HARBOUR SEDIMENTATION - COMPARISON WITH MODEL

B.D. Pratte, D.H. Willis and J. Ploeg[1]

ABSTRACT

A mobile-bed model study of Pointe Sapin Harbour, in the Gulf of St. Lawrence, resulted in construction of a detached breakwater and sand trap to prevent harbour entrance infilling. The sand trap is filling in at a faster rate than predicted from the model. This is partly due to incomplete modelling of the wave climate; partly to incorrect modelling of distribution of alongshore sand transport; and partly to a complex sand supply at the site. Nevertheless, the sand trap solution is performing well.

POINTE SAPIN HARBOUR

Pointe Sapin Harbour is a small fishing harbour on the Gulf of St. Lawrence, see Figs. 1 and 2. Records show that the first wharf was built there in 1913 on a soft sandstone coast. The situation quickly changed however, for aerial photographs taken between the World Wars clearly show a sandy coast, and what is worse, sedimentation in the harbour berths. Then began the familiar extensions of the structures seaward in an attempt to block the transport of sand into the harbour.

By the mid-1970s it was time for another extension. During northeast storms, two or three times a year, the harbour entrance would completely fill in to above Low Water within 12 hours, see Fig. 3. The danger in this is obvious: vessels were caught in open water by the storm, with no refuge; and they were trapped in the harbour after the storm, unable to see to their traps and nets until the entrance could be dredged.

THE CAUSE

The cause appeared to be alongshore transport of beach sand by waves. As shown in Fig. 1, Pointe Sapin Harbour is sheltered by Prince Edward Island from waves from the southeast. To the northeast however, the available fetch is 225 km and from this direction come storms with significant wave height, H_s, of 3 m and peak period T_p, of 8 s. The result is an overwhelmingly predominant northeast-to-southwest transport of beach sand.

How much transport is a matter for debate. This is due to all the usual reasons, plus:

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[1] Hydraulics Laboratory, Division of Mechanical Engineering, National Research Council Canada, Ottawa, Ontario K1A 0R6, Canada.

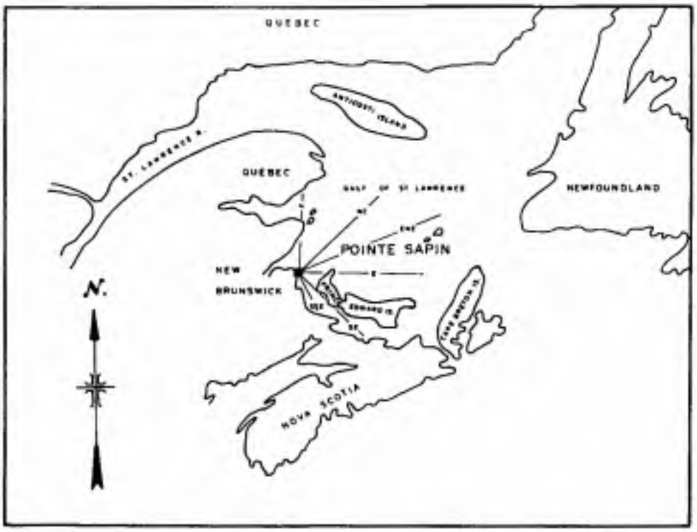

Fig. 1 Location of Pointe Sapin

Fig. 2 Harbour before sand trap construction

1. Sand supply is limited, there being a maximum of only a metre of sand overlying sandstone and till.

2. The profile is very shallow. The surf zone under the northeast storm waves can be as much as 1 km wide.

Estimates of the net northeast-to-southwest transport ranged from 120,000 m^3/yr (Pratte and Willis 1979) to 205,000 m^3/yr (Hydrotechnology Ltd. 1980). The only two fairly firm facts are: that 10,000 to 30,000 m^3 needed to be dredged annually from the harbour entrance; and that it took approximately 12 hours to fill in the entrance during storms.

THE MODEL

A physical model of Pointe Sapin Harbour was built in the Hydraulics Laboratory of the National Research Council Canada to seek engineering solutions to the infilling problem, see Fig. 4. The horizontal scale was 1:100 to fit into the available wave basin. Flume tests indicated a vertical scale of 1:30 (i.e. a distortion of 3:33) and a grain size of 260 µm would correctly model the beach slope under typical northeast storm conditions, wave height 3 m and period 8 s. An almost uniform silica sand of this size was used in a mobile bed 50 mm (1.5 m full scale) thick in the model.

Initial tests reproduced the observed infilling of the harbour entrance by running 90 minutes of the northeast storm waves. Assuming this corresponded to 12 hours full scale, an approximate sedimentological time scale of 8 was determined. However, since bedload transport

Fig. 3 Sand deposition in harbour entrance

Fig. 4 Sand deposition in model harbour entrance

on the model was being used to simulate suspended load transport in real life, it was recognized that the actual sedimentological time scale would be a function of the wave conditions and location in the model.

THE SOLUTION

The most obvious solution would have been to simply live with the existing entrance infilling and to make available a dredge on a permanent basis. This was not acceptable since Public Works' dredges were required to be mobile and serve many harbours. A second obvious solution, but one which we were determined to avoid, was buying a little more time for the harbour by extending into (temporarily) deeper water. Some such schemes were tested on the model of course, but so were more radical schemes attempting to achieve natural sand bypassing.

In the end, we proposed the solution shown in Fig. 5. This consists of a sand trap updrift of the entrance, protected by a detached breakwater. The breakwater not only provided calmer water to encourage settlement of the sand, but also created a sheltered area from which a dredger could clean out the trap and pump the sand across the entrance to the downdrift side of the harbour.

