Integrated Groundwater Study in Jalaier Valley, Shirin Tagab District of Faryab Province, Afghanistan

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List of Abbreviation and Technical Terms

Aquifer: A rock formation, group of formations, or part of a formation that is water bearing. Commonly used synonyms are ground-water reservoir, water-bearing bed, and water-bearing deposit.
Aquiclude: A geologic formation so impervious that for all practical purposes it completely obstructs the flow of groundwater (although it may itself be saturated with water).
AIMS: Afghanistan Information Management Service.
Contaminant: Any substance that when added to water (or another substance) makes it impure and unfit for consumption or use.
DACAAR: Danish Committee for Aid to Afghan Refugees
DW: Dug Well
EC: Electrical Conductivity or Salinity.
Evaporation: The conversion of a liquid (water) into a vapour (a gaseous state) usually through the application of heat energy during the hydrologic cycle; the opposite of condensation
Evapo-transpiration: The loss of water from the soil through both evaporation and transpiration from plants
FAO: Food and Agriculture Organization.
F- : Fluoride
GMWs: Groundwater Monitoring Wells.
Groundwater Discharge: Groundwater discharges include, evaporation, transpiration and groundwater flow to the surface as drainage, springs, karezes and pumping for irrigation and water supply
Groundwater Level: Indicates the position where the atmospheric pressure and hydraulic head are at equilibrium (balance) in the aquifer
Groundwater Recharge: Groundwater recharge is defined as the downward flow of water recharging the water level forming an addition to the groundwater reservoir.
Infiltration: The process whereby water enters the soil and moves downward toward the water table
Mg/l: Milligram per liter
Precipitation: The part of the hydrologic cycle when water falls, in a liquid or solid state, from the atmosphere to Earth (rain, snow, sleet).
pH: which is defined as the negative decimal logarithm hydrogen ion activity(H^+). The pH value is indicated where the water is acid or alkaline. Neutral water pH=7. If the pH of water is less than 7 is acidic and more than 7 is alkaline
TW: Tube Well.
Transpiration: The process by which water absorbed by plants (usually through the roots) is evaporated into the atmosphere from the plant surface (principally from leaves)
USGS: United States Geological Survey
WHO: World Health Organization.
Watershed or Sub Basin; water catchments larger than 40,000 km^2
Water quality: The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use
WSP: Water and Sanitation Programme

1. Introduction

The Jalaier valley is located in the western part of Shirin Tagab district. The people of this valley are involved in rain fed agriculture and animal husbandry. The Jalaier valley has more than 15 villages and has about 8,700 inhabitants. There are three primary schools and a basic health center. The people of this valley have been confronted with safe drinking water problems for many years. They spend on average 7 hours a day to collect their drinking water either from Shore Darya River (brackish/saline water) or from Atehkhan khavajeh (3) spring and Shirin Tagab river (fresh water) using camel and donkeys. The Shirin Tagab River is located in the northeastern part of the valley. The water of this river is also polluted and a source of water borne-diseases.

The shortage of safe drinking water affects the environment and socio-economic development of this valley. The shallow and deep groundwater is highly mineralized due to extension of evaporative basin during its long residence time and existence of thin layers of halite and gypsum minerals. Weathering and dissolution of halite and gypsum minerals have seriously affected the shallow and deep aquifers. The surface water (Shor Darya River) is also highly mineralized due to discharge of brackish/saline groundwater to the river. Therefore, there is urgent need to provide safe drinking water and development of other socio economic projects.

In the period from 27th September to 5th October 2005, DACAAR/WSP carried out a surface water and shallow ground water survey in the Shirin Tagab, Khwaja Sabz Posh and Dawlat Abad districts. The results of the survey indicated that the settlements located in the eastern and western parts of Shiri Tagab and Khwaja Sabz Posh districts (Jalaier and Astana valleys) have a safe drinking water problem. The survey indicated that the surface and shallow groundwater is brackish or saline

During the period 21st January 2009 to 31st January, 2010 DACAAR/WSP carried out an integrated groundwater study including Geophysical investigation (Vertical Electrical Sounding), drilling of two exploration wells and chemical and physical analysis of water samples, with financial support of the Royal Norwegian Embassy, for determining the hydrogeolgical structure, natural aquifer systems, water quality and as well as finding alternative solutions for provision of safe drinking water. Unfortunately the result of this study also indicated that the upper and lower parts of the aquifers are highly mineralized. Both shallow and deep aquifers have brackish or saline water. Groundwater development for water supply and irrigation is not feasible

Key words: Physical setting, Analysis of Geophysical investigation field data, Analysis of research borehole data, Analysis of water quality data and Analysis of sources of water.

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2. Objective

The main objectives of this study are;

1) Review physical setting of area (Climate, Geomorphology, Geologic and Hydrogeologic setting and surface water)
2) An analysis of Geophysical investigation (Vertical Electrical Sounding) field data for finding water level, lithology, interval of fresh and saline aquifers
3) An analysis of exploration wells data for modification of geophysical study
4) Evaluation of physical and chemical analysis of water samples which were taken from exploration wells, rivers and drinking water points
5) An analysis of source water and identify drinking water related problems
6) Recommendations for provision of safe drinking water for short term and long term

2. Physical setting

2.1. Geomorphology

Faryab province is located in the Shirin Tagab watershed. This watershed is dominated by rangeland (40%), rain fed land (36%) and irrigated land (7.2%). Most (64%) of the irrigated land is intermittently cultivated.

Table 1: Land covers classification for Shirin Tagab watershed (FAO, 1990)

LANDCOVER	Area (ha)	Area (sq. km.)	% Watershed
Fruit Trees	7653	76.5	0.51
Irrigated: Intensively Cultivated (1 Crop/Year)	38749	387.5	2.57
Irrigated: Intermittently Cultivated	70312	703.1	4.66
Marshland Permanently inundated	185	1.9	0.01
Rainfed Crops (flat-lying areas)	5417	54.2	0.36
Rainfed Crops (sloping areas)	535535	5355.4	35.48
Rangeland (grassland/forbs/low shrubs)	610315	6103.2	40.44
Rock Outcrop / Bare Soil	6638	66.4	0.44
Sand Covered Areas	233592	2335.9	15.48
Settlements	640	6.4	0.04
Water Bodies	187	1.9	0.01
	1509223	**15092.2**	**100.00**

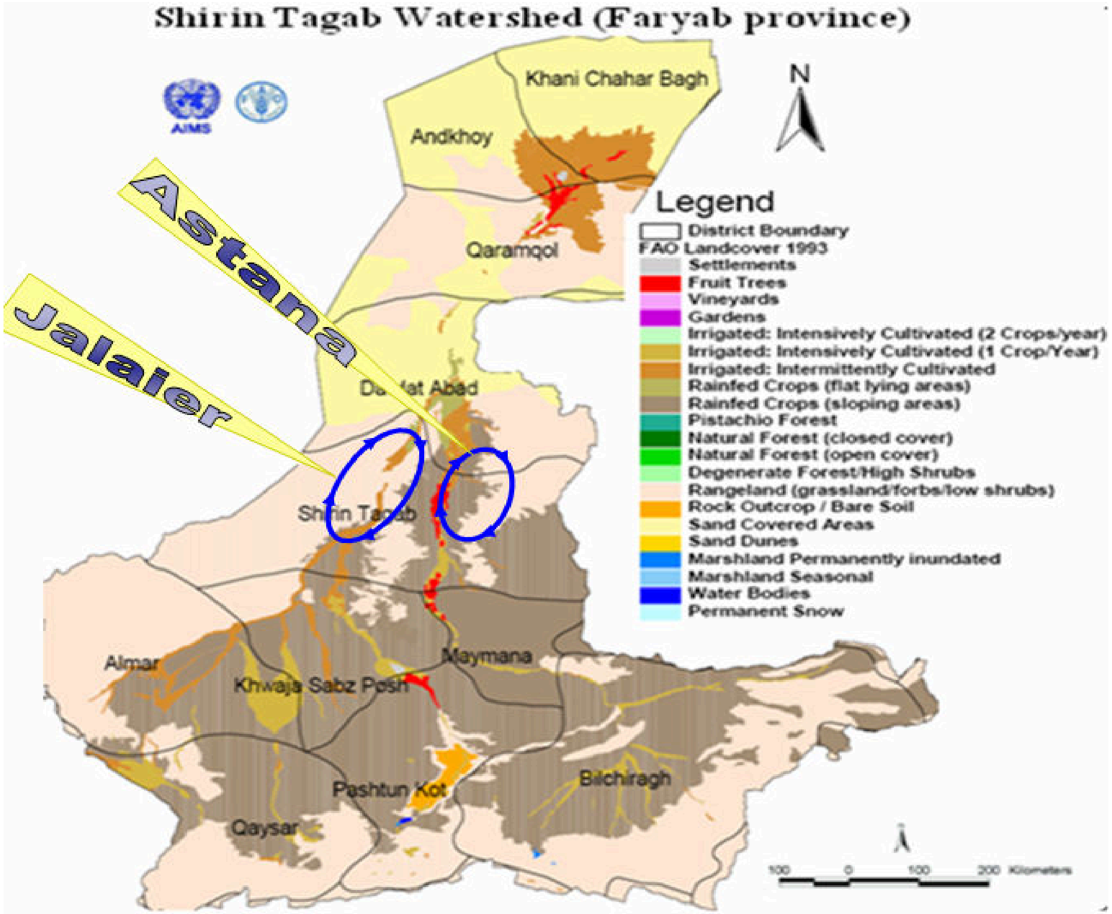

Fig.1, Shirin Tagab watershed land cover classification (FAO, 1990)

2.2. Climate

The climate of Faryab province climate is arid and semi-arid with major day-time and night-time fluctuations. The winter is characterized by low temperatures of less than - 4 ºC while the summer is dominated by high temperatures of more than 40 ºC. The mean average temperature recorded at the Maymana Meteorological station ranged between 28º C (July) to -4 ºC (January)

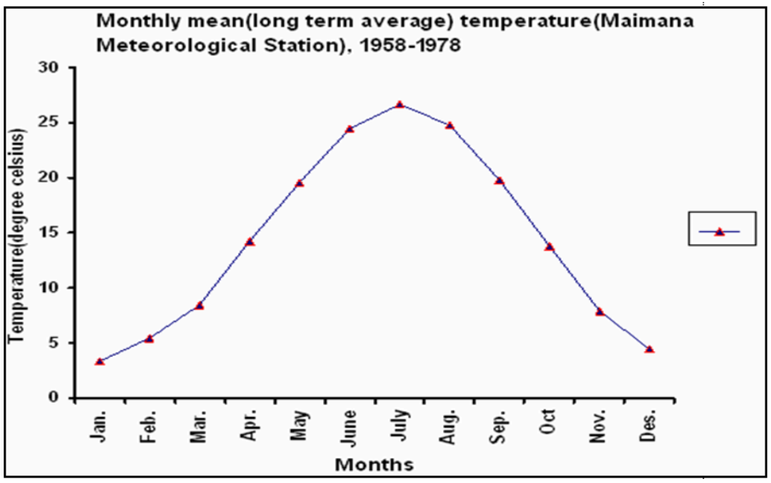

Fig. 2, Monthly mean temperature (Ministry of Water and Power, 1958-1978)

The mean maximum rainfall was 582 mm and evapo-transpiration (EPT) was 1,202 mm (Maymana Meteorological station, 1958-1978)

Table 2, Historical data of precipitation, temperature and EPT in Maymana Meteorological station (1958-1978)

