DACAAR

GROUNDWATER RESOURCES AT RISK IN AFGHANISTAN

(Evaluation of the past and present situation of groundwater resources and consequences for the future, on the basis of previous groundwater investigation and present groundwater monitoring data)

Scientific Investigation Report in Afghanistan

By M. Hassan Saffi, Hydro geologist
Edited by Leendert Vijselaar

June 2007

Paikob-e-Naswar, Wazirabad, PO Box 208, Kabul, Afghanistan
Phone: (+93)(020) 220 17 50 Mobile (+93)(0)70 28 82 32
E-mail: dacaar@dacaar.org Website: www.dacaar.org

Table of Content

List of Abbreviation and Technical Terms

Aquifer	A rock formation, group of formations, or part of a formation that is water bearing. Commonly used synonyms are ground-water reservoir, water-bearing bed, and water-bearing deposit
Capillary water	Just above the water table, in the aeration zone, is capillary water that moves upward from the water table by capillary action. This water can move slowly and in any direction. While most plants rely upon moisture from precipitation that is present in the unsaturated zone, their roots may also tap into capillary water or into the underlying saturated zone
Confined Aquifer	(also known as artesian or pressure aquifers) exist where the groundwater is bounded between layers of impermeable substances like clay or dense rock. When tapped by a well, water in confined aquifers is forced up, sometimes above the soil surface. This is how a flowing artesian well is formed.
Contaminant	Any substance that when added to water (or another substance) makes it impure and unfit for consumption or use
DACAAR	Aid Agency in Afghanistan
DE	Deepened Well
Depletion	The loss of water from surface water reservoirs or groundwater aquifers at a rate greater than that of recharge
DW	Dug Well
Evaporation	The conversion of a liquid (water) into a vapor (a gaseous state) usually through the application of heat energy during the hydrologic cycle; the opposite of condensation
Evapo-transpiration	The loss water from the soil through both evaporation and transpiration from plants
GMWs	Groundwater Monitoring Wells
Groundwater Discharge	Groundwater discharges include, evaporation, transpiration and groundwater flow to the surface as drainage, springs, karezes and pumping for irrigation and water supply.
Groundwater Level	Indicates the position where the atmospheric pressure and hydraulic head are at equilibrium (balance) in the aquifer
Groundwater Level Fluctuation	Any event that produces a change in pressure on ground water level cause the groundwater level to vary. Differences between supply and withdrawal of groundwater cause level to fluctuate.
Groundwater Management	Groundwater management is define as the ongoing performance of coordinated action related to groundwater withdrawal and replenishment to achieve long-term sustainability of the resource without detrimental effects on other resources
Ground-water movement	The movement of ground water in an aquifer. The movement of ground water through an aquifer is extremely slow, generally on the order of centimeters per day or meters per year.
Groundwater Recharge	Groundwater recharge is defined as the downward flow of water recharging the water level forming an addition to the groundwater reservoir.
Infiltration	The process whereby water enters the soil and moves downward toward the water table
Intermittent stream	A stream that flows only following precipitation or when receiving water from springs, ground-water seepage, or melting snow
Long Term Groundwater Level Dropping	In basins where the groundwater extraction exceeds recharge, a drawdown trend in groundwater level may continue for many years. The water level continuously declines (dropping dynamic water level) due to

	over extraction and low recharge, then the groundwater level dropping will be permanent.
pH	pH, which is defined as the negative decimal logarithm hydrogen ion activity (H^+).The pH value is indicated where the water is acid or alkaline. Neutral water pH=7. If the pH of water less than 7 is acid and more than 7 is alkaline.
Pollution	An alteration in the character or quality of the environment, or any of its components, that renders it less suited for certain uses. The alteration of the physical, chemical, or biological properties of water by the introduction of any substance that renders the water harmful to use
Precipitation	The part of the hydrologic cycle when water falls, in a liquid or solid state, from the atmosphere to Earth (rain, snow, sleet).
Runoff	Precipitation that flows over land to surface streams, rivers, and lakes.
Safe yield	Safe yield is defined the net annual supply (net recharge) of groundwater that may be developed without persistent lowering of groundwater levels (Lee 1914).
Salt water	Water that contains a relatively high percentage (over 0.5 parts per thousand) of salt minerals.
Seasonal Fluctuation	The seasonal fluctuation usually results from influence of precipitation, irrigation canal and ditch leakages, the pumping for drinking water or for irrigation purposes, all of which influence seasonal cycle or seasonal fluctuation of groundwater.
Short-term Fluctuation	Short-term or monthly fluctuation of groundwater level is measured in alluvial aquifer for any special purpose (municipality water supply and pumping for irrigation).
Specific yield or Safe Yield:	The ratio of the volume of water a saturated rock will yield by gravity drainage to its own volume.
Stalinization (mineralization):	The condition in which the salt content of soil accumulates over time to above normal levels; occurs in some parts of Afghanistan where water containing high salt concentration evaporates from fields irrigated with standing water.
Sustainability	Sustainability encompasses the beneficial use of groundwater to support present and future generation, while simultaneously ensuring that unacceptable consequences do no result from such use.
Transpiration	The process by which water absorbed by plants (usually through the roots) is evaporated into the atmosphere from the plant surface (principally from the leaves).
TW	Tube Well
Unconfined aquifers	An aquifer in which the upper boundary is the water table
Undesired Result	An undesired result is commonly interpreted to mean a progressive lowering of groundwater leading eventually to depletion of supply (recharge).
USGS	United States Geological Survey
Water quality	The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use
Water quality standard	Recommended or enforceable maximum contaminant levels of chemicals or materials (such as nitrate, iron and arsenic) in water.
WSP	Water and Sanitation Program

1. Introduction

Water is the most important natural resource on planet earth. Live cannot exist without it. It is a basic need like air and food to enable us to live and work therefore it is essential to protect the environment for continuation of life.

More than two decades of war and conflict with six years of persistent drought caused a vast majority of the population of our country to be without access to safe drinking water. Most parts of our country have for only few months of the year access to surface water which is contaminated. Therefore, groundwater is one of the main sources for provision of drinking water in all parts of our country. The groundwater monitoring, exploration, development, protection and management requires profound knowledge of the hydro geological setting of the areas quantitative parameters (porosity, permeability, recharge, discharge, storage, water table and yearly amplitude of groundwater table fluctuation) and qualitative characteristic (physical and chemical specification) of aquifers which are very important for planning and applying various methods and appropriate technologies for making good use of the groundwater.

So far, little has been known about hydro geological settings and groundwater resources in Afghanistan due to lack of sustainable management, exploration, development, coordination and keeping data. Therefore, DACAAR/WSP has initially improved a number of water points in selected provinces for monitoring of yearly amplitude of groundwater fluctuation and chemical, physical and bacteriological analysis which cover approximately 80 percent of hydrological basins of Afghanistan.

The activities relevant GMWs (Groundwater Monitoring Wells) from march/2005 to the end of 2006 are as follows:

- Selected and modified 78 No. water points (56 No. TW, 5 No. DE, 13 No. DW, 3 No. SEABA measuring instrument and one No. Diver Mat instrument) in sixteen provinces (72 districts) of Afghanistan (Fig 1 and Annex 7 refer)
- Measured water table and physical parameters (electro conductivity, pH, temperature) of modified water points on a two weekly basis (two times a month) (Annex 1, 2, 3a & b and 6 refer).
- Chemical and bacteriological analysis performed on all water points on a six monthly basis (Annex 4, 8. 9, 10, 11, 12 and 13 refer).
- National groundwater monitoring database for interring field data made after revising report which were received from field.
- Recent rainfall data recorded in the national groundwater data were received from Agromet (USGS) (Annex 5 refer).
- Collected geological and hydro geological information around each monitoring water points and recorded in the national groundwater monitoring database.
- Modified GMWs-Diver, tools for transferring field data to the national groundwater monitoring database.

2. Objective

The main objectives of this report are as follows:

1. Overview hydro geological basins of Afghanistan (hydro geological basins and aquifer system).
2. Near to countrywide GMWs groundwater levels variation in time data assessment.
3. Near to countrywide of GMWs water quality data assessment.

4. Address groundwater quality and quantity problem in the hydro geological Basins of Afghanistan.
5. Specify undesired result which is threatening security and sustainability of groundwater.
6. Recommendations for groundwater regular usage for sustainability, development and management.

3. Methodology

In January 2005 DACAAR /WSP with the support of USGS installed and monitored 78 No's of wells after selection criteria and wells were modified as GMWs (Groundwater Monitoring Wells) within hydro geological basins and sub basins of Afghanistan according to DACAAR/WSP instruction for secure and sustainable access to the locations. The selected wells are shown in Fig.1.

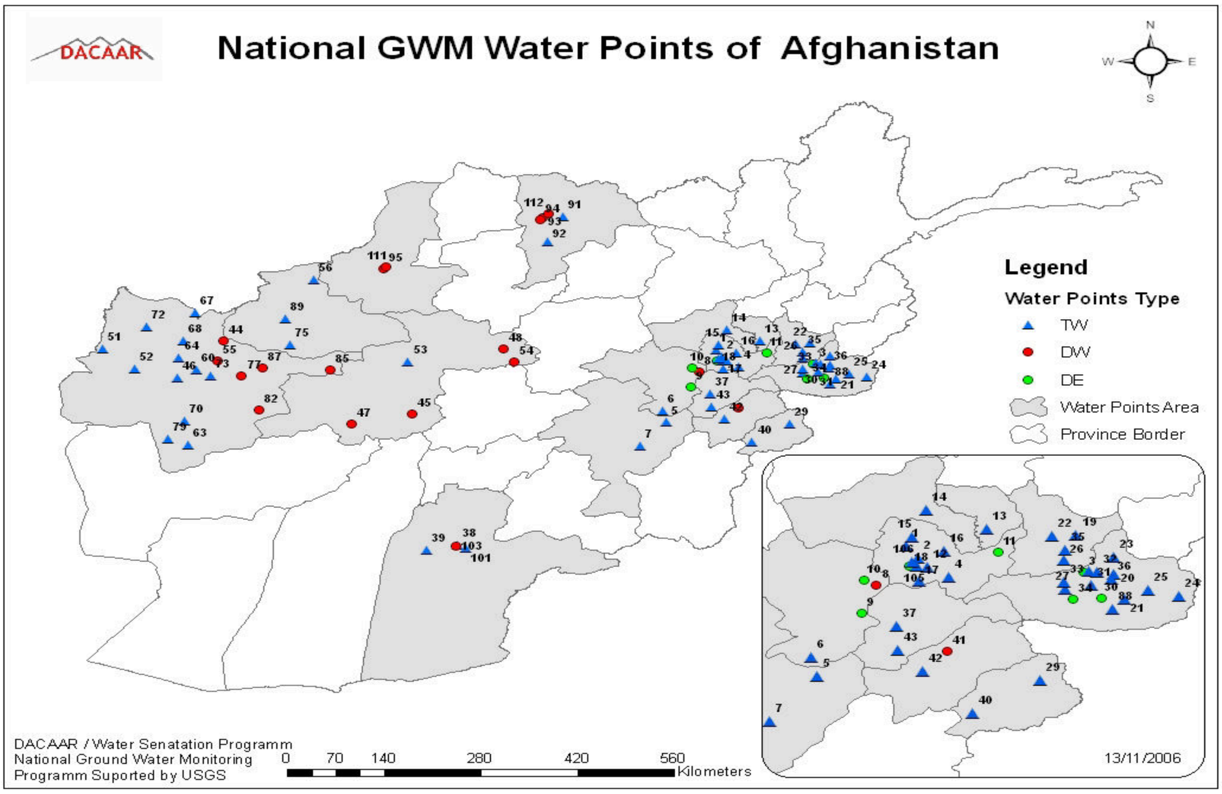


Fig. 1. Selected GMWs within Hydrological Basins and sub Basins of Afghanistan.

The selected groundwater monitoring wells modified for sustainable measurement (modified hand pumps installation on tube wells pipe from top to bottom below water level placed)

Fig. 2 Modified Tube Wells for Sustainable Measurement.

The wells locations were geo-referenced by GPS (Global Position System, see figure 3) for establishing groundwater monitoring wells database that can be assessed through GIS maps (see figure 1).

Fig. 3 GPS (Global Position System)

The water level of groundwater monitoring wells is being measured in field on two week period by water level indicator (see fig 4 Electrical water level indicator).

Fig.4. Water level Indicator.

The Electrical Conductivity (EC), pH and temperature of groundwater monitoring wells is being measured in field on two week period with Conductivity/pH Meter device (see Figure 5).

Fig. 5 Conductivity/pH Meter device

The bacteriological properties of groundwater monitoring wells determined on six monthly periods with micro bacteriology field test kit (see Figure 6).

Fig. 6 Micro Bacteriology test Kit.

The water sample were taken from ground water monitoring wells for chemical analysis (finding chemical parameters) every 6 month (previously once every three months) by Photometer 8000 (see figure 7) samples were transported to the DACAAR/WSP water quality laboratory where the chemical analysis were performed according to procedures).

Photo meter 8000 Sodium and PH Meter

Fig. 7 Chemical Analysis Kits.

The Diver (see Figure 8) is a reliable instrument for automatic measurement and registration of the ground water level and temperature over a long time. The Diver is installed in tube wells and after a while data are up-loaded from Diver to the Diver Mate, then down load the measured data from Diver Mate to PC.

Fig. 8 Diver Mate.

The SEBA water level recorder (ALFHA see Figure 9) is a floater operated measuring instrument. The recorder is driven by clockwork driven by a small electrical motor and batteries. The ALPHA water level recorder is a precise measuring instrument, careful placing and handling is always necessary to guarantee long operation.

Fig. 9 SEBA Water Level Recorder.

The SEBA water level recorder is also used for measuring the water table. The diagram chart must be changed after three months, and after digitizing of chart the data are transferred to the database.

4. The Hydrological Basins of Afghanistan

In Afghanistan there are essentially five main River basins:

4.1 Kabul/Indus River Basin

This basin is located in eastern part of the country including the south-eastern river sub-basin (fig 10 refers). The outflow of this is into Pakistan. The total catchments area of this basin is 143,000 km^2 which comprises 12% area of total land. The mean direction of flow is from west to east. Run-off generated in this basin is discharged by Kabul River from Afghanistan and, then enters the Indus River of Pakistan and discharges into the Indian Ocean

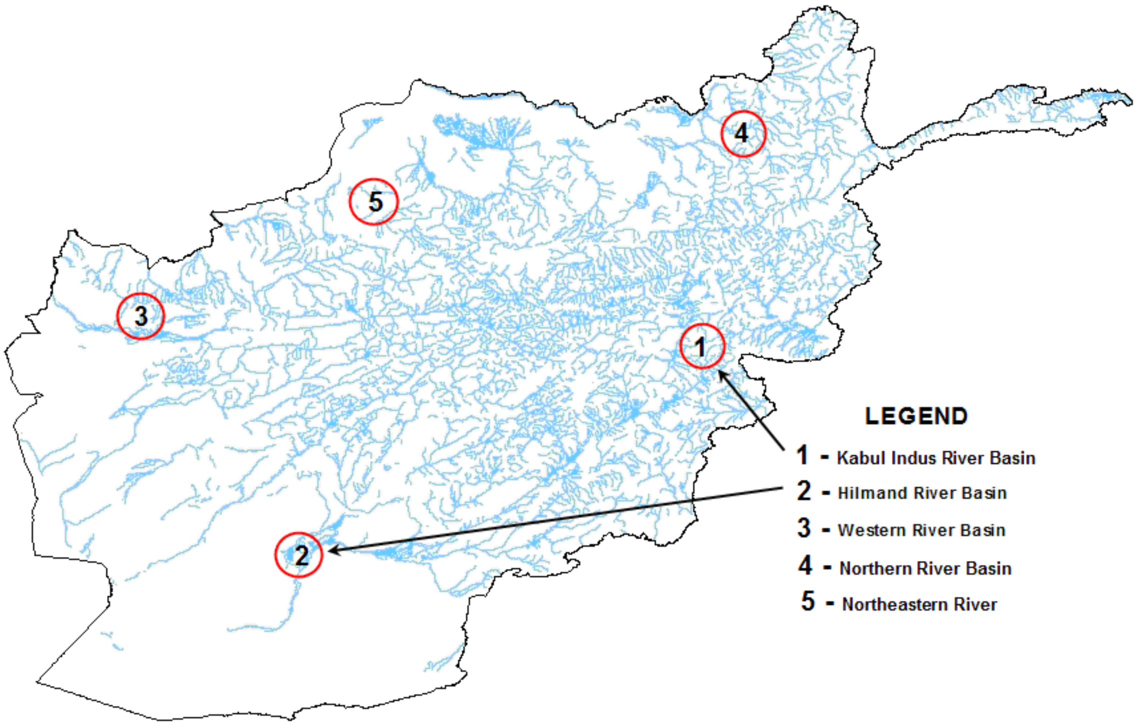


Fig. 10. Hydro logical Basin of Afghanistan.

4.2 Hilmand River Basin

This basin is located in the southern part of country, with total catchments area of 166,000 km^2. It covers 49% of Afghanistan. The mean direction of flow is from east to west. Originally the discharge of this basin drained to Hamoon-e-Helmand.

4.3 Western River Basin

This refers to the western watershed of the country. The watershed size of this basin is about 131,000 km^2. Hari Rod, Farah Rod and other smaller streams drain the run-off from the area. Hari Rod defines partially the boundary with Iran. The south-western River of this Basin drains into depressions situated along the Iranian border. The run-off is discharged by Murghab, Kashan, Kushk and Gulran Rivers out from the Basin to Turkmenistan by Amu (Oxus) River. The other rivers, such as Samangan, Balkhab, Sari Pul also join the Amu River.

4.4 North-eastern River Basin

This river basin is located in the north-eastern of county. The watershed size of this basin is about 86,000 $km^{2.}$ Run-off generated here is channelled to Amu River through Kunduz and Kokcha rivers. Amu River drains into Aral sea.

4.5 Northern River Basin

Several watersheds of the northern part of the country are classified as northern river basin. The watershed size of this basin is about 116,000 km^2. The run-off is discharged by Murghab, Kashan, Kushk and Gulran rivers out from the basin to Turkmenistan by Amu (Oxus) River. The other rivers, such as Samangan, Balkhab, Saripul and Shirin Tagab, however do not reach Amu River.

5. Climate

The prevailing climate of Afghanistan is semi-arid with mean annual precipitation values from 50 mm to more than 1000 mm (Fig. 11). Mainly precipitation occurs in winter: particularly from December to April. The wet seasons are winter and spring when the vegetation cover and crops water requirements are low. In higher elevations the precipitation falls in the form of snow that is highly critical for river flow and agricultural demand in summer. From June to October the country receives hardly any precipitation.

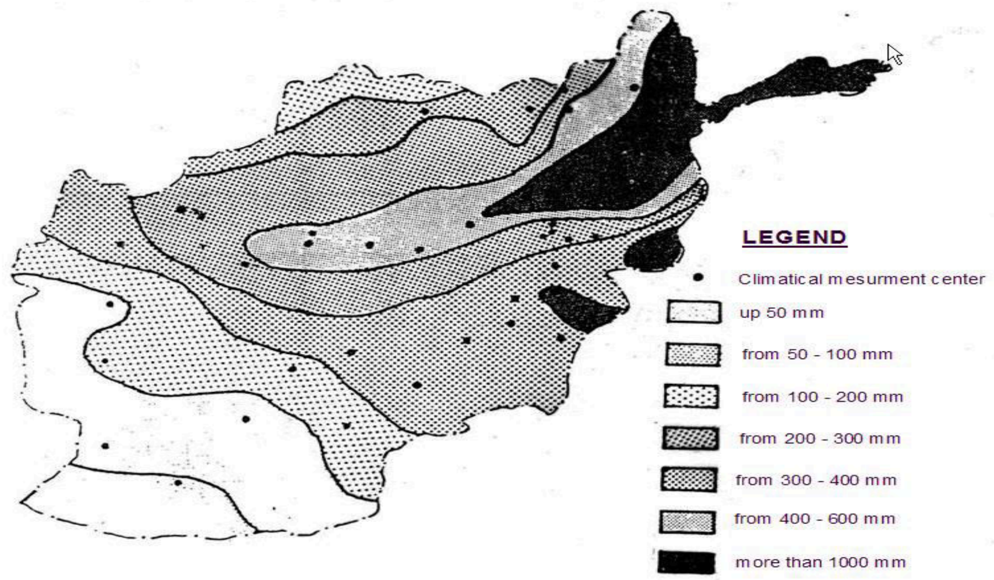


Fig. 11. Average annual rainfall which was registered in 1975 by Ministry of Water and Power.

In Afghanistan, there are a few months (December-March) rainfall and snowfall and, many moths there can be very little to no rainfall. Even during low rainfall months there occur thunder storms that cause high run off and floods of short duration and destroy agricultural lands.

The recent rain fall data (2005-2006) which are recorded by Agromet Meteorological stations (USGS) shows that the annual average rain fall is from 20 mm (April-November) to 40-140 mm (December-March).

Comparison of previous rainfall data (Fig. 11) to the recent rain fall data (Agromet Meteorological stations, 2005-2006) which shows, that recent rainfall data is considerably lower than previous rain fall data.

The recent rain fall data (2005-2006) measured by Agromet meteorological stations are enclosed to this report (Annex 5 Rainfall Data and Charts)

6. Geology of Afghanistan

The following geological formations have been identified (see Figure 12):
1. Quaternary (Q) sediments.
2. Neogene (N) sedimentary rocks.
3. Paleogene (Pg) sedimentary rocks.
4. Cretaceous-Paleogene (Cr-Pg) sedimentary rocks.
5. Cretaceous (Cr) sedimentary rocks.
6 Jurassic (Jr) sedimentary rocks.
7. Triassic (Tr) sedimentary rocks.
8. Permian-Triassic (Pr-Tr) sedimentary rocks
9. Palaeozoic (Pz) sedimentary and metamorphic rocks
10. Proterozoic (Pr) metamorphic rocks.
11. Volcanic Rocks.
12. Acidic Igneous Rocks.
13. Basic Igneous Rocks.

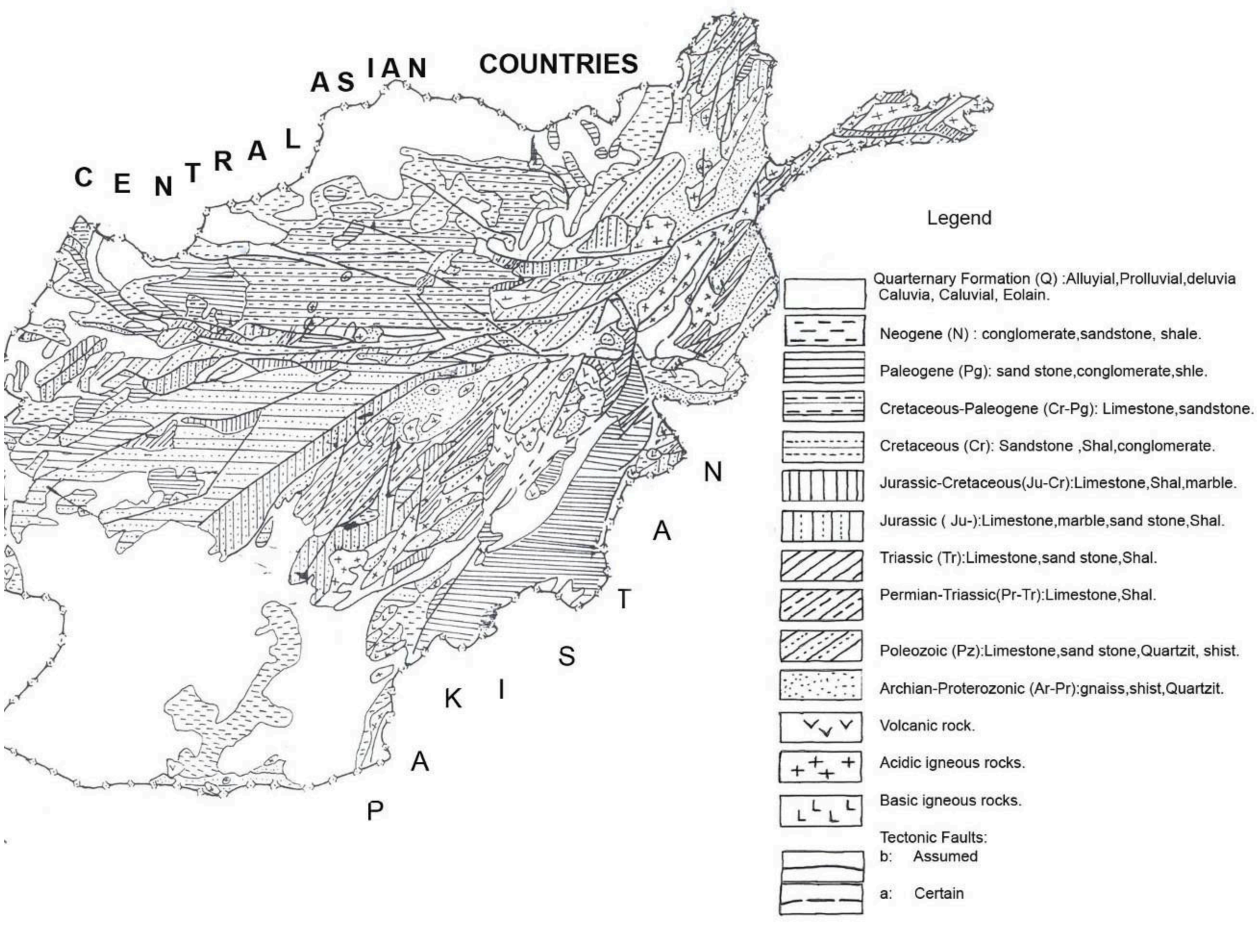


Fig.12. Geological Map of Afghanistan (W.A. Slawin, 1984).

1. The Quaternary sediments consist of alluvial, diluvia, proluvial, colluvia and eolain deposits. Sediments of this age are widespread in most parts of the country.

2. The Neogene sedimentary rocks are mainly exposed in the Northern Afghanistan platform, Badakshan trough South Afghanistan Platform which is composed of sandstone, siltstone, clay, conglomerate, gypsum, marl and limestone.

3. Paleogene (Pg) sedimentary rocks occur in Katawaz, Northern Afghanistan platform and middle Afghanistan Geosutures, which consist of limestone, clay, siltstone, sandstone, conglomerate and intermediate volcanic Rock.

4. The Cretaceous-Paleogene (Cr-Pg) sedimentary rocks occur in the north and north-east part of Helmand Arghandab uplift, Middle Afghanistan Geosutures and Northern Afghanistan platform which are composed of sandstone, siltstone, shale and limestone.

5. The Cretaceous (Cr) sedimentary rocks, extend in Farah Rod Trough along the Kash-Rod river, Helmand Arghandab uplift, Middle Afghanistan Geostures and Katawaz which are composed of dark sandstone, shale, siltstone, and limestone.

6. Cretaceous and Jurassic sedimentary rocks occur in Farah-Rod Trough, along the Kuhsh Rod River and Middle Afghanistan Geosutures, which are composed of sandstone, limestone, siltstone with intercalation of acid and basic volcanic rocks.

7. The Jurassic sedimentary rocks occur in the Afghanistan-Northern Pamirian Folded area, Northern Afghanistan Epi-Hercynian Platform, Middle Afghanistan Geosutures, Helmand-Arghandab area which are composed of calcareous marine sediments, polymictic sandstone, black shale, limestone, slate and marble.

8. Triassic sedimentary rocks are widespread in the Northern Afghanistan Epi-Hercynian Platform, Afghanistan-Northern Pamirian folded area and Middle Afghanistan Geosutures, which are composed of conglomerate, calcareous marine sediments, polymictic sandstone, shale, limestone, slate and marble.

9. Permian-Triassic (Pr-Tr) sedimentary rocks occur in the Northern Afghanistan Epi-Hercynian Platform, Afghanistan-Northern Pamirian Folded areas, central Badakhshan area and Helmand Arghandab uplift which are characterized by sandstone, shale, siltstone, conglomerate, terregenous-carbonate, limestone and calcareous shale.

10. Palaeozoic sedimentary and metamorphic rocks occur in central Afghanistan Median Mass, Afghanistan-Northern Pamirian Folded area, Middle Afghanistan Geosutures which are characterized basalt siliceous sandstone, limestone, dolomite, polymictic sandstone and siltstone.

11. Archean-Proterozoic (Ar-Pr) metamorphic rocks occur in the Pamitian- Nurestan Median Mass, Middle Afghanistan Geosutures, central Afghanistan Meddle Mass and Katawaz area, which are characterized schist, amphibolites, gneiss, marble, metamorphosed limestone, dolomite, chert, slate, sandstone and siltstone.

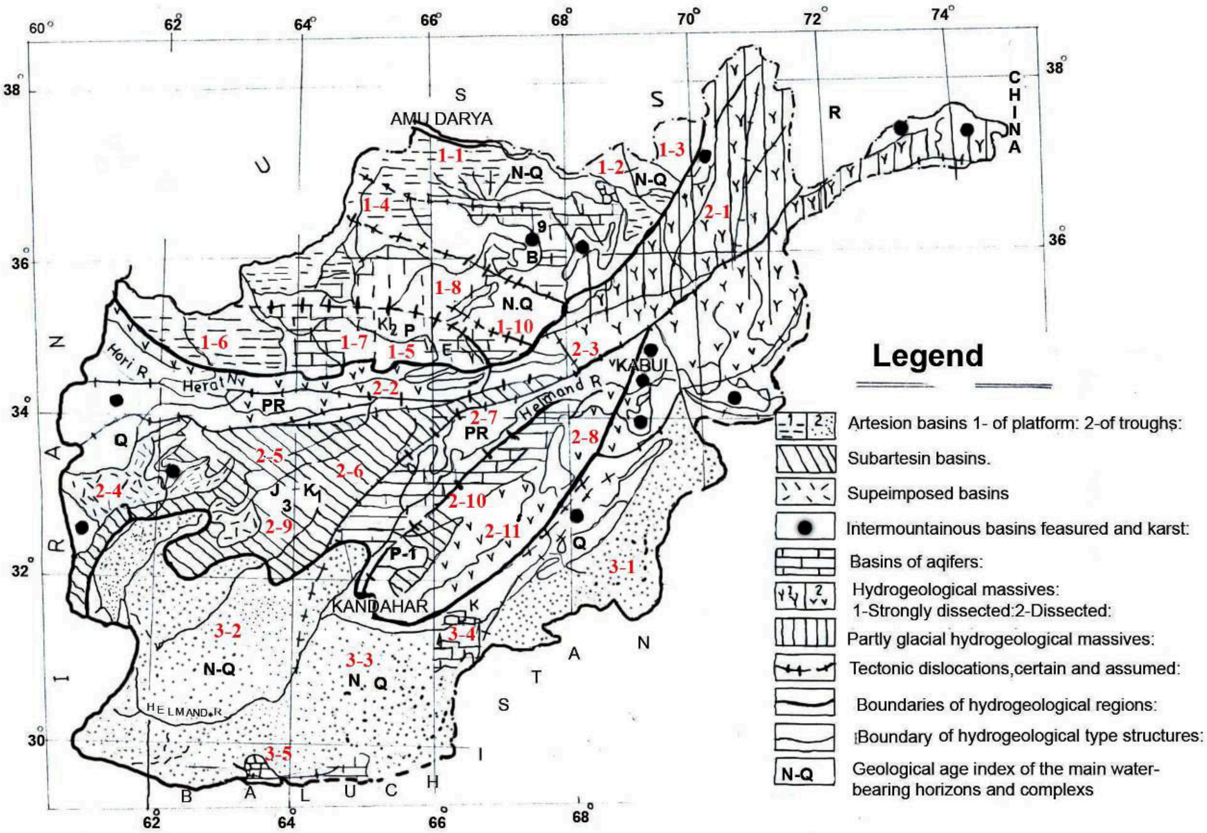
12. Volcanic rock found in the peripheral segment of the central Afghanistan Median Mass, Dasht-i-Nawar, Registan, Khanneshin area and Helmand and Arghandab complexe which is composed of linarite, decide, syenite porphyry and granodiorite porphyry.

13. Acid to Basic Igneous rocks with various age are exposed in the Haji-Gak pass, Pamirian-Norestam Middle Mass which are composed of granite, granodiorite, granosyenite magmatic rock.

7. Hydro geological Basins of Afghanistan

The hydro-geological basins of Afghanistan are divided as follow (see Figure 13):

1 Southern Afghanistan Artesian Basins.
2 North Afghanistan Artesian Basins.
3 Central and North- Eastern Afghanistan Folded Area (Karst or Fractured area).
4 Intermountain closed by Inter-mountainous Basin.



Hydrogeological Basins of Afghanistan, (E.P. Malyar ,1975 some improvment by Eng:M.Hassan Safi ,2006)

Fig. 13 Hydro-geological Basins of Afghanistan.

7.1 Southern Afghanistan Artesian Basins

The southern Afghanistan Artesian Basins extend from the southeast to the west for more than 1000 km. In the north, these basins border with the central Afghanistan folded area, in the northwest, it is limited by the Aab-e-Istada and the Muqur Tarnak fault in the west, it extends towards Iran and in the south and east it extends up to Baluchistan.

Southern Afghanistan Artesian Basins include:
7.1.1 Artesian Basins
7.1.2 Basins with fracture- karst water

Artesian Basins include:
7.1.1.1 Katawaz (3-1).
7.1.1.2 Lower Helmand (3-2).
7.1.1.3 Registan (3-3)

Basins with fracture- Karsts- water include:
7.1.2.1 Tarnak (3-4)
7.1.2.2 Chaghay (3-5)

Katawaz Artesian Basin (3-1) natural groundwater system consists of middle to recent Quaternary aquifers (Q_{II-IV}) and, Neogene multi alternating aquifers with various thicknesses, hydraulic properties and water qualities. These areas include Paktia, Paktika, Khost, Zabul, and part of Ghazni provinces. This basin is related to the Alpine Folded Area. Chaman fault separates it from Tarnak Artesian Basin. This area from ground water point of view has relatively good possibility for groundwater development. The ground water sources have extended to the Neogine and Quaternary sediments. There the groundwater is controlled by Quaternary and Neogene aquifers and discharging on the surface as kareses and springs which currently mainy dried out or decreased in yield, due to prolonged drought and motor-pumping of water supply for irrigation. From tectonic development point of view this area is formed by folded basement and cover. The folded and bent basement is formed Palaeozoic marble and limestone. The cover is formed by Neogene and Quaternary sediments.

From middle to recent Quaternary aquifers (Q_{II-IV}) are widespread in Muqure, Katawaz, Gardez, Sharan, Khost and Zabul areas, along the river valleys and foot hills of mountains, which are composed of alluvial, alluvial-proluvial an deluvial deposits (silt clay, sand, gravel, pebbles, cobles, conglomerate and breccias).

The thickness of aquifer ranges from 8 m (Qalat city) to 80 m (Khost), the water level ranges from 6.7 m (Katawaz) to 57 m (Khost), the discharge of Tube Wells ranges from 4 l/s (Muqure) to 100 l/s (Khost, Hyder Khil village) for 2-12 m drawdown, the mineralization of water ranges from 0,4g/l (Qalat) to 1.2 g/l (Khost).The discharge of karezes rangs from 4 l/s (Shahjoi) to 55 l/s Gardez city (Paktya Development project 1967-1968 and Ministry of Water and Power 1976-1978).

The Neogene multi aquifers system are widespread in Muqure, Katawaz, Gardez, Sharan, Khost and Zabul areas, which are composed of sandstone, siltstone, conglomerate, gravel and silt clay.

In Qalat city, the thickness of Neogene aquifer ranges 28 - 60 m, the discharge of Tube Wells ranges 5-13 l/s for 2.3-21 m drawdown, the mineralization of water ranges 0.2-0.64 g/l (Groundwater investigation 1976-1978, Ministry of Water and Power).

In Zurmate area, the thickness of Neogene aquifers ranges 12 - 65 m, the discharge of Tube Wells ranges 2-7 l/s for 4-12 m drawdown, the mineralization of water ranges 0.2 - 0.8 g/l (Paktya Development project 1967-1968).

In Katawaz (Zarghon Shahar) areas, the thickness of Neogene aquifers ranges 12 - 55 m, the discharge of Tube Wells ranges 0.89 - 5 l/s for 5.2 - 15 m drawdown, the mineralization of water ranges 0.2 - 0.9 g/l (Groundwater investigation 1967-1968, Ministry of Agricultural).

The lower Helmand and Registan artesian basins include Kandahar, Helmand, Nimroz and parts of Farah and Orozgan provinces. These areas related to the frontal trough of mountains of Afghanistan, which is formed Neogine and Quaternary terigenous sediments (gravel, conglomerate, sand, sandy loam, silt, silt clay, clay, loam-loess and loess). These areas have dry and desert climate.

From middle to recent Quaternary aquifers (Q_{II-IV}) are widespread in Kandahare, Helmand, Nimroz and Farah provinces, along the Rivers valleys and foot hills of mountains, which are composed of alluvial, alluvial-proluvial an deluvial deposits (silt clay, sand, gravel, pebbles, cobles, conglomerate and breccias).

The thickness of aquifer ranges from 12 m (along the Arghistan River) to 55 m (Zhari district), the water level ranges from 11 m (along Arghandab River) to 57 m (Shorabak district), the discharge of Tube Wells ranges from 1 l/s (Spin Boldak district) to 30 l/s (Kandahar city) for 2-12 m drawdown, the mineralization of water ranges from 0,4g/l (along Arghandab River) to 3.5 g/l (Zarang city), the discharge of karezes ranges from 6 l/s (Maywand district) to 65 l/s in Shib Koh distinct of Farah province (investigation groundwater in Kandahar, Nimroz, Hilmand and Farah provinces by Ministry of Water and Power and Ministry of Mine and Industry).

The Neogene multi aquifers system are widespread in Kandahar, Helmand, Nimroz and Farah provinces , which are composed of sandstone, siltstone, conglomerate, gravel and silt clay.

In Kandahar province, the thickness of Neogene aquifers ranges 8 - 39 m, the discharge of Tube Wells ranges 7 - 13 l/s for 4 - 15 m drawdown, the mineralization of water ranges 0.6 - 3.2 g/l (Groundwater investigation 1976 - 1978, Ministry of Water and Power).

In Helmand province, the thickness of Neogene aquifers ranges 4.3-80 m, the discharge of Tube Wells ranges 2 - 6 l/s for 8 - 12 m drawdown, the mineralization of water ranges 0.8 - 1.2 g/l (Groundwater investigation 1976 - 1978, Ministry of Water and Power).

There the groundwater is coming out to the surface as karezes and springs which most of them currently dried out due to prolonging drought and over exploitation of groundwater for irrigation.

In Urozgan province the interval of artesian aquifer is located at the depth of 75-85 m. There drilled Tube Wells in the center of Urozgan that the water is coming out to the surface as artesian Tube Wells (Afghan Development Association lift irrigation program 2002).

Basin with Fracture Karst Water in Tarnak and Chaghai Area.

The Basin with fracture karst water is composed of Cretaceous (Cr) carbonate rock (limestone, dolomite and dolomites limestone).

The natural groundwater aquifer consists of fault, contact zones and karsts development fractures, channel and cavities, with various thickness and hydraulic properties. Groundwater flow is controlled by the characteristic of aquifer and discharging as springs to the surface in the foothills of mountains (at the slopes of low elevations) and narrow valleys along the rivers course.

7.2 Northern Afghanistan Artesian Basins.

The North Afghan platform has a pre-Jurassic Basement of pre-Carboniferous to Triassic rocks unconformable overlain by Jurassic to Recent sedimentary rock. The pre-Jurassic basement is exposed mostly along the southern and eastern margins of the platform in the Parapamisus and Hindu Kush ranges. Northwards and westwards, it outcrops only in a few tectonic inliers, like the Bande Turkistan uplift. Along the southern edge and eastern edge of the platform, the basement is cut by an Early Mesozoic magma tic arc, which extends north-westwards (mostly obscured by the younger sediments) along the southern edge of the Amu Darya basin, and through the central Caspian Sea as far as the Crimea (Khain, 1979). It can also be traced through the North Pamir and into the Hindu Kush (Sengor et al., 1993).The North Afghan Platform, unlike areas to the west and east, is presently in is static equilibrium (Kaban et al., 1998). Along its northern and western edges the Platform drops beneath the Quaternary cover of the Tajik and Murghab basin. These basins separate the North Afghan Platform from the Turan platform to the
Pre-Jurassic basement

The pre-Jurassic basement of the platform is exposed in the Parapamisus, Bande Turkistan, and Hindu Kush Pamir mountains, where it consists of pre-Carboniferous to Triassic rocks deformed and intruded at the end of the Triassic, and again during younger Mesozoic-Cenozoic times. These reasonably well-studied mountains form the edge of the Jurassic and younger North Afghanistan Platform (Walfart and Wittekindt, 1980). The Parapamisus, north of the Harirud fault is basically the exposed southern edge of the north Afghan platform, though cut by a number of strike-slip faults. The Bande Turkistanis is a part of platform exposed along the oblique- slip Bande Turkistan fault. The Hindu Kush and north Pamir are thrust over the platform along the Ishkamish-Khohon and Darvaz fault zones and are tectonically complex due to Neogene deformation during the formation of the Pamir (Burtman and Molnar, 1993). The deformation associated with the collision of India with Asia has obscured much original structural and stratigraphic relationship close to the Harirud and related fault zones (Sborshchikov et al., 1974)

North Afghan platform cover
The North Afghan platform cover consists of Mid-Mesozoic to Neogene sediments covering Palaeozoic –Triassic rocks and structures. The platform has four main areas separated by major faults the Herat Trough, the Qualai Now, Maimana and Sherbergnan blocks. However the dominantly right-Lateral Neogene faults do not significantly offset any structures in the pre-Jurassic basement and have little effect on Mesozoic-Recent facies belts. To the north the platform is faulted against the Tajik basin, while to the northwest it passes gradually into the Murghab basin.

Tajik and Murghab basins
The North Afghan platform drops north and northwest into two basins filled with thick Jurassic to Recent deposits and separated by a broad sill. The Tadjik basin is separated by a major subsurface fault from the Sherbergnan platform area, while the Murghab basin lies northwest of, and is transitional to, the North Afghan platform. The Tajik basin is a typical south-eastward-facing passive margin basin involved in younger continental collision (Leith, 1985). Oceanic lithosphere is still descending beneath the Hindu Kush as shown by deep-focus earthquakes down to 200 km. (Mellors et al., 1995).

The Murghab basin is less well known, but has a section similar to the North Afghan platform. Both basin have rift-type Triassic bimodal basic-acid.

Extrusives interbedded with continental deposits at their bases, on deformed Paleozoic rocks, where exposed at the basin margins (Knuazev et al., 1971).

Northern Afghanistan Artesian Basins include:
7.2.1 Artesian Basins
7.2.2 Basins with Fracture- Karst Water
7.2.3 Hydro-geological massive

Artesian Basins are included:
7.2.1.1 Amu Darya (I - 1)
7.2.1.2 Kunduz (I - 2)
7.2.1.3 Kulab- Kukcha (I - 3)
7.2.1.4 Sheberghan (I - 4)
7.2.1.5 Kushka (I - 6)

Basin with fracture- Karst Water includes:
7.2.2.1 Murghab (I – 7)
7.2.2.2 Maymana (I – 8)
7.2.2.3 Shashan (I – 9)

Hydro-geological massif
7.2.3.1 Band-e-Turkistan (I - 5)
7.2.2.2 Surkha (I – 9)

The Northern Afghanistan artesian basins (Amu-Darya, Kulab-Kukcha, Kunduz, Sheberghan and Kushka) main Hydro geological units include:

Jurassic-Cretaceous aquifers which are composed of carbonate sandstone and siltstone sediments have pressure thermal water.

Pliocene to upper Eocene multi alternating aquifers which are composed of limestone, siltstone sandstone with thin layers of gypsum that are saturated brackish water.

The Quaternary aquifers consist of alluvia deposits (silt clay, silt, sand, gravel, pebble and cobble) with various thickness, hydraulic properties and water quality. These aquifers are extended in narrow and middle part of valleys along the rivers course mainly has fresh water. The thermal pressure groundwater is coming i out as to the surface in Dorahi Heratan (Balkh province) and Dasht-e-Lily (Joz Jan Province) with various discharge and temperature (Oil and Gas exploration Department drilled Tube Well).

The Amu Dariya Artesian Basin (I - 1) natural groundwater system consists of multi alternate layers of Neogene and Quaternary aquifers with various thicknesses, hydraulic properties and water qualities. These areas include Kaldar, Kholm, Mazar-e-Sharif, Balkh, Chemtal, Daulatabad, Shortepa, Hairatan, Aqcha, Karqin, and Mingajik, where it is separated by Mazar-e-Sharif fault from Sheberghan Artesian Basin and by Kunduz fault from Kunduz Artesian Basin. The discharge of groundwater (Quaternary formation) is increased from Marmul Mountain to Amu River, consequence the mineralization of groundwater also increased. The ground water level range from 40 m (near Marmul Mountain) to 2 m (near Amu River). The mineralization of water range from 0.8 mg/l (Marmul Mountain foot hills) to 3.7 mg/l (right course of Amu River). The discharge of drilled wells range 2 l/s (Dasht-e-Shadian) to 100 l/s (Balkh District) for 4.8 – 5 m drawdown.

The alluvial aquifer with good quality and quantity located at the depth between 65-95 m (Dorahi Hairatan to Balkh District), which is composed of sand, gravel, pebble, and conglomerate deposits. The discharge of Tube Wells between 5 m l/s (Dorahi Hairatan) to 80 l/s (Balkh District) for 4.8 - 6m drawdown. The mineralization of water is lower than 1 mg/l. The area where border with Uzbekistan the groundwater highly mineralized.

The aquifers contribute to the local ground water flow system extending from th mountain toward the low land and along the Rivers course.

Most areas of Balkh province (Khulm, Dawlatabad, Chimtal, Fayz Abad, Aqcha and Minga Jiek districts) suffer from an acute shortage of fresh drinking water, however the deep and shallow groundwater is highly mineralized, therefore the groundwater development by Tube Wells for providing drinking water is waste the time and money.

There are two possibilities to settle down regional piped water supply system:
1.Two large karst springs are situated over there: one on the left bank of Balkh River discharging 3,332 l/s and another on the right river bank discharging 1,522 l/s. Water of both springs is fresh and fit for drinking and household consumption.

2. A large Karst spring (Chashma-i-Hayat) is situated 12 Km upstream from Kulm district. The discharge of the spring is 1,600 l/s. The quality of water is quite fit for drinking and domestic purposes.

The Artesian Basin of Kunduz (I - 2) natural groundwater system consist of multi alternating layers of Neogene and Quaternary aquifers with various thicknesses, hydraulic properties and water qualities. These areas include Char Dara, Imam Sahib, Khanabad, Aliabad, Archi, Qala-e-Zal, Sher Khan Bandar, and the center of Kunduz City. There are widely extended Neogene and Quaternary deposits. The Quaternary sediments consist of sand, sandy loam, silt, silt clay, and clay. The thickness of alluvial Quaternary aquifer between 15-85 m , the water level between 8-42 m, the discharge between 6-17 m for the 2.3-4.8 m drawdown the mineralization between 0.8-4.3 mg/l. The area that borders with Tajikistan, the groundwater is highly mineralized.

The Artesian Basin of Kulab- Kokcha (I - 3) area extends on both sides of Amu River, which is the north border of Takhar Province. The Afghanistan side the area includes Yangi Qala, Rustaq,Warsaj, Kalafghan, Chah Ab, Khowaja Ghar, and Taluqan. The recharge of the ground water of this area takes place by the flow of Kukcha and Farkhar Rivers. The Neogene Formation, which consists of sandstone, siltstone and shale, has appreciable thickness. The Quaternary formation aquifer consists of gravel, conglomerate, sand, and sandstone.

The Artesian Basin of Sheberghan (I - 4) include the areas of Andkhoy, Khowaja Dokoh, Sar-e-Pol, Sheberghan, a part of Sherintagab, Maymona, Andkhoi, Qaramqule, Qaisar, Khwaja Sabz Posh, Pashtun Kot, Almar, Dowlatabad, Dasht-e-Laily, Ghormach and Bala Murghab.

The Quaternary aquifers are composed of alluvial medium and course sediments (gravel, pebbles, cobbles and boulder) with various thickness and hydraulic properties. The Quaternary deposits are located at the up streams mainly have fresh groundwater, however the Quaternary deposits are located at the down streams mainly have saline and brackish groundwater.

The Quaternary deposits underlying the Pliocene and Miocene sediments are characterized as successively bedded of sandstones, siltstone, conglomerate and clay with occurrence of gypsum and salt, which contain salty and brackish groundwater.

The groundwater level rang 3.2 m (in the river course) to 45 m (foot hill of mountains), the discharge of groundwater range from 2 l/s (foot hills) to 8 l/s (river valley) for 15 - 4 m drawdown, the electrical conductivity of ground water range from 840 µS/cm (Shu BAakhtu village of Khwaja Sabz district) to 52430 µS/cm (Atenkhwaja village of Shirin Tagab district).

Most areas of Faryab province (Dowlatabad Sherintagab, Maymona, Andkhoi and Qaram Qule districts) suffer from an acute shortage of fresh drinking water, however the deep and shallow groundwater is highly memorialized, therefore the groundwater development by Tube Wells for providing of drinking water is waste the time and money.

There are two possibilities to settle down regional piped water supply system:

1. A spring is situated on the right bank of Shirin Tagab river (Jug Ha village of Dawlat Abad district), that is discharging about 450 l/s. Water of spring is fresh and fit for drinking and household consumption.
2. A spring is situated in the Yanga Qala village of Maymona district. The discharge of the spring is about 40 l/s. The quality of water is quite fit for drinking and domestic purposes.

The Koshka (I - 6) Artesian Basin includes Kushk-e-Naw, Kushk-e-Kohna and Gulran district of Herate province.

The Quaternary aquifer is composed of alluvial medium and coarse sediments (gravel, pebbles, cobbles and boulder) with various thickness and hydraulic properties mainly have fresh groundwater. The thickness of Quaternary aquifer is very low only a few meters.

The Quaternary deposits overlie the Pliocene and Miocene sediments which are characterized successively bedded of sandstones, siltstone, conglomerate and clay with occurrence of gypsum and salt which have saline and brackish groundwater.

The groundwater level ranges from 3 m (Toraghondi) to 39.6 m (Qala-i-Safedak), the discharge of groundwater ranges from 1 l/s (foot hills) to 4 l/s (River valley) for 20-4 m drawdown, the electrical conductivity of ground water range from 1345µS/cm (Chil Dokhtaran district of Kushk-e-Naw) to 8400 µS/cm (Toraghondi). The mineralization of Pliocene and Miocene aquifer is increased from the upper part to the lower part.

It is notable the lower part of Quaternary aquifer underlying red clay which is highly mineralized, therefore the drilling of Tube Well for drinking water waste the time and money (there are many Tube Wells were improved which have saline water).

Basins with fracture-karst rock water (Murghab, Maimana and Shashan) are composed of Cretaceous (K) carbonate (limestone, dolomite, dolomatic limestone, marl and marble). The natural groundwater aquifers consist of fault, contact zones and karst development fractures, channel and cavities with various thickness and hydraulic properties. Groundwater flow is controlled by the characteristics of aquifer and discharging as springs on the surface at the foothills of mountains (at the slopes of low elevations).

