KayakFoundry – User Manual

Version 1.5
March 18, 2006

KayakFoundry is a graphical kayak design program that has been tailored specifically for creating designs suitable for the wood-strip technique of kayak construction. It provides a rich environment with intuitive controls that allows you to create a design, finely-adjust its shape, examine and evaluate its hydrostatic properties, and ultimately generate printed cross-sectional and stem forms for construction.

Key Features

KayakFoundry contains a number of interesting features:

- Simple, intuitive user interface with adjustable detail level
- Dynamically computed hydrostatics and graphics including waterlines and buttocks
- Imperial or Metric numeric display
- Undo/redo operations
- Multiple-cockpit support
- Auto-positioned cockpit(s) based on center of buoyancy
- Display panels that can be resized or hidden to adjust screen real estate
- Zoom settings from 100% to 400%
- Exaggerated curve settings from 1x to 5x
- Optional grid with user-specified interval
- Scaling function to adjust length, beam, and/or height
- Flexible form printing with multi-sheet support, user-specified strip thickness, printer calibration, and model scaling
- Integrated KAPER drag prediction and support for the Broze drag-prediction spreadsheet
- Form export as set of coordinates
- Print study drawing or export as a graphics file (png)
- Simultaneous display of multiple designs (for side-by-side comparisons)

Registration

This program is offered as donation-ware. There is no registration fee required to use this program. However, if you like the program and find it useful, you can make a contribution of any amount that you feel is appropriate. To make this convenient, I've placed a PayPal button on the [KayakFoundry webpage](). If you sell designs developed with KayakFoundry,

sell kayaks built from KayakFoundry designs, or in any way use the program commercially, I do ask that you purchase a one-time license distribution. Please contact me for details.

Please send correspondence to:

> Ross Leidy
> rleidy@blueheronkayaks.com or refer to
> http://www.blueheronkayaks.com/contact.html for a mailing address

Support

The KayakFoundry BBS is a public forum for submitting questions, problems, comments and suggestions about the program. Please use this as the primary avenue to obtain support. I will closely monitor the board and do my best to respond in a timely manner. By keeping the exchange public, the board will benefit all users who may have similar comments, and will (hopefully) encourage and facilitate discussion.

Concept

KayakFoundry 1.0 followed a design model that was similar to that used by Robert Livingston's Bearboat program. That is, most of the kayak dimensions were under the control of the user, but the program would partially control the hull cross sectional shape based on a user-controlled volume distribution curve. In this model, the volume distribution was an input specified by the user, and it was used to help define the appropriate cross sectional shape of the kayak.

In KayakFoundry 1.5, I've moved to a model where the user has full control over the hull cross-section, and the volume distribution curve is a derivation of the shape of the underwater portion of the hull. In version 1.5, you do not shape the volume distribution curve directly – it is simply another bit of hydrostatic information generated by the program. The goal of these changes was to provide a more intuitive approach to controlling the shape of the design (certainly it is more in-line with general purpose CAD programs).

While you have control over the cockpit's shape, KayakFoundry computes its longitudinal position. The program always places the paddler's center-of-gravity (CG) directly over the kayak's center-of-buoyancy (CB). (To simplify calculations, the program assumes bilateral symmetry of both paddler and kayak so that both CG and CB lie on the centerline of the kayak.) The cockpit(s) will automatically shift as the CB changes (due to changes in the distribution of volume over the length of the kayak). This ensures that the trim of the built kayak will match that of the design. You'll know exactly how the kayak will sit in the water before you begin construction.

Overview of Operation

Briefly, here's how you use the program to design a kayak:

- Shape the kayak in Plan view (top), Profile view (side), and the Active Section view (cross-section). Each of these views contain a fixed set of control points that can be moved around to define the kayak shape.

- Provide the weight of the paddler(s), anticipated cargo weight, and estimated finished boat weight. Taken together, these parameters define the total target displacement of the design.
- Adjust the Design Waterline (DWL) in the Profile view to control the design displacement. The DWL should be adjusted so that the design displacement closely matches the target displacement. All hydrostatic information reflects the state of the kayak at that DWL. You can play around with the DWL to see how paddlers of different weights will affect the trim.
- Shape the cockpit to your desired dimensions. In multi-cockpit designs, each cockpit can potentially have its own shape or the can all share the same shape. The position of the cockpit is automatically moved by the program to keep the paddler's center of gravity (CG) over the kayak's center of buoyancy (CB).
- As you shape your design, you can evaluate the effects of those changes on the predicted drag of the design. The Drag Prediction tab displays a plot of drag vs. paddling speed, computed using John Winter's KAPER algorithm.
- Continue to refine the design until you are satisfied with the design and its hydrostatic properties. When you're ready to print forms, switch to the Form Layout tab, and define the form parameters and arrange the forms on a virtual canvas. The form layout is printed across multiple pages, which are then assembled in a grid. Tape the pages together, cut out the forms, and you're not far from placing the first strip on your new design.

