Monitoring of Lar Dam: Finding New Leakage Regions

Kamran Koohestani[1],Mahsa Ali-Haghnezhad[2], Marjan Samuti[3], MohammadReza Zarsazi[4]

1- Technical manager of Projectin SamanAbSarzamin Consulting Engineer Company
Email: kamrankoohestani@gmail.com

2- Water Engineering Expert in SamanAbSarzamin Consultant Engineering Company
Email: Mahsa.haghnezhad@gmail.com

3- Head of Environmental Department in SamanAbSarzamin Consulting Company
Email: m_samuti@yahoo.com

4- Chairman of the Board in SamanAbSarzamin Consultant Engineering Company Water
Email: Zarsazi2@gmail.com

Abstract

Lar Dam is one the main drinking water resources of Tehran municipality in Iran and it has a strategic importance. By considering the climate change condition and water shortage, the importance of dam willsdouble in future. Unfortunately, Leakage problem was observed at the start of impoundment so that water surface elevation has never risen more than 2507m (A.S.L), which corresponds to 40% of designed capacity of the reservoir. Over the last 4 decades, several studies and attempts were performed in order to finding the leakage paths and implementing remedial works. Available estimations of water leakage show the rate of leakage at high level to 12 m^3/s. The aim of this study is to determine main regions of water leakage in dam site and providing necessary remedial plan. in line with this purpose, S.A.S Consultant Engineering Company (S.A.S) had chosen two approaches:Theory studies and reanalyzingavailable data and reports, conducting field monitoring to findmore leakage regions. It has revealed that there are some new leakage points specially in upstream of Emamanak Valley by measurement the velocity of stream flow and performing several dye tests at the problematic and suspicious points. All taken measures are important for calculating the stability of dam under the karstification condition.

.

Keywords: Dam, Leakage, Reanalyzing, Monitoring, Stability.

1. INTRODUCTION

Growth of population, development of human activities and increment of human needs are effective factors on development of construction the hydraulic structures and infrastructureseven in danger foundationswhich are difficult to control the sustainability of structure. Although construction of dam in karst terrain is associated with high risk, because of existence of important ground water resources (i.e. aquifers) it seems beneficial to moderate karst foundation to meet increasing demands such as drinking, flood control, irrigation and producing hydropower plants.

The Lar Dam site is situated in Khazar Basin and Haraz-Gharesu Sub-basin on Lar River with the area of 675 Km^2 in North of Iran. It considers as a main drinking water supplying sources of Tehran, capital of Iran, which has the largest storage volume of reservoir among the other dams of Tehran. In other words, one of the main purposes of this dam is that to supply drinking water of Tehran, irrigation water for the North of Iran and hydropowergeneration for downstream of dam. Leakage from reservoir had observed at the start of impoundment of reservoir so that water surface elevation has never raise more than 2507m (A.S.L) which corresponds to 40% of designed capacity of the reservoir. This issue was intensified by increasing the population of Tehran Municipality. Based on available reports on the climate change phenomena and its effects on reducing of rainfall, long-term drought and water shortages, the status of dam for supplying demands will get worse.The water leakage at Lar Dam is mostly due to the numerous of caves and conduits in underlying limestone bed (Urmeihy., A. 2000) [1].The problem of water leakage from reservoir of Lar Damhasknown as one of the most complicated problems of dam construction in karsticsites due to the complex nature of karst foundation (Milanovic, 2004) [2].Over the last 4 decades, several studies have accomplished in order to find leakage points and implementation of remedial works. In spite of many consultant engineers have proposed rehabilitation alternatives for Lar Dam such as grouting and filling of caverns, but still the leakage from reservoir has been continue. Therefore, investigation of previous changes by field monitoring of the site and observing the status of water tableof damduring operation is necessary. Accurate investigation the status of water leakage and settlement of foundation and its reasons have an undeniable role on estimation of costs and effectiveness of suggested rehabilitation plans.Several studies and reports, which accomplished by researchers and engineers are presented in the following:

Urmeihy, A. (2000) [1] studied on the water leakage of Lar Dam. According to this research, the fracturing had developed karstic area and sinkholes in the limestone below of the dam and acidic ground water, run-off from the Damavand Volcano increases the dissolution of the carbonate beds along the fractures and boreholes. They tried to document the relationship between the water level and the development of sinkholes that effects on the dam's stability. Also, the possibility of failure in the foundation and abutments of Lar Dam.

Feghhi (2006) [3] was succeed to find a fault lineament for the first time through the satellite images. It called Lar Dam-Polur lineament because it is elongated from the dam reservoir, passing the right bank of the dam axis and then, to the Polur springs (the second discharge area of the leaked water). This fault along with fractures and lateral sinkholes surround of it known as a main factor of water leakage from Lar Reservoir. Their result was in accordance with Setec Company's outputs.

Talebbeydokhti., N. Et al (2006) [4] conducted analytical studiesonKarstic bed problems in dams and suggestion of remedial works for each case. More than 100 dams and reservoirs were investigated in this research. They provided an accurate table as a reference for quick monitoring on dams with Karstic problems and their proposed remedies for engineers and designers. Salman Farsi Damwas specifically investigated as a case study in this researh. They studied on succeeded remedial samples at international level; also some general aspects were studied such as, developingkarstic channels, injection of dye into the caverns and all channels, hot microclimate on the base of observed karst features, large caves filled with piles of huge limestone rocks, caverns well filled with stratified, compressed and plastic clay, karstic channels were investigated. Five selected remedial measures included; (1) filling a part of karsts and having a deep cut-off wall, (2) filling all karsts and keeping grout curtain, (3) upstream and downstream by pass, (4) continuing the grout curtain to 15^{th} lithological, they chose upstream by pas as the best remedy measure to cope with the problem.

ZarghamMohammadi et al (2007) [5] studied on Karstic foundation of dam and leakage potential at Khersan 3 Dam, Iran. They claimed that previous studies on karstic features of dam, geological mapping, geomorphology and extension of boreholes were not efficient enough to investigate karst structure, also for analysis of hydrological behavior of the karst structure in different conditions of groundwater flow. They suggested a methodology that covered the conventional methods and cope with their shortages. The methodology included three stages: (a) recognition of geological and hydrological settings, (b) delineation and functioning of the karst system related to the future of the reservoir and (c) assessment of the leakage potentials

Soleinmani et al (2009) [6] applied the change detection technologies by using maximum likelihood supervised classification and post-classification on the Landsat images acquired in 1997 and 2000 for the Lar Dam water elevation changes. They considered three different classifications of minimum distance, parallel period and maximum likelihood with the aid of ground truth data. They collected truth data as control points during four field visits that conducted between 2003 and 2007. The investigations showed that elevation of surface water in the reservoir changed due to the seepage development of karst formation during the study period.

