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Project Title: **Capacity-Building and Institutional Cooperation in the Field of Hydrogeology for Faryab Province, Afghanistan**

Report Title:

A Methodology for Provincial Hydrogeological Mapping in Afghanistan

Part 2: Field Survey Methodology Statements (Faryab)

Version: F1.0

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Client: Ministry of Rural Rehabilitation and Development (MRRD), RuWatSIP Department, Islamic Republic of Afghanistan

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Abbreviations used in this report:

AGS = Afghan Geological Survey

AUWSSC = Afghan Urban Water Supply and Sewage Corporation (privatisation of CAWSS)

CAWSS = Central Authority for Water Supply and Sewage (reporting to MUDA). Now AUWSSC

FAO = Food and Agriculture Organization of the United Nations.

EC = electrical conductivity

IBE = ion balance error

m asl = m above sea level

meq/L = milliequivalents (of ionic charge) per litre

mg/L = milligrams per litre

mmol/L = millimoles per litre

mOD = metres above Ordnance Datum (i.e. above sea level)

m bgl = metres below ground level

m bwt = metres below well top

MAIL = Ministry of Agriculture, Irrigation and Livestock

MoEW = Ministry of Energy and Water

MoM = Ministry of Mines

MUDA = Ministry of Urban Development Affairs

MRRD = Ministry of Rural Rehabilitation and Development

RWL = rest water level (i.e. static groundwater level)

USGS = United States Geological Survey

WSG = Water and Sanitation Group (set up by UNICEF in Afghanistan)

Google Earth imagery used in this report: As our primary intention in using these images is ***not*** to present the Google Earth images themselves, but rather to use them as a geographical reference background on which we project our own data, we claim that this falls within the definition of "reasonable and fair use" of these images.

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1 Objective

The objective of this report is to summarise a broad methodology for hydrogeological mapping at a Provincial level in Afghanistan.

The methodology is based on principles used by NORPLAN when carrying out hydrogeological mapping of Faryab Province in the period 2012-14, in the context of the project "*Capacity-Building and Institutional Cooperation in the Field of Hydrogeology for Faryab Province, Afghanistan*", funded by the Norwegian Government, via NORAD.

Methodologies for hydrogeological mapping will differ somewhat from region to region, as both climate and rock type vary considerably within Afghanistan. For example, while it may be possible to produce maps showing systematic and gradual trends in factors such as well-yield, water chemistry and water table level in areas underlain by extensive granular aquifers, this may not be possible in areas where most aquifers are fractured bedrock (granites, slates, limestones etc.). In the latter cases, a more probabilistic approach will usually be recommended. Such *non-parametric statistical approaches* have been pioneered in Scandinavia and the Czech Republic and can be found summarised, for example, in:

- **Banks, D., Morland, G. & Frengstad, B. (2005).** Use of non-parametric statistics as a tool for the hydraulic and hydrogeochemical characterization of hard rock aquifers. ***Scottish Journal of Geology***, 41(1), 69-79. doi 10.1144/sjg41010069

The objective of a hydrogeological survey is to ***characterise the groundwater resources of the area in terms of quantity (availability), depth and quality***.

The objective of a hydrogeological survey is **not** to simply produce a register of wells or water resources infrastructure. This is a management task and not a hydrological or geological task. Of course, a well-documented hydrogeological survey will contribute a lot of information to such a register (and *vice versa*), provided that the raw data are diligently documented and quality assured.

Any hydrogeological mapping should be undertaken in line with the broad principles enshrined in the guidelines of the **International Association of Hydrogeologists (IAH):**

- **Struckmeier, W.F. & Margat, J. (1995).** Hydrogeological maps: a guide and standard legend. ***International Contributions to Groundwater***, Vol. 17, International Association of Hydrogeologists, Heise, Hannover. Available at http://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/Beratung/Ihme1500/standard_legend_hydro_maps.pdf?__blob=publicationFile&v=1 and at http://iah.org/wp-content/uploads/2013/03/IAHbook_ICH17.zip.

See Part 1; Appendix A.

This methodology is published in two Parts.

- Part 1 provides the main explanation of the Survey Methodology
- Part 2 (this document) is regarded as a supplement and contains the more detailed methodology statements for field surveys used in Faryab. The statement are tailored to analysis of samples for hydrochemistry and isotopes at the British Geological Survey, UK, with some duplicate analysis at DACAAR. Depending on laboratories chosen during the evaluation of further Provinces, these method statements will need to be modified.

2 Rapid Well / Spring Survey

In the case of Faryab, the objective of this was to collect information on c. 200 wells, boreholes, springs and karezes in districts with relatively poor coverage of existing information.

2.1 The methodology document

The purpose of this survey is to provide additional hydrogeological data points (springs, karezes, dug wells, tube wells) in areas where the existing DACAAR database has little information. **Particular attention should be paid to recording natural springs and karezes, as these are especially informative as regards overall hydrogeology.**

The survey should thus aim to find springs, karezes and wells that DACAAR has no records of. The purpose should *not* be to revisit wells that DACAAR has existing knowledge of. Possible prioritized areas are:

- The four northern districts around Andkhoi plus northern Dowlatabad
- Kohistan (especially karstic springs)
- Bilchiragh (especially springs)
- Qaysar (especially springs)
- Almar

We should aim to use two teams to add 200 additional features to the database (i.e. 100 features per team), paying particular attention to large natural springs. The team should visit the District Governor and/or the representative of PRRD, at the start of the survey to ask permission to commence survey and to gather local knowledge about the existence of wells, springs and karezes.

At each site, record:

- GPS location (digital latitude and longitude), and mark manually on map
- Well or spring name, if any
- Village and district name
- Use of water feature (private supply, not used, public supply, institutional supply, irrigation etc.)
- If karez or spring, estimate flow rate
- Type of pump
- Diameter of well/borehole and casing material.
- Height of well top (flange) above ground level
- Date of construction
- Who was responsible for construction (driller, implementing partner, donor), if known
- Functionality (any problems?)
- Is there a functioning user association?
- Note appearance, taste or smell of water
- In the case of wells and boreholes, pump well for minimum 5 minutes (or empty using bucket), to ensure that “fresh” groundwater is being sampled.
- Then record: temperature, pH, EC, (oxygen or Eh).
- After pumping for 5 minutes: take water sample at one-third of features (see below).
- If feasible: remove hand pump rods and valve assembly:

(i) Dip static water level below well top (flange) – (make sure water level has “recovered” from pumping / pump removal)
(ii) Plumb total depth of well (if possible)

Water sampling

At one feature in every three (i.e. c. 67 localities), take:

- a 500 mL (unfiltered) water sample for analysis at DACAAR. Mark this sample with the suffix “U”.
- 1 x 60 mL plastic flask of filtered water for chemical analysis at BGS England (using syringe and disposable filter capsule, according to protocol ***Water samples for chemical analysis at BGS (England)*** in the document *Water sampling methodologies.doc*). Mark this sample with the suffix “F”. See Section 6.

At six of these 67 localities, a duplicate 60 mL filtered sample should be taken for “blind” duplicate analysis at BGS

Of these 67 sampled localities, at one in every three (around 22 localities), additional samples will be collected for isotope analysis at BGS (England):

- 1 x 15 mL plastic flask of filtered water for isotopic analysis at BGS England (according to protocol ***Water samples for isotopic analysis at BGS (England)*** in the document *Water sampling methodologies.doc*). Mark this sample with the suffix “FIs”. See Section 6.

Labelling

Note: all water samples should have a unique number, which should be recorded in waterproof pen on the bottle and recorded on the field sheet. For example:

NOR-GW-01 F

(NOR = NORPLAN, GW = Gurziwan district, 01 = sequential number)

This should be followed by one of the following suffixes

U = unfiltered

F = filtered

UIs = unfiltered, for isotope analysis

FIs = filtered, for isotope analysis

2.2 Location Recording Sheet

NORPLAN	**RAPID FIELD ASSESSMENT 2013** **FARYAB PROVINCE**		
Type of feature: Spring ☐ Dug well ☐ Drilled well ☐ Karez ☐			
District:	Village:	Well or spring name:	
Latitude/longitude (decimal):			
Approx. Elevation (m asl)	m above sea level (from GPS)		
(If karez, give reference of karez mouth and mark course of karez on sketch map)			
Use:	Public supply ☐ Private supply ☐ Institution (e.g. school or clinic) ☐ Irrigation ☐ Other:		
Type of pump:	Hand pump ☐ Electric submersible ☐ Bucket ☐ Other:		
If karez or spring, estimated flow rate		L/s	
Diameter of well:		mm	
Height of well top (flange) above ground level		cm above / below ground level	
Casing material:			
Date of construction:			
Driller:			
NGO / implementing partner:			
Donor:			
Water appearance			
Visual:	Taste:	Odour	
Field analysis (after 5 minutes pumping)			
pH	EC	Temperature	DO or Eh
	µS/cm	°C	mg/L or mV
Water sample no.			
500 mL unfiltered for analysis at DACAAR ☐	60 ml filtered sample for chemical analysis in England ☐	15 ml filtered for isotope analysis in England ☐	
Static water level		m below well top	
Total depth		m below well top	
Is the well working as intended? Yes ☐ No ☐ If No, describe problem			
Is the there a community association managing the well: Yes ☐ No ☐ If Yes, provide details			
Recorded by:	Date:	Time:	
Name:			

3 Precipitation Survey

3.1 The methodology document

The objective of a precipitation (rain / snow) survey is to establish the chemical and isotopic signature of rainfall in Faryab, which will, in turn, shed light on the recharge mechanisms for groundwater and the mechanisms of soil salinisation.

There are two possible methods for obtaining samples of rainfall or snowfall. Whichever method is selected should be initiated by late autumn 2012, in order to collect samples during winter and spring 2012-13.

Method 1:

Liaise with Ministry of Water, MAIL and Meteorological Institute to ascertain if they can obtain samples of precipitation from existing meteorological stations. As far as we know these stations are:

Station	Longitude	Latitude	Altitude (m asl)
Maimana	64.772	35.931	860
Gurziwan	64.358	37.178	1380
Andkhoi	65.124	36.959	295

Possible points of contact may be :

- Mohammad Fareed Oriya, Deputy Project Manager of the Agromet Project at Ministry Of Agriculture (MAIL).
- Dr Shobair at Ministry of Water
- Mr Fahim Zaheer at USGS

The main points are that we require

- several 10s of mL (ideally 100 mL) of rainfall or snowmelt from each of the stations,
- ideally a sample from at least 2 (and preferably 3) episodes in different seasons.

The people collecting the samples must be aware that natural chemical concentrations in rain and snow are very low and the samples are thus easily contaminated. The key points are:

- Rain samples should be collected using clean plastic funnels into new polythene sample containers (if necessary, we can provide 500 mL or 100 mL flasks).
- Newly fallen snow can be collected (using a clean plastic trowel or spoon if necessary) into several 500 ml polythene sampling flasks and allowed to melt.
- Contact with human hands or any foreign object should be avoided.
- Samples should ideally not contain any wind-blown dust or debris (flies, leaves etc.).
- After the rainfall or snowfall episode the collected sample should be transferred to a new, clean 100 ml HDPE sample bottle and sealed.
- Ideally the 100 mL flask should be filled, if possible. If there is sufficient water, fill as many 100 mL flasks as possible.

Method 2:

DACAAR would set up the three precipitation collection points: ideally one in the mountains south of Maimana, one in Maimana and one in the north of the Province (Andkhoi?). The stations will only be set out during a rainfall/ snowfall event, as detailed above. DACAAR would then be responsible for sampling the rainfall or snow, as detailed above.

Thus, as a result of this survey, we would end up with 6-9 sets of samples:

- 2-3 sets of samples from each of three stations

The samples should be sealed tightly, kept in a cool, dark place (around 4°C, but not allowed to freeze).

The samples should be transported to DACAAR in Kabul as soon as possible, ideally in a coolbox or similar.

The samples would then be sent to BGS (England) for

- Analysis of chemical components at very low detection levels (using ICP-MS and similar methods)
- Analysis of hydrogen and oxygen isotopes

3.2 Location Recording Sheet for Precipitation Survey Samples

NORPLAN	**PRECIPITATION SAMPLE 2013 FARYAB PROVINCE**	
Precipitation station name:		
District:	Village:	Location name (if any):
Latitude/longitude (decimal):		
Approx. elevation (m asl)		
Date of sample		
Description of sample and sample event	e.g. rainwater sample during 3 hour rainfall event ***or*** snowfall sample of snow pack after 26 hours of snow	
Type of land use and terrain		
Sample number		
Number of flasks filled	e.g. 2 x 100 mL flasks	
Recorded by:	Date:	Time:
Name:		

4 River Profile Survey

4.1 The methodology document

The purpose of this survey is to provide information on how the flow and chemistry of the main rivers change along their length. This, in turn, provides information regarding groundwater recharge processes.

The survey should be timed such that the rivers are not in flood and yet such that there is discernible flow along the majority of the length of the rivers. Provisionally, we have suggested that April/May 2013 may be the optimal time for this, although this should also be verified by local information.

The surveys should be carried out along 2 reaches of river:

1) the course of Shirin Tagab River through Shirin Tagab and Dowlatabad Districts, from around Sar-e-Qala (36.106 64.855) to around 10 km north of Pata Taba (c. 36.688 64.900). This represents a profile of around 70 km

2) the course of Maimana River from Maimana city through Shirin Tagab district to Jalaier Chokazi. This represents of profile of around 70 km.

River Stations

The team(s) will drive downstream along the course of the two rivers and will stop every c. 5 km (this will depend on access and security: the exact distance is not critical) to record the river profile. I.e. around 15 River Stations per river (30 River Stations in total).

The team should visit the District Governor and/or the representative of PRRD, at the start of the survey to ask permission to commence survey. **During the survey any springs or karezes encountered should be recorded.**

At each River Station (every 5 km), record:

- GPS location (digital latitude and longitude), and mark manually on map
- Village and district name
- Take at least two digital photographs of the river channel (upstream and downstream views), and record date and time of photo.
- Describe the river at this point – single deep channel, many shallow channels etc.
- Estimate width of flowing river channel and its depth at the centre of the channel
- Use floating objects to record velocity of water in centre of channel (m/s)
- Estimate flow rate of river
- Record water temperature, electrical conductivity and pH, using field meters.
- Record any use of the river water (human drinking water, livestock, irrigation)
- Record land use in area.
- Record any major changes in flow since the previous (upstream) station
- Take water samples, as indicated below

Water sampling

At every second River Station (i.e. every 10 km), take:

- a 500 mL (unfiltered) water sample for analysis at DACAAR (8 samples per river: 16 samples total). Mark this sample with the suffix “U”.

- 1 x 60 mL plastic flask of filtered water for chemical analysis in England (using syringe and disposable 0.45 µm filter capsule, according to protocol ***Water samples for chemical analysis in BGS (England)*** in the document *Water sampling methodologies.doc*). Mark this sample with the suffix “F”. Filtration is important, as river water samples typically contain many particles. See Section 6.

At 4 of these locations, a second, filtered duplicate 60 mL sample should be taken for analysis at BGS (England)

At every fourth location (i.e. every 15-20 km), additional water samples will be taken for isotope analysis at BGS, UK (i.e. 4 samples per river – at the start and end of the profile and at two intermediate points - 8 samples total). At each isotope sampling location:

- Take 1 x 15 mL plastic flask of filtered water for isotopic analysis in England (using syringe and disposable 0.45 µm filter capsule, according to protocol ***Water samples for isotopic analysis in BGS (England)*** [Step 26, Section 6] in the document *Water sampling methodologies.doc*). Mark this sample with the suffix “FIs”. Filtration is important, as river water samples typically contain many particles.

