Benchmark Problem 5, laboratory: Solitary Wave on Composite Beach

The original experiment which constitutes BP 5 was conducted in Coastal & Hydraulics Laboratory of US Army Corps of Engineers. The description of the experiment can be found on CHL web site [1], and also in [2-3] and in the description of analytical BP 2.

A basin for the experiment was a long narrow flume with reflecting side walls (glass), shown in Figure 1 (reproduction from [2]). The depth variation and all the wave motion occurred strictly in the direction along the flume, and all the measurements were taken on the flume's centerline. Thus a 1-D approach seems reasonable to describe the case. For 2-D simulations, reflective boundary conditions on the three sides should be used.

File tsunami3_runup.zip [1] contains the data collected in the experiment, namely:

- wavemaker trajectories for cases A, B, C, corresponding to three solitary waves of different height;
- time histories at gages 4-10 for the three cases (also in files gA.txt, gB.txt, gC.txt used by Matlab plotting scripts);
- maximum run-up at the wall in the three cases.

The objective of the BP is to model the experiment, compute time histories at the gages 4-10 and maximum run-up on the wall, and compare the results with the measurements, with case A being required, cases B and C being optional.

Suggested format for the model outputs: 9-column text file of floating-point values per case (A,B,C), with the 1st column being time in sec, other columns being water elevation at gages 4-10 and by the wall, in meters.

Three ways of initiating the simulation of this benchmark are considered below.

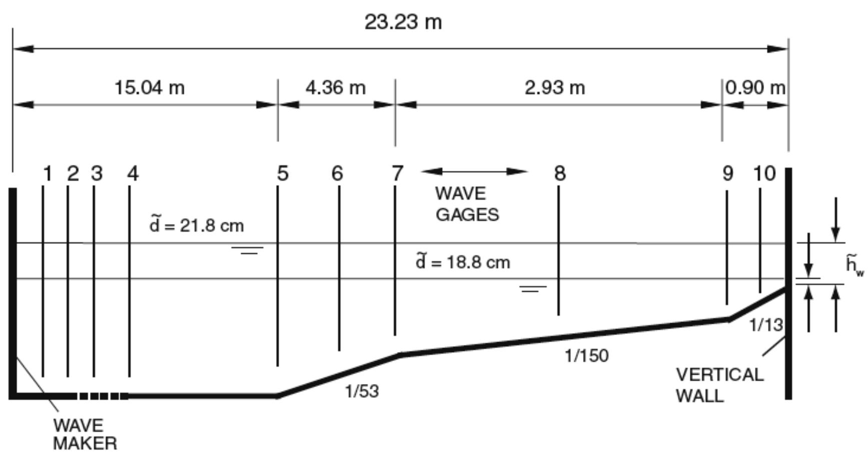

Figure 1: Sketch of the flume with the gage locations.

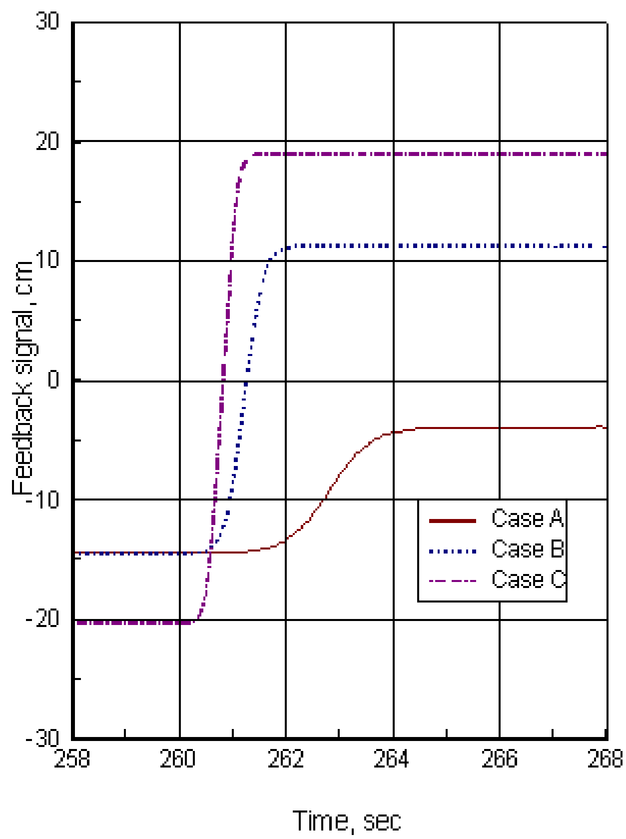

Figure 2: Paddle motion for cases A, B, C.