Mozafari and Raeisi(2015) [7] realized that despite grout curtain treatment works, the discharge of downstream springs were not reduced. They determined the general flow direction in karst for each sub-aquifer by hydrological analysis and water balance calculations. They applied two models for investigation of water flow: firstly, the main leakage route toward the downstream spring is most probably through arelict Karst conduit system developed along bedding planes of the Asmari formation according to the first model. The water leakage can significantly reduce by extension of the grout curtain further into the upstream impermeableGachsaran formation

Milanovic(2015), [8] suggested for providing a good geological map during construction and operation of dam to mitigate risk. Moreover, he believed that a proper risk reduction strategy is based on detection of caves and karst channels at the dam site. In spite of hard trying of many geologists to detect cavesbelow the water surface (deeper than 20 m) and applying last technology to prevent from water leakage through the karst channel, there are still several leakage points. By development of sophisticated geological investigation methods, the risk probability would be decrease.

In 2017, Mozafari and Raeisi [9] described that current karstification of reservoir related to existence of ancient and natural lake at this place which its level was about 2570 m and it is expected the kasrtic structure has extended up to this elevation.

NayebAsadollah., S. et al (2018) [10] estimated that water seepage from the reservoir of Lar dam based on the combination the results of geological studies and identification of the flow conduits in the right bank of the reservoir. Base on the results of reading piezometers and performing dye tests,measuring seepages mainly occurs in the right abutment of the dam. By performing dye test revealed that the North Tizkuh and F3 faults are two isolated conduits for seepage and conveyance into Lar Valley fault at downstream of Lar Dam. They applied finite elements method to calculate water seepage from the dam. The results of numerical method indicated that when the level of reservoir is at 2485 m A.S.L, the average discharge of water seepage was about 8.51 m^3 /s. The average discharge of springs in downstream of the dam used to verify the numerical method. The results showed a very close relation between estimated and observed rate of discharge.

In spite of extensive grouting and filling of the cavern about 42000 m^3 of materials, leakage from reservoirhas continued. SamanAbSarzamin Consulting Engineering Companyin2017 had conducted several field monitoring and studied on the theory of water leakage from the reservoir of LarDam. During thestudies, the expert team had attempted to identify the exact source and various aspects of the problem so that to lay a foundation for policy makers and operators to decide with sufficient certainty. During the studies, in addition of introducing new zones and leakage point, accurate re-analysis of previous data and information alsowere investigated. Since in previous studies could not find the leakage path, this study has focused on conducting some studies, finally some recommendations and suggestion were provided for future studies.

2. MAINE FEATURES OF LAR DAM

Lar Dam is located in Northeast of Tehran, Iran with 51˚35ˋ to 52° 00´ longitude and 35˚51´to 36 5 latitude (Khorsandi& Miyata, 2007) [11] in the Lar Valley. It has constructed on the Lar River with area of 675 Km^2 and in term of geographically, the Lar Dam has 75 Km distance from Tehran and 100 Km from Amol. The main features of Lar Dam ispresented in Table.1.

Table 1 Characteristics of Lar Dam

Type of dam	Embankment - homogenous
Year of completion	1980
Dam height above foundation (m)	107m
Height from bed's river (m)	105m
Dam crest width (m)	13
Dam crest length (m)	1170
Total water surface area of the reservoir (Km^2)	33.5
Reservoir width (Km)	1 to 6
Reservoir length (Km)	18
Total reservoir volume (MCM)	960
Inclination of reservoir bed	0.55%
Lateral facilities	1. Two gates with the total capacity of 185.5 m^3/s 2. Ogee spillway with 120m^3/s discharge capacity
Aims of dam construction	Supplying agricultural water requirement with cultivation area of 90000ha, supplying parts of drinking water for Tehran municipality and transmission of water about 140 MCM to the hydropower plant with capacity of producing 87 MW hydropower energy

Tectonically the study area considers as an active geological area. Bed and walls of the reservoir include seven geological structures; Shemshak, Delichay, Lar Limestone, Tizkuh, Karaj, sedimentions of the lake and Damavand lava. Among these geological structures, Lar limestone is the most challenging one because of high rate of dissolution. From the first impoundment of the reservoir, high leakage was observed in the range of 7.7 to 10.8 m^3/s and discharge amount from the springs in downstream of the dam (Haraz and Galugah) increased.The water leakage ofLar Dam is due to the abundance of caves and conduits in the underlying limestone beds. (Uromeihy., A., 2000)[1].

The karstification potential of Lar and Tizkuh faults has increased by construction of the dam and impoundment of the reservoir. The current karstic structure of the Lar and Tiz-kuh has extended to deep levels. Its ultimate depth still has remained unknown. This issue was observed in the first case of injection cement to fill kasrtic caves in the early years of impoundment of the reservoir. Significantly, even only for one case 100000-ton cement were injected to fill the holes, which had no effect on the impoundment of reservoir (setec, 1992). Based on the research of Mozaffari and Rayiesi (2017) [9] by studying on recent formed boreholes can be realized that current status of karstification has been made by formation of natural lake at this site which its elevation was almost 2570 m and it is expected that current karstic structure to be extended at this level.

3. REANALYSIS THE RESULT AND OUTPUTS OF PREVIOUS RESEARCHES

3.1. REANALYSIS OF PREVIOUS STUDIES

This researchis separated into two parts: (1) Theory studies, collection of previous data, information and reports, reanalyzing available data. (2) Study on the problem, field monitoring and visiting the site. During these studies all the previous experiences, researchesand results had taken on a practical aspect. It has tried to investigateleakage points with more details that ithad not been addressed before.

3.1.1. SETEC COMPANY

According to the geological studies of SETEC Company, the part of reservoir that has the potential of water leakage was estimated over 1 million m^2. They believed that the most of the water leakage pointsareon the reservoir's walls. While the ultimate assessment depends on determination of permeability of the deposits and the structure of lake's bed (6th volume, Remedial and Alternative Works Report). Hydrologic studies conducted by analyzing the level of piezometers at the site. Theyidentified rout and direction of groundwater flows and analyzingsome parameters such as geological structure, the location of piezometers, difference in time-phase between reservoir level and piezometer level to provide a good map of ground water flow status. By review on ground water elevations maps, hydraulic gradient changesare evident at different locations under the body of dam (the groundwater level in November 1986) at the junction of dam with theTizkuh formation.There is no water leakage problem due to the high gradient of groundwater at this point, which indicates the accumulation of water behind an impermeable structure. This issue can be related to several injections and grouting curtain. Based on SETEC's reports, the main issue is impossibility of determination the south boundaries of groundwater elevation on the map. To resolve it two assumptionswere defined, (1) outflow from the outlet points other than Haraz and Galugah springs and (2) there is a wider border in the study area rather than current state. SETEC described a mechanism for water leakage from the reservoir, which considers formation of a secondary reservoir under the elevation of reservoir's bed. It could store the water of reservoir after leaked into secondary dam, then the outflow will be exitfromGalugah and Haraz springs (Figure 1).

