Fig. 4 shows the horizontal velocity profiles for a submerged narrow-crested flow at five sections: $x$=-0.1m, 0m, 0.04m, 0.076m, and 0.24m. The submerge ratio of the downstream tailwater head above weir and upstream water head over weir is 0.89. The maximum velocity for each section varies from 0.4m/s to 0.7m/s. Relatively low velocity is observed at $x$=-0.1m. The velocity profile at the section x=0m shows the non-uniform pattern, and somewhat disturbed. This indicates the flow recirculation zone may develop at the entrance edge of weir. The developing recirculation zone is likely to affect the velocity distribution over the crest. At $x$= 0.04m, $x$=0.0.76m, and $x$=0.24m, the flow velocity profiles have the similar trend with velocity increasing toward the water surface. Velocities at the downstream are shown higher value than at the upstream. Due to the no-slip condition, the fluid velocity is zero at the bottom of channel and the weir crest. The flows shown in five sections are considered non-uniform, an increase in the horizontal velocity is observed along the flow direction.

The pressure distribution of simulated submerged flow over narrow-crested weir at the five section locations are shown in Fig.5. At the sections $x$=-0.1m, $x$=0.04m, $x$=0.076m, and $x$=0.24m, the pressure distribution all behaves similar to hydrostatic pressure under submerged flow condition. At $x$=0m, small difference in pressure distribution from hydrostatic pattern over the crest is believed to be caused by the recirculation zone at the entrance edge of weir crest.

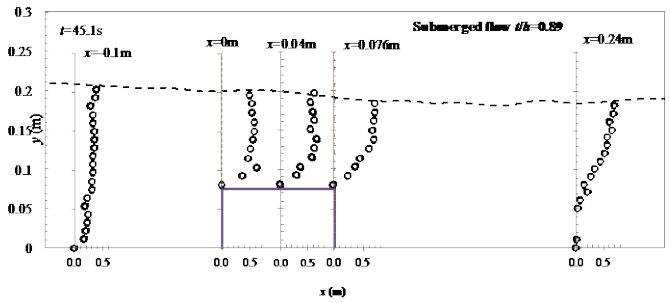


Fig. 4 Horizontal velocity profiles at different sections.

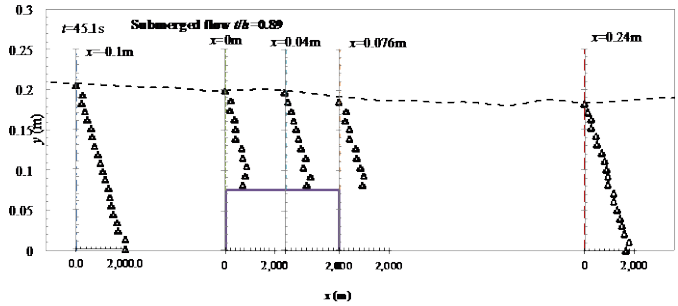


Fig. 5 Pressure profiles at different sections.

## SUMMARY

The numerical study of open-boundary free-surface flow over weir of finite crest length with squared-edge is explored by using the MPS method. In the study, MPS method has addressed its capability of successfully modeling the narrow-crested weir flow. For water surface, the simulation results from the MPS method are shown in a good agreement. Horizontal velocity and pressure profiles are plotted to show the distribution pattern at different locations along the flow direction. Despite of some patterns of horizontal velocity and pressure distribution varied from theoretical distribution, the simulation results from the MPS method are considered reasonable.

## ACKNOWLEDGEMENT

This research was supported in part by the Natural Sciences and Engineering Research Council of Canada.

## REFERENCES

Azimi, A. H., Rajaratnam, N., and Zhu, D. Z. (2014). Submerged Flows over Rectangular Weirs of Finite Crest Length. *J. of Irrigation and Drainage Engineering*, 140(5), 06014001.

Fu, L. and Jin Y.C. (2014). Simulating velocity distribution of dam break with particle method. *J. of Hydraulic Engrg.*, ASCE, 140(10): 04014048. (Doi: 10.1061/(ASCE)HY.1943-7900.0000915)

Hager, W. H., and Schwalt, M. (1994). Broad-crested weir. *J. of irrigation and drainage engineering*, 120(1): 13-26.

Hyatt, M. L.; Skogerboe, G.V. and Austin, L. H., (1966). Subcritical Flow Over Various Weir Shapes" (1966). Utah Water Research Laboratory Reports, 381. http://digitalcommons.usu.edu/water_rep/381

Koshizuka, S., and Oka, Y. (1996). Moving-particle semi-implicit method for fragmentation of incompressible fluid. *Nuclear science and engineering*, *123*(3): 421-434.

Liu, G. R., and Liu, M. B. (2003). *Smoothed Particle Hydrodynamics: A Meshfree Particle Method*. Singapore, SG: World Scientific, 472pp.

Nazari F, Jin Y.C., and Shakibaeinia A. (2012). Numerical analysis of submerged hydraulic jump using moving particle semi-implicit method. *Canadian J. of Civil Engineering*, 39(5): 495-505.

Shakibaeinia, A., & Jin, Y. C. (2010). A weakly compressible MPS method for modeling of open-boundary free-surface flow. *International J for Numerical Methods in Fluids*, 63(10), 1208-1232.

Sun Z., Djidjeli K., Xing J.T. and Cheng F. (2015). Modified MPS method for the 2D fluid structure interaction problem with free surface. *Computers and Fluids*, 122: 47-65.

Toyota, E., Akimoto, H., and Kubo, S. (2005). A particle method with variable spatial resolution for incompressible flows. Proceedings of the 19th Japan Society of Fluid Mechanics, 9, 2.

Xu, T., and Jin, Y. C. (2015). Numerical simulation of broad-crested weir flow using a mesh-free method. International Association of Hydro-Environment Engineering and Research 2015 Congress, The Hague, Netherlands.