Appendix B

The Displacement Sheet and Hydrostatics

Chapter 4 introduced the concepts of:

- Bonjean curves
- a displacement sheet as a concise way of calculating the displacement of a body defined by a table of offsets,
- hydrostatic curves.

Rather than place a lot of related numerical work in the main text, an example of how they can be derived is placed in this appendix.

Table B.1 is a displacement sheet, using Microsoft Excel, for a vessel in which the waterplanes are 2 m apart and the sections 14.1 m apart. The actual half ordinates defining the underwater form of a body are shown in bold. For greater definition in way of the turn of bilge, an intermediate waterplane has been introduced between waterplanes 5 and 6, the Simpson's multipliers being adjusted accordingly. To simplify the arithmetic the appendages which would usually be found below number 6, waterplane and aft of ordinate 11 have been ignored.

The figures in Row 6 are obtained from multiplying the half ordinates in Row 5 by the corresponding Simpson's multipliers in Row 3. Thus cell M6 is the product of the contents of cells M3 and M5. Cell R6 is the sum of the cells in Row 6 and represents the area of the section at ordinate 1 up to the summer waterline (SWL). The figures in Column S are the result of multiplying the figures in Column R by the Simpson's multipliers in Column B. Cell S28 is the sum of the figures in Column S and represents the volume of the immersed body. The figures in Column U are the products of Columns S and T. Cell U28 is the sum of the figures in Column U and represents the moment of the buoyancy force about amidships.

Correspondingly, the figure in cell D7 is the product of the figure in cell C7 and the Simpson's multiplier in cell B7. Then cell D28 is the sum of the figures in Column D and represents the area of waterplane 6. The figures in Row 30 are the result of multiplying the figures in Row 28 by the Simpson's multipliers in Row 3, noting that the SM for column D is that appearing in Column C, and so on. Cell R30 is the sum of the figures in Row 30 and

TABLE B.1 Displacement Sheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R	S	T	U
1	Waterline		6		5.5		5		4		3		2		SWL					
2																				
3	Ordinate	SM	0.5		2		1.5		4		2		4		1		*F*(*A*)	*F*(*A*) × SM	Lever aft	*F*(*M*)
4																				
5	1	1	**0.000**	0.000	**0.000**	0.000	**0.000**	0.000	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100				
6			0.000		0.000		0.000		0.400		0.200		0.400		0.100		1.100	1.1	−5	−5.5
7	2	4	**0.500**	2.000	**1.060**	4.240	**1.640**	6.560	**2.760**	11.040	**3.640**	14.560	**4.440**	17.760	**5.200**	20.800				
8			0.250		2.120		2.460		11.040		7.280		17.760		5.200		46.110	184.44	−4	−737.76
9	3	2	**1.900**	3.800	**3.280**	6.560	**4.700**	9.400	**6.660**	13.320	**8.100**	16.200	**9.100**	18.200	**9.840**	19.680				
10			0.950		6.560		7.050		26.640		16.200		36.400		9.840		103.640	207.28	−3	−621.84
11	4	4	**4.500**	18.000	**6.800**	27.200	**8.600**	34.400	**10.640**	42.560	**11.800**	47.200	**12.480**	49.920	**12.800**	51.200				
12			2.250		13.600		12.900		42.560		23.600		49.920		12.800		157.630	630.52	−2	−1261.04
13	5	2	**7.240**	14.480	**10.100**	20.200	**11.800**	23.600	**13.300**	26.600	**13.800**	27.600	**14.000**	28.000	**14.040**	28.080				

14			3.620		20.200		17.700		53.200		27.600		56.000		14.040		192.360	384.72	−1	−384.72
15	6	4	**9.000**	36.000	**11.900**	47.600	**13.240**	52.960	**14.200**	56.800	**14.500**	58.000	**14.500**	58.000	**14.400**	57.600				
16			4.500		23.800		19.860		56.800		29.000		58.000		14.400		206.360	825.44	0	0
17	7	2	**7.900**	15.800	**10.700**	21.400	**12.400**	24.800	**13.640**	27.280	**14.080**	28.160	**14.220**	28.440	**14.200**	28.400				
18			3.950		21.400		18.600		54.560		28.160		56.880		14.200		197.750	395.5	1	395.5
19	8	4	**5.500**	22.000	**8.000**	32.000	**9.700**	38.800	**11.900**	47.600	**13.020**	52.080	**13.540**	54.160	**13.700**	54.800				0
20			2.750		16.000		14.550		47.600		26.040		54.160		13.700		174.800	699.2	2	1398.4
21	9	2	**3.000**	6.000	**4.500**	9.000	**6.040**	12.080	**8.640**	17.280	**10.700**	21.400	**12.020**	24.040	**12.600**	25.200				
22			1.500		9.000		9.060		34.560		21.400		48.080		12.600		136.200	272.4	3	817.2
23	10	4	**0.940**	3.760	**1.560**	6.240	**2.160**	8.640	**3.700**	14.800	**5.700**	22.800	**8.000**	32.000	**10.060**	40.240				
24			0.470		3.120		3.240		14.800		11.400		32.000		10.060		75.090	300.36	4	1201.44
25	11	1	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100	**1.300**	1.300				
26			0.050		0.200		0.150		0.400		0.200		0.400		1.300		2.700	2.7	5	13.5
27																				
28				121.940		174.540		211.340		257.480		288.200		310.720		327.400		3903.66		815.18

(*Continued*)

TABLE B.1 Displacement Sheet—(cont.)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R	S	T	U
29																				
30				60.97		349.08		317.01		1029.92		576.4		1242.88		327.4	3903.66			
31	Lever			5		4.5		4		3		2		1		0				
32																				
33	Moment			304.85		1570.86		1268.04		3089.76		1152.8		1242.88		0	8629.19			
34																				
35	Volume	24463																		
36	Displacement	25075																		
37	LCB aft	2.94																		
38	VCB	5.58																		
39																				
40																				

represents the immersed volume of the body. *Note*: As a check on the accuracy of the arithmetic, the figures in Cells S28 and R30 are the same at 3903.66. The figures in Row 33 are obtained by multiplying the figures in Row 30 by the corresponding levers in Row 31. Cell R33 is the sum of the figures in Row 33 and represents the moment of buoyancy about the SWL.

