Dec 12th, 1:30 PM - 3:10 PM

Energy efficient fish attraction

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EFFISHENT

ENERGY ~~EFFICIENT~~ ~~FISH~~ ATTRACTION

International Conference on River Connectivity (Fish Passage 2018), 10th - 14th December 2018

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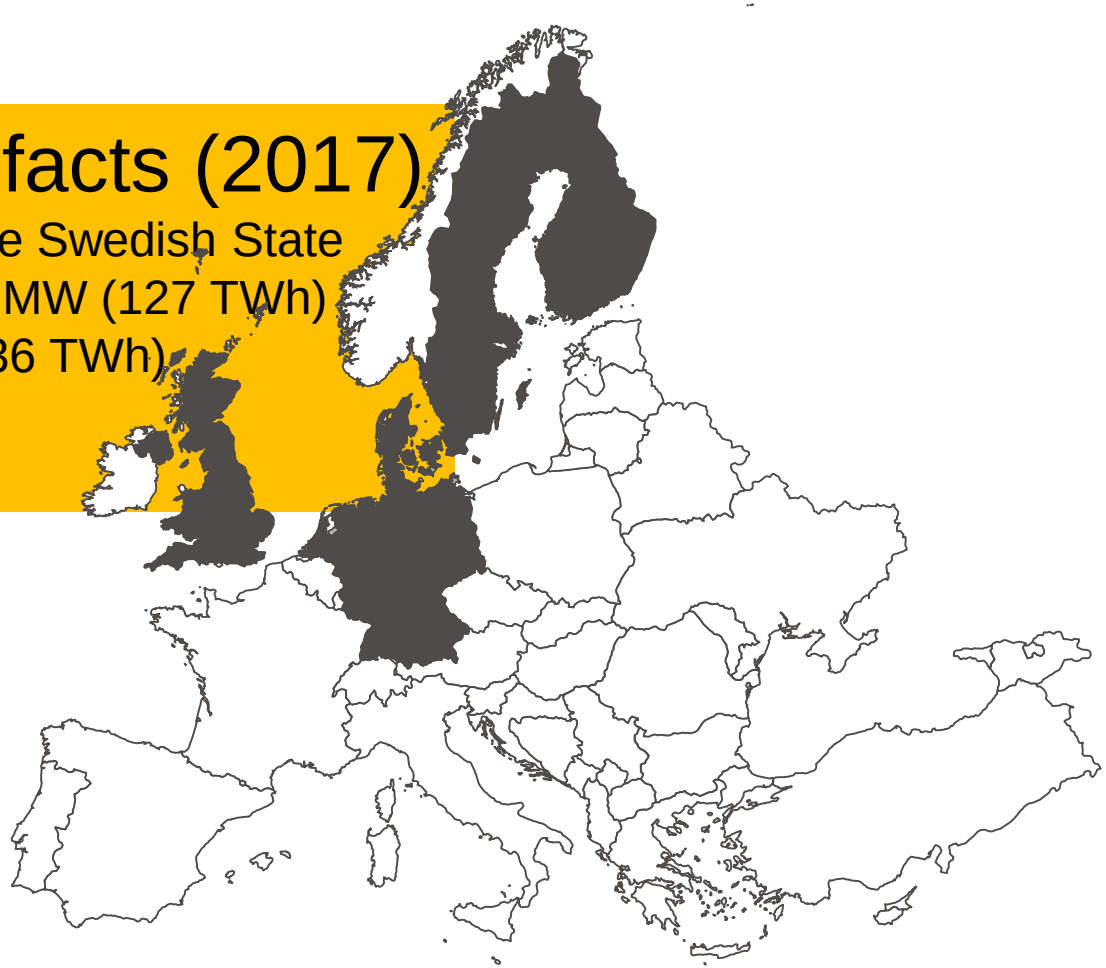
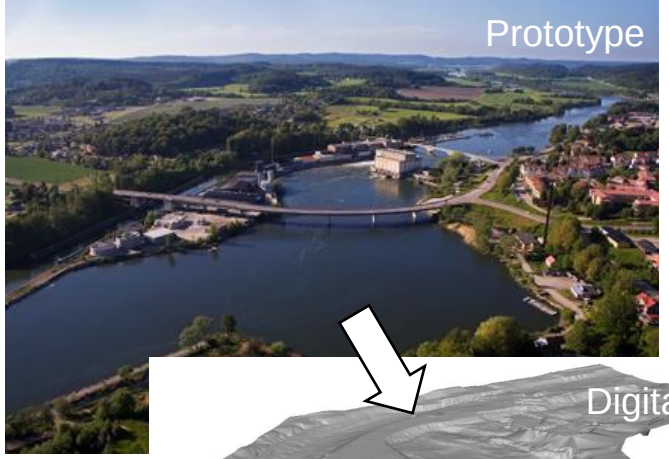
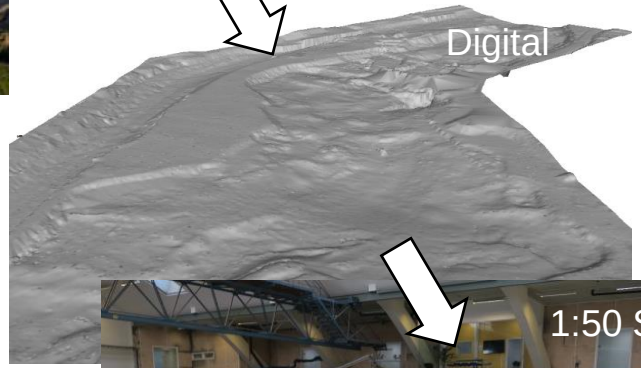
Vattenfall: selected facts (2017)

