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Analytic Study of Inductive Earthquake Occurring Due to Tabriz Vaniar Dam Reservoir Supplying with Water

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ABSTRACT

Tabriz Vaniar dam by reservoir volume about 360 milion cubic meters, and 50 meter height of river bed, is an earth dam with clay core. This dam is along with north Tabriz fault of active one by historical background of earthquake. Therefore, it requires studying possibility of inductive earthquake occurring on this dam.we have considered noram tensions$\sigma_x(t)$¡$\sigma_y(t)$¡$\sigma_z(t)$ and cross one $\tau_{xy}(t)$¡ $\tau_{zx}(t)$ ¡$\tau_{yz}(t)$,in limit of 40-45 kilometer from dam by considering reservoir loads in the center of earthquake for1×1network kilometer and on north fault of tabriz in order to study potential of inductive earthquake on Vaniar Tabriz dam. in this study, We have used of 19 december 2007 earthquake affairs in which shows stumbling direction in right direction and is concordant with north Tabriz fault. We have used of speedometer apparatus in order to determine earthquake affairs andrecognizing fault face and analyzed result by mathematic models. According to the amount of analysis, We concluded increasing earthquake deep decreases reservoir effects. The most effect of reservoir is on 1-4kilometers deep and also the amount of fault satability $S_r(t)$ is less than zero on north. Tabriz fault in which indicated the influence of Vaniar dam reservoir on Tabriz fault that push forward earthquake.

Key words: Inductive earthquake, Dam supplying with water, Fault stability.

INTRODUCTION

Making dam and creating reservoir in its back, leads toenvironmental changes in regions around dams.of the most important effects of dam reservoir in which has been observed in so many eras is beginning of earthquake or change in eras trembling mood andreservoir after supplyinh water. This phenomenon has been observed in different eras in the world and has been called induced earthquake or reservoir iduced seismicity and has been considered by engineers and expert in earthquake (Allen, *et al,.* 1996).

These earthquakes are along with disturbance and nature equilibrium disturbin and there is direct relation among induced earthquake and human activity.therefore, we should expect the center of these false earthquakes be on human activity eras (Assumpcao, *et al,* 2002).

In general, making dam changes natural tention center as:

- Entering added weight due to loading water height in back of dam
- Increasing penetrating water pressure in fault faces
- Decreasing fault face friction as the role of water softening and lubricating

Occurring induced earthquake in dam reservoir is due to parameters like tension eras condition, stone hydromechanical character uncer reservoir, eras geology and also dimensions and fluctuations of water level in dam reservoir (Berberian, *et al,.* 1999).

In general, Induced earthquake in water reservoir has occurred on the two types of preliminary and long term in which any one does have its own mechanism. In the first type, increasing the number ofearthquake has occurred in before water level andis along with or does lack trembling in deep parts of reservoir. In this case, during time passing the number and greatness of earthquake would decrease. In the long term type, earthquake has occurred on the deep part of reservoir and the eras around it. In this case, withour decrease in the number and its greatness, earthquake continues for the long term. The greateset earthquake occure when water level reaches to the highest one. Time delay among filling reservoir and the beginning of earthquake depends on reservoir characteristic, regional site character and it takes somemonths to some years long (Chander, R, 1990).

Based on ICOLD suggestion, induced earthquake has been considred on the height more than 100meters or reservoir volume is more than half milliard cubic meters and or small dams on sensitive region (Chander, R, Kalpna, 1997).

When we recognized induced earthquake dependence to the reserved volume of water and its height, in Mead Lake on the beginning of 1940, has occurred more than 100 induced earthquakesin different parts of the world by different greatness. In the last of 60 decade and the beginning of 70, after general agreement of researchers on this problem in which supplyin water in great reservoir could leads to induced earthquake by 5-6/5and destruction power, the induced earthquake has been considered, seriously. Early, it has been cleared eras without trembling activity and erasin which does have low level in earthquake on comparing to active eras does not have lower potential in induced earthquake occurring. For example, in Kremasta dam in Greece by th height of 160meter and reservoir volumeof 4/8miloliard cubic meters, after supplying water on 1966, ocuured an earthquake by 6/3rishter greatness.Also, in 9kilometer distance fromKoyna dam in india by the height of 103meters and reservoir volume about 2/7 milliard cubic meters on 1967, have had earhthquake by the same greatness (Chen, L, Talwani, P, 1998) (Chen. L, Talwani, P, 2001).

Fig. 1: Kariba dam

Karibe dam (figure1) in Zambia and Zimbabve border by the height of 128meters and reservoir volume of 175millirad cubic meters has been supplied by water from 1956 to 1971, and observed so many earthquakes in which have had coordination to the continuity of supplying water (Feng Deyi, Yu Xuejnu, 1992).The greatest earthquake by 6 rishter greatness occurred when water level reavhes the most level.induced earthquakes are dure to loading reservoir dam in other eras in the world like U.S, France, japan, Italia, Greece, brazillia. (Figure2) diagram 1 and table 1 summarize frequency distribution of these earhthquakes in different parts of the world (Gahalaut, *et al*,. 2007).

Ranking in the last column of tablehas been provided for different levels of induced earthquake

- Level I, induced earthquake by more than 6rishter greatness
- Level II, induced earthquake by 3/1-5/9rishter greatness
- Level III, induced earthquake by less than 3 greatness.
- A: Arch C:Concrete
- G: Gravity E:Earth
- RF: Rockfill H: Hollow
- M: Masonary D: Double Curvature
- EF: Earth Fill MU: Multiple

Sefidrood dam is the first dam in Iran in which we have studies the relation among dam lakes forming and increasing the number of regional earthquakes.before creating dam, there was no importantearthquake in this eras. Study of trembling registered on the sefidrood recognition trembling establishment shows of the beginning of making dam, there is about 120 light trembling, yearly. The center of these trembling is about40 kilometers of dam and its greatness is less than 2rishters. The number of these earthquakes is usually about 5-15 monthly and is dependent to the change ofwater height in dam lakes (Guha,S, K, Patil D, N, 1992).

Considering induced earthquake in some geart dams in Iran (karoon3, latian,lar, shirin dare, rajaee)shows increasing earthquakes by passing time after supplying water in dam. Diagram3

Study of larkhe dam on 2022 shows the greatnessof registered earethquake is less than 4/3 rishter. Although, these earthquakes greatness is low, but repeated earthquake occurring is influential on occurring gradient instability in the dal reservoir and its arounds (Gupta, H, K, Rastogi, B, K, 1976).

Methodology

In this studying analysis, possibility of induced earthquake occurring due to supplying water of veniar reservoir dam has been considered. Venire dam does have volume about 360million cubic meter and the height of 50 meter from bed and 92meters of foundation of gravel type and clay nucleus by reservoir level of 40/22 square kilometers.this dam is 3kilometers on north of Tabriz and along with north Tabriz fault. According to nearness of dam to active fault, we have applied tensions and stability in modeling Tabriz fault characteristic (Gupta, H, K, 1985) (Gupta, H, K, 2005).

