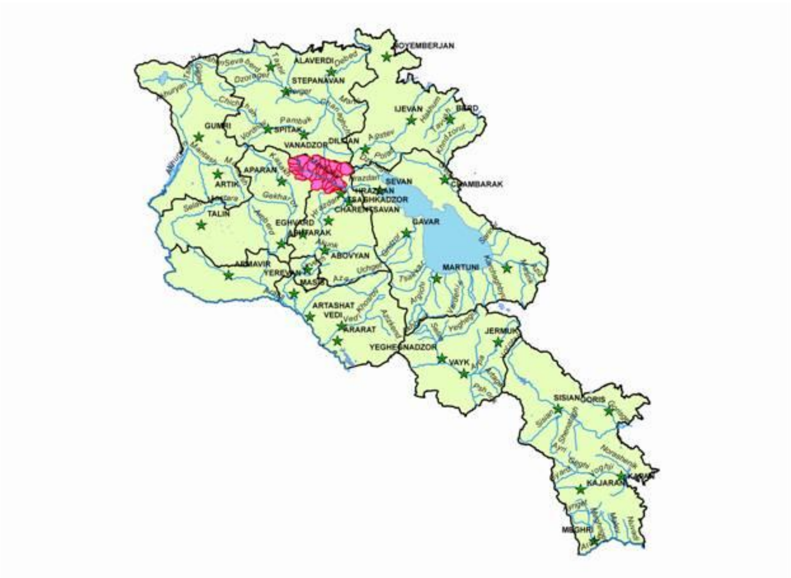
BASELINE CONDITIONS AND PRESSURE ON FOR INTEGRATED WATER RESOURCES MANAGEMENT IN THE MARMARIK RIVER BASIN IN ARMENIA



September 2007
Yerevan, Armenia

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ACHIEVEMENTS AND BOTTLENECKS ON INTRODUCING IWRM PRINCIPLES IN ARMENIA

Introduction

The reforms in sector of water resources management of the Republic of Armenia were initiated since 1999-2000 through the World Bank supported project "Integrated Water Resources Management". As a result of implementation of the project water resources of Armenia were assessed, structural reforms for water resources management were suggested, and outline of the management of water supply and demand was formulated. In addition to this, the idea of river basin management was proposed through introduction of annual and long-term planning mechanisms of water resources.

Taking into consideration the recommendations of the "Integrated Water Resources Management Program" in 2001 the Government of the Republic of Armenia initiated a targeted program for improving water sector in the country, revised the legal and institutional framework in the field. All this was incorporated in Resolution No. 92 on "Concept for Water Sector Reforms in the Republic of Armenia", adopted by the Government.

Legal Reforms

One of the most important steps in water sector reforms is the adoption of the new Water Code of Armenia on June 4, 2002. The Code contains the idea of integrated river basin planning, promotes the allocation of water resources based of supply and not demand, creates basis for establishment of the State Water Cadastre, obliges to issue water use permits based on available information, provides an opportunities for employing economic mechanisms in the course of management of water resources.

In order to ensure the proper application of the new Water Code of Armenia, since 2002 the Government has prepared over 80 regulations and by-laws, which relate to the procedures of issuing water use permits, river basin management, transparency and public participation in decision-making process, information accessibility, esttablishment of the State Water Cadastre (SWC), formation of water resources monitoring, management of transboundary water resources and others.

In 2005 Republic of Armenia Law on "Fundamental Provisions of the National Water Policy" was adopted, which presents a long-term development concept for strategic use and protection of water resources and water systems. Since 2005, the principles of river basin management have been applied in Armenia.

In 2006 "Law on the National Water Program of the Republic of Armenia" was adopted. The overall goal of the law is development of measures aimed at satisfying the needs of the population and economy, ensuring of ecological sustainability, formation and use of the strategic water reserve, and protection of the national water reserve.

The objectives of the law are as follows:

- development of measures aimed at definition of the national water reserve, strategic water reserve, useable water resources and conservation and enhancement of the national water reserve, classification of water systems, development of criteria for defining the state significance water systems and definition of a list of those systems,
- definition of maximal and minimal amounts of water use payments, including the definition of payment rates for water extraction and return and the rates of environmental fees,
- assessment of water demand and supply,
- development of a strategy for storage, distribution and use of water resources,

- development of measures aimed at adoption and implementation of normative acts that would support the implementation of the National Water Program, enforcement of suggestions for emendation of those acts, and coordination of activity performed by the State government bodies,
- definition of measures aimed at development of water standards, adjustment of ecological flow volumes and maximum permissible quantities of water withdrawn for consumption, definition of specially protected basin areas or a list of a part of them and zones of ecological emergencies and ecological disasters, prevention of negative impact on water eco-systems, improvement of water resources monitoring and pollution prevention,
- development of descriptions of measures envisaged by the National Water Program, their scopes, responsible bodies and time frames of implementation thereof,
- definition of financial requirements and funding sources suggested for the implementation of the National Water Program,
- ensuring of public awareness.

Short-term (until 2010), medium-term (2010-2015) and long-term (2015-2021) measures for implementation of the National Water Program objectives are defined in the law as well.

Institutional Reforms

Resolution No. 92 on "Concept for Water Sector Reforms in the Republic of Armenia", adopted by the Government in February 2001 clearly presented the strategy of institutional reforms of the Armenian Government in the field of water resources. Institutional framework envisaged by the Water Code of Armenia almost entirely implies from the above-mentioned Concept.

A new institutional system was introduced, according to which management of water sector is implemented by the following authorities:

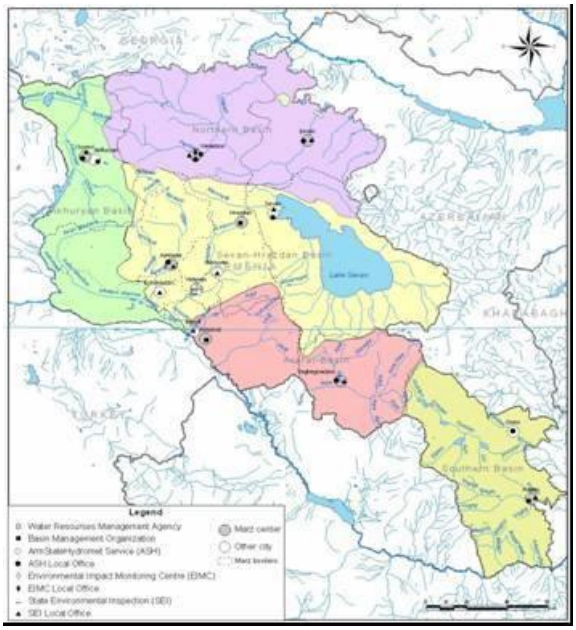
1. Ministry of Nature Protection of the Republic of Armenia, and its Water Resources Management Agency, which implements management and protection of water resources,
2. State Committee on Water Systems under the Ministry of Territorial Administration of Armenia, which implements the state management of water systems,
3. Public Services Regulatory Commission of Armenia, which implements tariff policy in water sector.

Table 1: Main functions of the agencies involved in water sector management

	Management and Protection of Water Resources	**Regulation of Tariffs**	**Management of Water Systems**
Authorized Agency	Water Resources Management Agency	Public Services Regulatory Commission	State Committee on Water Systems
Main Functions	Monitoring and allocation of water resources, Strategic management and protection of water resources	Regulation of tariffs for non-competitive water supply and discharge services in drinking, household and irrigation water sectors, Protection of consumers' rights	Management of water systems under the state ownership, Support to establishment of Water Users' Associations and Unions of Water Users, arrangement of tenders on management of water systems

	Management and Protection of Water Resources	Regulation of Tariffs	Management of Water Systems
Enforcement Tools	Water use permits	Water system use permits	Management contract

In order to promote more efficient, targeted and decentralized management of water resources, 5 territorial divisions (Northern, Akhuryan, Araratian, Sevan-Hrazdan and Southern) have been established under the auspices of the Water Resources Management Agency.



Picture 1: Water Basin Management Authorities of Armenia

Water Basin Management Authorities (WBMA) are responsible for development of river basin management plans, registration of water use permits, protection of water resources, compliance assurance of water use permits, definition of water regime, as well as development of water resources allocation plans for the five water basin management areas.

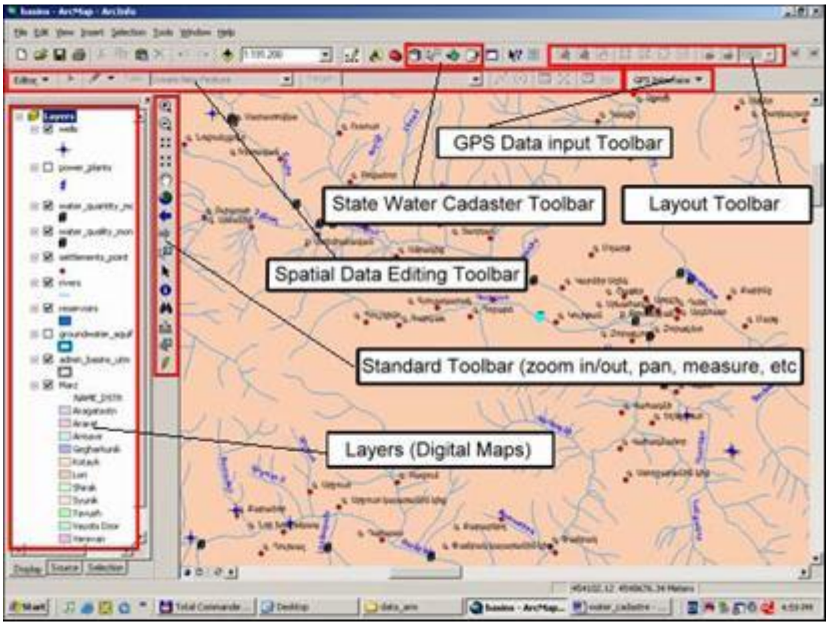
State Water Cadastre of Armenia

Parallel to the legal and institutional reforms mentioned above the State Water Cadastre for Armenia (SWC) has been developed, which is one of the most important supporting tools for introduction of IWRM process in Armenia. SWC is a continuously functioning system, which registers integrated data on water resources quantity and quality indicators, watersheds, materials extracted from river beds, composition of biological resources, water users, water use permits and water system use permits.

The institute of the SWC nowadays has corresponding supporting legal framework and implements the following tasks:

- Establishment of data warehouse related to water sector,
- Registration of documentations in the cadastre and provision of corresponding information,

- Formation of the tasks for water resources monitoring,
- Planning of the implementation of water resources monitoring, and inclusion of the monitoring results into the management process,
- Inventory of hydro-technical structures related to water resources, in order to increase the efficiency of water use,
- Composition of water resources balance, according to separate river basins and overall.



Picture 2: Combination of SWC-GIS Systems in Armenia

Challenges

Due to the above-mentioned institutional and legal reforms in the field of introduction of IWRM principles, the Republic of Armenia is one of the leaders in the field in the region. However, there are several issues which the Government of Armenia needs to address in the near future.

The legal framework in the water sector is new and dynamic, which requires significant efforts, and will face challenges as its implementation moves forward. Consistency of several legal documents is one of the areas of concern, which sometimes creates confusion in the institutional framework as well.

One of the key obstacles observed is the lack of coherence and consistency among several laws, regulation, by-laws and decrees adopted by the Government or water sector agencies. Also there is a need to develop additional laws in the field of water resources.

Several agencies involved in water resources management need strengthening both in technical and institutional aspects. Agencies within the Ministry of Nature Protection, that are in responsible for monitoring, compliance assurance and enforcement (ArmStateHydromet, Environmental Impact Monitoring Center, State Environmental Inspectorate), need considerable assistance in terms of strengthening and equipment. Several other agencies, directly under the Ministries, that are in charge of various aspects of water resources management, need capacity building. Among them are the agencies involved in spatial and environmental protection planning according to IWRM principles, since there is a need for significant cooperation among the water resources, nature protection and land use planning. In addition, in the above-mentioned strengthening efforts, it is critical to mention the need for coordination and cooperation between the agencies, and particularly data and information exchange.

In the long-run, the Water Resources Management Agency and its Water Basin Management Authorities should become the authority responsible for integrated water resources management and planning in Armenia. This requires a continuous process of institutional strengthening and capacity building. WRMA should continue his role of the leading agency in charge of overall management of the water resources. However, in a long-term, some functions and tasks of WRMA should be transferred to WBMAs.

As a summary, it is worth to mention that the key elements of international experience and integrated water resources management are already introduced in Armenia. Armenia has separated the following three functions of water resources management: a) overall water resources management, b) management of sectoral water services, and c) protection of the environment. All these three management functions are closely related to each other. Agencies involved in this three aspects should cooperate closely in order to achieve adequate level of water resources management in the country. In addition to this, in the field of management of sectoral water services, Armenia has separated the functions of management, regulation and operation and maintenance.

Of course most of the newly established agencies require significant institutional strengthening and capacity building, in order to implement tasks assigned to them. However, key IWRM principles are already introduced in Armenia through the above-mentioned institutional changes.

GENERAL DESCRIPTION OF MARMARIK RIVER BASIN

Executive Summary

River Marmarik is located on the northern part of Kotayq marz of Armenia. It includes 12 settlements with over 7,700 total population. 48.8% of the total population comprise men, and 51.2% women. Entire territory of Marmarik River Basin composes approximately 418 km^2, or 1.4% of the total territory of the Republic of Armenia. About 13% of the territory of the river basin (55 km^2) is covered by forest. Nearly 35% of the territory are irrigated lands. Climate is usually mild, and the river basin is considered as one of the major resort centers of the Republic of Armenia.

Marmarik River is the largest tributary to Hrazdan River. It has a length of 37 km, and the total area of the watershed is 418 km^2. River flow is formed by the small rivers flowing from Pambak and Tsaghkunyatz mountain ranges. The river flows into Hrazdan river at 116 km above the river mouth. River Marmarik is formed and flows only within the territory of Armenia.

