ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ
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RESIDUAL FLOW AND FISH MIGRATION FACILITIES ON WATER INTAKES OF A COLLECTING CHANNEL

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Keywords: *water intake, collecting channel, residual flow facility, fish migration facility*

ABSTRACT

For almost all water intakes of the collecting channels of the hydropower systems built in Bulgaria before the 90s of the previous century, both the residual flow in the diverted river bed and the fish migration facilities were not issues of consideration at all. Currently, however, with respect to the requirements of the contemporary regulations and good practices in the field of environmental protection, these water intakes have to be upgraded with such facilities.

In this paper, the upgrading equipment of a number of water intakes of an existing mountainous collecting channel either only with facilities for given residual flow or with combined facilities for both residual flow and migration of the local fish population is presented. The conceptual design solutions are discussed for the combination of the tasks formulated by the ichthyologists and the operational requirements of the client.

1. Introduction

From the 50s to the 80s of the 20th century, all main multi-purpose hydraulic engineering systems in Bulgaria were built including large hydropower systems. Later on, at the end of the 90s and in the first decade of the 21st century, the so-called “small hydropower” boomed. During all this time, the environmental aspects of the built and operated hydraulic

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engineering facilities, such as residual flow in diverted river reaches and fish migration possibilities at the developed barriers were no issues of consideration at all. The inception of the Water Frame Directive (WFD) [1] within the European Union (EU) and its subsequent incorporation into the national legislation of the member states requires in general, among many other environmental issues, restoration of the continuity (hydraulic and biological) of the affected water bodies, especially in environmentally protected areas. Otherwise, existing water rights permits for hydropower use could not be prolonged.

This work presents the case study for developing the necessary engineering solutions for providing the possibility for releasing as a priority either of a particular residual discharge or combining the latter with a fish migration facility for 8 water intakes at the collecting channel of a large hydropower system in the Middle Pirin Mountain in the South-West of Bulgaria. In the frame of the assigned detailed design, the private owner of the hydropower system wanted to obtain full conformity with the actual national legislation in this field for applying a water rights permit for the facilities for the next possible period. This means, the prescribed residual discharge and fish-pass parameters had to ensure as a priority real restoration of the continuity of the affected mountainous creeks as water bodies. At the same time, the owner also was highly interested to not unnecessarily lose water used for energy production.

It should be noted here that in Bulgaria, still no codes / regulations exist for the design, dimensioning, operation and monitoring of fish migration facilities. Hence, modern and well established good practices and corresponding regulations / recommendations have to be applied by the hydraulic engineers, preferably – from EU member states with similar natural conditions. In the particular case, the Terms of Reference (ToR) explicitly required the implementation of the English translation [2] of the well established document [3] – one of the very first in detail developed guidelines in this field, at least in Europe. Regarding the residual discharge according to a general rule, 10% of the mean multi-annual natural discharge serves as recommended value in all considered cases in this region.

2. Formulation of the Problem

The ToR for the detailed design were developed based on the detailed report from the hydro-biological study performed for the considered intake sites by a national team of renowned ichthyologists in the name of the National Museum of Natural History at the Bulgarian Academy of Sciences [4]. In this team, a national NGO militantly fighting against the hydropower in general was represented at this expert level, too. Thus, all specified in the ToR particular recommendations to the engineering solutions to be applied resulted from the above mentioned hydro-biological study [4].

In summary, three of the intakes needed only facilities for release as a priority of the residual discharge. For two other intakes, bypass channels were recommended. For one of the other intakes, development of a V-shaped boulder ramp with an intermediate rest pool was recommended. One intake had to be equipped with a vertical slot pass. At the last intake, a conventional pool pass is available, however, not efficient at all. It had to be thoroughgoing re-constructed. The residual discharge to be as a priority released at all intakes was specified according to the above mentioned rule, i.e. 10% of the mean multi-annual natural discharge. For all water intakes considered here, this rule defines particular values of the residual flow between 5,5 l/s and 61 l/s.

