



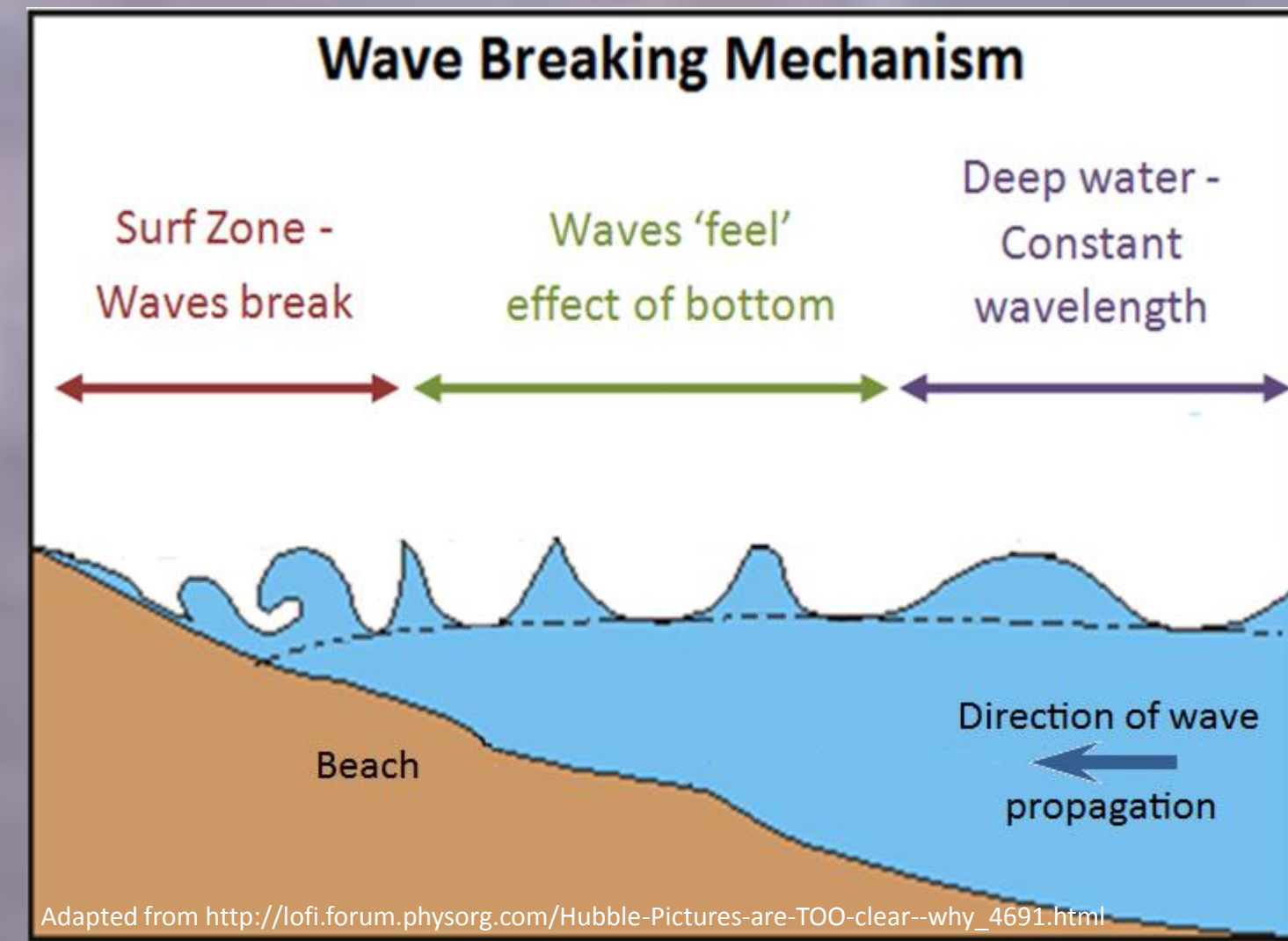
Impact of tsunami waves on structures

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Introduction

The word tsunami comes from the Japanese words “tsu” and “nami” which translates directly to “harbour wave”. A tsunami is a series of waves that are created by the displacement of a large volume of water. This displacement is usually caused by an earthquake that occurs offshore, beneath the surface of the ocean seafloor.



