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PROPOSALS FOR THE RESTORATION OF LONGITUDINAL CONNECTIVITY OF THE JIU RIVER AND ENSURING FISH MIGRATION UPSTREAM / DOWNSTREAM OF ISALNITA DAM

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Abstract

The aim of this paper is based on the necessity of ensuring the longitudinal connectivity of rivers in order to establish sustainable means of solving current problems related to ensuring the migration of fish fauna, generated by building dams on watercourses. The main purpose is to suggest solutions to restore the longitudinal connectivity of the Jiu River and ensure the fish migration upstream / downstream of Isalnita Dam, in the context of the issues typical of this area. The water body "Işalniţa reservoir" has been classified as heavily modified water body, due to the dam's presence. Therefore, the need to find solutions to restore the longitudinal connectivity and ensure the migration of fish fauna towards the breeding areas has led to the proposal of technical solutions to ensure fish migration upstream and downstream the Işalniţa dam. The proposed technical solutions consist in developing a lateral system set on the left bank of the Jiu River to ensure the migration of fish fauna and arrangement of obstacles encountered on the route of the proposed migration system. Achieving the proposed system in order to ensure fish migration will provide longitudinal connectivity restoration of the Jiu River and access of migratory species towards the aquatic habitats upstream, helping to restore natural ecosystems and to improve the water quality. In this way, the restoration of longitudinal connectivity of Jiu River near Işalniţa dam would provide habitats reconnection on the river sector located at the confluence between the Jiu River and Turceni Dam and create optimal conditions for fish migration and aquatic fauna development upstream and downstream of Işalniţa dam.

Keywords: longitudinal connectivity, fish migration, dams, water course

INTRODUCTION

Interruption of longitudinal connectivity of water courses in Romania and hindering fish migration upstream towards the breeding sites

as a result of water courses blocking for electricity production purposes, flood defense and water supply has decreased the number of migratory fish species present in Romanian rivers. Ecological and economic implications of this phenomenon has determined the experts to find solutions in order to restore the longitudinal connectivity of water courses and provide fish migration towards breeding habitats situated upstream of the dams.

An important element related to a good management of migratory fish species in rivers, both at European and national levels, is arranging or removing transversal obstacles hindering fish migration. Thus, the requirement to achieve environmental objectives under the Water Framework Directive (60/2000/CE) and similar directives entail finding solutions for ensuring fish migration and restoration of rivers longitudinal connectivity. Also, nationwide, the water legislation (Water Law no. 107, as amended and completed, G.O. 1163/2007), reflecting the European directives, mentions as mandatory the performance of works in order to ensure fish migration and maintain the ecological balance in the reservoirs area. The objective of this paper is based on the need to ensure longitudinal connectivity of the inland rivers in order to establish sustainable ways of solving present problems of fish migration generated by dam construction on the water courses. The main purpose is to suggest solutions to restore the longitudinal connectivity of the Jiu River and ensure fish migration upstream / downstream of Isalnita dam, in the context of issues typical of this area.

The water body "Işalnița reservoir" has been classified as heavily modified water body, due to the dam's presence. Therefore, the need to find solutions to restore the longitudinal connectivity and ensure the migration of fish fauna towards the breeding areas has led to propose technical solutions to ensure fish migration upstream and downstream the Işalnița dam.

The proposed technical solutions consist in developing a lateral system set on the left bank of the Jiu River to ensure fish migration and arrangement of obstacles encountered on the route of the proposed migration system. Achieving the proposed system for fish migration will provide longitudinal connectivity restoration of the Jiu River and access of migratory species towards the aquatic habitats upstream, helping to restore natural ecosystems and to improve the water quality.

In this way, the restoration of longitudinal connectivity of Jiu River near Işalnița dam would provide habitats reconnection on the river sector located between the confluence of the Jiu River and Turceni dam and create optimal conditions for fish migration and aquatic fauna development upstream and downstream of Işalnița dam.

1. STUDY AREA

The studied area is part of the basin of one of the major river systems in Romania - Jiu – having 3867 km length and covering a collection area of about 10,080 km^2 [1]. Geographically, the study area - the Isalnita dam – is part of the Jiu piedmont sector in the Sub-Carpathians and Getic Piedmont, situated nearby the morphological contact with the Oltenia Plain. This area ranges within the Pontic Ecoregion characterized by a slightly wavy relief in the north, a predominantly siliceous geology, a chernozem soil, deciduous forests and agricultural areas.

The Isalnita water intake with diversion dam is located on the Jiu River at about 12 km upstream from the city of Craiova in Dolj County and at about 99.5 km from the mouth of the Jiu River. The diversion dam has 18 m height and was put in operation in 1964 [3], [10] (Figure 1). The storage lake, created due to construction of the water intake with diversion dam on the Jiu River, in order to ensure drinking water supply for Craiova municipality and Isalnita industrial platform has an area of 180 hectares and a volume of 1.65 million m^3, being located between both sides of the Jiu River.