Of course, site visit was organized, and available archive technical documentation as well as extensive amount of photographs were supplied to the design team, too. Representatives of the Client also helped with all necessary additional information needed.

It should be noted as well that the terrain conditions were extremely heavy – wood, steep slopes of the river beds and banks, high falls and surface covered with large boulders.

3. Developed Design Solutions

In the following, the developed design solutions for the formulated set of tasks are shortly presented.

3.1. Solutions for Residual Discharge Only

Here, special attention will not be paid to the intakes where only residual discharge had to be ensured as a priority. In general, a module was proposed consisting of two sections – an inlet one for controlling of the inflowing discharge (for example during flood conditions) and a measuring one where triangular or rectangular sharp-crested measuring weir is installed. Depending on the discharge (i.e. on the necessary flume width), the measuring weir is foreseen to operate as “fully suppressed” one, or not. The hydraulic calculations of these weir sequences were performed according to [5]. Of course, the level of the inlet opening for the intake (and further to the collecting channel, respectively) was considered, too. Thus, the needed relations between the overflow height of the measuring weir, the actual residual discharge and the discharge into the intake were developed. Each such module also has to be equipped with a calibrated measuring ruler so that by means of the particular rating curve, direct reading of the current residual discharge could be possible.

In general, the described module was designed to be placed into the existing weir body. In the case of a Tyrolean weir, a small sill was designed at the upstream end of the inlet rack. The module itself was placed over the area of the rack. It also had to be proved in such cases that the original design catching ability of the intake would not be decreased. It was shown that the safety factor in this connection is large enough. Although a detailed design was developed, more than one variant was proposed to the Client. The following general considerations were always accounted for:

- possible operation of the intake during installation / repair works on the residual discharge facility;
- easy access, operation and reading.

3.2. Bypass Channels

As mentioned above for two of the intakes (built as Tyrolean weirs), bypass channels were developed as recommended by [4] and required by the ToR, respectively. For the inlet module consisting of two subsequent openings (submerged and not submerged, respectively), hydraulic computational procedure was developed for large rectangular openings of the mentioned types according to [6].

For these intakes, the necessary residual discharge (also – design discharge of the bypass channel) is 35 l/s and 61 l/s, respectively. These values are quite small, yet it became possible to obtain reasonable dimensions and parameters of the bypass channels by means of a special computational procedure developed according to [2, 3]. Their structure is conventional and corresponds to the recommendations of [2, 3], (Fig.1). Both facilities were traced with respect to the obtained necessary longitudinal slope although the terrain conditions are extremely hard, as mentioned above.

For water discharge values in the river (and flowing as a priority into the bypass channel, respectively) up to 75 l/s, the opening in the measuring section operates as a spillway (i.e. rectangular weir). With respect to the given residual discharge values, exactly this is the mode which serves the required readings. For larger discharge values, its mode changes to an opening. For preventing / minimizing the water losses for the intake structure (and to the collecting channel, respectively), a regulating possibility at the first inlet opening of the module was foreseen.

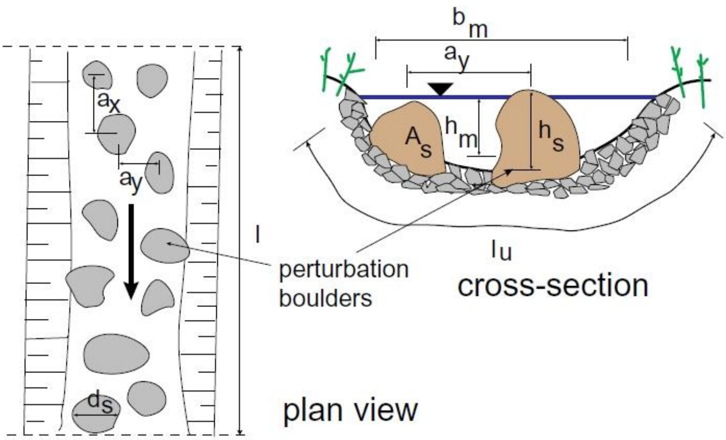

Figure 1. Typical solution of the bypass channel with perturbation boulders [2]

