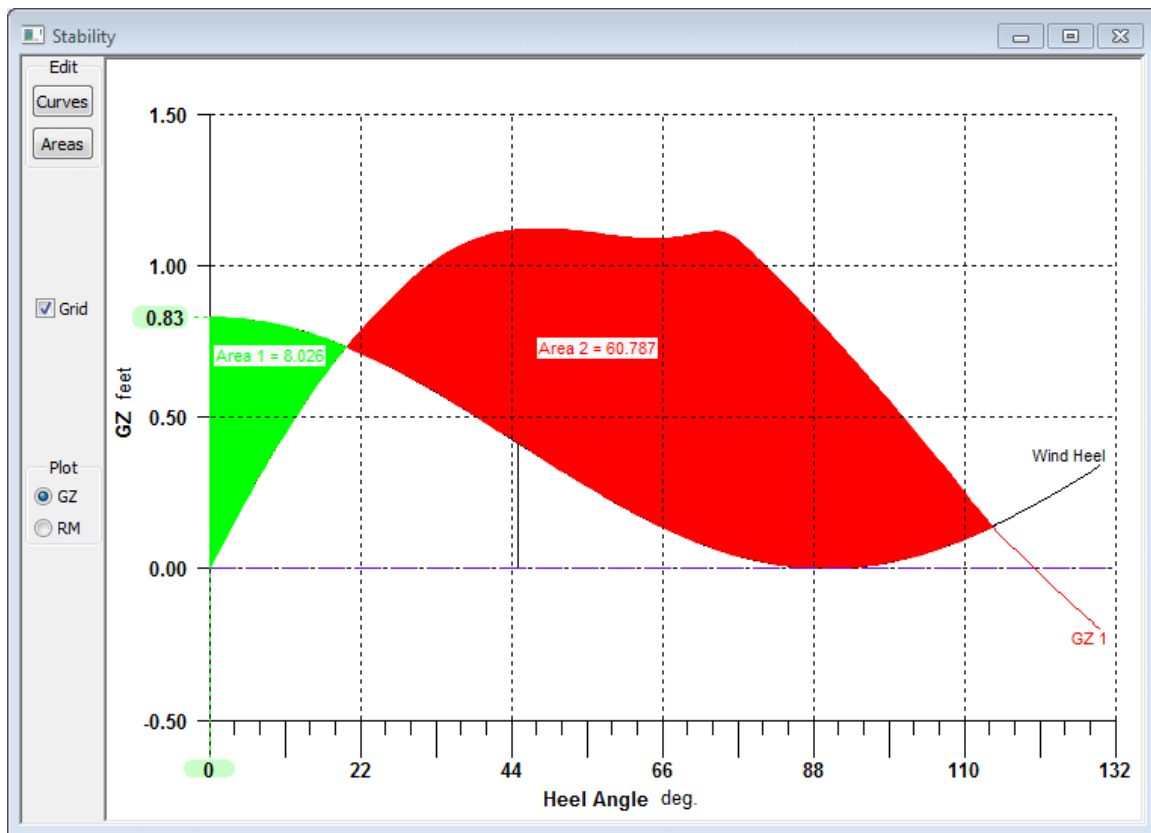
Integration

RhinoHyd does not use sectional data to integrate the hull. Instead, the mesh vertices located directly on the hull are used. This requires that the surface normals all be pointing outward toward the water. This can be checked by using Rhino's "Dir" command. If the direction is wrong, use Rhino's "Flip" command. Another integration issue that must be considered regards the treatment of structures inside the hull that are below the waterline. RhinoHyd only calculates the closed volume of the hull model. For example, a sailboat's cockpit volume is external to the closed hull and consequently would not be calculated in the hull volume. If a portion of the cockpit extended below the waterline, it would have to be included in the volume to get the correct displacement, but RhinoHyd is not capable of doing this. This is probably not the desired result unless a flooded cockpit is being modeled. The only solution is to remove these structures from the model.

After the model has been successfully meshed and the user has input the required information, RhinoHyd will enable five analysis buttons on the main dialog. The options are static stability, curves of form, cross curve, equilibrium, and sectional area analysis.

Static Stability Analysis

If stability is selected, RhinoHyd will calculate the heeling arm and moment for each heel angle requested as well as the trim angle required for equilibrium. RhinoHyd begins the analysis by first balancing the model to the required displacement by adjusting the sink and balancing the trim by rotating the ship about the transverse axis through the center of gravity. This balanced configuration is used as the starting point for the analysis. After successful completion of the analysis at each heeling angle, three graph buttons on the main dialog will be enabled in order to view the results. Launching the Heel graph allows graphing of the heeling arm or moment. An example is shown below.



In addition to plotting the righting arm and moment, user defined curves and areas can be added as shown above using the "Curves" and "Areas" buttons.

A graph pointer can also be displayed by selecting one from the main dialog shown earlier. As the slider on the main dialog is moved to animate the ship, the pointer is

simultaneously updated to move along the curve graph. Any of the displayed curves may be selected for the pointer to follow simply by clicking the mouse on the desired curve.

The "Curve" button in the upper left corner will launch the dialog shown below.

Edit Graph Curves

Wind Heeling Arm Formula

$$H(\Phi) = a \cdot V^2 \cdot \text{Area} \cdot \text{Lever Arm} \cdot \text{Gust Ratio} \cdot \cos^N(\Phi) / 2240 \cdot \Delta$$

Inputs

a: 0.00207

Projected Area: 1500 ft²

Wind Velocity: 10 kt

Lever Arm: 5 ft

Wind Pressure: lb/ft²

Gust Ratio: 1

Add

N: 2 Exponent

Displacement, Δ: 4.4642855 long tons

Wind

Center of Lateral Windage Area

V wind

Lever Arm

T draft

T/2

Righting Curves: GZ 1

Heel Curves: Wind Heel

Reference Lines: 45, Equilibrium

Righting: Save, Load

Heels: Save, Load

Close

There are six tabs located at the top of the dialog which will display templates to aid the user in creating heel curves. The formula for each template is also displayed. There is enough variability in the inputs to allow a great variety of curve shapes. After inputting the data into one of the templates, the "Add" button can be pressed to display the curve and launch the edit display dialog shown at right.