North Tabriz fault is one of the most active fault in northwest of Iran.the length of fault is about 150kilometer, of the northwestcontinues to the southeast. In direction of fault to the northwest leads to reverted faults of soufian and tasouj. The continue of these faults has changed to the north of Tabriz, whereas has tendency to the west- northwest. On the other hand, contibue of southeast fault of north Tabriz has ended to some reverted faults. (North

Fig. 2: Induced earthquake distribution in different countries of the world

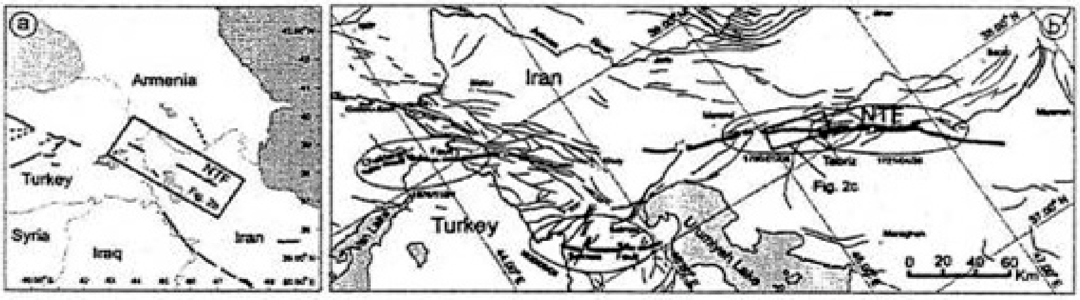

Fig. 3: North Tabriz fault

and south of bezghoush, dozdouzan fault and south of sarab fault) in which their change direction is to north-northeast. In the first published records, this fault has been introduced as reverted fault by high gradient. In this case, by studyingair images, there is observance to replace right-direction waterway in the length of north Tabriz fault (Hamzehloo, *et al,.* 1997) (Hessami*, et al,.* 2003)

In order to study and answer to the question, does veniar reservoir dam have the potential of creating induced earthquake? We have evaluated normal tensions ¡$(t)_z$ ó, $(t)_y$ ó, $(t)_x$ó and cross $(t)_{xy}$ô¡ $(t)_{zx}$ô¡$(t)_{yz}$ ô in 40 kilomteres to dam by reservoir loads in the center of earthquake on 1×1kilometers network and on north Tabriz fault. Fault face has been evaluated for calculating tensions on the center of earthquake in future by direction, gradient and rike, 310, 85, 170 by standard deviation of 0.25, respectively. They have been evaluated by speedometer data in Tabriz network. Then fault stability $S_r(t)$ has been calculated due to tensions of reservoir loads and controlled reservoir dam (Lixin Yi, *et al,.* 2012).

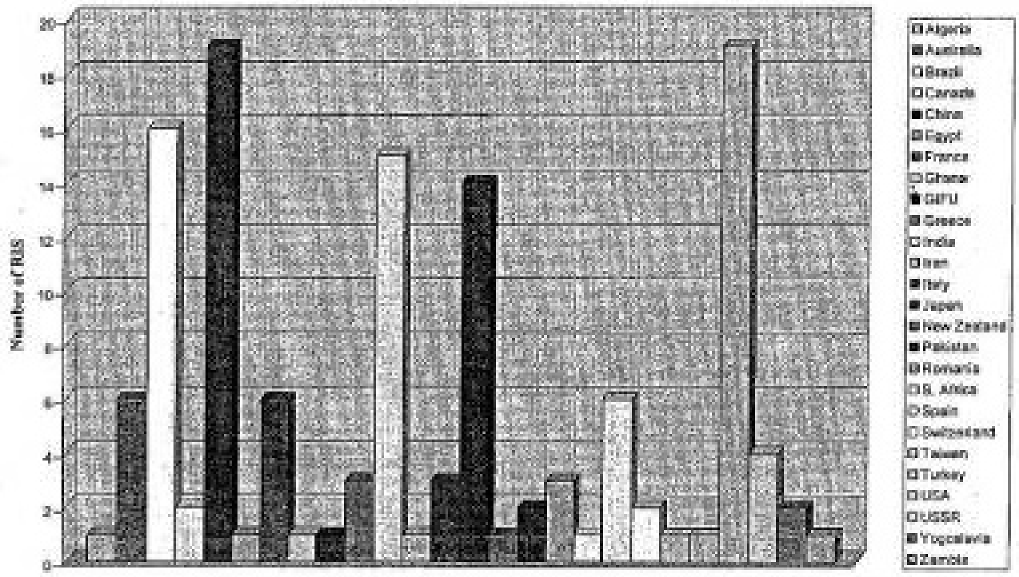

Diagram 1: Frequency distribution of induced earthquake in different countries in the world

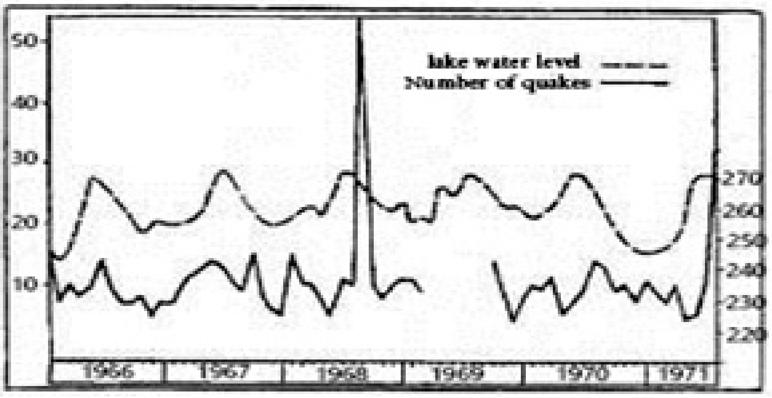

Diagram 2: The relation among water level fluctuation of sefidrood reservoir or the number of regions earthquakes

In order to forecast induced earthquake of reservoir, we should consider preindicators like water level changes and trembling, vp/vs changes and b parameter change (Hafezi Moghaddas, *et al,.* 2005).

