II. Suspended Matter

by

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In our previous report (1972) we already showed that a water mass with a high suspended matter content persists off the Belgian coast. Mean concentration attained 10 mg/ℓ [fig. 1 (1972)] and more during different campaigns held however at Beaufort < 8 . These concentrations can be attained in two ways :

i) hydrodynamic processes can create a concentration increase from sediment sources,

ii) constant reworking of underlying mud layers can cause increased turbidity.

The part of the North Sea under consideration has a diurnal tidal system. In some places velocities of 2 knots (± 100 cm/s) are attained (Scheur). However a more or less extended mud layer is found under these turbid waters [Bastin (1973)]. The muddy area extends from one or two km from the coast to some 20 km into the sea at its greatest extension (fig. 3.13). Depth is always less than 20 m .

Thus, hydrodynamic conditions must be such that accumulation and preservation of this mud is possible.

Many have worked on the relationship between water velocity and sedimentation erosion. Partheniades (1965) came to the conclusion that there must be a "critical velocity above which all clay stays in suspension and under which all clay settles". In his experiments, this happened at 0.5 ft/s (15 cm/s) . He stated however that turbulence should be much less in open water than in his laboratory flume at the same velocity. Terwindt and Breusers (1972) put forward that sedimentation in the North Sea starts as soon as the velocity 0.5 m of the bottom falls under 20 cm/s .

As the determination of near bottom velocities in the area had to be calculated on the basis of surface velocities, we take 20 cm/s at 1 m above the bottom as a possible critical velocity for the sedimentation of mud.

Terwindt, Breusers and Svasek (1968) found a critical shear stress of 1.1 N/m^2 for sand-clay laminations in the Haringvliet.

Table 3.1 compilates the results of some authors. We did not have the opportunity to take undisturbed samples. Mixing with underlying sand in sampling laminated sand-mud deposits may be occurred. This means that we cannot give an hydraulic valuable granulometric composition of the mud.

Table 3.1

Critical water velocities after some authors

Authors	Composition z = sand s = silt k = clay	U_c^* (cm/s)	U_{50} V at 50 cm off the bottom	U_{100} V at 1 m off the bottom
Partheniades (1965)	no sand	0.8	21	22
Terwindt, Breusers and Svasek (1967)	50% z 30% z 20% z	3.3	97	103
Terwindt and Breusers (1972)	37% z - 2 h	1.9	53	56
	2 1/2 h	2.1	59	63
	7% z - 2 h	0.8	21	22
	2% z - 2 1/2 h	1.4	38	41
	37% z - 1/4 h	0.7	18	19
	1/2 h	1.2	32	34
	1 h	1.75	49	52
	2 h	2	56	60

Terwindt and Breusers (1972) results could be applied to the situation off the Belgian coast as circumstances, comparable with those occuring in their experiments are found here. A critical velocity of 60 cm/s at 1 m above the bottom or U_c^+ of ~ 2 cm/s could be an acceptable value.

Thus, we put forward that at places where V_{100} (velocity at 100 cm above the bottom) does not exceed 60 cm/s and falls for some time below 20 cm/s , mud layers can very probably be formed and preserved.

On the basis of the *Stroomatlas* of the *Ministerie van Openbare Werken* V_{100} are calculated by means of the Van Veen (1936) equation :

$$V = a \sqrt{h}$$

with V the velocity at a m above the bottom, a the velocity at 1 m above the bottom and h the depth, based on MLLWS and the amplitude.

It seems that off the Western Belgian coast, the longest period with the lowest velocities is slackwater before flood.

This means, as the water turns anti-clockwise that settling is most intensive when the watermass moves in the seaward direction. So, export of mud towards the sea is difficult and concentration towards the coast is favorized.

For the *Stroomatlas*-stations, the velocity-vectors are added for every hour from 6 hours before to 6 hours after high water. The results are shown in fig. 3.7 and 3.8, for spring and neap tide. The western part of the area has a NE to E directed resultant. Material that stays in suspension will thus be transported along or towards the coast.

Tidal streams along the eastern part of the coast are much stronger. The resulting direction is S to SW here. Export of muddy suspended material can occur in the neighbourhood of the Wandelaar, especially at spring tides. Water velocity does not fall under 20 cm/s then, and the resultant stream direction is seaward.

As already shown by Bastin (1973), the Belgian coastal area is a place where spring and neap tide reststreams meet.

