



Full Length Article

Saving the Lake Urmia: from Slogan to Reality (Challenges and Solutions)

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ABSTRACT

The Urmia Lake is between the provinces of East Azerbaijan and West Azerbaijan in Iran, and west of the southern portion of the Caspian Sea. It is the largest lake in Iran and the second it is the largest lake in the Middle East and the sixth largest saltwater lake on earth. In recent years Lake Urmia, the largest saline lake in the Middle East located in northwestern Iran has undergone severe environmental changes. As a result of drought and anthropogenic impacts, the area of the Lake has been shrunk and the water level has been dropped. Since 1995-1996 in the result of Reduced rainfall, dehydration, increased evaporation from the lake, drought, uncontrolled construction of dams and preventing water from entering the lake, irresponsible construction of the Shahid Kalantari causeway bridge and lack of expertise and proper management of its environment, digging unauthorized and uncontrolled wells and indiscriminate permissions of digging wells, low irrigation efficiency and wrong cropping pattern have caused the lake level get lower with a growing trend which has led to the biggest challenge to Iranian and middle east environment. In this article the environmental, political and socio-economic impacts of drought in Lake Urmia basin has been reviewed and the obstacles regarding institutional water frameworks in national and regional levels has been studied and assessed. In this article we analyze the factors in reducing the level of the lake and suggest strategies for reviving the Lake by investigating the situation of large and small Zab.

Keywords: Drought, Ecological Crisis, Urmia Lake

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INTRODUCTION

Because of the development of civilization and technology and the increasing of the population, today the world is facing with the problem of environmental pollution that threatens people's lives. So, environmental protection is seriously considered by the authorities of all the countries. Today, the environmental situation is so that the people of a town are not immune from the effects of pollution in another city or country [3].

Lakes as natural systems are sensitive indicators and recorders of the impact of natural and anthropogenic disturbances inside, or even outside, their drainage basins. In addition to their function as storage bodies, they are dynamic ecosystems in which a large range of dissolved and particulate substances sink. Therefore, they are one of the most fragile aquatic ecosystems. Beside their storage function, they provide a foundation for people's livelihoods as they support a great extent of biodiversity and are the source of food and recreation for humans. In view of the above, studying the impact of natural factors (e.g. climate variability) as well as human's interventions (e.g. water diversion and pollution) on these vulnerable systems are of high importance [17].

Urmia Lake is one of the largest permanent salty lakes in the world, which is located in the catchment area in the North West of Iran [7].

One of the greatest challenges between the developed and developing countries is that developing countries just take and pay the lip service without any actions, however, in the developed countries beside planning for an objective the action exists and this is the greatest difference between these generations. In this century not only the water resources are considered among rare and valuable resources and cause the world development face a problem but they threaten the global peace and security [10].

Since 1995 the lack of precipitation and low relative water level of the Lake has caused the legalization of 2 dominant thinking on the use of natural and water resources: the first thinking believes that in any way natural resources are not limited and new resources will be found or generated through innovative thinking [16].

Drought is among the most damaging environmental phenomena in all climate zones ranging from arid, semi-arid and semi-humid regions while drought is a permanent phenomenon caused by the sudden reduction of humidity [1].

Drought is water scarcity based on the reduced amount of precipitation[3].

The average salinity of the Lake water is normally between 220-300 grams per liter based on the circumstances of time and place[13].

Lake Urmia in the northwestern corner of Iran is one of the largest permanent hyper saline lakes in the world and the largest lake in the Middle East[19]. It extends as much as 140 km from north to south and is as wide as 85 km east to west during high water periods [8].

The surface area of Lake Urmia has been estimated about 5200 km² and the area of the basin is estimated 51,876 km². Lake Urmia possesses more than 102 rocky saline islands and its ecosystem is the habitat for more than 212 species of birds, 41 reptiles, 7 amphibians, and 27 species of mammals which most of them are endemic species [14].

Two major aspects of drivers which are responsible for this environmental crisis are anthropogenic driving forces and natural driving forces. In this occurrence, anthropogenic drivers are more effective than environmental drivers. Sharp population growth during 1980 to 2011 and intensive immigration towards big cities raised the food and water demand. Regarding to the amount of water which is consumed instead of being discharged in the Lake Urmia, these participations can be obtained that agriculture sector is responsible for 91% of the water consumption, whereas industry and domestic consumption are responsible for 6 and 3% of the water consumption respectively [12].