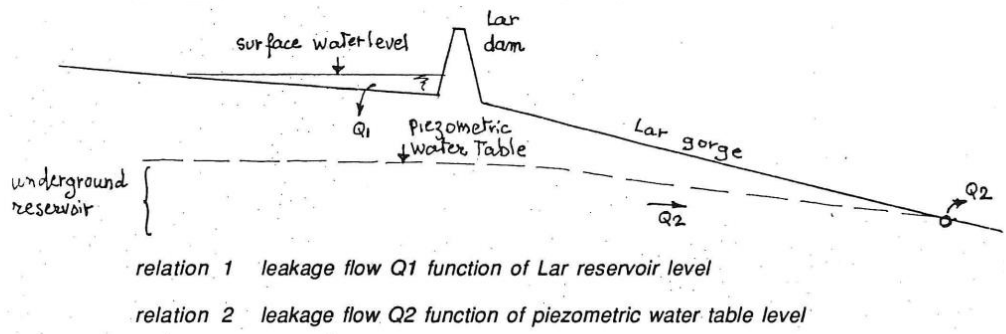

Figure 1. Schematic plan of water leakage by SETEC

They investigated the mechanism of formation the sinkholes of area, their size and categorizing them into two groups, "Large and deep" "type I" and "small and shallow" "type II". Tracing measures were carried out by applying dye test and radioisotope to find the location of water leakage from the reservoir, which its results are presented in table 2.

Table.2 Results of tracing measure (Mozaffari and Raeiysi, 2017)

Velocity (m/s)	Observation Location	Tracer Type	Injection Location	Year and phase
120 173	Galugah Spring Haraz Spring	Rhodamine	Reservoir	First Stage 1983
108 170	Galugah Spring Haraz Spring	Rhodamine	Reservoir	
107 154	Galugah Spring Haraz Spring	Uranine	Reservoir	
153 150	Galugah Spring Haraz Spring	Uranine	Right Abutment	Second Stage 1986
88 114	Galugah Spring Haraz Spring	Uranine	Right Abutment	
165 194	Galugah Spring Haraz Spring	Eosin	Right Abutment	Third Stage 1987
155 180	Galugah Spring Haraz Spring	Duasyn	Right Abutment	
175 210	Galugah Spring Haraz Spring	Uranine	Right Abutment	

According to the table above, most of injected substances had been existed through the Galugah and Haraz Springs and this fact indicates the relation between the mentioned springs and the reservoir. Moreover, it shows thatfew injections did not exist and remained in the reservoir or the exact location of their outflow was unknown. This issue could be remarkable because of impossibility in determination of the south boundary of counter lines of groundwater. The primary focus of this study is on theavailable geological reports and reanalyzing the data thatwere obtained by Terra Company to identify potentially leakage of the area. During the studies of SamanAbSarzamin Consultant Engineering Company (S.A.S), in addition of Tiz-Kuh structure, two new regions introduced as suspicious points that need to more investigation: (1) Right bank of entrance to Emamanak Valley (SLP02 area) and (2) 1.5 Km upstream ofEmamanak Valley (SLP01 area) Figure 3.

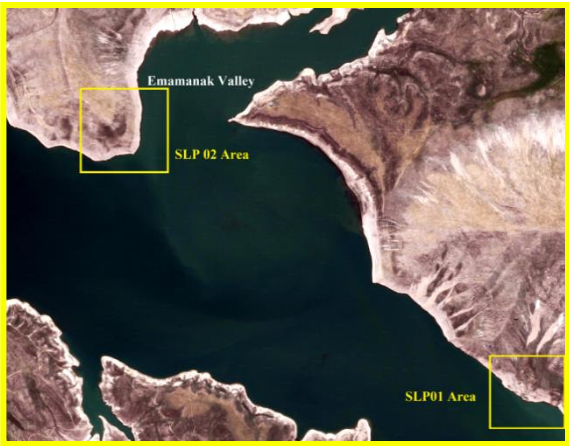

Figure 3. Identified probable leakage points for field monitoring

3.1.2. TERRA COMPANY STUDIES

Terra Company studied on Lar Dam in 2010 and using Acoustic Doppler Current Profiler (ADCP) device to determine the profile of stream flow near to reservoir’s wall. ACDP is a device which works on the basis of Doppler Effect and it is able to measure the speed of movement of water‘s participles. Therefore, it provides a profile of velocity changes in vertical direction. In addition, they measured the velocity of stream flow in almost 90 surveyed lines thatconducted at 2474 m level. S.A.S. analyzed the raw outputs of Terra. The data were analyzed and converted into the visual out puts for better understanding of the status of reservoir in that time. This issue had conducted by codifying and programming in MATLAB Software, drawing 2D diagram of velocity magnitude and the diagrams of flow vectors. In the following, one of the changes analyses of velocity is presented as a diagram (Figure.4).The weak point of these measures is related to the bad timing for surveying and surveying. At the end of the September and early of October, the water level was at 2474 m. Since many outlet points were identified at the above this level, it was more better to measure the velocity at the time of maximum level of the reservoir and more accurate information from outlet points could have obtained.