Since the ordinates are for half the hull, the total hull volume is given by:

Volume = $2 \times (2/3) \times (14.1/3) \times 3903.66 = 24{,}463\ m^3$.
Displacement, in tonnes = 24,463(1.025) = 25,075 tonnes in seawater.
The centre of buoyancy of the hull from amidships = 14.1(815.18)/(3903.66) = 2.94 m aft.
The centre of buoyancy below the SWL = 2(8629.19)/(3903.66) = 4.42 m.

If wished these figures can be calculated within Excel and placed in designated cells in the table.

Once a template has been created for the calculations, it can be used repeatedly with new sets of ordinates. If one figure has to be changed in the table, the computer will automatically correct all the related figures.

The computer naturally calculates figures to the full number of decimal places. The number printed out can be controlled by the relevant command. This should not lead the reader to suppose that the actual volume and centre of buoyancy position have been calculated this accurately. For one thing, the ordinates used will have limited accuracy and this will be compounded by the use of approximate integration methods. As a check on the latter, Table B.2

TABLE B.2 Comparison of VCB

Waterline	Area	SM	*F(V)*	Lever	*F(M)*1	Lever	*F(M)2*
SWL	3078	1	3078	0	0	10	30,780
2	2921	4	11,684	2	23,368	8	93,472
3	2709	2	5418	4	21,672	6	32,508
4	2420	4	9680	6	58,080	4	38,720
5	1987	1.5	2980.5	8	23,844	2	5961
5.5	1641	2	3282	9	29,538	1	3282
6	1146	0.5	573	10	5730	0	0
			36,695.5		162,232		204,723
Volume			24,463.67				
CB below SWL					4.421033		
CB above keel							5.57967

compares the vertical centre of buoyancy (VCB) position by taking moments about the SWL and the keel. It will be noted that the two figures added together correspond very closely to the draught of 10 m.

Waterplane and Section Areas

Embedded in Table B.1 are figures that can be used to derive the area of each waterplane and the area of each section up to the SWL. The former are in the second column of figures under each waterline (Columns D, F, H, etc.); the latter in the second row against each ordinate (Rows 6, 8, 10, etc.). These could be calculated within the main table, but for clarity of presentation they are here presented in Table B.3. The tonnes per centimetre immersion are calculated for each waterplane.

Tables can be produced for each waterplane, similar to Table 3.2 in Chapter 3, to give the area, centroid position and the longitudinal and transverse moments of inertia. These are presented in Tables B.4−B.10.

Note: In the row against *I*(long), the first figure is the moment of inertia about amidships and the second is the inertia about the centre of flotation.

For the body up to 3WL and 5WL, part-displacement sheets can be constructed as given in Tables B.11 and B.12, respectively.

A convenient way of calculating the volume of displacement and VCB position for waterlines 2 and 4 (as well as the SWL) is to plot the waterplane areas to obtain the figures for intermediate waterplanes as given in Table B.13.

Bonjean Curves

The Bonjean curves can be calculated, for any section, by integration up to each waterline in turn. The Simpson's rule chosen in each case, and hence the multiplying factor to be used, will depend upon the number of ordinates. Table B.14 derives the section areas up to 5.5WL and between SWL and 2WL using Simpson's 5, 8, 1 rule. Table B.15 derives the section areas between the SWL and 4WL and 5WL using the 1, 3, 3, 1 rule and between SWL and 5WL using the 1, 4, −1 rule. Then a table of cross-sectional areas can be drawn up as given in Table B.16 from which the Bonjean curves can be drawn. Figure B.1 uses the data given in Table B.16 to show the Bonjean curves for ordinates 2, 3, 4 and 5.

Volumes and Longitudinal Centres of Buoyancy

The section areas can be used to calculate the volumes of displacement up to each waterline and the corresponding longitudinal centres of buoyancy (LCBs) as given in Table B.17.

TABLE B.3 Waterplane and Section Areas

Waterplane Areas											
Waterplane	6	5.5	5	4	3	2	SWL				
F(*A*)	121.94	174.54	211.34	257.48	288.20	310.72	327.40				
Area = *F*(*A*) × 2 (14.1/3)	1146.24	1640.68	1986.60	2420.31	2709.08	2920.77	3077.56				
TPC (tonnes/CM) = area(1.025/100)	11.75	16.82	20.36	24.81	27.77	29.94	31.54				
Section areas up to SWL											
Ordinate	1	2	3	4	5	6	7	8	9	10	11
F(*A*)	1.10	46.11	103.64	157.63	192.36	206.36	197.75	174.80	136.20	75.09	2.70
Area up to SWL = *F*(*A*) × 2 × (2/3)	1.47	61.48	138.19	210.17	256.48	275.15	263.67	233.07	181.60	100.12	3.60

TABLE B.4 SWL

Station	Half Ord, *y*	SM	*F*(*A*)	Lever	*F*(*M*)	Lever	*F*(*I*) long	*yyy*	*F*(*I*) trans
1	0.10	1	0.10	5	0.50	5	2.50	0	0
2	5.20	4	20.80	4	83.20	4	332.80	141	562
3	9.84	2	19.68	3	59.04	3	177.12	953	1906
4	12.80	4	51.20	2	102.40	2	204.80	2097	8389
5	14.04	2	28.08	1	28.08	1	28.08	2768	5535
6	14.40	4	57.60	0	0.00	0	0.00	2986	11,944
7	14.20	2	28.40	−1	−28.40	−1	28.40	2863	5727
8	13.70	4	54.80	−2	−109.60	−2	219.20	2571	10,285
9	12.60	2	25.20	−3	−75.60	−3	226.80	2000	4001
10	10.06	4	40.24	−4	−160.96	−4	643.84	1018	4072
11	1.30	1	1.30	−5	−6.50	−5	32.50	2	2
Total			327.40		−107.84		1896.04		52,423
Area = (2/3) × 14.1 × *F*(*A*) =					3077.56				
Moment					−14,293.1				
Centre of flotation (CF)					−4.6443				
I(long)					3,543,346		3,476,965		
I(trans)					16,4258.9				

