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Implementation of the Post-Commissioning Monitoring of Dariali HPP in 2017

Final Report

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Document verification

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Revision	**Date**	**Authors**
Draft 1	27.12.2017	Mr. Igor Abramiuk, Dr. Prof. Sergey Afanasyev, Mr. Oleg Golub, Dr. Alexei Iarochevitch, Mr. Yurii Levchak, Dr. Olena Lietytska, Ms. Olena Marushevska, Ms. Kateryna Mudra
Final	15.01.2017	Mr. Igor Abramiuk, Dr. Prof. Sergey Afanasyev, Mr. Oleg Golub, Dr. Alexei Iarochevitch, Mr. Yurii Levchak, Dr. Olena Lietytska, Ms. Olena Marushevska, Ms. Kateryna Mudra

Contains

1. Goals and types of monitoring

The surveys in 2017 are conducted as a part of the post-commissioning monitoring of Dariali HPP in accordance with the requirements stated in the report *“Aquatic biodiversity: monitoring results in 2016 and mitigation measures proposed”* (2017).

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

The Dariali HPP was commenced late autumn 2016 and 2017 should be considered as the first post-commissioning year.

Types of monitoring

According to the monitoring programme, the monitoring included two types:

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

Types of monitoring and monitoring stations are presented in Table 1. Monitoring of the brown trout was done also at the fish pass and in water reservoir.

Table 1. Types of monitoring and monitoring stations

№	Monitoring station	Invertebrates monitoring	Fish / Flow and 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 these surveys are continuation of the earlier conducted surveys in 2015 and 2016 and in order to compare the post-commissioning situation with the baseline, the monitoring stations, established by the Consultant previously, were used. The location of the monitoring stations is presented at the Figure 1 and Table 2.

Table 2. Coordinates of the 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 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"

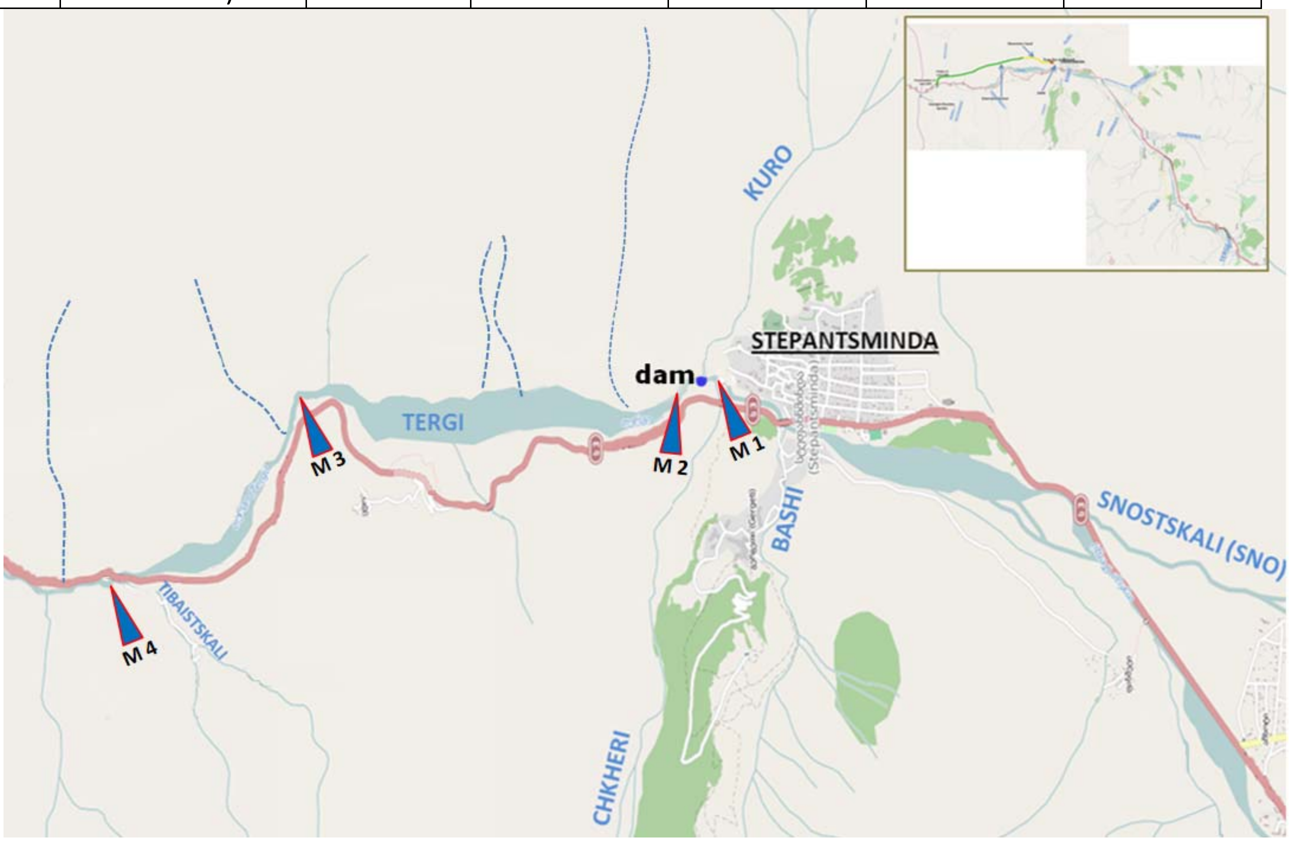


Figure 1. Location of monitoring stations

2. Results of ecological monitoring

2.1 Results of the brown trout monitoring

Time: 25-29 April, 10-14 October, and 18 - 21 November 2017 (for the fish trap only).

The brown trout monitoring included:

- Presence of the fish at all monitoring stations;
- Fish distribution in the water reservoir
- Fish pass efficiency.

Presence of the fish at all monitoring stations

The presence of the brown trout caught at monitoring stations is presented in the Table 3.

Table 3. Brown trout caught

№	Monitoring station	Spring		Autumn	
		Catching attempts	Fish caught	Catching attempts	Fish caught
M 2	Tergi downstream the Dariali headworks (boulder section)	14	0	18	0
M 3	Tergi downstream the Dariali headworks (braided section)	24	1	16	1
M 4	Tergi downstream the Dariali headworks (single thread section)	26	0	23	0
	Lower reach of the dam near the fish pass entrance	21	7	29	6

Figure 2. Caught trout at M 3 in spring

Figure 3. Caught trout at M 3 in autumn

All the fish caught were tagged for the future monitoring.

Assessment of results comparing with natural conditions

Comparing with the baseline conditions, fish distribution in the river has been changed:

- In the baseline, the fish was observed along the whole river course downstream the Dariali HPP intake, except boulders. At the single riverbed, the fish was seen rarely. Its biggest concentrations were fixed at braided riverbed, especially in the confluence with Tibistskali.

- This year, the length of the braided riverbed was significantly decreased because of low water levels in the river and only two brown trout were caught here (one in spring and one in autumn). No trout was caught in the single riverbed, which shows that the trout avoids these habitats in low water period because of increased danger from predators in conditions of low depths. In the same time, a new concentration place for the fish was identified – directly in the lower reach of the dam. Here trout prefers to stay both in spring and in autumn. It can be explained by additional deepenings and special hydrodynamic favorable conditions for fish fattening and hiding.

Study of the fish distribution in the water reservoir

In spring, the study was conducted using echo depth-sounder, bottom gill net and casting net. In total, 27 attempts by the casting net were done along the whole perimeter of water reservoir. 3 brown trout specimen were caught: 2 in upper right corner of the water reservoir and 1 - in left corner of water reservoir. During two days, bottom gill nets of the size 20 m long and 1,5 m high and size of the mesh a-15 and a-10 мм were installed. 1 trout specimen was caught in the net with the mesh size a-10 (Figure 4).

Figure 4. Caught trout by bottom gill net

During the study of the fish distribution in the water reservoir using echo depth-sounder, the biggest number of trout (5-8 specimen) were fixed in right upper corner (Figure 5). Also a few specimens were fixed at the entrance of the river into water reservoir and a bit upstream the water reservoir backwaters.

Figure 5. Study of the fish distribution using echo depth-sounder

Monitoring of the juvenile downgrading fish was conducted also at the entrance of Chkeri (water reservoir backwaters). 4 placements of roe net with interval of 6 hours were done during 24 hours. No downgrading juvenile fish was fixed.

<u>In autumn,</u> 24 catching attempts were done along the whole perimeter of the water reservoir. In total, 4 specimens of the brown trout were caught: 2 – in right upper corner of the water reservoir and 2 – in left upper corner of the water reservoir (Figure 6).

Figure 6. The brown trout caught by casting net in the water reservoir in autumn

2 daily placements of roe net with the size of 20 m long and 1.5 m height with mesh size a-15 and a-10 mm were placed in upper corner of the water reservoir. In total, 2 specimens of the brown trout was caught by the net with mesh size a-10 (Figure 7).

Figure 7. Caught brown trout in the water reservoir

No tagged fish were caught.

Assessment of the results

The trout likes the new habitat of water reservoir. Significant depth, large area of the water reservoir allows the trout using it for fattening and resting during migrations. New spawning places can appear in the water reservoir.

Control of fish presence and their distribution at water in-take and in sand trap showed that the trout effectively escapes the area of the water in-take and did not enter the sand trap neither in spring, nor in autumn.

Fish pass monitoring

Technical requirements

The Dariali HPP personal implemented a part of technical requirements regarding the fish pass, namely:

- The fish pass was cleaned from the construction garbage; the metallic pins were removed (Figure 8).
- The ladder was installed to go down to the fish pass, which allows cleaning the fish pass and fish monitoring (partial drying – “blocking method”).

Figure 8. Clean fish pass with the ladder

Figure 9. Driving pulley and winch

- The Dariali HPP installed driving pulley and winch above the ichthyologic platform, needed to put up and down the fish trap more comfortably (Figure 9).
- Prior the start of the autumn surveys, the changes were made in binding the fish trap. The welded four switches were replaced with the new ones taking into account the recommendations of Consultant.

The following requirements of the Consultant were not implemented:

- The inner barrier of ichthyologic platform was not done to ensure comfortable and safe monitoring. This inner barrier is important for work safety and to prevent falling of the specialists into the opening of the platform. The barrier will not complicate the fish trap extraction; moreover, it will be more comfortable to put the extracted trap at the handrails of the inner barrier instead of putting it on the floor.

- Prior the autumn surveys, the recommendation of the Consultant regarding deepening of the entrance for fish in the lower reach of the fish pass was not implemented.

