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WATER & TRANSPORTATION

An Overview Of The New German DWA Standard For Upstream Fish Passage

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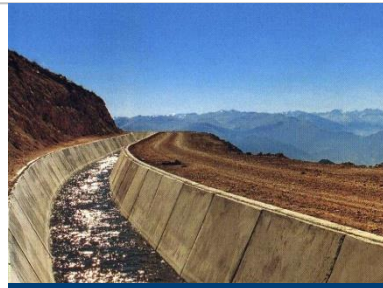


Review of fishway standard development in Germany

… and an alleged Hungarian pirate copy (2007)

- Former Standard 18 years old.
- Research and (field) monitoring have significantly increased understanding of fish behavior and movements, and efficiency of fishways.
- Important aspects were not adequately described, e.g. location of fishways, position of fishway entrance
- Lack of exact geometric and hydraulic design criteria to guarantee attraction and passage of fish (all species, sizes/ life stages and swimming performance)
- No testimony on passage of hydraulic structures (e.g. flood retention basins, culverts, tidal sluices etc.)
- Unintentional preference towards nature-like fishways

New classification of fishways for upstream passage

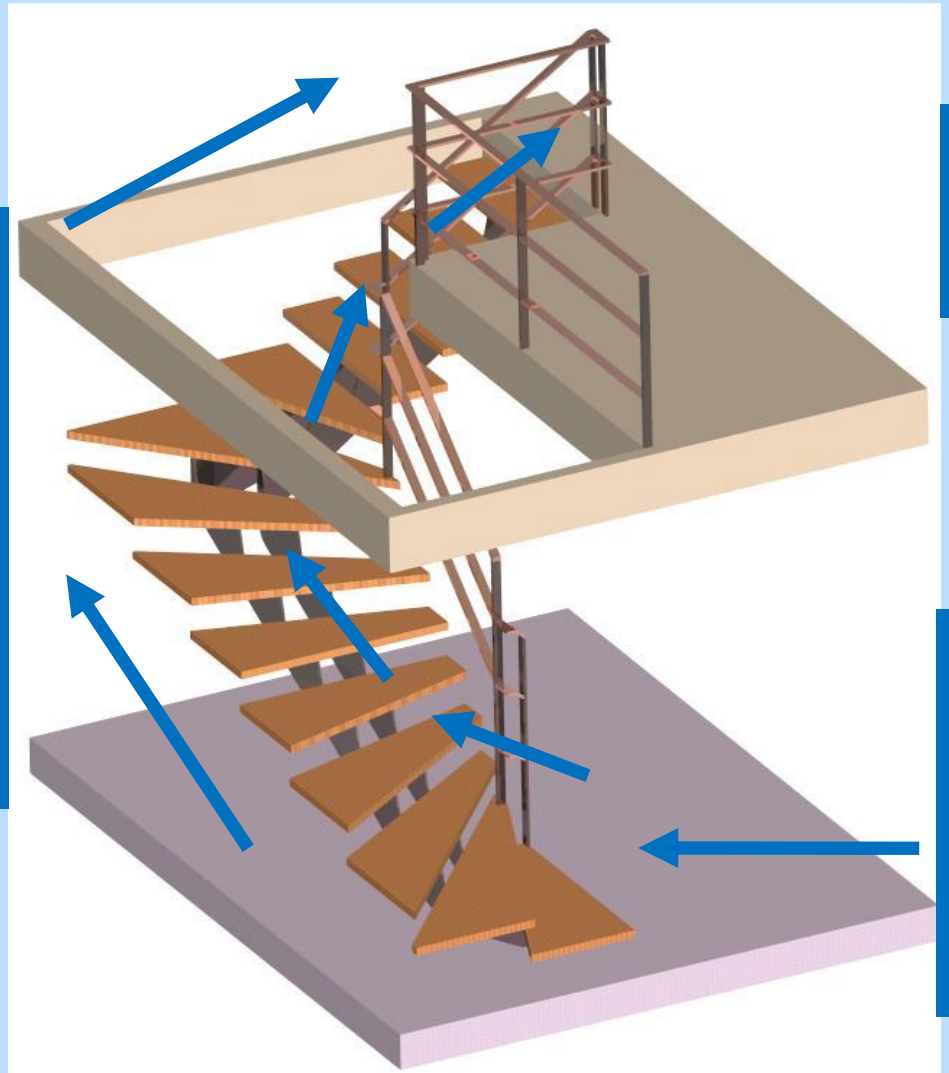
<table>
<tr><th colspan="5">Fishways/fish passes</th><th colspan="2">Hydraulic structures passable for fish</th></tr>
<tr><td>Special fishway structures</td><td>Channel-type fishways</td><td>Pool-type fishways</td><td>Partial roughened channels</td><td>Bypass channels</td><td>Bottom sills and bed structures</td><td>Crossing structures</td></tr>
<tr><td colspan="4">located at / very close to migration obstacle, or included in barrier</td><td>extend extensively around the migration barrier</td><td>Roughened channels extending over entire river width, (rock ramps)</td><td>Fish-friendly design and/or operation of hydraulic structure</td></tr>
<tr><td>Fish lock
Fish lift</td><td>Denil pass
Eel pass</td><td>Conventional pool-type fishyways
Vertical slot fishway
Other pool-type fishways</td><td colspan="2">Roughened channels:
• without friction (loss) elements
• with perturbation boulders
• with pools
• hybrid designs</td><td rowspan="3">Culvert
Ducts
Tidal sluices
Pumping stations
Boat/ canoe slides
Gauging stations
Flood retention basins</td></tr>
<tr><td rowspan="2">Hybrid designs</td><td></td><td colspan="2">Pool and boulder-type pass</td><td></td></tr>
<tr><td colspan="2">Bristle-type fishway</td><td colspan="2"></td></tr>
</table>

