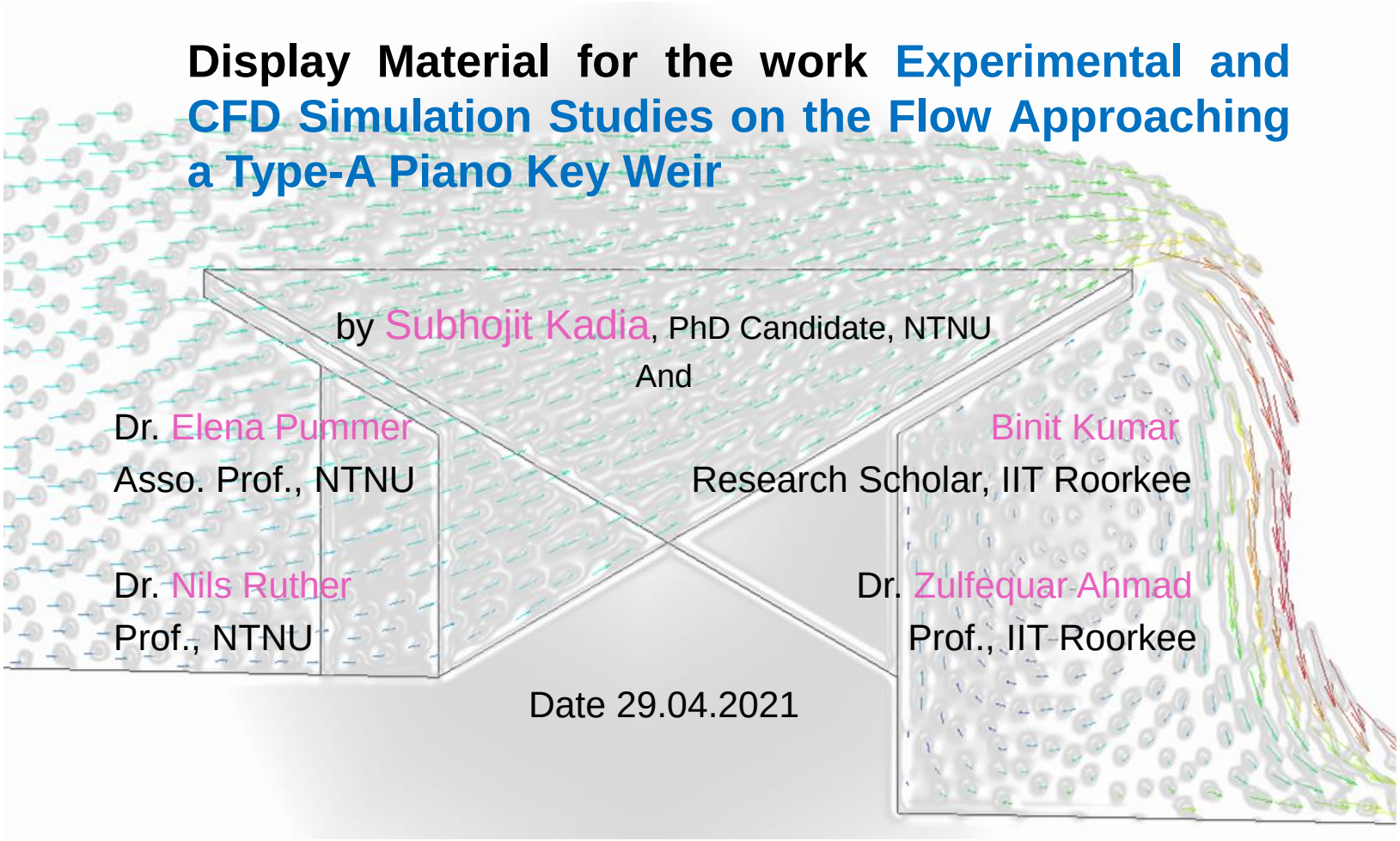
Display Material for the work Experimental and CFD Simulation Studies on the Flow Approaching a Type-A Piano Key Weir



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Date 29.04.2021

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Background and the Research Gap