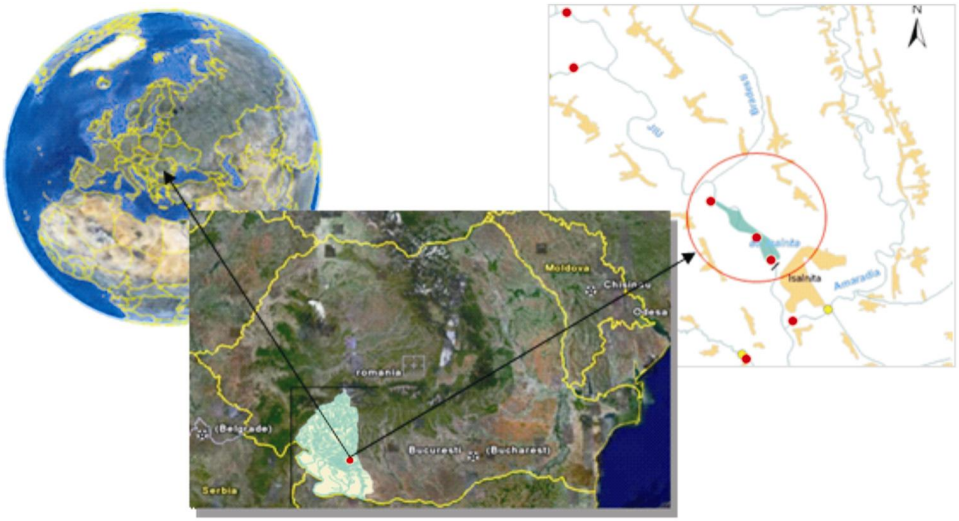

Figura 1. Location of study area (Image source:[6])

Water body "Isalnita reservoir" (ROLW7.1._B120) is located on the site of community importance ROSCI0045 - *Jiu Corridor*, along the middle and lower Jiu River watercourse which includes one of the rarest and most representative relict samples of less altered European meadow, and a major transbalkan corridor for bird migration (central European-Bulgarian corridor) followed by an impressive number of birds (33% of bird species

reported in Romania), of which 84% are protected at national and European level [10].

According to the Romanian rivers fish zoning (Banarescu,1964), the area of study belongs to *barbel fish zone,* characteristic for all plane and hills area rivers. The mane migratory fish species are: the barbel (*Barbus Barbus*), which are of protective interest at national and international level (Bern Convention, Directive on Freshwater Fish, annexes to the G.O. 1198/2005; ;;Natura 2000" network). Other migratory fish species present in the barbel fish zone are the burbot (*Lota Lota*) and the sterlet (*Acipenser ruthenus*), and also the migratory species characteristic of neighboring fish zones: see gudgeon (*Gobio uranoscopus*), ide (*Leuciscus idus*), asp (*Aspius aspius*) and the carp (*Cyprinus carpio*), which have an economical and industrial value [2].

Barbel are strong fish with overall measure between 30-50 cm and 500-800 g but can grow over 14 kg [8]. In Romania the barbell can be found in almost all lowland and hill waters and sometimes in the Danube River.

More demanding than other cyprinids, barbel prefers clean rivers, oxygenated, with pits and rocky-sand bottom. It feeds on grubs, worms, crustaceans, mollusks and vegetable detritus. Reproduction takes place in May-June when barbels gather in larger groups and migrate to the upper zone of rivers, where females spawning in the rocky areas with less current [8]. Winter shelter under rocks in shallow areas of rivers. Because of the precarious situation of the ecology of our rivers due to the dams' construction, the barbel population is not very developed, grasping the small and rare specimens.

1.1 Presenting the studied item

The *Işalniţa* water intake with the diversion dam operate like a system for raising the Jiu River water level in order to gravitationally lead the water flow towards a battery of 12 water settlers (Figure 2), the decanted water serving mainly as cooling water for Isalnita thermal power station (Q_i = 33.33 m^3/s) and Şimnic (Q_i = 0.67 m^3/s) and water for water treatment station Craiova (Q_i = 1.15 m^3/s) [3]. The secondary function is to attenuate the effect of tributary floods into the dammed section through the volume available between NNR and NMR. The dam situated at the Isalnita water intake is composed of 6 current openings and a cleaning opening having a dam crest of 129.10 m length and is ranked as "B-category of importance" (dam of high importance).

Figure 2. The Işalniţa water intake with the diversion dam

On the left bank of Jiu River, near the Isalnita reservoir there is a Jiu channel that ensure the necessary flow for secondary water intake, built in 2010. It is composed from underground cassette channel connected to the water settlers (Figure 2).

Given the designation of water body "Isalnita reservoir" (ROLW7.1._B120) as heavily modified water body and the presence of migratory fish species in the area, the proposed environmental aim in PMB - *good ecological potential* - provides identification and application of the necessary measures in order to restore the longitudinal connectivity. Therefore the need to solve issues related to longitudinal connectivity restoration of the Jiu River and ensuring fish migration has led to some technical solutions (lateral system) in order to ensure migrating of fish fauna upstream and downstream of Isalnita Dam.

2. SOLUTION FOR ENSURING THE FISH MIGRATION

Having visualized the study area and carried out the assessment of the situation on the site, together with the problems debated by the specialists from ABA Jiu and Isalnita Dam, also taking into account the analysis on technical data and cartographic projection on the study area, the suggestion of a lateral solution for ensuring the fish migration has been concluded.

The proposed solution consists in achieving a lateral system for fish migration upstream and downstream of Isalnita dam, located on the left bank of the Jiu River, along the present course of *the warm water disposal channel – the open water supply channel for Isalnita PP – the first water settler – the secondary water intake – the Jiu channel*.

The targeted migratory fish species is the barbel, protected at European and national levels (Bern Convention, Directive on Freshwater Fish, annexes to the G.O. 1198/2005; "Natura 2000" network). Moreover, the proposed system of fish migration can also be used for species considered not migratory (or migratory only for short distances, < 20 km) present or encountered in the study area.

The solution regarding the development of a system for fish migration upstream/downstream of Isalnita dam consists in the arrangement of obstacles encountered on the route so that the longitudinal connectivity of the Jiu River is restored on the studied reach. The obstacles found on this route have been carefully analyzed and, then, solutions on ensuring the fish migration have been provided for each.