TABLE B.5 2WL

Station	Half Ord, *y*	SM	*F*(*A*)	Lever	*F*(*M*)	Lever	*F*(*I*) long	*yyy*	*F*(*I*) trans
1	0.10	1	0.10	5	0.50	5	2.50	0	0
2	4.44	4	17.76	4	71.04	4	284.16	88	350
3	9.10	2	18.20	3	54.60	3	163.80	754	1507
4	12.48	4	49.92	2	99.84	2	199.68	1944	7775
5	14.00	2	28.00	1	28.00	1	28.00	2744	5488
6	14.50	4	58.00	0	0.00	0	0.00	3049	12,195
7	14.22	2	28.44	−1	−28.44	−1	28.44	2875	5751
8	13.54	4	54.16	−2	−108.32	−2	216.64	2482	9929
9	12.02	2	24.04	−3	−72.12	−3	216.36	1737	3473
10	8.00	4	32.00	−4	−128.00	−4	512.00	512	2048
11	0.10	1	0.10	−5	−0.50	−5	2.50	0	0
Total			310.72		−83.40		1654.08		48,516
Area = (2/3) × 14.1 × *F*(*A*) =					2920.768				
Moment					−11,053.8				
CF					−3.78456				
I(long)					3,091,168		3,049,334		
I(trans)					152,017.3				

TABLE B.6 3WL

Station	Half Ord, *y*	SM	*F*(*A*)	Lever	*F*(*M*)	Lever	*F*(*I*) long	*yyy*	*F*(*I*) trans
1	0.10	1	0.10	5	0.50	5	2.50	0	0
2	3.64	4	14.56	4	58.24	4	232.96	48	193
3	8.10	2	16.20	3	48.60	3	145.80	531	1063
4	11.80	4	47.20	2	94.40	2	188.80	1643	6572
5	13.80	2	27.60	1	27.60	1	27.60	2628	5256
6	14.50	4	58.00	0	0.00	0	0.00	3049	12,195
7	14.08	2	28.16	−1	−28.16	−1	28.16	2791	5583
8	13.02	4	52.08	−2	−104.16	−2	208.32	2207	8829
9	10.70	2	21.40	−3	−64.20	−3	192.60	1225	2450
10	5.70	4	22.80	−4	−91.20	−4	364.80	185	741
11	0.10	1	0.10	−5	−0.50	−5	2.50	0	0
Total			288.20		−58.88		1394.04		42,881
Area = (2/3) × 14.1 × *F*(*A*) =					2709.08				
Moment					−7803.96				
CF					−2.88067				
I(long)					2,605,201		2,582,721		
I(trans)					134,359.4				

TABLE B.7 4WL

Station	Half Ord, *y*	SM	*F*(*A*)	Lever	*F*(*M*)	Lever	*F*(*I*)long	*yyy*	*F*(*I*) trans
1	0.10	1	0.10	5	0.50	5	2.50	0	0
2	2.76	4	11.04	4	44.16	4	176.64	21	84
3	6.66	2	13.32	3	39.96	3	119.88	295	591
4	10.64	4	42.56	2	85.12	2	170.24	1205	4818
5	13.30	2	26.60	1	26.60	1	26.60	2353	4705
6	14.20	4	56.80	0	0.00	0	0.00	2863	11,453
7	13.64	2	27.28	−1	−27.28	−1	27.28	2538	5075
8	11.90	4	47.60	−2	−95.20	−2	190.40	1685	6741
9	8.64	2	17.28	−3	−51.84	−3	155.52	645	1290
10	3.70	4	14.80	−4	−59.20	−4	236.80	51	203
11	0.10	1	0.10	−5	−0.50	−5	2.50	0	0
Total			257.48		−37.68		1108.36		34,960
Area = (2/3) × 14.1 × *F*(*A*) =					2420.312				
Moment					−4994.11				
CF					−2.06341				
I(long)					2,071,319		2,061,014		
I(trans)					109,541.9				

TABLE B.8 5WL

Station	Half Ord, *y*	SM	*F*(*A*)	Lever	*F*(*M*)	Lever	*F*(*I*) long	*yyy*	*F*(*I*) trans
1	0.00	1	0.00	5	0.00	5	0.00	0	0
2	1.64	4	6.56	4	26.24	4	104.96	4	18
3	4.70	2	9.40	3	28.20	3	84.60	104	208
4	8.60	4	34.40	2	68.80	2	137.60	636	2544
5	11.80	2	23.60	1	23.60	1	23.60	1643	3286
6	13.24	4	52.96	0	0.00	0	0.00	2321	9284
7	12.40	2	24.80	−1	−24.80	−1	24.80	1907	3813
8	9.70	4	38.80	−2	−77.60	−2	155.20	913	3651
9	6.04	2	12.08	−3	−36.24	−3	108.72	220	441
10	2.16	4	8.64	−4	−34.56	−4	138.24	10	40
11	0.10	1	0.10	−5	−0.50	−5	2.50	0	0
Total			211.34		−26.86		780.22		23,284
Area = (2/3) × 14.1 × *F*(*A*) =					1986.596				
Moment					−3560.02				
CF					−1.79202				
I(long)					1,458,086		1,451,706		
I(trans)					72,957.44				

