Project “Development and Implementation of Aquatic Biodiversity Action Plan for Dariali HPP”

Blue Rivers ®

Environmental Consulting

Aquatic biodiversity:

monitoring results in 2016 and mitigation measures proposed

Report

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Executive summary

The report presents the results of the implementation of Aquatic Survey and Monitoring Program for 2016. It consisted of two main components: ecological monitoring and flow and physical habitat monitoring.

The main goal of the surveys was to identify the effect of Dariali HPP commencement on Tergi. To reach this objective, the affected reach (Tergi from downstream the Dariali headworks till the outlet of diversion section) were studied in detail. Additional studies were devoted to the fish pass efficiency assessment and its calibrations.

The results showed:

- Fish pass operates effectively: even in conditions of opened sluices, when dominating flow distracts fish from entrance to the fish pass, trout easily finds it and enters the upper reach.

- In condition of reduced flow, there is continuity of the flow at the whole affected reach. All three types of riverbed remain (the braided type of riverbed did not turn into single one). The minimal average depths (30 cm) at the affected reach were also higher than critical ones (7 cm).

- In the fish pass, the most comfortable conditions in terms of the flow velocity along the whole fish pass will be created when water level in the upper reach is 1733.86-1733.96 m a.s.l. and fish pass is fully open.

- The automatic measurement equipment at the Dariali HPP is not calibrated to show correct values of the water level and discharge.

The report proposes the updated mitigation measures (focused mainly on improvement of the fish pass monitoring and improving of the automatic hydrological monitoring).

The report also contains the post-commissioning monitoring programme with the protocols to be filled out (on ichthyologic monitoring, biological assessment of the river by bottom invertebrates and flow and physical habitat monitoring).

1. General description of the monitoring programme

In frame of the development, construction and operation of the 108 MW Dariali HPP (further the "Project"), the ESIA aimed at conserving aquatic biodiversity, a robust understanding of the baseline conditions of the reach of Tergi where the Project is to be implemented is required. To achieve this, the Aquatic Survey and Monitoring Program was developed by the Blue Rivers® Environmental Consulting experts. Its implementation is presented in the report for 2015, aimed at identification of baseline conditions. These results were used for the development of the Adaptive Management Plan, including redefining of the Aquatic Survey and Monitoring Program for the post-construction monitoring, including fish pass.

The aim of the Aquatic Survey and Monitoring Program, developed for 2016 was monitoring the impact of the HPP operation at flow and physical habitat and aquatic biodiversity.

The tasks of the Program were:

1. Identification of changes in the fish species composition and abundance during all fish life cycle (spawning, fattening, migration etc.),
2. Identification of changes in the invertebrates composition and abundance,
3. Fish pass calibration and assessment of its efficiency,
4. Flow and physical habitat monitoring during post-commissioning period,
5. Updating of the programme of measures, including programme of monitoring for the post-commissioning period.

The following monitoring stations are selected for the post-commissioning monitoring (Table 1, Figure 1).

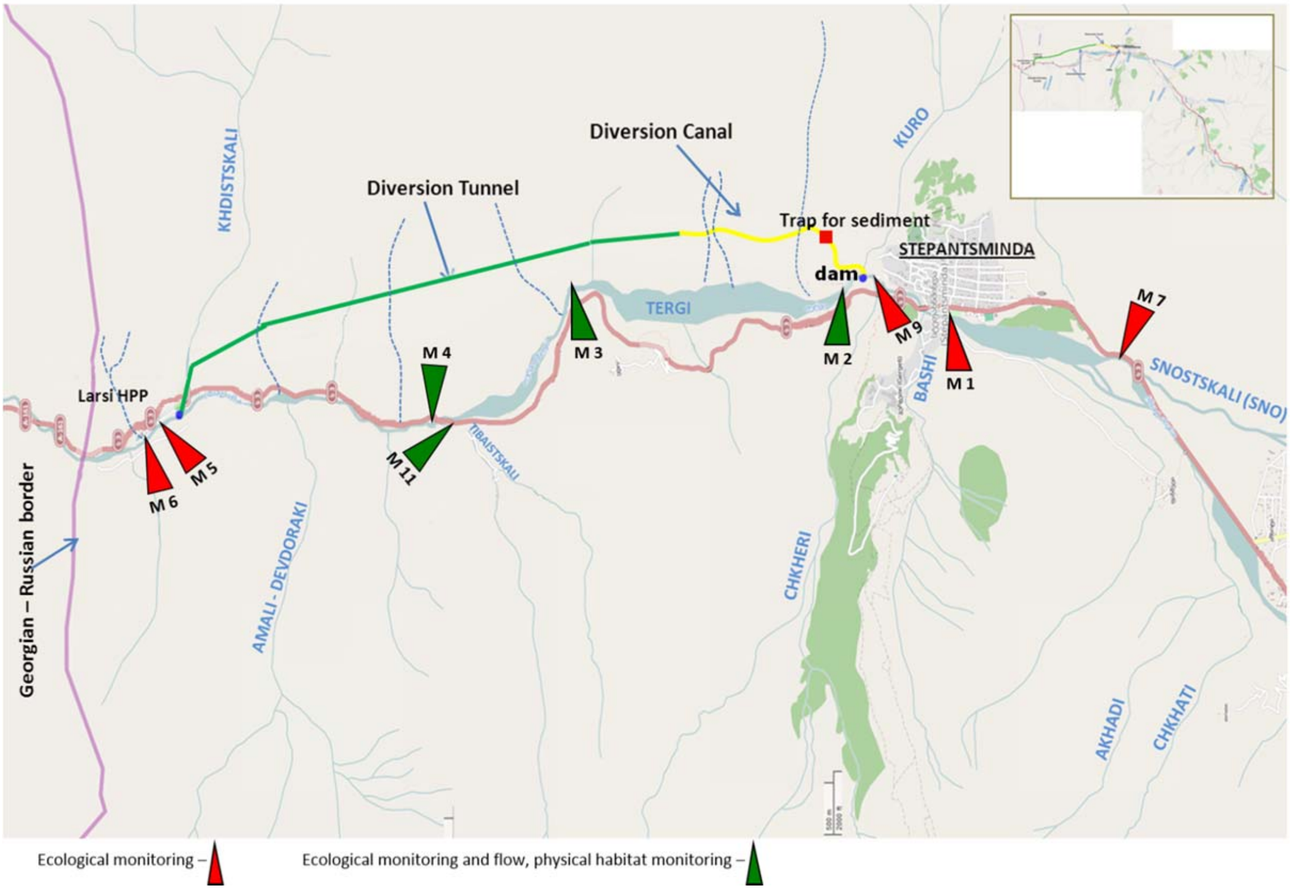


Figure 1. Location of the monitoring stations for post-commissioning monitoring

Table 1. Monitoring stations.

Number	Location	Ecological monitoring	Flow and physical habitat
M 1	Tergi upstream the Dariali headworks	+	
M 2	Tergi downstream the Dariali headworks (boulder section)	+	+
M 3	Tergi downstream the Dariali headworks (braided section)	+	+
M 4	Tergi downstream the Dariali headwork (single thread section)	+	+
M 5	Tergi upstream the Larsi headworks	+	
M 6	Tergi downstream the Larsi headworks	+	
M 7	Sno mouth	+	
M 9	Chkheri mouth	+	
M 11	Tibaitskali mouth	+	+

2. **Ecological monitoring**

2.1 Brown trout monitoring

Fish catching was done at all planned survey units except Chkheri in summer because of the floods. In total in summer, 465 catches of fly fishing rod, 62 catches by ichthyologic sweep net, and 8 placements of fishing basket were done. In total, 56 specimens of adult fish and 43 specimens of juvenile fish were caught. In total in autumn, 210 catches of fly fishing rod, 45 catches by ichthyologic sweep net, and 8 placements of fishing basket were done. In total, 86 specimens of adult fish and 48 specimens of juvenile fish were caught.

Fish tagging was continued to study the spawning and breeding migrations. In total, 39 specimens in summer and 55 specimens in autumn were tagged in the different locations at Tergi and its tributaries. 19 trout specimen of different age, hurt during the catching were delivered to Kyiv of biological analysis.

Results:

- The surveys showed that in summer period, large species of trout live at the Tergi riverbed both upstream and downstream of the HPP. The biggest amount of fish was concentrated in the locations, where Sno enters Tergi as well as near the entrance of Tibaitskali. In the same time, it was fixed the trout avoids the reaches with significant inclinations and boulders type of river channel and prefers single and braided riverbeds as well as the system of amelioration channels (this is especially the case of the mouth part of Sno).
- In autumn during the upstream spawning migration, the large specimen of trout could be seen everywhere in the Tergi riverbed, including the reaches with significant inclinations. The biggest concentration of trout was fixed downstream the Dariali HPP and in Sno mouth. In the same time, the number of trout near the Tibaitskali was low. The spawning aggregations of fish were also fixed in the channels located in the Sno mouth. The correlation of male and female trout as the last year is shifted towards males 1/12 ratio.

Limitations:

The Monitoring plan envisaged the monitoring of the affected reach in post-commissioning period. As fas as in the period of brown trout spawning migration, the HPP was not fully operational; therefore, effect on aquatic biodiversity is assessed partly. The further monitoring should be continued.

2.2 Invertebrates specie composition and abundance

The study of specie groups' composition of invertebrates and their abundance were conducted in all survey units, except Chkheri in summer period because of floods. In order to clarify daily migrations of invertebrates as well as to understand their role as a food basis for the trout, the traps for drifting macroinvertebrates were installed at all monitoring stations and survey units of ecological monitoring. Indication of the biological status of Tergi and its tributaries at all monitoring stations and survey units of ecological monitoring was also conducted.

However, as far as the HPP was not commissioned yet, the assessment of the impact of the operational HPP was not conducted. In frame of autumn field surveys, the task of the surveys to define the number of macroinvertebrates entering with drift the HPP water in-take was done only partly. When the water reservoir was filled, the flow distribution was studied, using floating bars, which gives the overview about the ways of drifting invertebrates and juvenile fish.

Results:

Study of macroinvertebrates during 2015-2016 in the Project area showed the high specie diversity – in total 115 species were identified (in 2015 – 104 species). The main groups by number and abundance were *Ephemeroptera, Plecoptera, Trichoptera, Chironomidae* and *Diptera* (96 species). The following species' groups were additionally identified in 2016: *Heteroptera* and *Lepidoptera*. In other groups, specie composition was enlarged. In summer period, Crustacea also included *Simocephalus vetulus* (O.F. Müller, 1776); *Ephemeroptera* - *Cloeon dipterum* (L., 1761), mayflies – *Chloroperla apicalis (*Newman, 1836) and *Taeniopteryx nebolosa* (Linnaeus, 1758); Trichoptera - *Apatania subtilis, Drusus simplex* and *Potamophylax excisus* (Mart.), Diptera - *Eristalis anthoporina* (Fallén, 1817), *Psychoda grisescens* (Tonnoir, 1922), *Tinearia lativentris* (Berden, 1952), *Tipula obsoleta* (Meigen, 1818), *Ulomyia umbripennis* (Vaillant, 1983) and *Usia marginata* (Brunetti, 1909) .

Invertebrates' composition (at the level of groups) comparing with 2015 was not changed, which shows the sustainability of their communities' structure. Biological indication showed that the biological status of the river reach directly after the water intake got improved for all types of river channel (single, braided and boulders). After mudflow at Amali, in August there was no one invertebrates 2016 fixed; in October – the abundance was very low (up to 50 specimen/m^2), presented mainly by insects with short life cycle with dominance of *Simulidae*, *Chironomidae* and *Diptera*, and a few *Ephemeroptera*, explained by absence of stable conditions for invertebrates development.

Intensity and composition of drift corresponds to seasonal dynamics defined in 2015. In conditions of partly opened sluices at the stations, drift of invertebrates into the sand tank was in appr. 100 times smaller comparing to natural drift in the riverbed (Figures 2 and 3).

Figure 2. Sampling of drifting invertebrates near sand traps

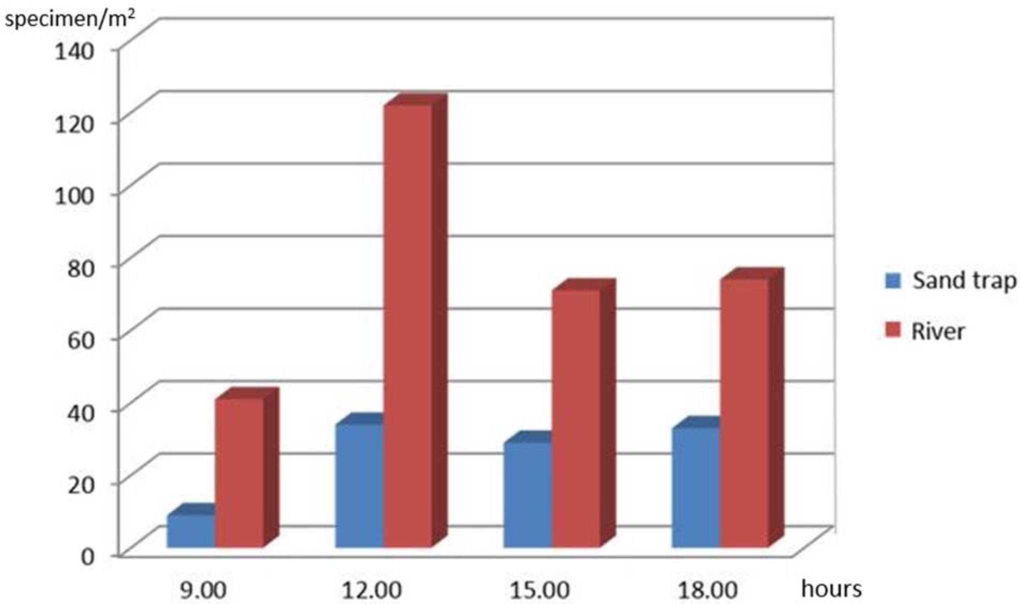


Figure 3. Abundance of invertebrates per trap

Limitations:

As far as the HPP was not fully commenced, the following issues should be further investigated: assessment of the changes of bottom invertebrates communities at the affected reach, development and distribution of invertebrates in water reservoir upstream the HPP; biological assessment of the affected reach by on bioindication; and assessment of the changes in drift and number of invertebrates entering the sand trap.

2.3 Assessment of the fish pass efficiency

The main goal of the survey was to study fish pass of Dariali HPP and its equipment in order to assess its readiness for effective operation. In the same time, efficiency of fish pass and sand trap of Larsi HPP as a small analogue of Dariali HPP was also planned to assess. Surveys at Larsi HPP showed that its main constructions were destroyed by mudflow in June 2016. At present, Tergi flow passes around the station; therefore, planned surveys at Larsi HPP were not conducted.

Fish pass

During the summer field survey, fish pass construction works were finished and timbering was taken away. All fish pass pools were filled with rainy water. In standing and warmed water, phytoplankton developed, leading to decrease of water transparency. However, the Consultant could see a lot of construction waste in the fish pass, including broken timbering, parts of reinforcing steel, which negatively influence the hydraulic regime and fish safety during its move by the fish pass. The serious danger for fish posed many (several hundreds) of metallic pillars with diameter 8-10 mm and length around 50 mm, sticking perpendicularly from walls. They were used to fasten timbering.

The situation with the fish pass waste and metallic pillars was improved after autumn hydrobiological surveys, which was confirmed during fish pass calibration in the end of November.

Fish trap

The fish trap framework for monitoring of fish pass was constructed according to the scheme provided by the Consultant. The hooks for fish trap instalment in the upper reach of Dariali HPP were welded at the fish pass in-take. During the autumn survey, the fish trap was finalized by the efforts of Consultant by covering it with nylon net (Figure 4).

Figure 4. Fish trap

At the beginning of the autumn surveys, ichthyologic platform and winch to move the fish trap, which should have been installed according to recommendations of the Consultant, were not ready. The ichthyologic platform was discussed again with the Dariali HPP and during two days the platform was constructed but without the winch.

Fish pass efficiency

During the autumn field surveys, the water level in upper reach of the Dariali HPP was not sufficient for watering the fish pass. Following the request of the Consultant, the water level was levelled up to working mode, which allowed testing the fish pass in operational mode (Figure 5).