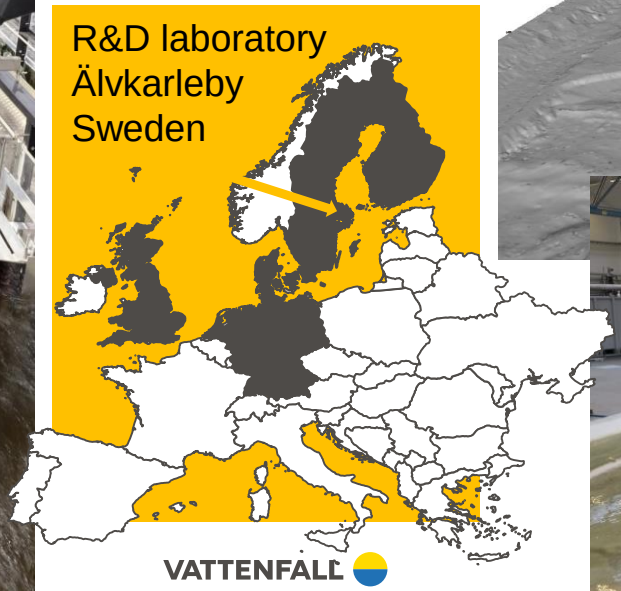
- Power Company owned by the Swedish State
- Electricity generation: 31 200 MW (127 TWh)
- Whereof hydro: 11 700 MW (36 TWh)
- >100 hydro power plants
- Hydro mostly in Sweden



Two straight 25 m test sections
Cross section: 2×4 m
Max flowrate: 16 m^3/s (2 m/s)







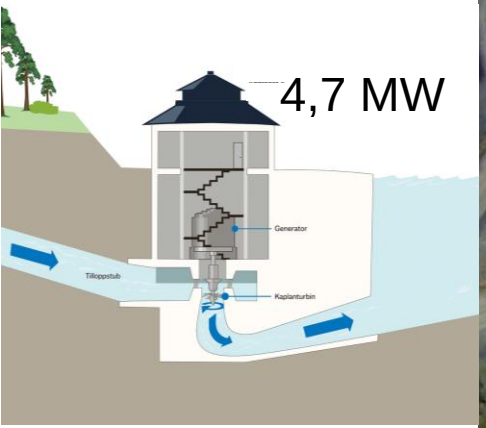
STORNORRFORS
599 MW, 75 m head

Fish ladder:

- 77 steps
- 350 m long

Attraction water:

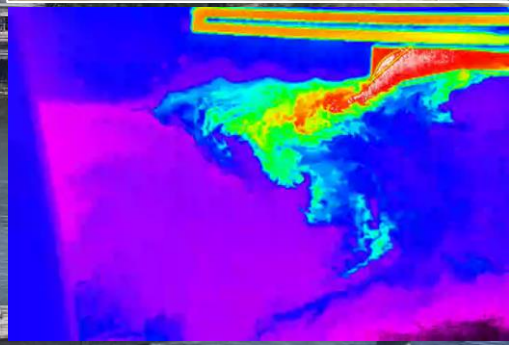
- May 20 – Sept. 30
- 10 – 23 m^3/s
- Corr. to 7-17 MW



Perforated floor

Fish ladder with additional 8 m^3/s attraction water (0.6 MW)

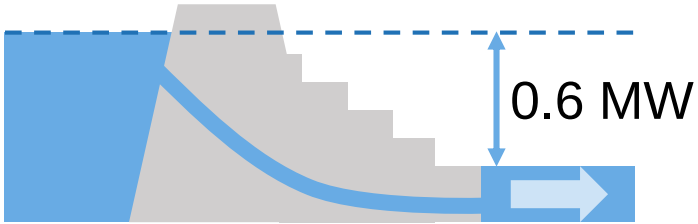
Lilla Edet HPP (46 MW, 7.3 m head)



Better use of water for attraction?

