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Development of hydropower converter for very low head differences

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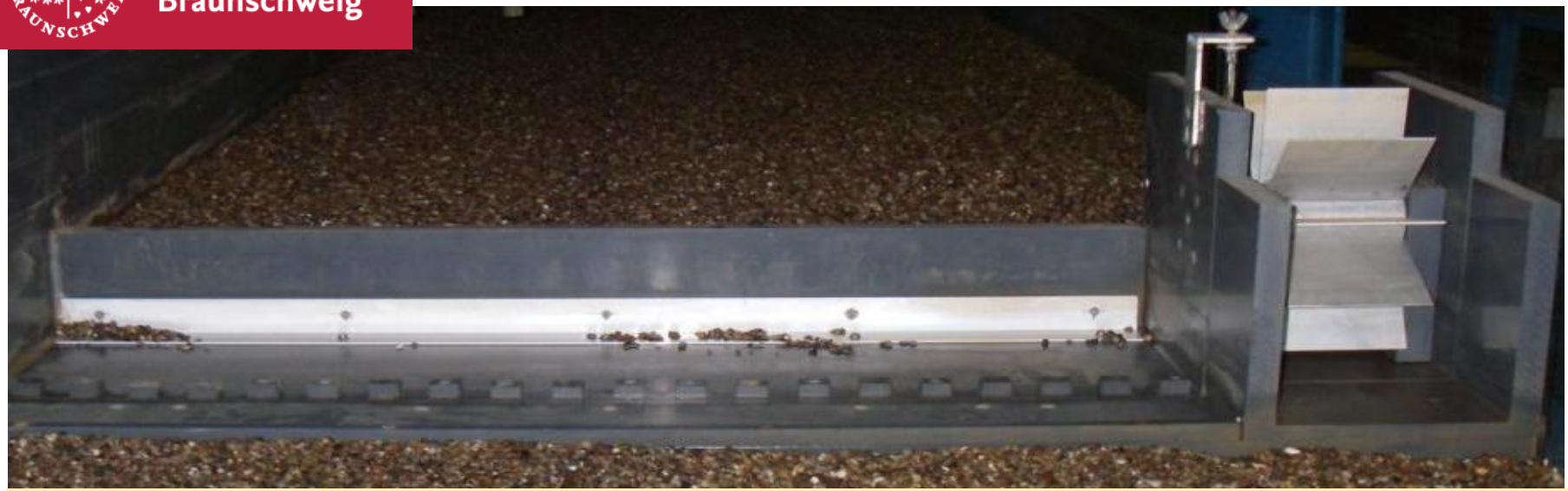

Influence of Small Head Hydropower on Upstream Bed Topography

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6th International Conference on Scour and Erosion (ICSE-6), Paris Aug. 27-31, 2012

Outline

- Introduction
- Experimental Setup
- Experimental Program
- Results
- Conclusion

Introduction

- Development of a hydrostatic pressure machine (HPM) for head differences up to 2.5 m
- HPM was designed for a use in existing weirs with silted backwater area. Sediment is allowed to pass through the wheel.
- Laboratory experiments were conducted to answer the following questions:

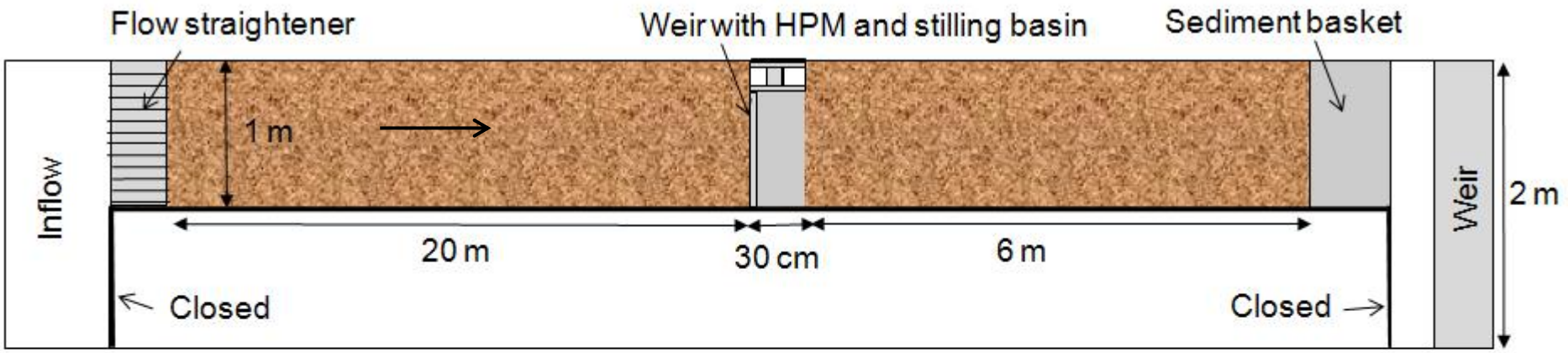
⇒ Can bed load transport damage the machine?

