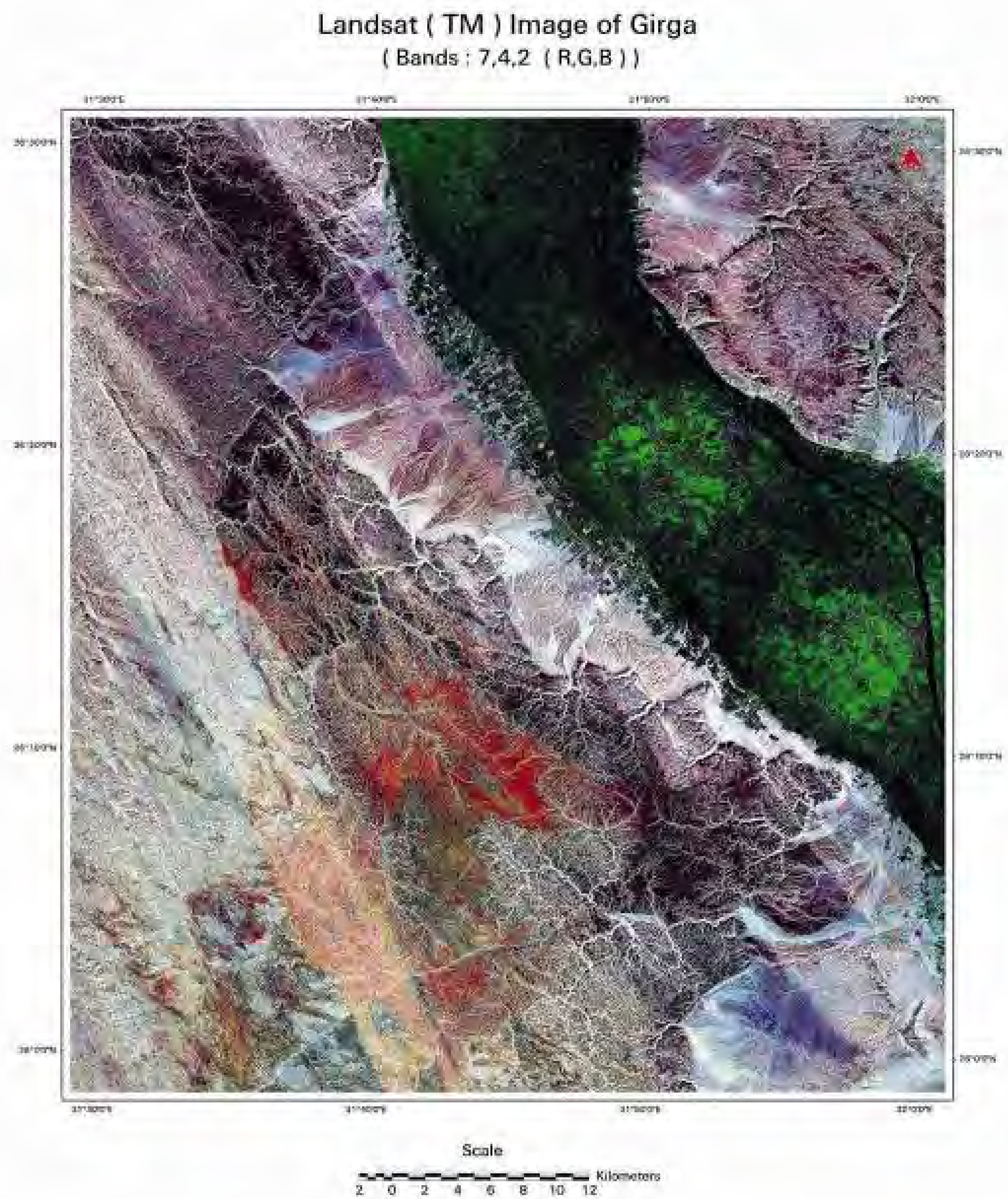

Figure (4.4) landsat image of Girga region in the year 2000 (Zaki, 2001)

4.2.4 Climate and Evapotranspiration

Girga lies in Upper Egypt which belongs to the arid region of North Africa. It is generally characterized by a hot and long summer and a worm and low rainfall winter with almost no precipitations. Climatic conditions in the area are characterized by (Zaki, 2001):

Temperature:

The average maximum temperature varies from 21.6ºC in January to 37ºC in June. The minimum temperature varies from 6.1ºC in January to 21.7ºC in August.