The main obstacles identified on the selected route were: ***drop sill at the junction between the overflow channel and the warm water disposal channel, drop sill at the junction between the overflow channel and the open water supply channel for Isalnita PP, the gate at the exit of water settlers, the gate at the first water settler, the cassette (compartmentalized) channel (secondary water intake)*** (figure 3).

Figure 3. Location scheme of identified obstacles on the fish migration route (Image source: [6])

The decision upon a lateral system for fish migration using the route of the mentioned channels (figure 3) follows the next criteria:

- a considerable water flow quantity on the channels route (39 m^3/ s = installed flow of water supply channel and 27 m^3/s = actual flow) and the possibility of additional quantities so that the activity of CET Isalnita to remain unchanged;
- few activities needed to develop the 6 obstacles on the chosen route;
- information on fish presence in the two channels and at the junction between the overflow channel and the warm water disposal channel, conforming the fact that, after arrangement has been performed, the selected route can be used for fish migration.

Furthermore, we provide bellow step-by-step solutions proposed for the arrangement of the 6 obstacles identified, that has to be followed to assure fish migration, following the route of fish migration from downstream to upstream. Thus, building a rectangular or oval-shaped (slot-type) *channel for fish migration* in order to ensure the fish migration downstream and upstream of Isalnita dam, has been proposed; it may be made of concrete modules, metal or carbon fibers and having one meter width and height (figure 4).

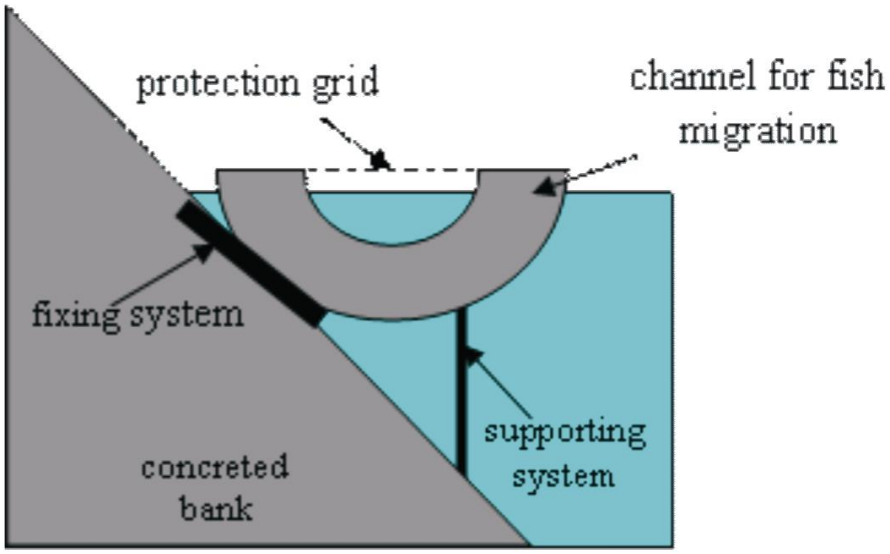

Figure 4. Channel for fish migration

The end of the first channel module for fish migration is into a natural-type basin arranged in a riverbed near the right bank of the warm water disposal channel of PP Işalnita, downstream the confluence with overflow channel. Thus, this channel flow of about 2 m^3/s will provide the

attraction water flow required at the fish migration channel entrance (figure 5).

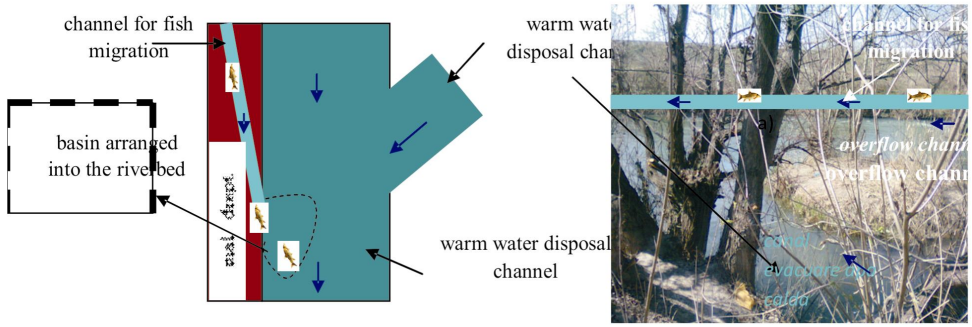

Figure 5. Positioning of the basin arranged into the riverbed, downstream the confluence of channel for fish migration with the warm water disposal channel

The fish migration channel entrance is provided with a system for fish guiding in order to help them find the entrance. Then, the fish migration channel will follow the right bank direction of the overflow channel up to the first obstacle (Figure. 6).