THE FULL-SIZE MODEL

At this point (1979) something rather unusual happened: the full-sized harbour was actually modified exactly as proposed by the model

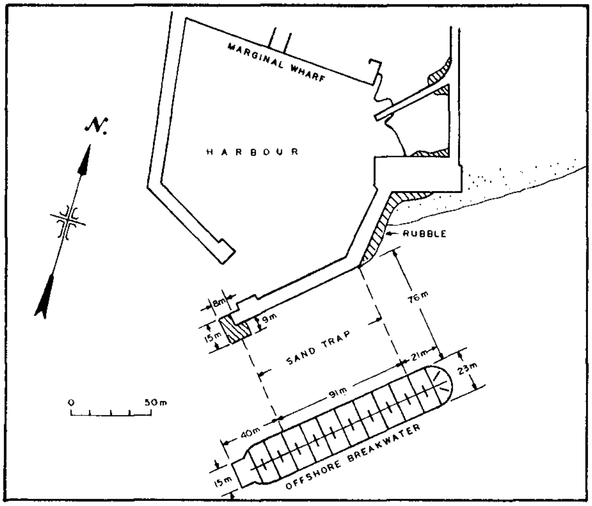

Fig. 5 Sand trap as built

study. This provided a rare opportunity to check the performance of a mobile-bed model.

Beginning in the spring of 1980 just before completion of the offshore breakwater, the National Research Council commissioned a time series of aerial photographs to be taken of the harbour. Five complete sets were obtained: May, August and November 1980, and May and November 1981. The similarities between model and nature are quite striking, as shown in Figs. 6 and 7.

However, the model considerably underestimated the rate at which the sand trap filled.

COMPARISON OF TRANSPORTS

To a certain extent, this underestimate could be explained by "model effect". For example, only the most severe annual storms were simulated on the model, whereas the real harbour was also exposed to every-day waves which contributed sand to the trap. We did attempt to compensate for this in analysing the model results, but perhaps that compensation was not enough.

Another model effect has already been mentioned: the representation of full-size suspended load by model bed load transport. As discussed above, our calculated sedimentological time scale of 8 could at

Fig. 6 Build-up in model sand trap

Fig. 7 Build-up in full-size sand trap

best be correct only within a narrow range of water depths close to the entrance. Expressed another way, the distribution across the beach profile of alongshore transport was incorrectly modelled.

In 1980, the opportunity presented itself to examine these two effects in greater detail. The Small Craft Harbours Directorate of Fisheries and Oceans Canada commissioned a 10-year hourly hindcast of breaking waves for several New Brunswick harbours (Hydrotechnology Ltd., 1980), one of which was Pointe Sapin. Palmer (1980) used this data to produce alongshore current statistics, including distribution, for Pointe Sapin from the method described in Willis (1978). These were converted to alongshore transport statistics, still including offshore distribution, following Willis (1979).

Fig. 8 presents the average annual transport rate distributions for the ten years of data. The approximate position of the breakwater is also shown. What is clear is that the major portion of the transport, 60%, is contained between the breakwater and the shore, in the sand trap in other words. By contrast, considerable transport had been noticed seaward of the breakwater in the model. Clearly, the use of only storm waves as well as the incorrect modelling of transport distribution were factors in the model underestimating trapping rates.

A third factor has come to light just this year, 1982: the complex distribution of sand sources at Pointe Sapin. The Canadian Coastal Sediment Study undertook two field surveys of the area as part of the process of choosing a site for a comprehensive investigation of

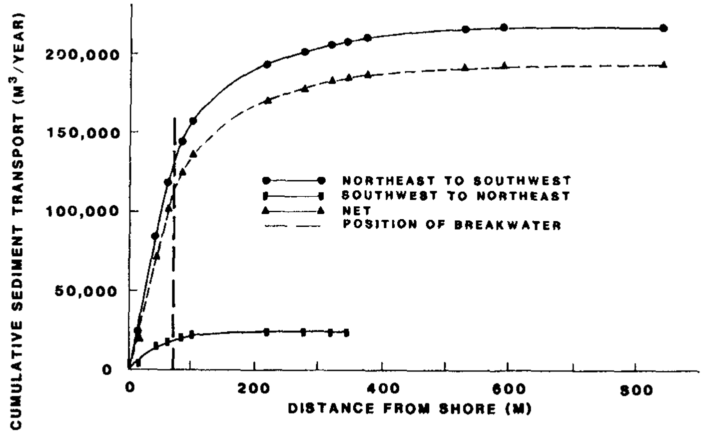

Fig. 8 Cumulative Sediment Transport

nearshore sand transport. These surveys found a predominantly soft sandstone nearshore seabed, with a thin sand layer only within 100 m from shore, see Forbes (1982). Forbes also found a second sand accumulation built up against a sandstone scarp farther offshore but still in relatively shallow water. It seems likely that some of this offshore material finds its way onshore and into the trap during storms.

CONCLUSIONS

Whatever the cause, the result remains that more sand than expected is accumulating in the Pointe Sapin trap, approximately 110,000 m^3/yr as compared to the previous dredging requirement of up to 30,000 m^3/yr. More dredging is required, and plans for a permanent dredging plant are being discussed. Nevertheless the main aim of the scheme has been attained, in that since the construction of the breakwater the harbour has remained open.

Meanwhile, the Canadian Coastal Sediment Study has chosen the Pointe Sapin site for its study of nearshore sand transport in the coming year. Pointe Sapin promises to be the most studied beach in Canada.

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