This dialog edits the text label and the curve color. Notes may also be stored here. As long as this dialog is displayed, the user can drag the labels shown on the graph to any position. Click on the graph text with the left mouse button while holding down the button and dragging the label to the desired position. When the user has finished editing, the "OK" button can be pushed and this dialog will close and the curve will be added to the "Heel Curve" box shown in the dialog above. The edit dialog can be launched again at any time by double clicking the text in the above box.

Edit Heel Display Properties

Color

Label

Wind Heel

Notes

Show Heel Curve

Show Heel Curve and Label

Hide Heel Curve and Label

Delete

Cancel

OK

In addition to heel curves, the user may add reference lines to the graph. The "Add" button under the box labeled "Reference Lines" in the above dialog will launch the lines creation dialog.

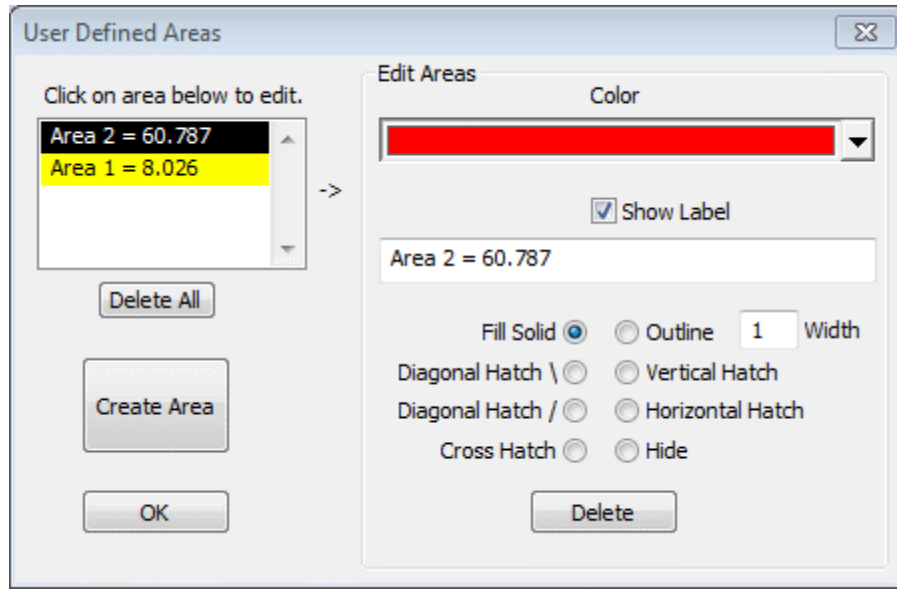
This dialog creates and edits user defined straight lines. These lines can be used just for graphical display or as an aid in the creation of areas, which will be explained later. The text and line color can be defined as well as the start and end coordinates. As the variables are changed, the graph will be updated in real-time. The label can be dragged into position directly on the graph.

When the "OK" button is pressed, the dialog will close and the line will be listed in the heel dialog shown above. This dialog can be launched again by double clicking the label in the box above.

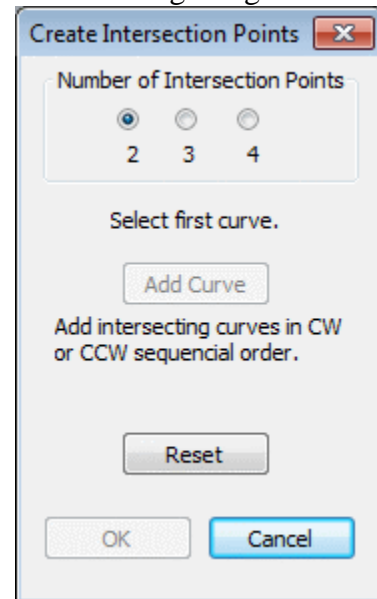
The final buttons on the heel dialog are the "Save" and "Load" buttons. These let the user save or load heel or GZ curves.

Edit Areas

In addition to adding curves to the GZ graph, user defined areas may also be created. In the upper left corner of the graph dialog, a button labeled "Areas" will launch the area definition dialog shown below.

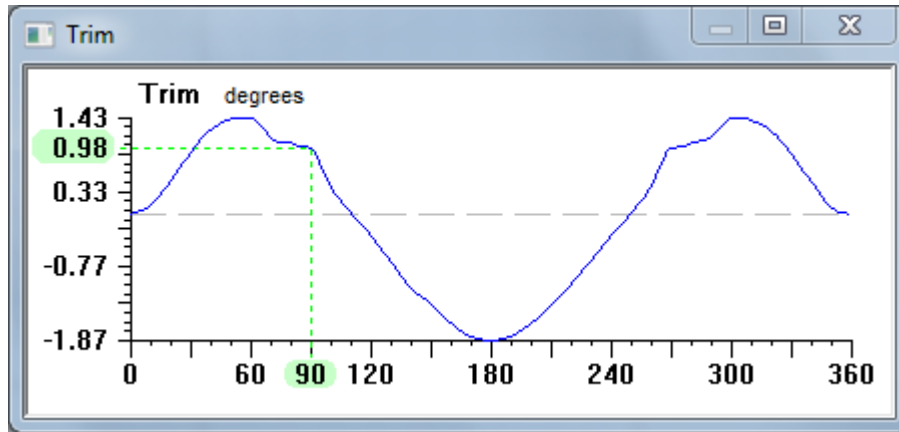


As the user creates areas, they will be displayed in the box at the upper left corner of the dialog. Clicking on one of these areas will activate the editing controls on the right side of the dialog. The fill style, color, and text label may be edited here. In order to create an area, the "Create Area" button can be pressed to launch the creation dialog at right. An area is created by selecting existing graph curves. These curves will be used to form the boundary of the area. Curve intersection points form the corners of the boundary. The user has the choice of using two, three, or four curves to form a closed area boundary. When a curve is selected with the mouse, it will be highlighted. If the curve is acceptable to the user, the "Add Curve" button must be pressed before selecting the next curve. If four curves will be used, they must be added in sequential order either clockwise or counter clockwise. After the specified curves have all been selected, they will all be highlighted along with the intersection points. The user may then select the "OK" button to add the area to the graph. This will close the dialog and the definition dialog shown above will appear again. The newly created area will appear in the areas list box along with the value of the area. The area squared units are the same as the current Rhino model length units.