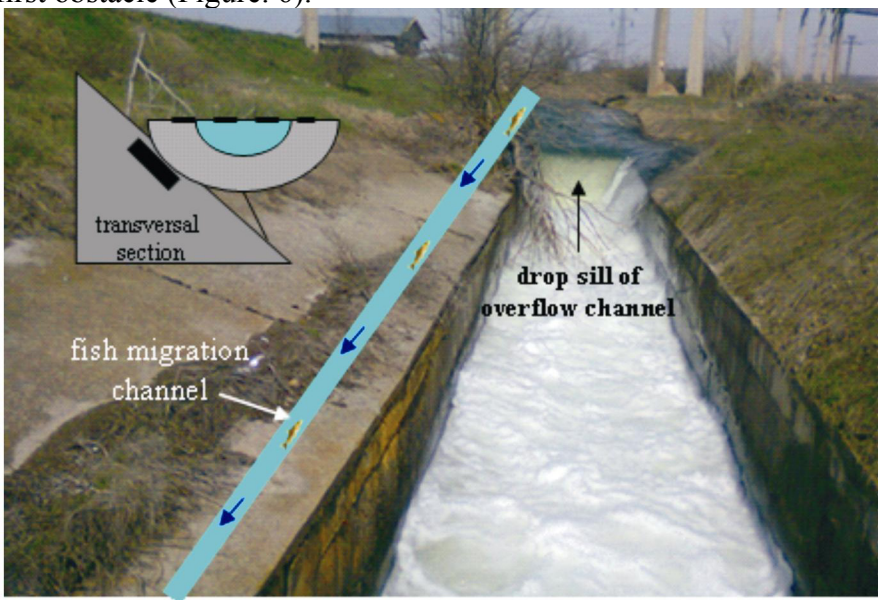

Figure 6. Location of fish migration channel in front of the first drop sill

The first identified obstacle requiring arrangement is the *drop sill at the junction between the overflow channel and the warm water disposal channel* (figure 6). Passing the drop threshold, situated at a distance of about 450 m from the confluence with the warm water disposal channel of Işalnita PP, will be performed on the right bank, bypassing the drop

threshold (figure 6). In this sector, the migration system will have the same semi-oval form as on the sector downstream of the drop sill.

The second obstacle identified on the route of fish migration is an irrigation system located on the overflow channel, at approx. 130 m downstream of the second drop sill, situated at the junction between the overflow channel and the open water supply channel (Figure 7). Along this sector, the channel for fish migration will bypass the irrigation system, creating a loop where a resting pool for fish can be arranged since the overflow channel slope is 0,385% [3] and the channel water speed is high enough to impede fish migration in good condition.

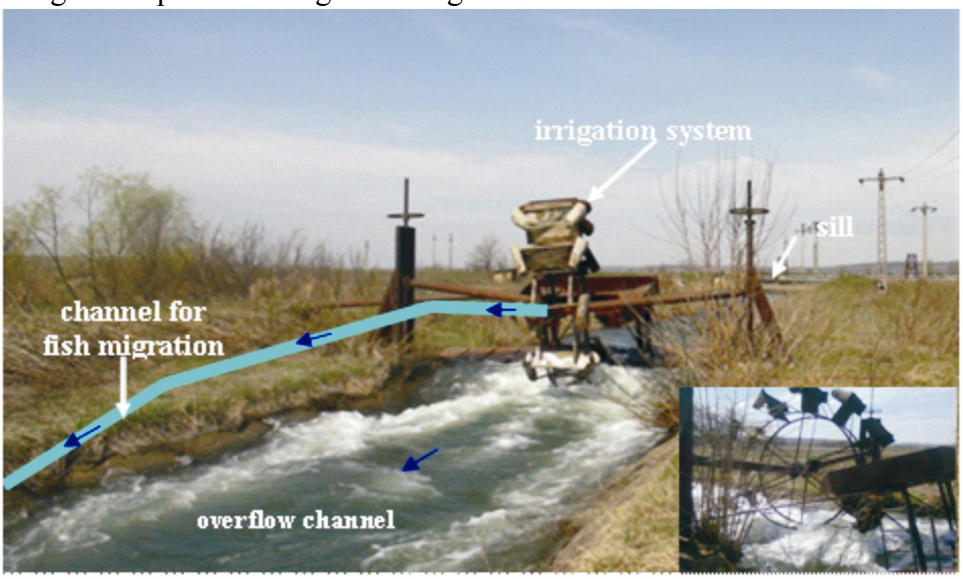

Figure 7. Bypassing the irrigation system

In order to ensure fish migration over the second drop sill located at the confluence between the open water supply channel for Isalnita PP and the overflow channel (making the connection with the warm water discharge channel), a concrete basin fixed between the sill and the right bank of concrete of the overflow channel has been designed. It will be larger than the width of channel for fish migration and will serve as a resting place for migratory fish. At the top, the resting basin will be provided with a loophole equipped with a crenel and a metal grille in order to ensure a constant volume of water. The basin bottom will be under water level in the overflow channel (figure 8).

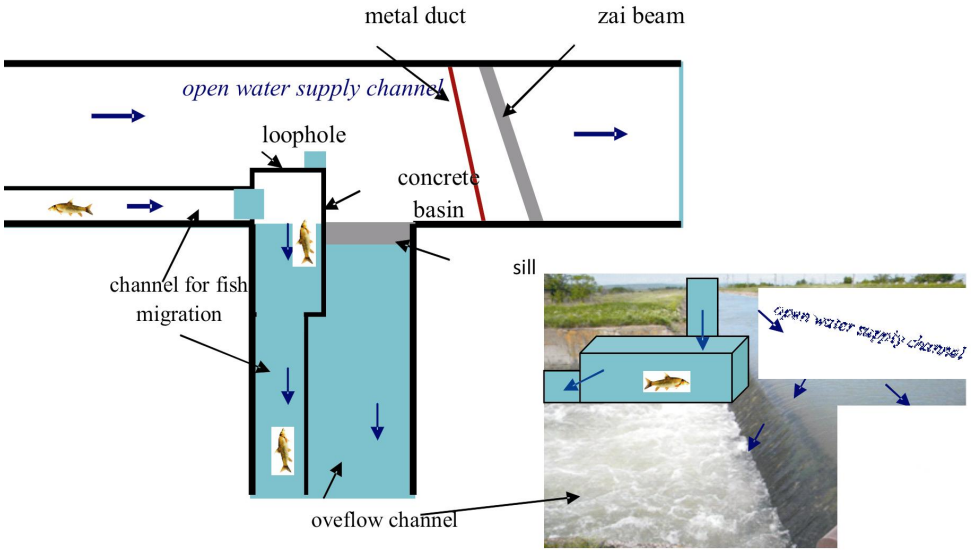

Figure 8. Positioning of migration system over the second drop sill – provisional scheme

Further, on the sector situated at the junction between the water supply channel and the overflow channel, up to the gate at the water settler exit on the open water supply channel towards the Isalnita PP, a concrete channel for fish migration will be executed; it will be semi-oval shaped and fixed on the concrete wall on its right bank, as presented in figure 4.

