HYDROLOGİCAL CLASSİFİCATİON SYSTEM FOR REGULATİON OF WATER USE BASED ON ECOSYSTEM FLOW

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Environmental Flow Methods

- One of hydromorphological indicators of ecological status of water body is the volume of water needed to be in the river to keep aquatic ecosystem functioning without significant degradation
- The term “Environmental Flow” is intensively used in many studies and scientific works as a minimal amount of water required to keep in the river to provide necessary aquatic environment for living organisms of rivers.
- It should also be noted that one fixed environmental flow value can’t meet requirements of all ecosystems corresponding to and supported by different level of water in the river. If there is more water in the river then the higher water level will support ecosystems of more higher surrounded by water areas of river bank
- The EU WFD also considers different environmental quality categories for different natural and impacted flow values to assess the degree of human impact according to results of classification.
- Therefore the degree of change of ecological status should be calculated according to changes of quality of dependant from water ecosystems when natural flow of different value reduces in result of water abstraction

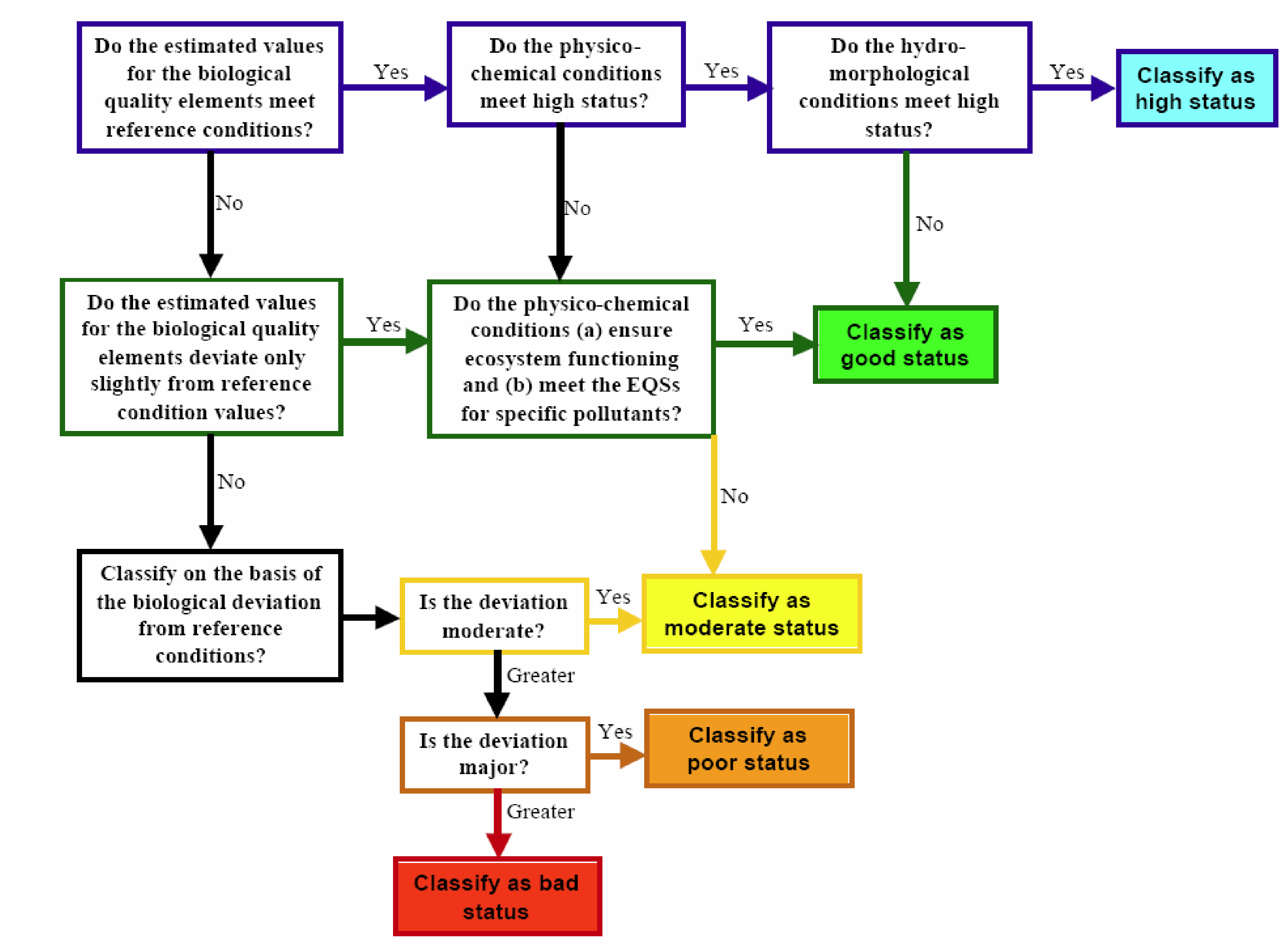
Environmental Flow Methods

- This can be done by Hydrological Classification System , considering changes of water discharges over entire diapason of their changes for giver month by dividing it to categories of different hydrological and ecological status bordered by relevant ecosystem flow values.

- As mentioned, currently similar approach is required by the EU Water Framework Directive and is applied in all European Union countries during ecological classification .

- According to that approach, when determining environmental status of water bodies, relevant requirements are also set for physical-chemical and hydro morphological (including the flow values)quality indicators of water in parallel with biological quality elements(Figure)

Ecological status classifictaion according to EU WFD



Hydrological Classification System

- In CAP-NET methodology in order to assess ecosystems flow needs is considered amount of water required not only to serve living organisms in the river but also to meet water demand of riparian areas ecosystems(which is interrelated with water and aquatic organisms living in the water) and it is named “Flow for Ecosystem”

- Therefore the classification system that would define the flow for river ecosystem shouldn’t be limited only to aquatic environment that corresponds to lowest water discharges of the assessed period of the year(during season, month, decade etc.) but

- It also should for considered month of the year cover all diapason of change of water discharges to characterize all the water environment corresponding to different (high, medium, low) flow periods as an indicator of interaction s between the water and surrounding ecosystem,

- In this regards entire diapason of change of water discharges and accordingly provided by them water environment in the considered period(month in this case) can be divided to different Hydrological categories by corresponding Ecosystem Flow values(for example very high, high, medium, low , very low and etc)

- The hydrological classification system developed based on hydrological information of natural(unaffected by human) observation period can be used to assess for different Hydrological categories corresponding biological quality elements and to use them in assessment of ecological status according to EU WFD Classification system. Then based on level of human impact(water abstraction) for each flow categories can be assessed relevant changes of ecological status.