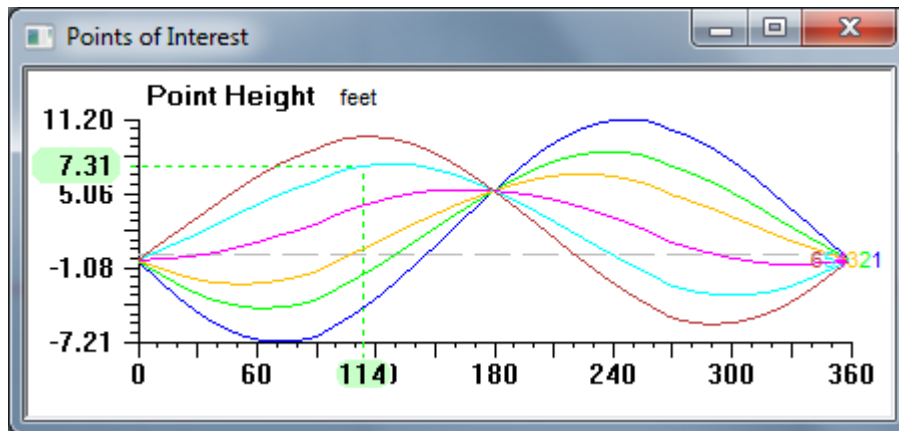
Trim Graph

On the main dialog, directly below the Heel button is a button labeled “Trim”. This launches the trim graph. The trim value will be displayed for each heel angle.



Points of Interest Graph

The button on the main dialog labeled “POI” will launch the points of interest graph.



The user will be prompted to input up to six points of interest. These can be picked with the mouse directly from the screen or the coordinates may be typed. The “POI” button may be selected as many times as liked to plot as many points as liked but only six points may be plotted together at one time. The points may also be animated on the screen with the slider control on the main dialog.

All the graphs in RhinoHyd may be saved as an image or as raw data by right clicking on the graph.

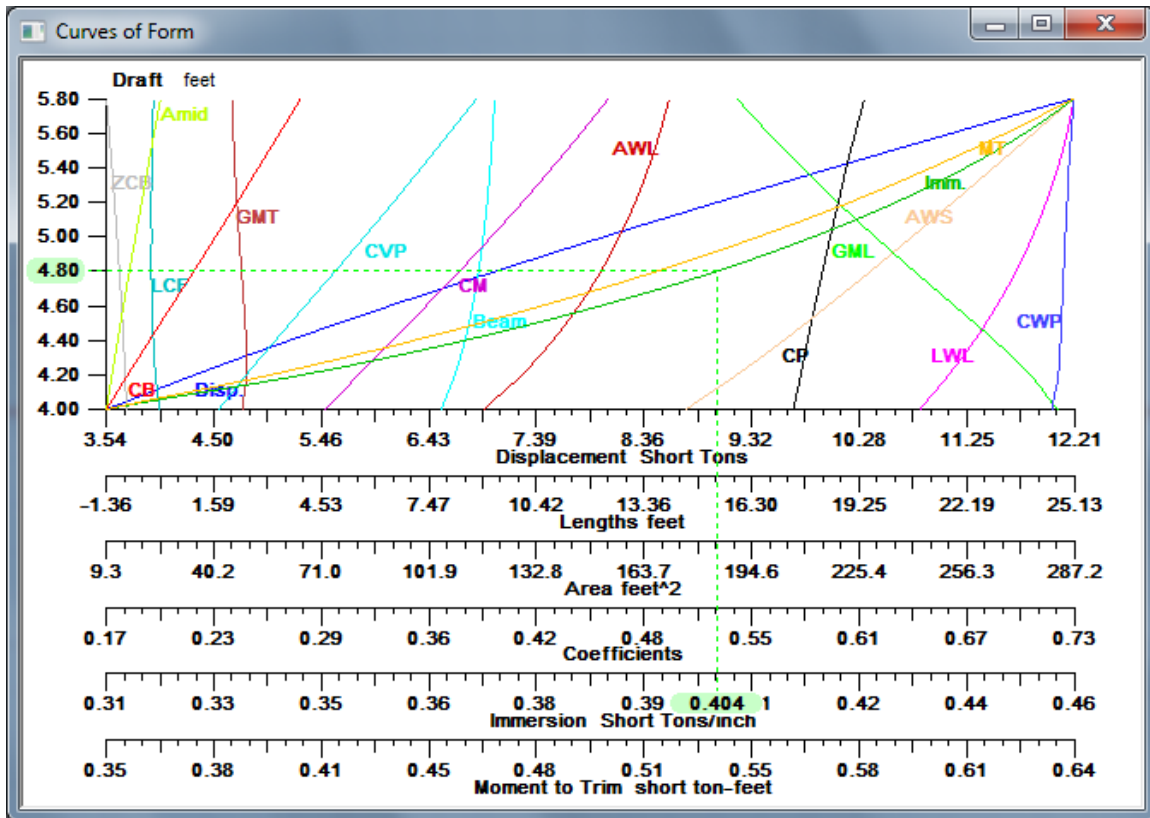
Hydrostatic Curves of Form Analysis

The next available analysis type will produce the curves of form. From the main dialog, select the button labeled “Form”. A small dialog, shown below, will be launched allowing the user to input the minimum and maximum draft along with the desired increment. Checking the box on the right forces RhinoHyd to balance the trim at each draft. Removing the check will lock the trim to its original configuration.