Relative Humidity:

It reaches a maximum value in winter which ranges from 51% to 61% and a minimum value in spring and in summer which are found between 33% to 41% and 35% to 42%, respectively.

4.3 Hydrogeology

4.3.1 Geology

A Hydro geological map for the Nile Valley in the study area is presented in Figure (4.5). The Hydro geological map is showing the three main litho logical units: Eocene limestone, Quaternary sands and gravel and Holocene silty clays. The valley is bounded on both sides by steep slopes made up of Eocene limestone, most probably accompanied by normal faults.

The surface is occupied by silty clay deposits in the floodplain with a maximum thickness of 20 m and an average thickness of about 15 m in the study area. These deposits have the maximum thickness near the Nile and become thinner towards the valley slopes. The silty clays are underlain by a Quaternary aquifer consisting of sands and gravel with minor clay lenses. The maximum thickness of the aquifer is about 250.0 m (RIGW/IWACO, 1989). The Quaternary aquifer is underlined by clayey sediments of Pliocene age. Figure (4.6) shows a cross section in the Hydro Geological map.

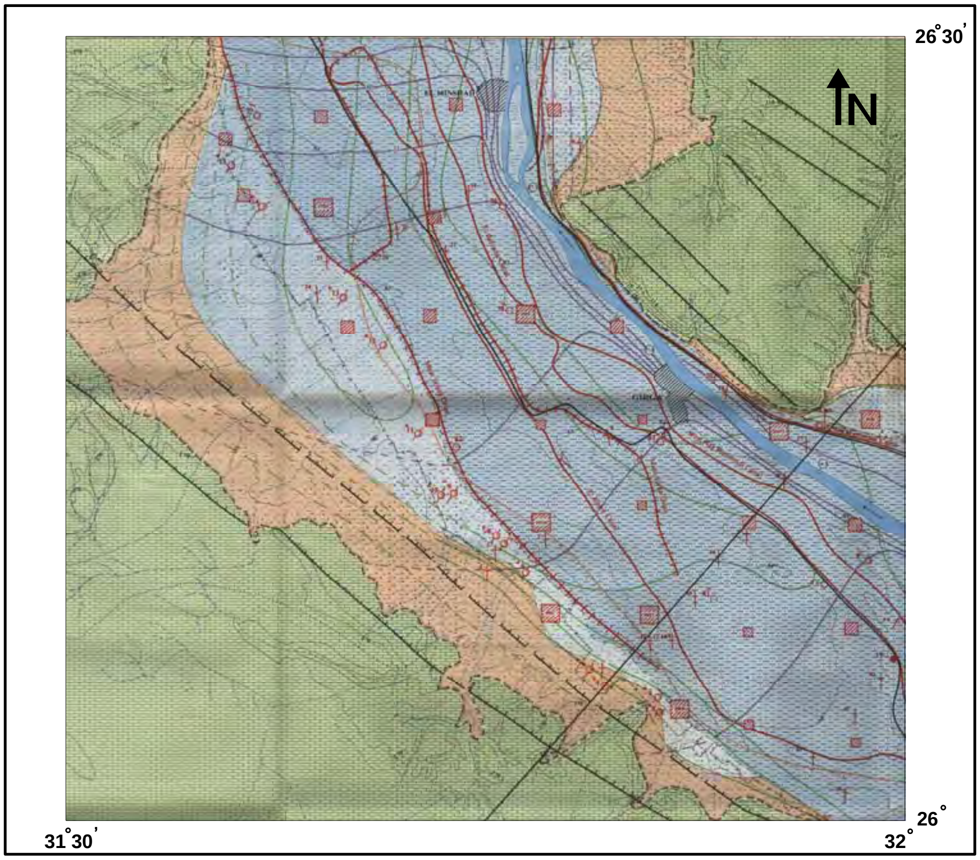

Figure (4.5) Hydro Geological Map for Girga Region (RIGW, 1990)