The karst springs in these areas play great role for irrigation of agricultural activities and suppling drinking water. The discharge of springs range from 2 l/s (in Ghormach District of Badghise province) to 3,332 l/s (up Stream of Balkh River). The quality of water quite fit for drinking and irrigation.

The karst spring with different discharge are emerging from various karst development aquifer seem to be best sources for water supply and irrigation. These sources there fore, are to be given the highest priority in the water supply programming and planning in the north part of country where the shallow and deep groundwater highly mineralized.

The Hydro logical Massif (Band-e-Turkistan and Surkhab), are located at the high topographic elevations of Band-e-Turkistan, Firoz Koh and Parapamisus mountains ranges, which there precipitate snowfalls and rainfalls. The snow melting and rainfall provide enough water for hydro logical Basins (rivers) of North Afghan platform and recharging groundwater.

There are various geological layers including Palaeozoic, Mesozoic and Cainozoic age with the exposure of igneous rocks (different age). The hydro geological condition is complex due to various layers, fracture, fault and weathering and contact zones. The natural groundwater system links to the hydro geological condition and hydraulic properties. There is groundwater system discharging as springs on the surface in the narrow valleys along the small River course.

7.3 Central and North-Eastern Afghanistan Folded Area (Karst or Fractured Area).

From southeast, it is separated by Tarnak-Moqoor fault and from north by North Artesian Basins along the major Harirod Fault. Also, from east and northeast, it is separated by Hindukush Badakhshan Massive from North Afghanistan Basin. In southwest, it is separated by the boundaries of hydro-geological basins. It forms from South Artesian Basin in the area of Dasht-e-Markoh and Sistan and from the west border with Iran and from north border with Tajikistan, and from the east it forms the border with Pakistan.

Central Afghanistan Hydro- geological folded area included:

1. Hydro geological Massif
2. Basin with fracture-Karst water
3. Sub Artesian Basins
4. Basin in super imposed formation

7-1 Hydro-geological massif included:

- 7.1.1 Hindukush- Badakhshan and Pamirian Nooristan (2-1)
- 7.1.2 Harirod (2-2)
- 7.1.3 Upper Helmand- Srobi (2-3)
- 7.1.4 Arghandab (2-11)

7-2. Basin with Fracture-Karst Water included:

- 7.2.1 Middle Helmand(2-6)
- 7.2.2.Tyrin (2-7)

7-3. Sub Artesian Basins included:

- 7.3.1.Upper Hriprod (2-5)
- 7.3.2.Orozgan (2-10)

7-4. Basins in Super Imposed Formation included:

- 7.4.1 Adraskan (2-4)
- 3.4.2 Dasht-e-Nawor (2-8)
- 7.4.3 Farahrod (2-9)

Hydro geological Massif, Sub Artesian Basins and Basin in super imposed formations are located at the high topographic elevations (Hindu-kush, Badakhshan, Pamirian-Nuristan, Helmand-Arghandab and Koh-e-Baba mountain ranges), which there precipitate snowfalls and rainfalls. The ice and snow melting and rainfall provide enough water for hydro logical Basins of Afghanistan and recharging of groundwater.

The Mountain ridges are dominantly composed of hard rocks of pre-Paleogene age, dominated by sedimentary and metamorphic rocks with the exposure of igneous rocks (granites and granodiorites). The rocks are faulted, fractured, tilled, folded and deformed. Most of the drainage system infiltration into joints, faults and fractures of crystalline formations. In the crystalline formations of with abundant folding and faulting groundwater movement occurs along faults, joints and fractures between lithogies of different hydraulic behaviours and in the cause of carbonates through solution opening. Groundwater moves from topographically high areas to the low land.

The natural groundwater system links to the hydro geological condition and hydraulic properties. Most of the drainage system are structurally controlled which enters by infiltration into faults, joints, and fractures of crystalline formation. The groundwater is discharging as springs to the surface along the streams and narrow valleys with various hydraulic properties.

The plains and narrow valleys surrounding the mountain ranges are filled with Neogene and Quaternary sediments. They comprise alternating layers of cobble, gravels, sands, silts and clay which are saturated with fresh groundwater. The thicknesses of aquifers are very low (only few meters).

The groundwater flow is controlled by the characteristics of fracture, fault and weathering zones which are either emerging as springs or storing in to the alluvial Quaternary sediments in the narrow valleys and rivers banks.

Basin with Fracture - Karst water (Middle Helmand and Tyrin) are composed of Cretaceous (Cr) carbonate rocks (limestone, dolomite, limestone, marl and marble) with the contact of various geological layers, fault and weathering zones.

Fracture permeability is enhanced due to dissolution of carbonate rock with interaction of water. Fractures, joints and faults constitute major water yielding openings in the crystalline carbonate rocks. The natural groundwater aquifer consists of fault, contact zones and karst development fractures, channel and cavities with various thickness and hydraulic properties. Groundwater flow is controlled by the characteristics of aquifer and discharging as springs on the surface in the foothills of mountains (at the slopes of low elevations) and along the bank of streams.
The karst spring with different discharge are emerging from various karst development aquifer seem to be best source for water supply and irrigation. These springs to be given the highest priority in the water supply programming and planning in the central part of Afghanistan.

7.4 Intermountain closed by Inter-mountainous Basin

The intermountain closed through includes Kabul, Jalal Abad, Aynak, Wakhan. Herat, Baghlan, Balkh, Obe-Istada and Katawaz. The geology of areas is composed of bedrock at the bottom (with various geological formation and age) under lie a Neogene and Quaternary sediments sequence.

The groundwater flow is controlled from the groundwater recharge areas (foothills of mountains) ranges towards discharge areas in the mid to lower reaches of rivers valleys. The Quaternary aquifers are likely to be recharged in foothills by rivers and streams coming from the high mountains and infiltrating into course- grained and fine-grained alluvial sediments. The recharge is likely to be highest during snowmelt season. Thus groundwater recharge is highly dependent on quantities of winter snow fall and rain fall. Further away from the mountains the recharge to the Neogene and Quaternary aquifer is likely to take place by infiltration of water through to the bed of perennial and seasonal Rivers and streams. In the irrigated areas substantial recharge is likely to occur via leakage from irrigation channels ditches and canals.

8. National Groundwater Monitoring Network

Appropriate and adequate surface and groundwater data are essential for the planning and management of water resources of Afghanistan. Water resources of the country have not been properly managed and used. Therefore, it is in need of monitoring, management and protects water resources of Afghanistan from contamination and over exploitation. Proper management requires finding balance between groundwater protection and socio-economic activities. The task of balancing between groundwater protection and socio-economic activities is particularly challenging groundwater, which obtain information about hydro geological setting, natural groundwater system flow, recharge, discharge, thickness, hydraulic properties and water qualities.

Monitoring of wells are therefore, closely linked to the need of management, since the result of monitoring may require change or modification in the management and planning. The data collected from groundwater monitoring network may result to the shortage or rich of information many attempts have been made to reduce the gap between the information needs and the data collected by the monitoring network.

So far, little has been known about hydro geological setting and groundwater resources in Afghanistan due to lack of sustainable management, exploration, development, coordination and keeping data. Therefore, DACAAR/WSP with the support of USGS as the first water supply agency in the country has initially selected and modified 78 numbers groundwater monitoring wells (GMWs) along the hydrological Basins and sub Basins to obtain water quality and quantity information for the water supply project planning and implementation in the future.

The coordinates, locations, depth and initial water level and other specification of GMWs is shown in Annex 1, which is enclosed to this report.

9. National GMWs Water Level and Water Quality Data Evaluation

The national groundwater monitoring wells (GMWs) network are divided according to:

1. The groundwater level and electrical conductivity (EC) measurement (Annex 6).
2. The groundwater quality analysis (physical, chemical and bacteriological properties) (Annex 1).

The groundwater level and electrical conductivity (EC) of GMWs measured on a month basis (for a while two week bases). All the field water level and EC data from GMWs checked and processed and, then recorded in the DACAAR national groundwater monitoring data.

The water quality (physical, chemical and bacteriological) of GMWs was analyzed on sixth month basis (previously three month period). All the water quality data from GMWs checked and processed and, then recorded in the DACAAR national groundwater monitoring Water Quality database.

9.1 Groundwater Level and EC field Data Evaluation

Various natural and artificial factors (precipitation, evaporation, and transpiration, surface run off, urbanization, earthquakes and external loads) influence in the groundwater level.
A ground water level indicates the position where the atmospheric pressure and hydraulic head are at equilibrium (balance) in the aquifer. Any event that produces a change in pressure on ground water level cause the groundwater level varies. Differences between supply and withdrawal of groundwater cause level to fluctuation.

The time variation (fluctuation) in groundwater level can be considered as:

Long-term
Seasonal and
Short- term

In over developed basins, where the groundwater extraction exceeds recharge, a drawdown trend in groundwater level may continue for many years. In this trend the water level continuously has been declining (dropping dynamic water level) due to over extraction and low recharge, which trend is defined long term groundwater level dropping.

The seasonal fluctuation usually results from influence of precipitation, irrigation canal and ditches leakage and pumping for irrigation, all of which defined seasonal cycle or seasonal fluctuation of groundwater.

Short-term or monthly fluctuation of groundwater level is measured in alluvial aquifer for any special purpose (municipality water supply and pumping for irrigation).

Groundwater recharge is defined as the downward flow of water recharging the water level forming an addition to the groundwater reservoir.

Many factors affect groundwater recharge including evaporation, transpiration, precipitation, pumping for irrigation and water supply, surface flow and urbanization.

Groundwater discharges include, evaporation, transpiration and groundwater flow to the surface as drainage, springs, karezes and pumping for irrigation and water supply.

Over all this study focus to find seasonal and long term fluctuation of groundwater level in Afghanistan for planning and implementation water supply project in the rural areas.

Most of GMWs are located in the narrow valleys and intermountain areas where are composed of alluvial Quaternary sediments. Only the GMWs_ID, 39, 94, 63, 67, 68 and 72 are located in the plain areas where are composed of Pliocene and Miocene formation.

The depth of GMWs range from 8 m (GMW_ID, 54) to 81.2 m (GMW_ID, 45) and the groundwater level range from 2.25 m (GMW_ID, 22) to 41 m (GMW_ID, 5).

The groundwater level and electrical conductivity (EC) of GMWs measured on a month basis (for a while on a three weekly basis). All the field water level and EC data from GMWs checked and processed then recorded in the DACAAR national groundwater monitoring database.

The GMWs water level fluctuation and EC variation in time can result from climatic variability (precipitation, evaporation and transpiration), hydrologic time series (run off during a year) and hydro geological and geomorphologic setting.

According to the mentioned factors the GMWs water level variation in time is divided as:

1. The GMWs are located in the up gradient of narrow valleys, Pedi plane (foot hills) and along the small intermittent streams. The ground water level is affected by recharge (precipitation and surface flow) and discharge (pumping of groundwater and coming out water as springs). In rainy period (January-May) the water level increased and, in the dry season (April- November) the water level declined due to low precipitation and evaporation, but a yearly amplitude of groundwater level did not change (GMW_ID, 36, 33, 28, 24, 20, 3, 26, 22, 19, 54, 87, 53, 48, 47, 54, 7, 72). There the aquifers consist of Quaternary deposits (coarse grained sand, gravel, pebble, cobble with thin layers of silt clay and clay), underlying by impervious pre-Paleogene (Pg) formation. Groundwater is recharged by precipitation (rain fall and snow fall), leakage from canals and infiltration water from intermittent and perennial streams. The groundwater flow mainly characterized from foot hills of mountains (mainly recharge area) towards the lower land valleys. There the aquifers are more vulnerable due to low thickness and low hydraulic properties.

2. The GMWs are located in the down gradient of narrow valleys, lowland and intermountain areas, relatively far from hydrological Basins and sub Basins. The ground water level is affected by recharge and discharge. In rainy period (January-May) the water level increased and in the dry period (April- November) the water level declined due to low precipitation, but the water level continuously declined due to over extraction and low recharge (GMW_ID, 91, 14, 88, 30.25, 32, 2, 15, 17, 4, 11, 12, 105, 6, 72, 39, 51, 52, 64, 67, 68, 73, 79, 86, 37 and 8). The aquifers consist of middle to recent Quaternary (Q_{II-IV}) alluvial, alluvial-proluvial, deluvial deposits, with various thickness, hydraulic properties and water quality. The Neogene aquifer (GMW_ID, 67, 68, 72 and 39) consists of silt, silt clay, sandstone with various thickness, hydraulic properties and water quality. The dropping of water level ranges 1.5- 3.5 m/year. There are an imbalance between recharge and discharge of groundwater. The aquifers are recharged in foothills of mountains (recharge area) by infiltration of precipitation (rain fall and snowfall), leakage from canals, ditches and streams flow in the rainy seasons.

Comparison of GMWs water level variation in time data to the rainfall data (Agromet, 2005-2006), which show that the high amount of recharge occur in rainy season (January-May). In these seasons the water requirement is lower. In the other seasons (April- November) the discharge of water is very higher than the recharge due to over pumping for irrigation and water supply and strong evaporation and transpiration.

3. The GMWs are located in the down gradient of valleys, semi- desert, intermountain and plain areas. The ground water level is less affected by recharge and discharge, but the water level continuously declined due to over extraction and low recharge (GMW_ID, 92, 34, 27, 23, 21, 32, 31, 13, 18, 16, 5, 46, 63, 70, 77, 85, 60, 38, 40, 29, 43, 42, 41, 10 and 21). The aquifers consists of upper to recent Quaternary (Q_{II-IV}) alluvial, alluvial-proluvial, deposits, with various thickness, hydraulic properties and water quality. The dropping of water level ranges 1.5- 3.5 m/year. There are an imbalance between recharge and discharge of groundwater. The recharge of groundwater characterized by lateral inflow, leakage of canals and streams, rainfall and snowfall infiltration and river bed seepage. The groundwater recharge is characterized by evaporation, transpiration and pumping for water supply and irrigation. The groundwater flow is mainly characterized from the high land towards the discharge areas (plain areas) reaches to the river valleys.

Comparison of GMWs water level variation in time data to the rainfall data (Agromet, 2005-2006), which show that the high amount of recharge occur in rainy season (January-May). The groundwater level less affected by recharge. The discharge of groundwater is very higher due to over exploitation and strong evaporation, transpiration. Over abstraction of groundwater in excess of the annual depletion of aquifer, consequence continuously dropped water level.

4. The GMWs are located in irrigated areas that the groundwater is considerably recharged via leakage from irrigation channels and ditches. The water level fluctuation related to the flowing of water in irrigated canals, ditches and channels (GMW_ID, 94, 93 and 9).

The above (1) is attributed to the seasonal groundwater level fluctuation and, the (2) and (3) are attributed to the long term dropping water level (the time variation in groundwater level for long term) for example the GMW_ID, 2 located in Kabul province the groundwater level continuously declined (August 2003 - November 2006).The water level did no come to the original level due to over exploitation and low annual precipitation. There the water level dropped from 1.5 m (1989) to 11.5 m (December, 2006). For more information review the charts of water level and EC variation in time, which are enclosed to this report (Annex 6).

The groundwater fluctuation range from 0.16 m (GMW_ID, 56 Ghormach district of Badghise province) to 10.71 m (GMW_ID, 68 Kushk-e-Kohna district of Herate province) and EC range from 75 µS/cm (GMW_ID, 41 Sayyed Karam district of Paktia province) to 2400 µS/cm (GMW_ID, 68 Kushk-e-Kohna district of Herate province)(Annex 1 and 7).

The site groundwater level and EC variation in time data is shown in Annex 2, which is enclosed to this report.

Comparison of GMWs water level variation in time data (Annex 2) to the recent rainfall data (Annex 5 Rain fall Data and Charts) show that the rainfall is lees affected the recharge of groundwater. The annual average rainfall is from 0-20 mm (April – Number 2005/2006) to from 40 - 120 mm (December- May 2005/2006).

The GMWs water level and EC variation in time charts according to GMW_ID is enclosed to this report (Annex 6 WL and EC Variation in Time Charts).

The GMWs EC variation in time show that the EC values vary in time, according to the water level fluctuation (recharge and discharge), evaporation, capillary rise, dissolution of minerals and ion exchange.

Comparison of GMWs data to the previous drilling Tube Wells data which are located near of these wells show long term ground water level dropping in Afghanistan. Due to prolonged drought, over exploitation, drilled tube wells without any scientific consideration and loss of vegetation cover(up rooting bushes, filling trees from natural forest) dropped groundwater level, consequences dried up most of karezes, springs and large diameter wells (traditional or hand irrigation and rural water supply system). There are not currently agricultural activities in country where karezes springs and large diameter wells dried out, in case replacing this traditional or hand irrigation and rural water supply system with the groundwater pumping system, which is basically not possible because of high cost and the low productivity of wells.

9.2 Water Quality

In samples from GMWs performed physical, chemical and bacteriological analysis according to the DACAAR/WSP water quality monitoring laboratory procedure. The physical, chemical and bacteriological analysis properties of groundwater monitoring wells (GMWs) are shown in the Annex 3a & b and the GMWs location according to the GMWs _ID are shown in the Annex 7 which are enclosed to this report.

9.2.1 Physical parameters

Physical parameters include temperature, pH and Electrical Conductivity in this particular case.

9.2.1.1 Temperature

The temperature of shallow groundwater is related to the recharge in time and, soil temperature, however, the temperature of deep groundwater is related to the content of host water bearing formation, dissolution of minerals and gas and other factors.

The field measuring data of groundwater monitoring wells (GMWs) are shown that the temperature of groundwater ranges 13 - 18 C°, during recharge of groundwater (after the snow melts, discharge river and recharge groundwater), however during the discharge of groundwater (dry seasons) the temperature rang from 19 - 25 C°.

9.2.1.2 pH

pH, which is defined as the negative decimal logarithm hydrogen ion activity (H^+).The pH value is indicated where the water is acid or alkaline. Neutral water pH=7. If the pH of water less than 7 is acid and more than 7 is alkaline. It is a very important for numerous hydro chemical reactions and assessing the usability of water in technical system. The WHO limit for pH is 6.5 - 8. Due to the acute water shortage in Afghanistan, pH values up to 8.5 are tolerated for human consumption.

The hydro chemical processes are dependent on pH:

1. Carbonates equilibrium.
2. The solubility of numerous minerals (calcium, magnesium, iron, manganese and aluminium minerals)
3. Surface charge of numerous minerals and thus their sorption capacity.

The pH of samples from GMWs varies in the range from 6.49 (GMW_ID, 10 is located in the Nirkh District of Wardak Province) to 8.93 (GMW_ID, 44 Kushk- e-Kohna District of Herat Province).

The high pH values were observed in samples from GMW_ID, 44 (8.93), 42 (8.5), 26 (8.49), 27 (8.44), 64 (8.43), 37 (8.35), 11 (8.27), 24 (8.24) and 68 (8.20) which are exceeded the WHO limit of 8.

The 99 % samples from groundwater monitoring wells (GMWs) are shown that the pH values in groundwater is more than 7, however which are indicated the water contains considerable quantities of sodium carbonate and sodium bicarbonate.

The 26% of samples (see figure 14) from GMWs are shown that the pH value is exceeded the WHO limit of 8.

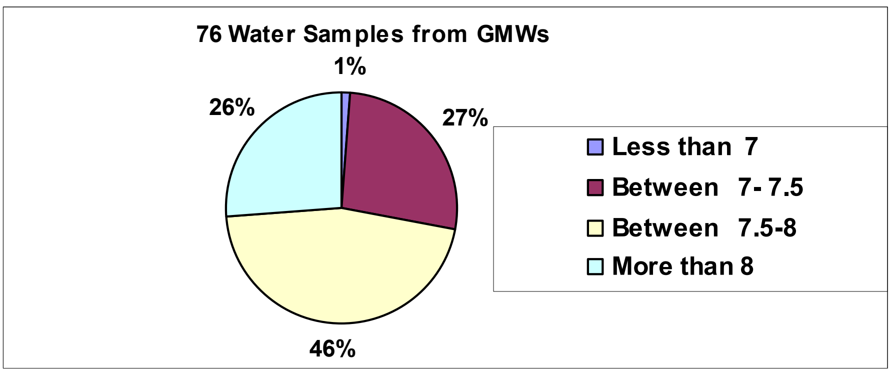


Fig.14 Percentage of pH concentration in samples from GMWs.

9.2.1.3 Electrical Conductivity (EC)

The electrical conductivity is sum parameter which approximately describes salt concentration in the water. The WHO guideline for electrical conductivity is 1500 micro mhos (µS/cm), but due to the acute water shortage in Afghanistan the electrical conductivity values up to 3000 µS/cm are tolerated for human consumption.

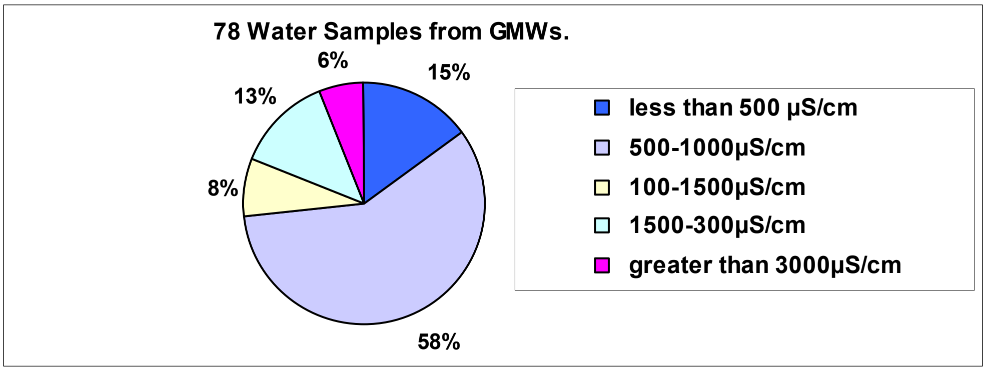


Fig.15 Percentage of EC concentration in sample from GMWs

The EC of samples from GMWs varies in the range from 251 µS/cm (GMW_ID, 36 Behsud District of Nangrahar Provinces) to 5260 µS/cm (GMW_ID, 63 Shindand District of Herat Province).

The highest electrical conductivity concentrations were observed in the samples from GMW_ID, 94 (3140 µS/cm), 68 (4000 µS/cm), 62 (4050 µS/cm), 67 (3190 µS/cm), 72 (4100 µS/cm) and 63 (5260 µS/cm) which are exceeded the WHO limit of 3000 µS/cm
The 19% samples from GMWs are shown that the EC concentrations is higher than WHO limit of 1500 µS/cm, and 81% of samples are shown that the EC concentration is lower than the WHO limit of 1500 µS/cm.

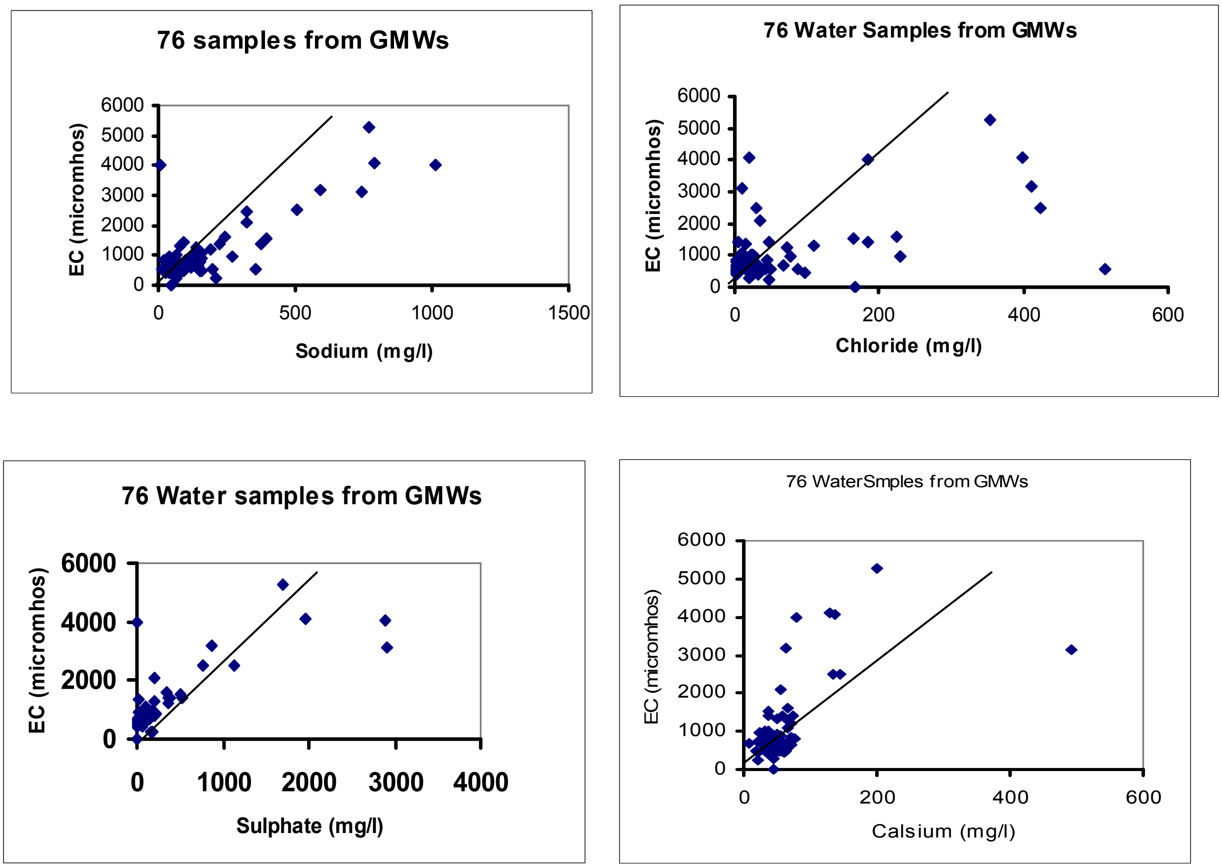


Fig. 16 Relationship between EC and Sodium, Chloride, Sulphate and Calcium.

The points with high values according to the spatial distribution of EC were recognized in the west, west-northern and north of the country where the area highly mineralized. The salt concentration within these areas probably caused by evaporation, salt and gypsum occurrence and rise of shallow groundwater capillary action. The points with low values (points close to each other) according to the spatial distribution of EC were recognized in the up gradient of Basins and sub Basins which have fresh groundwater.

The highest electrical conductivity concentration values were observed in the samples from groundwater monitoring wells (GMWs), which are located in Herat and Balkh provinces, however the lower electrical conductivity concentrations values were observed in the samples from groundwater monitoring wells which are located at the up stream of Basins.

9.2.2 Chemical Analysis Properties

9.2.2.1 Nitrogen species (nitrate, nitrite and ammonium)

The nitrogen species (nitrate, nitrite and ammonium) are very important for the assessment of drinking water hygiene. The distribution of nitrogen species is also a good indicator of the reduction environment of the groundwater. Nitrate reveals oxidation condition, but ammonium reveals reduction condition, however nitrite is shown reduction at the first of nitrate oxidation condition.

A high nitrate concentration can be considered as an indicator and warning that the water should be tested for the presence of harmful bacteria. Nitrate in concentration greater than 50 mg/l is undesirable in water for domestic purposes because of the possible toxic effect it may have on young infants, the effect is known as cyanosis. The high nitrate content in groundwater cause Blue Baby Syndrome for human, the effect is known as cyanosis.

The nitrate concentration of samples from GMWs varies, in the range from 0.08 mg/l (GMW_ID, 36 Behsud District of Nangrahar Province) to 90 mg/l (GMW_ID, 54 Lal wa Sargangal Dstrict of Ghor Province).

The high nitrate concentration were observed in the sample from GMW_ID, 63 (124 mg/l)), 54 (90 mg/l), 85(68 mg/l), 67 (60 mg/l), 68(58 mg/l) and 55 (50 mg/l), which are exceeded the WHO limit of 50 mg/l.

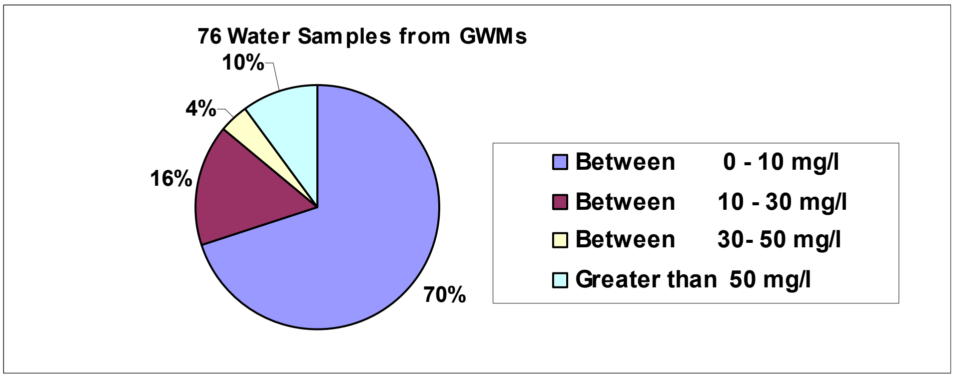


Fig.17 Percentage of nitrate concentration in samples from GMWs

The 10% samples from GMWs are shown that the nitrate concentration is higher than WHO limit of 50 mg/l, and 90% of samples of GMWs are shown that the nitrate concentrations is lower than WHO limit of 50 mg/l.

High nitrite concentration in samples from GMWs can be attributed to the surrounding physical contamination (direct flow of surface water into the wells or percolation of contamination water to aquifer from over lying zones) and use of nitrogen fertilizer in agricultural land.

The nitrite concentration in drinking water indicates bacteria pollution. In treated water nitrite can be present under special conditions without being an indicator of pollution. This can occur when the raw water contain ammonium, which is decomposed to nitrate as an intermediate phase.

The nitrite concentration in samples from GMWs varies in the range from 0.001 mg/l (GMW_ID, 16 Deh Sabz District of Kabul Province) to 1.01mg/l (GMW_ID, 45 Pasaband District of Ghor Province).

The high nitrite concentration values were observed in the samples from GMW_ID, 114 (0.23 mg/l) and 45 (1.01 mg/l) which are exceeded than the WHO limit of 0.2 mg/l.

The 4% samples from GMWs are shown that the nitrite concentrations is higher than WHO limit of 0.2 mg/l and 96% of samples of GMWs are shown, that the nitrate concentrations is lower than WHO limit of 0.2 mg/ (Fig. 18)

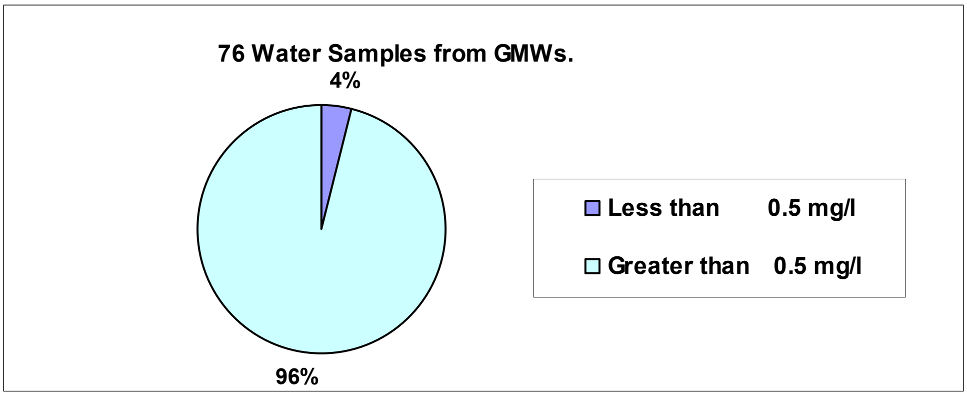


Fig.18 Percentage of nitrite concentration in samples from GMWs.

The ammonium is present in the water, it indicates contamination. A high content of ammonium is originated from physical surrounding pollution and geological formation.

The ammonium concentration in samples from GMWs varies in the range from 0.002 mg/l (GMW_ID, 77 Pashtun Zarghon District of Herat Province) to 2 mg/l ((GMW_ID, 62 Chimtal District of Balkh Province).

The sample from GMW_ID, 62 (2 mg/l) is shown, that the content of ammonium is higher than the WHO limit of 1.5 mg/l. Other samples from GMWs are shown, that the content of ammonium is lower than the WHO limit of 1.5 mg/l.

9-2-2-2 Sulphate

The sulphate content varies according to geological and hydro geological setting. High sulphate content is considered with high non-carbonate hardness. If a high quantity sulphate is present in water, it gives a bitter taste to the water and, the water as toxic for health.

The sulphate concentration in samples from GMWs varies in the range from 1 mg/l (GMW_ID, 8 Maydan Shahar District of Wardak Province) to 2900 mg/l (GMW_ID, 94 Chimtal District of Balkh Province).

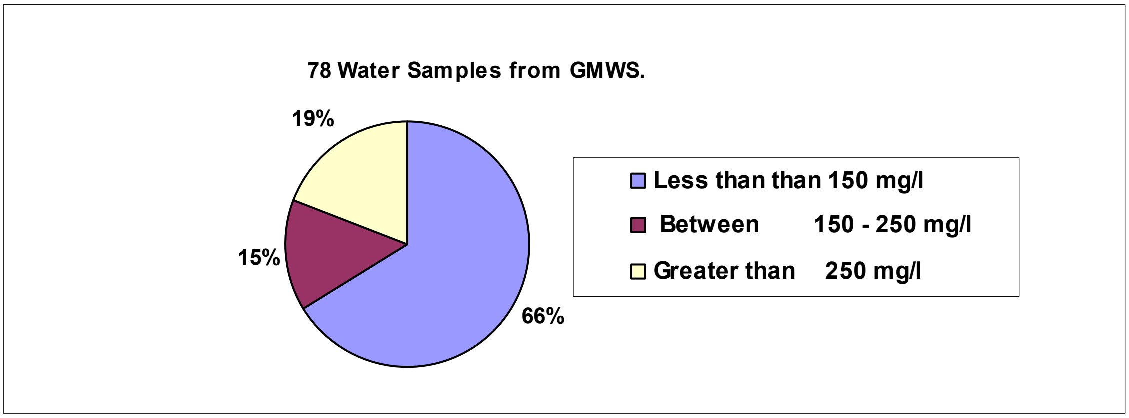


Fig.19 Percentage of sulphate concentration in samples from GMWs

The samples from GMW_ID, 53 (360 mg/l), 63 (1670 mg/l), 91 (1140 mg/l), 79 (495 mg/l), 67 (875 mg/l), 75 (376 mg/l), 89 (775 mg/l), 52 (350 mg/l), 64 (530 mg/l), 72 (1950 mg/l), 94 (2900 mg/l), 62 (2880) and 40 (390mg/l) are shown that the sulphate concentration are exceeded than the WHO limit of 250 mg/l.

The 19% of samples from GMWs are shown that the sulphate concentrations is higher than the WHO limit of 250 mg/l and, 81% of samples from GMWs are shown that the sulphate concentrations is lower than the WHO limit of 250 mg/l. The sulphate concentrations in samples from GMWs according to the GMWs_ID are shown in Annex 8 which is enclosed to this report.

It is notable the groundwater with the high sulphate concentration in groundwater is harmful for human but the inhabitants of areas are using due to shortage of drinking water. There are observed high sulphate content water diseases (loss of body fluid) and mortality of children.

The areas where (Herat, Faryab, Badghis and Balkh provinces) are considered higher content of sulphate in groundwater, which is attributed weathering of gypsum and anhydrite minerals with interaction of aquifer water.

9.2.2.3 Iron and Manganese

Iron and manganese have similar geochemical behaviour, therefore can be discussed jointly. These are dissolved under low reduction potential condition as reduced soluble species ferrous iron ($Fe^{2+)}$ and Manganese (Mn^{2+}).

The samples from groundwater monitoring wells are shown the content of iron is lower than the WHO limit of 0.3 mg/l, only sample from GMW_ID, 94 (Chimtal district of Balkh Province) is shown that the content of iron (1.4 mg/l) is higher than the limit of 0.3 mg/l

The samples from groundwater monitoring wells are shown, that the content of manganese is lower than the WHO limit 0.4 mg/l.

9.2.2.4 Sodium and Chloride

Sodium and chloride ions are important components of most groundwater. Because the mineral of sodium chloride (halite) is very soluble and both of the ions very mobile. Sodium and chloride ions are enriched in the residual solution during evaporation. At the same time the distribution of sodium is limited by ion exchange, chloride is a practically uncreative conservative tracer.

Water with chloride concentration is greater than 250 mg/l has saline taste. High concentrations can cause considerable damage to the body's fluid balance. One of the negative effects of highly saline water is also the corrosion of metal and destroys concrete elements.

A high content of sodium in drinking water injurious to health (increases blood pressure). Groundwater containing considerable quantities of sodium carbonate and sodium bicarbonate are alkaline and the pH value is more than 7.

The sodium concentration in samples from GMWs varies in the range from 7 mg/l (GMW_ID, 68 Kushk-e-Naw district of Herat Province) to 1010 mg/l (GMW_ID, 62 Chimtal District of Balkh Province).

The samples from GMW_ID, 36 (208 mg/l), 77 (352 mg/l), 94 (743 mg/l), 62 (1010mg/l), 40 (225mg/i), 52 (245 mg/l), 63 (880 mg/l), 51 (271 mg/l), 64 (374 mg/l), 67 (593 mg/l), 72 (788 mg/l), 79 (394 mg/l), 89 (504 mg/l) and 91 (325 mg/l) are shown the content of sodium are exceeded than the WHO limit of 200 mg/l.

The 18% of samples from GMWs are shown that the sodium concentrations is higher than the WHO limit of 200 mg/l and, 82% of samples from GMWs are shown that the sodium concentration is lower than the WHO limit of 200 mg/l. The sodium concentrations in samples from GMWs according to the GMWs_ID are shown in Annex 9.

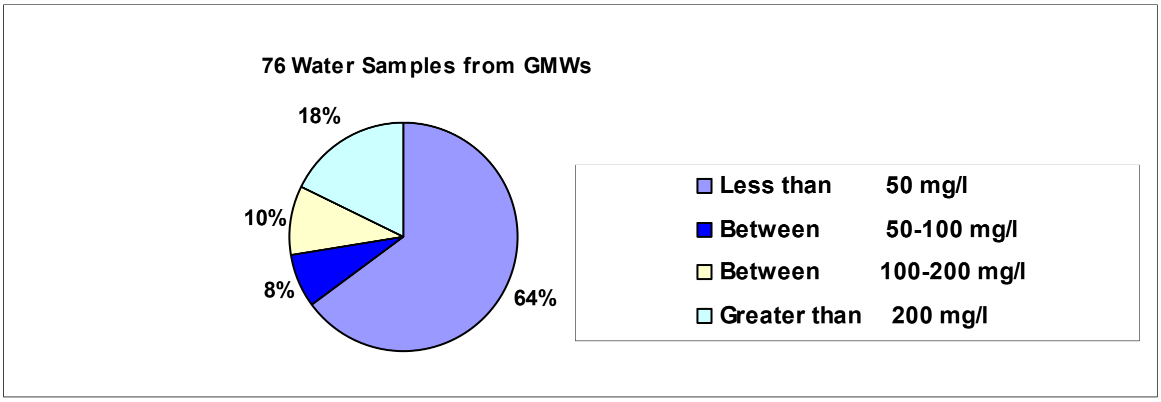


Fig.20 Percentage of sodium concentration in samples from GMWs

The chloride concentration in samples from GMWs varies in the range from 1.3 mg/l (GMW_ID, 41 Sayid Karam district of Paktya province) to 512 mg/l (GMW_ID, 77 Pashtun Zarghon district of Herat province).

The samples from GMW_ID, 77 (510 mg/l), 89 (424 mg/l), 67 (410 mg/l), 72 (398 mg/l) and 63 (353 mg/l) are shown that the content of chloride is exceeded than the WHO limit of 250 mg/l.

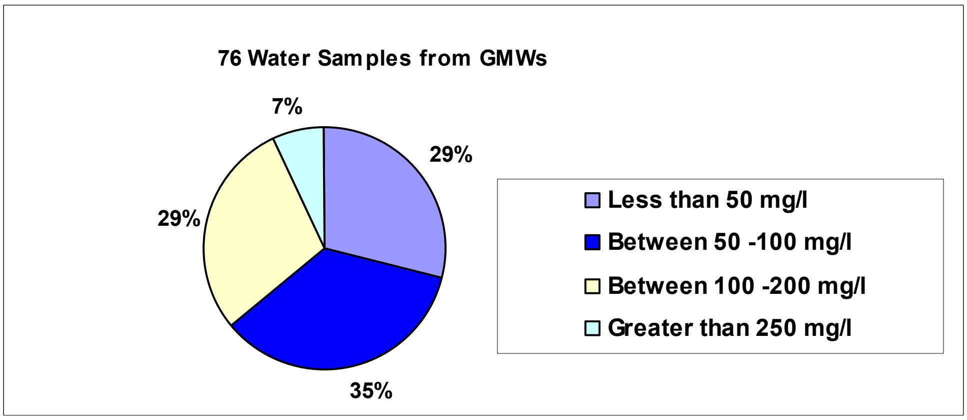


Fig. 21 Percentage of chloride concentration in samples from GMWs.

The 7% of samples from GMWs are shown that the chloride concentrations is higher than the WHO limit of 250 mg/l and 93% of samples from GMWs are shown that the chloride concentrations is lower than the WHO limit of 200 mg/l. The chloride concentrations in samples from GMWs according to the GMWs_ID are shown in Annex 10.

The high content of sodium and chloride in the mentioned areas is originated from following process and sources;
1. Dissolution of sodium chloride (halite) from surrounding water bearing formation.
2. Due to strong evaporation and groundwater table fluctuation (capillary rise) leaves behind dissolved salt, consequences is increased sodium chloride.

The areas where are considered higher content of chloride in groundwater which is originated from surrounding geological formation and strong evaporation.

9-2-2-5 Potassium

Potassium(K^{+1}) has a similar geochemical behaviour like sodium, however it is much lower concentration in rocks and is more strongly retained by soil. Concentration of potassium always lowers than sodium. The highest permissible level for potassium in groundwater is 10 mg/l. High concentrations of potassium values are shown a sign of pollution in groundwater.

The potassium concentrations in samples from GMWs vary in the range from 0.9 mg/l (GMW_ID, 39 Zhari District of Kandahar Province) to 58 mg/l (GMW_ID, 55 Karukh District of Herat Province).

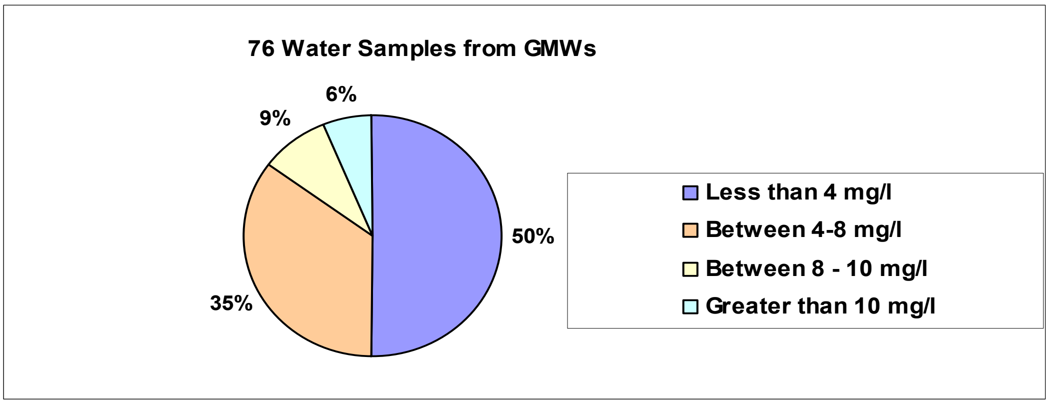


Fig. 22 Percentage of potassium concentration in samples from GMWs

The samples from GMW_ID, 112 (34 mg/l), 94 (15 mg/l), 13 (11.5 mg/l) and 53 (10.5 mg/l) are shown, that the content of potassium is higher than maximum permissible level of 10 mg/l.

The 6% of samples from GMWs are shown that the potassium concentration is higher than the maximum permissible level of 10 mg/l.

9-2-2-6 Silica

Dissolved silicon is produced by the reaction of groundwater with the silicate constituents of the rocks forming the aquifer. Volcanic rocks, in particular those with large amounts of silica (SiO2) minerals of low crystalline, are a major source of silica.

The silica concentration in samples from GMWs varies in the range from 0.04 mg/l (GMW_ID, 112 Balkh District of Balkh Province) to 74 mg/l (GMW_ID, 7 Qarabagh District of Ghazni Province).

The samples from GMW_ID, 22 (34 mg/l), 94 (15 mg/l), 13 (21 mg/l) and 53 (16.5 mg/l) are shown, that the content of silica is higher than maximum permissible level of 10 mg/l.

The 8% of samples from GMWs are shown that the silica concentrations are higher than the WHO limit of maximum permissible level of 10 mg/l.

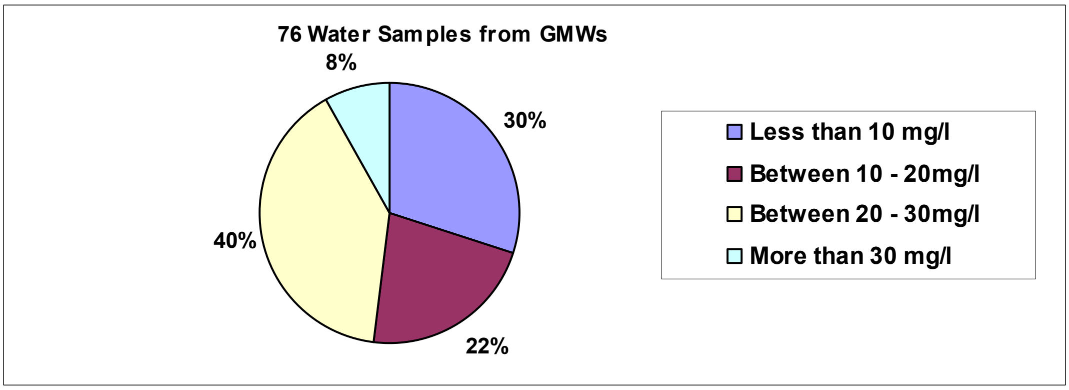


Fig.23 Percentage of silica concentration in samples from GMWs

9.2.2.7 Fluoride

Low concentrations of fluoride in drinking water are hygienically desirable, to strengthen teeth, the long term drinking of water with raised fluoride concentrations can give rise to fluorosis, a disease which initially damages the teeth and in serious cause can have a negative effect on bones and joints as a result of stiffening.
High concentrations of fluoride in groundwater are often found in areas with granite rocks

The fluoride concentration in samples from GMWs varies in the range from 0.02 mg/l (GMW_ID, 18 Char Qala district of Kabul province) to 63 mg/l (GMW_ID, Chimtal district of Balkh province).

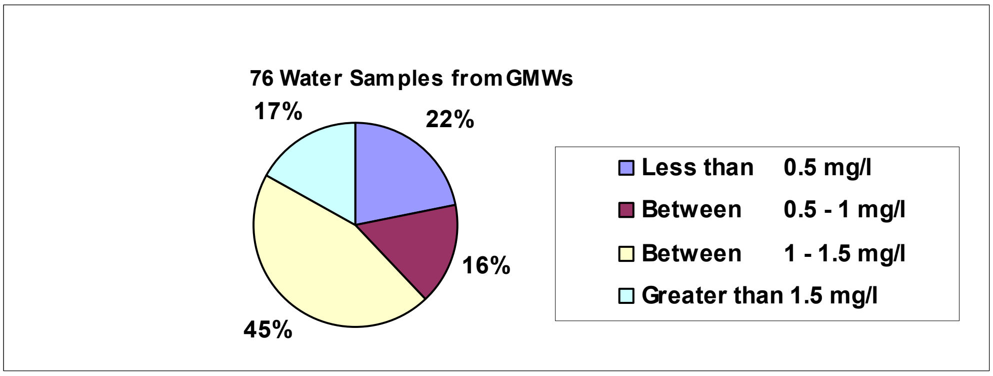


Fig.23 Percentage of fluoride concentration in samples from GMWs

In the samples from GMW_ID, 63 (10.7 mg/l), 44 (2.98), 62 (9 mg/l), 72 (7.1 mg/l), 67 (6.5 mg/l), 79(5.4 mg/l), 89 (5.2 mg/l), 91 (3.8 mg/l), 68 (2.94 mg/l), 75 (2.2 mg/l), 11 (2.14 mg/l) and 52 (2.06 mg/l) are shown, that the fluoride concentration has exceeded the WHO limit of 1.5mg/l.

The 17 % of samples from GMWs are shown that the fluoride concentration is higher than the WHO limit of maximum permissible level of 1.5 mg/l. The fluoride concentrations in samples from GMWs according to the GMWs_ID are shown in Annex 11.

The samples from groundwater monitoring wells are shown high fluoride concentration (the samples from Herat, Badghis, and Balkh), which is most probably originated from evaporative enrichment, however the samples from groundwater monitoring wells are shown medium and lower fluoride concentration which is may originated from dissolution of fluoride bearing-menials(quartz, k-feldspar, plagioclase, biotite, amphibolet and apatite).

9.2.2.8 Aluminium

The samples from groundwater monitoring wells are shown lower concentrations of aluminium in groundwater in hydrological Basins of Afghanistan, but only sample from GMW_ID, 114 (0, 33 mg/l) is shown high concentration of aluminium, however the WHO race for aluminium concentrations values is 0.2 mg/l.

9.2.2.9 Boron (B^-)

The element boron usually occurs in groundwater in the form of the anions borate (BO2). Borate is a highly mobile ions, however it can spread widely due to high solubility. The spread is prevented to a minor degree by sorption on iron oxide minerals. High boron concentration in irrigated water can negatively affect the growth of plants, however cause testicular lesion for human. The WHO race for boron content in drinking water is o.5 mg/l

The boron concentrations in samples from GMWs vary in the range from 0.05 mg/l (GMW_ID, 43 Puli Alam District of Logar Province) to 3.9 mg/l (GMW_ID, 9 Saydabad District of Wardak Province).

The highest boron concentrations values were observed in the sample from GMW_ID, 9 (3.9 mg/l), 10 (2.2 mg/l), 63 (1.44 mg/l), 72 (1.7 mg/l), 67 (1.6 mg/l), 94 (1.5 mg/l), 12 (1.35 mg/l), 2 (1.3 mg/l), 62 (1.2 mg/l), 91 (1.1 mg/l) , 44 (1.05 mg/l), 79 (1.05 mg/l), which are exceeded that the WHO limit of 0.5 mg/l. The boron concentrations in samples from GMWs according to the GMWs_ID are shown in Annex 12.

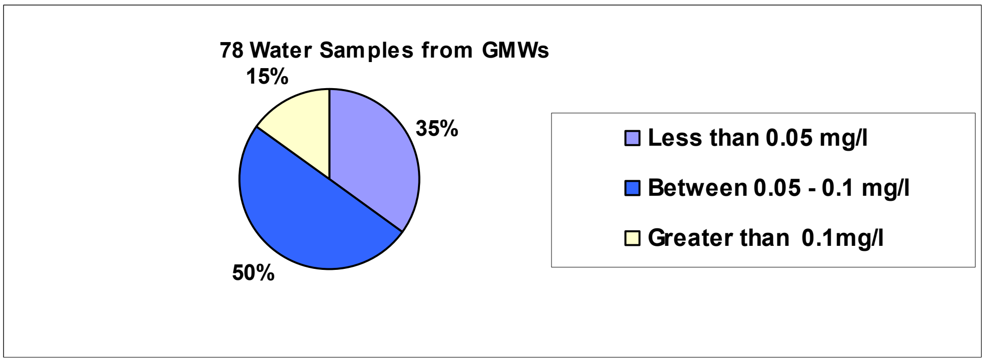


Fig.24 Percentage of boron concentration in samples from GMWs

The 15 % of samples from GMWs are indicated that the boron content in groundwater is higher than the WHO limit of 0.5 mg/l and 85 % samples from GMWs are indicated that the boron content in groundwater is lower than the WHO limit of 0.5 mg/l.

