# 8. Faryab: Groundwater Salinity

## *8.1 Previous Studies*

As we have previously seen, from Chapter 1, historical writings imply that salinity has always been the greatest water supply problem for the northern districts of Faryab.

Mishkin's (1968) delineates zones of groundwater salinity (total dry residue in g/L), as shown in Figure 8.1.

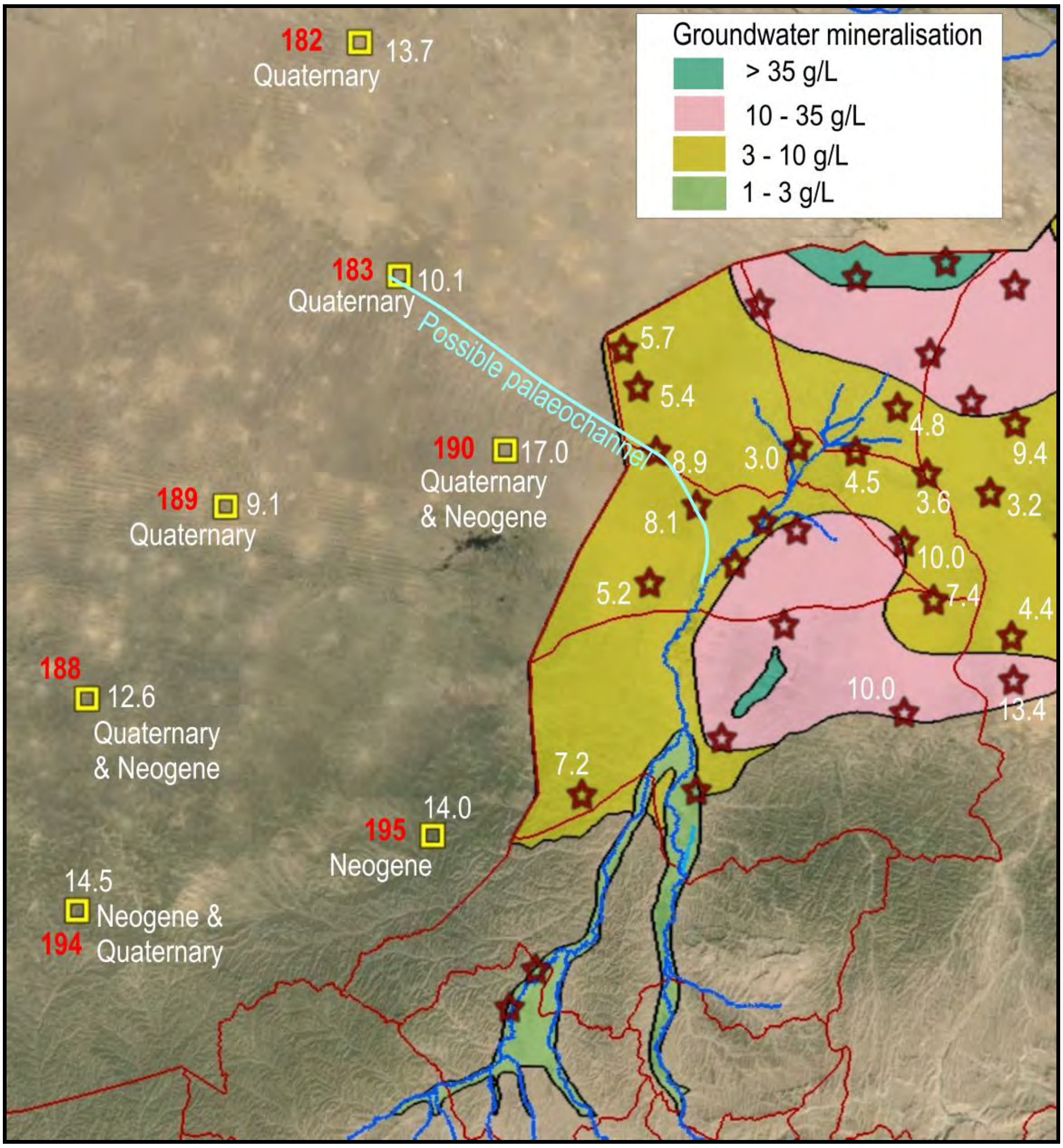



**Figure 8.1. Aerial image showing Mishkin's (1968) groundwater salinity zones (in g/L of total dry residue) for the Quaternary deposits of northern Faryab.** Red stars show the wells, boreholes and springs that Mishkin used to delineate his zones. White figures show groundwater total dry residue in g/L at individual boreholes and wells. Yellow squares show wells/boreholes in Neogene and/or Quaternary deposits in the Turkmen desert, taken from Krizhanovskii (1972). White text shows the aquifer horizons in these boreholes, while the red number is the Soviet borehole number. Red lines show district boundaries, blue lines show rivers.

Mishkin's map clearly shows:

- That groundwater salinity increases northward from values of 1-3 g/L in the alluvial deposits of the Maimana and Shirin Tagab valleys of Khwaja Sabz Posh, Pashtun Kot and Shirin Tagab districts, to >35 g/L in the far north of the Province.
- That there is also a zone of high groundwater salinity surrounding the regional groundwater discharge point of the Khwaja Mod saline lake.
- That there are generally lower salinities in the immediate vicinity of the main river channels. It should be noted, however, that zone of fresh groundwater along the Shor Darya in Mishkin's (1968) map is *not* supported by current data, which indicates saline groundwater along the Shor Darya.
- That around Andkhoi, groundwater salinity is generally > 3 g/L, even at depth (see Figure 6.11).
- That even further to the north (not shown on Figure 8.1), as one approaches the Amu Darya, groundwater salinity decreases again, and that a zone of fresher groundwater borders the Amu Darya valley (MUMTAZ 2007).
- That the intermediate salinity waters are often of sulphate type (sometimes chloride), while the highest salinity waters have more of a tendency to be of chloride type (not shown on Figure 8.1).

