Dec 12th, 11:00 AM - 12:40 PM

Adding auxiliary discharge into the entrance pool of a fishway: influence of pool design on fish passage

Cornelia Schuetz
German Federal Institute of Hydrology (BfG)

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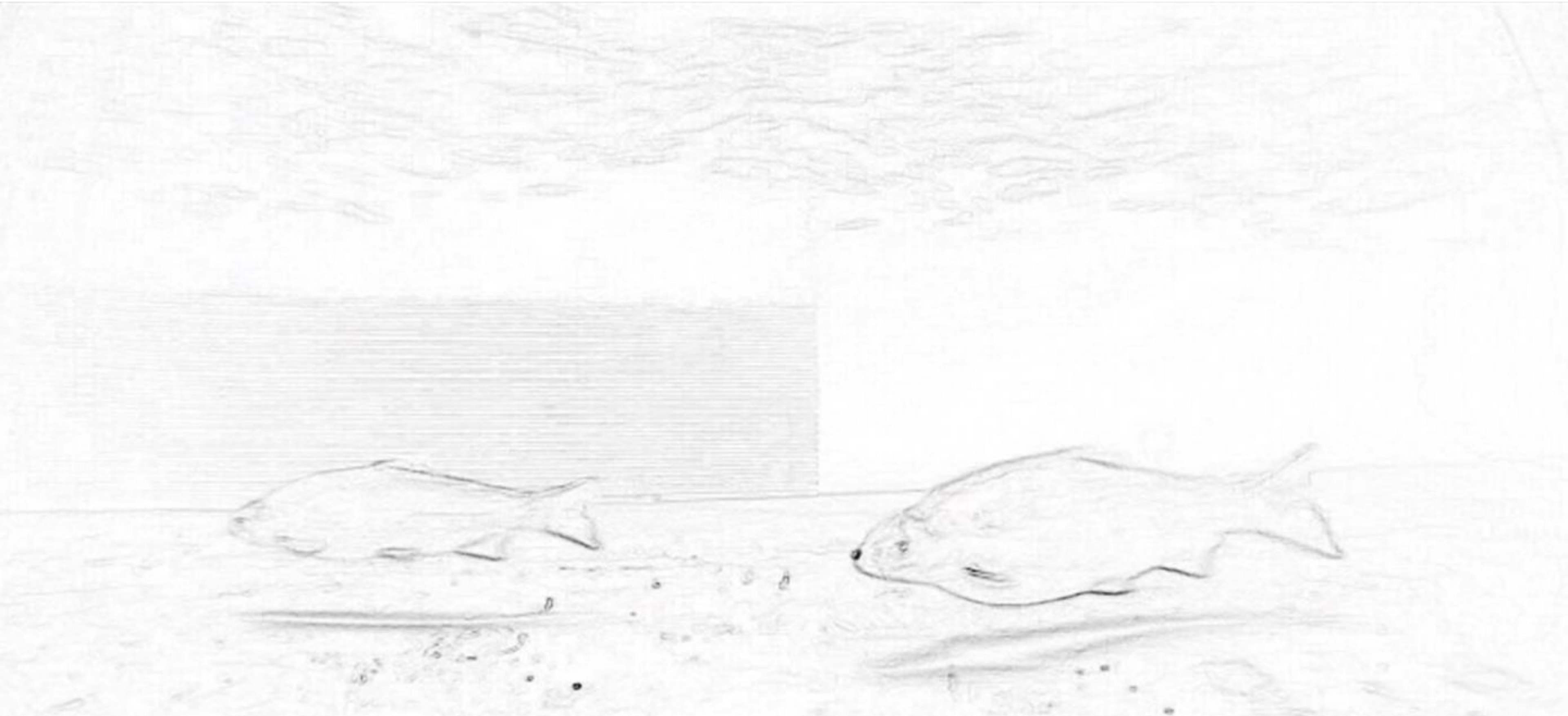

