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Groundwater Balance, Safe Yield and Recharge Feasibility in a Semi-Arid Environment: A Case Study from Western Part of Iran

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Abstract: In this study, detailed local geological, geophysical and hydrogeological investigations were carried out to delineate the architecture of different subsurface geological horizons using lithologs and generated vertical electrical sounding data. This study deals with the estimation of groundwater balance of the alluvial aquifer in Kangavar basin (West Iran), in order to assess the safe yield of the aquifer. The water-budget was calculated out using a developed computer program. The main water inputs and outputs were measured. It was calculated as, 91.1% of the total abstraction is consumed for agriculture supply. The present abstractions exceed both recharge and safe yield of the aquifer system, thus the aquifer is overexploited. The decrease in groundwater storage during the year 1982-2003 was estimated to be 12.23 Mm^3, representing an average yearly decline of 2.514 m of the water table. Attempt has also been made to delineate hydrogeological conditions of Kangavar basin to asses the feasibility of the application of artificial recharge, in order to restore the negative water balance. For this purpose hydrogeological, hydrological and geophysical data were obtained by field reconnaissance visit. Finally, some recommendations are proposed, in order to support a sustainable management of the groundwater resources in the basin.

Key words: Groundwater balance, safe yield, aquifer recharge, geoelectrical method, semi-arid basin, Iran

INTRODUCTION

Proper management of groundwater resources requires knowledge of magnitude, distribution and depletion. Without such assessment, the effects of past development and prediction of the influences future development can not be adequately determined. The assessment and development of groundwater can conceived by the application of water balance method, that equates demand for water against abstraction requirement needs (Hiscock, 2006). A hydrologic balance is an accounting of the surface and groundwater resources entering and leaving a specific geographic region. It is used to estimate the quantity of groundwater that may be safely and economically withdrawn (Roscoe Moss Company, 1990). Water Budget provides means of assessment of groundwater resources (Manual, 1981).

The estimation of groundwater balance is essential in order to assess the safe yield of the aquifer systems and therefore to establish their rational exploitation and sustainable management (Voudouris *et al*., 2006).

Safe yield should be less than average annual recharge to compensate for minor groundwater losses. Any withdrawal in excess of safe yield is an overdraft (Freeze and Cherry, 1987; Fetter, 1988; Davis and Deveist, 1966). Safe yield in groundwater basin is defined as amount of water that can be withdrawn from it annually with out producing any undesired result (Todd, 1980).

There are several methods in which artificial recharge may be adopted these include recharge basin, spray irrigation and wells type of recharge etc.

The feasibility of recharge is governed by availability of suitable sites, presence of source of water supply, lithological composition, thickness and permeability characteristics of geological formations, hydrodynamic conditions in the aquifers and cost benefit (Karanth, 1994).

Kangavar basin, is located in the western part of Iran, covering an area of 118.81 km^2. It is characterized by semi-arid climatic conditions. The economic development of this basin is influenced by both the availability and the seasonal variability of water resources. Water demands

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have increased due to rise of population and also introduction of high yielding varieties crops, which requires an assured, available and timely water supply. Groundwater has been extensively exploited for irrigation use. This reliability on groundwater as the most dependable source for irrigation and other uses has led to its over-exploitation in the most parts of the basin.

Over-abstractions of groundwater by rural population in basin resulted severe disequilibrium of its water balance. Many deep and shallow wells have been constructed by farmers in order to cover the water demands for irrigation supply. The increase in groundwater abstractions combined with prolonged dry periods has been accompanied by decline in water table. If pumping exceeds the total amount of recharge groundwater mining occurs and the aquifer is no longer sustainable (Sophocleous, 2005).

The present study deals with the estimation of the groundwater balance in Kangavar basin and safe yield value that has been increased due to, both groundwater deterioration and water level decline. A detail hydrogeological study was also carried out in order to investigate the hydrogeological conditions of the basin. All existing geological, hydrological and hydrogeological data were evaluated and reworked (Anonymous, 2003). Hydrogeological, hydrological and geophysical data were obtained by field reconnaissance visit. Furthermore, geophysical and pumping test data were used in order to determine the hydraulic parameters and the zones where groundwater recharge would be most beneficial to the aquifer system.

MATERIALS AND METHODS

Description of study area: Kangavar basin covers an area of 118.81 km^2. The study area is located in NE Kermanshah province, West Iran. It extends between latitude 34° 17′ and 34° 40′ North and longitude 47° 37′ and 48° 03′ East. The basin elevation ranges from 1400 to 3178 m above mean sea level. The area is mainly rural and dependent on agriculture. The major crops include wheat, barley, corn, sugar beet, grapes, apple and apricot. Kangavar is the only city in the area. The important villages in the area are Rostam Abad, Karmajan, Soltan Abad and Karim Abad.

