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# ASSESSMENT OF GROUNDWATER RESOURCES FOR IRRIGATION PURPOSES IN ASSIUT GOVERNORATE, UPPER EGYPT

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## Abstract

A general increase of water demand in Egypt is prominently denoted. This situation is more noticeable in the Middle and Upper Egypt of arid Zone and limited water resources in which Assiut is one of the governorates of this Zone. The main objectives of this study are to assess the groundwater quality for irrigation, and to present solutions for managing and protecting these resources in Assiut area. To achieve that, one hundred and nine groundwater samples were collected from Quaternary aquifer during autumn of the year 2013. Chemical analysis was carried out and analyzed for major and trace elements according to the irrigation water guidelines of (FAO, 1985), and Rowe, et al. 1995, taking into account the spatial variations and the representation of the hydrochemical data. The results show that 47% none degree of restriction on use and 52% Slightly to moderate degree of restriction on use, According TDS hazarded. 55 % belongs to (C2-S1) good water for irrigation all crops in all soils and45 % belongs to (C3 -S1) good water for irrigation all crops in all soils under ordinary and specific condition like adequate drainage and leaching, According U.S. salinity laboratory staff classification depend on (EC,TDS and SAR) hazarded. while according to RSC (residual sodium carbonate100% Low RSC hazard (safe water for irrigation. 89% Excellent water for irrigation sensitive all crops and low likelihood of soil problems and11% good to permissible for irrigation semi - tolerant and tolerant crops and slightly to moderate likelihood of soil problems according Boron content, in compared to recommended limits in (FAO, 1995, 2010) guideline for irrigation water. Consequently, it is recommended to prevent the sewage and domestic waste water, and the industrial waste water from direct disposal without treatment to the ground wells, irrigation canals and River Nile; avoiding the construction of open septic tanks, especially near the pumping wells; controlling the use of fertilizers and pesticides in the agriculture purposes; selected the suitable crops for every sector (area) according to the chemical character's of the available irrigation water and soil properties.

***Keywords:*** Quaternary; Groundwater; Irrigation; Assiut area; River Nile; Egypt.

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## 1. Introduction

As a result of increasing population and human activities, pollution became a serious problem affecting the surface and groundwater resources in Assiut Governorate. This study is an expansion of previous studies carried out on the surface and ground water resources of the western bank of the River Nile between EL-Edwa and Der Mawas cities of Minia Governorate in Upper Egypt (e.g. El Kashouty et al., 2012; Elewa et al., 2013 and Morsi M. S 2012). The main sources of surface and groundwater pollution in this area are the industrial and domestic sewage, and the waste water.

Surface water and groundwater are mainly exposed to contamination with hazardous industrial waste, fertilizes, and pesticides from agricultural activities, as well as oil pollution brought from ships and oil terminals (EEAA-EIMP, 1999 and UN, 2002). Another source of contamination in the study area is the domestic sewage from villages and cities, and human activities. Because the need of water increases due to population growth, industrial development and cultivation of desert land, the availability of water of acceptable quality in Egypt is limited and getting even more restricted. The main purpose of the present study is to assess and to evaluate the quality of groundwater for the irrigation purposes. All irrigation water contains some dissolved salts. These dissolved salts are present because some chemical elements have a strong attraction for water and a relatively weak attraction for other elements. Sodium and chloride are two such chemical elements; the amounts of these elements contained in water must be very high before sodium will combine with chloride to form the solid material sodium chloride, common table salt. The total amount and kinds of salts determine the suitability of the water for irrigation use. Water from some sources may contain so much salt that it is unsuitable for irrigation because of potential danger to the soil or crops. Irrigation water quality can best be determined by chemical laboratory analysis.

## Study Area

The study area is located on the eastern and western banks of the River Nile between the cities of Dirout at north and EL-Badary of Sedfa at south within Assiut Governorate. The area is bordered from the east and the west by cultivated areas and limestone plateau, approximately between latitudes $26^{o}\ 15^{-}$ and $27^{o}\ 10^{-}$ N and longitudes $30^{o}\ 40^{-}$ and $31^{o}\ 30^{-}$ E (Fig. 1). Assiut Governorate includes 11 cities, 56 main villages, and 235 subordinate villages, and the number of its population is about 4 million people, form which 73 % are living in the rural area and 27% are living in the urban area.

