6. Faryab: Groundwater Levels and Flow

6.1 *Regional Groundwater Flow*

Abdullah & Chmyriov (2008b) discuss the regional groundwater flow in the North Afghanistan basin as a whole. In a hydrogeological basin, it is normal to experience downward head gradients in areas where recharge is dominant (mountain areas) and upward head gradients where discharge is dominant (heads increase with depth, often leading to artesian heads at depth).

Deep strata

Across the northern plains of Faryab, artesian conditions are reported in boreholes drilled through the Quaternary/Neogene succession into the underlying Palaeogene/Cretaceous and Jurassic aquifer horizons.

According to Abdullah & Chmyriov (2008b), in the deep Cretaceous and Jurassic strata (potentially oil-bearing), formation pressures decrease to the north, away from the Band-e Turkestan.

In the Upper Jurassic / Hauterivian aquifer / oil reservoir systems, Abdullah & Chmyriov (2008b) argue that fresher recharge water from the foothills of the Band-e Turkestan is gradually displacing fossil marine (connate) sedimentation water from the aquifers. Where this has happened to a large extent, the water has a sodium bicarbonate nature, with relatively low mineralization, grading into higher mineralization water of sodium sulphate waters and eventually calcium chloride bribes (50-150 g/L mineralization). In the higher Aptian/Albian/Cenomanian reservoir strata, lower permeabilities mean that displacement of brines by fresher water has not taken place to such an extent. Unhelpfully, Abdullah & Chmyriov (2008b) do not define what they mean by a "low" mineralization.

The main discharge area for the deep aquifers is believed by Abdullah & Chmyriov (2008b) to be the Khwaja Mod saline lake, which occupies a graben and whose west shore appears to follow a fault line.

Abdullah & Chmyriov (2008b) suggest that the uppermost (Quaternary) aquifer system is disconnected from deeper artesian aquifers. They note that, even on the plains "*the Quaternary aquifer system is recharged by surface waters*."

6.2 *Mishkin's (1968) Map*

Mishkin's (1968) map of the Quaternary aquifer system of the northern Afghanistan plains reveals a pattern of declining groundwater head contours towards the north. The contours are typically convex northwards along the line of the Shirin Tagab river, suggesting that the river is recharging the aquifer system. Mishkin also maps zones of fresher groundwater along the river valleys, underlining this interpretation.

Figure 6.1 shows Mishkin's (1968) contours superimposed on the geological map of Wahl (2005). A limited number of flow lines have been drawn on the map. The map suggests that the Khwaja Mod saline lake operates as a local focus for groundwater discharge from the Quaternary aquifer system, as well as possibly the deeper aquifers (see above).

Furthermore, the contours suggest that groundwater flow in the Quaternary aquifer system does not discharge towards the Amu Darya, but rather to the Zeid depression or towards the Kelif Uzboy depression in Turkmenistan to the NW. Indeed, the map

suggests that there is a component of groundwater flow *from* the Amu Darya towards the Zeid depression.

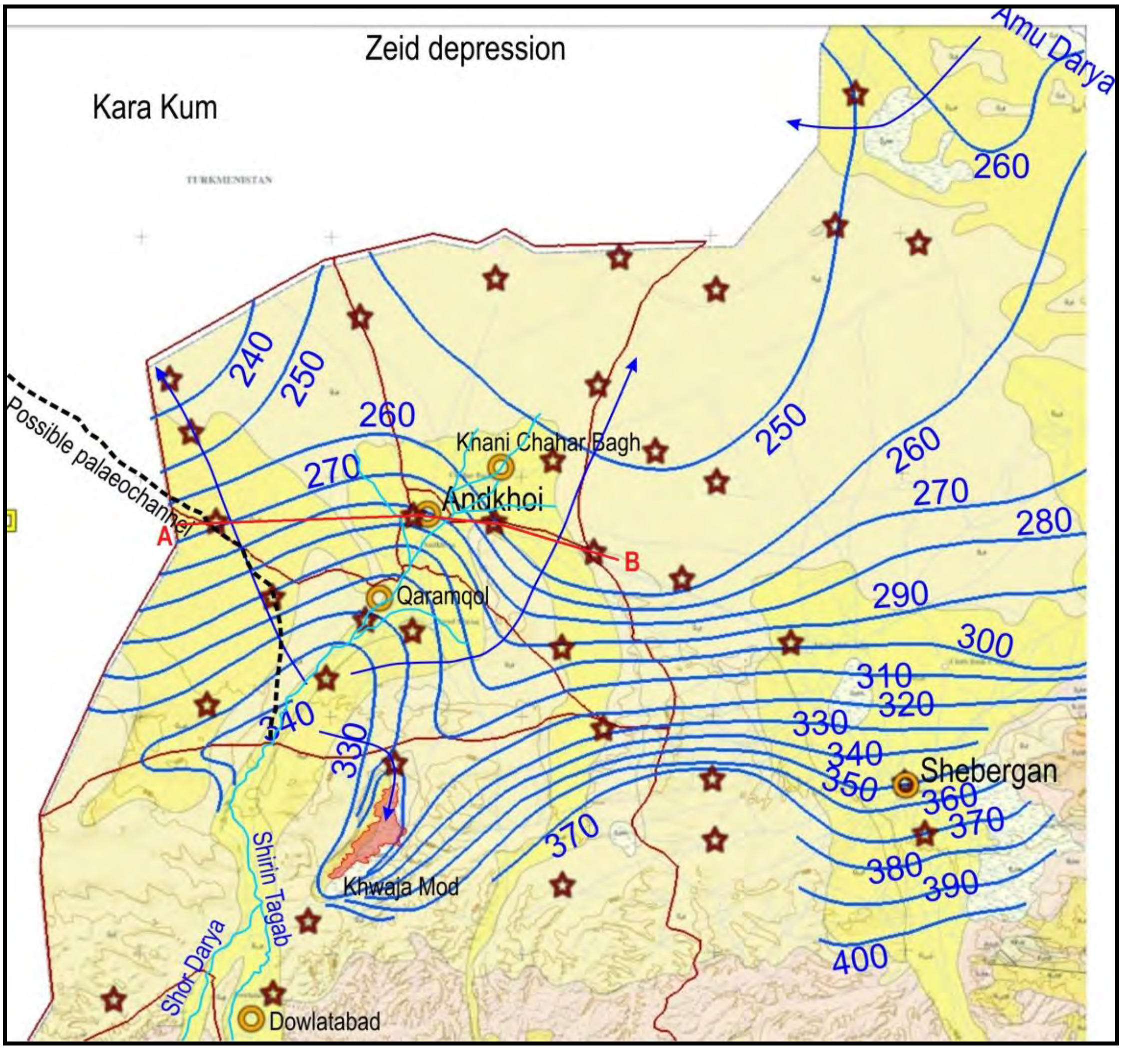


Figure 6.1. Mishkin's (1968) contours of groundwater head in the Quaternary aquifer system of Faryab, superimposed on the geological map of Wahl (2005). Groundwater flow lines and rivers are added in blue. Red stars show the locations of the wells and boreholes Mishkin used to calibrate his map. The red line A-B shows the line of the Andkhoi cross-section in Figure 6.11. The dashed black line shows a topographic depression which may be a palaeochannel of the Shirin Tagab.

6.3 Groundwater level map

Figure 6.2 shows the static groundwater, as measured in wells and boreholes registered in NORPLAN's project database in August 2014. Note that the vast majority of boreholes and wells occur within the valleys of the main rivers (Figure 5.2) and data from these cannot be extrapolated to higher-elevation interfluve areas, where there are few data and where the groundwater level may be much deeper.

Figure 6.16 shows a kriged version of the same mapped groundwater level data.