Geology and hydrometeorology: Stocklin (1986) has classified the area between tectonic zone of Zagros formation and Sanandaj-Sirjan zones and considered to be a tectonically active area. The area has been mapped at the 1:250,000 scale by the Geological Survey of Iran (GSI) and the geology is described by Braud (1970), Fotovat (1982) and Zadeh (2002).

The following brief description of geology is intended to bring out only the hydrogeological aspects. The geology of the area is shown in Fig. 1.

Unconsolidated alluvial deposits, underlain by a thick sequence of Mesozoic and Cenozoic formations, characterize the basin. The alluvial deposits are comprised of flood plain alluvium, poorly graded to well graded sands and gravels interbeded with clay lenses.

Low to moderately mountains occurs between the altitudes of 1000 and 2000 m above Mean Sea Level (MSL). It is massive mountain tracts metamorphic formations with a series of ridges and spurs. Two main rivers Shahab and Khoram, both originates from eastern catchments of the neighbouring areas and both are finally joining together in NE parts of the study area. The rivers are forming depositional terraces at the number of places and are causing head water erosion. The total annual discharge of these two rivers is about 53.43 Mm^3 occurring in wet period. The rivers beds are filled up with silts, sands and gravels at the NE part.

The average yearly minimum temperature is 4.3°C; January is the coldest month and the average yearly maximum temperature is 21.3°C and July is the hottest month. Average annual rainfall in this region is about 350 to 400 mm. The entire catchments comes under the influence of Mediterranean front and major part of precipitation is received between February (Bahman) and March (Farwarding). According to Thornthwaite type of classification (1948), the climate of the basin is of semi-arid conditions.

The Thornthwaite method (Thornthwaite and Mather, 1957) was applied to the region to calculate the water-budget. Based on Thornthwaite method, the mean real evapotranspiration is 263.5 mm year^{-1}, 65.5% of annual average rainfall for the period 1987-2003, accepting the maximum water storage in the soil 120 mm based on soil structure of the area. From the same method the recharge (infiltration) and runoff is estimated to be 163.2 mm year^{-1} (Table 1). This procedure was carried out using a computer program, developed by Eini (2007).

Hydrogeology: The occurrence of groundwater in the area is controlled by diverse geological factors e.g., structure, geological sequences and stratigraphical disturbances of hydrogeological units. Lithological data from exploitation wells shows that, the thickness of aquifer increases in central part of basin and reaches up to 110 m, whereas it ranges from 5 to 10 m in periphery. In order to show

Table 1: Estimated water balance in Kangavar basin for the hydrological year 1987-2003

Indexes	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
T	-0.10	1.80	6.90	12.40	17.30	22.80	27.00	26.30	21.00	15.00	8.20	3.30	13.5
i	0.00	0.21	1.63	3.96	6.54	9.95	12.85	12.35	8.78	5.28	2.11	0.53	
Ep	0.00	2.37	17.82	42.90	70.80	107.10	138.00	132.70	94.60	57.10	23.10	5.90	
N	0.76	0.79	1.02	1.14	1.31	1.33	1.34	1.23	1.05	0.93	0.77	0.72	
Ep’	0.00	1.90	18.20	48.90	92.70	142.40	184.90	163.20	99.30	53.10	17.80	4.20	
P	50.80	56.80	72.80	51.80	21.30	1.60	1.40	0.30	0.50	27.20	55.80	61.50	402.2
P-Ep’	50.80	54.90	54.60	2.90	-71.40	-140.80	-183.50	-162.90	-98.80	-25.90	38.00	57.30	
APWL	0.00	0.00	0.00	0.00	-71.40	-212.20	-395.70	-557.70	-656.50	-682.40	0.00	0.00	
Ws(mm)	120.00	120.00	120.00	120.00	66.20	20.50	4.43	1.15	0.50	0.40	38.40	95.70	
Δws	0.00	0.00	0.00	0.00	-53.80	-45.70	-16.70	-3.30	-0.60	-0.10	38.00	57.30	
E_r	0.00	1.90	18.20	48.90	75.10	47.30	18.10	3.60	1.10	27.30	17.80	4.20	263.5
S_t	50.80	54.90	54.60	2.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	163.2

T: Temperature, i: Heat index, E_p: Potential evapotranspiration, N: Factor depending on latitude, $E_{P'}$: Corrected potential evapotranspiration, P: Rainfall, APWL: Accumulated potential water loss, Ws: Maximum water storage in the soil, Δws: Ws-Ws_{i-1}, E_r: Real evapotranspiration and S_t: Total water surplus (infiltration and runoff)

