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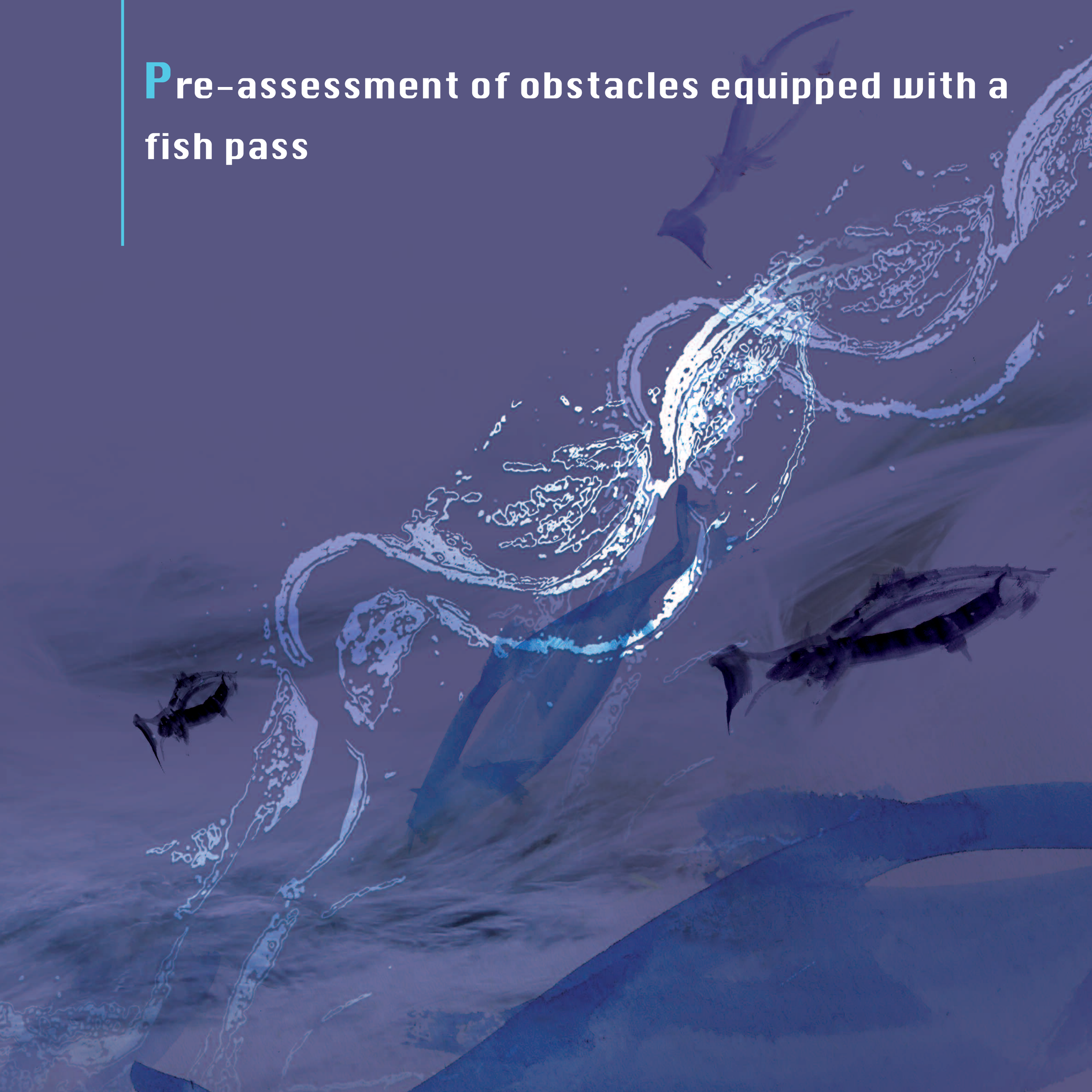
Pre-assessment of obstacles equipped with a fish pass



The different types of fish pass

This chapter presents the main types of fish pass likely to be encountered at structures and explains the general operating principles.

For more information, a number of technical guides on system sizing may be consulted, notably those listed below:

- *Larinier M., Porcher J.P., Travade F., Gosset C. (1994). Passes à poissons. Expertise, Conception des ouvrages de franchissement. Conseil Supérieur de la Pêche. Collection Mise au point.*
- *Larinier M., Courret D., Gomes P. (2006). Guide technique pour la conception des passes « naturelles ». Rapport Ghaappe RA.06.05-V1.*

Most of the information below is drawn from the two guides listed above. They may be consulted on the EauFrance portal (www.documentation.eaufrance.fr).

Pool-type fish passes

■ Basic idea behind pool-type fish passes

The basic idea is to divide the total height that the fish must overcome into a series of pools. The water can flow from one pool to the next by overflowing each partition, by flowing through one or more orifices in the partitions separating the pools or by flowing through one or more slots or notches. There are also hybrid fish passes where the water flows both over the partitions and through a submerged orifice.

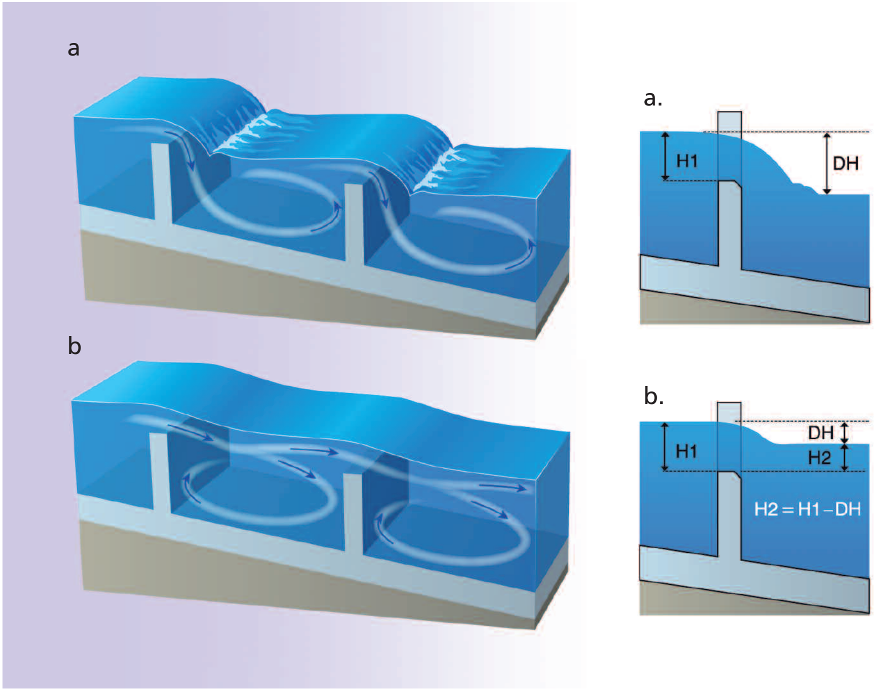
The main parameters of a fish pass are the size of the pools and the geometric characteristics of the partitions which, depending on the water level upstream and downstream of the fish pass, determine the hydraulic characteristics of the fish pass (discharge, water flow between pools, flow characteristics in each pool).

■ Head-drop between each pool and type of flow

The head-drop DH between each pool depends on the swimming and jumping capabilities of the species in question.
The flow may be a plunging jet (see Figure 108a) or a skimming flow (see Figure 108b). In the first type, the jet that forms over each partition plunges to the bottom of the pool. The energy is dissipated in the turbulent mixing and dispersed in the hydraulic jump at the foot of the fall. The fish must jump through the sheet of water flowing over the partition to reach the next pool. Plunging jets must imperatively be avoided for species that cannot jump.

When a skimming flow exists, the energy is dissipated in the lower pool through the creation of large recirculation currents. This type of flow occurs when the downstream water level is higher than the top of the partition and the depth of water higher than the partition is equal to approximately one-half of the overflow height.

Figure 108



Types of flow over partitions in pool-type fish passes. (a) Plunging jet, (b) skimming flow.

■ Size of pools

The minimum length of pools is primarily a function of the size of the fish using the fish pass. A minimum length of approximately 2.5 to 3 times the length of the largest fish is generally recommended.

Similarly, the minimum depth of the pools is also a function of the species in question. For large migratory salmonids, the minimum depth should be around one metre. For trout, lesser depths of approximately 0.75 metre are possible.

In fish passes with plunging jets, the depth of water immediately below the jet must be at least double the head-drop between pools to enable fish to prepare the jump.

Practically speaking, it is generally the hydrodynamic conditions (discharge, head-drop between pools, jet characteristics) that determine the minimum dimensions of the pools.

Difficulties for fish increase with the degree of turbulence and aeration in the pools. A simple indicator of the agitation in the pools of a fish pass is the dissipated power density (expressed in Watts/m^3).

■ Minimum dimensions of notches, orifices and slots

For skimming flows, notches and slots must generally be at least 30 to 40 cm wide for large migratory salmonids, 40 to 50 cm for shad, 25 cm for rheophilic cyprinids and 15 cm for very small species.

For plunging jets, much larger widths are required, particularly if fish must make a considerable effort to jump to the upper pool.

For all species, even the smallest, passageways should be wide enough (greater than 15 to 20 cm) to avoid making the pass excessively vulnerable to clogging by debris.