This operation was done on request of the Consultant by Dariali HPP personal two days after the start of the monitoring works (Figure 10).

Figure 10. Deepening of the entrance for fish in the lower reach of the fish pass

Conclusions: it is recommended to complete the last two technical requirements of the Consultant on the vertical switches and inner barriers at ichthyologic platform to ensure effective and safe operation

Monitoring of the fish pass efficiency

<u>In spring,</u> periodic control of the juvenile fish using the cone net at the outlet of the fish pass was conducted with the interval of 6 hours. Roe and juvenile trout were not fixed.

During the drying out of the fish pass at 4th step from down, the trout with the body length 11.5 cm was caught by ichthyologic net (Figure 11). This confirms that migrating fish uses the fish pass.

Figure 11. Caught trout in the fish pass

<u>In autumn,</u> the assessment of the fish pass effectiveness was done <u>using the fish trap</u>, installed at the fish pass outlet. In total, 8 fish trap placements were conducted. The presence of the trout was checked in morning (08:00 – 10:00) and evening (16:00 and 18:00).

The first trout was caught at 6th placement at 11-12 October from 17:30 till 8:00. It was ready for spawning male trout. It is worth to mention that the specimen had darker color comparing with dominating trout in Tergi (Figure 12).

Figure 12. Caught male trout by the fish trap (6th time)

Figure 13. Caught male trout by the fish trap (7th time)

7th placement done on 12th of October from 8:30 to 16:00 brought two male trout ready for spawning (Figure 13).

8th night placement done starting from 16:20 12 October to 16:20 13 October brought two trout.

Six placement of the fish trap in November showed the absence of upstream migration during this period.

So in total, in autumn during the period of surveys 5 trout were registered passing through the fish pass (3 in the evening and 2 in morning) with sizes from 14 to 23 cm.

In autumn, the Consultant also organized fish pass drying to assess its efficiency. In total, 5 dryings were done during different day hours.

Figure 14. Caught trout by the fish pass drying

On 13 October at 8:20 at the 3rd step from down, the trout was caught with the length 11,5 cm (Figure 14).

In general, the method of the fish pass drying proven to be not effective as far as due to high turbidity visual control of the fish was hard to implement. The Consultant saw the fish, but due to depths and turbidity it was hard to calculate them or catch them.

Conclusions:

The construction of the fish pass provides needed conditions for the active migration of the brown trout. During the trout monitoring, upstream migrations were fixed of both trout forms: typical for Tergi and typical for Sno, which proves that there is effective exchange of the gene pool of the two sub-populations after the HPP commencement.

In the same time, it is worth to mention that such migrations are possible only under a number of conditions:

- To ensure easy passability of lower in-let of the fish pass. Prior deepening of this place in autumn, such conditions were not assured.
- To ensure optimal velocity regime in the fish pass, especially in its lower in-let. Unfortunately, the automatic water discharge measuring device in the fish pass is not calibrated, which does not allow to ensure such an optimal regime. According to the information provided by the Dariali HPP management, this device was calibrated by the end of 2017.
- The depth of the deepening at the lower entrance to the fish pass should be sufficient (not less than 50 cm deep comparing with neighboring bottom). The control over the depth of the deepening should be conducted twice:

- in the beginning of autumn low water period (+ 2/3 to winter low water level);
- when water level is +1/3 for low water level.

It is also important to have Larsi HPP fish pass operational to ensure the brown trout migration at Tergi. In spring and autumn, the fish pass at Larsi HPP was not operational (Figure 15).

Figure 15. State of the fish pass at Larsi HPP

The surveys showed that the best method of the fish pass efficiency monitoring is the fish trap placement. The method of the fish blocking in the fish passing is not effective because of high water turbidity, which does not allow seeing fish. Also the Consultant considered it important to continue fish tagging to have sufficient number of the fish tagged for future monitoring system.

2.2 Results of water invertebrates monitoring

The main goal of the water invertebrates surveys was to assess the changes in status of Tergi river using biological indication after 6 months of its operation.

Time: 8 – 13 October 2017.

Monitoring stations: according to the Table 1.

For each of them the relevant protocols were filled out.

M 1 - Tergi upstream the Dariali headwork

At this station, there is riparian-meadow plants and some mosses (up to 2%.) Algae are presented by some *Bacillariophyceae* and *Chlorophyta*, out of microalgae there are *Hydrurus foetidus*. Their low development caused by summer flood in generally corresponds to results of the baseline survey.

The structure of the bottom biotsenosis includes mainly imago of *Chironomidae* (40-50%), there are much less imago of *Trichoptera*, *Ephemeroptera*, *Plecoptera* as well as *Gammaridae* and *Diptera* (6-15%) (see Table 4).

Express assessment by hydrobiological parameters showed that TBI and BBI indexes have 8 scores, corresponding to the water quality “clean”.

M 2 - river Tergi, downstream the Dariali headwork (boulder section)

At this station, there is only riparian-floodplain vegetation with bushes, sea-buckthorn, barberries and dog rose. There were a few *Fontinalis sp.* Algae are represented by *Bacillariophyceae* and *Chlorophyta*, *Hydrurus foetidus.*

Macroinvetebrates’ communities at this station at all years were characterized by the least abundance. The same situation is observed in 2017. The structure of biotsenosis includes mainly imago of *Chironomidae* and *Ephemeroptera,* there are a bit few imago of other *Diptera*; all other groups were very few in numbers.

Express assessment by hydrological parameters showed that TBI and BBI indexes have 8 scores, corresponding to the water quality “clean”.

It is worth to mention that comparing with the previous years, the state of the river at this station is improved due to stabilization of conditions after finishing the Dariali HPP construction.

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

The riparian plants are represented by sea-buckthorn, barberries and dog rose. Water plants are represented by moss *Fontinalis sp.* in the riverbed. Algae are represented by a few Bacillariophyceae; the share of *Chlorophyta* is increased, *Hydrurus foetidus* was developed insignificantly.

The structure of the bottom biotsenosis at this station includes mainly *Chironomidae* and *Ephemeroptera*, but the share of *Plecoptera* gets increased; there were a few of other Diptera and *Tricoptera*.

Express assessment by hydrological parameters showed that TBI and BBI indexes have 8-9 scores, corresponding to the water quality "clean – very clean".

Comparing to the previous years, the abundance and diversity of macroinvertebrates get increased, which shows the improvement of the ecological situation in general due to reduction of flow velocity and increase of habitats diversity with the reduction of the share of boulders.

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

This monitoring station is characterized only by riparian-meadow plants, there are a few of *Fontinalis sp.* Algae are represented by few colonies of Bacillariophyceae and Chlorophyta, out of microalgae there are colonies of *Hydrurus foetidus*.

The structure of biotsenosis includes mainly imago of *Chironomidae,* there are a bit few imago of *Ephemeroptera*; all other groups were very few in numbers.

Express assessment by hydrological parameters showed that TBI and BBI indexes have 8-9 scores, corresponding to the water quality "clean" and "very clean".

The general distribution of the macroinvertebrates' groups is presented in the Table 4. It also includes the data on macroinvertebrates' drift, done by the initiative of the Consultant in order to assess the impact of the Dariali HPP at macroinvertebrates migration.

Table 4. Abundance of the main groups of bottom fauna and drift intensity at monitoring stations

Invertebrates communities	speciment/m^2				Drift of specimen/ 15 min/ trap			
	M 1	M 2	M 3	M 4	M 1	M 2	M 3	M 4
Nematoda	1		1	1	1			
Oligochaeta	2	1	2	11	8	5	7	4
Ostracoda	2		1	1	4	1	1	
Cyclops	1				10		1	
Crustacea	1				2			
Gammaridae	80		1	4	10	1	2	2
Araneida	1				2	2	1	1
Acarina	2						1	
Collembola	2	1	1		3	1	1	
Heteroptera	1	2	1		9	4	10	6
Ephemeroptera	84	17	33	28	10	1	4	1

Invertebrates communities	speciment/m^2				Drift of specimen/ 15 min/ trap			
	M 1	M 2	M 3	M 4	M 1	M 2	M 3	M 4
Plecoptera	40	2	10	5	41	3	15	7
Lepidoptera	1						1	
Coleoptera	4		1				2	1
Trichoptera	31	3	4	9	7	1	5	1
Simmuliidae	2			1	2		1	
Chironomidae	244	17	12	47	116	54	104	53
Diptera	30	10	5	15	12	21	34	28
Total	529	53	72	122	237	94	190	104

Conclusions:

Species composition of bottom macroinvertebrates didn't change much comparing with 2016. In total, there are 95 species of invertebrates belonging to 14 groups.

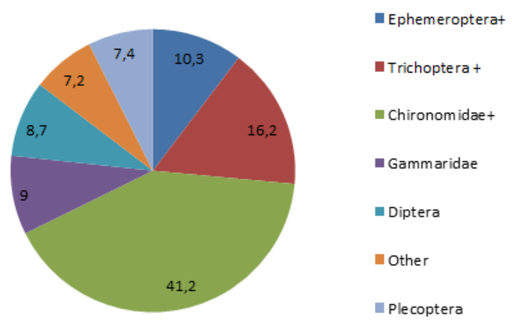


Figure 16. Composition of the Tergi river by groups of macroinvertebrates

By the results, the main group of invertebrates is *Chironomidae* – 41,2 % from the total number, *Trichoptera* – 16,2 %, *Ephemeroptera* – a bit more than 10,3 %, *Gammaridae* – 9%, *Diptera* – 8,7%, *Plecoptera* – 7,4%. The rest (7,2%) is shared between the following groups: *Nematoda, Nematomorpha, Oligochaeta, Ostracoda, Cyclopoida, Araneida, Acarina, Collembola, Heteroptera u Coleoptera, Lepidoptera, Simuliidae* (Figure 16).

In general, there is an increase of the values of bioindication indexes and indicators of abundance of bottom invertebrates observed comparing with the previous years. This shows the improvement of water quality and state of macroinvertebrates in post-commissioning period. Migration activity of the macroinvertebrates also corresponds to the level, fixed in the previous years of study. At present, stabilization of ecological conditions after the end of construction period did not lead yet to the changes in the structure of bottom habitats. In the same time, reduction of flow velocity supported the development of bottom invertebrates.

2.3 Conduction of training on ecological monitoring

On 27–28th of April 2017, in Stepantsminda, there was a training on ecological monitoring in the post-commissioning period held (according to the Monitoring programme[1] and the Action Plan[2]). The trainees include the staff of Dariali HPP and ichthyologist Archil Phartsvania (Figure 17).