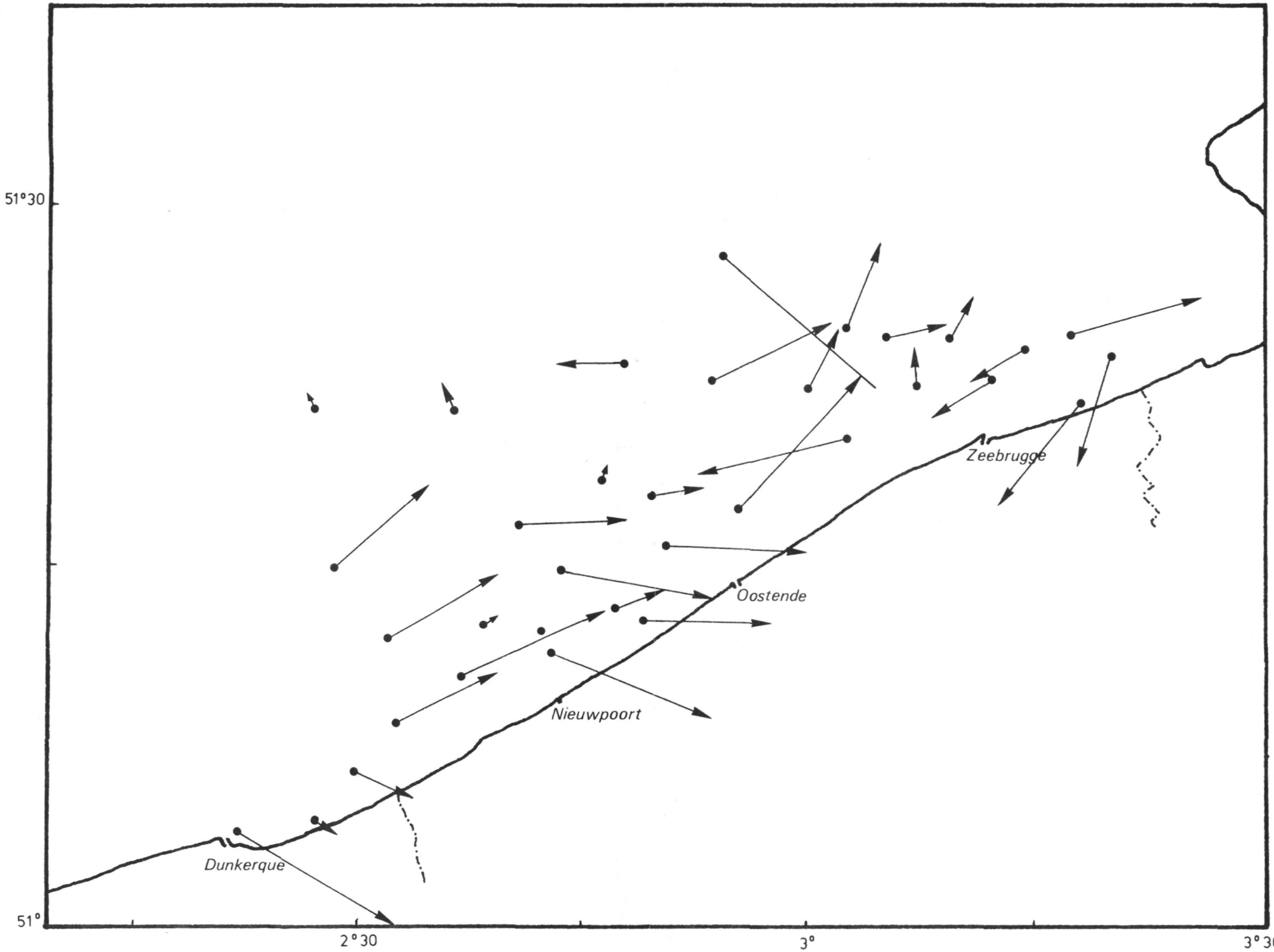

fig. 3.7.- Results of tidal currents taken over a spring tidecycle (12 hr) (from "Stroomatlas"). 1 km = 0.5 cm .