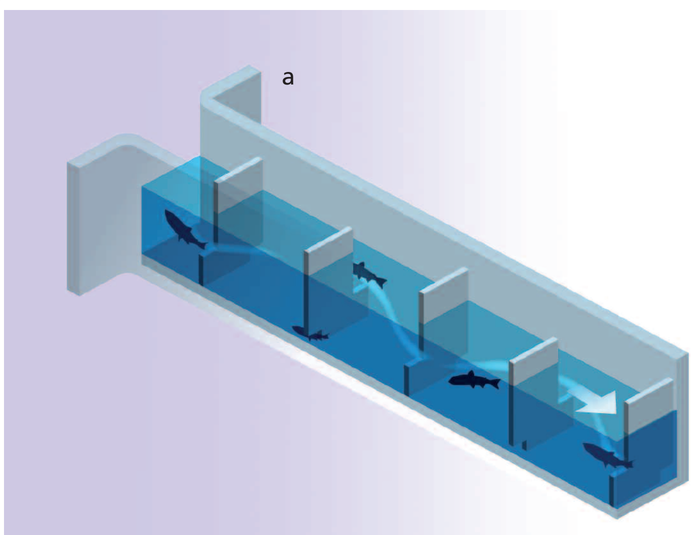
For orifices at the bottom of the pool intended for the passage of fish, the minimum surface area is approximately 0.1 square metre for large fish and 0.03 square metre for trout and most cyprinids.

■ The main forms of pool-type fish passes

Passes with deep, lateral notches and submerged orifices

Travel between pools takes place via lateral notches and bottom orifices located on opposite sides of each partition and changing sides from one partition to the next. A deflector on the upstream face of each partition stabilises the flow and reduces the "curl" of the water around the end of the partition (see Figure 109).

Figure 109



b © Mayeras - Ecogea
c © Voegtlé - Ecogea

Diagram and examples of fish passes with lateral notches and bottom orifices. (a) Diagram, (b) fish pass with lateral notches at the Las Rives weir on the Ariège River, (c) fish pass with lateral notches at the Eygun draw-off on the Gave d'Aspe River.

Fish passes with vertical slots

The currents passing through the slots (when two slots exist) converge and meet in the central section of the downstream pool, effectively dissipating the flow energy and creating calm zones on each side of the pool and in the area immediately downstream of the partition (see Figure 110).

The major advantage of fish passes with vertical slots is that they can handle significant variations in the upstream water level, on the condition that similar variations occur on the downstream level.

In addition, if the slots extend to the bottom of the pool, this type of pass is suitable for both benthic and open-water species due to the velocity gradient.

Figure 110

b, c © Voegtlé - Ecogea

Diagram and examples of fish passes with vertical slots. (a) Diagram, (b) fish pass with two slots for each pool at the Coy dam on the Gave de Pau River, (c) fish pass with a single slot for each pool at the Susmiou factory on the Gave d'Oloron River.

Fish passes with triangular notches

Fish passes with triangular notches were designed to create a type of pass capable of operating under a wide range of upstream discharge and water-level conditions without requiring added discharge in the downstream section or a device regulating the upstream discharge. In this type of pass, the water flows over each partition into the next pool. The profile of each partition is triangular or semi-triangular. The result is generally a mixed form of operation, with a skimming flow over the lower part of the partition and a plunging jet on the sides (see Figure 111).

Under high-water conditions, a fast skimming flow forms in the centre of the pass whereas the lateral flows remain manageable for the fish. Fish passes with triangular notches function as pool-type passes under low-flow conditions and as a rough channel under high-water conditions. There is consequently no point in attempting to reason in terms of the maximum dissipated power density in a given pool.

Figure 111

a © Larinier - Ecohydraulic centre
b © Voegtle - Ecogea

Examples of fish passes with triangular notches. (a) The Sarrancolin fish pass with triangular notches on the Neste River, (b) the Jaulnes fish pass with triangular notches on the Seine River.

Pre-barrages

Pre-barrages often represent an elegant solution to assist fish in overcoming relatively low obstacles. The system consists of several walls or weirs creating large pools downstream of the obstacle, thus splitting the total height that must be overcome (see Figure 112). They are generally located near one of the river banks to facilitate their maintenance. On small rivers, they can span the entire riverbed without causing any problems.

Given that the flow between two pools is generally a plunging jet and that the fall is greater than 40 to 50 cm, this type of fish pass is suitable for jumping species and specifically salmonids. However, particularly for low obstacles, this type of fish pass can be adapted to the needs of less agile species by reducing the height between pools and ensuring a skimming flow between pools.

Figure 112

b, c © Voegtlé - Ecogea

Examples of pre-barrages. (a) Pre-barrages at the Guilhot dam on the Ariège River, (b) pre-barrages at the Gurmençon dam on the Gave d'Aspe River.

Rock-chute fish passes

Rock-chute fish passes consist of a channel linking the upstream and downstream reaches in which the flow energy is dissipated by roughness along the bottom and sides and/or a succession of obstacles (rocks, groynes, weirs, etc.) positioned more or less regularly in order to create a passageway for the fish.

This type of pass represents a rough equivalent to a natural river with a high slope. They generally require the installation of large rocks to dissipate the energy, reduce flow velocities and increase the water depth.

The slope is fairly low compared to other fish passes and varies from 1% to a maximum of 10%, depending on the species in question.

The pass can be installed across part or the entire width of the obstacle or to the side (bypass branch).

Two main types of rustic rock-chute fish passes exist. They differ on how the energy is dissipated by the elements disrupting the flow:

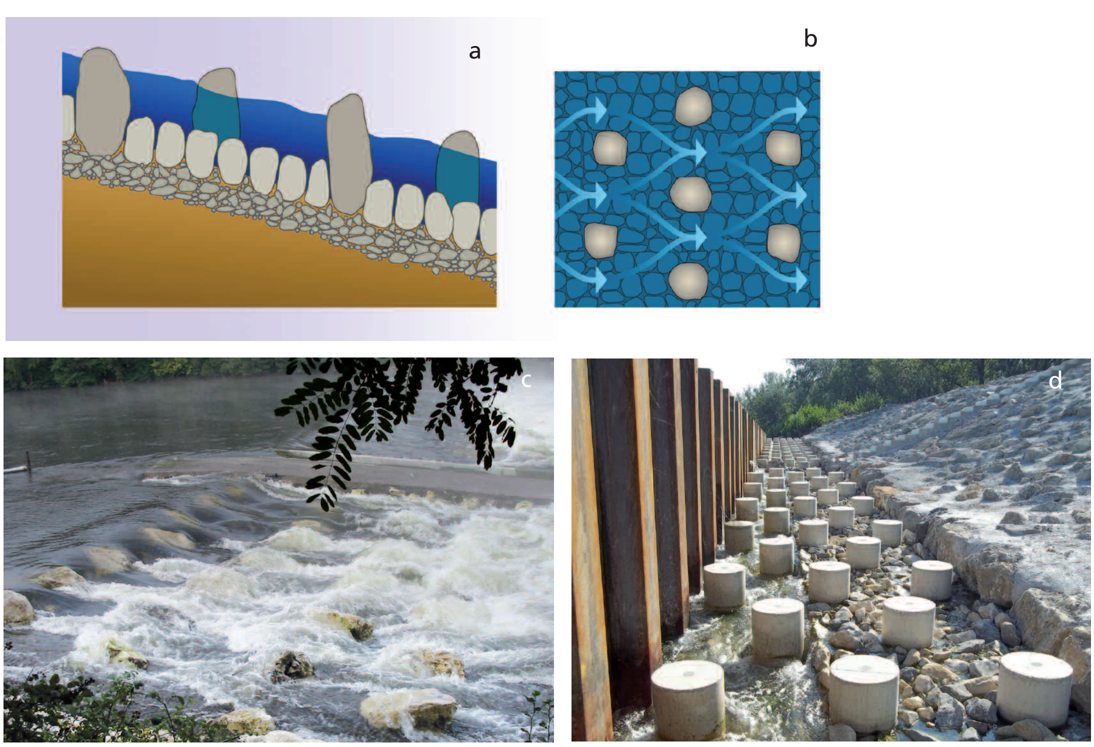
- **fish passes with staggered arrays of elements;**
- **fish passes with successive rows of elements.**

Rock chutes made up of joined riprap, in a compact layout forming a continuous rough surface, pose problems for many fish species. **They cannot be considered true fish passes unless the longitudinal slope remains very slight (less than 3%).**

Fish passes with staggered arrays of elements

In this configuration, the flow energy is dissipated by the more or less regularly distributed large elements spread separately over the rock chute (see Figure 113).

Figure 113



Diagrams and examples of rock chutes with staggered arrays of elements.
(a) and (b) Diagrams of rock chutes with staggered arrays of elements, (c) rock chute at the Carennac weir on the Dordogne River, (d) fish pass at the weir for the ASF A7 highway over the Rubion River.

a, b © according to Larinier et al, 2006
c © Chanseau - Onema
d © Roche - Onema

Each area immediately downstream of the large elements is a shelter and rest zone for migrating fish.

The spaces between elements (lateral and longitudinal distances) are generally regular and depend on the slope of the chute, the discharge transiting the pass and the passage capabilities of the given species.