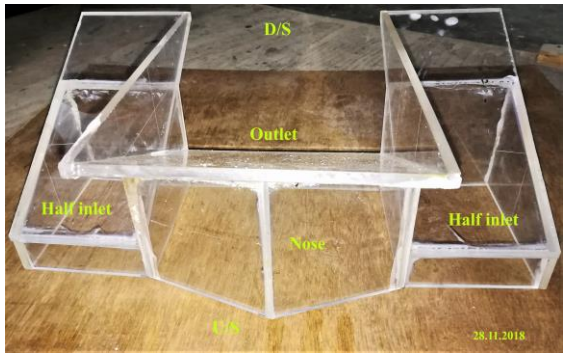
- Piano Key Weir (PKW) used to increase the discharge capacity in dam upgradation projects and in large diversion schemes.
- Most research focus on its discharge capacity.
- Flow around PKW is complex, three-dimensional and spatially varied.
- Aim:

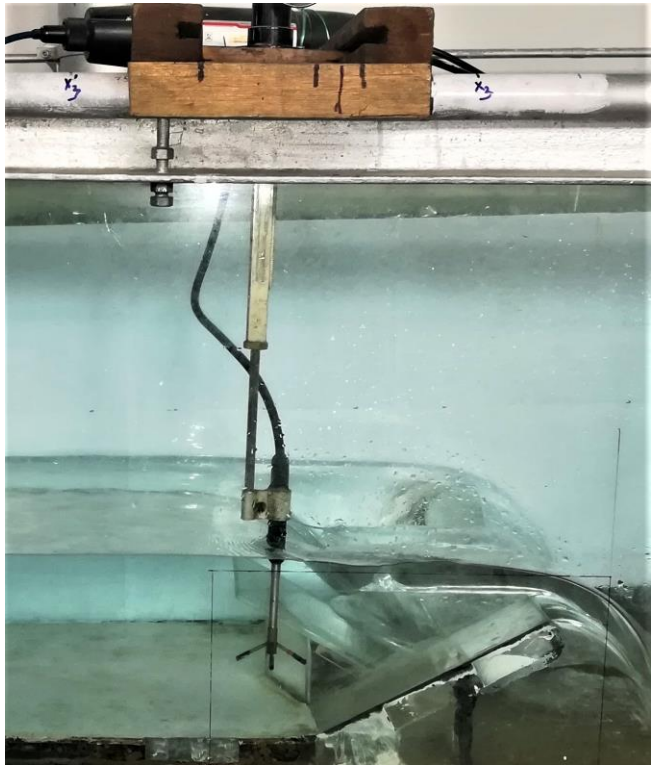
  Determining the effect of the approaching flow on the possible sediment transport over PKW.

View of the Goulours PKW (Leite Ribeiro et al. 2012)

Methodology: Experimental

- Flume: 15m x 0.39m x 0.52m (IIT Roorkee).
- Discharge: 16.1 and 18.45 l/s.
- Measurement equipment: 10-MHz Vectrino Acoustic Doppler Velocimeter (Nortek AS).