Hydrological Classification System

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- In order to calculate ecosystem flow (flow required for river ecosystem), first of all natural (relatively natural) flow range should be used.

- As main characteristic elements of the Hydrological Classification System for the assessed calendar month of the given year can be used daily maximal water discharges (considered as a highest during the month ecosystem flow) providing widest(compared to other days of the month) aquatic environment for river ecosystem and minimal daily water discharges (as a lowest ecosystem flow providing lowest aquatic environment for river ecosystem compared to other days of the month) to cover the entire diapason of change of the flow in the given month.

- Long term change of widest aquatic environment in the given calendar month can be assessed by diapason of change of daily maximal water discharges from their minimal values for entire period(($Q_{max,min}$) till maximal values(($Q_{max,max}$).

- In addition it is important to see how for considered minimal flow month(for long term period) these values are further reduced from its maximal daily water discharge ($Q_{max,max}$) till daily minimum water discharges of that month ($Q_{min,min}$) which in term also is a minimal daily discharge of the given month for entire period. This is also very important when there is a trend within the month. By dividing water discharges within the month into 2 groups one can minimize the impact of such a trend.

- Therefore in the given month within this diapason(between ($Q_{max,min}$ and $Q_{max,max}$) occur the changes of the living environment in the entire observation period from year to year and also within an individual low flow year(month) with lowest values of daily water discharge(changing between ($Q_{min,min}$ and $Q_{max,min}$).

Hydrological Classification System

According to the long term range of maximal monthly flow values can be calculated characteristic water discharges of different exceeding probability (**$Q_{10\%}$, $Q_{25\%}$, $Q_{50\%}$, $Q_{75\%}$, $Q_{90\%}$**) for 10%, 25%, 50%, 75% and 90% probability values based on theoretic distribution curves or empirical formula(when number of range is equal or exceed 10) $P=(m-0.3)/(n+0.4)$ by use of interpolation method. In cases when number of water discharges are less than 10 then in order to assess maxima flows of above probabilities together with daily maximal flow can also be used (included into assessment range) second maximum value of water discharges within the months.

In turn above fixed water discharge values can play role of ecosystem flow as it is shown below:

- Water discharges equal or higher than $Q_{10\%}$, will correspond to very high and wide aquatic environment and present by I category hydrological characteristics (Q_1) and corresponding biological quality elements (BQ_1) . In this case $Q_{10\%}$, as a lower bound of very wide aquatic environment will play role of Very High Ecosystem Flow (Q_{1EF})
- Water discharges below $Q_{10\%}$ and higher and equal than $Q_{25\%}$ will provide wide aquatic environment and present by II category hydrological characteristics (Q_2) and corresponding biological quality elements (BQ_2.) .In this case $Q_{25\%}$, as a lower bound of wide aquatic environment will play role of High Ecosystem Flow (Q_{2EF})
- In the same way can be classified water discharges below $Q_{25\%}$ higher and equal than $Q_{50\%}$ which corresponds to water medium above(higher than) mean aquatic environment and present by III category hydrological characteristics (Q_3) and corresponding biological quality elements (BQ_3). In this case $Q_{50\%}$, as a low bound of higher than mean aquatic environment wll play role of Mean Ecosystem Flow (Q_{3EF})

Hydrological Classification System

- Water discharges below $Q_{50\%}$ and higher and equal than $Q_{75\%}$ will correspond to water medium **lower than mean aquatic environment** and present by **IV category** hydrological characteristics (**Q_4**) and corresponding biological quality elements (B**Q_4.** .In this case **$Q_{75\%}$**, as a low bound of **lower than mean aquatic environment w**ill play role of **Low Ecosystem Flow (Q_{4EF})**

- Water discharges below $Q_{75\%}$ and higher and equal than $Q_{90\%}$ will correspond to **low aquatic environment** and present by **V category** hydrological characteristics (**Q_5**) and corresponding biological quality elements (**BQ_5**.) .In this case **$Q_{90\%}$**, as a low bound of **low aquatic environment w**ill play role of **Very Low Ecosystem Flow (Q_{5EF})**

- Water discharges below $Q_{90\%}$ and higher and equal than $Q_{max, min}$ will correspond to **very low aquatic environment** and present by **VI category** hydrological characteristics (**Q_6)** and corresponding biological quality elements **BQ_6.**). In this case **$Q_{max,min}$** as a low bound of **very low aquatic environment w**ill play role of **Extremely Low Ecosystem Flow (Q_{6EF})**

- Water discharges below **$Q_{max,min}$** and higher and equal than average value of **$Q_{max,min}$ and $Q_{min, min}$** will be present by **corresponding aquatic environment** (higher than mean water medium of this lowest minimal in entire natural period month). It will be present by **VII category** hydrological characteristics (**Q_7)** and corresponding biological quality elements (**BQ_7**). In this case average value of **$Q_{max,min}$ and $Q_{min, min}$** will as a low bound of **lowest aquatic environment** of the minimal flow month play role of **Mean Flow of Minimal month (Q_{7EF})**