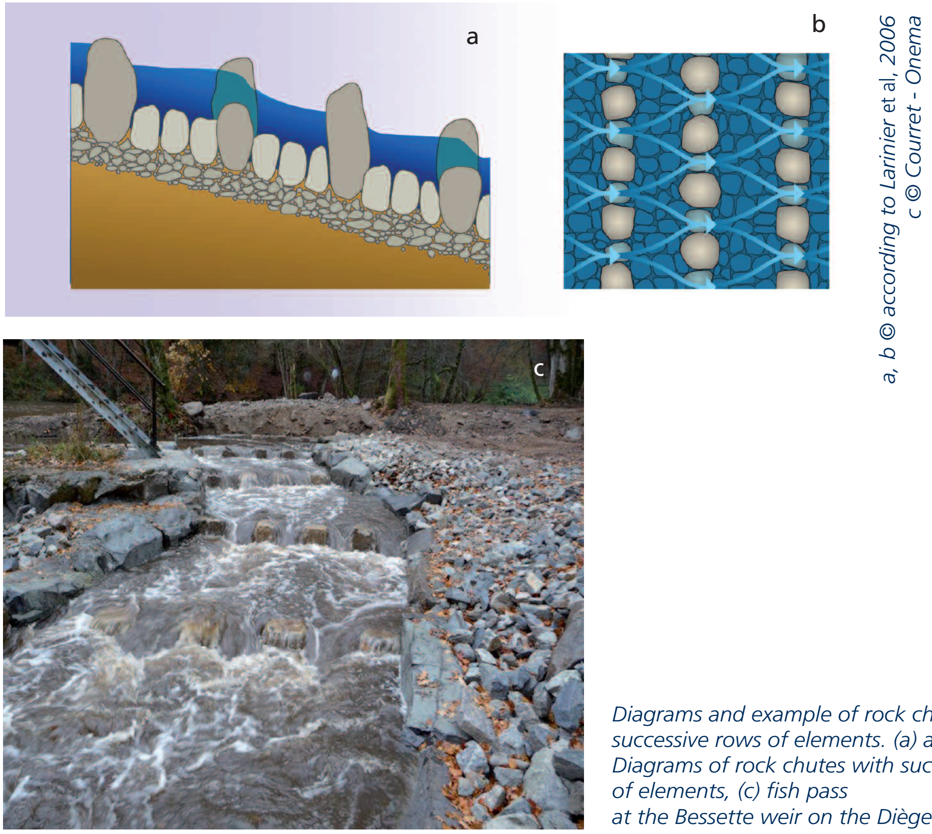
The surface roughness reduces the flow velocity near the bottom, which facilitates passage for smaller species.

Fish passes with successive rows of elements

One means to maintain sufficient water depths while limiting the discharge is to arrange the rocks in rows at regular intervals. The result is a set of virtual pools where fish are likely to find rest zones (see Figure 114).

This type of pass is very similar to "standard" pool-type fish passes and the sizing criteria are fairly comparable.

Figure 114



Diagrams and example of rock chutes with successive rows of elements. (a) and (b) Diagrams of rock chutes with successive rows of elements, (c) fish pass at the Bessette weir on the Diège River.

Denil fish passes

The general idea is to install in a straight, rectangular channel, with a relatively steep slope, baffles on the bottom and/or the sides to reduce the average flow velocities.

The baffles may be more or less complex in shape. They cause helical, secondary currents that significantly dissipate the flow energy.

Each section of a Denil fish pass does not provide rest zones and fish must transit without stopping. When the head-drop between upstream and downstream is significant, the fish must make an intense effort over a time span that can easily exceed their endurance. For this reason, it may be necessary to break the fish pass into sections with rest basins between each section.

■ Pros and cons of Denil fish passes

Flow velocities and aeration in Denil fish passes tend to be very high. This type of pass should be used for large fish having good swimming capabilities, such as salmonids migrating over long distances, lampreys and certain large holobiotic species (trout, barbel, etc.).

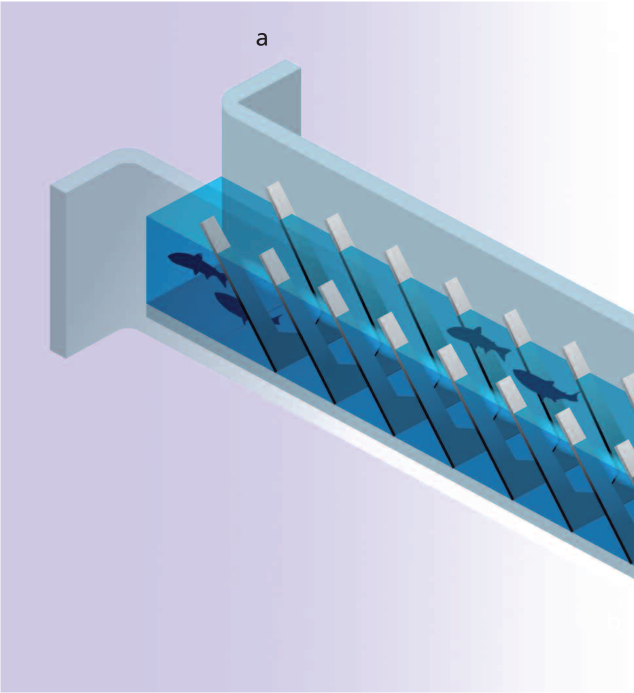
Generally speaking, Denil fish passes are intended for fish more than 30 cm long. They may be used for smaller species if the baffles are significantly reduced in size.

■ The different types of Denil fish passes

Fish passes with plane baffles

This is a commonly used type of fish pass. The main advantage is that the plane baffles, installed at a 45° angle to the slope of the channel, are very easy to manufacture (see Figure 115). The width of the channel can vary between 60 cm and one metre, and the slope can vary between 12 and 20%.

Figure 115



b © Voegtlé - Ecogea

Diagram and example of fish passes with plane baffles.
(a) Diagram, (b) St. Nicolas fish pass with plane baffles on the Sienne River.

Fish passes with Fatou baffles

Fish passes with Fatou baffles (see Figure 116) are highly effective hydraulically speaking. However, they have two major disadvantages, namely the baffles are difficult to manufacture due to their shape and the passes are vulnerable to clogging by branches and other floating debris. In as much as their intended use is very similar to that of fish passes with plane baffles, the latter are generally preferred. The operational conditions under which they are used are identical to those of fish passes with plane baffles.

Figure 116

Examples of fish passes with Fatou baffles. (a) Fish pass with Fatou baffles at Halsou on the Nive River, (b) idem at the Claies de Vire site on the Vire River.

Fish passes with floor baffles

This type of fish pass is used primarily in France.

The baffles are positioned along the bottom of the pass. They are made of sheet metal 8 to 10 mm thick and the height varies from 8 to 20 cm depending on the given species (see Figure 117).

For large migratory salmonids, a maximum slope of 15 to 16% is recommended with baffles between 10 and 20 cm high.

In passes designed specifically for trout, the size of the baffles (8 to 10 cm high) and the lengths of each straight section of pass must be reduced.

Figure 117

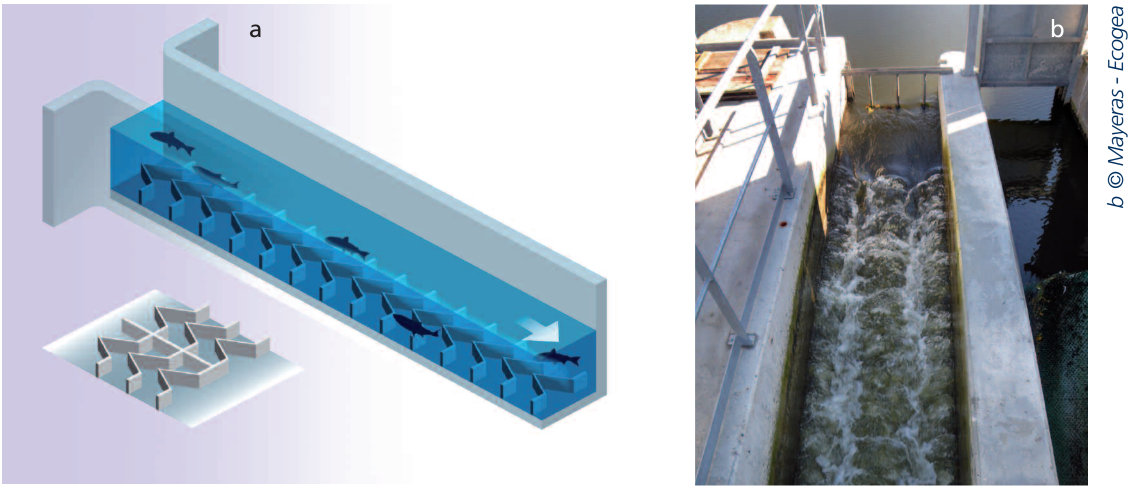


Diagram and example of fish passes with floor baffles.
(a) Diagram, (b) fish pass with floor baffles at the Soustons dam.

Fish passes with thick chevron baffles and "combined" fish passes

The basic idea is essentially the same as that for floor baffles. However, the baffles are much thicker and are generally made of wood in order to hurt fish less and to enable the passage of boats, e.g. canoes and kayaks (see Figure 118).

Unfortunately, they are less effective hydraulically speaking and are suitable only for large migratory salmonids. They are also highly sensitive to variations in the upstream water level. In that they are suitable for a very limited number of fish, this type of system is almost never used any more in France for fish passes.

Figure 118

*Examples of fish passes with thick chevron baffles.
(a) Fish pass with chevron baffles at the Moulin Neuf dam on the Trieux River, (b) Fish pass with chevron baffles combined with a pass for eels in the Haute-Normandie department.*

*a © Larinier - Ecohydraulic centre
b © Fagard - Onema*

Fish passes designed specifically for eels

■ Design principle

For adult and nearly adult fish, it is often possible to design a "standard" fish pass adapted to the needs of eels or to optimise existing installations by adding roughness along the bottom, reducing head-drops, etc.

For younger eels, on the other hand, given their limited swimming capabilities, special systems are generally proposed, targeting the crawling technique used by the fish.

Fish passes specifically designed for glass eels and elvers comprise two parts.

■ **A ramp,** the lower part of which is submerged below the downstream water level. The ramp is covered with a "substrate", a surface designed to facilitate the upward progression of the fish. Different types of surface may be used, depending on the region or country. The surface is always kept wet, either by water flowing from upstream or using a pump. The width of ramps can vary, but they generally have a longitudinal slope of 10 to 100%, which varies depending on the type of crawl surface used.