Case Lilla Edet

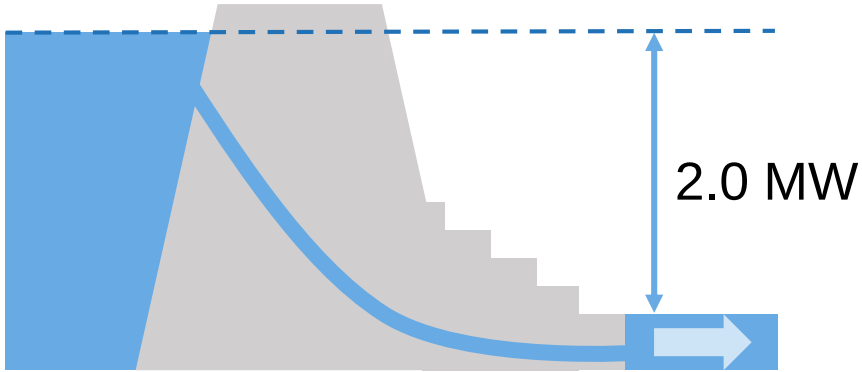
- Head 7.3 m
- 8 m^3/s
- Velocity <1 m/s



-99.3% <4 kW

Typical Swedish HPP

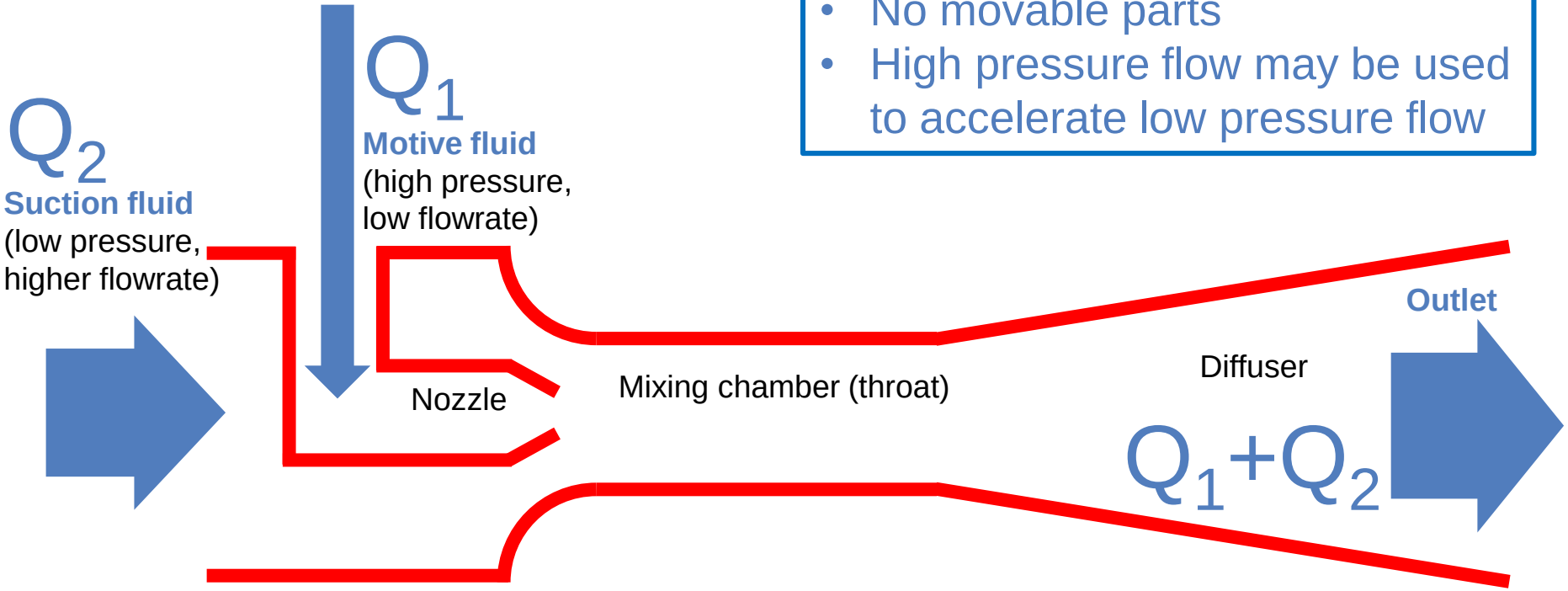
- Head 25 m
- 8 m^3/s
- Velocity <1 m/s



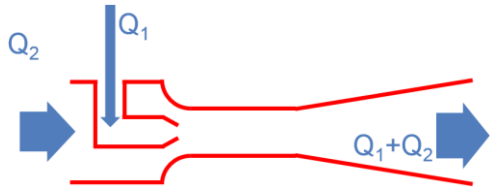
-99.8% <4 kW