Figure 5. Fish pass in the operational mode

In the same time, as far as the HPP was not commenced, most of water was passing through opened sluices directly to lower reach, creating distracting flow for the fish comparing to the flow in the fish pass. Further, all the flows united in one. In such conditions, the chance that trout will choose the narrow flow is not big. Nevertheless, the Consultant saw the brown trout jumping through the fish pass. The rest of the flow was discharged directly behind the dike. Therefore, Tergi riverbed downstream the HPP was split into three flows: narrow, central from the fish pass and two wide ones at right and left from it (Figure 6).

Figure 6. Tergi downstream the dam

Despite the absence of the winch, the Consultant placed four times the fish trap (Figure 7).

Figure 7. The fish trap lifting

The following results were obtained:

1. First placement of the fish trap in the daytime with exposition of 7 hours showed that the trout successfully enters and moves by the fish pass (Figure 8).

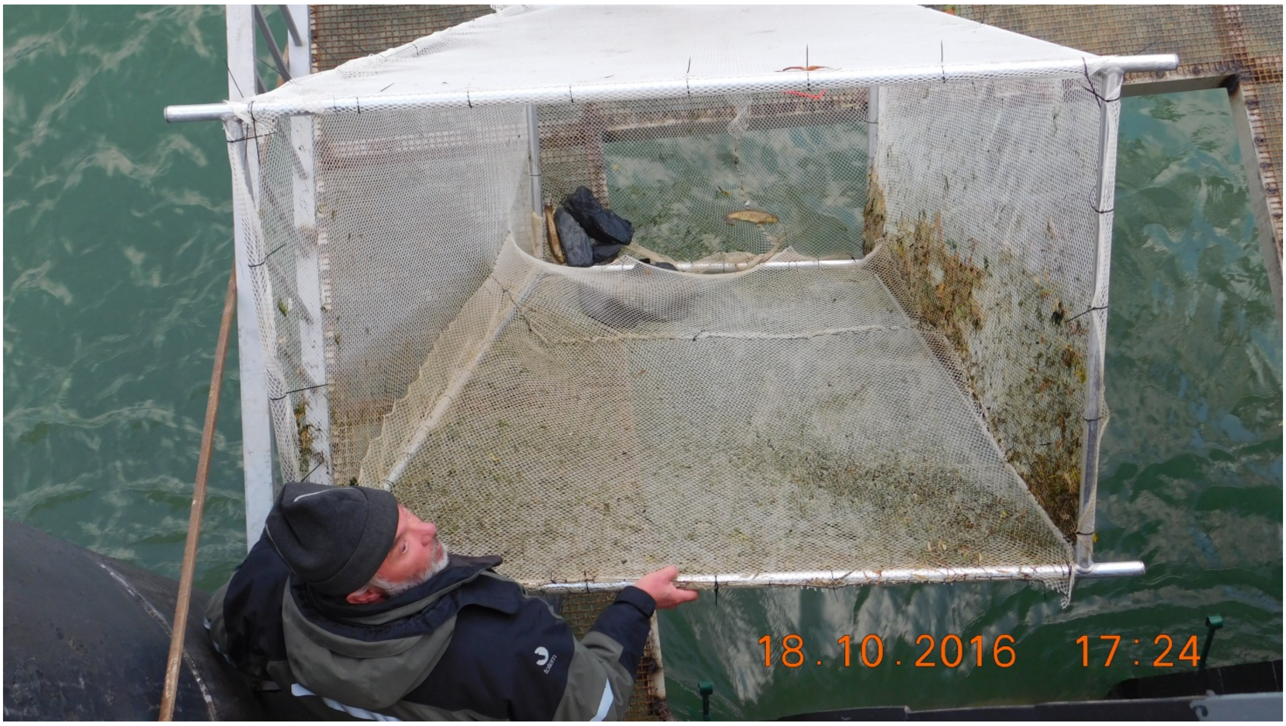


Figure 8. Trout specimen in the trap

The Consultant caught two fish – both ready for spawning males of the length 15 cm (Figure 9).

Figure 9. Trout caught in the fish pass

2. Second placement during nighttime did not give any results. As it was found out later, there was a wooden board, which acted as a barrier in the fourth pool and did not allow fish passing. (Figure 10). This was later removed and that monitoring measures will be implemented to avoid this in the future (Mitigation measure 1E). The further monitoring of litter in the fish pass ws confirmed by DE.

Figure 10. Wooden board closing the fish pass

3. Third placement for 24 hours led to catching of three males ready to spawn.

4. Fourth placement for 24 hours led to catchment of four fish out of which two males ready to spawn and two females. Both females were sub-pressed by flow to the fish trap and died because of hurting by stones, which the Consultant used as a loading for the fish trap (Figure 11).

Figure 11. Dead female trout in the fish trap

The fish pass drying out was completed twice in order to check efficiency of the fish pass, and to assess the number of fish in the pools at different distance from its entrance. The survey was conducted directly after the drying out. After the survey, the fish pass was again operational.

During the first survey in the morning (low sun and lateral illumination) there were three trout specimen fixed – one in upper pool, and two in the second from bottom pool. During the second survey in the day light, when sun was high and there was a lot of light, glaring surface of water did not allow assessing of the fish present in the pools. However, during the drying out there was one large trout fixed in the second from top pool, which later jumped to the third from top pool (Figure 12).

Figure 12. Trout at the temporary dried step of the fish pass (checking the efficiency of the fish pass)

<u>Results:</u>

- Even in conditions of opened sluices, when dominating flow distracts fish from entrance to the fish pass, trout easily finds it and enters the upper reach, which proved its efficiency.
- Water in water reservoir and in the fish pass in the autumn period is transparent, which allows for video control of the fish passing.
- The fish trap proved to be efficient, although there should be constructive amendments to the fish trap made to prevent the death of female trout as well as other technical adjustments.

3. Flow and physical habitat monitoring

3.1. General provisions

Field surveys

Hydrological and hydromorphological surveys were conducted during six days from 21th of November until 26th of November.

Limitations:

Surveys were conducted in the period, when the water discharges varied from 1.42 m^3/s to 3.71 m^3/s at the river reach between intake and powerhouse. In the same time, lateral inflow (Tibaitskali and other tributaries) was not more than 0.12 m^3/s.

According to the DE, ecological flow less than 2.5 m^3/s was only for 6 days during the process of 72 hours Trial Units (3 days each) for making TOC (BR monitoring coincided that period), in mentioned period the flow in river Tergi was enough just only for 30 MWT output that's why DE made TOC for Units with limited power 30 MWT (till flow will be enough for 36 MWT full load for 72 hours) that's why DE decided to use as much water as it was possible for mentioned 6 days otherwise DE would lose a lot output in further operation (in case to keep 2.5 m^3/s during mentioned 6 days, the limited output from Units would had been 26 MWT, that is 4 MWT difference), e.x. in December almost 15 days DE was working with 30 MWT output. When the 72 hours Trial heat run of Units were implemented from that period, DE keeps 2.5m3/s of ecological flow.

During the survey, weather conditions varied not significantly: sunny, the air temperature varied from +10 to -20 °C. According to the meteorological station Stepantsminda, the average monthly temperature in November is -2.6 °C[1]. Snow that fell earlier (about 100 – 120 mm) created difficulties for access to the river and proper assessment of the riparian zone. Tibaitskali river channel in its mouth was cover by ice in many places, which created some difficulties for measurements (Figure 13).

Figure 13. Ice at Tibaitskali

[1] Dariali Hydro Power Plant Construction and Operation Project. Environmental and Social Impact Assessment Report. 2011 (p.79)

The discharge measured at hydrological station (not operational at present) in Stepantsminda was 11.63 m^3/s (21.11.2016). Average monthly water discharges for Tergi for November in 50% of water provision year according to hydrological station in Stepantsminda is 9.81 m^3/s[2]. One can state, that the discharge in Tergi during field surveys was higher (by 19%) comparing with its average value for multiannual period.

Monitoring stations

Hydromorphological monitoring network includes 4 stations - 3 on entire Tergi and 1 on tributary – Tibaitskali (Table 2):

- At Tergi at affected reach, three monitoring stations located at each of the riverbed channel type. The steep boulders, lesser-graded single-thread and low gradient multichannel forms all have different channel sizes, gradients, sediment sizes and general morphology. Changing discharge will have different and complex hydraulic effects according to the type of morphology present at a given location. Thus, the impacts of reduced flow in each type of reach system needs to be considered.
- At mouth of the main tributary of the first order – Tibaitskali, one monitoring station.

Table 2. Flow and physical monitoring stations

№	Monitoring station	Elevation, m a.s.l.	Coordinates			
			Upper_Left	Upper_Right	Down_Left	Down_Right
M 2	Tergi downstream the Dariali headworks (boulder section)	1693	42°40'06.76" 44°38'32.52"	42°40'06.95" 44°38'32.90"	42°40'06.38" 44°38'32.80"	42°40'06.50" 44°38'33.01"
M 3	Tergi downstream the Dariali headworks (braided section)	1469	42°42'04.60" 44°38'00.16"	42°40'05.07" 44°38'01.01"	42°42'04.66" 44°38'00.56"	42°42'04.92" 44°38'01.49"
M 4	Tergi downstream the Dariali headworks (single thread section)	1413	42°42'53.94" 44°37'31.70"	42°42'54.00" 44°37'33.31"	42°42'53.30" 44°37'31.73"	42°42'53.27" 44°37'32.62"
M 11	Tibaitskali mouth	1436	42°42'35.54" 44°37'35.44"	42°42'35.59" 44°37'35.32"	42°42'35.82" 44°37'35.67"	42°42'35.84" 44°37'35.64"

During 2016, the borders of each monitoring station were fixed using GPS monitoring, as well as by colour marks at boulders or concrete walls (Figure 14) in order to return to the same monitoring stations during the post-commissioning monitoring 2016. Unfortunately, colour marks were washed away during high water season (Tergi boulder section station M2 and Tibaitskali mouth station M11) so GPS coordinates were used for finding exact location of stations.

[2] Dariali Hydro Power Plant Construction and Operation Project. Environmental and Social Impact Assessment Report. 2011 (p.96)

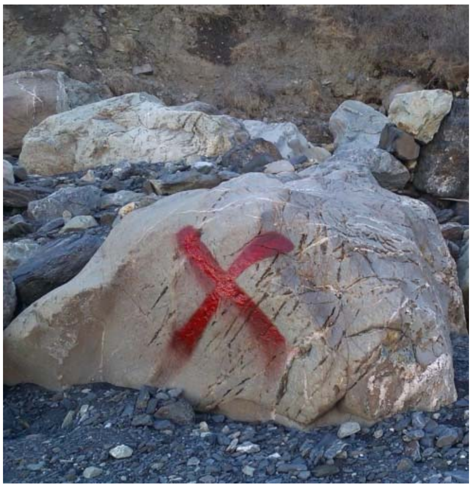
 

Figure 14. Marking of the monitoring station (March, 2015)

Cross-sections

The length of each monitoring station was 10 m, except Tergi braided section (M 3), where its length was 80 m.

Each monitoring station included five cross-sections, except Tergi braided section (M 3) where the number of cross-sections was twelve. As a result, 27 cross-sections were measured (Table 3).

Table 3. Cross-sections measured

№	Monitoring station	Number of cross-sections	Length of cross-section, m
M 2	Tergi downstream the Dariali headworks (boulder section)	5	10
M 3	Tergi downstream the Dariali headworks (braided section)	12	80
M 4	Tergi downstream the Dariali headworks (single thread section)	5	10
M 11	Tibaitskali mouth	5	10

Equipment used

The following equipment was used during hydrological and hydromorphological surveys:
- Universal hydrometric current meter – for flow velocity measurement,
- Large range finder – for distance and riverbed width measurements,
- Gauging rod – for measurements of water levels and flow depths,
- Frame 1 m^2 - for visual assessment of the percentage composition of sediments,
- GPS 60C Garmin – for coordinates measurements,
- Electronic goniometer – for inclination measurements,
- Electronic compass,
- Thermometer,
- Field computer and FieldMap equipment – for hydromorphological measurements,
- DJI Phantom 4 drone.

3.2. Results

Below the results for 2016 are given for the four monitoring stations in comparison with 2015.

Tergi downstream the Dariali headworks (boulder section) (M 2) - 23.11.2016

Figure 15. Tergi downstream the Dariali headwork (boulders section)

The average velocity was 0.54 m/s with maximum 2.0 m/s. Flow types included chute, chaotic, broken standing waves, and unbroken standing waves (Figure 15).

The average width of the river was 8.3 m with maximum 9.8 m. Bed elements included rapids and rocks.

In comparison with the results of monitoring in 2015, the average velocity reduced by 0.13 m/s (19%), maximum - by 0.17 m/s (12%). The average width of riverbed decreased by 1.3 m (14%), maximum one - by 3.8 m (28%) (Figure 16).

The average depth was 0.40 m with maximum 1.05 m. Ratio of average width of channel to the average depth was $C_{b/h}$=21. Flow thalweg located in the right part of the channel and had depth 1-1.05 m

In comparison with the results of monitoring in 2015, the average depth of the flow reduced by 0.29 m (42%), maximum one - by 0.2 m (16%) (Figure 17).

Both banks were made out of boulders up to 2 m and cobble. The riverbed was evenly covered by boulders (42%), cobble (26%) and pebble (15%) (Figure 18).

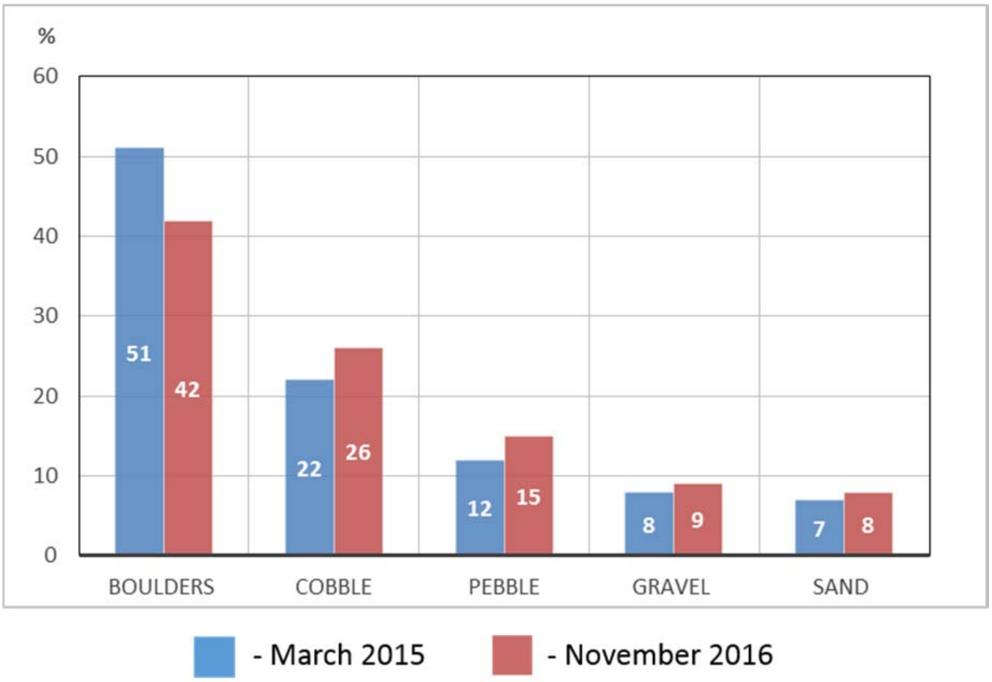


Figure 18. Distribution of the sediments, %

The following changes in the sediment composition were observed: percentage of boulders reduced by 9%, percentage of cobble, pebble, gravel, and sand increased by 4%, 3%, 1%, and 1% accordingly.

The calculated average multiannual discharge for this monitoring station was 26.0 m^3/s. Measured water discharge was 1.42 m^3/s (22.11.2016), which corresponded to 5.5% of multiannual discharge and 56% of minimum environmental flow.

