Hydraulic experiments with fish-friendly trashracks

FISKMARKNAD 2016

LULEÅ 23-25 AUGUSTI

Norwegian University of Science and Technology

Hydraulic experiments with fish-friendly trashracks

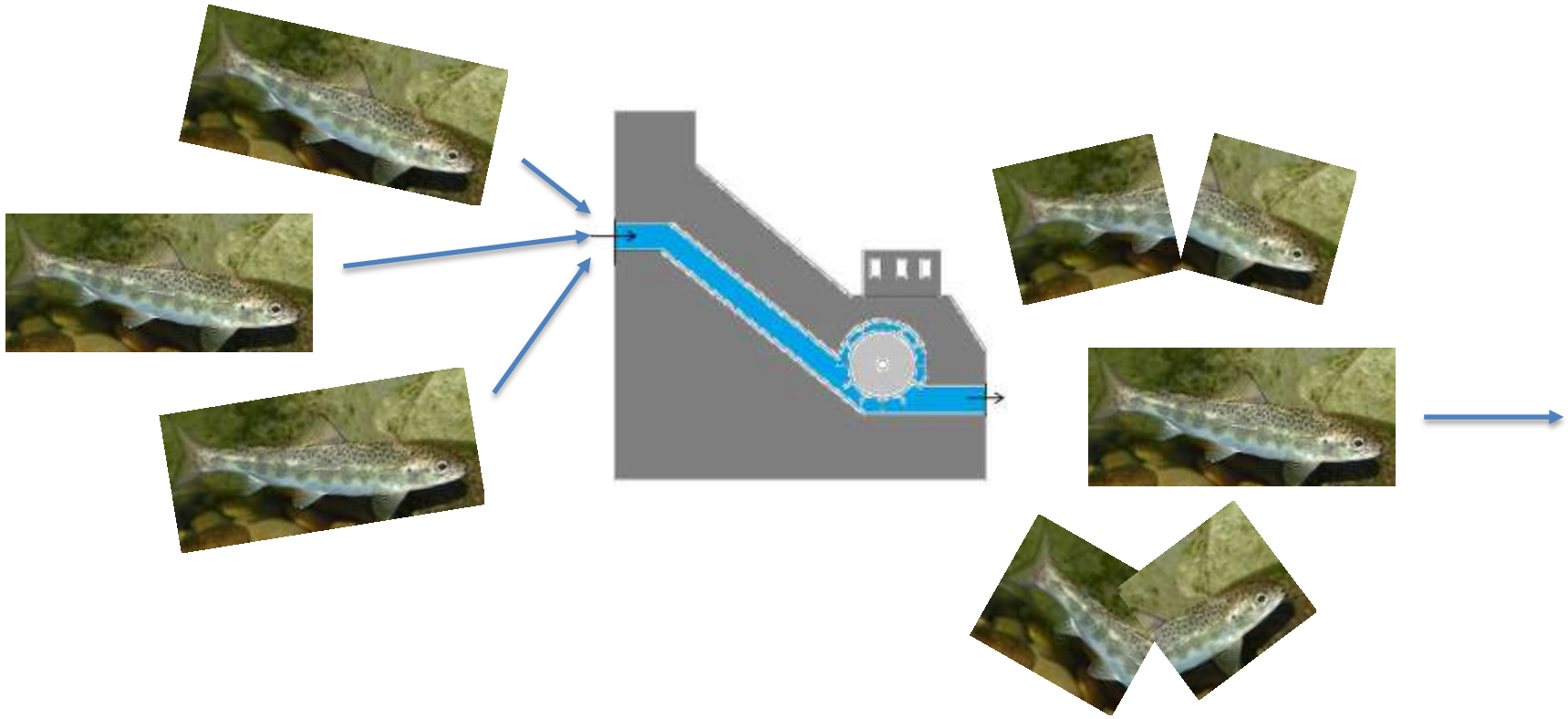
Project: SafePASS
(http://www.cedren.no/english/Projects/SafePass)

Ph.D. Candidate: Marcell Szabo-Meszaros,

Team members: Christy Ushanth Navaratnam, Jochen Aberle, Torbjørn Forseth, Ana T. Silva, Hans-Petter Fjeldstad, Olle Calles, Knut Alfredsen

Background

- During downstream movement some fish pass through the intake towards to the turbine



Background

- During downstream movement some fish pass through the intake towards to the turbine
- The crossing has high mortality for the fish

- What is the main aim goal of this work?

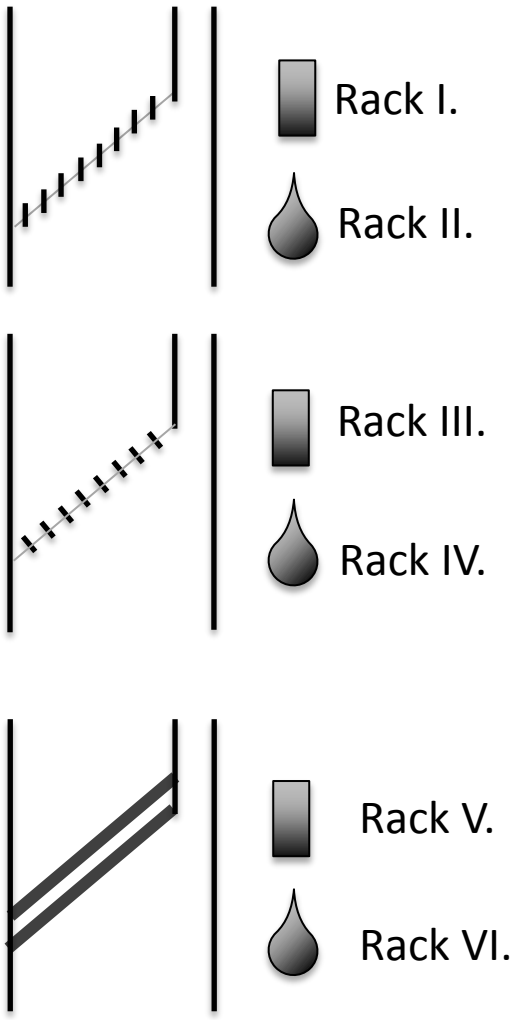
- Help to prevent fish to enter into the intake/tunel during their downstream migration with minimum of head-loss associated

Fish-friendly trashracks

- Designs and laboratory work are based on recent studies (Calles et. al 2013, Raynal et. al 2013a and Raynal et. al 2013b)
- Angled trashracks
- Two different bar profiles:
  - Rectangular
  - Drop shaped
- Three different bar positions
  - Vertical bars: aligned to the flow
  - Vertical bars: angled, perpendicular to the axis of the rack
  - Horizontal bars
- Bypass at the end of the rack

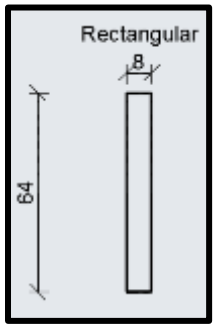
CALLES, O., KARLSSON, S., VEZZA, P., COMOGLIO, C. & TIELMAN, J. 2013. Success of a low-sloping rack for improving downstream passage of silver eels at a hydroelectric plant. *Freshwater Biology,* 58**,** 2168-2179.
RAYNAL, S., COURRET, D., CHATELLIER, L., LARINIER, M. & DAVID, L. 2013b. An experimental study on fish-friendly trashracks - Part 1. Inclined trashracks. *Journal of Hydraulic Research,* 51**,** 56-66.
RAYNAL, S., CHATELLIER, L., COURRET, D., LARINIER, M. & DAVID, L. 2013a. An experimental study on fish-friendly trashracks - Part 2. Angled trashracks. *Journal of Hydraulic Research,* 51**,** 67-75.

Rack label*

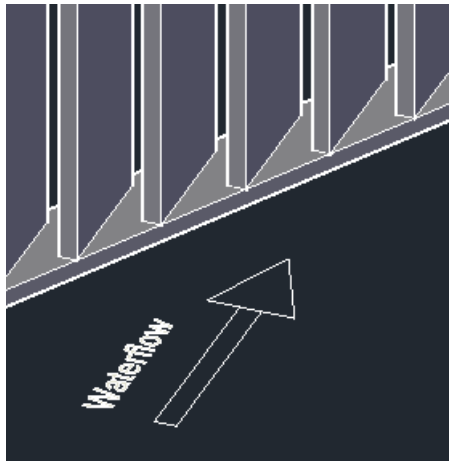


*appears where relevant

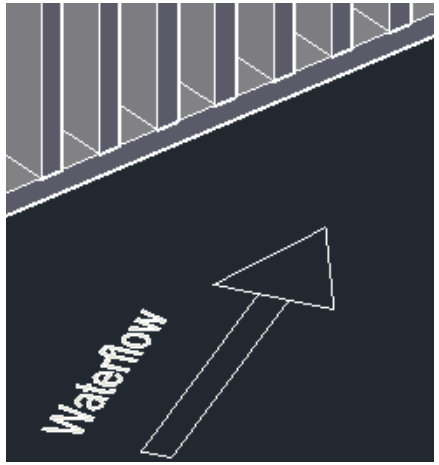
Fish-friendly trashracks



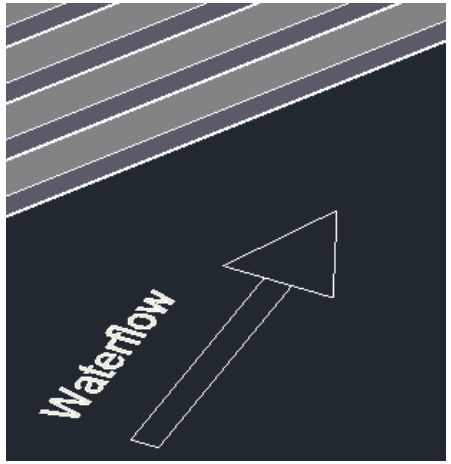
Rack I.