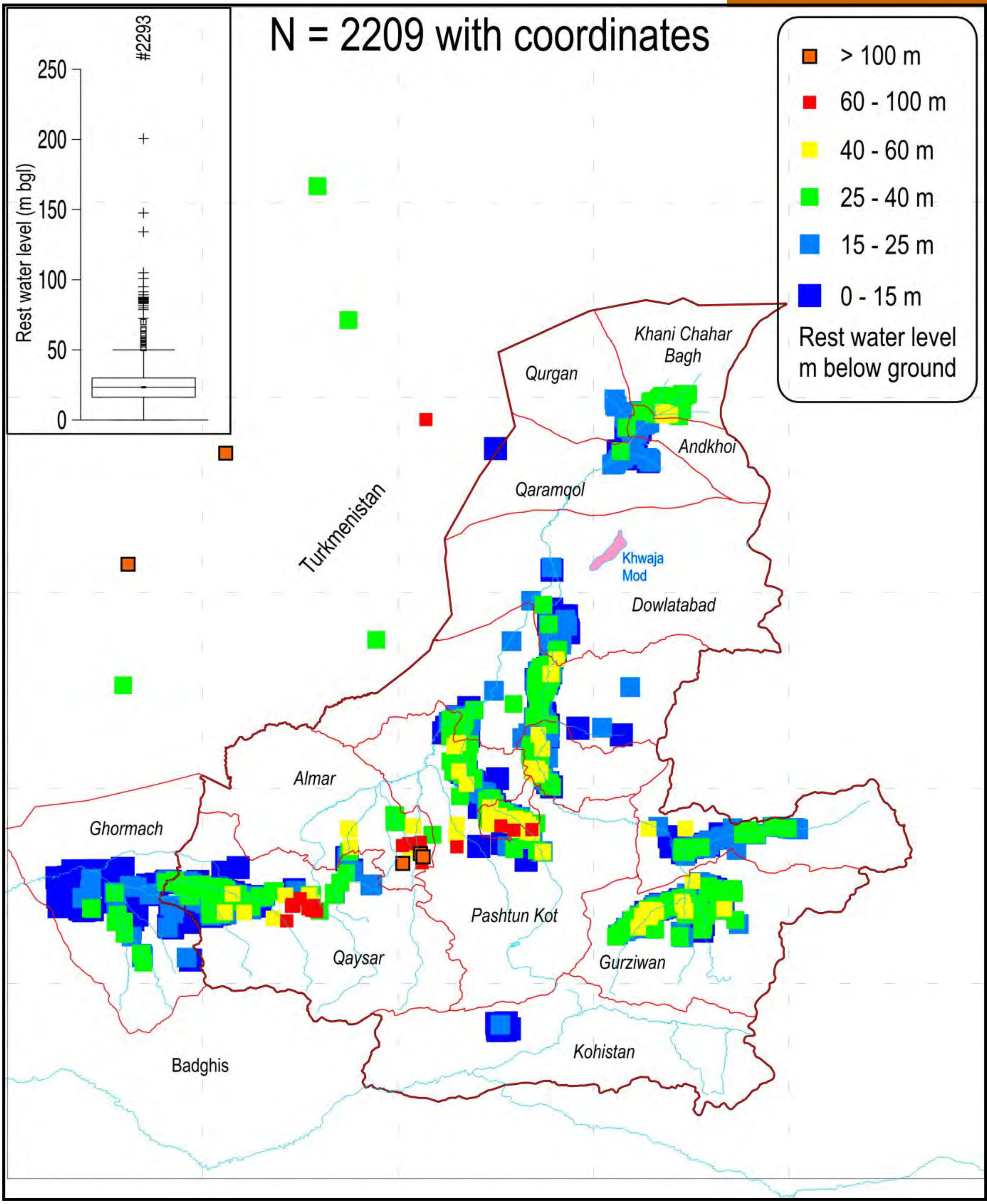


Figure 6.2. Map of Faryab and adjacent areas showing rest groundwater level in m below well top or m below ground level, for the 2209 data points in the database (as of August 2014) with both coordinates and water level data. The inset shows a boxplot of rest water levels for all 2293 features with rest water level data. *In boxplots, the central "box" represents the interquartile range with a horizontal line as the median. The "whiskers" represent the non-outlying extraquartile range, with outliers shown as small squares (near outliers) or crosses (far outliers).*

The map indicates that, in the main river valleys, groundwater level is typically in the range 20-40 m below ground level (m bgl). This, in turn, implies that:

- there is a general tendency for rivers to recharge the aquifer by infiltration (thus losing water).
- the groundwater gradient broadly follows the topography from south to north along these valleys.

Also, in general, in the southern portions of the main valleys, towards the mountain foothills, (e.g. Gurziwan, Pashtun Kot), the groundwater level is generally somewhat deeper. This reaches an extreme situation in the Qaysar and Almar areas, where depth to groundwater typically exceeds 50 m and can even reach depths of over 100 m below ground level (Nughayli Bala and Shoran Shikhan boreholes).

To explore the relationship between topography, depth to groundwater and surface watercourses, four characteristic sections (Figure 6.3) will be explored subsequently:

- in the southern part of the Quaternary valley fill aquifer, in the Almar area
- across the Maimana River, near Maimana Airport
- across the Shirin Tagab River, near Islam Qala
- in the Shirin Tagab delta / northern plains area, near Andkhoi.

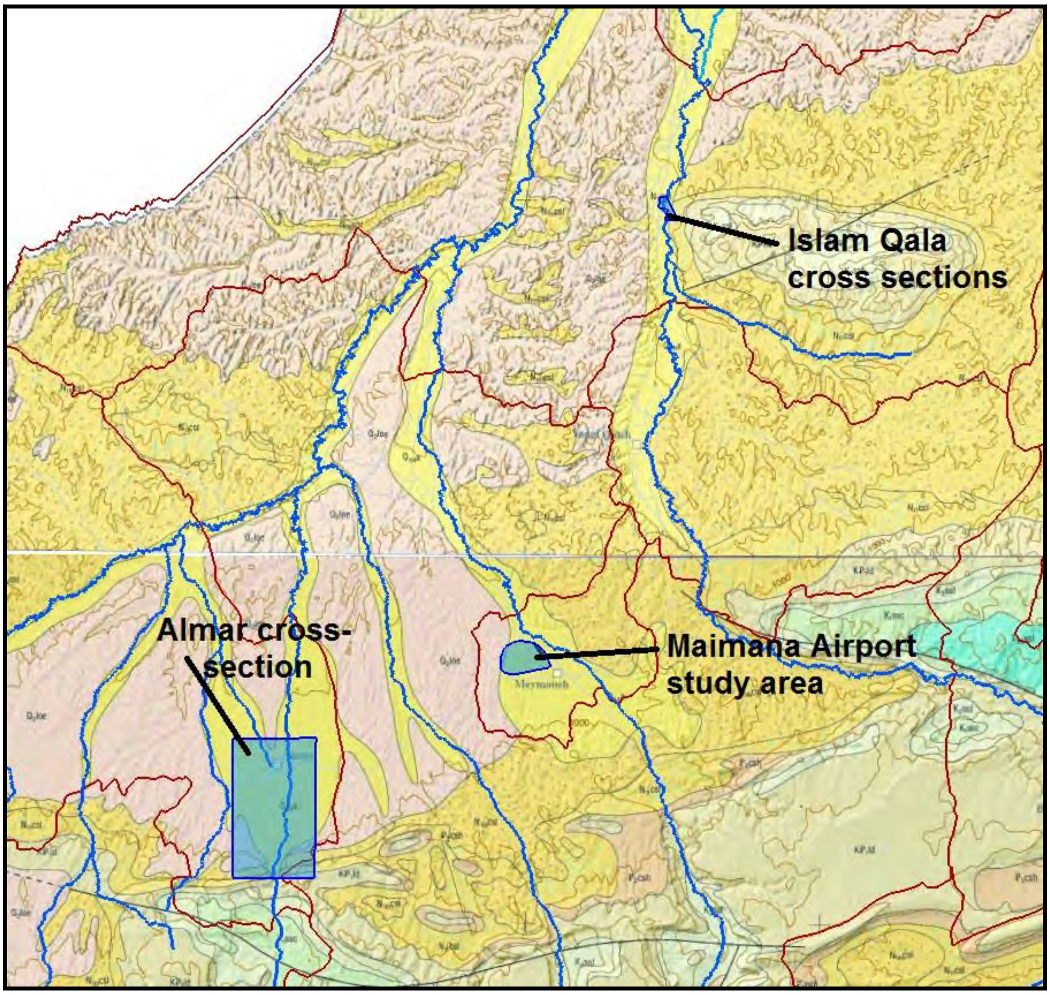


Figure 6.3. Locations of the Almar, Maimana Airport and Islam Qala cross-sections discussed in this chapter. Superimposed on the 1:250,000 scale geological maps of Wahl (2005) and McKinney & Sawyer (2005), published by the Afghan Geological Survey and US Geological Survey and believed to be public domain.

6.4 Almar section

Figure 6.4 shows the location of the section, encompassing the area where the Almar River emerges from the foothills of the Band-e Turkestan through a gorge (1000-970 m asl) onto alluvial terrain. As the river transits from the hilly Mesozoic and Tertiary terrain onto the alluvial area, it has historically deposited (and continues to do so) huge amounts of eroded sands, gravels, silts and clays as alluvial fans ("proluvial deposits" in Russian terminology). The river Almar has a braided, branching and rejoining, character in this section. This river morphology is characteristic of either a high sediment load, or a high terrain slope (caused by the build-up of sediment in the alluvial fans) or both.

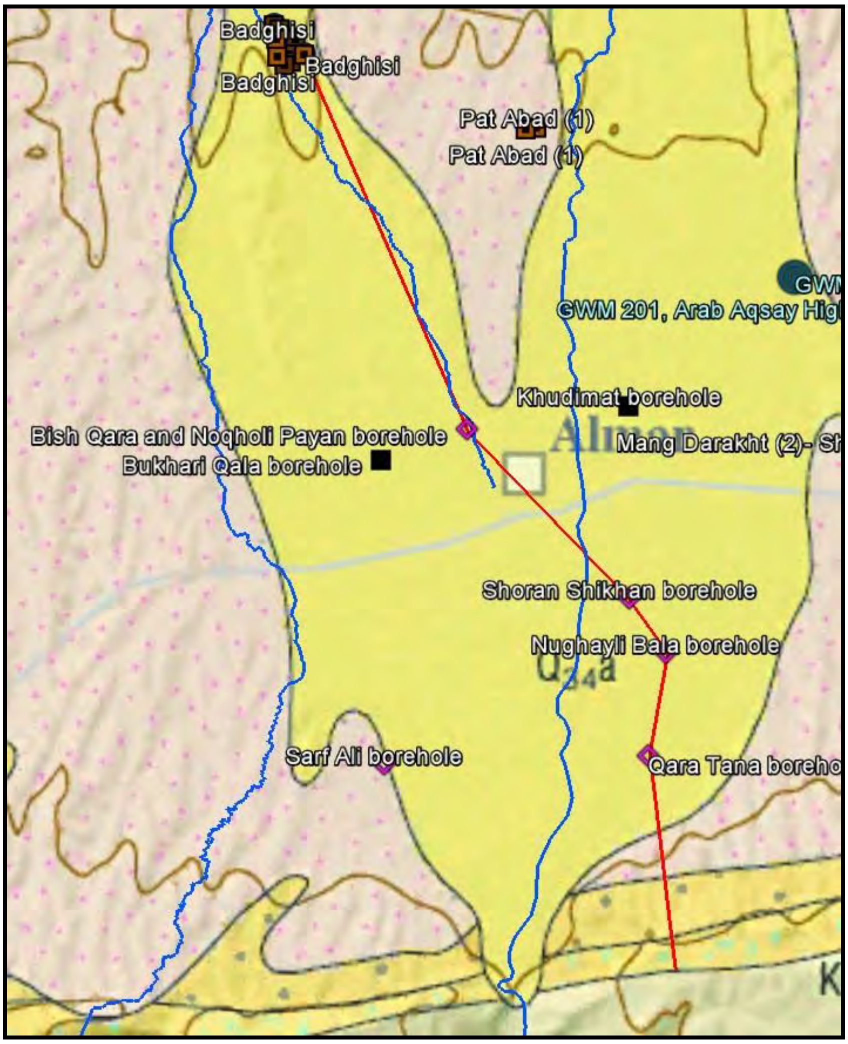


Figure 6.4. Line of cross-section in Figure 6.5, in Almar area, superimposed on the geological map of McKinney & Sawyer (2005), published by the USGS and believed to be public domain. See Figure 6.3 for location.