At the bottom of the dialog, the user may specify the longitudinal location to calculate the midship area. A value may be typed into the edit box or alternatively RhinoHyd will calculate the location at 50% of the waterline length at the first draft. This position will then be used for all subsequent drafts. After all the data is entered, the "Calculate" button may be pressed which will close this dialog and begin the analysis. If the user is curious as to what RhinoHyd calculated the 50% midship location to be, this dialog must be launched again after the analysis. RhinoHyd will remember the value used for the last analysis and display it in the edit box.

The world coordinate system used by RhinoHyd is shown in Appendix C. The positive “Z” axis points upwards and is zero at the waterline. Although the draft is in the negative “Z” direction, assume that whenever the term “draft” is used in the dialog display it means a positive number representing the distance below the waterline to the lowest point on the ship.

An analysis will begin at the first draft and increment the desired amount for a maximum of ten drafts or the maximum specified draft, whichever is less. The results plot will automatically launch.



Just like all the previous plots, as the ship is animated, the graph pointer will be simultaneously updated if desired. Right click on the graph to copy the data or graphic. The following is a description of all the plotted data.

- Displacement.
- LWL: Length. The length at the specified draft, at the waterline.
- Beam: The maximum waterline width at the specified draft.
- LCF: Longitudinal Center of Flotation.

$$LCF = \frac{\text{First Moment of Area}}{\text{Waterline Area}}$$

- A_{WP}: Area at the Waterplane.
- A_{WS}: Area of Wetted Surface.
- A_{MID}: Midship Area. The sectional submerged area at user specified location.
- GM_L: Longitudinal Metacentric Height.

$$GM_L = ZCB - ZCG + \frac{\text{Moment of Inertia of Area About Transverse Axis}}{\text{Volume Displacement}}$$

- GM_t: Transverse Metacentric Height.

$$GM_t = Z_{CB} - Z_{CG} + \frac{\text{Moment of Inertia of Area About Longitudinal Axis}}{\text{Volume Displacement}}$$

- Z_{CB}: “Z” Component of Center of Buoyancy.

- C_B: Block Coefficient.

$$C_B = \frac{\text{Volume Displacement}}{L_{WL} \times \text{Beam} \times \text{Draft}}$$

- C_M: Midship Coefficient.

$$C_M = \frac{A_{MID}}{\text{Beam} \times \text{Draft}}$$

- C_P: Prismatic Coefficient.

$$C_P = \frac{\text{Volume Displacement}}{L_{WL} \times A_{MID}} = \frac{C_B}{C_M}$$

- C_{WP}: Waterplane Coefficient.

$$C_{WP} = \frac{A_{WL}}{L_{WL} \times \text{Beam}}$$

- C_{VP}: Vertical Prismatic Coefficient.

$$C_{VP} = \frac{\text{Volume Displacement}}{C_{WP} \times L_{WL} \times \text{Beam} \times \text{Draft}} = \frac{C_B}{C_{WP}}$$

- Immersion: Tons Per Inch or Tons Per Centimeter.

Weight units will be the same as those selected for the displacement on the main dialog; not necessarily tons.

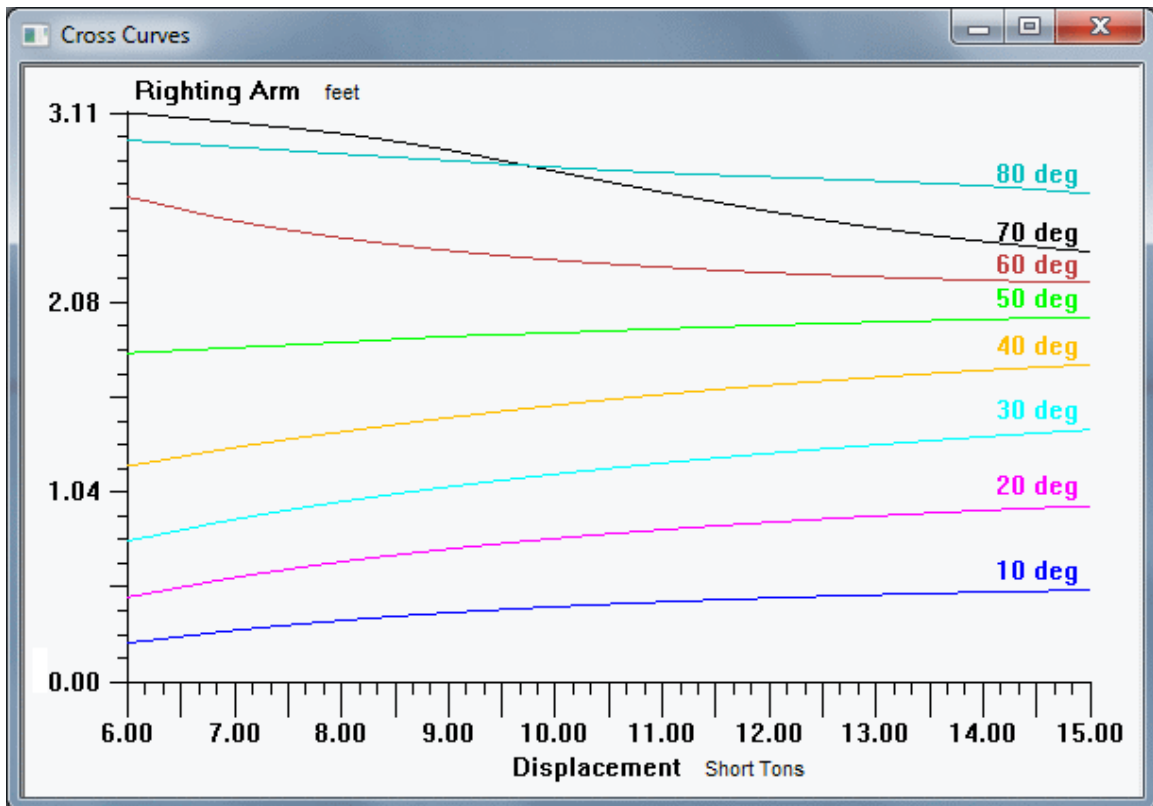
$$\text{Immersion} = A_{WL} \times \text{Water Density}$$