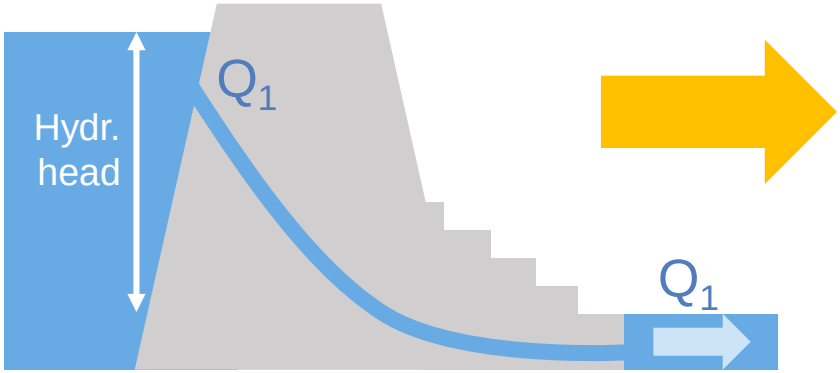
Ejector

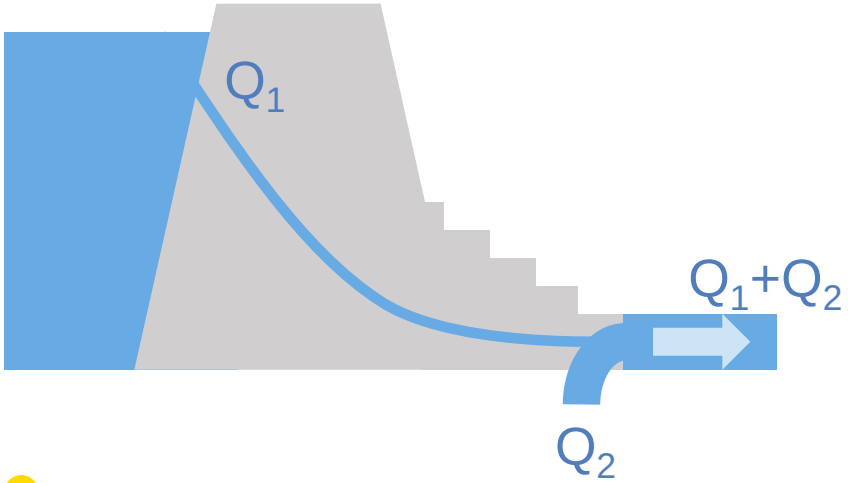
- No movable parts
- High pressure flow may be used to accelerate low pressure flow



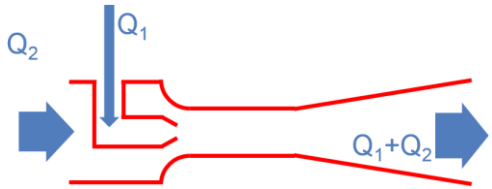
Use reservoir head to accelerate water below dam