The main freshwater resource is Zarrineh River, located in the south of the lake, supplying more than 50% of the annual inflow. Simineh River and Ghadar River are providing 35% of the inflow [13].

Some of the freshwater from these sources flows unimpeded to Lake Urmia, but much of it is impounded within reservoirs or water diversion dams for the sake of irrigation, drinking water, power generation (hydro-power plant) and industrial usage of water. For instance, Bukan dam was constructed on Zarrineh River in order to launch hydropower plant and supply water demand [12].

The Lake Urmia's drainage basin is 5200 km², between 38.29-35.40' N and 47.53-44.13'E. Wich is about 3% of the whole country area. The most important basin rivers are: Aji Chay, Alamlou River, Barandouz River, Gadar River, Ghaie River, Leylan River, Mahabad River, Nazlou River, Rozeh River, Shahar River, Simineh River, Zarrineh River, Zola River, Soofi Chay, KahrizeSheykhan, Mardagh Chay, Madag and Siloo. The Zarrine-Rud River with an annual contribution of 1,621 million cubic meters is responsible for the largest share of water supply. However, too much and irresponsible construction of dams and preventing water entering to the lake has caused a serious crisis[15].

The main drainages to the Lake Urmia are classified into 3 categories: the surface currents, precipitation and groundwater flow. Various rivers pour into this and the average annual discharge of water inflow to the lake from the river is about 6.4 billion cubic meters [4].

Major sources of water waste include: water evaporation from the sea, lakes and reservoirs. The Lake loses 2 meters of its depth annually due to water evaporation. Mechanical devices such as shade or cover may be used to decrease surface evaporation but these methods are not useful in huge water supplies (Tisseuilet al.2013).

MATERIAL AND METHODS

The Lake Urmia is one of the most important drainage basins in Iran which owns 45000 km² and considered an internal basin. This basin is divided into 7 sub drainage basins including: Nazlu Chay, Barandazlu Chay, Mahabad Chay, Simine-Rud, Zarrine-Rud and Talkhe-Rud. The approximately 230 km length river, is one of the longest rivers of the basin of Lake Urmia which springs from the mountains like Chehel-Cheshme-Kurdistan and Qare-Elias between Saqez and Baneh which is called Cham-e- Saqez. This River is formed of permanent, seasonal and flood branches. The tree main branches of Saroogh Chay, Khrkhere Chay, Saqez and Zarrine-Rud join in ShahisKazemi Dam and after getting the Holasoo, Ajorloo and different seasonal branches pour into the Lake Urmia. This North-South river is placed parallel to the Somine-Rud River and passed along to the Shahindezh and Miandoab Cities and forming a 10 km delta which is wet and marshy in the meadows, pours into the south of the lake. Shahid Kazemi dam is constructed on this river which is higher than the Aras Dam and it is the most important dam in the area after the Aras Dam.

Urmia Lake (formerly known as Lake Rezaieh) is a shallow terminal lake located in northwest Iran, near Turkey, and is one of the largest permanent lakes in the Middle East, a region with arid and hot climate. It is situated in the heart of two neighboring provinces of West Azarbaijan and East Azarbaijan at latitude 37°00' to 38°12' N, and longitude 44°40' to 45°50' E in the west of the Iranian Plateau (Figure 1).



Figure 1. Geographical localization of Urmia Lake in the northwestern of Iran.

The Lake and its various islands have been considered as the protected area since 1967 and they have been protected since 1969 as a national park. It is the greatest basin of the Plateau of Iran, which is currently at its lowest width and depth. There are 16 wetlands from 5 to 1200 hectares area (some of them are now dry) which have freshwater, salty and semi-salty with really high ecosystem value. The range of water has been 1271-1278 from sea level and the range of salt have been 250-370 g/lit. The level of the Lake has reduced more than 6m in recent years. And more than 3000 km² has turned into salt marsh. Figure (2) shows the retreat of Lake Urmia from 1984 to 2012, and Figure (3) shows the decrease in the water level of the Lake.