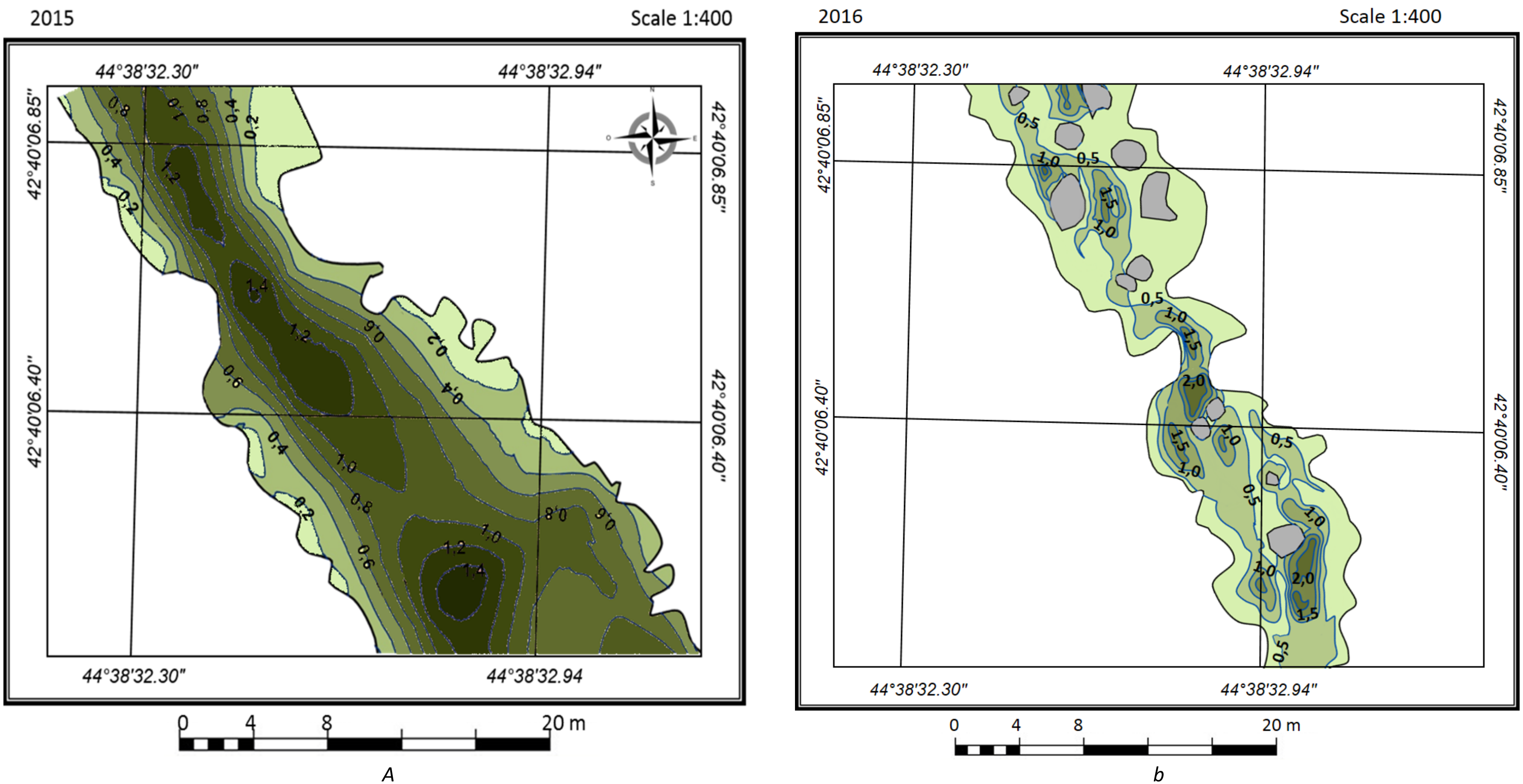


Figure 16. Isotaches of the stream velocity (a – 2015, b – 2016). Boulders channel type

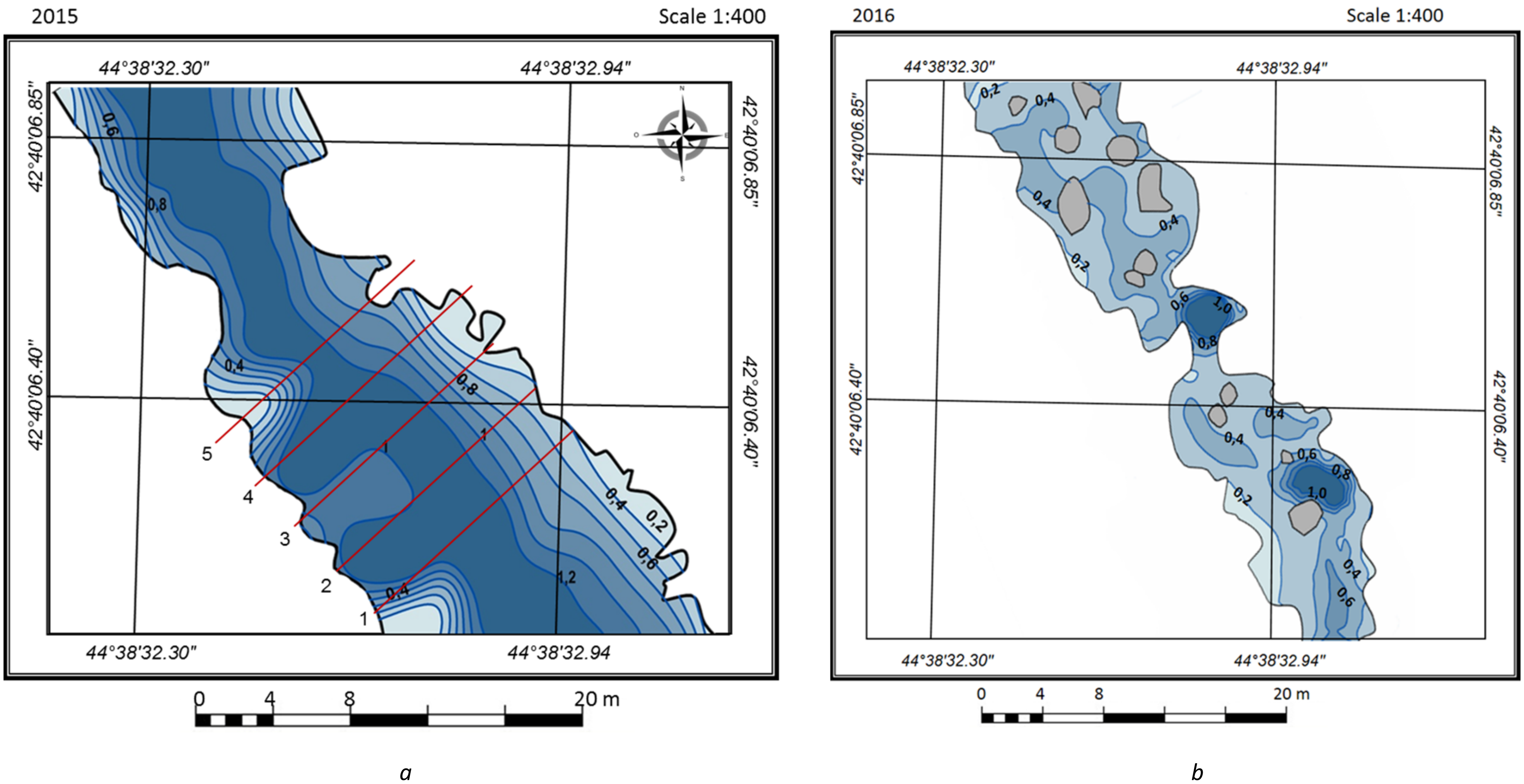


Figure 17. Isobaths of the stream depths (a – 2015, b – 2016). Boulders channel type.

Tergi downstream the Dariali headworks (braided section) (M 3) 25.11.2016

Figure 19. Tergi, downstream the Dariali headwork (braided section)

The average velocity was 0.64 m/s with maximum 1.85 m/s. Flow types included chute, chaotic, broken standing waves, and unbroken standing waves (Figure 20). The average width of the right arm was 4.8 m with maximum 5.2 m and the average width of the left arm was 10.8 m with maximum 15.3 m. Bed elements included island, riffles, and pools.

Comparing with results of monitoring in 2015, the average velocity reduced by 0.27 m/s (30%), maximum – by 0.15 m/s (8%). The average width of the right arm reduced by 6.4 m (57%), maximum – by 8.7 m (63%). The average width of the left arm increased by 1.0 m (26%), maximum – increased by 3.5 m (10%) (Figure 21).

The average depth was 0.31 m with maximum 1.0 m. Flow thalweg for both arms located in the middle part of the channel.

Comparing with results of monitoring in 2015, the average depth of the flow reduced by 0.16 m (34%), maximum – by 0.21 m (21%) (Figure 21).

The right bank was made mainly out of boulders; left bank was covered by cobble. The riverbed was evenly covered by pebble (46%) and cobble (32%), with 14% of boulders.

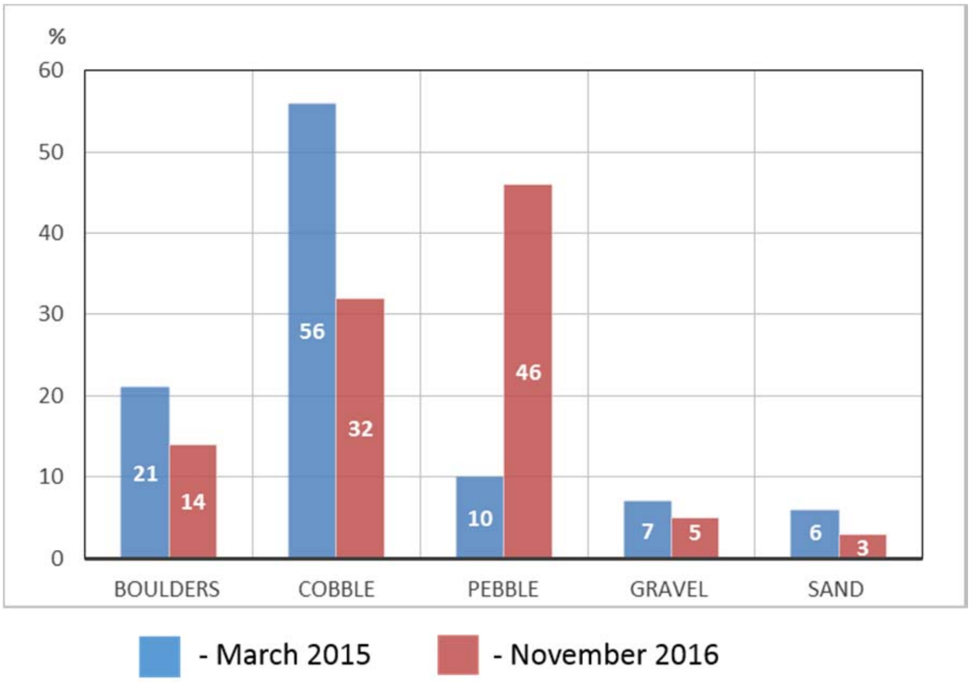
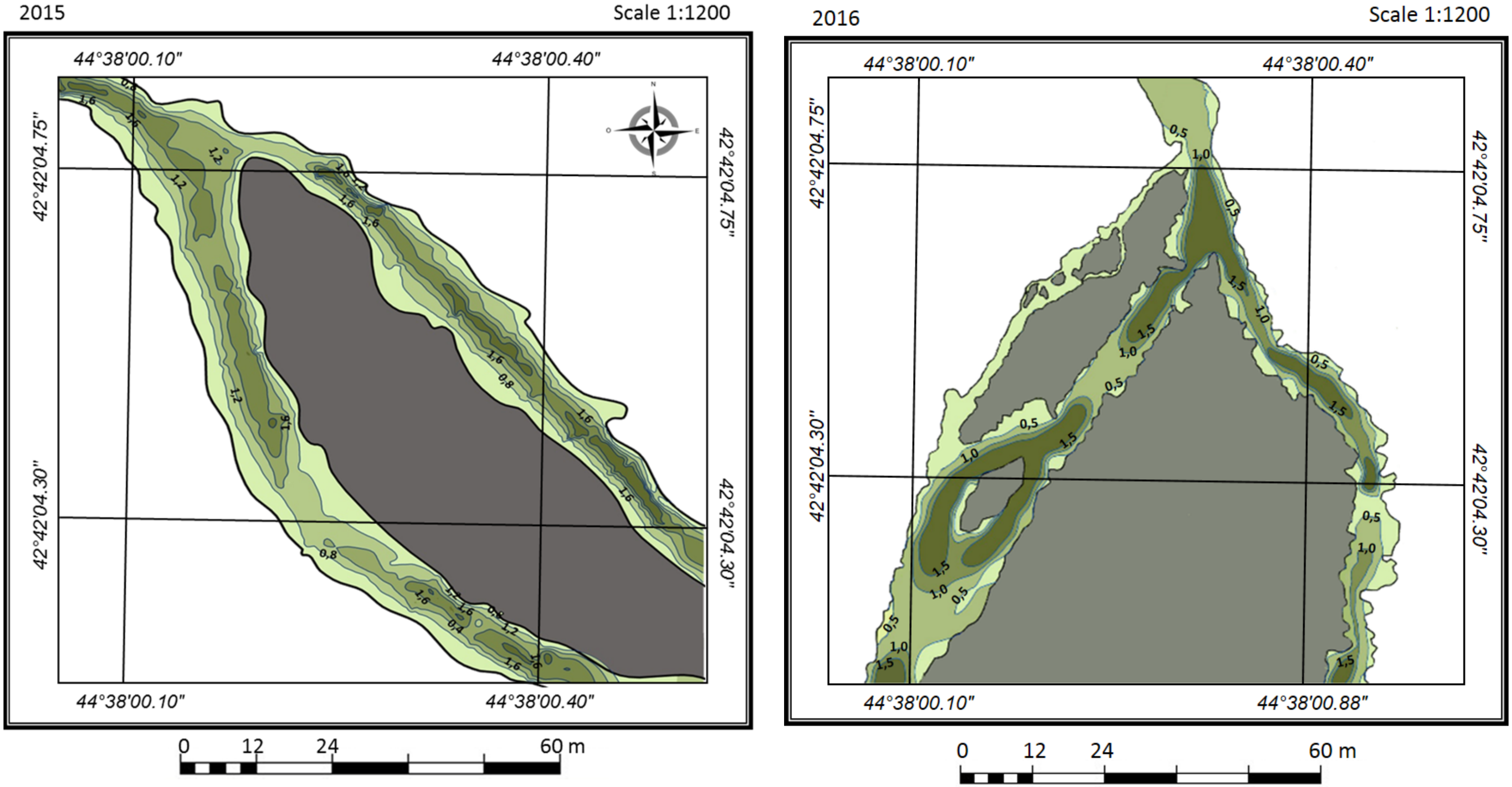


Figure 22. Distribution of the sediments, %

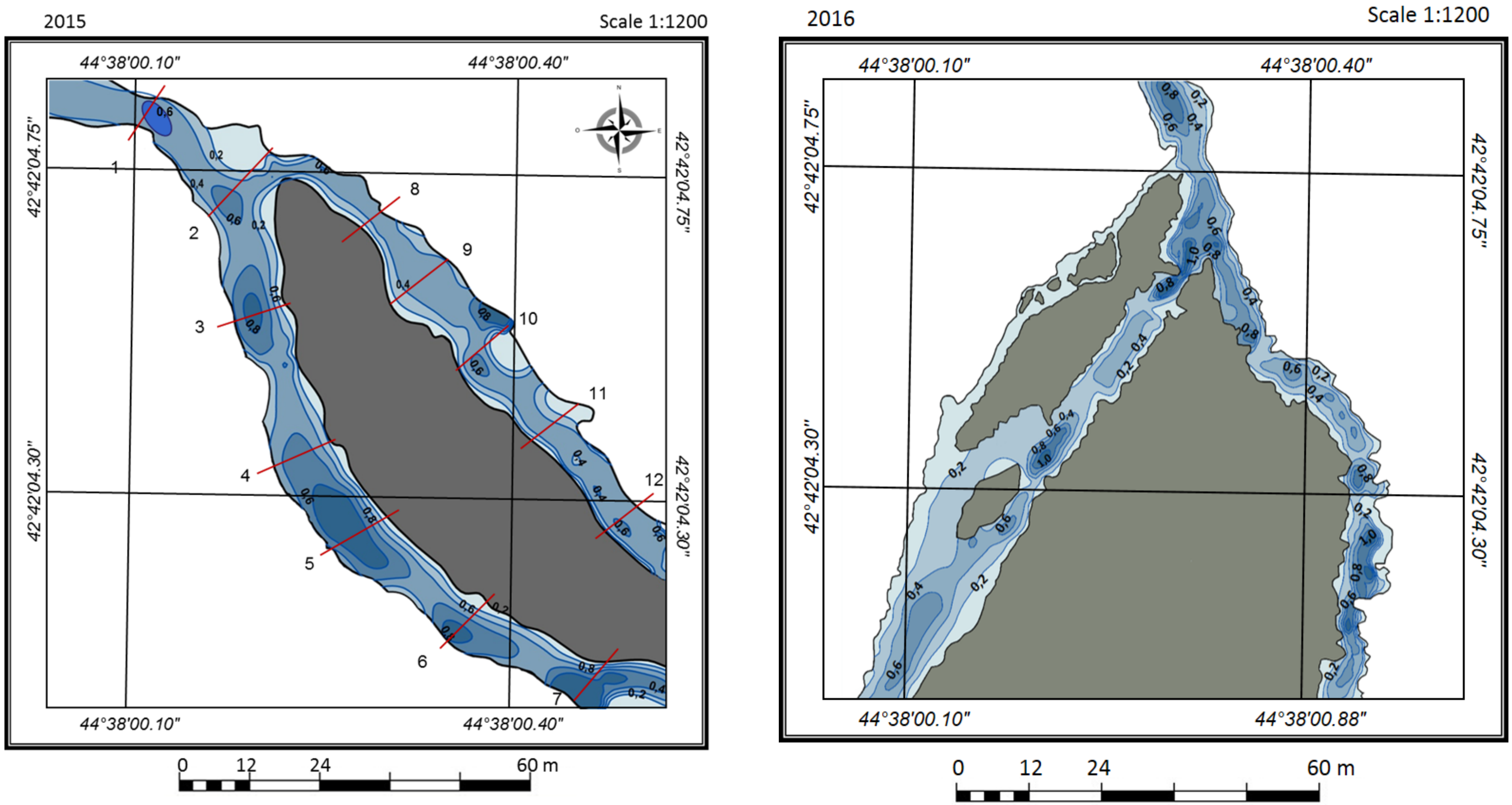
The following changes in the sediment composition were observed: percentage of boulders reduced by 7%, cobble - 24%, gravel - 2%, and sand - 3%. The share of pebble increased by 36% (Figure 22).