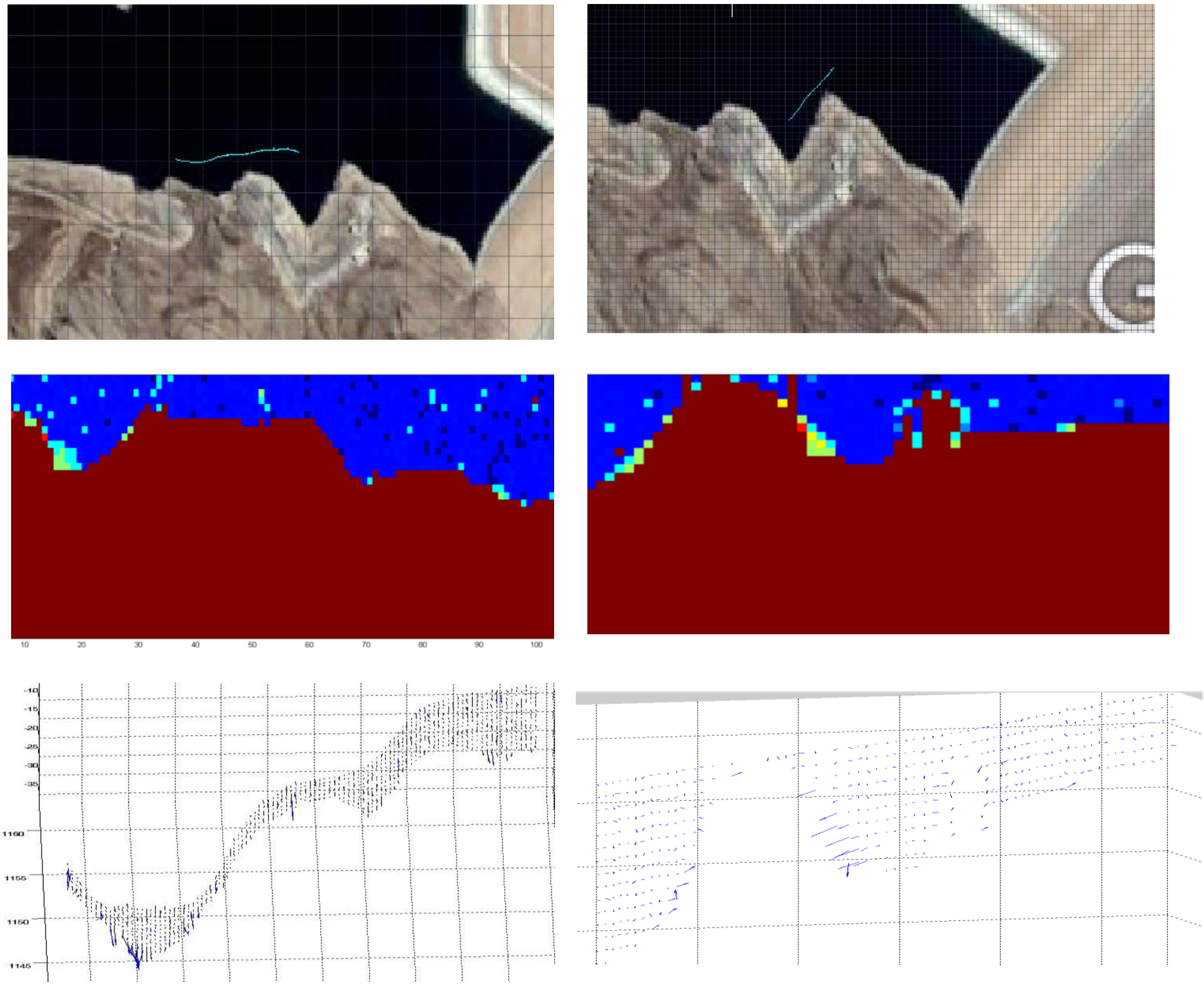

Fig 4. (a) Surveyed line, (b) 2D profile of water flow magnitude and (c) vector of stream flow in the profile

3.1.3. MAHAB GHODS CONSULTING ENGINEER COMPANY-DOYRY COMPANY

PORY Company and Mahab-Ghods consultant Engineering Company conducted studies on the leakage of Lar dam in 2012. They had done several fieldvisits and conducted remedial works with executive details including grouting deep holes and large cracks, surface lining with multi-layer rip-rap. During these studies they had only focused on Tiz-Kuh and right abutment of the dam. They neglected for visiting the upstream region including Emamnak Valley and the upstream of it. They believed that there is no need of providing remedial works for upstream of Emamanak Valley due to the piezometricelevations at this region. Treatment plans that they suggested including plan for cracks out of the water, under the surface of water and on the body of the dam.

3.1.4. MAHARAB OMRANGOSTAR CONSULTING ENGINEERING

This company started the field monitoring in 2014 and 2015at the elevation of 2450 m to 2490 m. Similar to other studies, they investigated the right abutment of dam (Tiz-Kuh). They recorded and quantified the water leakage from cracks and holes from the body of the dam.

4. FIELD MONITORING OPERATIONS

The field monitoring was started at the beginning of 2017 and it was continued till to reach the maximum water level of the reservoir. The first visiting was carried outfrom the lake and abutments of dam in April and the last one in November. Among different methods which applied for field monitoring dye injection was selected as the best method for this region. At the level of 2490.81 m dye testingperformed next to the walls and probable leakage points and cracks. The field monitoring was planned based on the average declining the water level between 1m to 1.5 m. For achieving to accurate results, monitoring plan continued up to maximum level, 2470.7 m level (average 1 m decline per visit). The observation results are characterized by three colors: green means there is water leakage at that point which is shown by which is shown by (+); red color means there is no water leakage, which is shown by (-) and orange means there is no defective detection of outflow at the injection site which is shown by (O).

4.1. FIELD OPERATION IN APRIL AND MAY

A technical field visit was conducted during this period, as the level of water's lake was rising. This stage of monitoring plan included investigating the lake and suspected sites on water leakage. All markings were made at the level of 0.5 m above the water surface.

4.2. FIELD MONITORING IN JUNE

During this period, the water level raised from 2490.9 m to 2488.7 m. In addition, Tizkuh structure and the body of dam at the place of sinkholeswere monitored. During the second field visit, new cases were observed. The first case was hearing loud sound of stream flow from the inside of the rock in Tiz-Kuh structure (P1 point). Injections at this point indicated the definitive water leakage in the whole range of this level and the location of injection and exiting of the injected substance for future monitoring was determined. The surveyed siteis presented in Figure 6. The large karstic holes and cracks that has not been identified in previous monitoring (like C1) investigated with more details (Figure.5)

Figure 5. of C1

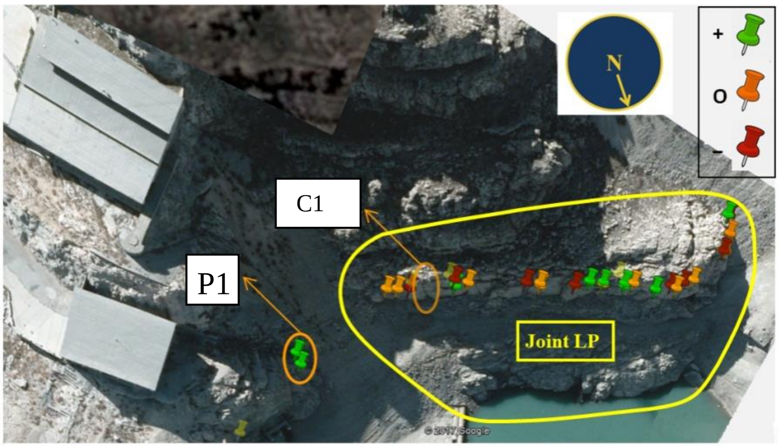

Fig6. Results of investigation and dyetest in 2017

4.3. FIELD VISITING IN JULY

During this period, Region S1 wasidentified as the most complex region in that time. The structure of Joint LP is located inside of the region S1 and it has a probability of water leakage at this point. Despite several injections, still deep cracks observed in it. The result of field monitoring in July is presented in Fig 7.