■ **An upstream section,** designed to facilitate access to the upstream waters. The objective is to ensure that this section constitutes a transition so that the eels are not blocked by either a discontinuity in the supply of water or zones with excessively high flow velocities. The main problem encountered has to do with fluctuations in the upstream water level.

A drop in the level can lead to the fish pass running dry. On the other hand, an increase can rapidly result in excess quantities of water in the fish pass. This problem can be handled in two ways:

- create a latitudinal slope in the ramp to mitigate the variations in the upstream water level and maintain a zone with a low water depth and moderate flow velocity to assist the fish (see Figure 119). The latitudinal slope is generally in the 20 to 100% range, with lower values below 50% when the crawl way comprises studs;
- extend the top end of the ramp to a level higher than the maximum upstream water level and use a pump to ensure the flow of water on the ramp. The fish arriving at the top of the ramp slide down a chute and fall into the upstream water or into a holding tank where they can be caught for transport or counting purposes.

The substrate type, slope and discharge are essential factors that determine obstacle passability for eels. The interaction between these different factors is generally very clear (Voegtlé and Larinier, 2000).

Figure 119

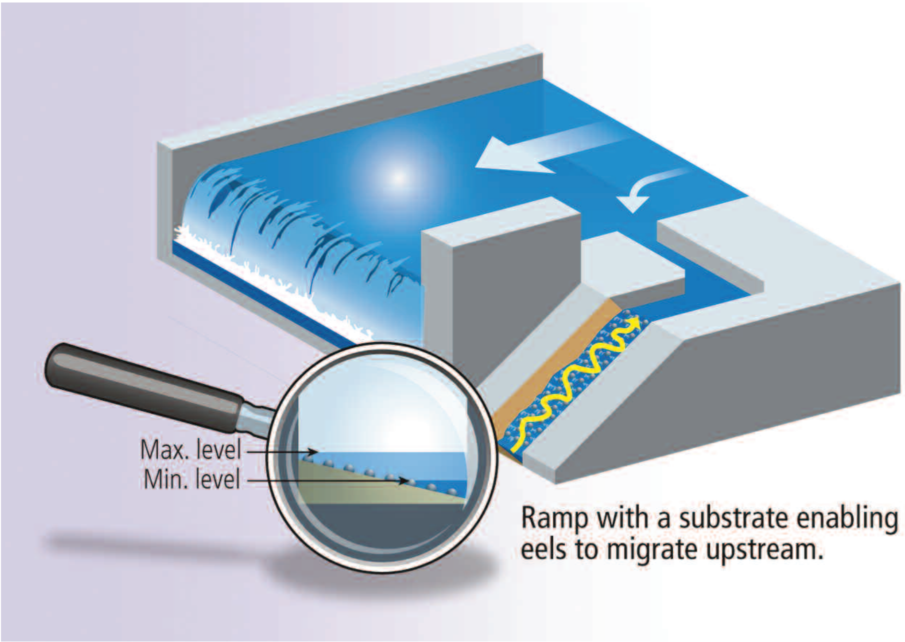


Diagram of a fish pass for eels supplied directly with upstream water.

■ The main substrates for eels available in France

The surfaces used for eel ramps are generally of the brush or stud type. The size and the spacing between each element in the surface depend on the size of the transiting fish. Spacing of approximately 14 mm between elements supporting the progression is the most common and useful for different fish sizes.

Brush-type substrates (see Figure 120a). These mats consist of synthetic fibres arranged in clumps on a PVC base. Different spacing (7 to 21 mm) between clumps is available depending on the biological stage of the given fish. This type of substrate is commonly used in France, notably for very young fish (glass eels).

Stud-type substrates (see Figure 120b). These concrete or polyurethane tiles have an array of studs. The technical characteristics (density and size of studs) of the tiles are such that they may be used exclusively for elvers and larger eels. A further consequence of these characteristics is that the latitudinal slope should be less steep than for brush substrates.

Figure 120

a © Voegtlé - Ecogea
b © Lagarrigue - Ecogea

Examples of fish passes for eels.
(a) Fish pass for eels on the Soustons River. Ramp equipped with a brush-type substrate.
(b) Fish pass for eels at the Bergerac dam on the Dordogne River. Ramp equipped with a substrate comprising polyurethane studs.

Locks and elevators

■ Fish locks

The idea behind fish locks (see Figure 121) is very similar to locks for boats. The fish are drawn into a downstream chamber and then floated up to the upstream section. They are encouraged to leave the lock by creating a downward current via a bypass.

The lock procedure may be summed up in three phases.

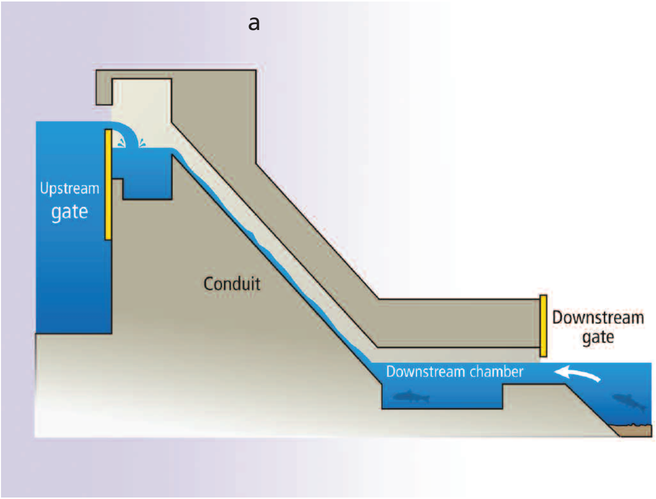
■ **Entry phase.** The downstream gate is open. The fish are attracted to the downstream chamber by the water flowing from upstream.

■ **Filling and exit phase.** Following a certain duration of the entry phase, the downstream gate closes and the lock fills with water. The fish follow the free surface up the conduit and enter the upstream chamber when the lock is full. A current is created to encourage the fish to exit the lock.

■ **Emptying phase.** After a given amount of time, the upstream gate closes. The lock is gradually emptied via a bypass. When the lock is almost completely empty and the pressure on the downstream gate is low enough, the gate opens again.

A complete cycle may last between one and several hours.

Figure 121



b © Chanseau - Onema

Diagram and example of a fish lock. (a) Diagram, (b) Saint-Maurice fish lock on the Adour River.

The effectiveness of a fish lock depends on the behaviour of the fish which must remain in the downstream chamber during the entire entry phase, then proceed up with the water level during the filling phase and exit the lock before the emptying phase.

Many locks have turned out to be not very effective or totally ineffective. As a result, they are now rarely used in France and abroad.

■ Fish elevators

Generally speaking, a fish elevator (see Figure 122) is a mechanical system that catches fish at the foot of an obstacle in a tank holding enough water for the given number of fish, then lifts the tank and empties it into the upstream reach.

The fish are first drawn into a holding basin by a discharge sufficient to attract them. They are caught in a wire cage equipped with a device to avoid travel back downstream. The lifting tank is located at the bottom of the cage. Immediately downstream of the cage is a mechanised, vertical screen that blocks access while the cage and tank are lifted to avoid crushing any fish when the cage and tank come back down.

An electric winch located at the top of the metallic or concrete structure lifts the cage and tank. The tank then tips or a gate is opened to allow the fish to transit to the upstream reach.

The procedure for this type of elevator may be summed up as follows.

■ **Trapping phase.** The tank is at the bottom of the shaft, the protective screen providing access to the cage is open. Attracted by the flow of water, fish enter the cage and are trapped by the anti-return device.

■ **Lifting and release phase.** The protective screen drops, blocking access, the cage and tank are lifted and the tank then releases the fish to the upstream reach.

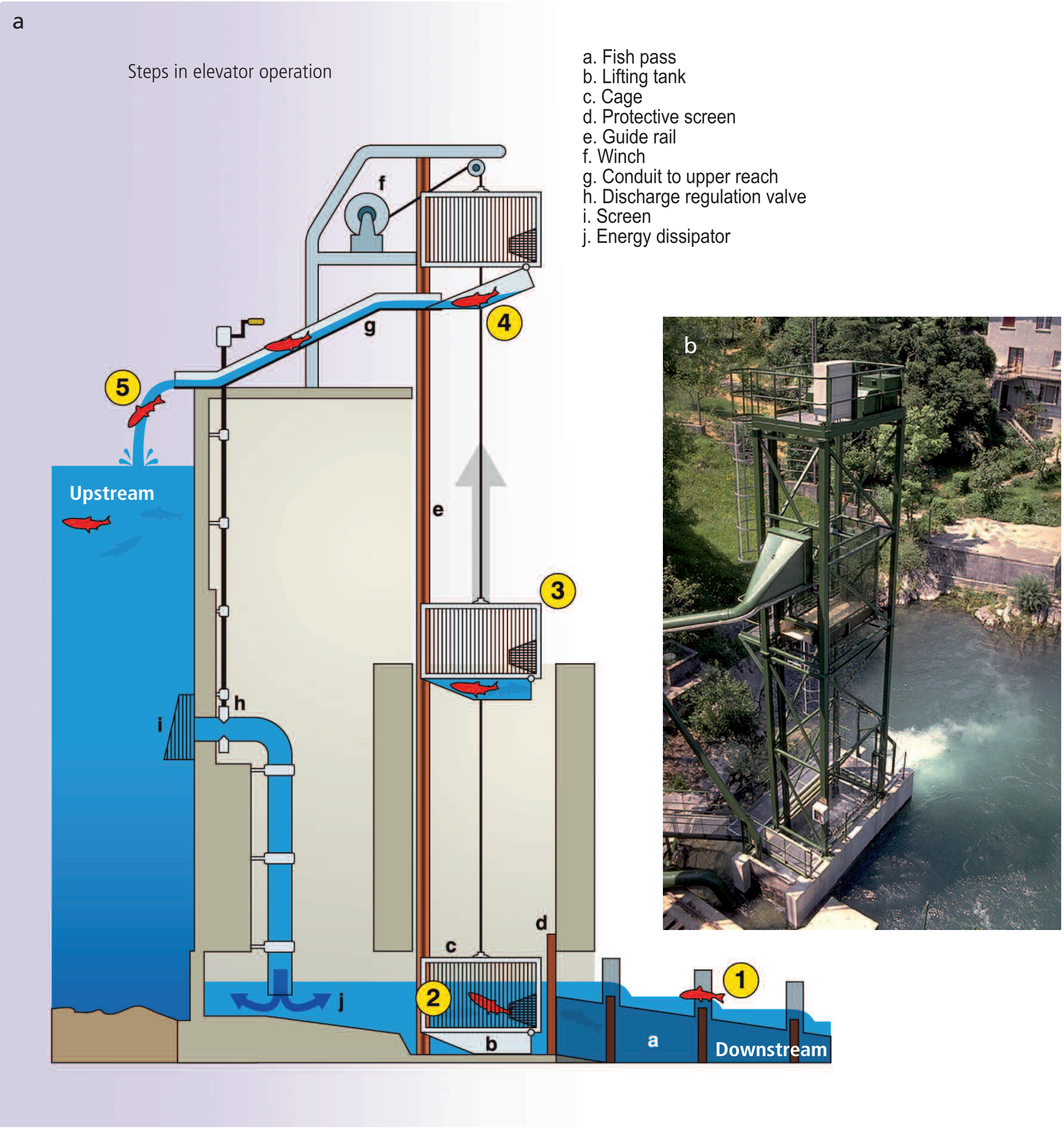
■ **Descent phase.** After releasing the fish, the cage and tank travel back down to the bottom. The protective screen then opens and fish may again access the cage.