Kayak Views

KayakFoundry displays the kayak design in a number of panels. Each panel provides some information that is useful during the design process. With a couple exceptions, the contents of each panel can be manipulated in some way to define or refine the shape of the kayak.

The main "Design" tab contains the following panels:

- **Hydrostatics** – Contains all the calculated numeric data about the design. It is organized in a hierarchical tree to make it easy to find the data that interests you. Nodes of the tree can be expanded or collapsed so the panel shows only the data you want to see at the time. Entries shown in blue can be modified directly. To edit the value, double-click or select the entry and hit <return>. Entries shown in black are derived values and cannot be modified directly.
- **Plan view** – The top-down view of kayak. It displays the sheerline, waterline(s), and cockpit(s). The cockpit shape and the curve representing the beam of the kayak along its length can be modified. The waterline curves are shown at 1-inch increments below the DWL.
- **Profile view** – The side view of the kayak. It displays the deck, sheerline and keel line, all of which can be modified. The buttock curves are derived.
- **Body Plan view** – The view of the kayak sighting down the longitudinal axis. Displays bow, stern or split bow/stern views. These curves are derived and cannot be directly manipulated.
- **Active Section view** – The section at the position of the sliding section marker. If this position corresponds with one of the 5 representative shaping sections, then the

hull and deck cross sections can be modified. Click on the graphical arrows to move to the previous/next representative shaping section. Also, the <spacebar> will move to the next section, and Shift-<spacebar> will move to the previous section.

- **Distribution of Volume** – The curve of areas along the length of the underwater portion of the kayak. This curve is derived from the underwater hull shape and cannot be directly manipulated.

- **Notes** – If you'd like to record notes to yourself or descriptions of the kayak as you create the design, you can enter notes in this panel.

The "Drag Prediction" tab contains the following:

- **Drag Plot** – Displays the drag resistance vs. paddling speed. There are 3 curves that represent frictional drag, residual drag, and total drag.

- **Drag Data** – Raw data for the 3 drag curves.

The "Forms" tab contains the following panels:

- **Forms Layout** view – Contains a virtual "canvas" for you to arrange the forms. The forms will be printed in the arrangement specified here. To move a form, click and drag it to the desired position. To rotate the form, use the left/right arrow keys while you have the form selected. To rotate to 45-degree increments, hold down the <shift> key while using the arrows. The stem forms can be mirrored using the right-click menu. If a form overlaps another, the forms will be shown in red. Usually, you probably don't want to print overlapping forms, so make sure you arrange the forms so that they're all green.

- **Profile Forms view** – Displays the position of each of the forms superimposed on the profile of the design. The red form can be dragged to define the position of the 1st form, which anchors the rest of the forms. The yellow form can be dragged to specify the form spacing. Its distance from the 1st form is replicated to all other form spacing. Both of these values can be specified in numeric forms in the edit fields on the left hand side. Bulkheads can be placed at arbitrary locations along the length of the kayak. Right-click to access the "Add a bulkhead" menu option. The bulkheads are shown in blue and are not subject to form spacing. They can be dragged to any position along the length. To remove a bulkhead, simply drag it off the end of the kayak and drop it.

  Tip: Use the "What's This" functionality to get context-sensitive help. Select Help/What's-This, Shift-F1, or click the icon to enter What's This mode. Then click on one of the panels or hydrostatic data items to get a brief description of its purpose.

Kayak Views

In the main Design tab, each panel can be hidden in order to gain more screen real estate for the view you're editing at the time. Panels can be shown or hidden using the corresponding View menu item or by using the right-click popup and selecting Hide. Panels can be resized dragging the splitter bars that separate the panels.