Across the border in Turkmenistan, groundwater salinities are even greater than in Faryab, typically > 10 g/L (Krizhanovskii 1972). There is no evidence from Figure 8.1 that a tentatively identified palaeochannel (Figure 6.1) stretching from the Shirin Tagab in Qaramqol to the Turkmen Unguz is associated with fresh groundwater reserves.

## *8.2 Salinity and Electrical Conductivity*

Electrical conductivity is measured in µS/cm and characterises how easily the water conducts an electric current. There is a direct relationship between the electrical conductivity (EC) and the water's content of charged ions - i.e. its salinity. In general, at 25°C (Misstear et al. 2006):

**1 meq/L of cations (or 1 meq/L of anions) results in 100 µS/cm of EC** (8.1)

up to around 2000 µS/cm

or

**M (mg/L) = EC (µS/cm) x f** (8.2)

where f = 0.55 for a water dominated by sodium chloride

f = 0.75 for a water dominated by calcium bicarbonate

M = total dissolved solids, mineralisation, dry residue or salinity in mg/L

**Guidance**

A former edition of the SPHERE standards (2000) for humanitarian relief indicated that total dissolved solids in drinking water should be less than c. **1000 mg/L** (**EC < 2000 µS/cm**). The most recent edition (2011) merely states that the water must be palatable.

The WHO (2011) drinking water guidelines suggest that water typically becomes significantly and increasingly unpalatable at TDS levels greater than about **1000 mg/L**.

In most cases, the data held in the NORPLAN project database for Faryab represent direct measurements of EC, although it is not always clear whether the measurements are representative of a field temperature or have been corrected to a standard temperature (25°C).

In a few cases, the groundwater's total mineralisation M has been cited (this is especially the case for a small number of typically saline wells derived from Soviet literature for Turkmenistan or northern Afghanistan). For the purposes of plotting, this has been back-estimated to electrical conductivity using the algorithm:

**IF (M <= 1500 mg/L) THEN (EC = M/0.7) ELSE (EC = M/0.6)** (8.3)

on the basis that the more saline waters are more likely to be dominated by sodium chloride.

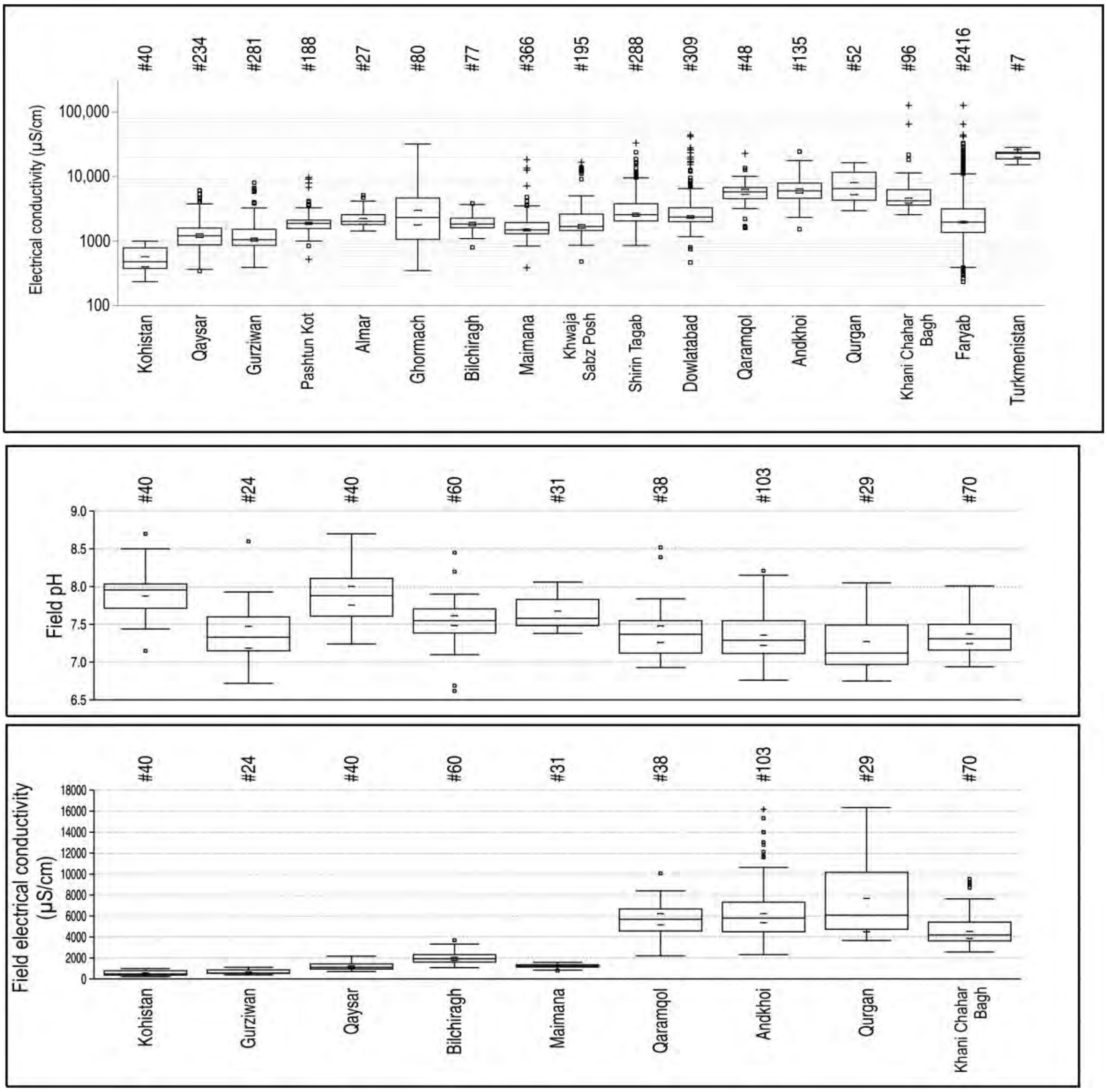



**Figure 8.2. Boxplots showing the distribution, by district, of (top) groundwater electrical conductivity (wells, boreholes, springs) from the entire NORPLAN database**, in Faryab and adjacent areas of Turkmenistan. The subset "Faryab" includes Ghormach. The lower two diagrams show (middle) **field pH** and (bottom) **field electrical conductivity** from 435 wells, boreholes and springs visited during the field survey of 2013. See text box below for an explanation of the boxplot.