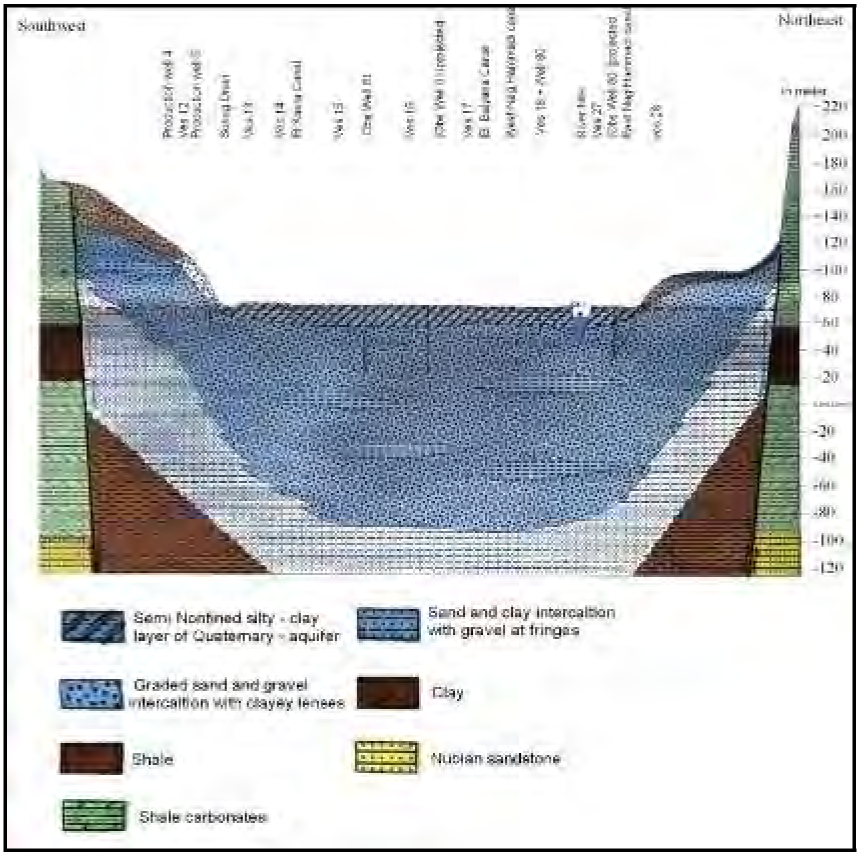

Figure (4.6) Geological cross section for Girga region (RIGW, 1990)

4.3.2 Aquifer system

The following hydro geological schematization is based on detailed study of the hydrogeology of the Nile Valley (Attia, 1985), on a geophysical receptivity survey in and around the reclaimed desert areas west of Girga area (RIGW.1990) and on drilling data of boreholes and observation wells.

The Nile floodplain is schematized by a semi-confined aquifer. The aquifer is made up of Quaternary sands and gravel with minor clay lenses, and is underlined by a virtually impervious layer, consisting of fine-grained Pliocene sediments. In the floodplain, the aquifer is covered by a semi- pervious layer consisting of silts and clays. Outside of the floodplain, (including the reclaimed area) the aquifer is unconfined and consists of graded sand and gravel. Towards the valley slops the aquifer becomes gravely thinner and bounded by faults, as shown in Figure (4.6).

The River Nile is more or less running along the eastern boundary of the valley. Its width varies from 500 m to 1,000 m. The river cuts completely through the surficial semi-pervious layer. The bed of the river is made up of fine clayey sands. The western boundary of the aquifer is bounded by an impervious barrier, consisting of Eocene Limestones.

The geometry of the aquifer was determined with the results of the geophysical receptivity surveys and data related to brothels, observation wells and production wells, in the study area. The maximum thickness of the aquifer amounts to 250 m in the central part of the valley.

In the reclaimed desert area, the thickness of the aquifer is not well known.

The geophysical survey and drilling data of boreholes indicate a rather irregular shape of aquifer. As an average, the thickness of the aquifer ranges from 40 to 60 m.

4.3.3 Hydraulic characteristics

The Average horizontal hydraulic conductivity of the Quaternary aquifer is about 75 m/day (Attia, 1985)**.**

The specific yield of the upper part of the quaternary aquifer under unconfined conditions is in the order of magnitude of 0.1. For the semi-pervious layer overlaying the quaternary aquifer ranges from 0.01 to 0.1 m\day. Relative large values of the vertical hydraulic conductivity occur in the levees along the river Nile and in El-Khufug sediments (west of the traditionally cultivated lands).