3.3. Recommended V-shaped Ramp with an Intermediate Rest Pool

For one Tyrolean weir intake, a V-shaped ramp with an intermediate rest pool was recommended in [4]. Although the height of the barrier is not high (about 0,90 m), it was proved after thorough analysis that the formulated recommendation (and requirement of the ToR, respectively) cannot be fulfilled due to the following reasons:

- the minimal dimensions of such facilities in the modern guidelines [7, 8] are bottom width 0,5 m and depth 0,3 m. The minimum discharge is at least several times larger than the one in this case (22 l/s), respectively.
- the developed calculation procedures [7, 8] for facilities of this type require minimum average boulder dimension of 0,6 m which is impossible in this case.
- there are built bypass channels for very low discharge values (30 l/s), however, with much lower longitudinal slope – less than 1:20, which in the given case in connection with the topographic conditions is impossible, either.

Thus, a pool pass proved to be the most appropriate one in this case. However, a minimum discharge 33,4 l/s (with given 22 l/s) for a pool pass only with bottom openings 0,15 / 0,15 m was obtained for water level difference in adjacent pools of Δh = 0,20 m. Hence, as only possible solution for preventing unjustified water losses for the water use, a conventional pool pass with notches in the walls between the pools was developed (Figs. 2, 3).

Furthermore, two variants for the inlet were developed – one with heightening (shown in the figures below), and another one with lowering of the pool pass inlet with respect to the level of the upper edge of the inflow rack of the Tyrolean weir. Of course, at the inlet of the fish pass, the above described measuring module consisting of two sections was designed.

The fish pass was traced over the area of the intake rack. All necessary hydraulic calculations were provided as well as the proof that the proposed solution would not decrease the design catchment ability of the intake.