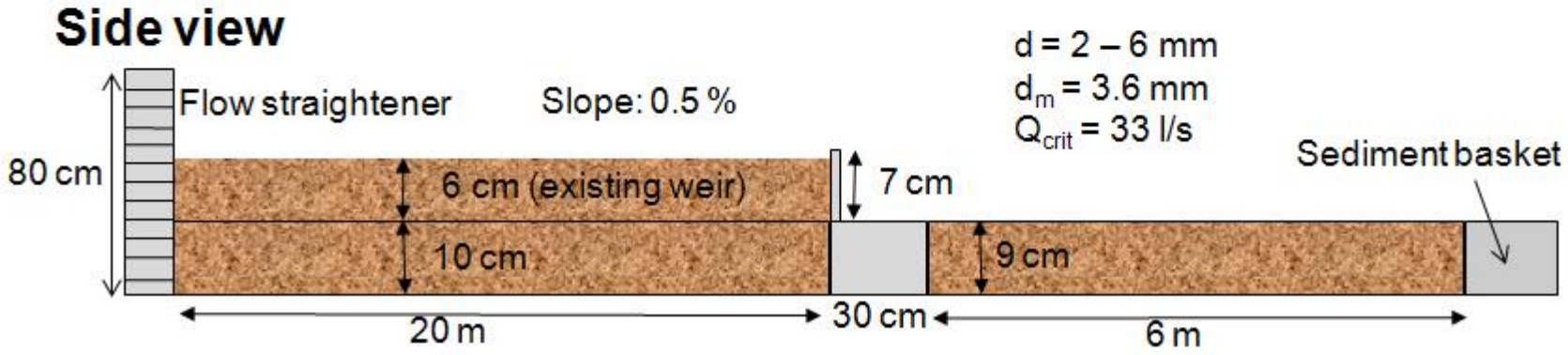
⇒ How will the morphology change?

⇒Can sediment deposition block the inlet?

Prototype of the HPM in Iskar River (Bulgaria)

Experimental Setup





Experimental setup

The geometric dimensions were scaled 1:30 to a prototype in Iskar River (Bulgaria).

Experimental Setup

Measurement Equipment

- IDM for discharge measure
- CNC controlled carriage with 3 D traverse (accuracy 0.01 mm)
- 3 ultrasonic probes for topography scan ‘Sonometer 05‘ from Sonotec
  $\Delta y = 8$ cm
- micro propeller to measure flow velocities

Experimental Program

Experiment No.	Theme	Q/Q_{crit} [-]	Comment
1	Existing Weir (silted backwater)	0.5	HPM position on the left side
2		1.0	
3		1.2	
4		1.5	
5		1.5	Sediment feeding rate: 10 g/s; HPM left
6		1.5	HPM position in the middle of the weir
7		1.5	Doubled HPM width; HPM left
8		1.5	Doubled HPM width; position in the middle of the weir
9	New Weir	1.5	Sediment feeding rate: 10 g/s; HPM left