Historical data on precipitation, temperature, potential ETP and wind

	Precipitation			ETP	ETP/Day*			Temp	Wind	Sunshine
	Max	Normal	Min	Total	Mean	Max Month	Min Month	Mean	Speed	Mean
STATION NAME	Mm	mm	mm	mm	mm	mm	mm	°C	m/s	Ratio
Baghlan				961	2.67	5.73	0.33	14.8	0.9	0.58
Bamyan	382.4	138.6	57.7					5.9		
Bust	196.0	92.7	32.4	1585	4.40	7.90	1.20	19.5	1.8	0.73
Chakhcharan	246.5	187.8	137.5					6.9		
Faizabad	791.0	501.3	300.1	925	2.57	6.07	0.27	13.2	0.9	0.54
Farah	193.0	90.1	38.0	1468	4.08	8.27	0.90	19.7	1.4	0.74
Gardez	521.1	319.3	141.2					9.3		
Ghazni	551.2	284.8	90.2	1359	3.78	7.57	*0.57*	9.5	3.1	0.73
Ghelmin	363.1	219.9	125.6	905	2.51	6.00	*0.37*	7.8	1.4	0.62
Herat	411.9	222.5	112.5	1737	4.83	11.03	0.87	16.3	2.9	0.62
Jabulsaraj	739.2	465.2	110.3	1409	3.91	8.40	*0.67*	15.0	2.5	0.69
Jalalabad	408.1	171.2	42.5	1274	3.54	6.80	0.70	21.5	1.0	0.68
Kabul Airport	547.8	316.0	164.9	1173	3.26	7.57	0.43	12.5	1.7	0.70
Qalat	461.3	281.3	144.8					13.4		
Kandahar Air	311.4	161.4	57.3	1644	4.57	8.27	1.30	19.0	2.1	0.78
Karizimir				955	2.65	5.77	0.47	10.5	1.1	0.70
Khost	657.3	449.9	206.2	1205	3.35	6.37	*0.93*	17.0	1.7	0.67
Kunduz	560.8	336.0	193.0	1285	3.57	8.13	0.43	16.5	1.8	0.58
Laghman	468.9	251.3	117.2					19.1		
Lal	429.3	227.4	168.0	695	1.93	4.33	*0.20*	2.9	1.2	0.69
Logar	372.2	222.0	101.4					10.7		
Mazari Sharif	379.1	189.1	87.4	1376	3.82	8.47	0.57	18.0	2.2	0.59
Maimana	582.1	353.6	200.3	1202	3.34	7.20	*0.63*	14.4	1.9	0.62
Moqur	451.1	239.5	49.3					10.2		
North Salang	1450.6	1018.5	376.5					-0.6		
Paghman	620.7	419.6	223.7					9.1		
Panjao	440.1	284.8	44.4					3.2		
Qaqis	450.5	344.8	210.9	1090	3.03	6.10	*1.03*	12.1	1.9	0.62
Shahrack	417.0	276.1	60.3					3.9		
Shebirghan	434.6	231.0	116.5	1364	3.79	7.90	0.73	16.4	2.2	0.60
South Salang	1354.0	1023.3	677.1					2.3		

[17] Source : Department of Meteorology, Department of Transport and Tourism. The data were entered by FAO Agro-meteorology department in Kabul under the supervision of Rabah Lekhal, FAO Agro-meteorologist.

A compression of the long term average monthly evapo-transpiration (ETP) and precipitation values show that the ETP value is higher than precipitation.

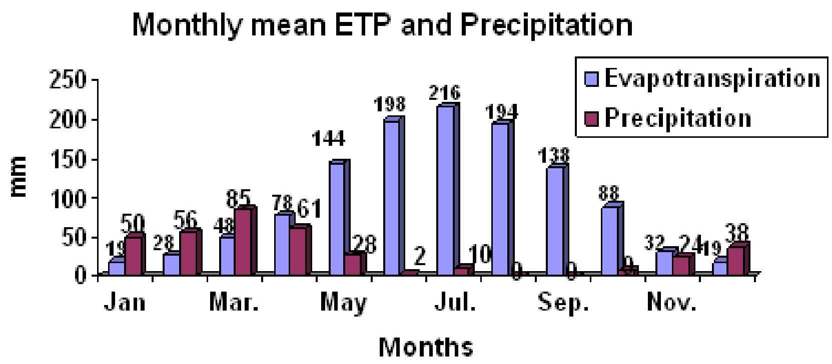

Fig.3, Mean monthly evapo-transpiration (ETP) and precipitation in Maymana Meteorological station

The rainfall data recorded by Agromit (2005-2006) indicated that the rainfall has considerably decreased as compared with historical data.

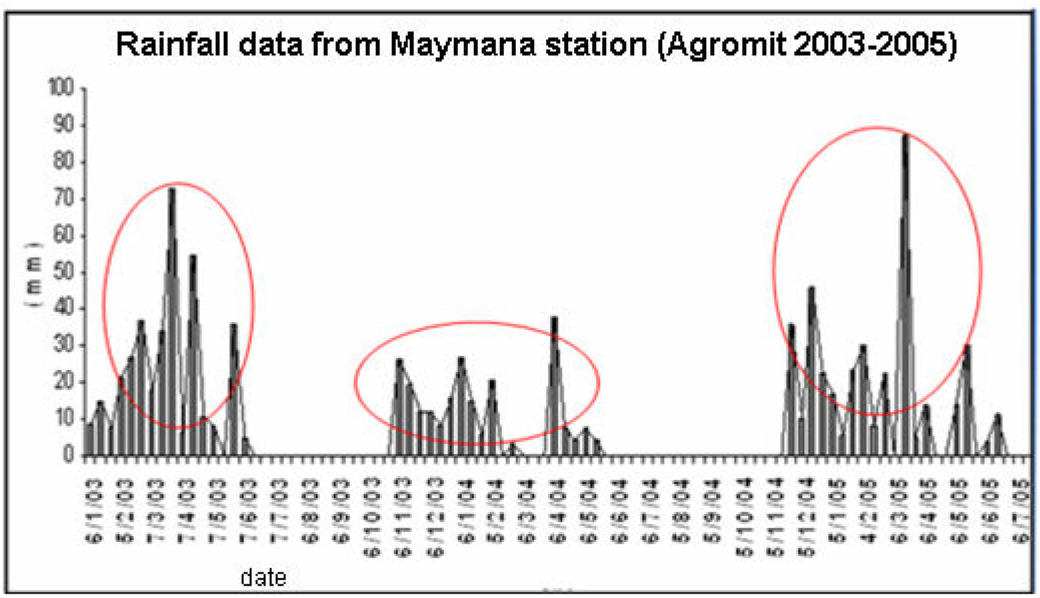

Fig. 4, Rainfall data from Maymana Meteorological station (USGS, Agromit, 2003-2005)

2.3. Shirin Tagab River

The Shirin Tagab River drains from Bilchiragh district (Shirin Tagab River) Pashtun Kot district (Maymana River) and Qaysar- Almar districts (Qaysar River) of Faryab province. The Shirin Tagab and Qaysar Rivers meet a few kilometers below Dawlat Abad district. The River then maintains the name of Shirin Tagab and dries in the irrigation canals of Andkhoi and Khani Chaharbagh districts after having traveled 320 km. The main tributary of the Shirin Tagab is the Maymana River, which takes it sources from Ser Hawz Dam in Pashtun Kot district south of Maymana center of Faryab province. The

Maymana River is supplemented by a number of small streams and Qaysar River which takes its source from the Selsala-i- Band Turkistan Mountain. The Shirin Tagab River takes its sources from Kohistan district. In Bilchiragh district the Chashma-i-khwab is divided into five small valleys: Darrah-i-Rabat, Darrah-i-Shakh, Darrah-i-Zang, Darrah-i-Takhara and Darrah-i-Khvajeh Ghar.

Fig. 5, The Rivers network of Faryab province (Shirin Tagab watershed)

The recorded data from Kushti Pul measurement station (ShirinTagab River) shows that the mean discharge fluctuated between 2.0 - 8.8 m^3/s (1964-1978).

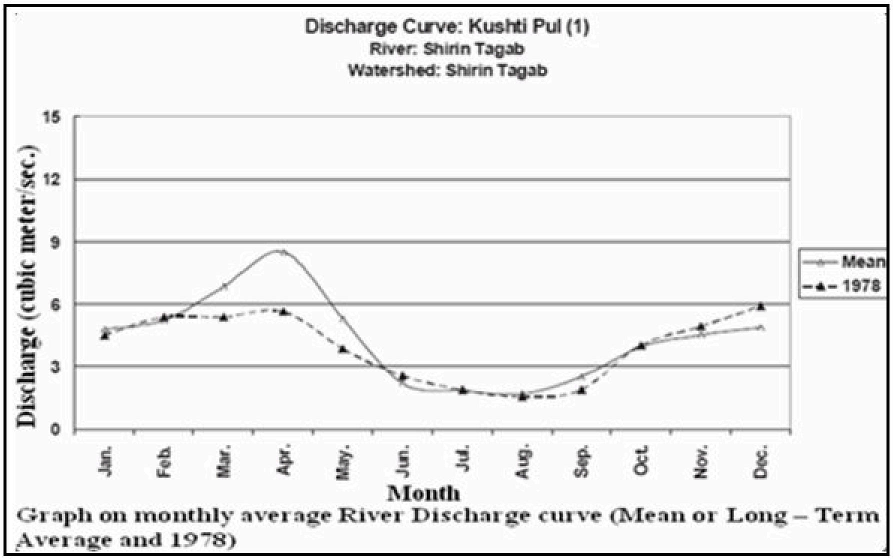

Fig. 6, Kushti Pul measurement station (Ministry of Water and Power, 1964-1978)

The recorded data from Khvaja Qushori measurement station (located near to the Kushtipul measurement station) shows that the discharge of Sirin Tagab River considerably decreased and fluctuated between 1.5-5.8 m^3/s (2007-2008).

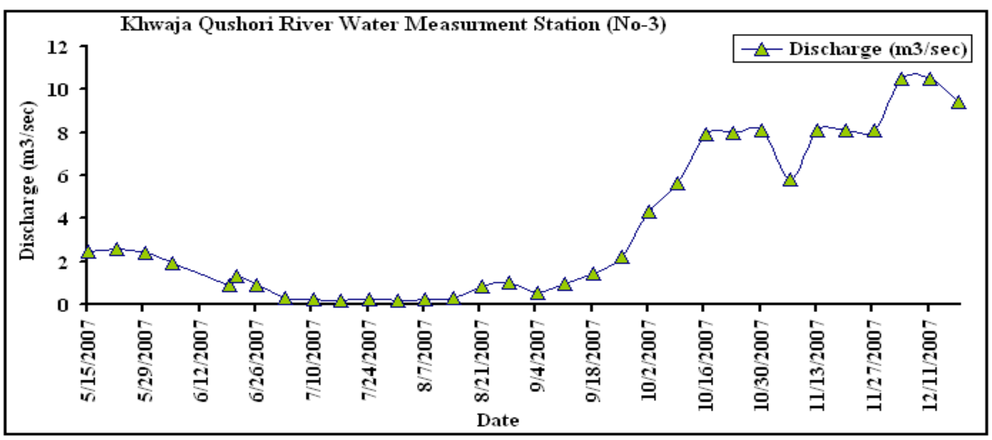

Fig. 7, Khvaja Qushori measurement station, 2007 (DACAAR/WSP, Shirin Tagab River)

The recorded data from Pata Baba measurement station (ShirinTagab River) shows that the mean discharge fluctuated between 1.2-11.8 m^3/s (1964-1978).

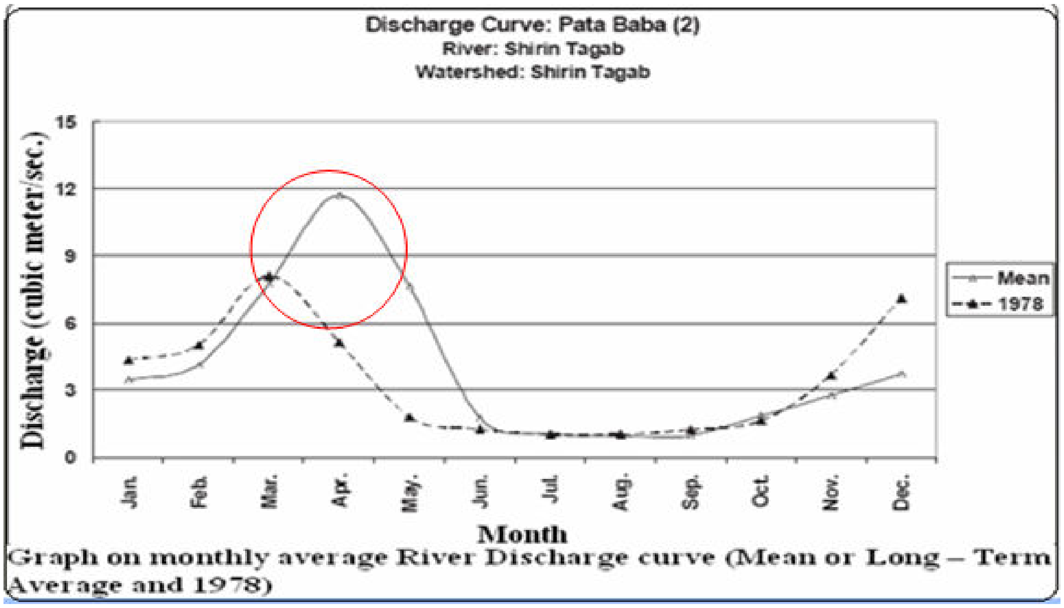

Fig.8, Pata Baba measurement station (Ministry of Water and Power, 1964-1978)

The recorded data from Pata Baba station (2007-2009) shows that the discharge of Shirin Tagab River considerably decreased and fluctuated between 0.1-7 m^3/s (2007-2008). During 2009 (March-May) The excessive rain fall and snowmelt during 2009 (March-May) caused flooding and increased the discharge of Shirin Tagab River.