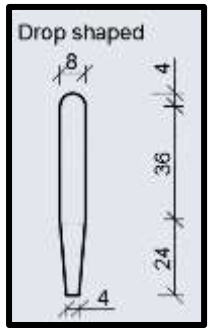


Rack III.

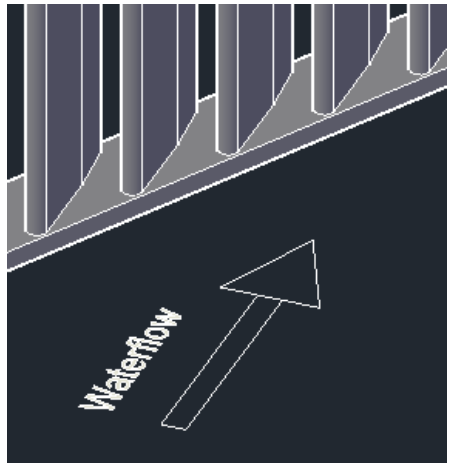


Rack V.

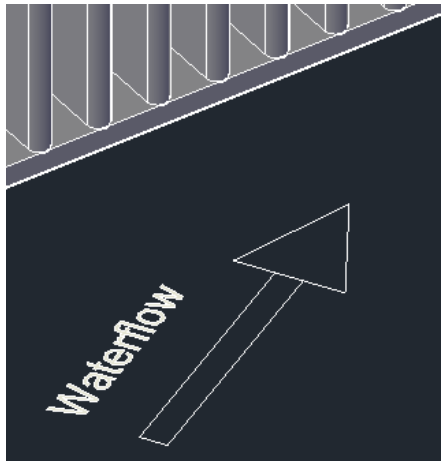




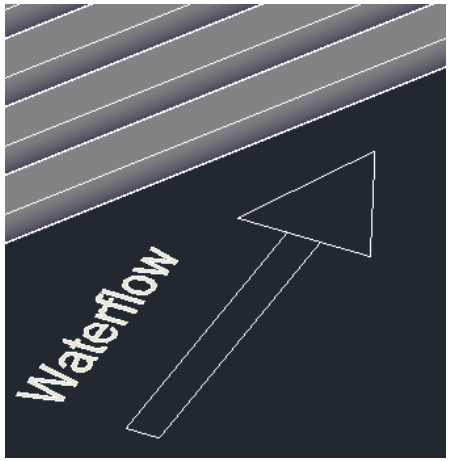
Rack II.



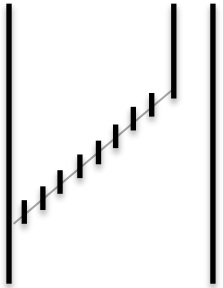
Rack IV.



Rack VI.

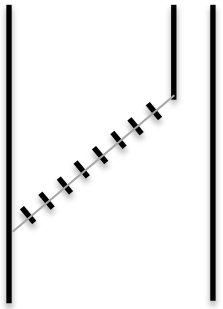


Rack label*



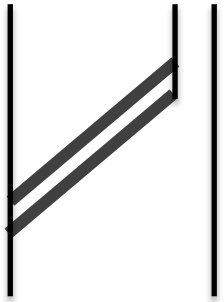
Rack I.

Rack II.



Rack III.

Rack IV.



Rack V.

Rack VI.

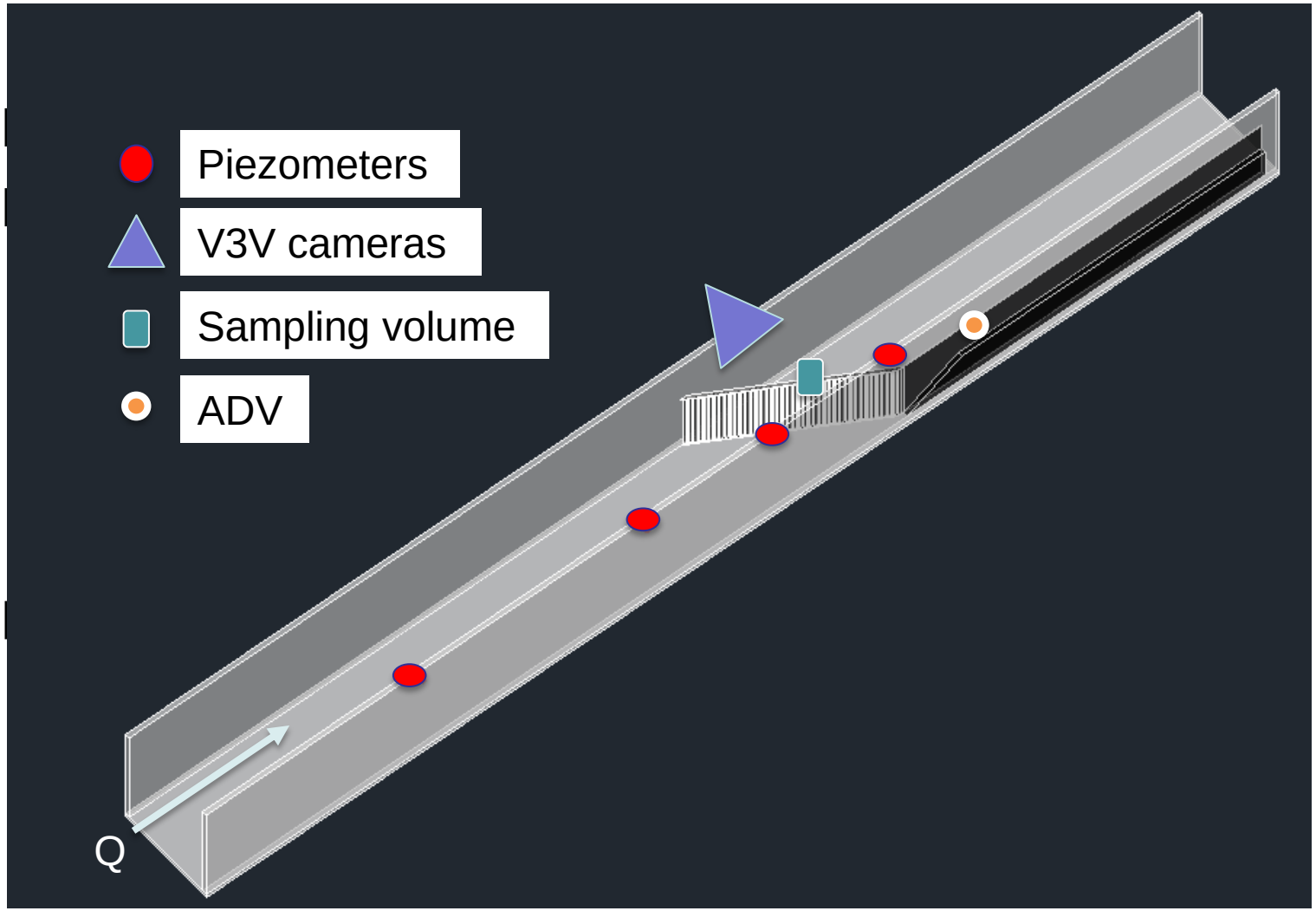
*appears where relevant

Laboratory setup

- Flume size: 1 x 1 x 12.5m
- Hydraulic conditions:
  - Horizontal flume
  - Water depth: 0.5 m
  - Approach velocity: < 0.5 m/s at 170 l/s
  - Discharges: 50 – 80 – … – 200 l/s
  - Discharge in the bypass: ~ 3-6% of the total flow
- Measuring system:
  - Head losses: 4 piezometers
  - Water velocities: ADV and PIV V3V