The open water supply channel has trapezoidal section of 2.0 m, slopes of 1:2 and horizontal berms, being lined with concrete slabs of 15 cm thickness. Its length is of 2325 m, the slope of the slab foundation of 0.385% and Q = 24 m³/s [3].

Another alternative solution for facilitate fish migration upstream to the irrigation system and second drop sill, located at the junction of the overflow channel and open water supply channel to the Isalnita PP is presented in figure 9. This solution involves creation of a meander bypass on the right bank of overflow channel to avoid the two mentioned obstacles (irrigation system and drop sill). The bypass will be provided with a resting area for fish. After resting pool fish migration channel will continuing on the right bank of the open water supply channel till the submerged module of fish migration channel (Figure 10).

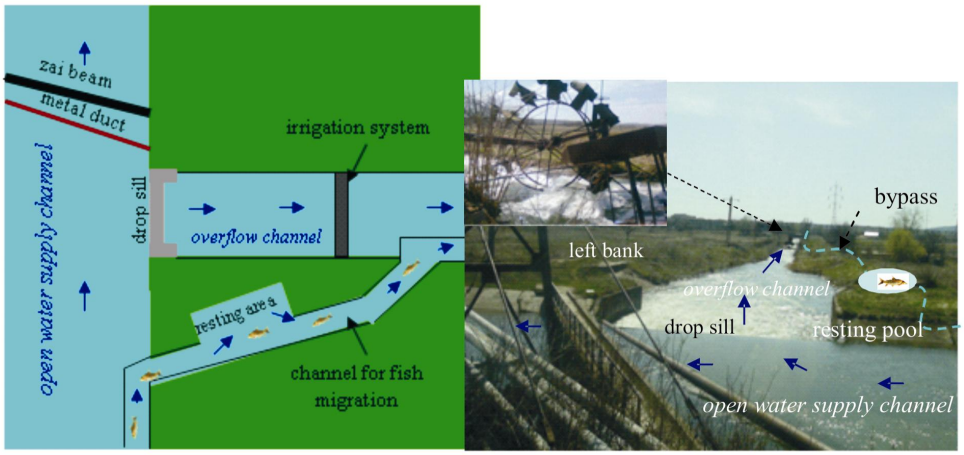

Figure 9. Scheme of alternative solution for ensure fish migration upstream the second drop sill

At a distance of about 100 m from the obstacle, from the water settler exit, the fish migration channel will be located on the left bank of the open water supply channel (Figure 10). The link between the two sides of migration channel will be done through a rectangular channel made of resistant glass with metal inserts placed under water (figure 10). Thus, in the channel located on the left bank the excess flow will pass through a grid placed on top, and the channel side located on the right bank of the open channel will receive water from it through a grid placed on top (Figure 11).

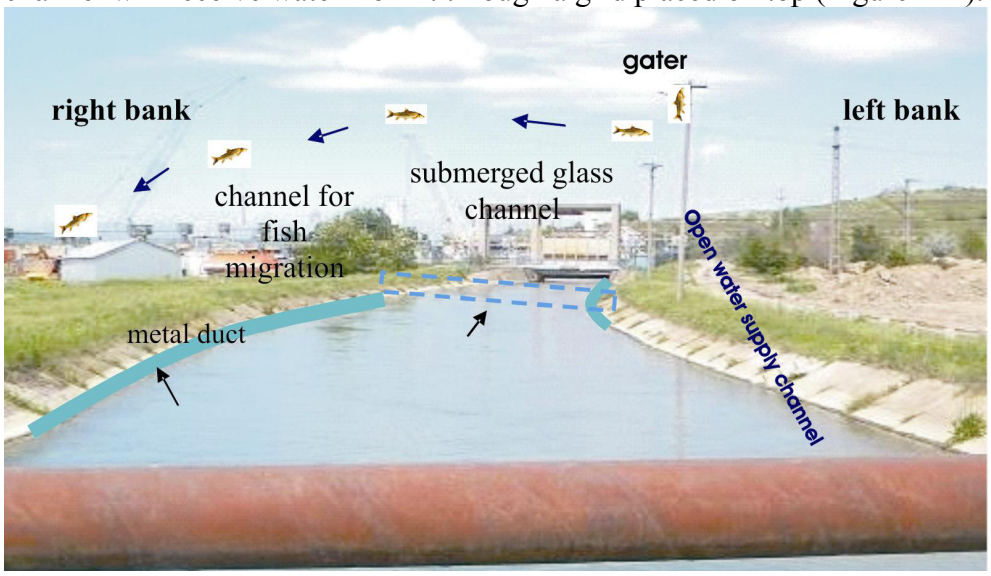

Figure 10. Location of system for fish migration downstream of the sluice, at the water settler exit