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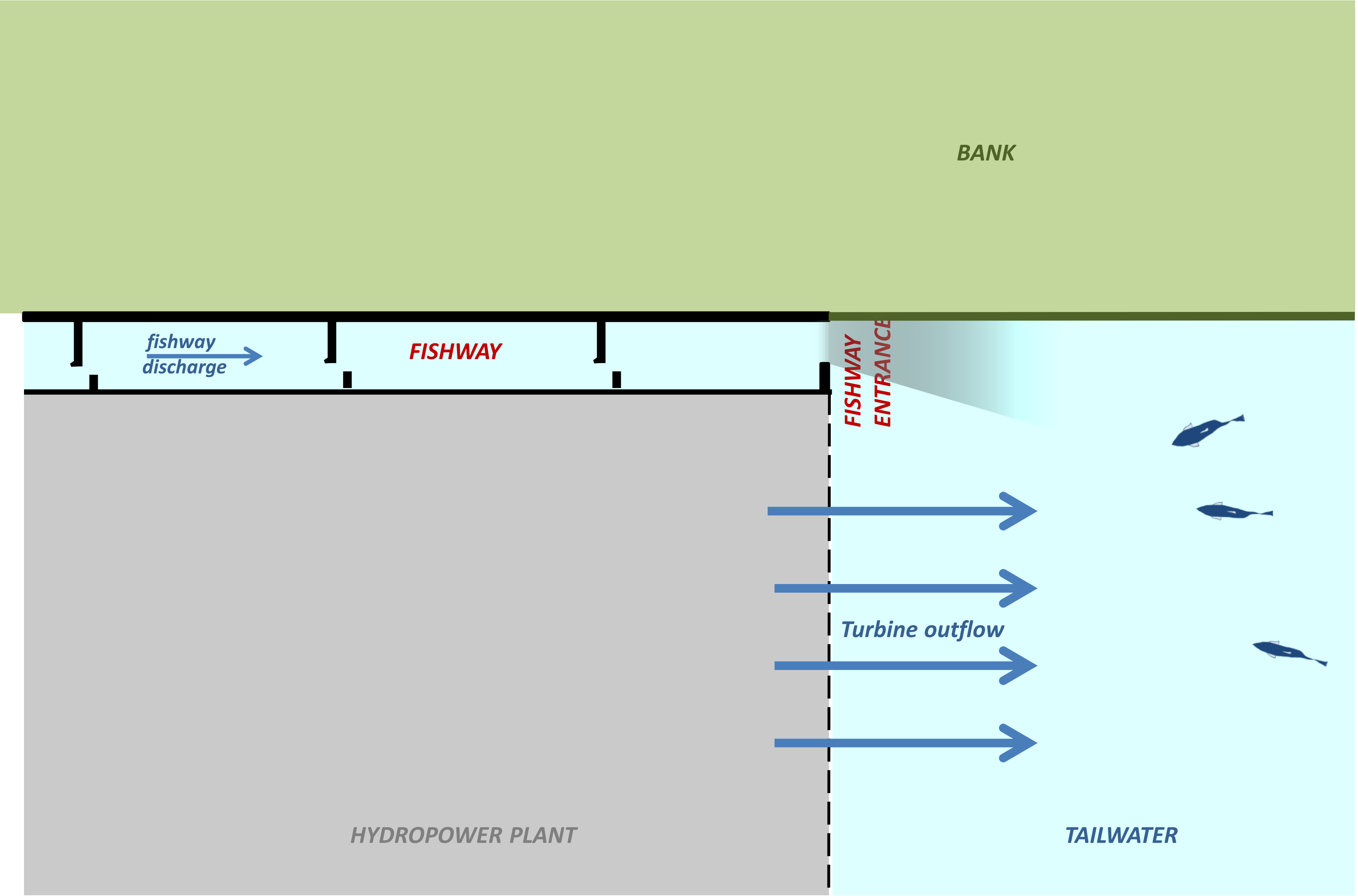
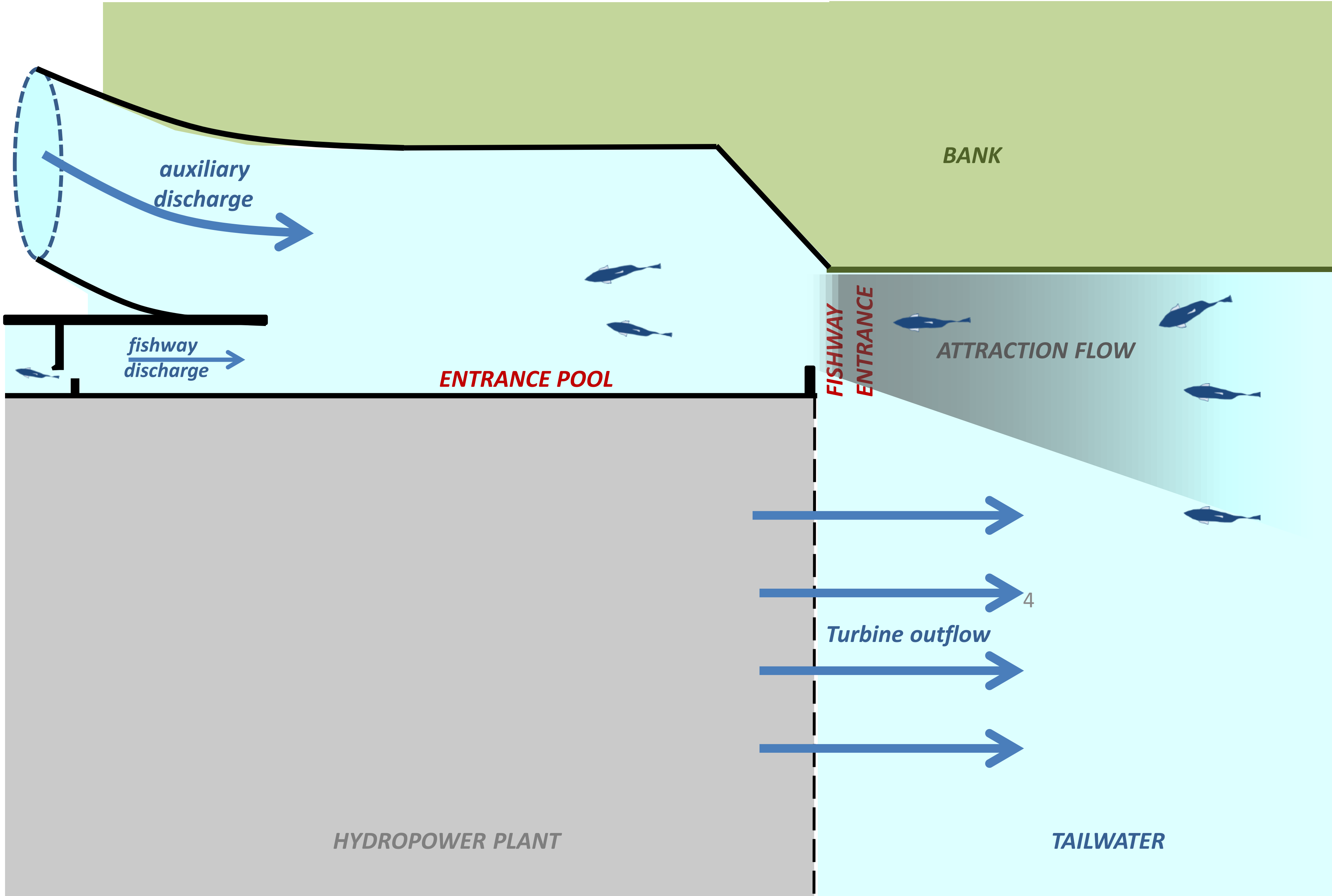
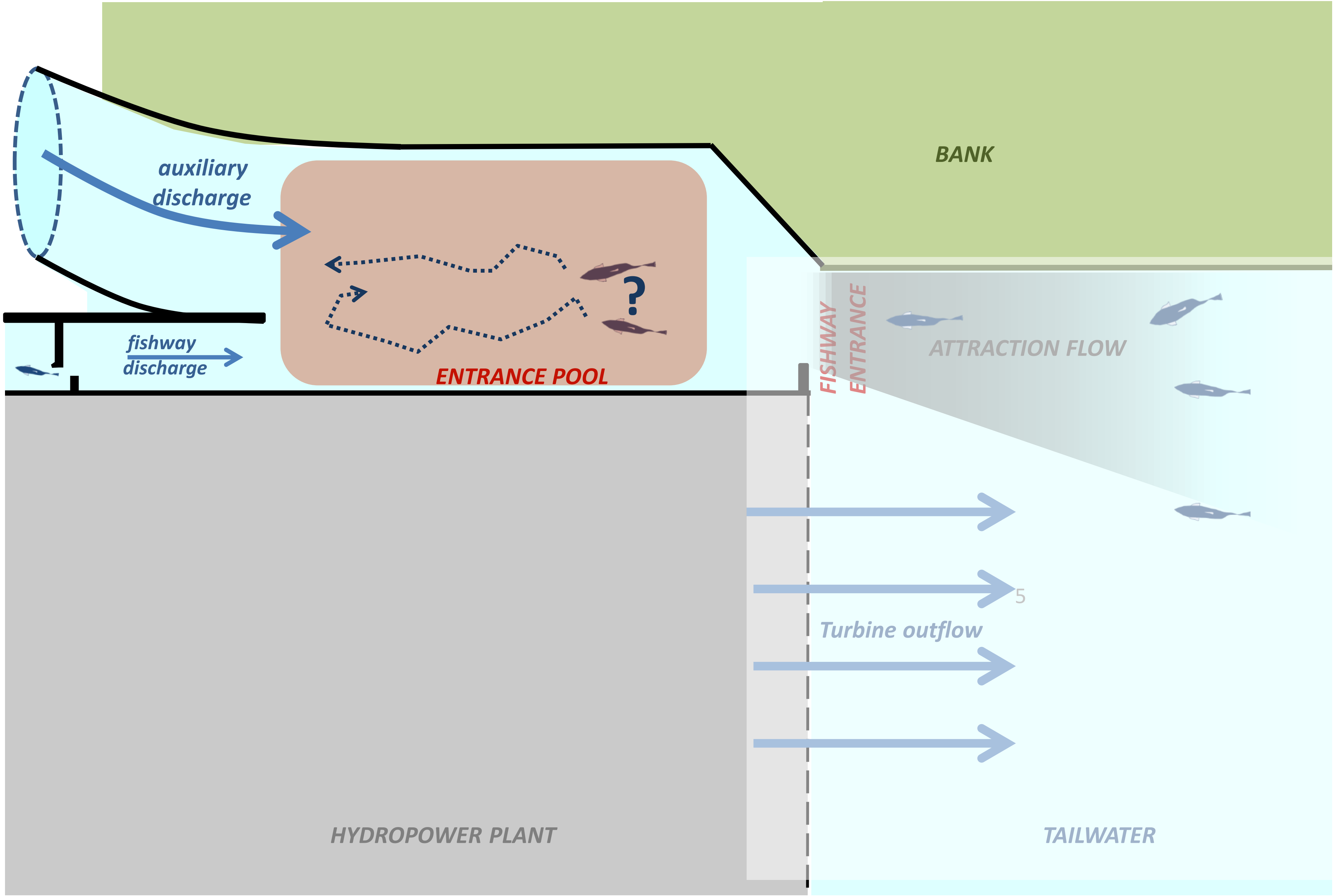
CHALLENGE


BANK
fishway
discharge
FISHWAY
FISHWAY
ENTRANCE
Turbine outflow
HYDROPOWER PLANT
TAILWATER

CHALLENGE

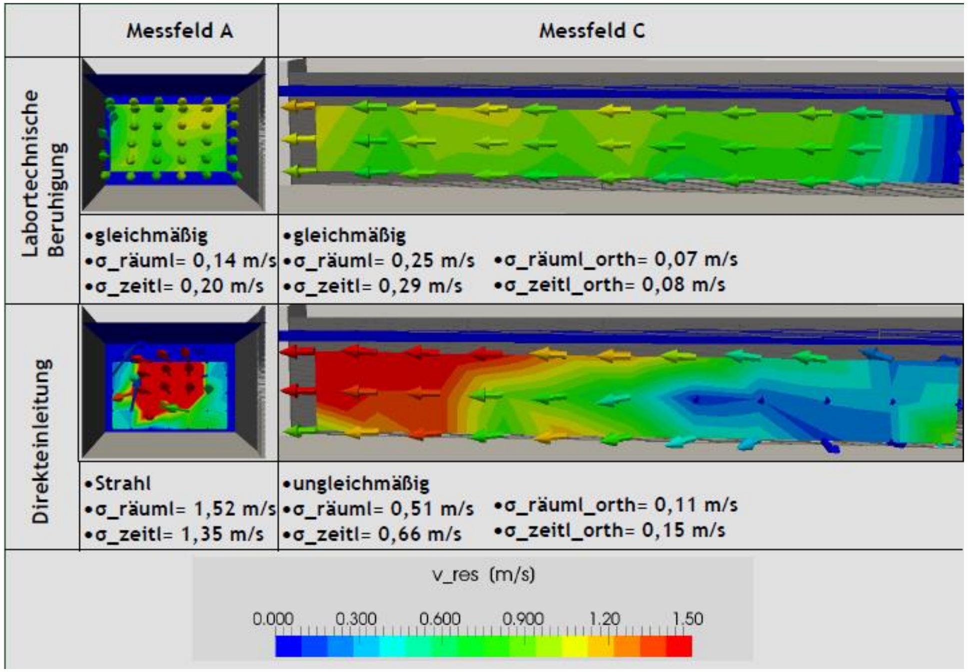

auxiliary discharge
BANK
fishway discharge
ENTRANCE POOL
FISHWAY ENTRANCE
ATTRACTION FLOW
4
Turbine outflow
HYDROPOWER PLANT
TAILWATER