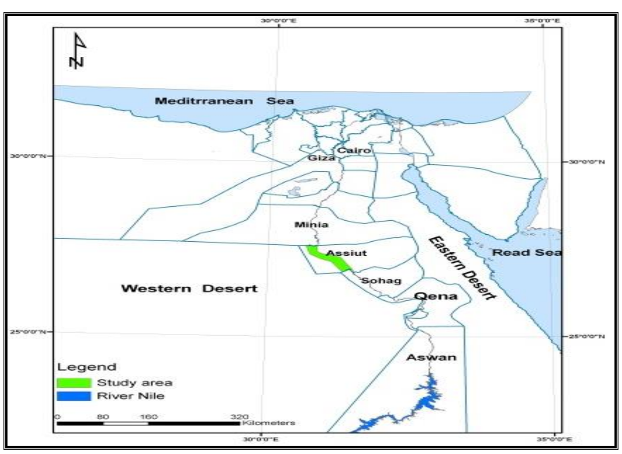


Figure 1: Location map of study area in Assiut Governorate

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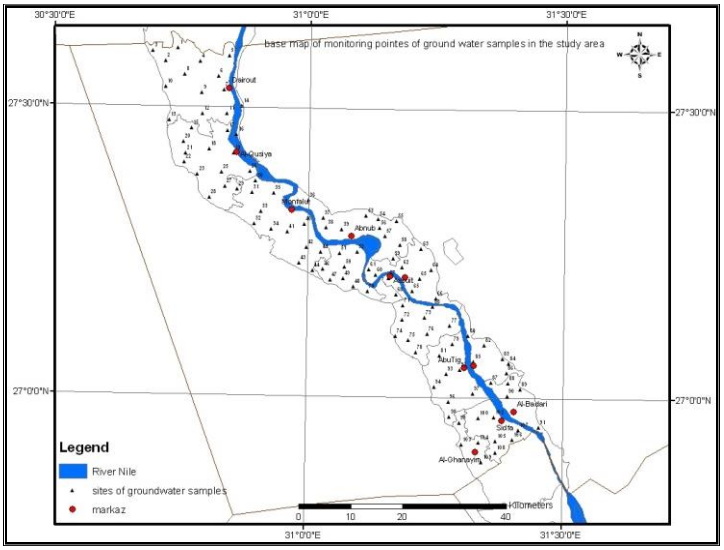

Figure 2: Location map of the collected groundwater Samples from the study area

## Climate

The study area is characterized by arid to semiarid, hot climate. The annual average of temperature is about 22.7$^o$ (the minimum temperature is 15.3$^o$, and the maximum temperature is about 30.3$^o$). The average rainfall value is about 0.7 mm/month. The average value of relative humidity is 38%. The average value of evaporation is about 14.2 mm/year. The winds reach the average of 7.5 Knot/hour (Egyptian metrological Authority, 1981-2001) and (EEAA, 2005)

## Geological Setting

The study area in recognized as a part of Nile Basin.

## Geomorphologically

the study area is dominated by four main geomorphic units which are; (Fig 3)

1) The young alluvial plains of the Nile which underlain by silty clay layer of Holocene that caps the graded sand and gravel units of Pleistocene Time.
2) Old alluvial plains which comprise the early Pleistocene terraces which are composed of travertine, conglomerates interbeded with clays, sands, and gravels, and late Pleistocene terraces made up debris, loose deposits, limestone cobbles and flint boulders. Its extends from the foot slope of the Eocene scarps to the boundary of the young alluvial plains of the Nile.
3) Limestone plateaux: composed of hard limestone of Eocene Time.
4) The desert-Hydrographic patterns which dissect the limestone plateaux surface and are directed into the Nile Valley.

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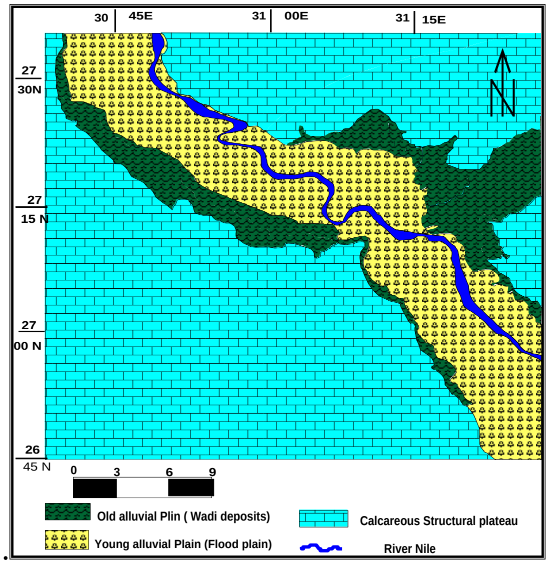


Figure 3: Geomorphologic map of Assiut governorate 1992, survey Egypt, 1957, and Said, 1962, 1981)