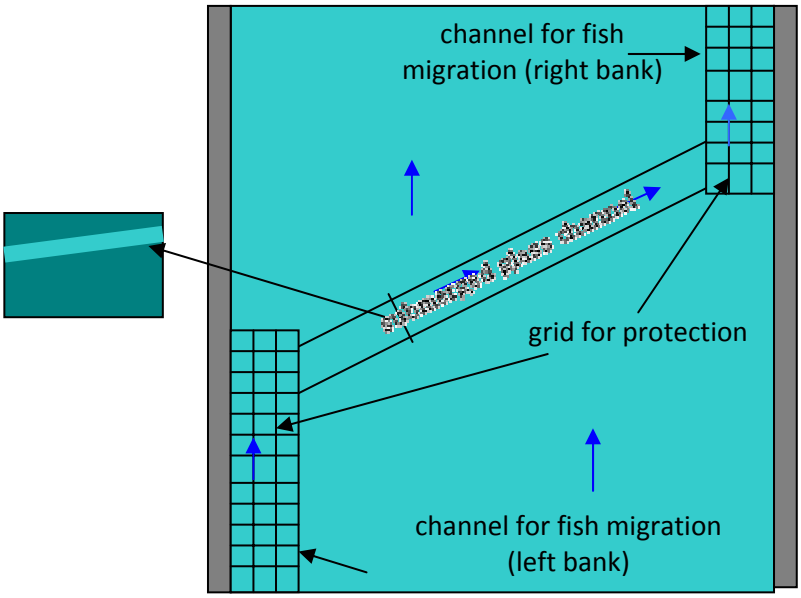

Figure 11. Scheme of submerged section of the channel for fish migration

In front of the gate which allows access to the open channel at the water settler exit (Figure 10), the channel for fish migration will have the same features as the module of the migration system located between two gates of the first water settler. In order to pass the mentioned gate, fish migration channel will be provided with two symmetrically placed loopholes, allowing the separation (if necessary) of the migration channel module located near the gate so that the gate to be functional (figure 12).

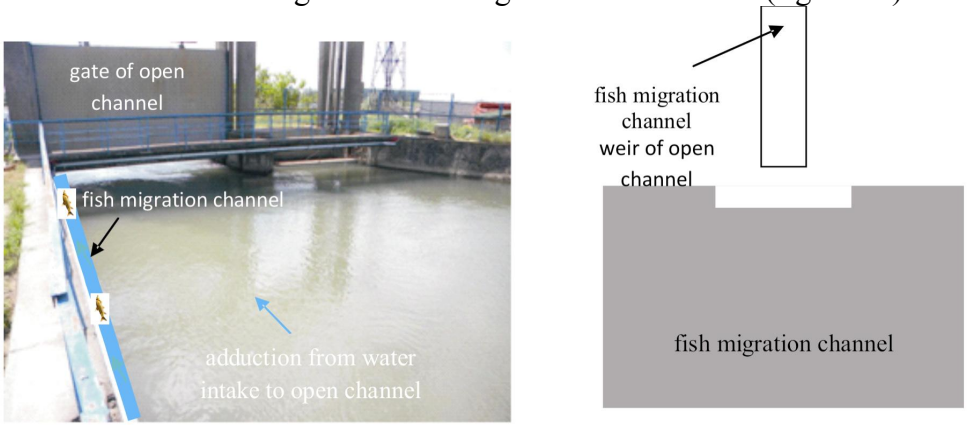

Figure 12. Scheme presenting the removable sector of the fish migration channel

Upstream of the third gate, the fish migration channel will be semicircle shaped in order to fit seamlessly into the water supply channel bend placed before the gate at the entrance of the first water settler (Figure 13). The fish migration channel modules located in this area will be made of the same material as the downstream section and have a rectangular shape.

Figure 13. Scheme presenting the location of the fish migration system between gates (Image source: [6])

The upstream end of the metal channel for fish migration will be fixed on both sides of the downstream tympanum of the temporary intake (the downstream end of the compartmentalized channel), covering half of its opening (Figure 14).

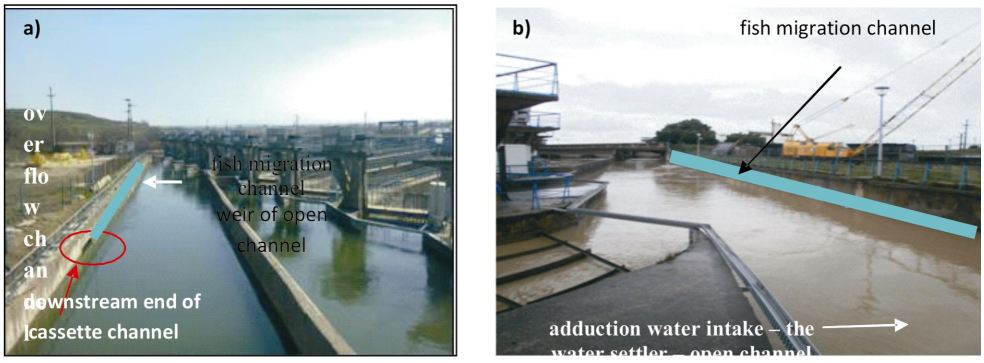

Figure 14. Location of the downstream tympanum of the temporary intake (a) and the channel for fish migration (b)

A metal grid will be placed between the metal channel and bottom of the cassette (compartmentalized) channel, so that fish cannot pass. Part of the flow passes through the metal channel and the rest through the grids (Figure 15).

