Integrated Groundwater Study in Astana 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/I: 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 settlements of Astana valley are located in the eastern part of the Shirin Tagab district of Faryab province. The people of this valley are involved in rain fed agriculture and animal husbandry. The Astana valley has more than 50 small and large villages and has about 9,600 inhabitants. There are nine secondary schools, eleven primary schools and a basic health centre. The people of this valley have been confronted with safe drinking water problems for many years. Most of the Astana valley inhabitants are very poor and lack development activity. They spend on average 8 hours a day to collect their drinking water either from Moghaito (2) spring or from Shirin Tagab River using camels and donkeys. The Moghaito (2) spring water is the best water in the entire valley but it is not according to the WHO drinking water guideline and it is not a long term solution. Shirin Tagab River water is polluted and a source of water related 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. The surface water 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 27 September to 5 October 2005 DACAAR/WSP carried out a surface water and ground water survey in Shirin Tagab, Khvaja Sabz Posh and Dawlat Abad districts. The results of the survey indicated that the settlements located in the eastern and western parts of Shirin Tagab and Khvajeh Sabz Posh districts (Jalaier and Astana valleys) have a safe drinking water problem. The survey indicated that the surface and shallow ground water is brackish or saline.

During the period 21st January 2009 to 13 November 2009, with financial support of the Royal Norwegian Embassy, 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 for determining the hydrogeolgical structure, natural aquifer systems, water quality as well as finding 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.

2. Objective

The main objectives of this study are;

1) Review physical setting of area (Climate, Geomorphology, Geologic and Hydro geologic 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 groundwater.
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 to identify drinking water related problems.
6) Recommendations for provision of safe drinking water for the 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**

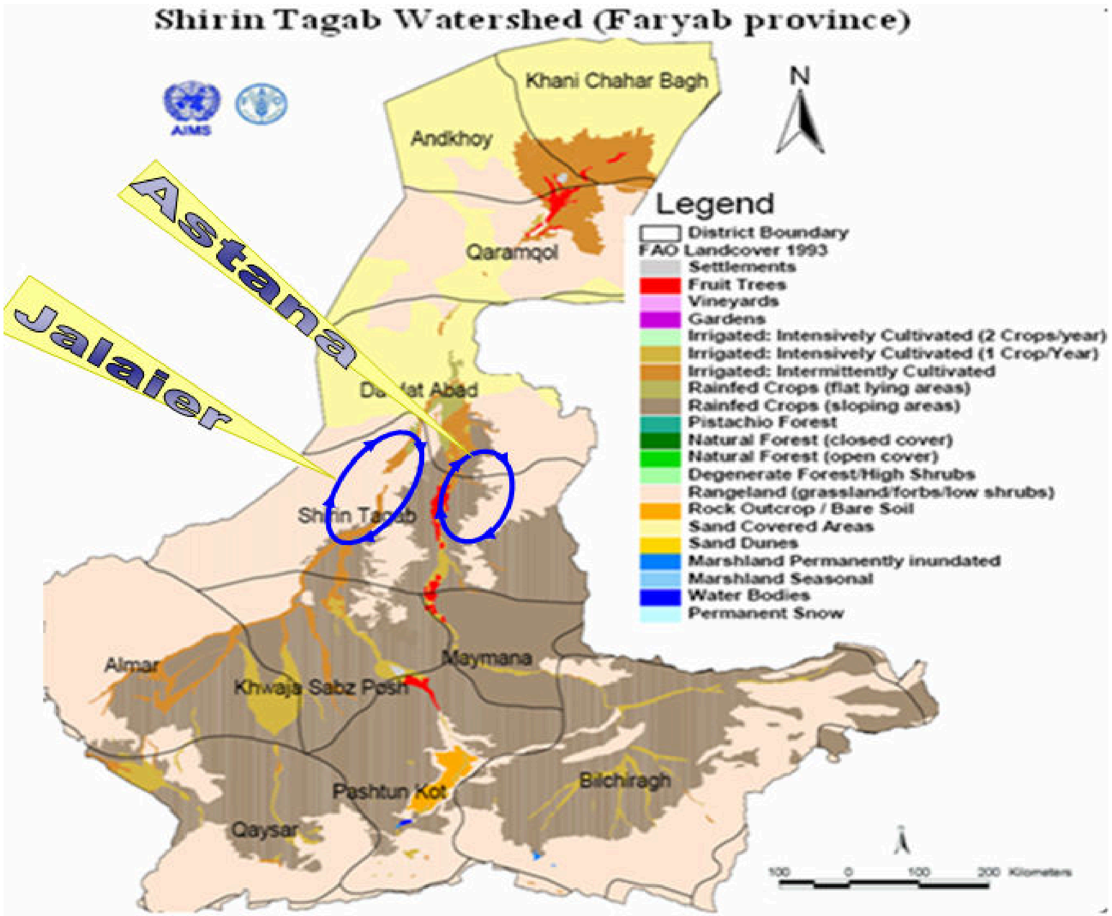


Fig.1, Shirin Tagab watershed land cover classification (FAO, 1990)

2.2. Climate

The climate of Faryab province 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)

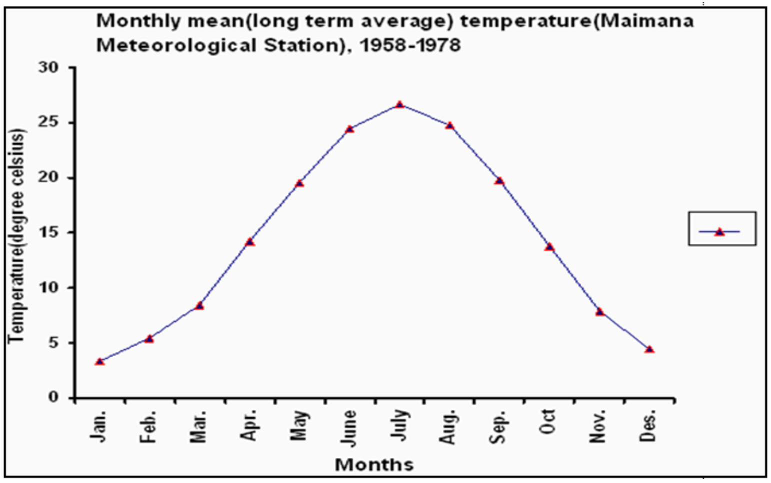


Fig. 2, Monthly mean temperature (Ministry of Water and Power, 1958-1978)

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.

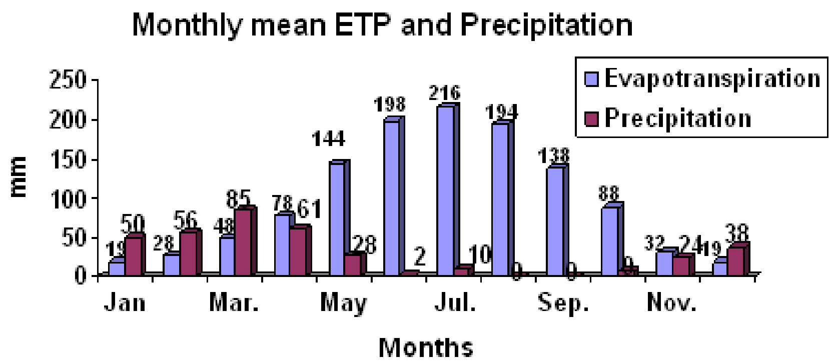


Fig.3, Mean monthly evapo-transpiration (ETP) and precipitation in Maymana Meteorological station

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

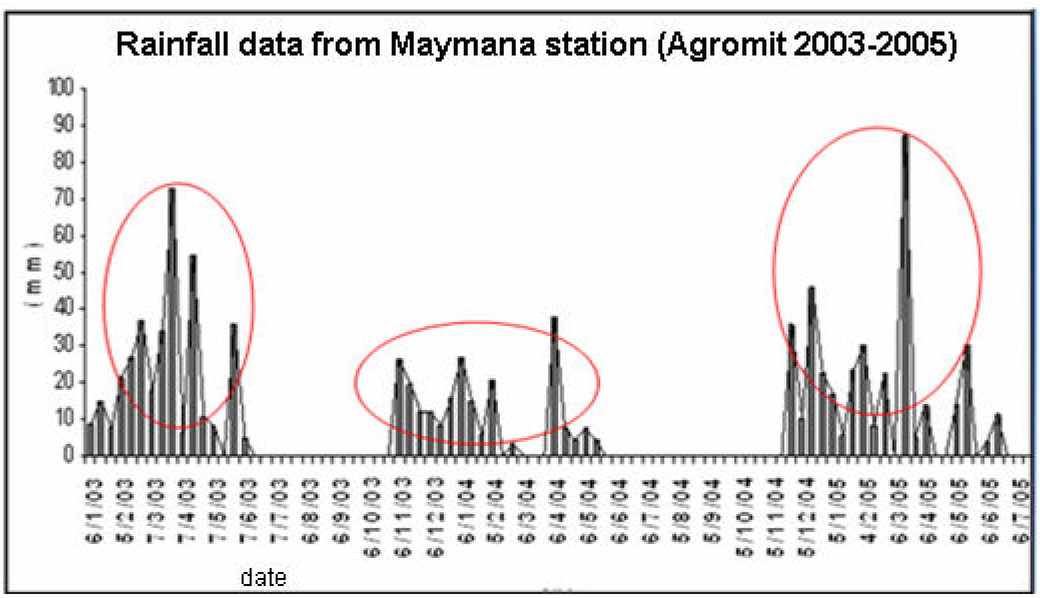


Fig. 4, Rainfall data from Maymana Meteorological station (USGS, Agromit, 2003-2005)

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 has its source 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 has its source from Selsala-i- Band Turkistan mountain. The Shirin Tagab River has its source 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).