General requirements of fish passage structures

Project-

Passage
- Migration corridor
- Geometry: water depth, channel/pool size, slots
- Hydraulics: flow velocity, turbulence

conditions



Operation time
- ≥300 days
- period Q_{30} to Q_{330}

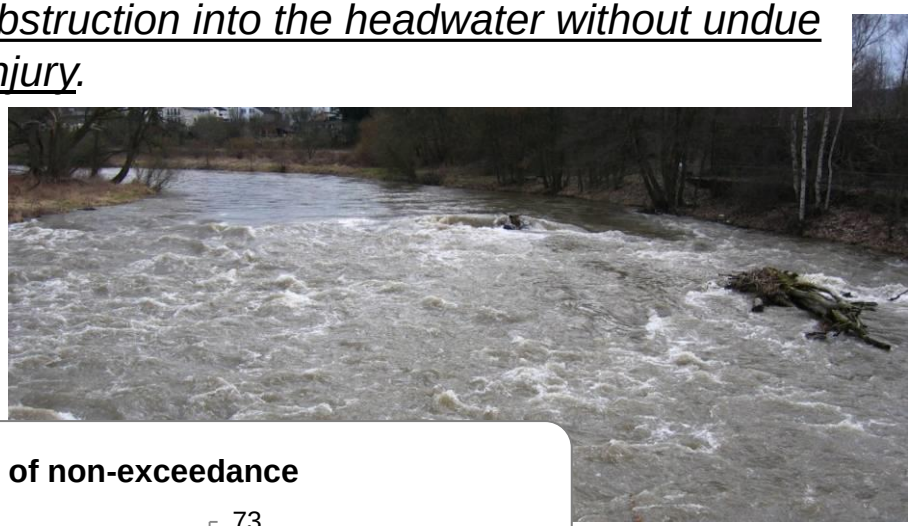
and site-specific

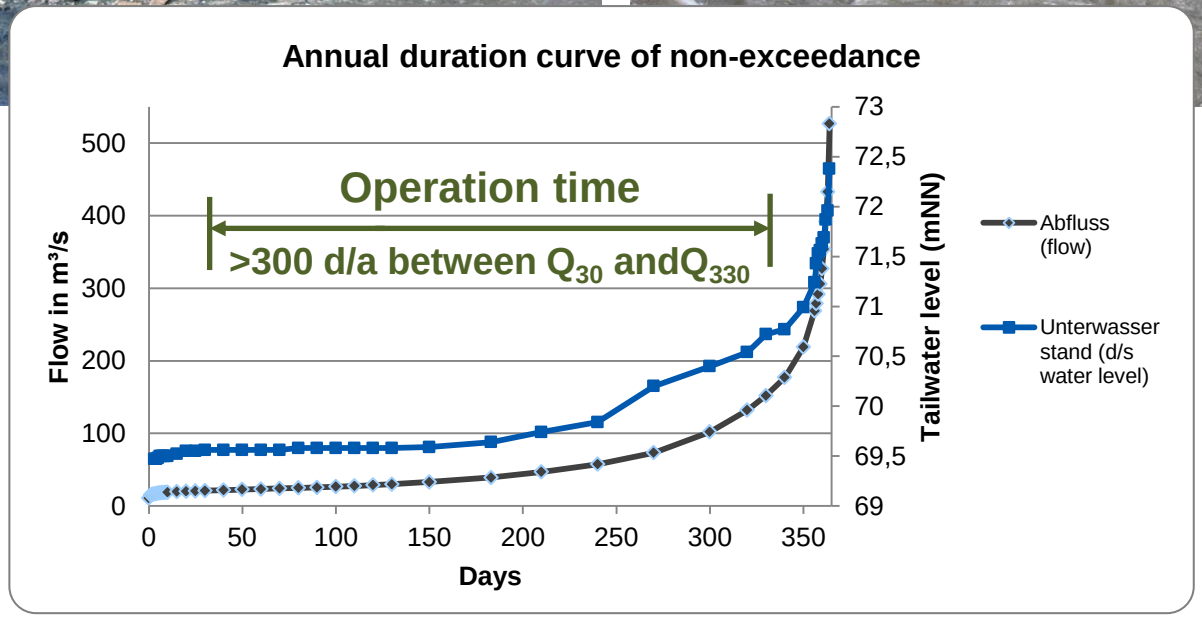
Attraction
- Large-scale location
- Entrance position
- Attraction flow: volume/flow impulse, angle, flow velocity

Operation time

Requiments of fishways (DWA-M 509 amended acc. to *Clay* and *Thorncraft & Harris*):

A fishway is a water passage around or through an obstruction that is found by all fish over a prolonged time of a year without excessive delay and energy loss, and designed to provide hydraulic conditions suitable for fish to pass the obstruction into the headwater without undue stress or injury.





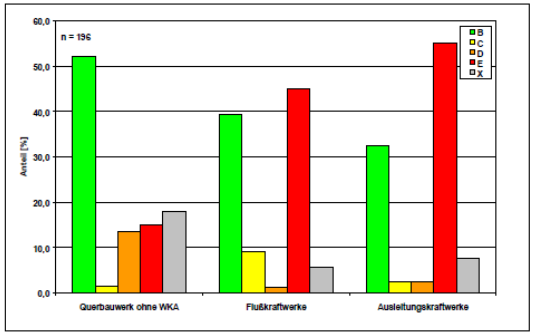
Attraction

DWA-Themen „Funktionskontrolle von Fischaufstiegsanlagen…“ (2006) (Function control of Fishways)

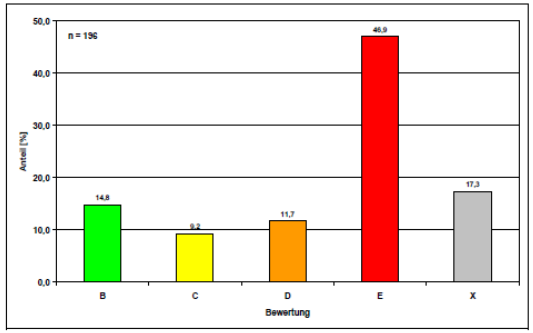
- review of 212 monitoring reports/ papers (published and grey literature)
- only ~1/3 of reports included information on fishway location and entrance position in order to assess fishway attraction
- of n = 196 fishways assessed retrospectively 47% were seriously wrong located (not category B)
- only 15 % of the fishways/ entrances were well placed
- in most occasions the entrance is placed too far away from the barrier (forms cul-de-sac)

Noonan et al. (2011)

- of 65 reports/ papers only n = 12 were evaluable as to attraction efficiency ($\bar{x}$ = 65,1%), and n = 11 as to entrance location efficiency ($\bar{x}$ = 39,6%)



Bewertung der Anordnung der untersuchten Fischaufstiegsanlagen an unterschiedlich genutzten Standorten gemäß der in Tab. 5 aufgeführten Kriterien