In order to modeling fault influence on the possibility of induced earthquake occurring, recent earthquake affairs have been analyzed on this fault and we concluded fault characteristic. Then reservoir dam has been divided to 76tearing prism. Point

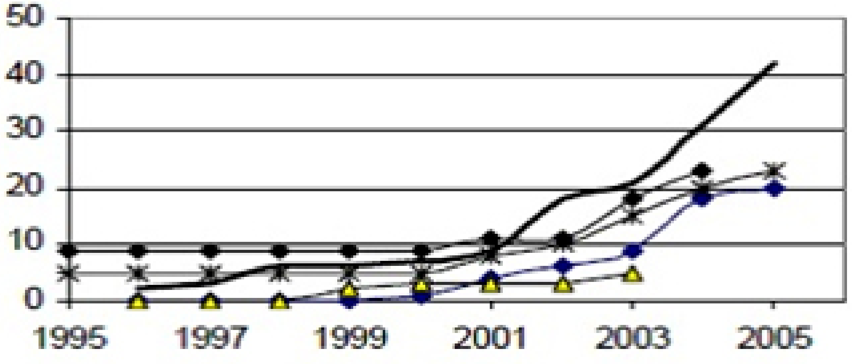

Diagram 3: Yearly gathering frequency of occurred earthquake in about 30 kilometers from 5great dams establishment in Iran

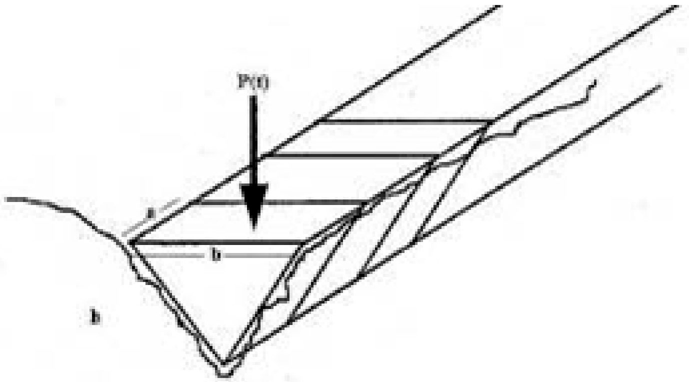

Fig. 4: Prism model of Tabriz veniar reservoir

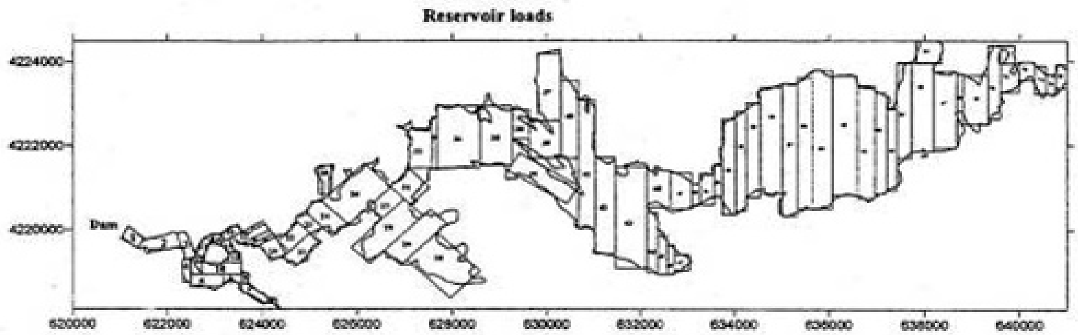

Fig. 5: Point laods modeling in dam reservoir

loads modeled of these prismas has passed from the center of aby prism. (figure 4, 5)

The most deep of reservoir near dam is 50meters in which is equal to dam height from bed. Water deep in other prism is based on reservoir topograpgy map.

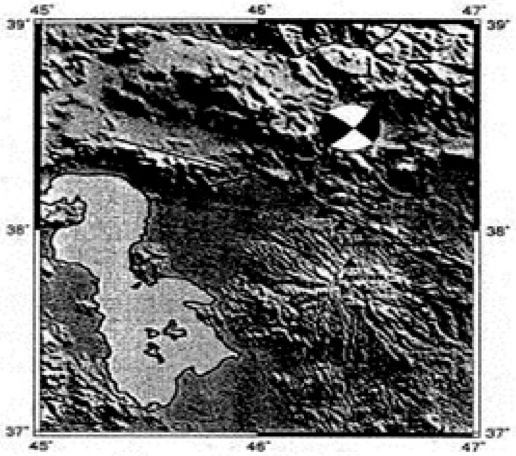

Fig. 6: Speedometer station in 14 december 2007 earthquake in tabriz

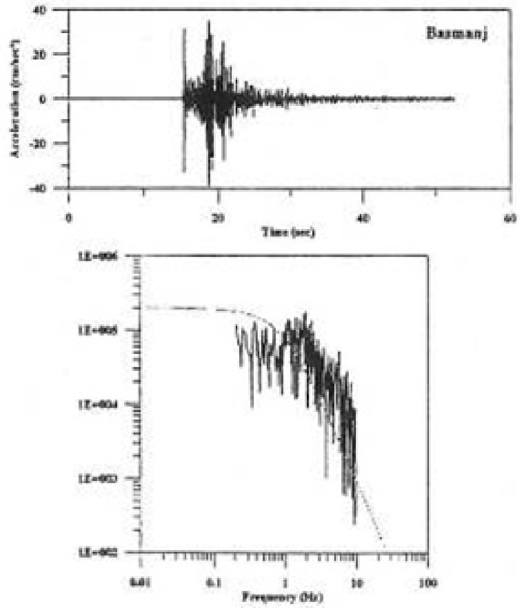

Fig. 7: SH indicator and immediacy spectre observance and estimated in yasmanj station

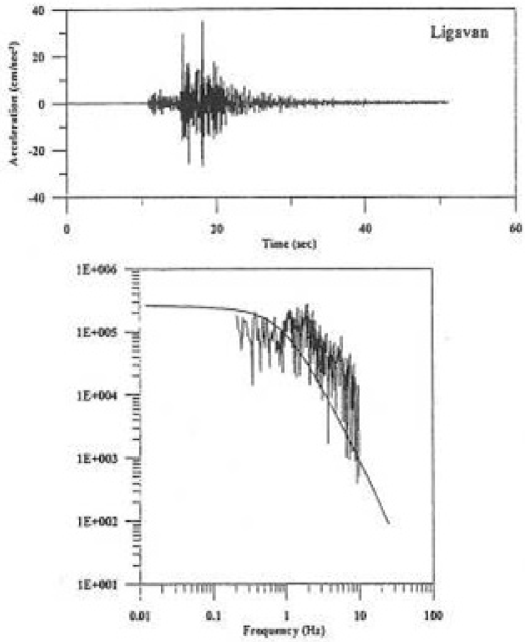

Fig. 8: SH indicator and immediacy spectre and estimated in lighvan station

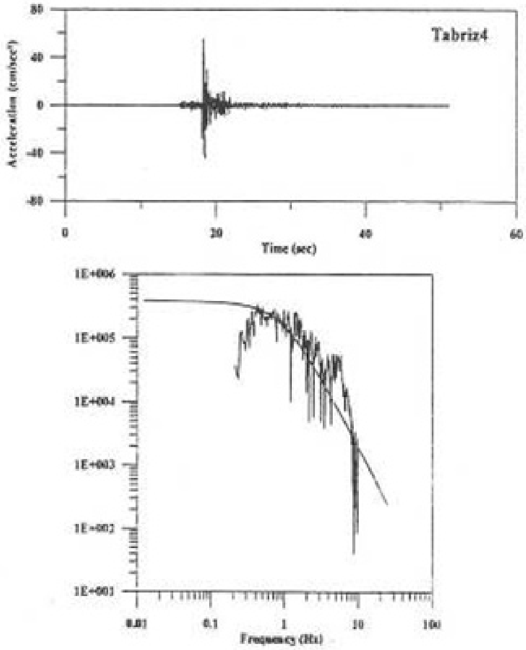

Fig. 9: SH indicator and observed immediacy spectre in Tabriz 4station

Achieved affairs through east and west of north Tabriz fault shows direction mechanism of trembling (Jackson, J, 1992) (Stabile, 2014).