Most Recent Tsunami Disasters

- 2004 Indian Ocean Tsunami
- 2010 Chile Tsunami
- 2011 Japan Tsunami



Nan Thong Beach, 2004

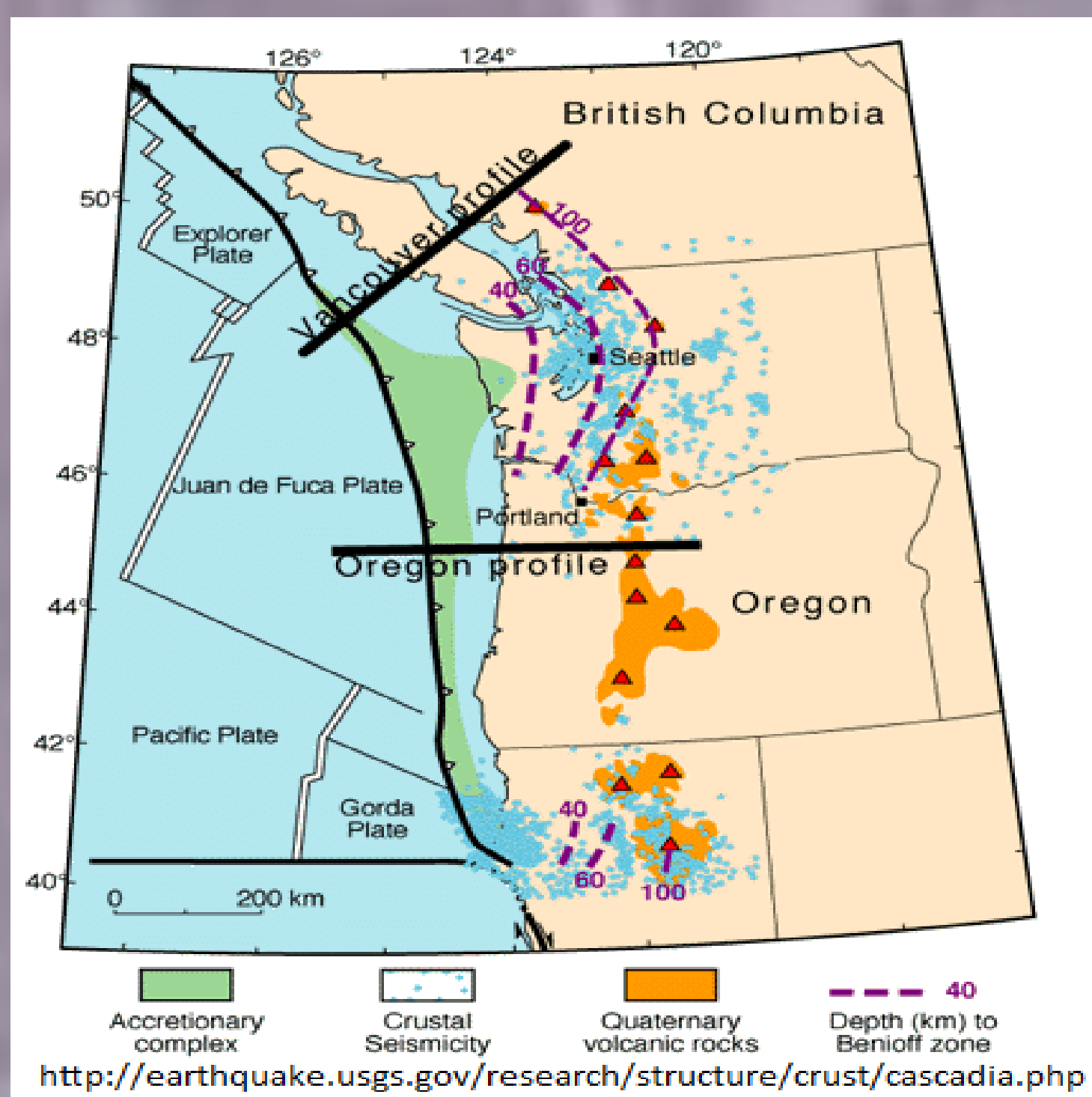


Japan, 2011

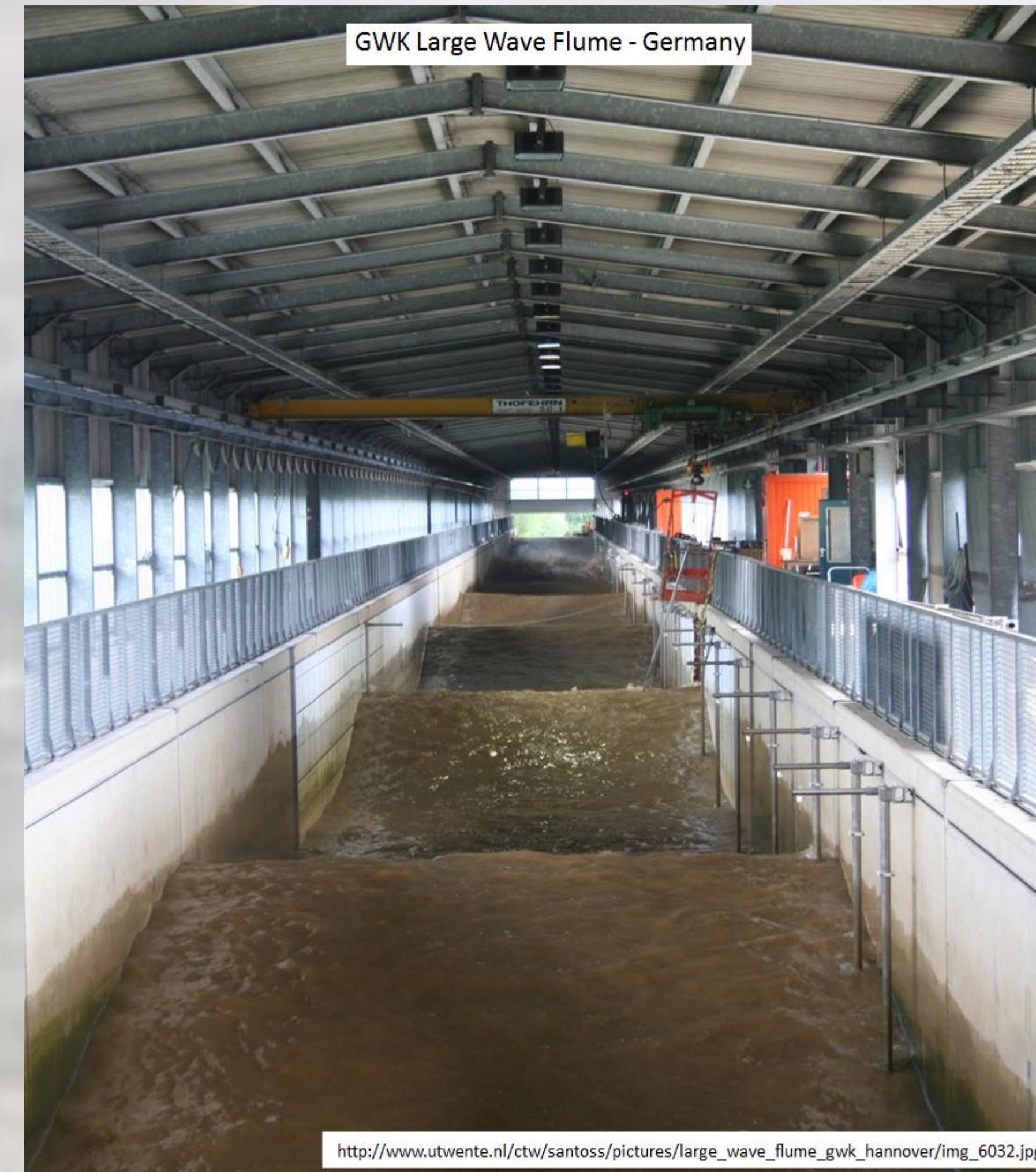
Chile, 2010

Current building codes for the design of structures along coastal regions that involve tsunami-induced loading are inadequate.

Canada is Susceptible to Tsunamis



In order to accurately represent the effects of a tsunami, a large scale experiment would require massive additional costs. These costs can be avoided through the use of a numerical model. The scope of this work is to focus on smoothed particle hydrodynamics (SPH) to numerically model and reproduce several physical experiments.