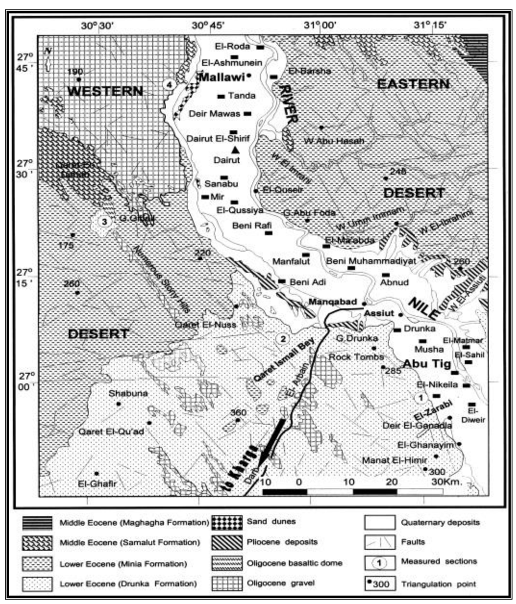


Figure 4: Geological map of the study area (modified after EGPS (after Wali, and Conoco, (1987)

## Stratigraphical Background

The study area is composed essentially of alluvial deposits, which are characterized by irregularities in their distribution. They are built of lenticular bodies of sands and gravels intercalated with clay and silt interbeded. At the upper and near the surface, parts of these sediments are generally unconsolidated and usually completely loose, overlying in most cases inhomogeneous sequences of sands and clays. the thickness of these sediments increasing generally towards the River Nile and may reach more than 300 m above the bed rock of the limestone succession .these sediments are relate to the Pleistocene age and were classified from the oldest to the youngest by (said 1983) into Protonile, Prenile and NeoNile sediments (Fig. 4).

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The carbonate rocks are representing by the plateau bordering the Nile Valley. In the subsurface the lower Eocone rocks form the bottom of the Nile Valley. The Nile Gorge is filled with the Pliocene and Quaternary deposited. The Pliocene deposited consist of clay interbeded with sand are unconformably resting on the Eocene carbonate rocks. (Said 1981).

Ageneralized stratigraphic section (Said, 1983 &1990) shows that the carbonate section of the Eocene is formed at the base from shale chalk, sandstone and on conglomerates while at the top: the clays marls and shales are dominating. Table (1)

## Geological Structures

The structural setting of Assuit area was studied by different authors as a part of the Nile Valley (Said 1961 &1962, Omara 1972, Omara el al., 1970&1974, Osman 1980, Bakhiet 1989, Mansour 2010 and shama,1972 and others) they mentioned that folds in the area northwest of Assuit have a general NW-SE direction. These folds are mainly related to faults formed as a result of tension rather than compressional forces. Also they showed that faulting is the major deformation feature affecting the area around Assuit which resulted from tensional force also they pointed out that the Eocone Limestone plateau at the area north west of Assuit was influenced by faults and folds .the fault trends were arranged according to their decreasing order as NW-NS, N-S, NE and E-W trends .The minor folds especially in south part the study area gave an apparently axial trend directed NNW-SSE and ENE-WSW (Fig. 4).

Table 1: Main Stratigraphic units of Eocene deposits in the study area (after Said, 1990) and (El Miligy, 2003)

| Age | Group | Formation deposit |
|---|---|---|
| Late Eocene | Maadi | Maadi 110m |
| | | Beni Suef 86m |
| Middle Eocene | Mokatam | El-Fashn |
| | | Qarara 170m |
| | | Maghagha 60m |
| | | Samalut 160 |
| Early Eocene | Minia Formation | |
| | Thebes | Durnka |
| | Esna Shale | |

## Hydrogeological Conditions

The Egyptian territory lies in general within to arid zone of North Africa. These are little rainfall throughout the year in addition to some irregular storms and sometimes torrents that take place during winter seasons. The main sources of groundwater recharging are the subsurface seepage from irrigation and drainage canals and direct infiltration of return flow irrigation. The River Nile acts as effluent stream especially after the construction of the High Aswan Dam in 1966. The groundwater depth varies from one locality to another. It ranges between 2-6 m in the young alluvial plain to more than 20 m the old alluvial plains. The general groundwater flows direction is to the north word.

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The Quaternary and Pliocene water bearing sediments are of particular importance in the area of the study (Fig. 4). The quaternary aquifer has A wide geographically distribution in the Nile valley and in the adjacent desert fringes. It is composed of graded sand and gravel with occasional clay intercalations. The aquifer in considered as unconfined to semi-confined one. The aquifer is partially overlain by semi-permeable silty clay layers .and by the middle portion of the Nile Valley, where it is considered semi-confined (Fig. 5-a, b).

From the hydrogeological investigation the Quaternary aquifer thickness varies from more than 300 m at Dirout District to 200 m at Abu Tij District.