The sample from GMW_ID, 2 and 12 (located in Kabul city) are shown the enrichment of boron is most probably originated as a result of evaporative processes during drought continuing and dropping water table.

The highest boron concentration is observed in the Herat, Badghis, Faryab and Balkh provinces which is most probably originated from weathering of the boron bearing formation or strong evaporation.
Boron enriched as a result of residual solution evaporating surface water (boron minerals are highly water soluble and only precipitate very late in evaporation sequence)

9.2.2.10 Bromide (Br)
Bromide and chloride have similar geochemical behaviour. They occur together in saline water. High concentrations of bromide in water are undesirable because of its toxicity.

The bromide concentrations in samples from GMWs range from 0.01 mg/l (GMW_ID, 19 Alingar District of Laghman Province) to 0.8 mg/l (GMW_ID, 44 Kushk-e-Kohna District of Herat Province).

Iin the sample from GMW_ID, 14 (0.6 mg/l)), 32 (0.32 mg/l), 33 (0.3 mg/l), 6 (0.21 mg/l), 8 (0.2mg/l), 12 (0.19 mg/l), 72 (0.17 mg/l), 2 (0.15 mg/l), 92 (0.14 mg/l), 9 (0.14 mg/l) , 113 (0.13 mg/l), 91 (0.13 mg/l), 75 (0.12 mg/l), 51 (00.12mg/l), 44 (0.8 mg/l), 62 (0.12 mg/l) and 29 (0.11 mg/l) are shown that the bromide content is exceeded than the WHO limit of 0.1 mg/l.

A high concentration of bromide in water is undesirable because during chlorination of drinking water for treatment that the such water bromide to oxidize to bromine, which in the presence of dissolved organic carbon (DOC) reacts further to produce bromine-hydro carbonates (tribromomethane or bromoform), which is a problem for drinking water hygiene because of its toxicity.

The 20% of samples from GMWs are indicated that the bromide content in groundwater is higher than the WHO limit of 0.1 mg/l and 67% of samples are shown that the content of bromide is lower than the WHO limit of 0.1mg/l. The bromide concentrations in samples from GMWs according to the GMWs_ID are shown in Annex 13.

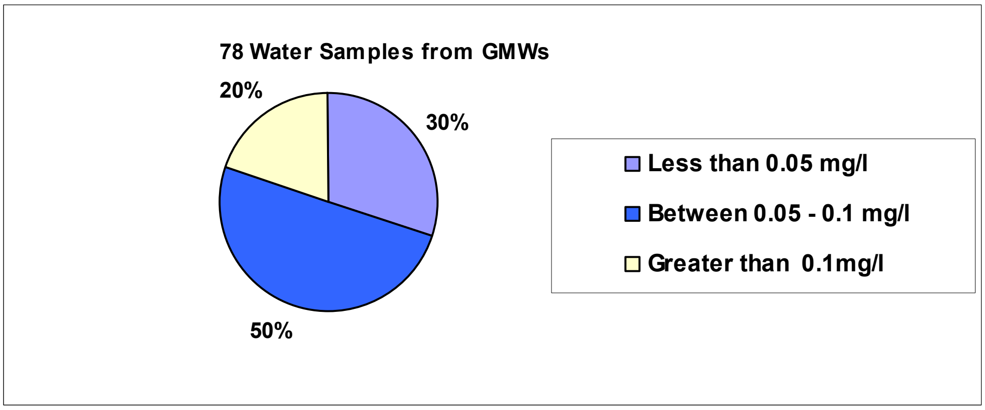


Fig.25. Percentage of Bromide concentration in samples from GMWs

9-2-2-11 Arsenic

Because of its strong toxicity, arsenic has very low limits of 0.01mg/l. The long term consumption of arsenic- bearing water can cause necrosis and cancer.

The arsenic concentrations in samples from GMWs range from 0.0025 mg/l (GMW_ID, 6 Khwaja Umari district of Ghazni Province) to 0.01 mg/l (GMW_ID, 19 Alingar District of Lagman Province).

In the samples from GMW_ID, 5 (0.01), 6 (0.0025 mg/l), 7(0.025), 19 (0.01 mg/l), 22 (0.01 mg/l), 27(0.05 mg/l), 67 (0.025 mg/l), 85(0.01) and 92 (0.025) are considered arsenic concentration that is equal or lower than the WHO limit of 0.01mg/l

The areas where are considered content of arsenic in samples from GMWs which is included Ghazni, Laghman, Logar, Herat, and Balkh provinces. It is suggested to study in detail for getting more information.

9.3.2.12 Copper

Copper is an essential trace element in human metabolism a generally considered to be non-toxic. Copper in public water supplies increases the corrosion of galvanized iron and steel fitting.

Human can tolerate up to 0.05 -0.5 mg copper per kg body weight. The WHO race for copper concentrations in drinking water is 1 mg/l.

The samples from GMWs are shown that the copper concentrations are lower than the WHO limit of 1mg/l.

9.2.2.13 Hardness

The properties of water hardness are related to the carbonate equilibrium (stability).The carbonate equilibrium is of major importance for the quality of many groundwater, because the carbonate minerals calcite ($CaCO_3$), aragonite ($CaCO_3$) and dolomite (Ca Ma $(CO_3)^2$) are frequent constituents of the matrix of natural aquifers. The main constituents in water associated with this system are there fore the ions calcium (Ca^{2+}), magnesium (Mg^{2+}), hydrogen carbonate (HCO_3 –) carbonate (CO_3)and dissolved carbon dioxide (CO_2).

The precipitation of carbonate from oversaturated waters cause major economic damage to pipes, extraction and treatment plants and domestic appliances.

Aggressive carbonate acid from carbonate-unsaturated water can lead to the corrosion of cemented and metallic materials. The hardness also affects the taste of drinking water. Calcium and magnesium cause almost all the hardness of water (total hardness). The total hardness of water may be divided into types, carbonate and non-carbonate. Carbonate hardness include that combine with bicarbonate and the small amount of carbonate present. This is used to be called temporary hardness, it can be removed by boiling the water by which calcium and magnesium carbonates precipitates. The non-carbonate hardness (calcium hardness) called permanent hardness this part of the hardness can not be removed by boiling.

The total hardness values in samples from GMWs range from 50 mg/l (GMW_ID, 26 Qarghayi district of Laghman Province) to 1850 mg/l (GMW_ID, 62 Chimtal District of Balkh Province).

The calcium hardness values in samples from GMWs range from 20 mg/l (GMW_ID, 26 Qarghayi District of Laghman Provinces) to 1230 mg/l (GMW_ID, 94 Chimtal District of Balkh Province).

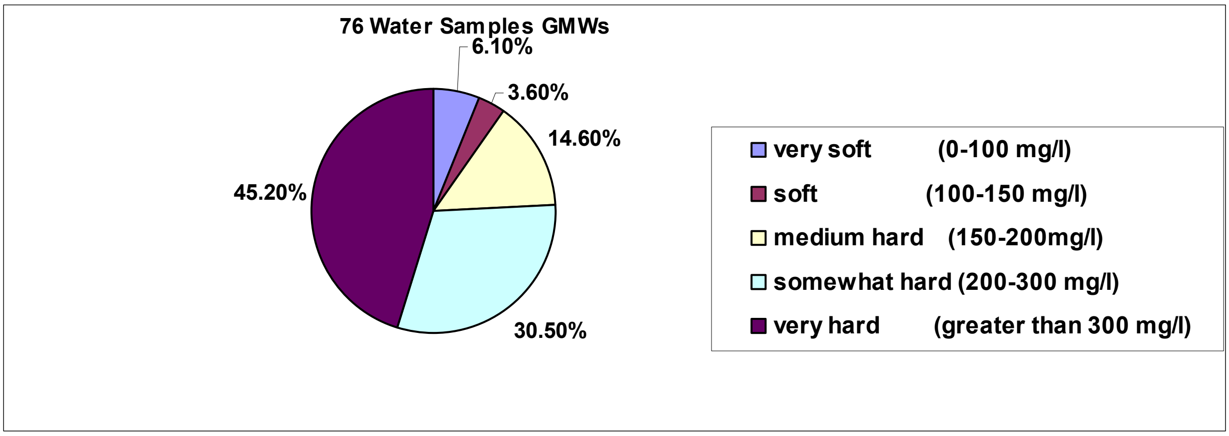


Fig.26. Percentage of Calcium Hardness concentration in samples from GMWs

9.2.3 Bacteriological determination

In the samples from GMWs were analyzed for themtolerant clliforms, as these are considered to be high sanitary (WHO 2004). According to the WHO standards, thermotolerant coliforms must be absent in a 100-ml water sample.

The faecal coliform is determined by Membrane filter method in the field. In the Membrane-filter method faecal coliform is determined with a procedure similar to that used for determining total coliform but the membrane is incubated at 44 C for 24 hours with 100% humidity. The number of colonies counted is directly related to the bacteriological count of water sample being analyzed.

The number of coliform bacteria is of the most important criteria for assessing the microbiological quality of drinking water.

The water samples from GMW_ID, 29, 30, 31, 33, 34, 35, 36, 40, 2, 42, 43, 44, 54, 62, 63, 79, 85, 88 and 112 exceeded the coliform bacteria of the WHO limit of 0 coli/100 ml (this limit is actually for piped drinking schemes).

Around 26% of water samples from GMWs had significant coli form bacteria contamination and considerably exceeded the WHO limit of 0 coli/100 ml.

9.2.4 Major Ion Chemistry

The major ion (anions and cat ions) chemical analysis of GMWs is shown in the (Annex 4), which is enclosed to this report.

The major ion chemistry of water samples from GMWs differences in chemical composition due to geologic and hydro geological setting and climatic condition. These differences in geochemistry are attributed to the water- rock interaction, minerals dissolution, evaporation and ion exchange which are characterized in variation of water type.

The samples from GMWs water type divided according to (Annex 4):

9.2.4.1 The Sodium Bicarbonate ($NaHCO_3$) water type observed in the up gradient of Ghazni, Wardak and Kabul provinces where the surrounding of GMWs are considered limestone gneisses and igneous rock.

9.2.4.2 The Sodium Sulphate ($NaSO_4$) and Sodium-Magnesium–Sulphate ($Na\text{-}Mg\text{-}SO_4$) water types observed in the Herat, Balkh and Badghis provinces where are considered the gypsum and in-hydrite occurrence.

9.2.4.3 The magnesium bicarbonate ($MgHCO_3$), calcium bicarbonate ($CaHCO_3$) and magnesium-Calcium Bicarbonate ($Mg\text{-}Ca\text{-}HCO_3$) water types observed in the Badghis, Laghman and Nangrahar provinces where the surrounding of GMWs are considered the carbonate sedimentary rocks.

9.2.4.4 The magnesium-sodium-bicarbonate ($Mg\text{-}Na\text{-}HCO_3$), sodium-magnesium-bicarbonate ($Na\text{-} Mg \text{-}HCO_3$) water types observed in the valleys of Logar, Laghman and Nangrahar provinces where the surrounding of GMWs are considered metamorphic and igneous rock (granite and granodiorite).

9.2.4.5 Mixed Water types magnesium-sodium-bicarbonate- sulphate ($Mg\text{-} Na \text{-}HCO_3\text{-} SO_4$) , sodium- magnesium- bicarbonate-chloride($Na\text{-} Mg \text{-}HCO_3\text{-} Cl_2$), calcium-sodium-bicarbonate-sulphate ($Ca\text{-} Na \text{-}HCO_3\text{-} SO_4$), magnesium-bicarbonate-sulphate ($Mg\text{-}HCO_3\text{-}SO_4$)) considered in the GMWs which are located in the up gradient valleys of Kabul, Nangrahar, Kapisa, laggma, Logar, Khost and Paktya provinces.

9.2.4.2 Major ion Correlation Coefficient Interpretation

9.2.4.2.1 Molar Na/Cl ratios relative Cl.

Molar Na/Cl ratio relative Cl, shows (Fig. 27) that the representative points remain constants between 0.5–1.5 around the halite dissolution line which are most probably attributed to the dissolution of halite ,evaporation (surface water during rainfall) and capillary rise (GMW_ID, 77, 67,72, 83, 89, 68, 44, 77 and 85). The areas where the mentioned GMWs are located, there the shallow and deep aquifer highly mineralized due to strong evaporation and halite occurrence.

This trend applicable for the areas where border with Pakistan, Iran, Turkmenistan, Uzbekistan and Tajikistan (DACAAR/WSP water quality data and previous groundwater investigation data). There the aquifer is composed Quaternary eolian loess, loam silt, silt clay, sand and gravel (in the narrow valleys river section with low thickness and low discharge). These deposits overlie the Pliocene and Miocene sediments composed of successive bedded of sandstone, siltstone, conglomerate, with the occurrences of gypsum and salt in the upper part of the series. This hydro geological condition supports the mentioned suggestion.

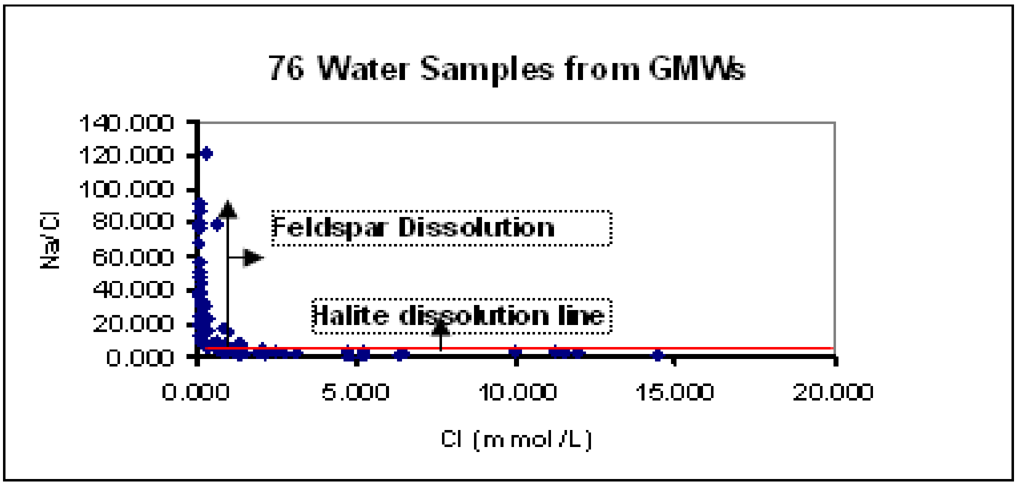


Fig. 27 Relationship between Na/Cl molar ratios relative Cl.

The high Na/Cl molar ratios (Na/Cl molar ratios are greater than 1.5) of fresh groundwater are most probably due to sodium derived from weathering of albitic feldspar (Na- feldspar) via a reaction such as:

$2NaAlSi_3O_8$ (Albite) + $9H_2O$ + $2H_2O_3$ + $2H_2CO_3$ ➞ $Al_2Si_2O_5(OH)_4$ (Kaolinite) + $2Na^+$ +$2H_2CO^-{}_3$ + $4Si_3O_8$

9.2.4.2.2 Molar Cl/Br ratios relative Cl show that the molar Cl/Br ratios range 19 -18509 (Fig.28) . Approximately 45 % water samples from GMWs are show, that the Cl/Br ratios are lower than the oceans limit of 575-600 (Davis, 1998), which are most probably to the flow path and ion exchange (input condition).

About 8% of water samples (GMW_ID, 6, 23, 29, 33, 34, 41and 8) are shown that the Cl/Br ratios are lower than 50, which is comparable to the fresh groundwater in the Riverin province in the south –central Murray Basin of Australia (Arad and Evans 1987, Watkins 1999). The water with this type may be described to the arid and semi-arid climate.

The samples from GMW_ID 63, 64, 89, 79, 17, 60 and 52 showed that the Cl/Br molar ratios 5075-18509 are attributed to the halite dissolution and evaporation. These types of water are comparable to the water in the Rivence of Australia (Cart Wright, 2004). Similarly, Smith (1991) recorded Cl/Br ratios of halite dissolution (14000-30000) in the east Saudi Arabia. The DACAAR/WSP water quality analyses are shown that the Cl/Br ratios are higher than the above mentioned record (greater than 30000) in Faryaab province. The Cl/Br ratios show some evidence of halite dissolution as cause of increasing salinity in the mentioned location.

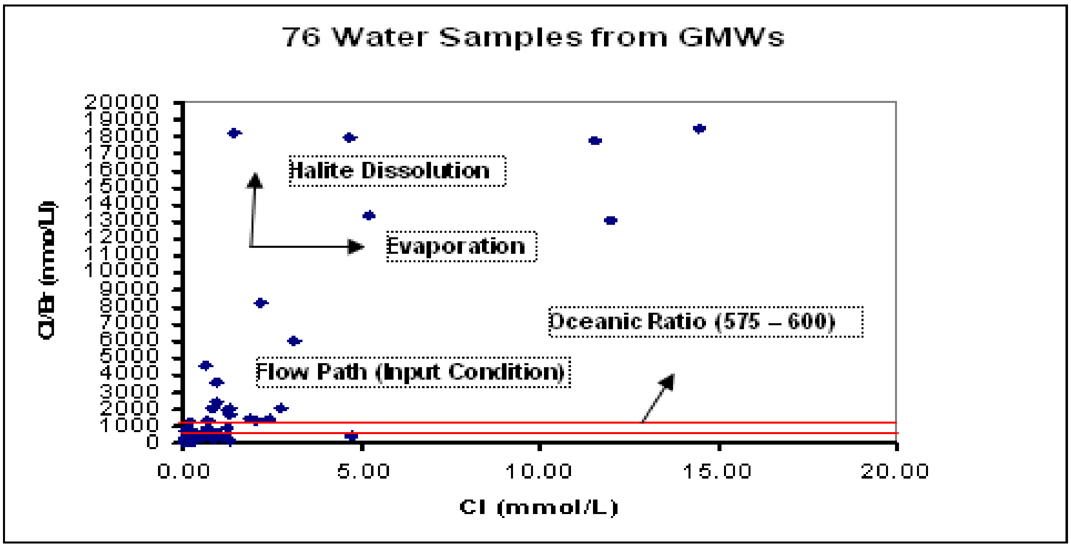


Fig.28. Molar Cl/Br ratios relative Cl indicate different water type in Afghanistan

9.2.4.2.1.3 The plot of Ca and SO_4 (Figure. 29) shows that the points marked close to each other which indicate good relationship between calcium and sulphate.

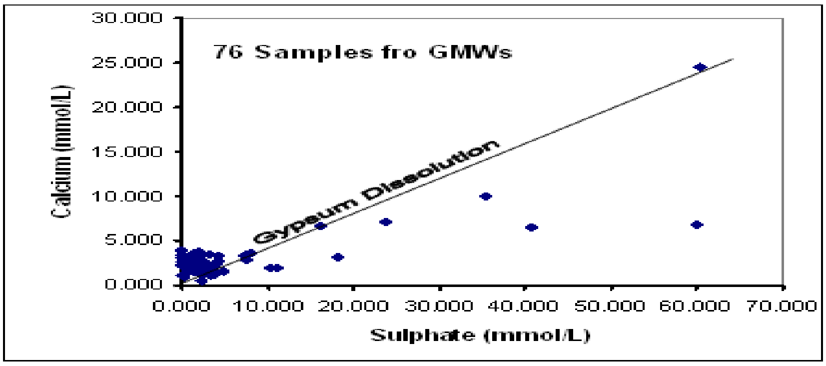


Fig. 29 Relationship between Calcium and Sulphate.

The points plotted either close to gypsum dissolution line or right of dissolution line which indicate gypsum dissolution (GMW_ID, 62, 64, 72, 94, 67 and 68). The areas where (Balkh, Herat and Badgis provinces) the mentioned GMWs located, there considered the gypsum occurrences

9.2.4.2.1.4 Molar Mg/Ca ratios relative HCO_3.
The highest magnesium, calcium and hydro carbonate concentration values in the samples from GMWs reveal that the interaction of groundwater with carbonate rocks play key role in the GMWs aquifers.
High bicarbonate (HCO_3) can result from the depletion of calcium (Ca^{2+}) due to cat ion exchange which cause a second stage of calcite dissolution (Walraevens 1990). An increase in sodium, potassium and magnesium also occur when minerals containing these ions such as feldspar dissolution (Stuy Fzand 1986)

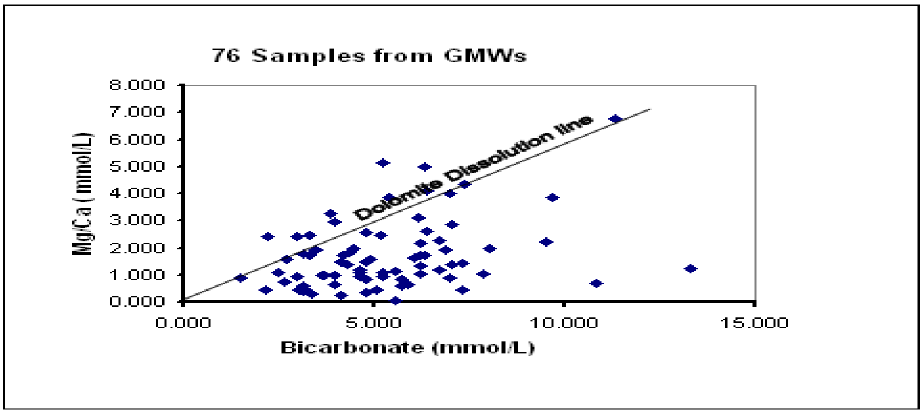


Fig. 29. Relationship between Magnesium/Calcium ratios relative Bicarbonate.

10. Conclusion

1. Most of GMWs are indicating that the groundwater level declined due to low precipitation, low recharge and over motor-pumping for water supply and irrigation.

2. Comparison of GMWs water levels variation in time data to the recent rainfall data (Agromet stations, USGS, 2005-2006) are shown that the rain fall less affected the recharge of groundwater due to low precipitation, prolonging drought and losing of vegetation cover and root-system.

3. Comparison of previous rainfall data (Meteorological Stations, Ministry of Water and Power 1975) to the recent rain fall data (Agromet stations, USGS, 2005-2006), are shown that the recent rainfall data is considerably lower than the previous rain fall data.

4. Comparison of GMWs water level data to the previous drilling Tube Wells water level data (drilled Tube Wells from 1970-1990), which are located surrounding of GMWs. They show that the long-term ground water levels are dropping countrywide. Due to prolonged drought, over exploitation without any scientific consideration, poor management and lose of vegetation cover and root-system (up rooting bushes, filling threes from natural forest) groundwater level dropped dramatically, consequences dried up most of karezes, springs and large diameter wells (traditional or hand irrigation and rural water supply system). There are not currently agricultural activities in country where karezes springs and large diameter wells dried out, in case replacing this traditional or hand irrigation and rural water supply system with the groundwater pumping system, which is basically not possible because of high cost and the low productivity of wells.

5. The 26 % of sample from GMWs show that the pH value is exceeded the WHO limit of 8. One of the negative effects of high pH value in water accelerating the corrosion of metal and destroying concrete elements.

6. The 19 % samples from GMWs show that the EC concentration is higher than WHO limit of 1500 µS/cm. High EC concentration in groundwater describes salt concentration in groundwater.

7. The 10 % samples from GMWs show that the nitrate concentration is higher than WHO limit of 50 mg/l. The high nitrate concentration in the rural areas most came from agricultural activities and surrounding physical contamination, however the high nitrate concentration in the urban areas particularly Kabul city came from sewage (septic tank) and waste water infiltration through groundwater and surrounding physical contamination.

Nitrate in concentration greater than 50 mg/l is undesirable in water for domestic purposes because of the possible toxic effect it may have on young infants. The effect is known as cyanosis. The high nitrate content in groundwater cause Blue Baby Syndsom for human.

The chemical analyses of groundwater in Kabul city (BGR, USGS and DACAAR water analyses) show that the nitrate concentration is very high than the WHO limit of 50 mg/l. Because most of the infiltration water is sewage, this most give rise to strong accumulation of salt particularly elevated nitrate concentration.

8. The 19 % of samples from GMWs show that the sulphate concentration is higher than the WHO limit of 250 mg/l. It is notable the groundwater with the high sulphate concentration in groundwater is harmful for human, but the inhabitants of areas are using due to shortage of drinking water. There are observed high sulphate content water diseases (loss of body fluid) and mortality of children.

Groundwater in Herat, Faryab, Badghis and Balkh provinces have higher content of sulphate, which can be attributed to the weathering of gypsum and anhydrite minerals with interaction of aquifer water.

9. The 18 % of samples from GMWs show that the sodium concentration is higher than the WHO limit of 200 mg/l. A high content of sodium in drinking water injurious to health (increases blood pressure).

11.The 7 % of samples from GMWs show that the chloride concentrations is higher than the WHO limit of 250 mg/l. Water with chloride concentrations greater than 250 mg/l has salty taste. High concentrations can cause considerable damage to the body’s fluid balance. One of the negative effects of highly salty water is also the corrosion of metal and destroys concrete elements.

12. The 15 % of samples from GMWs indicate that the boron content in groundwater is higher than the WHO limit of 0.5 mg/l. However, high concentration in irrigation water can negatively affect the growth of plants, however cause testicular lie son for human.

13. The 20 % of samples from GMWs show that the fluoride concentrations are higher than the WHO limit of maximum permissible level of 1.5 mg/l. The long term drinking of water with raised fluoride concentrations can rise to fluorosis, a disease which initially damages the teeth and in serious cause can have a negative effect on bones and joints as a result of stiffening.

14. The 20 % of samples from GMWs indicate that the bromide content in groundwater is higher than the WHO limit of 0.1 mg/l. High concentrations of bromide in water are undesirable because of its toxicity.

15. Due to high concentration of carbonate minerals (hardness) in GMWs cause major economic damage to pipes and domestic appliances. Aggressive carbonate acid from carbonate-unsaturated water can lead to the corrosion of cemented and metallic elements. The hardness also affects the taste of drinking water.

16. Around 26 % of water samples from GMWs had significant coliform bacteria contamination and exceeded the WHO limit of 0 coli/100 ml. The bacteria contamination came from surrounding physical contamination and agricultural activities and poor hygiene and sanitation awareness and development of community.

17. The numbers of GMWs are indicative and only reflect a sample of Afghanistan. Our assessment only indicates a countrywide indication of results. There is wide spread water quality and quantity problems which threaten sustainability and security of groundwater in Afghanistan.

18. The karst spring with different discharge and fractured aquifers seem to be best source for water supply and irrigation. These springs should be given the highest priority for development for water supply in the central and northern part of Afghanistan.

11. Recommendations

1. Establishing of countrywide groundwater and surface water monitoring program is a necessity for finding safe yield. Systematic and long-term hydrologic data sets (run off, groundwater level, water quality and hydraulic properties) need to be collected and collated. Meteorological data (precipitation, evaporation and temperature) need to be collected and connected to the groundwater data through statistical means. Data sets need to be collected of hydro geological setting and groundwater natural aquifer systems. Systematic and long-term groundwater and surface water comprehensive data collection, keeping and assessment may improve groundwater development, sustainability and management.

2. The near countrywide GMWs water level and water quality data evaluation and assessment shows results that need further monitoring on their effect on humans and the environment (lowering dynamic water levels, depletion storage from aquifers, and accumulated salt concentrations). It is needed to increase groundwater management and address the issue of security of groundwater resources and protect from further lowering and depletion of groundwater resources.

3. Groundwater is a resource that can be used and recover from depletion, provided if properly managed. Therefore, government and none government organization need to promote awareness of groundwater management issues with in the recipient community (experiments of hydro geologists in Iran, Pakistan, India and other countries around Afghanistan are applicable).

4. Suitable artificial recharge technique such as construction of ponds, large diameter wells, channel and trench infiltration should be practiced for artificial recharge purposes during the precipitation period (practised in Iran, Pakistan, India, USA and other countries).

5. Sufficient practical and scientific knowledge, as well as awareness and understanding of the groundwater resources and their proper management might result in finding appropriate solutions specific for the various areas of Afghanistan. It is beneficial to highlight problematic areas which resources are limited and find alternative solution for design, planning and implementation of water resource development. It is suggested to assess the groundwater storage, quality and hydraulic properties then design, plan and implement water supply projects.

6. In areas where the groundwater constitutes multi layered alternating aquifers with fresh and salty water, through proper probing, scientific knowledge, awareness and understanding to block fresh water from saline intrusion. The improvement of wells without scientific knowledge is waste the time and money. It is suggested to identify intervals of fresh and salty water during drilling of tube wells, then improve wells (practised in Iran, India and USA).

7. In many part of country the deep-rooted perennial native vegetation replacement with shallow-rooted annual crops has resulted in a general rise of water level and, therefore increase discharge to the surface via evaporation. Poor community with low socio-economic development in Afghanistan has been cutting trees from natural forests and up rooting

bushes (including the root systems) from mountain sides to sell in the markets as timber and fire wood and used for cooking. The loss of vegetation cover resulted to reduce water penetration through roots system and further accelerating the drop of water levels. It is needed to prevent cutting of trees from natural forests and uprooting of natural bushes from mountain sides and rehabilitate natural forest and vegetation cover.

8. Nitrate concentration has been increasing in the urban areas (particularly in Kabul city) due to infiltration of waste water from surface (septic tank – soak pits) to groundwater. It is needed to construct sewer network for separating waste water from groundwater.

9. Management requires finding a sustainable balance between groundwater protection and socio-economic activities. So far, there is not sufficient information about stabilising groundwater in the country. The groundwater has been abused by unskilled and poorly equipped private drilling contractors without hydro geological knowledge. This caused water quality and abstraction problems in aquifers (dropping water level and increasing salt concentration). Long- term declination of dynamic water level resulted in drying out karezes, springs and depleted groundwater storage in south, southwest and central Afghanistan. It is non-studied finding but observed and through anecdotal evidence which causes unacceptable lowering of water table and reduction of groundwater storage.

It is needed to find sustainable balance of groundwater (recharge and discharge) and protect groundwater from further unsustainable abstraction.

10. Around 26 % of water samples from GMWs had significant coliform bacteria contamination and exceeded the WHO limit of 0 coli/100 ml (WHO limits are for piped water system, in rural areas higher levels could be accepted but need to be set as guidelines for Afghanistan as then the Afghan government can accept and put up the funds to control the limits). The bacteria contamination came from surrounding physical contamination and agricultural activities and poor hygiene and sanitation awareness and development of community. It is needed to extend hygiene and sanitation program in the rural and urban areas and chlorination of wells for treatment.

12. REFERENCES

1	DACAAR/WSP, USGS, 2005-2006	National Groundwater Monitoring Wells Network Field measuring and Water Quality data
2	DACAAR/WSP 2003-2006	Nation Water Quality Analyses in Afghanistan.
3	DACAAR/WSP, M.Hassan Saffi, 2006.	Groundwater Salinity survey and pumping test data in Kushk-e- Kohna and Kushk-e-Naw districts of Herat Province, Afghanistan.
4	DACAAR/WSP, M.Hassan Saffi, 2005	Groundwater Salinity survey data in Faryab Province, Afghanistan.
5	DACAAR/WSP, M.Hassan Saffi, 2004	Groundwater Salinity survey data in Ghormach district of Badghis Province, Afghanistan.
6	Alim, A.K & Shobair, S.S., 2002.	The effect of climate on water resources in Afghanistan.
7	Oddmund Soldal & David Banks, NCA, 2001	Guidelines for sustainable use of groundwater in Afghanistan
8	Michael E. Brookfield & Ajruddin Hashmate, 2001.	The geology and petroleum potential of the northern Afghanistan.
9	World Health Organization, 2004	Guidelines for drinking-water quality-3rd edition.
10	E. Broshears, M. Amin Akbari, Michael P. Chornak, David.Mueller.	Inventory of Groundwater Resources in the Kabul Basin, Afghanistan.
11	Volume 15, Number 1, February 2007	Official Journal of the International Association of Hydro geologists.
12	Volume 14, Number 1-2, January 2006	Official Journal of the International Association of Hydro geologists.
13	Volume 14, Number 3, March 2006	Official Journal of the International Association of Hydro geologists.
14	Dr. Georg Houben, Torg Tunnemeir. 2003	Dr. Georg Houben, Torg Tunnemeir. Hydro geology of the Kabul Basin, part- 1 & part-2
13	Radojicic. S, 1977	Drinking water potential development technology in Afghanistan, UNICEF, Rural Water Supply Project Report
14	Ministry of Water and Power Kabul, 1982	Design of deep and shallow tube wells and dug wells in south and south-western of Afghanistan.
15	Radojicic. S, 1976	Report on Hydrogeological Survey of certain settlement along the Afghanistan ring road (Musa Qala and Nauzad Districts)
16	Malyar E.P, 1976	Groundwater investigation in south west of Afghanistan
10.	Kurennol, 1969	Hydro geological investigation in south-west Afghanistan, Ministry of Mines and Industries, Kabul
11.	Malyar, 1976	Hydrological Basins of Afghanistan
12.	W. A. Slawin, 1984	Geology of Afghanistan

ANNEXES

Annex 1 Groundwater Monitoring Wells

GMW ID	Agromet Station	District	Province	Village	LON	LAT	WP Type	Well Depth (m)	Well Diameter (m)	Org
1	AF016	Shakar Dara	Kabul	Qala-e-Murad Biek	69.07902	34.65884	TW	23	0.10	DACAAR
2	AF016	Kabul	Kabul	Kabul - DACAAR office	69.16004	34.55275	TW	14.6	0.10	DACAAR
3	AF015	Surkh Rod	Nangarhar	Musli khel	70.36052	34.43802	DE	17.4	0.10	DACAAR
4	AF016	Khak-e Jabar	Kabul	Khurd kabul	69.38399	34.38887	TW	52	0.10	DACAAR
5	AF099	Ghazni	Ghazni	Arbaba	68.43911	33.54383	TW	60	0.10	DACAAR
6	AF016	Jaghatu	Ghazni	Qala-I-naw	68.39050	33.71292	TW	23.3	0.10	DACAAR
7	AF032	Qara Bagh	Ghazni	Walikay	68.09195	33.16115	TW	56	0.10	DACAAR
8	AF016	Maidan Shahr	Wardak	Shahabudin	68.86778	34.32021	DW	10	1	DACAAR
9	AF016	Sayyidabad	Wardak	Shikh abdul	68.76060	34.08726	DE	25	0.10	DACAAR
10	AF016	Nirkh	Wardak	Deh hayat	68.77547	34.36844	DE	42	0.10	DACAAR
11	AF016	Sarobi	Kabul	Naway Qala	69.74756	34.60645	DE	20	0.10	DACAAR
12	AF016	Bagrami	Kabul	Gul buta	69.22864	34.47863	TW	40.5	0.10	DACAAR
13	AF016	Tagab	Kapisa	Firoz khel	69.65385	34.79947	TW	40	0.10	DACAAR
14	AF016	Bagram	Parwan	Shahie ya	69.22398	34.96389	TW	34.5	0.10	DACAAR
15	AF016	Mir Bacha Kot	Kabul	Shekhan	69.12266	34.72940	TW	32	0.10	DACAAR
16	AF016	Deh Sabz	Kabul	Kata khel	69.35124	34.60985	TW	44.5	0.10	DACAAR
17	AF016	Char Asiab	Kabul	Chaman	69.17281	34.35407	TW	26	0.10	DACAAR
18	AF016	Kabul	Kabul	Char Qala	69.10533	34.48651	DE	30	0.10	DACAAR
19	AF022	Alingar	Laghman	Qalatak(2)	70.30272	34.75413	TW	18.5	0.10	DACAAR
20	AF016	Kama	Nangarhar	Qaleh yeAkhund	70.57511	34.41641	TW	16.9	0.10	DACAAR
21	AF016	Rodat	Nangarhar	Jabeh	70.64901	34.20007	TW	41	0.10	DACAAR
22	AF022	Alishing	Laghman	Shama Ram	70.12511	34.73947	TW	12.4	0.10	DACAAR
23	AF015	Kuz Konar	Nangarhar	Qalagay (Malakzai)	70.57033	34.55982	TW	15.5	0.10	DACAAR
24	AF016	Lalpur	Nangarhar	Lal pur	71.04402	34.23229	TW	21.1	0.10	DACAAR
25	AF016	Bati Kot	Nangarhar	Ambar khana	70.81845	34.28256	TW	30	0.10	DACAAR
26	AF022	Qarghayi	Laghman	Farman khel	70.21006	34.53532	TW	45.8	0.10	DACAAR
27	AF015	Khogiani	Nangarhar	Babaker khel	70.22153	34.29006	TW	53	0.10	DACAAR
28	AF015	Surkh Rod	Nangarhar	Sawz Abad	70.38820	34.44563	TW	19.6	0.10	DACAAR
29	AF016	Bak	Khost	Kot kay (Pasachagan)	70.04154	33.50895	TW	65	0.10	DACAAR
30	AF016	Rodat	Nangarhar	Mazina	70.48627	34.21450	DE	38.5	0.10	DACAAR

GMW ID	Agromet Station	District	Province	Village	LON	LAT	WP Type	Well Depth (m)	Well Diameter (m)	Org
31	AF015	Chaparhar	Nangarhar	Terelay	70.41271	34.31956	TW	34.8	0.10	DACAAR
32	AF015	Jalalabad	Nangarhar	Jalalabad	70.45117	34.43425	TW	14	0.10	DACAAR
33	AF015	Surkh Rod	Nangarhar	Fateh Abad	70.21406	34.35188	TW	42	0.10	DACAAR
34	AF016	Pachir Wa Agam	Nangarhar	Sabre Ulya	70.27873	34.20602	DE	41.6	0.10	DACAAR
35	AF022	Mehtarlam	Laghman	Qaleh Akhund	70.21899	34.62350	TW	21	0.10	DACAAR
36	AF016	Behsud	Nangarhar	Sammar khel	70.55787	34.37573	TW	12.8	0.10	DACAAR
37	AF023	Pol-e Alam	Logar	Oni sayedan	69.00556	33.97439	TW	19	0.10	DACAAR
38	AF016	Kandahar	Kandahar	Loya Wialah	65.71470	31.63269	TW	41	0.10	DACAAR
39	AF103	Panjwai	Kandahar	House I Madad	65.30230	31.56131	TW	46	0.10	DACAAR
40	AF016	Speyra	Khost	Zanda taga	69.55567	33.23370	TW	41	0.10	DACAAR
41	AF010	Sayyid Karam	Paktya	Nora khel	69.37737	33.76376	DW	29.5	1	DACAAR
42	AF010	Gardez	Paktya	Khataba	69.19266	33.58677	TW	63	0.10	DACAAR
43	AF010	Pol-e Alam	Logar	Jawzar	69.01970	33.77194	TW	18.4	0.10	DACAAR
44	AF016	Kushk-e Kohna	Hirat	Shulyji	62.65620	34.78552	DW	11.3	1	DACAAR
45	AF016	Pasaband	Ghor	Astarghana	65.12406	33.65857	DW	81.2	1	DACAAR
46	AF016	Gozara	Hirat	Tezan	62.06575	34.22767	TW		0.10	DACAAR
47	AF016	Taiwara	Ghor	Shahr Sokhta	64.34017	33.50787	DW	9.9	1	DACAAR
48	AF016	Lal Wa Sarjangal	Ghor	Kara	66.31619	34.67457	DW	8.6	1	DACAAR
51	AF013	Kohsan	Hirat	Kamisary	61.09056	34.66615	TW	29.8	0.10	DACAAR
52	AF013	Ghurian	Hirat	Center	61.50554	34.35254	TW	27.5	0.10	DACAAR
53	AF016	Chaghcharan	Ghor	Ahangaran	65.06780	34.47120	TW	46	0.10	DACAAR
54	AF016	Lal Wa Sarjangal	Ghor	Espideyual	66.45639	34.47528	DW	8	1	DACAAR
55	AF016	Karukh	Hirat	Agha Sahib	62.58609	34.47787	DW		1	DACAAR
56	AF017	Ghormach	Badghis	Ab I Garmak	63.83602	35.73567	TW	22	0.10	DACAAR
60	AF016	Enjil	Hirat	Kahdistan	62.30587	34.34260	TW		0.10	DACAAR
63	AF016	Shindand	Hirat	Samizai	62.19654	33.18905	TW		0.10	DACAAR
64	AF016	Enjil	Hirat	Gandaw Parwan	62.08145	34.53142	TW	43	0.10	DACAAR
67	AF016	Kushk-e Naw	Hirat	Toraghundi	62.28473	35.23199	TW	31.7	0.10	DACAAR
68	AF016	Kushk-e Naw	Hirat	Rabat Sangi	62.13460	34.79738	TW		0.10	DACAAR
70	AF016	Adraskan	Hirat	Zulm Abad	62.15838	33.55578	TW	20.4	0.10	DACAAR
72	AF016	Gulran	Hirat	Kariz I Kar	61.65043	35.01271	TW	40.2	0.10	DACAAR
73	AF016	Pashtun Zarghun	Hirat	Salimi	62.49703	34.25212	TW		0.10	DACAAR
75	AF016	Qadis	Badghis	Moqama	63.53416	34.73255	TW	29	0.10	DACAAR
77	AF016	Pashtun Zarghun	Hirat	Marwa	62.90203	34.24429	DW	13.2	1	DACAAR
79	AF016	Shindand	Hirat	Qalai Pain	61.93130	33.26911	TW		0.10	DACAAR
82	AF016	Farsi	Hirat	Koshka	63.13009	33.72592	DW		1	DACAAR
85	AF016	Chesht-e Sharif	Hirat	Sargaz	64.05972	34.34393	DW	12.4	1	DACAAR

GMW ID	Agromet Station	District	Province	Village	LON	LAT	WP Type	Well Depth (m)	Well Diameter (m)	Org
87	AF016	Obeh	Hirat	Center	63.17507	34.37196	DW		1	DACAAR
88	AF016	Kot	Nangarhar	Pursha Khail	70.56300	34.12067	TW	23	0.10	DACAAR
89	AF016	Qadis	Badghis	Darah	63.46245	35.12768	TW		0.10	DACAAR
91	AF016	Mazar-e-sharif	Balkh	Baba Yadgar	67.08112	36.71851	TW	65	0.10	DACAAR
92	AF016	Sholgara	Balkh	Qadim	66.88485	36.31964	TW	41	0.10	DACAAR
93	AF016	Balkh	Balkh	Samar Qandyan	66.83037	36.69177	DW	26.2	1	DACAAR
94	AF016	Chimtal	Balkh	Palo	66.79360	36.65803	DW	42	1	DACAAR
95	AF016	Khwaja Sabz Posh	Faryab	unknown	64.75000	35.90000	DW		1	DACAAR
101	AF016	Kandahar	Kandahar		65.82175	31.58345	TW		0.10	DACAAR
103	AF016	Kandahar	Kandahar		65.70087	31.61665	DW		1	DACAAR
105	AF002	Kabul	Kabul	Aqa Alis Sham	69.15499	34.48169	TW		0.10	ACF
106	AF002	Kabul	Kabul	Kabul Eng Faculty	69.12299	34.51930	TW		0.10	Kabul University
111	AF016	Maimana	Faryab	Center	64.77626	35.93039	DW	10.5	1	DACAAR
112	AF016	Balkh	Balkh	Center	66.89885	36.75699	DW	10	1	DACAAR
113	AF016	Mahmud-e Raqi	Kapisa	Dehbab Ali Bazar	69.33126	35.04328	DW	21.6	1	SCA
114	AF016	Mahmud-e Raqi	Kapisa	Qalae Jabar	69.47720	34.94423	DW	10.8	1	SCA

Annex 2 Water Level and Electro Conductivity

Water Level (m)					Electrical Conductivity (µS/cm)				Record Date	
ID	Average	Minimum	Maximum	Difference	Average	Minimum	Maximum	Difference	First Date	Last Date
2	10.7	8.3	11.8	3.48	1,340	1210	1435	225	17/11/03	17/01/07
3	5.8	5.2	6.3	1.04	912	729	1103	374	06/06/05	14/12/06
4	37.2	36.7	37.5	0.85	828	786	860	74	07/07/05	16/12/06
5	41.4	40.0	42.4	2.4	741	680	775	95	04/05/05	04/11/06
6	12.7	11.9	13.7	1.82	525	480	590	110	04/05/05	04/11/06
7	4.8	4.5	5.1	0.67	544	528	558	30	03/05/05	03/11/06
8	9.5	8.9	9.7	0.84	559	469	898	429	03/05/05	16/12/06
9	18.1	16.1	19.1	2.98	1,618	1124	2120	996	03/04/05	16/12/06
10	20.2	17.9	25.6	7.76	877	703	1153	450	03/04/05	16/12/06
11	15.0	13.4	18.9	5.53	884	815	990	175	13/04/05	17/12/06
12	4.9	2.7	8.3	5.59	903	845	947	102	31/03/05	17/12/06
13	23.9	23.6	24.2	0.59	755	720	799	79	11/04/05	25/11/06
14	24.1	23.3	26.1	2.72	844	783	975	192	16/04/05	10/12/06
15	19.0	17.4	20.4	3.02	623	579	662	83	28/03/05	16/12/06
16	22.1	18.8	23.7	4.86	515	477	595	118	16/02/06	18/12/06
17	12.5	11.7	13.6	1.95	587	467	752	285	19/04/05	18/12/06
18	19.3	17.9	21.0	3.08	874	841	909	68	28/03/05	18/12/06
19	3.4	2.4	4.4	1.97	363	343	413	70	02/05/05	16/12/05
20	8.7	6.3	10.4	4.07	584	548	660	112	03/05/05	16/12/06
21	13.6	12.1	16.2	4.1	995	755	1243	488	07/05/05	06/12/06
22	2.9	1.8	3.8	1.94	406	351	470	119	02/05/05	16/12/06
23	3.1	2.5	3.5	1.02	657	561	789	228	03/05/05	14/12/06
24	12.7	11.6	13.4	1.83	347	296	390	94	05/05/05	16/12/06
25	5.3	5.2	5.4	0.23	834	776	862	86	05/05/05	14/12/06
26	16.2	15.8	16.5	0.61	590	564	696	132	02/05/05	16/12/06
27	15.5	13.4	18.4	4.98	654	632	679	47	05/05/05	04/12/06
28	4.0	3.7	4.4	0.73	783	760	830	70	04/05/05	17/12/06
29	30.4	28.7	32.7	3.97	418	367	494	127	09/07/05	17/12/06
30	12.4	10.1	13.9	3.79	668	579	751	172	08/05/05	16/12/06
31	15.8	15.1	17.4	2.31	810	780	838	58	04/05/05	08/12/06
32	9.5	9.2	9.9	0.66	980	799	1265	466	04/05/05	17/12/06
33	12.0	10.8	14.4	3.61	625	533	696	163	05/05/05	04/12/06
34	17.0	15.6	18.2	2.59	644	550	742	192	04/05/05	05/12/06
35	3.4	1.9	4.6	2.77	438	388	544	156	02/05/05	16/12/06
36	7.6	7.2	8.0	0.77	1,183	992	1306	314	06/05/05	14/12/06
37	11.6	11.0	12.0	0.93	474	449	490	41	20/06/05	14/12/06
38	36.4	35.0	37.7	2.72	850	824	907	83	06/04/05	29/07/06
39	28.3	27.0	31.2	4.16	731	682	790	108	27/04/05	25/08/06
40	33.7	31.7	35.3	3.69	1,250	1086	1541	455	04/06/05	17/12/06
41	24.2	22.7	26.9	4.15	554	514	589	75	21/06/05	09/12/06
42	45.0	43.1	46.4	3.28	500	469	535	66	12/06/05	09/12/06
43	7.1	6.3	7.7	1.38	442	275	535	260	20/06/05	13/12/06
44	10.4	9.9	10.8	0.9	2,548	1814	3110	1296	09/07/05	07/12/06
45	6.6	5.9	7.3	1.35	705	667	766	99	25/07/05	25/11/06
46	4.1	3.4	5.4	2	840	676	1090	414	07/07/05	20/12/06
47	7.9	7.8	8.1	0.3	705	674	741	67	28/07/05	28/11/05
48	4.8	2.4	6.2	3.81	391	270	496	226	19/07/05	12/11/06
51	13.0	12.3	13.8	1.52	1,095	929	1350	421	12/07/05	19/12/06
52	7.6	5.7	8.7	3.04	1,820	1552	2180	628	12/07/05	19/12/06

Water Level (m)					Electrical Conductivity (µS/cm)				Record Date	
ID	Average	Minimum	Maximum	Difference	Average	Minimum	Maximum	Difference	First Date	Last Date
53	20.3	15.8	25.5	9.66	2,665	1625	3580	1955	22/07/05	14/11/06
54	6.9	5.3	7.8	2.43	1,506	1290	1709	419	19/07/05	15/11/06
55	9.3	8.2	9.9	1.76	1,430	1279	1700	421	12/07/05	12/12/06
56	6.4	6.3	6.5	0.16	749	625	963	338	06/08/05	26/11/05
60	5.6	4.2	6.9	2.73	595	552	677	125	07/07/05	21/12/06
63	6.0	5.2	6.8	1.58	6,091	5100	7180	2080	13/07/05	13/12/06
64	7.7	6.6	9.7	3.06	1,452	1203	1677	474	10/07/05	23/12/06
67	6.5	6.3	6.7	0.41	3,472	2810	3910	1100	11/07/05	16/12/06
68	26.9	20.7	31.5	10.71	4,590	3100	7460	4360	10/07/05	23/11/06
70	9.6	8.4	11.0	2.58	865	577	1328	751	13/07/05	17/12/06
72	24.5	19.2	26.4	7.19	4,197	3750	4630	880	10/07/05	14/12/06
73	7.1	6.2	7.5	1.36	643	584	720	136	11/07/05	12/12/06
75	6.2	5.5	6.5	1.02	1,243	1218	1262	44	11/08/05	24/11/05
77	11.4	8.6	12.8	4.19	582	513	693	180	22/07/05	12/12/06
79	6.8	6.2	7.6	1.35	1,803	1508	2300	792	15/07/05	17/12/06
85	10.4	8.2	11.5	3.3	1,144	896	1354	458	22/07/05	20/12/06
87	13.6	13.5	13.9	0.46	570	556	598	42	22/07/05	10/10/05
88	10.8	10.6	11.0	0.4	1,108	1002	1275	273	16/07/05	06/12/06
89	3.3	3.1	3.5	0.38	2,640	2500	2720	220	11/07/05	25/11/05
91	7.1	6.3	7.8	1.55	2,294	2033	2580	547	13/12/05	13/12/06
92	28.3	25.7	30.8	5.1	739	625	985	360	14/12/05	14/12/06
93	23.6	23.2	23.9	0.7	947	803	1230	427	14/12/05	14/12/06
94	38.3	37.6	39.7	2.11	3,247	2970	3510	540	14/12/05	14/11/06
101	11.7	11.1	12.2	1.12					08/04/04	27/07/04
103	22.8	22.1	23.0	0.9					08/04/04	29/07/04
105	5.1	3.2	6.4	3.2					01/02/00	01/09/03
106	6.7	5.9	7.8	1.86					02/08/05	20/08/06
111	7.8	7.8	7.9	0.06					14/09/08	26/10/06
112	7.8	7.7	7.9	0.12					14/09/06	14/12/06
113	19.2	19.2	19.3	0.02	478	470	485	15	22/11/06	24/01/07
114	10.1	10.1	10.1	0.05	550	540	560	20	22/11/06	24/01/07

