CHAPTER 7

FISH LOCKS AND FISH LIFTS

F. TRAVADE (1) and M. LARINIER (2)

(1) Electricité de France, Research and Development, 6 Quai Watier, 78401 CHATOU Cedex - France.

(2) CSP-CEMAGREF, GHAAPPE, Institut de Mécanique des Fluides, Avenue du Professeur Camille Soula, 31400 TOULOUSE - France.

1. FISH LOCKS

1.1 Principle and operation

The Irish engineer BORLAND developed the first fish lock in scale model form around 1949. It was then constructed at the Leixlip dam on the River Liffey. Numerous fish locks of this type were subsequently built by the North of Scotland Hydro-Electric Board, which attempted to standardise the dimensions.

A fish lock generally consists of an upstream chamber situated at the level of the headpond, connected by either a sloping conduit or a vertical shaft to a large downstream chamber. Automatic sluice gates are fitted to each end of the chambers.

The characteristics and dimensions of a standardised lock proposed by the North of Scotland Hydro-Electric Board following the development of its first locks (AITKEN *et al.*, 1966) are shown in Figure 1.

The operating principle of a fish lock is very similar to that of a navigation lock. The migrating fish are attracted into the downstream chamber, and then passed though the lock in the same way as a boat. The fish are encouraged to leave the lock by creating a descending current within the fishway that is brought about by opening a bypass located at the downstream end of the facility.

The operating cycle can be summarised as follows (Figure 2):

- **Attraction phase:** the downstream sluice gate is open, the upstream sluice controls the flow into the fishway. The water flows into the intermediary pool formed by the upper chamber, then through the conduit towards the holding chamber, and finally out of the holding chamber into the tailwater. The current (*i.e.* momentum: discharge x velocity) thus created attracts the fish into the lower chamber.

- **Filling and exit phase:** after an attraction period lasting for a specified period of time, the downstream sluice closes and the lock fills up. The fish then follows the free surface of the water in the conduit, rising and reaching the upstream pool when the lock is

Article available at http://www.kmae-journal.org or http://dx.doi.org/10.1051/kmae/2002096

full. The fish are encouraged to pass into the headpond by opening a bypass in the lower chamber, which induces an attraction flow across the partially lowered upstream sluice.

- **Emptying phase:** after a further specified period of time, the upstream sluice is closed. The lock is gradually emptied by means of the still open bypass. When emptying is almost complete and the head on the downstream sluice is low enough, the downstream sluice is re-opened. Progressive emptying of the lock by means of the bypass prevents too high velocities occurring at the entrance to the fishway, which otherwise might repel any fish that are in the vicinity of the pass entrance.

The duration of the whole cycle generally takes between one and 4 hours.

The Borland fish lock design can be very flexible and has been adapted for several types of obstruction and for head differences varying from several metres to over 60 metres (AITKEN *et al.,* 1966).

When the head difference is less than 4 or 5 metres, it is possible to leave the whole system open, including the downstream pool (Figure 3).

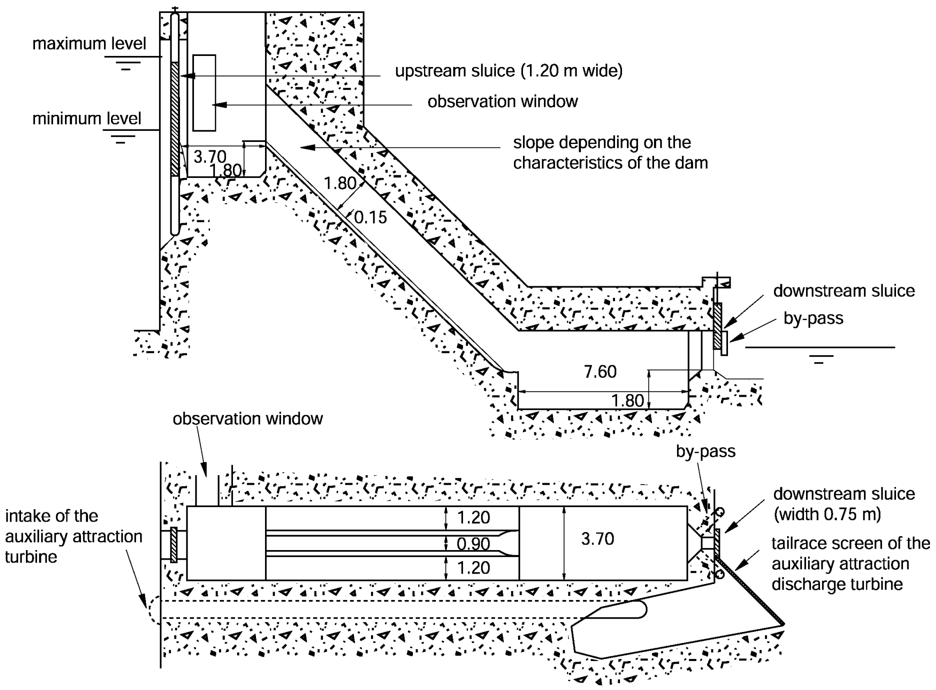


Figure 1: Cross-section of a fish lock (after AITKEN).