Hydrological Classification System

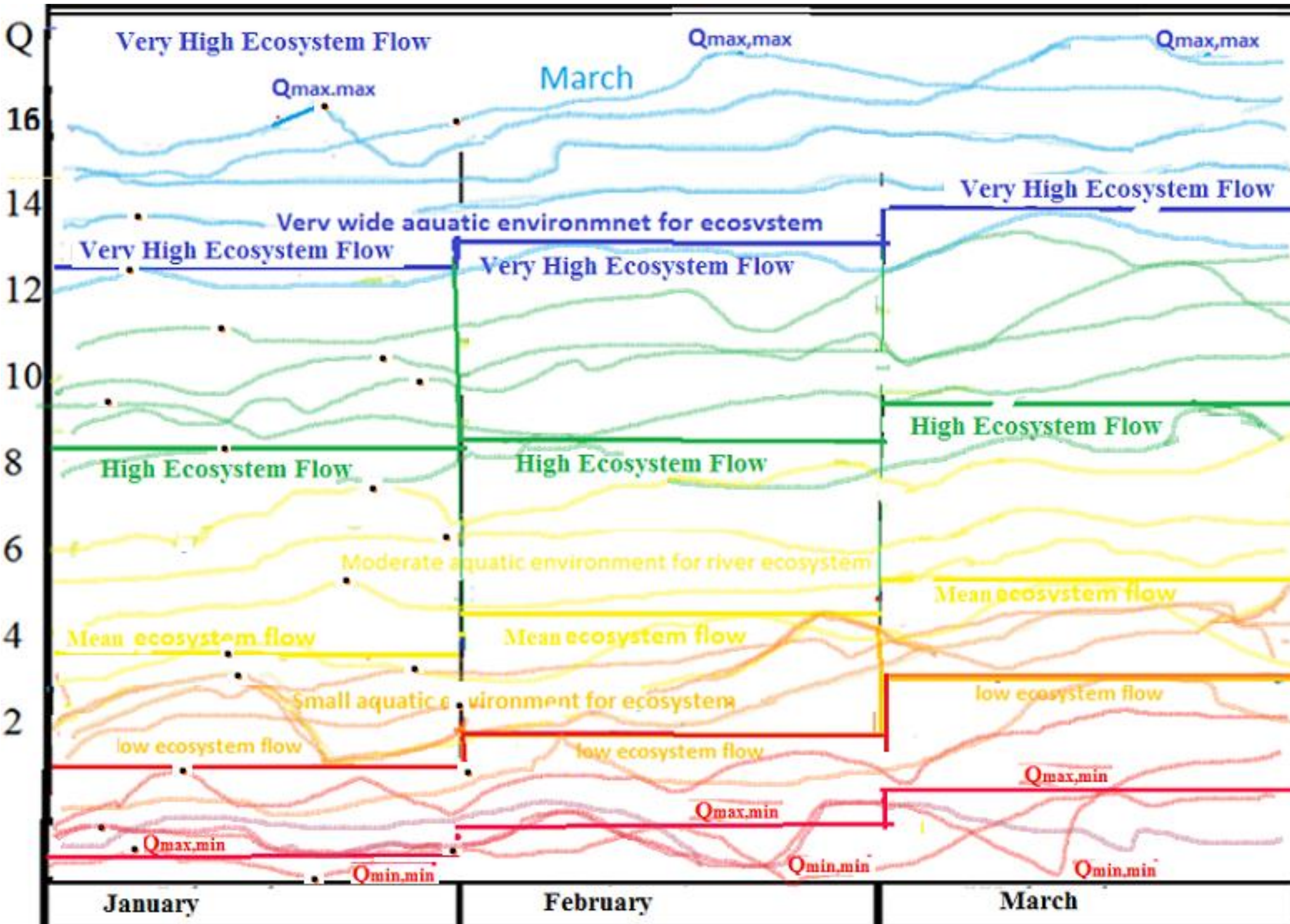
- Water discharges below than average value of **$Q_{max,min}$ and $Q_{min, min}$** and equal and higher than **$Q_{min, min}$** will correspond to water medium **between mean and lowest aquatic environment** for the minimal for entire period flow month. It will be present by **VIII category** hydrological characteristics (**Q_8**)and corresponding biological quality elements (**BQ_8**). In this case **$Q_{min, min}$** will as a low bound of **lowest aquatic environment** **w**ill play role of **Lowest ecosystem flow of minimal month (Q_{8EF})**

- If in the following(assessed) period during the month some daily water discharge is below **$Q_{min,min}$** (as result of natural flow fluctuation or climate changes) then in assessment **$Q_{min,min}$** should be replaced by these new minimal water discharge in the Hydrological Classification System

- If in the following(assessed) period the maximal observed daily water discharge is below **$Q_{max,min}$** (as result of natural flow fluctuation or climate changes) then in in the end of given month in the Hydrological Classification System **$Q_{max,min}$** should be replaced by its this new value.

- In the diagram as an example are demonstrated different flow hydrographs(high , average and low flow) and characteristic ecosystem flow values for considered month

Water discharges(Q, cub.m/sec) for selected different flow years during the



Relation between the hydrological classification system and ecological classification according to EU WFD

- When water abstraction leads to reduction of water discharges this may impact on biological and ecological status of water (because of reduction of **aquatic environment)** .

- In this case based on volume of changes(reduction) of water discharges and subsequently changing of hydrological and corresponding biological elements can be assessed impact of human activity to the ecological status.

- Relationship between the hydrological and biological(ecological) status can be established by use of hydrological and biological monitoring data collected during the observation period (natural).

- If in the assessment period there is no water abstraction or it is such insignificant that can't have any impact to hydrological or biological elements then hydrological status of all 8 aquatic environment categories will be **High (HQ_1 ,,,, HQ_8)**

- In this case corresponding biological quality elements for each of categories will also be same as in natural conditions without change**(BHQ_1 ,,,, BHQ_8)** . Therefore by use of methodology of EU WFD can be assessed biological quality for to different hydrological categories to see if natural reduction of water discharges from cone category to other lead to changing of biological quality elements according to EUWFD classification or it doesn't happen.