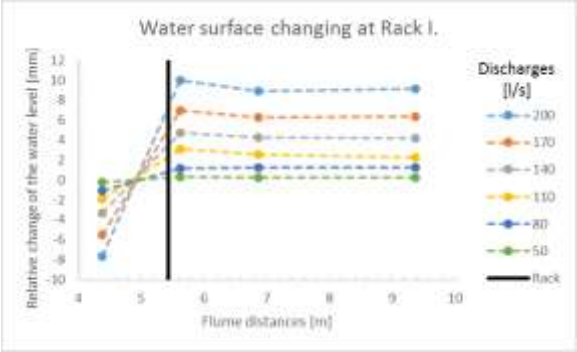
Laboratory setup

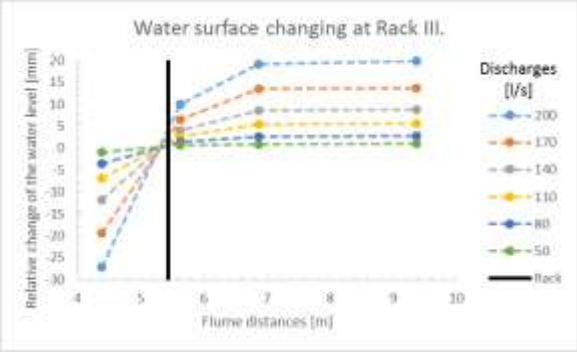
-
-
-

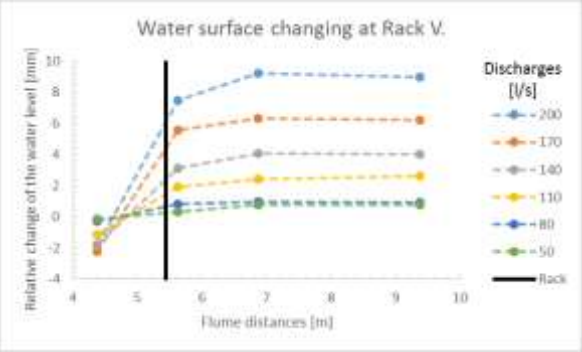


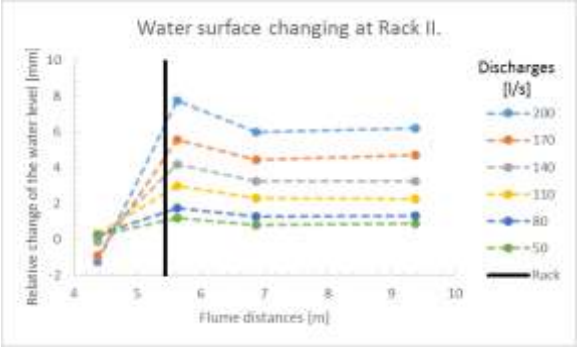
Head-losses

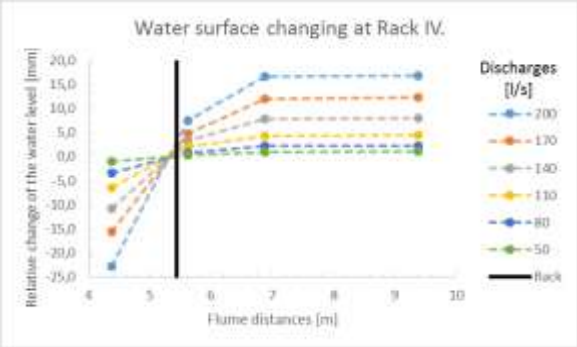
Flow direction

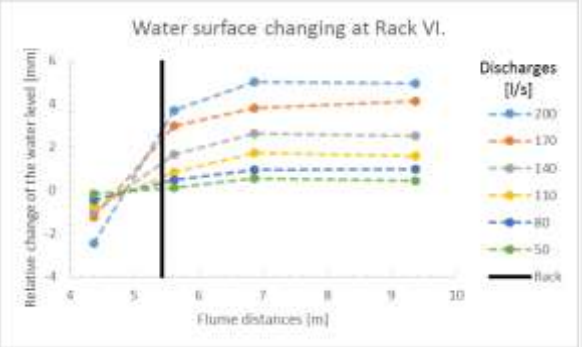




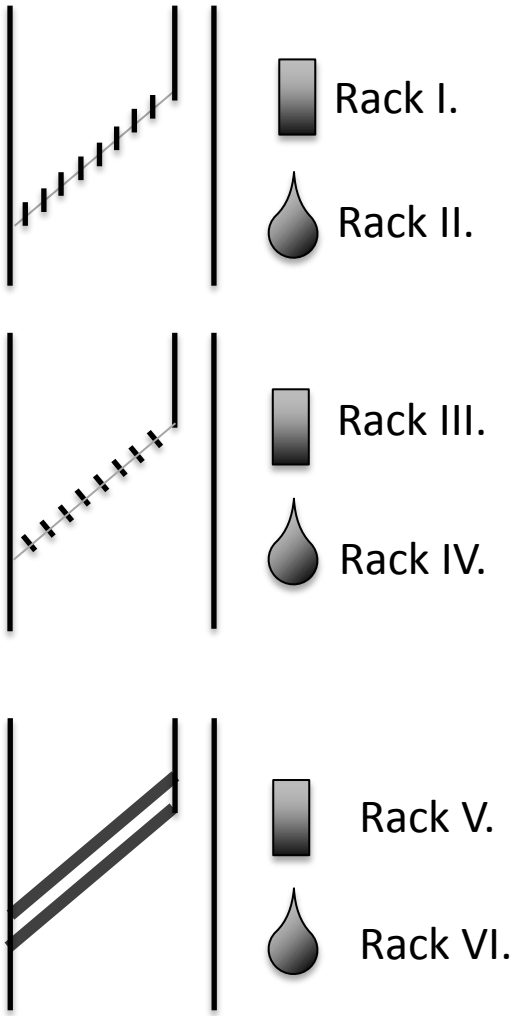






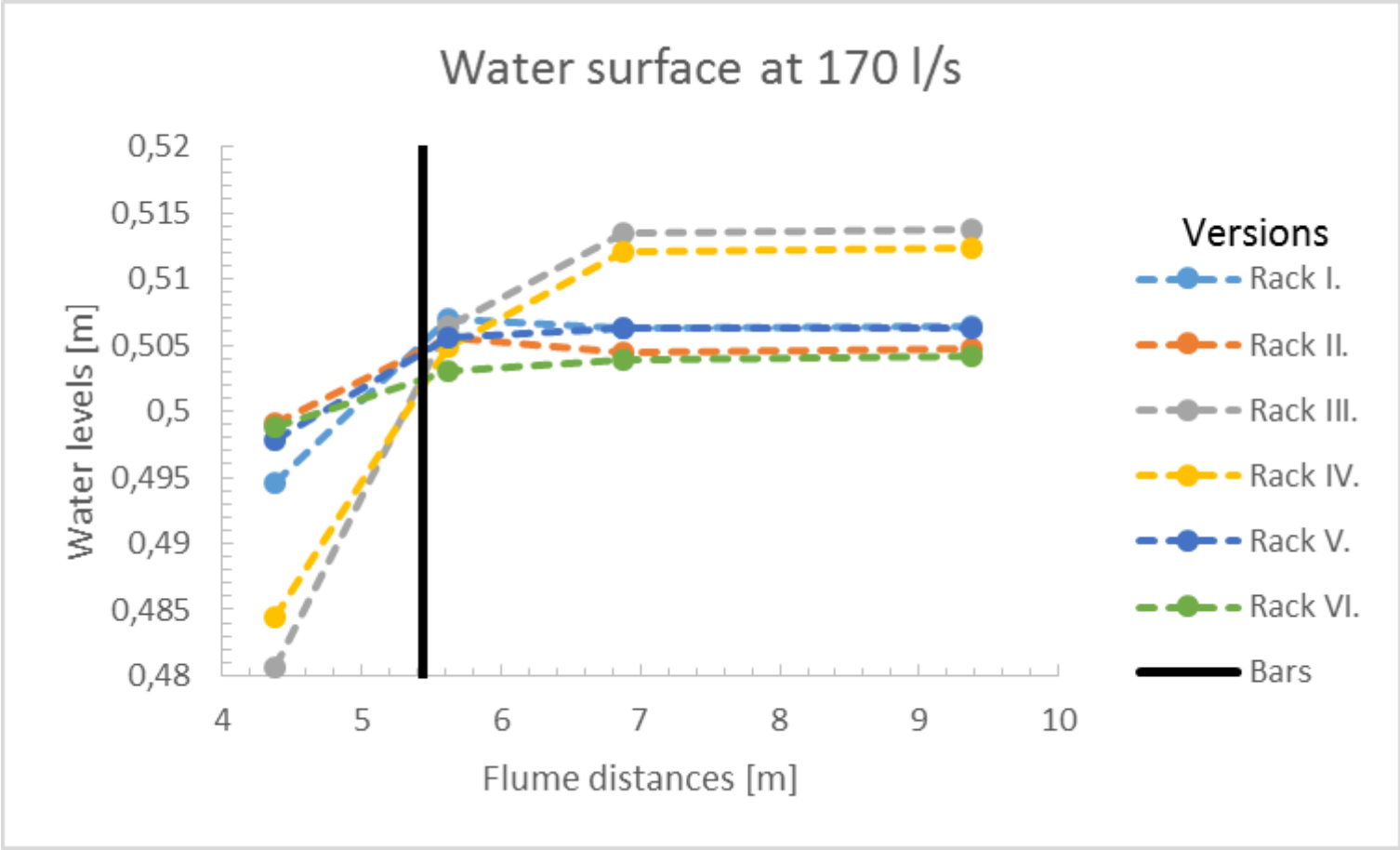