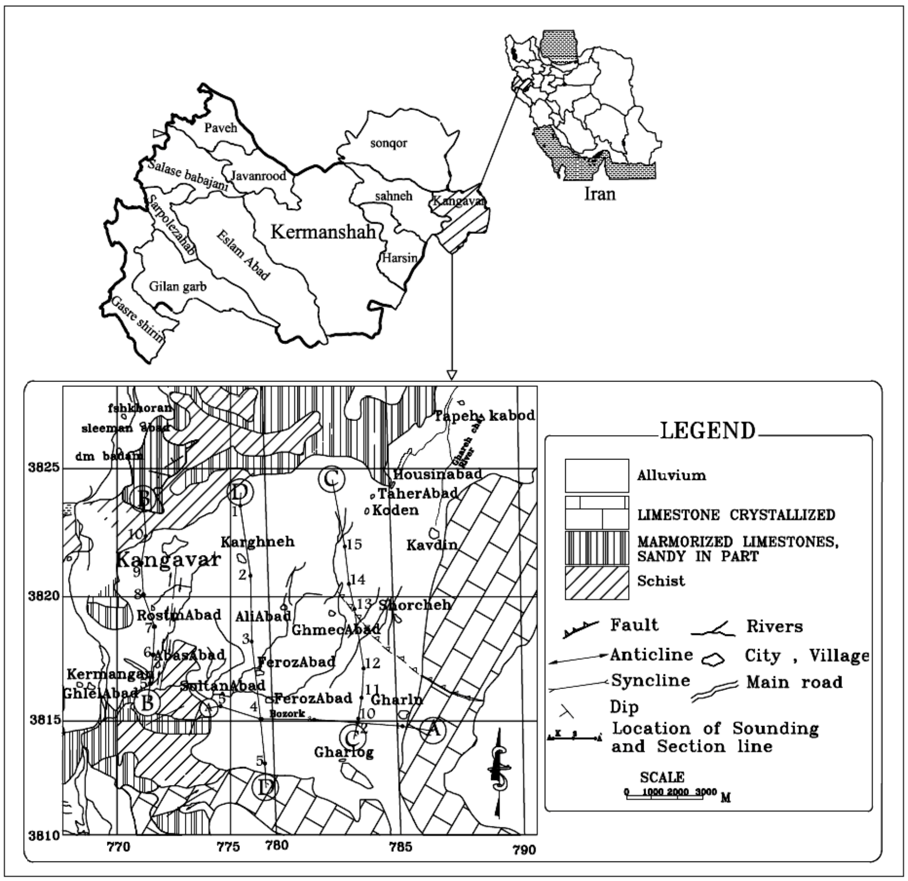

Fig. 1: Geological map of the study area, showing the location of VES

3-dimensional picture and groundwater conditions a fence diagram (Fig. 2) from lithological data has been prepared. The preparation of fence diagram of the study area has been attempted by using standard procedures outlined by Moore (1968) and Freeze and Cherry (1987). The fence diagram reveals the presence of clay in most parts of the study area, but pebbles and gravels appear to be predominate in the NE parts of the area.

Limited numbers of deep boreholes have been drilled in the basin, so existence of deeper layers can be