- Ecological status can also be assessed according to changes of biological elements (in cases when water discharges change by human impact) as it is identified in EU WFD

Relation between the hydrological classification system and ecological classification according to EU WFD

- If in result of water abstraction water discharges during one or several days of the month are **r**educed by I class form initial category then they will have **GOOD hydrological status (**present by **GQ_1 ,… , GQ_8** .

- In this case corresponding biological quality elements for each of categories will also be changed from their values identified in natural period(corresponding to unaffected water discharges in the river) till values corresponding to water discharges left in the river after abstraction(and present by **BGQ_1 ,… , BGQ_8**)

- Corresponding ecological status can also be assessed according to above changes of biological elements in result of water use as it is identified in EU WFD

- In the same way in cases when in result of water abstraction water discharges are **r**educed by II, III or IV classes form initial category for any of the hydrological categories(i=1 ,…, 8) then they will correspond to the flow **of MODERATE(MQ_i), POOR(PQ_i) or BAD(BQ_i)** hydrological status classes.

- In this case biological elements will also as above be assessed according to changes of their values form initial category till ones corresponding to the reduced values of water discharges by II, III or IV classes form initial category and will be present by the biological elements of flow **of MODERATE(BMQ_i), POOR(BPQ_i) or BAD(BBQ_i)** hydrological status classes.

- If water discharges corresponding to category VIII are lower in result of water abstraction and rare below of **$Q_{miin, min}$** for 20, 40 , 60% and more then accordingly them will correspond hydrological sub categories **GQ_8 , MQ_8 , PQ_8 and BQ_8 corresponding biological elements will be BGQ_8 , BMQ_8 , BPQ_8 and BBQ_8 .** In the same way also will be defined water discharges corresponding to lower status discharges belonging to category VII.
- This is also virtually demonstrated in following figure

Hydrological and biological characteristics determining ecological status

N	Daily water discharge in river (m^3/s)	Status Classes depending on impact of water abstraction									
		Natural Condition		Weak impact or reduction of flow by I level		Moderate impact or reduction of flow by II levels		Significant impact or reduction of flow by III levels		Very significant impact or reduction of flow by IV levels	
		Hydrological status	Biological Status	Hydrological status	Biological Status	Hydrological status	Biological Status	Hydrological status	Biological status	Hydrological status	Biological Status
1	≥Very high Ecosystem flow	HQ_1	BHQ_1	GQ_1	BGQ_1	MQ_1	BMQ_1	PQ_1	BPQ_1	BQ_1	BBQ_1
2	≤Very high Ecosystem flow a ≥High ecosystem Flow	HQ_2	BHQ_2	GQ_2	BGQ_2	MQ_2	BMQ_2	PQ_2	BPQ_2	BQ_2	BBQ_2
3	≤High ecosystem Flow ≥Mean Ecosystem Flow	HQ_3	BHQ_3	GQ_3	BGQ_3	MQ_3	BMQ_3	PQ_3	BPQ_3	BQ_3	BBQ_3
4	≤Mean Ecosystem Flow ≥ Low Ecosystem Flow	HQ_4	BHQ_4	GQ_4	BGQ_4	MQ_4	BMQ_4	PQ_4	BPQ_4	BQ_4	BBQ_4
5	≤Low Ecosystem Flow ≥Very Low Ecosystem Flow	HQ_5	BHQ_5	GQ_5	BGQ_5	MQ_5	BMQ_5	PQ_5	BPQ_5	BQ_5	BBQ_5
6	≤Very Low Ecosystem Flow ≥ Minimum Ecosystem Flow	HQ_6	BHQ_6	GQ_6	BGQ_6	MQ_6	BMQ_6	PQ_6	BPQ_6	BQ_6	BBQ_6
7	≤Minimal Ecosystem Flow(MEF) ; ≥ Middle of MEF and Minimal flow of minimal month	HQ_7	BHQ_7	GQ_7	BGQ_7	MQ_7	BMQ_7	PQ_7	BPQ_7	BQ_7	BBQ_7
8	Below Middle of MEF and Minimal flow	HQ_8	BHQ_8	GQ_8	BGQ_8	MQ_8	BMQ_8	PQ_8	BPQ_8	BQ_8	BBQ_8

Hydrological Classification System

- According to EU WFD in result of human impact(ecological status of water bodies shouldn't be below GOOD class for all European rivers.
- For water bodies in National Park areas or other strategic importance to keep hydrological and corresponding biological and ecological statuses (to be determined according to EU WFD classification) HIGH water abstraction shouldn't be allowed, only by permission of environment protection organization for sanitary or urgent strategic purposes maybe little amount of water (for example up to 10% of difference between the environmental flow of lower borders of considered category and environmental flow of lower category) can be abstracted .
- GOOD status in the river will be in cases when natural water discharges corresponding to any hydrological category of **High** status are reduced by one class.
- As an amount of abstracted water that may lead to change hydrological status by one category (in this case from HIGH to GOOD) can by used the ratio of two neighboring ecosystem flows(ecosystem flow of lower category divided by ecosystem flow corresponding to lower border of considered category) for each month
- This ratios can be used as a coefficients for transfer from one status class to other showing the ratio of water abstraction (coefficients of water abstraction) leading to change of hydrological status to one class.

Hydrological Classification System

- If we multiply water discharges belonging to the given category to this coefficient then the received value of water discharge will be equal(when its natural value is equal to ecosystem flow of category to which it belongs) or higher than the ecosystem flow of lower status class and will have one class lower hydrological status
- For example reduction of any natural water discharge of HIGH hydrological status belonging to I category (HQ_1) by one class, can be done by multiplying of this discharge to above described ratio for transfer from HIGH to GOOD status category. In result for the given month the reduced water discharge will correspond to GOOD status(GQ_1**)** and be calculated by formula:

$$GQ_1=HQ_1 * \mathbf{Q_{VHF} / Q_{HEF}}$$

- For moderate status flow of I category(HIGH status) should be reduced by 2 categories in result of water abstraction , for poor by 3 and for bad by 4 categories according to above described principle(see table above).
- In the same way for each month can be calculated status of further reduced in result of water abstraction water discharges corresponding to lower classes ((MQ_1,PQ_1, $BQ_{1)}$ by multiplying them to the ratio coefficients for further reduction
- It should be noted that as in many of Azerbaijan rivers in result of water abstraction in summer (and also in other seasons) rivers dry. Therefore reaching of GOOD status can be done based on step by step approach. In first 6 years period all rivers of POOR and BAD hydrological status can reach moderate status , through the improvement of condition of water supply infrastructure and application of modern technologies. In the second 6 year circle can be reached GOOD status by continuing of further improving of state of water supply infrastructure
- Ecological status can be assessed according to changes of biological elements from values corresponding to water discharges of higher hydrological classes to ones corresponding to water discharges of lower hydrological status