0.1 Initiating computations with initial free surface deformation

The wavemaker was used to generate solitary waves of the form:

$$\eta(x,0) = d_0 H sech^2(\sqrt{0.75H}x/d_0) \qquad (1)$$

where x is a coordinate alone the flume, $\eta(x,0)$ is initial free surface deformation, d_0 is depth at the wavemaker (0.218 m), H is targeted wave height relative to the depth. Target wave heights for cases A, B, and C were 0.05, 0.30, and 0.70, respectively.

In the demonstration below, the computations were initiated with the initial deformation of 2η placed at the wavemaker position $x = 0$. The computational domain was extended to include the basin and its double length at constant depth d_0 behind the wavemaker. Since measured wave heights H were usually smaller than target values, and the wavemaker stroke was not tied to $t = 0$ (see Fig. 2), the simulated solution was shifted in time and scaled vertically to match the peak of incident pulse recorded at gage 4.

0.2 Initiating computations with imitation of the paddle motion

The paddle trajectory time-series for the three case, shown in Figure 2, are provided and can be used to imitate wave due to a paddle stroke. The paddle trajectories were used to compute paddle velocity v. The velocities are complemented with corresponding elevation values η, obtained by solving the following equation for η:

$$v = \eta\sqrt{9.81/(d_0 + \eta)}. \qquad (2)$$

Since a paddle stroke was relatively short (less than the depth at the wavemaker), the actual reduction in the size of the domain can be neglected. The simulation is initiated with the boundary input of $\eta(0,t)$ and $v(0,t)$ at $x = 0$.

0.3 Initiating computations with a record at gage 4 (incident gage)

The computational domain starts at gage 4 (which position x_4 is different among the three cases A, B, C). The simulation is initiated with the boundary input of $\eta(x_4, t)$ and $v(x_4, t)$ at $x = x_4$, where η is taken from an actual record of a direct pulse (prior to 275 s) at the incident gage, and v is computed according to (2). **This is the recommended approach to modeling the experiment, since as demonstrated in the next section, it allows to reproduce the actual wave in the basin most closely.**

0.4 Numerical solution vs. data import

As a demonstration of how the numerical solution depends on which way to import the data was adopted, the experiment (case A) was simulated with the

MOST model, with the three ways to initiate the wave. The three sets of the gages time histories obtained in the three simulations of the same experiment are shown below.