Labelling

Note: all water samples should have a unique number, which should be recorded in waterproof pen on the bottle and recorded on the field sheet. For example:

NOR-GW-01 F

(NOR = NORPLAN, GW = Gurziwan district, 01 = sequential number)

This should be followed by one of the following suffixes

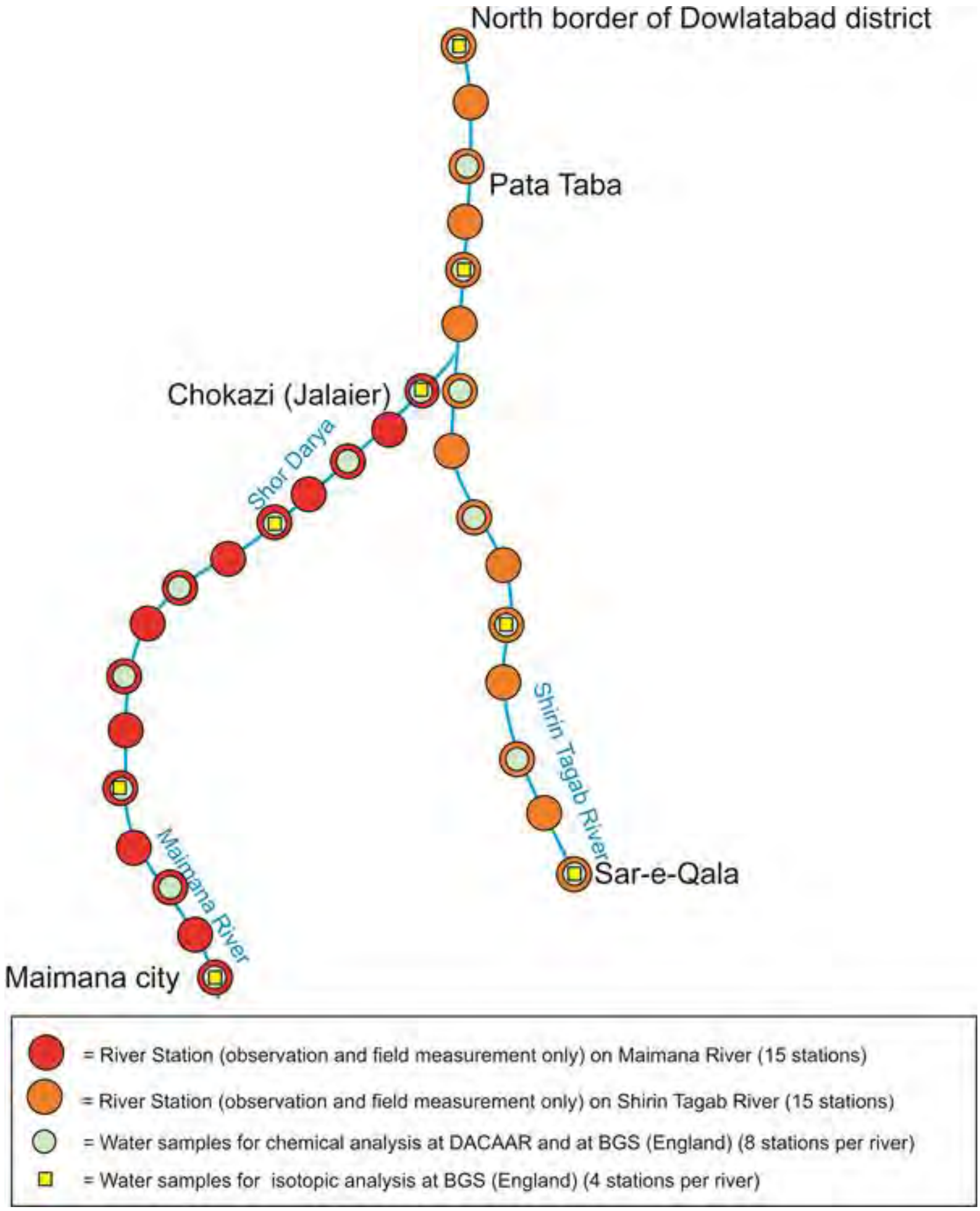
U = unfiltered

F = filtered

UIs = unfiltered, for isotope analysis

FIs = filtered, for isotope analysis

4.2 Schematic of River Sampling



N.B. Note that, in reality, it was not possible to sample the entire river lengths as indicated in this schematic, due to security concerns.

4.3 Location Recording Sheet for Each River Station (every c. 5 km)

NORPLAN	**RIVER PROFILE SURVEY 2013 FARYAB PROVINCE**		
River name:			
District:	Village:	Location name (if any):	
Latitude/longitude (decimal):			
Approx. Elevation (m asl)	m above sea level (from GPS)		
Use of river:	e.g. human potable water supply, livestock, irrigation		
Surrounding land use:	e.g. urban, irrigated land, semi-desert		
Number of photographs Camera reference			
Date and time of photographs			
Description of river channel	e.g. single deep channel, multiple channels		
Width of flowing river channel (m)			
Depth at centre of channel (cm)			
Estimated flow velocity at centre of channel	_______ metres in ______ seconds		
Estimate of flow rate (m3/s)			
Basis for estimate			
Any major change in flow since last locality?			
Appearance of water			
Field analysis			
pH	EC	Temperature	
	µS/cm	◦C	
Water sample no.			
500 mL unfiltered for analysis at DACAAR "U" ☐	60 ml filtered sample for chemical analysis in England "F" ☐	15 ml filtered for isotope analysis in England "FIs" ☐	Other ☐
Recorded by:	Date:	Time:	
Name:			

4.4 Location Recording Sheet for any Springs / Karezes Encountered

NORPLAN	**RAPID FIELD ASSESSMENT 2013** **FARYAB PROVINCE**	
Type of feature: Spring ☐	Dug well ☐ Drilled well ☐ Karez ☐	
District:	Village:	Well or spring name:
Latitude/longitude (decimal):		
Approx. Elevation (m asl)	m above sea level (from GPS)	
(If karez, give reference of karez mouth and mark course of karez on sketch map)		
Use:	Public supply ☐ Private supply ☐ Institution (e.g. school or clinic) ☐ Irrigation ☐ Other:	
Type of pump:	Hand pump ☐ Electric submersible ☐ Bucket ☐ Other:	
If karez or spring, estimated flow rate		L/s
Diameter of well:		mm
Height of well top (flange) above ground level		cm above / below ground level
Casing material:		
Date of construction:		
Driller:		
NGO / implementing partner:		
Donor:		
Water appearance		
Visual:	Taste:	Odour

Field analysis (after 5 minutes pumping)			
pH	EC	Temperature	DO or Eh
	µS/cm	◦C	mg/L or mV

Water sample no.		
500 mL for unfiltered for analysis at DACAAR ☐	60 ml filtered sample for chemical analysis in England "F" ☐	15 ml filtered for isotope analysis in England "FIs" ☐
Static water level		m below well top
Total depth		m below well top
Is the well working as intended? Yes ☐ No ☐ If No, describe problem		
Is the there a community association managing the well: Yes ☐ No ☐ If Yes, provide details		
Recorded by:	Date:	Time:
Name:		

Note that the form is intended to for wells, boreholes, springs and karezes. Ignore references to "pumping" for springs and karezes.

5 Soil Salinity Survey

This may not be found necessary in hydrogeological surveys of other provinces than Faryab.

5.1 The methodology document

The purpose of this survey is to provide information on the accumulation of salts in the subsoil in the semi-desert areas of the province.

The survey should be carried out as part of either the Rapid Well/Spring Survey (Section 2) or as part of the River Profile Survey (Section 4). It should not be necessary to organize a separate sampling expedition solely for soils.

Eight locations should be sampled. The following suggested locations are tentative only – they are subject to access and security:

3 on Neogene deposits

- on east side of Shirin Tagab and south of Astana Valley around 36.122 N 64.939 E
- on east side of Shirin Tagab around 36.286 N 64.982 E
- to the south of Maimana around 35.823 N 64.737 E

3 on Quaternary alluvial deposits

- just south of Maimana (but not on agricultural or urban land) c. 35.889 N 64.777 E
- in the Shirin Tagab Valley, near Pata Taba, c. 36.558 N 64.910 E
- in the semi-desert area of Qaram Qul, c. 36.847 N 64.989 E

2 on loess deposits

- just NW of Maimana at around 35.944 N 64.705 E
- between Shirin Tagab and Maimana Rivers in northern part of Shirin Tagab district, e.g. around 36.305 N 64.836 E

These grid references should only be construed as highly indicative - the objective should be to obtain a good distribution between different subsoil geologies and locations in the catchments.

At each of the eight sites

- Security and possibility of mines should be assessed
- A trial pit should be excavated to around 70 cm by hand. On completion, the trial pit should be photographed. The soils encountered should be described and logged by a geologist.
- The trial pit should be in “natural soil” - i.e. away from main roads, agricultural land or town/urban areas or any source of human contamination.
- Two x 1.5 kg samples of soil should be taken from *around* 40 cm depth in the trial pit. The samples should always be taken from below any organic soil layer. The two samples should be taken from opposite sides of the trial pit.
- Two x 1.5 kg samples of soil should be taken from *around* 70 cm depth in the trial pit. The samples should always be taken from below any organic soil layer and from opposite sides of the trial pit.
- During sampling, hand contact with the soils should be minimal. Samples should be taken from the wall of the pit using either (a) a stainless steel, unpainted trowel or spade, or a clean plastic trowel.
- In addition, if any salt horizon or hardpan horizon is encountered, a single sample should be taken.
- Samples should not be taken from below any water table.
- Each trial pit should be photographed and GPS coordinates taken.
- Four samples should thus be taken from each site. Each should be packed separately in geochemical grade strong brown bags / sealable polyethene bags or clean polythene sealable sample boxes.

- Samples should be clearly labelled with location, sample number, date, depth and sampler.
- The trial pit should be backfilled safely after sampling.
- Samples should be stored in the cool and dark and returned to DACAAR's Kabul laboratory for analysis as soon as possible.

Note: all soil samples should have a unique number, which should be recorded in waterproof pen on a label on the soil sample bag and recorded on the field sheet. For example:

NOR-GW-SS-01 40a

(NOR = NORPLAN, GW = Gurziwan district, SS = soil sample, 01 = sequential number)

This should be followed by one of the following suffixes

40a or 40b = samples collected at 40 cm

70a or 70b = samples collected at 70 cm

5.2 *Location Recording Sheet for Soil Survey Points*

NORPLAN	**SOIL SALINITY SURVEY 2013 FARYAB PROVINCE**	
District:	Village:	Location name (if any):
Latitude/longitude (decimal):		
Approx. elevation (m asl)		
Land use:	e.g. urban, irrigated land, semi-desert	
Number of photographs Camera reference		
Date and time of photographs		
Soil samples Cm below ground level (bgl)	Sample reference:	Depth (cm bgl):
	Sample reference:	Depth (cm bgl):
	Sample reference:	Depth (cm bgl):
	Sample reference:	Depth (cm bgl):
Sketch and Description of soil profile	Column / Depth / Description 0 cm 70 cm	
Recorded by:	Date:	Time:
Name:		

6 Water Sampling Methodology

Before Measuring or Sampling

1. Before sampling, wells and boreholes should be pumped (or emptied by bucket) for at least 5 minutes before any measurement or sampling commences (to ensure “fresh” water is sampled). Where wells and boreholes are in regular use, this may not be necessary.

2. Flowing springs or karezes can be measured / sampled directly

Field Measurements

3. At each site, field measurements should be made of electrical conductivity, pH and temperature. These measurements should be made as close to the source as possible and preferably in running water.

   - for flowing springs and karezes, the measurements can be made directly in the flowing water.
   - In the case of a handpump, one person can pump the borehole slowly into a clean overflowing bucket, while the second person takes the field measurements in the overflowing bucket.
   - Otherwise, water can be collected in a clean bucket and measurements can be made without delay in the bucket.

4. The calibration of the pH meter should have been checked at least every three days against standard buffer solutions (as the pH of most natural groundwaters is in the range 7-9, the calibration should be made between buffer solutions of pH 7 and pH 10.

Samples

5. Samples should be taken directly from the source or, if this proves impossible, from a clean, rinsed, plastic bucket filled with water from the source.

6. Before sampling, all sample flasks, caps and syringes should be rinsed with the water which is to be sampled.

7. All samples should be marked with the following information (markings should preferably be in indelible pen on a self-adhesive, waterproof label):

   - Sample number (the sampler should also record the sample number on the field sheet and keep a register of all the sample numbers). This should have the form:

     NOR-GW-01 F
     (NOR = NORPLAN, GW = Gurziwan district, 01 = sequential number)

     This should be followed by one of the following suffixes

     U = unfiltered
     F = filtered
     UIs = unfiltered, for isotope analysis

FIs = filtered, for isotope analysis

- The date
- The location

8. When samples have been taken, make sure that all the labels are legible and that all data / sample numbers have been carefully and legibly recorded in a field book.

9. Store samples in the dark in a cool place (e.g. a refrigerator but *not* a freezer). Transport samples in a dark cool place (e.g. a cool box). Do not freeze the samples. Send to laboratory and analyse as quickly as possible.

Protocol 1: Standard water samples for analysis at DACAAR

10. Label the 500 mL bottle with a waterproof marker showing time and date and the sample number with a suffix "U" (meaning that the sample is unfiltered).

11. The 500 mL analytical grade PE flask should be rinsed with the water to be sampled three times. Contact should be avoided between the sampler's fingers and the inside or rim of the bottle or cap.

12. The flask should be filled to the top, either by submerging the flask in the source or by letting water run into the flask.

13. The cap should be screwed firmly on the flask, avoiding contact between the samplers' fingers and the inside of the cap.

Protocol 2: Water samples for chemical analysis at BGS (England)

14. Label the 60 mL bottle with a waterproof marker showing time and date and the sample number with a suffix "F" (meaning that the sample is filtered).

15. The 60 mL analytical grade PE flask should be rinsed with the water to be sampled three times. Contact should be avoided between the sampler's fingers and the inside or rim of the bottle or cap.

16. The polypropylene syringe should be filled with water from the source and then ejected. This should be repeated three times to clean the syringe.

17. The polypropylene syringe should be filled with water from the source and a 0.45 μm filter fitted to the nose of the syringe.

18. The syringe should be slowly depressed to force a small amount of filtered water into the flask. The cap should be placed on the flask and the flask shaken to rinse the flask with filtered water. The water in the flask should then be discarded. This step should be repeated.

19. We are now ready to take the sample !

20. The polypropylene syringe should be filled with water from the source and the same 0.45 μm filter fitted to the nose of the syringe.

21. The syringe should be slowly depressed to force sufficient filtered water to fill the flask (the filter can be carefully removed when the syringe is to be refilled, and then replaced).

22. When full, the cap should be screwed firmly on the flask.

23. When the water contains a lot of particles, it may be necessary to use 2 or more filters to collect a sample, as the filter becomes clogged. For each new filter, allow the first few drops of filtrate to run to waste, before continuing to fill the sample flask.

24. With very turbid water, it may not be realistic to fill the entire flask. This is OK.....but we typically need a *minimum* of 30-40 mL for analysis.

25. Throughout entire procedure, avoid contact between fingers and the interior of the flask and cap, the rim of the flask and cap, the nozzle of the syringe and the two ends of the filter. Also avoid contact between the ground (or any other dirty surface) and these points.

Protocol 3: Water samples for isotopic analysis at BGS (England)

26. Use a 15 mL PE or glass flask to collect a filtered water sample for isotope analysis, using, Protocol 2, steps 14 to 23. You should fill the entire flask (negligible air space). Mark the sample “FIs”.

NOTE on sampling for isotopic analysis

If (and only if) you have difficulty collecting a full filtered flask (15 mL) for isotopic analysis, because the water has too many particles, *then* you can either:

(i) collect a 15 mL flask of unfiltered water, using essentially the same principles as Protocol 1 steps 10-13, but labelling the flask “UIs”. You should fill the entire flask (negligible air space).

OR

(ii) collect an additional full 500 mL flask of unfiltered water. When you return to base or to the lab, let this flask stand still for 1-2 days. Allow the particles to settle. Then use the syringe to take particle-free water from the top of the flask - use a disposable filter capsule to filter the water into the 15 mL flask, which can then be labelled “FIs” (meaning that the sample is filtered for isotopic analysis).

For isotopic analysis it is important that the 15 ml flask is full (negligible air space) and tightly sealed. Flasks should ideally be glass with a gas-tight seal, although HDPE can be used in most cases if the delay before analysis is not excessive. The top of the flask can be wrapped in laboratory “Parafilm” to hinder evaporation.

NOTE: Duplicate samples (applies to all types of analysis)

At around 10% of sites, duplicate sample sets should be taken and submitted to the laboratory. This in order to verify the analytical reproducibility of the results.

7 Soil Extraction / Analysis Methodology

Samples returned from field should be around 1.5 kg (see Chapter 5).

1. The samples should be spread out on a clean tray and allowed to dry at ambient room temperature at the laboratory. The location for drying must be clean and dust-free. The dried sample should be weighed.

2. The sample should then be passed through a clean 2 mm nylon mesh or sieve: this process can be assisted by hand, provided the technician is wearing clean ***talcum-free*** rubber or latex gloves.

   Note that David has purchased some 2 mm mesh, which can be stretched over a simple clean wooden frame to make a sieve.

3. The proportion of the sample passing through the mesh and the proportion retained should be measured by weighing.

4. 20 g of the < 2 mm fraction should be added to a clean 500 mL flask with 400 mL of deionised/distilled water and shaken for 1 hr.

5. The flask should then stand for 20 hours in the laboratory to allow the solid fraction to settle.

6. The supernatant liquid should then be extracted using a clean syringe, filtered through a 0.45 µm filter into a clean flask.

7. The liquid should be analysed for the following:

   Electrical conductivity, pH, Na, Ca, Mg, K, $SO_4^{=}$, HCO_3^- $CO_3^{=}$, Cl^-, F^-, NO_3^-

<u>**Duplicate samples**</u>

8. For all of the samples delivered to the lab (i.e. all 32 samples), the extraction procedure (Steps 1-6 above) should be duplicated for a second 20 g quantum of the < 2mm fraction.

9. From the supernatant liquid resulting from these 32 duplicates, 60 ml of the supernatant liquid should be filtered (0.45 µm filter) into a clean new 60 mL polythene flask and shipped to BGS (England) for duplicate analysis.

<u>**Quality control**</u>

10. Additionally, for quality control, four 60 mL samples of the distilled/deionised water should be subject to the “shaking/settlement” procedure, before being analysed, *without the addition of any sediment*. These “blank” samples should be labelled NOR-SS-B1, NOR-SS-B2, NOR-SS-B3, NOR-SS-B4 and submitted to BGS (England) for analysis.

