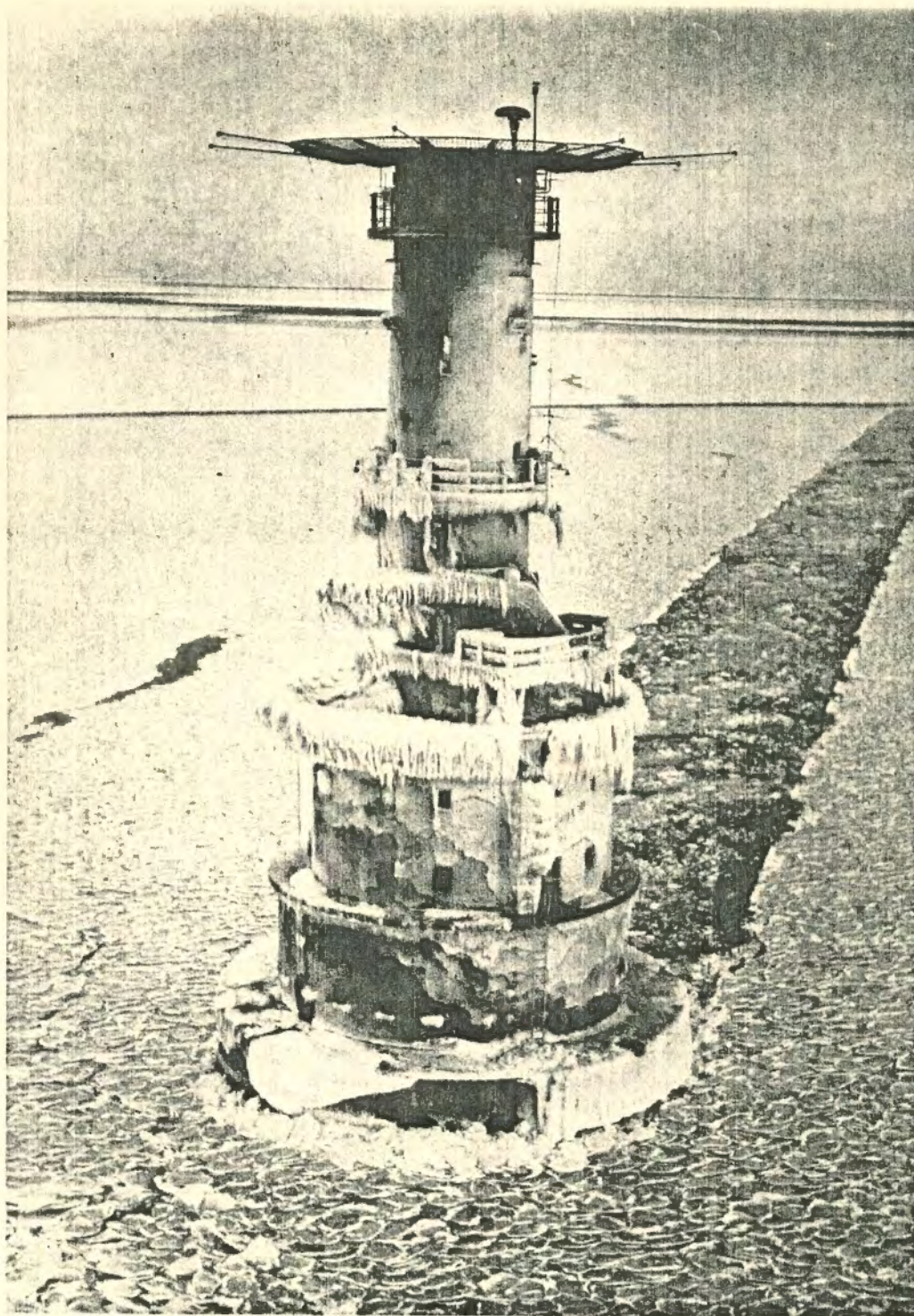




IMPACT OF ICE ON SWEDISH OFFSHORE LIGHTHOUSES

Ice drift conditions in the area at Sydostbrotten
ice season 1986/87

INTRODUCTION:

The caissunlight Sydostbrotten is situated in an area with rather great ice motions due to currents and winds, but also intensive navigation. The main vessel traffic runs east of it. However, in severe ice conditions the icebreakers break a channel in a more shallow fairway west of the caissunlight (Bonden fairway). As the vessel traffic is rather great the icebreaker working in the area often pass in the vicinity of the caissunlight. Ice observations are continuously done on board the icebreaker from the area it passes. Reports of ice concentration, ice thickness and ice drift are sent 4 times a day per telex. At times air reconnaissance from helicopter is done. Further more satellite images are treated to make a good picture of the ice situation.