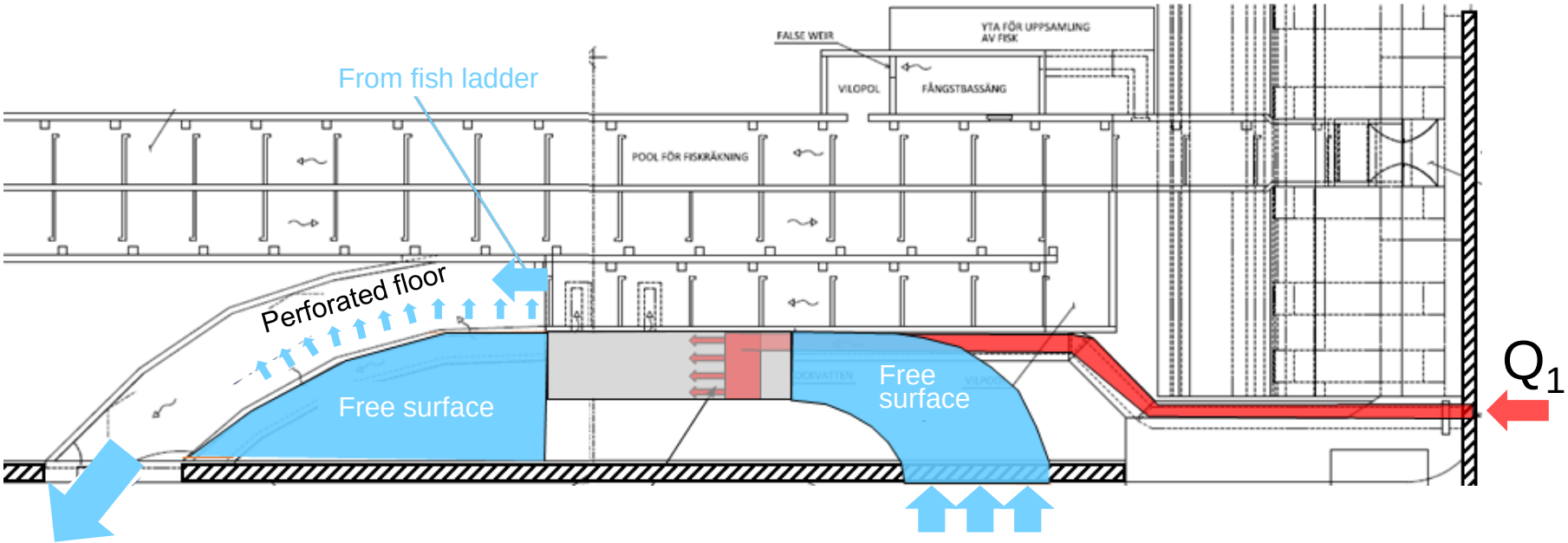






Ejectors in Lilla Edet HPP?





2+8 m^3/s

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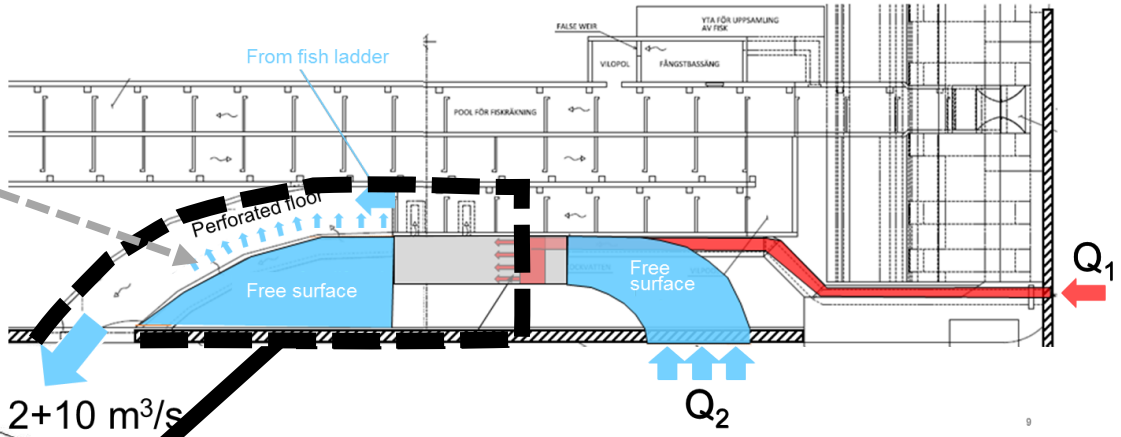
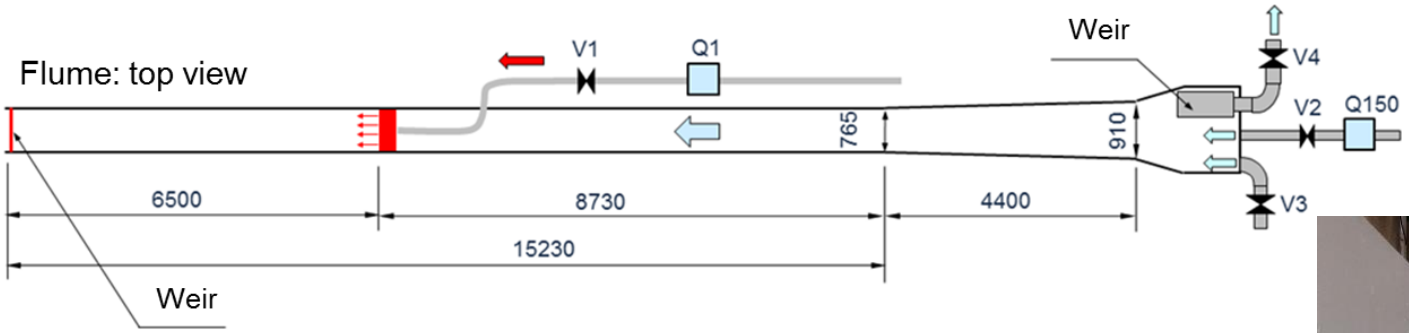
Losses after Ejectors?