BANK
auxiliary
discharge
fishway
discharge
ENTRANCE POOL
?
FISHWAY
ENTRANCE
ATTRACTION FLOW
5
Turbine outflow
HYDROPOWER PLANT
TAILWATER

POOL DESIGN

Basic hydraulic principles:

- few turbulences
- only moderate gradients of flow velocity
- ± homogeneous flow directions

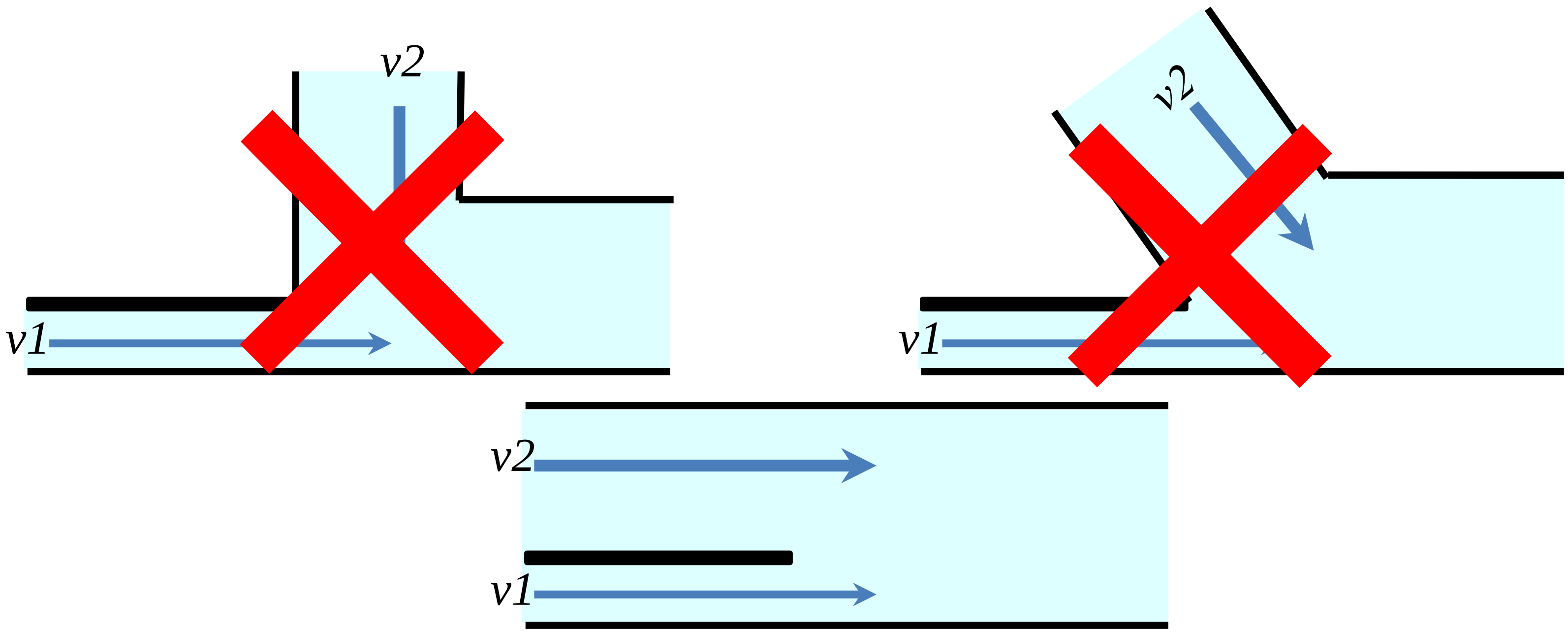


Basic hydraulic principles:

- **few turbulences**
- **only moderate gradients of flow velocity**
- **± homogeneous flow directions**

Design

- level ground area
- flow in fishway ($v1$) and auxiliary discharge ($v2$) run parallel to each other



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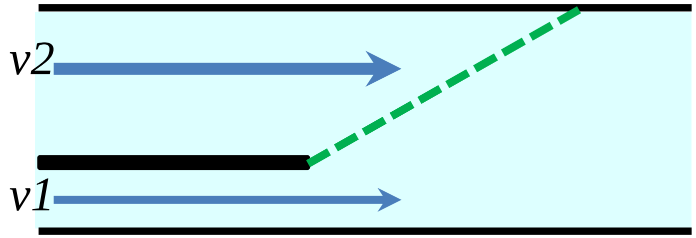
- level ground area
- flow in fishway (*v1*) and auxiliary discharge (*v2*) run parallel to each other
- separate entrance pool (fish) from auxiliary discharge pool by horizontal bar screen



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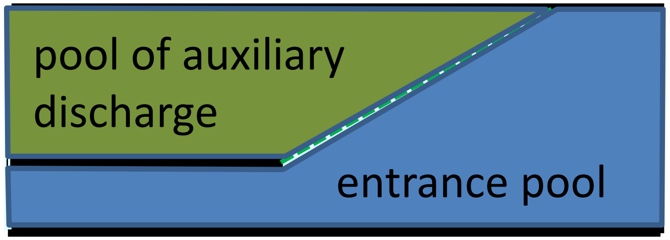
- **Pool of auxiliary discharge** and **entrance pool** merge along the screen by expanding the entrance pool



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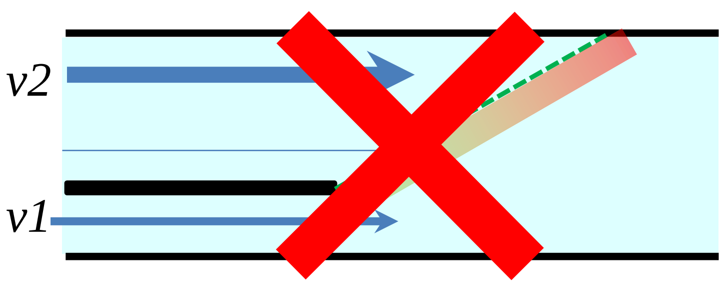
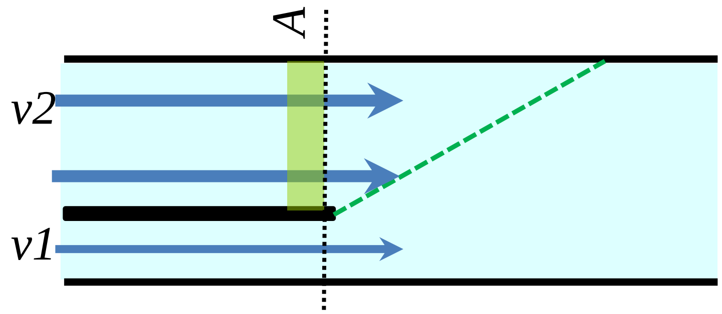
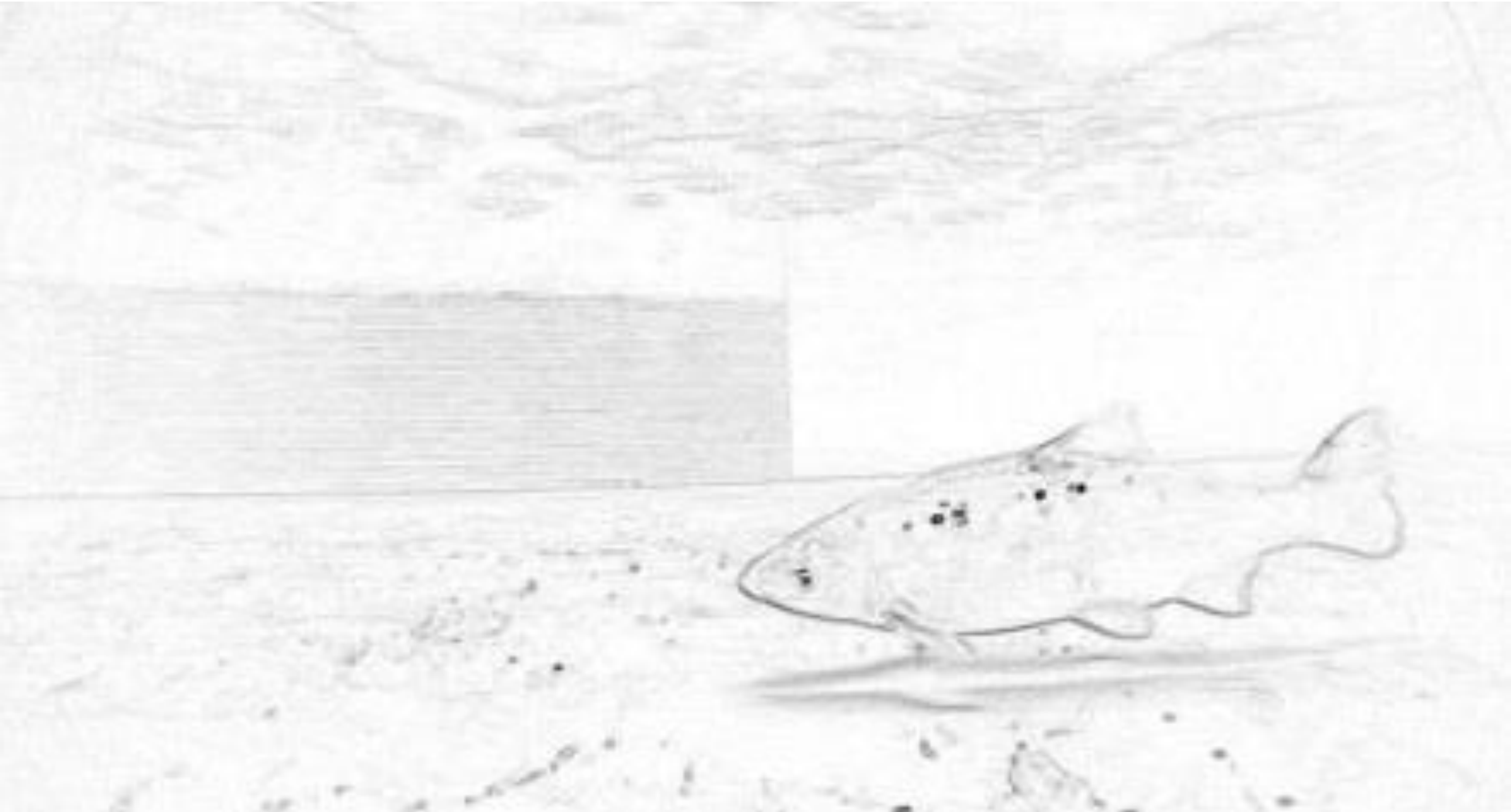
- level ground area
- flow in fishway ($v1$) and auxiliary discharge ($v2$) run parallel to each other
- separate entrance pool (fish) from auxiliary discharge pool by horizontal bar screen
- **Pool of auxiliary discharge** and **entrance pool** merge along the screen by expanding the entrance pool
- uniform flow along the total screen surface by uniform flow in cross section A