- MT: Moment to Trim One Inch or Moment to Trim One Centimeter.

$$MT = \frac{\text{Displacement Weight} \times GM_L}{L_{WL}}$$

Cross Curves of Stability Analysis

Selecting the button labeled “CC” on the main dialog launches a small dialog allowing the user to input the minimum and maximum displacements along with the desired increment. An analysis will begin at the first displacement and increment the desired amount for a maximum of ten displacements or the maximum specified displacement, whichever is less. The heeling angle range will be taken from the heel input boxes on the main dialog. The results plot will automatically launch.



There are no animation functions available when doing the cross curve analysis.

Equilibrium Analysis

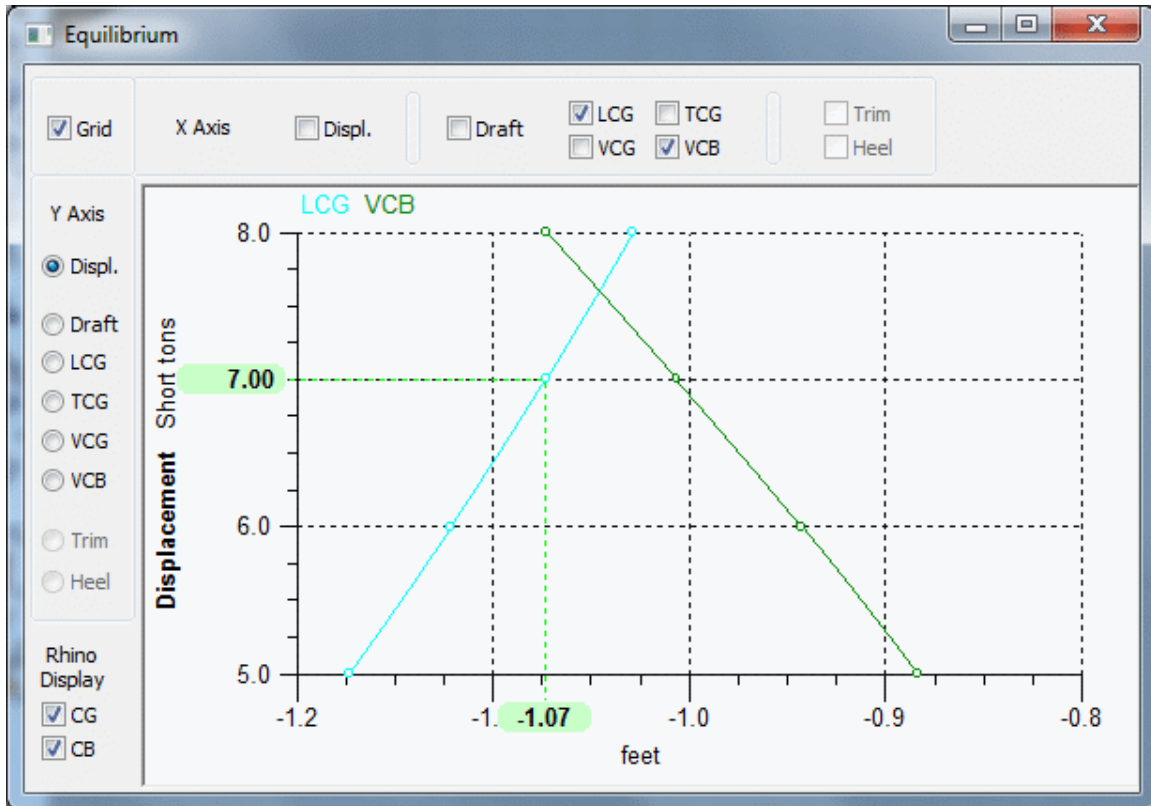
Selecting the button labeled “EQ” on the main dialog launches the equilibrium dialog.

The screenshot shows the 'Hull Equilibrium' dialog box. It has a title bar with 'Hull Equilibrium' and a close button. The main area is titled 'Variables' and contains four sections, each with a radio button and a text input field:

- Draft:** Radio button is unselected. Input field contains '4.3351, 4.5604, 4.7738'. Below it is the text 'Enter Comma Separated Draft Values'.
- Displacement:** Radio button is selected. Input field contains '5.0000, 6.0000, 7.0000'. Below it is the text 'Enter Comma Separated Displacement Values'.
- Fixed Trim / LCG:** Radio button for 'Fixed Trim' is unselected, and 'LCG' is selected. Input field contains '0.0000, 0.0000, 0.0000'. Below it is the text 'Enter Comma Separated LCG Values'.
- Fixed Heel / TCG:** Radio button for 'Fixed Heel' is selected, and 'TCG' is unselected. Input field contains '-0.2107, -0.2075, -0.2021'. Below it is the text 'Enter Comma Separated TCG Values'.

At the bottom of the dialog, there is a 'Calculate Equilibrium' button, and below that are 'OK', 'Cancel', and 'Plot' buttons.

RhinoHyd will perform a static equilibrium analysis based on the three input variables specified by the user. The variables are in three different categories. In the first category, the user may choose to specify either the required draft or the displacement. In the second category either the LCG is specified or a fixed trim. The final category is either a fixed heel or a TCG input. These selected variables become the independent variables for the static analysis and the unselected ones will be determined from the analysis and displayed in the edit boxes. Multiple tests may be performed by inputting the multiple test variables separated by commas. If RhinoHyd is unable to solve one of the multiple test cases, double commas will be displayed in the edit boxes for that case and will continue to solve the other cases. The ship may be animated to show the equilibrium state of the ship. If 3 or more test positions are calculated, the results may be plotted by pressing the "Plot" button.

