

# Bearboat Kayak Building Manual

Version: 9/2/2000

## About this Manual

This mini manual is intended to assist the user in understanding the functions of the bearboat kayak building program. I hope to make these instructions just extensive enough to guide a user through the basic structure of the program. The user is expected to “experiment” enough to come to a deeper understanding on their own. There is a tutorial at the end of the manual which will take a user through the basic steps of creating a kayak.

This program is shareware. It may be freely distributed. There is no charge for this program.

I would ask people who try and use this program to send me a short note to tell me whether or not they were successful installing the program. If people are having difficulty, then I would like to know, and perhaps one person's experience can help another.

If you ever actually build a kayak, I would enjoy seeing a picture of it.

The program runs in the Windows environment. A monitor capable of displaying 800 by 600 pixels is required.

I welcome comments and questions. Please communicate via e-mail. I will strive to answer such questions as I can. Users should understand that any questions directed to me are potentially public. I may simply accumulate in a document questions about the program and my answers to them to assist others that might have the same questions.

I encourage suggestions on improving the program but realize that my main interest in writing this program was to aid myself in designing my own boats. I am reluctant to spend a large amount of time adding functions that are of no value to me. On the other hand, people have already made suggestions that I have incorporated. Some are ideas that were simple and intriguing to me. Others are ideas that I had not thought of myself but which I nonetheless perceive of being of value to me in the design of my own boats. As the author of the program, I am aware of what things are easy to do and what things would require a major rewrite and the former are more likely to get adapted. If you find features of the

program confusing, drop me a line. I may be able to help you and others by making the manual clearer. Any feedback is appreciated.

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## Bugs

All programs have bugs. Therefore I am sure that this one does. The user should take the initiative to make sure that the output of this program makes sense before actually trying to build a boat. Make sure that the output fits your concepts of the boat you are trying to build. If the boat is supposed to be 21" wide, make sure that it is etc. It should be obvious that I cannot guarantee the accuracy of the output of this program. Let the user beware.

Having said this, I am interested in squashing any significant bugs. I have not spent a huge amount of time trying to prevent problems with users entering ridiculous (nonsensical) values. It is probably possible to crash the program by entering negative numbers or doing things like making the maximum width of the boat some point behind the stern.

If you see any anomalous (incorrect) results or strange behaviors when you are doing things that seem rational, please notify me so I can correct or clarify the situation.

There are "anomalies" that the user may notice at the very ends of the boat. This program is rooted in the character of the underwater cross-section. Once the boat leaves the water (at either end) it is difficult to assure a smooth transition for all the different shapes that the user might specify. Trying to write the program to always make smooth transitions from cross-section to cross-section at the point that the boat is leaving the water is complex enough that I have not devoted too much effort to it. I have written to code to "grossly" smooth the transitions here. *(As of version 10/31/99 these anomalies are largely a thing of the past. See the discussion of Area too Small to Determine the Water Angle in the Constraints section)*

In "real life" this is not much of an issue. The boat builder would sand or plane away these anomalies without much difficulty. I believe that the very ends of a kayak should be sculpted taking into account the aesthetics of the entire boat. If you have experience with building kayaks, you will realize that it is relatively easy to modify the bow and the stern but very difficult to modify the middle portions of the boat. Once you have the basic boat built, you can create any type of bow or stern that you desire. On the other hand, if you decide at this stage to make the middle of the boat a quarter of an inch thinner, you are in for a lot of fairing work.

## Introduction

The primary output of this program is a bunch of drawings of the cross-sections of the boat you have designed. The output is on simple 8.5 by 11 paper. The program accommodates to the fact that many of the cross-sections will require more than one piece of paper to draw. For these larger cross-sections, you tape a few pieces of paper together.

The program determines the shape of the underwater section of any cross-section of the boat by determining the minimum wetted surface that will enclose the area specified by the user and constrained by the waterline width and depth of the boat at that position. With these three values, (waterline width, submerged cross-sectional area and depth) there is a uniquely determined curve that will be drawn for that cross-section. When I wrote the earliest versions of this program 25 years ago, this was the issue that interested me the most. There is logic to minimizing the wetted surface as this helps minimize the resistance of the boat moving through the water. I wanted to figure out the family of curves that would be the minimum wetted surface subject to the constraints of the waterline width and depth, and I could not do that without a computer. Much of the rest of the program is window dressing for this fundamental idea.

Optionally, the program provides the possibility of additional constraints on the individual cross-sections beyond the basic three of underwater cross-sectional area, waterline width and depth. The designer can specify that the bottom of the cross-section cannot be completely flat by providing a minimum angle at the keel line. Similarly, it is possible to constrain the sides of the underwater area to an angle less than vertical.

Overtime, I have become more interested in the window dressing as once you get to a “reasonable” point in terms of wetted surface, there are other things that are of interest in terms a designing a boat that meets other needs (comfort, stability, storage capacity, surfing performance etc.) Despite this “maturation” of my thinking, the minimum wetted surface curves remain valuable, and this program still rigidly allows only the underwater curve that is the minimum wetted surface (subject to a few "constraints" that can optionally be applied - see below). This is not, in practical terms, that much of a straightjacket. You can easily modify the cross-sections that this program provides. The program can get you into the ballpark and you can go on from here. For example, it would not be hard to design a chine boat from the cross-sections that this program provides.

The curve of the deck and the curve of the above water sides of the kayak are decided by the user choosing from one of a number of “families” of possible curves.

There are many ways and materials that are used to make kayaks. In the past, I have made fiberglass boats and have used the predecessors of this program to make the plug. My own construction technique has been to cut out of foam the cross-sections of the boat at every 10 cm. I place these cross-sections, appropriately spaced apart, on a straight stick the length of the boat and plank the result.

It should be obvious that there are many other techniques and modifications that can be used.

The program is also capable of making reduced size models of the boat that you are designing. You can specify, for example, that you want cross-sections that are 1/5 life-size to allow you to make such a model which can be helpful in the design process.

A secondary output is a bunch of numbers describing the cross-sections of the boat that you have designed. (width, height etc). These files are created as comma delimited files that can be "read" by other programs (spreadsheets or word processors). The ability to document your design in this great detail is particularly useful for people who might have the opportunity to design more than one boat in their career. This enables you to compare your early designs (with whose behavior you have now become familiar) with later designs. This also enables you to compare

your design with existing kayaks that have features you either like or dislike.

Individual designs are stored on the computer as rather small files. You can create and modify many different kayak designs. If you want to try a variation on one of your ideas without "losing" your original, hit the Save as... button on the home screen and give your current kayak design a different name.

The smallness of these files make it convenient to collaborate or share with others who have the program. It is easy to e-mail them or to place them on a floppy and transmit them this way.

I am personally exploring trying to create an output that can be used by giant milling machines that exist in a few places in the country to carve out a life-size 3D foam copy of the boat the user has specified. I do not know if I will be able to achieve this but would like to use this technique for my own next boat. I would like to hear from anyone who has knowledge in these matters. Some of the additional work that I am doing with the program now is to make such an approach at least theoretically possible.

## Units of Measurement

Metric units are generally used throughout, primarily centimeters. Make sure that if you want to design a boat that is 21 inches wide you do not end up with a boat that is 21 centimeters wide. On some screens, I have a secondary expression of a measurement as foot-inches as an aid to those more familiar with these units. These measurements are provided as white text adjacent to the metric equivalent.

An exception is the displacement. Displacement is expressed in lbs. (pounds) a non-metric unit.

1 Kilogram = 2.2046 pounds.

On the same page that displays the displacement in pounds, one can see the underwater volume in cubic cm. For those more familiar with the metric weight unit, the underwater volume number in cubic cm is the displacement in grams. (1000 \* the displacement in kg). For fresh water,

1 cubic centimeter weighs 1 gram. The waterline is calculated as the fresh water waterline. Because salt water is slightly heavier, the boat will ride slightly higher in salt water

The bow of the boat is at position 0 (zero). The stern of the boat is at position x, where x is the length of the boat in centimeters. All the measurements of where things are on the boat are based on this framework.

The surface of the water is considered the zero point of the vertical plane. Entities, such as the height of the deck or the seam, are measured from the surface of the water NOT from the lowest point (bottom) of the boat.

## Definitions

Deck Line: The line running the length of the boat in the midline connecting the highest point of every cross-section

Keel Line: The line running the length of the boat in the midline connecting the lowest point of every cross-section

Seam Line: The lines running along each side of the boat connecting the widest point of every cross-section

Design Weight: The user designs a kayak effectively specifying a particular weight that determines where the waterline of that boat will be.