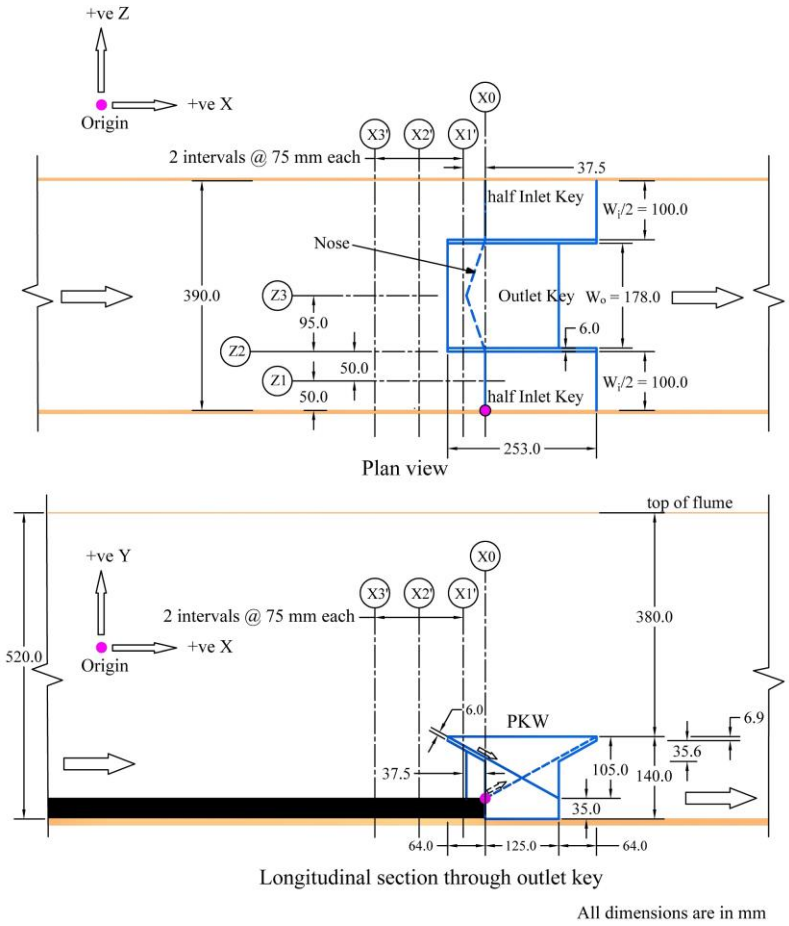




The PKW model (left) and a photograph of velocity measurement (right)

Methodology: Experimental

Schamatic diagram showing the PKW model, measurement gridpoints etc.



Methodology: CFD Simulation

- Performed in Ansys CFX solver (19.1 academic version).

Preparation of 3D geometry

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Meshing by fixing desired size, inflation, quality etc.

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Define **Model Physics**:
- Transient flow, time step and total time of simulation (30 s).
- Multiphase model and operating conditions setup.
- Setup of boundary conditions and domain initialisation.
- Define turbulent model (standard k-ε (Launder and Spalding (1974))

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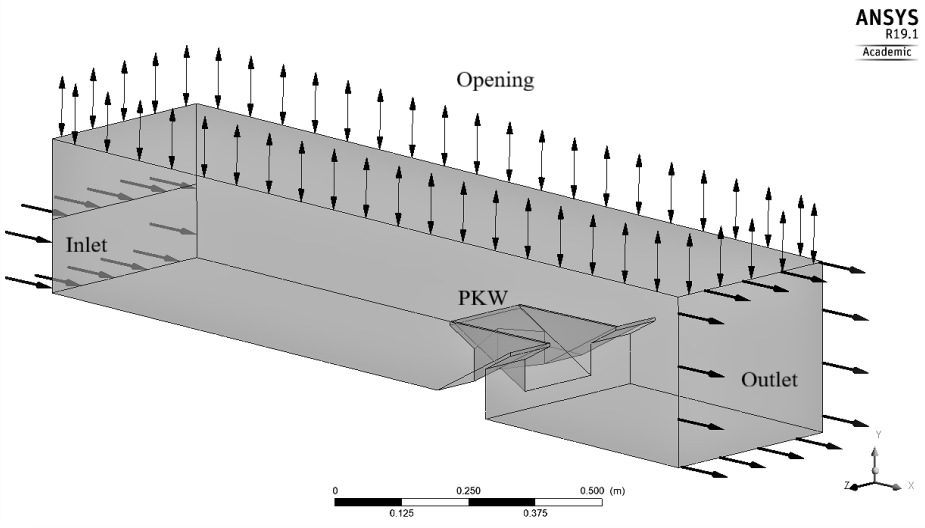
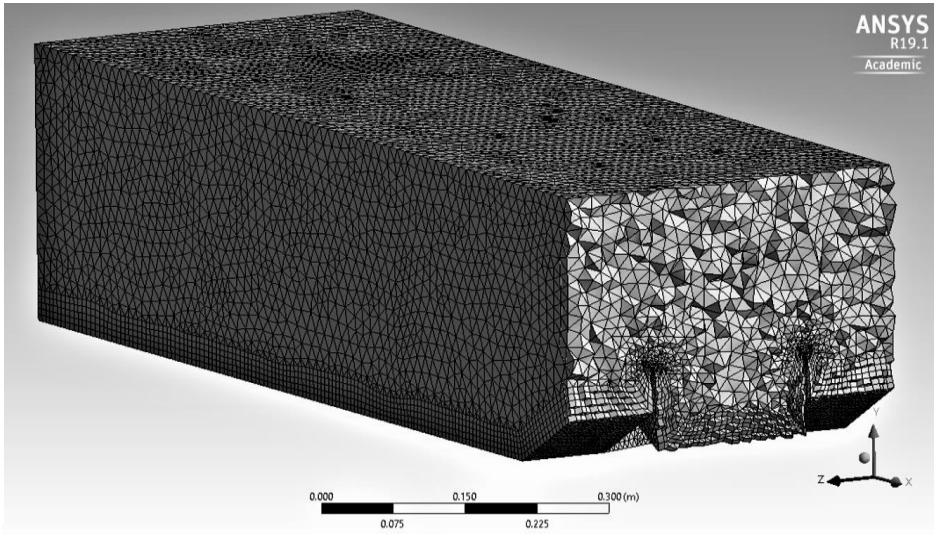
Simulation and comparison of results with experimental data