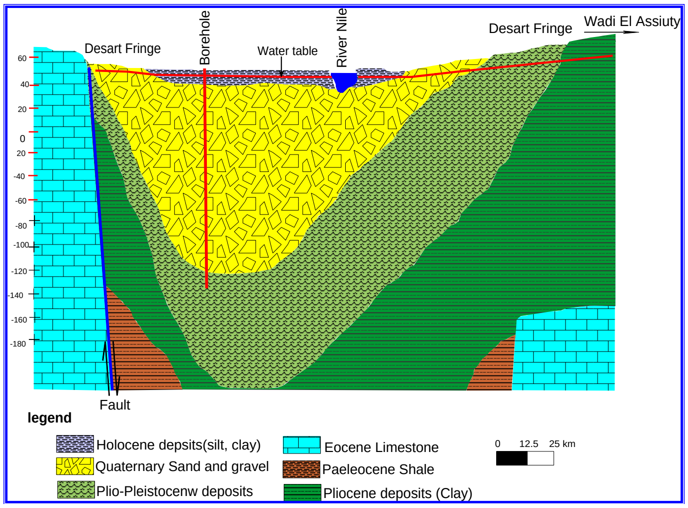


Figure 5-a: Hydro geological cross sections After (Dawoud et al., 2009)

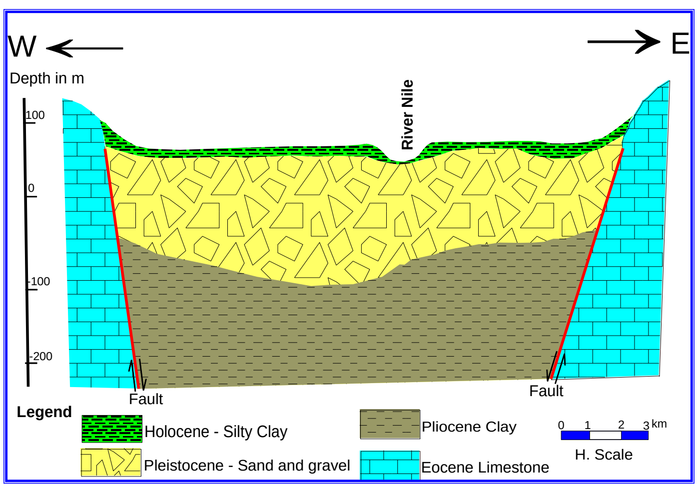


Figure 5-b: Hydrogeological cross-section South Assiut city (modified after (Mousa et al., 1994)

## 2. Materials and Methods

This research depend on the representation the published results of chemical analysis of 109 groundwater samples were collected from 109 pumping well all over the study area during autumn season 2013 from quaternary aquifer by (Morsi M. S., 2015) Figure (2). (Details materials and methods in Morsi 2015)

## 3. Results and Discussion

Soil scientists use common categories to describe the irrigation water effect on crop production and soil quality (e.g. salinity hazard, sodium hazard, chloride, boron, nitrate, PH and total alkalinity). The other potential irrigation water contaminants that might affect the suitability of agricultural use are heavy metals and microbial contaminants. Quality standards for irrigation water are based on important factors that affect the productivity of the crops. Several authors have proposed many different classifications for irrigation water. Considering the quality of water and their suitability for irrigation purposes, a number of concepts must be taken into consideration; these are:

1) The total concentration of soluble salt (TDS).
2) The relative proportion of sodium to other cataions (SAR).
3) The residual sodium carbonate (RSC).
4) The concentration of certain minor constituents, especially Boron.

It is notable that the quality requirements of irrigation water vary between crops types and drain ability of soils and climate.

The recommended water quality criteria for irrigation (according to FAO, 1985, 2010) and the guidelines for interpretation of water quality for irrigation (according to Ayers, 1977; Ayers and Wesrcot, 1985, Eaton, 1950, leeden et al. 1990,) are presented in Tables 1,2,3,4,5,6,7 and 8.

The application of these standards to the chemical data in the studied area (details chemical data in Morsi M. S. 2015) revealed the following results:

Table 1: Guidelines are based on (FAO) handbook 29 and PACE turf observations (2010)

| Quality parameter | Likelihood of soil problems | | |
|---|---|---|---|
| | **low** | **Medium** | **High** |
| ECw(ds/m,mmhos/cm) | <0.7 | 0.7 -3.0 | > |
| TDS(mg/l,ppm) | <450 | 450 – 2000 | > |
| SAR 0- 3 | ECW>0.7 | ECW 0.7-0.2 | ECW <0.2 |
| SAR 3 – 6 | ECW>1.2 | ECW 1.2- 0.3 | ECW <0.3 |
| SAR 6 – 12 | ECW>1.9 | ECW 1.9- 0.5 | ECW <0.5 |
| SAR 12 – 20 | ECW>2.9 | ECW 2.9- 1.3 | ECW <2.9 |
| Sodium Na (me/l) | <3 | 3 -9 | >9 |
| Sodium Na (mg/l, ppm) | <70 | 70 -200 | >200 |
| RSC (me/l) | <1.25 | >1.25 | |
| Nitrate NO3 –N (mg/l,ppm) | <5 | 5 -20 | >30 |
| Ammonium NH4-N(mg/l,ppm) | <5 | 5 – 20 | >20 |
| Boron B(mg/l,ppm) | <0.5 | 0.5 – 3.0 | >3.0 |
| Bicarbonate HCO3(me/l) | <1.5 | 1.5 – 8.5 | >8.5 |
| Bicarbonate HCo3 (mg/l,ppm) | 92 | 92- 520 | > 520 |
| Chloride CL(me/l) | <3 | >3 | |
| Chloride CL(mg/l,ppm) | <105 | >105 | |