The sediment deposited as the rivers emerge from the mountains is generally relatively coarse (high content of sands and gravels) and the river water is thus able to infiltrate from the river into the alluvial deposits.

Figure 6.5 shows the south-north section from the Almar gorge to Badghisy. It clearly shows that:

- The groundwater gradient is from south to north, as one would expect. There is no mysterious "depression" in the groundwater levels corresponding to the high depth to groundwater! (Figure 6.2)

- The groundwater gradient is relatively low (presumably due to the aquifer's modest recharge, coarse nature and high transmissivity).
- The topographic gradient is relatively high, due to the alluvial fan / braided river morphology.
- Thus, the terrain slopes more steeply than the water table. Thus, the depth to water table increases to the south (exceeding 100 m in places). The great depth to water table is thus *not* due to "low" groundwater levels, but rather due to "high" surface topography in these areas. To the north of the section, the depth to groundwater is around 30-40 m bgl.
- The water table is always below the level of the surface watercourses. There is thus a tendency for the rivers to infiltrate into the aquifer (although infiltration may be restricted by the generally clayey silty nature of the overbank [?] sediments in the uppermost portions of the borehole logs).

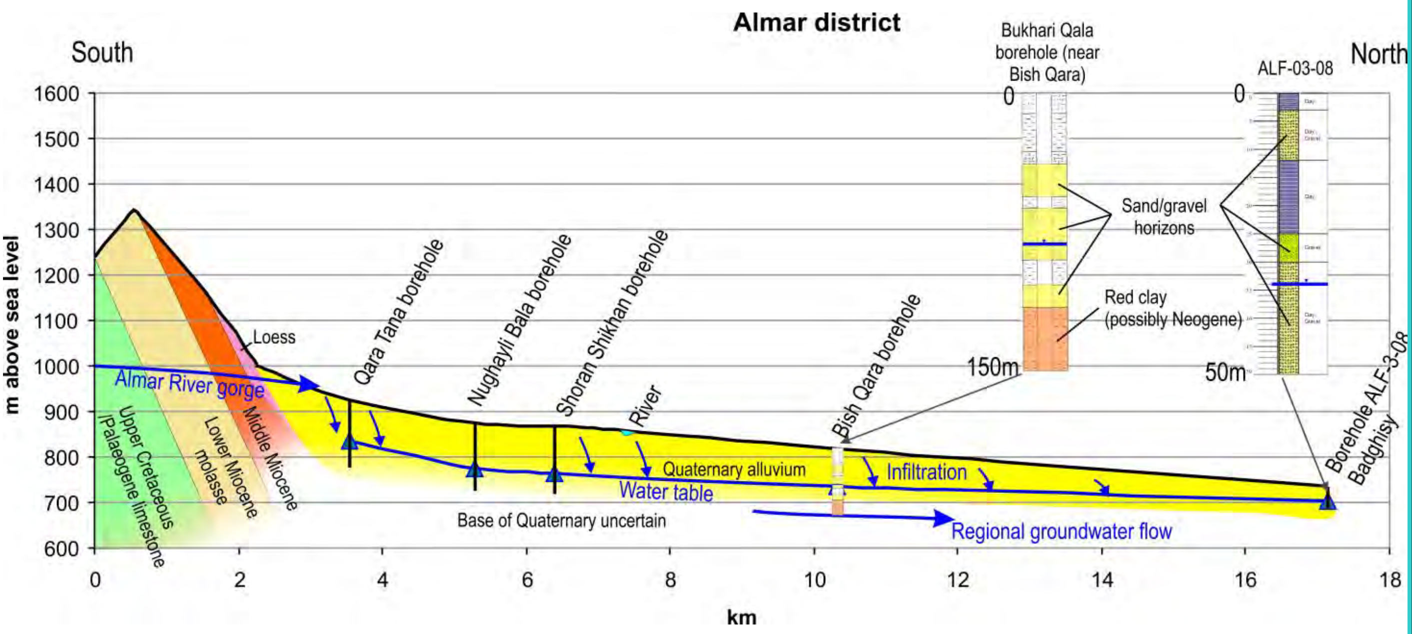


Figure 6.5. South-north section in Almar district (as indicated in Figure 6.4). The Almar river emerges from the mountains in a gorge at 1000-970 m asl. The Bukhari Qala borehole (whose lithological log is shown) is located slightly off the section, but is relatively close to Bish Qara borehole (which does not have a lithological log).

6.5 Maimana Airport section

An area to the north-west of Maimana city has been designated as a study area by NORPLAN - shown in blue in Figure 6.6. It occupies a flat alluvial plain, , underlain by significant thicknesses of Quaternary sand and gravel ,sloping gently from around 850 m asl in the west to around 830 m asl in the east, towards the Maimana River.

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. The published Afghan Geological Survey / USGS maps (McKinney & Sawyer 2005) 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 by Neogene sediments (and possibly also by loess), described as

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

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 (a) that there is a degree of discontinuity between river and aquifer and (b) that there is potential for the river to be infiltrating water into the ground.

The majority of boreholes drilled in the area yield groundwater of moderate electrical conductivity (1200 - 2000 µS/cm), implying a slightly brackish water quality. In the extreme SW of the area, higher conductivities of 2300-3600 µS/cm occur.

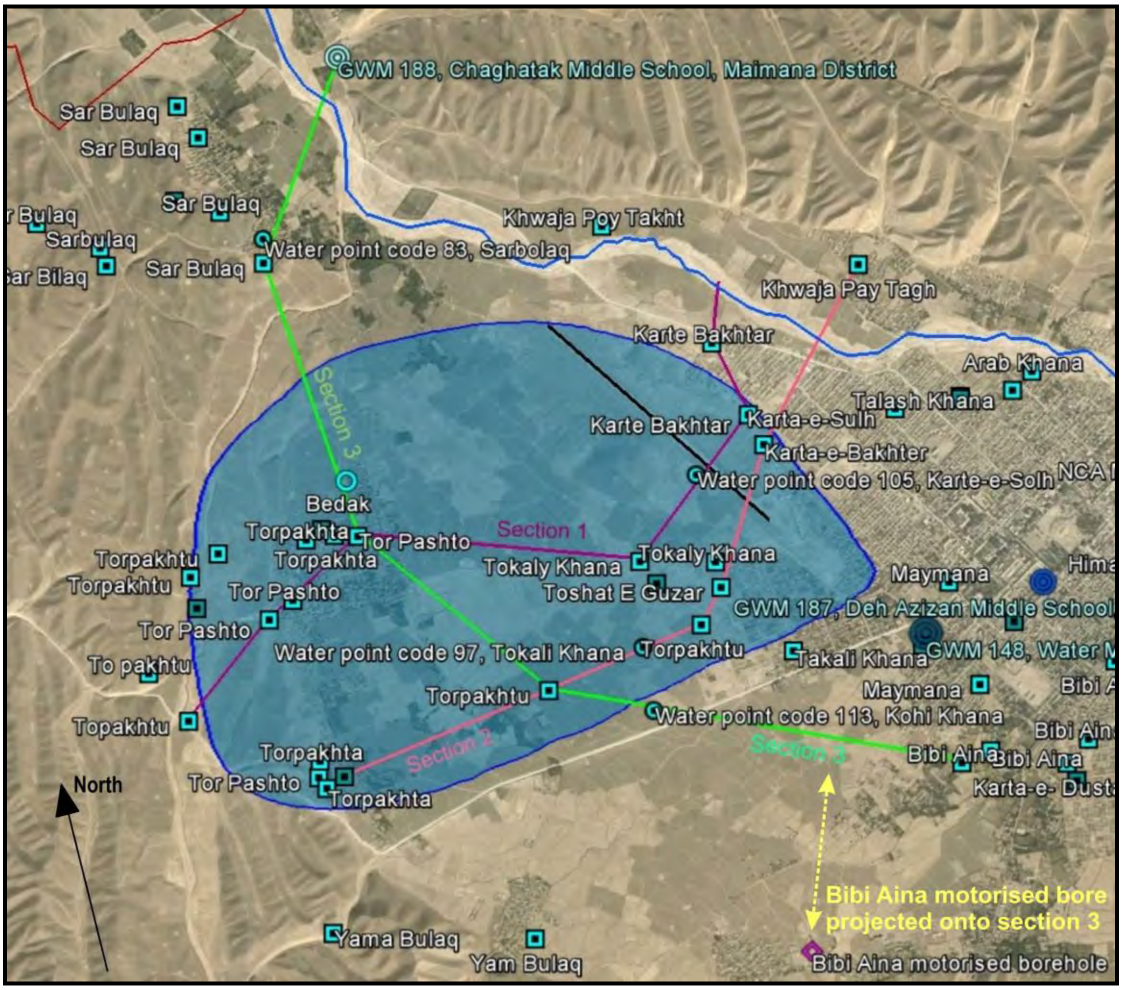


Figure 6.6. Maimana Airport (1.6 km long runway shown as black line) viewed in Google Earth, showing locations of selected drilled boreholes, and the River Maimana as a blue line. The purple, pink and green lines show the cross-sections in Figure 6.7. Note the Bibi Aina motorised borehole towards the bottom right of the map, projected onto the line of cross-section 3.

Cross section 1 (Figure 6.7) suggests that, below the study area, there is an initial clayey layer of thickness < 20 m. The origin of this layer is uncertain, but it may be a combination of overbank sediments and reworked wind/blown material. It is underlain by a substantial gravelly/sandy aquifer unit, which appears to be at least 30-40 m thick (saturated and unsaturated total thickness). This appears to pinch out east towards the

Maimana River, to be replaced by clayey sediments (at least within the depth range of 50-60 m penetrated by the boreholes).

In 2014, the NORPLAN project team carried out a series of geophysical vertical electrical resistivity soundings (VES) in the area, which allowed the aquifer base to be estimated. Interpolating between the Neogene outcrop (to the NE of the Maimana River) and the Neogene encountered at depth in the Bibi Aina borehole, it appears probable that the low resistivity aquifer base encountered in the VES survey represents the surface of the Neogene (Figure 6.8).