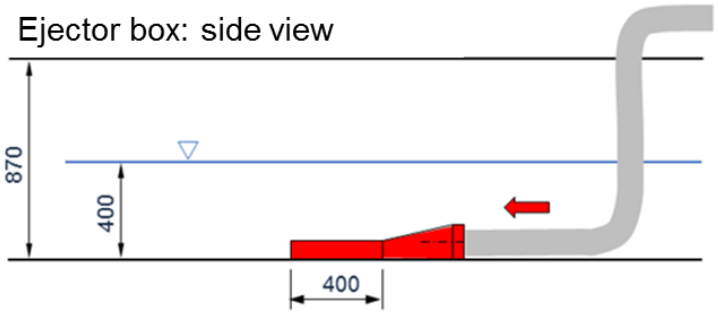


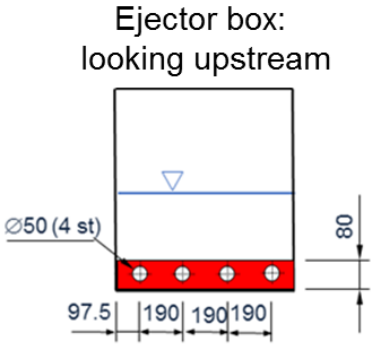
Velocities (speed) at a plane parallel with the perforated bottom just downstream fish ladder (at grey arrow heads)

Hydraulic losses were estimated with CFD to **0.3 m** head over the domain above (dotted line)

Efficiency of ejectors: Flume experiments







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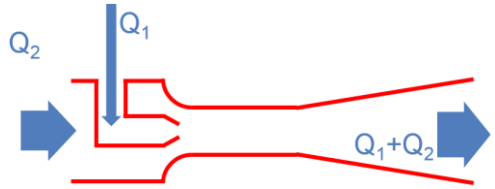
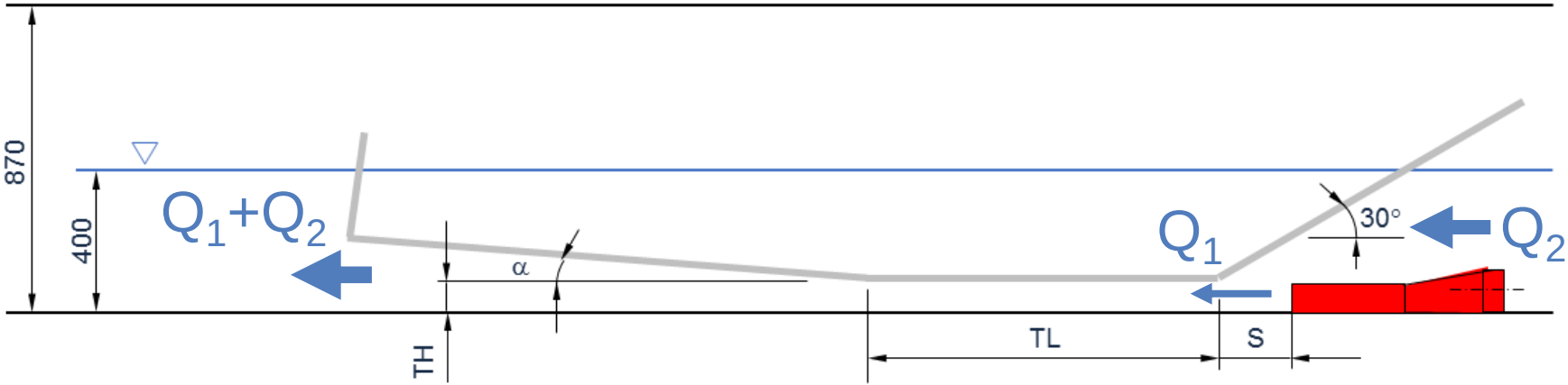
Civil Engineering design of “ejector house”

Flow rate: Q_1 20/36 l/s ($U_{vena\ contracta}$ = 4/7 m/s)
Throat length: TL 400/1000 mm
Throat height: TH 80/100/200 mm
Diffuser angle: α 2°/4°
Also ”no roof”