Table 2: guideline for interpretation of water quality for irrigation (FAO, 1985)

| **Potential irrigation water quality problem** | **Parameter** | **Degree of restriction on use** | | |
|---|---|---|---|---|
| | | **None** | **Slight to moderate** | **Severe** |
| Salinity(affects crop water availability) | ECiw (mmho/cm) | < 0.7 | 0.7 – 3.0 | > 3.0 |
| | Or TDS (mg/l) | < 450 | 450 – 2,000 | > 2,000 |
| Infiltration (affects water infiltration rate, evaluated by using ECiw and SAR together) | SAR | ECiw (mmho/cm) | | |
| | 0 - 3 | > 0.7 | 0.7 – 0.2 | < 0.2 |
| | 3 - 6 | > 1.2 | 1.2 – 0.3 | < 0.3 |
| | 6 - 12 | > 1.9 | 1.9 – 0.5 | < 0.5 |
| | 12 - 20 | > 2.9 | 2.9 – 1.3 | < 1.3 |
| | 20 - 40 | > 5.0 | 5.0 – 2.9 | < 2.9 |
| Specific ion toxicity (affects sensitive crops) | SARadj | < 3 | 3 – 9 | > 9 |
| ($Na^+$) surface irrigation | meq/l | < 3 | > 3 | |
| sprinkler irrigation | | | | |
| ($Cl^-$) surface irrigation | meq/l | < 4 | 4 – 10 | > 10 |
| sprinkler irrigation | meq/l | < 3 | > 3 | |
| Boron ($B^{+++}$) | Ppm/l | < 0.7 | 0.7 – 3.0 | > 3.0 |
| ($HCO_3^-$) Bicarbonate (overhead sprinkler only) | meq/l | < 1.5 | 1.5 – 8.5 | > 8.5 |

| **Plugging potential from irrigation water used in micro irrigation system** | | | |
|---|---|---|---|
| **Problem** | **Low** | **Medium** | **Severe** |
| Physical | | | |
| Suspended Solids (ppm) | < 50 | 50 – 100 | > 100 |
| Chemical | | | |
| pH | < 7.0 | 7.0 – 8.0 | > 8.0 |
| TDS (ppm) | < 500 | 500 – 2000 | > 2000 |
| Manganese (ppm) | < 0.1 | 0.1 – 1.5 | > 1.5 |
| Iron (ppm) | < 0.1 | 0.1 – 1.5 | > 1.5 |
| Hydrogen sulfide (ppm) | < 0.5 | 0.5 – 2.0 | > 2.0 |
| Biological | | | |
| Bacteria pop. (no./ml) | < 10,000 | 10,000 – 50,000 | > 50,000 |

[1] Adapted from Western Fertilizer Handbook, 2002, Ninth edition, California Plant Health Association, Interstate Publications, Inc., Danville, Illinois.

Table 3: recommended water quality criteria for irrigation (Ayers 1977)

| **Constituents** | **Unit** | **Suitability for irrigation** | | | **Specific crops affected** |
|---|---|---|---|---|---|
| | | **Suitable** | **Marginal** | **Unsuitable** | |
| EC | µmmhos/cm | <750 | 750-3000 | >3000 | |
| TDS | mg/l | <250 | 500-2000 | >2000 | |

| | | | | | |
|---|---|---|---|---|---|
| $B^{++}$ | mg/l | <0.5 | 0.5-2 | >2 | Fruit and citrius trees 5-1 mg/l& field crops 1-2 mg/l & crasses mg/ |
| $CL^{-}$ | mg/l | <142 | 142-355 | >355 | Tree crops and ornamentals – root adsorption Field and vegetable crops- foliar damage at >106 mg/l |
| SAR | | <3 | 3 – 9 | >9 | Tree crops- root adsorption |
| $SO_4^{-}$ | mg/l | <350 | 350 - 600 | >600 | |