Hydrological Classification System for Ganjachay river at Zurnabad station

- Based on this method, “Ecosystem Flow” has been evaluated for Ganjachay-Zurnabad point.
- Thus, first flow indicators for environment have been identified by using information from observation range covering years 1926-1990.
- Then relevant monthly water discharges in years 1991-2015 have been compared to these quality indicators.
- As there is no water abstraction data therefore in order to see if the average reduction of flow by up to 5% in the second period is because of human impact or natural changes was done comparative analyse of changes of water discharges and climatic elements(as in second period temperature increased and precipitation reduced) for above 2 periods. This allowed to link above flow reduction also to climatic changes.
- It should be noted that in average there is some flow reduction in second period compared to previous and as result it leads to certain change in flow categories. For example in second period $\mathbf{Q}_{max,min}$ and $\mathbf{Q}_{min,min}$ were reduced comparing to their values in first period which lead to change of their status classes(Figure)
- In order to see if this is because of natural changes or human impact was also assessed impact of climatic changes to the flow in this work
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			Ecosystem Flows of r. Ganjachay -p.Zurnabad									
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Extremally high(maximum) Ecosystem flow(Q 0EF Q max,max)												
4,46	8,85	18	52	95,5	54,5	107	78,5	23,5	22,6	10,2	5,71	$Q_{max,max}$
Very high Ecosystem flow (Q 1EF =Q 10%)												
3,32	4,86	9,7	25,4	31,8	46,1	38,8	24,7	11,6	10,1	7,22	4,11	$Q_{10\%}$
0,78	0,64	0,77	0,71	0,83	0,79	0,64	0,54	0,62	0,63	0,6	0,69	$Q_{25\%}:Q_{10\%}$
High Ecosystem flow(Q 2EF =Q 25%)												
2,59	3,13	7,44	18,1	26,6	36,4	24,9	13,4	7,23	6,36	4,35	2,87	$Q_{25\%}$
0,79	0,74	0,68	0,67	0,64	0,64	0,47	0,49	0,65	0,67	0,66	0,79	$Q_{50\%}:Q_{25\%}$
Mean Ecosystem Flow (Q 3EF =Q 50%)												
2,05	2,32	5,09	12,1	17,1	23,2	11,8	6,64	4,72	4,29	2,88	2,28	$Q_{50\%}$
0,83	0,73	0,73	0,8	0,81	0,63	0,66	0,73	0,69	0,63	0,82	0,85	$Q_{75\%}:Q_{50\%}$
Low Ecosystem Flow (Q 4EF =Q 75%)												
1,7	1,68	3,72	9,62	13,8	14,6	7,81	4,85	3,28	2,7	2,35	1,94	$Q_{75\%}$
0,86	0,72	0,86	0,77	0,79	0,66	0,63	0,62	0,84	0,83	0,88	0,84	$Q_{90\%}:Q_{75\%}$
Very Low Ecosystem Flow (Q 5EF+ Q 90%)												
1,47	**1,22**	**3,2**	**7,34**	**10,9**	**9,62**	**4,11**	**2,99**	**2,75**	**2,25**	**2,07**	**1,64**	$Q_{90\%}$
0,57	0,82	0,56	0,29	0,5	0,43	0,57	0,69	0,62	0,63	0,69	0,68	$Q_{max,min}:Q_{90}$
Minimal Ecosystm Flow(Q 6EF =Q max,min)												
0,84	**0,99**	**1,8**	**2,15**	**5,46**	**4,11**	**2,33**	**2,06**	**1,72**	**1,42**	**1,42**	**1,12**	$Q_{max,min}$
0,89	0,81	0,62	0,73	0,77	0,74	0,9	0,83	0,75	0,85	0,8	0,78	$(Q_{max,min} + Q_{min,min})/2 : Q_{max,min}$
Mean ecosystem flow of minimal flow month(Q 7EF =Qmin,min+Q min,min)/2												
0,75	**0,81**	**1,11**	**1,57**	**4,18**	**3,04**	**2,09**	**1,7**	**1,29**	**1,21**	**1,13**	**0,87**	$(Q_{max,min} + Q_{min,min})/2$
0,89	0,78	0,37	0,76	0,7	0,68	0,88	0,79	0,67	0,83	0,75	0,72	$Q_{min,min}):(Q_{max,min} - Q_{min,min})/2$
Minimal ecosystem flow of minimal flow month(Q8EF=Qmin,min)												
0,67	**0,63**	**0,41**	**1,19**	**2,91**	**2,08**	**1,84**	**1,34**	**0,86**	**1**	**0,85**	**0,62**	$Q_{min,min}$