Figure 2. The condition of Lake Urmia 1984-2012

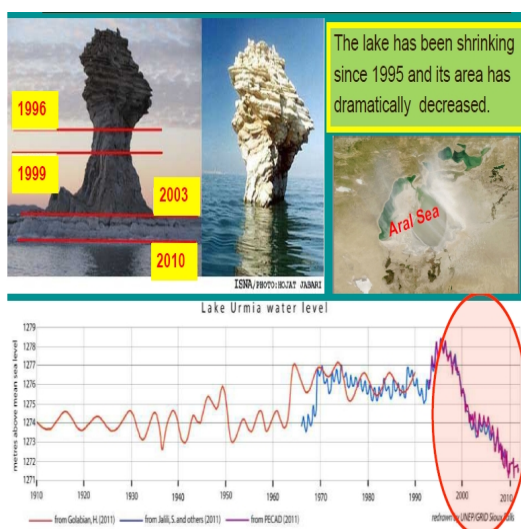


Figure 3. Water level changes of Lake Urmia 1996-2012

For the operation of the program, monitoring activities, review of the program sections and a monitoring mechanism are required. Appointing monitoring the implementation of the management program to the general environmental institutes is agreed as the most appropriate choice. The process is represented in the following figure (Fig. 4).

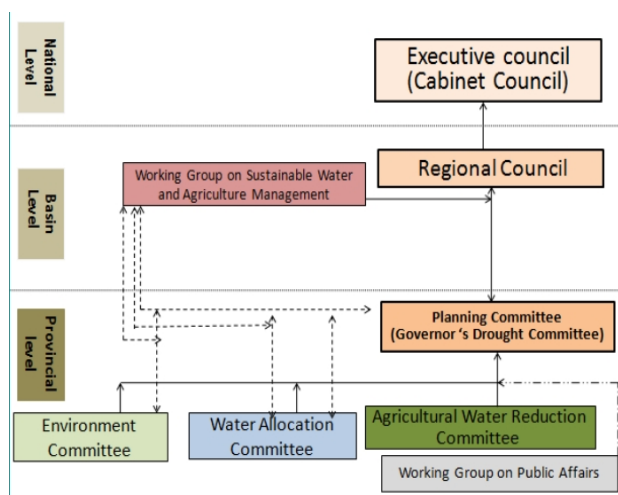


Figure 4. Environmental crisis factors of Lake Urmia

Construction of the Shahid Kalantari causeway bridge

The 15 km Shahid kalantari highway is constructed by drying 85% of boundary between the western-eastern sides of the lake by the use of a 12 km earthwork and only less than 15% of it is made of steel and concrete piers damaging the environment. Construction of the highway has caused the northern and southern half disconnected and has made natural and fundamental changes in the hydrodynamic and ecological characteristics of the lake region. Due to this action the water salinity is increased in northern half to 300 grams per liter due to lack of exchange between northern-southern halves which has gradual disappearance of the *Artemia*, while the average salinity of the Lake is 166 g/lit. The movement of vehicles, discharge of pollutants to the lake and making a lot of noise has caused the loss of secure habitat for migratory and resident birds (Fig 5.).



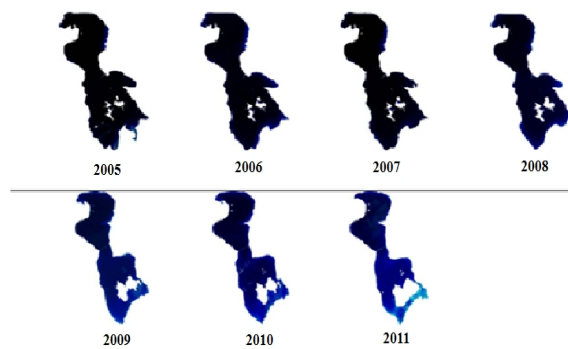
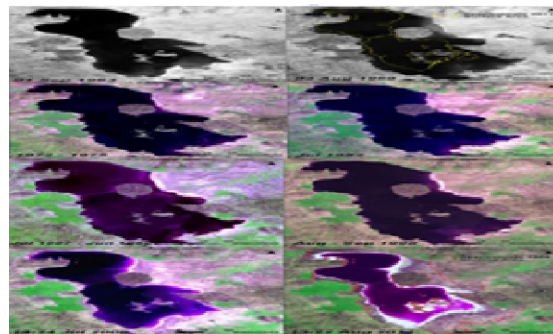
Fig5. Shahi Kalantari Causeway Bridge