QUESTIONS

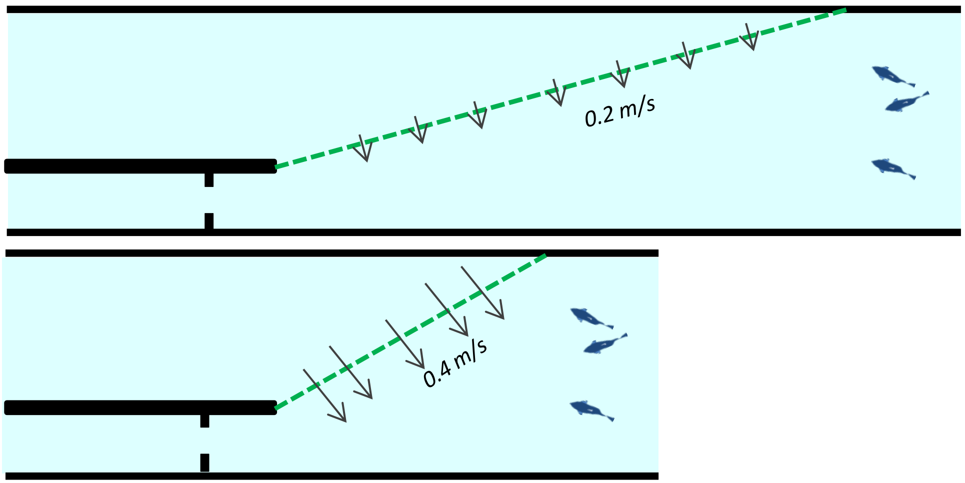


Questions that were left:

What is the best design velocity of the screen (= screen size)

A more compact design
- is cheaper
- allows more opportunities in planning (restricted space)

but is it also better for fish passage?



design velocity = orthogonal component of flow vector; used to calculate screen size for a given dischare

Test:

0.2 m/s - low design velocity (based on rheotactic behavior of adult cyprinids)

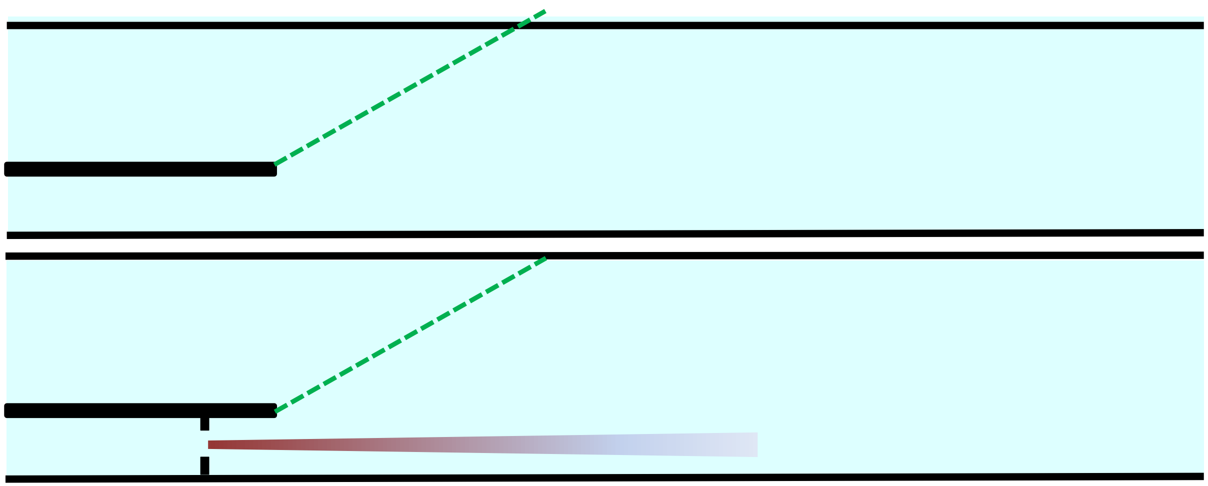
versus

0.4 m/s - high design velocity (based on rheotactic behavior of adult salmonids).

Questions that were left:

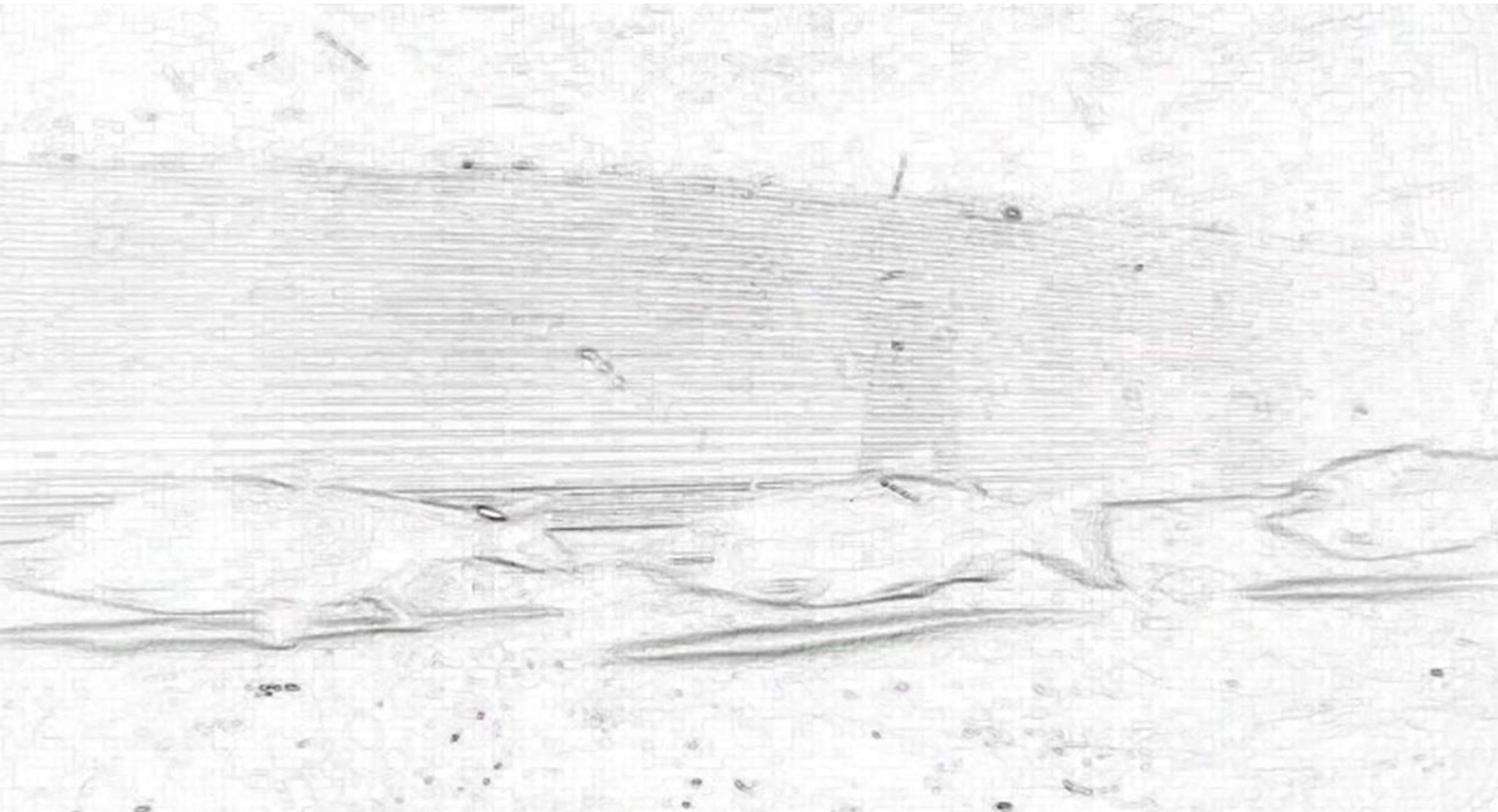
Can we guide fish through the entrance pool?

