ENVIRONMENTAL CHALLENGES ON HARAZ RIVER OPERATION SYSTEM (HROS)

DEFIS QUE POSE L'ENVIRONNEMENT AU SYSTEME D'EXPLOITATION DE LA RIVIERE HARAZ (HROS)

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ABSTRACT

The Haraz River Operation System (HROS), composed of Babol-Rud and Haraz surface water resources branches, is very complex and noteworthy. Considering the Lar storage dam on the upstream of this river basin, we notice that the water transferred from this basin flows into the Salt Lake basin. There is also another inter-basin water transfer in smaller scale via Cari River channel from Haraz River into Babol-Rud. Lack of enough data relevant to agriculture water uses and inter-basin water transfer processes cause complexities in the operational management of Haraz River. Fulfilling aquatics and agricultural water requirements in various parts of the river, we have estimated water withdrawals by two methods: calculating water consumptions from down-stream, and estimating water right from the capacity of water withdrawal points by GIS and RS. The region's environmental requirements have also been estimated by a combination of various methods such as Montana method and estimated probable percentages. Having studied the river inputs and outputs, we noticed that even the average stream flow (without considering drought years) supply of the river cannot meet the environmental flow requirements.

Key words: *Haraz; water requirement; Montana Method; RS; GIS; River Operation.*

RESUME ET CONCLUSIONS

Aujourd'hui, l'exploitation anormale des ressources en eau du bassin a malheureusement endommagé de manière irréversible les ressources naturelles, particulièrement le secteur d'environnement. La croissance de la demande d'eau en particulier dans le secteur agricole, ainsi que les sécheresses a donné lieu aux difficultés d'exploitation des ressources en eau de surface. Le manque de ressources en eau pour satisfaire les exigences pertinentes, ainsi que les changements anthropiques dans le système fluvial sans tenir compte de leurs effets sur le cycle

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naturel de la rivière, et le manque de prévoyance du développement durable dans l'exploitation des ressources en eau de surface ont intensifiées ces crises. Au cours de ces dernières années, les questions de l'eau, le droit de l'eau et l'environnement ont été sérieusement prises en considération dans l'ordre du jour du Ministère de l'Énergie et d'autres entités pertinentes. Cependant, les difficultés d'infrastructure tels que le manque de dispositifs de mesure et le contrôle sur le débit de l'eau, ainsi que, certaines questions juridiques ont causé obstacles dans le processus. Le bassin fluvial de Haraz est situé sur la côte sud de la mer Caspienne (au nord de l'Iran). La diversité des caractéristiques comporte le bassin, les prairies, les forêts et les jungles s'étendent des plages de la mer Caspienne jusqu'à la Sierra et à l'Elbourz, y compris le mont Damavand, le plus haut sommet du volcan au Moyen-Orient et en Asie occidentale.

Compte tenu de la condition spécifique du climat du bassin - plus de 1000 mm de précipitation dans les plaines et 300-500 mm de précipitation dans les zones montagneuses - il est difficile de trouver le site approprié pour la construction des barrages. Par conséquent, en utilisant les étangs naturels ou artificiels, appelés Ab-Bandan, le peuple accumule les eaux de précipitations au cours de la saison humide pour usage dans la saison agricole.

En outre, le Sustème d'exploitation de la rivière Haraz des ressources en eau, composé de Babol-Rud et Haraz, est très complexe et remarquable. Compte tenu du barrage de stockage d'eau Lar sur l'amont du bassin, il est remarqué que l'eau transférée de ce bassin tombe dans « Salt Lake Basin ». Il existe un autre transfert d'eau interbassin à petite échelle du canal Cari de la rivière Haraz au Babol-Rud. Le manque de données relevant de l'usage de l'eau agricole et du processus de transfert d'eau interbassin rend complex l'exploitation du système fluvial de Haraz. En satisfaisant les besoins en eau agricole, nous avons calculé les prélèvements d'eau par deux méthodes : calcul de la consommation d'eau en aval, et calcul des droits de l'eau des points de prélèvement d'eau par SIG et télédétection. Les besoins environnementaux de la région ont été calculés par une combinaison de diverses méthodes telles que Montana qui a calculé le pourcentage probable. Finalement, après avoir étudié les apports fluviaux et les prélevements, nous avons remarqué que même en débit moyen (sans considérer les années de sécheresse), il n'est pas possible de satisfaire les besoins environnementaux en eau.