Each panel has a right-click popup menu containing entries to control aspects of that panel. Most entries will be self-explanatory. The only one that requires some discussion is "Hull Controls" that appears in the Plan and Profile panels. It provides a top and side view of the position of the hull-shaping control points along the length of the kayak. You cannot manipulate these points in the Plan and Profile views – the display is for information only. The hull can be shaped using the 5 representative sections in the Active Section view. (See Cross-Section Shaping)

Superimposed on the views are floating markers that indicate certain important positions – e.g., maximum beam at sheer (BOA), maximum beam at waterline (BWL), etc. These markers move automatically as you shape the design.

All of the curves can be shaped by manipulating control points (See Control Points and Curves). The control points are visible only in the panel that has focus. This makes it easy to identify which panel is being shaped, and it gets rid of clutter in the other views so you can focus on the shape of the kayak.

In the Plan, Profile, and Distribution of Volume panels, there is a sliding active section line that can be positioned anywhere along the length of the boat. The Body Plan and Active Section views display the cross section at that position. In addition, the Hydrostatics panel displays all the relevant data about that section (e.g., deck height, sheer width, etc.). Position the line by dragging the control arrow at the bottom of the line.

> **Tip:** Double-click in the panels to move the active section line instantly to a particular position. Double-click on individual sections in the Body Plan panel to that section the active section.

Input Fields

The Hydrostatics panel has a number of entries that can be modified directly. These entries are shown in blue to distinguish them from the static fields. To modify their value, double-click on the entry or select the entry and hit <enter>.

Some entries are string fields and there is no specified format. For example, the entry for the Design Name can contain whatever text you like.

Numeric entry fields have specific format requirements. Most fields will require you to enter a units designator after the value. If an invalid value is entered, or if the units cannot be determined, then the contents of the field will revert to the original value. With the exception of weight entry fields, all numeric entries must have units specified. Weight values without units will be assumed to be in the units corresponding to the current display mode. That is, if Imperial units are being displayed, then a unit-less number will be treated as lbs. If Metric units are being displayed, then a unit-less number will be treated as kgs.

The supported units are as follows:

Length Units: `<double quote>, in, ins, <single-quote> ft, mm, cm`

Weight Units: `lb, lbs, kg, kgs`

All entries must use only one unit designator, so if you want to enter 1 ft 3 inches, you must type **15in** or **15"** or **1.25ft**, etc.

In addition, the following numeric fields have valid ranges:

Bow Tip Radius:	0-25mm or 0-1 inch
Stern Tip Radius:	0-25mm or 0-1 inch
Cargo Weight:	0-136 kg or 0-300 lbs
Finished Boat Weight:	0-136 kg or 0-300 lbs
Half-angle Distances:	50-200 cm or 19 inches – 6.5 feet
Cockpit edge to CG:	0-200 cm or 0 inches – 6.5 feet
First Form Position:	10-61 cm or 4-24 inches
Form Spacing:	10-61 cm or 4-24 inches
Minimum Stem Length:	10-100 cm or 4 inches – 3.25 feet
Strip Thickness:	0-13 mm or 0-0.5 inches
Printer Calibration Multipliers:	0.1 – 1.5 (no units)

If you enter a value that is less than the minimum, the value will be set to the minimum. Similarly, if you enter a value that exceeds the maximum, the value will be set to the maximum.

> **Tip:** Notice that there is no specified range for paddler weight, but my advice is to keep it at a healthy level.

Control Points and Curves

All of the curve shaping is done by moving control points. Left-click on a point to select it. A red halo is drawn around the point to indicate that it is the selected point. You can drag the control point with the mouse, or nudge it in any direction using the keyboard arrow keys.

> **Tip:** Use the arrow keys when you want very fine control over positioning control points. Each keystroke (a nudge) moves the selected control point(s) 1mm.

Each control point has a specific degree of freedom. Most control points can be moved in any direction. Some are restricted to movement only in only x or y, and a couple of them are stationary. For instance, in the profile view, in order to force the bow to start at x=0, the control point at the tip of the bow can only be moved in the y direction. Similarly, in the plan view, the extreme end points of each curve ends at the centerline of the boat. Those control points allow motion in the x direction only – so don't worry about dragging those control points off center; they won't budge off the centerline.

Within a panel, multiple control points can be selected at once by using Ctrl-left-click on each point. Each newly selected point will have a red halo. When you move a selected group of control points, they all move so that they remain in the same position relative to each other. You can move the group by click/dragging any of the selected points, or by using the arrow keys. This can be convenient when you've got a curve about right, but want to shift its position a bit. The selected group of control points has its own degree of freedom based on the cumulative effects of each of the selected points. So, if you select one point that's restricted to x motion and another that's restricted to y motion, the group of points won't move at all.