TABLE B.9 5.5WL

Station	Half Ord, y	SM	$F(A)$	Lever	$F(M)$	Lever	$F(I)$ long	yyy	$F(I)$ trans
1	0.00	1	0.00	5	0.00	5	0.00	0	0
2	1.06	4	4.24	4	16.96	4	67.84	1	5
3	3.28	2	6.56	3	19.68	3	59.04	35	71
4	6.80	4	27.20	2	54.40	2	108.80	314	1258
5	10.10	2	20.20	1	20.20	1	20.20	1030	2061
6	11.90	4	47.60	0	0.00	0	0.00	1685	6741
7	10.70	2	21.40	−1	−21.40	−1	21.40	1225	2450
8	8.00	4	32.00	−2	−64.00	−2	128.00	512	2048
9	4.50	2	9.00	−3	−27.00	−3	81.00	91	182
10	1.56	4	6.24	−4	−24.96	−4	99.84	4	15
11	0.10	1	0.10	−5	−0.50	−5	2.50	0	0
Total			174.54		−26.62		588.62		14,830
Area = (2/3) × 14.1 × $F(A)$ =					1640.676				
Moment					−3528.21				
CF					−2.15046				
I(long)					1,100,021		1,092,434		
I(trans)					46,466.79				

TABLE B.10 6WL

Station	Half Ord, *y*	SM	*F*(*A*)	Lever	*F*(*M*)	Lever	*F*(*I*) long	*yyy*	*F*(*I*) trans
1	0.00	1	0.00	5	0.00	5	0.00	0	0
2	0.50	4	2.00	4	8.00	4	32.00	0	1
3	1.90	2	3.80	3	11.40	3	34.20	7	14
4	4.50	4	18.00	2	36.00	2	72.00	91	365
5	7.24	2	14.48	1	14.48	1	14.48	380	759
6	9.00	4	36.00	0	0.00	0	0.00	729	2916
7	7.90	2	15.80	−1	−15.80	−1	15.80	493	986
8	5.50	4	22.00	−2	−44.00	−2	88.00	166	666
9	3.00	2	6.00	−3	−18.00	−3	54.00	27	54
10	0.94	4	3.76	−4	−15.04	−4	60.16	1	3
11	0.10	1	0.10	−5	−0.50	−5	2.50	0	0
Total			121.94		−23.46		373.14		5763
Area = (2/3) × 14.1 × *F*(*A*) =					1146.236				
Moment					−3109.39				
CF					−2.71269				
I(long)					697,329.3		688,894.4		
I(trans)					18,056.23				

TABLE B.11 Part-Displacement Sheet up to 3WL

Waterline		*6*		*5.5*		*5*		*4*		*3*						
Ordinate	SM	0.5		2		1.5		4		1		*F*(*A*)	*F*(*A*) × SM	Lever aft	*F*(*M*)	Area	CB aft
1	1	**0.000**	0.000	**0.000**	0.000	**0.000**	0.000	**0.100**	0.100	**0.100**	0.100						
		0.000		0.000		0.000		0.400		0.100		0.500	0.5	−5	−2.5	0.67	
2	4	**0.500**	2.000	**1.060**	4.240	**1.640**	6.560	**2.760**	11.040	3.**640**	14.560						
		0.250		2.120		2.460		11.040		3.640		19.510	78.04	−4	−312.16	26.01	
3	2	**1.900**	3.800	**3.280**	6.560	**4.700**	9.400	**6.660**	13.320	**8.100**	16.200						
		0.950		6.560		7.050		26.640		8.100		49.300	98.6	−3	−295.8	65.73	
4	4	**4.500**	18.000	**6.800**	27.200	**8.600**	34.400	**10.640**	42.560	**11.800**	47.200						
		2.250		13.600		12.900		42.560		11.800		83.110	332.44	−2	−664.88	110.81	
5	2	**7.240**	14.480	**10.100**	20.200	**11.800**	23.600	**13.300**	26.600	**13.800**	27.600						
		3.620		20.200		17.700		53.200		13.800		108.520	217.04	−1	−217.04	144.69	
6	4	**9.000**	36.000	**11.900**	47.600	**13.240**	52.960	**14.200**	56.800	**14.500**	58.000						
		4.500		23.800		19.860		56.800		14.500		119.460	477.84	0	0	159.28	
7	2	**7.900**	15.800	**10.700**	21.400	**12.400**	24.800	**13.640**	27.280	**14.080**	28.160						
		3.950		21.400		18.600		54.560		14.080		112.590	225.18	1	225.18	150.12	

(*Continued*)

TABLE B.11 Part-Displacement Sheet up to 3WL—(cont.)

Waterline		*6*		*5.5*		*5*		*4*		*3*							
Ordinate	SM	0.5		2		1.5		4		1		*F*(*A*)	*F*(*A*) × SM	Lever aft	*F*(*M*)	Area	CB aft
8	4	**5.500**	22.000	**8.000**	32.000	**9.700**	38.800	**11.900**	47.600	**13.020**	52.080				0		
		2.750		16.000		14.550		47.600		13.020		93.920	375.68	2	751.36	125.23	
9	2	**3.000**	6.000	**4.500**	9.000	**6.040**	12.080	**8.640**	17.280	**10.700**	21.400						
		1.500		9.000		9.060		34.560		10.700		64.820	129.64	3	388.92	86.43	
10	4	**0.940**	3.760	**1.560**	6.240	**2.160**	8.640	**3.700**	14.800	**5.700**	22.800						
		0.470		3.120		3.240		14.800		5.700		27.330	109.32	4	437.28	36.44	
11	1	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100						
		0.050		0.200		0.150		0.400		0.100		0.900	0.9	5	4.5	1.20	
			121.940		174.540		211.340		257.480		288.200		2045.18		314.86		2.170726
			60.97		349.08		317.01		1029.92		288.2	2045.18					
Lever			0		0.5		1		2		3						
Moment			0		174.54		317.01		2059.84		864.6	3415.99					
CB above base													3.340527				

