4 UNET Model Comparison to Physical Model Experiments

UNET is a one-dimensional unsteady flow program that can simulate dynamic flow in a network of open channels. This model was created by Dr. Robert L. Barkau. For the UNET runs that follow, version 2.0 was used (Barkau 1992) because later versions did not allow the small time steps required in this simulation. UNET input had to be in English units but the discussion herein will remain in metric with the exception of pool elevation (NGVD) and river miles. All computations were in prototype dimensions.

The UNET model simulated the backwater only in both the physical model and Illinois Waterway applications. The boundary conditions on the end away from the main channel specified no flow. The boundary condition at the end connected to the main channel was a stage hydrograph that followed the time history of drawdown at the mouth of the backwater. Because the UNET model only simulates the backwater, the presence of flow in the main channel is not modeled. There are two input data files required to run UNET; these are described below.

Cross Section Input Data Description

The cross section input data file (Figure 9) is set up to contain cross-section input data for UNET. By using cross-section coordinates, any cross-section shape can be input into UNET. Just like most one-dimensional approaches, cross-section shape effects are incorporated into the hydraulic radius (= area/ wetted perimeter). The channel ›n‹ value was set to 0.025. This was based on scaling up the model ›n‹ values of about 0.014 for the plastic coated plywood and sheet metal boundaries of the model to its prototype equivalent. While 0.014 may seem high for prototype smooth boundaries like sheet metal or plastic coated plywood, the relatively small Reynold‹s number in the model and the minimum resistance dictated by hydraulically smooth boundaries make this value correct. Mannings ›n‹ value for the left and right overbank was not important because flow was restricted to the backwater channel.

The UNET model must have a bottom elevation throughout the model, but particularly at the upstream end, that is below the minimum water surface elevation that occurs throughout the simulation. In the input file shown in Figure 9, the file is based on the physical model backwater. The first line of each

cross section is identified by a cross section number, the number of ground points, the stations of the left bank and the right bank of the channel, and the length of the left overbank, right overbank, and channel reach. The next line is used to specify whether to write stage and flow hydrographs for the current cross section, to the UNET output file. The last line(s) specifies the elevation and station of each point in a cross section used to describe the ground profile. The cross sections are defined perpendicular to the direction of the flow. A cross section is required at representative locations along a river reach and at locations where changes occur in discharge, slope, shape, or roughness.

UNET Input Data File Description

The UNET input data file (Figure 10) is set up to contain job control parameters, initial and boundary conditions, and hydrograph specifications. The job control line specifies calculating maximum water surface profile, a time step, a time to cease computations, levee routines are disabled, an implicit weighting factor of 0.6 is used, and flow and stage data are output at hydrograph nodes at each time step to the UNET output file. The A-30MIN@ on Figure 10 is an output option and does not affect the computations.

In each experimental series, the initial flow conditions were set to zero. The upstream boundary connection is set in the UNET input data file using a 34 step inflow discharge hydrograph which for the physical model input was zero for all steps. The downstream stage hydrograph is a 34 step stage hydrograph. Both stage and discharge hydrographs use a time increment of 15 secs to discretize the hydrograph. The maximum number of iterations for Newton Raphson iteration scheme is set to 100. A stage tolerance is set to 3.05×10^{-6} m for convergence criteria.

Sensitivity Analysis for Physical Model Application

Barkau (1992) states "...any model application should be accompanied by a sensitivity study, where the accuracy and the stability of the solution is tested with various time and distance intervals." The backwater channels investigated herein are relatively short and small Δx and ΔT can be used without having to worry about run time. Sensitivity experiments were conducted to determine the effect of distance between cross sections Δx and computational time step ΔT. The backwater channel Manning's n value was 0.025 in all sensitivity runs with the exception of the runs used to evaluate Manning's n effects and all sensitivity runs were based on Experimental Series 1 having no flow in the model and a vessel speed of 3.95 m/sec. The relationship between Δx, wave speed, and ΔT is generally expressed as the Courant number defined as

$$Courant\ No. = \frac{c\Delta T}{\Delta x} \tag{2}$$

where c is the wave speed = $(gd)^{1/2}$, g is the gravitational acceleration, and d is the depth. Courant numbers determined herein were based on an average depth in the physical model backwater of 2.44 m. The sensitivity runs for Δx of 4.9 m, 9.8 m, and 19.6 m and corresponding ΔT of 1 sec, 2 secs, and 4 secs are shown in Figure 11. All runs in Figure 11 have a Courant number of 1.0 and the magnitude of the initial computed water level drawdown is not affected by the increasing Δx and ΔT but reduced magnitude can be observed in the subsequent oscillations. Figure 12 shows the effect of a range of Courant #-s for Δx of 4.9 m. Results are similar to the previous Figure 11; almost no effect on the initial drawdown and differences in subsequent oscillations. The sensitivity of computed results to changes in Manning-s n are shown in Figure 13. Again, the initial drawdown is not affected but subsequent oscillations show a small effect. This is almost certainly due to the relatively small channel velocity ($\leq$ 0.5 m/sec) that occurs during vessel induced drawdown events. <u>All subsequent comparisons to physical model data are based on a Δx = 4.9 m, computational time step ΔT = 1.0 secs, Courant # = 1.0, and Manning-s n = 0.025.</u>

Results of Comparison to Physical Model

The downstream stage hydrograph used as input to the UNET model was created by using the physical model data collected at the entrance to the backwater channel. The data points for the hydrograph were picked off a moving average of the time history of water level every fifteen seconds from before the tow passed until the event was completed.

Computed water level drawdown from the UNET model at the upper end of the backwater for Experimental Series 1 with no flow is shown in Figure 14 versus the observed water level drawdown from the physical model. The initial rise and the initial drawdown were similar in magnitude and shape for computed versus observed. The computed peak magnitude for subsequent oscillations of the water level were larger than the observed peak values. The comparison of computed UNET velocity and the observed velocity data for Experimental series 1 with no flow are shown in Figures 15 and 16 for 9 m and 68 m from the backwater entrance, respectively. Positive velocities are toward the mouth of the backwater. Figure 15 is one of the physical model runs where lack of seeding caused the data after about 400 secs to not be valid. Velocities in both Figures 15 and 16 are in good agreement during the early portion of the vessel event but subsequent oscillations have computed values greater than observed values.

Computed water level drawdown from the UNET model at the upper end of the backwater for Experimental Series 2 with flow and a downbound tow is shown in Figure 17 versus the observed water level drawdown from the physical model. Good agreement is found between computed and observed water level throughout the event. The comparison of computed UNET velocity and the observed velocity data for Experimental series 2 with flow and a downbound tow are shown in Figures 18 and 19 for 9 m and 68 m from the backwater entrance, respectively. Figure 18 is another one of the physical model runs where lack of seeding caused the data after about 525 secs to not be valid. Velocities in both

Figures 18 and 19 are in good agreement during the early portion of the vessel event but subsequent oscillations have computed values greater than observed values.

For the backwater used in the physical model, both the physical model and UNET show that the maximum drawdown at the rear of the backwater is about 1.5-2 times the maximum at the mouth which results from the smooth boundaries, straight alignment, and vertical walls in the physical model. The agreement between UNET and the physical model is important because the physical model is a worst case in terms of the water level drawdown. While some of the physical model data was missing because of seeding problems, the comparison shows that the shape and magnitude of the initial wave of the drawdown event is correct. With few exceptions, the initial wave is the largest and most significant of all the wave events. No claims are made herein that UNET can simulate the complete time history of drawdown.