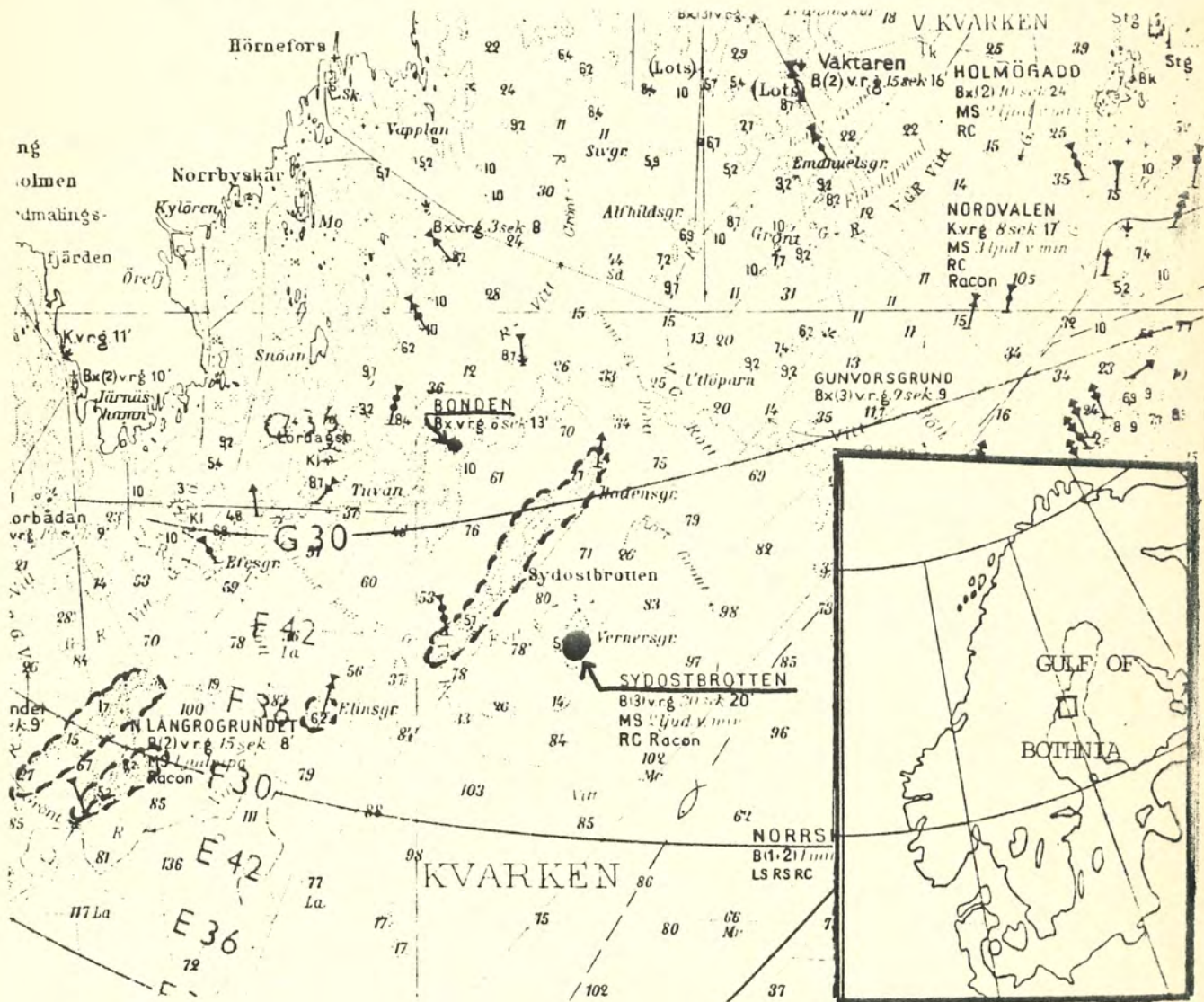


Fig 1. Map of the Gulf of Bothnia with detail of Sydostbrotten and environments.

This report is an attempt to make a statistical review of the ice drift around the caissunlight using all this ice information and the weather observations from the automatic weather station at Sydostbrotten.