Waterline: This is the line running along each side of the boat where the surface of the water is when the kayak is at its design weight. Used in some places as synonymous with the greatest depth of the boat. (Draft is another, perhaps more correct, term for this)

Waterline Width: This is the distance between the waterlines on each side of the boat, i.e. the width of the boat at the waterline. With a boat constructed using this program, the waterline width at any point is less than (or rarely equal to) the Seam Width at that point.

Deck Height: Distance from the highest point of the deck to the surface of the water. Deck heights vary along the length of the boat.

Depth: Distance from the bottom of the boat to the surface of the water. The depths are expressed as positive numbers for the submerged part of the boat. Where the keel line is above the waterline, (at the bow and stern) the depth is expressed as a minus number.

Seam Width: Distance between the two seam lines at any given point, which is the same thing as the width of the boat at that point.

Seam Height: Distance of the Seam Line above the surface of the water.

Bow Seam Height: Distance of the bow of the boat above the surface of the water

Stern Seam Height: Distance of the stern of the boat above the surface of the water

Position: Distance in centimeters from the bow of the boat.

Entry: Position near the bow where the keel line enters the water

Exit: Position near the stern where the keel line leaves the water

Waterline Length: Length of the part of the boat that is in the water (Exit-Entry)

Wetted Surface: As applied to a boat, this is the area of the boat that is in contact with the water. It would be expressed in centimeters squared. I also apply this term to an individual cross-section. In this context, it is the length of the line of that cross-section which is in contact with the water and would be expressed in cm.

MinKeel: This is a minimum width that the boat hull can attain. This assures that keel-like structures are thicker than the specified minimum.

MinSeam: This is a minimum width that the boat can attain at the seam line. This assures that the ends of the boat are not knife edges. For many methods of construction this is not particularly important as "real-life" will prevent knife edges.

# Home

This is a screen that contains a number of buttons that either perform simple functions or take you to the parts of the program that perform more complex functions. This is the screen that opens up when the program starts.

## **Restore Generic Kayak Defaults**

May be used to return to the default values that the program uses as a starting point. If the designer has specified other parameters, they will be replaced by the default values. If you wish to be able to restore the values as they currently exist, remember to save your kayak design before using this button.

The Generic Kayak is not any "real" design. It just is a set of parameters that can start you on your way to your own design.

## **Open Kayak**

Allows the user to find and open the file that contains data on a boat that they have already designed or partially designed and previously saved to disk.

## **Save**

Allows the user to save any changes that have been made to the kayak being designed. The user can thus return to the project at another time. If a friend has the same program on their computer, you can send them this very small file by e-mail or whatever. In this way, you can collaborate with others very simply.

## **Save as...**

Saves the kayak design currently being worked on. The designer will be prompted to provide a name for this kayak so as to create a new file.

## **Save Text Records of Boat Defining Parameters**

Allows user to create a text file that contains the various parameters that have been specified for the boat that they are working on. Any spreadsheet or word processing program can open this text file. The user could then print out the text on paper This is one form of "backing up"

your work. If you lost your files off your hard disk, the paper copy could be used to help reenter the defining parameters.

If you are using Excel or Word to open these files, make sure that in the Open dialogue box "All files" is selected so that you can "see" the file that was created. By convention, the name of the file contains the date that it was saved as well as the name of the kayak being designed. Once these text files are in Excel or Word or Word Perfect then you can print them out or print out pieces of them.

The file created is a comma delimited file so follow the instructions of your spreadsheet to open this kind of a file.

### **Bow Right Checkbox**

By default, the graphics show the bow of the boat to the left. After this program was substantially complete, I received feedback that many boat designers are accustomed to have the bow of the boat to the right. This checkbox is to accommodate such people.

### **Jumbo Kayak Checkbox**

Some people might wish to use this program to pursue boat designs with boat parameters (length, width etc) that are greater than those expected in strict kayak design. Checking this preference relaxes some of the constraints on entered values that are otherwise in place.

### **Decimal Feet**

This program uses metric measurements. In some places, the equivalent value in feet/inches is provided for the assistance of people who "think" in these measures. If this preference is checked then these ancillary measurements are displayed as "decimal feet". For example, 6'4" would be 6.33'

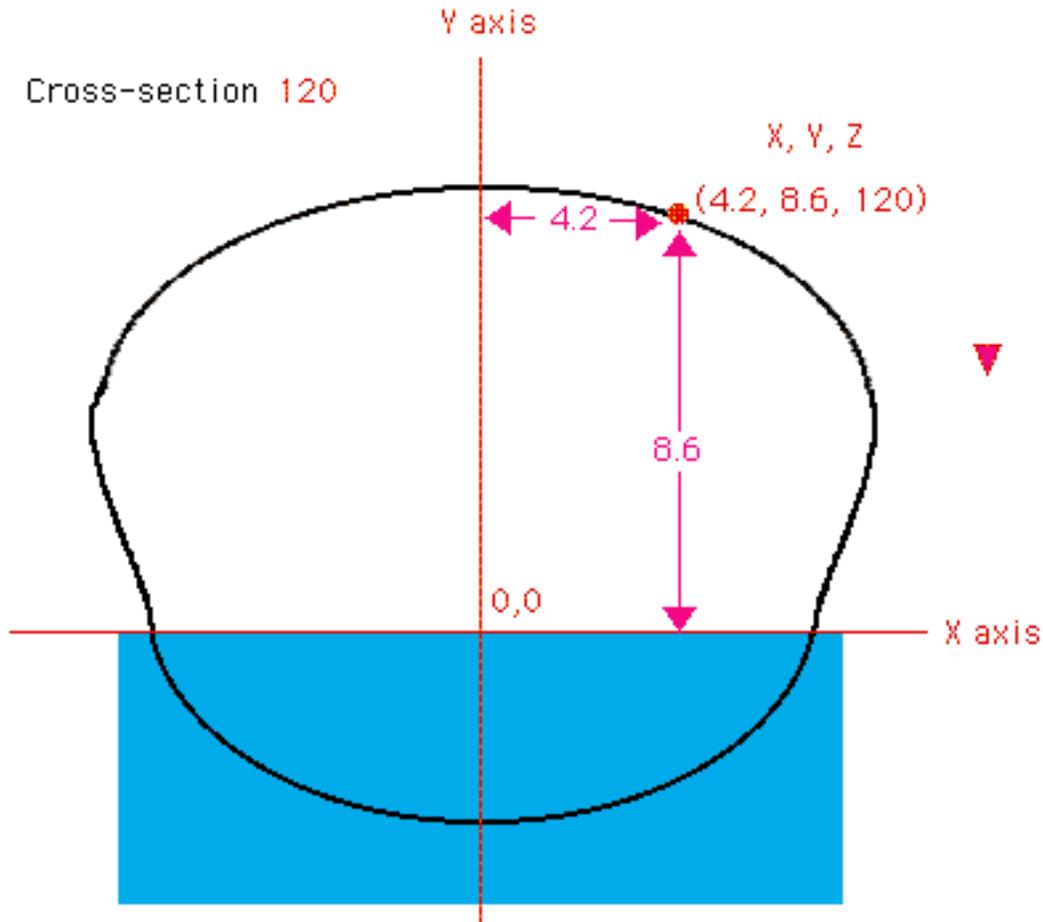
### **Print Plans...**

This will allow you to print on paper all or some of the cross-sections of the boat being designed. In the left upper box, you specify which cross-sections that you want to deal with. Underneath, in the box at the lower left, you chose whether you want the drawn cross-sections to be full size or smaller. (you can draw the cross-sections 1/6<sup>th</sup> life-size , for example, so that you can model your design on a smaller scale.)

As of version 00621, there is a new box labeled Table of Offsets. This allows you to create text files (comma-delimited) that contain the digital data that describes the various cross-sections that have been chosen. The purpose of this is primarily to get the data from this program into a form that it can be imported into other programs. There are 3D visualization programs and 3D modeling programs that could allow you to "see" your design or to modify your design with the tools these other programs provide. This also allows you to export data in a form that can be read by some computers that do 3D milling of shapes.

I have adhered to a couple of conventions. The data is provided for "half" the boat. Since kayaks are bilaterally symmetric, this essentially describes the entire boat. You may have to duplicate the data set with one of the parameters (X) made equal to the negative of its value in the other set.