GWK Large Wave Flume - Germany

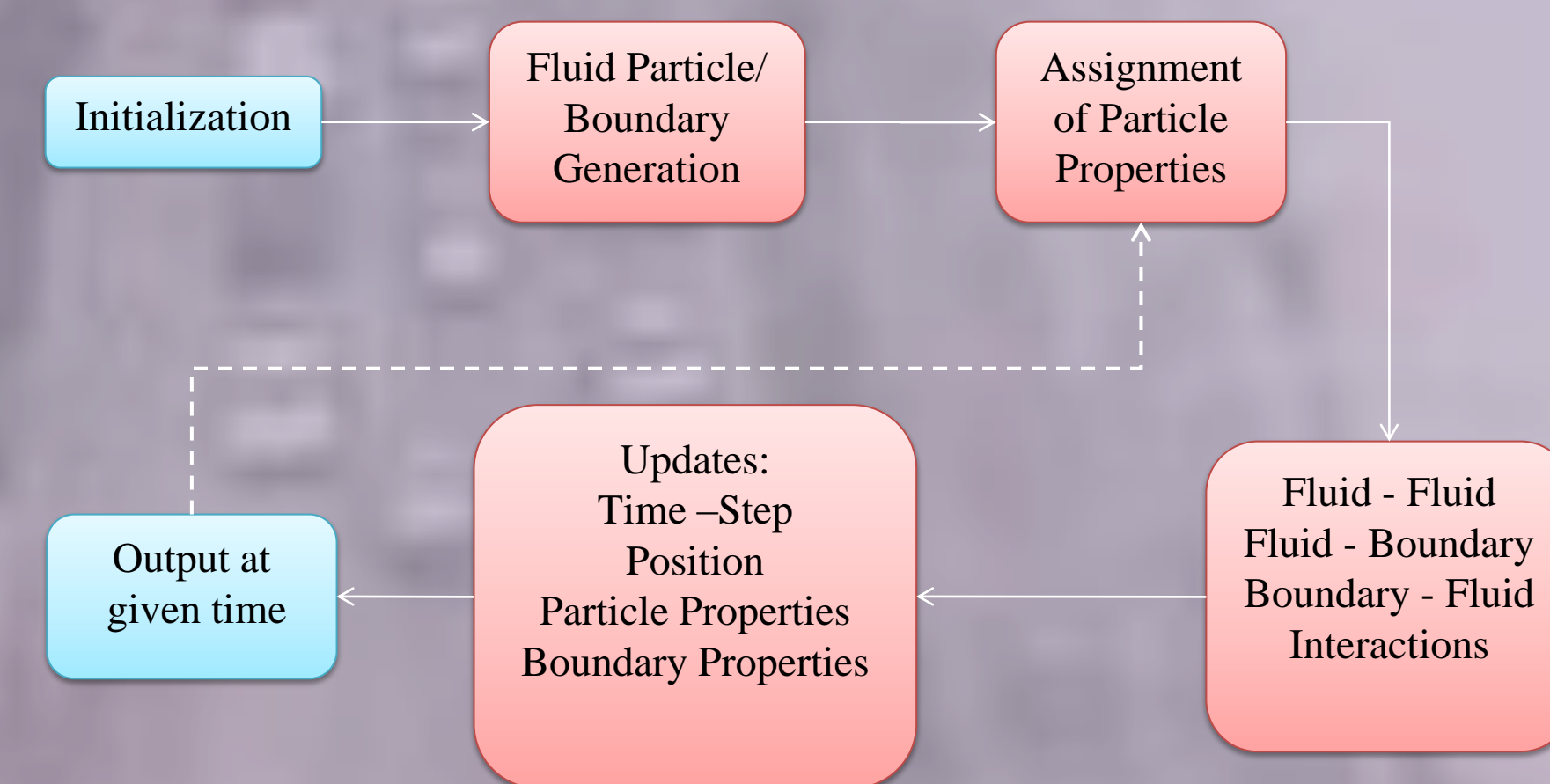


Delta Flume - Netherlands

Methodology

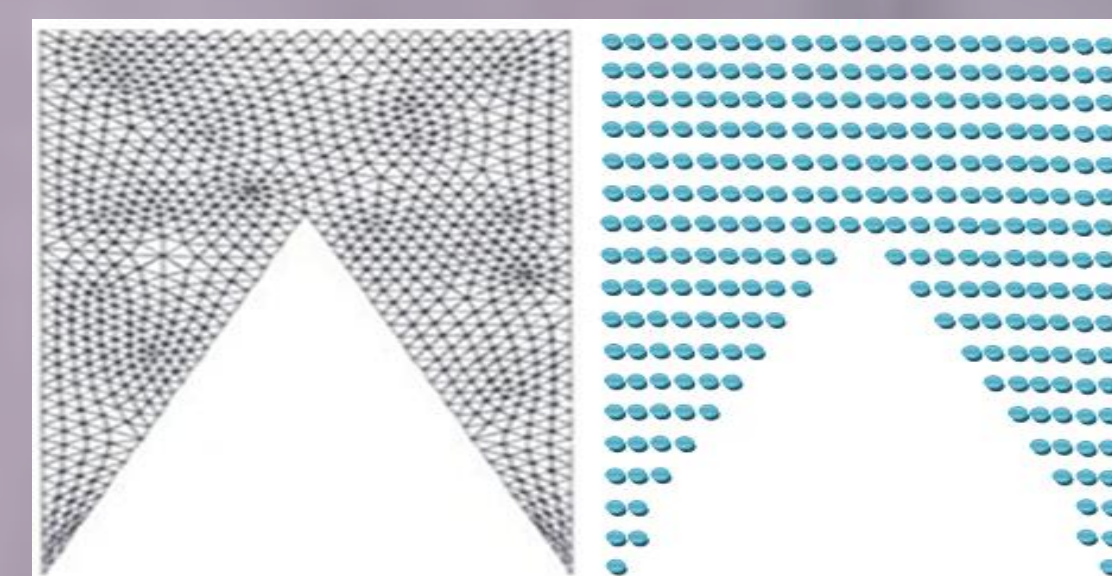
Traditionally, numerical wave modelling is done using the Eulerian approach in which a mesh or grid is involved. These methods however have computational drawbacks. SPH is a Lagrangian based approach that represents a fluid through individual particles each having their own specific properties.

SPHysics Model



SPH is a mesh-free method that avoids computational deficiencies prevalent in grid-based methods.

Mesh Method vs SPH Method



The physical experiment considered for this research was conducted by Ramsden in 1996. Ramsden's experiment focused on the impact of a hydraulic bore on a vertical surface. The bore was created by the breaking of a solitary wave that was generated using a piston-type wave maker. After the model is run, a comparison of results is made to the physical experiment in order to determine the model's accuracy.