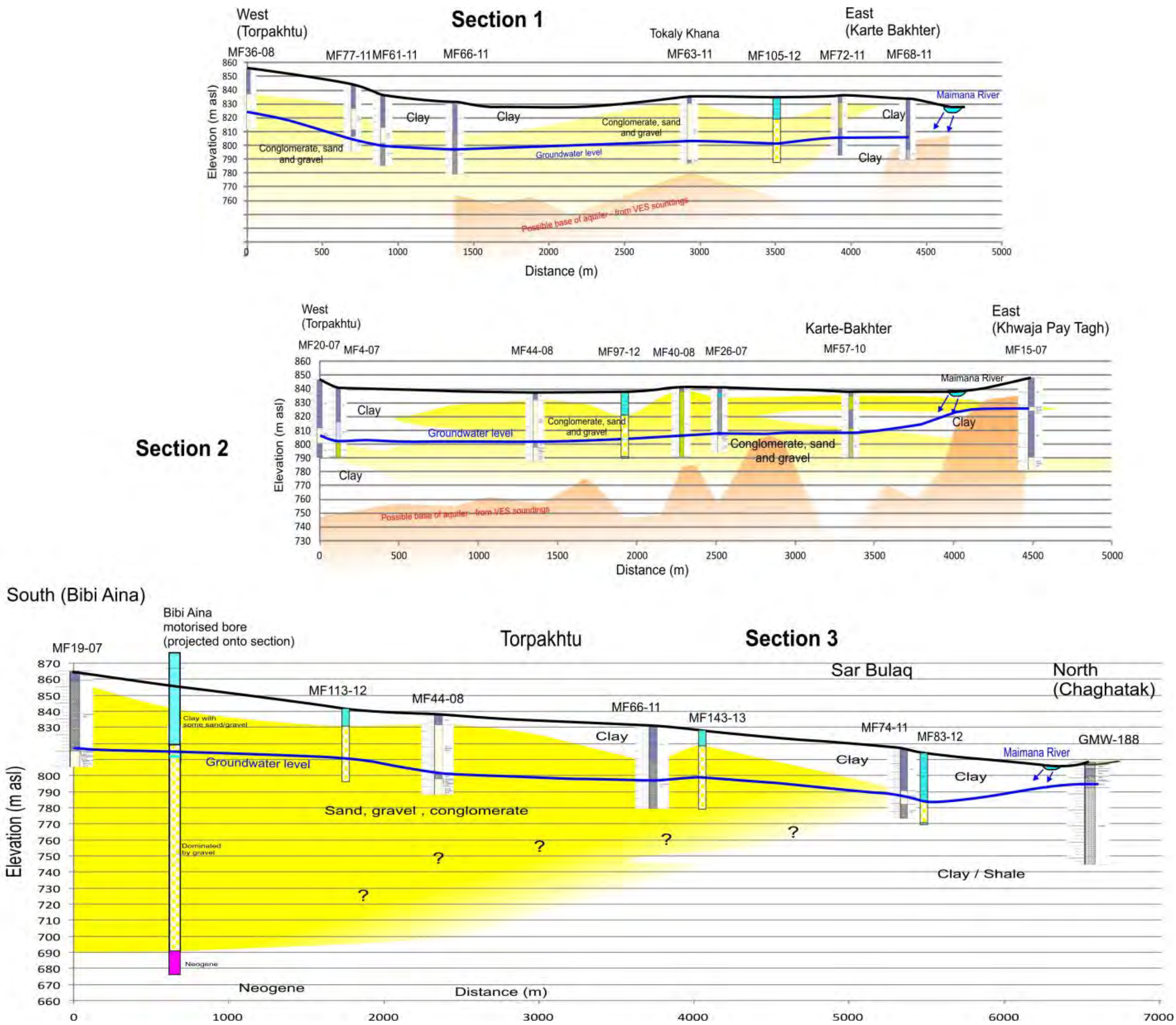


Figure 6.7. Cross-sections 1, 2 and 3, as marked on Figure 6.6, showing the relationships of the sandy/gravelly alluvial aquifer (shaded yellow) and the water table (blue line) to the surface and the Maimana River. In Sections 1 and 2, the base of the aquifer, as indicated by VES (Figure 6.8) is tentatively shown in orange.

In cross-section 1, the groundwater level is typically 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 Sections 1 and 2, again suggesting an infiltrating river regime. The second east-west cross-section, Cross-section 2 broadly supports the findings of cross-section 1.

Cross-section 3 is broadly 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 around 200 m2/d (Table 5.1), with hydraulic conductivity between 1 and 1.7 m/d on average (Table 5.2)) is projected onto the cross section (although it lies some distance to the south of the section - see Figure 6.6). The Bibi Aina borehole encountered clayey-dominated strata with some sands/gravels to 56 m depth, then a gravel-dominated 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).

Cross section 3 also confirms that groundwater levels are below the level of the River Maimana. Despite being disconnected from the River, they do have a gentle, broadly south-to-north gradient, confirming that the general direction of groundwater flow follows the topography from south to north.

Finally, the sand/gravel aquifer seems to pinch out towards the River, in the region of Sar Bulaq, being replaced by clayey / shaley strata, presumably representing the Neogene approaching surface outcrop. The Quaternary sand/gravel aquifer does not seem to extend in any great thickness to the eastern bank of the Maimana River.

In conclusion, 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, then the aquifer thickness could be in excess of 100 m in some places (e.g. the south-west). The aquifer's indicative transmissivity at Bibi Aina is around 200 m^2/d. The aquifer is overlain by clayey sediments ranging in thickness from a few metres to around 20 m.

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.

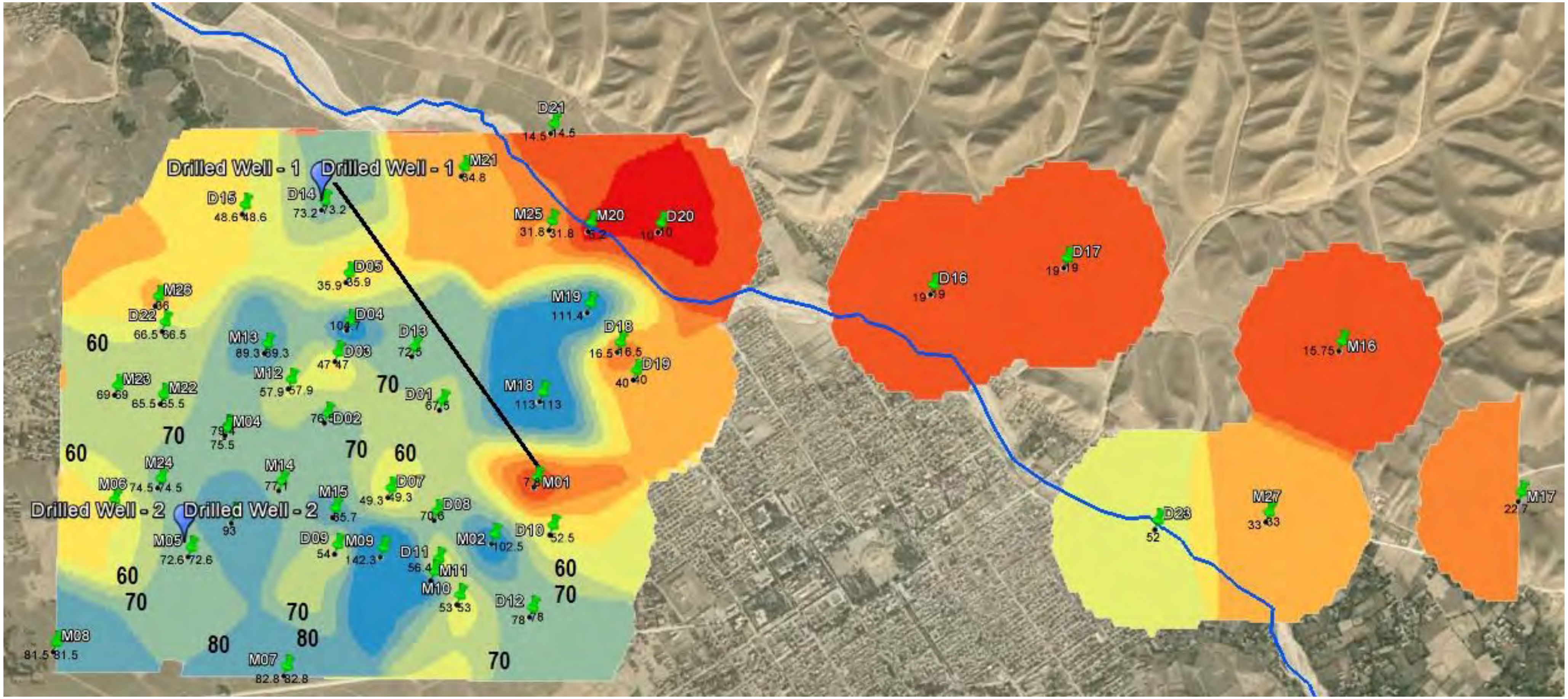


Figure 6.8. Google Earth image used as background to show locations of VES soundings (green pins) with estimated depth to base of aquifer (m bgl) as small black figures. Larger black figures are labels on contours (blue = deep, red = shallow). Large blue pins show locations of exploration wells drilled by MRRD/NORPLAN in late 2014. The depth of the aquifer broadly increases from NE to SW. The black line shows Maimana Airport runway and the blue line is the Maimana River. See Figure 6.6. North is up the page.

6.6 Islam Qala (Shirin Tagab) section

The third examples of hydrogeological cross-sections are taken across and along the Shirin Tagab River, near the settlement of Islam Qala in the southern part of Shirin Tagab district (Figure 6.9).