The calculated average multiannual discharge for this monitoring station was 26.8 m^3/s. Measured water discharge was 3.71 m^3/s (25.11.2016), which corresponded to 14% of multiannual discharge and by 46% more than minimum environmental flow.



a　　*b*

Figure 20. Isotaches of the stream velocity (a – 2015, b – 2016). Braided channel type



a *b*

Figure 21. Isobaths of the stream depths (a – 2015, b – 2016). Braided channel type

Tergi downstream the Dariali headworks (single thread section) (M 4) 24.11.2016

Figure 23. Tergi downstream the Dariali headworks (single thread section)

The average velocity was 0.58 m/s with maximum 2.0 m/s. Flow types included chute, chaotic, broken standing waves, and unbroken standing waves. The average width of the river was 12.9 m with maximum 14.5 m. Bed elements included rapids, riffles and pools (Figure 24).

Comparing with results of monitoring in 2015, the average velocity increased by 0.03 m/s (5%), maximum one reduced by 0.42 m/s (23%). The average width of the riverbed reduced by 5.1 m (28%), maximum – by 6.5 m (31%) (Figure 24).

The average depth was 0.40 m with maximum 0.81 m. Ratio of average width of channel to the average depth was $C_{b/h}$=32. Flow thalweg was located in middle of the channel.

Comparing with results of monitoring in 2015, the average depth reduced by 0.35 m (46%), maximum – by 0.29 m (26%) (Figure 25).

The riverbed was mainly covered by cobble (31%), gravel (27%) and boulders (18%)

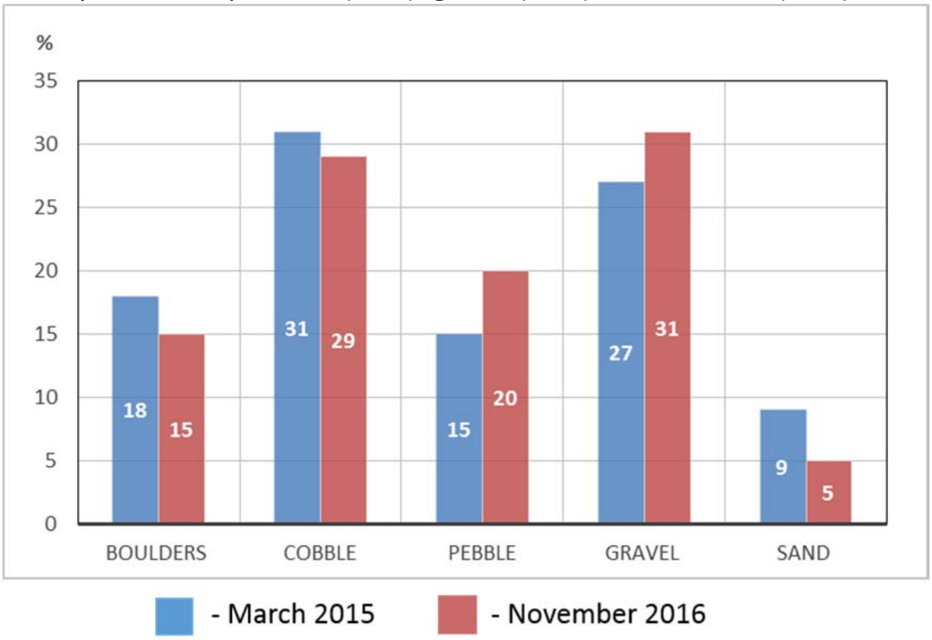


Figure 26. Distribution of the sediments, %

The following changes in the sediment composition were observed: percentage of boulders reduced by 3%, cobble - 2%, and sand - 4%. Percentage of pebble and gravel increased by 5% and 4% accordingly (Figure 26).

The calculated average multiannual discharge for this monitoring station was 27.2 m^3/s. Measured factual water discharge was 3.49 m^3/s (24.11.2016), which corresponded to 13% of multiannual discharge and was by 37% more than minimum environmental flow.

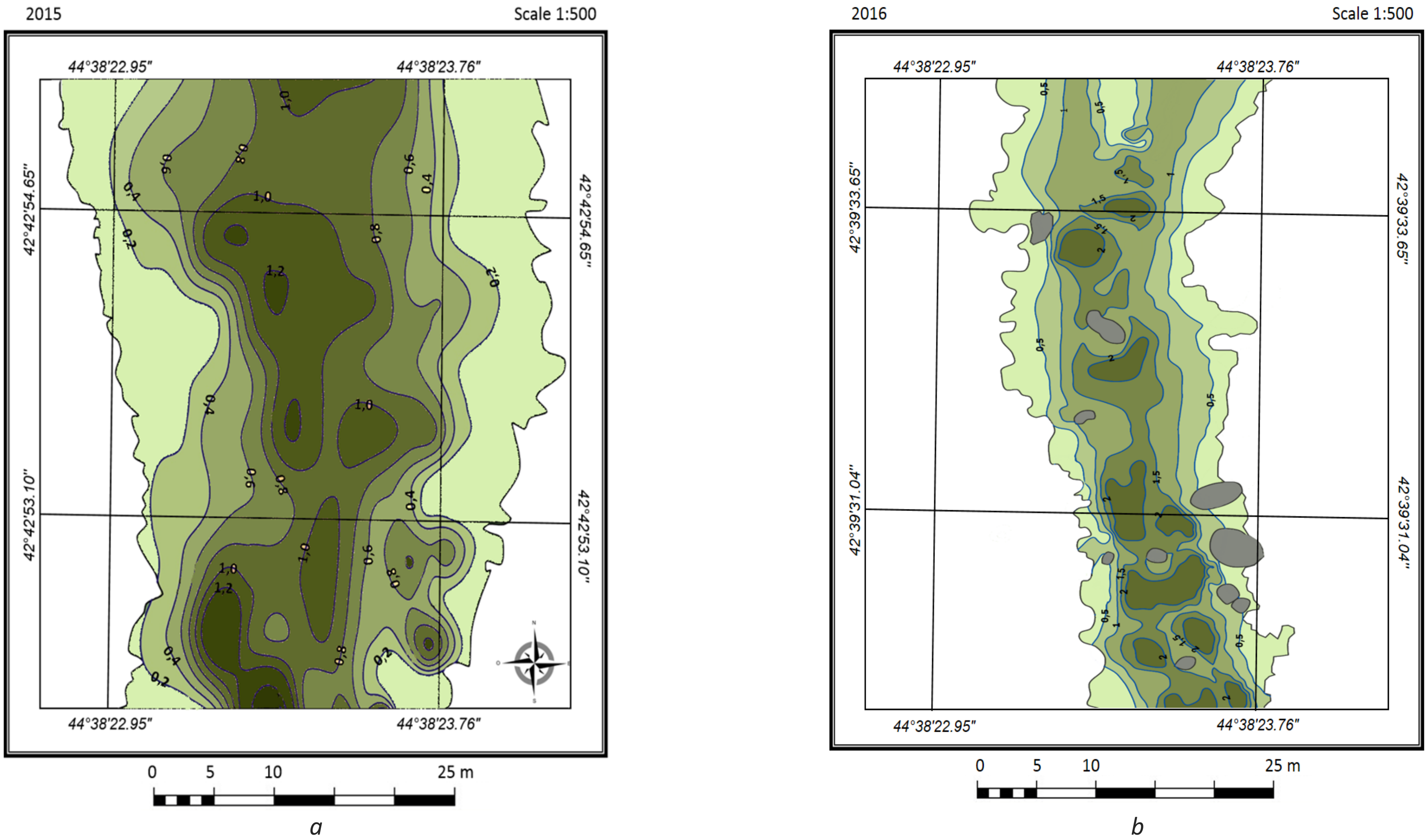


Figure 24. Isotaches of the stream velocity (a – 2015, b – 2016). Single channel type

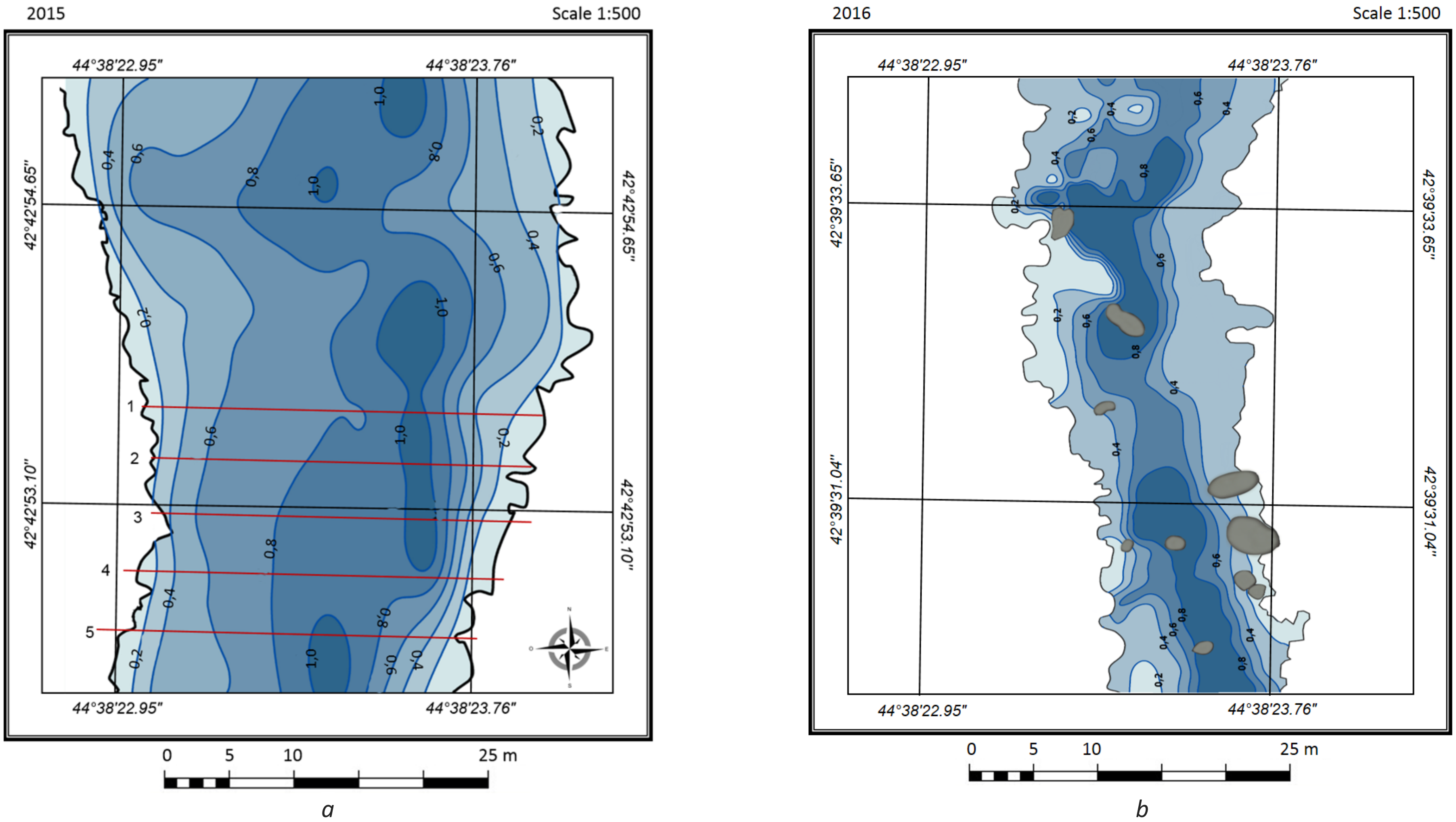


Figure 25. Isobaths of the stream depths (a – 2015, b – 2016). Single channel type

Tibaitskali mouth (M 11) 22.11.2016

Figure 27. Tibaitskali mouth

The average velocity was 0.44 m/s with maximum 1.2 m/s. Flow types included chute, chaotic, broken standing waves, and unbroken standing waves (Figure 28). The average width of the river (not covered by ice) was 1.2 m with maximum 2.16 m. Bed elements included rapids, riffles and pools.

Comparing with results of monitoring in 2015, the average velocity increased by 0.07 m/s (19%), maximum one increased by 0.72 m/s (150%). The average width of the riverbed reduced by 1.7 m (61%), maximum – by 1.5 m (42%) (Figure 28).

The average depth was 0.25 m with maximum 0.4 m. Ratio of average width of channel (not covered by ice) to the average depth was $C_{b/h}$=4.

Comparing with results of monitoring in 2015, the average depth increased by 0.14 m (127%), maximum – by 0.14 m (54%) (Figure 29).

The bank line of both banks was made mainly by cobble; there were some boulders. The riverbed was covered by gravel (36%), pebble (24%) and cobble (21%).

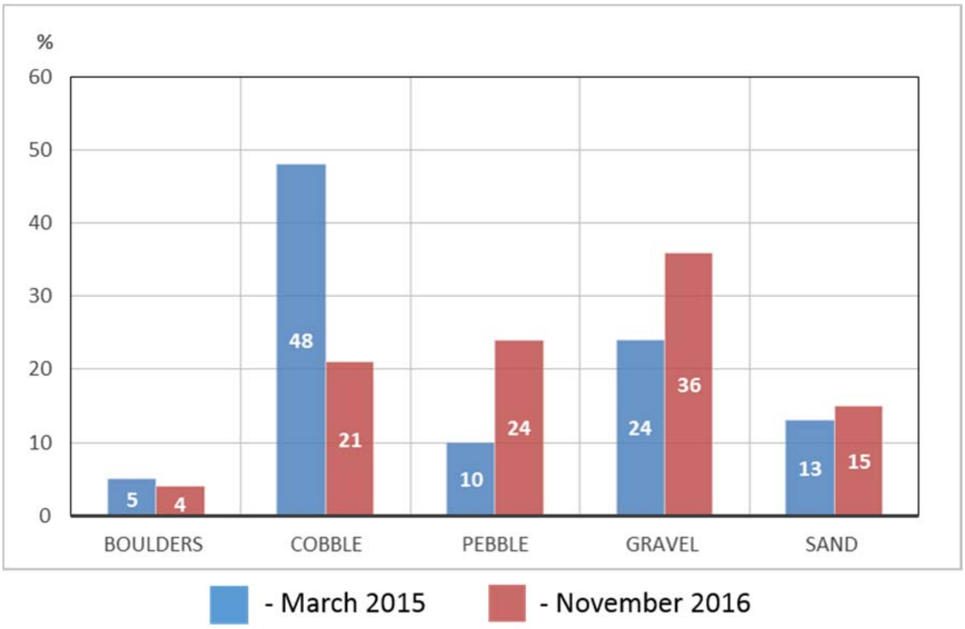


Figure 30. Distribution of the sediments, %

The following changes in the sediment composition were observed: percentage of boulders reduced by 1%, and cobble - 27%. Percentage of pebble, gravel and sand increased by 14%, 12% and 2% accordingly (Figure 30).