Earthquake affairs have been determined based on the first move in different stations registering earthquake.

By developing speedometers in around eras, there is possibility to determine earthquake affairs to these datas.(speedometer are data in which register time history of speed)in these methos, fault parameter along with speed, dimension, break speed and beginning point of break, has been considred as entry model.

14 december 2007 Tabriz earthquake affairs

2007 earthquake in Tabriz has been registered in6 stations. (figure5) speed spectrre has been shown for basmanj, khaje, tabriz4, 6 by SH indicator in figures6-12. By solving fault face for this earthquake by the aid of stations spectre, direction, gradient and rike has been evaluated 310, 85,170degree by 25% standard deviation, respectively. Achieved affairs shows right dirtection of trembling in which is coordinated to north Tabriz

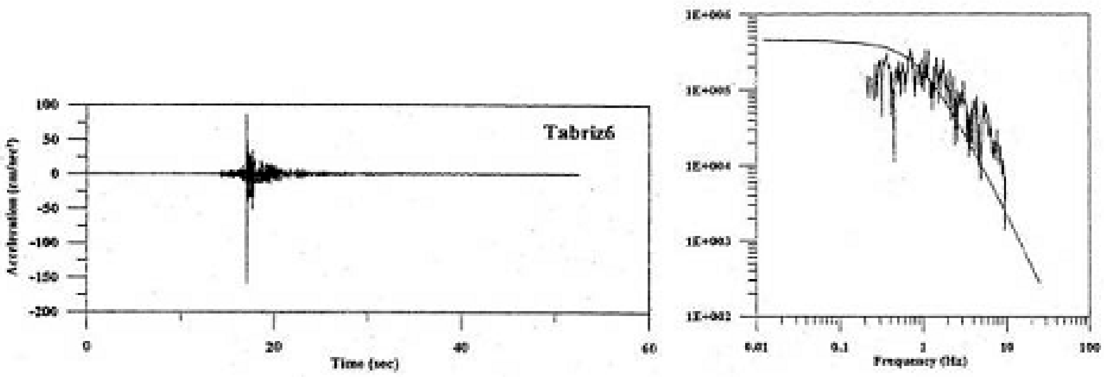

Fig. 10: SH indicator and obserned immediacy spectre and estimated in Tabriz 6 station

Table1: induced earthquake in different eras in the world

RIS level	Magnitude	Date	Maximum depth	Dam type	country	Dam name
II	5.3	11.1964	109	RF	Ghana	Akosombo
III	2	1.1972	185	CA	Spain	Almendra
II	>=3.5				Japan	Arimine
II	>-=3.5				GIFU	Asahi
II	5.6	14.11.1981	111	ER,RF	Egypt	Aswan
II	4.8	3.7.19.67	81	HCG	Yogoslavia	Bajina Basta
II	5	7.7.1966	96	EF	New Zealand	Benmore
II	4.8	15.9.1983	57.5	mG	India	Bhatsa
II	3.5	6.1.1973	95	EF	Australia	Blowering
III	2	1968	46	RF	USA	Cabin Creek
II	4.7	23.1.1972	20.7	CG	Brazil	Cajuru
II	4.1	15.4.1964	43.6	CG	Spain	Camarillas
II	4.7	9.6.1962	132	CA	Spain	Canells
II	4	15.3.1977	130	EF	USSR	Charvak
II	4.3	2.8.1974	54	CG	USA	Ciark Hill
III	3	10.1965	190	CA	Switzerland	ontra
II	5.2	6.6.1962	22	E	USA	Coyote Vally

fault, achieved parameters of this analysis has been used for evaluating stress due to reservoir loads on north Tabriz fault.

2007earthquake in Tabriz has been registered in 4 ststions in Tabriz(figure6)immediacy spectre of speed has been shown for basmanj, lighvan, tabriz4, 6, stations by SH indicators in figures7-11

Study of datas from registered trembling in these stations around north Tabriz fault and mathematics modeling, tensions evaluation and fault stability and also cotensions lines has been achieved for the deeps of 1,2,3,4,5,10, 15, 20 kilometers.

By the aid of relation1: affairs related to Tabriz 14 december2007 earthquake,normal tensions¡(t)$_y$ ó¡(t)$_{z,}$ó(t)$_x$ó and cross(t)$_{xy}$ô¡ (t)$_{zx}$ô¡(t) $_{yz}$ô in 40 kilomteres of dam and reservoir loads in the center od earthquake has been evaluated for network1 in 1kilometer. In these relationa, cooredinated axis of ox is in north direction, oy axis in east direction, oz axis is vertical to the two axes and inner sides of earth, and v is coeffiecent of poasun. Supoosed earthquake center is considered on 1, 2,3,4,5,10,15,20 kilometers.

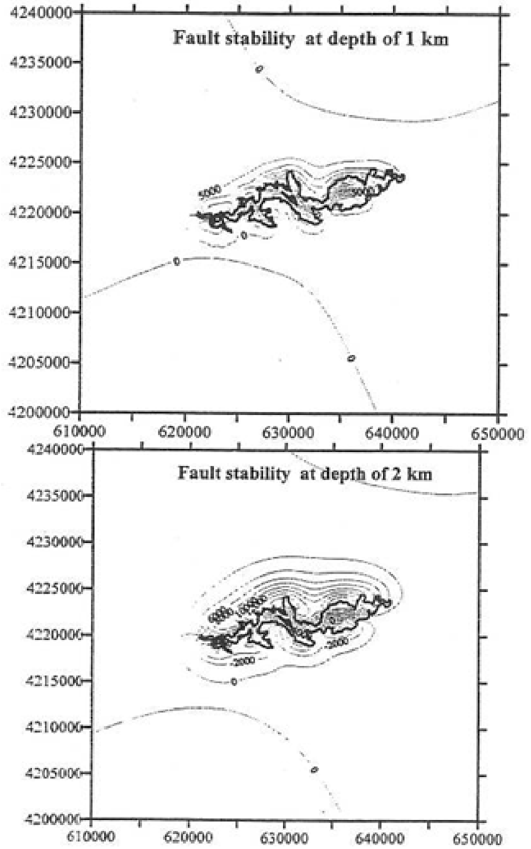

Fig. 11: Stability lines based on paskal on 1-2kilometers deep

Relations1:

$$\sigma_x(t) = \frac{p(t)}{2\pi}\left[\frac{3X^2Z}{R^5} + (1-2v)\left\{\frac{y^2+Z^2}{R^3(Z+R)} - \frac{Z}{R^3} - \frac{X^2}{R^2(Z+R)^2}\right\}\right]$$

$$\sigma_y(t) = \frac{p(t)}{2\pi}\left[\frac{3X^2Z}{R^5} + (1-2v)\left\{\frac{y^2+Z^2}{R^3(Z+R)} - \frac{Z}{R^3} - \frac{X^2}{R^2(Z+R)^2}\right\}\right]$$

$$\sigma_z(t) = \frac{3P(t)}{2\pi}\frac{Z^3}{R^5}$$

$$\tau_{y2}(t) = \frac{3P(t)}{2\pi}\frac{yZ^2}{R^5}$$

$$\tau_{2x}(t) = \frac{3P(t)}{2\pi}\frac{xZ^2}{R^5}$$

$$\tau_{xy}(t) = \frac{p(t)}{2\pi}\left[\frac{3XyZ}{R^5} + (1-2v)\frac{xy(Z+2R)}{R^3(Z+R)^2}\right]$$

In order to calculate fault stability, we suppose tensions are due to different coactions leads to center of earthquake in future. These tensions are related to topography changes on techtonical coactions or ambient stress. In addition, water penetration could active regional faults. Inaddition to above tensions, dam reservoir creates tensions on the center of earthquake in future and put forward earthquake occurring. Stability on fault face when there is no reservoir dam includes:

Relation 2:

$$S_a(t) = \sigma_a(t)\ tan\varphi - \tau_a\ (t)$$

Tensions of $\sigma_a(t)$ æ $\tau_a(t)$ are sum of normal and cross in the center of earthquake on fault face in which changes by time passing. Therefore, anatural earthquake occurs when S_a(t) is equall to zero.when we have reservoir dam, fault stability due to reservoir has been described by :

Relation 3:

$$S_r(t) = \sigma_r(t)\ tan\varphi - \tau_r(t)$$

Tensions of $\sigma_r(t)$ æ $\tau_r(t)$ are normal and cross one. General stability of fault due to techtonical and reservoir coactionsis:

Relation 4:

$$S(t) = S_a(t) - S_r(t)$$

If$S_r(t)$ is more than zero,the influence of reservoir on faultdelays occurring earthquake
If $S_r(t)$ is less than zero, the influence of reservoir on fault delays occurring earthquake.
If $S_r(t)$ is equal to zero, the influence of reservoir on fault is neutral.

According to relation3,stability lines on network 40 in 40kilometers has been accounted. wehave considred normal tension and cross æ acting tensions on fault face.we have considred the two tensions'sum of cross tensions.related stability lines has been shown on 11-14figures.

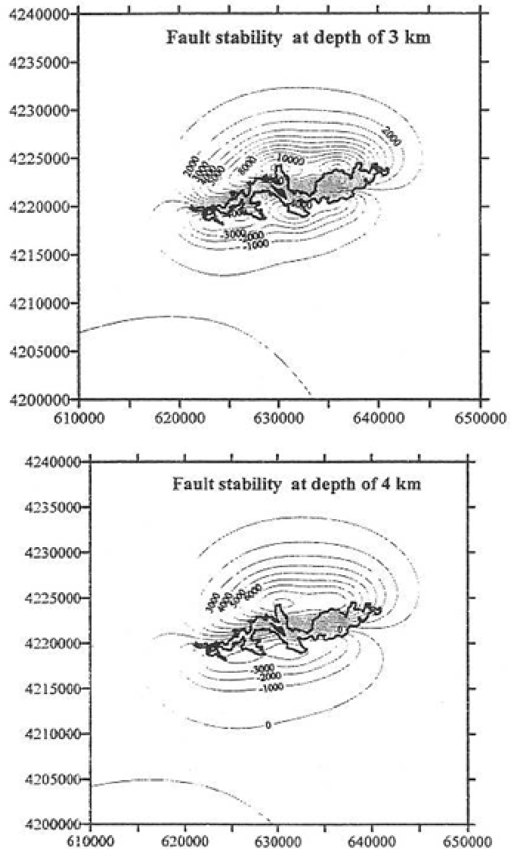

Fig. 12: Stability lines based on paskal in 3-4kilometers deep

RESULTS

Figure15 shows fault stability changes by increasing earth deep. Whereas, by increasing earthquakes deep, the influence of reservoir decreases and reservoir would be neutral. The most influence of reservoir in the deep of 1-4kilometers is observed in whichis coordinated to the deep of induced earthquake.

Figures page 16-21 shows normal tensions , , and cross one, on north Tabriz fault to 20kilometers deep due to veniar dam reservoir loads.

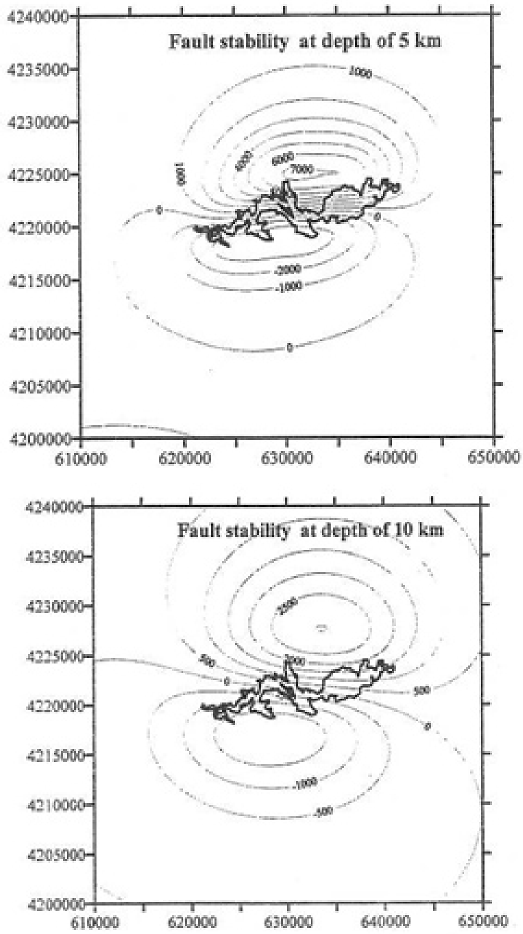

Fig. 13: Stability lines based on paskal in 5-10 kilometers deep.