Table 4: Guidelines for interpretations of water quality for irrigation (Ayers and wesrcot 1985)

| **Potential irrigation Properties** | **Units** | **Degree of restriction on use** | | | |
|---|---|---|---|---|---|
| | | **None** | **Sligh to moderate** | **Severe** | |
| Crop Effects | | | | | |
| Salinity | $EC_w$(ds/m) | <0.7 | 0.7-3.0 | >3.0 | |
| Soil Effects | | | | | |
| Infiltration | SAR=0-3 | And $EC_w$ | >0.7 | 0.7-0.2 | <0.2 |
| | 3-6 | | >1.2 | 1.2-0.3 | <0.3 |
| | 6-12 | | >1.9 | 1.9-0.5 | <0.5 |
| | 12-20 | | >2.9 | 2.9-1.3 | <1.3 |
| | 20-40 | | >5.0 | 5.0-2.9 | <2.9 |
| Crop Effects | | | | | |
| Specific ion toxicity | Sodium SAR | <3.0 | 3.0-9.0 | >9.0 | |
| | Chloride(meq/l) | <4.0 | 4.0-10.0 | >10.0 | |
| | Boron(mg/l) | <0.7 | 0.7-3.0 | >3.0 | |
| Miscellaneous | Nitrogen(mg/l) | <5 | 5.0-30 | >30 | |
| | Bicarbonate(meq/l) | <1.5 | 1.5-8.5 | >8.5 | |
| | PH | Normal range 6.5-8.4 | | | |

Table 5: Eaton classification (1950) based 0n (RSC)

| **Suitability of water samples for irrigation** | **Values of RSC in epm** |
|---|---|
| Safe | < 1.25 |
| Marginal | 1.25 - 2.5 |
| Unsuitable | > 2.5 |

Table 6: shown limits of boron in irrigation water (leeden *et. Al.* 1990) permissible limits boron (in parts par million)

| **Class of water** | **Crop group** | | |
|---|---|---|---|
| | **Sensitive** | **Semi- tolerant** | **Tolerant** |
| Excellent | < o.33 | < 0.67 | < 1.00 |
| Good | 0.33 to 0.67 | 0.67 to 1.33 | 1.00 to 2.00 |
| Permissible | 0.67 to 1.0 | 1.33 to 2.00 | 2.00 to 3.00 |
| Doubtful | 1.o to 1.25 | 2.00 to 2.5 | 3.00 to 3.75 |
| Unsuitable | > 1.25 | > 2.5 | >3.75 |

Table 7: shown crop groups of boron tolerance (Leeden *et.at*.1990)

| **Sensitive** | **Semi tolerant** | **Tolerant** |
|---|---|---|
| Pecan | Sunflower (native) | Athel ( tamarix aphylly) |
| walnut(black, Persian or English), | Potato | Asparagus |
| | Cotton ( Acala and pima) | Palm( phoenix canariensis) |
| Jerusalem – artichoke | Tomato | Date palm (p.dactylifera) |
| Navy bean | Sweet pea | Sugar beet |
| Plum | Radish | Mangel |
| Pear | Field pea | Garden beet |
| Apple | Ragged robin rose | Alfalfa |
| Grape (sultania and Malaga) | Olive | Gladiolus |
| Kadota fig | Barley | Broad bean |
| Persimmon | Wheat | Onion |
| Cherry | Corn | Turnip |
| Peach | Milo | Cabbage |
| Apricot | Oat | Lettuce |
| Thom less blackberry | Zinnia | Carrot |
| Orange | Pumpkin | |
| Avocado | Bell pepper | |
| Grapefruit | Sweet potato | |
| Lemon | Lima bean | |

Table 8: U.S. salinity staff classification (Richards 1954) which based on the sodium adsorption ratio (SAR) and the specific conductance (in micro mhos) the water divided into four classes

| **Conductivity** | **Quality** | **Range** | **Usage** |
|---|---|---|---|
| C1 | Low salinity water | 100 - 250 | Can be used for irrigation of most crops in most soils with little likelihood that soil salinity develop |
| C2 | Medium salinity water | 250 - 750 | Can be used if a moderate amount of leaching occurs |
| C3 | High salinity water | 750 – 2250 | Canot be used on soil with restricted Drainage even with adequate Drainage special management for salinity control may be required and plants with good salt tolerant should be selected. |
| C4 | Very high salinity water | > 2250 | Is not suitable for irrigation under ordinary conditions but may be used occasionally under special conditions as the soils must be permeable, and Drainge must be adequate, irrigation water must be applied in excess to provide considerable leaching. |
| **SAR** | **quality** | **Range** | **Usage** |
| S1 | Low sodium water | 0 – 10 | Can be used for irrigation of almost all soils with little changes of the development of harmful levels of exchangeable sodium. |

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| Conductivity | Quality | Range | Usage |
|---|---|---|---|
| S2 | Medium sodium water | 10 -18 | Will represents an appreciable sodium hazard in fine-textured soils having high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil. |
| S3 | High sodium water | 18 – 26 | May produce harmful levels of exchangeable sodium in most soils and will require special soil management, good Drainage, high leaching and organic matter condition. |
| S4 | Very high sodium water | 26 – 100 | Is generally unsatisfactory for irrigation purposes except at low and perhaps land perhaps medium salinities. |