The main advantages of fish elevators compared to other types of fish passes lie in their construction costs, which do not depend significantly on the height of the obstacle, in their small footprint and in their lesser sensitivity to variations in the upstream water level.

The main disadvantages have to do with operating difficulties, higher operating costs and longer down times than for "static" fish passes due to the higher potential for breakdowns. In addition, the effectiveness of elevators for small species is relatively limited due to the impossibility of using, for operational reasons, screens with a sufficiently fine mesh.

Given the advantages and disadvantages of these systems, they are generally used when the head-drop between the upstream and downstream reaches is close to or exceeds ten metres. For smaller head-drops, it is often better to use standard fish passes.

Figure 122



b © Voegtlé - Ecogea

Diagram and example of a fish elevator. (a) Diagram of a fish elevator with a built-in lifting tank, (b) Castet elevator on the Ossau River.

Tidal structures

In most cases, particularly when estuarine structures are designed to avoid or limit the entry of water further upstream, they create major problems for the passage of the fish species that use the tidal currents to travel upstream.

When the purpose of estuarine structures is the opposite, i.e. when they are used to prevent the outflow of high-tide waters during low tide, there are generally far fewer problems because upstream migration generally occurs during the rising tide.

To facilitate the upstream passage of fish, there are two main possibilities for structures (not including automated management systems):

■ let water penetrate upstream in one of three ways, namely by maintaining one or more gates open or slightly open, by creating one or more orifices in the structures or by delaying the closing of gates;
■ implement the same solution as for other types of structures, i.e. create a fish pass.

■ Solutions letting sea or brackish water penetrate upstream

Maintain one or more gates open or slightly open

This solution consists of leaving the system (gates, doors, flaps) open or slightly open during the rising tide (see Figure 123). The volume of water penetrating upstream depends on the strength of the tide and the size of the opening.

This very simple and inexpensive solution generally makes it possible, particularly for tide gates, to allow a continuous inflow during (virtually) the entire rising tide and from top to bottom of the water column.

Figure 123

a © Chanseau - Onema
b © Voegtlé - Ecogea

Examples of tidal structures left partially open or chocked open to enable passage upstream. (a) Gates held open at the Saubusse structure on the Adour River, (b) tide gates chocked open in the Arcins marshes.

The devices used to maintain the gates open are generally permanent and difficult to remove, which may cause problems in the case of particularly high tides.

The openings, which span the entire height of the gate, theoretically allow the entry of greater volumes of water with high levels of suspended matter and salt, which may, in certain cases, be a problem for the upstream environment.

In addition, if the water volumes that the upstream environment can accept are limited, which is often the case, that reduces the permissible input volumes during the slack period around high tide, considered a strategic moment at least for glass eels (Lafaille *et al.*, 2007).

Finally, particularly before installing chocks, it is necessary to check that the gate/flap and the support structure can handle the hydraulic pressures, which can be considerable. There is a non-negligible risk of deforming the moving parts or the structure.

Create one or more orifices in the structure

This solution consists of creating one or more orifices in the gate (tide gate, flap, lift gate) or in the structure itself.

The orifices (see Figure 124) are themselves generally equipped with a lift gate used to adjust the throughput. Depending on the situation upstream, this system can be used to easily adapt the throughput to seasonal limitations upstream and to the strength of tides.

Figure 124

a © Chanseau - Onema
b © Voegtlé - Ecogea

Examples of orifices created to allow the passage of fish.
(a) and (b) Orifices positioned in the lower section of tide gates to allow the passage of fish when open, at Jalles in South-West France.

Depending on the size of the orifice and its position (height) in the gate, more or less water will penetrate upstream.

The lower the position of the orifice in the gate, the more water will penetrate upstream and the earlier the water will enter during the rising tide. On the other hand, a low position in the gate is likely to result in more suspended matter arriving upstream, which may be a negative factor in some cases.

In that the fish are required to pass through a precisely identified and relatively small orifice, there is a risk of poaching and simple measures should be foreseen, if necessary, to limit the risks.

Delay closing of the gates

Systems designed to delay the closing of gates (floats, counter-weights, springs, etc.) are occasionally used on certain sites in France and abroad (see Figure 125, Environment Agency, 2011). The general idea is to ensure the passage of water upstream at a particular time during the rising tide.

The systems are more or less effective depending on the volume of water penetrating upstream and on the time when the gates fully close. Their effectiveness drops sharply in particular if the gates close (or the volume of incoming water is severely limited) at the time when a maximum number of fish arrive at the foot of the obstacle, i.e. a few hours before the slack period around high tide.

Figure 125

a, b, c © Williams - UK Environment Agency (2011)

The SRT system developed by the U.K. Environment Agency (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291577/scho0811buay-e-e.pdf). (a) and (b) SRT system in the closed position, (c) system partially open, depending on the water level caused by tides.

■ Creation of "standard" fish passes

For certain estuarine structures where it is not possible to manage or modify the system to allow the passage of water upstream, "standard" fish passes (pool-type passes, eel passes, etc.) may be installed (see Figure 126).

Figure 126

a, b © Voegtlé - Ecogea
c, d © IAV

Examples of fish passes in estuaries. (a) and (b) Fish pass inside the Durdent estuarine structure, (c) and (d) fish pass for eels at the Arzal dam on the Vilaine River.

Pre-assessment of the different types of fish pass

Method used for the ICE protocol

■ An assessment prior to in-depth study of fish-pass hydraulic operation and attractiveness

The general strategy for a fish pass is to attract the migratory fish and to encourage them (or oblige them in the case of an elevator) to transit upstream via the structure.

An effective fish pass is one where the fish can find the entry rapidly and transit upstream without difficulty, delay, stress or injury detrimental to further migration. Consequently, **a fish pass must be attractive and functional.**

The attractiveness of a fish pass depends on how it is installed with respect to the obstacle and in particular on the characteristics of the entry, the discharge flowing through the pass, the geometry of the bed and the nearby hydraulic conditions. The current flowing out at the foot of the pass must be sufficient and must not be masked by flows from the turbines and spillways, or by backflows.

The effectiveness of a fish pass, i.e. the compatibility of the hydraulic conditions in the pass with the behaviour and swimming capabilities of the targeted species, is determined by the internal hydraulic conditions which depend on the pass geometry (type of pass, size, slope, etc.) and on the hydrological conditions during migratory periods, as well as, in some cases, on the management of the gates in the overall structure. The variability of the hydrological conditions and of gate management generally produce fluctuations in the water levels upstream and downstream of the obstacle and consequently some variability in the hydraulic conditions inside the fish pass.

Though it is possible to roughly gauge the suitability of the overall physical characteristics of a fish pass (the type of pass and its geometry) for the given species, **it is impossible to rapidly set simple and relevant criteria (the objective of the ICE protocol) in view of assessing pass attractiveness and its adaptability to variations in the hydrological conditions.**

This type of assessment requires a high level of technical know-how in sizing hydraulic systems and in the behaviour of fish. Further prerequisites include in-depth knowledge on the hydrology of the given river, the breakdown of discharges on the site depending on the hydrological conditions and the upstream and downstream water levels and their variations during the migratory periods of the given species.

For the ICE protocol, the first step is to make sure that the type and characteristics of the fish pass are suitable for the given species.

Caution. The pre-assessment procedures presented below for the various types of fish pass are simply the preliminary studies undertaken prior to a complete analysis of the fish pass. In a context of surveillance monitoring of the ecological status of aquatic environments, the purpose of the pre-assessments is to rapidly identify, using simple criteria based on easily measured parameters, fish passes that are clearly not well suited or not at all suited to the given fish species. In the framework of projects to restore ecological continuity and particularly for the assessment of obstacles subject to legal requirements, a complete study must subsequently be carried out, taking into account other criteria of pass effectiveness (attractiveness, other functional hydraulic factors pertaining to the fish pass itself and to the overall obstacle, etc.) and targeting all the necessary assessment parameters, in order to identify the causes of the malfunction and to determine the extent of the corrective measures.