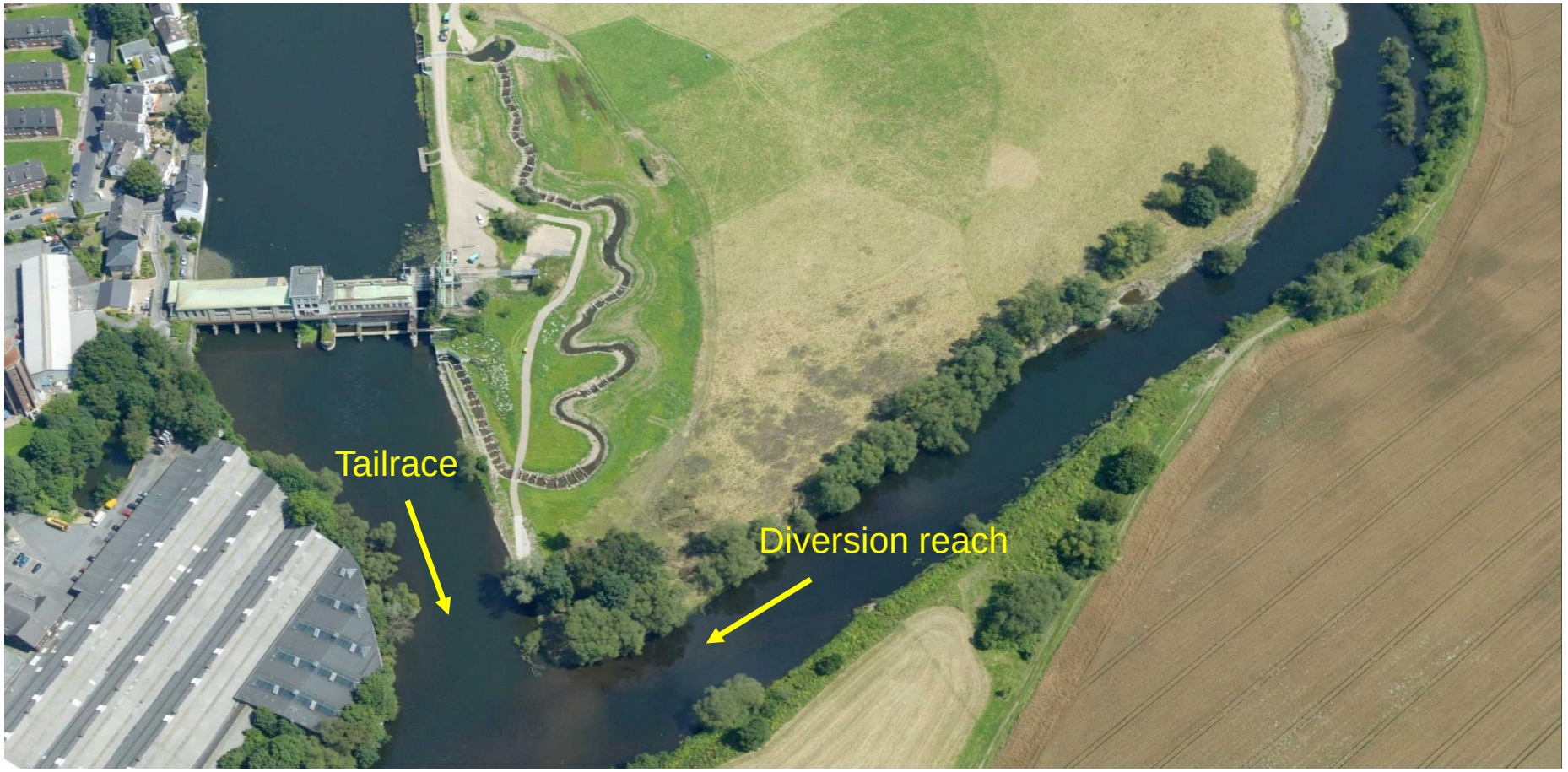


Bewertung der Positionierung des Einstiegs der untersuchten Fischaufstiegsanlagen gemäß der in Tab. 6 aufgeführten Kriterien

Tab. 5: Bewertung der Anordnung von Fischaufstiegsanlagen

Bewertungsstufe	Wehr ohne WKA	Flußkraftwerk	Ausleitungskraftwerk
A	Es ist kein Querbauwerk vorhanden.		
B	Die FAA liegt am Prallhang oder der Uferseite, an der an mindestens 300 Tagen/Jahr die Hauptströmung vorbeistreicht.	Die FAA liegt uferseitig neben der WKA. Bei Gewässern ab 50 m Breite ist mindestens eine zusätzliche FAA am gegenüber liegenden Ufer vorhanden.	Die FAA liegt uferseitig neben der WKA, zu der die aufwanderwilligen Fische an mindestens 300 Tagen/Jahr geleitet werden. Ist die Auffindbarkeit der FAA neben der WKA an weniger Tagen gewährleistet, ist am Ausleitungswehr eine weitere FAA vorhanden.
C	Die FAA ist in geringem Abstand vom Ufer gelegen.	Die FAA liegt zwischen WKA und Wehr; selten auch zwischen WKA und Schiffsschleuse.	Die FAA liegt uferseitig neben der WKA, die von aufwanderwilligen Fischen an mindestens 225 Tagen/Jahr aufgefunden wird. Liegt die FAA hingegen am Ausleitungswehr, ist am Zusammenfluß von Mutterbett und Unterwassergraben eine Sperre vorhanden, die eine Aufwanderung der Fische zur WKA sicher verhindert.
D	Die FAA ist inmitten des Wehres bzw. zwischen Wehr und Schiffsschleuse oder anderen Bauelementen gelegen, so daß aufwanderwillige Fische die FAA nur durch Suchen finden.	Die FAA ist in deutlichem Abstand von der WKA gelegen.	Die FAA liegt am Ausleitungswehr, wobei am Zusammenfluß von Mutterbett und Unterwassergraben eine Sperre vorhanden ist, die zumindest einen Teil der Fische von einer Aufwanderung zur WKA abhält.
E	Die FAA liegt am Gleitufer.	Die FAA liegt uferseitig gegenüber der WKA.	Die FAA liegt am Ausleitungswehr und es ist keine Aufwandersperre im Unterwasserkanal vorhanden.