TABLE B.12 Part-Displacement Sheet up to 5WL

Waterline		*6*		*5.5*		*5*							
Ordinate	SM	0.5		2		0.5		*F*(*A*)	*F*(*A*) × SM	Lever aft	*F*(*M*)	Area	CB aft
1	1	**0.000**	0.000	**0.000**	0.000	**0.000**	0.000						
		0.000		0.000		0.000		0.000	0.00	−5	0.00	0.00	
2	4	**0.500**	2.000	**1.060**	4.240	**1.640**	6.560						
		0.250		2.120		0.820		3.190	12.76	−4	−51.04	4.25	
3	2	**1.900**	3.800	**3.280**	6.560	**4.700**	9.400						
		0.950		6.560		2.350		9.860	19.72	−3	−59.16	13.15	
4	4	**4.500**	18.000	**6.800**	27.200	**8.600**	34.400						
		2.250		13.600		4.300		20.150	80.60	−2	−161.20	26.87	
5	2	**7.240**	14.480	**10.100**	20.200	**11.800**	23.600						
		3.620		20.200		5.900		29.720	59.44	−1	−59.44	39.63	
6	4	**9.000**	36.000	**11.900**	47.600	**13.240**	52.960						
		4.500		23.800		6.620		34.920	139.68	0	0.00	46.56	
7	2	**7.900**	15.800	**10.700**	21.400	**12.400**	24.800						
		3.950		21.400		6.200		31.550	63.10	1	63.10	42.07	

(*Continued*)

TABLE B.12 Part-Displacement Sheet up to 5WL—(cont.)

Waterline		*6*		*5.5*		*5*							
Ordinate	SM	0.5		2		0.5		*F*(*A*)	*F*(*A*) × SM	Lever aft	*F*(*M*)	Area	CB aft
8	4	**5.500**	22.000	**8.000**	32.000	**9.700**	38.800						
		2.750		16.000		4.850		23.600	94.40	2	188.80	31.47	
9	2	**3.000**	6.000	**4.500**	9.000	**6.040**	12.080						
		1.500		9.000		3.020		13.520	27.04	3	81.12	18.03	
10	4	**0.940**	3.760	**1.560**	6.240	**2.160**	8.640						
		0.470		3.120		1.080		4.670	18.68	4	74.72	6.23	
11	1	**0.100**	0.100	**0.100**	0.100	**0.100**	0.100						
		0.050		0.200		0.050		0.300	0.30	5	1.50	0.40	
			121.940		174.540		211.340		515.72		78.40		2.143
			60.97		349.08		105.67	515.72					
Lever			0		0.5		1						
Moment			0		174.54		105.67	280.21					
CB above base									1.087				

TABLE B.13 Volumes and VCBs for intermediate waterplanes

Waterline	Area	SM	*F*(*V*)	Lever	*F*(*M*)1	Lever	*F*(*M*)2	SM	*F*(*V*)	Lever	*F*(*M*)	SM	*F*(*V*)	Lever	*F*(*M*)
SWL	3078	1	3078	0	0	10	30,780								
1.5	3015	4	12,060	1	12,060	9	108,540								
2	2921	2	5842	2	11,684	8	46,736	1	2921	8	23,368				
2.5	2820	4	11,280	3	33,840	7	78,960	4	11,280	7	78,960				
3	2709	2	5418	4	21,672	6	32,508	2	5418	6	32,508	1	2709	6	16,254
3.5	2570	4	10,280	5	51,400	5	51,400	4	10,280	5	51,400	4	10,280	5	51,400
4	2420	2	4840	6	29,040	4	19,360	2	4840	4	19,360	2	4840	4	19,360
4.5	2230	4	8920	7	62,440	3	26,760	4	8920	3	26,760	4	8920	3	26,760
5	1987	2	3974	8	31,792	2	7948	2	3974	2	7948	2	3974	2	7948
5.5	1641	4	6564	9	59,076	1	6564	4	6564	1	6564	4	6564	1	6564
6	1146	1	1146	10	11,460	0	0	1	1146	0	0	1	1146	0	0
			73,402		324,464		409,556		55,343		246,868		38,433		128,286
Volume			24,467.33						18,447.67				12,811		
CB below SWL					4.42037										
CB above keel							5.57963				4.460691				3.337913

TABLE B.14 Calculations for Bonjean Curves

Ordinate	Area Between Keel and 5.5WL						F(*A*)	Area	F(*V*)	Areas Between SWL and 2WL						F(*A*)	Area	F(*V*)
	SM	*5*		*8*		*−1*				*−1*		*8*		*5*				
1	1	**0.000**	0.000	**0.000**	0.000	**0.000**				**0.100**	0.100	**0.100**	0.100	**0.100**	0.100			
		0.000	0.000	0.000		0.000	0.00	0.00	0.00	−0.100		0.800		0.500		1.20	0.40	0.4
2	4	**0.500**	2.000	**1.060**	4.240	**1.640**				**3.640**	14.560	**4.440**	17.760	**5.200**	20.800			
		2.500		8.480		−1.640	9.34	1.56	6.23	−3.640		35.520		26.000		57.88	19.29	77.17333
3	2	**1.900**	3.800	**3.280**	6.560	**4.700**				**8.100**	16.200	**9.100**	18.200	**9.840**	19.680			
		9.500		26.240		−4.700	31.04	5.17	10.35	−8.100		72.800		49.200		113.90	37.97	75.93333
4	4	**4.500**	18.000	**6.800**	27.200	**8.600**				**11.800**	47.200	**12.480**	49.920	**12.800**	51.200			
		22.500		54.400		−8.600	68.30	11.38	45.53	−11.800		99.840		64.000		152.04	50.68	202.72
5	2	**7.240**	14.480	**10.100**	20.200	**11.800**				**13.800**	27.600	**14.000**	28.000	**14.040**	28.080			
		36.200		80.800		−11.800	105.20	17.53	35.07	−13.800		112.000		70.200		168.40	56.13	112.2667
6	4	**9.000**	36.000	**11.900**	47.600	**13.240**				**14.500**	58.000	**14.500**	58.000	**14.400**	57.600			
		45.000		95.200		−13.240	126.96	21.16	84.64	−14.500		116.000		72.000		173.50	57.83	231.3333