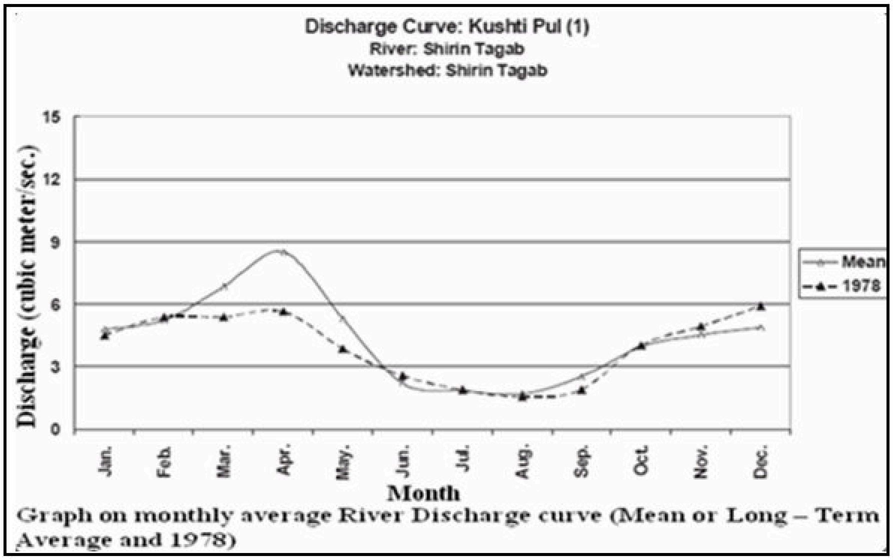


Fig. 6, Kushti Pul measurement station (Ministry of Water and Power, 1964-1978)

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

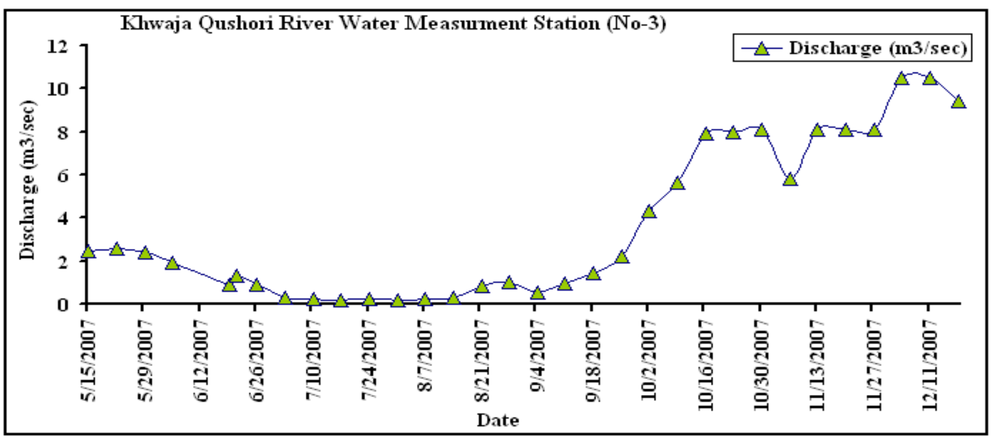


Fig. 7, Khvaja Qushori measurement station, 2007 (DACAAR/WSP, Shirin Tagab River)

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

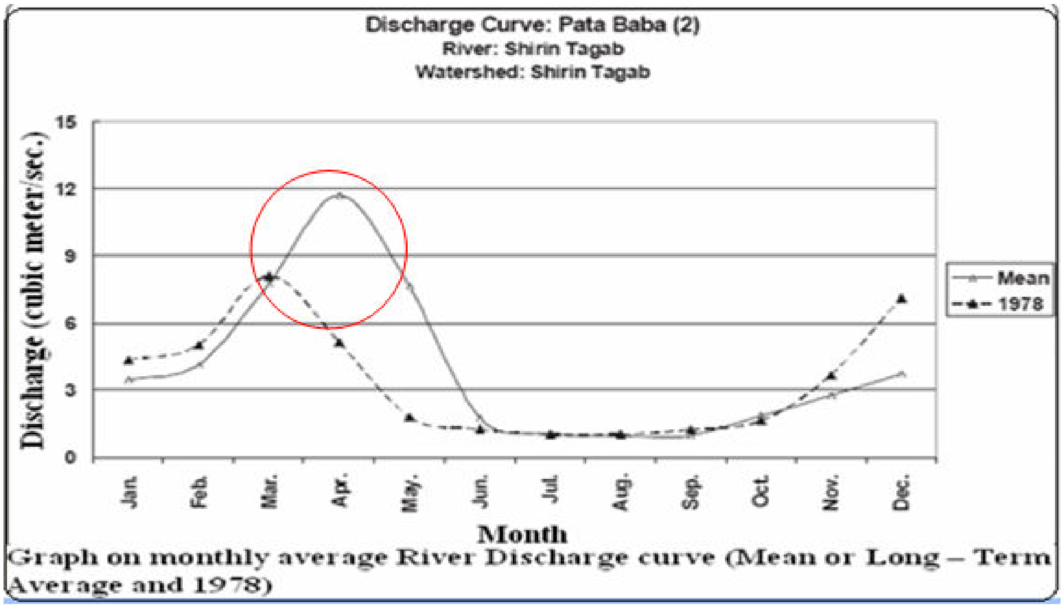


Fig.8, Pata Baba measurement station (Ministry of Water and Power, 1964-1978)

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). The excessive rain fall and snowmelt during 2009 (March-May) caused flooding and increased the discharge of Shirin Tagab River.

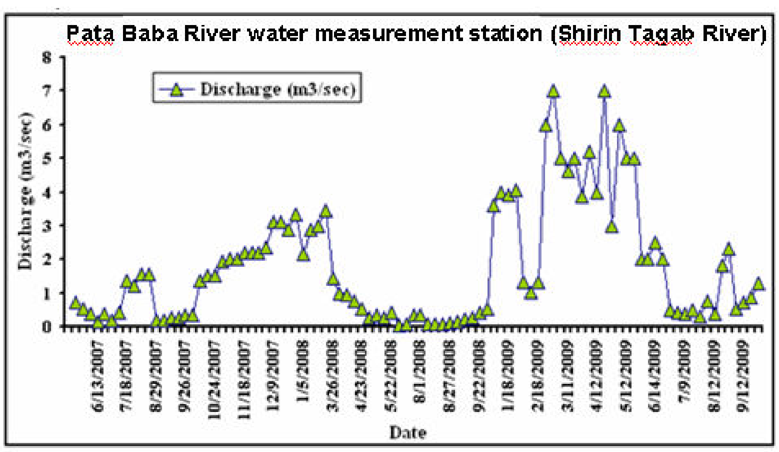


Fig. 9, Pata Baba measurement station (2007-2009)

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 joins with Qaysar river and drains through Jalaier valley.

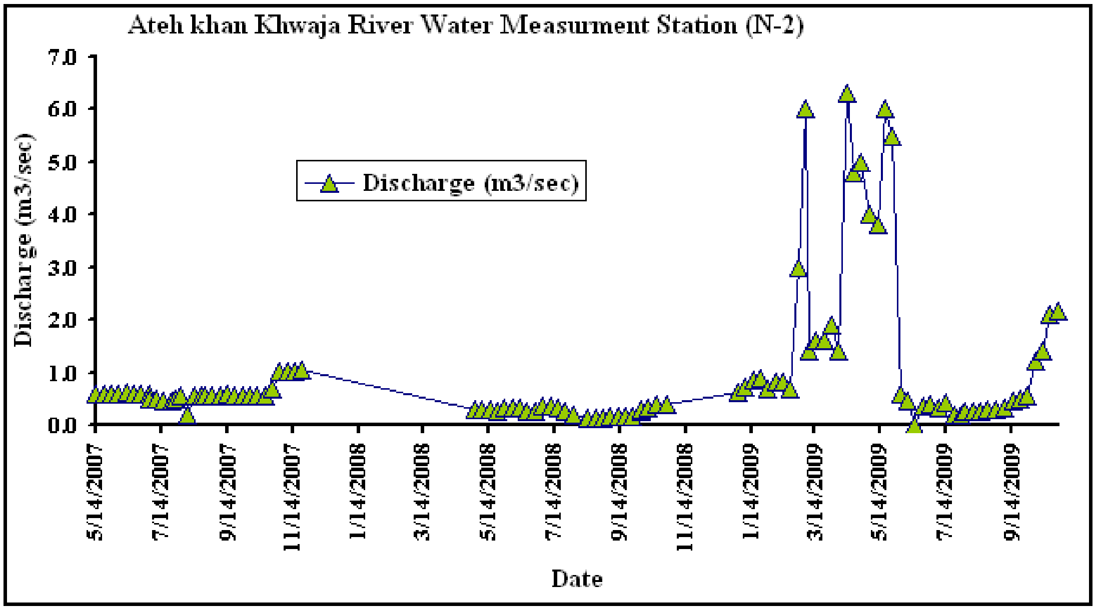


Fig. 10, Ateh Khan Khvajeh River (Maymana River) measurement station (DACAAR/WSP, 2007-2009)

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 Afghan 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)

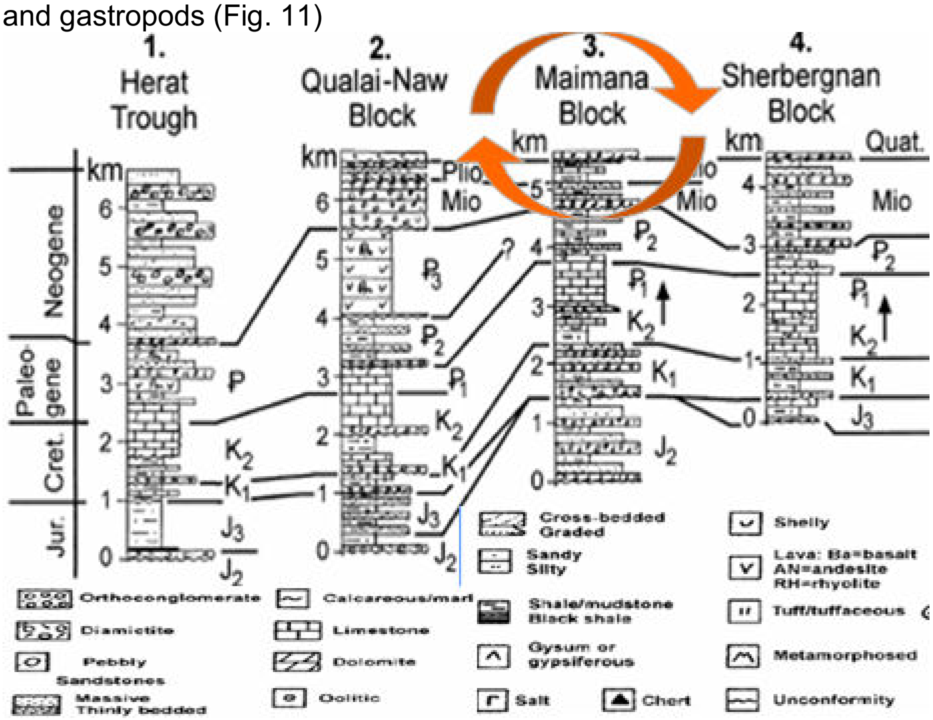


Fig. 11, Jurassic-Recent section in north Afghan Platform (Benda 1964, Bratash 1970)