Ramsden's experiment

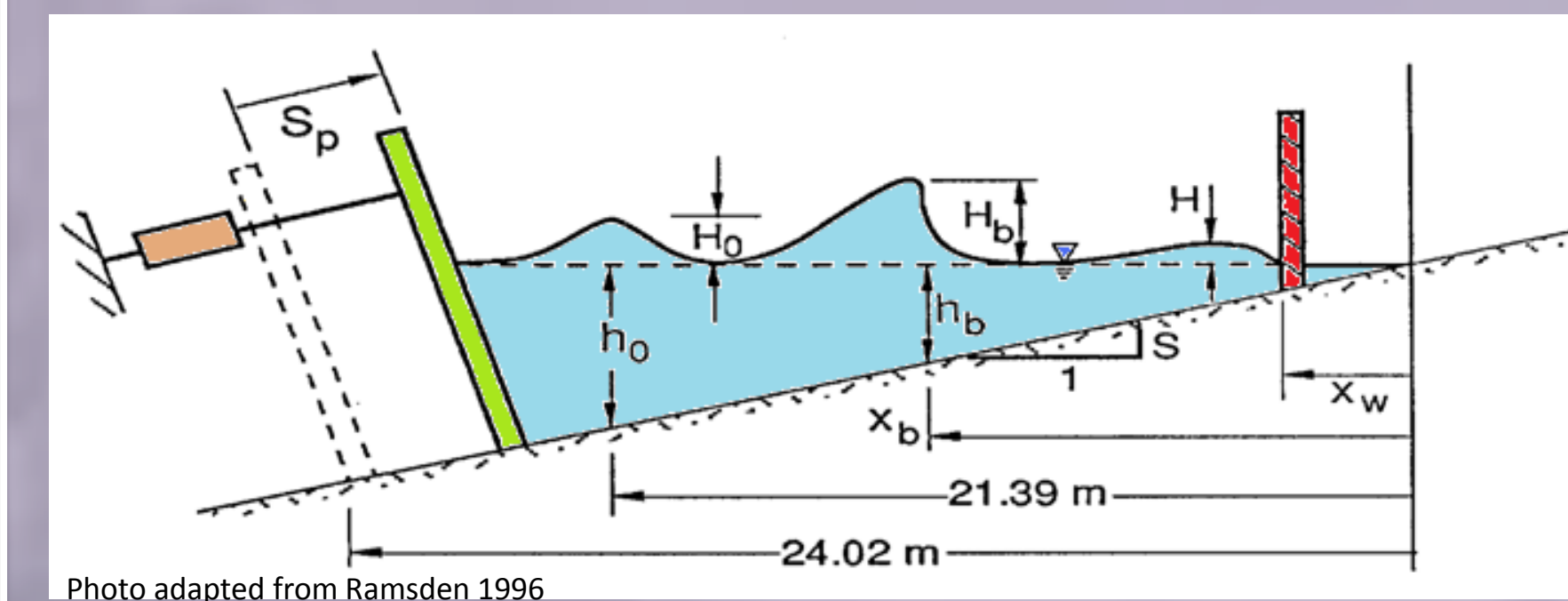
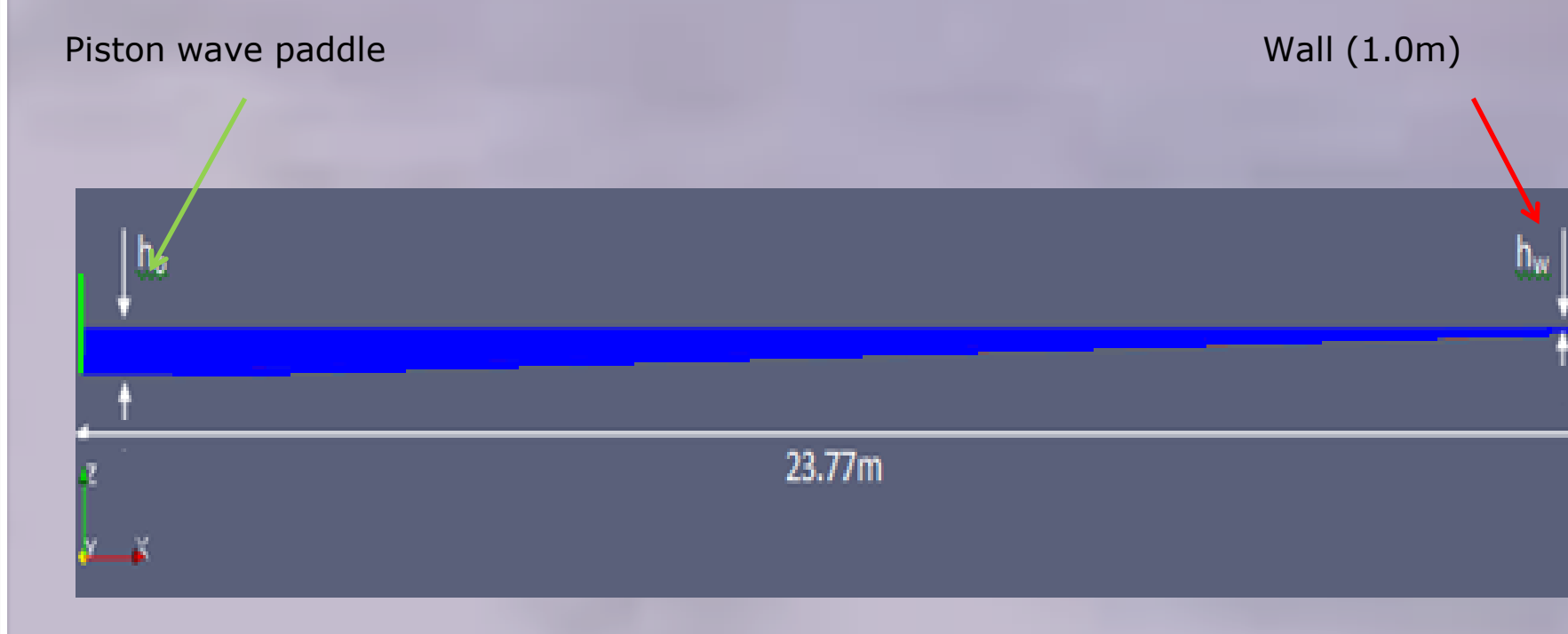