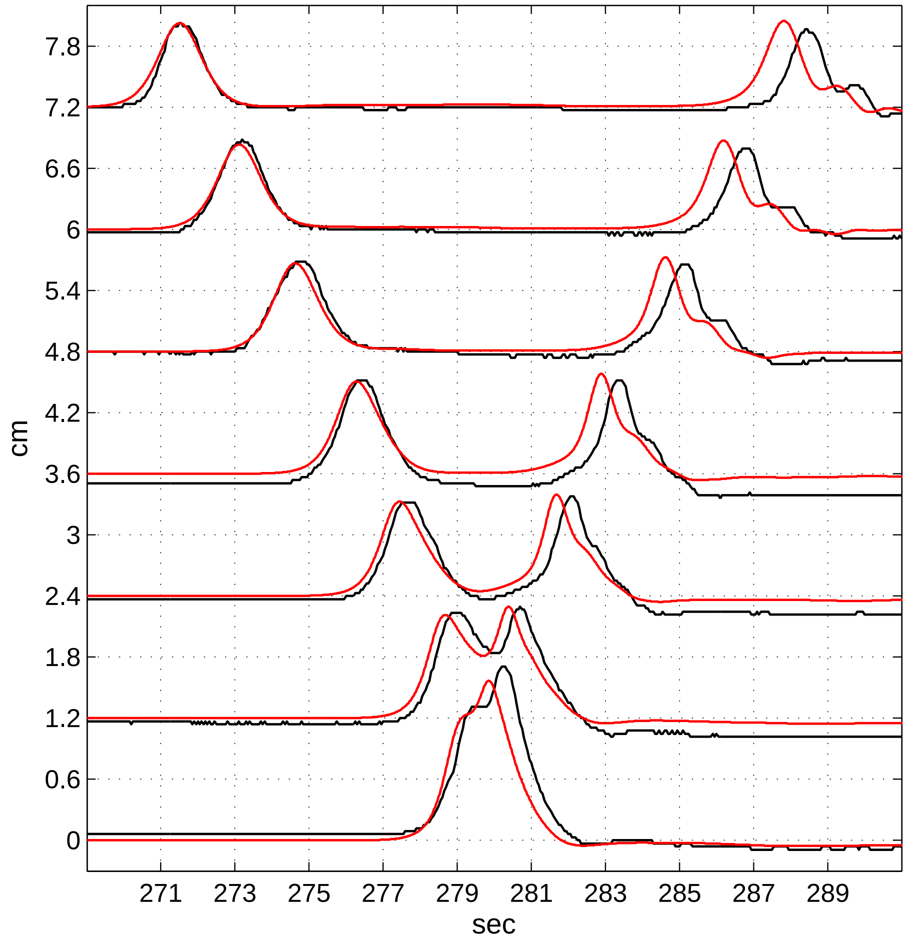

Figure 3: Measure (black) and computed (red) time histories at gages 4-10 (top to bottom). Computations are initiated with the initial deformation of the free surface.