Attraction – large-scale location



Main factors:

- Site without hydropower (⇒ Fishway usually on undercut bank)
- Site with hydropower (run-of-the-river/diversion plant)

Attraction – entrance position

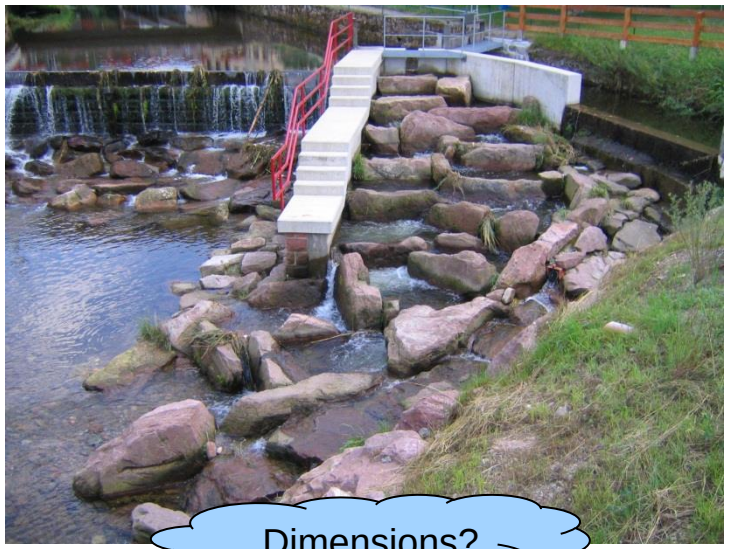
Attraction – retrofit

Attraction – attraction flow

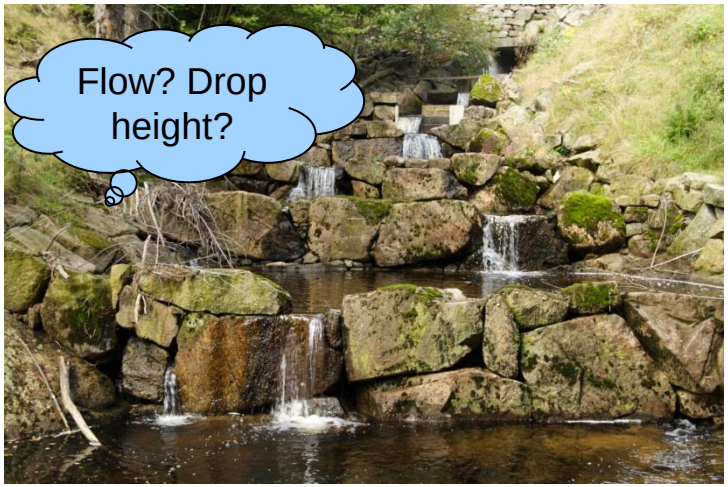
- Essential: Flow impulse = flow velocity x volume
- Attraction is better the more attraction flow compared to competing/ total flow
- Recommendations:
  1 - 5% of competing flow (according to Larinier et al.)
  NMFS: 5 - 10% of fish passage design high flow (Q_{95} during migration periods)

Passage

Geometry/ migration corridor

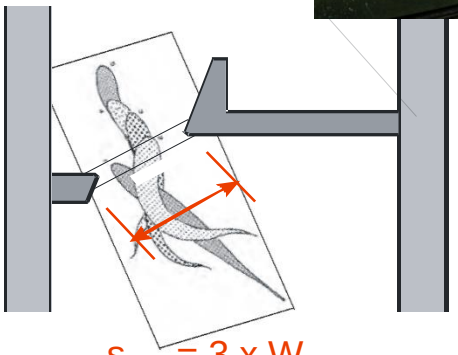


Hydraulics



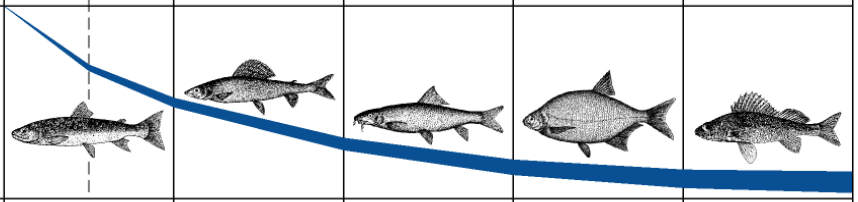
Passage – threshold values

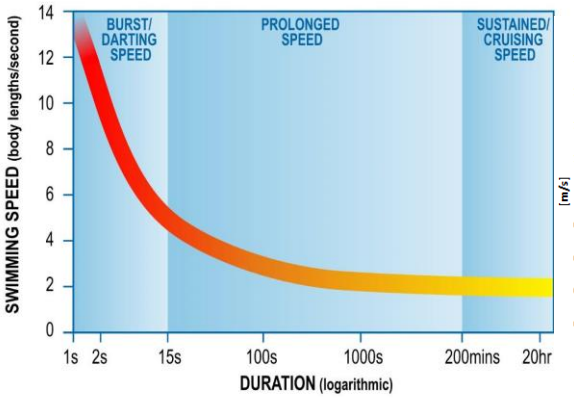
Geometry



$s_{min} = 3 \times W_{Fisch}$

Hydraulics

	Rhitral		Potamal		
Fliessgewässer-zonierung	Forellenregion obere | untere	Äschenregion	Barbenregion	Brachsenregion	Kaulbarsch-Flunderregion
Schematische Abnahme des Gefälles und der Strömung und schematische Zunahme der Wasserführung					
Gefälle [%]	10 - 0,45	0,75 - 0,125	0,3 - 0,025	0,1 - 0,0	Gezeiteneinfluss



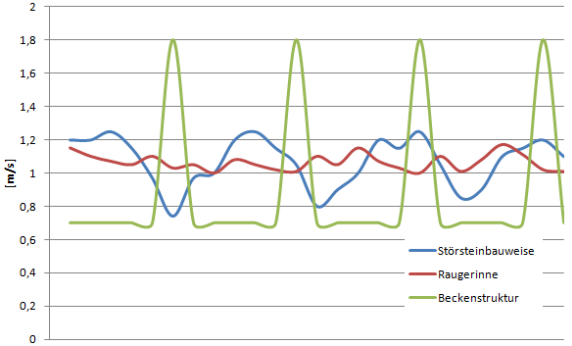


Figure: Göhl

- Geometric criteria based on orientation mechanism, total length and body size/ proportion of adults of the largest prevailing or target species
- Hydraulic criteria based on river zones model of Huet (i.e. typical distribution of species along a river in Central Europe), performance of weakest prevailing or target species as well as swimming mode.

