Appendix 1

Mesh Analysis

A mesh analysis was done to determine the optimal mesh size for the work applying on the manhole Type C. Three different computational meshes were constructed having average mesh size dx = 10 mm (Mesh C1), 14 mm (Mesh C2) and 20 mm (Mesh C3). They had total cell counts as 2 137 000, 865 000 and 329 000 in the order. The analysis follwed Richardson extrapolation method reported by Celik et al. (2008). The procedue recommends a minimum refinement ratio of 1.3, which was less than those of the mesh size ratios between Mesh C2 and C1 as well as Mesh C3 and C2.

All three meshes were simulated with a combination of 120×10^{-3} m^3/s inlet discharge using constant velocity profile and 0.8 m of outlet pressure head. The streamwise velocity profiles were extracted at the center of the manhole and the pipe outlet at 60 different point locations. The comparisons are shown in Figure 3 and Table 3.

The analysis showed oscillatory convergence at 32 points (53%). A numerical uncertainties observed at the outlet pipe were 2.4% comparing Mesh C1 and C2 and 4.0% comparing Mesh C2 and C3. Corresponding numerical uncertainties at the manhole jet located at the center were 2.71% and 4.37% comparing Mesh C1-C2 and Mesh C3-C2 respectivelty. Uncertainty was found less at the manhole center near the jet stream. However, model prediction uncertainty near the free surface were higher due to high velocity gradient; 32% comparing Mesh C1-C2 and 54% comparing Mesh C2-C3. Although the velocity was minimal near the surface (in the range of 0.1 m/s). The average grid convergence index (GCI) was recorded at the outlet pipe as 1.38% and 2.7% for Mesh C1 and Mesh C2 respectively, when compared to their immediate coarser meshes.

In Figure 3 (left panel), the coarse mesh of 20 mm (Mesh C3) created different flow structure close to the water surface, while the other two meshes (14 mm and 10 mm) created similar flow in the manhole. As for this work, emphasis was given to manhole head loss coefficient K ($=2g.\Delta H/v^2$), the values were checked for all the three meshes. The K value in Mesh C1, Mesh C2 and Mesh C3 were found 0.086, 0.086 and 0.088 respectively, which were very similar to each other. So, it was concluded that Mesh C3 showed different flow structure in the small scale compared to Mesh C1 and Mesh C2, however, considering the flow at the large scale, Mesh C3 gave considerably good results. For this reason similar mesh sizes were used for all the simulations in this study.

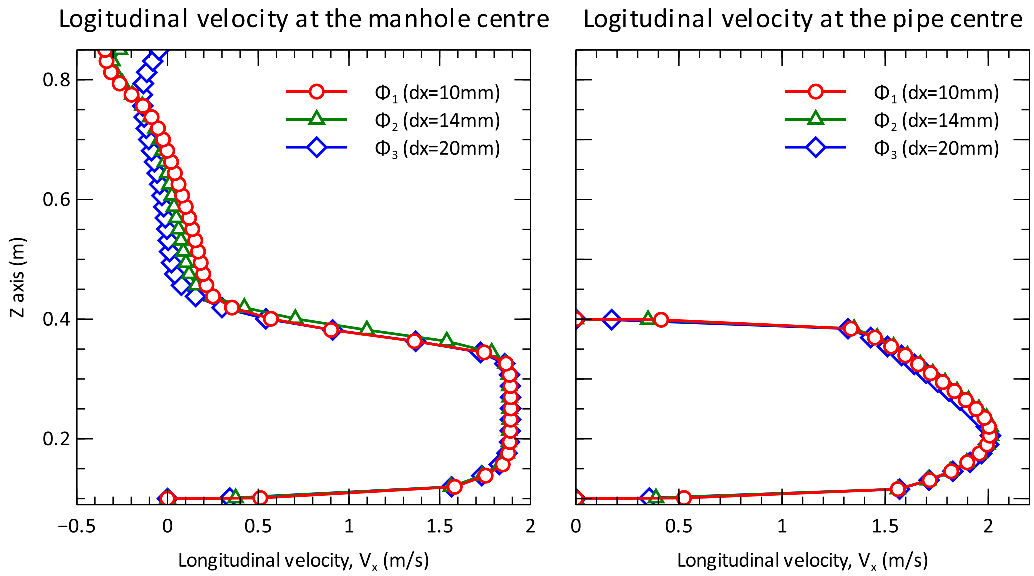

Figure: Mesh analysis using three meshes for Manhole Type C. Left panel shows longitudinal velocity profile at the manhole center and the right panel shows longitudinal velocity profile at the outlet pipe (adapted from (Beg, Carvalho, & Leandro, 2017))

Table: Comparison between different mesh properties

Name of mesh	Mesh size, dx (mm)	No. of cells	Grid Convergence Index, GCI	Coefficient of head loss, K
Mesh C1	10	2,137,000	1.38%	0.086
Mesh C2	14	865,000	2.7%	0.086
Mesh C3	20	329,000	---	0.088

Reference:

Beg, M. N. A., Carvalho, R. F., & Leandro, J. (2017). Comparison of flow hydraulics in different manhole types. In A. A. Ghani (Ed.), *Managing Water for Sustainable Development: Learning from the past for the future: Proceedings of the 37th IAHR World Congress* (Vol. 6865, pp. 4212–4221). Kuala Lumpur, Malaysia: IAHR & USAINS HOLDING SDN BHD.

Celik, I. B., Ghia, U., Roache, P. J., Freitas, C. J., Coleman, H., & Raad, P. E. (2008). Procedure for Estimation and Reporting of Uncertainty Due to Discretization in CFD Applications. *Journal of Fluids Engineering*, *130*(7), 78001. https://doi.org/10.1115/1.2960953