

# Fish passage solutions in the Upper Scheldt: restrictions and possibilities

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**ABSTRACT:** Free migration of fish species in all hydrographic basins in Belgium, Luxemburg and the Netherlands should be guaranteed by 1 January 2010. Together with the renewal of three similar weir constructions on the Upper Scheldt, construction of a fish pass was investigated. A scale model (1/10) of the weirs and the downstream channel showed that the entrance of the fish passage should be between 20 and 30 m downstream of the weir, in combination with a dike dam which leaves an opening over the total depth of the flume. The discharge to attract fish seemed about 10 to 15% of the most occurring discharge of the Upper Scheldt. Tests with juvenile fish species confirmed the above findings. By adding natural roughness elements the length of the preferred more natural bypass channel could be reduced by about factor 8 to an acceptable length on the field.

## 1 INTRODUCTION

The disruption of longitudinal habitat connectivity by man-made obstacles has many consequences for the present and future fish communities. Migration between different habitats is sometimes prohibited and as a consequence gene flow between populations is restricted. Following a decision made in 1996 free migration of fish species in all hydrographic basins in Belgium, Luxemburg and the Netherlands should be guaranteed by 1 January 2010.

Together with the renewal of three similar weir constructions on the Upper Scheldt at Asper, Oudenaarde and Kerkhove (Flanders, Belgium) the possibilities for fish passage facilities had to be investigated. The best and most effective one is the removal of the obstruction. Because this was not an option due to navigability of the Upper Scheldt, construction of a fish pass was necessary.

One of the most important needs for an effective fish passage facility is the attraction flow which locates the passage entrance. Only considering weir overflow, downstream of the weir 3 different zones can be distinguished, according to figure 1. Zone 1 is a zone of intense mixture of water and air, characterised by high velocities and horizontal eddies. Zone 2 is a transient zone where the overflowing water meets the surface again, characterised by velocities orientated in different directions. Zone 3 is characterised by an approximately uniform flowing regime. In order to prevent fish species from becoming dis-

oriented in the turbulent zones downstream of the weirs the necessary discharge and the location of the entrance had to be defined regarding these different zones.

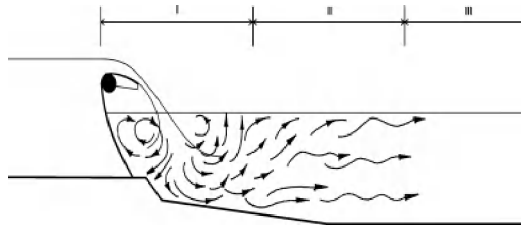


Figure 1 Turbulent zones downstream of a weir only considering overflow.

Once a fish species enters the passage, there is also the need for good flow conditions inside the fish passage. Based on literature it appears that for the fish population in this area, with mainly weak swimmers, only a V-shaped pool fishway or a bypass channel generate flow conditions that allow fish migration (Boiten 1989). Because a pool fishway is a rather technical solution, a more natural bypass channel was aimed. Findings of the "Fish Migration and Fish Bypasschannels" congress in Wenen (24-26/09/98) indicated that bypass channels on lowland rivers could be effective when mean velocity and channel slope can be limited to respectively 0.5 m/s and 0.3%.

## 2 MATERIALS AND METHODS

A scale model of the new weirs at Asper was constructed in the laboratory. Table 1 indicates the scales in the model.

Table 1. Modelscales.

Scale	Factor
longitudinal	10
discharge	316
velocity	3.16

Only a small part of the upstream channel and a major part of the downstream channel were constructed. The constant up- and downstream water level is about respectively 8.25 mTAW and 5.61 mTAW (Figure 2) (meter Tweede Algemene Waterpassing is a reference level used in Belgium).

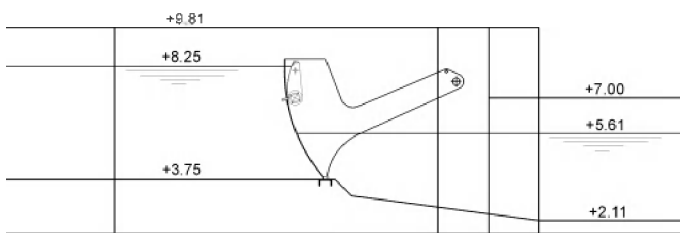


Figure 2 Detail of Asper, as constructed in the laboratory scale model (1/10).

Average discharges at Asper on a daily basis were investigated from 1988 until 1995 and divided into classes of 5 m<sup>3</sup>/s. The most occurring daily average discharge was defined.

Knowing the most occurring discharge, calculation of the maximum renewed weir overflow, based on experiments, determined whether only overflow was sufficient to supply in the most occurring discharge.

After confirmation, the extent of the different zones downstream of the weirs according to figure 1 was visually defined in the scale model by reflecting floats and cords placed on vertical bars. Velocities were measured along the downstream part of the weirs. Field observations at Asper had to confirm the findings.