Hydrological Classification of Ecosystem Flows of r. Ganjachay -p.Zurnabad

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
4,46	8,85	18	52	95,5	54,5	107	78,5	23,5	22,6	10,2	5,71	$Q_{max,max}$
HIGH Hydrological status($Q \geq HQ_1 - 0,2(Q_{1EF} - Q_{2EF})$)												
3,32	4,86	9,7	25,4	31,8	46,1	38,8	24,7	11,6	10,1	7,22	4,11	$Q_{10\%}$
0,7801	0,644	0,767	0,7126	0,8365	0,7896	0,6418	0,5425	0,6233	0,6297	0,6025	0,6983	$Q_{25\%}:Q_{10\%}$
GOOD Hydrological status($Q = GQ1 \geq Q_{25\%}$)												
2,59	3,13	7,44	18,1	26,6	36,4	24,9	13,4	7,23	6,36	4,35	2,87	$Q_{25\%}$
0,7915	0,7412	0,6841	0,6685	0,6429	0,6374	0,4739	0,4955	0,6528	0,6745	0,6621	0,7944	$Q_{50\%}:Q_{25\%}$
MODERATE Hydrological status($Q = MQ1 \geq Q_{50\%}$)												
2,05	2,32	5,09	12,1	17,1	23,2	11,8	6,64	4,72	4,29	2,88	2,28	$Q_{50\%}$
0,8293	0,7241	0,7308	0,795	0,807	0,6293	0,6619	0,7304	0,6949	0,6294	0,816	0,8509	$Q_{75\%}:Q_{50\%}$
POOR Hydrological status($Q = PQ1 \geq Q_{75\%}$)												
1,7	1,68	3,72	9,62	13,8	14,6	7,81	4,85	3,28	2,7	2,35	1,94	$Q_{75\%}$
0,8647	0,7262	0,8602	0,763	0,7899	0,6589	0,5262	0,6165	0,8384	0,8333	0,8809	0,8454	$Q_{90\%}:Q_{75\%}$
BAD Hydrological status($Q < PQ1$)												
1,47	**1,22**	**3,2**	**7,34**	**10,9**	**9,62**	**4,11**	**2,99**	**2,75**	**2,25**	**2,07**	**1,64**	$Q_{90\%}$
Monthly maximum water discharges for period (1930-1990)												
4,46	8,85	18	52	95,5	54,5	107	78,5	23,5	22,6	10,2	5,71	$Q_{max,max(1930-1990)}$
Monthly maximum water discharges for period (1991-2016)												
4,6	9,93	13,8	41,9	42,3	38,8	32,8	9,81	22,5	11,1	11,8	7,83	$Q_{max,max(1991-2016)}$

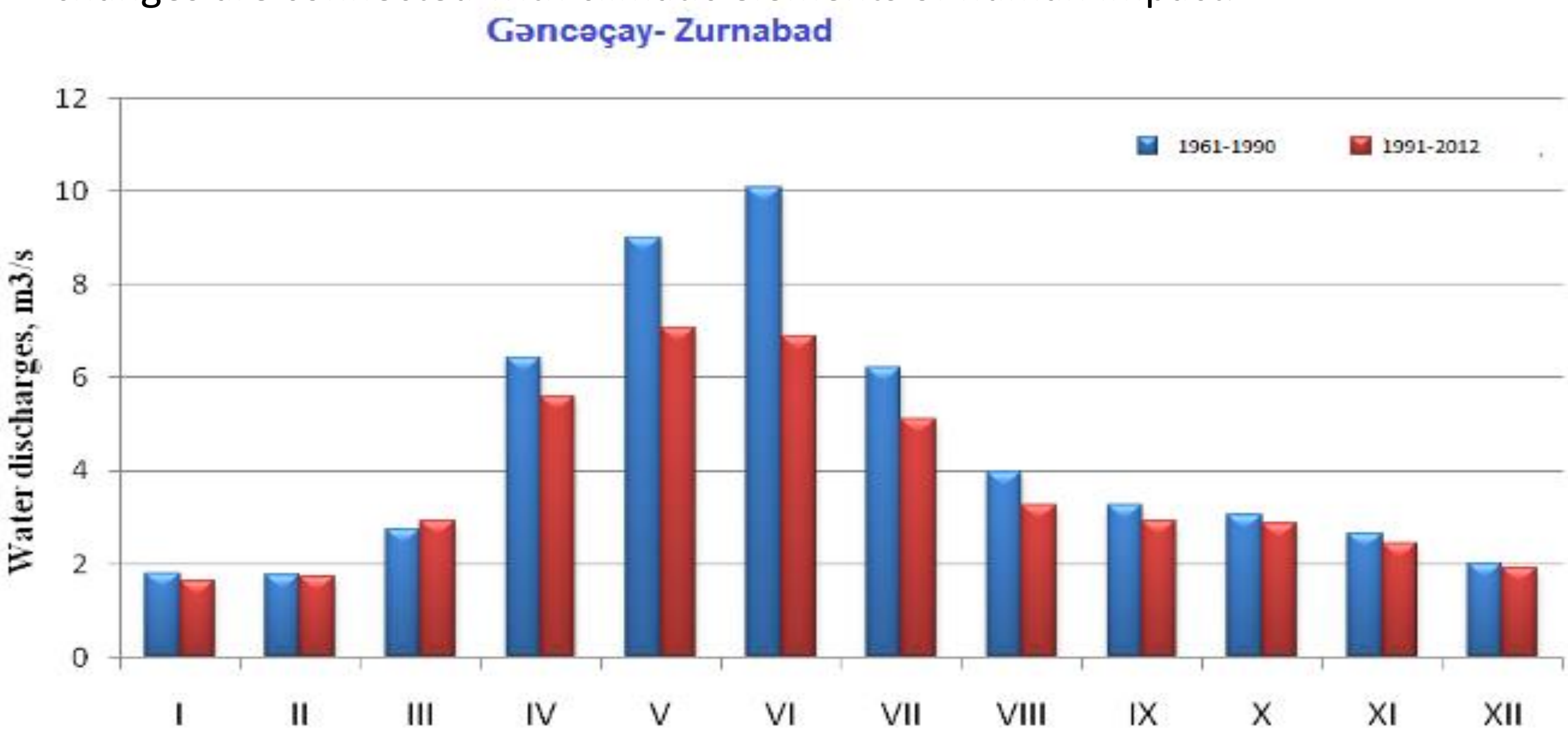
	Hydrological Classification of Ecosystem Flows of r. Ganjachay -p.Zurnabad for period 1991-2016											
	HIGH Hydrological status($Q \geq H_{Q7} - 0.2(Q_{7EF} - Q_{8EF})$)											
0,84	**0,99**	**1,8**	**2,15**	**5,46**	**4,11**	**2,33**	**2,06**	**1,72**	**1,42**	**1,42**	**1,12**	$Q_{max,min}$
0,8929	0,8182	0,6167	0,7307	0,7656	0,7397	0,897	0,8252	0,75	0,8521	0,7958	0,7768	(Qmax,min +Qmin,min)/2 :Qmax,mi
GOOD Hydrological status($Q = GQ7 \geq Q_{max,min} + Q_{min,min})/2$)												
0,75	**0,81**	**1,11**	**1,571**	**4,18**	**3,04**	**2,09**	**1,7**	**1,29**	**1,21**	**1,13**	**0,87**	(Qmax,min +Qmin,min)/2
0,8933	0,7778	0,3694	0,7575	0,6962	0,6842	0,8804	0,7882	0,6667	0,8264	0,7522	0,7126	Qmin,min):(Qmax,min -Qmin,min)/2
MODERATE Hydrological status(Q =MQ7≥Qmin,min)												
0,67	**0,63**	**0,41**	**1,19**	**2,91**	**2,08**	**1,84**	**1,34**	**0,86**	**1**	**0,85**	**0,62**	Qmin,min
0,13	**0,13**	**0,08**	**0,23**	**0,68**	**0,62**	**0,37**	**0,26**	**0,17**	**0,2**	**0,17**	**0,12**	0.2*Qmin,min
		POOR Hydrological status(Q =PQ7≥0.8*Qmin,min)										
0,52	**0,51**	**0,33**	**0,96**	**2,23**	**1,46**	**1,47**	**1,08**	**0,69**	**0,8**	**0,68**	**0,5**	0.8*Qmin,min
0,27	**0,25**	**0,16**	**0,48**	**1,16**	**0,83**	**0,74**	**0,54**	**0,34**	**0,4**	**0,34**	**0,25**	0.4*Qmin,min
		BAD Hydrological status(Q <PQ7)										
0,4	**0,38**	**0,25**	**0,71**	**1,77**	**1,25**	**1,1**	**0,8**	**0,52**	**0,6**	**0,51**	**0,37**	0.6*Qmin,min
Minimal value of monthly maximum water discharges for period (1930-1990)												
0,84	0,99	1,8	2,15	5,46	4,11	2,33	2,06	1,72	1,42	1,42	1,12	$Q_{max,min(1930-1990)}$
Minimal value of monthly maximum water discharges for period (1991-2016)												
0,9	0,9	1,36	1,7	4,9	3,6	2,9	2,17	1,8	0,9	1,19	0,85	$Q_{max,min(1991-2016)}$