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)

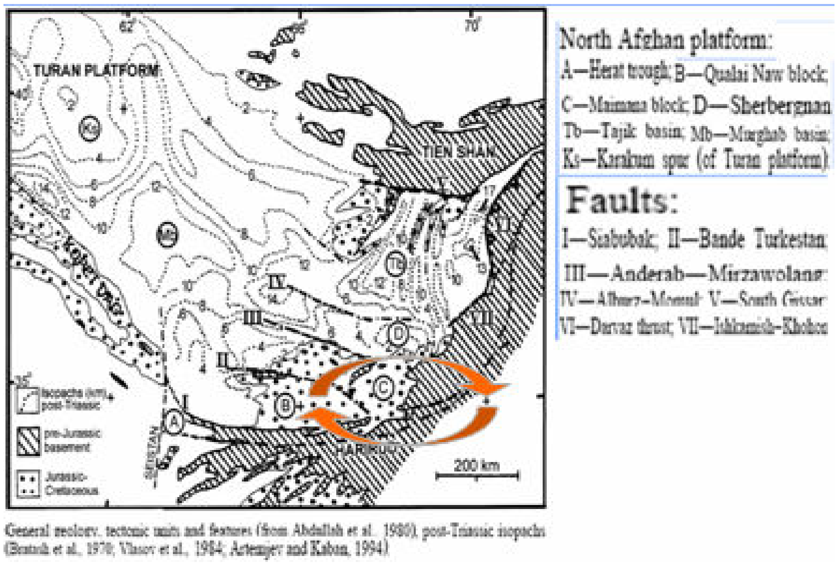


Fig. 12, North Afghan platform and fault system.

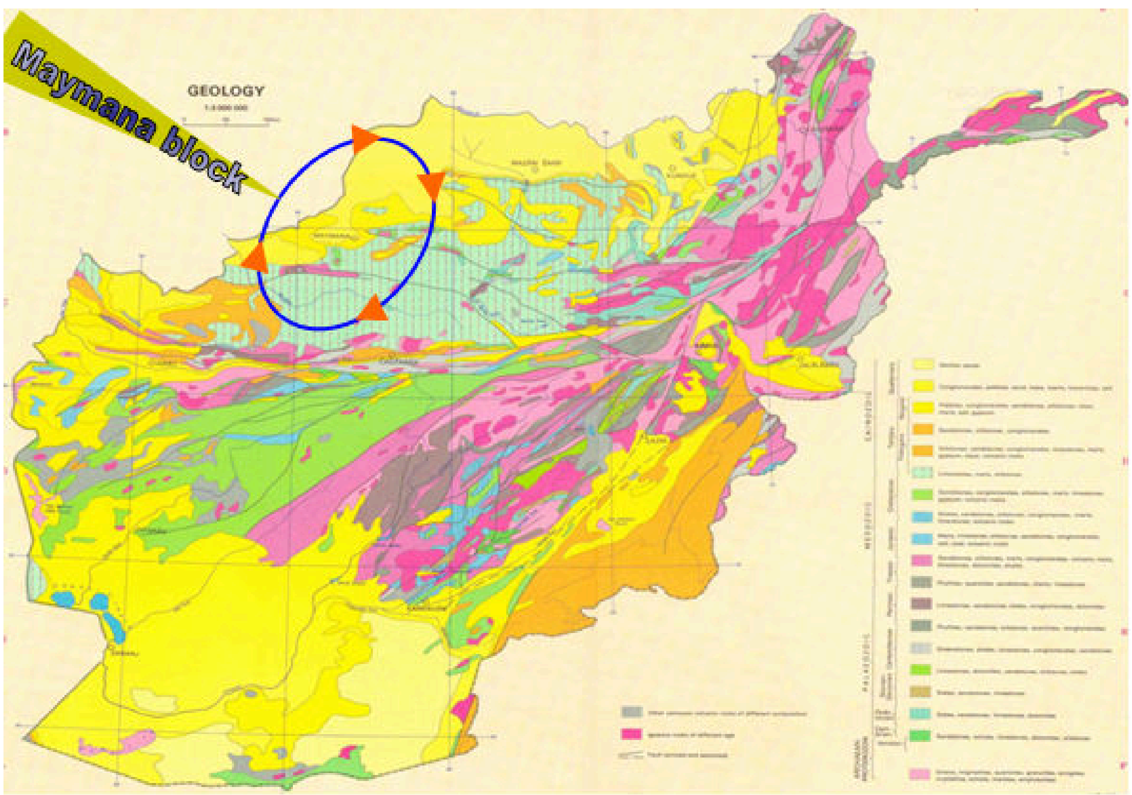


Fig. 13, Geology of Afghanistan

2.5. Hydrogeologic setting

Faryab natural groundwater systems characterized by three hydro geologic unit: 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 ranges between 1.75 l/s (Moghito (2) spring) and 35 l/s (Char Tut (1) spring). The Electrical 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 the Faryab province where the shallow and deep groundwater is highly mineralized.

The Cretaceous-Paleogene (Cr-Pg) fracture- Karst water formation overlie the Neogene (Pliocene and Miocene) aquifers and aquitard system which is characterized by successive beds 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 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 thicknesses 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 water users in Dawlat Abad, Qaramqol, Qurghan, Andkhoy and Khan-e Chahar Bagh districts.

Fig. 14, Astana brackish/saline stream feature

The Shor Darya River and Astana stream receive discharge from brackish/saline groundwater which has caused problems in the Astana and Jalaier valley and for downstream users.

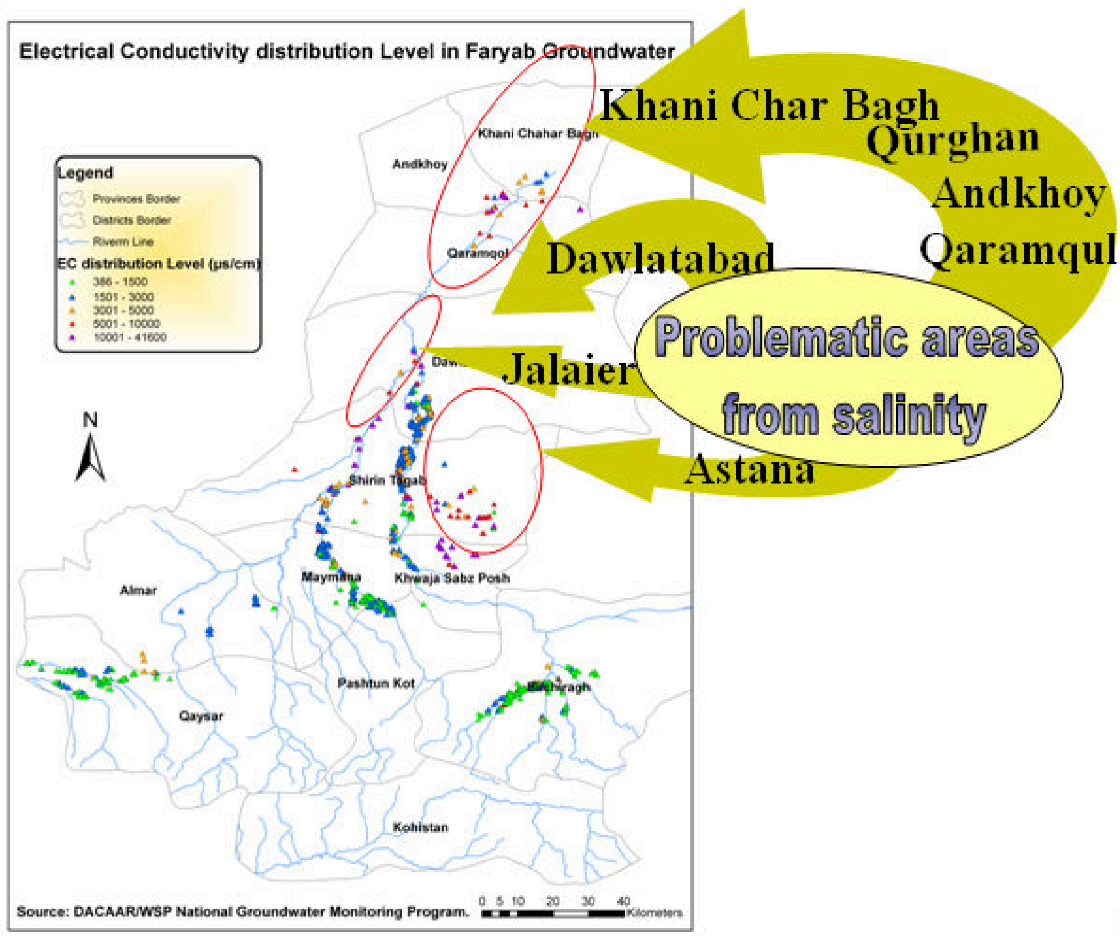


Fig. 15, Areas of salinity problem due to brackish/saline Shor Darya River and Astana stream

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, 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.