4.3.4 Recharge and discharge condition

The main sources of recharge to the aquifer are the seepage from the main and lateral irrigation canals and meskas and by deep percolation of excess irrigation water from the fields. The recharge of the aquifer has been determined by assessing detailed water balance of the study area. The water balance showed that the total recharge of the aquifer ranges from 0.4 to 0.6 mm/day.

The major part of the area east of reclamation has been supplied with tile drainage the subsurface drainage water is mainly discharge by these tile drains. The levees along the River Nile are provided with a system of open collector drains. In this area, the groundwater table and groundwater heads are relatively deep. The major part of the subsurface drainage water in this area percolates to the aquifer (natural drainage) .The recharge of the aquifer underlaying the levees is in order of magnitude of 1-2 mm/day (Attia, 1985)

In the reclaimed lands west of Girga, all the private wells abstract groundwater for irrigation purposes. Generally, these wells have a depth of about 50 m or less. The present total volume of this abstracted groundwater equals about 43 million m^3/yr

4.3.5 Groundwater flow

Figure (4.7) shows the regional piezometric contour map of the quaternary aquifer. This map is based on the average observed piezometric heads in the study area. In areas, only scarcely provided with observation wells, contour lines are reconstructed, by using old records of the groundwater monitoring network of the observation wells combined with recent field observation and additional hydrogoelogical calculations.

The piezometric map shows that the groundwater in the Nile Valley mainly flows in a north-eastern direction. Along the fringes of the desert this pattern is strongly influenced by the groundwater flow from the reclaimed area. In the northern part of this area, hydraulic gradient of more than 7m/km appear in west-east direction.

Since the reclamation of desert lands started in the year 1987, the piezometric heads in the aquifer in and around the reclaimed areas have risen substantially.