Construction of numerous dams

Most experts consider fast and irresponsible inhibition of the flow of surface waters of the Lake as the most important threatening factor. Dams control flood and water flow is adjusted and used for other purposes without entering the Lake. Most of the adjusted water is used for agricultural purposes while irrigation efficiency is only 30% due to mismanagement and inefficient pattern of cropping which means 70% of the accumulated water is wasted. The construction of dams has led to the salinity of waters.

Table1. The features of Dams in Urmia

Construction level	Number	Annual adjustable water(million m ³)	Used by industry (million m ³)	Used for drink (million m ³)	Agriculture (million m ³)	The environment's need (million m ³)	The source's volume
Operated	36	1974.36	-	389.14	1241.22	-	1709.33
Under construction	13	1460.93	35	144.50	1204.43	73.75	1236.50
Under study	40	532.74	0.10	0.05	462.69	12	600.2

**Figure 6.**Changes of Lake Urmia coastline, 2005-2011**Figure7.**Changes of Lake Urmia level 1963-2011

RESULTS

All of these drivers and pressures have led to the current lake situation. As the Lake Urmia basin is an internal drainage system, the climatic factors have driven the lake to the more evaporation and less precipitation and the anthropogenic factors have led to less freshwater input. Less freshwater inflow and higher evaporation have led to higher salinity and water level decline. Figure (8) represents the gradual change in surface area of the Lake. After fluctuations between 1963 and 1998, sharp drop of surface area has been observed. As shown in Figure (9), in terms of water quantity, although there are fluctuations in water level over the past 100 years, the trend line slope is negative which implies that the lake situation is getting worse. In terms of water quality, recent investigations denotes that in early 2003 salinity of the lake has been raised up to 250 g/L in the southern part, whereas salinity was as high as 280 g/L in the northern part. More recent studies illustrate the amount of salt in the lake water increased from 160 to 170 g/L up to 400 g/L [18].

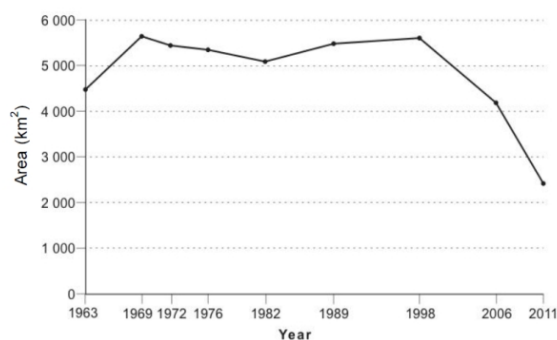


Figure 8. Lake Urmia surface area, 1963-2011 (Chander, 2012).

