2 Physical Model Description

Similitude

Similarity of form resistance, flow patterns, and water surface changes in navigation models is best achieved when the ratio of inertia to gravitational forces is the same in model and prototype. This ratio, the Froude number F, is defined as

$$F = \frac{V}{\sqrt{gD}} \tag{1}$$

Where V is generally the vessel speed, g = gravitational constant, and D is a characteristic length such as depth, draft, or vessel length. The equations of hydraulic similitude, based on the Froude criteria, were used to express mathematical relations between the dimensions of hydraulic quantities of the physical model and prototype. General relations for transferring 1:30 scale model data to prototype equivalents are as follows:

Characteristic	Dimension*	Scale Relations Model:Prototype
Length	$L_r=L_p/L_m$	1:30
Area	$A_r=L_r^2$	1:900
Velocity	$V_r=L_r^{1/2}$	1:5.477
Time	$T_r=L_r^{1/2}$	1:5.477
Discharge	$Q_r=L_r^{5/2}$	1:4929.5
Roughness Coefficient	$N_r=L_r^{1/6}$	1:1.763
Force	$F_r=L_r^3$	1:27000
Revolutions or frequency	$R_r=1/L_r^{1/2}$	5.477:1

*Dimensions are in terms of length.

However, viscous forces cannot be neglected in physical navigation models. If one is interested in the forces on a vessel as in typical towing tank studies, the relatively higher viscous forces in the physical model cause greater frictional resistance on the model vessel. If, as in this study, one is interested in the opposite problem of the forces the vessel imposes on the waterway, the relatively higher viscous forces in the model cause the model vessel to be effectively larger than the prototype vessel. Additional information on scale effects and model verification can be found in the Clark=s Ferry Report (Maynord and Martin, 1998). Both the Kampsville (Maynord and Martin, 1997) and the Clark=s Ferry studies showed the similarity of the shape of the return velocity and drawdown time histories. In the physical model used herein, the tow was only used to produce a drawdown typical of a vessel at the mouth of the backwater. The presence of viscous scale effects on the vessel was not important in this study because the UNET model being evaluated herein only simulates the backwater..

Model Flume and Appurtenances

The Navigation Effects Flume (Figure 1) is 125 meters (model) in length, 21.3 meters (model) in width, and has a maximum model depth of 1.22 meter. Unless noted, all units are in prototype equivalent. Ten pumps, each having an approximate discharge capacity of 0.16 cubic meters/second (model), recirculate flow through the flume. A sharp crested overflow weir at the upstream end of the flume evenly distributes the flow across the flume.

The 1:30 scale model of Clark=s Ferry on the Upper Mississippi River was modified by removing the dikes and adding a vertical wall left of the thalweg and adding a generic backwater as shown in Figure 2. The cross-section of the modified Clark=s Ferry reach at RM 468.2 and the dimensions of the backwater are shown in Figure 3. Additional information on the navigation effects flume can be found in the Upper Mississippi report for Clark=s Ferry (Maynord and Martin, 1998).

Instrumentation

Wave heights were measured using two capacitance type wave gauges manufactured at WES. Velocity measurements were taken using two Acoustic Doppler Velocimeters (ADV=s) (Kraus, Lohrmann, and Cabrera, 1994). Both of these probes were two-dimensional side-looking probes that measured velocity in the horizontal plane. The ADV=s take data approximately 5 cm from the transmit and receive transducers. The side-looking two-dimensional probes were needed for the shallow water in the backwater. The ADV=s use acoustic sensing techniques to measure flow in a remote sampling volume. No cables were in the water and the measured flow is relatively undisturbed by the presence of the probe. Data are available at an output rate of up to 25 Hz. The horizontal velocity range is +/- 2.5 m/s and there is no zero-offset in the velocity output. Data can be collected as close as 5 mm from a solid boundary. The ADV=s require particles of a certain size to be present in the water to measure the water velocity. Hollow glass spheres having a mean diameter of 10 microns and specific gravity slightly greater than 1 were used as the seed material in the model. Velocity measurements inside the backwater presented a difficult environment for the ADV=s because the seed tends to settle out because there was no flow in the physical model backwater. Once the meter cannot detect adequate seeding particles, the ADV gives extremely erratic data. If the lack of seed is momentary, the erratic data can be filtered out. If the seeding problem persists, the data become invalid and must be ignored. A wave gauge, a 2D ADV, and a 3D ADV are shown in Figure 4.