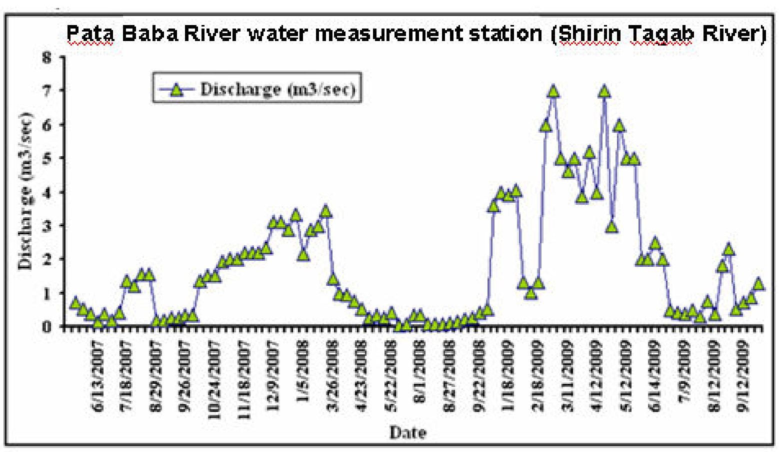

Fig. 9, Pata Baba measurement station (2007-2009)

The recorded data from Ateh Khan Khvajeh station (2007-2009) shows that the discharge of the river fluctuated between 1- 6 m^3/s (2007-2009). This measurement station is located where the Maymana river joints with Qaysar river and drains through Jalaier valley.

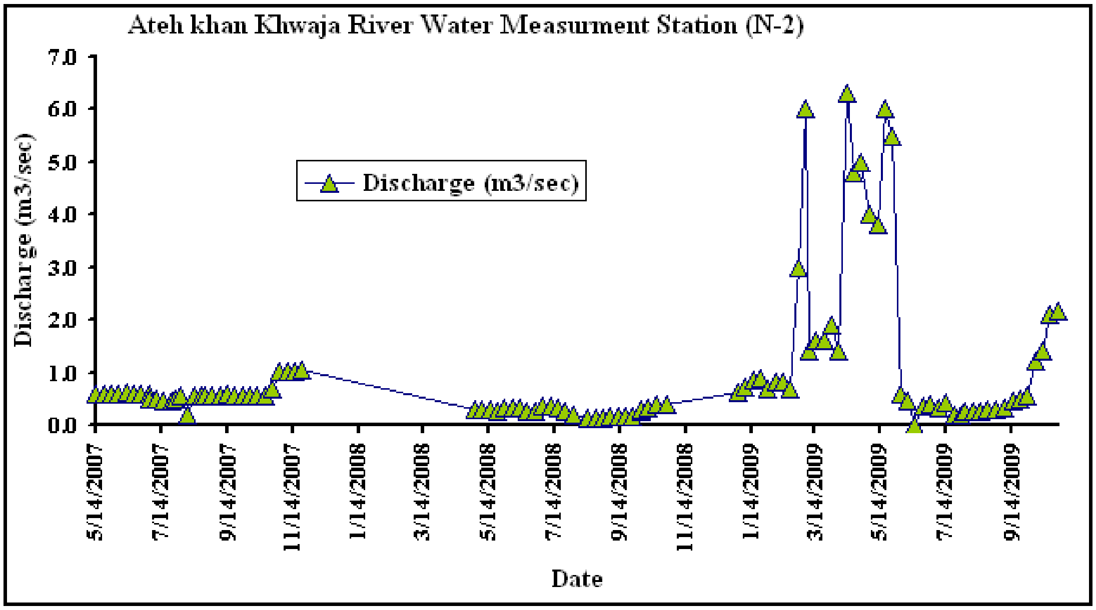

Fig. 10, Ateh Khan Khvajeh River (Maymana River) measurement station (DACAAR/WSP, 2007-2009)

2.4, Geologic setting

The study area is related to the north Afghan platform. The north Afghan platform has a pre-Jurassic basement unconformable overlain by a Jurassic to Paleogene oil and gas bearing sedimentary rock platform cover, unconformable overlain by Neogene and post-orogenic continental clastics.

The pre-Jurassic basement has four units : 1) An Ordovician to lower Devonian passive margin succession developed on oceanic crust; 2) An upper Devonian to Lower Carboniferous magmatic arc succession developed on the passive margin; 3) A Lower Carboniferous to Permian rift-passive margin succession; 4) A Triassic continental magmatic arc succession.

The Mesozoic-Paleogene cover has three units: 1) A Late Triassic to Middle Jurassic rift-succession is dominated by variable continental clastics. Thick coarse, lenti color coal-bearing clastics were deposited by braided and meandering streams in linear grabens, while bauxites formed on the adjacent horsts; 2) A Middle to Upper Jurassic transgress-regressive succession consists of mixed continental and marine clastics and carbonates overlain by regressive evaporative-bearing clastics; 3) A Cretaceous succession consists of Lower Cretaceous red beds with evaporative, resting unconformable on Jurassic and older deposits, overlain unconformable by shallow marine limestone, which form a fairly uniform transgress succession across most of Afghanistan and; 4) A Paleogene succession rests on the upper Cretaceous limestone, with a minor break marked by bauxite in places. Thin Paleocene to Upper Eocene limestone with gypsum is overlain by thin conglomerate, which pass into shale with a limited brackish water Upper Oligocene and Lower Miocene marine fauna.

The Neogene succession consists of a variable thickness of coarse continental sediments derived from the rising Pamir Mountain and adjacent ranges.

The typical Jurassic-Recent section in the four tectonic units of the North Afghanistan platform shows that the lower Cretaceous to Oligocene stage is more complex. Lower Cretaceous red beds with evaporates rest unconformable on Jurassic and older deposits. These Lower Cretaceous red beds are coarser in the south and pass northwards into finer-grained elastics. They are overlain by upper Cretaceous shallow marine limestone, which forms a fairly uniform transgress succession across most of Afghanistan. This limestone cuts across the Paleozoic-Triassic metamorphic core of the Hindu Kush. Overlying the Upper Cretaceous places are thin Paleocene to upper Eocene limestone with gypsum. An overlying thin conglomerate passes up into shale with restricted brackish water. Upper Oligocene-Lower Miocene marine fauna of foraminifera and gastropods (Fig. 11)

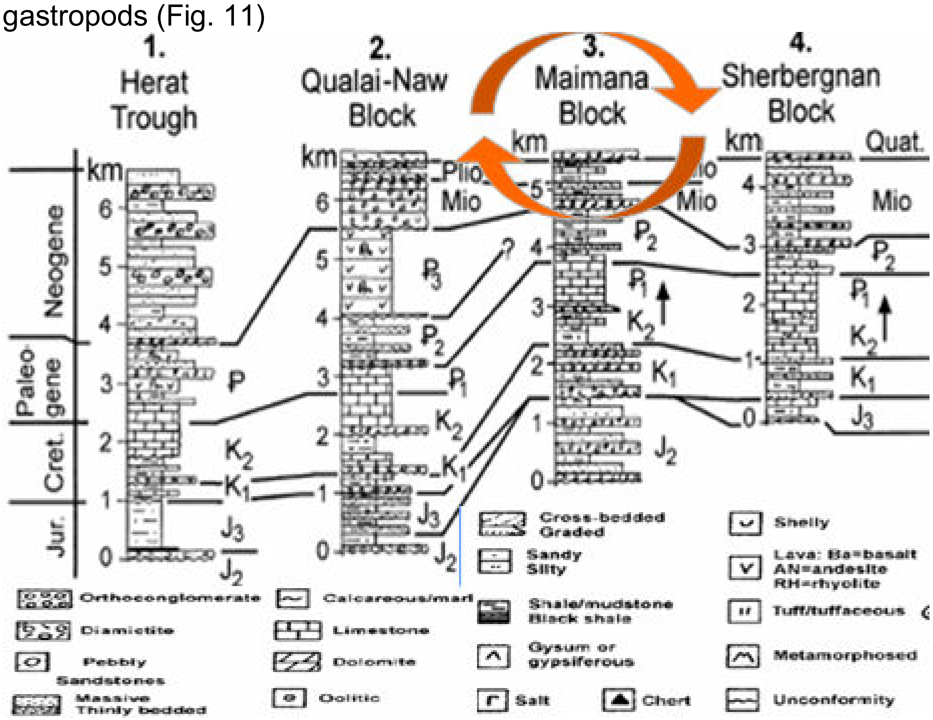

Fig. 11, Jurassic-Recent section in north Afghan Platform (Benda 1964, Bratash 1970)

North Afghanistan from a tectonic development point of view is characterized by A-Herat trough, B-Qualai Naw block, C-Maymana block, D-Sheberghan, Tb-Tajic basin, Murghab basin, Karakuram spur tectonic unit and feature and Siabubak, Bande Turkestan, Andrab, Mirzawolang, Alburz-Marmul, south Gissar and Darwaz Faults(Fig.12)

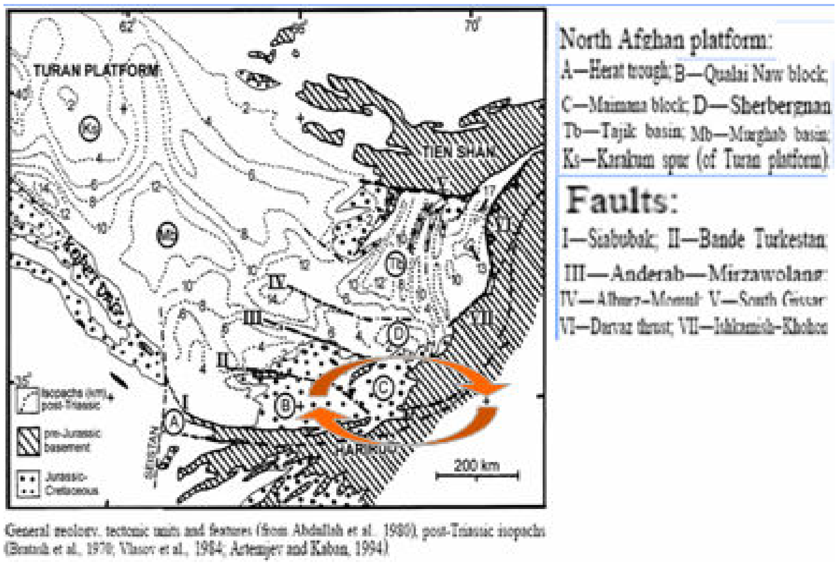

Fig. 12, North Afghan platform and fault system.

