NATURE CONSERVATION AGENCY OF THE CZECH REPUBLIC

STANDARDS FOR NATURE AND LANDSCAPE MANAGEMENT		
WATER IN LANDSCAPE SERIES B	FISH PASSES	SPPK B02 006: 2014

Rybí přechody
Fischaufstiegsanlagen

This standard contains definitions of technical and technological practices for free passage restoration of migration barriers in watercourses.

References:
ČSN 75 0121 Water management. Terminology of watercourses.
ČSN 75 1400 Hydrological data on surface water
ČSN 75 2101 Ecological improvements of watercourse regulation

ČSN ISO 26906 (25 9360) Hydrometry – Fish passes at flow measurement structures
ČSN P 75 2323 Ensuring of downstream migrations in watercourses.
TNV 75 2102 Modifications of brooks
TNV 75 2103 Modifications of rivers
TNV 75 2303 Hydrotechnology. Weirs and steps
TNV 75 2321 Passability of migration barriers with fish passes
TNV 75 2322 Devices for migration of fish and other aquatic animals across barriers in minor watercourses
TNV 75 2910 Handling rules for hydraulic structures on watercourses
TNV 75 2920 Operating rules for hydraulic structures
Act no. 17/1992 Coll., on the Environment, as amended
Act no. 114/1992 Coll., on Nature and Landscape Protection, as amended
Act no. 254/2001 Coll., on Water and amendments to some acts (Waters Act), as amended
Act no. 99/2004 Coll., on Aquaculture, exercise of fishing rights, angler guards, protection of marine fisheries and on amendment of certain acts (Fisheries Act), as amended
Act no. 183/2006 Coll., on Town and Country Planning and Building Code (Building Act), as amended
Government Regulation no. 318/2013 Coll., laying down the national list of Special Areas of Conservation
Methodological instruction of MoE Water Protection Department laying down minimum residual flow values for watercourses (MoE Newsletter, vol. 1998, no. 5)
Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
Decree No. 395/1992 Coll. implementing selected provisions of Czech National Council Act no. 114/1992 Coll., on Protection of the Environment and the Natural Landscape, as amended
Decree no. 414/2013 Coll., on scope and method of record keeping on decisions, general measures, binding position statements, approvals and notifications approved under the Waters Act, and parts of decisions under the Integrated Prevention Act (water management records)
Decree no. 197/2004 Coll., executing Act no. 99/2004 Coll., on Aquaculture, exercise of fishing rights, angler guards, protection of marine fisheries and on amendment of certain acts (Fisheries Act), as amended
Decree no. 166/2005 Coll., executing certain provisions of Act no. 114/1992 Coll. on Nature and Landscape Protection, as amended, in connection with establishment of Natura 2000, as amended
Government Regulation no. 71/2003 Coll., specifying surface waters suitable for life and reproduction of native species of fish and other aquatic animals and identification and assessment of quality of such waters, as amended
Passability Concept of the River Network in the Czech Republic, MoE CR, 2009

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1. Standard purpose and content

The following standard “Fish Passes” brings an overview of particular steps and procedures needed for restoration of free passage in watercourses. The aim of this standard is to provide sufficient information for preparation, execution and inspection of implemented measures.

The standard “Fish Passes” is predicted on standards TNV 75 2321 and P ČSN 75 2323. These documents are completed (enhanced) by the following standard.

Legislative framework

A fish pass can be built only when supporting evidence clearly shows that its construction is eligible, technically feasible and economically viable. Consequently, other solutions for maintaining migration passability (e.g., overall removal of obstacles or comprehensive watercourse revitalisation) have to be evaluated and found to be less suitable.

Creation of impassable barriers to migration of fish and aquatic fauna in both directions by water dams is allowed under conditions specified in Section 15, Para. 6 of Act no. 254/2001 Coll. on Waters and amendments to some acts (Waters Act), as amended.

2. Fish pass and migration barrier definition

2.1 Fish pass

2.1.1 A fish pass (FP) is a structure that allows fish to pass a migration barrier and swim from the lower part of a watercourse to the upper part of a watercourse (and vice versa in the case of downstream migration).

Note: If there are any expectations of migration of other animals (e.g., otters, beavers) with no migration possibility on the banks (built up areas), it is advisable to modify fish passes for migration of these species as well.

2.2 Migration barrier

2.2.1 For the purpose of this standard, any cross-river obstruction which disables the migration of fish and other aquatic animals by its height (due to different water levels) is considered a migration barrier.

3. Documentation for the design of fish passes

In the preparation of the fish passage design, the necessary background information characterising the site must be available and, on this basis, a basic analysis of the conditions and needs for the design and execution of the fish passage must be carried out.

3.1 Ichthyological survey

Ichthyological survey provides information about species composition and fish assemblage conditions on the particular site, and about the ichthyofauna of given watercourse as well. In fourth-order watercourses and below, knowledge of the ichthyofauna of the adjacent higher-order watercourse is necessary.

3.1.1 The ichthyological survey is expertly elaborated by a qualified person (authorisation holder as specified in Section 45i of Act no. 114/1992 Coll.).

3.1.2 The ichthyological survey is not elaborated if information about the fish assemblage is provided by NCA CR, and consequently if NCA CR does not alert to the necessity of completing or verifying that information by an ichthyological survey according to article 3.1.1 and in the range of article 3.1.3 of this Standard.

Also, it is not elaborated in the case of existence of a biological evaluation or a biological survey (as specified in Section 67 of Act no. 114/1992 Coll.) not older than 5 years which includes an ichthyological survey.

3.1.3 The ichthyological survey is processed in the following structure:

- Author's identification and survey processing qualifications.
- Aim and purpose.
- Site description – conditions influencing survey results and presence of fish species.
- Methodology – monitoring method used, facilities used, monitoring period (survey monitoring time).
- Fish assemblage characteristics – basic parameters of the fish assemblage (fish species composition, determination of main fish species – see opulation parameters of any other particular species, their abundance and biomass), evaluation of available data (information not older than 5 years, e.g., from NCA CR Species Occurrence Database), further relations (following other watercourses and typical fish communities, possibility of restoration of native species occurrence).
- Further information – classification of monitored watercourse section in fishing grounds as specified in Act no. 99/2004 Coll., information about stocked fish species and catches, historical data illustrating the original baseline.
- Final evaluation – includes mainly an evaluation of the fish assemblage condition, its potential regarding migration passability

and a statement of suitability of execution of a fish pass (or other measures for migration passability).

3.2 Tachymetric documentation

3.2.1 Geodetical planimetric and altitudinal capturing of the cross-river obstruction, water levels, watercourse bed (bottom and both banks) above and below the barrier in the necessary area, capturing the functional structures in relation with the cross-river obstruction (e.g., feeding canal, diversion structure, SHPP outfall, etc.).

3.2.2 Capturing of the site in S-JTSK coordinate system with connection to the nationwide Baltic altitudinal system.

3.3 Geological engineering survey

3.3.1 Provides an overview of the site geological profile composition (characterisation of soil properties in relation to permeability, stability, carrying capacity), depth of particular layers and water table, etc.

3.3.2 The scope and complexity of these surveys depends on local conditions and size of the structure.

3.3.3 In the case of existing hydraulic structures, the building records for such structure can be used. Alternatively, some conclusions can be drawn from existing building arrangement of this structure.

3.4 Watercourse hydrological data

3.4.1 These are used in designing the fish pass and setting the water discharge in this fish pass.

3.4.2 Hydrological data are processed and provided by CHMI.

3.4.3 Basic hydrological data are stated in M-day and N-year discharge scope. Enhanced data include, e.g., the discharge distribution in the months of a year.

3.4.4 Some indicative information can be obtained from watercourse administrators, watercourse operators, field surveys (repeated in various periods of the year) or optionally from local inhabitants.

3.5 Site reconnaissance

3.5.1 The field survey should be repeated in several periods of the year with respect to the hydraulic conditions in the watercourse.

3.5.2 Within each field survey, the nature of the stream, water debris regime and approximate streamline should be evaluated.

3.5.3 This information serves evaluation of the suitable location of the fish pass, its entrance and exit regarding existing structures or their possible silting up by water debris, etc.

3.6 Hydrotechnical records

3.6.1 Hydraulic structure (migration barrier) description data, connected structures, valid Permission for water use and approved Rules of operation.