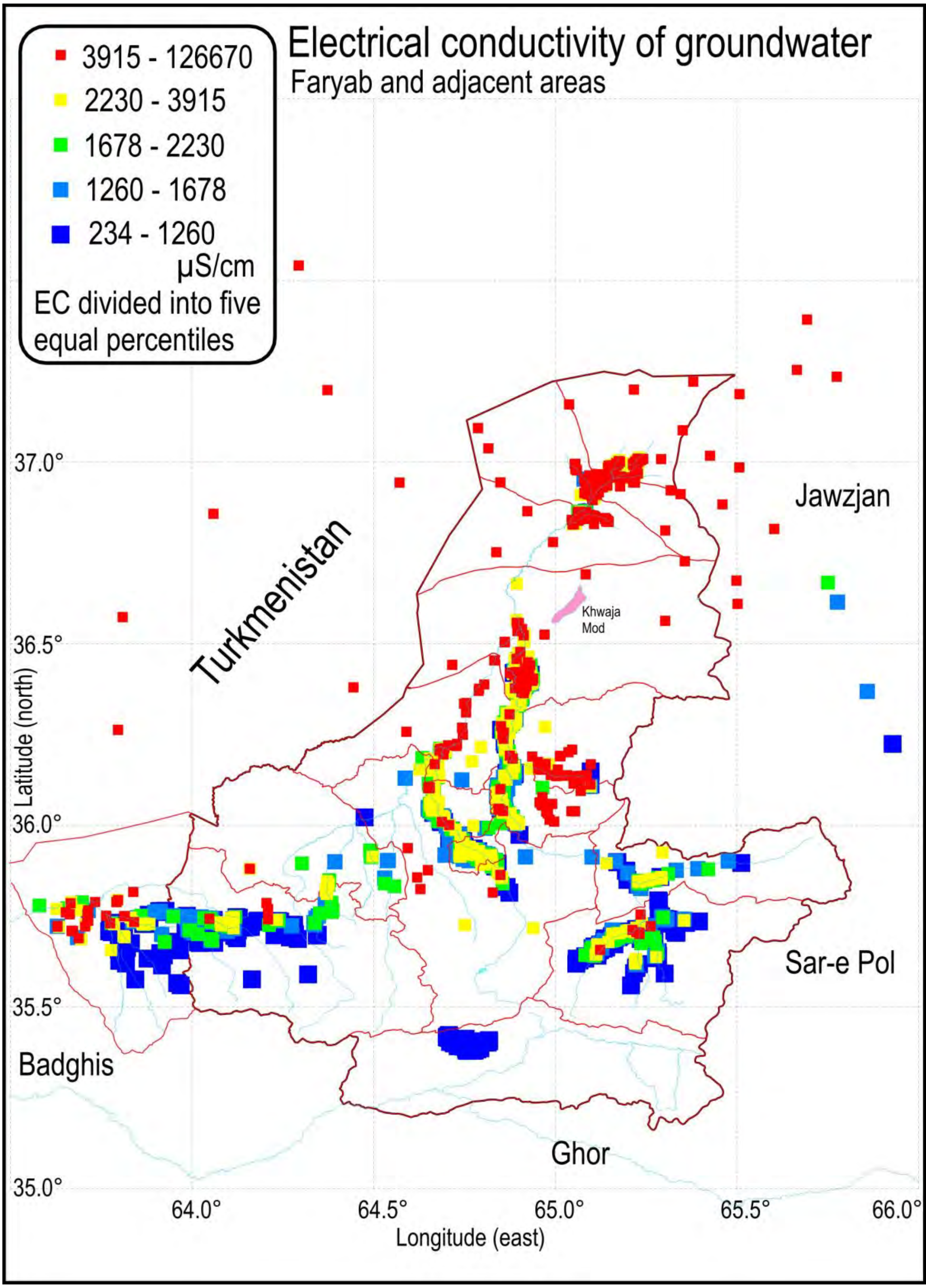



**Figure 8.3. Electrical conductivity of groundwater in Faryab and adjacent areas, using all data in NORPLAN database as of September 2014.** N=2354 for map. Note that data are concentrated in valleys and symbols for red "high" values can obscure lower values behind them. Also note that the EC of a few very saline waters may be somewhat overestimated due to the conversion algorithm from mineralisation (Equation 8.3).