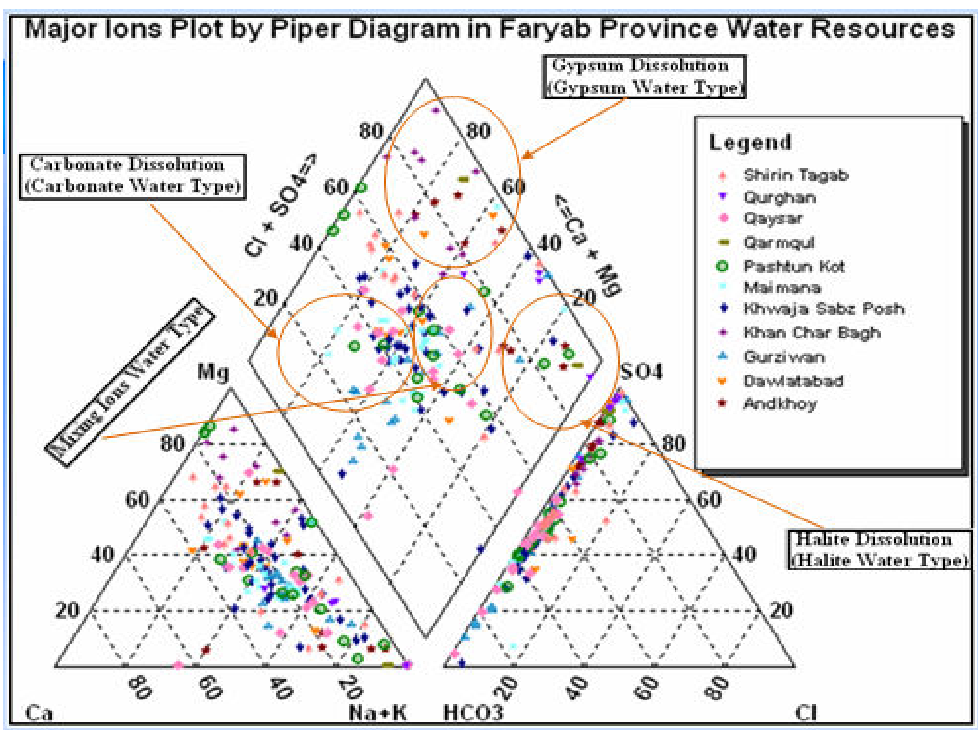


Fig. 17, Assessment of water quality (major ions) by Piper diagram

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 valley drinking water points indicated that the fluoride concentrations in ground water and surface water are higher than the WHO limit of 1.5 mg/l.

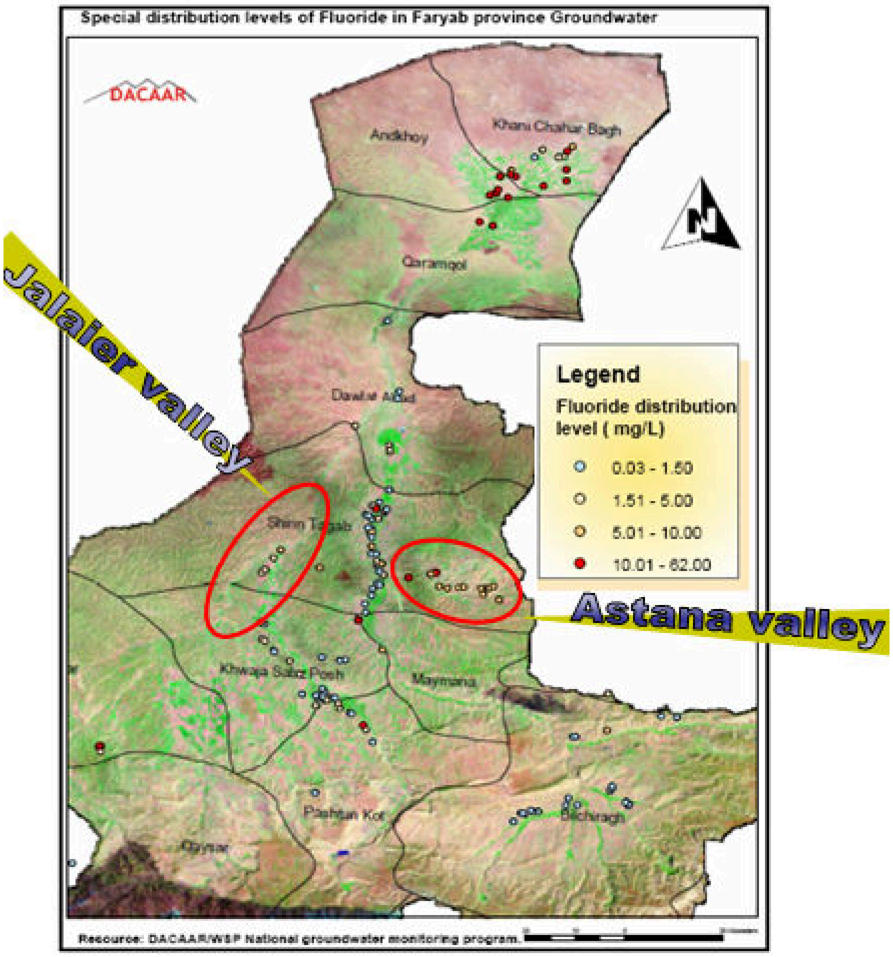


Fig. 18, Fluoride distribution levels in Faryab province

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

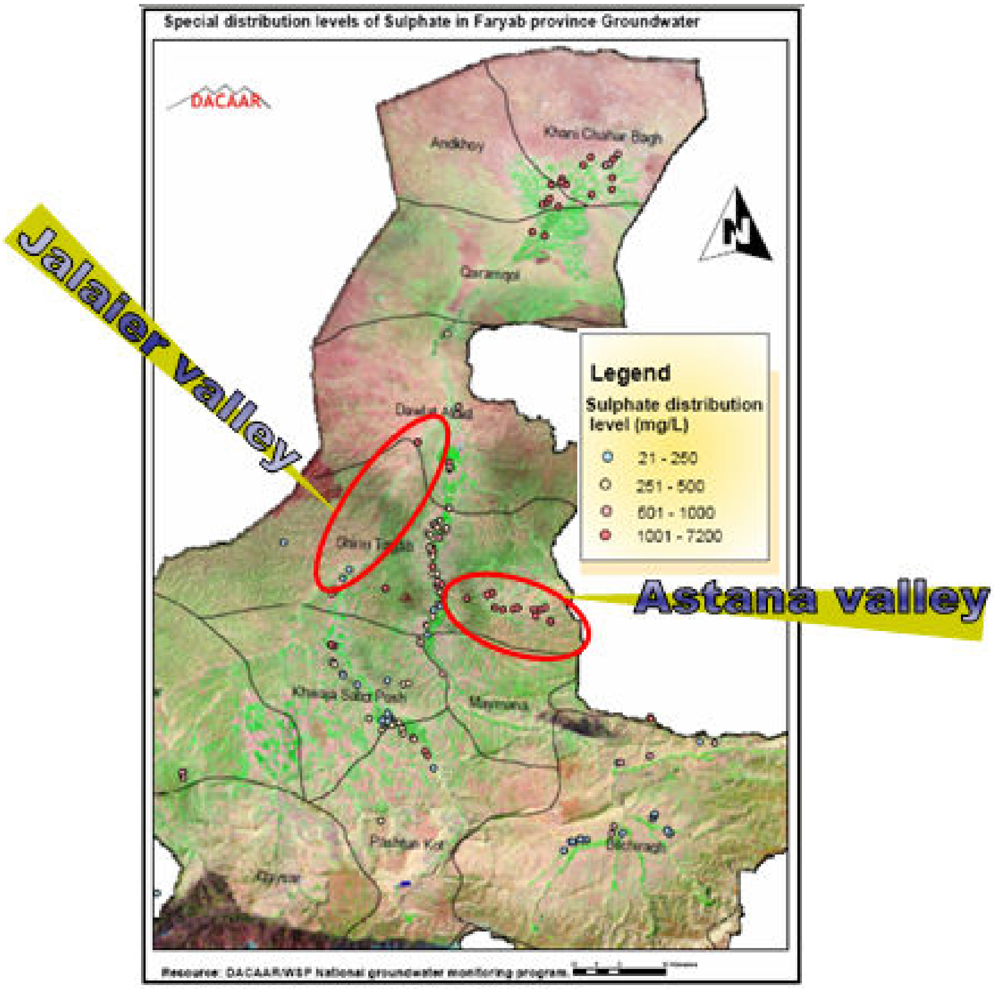


Fig. 19, Sulphate distribution levels in Faryab province

3. Integrated groundwater study in Astana valley

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

3.1. 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 10 profile stations. Each profile station contained 5 profile lines. The 10 profile stations contained a total of 50 profile lines. The profile stations were selected from west to east along the valley. The length of current (AB) selected was 300 m and the depth of penetration selected was 150 m. The direction of the profile stations was selected perpendicular to the Astana stream which drains through the valley. In this method the applied Schlumberger arrangement was used. The 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.

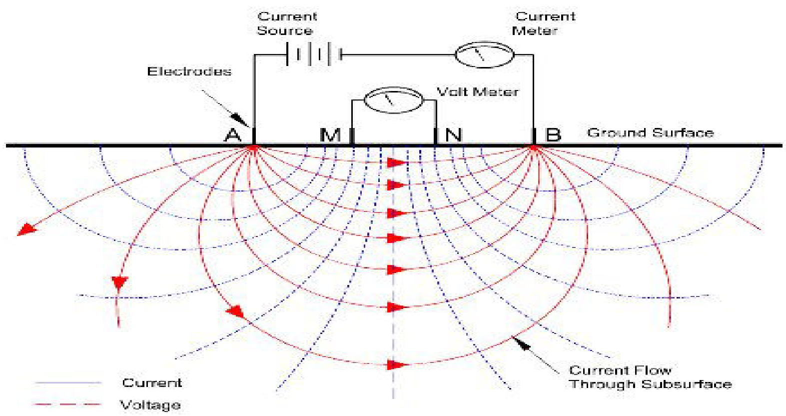


Fig.20, Vertical electrical sounding method

Apparent resistivity value is calculated:

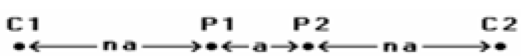
Pa = K V / I

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

K = πn (n + 1) a



The field data inter-related according to the following resistivity scale for water and rocks.