The surface of the kayak is described as points in space specified by their X, Y, Z coordinates. The Z coordinate identifies where along the length of the boat the cross-section lies. A point with a Z coordinate of 50 is on the cross-section that is 50 cm from the bow. The X coordinate describes how far from the midline of the kayak that point lies. The midline of the boat has an X value of 0. The point that is at the widest place on the boat will have an X value of half the boat's width. The Y value is the distance of the point from the waterline. Negative values refer to points that lie underwater. Positive values refer to points that are above water.



These text files can be quite large as you can produce the X Y Z values for many points on many cross-sections. The cross-sections are specified in the box in the upper left of the form as is the case for specifying which cross-sections to draw out. There is a slider that determines the "granularity" of the data. You can create data at X-values of every so many millimeters as specified by this slider. The default is every 10 mm (1 cm) but you can set the slider to produce points at every 1 mm. This can produce many tens of thousands of points if you use a value here of 1 mm for every cross-section of the boat. The number of points can even overwhelm the program into which you intend to import the data so care should be taken with this. The more points you specify, the longer is required for the program to complete the task, but it can be expected to finish within a few minutes even for very large files.

There are a few options for exactly how the data is output. The most "primitive" and least structured is the X Y Z choice which simply produces a large text file with every line just consisting of another point

specified as X, Y, Z (for example 10.5, 4.4, 100). This is probably the most likely form to be directly imported into another program. Other options provide a form that is more "formatted" for human consumption and can be opened with Excel as an example, to see the numbers. Just follow the instructions for opening a comma-delimited file. If you use Excel, be sure to open the program first, then go to the file menu to open the file after setting the open dialogue to see all files, and then follow the instructions for opening a comma-delimited file.

This functionality has not been heavily tested so use these numbers with care. If you do import them into a 3D visualization program, you should be able to see any "anomalies" that are present. I have not had problems with my own designs.

### **Hatches**

I have included an option to locally modify the deck profile to accommodate hatches of the design that I happen to prefer. I have included this options for others who might like to use it.

### **Construction**

The four buttons in this area allow the user to move to the major windows that are used to actually design the kayak.

## **Curve of Areas**

As the kayak is designed, the user can go back and forth between Curve of Areas, Sideview, Birdview and Cross-Section. It makes the most sense to start with the Curve of Areas although some may find this a little abstract. This is a curve created by drawing a graph of the underwater area of the boat (y axis) vs. the position from the bow to the stern (x axis). The smoothness of this graph assures that the boat will have a smooth shape as it start thin and small at the bow, expands to a point somewhere near the center of the boat and then tapers toward the stern. This curve determines a host of parameters that characterize your design such as the displacement, center of buoyancy and the prismatic coefficient.

There are a number of parameters that determine the shape of the curve of areas. Entry and Exit define the waterline length and determine where the keel line enters and leaves the water. The Max Cross Sec Area is the

size of the largest cross-sectional area. The Loc of Max Area is the position of this largest cross-sectional area. The Length is just the overall length of the boat and is less important here as the curve of areas is primarily concerned with the underwater length.

There are 4 arbitrary parameters that can be adjusted to affect the shape of the curve. Many of the curves in this program use this technique. The first parameter affects primarily the first quarter of the curve while the second the second quarter etc. As the number increases, that part of the curve becomes “fuller”. By default, the left side of the graphic is the bow and the right the stern.

The curve of areas determines many of the properties of the boat. Any reasonable curve of areas will produce a reasonable boat. Here you can decide how fine the entry of the boat will be. Here you decide the weight capacity of the boat. The center of buoyancy and the displacement of the boat are all determined by the curve of areas. The prismatic coefficient is determined by the curve of areas.

Grid and Line Location are simply tools that might aid some users in creating the curve of areas that they want. Enter a value into the box. Notice that the labels of those tools are colored rather than simply black. Click on the label to put them on the graph. This is a convention used throughout the program. Look for the colored labels. Click on them. This will frequently result in a related change to the graphic.

There is a new checkbox Show Max Limit. If this is activated, it indicates the upper bounds of what cross-sectional area is possible at any given point along the boat. It displays a red zone. If your curve of areas moves into this "red zone" then you are asking the "impossible".

This issue is discussed elsewhere in this manual but basically there is an upper limit of underwater cross-sectional area that can be accommodated by a kayak of any given waterline width and depth. This is not that complex to understand. Let's say there is a point along the length of the boat that has a waterline width of 50 cm and a depth of 10 cm. It is not going to be able to accommodate a cross-sectional area of greater than 500 cm<sup>2</sup> (10 cm \* 50 cm). That would be a rectangular underwater cross-section. If you "ask" for more than this in the curve of areas module, then later you are going to have to change other parameters in other modules (primarily the width and or depth of the boat) You cannot

expect to specify a boat 16 feet long, 21 inches wide with a draft of 2 inches and expect it to carry 900 lbs. The curve of areas module does not prevent you from creating whatever curve of areas you want, but if you do not adjust other parameters when you find yourself in the "red zone" then the cross-sections will be "impossible". You will see this when you try and visualize the cross-sections in the cross-section module.

As changes are made, they accumulate on the graphic. To refresh the graphic and erase all the accumulated lines, click anywhere on the graphic. This "clean-up" method is used throughout the program.

Derived values, such as the Center of Buoyancy, are displayed on a yellow background. This convention is used to indicate values that cannot be directly changed by the user but which are derived from parameters that the user has provided.

While a number of the parameters can affect the displacement, the major variable is the size of the largest cross-sectional area. The program allows you to enter a value in the displacement box and the maximum cross-sectional area will be adjusted to match this displacement. This is an exception to the general rule that the values in yellow are derived from the primary data and cannot be changed except by changing the primary data. Although the displacement is a derived value, in this case one can enter data into it and the primary value (largest cross-sectional area) will be changed to match it.

The Old Curve button allows the user to see the curve on the boat as it existed the last time that boat was saved to disk. This can help orient the user to where she started if the accumulation of changes has become confusing.

## **Birdview**

Allows the user to view the boat under design from the top. Here the user provides the parameters that determine the width of the waterline and the width of the seam line along the length of the boat. This program assumes that the seam width at any point is greater than or equal to the waterline width. Occasionally boats are designed that do NOT obey this rule. In canoe design, it is called tumblehome. This program will not behave properly if you enter values that result in the waterline width being greater than the seam width.

The waterline is displayed in blue. The seam line is displayed in black.

There are 4 arbitrary parameters that can be adjusted to affect the shape of the waterline and 4 arbitrary parameters that can be adjusted to affect the shape of the seam line. Many of the curves in this program use this technique. The first parameter affects primarily the first quarter of the curve while the second the second quarter etc. As the number increases, that part of the curve becomes "fuller". By default, the left side of the graphic is the bow and the right the stern. Click on the graphic to refresh it and remove extraneous lines that may have accumulated.

Checking Big Seam or Big Waterline exaggerates the side to side scaling of the drawing which might assist some users.

The Location line will draw a line on the graphic to indicate a particular position. To see where position 300 is, enter this value in the box and then TAB out of it. A green line will indicate this position on the graphic. This line is "erased" if you refresh the graphic by clicking on it. It can be restored by clicking on the wording Location Line.

The half angle of entry and exit are values that are of use to some kayakers trying to optimize their design. This is a measure of how fine the bow (or stern) are at the waterline. Clicking on the colored lettering will result in graphics indicating these values being projected on the picture. The point used to measure the half angle is arbitrarily defaulted to 100 cm down the hull. This can be changed by the user.

The Print button will provide you with a copy of the overhead view of your boat printed on a single sheet of paper.

## Sideview

Allows the user to view the boat under design from the side. Here the user provides the parameters that determine the depth of the keel, the height of the deck and the height of the seam line along the length of the boat.

There are 4 arbitrary parameters that can be adjusted to affect the shape of the seam line and 4 arbitrary parameters that can be adjusted to affect the shape of the keel line. Many of the curves in this program use this technique. The first parameter affects primarily the first quarter of the

curve while the second the second quarter etc. As the number increases, that part of the curve becomes “fuller”. By convention, the left side of the graphic is the bow and the right the stern. Click on the graphic to refresh it and remove extraneous lines that may have accumulated.

In this module, you are determining the seam line as seen from the side. This program assumes that the seam line is straight or that it dips down in the middle. Occasionally boats are designed with what is called reverse sheer. The seam line (sheer line) of these boats is higher in the center than it is at the ends. This program does not support this sort of seam line. The seam line is determined by black parameters.