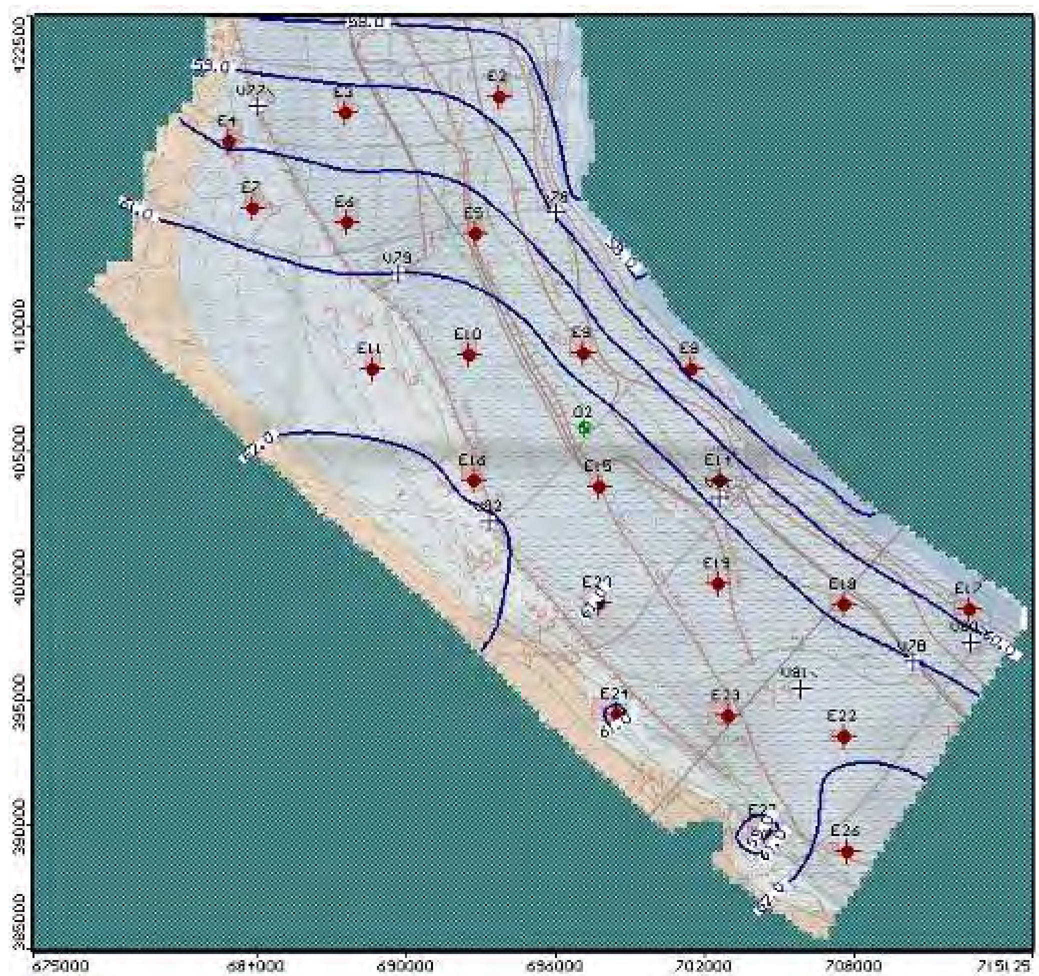

Figure (4.7) shows the piezometric heads of the study area

4.3.6 Groundwater quality

4.3.6.1 Groundwater Sampling and analysis

Nineteen groundwater samples were collected from different locations in Girga region in August 2007 and analyzed in the Central lab for NWRC to be used in the study (Annex 1).

The chemical analysis of the samples was carried out to represent the present status of the groundwater quality in the study area. Figure (4.8) shows the locations of the collected samples.

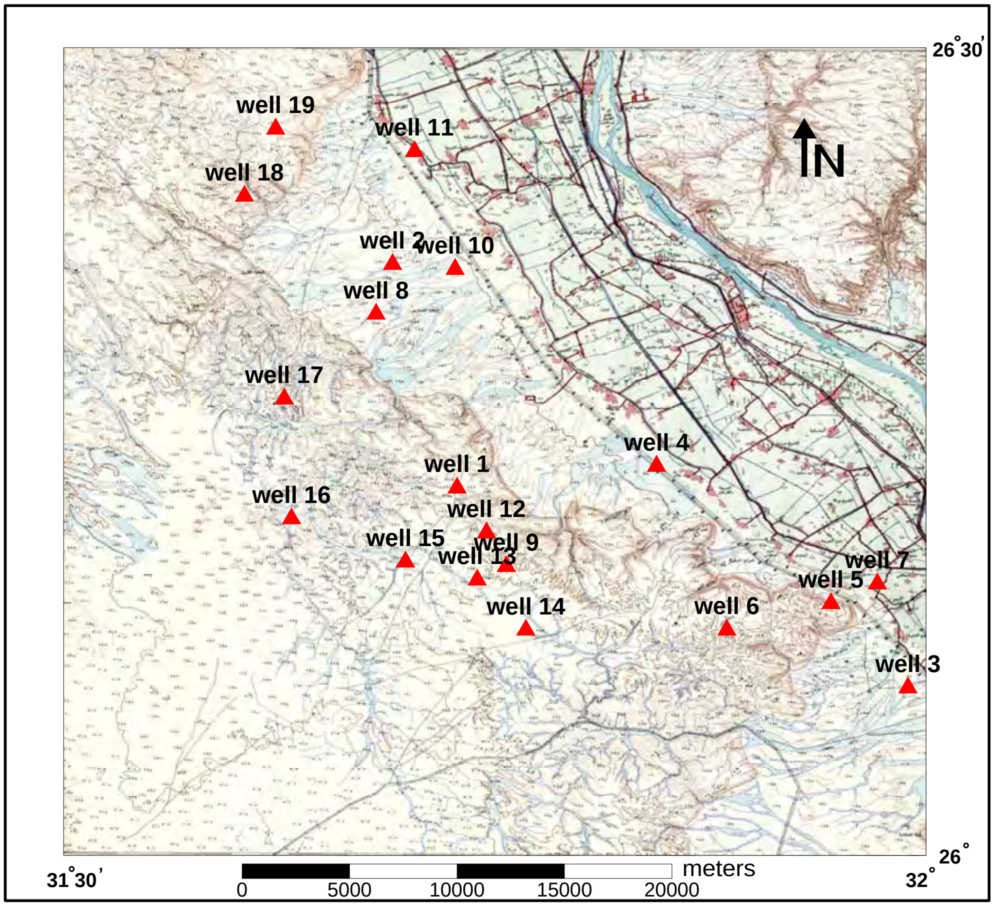

Figure (4.8) Locations of the collected samples

The analysis of the samples shows that the minimum value for the Total Dissolved Solids TDS in the study area is 356 ppm which in found near the Nile River. While the maximum value for the TDS is 1700 ppm and it is found near the desert fringes (Annex 1). The quality of the groundwater shows large special diversities.

