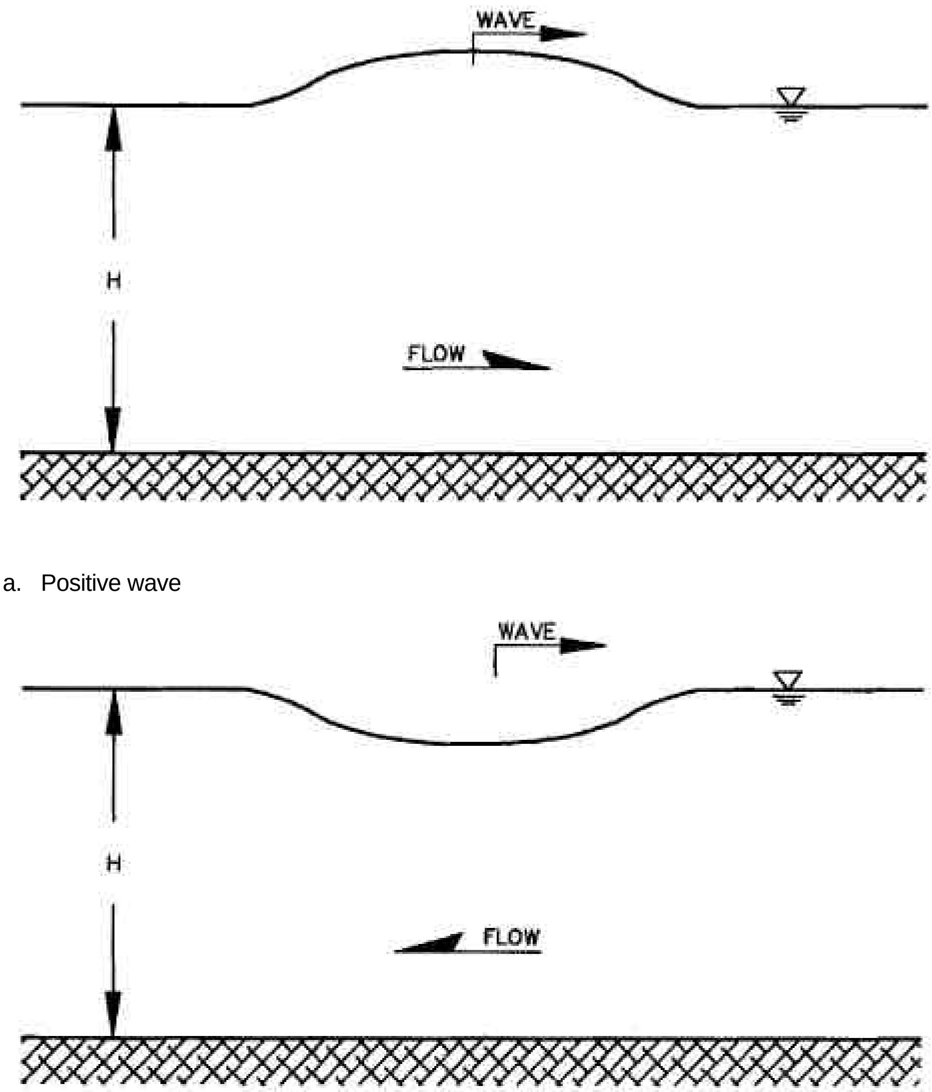
5 Screening Cases

This section contains several example runs for two general cases. One is termed a backwater example. This is a simple branch off the main stem channel that is a dead end. That is, it has only the one connection to the main channel and the other end is closed. The second example type is a side channel. This is a branch off the main stem that re-enters the main channel. This could represent the conditions in the shore side channel behind an island. The results of these runs appear complicated but, at least qualitatively, are made up by the superposition of rather simple descriptions.

First, consider a small solitary wave traveling along an initially stagnant, long uniform channel of constant depth H. A positive wave (the displacement is above the flat water surface) will generate velocity in phase and in the direction of wave travel. This positive solitary wave schematic is shown in Figure 2a. A negative wave (a depression in the water surface), on the other hand, will generate velocity that is in phase but in the opposite direction of the wave travel (Figure 2b).