There are 2 hydrological observation points (Marmarik-Aghavnadzor and Marmarik-Hanqavan) and 2 water quality sampling points in Marmarik River Basin. The table below provides the main hydrological characteristics of Marmarik River in the hydrological observation points Marmarik-Aghavnadzor and Marmarik-Hanqavan.

Table 2: Hydrological characteristics of the observation points

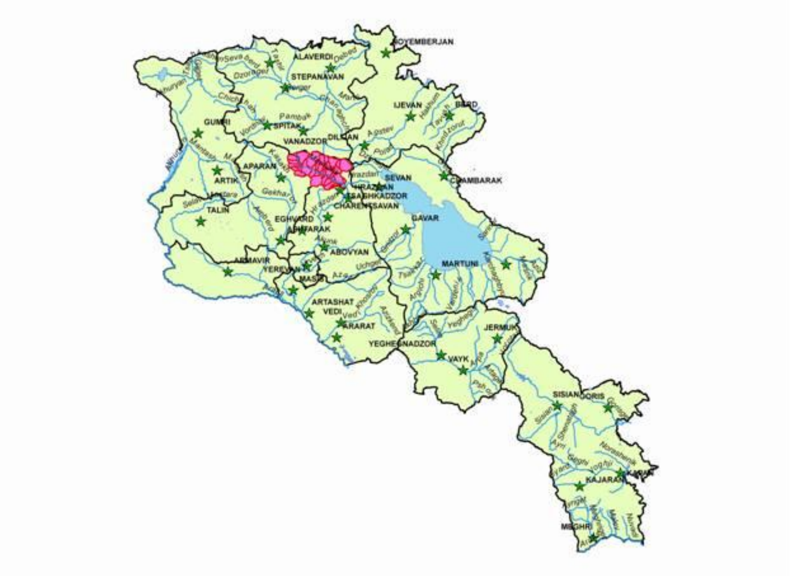
Observation point	W, Flow Volume, km^2	M Flow Module, l/sec. km^2	H, Flow Layer, mm	F, Area of the Watershed, km^2
Marmarik-Hanqavan	0.048	16.1	509	93.5
Marmarik-Aghavnadzor	0.19	15.7	494	324.5

According to 2007 data annually approximately 12.6 mln. m^3 of water is being used from Marmarik River for various water use purposes (excluding the annual use of approximately 3 mln. m^3 of water for hydro-energy purposes). Thus, if we include also hydro-energy, then the total water use will be 2.89 m^3/second. Subtracting 2.89 from the free flow (4.7 m^3/sec.), we receive 1.81 m^3/sec. Thus, in the territory under the impact of water use for hydro-energy purposes about 60% of the actual potential of water is being used, whereas during the irrigation seasons a water deficit is observed.

The analysis of water quality conducted by the Environmental Impact Monitoring Center of the Ministry of Nature Protection of Armenia shows that the water of Marmarik River has average hardness. The concentration of suspended elements is low and is within the allowable limits. Alongside the river no significant changes of the parameters are observed, and their concentration near the river mouth and upstream part of the river is almost the same, within the range of error margin. The oxygen regime of the river for 1986-2007 has been satisfactory and the level of oxygen varied within the range of norm (7.6-10.7). The average values of BOD_5 and COD for 2006 and the first 8 months of 2007 were within the allowable limits of corresponding MACs for fisheries. High values of oxygen, and the fact that for 2006 and the first 8 months of 2007 the average values of BOD_5 and COD are within the MACs for fisheries shows that the level of organic pollutants in the river's water is low and that the river has high self-cleaning potential. The average annual values of all hydro-chemical indicators except from V, Mn and Al, are within the limits of MAC for fisheries. The concentrations of the elements Cr, V, Cu are almost the same near the river mouth and the upstream part and exceed the corresponding MACs for fisheries 2-4 times. This is due to the geo-chemical and hydro-geo-chemical peculiarities of the watershed.

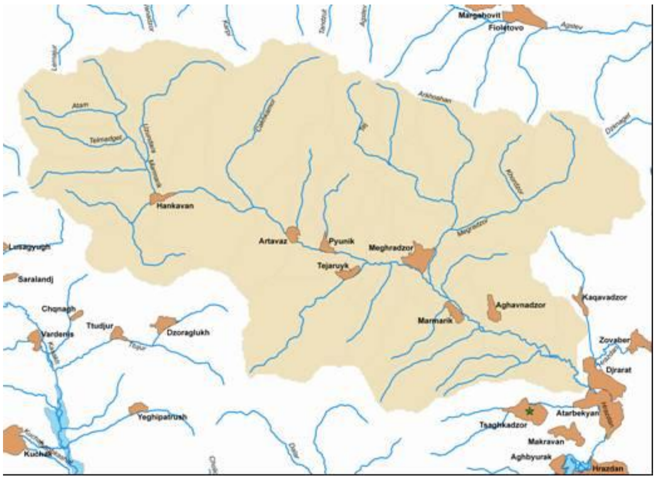
Description of the River Basin

Marmarik River Basin is located in the northern part of Kotayq Marz of the Republic of Armenia.



Picture 3: Location of Marmarik River Basin in Armenia

Marmarik River Basin includes 12 settlements with more than 7,700 total population. 48.8% of total population are men, and 51.2% women.

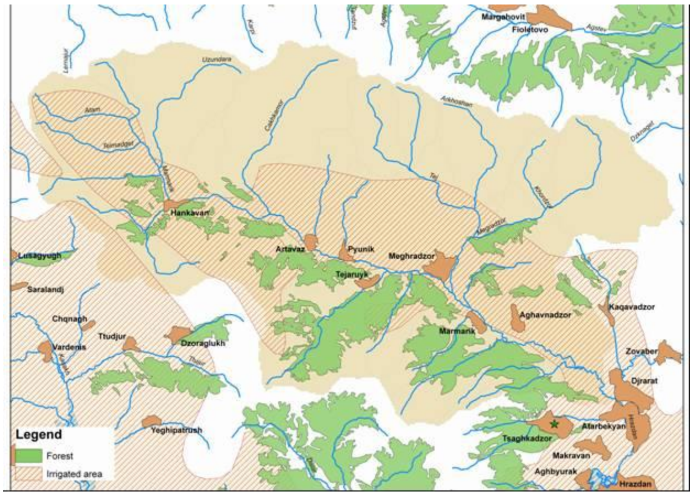


Picture 4: Settlements of Marmarik River Basin

Table 3: Distribution of population in Marmarik River Basin by settlements

Settlement	Population number	Of which men	Men in %	Of which women	Women in %
Maqravar	0	0	-	0	-
Jrarat	380	181	47.6	199	52.4
Atarbekyan	0	0	-	0	-
Tsaghkadzor	1578	758	48.0	820	52.0
Aghavnadzor	1261	630	49.9	631	50.1
Marmarik	765	378	41.6	387	58.4
Meghradzor	2678	1319	49.3	1359	50.7
Tejaruyq	29	12	41.4	17	58.6
Pyunik	375	189	50.4	186	49.6
Artavaz	547	254	46.4	293	53.6
Hanqavan	118	54	45.7	64	54.3
Kaqavadzir	0	0	-	0	-
Total	**7731**	**3775**	**48.8**	**3956**	**51.2**

Entire territory of Marmarik River Basin is 418 km^2, or 1.4% of the total territory of the Republic of Armenia. Approximately 13% of the territory of the river basin, or 55 km^2, is covered by forest, and 35% are irrigated lands. The climate in the river basin is mild, and makes the basin one of the popular resorts centers in Armenia.



Picture 5: Forest cover and irrigated lands in Marmarik River Basin

In order to provide for scientifically justified complex and rational use and protection of water resources of the basin, and in order to maintain the natural regime of the River, on March 23, 1981 a Decision No. 148 of the Council of Ministers of the Armenian Soviet Socialist Republic was adopted on "Establishment of Hydrological Reserve in the Upstream Part of Marmarik River". The territory of the Hydrological Reserve is defined from the mouth of Marmarik River until its end, village Hanqavan, with a territory of 93.5 km^2. According to the Decision, in order to maintain the etalon regime in the territory of the Hydrological Reserve, the following activities are prohibited:

- Construction of artificial lakes, obstacles, distribution systems, irrigation and drainage systems on the river,
- Change of flow direction of the river,
- Extraction of surface and underground water resources in volumes that have impact on the hydrological regime of the River,
- Discharge of mineral waters into the river, as well as water taken outside of the river basin,
- Draining of forests and wetlands,
- Change of nature of the areas (construction of large open-mines and others),
- Other activities, which might have significant impact on the hydrological regime of the water object.

Hydrological and Morphological Characteristics of Marmarik River

Description of the River

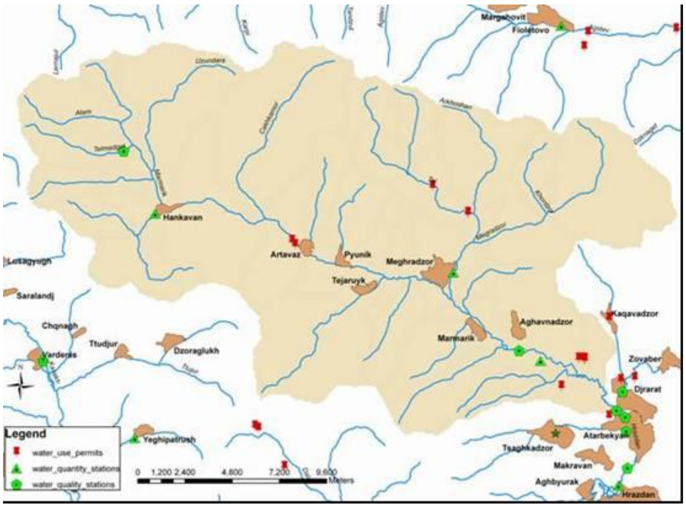
Marmarik River is the largest tributary to Hrazdan River. It has a length of 37 km, and the total area of the watershed is 418 km^2. River flow is formed by the small rivers flowing from Pambak and Tsaghkunyatz mountain ranges. The river flows into Hrazdan river 116 km above the river mouth. River Marmarik is formed and flows only within the territory of Armenia.

Table 4: Main morphological characteristics of Marmarik River

Name of the river	Flows into	Altitude at Source, m	Altitude at River Mouth, m	Length, km	Average incline	Area of Watershed, km^2
Marmarik	Hrazdan	2520	1699	37.0	22	418

The average incline of rivers in Armenia varies between 25-35%. As a matter of fact, Marmarik River being typical mountainous river, is not considered so according to the Armenian criteria. One of the main advantages of mountainous rivers is the high capacity for self-cleaning, which is formed particularly from the average incline and altitude above the sea level. Taking into consideration this, it is possible to provide initial conclusion, that the self-cleaning capacity of Marmarik River is average, compared to other river in Armenia. And, of course, in order to evaluate the self-cleaning capacity of Marmarik accurately it is necessary to conduct further detailed studies.

There are 2 hydrological observation points (Marmarik-Aghavnadzor and Marmarik-Hanqavan) and 2 water quality sampling points in Marmarik River Basin.



Picture 6: Hydrological observation points, water quality sampling points, and location of water use permits in Marmarik River Basin

The table below provides some morphological characteristics for Marmarik River at the hydrological observation point Marmarik-Aghavnadzor.

Table 5: Morphological characteristics of the river for the main sections of hydrological observation points

River-observation point	Distance from the river mouth, km	Incline of the river		Main characteristics of the watershed			
		Average from the forest point	Average balanced from the farthest point	Area, km^2	Average altitude, m	Average incline	Forest cover, %
Marmarik-Aghavnadzor	8.0	37	22	375	2350	338	13

Table 6: Morphological characteristics of Marmarik River

		Flow					
River-observation point	Average altitude, m	Module, l/sec. km^2	Average annual discharge, m^3/sec.	Flow coefficient	Seasonal distribution, %		
					III-VI	VII-XI	XI-II
Marmarik-Aghavnadzor	2350	14,5	5,43	0,57	75	19	6

As seen from the table, the distribution of flow of Marmarik River is closely related to seasonal variations. Maximum flow is observed in spring months. Afterwards, the flow is mainly formed through feeding from groundwater sources, and to some extent from precipitations.

The multi-year average flow of Marmarik River, as well as all rivers in Armenia, is highly fluctuating. It is important thing to know for the guaranteed use of the flow. Dry years, and particularly the sequence of dry years, decrease the use water flow in the river.

Table 7: River flow in calculated sections in average and calculated years

River, Calculated Section	Change in flow coefficient	River flow, m^3/sec.				
		5%	25%	50%	75%	95%
Marmarik-Aghavnadzor	0.25	7,96	6,24	4,90	4,40	3,16

Multi-year variability of the flow numeral is expressed with the coefficient CV, which is defined as the ratio of differences in average square value multi-year annual flow and average annual flow.

Table 7 presents the changes in flow coefficient for Marmarik River. It can be different not only for various rivers, but also for various segments of the same river. As a matter of fact, the change in flow coefficient in the upstream part of Marmarik River is quite high (CV=0.25-0.35 - for all rivers). This means that the volume of flow of the river is highly contingent upon seasonal variations. A careful attention should be paid to this fact while presenting the distribution of river water supply.

Table 8: Sources of the River (%)

River-Observation Point	Melting	Precipitation	Underground
Marmarik-Aghavnadzor	55	18	27

As seen from Table 8, Marmarik River has mixed water sources, where, however, melting prevails. Breakdown by months shows that there are also some differences between the warm and cold seasons. During the warm seasons, i.e. between 4th and 10th months, 60-90% of the total annual flow is observed in the river. Particularly, the upstream segment of the river mainly relates to surface flow.

However, for Marmarik River the feeding from groundwater sources has also significant importance, which is seen from the information presented in Table 10. Here the maximum average module is greater than the maximum average discharge by approximately 2.5 times. When such difference is significant (more than 4 times), it can be claimed that the river or its segment has prevailing feeding from surface sources. In case of Marmarik River it can be claimed that feeding from groundwater sources has also its role in forming the annual flow.