Passage – threshold values

Geometry

Art	Hauptverbreitungsgebiet: Forellenregion	Äschenregion	Barbenregion	Brachsenregion	Kaulbarsch-Flunder-Region	Längsabstand von Einbauten (m)	Wassertiefe (m): Wanderkorridor	Wassertiefe (m): Engstelle	Breite Wanderkorridor (m): Länge der Engstelle: punktuell	≤ 2 m	> 2 m
						$3\ L_{Fisch}$	$2{,}5\ H_{Fisch}$	$2\ H_{Fisch}$	$3\ D_{Fisch}$	$6\ D_{Fisch}$	$9\ D_{Fisch}$
Bachforelle						1,50	0,24	0,19	0,15	0,30	0,45
Äsche						1,50	0,24	0,19	0,15	0,30	0,45
Huchen						3,00	0,40	0,32	0,36	0,72	1,08
Seeforelle						3,00	0,53	0,42	0,36	0,72	1,08
Perlfisch						2,10	0,32	0,25	0,21	0,42	0,63
Döbel						1,80	0,40	0,32	0,30	0,59	0,89
Lachs						3,00	0,42	0,34	0,30	0,60	0,90
Meerforelle						2,40	0,42	0,33	0,27	0,54	0,81
Quappe						1,80	0,27	0,22	0,32	0,63	0,95
Plötze						1,20	0,32	0,25	0,18	0,35	0,53
Barbe						2,10	0,33	0,26	0,25	0,51	0,76
Nase						1,80	0,39	0,31	0,28	0,56	0,84
Zährte						1,50	0,31	0,25	0,17	0,33	0,50
Sterlet						2,70	0,38	0,31	0,32	0,65	0,97
Aland						1,80	0,45	0,36	0,28	0,55	0,83
Brachsen						1,80	0,52	0,42	0,18	0,36	0,54
Rapfen						2,10	0,37	0,30	0,22	0,45	0,67
Barsch						1,20	0,31	0,25	0,21	0,42	0,63
Hecht						3,00	0,35	0,28	0,30	0,60	0,90
Zander						2,40	0,38	0,30	0,29	0,58	0,87
Wels						4,80	0,64	0,51	0,72	1,44	2,16
Maifisch						2,40	0,40	0,32	0,45	0,90	1,35
Karpfen						2,40	0,60	0,48	0,38	0,77	1,15
Karausche						1,35	0,34	0,27	0,22	0,43	0,65
Schleie						1,80	0,39	0,31	0,27	0,54	0,81
Stör						9,00	1,28	1,02	1,08	2,16	3,24
Finte						1,50	0,25	0,20	0,15	0,30	0,45
Schnäpel						1,20	0,20	0,16	0,12	0,24	0,36

ANMERKUNGEN
Die farbliche Markierung des Hauptverbreitungsgebietes entspricht der Farbgebung der Fließgewässerregionen gemäß 3.1.4.1.
Für die Breite der Schlupflöcher konventioneller Beckenpässe gelten gemäß 4.6.3.5 höhere Werte.

Hydraulics

Threshold values: Velocity in pool- & channel-type fishways

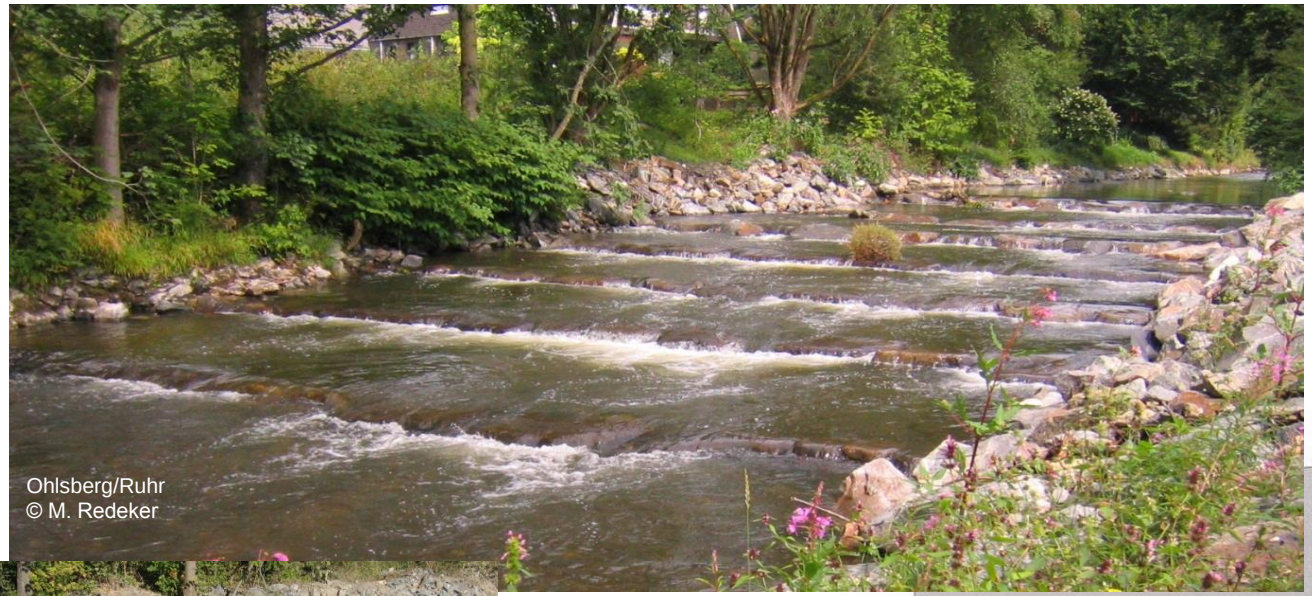
Gesamthöhenunterschied	Fließgewässerregion: Obere Forellenregion	Untere Forellenregion	Äschenregion	Barbenregion	Brachsenregion	Kaulbarsch-Flunder-Region
< 3 m	2,2	2,1	2,0	1,8	1,7	1,6
3 m bis 6 m	2,1	2,0	1,9	1,7	1,6	1,5
6 m bis 9 m	2,0	1,9	1,8	1,6	1,5	1,4
>9 m	1,9	1,8	1,7	Einzelfallentscheidung		