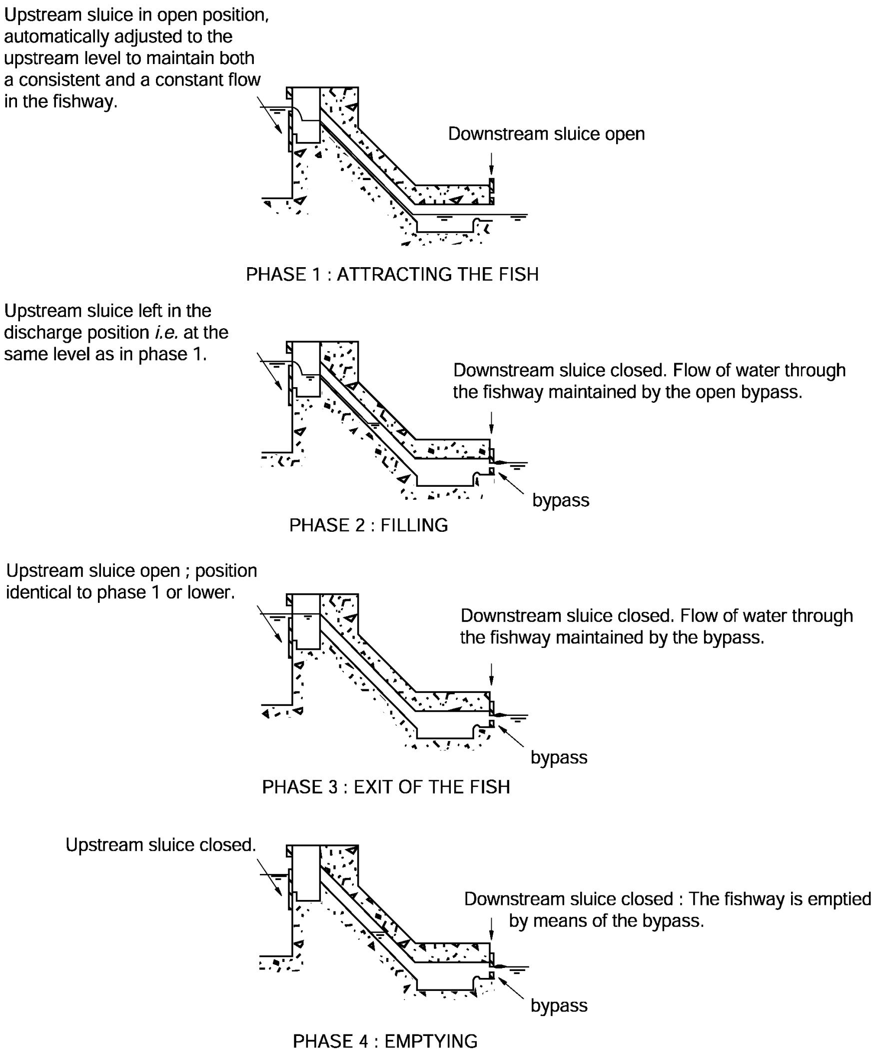


Figure 2: Diagram showing the operating principle of a fish lock.

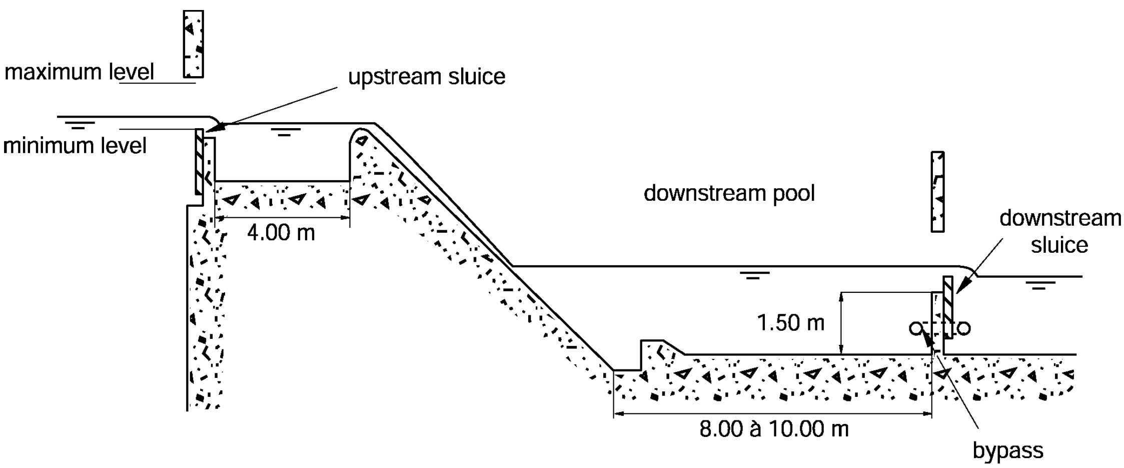


Figure 3: Schematic plan of an open fish lock for a low head installation.

1.2 Efficiency of fish locks

Like any other fish passage facility, the efficiency of a fish lock depends on its capacity to attract fish. The entrance to the lock must be well located. As the flow through the lock itself is generally limited to a few hundreds litres/s, it may prove necessary to provide an auxiliary flow. When the downstream level varies, the downstream sluice must be adjusted at the same time in order to maintain sufficient velocity at the entrance. Finally, it seems preferable to light the interior of the lock in order to provide a gradual transition between the external light environment and that in the lock itself.

The **efficiency** of such a fishway is very dependent **on the behaviour** of the fish. They must remain in the downstream pool during the whole of the attraction phase, follow the rising water level during the filling stage, and then leave the lock before it empties.

In this respect, it is necessary to ensure that the velocity and turbulence conditions in the downstream holding pool are acceptable for the fish during the attraction phase. On the other hand, the lock should not be filled up too quickly in order to avoid excess turbulence and air entrainment since these factors may encourage the fish to remain in the lower chamber. Finally, the fish must have sufficient time to leave the lock in order to prevent any chance of them being swept back downstream when the lock empties.

It is clearly impossible to determine *a priori* the optimum hydraulic conditions for the migrating fish. The optimum characteristics of the operating cycle are also closely linked to the behaviour of the species concerned. It is therefore essential that the lock be designed to have maximum flexibility in its operation (in the duration of each phase of the cycle, the time and extent of opening of the sluices upstream and downstream, etc.).

In spite of all these precautions (and especially where they have not been taken), numerous locks have proved to be either not very efficient, or else totally inefficient. The main drawback of a lock is that it has a limited capacity in terms of the number of fish that it can handle when compared to that of a traditional fishway. This is the result of the discontinuous nature of its operation and the restricted volume of the lower chamber. The system only “traps” fish for a part of the time. Since no significant attracting flow is available to enable fish to detect the facility during the filling and exit phase, any fish arriving at the lock at the same time may well leave the area before the cycle returns to the trapping phase. Fish that have been attracted into the lock may also leave the downstream chamber before the end of the trapping stage.

The first locks constructed at the first dams on the Columbia River (Bonneville, The Dalles, McNary), and elsewhere in the USA were abandoned in favour of pool fish passes. Similarly, most locks in France are considered to be ineffective (some of them for obvious design reasons), and some of these have been, or will be, replaced by pool passes or lifts.

Several modifications have been recommended to reduce some of the aforementioned drawbacks of fish locks in the USA (RIZZO, 1968 and 1969), in Russia (KIPPER & MILEIKO, 1962; MALEVANCHIK & RYAKHOVSKAYA, 1971; PAVLOV, 1989) and more recently in Australia (BEITZ, 1997):

- The migrating fish are trapped in a large holding pool at the downstream end of the lock,

- They are pushed into the lock itself by means of a moving screen (*i.e.* crowder) fixed on a trolley running on horizontal rails along the side walls of the pool,

- A floor screen (the “follower”) moves gradually upward with the water level during the filling cycle, thus forcing the fish to pass upstream.

When this degree of sophistication is required the more simple approach of using either a mechanical fish lift or else a traditional fishway, is often preferable.

1.3 Use of navigation locks for passage of fish

Passage of migrating fish by means of navigation locks is usually accidental and unintended. This is because, in order to enable boats to manoeuvre, locks are generally located in relatively calm zones and are thus not very likely to attract to actively migrating fish. Moreover some species, such as shad, seem to have difficulty in passing upstream when the lock is full and the upstream gates are open.