Note: The detailed methodology is available in Kadia et al. (2020); Kumar et al. (2021)

Methodology: CFD Simulation cont'd

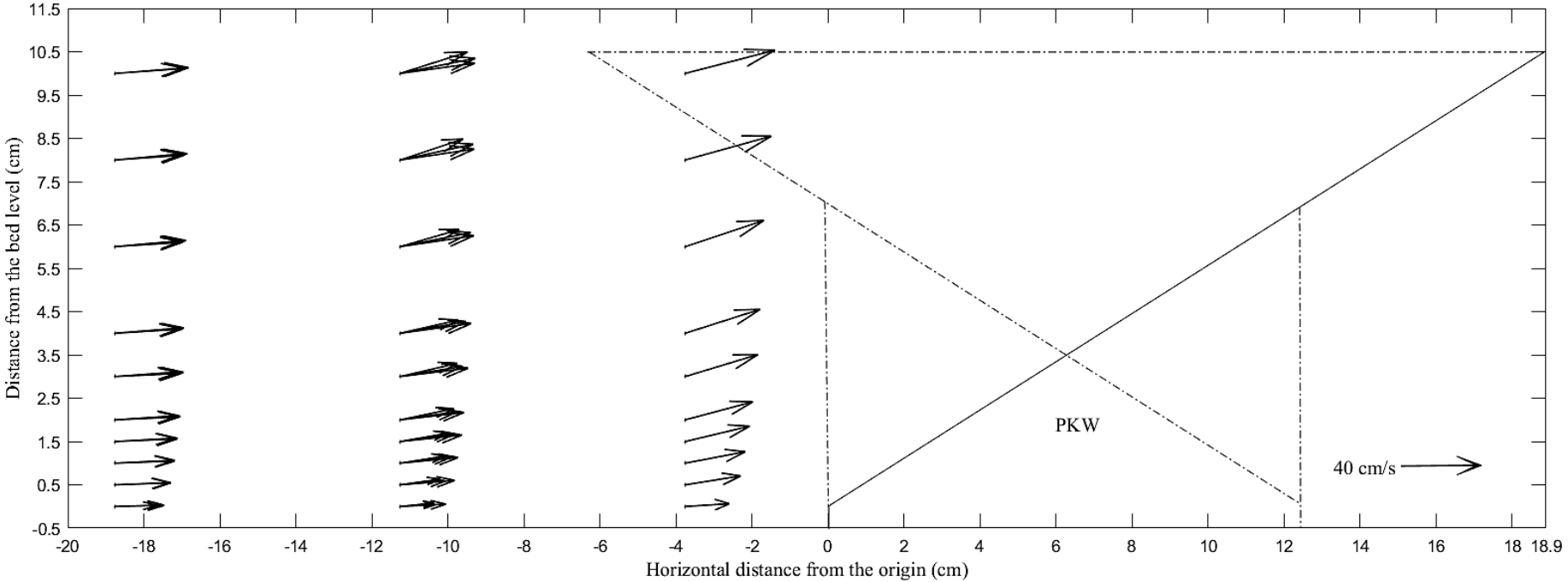




- **Inlet:** Mean velocity
- **Outlet:** Pressure based
- **Opening:** Atmospheric pressure normal to the plane
- **Walls and bed:** Smooth