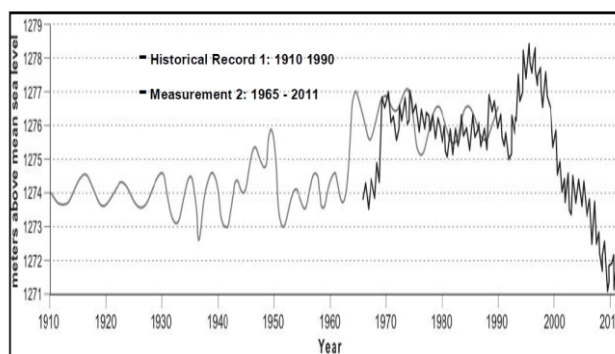


Figure 9. Lake Urmia water level change and its fluctuations, 1910-2011

Desiccation of Urmia Lake is, indeed, a socio-economic-hydrologic-ecologic problem. The lake has a significant sociologic feature in the region due to its cultural and recreational value for the residents adjacent to the lake. The lake could also be seen as an economic resource since it is a rich source of shrimps. Moreover, it could be utilized for tourism and recreational purposes. Urmia Lake is the ecological indicator of its own basin for its unique but fragile ecosystem which is due to the sensitive pyramid food chain of this hyper saline system. And finally it is a vital hydrological subsystem since it is the terminal in which all inflowing rivers sink. The issue of desiccation due to anthropogenic interventions is an ongoing global challenge which has affected different environmental systems in different scales and to different extents. Comparing the current status of the lake to the 80s (Figure 10) markedly shows the extent of this unfortunate but ongoing environmental disaster and the importance of a comprehensive study. Prior to its depletion, Urmia Lake was the 6th largest saline lake in the world by the average surface area of about 5500 km^2 . Landsat satellite observations, however, show that more than 50% of the lake surface area has been desiccated during the last two decades and its surface area has shrunk to less than 2500 km^2 . It well elaborates the importance of this issue and why such a strong emphasis has been placed on this issue as a motivation for this project.



Figure 10. Satellite images of recent changes in Urmia Lake's surface area and its surroundings, comparing 1984 with 2012

Experts believe the current situation of Urmia Lake is a result of global climate change, dam projects in the watershed, and the development of non-mechanized farming in the lake basin. However, historical documents indicate that Urmia Lake experienced a severe drought more than 200 years ago. In 1800, the maximum depth was only 75 cm. The lake was so shallow that an east-west road was created through the lake bed and oral histories from elders confirm the presence of this road. This history indicates that Urmia Lake has undergone more extreme droughts than present but the lake subsequently recovered. Figure 4 shows the water level fluctuations of Urmia Lake from 1965 to 2009. Figure (11) indicates that Urmia Lake experienced a drought from 1965 to 1968. The water level in that period matches that of 2003-2004 and the average salinity at that time was conceivably greater than 280 g/L.

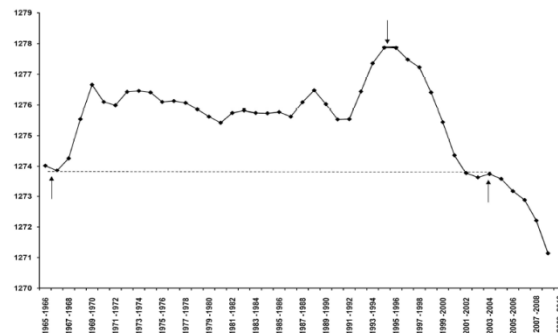


Figure 11. Water level fluctuation of Urmia Lake (1965-2007)

Satellite altimeter data measured the lake's level in 1995 to be at its highest level of any time in the past 40 years (Figure 12). Measures show a steady decline from that year forward with the most recent satellite altimeter data indicating a drop of approximately 7 meters between 1995 and 2011.

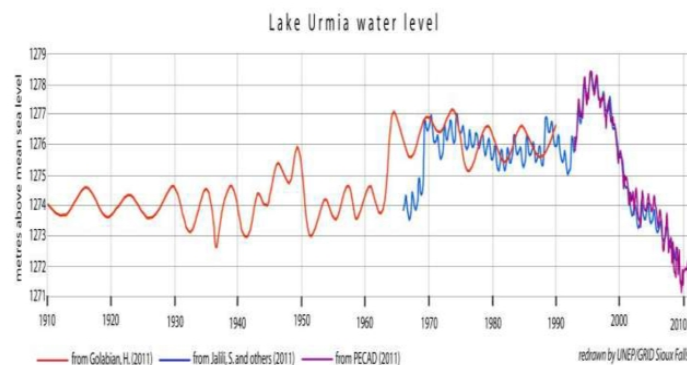


Figure 12. Overlaying multiple records of the lake's surface elevation shows generally good agreement. These data suggest that sometime around 2008, Lake Urmia declined below any point in the past 100 years of recorded lake levels and well below the long term average.