The keel line is determined by the blue parameters. Display of the boat profile at the bow and stern of the boat (The part that is out of the water) is arbitrary. I have selected mathematical formulas that create a curve that I happen to like over a wide range of values.

The bow (and stern) of a kayak are small and easily modified. Much of the character and aesthetics of a kayak come from how these elements are treated. I consider this really to be outside the bounds of the computer program. This is where the sculptor and the artist hold sway. When building a boat, I generally recommend that designers deal with the bow and the stern last and integrate these elements in with the rest of the boat. A beautiful bow can make an ordinary boat shine.

The deck line is handled somewhat differently. The user provides as many values of the deck height as are desired and the program connects them with lines. This determines the height of the deck at any point. Remember the height measurements are from the surface of the water and NOT from the bottom of the boat. These lines can be smoothed if desired. (Soft vs. Angular)

The Print button will provide you with a copy of the side view of your boat printed on a single sheet of paper.

## **Cross-sections**

Allows the user to view the boat cross-sections. The top third of the control area allows the user to specify the visualization of multiple cross-sections. By convention the bow half of the boat is displayed in white and the rear half in black.

The middle third allows the user to display an individual cross-section, which is shown in yellow. Details about that particular cross-section are provided. If you do not want to see this yellow cross-section, click on the word Position. By clicking on the slider controls in the middle section you can visually travel down the boat seeing one cross-section after another. One you have clicked on the slider, it is "activated" and the right arrow and left arrow keys on the keyboard become alternative ways to move one cm toward or away from the bow. For me, traveling back and forth over a segment of the boat in this fashion, gives me a feel for the how the shape transitions that I cannot get in any other way.

The bottom third allows the user to determine what shape is desired for the sides and deck of the boat. If you click on the check box Include Straight Lines, you will see the pentagon whose vertices have been determined by the other modules (Birdview and Sideview). The underwater section is already determined by the program minimizing the wetted surface but it is arbitrary how the waterline is to be connected to the seam line and the seam line to the deck line. In this bottom third of the control area, the user chooses from the families of curves that are available to determine the shape, as seen in cross-section, of the sides and deck of the boat. You choose one family for the side and one family for the deck and that is applied to the entire boat. This gives an aesthetic unity to the craft.

For the deck, I have always used semi-ellipse, which has worked well for me. Others like a more peaked deck and I have provided other options to allow for this. For the side, I have always used straight, but the default is Bezier. If Bezier is selected, two slider bars appear that allow you to modify the curve of the side of the boat. The upper slider affects the curve more toward the top which the lower slider affects the curve more on the bottom. Moving the sliders to the right tends to make the curve "fuller" while moving them to the left makes the curve "flatter".

If the Bezier option is chosen for the deck shape, similar slider bars will appear to allow slight modifications to the deck shape.

It is possible to have made incompatible choices in the other modules. It is possible that you have chosen a cross-sectional area at a given point that is larger than can be achieved with the depth and waterline width chosen for that same point. The program will indicate this by drawing the underwater cross-section in red and appending a triangle shape to the

underwater area. This can be solved by making the cross-sectional underwater area smaller here in the Curve of Areas module or by increasing the depth in the Sideview module or increasing the waterline width in the Birdview module or some combination of the above. The generic boat has some "incompatible" values at the very bow and stern of the boat. These will display in red. One could chase these down by modifying some combination of parameters but in these particular locations they are not very important. A couple of strokes with a sander in the "real" world will take care of them. You need not be very concerned with red cross-sections that appear very close to the bow or the stern.

### **Constraints**

This allows the user to specify additional constraints on the computer's construction of the underwater cross-section. With no additional constraints, the computer will create the cross-section with the minimum wetted surface given the task of creating a cross-section of a given area, depth and width.

The MinKeel parameter forces the kayak to have a minimum width at all points to the underwater cross-section (i.e. there are no knife edges at the bow or stern or at the keel line. This is to further a goal of mine of producing output that can be used by a computer driven 3D milling machine. This function is not very relevant for someone intending more conventional construction techniques. Knife edges will be suppressed by the nature of the material of which the boat is being constructed.

The MinSeam parameter forces the kayak to have a minimum width at the seam. It is impossible to have a MinSeam that is narrower than the MinKeel. Again this function is not very relevant for someone intending more conventional construction techniques. Knife edges will be suppressed by the nature of the material of which the boat is being constructed.

With no additional constraints, certain cross-sections may have a completely flat bottom and certain cross-sections may have a completely vertical sides. There is nothing intrinsically wrong with either of these two things, but it is possible to constrain the program to prevent them. The water angle is that angle that the side of the underwater cross-section makes with the water surface. Vertical would be 90 degrees. This can be constrained to some lesser value. The keel angle is that angle that the

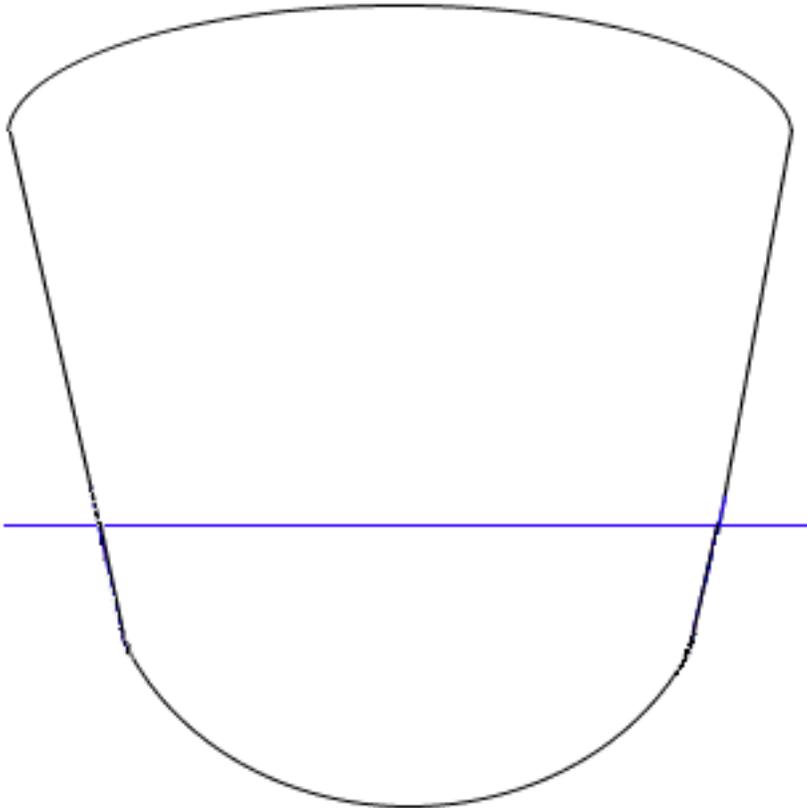
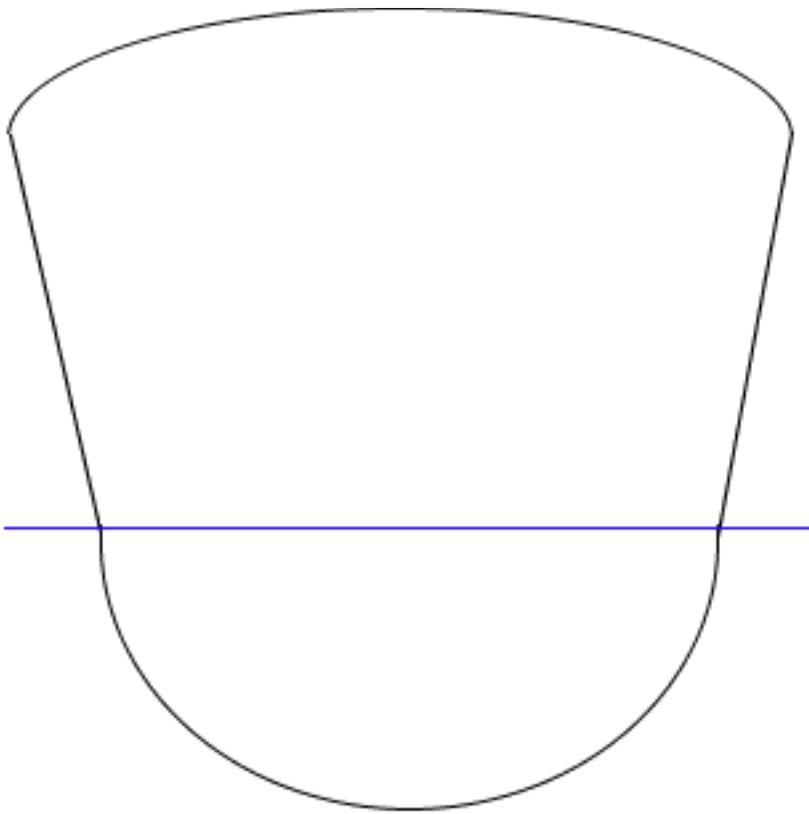
bottom of the boat makes with the vertical in the midline. If the boat is completely flat in the midline that angle would be 90 degrees. This can be constrained to some lesser value which will assure that there is a definable keel line that runs the entire length of the boat and that the boat is nowhere flat on the bottom. Some designers prefer this. A slight angle at the keel line helps to stiffen the boat which some the construction materials will require. The program does not allow a constraint of less than 60 degrees for either of these parameters.