3.6.2 Mainly water levels and gradient conditions in various discharges, information about operation, water draws and its time schedule, information about facilities in related structures and their operation, optionally the information for technical condition evaluation of hydraulic structures and protection of existing structures (e.g., existence of screens, sluice gates, type of facility, etc.).

3.7 Minimum residual flow

3.7.1 Its value is stated in approved permission for water use or should be determined as specified in Section 36 of the Waters Act.

3.8 Property ownership

3.8.1 Ownership of buildings and properties situated above and below the cross-river obstruction significantly limit design of the fish pass in general, or the area of fish pass location (within watercourse bed or bypass).

3.9 Further information about watercourse

3.9.1 Categorisation of the watercourse in the Passability Concept of the River Network in the Czech Republic (https://www.mzp.cz/cz/koncepce_migracni_zpruchodneni), where cross-river obstructions and their priority for migration passability are listed.

3.9.2 The Concept states the numbers and locations of existing obstacles to migration, optionally it also states the concept of future fish passes within named sections.

3.9.3 The River Basin Management Plans as specified in Section 24 of Act no. 254/2001 Coll.

4. Design of migration passability solutions

When planning the fish pass location, determining its optimal function as free passage through the migration barrier for most of the fish assemblage (mainly the target species), as well as its year-round operation is crucial.

The fish pass location should comply with the layout of existing migration barriers in the watercourse, with the watercourse characteristics (bottom and bank morphology), its uses, surrounding morphology and available placing of the construction project on land plots.

Important aspects for designing the fish pass are the migration barrier original purpose (bottom stabilisation, water accumulation, water abstraction, utilisation of hydropower potential of the site, sports use, etc.), divide of discharge at the barrier and minimizing of future fish pass maintenance requirements.

4.1 Fish pass design policy

The general approach to fish pass design is based on the following fact patterns:

4.1.1 Fish assemblage composition (or life demands of present fish species).

4.1.2 Design discharge through the fish pass (see Article 4.2).

4.1.3 Fish pass gradient – determined mainly by demands of target fish species and influenced by space allowance of the site (terrain continuity, structures, land plots) and by the migration barrier gradient.

4.2 Suggested discharge

4.2.1 When setting the discharge in the fish pass, the following should be considered:

- M-day discharge values;
- migration barrier structure type (stable/movable structure);
- water level management regime in headwater (automatic/manual adjustment);
- approved permission for water use for the whole site;
- defined minimum residual flow (MRF);
- divide of discharge at the stream profile.

4.2.2 Setting of the discharge must be based on the optimal parameters of the fish pass; consequently, it has to respect the determined MRF below the migration barrier and approved permission for water use.
It is necessary to transfer a part of the discharge (or MRF) to the fish pass which is needed for maintaining its function while keeping the necessary discharge across the structure of migratory barrier itself (protecting the structure, downstream migration – see Article 5.2.).

4.2.3 If the MRF value, approved permission for water use or other requirements do not allow the necessary discharge for the fish pass functioning, the fish pass cannot be implemented before a proper re-evaluation of the situation (e.g., amendments to permission for water use).

4.2.4 The discharge amount is strongly influenced by the headwater level fluctuation. In the case of movable and automatic water level control, the water level in the upper weir, and thus the flow in the fish pass, is kept stable within the water level control range. In the case of a fixed weir or manual control weir, the flow through the fish pass is dependent on the current flow in the watercourse.

4.2.5 The suitable shape of the inlet structure (especially appropriately modified first traverse) is determined by the discharge of the fish pass.

4.3 Fish pass gradient

4.3.1 The longitudinal gradient of the fish pass body is based on the space, land and morphological parameters of the site. It also strongly influences the passability of the fish pass.

4.3.2 The overall length of the fish pass includes the length of the entrance and exit, as well as the connection to watercourse and riverside lands.

The active length of the fish pass is the real distance over which it is necessary to pass the different in water levels between the tailwater and headwater.

4.3.3 The fish pass gradient is calculated from the total height of the migration barrier (differences between fish pass entrance and exit water levels) and the active length of the fish pass (Appendix 5, Fig. 1), or by dividing the total sum of differences between water levels in particular cross-walls and total sum of lengths of particular pools.

4.3.4 The maximum gradient for cyprinid waters is 1 : 20, the optimal gradient is less.

4.3.5 The maximum gradient for salmonid waters is 1 : 15, the optimal gradient is less.

4.3.6 These limits should be respected when designing the fish pass as well as in its execution. Exceptions apply to stream sections with gradients higher than the above values.

4.4 Fish pass typology

Only approved and used types of fish passes are described.

4.4.1 Pool pass

4.4.1.1 Close-to-nature or technical channel divided up by cross-walls to form a system of stepped pools (ponds).

There are openings in the cross-walls to dissipate the water discharge. This creates a water level difference on the sides of the cross-wall. This difference is easily passable for migrating animals from the flow velocity point of view.

Dimensions of pools, width of openings, number of openings and the height difference depend on the fish species, discharge intensity and on the total gradient to overcome.

4.4.1.2 **Close-to-nature bypass channels** – usually of trapezoidal profile with natural bottom and bank stabilisation.

The cross-walls are built from natural materials – boulders of suitable size and shape.

To secure free passage from pool to pool, there are gaps between boulders in the cross-walls.

The width of the gaps varies from 10 to 25 cm. Also, one extended gap of variable width is left between the boulders. The size of this gap varies from 30 to 60 cm. The gap varies with the height and does not have to reach the bottom of the fish pass. It is located alternately in consecutive traverses (Appendix 5, Fig. 2).

The bottom should be dish-shaped.

If needed due to space allowance, combination of vertical walls is also acceptable.

4.4.1.3 **Slot pass** – the channel of the slot pass has a rectangular shape and is made of stone or concrete.

The cross-walls are notched by vertical slots with a strictly defined discharge profile.

The shape of the slot creates the streamline, regulates its trajectory and current shades along the whole pool.

Due to the simple maintenance, cleaning and occasional modifications, it is advisable to make the cross-walls from natural materials and set them into the vertical slides built in channel sites (Appendix 5, Fig. 3 and 4).

A layer of raw gravel or aggregate (thickness, grain size and stabilisation set according to structural assessment) is placed on the bottom.

4.4.2 Riffles and ramps

4.4.2.1 Structures characterised by direct route built in a transverse barrier or close to it.

Riffles and ramps are characterised by higher gradients and shallower water.

The water discharge and speed of the current are limited by the coarseness of the slide through a continuous layer of rough stone or solitary dispersed boulders or sills made from stone, concrete, etc.

4.4.2.2 The riffle stretches all across the bed in narrow streams; in other cases, a ramp with a width proportional to the width of the stream (but no less than 1.0 m) is chosen (Appendix 5, Fig. 5).

4.4.3 Baffle-brush fish pass

4.4.3.1 The cross-walls are made of segments of brushes which are composed of flexible rods installed into bundles.

Each segment is anchored in the bottom of the bed.

Gaps between the bundles are maintained in the cross section of the fish pass. Resting zones are kept along the fish pass.

4.4.3.2 The gradient threshold of the baffle-brush fish pass is 1 : 25, but the optimal gradient is gentler.

The maximum water depth is 0.6 m. A layer of coarse gravel or aggregate is placed on the bottom.

4.4.3.3 Utilization of brushes is possible only as addition to boat sluices.

4.4.4 Passability improving structures

4.4.4.1 These structures are not fish passes by themselves, they are modifications of the cross-river obstruction with the purpose of improving migration of fish (or other aquatic organisms) .

4.4.4.2 **Boulder chute** – the chute area provides migration passability for fish or other aquatic organisms.

Chutes are constructed mainly in salmonid waters.

If constructed with suitable parameters for target fish species, it is possible to use boulder chutes as the main structures for watercourse migration passability.

4.4.4.3 **Sluices (for boats, rafts, etc.)** – installing cross-walls can partly improve the migration of aquatic organisms through these structures.

Using of such structures is mainly optional to fish pass execution.

4.4.5 Bottom coarsening

4.4.5.1 Coarsening of the bottom is necessary for slowing the water flow just above the bottom, where the main migration corridor is.

It is implemented according to structural assessment calculation (Appendix 5, Fig. 5).