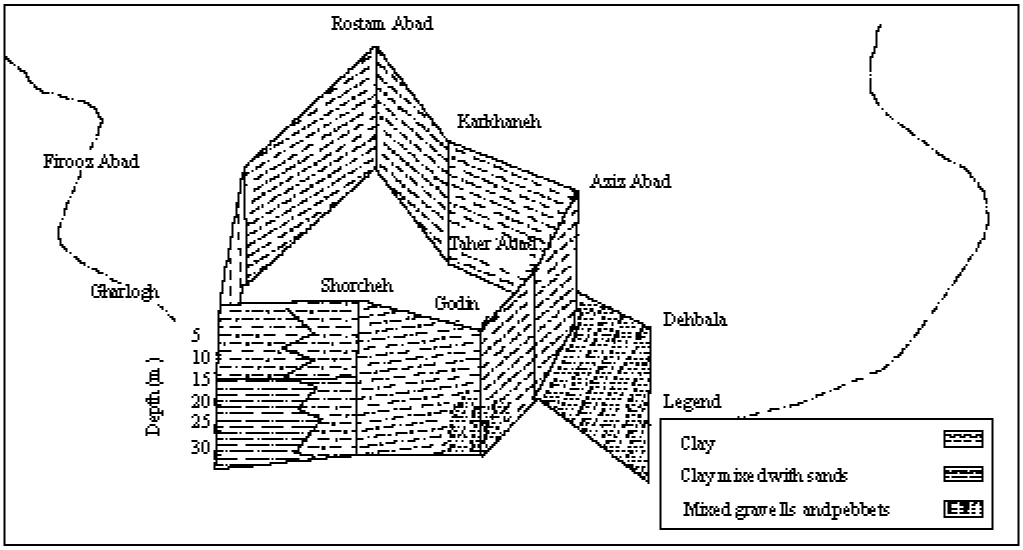

Fig. 2: Fence diagram of the study area

furnished through aid of geoelectrical data. There are 1058 shallow and deep wells discharging about 70 Mm^3 of groundwater annually. There are two springs and one Qanat. The Qanats are gently sloping horizontal wells were dug through alluvial materials to lead water by gravity flow from beneath the water table at its upper end to ground surface outlets. The main spring known as Kabutar Laneh having minimum discharge of 76 L sec^{-1} and the maximum discharge of 8304 L sec^{-1}.

Groundwater recharge in the aquifer occurs via the following mechanisms: Direct infiltration of rainfall, infiltration through river/torrent beds and lateral subsurface inflows. Return flow of water applied for irrigation is essential to the aquifer system's replenishment.

The movement of groundwater is from recharge area of upper hills towards central part of basin and ultimately the discharge is towards river of Khoram.

The transmissivity ranges between 500-1000 m^2 day^{-1} in southern part and 40 m^2 day^{-1} in outlet areas. The highest value of transmissivity (2000 m^2 day^{-1}) is recorded in NE part of the basin.

The study of water level data of wells offers a useful technique for evaluating the subsurface geohydrological regime. Depth to water table as shown in (Fig. 3) is highly variable being shallow in the eastern part and as deep as greater than 30 m below ground level (b.g.l.) in the central part of the basin. Based on water level rise and wet season recharge, using the following equation, we can estimate the specific yield (Goes, 1999):

$$R = S_y \times A \times DL_w + Q$$

Where:

- R = The recharge in wet season
- S_y = The specific yield
- DL_w = The average water level rise in wet period
- Q = The total volume of groundwater abstraction during the recharge period, that is equal to the volume of water used for domestic use and the lateral subsurface outflow in rainy season
- A = The effective area

Accepting the recharge volume in wet season (R) equal to 13.484 Mm^3, effective area 118.81 km^2, average water level rise in wet period (DL_w) equal to 3 m, domestic use in rainy season 1.367 Mm^3 and subsurface outflow in the same period 0.41 Mm^3, the specific yield was estimated to be 3.5% or 0.035.

The quality of water can be affected by hydrometeorological events, geological specifications of area and human pollution (Marofi, 2006). Groundwater quality do not show any significance abnormalities in the area. The value of EC is between 400 to 1000 μs cm^{-1}. Maximum values of electrical conductivity is observed in discharging area of the basin. The hardness of groundwater ranges from 157 to 173 mg L^{-1} $CaCO_3$. The mean concentration of sulphate observed to be 200 mg L^{-1} in 24 wells, not exceeding the permissible limit for drinking purpose.

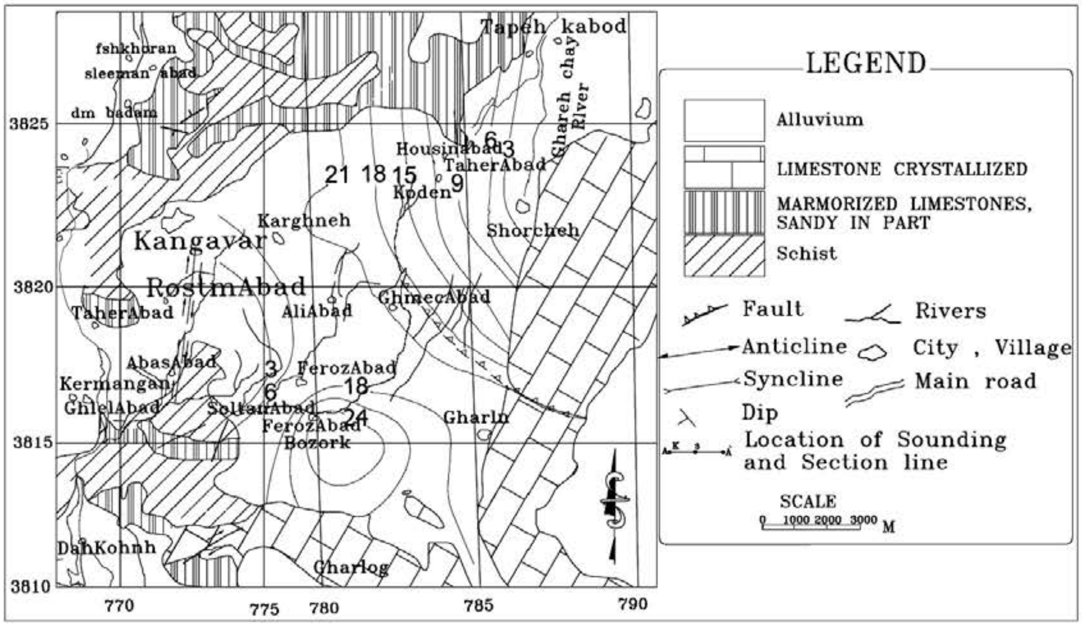

Fig. 3: Depth to water table (in meters from ground surface)