The example channels in this report are not infinitely long, but they have either a closed end or a junction with the main river. Extension of the simple infinite channel concept must include these closed-end and main-river-junction boundary types. When a wave hits a solid barrier, a positive reflection occurs. That is, if a positive displacement wave is traveling to the right into a barrier, a reflected wave that is also positive and traveling to the left will result. The superposition of the waves at the barrier produces a velocity of zero but the wave height is amplified, as shown in Figure 3. If there is no damping, the wave amplitude at the barrier will be double the initial wave amplitude. The junction of the channel with the main river constitutes an abrupt expansion. The water surface at the channel inlet will tend to remain at a constant height, as a reservoir does. A wave impinging on a reservoir will produce a negative reflection. The reflected wave will have the opposite displacement and will be traveling in the opposite direction of the original incident wave. The currents of the incident and the reflected waves are in the same direction. At impact with the reservoir, the superposition of the incident and reflected waves results in a constant water-surface elevation but an amplified velocity magnitude, as depicted in Figure 4.

These descriptions are qualitative in that they consider no friction, viscosity, or reflection losses; however, they are useful in interpreting the model results. These conceptual models need to be related to the specific problem of a vessel passage in



a. Positive wave

b. Negative wave

Figure 2. Solitary wave propagation

the main river. The moving vessel develops a drawdown that travels beside and with the vessel. This depression in the water surface will then propagate into the backwaters and side channels, resulting in an exchange of volumes between the channel and these off-channel features. This vessel-generated water-surface depression will produce a drawdown at the inlet of a side channel or backwater, and a depression wave that travels through these channels. This wave has a speed, or celerity, of roughly $(gH)^{1/2}$.