Tests carried out in the USA have shown that less than 1.5% of migrating fish use the lock at the Bonneville dam on the Columbia River (MONAN *et al.* 1970).

However, navigation locks may constitute a significant back-up facility, or even provide an interesting alternative to the construction of a fish passage facility at existing plants, provided that they are used in a suitable way. A number of experiments (KREITMANN, 1925; KIPPER, 1962; JOLIMAITRE, 1992) have shown that a condition which must be fulfilled, as for any other fish passage facility, is that a sufficient attraction flow must be created in the downstream approach channel to the lock. This is generally achieved by opening the filling sluices (partially or fully) with the downstream gates also held open. Once the lock is full, it is necessary to maintain sufficient velocity to encourage the fish to proceed upstream out of the lock. Clearly this involves operation of the lock in a way for which it has not been designed.

In 1992, more than 10,000 shad passed through the navigation lock at the Beaucaire installation on the river Rhône in 49 lock cycles. The optimum auxiliary flow was around 60 m^3/s, which corresponds to between 2% to 8% of the turbine discharge (JOLIMAITRE, 1992). The exit of fish into the upstream impoundment was guaranteed by maintaining a flow of several m^3/s in the lock, and by creating a streaming surface flow by partially raising the upstream gate.

However, such use of navigation locks as fish passage facilities is limited because the operating regime is clearly incompatible with that required for boat navigation.

2. FISH LIFTS

2.1 Operating principle

In principle, a fish lift is a mechanical system that first traps the migrating fish in a suitably sized tank of water located at the base of an obstruction, and then raises and empties it upstream.

Figures 4 and 5 illustrate this type of facility. An auxiliary flow attracts the migrating fish into a trapping (or holding) pool. They are trapped in a wire mesh cage fitted with an inscale (non-return device), and with a lower section which forms the transport tank. Immediately downstream from this trap is a mechanised vertical screen that is operated as a portcullis in order to prevent other fish from entering the chamber during the phase when the tank is being lifted.

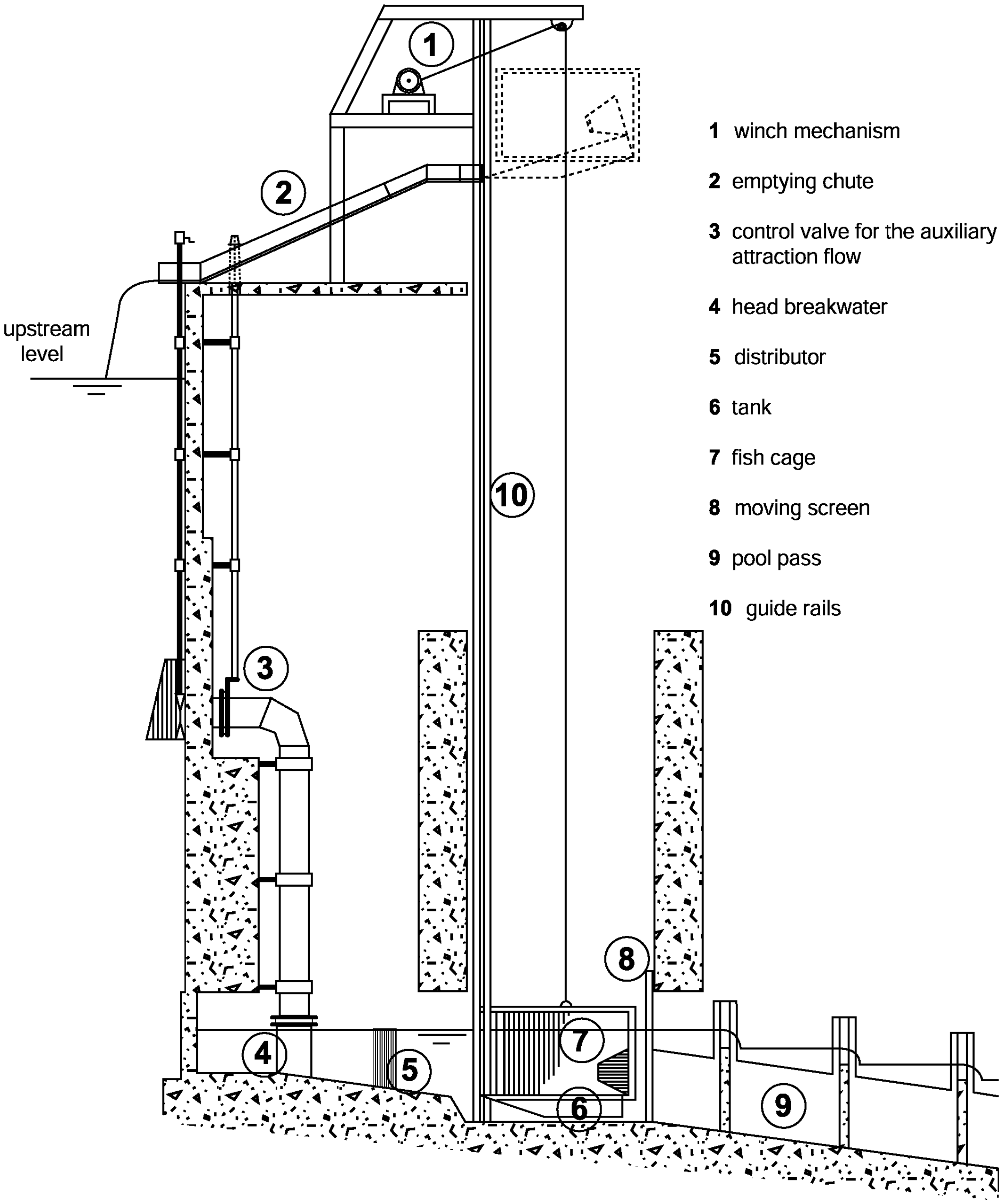


Figure 4: Cross-section of a typical fish lift for salmonids (Poutes dam on the Allier river).

An electric winch, supported on either a metal or a concrete superstructure, is used to raise the tank. The fish are discharged upstream by tipping the tank or by using a valve.

There are two ways of discharging the fish. This is either directly from the tank into the headpond via a chute, or, if the lift is not incorporated into the headpond wall, then into a channel connecting to the upstream impoundment. A permanent current is maintained in the channel both to enable the fish to orientate and to encourage them to move through into the headpond.