In general, the groundwater is of calcium-bicarbonate type ($Ca\text{-}HCO_3$) in inlet areas and sulphate concentration increases in central parts of the area. The reason for such enrichment needs to be looked in and detailed hydrogeochemical studies would be very useful. To provide a synoptic picture of the subsurface features especially in the central part of the area, attempts are made to decipher the subsurface picture from the interpretation of the generated geoelectrical data.

RESULTS

Groundwater balance: The water balance study is a convenient way to establish for estimation of groundwater losses. The groundwater balance of the shallow aquifer has been attempted. The hydrologic year has been taken from April to August as dry period and from September to March next year as wet period.

Based on hydrograph of groundwater table fluctuation in Kangavar basin (Fig. 4), we have had an average yearly decline of groundwater table about 0.62 m during 1982-2003, but as it is shown in this figure, abstraction from groundwater resources in recent years has been severe and according to the reports of Water Organization of West Iran, (Anonymous, 2003) in Kangavar basin, declining of ground water table in dry period (Dl_d) is 5.514 m and its rising in wet season (Dl_w) is 3 m, therefore average yearly decline of 2.514 m is estimated for this basin. The negative balance value will be:

$$V = (DL_d - DL_w) \times S_y \times A = 2.514 \times 0.035 \times 111.81 = 9.84\ Mm^3$$

Water budgeting method is another method based on comparison of inputs and outputs. The basic equation for the groundwater balance during a hydrologic year may be written as:

$$Q_{in} = Q_{out} \pm \Delta S$$

Where:

$$Q_{in} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$$
$$Q_{out} = Q_6 + Q_7 + Q_8 + Q_9 + Q_{10}$$

The total groundwater input (Q_{in}) consists of rainfall recharge (Q_1), lateral subsurface inflow (Q_2), recharge from rivers (Q_3), recharge due to irrigation return (Q_4), sewage return (Q_5).

The total amount of output (Q_{out}), consists of irrigation water uses (Q_6), discharge from springs and qanats (Q_7), lateral subsurface out flow (Q_8), evaporation from groundwater table (Q_9), domestic and industrial water uses (Q_{10}).

Table 2: Precipitation and recharge values during different months of year in study area

Parameters	Months												Total
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Temperature (°C)	0.200	2.180	6.300	11.500	15.800	20.70	25.00	24.6	20.00	14.500	8.900	3.600	
C index	0.910	1.020	1.450	1.820	2.070	2.28	2.42	2.4	2.27	2.000	1.660	1.210	
Precipitation (mm)	47.700	60.500	71.100	55.100	36.000	4.00	0.20	1.9	0.00	18.400	46.600	62.500	
Potential ET (mm)	24.000	36.000	61.000	112.000	152.000	217.00	254.00	238.0	186.00	105.000	54.000	30.000	
Deep percolation (mm)	5.452	6.140	6.622	5.734	4.496	0.00	0.00	0.0	0.00	3.031	5.290	6.233	42.9980
Infiltration volume (MCM)	0.610	0.687	0.740	0.641	0.503	0.00	0.00	0.0	0.00	0.339	0.592	0.697	4.8090

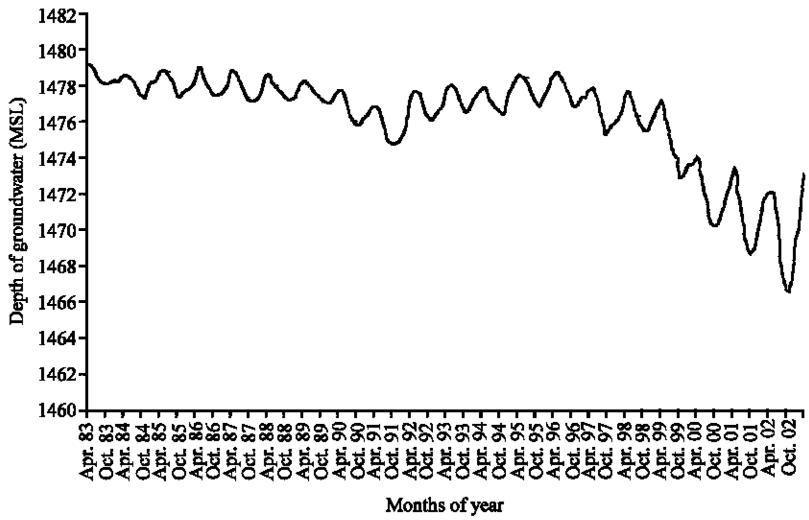

Fig. 4: Unit hydrograph of the Kangavar basin

The change in groundwater storage (ΔS) has been estimated by taking the difference between the average water level at the beginning and the end of the hydrological year (Naik and Awasthi, 2003).