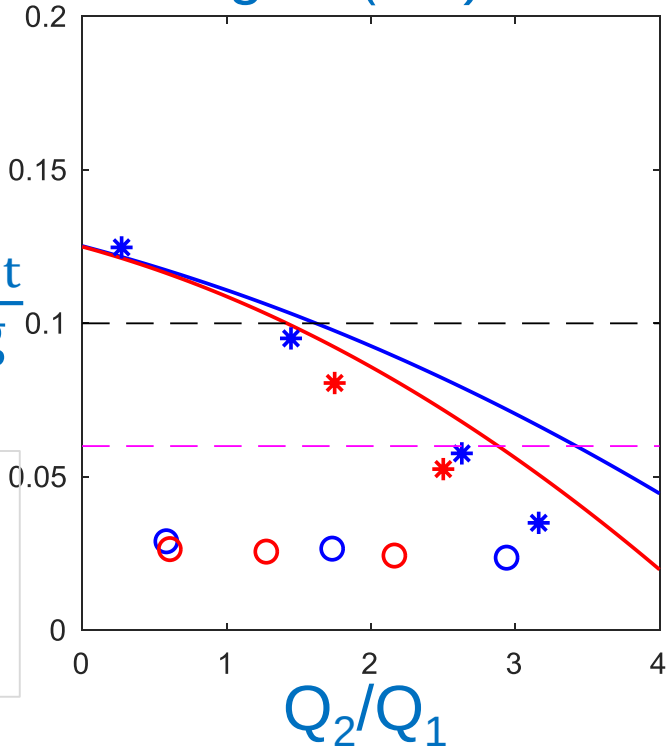




Example of experimental results

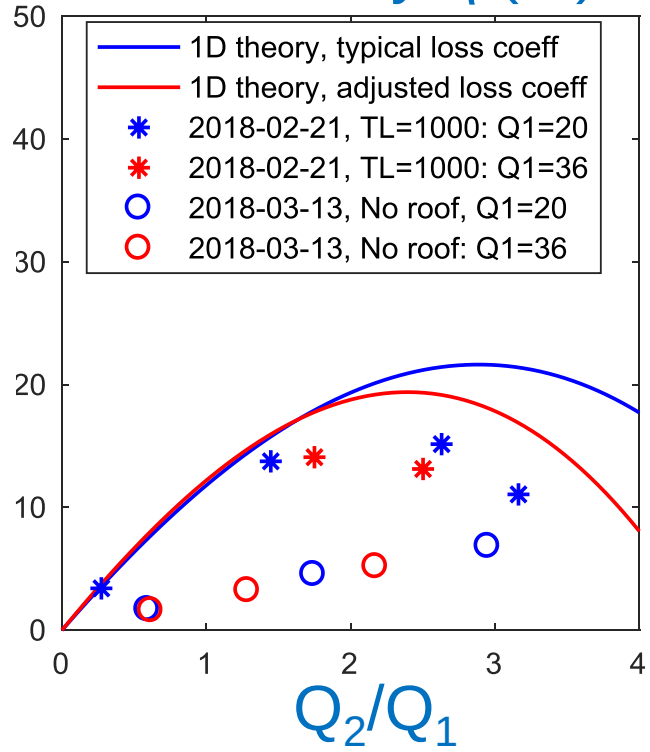
”Lift height” (ΔH) vs. flow

$$\Delta H \Big/ \frac{U_{jet}^2}{2g}$$

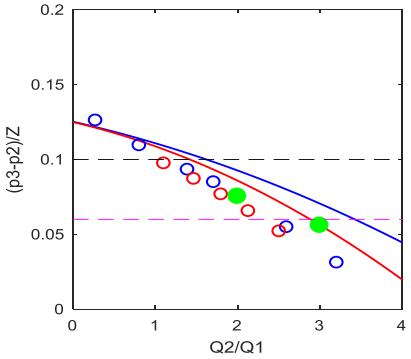


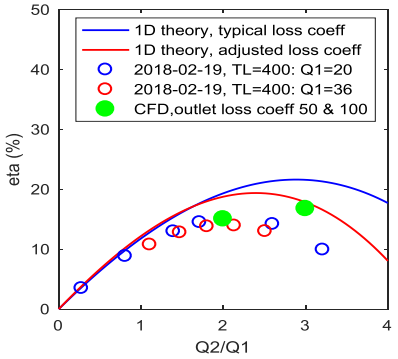
1D theory:
See Cunningham equations in Karassik *et al*. (2001) or ESDU (1985)