Calculation

11. The concentration (C_{liq}) mg/L in the supernatant fluid can be converted back to a soluble salt content in the air-dried solid (C_{sol}) by the formula:

    C_{sol} (mg/kg) = C_{liq} (mg/L) x 0.4 x 50 = C_{liq} (mg/L) x 20

NOTE: The flasks should be labelled with the same sample number as the soil samples. I.e.

All soil samples should have a unique number, which should be recorded in waterproof pen on a label on the soil sample bag and recorded on the field sheet. For example:

NOR-GW-SS-01 40a

(NOR = NORPLAN, GW = Gurziwan district, SS = soil sample, 01 = sequential number)

This should be followed by one of the following suffixes

40a or 40b = samples collected at 40 cm

70a or 70b = samples collected at 70 cm

8 Site-Specific Geophysical and Drilling Investigations

In Section 9 of Part 1 of this document, it was pointed out that, as part of a Provincial Hydrogeological Survey, it may be necessary to carry out geophysical or drilling investigations / test pumping at one or more specific sites. The reasoning behind such surveys is discussed in Section 9, Part 1.

For such activities, whether for investigative purposes, or for the full scale development of a new groundwater source, there are several steps of pre-assessment to go through.

In this document, we will only address the technical assessments directly related to hydrogeology. Of course, there are a number of other assessments that need to be done, including:

1. Social and demand assessment. Who requires the investigation or new borehole? The authorities? The community? Specific individuals in the community? How can the demand be demonstrated? Who will own the resulting borehole? Who will manage it? What level of service is demanded and how willing are people to pay?
2. Stakeholder assessment. Who will gain from the investigation / new groundwater source ? Who will lose? and how?
3. Economic assessment. Who will pay for the borehole, and how? Who will be responsible for the running costs and maintenance? How will revenue be generated? Will be source be run as a private business, a public business or a social service? How will depreciation / eventual replacement of components be financed?
4. If solely an investigation is proposed, is it appropriate to involve the local community or authority figures? Can any boreholes resulting from investigations responsibly be converted, after the investigation, to the community as functional water wells?

Overarching these socioeconomic analyses, will be some consideration of gender and how the proposed investigation or development will relate to the needs, wishes and interests of men and women (and such an analysis may be extended to other identified interest groups such as children, the elderly and disabled).

Before visiting the proposed site:

5. A security assessment will need to be carried out by an authorised and responsible person, which should include an assessment of risk from landmines or UXO.

For an intrusive investigation, test drilling, test pumping or small-scale groundwater abstraction well or borehole, we would recommend that the following technical / hydrogeological surveys are additionally carried out:

6. ***Walkover Survey*** and ***Water Features Survey***. The purpose of this should be to identify other water points (springs, karezes, wells) that may be affected adversely by drilling, test pumping or groundwater abstraction. Such negative affects may be related to ground stability, vibration, water contamination, or drawdown of water level. The walkover survey should also identify potential sources of contamination that may affect any newly drilled well or borehole (latrines, defecation areas, fuel stores, pesticide stores etc.). Section 8.1 provides a form for recording findings. Section 8.2 provides a fictional completed assessment.
7. ***Environmental Impact Assessment***: to evaluate whether the investigation or drilling activity poses risks to the environment or to neighbouring inhabitants or businesses. Section 8.3 provides an Environmental Impact Assessment checklist.

8. ***Desk study***. Don't start an intrusive or geophysical investigation until you have evaluated all the *existing* information systematically. Sections 8.4 and 8.5 provide two real desk studies for two proposed sites in Faryab Province.

8.1 Water Features Survey Report

WATER FEATURES SURVEY REPORT

Explanatory note:

A Water Features Survey is a brief field survey which is performed **before** drilling a new well or borehole.

Its MAIN purpose is:

- To identify any other water features (boreholes, wells, springs, karezes, streams or rivers) that might be affected by drilling, testing or pumping the proposed new well.

Any water features identified can be monitored during drilling and test pumping. If necessary, action should be taken to mitigate any adverse affects.

The SECONDARY purpose is

- To collect additional information from nearby water features that will help in planning the new well or borehole. Such as water level, electrical conductivity, pH, yield etc.

The SEARCH RADIUS of the Water Features Survey will be related to the pumping rate of the new borehole:

- For a hand-pump well, a radius of 100 - 200 m should usually be enough.
- For a motorised well, you may need to consider a radius of 500 m or more, depending on pumping rate.

See Banks, D. & Soldal, O. 2002. Towards a policy for sustainable use of groundwater by non-governmental organisations in Afghanistan. *Hydrogeology Journal* **10**, 377-392.

and Guidelines for the Sustainable Use of Groundwater in Afghanistan at http://www.holymoor.co.uk/Poldok.PDF

At the same time as doing the Water Features Survey, you can also identify potential pollution sources that may affect your new well, and note the details on the Table. These may include:

- Latrines
- Depots of fuel and petrol
- Depots of agricultural chemicals, etc.

WATER FEATURES SURVEY REPORT

For (location): ____

Search radius: ____

Carried out (dates): ____

MAP / GOOGLE EARTH PHOTO of locality, showing features

Feature ID (on map): ______________ **Grid ref:** ____________**E** ___________ **N** **Type:** River / Lake / Spring / Dug well / Drilled borehole / Karez / Other **Description:** (to include: depth, static water level, use, ownership, construction details, water quality) **Owner:**	Photo
Feature ID (on map): ______________ **Grid ref:** ____________**E** ___________ **N** **Type:** River / Lake / Spring / Dug well / Drilled borehole / Karez / Other **Description:** (to include: depth, static water level, use, ownership, construction details, water quality) **Owner:**	Photo
Feature ID (on map): ______________ **Grid ref:** ____________**E** ___________ **N** **Type:** River / Lake / Spring / Dug well / Drilled borehole / Karez / Other **Description:** (to include: depth, static water level, use, ownership, construction details, water quality) **Owner:**	Photo

ALTERNATIVELY: A full registration form can be filled out for each feature.

Feature ID (on map)			
Type of feature: Spring ☐ Dug well ☐ Drilled well ☐ Karez ☐			
Province and District:	Village:	Well or spring name:	
Latitude/longitude (decimal):			
Approx. Elevation (m asl)	m above sea level (from GPS)		
(If karez, give reference of karez mouth and mark course of karez on sketch map)			
Use:	Public supply ☐ Private supply ☐ Institution (e.g. school or clinic) ☐ Irrigation ☐ Other:		
Type of pump:	Hand pump ☐ Electric submersible ☐ Bucket ☐ Other:		
If karez or spring, estimated flow rate		L/s	
Diameter of well:		mm	
Height of well top (flange) above ground level		cm above / below ground level	
Casing material:			
Date of construction:			
Driller:			
NGO / implementing partner:			
Donor:			
Water appearance			
Visual:	Taste:	Odour	
Field analysis (after 5 minutes pumping)			
pH	EC	Temperature	DO or Eh
	µS/cm	◦C	mg/L or mV
Water sample no.			
_______ mL unfiltered ☐	_______ mL filtered ☐	Other ☐	
Static water level		m below well top	
Total depth		m below well top	
Is the well working as intended? Yes ☐ No ☐ If No, describe problem			
Is the there a community association managing the well: Yes ☐ No ☐ If Yes, provide details			
Recorded by:	Date:	Time:	
Name:			

NORPLAN

POLLUTION SOURCES

Feature ID (on map): _______________ **Grid ref:** _____________**E** ____________ **N** **Description of pollution source:** **Owner:**	Photo
Feature ID (on map): _______________ **Grid ref:** _____________**E** ____________ **N** **Description of pollution source:** **Owner:**	Photo
Feature ID (on map): _______________ **Grid ref:** _____________**E** ____________ **N** **Description of pollution source:** **Owner:**	Photo

8.2 Fictional Example of a Water Features Survey Report

WATER FEATURES SURVEY REPORT

For (location): __Lal wa Sarjangal, Ghor Province_____

Search radius: __500 m (proposed borehole with handpump)___

Carried out (dates): ___12th August 2013____

Feature ID (on map): __LAL001______ **Grid ref: __66.2842____E __34.5020___ N** **Type:** ~~River / Lake / Spring / Dug well /~~ Drilled borehole ~~/ Karez / Other~~ **Description:** (to include: depth, static water level, use, ownership, construction details, water quality) Drilled borehole 73 m deep. Static water level 40 m bgl. PVC 100 mm casing Fitted with handpump and used for communal supply. Water quality good, EC = 600 µS/cm. **Owner:** Owned by community water council, managed by DACAAR.	
Feature ID (on map):LAL002 (karez mouth) **Grid ref: __66.2831____E __34.4973___ N** **Type:** ~~River / Lake / Spring / Dug well / Drilled borehole /~~ Karez ~~/ Other~~ **Description:** (to include: depth, static water level, use, ownership, construction details, water quality) Karez 1.4 km long extending SSW from mouth Flow measured to be 0.3 L/s Used for drinking water and limited agricultural purposes including irrigation. Water quality good EC = 740 µS/cm **Owner:** Owned by community and managed by mirab xxx xxx	
Feature ID (on map): _LAL003_______ **Grid ref: __66.2812____E __34.5023___ N** **Type:** River / ~~Lake / Spring / Dug well / Drilled borehole / Karez / Other~~ **Description:** (to include: depth, static water level, use, ownership, construction details, water quality) River Hari Rud Braided river flowing west. Estimated flow on 12/8/13 = 2 m^3/s Water quality fresh 400 µS/cm Used for watering livestock	

8.3 *Environmental Impact Assessment Checklist*

ENVIRONMENTAL IMPACT ASSESSMENT: DRILLING ACTIVITIES

NOTE: This assessment should be undertaken in addition to:

- Water features survey, whose radius will be related to the proposed pumping rate, but which may extend to several km for very large abstractions (see Sections 8.1 and 8.2).

For boreholes which are to be used with motorised pumps the following assessments should also be undertaken:

- Full hydrogeological impact assessment, using, as a minimum criteria, the guidelines suggested by **Banks, D. & Soldal, O. 2002:** *Towards a policy for sustainable use of groundwater by non-governmental organisations in Afghanistan.* **Hydrogeology Journal** 10, 377-392.

For exploratory drilling or drilling of water supply boreholes

Before commencing drilling, the following factors should be considered:

1. Is there any well, borehole, spring or karez located within 200 m of the proposed drilling site?	*If so, you should make an assessment of whether the drilling activity could negatively impact the level or quality of water within the other source. This will depend on the drilling method and hydrogeology of the site. Use of large qualities of drilling fluid, or extensive pumping / air lift may have impacts.*
Response:	
2. Is there a risk that any pipeline, cable, karez or other underground structure may occur below the drilling site?	*Ascertain the course of such underground services and avoid them.*
Response:	
3. Is there any possibility of encountering artesian water during drilling?	*Avoid drilling in such situations. Uncontrolled outflow of artesian water can cause flooding and is a gross waste of water resources. Before penetrating the artesian horizon, a string of plain casing, with a sealable flange plate, should be securely grouted into the strata overlying the artesian aquifer. This allows any flow of artesian water to be controlled (this step is essential with percussion drilling: artesian flows may also be controlled during mud-flush rotary drilling by an appropriately dense mud)*
Response:	
4. Is there any risk of encountering natural gas or oil during drilling?	*Avoid drilling at this location! If essential, prepare a thorough contingency plan to avoid the risk of explosion, asphyxiation or oil leakage from the well.*
Response:	

5. Is the drilling site located within 30 m of a load-bearing wall or foundation, or artificial embankment?	*Evaluate whether drilling activities could affect the integrity of the structure: this is particularly important for drilling methods using percussion (cable tool, down-the-hole hammer)*
Response:	
6. Is there any risk of contamination (other than contamination related to agricultural manure or normal sanitation activities) at the site?	*Ascertain the nature of the contamination. If significant, avoid the site. If drilling is unavoidable, develop a detailed health and safety plan which provides adequate protection for drilling workers and the public. Any pumped groundwater or drilling cuttings may need to be treated as hazardous waste, requiring removal from site and appropriate disposal.*
Response:	
7. If the drilling activity requires provision of water (e.g. to mix drilling fluid or grout), where will the water be obtained from, and will it be of suitable quality (i.e. not saline)?	*Agree with the local community where the water will be obtained from, whether any payment will be required. Ensure that extraction of water will not infringe others' rights to the water and that the community and/or owner understand the quantities and timings of water usage.*
Response:	
8. How will any pumped water or drilling fluid from the borehole be disposed of?	*Usually disposal of such water in rural areas should not be problematic. Ensure that adequate pipe-work exists to remove the pumped fluids from the drilling site to a suitable recipient, without risk of local flooding or inundation of houses or areas regularly used by the local community. If chemical additives have been used in the drilling fluid, you should ensure that these are non-toxic and can be responsibly disposed to the intended recipient. If the pumped groundwater is saline, avoid disposing of it to arable fields or to recipients which have immediate potable water resource value.*
Response:	
9. How will any drilling cuttings be disposed of?	*Drilling cuttings are typically natural soils and should be able to be unproblematically disposed of to rural land in the vicinity of the drilling site. Avoid, however, unsightly piles of cuttings and heaps of material which may obstruct roads, tracks or pathways. If the drilling cuttings are saline, avoid disposing of these to arable land or in the vicinity of potable water sources.*

Response:	
10. Have you considered the impact of noise and fumes on nearby residents, businesses or institutions (schools, clinics)?	*Consider the impact of drilling noise and fumes on the local residents, schools etc. Talk to them and endeavour to agree a drilling plan which avoids unnecessary excessive disturbance.*
Response:	
11. How will fuel and oil products be managed?	*All fuel and oil products should be stored within a designated area, which should be outside the source protection zone of any water source. All storage containers should be robust, undamaged and free from leaks. Appropriate equipment should be provided for filling of equipment (rig, generators, compressors etc.), which minimises the risk of spillage and leaks. A response plan should be developed, which can be implemented in the case of serious spillage of hydrocarbons. If storage of hydrocarbons within a water source protection zone cannot be avoided, "double barrier" storage of hydrocarbons or other solvents should be implemented.*
Response:	
12. How will solid waste from the site and drillers' camp be disposed of?	*You should avoid any risk of unsanitary conditions or vermin, and any risk of litter. A responsible final and permanent solution to litter disposal should be sought. Safe and responsible "recycling" of non-contaminated materials or containers to the community may be an option.*
Response:	
13. How will public access to the drilling site be restricted?	*Drilling sites are dangerous places. Public access should be restricted. Develop a plan for how you will prevent public access to the drilling site or the vicinity of any mud pit. (As a rough rule of thumb, public access should be excluded from the "falling radius" of the drilling mast.)*
Response:	

8.4 *Faryab Desk Study 1: Maimana Airport Investigation Site*

Location

The proposed study area is located immediately NW of Maimana city.

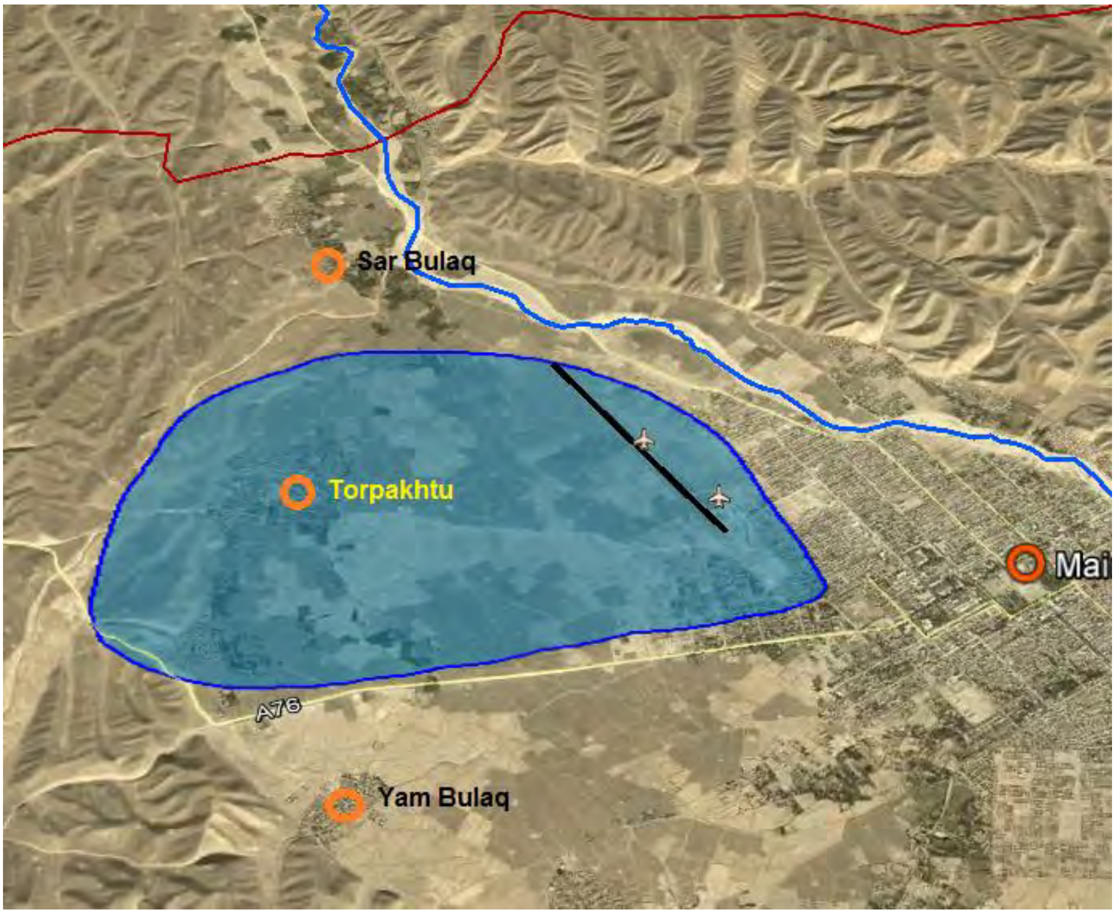


Figure 1. Location of Maimana study area (Google Earth). (Airport runway shown as black line and is c. 1.65 km long). The blue line shows the Maimana River, flowing north.