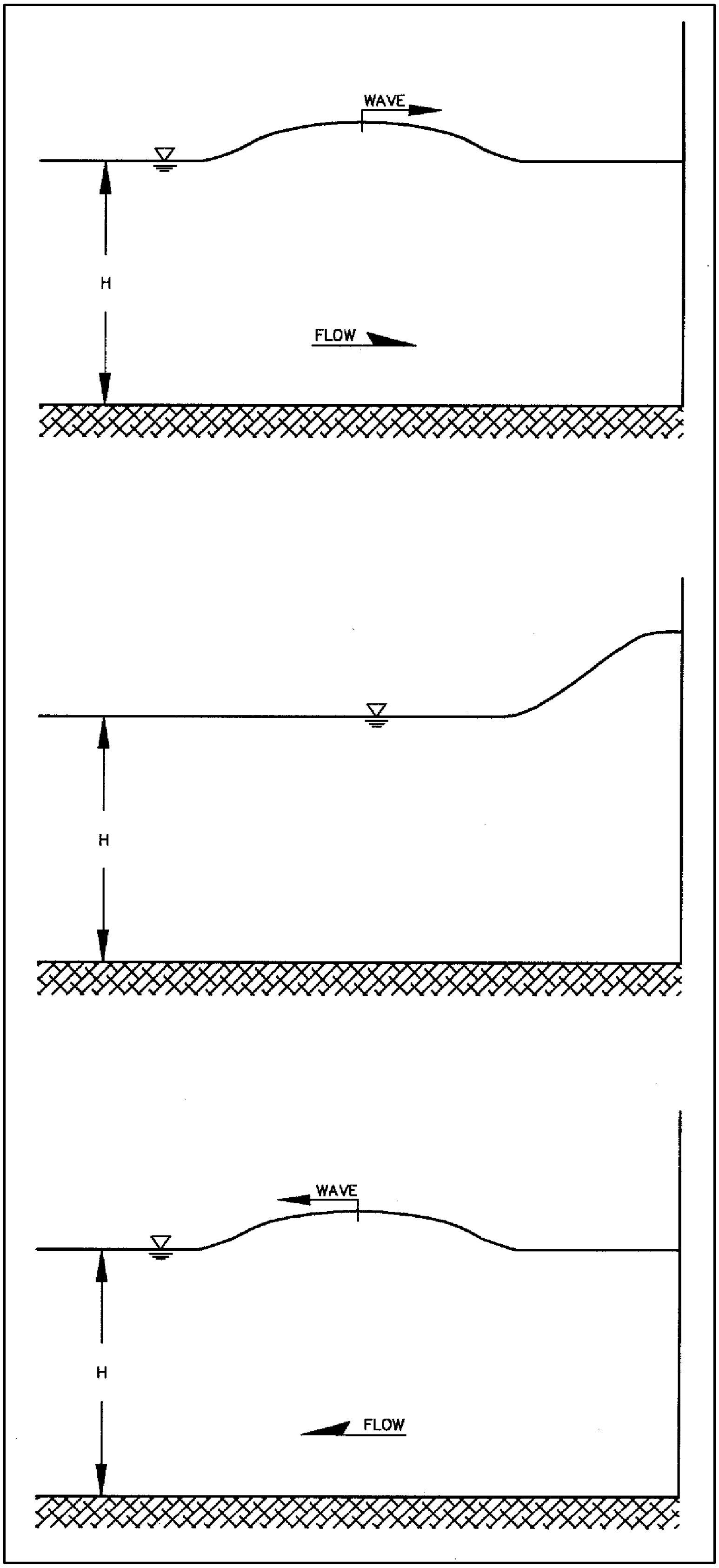


Figure 3. Solitary wave traveling into a barrier

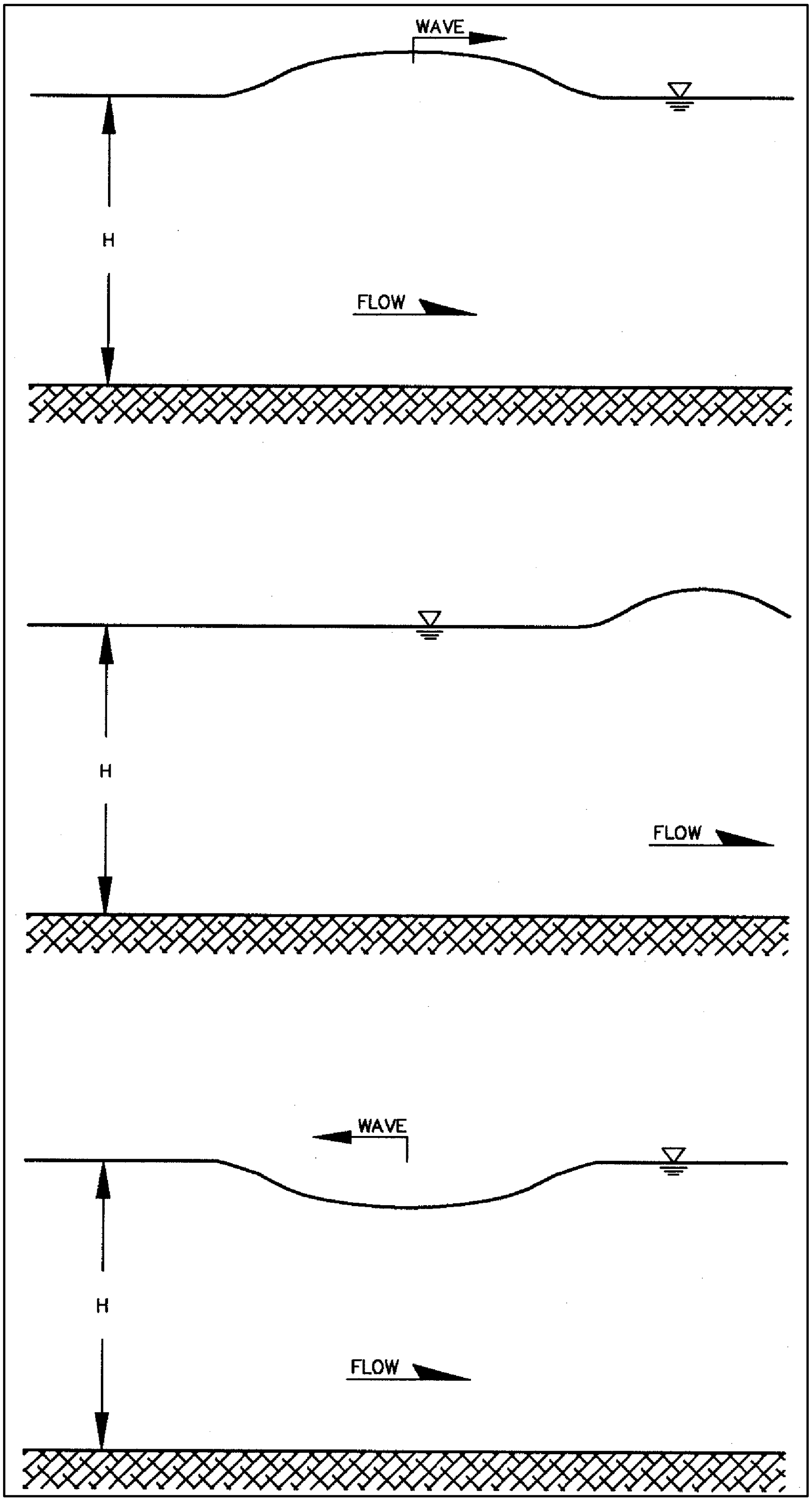


Figure 4. Solitary wave traveling into a reservoir

Side Channels

A series of numerical experiments was conducted to assess the influence within secondary channels of forces generated by a vessel navigating the main channel. Geometric and hydraulic parameters used to describe the features of a river side channel are shown in Figure 5. Dimensional analysis of the representative terms *l*, *L*, *B*, *b*, *D*, *d*, *V*, and *v* leads to the geometric ratios *L/l*, *B/b*, and *D/d*. Here, *B/b* and *D/d* describe a cross section and *L/l* describes the island length. Appropriate values of these descriptive ratios were determined from the Upper Mississippi River Database for Pool 8. Island lengths (*L/l*) vary from 3.6 to 10, so a range of island-to-vessel length ratios of 2 to 10 were modeled. Secondary channel widths (*b/B*) were found to vary only between 0.2 and 0.3, so the secondary-channel-to-main-channel width ratio was held constant at 0.25. Secondary channel depths (*d/D*) vary from 0.4 to 0.9. A range of main channel depth from 1 to 3 times the secondary channel depth was simulated.

The main channel cross section for these experiments was similar to that found at Kampsville (Plate 3). Specifically, the main channel was 306.48 m wide with a maximum depth of 4.67 m. The thalweg was located 125.54 m from the right bank. The sailing line was 1.5 m left of the thalweg.

The vessel configuration was 297.2 m long by 32.0 m wide, drafted at 2.74 m. This represented a 3-wide by 5-long barge train. The tow traveled at 2.9 m/sec. Ambient conditions for each test were still water since vessel effects on the flow field are the interest in this study. The model parameters used for these experiments are provided in the following tabulation. Each simulation accelerated the vessel from rest to terminal speed (2.9 m/sec) in about 10.3 sec.

Schematics of the various geometries modeled and the corresponding time-histories of drawdown and current changes in the main channel and at the inlet, middle, and outlet of the secondary channel are shown in Plates 30-109. The zero abscissa is the time at which the bow of the vessel reaches the x-coordinate of the node plotted. The x-component of velocity is positive in the direction of the travel of the boat. The *y* velocity component is positive if it is directed into the side channel. At the entrance, the *y* velocity components are indicators of flow into the side channels.