Table 9: Mean values of the main characteristics of the spring mudflows

River-observation point	Mudflows				Flow layer compared to annual, %
	Date (day, month)		Duration, days	Flow layer, mm	
	Beginning	End			
Marmarik-Aghavnadzor	30.03	30.06	93	294	74

Mudflows in spring are one of the main phases for Marmarik River flow. Usually, the maximum discharge is observed during the spring mudflows.

Table 10: Maximum discharge of the river

River-observation point	Duration of observation, years	Absolute maximum discharge		Maximum average discharge and module	
		m^3/sec.	day, month, year	m^3/sec.	l/sec. km^2
Marmarik-Aghavnadzor	52	86.7	03/05/87	40.0	107

Table 11: Description of the average multi-year minimum flow of the river

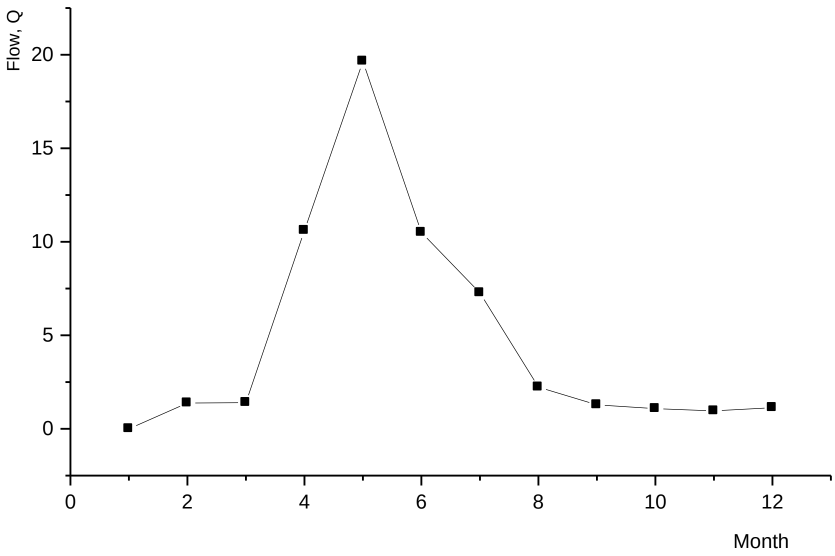
River-observation point	30-day discharge and module		Daily discharge and module	
	m^3/sec.	l/sec. km^2	m^3/sec.	l/sec. km^2
Marmarik-Aghavnadzor	0,87	2,25	0,91	1,53

During the summer dry-season periods feeding from groundwater sources prevails. Despite the fact that melting water contributes to increase of feeding from groundwater sources, during spring mudflows the surface flow significantly supersedes groundwater flow due to the large quantity of precipitations. For Marmarik River, and in general most rivers in the Republic, the average multi-year 30-day and average multi-year daily minimum flow modules vary insignificantly (as seen from Table 11, the average multi-year 30-day and average multi-year daily minimum flow modules for Marmarik River vary only by 0.7 l/sec. km^2). Exceptions for differences in flow modules are usually observed in small tributaries which are feed from groundwater sources and originate from high-mountain snow melting. For such tributaries the minimum 30-day and daily flow module difference is on average 5-9 l/sec. km^2.

When observed as water use resource, for Marmarik River the flow discharge is very important observed by average monthly values. Breakdown of annual flow of Marmarik River in years with 50% of flow is one of such characteristics (Table 12).

Table 12: Breakdown of annual flow of Marmarik River in years with 50% of flow (m^3/sec.)

River name	I	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII	Average
Marmarik-Aghavnadzor	1.38	1.38	1.40	10.60	19.65	10.50	7.27	2.23	1.28	1.08	0.96	1.13	4.90



Picture 7: Breakdown of annual flow of Marmarik River in years with 50% of flow (m^3/sec.)

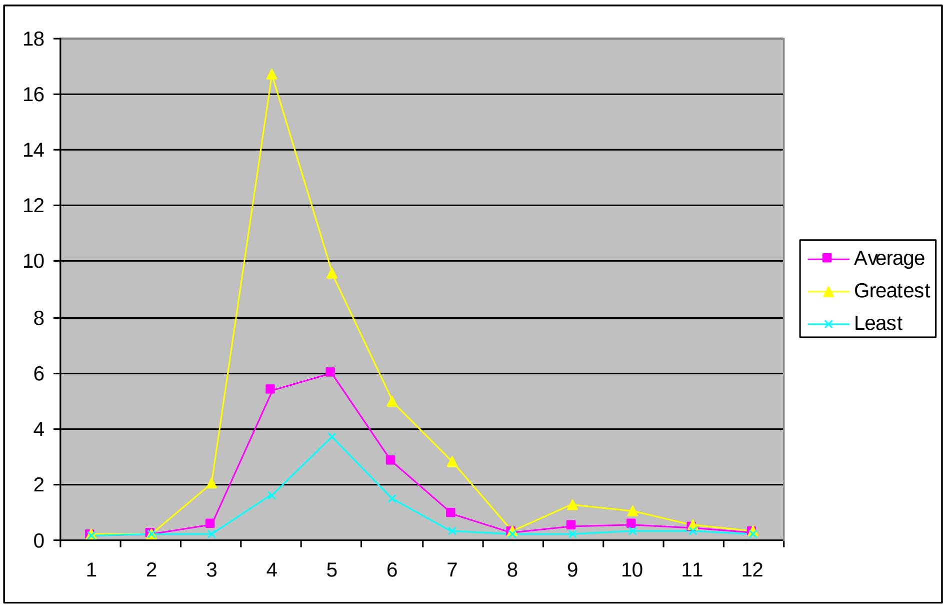
The above-mentioned characteristics relate to the natural flow of the river. For that purpose, in order to realistically assess the sources of the river flow and of its segments, it is necessary to take into consideration both actual, and anticipated volumes of water use, as well as their regimes.

Annual distribution of the river water shows that starting from the month of July the water discharge compared to average annual discharge significantly decreases during intensive water use (mainly irrigation) period. Picture 7 presents the breakdown of annual flow of Marmarik River. In order to assess the river flow as a source for water supply and irrigation, one should take into consideration that in winter-time the river feeds exceptionally from groundwater sources.

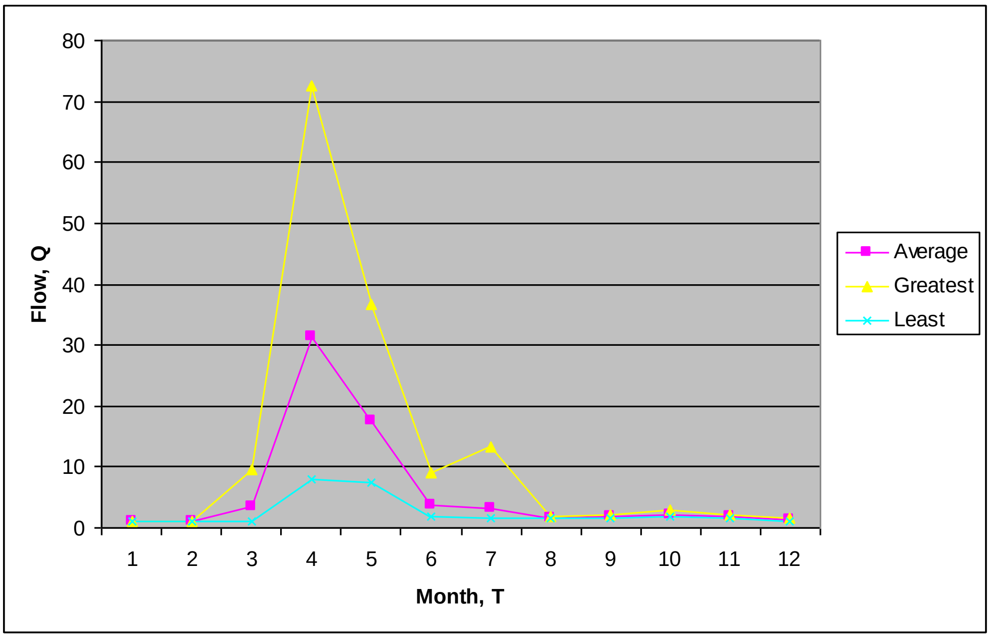
Table 13: Discharge of Marmarik River

Observation point		Month											
		I	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII
Marmarik-Hanqavan	Ave.	0.19	0.22	0.55	5.37	5.98	2.80	0.95	0.26	0.52	0.57	0.43	0.27
	Max.	0.20	0.23	2.04	16.7	9.58	5.00	2.83	0.33	1.25	1.07	0.56	0.32
	Min.	0.18	0.20	0.24	1.59	3.73	1.48	0.31	0.23	0.23	0.36	0.32	0.24
Marmarik-Aghavnadzor	Ave.	1,04	1,03	3,50	31,3	17,6	3,78	3,27	1,68	1,81	2,20	1,82	1,37
	Max.	1,13	1,08	9,53	72,5	36,8	8,94	13,2	1,89	2,05	2,89	2,05	1,62
	Min.	0,98	0,99	1,14	7,88	7,41	1,96	1,62	1,56	1,62	1,96	1,56	1,13

Pictures 8 and 9 present breakdown of annual average, maximum and minimum distribution of Marmarik River flow by months in the 2 hydrological observation points.



Picture 8: Breakdown of annual average, maximum and minimum distribution of Marmarik River flow by months in observation point Marmarik-Hanqavan



Picture 9: Breakdown of annual average, maximum and minimum distribution of Marmarik River flow by months in observation point Marmarik-Aghavnadzor

Table 14: Average characteristics of Marmarik River in observation point Marmarik-Hanqavan

Average water discharge		Maximum	Min. in summer-autumn low flow period	Min. in winter-time
		Discharge	Discharge	Discharge
Annual	1.51	16.7	0.23	0.18
1956-2006	1.67	31.3	0.18	0.12

Table 15: Average characteristics of Marmarik River in observation point Marmarik-Aghavnadzor

Average water discharge		Maximum	Min. in summer-autumn low flow period	Min. in winter-time
		Discharge	Discharge	Discharge
Annual	5.87	72.5	1.56	0.98
1956-2006	4.80	86.7	0.23	0.14

Table 16: Hydrological characteristics of Marmarik River in observation points Marmarik-Hanqavan and Marmarik-Aghavnadzor

Observation point	W, Flow volume, km^2	M Flow module, l/sec. km^2	H, Flow layer, mm	F, Area of the watershed, km^2
Marmarik-Hanqavan	0.048	16.1	509	93.5
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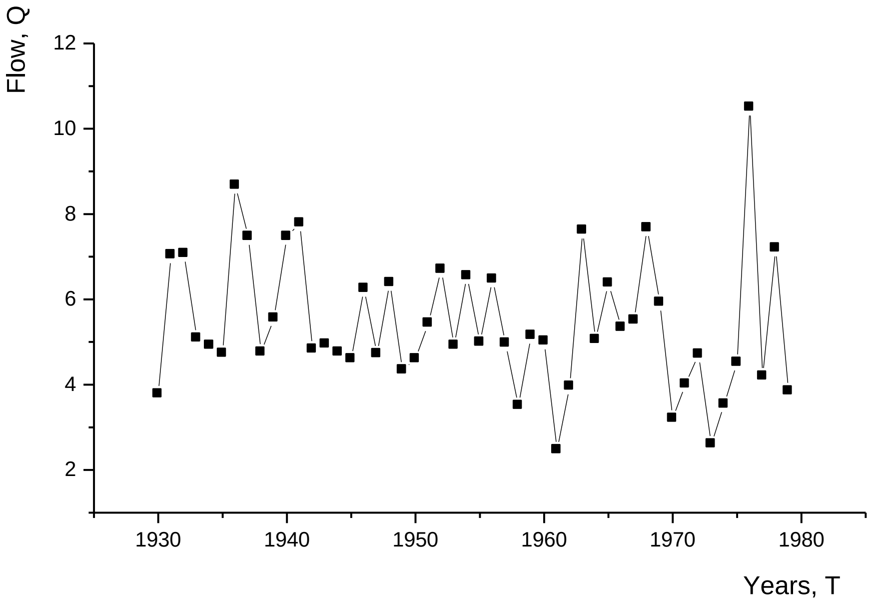


Picture 10: Graph of the average annual water discharge for the period 1930-1979 in observation point Marmarik-Aghavnadzor of Marmarik River

As seen from the picture, the maximum annual distribution of Marmarik River is in 1976 (10.5 m^3/sec). The minimum is in 1961 (2.47 m^3/sec). The figure of 1973 is also very close to the minimum (2.61 m^3/sec).

Strategy for Formulation of Supply in Marmarik River

According to 2007 data, approximately 12.6 mln. m^3 of water is being used annually for various purposes from Marmarik River (excluding the annual use of 3 mln. m^3 of water for hydro-energy purposes). It should be noted that there is Meghradzor Gold Mine is Marmarik River Basin, which uses approximately 0.3 mln. m^3 of water from the tributaries to Marmarik River. The volume of the annual wastewater from the gold mine is 0.13 mln. m^3, which is considered as normative wastewater not requiring treatment.

However, the above-mentioned water use data does not include irrigation water. Irrigated lands compose approximately 35% (146,3 km^2) of the total territory of the River Basin. Taking into consideration the guidelines on "Temporary Norms and Periods of Agricultural Irrigation for the Regions of the Armenian SSR", it can be calculated that for the irrigated lands belonging to the rural communities of Meghradzor, Marmarik and Aghavnadzor, annually 3340 m^3 of water is required for irrigating 1 ha of agricultural land. Thus the average water demand for irrigation period for those territories is approximately 49 mln. m^3/year.

As seen from the table 13, taking into consideration the average data of Marmarik-Aghavnadzor hydrological observation point, the average annual water discharge in that observation point is roughly 4.9 m^3/sec. On its turn, the registered water use is approximately 0.4 m^3/sec. If we add to this number the average required quantity for irrigation, we will receive 1.95 m^3/sec.