The study area occupies a flat plain, sloping gently from around 850 m asl in the west to around 830 m asl in the east, towards the Maimana River.

The southern end of the airport runway lies around 1.5 km NW of Maimana city centre.

The study area contains several inhabited villages, especially in the west, of which the largest is Torpakhtu. The study area is largely occupied by agricultural land.

Geology

The published Afghan Geological Survey / USGS maps show that the plain is underlain by Quaternary alluvial deposits of the Maimana River. These are described as:

Q_{34}a - Conglomerate and sandstone (Holocene and late Pleistocene) - Alluvium: shingly and detrital sediments, gravel, sand more abundant than silt and clay.

These alluvial deposits are underlain at unknown depth by Neogene sediments, described as

N_{1m}csl - Clay and siltstone (middle Miocene) - Brown clay, siltstone more abundant than sandstone, conglomerate, limestone.

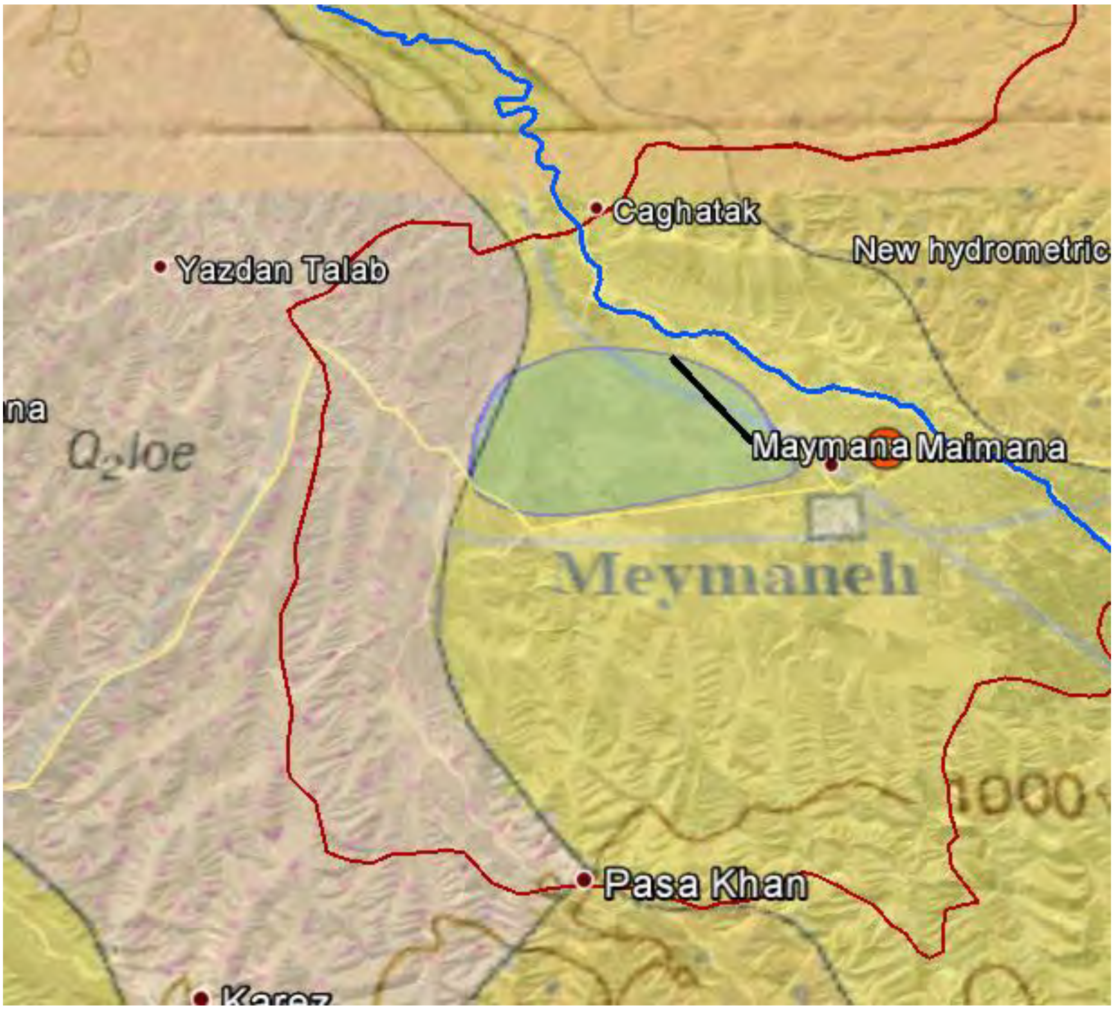


Figure 2. Geology of Maimana study area (Google Earth). AGS / USGS geological maps overlaid. See key below.

$Q_{34}a$	Conglomerate and sandstone (Holocene and late Pleistocene)—Alluvium: shingly and detrital sediments, gravel, sand more abundant than silt and clay	
Q_2loe	Loess (middle Pleistocene)—Loess more abundant than sand, clay	Q_2loe
N_{1m}csl	Clay and siltstone (middle Miocene)—Brown clay, siltstone more abundant than sandstone, conglomerate, limestone	N_{1m}csl

Registered Wells

Dug Wells

No dug wells are registered in the study area. Several are however registered in the valley of the Maimana River (Figure 3)

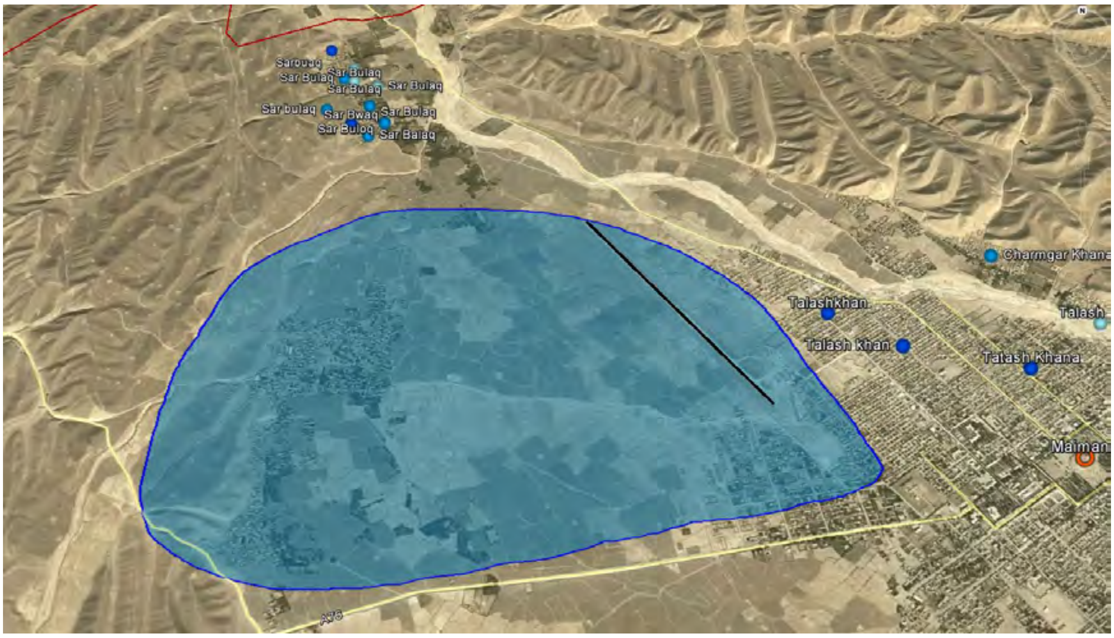


Figure 3. Registered dug wells in the Maimana study area (Google Earth).

There are, however, a number of drilled boreholes registered in and around the study area.

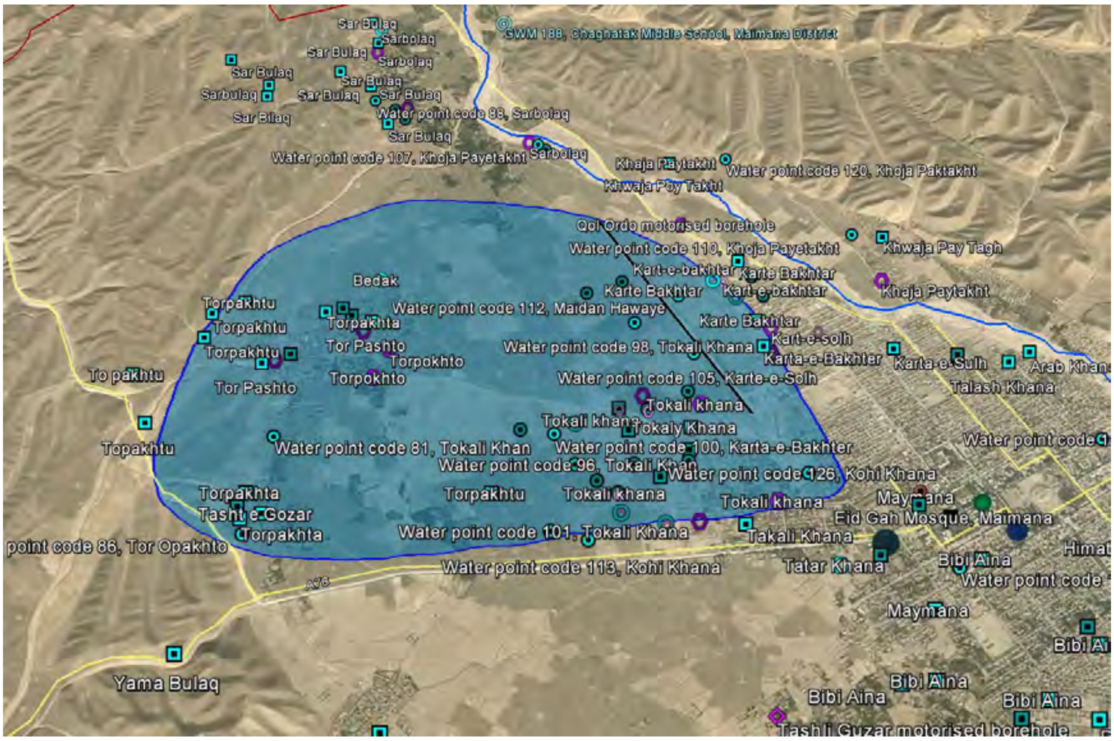


Figure 4. Registered drilled boreholes in the Maimana study area (Google Earth).

Groundwater levels typically range from 40 m below ground level in the extreme west of the study area to around 30 m bgl in the east. It should be noted that this appears to be **below** the level of the Maimana River, suggesting:

1) There is a degree of discontinuity between river and aquifer
2) The River is likely to be infiltrating water into the ground.

There are three groundwater monitoring wells in the near vicinity of the study area:

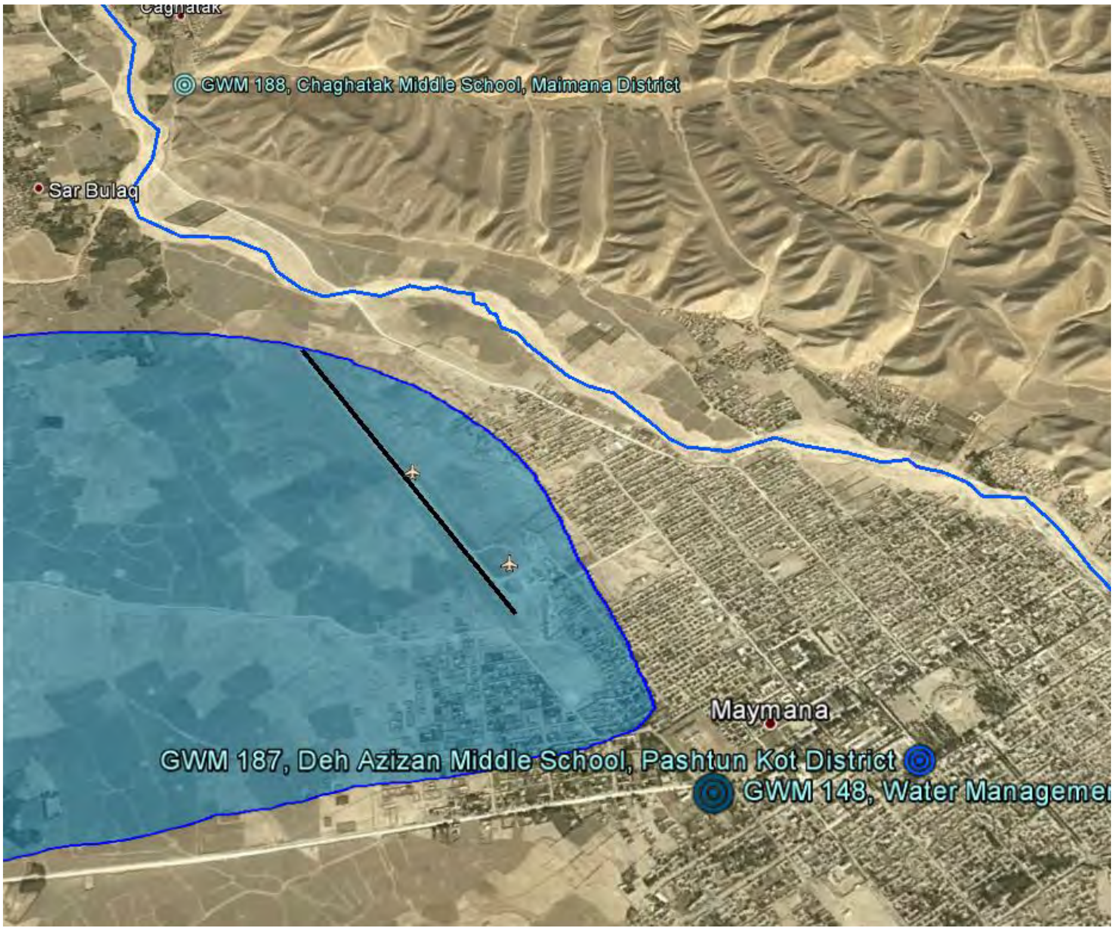


Figure 5. Registered groundwater monitoring boreholes near the Maimana study area (Google Earth).

GWM 148: Water Management Department, Maimana District is 52.5 m deep and has a typical water level of 38 m bgl.

GWM 187: Deh Azizan Middle School is 63 m deep and has a typical water level of 32 m bgl, and an electrical conductivity of 2030 µS/cm.

GWM 188: Chaghatak Middle School is 63 m deep and has a typical water level of 14 m bgl, and an electrical conductivity of 2300 µS/cm.

Water quality

There is a considerable amount of data on electrical conductivity within the study area (Figure 6).

The majority of boreholes are colour-coded green (1203 - 1517 µS/cm) or yellow (1517 to 1996 µS/cm), implying a slightly brackish water quality, with conductivity in the range 1200 - 2000 µS/cm. In the extreme SW of the area, higher conductivities of 2300-3600 µS/cm occur, maybe associated with the boreholes penetrating to the underlying Neogene sediments, at the edge of the Quaternary alluvial plain.

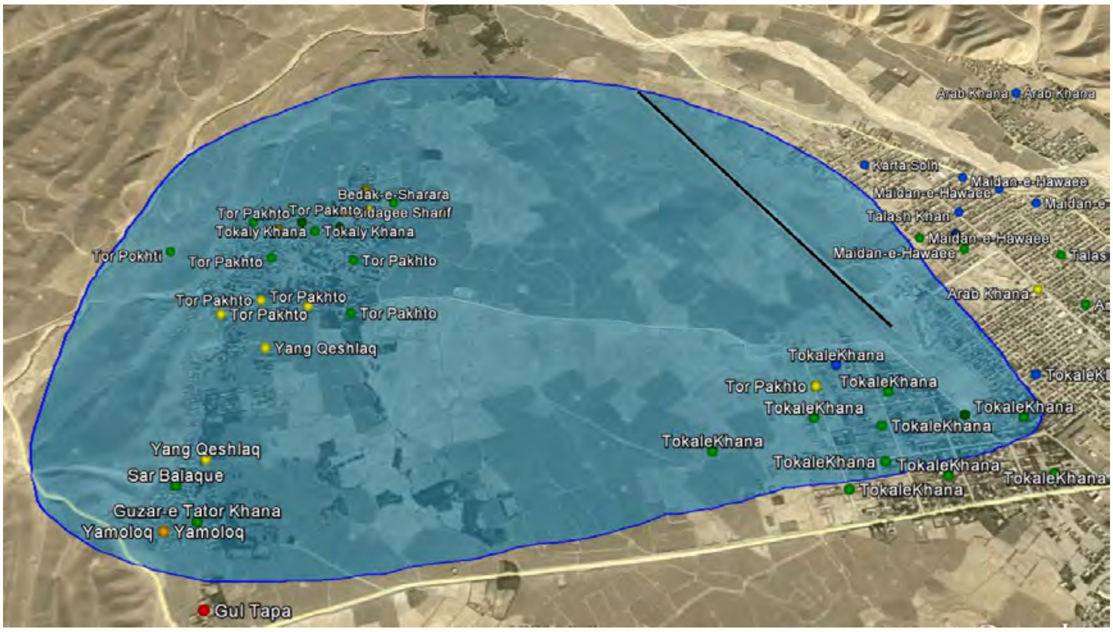


Figure 6. DACAAR groundwater electrical conductivity observations in the Maimana study area (Google Earth).