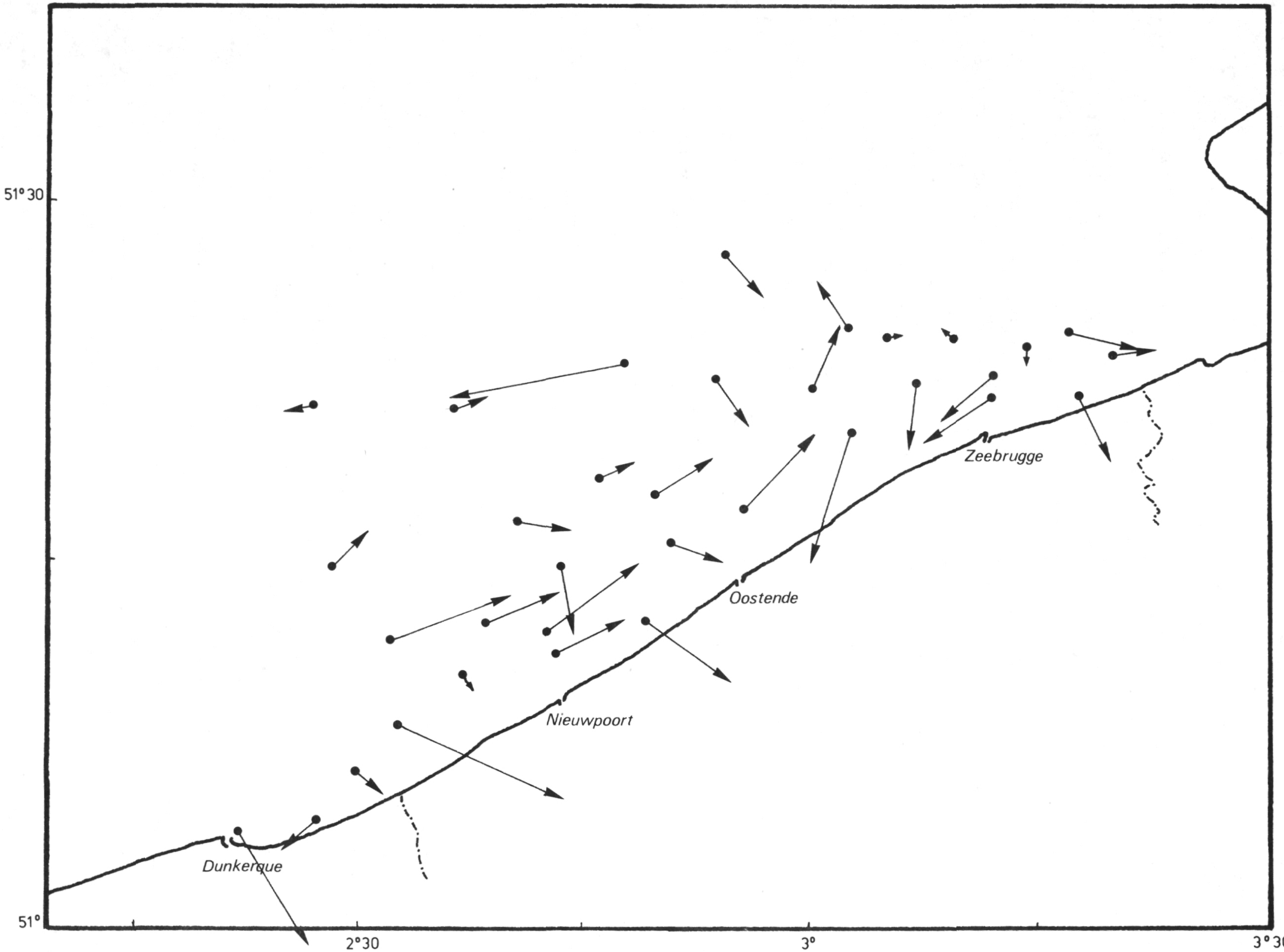

fig. 3.8.- Results of tidal currents taken over a neap tidecycle (12 hr) (from "Stroomatlas").

We already mentioned that this area is usually more turbid than surrounding waters.

Draper (1966) and McCave (1971) showed that wave action is highly effective at depths of less than 15 to 20 m . We thus know that the area under consideration is regularly reworked by waves.

The higher concentration of suspended matter can be explained by the constant and periodical reworking of this material.

Based on the *Stroomatlas*, the figures 3.9, 3.10, 3.11 and 3.12 were drawn. They show the distribution of minimum and maximum velocities at 1 m above the bottom at spring and neap tides (V_{100}^{min} and V_{100}^{max}). The aim was to correlate mud distributions and hydrodynamic conditions.