Inputs

Rainfall recharge (Q_1): Based on Richard and Allen, 1998 and parameters of rainfall, potential evaporation and temperature, rainfall recharge can be calculated as follow:

$$F = 0.8\,(P\text{-}C\log E)^{0.5}$$

That E is monthly potential evaporation in (mm), C is infiltration index and is related to monthly temperature, P is monthly precipitation and F is monthly infiltration value in (mm) as shown in Table 2.

The rainfall recharge volume estimated by aforementioned formula is 1.483 Mm^3 for dry period (March to August) and 3.327 for wet period (September to February). Therefore the total annual rainfall recharge is equal to 4.809 Mm^3.

Lateral subsurface inflow (Q_2): Using Darcy equation the volume of lateral inflows from the upstream boundary of the aquifer is equal to 0.717 Mm^3 for dry period and 0.512 for wet periods. Therefore annually lateral subsurface inflow is 1.229 Mm^3.

Recharge from rivers beds (Q_3): Based on results of hydrological studies, the volume of annually surface recharge in to the basin is about 111.23 Mm^3. The recharge to the aquifer system directly or indirectly or controlled by farmers is about 8.403 Mm^3 for wet period and 3.58 Mm^3 for dry periods. Therefore the total average of annually stream bed infiltration is 11.985 Mm^3.

Recharge due to irrigation returns (Q_4): The total amount of water abstracted from wells, Qanats and springs is about 111.66 Mm^3. Based on (Richard and Allen, 1998) and considering soil characteristics, cultivating type and ground leveling condition, about 35% of irrigation water can be considered as recharge from irrigation return. Therefore the annual recharge due to irrigation return is about 39.15 Mm^3.

Sewage infiltration (Q_5): Based on reports of Water Organization of West Iran in Kangavar basin (Anonymous, 2003), it has been estimated that the volume of groundwater recharge from sewage is about 65% of total domestic and industrial uses that are about 1.367 Mm^3 for wet period and 1.911 Mm^3 for dry period. Therefore, the volume of about 0.89 Mm^3 for wet period and 1.242 Mm^3 for dry period was estimated to recharge the aquifer system from sewage infiltration. Thus total annually amount of sewage infiltration in to ground water table is about 2.131 Mm^3.

From the estimates made above, the annual input to the aquifer system is:

$$Q_{in} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 = 59.30 \text{ MCM}$$

Outputs

Irrrigation water uses (Q_6): Irrigation starts from the beginning of April until August. Most cultivated crops in the area are wheat, barley, sorghum, sugar beet, apple, apricot. Irrigation type is surface irrigation and water requirement is about 111.66 Mm^3 that its 60% is provided from groundwater resources. Based on field measurements on number of wells and their different discharges, yearly abstraction from the aquifer system for irrigation water uses is about 66.09 Mm^3.

Contribution to surface water (Q_7): There are two springs and one qanata in the basin and amount of water abstracted from aquifer system is 0.027 Mm^3 via springs and 0.021 Mm^3 via qanat.

Subsurface outflow (Q_8): Utilizing Darcys law an estimate of average annual subsurface outflow from the aquifer system is based on piezometric map is about 0.41 Mm^3 for wet period and 0.572 Mm^3 for dry period of the year. Therefore, the total amount of subsurface out flow is 0.982 Mm^3.

Evaporation from groundwater table (Q_9): In areas with shallow groundwater table groundwater can be evaporated. Based on groundwater table depth map and pan evaporation values, that relate the groundwater table depth to the percentage of pan evaporation values that can be evaporated, annual evaporation from groundwater table is about 1.13 Mm^3.

Domestic and industrial water uses (Q_{10}): There is no important industry or factory in the area and base on population and accepting 160 (L/S)/person for dry period and 110 (L/S)/person during wet period and 0.5 Mm^3 for total industrial water uses, total amount of water abstracted for domestic and industrial uses in the case study area is about 3.278 Mm^3 (1.911 Mm^3 for dry period and 1.367 Mm^3 for wet period).