- Blue = <1203 µS/cm
- Green = 1203 - 1517 µS/cm
- Yellow = 1517 to 1996 µS/cm
- Orange = 1996 - 2950 µS/cm
- Red = 2950 - 5000 µS/cm

Meteorology

A considerable amount of data exists on the meteorology of Maimana. The World Meteorological Office data from 1959-83 result in the following graphs:

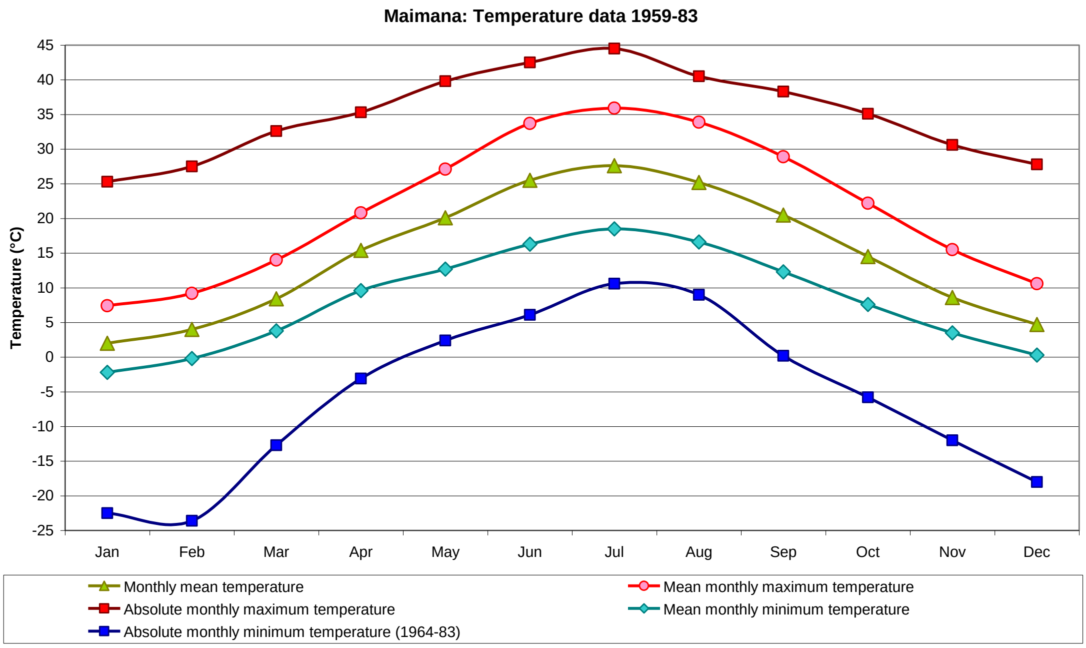


Figure 7. Monthly mean temperature data 1959-83 for WMO station 40922 Maimana.

Mean annual precipitation is around 356 mm and temperature around 14.7°C. The low precipitation and arid climate suggest that opportunities for direct recharge of groundwater systems are very limited. Some opportunities for small amounts of direct recharge may exist in the wettest, coolest months (January and February) or during snowmelt. The other potential source for groundwater recharge is infiltration from the Maimana River.

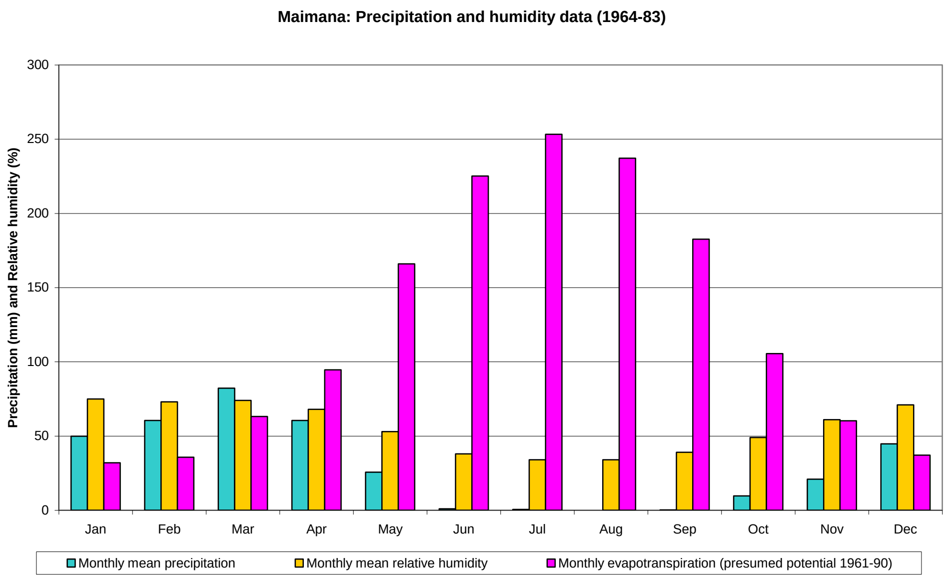


Figure 8. Monthly mean precipitation data 1964-1983 for WMO station 40922 Maimana.

Cross sections

Three geological cross-sections have been constructed as follows:

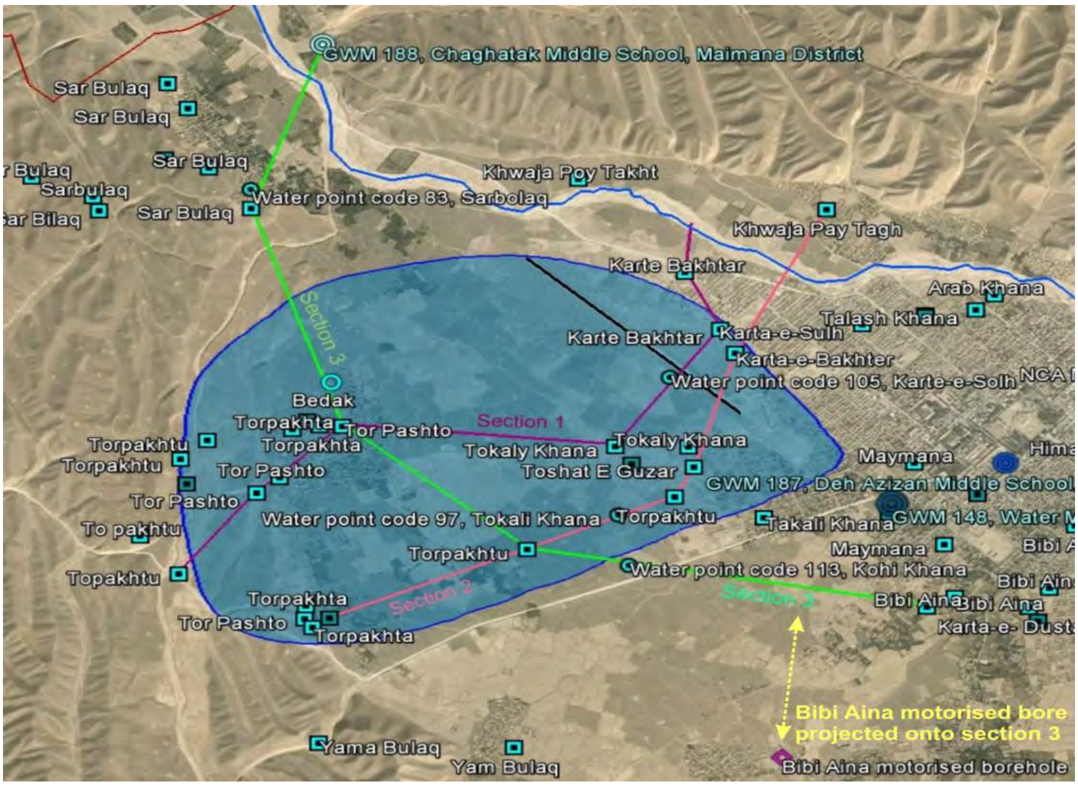


Figure 9. Locations of cross-sections 1-3 in study area Maimana *(only selected boreholes are shown). Section 1 = purple, section 2 = pink, section 3 = green. North is up the page. Runway (black line = c.1.6 km). Note the Bibi Aina motorised borehole at the lower right of the frame.*

<u>Cross section 1</u>

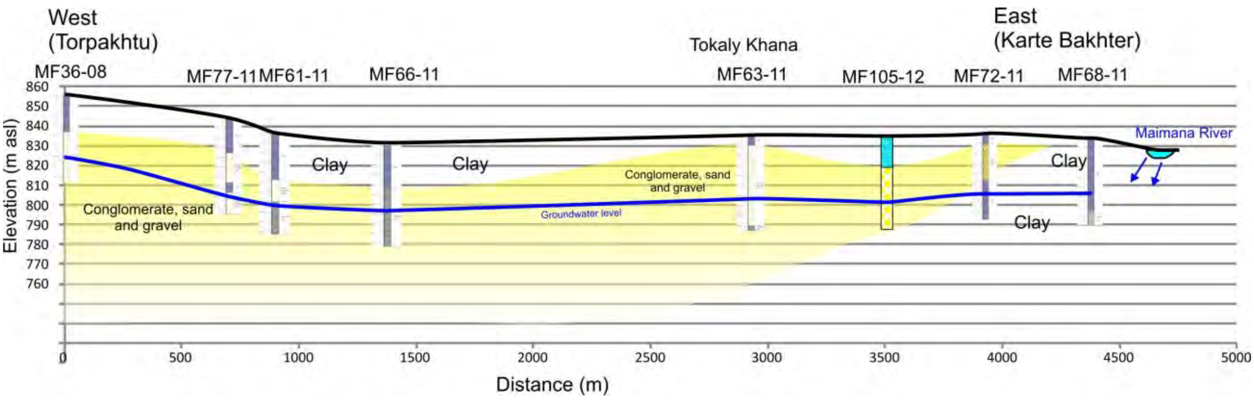


Figure 10. Cross section 1 of study area Maimana. *Elevation in m asl, horizontal distance in m.*

Cross section 1 suggests that, below the study area there is an initial clayey layer of thickness < 20 m, underlain by a substantial gravelly/sandy aquifer unit, whose base has not been proved but which appears to be at least 30-40 m thick (saturated and unsaturated total thickness). This appears to disappear towards the east, to be replaced by clayey sediments (at least within the depth range of 50-60 m penetrated by the boreholes).

The groundwater level is around 30 m below ground level and appears to be below the elevation of the Maimana River, suggesting:

1) There is a degree of discontinuity between river and aquifer
2) The River is likely to be infiltrating water into the ground.

However, the sediments in the vicinity of the river are generally clayey, so the degree of river infiltration to the aquifer is likely to be rather limited.

Lack of good terrain elevation data renders the following observation very tentative, but it appears there is a slight slope of the groundwater level surface *away* from the Maimana River over much of the section, again suggesting an infiltrating river regime.

<u>Cross section 2</u>

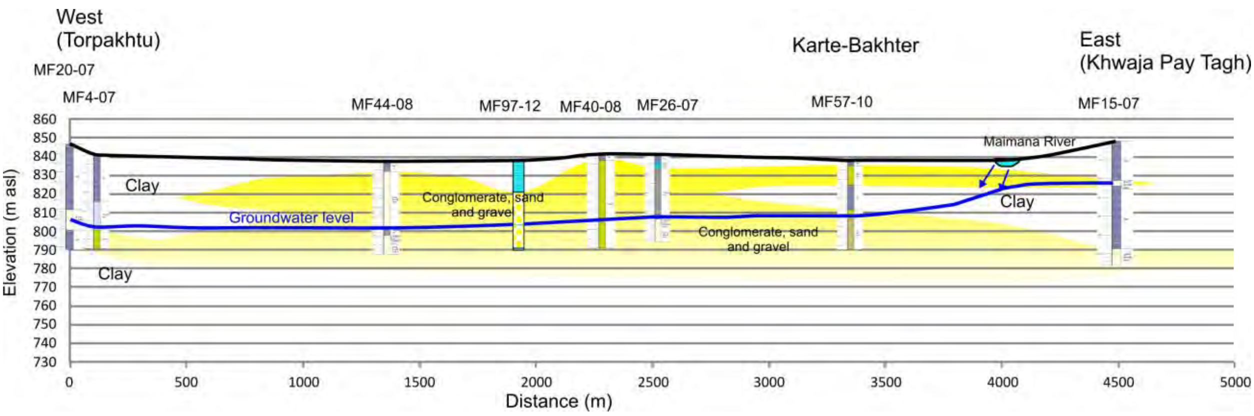


Figure 11. Cross section 2 of study area Maimana. *Elevation in m asl, horizontal distance in m.*

The second east-west cross-section, cross-section 2 (Figure 11) broadly supports the findings of cross-section 1.

<u>Cross section 3</u>

The third cross section (Figure 12) is north-south. The 200 m deep Bibi Aina production borehole, supplying water to a piped network in Maimana, and test pumped at 8 L/s with only 6 m drawdown (specific capacity 115 m2/d, likely transmissivity = c. 200 m2/d, average hydraulic conductivity based on

120 m aquifer thickness = c. 1.6 m/d) is projected onto the cross section (although it lies some distance to the south of the section - see Figure 9).

The Bibi Aina borehole encountered clayey dominated strata with some gravels to 56 m depth, then a gravel aquifer to 185 m (at least 129 m good aquifer thickness, of which 120 m is saturated). At 185 m depth, the borehole encountered lower permeability Neogene deposits (although there is some debate amongst hydrogeologists regarding where the Quaternary - Neogene boundary is located in the borehole).

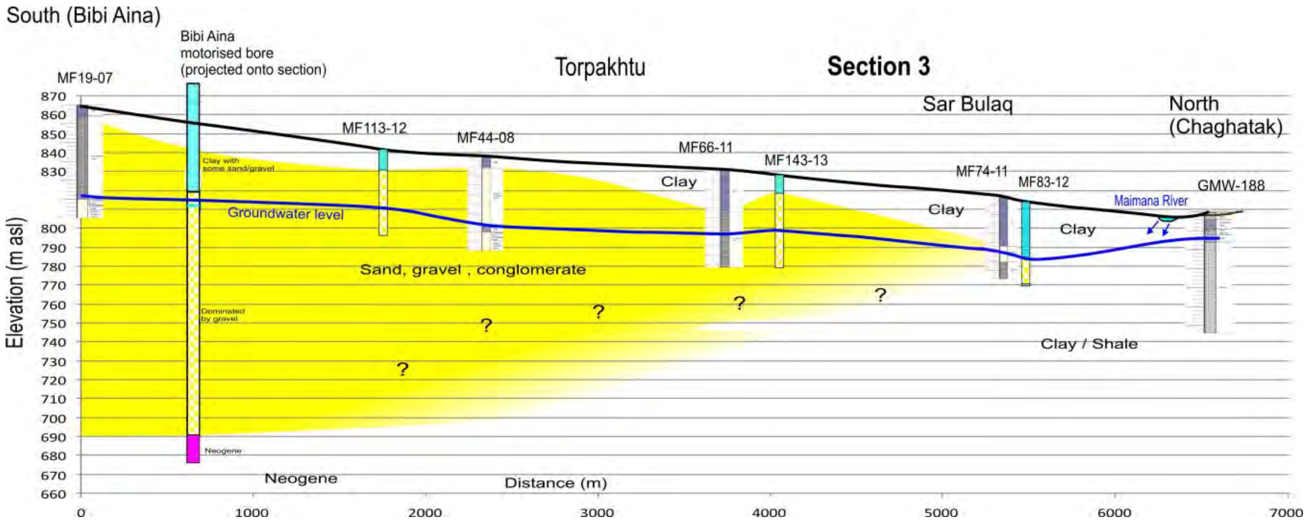


Figure 12. Cross section 3 of study area Maimana. *Elevation in m asl, horizontal distance in m.*

Cross section 3 also confirms that groundwater levels are below the level of the River Maimana.

Finally, the gravel aquifer seems to peter out (at least, at shallow depth) towards the River, in the region of Sar Bulaq, being replaced by clayey / shaley strata. The aquifer does not seem to extend, at shallow depth, to the eastern bank of the Maimana River .

Conclusions

There appears to exist a substantial aquifer storage of moderately fresh to brackish groundwater below the study area in a Quaternary alluvial sand/gravel/conglomerate unit of thickness at least 30-40 m.

If the Bibi Aina borehole is representative of the Maimana Airport study area (including the rather tentative depth to Neogene), then the aquifer thickness could be in excess of 100 m. The aquifer's indicative transmissivity at Bibi Aina is around 200 m^2/d, with hydraulic conductivity between 1 and 2 m/d on average. The aquifer is overlain by clayey sediments ranging in thickness from a few metres to around 20 m.

The aquifer is overlain by clayey sediments ranging in thickness from a few metres to around 20 m.