Measured water discharge for this monitoring station was 0.09 m^3/s (22.11.2016).

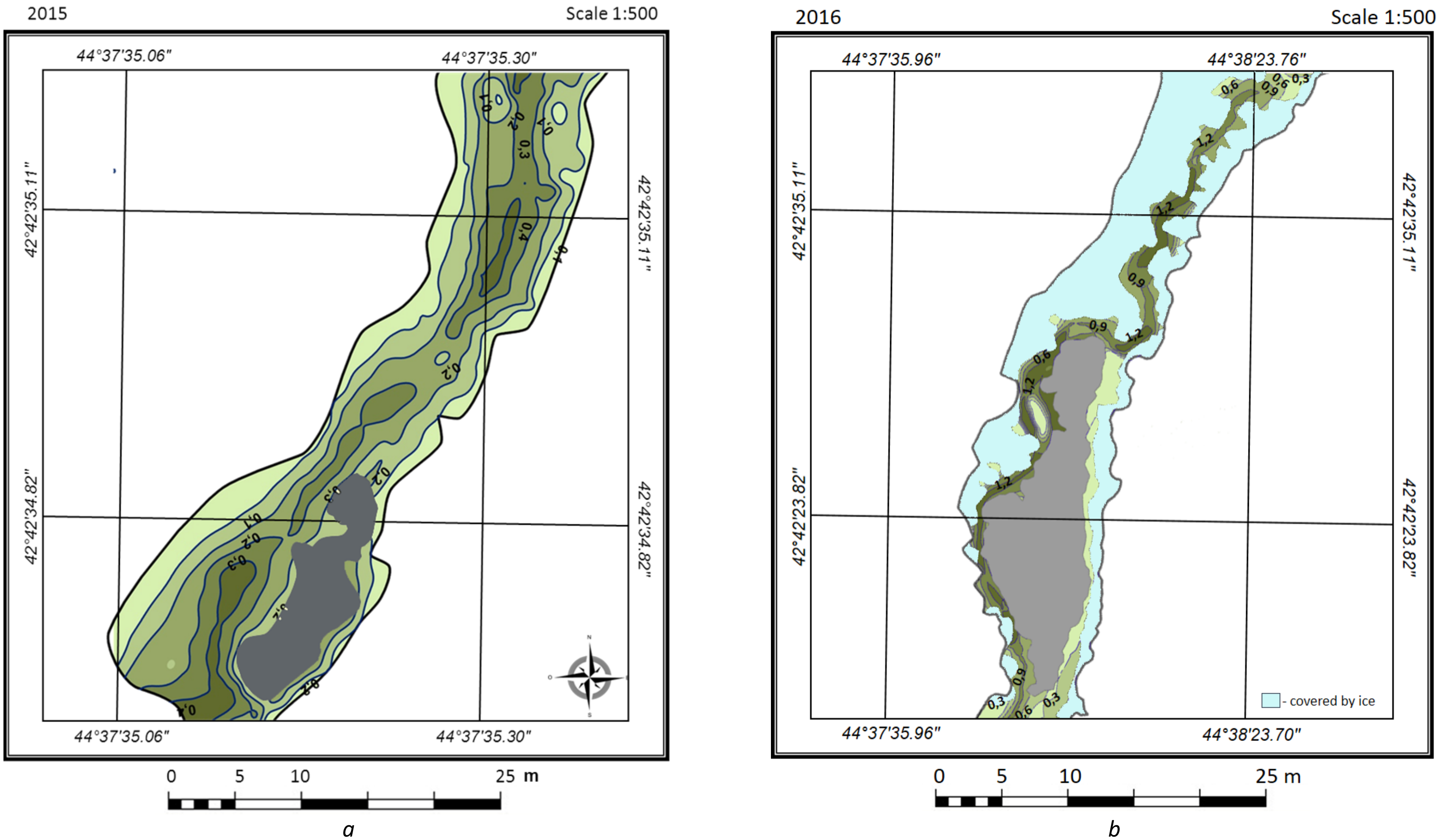


Figure 28. Isotaches of the stream velocity (a – 2015, b – 2016)

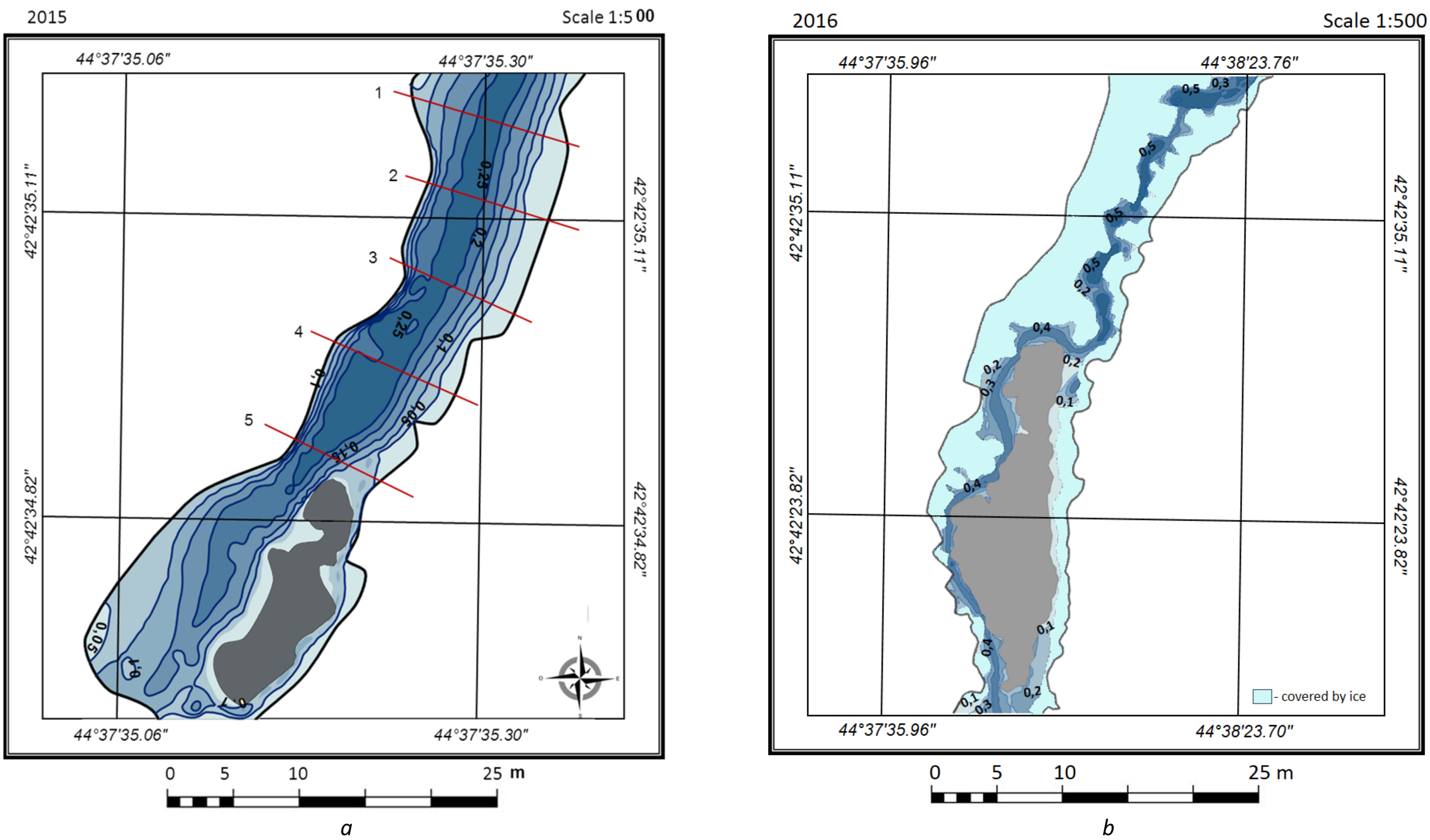


Figure 29. Isobaths of the stream depths (a – 2015, b – 2016)

Results:

Changes of morphological parameters in all monitoring stations were observed caused not only by reduction of flow but active / dynamic processes in riverbed, banks and riparian zone since monitoring survey in spring 2015. Besides changes in morphological parameters, river channel shapes have been modified heavily. For the next years, it is important to define accurately the exact place of the monitoring station.

The most significant changes of river channel parameters happened in boulders riverbed type. The average depth reduced by 54%, the average velocity – by 45% and average width of riverbed by 14%.

Reduction of average depths is visible at all types of the riverbed. Their average values are not less than 0.30 m, which are significantly higher than critical ichthyologic depth (which is equal to 1.2 of the average height of the brown trout body = 7 cm). In the same time, depths variability remains very high.

The braided type of riverbed did not turn into single one, although that one arm became significantly lower in water. However, the average depths there (0.30 m) are also higher than critical ones.

Boulders type of the riverbed in general kept its main features: high variability of the depths and velocities and variability of the flow types.

Sediment types' distribution in general remains the same.

4. Fish pass calibration

4.1 General provisions

Methodology

Hydrological survey of the fish pass included the measurements of water levels and flow velocity in the fish pass sluice. The goal was to assess if the fish pass has critical for brown trout zones in it depending of water level at threshold of the sluice.

Methodology included visual assessment of the fish pass zones and calculation of maximum flow velocities and minimal water depths in conditions of different water levels at threshold of the sluice of the fish pass (Figure 31).

Figure 31. Sluice at the fish pass

The survey also envisaged the fish pass calibration and identification of the dependency of the water discharge and flow velocity on water level at the first step of the sluice or in the upper reach of water reservoir.

The following equipment was used: for water level measurements – standard hydrometric rod and technical meter and for flow velocity measurements – hydrometric current meters of type ГР-55

(Georgia) and SIAP+MICROS (Italy). The equipment used is standard calibrated hydrometric equipment with valid calibration certificates.

During the survey, accuracy of the automatic water level and discharge measurement devices in the upper reach of water reservoir and fish pass was assessed.

The fish pass was clean from sediments and construction waste. In some places, the fish pass bottom and walls were covered by up to 3 cm of ice. When fish pass is closed, some water leaking in the lower reach was observed because of ice at the edges of sluice and its bottom (threshold) (Figure 32).

Figure 32. Water leaking during the full closure of the fish pass

4.2 Results

The field survey included three stages:

1. Assessment of the fish pass to identify the critical zones in terms of depths and velocity;
2. Measurements of water depths, flow velocities and water discharges at threshold of the sluice;
3. Checking the accuracy of the installed automatic meters of water level and discharge.

Figure 33. Fish pass calibration

1. *Assessment of the fish pass to identify the critical zones in terms of depths and velocity*

There was primary overflow of the water through the partition of the fish pass. It can be observed at the threshold of the fish pass above 28 cm. Flow velocity along the length of the fish pass, except the threshold of sluice of the fish pass was distributed quite equally and was not more than 1.6 m/s in conditions of depths variation at the sluice threshold up to 30 cm. Detailed correlation between water depths and flow velocity (with / without pressure) is given at Figure 35.

Zones of significant turbulence were fixed in the places of the flow velocity reduction by the partitions of the fish pass. This phenomenon is positive for fish because it creates zones with small flow velocities in the lower parts of the partitions (0.12-0.6 m/s).

2. *Measurements of water depths, flow velocities and discharges at threshold of the sluice*

The fish pass measurements were conducted with technical support of the staff of "Dariali Energy" during 22-25 November 2016 in conditions of flow velocity under and without pressure. Pressure on the flow velocity is caused by two factors:

- water levels variability in the upper reach of water reservoir and
- height of the opened sluice.

The surveys were conducted when the level in in the upper reach of water reservoir was from 1733.80 to 1734.80 m a.s.l. and in both regimes: when the sluice was fully opened and partly (based on the electronic device, showing the level of the sluice opening). As far as the data of automatized water levels measurements in the water reservoir did not correspond to real figures, the surveys were conducted following the water level above the threshold of the sluice of the fish pass (1733.8 m a.s.l.).

During the above-mentioned period, there were 54 measurements done (22 at the sluice of the fish pass, 37 measurements at thresholds №1 and №2 from the sluice (Figure 34). The relevant data are present in Tables 4-7 and at Figures 34-36.

Figure 34. Thresholds, where depths and velocities were measured

Table 4. Monitoring data in the sluice of the fish pass (without pressure)

№	Width of cross-section (m)	Depth in the threshold of sluice, m	Area of water crosscut (m²)	Flow velocity (pulsing), m/s	Water discharges (calculated), m^3/s	Water level in upper reach m a.s.l.
1	1.50	0.05	0.08	1.06	0.08	1733.85
2	1.50	0.09	0.14	1.44	0.20	1733.89
3	1.50	0.10	0.15	1.51	0.23	1733.90
4	1.50	0.14	0.21	1.66	0.35	1733.94
5	1.50	0.15	0.23	1.78	0.41	1733.95
6	1.50	0.20	0.30	1.95	0.59	1734.00
7	1.50	0.22	0.33	1.99	0.66	1734.02
8	1.50	0.25	0.38	2.09	0.79	1734.05
9	1.50	0.55	0.83	2.68	2.22	1734.35

Table 5. Monitoring data in the sluice of the fish pass (under pressure)

№	Width of cross-section (m)	Depth in the threshold of sluice, m	Area of water crosscut (m²)	Flow velocity (pulsing), m/s	Water discharges (calculated), m^3/s	Water level in upper reach m a.s.l.
1	1.50	0.03	0.05	1.53	0.08	1734.53
2	1.50	0.03	0.05	1.57	0.08	1734.61
3	1.50	0.03	0.05	1.68	0.08	1734.75
4	1.50	0.06	0.09	1.99	0.18	1734.56
5	1.50	0.06	0.09	1.98	0.18	1734.63
6	1.50	0.06	0.09	2.11	0.19	1734.79
7	1.50	0.09	0.14	2.34	0.33	1734.57
8	1.50	0.09	0.14	2.37	0.33	1734.64
9	1.50	0.09	0.14	2.66	0.37	1734.79
10	1.50	0.12	0.18	2.59	0.47	1734.65
11	1.50	0.12	0.18	3.36	0.60	1734.80
12	1.50	0.15	0.23	2.90	0.67	1734.68
13	1.50	0.15	0.23	3.45	0.79	1734.80

Table 6. Monitoring data at sluice of the fish pass (threshold # 1)

№	Width of cross-section (m)	Height of the opened sluice	Depth in the threshold, m	Area of water crosscut (m²)	Flow velocity (pulsing), m/s	Water discharges (calculated), m^3/s	Water level in upper reach m a.s.l.
1	1.40	0.03	0.13	0.18	0.85	0.15	1734.53
2	1.40	0.03	0.14	0.20	0.88	0.18	1734.61
3	1.40	0.03	0.20	0.28	0.67	0.19	1734.75

№	Width of cross-section (m)	Height of the opened sluice	Depth in the threshold, m	Area of water crosscut (m²)	Flow velocity (pulsing), m/s	Water discharges (calculated), m^3/s	Water level in upper reach m a.s.l.
4	1.40	0.03	0.09	0.13	0.80	0.10	1733.99
5	1.40	0.03	0.10	0.14	0.79	0.11	1733.97
6	1.40	0.03	0.10	0.14	0.71	0.10	1733.94
7	1.40	0.05	0.07	0.10	0.65	0.07	1733.87
8	1.40	0.05	0.04	0.06	0.52	0.03	1733.84
9	1.40	0.06	0.20	0.28	1.00	0.28	1734.56
10	1.40	0.06	0.22	0.31	1.00	0.31	1734.63
11	1.40	0.06	0.25	0.35	0.69	0.24	1734.79
12	1.40	0.09	0.28	0.39	1.11	0.43	1734.57
13	1.40	0.09	0.28	0.39	1.07	0.42	1734.64
14	1.40	0.09	0.30	0.42	0.87	0.37	1734.79
15	1.40	0.10	0.11	0.15	0.86	0.13	1733.90
16	1.40	0.10	0.11	0.15	0.90	0.14	1733.90
17	1.40	0.12	0.33	0.46	1.11	0.51	1734.59
18	1.40	0.12	0.36	0.50	1.11	0.56	1734.65
19	1.40	0.12	0.36	0.50	0.84	0.42	1734.80
20	1.40	0.15	0.38	0.53	1.15	0.61	1734.68
21	1.40	0.15	0.40	0.56	0.96	0.54	1734.80