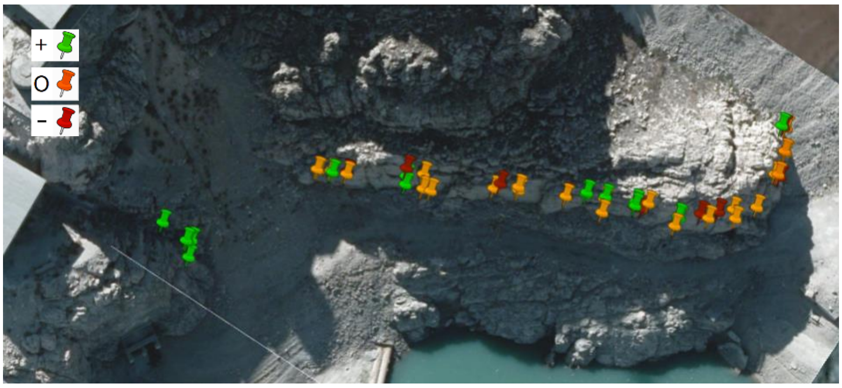

Fig 7. The results of investigations and dye test in field visit in July

On 2017-Aug-05, a huge hole was observed at Joint LP, but due to the high level of surface water, it was not possible to go inside it. In field monitoring on 2017-Aug-17 by decreasing surface water level, it became possible to inspect the size of the cave, which called C1. Numerous of corrosions and cracks on the wall showed the water leakage in C1. Injections showed the water leakage from the western cracks and holes on the cave and the body of dam.

4.4. FIELD VISITING IN JULY

The right abutment, EmamanakValley and the upstream of it (SLP01, SLP02)monitored. In right abutment and the structure of Tiz-Kuh besides dye injection in cracks, investigations were carried out with more details onthe dissolution cavities. Above the level of LP04a new crack observed. The scouring erosion in eastward and inside of the caves, existence of wood and debris within a few meters inside of the cave were evidences of water leakage.A series of injections were carried out from 2491 m level to the lowest level 2482 m.The result of injection at this place is presented in Figure 8.

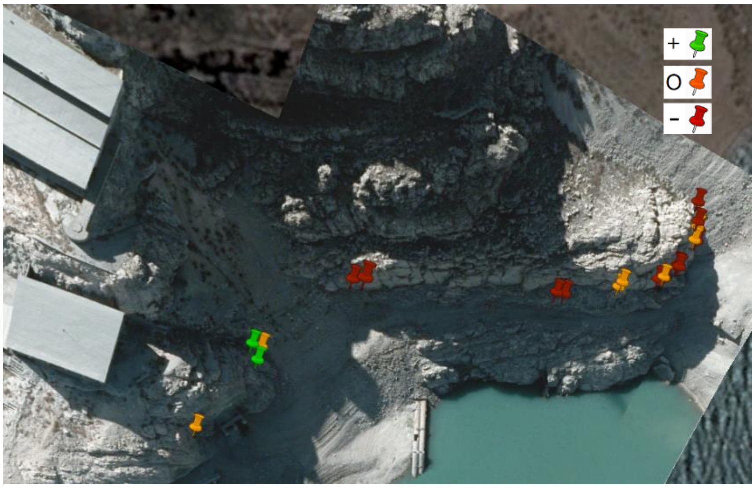

Figure 8.The results of field monitoring and dye injection in September 2017

4.5. FIELD MONITORING IN OCTOBER, NOVEMBER AND DECEMBER

Due to the decreasing of water level and appearing suspicious water leakagepoints, besides common inspections, identified leakage points in previous field visits were investigated again to measure size and dimensions of the holes more accurately. in general three types of signs for water leakage were evident at these points, the first one was changes the color of the rock masses and darken them. Secondly, existence of dried algae and accumulation of them in holes and crack and thirdly, decreasing the sharpening of the edges of rock masses which were exposure of outflows. Some of these evidences is presented in Figure.9.

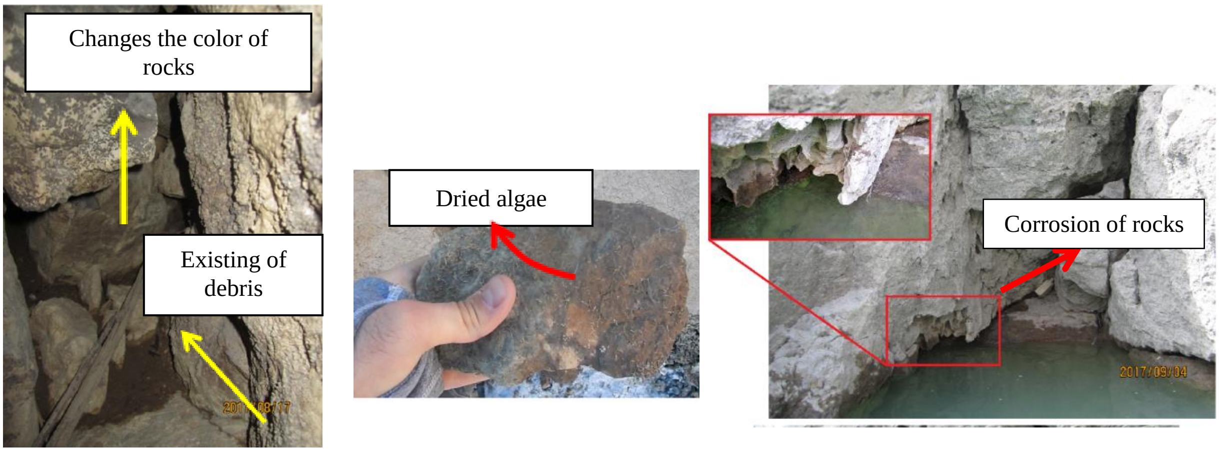

Figure 9. Evidences of water leakage

Due to the lack of remedial works at upstream of Emamanak Valley, when the surface water elevation reaches to higher level, the water leakage in this part will be by far higher and greater than right abutment of dam. As it is presented in Figure.10, leakage of water from holes and cracks clearly observed in form of vertices on surface of water.