Mots clés : *Haraz; besoins en eau; méthode Montana; RS; SIG; exploitation fluviale.*

1. INTRODUCTION

Nowadays abnormal operation of basin water resources have unfortunately damaged the environmental sector irretrievably. The growth of demand for water, especially in the agriculture sector, and intensification of the damand during droughts have posed severe challenges to the operation of the surface water resources. Lack of water resources to meet the demands, as well as, anthropogenic factors in the river basins and a lack of foresight for sustainable development and operation of the surface water resources have further aggravated such crises. During the recent years, issues of water, water right, and environment are seriously considered in the agenda of Ministry of Energy and the other concerned organizations. However, infrastructural difficulties such as lack of measuring devices and water flow control, as well as, some legal issues have caused hindrances on the process.

Considering the above-mentioned issues, we have used the existing data and RS and GIS technology to estimate water uses from Haraz River basin with a view to evaluating the river operation challenges by estimating the river environmental requirements and the existing water system rate.

2. STUDY AREA AND DATA SOURCES

Haraz river basin is located on the southern coast of the Caspian Sea (in the North of Iran). The diverse nature of the basin features plains, prairies, forests and jungles stretching from the sandy beaches of the Caspian Sea to the rugged and snowcapped Elburz sierra, including Mount Damavand, the highest peak and volcano in the Middle East and Western Asia. Figure 1 shows the situation of Haraz River basin, hydrometry stations, planned agriculture areas and the Lar, Shydeh, and Sonbol Rud reservoir dams. Haraz basin, comprising the area drained by the two rivers of Haraz and Babol-Rud, covers about 6700 km2 of which the borders are Talar River basin on the east, Alish River basin on the west, Salt Lake basin on the south, and Caspian Sea on the north. As it is illustrated on Fig. 1, , agricultural areas of Haraz basin extend to the left and right shores of Babol-Rud River, and to the left and right shores of Haraz River. In this study, long-term data recorded at the hydrometry stations at Kare Sang (on Haraz River), Gharan Talar (on Babol-Rud River), Galugah (on Sajad-Rud River), Diva (on Kola-Rud River), and Boliran (on Garm-Rud River) were used to illustrate the balance of water resources and consumption. The above-mentioned hydrometry stations are located on the borders of the plain and agricultural areas. Babol hydrometry station on down-stream of Babol-Rud River is used as control point as well. Data of the above-mentioned stations are under quality control by Run-test and Double mass curve test. Void of data is also after filling them by using linear correlation with adjacent stations. It may be mentioned that the water discharge of each station for obtaining various probabilities are 50 years long (1957 up to 2006).

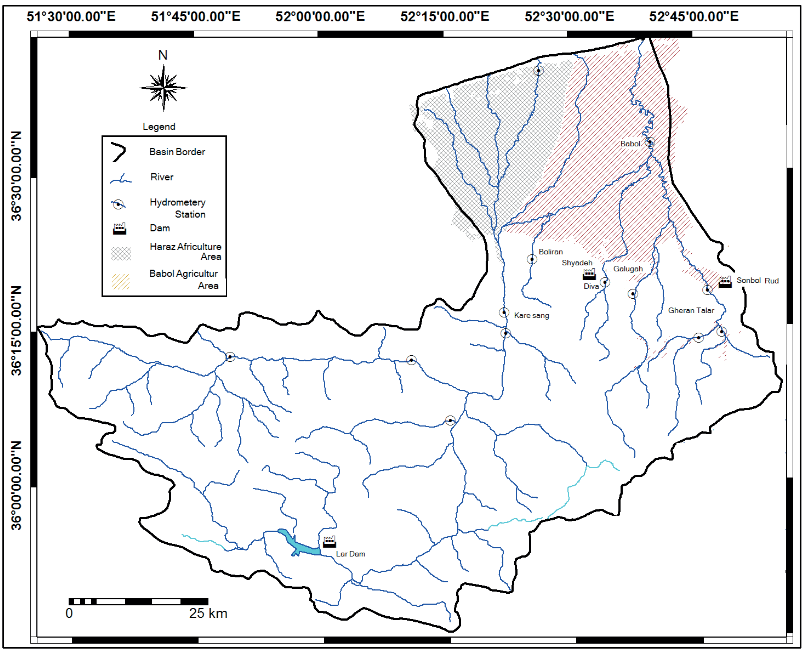

Fig. 1. Situations of Haraz basin, main rivers, dams, hydrometry stations and agricultural areas of Haraz River basin.

3. RESEARCH METHODOLOGY

One of the main problems in Planning and optimal operation of water resources in Iran is the lack of enough data on water consumption, especially in the agricultural sector.