## Salinity and Total Dissolved Solids

Electrical conductivity (EC) and salinity usually contribute to the total dissolved solids (TDS). The problem occurs when the salts accumulate in the root level in an extent preventing the crop to be able to extract sufficient water from the salty soil solution, causing a water stress for a significant period. If water uptake is appreciably reduced, the plant slows its rate of growth. The most influential water quality guideline on crop productivity is the water salinity hazard that is measured by electrical conductivity ($EC_w$). The primary effect of the high $EC_w$ on crop productivity is the inability of the plant to compete with ions in the soil solution for water. The higher the $EC_w$, the lower the level of water content available to plants; even though the soil may appear wet (Yousry et al., 2009). the TDS values range from 210 to 1355 mg/l 53% of samples within the range of Low Likelihood of soil problems, and 47% of samples is considered as medium likelihood of soil proplems (marginal) relatively to the TDS concentration, but the other parameters can be controlled in its use (Fig. 6-a,b).

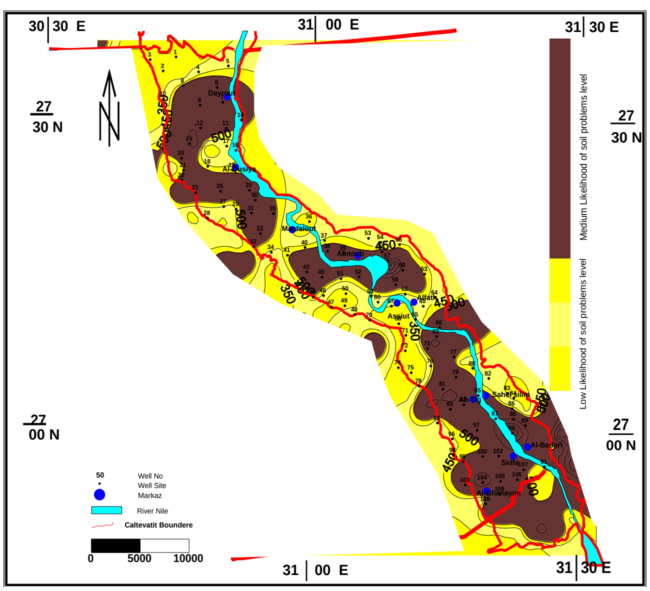


Figure 6-a: contour map distribution groundwater samples according TDS hazard (FAO, 1985, 2010)

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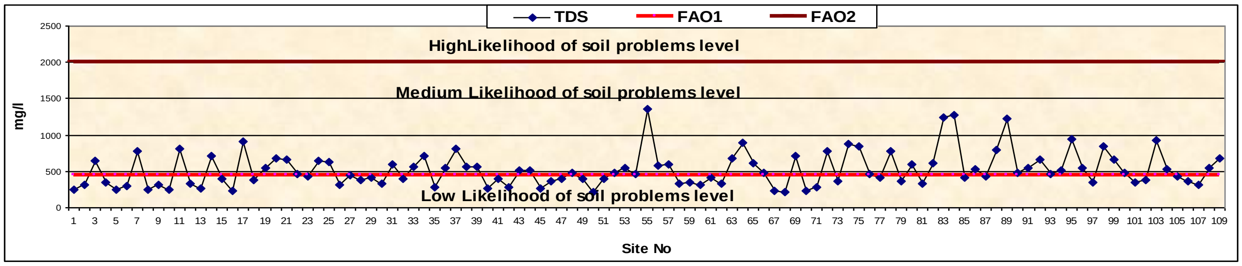


Figure 6-b: histogram show classification of groundwater samples according TDS hazard (FAO, 19985 , 2010)

## Sodium hazard

### Sodium ions

Sodium toxicity is often reduced if sufficient calcium is available in the soil. Excessive sodium causes mineral particles of soil to disperse and water penetration to decrease. High sodium concentration accompanied by decrease in the infiltration rate causes problem as the crop could not be adequately supplied with water especially when the hydraulic conductivity of the soil profile is too low to provide adequate drainage. If calcium and magnesium are the predominant adsorbed cations on the soil exchange complex, the soil tends to be easily tilled and have a readily permeable granular structure (Yousry, et al., 2009).

For groundwater samples (Fig.7-a,b), the sodium concentration ranges between 17 mg/l (0.77 meq/l) to195 mg/l (8.85 meq/l), and about 21.1% of samples is considered to have medium likelihood of soil problems (marginal) relatively to the sodium ions concentration, but the remaining samples indicate that there is no restriction of using sensitive crops, and lies within the low likelihood of soil prop problem. It is notable that sodium is toxic to certain plants and causes an adverse effect on the soil structure, infiltration, and permeability characteristics (El-Sherbini et al., 1997). Investigations exhibit that the excessive sodium exceeds three times as much as calcium. This high sodium content (>3:1) often results in severe water infiltration problem due to soil dispersion and plugging of the surface pores; this effect is similar to that of water with low salinity.