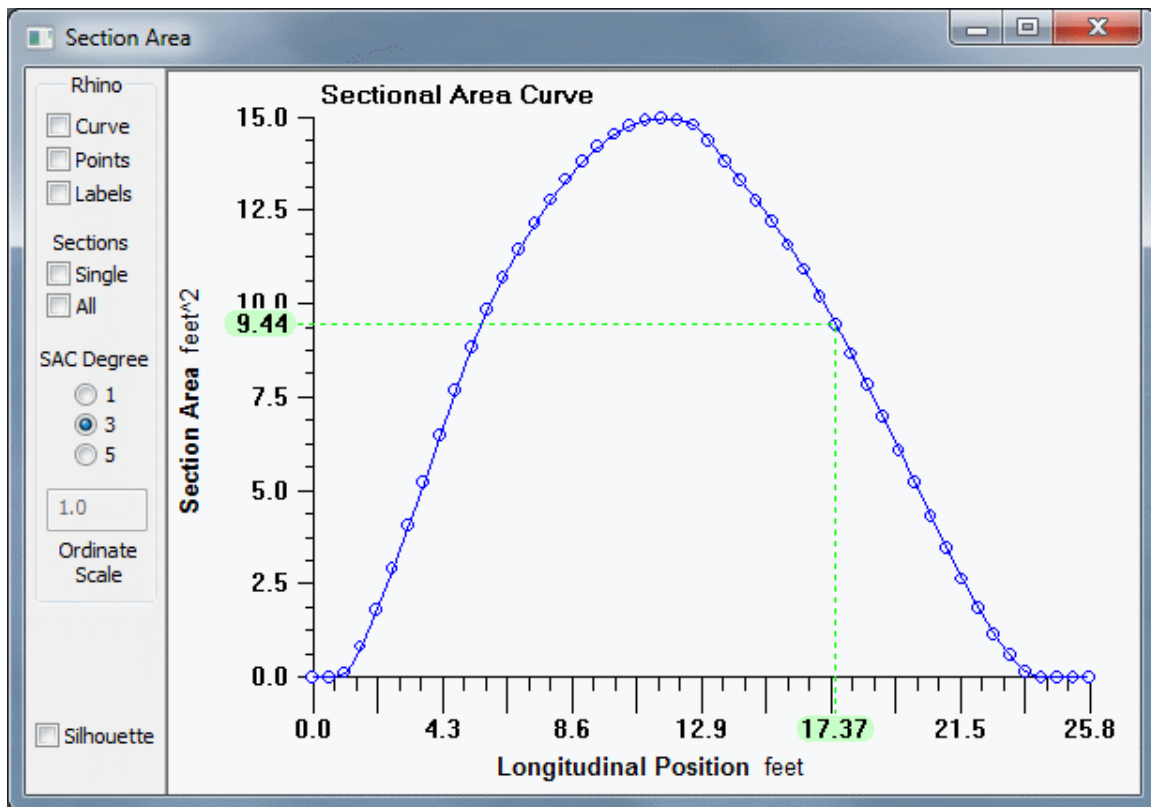


The ship CG and CB may also be animated by checking the appropriate boxes on the plotting window. The ship and points may be copied to Rhino by pressing the "Copy" button on the RhinoHyd main dialog.

Caution: If the equilibrium requires adjusting both the trim and heel angles, the resulting ship orientation as displayed in the animation may not align with the x-axis in the way you might expect. Although the ship will be in equilibrium, there might be some "yaw" (rotation about the z-axis) causing a very small change in the ship heading. This is the result of performing multiple finite rotations.

Sectional Area Curve Analysis

The final analysis mode calculates the area of sections below the waterline. The hull orientation will be just as you picked it with no hydrostatic balancing being applied. Selecting the button on the main dialog labeled "SAC" will prompt you to enter the number of sections you desire. Enter a number between 10 and 400. These sections will be evenly spaced along the hull and will be created directly from the hull surface, not the mesh.



The results are displayed in a graph as shown above. The usual animation controls are available. Additionally, the graph may also be displayed superimposed on your Rhino model. Selecting the check boxes located on the left side of the graph window, the SAC curve along with the data points and labels may be displayed. You may also display the sections. The "Single" check box will display the current section based on the animation slider position. It will also be highlighted. Selecting the "All" check box will display all the stations without highlighting. Selecting both check boxes will display all sections and highlight the current animated section. The "SAC Degree" radio buttons determine the degree of the interpolation curve to display in Rhino. The "Ordinate Scale" input determines how tall the curve will appear in Rhino. Using a negative value will flip the curve below the waterline. The "Copy" button on the main dialog will allow you to copy all displayed objects to the Rhino document. The "Silhouette" check box will draw a rough silhouette of your hull in the graph window.

Graph and Animation Controls.

Graph controls are located on the right side of the main dialog. The first two radio buttons control the curve interpolation. The “Curved” button creates a curved interpolation to be plotted and the “Linear” button creates a linear straight line interpolation. The “Data Pts” check box displays symbols at the location of the actual data points. The “Zero Line” check box displays a horizontal reference line at the zero ordinate value, if one exists.

Below these controls is a group box of controls labeled “Animation”. On the left side of the dialog are four check boxes to control what entities are animated. The first one is the mesh of the ship. Below that is a shaded mesh and a copy of the original ship surface. The last box displays any points of interest that may have been selected after a statical stability analysis. To the right of the dialog are four radio buttons to control the type of animated pointer for any displayed plots. The first is just a vertical pointer that will move horizontally over the graph as the ship is animated. The next is the crosshair pointer discussed above. It displays the ordinate and abscissa values for the ship in the current animated orientation. The next check box is a dot that moves along the curve as the ship is animated. When more than one curve is displayed, the mouse may be clicked on any of the curves to change which curve is followed.

The animation is controlled by the slider on the right side of the dialog. The output box above the slider will display the current position of the ship. For a statical stability analysis this will be the heeling angle and for a curves of form analysis this will be the draft of the ship.