The aquifer appears to be underlain by Neogene lower permeability materials at 185 m bgl at Bibi Aina (although the depth to Neogene is controversial). The Neogene may be encountered at shallower depths beneath the study area depending on the basement topography.

The aquifer is generally unconfined with groundwater levels typically a little over 30 m bgl in shallow boreholes.

The river-aquifer system seems to be characterised by downward vertical head gradients, with the Maimana River seemingly disconnected from regional groundwater heads and presumably with a tendency to infiltrate river water into the ground.

BUT the source of recharge to the aquifer is not clear.

- The climate (and the clayey overburden) means that opportunities for direct recharge are very limited.
- The aquifer tends to be separated from the Maimana River by lower permeability clayey materials.

Thus, a large question mark must be placed over the ultimately sustainability of a major groundwater abstraction from this aquifer.

Proposed Investigatory Programme

Summer 2013

Send a field hydrogeological and geophysical team to Maimana to

1) Interview locals about possible deep motorised boreholes constructed recently in the area, possibly by Norwegian occupying forces based around Maimana Airport. NORPLAN to make enquiries regarding this in Norway.
2) Field team to locate and sample any such boreholes for chemical and isotopic composition.
3) Field team to carry out Water Features Survey within 1 km radius around study focus area (study focus area = orange area in Figure 13) and to locate any springs or karezes within 2 km of study focus area. Electrical conductivity to be determined at all visited boreholes.
4) Field team to collect chemical and isotopic samples from up to 15 boreholes in and around study area, and in the potential infiltration zone (green area in Figure 13) near to the Maimana River. Electrical conductivity to be determined at all visited boreholes. To include deep Bibi Aina borehole. Samples to be sent to BGS England for analysis.
5) Identification of geophysical lines within study focus area (orange area in Figure 13). Obtain permissions and consent for geophysical survey.

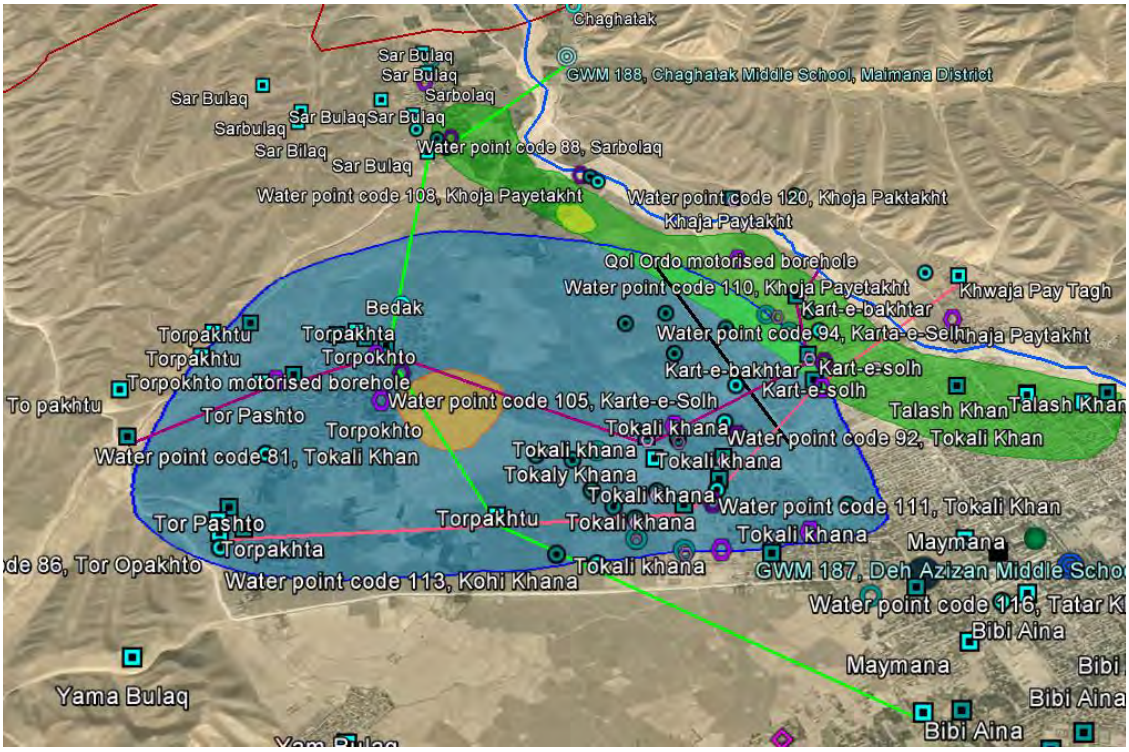


Figure 13. Orange area = proposed study focus area; green area = potential infiltration area from Maimana River; Yellow area = proposed area for observation borehole in infiltration area.

6) Identification of possible drilling sites for

- 1 deep exploration borehole to up to 200 m within the study focus area (orange area in Figure 13).
- 1 observation borehole up to 120 m (depending on findings from deep exploration borehole), no more than 30 m distance from exploration borehole.
- 1 observation borehole to 50 m, no more than 30 m distance from exploration borehole.
- 1 observation borehole to 60 m in the zone of infiltration, in or near the yellow area in Figure 13.

Obtain permissions and consent for drilling

7) **August-September 2013.** Geophysical survey[1] of study area using identified geophysical lines (Step 5). **Eng. Jalil (MRRD), possibly assisted by DACAAR.**

Spring/Summer 2014

Drilling and test pumping program to commence

8) **April 2014.** Drilling of boreholes at study area. Tentatively:

- 1 x exploration well to c. 200 m depth at 200 mm final diameter
- 1 x Quaternary observation well up to 120 m (depending on findings from deep exploration borehole), at 150 mm final diameter.
- 2 x Quaternary observation wells (1 and 3) to c. 50-60 m depth at 150 mm final diameter.

Sampling and geophysical logging of all boreholes.

Installation of 4 water level divers in boreholes

Installation of 1 barometric diver

Installation of river level gauging post in Maimana River

Possible installation of 1 water level diver in Maimana River (within constructed, protected unit).

Accurate surveying (levelling) of all well-heads and Maimana gauging post.

9) **July 2014**. Test pumping and water sampling of all wells.

Clearance pumping.

Short term (6 hour) test of all 3 observation wells, with drawdown response being monitored.

Regular monitoring of electrical conductivity during test pumping.

Water sample from all 3 wells after 1 hour pumping and after 6 hours pumping.

10) **August 2014.** Test pumping of exploration well

Step testing of exploration well at 4 different rates

Constant rate testing of exploration well for at least 7 days (and possibly longer), with regular water sampling.

Recovery test of production well.

[1] At present, it is envisaged that the geophysical survey will comprise a systematic series of VES soundings along pre-agreed lines. Following the recommendations of Eng. Jalil and Dr de Jong, these may be upgraded to full 2-D resistivity profiles.

11) **August-September 2014.** Securement of all well heads and conversion to permanent monitoring facilities.

Necessary purchases

- Surveying equipment (presumably already available from MRRD??) with 1 cm accuracy.
- Geophysical equipment and teams from MRRD or DACAAR
- Drilling rigs from MRRD capable of constructing 8" completed diameter holes to 200 m.
- Geophysical logging equipment
- 5-6 SWS water level divers with appropriate ranges.
- Flow meter gauging kit
- River gauging post
- Water sampling bailer / Waterra type hand sampling pump.
- Appropriate pumps (possibly two different types required, depending on well yield characteristics)
- Generator.

AFTER THE STUDIES

It will be problematic to prevent the wells being utilised following the study. This would be especially difficult if private farmers take them into use for motorised irrigation. While the short term capacity of the aquifer may be high, we know nothing about the long-term capacity or sustainability. NORPLAN needs to develop a strategy to limit the unauthorized use of the wells following the study (e.g. restricting the diameter at the headworks and installing monitoring equipment).

8.5 Faryab Desk Study 2: Shirin Tagab Investigation Site

Location

The proposed study area is located in the valley of the Shirin Tagab River, towards the south of Shirin Tagab district, to the south of Faisabad.

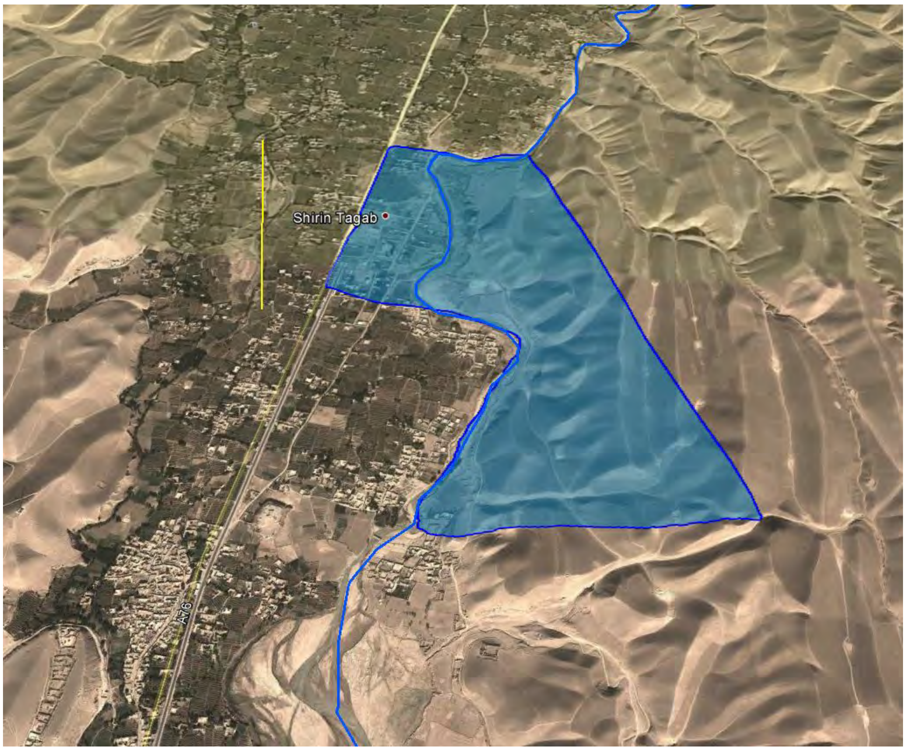


Figure 1. Location of Shirin Tagab study area (Google Earth). The blue line shows the Shirin Tagab River, flowing north. The yellow line is 1 km long.

The study area has been selected because:

- it straddles the boundary between the Quaternary (alluvial) aquifer system and the Neogene aquifer system.
- it allows us to evaluate the interaction between the River Shirin Tagab and the aquifer systems.

The study area straddles the valley bottom of the Shirin Tagab river, at around 520 m asl. To the east of the study area, the terrain rises, as hills underlain by Neogene sedimentary rocks, to above 600 m asl.

The valley bottom contains habitation (the diffuse village of Islam Qala) and irrigated fields. The Neogene hilly terrain is largely uninhabited and appears uncultivated.

Geology

The published Afghan Geological Survey / USGS maps show that the valley floor is underlain by Quaternary alluvial deposits of the Shirin Tagab River. These are descried as:

Q_{34}a - Conglomerate and sandstone (Holocene and late Pleistocene) - Alluvium: shingly and detrital sediments, gravel, sand more abundant than silt and clay.

These alluvial deposits are underlain at presumed relatively shallow depth by Neogene sediments, which also outcrop as hilly terrain in the east of the study area. These are described as

N_{1l}csl - Clay and siltstone (early Miocene) - Red clay, siltstone more abundant than sandstone, conglomerate, limestone

Figure 2. Geology of Shirin Tagab study area (Google Earth). AGS / USGS geological maps overlaid. See key below.

Q_{34}a	Conglomerate and sandstone (Holocene and late Pleistocene)—Alluvium: shingly and detrital sediments, gravel, sand more abundant than silt and clay	
Q_2loe	Loess (middle Pleistocene)—Loess more abundant than sand, clay	Q_2loe
N_{1m}csl	Clay and siltstone (middle Miocene)—Brown clay, siltstone more abundant than sandstone, conglomerate, limestone	N_{1m}csl
N_{1l}csl	Clay and siltstone (early Miocene)— Red clay, siltstone more abundant than sandstone, conglomerate, limestone	N_{1l}csl

Registered Wells

Dug Wells

No dug wells are registered in the study area. Several are, however, registered just outside the study area in the valley of the Shirin Tagab River (Figure 3). Water levels in these range from 16 to 32 m bgl.

***Figure 3. Registered dug wells in the Shirin Tagab study area (Google Earth).** Dark blue symbols indicate dug wells with water level between 25 and 35 m bgl.*

There are also a number of drilled boreholes registered in and around the study area.

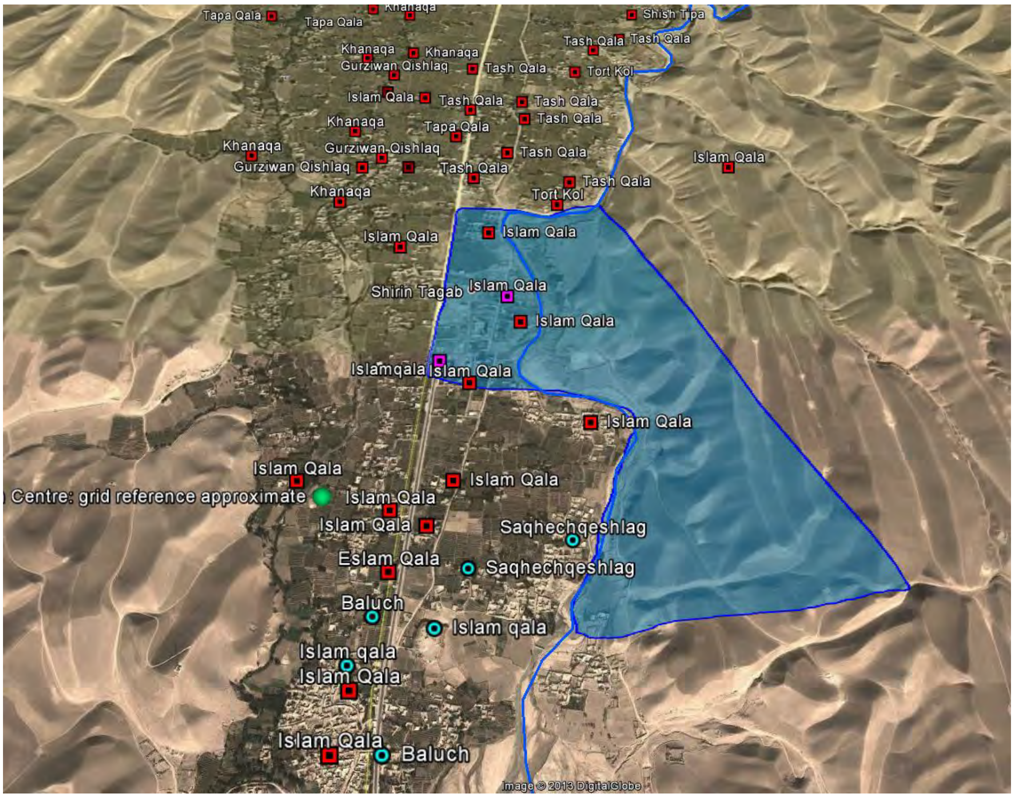


Figure 4. Registered drilled boreholes in the Shirin Tagab study area (Google Earth).

Groundwater levels in the valley floor typically range from 20-30 m below ground level. It should be noted that this appears to be **below** the level of the Shirin Tagab River, suggesting:

3) There is a degree of discontinuity between River and aquifer

4) The River is likely to be infiltrating water into the ground.

There is only one groundwater monitoring well in the near vicinity of the study area, around 6.5 km north of the study area.

a. GWM 140: Fiz Abad Shamsudin School, Shirin Tagab District is 51 m deep and has a typical water level of 16 m bgl.

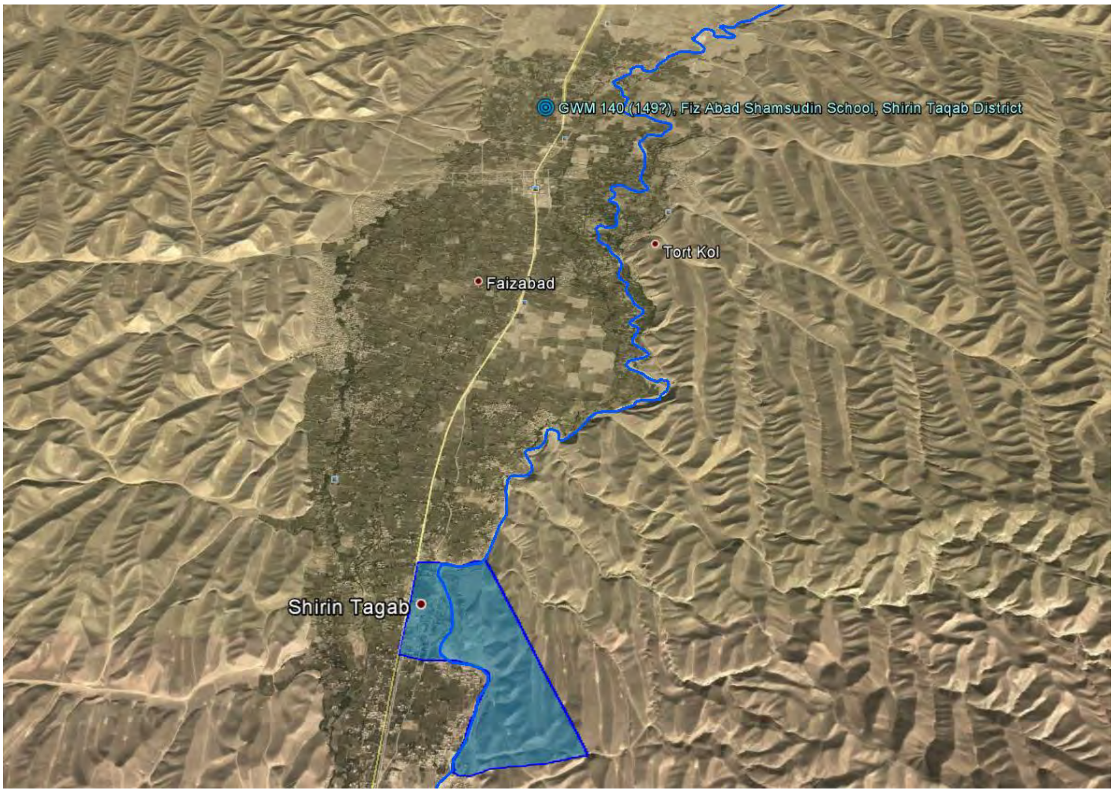


Figure 5. Registered groundwater monitoring boreholes near the Shirin Tagab study area (Google Earth).