Gesamtlänge	Fließgewässerregion: Obere Forellenregion	Untere Forellenregion	Äschenregion	Barbenregion	Brachsenregion	Kaulbarsch-Flunder-Region
< 5 m	2,0	1,9	1,8	1,6	1,5	1,4
5 m bis 10 m	1,7	1,6	1,5	1,4	1,3	1,2
>10 m bis 25 m	1,5	1,4	1,3	1,2	1,1	1,0

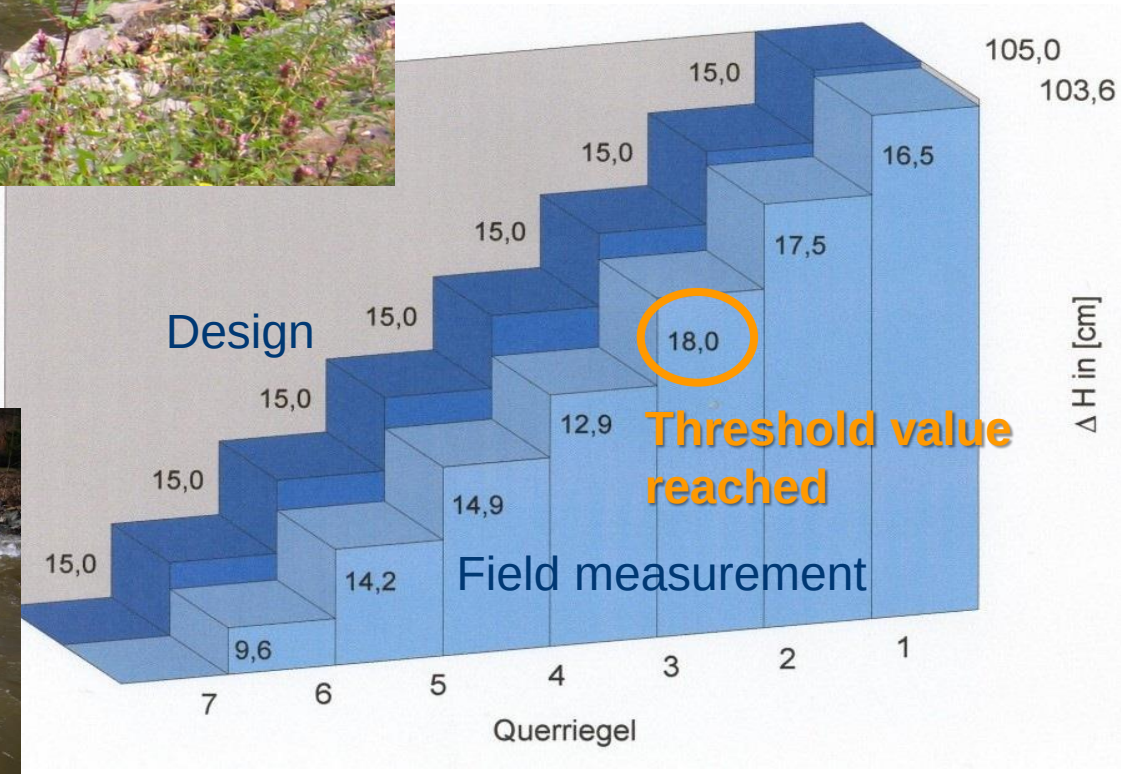
Threshold value: Turbulence

Fließgewässerregion	Spezifische Leistungsdichte, Grenzwerte für Fischaufstiegsanlagen und fischpassierbare Bauwerke: Beckenbauweise ohne Zander und Hecht	Beckenbauweise mit Zander oder Hecht	Störsteinbauweise
Obere Forellenregion	250 W/m³		300 W/m³
Untere Forellenregion	225 W/m³		275 W/m³
Äschenregion	200 W/m³		250 W/m³
Barbenregion	150 W/m³	100 W/m³	200 W/m³
Brachsenregion	125 W/m³	100 W/m³	175 W/m³
Kaulbarsch-Flunder-Region	100 W/m³	100 W/m³	150 W/m³

New design philosophy: threshold & design values



- material variations
- type-specific tolerances (bypass/channel type etc.)
- hydraulic uncertainties
- operational aspects



New design philosophy: threshold & design values

Velocity:	$v_{design} = S_v \times S_b \times v_{crit}$
Turbulence:	$P_{D,bem} = S_p \times P_{D,crit}$
Geometric design values:	Threshold value/S_g

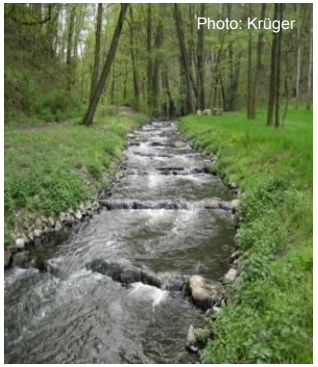
Safety factors:

- S_v: Hydraulic uncertainties (e.g. friction coefficients)
- S_g: Material/geometric variations (concrete, rock …)
- S_p: Turbulence (and velocity pattern)
- S_b: Operational aspects (e.g. debris, maintenance intervals)