From the estimates made above, the mean annual output from aquifer system is:

$$Q_{out} = Q_6 + Q_7 + Q_8 + Q_9 + Q_{10} = 71.53 \text{ Mm}^3$$

Safe yield: Many concepts are used in the management of groundwater systems (Gau and Liu, 2002; Sharp, 1998). In groundwater management the safe yield is the rate at which groundwater can be withdrawn from an aquifer with out causing an undesirable adverse effect (Dottridge and Jaber, 1999; Heath and Spruill, 2003). The traditional definition of the safe yield assumes the pumpage rate equal to the total recharge. Nian-Feng *et al*. (2001) assume that the safe yield is 50% of total natural recharge of groundwater.

In this study, the concept of safe yield as a management concept was estimated from Naik and Awasthi (2003):

$$\text{Safe yield} = Q_{ed} + Q_{dom} + Q_4 + Q_5,$$

Where:

Q_{ed} = Te exploitable dynamic groundwater reserve
Q_{dom} = The volume of water used for domestic use in rainy season and Q_4, Q_5 were defined earlier

The exploitable dynamic groundwater reserve was calculated using the following formula:

$$Q_{ed} = A \times S_y \times DL_d = 111.81 \times 0.035 \times 5.514 = 21.57 \text{ Mm}^3,$$

Where:

S_y = The specific yield (3.5%)
A = The effective area for groundwater recharge (111.81 km^2)
DL_d = The average water level decline in dry period (5.514 m)

Thus the safe yield is calculated to be

$$\text{Safe yield} = 21.57 + 1.367 + 2.115 + 39.15 = 64.202 \text{ Mm}^3$$

It is obvious that the annual abstraction exceeds both natural recharge and safe yield and we are faced with an over exploitation of the aquifer. Based on hydrograph analysis of observing well stations during the period 1982-2003, it can be seen that there is a decline of about 10 m in the static water level in the basin. Figure 4 shows the unit hydrograph of the basin. These issues call for better water resources management. The safe yield can be attained by an increase in groundwater recharge (artificial recharge) or a decrease in water abstraction or a combination of two (Voudouris, 2006).

Geoelectrical method in selecting feasible recharge zone: Geoelectrical method is an effective tool for ascertaining subsurface geologic framework of an area (Keller and Friscknecht, 1966; Griffith and King, 1965; Zohdy *et al*., 1974; Zohdy, 1989). Application of geoelectrical method has lead the researchers to develop surface resistivity techniques for making quantitative estimates of water transmitting properties of aquifers (Taheri and Singhal, 1993).

In direct current electrical prospecting two methods are used, the first one is electrical profiling, which provides the information about the lateral variation of resistivity. The other method (Vertical Electrical Sounding, VES) provides information about the resistivity variation with depth.

Vertical electrical soundings were conducted with Schlumberger configuration in the study area. The advantages of the Schlumberger method (Bhattacharya and Patra, 1968; Keller and Frischknecht, 1966; Zohdy *et al*., 1974), particularly the interpretation techniques available, made in the choice of this study.

The maximum current electrode spacing was kept between 400 and 500 m. The apparent resistivity data for different values of AB/2 have been processed for 35 VES locations Fig. 5.

In order to ascertain the subsurface geological framework the general distribution of resistivity response of the geological formations has obtained and geoelectrical sections along number of lines have been prepared to study the variation in lithology. The location of these section lines and position of respective sounding points are shown in Fig. 1. It is observed that resistivity for sandy horizon varies from 35 to 100 ohm-m whereas for predominantly clay zones, it ranges from low to high resistivity. The rock formations exhibit wider ranges of