Table 7. Monitoring data at sluice of the fish pass (threshold # 2)

№	Width of cross-section (m)	Height of the opened sluice	Depth in the threshold, m	Area of water crosscut (m²)	Flow velocity (pulsing), m/s	Water discharges (calculated), m^3/s	Water level in upper reach m a.s.l.
1	1.20	0.03	0.11	0.13	1.00	0.13	1734.53
2	1.20	0.03	0.15	0.18	1.00	0.18	1734.61
3	1.20	0.03	0.21	0.25	0.81	0.20	1734.75
4	1.20	0.06	0.21	0.25	1.25	0.31	1734.56
5	1.20	0.06	0.23	0.28	1.23	0.34	1734.63
6	1.20	0.06	0.25	0.30	0.94	0.28	1734.79
7	1.20	0.09	0.26	0.31	1.32	0.41	1734.57
8	1.20	0.09	0.26	0.31	1.26	0.39	1734.64
9	1.20	0.09	0.32	0.38	0.94	0.36	1734.79
10	1.20	0.10	0.12	0.14	0.89	0.12	1733.90
11	1.20	0.10	0.10	0.12	1.01	0.12	1733.90
12	1.20	0.12	0.34	0.41	1.19	0.49	1734.59

№	Width of cross-section (m)	Height of the opened sluice	Depth in the threshold, m	Area of water crosscut (m²)	Flow velocity (pulsing), m/s	Water discharges (calculated), m^3/s	Water level in upper reach m a.s.l.
13	1.20	0.12	0.37	0.44	1.21	0.53	1734.65
14	1.20	0.12	0.38	0.46	0.99	0.46	1734.80
15	1.20	0.15	0.40	0.48	1.33	0.64	1734.68
16	1.20	0.15	0.40	0.48	1.10	0.53	1734.80

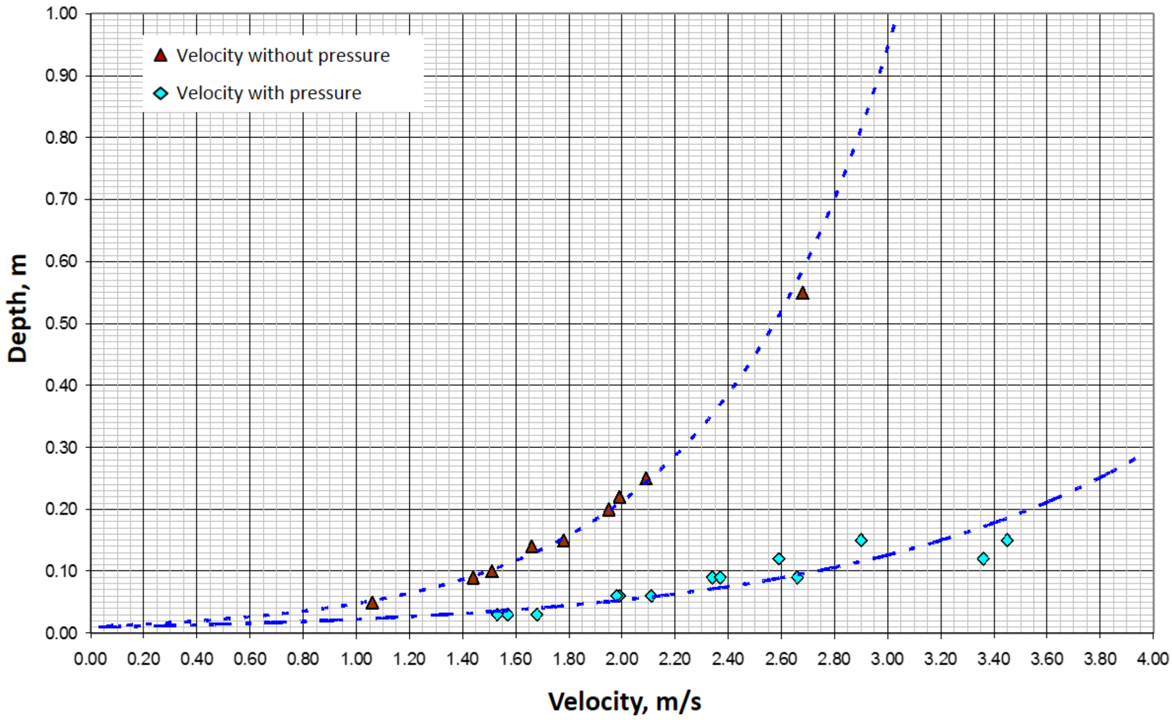


Figure 35. Chart of dependency of flow velocity and water depth at the threshold of sluice of the fish pass or height of the sluice opening (with pressure and without)[3].

Figure 36. The electronic device showing the level of the openness of the sluice

[3] Flow velocity under pressure were measured at the water level in upper reach of water reservoir at the range of 1734.53-1734.80)

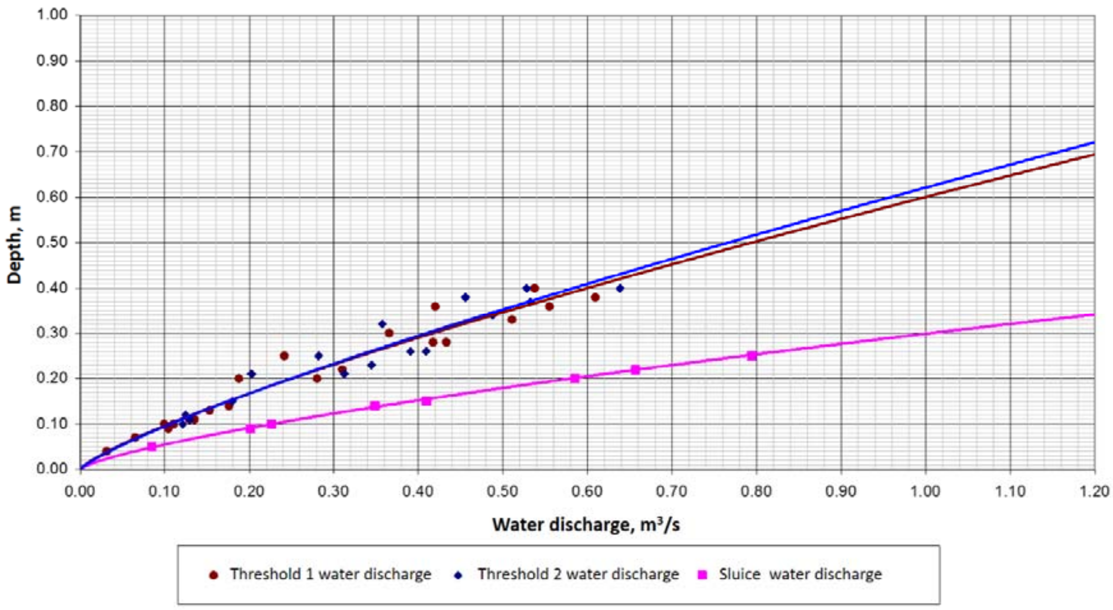


Figure 37. Chart of dependency of water discharges on water levels

Taking into account the above-mentioned measurements of the first two thresholds of the fish pass, which are the shallowest, the Consultant considers that at all steps of the fish pass, the depth variation is not less than 7 cm (defined as critical ichthyologic depth). When water levels in water reservoir are above 1733.97 m a.s.l., due to the turbulence at the thresholds of the fish pass, the depths increase (up to 9 cm).

Under pressure and opened sluice by 25 cm and more, the measured flow velocity at the sluice is 2.2 m/s and more, which is critical for successful leaving by the brown trout of the fish pass because optical velocity for the brown trout is in range of 0.8 -1.5 m/s. The comfortable conditions for the fish correspond to the opened sluice of the water reservoir between 3 and 25 cm (Figures 38, 39 and 40). In general, the fish pass sluice is the most critical place in the fish pass for the free moving of the fish from lower reach to upper reach of Dariali HPP.

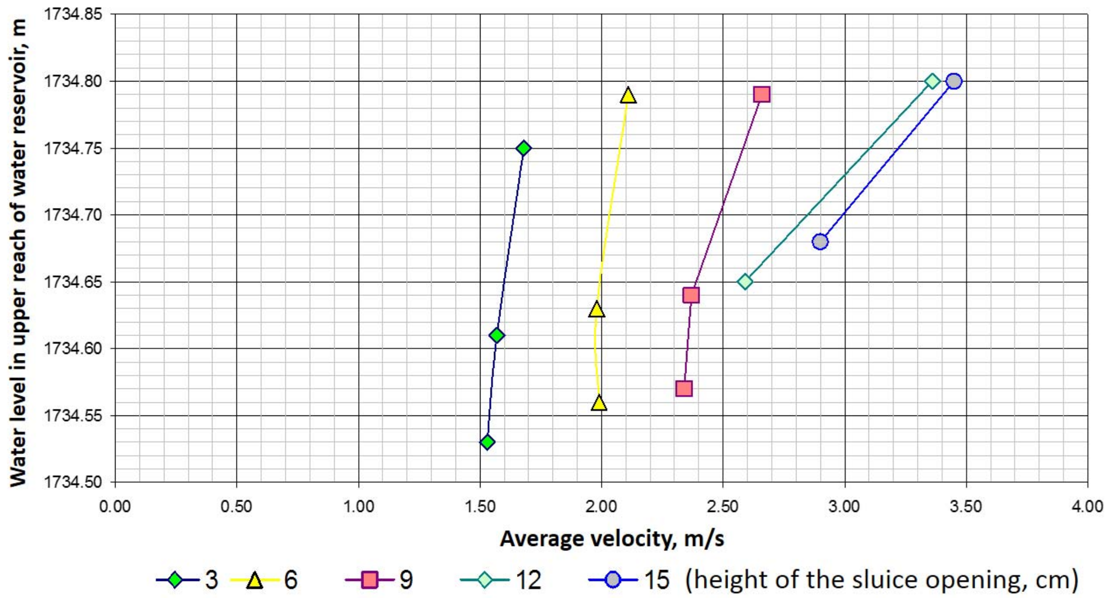


Figure 38. Dependency of the flow velocity under pressure on the height of the opened sluice and water level in upper reach of the water reservoir

Assessment of the features of the flow of the fish pass confirmed that there is homogeneity of flow velocity and water level regime along the whole length of the fish pass. Based on the surveys data on the thresholds №1 and №2 of fish pass, there are no critical for the fish velocities in the measured framework fixed.

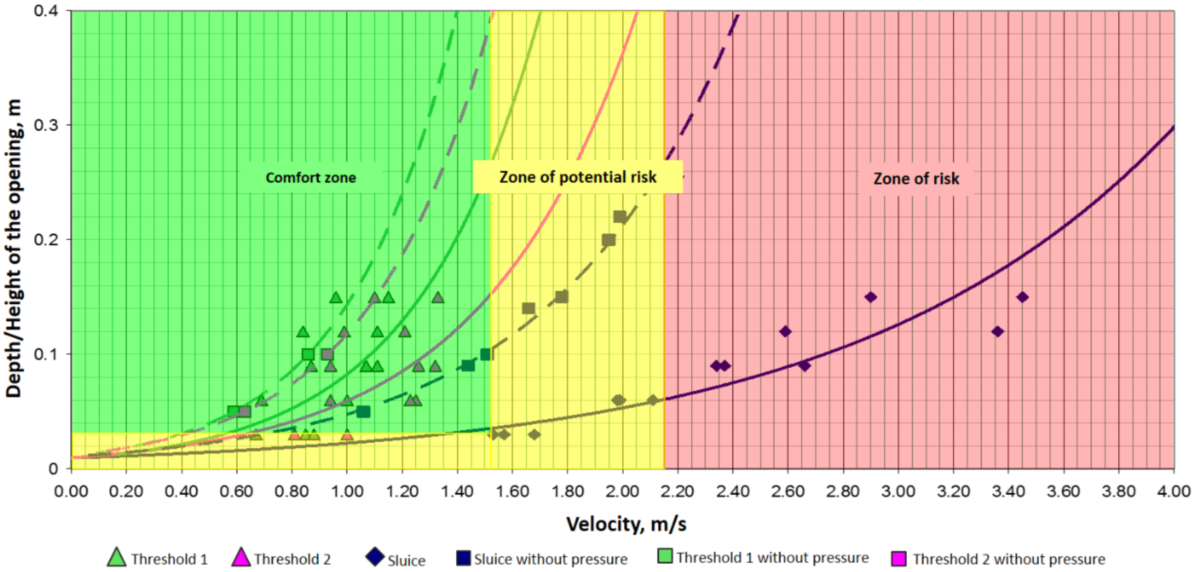


Figure 39. Chart of dependency of flow velocity at thresholds # 1, #2 and sluice of the fish pass on water depth at the threshold of sluice / height of the opened sluice with / without pressure as well as zones of comfort for brown trout

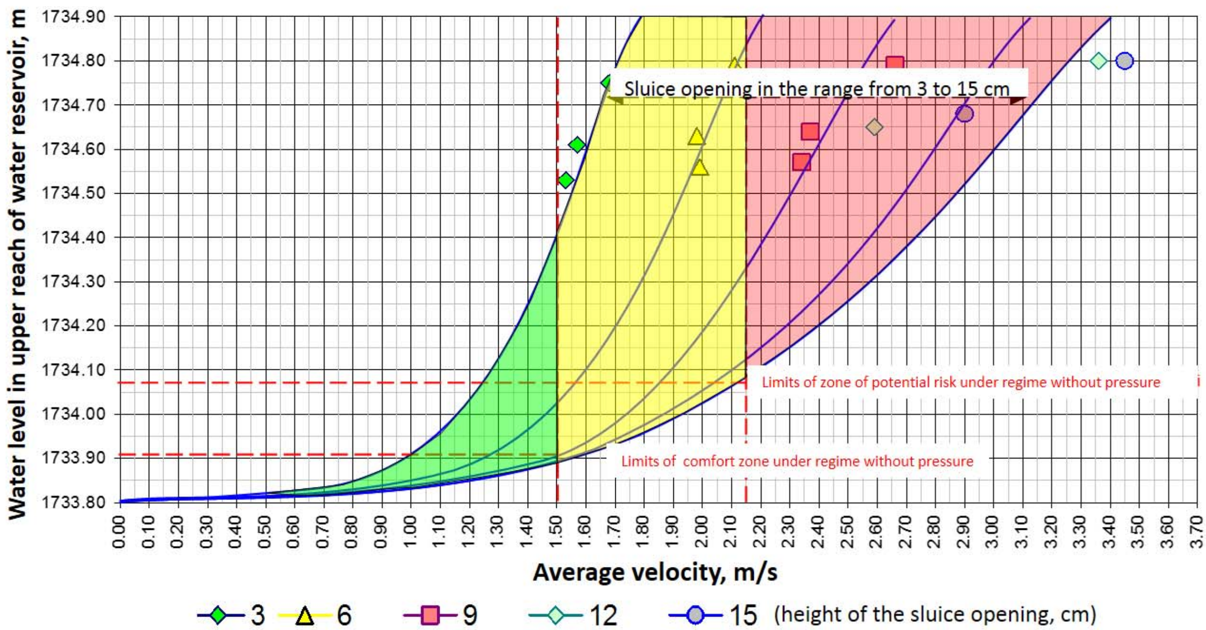


Figure 40. Dependency of flow velocity under pressure on height of the opened sluice and water level in upper reach of water reservoir

***3.** Checking the accuracy of the installed automatic meters of water level and discharge.*

The Consultant compared the obtained field data with the data shown by the installed automatic meters.