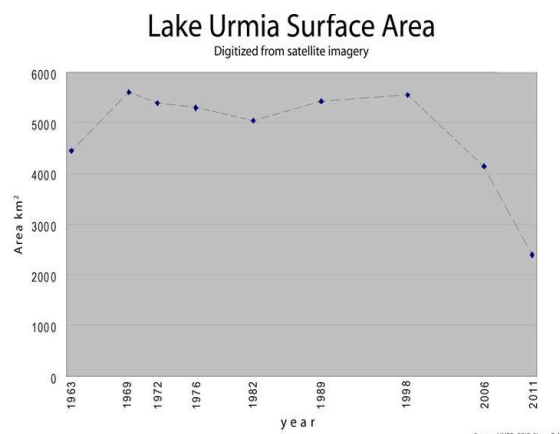


Figure 13. Surface area estimated from Landsat satellite imagery.

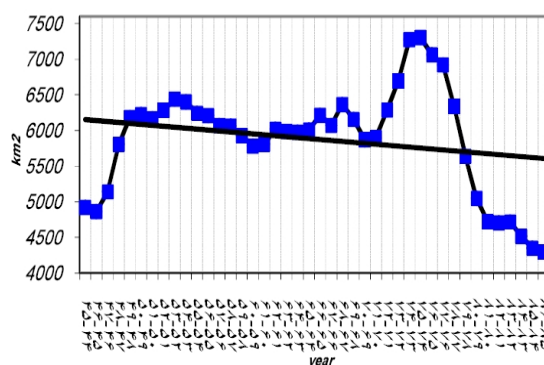


Figure14. Fluctuation of area of Urmia Lake during 40 years' time period

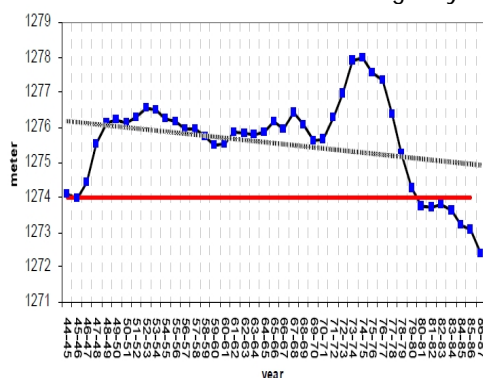


Figure15. Fluctuation of Urmia Lake water level during 40 years' time period. Stable line shows the minimum level that was assigned by high council of water regulation

Solutions of Lake Urmia crisis:

Water transfer

This plan was used in transferring water from Gelas Lake into Lake Urmia at Kani Sib and Siloo regions. The required water for the Lake from the Kani Sib Dam is 640 million m³ in phase 1 and 1 billion m³ in phase 2. Also the Silveh Dam will provide 100 million m³ which will be poured into the Godar Lake and then into Urmia Lake using numerous tunnels. The area under study is 120 km far from Urmia City at the south of West Azerbaijan; the Kani Sib Dam is situated in 15km from Piranshahr City. It consists of the drainage basins of the Zab and Godarchay Rivers. The Godarchay basin and River is situated in the north of the Zab basin. The Godarchay River basin is in 36:45- 37:10'N and 44:45- 45:43'E and the Zab River basin is situated in 36:18-36:55'N and 44.45-45.50'E to the Garzhal Hydrometer.

The Kani Sib dam is one of the main water transfer chains to the Lake Urmia from the neighbor basins. This dam stores 370 million m³ water. One of the main parts of this project is the 35 transfer tunnel which is being constructed in two work sites using modern tools. Water transfer from the neighbor basins like Aras in the north and Zan in the south, improving the irrigation methods and cloud seeding are among the predicted plans. The transference of zarineh-Rud Lake water to the East Azerbaijan province has raised some questions. Witnessing the salt march every day which used to be a part of Lake Urmia closes every door to scientific explanations. The second phase will increase water transference from 5 to 10 m³ per a second and at the same time 17 m³ must be transferred to Tabriz by the open canal. The pipeline related to the transference of Zarrine-Rud water to Tabriz is broken in more than 40 km of its way.