Figure 10. Formation of vertices

During field visiting on 12 October, dye test was performedat suspicious areas, also sampling from the surface of the rock with corrosionproblem were conducted to assessment the efficient of past operations. Some sinkholes were visited such as S1 sinkhole during this series of site inspection (Figure. 11)

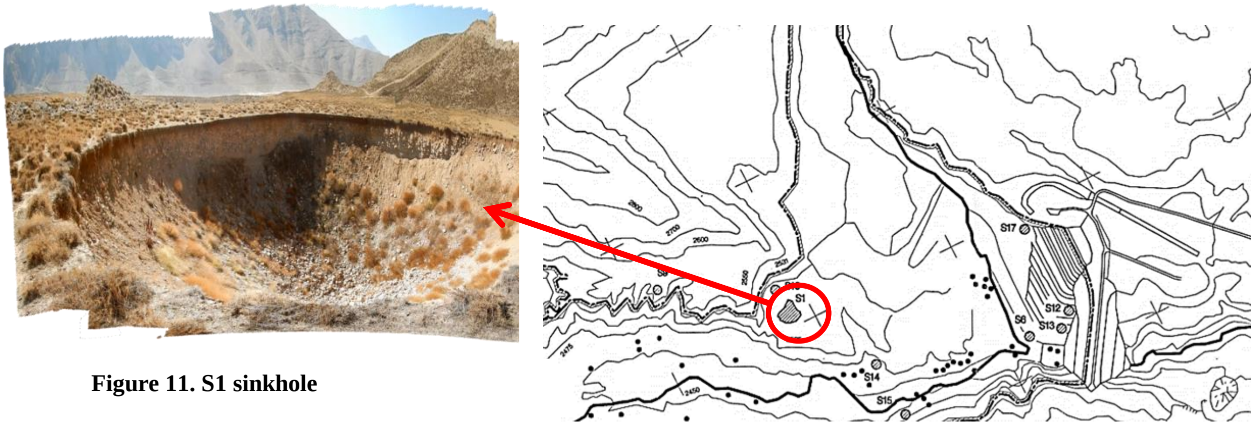

Figure 11. S1 sinkhole

Based on the last field monitoring, some points that were under the water surface and after decreasing the level of water they appeared, accurately investigated to find more leakage points, which were not accessible during previous monitoring (Figure12).

Figure 12. Conducted measures at upstream of Emamanak Valley

On 28 of November, the last field visiting was conducted to investigate the suspicious leakage points which had not been visited before. The elevation of surface water was about 2470.7 m. Two remarkable points were, gravel and plum stone which acts as a porous and permeable cover and a conduit for passing the stream flow also,folds and fractures in the rock structure continue to the highest level of this structure and it indicates existence of fault and cracks in whole of the structure.The diversion Tunnel 01 is one of the major leakage pints. At high water levels, when the tunnel were 3 meters below the water surface, vertices were formed which indicated suction of water into the tunnel and depth of lake. During several visits, by entering in to inside of tunnel and observing cracks on the walls of the tunnel and debris inside the holes clearly revealed that water leakage from the body of the tunnel was happened. Since the tunnel was drilled by explosion, the crack and holes become wider and the corrosion of stones has increased during these years.

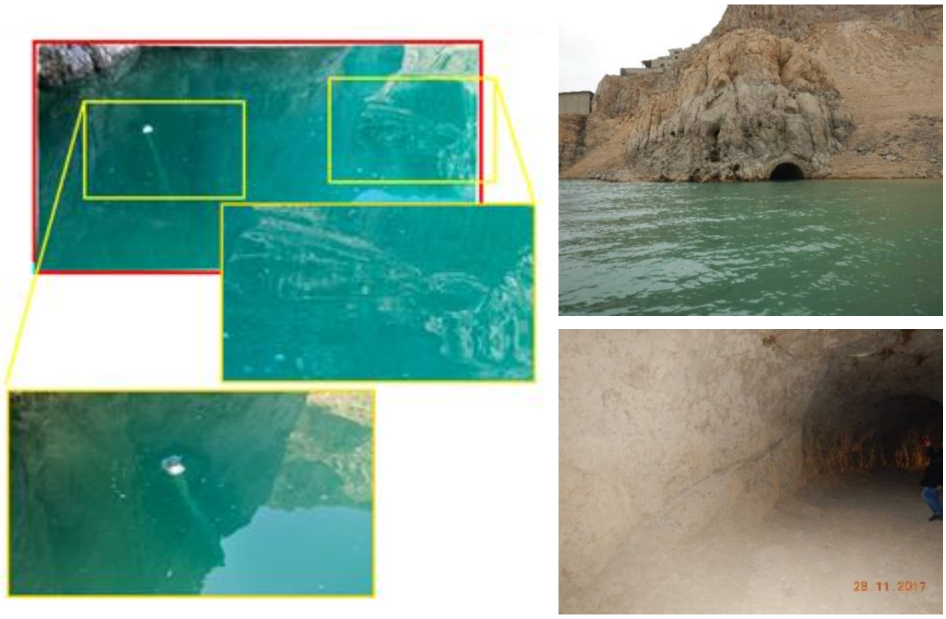

Figure 13. Vertices formed on above the Tunnel 01, visiting inside of the tunnel

5. CONCLUSION AND RESULTS

The first step for study on water leakage from the Lar Dam is theory and reanalyzing the available data and reports. The results of reanalyzing the previous research of consultancy measures showed tahtSetec Consultant Company had conducted very good studies in the field of geology and hydrology of the site. Terra Company has provided accurate measures on water flow near to reservoir's walls. Although they did not choose a good time for measuring and during that time the water level was at 2474 m, if they did measuring when the water level was at maximum level, the better understanding on flows and velocities will be reached. Geological studies showed that there was an old natural lake at this place, whichwas created by natural dam with Damavand lava. This dam was created on the Haraz River. Among of different geological structures of the area, Lar limestone rocks in contact with water are the most dangerous one. Because of the presence of natural and old lake at this place have been transformed into the karstic structure up to level of 2570 m. and these karstic holes provide some passage ways for crossing water flow. According to research of Feghhi in 2006 water flow by passing through this paths will reach to the Lar-Polour fault and Haraz and Galugah springs are outlet points for the stream flow. This shows all the field studies should be extended up to the level of 2531 m. Previous studies indicated the water leakage from the right abutment at the place of TizKuh structure. The diversion tunnel 01as the main leakage point were monitored several times by S.A.S Company. The results of visiting indicated that presence of numerous cracks on the walls of tunnel and using explosion way to create this tunnel leads to widening and increasing these holes and water leakage at this tunnel. Presence of caverns and boreholes on the way of this tunnel to the Joint LP showed that digging of this tunnel could have a large impact on the intensifying this problem. Figure 14shows a map of tunnel pathway.