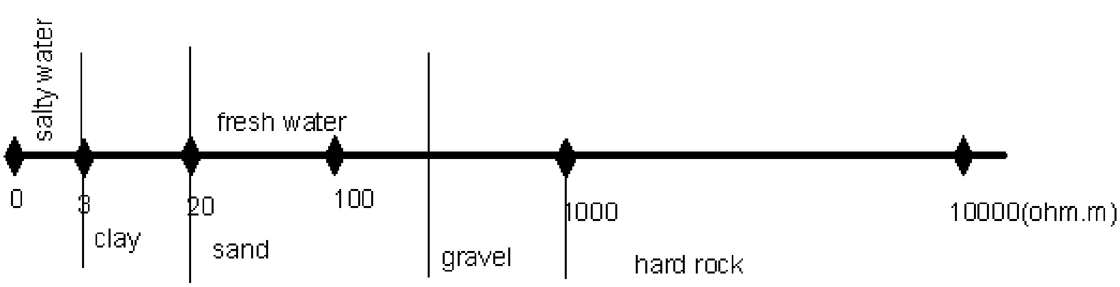


Fig. 21. Resistivity scale for water and rocks

The geophysical field study in Astana valley was conducted between 2-7 September 2009

Fig. 22, Applying vertical electrical sounding (VES) in the field.

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 Fig. 23.

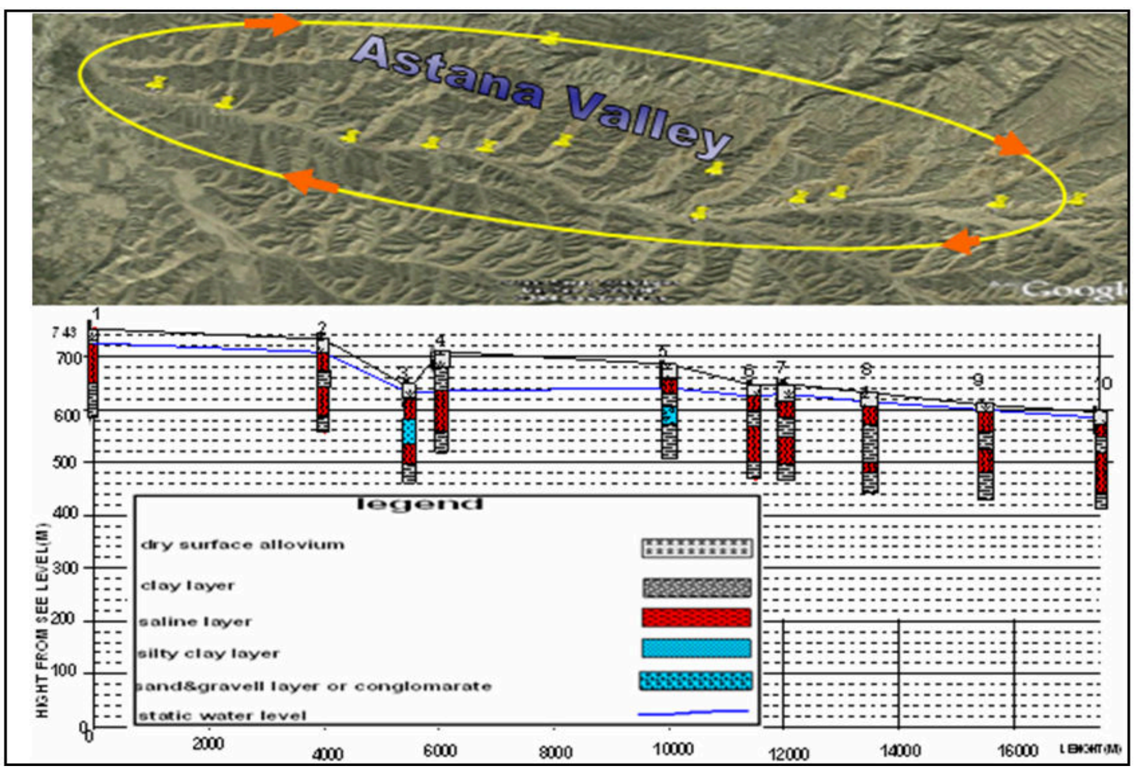


Fig. 23, Astana valley profile stations hydro geological section according to the VES field data.

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

3.2. Drilling of two pilot or exploration wells

Two pilot or exploration wells were drilled in the Mahad (middle part of the valley) and Gul Quduq (upper part of the valley) villages for modification of geophysical study**.** The drilling of the first well (exploration No-1) started on 27 March and ended on 7 June 2009.

Fig. 24, Drilling process of exploration well in Mahad village

This well was drilled to a depth of 200 m. Based on the well logging geophysics, the well lithology is composed of Neogene aquifers and aquitard systems mainly consisting of clay, sandy clay with intercalation of sand and gravel saturated with seepage brackish/saline water. The results of this well modified the geophysical study which was carried out through the valley. The electrical conductivity or salinity of groundwater increased from the upper part (10,200 µs/cm) to the lower part of the well log (16,710 µs/cm)

The physical and chemical analysis of the water sample from the upper part of exploration well No-1 indicated that the sulphate (3,720 mg/l), fluoride (13.6 mg/l), bromide (0.41 mg/l) and sodium (1,695 mg/l) concentration levels are higher than WHO drinking water guidelines, which are respectively 250 mg/l, 1.5 mg/l, 0.01 mg/l and 200 mg/l (WHO, 2004). The water type is sodium-sulfate (Na-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 sulphate (5,600 mg/l), fluoride (15.2 mg/l), bromide (0.29 mg/l) and sodium (2576 mg/l) concentration levels are higher than the WHO drinking water guideline. The water type is sodium-sulfate (Na-SO_4). The water originated from dissolution of gypsums and halite minerals.

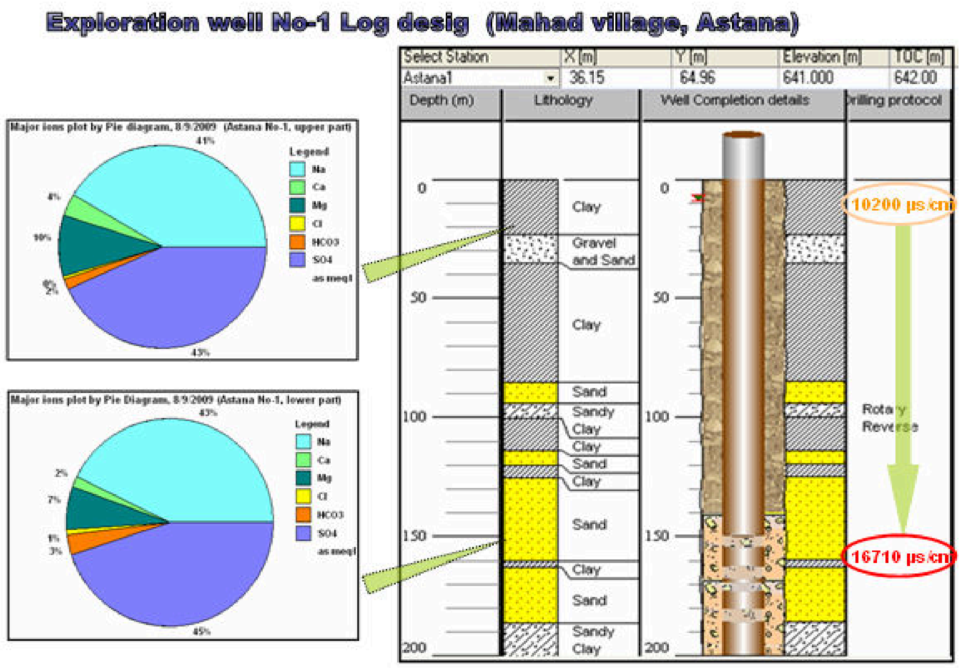


Fig. 25, Exploration well No-1 (Mahad village) log design and major ions plot

The pumping test result indicated that the discharge of the well was 2 l/s for 13 m drawdown during 7 hours. The salinity of water also increased with lowering of water level. The pumping test data is shown in Table 3 below:

Time (sec)	WL (m)	EC (µS/cm)	Q(l/s)
0	10	17,120	22
60	14		
120	17.5		
180	19		
240	20.1		
540	21.5		
840	22.5	16,860	
1,140	22.9		
1,440	23		
1,740	23		
2,040	23		
2,340	23		
2,640	23		
2,940	23		

3,240	23		
3,840	23		
4,440	23		
5,040	23	16,600	
6,840	23	16,700	
8,640	23		
10,440	23		
12,240	23		
14,040	23		
17,640	23		
21,240	23		
24,840	23		

The drilling of the second well (exploration well No-2) started on 5th July and ended on 13th November 2009. This well was drilled to a depth of 200 m. Based on the well logging geophysics, the well log was composed of Neogene aquifers and aquitard systems mainly consisting of clay, sandy clay with intercalation of sand and gravel and conglomerate mainly saturated with seepage brackish or saline water. 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 (9,530 µs/cm) to the lower part of the well log (11,210 µs/cm).

Fig. 26 Gul Quduq village exploration well drilling process

The physical and chemical analysis of the water sample from the upper part of exploration well No-2 indicated that the sulphate (2,000 mg/l), fluoride (7.6 mg/l), bromide (0.29 mg/l) and sodium (990 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.

The chemical analysis of the water sample from the lower part of exploration well No-2 indicates that the sulphate (2,000 mg/l), fluoride (7.4 mg/l), bromide (0.28 mg/l) and sodium (1,250 mg/l) concentration levels are higher than WHO drinking water guidelines. The water type is sodium-sulfate ($Na\text{-}SO_4$) and the water originated from dissolution of gypsum and halite minerals.