The training included presentation of the theory as well as practical exercises during the field surveys (on job training).

Figure 17. Start of the training

During training, the provisions of Monitoring programme were presented in detail, namely:

- Selected monitoring stations, where monitoring of invertebrates and fish should be conducted to ensure comparison of the post-commissioning situation with the baseline.

- Monitoring of the brown trout should be conducted at least twice per year: upstream spawning migration (autumn), including checking of the fish pass efficiency and juvenile fish downstream migration (spring and summer). This 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 in. 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.

- Methods of monitoring of fish pass, sand trap and water reservoir were demonstrated:
  - ✓ The main goal is to assess the possibility of fish entering the HPP turbines. 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 night-time with the duration of 6 hours. 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 night-time with the duration of 6 hours.
  - ✓ Periodical catch of the fish using the cone net in the fish pass outlet. The fish should be caught in daytime and night-time.

[1] Aquatic Survey and Monitoring Programme. / March 2015. p.28
[2] Development & Implementation of Aquatic Biodiversity Action Plan. Terms of Reference / October 2014. p. 6

On 28th of April, the training of the macroinvertebrates monitoring was conducted. Its main goal was to identify the changes in biological status of the river using bioindication at all four stations mentioned in the Table 1.

After the end of the training the final discussion was held about the methods of environmental monitoring, fish pass supervision and ensuring favourable water levels.

The staff of Dariali HPP and expert Archil Phartsvania got needed knowledge for the further continuation of the ecological monitoring in the post-monitoring period (Figure 18).

Figure 18. Training on ichthyology and macroinvertebrates

Conclusion: the training on ecological monitoring was conducted for the identified by the Dariali HPP specialist. At the same time, the Consultant considers that taking into account the complexity of the river, additional field surveys and practice is needed for the local specialist to be able to conduct the ecological monitoring independently.

The training on hydromorphology was not conducted in 2017, as far as it was conducted in 2016.

3. Results of flow and habitat monitoring

Time: 18 - 21 November.

The weather during the survey was warm and windy. The air temperature varied from +7 to +17°C. On 21st of November, it was raining (10 mm precipitation according to the meteorological station Stepantsminda) and cold (1 – 3 °C).

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,
- DJI Phantom 4 Advanced drone.

During field surveys 2017, continual survey of Tergi River was done from Dariali headworks to Larsi headworks. The length of surveyed stretch is 8.2 km.

Below the results for 2017 are given for the four monitoring stations (Table 1) in comparison with 2015 when HPP was not operational and hydrological regime of Tergi River was not altered (natural).

According to information received from staff of Dariali HPP the water discharge upstream Dariali headworks was 11.4 m^3/s on 18.11.2017. Multiannual water discharge for Tergi for November is 9.81 m^3/s. The discharge in Tergi during field survey 2017 was higher by 16% comparing with its average monthly value.

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

Figure 20. Tergi downstream the Dariali headwork (boulders section)

Within M 2, the riverbed type has been changed. Now it is braided channel type (Figure 20).

The average velocity was 0.43 m/s, with maximum 1.09 m/s. Flow types included chute, chaotic, broken standing waves, and unbroken standing waves.

The average width of the river was 4.2 m, with maximum 6.8 m. Bed elements included rapids and rocks.

The average velocity reduced by 0.24 m/s (36%), maximum reduced by 0.36 m/s (25%). The average width of riverbed reduced by 5.4 m (57%), maximum one - by 6.8 m (50%) (Figure 21).

The average depth was 0.39 m with maximum 0.64 m. Ratio of average width of channel to the average depth was Cb/h=11.

The average depth of the flow reduced by 0.3 m (44%), maximum reduced by 0.61 m (49%) (Figure 21).

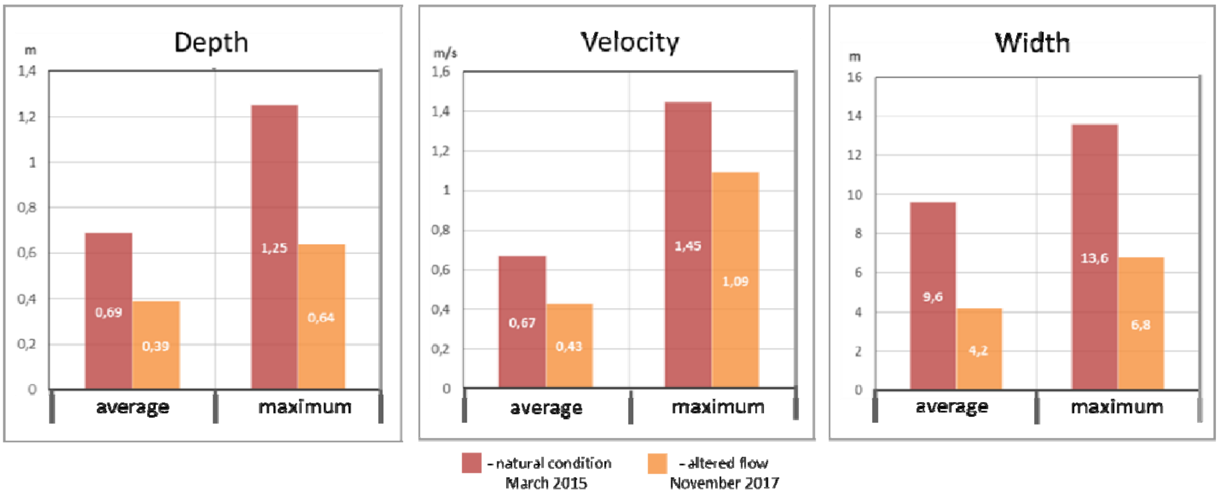


Figure 21. The river depth, velocity and width at M 2

Both banks were made out of boulders up to 2 m. The riverbed was evenly covered by boulders (37%) and gravel (20%) (Figure 22).

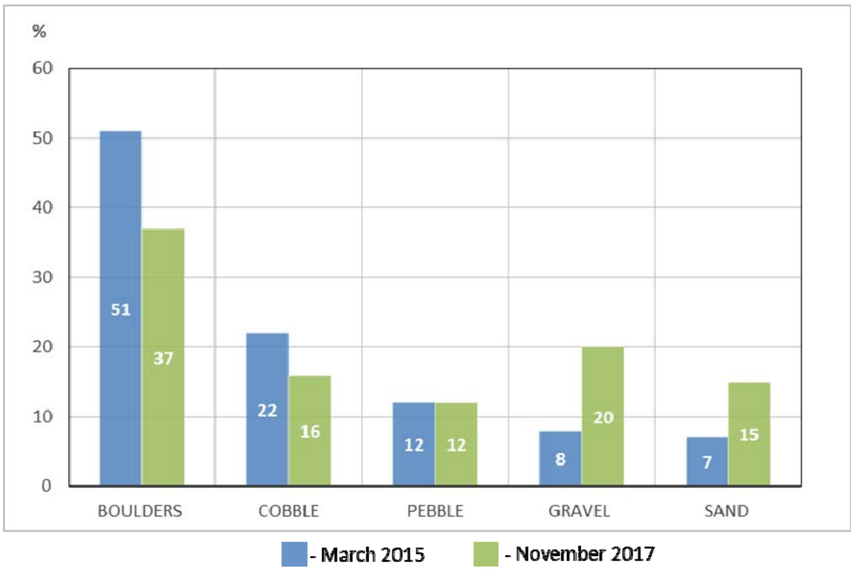


Figure 22. Distribution of the sediments, %

The following changes in the sediment composition were observed: percentage of boulders and cobble reduced by 14% and 6% accordingly; percentage of gravel and sand increased by 12% and 8% accordingly.

The calculated average multiannual discharge for this monitoring station was 26.0 m^3/s. Measured water discharge was **2.11 m^3/s** (19.11.2017), which corresponded to 8% of multiannual discharge and it made only **83% of environmental flow (2.54 m^3/s).** This value includes the discharge passing through the sluice for environmental flow, flow in the fish pass and water, leaking through sluices shallow water infiltration.

The comparative maps of the depths and velocities for this monitoring station are presented at Figures 23-24.

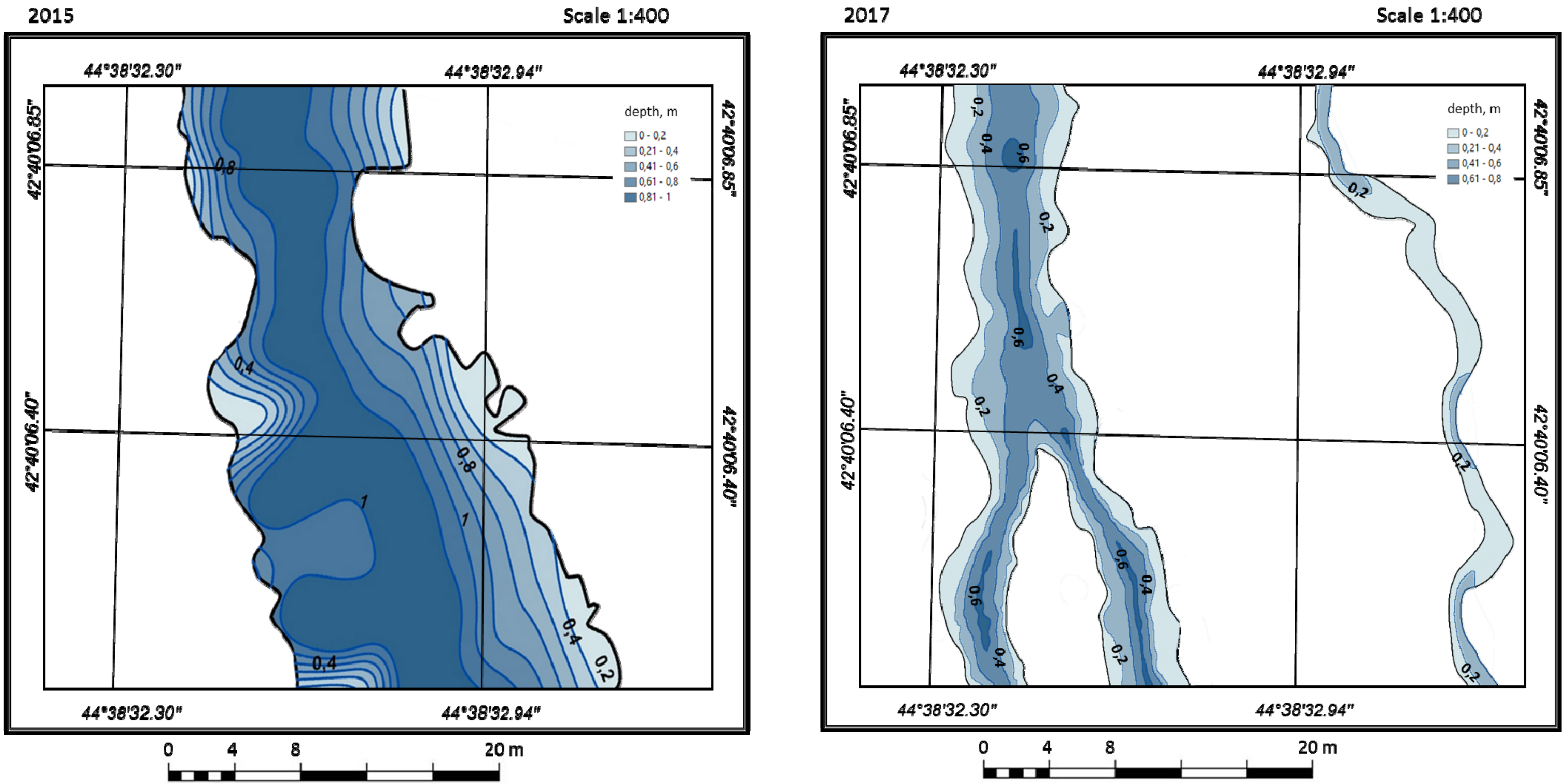


Figure 23. Isobaths (depths)