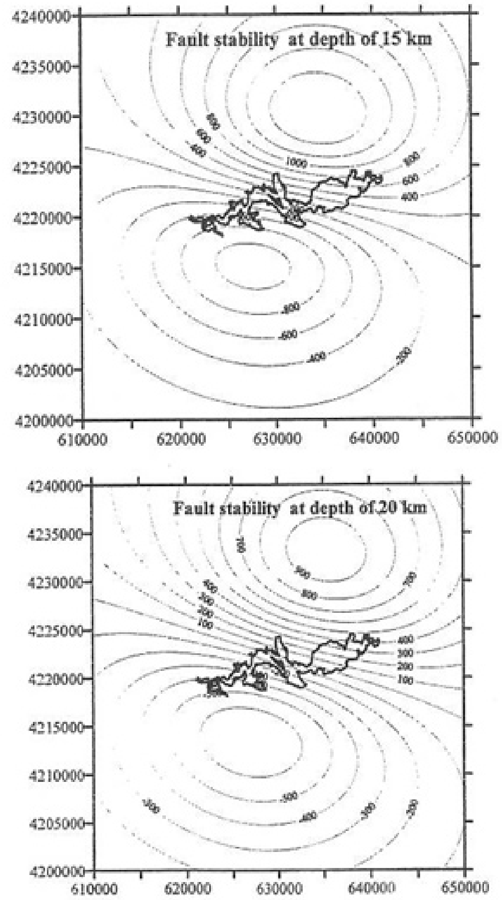

Fig. 14: Stabilioty lines based on paskal in 15-20 kilometers deep

North Tabriz fault stability due to veniar reservoir dam and around reservoir dam loads

Figure23 shows loeads of around dams as pointed add to the whole loads of around dam's reservoir. Figure24 shows the negiligible influence of these reservoirs.

DISCUSSION

The result shows created tensions due to different coactions leads creatingearthquake center. These tensions are related to changes in topography and techtonical coactions.in addition to above tensions, dam reservoir iscreating tensions on the center of earthquake and put forward occurance of earthquake.

Analyzing result shows

- According to the amount less than zero stability for sr (t), therefore, veniar dam reservoir influence on Tabriz fault put forward earthquake.
- The amountfor veniar dam(-1/3 kpa) compared to estimated amount fot Loyna dam in india(30kpa)and india rihand dam reservoir(90kpa)is very negiligible in which has been approved occurring induced earthquake there. Veniar reservoir dam is