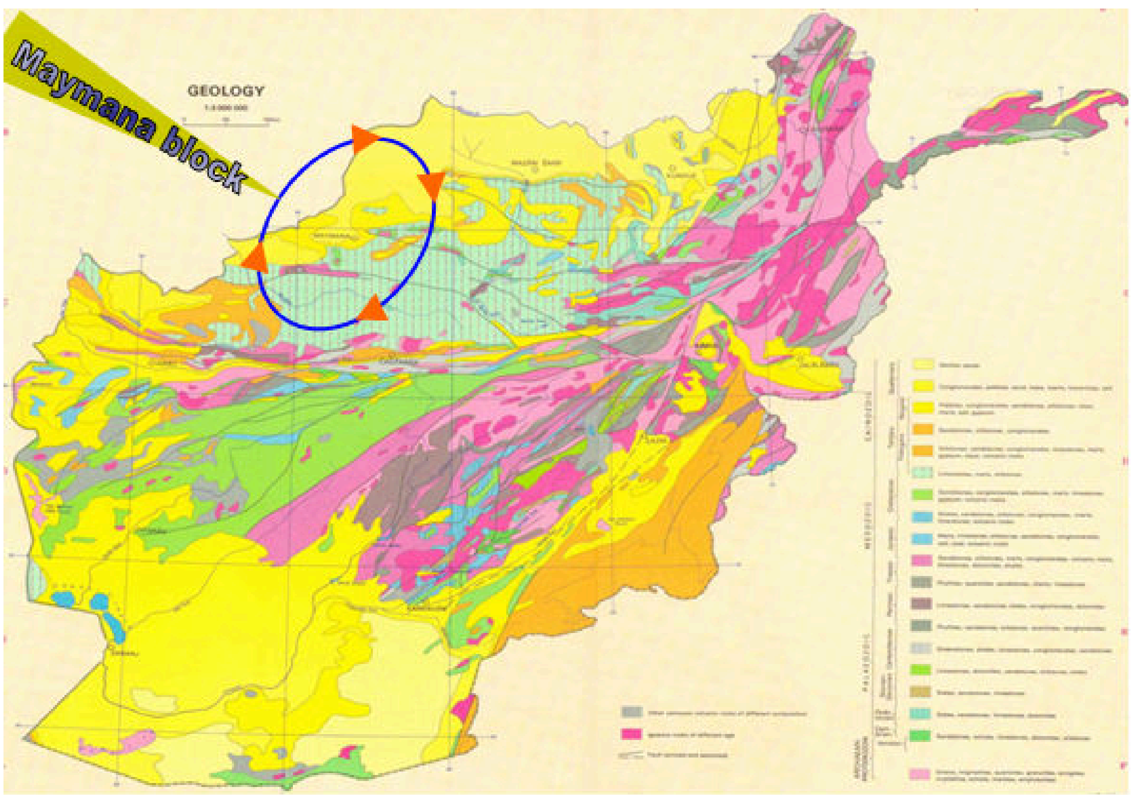

Fig. 13, Geology of Afghanistan

2.5. Hydrogeologic setting

Faryab's natural groundwater systems are characterized by three hydrogeologic units: 1) Cretaceous-Paleogene (Cr-Pg) fracture- Karst Water; 2) Neogene aquifers and aquitards system; and 3) Quaternary sediments.

Cretaceous-Paleogene (Cr-Pg) fracture - Karst Water consists of karst development fractures, channel and cavities of various thickness and hydraulic properties. Groundwater flow is controlled by the characteristics of the aquifer and discharges as springs on the surface at the foothills of mountains (at the slopes of low elevations). The discharge of the springs varies and range between 1.75 l/s (Moghito (2) spring) and 35 l/s (Char Tut (1) spring). The Electro conductivity of water also varies and ranges between 1,066 µS/cm (Char Tut (1) spring) and 3,400 µS/cm (Moghito (2) spring)

Springs with different discharges emerging from various Karst development aquifers seem to be the best sources for water supply and irrigation. These sources therefore are to be given the highest priority in water supply planning in Faryab province where the shallow and deep groundwater is highly mineralized.

The Cretaceous-Paleogen (Cr-Pg) fracture- Karst water formation overlie the Neogene (Pliocene and Miocene) aquifers and aquitards system which is characterized by successively bedded layers of sandstones, siltstone, conglomerate and clay with intercalation of gypsum and salt sediments. The gypsum and halite minerals have thin layers originating from extension of the evaporative basin during a long residence time.

The Quaternary aquifers are composed of alluvial medium and course sediments (gravel, pebbles, cobbles and boulders) of various thickness and hydraulic properties. The Quaternary deposits located more upstream mainly have fresh groundwater; while the Quaternary deposits located more downstream mainly have saline and brackish groundwater. These settlements have experienced severe safe drinking water shortages for many years.

2.6. Water quality assessment

The physical and chemical analysis of 240 water samples from drinking water points (groundwater monitoring wells network, springs and rivers) indicated that the salinity of water increased from the upstream to the downstream area of Faryab province. The brackish/saline Shor Darya River and Astana stream (Fig. 6) have caused significant socio-economic and environmental problems to the downstream (Dawlat Abad, Qaramqol, Qurghan, Andkhoy and Khan-e Chahar Bagh districts) water users.

Fig. 14, Astana brackish/saline stream feature

The Shor Darya River and Astana stream have mainly discharged from brackish/saline groundwater and have caused problems in the Astana and Jalaier valley and for downstream users.

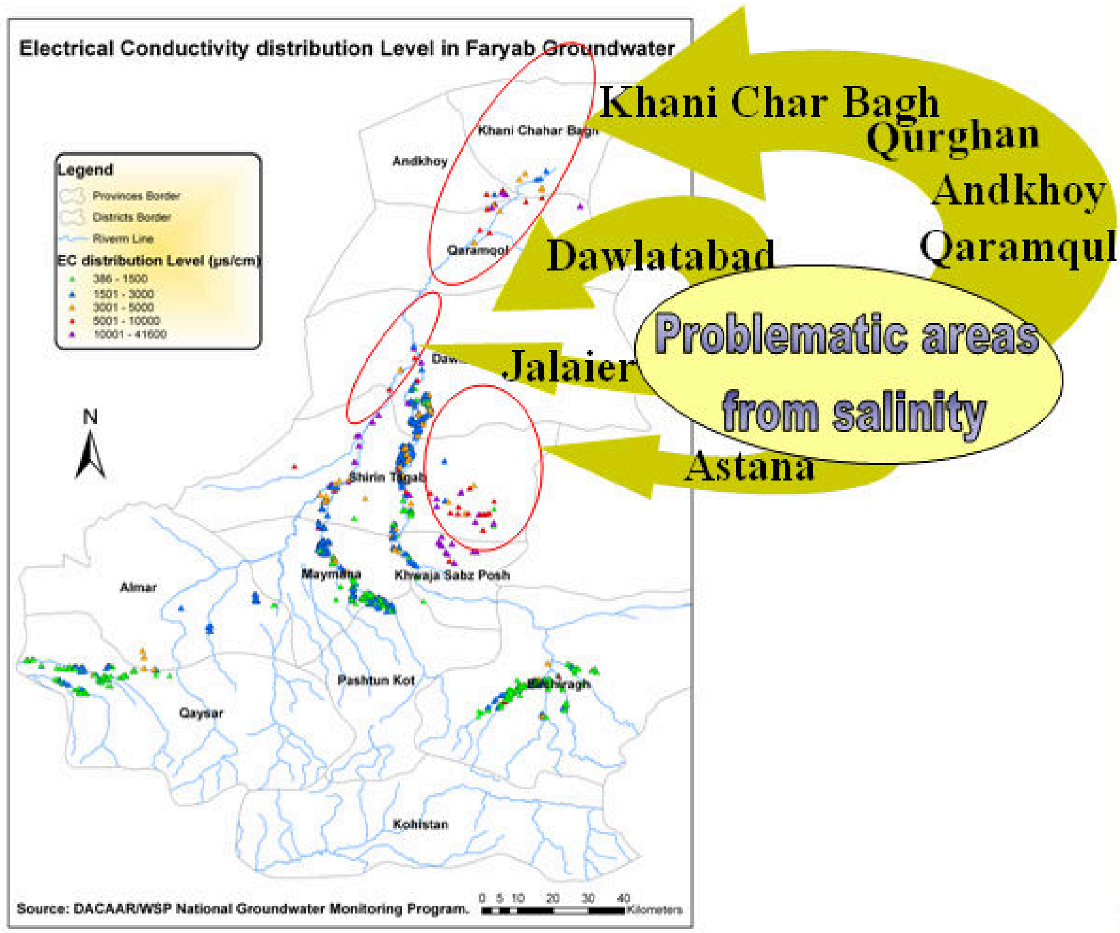

Fig. 15, Areas of salinity problem due to brackish/saline Shor Darya River and Astana stream

Plot of major ions on a piper diagram (Fig. 15) show four water types; gypsum dissolution, halite dissolution, carbonate dissolution and mixing.

The water samples from upstream (Qaysar, Gurziwan, Pashtun Kot) are clustered near the left corner of the tri linear diagram and indicate that the water is rich in Ca, Mg, and HCO_3. This water comes from dissolution of carbonate minerals. There are no salinity problems and the water is mostly suitable for irrigation and water supply

The water samples from downstream of Shirin Tagab Watershed (Shirin Tagab, Qurghan, Qarmqol, Andkhoy, Khan Chahar Bagh and Dawlat Abad districts) are clustered near the right and top corner of the tri linear diagram and indicate that the water is rich in Ca, Mg, Na, SO_4 and Cl. These water types originated due to dissolution of gypsum, anhydrite and halite minerals during their long residence time. There are identified gypsum and halite mines in Andkhoy, Dawlat Abad and Shirin Tagab districts).

Fig. 16, Gypsum occurrence in Astana valley, Shirin Tagab district of Faryab province

There are salinity problems and the water is mostly not suitable for irrigation and water supply.

The water samples from left and right bank of Maymana and Shirin Tagab rivers are clustered in the middle of the tri linear diagram which indicates mixing ions water type

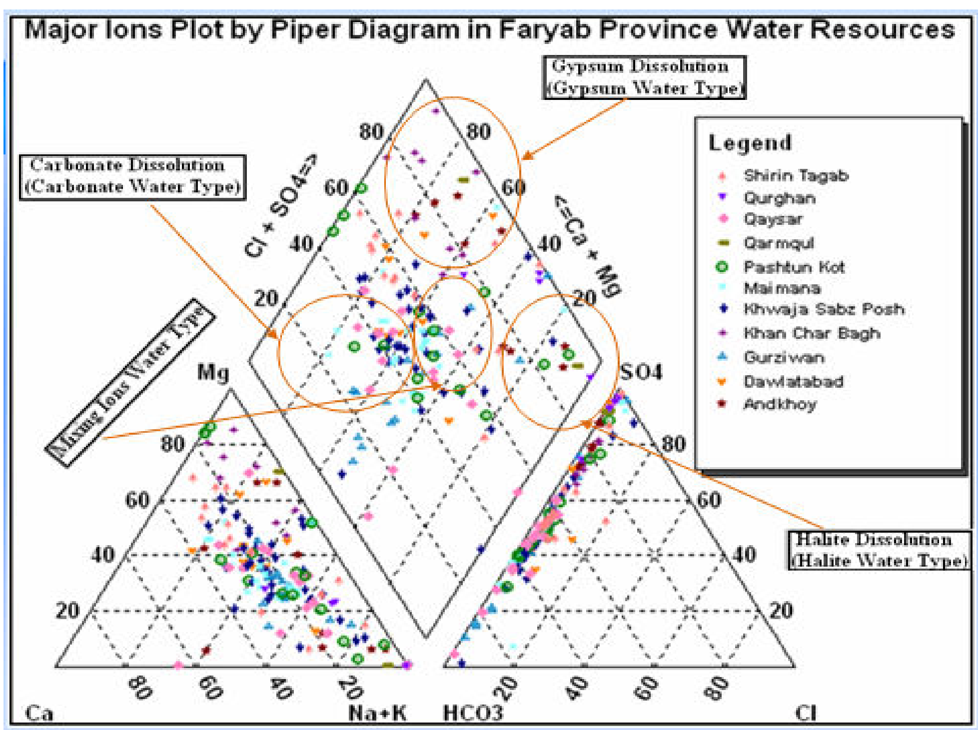

Fig. 17, Assessment of water quality (major ions) by Piper diagram

The chemical analysis of water samples from different water points (240 water samples) indicated the fluoride concentration level progressively increases from upstream to downstream. Most of the water samples from Astana and Jalaier valleys drinking water points indicated that the fluoride concentrations in ground water and surface water are higher than the limit of 1.5 mg/l.