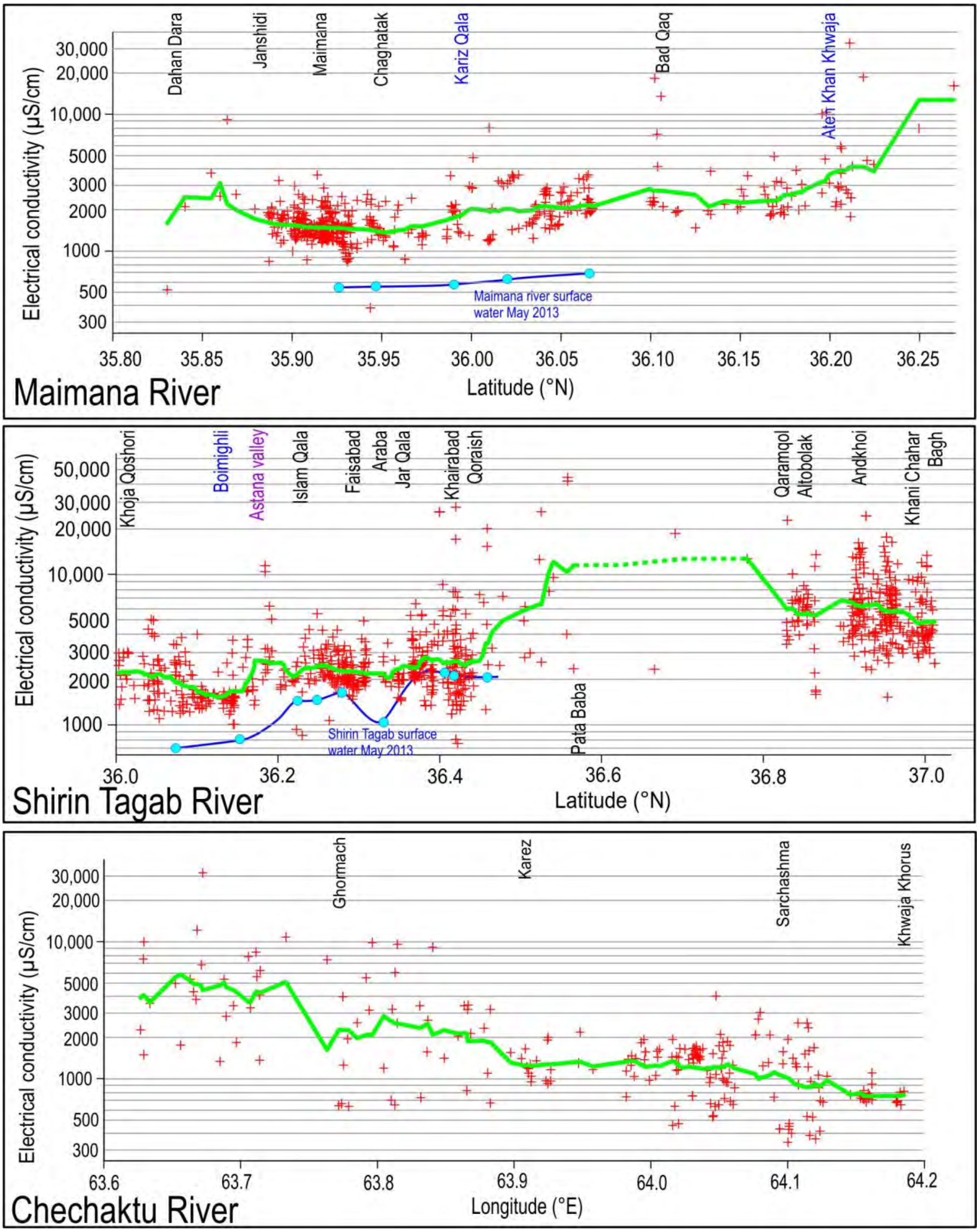



**Figure 8.4. Electrical conductivity of groundwater in (top) the Maimana valley (middle) Shirin Tagab valley and (bottom) Chechaktu valley corridors, using all data in the NORPLAN database for these areas as of September 2014.** The green line shows a running average; red symbols show actual data points. Note that the EC of a few very saline waters may be somewhat overestimated due to the conversion algorithm from mineralisation (Equation 8.3). In the Maimana and Shirin Tagab profiles, the blue symbols and lines show the electrical conductivity in the rivers' surface water (Chapter 3).

Figure 8.2 shows the total distribution of groundwater electrical conductivity by district, as boxplots, while Figure 8.3 shows a map. Figure 8.4 shows the variation in groundwater electrical conductivity along three alluvial valley corridors.

**Boxplots**

In boxplots, the central "box" represents the interquartile range, with a horizontal line at the median. The "whiskers" represent the non-outlying extraquartile range, with outliers shown as small squares (near outliers) or crosses (far outliers). Parentheses around the median represent a robust 95% confidence interval on the median. The #numbers along the top represent the number of data in each subset.

It should be noted that EC has a tendency to increase northward (Figure 8.2). In Kohistan, EC is in the range 200-1000 µS/cm. In Qaysar and Gurziwan, values in the range 800-1600 µS/cm are more typical, while in the central districts of Faryab values 1200-2500 µS/cm are normal. In Shirin Tagab and Dowlatabad, EC values in excess of 3000 µS/cm begin to become common, while in the four northern districts are often in the range 4000 to <10,000 µS/cm. In the northernmost district of Khani Chahar Bagh, where groundwater levels become deeper (see Chapter 6), the salinity decreases a little again, with values of 3000-6000 µS/cm becoming typical.

## *8.3 Maimana Valley*

From Figure 8.4, it should be noted that the groundwater salinity in the Maimana valley actually appears to decrease slightly in a downstream direction above and around Maimana.

In the section of the valley just downstream of Maimana, it is noteworthy that the salinity of the river water, as sampled in May 2013 (see Chapter 3), was significantly lower than that of the groundwater. This may simply be due to the fact that river sampling was at a time of snowmelt in the mountains (abundant fresh surface water, with the possibility that surface water salinity increases later in the year), but it may also indicate that some amount of fresh river water has the potential to infiltrate the ground, mix with higher salinity regional groundwater and create a zone of fresher groundwater near the river.

Figure 8.5 shows the variation of electrical conductivity in the immediate vicinity of the Maimana River near Maimana. It is clear that, although there is a very large variability in the data, the very lowest salinity groundwater sources are in the immediate vicinity of the river channel, strongly supporting the hypothesis that recharging river water creates a zone of fresh groundwater near the river channel. This progressively mixes with more saline "ambient" groundwater with distance from the river.