1. General ice information and statistic.

The ice winter 1986/87 was somewhat more severe than normal in the area. The ice formation started normal time but the ice breaking up was about 10 days later than normal. The maximum ice thickness may be compared with some of the severe winters. However, the winter was not extreme, the frequency of ice pressure with ridges rather small and a lot of cases with broken ice and leads occurred. Fig. 2 shows the development during the winter. During the period of ice formation the new formed ice drifted southwards due to northerly winds and followed by further ice formation. This often occurred in January and February. Also periods with open ice occurred. During March the ice was maximum. The ice was often stationary, grew thicker and became more ridged due to partly heavy ice pressure. At the end of April the ice broke up and a lead was formed. However, close or open drift ice drifted into the area in the beginning of May. The ice was broken into small rotten floes among big heavy floes. From 17 May almost ice free.

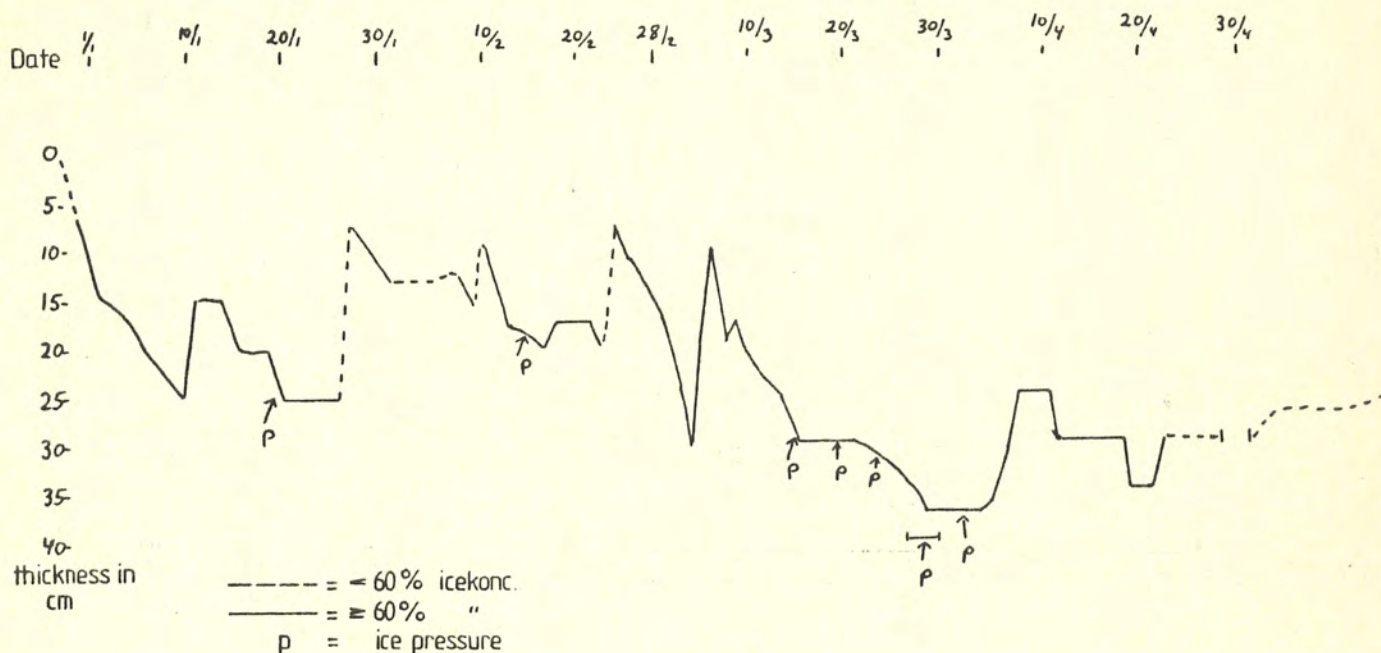


Fig 2. Ice development during the winter 1986/87.

2. Ice drift.

The ice drift has been observed, calculated and estimated, based upon wind- and temperature-observations registrated at Sydostbrotten. The current is estimated from the water-level changes. Data from regular ice drift forecasts are checked up. (A numerical model for forecasting the ice motion in the Bay and Sea of Bothnia. I. Udin and A. Ullerstig 1977, Research Report No 18, serie WINTER NAVIGATION Research Board.)