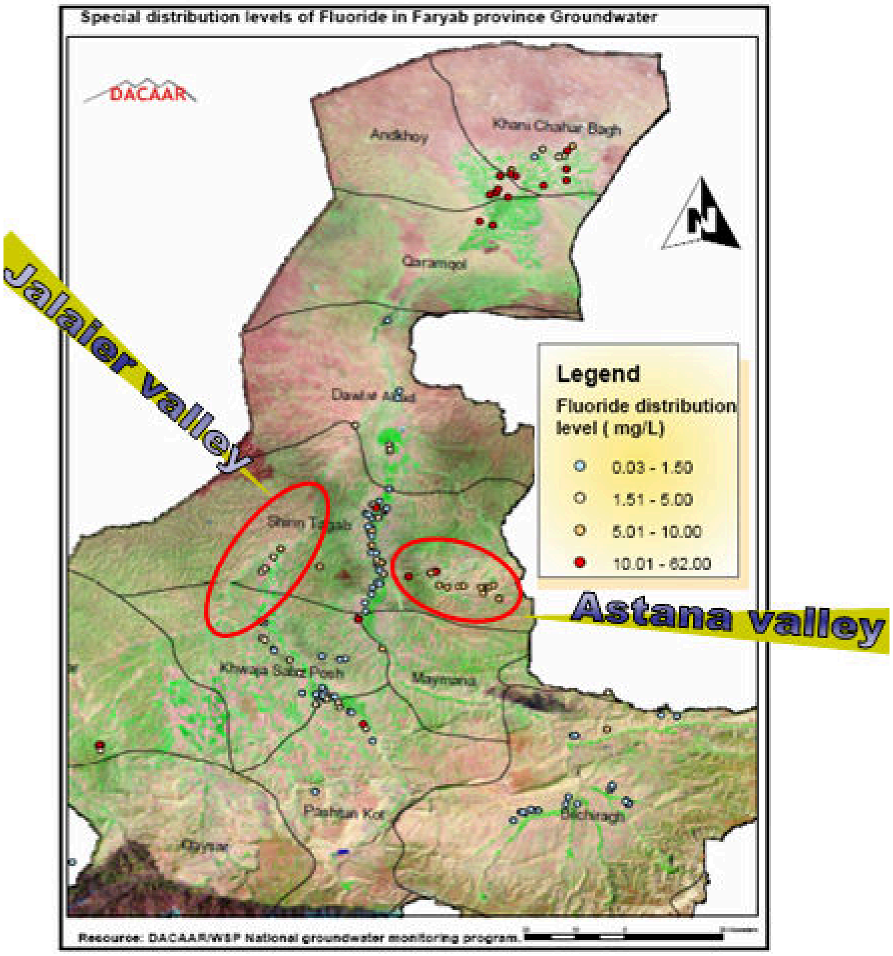

Fig. 18, Fluoride distribution levels in Faryab province

The chemical analysis of water samples from different water points (240 water samples) indicated that the distribution of sulphate concentration level increases from upstream to the downstream of Shiriin Tagab River. Most water samples indicated that the sulfate concentration level is higher than the WHO limit of 250 mg/l.

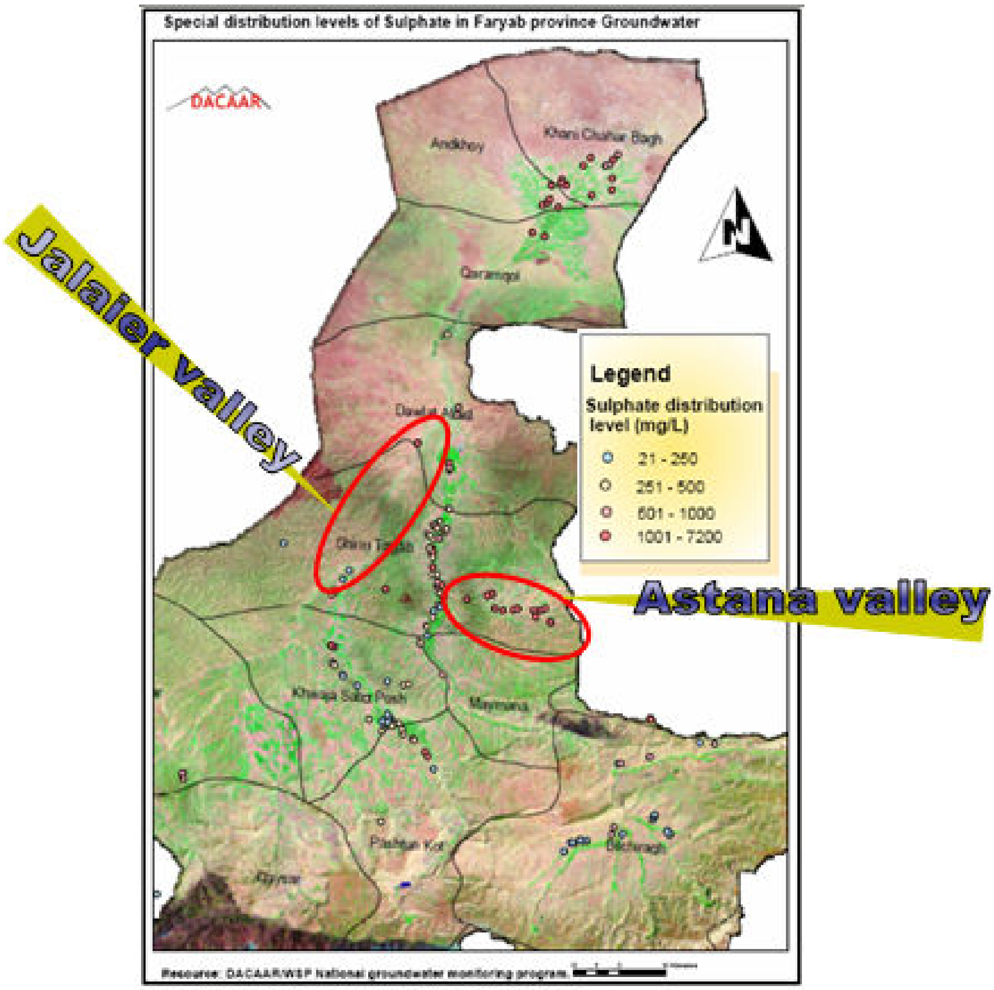

Fig.19, Sulphate distribution levels in Faryab province

4. Integrated groundwater study in Jalaier valley

An integrated groundwater study was conducted in the Jalaier valley including geophysical investigation (vertical electrical sounding), drilling of two exploration wells and physical and chemical analysis of water samples to determine the hydrogeological structure, natural aquifers systems and water quality. The details of this study are as follow:

4.1. Geophysical study

The geophysical study was conducted to identify groundwater level, lithology, interval of fresh and saline water and weathering zones. This study used vertical electrical sounding method with 15 profile stations. Each profile station contained 5 profile lines. The 15 profile stations contained 75 profile lines in total. The profile stations were selected from south to north along the valley.

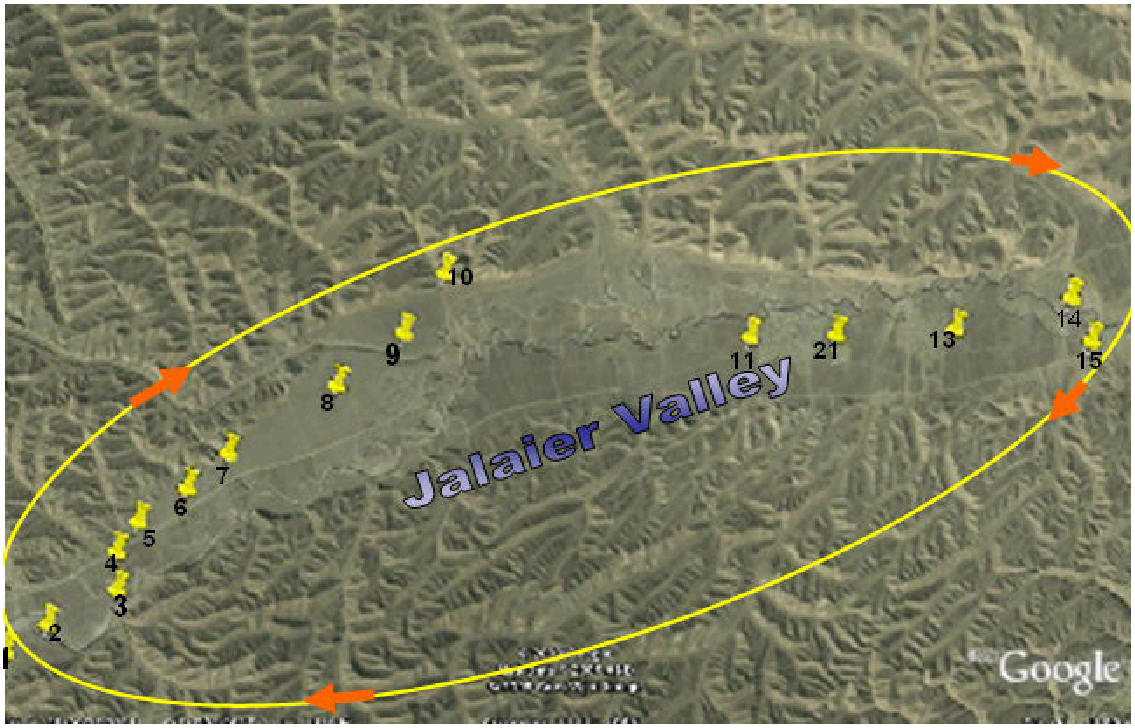

Fig. 20, Location of profile stations in Jalaier valley

The length of current (AB) selected was 300 m and the depth of penetration selected was150 m. The direction of profile stations was selected perpendicular to the Jalaier stream which drains through the valley.

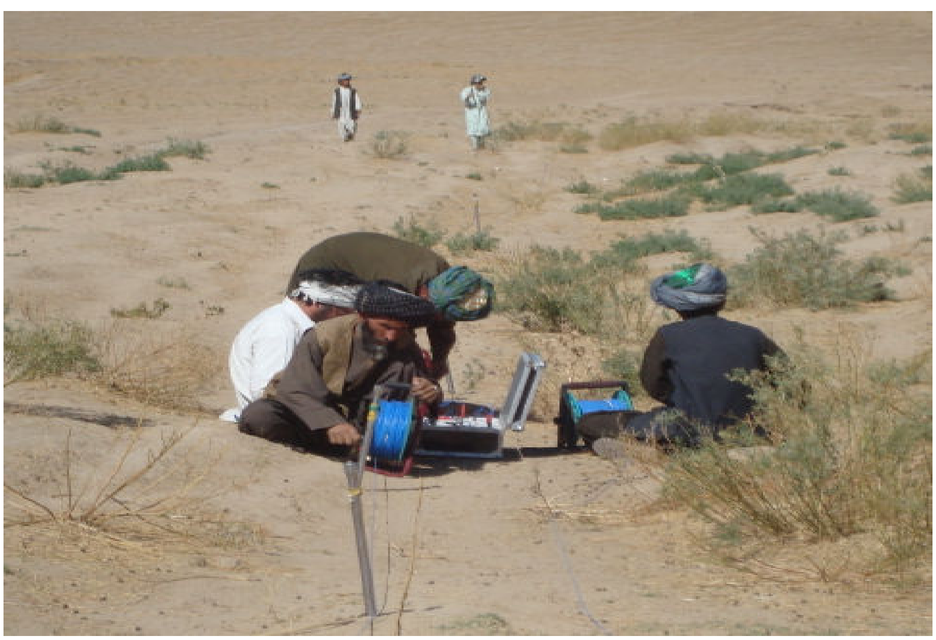

Fig. 21, Using VES for obtaining field data

In this method the applied Schlumberger arrangement was used. Current was transmitted into the ground from DC or low frequency sources by two electrodes (A and B) and the potential difference between a second pair of electrodes (M and N) was measured.

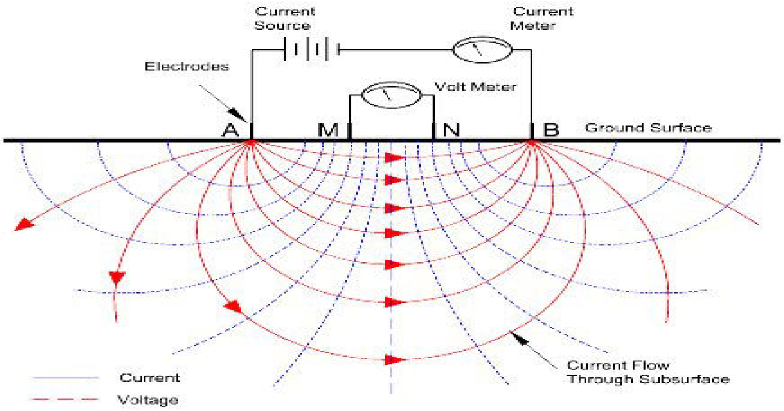

Fig. 22, Vertical electrical sounding method

Apparent resistivity value is calculated:

Pa = K V / I

Where:

Pa is the apparent resistivity
K is the geometric factor,

V is a voltage or potential difference between a second pair of electrodes in volts
I is the current from DC or low frequency sources by two electrodes in ampere
In this method the Schlumberger arrangement is used.