7	2	**7.900**	15.800	**10.700**	21.400	**12.400**				**14.080**	28.160	**14.220**	28.440	**14.200**	28.400				
		39.500		85.600		−12.400	112.70	18.78	37.57	−14.080		113.760		71.000		170.68	56.89	113.7867	
8	4	**5.500**	22.000	**8.000**	32.000	**9.700**				**13.020**	52.080	**13.540**	54.160	**13.700**	54.800				
		27.500		64.000		−9.700	81.80	13.63	54.53	−13.020		108.320		68.500		163.80	54.60	218.4	
9	2	**3.000**	6.000	**4.500**	9.000	**6.040**				**10.700**	21.400	**12.020**	24.040	**12.600**	25.200				
		15.000		36.000		−6.040	44.96	7.49	14.99	−10.700		96.160		63.000		148.46	49.49	98.97333	
10	4	**0.940**	3.760	**1.560**	6.240	**2.160**				**5.700**	22.800	**8.000**	32.000	**10.060**	40.240				
		4.700		12.480		−2.160	15.02	2.50	10.01	−5.700		64.000		50.300		108.60	36.20	144.8	
11	1	**0.100**	0.100	**0.100**	0.100	**0.100**				**0.100**	0.100	**0.100**	0.100	**1.300**	1.300				
		0.500		0.800		−0.100	1.20	0.20	0.20	−0.100		0.800		6.500		7.20	2.40	2.4	
			F(*V*)						299.11										1278.187
			Volume						1405.83										6007.48

TABLE B.15 Section Areas Between SWL and 4WL and 5WL

		5		4		3		2		SWL				
WL	*SM*	*1*		*4*		*2*		*4*		*1*	*F(A)*		*F(A)*	
Ordinate	SM			1		3		3		1	(4WL)		(5WL)	*Area*(5)	*Area*(4)
1	1	**0.00**	0.00	**0.10**	0.10	**0.10**	0.10	**0.10**	0.10	**0.10**	0.10				
		0.00		0.40		0.20		0.40		0.10			1.10	1.47	
				0.10		0.30		0.30		0.10		0.80			1.20
2	4	**1.64**	6.56	**2.76**	11.04	**3.64**	14.56	**4.44**	17.76	**5.20**	20.80				
		1.64		11.04		7.28		17.76		5.20			42.92	57.23	
				2.76		10.92		13.32		5.20		32.20			48.30
3	2	**4.70**	9.40	**6.66**	13.32	**8.10**	16.20	**9.10**	18.20	**9.84**	19.68				
		4.70		26.64		16.20		36.40		9.84			93.78	125.04	
				6.66		24.30		27.30		9.84		68.10			102.15
4	4	**8.60**	34.40	**10.64**	42.56	**11.80**	47.20	**12.48**	49.92	**12.80**	51.20				
		8.60		42.56		23.60		49.92		12.80			137.48	183.31	
				10.64		35.40		37.44		12.80		96.28			144.42
5	2	**11.80**	23.60	**13.30**	26.60	**13.80**	27.60	**14.00**	28.00	**14.04**	28.08				
		11.80		53.20		27.60		56.00		14.04			162.64	216.85	
				13.30		41.40		42.00		14.04		110.74			166.11

6	4	**13.24**	52.96	**14.20**	56.80	**14.50**	58.00	**14.50**	58.00	**14.40**	57.60				
		13.24		56.80		29.00		58.00		14.40			171.44	228.59	
				14.20		43.50		43.50	1.0	14.40		115.60			173.40
7	2	**12.40**	24.80	**13.64**	27.28	**14.08**	28.16	**14.22**	28.44	**14.20**	28.40				
		12.40		54.56		28.16		56.88		14.20			166.20	221.60	
				13.64		42.24		42.66		14.20		112.74			169.11
8	4	**9.70**	38.80	**11.90**	47.60	**13.02**	52.08	**13.54**	54.16	**13.70**	54.80				
		9.70		47.60		26.04		54.16		13.70			151.20	201.60	
				11.90		39.06		40.62		13.70		105.28			157.92
9	2	**6.04**	12.08	**8.64**	17.28	**10.70**	21.40	**12.02**	24.04	**12.60**	25.20				
		6.04		34.56		21.40		48.08		12.60			122.68	163.57	
				8.64		32.10		36.06		12.60		89.40			134.10
10	4	**2.16**	8.64	**3.70**	14.80	**5.70**	22.80	**8.00**	32.00	**10.06**	40.24				
		2.16		14.80		11.40		32.00		10.06			70.42	93.89	
				3.70		17.10		24.00		10.06		54.86			82.29
11	1	**0.10**	0.10	**0.10**	0.10	**0.10**	0.10	0.10	**0.10**	**1.30**	1.30				
		0.10		0.40		0.20		0.40		1.30			2.40	3.20	
				0.10		0.30		0.30		0.10	1.30		2.00		3.00

Area to 5WL = $F(A)(5WL) \times 2 \times 2/3 = (4/3)F(A)(5WL)$.
Area to 4WL = $F(A)(4WL) \times 2 \times 2 \times (3/8) = 1.5F(A)(4WL)$.