One can see that, apart from the Scheur, V_{100}^{max} and V_{100}^{min} during spring and neap tides are almost always lower than 50 cm/s and 20 cm/s .

A zone of changing with along the coast has at all times slack-water velocities lower than 10 cm/s . Slackwater sedimentation should occur if it is not inhibited by wave action.

Off the eastern part of the coast, V_{100}^{min} is always higher than 20 cm/s . Mud sedimentation is less probable than elsewhere.

V_{100}^{max} increases during spring tides from 50 cm/s off the western part of the coast to more than 100 cm/s at the Scheur. Current strength is high enough to cause erosion of mud provided its consolidation is not too high.

It is apparent that in a near coastal zone sedimentation of mud can occur during spring tides and during neap tides as well. Probably in the western part the mud is less subject to erosion by streaming water. Nevertheless, stirring up by waves will make this material available to transport. A comparison between the figures 1 (1972) and 3.10 of the actual report shows that the area with the highest current velocities is also more turbid than surrounding zones.

Some elements were lacking to explain the high suspended matter concentrations. For instance, the resulting current direction of the velocities between ± 20 cm/s and 60 cm/s must be as useful indication of transport of fine grained material. The position of a water particle after one tidal cycle is also a very important aid, as well as good

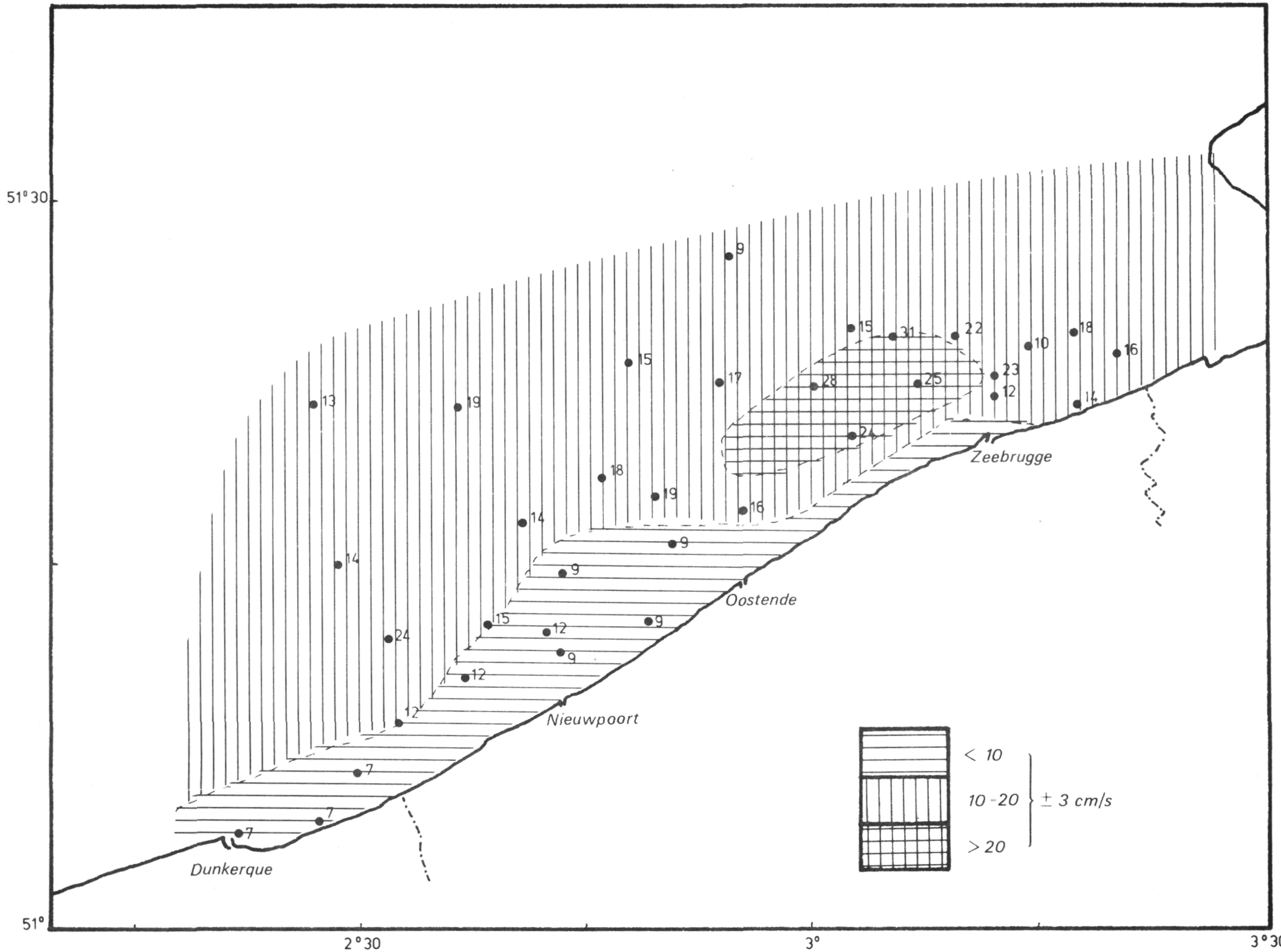

fig. 3.9.- Distribution of the V_{100}^{min} at springtide (minimum speed at 1 m from the bottom).

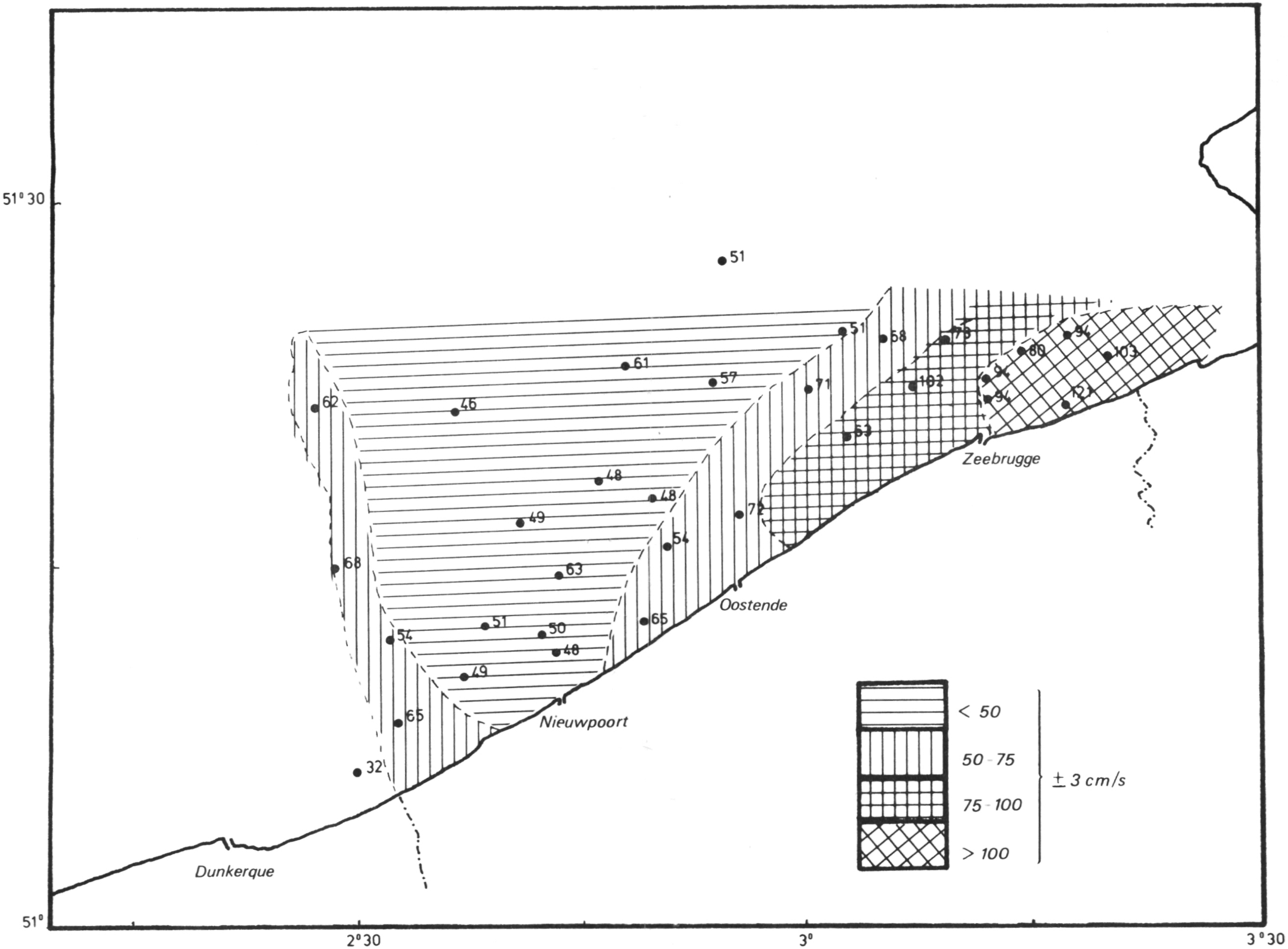

fig. 3.10.- Distribution of the V_{100}^{max} at springtide.