Downstream of Maimana, groundwater salinity creeps up until the junction with the River Qaysar and the Shor Darya (Figure 8.4). Afghan hydrogeologists with experience from the area state that, although the Qaysar River's surface water is already relatively saline (c. 4000 µS/cm) at the confluence, its salinity creeps up downstream of the confluence (where the relatively low salinity Ateh Khan Khwaja spring is located) to values of around 8000 µS/cm, due to seepages of saline groundwater into the bed of the Shor Darya (Hassan Saffi, *pers. comm.* Sept. 2013).

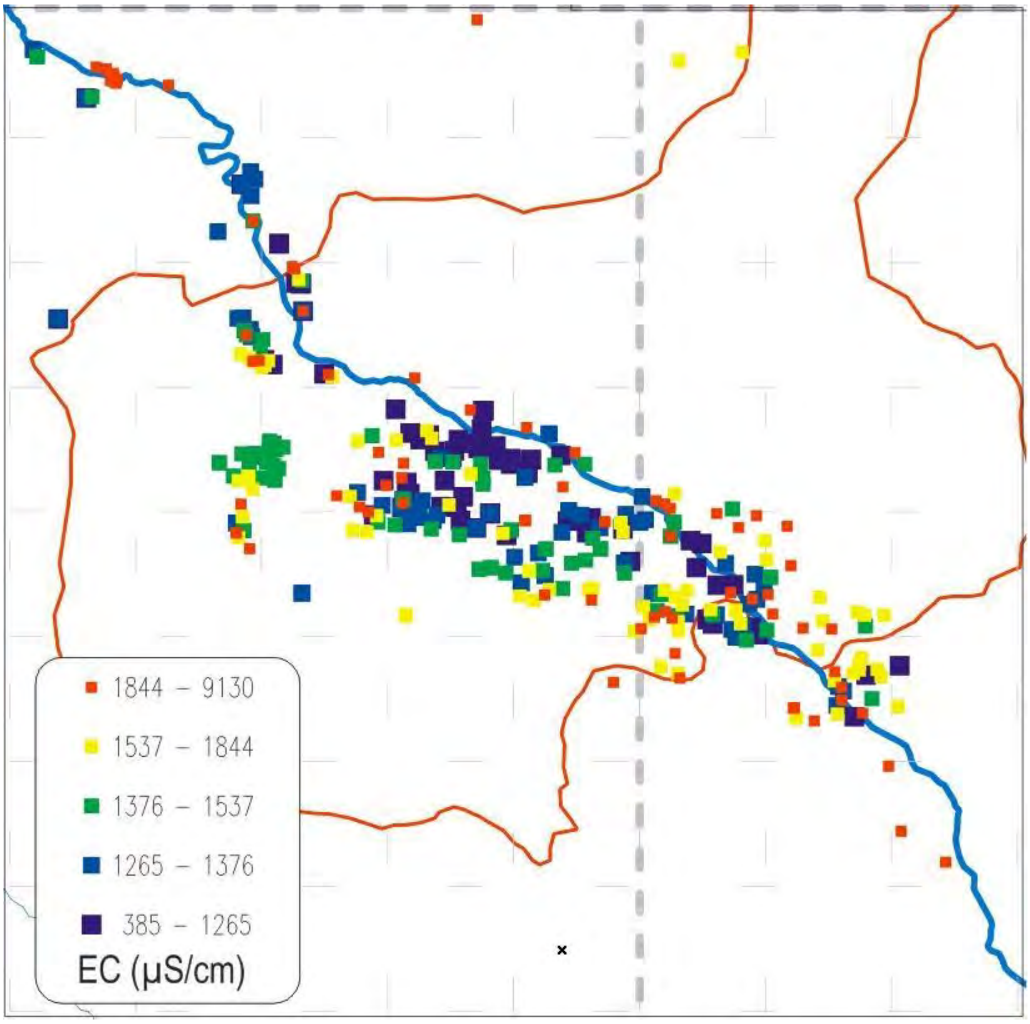



**Figure 8.5. Groundwater electrical conductivity in wells, boreholes and springs in and around Maimana district** (red outlines show district boundaries, blue line shows Maimana River). All available data in the NORPLAN database as of September 2014 have been used. For location, see Figure 8.3. Symbols are based on 5 equal percentile classes of 20%.

## *8.4 Shirin Tagab Valley*

In the left hand section of the middle diagram of Figure 8.4, we can see that groundwater salinity has a weak tendency to decrease in a downstream direction, while surface water salinity in May 2013 is lower than groundwater salinity. This is again suggestive that recharging river water has the potential to create a zone of fresh groundwater near the river channel.

Groundwater salinity increases downstream of the Astana Valley, as does river water salinity. We know that the Astana River is itself saline, being fed by saline groundwater baseflow from the Neogene (and stratigraphically lower) aquifers of the area. It is also possible that the Astana Valley is also associated with a discharge of saline *groundwater* into the alluvial deposits of the Shirin Tagab valley.

Downstream of the Astana confluence, the salinity of both river and groundwater increases, although the river water salinity (as of May 2013) is still lower than the groundwater salinity.

Figure 8.6 shows the variation of electrical conductivity in the immediate vicinity of the Shirin Tagab in the southernmost part of Shirin Tagab district (near Islam Qala). As in Figure 8.5, the very lowest salinity groundwater sources are in the immediate vicinity of the river channel, strongly supporting the hypothesis that recharging river water creates a zone of fresh groundwater near the river channel. This progressively mixes with more saline "ambient" groundwater with distance from the river.