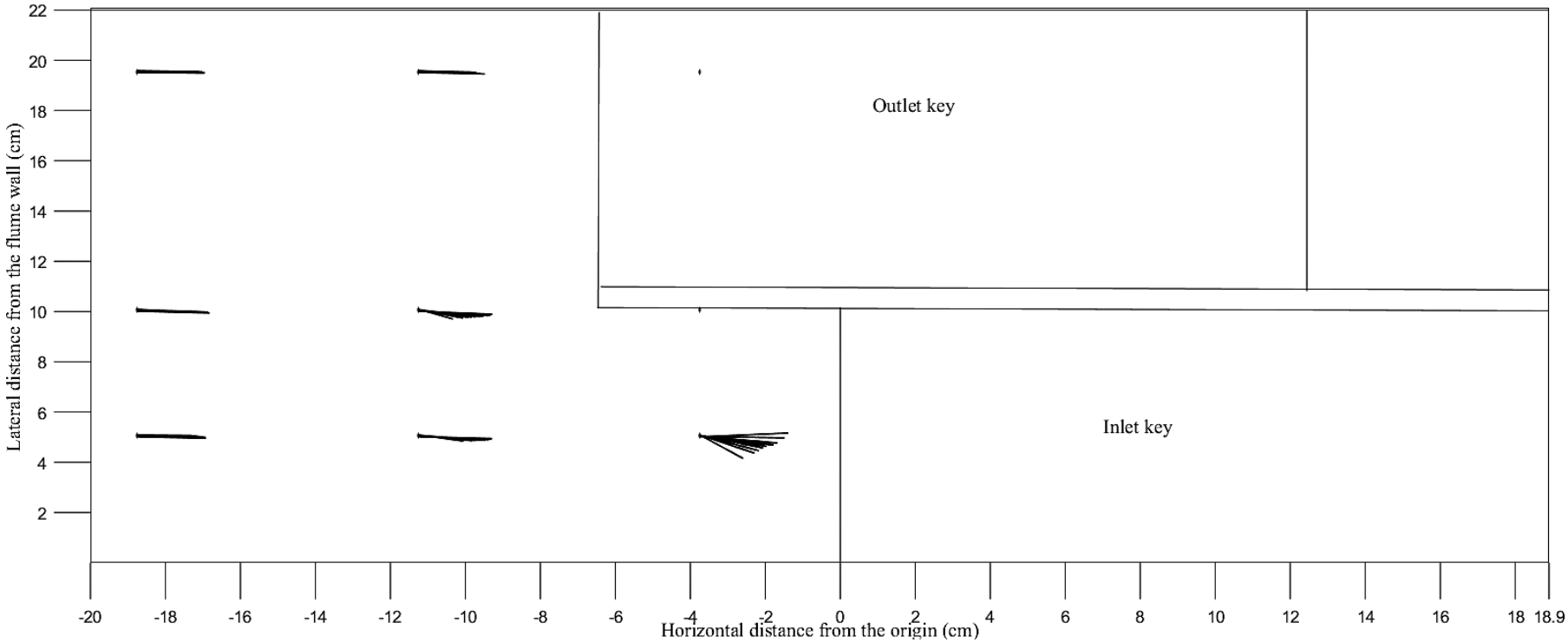
Note: The detailed methodology is available in Kadia et al. (2020); Kumar et al. (2021)

Results and Discussion: Experimental



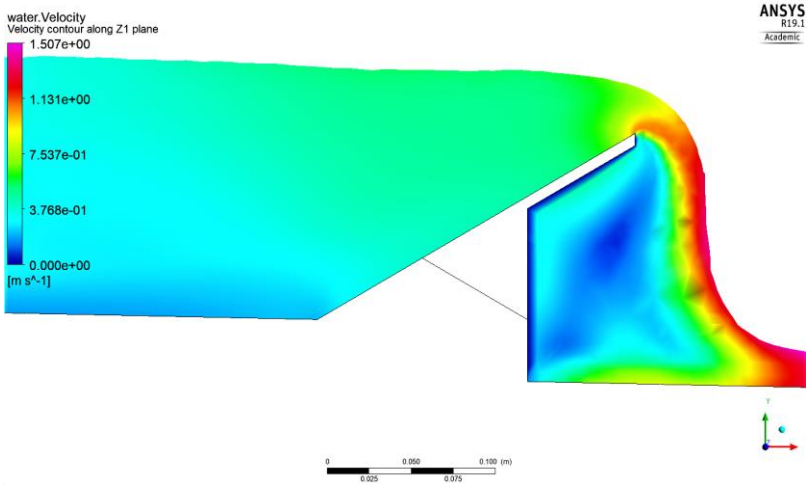
Resultant velocity vector diagram for 18.45 l/s discharge along a longitudinal plane (Kadia 2019)