Therefore, in spite of having the existing water resources data we confront with uncertainty in our planning. Using the information obtained by satellite images, remote sensing, and geographic information system, we try to solve this problem.

Iran pastures and forests organization has completed the landuse survey and planning throughout Iran including Haraz River basin. Landuse layer of Landsat Images is relevant to August 2002 and its map covers agricultural areas, forests, pastures and barren lands. The important point is that almost all of the existing agricultural sector water requirements of Haraz basin are based on paddy cultivation. Of course, there are some gardens in the region with little water consumption, but being very small, they were not considered in the calculations.

Considering the above-mentioned explanations, we have used the area of shown in Fig. 1 to calculate the agricultural sector water consumption for each branch of Haraz River.

Water requirements are also obtained from Netwat adjusted software. This software is provided by Iran Meteorology Organization. In this software, Penman-Monteith Method is used to calculate potential evapotranspiration. According to on-field studies, the crop coefficient (Kc) and the total efficiency the input to this software. Paddy cultivation average efficiency throughout the region is 60%.

Determining water requirements by the above-mentioned method had certain constraints such as lack of the correct estimates of areas, total efficiency, estimation errors of potential evapotranspiration, and Kc. Therefore, by using another method, we have updated the estimated figures. .

Iran Water Resources Management Company in a project titled “Trans-Iranian Surface Water Statistics” has given the specifications of all water withdrawal points from the Haraz River such as pumping stations, diversion dams, natural ponds (Abbandan), etc. Such data are composed of withdrawal capacity, down-stream areas and cropping pattern, etc. Figure 2 shows agricultural water withdrawal points in Haraz River basin.

Abbandans are natural or man-made water reservoirs and ponds, generally used in the northern regions of Iran. During the precipitation seasons these water reservoirs are refilled with water to be used for farming; however, most of precipitations near the seaside flow into the sea. These abbandans are also used for aquaculture. In Fig. 3, a typical abbandan in the study area is shown.

Therefore, in GIS environment, the information on the total capacity of all the withdrawal points were extracted and the potential volume of agricultural water withdrawal for each branch of Haraz River was superimposed to control agricultural water consumption. By fassuming that a part of the agricultural requirements will be met from the existing abbandans in the region, these were added to the total capacity of water withdrawal points.