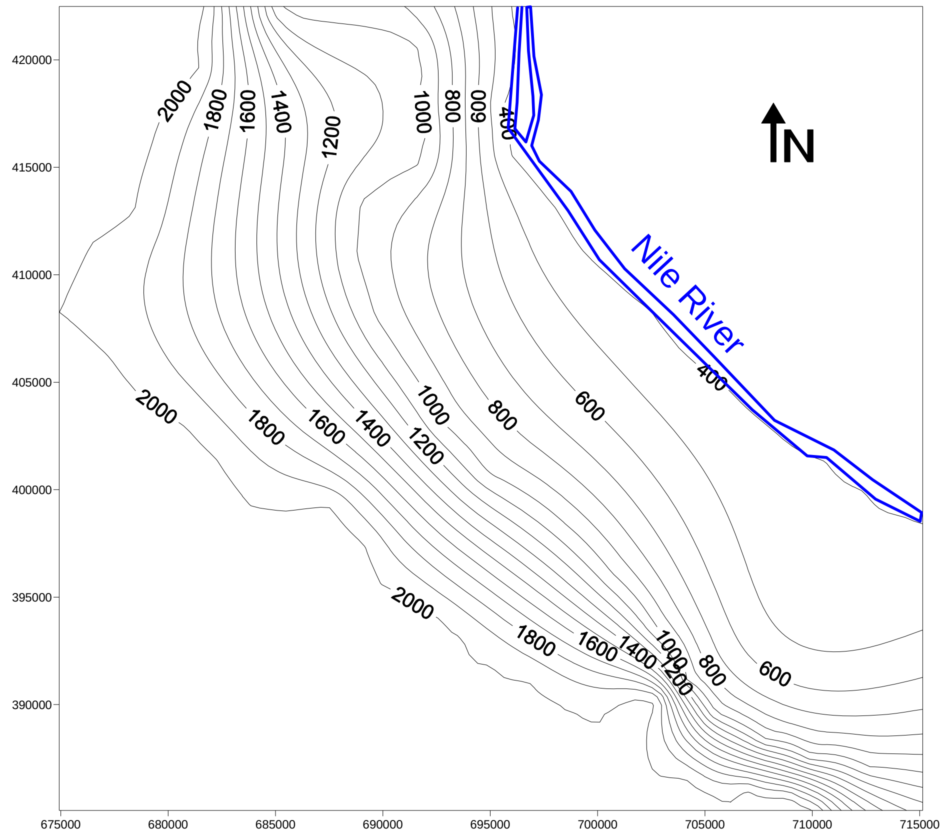

Figure (4.9) The Salinity Contour Map for The Study Area

4.3.6.2 Interpretation of chemical analysis of the collected samples:

● **General background:**

An important task in groundwater investigation is the compilation and presentation of chemical data in a convenient manner for visual inspection. For this purpose several commonly used graphical methods are available.

The first one, developed by Piper (1944) from a somewhat similar design by Hill (1940), is shown in figure (4.10)

Both of these diagrams permit the cation and anion composition of many samples to be represented on a signal graph in which major groupings or trends in the data can be discerned visually.

A signal trilinear diagram has greater potential to accommodate a larger number of analyses without becoming confusing and is convenient for showing the effects of mixing two waters from different sources.

