Kubla Ports Technical Manual

Version 5.1

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Chapter 1

Introduction

Topics:

- Co-Ordinates and units

Kubla Ports is software which facilitates the design of Approach Channels, allowing many channel alignment options to be considered in very little time. Once site data is loaded into the software and channel alignments are drawn by the user, the software automatically calculates appropriate channel dimensions (e.g. widths, depths) based on the concept design method described in PIANC's guideline *'Harbour Approach Channels Design Guidelines'*. If necessary, the user can override automatically calculated dimensions based on their judgement and experience. Whether the channel dimensions are automatically or manually defined, the software will instantly calculate and display the dredging quantities.

This Technical Manual describes how *Kubla Ports* determines channel dimensions and calculates dredging quantities. A description of how to use the software is provided separately in the User Manual, which is available from www.kublasoftware.com.

Important Note: No software is a substitute for engineering knowledge and judgement. *Kubla Ports* is designed to make it easier and quicker for a qualified and experienced professional to develop concept design options for approach channels. The user is assumed to understand the channel concept design process described in the PIANC Guidelines. They should also familiarise themselves with how the software works by reading the Technical Manual, and apply their experience to the design process, and never blindly accept the designs that the software produces.

Co-Ordinates and units

Kubla Ports works with Eastings, Northings and Elevations in metres. No other co-ordinate systems or units are currently supported.

If you have data, such as bathymetry or wave heights, in another co-ordinate system it will be necessary to convert it before you load it into *Kubla Ports*. Converters are available which enable different co-ordinate systems to be converted into, for example, the Universal Transverse Mercador (UTM) system which can be used by *Kubla Ports*.

Chapter 2

Channel Dimensions

Topics:

Channel dimensions are determined by *Kubla Ports* based on the concept design method in the PIANC Guidelines *'Harbour Approach Channels - Design Guidelines'* (2014). Using these guidelines, and some necessary assumptions, the minimum channel dimensions are determined for each of the design vessels and the minimum overall dimensions for the channel are found.

Design Vessels

The user can specify as many design vessels as they require. If more than one design vessel is specified then the design process will be repeated for each one in turn and the most critical vessel will be used to set the channel dimensions. It may be that the channel's width, for example, is set based on the requirements of one design vessel and the channel's depth is set based on another.

The calculations outlined in the following pages are described for a single vessel. If more than one design vessel is specified then these same calculations will be repeated for each one.

Order of Calculations

Channel dimensions are interrelated. For example, a shallower channel may require additional width to compensate. A further complication comes from the bend radii, as these affect the location of the centre line points along the channel which are checked to determine channel widths and depths. In order to avoid these inter-dependencies, it is necessary to fix the order of calculations and to make some assumptions in the earlier calculations regarding the later ones. Channel dimensions are calculated in the order below using the methods described in the following pages.

- Bend Radii
- Channel bottom levels
- Channel widths

Inner Channel or Outer Channel

In the PIANC guidelines the recommended depths and widths depend on whether a channel section is an Inner Channel (protected water) or an Outer Channel (open water). The user can set this value for each section of the channel, or alternatively the software can make assumptions to set it automatically.

If set to automatic, the software will analyse every point along each section of the channel. It will set the section to be an outer channel if either of the two following conditions are met.

- If the wave height is greater than 1.0m
- If the cross current is equal to or more than 1.5 knots

If neither of these conditions are met, it will set it to be an inner channel.

Points along Channel

Since some design parameters (e.g. waves) can vary along the channel, channel dimensions are determined by checking a series of points along the channel. These points are spaced along the channel with the following criteria:

- Points along straights are separated by not more than the minimum design vessel length (rounded to the nearest 25m)
- In bends, the same criteria are applied as for points. Additionally, points are not more than 5° apart around the curvature of the bend

The critical point for a particular channel element (i.e. straight section or bend) is found. This is the point which requires the deepest or widest channel section, and the width and depth for the whole channel element is set based on this point. While widths and depths cannot vary within a single channel element, it is possible for the dimensions of channel elements to be different.

Determination of Parameters

In order to calculate the channel dimensions environmental parameters are determined for each point along the channel. These determinations are described below:

- **Cross wind.** Taken from the wind climate that the user has defined. The two angles which are 90° to each side of the channel (i.e. crossing it) are determined, and the wind speed for these two directions are determined from the wind rose by linear interpolation. The cross wind is taken to be the larger of the two values.
- **Cross current.** Taken from the currents that the user has defined. The two angles which are 90° to each side of the channel (i.e. crossing it) are determined, and the current speed for these two directions are determined. The cross current is taken to be the larger of the two values. The currents for both directions are determined based on a Delaunay triangulation of the current locations which the user has defined, including the coastline and the outline of the bathymetry. Coastline and outline points take the currents of the closest current point which the user has input. Based on this triangulation the triangle which encloses a given point will be determined. The cross currents will be calculated at each vertex of this triangle (using linear interpolation of current directions) and the cross current will be determined (using bilinear interpolation in space).
- **Longitudinal current.** Taken from the currents that the user has defined. The two angles longitudinal to the channel section are determined, and the current speed for these two directions are determined. The cross current is taken to be the larger of the two values. The currents for both directions are determined based on a Delaunay triangulation of the current locations which the user has defined, including the coastline and the outline of the bathymetry. Coastline and outline points take the currents of the closest current point which the user has input. Based on this triangulation the triangle which encloses a given point will be determined. The cross currents will be calculated at each vertex of this triangle (using linear interpolation of current directions) and the cross current will be determined (using bilinear interpolation in space).
- **Wave height.** Wave height points input by the user are triangulated along with the coastline and the outline of the bathymetry. Coastline and outline points take the wave height of the closest wave height point which the user has input. The wave height at the point in question is determined from this triangulation using bilinear interpolation.
- **Swell Height.** Swell height points input by the user are triangulated along with the coastline and the outline of the bathymetry. Coastline and outline points take the swell height of the closest wave swell point which the user has input. The swell height at the point in question is determined from this triangulation using bilinear interpolation.
- **Depth of waterway.** The depth of the waterway is determined based on the dredged channel level at the given point.

Bend Radii

The bend radius for the bends of the channel is simply set to be the smallest of the minimum bend radii specified for each of the design vessels. The bend radius is rounded to the nearest 10m.

Manual Overrides

It is possible for the user to manually override dimensions for a channel element, such as the width, the depth or the radius for bends. In this case *Kubla Ports* will continue to automatically calculate the dimensions which have not been overridden. For example, if the user manually overrides the depth of a channel element, but not the width, then the software will calculate the channel width using the depth which has been specified manually.

Channel Bottom Levels

For an Inner Channel required depth/draught ratios are based on the following criteria, from table 2.2 of the PIANC guidelines. The vessel speed is calculated by adding the longitudinal current to the absolute vessel speed which has been defined by the user.

Vessel Speed (knots)	Min. depth/draught ratio
<10 knots	1.1
10-15 knots	1.12
>15 knots	1.15

Whereas for an outer channel the minimum depth/draught ratios are based on the following criteria, also based on table 2.2 of the PIANC guidelines (guidelines values are in black, values used by software are highlighted).

Swell Height (m)	Min. depth/draught ratio
Hs < 1m	1.15 - 1.2 (1.2)
1m < Hs < 2m	1.2 - 1.3 (1.3)
Hs > 2m	1.3 - 1.4 (1.4)

In additional to these minimum depth/draught ratios, the following values are also added for the channel bottom type, from table 2.2 of the PIANC guidelines.

Bottom Type	Inner Channel	Outer Channel
Mud	0.0m	0.0m
Sand / Clay	0.4m	0.5m
Rock / Coral	0.6m	1.0m

Finally, the following addition to the channel depth is also made for rolling if the vessel is a container ship or car carrier, based on section 2.3.2 of the PIANC guidelines.

0.90x(B/2)sin(2°)

- where B is the vessel's beam

The total channel depth for each design vessel is calculated as follows:

Total Channel Depth = Vessel Draught x Min. depth/draught ratio + Additional depth

For each design vessel the minimum channel bottom level is calculated as follows:

Min. bottom level = Transit water level - Total Channel Depth

Final Bottom Level

The bottom level for each channel element (straight section or bend) is determined based on the lowest of each of the points considered along that element. Minimum bottom levels determined in this way are rounded to the nearest 0.1m before the addition of any allowances for over-dredging that the user has specified.

Channel Widths

Channel widths are set based on the concept design method outlined in the PIANC Guidance and using the data which the user has input to define the site conditions and also in the properties of each channel element. The calculations are repeated with two design vessel speeds to determine the worst case.

- Adding the max. longitudinal current to the absolute vessel speed defined by the user.
- Subtracting the max. longitudinal current from the absolute vessel speed defined by the user.

The channel width for a given point along the channel is determined using the following expression for vessels where one-way traffic is specified:

$w = w_{BM} + \Sigma w_i + 2w_B$

...and with the following expression where two-way traffic is specified.

$w = 2w_{BM} + 2\Sigma w_i + 2w_B + \Sigma w_p$

- Where w_{BM} = basic manoeuvring lane, taken from the user-specified manoeuvrability for the vessel at the depth in question, using the following table:

Vessel Manoeuvrability	Good	Moderate	Poor
w_{BM}	1.3B	1.5B	1.8B

Where B is the beam of the design vessel

- w_i = additional widths, taken from the following table.