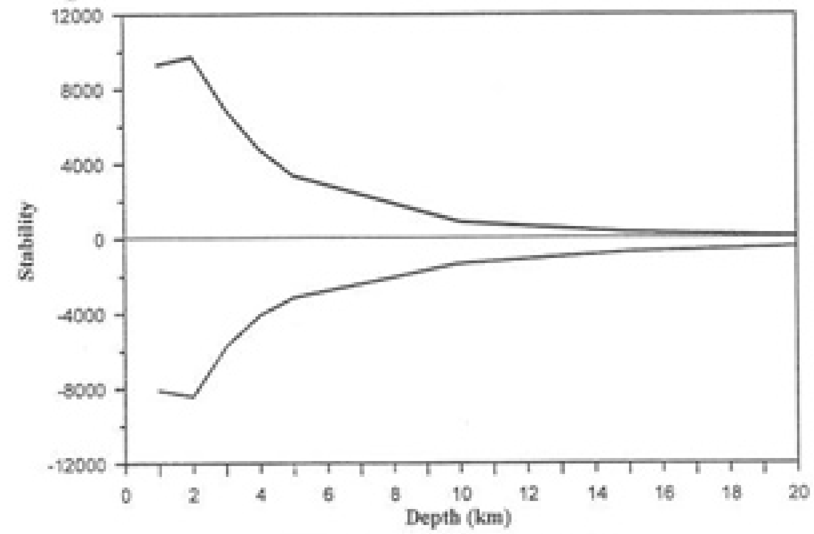

Fig. 15: Fault stability change by increasing deep

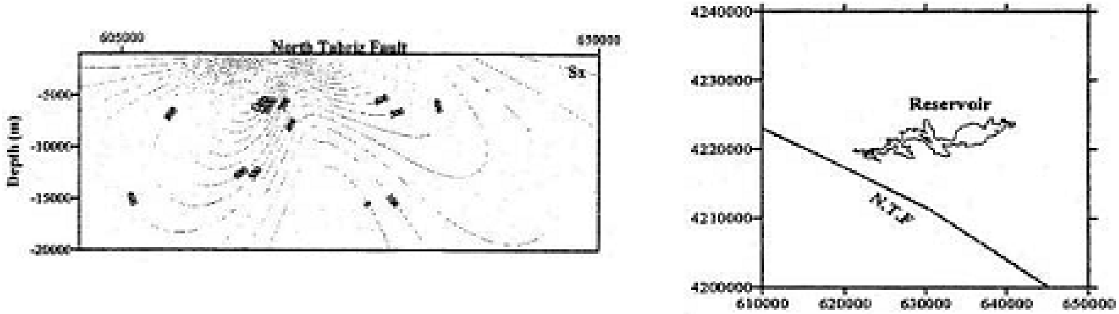

Fig. 16: Tension change or deep on north Tabriz fault

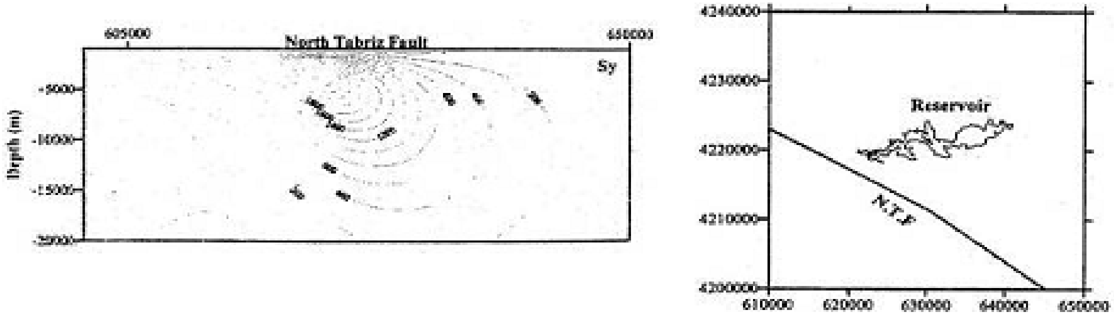

Fig. 17: Tension S_y change or deep on north Tabriz fault

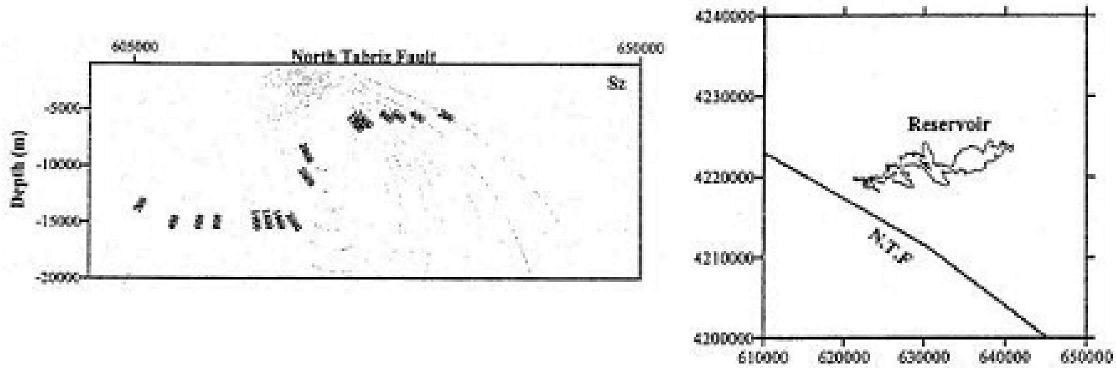

Fig. 18: Tension S_z change or deep on north Tabriz fault

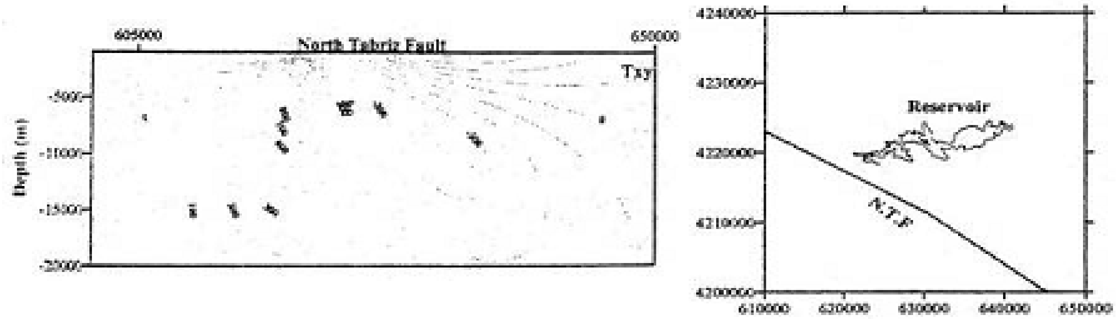

Fig. 19: Tension t_x change or deep on north Tabriz fault

fitted fior induced earthquake butput forward earthquake on north Tabriz fault.

- Fault stability changes by increasing deep shows by increasing deep of earthquake, the influence of reservoir decreases and reservoir would be neutral.
- The most influence of reservoir is in the deep of 1-4kilometers in which is cooridinated to induced earthquake deep. Because we have observed induced earthquake after supplying water in dam or some time after that (some weeks after supplying water), therefore,

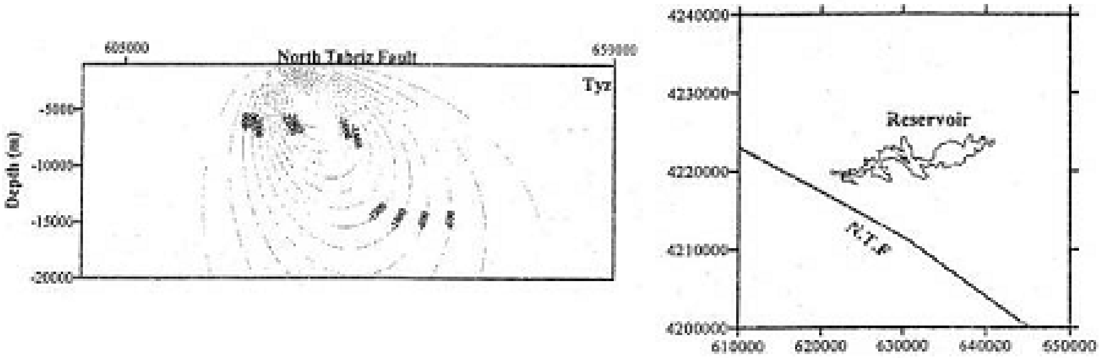

Fig. 20: Tension t_y change or deep on north Tabriz fault

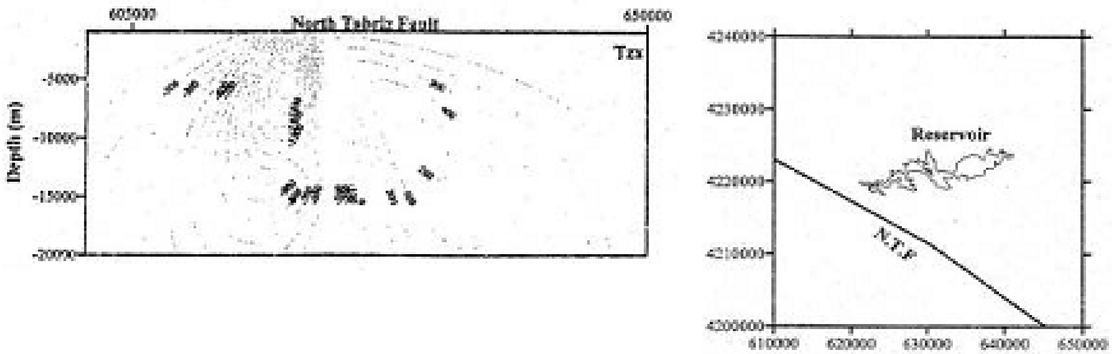

Fig. 21: Tension t_x changes or deep on north Tabriz fault.

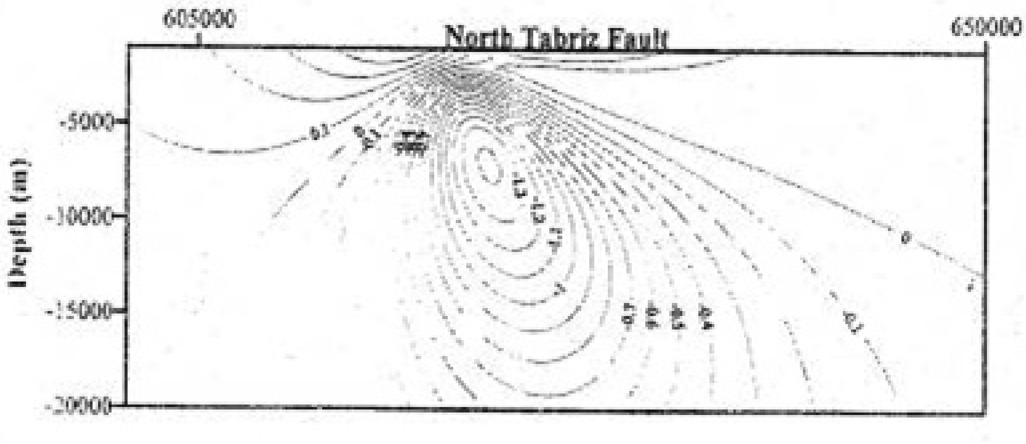

Fig. 22: Stability changes (kap) by deep on north Tabriz fault by considering veniar dam

Table 2: Shows these prism characteristic and the amount of volume and point loads coordinates