4.4.5.2 It is composed of three layers:

- the base consists of bigger boulders anchored in the bottom (1/3 of their size at minimum) and arranged in lines against the slot for effective inhibiting of the water flow. The size of the boulders is 30-50 cm, according to the depth of free water in the FP body;
- coarse gravel sized 10-20 cm, filling the gaps between the anchored boulders,
- fine fraction of sand or gravel (this fraction is mostly deposited spontaneously).

4.5 Fish pass components and its parameters

4.5.1 **Fish pass entrance** – attractiveness of the entrance is crucial for guiding the fish to swim into the fish pass.

4.5.1.1 The entrance is situated near the head streamline due to the presence of sufficient attraction current and sufficient water depth maintained all over the year.

4.5.1.2 The stream running out the FP and into the tailwater has to be recognisable for fish. The water outlet from the FP has to extend as far as possible to the streamline and reach as high an angular value as possible to the longitudinal axis of the riverbed.

4.5.1.3 It should be placed as close as possible to the migration barrier, but far enough from the disturbing influence of the flow in the tailwater.

4.5.1.4 There must be no altitudinal obstacle in the FP entrance. Any height difference has to be compensated for by a slow crossing ramp (Fig. 6).

4.5.2 The **fish pass body** is the main space for fish migration. Close-to-nature types of arrangement are preferred. Such arrangements simulate natural conditions for fish migration and can also serve as a biotope.

4.5.2.1 The flow velocity has to be diversified in a range from 0.2 to 1.2 $m.s^{-1}$, taking the target fish species migration efficiency into account. From the water flow point of view, turbulent flow should be eliminated and significant variation in flow velocity should be secured.

4.5.2.2 Bottom and bank morphology – the FP bottom should be structured with boulders, rocks and fine substrate. Big boulders have to be anchored in the bottom (substrate stabilisation). Elimination of straight and flat bottom sections significantly contributes to increasing the diversity of flow velocity, as well as creating flow shadow.

4.5.2.3 Pool size – dimensions of different pools have to provide sufficient space for longitudinal as well as diagonal movement of fish, sufficient water depth and space for optional flow shadows where migrating organisms can rest.

4.5.2.4 Resting pools are suggested in steep or long fish passes. Such pools can be created by elongation or widening of target pools. These extensions lower the flow velocity and modify the velocity field while keeping the same discharge.

4.5.3 **A list of the basic parameters** is shown in Appendix 1. The parameters shown can vary due to local specific requirements (see Passability Concept of the River Network in the Czech Republic).

4.5.4. **Fish pass exit** leads to the headwater and must not be blocked by physical elements (alluvial deposits, screens, railings), turbulent flow or high flow velocity.

4.5.4.1 The optimum flow velocity for fish in the FP exit (headwater) is less than 0.4 $m.s^{-1}$.

4.5.4.2 The exit into the headwater has to be far enough from the crest of the weir as well as from the inlet structures to protect migrating fish from drifting underneath the diagonal barrier or into the inlet structure during water withdrawal or other water use.

4.5.4.3 In structures placed outside the weir, the fish pass exit should be situated at an angle of 45° (max. 90°) to the longitudinal axis of the flow, considering the space allowance and flow velocity.

4.5.4.4 The fish pass exit (entrance) is designed as an inlet structure that can be closed with gate valves or another type of barrier.

4.5.4.5 The option to seal the fish pass is necessary for protecting the fish pass during flood discharges (mainly in fixed weirs) and for occasional maintenance, inspections and monitoring.

4.6 Optional equipment and structures

4.6.1 Floating boom – component of FP exit (part of inlet structure and barrier arrangement). The floating boom serves to protect the FP from inflow of alluvial debris and subsequent clogging of slots in the cross-walls. It is advisable to use an floating boom to decrease the need for fish pass maintenance.

4.6.2 Anchor possibility for capturing devices – it is suitable to equip an inlet/outlet structure (FP exit/entrance) with, e.g., side or central wiring for possible installation of capturing nets, baskets, pots, etc.

4.7 Use of raceways for fish migration

4.7.1 Use of raceways for migration is possible in weirs with secondary water collection only if migration passability within the whole riverbed is subsequently addressed as a priority. Also, suitable situational, operating and structural conditions and living conditions for aquatic organisms (flow rate, flow velocity, type and form of bank and bottom fortification, raceway cover, etc.) have to be addressed.

4.8 Fish pass location regarding migration barrier type

4.8.1 In weirs without secondary water collection, the fish pass entrance is usually placed by one of the banks. The angle of the weir direction to the longitudinal axis of the watercourse, local flow and fish behaviour have to be considered.

4.8.2 In structures where the elevation crest takes an acute angle to the longitudinal axis of the watercourse, the fish pass entrance is placed on the side that lies higher upstream (Appendix 5, Fig. 7).

4.8.3 In weirs with a V-shaped profile, it is optimal to situate the fish pass in the point of the angle of the weir structure, unless such a solution results in a discharge diversification at the weir body, and unless it enables FP maintenance.

4.8.4 In weirs with the elevation crest longer than 50 m, construction of two fish passes is suggested, optimally on both sides of the weir.

4.9 Hydraulic calculation of main FP components

4.9.1 The hydraulic calculation is based on the design or assessment of the main characteristics of a particular fish pass, i.e., discharge, water level differences and flow velocity at the cross-walls in relation to the bottom width, water depth, numbers of and distances between cross-walls, slot width, pool length, longitudinal gradient of the fish pass, velocity at slots and in pools.

4.9.2 The calculation procedure for fish passes including examples is shown in Appendix 2.

5. Ensuring downstream fish migration

5.1 Measures ensuring downstream migration are implemented on weirs where using the water manipulates the water level at the overfall as far as it disables downstream migration. Such measures can be implemented in cases justified by technical expertise (e.g., migration study, ichthyological survey, etc.).

5.2 If there is water withdrawal or collection via a protected headrace (with a device preventing fish from entering), it is necessary to secure suitable conditions for migration over the overfall in the permission for water use. Such measures can be applied only if allowed by ownership and structural, technical and functional conditions of the barrier structure.

5.3 If there is water withdrawal or collection via an unprotected headrace (no device preventing fish from entering), a safe passage for aquatic organisms into the tailwater has to be provided.

5.3.1 A downstream bypass is made of an open or closed profile with running water. The structural arrangement of the water abstraction facility (e.g., side sluice, operational bypass) can also be used for such purposes.

5.3.1.1 The entrance profile of a bypass is set into a place where migrating fish are guided by barriers or other diversion devices. The entrance size is designed in correspondence to the size and number of migrating fish.

5.3.1.2 If the width of the headrace exceeds 10 m, constructing two bypasses has to be considered.

5.3.2 If there are suitable SHPP technological conditions (e.g., low gradient, size of openings between machinery blades, structural arrangement of machinery, rotational speed of impellers), downstream migration can optionally be guided through the SHPP body. In such cases, the success rate of the target species migration (mortality in the turbines) has to be specified.

6. Protection against injury or killing of fish migrating downstream

6.1 Screens

6.1.1. To prevent fish from entering into the machinery parts of the water abstraction facility, fine screens are used. The clearance between the rakes is 20 mm.

6.1.2 Higher clearance (max. 40 mm) is acceptable only when considering the composition of the fish assemblage, purpose and technology of water withdrawal, with no threats of excessive injury or killing of animals passing the technological facility and if the system is complemented by a behavioural barrier. A combination of the measures mentioned above is recommended.

6.2 Bottom sills and troughs

6.2.1 Shaped bottom sills (or end joints) are installed in the bottom of the riverbed cross-section. They point towards the bypass entrance.

6.2.2 The height of the sill ranges from 0.30 m to 1.0 m, depending on the water depth in the inlet channel.

6.3 Electrical barriers and distress machines

6.3.1 A system of electrodes creating a continuous electric field which repels the fish from entering the secured area.

6.3.2 Electric barriers are placed in parallel with the river bank, at the point where the bed of the collection canal or headrace turns towards the SHPP.

6.3.3 The effectiveness of the device is influenced by the physical and chemical parameters of the aquatic environment. The installation has to be implemented according to the device manufacturer’s technical guidelines.