Levels	Trout	Salmon
a	0.15	0.20
b	0.20	0.30
c	0.60	0.90
d	0.50	0.75
e	0.02	0.035
h	0.80	1.00
H	1.40	1.80
l	1.00	1.50
L	1.50	2.50
p	0.20	0.30

minimum dimensions (in metres)
for trout and salmon

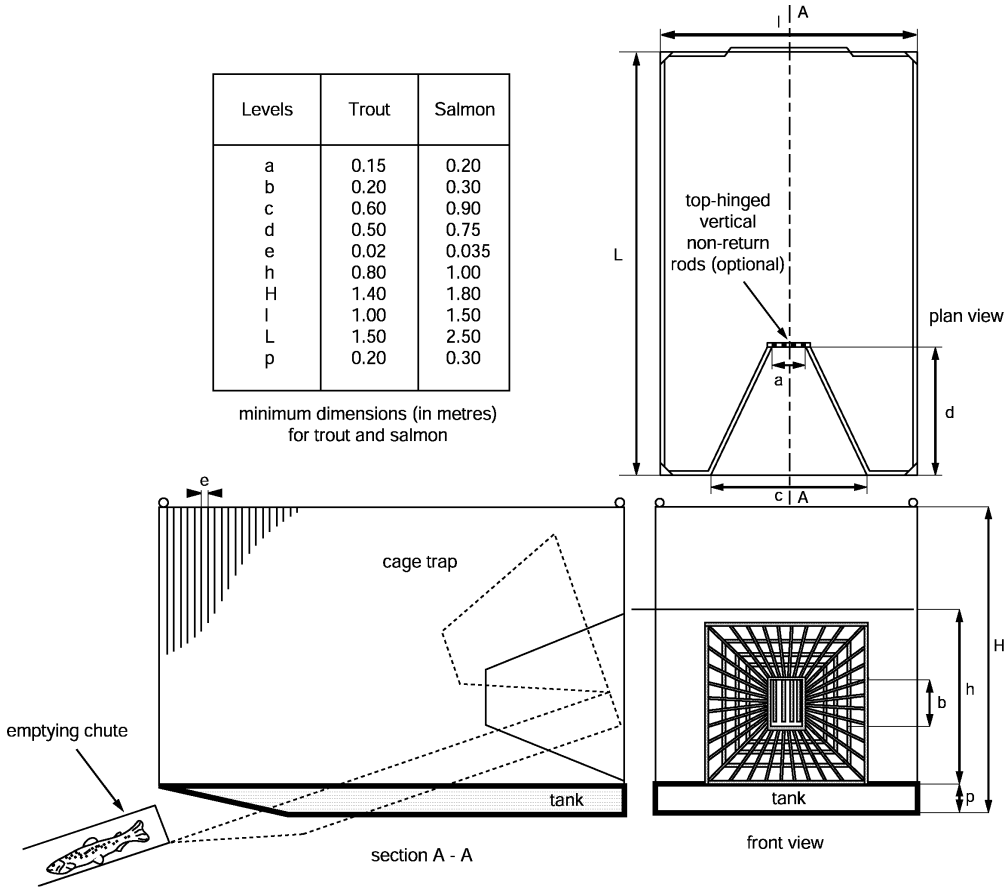


Figure 5: Schematic plans and dimensions of trap and tank for a salmonid fish lift.

When there are a lot of fish to be moved upstream, or when the fish cannot tolerate confinement (such as shad, for example), a large holding area is required. This type of lift, which has an integrated trapping and transport facility, becomes increasingly unwieldy and difficult to use because it is so large and heavy. A possible remedy is the use of a different device in which the trapping, holding and raising functions are separated (Figure 6 and Figure 7). The fish are trapped and held in a large pool, the entrance to which is fitted with an inscale. The tank is embedded into the floor at the upstream extremity of the holding pool. Immediately before lifting the fish are crowded and pushed by a moving vertical screen on a trolley that moves horizontally, confining them in the space above the tank. The same screen, consisting of two hinged panels, generally serves to trap the fish (panels positioned open to form the trap inscale), and to crowd them together (panels closed to form a flat screen). This principle was first used at the Holyoke hydroelectric facility on the Connecticut river (USA), and has since been used successfully in France for the lifts at Golfech (Garonne) and Tuilières (Dordogne).

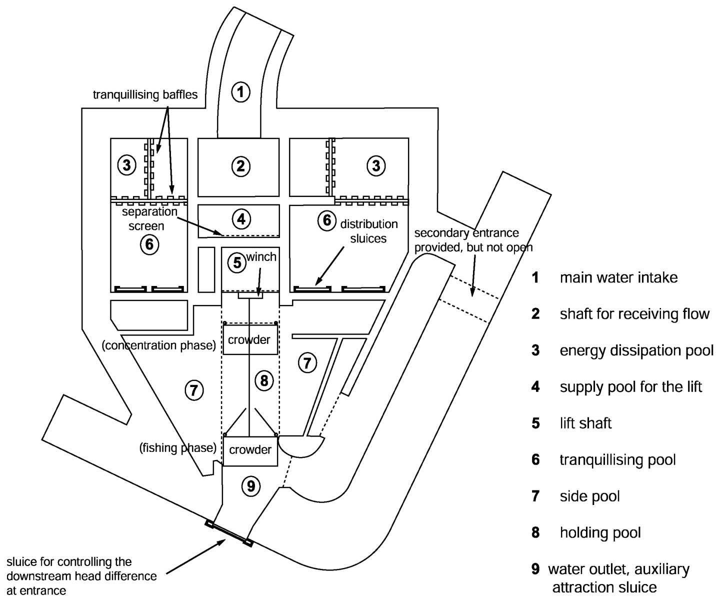
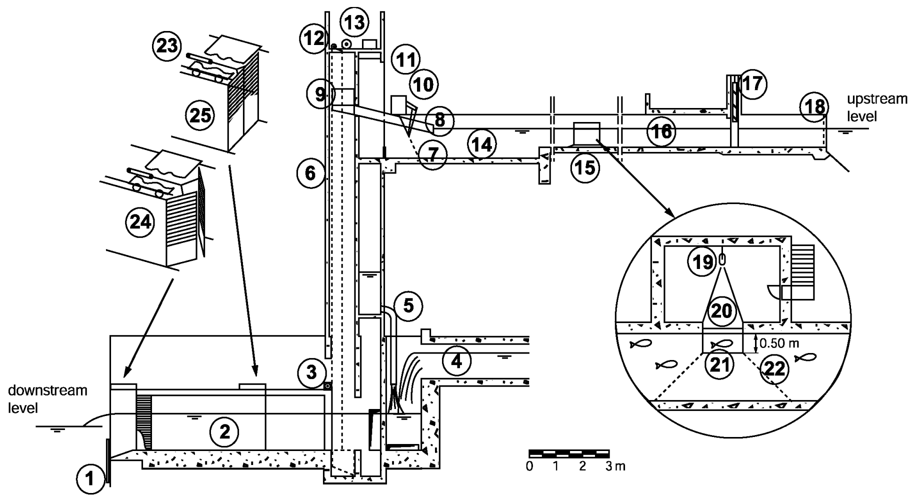


Figure 6: Lower part of a fish lift with a mechanical crowder: water supply, capture and holding pool (Golfech dam on the Garonne river).