TABLE B.16 Table of Section Areas

Ord	Area to						
	6WL	*5.5WL*	*5WL*	*4WL*	*3WL*	*2WL*	*SWL*
1	0.00	0.00	0.00	0.27	0.67	1.07	1.47
2	0.00	1.56	4.25	13.18	26.01	42.19	61.48
3	0.00	5.17	13.15	36.04	65.73	100.22	138.19
4	0.00	11.38	26.87	65.75	110.81	159.49	210.17
5	0.00	17.53	39.63	90.37	144.69	200.35	256.48
6	0.00	21.16	46.56	101.75	159.28	217.32	275.15
7	0.00	18.78	42.07	94.56	150.12	206.78	263.67
8	0.00	13.63	31.47	75.15	125.23	178.47	233.07
9	0.00	7.49	18.03	47.50	86.43	132.11	181.60
10	0.00	2.50	6.23	17.83	36.44	63.92	100.12
11	0.00	0.20	0.40	0.60	1.20	1.60	3.60

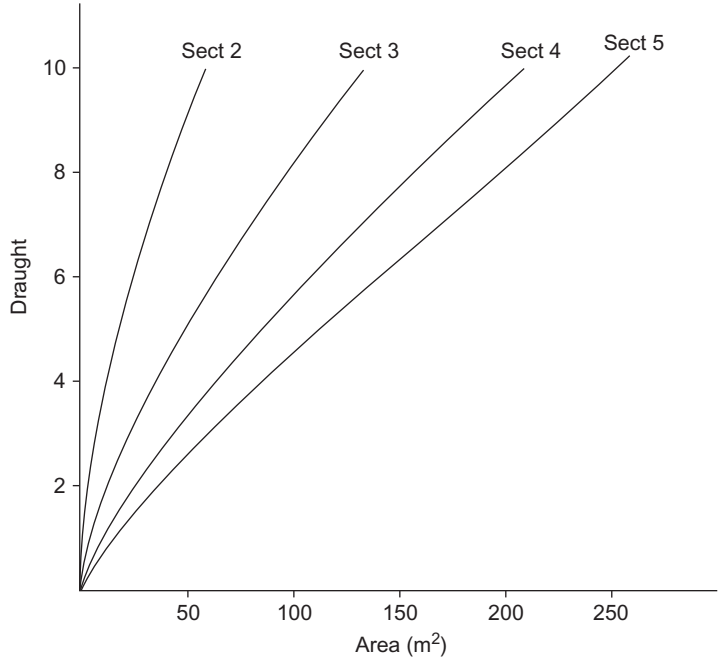

FIGURE B.1 Bonjean curves.

TABLE B.17 Volumes and LCBs

Ord	*SM*	*Lever*	*Area to*					
			5.5WL			*5WL*		
			Area	*F(V)*	*F(M)*	*Area*	*F(V)*	*F(M)*
1	1	5	0.00	0.00	0.00	0.00	0.00	0.00
2	4	4	1.56	6.24	24.96	4.25	17.00	68.00
3	2	3	5.17	10.34	31.02	13.15	26.30	78.90
4	4	2	11.38	45.52	91.04	26.87	107.48	214.96
5	2	1	17.53	35.06	35.06	39.63	79.26	79.26
6	4	0	21.16	84.64	0.00	46.56	186.24	0.00
7	2	−1	18.78	37.56	−37.56	42.07	84.14	−84.14
8	4	−2	13.63	54.52	−109.04	31.47	125.88	−251.76
9	2	−3	7.49	14.98	−44.94	17.53	35.06	−105.18
10	4	−4	2.50	10.00	−40.00	6.23	24.92	−99.68
11	1	−5	0.20	0.20	−1.00	0.40	0.40	−2.00
Total			99.40	299.06	−50.46		686.68	−101.64
Volume	CB aft			1405.582	−2.379074		3227.396	−2.087033
Displacement				1440.722			3308.081	

(*Continued*)

TABLE B.17 Volumes and LCBs—(cont.)

Ord	*SM*	*Lever*	*4WL*			*3WL*		
			Area	*F(V)*	*F(M)*	*Area*	*F(V)*	*F(M)*
1	1	5	0.27	0.27	1.35	0.67	0.67	3.35
2	4	4	13.18	52.72	210.88	26.01	104.04	416.16
3	2	3	36.04	72.08	216.24	65.73	131.46	394.38
4	4	2	65.75	263.00	526.00	110.81	443.24	886.48
5	2	1	90.37	180.74	180.74	144.69	289.38	289.38
6	4	0	101.75	407.00	0.00	159.28	637.12	0.00
7	2	−1	94.56	189.12	−189.12	150.12	300.24	−300.24
8	4	−2	75.15	300.60	−601.20	125.23	500.92	−1001.84
9	2	−3	47.50	95.00	−285.00	86.43	172.86	−518.58
10	4	−4	17.83	71.32	−285.28	36.44	145.76	−583.04
11	1	−5	0.60	0.60	−3.00	1.20	1.20	−6.00
Total				1632.45	−228.39		2726.89	−419.95
Volume	CB aft			7672.515	−1.972678		12,816.38	−2.171446
Displacement				7864.328			13,136.79	

Ord	*SM*	*Lever*	*2WL*			*SWL*		
			Area	*F(V)*	*F(M)*	*Area*	*F(V)*	*F(M)*
1	1	5	1.07	1.07	5.35	1.47	1.47	7.35
2	4	4	42.19	168.76	675.04	61.48	245.92	983.68
3	2	3	100.22	200.44	601.32	138.19	276.38	829.14
4	4	2	159.49	637.96	1275.92	210.17	840.68	1681.36
5	2	1	200.35	400.70	400.70	256.48	512.96	512.96
6	4	0	217.32	869.28	0.00	275.15	1100.60	0.00
7	2	−1	206.78	413.56	−413.56	263.67	527.34	−527.34
8	4	−2	178.47	713.88	−1427.76	233.07	932.28	−1864.56
9	2	−3	132.11	264.22	−792.66	181.60	363.20	−1089.60
10	4	−4	63.92	255.68	−1022.72	100.12	400.48	−1601.92
11	1	−5	1.60	1.60	−8.00	3.60	3.60	−18.00
Total				3927.15	−706.37		5204.91	−1086.93
Volume	CB aft			18,457.61	−2.536144		24,463.08	−2.944472
Displacement				18,919.05			25,074.65	