Rack label

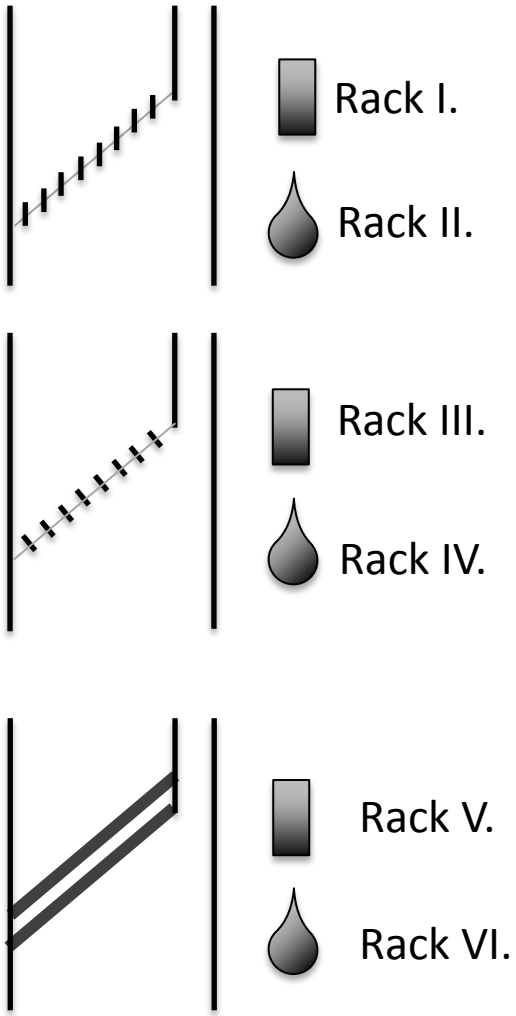


Head-losses

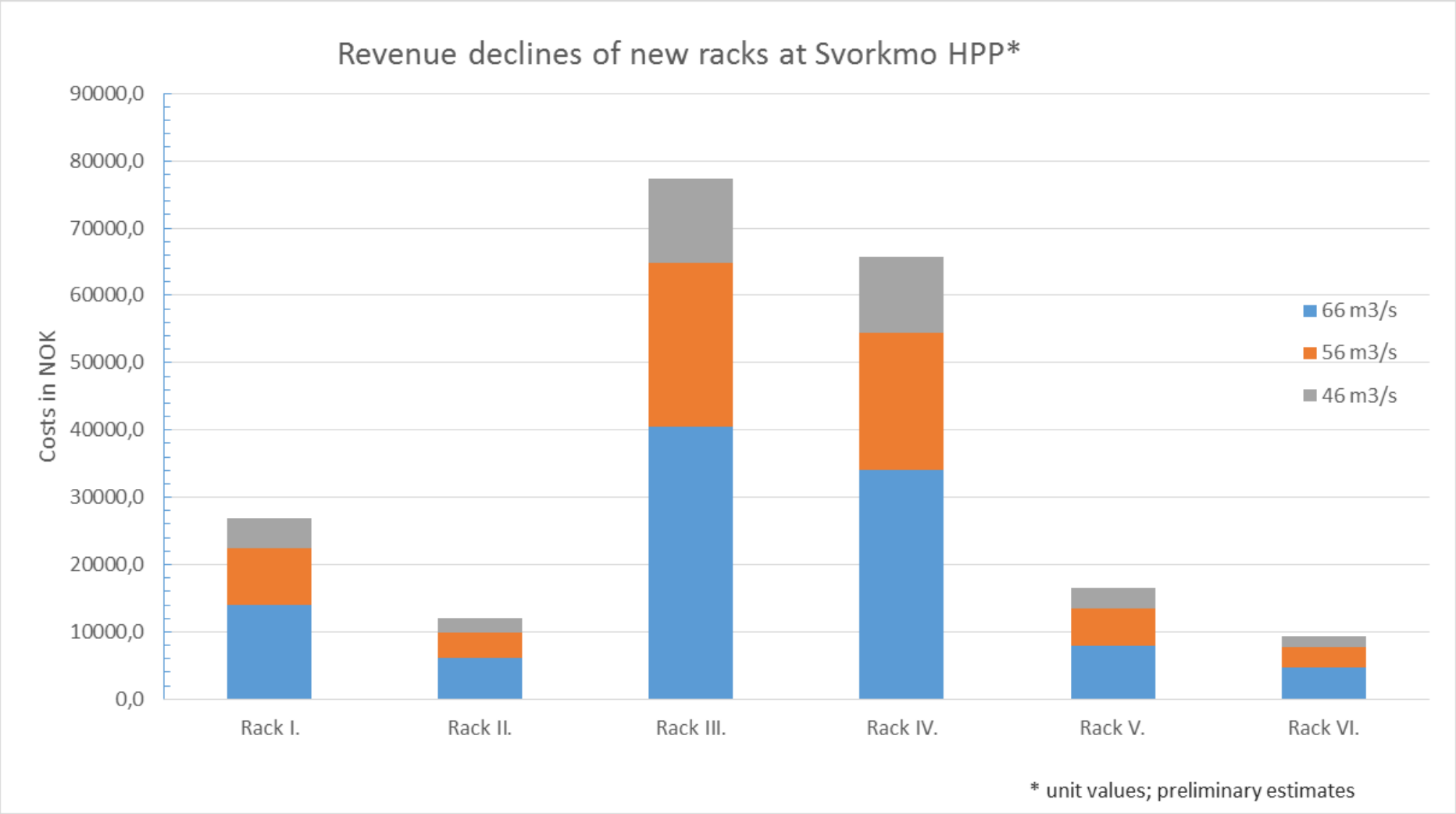
Flow direction



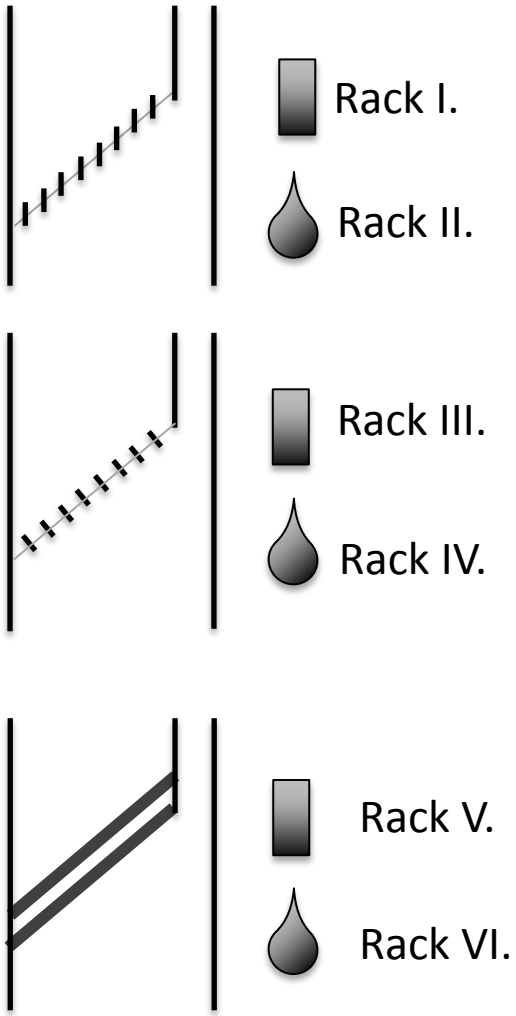
Rack label



Head-losses



Rack label



Head-losses

Volume based blockage ratio

Rack I.	Rack II.	Rack III.	Rack IV.	Rack V.	Rack VI.
0,18	**0,16**	**0,34**	**0,30**	**0,35**	**0,32**