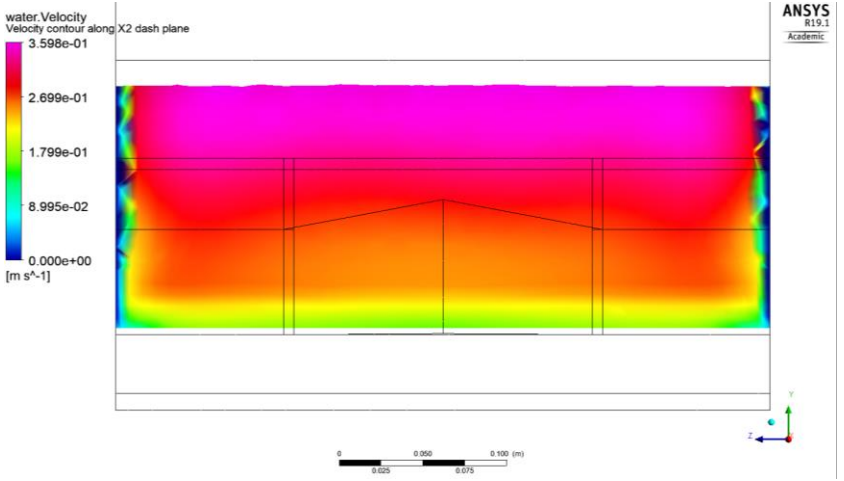
Results and Discussion: Experimental

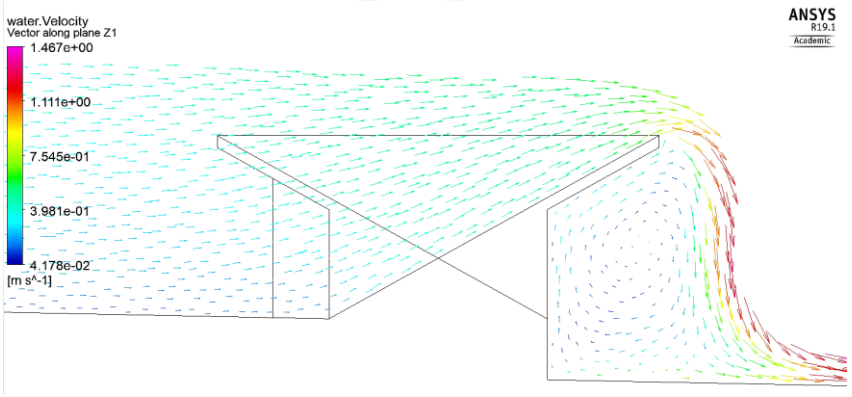


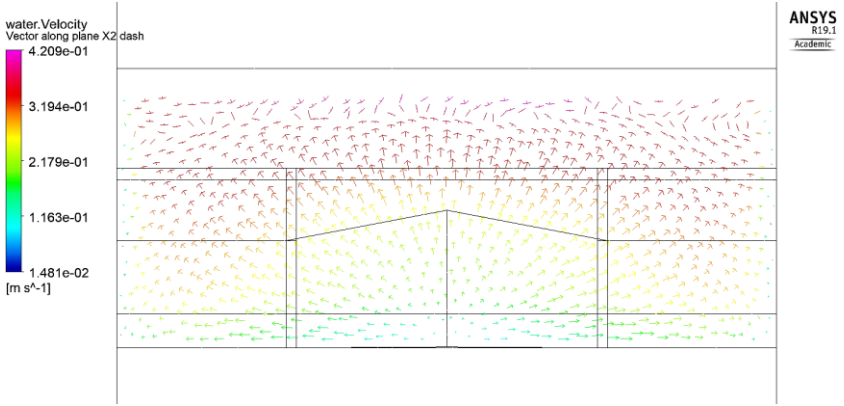
Resultant velocity vector diagram for 18.45 l/s discharge along a horizontal plane (Kadia 2019).