About 30 juveniles of 4 different fish species were used to confirm the ability of these species to survive in the modelwater. The used species were *Salmo trutta fario*, *Leuciscus idus*, *Gobio gobio* and *Scardinius erythrophthalmus*.

In order to optimise the entrance of the fish passage 2 different entrance designs were evaluated:

- a dike dam which leaves an opening over the total depth of the downstream channel part
- a repelling bank which creates a quiet zone in which the attraction flow will be easily noticed.

Reflecting floats were dispersed at the entrance of the fish pass and photographed from above to detect the extent of the attraction flow.

In order to have a more reasonable indication of the effectiveness of the attraction flow, juveniles of the same 4 fish species were tested during several weeks. The best location for the entrance is stated as the place where the fish will hold up and frequently try to reach the weirs. Regarding limited condition, the fish species were replaced after about 3 weeks. Table 2 gives an overview of the used amount of fish species.

Table 2. Fish species used in the scale model to detect attraction flow efficiency.

Group	species	length	number
1	<i>Salmo trutta fario</i>	7-9 cm	30
	<i>Leuciscus idus</i>	6-7 cm	100
	<i>Scardinius erythrophthalmus</i>	3-4 cm	200
2	<i>Leuciscus idus</i>	6-7 cm	100
	<i>Scardinius erythrophthalmus</i>	3-4 cm	100
	<i>Gobio gobio</i>	8-10 cm	10

To optimise flow conditions in the passage itself and to have a more natural solution, a bypass channel with an acceptable length was aimed. Considering uniform flow regime in the bypass channel one can use the next formula (1):

$$U = \frac{1}{n} R^{1/6} \sqrt{RS_0} \quad (1)$$

where U = mean velocity (m/s); n = Manning roughness coefficient (s/m<sup>1/3</sup>); R = hydraulic radius (m); S<sub>0</sub> = channel slope.

Both literature and experimental roughness data are used to calculate the effective length of the channel. Considering limited space available on the field, the length of the bypass channel had to be reduced by adding roughness elements. Despite many literature data about Manning-n roughness values, there is a huge spread and uncertainty among them, especially for the higher values concerning bypass channel roughness elements (Chow 1959). A scale model of a bypass channel was constructed to test several different roughness elements.

Findings for Asper will be used for similar conclusions at Oudenaarde and Kerkhove.

## 3 RESULTS

The largest parts of the daily discharges at Asper are in the classes 5-30 m<sup>3</sup>/s, especially during spring and summer seasons. Neglecting winter periods from november until february, periods in which migration is less important, 77% of the discharges are in the

above classes. 20 m<sup>3</sup>/s is therefore stated as the most occurring average discharge on a daily basis.

Experiments with the renewed weirs indicated that weir overflow was sufficient to meet discharges up to 30.8 m<sup>3</sup>/s.

Regarding discharges from 10 to 30 m<sup>3</sup>/s, the extent of zone 2 in the scale model seemed to be about 15-25 m downstream of the weirs. Field survey at Asper combined with recalculation for the renewed weirs indicated the extent of the zone for comparable discharges to be between 15 to 35 m downstream of the weirs (figure 3).

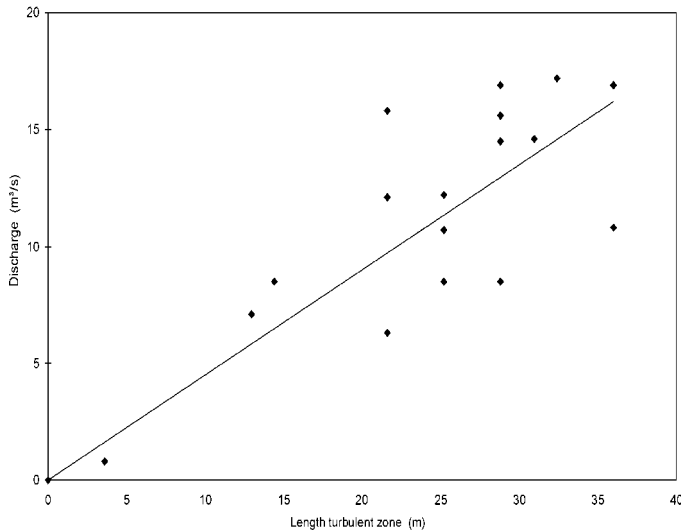


Figure 3. Extent of the turbulent zone downstream of the weirs at Asper in relation to discharge over the weirs, as calculated for the renewed weirs.

Experiments with the above fish species indicated that the juveniles of the different species seemed to hold up separately in this zone 2. Therefore the best location for the entrance should be between 20 to 30 m downstream of the weirs.

We noted that not all of the species showed the same migration behaviour. Of the total fishes used during the experiments some 40 to 60 individuals showed migration behaviour, especially the *Salmo trutta fario* and the *Gobio gobio*.