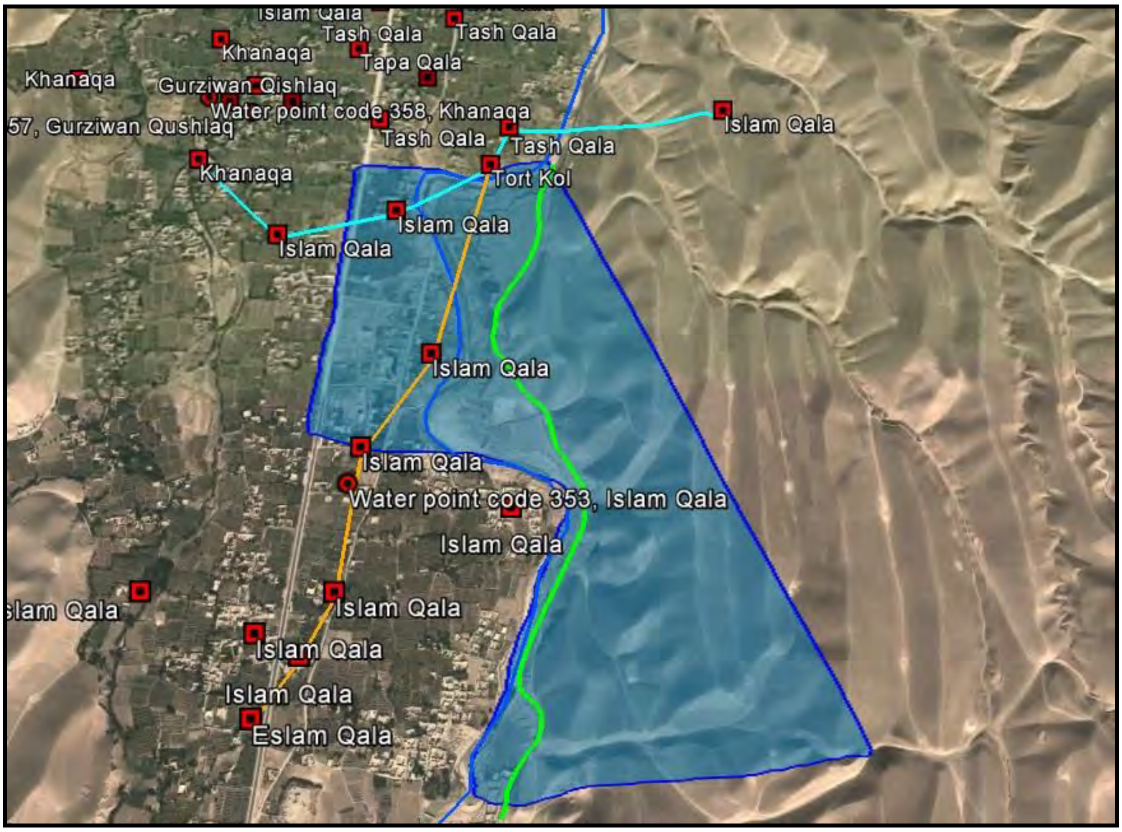


Figure 6.9. Location of Shirin Tagab study area (powered by Google Earth). The dark blue line shows the Shirin Tagab River, flowing north. The green line shows the edge of the alluvial plain and the boundary with the Neogene scarp. Water boreholes are shown as red dots and squares. Pale blue line = cross-section 1; orange line = cross-section 2 (Figure 6.10).

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.

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

- **Q34a - 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

- **N1lcsl - Clay and siltstone (early Miocene)** - Red clay, siltstone more abundant than sandstone, conglomerate, limestone

with some **middle Miocene (N_{1m}csl)** at the northern end of the study area. There are a number of registered drilled boreholes in the area. 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.

There is a considerable amount of data on groundwater electrical conductivity within the study area. The groundwater appears to have a variable, but generally high, electrical conductivity, in the range 1800 - 4000 µS/cm.

Two hydrogeological cross-sections have been drawn across the study area, as shown on Figure 6.10.

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:

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

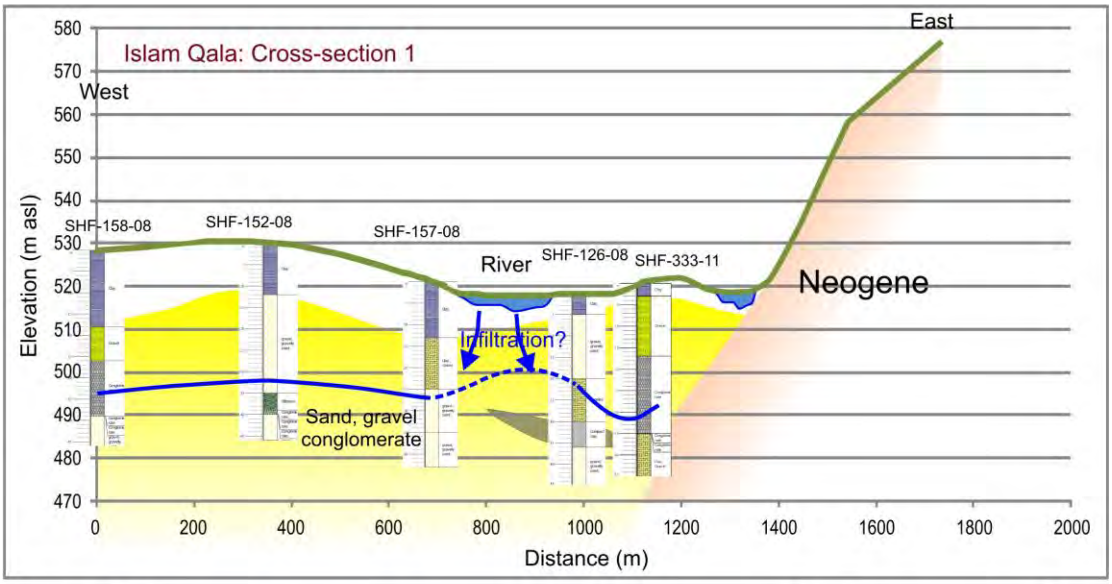
However, the sediments in the vicinity of the river are generally clayey in their upper portion, so the degree of river infiltration to the aquifer may possibly be limited.

The second, south-north **cross-section 2** 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 (although it is likely that they were somewhat north of this study area). They suggest that yields in the range 2 to 12 L/s might be expected from the alluvial aquifer, with drawdowns of 5-7 m.

- 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 1.6 L/s with 3.8 m drawdown after 20 hrs. Optimum yield judged to be 2.6 L/s with 6.9 m drawdown. Electrical conductivity = 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; Electrical conductivity = 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. (Information from Radojicic, 1978). An older handwritten Dari summary suggests that the rest water level on completion was 22.9 m bgl, not 22.2 m bgl.



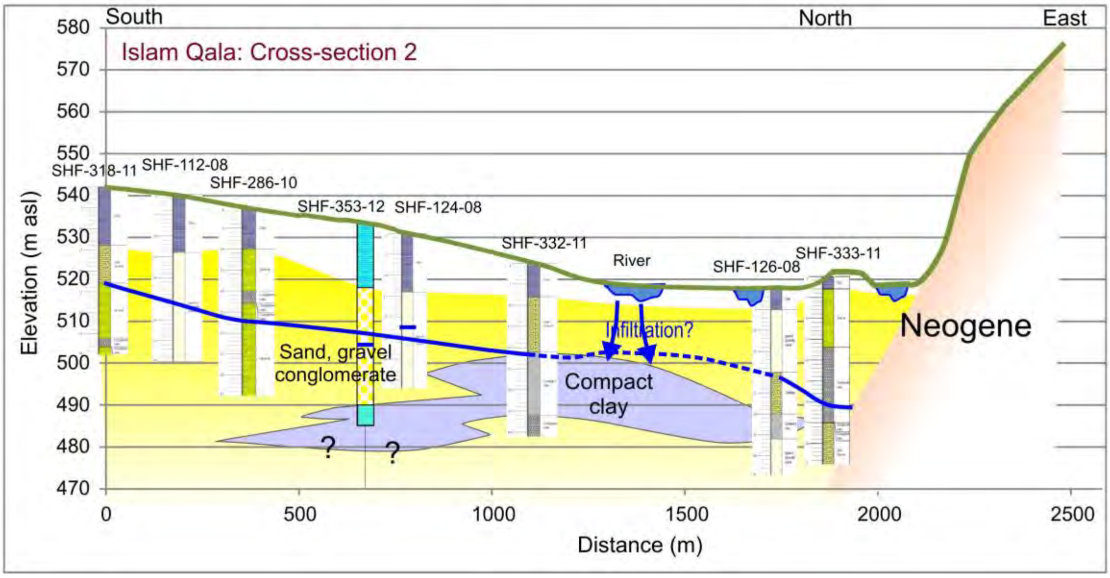


Figure 6.10. Cross-sections 1 and 2, as marked on Figure 6.9, showing the relationships of the sandy/gravelly alluvial aquifer (shaded yellow) and the water table (blue line) to the surface and the Shirin Tagab river. The unshaded surficial layer is clay/silt.

In conclusion, 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 south-north 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.

The climate (and the clayey overburden) means that opportunities for direct recharge are very limited. The clayey overburden may also hinder indirect recharge by infiltration from the river. Thus, a large question mark must be placed over the ultimate sustainability of a major groundwater abstraction from this aquifer.

6.7 Andkhoi cross-section

The cross-section (Figure 6.11) through Andkhoi is taken from Mishkin's (1968) map, and the reproduction thereof in Marinova (1974). The line of the cross-section is shown in Figure 6.1.