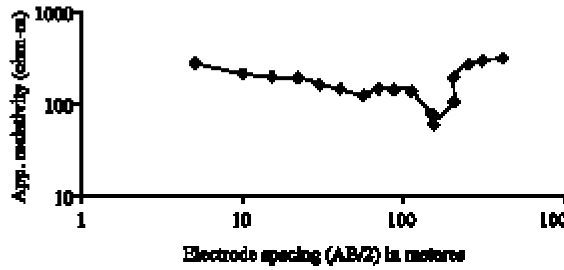

Fig. 5: A selected VES field curve

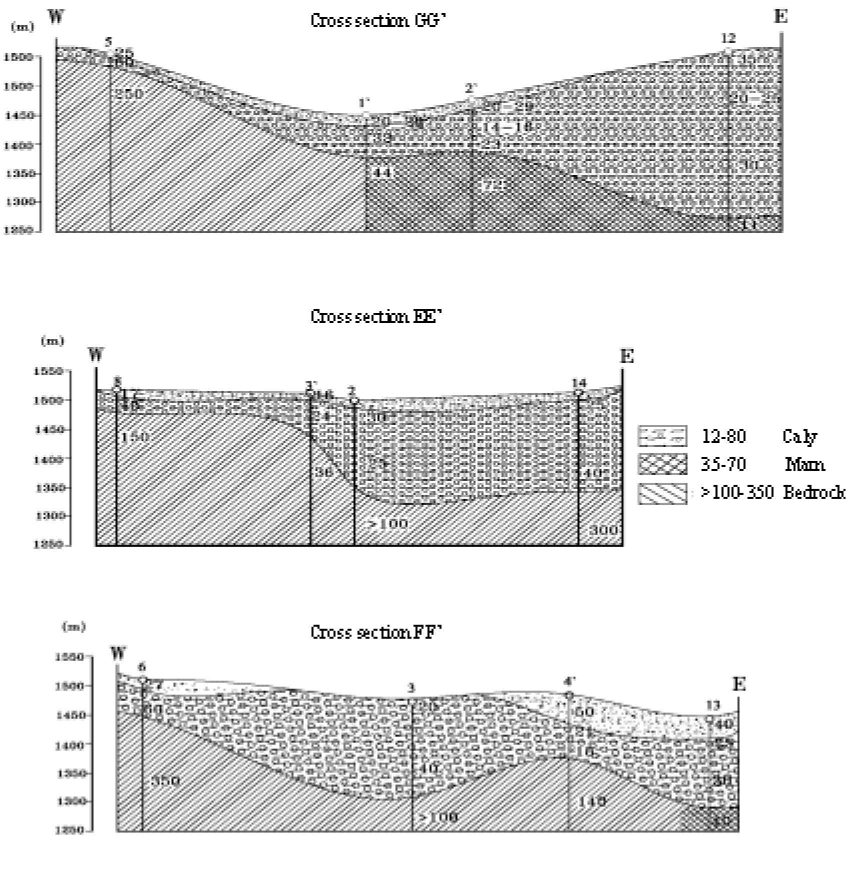

Fig. 6: Selected schematic geoelectrical sections as shown in Fig. 1

resistivity i.e., 150 to 400 ohm-m, respectively. The low values of resistivity for these formations will imply their friable and weathered nature.

The geoelectrical sections and profiles lines are shown in Fig. 6. It is concluded that the thickness of the alluvial deposits increases in the central part of the basin, which are comprised of an alternating sequence of clays and sands. A thick sandy horizon, probably saturated, is found in NE parts of the study area, which can be considered as feasible recharging zone. The bedrock is showing general deepening towards SE.

CONCLUSIONS

Kangavar basin is located in the western part of Iran and it is characterized by semi-arid climatic conditions and intensive agriculture. The main aquifer system is developed within the unconsolidated alluvial deposits of the basin. Groundwater is the main source of fresh water, supplying water for irrigation and domestic use.

The total annual input to the aquifer is 59.3 Mm^3 and the total annual output from the aquifer is 71.53 Mm^3. The irrigation abstraction is about 91.1% of the estimated total abstraction. Based on groundwater balance, it is found that the average yearly decline of the water table during the period 1982 to 2003 is 0.62 and 2.514 m for recent years; thus the decrease in groundwater storage is found to be 9.84 Mm^3.

It can be concluded that the current abstraction is not sustainable. Augmentation of groundwater through artificial recharge measures should be applied in the aquifer system of the basin in order to maintain groundwater levels and sustain additional extraction. Artificial groundwater recharge is an environmentally acceptable solution, as part of an integrate water resources management program (Voudouris *et al*., 2006). Field tests in other countries have shown that (Hionidi *et al*., 2001; Voudouris *et al*., 2006) artificial recharge through boreholes with water, originating from the wintertime runoff, could augment the inflows and improve the groundwater quality of the aquifer system. The feasibility of recharge is governed by availability of suitable sites, presence of source of water supply, lithological composition, thickness and permeability characteristics of geological formations, hydrodynamic conditions in the aquifers and cost benefit (Todd, 1980). The fence diagram reveals the presence of clays in most part of the area but pebbles and gravels appear to be predominate in the NE parts of the area. Lithogical studies were helpful in order to select the type of recharge method. Geoelectrical findings shows a thick sandy horizon is appear to be saturated found in NE parts of the area which can be considered as feasible recharging zones.

It can be concluded that the recharge method can be implemented in the NE parts of the basin, where two main rivers Shahab and Khoram, with total annual discharge of 53.43 Mm^3 occurring in wet period can be used for construction of diversion dam. Therefore implementation of artificial recharge should take place in the rivers beds, which are filled up with silts, sands and gravels.

Water-saving techniques such as spray irrigation and drip irrigation should be applied in order to decrease the groundwater quantities used for agriculture. Finally, a rational water resources management policy, including water conservation and quality protection measures, improvement of current legislation and public education should be adopted.

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