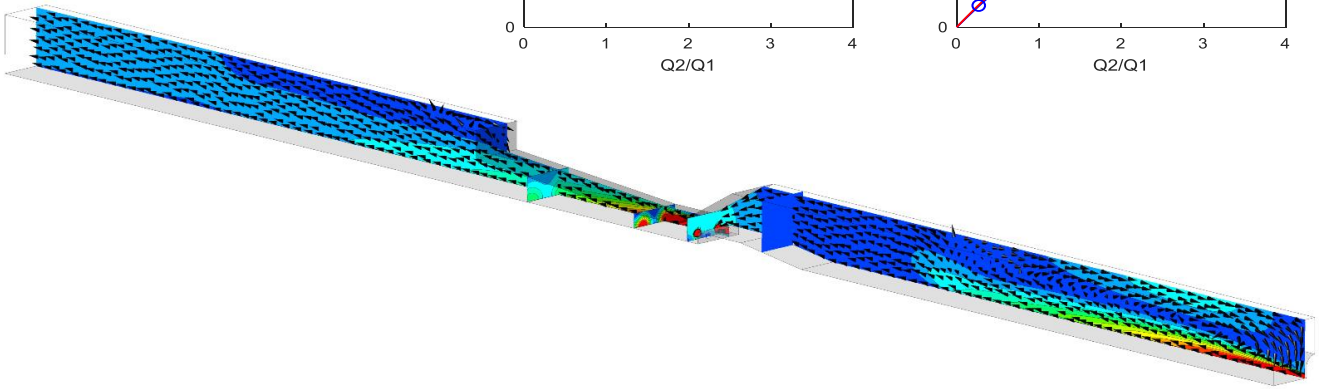
Efficiency η (%)

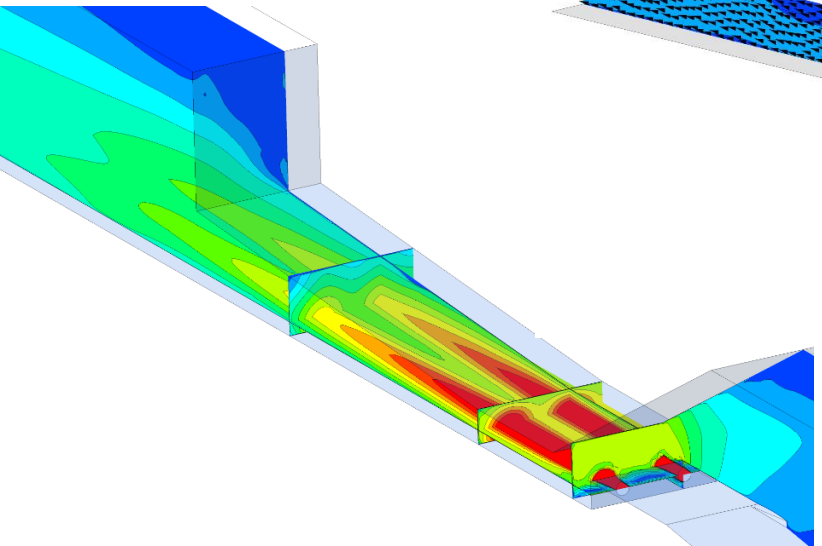


CFD validation (symmetry plane in mid channel, volume of fluid, standard k-ε)









CFD
Measured

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Conclusions

Savings

- Even a non ideal ”civil engineering” design of ejectors still gives major savings of spill for attraction water
- Ejectors may be used to reduce spill flow for attraction water by 67-70%
- By better design of ejector and/or in-feeding of attraction water: 80% is reachable…
- Lower investment in tunnel/tube from reservoir correspondingly (smaller dimensions)

Design

- CFD may be used in design (close to experimental results)
- Primarily design of diffusor part of ejector could be improved
- Technique best suited when downstream main river is adjacent to fish ladder
- Pump for Q_1 may replace spill entirely (or be used for entire attraction flow)

Typical Swedish and Lilla Edet HPP case

- For a typical Swedish HPP (25 m head) savings of 1.5 – 1.6 MW is possible
- For Lilla Edet HPP with complex attraction water in-feeding savings of 0.4 MW is possible

References

- ESDU (1985) Ejector and Pump-Design and Performance for Incompressible Liquid Flow, Royal Aeronautic Society, Dec.

- Karassik, I.J., J.P. Massina, P. Cooper, & C.C. Herald, 2001, Pump Handbook, 3rd Ed., McGraw-Hill (Chapter 4.1).

- Westin, J. & G. Hellström, 2018, Lilla Edet lockvatten. Ejektorlösning (Swedish), Vattenfall AB, R&D, Report no. VRD-R40-2018.

Report on results from experiments, etc. Contact main author for possible pdf-copy: johan.westin@vattenfall.com
(or presenter patrik.andreasson@vattenfall.com)

Reserve:
Hydraulic test ”attraction raft”

Reserve:
Pictures of components