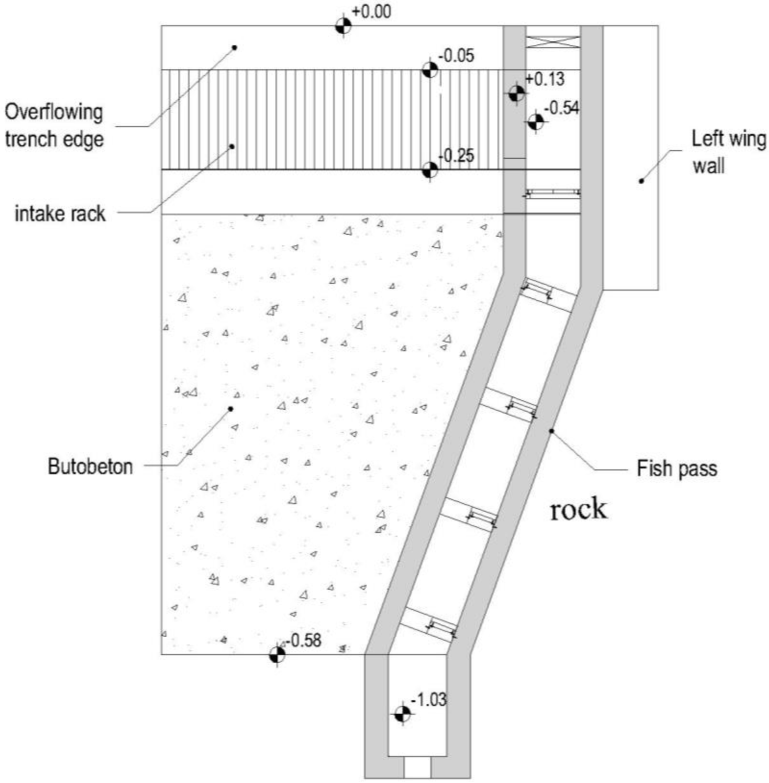

Figure 2. Pool pass with surface notches at the walls between the pools – layout

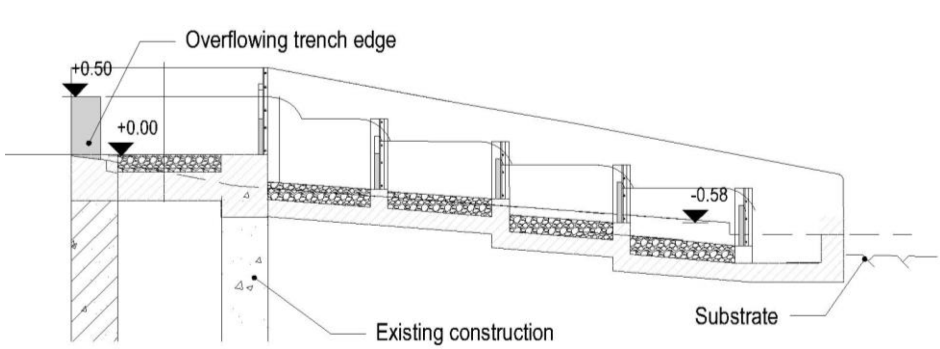

Figure 3. Pool pass with surface notches at the walls between the pools – longitudinal section

3.4. Recommended Vertical Slot Pass

For another Tyrolean weir intake, construction of a vertical slot fish pass was recommended [4]. In the particular case, the intake facility consists of a combination between an inlet rack of Tyrolean type and a massive weir (Figs. 4, 5). With respect to the given recommendation, the following considerations had to be accounted for:

- A fish pass of the recommended type (vertical slot pass) cannot be built here. The reason is the combination of desired / recommended parameters of the pools (i.e. dimensions, depth and hydraulic connection) as well as the relatively small water discharge (29 l/s). Extensive preliminary calculations showed that for satisfaction of the specified requirements [4], a minimum water discharge of at least 100 l/s (according to [7]) or 96 l/s (according to [3]) would be needed. On the reverse, the given discharge could satisfy these requirements with water level difference between the adjacent pools of 1 cm which would be absurd.
- Obviously, another type of fish pass had to be applied. The most appropriate one was the pool pass. Due to the small discharge, neither combination of bottom openings and notches [7], nor only bottom openings [2, 3] could be implemented. Preliminary calculations showed that yet a pool pass with only bottom openings with minimal dimensions 0,15 / 0,15 m could operate with the specified discharge of 29 l/s by means of 12 pools with minimum length of 0,90 m and water level difference between the adjacent pools 0,15 m.