Also observations on board icebreaker passing in the vicinity are checked as well as data calculated from videotape used by LTH (Luleå Tekniska Högskola). The ice thickness and ice concentration represent the area close the caissunlight Sydostbrotten.

In the figures 3, 4 and 5 the ice drift is presented in drift roses for different ice thickness. As the ice thickness varies a lot with thin ice among thicker floes the thickness intervals overlap each other. The ice thickness may represent a sort of mean ice thickness. The rose shows the ice drift towards a direction, i.e. southwesterly ice drift the ice is drifting towards southwest. The velocity is in cm/s with three intervals showing the total number of cases. In fig 3, i.e 20,3% of the observations are in the directions 202,5 degrees and velocity above zero. About 11,5% of the cases are velocity above 20 cm/s of the same direction. The data is four observations/day, in other words every 6-hour.

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OCEANOGRAPHISKA OBSERVATIONER
Sydostbrotten 5-15 cm ICE THICKNESS
sort cm/s

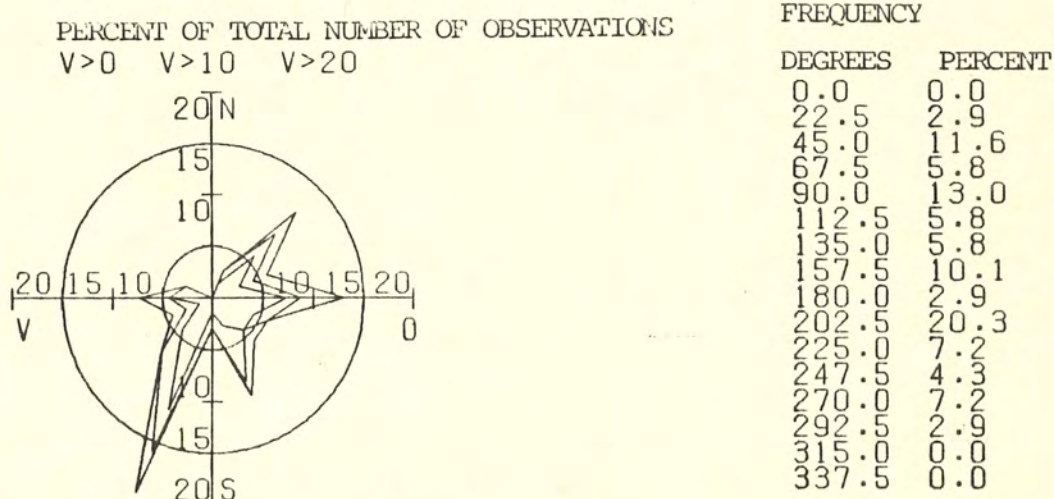


Fig 3. Ice drift. Ice thickness 5-15 cm.

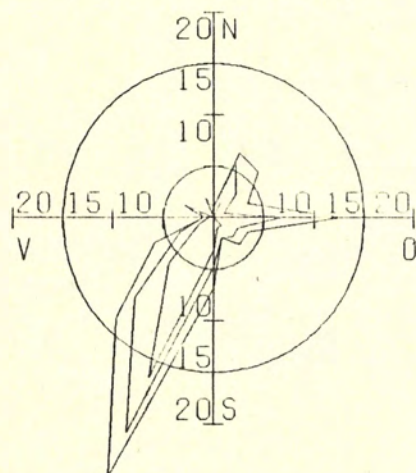
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OCEANOGRAPHISKA OBSERVATIONER
Sydostbotten 10-30 cm ICE THICKNESS

sort cm/s

PERCENT OF TOTAL NUMBER OF OBSERVATIONS

V>0 V>10 V>20



FREQUENCY

DEGREES	PERCENT
0.0	1.0
22.5	6.8
45.0	6.3
67.5	3.7
90.0	12.6
112.5	3.7
135.0	3.7
157.5	2.1
180.0	6.8
202.5	27.2
225.0	13.6
247.5	6.3
270.0	1.0
292.5	3.1
315.0	0.0
337.5	2.1

Fig 4. Ice drift. Ice thickness 10-13 cm.