■ Pre-assessment method

The method indicates for the main sizing parameters, for each species group and for each type of fish pass suited to a given group of species:

- **minimum values,** corresponding to the size and morphology of the fish (minimum size of pools and of slots/notches, minimum water depths, minimum discharge for given slots/notches);
- **maximum recommended values** or value ranges, corresponding to the swimming/jumping capabilities of a species or group of species (flow velocities, head-drops between pools, etc.).

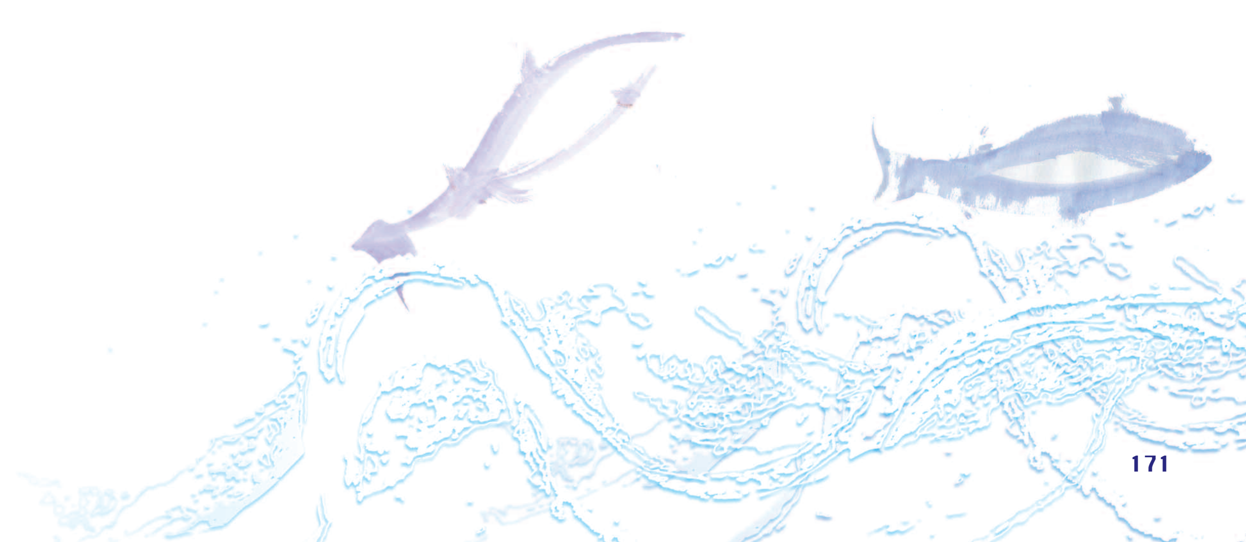
Certain results proposed for fish passes will not appear to be consistent with the values indicated previously for the assessment of obstacle passability.

This is particularly true for the recommended head-drops between pools in fish passes, which do not correspond to the threshold values for the ICE protocol 1 and 0.66 passability classes.

These differences in values or value ranges take into account factors other than those strictly related to the given species or group of species, in particular factors having to do with:

- the hydrodynamic conditions in the fish pass, which is a confined environment where discharges and head-drops are limited and depend on the volume of the pool;
- pass construction and maintenance;
- the fact that, for the least agile species, the hydraulic conditions in the pass can be much more rigorously controlled than those for a weir, in particular by installing rough surfaces (having precise sizes and layout) on the bottom of the pass that benefit small, benthic species.

Sizing criteria other than those used for the ICE protocol may also be important, depending on the type of fish pass (size of deflectors, baffles and/or orifices, width of pools, length of straight sections, etc.). They are not covered during the pre-assessment and must be checked during the subsequent in-depth study, using in particular the technical sizing guides.



Pool-type fish passes

Pool-type fish passes can be adapted to all fish species if the head-drops between pools and at the pass outlet, the types of flow and the pool dimensions (width, length and depth) are compatible with the behaviour and passage capabilities of all the fish.

■ *Fish passes with skimming flows (vertical slots, deep lateral notches or triangular notches)*

The following points must be analysed during the pre-assessment.

1. Type of flow

It is necessary to check that the flow in a pool-type fish pass is effectively a skimming flow.

If the flow over the slots or notches is a skimming flow ($H \geq 2$ DH or DH ≤ 0.5 H), proceed with the analysis of the main dimensions indicated in Table 24, starting with Step 2.

If the flow is a plunging jet ($H < 2$ DH), it is clear that the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose. However, for the jumping species, it is nonetheless worthwhile to check the main dimensions using the pre-assessment procedure for passes with plunging jets (see the next section).

2. Analysis of head-drops

If the head-drops DH between pools and at the pass outlet are greater than the values (maximum head-drop) indicated in Table 24, the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 3.

3. Analysis of the widths of passageways (slots, notches)

If the widths of the slots or notches are less than the minimum values indicated in Table 24, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 4.

4. Analysis of pool depths

If the pool depths are less than the minimum values indicated in Table 24, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 5.

5. Analysis of pool lengths

If the pool lengths are less than the minimum values indicated in Table 24, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, the pre-assessment result is positive, however **it is necessary to proceed with the in-depth study of the hydraulic conditions in the fish pass and of its attractiveness.**

Tableau 24 *Threshold values for pre-assessment of pool-type fish passes with skimming flows.*

ICE species group	Species	Maximum head-drop (m) *	Recommended head-drop (m) *	Minimum width of slots and lateral notches (m) *	Minimum depth of pools (m) *	Minimum length of pools (m) *
1	Atlantic salmon (*Salmo salar*) Brown or sea trout [50-100] (*Salmo trutta*)	0.35	0.30	0.30	1.00	2.50
2	Mullets (*Chelon labrosus, Liza ramada*)	0.35	0.30	0.20	1.00	1.75
3a	Allis shad (*Alosa alosa*)	0.30	0.25	0.40	1.00	3.50
3b	Twaite shad (*Alosa fallax fallax*)					
3c	Sea lamprey (*Petromyzon marinus*)			0.15		1.25
4a	Brown or sea trout [25-55] (*Salmo trutta*)	0.35	0.30	0.20	1.00	1.75
4b	Brown trout [15-30] (*Salmo trutta*)	0.30	0.25	0.15	0.75	1.25
5	Asp (*Aspius aspius*) Pike (*Esox lucius*)	0.30	0.25	0.30	0.75	2.50
6	Grayling (*Thymallus thymallus*)	0.30	0.25	0.20	0.75	1.75
7a	Barbel (*Barbus barbus*) Chub (*Squalius cephalus*) Nase (*Chondrostoma nasus*)	0.30	0.25	0.25	0.75	2.00
7b	River lamprey (*Lampetra fluviatilis*)			0.15		1.25
8a	Common carp (*Cyprinus carpio*)	0.25	0.20	0.30	0.75	2.50
8b	Common bream (*Abramis brama*) Pikeperch (*Sander lucioperca*)					
8c	White bream (*Blicca bjoerkna*) Ide (*Leuciscus idus*) Burbot (*Lota lota*) Perch (*Perca fluviatilis*) Tench (*Tinca tinca*)					
8d	Daces (*Leuciscus spp.* except *Idus*)					
9a	Bleak (*Alburnus alburnus*) Schneider (*Alburnoides bipunctatus*) Mediterranean barbel (*Barbus meridionalis*) Blageon (*Telestes souffia*) Crucian carp (*Carassius carassius*) Prussian carp (*Carassius gibelio*) Roach (*Rutilus rutilus*) Rudd (*Scardinius erythrophthalmus*) SW European nase (*Parachondrostoma toxostoma*)	0.25	0.20	0.25	0.75	2.00
9b	Streber (*Zingel asper*) Bullheads (*Cottus spp.*) Gudgeons (*Gobio spp.*) Ruffe (*Gymnocephalus cernuus*) Brook lamprey (*Lampetra planeri*) Stone loach (*Barbatula barbatula*) Spined loach (*Cobitis taenia*)	0.20	0.15	0.15	0.50	1.25
10	Sunbleak (*Leucaspius delineatus*) Bitterling (*Rhodeus amarus*) Threespine stickleback (*Gasterosteus gymnurus*) Smoothtail ninespine stickleback (*Pungitius laevis*) Minnows (*Phoxinus spp.*)	0.20	0.15	0.15	0.50	1.25
11a	European eel [yellow eel] *(Anguilla anguilla)*	0.25	0.20	0.15	0.50	1.25
11b	European eel [glass eel] *(Anguilla anguilla)*	-	-		-	-

(*) The values shown above are recommended values. Under certain conditions (discharge, available space, etc.), it may be necessary to select slightly different values. The greater the overrun of the threshold values by the measured values, the greater the non-suitability of the fish pass.

■ Fish passes with plunging jets (rectangular notches, pre-barrages, triangular notches)

The following points must be analysed during the pre-assessment.

1. Type of flow

It is necessary to check that the flow in the pool-type fish pass is effectively a plunging jet.

If the flow over the notches is a skimming flow ($H \geq 2$ DH or DH ≤ 0.5 H), proceed with the analysis of the main dimensions indicated in Table 24 (see the previous section on fish passes with skimming flows).

If the flow is a plunging jet ($H < 2$ DH), it is clear that the fish pass is suitable only for jumping species. Go to Step 2.

2. Analysis of head-drops

If the head-drops DH between pools and at the pass outlet are greater than the values (maximum head-drop) indicated in Table 25, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 3.

3. Analysis of pool depths

If the pool depths are less than the minimum values indicated in Table 25 or if the pool depths are less than twice the head-drop upstream of the pool, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 4.

4. Analysis of the overflow height over the notches

If the overflow height over the notches is less than the minimum values indicated in Table 25, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 5.