Annex 3a Physical, Chemical and Bacteriological Analysis - Anions

ID	Physical Parameters					Chemical Parameters													Analysis Date
						Anions (mg/l)													
	EC (µS/cm)	TDS (mg/l)	Turbidity (NTU)	pH	T (°C)	HCO^{3-}	CO_3^{2-}	Cl^-	SO_4^{2-}	SO_3^{2-}	S^{2-}	F^-	NO_3^-	NO_2^-	PO_4^{3-}	B	Br-	Total Anions	
2	978	673	1.56	7.8	16	385	110	28	106	2	0.02	0	8	0	0.16	1.3	0.15	640.64	12/3/05
3	864	594	0.01	7.8	15	280	20	3	155	2	0.01	1	6.4	0	0.1	0.2	0.09	467.72	16/5/05
4	894	615	0.41	7.7	17.6	265	50	13	116	2	0.00	0.7	9.3	0	0.11	0.2	0.06	455.87	23/11/05
5	782	538	0.2	7.8		375	20	3.2	37	1	0.01	0.6	1.5	0	0.18	0.6	0.03	439.14	25/11/05
6	525	361	18.3	7.9	14.5	350	30	1.9	30	14	0.01	0.6	5	0	0.31	0.3	0.21	432.32	29/11/05
7	540	372	25.5	7.3	14.3	240	10	40	21	0	0.02	0.4	9.2	0	0	0.6	0	321.12	30/11/05
8	481	331	0.51	7.8	14	250	60	4.7	1	0	0.01	0.1	3.3	0	0.1	0.2	0.2	319.64	1/12/05
9	2100	1445	7.3	7.3	15	810	50	34	208	2	0.01	1	2.5	0	0.1	3.9	0.14	1111.6	1/12/05
10	925	636	1.57	6.5	14	340	40	6.3	24	1	0.01	0.1	5.3	0	0.1	2.2	0.05	419.1	1/12/05
11	875	602	23.8	8.3	19.6	185	60	8.3	185	4	0.01	2.1	3.1	0	0.12	0.1	0.06	447.81	27/11/05
12	972	669	3.79	8	16.9	425	50	7.7	108	3	0.01	0.5	1.5	0	0.14	1.4	0.19	597.36	25/11/05
13	767	528	20.2	7.8	18.3	195	80	3.1	200	2	0.01	1.2	19	0	0.15	0.5	0.08	501.21	27/11/05
14	849	584	1.34	7.4	15.7	430	60	46	57	3	0.01	0.4	2	0	0.07	0.7	0.6	599.79	7/11/05
15	644	443	1.1	7.4	16.1	360	70	32	2	1	0.01	0.4	2.5	0	0.09	0.2	0.13	468.35	27/11/05
16	505	347	0.02	7.2	16.9	445	50	3	56	4	0.02	0.4	1.7	0	1.7	0.1	0.1	561.92	25/11/05
17	576	396	0.22	8.2	14	290	70	4.4	78	2	0.01	0.8	2.5	0	0.1	0.6	0.09	448.45	25/11/05
18	866	596	0.12	7.5	14	425	40	3.1	75	2	0.01	0	1.5	0	0.09	0.4	0.06	547.13	1/12/05
19	407	280	0.89	7.4	20.5	190	30	1.7	4	1	0.01	0.4	6.8	0	0.22	0.2	0.01	234.36	23/11/05
20	657	452	0.46	7.7	20.8	350	60	32	67	4	0.01	0.7	1.2	0	0.16	0.3	0.11	515.42	24/11/05
21	991	682	1.27	7.9	22.3	450	50	25	136	0	0.01	1	1	0	0.07	0.2	0.06	663.31	19/11/05
22	492	338	1.86	7.5	20.4	205	40	4.2	4	0	0.01	0.3	7.6	0	0.16	0.3	0.01	261.52	23/11/05
23	669	460	0.57	7.8	21.9	320	70	21	72	2	0.01	0.5	1	0	0.07	0.3	0.07	486.91	24/11/05
24	417	287	2.79	8.2	22.3	90	50	33	53	3	0.01	0.4	10	0	0.04	0.3	0.02	240.15	22/11/05
25	846	582	0.96	8.1	23.5	330	0	46	150	0	0	1	1.4	0	0.03	0.2	0.02	528.57	18/11/05
26	672	462	0.4	8.5	25	200	30	30	104	9	0.01	0.6	19	0	0.06	0.4	0	392.88	22/11/05
27	663	456	3.39	8.2	15.3	190	100	2.3	100	8	0	0.9	15	0	0.15	0.2	0.1	416.35	16/11/05
28	778	535	0.07	7.8	22.7	380	30	2.8	104	4	0.01	0.3	0.8	0	0.29	0.3	0.09	522.53	20/11/05
29	437	301	0.43	7.9	20.6	225	40	1.6	4	1	0.01	0.1	2	0	0.17	0.3	0.12	274.19	4/12/05
30	665	458	8.43	8	20	370	20	25	48	1	0.03	0.8	1	0	0.07	0.2	0.04	466.13	12/11/05
31	818	563	1.59	7.9	22.8	380	20	2.7	136	1	0.01	1	2.2	0	0.19	0.3	0	543.43	20/11/05

ID	Physical Parameters					Chemical Parameters													Analysis Date
						Anions (mg/l)													
	EC (µS/cm)	TDS (mg/l)	Turbidity (NTU)	pH	T (°C)	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}	SO_3^{2-}	S^{2-}	F^-	NO_3^-	NO_2^-	PO_4^{3-}	B	Br-	Total Anions	
32	912	627	0.38	8	22.8	380	30	7.8	94	1	0.01	0.9	3.2	0	0.1	0.6	0.32	517.92	21/11/05
33	610	420	0.31	8	15.2	220	40	2.8	108	2	0.01	0.9	5.2	0	0.2	0.2	0.3	379.52	16/11/05
34	621	427	0.55	8.1	19.5	260	90	2.2	76	1	0.01	0.6	1.2	0	0.08	0.2	0.11	431.34	20/11/05
35	486	334	0.48	7.9	13.5	290	60	3.2	16	3	0.02	0.5	1.2	0	0.28	0.3	0.04	374.53	21/11/05
36	251	173	10.1	8	22.2	690	50	47	155	4	0.01	1.1	0.1	0	0.04	0.7	0.05	947.95	19/11/05
37	466	321	0.68	8.4	19	235	40	2.2	18	3	0.01	0	6.6	0	0.13	0.5	0.07	305.46	24/11/05
38	840	578	0.61	7.9		190	40	6	228	2	0.01	0.7	9	0	0.01	0.5	0.07	476.31	30/11/05
39	706	486	0.23	8		165	70	13	114	4	0.01	1.1	2.8	0	0.1	0.2	0.08	369.74	30/11/05
40	1400	963	1.46	7	18.6	580	80	47	390	0	0.01	1	8	0	0.02	0.2	0.06	1106.3	4/12/05
41	545	375	19.3	7.6	14.5	320	20	1.3	45	1	0.01	0.3	3.7	0	0.05	0.3	0.07	391.74	4/12/05
42	490	337	0.46	8.5	19	290	20	1.6	35	3	0	0.2	3	0	0.1	0.1	0.02	353.05	4/12/05
43	463	319	10.7	7.7	19.2	310	80	21	4	1	0.01	0.5	8.4	0	0.09	0.1	0.01	425.05	4/12/05
44	2.46	1.69	2.2	7.9	22.7	390	30	168	4	6	0.01	3	46	0	0.55	1.1	0.8	649.42	7/11/05
45	641	441	3.91	7.7		340	40	28	3	1	0	0.4	1.9	1	0.06	0.2	0	415.55	30/10/05
46	676	465	2.46	7.8	19	270	10	67	128	1	0.00	0.2	0.7	0	0.45	0.5	0.1	477.96	11/10/05
47	662	455	0.25	8.4		180	30	3.6	136	1	0.01	0.7	3.1	0	0.1	0.2	0.02	354.74	31/10/05
48	326	224	3.55	8.3	19.4	130	50	16	11	0	0.00	0.5	168	0	0.71	0.1	0.09	376.36	11/10/05
51	929	639	2.7	7.9	21.8	240	60	230	180	7	0.00	1.2	10	0	0.44	0.6	0.11	729.3	12/8/05
52	1593	1096	3.03	7.5	22	410	20	225	350	3	0.00	2.1	25	0	0	0.6	0.03	1035.5	4/9/05
53	1421	978	1.19	7.4		430	20	5.7	360	1	0.00	0.9	0.8	0	0.1	0.6	0.01	819.18	30/10/05
54	270	186	4.88	8.7	20.6	180	90	20	180	3	0.00	0.8	2.8	0	0.48	0.2	0.08	477.32	12/10/05
55	1279	880	1.54	7.3	19.1	490	30	110	208	1	0.01	1.2	50	0.1	0.57	0.5	0.04	891.36	14/7/05
56	828	570	163	8.1	19	300	60	5	89	5	0.01	0.7	7.5	0	0.15	0.3	0.02	467.7	17/11/05
60	587	404	21.3	7.4	19.6	210	10	51	104	8	0.00	1	14	0	0.32	0.5	0	398.81	18/10/05
62	4050	2786	12.8	7.7	24	390	50	20	2880	0	0.01	9	3.8	0	0.22	1.2	0.12	3354.4	15/9/05
63	5260	3619	45	7.8	26.3	160	30	353	1700	0	0.02	11	81	0	0.28	1.4	0.06	2336.3	17/9/05
64	1391	957	2.08	8.4	24.5	200	40	185	530	0	0.00	1.5	38	0	0.27	0.4	0.03	994.78	10/11/05
67	3190	2195	6.1	8.2	21.5	290	50	410	875	4	0.01	6.5	42	0	0.26	0.7	0.05	1678.1	18/10/05
68	4000	2752	2.37	8.2	21.4	255	20	185	5	5	0.00	2.9	58	0	0.39	0.6	0.03	531.91	24/12/05
70	577	397	2.4	8.1	23.3	250	60	43	86	0	0.00	0.9	14	0	0.23	0.3	0.1	454.07	26/11/05
72	4100	2821	5.04	8.3	23.2	135	50	398	1950	2	0.00	7.1	27	0	0.19	1.7	0.17	2571.4	15/10/05

ID	Physical Parameters					Chemical Parameters													Analysis Date
						Anions (mg/l)													
	EC (µS/cm)	TDS (mg/l)	Turbidity (NTU)	pH	T (°C)	HCO^{3-}	CO_3^{2-}	Cl^-	SO_4^{2-}	SO_3^{2-}	S^{2-}	F^-	NO_3^-	NO_2^-	PO_4^{3-}	B	Br-	Total Anions	
73	634	436	1.67	7.8	23.3	290	40	45	83	1	0.00	0.7	9.2	0	0.25	0.2	0.05	469.41	12/9/05
75	1218	838	4.9	7.6	20.2	420	50	72	370	5	0.00	2.2	8	0	0.29	0.7	0.12	928.28	14/11/05
77	539	371	3.2	8.5	20.5	240	20	512	88	4	0	0.5	1.5	0	0.1	0.1	0.06	866.26	11/11/05
79	1540	1060	1.81	7.7	24.3	280	30	165	495	3	0	5.4	13	0	0.26	1.1	0.02	992.55	28/10/05
85	941	647	2.48	8.1	20	320	40	76	122	8	0	1.1	68	0	0.31	0.5	0.02	635.93	14/12/05
87	598	411	3.51	7.8	21.7	380	40	33	67	4	0.01	0.7	13	0	0.22	0.3	0.03	538.38	28/10/05
88	1022	703	1.4	7.9	20.9	590	30	22	100	0	0.01	0.7	1.8	0	0.07	0.3	0.1	745.02	19/11/05
89	2500	1720	3.3	7.6	20.2	150	140	424	775	7	0.01	5.2	33	0.2	0.52	0.7	0.07	1535.9	13/8/05
91	2480	1706	0.7	7.4	16.2	385	80	29	1140	2	0	3.8	1.2	0	0.7	1.1	0.13	1642.9	13/3/06
92	695	478	3.19	7.5	14	410	40	4.3	80	2	0.01	0.6	1.3	0	0.07	0.3	0.14	538.74	3/12/06
93	808	556	0.95	7.3	13.7	445	30	3.5	92	1	0	0.4	1.1	0	0.1	0.2	0.07	573.33	13/3/06
94	3140	2160	4.24	7.2	14.3	660	40	9.6	2900	20	0	0.6	1.2	0	0.6	1.5	0.09	3633.6	3/12/06
112	1102	758	3.26	7.8	14.2	280	210	11	104	2	0	0.6	1.4	0	0.79	0.5	0.04	610.38	18/12/06
113	540	372	2.3	7.6	6.6	315	150	86	56	3	0.01	0.6	2.4	0	0.16	0.4	0.13	613.74	23/11/05
114	470	323	3.41	7.2	19	480	60	96	34	5	0.01	0.5	4.6	0.2	0.15	0.5	0.1	681.06	23/11/06

Annex 3b Physical, Chemical and Bacteriological Analysis - Cations

	Physical Parameters					Cations (mg/l)													
GMW_ID	EC (µS/cm)	TDS (mg/l)	Turbidity (NTU)	pH	T (°C)	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cr^{6+}	NH_4^+	Mn^{2+}	Cu^{2+}	Al^{3+}	Fe	Zn^{2+}	As	Total Catio	
2	978	673	1.56	7.8	16	42	6.8	37.6	114	0	0.11	0.003	0.12	0	0	0.00	0	655.35	12/3/05
3	864	594	0.01	7.8	15	23	6.5	70	50	0.03	0.04	0.004	0.04	0	0	0.00	0	646.68	16/5/05
4	894	615	0.41	7.7	17.6	44	3.5	50	55	0.02	0.02	0.002	0.12	0	0.02	0.00	0	503.25	23/11/05
5	782	538	0.2	7.8		39	4	29.2	55	0.02	0.03	0.003	0.1	0	0	0.00	0	514.43	25/11/05
6	525	361	18.3	7.9	14.5	92	3.1	42	21	0.01	0.02	0.002	0.1	0	0.01	0.00	0	402.24	29/11/05
7	540	372	25.5	7.3	14.3	63	5.8	38	15	0.02	0	0.003	0.1	0.01	0.01	0.00	0	389.08	30/11/05
8	481	331	0.51	7.8	14	68	4	52	8	0.04	0.02	0.001	0.18	0	0	0.00	0	1413.14	1/12/05
9	2100	1445	7.3	7.3	15	322	8.4	56	42	0.06	0.18	0.006	0.16	0.02		0.00		498.14	1/12/05
10	925	636	1.57	6.5	14	50	3.4	50.8	35	0.01	0.6	0.008	0.12	0	0.09	0.00	0	710.56	1/12/05
11	875	602	23.8	8.3	19.6	160	2.8	30.4	8	0.3	0	0.002	0.1	0	0.01	0.00	0	769.54	27/11/05
12	972	669	3.79	8	16.9	126	4.8	22.8	55	0.01	0.05	0.003	0.12	0	0	0.00	0	807.35	25/11/05
13	767	528	20.2	7.8	18.3	154	11.5	50	13	0.02	0.03	0.002	0.12	0	0	0.00	0	768.98	27/11/05
14	849	584	1.34	7.4	15.7	128	5.1	50	42	0.02	0.01	0.003	0.42	0	0.02	0.00	0	576.57	7/11/05
15	644	443	1.1	7.4	16.1	86	4	66	26	0.04	0.01	0.002	0.44	0	0	0.00	0	678.74	27/11/05
16	505	347	0.02	7.2	16.9	153	3.7	30.4	26	0.02	0.02	0.001	0.14	0	0	0.00	0	606.82	25/11/05
17	576	396	0.22	8.2	14	121	2.9	39.6	20	0.02	0.4	0.003	0.16	0	0	0.00	0	669.20	25/11/05
18	866	596	0.12	7.5	14	112	3.2	54	29	0.01	0.4	0.002	0.1	0	0	0.00	0	278.71	1/12/05
19	407	280	0.89	7.4	20.5	26	2.6	46	11	0.02	0.01	0.006	0.06	0	0	0.00	0	680.73	23/11/05
20	657	452	0.46	7.7	20.8	100	4.1	72	26	0.02	0.02	0.006	0.1	0	0	0.00	0	876.56	24/11/05
21	991	682	1.27	7.9	22.3	64	9.5	36	95	0.03	0.21	0.002	0	0	0	0.00	0	318.03	19/11/05
22	492	338	1.86	7.5	20.4	24	4.1	60	11	0.03	0	0.008	0.16	0	0.03	0.00	0	653.75	23/11/05
23	669	460	0.57	7.8	21.9	82	7.2	58	38	0.02	0.19	0.005	0.08	0	0	0.00	0	390.28	24/11/05
24	417	287	2.79	8.2	22.3	42	3.9	38	20	0.02	0.02	0.005	0.04	0	0	0.00	0	727.12	22/11/05
25	846	582	0.96	8.1	23.5	46	6	32	75	0.03	0.01	0.003	0	0	0.01	0.00	0	585.76	18/11/05
26	672	462	0.4	8.5	25	147	3.5	8	12	0.02	0	0.004	0	0	0	0.00	0	642.60	22/11/05

	Physical Parameters					Cations (mg/l)													
GMW_ID	EC (µS/cm)	TDS (mg/l)	Turbidity (NTU)	pH	T (°C)	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cr^{6+}	NH_4^+	Mn^{2+}	Cu^{2+}	Al^{3+}	Fe	Zn^{2+}	As	Total Catio	
27	663	456	3.39	8.2	15.3	134	7.9	38	14	0.02	0.03	0.004	0.06	0	0	0.00	0.1	664.97	16/11/05
28	778	535	0.07	7.8	22.7	68	8.2	56	45	0.03	0	0.003	0.06	0	0	0.00	0	323.26	20/11/05
29	437	301	0.43	7.9	20.6	69	1.8	22	13	0.02	0.03	0.002	0.08	0	0	0.00	0	562.22	4/12/05
30	665	458	8.43	8	20	54	6.5	46	45	0.05	0.02	0.007	0	0	0	0.00	0	706.86	12/11/05
31	818	563	1.59	7.9	22.8	96	9.4	48	30	0.02	0.01	0.003	0.1	0	0.07	0.00	0	655.52	20/11/05
32	912	627	0.38	8	22.8	62	8.8	42	55	0.2	0.03	0.003	0.08	0	0	0.00	0	538.74	21/11/05
33	610	420	0.31	8	15.2	63	8.2	46	27	0.04	0.01	0.004	0	0	0	0.00	0	602.57	16/11/05
34	621	427	0.55	8.1	19.5	67	5.4	50	42	0.03	0.01	0.003	0.1	0	0	0.00	0	459.02	20/11/05
35	486	334	0.48	7.9	13.5	79	3.2	56	12	0.04	0.03	0.006	0.04	0	0	0.00	0	1205.85	21/11/05
36	251	173	10.1	8	22.2	208	7.3	22	90	0.02	0.03	0.003	0.08	0	0	0.00	0	375.85	19/11/05
37	466	321	0.68	8.4	19	43	3.1	18.8	37	0.02	0.04	0	0.04	0	0	0.00	0	762.56	24/11/05
38	840	578	0.61	7.9		119	2.4	31.6	34	0.04	0.01	0.003	0.01	0	0	0.00	0	574.40	30/11/05
39	706	486	0.23	8		124	0.9	20	19	0.02	0.01	0.002	0.08	0	0	0.00	0	1632.52	30/11/05
40	1400	963	1.46	7	18.6	226	3.2	74	100	0.02	0.06	0.006	0.2	0	0.01	0.00	0	463.41	4/12/05
41	545	375	19.3	7.6	14.5	15	1.7	64.8	37	0.05	0	0.002	0.26	0	0.01	0.00	0	416.08	4/12/05
42	490	337	0.46	8.5	19	88	1.6	36	8	0.05	0.01	0.001	0.1	0	0	0.00	0	540.09	4/12/05
43	463	319	10.7	7.7	19.2	94	4.7	60	17	0.02	0.52	0.004	0.06	0	0	0.00	0	908.04	4/12/05
44	2.46	1.69	2.2	7.9	22.7	45	4.9	44	110	0.01	0.08	0.003	0.06	0	0.01	0.00	0	491.10	7/11/05
45	641	441	3.91	7.7		122	5.3	45.2	2	0.05	0	0	0.06	0	0	0.00	0	685.82	30/10/05
46	676	465	2.46	7.8	19	111	2.1	32	38	0.02	0.24	0.002	0.04	0	0	0.00	0	529.46	11/10/05
47	662	455	0.25	8.4		50	3.7	48.8	28	0.05	0.04	0.01	0.1	0	0	0.00	0	622.63	31/10/05
48	326	224	3.55	8.3	19.4	81	1.5	50	14	0.01	0.31	0.002	0.06	0	0	0.00	0	1218.49	11/10/05
51	929	639	2.7	7.9	21.8	271	3.4	24	43	0	0.06	0.003	0.04	0	0.07	0.00	0	1661.03	12/8/05
52	1593	1096	3.03	7.5	22	245	6.7	66	90	0.02	0.84	0.007	0.08	0	0.01	0.00	0	1208.34	4/9/05
53	1421	978	1.19	7.4		94	10.5	57.6	100	0.06	0.12	0.003	0.04	0	0	0.00	0	774.56	30/10/05
54	270	186	4.88	8.7	20.6	63	5.2	44	65	0	0.53	0.004	0	0	0	0.00	0	1292.68	12/10/05
55	1279	880	1.54	7.3	19.1	138	58	66	80	0	0.55	0.002	0.66	0	0.02	0.00	0	635.39	14/7/05

GMW_ID	Physical Parameters					Cations (mg/l)													
	EC (µS/cm)	TDS (mg/l)	Turbidity (NTU)	pH	T (°C)	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cr^{6+}	NH_4^+	Mn^{2+}	Cu^{2+}	Al^{3+}	Fe	Zn^{2+}	As	Total Catio	
56	828	570	163	8.1	19	104	2.2	36	34	0.01	0.07	0.011	0.48	0	0.03	0.00	0	587.62	17/11/05
60	587	404	21.3	7.4	19.6	72	4.1	32	37	0.01	0.07	0.005	0.02	0	0	0.00	0	6318.59	18/10/05
62	4050	2786	12.8	7.7	24	1010	10	138	220	0.02	2	0.009	0.16	0	0	0.00	0	4512.60	15/9/05
63	5260	3619	45	7.8	26.3	768	2.3	200	90	0.01	0.48	0.01	0.12	0	0.03	0.00	0	1789.53	17/9/05
64	1391	957	2.08	8.4	24.5	374	3.3	38	40	0.02	0.16	0.002	0.04	0	0.04	0.00	0	3066.09	10/11/05
67	3190	2195	6.1	8.2	21.5	593	4	64	100	0.01	0.56	0.01	0.04	0	0.02	0.00	0	808.79	18/10/05
68	4000	2752	2.37	8.2	21.4	7	4.4	80	85	0.02	0.2	0.014	0.18	0	0	0.00	0	658.04	24/12/05
70	577	397	2.4	8.1	23.3	117	2.4	34	31	0.01	0.05	0.002	0.02	0	0.01	0.00	0	5007.59	26/11/05
72	4100	2821	5.04	8.3	23.2	788	6.6	130	190	0.01	0.87	0.007	0	0	0	0.00	0	648.77	15/10/05
73	634	436	1.67	7.8	23.3	59	3	54	48	0	0.23	0.004	0	0	0.01	0.00	0	1436.44	12/9/05
75	1218	838	4.9	7.6	20.2	192	3.4	70	82	0	0.27	0.006	0.22	0	0.04	0.00	0	1492.46	14/11/05
77	539	371	3.2	8.5	20.5	352	4.1	56.4	34	34	0.002	0.1	0	0.01	0.01	0.00	0	1705.08	11/11/05
79	1540	1060	1.81	7.7	24.3	394	0.9	38	25	0.01	0.23	0.001	0	0	0	0.00	0	951.84	28/10/05
85	941	647	2.48	8.1	20	62	3.6	32	100	0	0.14	0.003	0.02	0	0	0.00	0	696.73	14/12/05
87	598	411	3.51	7.8	21.7	54	2.8	58	60	0.01	0.17	0.002	0.06	0	0	0.00	0	899.94	28/10/05
88	1022	703	1.4	7.9	20.9	128	4.1	32	75	0.02	0.02	0.004	0.04	0	0	0.00	0	2921.73	19/11/05
89	2500	1720	3.3	7.6	20.2	504	4.9	135	90	0.01	0.85	0.004	0.08	0	0.02	0.00	0	2900.73	13/8/05
91	2480	1706	0.7	7.4	16.2	325	4.7	144	150	0.01	1.1	0.002	0.14	0	0.01	0.00	0	667.34	13/3/06
92	695	478	3.19	7.5	14	70	3.3	62.8	45	0.02	0.01	0.001	0.14	0	0.04	0.00	0	701.60	3/12/06
93	808	556	0.95	7.3	13.7	112	2.6	76	20	0.02	0.2	0.001	0.22	0	0.03	0.00	0	6607.09	13/3/06
94	3140	2160	4.24	7.2	14.3	743	15	492	200	0.01	0.7	0.009	0.18	0.1	1.4	0.00	0	940.72	3/12/06
112	1102	758	3.26	7.8	14.2	159	34	65.5	38	0.04	0	0	0.06	0	0.04	0.00	0	912.35	18/12/06
113	540	372	2.3	7.6	6.6	200	5.5	29.2	44	0.02	0.02	0.001	0.08	0.02	0.02	0.00	0	882.02	23/11/05
114	470	323	3.41	7.2	19	158	5.4	64.4	40	0	0.03	0.001	0.12	0.35	0.03	0.00	0	0.00	23/11/06

Annex 4 Major Ions (Anions and Cat ions) Chemistry of GMW

	Anions (mg/l)				Anions (meq/l)				∑ A (meq/l)	Cation (mg/l)				Cation (meq/l)				∑ C (meq/l)	Anion (%meq)				Cation (%meq)			
ID	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}		Na^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	Ca^{2+}	Mg^{2+}		HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
2	385	110	28	106	6.31	3.67	0.79	2.21	12.973	42	6.8	38	114	1.826	0.174	1.876	9.383	13.259	49	28	6	17	14	1	14	71
3	280	20	3	155	4.59	0.67	0.08	3.23	8.568	23	6.5	70	50	1.000	0.166	3.493	4.115	8.775	54	8	1	38	11	2	40	47
4	265	50	13	116	4.34	1.67	0.35	2.42	8.777	44	3.5	50	55	1.913	0.090	2.495	4.527	9.025	49	19	4	28	21	1	28	50
5	375	20	3.2	37	6.15	0.67	0.09	0.77	7.674	39	4	29	55	1.696	0.102	1.457	4.527	7.782	80	9	1	10	22	1	19	58
6	350	30	1.9	30	5.74	1.00	0.05	0.62	7.415	92	3.1	42	21	4.001	0.079	2.096	1.728	7.904	77	13	1	8	51	1	27	22
7	240	10	40	21	3.93	0.33	1.13	0.44	5.832	63	5.8	38	15	2.739	0.148	1.896	1.235	6.019	67	6	19	7	46	2	32	21
8	250	60	4.7	1	4.10	2.00	0.13	0.02	6.251	68	4	52	8	2.957	0.102	2.595	0.658	6.312	66	32	2	0	47	2	41	10
9	810	50	34	208	13.28	1.67	0.96	4.33	20.232	322	8.4	56	42	14.002	0.215	2.794	3.457	20.468	66	8	5	21	68	1	14	17
10	340	40	6.3	24	5.57	1.33	0.18	0.50	7.583	50	3.4	51	35	2.174	0.087	2.535	2.881	7.677	73	18	2	7	28	1	33	38
11	185	60	8.3	185	3.03	2.00	0.23	3.85	9.118	160	2.8	30	8	6.957	0.072	1.517	0.658	9.204	33	22	3	42	76	1	16	7
12	425	50	7.7	108	6.97	1.67	0.22	2.25	11.098	126	4.8	23	55	5.479	0.123	1.138	4.527	11.266	63	15	2	20	49	1	10	40
13	195	80	3.1	200	3.20	2.67	0.09	4.16	10.114	154	12	50	13	6.697	0.294	2.495	1.070	10.556	32	26	1	41	63	3	24	10
14	430	60	46	57	7.05	2.00	1.30	1.19	11.532	128	5.1	50	42	5.566	0.130	2.495	3.457	11.648	61	17	11	10	48	1	21	30
15	360	70	32	2	5.90	2.33	0.90	0.04	9.178	86	4	66	26	3.740	0.102	3.293	2.140	9.275	64	25	10	0	40	1	36	23
16	445	50	3	56	7.29	1.67	0.08	1.17	10.211	153	3.7	30	26	6.653	0.095	1.517	2.140	10.405	71	16	1	11	64	1	15	21
17	290	70	4.4	78	4.75	2.33	0.12	1.62	8.834	121	2.9	40	20	5.262	0.074	1.976	1.646	8.958	54	26	1	18	59	1	22	18
18	425	40	3.1	75	6.97	1.33	0.09	1.56	9.948	112	3.2	54	29	4.870	0.082	2.695	2.387	10.033	70	13	1	16	49	1	27	24
19	190	30	1.7	4	3.11	1.00	0.05	0.08	4.245	26	2.6	46	11	1.131	0.066	2.295	0.905	4.398	73	24	1	2	26	2	52	21
20	350	60	32	67	5.74	2.00	0.90	1.39	10.034	100	4.1	72	26	4.348	0.105	3.593	2.140	10.186	57	20	9	14	43	1	35	21
21	450	50	25	136	7.38	1.67	0.71	2.83	12.579	64	9.5	36	95	2.783	0.243	1.796	7.819	12.641	59	13	6	23	22	2	14	62
22	205	40	4.2	4	3.36	1.33	0.12	0.08	4.895	24	4.1	60	11	1.044	0.105	2.994	0.905	5.048	69	27	2	2	21	2	59	18
23	320	70	21	72	5.24	2.33	0.59	1.50	9.669	82	7.2	58	38	3.566	0.184	2.894	3.128	9.772	54	24	6	16	36	2	30	32
24	90	50	33	53	1.48	1.67	0.93	1.10	5.176	42	3.9	38	20	1.826	0.100	1.896	1.646	5.468	29	32	18	21	33	2	35	30
25	330	0	46	150	5.41	0.00	1.30	3.12	9.829	46	6	32	75	2.000	0.153	1.597	6.173	9.923	55	0	13	32	20	2	16	62
26	200	30	30	104	3.28	1.00	0.85	2.17	7.289	147	3.5	8	12	6.392	0.090	0.399	0.988	7.869	45	14	12	30	81	1	5	13
27	190	100	2.3	100	3.11	3.33	0.06	2.08	8.594	134	7.9	38	14	5.827	0.202	1.896	1.152	9.077	36	39	1	24	64	2	21	13
28	380	30	2.8	104	6.23	1.00	0.08	2.17	9.472	68	8.2	56	45	2.957	0.210	2.794	3.704	9.665	66	11	1	23	31	2	29	38
29	225	40	1.6	4	3.69	1.33	0.05	0.08	5.149	69	1.8	22	13	3.000	0.046	1.098	1.070	5.214	72	26	1	2	58	1	21	21
30	370	20	25	48	6.06	0.67	0.71	1.00	8.436	54	6.5	46	45	2.348	0.166	2.295	3.704	8.513	72	8	8	12	28	2	27	44
31	380	20	2.7	136	6.23	0.67	0.08	2.83	9.803	96	9.4	48	30	4.174	0.240	2.395	2.469	9.279	64	7	1	29	45	3	26	27

	Anions (mg/l)				Anions (meq/l)				∑ A (meq/l)	Cation (mg/l)				Cation (meq/l)				∑ C (meq/l)	Anion (%meq)				Cation (%meq)			
ID	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}		Na^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	Ca^{2+}	Mg^{2+}		HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
32	380	30	7.8	94	6.23	1.00	0.22	1.96	9.405	62	8.8	42	55	2.696	0.225	2.096	4.527	9.544	66	11	2	21	28	2	22	47
33	220	40	2.8	108	3.61	1.33	0.08	2.25	7.266	63	8.2	46	27	2.739	0.210	2.295	2.222	7.467	50	18	1	31	37	3	31	30
34	260	90	2.2	76	4.26	3.00	0.06	1.58	8.905	67	5.4	50	42	2.913	0.138	2.495	3.457	9.003	48	34	1	18	32	2	28	38
35	290	60	3.2	16	4.75	2.00	0.09	0.33	7.176	79	3.2	56	12	3.435	0.082	2.794	0.988	7.299	66	28	1	5	47	1	38	14
36	690	50	47	155	11.31	1.67	1.33	3.23	17.529	208	7.3	22	90	9.045	0.187	1.098	7.407	17.737	65	10	8	18	51	1	6	42
37	235	40	2.2	18	3.85	1.33	0.06	0.37	5.622	43	3.1	19	37	1.870	0.079	0.938	3.045	5.932	69	24	1	7	32	1	16	51
38	190	40	6	228	3.11	1.33	0.17	4.75	9.363	119	2.4	32	34	5.175	0.061	1.577	2.798	9.611	33	14	2	51	54	1	16	29
39	165	70	13	114	2.70	2.33	0.35	2.37	7.763	124	0.9	20	19	5.392	0.023	0.998	1.564	7.977	35	30	5	31	68	0	13	20
40	580	80	47	390	9.51	2.67	1.33	8.12	21.618	226	3.2	74	100	9.827	0.082	3.693	8.230	21.832	44	12	6	38	45	0	17	38
41	320	20	1.3	45	5.24	0.67	0.04	0.94	6.885	15	1.7	65	37	0.652	0.043	3.234	3.045	6.975	76	10	1	14	9	1	46	44
42	290	20	1.6	35	4.75	0.67	0.05	0.73	6.194	88	1.6	36	8	3.827	0.041	1.796	0.658	6.322	77	11	1	12	61	1	28	10
43	310	80	21	4	5.08	2.67	0.59	0.08	8.423	94	4.7	60	17	4.087	0.120	2.994	1.399	8.601	60	32	7	1	48	1	35	16
44	390	30	168	4	6.39	1.00	4.74	0.08	12.214	45	4.9	44	110	1.957	0.125	2.196	9.053	13.331	52	8	39	1	15	1	16	68
45	340	40	28	3	5.57	1.33	0.79	0.06	7.758	122	5.3	45	2	5.305	0.136	2.255	0.165	7.861	72	17	10	1	67	2	29	2
46	270	10	67	128	4.43	0.33	1.89	2.66	9.313	111	2.1	32	38	4.827	0.054	1.597	3.128	9.605	48	4	20	29	50	1	17	33
47	180	30	3.6	136	2.95	1.00	0.10	2.83	6.883	50	3.7	49	28	2.174	0.095	2.435	2.305	7.008	43	15	1	41	31	1	35	33
48	130	50	16	11	2.13	1.67	0.45	0.23	4.477	81	1.5	50	14	3.522	0.038	2.495	1.152	7.208	48	37	10	5	49	1	35	16
51	240	60	230	180	3.93	2.00	6.49	3.75	16.168	271	3.4	24	43	11.784	0.087	1.198	3.539	16.608	24	12	40	23	71	1	7	21
52	410	20	225	350	6.72	0.67	6.35	7.29	21.020	245	6.7	66	90	10.654	0.171	3.293	7.407	21.526	32	3	30	35	49	1	15	34
53	430	20	5.7	360	7.05	0.67	0.16	7.50	15.370	94	11	58	100	4.087	0.269	2.874	8.230	15.461	46	4	1	49	26	2	19	53
54	180	90	20	180	2.95	3.00	0.56	3.75	10.261	63	5.2	44	65	2.739	0.133	2.196	5.350	10.418	29	29	5	37	26	1	21	51
55	490	30	110	208	8.03	1.00	3.10	4.33	16.464	138	58	66	80	6.001	1.483	3.293	6.584	17.362	49	6	19	26	35	9	19	38
56	300	60	5	89	4.92	2.00	0.14	1.85	8.911	104	2.2	36	34	4.522	0.056	1.796	2.798	9.173	55	22	2	21	49	1	20	31
60	210	10	51	104	3.44	0.33	1.44	2.17	7.379	72	4.1	32	37	3.131	0.105	1.597	3.045	7.878	47	5	19	29	40	1	20	39
62	390	50	20	2880	6.39	1.67	0.56	59.96	68.583	1010	10	138	220	43.919	0.256	6.886	18.107	69.168	9	2	1	87	63	0	10	26
63	160	30	353	1700	2.62	1.00	9.96	35.39	48.972	768	2.3	200	90	33.396	0.059	9.980	7.407	50.842	5	2	20	72	66	0	20	15
64	200	40	185	530	3.28	1.33	5.22	11.03	20.864	374	3.3	38	40	16.263	0.084	1.896	3.292	21.536	16	6	25	53	76	0	9	15
67	290	50	410	875	4.75	1.67	11.56	18.22	36.201	593	4	64	100	25.786	0.102	3.194	8.230	37.312	13	5	32	50	69	0	9	22
68	255	20	185	5	4.18	0.67	5.22	0.10	10.168	7	4.4	80	85	0.304	0.113	3.992	6.996	11.405	41	7	51	1	3	1	35	61
70	250	60	43	86	4.10	2.00	1.21	1.79	9.101	117	2.4	34	31	5.088	0.061	1.697	2.551	9.397	45	22	13	20	54	1	18	27
72	135	50	398	1950	2.21	1.67	11.23	40.60	55.703	788	6.6	130	190	34.265	0.169	6.487	15.638	56.559	4	3	20	73	61	0	11	28
73	290	40	45	83	4.75	1.33	1.27	1.73	9.084	59	3	54	48	2.566	0.077	2.695	3.951	9.288	52	15	14	19	28	1	29	43

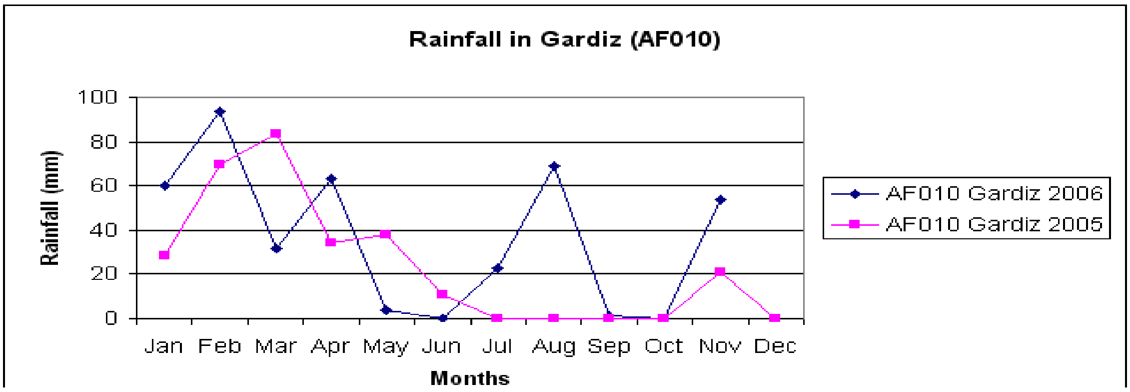
	Anions (mg/l)				Anions (meq/l)				∑ A (meq/l)	Cation (mg/l)				Cation (meq/l)				∑ C (meq/l)	Anion (%meq)				Cation (%meq)			
ID	HCO^{3-}	CO_3^{2-}	Cl^-	SO_4^{2-}	HCO^{3-}	CO_3^{2-}	Cl^-	SO_4^{2-}		Na^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	Ca^{2+}	Mg^{2+}		HCO^{3-}	CO_3^{2-}	Cl^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}
75	420	50	72	370	6.88	1.67	2.03	7.70	18.284	192	3.4	70	82	8.349	0.087	3.493	6.749	18.678	38	9	11	42	45	0	19	36
77	240	20	512	88	3.93	0.67	14.44	1.83	20.874	352	4.1	56	34	15.306	0.105	2.814	2.798	21.024	19	3	69	9	73	0	13	13
79	280	30	165	495	4.59	1.00	4.65	10.31	20.549	394	0.9	38	25	17.133	0.023	1.896	2.058	21.110	22	5	23	50	81	0	9	10
85	320	40	76	122	5.24	1.33	2.14	2.54	11.262	62	3.6	32	100	2.696	0.092	1.597	8.230	12.615	47	12	19	23	21	1	13	65
87	380	40	33	67	6.23	1.33	0.93	1.39	9.887	54	2.8	58	60	2.348	0.072	2.894	4.938	10.252	63	13	9	14	23	1	28	48
88	590	30	22	100	9.67	1.00	0.62	2.08	13.373	128	4.1	32	75	5.566	0.105	1.597	6.173	13.440	72	7	5	16	41	1	12	46
89	150	140	424	775	2.46	4.67	11.96	16.14	35.219	504	4.9	135	90	21.916	0.125	6.737	7.407	36.185	7	13	34	46	61	0	19	20
91	385	80	29	1140	6.31	2.67	0.82	23.73	33.529	325	4.7	144	150	14.132	0.120	7.186	12.346	33.784	19	8	2	71	42	0	21	37
92	410	40	4.3	80	6.72	1.33	0.12	1.67	9.840	70	3.3	63	45	3.044	0.084	3.134	3.704	9.966	68	14	1	17	31	1	31	37
93	445	30	3.5	92	7.29	1.00	0.10	1.92	10.308	112	2.6	76	20	4.870	0.066	3.792	1.646	10.375	71	10	1	19	47	1	37	16
94	660	40	9.6	2900	10.82	1.33	0.27	60.38	72.798	743	15	492	200	32.309	0.384	24.551	16.461	73.704	15	2	0	83	44	1	33	22
112	280	210	11	104	4.59	7.00	0.31	2.17	14.064	159	34	66	38	6.914	0.870	3.268	3.128	14.180	33	50	2	15	49	6	23	22
113	315	150	86	56	5.16	5.00	2.43	1.17	13.754	200	5.5	29	44	8.697	0.141	1.457	3.621	13.916	38	36	18	8	62	1	10	26
114	480	60	96	34	7.87	2.00	2.71	0.71	13.283	158	5.4	64	40	6.870	0.138	3.214	3.292	13.514	59	15	20	5	51	1	24	24

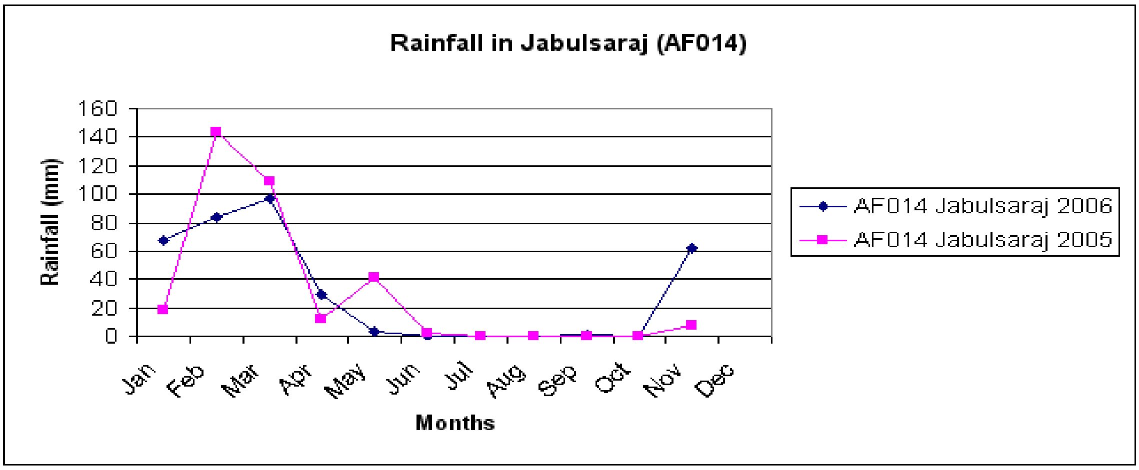
Annex 5 Rainfall Data

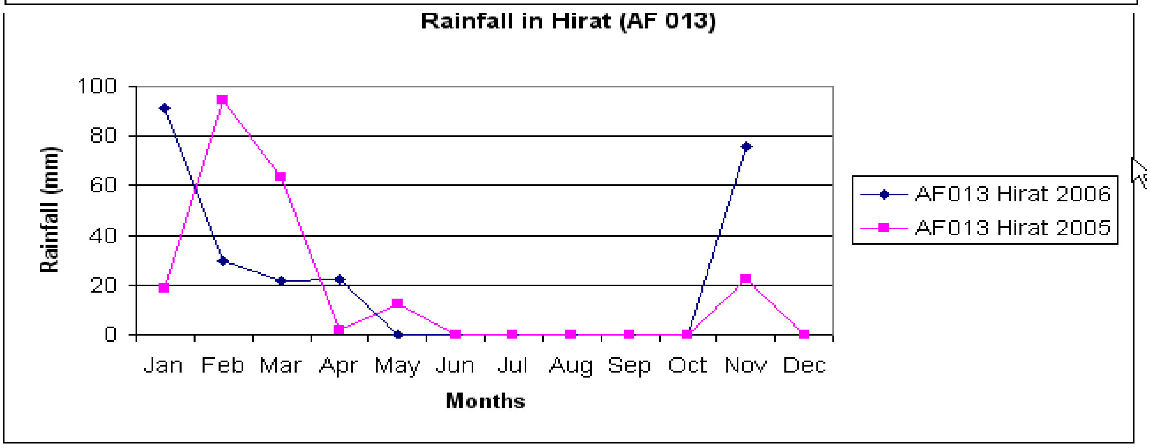
ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF010	Gardiz	2006	60	93.5	31.5	63	3.5	0	23	69	1	0	54		398.5
		2005	28.5	69.5	83.8	33.9	37.8	10.8	0	0	0	0	21	0	285.3

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF013	Hirat	2006	91.6	30	22	22.4	0	0	0	0	0	0	76		242
		2005	18.5	94.3	63.3	2	12.5	0	0	0	0	0	22.1	0	212.7

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF014	Jabulsaraj	2006	68	83.6	96.6	29.8	3	0	0	0.5	1	0	62		344.5
		2005	19	144	108.9	12.1	41.7	2.3	0	0	0	0.5	7.5		336



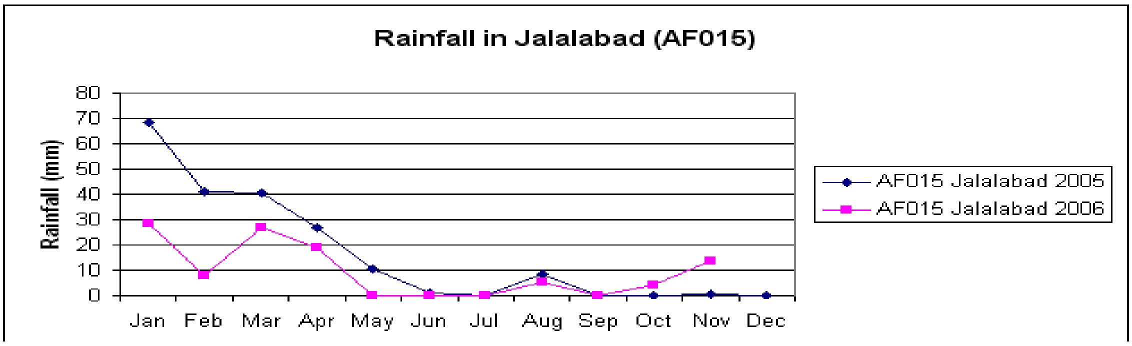


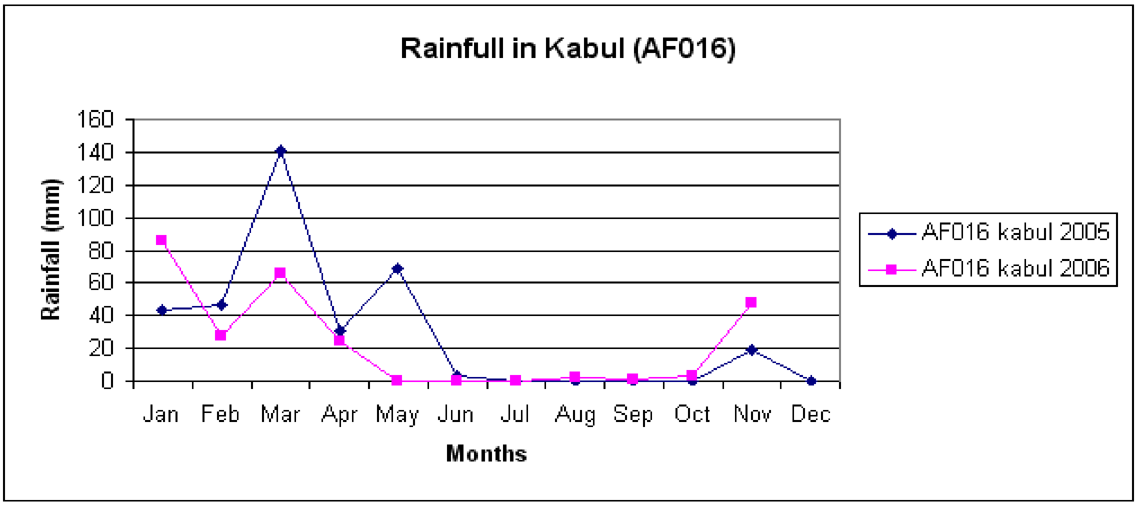


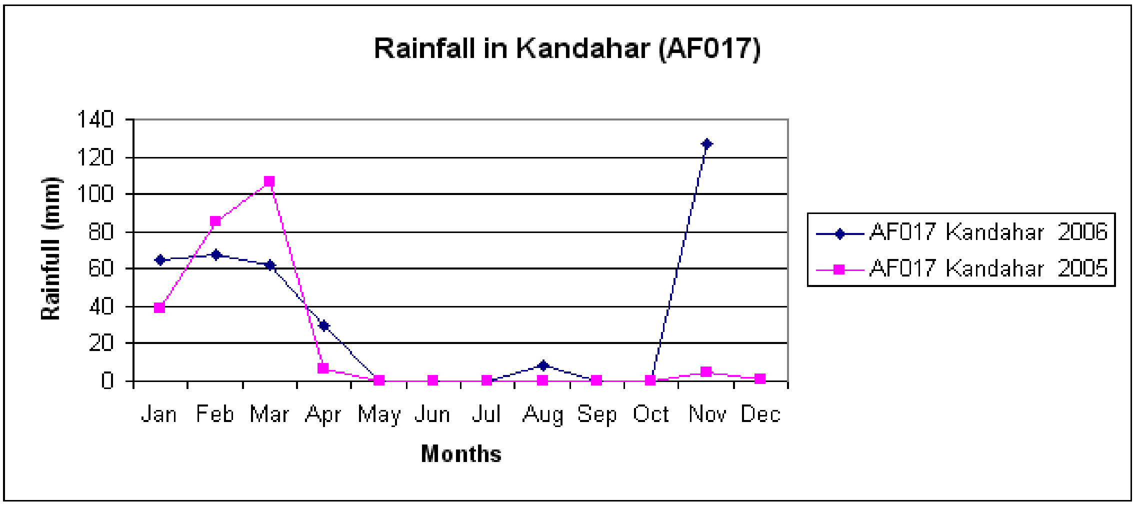
ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF015	Jalalabad	2005	68	41	40.4	27	10.4	1	0	8.4	0	0	0.4	0	196.7
		2006	28	7.9	26.6	19	0	0	0	5.3	0	4.4	14		105.5