Hydrometeorological characteristics of Ganjachay river basin

Reduction of rainfall and increase in air temperature by 0.7 ^{0}C lead to annual and seasonal flow getting diminished in Ganjachay river (especially in summer season).

Decline in flow rate was observed in all months of the year except from February and March as a result of raising air temperature. Mainly because of snow melting in these two months due to rising air temperature it leads to increasing of flow in the river

Therefore it is important to have also water abstraction data to see if these changes are connected with climatic elements of human impact.



Hydrological Classification of flow of Ganjachay river below Ganja city

- In order to assess impact of water abstraction to hydrological status of flow of Ganjachay river below Ganja city(where river dries in summer and some other periods as well) based on ratio of long term average value of flow in Zurnabad and near mouth of river (based on data from (S.Rustamov and R. Gashgay) was assessed monthly Ecosystem Flow characteristic of Ganjachay river below Ganja city(Figure).
- The observed amounts of monthly flow of Ganjachay river near Ganja city ((calculated approximately based on some field survey materials conducted in 2016, by expert judgment and also taking into consideration the fact that in this year river by impact of water abstraction dried many days in summer and also flow value usually were near and lower than 1 cub.m in spring and autumn and below 0,5 cub/m in winter)
- Result of classification of flow of river show that human impact lead to reduction of flow till BAD hydrological status, even often drying of river
- Results of classification is given in Figure. As it is shown in spite of the fact that in 2016 in Ganjachay river based on correlation with at Zurnabad point the natural flow values were in some months to be near mean and in others above High Ecosystem flow values, but as result of water abstraction they were reduced significantly and BAD hydrological status has been observed for all moths of the year
- This show that in first 6 tears circle there will be need to reach Moderate status by implementing water saving measures and in following 6 years actions needed to be continued to reach GOOD hydrological status