K = πn (n + 1) a

The field data interrelated according to the following resistivity scale for water and rocks.

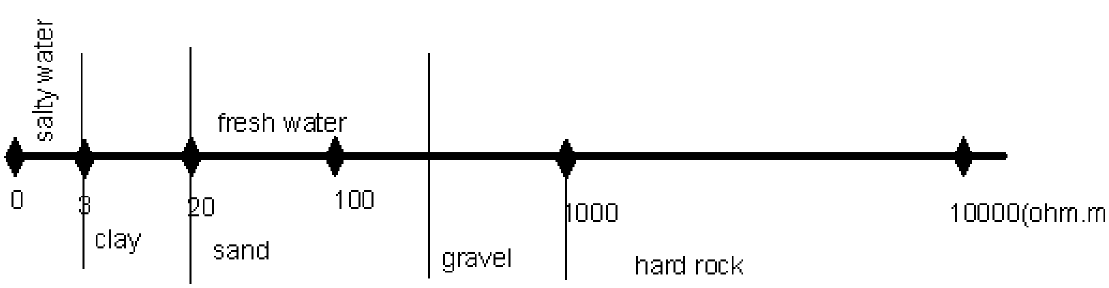

Fig. 23, Resistivity scale for water and rocks

The geophysical field study in Jalaier valley was conducted between 7-12 September 2009.

The result of this study indicated that the upper and lower parts of the aquifer are highly mineralized and the water is brackish or saline. This is summarized graphically in Figure. 24.

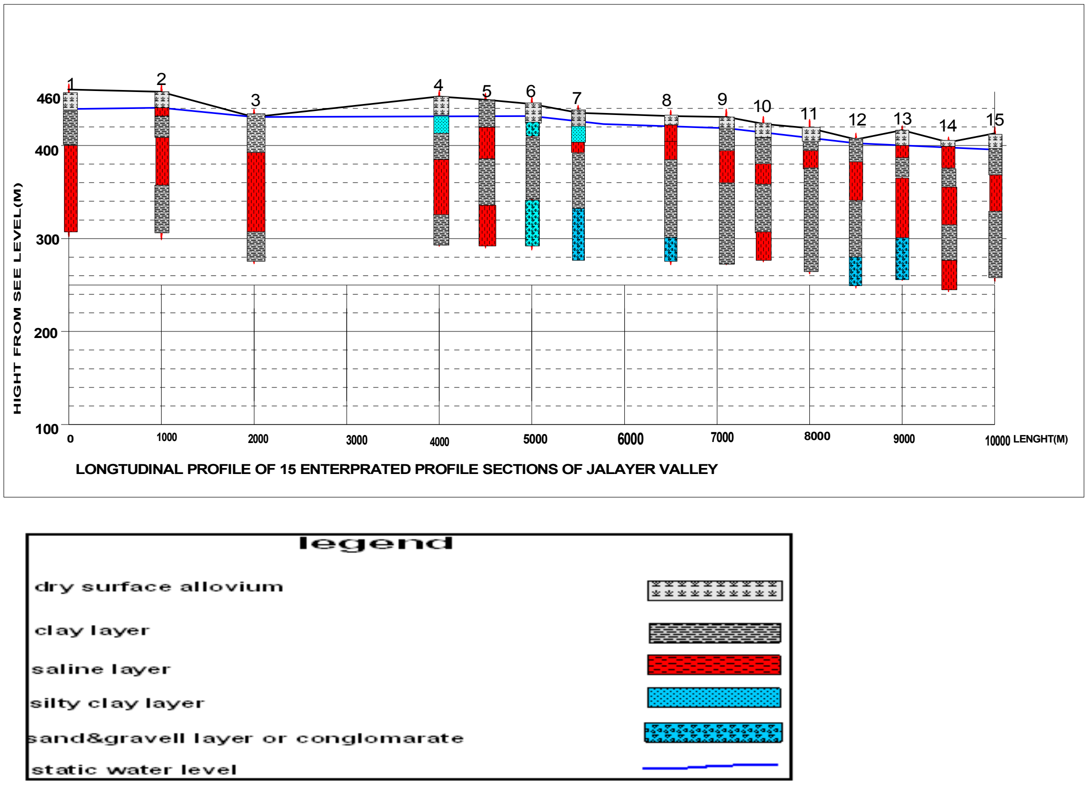

Fig. 24, Jalaier valley profile stations hydrogeologic section according to the VES field data

More information is contained in the geophysical investigation report which is enclosed separately with this report.

4.2. Drilling of pilot or exploration wells

Two pilot or exploration wells were drilled in the Chokazie (middle part of the valley) and Atonchi (upper part of the valley) villages for modification of the geophysical study**.** The drilling of the first well (exploration No-1) started on 27 October 2009 and ended on 24 December 2009. This well was drilled to a depth of 200 m.

Fig. 25, Exploration well No.1 drilling process (Chokozie village, Jalaier valley)

Based on the well logging geophysics, the well lithology is composed of Neogene aquifers and aquitards systems which mainly consist of clay, sand clay, sand and some conglomerate. The aquifer system is saturated with brackish or saline water. The results of this well modified the geophysical study which was carried out through the valley.

The EC values vary with depth, with high EC values indicating less permeability. The results of this well modified the geophysical study which was carried out through the valley. The electrical conductivity (salinity) increased from the upper part (8,920 µs/cm) to the lower part of the well (10,400 µs/cm).

The physical and chemical analysis of the water sample from the upper part of exploration well No-1 indicated that the sulphate (2,040 mg/l), fluoride (4.3 mg/l), bromide (0.46 mg/l) and sodium (1,428 mg/l) concentration levels are higher than WHO drinking water guidelines, which for sulphate, fluoride, bromide and sodium concentrations in drinking water are respectively 250 mg/l, 1.5 mg/l, 0.01 mg/l and 200 mg/l (WHO, 2004). The water type is sodium-sulphate ($Na\text{-}SO_4$). The water originated from dissolution of gypsums and halite minerals.

The physical and chemical analysis of the water sample from the lower part of exploration well No-1 indicated that the sulfate (3,400 mg/l), fluoride (6.4 mg/l), bromide (0.49 mg/l) and sodium (1,988 mg/l) concentrations levels are higher than WHO drinking water guidelines. The water type is sodium-sulphate ($Na\text{-}SO_4$). The water originated from dissolution of gypsums and halite minerals.

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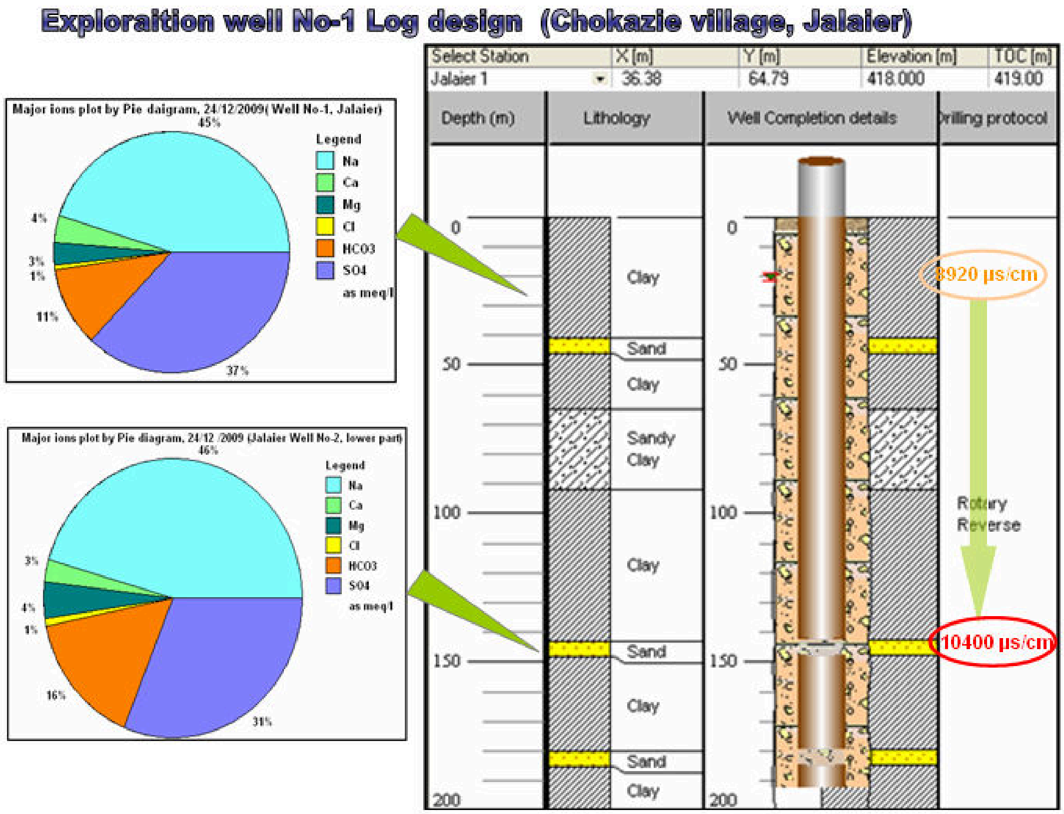

Fig. 26, Exploration well No-I (Chokazie village) design and Major ions plot

The pumping test result indicated that the discharge of the well was 4 l/s for 7.8 m drawdown during 8 hours. The salinity of water also increased with falling of water level. The pumping test data is shown in Table 3.

Table 3, Pumping test data of exploration of well No 1 (Chokazie village) conducted on 4th December 2009

Time (min)	WL (m)	EC (µS/cm)	Q (l/s)
0	23	9,830	4
120	23.9		
180	24.8		
240	25.7		
300	26.8		
600	27.1		
900	27.3	9,800	
1,200	27.44		
1,500	27.9		
3,000	28.3		
4,500	29.05		

6,000	29.45	10,600	
7,200	29.9		
8,700	30.35		
9,900	30.9		
11,700	31.8		
13,500	32.2		
17,100	33.8		
20,700	34	10,400	
24,300	34.1		
27,900	34.1		
31,500	34.1		

The physical and chemical analysis of water samples from exploration well No. 1 is shown in Table 4.

Using drinking water of high sulphate content (more than 600 mg/l) can cause severe diarrhea and loss of body fluid of users, and gives a bitter taste. The water is toxic for health (Quality of Domestic Water Supplies, Volume 1, Assessment Guide, Ministry of Urban Development, Afghanistan). Using drinking water of high sodium content (more than 200 mg/l) can cause severe diarrhea and loss of body fluid of users. Using drinking water of high fluoride content (more than 1.5 mg/l) can cause skeletal fluorosis and dental fluorosis.

Table 4, Physical and chemical analysis of water samples from exploration wells in Jalaier valley

	Exploration Well No 1		Exploration Well No 2	
Description	Lower part	Upper Part	Lower part	Upper Part
LAT.	36.37659	36.37610	36.24967	
LON.	64.78998	64.78998	64.74518	
Province	Faryab	Faryab	Faryab	
District	Shirin Tagab	Shirin Tagab	Shirin Tagab	
Village	Jalair Chokozi	Jalair Chokozi	Jalair Atomchi	
Sampled Date	24/12/2009	24/12/2009	01/02/2010	
Analyzed Date	28/12/2009	28/12/2009	07/02/2010	
Temperature	18	11.4	17.18	
EC (µS/cm)	1,0400	8,962	7,880	
pH	7.6	8.33	7.9	
Potassium (mg/l)	28	29	27.50	
Sodium(mg/l)	1988	1428	1030	
Calcium(mg/l)	140	70.8	554	
Magnesium(mg/l)	70	70	70	
Total iron(mg/l)	0.22	0.19	0.01	
Aluminum(mg/l)	0	0.01	0	
Arsenic (mg/l)	0	0	0	
Ammonium as NH_4(mg/l)	0.6	0.4	0.36	
Chromium (mg/l)	0.02	0.06	0.11	
Manganese (mg/l)	0.03	0.001	0.006	

Copper (mg/l)	0.2	0.2	0.06	
Bromide (mg/l)	0.49	0.46	0.1	
Boron (mg/l)				
Chloride (mg/l)	44	42	44	
Phosphate (mg/l)	0.5520	0.23	0.09	
Fluoride (mg/l)	6.4	4.3	5.15	
Sulphate as SO_4	3,400	2,040	1,000	
Carbonate as CO_3	200	200	90	
Bicarbonate (mg/l)	1,250	1,300	175	
Nitrate as NO_3(mg/l)	6.7	12.4	20	
Faecal Coliforms	7	10		
Nitrite as NO_2(mg/l)	0.19	0.43	0.785	
Total Coliforms				
Sulphite (mg/l)	11	4	2	
Silica as SiO_2 (mg/l)	0.62	0.43	0.46	

The drilling of the second well (exploration well No-2) started on 28th December 2009 and ended on 1st February 2010. This well was drilled to a depth of 200 m.