Figure 14.Schematic location of diversion tunnel 01 and its connection to Joint LP

SamanAbSarzamin decided to conduct dye injections at levels under the water surface.Otherwise all calculations of the outflow velocity would be unreliable because of neglecting the head pressure and velocity in the holes under the water surface. There are 4 leakage points along with D-3 line which is surveyed by Terra company (Figure. 15).

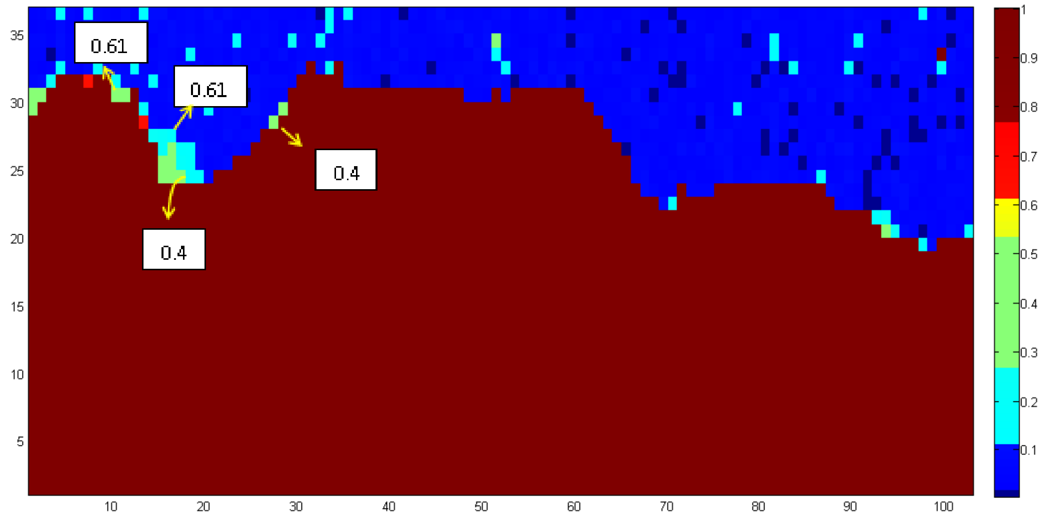

Figure 15.velocity magnitude of flow in D-3 line (Terra Company) (m^3/s)

The results of measuring dischargeat LP01 point by S.A.S Company and Terra Company are compared with each other in table 3.

Table 3. Calculations for 2012 (surface of water) and 2017 (under the pressure)

(m^3/s) Discharge	(m^2)Cross- Section	(m/s) Velocity	Calculator	Year
0.381	-	-	MaharAbOmranGostar Company	2012
0.5	1	0/5	S.A.S Company	2017

MaharAbOmranGostaran Co. considered four outlet points near to the LP01 point. If the average velocity of outlet point assumed 0.5 m/s and total cross-sections of four outlet points would be 1 m^2, discharge of outflow is calculated as below:

$$0.5 \times 1 = 0.5 \frac{m^3}{s} \quad (1)$$

Based on these calculated value of discharge about 381L/s has 30% error. There are two important points for the discharge with the rate of 0.5 m^3/s: considering 0.5 m/s for velocity of water flow wasobtained by surveying of Terra Company with ADCP device. This device measures the velocity at least 1 m above the bed of reservoir. Therefore, the real velocity exactly at the place of holes probably is higher than calculated discharge. Finally, during several site visiting S.A.S Company found out there is a need to have more focus on small leakage points that could accumulatively produce a significant leakage flow rate. They also found out a loud voice, which came out from inside of the mountain at outlet points and under the lateral facilities at the right abutment,Emamanak Valley and its upstream that neglected before considered as probable leakage points. After the last field monitoring, by using the obtained data of water surface elevation in each monitoring period, the changes of water elevation during total periods of monitoring investigated (Figure.16).