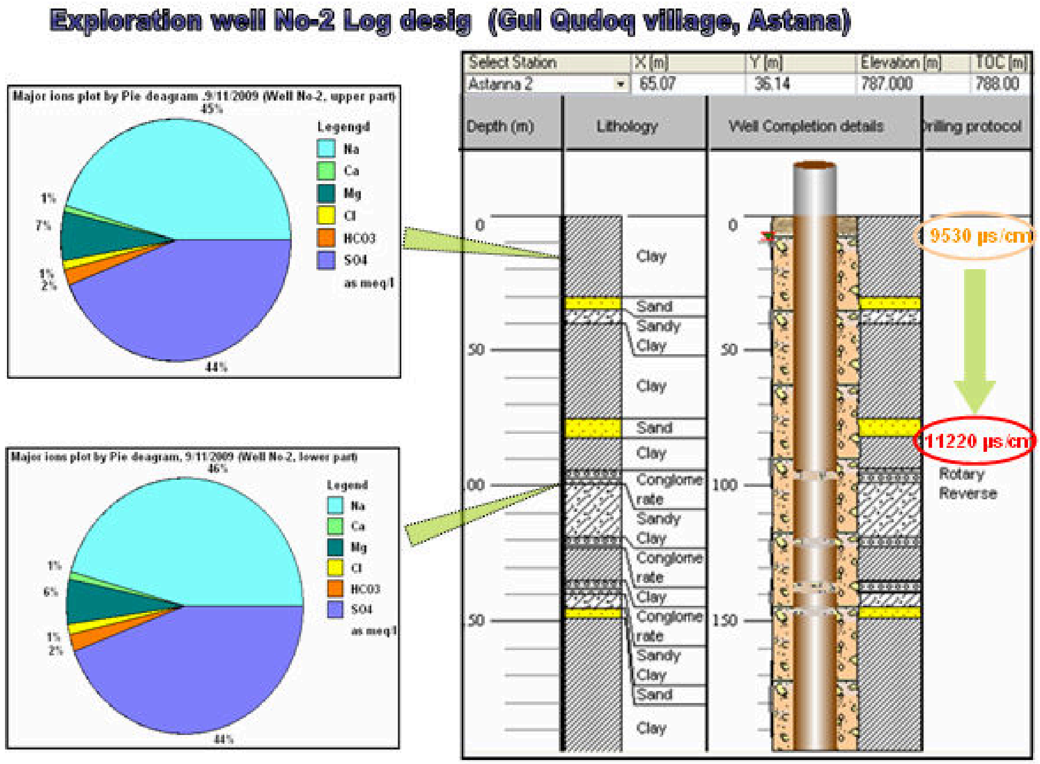


Fig.27 Exploration well No-1 (Mahad village) design and major ions plot

The physical and chemical analysis of water samples from exploration wells in Astana valley is shown in the table 5. Drinking high sulphate content water (more than 600 mg/l) can cause severe diarrhea and loss of body fluid of users. It also gives a bitter taste to the water. Drinking high sodium content water (more than 200 mg/l) can cause severe health problems and loss of body fluid of users. Drinking high fluoride content water (more than 1.5 mg/l) causes skeletal fluorosis and dental fluorosis.

The pumping test result indicated that the discharge of the well was 1.5 l/s for 101 m drawdown during 39 minutes. After 55 minutes the well dried up. The well does not have aquifer water, only seepage water. The salinity of the water also increased with the lowering of the water table. The pumping test data is shown in Table 4.

Table 4. Pumping test data of exploration well No.2 (Gul Qudoq village) Conducted on 6th November 2009

Time(s)	WL (m)	EC (µS/cm)	Q (l/s)
0	9	9,530	1.5
60	15.4		
120	19.3		
240	29		
540	39		

840	55		
1,440	71		
1,740	96		
2,340	110	11,220	
2,640	130	11,220	

.

Table 5. Physical and chemical analysis of water samples from exploration wells in Astana valley

Description	**Exploration Well No 1**		**Exploration Well No 2**	
	Lower Part	**Upper Part**	**Upper Part**	**Lower part**
Latitude	36.15363	36.15363	36.13655	36.13655
Longitude	64.96008	64.96008	65.07095	65.07097
Province	Faryab	Faryab	Faryab	Faryab
District	Shirin Tagab	Shirin Tagab	Shirin Tagab	Shirin Tagab
Village	Mahad	Mahad	Gul Qudoq	Gul Qudoq
Sampled Date	8/9/2009	8/9/2009	9/11/2009	9/11/2009
Analyzed Date	10/9/2009	10/9/2009	10/11/2009	10/11/2009
Temperature (ºC)	21.7	22.4	21.8	17.2
EC (µS/cm)	16,710	10,200	9,530	11,210
pH	7.14	7.5	7.18	7.21
Potassium (mg/l)	192	59	28	95
Sodium (mg/l)	2,576	1,695	990	1,250
Calcium (mg/l)	192	57.6	16	17.6
Magnesium (mg/l)	320	140	75	65
Total iron (mg/l)	0.07	0.04	0.06	0.07
Aluminium (mg/l)	0	0	0.01	0
Arsenic (mg/l)	0	0	0	0
Ammonium as NH_4(mg/l)	2.8	0.1	0.21	0.72
Chromium (mg/l)	0.01	0.02	0.1	0.07
Manganese (mg/l)	0.029	0.002	0.002	0.008
Copper (mg/l)	0.06	1.6	0.16	0.1
Bromide (mg/l)	0.29	0.41	0.29	0.28
Boron (mg/l)				
Chloride (mg/l)	44	50	40	44
Phosphate (mg/l)	0.6	3.5	0.07	0.14
Fluoride (mg/l)	15.2	13.6	7.6	7.4
Sulphate as SO_4	5,600	3,720	2,000	2,000
Carbonate as CO_3	20	120	140	140
Bicarbonate (mg/l)	280	330	125	125
Nitrate as NO_3(mg/l)	51.6	16.5	49.2	67.2
Faecal Coli forms				
Nitrite as NO_2(mg/l)	0.013	0.042	0.086	1.8
Total Coliforms				
Sulphite (mg/l)	15	11	3	5
Silica as SiO_2 (mg/l)	0.44	0.78	0.64	0.54

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

In Astana valley, most of the inhabitants are in a worse position as far as the provision of safe drinking water is concerned. The inhabitants of Astana valley utilize drinking water from either Moghai To (1) or Moghai To (2) springs, Dug Wells (DW) and improved Tube Wells (TW) brackish/saline water or fresh water from Shirin Tagab River.

4.1 Moghai To (1) spring

Moghai To (1) spring emerges from limestone and has Karstic characteristic. The discharge of the spring is about 1.5 l/s. The spring water discharge fluctuated during the year but did not go lower than 1.3 l/s. Half of the spring water discharge is conveyed by 1.5 inch PVC pipe to a 6 m^3 reservoir constructed by the NGO INTERSOS. The other half of the spring water discharge drains through the Moghai To (1) village. The inhabitants of Moghai To (1) village get their drinking water from this spring which is flows into open channels. The spring water is extremely polluted and a source of different water borne diseases. The water from the reservoir is distributed by gravity piped water supply system to Mahad village with 4 stand posts. There is leakage in some parts of the system, therefore, it needs to be repaired and the existing network improved. The water from the reservoir is distributed on a part time basis. People spent 5-6 hours collecting drinking water from the stand posts.

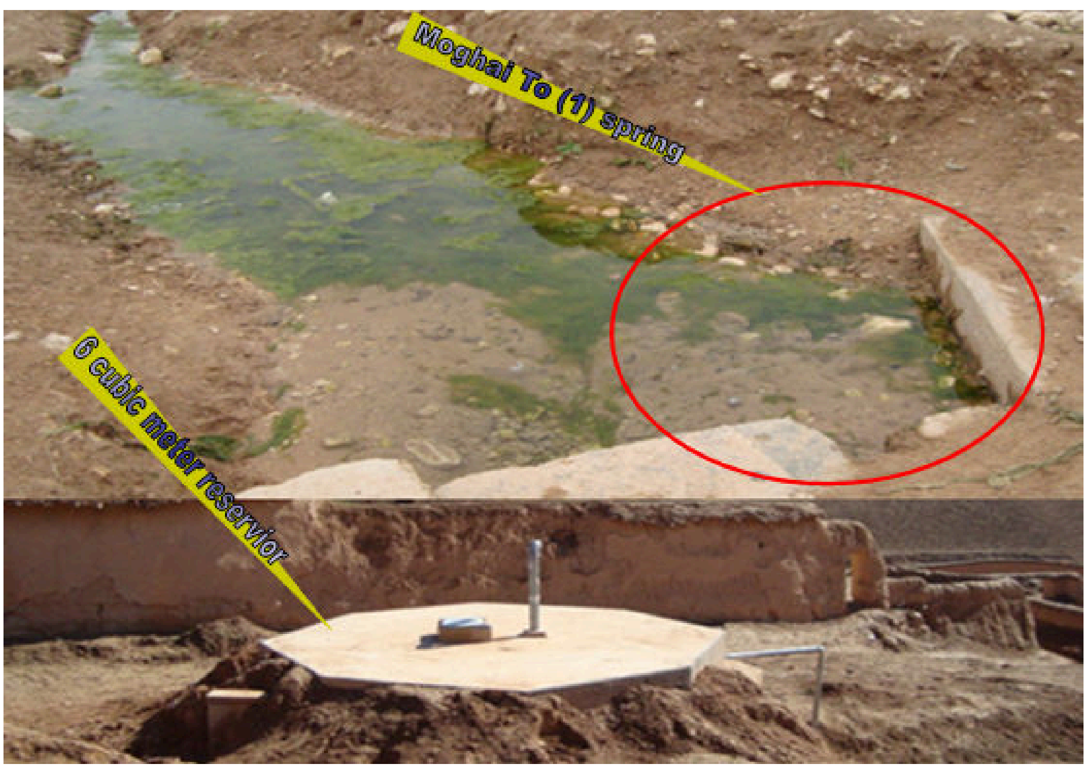


Fig.28. Moghai To (1) spring and reservoir feature.

The chemical analysis of the water sample from Moghai To (1) spring indicated that the sulphate (1,050 mg/l), fluoride (4.3 mg/l), bromide (0.23 mg/l), sodium (701 mg/l), boron (3.2 mg/l) and EC (4,520 µS/cm) concentration levels are higher than WHO drinking water guidelines, The water type is Sodium-Magnesium-Sulfate (Na-Mg-SO_4). The water mainly originated from dissolution of gypsums mineral. The physical and chemical analysis of water samples from Shirin Tagab River is shown in Table 6. The Moghai To (1) spring features and water quality is illustrated in Figure 32. The Moghai To (1) spring water is not suitable for drinking also it is not according to the WHO drinking water guidelines and is not a long term solution.

4.2. Moghai To (2) spring

Moghai To (2) spring emerges from limestone and has Karstic characteristic. The discharge of the spring is about 2 l/s. It fluctuated during the year but did not go lower than 1.5 l/s. The spring water emerges from the main parts (upper part) conveyed to a 10 m^3 reservoir in a 3 inch PVC pipe which was constructed by the NGO INTERSOS. The seepage water coming from different areas drains to the village. The discharge of spring water flowing to the village is about 1.3 l/s. The water from the reservoir is distributed by gravity piped water supply system to some villages of Astana valley by construction of 14 stand posts.