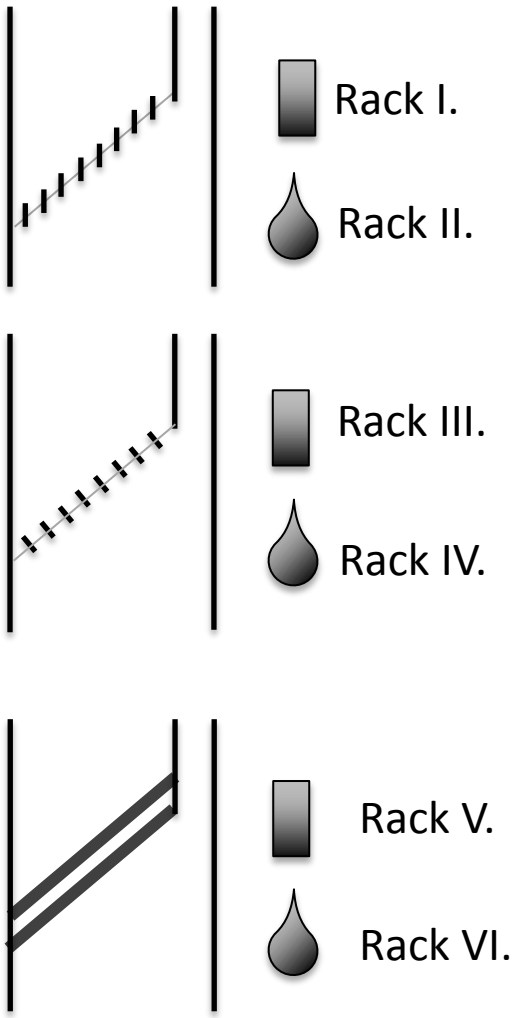
Head-losses and head-loss coefficients

Q = 170 - 200l/s	Rack I.	Rack II.	Rack III.	Rack IV.	Rack V.	Rack VI.
ΔH [mm]	**9,8 - 14,2**	**3,4 - 4,9**	**30,9 - 43,8**	**25,7 - 37,2**	**6,6 - 8,7**	**3,1 - 5,1**
ξm [-]	**1,70 - 1,81**	**0,59 - 0,62**	**5,54 - 5,79**	**4,58 - 4,87**	**1,15 - 1,10**	**0,54 - 0,64**

Discharge in the bypass

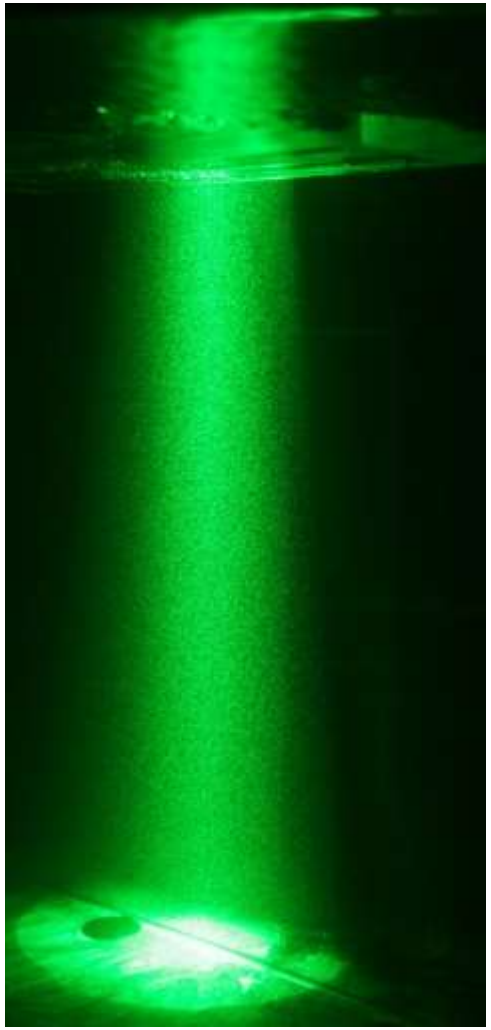
	Rack I.	Rack II.	Rack III.	Rack IV.	Rack V.	Rack VI.
Q=170 l/s	**4,1 %**	**3,5 %**	**5,8 %**	**5,6 %**	**3,3 %**	**3,1 %**
Q=200 l/s	**4,1 %**	**3,5 %**	**5,4 %**	**5,7 %**	**3,4 %**	**3,1 %**

Rack label

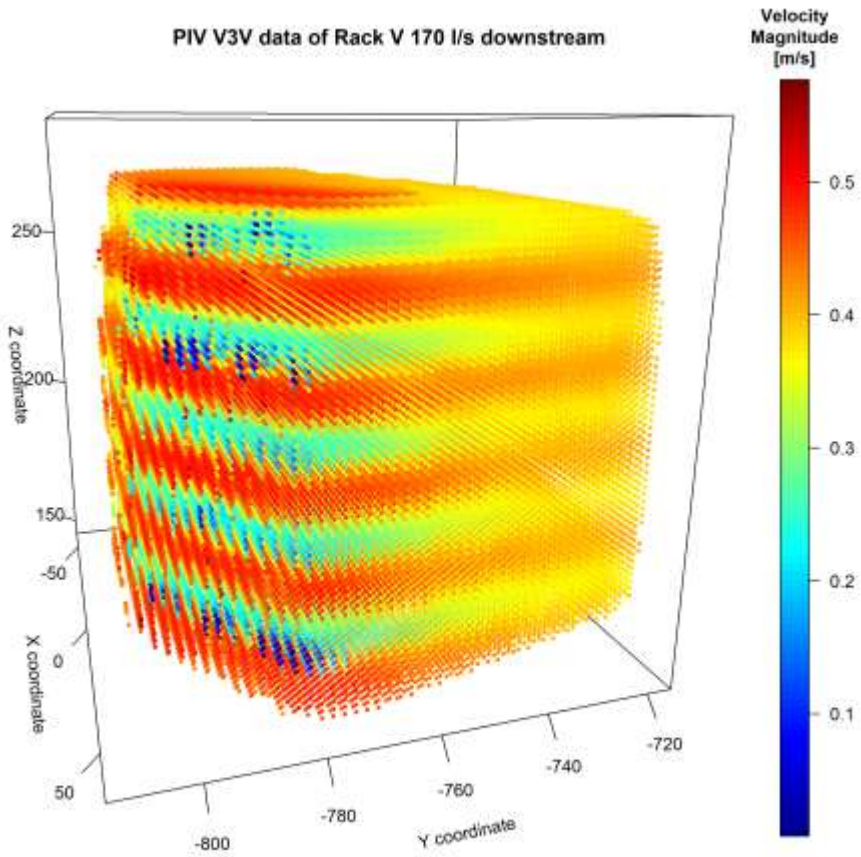


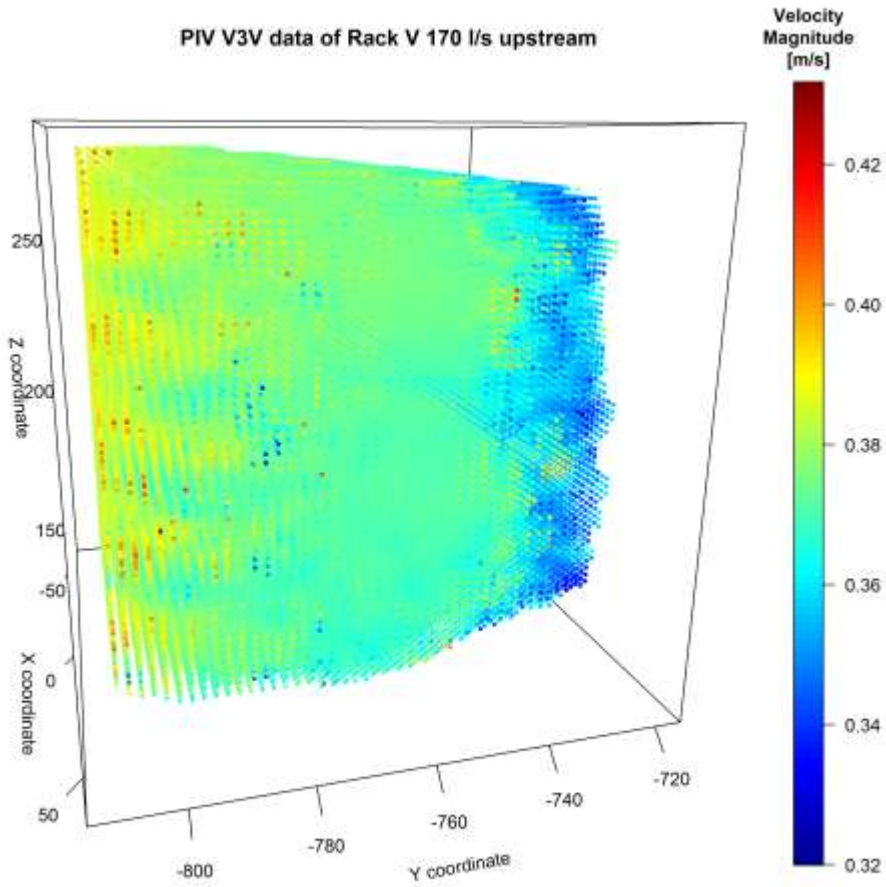
About the PIV - V3V system

- Volumetric 3-Component Velocimetry (V3V)
  - Based on the method of Particle Image Velocimetry (PIV)
  - 140x140x100 mm measured volume
  - Gives high resolution of 3D velocities
- Conditions:
  - Installed laser and camera system (3 high speed cameras)
  - 55 µm particles were mixed into the water
- Method:
  - Calibration in calm water
  - Capturing when firing the laser

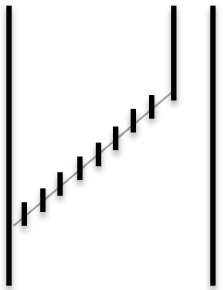


PIV - V3V results I. – Massive datasets



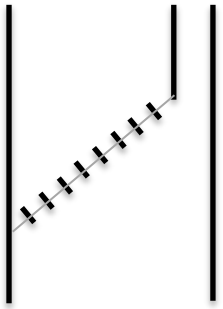


Rack label



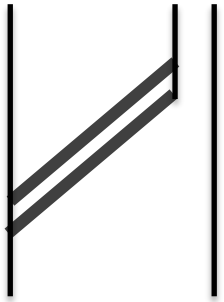
Rack I.