It is possible to calculate the approximate value of the minimum environmental flow of Marmarik River at hydrological observation point Marmarik-Aghavnadzor, taking into consideration the methodology mentioned in Appendix 2 of the Government of Armenian Resolution No. 592N of 22 March 2003 on "Defining the Volumes of Environmental Flows and Maximum Allowable Limits for Extracting Water in Each Segment of the Water Object". According to that methodology, the approximate environmental flow at Marmarik-Aghavnadzor observation point will compose 0,2 m^3/sec. (this number is approximate, since in order to define 95% provision of water more precisely, it is necessary to conduct more detailed studies on minimum flows). Exact calculation of the environmental flow is very important, since being priority natural, non-anthropogenic water use, it represents a guarantee for equilibrium and rehabilitation of water ecosystem. Apart from that, the value of the environmental flow is inseparable part of the National Water Reserve.

If we deduct 0.2 from 4.9 m^3/sec, we will obtain the approximate value of the free flow (4,7 m^3/sec.). Subtracting the actual water use from this number (1.95 m^3/sec.), we will receive the free, usable flow at Marmarik-Aghavnadzor hydrological observation point (2,75 m^3/sec.). Thus, currently only 41.5% of the water supply potential of the segment Marmarik-Aghavnadzor of Marmarik River is being used.

If we include in the above-mentioned calculations also the hydro-energy, then the water use will compose 2.89 m^3/sec. Further, if we deduct 2.89 from the free flow (4,7 m^3/sec.), we will receive 1,81 m^3/sec. Thus, only 60% of the actual water supply potential is being used in the territories impacted by hydro-energy, whereas in irrigation period there is a water deficit.

As seen from the above-mentioned pictures and tables, Marmarik River is distributed very unevenly, like most of the rivers in Armenia. The flow maximum occurs in spring mudflows season (April, May, June) and later on the flow decreases. As already mentioned, this is due to the fact that surface feeding source (melting) is prevailing. From this it can be implied that despite the sufficient average annual distribution, in summer and autumn seasons, when the water use intensifies (mainly due to increased irrigation needs), one can observe sharp deficit of water demand, which on its turn implies socio-economic issues and complaints from the population. As a matter of fact, having significant water resources, it is very difficult to plan their proper management. This problem can be effectively solved only through implementation of a strategy on reservoir construction.

The main solution for distribution of the free flow relates to accumulation of the water resources. The accumulated water resources can be further distributed equally in order to meet the water demand. This can be solved through constructing new reservoirs.

Previously Marmarik reservoir was being built on Marmarik River, which should have accumulated 24 mln. m^3 of water from Marmarik River free flow. This would satisfy part of the water deficit occurring particularly in the field of agriculture. However, because of low quality construction works, the reservoir has not been exploited since completion of construction. Currently works are undertaken for renovation of the reservoir within the frameworks of the Word Bank "Irrigation Dam Safety" Project.

While developing a long-term concept program for reservoir construction in the Republic of Armenia, data from various programs related to water use in the Republic at different levels, as well as initial calculation of water balance in 2020 and other statistical information on water resources have been used. The idea of reservoir construction is important in the line with global climate changes implications assessed by the scientists. According to these estimations, by the year 2025 approximately 4-5% reduction of water resources is anticipated. Also, taking into consideration the long-term water demand in the Republic, it is estimated that the annual water deficit will comprise approximately 744 mln m^3, which is approximately 30% of the total water use in the Republic nowadays.

In the long-term development program of reservoir construction it is anticipated to build the Meghradzor reservoir in Marmarik River Basin with an overall volume of 9 mln m^3.

Currently, due to lack of financial resources, the field of reservoir construction is not being developed in the Republic. Construction of previously uncompleted reservoirs has stopped, and maintenance of the existing reservoirs requires a lot of financial resources, which the state budget cannot afford nowadays. The Water Code of Armenia allows privatization of small reservoirs of local importance, however, the legislation does not provide for provisions for them to be profitable and attractive. Inclusion of incentive measures and profitability aspects in reservoir construction in legislation will seriously promote the process of integrated water resources management and planning in the Republic.

The tables below present information on strategy for storage of water resources (including the National Water Reserve and Strategic Water Reserve) in Marmarik River Basin and Kotayq marz, as well as construction of new reservoirs *(The reservoirs being constructed in Marmarik River Basin are highlighted in yellow).*

Table 17: Designed reservoirs in Kotayq marz

No.	Name of the Reservoir	Volume, mln. m^3	Marz
1.	Aragyugh	1.0	Kotayq
2.	Geghashen	1.43	Kotayq

Table 18: Uncompleted reservoirs in Kotayq marz and Marmarik River Basin

No.	Name of the Reservoir	Volume, mln. m^3	Marz
1.	Yeghvard	228.0	Kotayq
2.	Marmarik	24.0	Kotayq

Table 19: Planned and initially studies reservoirs in Kotayq marz and Marmarik River Basin

No.	Name of the Reservoir	Volume, mln. m^3	Marz
1.	Tsaghkunq	1.75	Kotayq
2.	Yayta	1.8	Kotayq
3.	Buzhakan	0.55	Kotayq
4.	Meghradzor	9.0	Kotayq
5.	Garni	12.4	Kotayq

Reservoir construction project implementation will establish additional capacities to storage approximately annually 33 mln. m^3 of water only for Marmarik River, which on its turn will make it possible to extend the possibilities for regulating water resources. This will also solve several strategic issues, including the following:

- Extend irrigated land areas,
- Replace the majority of mechanical/pumped irrigation systems to gravity ones,
- Establish new potential for increasing energy capacity of the country,
- Protect settlements, agricultural lands and communication roads located nearby the river bank from frequent mudflows and flooding,
- Provide for water supply in dry areas of the Republic,
- Define and develop water protection and recreation zones.

Water Quality

Water quality monitoring of Marmarik river is being conducted since 1986, by the Environmental Impact Monitoring Center of the Ministry of Nature Protection of Armenia. There are two water quality sampling sites (No. 57 and No. 58), one of which is upstream of the river, and the other one near the river mouth (see Picture 6). 24 water-chemical indicators have been determined in samples taken within the period 1986-2004 (see Table 20). Sampling, conservation of samples and analysis have been conducted according to existing regulations. For the period 2005-2007, 35-45 water-chemical indicators have been analyzed according to ISO and EPA standards. Assessment of chemical quality of Marmarik River's water has been conducted according to water use purpose, taking into consideration corresponding Maximum Allowable Concentrations (MAC).

Table 20: Water quality indicators and their corresponding Maximum Allowable Concentrations (MACs)

Quality Indicator	MAC, Fishery	MAC, Household	MAC Drinking, WHO
pH	6.5-8.5	6.5-8.5	6.5-8.5
Dissolved oxygen, mg/l	6<	4<	-
Calcium, mg/l	180	180	180
Magnesium, mg/l	40	40	40
Na+K , mg/l	170 (120+50)	170 (120+50)	250 (200+50)
Sulfate Ion, mg/l	100	500	250
Chloride Ion, mg/l	300	350	250
Nitrate Ion, mg /l ; mg N /l	40/ 9	40/ 9	50/11.25
Nitrite Ion, mg/l ; mg N /l	0.08/0.024	0.08/0.024	3/0.91
Ammonium Ion, mg/l ; mg N /l	0.5/0.39	2.6/	1.5/
Sum of Ions, mg/l	1000	1000	500
Silicium, mg/l	18.4	-	-
BOD_5, mg/l	3	6	3
COD Cr_2O^{-7}, mg O/l	30	30	15
Oil Products, mg/l	0.05	0.3	0.03
$P_{Phosphate}$, mg/l	3.5	3.5	3.5
Fe, mg/l	0.5	0.5	0.3
Cu, mg/l	0.001	0.01	1
Zn, mg/l	0.01	1	3
Pb, mg/l	0.01	0.03	0.01
Cd, mg/l	0.005	0.01	0.003
Co, mg/l	0.01	1	-
Ni, mg/l	0.01	0.1	0.02
Ti, mg/l	0.1	0.1	-
As, mg/l	0.05	0.05	0.01
Mo, mg/l	0.5	0.5	0.07
V, mg/l	0.001	0.001	-
Mn, mg/l	0.01	-	0.1
Al, mg/l	0.04	-	0.2
Cr, mg/l	0.001	0.5	-
Be, mg/l	0.0002	-	-

The results of hydro-chemical analysis for the period 2006-2007 are summarized in Table 21, where the water quality analysis results (average, maximum and minimum) for 2006 and the first 8 months of 2007 are presented. Table 21 presents only those indicators, for which at least one case of exceeding the MAC for fisheries is observed. The studies conducted show that currently (2006-2007) the water of Marmarik River has average hardness. The concentration of suspended elements is low and is within the allowable limits. Alongside the river no significant changes of the above-mentioned parameters are observed, and their concentration near the river mouth and upstream part of the river is almost the same, within the range of error margin. The oxygen regime of the river for the above-mentioned period has been satisfactory and the level of oxygen varied within the range of norm (7.6-10.7). The average values of BOD_5 and COD for 2006 and the first 8 months of 2007 were within the allowable limits of corresponding MACs for fisheries. High values of oxygen, and the fact that for 2006 and the first 8 months of 2007 the average values of BOD_5 and COD are within the MACs for fisheries show that the level of organic pollutants in the river's water is low and that the river has high self-cleaning potential. The average annual values of all hydro-chemical indicators except for V, Mn, Cu and Al, as seen from the Table 21, are within the limits of MAC for fisheries. The concentrations of the elements Zn, Cr, V and Cu are almost the same near the river mouth and the upstream part and exceed the corresponding MACs for fisheries by 2-4 times. This is due to the geo-chemical and hydro-geo-chemical peculiarities of the watershed. In the samples taken upstream part of Marmarik River the concentrations of Mn and Al are within the limits of MACs for fisheries. As of the samples taken in the Marmarik River mouth, the concentrations of Mn and Al exceed the MACs for fisheries correspondingly 2-4 and 3-9 times. Due to the lack of statistical information, it is still difficult to explain why the concentrations of Mn and Al exceed the fisheries MAC near the river mouth of Marmarik.

Table 21: Average, maximum and minimum values of water quality indicators in 2006-2007

Parameters	2006			2006			2007			2007		
	Sampling point 57			Sampling point 58			Sampling point 57			Sampling point 58		
	Ave.	Max	Min	Aver	Max	Min	Aver	Max	Min	Aver	Max	Min
DO, mg/l	10.31	12.4	6.85	10.69	13.25	7.64	7.55	9.56	6.40	9.74	13.48	5.80
Nitrates, mgN /l	1.18	4.51	0.01	1.50	10.03	0.054	1.564	1.94	1.241	2.05	4.47	0.06
Nitrite, mg N /l	0.007	0.022	0.00	0.014	0.043	0.000	0.00	0.00	0.00	0.017	0.026	0.005
NH_4^+,mgN/l	0.143	0.447	0.00	0.127	0.557	0.000	0.065	0.130	0.000	0.101	0.356	0.000
BOD_5, mg/l	1.83	2.71	0.90	2.285	3.60	0.960	2.7	4.2	1.3	2.12	3.20	1.23
COD $_{Cr+6}$, mgO/l	9.2	17.0	3.0	10.75	17	3	11.33	12	10	8.11	13	2
Fe mg/l	0.206	0.643	0.02	0.328	1.140	0.036	0.097	0.124	0.069	0.227	0.676	0.152
Cu mg/l	0.004	0.009	0.001	0.003	0.006	0.001						
Zn mg/l	0.005	0.010	0.001	0.004	0.021	0.000						
V mg/l	0.003	0.014	0.000	0.002	0.004	0.000						
Mn mg/l	0.017	0.056	0.004	0.046	0.107	0.020						
Al mg/l	0.05	0.096	0.024	0.071	0.089	0.046						
Cr mg/l	0.001	0.003	0.000	0.001	0.002	0.000						

As seen from Table 21 some cases of exceeding fisheries standards were observed in the period 2006-2007 near Marmarik river mouth, and in some instances upstream of the river. This is observed for BOD_5, COD and Dissolved Oxygen.

According to Table 21, sustainability and level of pollution of water at the water quality sampling points 57 and 58 of Marmarik Rivers have been within the limits of standards for fisheries (see correspondingly Table 22 and Table 23).

Table 22: Sustainability and level of water pollution in 2006-2007 in Marmarik River mouth, Observation Pint 57

Quality Indicator	2006				2006				2007				2007			
	Sustainability of Pollution				Level of Pollution				Sustainability of Pollution				Level of Pollution			
	Unique	Unstable	Stable	Characteristic	Low	Average	High	Extremely high	Unique	Unstable	Stable	Characteristic	Low	Average	High	Extremely high
DO,																
NO_3^-																
NO_2^-																
NH_4^+		TRUE			TRUE											
BOD_5,										TRUE			TRUE			
COD	TRUE				TRUE											
Fe		TRUE			TRUE											
Cu				TRUE		TRUE										
Zn																
V	TRUE					TRUE										
Mn		TRUE				TRUE										

Quality Indicator	2006				2006				2007				2007			
	Sustainability of Pollution				Level of Pollution				Sustainability of Pollution				Level of Pollution			
	Unique	Unstable	Stable	Characteris tic	Low	Average	High	Extremely high	Unique	Unstable	Stable	Characteris tic	Low	Average	High	Extremely high
Al		TRUE				TRUE										
Cr		TRUE				TRUE										

As seen from table 22, pollution with heavy metals Cu, V, Mn, Cr is characteristic for upstream parts of the river with average level. Pollution with the element Fe, which was observed in 2006 is not stable, is at low level and has strictly seasonal nature. It is characteristic during mudflow periods.