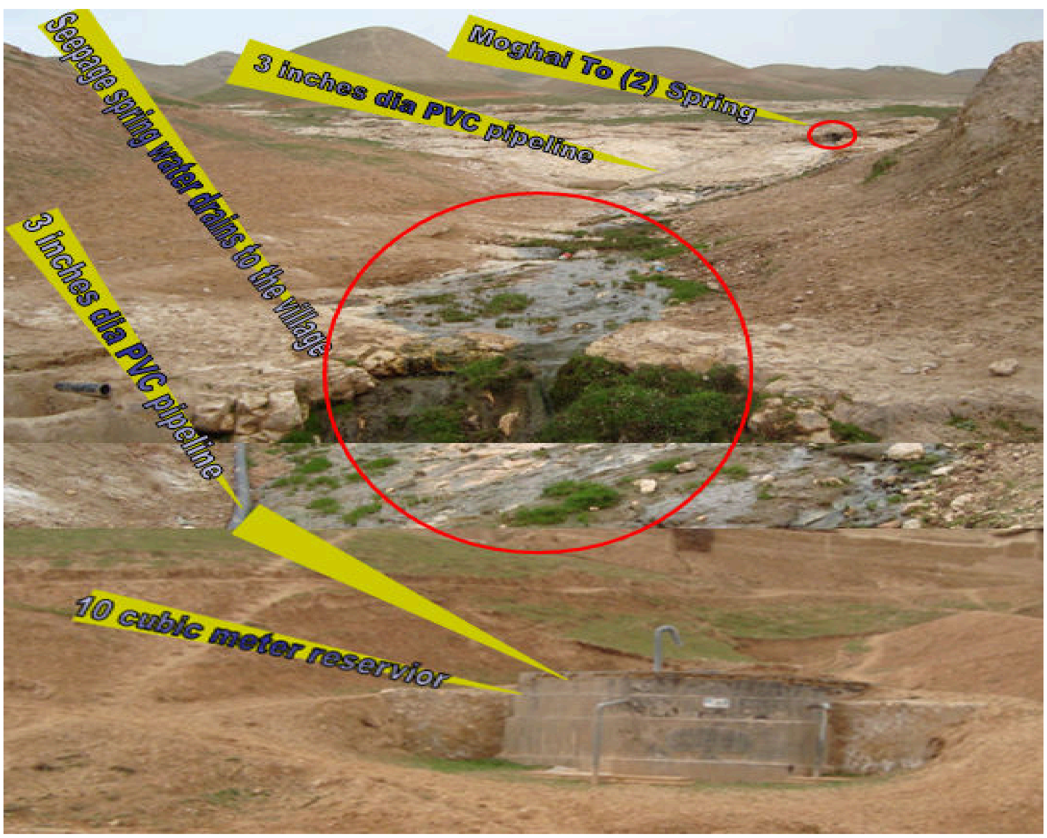


Fig.29. Moghai To (2) spring and reservoir location

Water leaks from some parts of the gravity piped water supply system, therefore, it needs to be repair and the existing network improved.

Fig.30 Feature of water wastage from a stand post without tap

The chemical analysis of the water sample from Moghai To (2) spring indicated that the sulphate (700 mg/l), fluoride (2.3 mg/l), bromide (0. 23 mg/l), sodium (540 mg/l), boron (2.1 mg/l) and EC (3,430 µS/cm) concentration levels are higher than WHO drinking water guidelines, however the people have to use because of shortage of safe drinking water in the whole valley. The water type is Sodium-Magnesium-Sulfate (**Na-Mg-SO_4**). The water originated from dissolution of gypsums minerals.

The physical and chemical analysis of water samples from Shirin Tagab River is shown in Table 6.

The chemical analysis of water samples from point sources shows that the Moghai To (2) spring is relatively best water in the entire valley but it is not according to the drinking water guidelines and is not a long term solution. The water from the reservoir is distributed part time. People spend 5-6 hours collecting drinking water from stand posts.

Fig.31. People collecting their water from a stand post and waiting for 5-6 hours to access their drinking water

The Astana valley ground and surface water salinity levels and Moghai To (1) and Moghai To (2) springs water quality are illustrated in Figure 32.

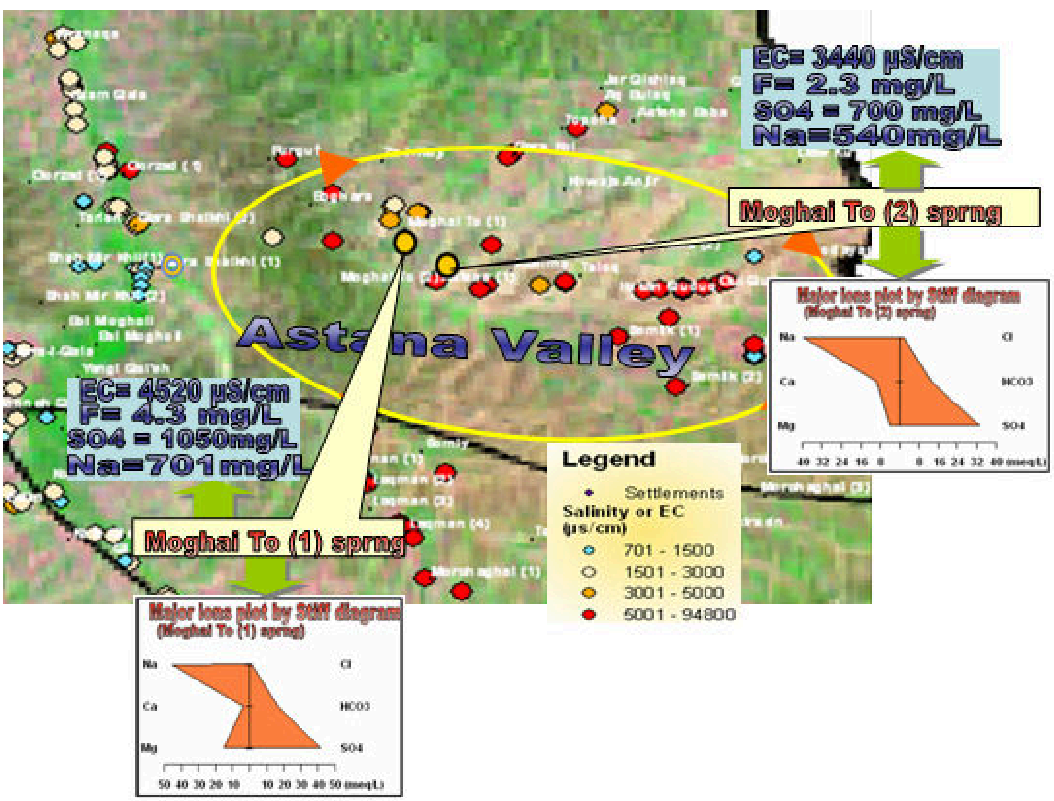


Fig.32, Astana valley ground and surface water salinity levels and Moghai To (1) and Moghai To (2) springs major ions plots illustration

4.3. Dug wells and improved Tube wells

The settlements in the valley are not connected to a water supply system. Villagers are forced to collect their drinking water from dug wells and improved tube wells with brackish/saline water. It is not potable for humans, animals and for irrigation.

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Fig.33. People using brackish or saline water from a Dug Well

The chemical analysis of water sample from a Dug Well (Tashlic village) indicated that the sulphate (3,000 mg/l), fluoride (7.8 mg/l), bromide (0. 28 mg/l), sodium (681 mg/l), boron (5.5 mg/l) and EC (7,500 µS/cm) concentration levels are higher than WHO drinking water guidelines. The water type is Sodium-Calcium-Sulfate (Na-Ca-SO_4). The water originated from dissolution of gypsums and halite minerals.

The physical and chemical analysis of water samples from Shirin Tagab River is shown in the Table 6.

4.4. Shirin Tagab River

Most people of Astana valley collect their drinking water from Shirin Tagab River and transport it using donkeys and camels. The surface water is fresh, but it is polluted and a source of water borne diseases. People spent 6-8 hours each day for collection of their drinking water.

Fig.34 People collecting their drinking water from Shirin Tagab River by donkeys

The chemical analysis of water sample from Shirin Tagab River indicated that the sulphate (150 mg/l), fluoride (0.46 mg/l), bromide (0.06 mg/l), sodium (32 mg/l), boron (0.2 mg/l) and EC (800 µS/cm) concentration levels are lower than WHO drinking water guidelines. The physical and chemical analysis of water samples from Shirin Tagab River is shown in Table 6. The Shirin Tagab River and Astana brackish/saline steam location and major ions plots are illustrated in Figure 34.

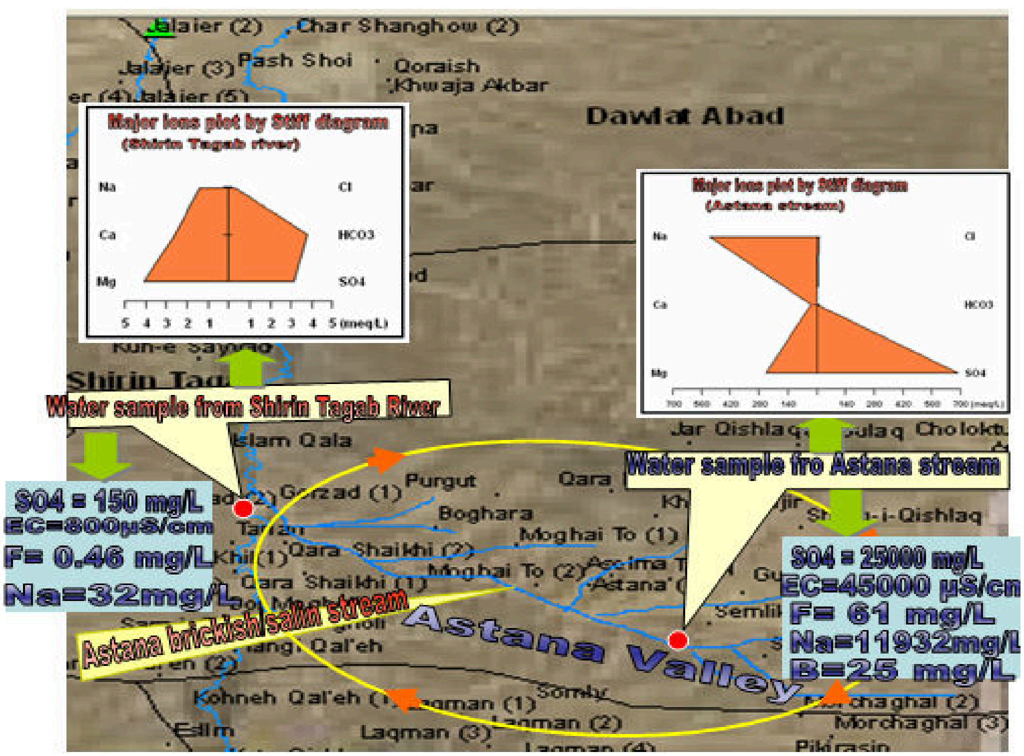

Fig.35 Shirin Tagab River and Astana brackish/saline steam water samples location and major ions plots.