Rack II.



Rack III.

Rack IV.



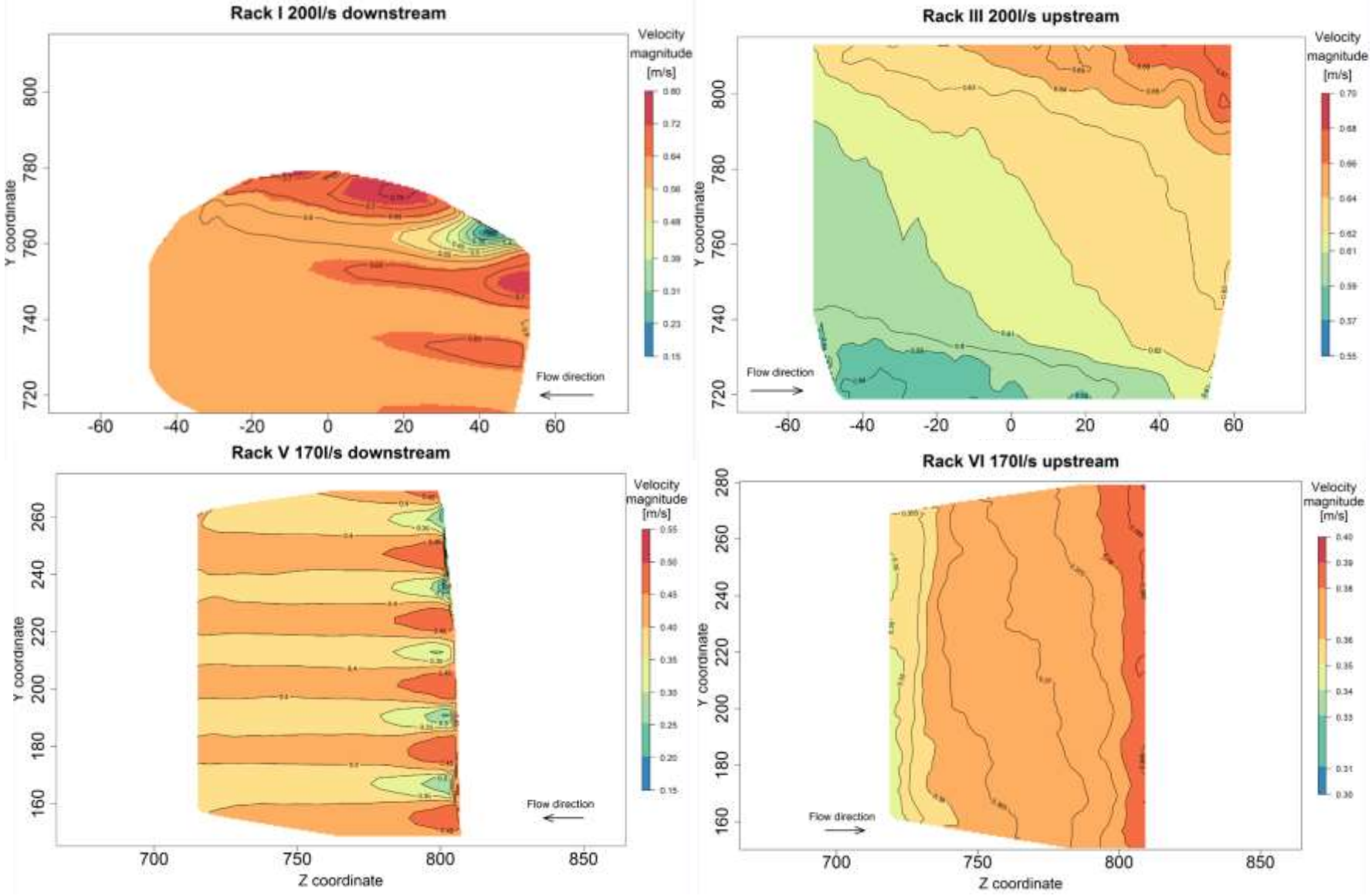
Rack V.

Rack VI.