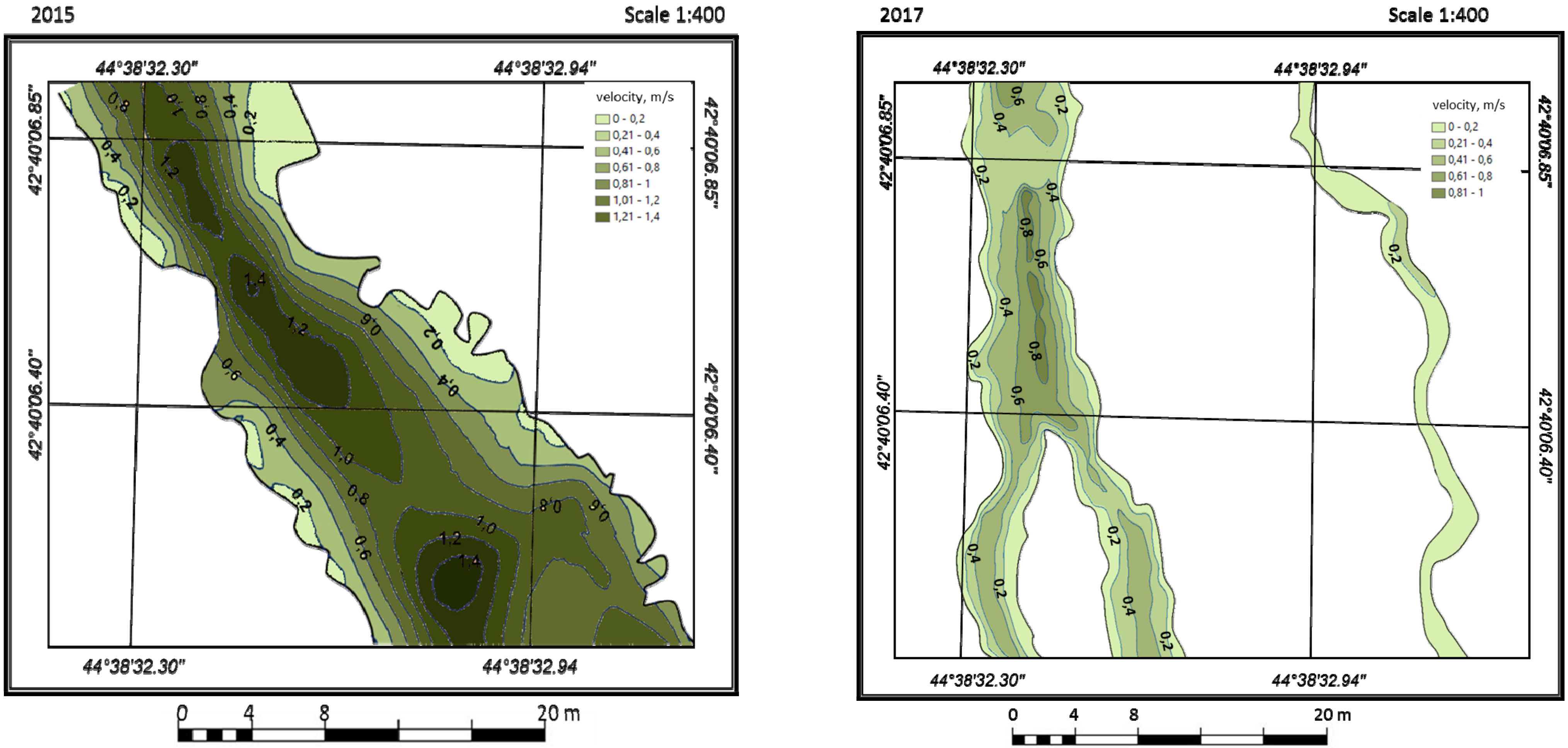


Figure 24. Isotaches (stream velocity)

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

Figure 25. Tergi downstream the Dariali headwork (braided section)

Within M 3, the type has been changed, now it is single channel type. Only left arm is active.

The average velocity was 0.63 m/s, with maximum 1.02 m/s. Flow types included chaotic, broken standing waves, and unbroken standing waves (Figure 25). The average width of the river was 7.8 m, with maximum 9.2 m. Bed elements included rapids and rocks. The average velocity reduced by 0.28 m/s (31%), maximum reduced by 0.98 m/s (49%). The average width of riverbed reduced by 2.2 m (22%), maximum one - by 4.7 m (34%) (Figure 26). The average depth was 0.43 m with maximum 0.74 m. Ratio of average width of channel to the average depth was Cb/h=18. The average depth of the flow reduced by 0.04 m (9%), maximum one - by 0.26 m (26%) (Figure 26).

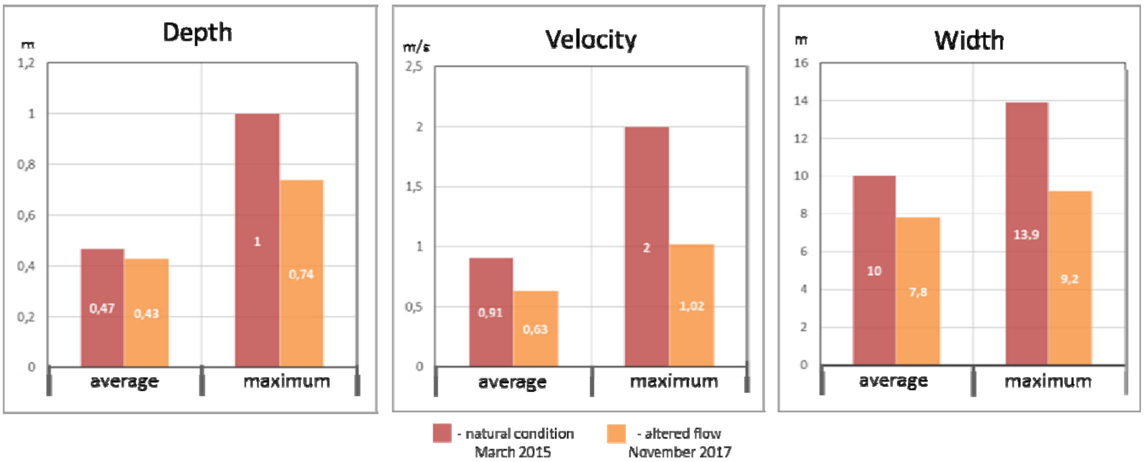


Figure 26. The river depth, velocity and width at M 3

Both banks were made mainly out of cobble. The riverbed was evenly covered by cobble (40%) and pebble (27%).

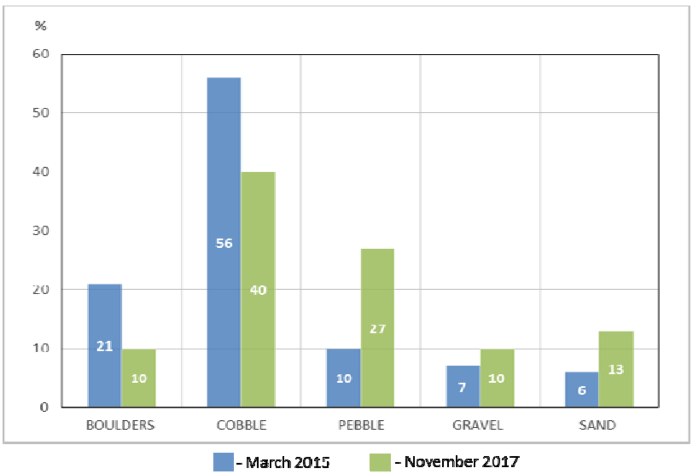


Figure 27. Distribution of the sediments, %

The following changes in the sediment composition were observed: percentage of boulders and cobble reduced by 11% and 16% accordingly. Percentage of pebble, gravel and sand get increased by 17%, 3% and 7% accordingly (Figure 27).

The calculated average multiannual discharge for this monitoring station was 26.8 m^3/s. Measured water discharge was 2.55 m^3/s (19.11.2017), which corresponded to 9% of multiannual discharge and by 0.4% more than environmental flow.

The comparative maps of the depths and velocities for this monitoring station are presented at Figures 28-29.