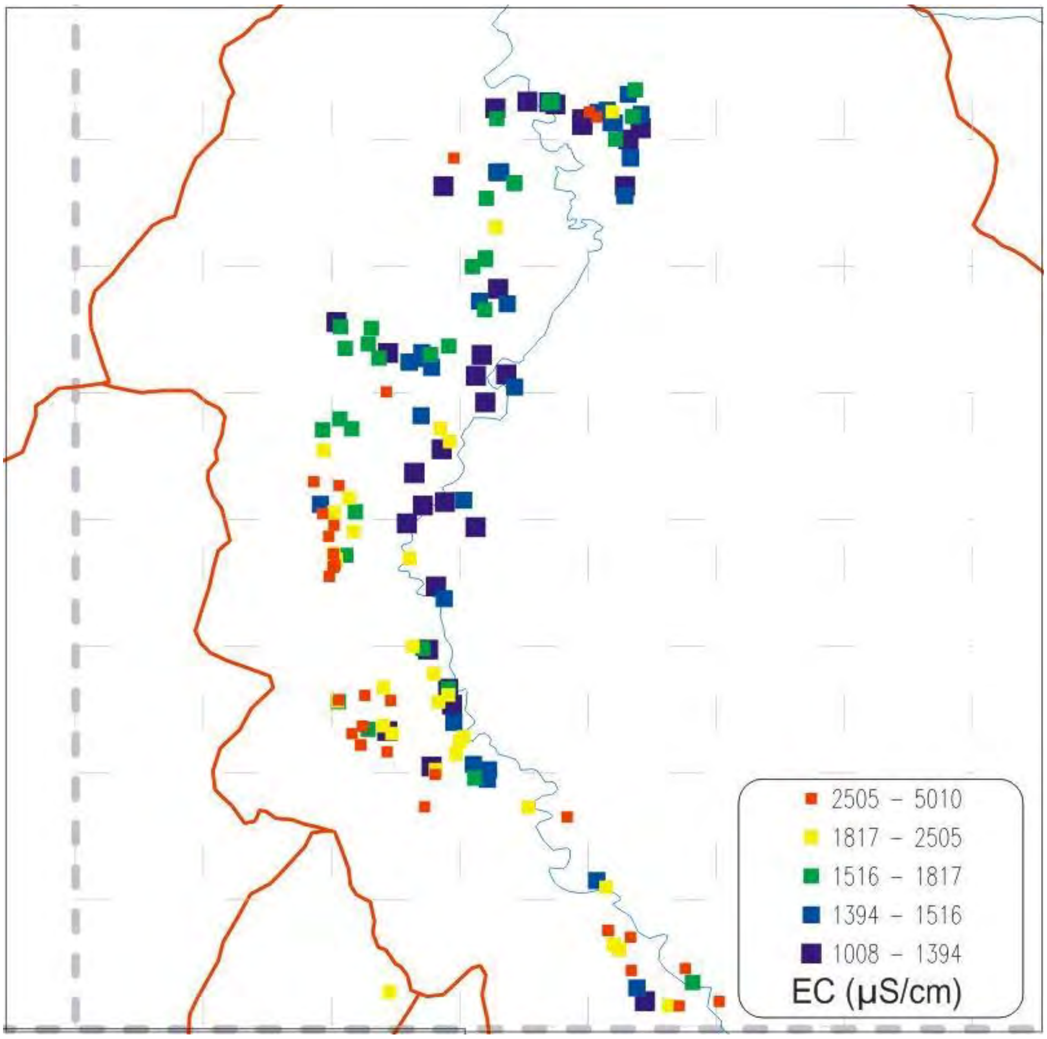



**Figure 8.6. Groundwater electrical conductivity in wells, boreholes and springs in the Islam Qala area of Shirin Tagab district** (red outlines show district boundaries, blue line shows Shirin Tagab River). All available data in the NORPLAN database as of September 2014 have been used. For location, see Figure 8.3. Symbols are based on 5 equal percentile classes of 20%.

Downstream of Araba and Jar Qala there is no great increase in the mean electrical conductivity of groundwater (Figure 8.4), although its variability seems to increase. We will recall from Chapter 6 that, at Araba, the river loses almost all its flow to irrigation offtake, and then regains it by groundwater baseflow. It is thus no surprise to see, in Figure 8.3, the river water gaining an electrical conductivity comparable to the groundwater's in this section.

Below Qoraish, there are very few groundwater abstractions and the apparent increase in salinity (green line) is probably partially an artefact of very few data. However, the very fact that there are few registered abstractions is probably an indication that the groundwater is saline. This zone coincides with an influx of saline water from the Shor Darya (which means "salty river").

## 8.5 Andkhoi area

By Andkhoi (Figure 8.4), the salinity is up in the several thousands of µS/cm, although salinity does appear to decrease northwards (Figure 8.2) as the groundwater level becomes deeper in the Khani Chahar Bagh region (Figure 6.13b). This can be clearly seen in the map of Figure 8.7.