Table 22: Sustainability and level of water pollution in 2006-2007 in Marmarik River Observation Pint 58

Quality Indicator	2006				2006				2007				2007			
	Sustainability of Pollution				Level of Pollution				Sustainability of Pollution				Level of Pollution			
	Unique	Unstable	Stable	Characteristic	Low	Average	High	Extremely high	Unique	Unstable	Stable	Characteristic	Low	Average	High	Extremely high
DO,									TRUE				TRUE			
NO_3^-	TRUE				TRUE											
NO_2^-		TRUE			TRUE				TRUE				TRUE			
NH_4^+	TRUE				TRUE											
BOD_5,		TRUE			TRUE				TRUE				TRUE			
COD																
Fe		TRUE				TRUE			TRUE				TRUE			
Cu				TRUE		TRUE										
Zn		TRUE				TRUE										
V		TRUE			TRUE											
Mn				TRUE		TRUE										
Al		TRUE		TRUE												
Cr	TR UE					TRUE										

Pollution of Marmarik River's water with heavy metals Cu, V, Mn, Cr, as seen from Table 23, is characteristics and is of average level. Pollution with the element Fe is unstable, and in 2007 it is even unique. The level of pollution is average or low and has strictly seasonal nature. It is characteristics for the periods of mudflows. Pollution with the elements Zn and Al is unique, and the level of pollution is low and has strictly seasonal nature. It is characteristics to mudflow periods. The pollution with Ammonium, Nitrate, Nitrite Ions and BOD_5 is unique or of low level. This also has seasonal nature.

ASSESSMENT OF NATURAL AND ANTHROPOGENIC IMPACTS ON WATER

Executive Summary

The following approaches were applied in identifying the factors, possible pollution sources and nature of pollution on the chemical quality of waters of Marmarik River.

1. Analysis, corresponding to the dynamics and norms of the water quality indicators concentration, was conducted. The indicators that are pollutants (for which the corresponding MACs were exceeded) were separated. An analysis of possible factors of pressures was conducted taking into consideration the nature of the pollutant concentrations.
2. A comparison of the chemical quality of the water of river was conducted in the downstream and upstream segments of the river, which made it possible to identify the possible factors of pressure and sources of pollution.
3. An analysis was conducted on inter-relationship between the dynamics of pollutant concentrations and hydrological cycle and season, in order to identify the possible sources and nature of pollution.
4. An analysis of 20-year long-term series of information (1986-2007) was conducted, in order to identify the main, stable and temporary factors of pollution of chemical quality of the river, their nature and origin.

The analysis of the polluter groups shows that the pollutants can be divided into three groups.

The first group is composed of biological combinations of Nitrogen (Nitrate, Nitrite, Ammonia, BOD_5 and COD). The existence of this group of polluters in the water of river, upstream parts, and particularly downstream parts, is most likely due to the anthropogenic factors. The unstable and low level of pollution in the upstream segments of the river with Ammonia Ions and BOD_5 is seasonal, and is most likely related to the use of fertilizers in the river basin. As a result of washing cultivated land areas, a diffused water plenty of Nitrogen combinations flows into the water, which on its turn increases the concentration of the above-mentioned elements in the river and brings to partial, short-term decline in river's water quality. The unstable, low level pollution with Ammonia, Nitrate, Nitrite Ions and BOD_5 in the upstream segments of the river has also seasonal nature, and is also most likely related to the use of fertilizers in the watershed. As a result of washing cultivated land areas, a diffused water plenty of Nitrogen combinations flows into the water, which on its turn increases the concentration of the above-mentioned elements in the river and brings to partial, short-term decline in river's water quality. One cannot also exclude the inflow of wastewater from livestock and households, since there are no wastewater treatment facilities in any of the settlements of the watershed. Such wastewater may flow to river directly or in diffused way and impose additional pressures on the quality of the river.

There are several factor for unstable nature and low level of pollution.

- Firstly, the use of fertilizers in the watershed is at decent level.
- Secondly, urbanization in the watershed is at low level, and the volume of household wastewater from settlement, though untreated, is limited.
- Thirdly, cattle-breeding is not very popular in the watershed, and the direct or diffuse polluted inflow to river from livestock is limited.

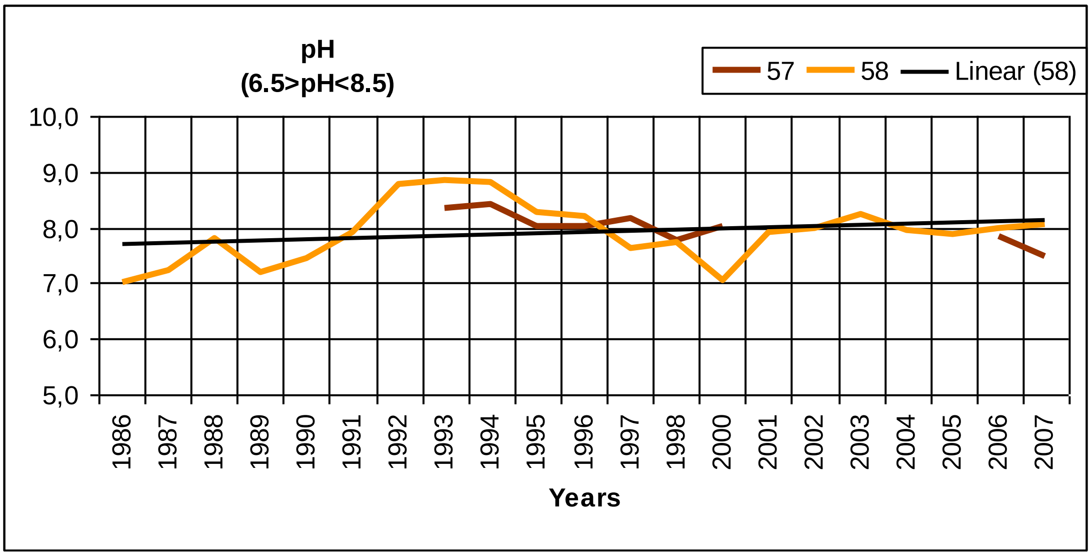
In general, the pollution from the first group of indicators (biological forms of Nitrogen, BOD_5, COD) and violations of oxygen regime is mainly due to anthropogenic factors. However, pressure from the above-mentioned pollutants to the water of the river is not that high. Due to river's high potential of self-cleaning and insignificant pressures with the above-mentioned pollutants there is currently some sort of equilibrium between the processes of pollution and self-cleaning, thanks to which the water in the river high rather high quality.

The second group of the polluters compose the heavy metals Cr, Cu, Mn, V. Their concentrations are stable, and exceed the MACs for fisheries. The concentrations of Cr, Cu, Mn, V in the river mouth and upstream segments of the river do not vary too much, which implies that such concentration is background for Marmarik River and is due to the geo-chemical and hydro-chemical peculiarities of the territory and watershed.

The third group of polluters compose the heavy metals Zn, Fe, Cr and Al. The concentrations of Zn and Al taken from the upstream segments of the river are within the limits of MAC for fisheries. The concentrations of Zn and Al taken from the river mouth sometimes exceed MAC for fisheries. Some correlation is noticed between the increase of their concentrations and mudflows. Pollution with Fe is unstable, at low level and has strictly seasonal nature in the upstream and downstream segments of the river. Like in the case with Zn and Al, pollution with Fe is characteristic to mudflow periods. Most likely pollution with this group of elements, particularly with Fe, is a results of penetration of surface soil layer to river due to precipitations and melting. Because of insufficient statistical information, it is still hard to explain profoundly the periodical increases in concentrations of Zn and Al. In general, the pollution with Fe, Zn and Al is most likely due to the natural pressure, such as the geo-chemical, hydro-chemical and hydro-meteorological peculiarities of the watershed.

Assessment of Natural and Anthropogenic Impact

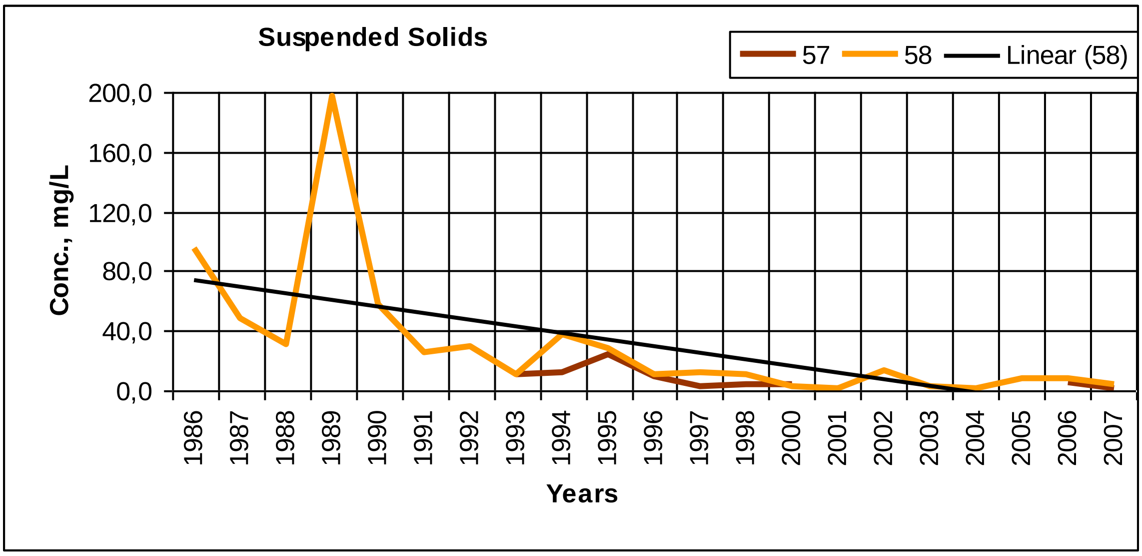
In order to identify the main, sustainable and temporary factors, as well as nature and origin of pollution of the hydro-chemical quality of Marmarik River, analysis was conducted for the long-term information series of pollutants for the period of 1986-2007 (see Pictures 8-25).



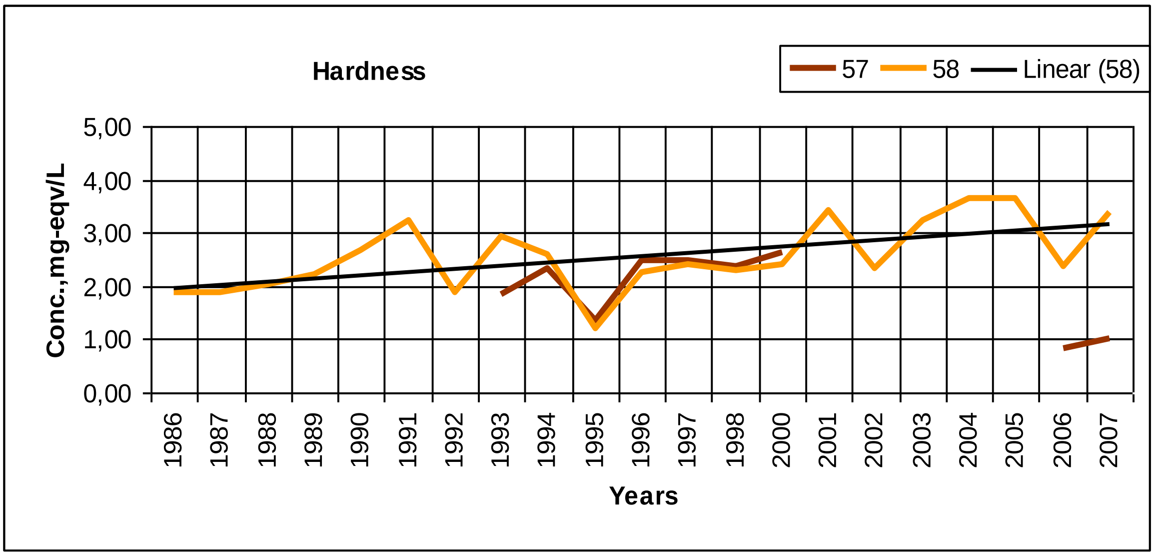
Picture 8: Changes of average annual values of pH for the period 1986-2007

According to 20-year information analysis (as seen from Picture 8), the values of pH for the downstream and upstream segments of the river are close to each other and are stable. Such values of pH show the absence of acidic anthropogenic and natural impacts on the river.

Contents of suspended solids was high in the period 1986-1990 (see Picture 9), after which sharp decline is observed. This shows that there was a sharp decrease of pressure on the river. From 1993 to 2008 there is virtually no change in the contents of suspended solids. In the upstream and downstream segments of the river the contents of suspended solids is practically similar, which shows the absence of natural and anthropogenic pressures on the quality of river's water related to suspended solids.