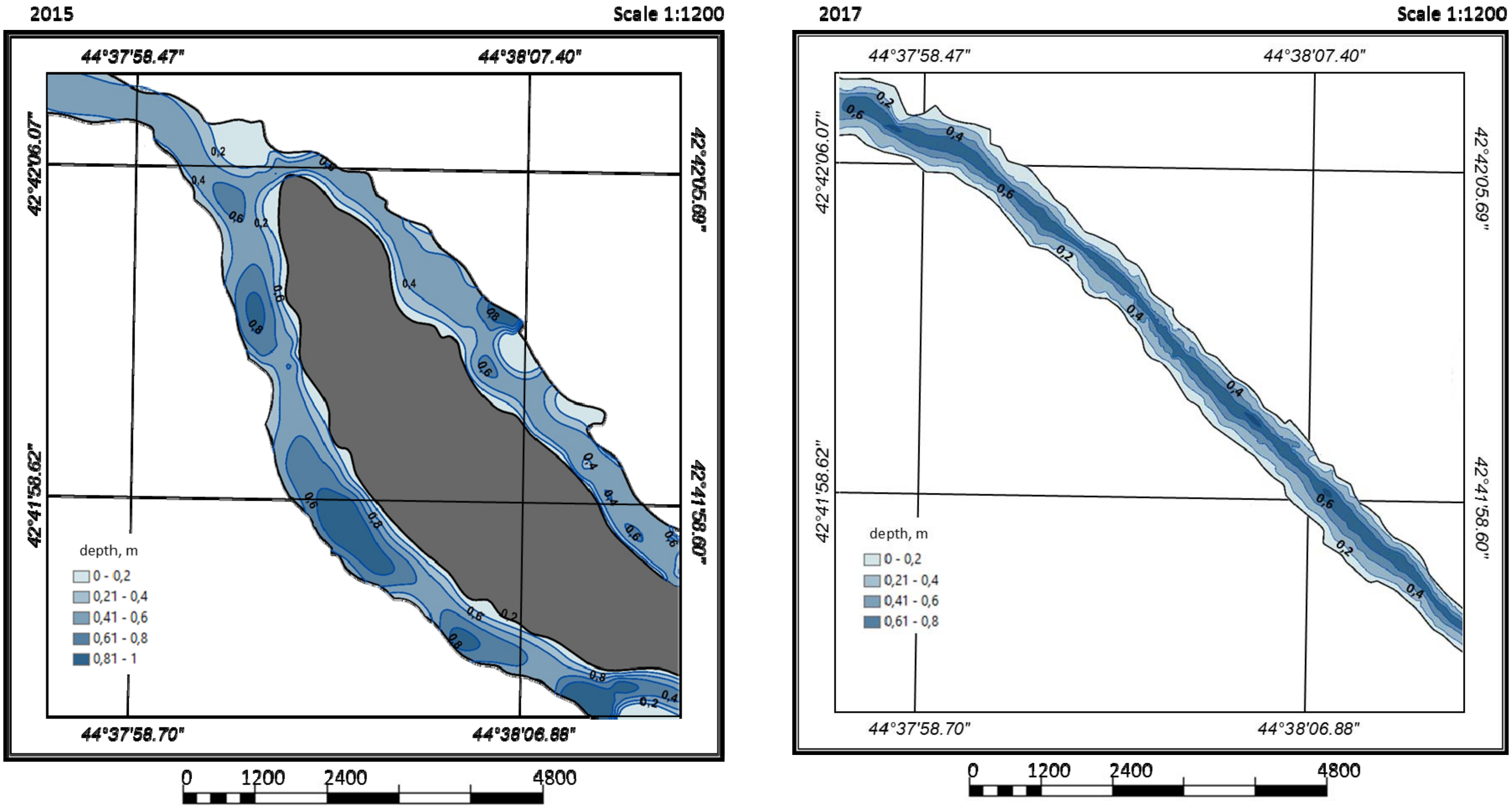


Figure 28. Isobaths (depths)

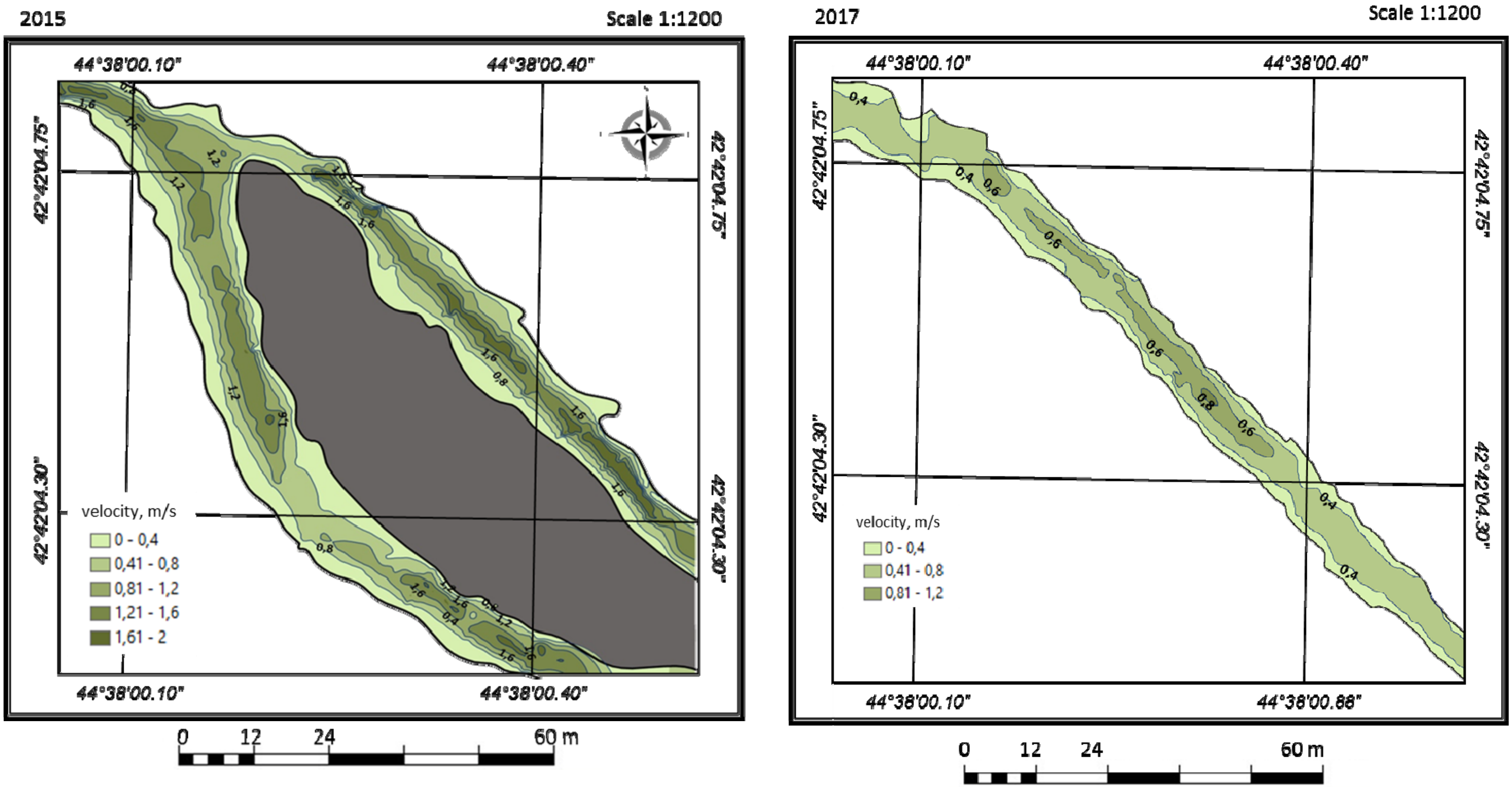


Figure 29. Isotaches (stream velocity)

M 4 - Tergi downstream the Dariali headworks (single section)

Figure 30. Tergi downstream the Dariali headwork (single section)

The average velocity was 0.57 m/s, with maximum 1.04 m/s. Flow types included chaotic, broken standing waves and unbroken standing waves (Figure 30).

The average width of the river was 9.3 m, with maximum 12.1 m. Bed elements included rapids and rocks.

The average velocity increased by 0.02 m/s (0.3%), maximum reduced by 0.79 m/s (43%). The average width of riverbed reduced by 8.7 m (49%), maximum one - by 7.9 m (43%) (Figure 31).

The average depth was 0.4 m with maximum 0.52 m. Ratio of average width of channel to the average depth was Cb/h=23.

The average depth reduced by 0.35 m (47%), maximum reduced by 0.58 m (53%) (Figure 31).

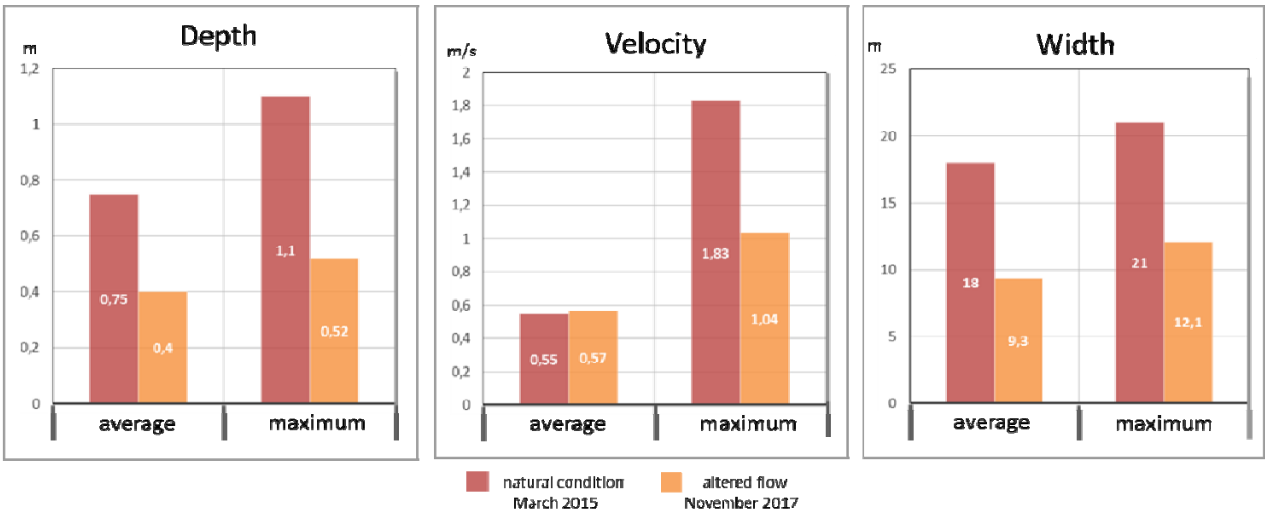


Figure 31. The river depth, velocity and width at M 4

Both banks were made mainly out of cobble. The riverbed was evenly covered by cobble (41%) and pebble (23%).