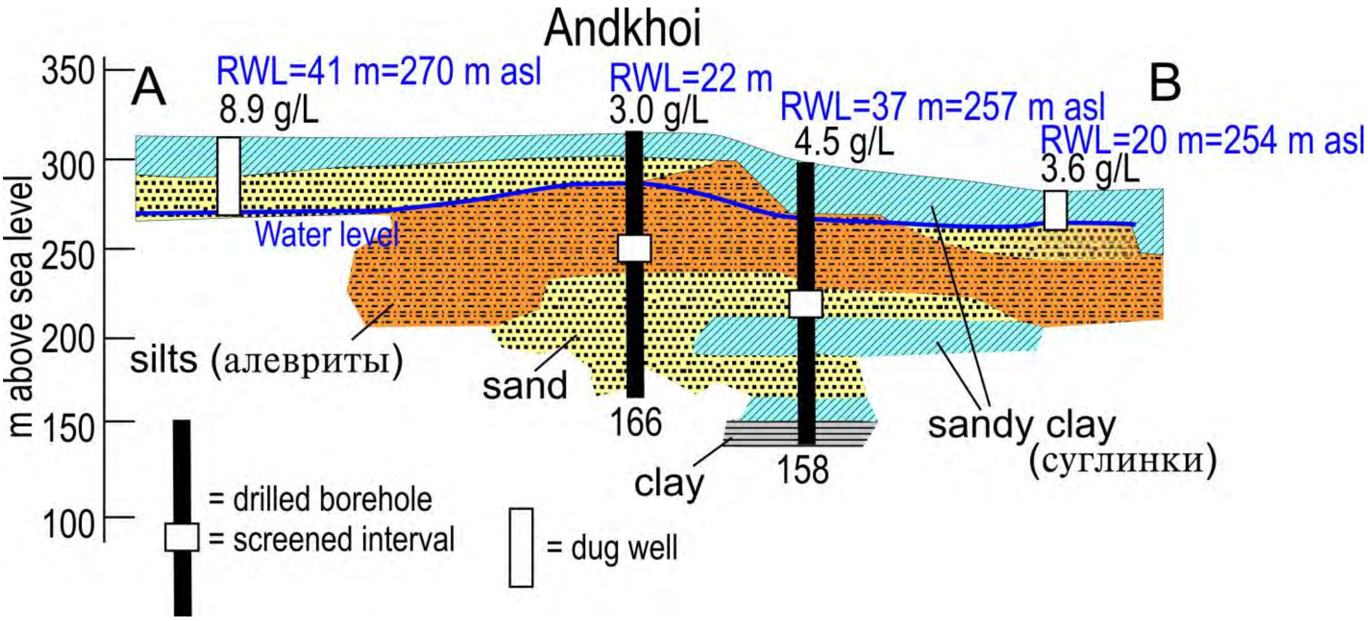


Figure 6.11. West (A) to east (B) section through Andkhoi, from the map of Mishkin (1968) and reproduced by Marinova (1974). RWL = rest (static) ground water level (m below ground level), converted also to m above sea level (m asl). The figure given as g/L is the total mineralization of the water from the dug well or screened interval of the borehole. For the two drilled boreholes, the figure at the base of the well is the depth in m. The stratigraphy extends from Q_I to Q_{IV} (early Pleistocene to Holocene).

The section shows that the ground level in Andkhoi is around 310-320 m asl. The static groundwater level in the deep borehole in the north of Andkhoi (where the well-screen is placed around 60 m down) is around 22 m bgl. This correspond with more recent data from dug wells collected during the 2013 survey, where groundwater levels in Andkhoi and the region immediately north of Andkhoi were typically 15-25 m bgl (Figure 6.13b).

In the top 60-70 m of the section the dominant sediment types are sandy clays and silts, with some modest inferred sand layers, probably enough to provide modest yields of groundwater. Below 60-70 m, a sand horizon(s) of a few tens of m thickness is recorded in the two deep boreholes. The water in these boreholes is still brackish, however, in excess of 3 g/L.

It is interesting that the static groundwater level appears to "mound" beneath the Andkhoi delta area, which is indicative of recharge, possibly via infiltration from the distributary channels of the Shirin Tagab. Received wisdom amongst hydrogeologists working in the area is that the least saline groundwater resources are typically found in the vicinity of distributary and irrigation channels, where infiltration of fresher surface water to the ground may occur at some times of the year (see also Figure 8.7). This is tentatively supported by the fact that the least brackish water (3.0 g/L) is recorded immediately beneath the Shirin Tagab delta at Andkhoi, as compared with 8.9 g/L in the shallow well near the Turkmenistan border.

The ground surface and groundwater level fall away to the east, into what appears to be a valley formerly occupied by a river channel and now currently only marked by a strip of late Pleistocene/Holocene alluvium in Figure 6.1.

6.8 Groundwater level fluctuation

DACAAR operates a network of observation boreholes in Faryab (marked as blue square symbols on Figure 5.2; DACAAR 2011). However, at present, it has only been possible to use data from one of these boreholes to construct a hydrograph. This borehole is at Kariz Qala school, Pashtun Kot district, just north of Maimana, in the vicinity of Kariz Qala / Jar Qala spring (Figures 5.1, 5.2). The borehole is 50 m deep, with a filter installed between 45-49 m depth in compact clayey gravels. The borehole is within a few hundred metres of the Maimana River. The hydrograph, from electronically logged data, is shown in Figure 6.12. Water level amplitude is modest (<60 cm annually). The hydrograph is not corrected for barometric fluctuations, thus the small-scale variations in logged pressure could be due to variations in atmospheric pressure and not water level. However, it is possible to observe

- a rise in water levels from Sept/Oct to April/May in 2009-2010, coinciding with autumn/winter rainfall and snowmelt, and thus with peak river flows.
- a fall in water levels from May to September.

It is important to remember that the changes in water level may be due to actual recharge of the aquifer with water, but that they could also be simply due to "loading" of a confined aquifer by excess water in the nearby River Maimana, without any recharge taking place (and the compact sand / gravel aquifer in the borehole may have some confined nature, being overlain by over 10 m of clay).

If we take the rise in water level as representing recharge (either from the river or from rainfall), a rise in water level of 50-60 cm, combined with a specific yield of 10-20%, might imply a recharge of the order of 50-120 mm of water per year.

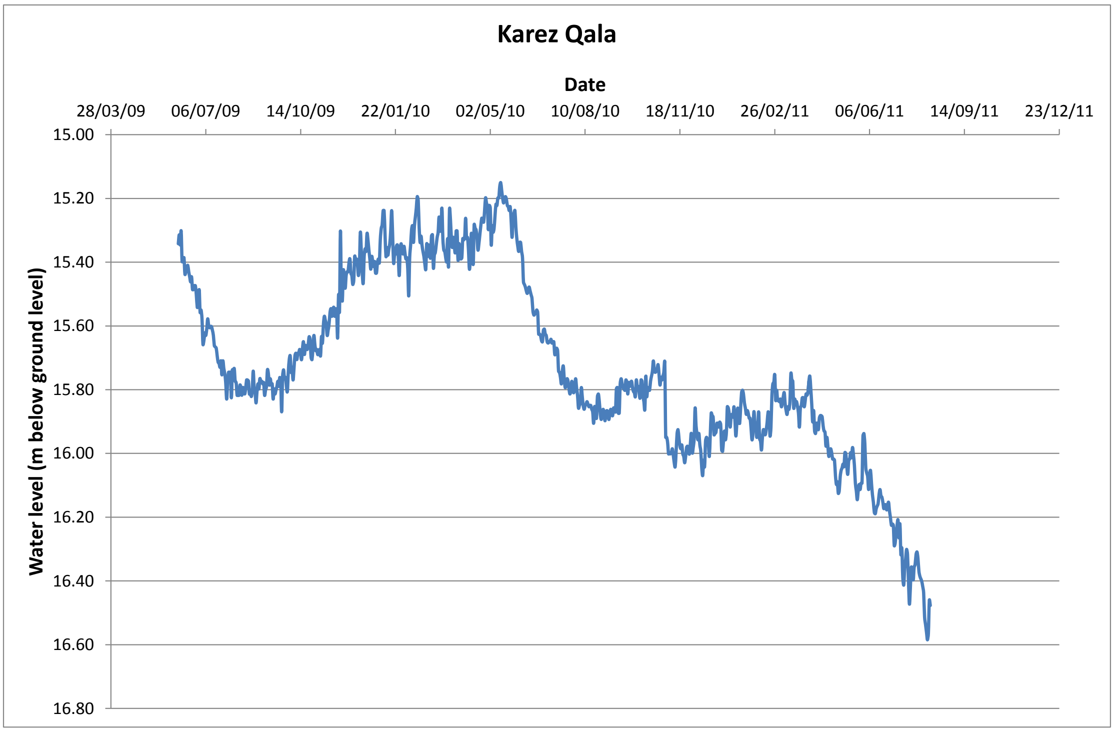


Figure 6.12. Reconstructed hydrograph for DACAAR's 50 m deep Kariz Qala school observation borehole (MW-179) in Pashtun Kot district for 2009-2011. The hydrograph is subject to some uncertainty due to a single manual calibration. The hydrograph is uncorrected for barometric pressure.

6.9 Conclusions: Recharge and Discharge

Groundwater Recharge

Thus far, the picture that we have gained from examining the example cross-sections in Sections 6.4 to 6.7 is one where:

- that direct infiltration of rainfall and snowfall probably takes place in the Band-e Turkestan mountains and their Mesozoic / Palaeogene foothills. The groundwater recharge emerges as spring flow (especially from the karstic limestone aquifers) and base-flow, supporting the discharge in the main rivers.
- as there rivers cross from the mountain foothills onto the alluvial valleys and plains or central and northern Faryab, the main water table in the alluvial aquifers falls consistently below the level of the main rivers.
- there would thus be a general tendency for the rivers to infiltrate into the ground, into the alluvial aquifers. The magnitude of this recharge would likely be limited by the modest permeability of the generally clayey / silty nature of the strata in the upper part of the alluvial geological succession.
- one might thus expect the groundwater in the immediate vicinity of the river channels to be fresher than elsewhere.
- the depth to groundwater gradually decreases northwards: from in excess of 50 m bgl in the Qaysar and Almar areas, to 20-40 m in the Maimana and Shirin Tagab areas, and to 15-25 m bgl around Andkhoi / Khani Chahar Bagh. Figure 6.13b suggests that rest water levels decline to depths in excess of 30 m again in the very north of the Andkhoi / Khani Chahar Bagh area.