The water angle can be additionally constrained by checking the box Underwater Angle Constrained by Side Angle. The side angle is determined by the height of the seam and the overhang (the difference between the width of the seam line and the width at the water). Normally, the underwater shape of the boat is totally independent of these variables. The effect of this independence is that there can be a concavity at the waterline under some circumstances. In other words, when looking at the cross-section, it is possible that the side of the underwater part of the curve is more vertical than the side of the over the water part of the curve. Most commercial designs will not show cross-sections of this type from which we can conclude they are not popular although I prefer them under some circumstances. In any case, to avoid this one can check the Underwater Angle Constrained by Side Angle box. This constrains the shape of the underwater part of the curve to be no more vertical than the line between the seam and the side of the boat at the waterline. There are limitations on the power of this constraint. It will not force the underwater side to be less vertical than 60 degrees.

It is possible to "increase" this constraint by a few degrees by using the slider that appears when this constraint is checked. This is primarily useful if you have chosen to use Bezier sides. There are many factors that influence the appearance of the cross-section when you use Bezier sides. This is just one of them. On the cross-section window itself, when you chose Bezier sides, two slider bars appear that also have an influence on the shape of the cross-section. Adjust these parameters to get the effect that you want.

In the figure below, the top cross-section is not constrained, and there is a slight concavity at the waterline. The bottom cross-section has been constrained by the side angle and there is no concavity at the waterline. This illustration is from a setting where Straight sides have been chosen. The effect of this constraint is clearest in this situation. As discussed in

the previous paragraph, the situation is more complex when Bezier sides have been chosen.



An entry box will accept a value for Area too Small to Determine the Water Angle. In general, this should just be left at the default of 15. This is a new feature that was introduced into the program on 10/31/99. For those who have designed boats using previous versions of the program, this value will be zero. You might consider changing the value to 15. This

will smooth the transition of the cross-sections of the boat as they emerge from the water at the bow and the stern.

It is difficult to explain the effect of this parameter but it is not difficult to demonstrate. Take the Generic boat and in the cross-section area make

Start=2

End=50

Skip=2

Then click the Draw button. The cross-sections will meld with each other very smoothly. Now go to the constraints area and change the Area too Small to Determine the Water Angle to zero. Now go back to the cross-section area and click on the Restore button. You will see a region near where the boat is exiting the water where the cross-sections do not appear to be blending together well.

This occurs because when the cross-sectional area becomes very small the angle at which the underwater section emerges from the water becomes very sensitive to tiny changes in the parameters. Thus adjacent cross-sections can have considerably different angles and this causes the above water sides of the boat to vary in their appearance, particularly when Bezier sides are chosen. By making the value of Area too Small to Determine the Water Angle 15, the program uses an alternate method to calculate this angle when the cross-sectional area falls below 15 which assures a more rational behavior. You may find for some design that a value greater than 15 is required to deal with this "instability" but generally 15 should do the job.

Most designers will want to simply leave this value at 15. If you have designs created with versions prior to 10/31/99, you should consider modifying them by changing that parameter from zero to 15.

### **Drag Spreadsheet**

Matt Broze has created a spreadsheet, available on the Mariner Kayaks web page ([www.marinerkayaks.com](http://www.marinerkayaks.com)), that analyses aspects of kayak performance given the values of various parameters. The button here will pull up a window that summarizes the data for your design that should be entered in this spreadsheet should you care to take advantage of it. It is

possible to simply cut and paste from this window into the spreadsheet. If you copy the text from the Copy and Paste window, you can paste this into the cell A9 in the spreadsheet to save the bother of individually entering many of the parameters.

### **Wetted Surface**

Pushing this button will provide the user with additional information about the wetted surface of the kayak. A graph of the wetted surface from the bow to the stern of the boat is provided. This is compared with the wetted surface of an idealized boat that has the minimum possible wetted surface for that displacement, underwater length, and curve of areas. This would be a boat that had perfect hemispheres for its underwater cross-sections. (It is possible to build such a boat but they are rather tipsy craft.) A second graph is provided of the "difference" at every point between the kayak being designed and an idealized boat with hemispherical cross-sections. There is also a button on this page that will provide you a text file that contains the wetted surface and other measurements at every cm of the boat. This file, after it is created, can be read by a spreadsheet such as Excel or by a word processor.

### **Print Plans**

Allows the user to print out on paper the cross-sections of the boat. You can specify that you want a printout of the entire boat at any given interval or ask for just one or two cross-sections. It is also possible to get a scaled down model of the boat you have designed. You can print out the cross-sections using a B&W or a color printer.

To orient the various cross-sections with each other, the waterline is indicated in BLUE on the color print out and there is a grid relative to this waterline plane. The grid is GREEN. The vertical midline is also in BLUE. You may have to look carefully to appreciate this difference. On the B&W print out, the waterline is a solid line while the grid is a dotted line.

When the size of the cross-section does not fit on a single sheet of paper, multiple sheets of paper are printed out for each cross-section with enough overlap that you can tape these pieces together to create a full-size cross-section. To aid in this process, the sheets are labeled at the top with the notation A1 or B3 etc. The letter refers to the column and the number with the row. Thus if three columns of paper with two rows (6 sheets) were required to draw out that particular cross-section, they

are labeled A1, B1, C1, A2, B2 and C2. The grid uses dotted lines every 2 cm and dashed lines every 10 cm. This aids in orienting the various sheets of paper with one another so that they may be properly taped together.

This area also allows you to create a file that contains all the values of the specified cross-sections and can be read using a word processor or a spreadsheet. It is best read using a spreadsheet. The file created is a comma delimited file so follow the instructions of your spreadsheet to open this kind of a file. (This is easy to do in Excel. Start Excel. Then choose Open from the file menu. In the dialogue box adjust so that it "sees" all files. Open the file you have created and choose comma delimited from the appropriate check boxes.)

## Hatches

There are an infinite number of hatch designs, and I would expect only a minority of builders to agree with my own preferences in this regard. For those who do share my preferences, the Hatches window will allow you to specify hatches of a given diameter and position along the deck. These parameters will locally modify the deck profile to create flat circular areas where a hatch can be mounted. This focal, round, flat area will be integrated with the rest of the deck. This module will not "work" if the arched deck option has been selected (it does work with Bezier and the Semi-Ellipse deck shape options).

There is an additional parameter, Angle, which determines how the edge of the hatch area slopes up (or down) to meet the normal deck contour. An angle close to 90 degrees will create close to vertical sides to the hatch area. Lesser angles will create more gentle transitions.

## Summary

This manual covers most of the highlights, but to learn the program you have to use it. Feel free to push buttons and try anything that you want. This is the way to come to a better understanding of the program. There is nothing in this program that is particularly difficult.

Remember to save some time for paddling.