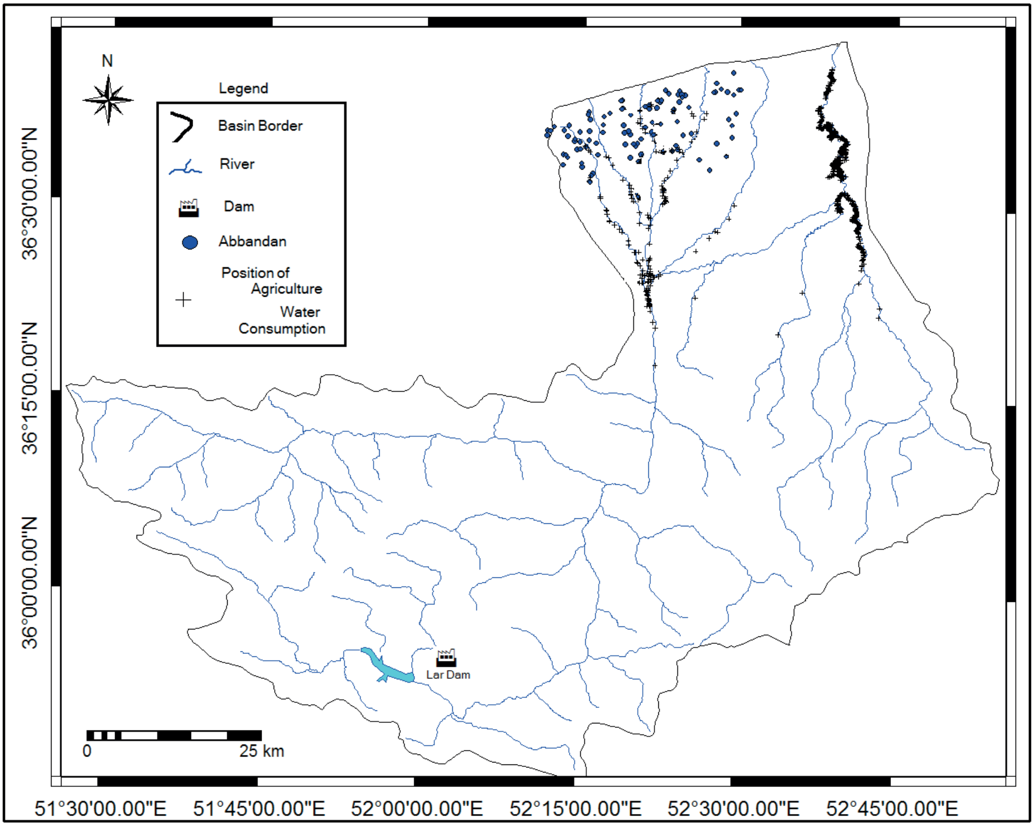

Fig. 2. Agricultural water withdrawal points in Haraz River basin

4. EXISTING WATER RESOURCES ENTERING THE PLAIN WITH VARIOUS PROBABILITIES

• Water Entry into the Plain with Various Probabilities

As it is shown in Fig. 1, major part of the accessible water resources to provide for surface water consumptions is from Haraz and Babol-Rud Rivers (head reaches of Babolrud, Sajad-Rud, Kla-Rud and Garm-Rud).

Therefore, we can conclude that the total water entering the Haraz basin is the total water discharged from hydrometry stations of Kore Sang, Gharan-Talar, Galugah, Diva, and Boliran, plus the volume of water in reservoir dams of Sonbol-Rud and Shyadeh.

Fig. 3. A typical abbandan in the study area

It is to mention that the Sonbol-Rud dam and the Shyadeh dam with the reservoir volume of 1.2 and 4.5 million cubic meters(MCM), respectively, with the corresponding rateable volumes of 2.6 and 6 MCM were constructed on the head reaches of Haraz River basin.

Using long-term data of the above-mentioned discharges from the hydrometry stations, we have calculated various probability percentages of supplying the flow rate by applying Weibull probability method.

The Kare Sang hydrometry station inflows have been under the influence of Lar dam out-flows in the up-stream since 1970-71. Therefore, providing a 50-year statistics period of this station, we have assumed that the dam effect on this station has existed since the beginning of the 50-years period (1957-58). Then the statistics period of 1957-58 up to 1979-70 has been rebuilt by the monthly and yearly linear correlation.

This procedure was adopted to calculate the various probabilities of Tajan River discharge at Kare Sang hydrometry station to consider the effects of Lar reservoir dam. For example, in Tables 1, 2 and 3, values of monthly and yearly mean discharge of Haraz River at Kare Sang hydrometry station, total discharges of Haraz basin relevant to Babold-Rud laterals (total discharges at Kare Sang hydrometry station, Gharan Talar, Galugah, Diva, and Boliran), total discharges of Haraz basin from Babol-Rud and Haraz laterals at probabilities of 60, 70, 80, 90, and 95 per cent are illustrated.

Table 1. Values of monthly and yearly mean discharge of Haraz River at Kare Sang hydrometry station with considered effects of Lar reservoir dam (MCM)

Probabilities (%)	Oct	Nov	Des	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Annual
95	31.4	30.7	31.3	29.8	30.5	33.9	44.9	82.8	64.2	53.1	39.3	34.4	506.4
90	35.2	38.2	34.7	33.6	32.8	35.6	53.1	105.2	103.9	62	44.3	37.6	616.2
80	43.9	41.1	38.5	35.7	35.9	36.9	61.8	113.1	111	64.7	48.2	39.2	669.8
70	45.1	44.7	40.5	38.1	37.3	38.6	68.4	124.4	116.4	77.4	54.7	44.3	729.9
60	47.4	45.9	42.9	39.9	39.3	40.7	73.2	129.9	124.4	83.3	57.5	48.4	772.9
Mean discharge	55.2	50.7	47.7	44.6	43.9	47.1	84.1	146.7	142	97.5	69.2	57.4	886

Table 2. Values of monthly and yearly mean discharge plus various probabilities of total surface water of Babol-Rud Laterals entered into the plain (MCM)

Probabilities (%)	Oct	Nov	Des	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Annual
95	8.7	12.3	15.2	14.7	19.7	25.1	31.1	10.5	7.3	6.7	6	9.9	167.2
90	15.4	15.6	17.2	17.1	21.2	31.4	35.4	13.6	8.5	9.5	8.5	11.3	204.9
80	19.7	20.5	19.8	20.3	23.5	36.5	38.5	18.6	10.6	11.4	11.2	14.5	245.2
70	23.6	24.6	24.1	23	27.2	39.8	42.9	22.7	13.4	13.5	13.5	19.7	288
60	27.1	29.1	27.8	25.1	29.9	43.5	46.9	26.8	17	18.6	16.9	23.6	332.3
Mean discharge	39.4	38.8	32.3	29.8	35.7	47.7	57.2	38.4	23.1	23.6	21	33.7	420.8