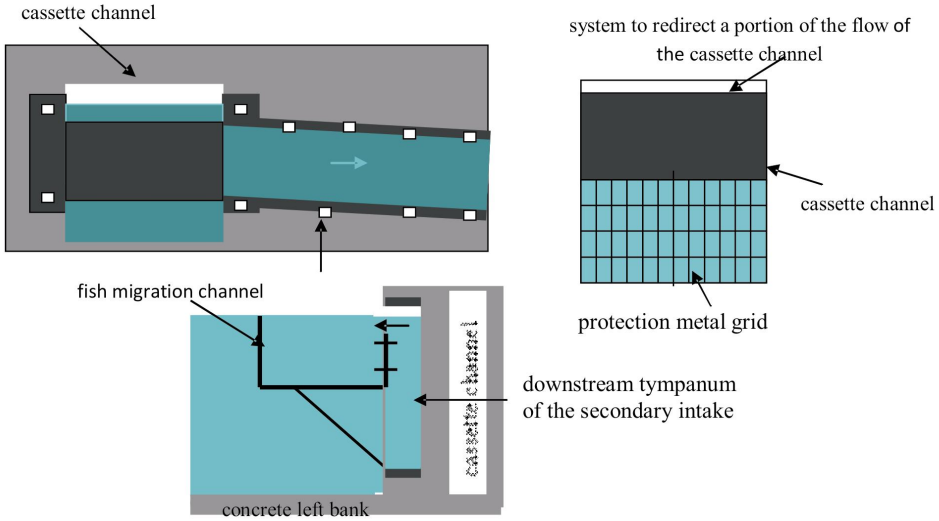

Figure 15. Positioning of fish migration channel (a, c) and the metal grid (b) in relation with the exit of the cassette (compartmentalized) channel .

The cassette (compartmentalized) channel represents the approach channel of the secondary water intake (made in 2010), which captures water from channel located on the left side of the Isalnita reservoir and is directly related to the Jiu River (Figure 16). This compartmentalized channel is rectangular having the following dimensions: h = 2.5 m, L = 2.70 m and L = 167. Flow through this channel is of 14 m^3/s [3].

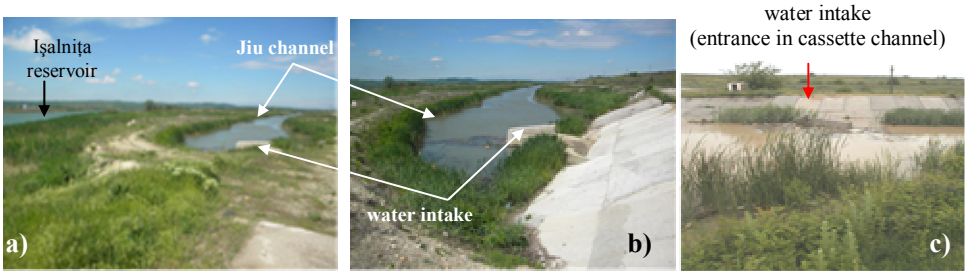

Figure 16. Channel deriving from the Jiu River (a), secondary water intake on Isalnita (b, c).

In order to ensure the migration of fish fauna inside the compartmentalized channel, it is recommended to perform the following development works:

- developing lighting systems inside the cassette (compartmentalized) channel throughout its length through vertical drilling;
- developing of a semicircle-shaped metal grid located in front of water intake to avoid blocking the entrance into the water intake.

The lighting systems of the compartmentalized channel are actually some "rectangular windows" (rectangle-shaped sun light wells) having the following dimensions of 3.0 x 2.5 m and a depth of about 2.7, drilled from the ground surface to the upper gallery of reinforced concrete and having 0.40 m thickness. These "light wells" will be made of concrete and placed one at every 5 m along the entire length of the channel (figure 17).

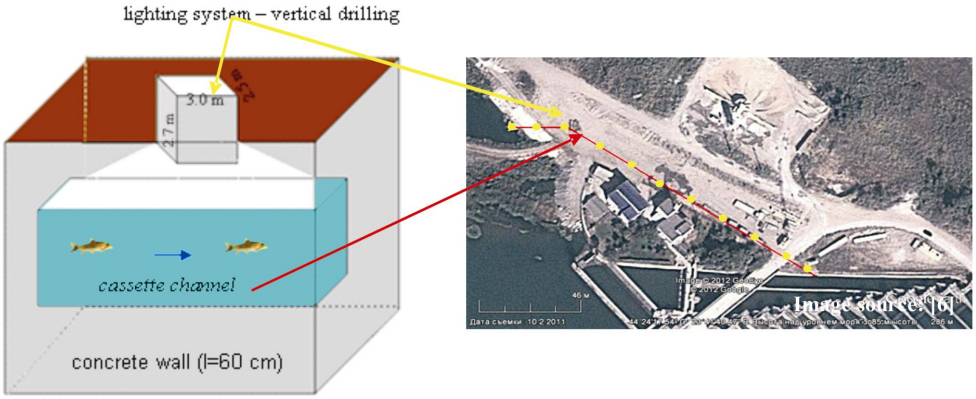

Figure 17. Positioning the lighting system of the cassette (compartmentalized) channel

After drilling, the lighting area will be compartmentalized using a few centimeters thick concrete and a protective metal grille with 5 cm distance between the bars and 1 cm thickness will be fixed above it (Figure 18). The metal grid is fastened using two hinges and a key locking system. The lighting systems will be provided also with metal stairs to facilitate access if needed (maintenance, water sampling, repairing, etc..).

The first lighting system be drilled obliquely downstream tympanum of the water intake, the others will be vertically drilled from the ground surface to the water intake approach gallery (compartmentalized channel) (Figure 19).