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF016	kabul	2005	44	46	141	31	69.1	3.2	0	0	0	0	19	0	352.9
		2006	86	27	65.9	24	0	0	0	2.2	1	2.8	48		256.9

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF017	Kandahar	2006	65	68	62	30	0	0	0	8	0	0	127		360
		2005	39	85	107	6.5	0	0	0	0	0	0	5	1	243.2



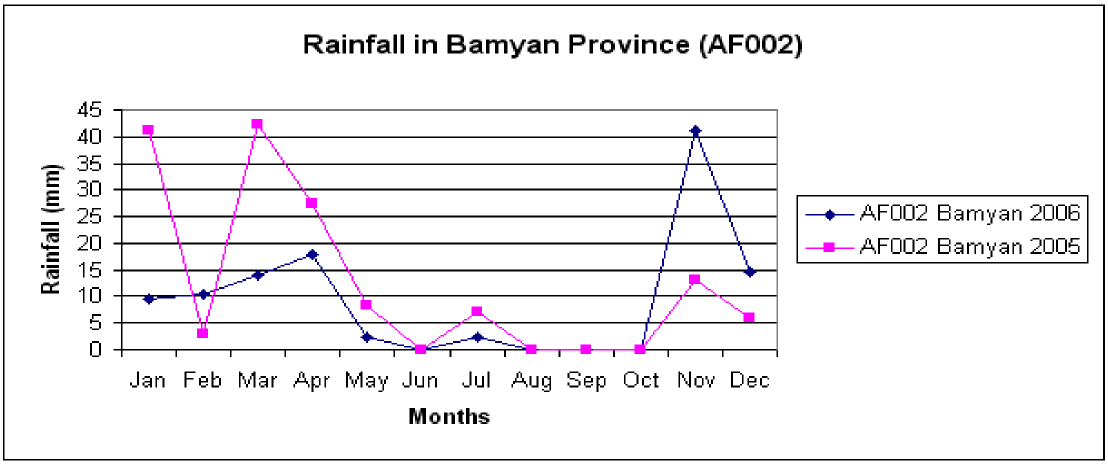


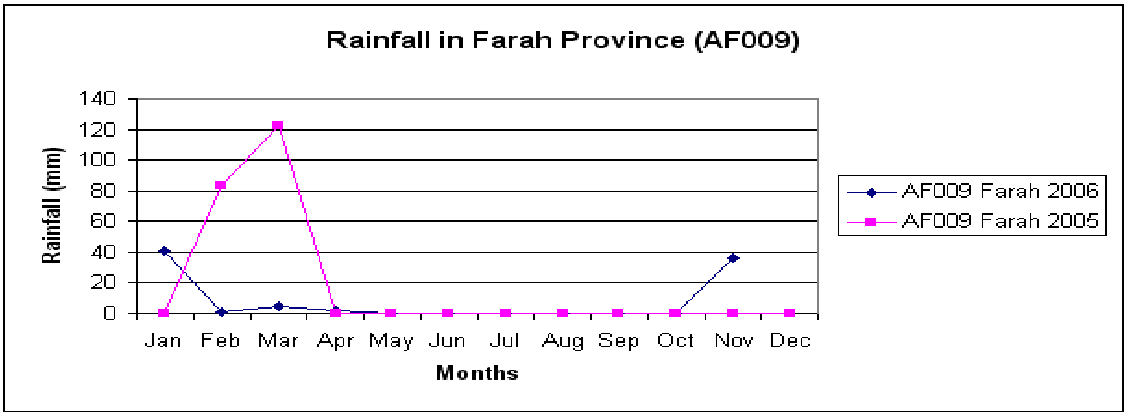


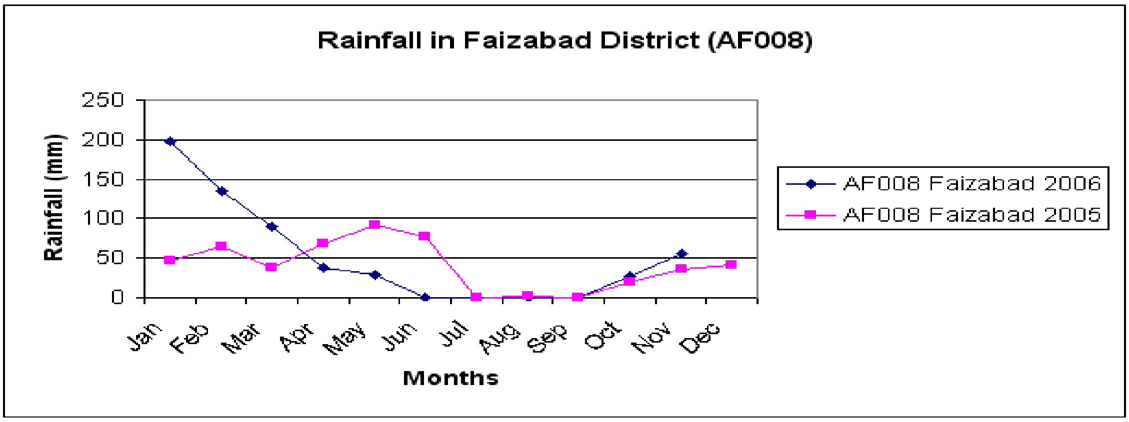
ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF002	Bamyan	2006	9.5	11	14	18	2.5	0	2.5	0	0	0	41	15	112.5
		2005	41	2.9	42	28	8.2	0	7.2	0	0	0	13	6	148

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF009	Farah	2006	41	1	4.6	1.7	0	0	0	0	0	0	36		84.4
		2005	0	84	122	0	0	0	0	0	0	0	0	0	205.5

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF008	Faizabad	2006	198	135	90	39	28.5	0	0	0	0	27	56		572.1
		2005	46	64	37	69	91	78	0	1	0	20	36	41	483



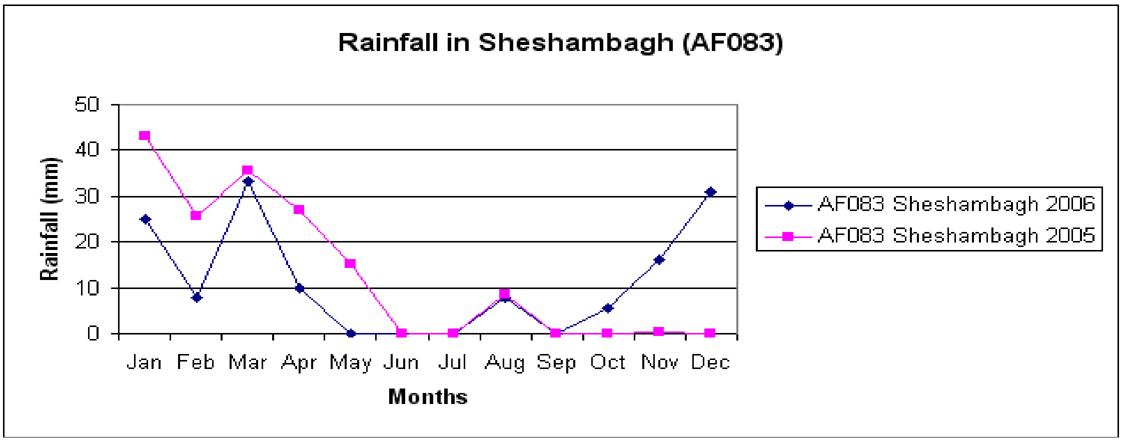


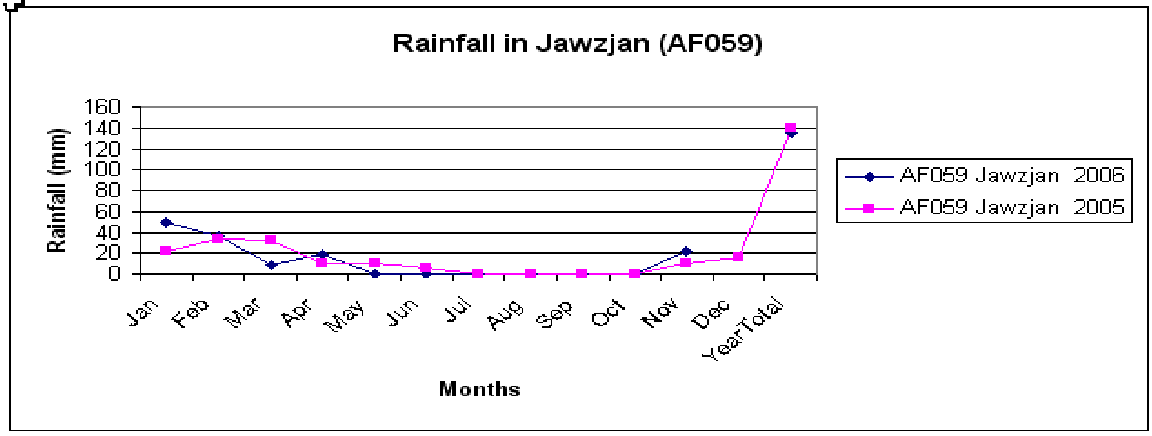


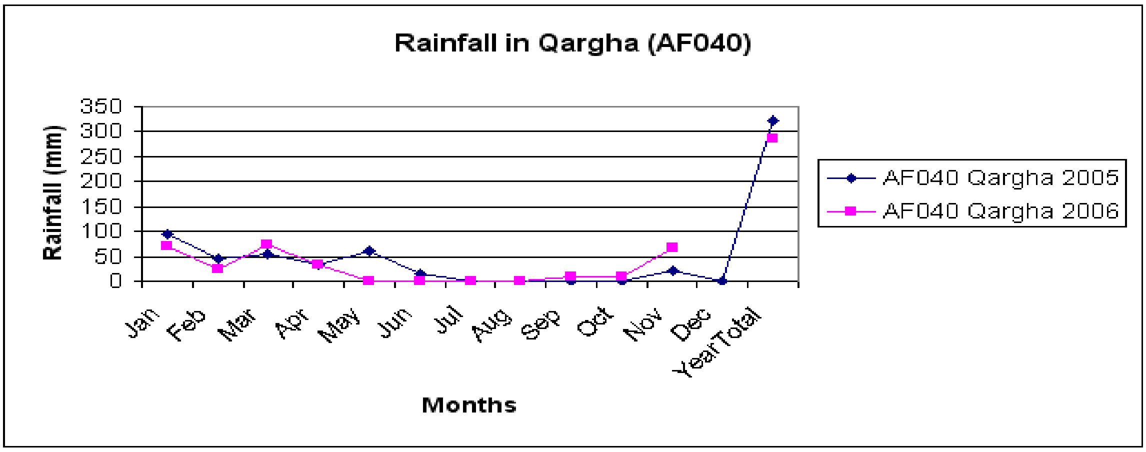
ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF040	Qargha	2005	93	45	54	33	60	15	0	0	0	0	23	0	322
		2006	70	24	73	34	0	0	0	0	9	9	68		286.5

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF059	Jawzjan	2006	50	37	8.1	18	0	0	0	0	0	0	22		135.4
		2005	22	33	32	9.7	10.6	6	0	0	0	0	11	17	140.2

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF083	Sheshambagh	2006	25	8	33	10	0	0	0	8	0	5.5	16	31	136.6
		2005	43	26	36	27	15	0	0	8.4	0	0	0.4	0	154.8



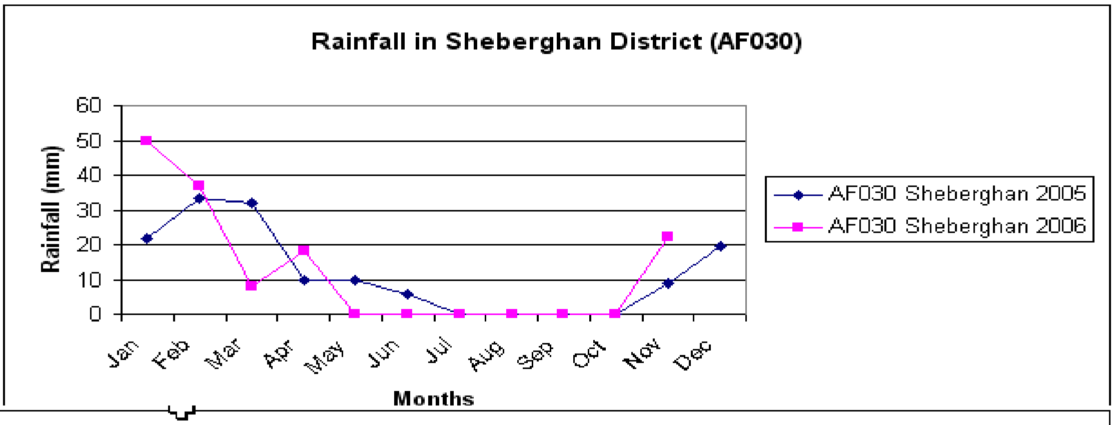


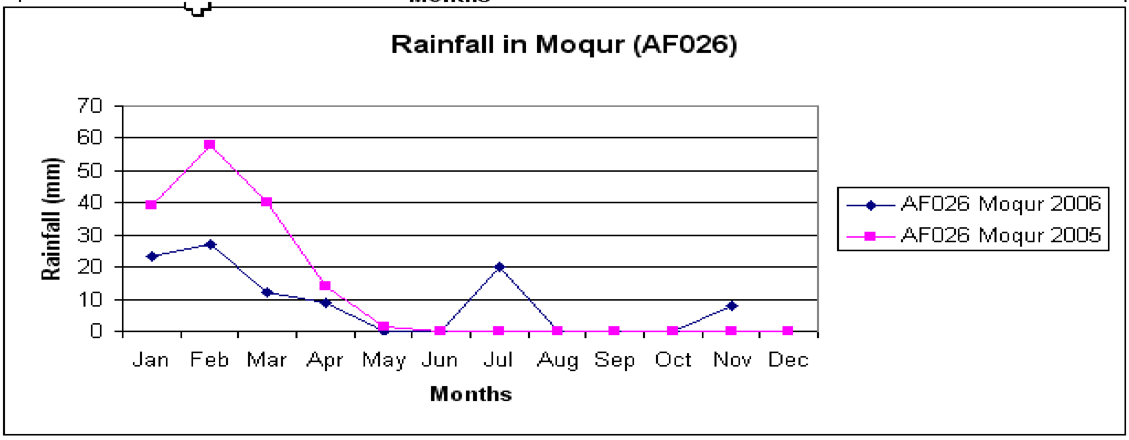


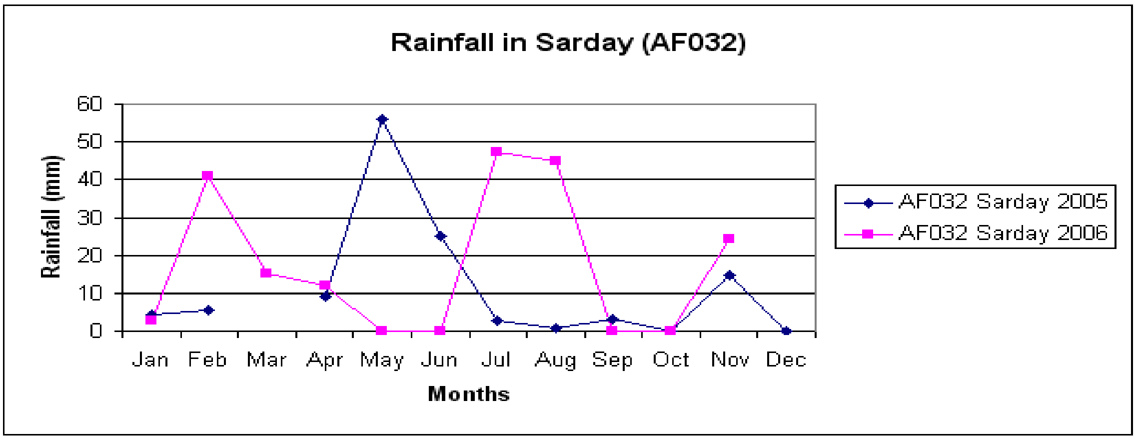
ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF026	Moqur	2006	23	27	12	9	0	0	20	0	0	0	8		99.3
		2005	39	58	40	14	1.3	0	0	0	0	0	0.2	0	152.5

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF030	Sheberghan	2005	22	33	32	9.7	9.7	6	0	0	0	0	8.8	20	140.6
		2006	50	37	8.1	18	0	0	0	0	0	0	22		135.4

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF032	Sarday	2005	4.3	5.6		9.2	56.1	25	2.6	0.7	3.1	0	15	0	121.6
		2006	2.6	41	15	12	0	0	47	45	0	0	24		187.2

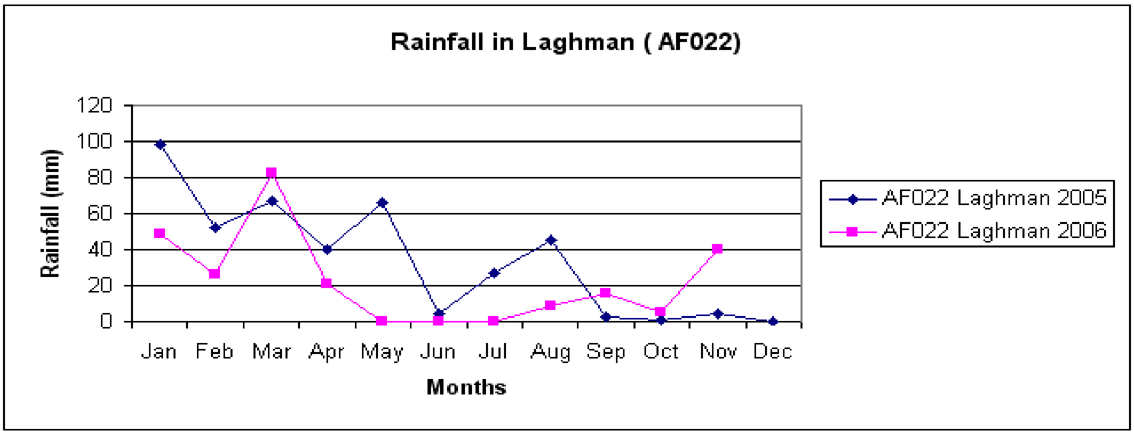


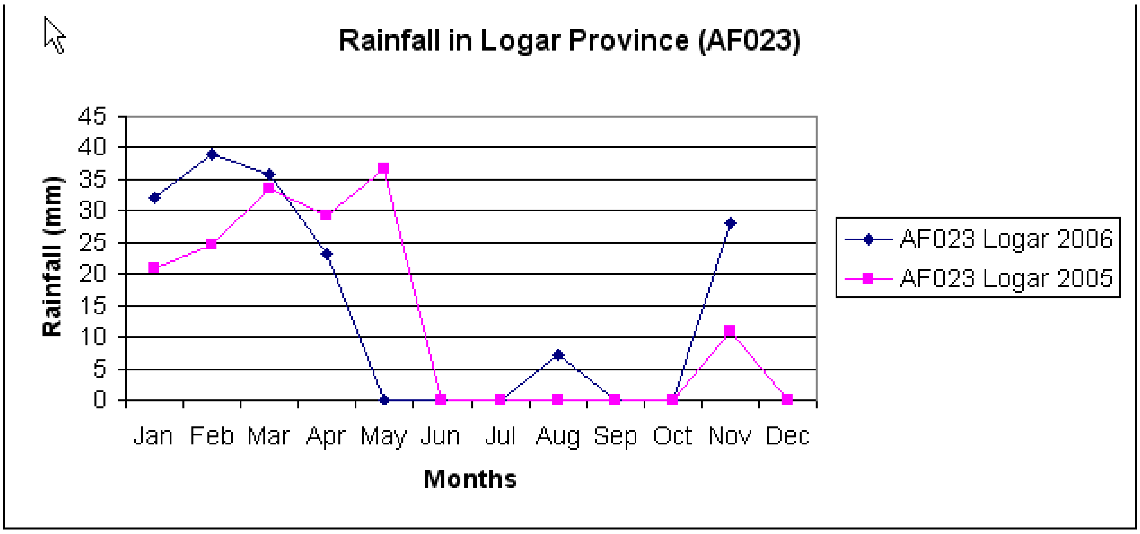




ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF022	Laghman	2005	98	52.2	67.3	40	65.8	4.4	27	45	2.4	1	4	0	407.7
		2006	49	26	83	21	0	0	0	8.7	16	5.5	40		249.6

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF023	Logar	2006	32	39	35.7	23.2	0	0	0	7.2	0	0	28		165.3
		2005	21	24.6	33.5	29.3	36.7	0	0	0	0	0	11	0	155.9



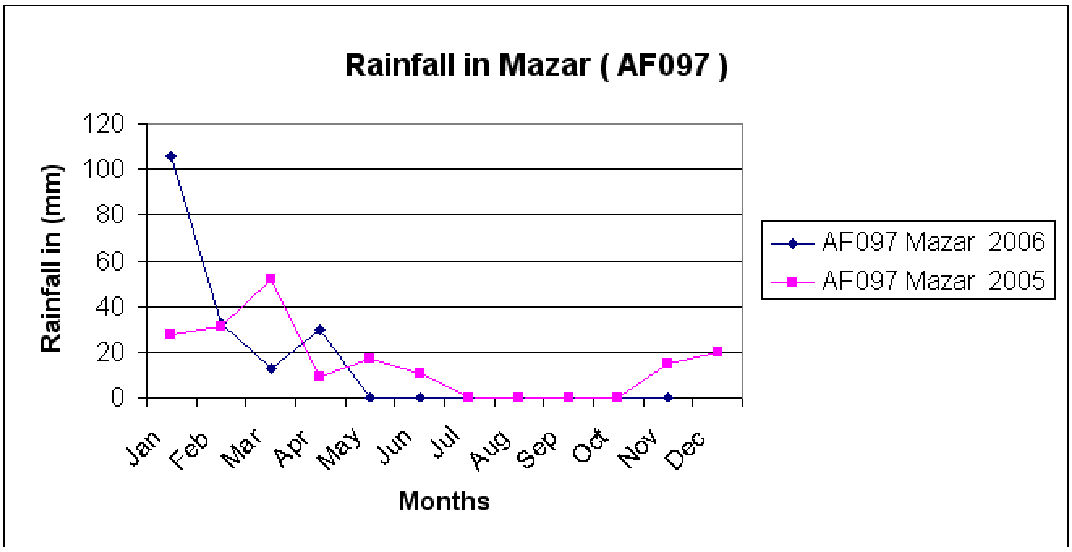


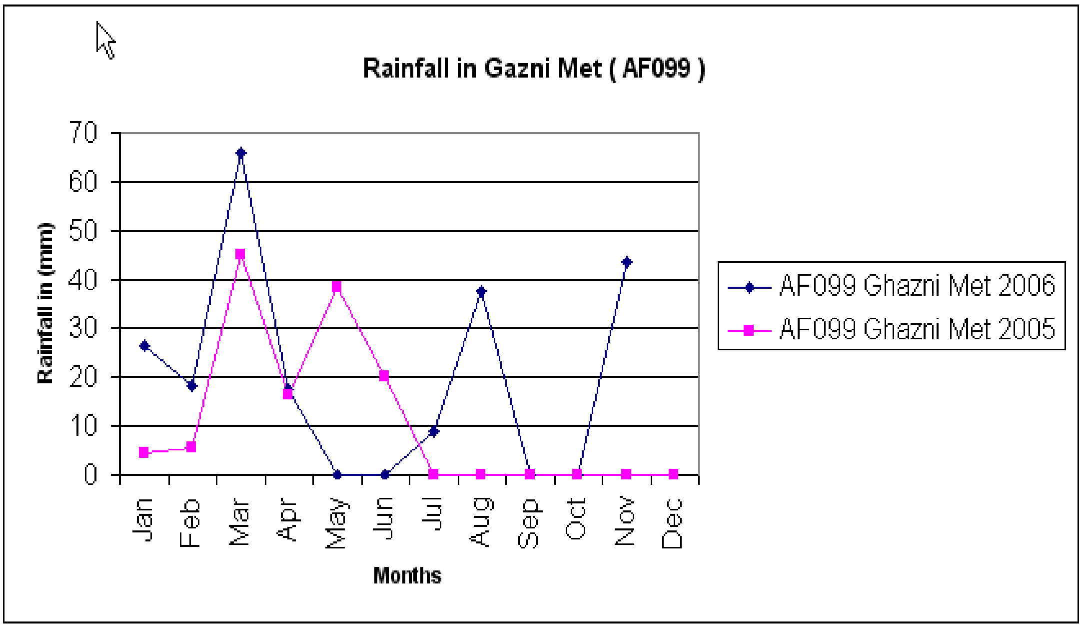
ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF097	Mazar	2006	105.9	33	13	30	0	0	0	0	0	0	0		181.9
		2005	27.9	31	52	9	17	11	0	0	0	0	15	20	182.9

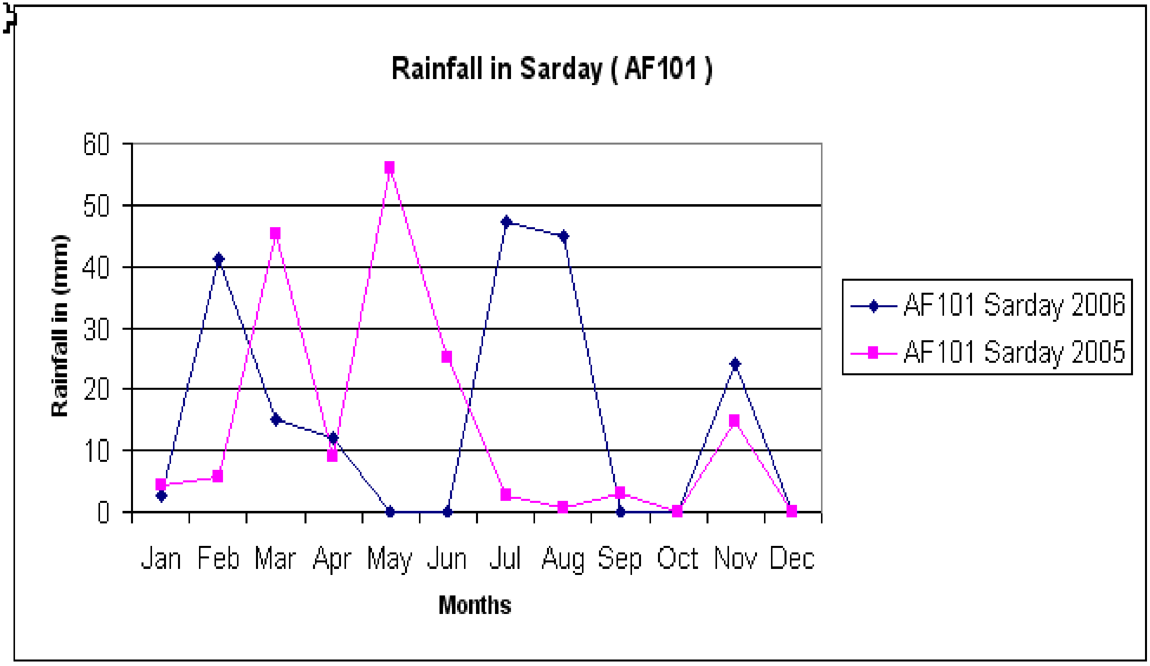
ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF099	Ghazni Met	2006	26.5	18.1	65.8	17.5	0	0	9	38	0	0	43.6		218
		2005	4.3	5.6	45.1	16.5	38.5	20	0	0	0	0	0	0	130

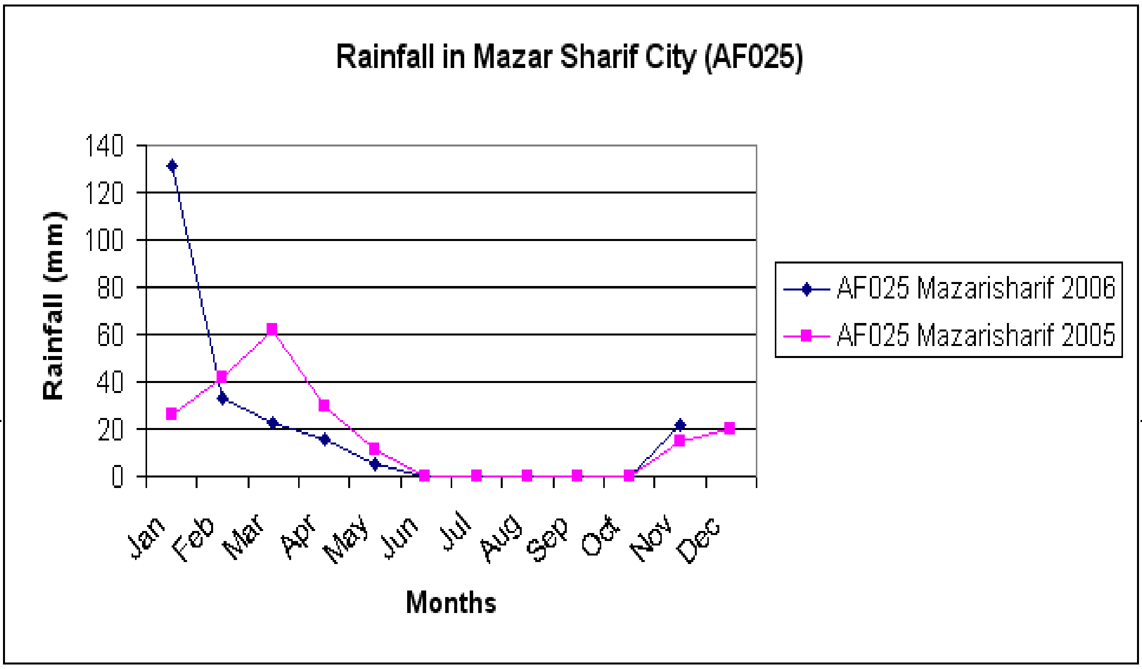
ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF101	Sarday	2006	2.6	41.1	15	12	0	0	47	45	0	0	24.2	0	187.2
		2005	4.3	5.6	45.1	9.2	56.1	25.1	2.6	0.7	3.1	0	14.9	0	166.7

ID	Province Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YearTotal
AF025	Mazarisharif	2006	131	33	23	15.8	5	0	0	0	0	0	22		229.8
		2005	26	41.9	61.4	29.3	11.5	0	0	0	0	0	15	20	205.1

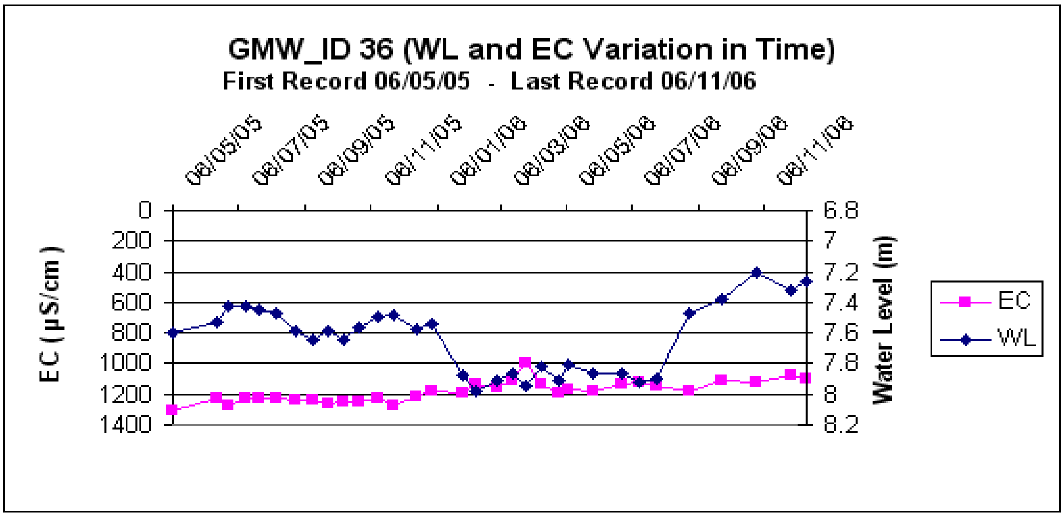


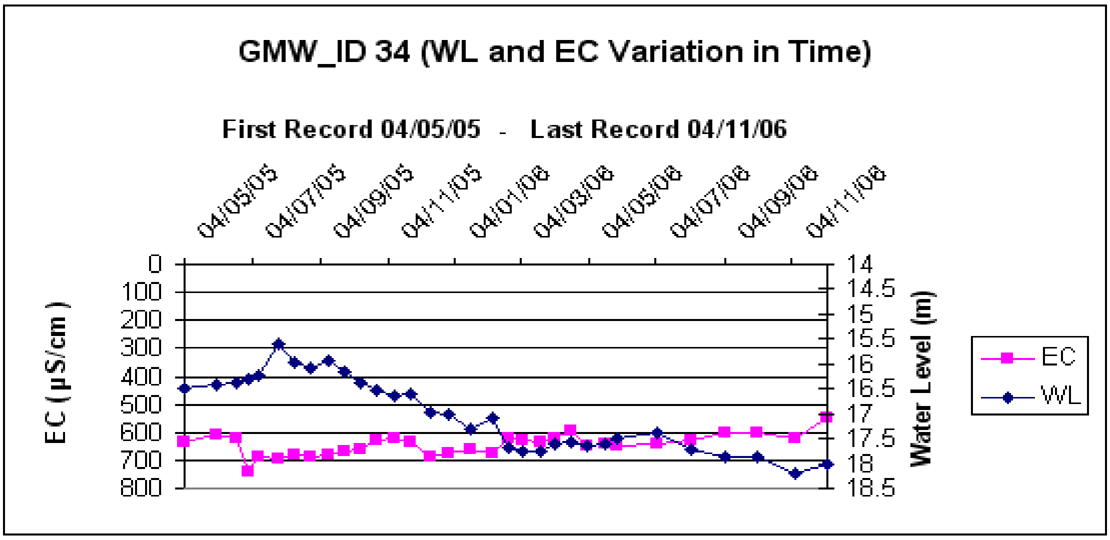


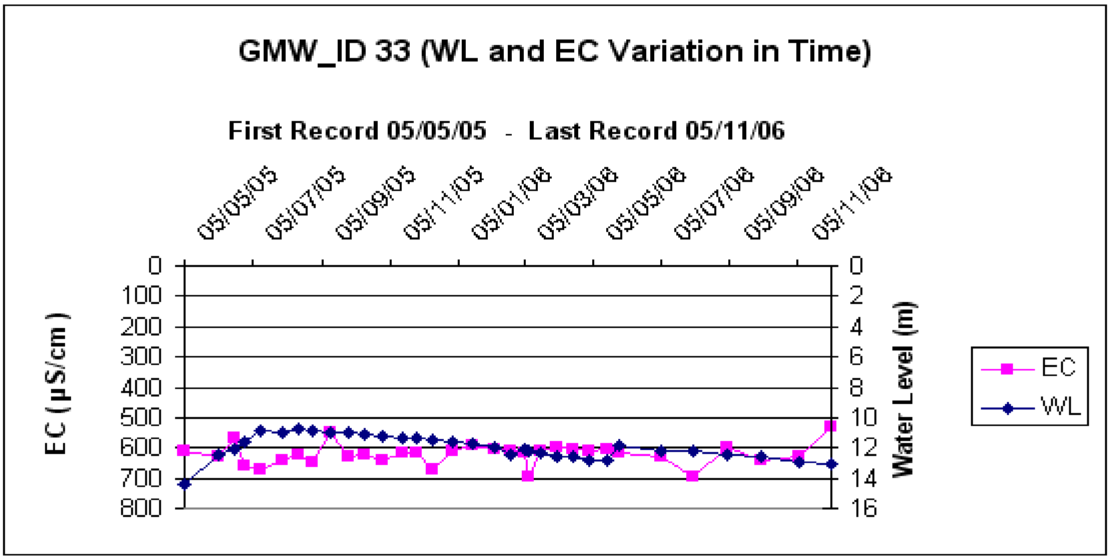

Rainfall in Sarday (AF101)
Rainfall in (mm)
60
50
40
30
20
10
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months
AF101 Sarday 2006
AF101 Sarday 2005

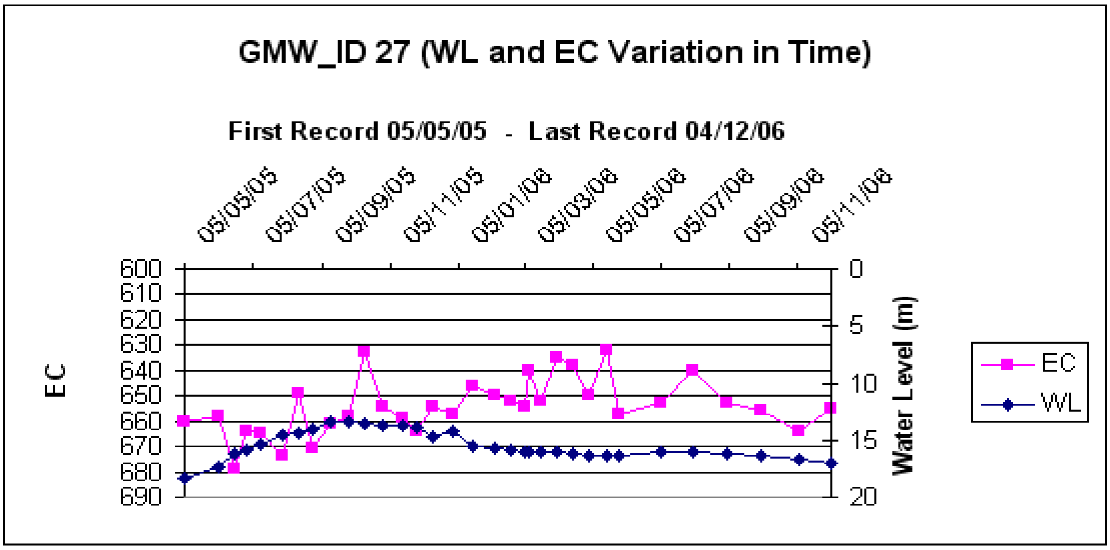

Rainfall in Mazar Sharif City (AF025)
Rainfall (mm)
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months
AF025 Mazarisharif 2006
AF025 Mazarisharif 2005

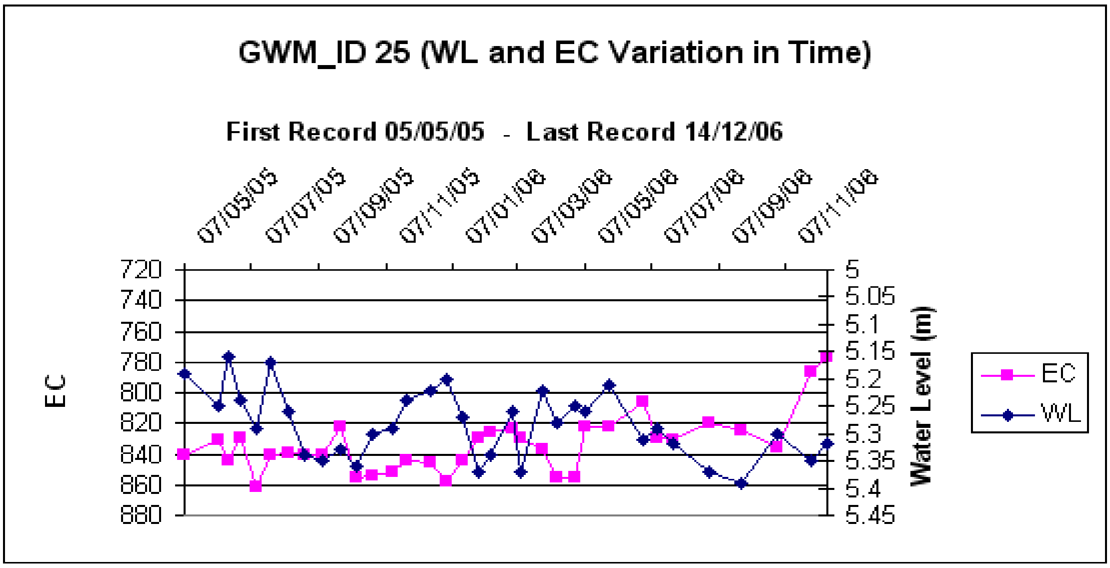
Annex 6 Water Level and EC variation over time

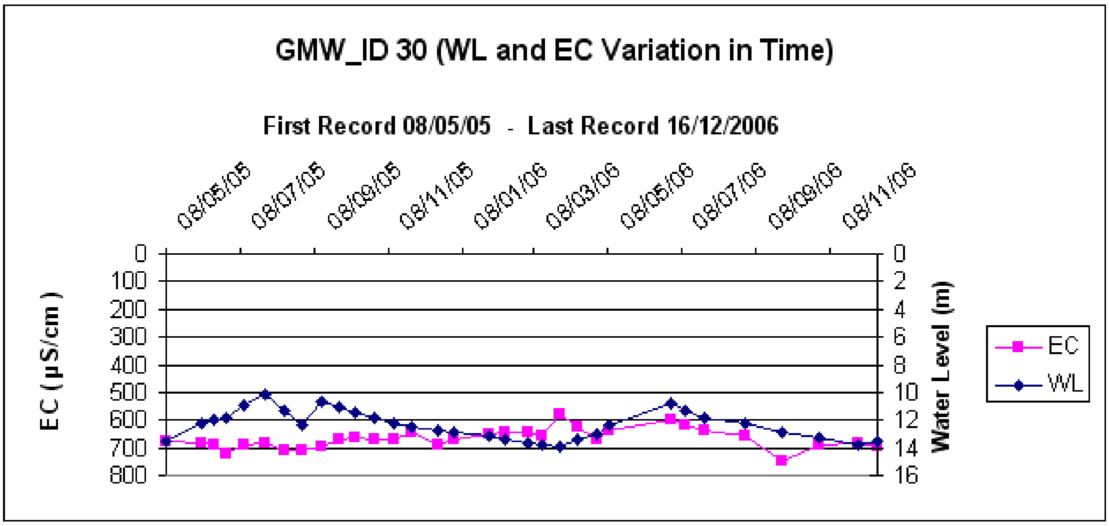


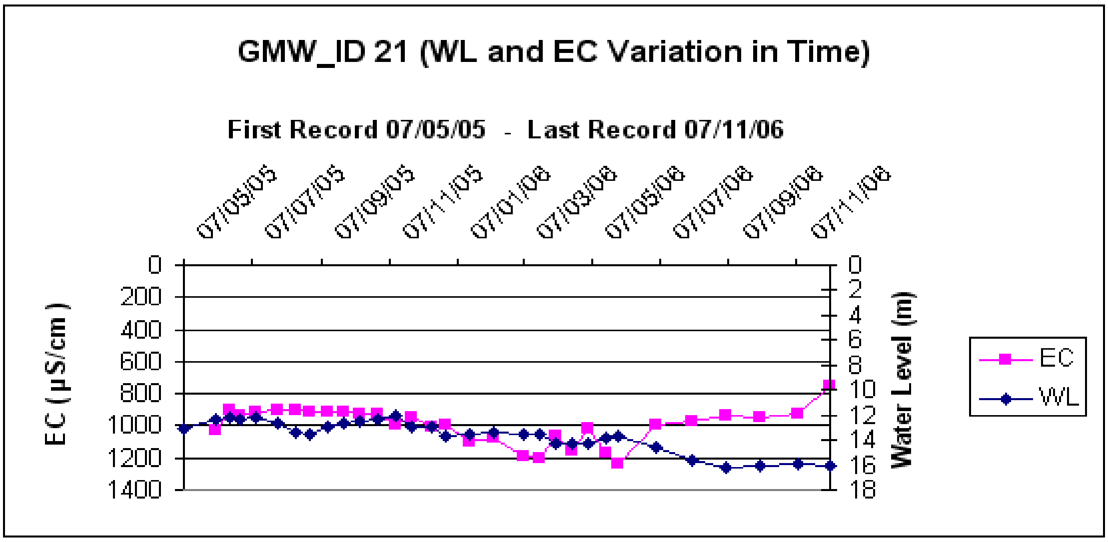


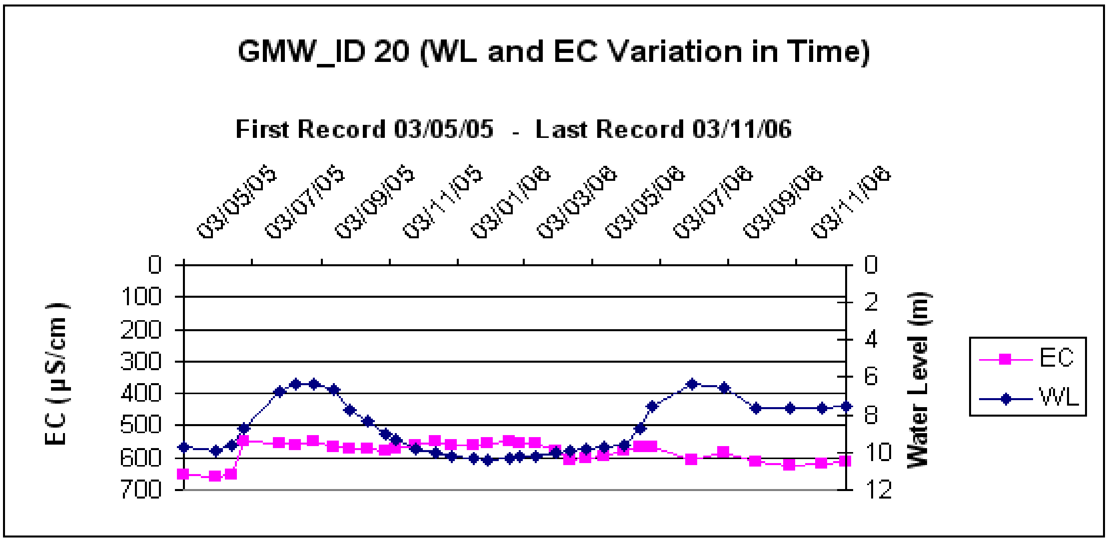


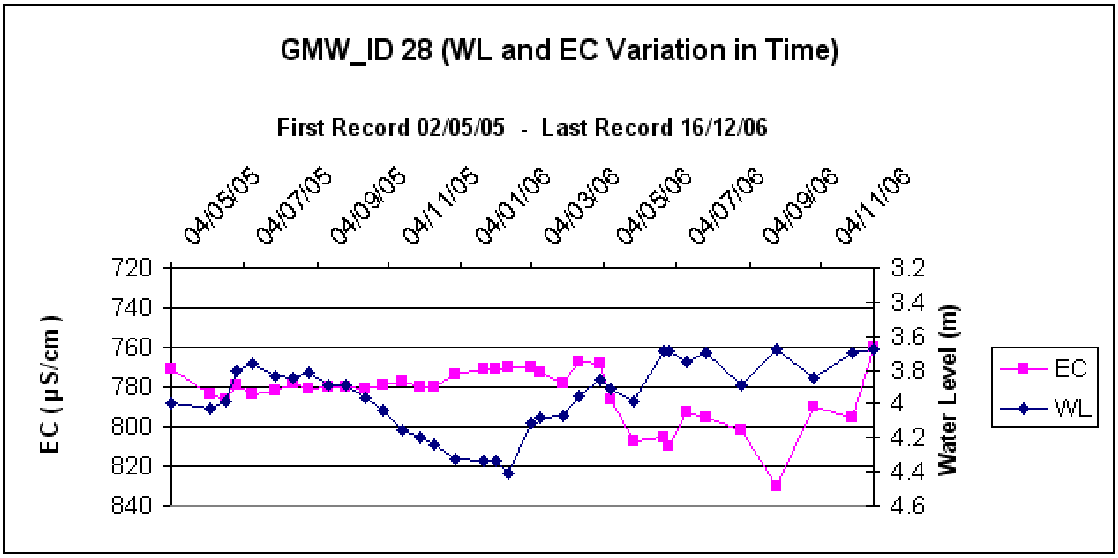

GMW_ID 27 (WL and EC Variation in Time)
First Record 05/05/05 - Last Record 04/12/06
05/05/05
05/07/05
05/09/05
05/11/05
05/01/06
05/03/06
05/05/06
05/07/06
05/09/06
05/11/06
EC
600
610
620
630
640
650
660
670
680
690
Water Level (m)
0
5
10
15
20
EC
WL

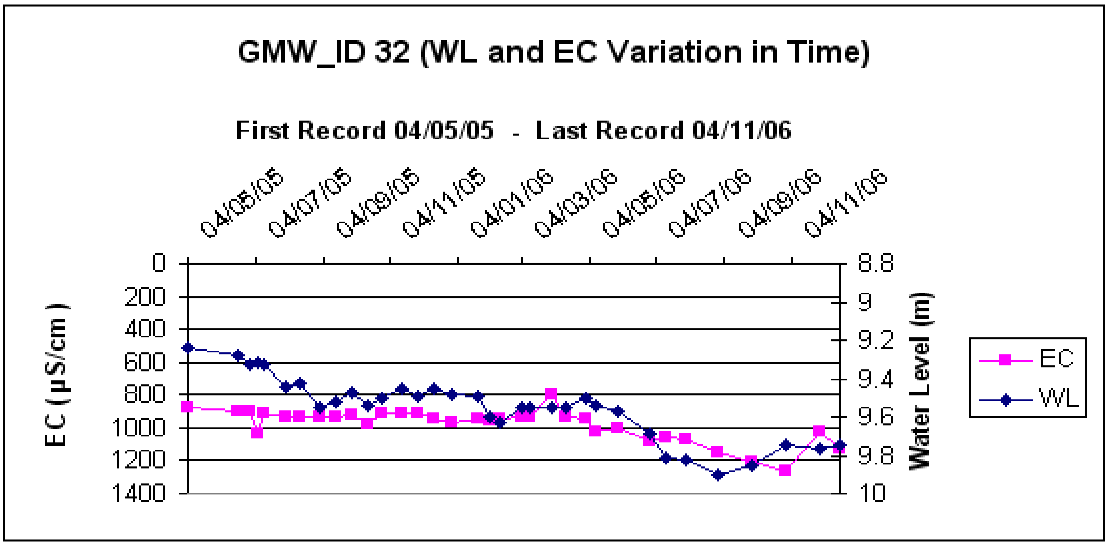

GWM_ID 25 (WL and EC Variation in Time)
First Record 05/05/05 - Last Record 14/12/06
07/05/05
07/07/05
07/09/05
07/11/05
07/01/06
07/03/06
07/05/06
07/07/06
07/09/06
07/11/06
EC
720
740
760
780
800
820
840
860
880
Water Level (m)
5
5.05
5.1
5.15
5.2
5.25
5.3
5.35
5.4
5.45
EC
WL