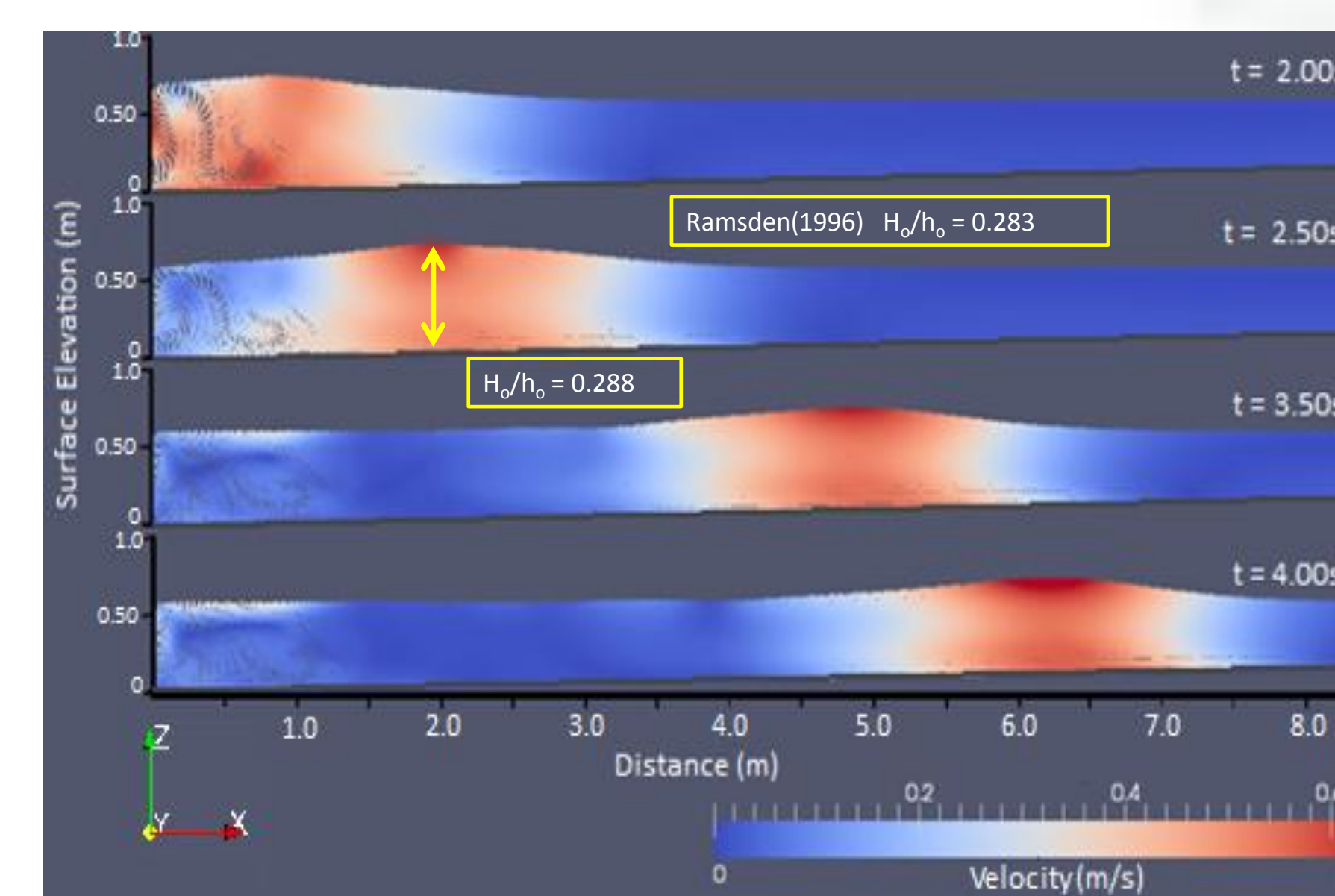
Photo adapted from Ramsden 1996

Numerical model domain



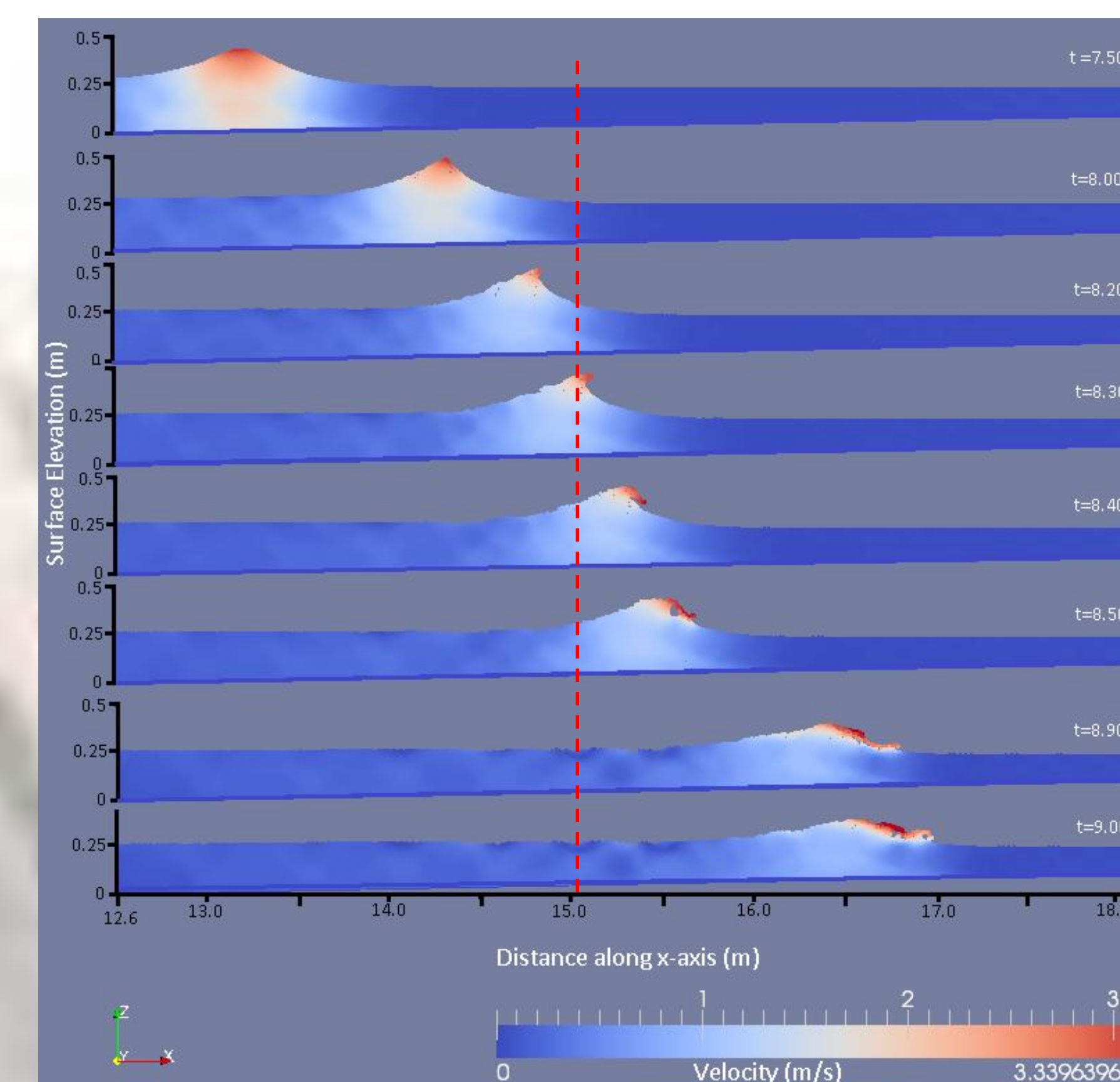
Results

Figure 1: Generation of the solitary wave



In this stage of the experiment the wave is just starting to form and the wave height ratio (H_0/h_0) at the point indicated by the yellow arrow in Figure 1 is 0.288. The wave-height ratio is a means to measure a wave by relating the water depth to the amplitude of the wave. Breaking of the wave will commence when this ratio exceeds a value of 1. The value obtained in Ramsden's physical experiment was 0.283.