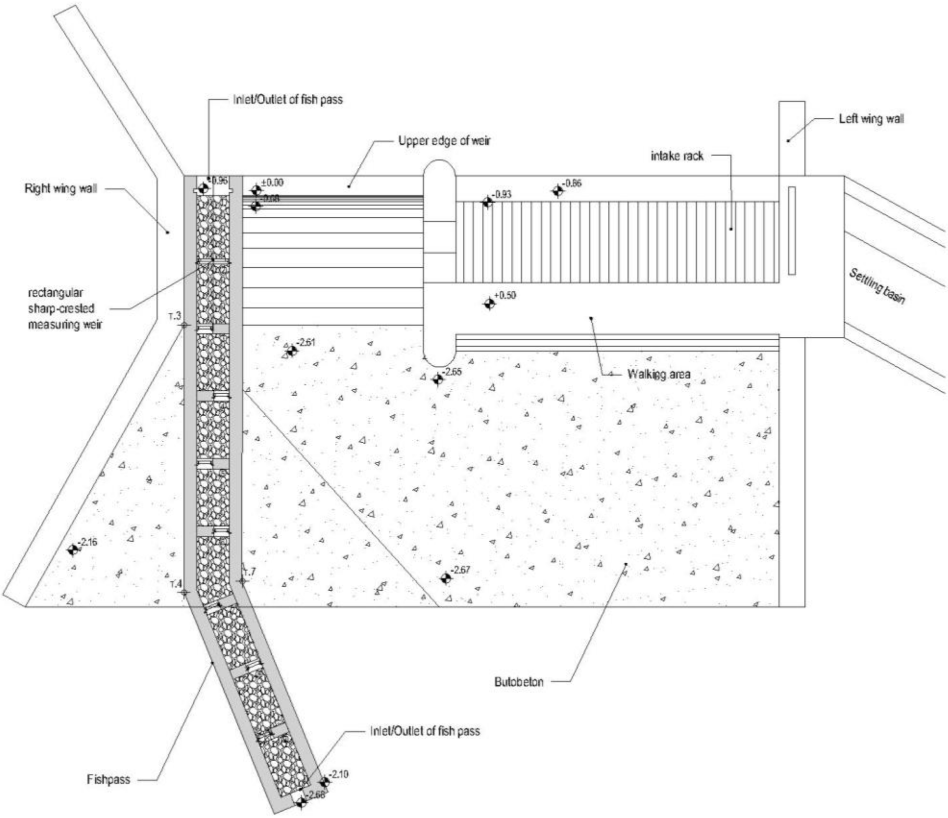

Figure 4. Pool pass with surface notches at Tyrolean intake with massive weir – layout