> **Tip:** Use Control-click to select additional control points or click-and-drag to draw a rectangle around a group of points to select.

To deselect all selected points, click in an open area on the panel. When switching back and forth between panels, when you first give focus to a panel by clicking in it, the previously selected control points remain active. A second click in an open area will clear all selections. This lets you pop back an forth between panels to tweak the same control points in each without having to re-select the points each time.

Bezier Curve Details

All curves are cubic Bezier curves that have 4 control points each. KayakFoundry draws the first and last points as squares and the two middle points as circles. The first two and last two sets of points are connected by a dotted line. Bezier curves always pass through the first and last control points. This means that the square control points will fall somewhere along the curve of the kayak. Also, the shape of the curve at the endpoints is tangent to the line between the endpoint and the adjacent middle point. Anywhere you see a square endpoint, a circle control point, and a dotted line between them, the curve will be tangent to the dotted line as it approaches the square endpoint.

Each curve of the kayak is a spliced set of Bezier curves with shared endpoints. The last control point of the first segment is the first control point of the next segment, so they share a square control point. To ensure that there are no discontinuities where the segments are joined, the program forces many of these adjacent segments to share the same tangent. Visually, this appears as a teeter-totter motion between three control points with a square point at the center. This behavior is consistent throughout the different views.

The control points for a set of spliced curves all have the same color. Each set of spliced curves has a unique color within the panel. This helps distinguish which control points affect which curves.

> **Tip:** The orange and red control points affect underwater curves, gray control points affect the sheer curves, and green control points affect the deck curve.

Cross-Section Shaping

The mechanism for shaping the cross-sectional shape of the design deserves special attention. KayakFoundry defines five special sections spaced along the length of the kayak. These sections are referred to as representative shaping sections. The shape of these five sections indirectly controls the shape of all other sections. KayakFoundry blends settings of consecutive representative sections to arrive at the shape of the intermediate sections. At each representative shaping section, you can control two deck control points and two hull control points. Move between the shaping sections by using the arrow buttons in the Active Section view or use <space> or shift-<space> to move to next/previous shaping section.

As you drag the control points to shape the cross section, the curve will be drawn in **red** if any part of the curve falls outside the rectangle bounded by the top of the deck, the keel, and the max beam of the section. Any red is generally not a good idea since it means that cross section is not a "standard" shape. You should always take steps to remedy this situation.

When the Active Section view displays any section other than the representative shaping sections, it will display the interpolated positions of all cross-sectional control points as smaller dots. You cannot manipulate them directly, but they do let you see where the points are located.

Zoom/Exaggerate

There are two features that help you to generate smooth curves: Zoom and Exaggerate. Each panel can be zoomed from 100% to 400% in 25% increments. The right-click popup has a Zoom entry to let you select a particular setting. You can also use the plus/minus keys to increment/decrement the zoom level. With all zoom settings but 100%, the panel will contain scroll bars. Drag the scroll bars or use Shift-<arrow key> to position the view.

The curves in the Plan and Profile panels can exaggerated to make it easier to judge fairness. The exaggerate function scales-up the y-coordinate of each curve in the panel. The scaling settings are 2, 3, 4, or 5 times actual y values. The right-click popup has an Exaggerate entry to let you select a particular setting. You can also use Control-plus/minus to increment/decrement the exaggerate level. You may need to hide some of the panels to see the entire exaggerated curve.

Used together, the Zoom and Exaggerate features provide an effective combination to aid in creating fair curves.

Detail Level

The Options/Detail-level menu gives you control over the detail level used in the display panels. If you find that the program is slow to update the screen (particularly true when one panel is maximized), you can drop the detail level and the performance will improve. This is a global setting and will affect all active designs.

This setting controls the details in the following way:

- **High** – Displays clouds and color gradients
- **Medium** – Displays color gradients
- **Low** – Displays no color gradients

Single, Double, or Triple

KayakFoundry lets you design a single-, double-, or triple-cockpit kayak. Control-A adds another cockpit, Control-R removes a cockpit. When you change the number of cockpits, the Hydrostatics panel changes to reflect the new number of cockpits. Each cockpit has settings for shape, the weight of the paddler, and the distance from the aft-edge of the cockpit to that paddler's center-of-gravity.