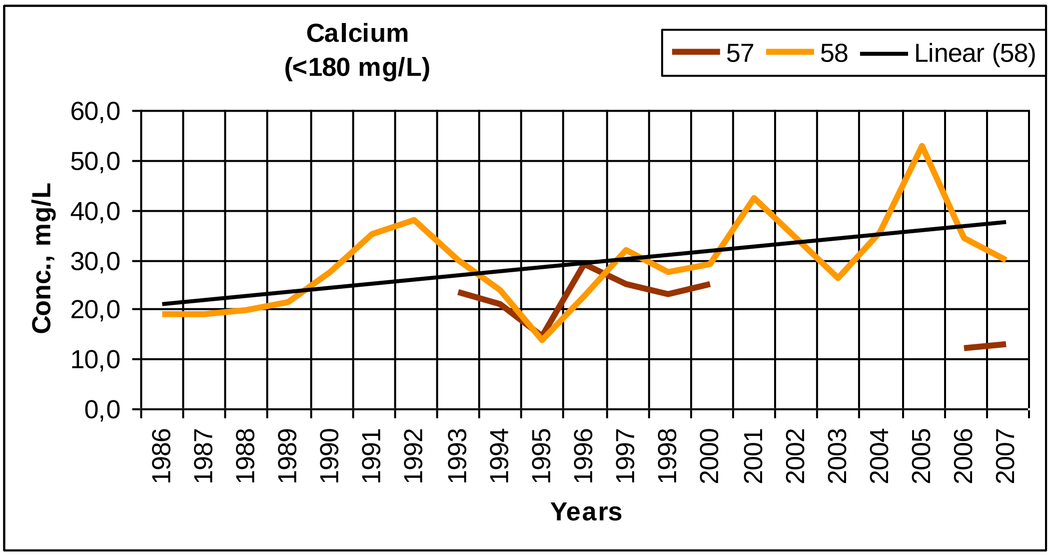


Picture 9: Changes of average annual values of Suspended Solids for the period 1986-2007

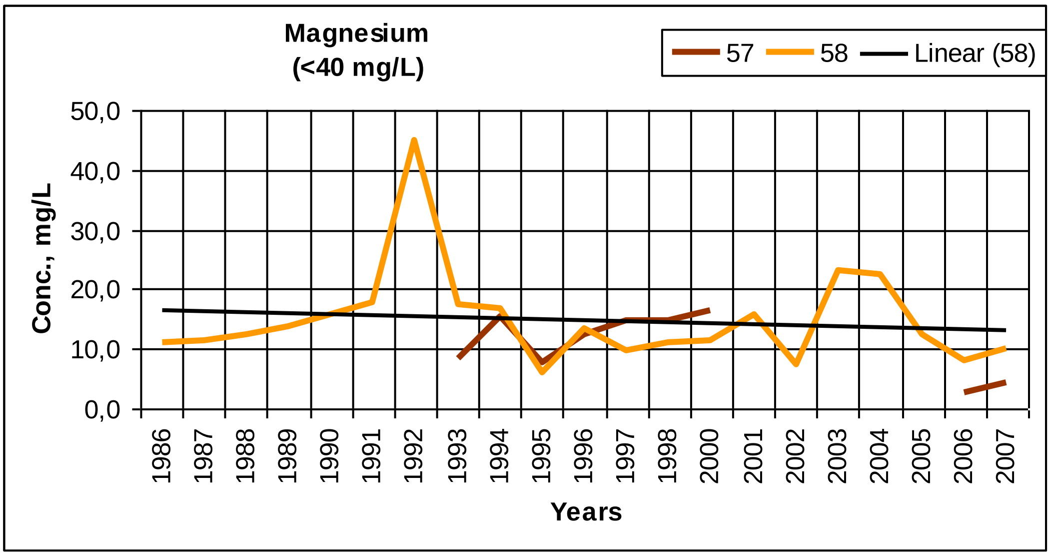


Picture 10. Changes of average annual values of water hardness for the period 1986-2007

As seen from Picture 10, water in the river has an average hardness. In the study period a stable growth of hardness values is observed in the river mouth. Until 2000 the hardness of water in the upstream and downstream segments of the rivers is the same, however, in 2006-2007 significant differences in hardness value are observed. In the upstream sampling point the hardness is much lower. This difference shows that during the last decade some changes occurred in the hydro-geological structure of the watershed. The nature and scale of such changes are not clear yet. For clarification, more detailed study is required.

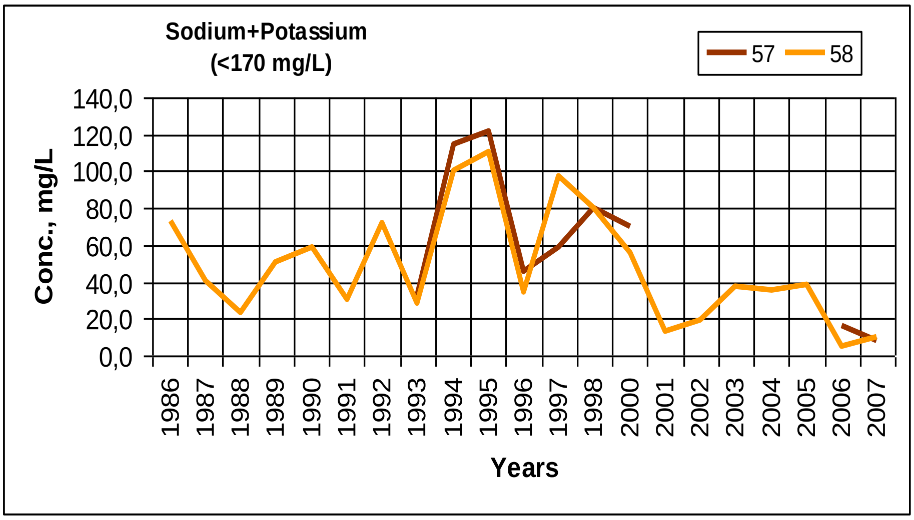


Picture 11: Changes of average annual values of Calcium for the period 1986-2007

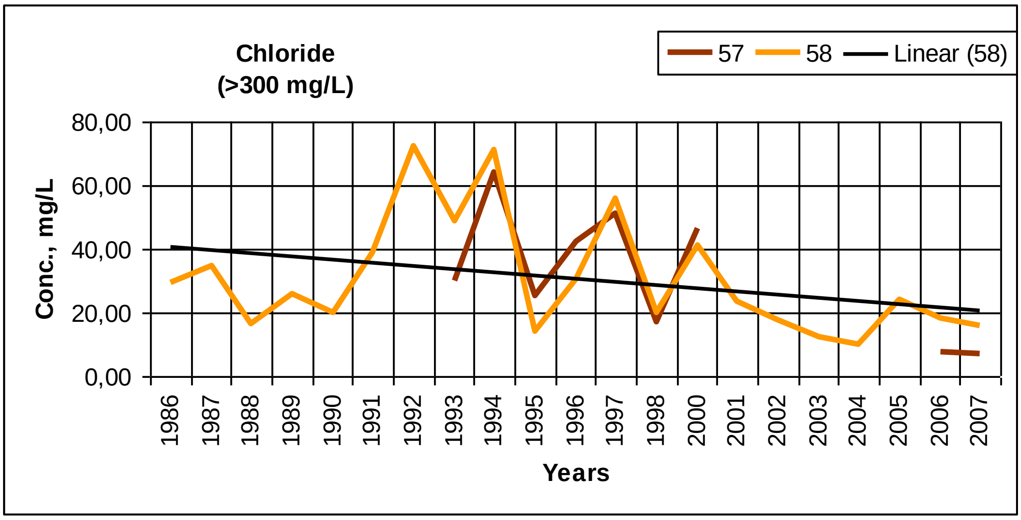


Picture 12: Changes of average annual values of Magnesium for the period 1986-2007

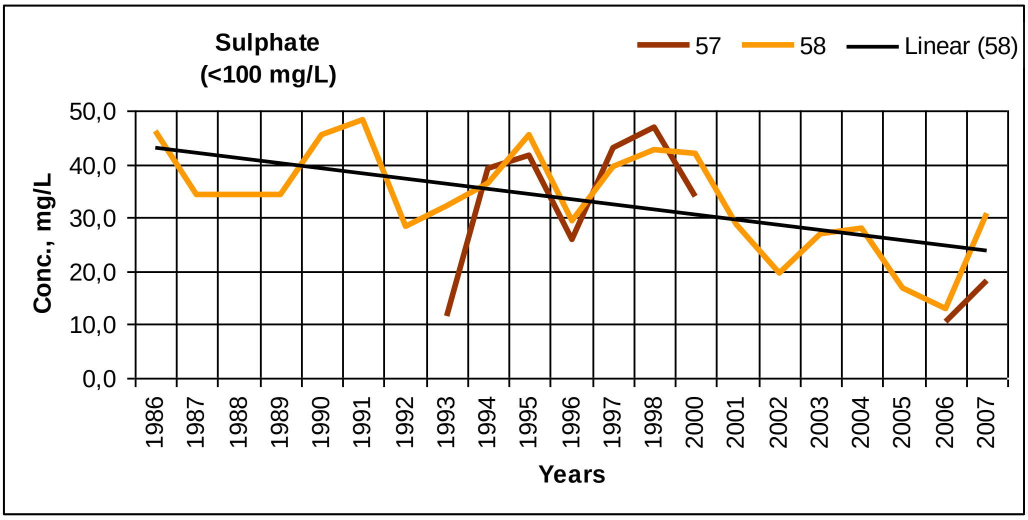
As seen from Pictures 11 and 12, for the period of 1986-2007 the concentration of Calcium in the river mouth increases, and the concentration of Magnesium decreases. This implies that increase is hardness is contingent upon increase of Calcium contents in the water. Before 2000 the concentrations of Calcium and Magnesium in the upstream and downstream segments of the river were the same, however in 2006-2007 in the upstream segment of the river a decrease of concentration for both Calcium and Magnesium is observed. This information explains the differences in the river mouth and upstream segment of the river. However, it does not explain the cause and nature of such occurrence. As a matter of fact, a change in ratio Calcium/Magnesium (g.-equivalent/q. equivalent) occurs in the river mouth. This ratio has grown from 1:1 in 1986 to 2:1 nowadays. Such change also implies that during the last decade some changes in hydro-chemical composition of the watershed occurred.



Picture 13: Changes of average annual values of Sodium+Potassium for the period 1986-2007

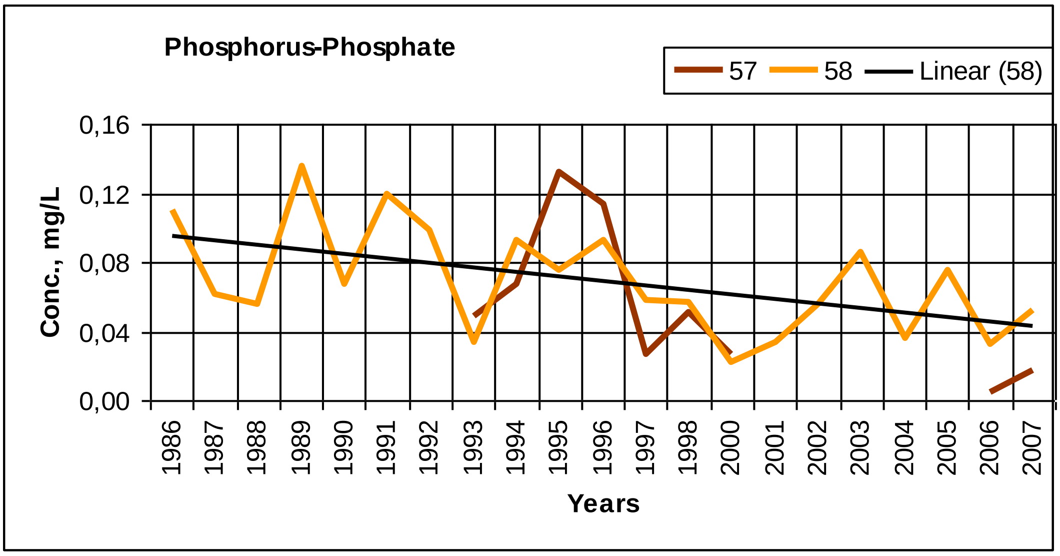


Picture 14: Changes of average annual values of Chloride Ions for the period 1986-2007



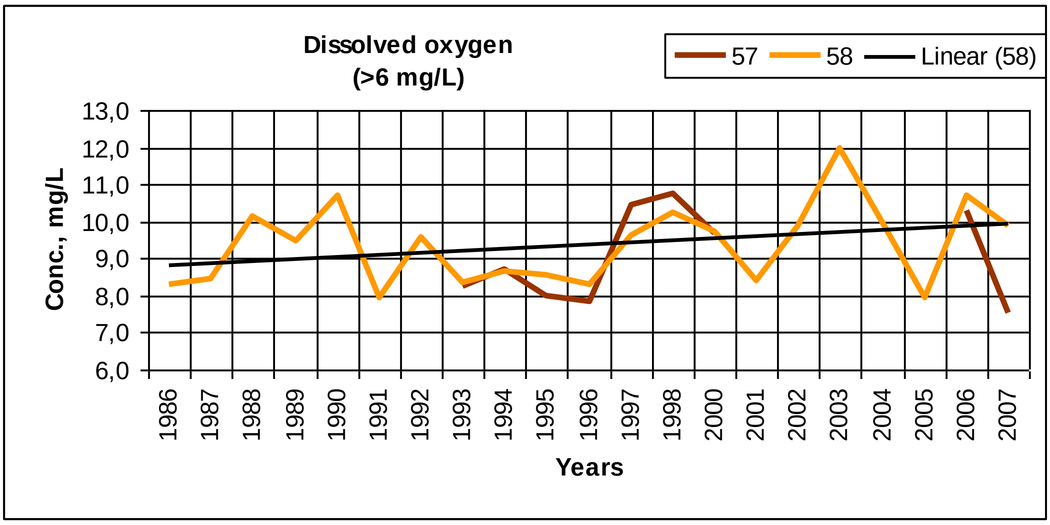
Picture 15: Changes of average annual values of Sulfate Ions for the period 1986-2007

Significant decrease of values of concentrations of Sodium+Potassium, Chloride and Sulfate Ions is observed in the waters of Marmarik River. The concentration of Sodium+Potassium has decreased 10-12 times compared to the maximum value of concentrations in 1993-1994. The concentrations of Chloride Ions have decreased approximately 3 times compared to the maximum concentration values in 1992-1994. And the concentrations of Sulfate Ions have decreased about 2 times within 1986-2007. Unlike the hardness, Calcium and Magnesium, the concentration values of the major ions (Sodium+Potassium, and Sulfate) have changed harmonically in the river mouth and upstream segment and mostly coincide. The concentration of Chloride Ions has decreased rapidly in the upstream segments starting from 2000, and in 2006-20007 is already twice smaller comparing to the concentration in the river mouth. Such changes imply that during the last decade some changes have occurred in the hydro-geological structure of the watershed, which led to changes in chemical composition of the river.