## Frequently Asked Questions (FAQ)

1. "Why doesn't the program fit on the screen?" Answer: You must have your screen set to at least 800 by 600 pixels. There is a control panel in Windows called Display. One of the settings set by that control panel is the Desktop Area. This determines whether you are displaying enough pixels to run this program.
2. "I have the Display set to 800 by 600 pixels and I STILL do not have enough room to run the program. Why not?" Answer: The Display control panel has an additional setting called Font Size. The font size should be set to Small Fonts. Otherwise, with 800 by 600 pixels you may still not have enough room to run the program.
3. "I ran into a problem when running the 'setup' exec. It was looking for a file called Kayak990708.ex and couldn't find it. There was a program called Kayak990.ex in the zip files, so I changed the setup file to look for this one, and that worked." Answer: Probably you are trying to run the program on a version of Windows prior to Windows 95 and those older versions will not recognize file names longer than 8 characters. This user was able to figure this out and correct the problem. I would either upgrade to a later version of Windows or try the solution that this user was successful with.
4. Another user writes: "It appears that the setup program looks for a file called "kayak991031.ex" When I looked more carefully at the results arising from the un-zipping expansion of the download from Mariner Kayaks' site; I could find a file titled something like 991031Kayak, but not "kayak991031.ex. I was, however able to find a file called "kayak991.ex", which looked suspiciously like it might be the one "setup" wanted. I therefore used explorer to re-name "kayak991.ex" with the moniker "setup" had been unable to locate (kayak991031.ex). After doing the above, "setup" seemed to run perfectly; and I was able to start the program, run the tutorial, etc." This user had problems similar to what is outlined in 3 and again was able to solve the problem. I am not sure why this occurred because he was not using an old version of Windows. The newer versions of the program will, by the way, have different names (ie "Kayak000314.ex" rather than " Kayak991031.ex ")

If you have questions about the program, e-mail to me at [bearboat@attglobal.net](mailto:bearboat@attglobal.net) or [rlivingston@mac.com](mailto:rlivingston@mac.com), and I will strive to answer them in this section for future versions.

## **More on Constraints (or Why the Red Lines?)**

The subject of constraints causes users more confusion than any other part of this program. Many users are confused by the fact that their designs are producing many cross-sections in “red”. The “red” is used to indicate a conflict in the chosen parameters. A further discussion of this topic follows.

Consider any random cross-section on your design. There is a basic hexagon made up of six vertices that determine the shape of the cross-section (FIGURE 1).

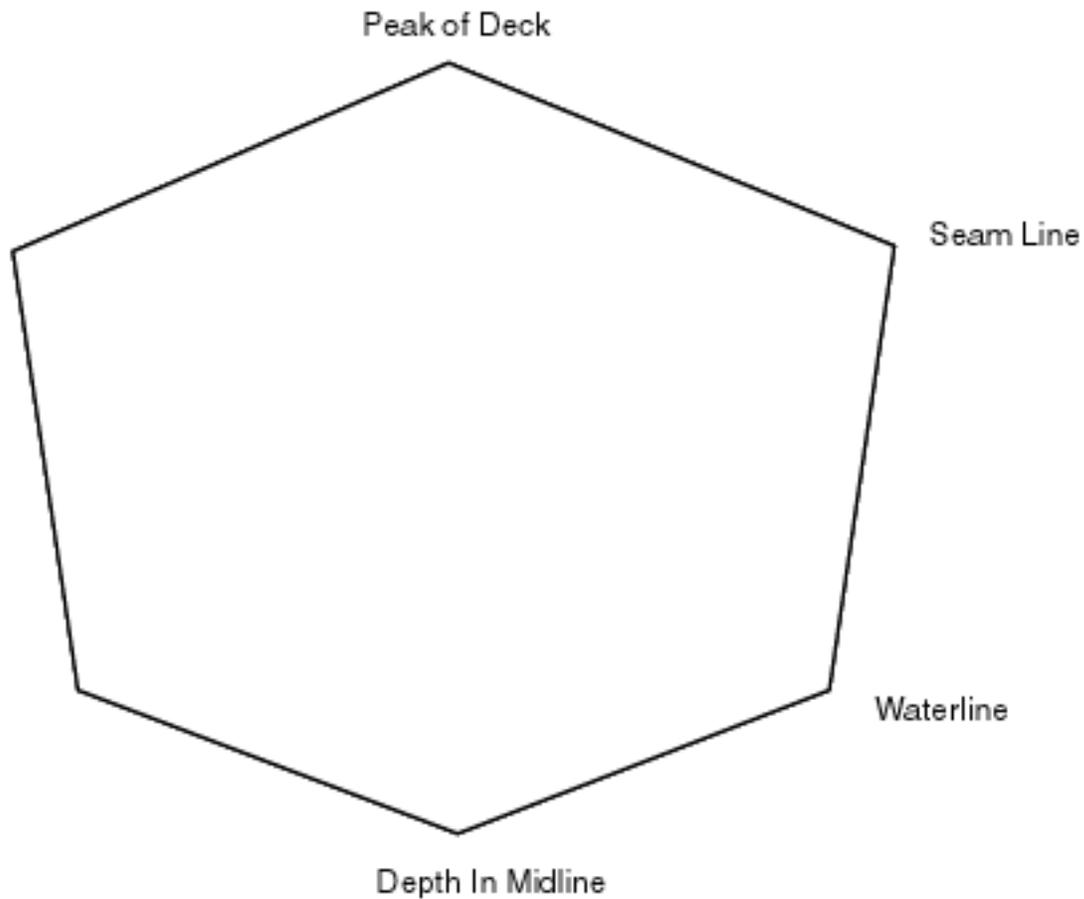


FIGURE 1

1. There is a vertex in the midline at the top. The Sideview module determines the position of this vertex; it is the height of the peak of the deck.
2. There are two vertices that define the seam lines. The height of these vertices is determined by the Sideview module, the horizontal distance between these two vertices is determined by the Birdview module.
3. There are two vertices that define the waterline. The horizontal distance between these two vertices is determined by the Birdview module.
4. The final vertex is in the midline at the bottom. Its position is determined by the Sideview module; it is the depth of the kayak at that position.

Once these vertices are fixed, the program creates the curves that connect them and defines that particular cross-section. Above the

waterline, this is fairly simple. The program allows the user to choose from a limited number of families of curves that determine the character of the curve that creates the deck and a limited number of curve families that determine the curve that creates the above water side of the kayak.

The creation of the curve below the waterline is more complex. The program will draw the curve that will result in the minimum wetted surface and still conform to the constraints. This depends on one additional parameter that the user has specified in the Curve of Areas module, i.e. the cross-sectional area of that underwater section. It is possible that a conflict will occur among the three parameters that determine the underwater curve of the cross-section. Those three parameters are the depth of the underwater curve, the width of the waterline and the cross-sectional area. The most frequently encountered problem occurs when the cross-sectional area is greater than that which can be accommodated by the depth and the width of the waterline. The program indicates the problem by drawing the underwater cross-section in red.

To illustrate these issues, consider the family of curves that would be created to accommodate progressively greater underwater areas if the ONLY constraint were a given waterline width and with the program trying to minimize the wetted surface. These curves seem reasonable as long as the cross-sectional area remains below a certain value. After this value is reached, the underwater sides start to blow out laterally. In FIGURE 2, you can see that the curve 5 and curve 6 are starting to bow laterally

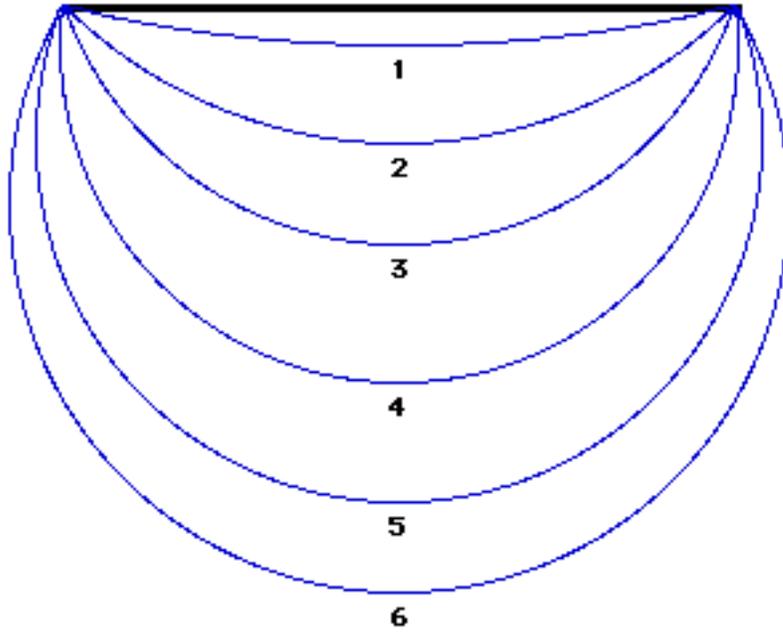


FIGURE 2

Now consider the family of curves that would be created to accommodate progressively greater underwater areas if there were TWO constraints, the waterline width and the depth. This is closer to the actual behavior of the program. Again these curves seem reasonable as long as the cross-sectional areas remain below a certain value. After this value is reached, the underwater curve starts bulging out laterally and down on each side of the midline. In FIGURE 3, you can see that curve 4 are bowing out laterally and inferiorly.