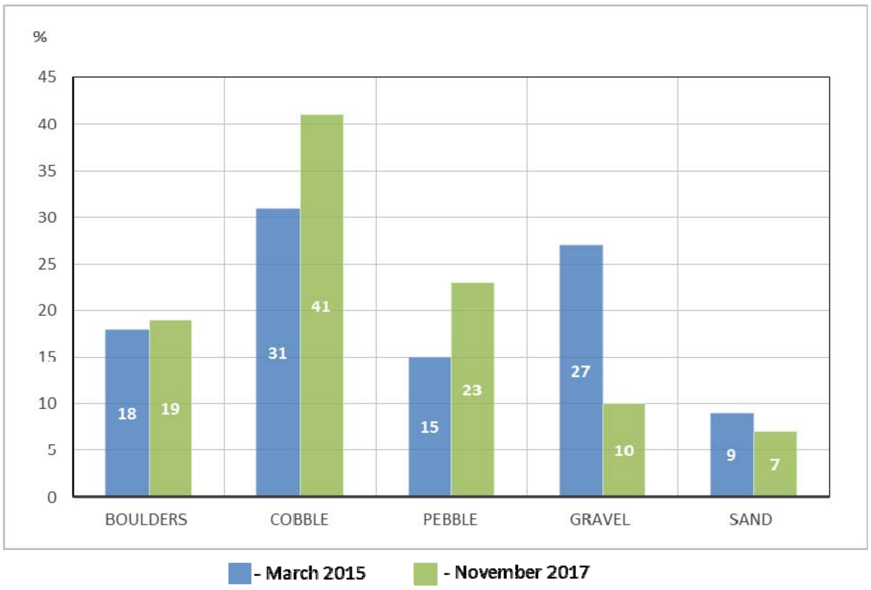
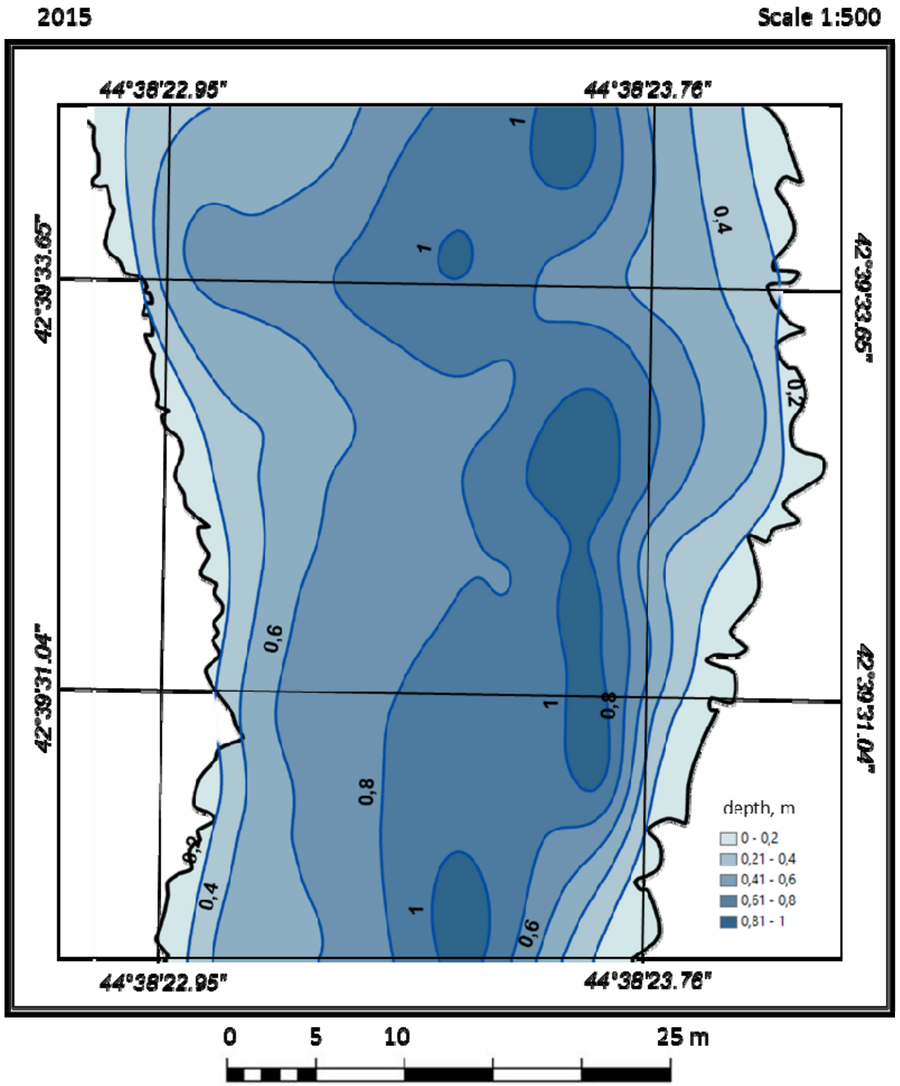


Figure 32. Distribution of the sediments, %

The following changes in the sediment composition were observed: percentage of boulders, cobble and pebble increased by 1%, 10% and 8% accordingly. Percentage of gravel and sand get reduced by 17% and 2% accordingly (Figure 32).

The calculated average multiannual discharge for this monitoring station was 27.2 m^3/s. Measured water discharge was 2.76 m^3/s (18.11.2017), which corresponded to 10% of multiannual discharge and by 9% more than environmental flow.

The comparative maps of the depths and velocities for this monitoring station are presented at Figures 33-34.



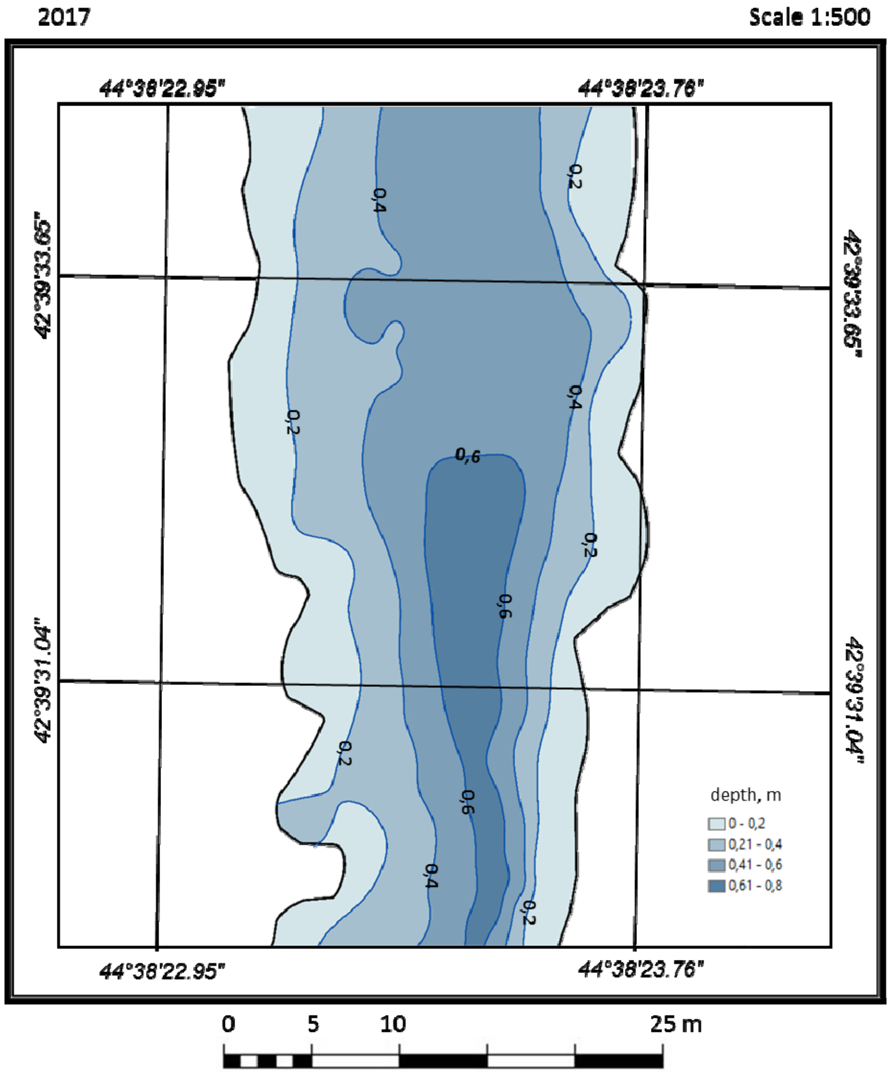


Figure 33. Isobaths (depths)

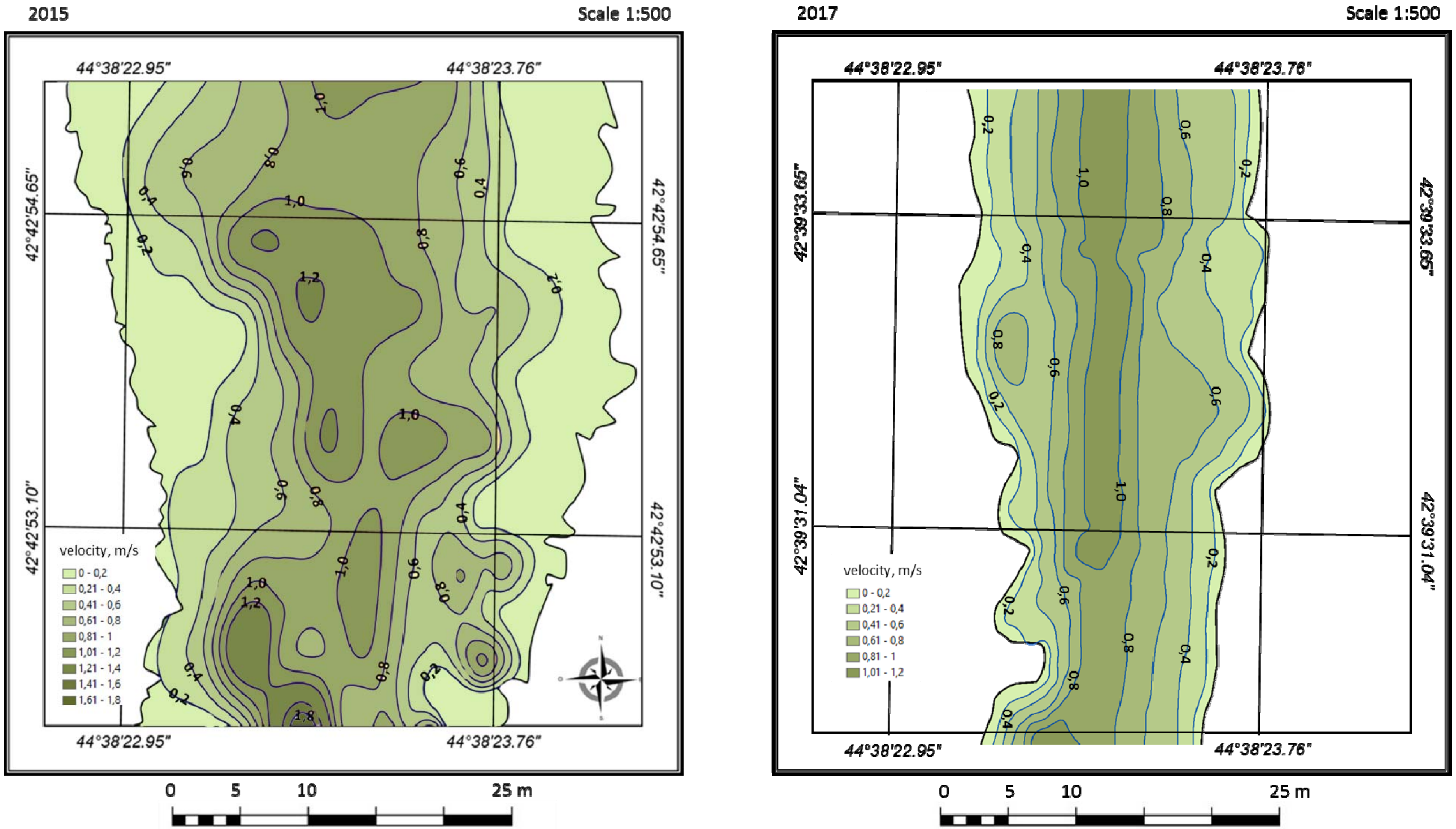


Figure 34. Isotaches (stream velocity)

Additionally to monitoring stations at Tergi river, Tibistkali river was surveyed, taking into consideration that its flow should be considered as natural mitigation.