Rhino Document.

When the user selects objects for analysis, RhinoHyd makes working copies so that the originals don’t get corrupted. No changes are made to the user's model document. When animations are performed, working copies of the document objects are used. These objects are displayed in Rhino’s display pipeline. The objects appear the same as the actual model objects but are really just graphical representations. The user can’t select or edit them. This allows for fast animations without having to modify the Rhino document and add objects to the undo list.

At the bottom of the dialog is a group box labeled “Rhino”. One of the buttons is labeled “Copy”. This button will take whatever objects are currently being animated or displayed in the pipeline and copy them into the Rhino document. This includes the meshed ship, the ship surface, and points of interest. If a shaded mesh is displayed, it will be copied simply as a mesh. The objects will also be added into Rhino’s undo list so that they may be removed with Rhino’s undo button.

The remaining button is labeled “Hydro” and is used to launch Rhino’s hydrostatic command. RhinoHyd will temporarily add the ship surface to the Rhino document in the current animated position. Rhino will then make the calculation and display its usual output dialog. When the user closes this dialog, RhinoHyd will delete the temporary ship from the Rhino document. This is a good way to double check the accuracy of RhinoHyd.

Appendix A. Scripting

Rhinoceros provides a scripting environment for programmers to interface and control Rhino from a Visual Basic script. See the Rhino web site for information.

Stability and curves of form analysis functions are exposed to script writers in order to extend the capabilities of RhinoHyd. Listed below are scripts demonstrating how to call the stability and curves of form functions. Input arrays are declared and filled with the required input information. Output arrays are declared and will be filled with information upon successful analysis. Both RhinoHyd functions will have a return value. If a return value of 1 is received, the analysis was successful. If a value less than zero is returned, the analysis failed. The returned arrays for stability contain data representing the righting arm, righting moment, the trim angle, and the heel angle. The returned heel angle array should always be checked because it may not be the same as what was initially requested, as has been explained in the body of this manual.

‘Demonstration script calling the RhinoHyd statical stability function.

Option Explicit

Call MyStabilitySub()

Sub MyStabilitySub()

Dim strSurf, arrIn(9), arrSetMesh(9), arrGZ(360), arrRM(360)

Dim arrGZarea(360), arrRMarea(360), arrTrim(360), arrHeel(360)

Note: The arrGZarea(360) and arrRMarea(360) arrays have been deprecated and no longer return any values.

'User Input

'Rhino.command "selnone"

strSurf = Rhino.GetObject ("Select Surface", 8+16)

If IsNull(strSurf) Then

Exit Sub

End If

Dim arrCG

arrCG = Rhino.GetPoint("Select Center of Gravity Point")

If IsNull(arrCG) Then

Exit Sub

End If

‘Required Input Arrays.

```

arrIn(0) = arrCG(0) 'X component of ship center of gravity point.
arrIn(1) = arrCG(1) 'Y component of ship center of gravity point.
arrIn(2) = arrCG(2) 'Z component of ship center of gravity point.
arrIn(3) = 10      'Ship displacement.
arrIn(4) = 0      'Ship displacement units code. (See below)
arrIn(5) = 64.2   'Water density. Units: Metric kg/m^3, English lb/ft^3.
arrIn(6) = 70     'Maximum heeling angle. Degrees.
arrIn(7) = 10     'Heeling angle step size. Degrees.
arrIn(8) = 0      'Include negative heeling angles? 1 = Yes, 0 = No.
arrIn(9) = 0.1    'Not used.

arrSetMesh(0) = 0.5 'Density. Range: 0 to 1.0.
arrSetMesh(1) = 20.0 'Maximum angle. Range: 5 to 90.
arrSetMesh(2) = 0.0 'Maximum aspect ratio. Range: 0.0 or 1.0 to 100.0.
arrSetMesh(3) = 0.0001 'Minimum edge length.
arrSetMesh(4) = 1.0 'Maximum edge length.
arrSetMesh(5) = 0.0 'Maximum distance, edge To surface.
arrSetMesh(6) = 16 'Minimum initial grid quads. Integer Range 0 to 10,000.
arrSetMesh(7) = 1 'Add mesh To Rhino document? 1 = Yes, 0 = No.
arrSetMesh(8) 'Not used.
arrSetMesh(9) = 0 'Refine mesh? 1 = Yes, 0 = No.

```

```
Dim rtn, MyObj
```

```
'Get RhinoHyd Object.
```

```
Set MyObj = Rhino.GetPluginObject("RhinoHyd")
```

```
'Call RhinoHyd's Stability Function.
```

```
rtn = MyObj.Stability(strSurf, arrIn, arrSetMesh, arrGZ, arrRM, arrGZarea, arrRMarea,
                    arrTrim, arrHeel)
```

```
'debug
```

```
Rhino.MessageBox rtn
```

```
If rtn < 0 Then 'error.
```

```
Exit Sub
```

```
End If
```

```
'Use arrays...
```

```
End Sub
```

```
.....
'Displacement Units Code
```

```
'English or metric is determined from Rhino document.
```

```
'English
```

```
'0 = Short Tons
```

```
'1 = Long Tons
```

'2 = Pounds

'Metric

'0 = Tons

'1 = Kilograms

'2 = Newtons

''''''''''''''''

'Length units are taken from current Rhino document.

The next script example demonstrates how to call RhinoHyd's curves of form function. The same return codes are used as the previous example.

'Demonstration script calling the RhinoHyd curves of form function.