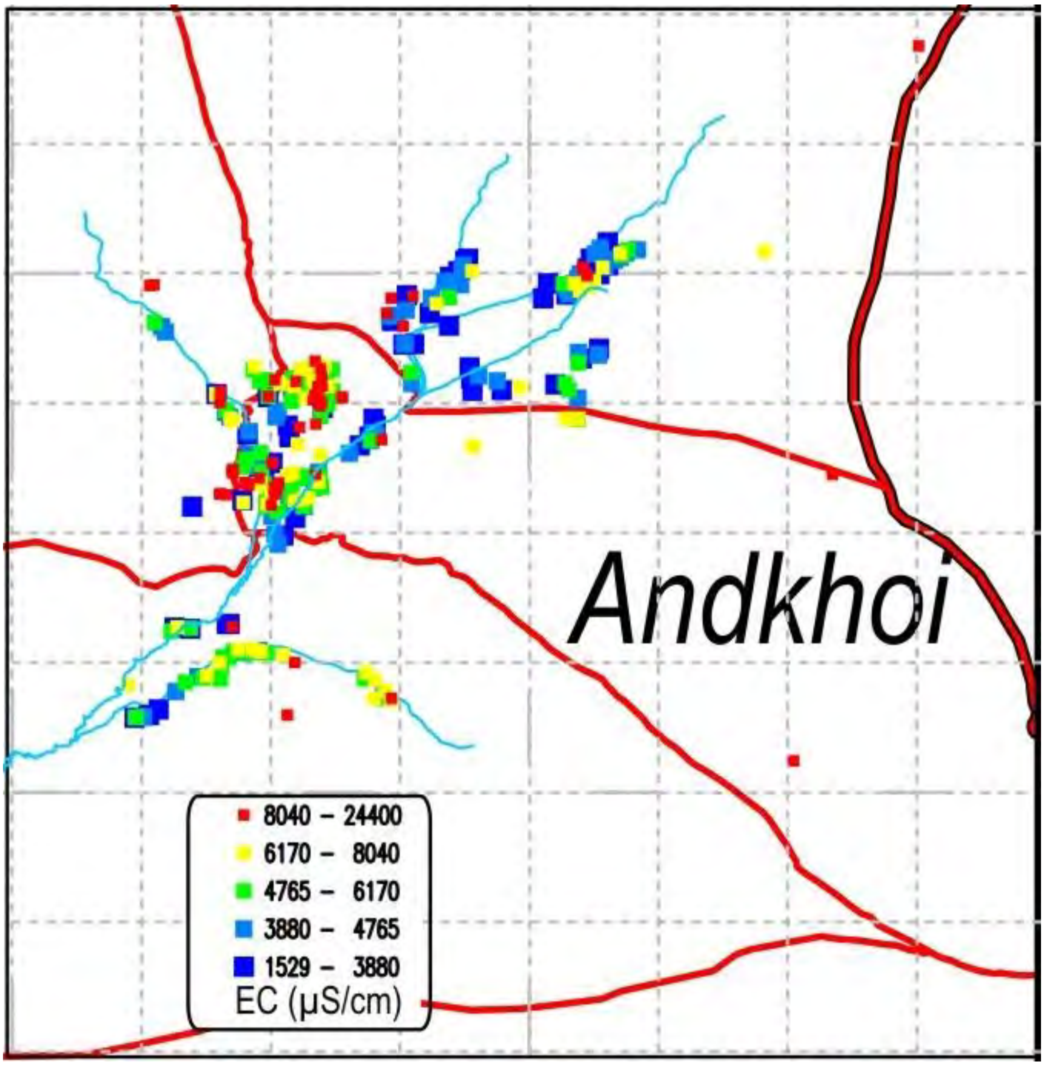



**Figure 8.7. Groundwater electrical conductivity in wells, boreholes and springs in the Andkhoi area** (red outlines show district boundaries, blue line shows Shirin Tagab River and distributaries). All available data in the NORPLAN database as of September 2014 have been used. For location, see Figure 8.3. Symbols are based on 5 equal percentile classes of 20%.

In NORPLAN's opinion, the question of the reason for the less saline groundwater at the northern end of the Andkhoi delta should form an important research topic for future years:

- Is it because the groundwater is deeper here, and, if so, could fresher groundwater be found at depth throughout Andkhoi?
- Or is it because very little evapoconcentrated surface water reaches the northern end of the Andkhoi delta to recharge and "contaminate" the groundwater? Are we looking at resources of "fresher" river recharge water from a wetter geological epoch (pluvial period)?

- Or is it simply that wells in Khani Chahar Bagh tend to be located close to major irrigation channels, with potential for infiltration?

Some hydrogeologists active in the Andkhoi area accept that the shallowest groundwater near Andkhoi is very saline, while there is some decrease in salinity with depth (possibly resulting from palaeo-recharge of infiltrating water from a time when the river distributaries were fresher), before becoming saline again with greater depth. Most hydrogeologists accept that less saline groundwater tends to be found near the major irrigation channels and distributaries.

In fairness it should be pointed out the concept of "fresh" is relative: the least saline water of the Andkhoi area (Figure 8.7) has a conductivity of 1529 µS/cm and over 80% of the groundwaters have a salinity exceeding 3800 µS/cm.

## 8.6 Chechaktu Valley

Finally, the alluvial corridor of the Chechaktu and associated rivers shows a very similar picture (Figure 8.4): i.e. one of steadily increasing groundwater salinity in a downstream (westerly) direction.

## 8.7 Empirical relationship between electrical conductivity and dissolved solids

In 2013, 132 wells, boreholes and springs were sampled in Kohistan, Qaysar, Gurziwan, Bilchiragh and the four northern districts around Andkhoi. The samples were analysed at the laboratory of the British Geological Survey (BGS) at Keyworth, Nottinghamshire, UK. The BGS calculated total dissolved solids (TDS) in mg/L for the samples. The analyses also allowed us to calculate the anion and cation contents in meq/L.