Table 3. Values of monthly and yearly mean discharge plus various probabilities of total surface water of Haraz basin, Haraz and Babol-Rud Laterals (MCM)

Probabilities (%)	Oct	Nov	Des	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Annual
95	40.1	43	46.6	44.5	50.2	59	76	93.3	71.5	59.8	45.3	44.4	673.6
90	50.7	53.8	51.9	50.7	54.1	67	88.4	118.9	112.4	71.5	52.8	48.9	821.1
80	63.6	61.5	58.3	56	59.4	73.3	100.3	131.7	121.6	76	59.4	53.7	915
70	68.7	69.3	64.6	61.2	64.5	78.4	111.3	147.1	129.8	90.9	68.2	64	1017.9
60	74.5	75	70.7	65	69.2	84.3	120.1	156.7	141.4	101.9	74.4	72	1105.2
Mean discharge	94.6	89.4	80	74.5	79.5	94.7	141.3	185.1	165.1	121.1	90.3	91.1	1306.8

• Abbandans as Natural Reservoirs of Surface Water Resources

On the basis of surface water statistics data, there are 351 Abbandans with the area of 4028 hectares and useful volume of 104.5 MCM on Haraz river basin agricultural areas, of which 107 Abbandans with useful volume of 31.5 MCM are located on Haraz river and 244 Abbandans with useful volume of 73 MCM are located on Babol-Rud river. Considering Abbandan's aquaculture requirements, out of the total volume of 104.5 MCM, about 35.6 MCM of water volume is used for aquaculture and the rest (68.9 MCM) is used for agriculture.

5. AGRICULTURAL AND ENVIRONMENTAL REQUIREMENTS OF SURFACE WATER RESOURCES

• Agricultural Requirements

As mentioned earlier, the agricultural water requirement was estimated by two methods. In the first method using the Penman-Monteith method, , the total annual agricultural water consumption was equal to 812.5 MCM. In the second method, the total capacity of water withdrawal points was equal to 729.4 MCM. Adding to it the capacity of water withdrawal from Abbadans (68.9 MCM), one arrives at 798.3 MCM as the annual water withdrawal capacity. The difference between the latter and the former method is 14.2 MCM which is being too sall, can be ignored. Therefore, the calculation method of agricultural water consumption by the first method is confirmable. Thus, Table 4 illustrates the total agricultural monthly water uses throughout Haraz river basin. On the basis of Table 4, it is observed that paddy agriculture period is during spring and summer month.

Table 4. Agricultural and aqua-cultural monthly water uses from the surface water resources throughout Haraz river basin without water supply from Abbandan resources (MCM)

Consumption	Oct	Nov	Des	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Total
Agriculture	0	0	0	0	0	0	124.5	138.6	152.6	173.2	103.9	0	692.9
Aquaculture	8.3	8.4	8.4	8.5	8.5	8.5	0	0	0	0	0	0	50.6
Total	8.3	8.4	8.4	8.5	8.5	8.5	124.5	138.6	152.6	173.2	103.9	0	743.5

• Environmental Requirements

In estimating environmental requirement in Haraz basin along various stretches of the river during different months, we have used a combination of Montana method, 30% method, ecologic and Bantic methods. The reason of not using one specific method is due to the merits and the demerits in each of the methods. For example, in Montana method recommended by Iran Ministry of Energy, the ecologic conditions relevant to each river are not considered. Besides, in some cases, data resulted from calculating 30% of discharge may be more than the river long-term monthly data. Some of the rivers may practically lack ecologic value; therefore, ecologic and Bantic method is not applicable in such rivers. On the basis of these explanations, Fig. 4 gives an example for determining the environmental water requirement of Haraz River at Kare Sang hydrometry station. Table 5 also illustrates environmental water requirement in various parts of Haraz River.