1 automatic sluice
2 fish holding pool
3 winch for the crowder
4 main auxiliary attraction discharge
5 discharge of the flow from the channel
6 lift shaft
7 screen
8 chute
9 tank in raised position
10 automatic trash rake
11 control sluice for discharge channel flow
12 winch for the moving screen
13 winch for the tank
14 reception pool
15 counting window
16 transfer channel
17 isolating sluice
18 protective screen
19 camera
20 counting window
21 white PVC sheet
22 screen
23 jack
24 crowder in fish trapping mode
25 crowder in fish concentrating mode

Figure 7: Cross-section of a fish lift with crowder (Golfech dam on the Garonne).

The operating cycle of these two types of lifts is as follows:

Lift with integrated trapping tank

- Fish trapping phase: the tank is in its lowered position, the mobile vertical separation screen between the superstructure of the lift and the fish trap is raised. The fish are attracted by the current, enter the trap, and are trapped by the inscale;

- Tank raising and emptying phase: the mobile vertical separation screen preventing access of other fish is lowered. The tank is hoisted up and emptied upstream;

- Tank lowering phase: after it has been emptied, the tank descends to the trapping position. The vertical separation screen is raised again.

Fish lift with mechanical crowder

- Fish trapping phase: the tank is in the lowered position, and the mobile vertical separating screen is raised. The fish are attracted by the current, and swim naturally into the holding pool and the section above the tank. They are trapped by the inscale at the entrance to the pool;

- Crowding, and moving the fish over the tank phase: the moving crowder-screen approaches and pushes the fish above the tank. When the crowder is at the end of its travel the mobile vertical separation screen descends to prevent other fish entering the lift chamber while the lift is being raised;

- Tank raising phase: the tank is hoisted and emptied upstream. At the same time the crowder-screen withdraws, moving back into its trapping position;

- Descent of tank phase: After it is emptied, the tank returns to its trapping position. The mobile vertical separation screen is raised again.

2.2 Design criteria

The following criteria are based mainly on experience acquired on the east coast of the USA (BELL, 1986; DALLEY, 1980; RIZZO, 1986), and more recently in France (TRAVADE *et al.,* 1992).

Selecting the type of lift

The choice between a lift with an integrated trapping tank and a lift with a mechanical crowder depends on the number and species of fish that are likely to use the facility.

An integrated trapping tank is suitable for sites where the number of fish present in the plant at any one time does not exceed more than several dozen, and where there are no delicate species which might be easily injured or become over-stressed. As a general rule it is perfectly suitable for salmonid populations (salmon, sea trout, trout) where the annual migration does not exceed more than several thousand fish. This is always provided that the facility is located in a section of the river where the number of potamodromous species that may use the facility is low (small watercourses or the upper reaches of large rivers containing migratory salmonids). This type of lift is not recommended for shad because of the susceptibility of the species to stress and damage, and because they tend to migrate in extremely large and concentrated shoals at irregular intervals. It is possible to adapt this type of lift to sites where there is a large number of migratory fish, but it requires lifting a very large tank (as at the Pejepscot installation on the Androscoggin River in the USA).

Whenever a large number of fish are likely to arrive at the facility simultaneously (several hundred to several thousand fish), or whenever fragile species such as shad are present, it is better to use a lift with a crowder. This is generally the case in the lower section of large rivers (*e.g.* the Dordogne and Garonne in France) where, besides shad, several tens of thousands of fish of more than twenty potamodrous species are also likely to use the facility. As an example, around 100,000 shad were counted using the lift at Golfech in 1997 (representing a weight of around 200 tonnes) together with around 50,000 fish of around 20 other different species (CHANSEAU *et al.*, 2000).

Choosing the location of a lift

The criteria used for siting a lift are similar to those for other types of fish passage facilities. The location of the entrance depends on the conditions at the site. The attraction flow discharge must be sufficient in relation to that in the river, and a significant head differential at the entrance (0.2 to 0.3 m for most species) should be maintained to encourage the fish to enter.

In the case of lifts with integrated trapping tanks it may be useful to install the lift upstream of a short section of either a pool or a baffle fishway. This makes it possible to limit the depth dimension of the trapping cage and the inscale thus protecting the device from rising levels associated with floods, as well as limiting maintenance requirements.

Water supply

All or some of the water can be supplied to the holding pool. When the flow required in order to attract the migrating fish does not create a very high velocity in the trap or the holding pool, then the full flow can be directed through the pool itself. In the case of lifts with an integrated trapping tank the water is injected upstream of the capture tank after dissipation of the energy. In lifts with a crowder the flow should be injected at several feeder points; one part upstream of the tank and one part through the side-walls of the pool. It should be injected through the screens at a velocity of less than 0.40 m/s.

If the whole flow cannot be fed into the holding pool, then part of it must be fed in downstream of the inscale. As with other fish passage facilities, this flow should be injected through screens at a velocity of less than 0.30 m/s. In North America, this attraction flow is achieved by injecting it through diffusers in the floor of the facility. Although an advantage of this solution is that constant velocities are maintained through the injection screen whatever the water level may be, the disadvantage is that it presents serious cleaning problems. As a result, in France, it is generally preferred to inject the attraction flow through vertical screens. These screens are located as close as possible to the inscale in order to discourage any hesitation in entry, a behavioural trait which fish frequently exhibit at the entrance to trapping pools.

Trapping and holding pool (or cage)

The overall size of the structures depends on several criteria: the minimum volume of water required per fish during periods of maximum use, water velocities, and the minimum dimensions of the structure (length, width, depth) which are necessary for the species in question.

A **volume of water** of approximately 15 litres per kg of fish held should be used, *i.e.* 5 to 15 litres per individual brown trout, 80 to 150 litres per Atlantic salmon or sea trout, and around 30 litres per Allis shad.

The **minimum dimensions** of the structure (length x width x depth) should be as follows:

- Salmon: 2.5 m x 1.5 m x 1 m (3.75 m^3)

- Trout: 1.5 m x 1.0 m x 0.8 m (1.2 m^3)

- Shad: 5.0 m x 2.5 m x 1.5 m (19 m^3)

The trapping device generally comprises of screens that are used to form an inscale. A minimum velocity of 0.6-1.0 m/s must be maintained in the entrance orifice to attract the fish. Fitting hinged vertical strips in the orifice to act as a valve can enhance the "non-return" effect. They must be light enough not to prevent the fish from entering. Figures 4 and 5 show the main criteria to be taken into account when sizing an integrated trapping tank. In lifts with mechanical fish crowders, where the moving screens form both the fish trapping and holding screens (Figures 6 and 7), the gap between the two screens in the trapping position is between 30 cm to 40 cm.