Option Explicit

Call MyFormSub()

Sub MyFormSub()

Dim strSurf, arrInput(8), arrSetMesh(9), arrResults(16,10)

'User Input

'Rhino.command "selnone"

strSurf = Rhino.GetObject ("Select Surface", 8+16)

If IsNull(strSurf) Then

Exit Sub

End If

Dim arrCG

arrCG = Rhino.GetPoint("Select Center of Gravity Point")

If IsNull(arrCG) Then

Exit Sub

End If

arrInput(0) = arrCG(0)	'X component of ship center of gravity point.
arrInput(1) = arrCG(1)	'Y component of ship center of gravity point.
arrInput(2) = arrCG(2)	'Z component of ship center of gravity point.
arrInput(3) = 0	'Ship displacement units code. (See above)
arrInput(4) = 64.2	'Water density. Units: Metric kg/m^3, English lb/ft^3.
arrInput(5) = 5	'Maximum draft.
arrInput(6) = 4	'Minimum draft.
arrInput(7) = 0.2	'Draft increment size.
arrInput(8)	'Not used.

arrSetMesh(0) = 0.5 'Mesh density. Range: 0 to 1.0.
 arrSetMesh(1) = 20.0 'Maximum angle. Range: 5 to 90.
 arrSetMesh(2) = 0.0 'Maximum aspect ratio. Range: 0.0 or 1.0 to 100.0.
 arrSetMesh(3) = 0.0001 'Minimum edge length.
 arrSetMesh(4) = 1.0 'Maximum edge length.
 arrSetMesh(5) = 0.0 'Maximum distance, edge To surface.
 arrSetMesh(6) = 16 'Minimum initial grid quads. Integer Range 0 to 10,000.
 arrSetMesh(7) = 0 'Add mesh To Rhino document? 1 = Yes, 0 = No.
 arrSetMesh(8) 'Not used.
 arrSetMesh(9) = 0 'Refine mesh? 1 = Yes, 0 = No.

Dim rtn, MyObj

'Get RhinoHyd Object.

Set MyObj = Rhino.GetPluginObject("RhinoHyd")

'Call RhinoHyd's Curves of Form Function.

rtn = MyObj.CurvesOfForm(strSurf, arrInput, arrSetMesh, arrResults)

'debug

Rhino.MessageBox rtn

If rtn < 0 Then 'error.

Exit Sub

End If

'Use arrays...

End Sub

Output Array.

The output array, arrResults(16 x 10), is a 2 dimensional array. The first dimension represents the data type being output and is listed below. The second dimension will range from 3 to 10 draft values. For example, arrResults(0,0) is the displacement at the first draft value, arrResults(0,1) is the displacement at the second draft value.

- (0,) Displacement.
- (1,) Waterline length.
- (2,) Waterline beam.
- (3,) Longitudinal center of force.
- (4,) Longitudinal metacentric height.
- (5,) Transverse metacentric height.
- (6,) Center of buoyancy Z component.
- (7,) Waterplane area.
- (8,) Midship area.
- (9,) Block coefficient.
- (10,) Prismatic coefficient.
- (11,) Waterplane coefficient.
- (12,) Midship coefficient.
- (13,) Vertical prismatic coefficient.
- (14,) Wetted Surface Area.

(15,) Immersion. Displacement units per (Metric) centimeter, (English) inch.

(16,) Moment to change trim.

Returned error codes:

1 = No errors.

-10 = Invalid ship surface.

-11 = Failed to convert ship surface ON_Object to CRhinoObject.

-20 = VB VariantToArray() conversion failed on mesh parameter input array(arrSetMesh).

-21 = Failed to mesh.

-30 = VB VariantToArray() conversion failed on input array.

-40 = Failed to convert units. (Conversions needed to keep consistent units for calculations)

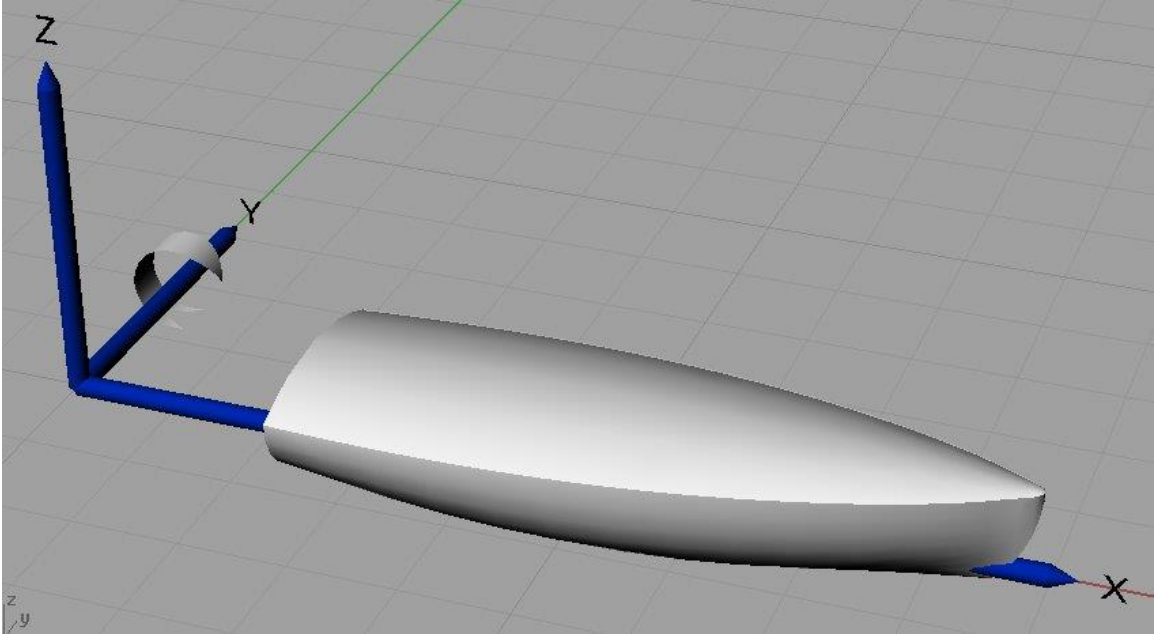
-41 = Maximum heel(arrIn(6)) less than 1 or heel angle step size (arrIn(7)) less than 1.

-50 = Sunk ship. Not enough ship volume to support the specified displacement.

-51 = Not enough RAM memory.

-52 = Other.

Appendix B. Orientation



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