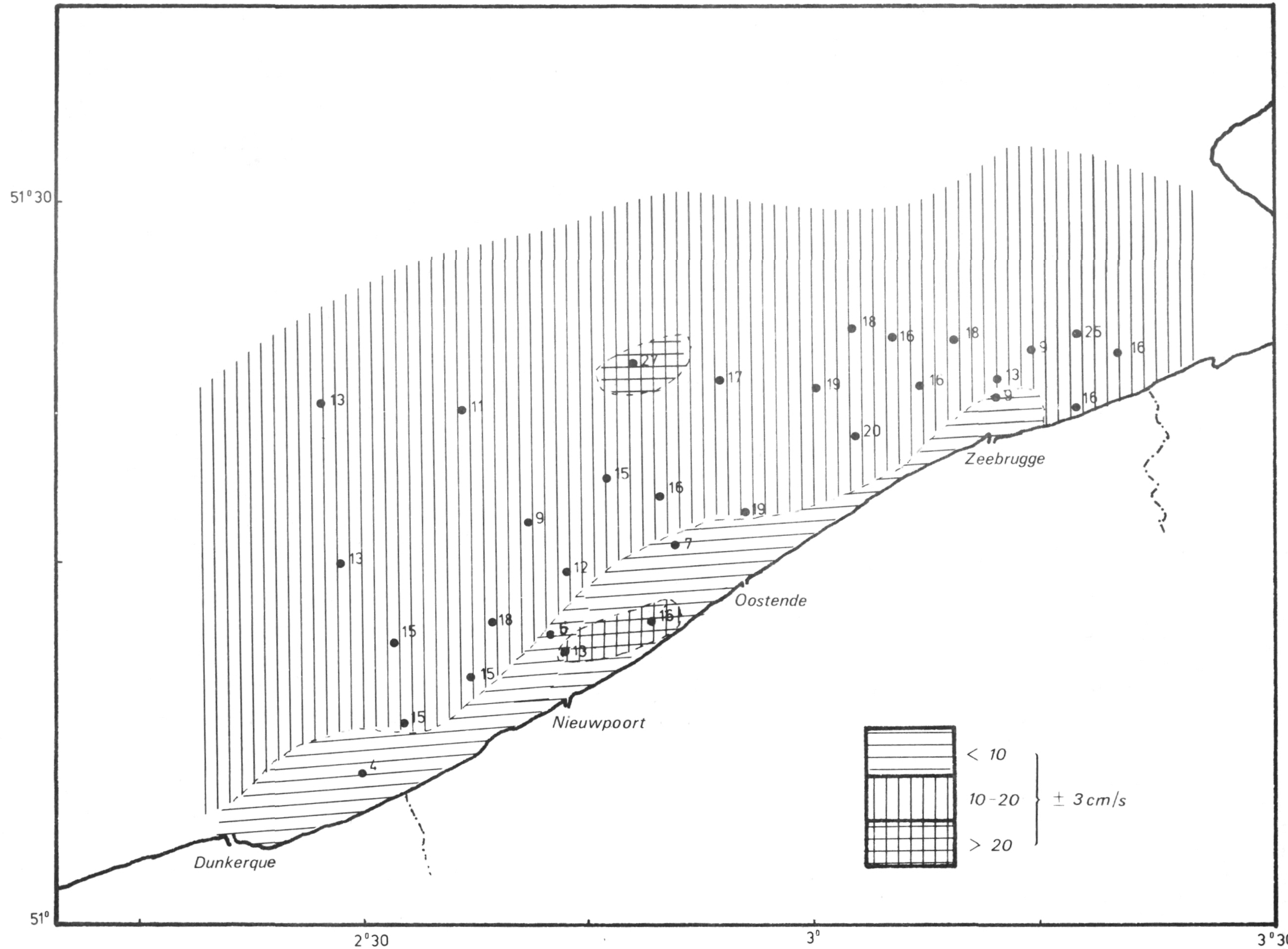

fig. 3.11.- Distribution of the V_{100}^{min} at neaptide.