The **maximum velocity** inside the holding pool must be between 0.3 to 0.6 m/s, depending on the species.

Lifting tank

A minimum volume of around 6 litres per kg of fish lifted should be taken, *i.e.* 2 to 6 litres for each trout, 30 to 60 litres for each Atlantic salmon and sea trout, and around 10 litres for each Allis shad.

The **minimum** dimensions of the tank should take into account the size of the fish concerned. A minimum length of 1.5 m and 1.0 m, and a minimum depth of 0.3 and 0.2 m should be taken for salmon and trout respectively.

In the case of shad, the minimum dimensions of the tank are generally determined by the maximum number of fish that it is likely to be required to lift during the peak of the migration. Minimum dimensions based on fish size are wholly inappropriate because of the very large numbers arriving at peak migration time.

Small tanks (300-800 litres) in lifts for salmonids can be emptied easily by tipping. Large tanks must be fitted with an emptying sluice. Particular care should be taken with the design and finish to ensure that the risks of injury are minimised (rounded corners, no roughness, etc.). The structure of the tank should also guide the fish towards the emptying sluice (sloping base, converging sides), to ensure that no fish are left trapped in the tank after emptying. The depth of the water should be minimised and the surface area of the tank increased in order to reduce the velocity at the outlet when the emptying sluice is opened.

Confinement and crowding screens

The type and free gap of the various screens for injecting the auxiliary flow, for confining the fish in the trap and holding pool, or for crowding them above the tank depend upon the species of fish and their size. These have to be carefully designed in order to prevent passage through, or jamming in, the screen. The constraints in respect of maintenance (cleaning and handling) also need to be taken into account. In order to help prevent fish from becoming stuck between them, screens with bars of rectangular cross-section are preferable to bars with circular cross-section.

The free gap between the bars (e) must be small enough to stop the smallest fish from being trapped by the bony part of the head. For salmonids, the bar spacing must be equivalent to about one tenth of the total length of the fish to be trapped.

The maximum free gap (e) should be as follows:

e = 4.0 cm for Atlantic salmon and sea trout
e = 3.0 cm for shad
e = 2.0 cm for brown trout
e = 2.5 cm for sea lamprey
e = 0.5 cm for small migrating eels travelling upstream.

The free surface area of the screen must be such that it complements the established velocity criteria for auxiliary flow injection into the fish passage facility (Vmax < 0.30-0.40 m/s).

The speed of travel of the mechanised crowder screen is around 5-15 m/min.

Discharging the fish upstream

The tank must be emptied into the upstream impoundment or transfer channel, in an area which is sufficiently deep and wide to prevent the fish from striking the walls or the bed. The emptying point must be selected so that the fish that have poorest swimming ability are not entrained into the turbines or spillways. Recirculation or stagnant zones, or those which are too turbulent, and thus disorientate the fish, must also be avoided.

If a chute is necessary to discharge the fish from the tank then it must be perfectly smooth, and preferably of circular cross-section. A length of up to ten metres has not been found to cause any problems in the lifts currently in use. In order to prevent the fish from being injured or suffering shock the height of the drop between the emptying point and the receiving water surface must not exceed 5 metres.

A transfer channel must be both wide enough and deep enough not to cause any disturbance to the behaviour of the fish. The minimum width should be 0.5 m for trout, 1 m for salmon and 1.5 m for shad. The velocity of the flow must encourage the fish to swim upstream, while also remaining within the swimming abilities of all the species which may use it. A velocity of between 0.3 m/s and 0.6 m/s should be provided.

If fluctuations in the upstream head are large, or if the design of the dam makes it difficult for the channel to be gravity-fed from the water upstream, it is possible to use a pumped channel suspended above the headpond. A special device ("false weir") is necessary to allow the fish to reach the upstream water level. Such a device is installed at the Castet fish lift on the Gave d'Ossau.

2.3 Size and operation

The duration of the operating cycle must be adapted to suit the migration patterns of the various different species. For fish like migratory salmonids that travel either singularly or else in small groups, the trapping phase lasts from one to several hours. On the other hand, in the case of shad, which migrate in fairly dense shoals, the total duration of the cycle at the peak of upstream migration should be as short as possible (about 10 minutes).

The size of the holding pool and the tank are determined as a function of both the **maximum number** of fish (Nc) which could arrive at the facility during the shortest cycle available, and on the volume criteria given in the previous section (RIZZO, 1986; TRAVADE *et al.*, 1992). (Nc) depends upon both the natural migration pattern and the frequency of operation of the lift. This means that it is particularly important to have good information on the migration rhythms (peak periods each day compared to annual migration and peak times during the day), and to determine in advance the maximum frequency with which it is possible to raise the tank at the installation.

The volumes required for the holding pool and the tank are expressed by the formula:

$$V = C + Nc\ Vmin$$

where:

- Nc is the maximum number of the most abundant species of fish in the holding pool during a cycle;

- Vmin is the volume required for each individual fish of the most common species;

- C is a correction coefficient, taking the presence of other species into account.

For example, the parameter Nc is obtained for both American shad (*Alosa sapidissima*) and for Allis shad (*Alosa alosa*) by taking a daily peak equivalent to 10% of the annual migration, and an hourly peak during this specific day of 15% of the daily peak. Taking account of the size of the migratory population (Nt) and the minimum duration of a cycle (d) expressed in minutes, the maximum number of fish arriving during one cycle (Nc) is obtained by the formula:

$$Nc = (Nt \times 0.1 \times 0.15 \times d)/60.$$

2.4 Care and maintenance

Fish lifts comprise mechanical equipment with many moving parts including screens that are partially or fully submerged. As such they demand greater operational attention, and therefore have much higher operating costs than other types of fish passage facility.

The main demands are for the regular inspection and maintenance of the mechanical and electromechanical parts (hoists, sluices, screens, and machinery), and for the cleaning of the screens.

These constraints and the costs related to them depend greatly on the type of lift, the site, and the quality of the materials used. To minimise the cost of operation several important points must be taken into account during design and construction of the lifts:

- Strong and durable equipment should be used, without any unnecessarily sophisticated automation (similar to “agricultural machinery”);

- Fully or partially submerged metal parts should be protected against corrosion. In this respect, electro-plating is generally considered to be better than galvanising;

- The attraction water supply should be properly protected from drifting debris in order to prevent blockage of the screens and/or the fish trap as much as possible. The water intake must therefore be located in a zone where debris does not accumulate and a screen with a mesh smaller than that of the screens of the lift should be installed at the intake, fitted with an automatic trash rake if necessary;

- Facilities should be provided for cleaning and maintenance of the screens, including moveable screens, sluices, and a drainage pump to drain the trapping pool.

