FLOW INFORMATION FOR THE WHOLE AREA; TODAY AND TOMORROW

Real Time Flow Information System

Ships and their pilots have difficulties in entering a harbour during periods of relatively high flow velocities. We developed a system that gives real time depth average flow velocity and direction vectors over a large area. The system also predicts the flow in that area for 24 hours, allowing ships to plan their voyage more accurately and safely. The system consists of a Horizontal Current Profiler which is mounted at the side of the river. A computer flow model computes the depth average flow in the area based on measured flow and on measured water levels. The flow prediction is also based on measured currents and on measured water levels.

The Port of Rotterdam has deepened the river Rhine and the Meuse branch, which are the main access channels to the Waalhaven. This allows large container ships to enter the harbour. At present ships and their pilots are allowed to enter the harbour only during periods when the water level is sufficiently high and the current velocity in the river is smaller than 0.5 knots. This limits the time allowance for entering the harbour to 1 hour in every tidal cycle and makes planning of a trip difficult.

Conditions
The area of interest, Figure 1, is situated at approximately 25km from the North Sea, along one of the branches of the river Rhine. The currents are dominated by the 400m wide river and the tide. During a typical tidal cycle, the flow on the river varies between 0.75m/s downstream during ebb and 0.75m/s upstream during flood. However, currents vary considerably with river discharge, tide and water level at sea. The flood period is shorter than the ebb period. Local wind influence on the currents is negligible. In the 300m wide harbour entrance the flow is inward during flood and outward during ebb. During flood, a vortex is formed at the entrance, producing flow velocities of approximately 0.7m/s at the east side of the entrance. The bottom is soft and dredged regularly to maintain a water depth of 15m. Stratification may occur due to fresh river water flowing over salty sea water. However, as this area is quite far from the sea, stratification is rare and will only occur during a period of low river discharge or during spring tide.

Requirements
The problem is that fast currents make it difficult for large container ships of length greater than 200m and depth more than 14m to enter the harbour. The flow of the river exerts a great force on the back of the ship, while the front has already entered the more calm waters of the harbour entrance. Ship pilots are interested in the currents from about 2km downstream and up to the harbour entrance, on a grid of 20 x 20m. For the operational guidance of large vessels, depth average current information is required with an accuracy of 0.1m/s (standard deviation). Current information should be real-time and carry a prediction rate of at least 13 hours. The prediction allows planning of trips while the ships are still far away at sea.

Measurement, Modelling and Prediction
As the basis of the system, we chose to measure currents locally.
A Horizontal Current Profiler is mounted on a quay along the river on the other side of the harbour entrance. The currents are measured in range cells of 10m, from 20m to 130m distance from the instrument. The instrument is mounted at mid-water depth. The instrument measures every second and averages data to 10 minute intervals.
The measured current data is extrapolated to represent depth averaged flow. A 2-dimensional flow model (2D) is used to compute flow vectors in the area of interest on a computational grid of 20 x 20m. In this way, the flow vectors obey the shallow water flow equations for depth-averaged flow. Local bathymetry and water level variations are taken into account on the computational grid.
The flow prediction is based on measured water level and measured currents, see Figure 4. Essentially, the measured flow vector is predicted. The 2D flow model is used to extend the predicted vector to the whole area, with an accuracy of 0.08m/s (standard deviation). During spring tide the accuracy is better (0.06m/s) than during neap tide. The accuracy of the prediction depends only slightly on the period of prediction (approx. 0.01m/s per day). We presently predict for a period of 24 hours; however, this will be extended to longer periods.

Software
The whole system has been incorporated in the software, shown in Figure 3, with separate parts for the operation of the Current Profiler and for the data processing. In Figure 3 the software shows the area with the flow vectors on a grid during flood conditions. The vortex in the harbour entrance can be seen nicely. Also to be seen are time series graphs of the flow at a number of specific points. Future versions will allow the user to present a specific moment. It will also become possible to view several moments, for example for prediction during flood, in a single window.

Conclusions

The operational accessibility of the harbour has been extended by providing pilots with information on the currents both in real-time and predicted over at least 13 hours, with an accuracy better than 0.1m/s. The system consists of four elements: a horizontal current profiler, an online flow model, a flow prediction module and presentation software. Pilots will use the system to plan their trip and manoeuvre more safely while entering the harbour.

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