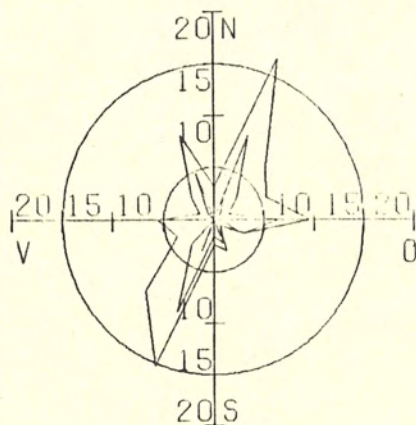
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OCEANOGRAPHISKA OBSERVATIONER
Sydostbotten 20-50 cm ICE THICKNESS

sort cm/s

PERCENT OF TOTAL NUMBER OF OBSERVATIONS

V>0 V>10 V>20



FREQUENCY

DEGREES	PERCENT
0.0	3.2
22.5	16.8
45.0	7.2
67.5	5.6
90.0	9.6
112.5	3.2
135.0	0.8
157.5	3.2
180.0	2.4
202.5	15.2
225.0	9.6
247.5	4.0
270.0	5.6
292.5	1.6
315.0	3.2
337.5	8.8

Fig 5. Ice drift. Ice thickness 20-50 cm.

The three figures have some similarities. The southwesterly and northeasterly ice drift dominates. Very few northwesterly ice drift occur. However, in a period in March moderate or heavy ice pressure occurred. The ice pressure was northwesterly which is shown in figure 5. When ice pressure occur the ice drift is very small and irregular. The ice is ridging and the ridges may have formed in the environments. That means the ice drift may have been overestimated. (Fig.1.). Looking at the bottom topography in the area one will find that the conditions is great for ice ridging. Fast ice often occur insides the shoals northwest of Sydostbrotten.

This winter westerly or northwesterly winds have occurred more than normal and leads have formed west of the lighthouse partly due to icebreaker breaking the Borden fairway. This is shown as an easterly and southeasterly arrow.

The figures also show a wellknown fact, the thicker ice and high ice concentration cause less velocity.

In figure 5 only a few cases with velocity above 20 cm/s are noted compared with the 5-15 cm ice.

This conditions can be illustrated in a table below

Ice thickness	5-15 cm		10-20 cm		20-50 cm	
	mean		mean		mean	
	cases	ice	cases	ice	cases	ice
		conc.		conc.		conc.
stationary	16		70		55	
0-10 cm/s	14	57%	55	93%	67	92%
10-20 cm/s	18	67%	73	87%	43	73%
> 20 cm/s	36	45%	63	82%	17	72%
total	84	55%	261	85%	182	83%

In the last column 17 cases 20-50 cm ice with rather rapid ice motion is mostly broken small and big floes.

3. Summary.

The ice drift at Sydostbrotten and also generally in the Sea of Bothnia is caused by the wind. Combined with an often weak current, which may change the direction for some 10:ths of degrees.

The report shows a statistical review of the ice drift, ice thickness and ice concentration in the area close Sydostbrotten. It may not give the absolute ice mass transport at the construction.

One may draw one conclusion: southwesterly and northeasterly ice drift dominates. This conditions may be compared with the normal wind statistic where these wind sectors are frequent. Southerly current dominates during winter period January - April.

The calculated ice drift values are listed below. The tables refer to the ice thickness 5-15 cm, 10-30 and 20-50 cm. The data presented are the date, ice drift speed in cm/s and the direction towards, i.e. 180° means southrunning icedrift.

Sydostbrotten 5-15 cm

cm/s	degrees		
27/12	40 270	8/2	40 210
	40 260		40 210
	40 260		30 220
	40 250	9/2	30 210
30/12	55 220		15 210
	55 200	11/2	15 290
	40 200		15 290
	25 200		
31/12	05 200		
	05 240		
		24/2	05 150
			05 200
			15 240
27/1	05 270	25/2	10 200
	05 270		05 200
28/1	15 180		05 140
	20 210		05 080
	15 230	26/2	20 030
29/1	10 160		10 150
	20 140	27/2	10 150
	40 120		15 150
	15 120		20 160
30/1	10 070		50 190
	10 030		
31/1	20 100		
	40 110		
	30 150		
	30 140		
1/2	20 130	5/3	05 050
	20 120		
	10 090		
	20 090		
2/2	20 100		
	05 100		
	05 080		
	05 060		
3/2	05 040		
	15 040		
	30 050		
	40 050		
4/2	50 050		
	40 090		
	20 090		
5/2	20 060		
	20 060		
	20 050		
	15 050		
6/2	15 220		