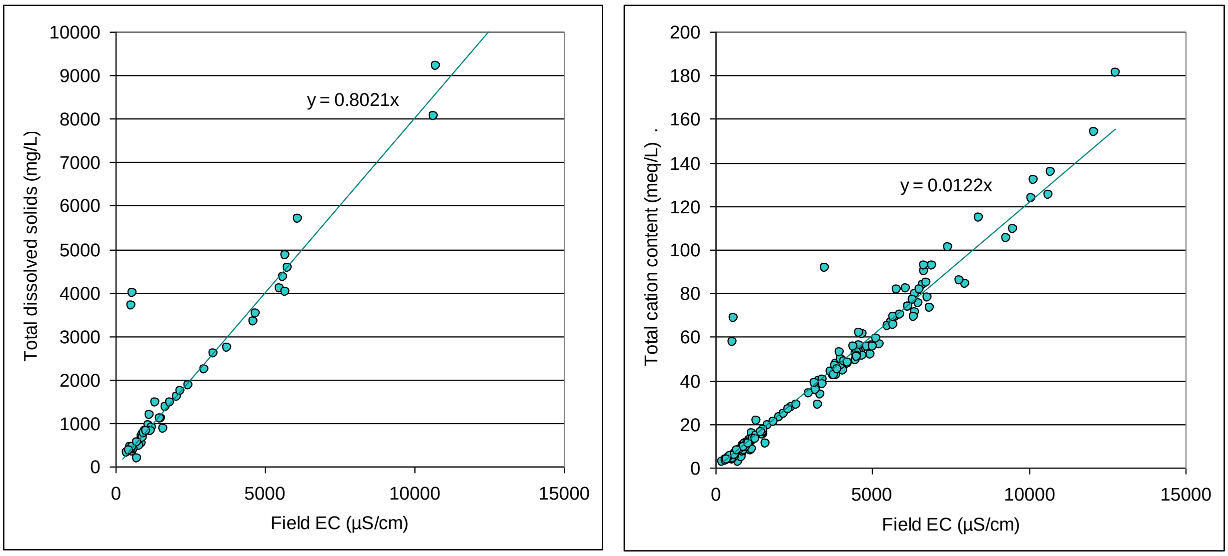



**Figure 8.8. Relationship between field electrical conductivity (µS/cm, x axis) and** (left) **Total dissolved solids (mg/L) according to analyses by BGS and** (right) **cation content in meq/L.** A couple of "rogue" field EC values occur in the data-set.

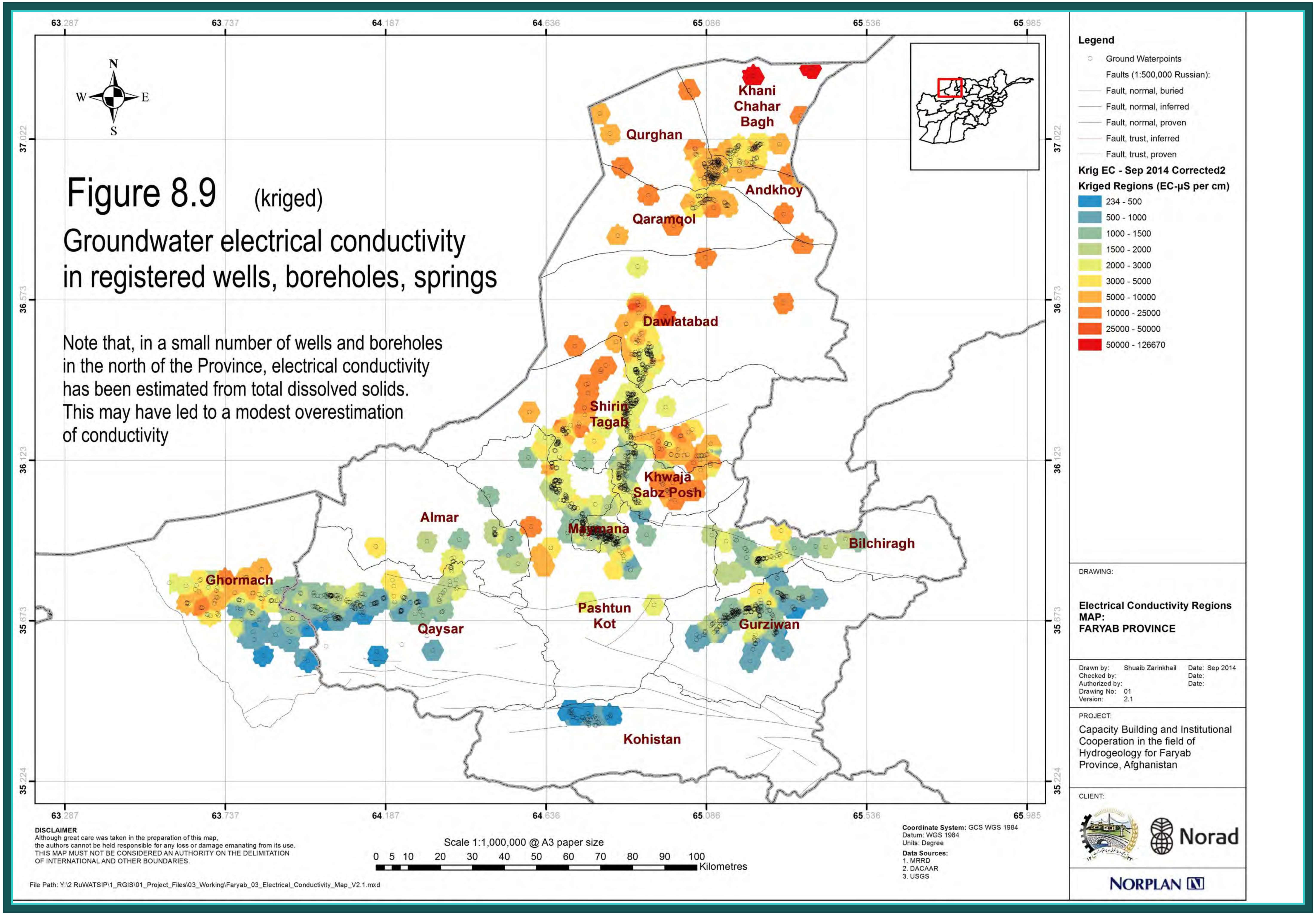
From these empirical data it appears that, for this data set:

**1 meq/L of cations (or 1 meq/L of anions) results in 82 µS/cm of EC** (8.4)

or

**M (mg/L) = EC (µS/cm) x 0.8** (8.5)

The use of Equation 8.3 to convert groundwater mineralisations from Soviet literature to equivalent electrical conductivities will therefore have probably led to a modest overestimation of a few of the highest electrical conductivities in the plots of this Chapter.




# Figure 8.9 (kriged)

## Groundwater electrical conductivity in registered wells, boreholes, springs

Note that, in a small number of wells and boreholes in the north of the Province, electrical conductivity has been estimated from total dissolved solids. This may have led to a modest overestimation of conductivity