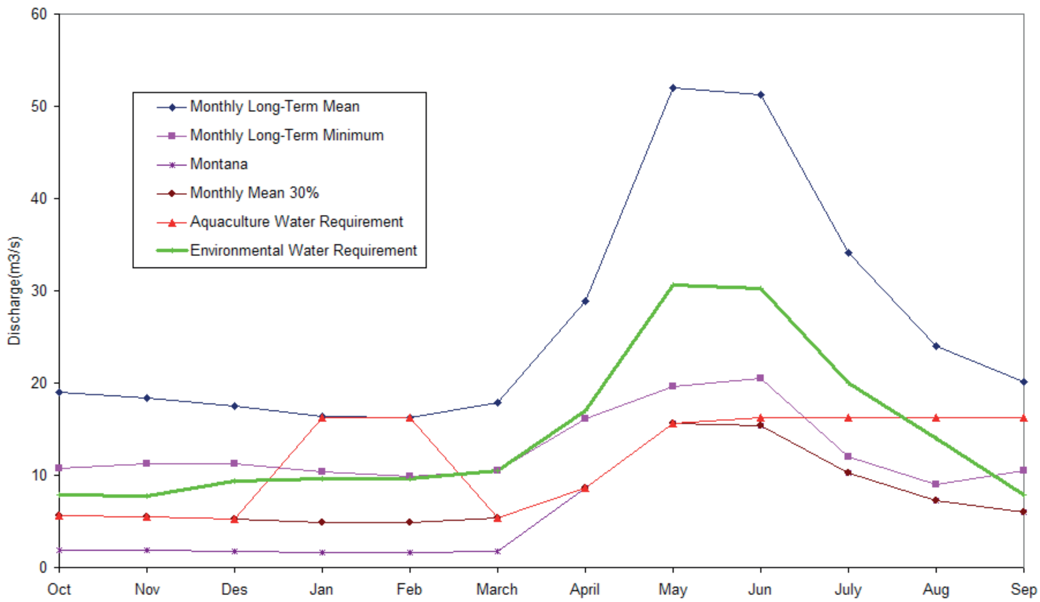

Fig. 4. Month-wise environmental flow requirement of Haraz River.

Table 5. Monthly and yearly environmental water requirement in Haraz basin (MCM)

Station	Oct	Nov	Des	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Total
Kare Sang	20.5	20	24.4	24.9	24.9	26.3	45.5	82	80.9	53.6	37.5	21.2	461.5
Sorkh-Rud	4.5	6.5	4.7	4.4	3.6	3.3	2.1	2.9	1.9	1.9	1.9	1.9	39.5
Gheran-Talar	6.2	6.5	5.4	3.4	4.1	5.8	10.4	6.2	4.7	3.1	3.5	5.6	64.9
Babol	17.1	17.6	15.8	14.3	15.6	18.8	17.9	9.4	4.7	5.5	5	12.3	154

6. COMPARING RESOURCES AND USES IN THE VARIOUS PARTS OF THE RIVER (OPERATIONAL CHALLENGES)

- ## Comparing withdrawals and inflows of Babol-Rud river at Gharan-Talar Hydrometry Station

Figure 5 shows the balance of resources and requirements in Gharan-Talar station. On the basis of this figure, we notice that with the probability of 80 percent, all of the requirements (including environment) can annually be fulfilled. With such probability, the surplus flow shall be about 66.6 MCM. With the probability of 90 percent, in all months (except June), the requirements shall totally be fulfilled as well. With the average flow, there are also about 165.3 MCM surplus flows.

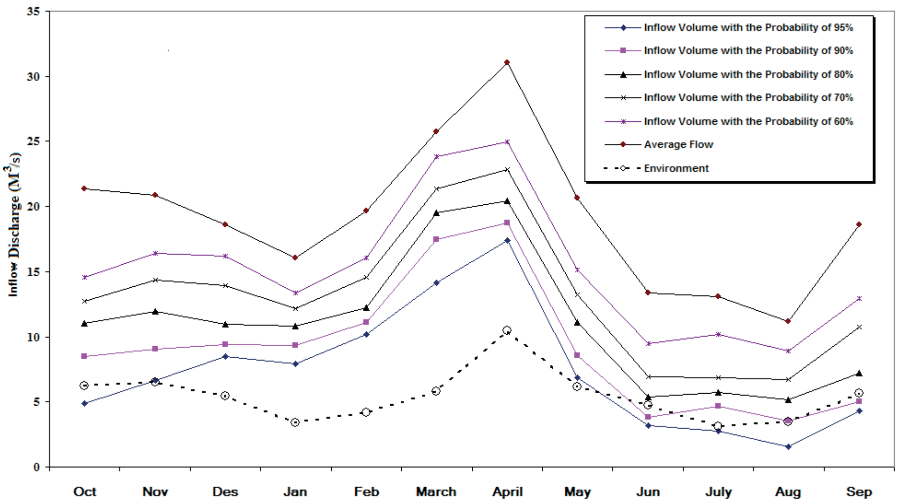

Fig. : Various probabilities of Babol-Rud river flow at Gharan-Talar hydrometry station compared with requirements

- ## Comparing Resources and Uses of Babol-Rud river up to Babol Hydrometry Station

Figure 6 shows the balance of resources and requirements in this part of Babol-Rud River. In this figure, we notice that even for the average inflow case, water consumption in July and August is not completely fulfilled.