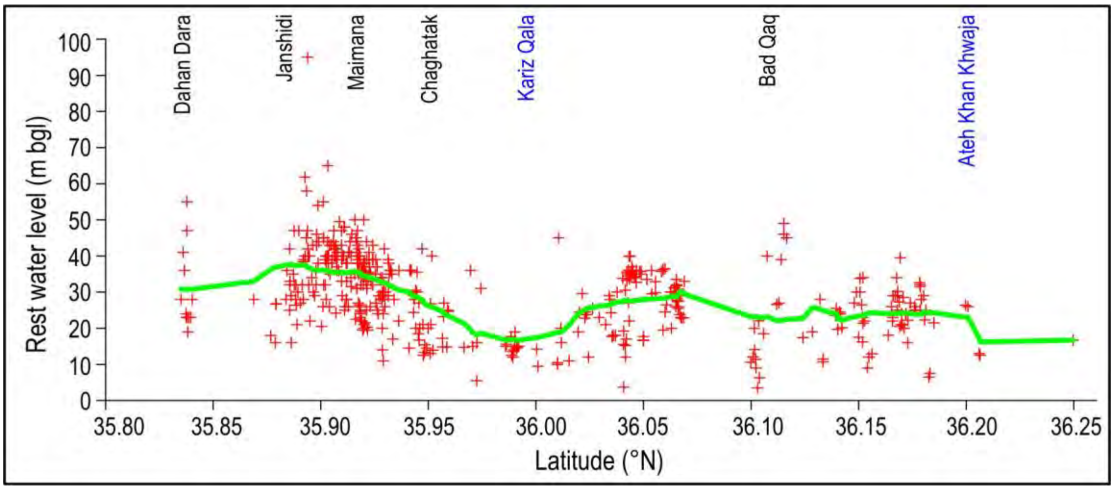


Figure 6.13a. Rest water levels in wells and boreholes registered along the valley of the Maimana River, from south (left) to north (right). Levels in metres below ground level (m bgl**).** The green line shows a moving average through the data. Kariz Qala / Jar Qala and Ateh Khan Khwaja springs are marked in blue.

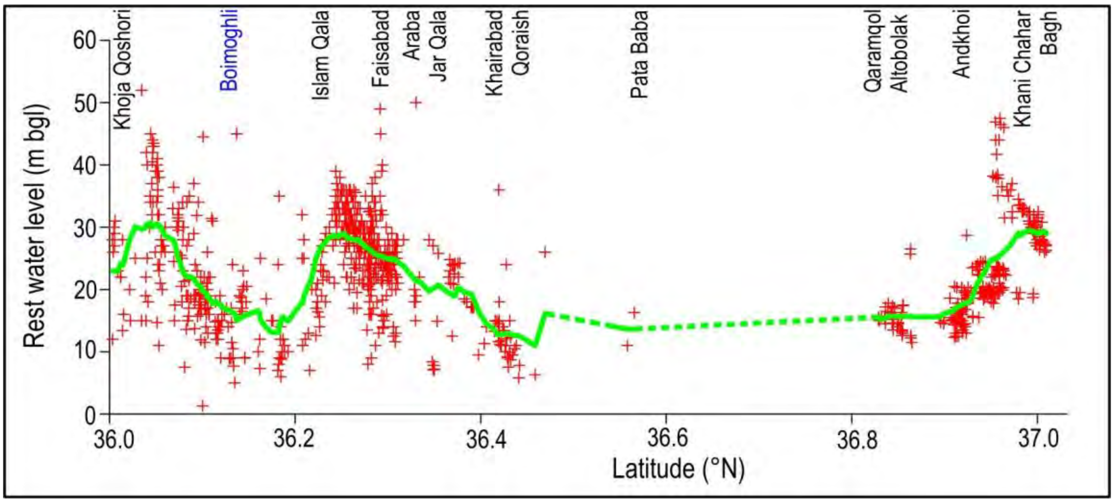


Figure 6.13b. Rest water levels in wells and boreholes registered along the valley of the Shirin Tagab River, from south (left) to north (right). The green line shows a moving average through the data. Boimoghli spring is marked in blue.

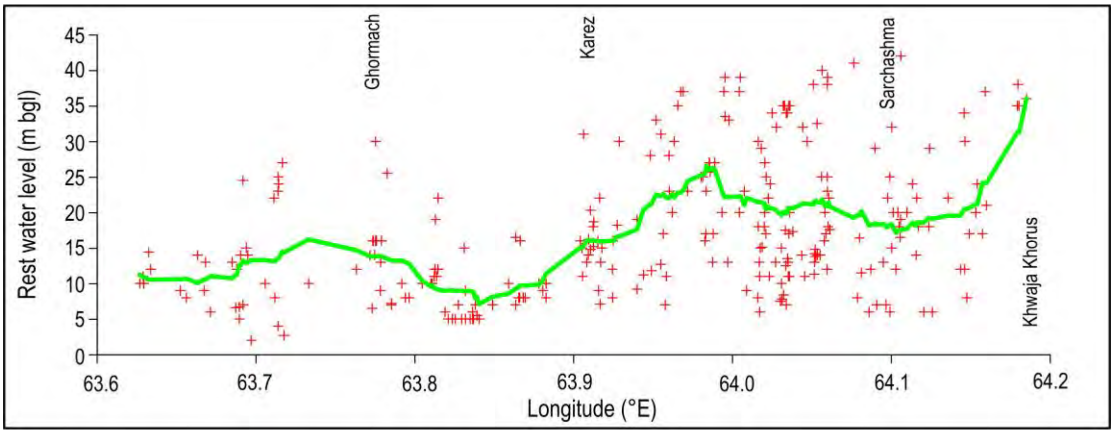


Figure 6.13c. Rest water levels in wells and boreholes registered along the valley of the Chechaktu River, from west (left) to east (right). The green line shows a moving average through the data.

Figure 6.13c suggests that groundwater levels also become shallower downstream along the Checkaktu valley from east to west, with groundwater levels <10 m deep becoming common in the Chechaktu valley in Ghormach.

Specific Loci of Groundwater Discharge

Despite the general impression of groundwater levels typically being >10 m below ground level in the main river valleys, there are loci of groundwater discharge in the northern regions of Faryab. The most obvious of these is the **Khwaja Mod saline lake**, which appears to act as a discharge locus for local groundwater flow in the alluvial / Neogene aquifers (Figure 6.1). It also is believed to act as a discharge for deeper regional groundwater flows via a major fault zone (see Section 6.1). The groundwater discharge at this location is evaporated away, leaving deposits of halite and gypsum.

There are other, very specific, springs in the northern part of Faryab, which act as important sources of water supply for the local population. Some of these are relatively easy to understand: the springs at Moghaito emerge from higher elevation aquifer strata in a Mesozoic inlier and are presumed to be fed by direct infiltration of modest amounts of precipitation.

The other springs, which are less easily understood, include (Figure 5.1):

- The **Boimoghli spring**, with an estimated discharge of some 35 L/s and electrical conductivity of 1510 µS/cm (2007 data), emerging from the side of the Shirin Tagab valley in the northern part of Khwaja Sabz Posh district. A number of wells near the spring record water levels of c. 10 m bgl in the alluvial deposits. As the spring is approached, however, groundwater levels become shallower, with the nearest well (KHF-148-07, Turk Man Qishlaq) recording a water level of only 5 m bgl.

- The **Jar Qala spring**, with an estimated discharge of some 25 L/s and electrical conductivity of 1385 µS/cm (2007 data), emerging from the valley side of the Maimana River, in Pashtun Kot district, some 10 km NW of Maimana city. A spring in a similar location, on the alluvial floor of the Maimana River valley, was registered as **Kariz Qala spring** in 2013 (Figure 5.5), with a discharge estimated as only 2 L/s and an electrical conductivity of 1350 µS/cm. It is uncertain whether these represent two different springs. The location of the spring area is difficult to understand: a number of nearby dug wells and a DACAAR observation borehole at Karez Qala school all record a groundwater level of around 15 m bgl (Figure 6.12).

- The **Ateh Khan Khwaja spring**, at the junction of the Maimana and Qaysar rivers (i.e. at the start of the Shor Darya), in Shirin Tagab district. This has a discharge of some 35 L/s and electrical conductivity of 2450 µS/cm (2007 data). The location of the spring area is difficult to understand as the wells and boreholes in the vicinity exhibit groundwater levels of >20 m bgl in the alluvial deposits (Figure 6.13a). These are upstream of the spring, so we have no good data on groundwater levels downstream of the spring, although Hassan Saffi (*pers. comm.* Sept 2013) indicates that the Shor Darya's surface water salinity creeps up downstream of the Ateh Khan Khwaja spring, due to seepage of saline groundwater in the bed of the Shor Darya, suggesting the water table is close to the surface.

On the cross-sections of Figures 6.13a and b, it is noticeable that the depth of the water level below ground does not show a smooth trend. Indeed, there are four clear locations where the water table approaches more closely to the surface:

(i) In the Maimana valley, in the vicinity of Kariz Qala / Jar Qala springs.

(ii) In the Maimana valley, in the vicinity of Ateh Khan Khwaja (but based on very few data).

(iii) In the Shirin Tagab valley, just downstream of Boimoghli spring.

(iv) In the Shirin Tagab valley, along the stretch of river north of Jar Qala.

...in other words, in the vicinity of the major springs, and the zone of the Shirin Tagab where flow accretion is registered (see Chapter 3 and below).

Thus, it appears that the major spring discharges emerge where the water table approaches the surface (and, although the registered groundwater levels still appear well below the surface in nearby boreholes, this could simply be a topographic effect if the springs occur in incised spring-flow channels or the incised recent valley of the river itself).

The reasons why the rest water table appears to approach this surface in these locations could include:

(i) constrictions of the permeable alluvial channel, reducing its transmissivity. These constrictions could be lateral (width of channel) or vertical (depth of channel), forcing groundwater flow to the surface.

(ii) The fact that a major lateral groundwater flow joins the main alluvial channel, e.g. from a side channel. The excess groundwater flow being constricted in a single channel could force it to emerge at the surface. This could be the reason for the location of the Ateh Khan Khwaja spring at the confluence of the Maimana and Qaysar rivers.

The Jar Qala (near Maimana) spring appears (on Google Earth) to emerge from the western valley side. If so, it would appear to originate in loess / Neogene deposits. Given the name of the location (Kariz Qala), it is not inconceivable that the feature is not really a spring at all, but a karez construction into the valley side. The Kariz Qala spring in the valley floor could simply be a re-emergence resulting from the excess water entering the alluvial deposits.

Flow Accretion in the Lower Shirin Tagab

It was noted, in Chapter 3, that the Shirin Tagab loses the majority of its flow to the Araba irrigation channel, at the border between Shirin Tagab and Dowlatabad districts. However, flow re-accretes in the Shirin Tagab downstream.