A slot from the upper fishway may guide fish through entrance pool and thus speed up the passage.



Test:
upper fishway without slot
versus
upper fishway with slot

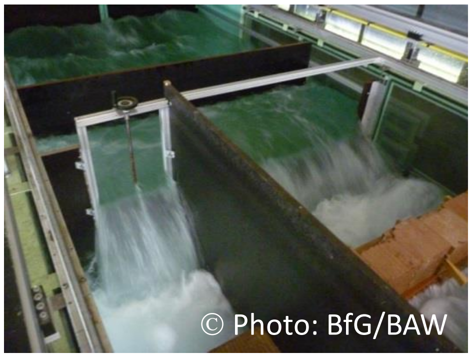
STUDY

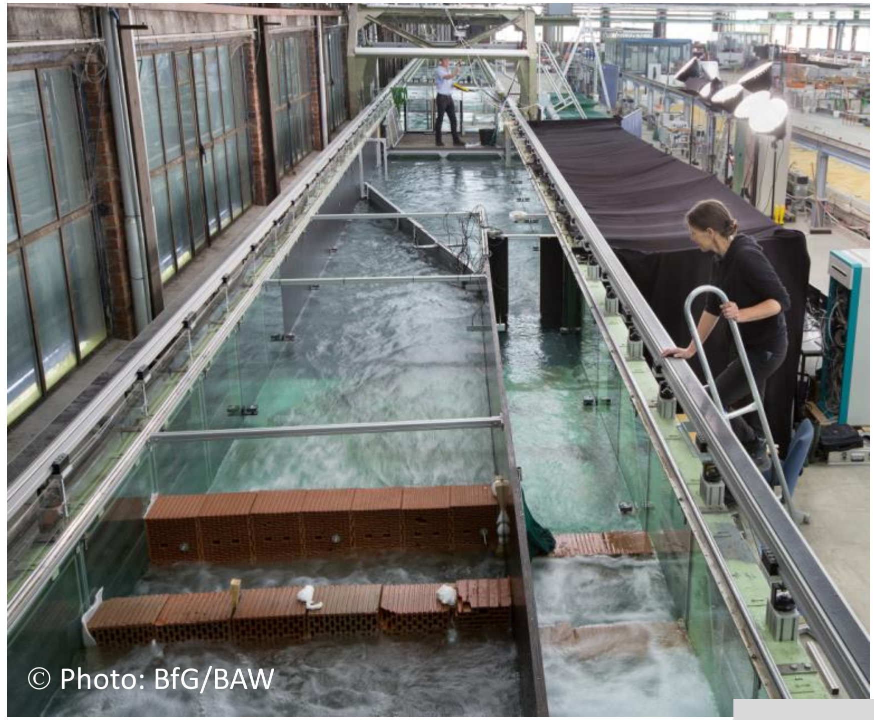


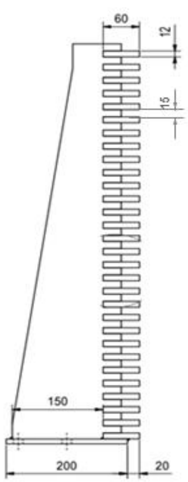
Open flume at the BAW, Karlsruhe:

- 2.5 m width
- 1.3 m high
- discharge $1 m^3/s$
- altogether 60 m long
- experimental section ~ 12m long

Flume setup


© Photo: BfG/BAW


© Photo: BfG/BAW




© Photo: BfG/BAW

In our experiment:

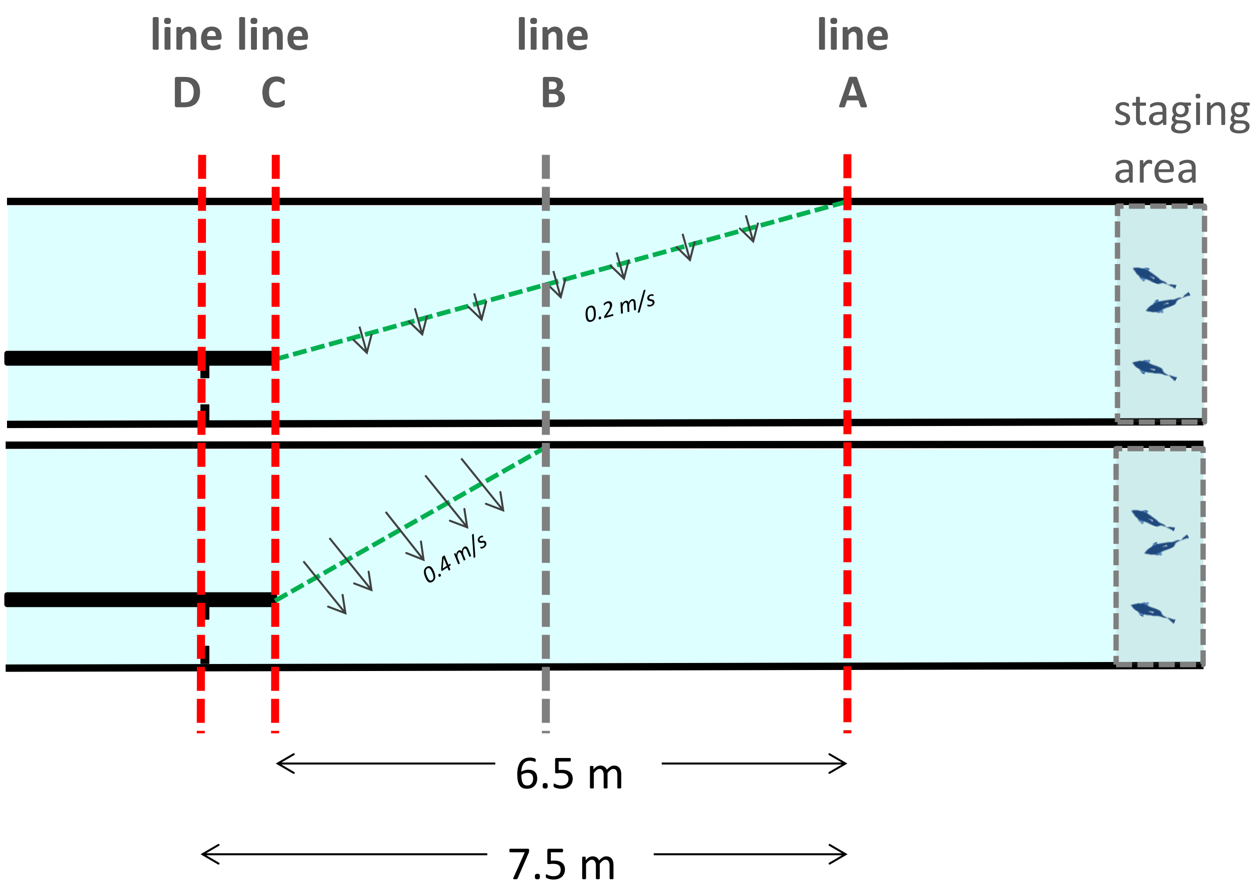
- *screen bars: rectangular profile 12 mm x 60 mm; 15mm spacing*
- *good results with fish ≥ 10 cm length (no smaller fish in the test)*

Five species

- relevant in German shipways
- different migration characteristics/demands
- pragmatic and legal considerations

	size
Nase *Chondrostoma nasus* (Linnaeus, 1758)	40 - 50cm
Gudgeon *Gobio gobio* (Linnaeus, 1758)	10 - 15 cm
Schneider *Alburnoides bipunctatus* (Bloch, 1782)	10 - 15 cm
Roach *Rutilus rutilus* (Linnaeus, 1758)	10 - 20 cm
Brown trout *Salmo fario* (Linnaeus, 1758)	20 - 35 cm