Tibistskali mouth

Figure 35. Tibistskali mouth

The average velocity was 0.47 m/s, with maximum 0.95 m/s. Flow types included chute, chaotic, broken standing waves, and unbroken standing waves (Figure 28).

The average width of the river was 1.8 m, with maximum 2.6 m. Bed elements included rapids and rocks.

The average velocity increased by 0.1 m/s (27%), maximum by 0.47 m/s (97%). The average width of riverbed reduced by 1.1 m (38%), maximum one - by 1.1 m (30%) (Figure 36).

The average depth was 0.15 m with maximum 0.2 m. Ratio of average width of channel to the average depth was Cb/h=12.

The average depth of the flow increased by 0.04 m (36%), maximum reduced by 0.06 m (24%) (Figure 36).

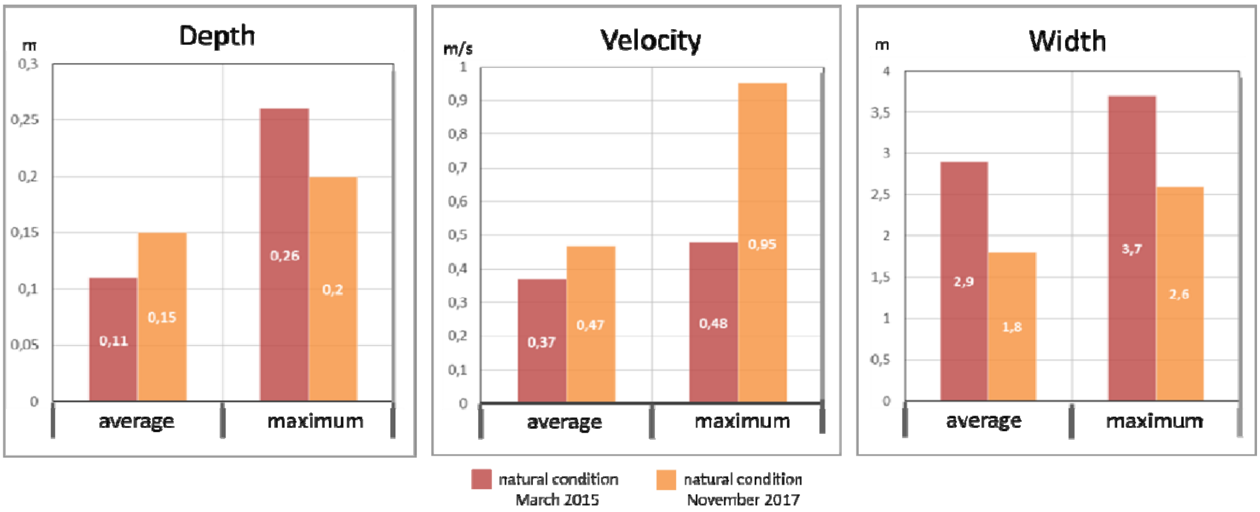


Figure 36. The river depth, velocity and width at Tibistskali

The left bank was made mainly by boulders, right was covered by cobble. The riverbed was evenly covered by cobble (37%) and gravel (26%) (Figure 37).

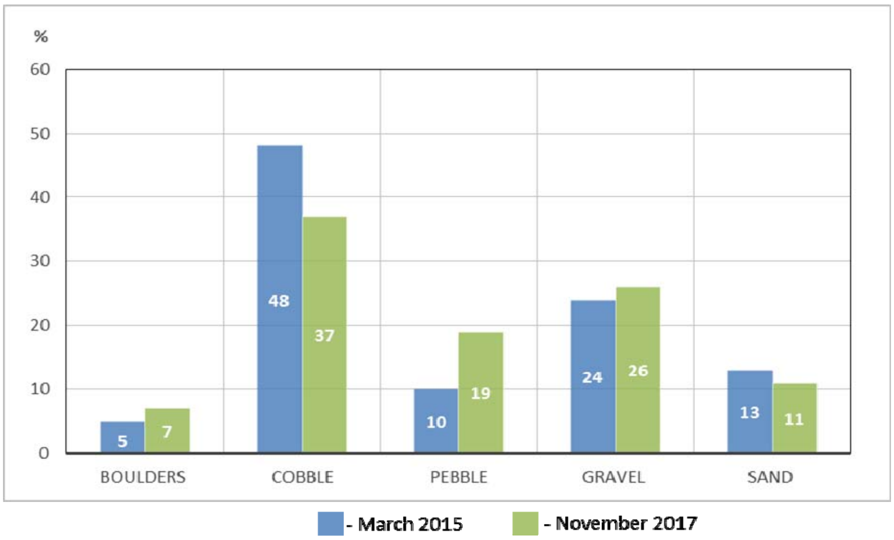


Figure 37. Distribution of the sediments, %

The following changes in the sediment composition were observed: percentage of boulders, pebble and gravel increased by 2%, 9% and 2% accordingly; percentage of cobble and sand reduced by 11% and 2% accordingly.

Measured water discharge for this monitoring station was 0.22 m^3/s (18.11.2017).

The comparative maps of the depths and velocities for this monitoring station are presented at Figures 38-39.

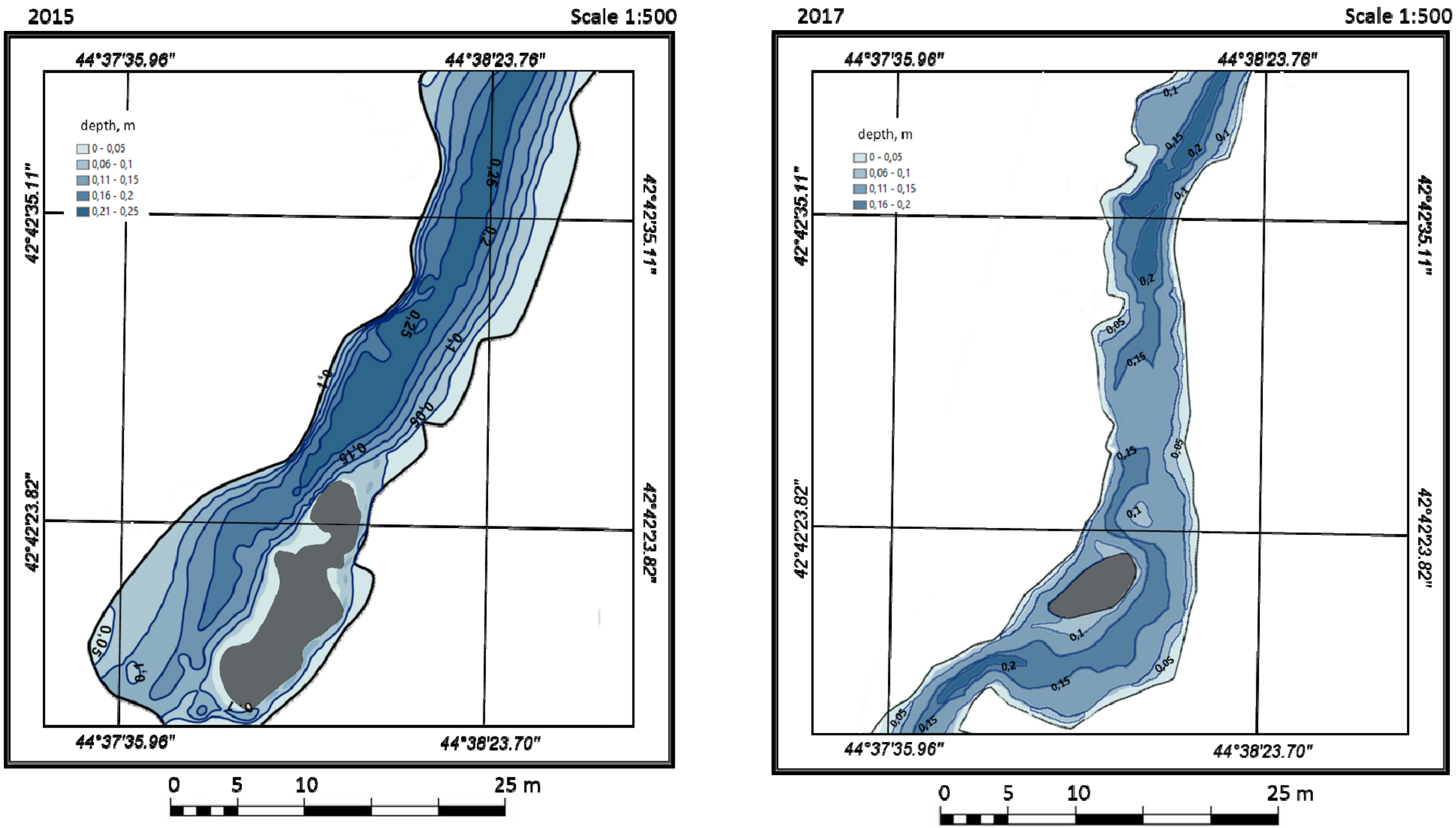


Figure 38. Isobaths (depths)