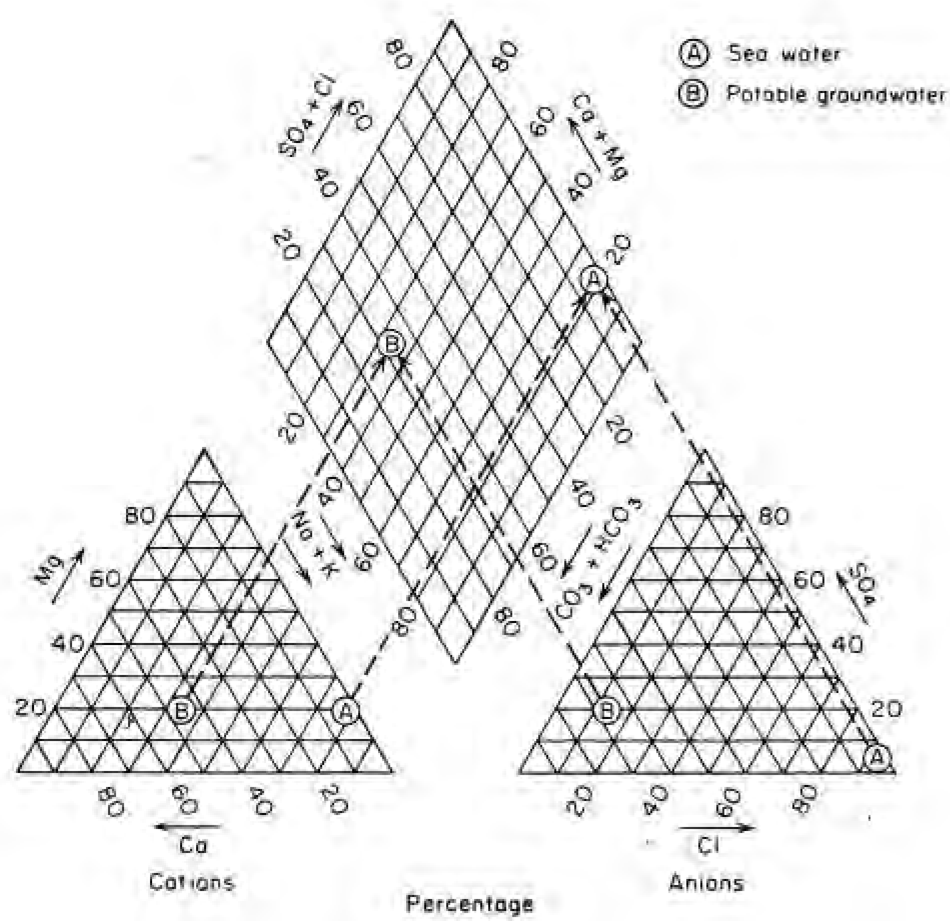

Figure (4.10) chemical analysis of water represented as percentage of total equivalents per liter on the diagram developed by Hill (1940) and Piper (1944).

● **Chemical analysis of the collected samples:**

The trilinear (Piper, 1944) diagram method is applied for the Souhag samples, Figure (4.11), shows more about the genetic origin of groundwater in the studied area and the hydrochemical relationships in the aquifer systems (Piper, 1944, 1953; Freeze and Cherry, 1979). On this graph, the percentage reacting values (percentage equivalents) of the major constituents of the water are plotted. Anions (acid radicals) are plotted in the lower right triangle and cations (basic radicals) are plotted in the lower left triangle. The single-point plots in the diamond field indicate the overall character of the water. The chemical character of water is defined through the relationships between the alkalies (K+ + Na+), the alkaline earths (Ca2+ + Mg2+), alkalinity (CO3- + HCO32-), and the salinity (Cl- + SO42-) through the plotting of water analyses in certain subareas of the diamond-shaped field. The diagram shown in the above figure reveals the following explanation:

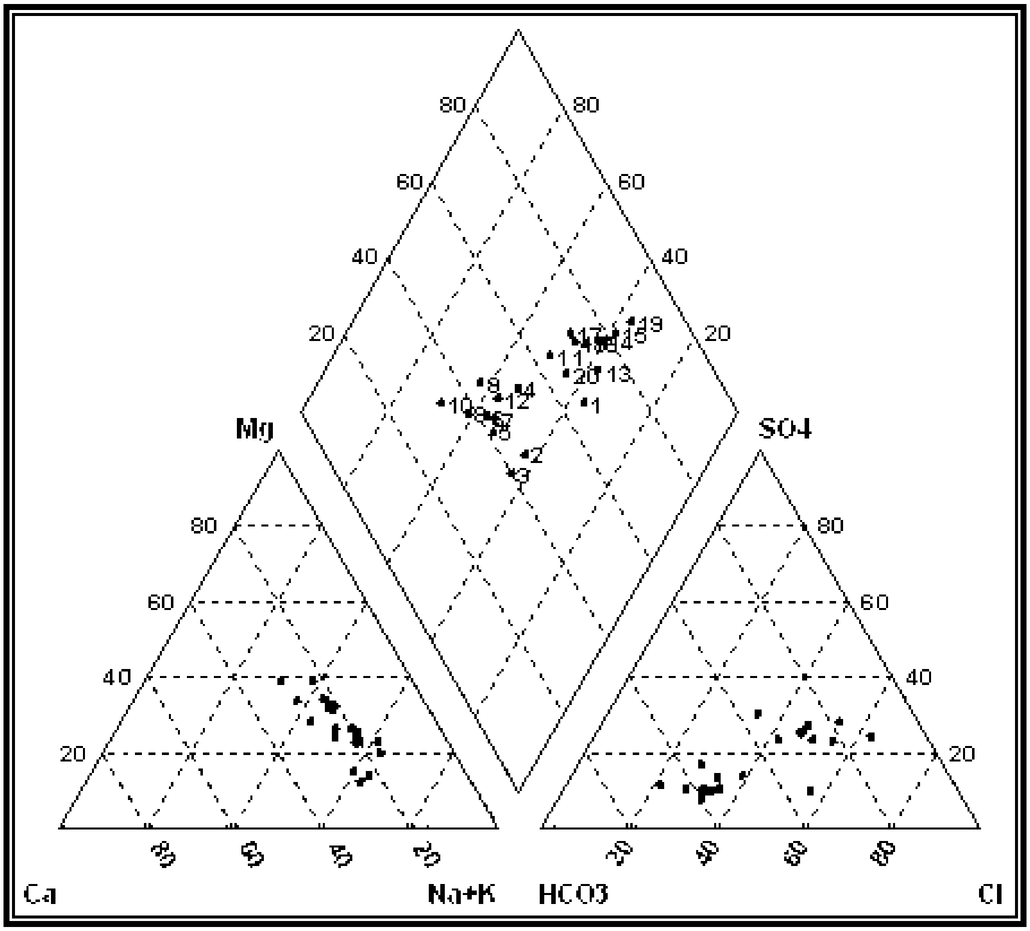

Figure (4.11) Piper diagram for the analyzed samples for the study area

- Samples No. 4, 5, 6, 7, 8, 9, 10, 11, and 16 are plotted in the area of diamond shape indicating that the alkaline earths exceed alkalies i.e. {(Ca2+ + Mg2+)>(K+ + Na+)}. This could be explained as an indication for the dissolution from carbonate rocks in the area, in the desert fringes.
- Samples No. 1, 4, 10, 12, 13, 14, 15, 16, 17, 18, and 19 indicate that the strong acids exceed weak acids i.e. {(Cl- + SO42-)>(CO3- + HCO32-)}. This indicates dissolution of

salts from sediments in the area as halite and gypsum during flow of groundwater for a long time in location.

- Samples No. 1, 2, 3, 12, 13, 14, 15, 17, 18, and 19 lie in the area indicating that the alkalies exceed alkaline earths i.e. $\{(K^{+} + Na^{+})>(Ca^{2+} + Mg^{2+})\}$. Indicating cation exchange in the soil zone with clay sediments (clay lenses) in the quaternary aquifer.

- Samples No. 2, 3, 5, 6, 7, 8, 9, and 11 lie in the area indicating that the weak acids exceed strong acids i.e. $\{(CO_3^{-} + HCO_3^{2-})>(Cl^{-} + SO_4^{2-})\}$. This indicates fresh water due to recharge from the Nile water in old lands due to excess irrigation.

- Samples No. 1, 12, 13, 14, 15, 17, 18 and 19 indicate that the Noncarbonate alkali (Primary salinity) exceeds 50% i.e. alkalies and strong acids dominate chemical properties. This can be attributed to the mixing of drainage water from irrigated lands, after leaching processes in the soil zone, with the upward flowing groundwater from deeper horizons or even deep aquifers.

- The isotopic analysis of the groundwater samples from similar areas along the desert fringes gave proof to the mixing with Paleo-water (Awad et al, 1994), from deep aquifer through the fault bounded the study area. Also Sodium Chloride may be due to pumping from the diffusion zone which is close to marine Pliocene caly.