6.4 Light barriers

6.4.1 A light curtain is created by stroboscopic lights with a frequency up to 200 light pulses per minute.

6.4.2 Light barriers work selectively, so they have to be used only in combination with another type of barrier.

6.4.3 It is necessary to consider the physical properties of the aquatic environment when designing the light barrier (turbidity, floating debris, etc.).

6.5 Sonic deterrents

6.5.1 A low-frequency sound projector with a frequency from 20 to 500 Hz.

6.5.2 Sonic deterrents have to be used only in combination with another type of barrier.

6.6 Bubble barrier

6.6.1 A curtain of gas bubbles released from perforated tubes or air-jets which are placed at the bottom of the headrace.

6.6.2 Bubble barriers has to be used only in combination with another type of barrier.

7. Fish pass effectiveness monitoring

7.1 The outcome of the monitoring is a report stating whether the fish pass meets the hydrotechnical parameters specified in the project design. The report should identify shortcomings (problematic parameters from the fish migration point of view) as well as proposals for their possible adjustments.

7.2 The monitoring is carried out at a sufficient time gap after the fish pass completion due to its operational response to the final conditions with no disturbances caused by abnormal influences related to the construction execution.

Appendix 1: Basic parameters of fish passes

Parameter	Unit	Limits for cyprinid waters	Limits for salmonid waters
Gradient of fish pass bottom level line	-	threshold 1 : 20, optimal 1 : 25	threshold 1 : 15, optimal 1 : 20
Difference between water levels at cross-walls (dH)	m	0.10	0.10 to 0.15
Water depth - riffle - pool	m	0.4 0.5 to 0.8	0.2 0.5
Reduced pool length (distance between opposite sides of slots above and below the pool)	m	1.5	2.0 for salmon 3.0
Fish pass bottom width	m	depending on discharge, min. 1.5 for salmon 2.0	depending on discharge, min. 1.2 for salmon 1.8
Width of slots in passable cross-walls (depends on width of fish pass body, number of slots, water discharge, barrier water overflow)	m	minimum 0.10 maximum 0.60	0.15 to 0.20 maximum 0.30
Maximum energy dissipation	$W \cdot m^{-3}$	90 to 135	100 to 125

Characterisation of salmonid and cyprinid waters (Section 2 of Government Decree no. 71/2003 Coll.):

a) Salmonid waters – surface waters which already are or will become suitable for salmonids (*Salmonidae*) and graylings (*Thymallus thymallus*)

b) Cyprinid waters – surface waters which already are or will become suitable for cyprinids (*Cyprinidae*), pikes (*Esox lucius*), perches (*Perca fluviatilis*), eels (*Anguilla anguilla*) and others

Appendix 2: Hydraulic calculation of fish pass components

There are different calculation procedures and formulas used for various fish pass types. The slot fish pass is considered the basic technical type of fish pass; due to that, the following calculation is linked to this type. The fish pass body comprises a concrete channel with a rectangular profile (i.e., vertical walls) and constant longitudinal gradient of the bottom.

Basic geometrical characteristics:

Total altitudinal gradient	H_{fp}	(m)
Recommended FP discharge	Q_{fp}	($m^3.s^{-1}$)
Recommended longitudinal gradient	i_{rec}	(-)
FP length	L_{fp}	(m)
Inlet (exit) length	L_{inlet}	(m)
Channel width	B_{fp}	(m)

Pools:

Pool length	L_{pool}	(m)
Pool width	B_{pool}	(m)
Poll medium velocity	v_{pool}	($m.s^{-1}$)

Slot:

Slot width	B_{slot}	(m)
Number of slots in cross-wall	n_{slot}	(pc)
Minimum water depth	h_{min}	(m)
Maximum water depth	h_{max}	(m)
Water level difference in slot	dh	(m)
Water velocity in slot	v_{max}	($m.s^{-1}$)

Calculation procedure

1. Calculation of maximum water level differences between cross-walls based on v_{max}

$v_{authorised}$ is determined by target fish species

$$v_{authorised} = \varphi \cdot \sqrt{2 \cdot g \cdot \Delta h_{authorised}}$$ after adjustment

$$\Delta h_{authorised} = \frac{{v_{authorised}}^2}{2 \cdot g \cdot \varphi^2}$$ where the outlet factor φ = 0.70-0.80

2. The minimum number of slots can be calculated from the total FP gradient

$$n_{min} = \frac{dH}{\Delta h_{authorised}}$$

The resulting number of slots is rounded up.
$n = \text{round\_up}(n_{min})$

3. Recommended gradient in the cross-wall is calculated

$$\Delta h = \frac{dH}{n}$$

4. Checking the maximum outlet velocity in a slot

$$v_{max} = \varphi \cdot \sqrt{2 \cdot g \cdot \Delta h} < v_{authorised}$$

For possible decreasing of water velocity, it is necessary to lower the gradient in the cross-wall, consequently increase the number of cross-walls and repeat the calculation from point 3.

5. Minimum depth *(h_{min})* of a fish pass pool is designed according to recommendation.

6. Reduced width of a slot *(B_{slot})* is calculated; in the case of more slots, the total width *∑B* is established.

$$B_{slot} = \frac{Q_{recommended}}{\varphi \cdot h_{min} \cdot \sqrt{2 \cdot g \cdot \Delta h}}$$

B_{slot} is rounded.

7. Discharge in the fish pass is calculated according to the following:

a) In the case of height continuity of bottoms in adjoining pools, it is recommended to use the equation for an outlet flooded from below at the pressure head *dh*.

$$Q = \varphi \cdot h_{min} \cdot B_{slot} \cdot \sqrt{2 \cdot g \cdot \Delta h},$$

b) In the case of a higher sill above the pool bottom, it is recommended to use the equation for a submerged spillway with a height of overflow jet h_{max} and flooding h_{min} (higher sills are not suggested for technical slot fish passes).

$$Q = \frac{2}{3} \cdot \mu \cdot \sigma_Z \cdot B_{slot} \cdot \sqrt{2 \cdot g} \cdot (h_{max})^{3/2}$$

where μ = 0.70 – 0.80 as the overflow factor, σ_z as the flooding factor.

$$\sigma_z = \left[1 - \left[1 - \frac{\Delta h}{h_{max}}\right]^{1,5}\right]^{0,385}$$

The slot width is modified according to the required discharge.

8. Checking of fish pass inlet according to the overflow equation; it is necessary to take into account the loss at the inlet and the water level decrease when the velocity increases (Note: *Because the losses are presented as the function v^2, discharge reduction due to water level decrease can become critical. Due to this, it is recommended to design the inlet and slot size in the first cross-wall slightly larger)*.

$$v_0 = \frac{Q}{B_{fp} \cdot h_{max}}$$

where v_0 is the inflow velocity at the FP inlet.

$$h_e = 0,85 \cdot (h_{max} + \frac{v_0^2}{2 \cdot g})$$

where h_e is the reduced total head including hydraulic losses in the inlet.

$$Q_{kap} = 0,54 \cdot B_{slot}\sqrt{2 \cdot g} \cdot h_e^{3/2}$$

The control term is $Q_{kap} > Q$

In the case of non-compliance, it is necessary to increase the water inlet volume by widening or deepening it.

9. Checking the character of flow in the slot

$$Fr_{slot}^2 = \frac{v_{max}^2}{g \cdot h_{min}}$$

Fr <1 in riverine flow.

Note: It is necessary to maintain the riverine flow regime in the slot to prevent hydraulic jump. In the case of non-compliance, it is necessary to decrease v_{max} or increase h_{min}.

10. Designing the pool length

Based on the recommended longitudinal gradient, the recommended pool length is calculated. Based on the recommended pool length, the appropriate higher L_{pool} value is set.

$$L_{recommended} = \frac{100 \cdot \Delta h - i_{recommended} \cdot w}{i_{recommended}}$$,

where $i_{recommended}$ recommended longitudinal gradient of bottom (%)
L_{pool} pool length (m)
w cross-wall width (m)

$L_{pool} \geq L_{recommended}$

The total length of the FP trough is given by

$L_{FP} = (n-1) \,.\, (L_{pool} + w)$,

where L_{FP} is the total FP trough length (m) excluding the inlet and outlet lengths.