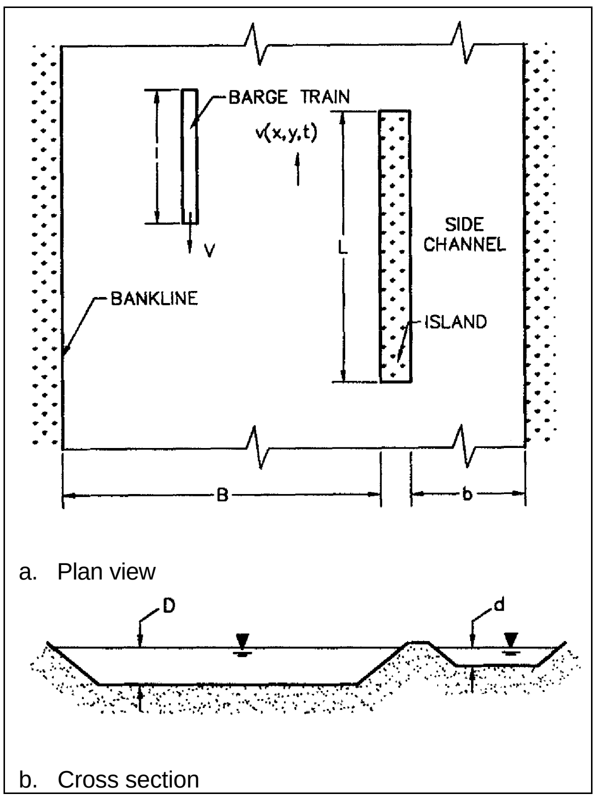


Figure 5. Geometric and hydraulic parameters describing side channels

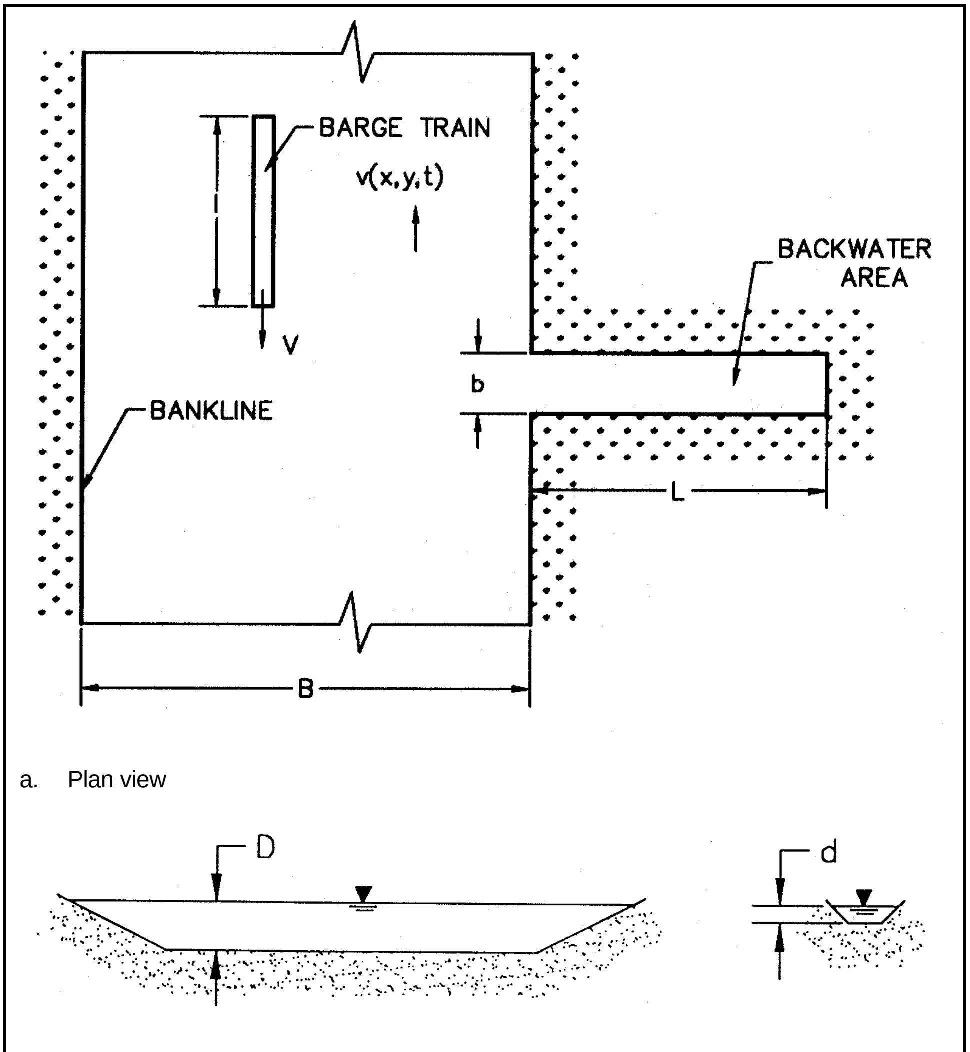
Model Parameter	Value
g, m/sec^2	9.81
n	0.025
C	0.1
A, m/sec^2	0.2828
T_s, sec	10.2552
β	0.25
α	1.5
Δt, sec	5.128