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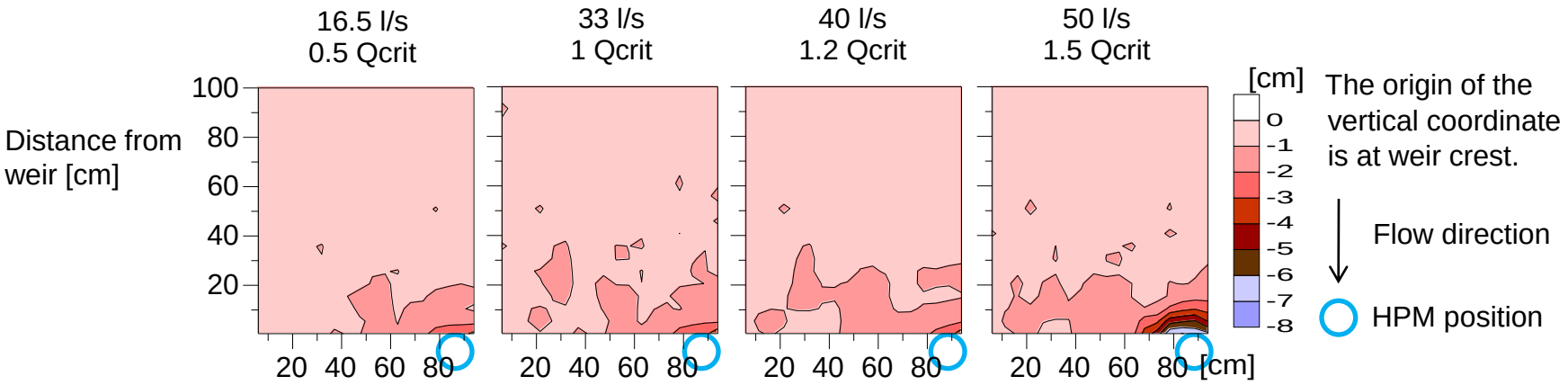
Results – Existing Weir

Influence of discharge

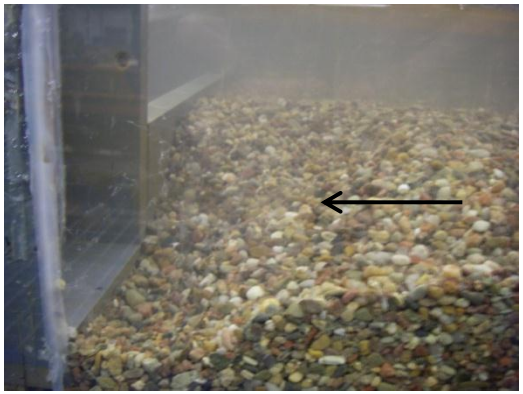


⇒ Only negligible changes in bed topography up to 1.2 Q_{crit}

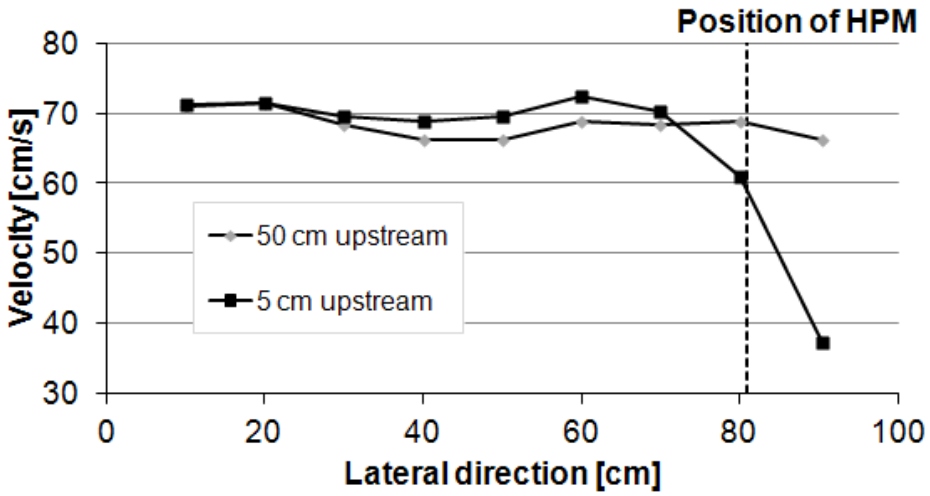
⇒ Scouring in front of the inlet structure at 1.5 Q_{crit}