The slope on the irrigation channel is less than that of the river and the river thus sinks progressively below the level of the irrigation channel northwards. We speculate that the irrigation channel loses water, either by leakage, or direct application to fields, to the ground. This leakage to groundwater may flow north and west towards the river channel to gradually re-emerge as baseflow to the river channel. There may even be some direct overland flow from the irrigation channel to the river, via irrigated fields, or interflow via shallow soils and drains.

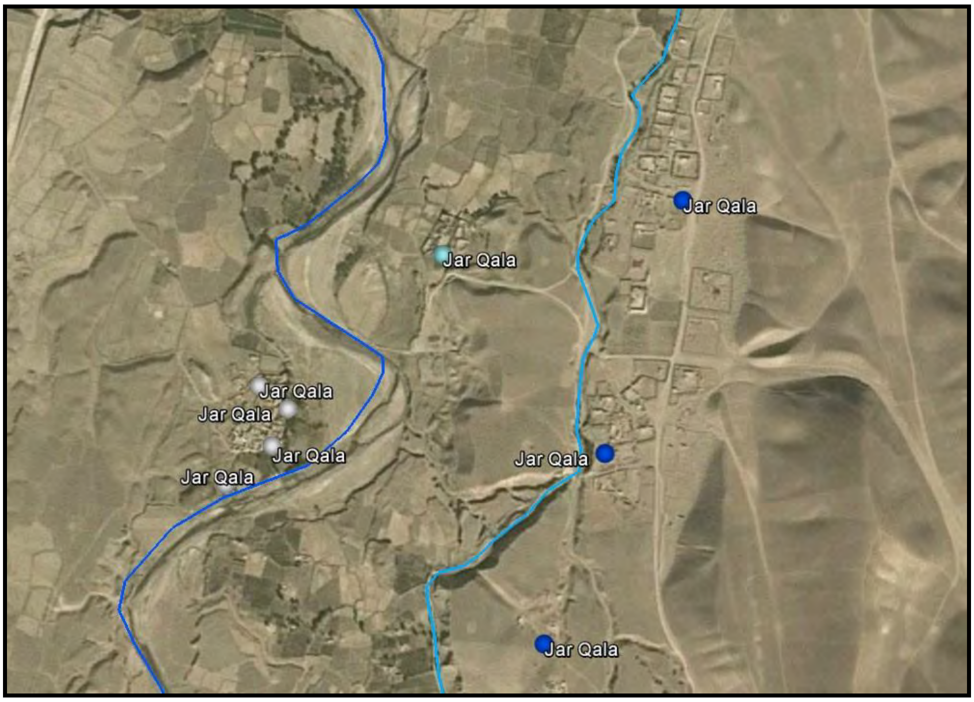


Figure 6.14. The Jar Qala region of Dowlatabad district, some 3 km north of Araba. The irrigation channel (pale blue) is to the right and the River Shirin Tagab (dark blue) is to the left. Dark blue dots show wells with groundwater levels around 25-30 m bgl, pale blue around 15 m bgl and white around 7-8 m bgl.

At Jar Qala, the river and irrigation channel are separated by only some 500 to 700 m. The irrigation channel is at an elevation of 455 m asl, while the River Shirin Tagab is at some 435 m asl. In wells near the river, the groundwater level is less than 10 m from the surface, suggesting the potential for upwelling of groundwater discharge and flow accretion, in addition to possible overland flow and interflow. Indeed, Hassan Saffi (*pers. comm.*, Sept. 2013) confirms that there are numerous groundwater springs in the bed of the River in this region of Dowlatabad district.

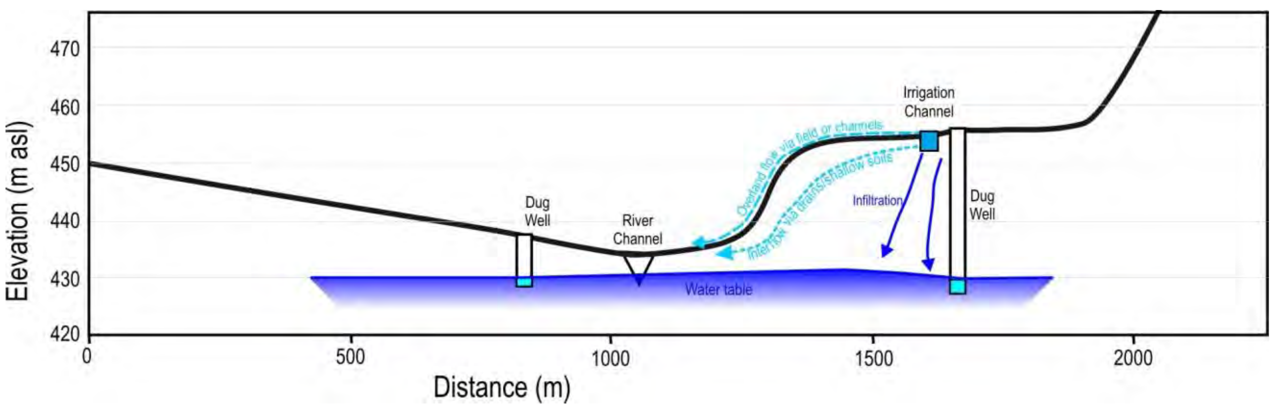


Figure 6.15. Schematic cross-section across the Jar Qala region of Dowlatabad district, some 3 km north of Araba, based on Figure 6.14, showing the various mechanisms for flow re-accretion in the river channel. This interpretation is highly speculative, using terrain elevations extracted from Google Earth. The correctness of this possible interpretation would depend on highly accurate surveying of ground and groundwater levels.

A similar situation pertains further to the north, in the Khairabad, Qoraish and Dowlatabad areas, where a large area of groundwater levels of <10 m bgl is located between the irrigation channel and the river.

In all cases, the explanations for the emergence of groundwater and spring flow discharges at these locations are very tentative. Much depends on accurate surveying or terrain and water levels, as any groundwater gradients involved would be very shallow. Research projects to investigate the hydrogeology of these areas would undoubtedly be most productive in terms of increased hydrogeological understanding.

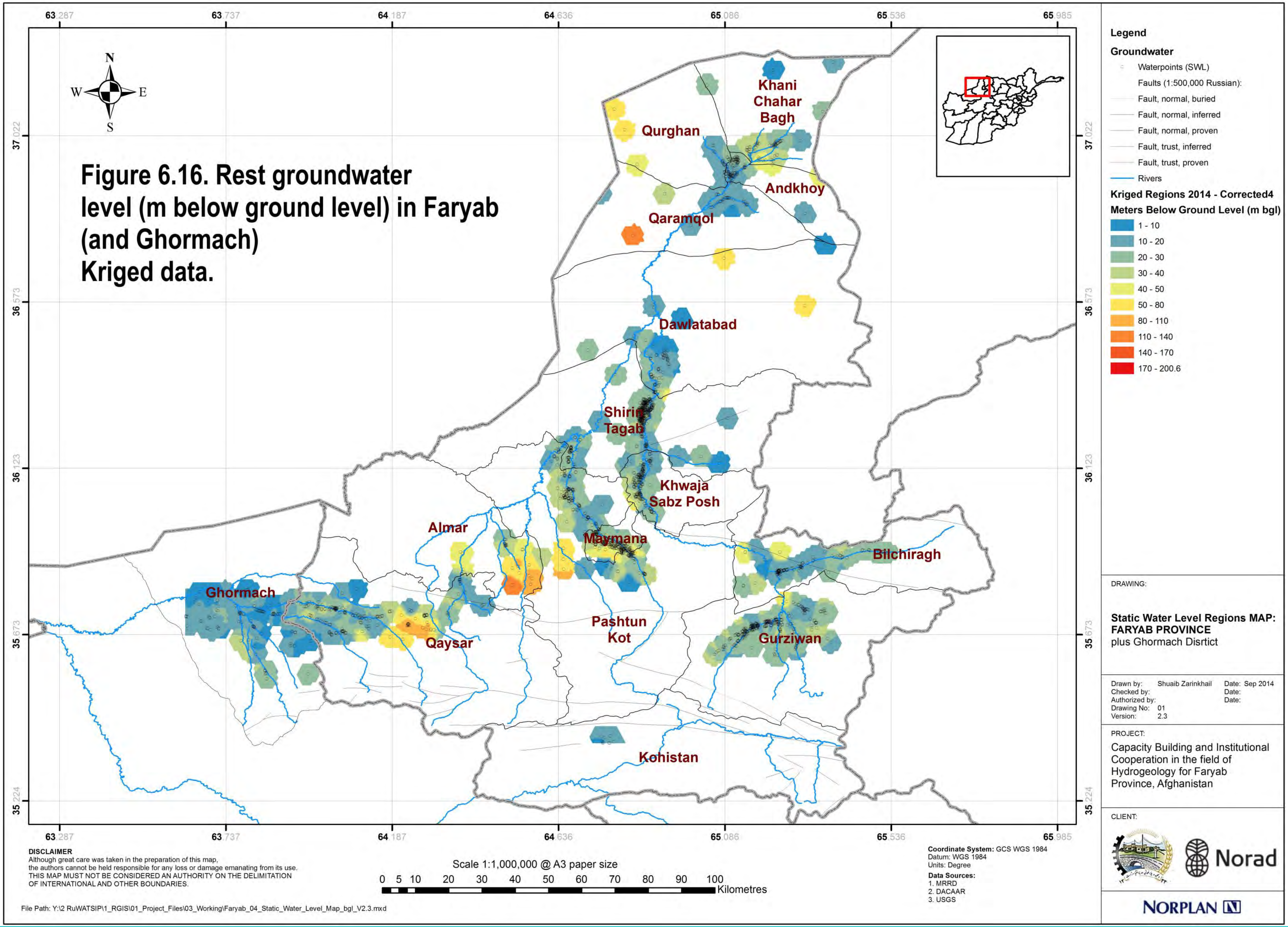


Figure 6.16. Rest groundwater level (m below ground level) in Faryab (and Ghormach) Kriged data.