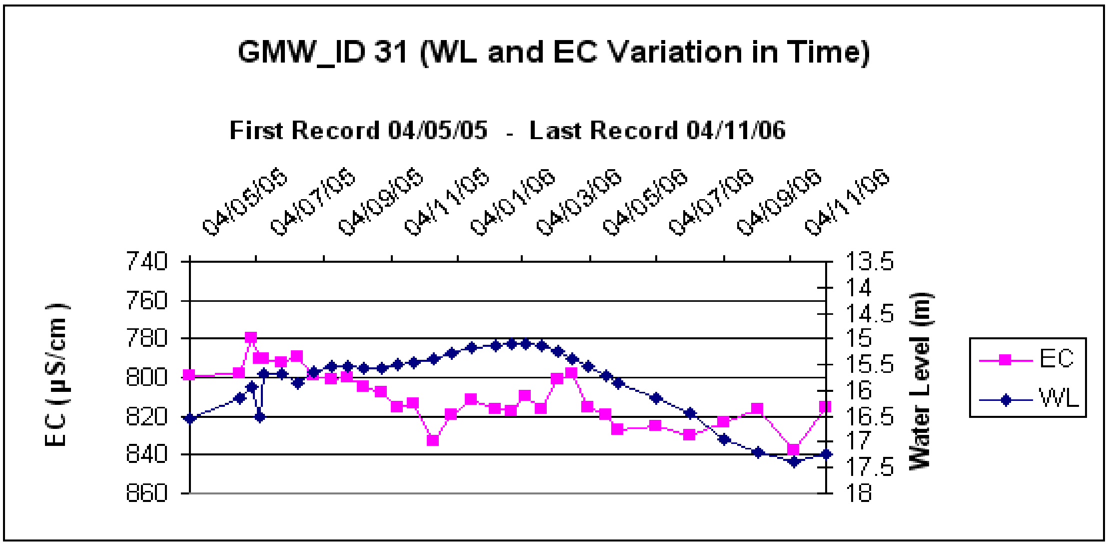

GMW_ID 30 (WL and EC Variation in Time)
First Record 08/05/05 - Last Record 16/12/2006
08/05/05
08/07/05
08/09/05
08/11/05
08/01/06
08/03/06
08/05/06
08/07/06
08/09/06
08/11/06
EC (µS/cm)
0
100
200
300
400
500
600
700
800
Water Level (m)
0
2
4
6
8
10
12
14
16
EC
WL

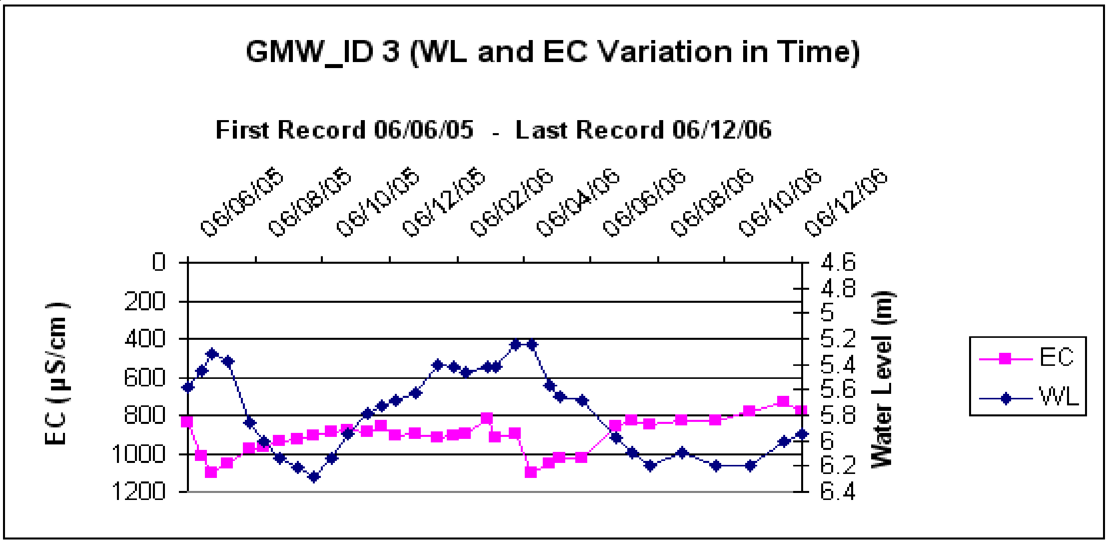

GMW_ID 21 (WL and EC Variation in Time)
First Record 07/05/05 - Last Record 07/11/06
07/05/05
07/07/05
07/09/05
07/11/05
07/01/06
07/03/06
07/05/06
07/07/06
07/09/06
07/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
Water Level (m)
0
2
4
6
8
10
12
14
16
18
EC
WL

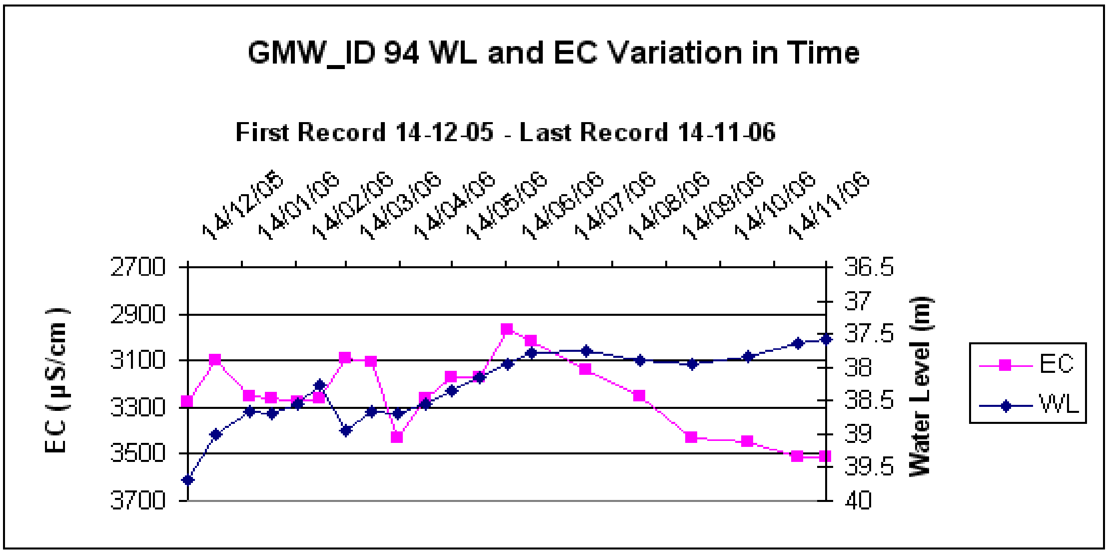

GMW_ID 20 (WL and EC Variation in Time)
First Record 03/05/05 - Last Record 03/11/06
03/05/05
03/07/05
03/09/05
03/11/05
03/01/06
03/03/06
03/05/06
03/07/06
03/09/06
03/11/06
EC (µS/cm)
0
100
200
300
400
500
600
700
Water Level (m)
0
2
4
6
8
10
12
EC
WL

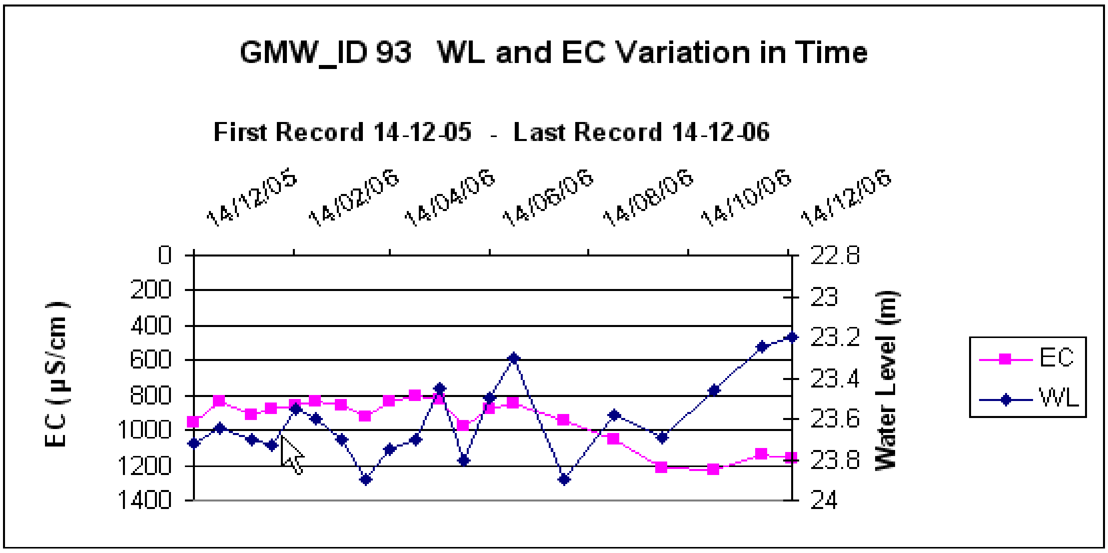

GMW_ID 28 (WL and EC Variation in Time)
First Record 02/05/05 - Last Record 16/12/06
04/05/05
04/07/05
04/09/05
04/11/05
04/01/06
04/03/06
04/05/06
04/07/06
04/09/06
04/11/06
EC (µS/cm)
720
740
760
780
800
820
840
Water Level (m)
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
EC
WL

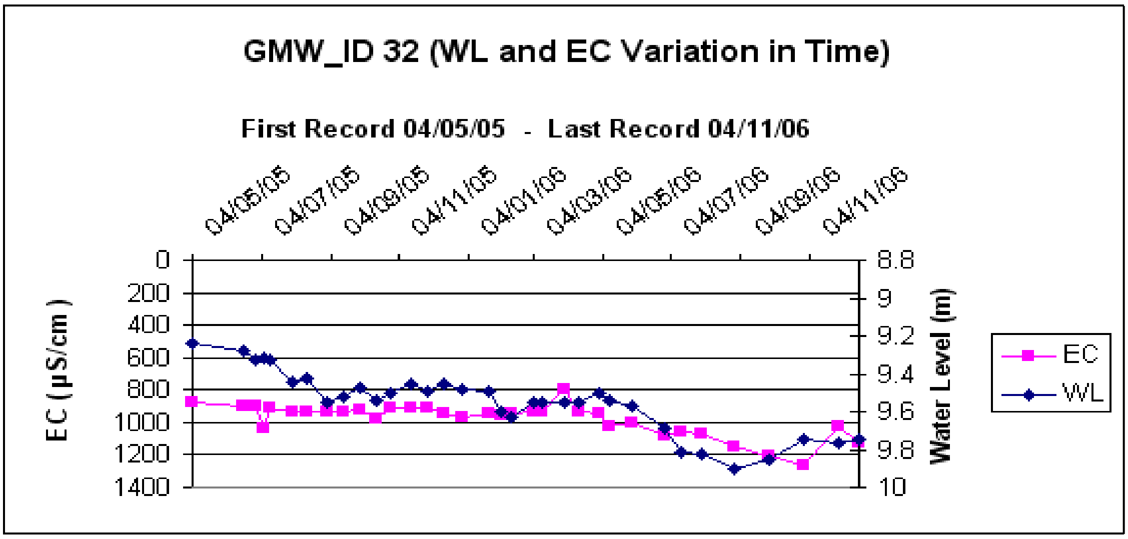

GMW_ID 32 (WL and EC Variation in Time)
First Record 04/05/05 - Last Record 04/11/06
04/05/05
04/07/05
04/09/05
04/11/05
04/01/06
04/03/06
04/05/06
04/07/06
04/09/06
04/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
Water Level (m)
8.8
9
9.2
9.4
9.6
9.8
10
EC
WL

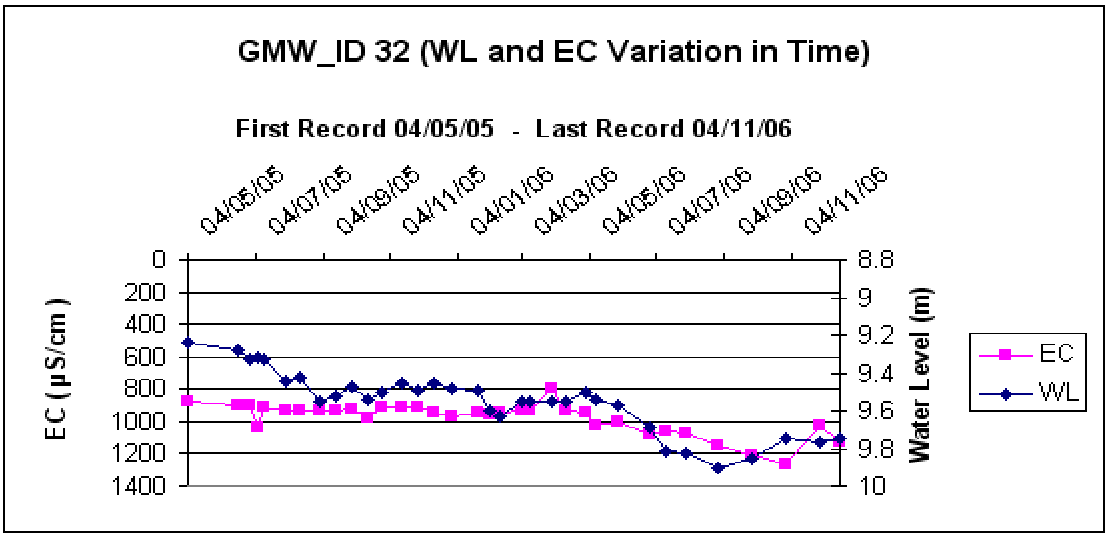

GMW_ID 31 (WL and EC Variation in Time)
First Record 04/05/05 - Last Record 04/11/06
04/05/05
04/07/05
04/09/05
04/11/05
04/01/06
04/03/06
04/05/06
04/07/06
04/09/06
04/11/06
EC (µS/cm)
740
760
780
800
820
840
860
Water Level (m)
13.5
14
14.5
15
15.5
16
16.5
17
17.5
18
EC
WL

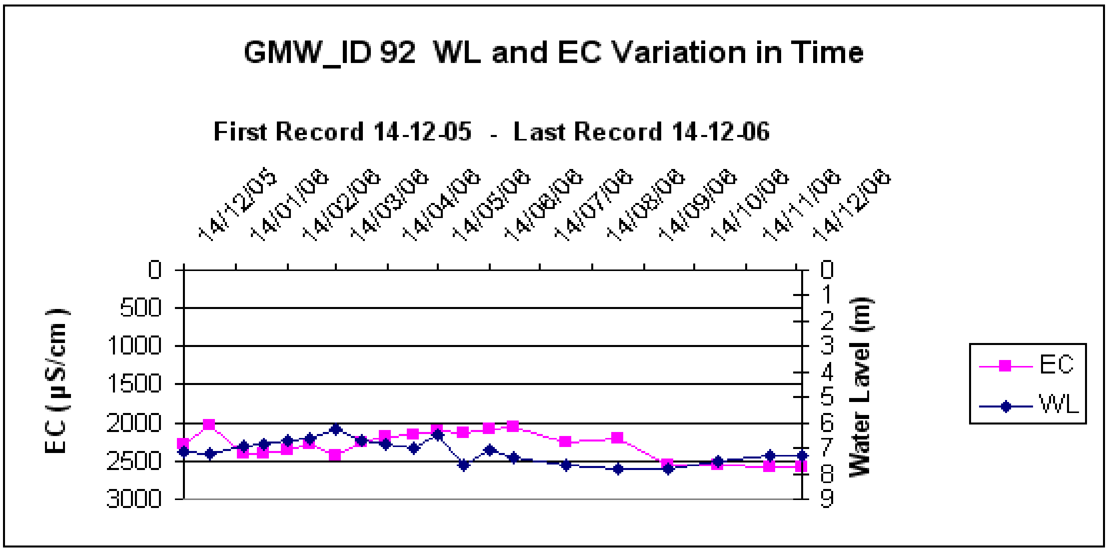

GMW_ID 3 (WL and EC Variation in Time)
First Record 06/06/05 - Last Record 06/12/06
06/06/05
06/08/05
06/10/05
06/12/05
06/02/06
06/04/06
06/06/06
06/08/06
06/10/06
06/12/06
EC (µS/cm)
0
200
400
600
800
1000
1200
Water Level (m)
4.6
4.8
5
5.2
5.4
5.6
5.8
6
6.2
6.4
EC
WL

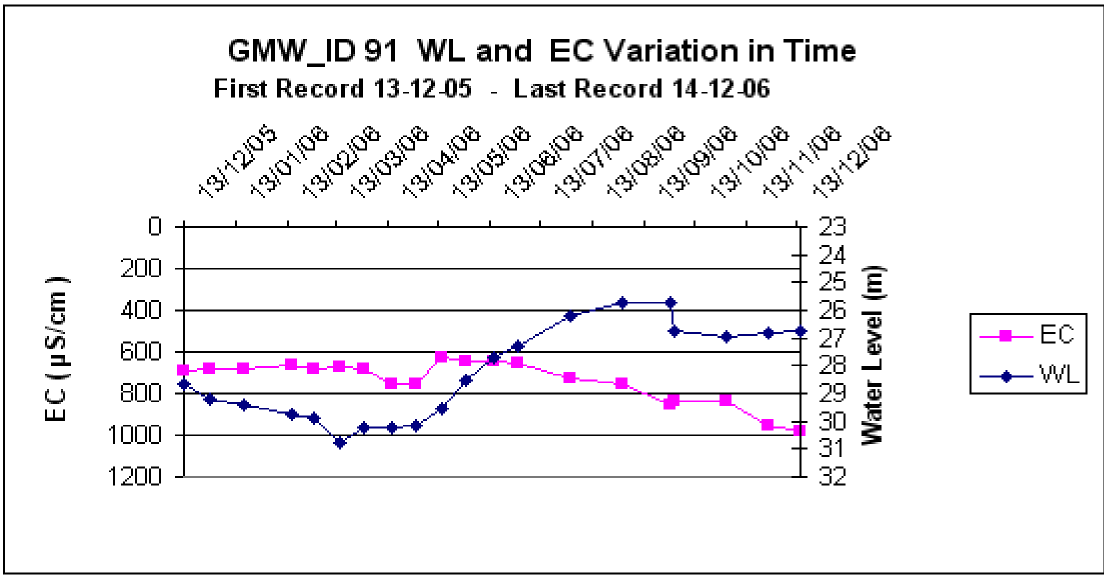

GMW_ID 94 WL and EC Variation in Time
First Record 14-12-05 - Last Record 14-11-06
14/12/05
14/01/06
14/02/06
14/03/06
14/04/06
14/05/06
14/06/06
14/07/06
14/08/06
14/09/06
14/10/06
14/11/06
EC (µS/cm)
2700
2900
3100
3300
3500
3700
Water Level (m)
36.5
37
37.5
38
38.5
39
39.5
40
EC
WL

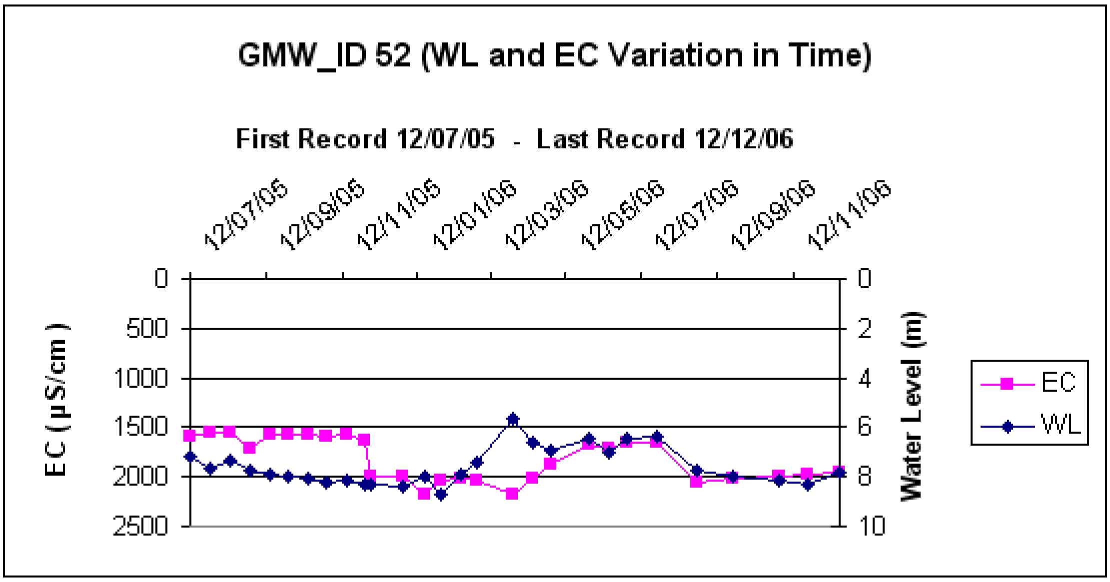

GMW_ID 93 WL and EC Variation in Time
First Record 14-12-05 - Last Record 14-12-06
14/12/05
14/02/06
14/04/06
14/06/06
14/08/06
14/10/06
14/12/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
Water Level (m)
22.8
23
23.2
23.4
23.6
23.8
24
EC
WL

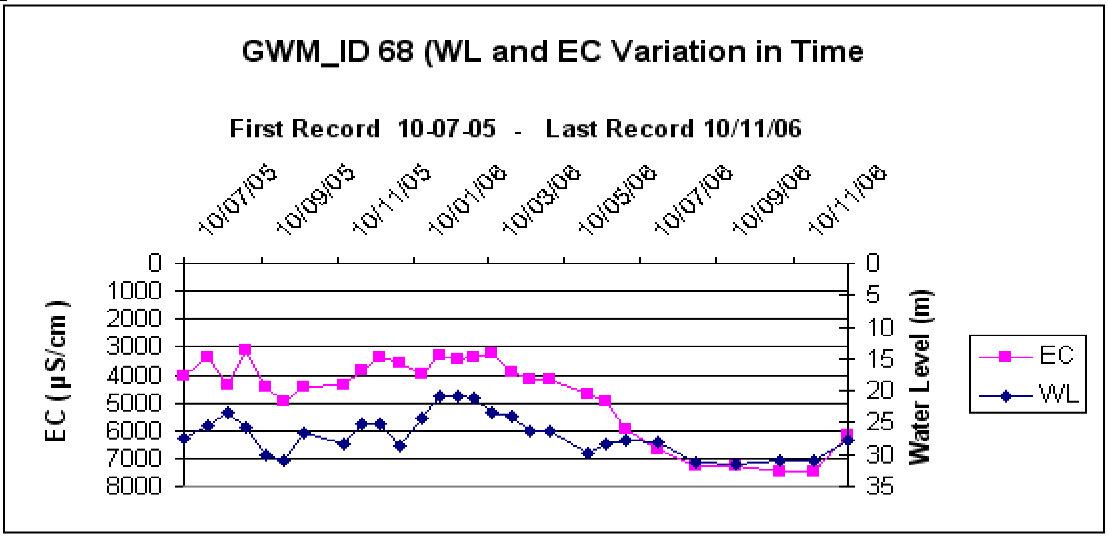

GMW_ID 32 (WL and EC Variation in Time)
First Record 04/05/05 - Last Record 04/11/06
04/05/05
04/07/05
04/09/05
04/11/05
04/01/06
04/03/06
04/05/06
04/07/06
04/09/06
04/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
Water Level (m)
8.8
9
9.2
9.4
9.6
9.8
10
EC
WL

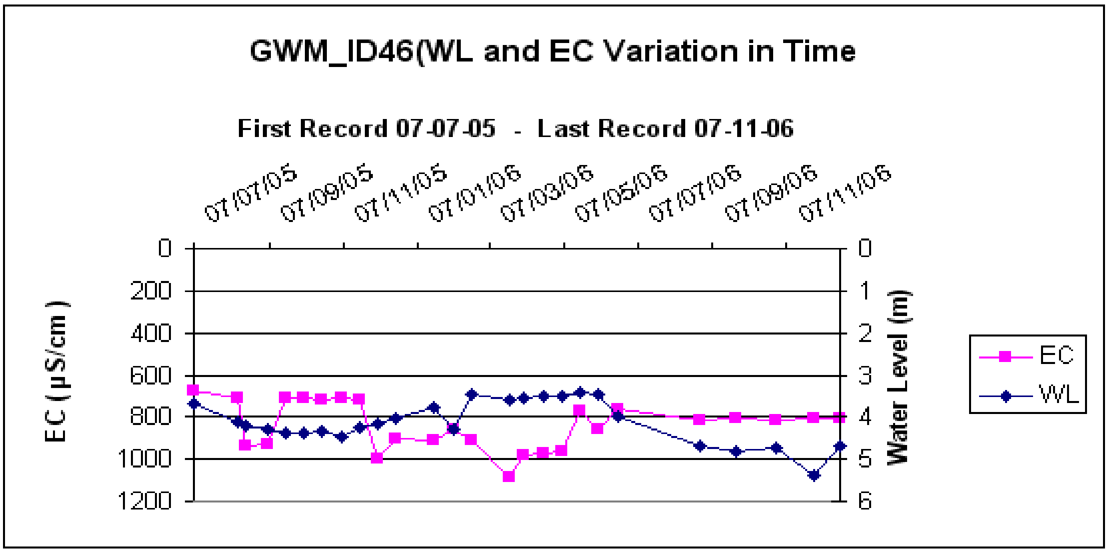

GMW_ID 32 (WL and EC Variation in Time)
First Record 04/05/05 - Last Record 04/11/06
04/05/05
04/07/05
04/09/05
04/11/05
04/01/06
04/03/06
04/05/06
04/07/06
04/09/06
04/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
Water Level (m)
8.8
9
9.2
9.4
9.6
9.8
10
EC
WL

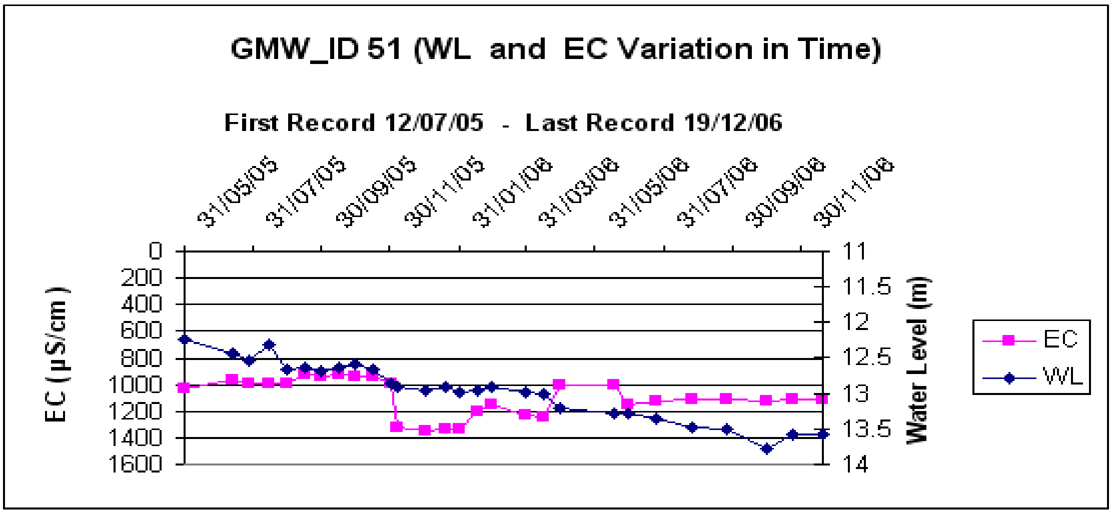

GMW_ID 92 WL and EC Variation in Time
First Record 14-12-05 - Last Record 14-12-06
14/12/05
14/01/06
14/02/06
14/03/06
14/04/06
14/05/06
14/06/06
14/07/06
14/08/06
14/09/06
14/10/06
14/11/06
14/12/06
EC (µS/cm)
0
500
1000
1500
2000
2500
3000
Water Lavel (m)
0
1
2
3
4
5
6
7
8
9
EC
WL

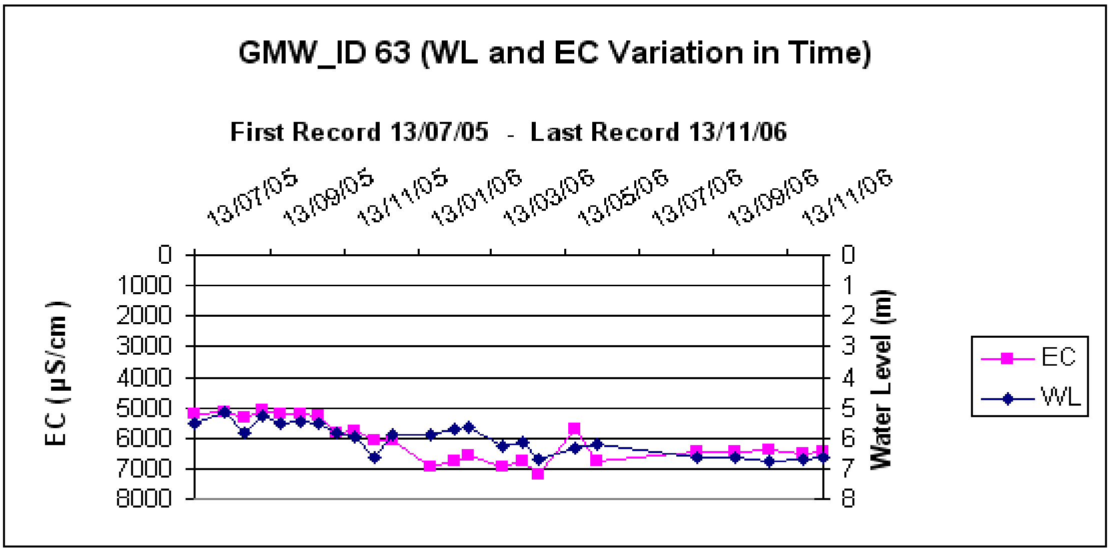

GMW_ID 91 WL and EC Variation in Time
First Record 13-12-05 - Last Record 14-12-06
13/12/05
13/01/06
13/02/06
13/03/06
13/04/06
13/05/06
13/06/06
13/07/06
13/08/06
13/09/06
13/10/06
13/11/06
13/12/06
EC (µS/cm)
0
200
400
600
800
1000
1200
Water Level (m)
23
24
25
26
27
28
29
30
31
32
EC
WL

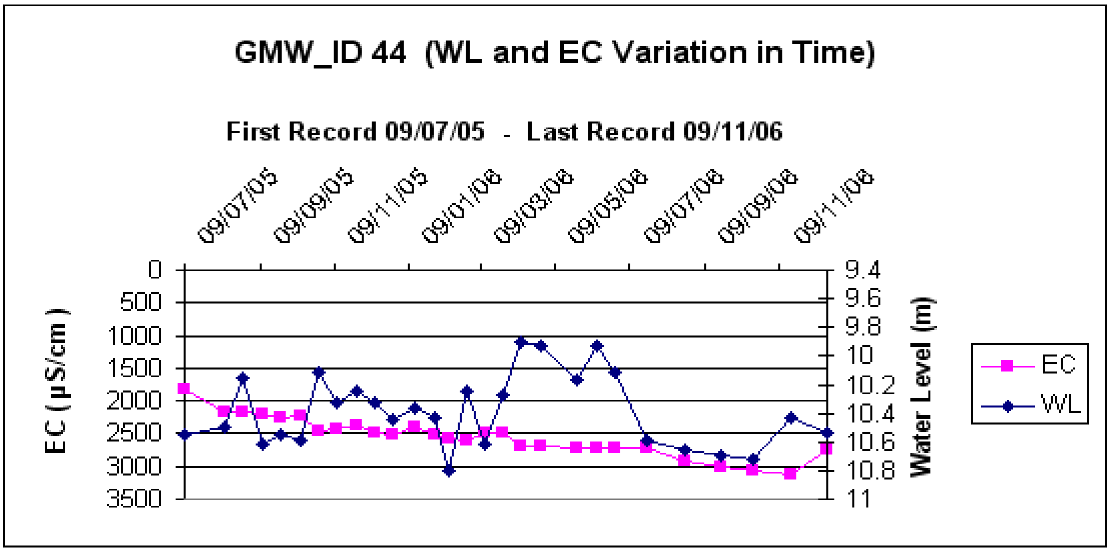

GMW_ID 52 (WL and EC Variation in Time)
First Record 12/07/05 - Last Record 12/12/06
12/07/05
12/09/05
12/11/05
12/01/06
12/03/06
12/05/06
12/07/06
12/09/06
12/11/06
EC (µS/cm)
0
500
1000
1500
2000
2500
Water Level (m)
0
2
4
6
8
10
EC
WL

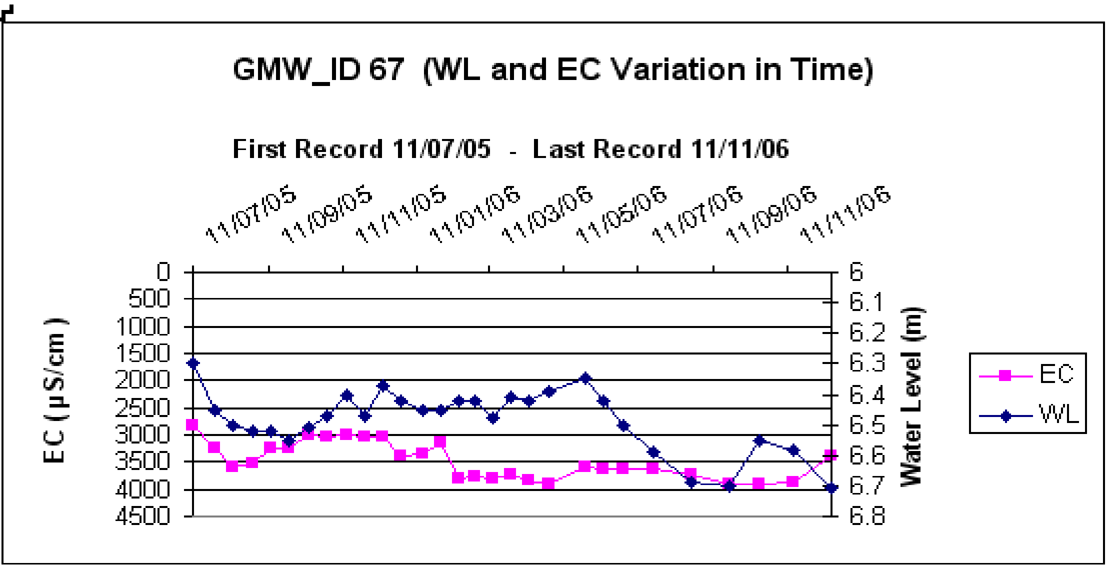

GWM_ID 68 (WL and EC Variation in Time
First Record 10-07-05 - Last Record 10/11/06
10/07/05
10/09/05
10/11/05
10/01/06
10/03/06
10/05/06
10/07/06
10/09/06
10/11/06
EC (µS/cm)
0
1000
2000
3000
4000
5000
6000
7000
8000
Water Level (m)
0
5
10
15
20
25
30
35
EC
WL

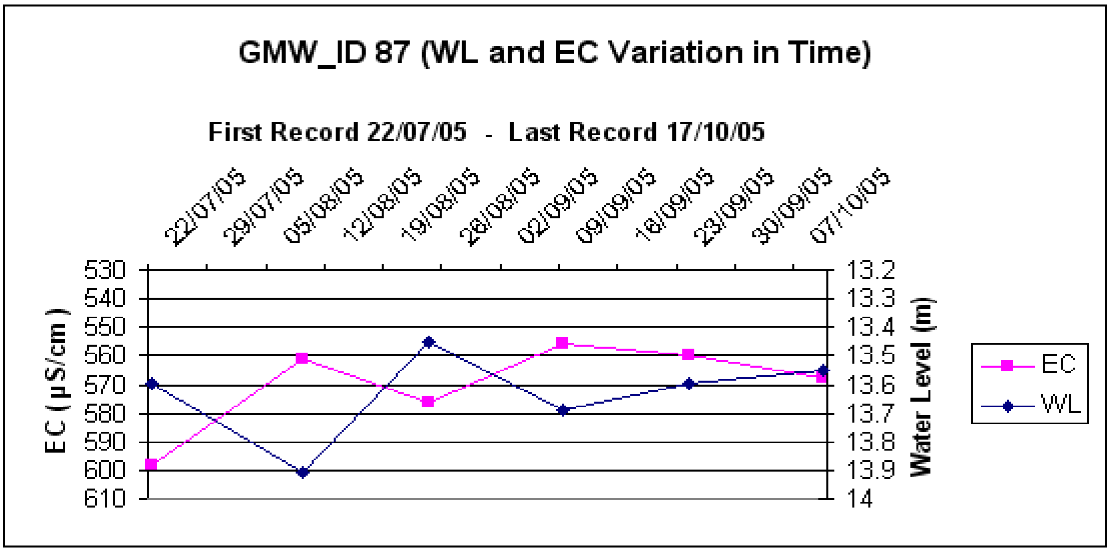

GWM_ID46(WL and EC Variation in Time
First Record 07-07-05 - Last Record 07-11-06
07/07/05
07/09/05
07/11/05
07/01/06
07/03/06
07/05/06
07/07/06
07/09/06
07/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
Water Level (m)
0
1
2
3
4
5
6
EC
WL

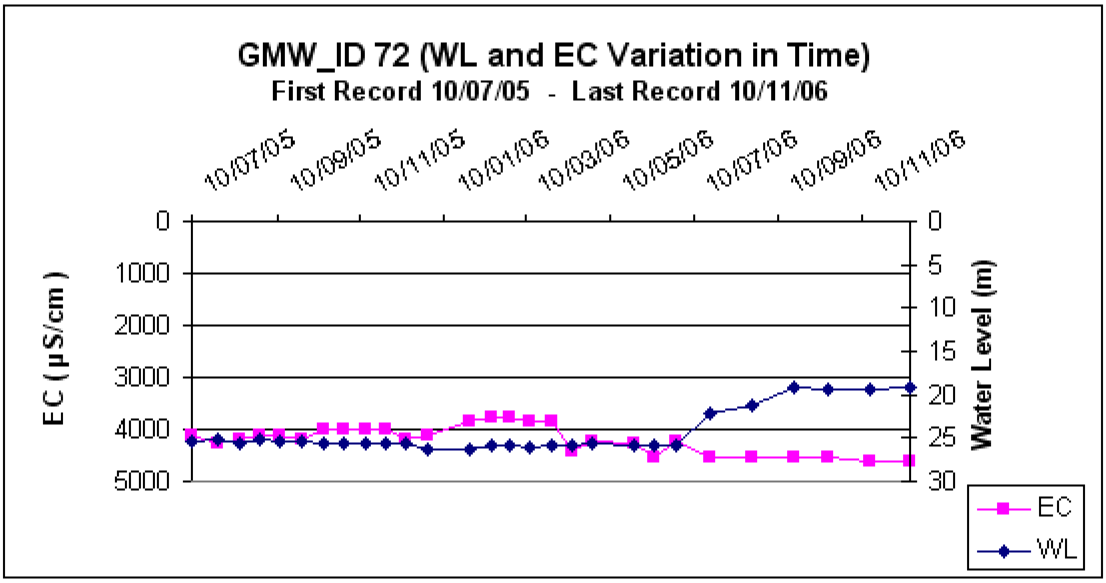

GMW_ID 51 (WL and EC Variation in Time)
First Record 12/07/05 - Last Record 19/12/06
31/05/05
31/07/05
30/09/05
30/11/05
31/01/06
31/03/06
31/05/06
31/07/06
30/09/06
30/11/06
EC (µS/cm)
Water Level (m)
0
200
400
600
800
1000
1200
1400
1600
11
11.5
12
12.5
13
13.5
14
EC
WL

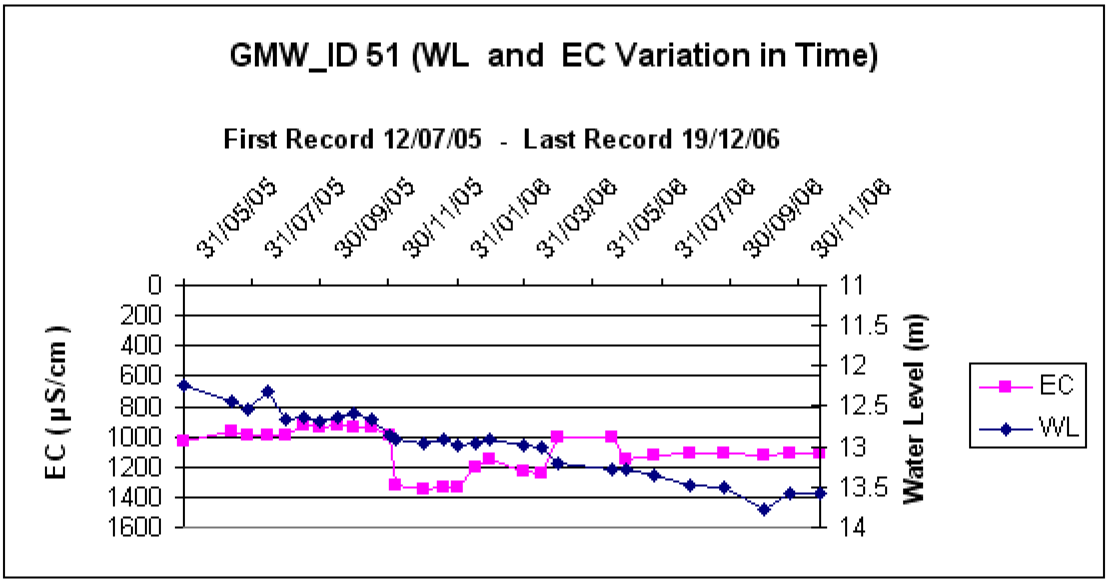

GMW_ID 63 (WL and EC Variation in Time)
First Record 13/07/05 - Last Record 13/11/06
13/07/05
13/09/05
13/11/05
13/01/06
13/03/06
13/05/06
13/07/06
13/09/06
13/11/06
EC (µS/cm)
Water Level (m)
0
1000
2000
3000
4000
5000
6000
7000
8000
0
1
2
3
4
5
6
7
8
EC
WL

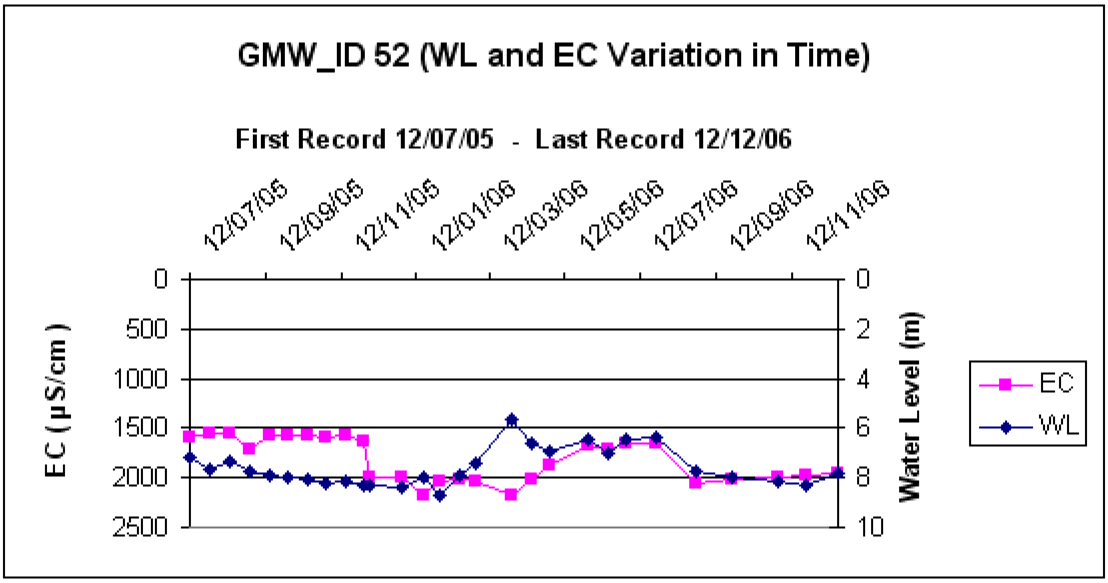

GMW_ID 44 (WL and EC Variation in Time)
First Record 09/07/05 - Last Record 09/11/06
09/07/05
09/09/05
09/11/05
09/01/06
09/03/06
09/05/06
09/07/06
09/09/06
09/11/06
EC (µS/cm)
Water Level (m)
0
500
1000
1500
2000
2500
3000
3500
9.4
9.6
9.8
10
10.2
10.4
10.6
10.8
11
EC
WL

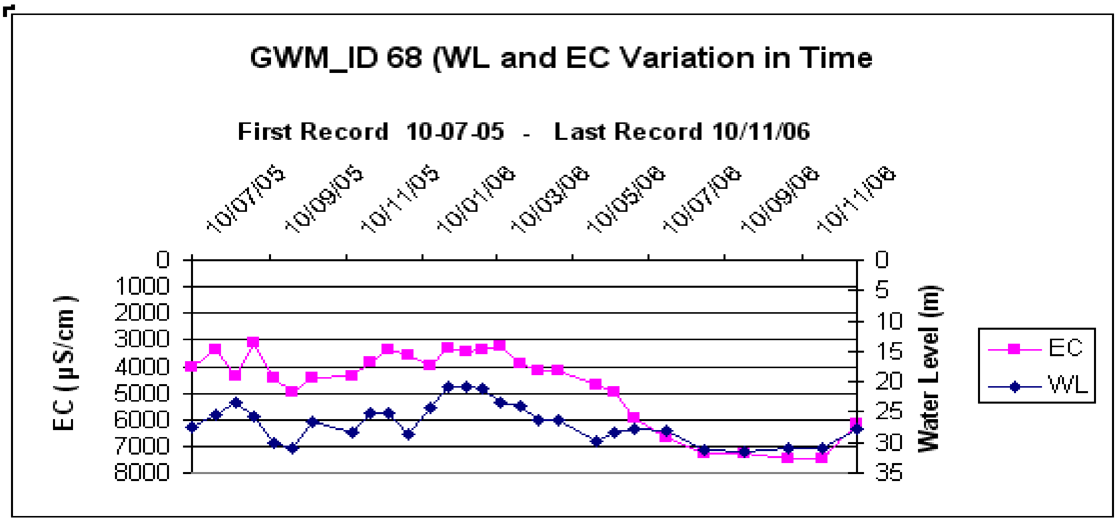

GMW_ID 67 (WL and EC Variation in Time)
First Record 11/07/05 - Last Record 11/11/06
11/07/05
11/09/05
11/11/05
11/01/06
11/03/06
11/05/06
11/07/06
11/09/06
11/11/06
0
500
1000
1500
2000
2500
3000
3500
4000
4500
EC (µS/cm)
6
6.1
6.2
6.3
6.4
6.5
6.6
6.7
6.8
Water Level (m)
EC
WL

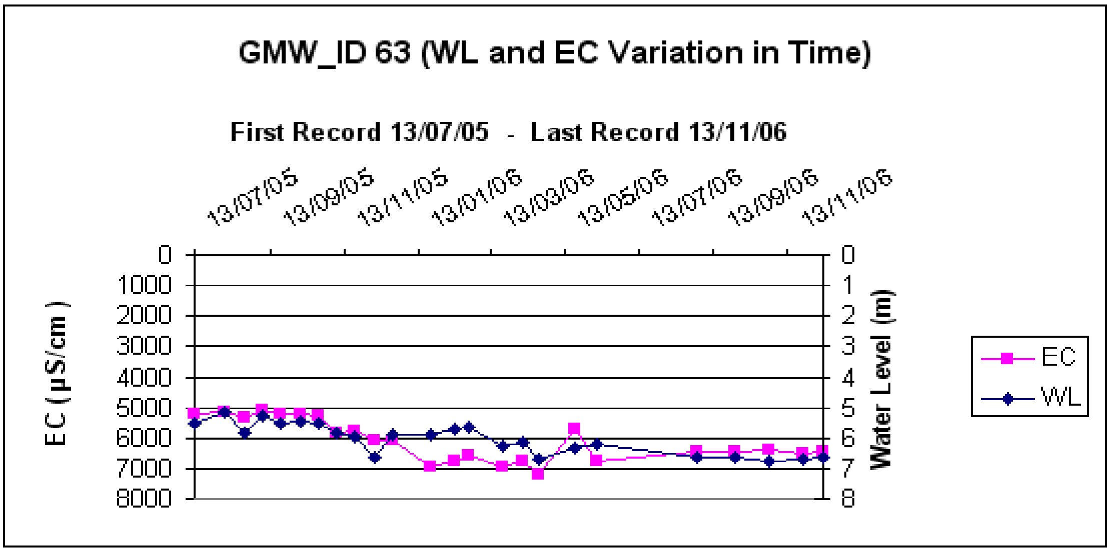

GMW_ID 87 (WL and EC Variation in Time)
First Record 22/07/05 - Last Record 17/10/05
22/07/05
29/07/05
05/08/05
12/08/05
19/08/05
26/08/05
02/09/05
09/09/05
16/09/05
23/09/05
30/09/05
07/10/05
530
540
550
560
570
580
590
600
610
EC (µS/cm)
13.2
13.3
13.4
13.5
13.6
13.7
13.8
13.9
14
Water Level (m)
EC
WL

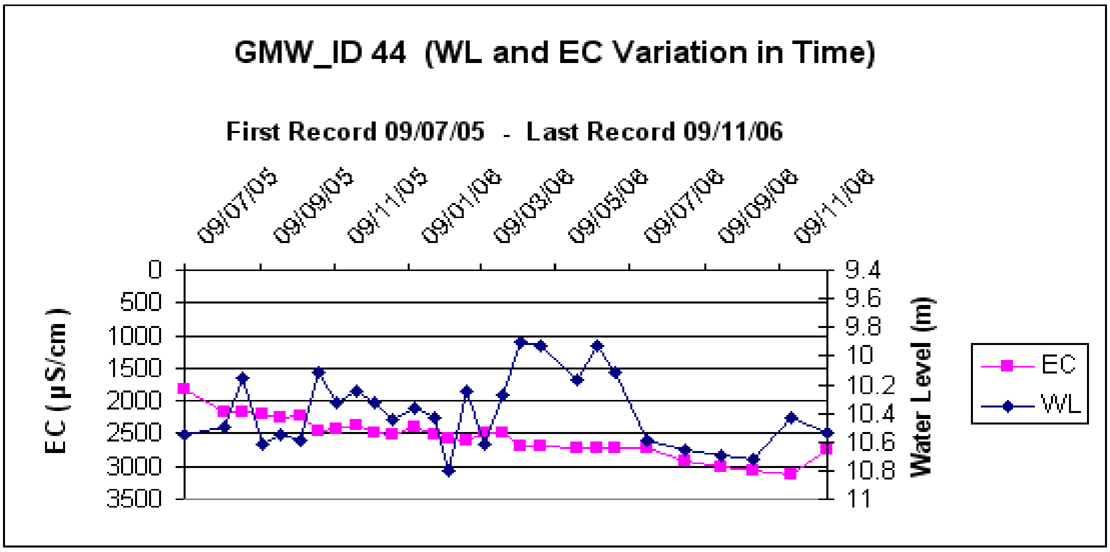

GMW_ID 72 (WL and EC Variation in Time)
First Record 10/07/05 - Last Record 10/11/06
10/07/05
10/09/05
10/11/05
10/01/06
10/03/06
10/05/06
10/07/06
10/09/06
10/11/06
0
1000
2000
3000
4000
5000
EC (µS/cm)
0
5
10
15
20
25
30
Water Level (m)
EC
WL