The results showed that automatic device measuring the water level in upper reach is not calibrated to show the real water level (Figure 41). The relevant mitigation measure is stated under 2A. Data of the automatic device varied between 1731.4-1732.1 m a.s.l. when in reality the values were 1733.8 -1734.8 m a.s.l.

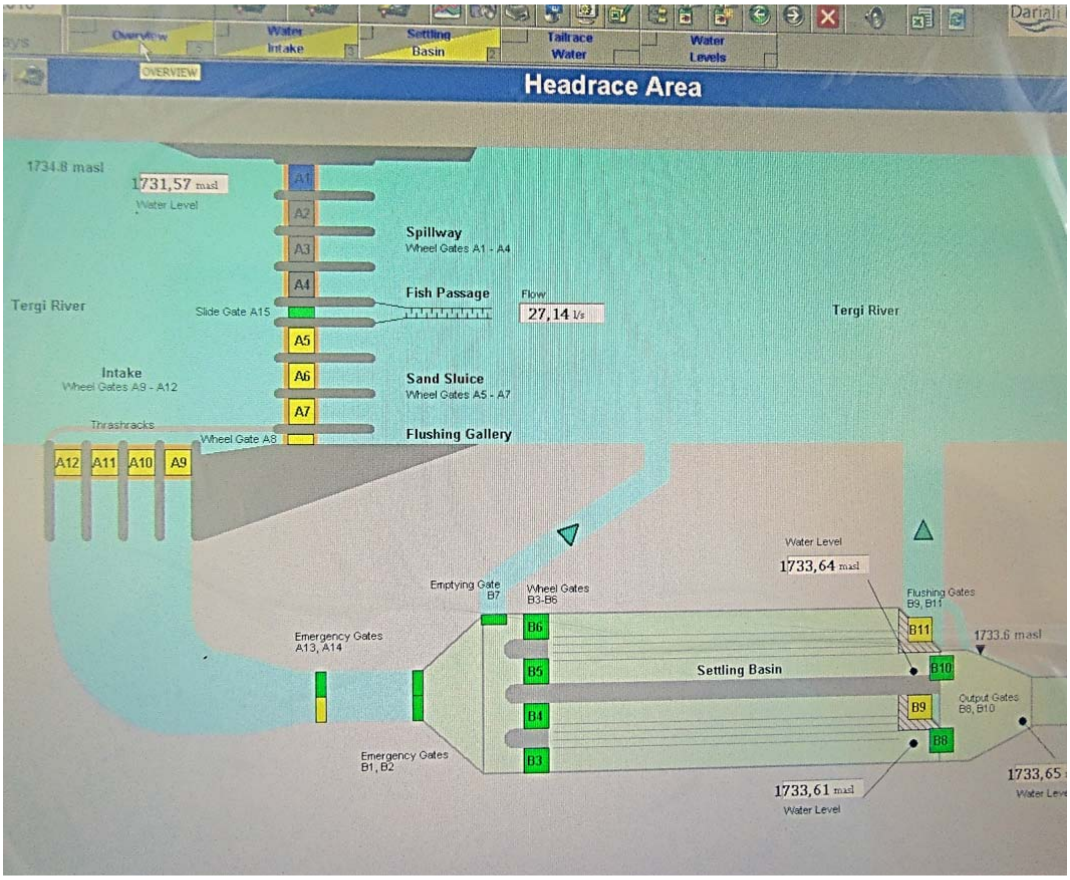


Figure 41. Monitor showing the values of the water level in the upper reach

Figure 42. Maximum value showed at AVFM 5.0 during the surveys

Automatic device measuring the water discharge in the fish pass (AVFM 5.0 Area Velocity Flow Meter) is not calibrated to show the real discharges. The data of the automatic device varied between 0.15 l/s and 81.6 l/s (Figure 42) when measured data varied between 120 l/s and 640.0 l/s.

Results:

1. Flow velocity along the length of the fish pass, except at the sluice of the fish pass is distributed quite equally. There are zones of significant turbulence near partitions of the fish pass fixed. All of these create favourable conditions for the fish passing.

2. The comfortable conditions in terms of the flow velocity are created (if the fish pass is fully open – without pressure) when water level in upper reach is around 1733.9 m a.s.l., and the threat for the fish passing will appear when water level in upper reach is 1734.07 m a.s.l. In conditions under pressure (if the fish pass is partly open for 6 - 15 cm), the comfortable conditions for the fish pass will appear, when water levels in upper reach will be 1733.80 – 1734.53 m a.s.l., and zone of potential danger is between 1734.53 m a.s.l. to 1734.8 m a.s.l. The Consultant does not recommend using the regime under pressure with small sluice opening and high water level in the upper reach.

3. The most comfortable conditions in terms of the flow velocity along the whole fish pass will be created when:
   - Water level in the upper reach is 1733.86-1733.96 m a.s.l. and
   - Fish pass is fully open.

   DE reaction:

   During construction of settling basin, DE increased the crest of the weir from 1733.60 to 1734.00 at the exit bulkhead of settler for purpose of discharge excess water automatically in case of unexpected trip of HPP, that gives HPP opportunity to keep water level upstream at headworks from 1733.80 (fishway threshold elevation) to 1734.00 in range when the flow in the river is less than 25m^3/s because of very small hydraulic loses from headwork to the end of settler, that means in autumn period mostly October-November (in winter for sure and March and April as well) DE can easily keep 1733.90-1734.00 at upstream, so no need to close the fishpass entrance gate partly and therefore will not be turbulences and also no need to reach 1734.07 level that is potential threat for trout - at this period DE will have calibrate measurement equipment and we can always adjust levels in range 1733.80-1734.00 to keep 0.7m^3/s in fish pass, this scenario is working almost 8 months when in river flow is less than 25 m^3/s.

   So we can easily state that normal operational level on headwork is 1733.90 - 1734.00 when flow less than 25m^3/s in the river Tergi.

   All above mentioned is for condition without pressure – fishway gate is full open. DE can also use scenario 2 like keep elevation at upstream till 1734.53 but with partly closed gate to keep 700 m^3/s accordingly. Both scenarios are acceptable till flow is less than 25 m^3/s.

   Flow more than 25m^3/s (second half of May, June, July, August)
   Regarding summer period when in Riv Tergi flow is more than 25 m^3/s DE have to keep 1734.60 (that is normal operation level) because hydraulic loses are increased as well, so to release 33 m^3/s to the penstock entrance DE have to keep 1734.60 to take elevation at penstock entrance 1734.00 and less to avoid water overflowing on the crest. Of course DE can keep 1734.53 (the maximum comfortable level) upstream, - 7 cm is nothing but in case

of water in the river is app 40 m^3/s the rest water out of 33 m^3/s should be overflowed on spillway gates on headwork (the elevation is 1734.80). In this scenario DE have to close fishway gate partly that will cause turbulences under gate. According BR recommendations regarding this issue DE have several solutions: DE can install another gate just after first entrance gate as called "constant head orifice" with this solution DE can reduce the velocity under the gates from 2.2 to 1.5 m/s, this can be negotiated with BR and EBRD in 2017.

4. Automatic device measuring the water level in upper reach and automatic device measuring the water discharge in the fish pass (AVFM 5.0 Area Velocity Flow Meter) are not calibrated to show the real values.

   DE reaction: DE will calibrate all measurement equipment during summer period.

5. At present, it is impossible in real time mode to monitor the released water into the affected reach, including control the minimum environmental flow release by the HPP, as it was required by the Adaptive Management Plan (as far as water level devices are not installed at all gates). The relevant mitigation measures are described below under point 2.

6. Trainings

General provisions

According to the Aquatic Survey and Monitoring Programme (2016) and Adaptive management plan 2016, *"trainings and skills transfer for local staff should be conducted to ensure further post-commissioning monitoring (from 2017). The Dariali HPP should identify the staff to be trained prior the monitoring missions, so that monitoring during 2016 will be conducted jointly with Georgian specialists to ensure on-job trainings*".

The following specialists need to be trained:

1. Ichthyologist (3 people),
2. Zoologist (3 people),
3. Hydrologist and hydromorphologyst (2 people).

The relevant description of qualifications for the trainees were provided to "Dariali Energy" (Annex 3. Qualification requirements to the Georgian specialists of the Aquatic Survey and Monitoring Programme (2016)).

During 2016, the trainings of hydrologists and hydromorphologysts were conducted. The trainings of the ichthyologists and zoologists were not condcuted because "Dariali Energy" did not provide the trainees. However, it was agreed that this training could be conducted during 2017, if the trainees will be provided.

Hydrology and hydromorphology training

The on-job training took place on November, 23 and 25. The trainees were also involved in the fish pass calibration (Figure 43).

Figure 43. Involvement of the Georgian specialists in the training

The list of the trained specialists, done on the basis of final session on 26.11.2016 is given in Table 8.

Table 8. List of the trained Georgian specialists

№	Name, Surname	Place of work	Position
1	Nukzar Dzhamardzhasvili	Dariali HPP	Operator
2	Roland Vardzukashvili	Dariali HPP	Operator
3	Vazha Pitskhelauri	Dariali HPP	Operator
4	Zviad Chopikashvili	Dariali HPP	Operator
5	Vladimer Marsagishvili	Dariali HPP	Operator
6	Besik Geladze	Dariali HPP	Operator

The trainees gave obtained the following skills during the training (Figure 44):

- Measurement of the flow velocity using universal hydrometric current meter ME4001 (SiapMicros) and current meter ГР-55,
- Measurement of the width and depth of the riverbed using large range finder and technical meter,
- Sediments composition in % using frame 1 m^2,
- Geolocation using GPS,
- Use of Field Map equipment and its software for hydromorphological measurements and use of DJI Phantom 4 drone for aerial images,
- Types of ice phenomena and their impact on Dariali HPP,
- Measuring of water level in water reservoir and at the threshold of sluice of fish pass.

Figure 44. Training of the Georgian specialists

The training included theoretical basis of the methodology of the surveys and field (on-job) training using the above-mentioned equipment.

Results:

The above-mentioned specialists took active part in the measurements of water levels of upper reach of water reservoir using manual methods of research and made comparison with the data of relevant automatic water level device. They conducted field measurements of flow velocity and further water discharge and compared it with the data of automatic device measuring the water discharge in the fish pass (AVFM 5.0 Area Velocity Flow Meter). They managed to regulate and sustain the needed level of upper reach of the HPP, needed for stable water level in the fish pass. These practical skills are important for good-quality management of HPP in order to assure stable water level in the fish pass during the brown trout upstream spawning migration. Practical skills on measurements of water discharge allow them to conduct independently the reliability of the automatic devices measurements.

In the same time, it does not sound realistic that specialists of Dariali HPP could conduct independently (without external supervisor) complete hydromorphological monitoring and monitoring of the fish pass. Conduction of the monitoring requires professional skills and experience, understanding of the process of riverbed formation, dynamics of the water streams and sediments.

Besides, the staff should have relevant equipment (at least stream current meter, rods, high accuracy GPS, theodolite), which require additional investments.

7. Mitigation measures

Flow and physical habitats measures

In general, flow and physical habitat monitoring surveys in conditions of reduced flow showed continuity of the flow at the whole affected reach. All three types of riverbed remain (the braided type of riverbed did not turn into single one). The minimal average depths (30 cm) at the affected reach were also higher than critical ones (7 cm). If the same situation is observed during the environmental flow only, no specific riverbed mitigations measures will be needed.

Based on the results of the survey, there is no significant changes in the sediment composition fixed. It could be assumed that sediment composition will be changed after the station will be fully operational. Based on the results of the post-commissioning monitoring in 2017 and 2018, specific measures could be identified.

Aquatic biodiversity measures

The aquatic biodiversity measures are limited to the measures to improve fish pass monitoring

Check list:
1 Improving of the fish pass monitoring

1A	Fish pass should operate during the whole year as minimum 300 days and obligatory during autumn upstream spawning migration. Obligatory fish pass operation in autumn is stated because the only fish specie living in Tergi (brown trout) has upstream spawning migrations in autumn. This recommendation does not mean that fish pass should not be operational in spring. In spring, the juvenile fish can migrate downstream using fish pass, as well as through fixed orifice.
1B	Winch should be installed for safe uploading and instalment of the fish trap.
1C	Ladder should be installed which would allow reviewing the state of the fish pass periodically and cleaning the pools of the fish pass.
1D	Fish trap construction should be changed according the scheme in the Box 1.
1E	The fish pass should be regularly checked to take away the garbage, which can lead to change of its hydraulic characteristics leading to rejection of the fish to enter the fish pass. Optimal frequency of fish pass checks should be defined during the fish pass operation, but not less than once per week and obligatory once per week and prior spawning migration (September). In case of the need to clean the fish pass, its intake in upper part should be closed by lock. During fish pass closure, the minimum environmental flow should be compensated by increase of the flow through flushing orifice.

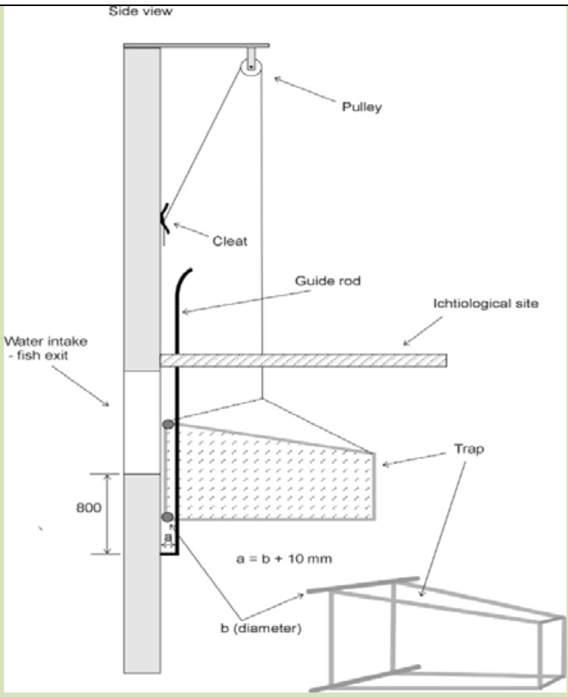


Figure 45. Way to fix the fish trap

Box 1

Changes in the fish trap
Four hooks should be replaced with two round smooth rods with diameter 18 — 20 mm and length 2.5 m. The lower ends of rods should be welded-in to steel channel 800 mm lower than threshold of outlet. The upper part of rods should be welded-in to ichthyologic platform. Distance «a» from frontal surface of fish pass window should be by 10 mm more than diameter «b» of the external ends of the fish trap framework. Such construction allows using driving pulley to move the trap up and down. This will establish internal fence and allow working safety in standing position. Fixation of the trap will be done by cleat, installed at the wall of dam.

Measures related to the HPP operation

Check list:

2 Improving of the automatic hydrological monitoring

2A Two automatic devices:

- device measuring the water level in upper reach and
- automatic device measuring the water discharge in the fish pass (AVFM 5.0 Area Velocity Flow Meter)

should be calibrated or replaced by the new ones to show the real values.

DE reaction: during winter period mainly January-February when outdoor temperature is -10 - -25 C°, the fish pass ladders/thresholds easily freeze that means automatic measurement equipment does not give real/precise information (the shape where water flows is reduced by ice) so there is no reason to calibrate during this period, DE will calibrate equipment in spring period. Despite this DE is keeping 0.7 m^3/s in fishway by position of entrance gate, the opening of gate corresponds to 0.7 m^3/s.

2B Additional automatic water level meters should be installed at all gates

As it was stated in the Adaptive Management Plan (Measure 2), the objective is in real time mode to monitor the released water into the affected reach, including control the minimum environmental flow release by the HPP.

DE reaction: At presemt, all gates are equipped with sensors to monitor each movement of gates and figures are displayed on screen at powerhouse and operational rooms on Headworks. It should be mentioned that DE finished installation of gates and sensors at late December, when almost all gates are frozen and cannot be operated besides gate installed at flushing gallery. So when DE can operate gates from March it will calibrate all sensors and moreover DE is going to install mechanical rulers and all operational movement of gates can be visible directly at each gate. From March, the decision on how to make real time monitoring system of gates position can be taken (for more better clarification it can be decided during EBRD visit in February).

2C Hydrological rods should be placed near the automatic devices to ensure their calibration. ☐

See DE reaction above.