Due to the experimental setup there was discharge over the weir and through the HPM,

no sediment passed the HPM



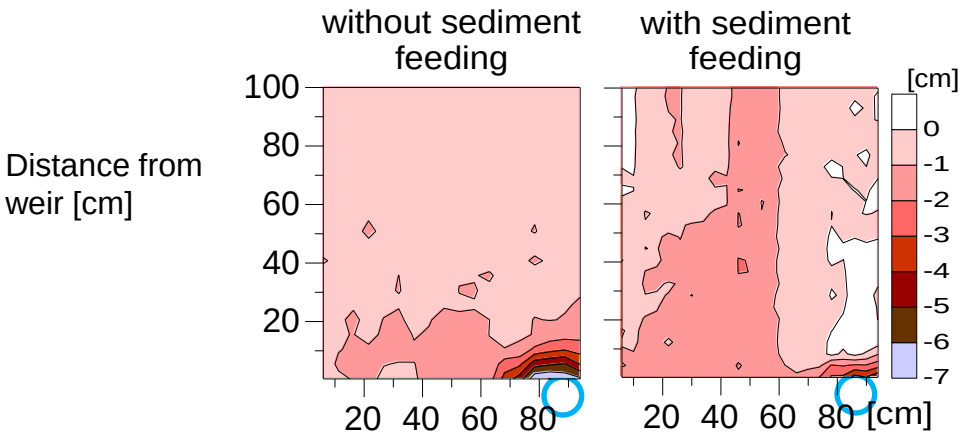
Results



- Directly upstream of the HPM the flow was decelerated and directed towards the weir
- Sediment entered the scour area, but was remobilized and transported over the weir
- Sediment near the inflow to the HPM was pushed back by vortices, induced by the straight blades of the wheel

Results – Existing Weir

Influence of sediment feeding



The origin of the vertical coordinate is at weir crest.
The experiments were run with 1.5 Q_{crit}.

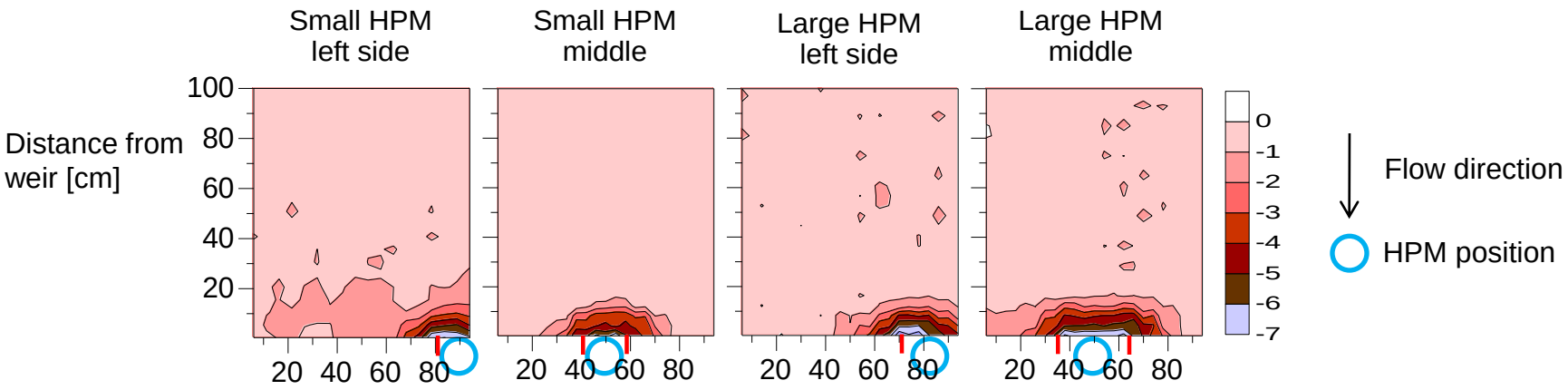
Flow direction

HPM position

⇒ With sediment feeding (10 g/s), the scour size decreased and a small gravel bar developed. A narrow channel eroded in the middle of the flume.
No sediment passed the HPM.