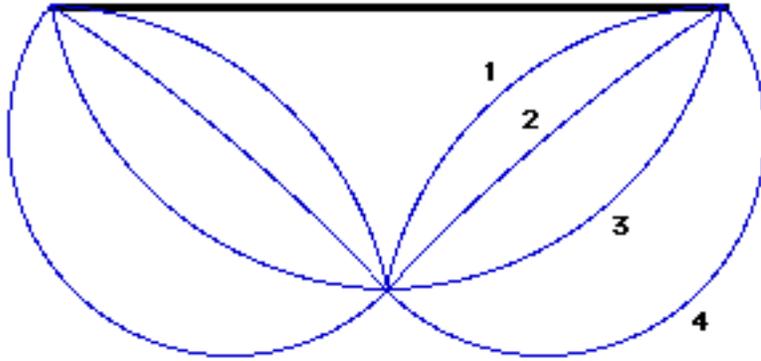


FIGURE 3

The fact that the program does NOT show curves with these bulges reflects the fact that there is an additional “unstated” constraint on the minimum wetted surface curves. First, the depth of the boat can nowhere be greater than the depth of the boat in the midline. Secondly, the width of the underwater section can nowhere be greater than the width of the boat at the waterline. So really, the family of underwater curves is constrained by a rectangle whose width is the waterline width and whose depth is the midline depth of the boat (FIGURE 4).

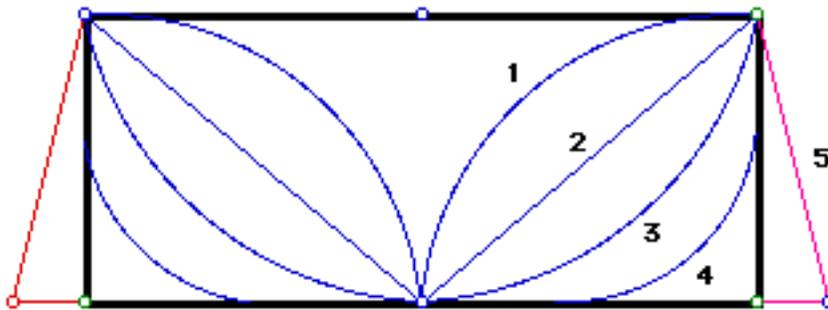


FIGURE 4

With the curves constrained by this rectangle, a problem occurs when the specified cross-sectional area is greater than the area of this rectangle. The designer is responsible for adjusting the relevant parameters so that this does not happen. The program alerts the user to this problem by drawing the cross-section in red and by appending triangles to each side of the rectangle to create a cross-sectional areas as great as that

demanded by the curve of areas. This is illustrated by curve 5 of FIGURE 4. The size of these appended triangles gives the user a visual cue of how far off he is. To “cure” the situation, one can increase the depth or increase the waterline width or decrease the cross-sectional area or some combination of the above.

This is relatively straightforward. But the situation becomes more confusing when the user specifies additional constraints, particularly the water angle and the keel angle. By placing these additional constraints, the likelihood of a conflict greatly increases. The area in which the underwater curve is created is now more confined (FIGURE 5). Users may find that many of their cross-sectional drawings are plagued with red. It has become easier to specify at any given location a cross-sectional area that is larger than that possible within the other constraints.

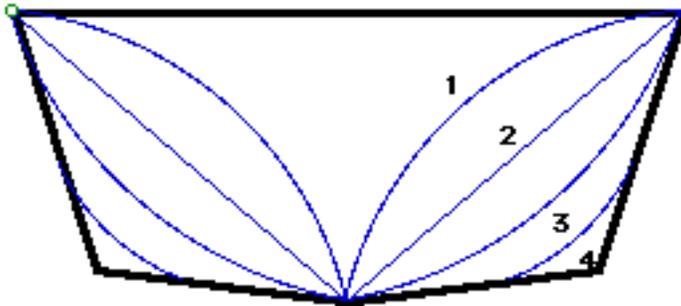


FIGURE 5

As a practical matter, it is wise to design your craft first with NO additional constraints. Once the kayak has been roughly specified, start judiciously applying the additional constraints. If you want a keel angle of 75 degrees, do not apply that value at first. Try a value like 85 degrees and then review your cross-sections to see if things are still OK. Then try 80 degrees. By working your way down towards the goal of 75 degrees in steps, reviewing the cross-sections at each step, it is much easier to understand the conflicts that may arise. Do not change the water angle and the keel angle at the same time. Make a change in only ONE constraint and see its affect on all the cross-sections before changing the other one. This cautious technique will allow you, the designer, a much better understanding of what is happening than would be the case if you radically changed the water angle and the keel angle. If you do the latter, you can go back to the cross-sections and just see them all “having problems” i.e. all drawn in red.

Applying a marked water angle can create another conflict that will be indicated by the underwater cross-section being drawn in purple. If the boat at a given cross-section is relatively deep and narrow then a given water angle may be too severe and prevent the underwater section from getting to the required depth. The program will draw a cross-section in this circumstance that breaks out of the confines of the water angle. It is easy to simply ignore this “problem”. The underwater cross-sections will be reasonable. They are drawn in purple just to bring the situation to your attention. This circumstance is relatively rare.

As was pointed out elsewhere, minor problems at the very ends of the boat are not really all that important. Where the underwater area is very small and the depth is shallow and the width is narrow, it is easier for conflicts to occur. In this location, they are not very important as they are easily “sanded out” in the real world.

To summarize, if you are having a problem with understanding why some of your cross-sections are drawn in red, start removing or lessening any constraints that are present. By loosening these constraints, the red cross-sections will disappear. Then start reapplying the constraints in a graduated fashion, checking the cross-sections at every step. This will allow you to understand the problem and where and why it is occurring. If you do not have any special constraints applied and are still having problems, try considerably increasing the depth of the boat. This will make the red cross-sections go away. Then start gradually reducing the depth of the boat reviewing the cross-sections at every step. This process should make things clearer. Even as the designer of this program, I occasionally find myself confused as to exactly why a cross-section is violating its parameters. The technique outlined above always clarifies the situation.

## Version Notes

Notes: 990927

1. Corrected minor bug with the drawing of the arched decks where the boat was very narrow
2. Corrected a bug with the screen drawing of hull shapes that tended to be more evident with small hull cross-sections.
3. Added the functionality of an additional cross-section constraint - Underwater Angle Constrained by Side Angle. This is applied by

checking the appropriate checkbox in the constraint window that is accessible from the Cross-section view. (The effect of this is discussed in the documentation above.)

Notes: 991031

4. Improved the smoothness of the transitions between the cross-sections of the boat at the extreme ends where the boat is emerging from the water. There is a new parameter in the constraints form: Area too Small to Determine the Water Angle. This will now default to 15. Old designs made before this version will have this value set to zero and you might consider converting these older designs by changing the value here to 15. Most users will be happy just setting this value to 15 and not worrying anymore about it. For complicated mathematical reasons, as the underwater cross-section of the boat approaches zero, some of the parameters start becoming "unstable" and the effect was visible under some circumstances in the appearance of the cross-sections in the immediate vicinity of the position where the boat entered or exited the water at the bow and stern. If you are seeing this effect even when the value is 15, you can try increasing the value somewhat.
5. Added to the flexibility of the constraint that the angle of the sides above the waterline influences the angle of the side below the waterline. If this constraint is used, it is now possible to "strengthen" this constraint by adding a few additional degrees so that the angle of the underwater sides are forced to be less than the angle of the sides above the water.

Notes: 000314

6. A new family of curves for the side of the boat has been added. This one is called Circle, and it is a fairly "full" curve. It, in fact, adds little to what one can obtain just tweaking the Bezier curve family
7. There is a new feature in the curve of areas module. A checkbox option allows you to visualize a "red zone" that warns you that you are creating a kayak with cross-sectional areas that are too big for the other parameters (principally depth and waterline width) that are in place. This is just to warn you that you will have to increase these parameters in other modules. You cannot build a 17 foot long, 20" wide kayak with a draft of 2 inches and expect it to hold 800 pounds.

You will either have to pull back on the curve of areas or increase the depth and/or width of the boat as you work with the other modules.