Fig. 27. Exploration well No.2 drilling process (Atonchi vpllag, Jalaier valley)

Based on the well logging Geophysics, the well log was composed of Neogene aquifer and aquitard systems which mainly consist of clay, clay sand and sand, saturated with brackish or saline water. The results of this well modified the geophysical study which was carried out through the valley. The electrical conductivity (salinity) of water is 7,880 µs/cm. The upper and lower part of the aquifer is highly mineralized. The aquifers' systems have seepage water. The discharge of water is very low.

The physical and chemical analysis of the water sample from exploration well No-2 indicated that the sulphate (1,000 mg/l), fluoride (5.15 mg/l), bromide (0.1 mg/l) and sodium (1,040 mg/l) concentration levels are higher than WHO drinking water guidelines. The water type is sodium-sulfate (Na-SO_4). The water originated from dissolution of gypsums and halite minerals.

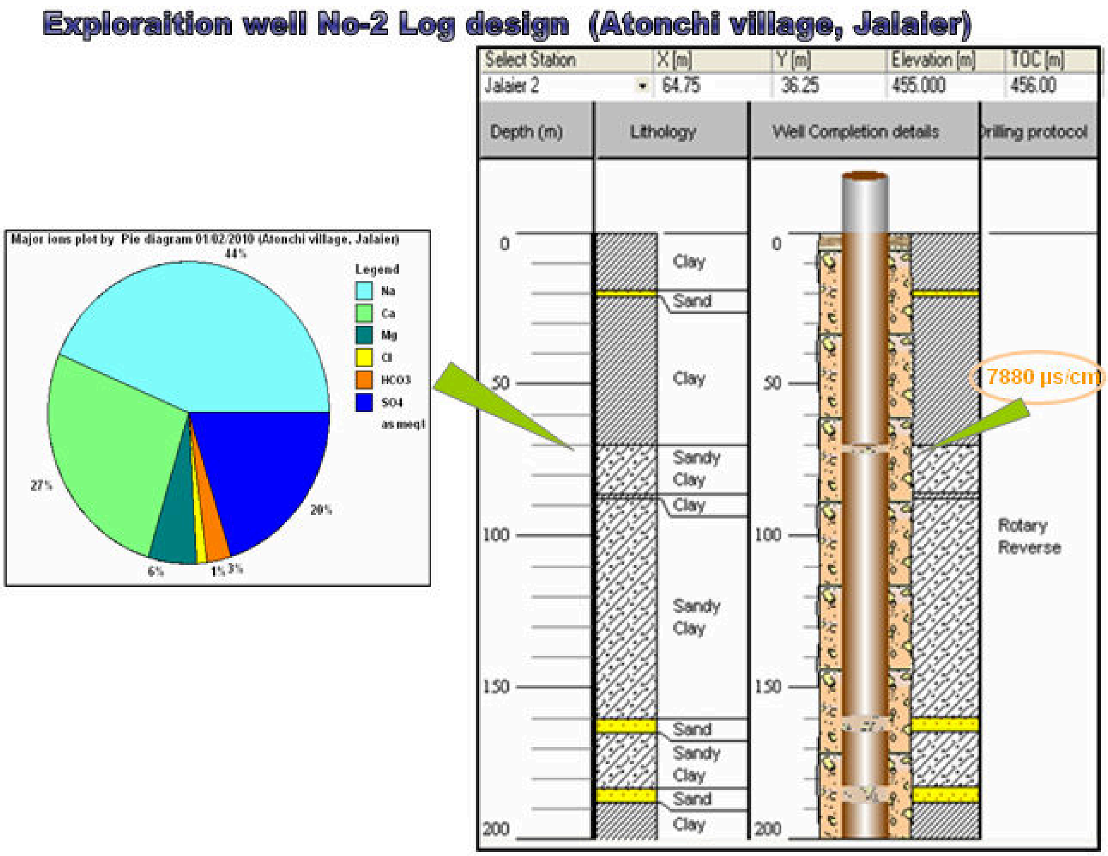

Fig. 28, Exploration well No-2 (Atonchi village) design and Major ions plot

The physical and chemical analysis of water samples from exploration well No. 2 is shown in table 4.

The pumping test result indicated that the discharge of well was 0.75 l/s for 129.1 m drawdown during 6 hours. The salinity of water also increased from 7,550 to 7,980 µS/cm with increasing depth. The pumping test data is shown in Table 5.

Table 5, Pumping test data of exploration of well No 2 (Atonchi village) conducted on 1st February 2010

Time(s)	WL (m)	EC (µS/cm)	Q (l/s)
0	16.7	7,550	0.75
60	25		
120	29		
180	42		

1,260	52		
1,320	58	7,750	
1,920	71		
2,220	78		
2,520	82	7,880	
2,820	87		
6,420	89		
10,020	91		
13,620	94		
17,220	97		
20,820	98	7,890	
21,600	145.8		

5. Assessment of source water quality and drinking water collection problem

In Jalaier valley, most of the inhabitants are in a worse position as far as the provision of safe drinking water is concerned. The inhabitants of Jalaier valley utilize drinking water either from Shor Darya River (brackish/saline water) which drains through the Jalaier valley or from Ateh Khan Khwaja spring and Shirin Tagab River, transporting the water using camels and donkeys.

5.1. Shor Darya River

Maimana River merges with Qaysar River at Ateh Khan Khvajeh (3) village and then is called the Shor Darya River (Fig. 5). The Shor Darya River is perennial and mainly discharges from brackish/saline groundwater. The salinity of the river is reduced during the flooding season but the water is muddy and polluted. The salinity of the river increases during the dry season (10 months of the year). In general, the river has brackish and saline water and it is not usable for drinking, domestic and sanitary purposes. It is also a source of different diseases and is the biggest problem in the area threatening the health of the people. The salinity (EC) of the river water progressively increases from upstream to downstream of the valley. The salinity of water in the upstream area (Ateh Khan Khvajeh (3) village) was 6,000 µS/cm, and in the downstream area (Chokazai village) was 8,730 µS/cm.

The chemical analysis of water samples from the upper part of Shor Darya River (upstream) indicated that the sulphate (1,200 mg/l), fluoride (8.7 mg/l), bromide (0.04 mg/l) and sodium (891 mg/l) concentration levels are higher than WHO drinking water guidelines.

The chemical analysis of water samples from the lower part of Shor Darya River (downstream) indicated that the sulphate (1,650 mg/l), fluoride (9.27 mg/l), bromide (2.4 mg/l) and sodium (901 mg/l) concentration levels are higher than WHO drinking water guidelines.
In general, the water of this river is not usable for water supply and irrigation due to high coliform bacteria, salinity, boron, bromide, sulphate and fluoride concentrations. It has

caused socio- economic and environmental problems to the down stream users in Dawlat Abad, Qaramqol, Qurgha, Andkhoy and Khani Char Bagh districts.

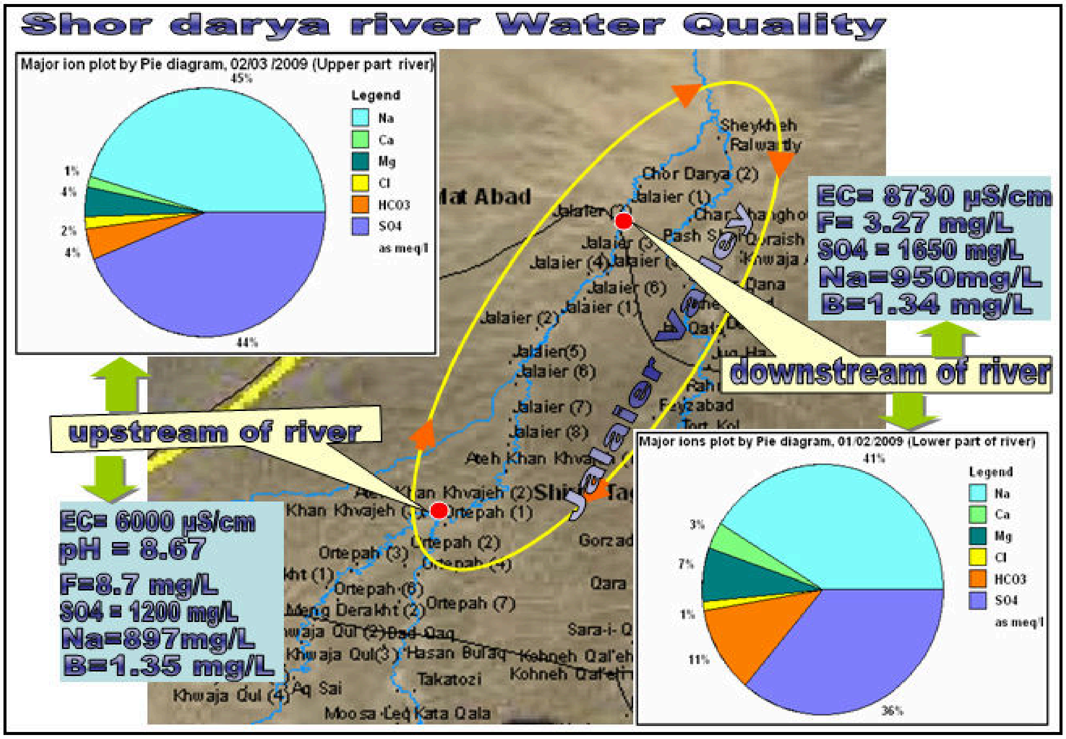

Fig. 29, Shor Darya river location and water quality

The physical and chemical analysis of water sample from the upper and lower parts of the Shor Darya River and Ateh Khan Khwaja spring are shown in Table 6.

Table 6, Physical and chemical analysis of water samples from Shor Darya River and Ateh Khan Khwaja spring in Jalaier valley

Station Name	Atehkhan khavajeh (3) spring	Shor Darya upstream	Shor Darya downstream
X coordinate	36.19557	36.21174	36.45726
Y coordinate	64.68611	64.69937	64.83451
Province	Faryab	Faryab	Faryab
District	Pashtun Kot	Pashtun Kot	Shirn Tagab
Village	Ateh Khan Khwaja (2)	Ateh Khan Khwaja (1)	Chokazi (Jalair)
Sampling Date	11/05/07	14/05/07	01/02/09
Analysis Date	11/05/07	14/05/07	01/02/09
Temperature	21	25.7	22.3
EC (µS/cm)	2,660	6,000	8,730
pH	8.2	8.67	8.36
Potassium (mg/l)	7.7	18	29

Sodium (mg/l)	273	891	901
Calcium (mg/l)	72.8	24	66.4
Magnesium (mg/l)	60	40	80
Total iron (mg/l)	0.02	0	0.01
Aluminum (mg/l)	0	0	0
Arsenic (mg/l)	0.008	0	0
Ammonium as NH_4	0.82	0.4	0.5
Chromium (mg/l)	0.01		
Manganese (mg/l)	0.004	0.001	0.003
Copper (mg/l)	0.06	0	0.06
Bromide (mg/l)	0.09	0.04	2.24
Boron (mg/l)	0.8	1.35	
Chloride (mg/l)	40	48	40
Phosphate (mg/l)	0.2	0.02	0
Fluoride (mg/l)	1.2	8.7	9.27
Sulphate as SO_4	280	1,200	1,650
Carbonate as CO_3	30	20	100
Bicarbonate (mg/l)	330	210	650
Nitrate as NO_3(mg/l)	2.42	1.68	5
Faecal Coliforms			15
Nitrite as NO_2(mg/l)	0.011	0.023	0.22
Total Coliforms			
Sulfite (mg/l)	6	1	5
Silica as SiO_2 (mg/l)	0.06	1.5	2.7

5.2. Atehkhan khavajeh (3) spring

Ateh Khan khavajeh (3**)** spring is situated in the right bank of Shor Darya River where the Maymana River merges with Qaysar River. This spring emerges from a shear zone. The discharge of the spring is about 25 l/s and fluctuates during the year with a minimum flow of about 15 l/s. The EC of the spring is 2,660 µS/cm.