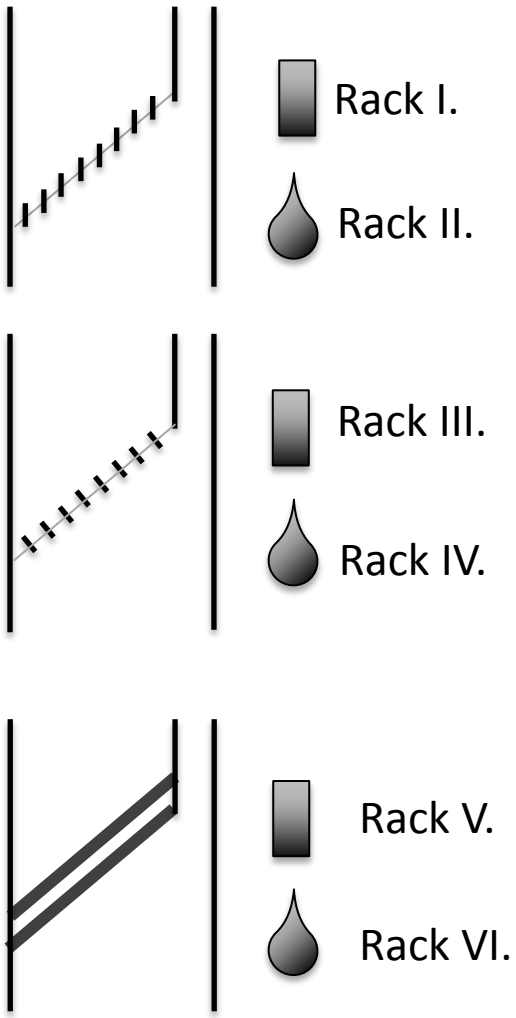
PIV – V3V results II. – Slices

Horizontal slices

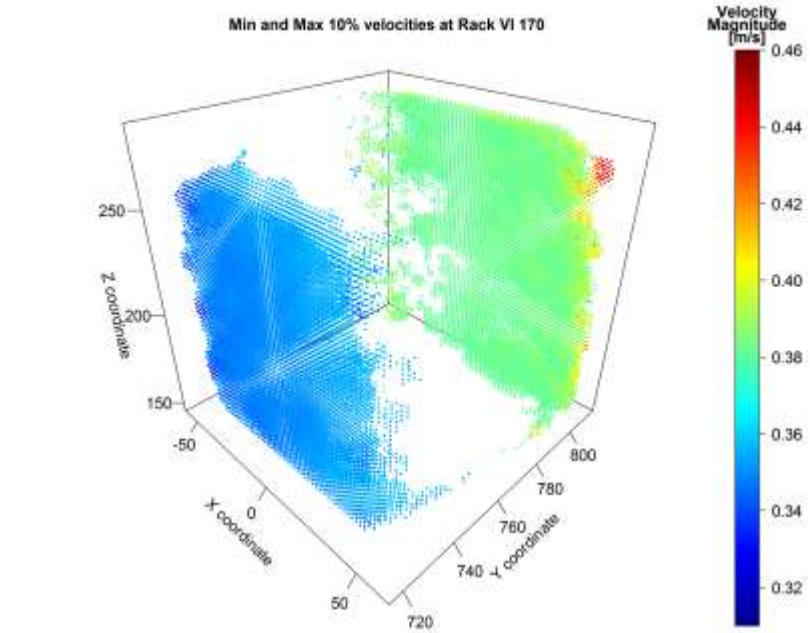
Vertical slices

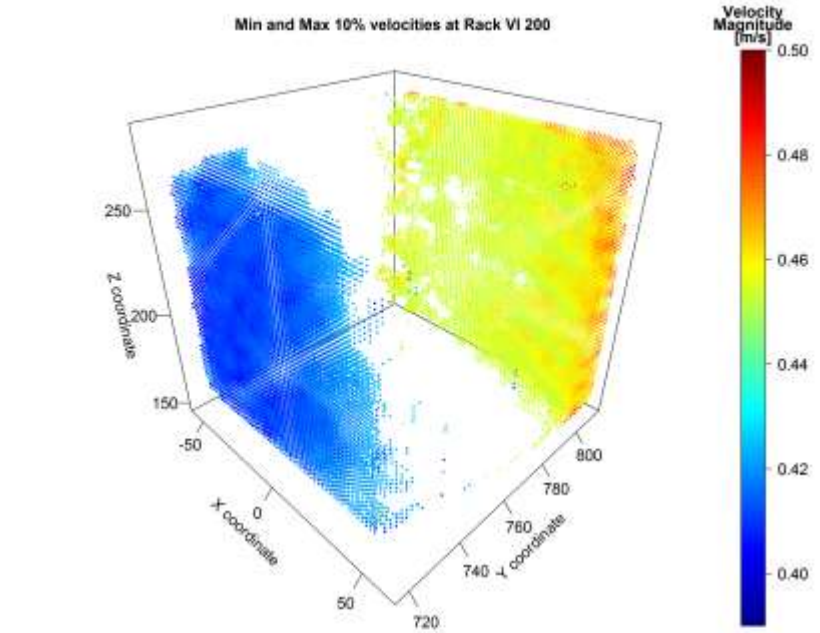


Rack label

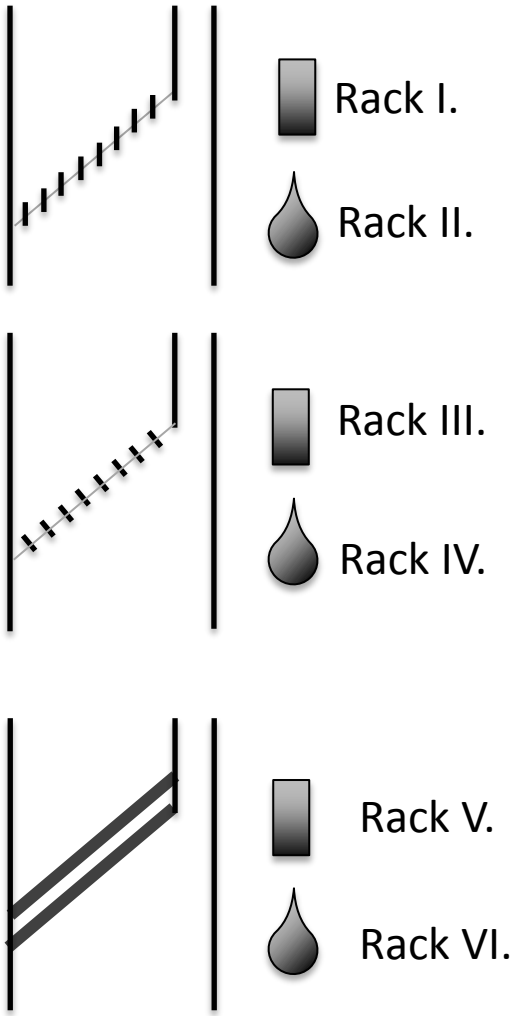


PIV - V3V results III. – Filtered data



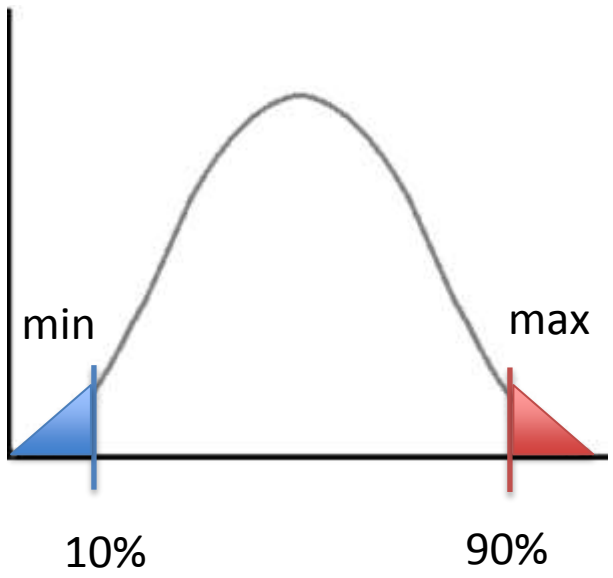


Rack label



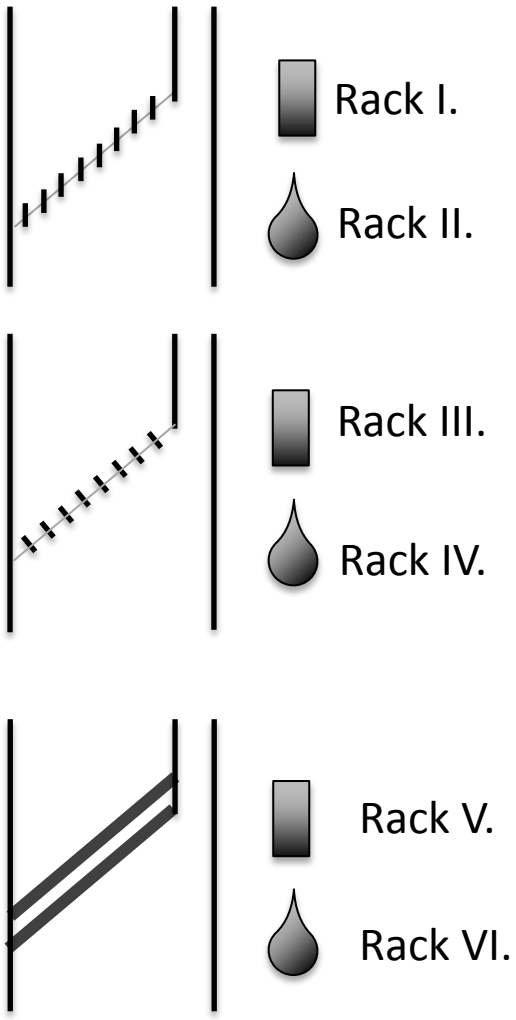
PIV - V3V results III. – Filtered data

Dataset	Min velocities	Max velocities
Rack I 170	**0,383**	**0,597**
Rack I 170 us	**0,318**	**0,342**
Rack I 200	**0,527**	**0,697**
Rack I 200 us	**0,372**	**0,401**
Rack II 170	**0,421**	**0,503**
Rack II 170 us	**0,287**	**0,314**
Rack II 200	**0,495**	**0,593**
Rack II 200 us	**0,344**	**0,381**
Rack III 170 us	**0,504**	**0,559**
Rack III 200 us	**0,588**	**0,655**
Rack IV 170 us	**0,518**	**0,573**
Rack V 170	**0,317**	**0,463**
Rack V 170 us	**0,352**	**0,385**
Rack V 200	**0,391**	**0,55**
Rack VI 170	**0,316**	**0,426**
Rack VI 170 us	**0,352**	**0,386**
Rack VI 200 us	**0,416**	**0,459**
	[m/s]	[m/s]



Distribution of the velocity dataset

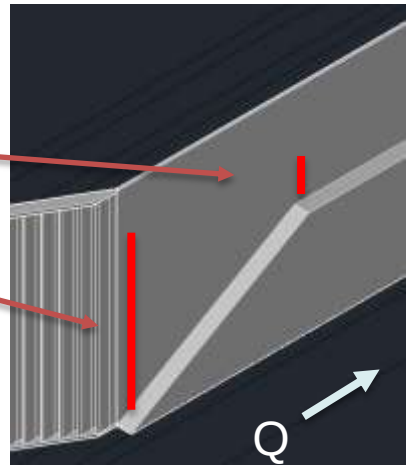
Rack label



Accelaration at the bypass

- What a fish could sense?

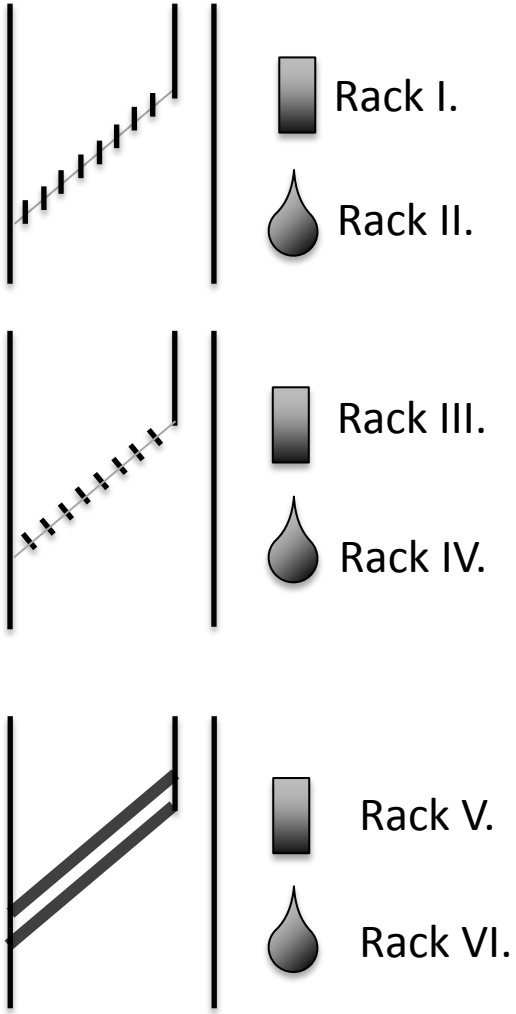
$$a_{bypass} = \frac{v_{cont}}{v_{ent}}$$



a_{bypass}

Q \ Rack	I.	II.	III.	IV.	V.	VI.
170	**2,93**	**3,10**	**2,93**	**2,88**	**2,80**	**2,80**
200	**2,96**	**3,22**	**2,40**	**2,63**	**2,62**	**3,02**