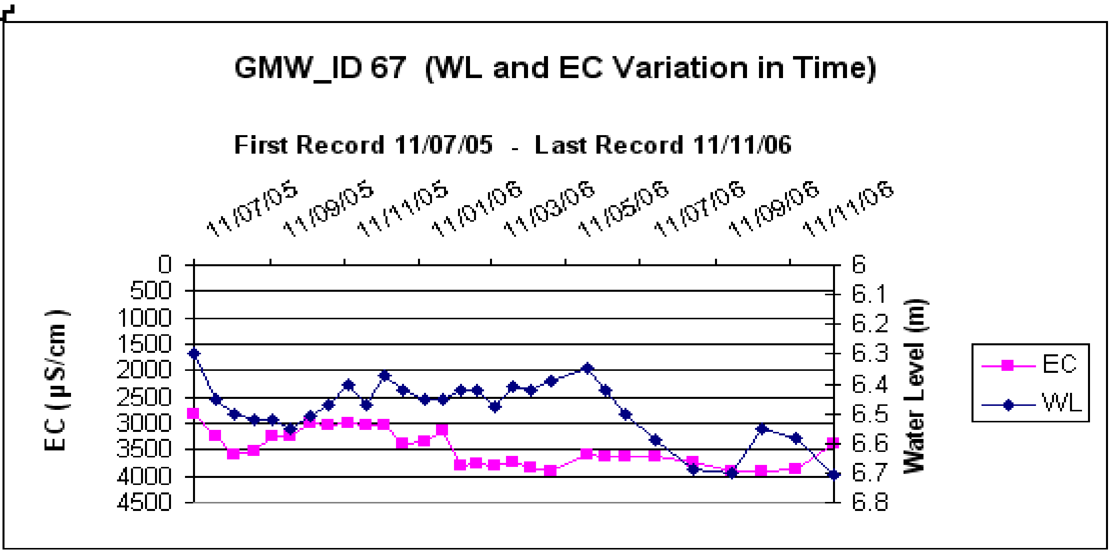

GMW_ID 51 (WL and EC Variation in Time)
First Record 12/07/05 - Last Record 19/12/06
31/05/05
31/07/05
30/09/05
30/11/05
31/01/06
31/03/06
31/05/06
31/07/06
30/09/06
30/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
1600
Water Level (m)
11
11.5
12
12.5
13
13.5
14
EC
WL

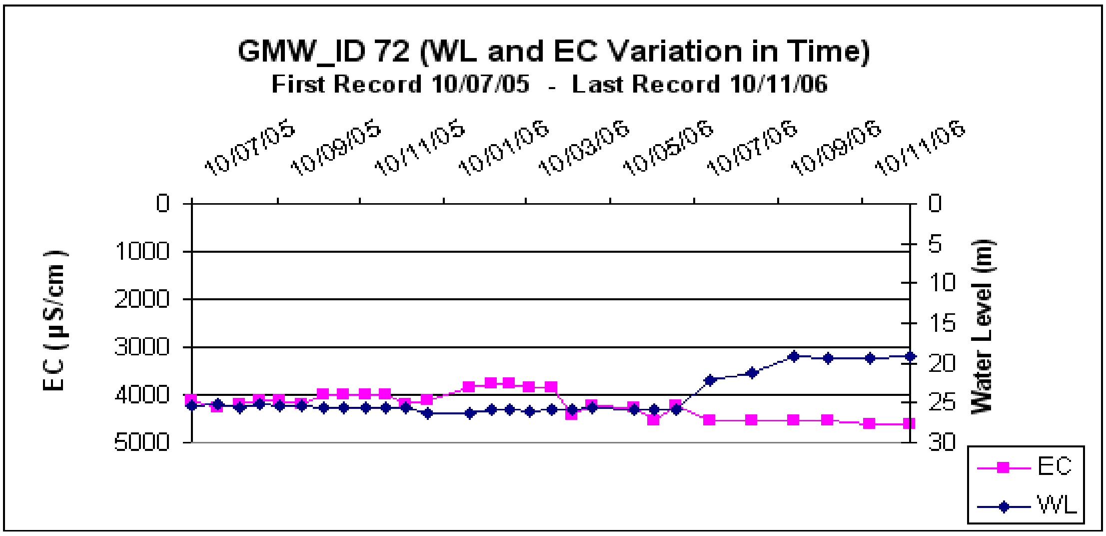

GMW_ID 52 (WL and EC Variation in Time)
First Record 12/07/05 - Last Record 12/12/06
12/07/05
12/09/05
12/11/05
12/01/06
12/03/06
12/05/06
12/07/06
12/09/06
12/11/06
EC (µS/cm)
0
500
1000
1500
2000
2500
Water Level (m)
0
2
4
6
8
10
EC
WL

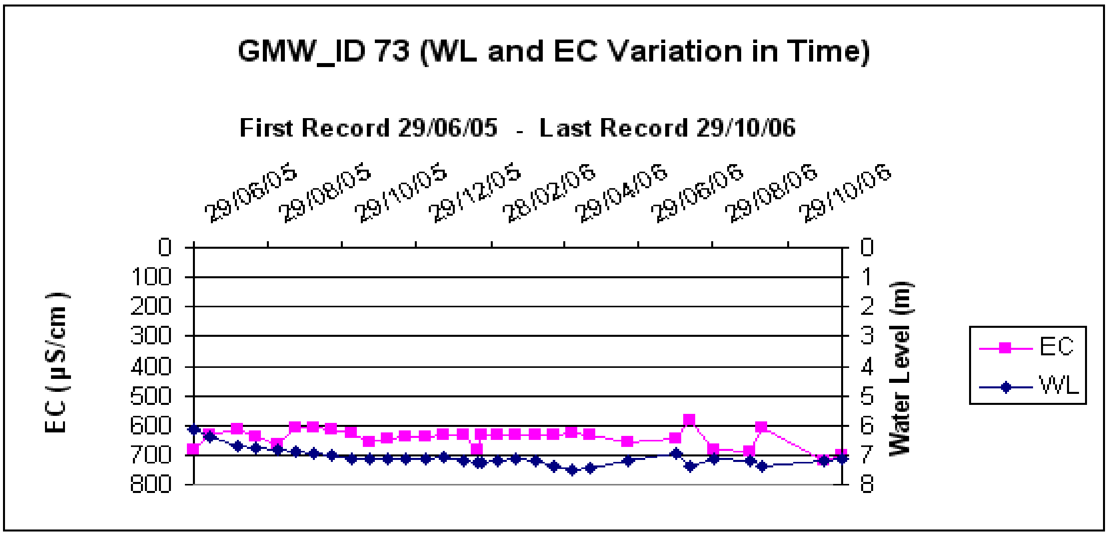

GWM_ID 68 (WL and EC Variation in Time
First Record 10-07-05 - Last Record 10/11/06
10/07/05
10/09/05
10/11/05
10/01/06
10/03/06
10/05/06
10/07/06
10/09/06
10/11/06
EC (µS/cm)
0
1000
2000
3000
4000
5000
6000
7000
8000
Water Level (m)
0
5
10
15
20
25
30
35
EC
WL

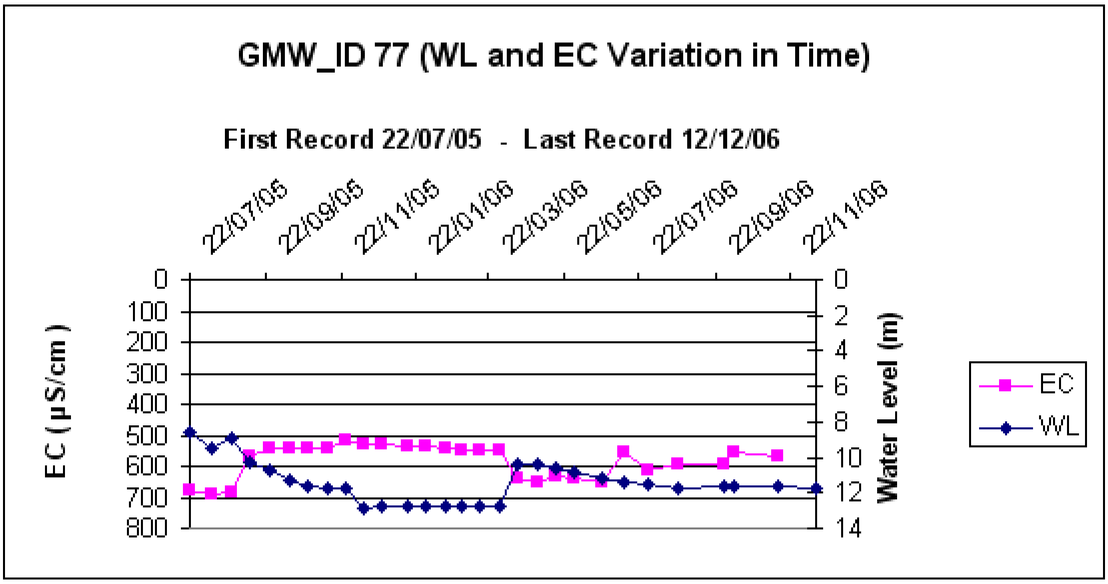

GMW_ID 63 (WL and EC Variation in Time)
First Record 13/07/05 - Last Record 13/11/06
13/07/05
13/09/05
13/11/05
13/01/06
13/03/06
13/05/06
13/07/06
13/09/06
13/11/06
EC (µS/cm)
Water Level (m)
EC
WL

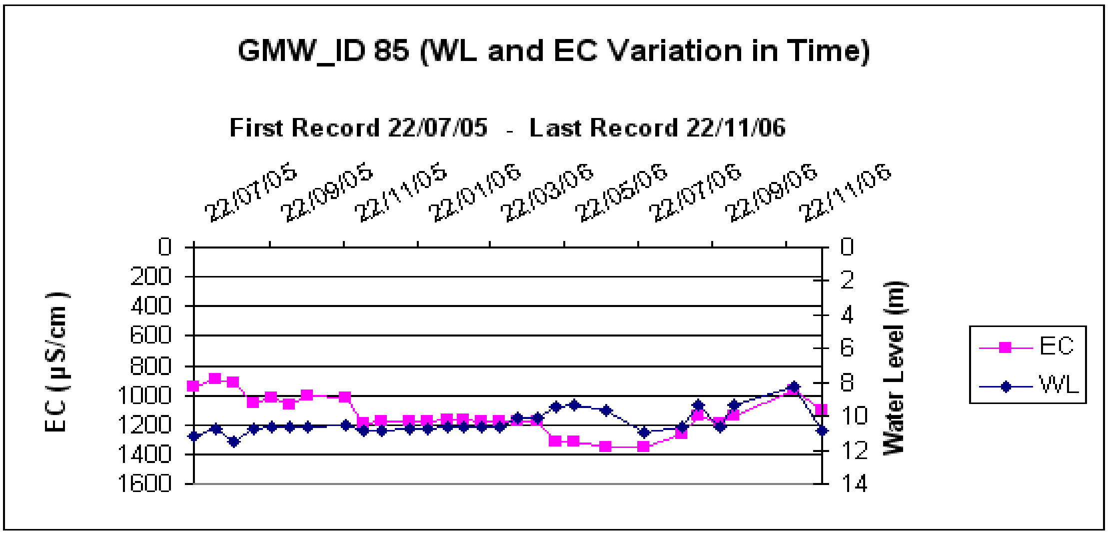

GMW_ID 44 (WL and EC Variation in Time)
First Record 09/07/05 - Last Record 09/11/06
09/07/05
09/09/05
09/11/05
09/01/06
09/03/06
09/05/06
09/07/06
09/09/06
09/11/06
EC (µS/cm)
Water Level (m)
EC
WL

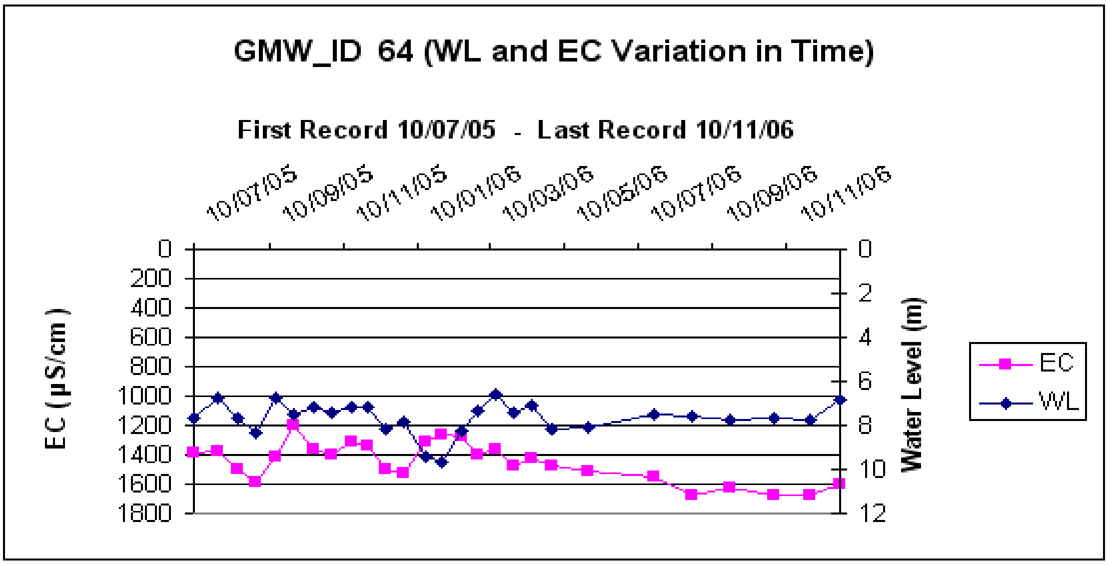

GMW_ID 67 (WL and EC Variation in Time)
First Record 11/07/05 - Last Record 11/11/06
11/07/05
11/09/05
11/11/05
11/01/06
11/03/06
11/05/06
11/07/06
11/09/06
11/11/06
EC (µS/cm)
Water Level (m)
EC
WL

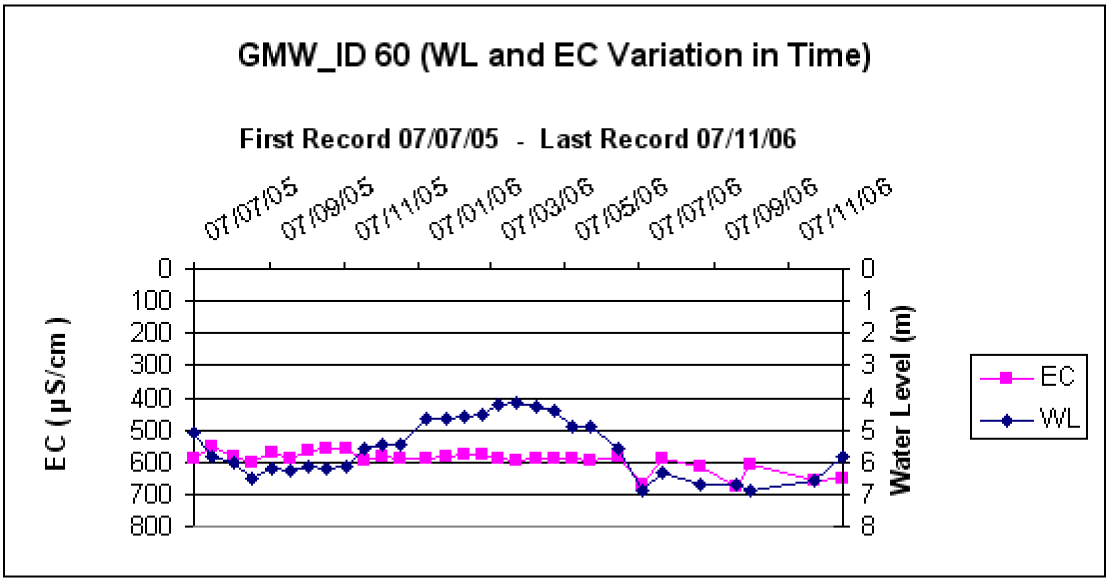

GMW_ID 72 (WL and EC Variation in Time)
First Record 10/07/05 - Last Record 10/11/06
10/07/05
10/09/05
10/11/05
10/01/06
10/03/06
10/05/06
10/07/06
10/09/06
10/11/06
EC (µS/cm)
0
1000
2000
3000
4000
5000
Water Level (m)
0
5
10
15
20
25
30
EC
WL

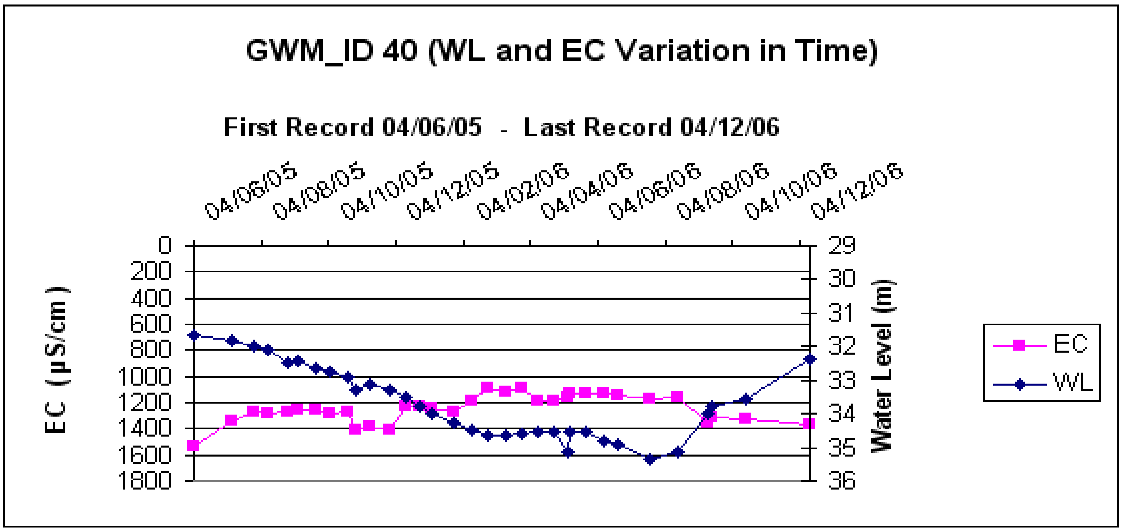

GMW_ID 73 (WL and EC Variation in Time)
First Record 29/06/05 - Last Record 29/10/06
29/06/05
29/08/05
29/10/05
29/12/05
28/02/06
29/04/06
29/06/06
29/08/06
29/10/06
EC (µS/cm)
0
100
200
300
400
500
600
700
800
Water Level (m)
0
1
2
3
4
5
6
7
8
EC
WL

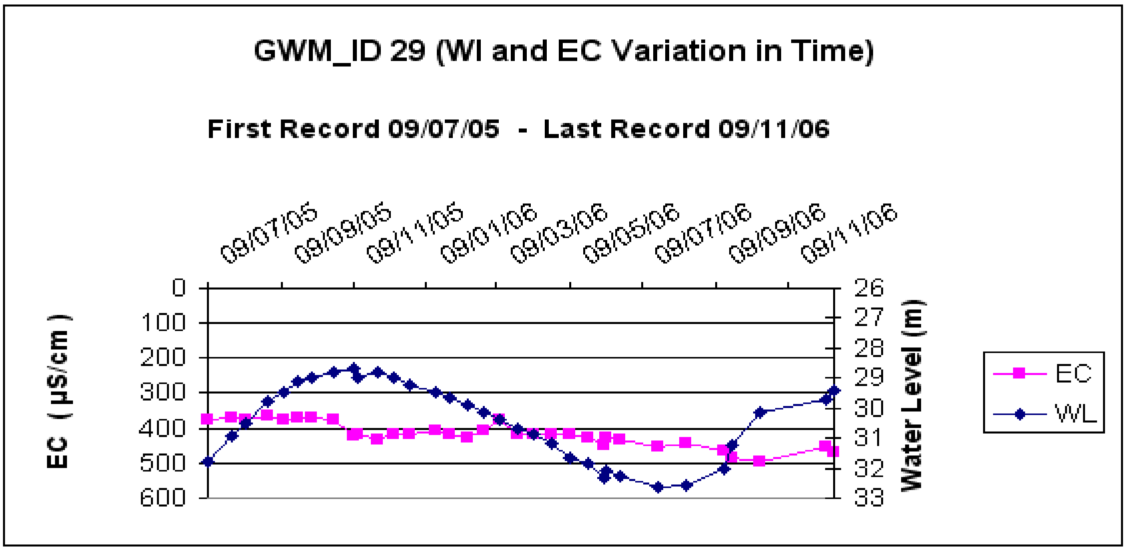

GMW_ID 77 (WL and EC Variation in Time)
First Record 22/07/05 - Last Record 12/12/06
22/07/05
22/09/05
22/11/05
22/01/06
22/03/06
22/05/06
22/07/06
22/09/06
22/11/06
EC (µS/cm)
0
100
200
300
400
500
600
700
800
Water Level (m)
0
2
4
6
8
10
12
14
EC
WL

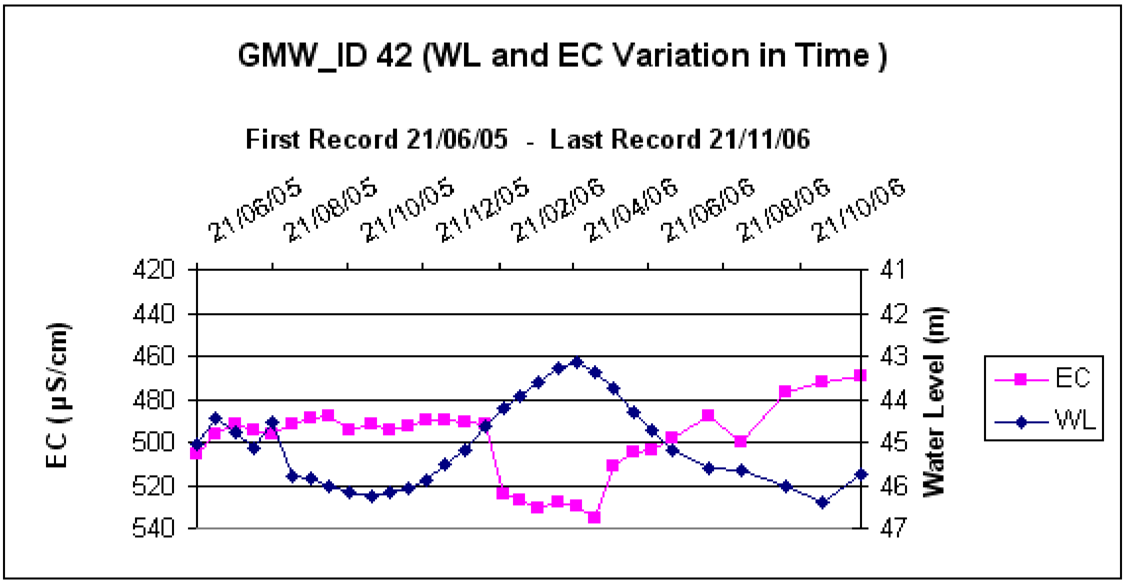

GMW_ID 85 (WL and EC Variation in Time)
First Record 22/07/05 - Last Record 22/11/06
22/07/05
22/09/05
22/11/05
22/01/06
22/03/06
22/05/06
22/07/06
22/09/06
22/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
1600
Water Level (m)
0
2
4
6
8
10
12
14
EC
WL

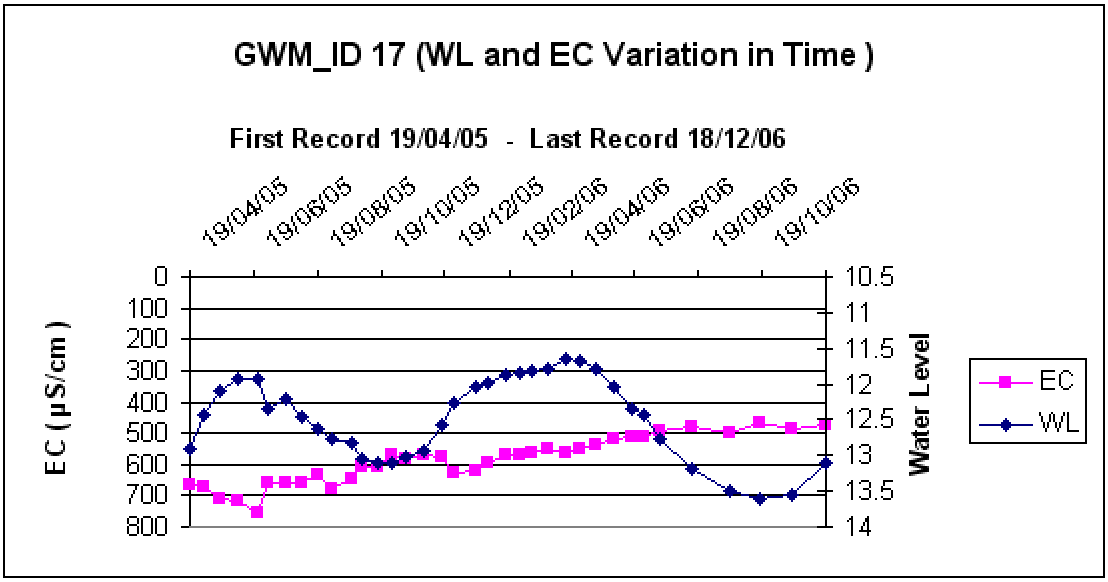

GMW_ID 64 (WL and EC Variation in Time)
First Record 10/07/05 - Last Record 10/11/06
10/07/05
10/09/05
10/11/05
10/01/06
10/03/06
10/05/06
10/07/06
10/09/06
10/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
1600
1800
Water Level (m)
0
2
4
6
8
10
12
EC
WL

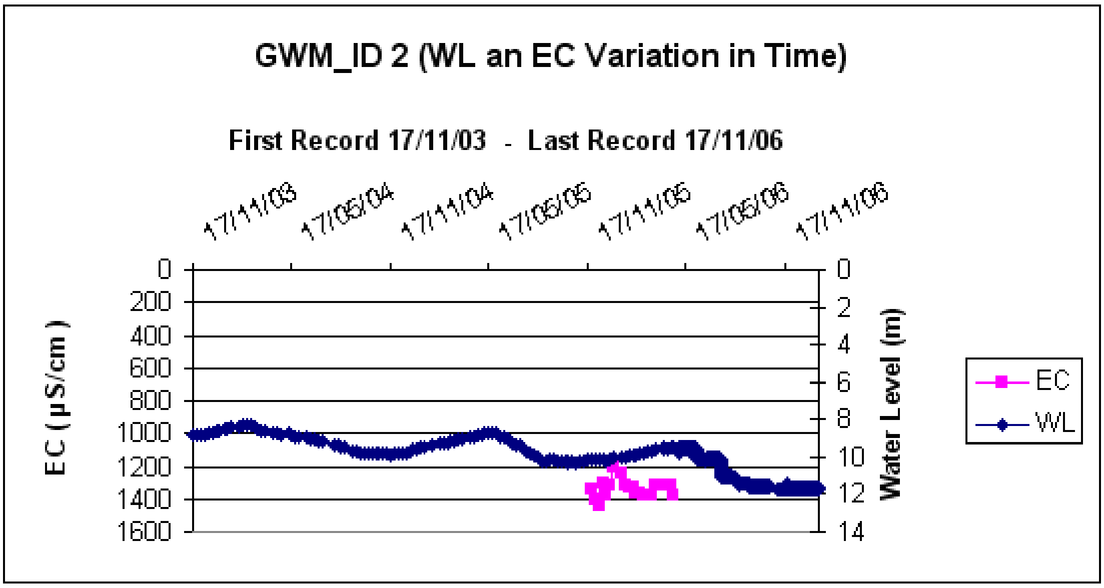

GMW_ID 60 (WL and EC Variation in Time)
First Record 07/07/05 - Last Record 07/11/06
07/07/05
07/09/05
07/11/05
07/01/06
07/03/06
07/05/06
07/07/06
07/09/06
07/11/06
EC (µS/cm)
0
100
200
300
400
500
600
700
800
Water Level (m)
0
1
2
3
4
5
6
7
8
EC
WL

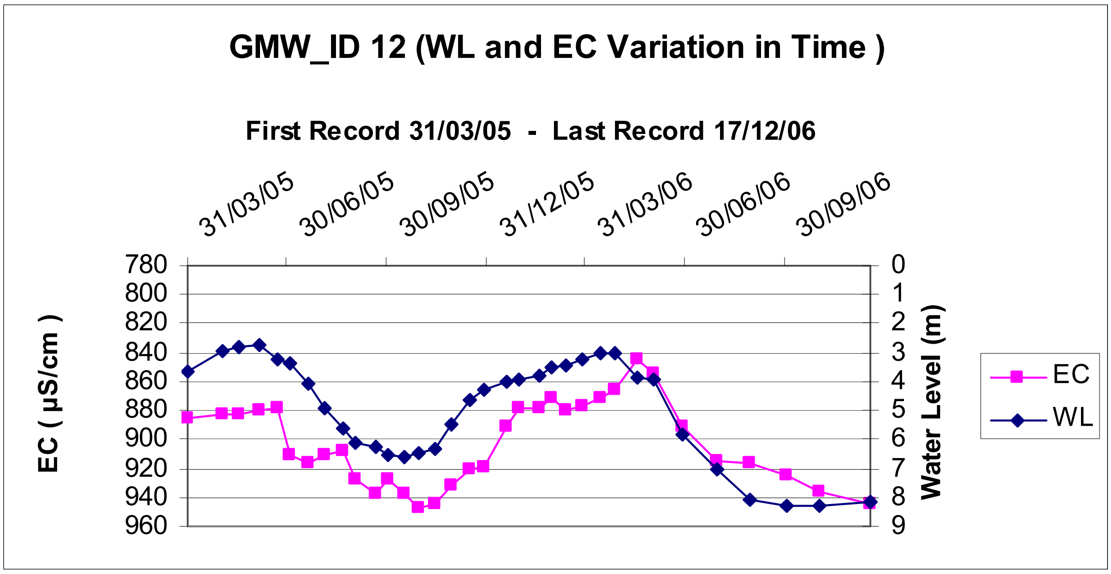

GWM_ID 40 (WL and EC Variation in Time)
First Record 04/06/05 - Last Record 04/12/06
04/06/05
04/08/05
04/10/05
04/12/05
04/02/06
04/04/06
04/06/06
04/08/06
04/10/06
04/12/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
1600
1800
Water Level (m)
29
30
31
32
33
34
35
36
EC
WL

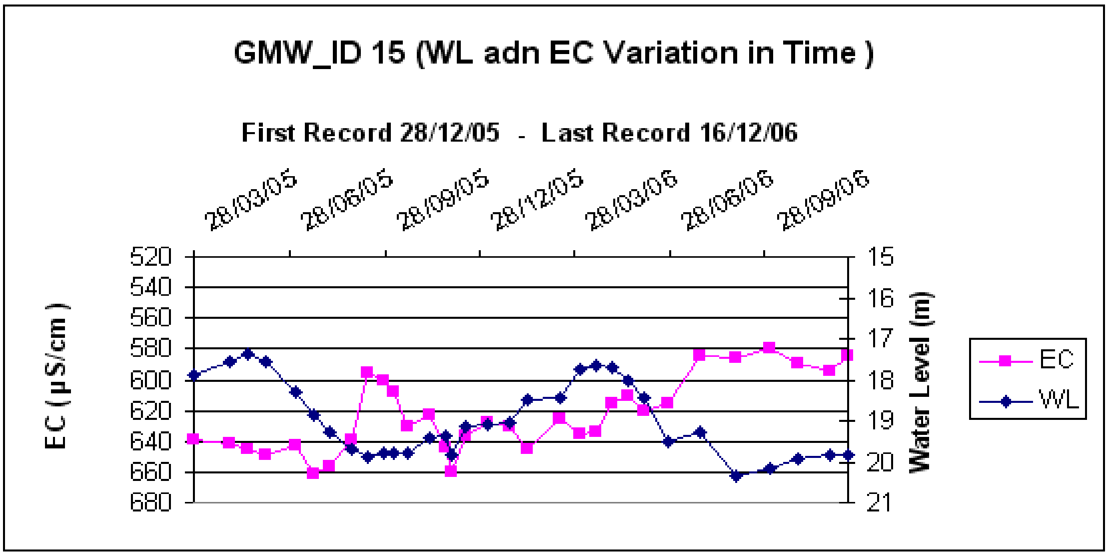

GWM_ID 29 (Wl and EC Variation in Time)
First Record 09/07/05 - Last Record 09/11/06
09/07/05
09/09/05
09/11/05
09/01/06
09/03/06
09/05/06
09/07/06
09/09/06
09/11/06
EC (µS/cm)
0
100
200
300
400
500
600
Water Level (m)
26
27
28
29
30
31
32
33
EC
WL

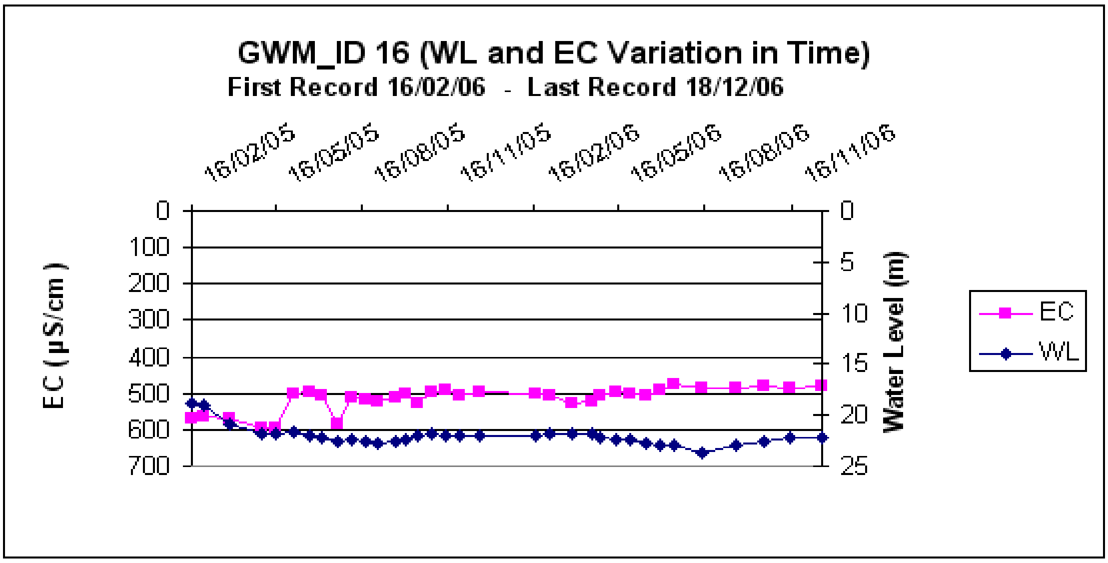

GMW_ID 42 (WL and EC Variation in Time)
First Record 21/06/05 - Last Record 21/11/06
21/06/05
21/08/05
21/10/05
21/12/05
21/02/06
21/04/06
21/06/06
21/08/06
21/10/06
EC (µS/cm)
420
440
460
480
500
520
540
Water Level (m)
41
42
43
44
45
46
47
EC
WL

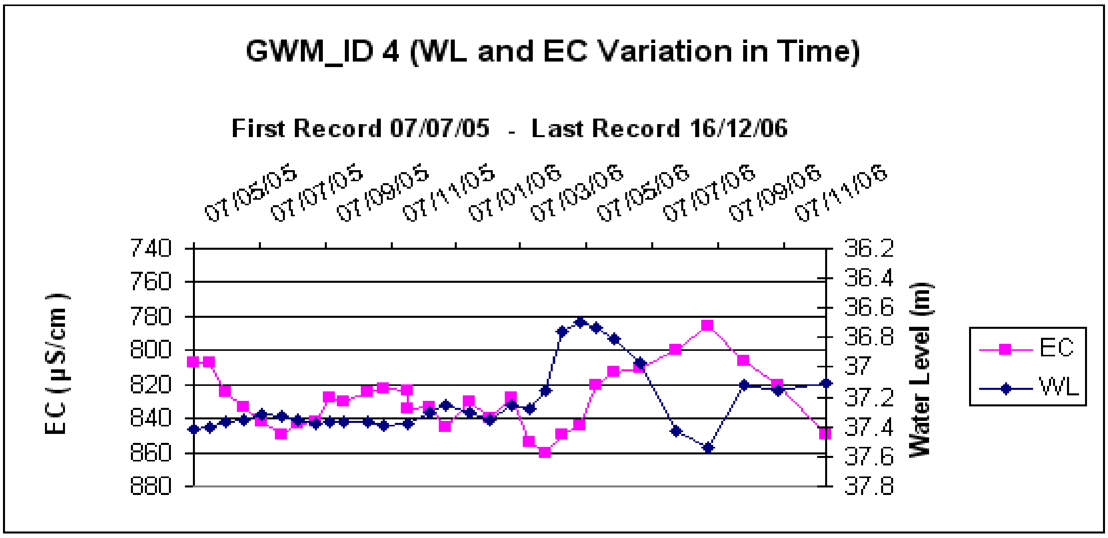

GWM_ID 17 (WL and EC Variation in Time)
First Record 19/04/05 - Last Record 18/12/06
19/04/05
19/06/05
19/08/05
19/10/05
19/12/05
19/02/06
19/04/06
19/06/06
19/08/06
19/10/06
EC (µS/cm)
0
100
200
300
400
500
600
700
800
Water Level
10.5
11
11.5
12
12.5
13
13.5
14
EC
WL

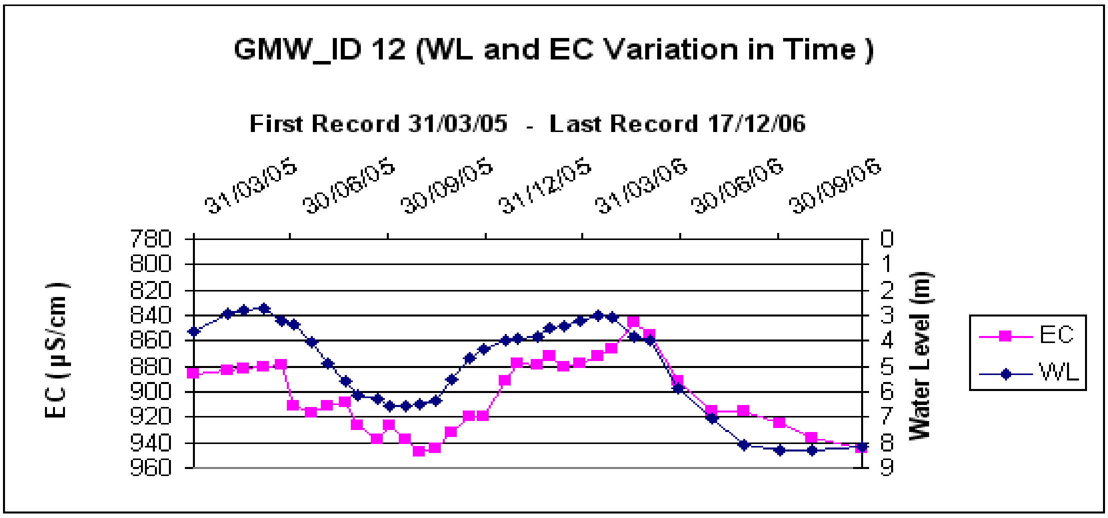

GWM_ID 2 (WL an EC Variation in Time)
First Record 17/11/03 - Last Record 17/11/06
17/11/03
17/05/04
17/11/04
17/05/05
17/11/05
17/05/06
17/11/06
EC (µS/cm)
0
200
400
600
800
1000
1200
1400
1600
Water Level (m)
0
2
4
6
8
10
12
14
EC
WL

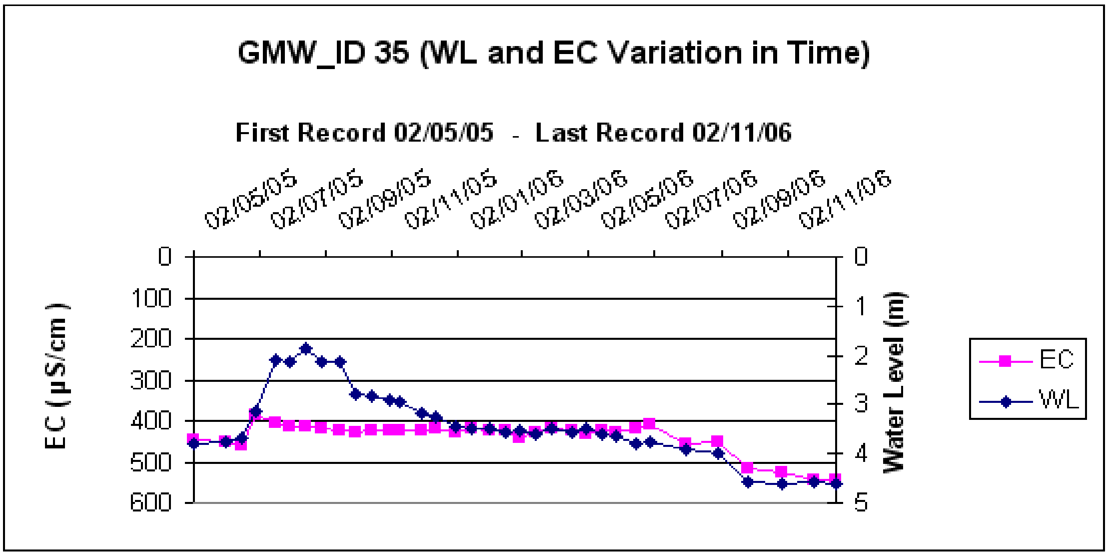

GMW_ID 12 (WL and EC Variation in Time)
First Record 31/03/05 - Last Record 17/12/06
31/03/05
30/06/05
30/09/05
31/12/05
31/03/06
30/06/06
30/09/06
EC (µS/cm)
780
800
820
840
860
880
900
920
940
960
Water Level (m)
0
1
2
3
4
5
6
7
8
9
EC
WL

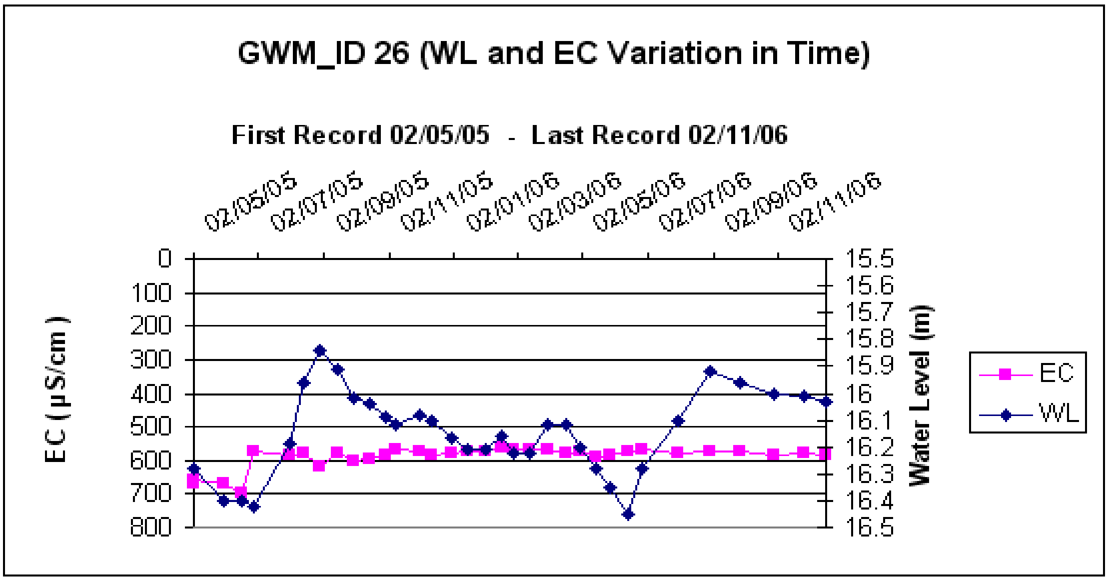

GMW_ID 15 (WL adn EC Variation in Time)
First Record 28/12/05 - Last Record 16/12/06
28/03/05
28/06/05
28/09/05
28/12/05
28/03/06
28/06/06
28/09/06
EC (µS/cm)
Water Level (m)
EC
WL

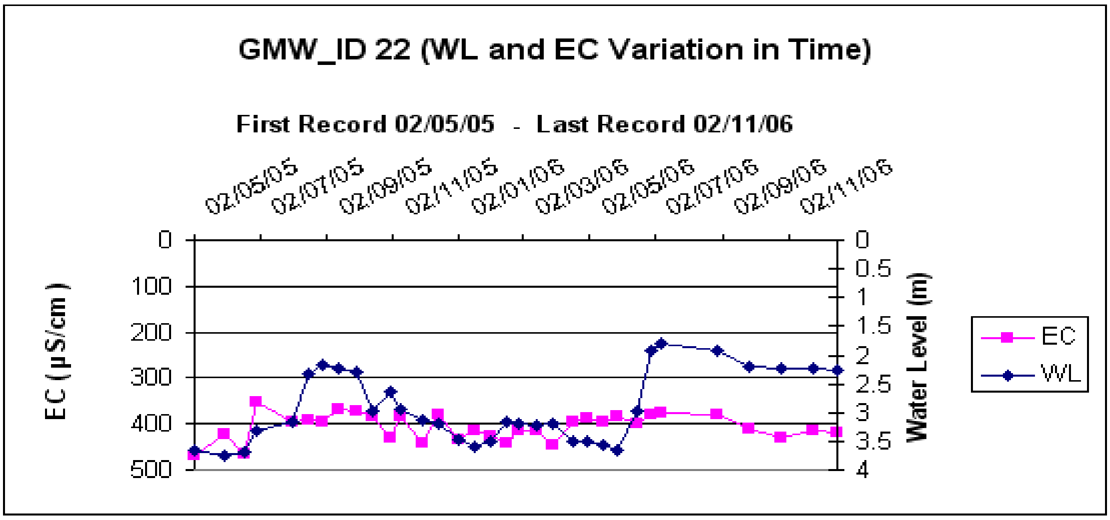

GWM_ID 16 (WL and EC Variation in Time)
First Record 16/02/06 - Last Record 18/12/06
16/02/05
16/05/05
16/08/05
16/11/05
16/02/06
16/05/06
16/08/06
16/11/06
EC (µS/cm)
Water Level (m)
EC
WL

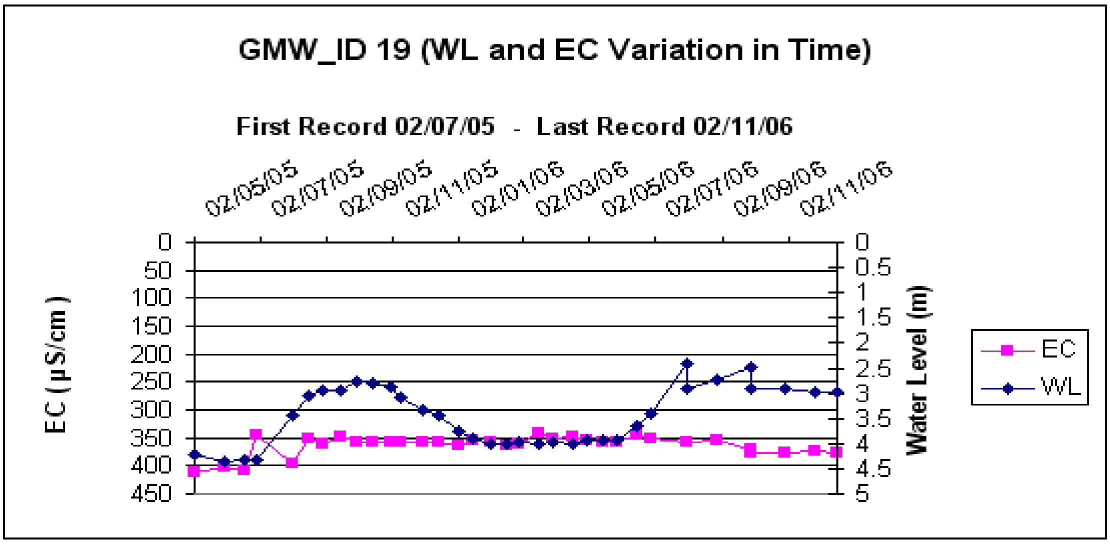

GWM_ID 4 (WL and EC Variation in Time)
First Record 07/07/05 - Last Record 16/12/06
07/05/05
07/07/05
07/09/05
07/11/05
07/01/06
07/03/06
07/05/06
07/07/06
07/09/06
07/11/06
EC (µS/cm)
Water Level (m)
EC
WL

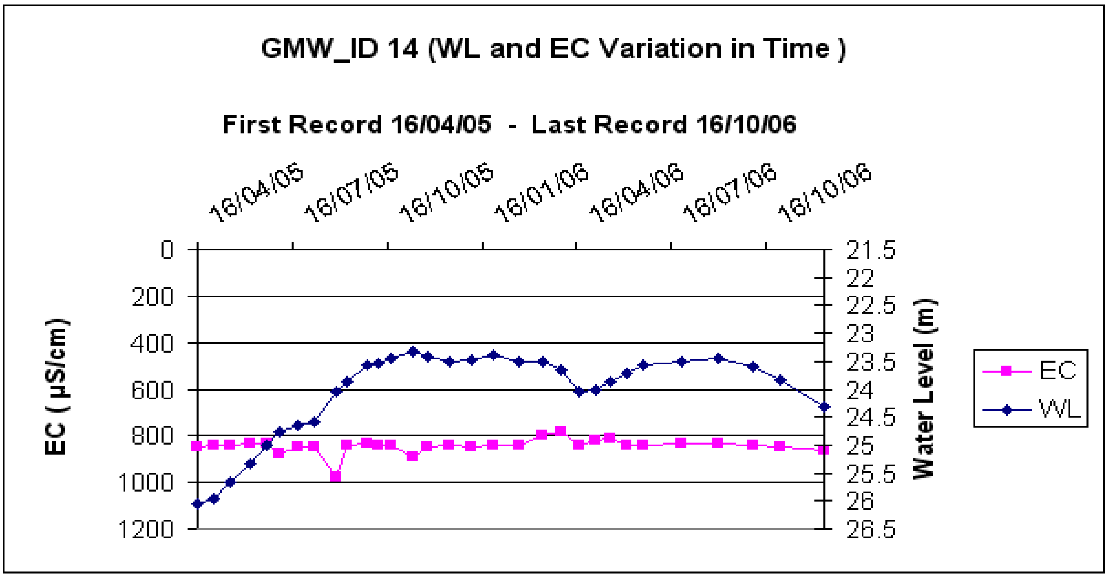

GMW_ID 12 (WL and EC Variation in Time)
First Record 31/03/05 - Last Record 17/12/06
31/03/05
30/06/05
30/09/05
31/12/05
31/03/06
30/06/06
30/09/06
780
800
820
840
860
880
900
920
940
960
EC (µS/cm)
0
1
2
3
4
5
6
7
8
9
Water Level (m)
EC
WL