The physical and chemical analysis of the water sample from this spring indicated that the sulphate (280 mg/l) and sodium (273 mg/l) concentration levels are higher than WHO drinking water guidelines, while those for fluoride (1.2 mg/l) and bromide (0.009 mg/l) are within guidelines.

The chemical analyzed water samples from source points show that the Ateh Khan khavajeh (3**)** spring is relatively best water in the entire Jalaier valley and could be used for both drinking water and irrigation.

The spring water currently joins Shor Darya River (brackish and saline water) without being used for drinking or irrigation purposes. The physical and chemical analysis of water samples from Ateh Khan khavajeh (3) spring is shown in Table 6.

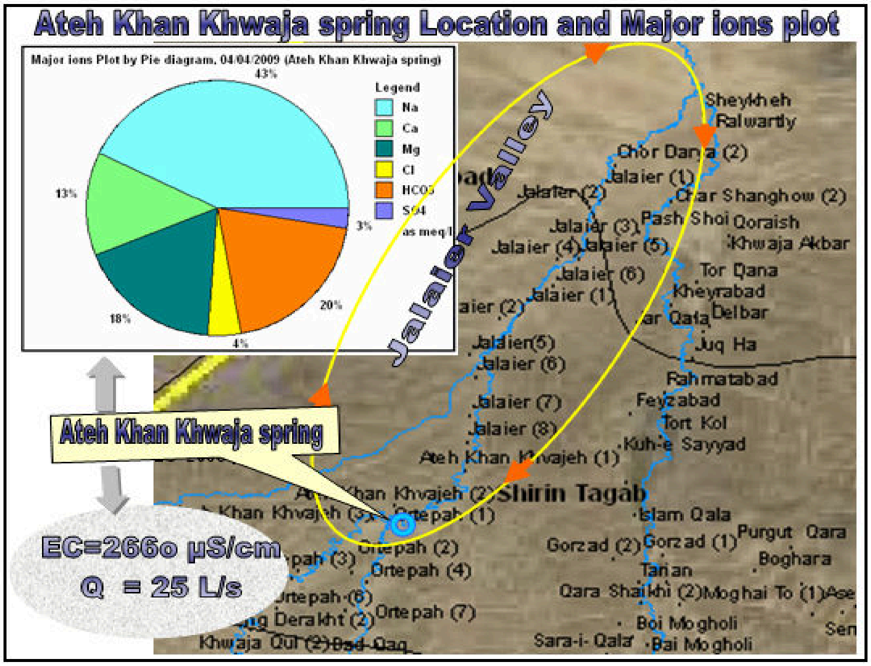

Fig. 30, Ateh Khan Khwaja spring location and major ions plot

5.3. Shirin Tagab River

The Shirin Tagab River is located in the northeastern part of the Jalaier valley. The water of this river is fresh and the EC was measured at 840 µS/cm, but it is a source of different of water borne diseases and threatens the health of people, who spend about 7 hours collecting and transporting water by camel and donkey.

Fig. 31, People spend about 7 hours collecting water from Shirin Tagab River

6. Conclusions

1) A review of historical and recent data shows a change in temperature, precipitation and evaporation over time which has had an adverse effect on groundwater recharge in Faryab province.

2) The surface water is the Shor Darya River, which drains through the Jalaier valley. It is perennial and has brackish/saline water. The chemical analysis of water samples from this river showed that the salinity of the river progressively increases from upstream to downstream of the valley. The salinity of the river reduces during the flooding season but the water is muddy and polluted, however, the salinity increases during the dry season (10 months of the year) due to discharging of groundwater.

3) The chemical analysis of water samples from pilot drilling wells of Jalaier valley shows that the shallow and deep aquifers are highly mineralized due to extension of the evaporative basin and dissolution of halite and gypsum minerals.

4) The people of this valley have been confronted with safe drinking water problems for many years. They spend on average about 7 hours a day to collect their drinking water either from Atehkhan khavajeh (3) spring or Shirin Tagab river (fresh water) using camel and donkeys.

5) Different water related diseases like diarrhoea, dysentery and hepatitis are common in Jalaier valley.

6) The chemical analysis of water samples from shallow and deep aquifers show that it is impossible to obtain potable drinking water from groundwater by drilling of tube wells due to high mineralization of the shallow and deep aquifers.

7) The chemical analysis of water samples from different source points (surface and ground water) shows that the Ateh Khan khavajeh (3) spring is relatively the best water in Jalaier valley. It is possible to construct a pumped piped water supply system on the basis of this spring.

7. Recommendations

7.1. Short term solution

There are three options to provide safe drinking water:

1) Improve and expand rainwater harvesting during the rainy seasons. Rainwater harvesting has been common in the Jalaier valley as well as in Faryab province for many years.

2) Provide drinking water by tanker.

3) Install two Reverse Osmosis Desalinization Plants, one on the first exploration well (Chokazie village) and other in the Atonchi village based on desalination of the river water. Reverse Osmosis Desalinization Plants (RODP) have been installed by Norwegian Church Aid (NCA) in the Qurghan and Qaramqul districts of Faryab province. DACAAR analyzed raw water from these RODPs (dug wells) in which the EC (electrical conductivity or salinity) ranged between 7,450 and 24,400 µS/cm. After treatment, the EC values decreased and ranged between 1,545 and 2,420 µS/cm, hence Reverse Osmosis Desalinization Plants are a suitable method for reducing salinity in water for drinking in Jalaier.

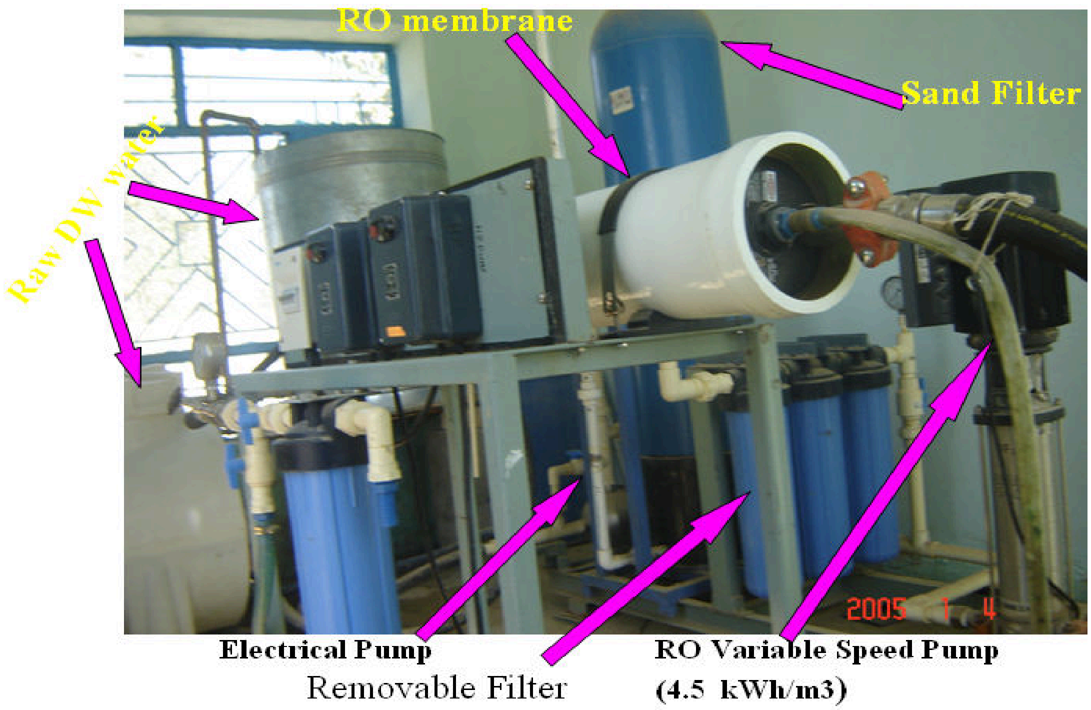

Fig. 32, Reverse Osmosis Desalinization Plants (RODP) in Qurghan district of Faryab province

7.2. Long term solution

7.2.1. Atehkhan khavajeh (3) spring

Atehkhan khavajeh (3) village spring is located in the river bank where the Maymana River merges with the Qaysar River. The spring emerges from a shear zone. The discharge of the spring is 25 l/s and the EC of the water is 2,660 µS/cm. The spring is located in the upper part of the valley on the right bank of the river. The river bank where the spring emerges needs to be protected from erosion and flooding. It is also necessary to construct a covered collection chamber, filtration system for water treatment, pump house and a surface reservoir on the top of the hill on the right bank of the river. The ground elevation of the spring is about 486 m above sea level and the ground elevation at the top of the hill is 610 m above sea level. The differences of elevation between pump house and reservoir is about 124 m. The water from the spring, after collection and treatment, should be pumped by two diesel centrifugal pumps to the reservoir then distributed by gravity piped water supply system. The main pipe line will be approximately 35 km long from the reservoir through the valley connecting to about 120 stand posts in the villages. A detailed feasibility study, design and cost estimate is required prior to the construction of the above recommended system.

The spring water currently joins Shor Darya River (brackish and saline water) without being used for drinking or irrigation purposes. The construction of a water supply system based on this spring will depend on the Jalaier valley community elders' decision and also on that of the Faryab provincial authorities.

7.2.2, Shirin Tagab Rive water purification and treatment

The Shirin Tagab River is located in the northeastern part of the Jalaier valley. The water of this river is fresh and the EC of the water was 840 µS/cm. A treatment plant could be constructed near to the Dawlat Abad district main bridge on the left river bank, but it will be very expensive. A detailed feasibility study, design and cost estimate is required prior to the construction of the above recommended system.

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- Ahmad Jawid, WSP Hydrogeologist, responsible for recording and managing data for integrated groundwater study.
- Shir Habib, Supervisor for physical and chemical analysis of water samples.
- Bashir Ahmad, Abdul Hadi and Shakar Khan, Laboratory Assistants, responsible for water samples bacteriological, physical and chemical analysis.
- MUMTAZ Construction Group preformed well logging geophysics and carried out geophysical investigation.
- MES Company drilled the pilot wells.

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WHO Water Quality Guidelines - 2004			
Parameter		Upper Limit	Unit
Electrical Conductivity	EC	1500	µS/cm
pH	pH	6.5 - 8	
Total Dissolved Solids	TDS	1000	mg/l
Chloride	Cl^{-}	250	mg/l
Sulphate	$SO_4{}^{2-}$	250	mg/l
Fluoride	F^{-}	1.5	mg/l
Nitrate	NO_3^{-}	50	mg/l
Nitrite *(Nitricol)*	NO_2^{-}	0.2 - 3	mg/l
Boron	BO_2^{-}	0.5	mg/l
Sodium	Na^{+}	200	mg/l
Chromium	Cr^{6+}	0.05	mg/l
Ammonia	NH_4^{+}	1.5 - 35	mg/l
Manganese	Mn^{2+}	0.4	mg/l
Copper	Cu^{2+}	5	mg/l
Iron	Fe^{2+}	0.3	mg/l
Arsenic	As^{3+}	0.01	mg/l
Bromine	Br^{-}	0.1	mg/l
Zinc	Zn^{2+}	5	mg/l
Aluminium	Al^{3+}	0.05 - 0.2	mg/l
Bicarbonate	HCO^{3-}	–	mg/l
Carbonate	CO_3^{2-}	–	mg/l
Phosphate	PO_4^{3-}	–	mg/l
Potassium	K^{+}	–	mg/l
Calcium	Ca^{2+}	–	mg/l
Magnesium	Mg^{2+}	–	mg/l
Silica	SIO_2	–	mg/l