TABLE B.18 KB and KM Values

WL	6	5.5	5	4	3	2	SWL
Trans *I*	18,056	46,467	72,957	109,542	134,359	152,017	164,259
Volume, *V*	0	1406	3232	7505	12,816	18,470	24,463
Trans BM		33.05	22.57	14.60	10.48	8.23	6.71
KB	0	0.53	1.09	2.22	3.34	4.46	5.58
Trans KM		33.58	23.66	16.82	13.82	12.69	12.29
Long *I*	688,900	1,092,400	1,451,700	2,061,000	258,700	3,049,300	3,477,000
Long BM		777	449	275	202	165	142
Long KM		777	450	277	205	170	148
Additional data for plotting hydrostatic curves							
Mass displacement	0	1441	3313	7693	13,136	18,932	25,075
TPC	11.75	16.82	20.36	24.81	27.77	29.94	31.54
CF aft	2.71	2.15	1.79	2.06	2.88	3.78	4.64
LCB aft		2.38	2.09	1.97	2.17	2.54	2.94
Further if KG = 11 m							
Long GM		766	439	266	194	159	137
MCT		7830	10,320	14,510	18,070	21,350	24,360

Metacentric Diagram

As discussed in Chapter 4, the metacentric diagram shows how the VCB and metacentre positions vary with draught. The VCB values have been found above. BM is given by I/V and values are derived in Table B.18 using I and V figures from the other tables. KM is KB + BM and thus a metacentric diagram can be produced for the body which is the subject of this appendix. Table B.18 also includes a calculation of the longitudinal metacentre position which is needed to obtain the hydrostatic curves. The metacentric diagram is plotted in Figure B.2.

Hydrostatic Curves

Chapter 4 also introduced the concept of hydrostatic curves. The information in Table B.18, assuming a KG of 11 m, is used to plot Figure B.3.

Note: The data used in the Bonjean and hydrostatic curves can be derived in a number of different ways. Those above have been selected to give the reader an idea of the procedures involved.

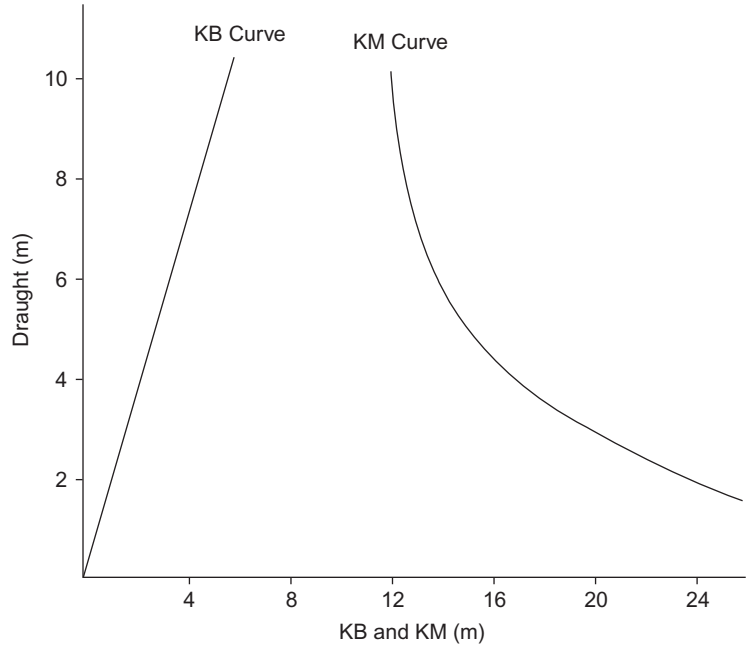

FIGURE B.2 Metacentric diagram.

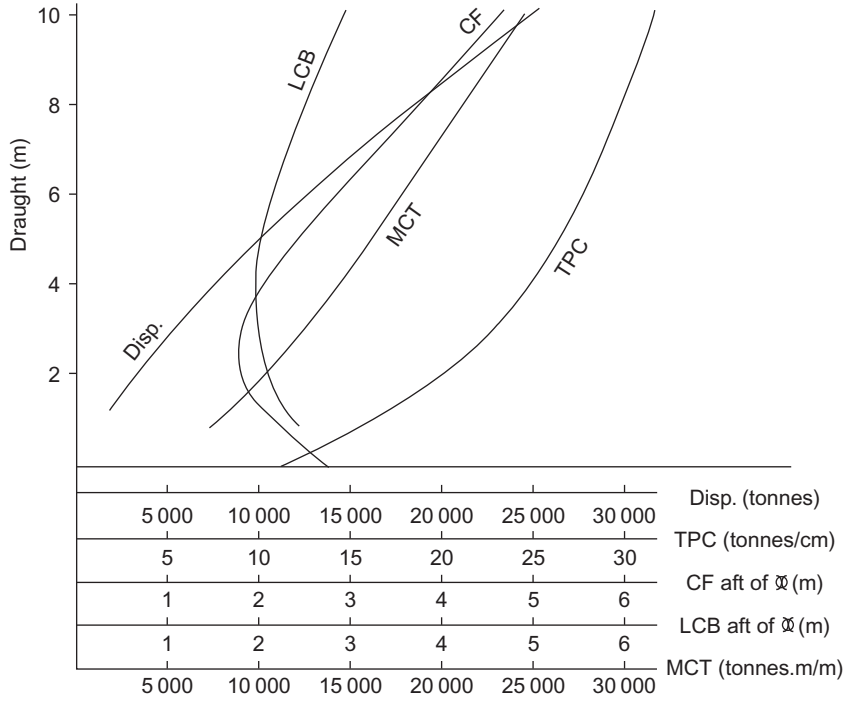

FIGURE B.3 Hydrostatic curves.