The 2nd and 3rd cockpits have settings for spacing. This spacing corresponds to the distance from the aft edge of that cockpit to the aft edge of the cockpit directly in front of it. Based on all these settings, the program calculates a cumulative center-of-gravity, which it always places directly over the kayak's center-of-buoyancy.

Each cockpit can have a separate shape, or they can all share the same shape. Only the first cockpit of a particular shape will have control points in the Plan view.

As you add cockpits, the kayak's total displacement will increase. You will need to move the DWL upwards to compensate for the extra displacement. Adjust the DWL until the Design Displacement is approximately equal to the Target Displacement. This will give you an indication of how the kayak will trim with the specified paddler weights.

Undo/Redo

The program supports unbounded number of undo/redo operations. Undo the last movement with Ctrl-Z, redo the operation with Ctrl-Y. Multiple consecutive movements of a particular point is considered one movement. So, if you move one control point around to ten locations, an undo operation will move it back to its original location. Movement of a group of selected points is considered a single operation. As you undo/redo control point movement operations, the program displays the points selected. If the panel containing those control points happens to be hidden, you will not be able to see any undo/redo activity, but the undo/redo operation does still occur.

Printing

KayakFoundry can print station forms, stem forms, and cockpit templates. Before printing, the forms should be arranged on the virtual canvas in the "Forms" tab. The forms will be printed according to this layout. Forms that are overlapping at all will show in red. Usually, you don't want any overlap, so make sure all forms are shown in green before printing.

The Print Forms dialog contains a checkbox for each form. The checkboxes control which of the forms will print. Forms are printed according to the form layout canvas using with multiple sheets of paper. Each page will contain registration marks to make it easy to align adjacent pages.

The printer calibration option allows you to fine-tune the accuracy of the printed forms. It's a good idea to do this once on each printer to check the dimensions of the calibration sheet. If it's off, you can specify a multiplier to allow KayakFoundry to compensate for the inaccuracy. Print the calibration sheet, then measure the true dimensions of the printed rectangle. If the dimensions are incorrect, calculate the ratios that are described on the sheet, and enter the values in the specified edit fields. Print another calibration sheet to verify the new dimensions.

The Print Forms dialog also allows you to print scaled-down forms for use in constructing models. There are pre-set selections for 1/2 , 1/3, and 1/4 scale factors and a custom scale factor that allows values from 1/0.5 to 1/12. When printing scaled forms, the printed forms indicate the scaling factor, and the printed dimensions and distances are adjusted to reflect the scaling. So, if you have specified 12" as the form spacing and you select 1/3 scale, then the printed forms will show a spacing of 4". The strip thickness setting is scaled as well.

> **Note:** As the forms are scaled-down in size, the inner curve that accounts for strip thickness will become less accurate - (e.g., it won't exactly follow the outer curve in a parallel fashion). Expect smaller forms to get a little funky as they are scaled-down – especially the tips of the stem forms.

The printed study plans provides a one-sheet view of the kayak design along with the designer's notes (if any) and some of the more pertinent hydrostatic values. The outline views of both the deck and profile can be used to sketch possible strip patterns. Study plans for most kayaks will look best if printed in landscape orientation, but if you are designing a relatively short kayak, portrait orientation may be more appropriate.

On both printed forms and study plans, the dimension will be printed using the currently active numeric display mode (Imperial or Metric).

Export

Should you want to import forms into a separate CAD package, KayakFoundry provides an Export dialog. The Export dialog is very similar to the Print Forms. The Export dialog contains additional settings to allow you to tailor the format of the exported form coordinates. Each form curve is represented as a list of X,Y coordinates that can be processed by other applications. With Microsoft Excel, the exported file can be imported as a comma-delimited file. Select the X and Y columns, and create a XY scatter chart to view and verify the exported coordinates.

A Word about Precision

All dimensions are stored and manipulated in millimeters (mm). When converted to Imperial units, some imprecision can result. For the most part, this is not a problem because the sheer size of the kayak dwarfs any resulting rounding error. KayakFoundry varies the precision of displayed Imperial units to reduce useless fractional information for larger values. The following scale is used to determine the displayed precision of decimal numbers.

- **Values < 1 inch** – rounded to the nearest 1/1000th of an inch
- **Values < 2 inches** – rounded to the nearest 1/100th of an inch
- **Values >= 2 inches** – rounded to the nearest 1/10th of an inch