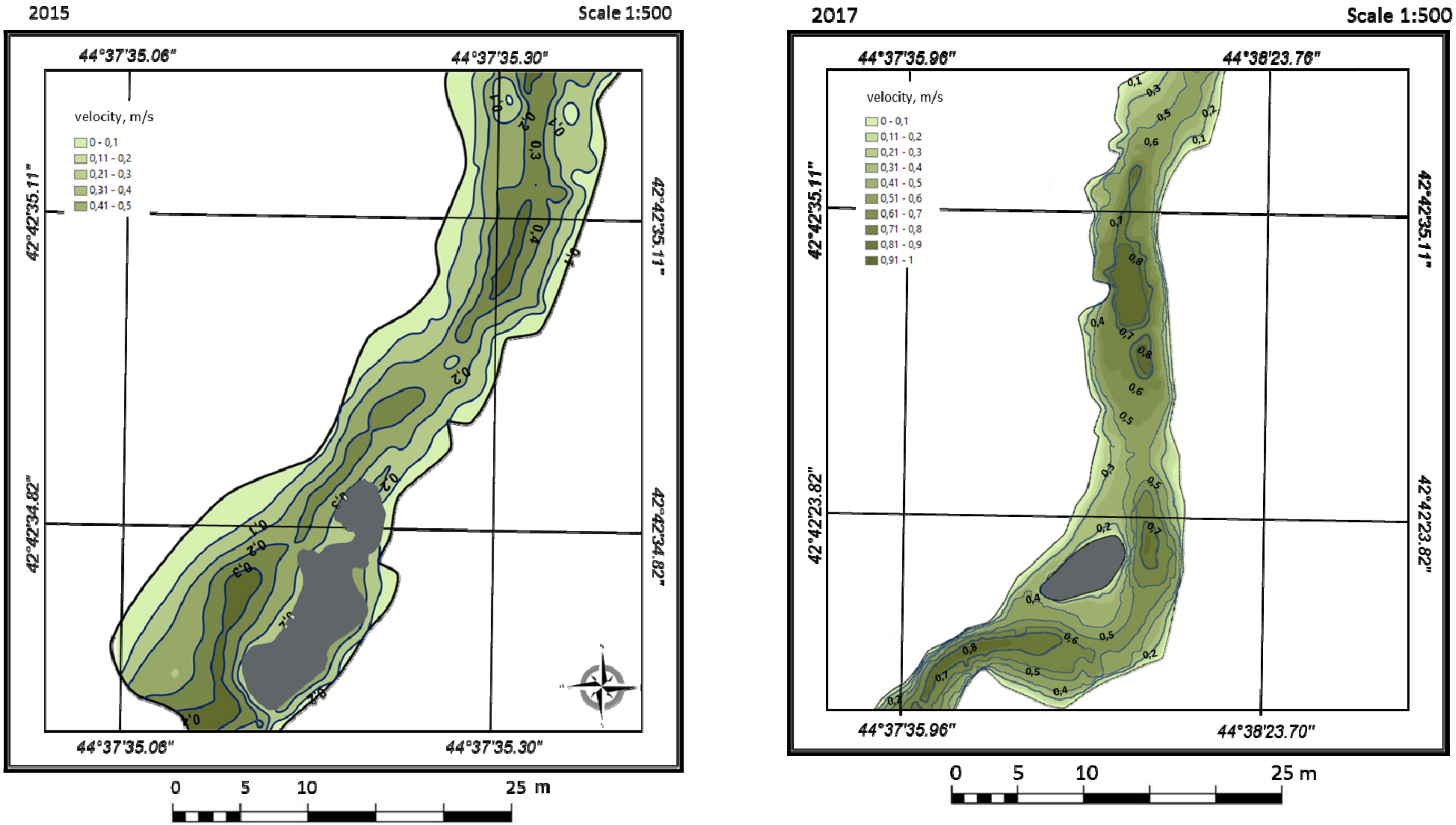


Figure 39. Isotaches (stream velocity)

Summary of the observed results are presented in Tables 5 and 6.

Table 5. Variation of depths, velocities and widths

№	Monitoring station	Depth (m)				Velocity (m/s)				Width (m)			
		average		maximum		average		maximum		average		maximum	
		2015	2017	2015	2017	2015	2017	2015	2017	2015	2017	2015	2017
M 2	Tergi downstream the Dariali headworks (boulder section)	0.69	0.39	1.25	0.64	0.67	0.43	1.45	1.09	9.6	4.2	13.6	6.8
M 3	Tergi downstream the Dariali headworks (braided section)	0.47	0.43	1	0.74	0.91	0.63	2	1.02	10	7.8	13.9	9.2
M 4	Tergi downstream the Dariali headworks (single thread section)	0.75	0.4	1.1	0.52	0.55	0.57	1.83	1.04	18	9.3	21	12.1
M 11	Tibaitskali mouth	0.11	0.15	0.26	0.2	0.37	0.47	0.48	0.95	2.9	1.8	3.7	2.6

Table 6. Variations of the sediments composition

№	Monitoring station	Sediments (%)									
		boulders		cobble		pebbel		gravel		sand	
		2015	2017	2015	2017	2015	2017	2015	2017	2015	2017
M 2	Tergi downstream the Dariali headworks (boulder section)	51	37	22	16	12	12	8	20	7	15
M 3	Tergi downstream the Dariali headworks (braided section)	21	10	56	40	10	17	7	10	6	13
M 4	Tergi downstream the Dariali headworks (single thread section)	18	19	31	41	15	23	27	10	9	7
M 11	Tibaitskali mouth	5	7	48	37	10	19	24	26	13	11

Conclusions:

The results of monitoring confirm that continuity of the Tergi River is ensured at the whole length of the affected reach.

It is worth to mention that directly downstream Dariali HPP dam, the measured water discharge was 2.11 m^3/s (19.11.2017), which made 83% of environmental flow only (2.54 m^3/s). More downstream the discharge gradually increases to more than value of the environmental flow. According to the information provided by the Dariali HPP management, they follow to the environmental flow (2.54 m^3/s) in average per day, but there are fluctuations within the day.

Nevertheless significant changes of river channel types were fixed. Comparing with 2015, the share of braided and boulders channel types get reduced significantly - by 18% and 10% accordingly and share of the single channel type get increased by 28% (Table 7, Figure 40).

Table 7. Lengths and % of the different channel types

Channel type	Length			
	2015		2017	
	km	%	km	%
boulders	2.2	27	1.4	17
single	2.4	29	4.6	57
braided	3.6	44	2.2	26

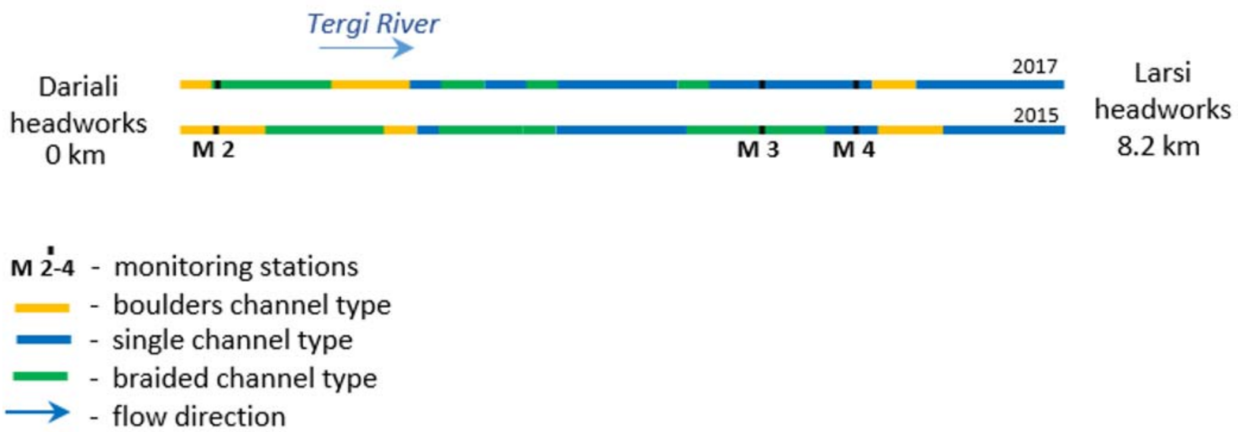


Figure 40. Channel types at Tergi River

The value of morphometric parameters of river channel (width and depth) were significantly reduced but still remain sufficient for fish migration.

Stream velocity was reduced but variety of flow types remains high.

Concerning sediments it can be concluded that its distribution remains the same in comparison with natural conditions due flashing of fine sediments from sand traps and sediment transport (including large fractions) through Dariali dam in time of high water.

4. Proposals regarding continuation of postcommissioning monitoring

It is important to continue the post-commissioning monitoring programme, developed earlier by the Consultant. The special attention during the post-commissioning monitoring should be paid to the following:

- In 2018 it is expected to have sufficient number of fish tagged to use tagging as method for identification of the exact area of the fish migration;
- 2018 is the year when the effect of the HPP operation on the trout population will be more visible. The comparison should be made with 2015 (baseline)
- Having automatic water level and water discharge devices calibrated, the optimal regime of the fish pass operation (water velocity and discharges) can be identified and implemented.
- Based on experience of 2017, the Consultant proposes to change the terms of the aquatic diversity surveys:
    - For brown trout, the upstream spawning surveys should be conducted earlier – last decade of September. The surveys should also include spawning places with catching of ready for spawning trout.
    - For macroinvertebrates, the surveys should be shifted to April prior the summer rising of water flow. It is also important to include sampling at braided and single riverbed upstream Stepantsminda to obtain the complete picture of their development.
- This year, fine sediment starvation was not observed. However, such a process takes time. It should be a subject of special attention during the next year and comparison should be made with baseline situation.

5. **Conclusions**

Based on the conducted studies, the Consultant can make the following conclusions:

- No negative consequences of the Dariali HPP operation for aquatic biodiversity are observed during monitoring in 2017.
- The Consultant confirmed that fish pass is designed properly, ensuring brown trout migration. However, it is important for stuff of Dariali HPP to ensure regular fish pass maintenance (absence of the litter or tree debris, blocking the fish pass, ensuring deepening of the low entrance to the fish pass etc.).
- The assessment of the state of Tergi by the composition of the main groups of invertebrates didn't show the deterioration of their communities.
- The flow and habitat monitoring showed that continuity of the Tergi River is ensured at the whole length of the affected reach and no significant changes in sediment distribution were fixed. However, the river channels types have been changed (simplified) for significant part of affected reach. The value of width and depth were significantly reduced but still remain sufficient for fish migration.