The x-component is simply the return currents produced by the vessel. This discussion will focus on flow in the side channel rather than the return currents.

Side channels behave somewhat differently from backwaters. The depression caused by the vessel will depress the water surface at the side channel entrance initially, but thereafter, the entrance behaves like a reservoir, i.e., the water surface remains fixed. In fact, both ends of the side channel are reservoirs. So the initial depression pulse will travel to the opposite end of the side channel where it will be negatively reflected and return as a positive wave. When this positive wave reaches the original end, it will be negatively reflected again and return as a depression. A complete cycle has a period of approximately $2L/(gH)^{1/2}$. Note that at all times the velocity pulse is directed toward the entrance where the vessel originally passed. Velocities at the ends of the side channels are amplified and so are typically larger than the velocities within the side channels. The vessel will continue to move along the river, passing the other inlet of the side channel. The velocity pulse produced at this inlet will tend to cancel those generated when the vessel passed the first inlet to the side channel. So in many of these examples one will see a fairly regular velocity-wave pattern until the vessel has time to reach the opposite channel end. At this point the velocity wave magnitude will reduce and appear to have shorter wave periods.

Backwaters

Backwater parameters are displayed in Figure 6. The backwater plan shape was represented as a straight channel. Dimensionless parameters include the width of the channel into the backwater area (b/B), the measure of the backwater area length (L/l), and the measure of the backwater area depth (d/D). Two backwater-to-vessel length ratios (L/l = 1 and 10) were examined. Two different backwater entrance widths were simulated. The main-channel-to-backwater entrance width ratios (B/b) of 2 and 10 were simulated. Main-channel-to-backwater-depth ratios (D/d) were varied from 1 to 4. Sketches of these geometries followed by the corresponding time-histories of the drawdown and currents generated by the vessel passage are shown in Plates 110-133. The main channel stations are located in the main channel



a. Plan view

b. Cross section

Figure 6. Geometric and hydraulic parameters describing backwaters

adjacent to the island center at a point one-half the distance from the sailing line to the island.

The depression caused by this vessel-generated pulse in a backwater initially causes a pulse of flow from the backwater channel into the main stem. This depression travels upstream until it is reflected off the closed end of the backwater. The reflected pulse is a depression, but the velocity is now directed into the backwater, toward the closed end. This reflected wave will then travel to the main stem. When the wave reaches the main stem, the junction of the main stem and backwater behaves like a reservoir so that the water surface will remain a constant but the velocities will be amplified. In some cases, the results will show larger velocity magnitudes at this point than from the initial drawdown velocity. So the reflection at the junction of the main stem and the backwater represents an overshoot in which the reflection of the depression wave is a positive wave traveling back into the backwater. A complete cycle requires the wave to travel the length of the backwater channel four times. This is a period of $4L/(gH)^{1/2}$, where L is the channel length. The sum of the wave and its reflection produces a standing wave in the backwater. Here the water surface through the backwater will rise and fall in phase. The velocity will be out of phase with the water-surface wave. This is apparent in the plates for the backwater with length L/l =1. The largest velocity amplitude is found at the entrance, and the largest water-surface amplitude is at the closed end of the backwater.