11. Checking the dissipated energy in each pool

$P = Q . \Delta h . \rho . g$,

Where P dissipated energy in each pool (W)
ρ specific gravity of water (1000 kg.m^{-3})
g acceleration of gravity (9.81 m.s^{-2})

$V_{pool} = h_{min} \,.\, B_{fp} \,.\, L_{pool}$,

where V_{pool} is the water volume in the pool (m^3)

$$P_{spec} = \frac{P}{V_{pool}}$$,

where P_{spec} is specific dissipated power (W.m^{-3}).

Depending on the fish species and size, it is necessary to determine the admissible specific dissipated power.

$P_{spec} < P_{spec\_authorised}$,

where $P_{spec\_authorised}$ is the maximum admissible specific dissipated energy (W.m^{-3}).

If the condition is not met, it is recommended to increase the pool volume by lengthening or deepening it.

Notes on basic characteristics of FP:

- If limited by space, it is possible to fold the channel or lower the required discharge and thus reduce the length of each pool while maintaining the slot gradient.

- When increasing the design discharge, it is necessary to increase the pool length or even the water depth in the pool because it is necessary to limit the specific dissipated energy. If the construction space is limited, the most suitable option is to decrease the design discharge.

- It is practical to oversize the volume of the first slot and subsequently, when the FP comes into operation, modify the size of the slot in the first cross-wall. It is suitable to use, e.g., a higher bottom sill with a ramp leading to the original bottom. This reduces the discharge to meet the water level requirements – especially to prevent the overflowing of vertical walls of cross-walls and secure the minimum water depth in pools. In the case of insufficient inlet capacity, increasing it additionally will lead to technical problems.

Step	Example calculation of slot fish pass characteristics – Cyprinid waters					
	Variable	**Symbol**	**Value**	**Unit**	**Requirement**	**Evaluation**
Input data	**Total gradient**	**dH**	2.000	m	Depending on water level differences	
	Recommended discharge	**Q**	0.250	m^3/s	NCA CR requirement	
	Maximum authorised velocity	v_authorised	1.000	m/s	According to recommendations	
1	Outlet factor	fi	0.710	-		
	Calculated gradient in slot		0.101	m		
	Minimum number of cross-walls		19.8	Pc		
2	**Number of cross-walls**	**n**	20.0	pc		
3	**Gradient in slot**	**dh**	0.100	m		
4	**Maximum velocity in slot**	**v_max**	0.994	m/s	<= v_approved	approved
5	**Minimum water depth in pool**	**h_min**	0.600	m	According to recommendations	
	Maximum water depth in pool	**h_max**	0.700	m		
	Calculated slot width		0.419	m		
	Recommended slot width	**B_slot**	0.420	m	According to recommendations	
7a	Discharge – lower outlet	Qa	0.250	m^3/s	>= Q	approved
7b	*Flooding factor*	*σ*	*0.545*	-		
	Overflow factor	*μ*	*0.710*	-		

	Discharge – flooded overflow	*Qb*	*0.281*	*m^3/s*		
8	**FP width**	**B_fp**	1.800	m		
	Water velocity in inlet	v_o	0.198	m/s		
	Reduced energy height	h_e	0.597	m		
	Inlet capacity	Q_inlet	0.463	m^3/s	>= Q	approved
9	Froude number	Fr_ slot^2	0.168	-	< 1	approved

Step	**Example calculation of slot fish pass characteristics – Cyprinid waters**					
	Variable	**Symbol**	**Value**	**Unit**	**Requirement**	**Evaluation**
10	Recommended longitudinal gradient	i_recommended	4.000	%	1:20 - 1:25	
	Cross-wall with	w	0.120	m		
	Recommended pool length		2.380	m		
	Pool length	**L_pool**	2.400	m	>= L_recommended	approved
	Longitudinal gradient	**i_fp**	3.968	%	< i_recommended	approved
	Trough length	L_fp	47.880	m		
11	Dissipated power at cross-wall	P	245.3	W		
	Pool volume	V_pool	2.592	m^3		
	Maximum specific dissipated power	P_spec_max	100.0	W/m^3	According to recommendations	
	Specific dissipated power	P_spec	94.6	W/m^3	< P_spec_max	approved

Step	**Example calculation of slot fish pass characteristics – Salmonid waters**					
	Variable	**Symbol**	**Value**	**Unit**	**Requirement**	**Evaluation**
Input data	**Total gradient**	**dH**	2.000	m	Depending on water level differences	
	Recommended discharge	**Q**	0.250	m^3/s	NCA CR requirement	

	Maximum authorised velocity	v_authorised	1.200	m/s	According to recommendations	
1	Outlet factor	fi	0.710	-		
	Calculated gradient in slot		0.146	m		
	Minimum number of cross-walls		13.7	pc		
2	**Number of cross-walls**	**n**	14.0	pc		
3	**Gradient in slot**	**dh**	0.143	m		
4	**Maximum velocity in slot**	**v_max**	1.188	m/s	<= v_approved	approved
5	**Minimum water depth in pool**	**h_min**	0.500	m	According to recommendations	
	Maximum water depth in pool	**h_max**	0.643	m		

Step	**Example calculation of slot fish pass characteristics – Salmonid waters**					
	Variable	**Symbol**	**Value**	**Unit**	**Requirement**	**Evaluation**
6	Calculated slot width		0.421	m		
	Recommended slot width	**B_slot**	0.425	m	According to recommendations	
7a	Discharge – lower outlet	Qa	0.252	m^3/s	>= Q	approved
7b	*Flooding factor*	*σ*	*0.640*	-		
	Overflow factor	*μ*	*0.750*	-		
	Discharge – flooded overflow	*Qb*	*0.311*	*m^3/s*		
8	**FP width**	**B_fp**	2.050	m		
	Water velocity in inlet	v_o	0.190	m/s		
	Reduced energy height	h_e	0.548	m		
	Inlet capacity	Q_inlet	0.412	m^3/s	>= Q	approved
9	Froude number	Fr_ slot^2	0.288	-	< 1	approved
10	Recommended longitudinal gradient	i_recommended	5.000	%	1:20 - 1:25	
	Cross-wall width	w	0.120	m		

	Recommended pool length		2.737	m		
	Pool length	**L_pool**	2.800	m	>= L_recommended	approved
	Longitudinal gradient	**i_fp**	4.892	%	< i_recommended	approved
	Trough length	L_fp	37.960	m		
11	Dissipated power at cross-wall	P	350.4	W		
	Pool volume	V_pool	2.870	m^3		
	Maximum specific dissipated power	P_spec_max	125.0	W/m^3	According to recommendations	
	Specific dissipated power	P_spec	122.1	W/m^3	< P_spec_max	approved

Applying the hydraulic calculation to different types of FP:

The slot fish pass can be considered basic due to its precisely specified structural geometry. Chutes are very sensitive to water level fluctuation in the headwater, i.e., the recommended parameters (mainly velocities) can be exceeded even during slightly higher water conditions.

The calculation procedure for the basic parameters of the boulder pool fish pass does not vary from the slot FP type, but a few differences should be considered:

- There are random deviations between the real and recommended dimensions of the trough and the boulder cross-walls (i.e., height and width).
- There is no constant clearance along the slot; the slot width has to correspond to the minimum authorised width for the actual fish species.
- Non-vertical boulder sidewalls direct the flow differently. Due to this, the final flow in the pool varies from the planned flow.
- Intensive coarsening of walls and the bottom induces more effective buffering of the water energy in comparison to a concrete structure. That is why it is possible to stay close to the maximum approved values (e.g., specific dissipated power) and keep the same recommended parameters.
- It is necessary to calculate with the real water volume in the pool when evaluating the specific dissipated energy in the dish-shaped cross-section of the pool fish pass.
- If the fish pass location is limited by space, a smaller number of slots is recommended because water discharge and demands on the pool water volume increase with the number of slots.
- The first two slots should be higher to prevent overflow of the cross-wall during high water; excess water would increase the specific dissipated power. Also deeper

slots with higher cross-walls are suggested to prevent non-flood overflow over the low edge of the boulder; non-flood overflow usually has insufficient height and increases the water turbulence in the pool.

- Due to the randomness of shapes and dimensions of boulders used, it is suitable to oversize the volume of the first two cross-walls (about 10–20%). When brought into operation, required discharge and water levels in the fish pass can be modified by narrowing the slot or raising the slot sill. Within the recommended layout (headwater and tailwater), the difference in water levels in each slot will be approximately identical all across the fish pass. In the case of variances, different water levels can be set by modifying the slot area. In the case of significant differences in gradient between the slots, the maximum approved velocities will be probably exceeded.