5. Analysis of pool lengths

If the pool lengths are less than the minimum values indicated in Table 25, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, the pre-assessment result is positive, however **it is necessary to proceed with the in-depth study of the hydraulic conditions in the fish pass and of its attractiveness.**

Tableau 25 *Threshold values for pre-assessment of pool-type fish passes with plunging jets.*

ICE species group	Species	Maximum head-drop (m)*	Recommended head-drop (m)*	Minimum depth of pools (m)*	Minimum overflow height over notches (m)*	Minimum length of pools (m)*
1	Atlantic salmon (*Salmo salar*) Brown or sea trout [50-100] (*Salmo trutta*)	0.75	0.30	1.00	0.30	2.00
2	Mullets (*Chelon labrosus, Liza ramada*)	0.60	0.30	0.75	0.20	1.25
3a	Allis shad (*Alosa alosa*)	-	-	-	-	-
3b	Twaite shad (*Alosa fallax fallax*)					
3c	Sea lamprey (*Petromyzon marinus*)					
4a	Brown or sea trout [25-55] (*Salmo trutta*)	0.40	0.30	0.75	0.20	1.25
4b	Brown trout [15-30] (*Salmo trutta*)	0.30	0.25	0.75		1.00
5	Asp (*Aspius aspius*) Pike (*Esox lucius*)	-	-	-	-	-
6	Grayling (*Thymallus thymallus*)	0.30	0.25	0.75	0.20	1.00
7a	Barbel (*Barbus barbus*) Chub (*Squalius cephalus*) Nase (*Chondrostoma nasus*)	-	-	-	-	-
7b	River lamprey (*Lampetra fluviatilis*)					
8a	Common carp (*Cyprinus carpio*)	-	-	-	-	-
8b	Common bream (*Abramis brama*) Pikeperch (*Sander lucioperca*)					
8c	White bream (*Blicca bjoerkna*) Ide (*Leuciscus idus*) Burbot (*Lota lota*) Perch (*Perca fluviatilis*) Tench (*Tinca tinca*)					
8d	Daces (*Leuciscus spp.* except *Idus*)					
9a	Bleak (*Alburnus alburnus*) Schneider (*Alburnoides bipunctatus*) Mediterranean barbel (*Barbus meridionalis*) Blageon (*Telestes souffia*) Crucian carp (*Carassius carassius*) Prussian carp (*Carassius gibelio*) Roach (*Rutilus rutilus*) Rudd (*Scardinius erythrophthalmus*) SW European nase (*Parachondrostoma toxostoma*)	-	-	-	-	-
9b	Streber (*Zingel asper*) Bullheads (*Cottus spp.*) Gudgeons (*Gobio spp.*) Ruffe (*Gymnocephalus cernuus*) Brook lamprey (*Lampetra planeri*) Stone loach (*Barbatula barbatula*) Spined loach (*Cobitis taenia*)					
10	Sunbleak (*Leucaspius delineatus*) Bitterling (*Rhodeus amarus*) Threespine stickleback (*Gasterosteus gymnurus*) Smoothtail ninespine stickleback (*Pungitius laevis*) Minnows (*Phoxinus spp.*)	-	-	-	-	-
11a	European eel [yellow eel] *(Anguilla anguilla)*	-	-	-	-	-
11b	European eel [glass eel] *(Anguilla anguilla)*	-	-	-	-	-

(*) The values shown above are recommended values. Under certain conditions (discharge, available space, etc.), it may be necessary to select slightly different values. The greater the overrun of the threshold values by the measured values, the greater the non-suitability of the fish pass.

■ Fish passes with successive rows of elements

The following points must be analysed during the pre-assessment.

1. Type of flow

It is necessary to check that the flow is effectively a skimming flow over the successive rows of elements (riprap, concrete blocks, separate sheet piles, etc.).

If the flow over the rows is a skimming flow ($H \geq 2$ DH or DH ≤ 0.5 H), proceed with the analysis of the main dimensions indicated in Table 26, starting with Step 2.

If 0.5 H ≤ DH ≤ H, the flow is almost a plunging jet and the pass may be considered not well suited to the given purpose.

If the flow is a plunging jet (DH > H), it is clear that the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not at all suited to the given purpose.

2. Analysis of head-drops between pools

If the head-drops over the rows of elements are greater than the values (maximum head-drop) indicated in Table 26, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 3.

3. Analysis of the overflow height over the rows

If the overflow height over the rows is less than the minimum values indicated in Table 26, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 4.

4. Analysis of pool depths

If the pool depths are less than the minimum values indicated in Table 26, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, the pre-assessment result is positive, however **it is necessary to proceed with the in-depth study of the hydraulic conditions in the fish pass and of its attractiveness.**

Special analysis for eels

If a crawl way exists in the fish pass (notably one with a suitable latitudinal slope), a pre-assessment may be run using the procedure presented in the section of Chapter C on eels.

If the fish pass with a crawl way is not a low-impact passable barrier (ICE class ≠ 1), the pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, if the fish pass with a crawl way is a low-impact passable barrier (ICE class = 1), the pre-assessment result is positive, however **it is necessary to proceed with the in-depth study** (hydraulic conditions, attractiveness, presence of a suitable crawl way under all hydrological conditions, etc.).

Tableau 26 *Threshold values for pre-assessment of rock-chute fish passes with successive rows of elements.*

ICE species group	Species	Maximum head-drop (m)*	Recommended head-drop (m)*	Minimum overflow height over the rows (m)*	Minimum depth of pools (m)*
1	Atlantic salmon (*Salmo salar*) Brown or sea trout [50-100] (*Salmo trutta*)	0.30	0.25	0.30	0.50
2	Mullets (*Chelon labrosus, Liza ramada*)	0.30	0.25	0.20	0.50
3a	Allis shad (*Alosa alosa*)	0.25	0.20	0.40	0.40
3b	Twaite shad (*Alosa fallax fallax*)				
3c	Sea lamprey (*Petromyzon marinus*)			0.15	
4a	Brown or sea trout [25-55] (*Salmo trutta*)	0.30	0.25	0.20	0.50
4b	Brown trout [15-30] (*Salmo trutta*)	0.25	0.20		0.40
5	Asp (*Aspius aspius*) Pike (*Esox lucius*)	0.25	0.20	0.20	0.40
6	Grayling (*Thymallus thymallus*)	0.25	0.20	0.20	0.40
7a	Barbel (*Barbus barbus*) Chub (*Squalius cephalus*) Nase (*Chondrostoma nasus*)	0.25	0.20	0.20	0.40
7b	River lamprey (*Lampetra fluviatilis*)			0.15	
8a	Common carp (*Cyprinus carpio*)	0.20	0.15	0.20	0.30
8b	Common bream (*Abramis brama*) Pikeperch (*Sander lucioperca*)				
8c	White bream (*Blicca bjoerkna*) Ide (*Leuciscus idus*) Burbot (*Lota lota*) Perch (*Perca fluviatilis*) Tench (*Tinca tinca*)				
8d	Daces (*Leuciscus spp.* except *Idus*)				
9a	Bleak (*Alburnus alburnus*) Schneider (*Alburnoides bipunctatus*) Mediterranean barbel (*Barbus meridionalis*) Blageon (*Telestes souffia*) Crucian carp (*Carassius carassius*) Prussian carp (*Carassius gibelio*) Roach (*Rutilus rutilus*) Rudd (*Scardinius erythrophthalmus*) SW European nase (*Parachondrostoma toxostoma*)	0.20	0.15	0.20	3.00
9b	Streber (*Zingel asper*) Bullheads (*Cottus spp.*) Gudgeons (*Gobio spp.*) Ruffe (*Gymnocephalus cernuus*) Brook lamprey (*Lampetra planeri*) Stone loach (*Barbatula barbatula*) Spined loach (*Cobitis taenia*)	0.15	0.10	0.20	0.20
10	Sunbleak (*Leucaspius delineatus*) Bitterling (*Rhodeus amarus*) Threespine stickleback (*Gasterosteus gymnurus*) Smoothtail ninespine stickleback (*Pungitius laevis*) Minnows (*Phoxinus spp.*)	0.15	0.10	0.20	0.20
11a	European eel [yellow eel] *(Anguilla anguilla)*	0.20	0.15	0.05	0.20
11b	European eel [glass eel] *(Anguilla anguilla)*	-	-	-	-

(*) The values shown above are recommended values. Under certain conditions (discharge, available space, etc.), it may be necessary to select slightly different values. The greater the overrun of the threshold values by the measured values, the greater the non-suitability of the fish pass.

■ Rock-chute fish passes with staggered arrays of elements

The following points must be analysed during the pre-assessment.

1. Analysis of the minimum water depth

If the water depth is less than the minimum values indicated in Table 27, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 2.

2. Analysis of flow velocities

It is necessary to determine the maximum flow velocity.

If the maximum velocity is greater than the maximum values indicated in Table 27, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, the pre-assessment result is positive, however **it is necessary to proceed with the in-depth study of the hydraulic conditions in the fish pass and of its attractiveness.**

Special analysis for eels

If a crawl way exists in the fish pass (notably one with a suitable latitudinal slope), a pre-assessment may also be run using the procedure presented in the section of Chapter C on eels.

If the fish pass with a crawl way is not a low-impact passable barrier (ICE class ≠ 1), the pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, if the fish pass with a crawl way is a low-impact passable barrier (ICE class = 1), the pre-assessment result is positive, however **it is necessary to proceed with the in-depth study** (hydraulic conditions, attractiveness, presence of a suitable crawl way under all hydrological conditions, etc.).