2D Public disclosure of the data of monitoring of the released water into the affected reach, including control the minimum environmental flow release by the HPP. It corresponds to the requirements of Environmental and Social Action Plan (Action 6.1), where it is stated *"flow data made available to the public on the company website"*[4]*.* It is important to ensure it and present it to the public during public event of the HPP inauguration. ☐

[4] Environmental and Social Action Plan – p. 6.

8. Post-commissioning monitoring programme

7.1 General provisions

The goal of the post-commission monitoring is to monitor the impact of the HPP operation at flow and physical habitat and aquatic biodiversity.

Types of monitoring

The monitoring should include two types:

- Ecological monitoring (brown trout and invertebrates)
- Flow and fish habitat monitoring.

Table 9. Types of monitoring

№	Monitoring station	Invertebrates monitoring	Flow and fish habitat monitoring
M 1	Tergi upstream the Dariali headworks	+	
M 2	Tergi downstream the Dariali headworks (boulder section)	+	+
M 3	Tergi downstream the Dariali headworks (braided section)	+	+
M 4	Tergi downstream the Dariali headworks (single thread section)	+	+

Locations of the monitoring stations

As far as this monitoring programme is continuation of the already conducted surveys and in order to compare the post-commissioning situation with the baseline, it is proposed the use the same monitoring stations, which were established by Consultant, but in reduced number. The location of the monitoring stations is presented at the Figure 46 and Table 9.

Table 10. Coordinates of proposed monitoring stations

№	Monitoring station	Elevation, m a.s.l.	Coordinates			
			Upper_Left	Upper_Right	Down_Left	Down_Right
M 1	Tergi upstream water reservoir upstream the Chkeri	1728	42°39'52.34"N 44°38'37.54"E			
M 2	Tergi downstream the Dariali headworks (boulder	1693	42°40'06.76" 44°38'32.52"	42°40'06.95" 44°38'32.90"	42°40'06.38" 44°38'32.80"	42°40'06.50" 44°38'33.01"

№	Monitoring station	Elevation, m a.s.l.	Coordinates			
			Upper_Left	Upper_Right	Down_Left	Down_Right
	section)					
M 3	Tergi downstream the Dariali headworks (braided section)	1469	42°42'04.60" 44°38'00.16"	42°40'05.07" 44°38'01.01"	42°42'04.66" 44°38'00.56"	42°42'04.92" 44°38'01.49"
M 4	Tergi downstream the Dariali headworks (single thread section)	1413	42°42'53.94" 44°37'31.70"	42°42'54.00" 44°37'33.31"	42°42'53.30" 44°37'31.73"	42°42'53.27" 44°37'32.62"

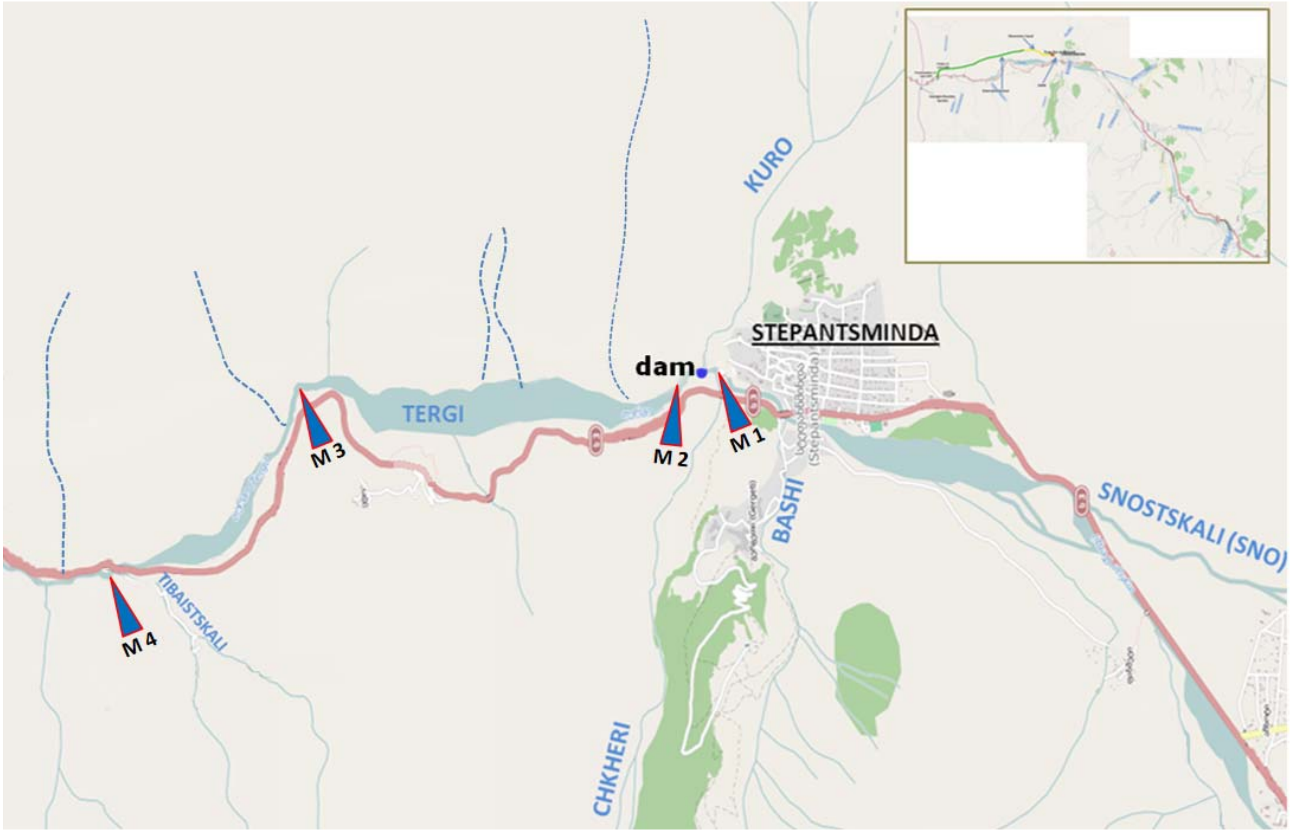


Figure 46. Location of monitoring stations

7.2 Monitoring programme

Brown trout monitoring

It should be conducted twice during the year during the main periods: upstream spawning migration (autumn) and downstream migration (spring and summer).

- **Upstream spawning migration**

Time: for Tergi from September till December with mass spawning from 15.10 to 15.11 with variations up to 2 weeks depending on weather conditions.

The main goal is to assess the fish pass efficiency.

It could be conducted by two methods:

- First method gives qualitative assessment of the fish pass efficiency. For this, daily catches by cast net and fishing rod in the lower and upper reaches. If the tagged fish will be caught in the upper reach, it proves the fish pass efficiency.

- Second method gives quantitative assessment of the fish pass. For this, fish trap should be installed at the fish pass outlet.

For the caught fish, the relevant protocol (see Annex 1) should be filled. The caught fish should be tagged as Consultant did by bead.

Assessment of the total number of the fish, passing the fish pass without electronic devices, can be done using the fish trap or by blocking method. Blocking method means to block the trout in the fish pass by nets in the upper outlet and lower outlet of the fish pass. The assessment should start prior the massive migration and finish after significant decrease of the number of caught fish in the fish pass. The time of the application of the method should be divided by 24 hours in order to calculate time coefficient. The doubled sum of the number of registered fish taking into account the time coefficient gives the total number of the fish passed the fish pass. Extrapolation of upgrading and downgrading curve of the distribution of the daily number of the passed fish during assessment will also allow assessing the number of fish passed prior and after the assessment.

- **Downstream migration**

Time: start in the second half of March and last till August with different intensity. The most intensive migration is in the end of March till the mid of April.

The main goal is to assess the possibility of fish entering the HPP turbines.

Activities:

1. Study of the fish distribution in the water reservoir. Fish should be caught (by framed net and casting net) at left and right banks. Other methods include trawling by cone net near the bottom and surface near the fish pass and HPP water intake. The fish should be caught in daytime and nighttime with the duration of 6 hours. Schedule: 2-4 days in April.
2. Control of the fish presence and distribution in the sand trap (by framed net and casting net). The fish should be caught in daytime and nighttime with the duration of 6 hours. Schedule: 2-4 days in April.
3. Periodical catch of the fish using the cone net in the fish pass outlet. The fish should be caught in daytime and nighttime. Schedule: 2-4 days in April.

For the caught fish, the relevant protocol (see Annex 1) should be filled. If juvenile and adult trout is found near the water in-take or in the sand trap near deep gates, it shows the possibility of the fish to enter the HPP turbines.

Invertebrates monitoring

Time: September in the period of low water after stabilization of the environmental conditions after summer flood.

The main goal is to assess changes in the ecological status of the river using bioindication.
The relevant protocol should be filled out (see Annex 2) for the four stations mentioned in the Table 10.

Flow and physical monitoring

Time: period with only environmental flow at the affected reach

The main goal is to check the changes in the depths and velocities at three riverbed types in order to ensure absence of the critical depths and unpassable barriers for the fish.

The relevant protocol should be filled out (see Annex 3) for the three stations mentioned in the Table 10.

According to the contract, Blue Rivers® "will review the reporting outputs (in our case protocols) on behalf of the Sponsor on a quarterly basis for the first two years, semi-annually for the next two years and annually up to the first 10 years of operation[5]".

7.3 Other requirements

Despite the conduction of training on hydrology and hydromorphology and planned ichthyologic training in spring 2017, there is no capacity in "Dariali Energy" to conduct the monitoring at present independently. It is proposed to subcontract a specialized organization for this task.

The special equipment should be purchased to ensure conduction of the field surveys by stuff of "Dariali Energy" (see Chapter 4. Trainings for details).

[5] Terms of Reference, October 2014

Annex 1. Field protocol of ichthyologic monitoring

Date:	
Time:	
Location:	
GPS coordinates:	
Remarks:	

Weather condition:

Air temperature, ^{o}C	
Water temperature, ^{o}C	
Cloudiness, %	
Precipitation (snow, rain etc.)	
Wind	

River channel:

Width, m	
Depth, m	

or

Water reservoir:

Place of catching (right, left or centre)	
Depth, m	
Distance from fish pass, m	
Distance from the water in-take, m	

****Fish catching:**

Catching devices	Type (casting net, cone net etc.)						
	Size of the mesh						
	Type of baits						
Time	Used for catching, min						
	Number of attempts,						
Brown trout	Number	n					
		1	2	3	4	…	n
	Length, mm						
	Weight, g						

* All positions should be filled, even if the fish is not caught.

**After the fish is caught and 10-20 scales of it are taken, it should be released alive into the river. The collected scales should be dried out in cool and windy place, as far as if they will be dried too quickly, they got broken and it is impossible to identify the fish age. The scales should be provided to the Consultant together with the report.

Annex 2. Field protocol for biological assessment of the river

<table>
<tr><th>Name of the water body</th><th>Monitoring station 2</th></tr>
<tr><td>Tergi downstream the Dariali headworks (boulder section)
</td><td>Downstream the dam of Dariali HPP
Coordinates:
N – 42^{0}40'06,7"
E – 44^{0}38'32,5"
H – 1693 m</td></tr>
<tr><td>Date 2015-03-29; 04; 11-01</td><td>Weather: sunny +4 – + 26</td></tr>
</table>

DESCRIPTION BLOCK

Landscape and habitat description:	
Width of the water body	*on the water's edge 15 m, width of the dry riverbed – 25 m*
Depth	*Near the bank 10-50 cm, deepening - to 140 cm*
Flow velocity (m/ s)	*0,15-2,53*
Water use	*no*
Visible pollution	*household waste*
Temperature (C°)	*the average daily of 14,4*
Colour	*cannot be determined*
Transparency of Secchi depth	*to 0,5 m (slight turbidity of water)*
pH	*7,75*
O_2%	*135-140*
Additional Information	*samples were taken of bottom fauna (washout from stones + kick & sweep) № 7, ichthyologic catches*

Biotsenotic description	
Survey method	*manual collection*
Macrophytes	*riparian floodplain vegetation, Fantinalis - sometimes*
Microalgae	*fouling of stones less than to 10% Hudrurus in spring fouling filamentous algae sometimes*
Macroinvertebrates	*stoneflies - 3 species, mayflies - 4 species, caddis flies - 4 species, chironomids, oligochaetes, dipterans, midges, gammarids*
Amphibian	*no*
Ichthyofauna	*no*

ASSESSMENT BLOCK

<table>
<tr><td colspan="4">Plecoptera 3+</td></tr>
<tr><td colspan="2">Ephemeroptera
(Baetis excluded) 4+</td><td>Trichoptera
(Ecnomus excluded) 4+</td><td>Gammaridae +</td></tr>
<tr><td>Odonata –</td><td>Bivalvia (Sphaeridae excluded) –</td><td>Gastropoda –</td><td>Bryozoa –</td></tr>
<tr><td>Spongia –</td><td>Asellus –</td><td>Hirudinea –</td><td>Sphaeridae –</td></tr>
<tr><td colspan="2">Chironomidae +</td><td colspan="2">Tubificidae +</td></tr>
<tr><td colspan="4">Other: larvae of midges, diptera</td></tr>
</table>

Biotic indices	Periphyton	Benthos	General
Trent Biotic Index	6-7	5-6	6-7
geobotanical indicators			

Annex 3. Field protocol of flow and physical habitat monitoring

Date:	
Channel type:	
Length of monitoring station:	
Number of cross sections:	

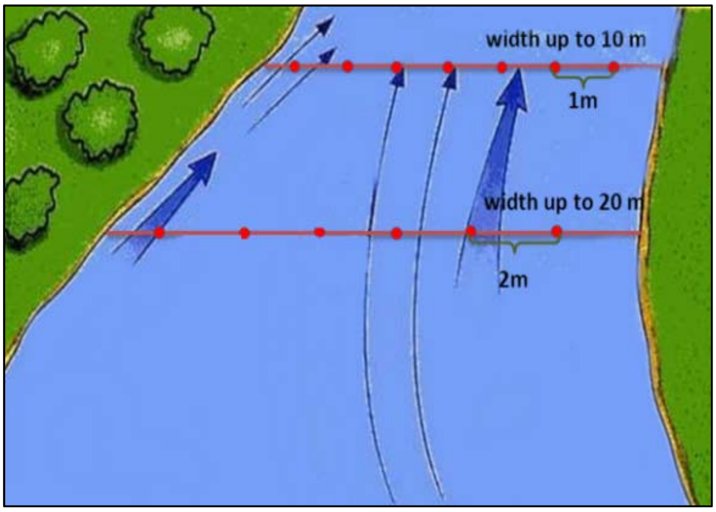
*Cross section:	(identification number)
Width (m) :	
**Distance between the measuring points (m):	

Number of points	Distance from the bank (left/right) to the point, (m)	Depth, m	Velocity, m/s
1			
2			
3			
4			
5			
6			
7			
8			
…			
n			

Equipment: GPS, rode, current meter and theodolite.

*Monitoring stations M2, M4 includes 5 cross-sections with the interval of 2 m; monitoring station M3 includes 12 cross-sections

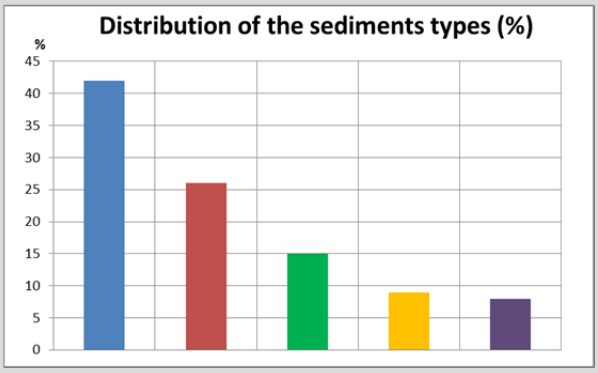
**The preliminary distance between the measuring points of the cross-section will be 1 m for the river width up to 10 m and 1- 2 m for the river width up to 20 m



Proposed intervals of cross-sections

Distribution of the sediments types

Substrate types	% of sediments
Boulder (256 mm – 2048 mm)	42
Cobble (64 mm – 256 mm)	26
Pebble (17 mm – 64 mm)	15
Gravel (2 mm – 17 mm)	9
Sand (0.06 mm – 2 mm)	8



Distribution of the sediments (example)

Analysis of the sediment composition is conducted at the bank, in direct vicinity at river. Equipment: frame 1x1 m^2 for visual assessment of the percentage composition of sediments.