Appendix 3: Schematic representation of fish pass design (activities supported by grant programmes)

Basis	Water management conditions – discharge, water debris transport and other hydrological data. Property conditions – ownership, watercourse, water dam, adjacent land or buildings and thoroughfares. Ichthyological conditions – survey and assessment.
Investor (natural or legal person)	Pre-project studies Feasibility studies Investment project (IP) Consultations with Nature Conservation Authority and NCA CR regional office
Authorised designer	Elaboration of documents
NCA CR	Expert advice on investment project or on documents elaborated for zoning planning procedure (or technical documentation for building permit if required by investor or authorised designer)
Building authority	Zoning planning procedure for building location Binding opinion of Nature Conservation Authority Location decision
Investor	Grant application* including approved design documents and final decision on building location
Water authority (special building authority)	Building proceedings Documentation for building permit Hydraulic structure building permit procedure Permission for water use procedure Binding opinion of Nature Conservation Authority Documents for project execution Buildings for notification
Investor	Grant awarding Technical and authorial supervision Construction work
Water authority	Inspection procedure including conclusions from building inspection As-built documentation (decision on entry into early or trial operation) Completion of construction and permanent use of building –final inspection
NCA CR	FER granting within aid programme administration (based on results of FP

	monitoring, evaluation of its functionality, or minor modifications to FP routes if any)

* Aid programmes enabling aid for construction of fish passes:
  - Operational Programme Environment (OPE)
  - Landscape Natural Function Restoration Programme (LNFRP)

List of acronyms and abbreviations:

NCA CR = Nature Conservation Agency of the CR
CHMI = Czech Hydrometeorological Institute
NCSOFDD = Species Occurrence Database
SHP = Small hydropower plant
MRF = Minimum residual flow
MoE = Ministry of the Environment of the CR
OPE = Operational Programme Environment
FP = Fish pass
FER = Final evaluation report

Appendix 4: Indicative list of fish species in salmonid and non-salmonid communities of small streams (by distance from spring)

Watercourse length from spring		
under 10 km	10 to 20 km	20 to 40 km
Salmonid community	**Salmonid community**	**Salmonid community**
Brown trout (*Salmo trutta* m. *fario*) Eurasian minnow (*Phoxinus phoxinus*) European bullhead (*Cottus gobio*) Alpine bullhead (*Cottus poecilopus*) Stone loach (*Barbatula barbatula*) Brook lamprey (*Lampetra planeri*)	Brown trout (*Salmo trutta* m. *fario*) European grayling (*Thymallus thymallus*) Eurasian minnow (*Phoxinus phoxinus*) Gudgeon (*Gobio gobio*) Stone loach (*Barbatula barbatula*) European bullhead (C*ottus gobio*) Alpine bullhead (*Cottus poecilopus*) Brook lamprey (*Lampetra planeri*)	Brown trout (*Salmo trutta* m. *fario*) European grayling (*Thymallus thymallus*) Eurasian minnow (*Phoxinus phoxinus*) Gudgeon (*Gobio gobio*) Riffle minnow (*Alburnoides bipunctatus*) Stone loach (*Barbatula barbatula*) European bullhead (C*ottus gobio*) Brook lamprey (*Lampetra planeri*)
Non-salmonid community	**Non-salmonid community**	**Non-salmonid community**
Common chub (*Leuciscus cephalus*) Eurasian minnow (*Phoxinus phoxinus*) Gudgeon (*Gobio gobio*) Stone loach (*Barbatula barbatula*) Brook lamprey (*Lampetra planeri*)	Common chub (*Leuciscus cephalus*) Common dace (*Leuciscus leuciscus*) Common barbel (*Barbus barbus*) Gudgeon (*Gobio gobio*) Riffle minnow (*Alburnoides bipunctatus*) Stone loach (*Barbatula barbatula*)	Common roach (*Rutilus rutilus*) Common chub (*Leuciscus cephalus*) Common dace (*Leuciscus leuciscus*) Common nase (*Chondrostoma nasus*) Common barbel (*Barbus barbus*) Gudgeon (*Gobio gobio*) Riffle minnow (*Alburnoides bipunctatus*) Stone loach (*Barbatula barbatula*) Burbot (*Lota lota*)

Appendix 5: Figures

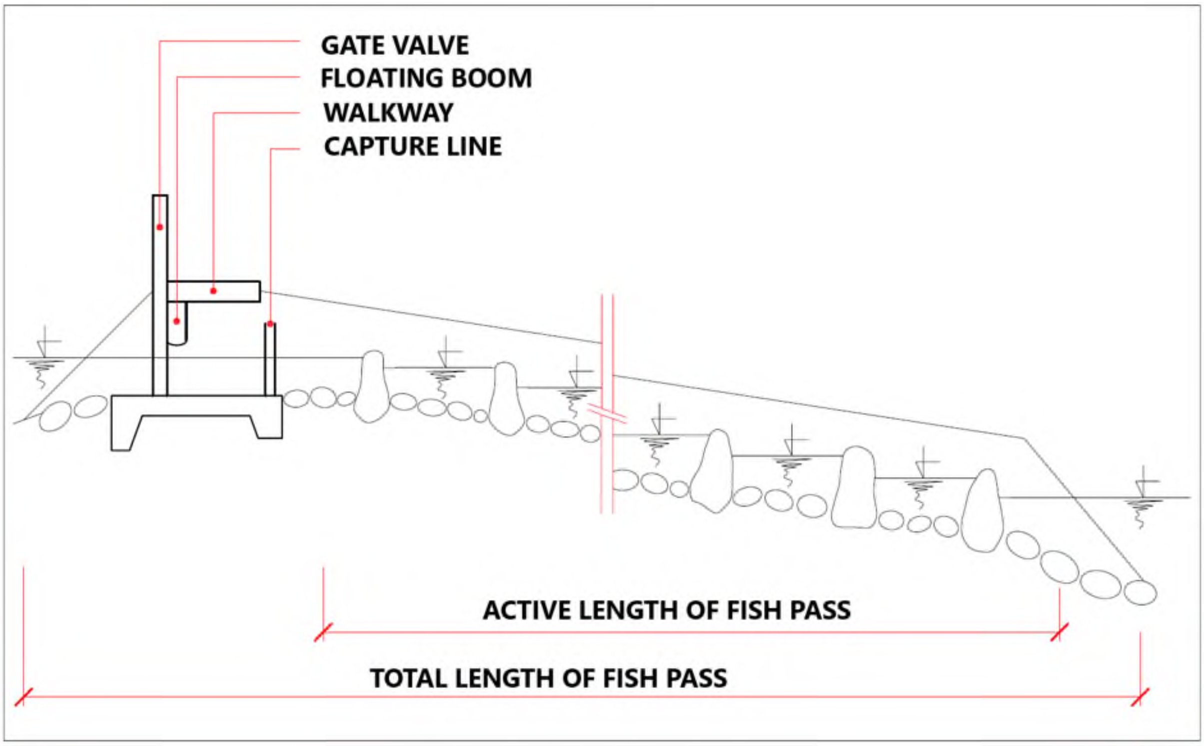

Fig. 1: Fish pass gradient (4.3.3)