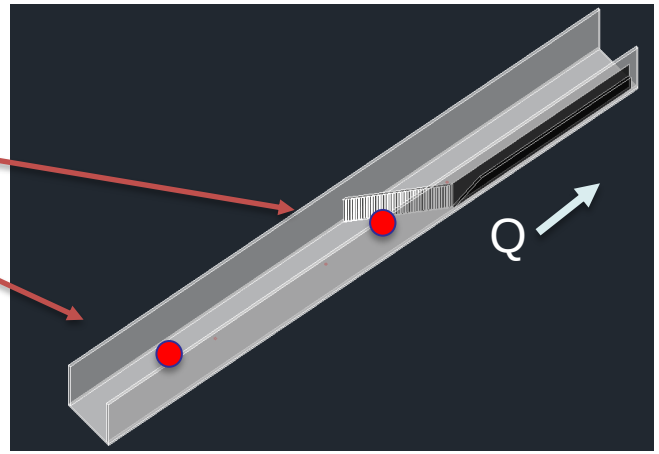
Rack label



Accelaration towards the racks

- What a fish could sense?

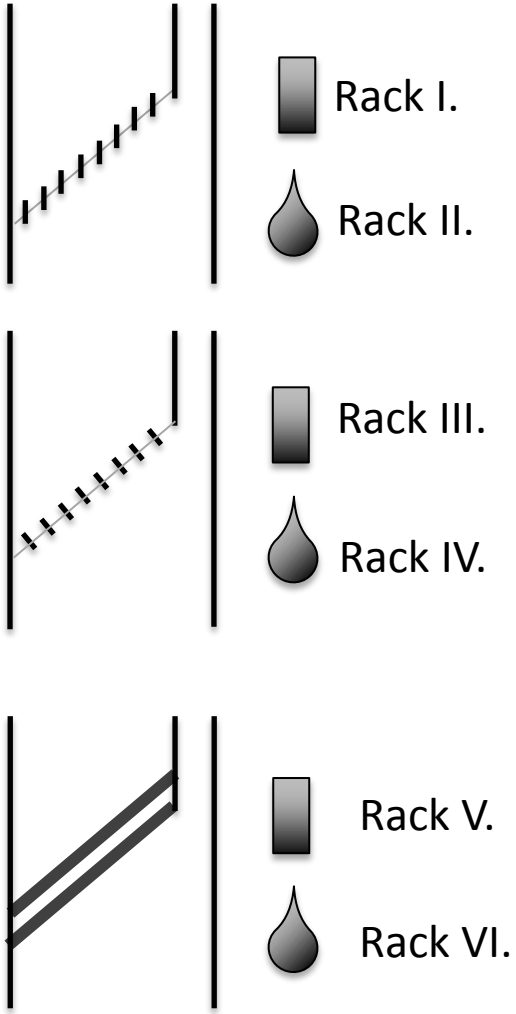
$$a_{1-PIV} = \frac{v_{PIV}}{v_1}$$



a_{1-PIV}

Q \ Rack	I.	II.	III.	IV.	V.	VI.
170	**1,02**	**0,93**	**1,69**	**1,73**	**1,15**	**1,14**
200	**1,02**	**0,96**	**1,70**	**-**	**-**	**1,16**

Rack label



Conclusion

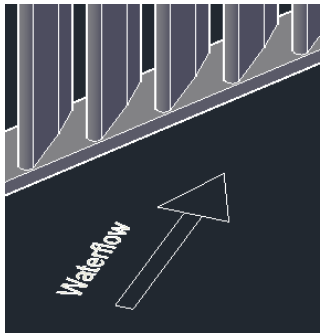
<u>Different rack types</u>

- Head-losses: 3,0 – 44,0 mm
- Blockage ratio: 0,16 – 0,35
- Bypass measurements (vel -> Q)

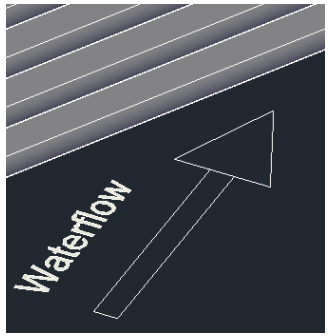
- Revenue decline during operation
  - How much does it cost over operation to implement new design(s)?
  - Extra maintaince investments (and costs?) Must be taken into account!
- Ecological benefits
  - Fish–friendly approach: What a fish could sense?
  - Velocity fields in front of the bars
    - changing of the flow is slight - moderate

- Most promising ones are so far…->

!

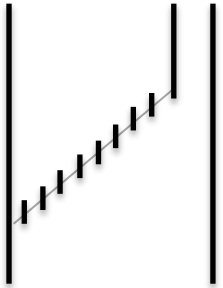


Rack II.



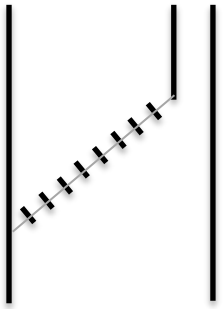
Rack VI.

Rack label



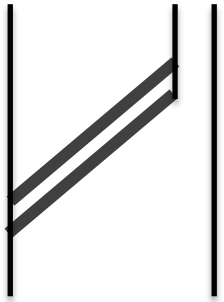
Rack I.

Rack II.



Rack III.

Rack IV.



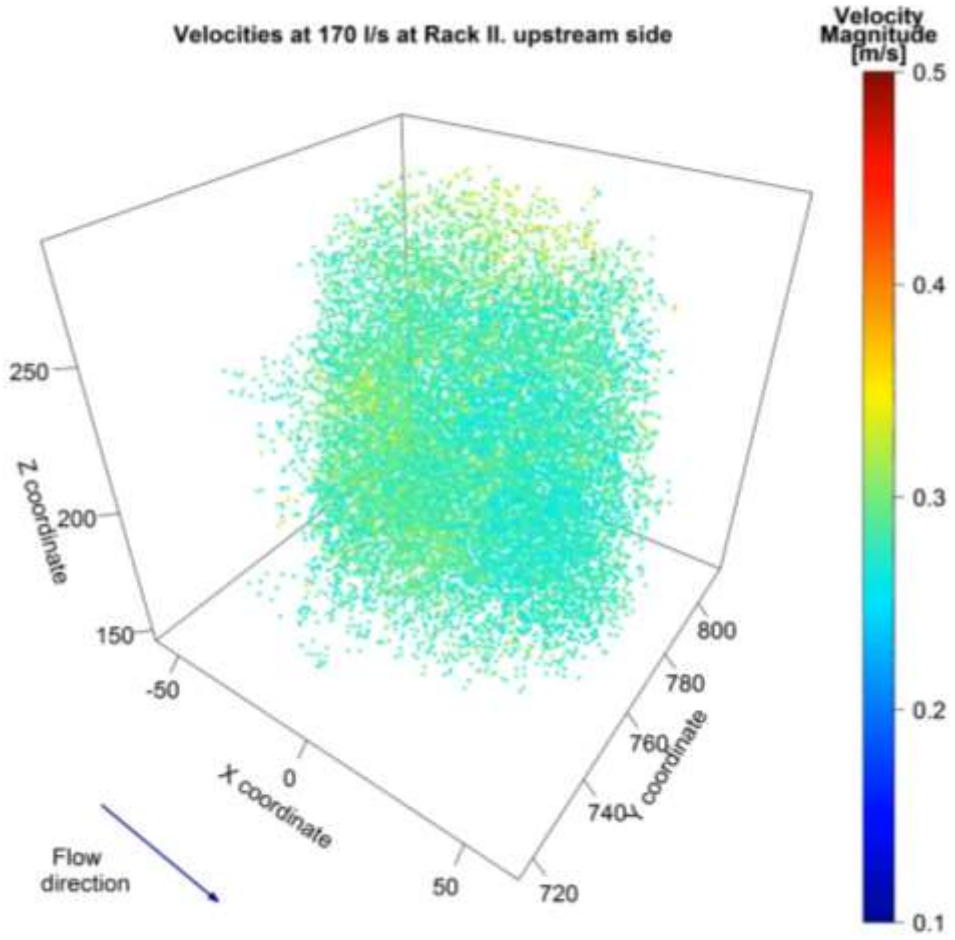
Rack V.

Rack VI.

Outlook

- Continue the evaluation according to
  - time averaged hydraulics: isosurfaces-isolines of velocities
  - time dependent parameters: turbulence analysation
    - Reynolds stresses
    - Turbulent kinetic energy

Preview



Thank you for your attention!

Contact: marcell.szabo-meszaros@ntnu.no