Results and Discussion: CFD Simulation









Simulated flow along Z1 (left) and X2´ (right) for 16.1 l/s discharge

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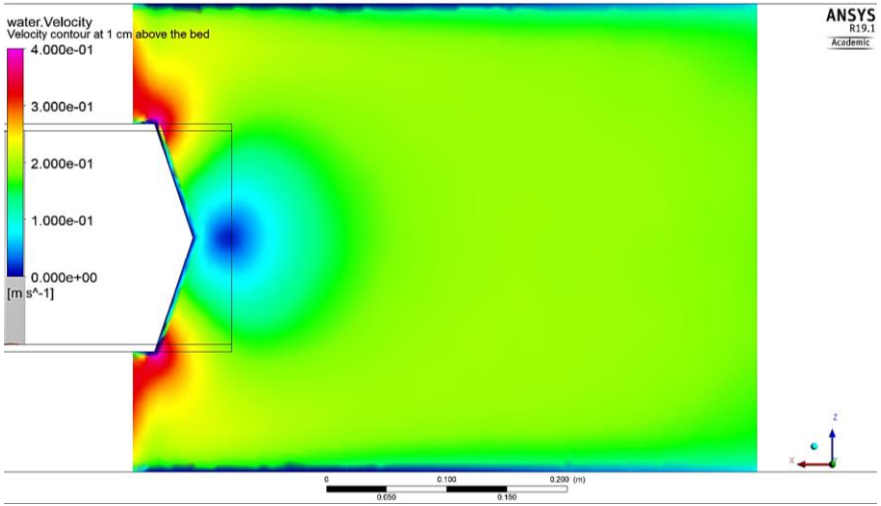
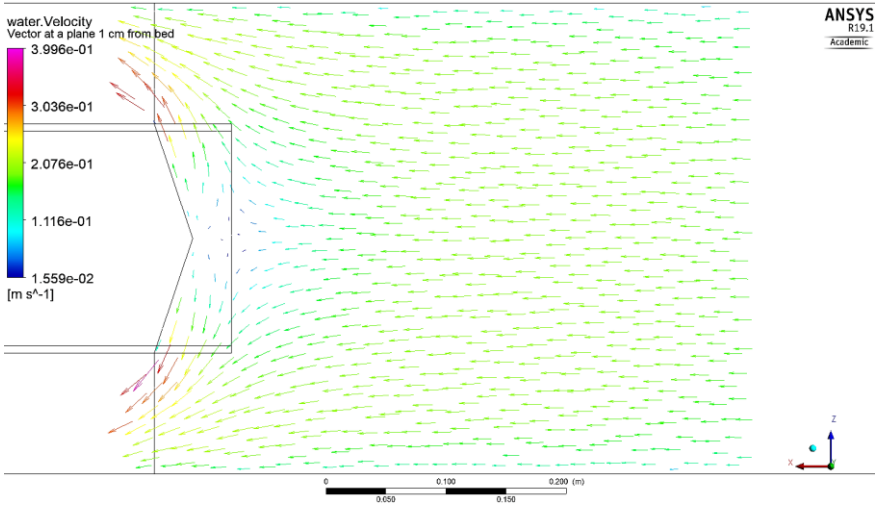
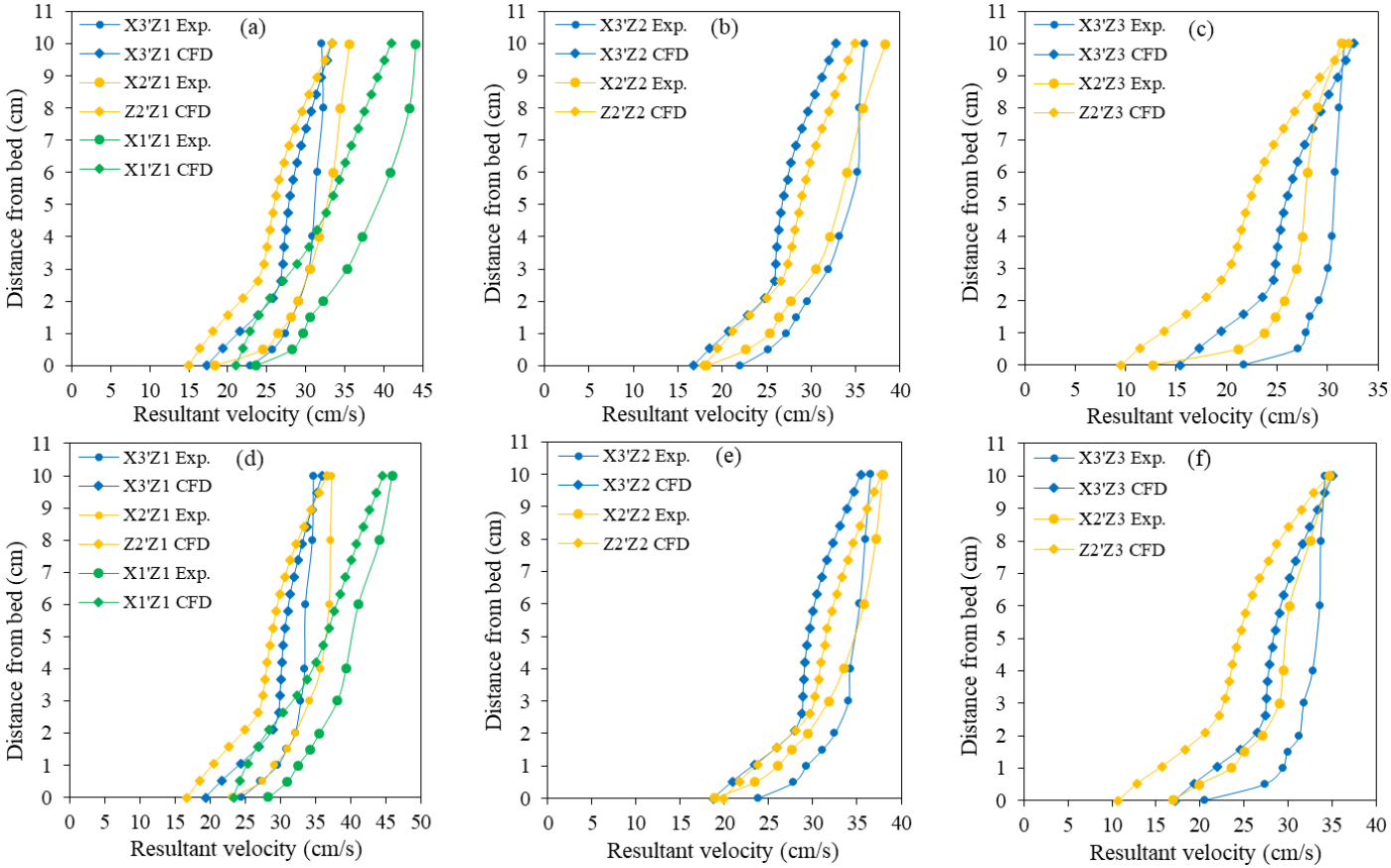
Results and Discussion: CFD Simulation