4.5. Astana brackish/saline stream

Astana stream is perennial and flows through the Astana valley then merges with the Shirin Tagab River. It mainly discharges from brackish/saline groundwater. In general the water of this stream is not suitable for drinking 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 downstream water users in Dawlat Abad, Qaramqol, Qurghan, Andkhoy and Khani Char Bagh districts.

The chemical analysis of the water sample from Astana stream indicated that the sulphate (33,000 mg/l), fluoride (61 mg/l), bromide (25 mg/l), sodium (11,932 mg/l), boron (12.5 mg/l) and EC (45,000 µS/cm) concentration levels are higher than WHO drinking water guidelines. The water type is Sodium-Magnesium-Sulfate (Na-Mg-SO_4) and it originates from dissolution of gypsums and halite minerals.

The physical and chemical analysis of the water samples from Shirin Tagab River is shown in Table 6.

The Shirin Tagab River and Astana brackish/saline steam location and major ions plot is illustrated in Figure 34.

Table 6 Physical and chemical analysis of source water in Astana valley

Description	Spring	Spring	Shirin Tagab River	Shirin Tagab River	DW
Province	Faryab	Faryab	Faryab	Faryab	Faryab
District	Shirin Tagab	Shirin Tagab	Khvajeh Subz	Shirin Tagab	Shirin Tagab
Village	Moghaito (1)	Moghaito (2)	Khvajeh Qushori	Chel Quduq	Tashlic
Sample Date	06/02/09	06/02/2009	12/05/2007	10/10/05	30/11/08
Analysis Date	07/02/09	07/02/2009	12/05/2007	11/10/05	01/12/08
Latitude	36.16386	36.16682	36.01012	36.11281	36.13883
Longitude	64.97217	64.98152	64.89090	65.09676	64.98739
EC (µS/cm)	4,520	3,430	800	45,000	7,500
pH	8.36	7.75	8.66	8.26	7.8
Temp (^{O}C)	10.1	10.1	27	23.3	20
HCO_3 (mg/l)	1,010	810	230	0	410
CO_3 (mg/l)	140	140	20	2,500	90
Cl (mg/l)	38	54	11.2	446	44
SO_4 (mg/l)	1,050	700	150	33,000	3,000
Sulphite (mg/l)	2	4	10	250	3
F (mg/l)	4.3	2.3	0.46	61	7.8
Nitrate as NO_3 (mg/l)	36.8	15.2	1.22	340	32.88
Nitrite as NO_2 (mg/l)	0.005	0.004	0.013	32.5	0.098
Phosphate (mg/l)	0.03	0.05	0.19	2	0.18
Boron (mg/l)	3.2	1.2	0.2	12.5	5.5
Br (mg/l)	0.23	0.23	0.06	2.5	0.28
Na (mg/l)	701	540	32	11932	681
K (mg/l)	36	23	3.7	115	29
Ca (mg/l)	78.8	188	51.6	600	292.8
Cr (mg/l)	0.04	0	0.01	1.5	0.08
Mg (mg/l)	180	50	50	3,000	360
NH_4 (mg/l)	1	0.4	0.02	3	0.3
Mn (mg/l)	0.001	0.001	0.002	0.15	0.001
Cu (mg/l)	0.08	0.12	0	8	0.04
Al (mg/l)	0	0	0.04	0.5	0
Fe (mg/l)	0.01	0.01	0.02	1	0.01
As (mg/l)	0	0	0	0	0
Si (mg/l)	3.2	2.1	0.1	1.1	3.10

5. 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 Astana stream, which is brackish/saline. The chemical analysis of water samples from this river shows that the salinity progressively increases from upstream to downstream of the valley. The salinity of the river reduces during the flooding season but the water is muddy, however, the salinity of the river 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 Astana valley shows that the shallow and deep groundwater is highly mineralized due to extension of the evaporative basin and dissolution of halite and gypsum minerals.

4) The settlements of this valley have experienced severe safe drinking water shortage for many years. They spend on average 7 hours a day to collect their drinking water either from Moghai To (2) spring or Shirin Tagab river (fresh water) using camel and donkeys.

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

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

7) The chemical analysis of water samples from different source points (surface and ground water) shows that the Moghai To (2) spring is relatively the best water in the Astana valley. It is possible to extend the existing water supply system on the basis of this spring.

6. Recommendations

6.1. Short term solution

There are three possibilities to provide safe drinking water:

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

2) Install two Reverse Osmosis Desalinisation Plants (RODPs) with the first in Mahad village, based on the Moghai To (1) spring, and the second in Gul Quduq village, based on the second exploration well. Reverse Osmosis Desalinisation Plants have been installed by Norwegian Church Aid (NCA) in Qurghan and Qaramqol districts of Faryab province. DACAAR analyzed raw water from these

installed RODPs 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. Reverse Osmosis Desalinization Plants are suitable method for reducing of salinity from water for drinking in Astana Valley.

3) Repair the existing gravity piped water supply system from Moghai To (2) spring which was constructed by INTERSOS. The Moghai To (2) spring is located in Moghai To (2) village in the northern part of Astana valley within the mountainous area. The spring emerges from the limestone formation and has Karstic characteristic. The discharge of the main part of the spring is about 1.5 l/s, conveyed by 3 inch PVC pipe to a 10 m^3 reservoir. The water from the reservoir is distributed by gravity water supply system to 14 stand posts. Some parts of the gravity piped water supply system leak and require repair and the existing network needs to be improved.

4) Construct a 25 m^3 surface reservoir (near to the existing reservoir) based on the Moghai To (2) village spring which is coming out from different parts and flowing through the village. The spring water should be conveyed by 2 inch PVC pipe line to the reservoir. The water from the reservoir should be distributed by gravity piped water supply system and a pumped piped water supply system (with 3 inch PCV pipe line) to the villages which are located in the eastern and western part of Shor Bazar (center of Astana valley). The pipe line will be approximately 17 km long. A pumped piped water supply system needs to constructed between Moghai To (2) village and Shor Bazar because the elevation of the spring is 740 m above sea level, whereas the elevation of Gul Quduq village, which is located in the east part of Shor Bazar, is 781m.

   A detailed feasibility study, design and cost estimate is required prior to the construction of the above recommended systems.

6.2. Long term solution

It is recommended to drill wells along the right bank of Shirin Tagab River in the Qara Shaikhi (2) village area and distribute water from these wells by pumped piped water supply system in several stages. This, however, will be very expensive. A detailed feasibility study, design and cost estimate is required prior to the construction of this system.

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- Implementation facilitators: Gerry Garvey, Chief of WSP, Shah Wali WSP Programme Manager, Arif Basiri, Deputy Programme Manager, Bismillah Patan Faryab WSP Provincial Manager.

- Security facilitators: Faryab Provincial Governor, Shirin Tagab district authorities and Astana valley community elders.
- Engineer Shirin Aqa and Abdul Aziz Astana, WSP Project Supervisors.
- M.Hassan Saffi, WSP Senior Hydrogeologist: Technical Supervisor for implementation of integrated groundwater study approach.
- Ahmad Jawid: WSP Hydrogeologist, responsible for recording and managing data for integrated groundwater study approach.
- Shir Habib: Supervisor for physical and chemical analysis of water samples.
- Bashir Ahmad, Abdul Hadi and Shakar Khan: Laboratory Assistants, responsible for water samples physical and chemical analysis.
- MUMTAZ Construction Group preformed well logging geophysics and carried out geophysical investigation.
- MES Company drilled the wells.

8. References

1. Historical Meteorological data, 1958-1978, Department of Meteorology, Transport and Tourism, Afghanistan
2. Ministry of Water and Power, 1957-1978, long term Shirin Tagab River discharge data, Faryab Province, Afghanistan
3. WARSA, 1984 (Maymana Meteorological station), National Atlas of Democratic Republic of Afghanistan
4. Radojicic. S, 1976, Report on Hydrogeological Survey of certain settlement along the Afghanistan ring road.
5. Radojicic. S, 1977, Drinking water potential development technology in Afghanistan (UNICEF, Rural Water Supply Project Report)
6. Government of Afghanistan, 1984, Yearbook statistic precipitation data.
7. Michael E. Brookfield & Ajruddin Hashmate, 2001. The geology and petroleum potential of northern Afghanistan
8. U.S. Geological Survey Bulletin, 2004, Petroleum Geology and Resources of Amu Darya Basin, Turkmenistan, Uzbekistan, Afghanistan, and Iran.
9. W. A. Slawin, 1984, Geology of Afghanistan
10. USGS, Agromet, 2003-2005, Rainfall data in Maymana Meteorological of Faryab province
11. DACAAR/WSP, 2007-2009, Shirin Tagab River measurement stations
12. DACAAR/WSP, 2005-2009, Physical and Chemical Analyzed water samples (204 water samples) from Rivers, Springs, Dug Wells and Tube Wells
13. DACAAR/WSP, M.Hassan Saffi, 2005, Groundwater Salinity survey data in Faryab Province, Afghanistan
14. DACAAR/WSP, M.Hassan Saffi, 2005, Groundwater at risk in Afghanistan, Kabul, Afghanistan
15. DACAAR/WSP, 2005-2009, National Groundwater Monitoring Wells Network data in Faryab province
16. DACAAR/WSP, M.Hassan Saffi, 2009, Research on Reverse Osmosis Desalinization Plants (RODP) In Qurghan and Qaramqol districts of Faryab province, Afghanistan
17. DACAAR/WSP, M.Hassan Saffi, June 2007, Fluoride contamination in Afghanistan, Kabul, Afghanistan.

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