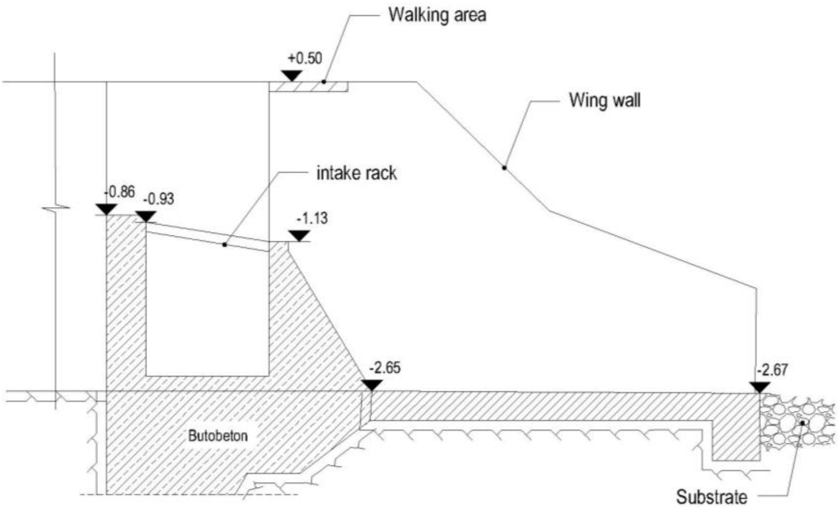

Figure 5. Tyrolean intake with inlet rack in the weir – section

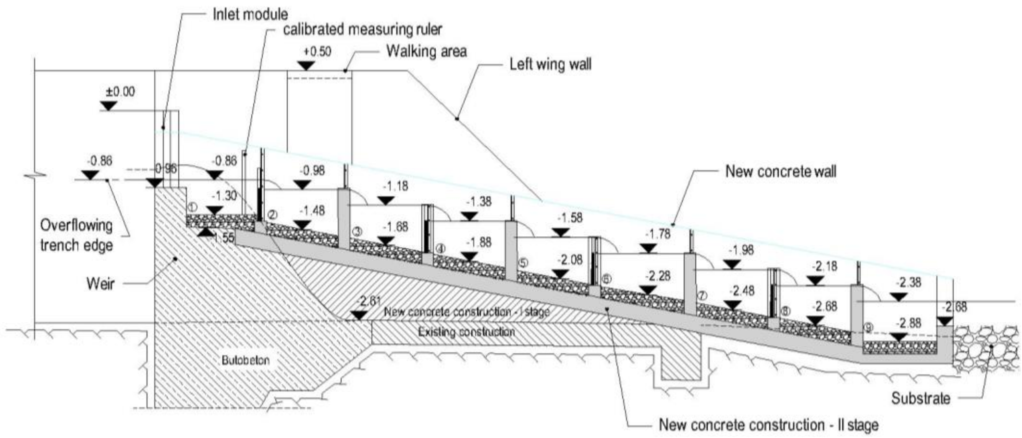

Figure 6. Pool pass with surface notches at the walls between the pools – longitudinal section

Finally, however, a pool pass with notches in the walls between the pools was designed due to the following reasons:

- considerably less construction works needed;
- considerably easier operation, maintenance and control of functionality (the bottom openings with minimal dimensions are hard to observe, their cleaning when clogged is not so easy, either);
- the characteristics of the local fish population – as it is mentioned in the report [4], the trout is representative here in the case. It is well known that trout, as a good swimmer, prefers to swim over handicaps (in this case – the wall between the pools).

All necessary hydraulic calculations were provided including the rating curves needed for the operation. Here again, the measuring module was designed at the inlet of the fish pass (Fig. 6).

3.5. Recommended Conventional Pool Pass

At the considered intake, a pool pass already exists. However, it does not comply with the requirements of the contemporary guidelines / recommendations regarding the parameters and operation of such facility due to the following reasons:

- the pool dimensions are smaller than the minimal acceptable ones (Fig. 7);
- the downstream hydraulic connection with the natural river bed in fact does not allow for any fish migration (Fig. 8).

These detections actually require complete re-construction of the facility at its current place. The developed design solutions aimed at minimum volume of the necessary works additionally to satisfying the formulated particular requirements [4].

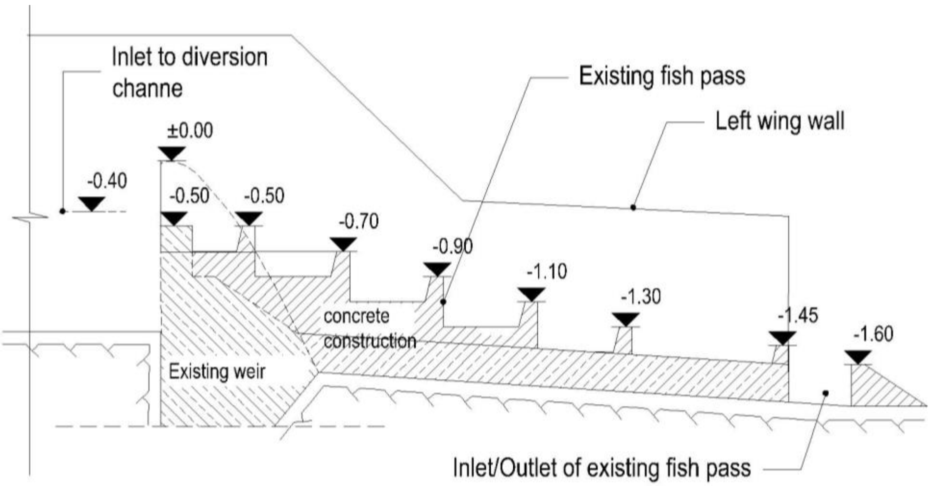

Figure 7. Existing pool pass – longitudinal section

For a conventional pool pass, as recommended in the hydro-biological report [4], with bottom openings with minimal dimensions of 0,15 / 0,15 m, minimal pool dimensions (for trout in the epirhithral region) and water level difference between two adjacent pools of 0,20 m, the necessary minimum discharge would be much more than the given here value of 18 l/s. Hence, a conventional pool pass with notches at the walls between the pools was designed for preventing water losses for the intake. On Fig. 9 the newly designed longitudinal profile of the fish pass is shown.