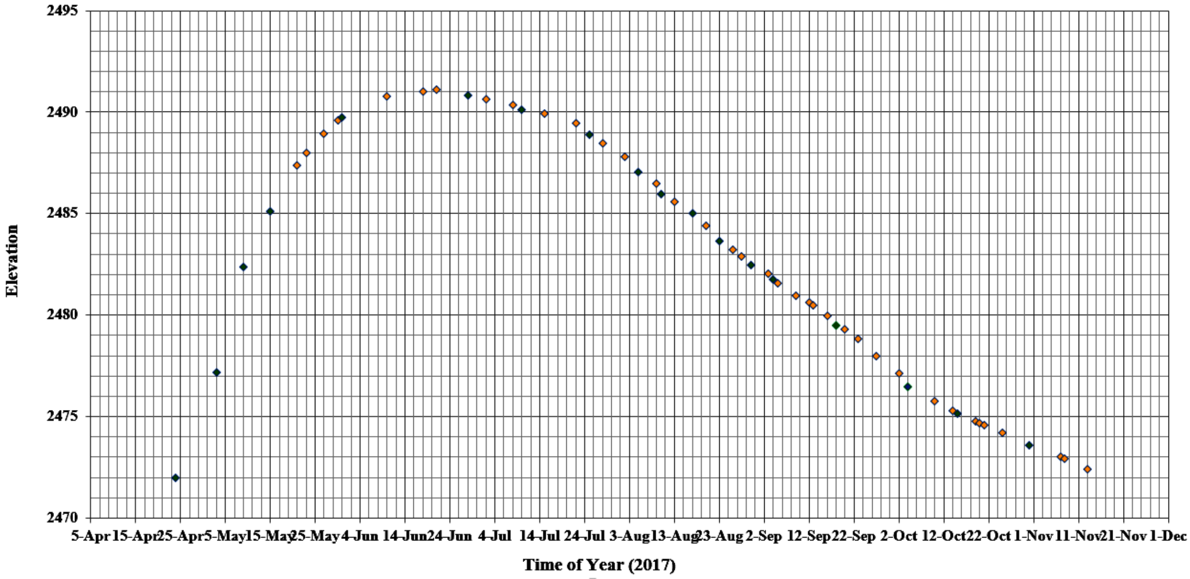

Figure 16. Changes of surface water elevation during monitoring periods

6. RECOMMENDATION OF REMEDIAL WORKS

It is necessary to identify all leakage points before implementation of remedial plans. The obtained results by S.A.S showed that two points are sensitive the first one is diversion tunnel 01 and the second one is upstream of Emamanak Valley. The tunnel has no lining and there are several long cracks and holes on the wall of this tunnel. Therefore, providing surface lining and grouting cement for the Tiz-Kuh structure without sealing lining will not so effective to solve the problem because this tunnel conduct water stream by cracks and hole into the surface water and this problem will be intensified under the hydrostatic pressure when the water level is high. Moreover, the upstream site of Emamanak valley is recommended to coverby sealing lining because when the elevation of surface water is high, this region will be a main leakage point. There is need to investigate the stability and vulnerability of dam by considering the fractures, determination the capacity of dam for current status which it is able to store water up to 2531 m level. Investigation of changes in water level at Galugah and Haraz springs as outlet points should be carrying out by doing tracing inspection and dye injections. Investigating the required strength to withstand the double hydraulic pressure at the level of 2531 m should be addressed in future. Hereis provideda prioritized treatment plan in regions at risk of water leakage (Figure. 17).

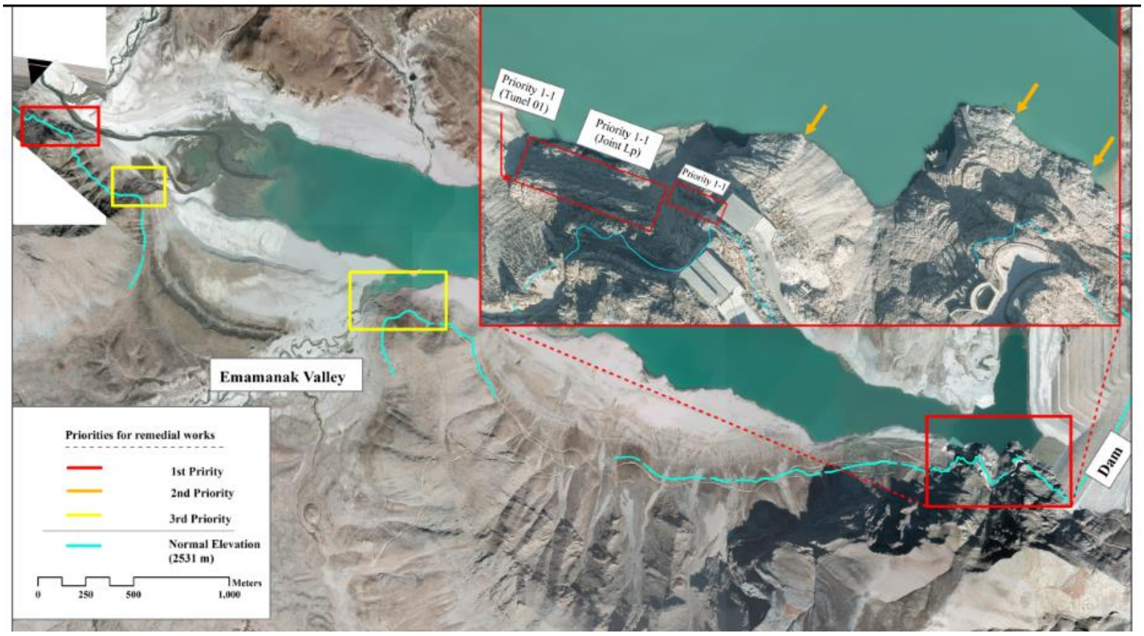

Figure 17. Prioritized treatment plan

7. ACKNOWLEDGMENT

As a member of SamanAbSarzamin Consulting Engineering Company (S.A.S), we need to appreciate honorable Regional Water Company of Tehran Municipality at the client of the project, which provide us with sufficient data required for preparation at the project and this paper.

8. REFERENCES

1. Urmeihy., A. (2000), " The LarDam:an example of infrastructure development in a geological active Karstic region", Journal of Asian Earth Science, 18, 25-31.
2. Milanovic, P.T., (2004), "Water Resources in Karst, CRC Press", Florida, U.S.A SETEC Consulting Engineering, 1996, Lar Dam Rehabilitation Studies, Stage 1 (preliminary report), VOL 1.
3. Feghhi. K., (2006), "Contribution of the Lar Dam-Polour Lineament in the Lar Dam Leakage", International Symposium on dams in the societies of the 21st century, dams and reservoirs, societies and environment in the 21st century ICOLD-SPANCOLD, Barcelona, Spain.
4. N. Talebbeydokhti., M.H. Fattahi& A. Shmasai (Iran), (2006), "Analytical and comparative study on karst problem and treatments in world's dams", Dams and Reservoirs, Societies and Environment in the 21st Century, Volume 1&2, Spanish National Committee on Large Dam.
5. Zarghami, M., (2007), "Method of leakage study at the karst dam site, A case study Khersan 3Dam, Iran", Dams and Reservoirs, Societies and Environment in the 21st Century, Volume 1&2, Spanish National Committee on Large Dam.
6. Soleimani. (2009), "Effects of gypsum karstification on the performance of upper Gotvand dam 2D and 3D approach", Dams and Reservoirs, Societies and Environment in the 21st Century, Volume 1&2, Spanish National Committee on Large Dam
7. Mozafari., M &Raeisi., E., (2015), "Understanding karst leakage at the Kosar Dam, Iran by hydrological analysis", Dams and Reservoirs, Societies and Environment in the 21st Century, Volume 1&2, Spanish National Committee on Large Dam
8. Milanovic., P.T., (2015), "Problems of construction and operation of reservoirs in kast areas", Dams and Reservoirs, Societies and Environment in the 21st Century, Volume 1&2, Spanish National Committee on Large Dam.
9. Mozafari, M., &Raeisi, E., (2017), "Salman-Farsi Dam reservoir, a successful project on karstified foundation, SW Iran", Environmental Earth Sciences, 75, 12
10. NayebAsadollah, S., Aalianvari., A., and Hajialibeigi., H., (2018), "Role og geological structures in seepage from lar dam reservoir", Arabian Journal of Geosdences, 11:632
11. KhorsandiAghai, A, (2007), "Fault determination due to sinkhole array on LarValley, Northeast of Tehran (Iran)", ActaCarsologica / KarsoslovoniZbornik, 36(2), 203-208.