Simulated flow along a plane 1 cm above the bed for 16.1 l/s discharge

Results and Discussion: Experimental vs CFD



Resultant velocity profiles (a-c) for 16.1 l/s and (d-f) for 18.45 l/s discharges (Kadia 2019)

Summary of the Results

- Experimentally found that longitudinal velocity increases towards the inlet but decreases towards the outlet.
- Rise in upward velocity (in the outer flow region) towards both the keys was observed experimentally and numerically.
- Both approaches also indicated a significant increase in the lateral velocity near the inlet, especially in the inner flow region.
- Accelerating flow was found in front and over the inlet key.
- Mean absolute error: 18.32% for 16.1 l/s and 15.52% for 18.45 l/s.

Concluding remarks

- Velocity profiles inside the inlet key could not be measured experimentally (Kumar et al. 2021 indicated the reasons), and it demands further research.

- The CFD results generally underestimated the velocity values for the measured 0.1 m depth of flow.

- Increasing flow velocity towards and over the inlet enhances the opportunity of sediment passage over a PKW in comparison to other weirs. And it helps sediment to pass over PKW as found by Kumar et al. (2021).

Future research

- Use of other turbulence closures like: RNG k-ε, k-ω SST etc. for better results.

- Comparison study for different PKW configurations to have generalised conclusions.

References

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Kadia, S., Kumar, B., and Ahmad, Z. (2020). “Discharge Characteristics of Triangular Weir with Upstream Ramp and Its CFD Modelling Using Ansys CFX Module.” Recent Trends in Environmental Hydraulics. GeoPlanet: Earth and Planetary Sciences, M. B. Kalinowska, M. M. Mrokowska, and P. M. Rowiński, eds., Springer, Cham, 77–90.

Kumar, B., Kadia, S., and Ahmad, Z. (2021). “Sediment Movement over Type-A Piano Key Weirs.” Journal of Irrigation and Drainage Engineering, 147(6), 04021018.

Launder, B. E., and Spalding, D. B. (1974). “The Numerical Computation of Turbulent Flows.” Computer Methods in Applied Mechanics and Engineering, 3(2), 269–289.

Leite Ribeiro, M., Bieri, M., Boillat, J.-L., Schleiss, A. J., Singhal, G., and Sharma, N. (2012). “Discharge Capacity of Piano Key Weirs.” Journal of Hydraulic Engineering, 138(2), 199–203.