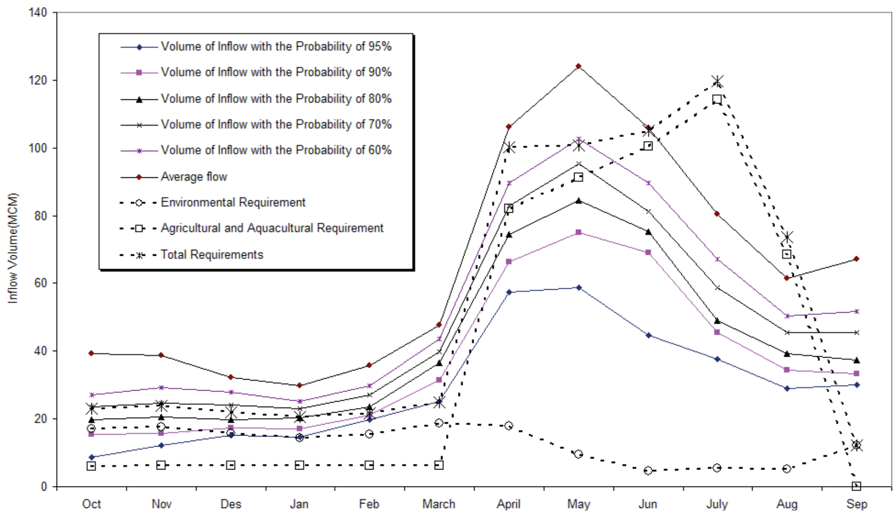

Fig. .: Various probabilities of Babol-Rud river inflows at Babol hydrometry station compared with total downstream requirements

• Comparing Resources and Uses of the Whole Babol-Rud river

Figure 7 illustrates the balance of resources and requirements of the whole Babol-Rud River. On the basis of figure No.7, we notice that even in the normal flow condition of the river, fulfillment of the total water consumption is not probable. In case of normal flow, there is also about 90.4 MCM annual surplus flows, however, in the other probabilities, there is deficit of inflow between 44.8 MCM up to 325.4 MCM.

• Comparing Withdrawals and Inflows Relevant to Haraz river at Kare Sang Hydrometry Station

Figure 8 shows the balance between the available resources and the requirements relevant to Haraz River at Kare Sang hydrometry station. On the basis of this figure, we notice that with the probability of 90 percent, total requirements (including environment) can annually be supplied, and with this probability, flow surplus shall be about 154.7 MCM. With the probability of 95 per cent, in all months (except June and July), total requirements shall also be fulfilled. It is to mention that in the average inflow case, about 424.6 MCM flow surplus shall exist.

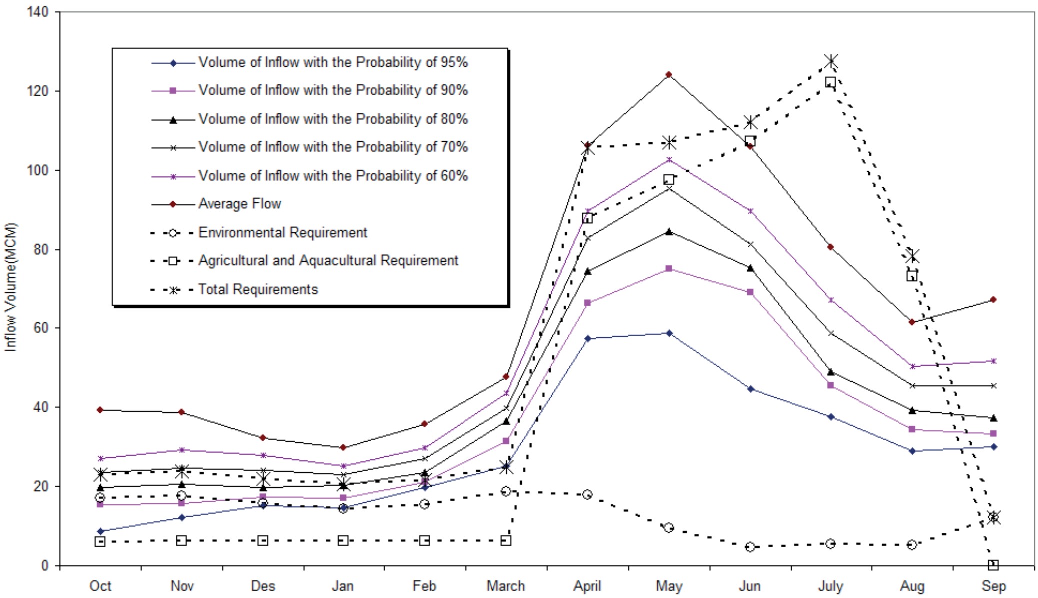

Fig. 7. Various probabilities on total Babol-Rud river inflows compared with total downstream requirements