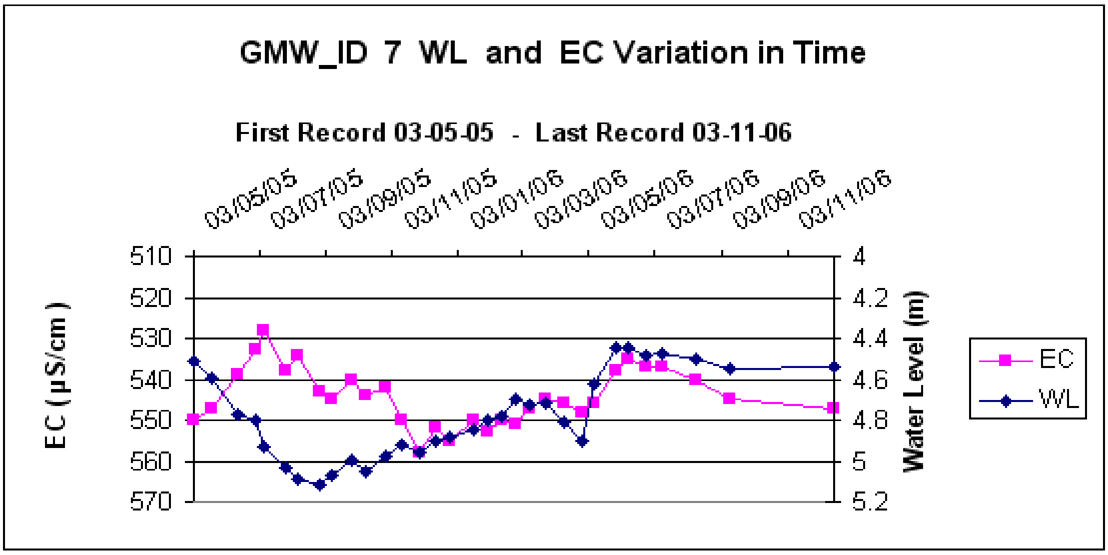

GMW_ID 35 (WL and EC Variation in Time)
First Record 02/05/05 - Last Record 02/11/06
02/05/05
02/07/05
02/09/05
02/11/05
02/01/06
02/03/06
02/05/06
02/07/06
02/09/06
02/11/06
0
100
200
300
400
500
600
EC (µS/cm)
0
1
2
3
4
5
Water Level (m)
EC
WL

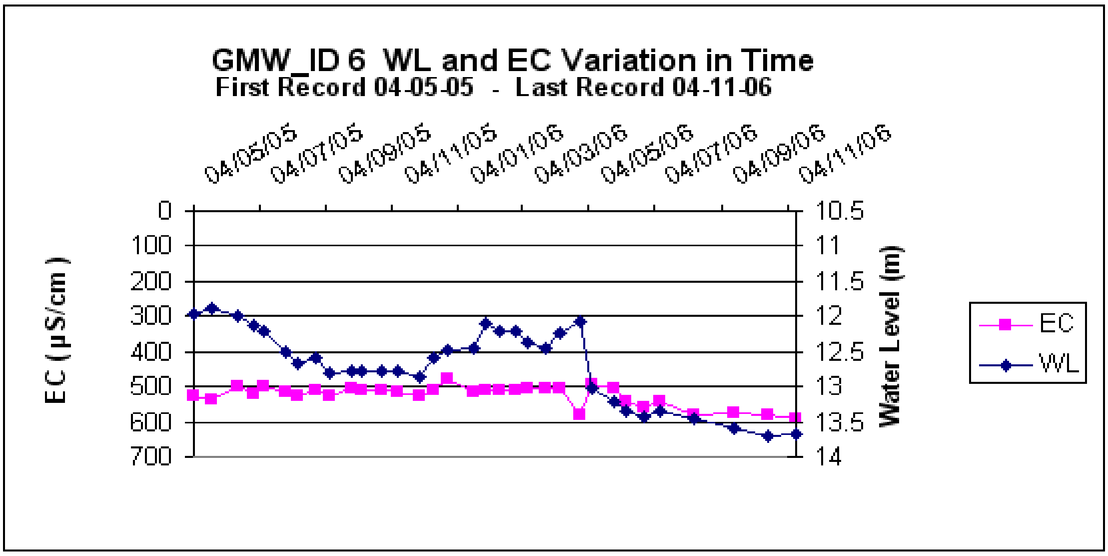

GWM_ID 26 (WL and EC Variation in Time)
First Record 02/05/05 - Last Record 02/11/06
02/05/05
02/07/05
02/09/05
02/11/05
02/01/06
02/03/06
02/05/06
02/07/06
02/09/06
02/11/06
0
100
200
300
400
500
600
700
800
EC (µS/cm)
15.5
15.6
15.7
15.8
15.9
16
16.1
16.2
16.3
16.4
16.5
Water Level (m)
EC
WL

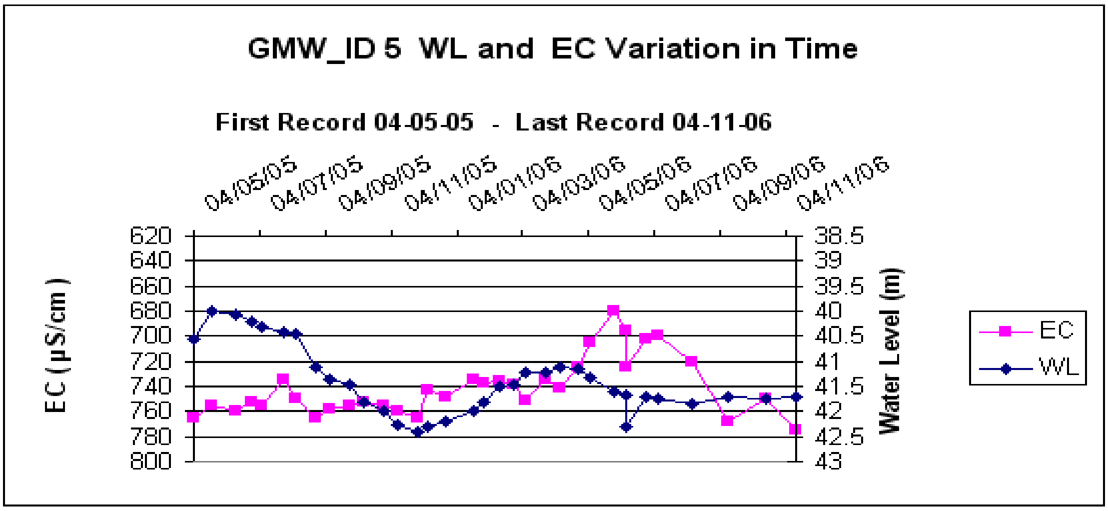

GMW_ID 22 (WL and EC Variation in Time)
First Record 02/05/05 - Last Record 02/11/06
02/05/05
02/07/05
02/09/05
02/11/05
02/01/06
02/03/06
02/05/06
02/07/06
02/09/06
02/11/06
EC (µS/cm)
Water Level (m)
EC
WL

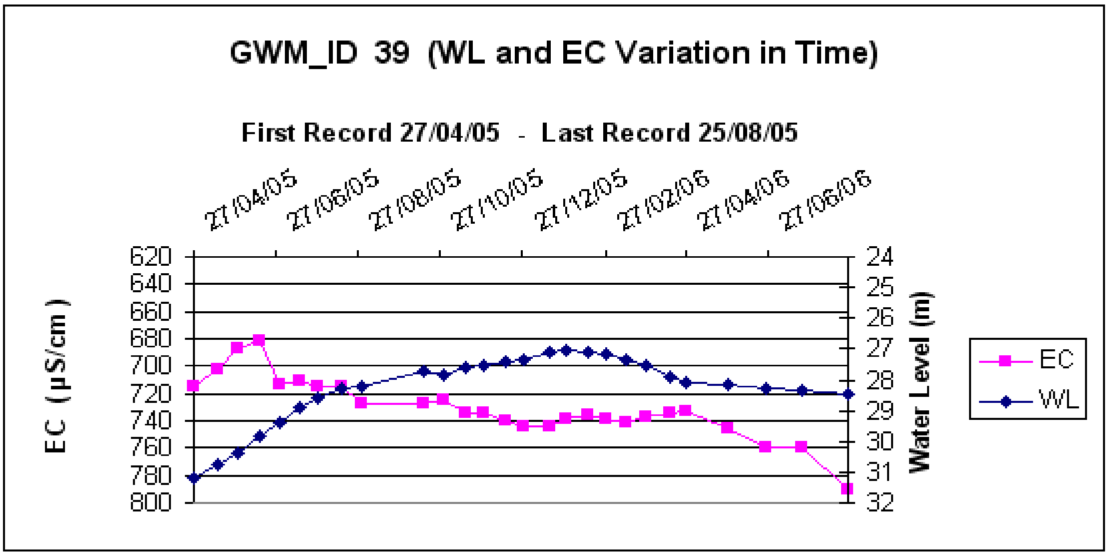

GMW_ID 19 (WL and EC Variation in Time)
First Record 02/07/05 - Last Record 02/11/06
02/05/05
02/07/05
02/09/05
02/11/05
02/01/06
02/03/06
02/05/06
02/07/06
02/09/06
02/11/06
EC (µS/cm)
Water Level (m)
EC
WL


GMW_ID 14 (WL and EC Variation in Time)
First Record 16/04/05 - Last Record 16/10/06
16/04/05
16/07/05
16/10/05
16/01/06
16/04/06
16/07/06
16/10/06
EC (µS/cm)
Water Level (m)
EC
WL

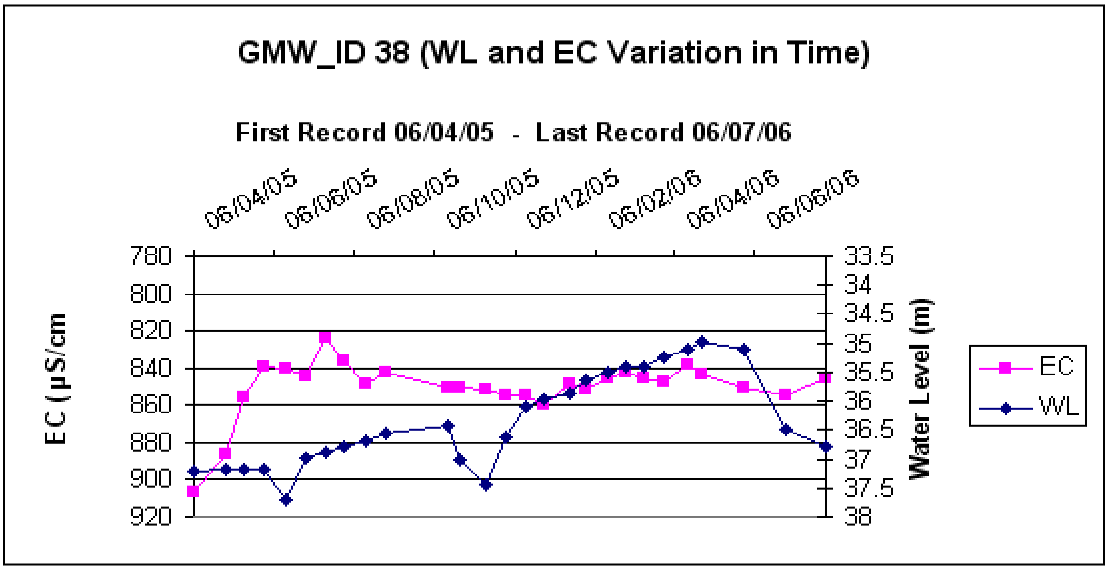

GMW_ID 7 WL and EC Variation in Time
First Record 03-05-05 - Last Record 03-11-06
03/05/05
03/07/05
03/09/05
03/11/05
03/01/06
03/03/06
03/05/06
03/07/06
03/09/06
03/11/06
EC (µS/cm)
Water Level (m)
EC
WL


GMW_ID 6 WL and EC Variation in Time
First Record 04-05-05 - Last Record 04-11-06
04/05/05
04/07/05
04/09/05
04/11/05
04/01/06
04/03/06
04/05/06
04/07/06
04/09/06
04/11/06
EC (µS/cm)
Water Level (m)
EC
WL

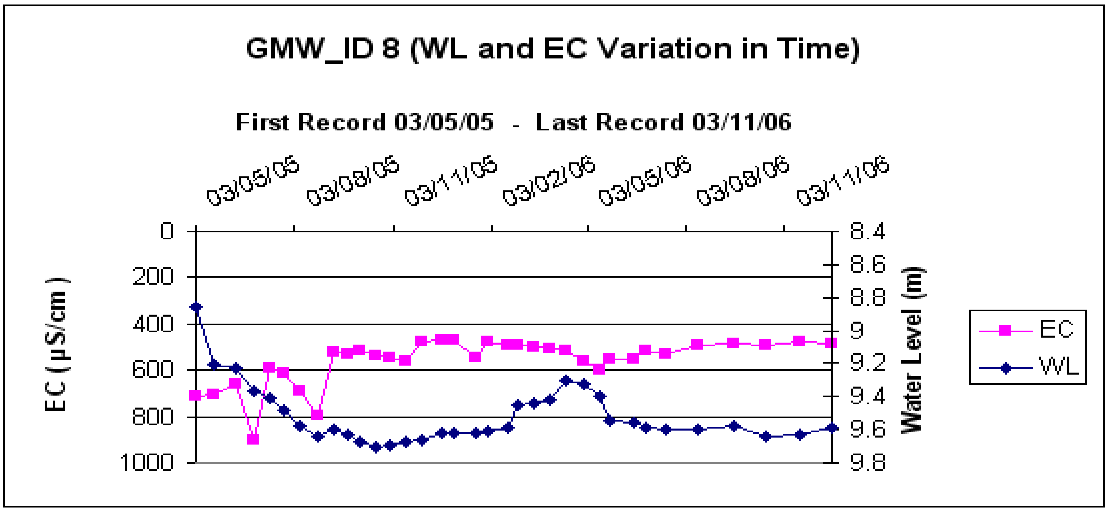

GMW_ID 5 WL and EC Variation in Time
First Record 04-05-05 - Last Record 04-11-06
04/05/05
04/07/05
04/09/05
04/11/05
04/01/06
04/03/06
04/05/06
04/07/06
04/09/06
04/11/06
EC (µS/cm)
Water Level (m)
EC
WL



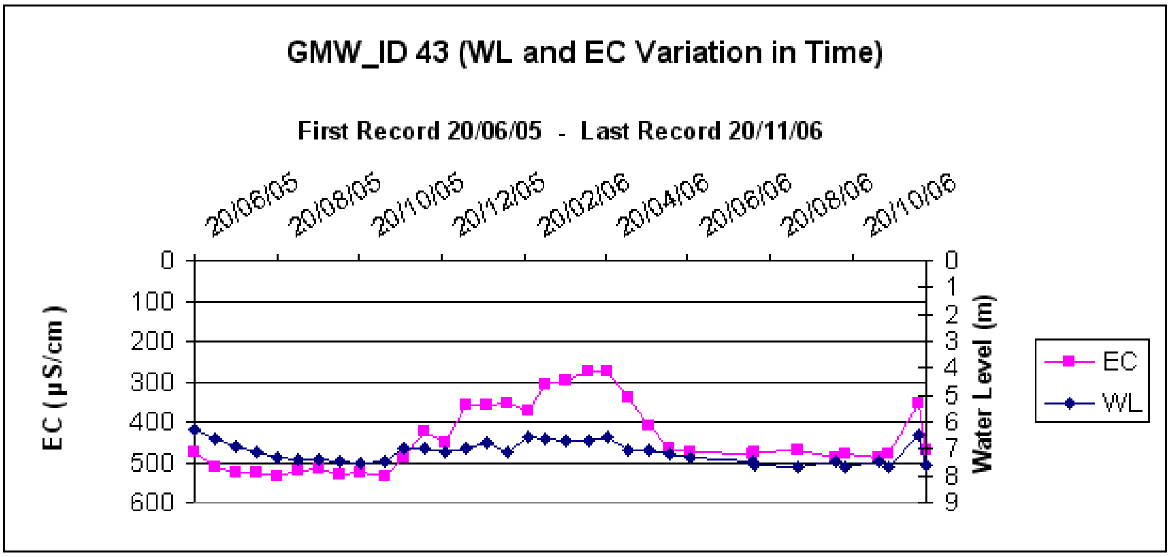
GWM_ID 39 (WL and EC Variation in Time)
First Record 27/04/05 - Last Record 25/08/05
27/04/05
27/06/05
27/08/05
27/10/05
27/12/05
27/02/06
27/04/06
27/06/06
EC (µS/cm)
620
640
660
680
700
720
740
760
780
800
Water Level (m)
24
25
26
27
28
29
30
31
32
EC
WL

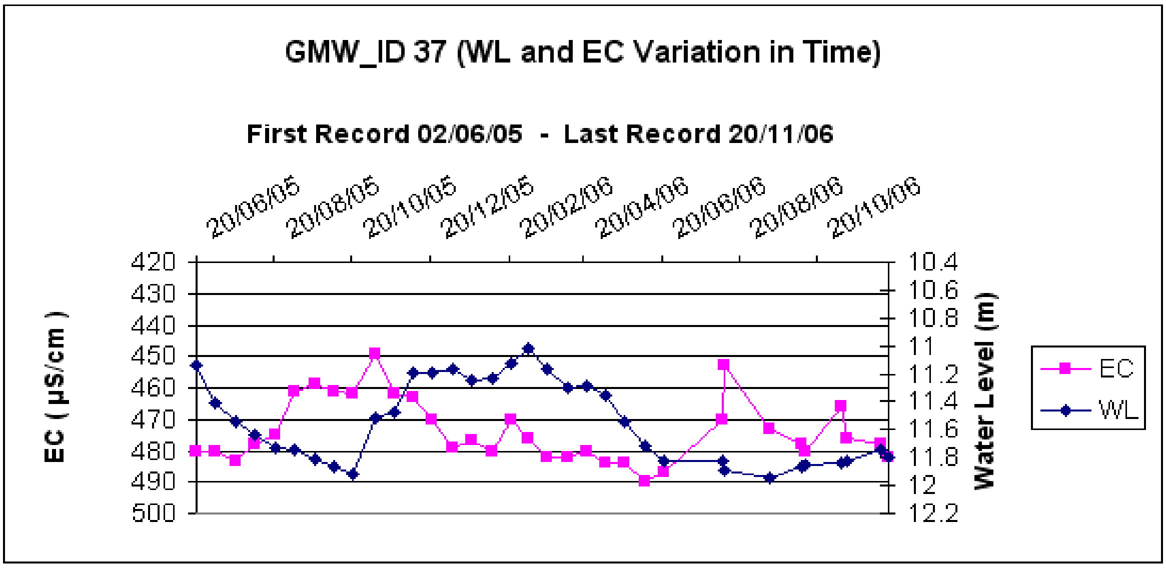


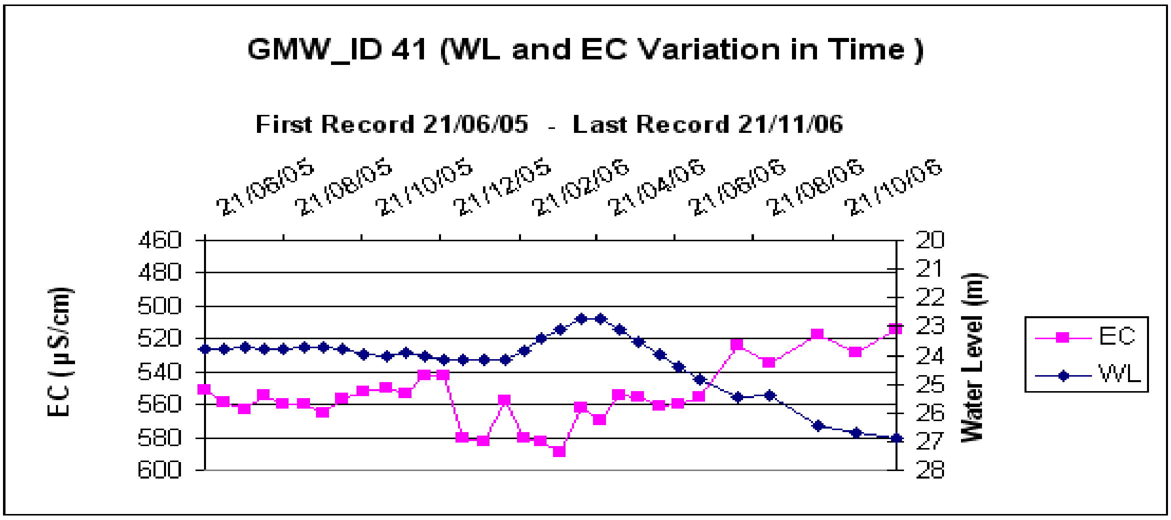
GMW_ID 38 (WL and EC Variation in Time)
First Record 06/04/05 - Last Record 06/07/06
06/04/05
06/06/05
06/08/05
06/10/05
06/12/05
06/02/06
06/04/06
06/06/06
EC (µS/cm
780
800
820
840
860
880
900
920
Water Level (m)
33.5
34
34.5
35
35.5
36
36.5
37
37.5
38
EC
WL

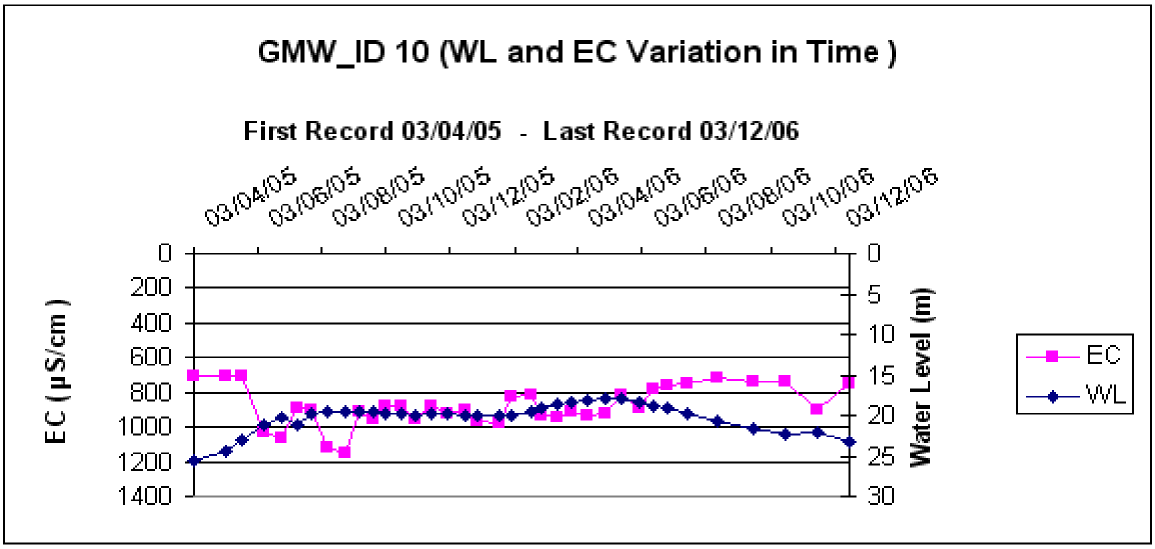


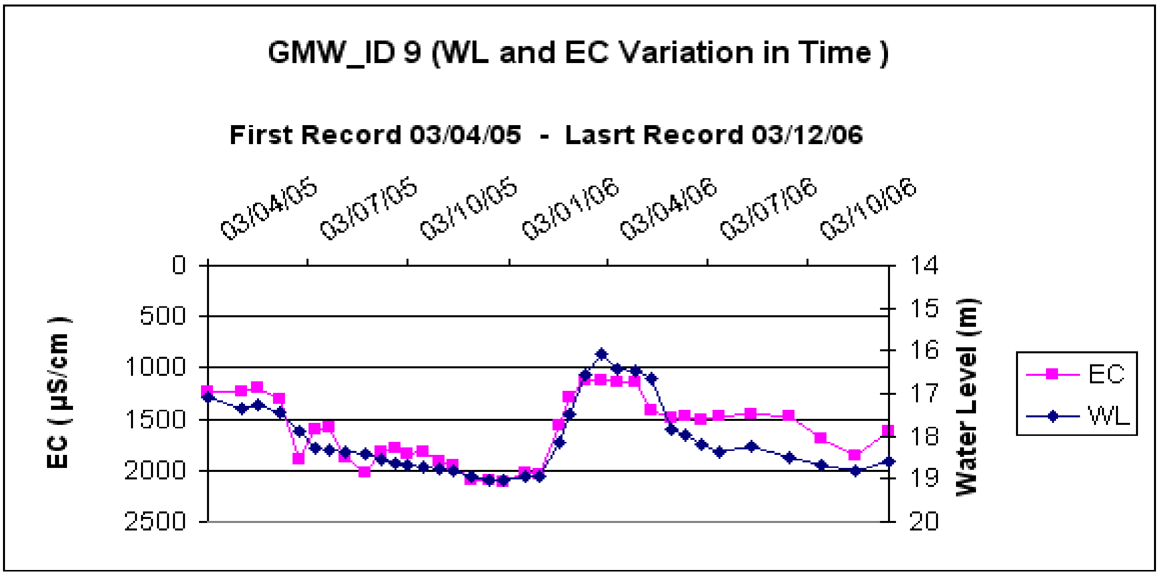
GMW_ID 8 (WL and EC Variation in Time)
First Record 03/05/05 - Last Record 03/11/06
03/05/05
03/08/05
03/11/05
03/02/06
03/05/06
03/08/06
03/11/06
EC (µS/cm)
0
200
400
600
800
1000
Water Level (m)
8.4
8.6
8.8
9
9.2
9.4
9.6
9.8
EC
WL

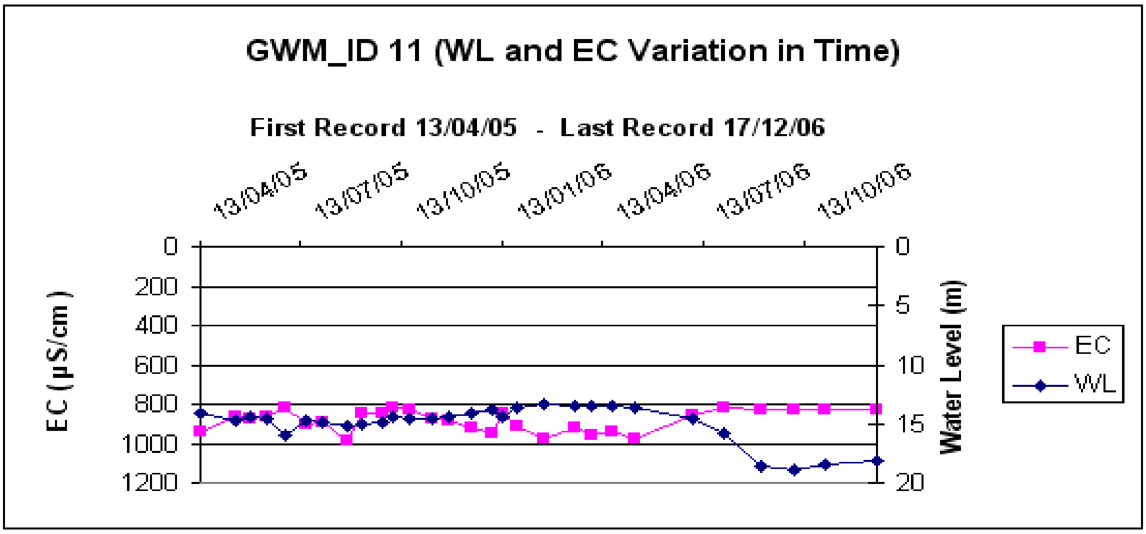

GMW_ID 43 (WL and EC Variation in Time)
First Record 20/06/05 - Last Record 20/11/06
20/06/05
20/08/05
20/10/05
20/12/05
20/02/06
20/04/06
20/06/06
20/08/06
20/10/06
EC (µS/cm)
Water Level (m)
EC
WL


GMW_ID 37 (WL and EC Variation in Time)
First Record 02/06/05 - Last Record 20/11/06
20/06/05
20/08/05
20/10/05
20/12/05
20/02/06
20/04/06
20/06/06
20/08/06
20/10/06
EC (µS/cm)
Water Level (m)
EC
WL

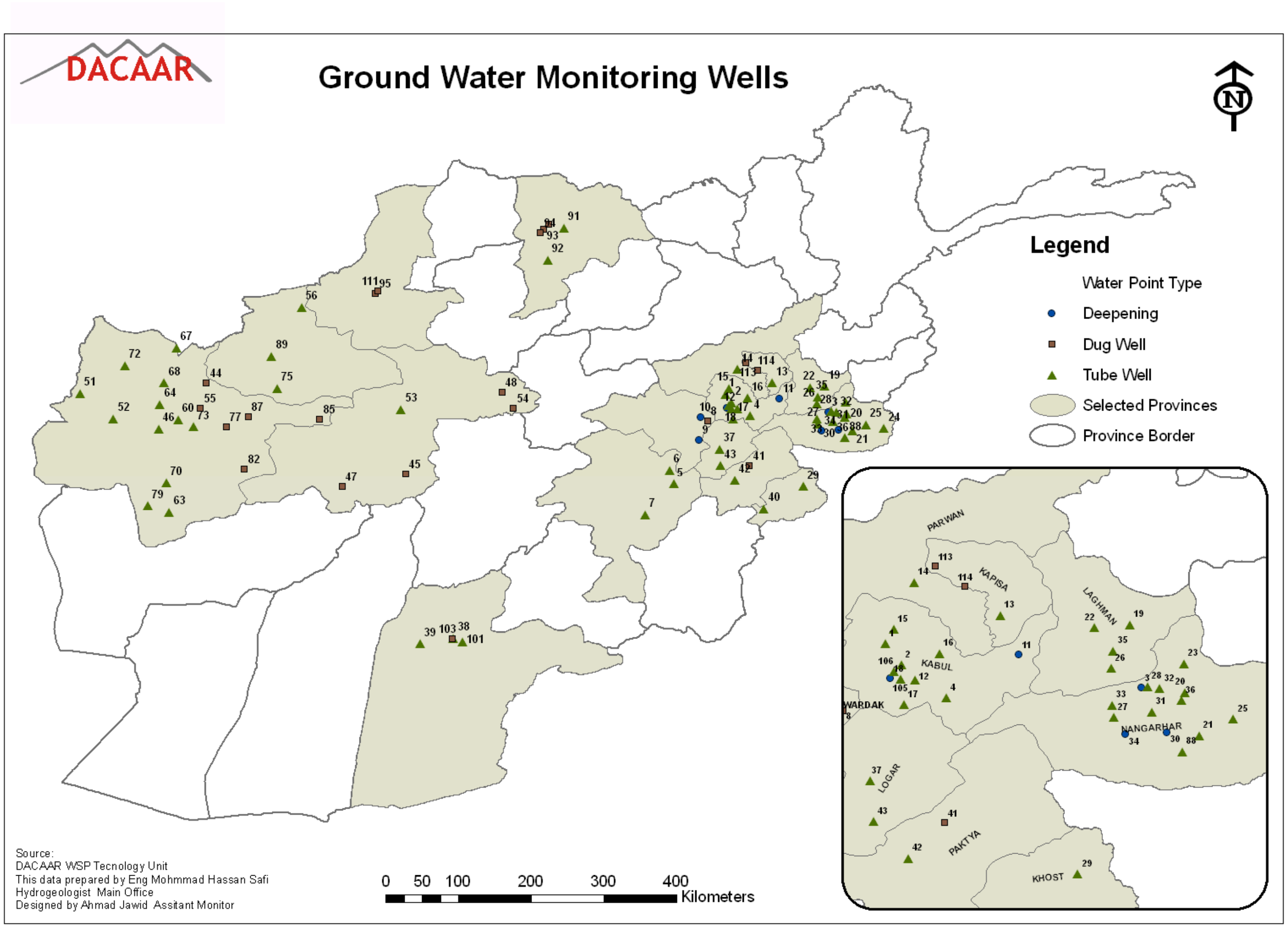

GMW_ID 41 (WL and EC Variation in Time)
First Record 21/06/05 - Last Record 21/11/06
21/06/05
21/08/05
21/10/05
21/12/05
21/02/06
21/04/06
21/06/06
21/08/06
21/10/06
EC (µS/cm)
Water Level (m)
EC
WL


GMW_ID 10 (WL and EC Variation in Time)
First Record 03/04/05 - Last Record 03/12/06
03/04/05
03/06/05
03/08/05
03/10/05
03/12/05
03/02/06
03/04/06
03/06/06
03/08/06
03/10/06
03/12/06
0
200
400
600
800
1000
1200
1400
EC (µS/cm)
0
5
10
15
20
25
30
Water Level (m)
EC
WL

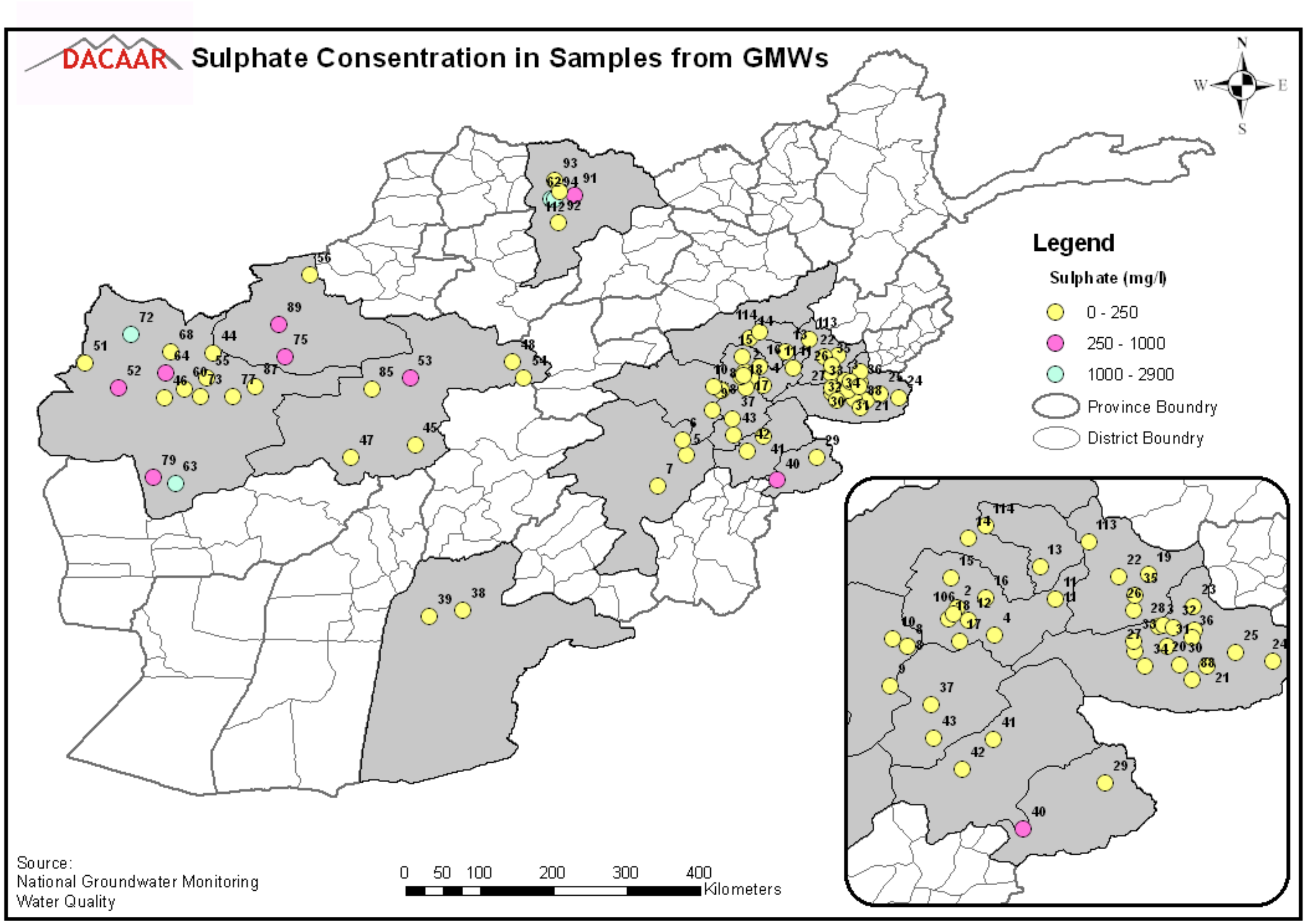

GMW_ID 9 (WL and EC Variation in Time)
First Record 03/04/05 - Lasrt Record 03/12/06
03/04/05
03/07/05
03/10/05
03/01/06
03/04/06
03/07/06
03/10/06
0
500
1000
1500
2000
2500
EC (µS/cm)
14
15
16
17
18
19
20
Water Level (m)
EC
WL


GWM_ID 11 (WL and EC Variation in Time)
First Record 13/04/05 - Last Record 17/12/06
13/04/05
13/07/05
13/10/05
13/01/06
13/04/06
13/07/06
13/10/06
0
200
400
600
800
1000
1200
EC (µS/cm)
0
5
10
15
20
Water Level (m)
EC
WL

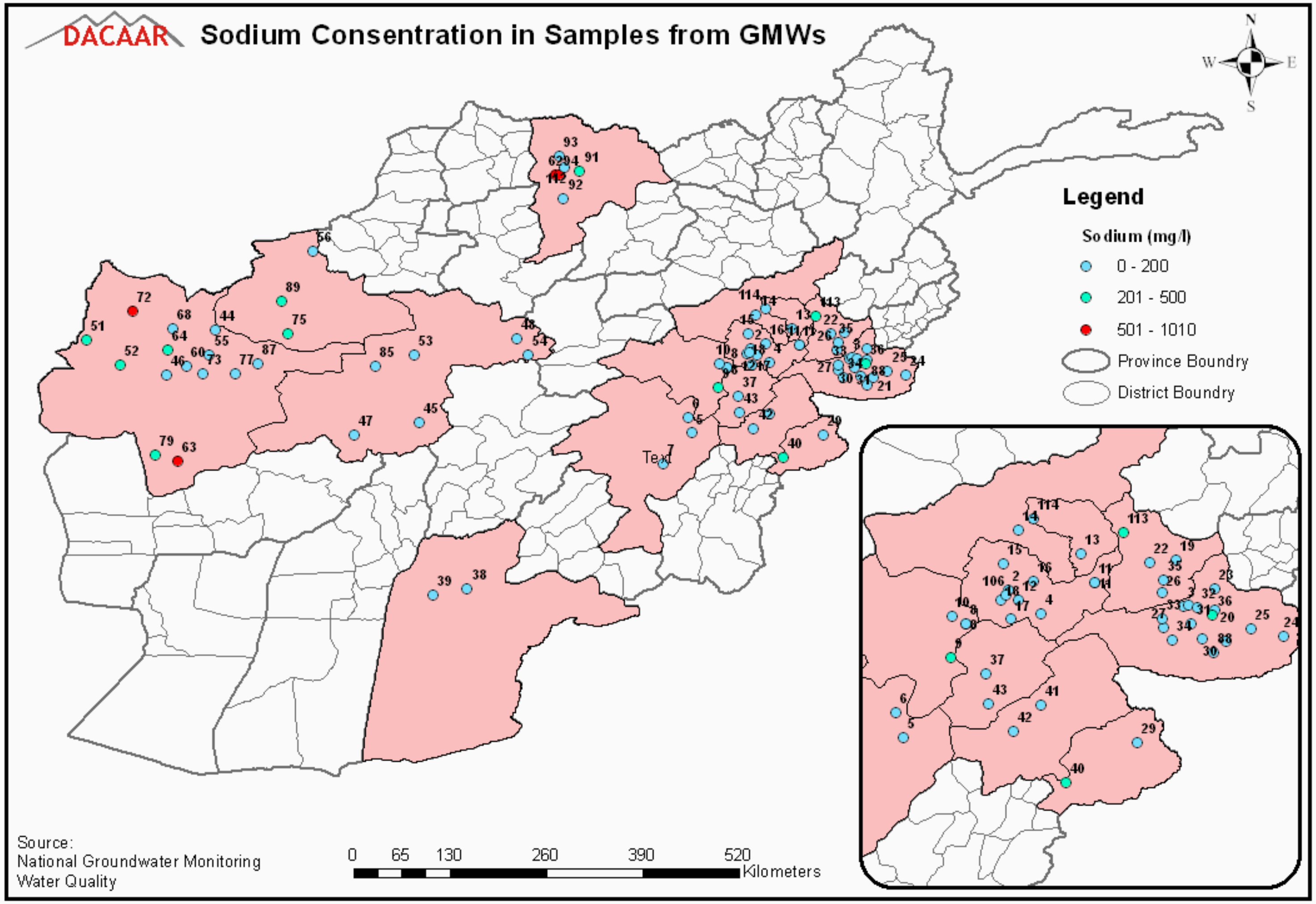
Annex 7 Ground Water Monitoring Wells Placement



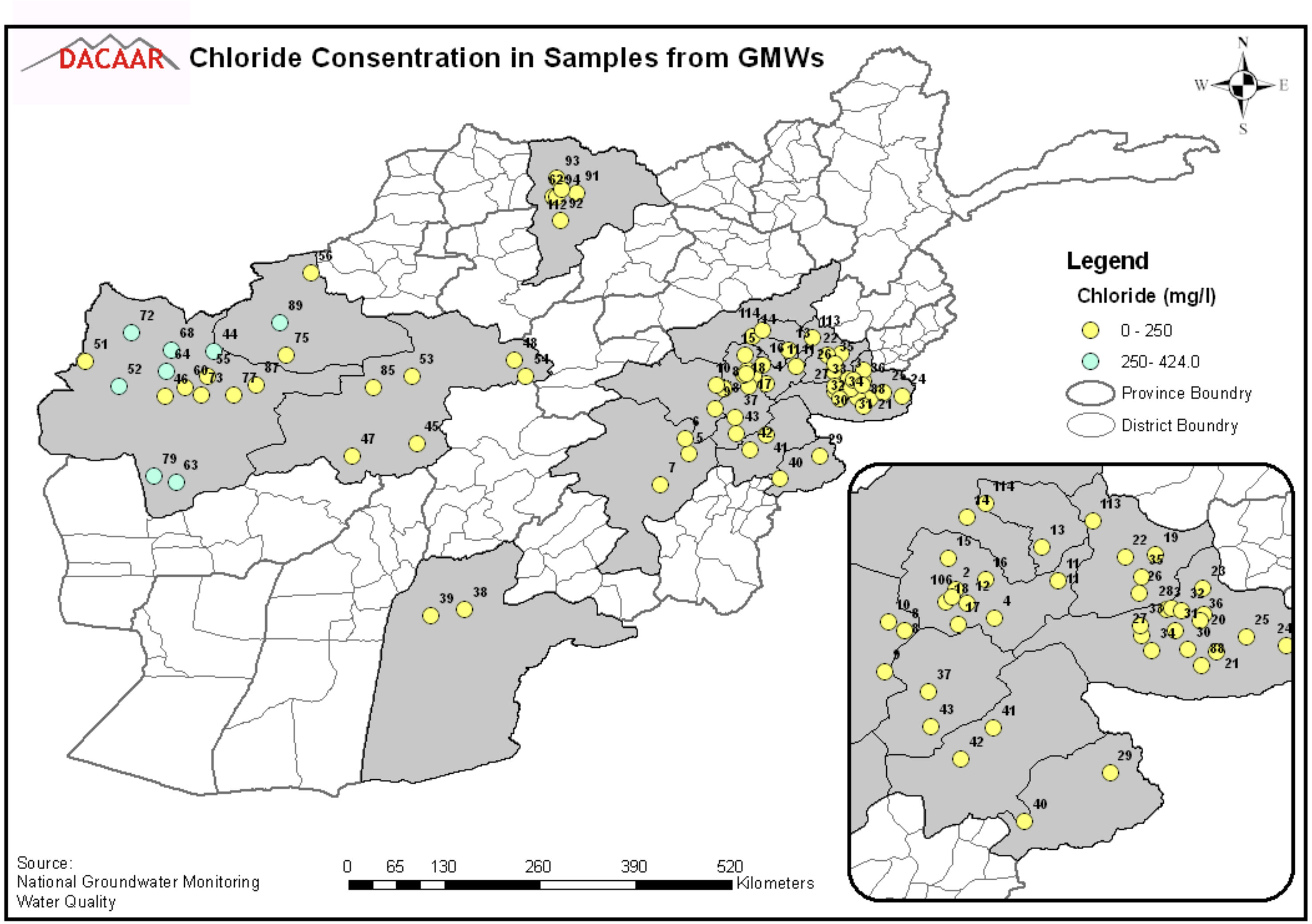
Annex 8 Sulphate Concentration



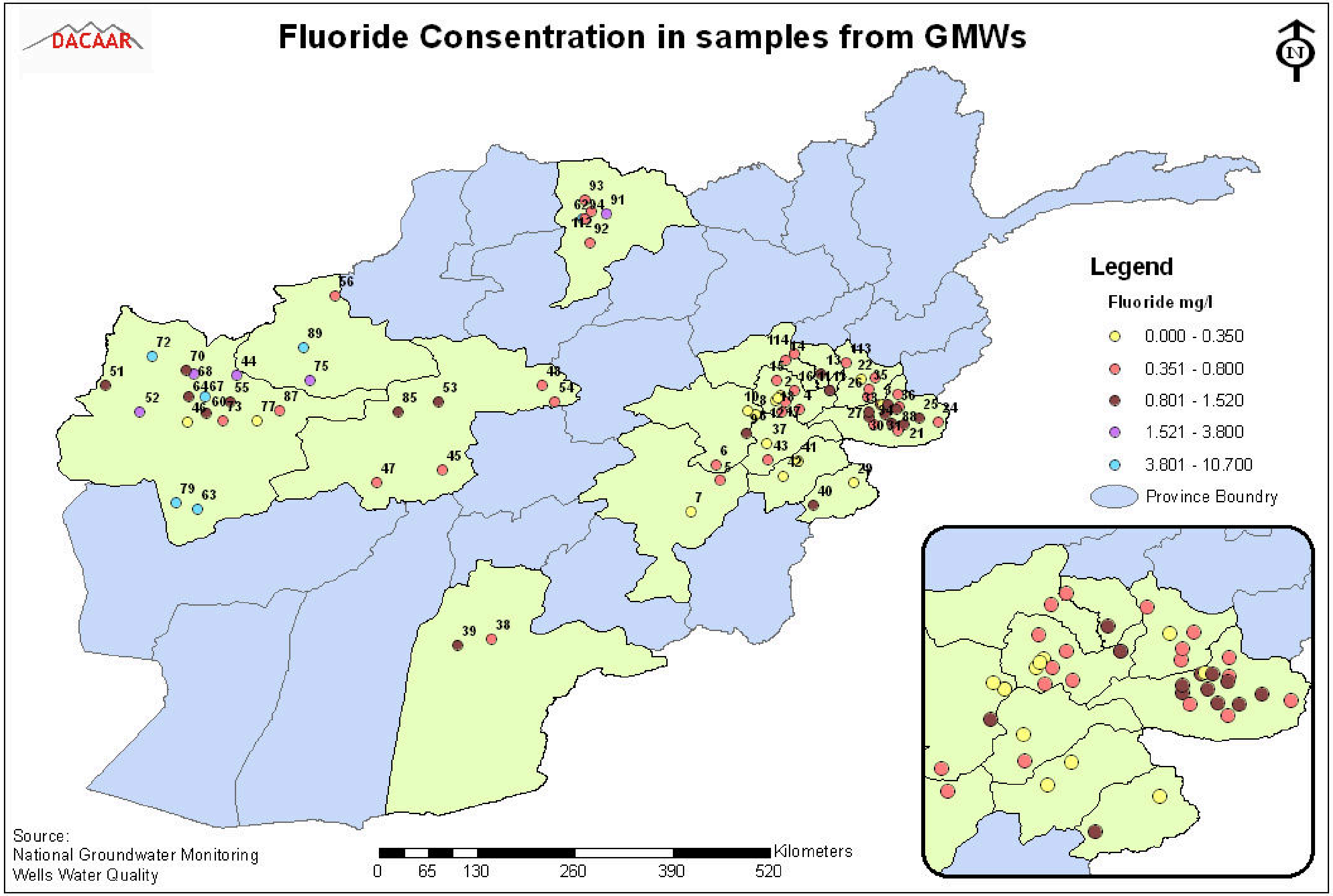
Annex 9 Sodium Concentration



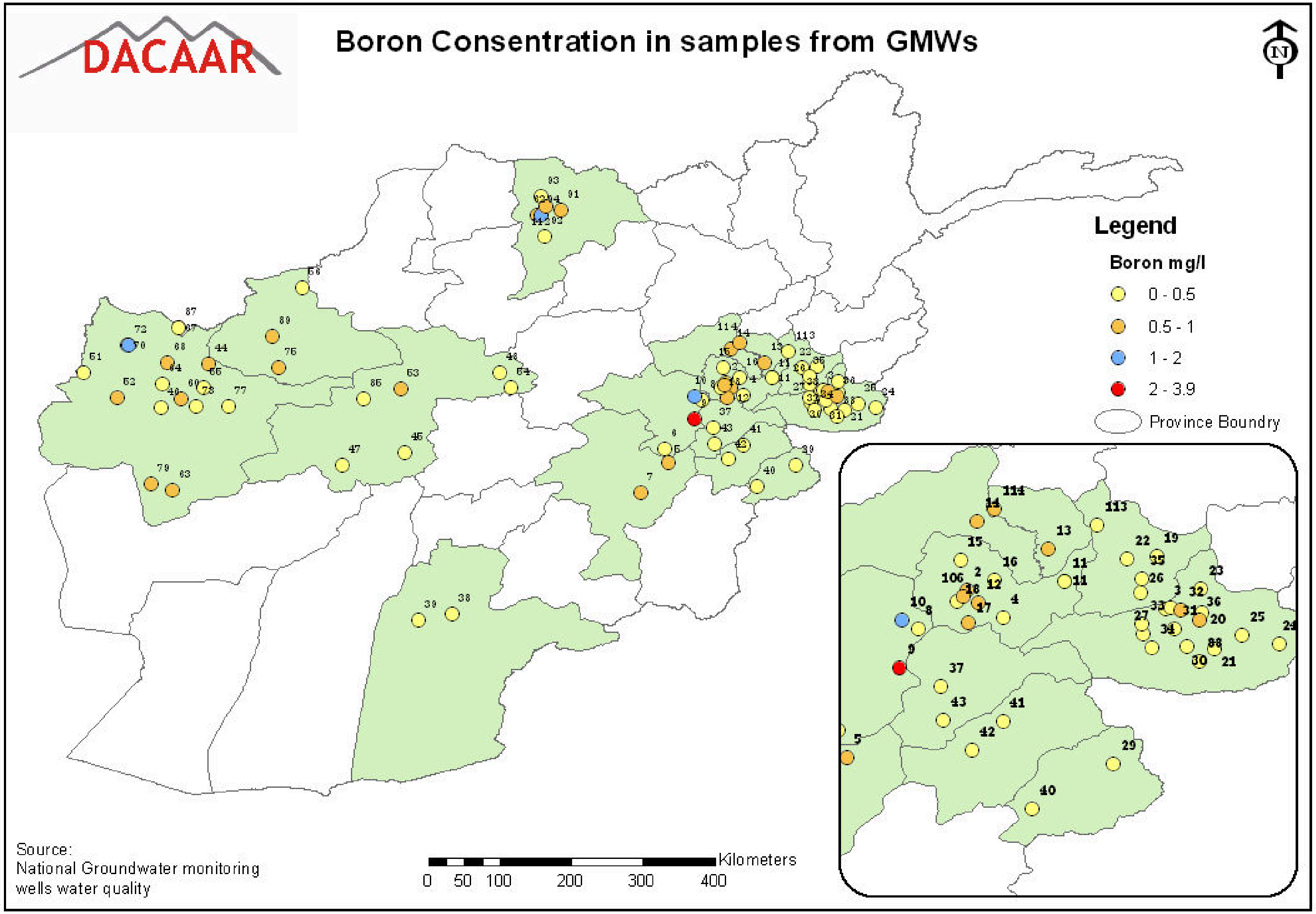
Annex 10 Chloride Concentrations



Annex 11 Fluoride Concentrations



Annex 12 Boron Concentrations



Annex 13 Bromine Concentrations