The extent of the attraction flow is illustrated in figure 4 for a discharge of 3 m<sup>3</sup>/s through the fish pass in combination with a dike dam and a discharge of 20 m<sup>3</sup>/s over the weirs. It is clear that the attraction flow reaches the other side of the river and limits the turbulent region to the part immediately downstream of the weirs. Tests with the 4 fish species indicated the relative importance of a dike dam in contrast to a repelling bank. In combination with a discharge through the fish pass of about 2.5 m<sup>3</sup>/s, or 10 to 15 % of the most occurring daily discharge at Asper, the attraction flow was most effective.

Based on formula (1) the effective length of a bypass channel with an earth bottom and rubble sides ( $n = 0.030 \text{ s/m}^{1/3}$ ) (Chow 1959) for:

- mean velocity U: 0.5 m/s
- discharge Q: 2.5 m<sup>3</sup>/s

- waterdepth : 0.5 m
- bed width: 10 m
- hydraulic radius R: 0.45
- fall: 2.64 m

can be calculated as  $L = 2.64/S_0 = 3250 \text{ m}$ .

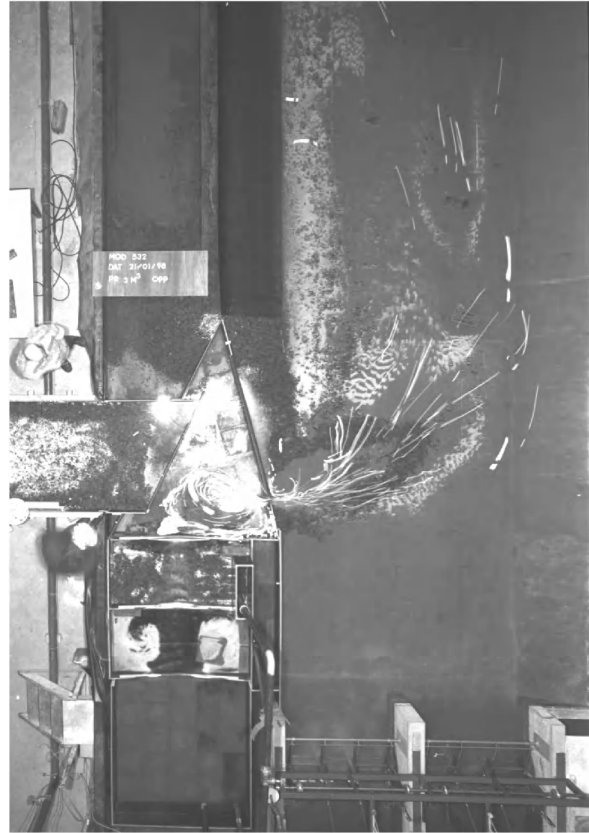


Figure 4. Extent of the attraction flow with  $Q_{\text{fishpassage}} = 3 \text{ m}^3/\text{s}$  and  $Q_{\text{total}} = 20 \text{ m}^3/\text{s}$  in combination with a dike dam. Q = Discharge

Tests with several different roughness elements like deflectors, constriction and widening of the channel section, macrophytes,... (figure 5) allowed us to define Manning-n values of about  $0.1 \text{ s/m}^{1/3}$ . Hereby the effective length on the field for Asper could be reduced by factor 9 to an acceptable 360 m. Based on these insights, recalculations for Oude-naarde already resulted in the construction of a bypass channel of 350 m long, 10 m wide, a depth of 0.4 m, and a mean velocity of 0.4 m/s.



Figure 5. Bypass channel with natural roughness elements like macrophytes, deflectors, meanders, constrictions, ...

## 4 CONCLUSION

This research emphasizes the possibilities of fish migration together with the renewal of the weirs at Asper, Oudenaarde and Kerkhove. A dike dam, which leaves an opening over the total depth of the downstream channel part seemed to be the best entrance design. In combination with a fish pass discharge of about 10-15 % of the most occurring daily discharge of 20 m<sup>3</sup>/s on the Upper Scheldt at Asper, an efficient attraction flow is generated.

Although the use of fish species in a scale model can be questioned, 4 fish species were successfully used to evaluate the efficiency of the fish pass entrance design and attraction flow. The main aspect was the behaviour of the fish to a different flow regime caused by an attraction flow. We noted hereby that not all of the used species showed the same migration behaviour.

Once a good entrance, not yet a successful fish passage. Therefore a natural bypass channel was designed with acceptable velocities for the mainly weak swimmers in this area. By adding natural roughness elements like meanders, deflectors, constrictions,... the length of the preferred more natural bypass channel could be reduced by about factor 9 to an acceptable length on the field. The findings at Asper are already used on the field for Oudenaarde after recalculation.

## 5 REFERENCES

- Boiten, W. 1989. *De V-vormige vistrap - Optimalisatie van het hydraulisch ontwerp*. Delft: Waterloopkundig Laboratorium.
- Chow, V. 1959. *Open Channel hydraulics*. Singapore: MCGraw-Hill, Civil Engineering Series.