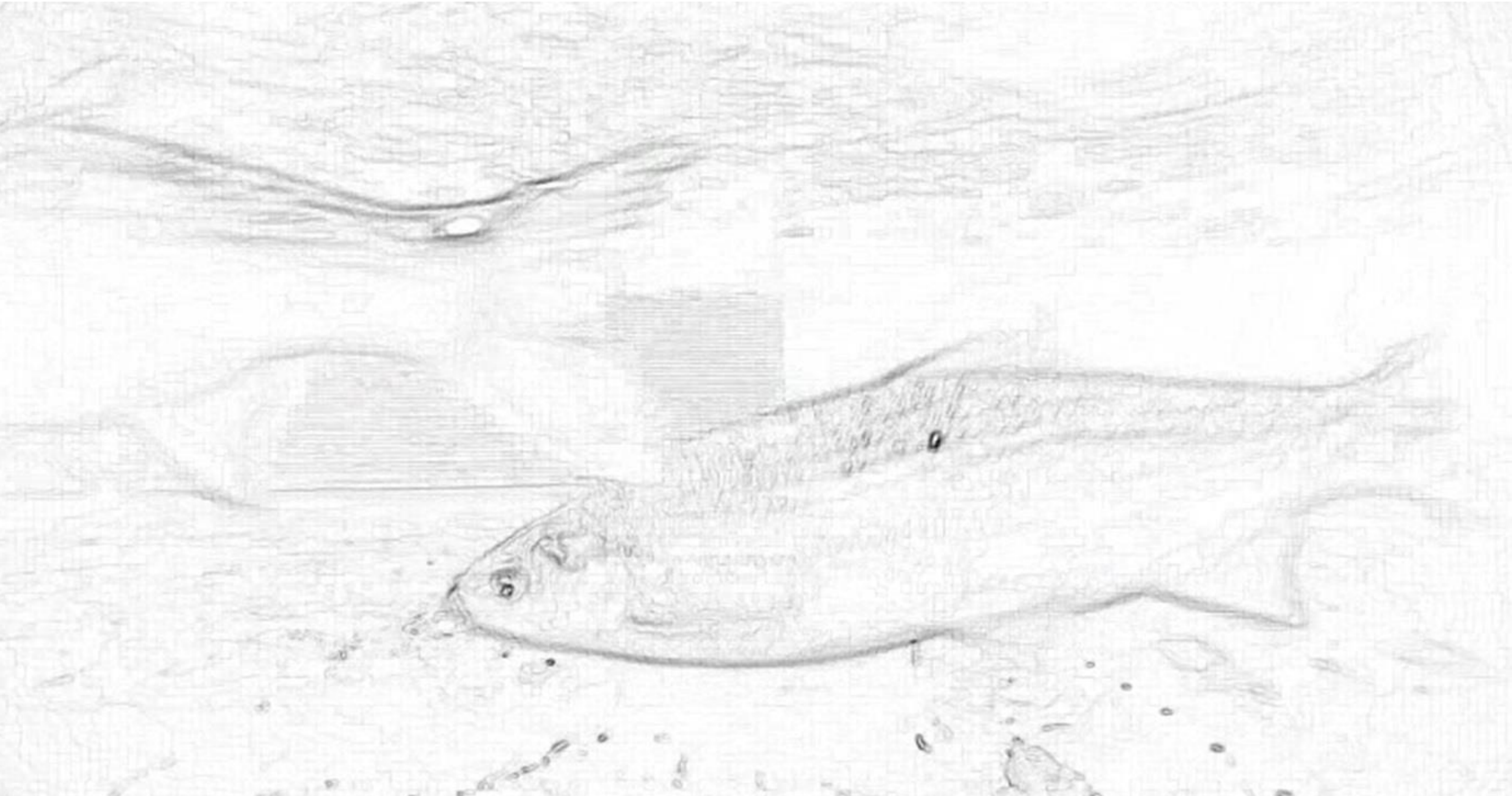
Data:
times of fish crossing different lines



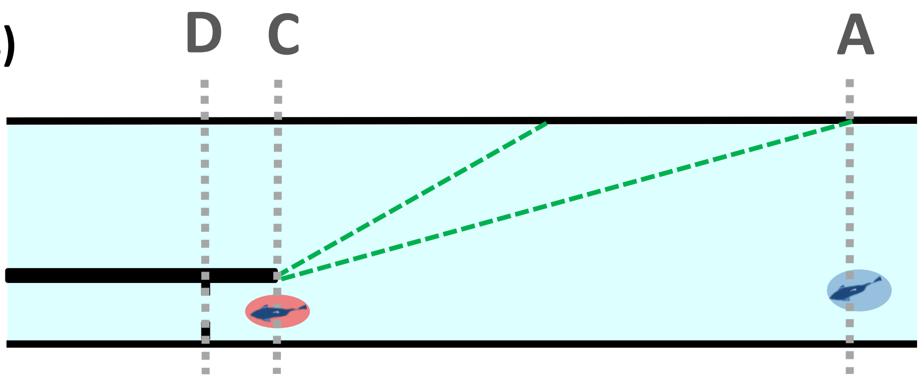
From staging area to line A:
max. 30 Minutes
otherwise:
non-valid fish

From line A to line D:
max. 1 hour
otherwise:
experiment ends

Results



Long screen (0.2m/s) vs. short screen (0.4 m/s)



Time-to-Event Analysis

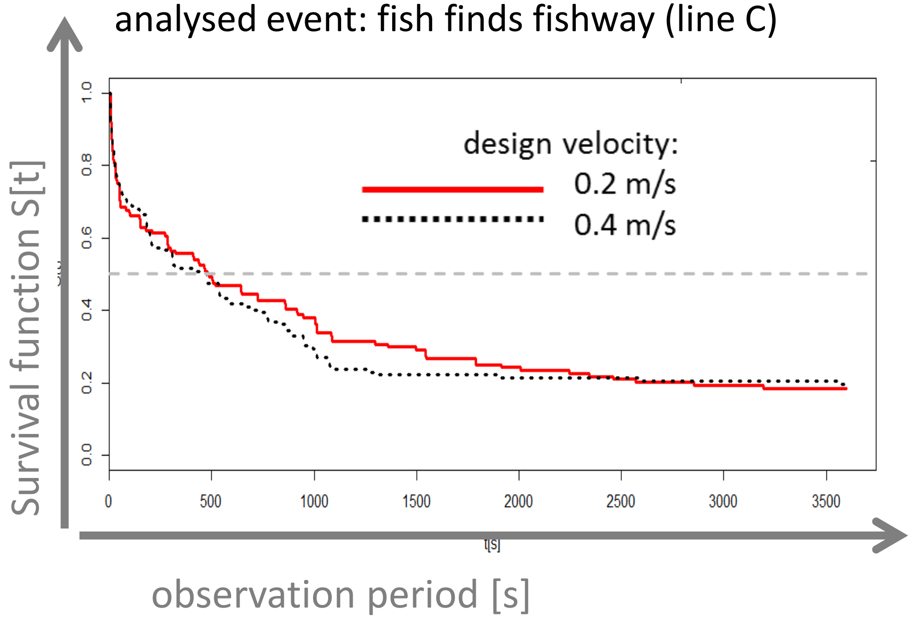
Event "reaching line C": fish has passed the screen and found the the fishway

S[t] = probability **of not finding the fishway** (at a given point in time)

H_1
differs between long and short screen

H_0
no difference between long and short screen

Long screen (0.2m/s) vs. short screen (0.4 m/s)

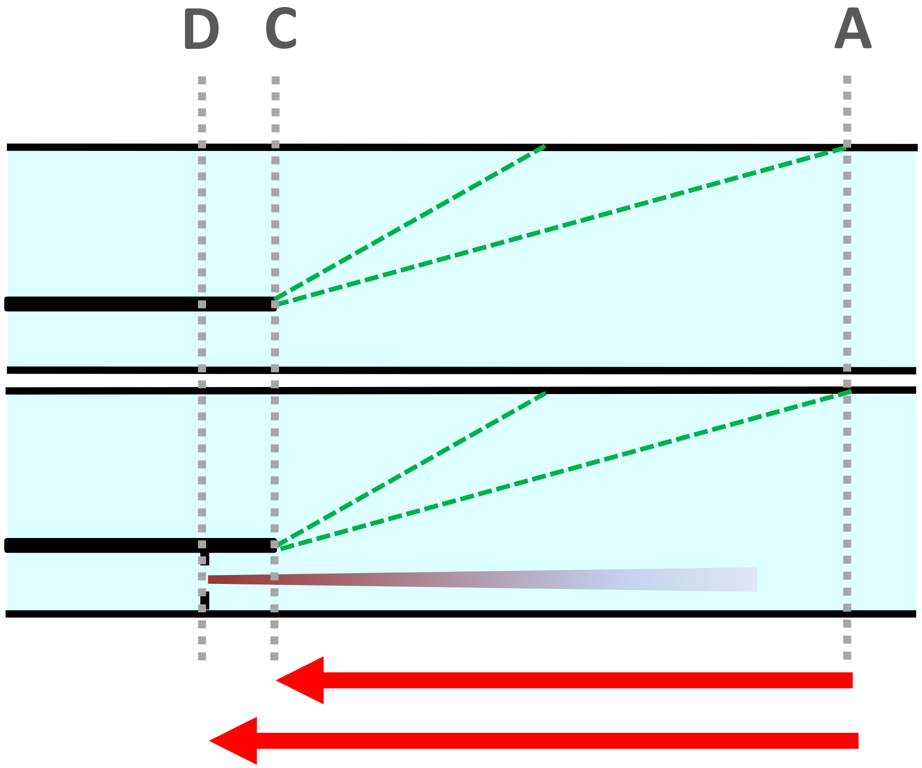


n = 246
all species,
fishway with slot

log rank test p-value 0.76
survival curves are statistically equivalent

→ We accept the null hypothesis

Slot (flow velocity „impuls“) vs. no slot:



Comparison of Means
Kruskall-Wallis Test

Only Finisher at lines
C and D

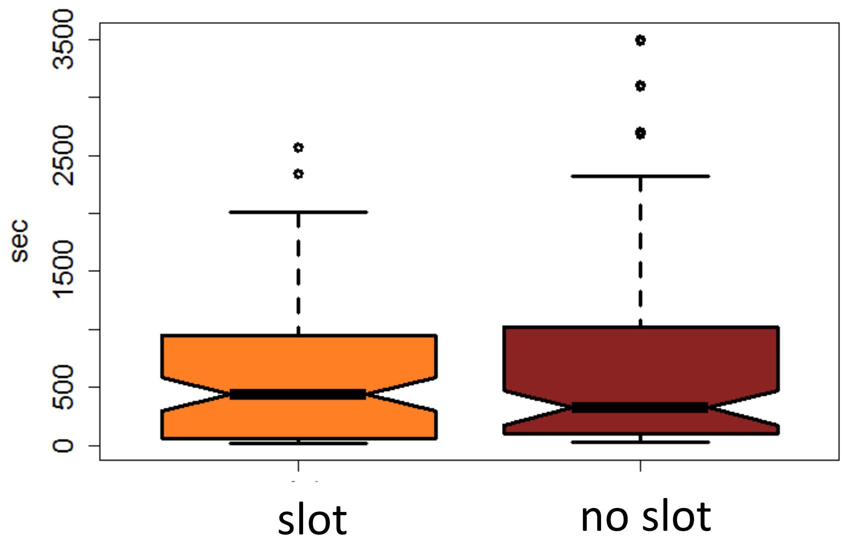
passage times of all Finishers [s]

H_1
differs
between slot
and no slot

H_0
no difference
between slot
and no slot

Slot (flow velocity „impuls“) vs. no slot:

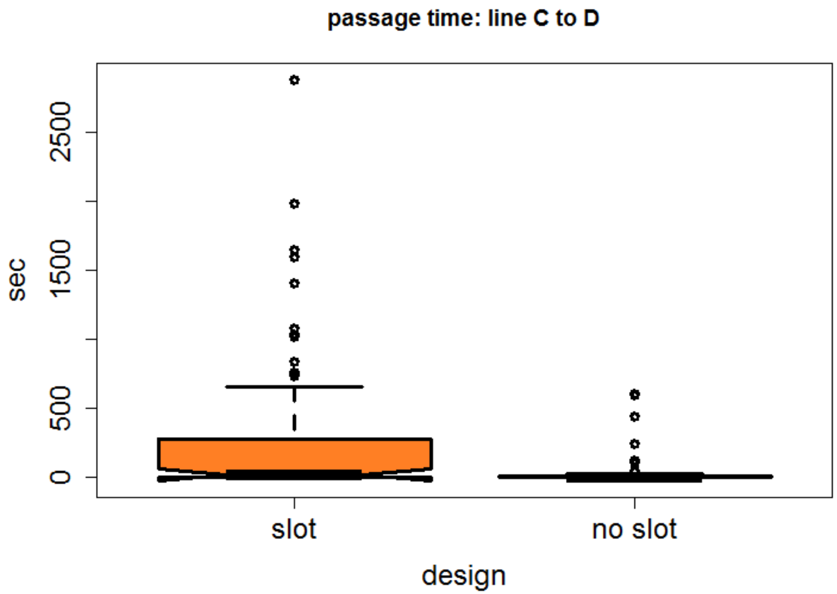
passage times: line A to C

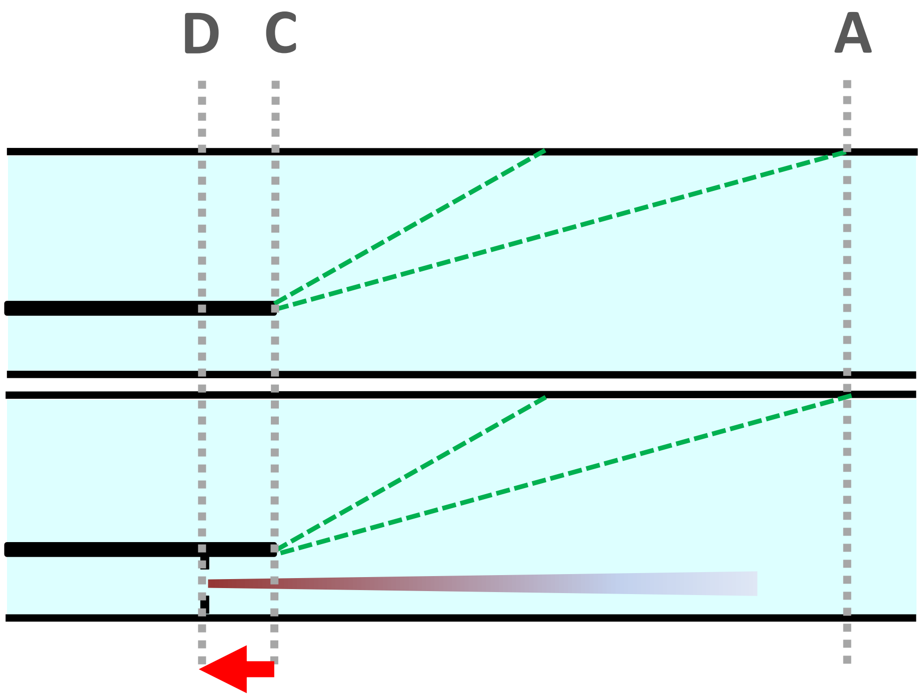


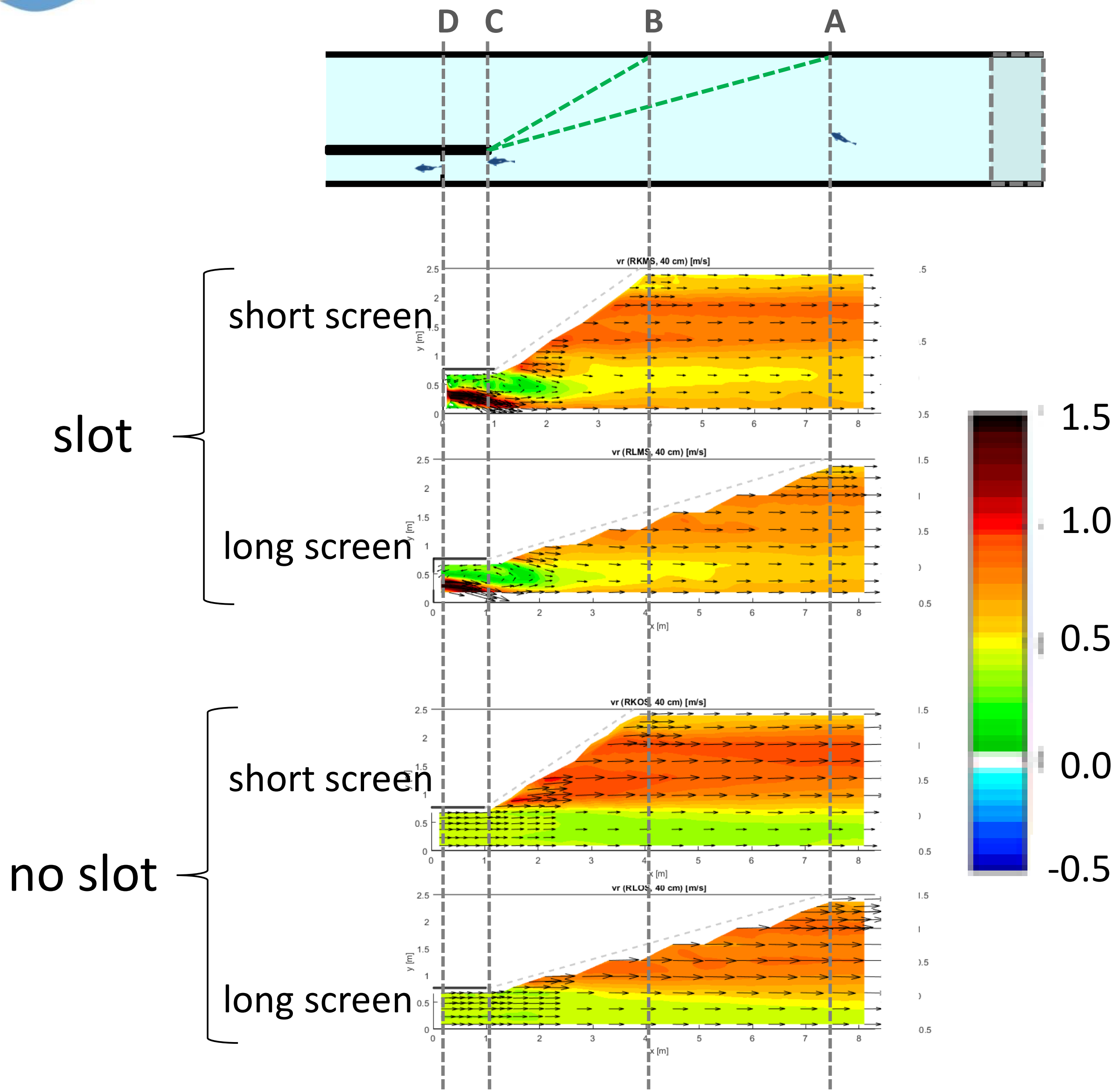
Data pooled from both screen lengths,
only Brown Trout and Schneider