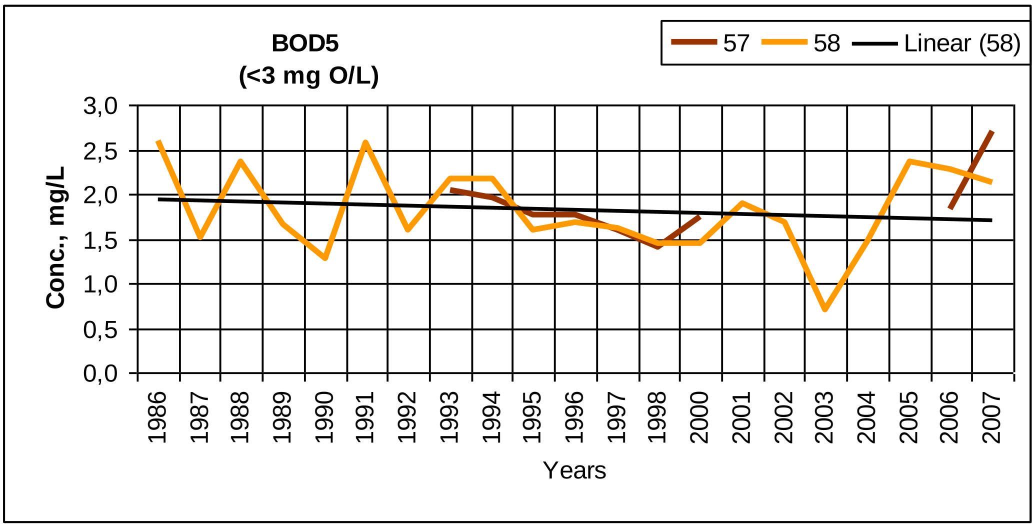


Picture 16: Changes of average annual values of Phosporus+Phosphate for the period 1986-2007.

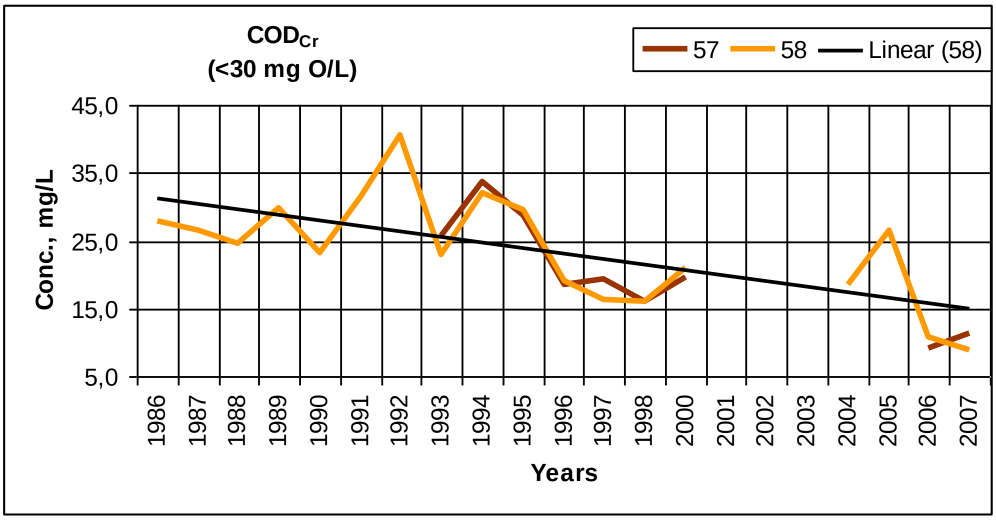
Approximately 2.5-3 times decrease of concentration values of Phosphorus+Phosphate are observed in Marmarik River for the period 1986-2000. Since 2000 the concentrations of Phosphorus are stable in the river mouth and vary within the range of 0.04-0.08 mg/l. Until 2000 the concentrations of Phosphorus+Phosphate in the river mouth were identical to the concentrations in the upstream segments of the river. However, the concentrations of Phosphorus+Phosphate decreased in the upstream segments of the river after 2000, and in 2006-2007 the concentrations were 2-3 times smaller compared to the concentrations in the river mouth. This changes suggest that during the last decade some changes in the hydro-geological composition of the watershed occurred, which on its turn led to changes in the chemical composition of the water of river.



Picture 17: Changes of average annual values of Dissolved Oxygen for the period 1986-2007



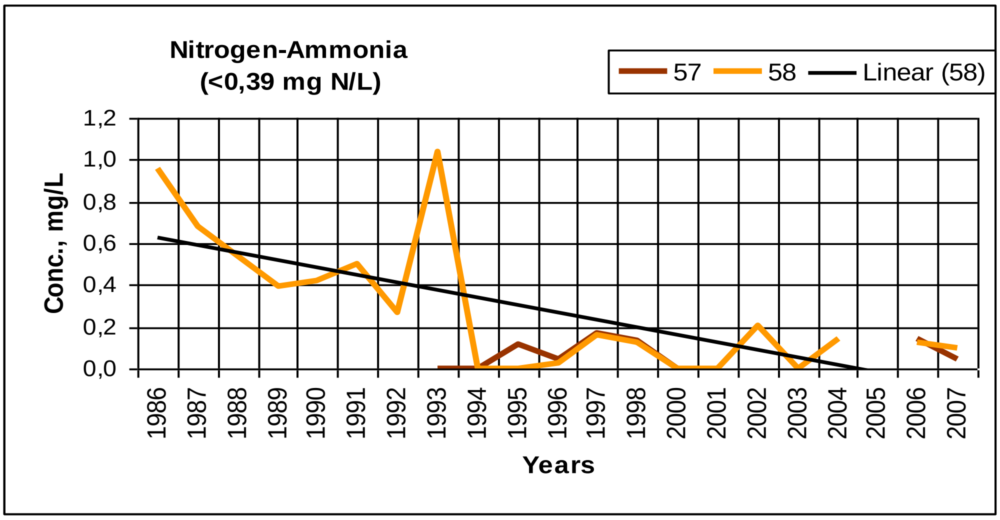
Picture 18: Changes of average annual values of Biological Oxygen Demand$_5$ for the period 1986-2007



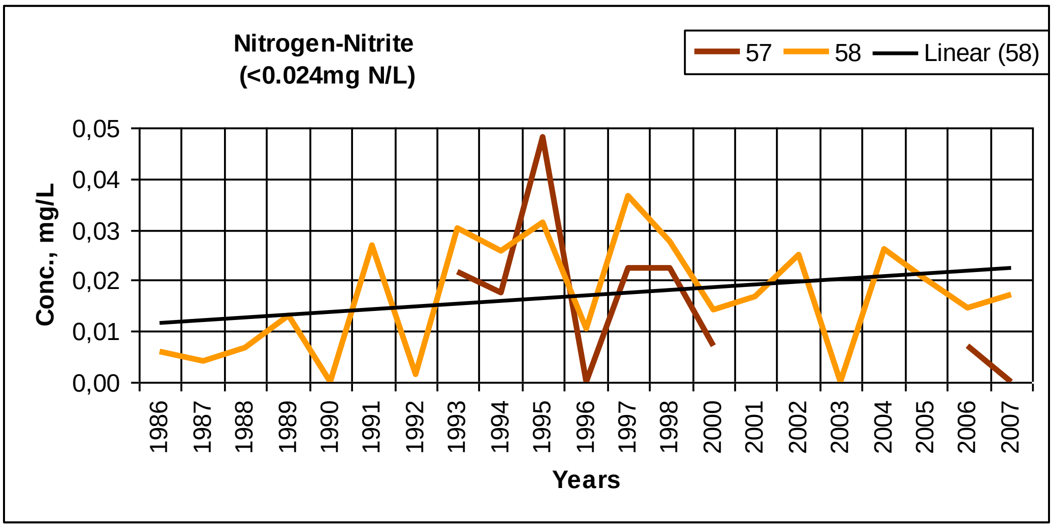
Picture 19: Changes of average annual values of Chemical Oxygen Demand for the period 1986-2007

Picture 17-19 present the dynamics of the average annual values of Dissolved Oxygen, BOD_5 and COD for the period of 1986-2007. As seen from Picture 17, the oxygen regime of the river is in good shape. In recent years even some increase of oxygen concentration in the river is observed, which implies that anthropogenic pressure on the river is decreasing.

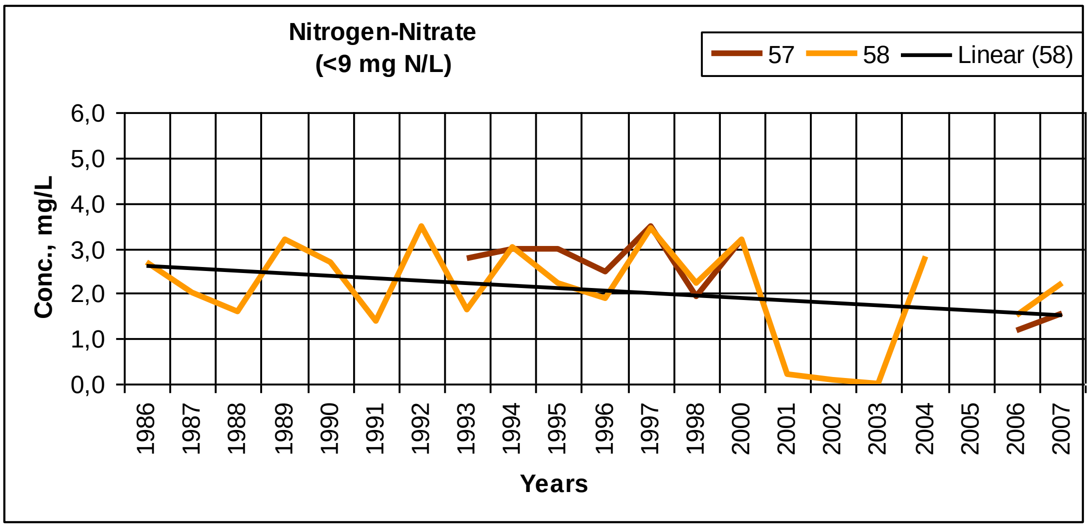
As seen from the Pictures 18 and 19, the average annul values of BOD_5 and COD are within the range of allowable limits. In the downstream and upstream segments of the river the average values of BOD_5 and COD practically coincide, which shows the limited nature of human pressure on the water quality alongside the river. For the period 1986-2007 almost 3 times reduction of average values of COD is observed, which undoubtedly implies the reduction of human pressures on the quality of river.



Picture 20: Changes of average annual values of Nitrogen-Ammonia for the period 1986-2007



Picture 21: Changes of average annual values of Nitrogen-Nitrite for the period 1986-2007



Picture 22: Changes of average annual values of Nitrogen-Nitrate for the period 1986-2007

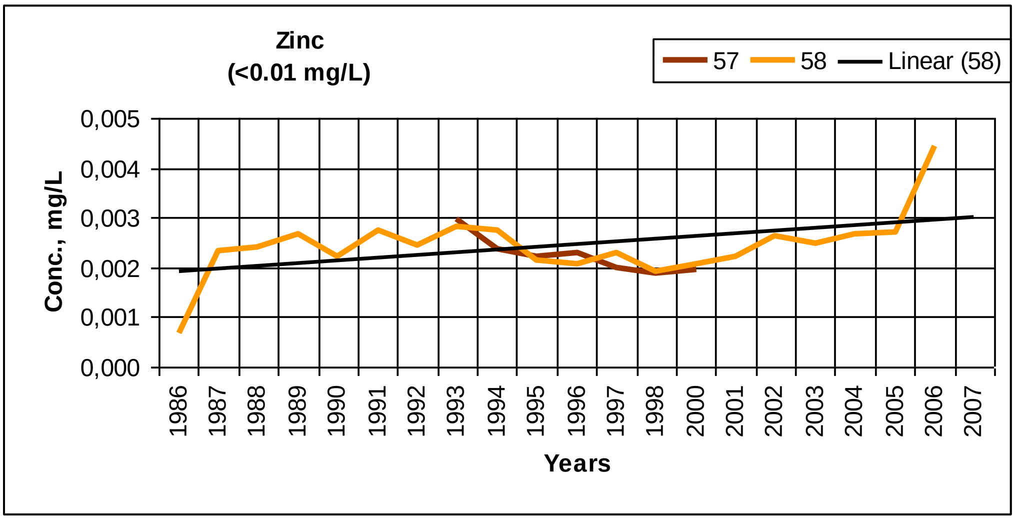
As seen from Picture 20, the concentrations of Nitrogen-Ammonia for the period 1986-1994 have been extremely high and almost always exceeded MAC for fisheries. Since 1994 a sharp decline of the average annual value of concentrations of Nitrogen-Ammonia is observed, and in 1994-2007 the concentration of Nitrogen-Ammonia were within the limists of MAC for fisheries. The average values of concentration of Nitrogen-Ammonia in the river mouth and upstream segments virtually coincide, which shows that the human pressure alongside the river is limited. It also shows that the sharp decline of concentration since

1994 is a result of dramatic reduction of human pressure on the quality of the lake. Currently it is difficult to present the factors causing such reduction of anthropogenic impact, since the sharp reduction of the use of Nitrogen fertilizers in agriculture in the watershed is not enough to explain the sharp reduction of average annual values of Nitrogen-Ammonia concentrations (as seen from Pictures 21 and 22, no dramatic changes in the concentrations of Nitrogen-Nitrite and Nitrogen-Nitrate are observed, as someone would expect). Moreover, the concentrations of Nitrogen-Nitrate have almost not changed until now. As of Nitrogen-Nitrite concentration, their values for the river mouth and the upstream segment of the river have been very close also in1993. This shows that the limited Nitrate pressure on the quality of the lake has been and is active even now, and, as a matter of fact, has not changed. If the high concentrations of Nitrogen-Ammonia were due to pressure from Silitric Ammonia, then after stopping use of fertilizers the concentrations of Nitrate would have been decreased harmonically in the waters of the river, which is not the case. And as the concentrations of Nitrogen-Nitrate in the period 1986-1994 varied within the same range which is nowadays, then high concentrations of Nitrogen-Ammonia would have been observed, which is also not the case. The above-mentioned analysis shows that the high concentrations of Nitrogen-Ammonia, observed until 1993 are not only a results of intensive use of selitric fertilizers. The analysis of Nitrogen-Nitrite concentration changes for the period 1986-2007 is also proving the above-mentioned conclusion.