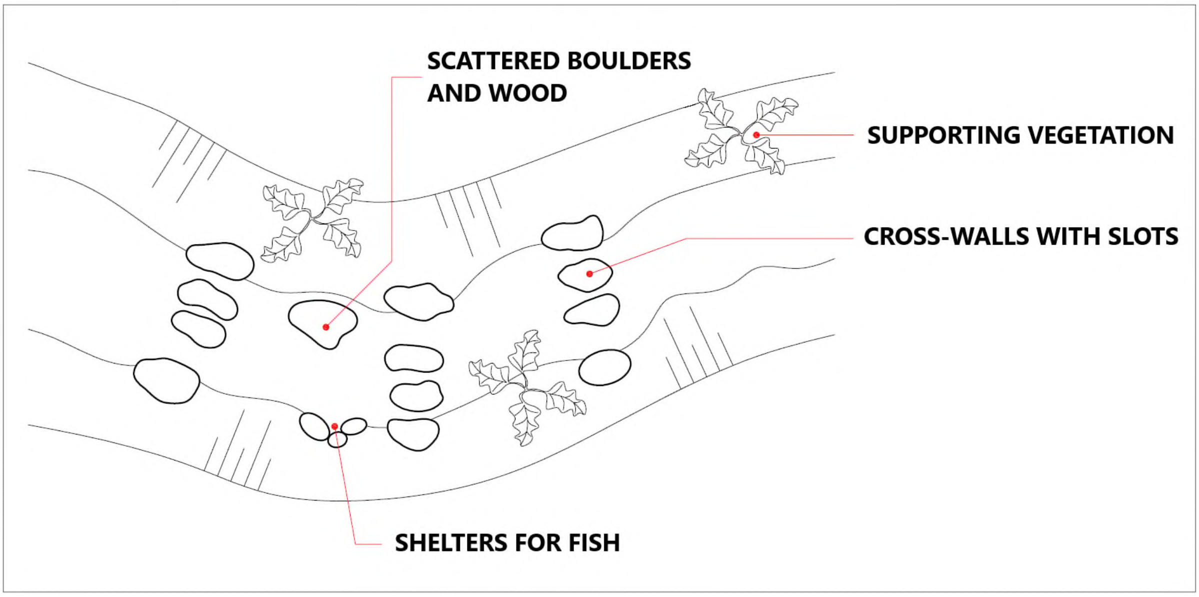

Fig. 2: Close-to-nature bypass channel (4.4.1)

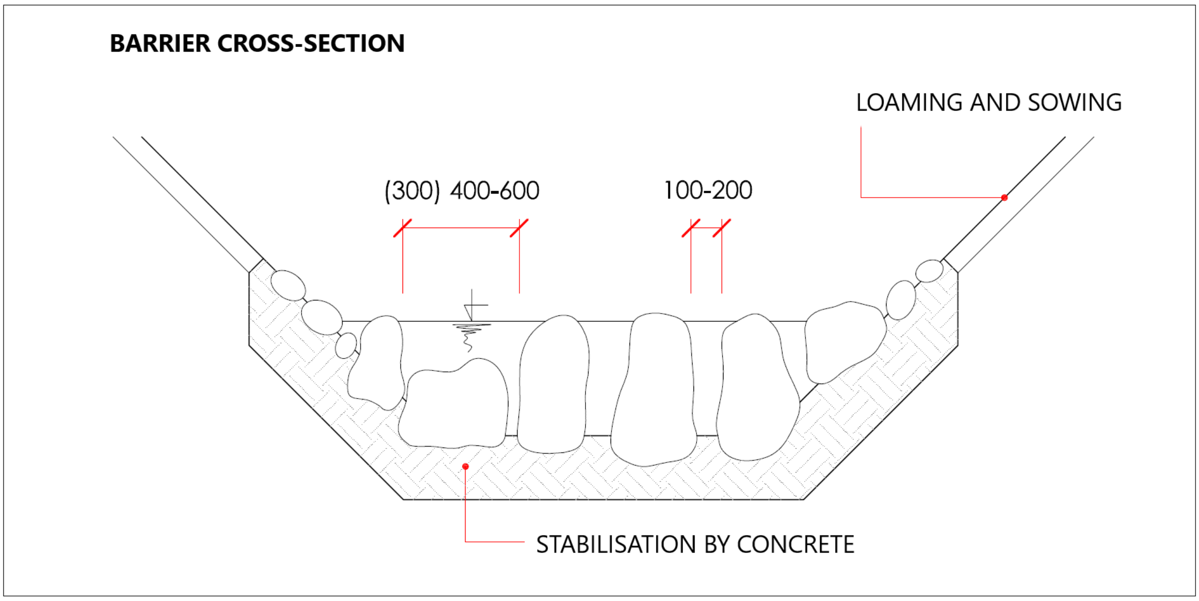

Fig. 3 Barrier cross-section (4.4.1)

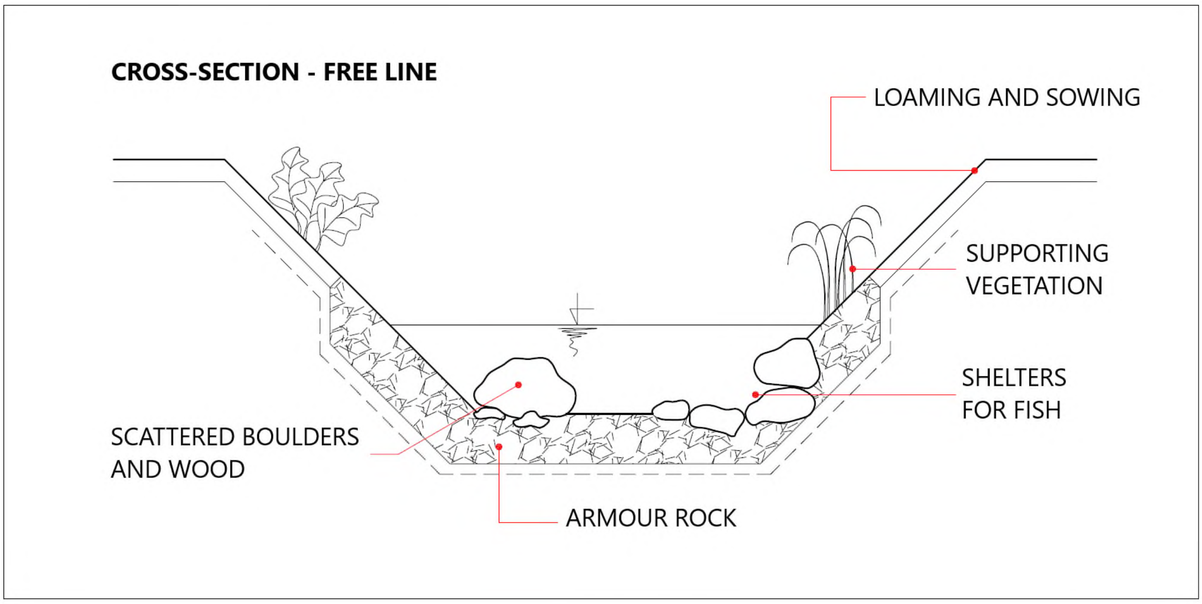

Fig. 4: Pool cross-section (4.4.1)