Tunnel construction

Zab River is a river that flows in the Kurdistan region and the Greeks used to call it Lycos. Zab River originates from the Mt.Darujan and irrigates Zab plains passes Ahangaran and Yazdabian mountains and pours into Diale River and it is called Gav-Rud, Sirvan and Dialeh River. This river origins from the mountains near Asad-Abad in west of Alvand and flows from east to west to Iraq and passes through narrow canyons it deviates into Shahoo and Kalesar and southeast and finally to Tigris. Also it is said that many rivers are called Zab in Iraq and also two rivers near Tigris are called Zab. One of them is the little and the other is the great Zab and another one is AsfalZab. These two rivers pour into Tigris from the mountains of Iran. This River is 400km long and it has 22000km basin. There are two dams on this river. This river origins from Zagros and leaves from the west. The Little Zab flows in the upside zagros downs. the Kalvy (Zab) river origins 2140 meters above sea level and flows from East to West and then flows

into the southern district and in a wide canyon flows into Piranshahr- Sardasht. At the beginning of the plain it flows to the west and pour into Tigris (Fig 16).



Figure 16. Little Zab River Bridge



Figure 17. Little Zab River in Sardasht.



Figure 18. Little Zab River

Water transfer from Zab or Gelas to the Lake is another action to survive Lake Urmia the execution of which is started from one year ago by constructing Kani Sib dam. This tunnel is 35km long with 680billion Toman budget. It is predicted that it will provide 700 million m² to the Lake. Also the construction of Silve and chapar Abad are complementary actions. These dams will provide 100 million m² annually. The Lake needs 3.1 billion m² water to ecologically survive. This amount of water must be supplied by west and east Azerbaijan and Kurdistan. And weat Azerbaijan has 1.8 million m² one million of which is paid by the implementation of the plan. Transference of Alavian dam water is one of these plans.

DISCUSSION

Water transfer to Lake Urmia

The purposes of this plan is to transfer 623 million m² from the Gelas basin into Lake Urmia drainage basin through constructing the Kani Sib dam and a 35km tunnel, saving a part of Zab river and preventing it from flowing out of the country, solving the environmental problems of the Lake, Providing the drinking and industrial water of Naqade city which is about 20 million m². The water transfer of the Zab River into Lake Urmia consists of three parts: The Kani Sib dam, the tunnel to transfer water from the Kani Sib Dam to the Lake and Badini Abad diversion dam and transport canal. The Kani Sib Dam is an embankment dam, 51 m height, crest length of 776 m, crest width of 9 m, the total volume of the reservoir at normal level. 326 million cubic meters, adjustable volume 740 million cubic meters per year, with Ogee weirs, the spillway crest length 60 m, Height of the coffer dam to bedrock 20 meters, The diversion tunnel on the

right, number and shape of the diversion tunnel with circular double-stranded length of the tunnel (1) 252 m, the length of the tunnel (2) 282 m, internal diameter tunnels 5/5.



Figure 19. The entrance of diversion dam



Figure 20. The outlet of diversion dam

The features of Kani Sib Dam water transfer tunnel to the Urmia Basin

Tunnel length 35.3 km, the tunnel diameter of 5.5 meters, 1354 m access tunnel length, drilling method: 2 TBMs, Steny segment type, a body of 646 million cubic meters per year water transport, with the free flow slope of 0.085.

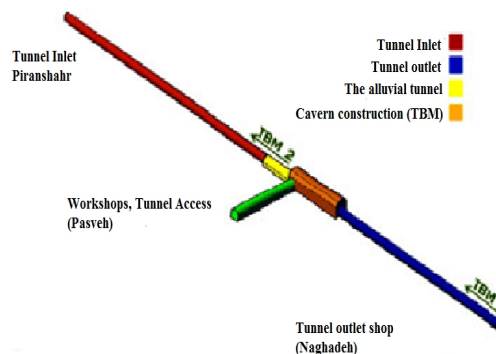


Figure 21. 35.5 km water transfer

Badini Abad diversion dam and transport canal

5.5 meters high, 42 meters long spillway, concrete rectangular channel length of 616 meters to clarification pond, pond clarification after transmission over 5.5 km, the transmission capacity is 27 cubic meters per second.