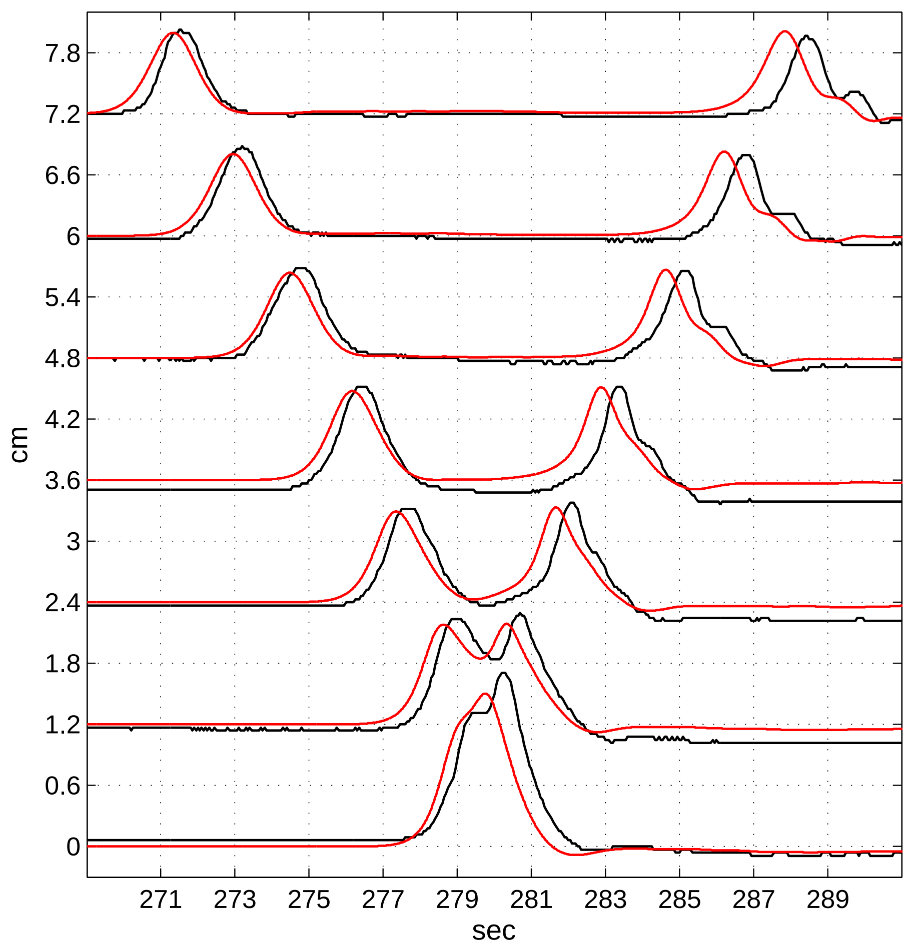

Figure 4: Measure (black) and computed (red) time histories at gages 4-10 (top to bottom). Computations are initiated with imitation of the paddle motion.

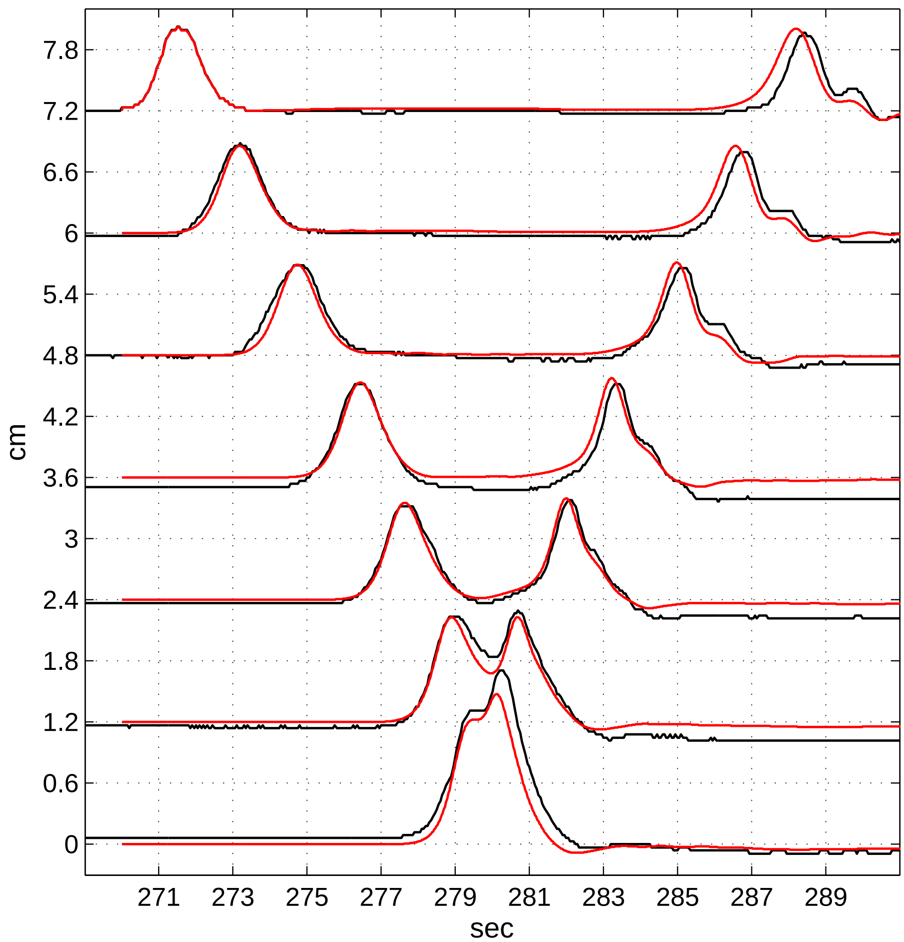

Figure 5: Measure (black) and computed (red) time histories at gages 4-10 (top to bottom). Computations are initiated with the incident pulse record at gage 4.

References

1. http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=Projects;36
   http://chl.erdc.usace.army.mil/data/tsunami/tsunami3/tsunami3_runup.zip

2. http://nctr.pmel.noaa.gov/benchmark/Solitary wave/

3. Synolakis, C.E., E.N. Bernard, V.V. Titov, U. Kanoglu, and F.I. Gonzalez (2007): Standards, criteria, and procedures for NOAA evaluation of tsunami numerical models. NOAA Tech. Memo. OAR PMEL-135, 55 pp.