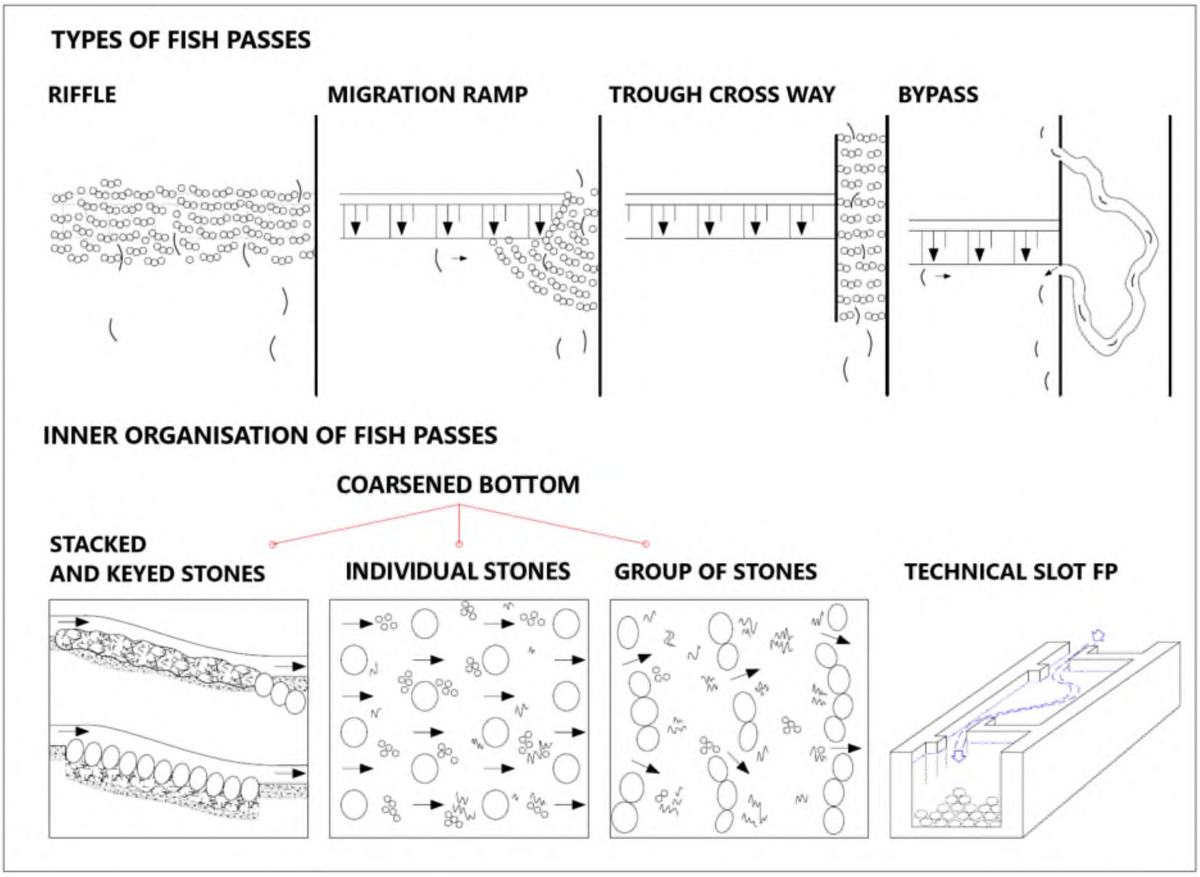

Fig. 5: Bottom riffles and ramps, bottom coarsening (4.4.2 and 4.4.5)

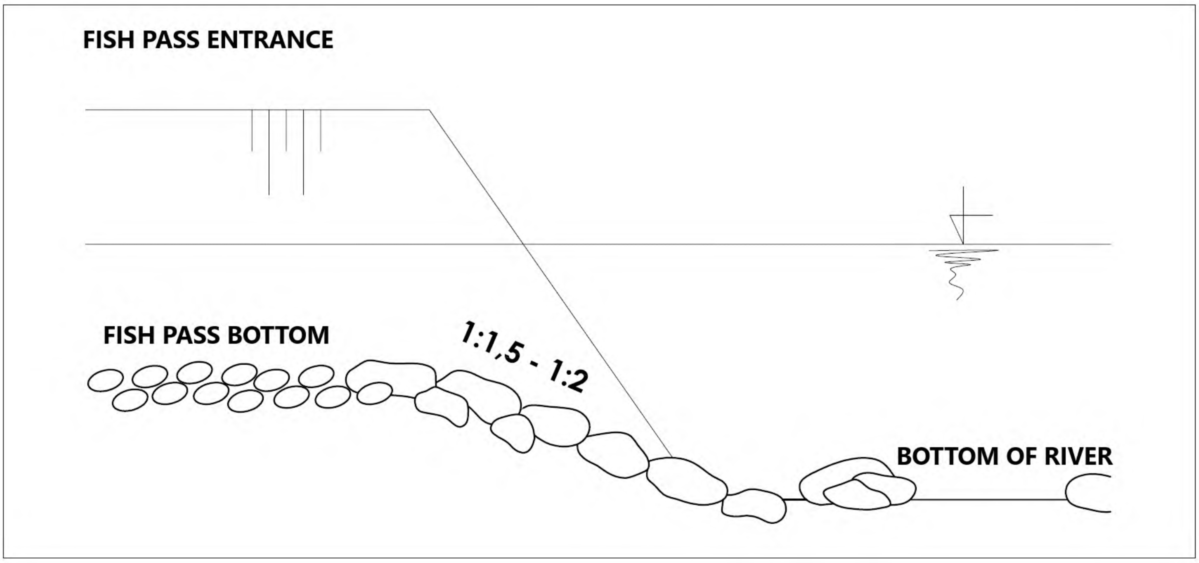

Fig. 6: Fish pass entrance (4.5.1)

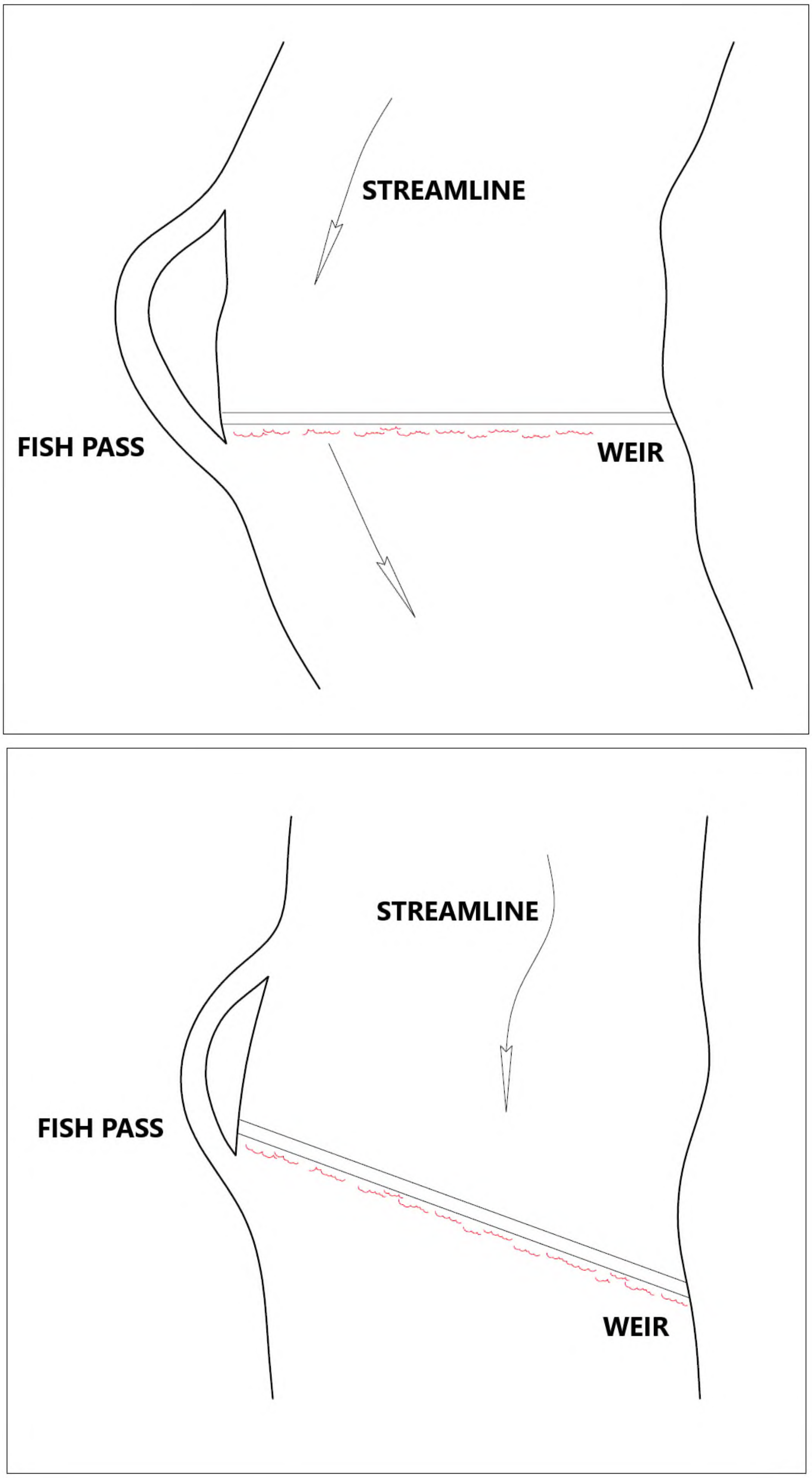

Fig. 7: Fish pass location depending on migration barrier type (4.8.2)

Appendix 6: List of existing standards for nature and landscape management (water in landscape)

00	**General**
00 001	Terminology
01	**Controls, evaluation, planning**
01 001	Controls, evaluation, planning
02	**Technological processes**
02 001	Creation and restoration of pools
02 002	Renaturisation of the water regime of mires and springs
02 003	Restoration of watercourses and their floodplains
02 004	River management including bank vegetation
02 005	Nature-friendly fishpond management
02 006	Fish passes
03	**Safety at work and health protection**

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SPPK B02 006: 2014
aopk.gov.cz/platne-standardy
2014