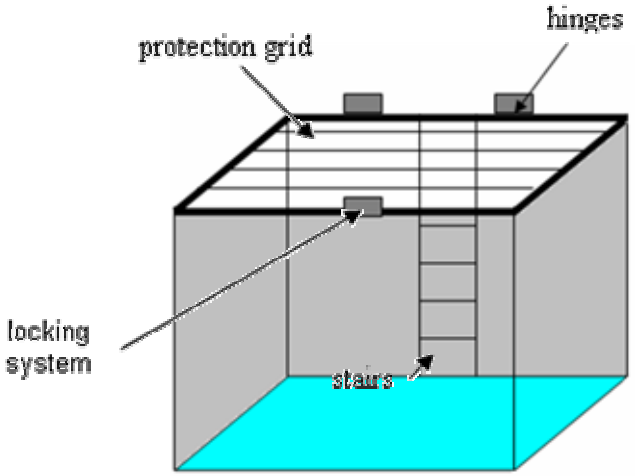

Figure 18. Scheme of lighting sistem

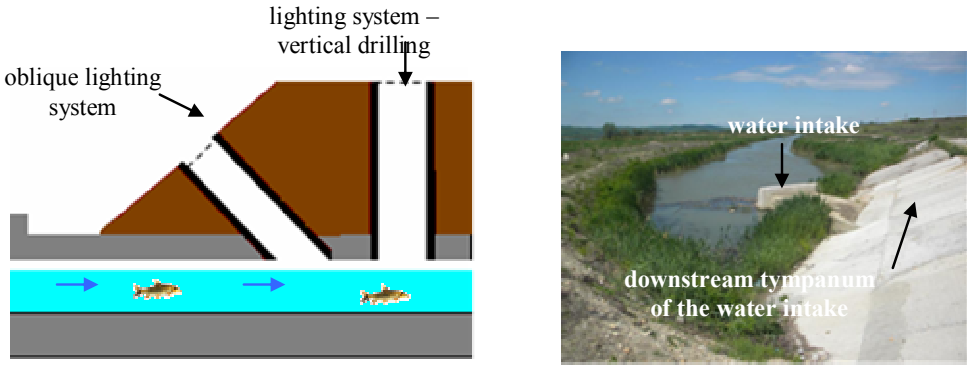

Figure 19. Lighting system at the entrance of secondary water intake (compartmentalized channel)

To avoid blocking the entrance in the water intake, a semicircle-shaped metal grid will be placed between the two banks, in front of the water intake (Figure 20).

After passing through the cassette (compartmentalized) channel, the route of fish migration will continue on the Jiu bypass channel towards the Isalnita lake tail, and then up to the Jiu River (Figure 16 a, b).

Throughout its length, the system of fish migration (Figure 3 and 20) must meet a number of conditions (attraction current, slope, lightning, water flow and speed, protection, etc..), so that fish can migrate safety upstream and downstream. In winter, this system can be closed by detaching the underwater channel and blocking the migration channel located on the left bank by the means of a sluice and by detaching modules located near gates.

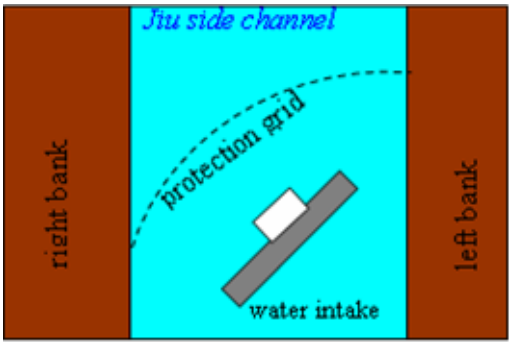

Figure 20. Scheme presenting the location of protection grid

Figure 21. Scheme on the proposed system route of fish migration upstream of Isalnita Dam.

To protect fish and prevent illegal fishing, all channel modules can be provided with a metal mesh grill in order to ensure the migration of fish fauna. During maintenance, the grills mentioned will be attached to the front of the dam pillars using a metal fastening system.

After implementing the proposed system of fish migration upstream of Isalnita dam, the migration route including the sector located between the confluence of the warm water discharge channel and the confluence of Jiu River with the Isalnita reservoir tail (Figure 20), will cover a distance of *about 3145 m*. The total length of reconnected habitat, located on the river sector between the confluence of Jiu River and Turceni Dam will be about 130 km, being considered as part of >50 km *class of reconnected habitat of high quality* determined by the ICPDR to internal rivers.

An alternative to proposed fish migration system is to use, in some areas, for fish migration the open water supply channel and the adduction channel from water intake to open water supply channel, reducing the migration system length and the costs needed for building it.

CONCLUSIONS

- The proposed technical solutions involve the creation of a lateral system to ensure fish migration, located on the left bank of the Jiu River and arranging obstacles encountered on the route of the proposed migration system.
- The proposed technical solutions to achieve a lateral system for fish migration upstream/ downstream of Işalnița Dam do not require technical knowledge and special engineering, making them feasible in this regard.
- The solutions are neither radical nor invasive maintaining the property owned by Hidroelectrica S.A. (intakes, dams, water supply pipelines, drop thresholds).
- The costs of execution for each activity are not high, except for the lighting system of the compartmentalized channel, which can increase due the complexity of these works.
- The achievement of these solutions presents a major environmental benefit, helping to restore longitudinal connectivity of the Jiu River at Isalnita Dam and facilitating fish migration, improving biodiversity and aquatic habitats, creating new habitats and ensuring safety for the protected fish species as follows: (barbell (*Barbus Barbus*), the burbot (*Lota Lota*), the sterlet (*Acipenser ruthenus*), and also the migratory

species characteristic of neighboring areas: see gudgeon (*Gobio uranoscopus*), carp (*Cyprinus carpio*), the ide (*Leuciscus idus*) and the asp (*Aspius aspius*)), invertebrates and birds on the site of Community Interest ROSCI0045 – Jiu Corridor located along the Middle and Lower Jiu.

- The total length of reconnected habitat, located on the river sector between the confluence of Jiu River with Danube River and Turceni Dam will be about 130 km, being considered as part of *>50 km class of reconnected habitat of high quality* determined by the ICPDR to internal rivers.

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