Sydostbrotten 10-30 cm
cm/s degrees

Appendix 2

10 340	05 060	23/2 10 120	25/4 10 230
24/1 15 360	19/1 05 030	20 180	10 230
20 210	10 030	40 200	20 230
1/1 25 220	10 020	60 200	15 210
30 220	10 020	23/2 50 180	26/7 10 220
20 210	26/1 10 030	40 160	05 250
05 210	05 040	20 160	27/7 05 040
2/1 05 220	22/1 05 130	10 120	10 030
05 220	15 160	30 210	10 040
10 210	15 190		10 060
10 210	05 190		28/4 25 090
3/1 30 190	24/1 05 060	28/2 40 200	15 090
40 200	05 070	20 210	15 090
50 200	05 080	20 230	
40 200	05 090	20 230	
4/1 40 200	25/1 05 120	1/3 20 220	
40 210	10 200	10 220	
20 230	40 210	05 220	
20 240	50 200	05 200	
5/1 15 250	26/1 50 200	2/3 20 230	
20 260	50 200	40 230	
15 250	20 220	40 230	
20 250	05 200	40 220	
6/1 30 210	27/1 05 300	3/3 20 210	
20 210	6/2 25 240	4/3 20 210	
05 180	40 200	20 210	
10 150	40 200	10 190	
7/1 20 140	7/2 10 200	05 180	
40 200	10 200	6/3 05 340	
15 200	20 180	05 340	
05 200	20 180	10 350	
8/1 05 300	8/2 50 180	7/3 05 330	
05 230	50 210	05 240	
20 200		15 220	
9/1 40 200		10 220	
40 200	11/2 30 290	8/3 10 210	
30 210	15 280	05 210	
10 220	12/2 05 250	05 060	
10/1 10 220	15 200	15 080	
20 210	05 200	10 070	
20 210	13/2 05 250	10/3 05 060	
10 190	05 250	05 050	
11/1 10 240	05 300	12/3 05 210	
10 240	10 290	13/3 05 040	
12/1 05 110	14/2 15 300	14/3 15 030	
10 100	20 030	20 030	
10 100	20 090	25 020	
13/1 05 090	20 090	10 020	
05 090	15/2 10 090		
14/1 05 090	05 090		
05 090	16/2 10 020		
10 100	05 030	7/1 05 040	
10 100	17/2 05 210	05 230	
15/1 10 090	10 220	10 210	
10 120	20 210	05 170	
10 120	18/2 15 210	10/1 10 050	
10 120	05 200	10 040	
16/1 15 130	19/2 05 100	10 040	
20 140	10 100		
10 140	20/2 05 040		
05 140	10 040		
18/1 05 090	21/2 10 040		
05 090	05 080		
	15 130		

Sydostbrotten 20-50 cm

cm/s degrees

3/3 40 210	11/4 05 030	2/5 20 030
20 210	05 020	20 090
20 210	05 030	10 090
	05 030	3/5 10 230
15/3 10 020	12/4 05 030	10 210
10 020	05 030	10 210
05 010	13/4 05 040	15 200
18/3 05 360	05 040	4/5 05 200
05 330	14/4 05 060	05 240
05 320	10 080	05 200
05 320	15/4 10 030	5/5 10 040
19/3 05 300	10 030	10 040
05 290	10 060	10 040
20/3 05 210	15 090	10 030
05 200	16/4 10 090	6/5 10 030
	15 090	10 030
	15 070	05 060
	20 120	20 150
23/3 05 360	17/4 15 120	7/5 20 160
05 350	10 190	15 210
24/3 05 330	10 210	10 190
10 340	18/4 25 210	9/5 05 270
20 340	10 210	05 230
27/3 10 340	19/4 05 150	10 270
05 330	05 230	10 270
28/3 20 310	20/4 05 210	10/5 10 230
15 340	05 250	15 230
10 340	05 240	15 230
10 340	05 220	15 210
29/3 05 320	21/4 05 250	
05 330	05 270	
05 330	05 280	
30/3 02 100	05 280	
05 100	22/4 05 020	
05 100	20 040	
3/3 05 050	15 090	
02 040	23/4 15 100	
02 020	20 120	
05 020	20 120	
1/4 20 020	20 140	
20 020	24/4 15 150	
10 020	05 170	
05 020		
2/4 02 280		
05 230		
05 230		
02 230		
3/4 02 250		
05 090		
4/4 05 070		
05 040		
05 060		
05 060		
5/4 05 210		
05 200		
6/4 10 200		
05 230		
05 220		

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