Figure 2: Breaking stages of the solitary wave



In Figure 2 the breaking stages of the wave as it collapses into a bore are shown. As indicated by the dotted red line, the wave breaks at a distance around 15m. The breaking wave-height ratio (H_b/h_b), which indicates what the wave-height ratio is when the wave breaks, is 1.35. Ramsden's wave broke at a distance of 15.6m with a breaking wave-height ratio of 1.21.

Figure 3: Comparison of bore profile before impact:

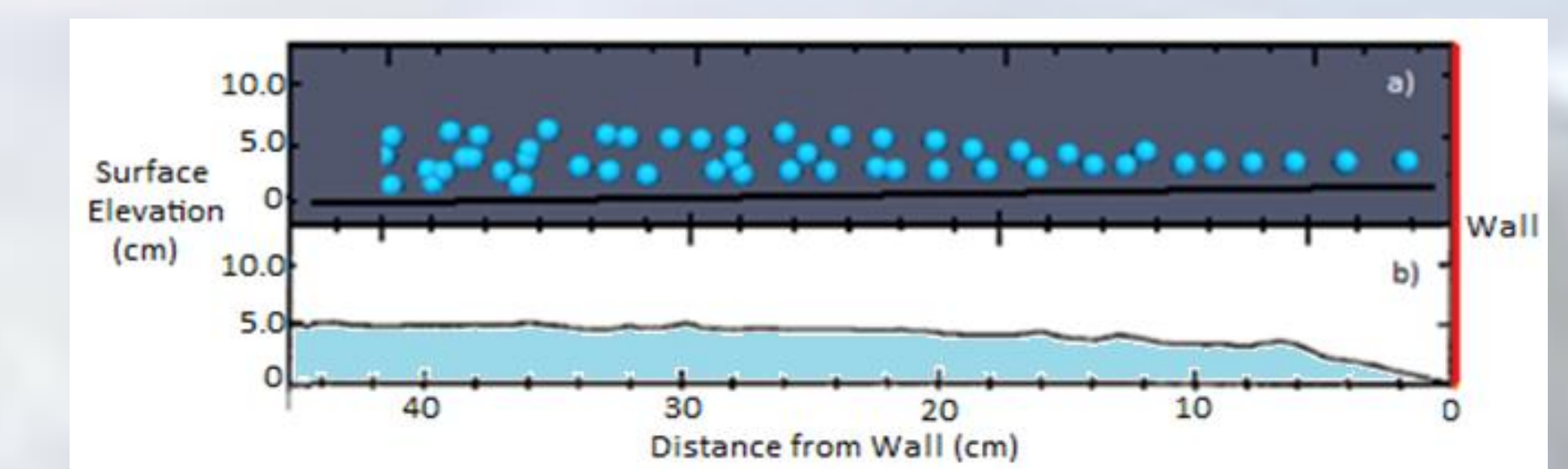


Figure 4: Comparison of bore profile after impact:

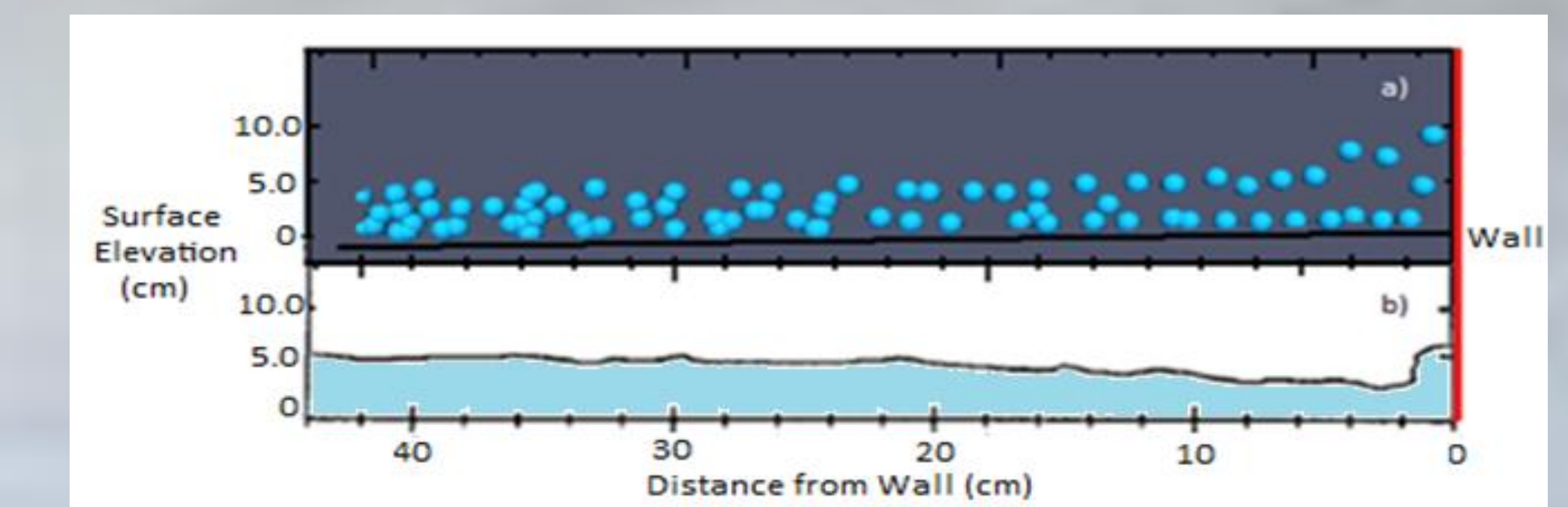
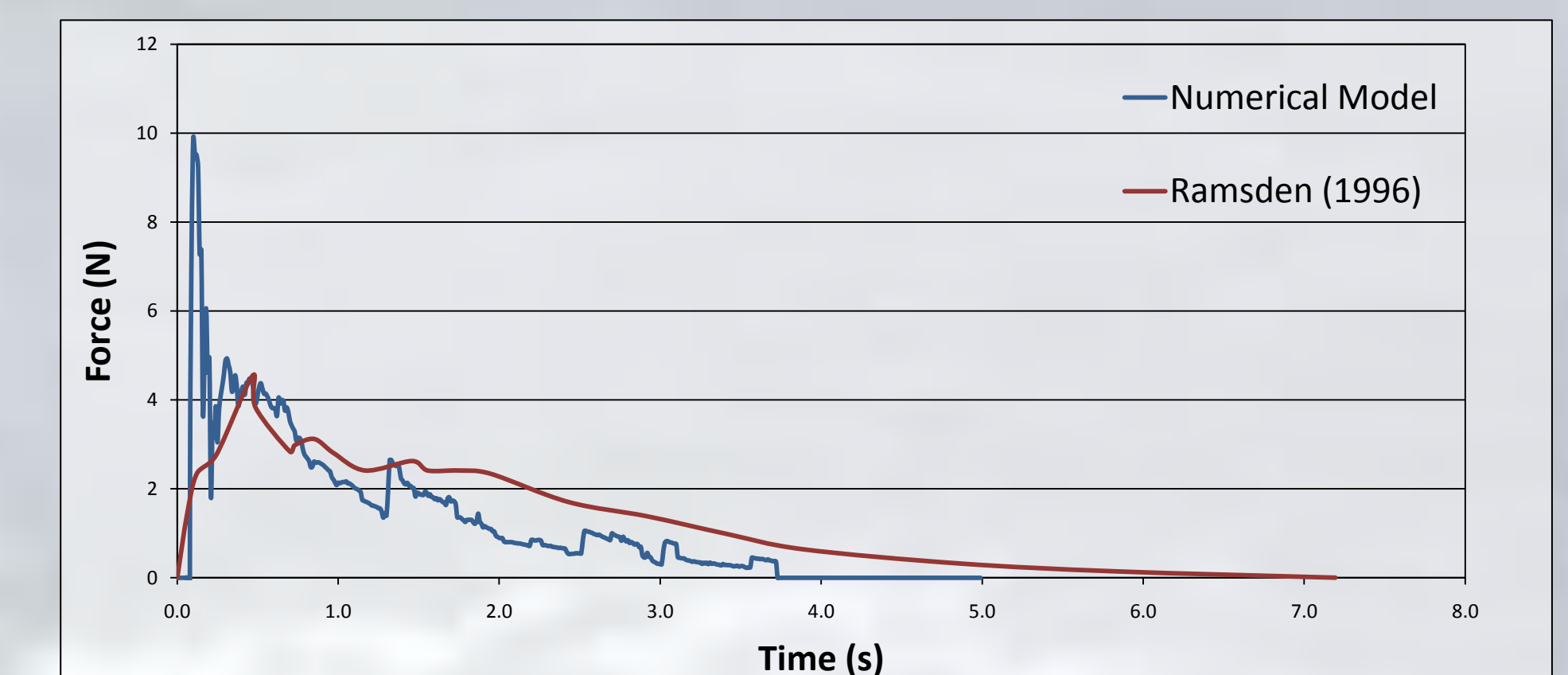


Figure 3 and Figure 4 compare two instants at the wall in both the numerical and physical experiments. The first is the instant right before impact on the wall and the second is just a few moments after. At 0.4m from the wall, the height of the bore is 5cm in Ramsden and 6cm in the model. The initial run-up height was approximately 6cm in Ramsden (1996) and 10cm in the SPH model. A better estimation of the run-up height could be made in the SPH model if more particles were added to the computational domain; however, this would significantly increase computation time.

Figure 5: Force-time history of bore impact



The Force vs. Time graph shows the comparison between the numerical and physical model results of the hydrodynamic force acting on the wall from the time of impact until the force subsides. In the numerical model force profile there is a signal spike that is not present in the Ramsden (1996) profile. This is because the sampling frequency of the pressure transducers used by Ramsden did not register the force impulse.

Conclusions

The SPH numerical model was used to represent the Ramsden's (1996) physical experiment. The model was shown to be fairly accurate however it still requires some minor “tweaking”. By improving the numerical model, this work can contribute to the development of design guidelines and building codes for tsunami-resistant infrastructure. Future work could include reproducing the experiment on a larger scale which would be more applicable to a real-world tsunami scenario.

References and Acknowledgments

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