Parameter	Value	Vessel Speed	Outer Channel	Inner Channel
Vessel speed (knots)	> 12 (Fast)	0.1B		
	8 - 12 (Moderate)	0.0		
	5-8 (<8)(Slow)	0.0		
Prevailing cross wind (knots)	< 15 (Mild)	Fast	0.1B	
		Mod	0.2B	
		Slow	0.3B	
	15-33 (Moderate)	Fast	0.3B	
		Mod	0.4B	
		Slow	0.6B	
	33-48 (>33) (Severe)	Fast	0.5B	
		Mod	0.7B	
		Slow	1.1B	
Prevailing cross current (knots)	≤ 0.2 (Negligible)	All	0.0	0.0
	0.2-0.5 (Low)	Fast	0.2B	0.1B
		Mod	0.25B	0.2B
		Slow	0.3B	0.3B
	0.5-1.5 (Moderate)	Fast	0.5B	0.4B
		Mod	0.7B	0.6B
		Slow	1.0B	0.8B
	1.5-2.0 (Strong)	Fast	1.0B	-
		Mod	1.2B	-
		Slow	1.6B	-
Prevailing longitudinal current (knots)	≤ 1.5 (Low)	All	0.0	
	1.5-3.0 (Moderate)	Fast	0.0	
		Mod	0.1B	

Parameter	Value	Vessel Speed	Outer Channel		Inner Channel	
		Slow	0.2B			
	>3 (Strong)	Fast	0.1B			
		Mod	0.2B			
		Slow	0.4B			
Bow and stern quartering H_s (m)	$H_s \leq 1$ (irrespective of direction)	0.0		0.0		
	$1 < H_s < 3$ (irrespective of direction)	≈0.5B (0.5B)		-		
	$H_s \geq 3$ (irrespective of direction)	≈1.0B (1.0B)		-		
Aids to Navigation	Excellent	0.0				
	Good	0.2B				
	Poor	0.4B				
Bottom Surface	Depth ≥ 1.5 T	0.0				
	Depth < 1.5 T					
	- Smooth and soft (Mud or Sand/Clay)	0.1B				
	- Rough and hard (Rock/ Coral)	0.2B				
Depth of Waterway			≥ 1.5T	0.0	≥ 1.5T	0.0
			1.5T-1.25T	0.1B	1.5T-1.15T	0.2B
			<1.25T	0.2B	<1.15T	0.4B

Where T = vessel draft and H_s = Significant wave height, and fast is > 12 knots, moderate is 8-12 knots, and slow is < 8 knots

- w_B = additional width for bank clearance, taken from the table below, based on Table 3.6 of the PIANC guidelines (guideline values in black, values used by software are highlighted)

	Vessel Speed	Additional Width
Gentle underwater channel slope (1:10 or less steep) (Slope ≥ 1:10)	Fast	0.2B
	Moderate	0.1B
	Slow	0.0
Sloping channel edges and shoals (Slope ≥ 1:2)	Fast	0.7B
	Moderate	0.5B
	Slow	0.3B
Steep and hard embankments, structures (Slope > 1:2)	Fast	1.3B
	Moderate	1.0B

	Vessel Speed	Additional Width
	Slow	0.5B

Where fast is > 12 knots, moderate is 8-12 knots, and slow is < 8 knots

- w_p = additional width for passing distance, taken from Table 3.7 of the PIANC guidelines.

Vessel speed (knots)	Outer Channel	Inner Channel
Fast	2.0B	1.8B
Moderate	1.6B	1.4B
Slow	1.2B	1.0B

In addition to this, 0.5B is added to the additional width for passing distance in the case of heavy traffic (>3 design vessels / day)

Widths in Bends

In bends the method outlined for straight sections will be followed for each point in the bend, but the following additional widths are included.

The following additional width is added (for each lane) in bends for the drift angle, which is based on section 3.1.6.2 from the PIANC guidelines

$\Delta W_{DA} = L^2/aR_c$

- Where L = Length (overall) of vessel
- a = factor based on ship type
- 4.5 if ship is tanker and dwt > 60,000 tonnes, or ship is bulk carrier and dwt is 40,000 tonnes
- 8.0 Otherwise
- R_c = Bend radius

Additional Width for response time, which is from section 3.1.6.2 of the PIANC guidelines

$\Delta W_{RT} = 0.4B$

- Where B = vessel beam

Final Channel Widths

The width of each channel element (straight section or bend) is determined based on the widest of each of the points considered along that element. Channel widths determined in this way are rounded to the nearest 1.0m.

Chapter 3

Determination of Dredging Quantities

Kubla Ports uses the cutting-edge triangular prism method to calculate dredging volumes.

This method starts by triangulating the existing terrain. This involves joining the points in the existing bathymetry to create a continuous surface of connected triangles. This is known as a Triangulated Irregular Network, or TIN for short. This step is repeated for the proposed dredging levels.

The next stage is to merge these two triangulations, to create a third triangulation which contains all the edges of the original triangulations. This merged mesh will be used to perform the calculations. Merging the two input triangulations means that every detail of both the existing and the proposed will be included in the calculations. This is the basis of this method's accuracy.

The last stage is to calculate the cut and fill of each vertex on the calculation TIN. These values can be used to calculate the cut and fill for each triangle, and the total volumes are easily obtained by adding the volumes of each individual triangular prism together.