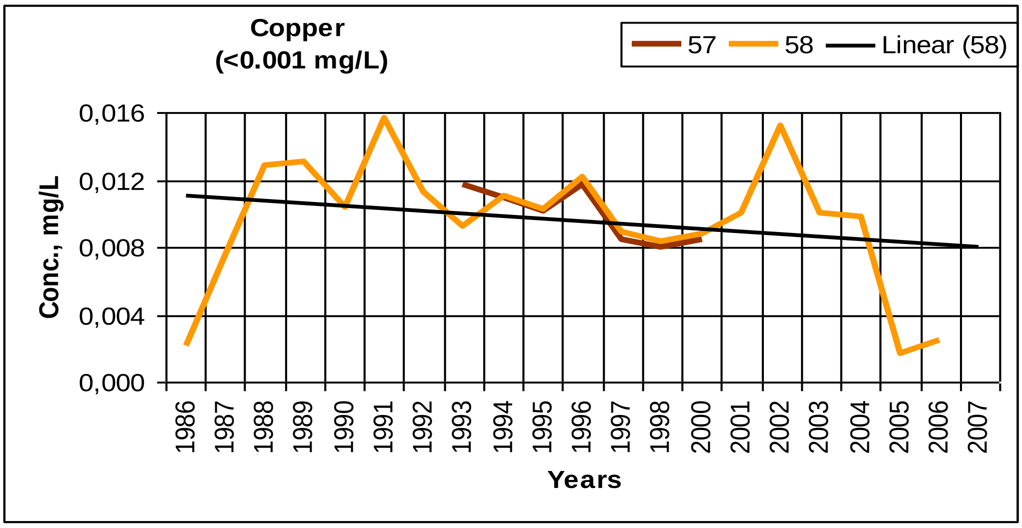
Approximately 3-fold increase of concentrations of Nitrite-Nitrogen for the period of 1986-1993 is observed in the river mouth of Marmarik. However, from 1994 until 2007 those values have decreased for about 1.5-2 times. The concentrations of Nitrite-Nitrogen for the period 1993-2007 in the river mouth have varied within the range of MAC for fisheries, and the observed decrease of concentration might be a short-term tendency. The concentration of Nitrite-Nitrogen for the period of 1993-2000 in the upstream segment of the river has been close to concentrations observed in the river mouth. However, for the period 2000-2007 the concentration in the upstream segments has decreased and currently is 2-4 times lower compared to the concentration in the river mouth. Such decrease is undoubtedly due to the decrease of human pressure on the quality of the river, particularly through diffused water. At the same time such different shows the existence of human pressure on quality of the river, though limited, in the downstream segments of the river.

The long-term (1986-2007) analysis of Copper concentrations in the river mouth and upstream segments shows that the contents of Copper is similar and has exceeded the MAC for fisheries (up to 16 MAC, see Picture 23), from which it implies the existence of background concentrations of Copper.

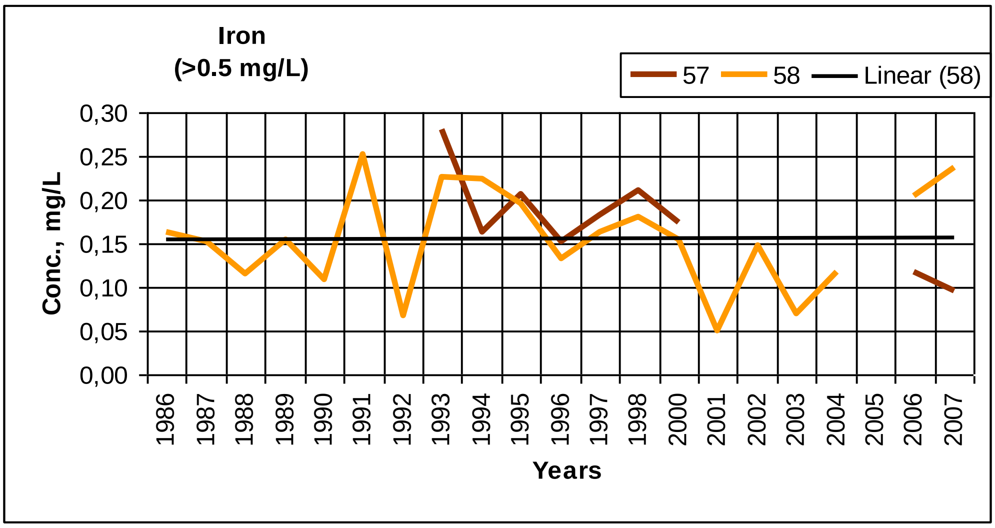
The average annual concentration values of Zinc and Iron during the entire period of analysis were within the range of MAC for fisheries (see Pictures 24 and 25).



Picture 23: Changes of average annual values of Zinc for the period 1986-2007



Picture 24: Changes of average annual values of Copper for the period 1986-2007



Picture 25: Changes of average annual values of Iron for the period 1986-2007

IDENTIFICATION OF PREFERRED WATER USE AND FUNCTIONS

Based on the results of monitoring for the period of 2006-2007, water quality of Marmarik River has been calculated according to Oregon Index, Canadian Index, Water Quality Combinatorial Index, Complexity Coefficient and Irrigation Coefficient. The calculations have been done with corresponding methodologies. The calculated indices and coefficients are summarized in Table 25.

Water Quality Oregon Indices have been determining according to the existing fisheries standards of USA, as indices for water resources for fisheries. Oregon index is defined using 6 parameters of water quality – temperature, pH, Dissolved Oxygen, BOD_5, Dissolved Saline, Sum of Ammonium and Nitrate-Nitrogen. Usually the Oregon index shows low values and low grade for water quality, which is based on the peculiarity of the methodology and the existence of strict MACs. For example MAC for Nitrogen is 9 times stricter than the MAC in Armenia. Oregon index is useful to assess the tendencies, since it is very sensitive of the existence of Nitrogen pollutants in water, and particularly reveals the pollution of with biological forms of Nitrogen.

Water quality Canadian Index, Water Quality Combinatorial Index and Complexity Coefficient have been determined based on the existing fisheries and household standards for Armenia, and drinking water quality standards of the World Health Organization. They have been determined as separate indices and coefficients for fisheries, household and drinking water purposes. The indices have been determined using 19 water quality parameters, which are presented in the lines 1-18 of the Table 20.

Water quality irrigation coefficient has been determined according to corresponding water resources standards of the Republic of Armenia. Irrigation coefficients have been determined for 3 water quality parameters – Chloride, Sulfate and Natrium Ions.

Assessment and classification of hydro-chemical quality of Marmarik River has been done based on the calculated integral indices and coefficients. Assessment has been done according to corresponding methods and classification. The assessment and classification results are summarized in Table 24 according to water use purpose.

According to Oregon Index the quality of Marmarik River water is assessed and classified as water resource corresponding for fishery purpose.

According to Canadian Index, Water Quality Combinatorial Index and Complexity Coefficient, water quality of Marmarik River is assessed and classified as corresponding for the purposes of fisheries, household and drinking.

According to Irrigation Coefficient water quality of Marmarik River is assessed as water resources corresponding for irrigation purposes.

As seen from Table 25, assessment obtained by different methodologies mainly coincides. This shows that for the purposes of fisheries, household, drinking and irrigation, water quality of Marmarik River is of excellent of good condition. From this it can be applied that the water is Marmarik River can be considered as high quality for the purposes of fisheries, household, drinking and irrigation.

In order to identify the factors of impact on the chemical quality of water of Marmarik River, possible sources of pollution, their nature, duration of the impact and its scale, the annual Oregon, Canadian, Combinatorial Indices and Complexity Coefficients are calculated in the river mouth of Marmarik for the period of 1986-2007, based on the monitoring results. Based on the integral indices and coefficients, assessment and categorization of the chemical quality of the water of Marmarik River was conducted for the entire period of 1986-2007. Assessment of annual dynamic analysis of the water quality was conducted.

Table 24: Water quality categories according to Combinatorial Index, Canadian Index, Oregon Index and Complexity Coefficient

Categories	Specific Combinatorial Water Quality Index	Canadian Water Quality Index	Oregon Water Quality Index	Complex Water Quality Index
I	<1 Good	(95-100) Excellent	(90-100) Excellent	(0-10] Good
II	(1-2] Slightly polluted	(80-94) Good	(85-89) Good	(10-40] Marginal
III	(2-4] Polluted	(65-79) Fair	(80-84) Fair	(40-100] Poor
IV	(4-11] Poor	(45-64) Marginal	(60-79) Poor	-
V	>11 Very poor	(0-44) Poor	(1-59) Very Poor	-

Taking into consideration the priorities set in the Water Code of the Republic of Armenia, the quality of water in Marmarik River should be categorized by the following order – drinking, household, irrigation and fisheries, at the same time taking into consideration the desired priority. If possible, it is suggested to use the water of river in a way that it does not impose additional Nitrogen pressure on the river. Otherwise corresponding water treatment works should be planned.

Table 25: Assessment of Marmarik River water quality according to hydro-chemical monitoring results in two water quality sampling points based on Oregon Index, Canadian Index, Water Quality Combinatorial Index, Complexity Coefficient and Irrigation Coefficient, and according to water use type or condition importance of the water resource

		Water use type or conditional importance of the water resource										
		Fisheries				**Household**			**Drinking**			**Irrigation**
Sampling Point No.	Year	Oregon	Canadian	WQCI	Complexity coefficient	Canadian	WQCI	Complexity Coefficient	Canadian	WQCI	Complexity Coefficient	Irrigation Coefficient
57	2006	73.4	95.9	0.25	2.22	100	0	0	100	0	0	
Quality order		4	1	1	1	1	1	1	1	1	1	1
Assessment		Poor	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent	Excellent	Good	Excel
58	2006	73.9	55	2.11	7.19	80.5	0.83	2.83	93.6	0.52	0.98	
Quality order		4	3	3	1	2	1	1	2	1	1	1
Assessment		Poor	Marg	Fair	Good	Good	Excellent	Good	Good	Excellent	Good	Excel
57	2007	73.9	80.7	1.09	5.16	87.1	0.4	1.89	93.7	0.4	1.39	
Quality order		4	2	2	1	2	1	1	2	1	1	1
Assessment		Poor	Good	Good	Good	Good	Excellent	Good	Good	Excellent	Good	Excel
58	2007	64.4	84.3	0.67	3.02	88.4	0.63	3.02	96.2	0.30	0.79	
Quality order		4	2	2	1	2	1	1	1	1	1	1
Assessment		Poor	Good	Good	Good	Good	Excellent	Good	Excellent	Excellent	Good	Excel

SUGGESTIONS

Summary

The analysis of baseline conditions and pressures for integrated water resources management in the Marmarik River basin shows that there are several issues and priority directions in this regards. Those issues and priority directions can be categorized in the following groups:

- Development/improvement of data management tools to support decision making and to develop various water use scenarios,
- Development of methodology for water quality indices, and accordingly, revision of water quality standards,
- Management/regulation of water flow, including study of construction of reservoirs.

All the above-mentioned priority directions are components of IWRM and are in line with the priorities identified in other river basins of the Republic of Armenia.

There are several other priorities, such as lack of sewage collector networks in rural communities, insufficient level of implementation of flood-control measures, and diffused pollution from agricultural sources, which at this point are not critical for Marmarik River Basin. However, the analysis shows that these problems might become acute, particularly parallel to development of economy, if no preventive measures are taken on time.

Next Steps

Taking into consideration the summary of analysis of baseline conditions and pressures for integrated water resources management, it is suggested to support the process of IWRM planning in the Republic of Armenia as a next step. The support is suggested to perform through development of IWRM plan model, particularly through the examples of Marmarik River Basin.

Such approach is also envisaged in the Law on National Water Program of the Republic of Armenia adopted in 2006. Particularly, the appendix of the law "Phased Program of Measures for Implementation of the National Water Program" prioritizes such approach.

In the phased program of measures, development of IWRM plans is mentioned is one of the priority needs for water resources management in the country. To achieve that objective, it is suggested to implement the following two short-term measures in the "Phased Program of Measures for Implementation of the National Water Program":

- Capacity building for the Water Resources Management Agency and Water Basin Management Authorities in order to achieve IWRM, and
- Development of IWRM plan and identification of information needs.

Thus, taking into consideration both the priority measures of the National Water Program and analysis conducted for Marmarik River Basin, it is suggested to discuss the possibility of providing support to one of the proposed projects under the National Policy Dialogue.

Table 26: Proposed Project 1 - Strengthening Capacities of WRMA, and particularly WBMA, in terms of development IWRM plans

Criteria	Brief Description
Objective	Strengthening of capacities of WRMA, and particularly WBMA, in order to achieve IWRM and planning at national and river basin levels
Leading Organization	WRMA
Target Group	All water sector agencies
Expected Results	WRMA and WBMA are the main authorized agencies for development and implementation of IWRM plans
Deliverable	• Clarification of roles and responsibilities of WRMA, and particularly WBMA, in achieving IWRM • Trained staff of WRMA, and particularly WBMA, in terms of IWRM and planning
Monitoring and Evaluation	National Policy Dialogue
Impact of Non-Implementation	• Insufficient understanding of IWRM process at river basin level, • Inadequate capacities at WRMA, and particularly WBMA, in terms of IWRM
Implementation Tools	Studies, seminars, training

Table 27: Proposed project 2 - Development of Methodology for Formulation of IWRM plans

Criteria	Brief Description
Objective	Demonstration of IWRM planning methodology for further replication in the fiver river basins of Armenia
Leading Organization	WRMA, and particularly WBMA
Target Group	WRMA, MNP, NWC, PBC, other water sector agencies
Expected Results	Model for development of IWRM plans in the five river basins
Methodology	Development of methodology for IWRM, which will be further applied for planning in the fiver river basins. The methodology will include the following: • Scope of studies • Definition of goals and principles • Definition of needs, issues and opportunities • Assessment of resources • Identification of elements of the plan • Development of alternative plans • Assessment of alternative plans • Selection of the preferred plan • Plan implementation • Update of the plan
Deliverable	Model of IWRM Master Plan
Monitoring and Evaluation	National Policy Dialogue
Impact of Non-Implementation	• Insufficient level of understanding of IWRM principles, • Obstacles in decision-making on water resources infrastructures in river basins
Implementation Tools	Study, Seminars, Training