Examples

$S_v = 0.95$
$S_g = 1.0$
$S_p = 0.9$
$S_b = 0.95$

Vertical Slot



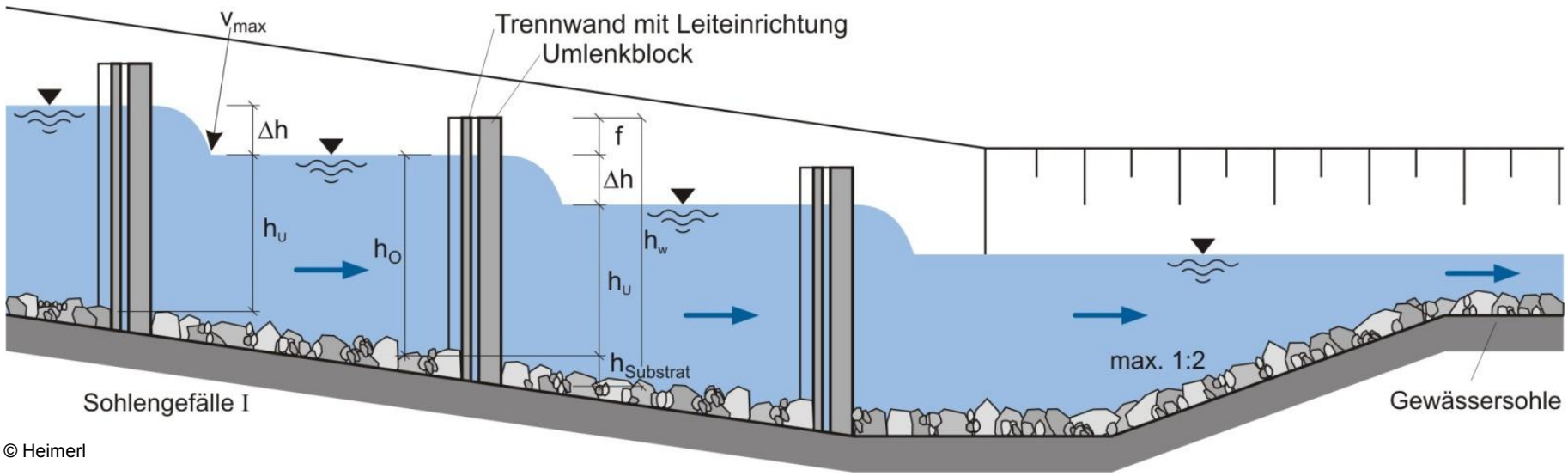
$S_v = 0.85$
$S_g = 0.9$
$S_p = 0.9$
$S_b = 0.9$

Roughened channel

$S_v = 0.8$
$S_g = 1.0$
$S_p = 0.9$
$S_b = 0.95$

Denil pass

Passability – Entrance at tailwater



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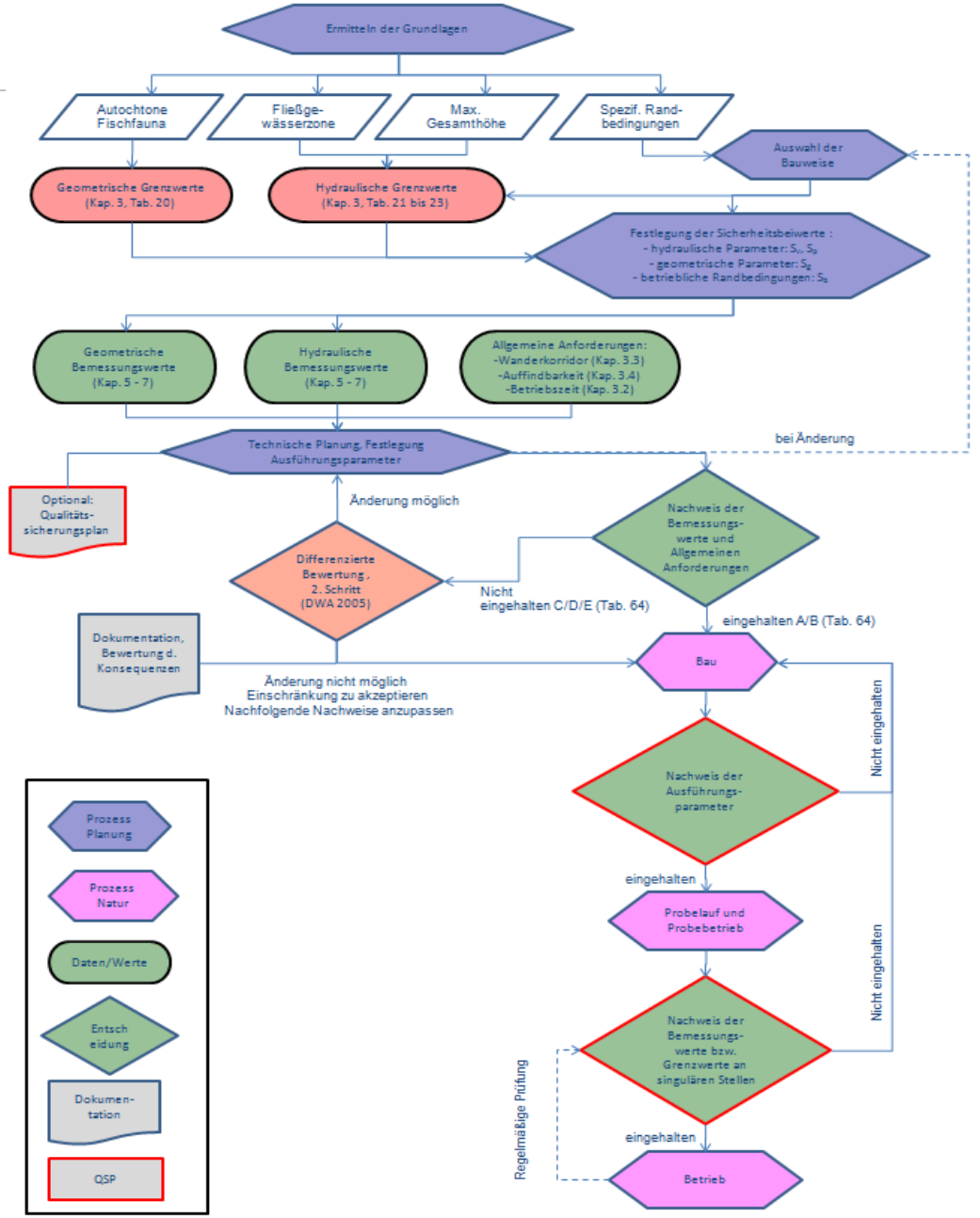
Quality assurance concept

Rationale

- ensure all criteria are met that are decisive for efficiency of a fishway (attraction & passage)
- during all phases, i.e. design, construction & operation

Goals

- process to support design and inauguration
- transparency for all stakeholders involved
- quality assurance & management



Monitoring

- biological monitoring usually (only) conducted post construction, i.e. too late
- many (technical) deficits cannot be/are not resolved post construction
- conventional monitoring with traps (fish counts) at exit is not suitable to assess overall efficiency (attraction & passage)