Tableau 27 *Threshold values for pre-assessment of rock-chute fish passes with staggered arrays of elements.*

ICE species group	Species	Minimum water depth (m)*	Maximum flow velocity (m/s)*
1	Atlantic salmon (*Salmo salar*)	0.40	2.50
	Brown or sea trout [50-100] (*Salmo trutta*)		
2	Mullets (*Chelon labrosus, Liza ramada*)	0.30	2.50
3a	Allis shad (*Alosa alosa*)	0.40	2.00
3b	Twaite shad (*Alosa fallax fallax*)		
3c	Sea lamprey (*Petromyzon marinus*)	0.15	
4a	Brown or sea trout [25-55] (*Salmo trutta*)	0.30	2.00
4b	Brown trout [15-30] (*Salmo trutta*)	0.20	
5	Asp (*Aspius aspius*)	0.30	2.00
	Pike (*Esox lucius*)		
6	Grayling (*Thymallus thymallus*)	0.30	2.00
7a	Barbel (*Barbus barbus*)	0.30	2.00
	Chub (*Squalius cephalus*)		
	Nase (*Chondrostoma nasus*)		
7b	River lamprey (*Lampetra fluviatilis*)	0.15	
8a	Common carp (*Cyprinus carpio*)	0.3	1.50
8b	Common bream (*Abramis brama*)		
	Pikeperch (*Sander lucioperca*)		
8c	White bream (*Blicca bjoerkna*)		
	Ide (*Leuciscus idus*)		
	Burbot (*Lota lota*)		
	Perch (*Perca fluviatilis*)		
	Tench (*Tinca tinca*)		
8d	Daces (*Leuciscus spp.* except *Idus*)		
9a	Bleak (*Alburnus alburnus*)	0.20	1.50
	Schneider (*Alburnoides bipunctatus*)		
	Mediterranean barbel (*Barbus meridionalis*)		
	Blageon (*Telestes souffia*)		
	Crucian carp (*Carassius carassius*)		
	Prussian carp (*Carassius gibelio*)		
	Roach (*Rutilus rutilus*)		
	Rudd (*Scardinius erythrophthalmus*)		
	SW European nase (*Parachondrostoma toxostoma*)		
9b	Streber (*Zingel asper*)		
	Bullheads (*Cottus spp.*)		
	Gudgeons (*Gobio spp.*)		
	Ruffe (*Gymnocephalus cernuus*)		
	Brook lamprey (*Lampetra planeri*)		
	Stone loach (*Barbatula barbatula*)		
	Spined loach (*Cobitis taenia*)		
10	Sunbleak (*Leucaspius delineatus*)	0.20	1.50
	Bitterling (*Rhodeus amarus*)		
	Threespine stickleback (*Gasterosteus gymnurus*)		
	Smoothtail ninespine stickleback (*Pungitius laevis*)		
	Minnows (*Phoxinus spp.*)		
11a	European eel [yellow eel] *(Anguilla anguilla)*	0.05	1.50
11b	European eel [glass eel] *(Anguilla anguilla)*	-	-

(*) The values shown above are recommended values. Under certain conditions (discharge, available space, etc.), it may be necessary to select slightly different values. The greater the overrun of the threshold values by the measured values, the greater the non-suitability of the fish pass.

Denil fish passes

Denil fish passes are not suitable for all species. They should be used only for fish with good swimming capabilities.

The following points must be analysed during the pre-assessment.

1. Check that a downstream fall does not exist

If there is a fall at the downstream end, the fish pass does not comply with the minimum general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 2.

2. Check on the species

Check that the species or group of species is capable of using this type of fish pass (i.e. that the species belongs to an ICE species group ≤ 7a). If OK, go to Step 3.

Shad prefer regular flows in parallel streamlines and avoid wherever possible whirlpools and highly turbulent zones. For the two shad subgroups 3a and 3b, in the context of the ICE pre-assessment, Denil fish passes may be considered not well suited or not at all suited to the given purpose.

The river lamprey (group 7b) should have passage capabilities theoretically sufficient to swim up Denil fish passes without any great difficulties. However, given the limited current knowledge and as a precautionary measure, river lampreys should not be included in the pre-assessment.

Denil fish passes are not suitable for the species groups numbered 8 and higher.

3. Analysis of the water depth

If the water depth over the baffles is less than the threshold values indicated in Table 28, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 4.

4. Analysis of the slope

If the slope is greater than 16% (floor baffles) or 20% (plane baffles), the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, **it is necessary to proceed with the in-depth study** (hydraulic conditions in the fish pass as a function of hydrology during the migratory period, analysis of the length of straight sections and of the dimensions of rest pools, attractiveness, etc.).

Tableau 28 *Threshold values for pre-assessment of Denil fish passes.*

ICE species group	Species	Minimum water depth for floor baffles (m)	Minimum water depth for plane baffles (m)
1	Atlantic salmon (*Salmo salar*) Brown or sea trout [50-100] (*Salmo trutta*)	0.20	0.30
2	Mullets (*Chelon labrosus, Liza ramada*)	0.15	0.25
3a	Allis shad (*Alosa alosa*)	0.20	0.30
3b	Twaite shad (*Alosa fallax fallax*)	0.15	0.25
3c	Sea lamprey (*Petromyzon marinus*)	0.10	0.10
4a	Brown or sea trout [25-55] (*Salmo trutta*)	0.15	0.25
4b	Brown trout [15-30] (*Salmo trutta*)	0.10	0.20
5	Asp (*Aspius aspius*) Pike (*Esox lucius*)	0.20	0.30
6	Grayling (*Thymallus thymallus*)	0.15	0.25
7a	Barbel (*Barbus barbus*) Chub (*Squalius cephalus*) Nase (*Chondrostoma nasus*)	0.15	0.25
7b	River lamprey (*Lampetra fluviatilis*)	0.10	0.10

The values shown above are recommended values. Under certain conditions (discharge, available space, etc.), it may be necessary to select slightly different values. The greater the overrun of the threshold values by the measured values, the greater the non-suitability of the fish pass.

Fish passes designed specifically for eels

The following points must be analysed during the pre-assessment.

1. Check that a downstream fall does not exist

If there is a fall at the downstream end, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, go to Step 2.

2. Check that a continuous crawl way exists

Inspect the entire height and distance that the fish must overcome to ensure that a passageway suitable for crawling exists for eels (wettened zone, but where the depth is less than 10 mm for elvers and 5 mm for glass eels). If OK, go to Step 3.

Otherwise, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

NB A maximum depth of 20 mm is tolerable for slight longitudinal slopes in the 15 to 20% range or for brush-type substrates, which are less sensitive to water depths than stud-type substrates. For glass eels, the water depth must always be less than 5 mm, whatever the longitudinal slope.

In light of these threshold values, it is best to create a latitudinal slope even if the fish pass is supplied with pumped water.

3. Analysis of the longitudinal slope

Check that the longitudinal slope of the crawl way is less than the recommended maximum of 100% for brush-type substrates and 70% for stud-type substrates. If OK, go to Step 4.

Otherwise, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

NB The value for the longitudinal slope of stud-type substrates is a recommended value. Under certain conditions (discharge, available space, slight latitudinal slope, head-drop, etc.), it may be necessary to select a slightly higher value. The greater the overrun of the threshold values by the measured values, the greater the non-suitability of the fish pass.

4. Analysis of the latitudinal slope

If the fish pass has a latitudinal slope (supplied directly with upstream water), check that the latitudinal slope of the crawl way is less than the recommended maximum of 50% for brush-type substrates and 25% for stud-type substrates. If OK, go to Step 5.

Otherwise, the slope is too steep, the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

NB The values indicated for latitudinal slopes are recommended values. Under certain conditions (discharge, available space, slight longitudinal slope, head-drop, etc.), it may be necessary to select a slightly higher value. The greater the overrun of the threshold values by the measured values, the greater the non-suitability of the fish pass.

5. Type of substrate

If very young eels (glass eels in particular) are likely to use the fish pass and the substrate is not of the brush type (or similar), the substrate is not suitable and the fish pass does not comply with the general sizing criteria, i.e. the pass is not well suited or not at all suited to the given purpose.

Otherwise, the pre-assessment result is positive, however **it is necessary to proceed with the in-depth study of the hydraulic conditions in the fish pass and of its attractiveness.**

Bypass channels

In a bypass channel, linking the upstream and downstream reaches, the flow energy is dissipated and flow velocities are reduced. These characteristics are due to the roughness of the bed and banks, and a succession of elements (rocks, groynes, weirs, etc.) positioned more or less regularly. The objective is to create a flow similar to that of a natural river. The slope can vary somewhat, from 1 to over 6%. It depends on the given species and on the discharges in the channel.

In general, bypass channels are not easy to create given the slight slope (which often makes considerable lengths necessary) and the difficulty in adapting them to the often considerable variations in water levels without special systems (gates, flaps, pool-type fish passes).

There are two main types of bypass channel.

- **Channels in which energy dissipation is achieved primarily by regularly spaced weirs.** These weirs create a series of pools whose length is calculated to dissipate the energy before the next weir. In this case, a pre-assessment can be carried out by analysing each weir using the criteria proposed for pool-type fish passes.
- **Channels in which energy dissipation takes place more or less regularly along the entire channel due to bed/bank roughness and individual elements (rocks, groynes, etc.).** For this type of bypass channel, an in-depth study of the operating conditions and the hydraulic conditions in the channel is required.

Figure 127

(a) Bypass channel for the Graves lake on the Gave de Pau River, (b) Biron bypass channel on the Gave de Pau River, (c) Vilette bypass channel on the Eure River, (d) Hamet bypass channel on the Eure River.

Locks, elevators and tidal structures

It is difficult to provide simple and easily measurable criteria in order to determine rapidly whether a given system is not well suited or not at all suited for the given species.

For this type of structure, an in-depth study of the operating conditions and the hydraulic conditions in the structure is required.