	Xc	Yc	L(m)	D(m)	Depth
1	621274.0816	4219804.579	426.13	288	50
2	621890.0147	4219683.014	736.13	350.33	45
3	622408.6932	4219626.283	741.76	220.02	40
4	622408.6932	4219018.456	528	174.58	35
5	622846.3283	4218799.638	654.5	293.52	35
6	623356.9033	4218856.369	386.7	189.54	27
7	623859.3726	4218491.674	652.7	185.61	17
8	624248.3825	4218321.481	156.23	108	8
9	623640.5551	4218864.475	226.5	178.9	17
10	623121.8766	4219083.292	850.38	295.59	29
11	622676.1359	4219294.004	189.81	116.72	29
12	623413.634	4219358.84	251.84	233.5	24
13	622740.9723	4219585.761	251.84	233.5	29
14	623032.7276	4219780.266	252	189.84	29
15	623275.8599	4219601.971	300.35	170.25	28
16	623348.7976	4219934.25	423.26	189.93	28
17	623802.6418	4219934.25	776.84	268.58	27
18	623940.416	4219804.579	661.2	99034	27
19	624037.6685	4219747.848	543.53	88.39	27
20	624248.3825	4219545.24	471.85	354.25	27
21	624872.417	4219545.24	792.17	330.31	27
22	624586.0176	4219828.892	614.49	353.69	27
23	625010.1912	4220144.962	550.05	283.73	27
24	625358.6894	4220290.841	825.85	425.86	26
25	625342.4703	4221158.006	664.5	270.06	25
26	626007.0285	4220850.042	1251.69	781.88	24
27	626614.8539	4220639.328	658.32	407.91	23
28	626639.1665	4219982.875	1595.17	554.73	17
29	627230.7848	4219845.101	1365.56	501.21	13
30	627822.4032	4219164.336	1290.52	903.5	9
31	627117.3254	4221020.232	578.68	611.69	24
32	627344.2464	4221944.129	934.5	463.52	23
33	627636.0039	4222008.964	1208	127.75	21
34	628138.4732	4222154.843	1475	894.25	21
35	628900.284	4222187.259	1398	675.18	21
36	629451.3806	4222479.017	686	346.75	21
37	630042.9969	4223346.184	1569.54	507.39	13
38	629970.0591	4222162.947	883.5	682.51	18
39	629978.1626	4221198.528	1493.18	472.02	9
40	630480.6341	4222560.06	1839.5	372.33	13
41	630869.6419	4221441.66	3037	357.68	17
42	631242.4427	4220517.762	2277.51	416.19	16
43	631834.0611	4220258.423	2394.01	657	16
44	632255.2438	4219685.186	1438.07	241.05	15

45	632463.4829	4219417.451	912.5	197.18	14
46	632649.4107	4219283.583	708	168.04	8
47	632902.2701	4219216.65	365.07	313.94	6
48	632389.1113	4220949.49	890.53	51803	18
49	632865.0854	4220919.741	832	452.85	16
50	633177.443	4220823.06	482.05	160.56	16
51	63343045	4220949.49	722.5	321.18	16
52	633668.2905	4221127.98	774	160.56	16
53	633876.5296	4221484.96	22.63	277.52	16
54	634129.389	4221574.205	2343.5	233.68	16
55	634397.124	4221812.191	2226.5	299.4	15
56	634776.4153	4222079.926	2503.5	467.18	15
57	635170.5822	4221879.24	3117	328.58	14
58	635460.6285	4222035.303	3109.5	306.64	14
59	635869.6667	4222042.741	3277.53	408.88	13
60	636338.205	4222206.357	2810.5	547.48	12
61	636791.8658	4222027.867	2657	358.04	11
62	637081.9121	4222057.614	2394	240.87	11
63	637327.3359	4221953.496	1927.01	211.82	10
64	637572.7596	4222801.324	2241	299.31	8
65	637959.4866	4222831.073	2095.01	474.49	7
66	638100.7919	4224221.806	504.05	554.75	7
67	638442.8985	4222823.635	1810.5	481.81	7
68	638747.8182	4223240.111	980.5	138.89	5
69	639075.0492	4223069.059	1146	526.08	5
70	639476.6517	4223426.039	1730	255.5	5
71	639796.4471	4223589.653	686	379.69	4
72	640153.4271	4223760.707	409.06	350.37	4
73	640443.4734	4223537.595	657	233.68	4
74	640659.1481	4223470.661	460.23	204.95	4
75	640874.825	4223611.964	562.19	233.56	4
76	624323.5969	4218190.332	131.98	47.02	2

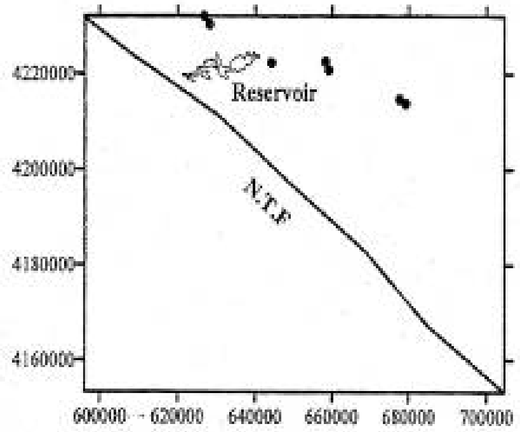

Fig. 23: Shows loeads of around dams as pointed add to the whole loads of around dam's reservoir.

according to this conditions, we should supply water in dam, gradually.

Suggestions

1. Veniar dam is 5 kilomters to Tabriz cityand on the north faultof Tabriz, desigining and assemblingregional network of registering earthquake for registering behavior before and after supplying water is required.

Regional network assembling includes 6 apparatus for registering earthquake by feasible band for registering regional earthquake in which could have induced origin, before and at the same time of supplying water….could determine the exact place of techtonic earthquake in dam arounds and

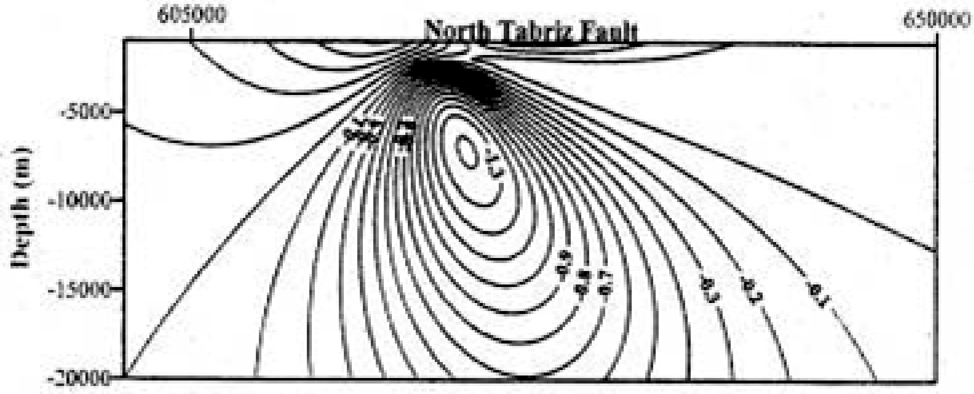

Fig. 24: Shows the negiligible influence of these reservoirs

also induced earhthquake along with dam supplying water ocuured and report to audit establishment by descriptive lists. On the other hand, this network as speedy alert system could be used for Tabriz city by high background in earhthquake.

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