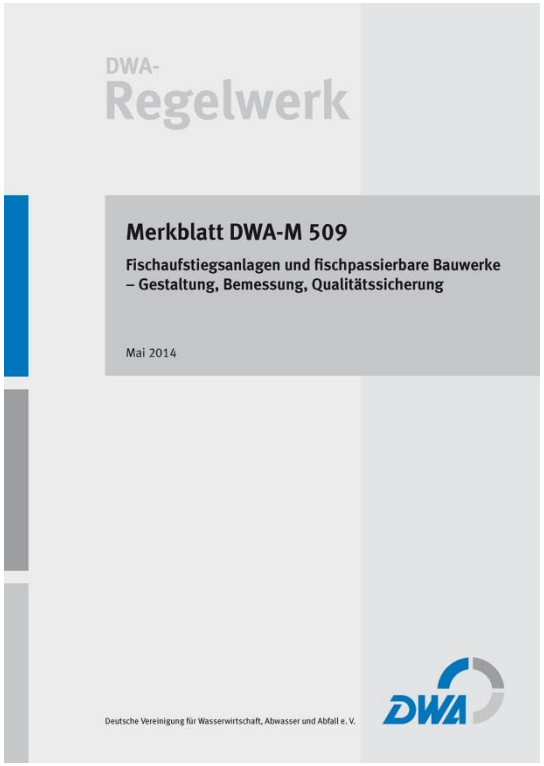
➔ QA process to ensure all criteria are met

➔ Additional technical monitoring during construction & operation

Biological monitoring is useful:

- if assessment of attraction is limited or impossible (e.g. due to hydraulics or topography) based on technical criteria;
- if deviation from design criteria is unavoidable;
- for special ecological assessments (of certain design criteria), e.g. fishway operation optimization;
- for R&D purposes.

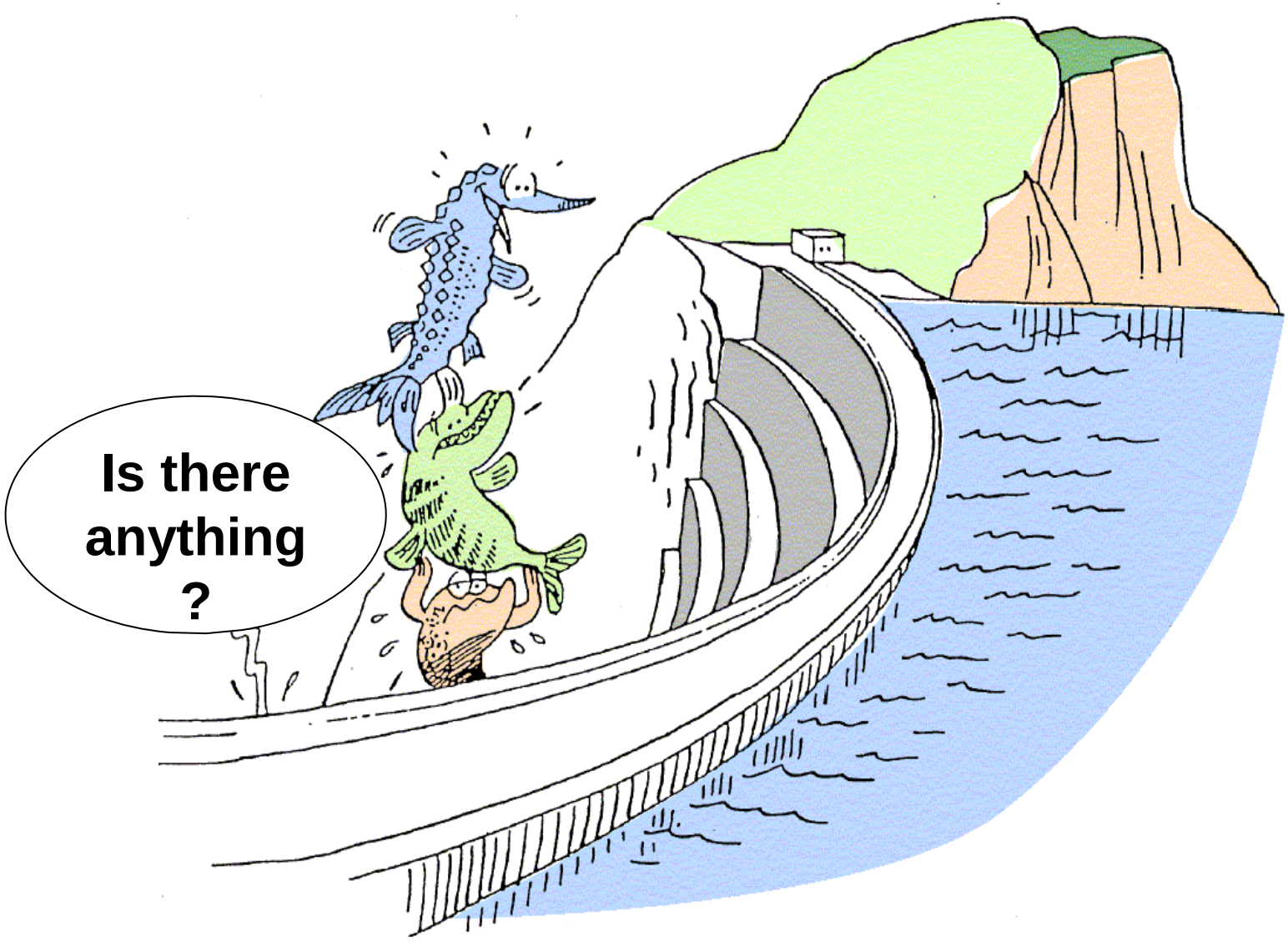
Summary: What‘s new in DWA-M 509?



- philosophy: „*fishway design must be based on the fish one intends to guide“ (Gerhard, 1912)*
- established geometric und hydraulic threshold values based on body size/proportions and swimming performance
- introduced new design concept: threshold & design values
- initiated QA process – biological monitoring is only required in principle, if design criteria are not complied with (reduced monitoring effort in standard projects/ locations)
- assessed new fishway structures, e.g. Round Vertical Slot Fishway, Bristle-type Fishway
- regarded various hydraulic structures passable for fish
- considered regional features (e.g. dry Eastern Germany)
- made clear that nature-like fishways do not function better per se than technical fishways
- included information on costs and OPEX

➔ Think like a fish by designing fishways!

Thanks for your attention!



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