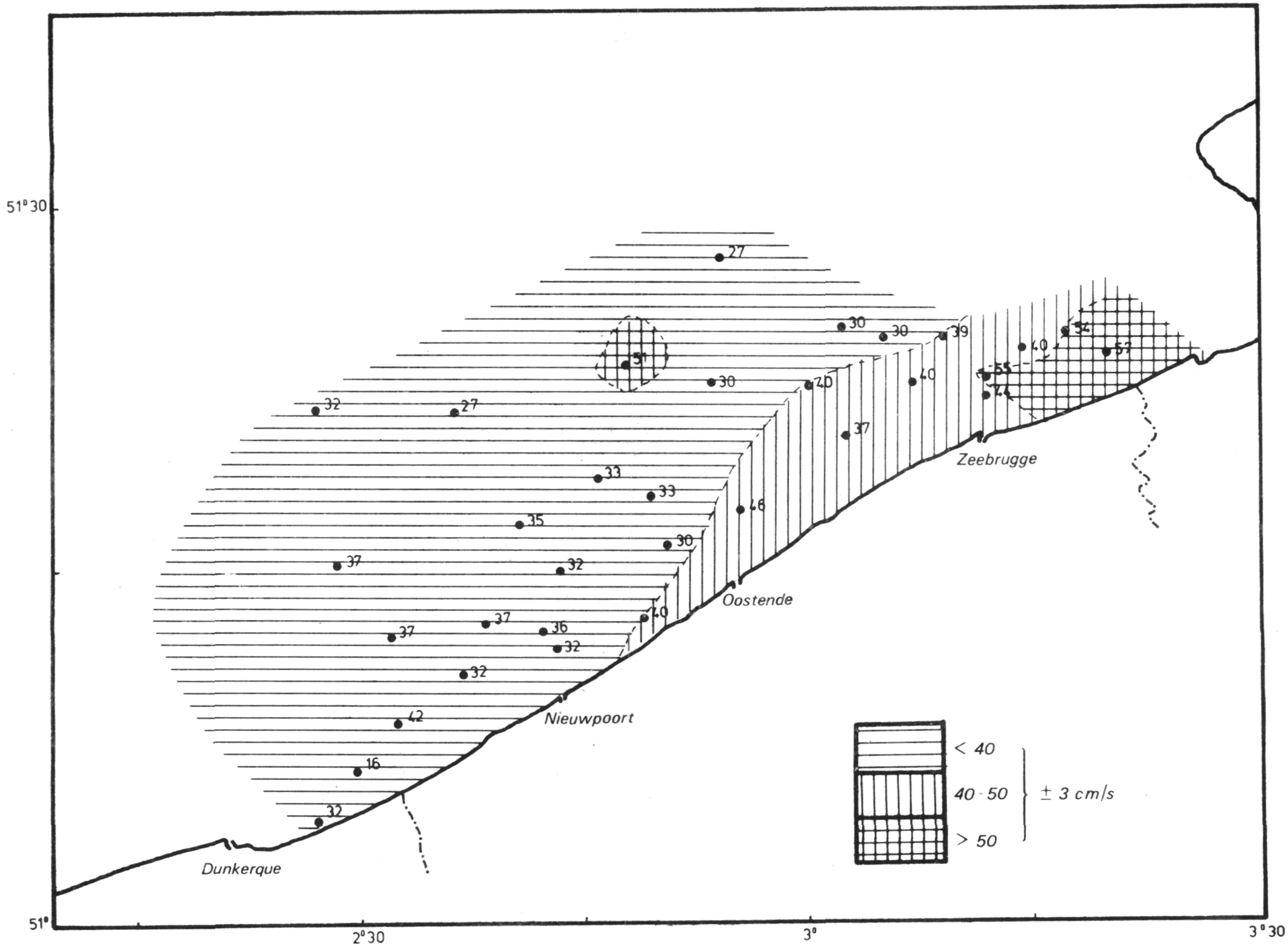

fig. 3.12.- Distribution of the V_{100}^{max} at neaptide.

wave action observations. Grainsize distributions of the suspended sediment is unknown too. Samples gathered by centrifugation were too small to accomplish a classic analysis. Besides, this material was so hard to peptisize that the obtained results are unreliable.