Kruskal Wallis Test p-value > 0.3

→ We accept the null hypothesis


passage time: line C to D
sec
0
500
1500
2500
slot
no slot
design


D
C
A



mean flow velocities vr [m/s] - 40cm above ground

hydraulics from slot influence fish behavior:

passage delayed

→ **both screen lengths** (long - 0.2m/s and short - 0.4 m/s) **are similar regarding the probability of successful passage**

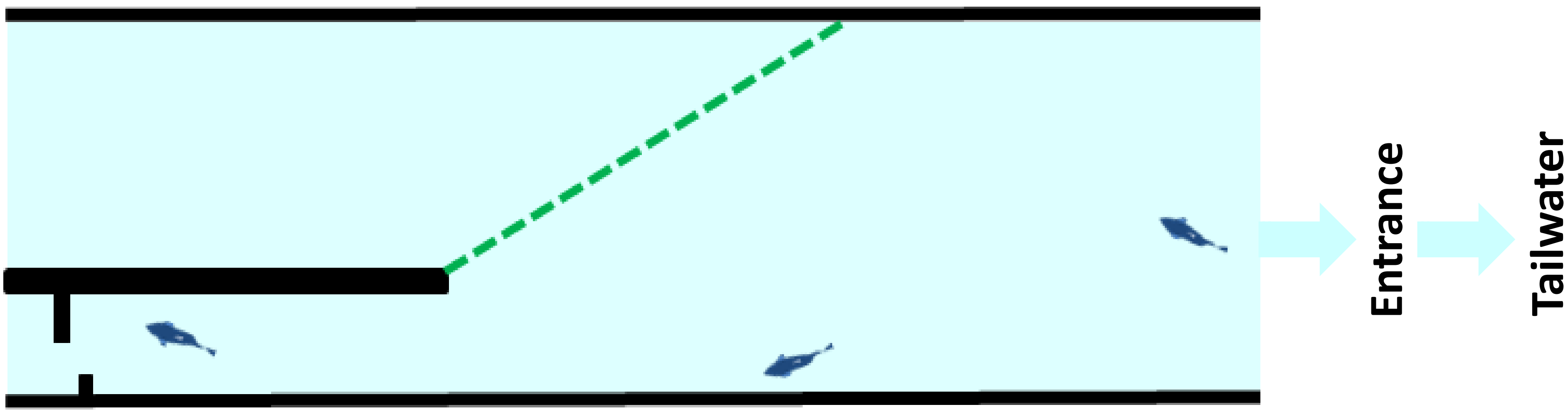
Planning recommendation:
Use the geometrical advantages of a smaller screen.

→ **a slot makes no significant difference for the passage time of fish along the screen**

→ **fish react to the hydraulics of a slot (slow down)**

Planning recommendation:
The slot influences fish behavior - therefore hydraulics from a slot and from the auxiliary discharge should not interfere with each other
(keep a minimum distance of first fishway slot to entrance pool)

How was the perfomance of the now recommended pool design?



How was the perfomance of the now recommended pool design (line A to C)?

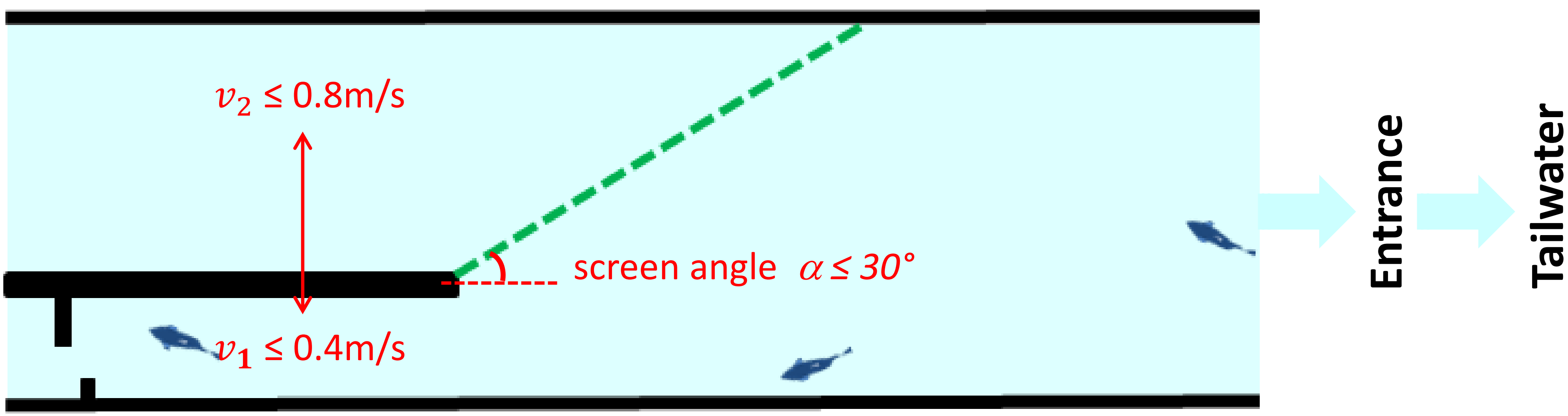
non valid fish		N	Finisher line C	Median time [min:sec]	Passage „speed“ [m/sec]	IQR time [sec]
23.6%	all species	171	**87%**	03:29	0.031	725
0%	Nase	27	**93%**	00:11	0.590	14
22.2%	Gudgeon	21	**67%**	12:02	0.009	402
3.6%	Schneider	52	**96%**	07:55	0.013	797
62.6%	Roach	22	**64%**	04:40	0.023	148
13.3%	Brown Trout	52	**92%**	02:28	0.044	683

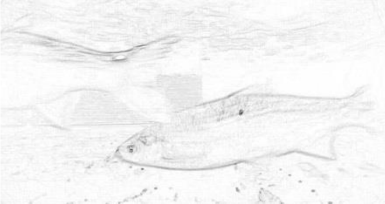
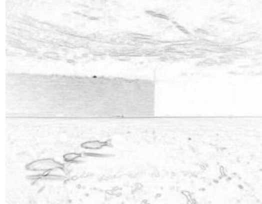
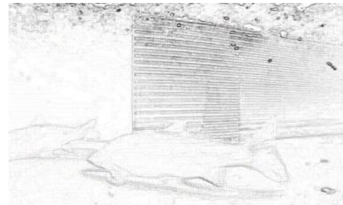
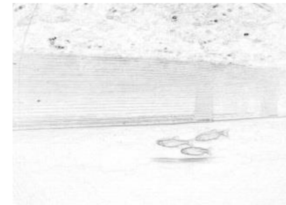
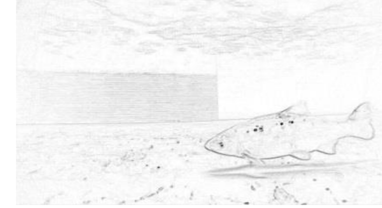
Finisher rate ≠ passage rate in nature!

Influence on Finisher rates of the different species:

- Artificial situation in the flume: full light, no structures/roughness ....
- Artificial holding conditions: holding tanks with tap-water, fish handling ....
- definition of valid fish
- Motivation to migrate, to explore....

Other designs may work as well,
but we can only recommend designs
where we have evidence of good function.



Thank you for your attention!

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of the German Federal Institute of Hydrology
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German Federal Waterways Engineering and Research Institute