Water quality

There is a considerable amount of data on groundwater electrical conductivity within the study area (Figure 6).

The groundwater appears to have a variable, but generally high, electrical conductivity, in the range 1800 - 4000 µS/cm.

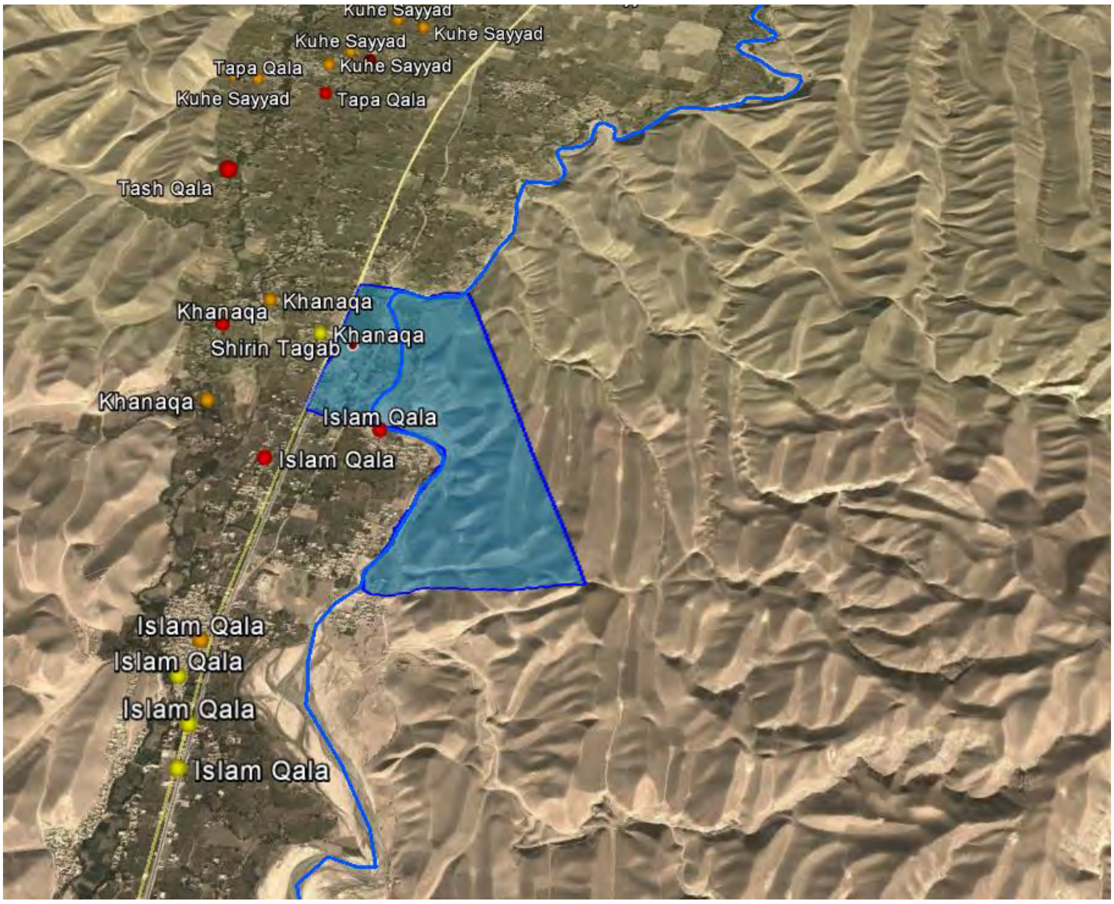


Figure 6. DACAAR groundwater electrical conductivity observations in the Shirin Tagab study area (Google Earth).

- Blue = <1203 µS/cm
- Green = 1203 - 1517 µS/cm
- Yellow = 1517 to 1996 µS/cm
- Orange = 1996 - 2950 µS/cm
- Red = 2950 - 5000 µS/cm

Meteorology

A considerable amount of data exists on the meteorology of Maimana. The World Meteorological Office data from 1961-83 result in graph in Figure 7.

The low precipitation and arid climate suggest that opportunities for direct recharge of groundwater systems are very limited. Some opportunities for small amounts of direct recharge may exist in the wettest, coolest months (January and February) or during snowmelt. Further north, at the Shirin Tagab study area, the opportunities for direct recharge will be even more limited.

The other potential source for groundwater recharge is infiltration from the Shirin Tagab River.

In addition, the GPCC Precipitation data set from NOAA provides mean precipitation data for the 0.5 x 0.5° grid square centred on 64.75°E 36.25°N, based on the period 1981-2010. This indicates that the mean annual precipitation near Shirin Tagab is 312 mm, distributed as shown in Figure 8a.

The GHCN Gridded V2 data provided by the NOAA provides mean air temperature data for the 0.5 x 0.5° grid square centred on 64.75°E 36.25°N, based on the period 1981-2010. This indicates that the mean annual air temperature near Shirin Tagab is 14.5°C, distributed as shown in Figure 8b.

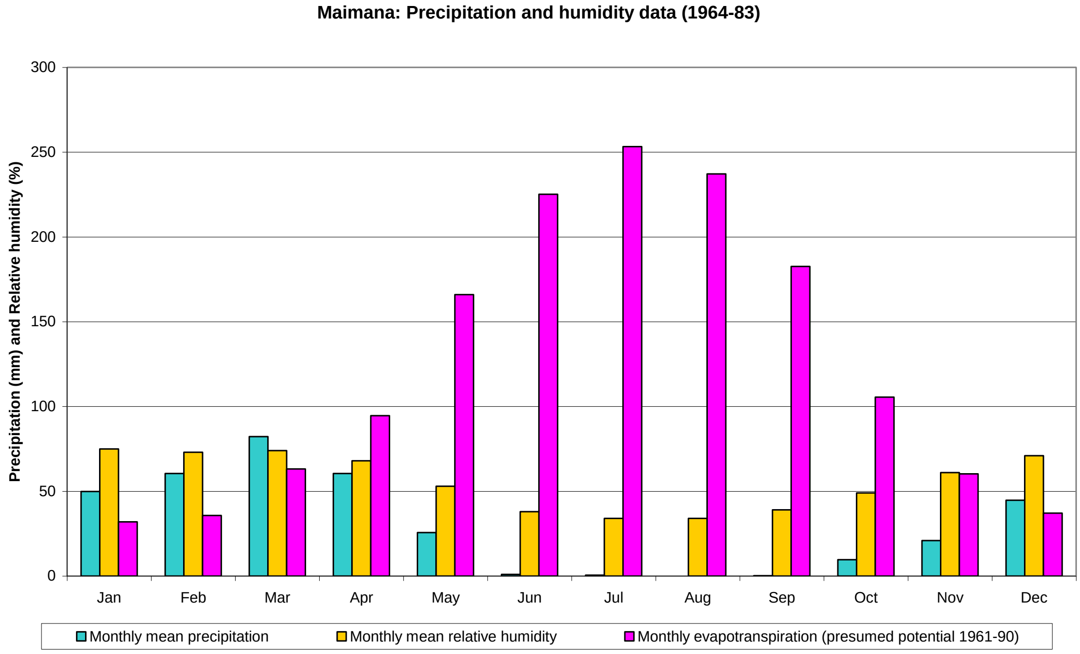


Figure 7. Monthly mean meteorological data 1964-1983 for WMO station 40922 Maimana.

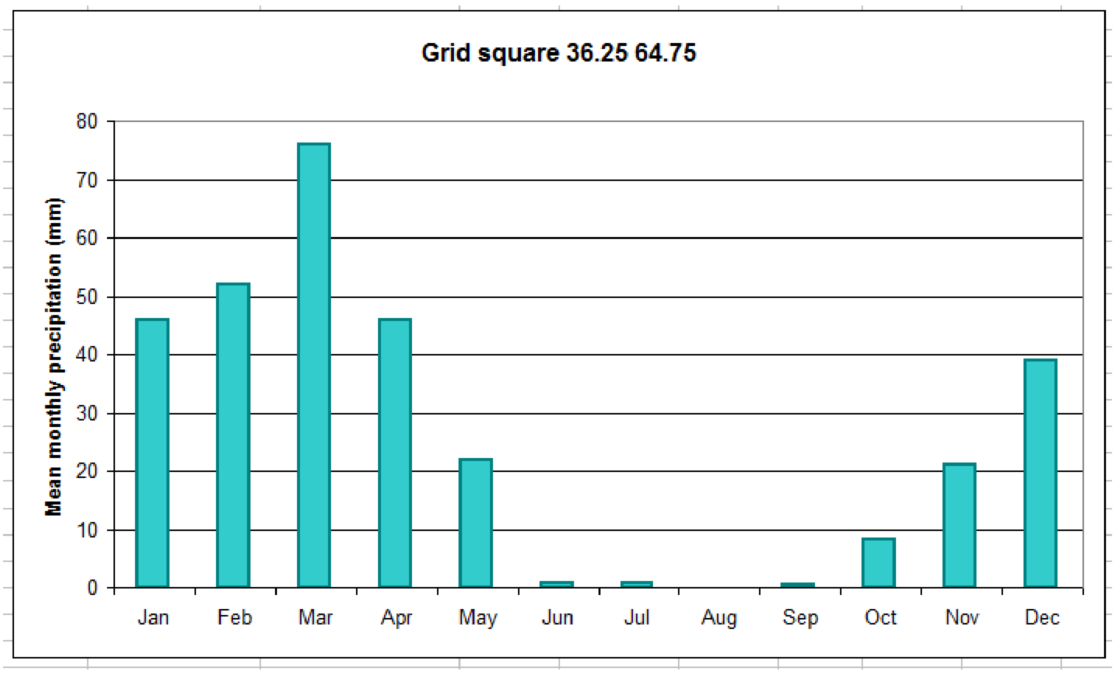


Figure 8a. Monthly mean precipitation data 1981-2010 for 0.5 x 0.5° grid square centred on 64.75°E 36.25°N, derived from the GPCC Precipitation data set from NOAA. *Data derived from GPCC Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/. Reference: Schneider, Udo; Becker, Andreas; Finger, Peter; Meyer-Christoffer, Anja; Rudolf, Bruno; Ziese, Markus (2011): GPCC Full Data Reanalysis Version 6.0 at 0.5°: Monthly Land-Surface Precipitation from Rain-Gauges built on GTS-based and Historic Data. DOI: 10.5676/DWD_GPCC/FD_M_V6_050*

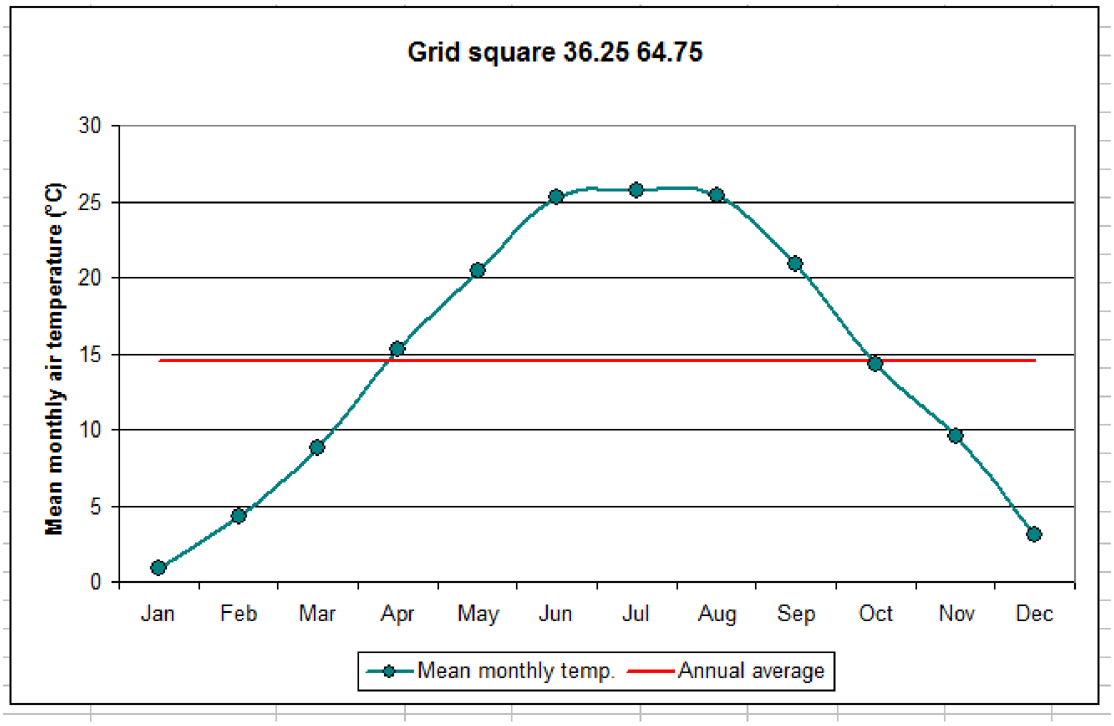


Figure 8b. Monthly mean air temperature data 1981-2010 for 0.5 x 0.5° grid square centred on 64.75°E 36.25°N, derived from the GHCN Gridded V2 data provided by the NOAA. *Data derived from GHCN Gridded V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/. Reference: Fan, Y., and H. van den Dool (2008), A global monthly land surface air temperature analysis for 1948-present, J. Geophys. Res., 113, D01103, doi:10.1029/2007JD008470.*

Cross sections

Two geological cross-sections have been constructed as follows:

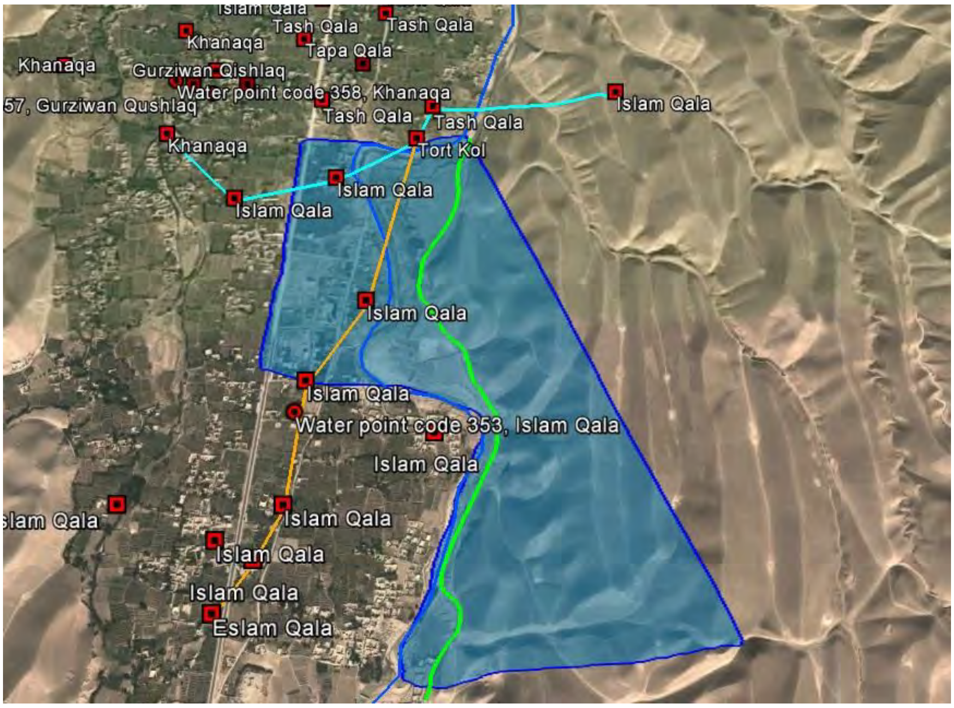


Figure 9. Locations of cross-sections 1-2 in study area Shirin Tagab. *Pale blue line = cross-section 1; orange line = cross-section 2; green line = approximate edge of Neogene outcrop. Deeper blue line = River Shirin Tagab.*