Results – Existing Weir

Influence of position and HPM size



Scour depth [cm]	7.0	6.7	7.8	7.4
Scour extent [cm]	16.5	17.0	28.5	20.5

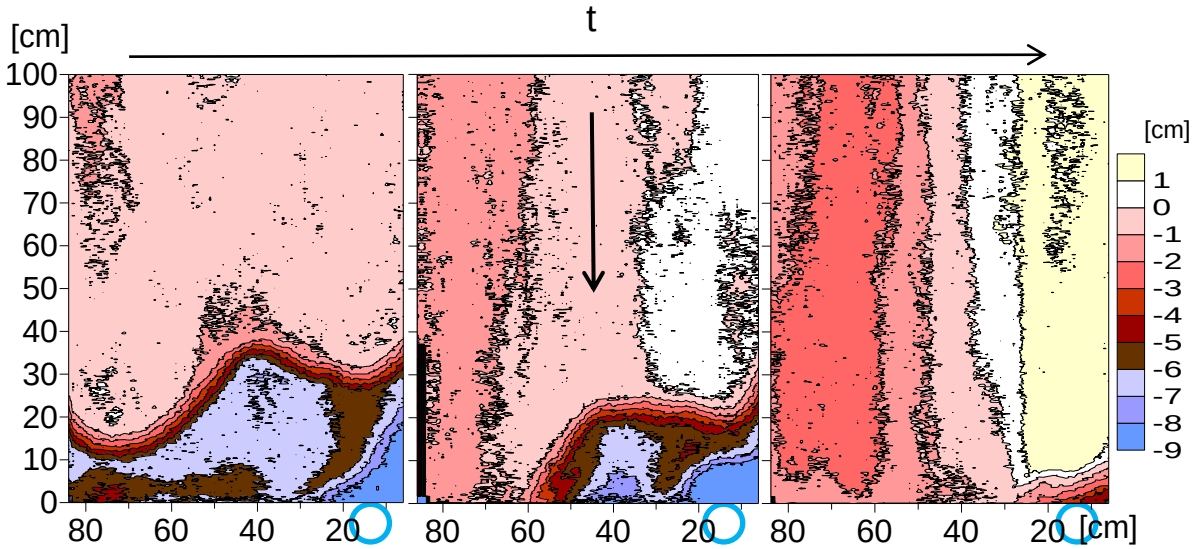
The origin of the vertical coordinate is at weir crest.

The experiments were run with 1.5 Q_{crit}.

⇒ The relative scour dimension and depth increases with increasing wheel width, the position of the wheel has no influence.

Scour extend:

Results – New Weir (Sediment feeding)



- Low shear stress → bed form development with advancing front
- Strong scouring at inlet during sedimentation
  (≈ 12 cm below weir crest; 5 cm below inlet)
- Distinct topography but smaller scour size due to incoming sediment

Conclusion

- Negligible changes in bed topography up to a discharge of 1.2 Q_{crit};
- Erosion upstream of HPM;
  affected area depends on sediment transport rate and the HPM size, but not the position

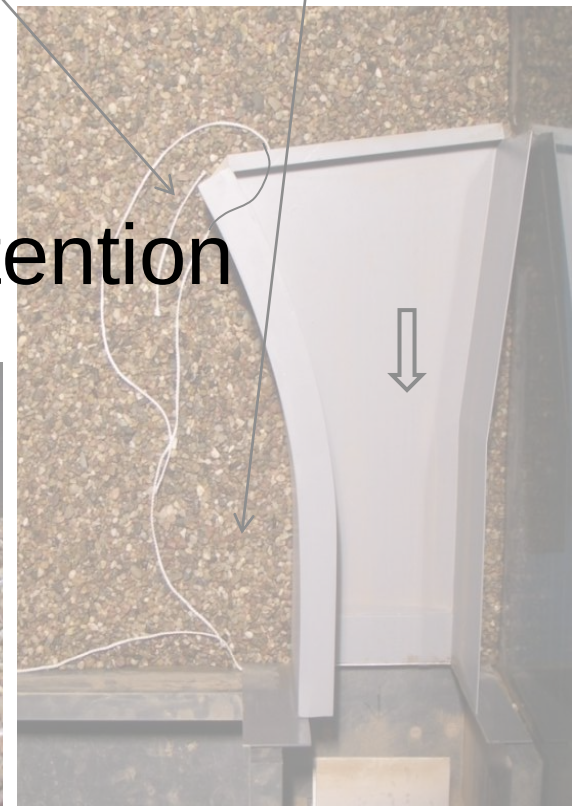
  $\Rightarrow$ No sediment passage through HPM observed;
  influenced by blade shape and discharge distribution

  $\Rightarrow$ No blockage of HPM due to sediment deposition
- The flow was decelerated in front of the HPM and sediment particles transported into the erosion zone were pushed towards the side of the HPM and passed the weir;
- Very deep scour depth during sedimentation of backwater area (New Weir)
  (filled up by incoming sediment);

  $\Rightarrow$ Stability of constructions may be endangered

Scour

Gravel Bar



Thank you for your attention