Ecosystem Flows of r. Ganjachay -p.Ganja(mouth)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Extremally high(maximum) Ecosystem flow(Q_{0EF} $Q_{max,max}$)												
5,35	10,62	21,6	62,4	115	65,4	128	94,2	28,2	27,1	12,2	6,85	$Q_{max,max}$
Very high Ecosystem flow ($Q_{1EF}=Q_{10\%}$)												
3,98	5,83	11,6	30,5	38,2	55,3	46,6	29,6	13,9	12,1	8,66	4,93	$Q_{10\%}$
0,78	0,64	0,77	0,71	0,83	0,79	0,64	0,54	0,62	0,63	0,6	0,69	$Q_{25\%}:Q_{10\%}$
High Ecosystem flow($Q_{2EF}=Q_{25\%}$)												
3,11	3,75	8,93	21,7	31,9	43,7	29,9	16,1	8,68	7,63	5,22	3,44	$Q_{25\%}$
0,79	0,74	0,68	0,67	0,64	0,64	0,47	0,49	0,65	0,67	0,66	0,79	$Q_{50\%}:Q_{25\%}$
Mean Ecosystem Flow ($Q_{3EF}=Q_{50\%}$)												
2,46	2,78	6,11	14,5	20,5	27,8	14,1	7,97	5,67	5,14	3,46	2,74	$Q_{50\%}$
0,83	0,73	0,73	0,8	0,81	0,63	0,66	0,73	0,69	0,63	0,82	0,85	$Q_{75\%}:Q_{50\%}$
Low Ecosystem Flow ($Q_{4EF}=Q_{75\%}$)												
2,04	2,02	4,47	11,5	16,6	17,5	9,37	5,82	3,94	3,24	2,82	2,33	$Q_{75\%}$
0,86	0,72	0,86	0,77	0,79	0,66	0,63	0,62	0,84	0,83	0,88	0,84	$Q_{90\%}:Q_{75\%}$
Very Low Ecosystem Flow (Q_{5EF+} $Q_{90\%}$)												
1,76	1,46	3,84	8,8	13,1	11,5	4,93	3,59	3,3	2,7	2,48	1,97	$Q_{90\%}$
0,57	0,82	0,56	0,29	0,5	0,43	0,57	0,69	0,62	0,63	0,69	0,68	$Q_{max,min}:Q_{90}$
Minimal Ecosystm Flow($Q_{6EF}=Q_{max,min}$)												
1,01	1,19	2,16	2,58	6,55	4,93	2,8	2,47	2,06	1,7	1,7	1,34	$Q_{max,min}$
0,89	0,81	0,62	0,73	0,77	0,74	0,9	0,83	0,75	0,85	0,8	0,78	$(Q_{max,min}+Q_{min,min})/2:Q_{max,min}$
Mean ecosystem flow of minimal flow month($Q_{7EF}=Q_{min,min}+Q_{min,min})/2$												
0,9	0,97	1,33	1,89	5,02	3,65	2,51	2,04	1,55	1,45	1,36	1,04	$(Q_{max,min}+Q_{min,min})/2$
0,89	0,78	0,37	0,76	0,7	0,68	0,88	0,79	0,67	0,83	0,75	0,72	$Q_{min,min}):(Q_{max,min}-Q_{min,min})/2$
Minimal ecosystem flow of minimal flow month($Q_{8EF}=Q_{min,min}$)												
0,8	0,76	0,49	1,43	3,49	2,5	2,21	1,61	1,03	1,2	1,02	0,74	$Q_{min,min}$
							Ganjachay Ganja observed flow					
<0,5	<0,5	<0,5	<1,0	<1,0	<0,5	0	0	<0,5	<1,0	<0,5	<0,5	

Ecosystem Flows of r. Ganjachay -p.Ganja(mouth)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Extremally high(maximum) Ecosystem flow(Q_{0EF} $Q_{max,max}$)												
5,35	10,62	21,6	62,4	115	65,4	128	94,2	28,2	27,1	12,2	6,85	$Q_{max,max}$
Very high Ecosystem flow ($Q_{1EF}=Q_{10\%}$)												
3,98	5,83	11,6	30,5	38,2	55,3	46,6	29,6	13,9	12,1	8,66	4,93	$Q_{10\%}$
0,78	0,64	0,77	0,71	0,83	0,79	0,64	0,54	0,62	0,63	0,6	0,69	$Q_{25\%}:Q_{10\%}$
High Ecosystem flow($Q_{2EF}=Q_{25\%}$)												
3,11	3,75	8,93	21,7	31,9	43,7	29,9	16,1	8,68	7,63	5,22	3,44	$Q_{25\%}$
0,79	0,74	0,68	0,67	0,64	0,64	0,47	0,49	0,65	0,67	0,66	0,79	$Q_{50\%}:Q_{25\%}$
Mean Ecosystem Flow ($Q_{3EF}=Q_{50\%}$)												
2,46	2,78	6,11	14,5	20,5	27,8	14,1	7,97	5,67	5,14	3,46	2,74	$Q_{50\%}$
0,83	0,73	0,73	0,8	0,81	0,63	0,66	0,73	0,69	0,63	0,82	0,85	$Q_{75\%}:Q_{50\%}$
Low Ecosystem Flow ($Q_{4EF}=Q_{75\%}$)												
2,04	2,02	4,47	11,5	16,6	17,5	9,37	5,82	3,94	3,24	2,82	2,33	$Q_{75\%}$
0,86	0,72	0,86	0,77	0,79	0,66	0,63	0,62	0,84	0,83	0,88	0,84	$Q_{90\%}:Q_{75\%}$
Very Low Ecosystem Flow (Q_{5EF+} $Q_{90\%}$)												
1,76	1,46	3,84	8,8	13,1	11,5	4,93	3,59	3,3	2,7	2,48	1,97	$Q_{90\%}$
0,57	0,82	0,56	0,29	0,5	0,43	0,57	0,69	0,62	0,63	0,69	0,68	Qmax,min:Q90
Minimal Ecosystm Flow($Q_{6EF}=Q_{max,min}$)												
1,01	1,19	2,16	2,58	6,55	4,93	2,8	2,47	2,06	1,7	1,7	1,34	$Q_{max,min}$
0,89	0,81	0,62	0,73	0,77	0,74	0,9	0,83	0,75	0,85	0,8	0,78	(Qmax,min +Qmin,min)/2 :Qmax,min
Mean ecosystem flow of minimal flow month($Q_{7EF}=Q_{min,min}+Q_{min,min})/2$												
0,9	0,97	1,33	1,89	5,02	3,65	2,51	2,04	1,55	1,45	1,36	1,04	(Qmax,min +Qmin,min)/2
0,89	0,78	0,37	0,76	0,7	0,68	0,88	0,79	0,67	0,83	0,75	0,72	Qmin,min):(Qmax,min -Qmin,min)/2
Minimal ecosystem flow of minimal flow month($Q_{8EF}=Q_{min,min}$)												
0,8	0,76	0,49	1,43	3,49	2,5	2,21	1,61	1,03	1,2	1,02	0,74	Qmin,min
Ganjachay Ganja observed flow												
<0,5	<0,5	<0,5	<1,0	<1,0	<0,5	0	0	<0,5	<1,0	<0,5	<0,5	
Ganjacay Ganja(mouth) natural flow												
5,04	8,97	10,1	21,7	50,8	27,8	16	10	11,8	11,8	14,2	5,49	

Thanks for your attention!