From about 10 years experience, the order of magnitude of costs associated with the maintenance and operation of the lifts installed in France are as follows:

- Small lifts for salmonids (with integrated trapping tank): annual current operational maintenance and inspection costs are around 200 to 1,000 € (equipment). The corresponding labour required is 5-10 man/days per year. The cleaning requirements vary from site to site. At the lift at Poutès (Allier) where blockage is not a problem, it represents 2 to 5 man/days per year;

- Large lifts (with mechanical crowders): annual current operational maintenance and inspection costs are around 15,000 €. The labour required for current maintenance and inspection of the equipment, including cleaning work, corresponds to 100 man/days per year (around 30,000 €).

Compared to other maintenance costs, the cost of energy required for operation can be considered to be low. Consumption of around 0.1 to 0.2 kWh for raising a small salmonid lift, and 6.0-7.5 kWh for raising a large lift, over a height of 10 metres are typical.

2.5 Advantages and disadvantages of fish lifts

The main advantages of fish lifts compared to other types of fish passage facilities are:

- Relatively low cost (which is relatively independent of the height that the fish have to raised);

- Small overall dimensions (which makes them relatively easy to construct and locate in the structure);

- Low sensitivity to variations in the upstream level of water.

They can also be considered to be more efficient for those species that have difficulty in using traditional fishways, such as shad or pike-perch. It was the latter factor that led to the choice of a lift at Golfech on the Garonne, and Tuilières on the Dordogne. Monitoring in recent years has also demonstrated that all species present in the watercourses use them, including species that are very rarely seen in other types of fishway. This type of facility has proved its efficiency for American shad at the Holyoke dam (Connecticut River, USA), whereas development of efficient pool passes for this species at other sites on the same river had encountered numerous difficulties.

In comparison to static passes, fish lifts have the following disadvantages:

- Higher operating costs;

- More chance of downtime because of breakdowns or maintenance;

- Low efficiency for small fish or small-sized species (*e.g.* eel) because operational considerations prevent the use of sufficiently fine screens.

Finally, radiotracking studies has recently showed in France that salmon can be reluctant to enter the trap, and may make many approaches before doing so. This can significantly delay migration. Further work on this issue still remains to be done.

BIBLIOGRAPHY

AITKEN P.L., DICKERSON L.H., MENZIES W.J.M., 1966. Fish passes and screens at water power works. Proc. Inst. Civ. Eng., 35: 29-57.

BELL M.C., 1986. Fisheries handbook of engineering requirements and biological criteria. Fish. Eng. Res. Prog., U.S. Army Corps of Eng., North Pacific Div., Portland, Oregon, 290 p.

BEITZ E., 1997. Development of fishlocks in Queensland. Second National *In* : Fishway technical report,. BERGUIS A.P., LONG P.E., STUART I.G. (Eds), Rockhampton, Australia, 125-152.

CHANSEAU M., DARTIGUELONGUE J., LARINIER M., 2000. *Analyse des données sur les passages enregistrés aux stations de contrôle des poissons migrateurs de Golfech et du Bazacle sur la Garonne et de Tuilières sur la Dordogne.* (Analysis of fish passage at the monitoring stations of Golfech and Bazacle dams on the Garonne river and Tuilières dam on the Dordogne river. GHAAPPE/MIGADO Rep. RA00.02, 64 p.

DALLEY P.J., 1980. A review of fish passage facilities for american shad. Northeast Fish and Wildlife Conf., Ellenville, New-York, 32 p.

JOLIMAITRE, J.F., 1992: *Franchissement par l'alose feinte de l'aménagement de la chute de Vallabrègues: étude du franchissement de l'écluse de navigation. Avant-projet de passe à poissons sur le seuil de Beaucaire* (Passage of the Vallabrègues dam by Allis shad: study of The use of the navigation lock. Preliminary plan of fish passage facility of the Beaucaire weir). Conseil Supérieur de la Pêche Rep., 42 p.

KIPPER Z.M., MILEIKO I.V., 1962. Fishways in hydro-developments of the USSR. Rybnoe Khozyaistwo, Moscva, 57 p.

KREITMANN, L., 1925. *Passes à poissons et lacs de barrage en Suisse Compte rendu de mission piscicole* (Fish passage facilities and reservoirs in Switzerland. Report on fisheries project). Ministry for Agriculture. General Directorate of Waterways and Forestry, 43 p.

MALEVANCHIK B.S., RYAKHOVSKAYA G.N., 1971. Design of fish ladders at hydro-developments. Gidrotekh. Stroit., 2: 6-11.

MONAN G., SMITH J.,LISCOM K., JOHNSON J., 1970. Evaluation of upstream passage of adult salmonids through the navigation lock at Bonneville dam during the summer of 1969. 4th Progress Rep. on Fish. Eng. Res. Prog. 1966-1972, U.S. Army Corps of Eng., North Pacific Div., 104-113.

PAVLOV D.S., 1989. Structures assisting the migrations of non-salmonids fish: USSR. FAO Fish. Rome, Tech. Pap. 308, 97 p.

RIZZO B., 1968. Fish passage facilities design parameters for Connecticut river dams. Holyoke dam. Bureau of Sport Fisheries and Wildlife, Boston, Massachusetts, 40 p.

RIZZO B., 1969. Fish passage facilities design parameters for Connecticut river dams. Turners Falls dam. Bureau of Sport Fisheries and Wildlife, Boston, Massachusetts, 33 p.

RIZZO B., 1986. Fish passage design information. Fish passageways and diversion facilities course. Merrimack, New Hampshire, 26 p.

TRAVADE, F., LARINIER, M., TRIVELLATO, D., DARTIGUELONGUE, J., 1992. Conception d'un ascenseur à poissons adapté à l'alose (*Alosa alosa*) sur un grand cours d'eau: l'ascenseur de Golfech sur la Garonne (Design of a fish lift suitable for shad (*Alosa alosa*) on a large watercourse: fish lift at Golfech on the Garonne). Hydroécol. Appl., 4(1): 91-119.

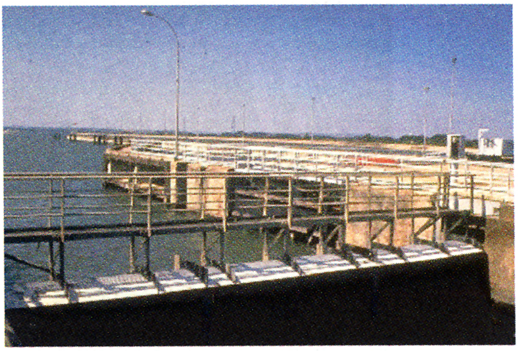


Photo 1: Upstream section of the navigation lock at the Beaucaire power plant (river Rhone) showing the upstream sliding gate.