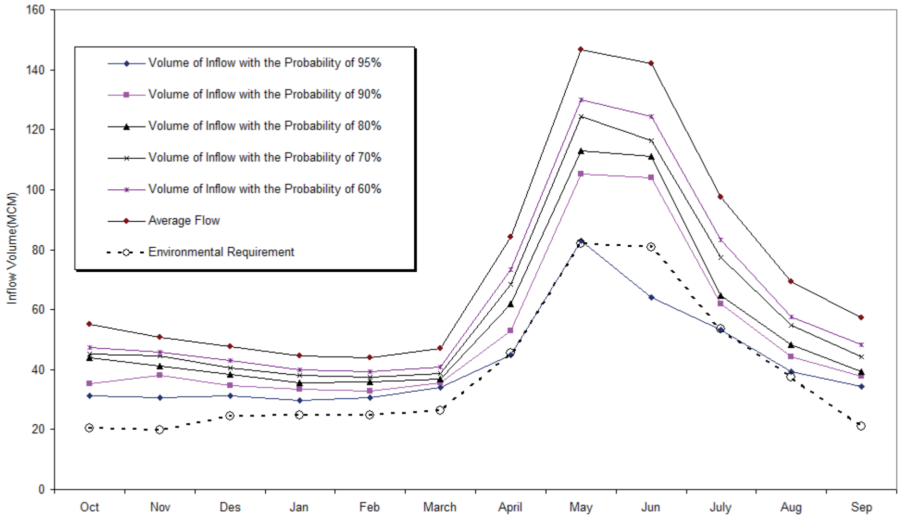

Fig. 8. Various probabilities relevant to Haraz river at Kare Sang hydrometry station compared with total downstream requirements

• Comparing Withdrawals and Inflows Relevant to Haraz River Somewhat after Hezar-Sangar Diversion Dam

In this part of the river, with inter-basin water transfer in the agricultural season with the ratio of 7 to 5, part of water flow shall be conveyed to Babol-Rud via Kari canal. Therefore, considering this point, Fig. 9 shows balance of resources and requirements relevant to Haraz River somewhat after Hezar-Sangar diversion dam.

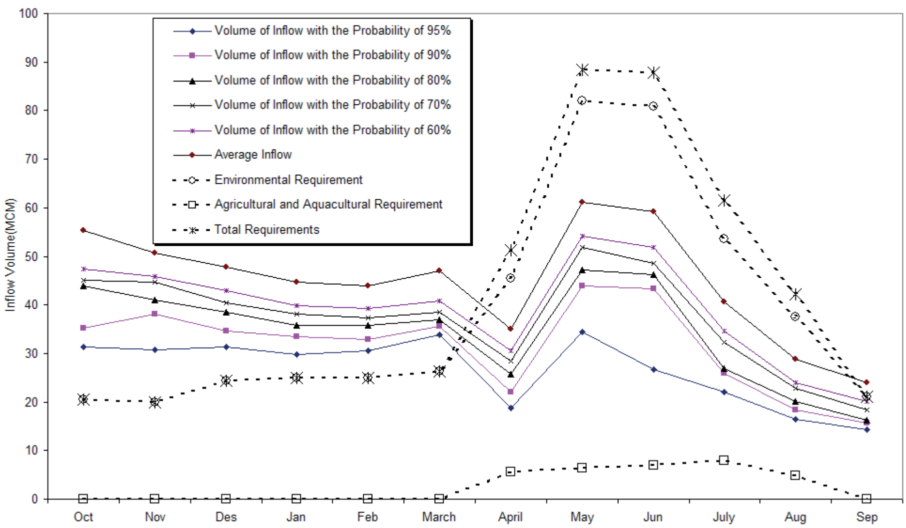

Fig. 9. Various probabilities relevant to Haraz river inflows somewhat after Hezar-Sangar diversion dam compared with total downstream requirements

Considering this figure, we notice that during April up to August due to water transfer from Haraz River into Babol-Rud River, environmental requirements even in normal conditions shall not be fulfilled. This case can be one of the main challenges in this region. Of course, in average conditions, there is about 44.7 MCM flow surplus.

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