Here, as applied at the other sites as well, the described measuring module was designed at the inlet of the fish pass. For this intake, the level of the intake opening was not exactly known. But the exact height position of the spillway at the end of the settling basin was known. Thus, it was possible to design the inlet of the fish pass (and the measuring module, respectively) so that the water level there for the residual discharge is exactly at the elevation of the spillway crest at the end of the settling basin. Hence, any increase of the discharge above this value (and of the water level, respectively) would lead to water flow to the intake and to the collecting channel, respectively. At the same time, the inlet opening of the fish pass would get submerged and change its operation modus (hydraulic model, respectively) from spillway / weir to a large rectangular opening.

Figure 8. Existing pool pass – downstream hydraulic connection with the natural river bed

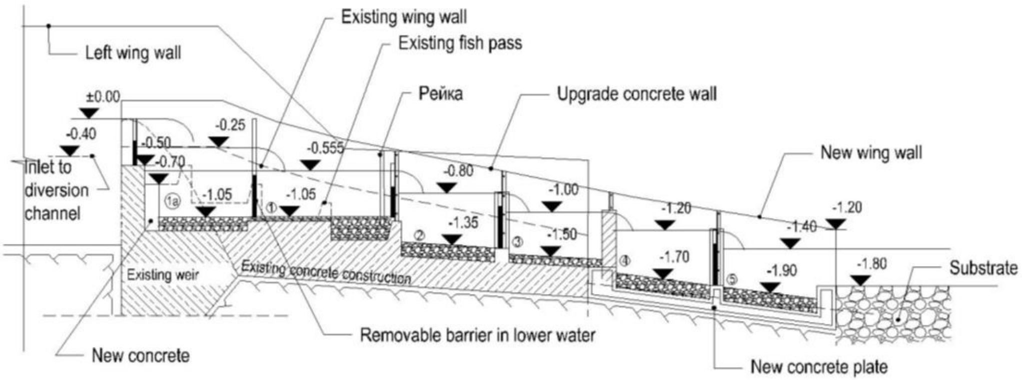

Figure 9. The newly designed pool pass – longitudinal section

4. Conclusion

The presented set of developed design solutions for providing both residual discharge and fish migration possibilities for a series of relatively small water intakes on the collecting channel in a high mountainous region have shown that despite differing from the recommendations of the hydro-biological study and the requirements of the ToR, respectively, the creatively elaborated and justified parameters of the proposed facilities can ensure working solutions to the formulated environmental engineering problems under the hard real natural conditions. Moreover, it became possible to even develop and apply a modular solution system for the given set of intake facilities with quite different parameters.

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ОТВОДНИТЕЛНИ И РИБОПРОВЕЖДАЩИ СЪОРЪЖЕНИЯ НА ВОДОХВАЩАНИЯ ОТ СЪБИРАТЕЛНА ДЕРИВАЦИЯ

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Ключови думи: *водохващане, събирателен канал, отводнително съоръжение, рибопровеждащо съоръжение*

РЕЗЮМЕ

За почти всички водохващания на събирателните канали от хидроенергийните системи у нас, изградени преди 90-те години на миналия век, въпросите за остатъчно водно количество за нарушения участък от реката и за рибопровеждащи съоръжения изобщо не са били разглеждани. Понастоящем обаче, в съответствие с изискванията на съвременните регулативни документи и добри практики в областта на околната среда, тези водохващания трябва да бъдат снабдени с такива съоръжения.

В настоящия доклад се разглежда оборудването на определен брой водохващания от съществуваща високопланинска събирателна деривация със съоръжения или само за пропускане на зададено остатъчно водно количество, или с комбинирани такива за осигуряване и на възможност за миграция на местната популация от риби. Представени са концептуалните проектни решения на комбинацията от формулираните от ихтиолозите задачи и експлоатационните изисквания на възложителя.

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