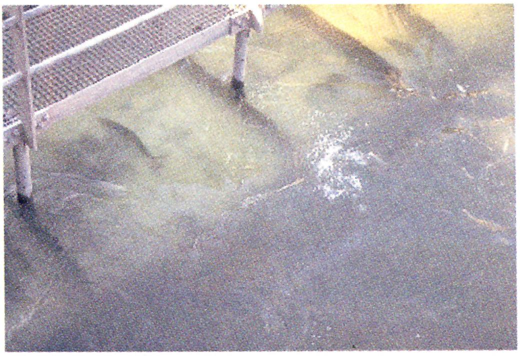


Photo 2: Shad leaving through the upstream sluice of the lock at the Beaucaire navigation lock after a specific manoeuvre of the lock.

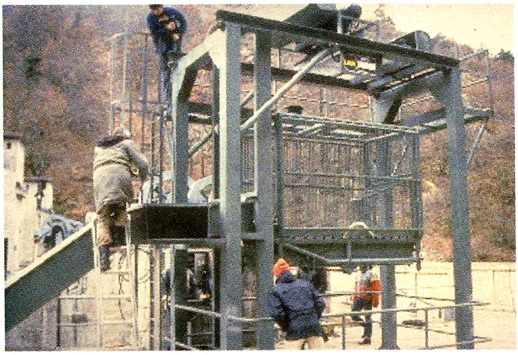


Photo 3: Hoisting equipment for the lift at the Poutès dam on the river Allier (Haute-Loire), with the trap is in its raised position. On the left, the upstream section of the emtying chute.

Photo 4: Trapping tank at the Poutès fish lift (Allier river) during hoisting.

Photo 5: Fish in the trapping tank at the Poutès fish lift.

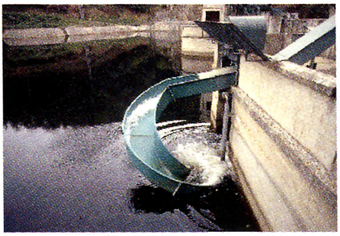


Photo 6: Emptying the tank of the fish lift in the headpond through the chute at Poutès dam.

Photo 7: View from upstream of the tank , the vertical screen and the downstream plane baffle fish pass section at the Kernansquillec fish lift (Britanny).

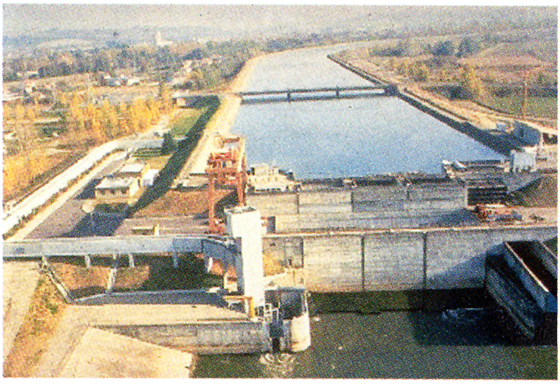


Photo 8: General view of the fish lift at Golfech (river Garonne).

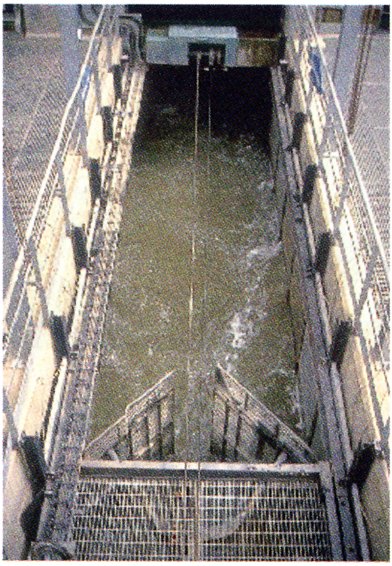


Photo 9: Holding pool and screen device at the Golfech fish lift.

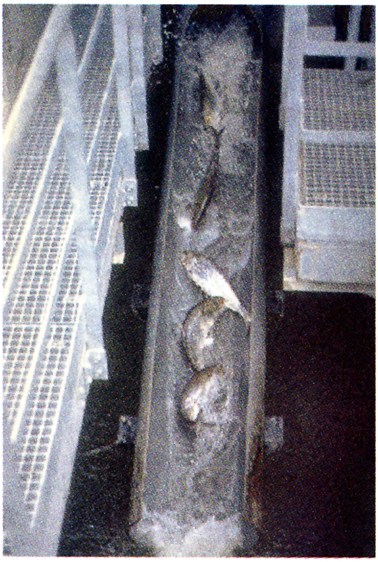


Photo 11: Allis shad being emptied into the upstream canal of the Golfech fish lift.

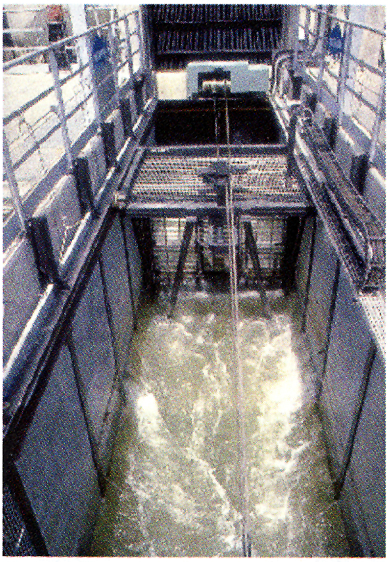


Photo 10: Crowder in fish concentating stage at the Golfech fish lift.

Photo 12: General view of the Golfech fish crowder during construction.

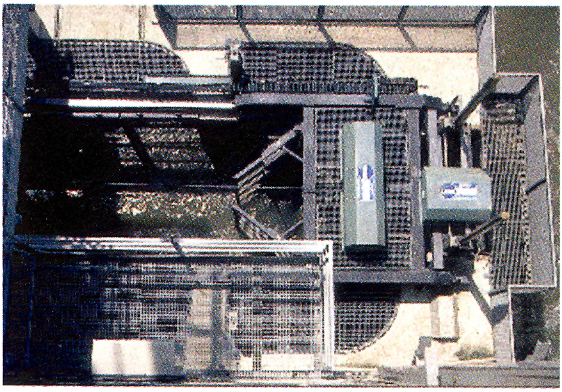


Photo 13: View from above of the holding pool and crowder in fish trapping mode at the Tuilières fish lift (river Dordogne).