Figure22. The transfer tunnel outlet

SUGGESTIONS

1. efficient water use in agriculture, industry and drinking water in the basin and determine the proper cultivation and transfer of surplus water to Lake
2. Implementation of watershed projects with biological priority in pasture and forest and development of rain gardens plans
3. Water transfer from adjacent basins, including Zab basin
4. Implementation of Atmospher control with cloud seeding priority and deployment of Meteorological Observing System
5. Investigating about the methods of evaporation decline with environmental, economic and social objectives
6. integrated and comprehensive management for all relevant parts of the lake and the culture and increasing awareness
7. Improving construction of the Shahid Kalantari causeway bridge, construction of aqueducts so that the water flow is kept similar to the previous condition.
8. Extraction of salt
9. Refraining from construction at the river basin of the lake and releasing water collected in dams in operation
10. Modification of the cropping pattern with virtual water trade approach
11. Reducing water waste on the path of the rivers and dredging the rivers.

REFERENCES

1. Barnes, G.T. (2012). "The potential for monolayers to reduce the evaporation of water from large water storages". *Agricultural water management* 95 (2 0 0 8) 3 3 9 – 3 53.
2. Chander A (2012). The drying of Iran's Lake Urmia and its environmental consequences. *Environ. Dev.* 2(2):128-137.
3. Dalezios, N, R., Z.G.Papazafiriou, D. M. Papamichail & T. S. Karakostas, 2006, Drought Assessment for the Potential of Precipitation Enhancement in northern Greece. *Theoret. Appl. Climatol.* 44, 75-88.
4. DarvishiKhatun, J., Narimi Sa, S, Mohammadi, A., Saleh Ali Milani, A., (2010), the environmental lake water and river water needed to maintain an optimal level of program effects development on the lake, the Fourteenth Congress of geological Society of Iran, Urmia University, Iran
5. Faramarzi N (2012). *Agricultural Water Use in Lake Urmia Basin, Iran: An Approach to Adaptive Policies and Transition to Sustainable Irrigation Water Use*. Master Thesis, Upsala University, Department of Earth Science, p. 44.
6. Hsin, Yu-LunLawrence(2009). "Feasibility Experiments into the Use of Hexadecanol for Hurricane Mitigation and the Planning and Construction of the Monolayer Evaporation Retardation Laboratory". B.S. thesis. Massachusetts Institute of Technology.
7. Jafari, R, 2009, studying the corrosive effects of the water of Orumiyeh Lake on the foundations of Shahid Kalantari Bridge.
8. Jalili, S., Kirchner, I., Livingstone, D., Morid, S. (2011). The influence of large-scale atmospheric circulation weather types on variations in the water level of Lake Urmia, *International Journal of Climatology*, and Iran.
9. Laabat,J,2008,the industrial capacities of Orumiyeh Lake. *Water resources Management journal*,Shahrekord,Iran
10. Lin,Y,(2012),,"Water Resources Crisis and War Threat .", *Social watch*, vol. 20, pp 61
11. Mohaggeg MH (2007). Reducing on the water level of Urmia Lake, future view and recomondations. *Urmia Lake and its potentials to development*. Urmia University pp. 1:69
12. Morid S (2012). *Introducing Lake Urmia Basin (Iran) Drought Risk Management Plan*. High Level Meeting on National Drought Policy, Geneva, Switzerland.

13. Rassouli, .A, Abbasian, S, Jahanbakhsh, S., (2008), fluctuations in lake monitoring with multi-sensor and multi-temporal satellite image processing, the Third Conference on Water Resources Management, Iran
14. Rezvantab S, Amrollahi, MH (2011). Investigation of Recent Changes in Urmia Salt Lake. *Int. J. Chem. Environ. Eng.* 2(3):168–171.
15. ShafieAlavijeh, R.A, (2009), coming from the perspective of lake water and salt balance, water management conference, Iran
16. Tisseuil C, Roshan G, Nasrabadi T, Asadpour GA (2013). Statistical modeling of future lake level under climatic conditions: Case study of Urmia Lake (Iran). *Int. J. Environ. Res.* 7(1):69-80.
17. Waiser, M. &Robarts, R., 2009.Saline Inland Waters.*Encyclopedia of Inland Waters*, p. Pages 634–644.
18. Zafarnejad F (2010). The contribution of dams to Iran's desertification. *Int. J. Environ. Stud.* 66(3):327-341.
19. Zarghami, M. (2011).Effective watershed management; Case study of Urmia Lake, Iran. *Lake and Reservoir Management*, 27(1), 87-94.doi: 10.1080/07438141.2010.541327.