8. A few more derived values are displayed in the curve of areas module (for example Section Coefficient)

Notes: 000621

9. Bug-fix for a crash that could occur while playing the "movie" of the consecutive cross-sections.
10. Added extensive digital output. The program primarily produces cross-sections as drawn on pieces of paper to permit the construction of a kayak. However, the program, of course, "knows" all the digital measurements of the position of the kayak surfaces in space. Outputting this data in a digital form has an advantage when communicating with other computers. This digital description of the boat can be created under Print Plans on the Home page. There is a area in this section that permits output in a variety of forms. This area is labeled Table of Offsets. The files that are produced can be very large depending on what settings are used. The user can open these comma-delimited files with spreadsheets such as Excel or word processors or, indeed, other programs. I have used this functionality to "display" my kayak designs in 3D Visualization programs and to communicate with a computerized 3D milling machine.

Notes: 000701

11. Bug-fix for frequent bizarre printing of Bezier sides when anything except life-size scaling was used.

Notes: 000902

12. Bug-fix to display the arched deck form. In the course of some previous revision, the display of the arched deck was lost in the cross-section view.
13. Added differentiating grid pattern on the graphic printout of the various cross-sections (the 10 cm grid lines are differentiated) This aids in the process of reconstructing a large cross-section from the multiple sheets of paper that the program produces. The proper

organization of these sheets is also aided by labeling the sheets A1 or B3 etc. to indicate where each sheet is to be placed relative to its companions (the letters indicate the column and the number the row)

14. Slightly modified the window that displays the drag spreadsheet parameters and added additional values to the copy and paste text block.

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## Tutorial

To familiarize you with the program, this tutorial will go through the process of designing a long narrow kayak intended for day paddling.

1. Go to the Home page and click on the button **Restore Generic Kayak Defaults**. This will restore the values in the program that were in place when the program first opened.
2. Click on the button **Curve of Areas**. Now you will see a graphic of the underwater area of the boat plotted as a function of the position on the boat.
3. We want a kayak about 18 feet long. Go to the length box and enter 550. Hit the TAB key to have the value that you have entered register. This is 550 centimeters which is 18' 1" long.
4. We want a long swept up bow so lets make the point of entry into the water 40 cm from the bow itself. Type 40 in the Enter box and hit the TAB key to have the value inserted. You will notice that as you make changes the graphic will add them to the preexisting drawing. To refresh the drawing and erase all the old data, click anywhere on the graphic. Do this whenever the graphic is looking cluttered.
5. We want the end of the underwater portion of the boat to be close to the stern. Place 545 in the Exit box. This is just 5 cm from the end.
6. Lets change the curve of areas slightly. Perhaps we want the prismatic coefficient of the bow portion to be a little greater. Enter 30 in the Bow box (to replace the 26 that is currently there). Note that the curve of areas changes slightly. Lets make the stern prismatic coefficient a little less. Look at the MidStern box. Use the adjacent arrow buttons to adjust the value from 86 to 80. This method is in

general “easier” than actually typing in the new value but the effect is the same.

7. The Displacement now reads 312 pounds but this is more than we want for this boat. If we weigh 170 lbs. and anticipate the boat will weigh 40 lbs. and are going to be using it on day trips and taking about 20 lbs. of equipment (paddle, safety equipment, food etc) we would like the design displacement to be 230 lbs. ( $170+40+20$ ). Enter this figure and see how the value for the Max Cross-Sec Area changes. The Max Cross-Sec Area is a primary parameter, but in this case we have set it indirectly by changing a secondary parameter. This is convenient in this setting so this method is enabled. In general, the secondary (derived) values such as Displacement cannot be directly changed.
8. For now we are through with the curve of areas. Lets go to Birdview area to get a look at the kayak as viewed from above. Click on the **Bird** button.
9. The seam line of the boat is presented in black. Within this, the waterline is visible in blue. We are trying to make a long skinny boat so lets change the Max Seam width to 54. This will make the width of the boat just over 21”. Lets make the Max Water Width 51 cm. This will make the width of the boat at the waterline a little over 20 inches. To make the waterline bow a little finer, make the MidBow parameter a little less (change the 145 to 135). This change affects the shape of the boat to the greatest degree in the region of the Bow side of the mid boat. Note that the blue numbers refer to the waterline and the black numbers to the seam line.
10. Lets make the seam line of the boat a little wider at the stern than it currently is. Change the Stern parameter to 75 from 55. Note the birds eye view of the seam line shows it wider toward the stern than it was before. By changing the various parameters you can create a wide variety of shapes.
11. Let’s say you have decided to place the seat 20 cm behind the center of buoyancy. You can click on the red lettering (**Center of Buoyancy**) to have a red indicator line placed on the kayak drawing. To show where you are planning your seat, type 325 ( $20+305$ ) into the Location Line box. This will allow you to visualize where your seat is going, Note that the values of the width, depth etc of the boat at that position (325) are provided.

12. Now we will take a view of the boat from the side. Click on the **Side** button. Looking at it, we decide that we want 50 cm of bow overhang instead of the 40 cm that we entered earlier. Change Enter to 50. There are several parameters such as this that can be changed in multiple locations. Be careful as some of these changes will affect other parameters such as the displacement and the center of buoyancy. Indeed, moving the Enter point has slightly pushed back the center of buoyancy.
13. The side profile of the deck is entered manually by providing values in the Deck Heights box. At the bow and stern we want the deck to be above the seam line where it sits by default. In the Position box enter 1 and in the Ht box 35 which is 2 cm above the seam line at the bow. Then click the **Add** button. Next Enter 549 in the position box and 20 in the height box which is 2 cm above the stern seam line. Again click on the **Add** button. Lets say that we want the deck a little lower where we are sitting which we decided would be at position 325. In the Position box enter 325 and in the Ht box 18. If we want a little more storage room behind the paddler, we might enter at position 330 a height of 24. If the transitions seem too abrupt, they can be smoothed with the slider bar underneath. Moving the slider toward Soft creates gentler curves in the profile. Let's move it to 8.
14. We have changed the parameters considerably. Go back to the Home page (click on **Home**). There click on the button **Save As... .** Enter TutorialBoat as the name of the file. This will preserve a copy of this boat on the hard disk. It can be accessed in the future by clicking on the **Open Kayak** button and finding "TutorialBoat"
15. Now take a look at the cross-sections that we have specified. Click on the **Cross section** button. Move the Position slider (sits under the yellow word Position) to see the boat at various stations along its length. The underwater portion of the cross-section is rather angular. Remember that this program is creating the minimum wetted surface at each position within the constraints that have been imposed. The depth of the boat (14 cm) is probably too great. Try changing the waterline to 10 cm. (This can be done here or in the Side form). Notice that there is now a more rounded hull shape.
16. Go to position 60 (near where the boat is entering the water). You will see that the underwater shape is "peculiar" and it is displayed in red. The reason is that here there is conflict among the various

parameters. The program has been asked to put an underwater area here that is GREATER than a rectangle with a side to side dimension of waterline width and a height dimension equal to the waterline.

Therefore, the underwater area has to expand out beyond the confines of a simple rectangle. When this is seen at the extreme ends of the boat it is not of much consequence. At the time of building the plug, the “extra” will be sanded off. You can largely get rid of these “problem” areas by readjusting the parameters. (Some combination of widening the waterline at this position, increasing the draft of the boat, increasing the depth of the boat at this position, decreasing the cross-sectional area at this point etc. could be used)

17. One approach is to increase the waterline width at the bow. Hit **Bird** button to return to the bird’s eye view. Let’s increase the fullness of the bow by changing the bow parameter from 35 to 55. Return to the cross-section views to see that this has, for all intents and purposes, gotten rid of the peculiar red areas.
18. Look at position 370. Some might see the bottom as too flat. This can be prevented. Click on the **Constraints...** button. Set the Max Keel angle to 85. Then click on the **Return** button. You can see that this constraint prevents a completely flat bottom to the kayak.
19. Click on the **Home** button to return to the Home window. Here click on the **Print Plans** button. In the box in the upper left, specify which cross-sections that you want to print out. For now, to save paper, just chose one cross-section. Choose a 1/5 size and then click on the **Print Graphic Cross-Section**. You should get a one fifth life-size printout of the kayak cross-section you have designed.
20. If this were a real design, you would want to click on the Save button so that all your changes would be saved to disk under the name TutorialBoat or whatever you have named your craft.

This concludes the tutorial. There are many other functions of the program that you can learn by playing with it and going through the short manual and simply trying things out.