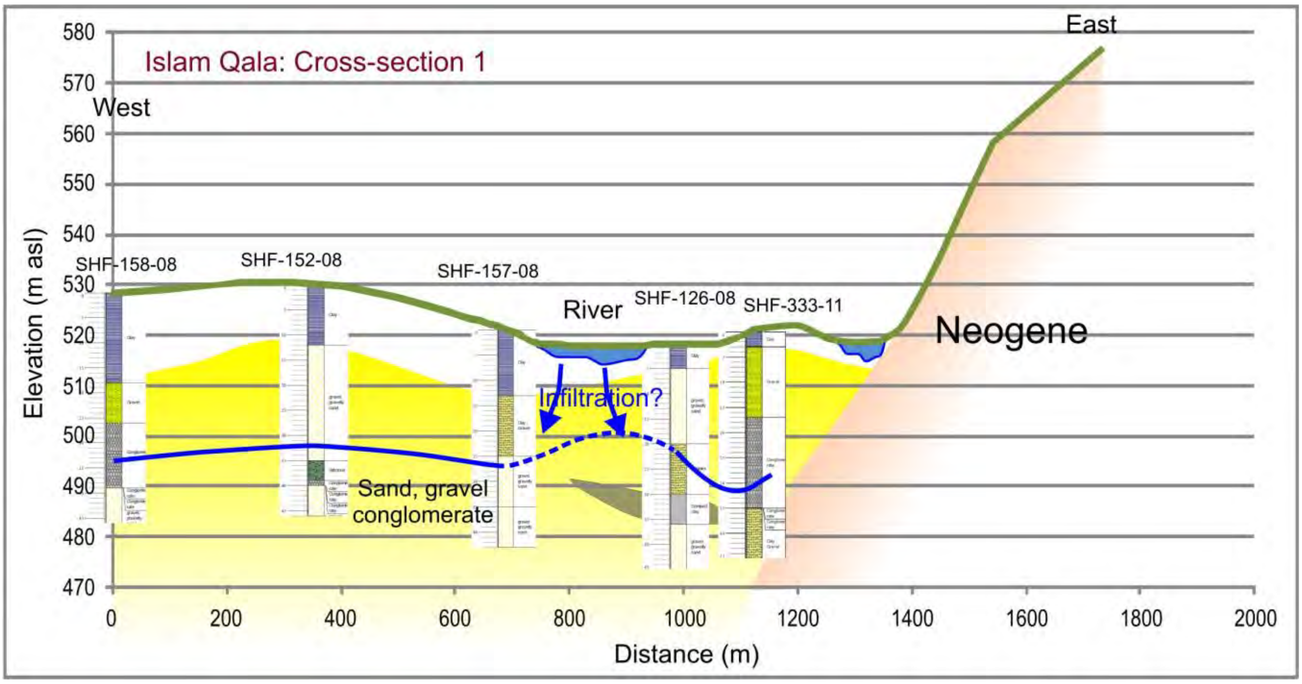


Figure 10. Cross section 1 of study area Shirin Tagab. *Elevation in m asl, horizontal distance in m.*

Cross section 1, approximately west-east, suggests that, below the study area there is an initial clayey layer of thickness 3-18 m, underlain by a substantial sandy-gravel / conglomerate aquifer unit, whose base has not been proved but which appears to be at least 30-40 m thick (saturated and unsaturated total thickness).

In no borehole has the top of the Neogene been unequivocally identified, despite its presumed outcrop in the east of the study area.

The groundwater level is around 20-30 m below ground level, at an elevation of 490-500 m asl. It thus appears to be at least 20 m below the elevation of the Shirin Tagab River, suggesting:

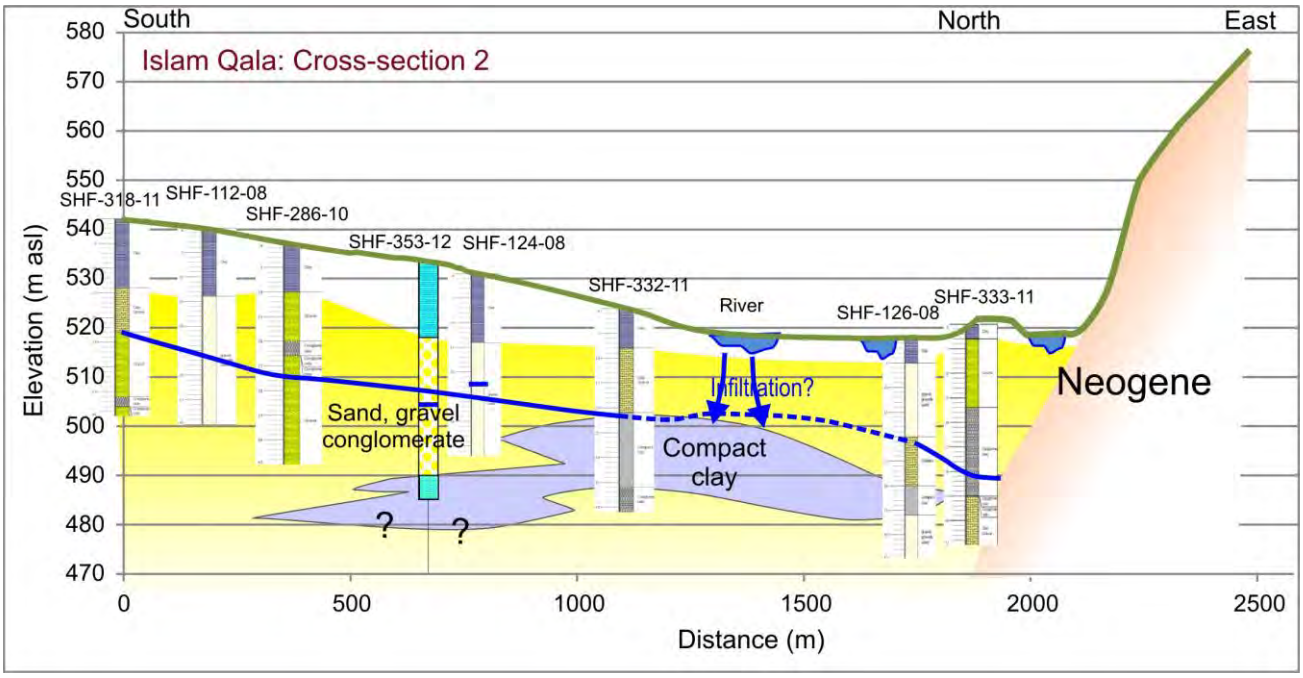


Figure 11. Cross section 2 of study area Shirin Tagab. *Elevation in m asl, horizontal distance in m.*

1) There is a degree of discontinuity between River and aquifer
2) The River is likely to be infiltrating water into the ground.

However, the sediments in the vicinity of the river are generally clayey in their upper portion, so the degree of river infiltration to the aquifer may possibly be limited.

The second, south-north cross-section, cross-section 2 (Figure 11) broadly supports the findings of cross-section 1. It confirms, however, that there is a groundwater hydraulic gradient along the course of the Shirin Tagab valley from south to north, with heads falling from +520 m asl to less than +500 m asl.

Two old pumped abstraction wells have formerly been drilled in the Shirin Tagab area:

- Shirin Tagab Health Centre: Aquifer = 33 m thick. Drilled to 50 m but only completed to 42 m. Rest water level = 21.5 m below well top. Test pumped at 1.4 L/s with 3.8 m drawdown after 20 hrs. Optimum yield judged to be 2.6 L/s with 6.9 m drawdown. EC = 850 µS/cm. Constructed by cable tool methods 10/6/1978 to 21/6/1978. No exact grid reference given. Information from old Dari handwritten table from MRRD
- Shirin Tagab Markaz (Centre): Drilled to 43 m but only completed to 41 m. German PVC screen 2.0 mm slots. Aquifer = 16.9 m of sand, gravel, cobbles. Rest water level = 22.2 m below well top; EC = 1650 µS/cm. Tested at 5 L/s for 5 hrs with 1.32 m drawdown. Optimal yield calculated as 11.8 L/s with 5.3 m drawdown. Constructed by cable tool method in Feb 1975. No exact grid reference given. An older handwritten Dari summary suggests that the rest water level on completion was 22.9 m bgl, not 22.2 m bgl. *Information from Radojicic, S. (1978): Summary report on deep tube wells constructed by Water and Soil Survey Dept., Ministry of Water and Power, 1973-78, UNICEF/WHO Assisted Rural Water Supply Project, Kabul, October 1978.*

It thus appears that yields in the range 2 to 12 L/s can be expected from this aquifer, with drawdowns of 5-7 m.

Conclusions

There appears to exist a substantial aquifer storage of brackish groundwater below the study area in a Quaternary alluvial sand/gravel/conglomerate unit of thickness at least 30-40 m, of which we know that at least 10-20 m are saturated.

The aquifer is overlain by clayey sediments ranging in thickness from a few metres to around 18m.

The aquifer is believed to be underlain by Neogene lower permeability materials at unknown depth. None of the boreholes in the area have unequivocally encountered Neogene and nothing is conclusively known about their hydraulic properties.

The aquifer is generally unconfined with groundwater levels typically 20- 30 m bgl in shallow boreholes. In an east-west orientation (perpendicular to the River) there is no clear hydraulic gradient on the water table. There is, however, a clear north-south hydraulic gradient down the River valley, indicating the groundwater flow in the Quaternary alluvial aquifer is generally northwards.

The aquifer system seems to be characterised by downward vertical head gradients, with the Shirin Tagab River seemingly disconnected from regional groundwater heads and presumably with a tendency to infiltrate river water into the ground.

It appears that yields in the range 2 to 12 L/s can be expected from this aquifer, with drawdowns of 5-7 m. BUT the source of recharge to the aquifer is not clear.

- The climate (and the clayey overburden) means that opportunities for direct recharge are very limited.

- The clayey surface layer may hinder infiltration from the Shirin Tagab River to the aquifer.

Thus, a large question mark must be placed over the ultimately sustainability of a major groundwater abstraction from this aquifer.

Proposed Investigatory Programme

<u>Summer 2013</u>

Send a field hydrogeological and geophysical team to the Shirin Tagab area to

1) Carry out Water Features Survey (1 km radius around study focus area) and locate any springs or karezes within 2 km of study focus area. Electrical conductivity to be determined at all visited springs, karezes, wells or boreholes.
2) Field team to collect chemical and isotopic samples from up to 10 boreholes and wells in and around study area. Electrical conductivity to be determined at all visited boreholes/wells. Samples to be sent to BGS England for analysis.
3) Identification of geophysical lines within study focus area (proposed geophysical lines shown in Figure 12). Obtain permissions and consent for geophysical survey.

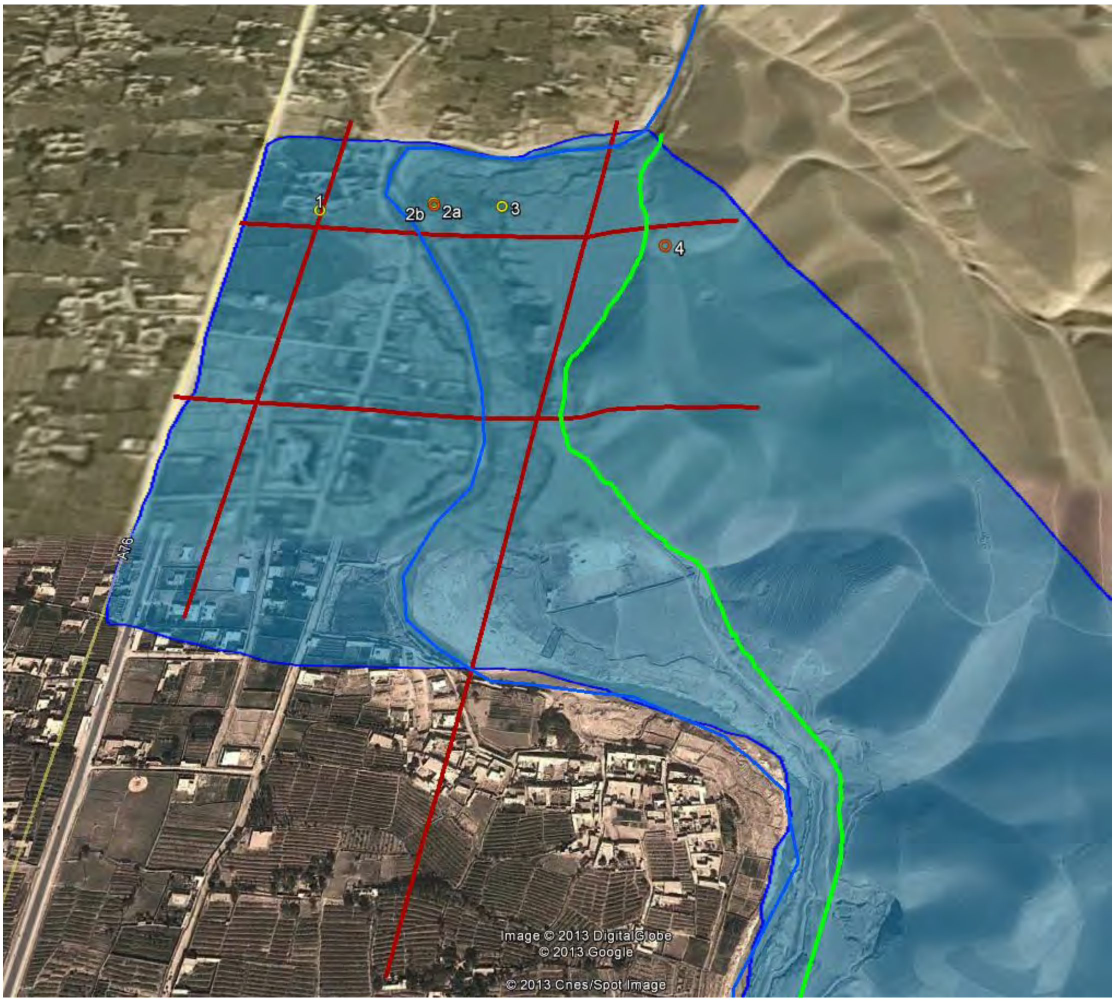


Figure 12. Shirin Tagab study area showing possible proposed geophysical lines (red), edge of Neogene outcrop (green) and proposed new boreholes.

4) Identification of possible drilling sites for

- 1 x production well (2a) to c. 60 m depth at 200 mm final diameter
- 1 x Neogene borehole (2b) to c. 100 m depth at 150 mm final diameter.
- 2 x Quaternary observation wells (1 and 3) to c. 60 m depth at 150 mm final diameter.
- 1 x Neogene observation well (4) to c. 60 m depth at 150 mm final diameter.

Obtain permissions and consent for drilling

5) **August-September 2013.** Geophysical survey[2] of study area using identified geophysical lines (Step 3). **Eng. Jalil (MRRD), possibly assisted by DACAAR.**

Spring/Summer 2014

Drilling and test pumping program to commence

6) **April 2014.** Drilling of boreholes at study area. Tentatively:

- 1 x production well (2a) to c. 60 m depth at 200 mm final diameter
- 1 x Neogene borehole (2b) to c. 100 m depth at 150 mm final diameter.
- 2 x Quaternary observation wells (1 and 3) to c. 60 m depth at 150 mm final diameter.
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Sampling and geophysical logging of all boreholes.

Installation of 5 water level divers in boreholes

Installation of 1 barometric diver

Installation of river level gauging post in Shirin Tagab River

Possible installation of 1 water level diver in Shirin Tagab river (within constructed, protected unit).

Accurate surveying (levelling) of all well-heads and Shirin Tagab gauging post.

7) **July 2014**. Test pumping and water sampling of all wells.

Clearance pumping.

Short term (6 hour) test of all 4 observation wells, with drawdown response being monitored.

Regular monitoring of electrical conductivity during test pumping.

Water sample from all 4 wells after 1 hour pumping and after 6 hour pumping.

Sampling of Shirin Tagab River.

Chemical and stable isotope analysis of all samples.

8) **August 2014.** Test pumping of exploration well

Step testing of production well at 4 different rates

Constant rate testing of production well for at least 7 days (and possibly longer), with regular water sampling.

Recovery test of production well.

[2] At present, it is envisaged that the geophysical survey will comprise a systematic series of VES soundings along pre-agreed lines. Following the recommendations of Eng. Jalil and Dr de Jong, these may be upgraded to full 2-D resistivity profiles.

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Necessary purchases

- Surveying equipment (presumably already available from MRRD??) with 1 cm accuracy.
- Geophysical equipment and teams from MRRD or DACAAR
- Drilling rigs from MRRD (percussion rigs preferred) capable of constructing 8" completed diameter holes to 70 m and 6" completed diameter holes to over 100 m.
- Geophysical logging equipment
- 5-6 SWS water level divers with appropriate ranges.
- Flow meter gauging kit
- River gauging post
- Water sampling bailer / Waterra type hand sampling pump.
- Appropriate pumps (possibly two different types required, depending on well yield characteristics)
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AFTER THE STUDIES

It will be problematic to prevent the wells being utilised following the study. This would be especially difficult if private farmers take them into use for motorised irrigation. While the short term capacity of the aquifer may be high, we know nothing about the long-term capacity or sustainability. NORPLAN needs to develop a strategy to limit the unauthorised use of the wells following the study (e.g. restricting the diameter at the headworks and installing monitoring equipment).