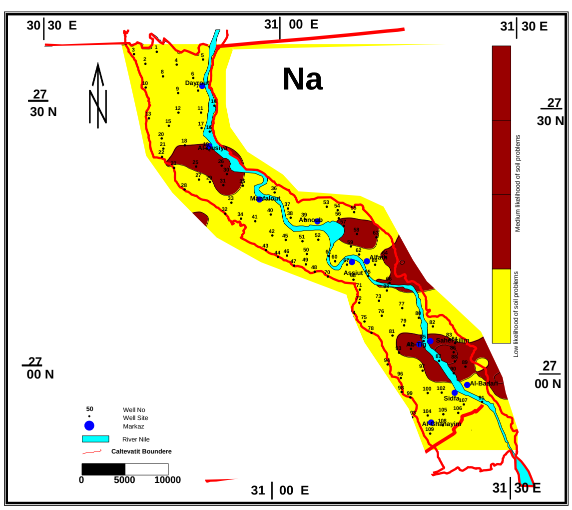


Figure 7-a: contour map distribution groundwater samples according $Na^{+}$ ions hazard (FAO, 1985, 2010)

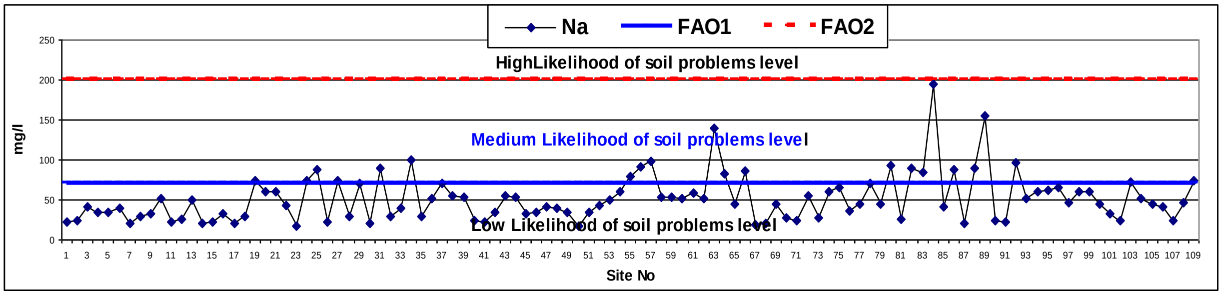


Figure 7-b: Histogram show classification of groundwater samples according $Na^+$ hazard (FAO, 19985, 2010)

## Infiltration Concerns

Calcium, magnesium, and sodium are used to calculate the sodium adsorption ratio (SAR) of the irrigation water. The adjusted SAR is calculated using information from (Suarez 1981), which includes the bicarbonate content of the irrigation water. The permeability hazard of an irrigation water sample is related to both the SAR and EC of the irrigation water (Flynnl, 2009).

An infiltration problem occurs if the irrigation water does not enter the soil rapid enough during a normal irrigation cycle to replenish the soil with water needed by the crop before the next irrigation. Low salinity water (less than 0.5 ds/m and especially below 0.2 ds/m) is corrosive and tends to leach surface soils free of soluble minerals and salts, especially calcium, reducing their strong stabilizing influence on soil aggregates and soil structure without salts and without calcium. The soil disperses and the dispersed finer soil particles fill many of the smaller pore spaces, sealing the surface and greatly reducing the rate at which water infiltrates the soil surface. We herein used the method of (Richards 1954) to evaluate the infiltration potential (e.g. the sodium adsorption ratio; SAR).

## Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) is used to estimate the sodality hazard of the Water.

SAR is a measure of the tendency of the irrigation water to the soil clay minerals with sodium ions, sodium clays have poor structure and develop permeability problems (George, 1983).

SAR is defined as in equation

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

Where $Na^+$, $Ca^{2+}$ and $Mg^{2+}$ represent meq $1^{-1}$ of sodium, calcium and magnesium ions, respectively. SAR values were evaluated according to FAO guidelines.

According to the U.S. salinity staff classification (Richards 1954) which based on the sodium adsorption ratio (SAR) and the specific conductance (in micro mhos) the water divided into four classes (table, 9).

For groundwater samples (Fig.8-a,b), the SAR values range from 0.29 to 3.53. 55% are good (suitable) for irrigation in all soils as they are located in class [C2-S1] and 45% located in class [C3-S1], (Ayers and westcot, 1985). [C denotes conductance and S denote SAR].

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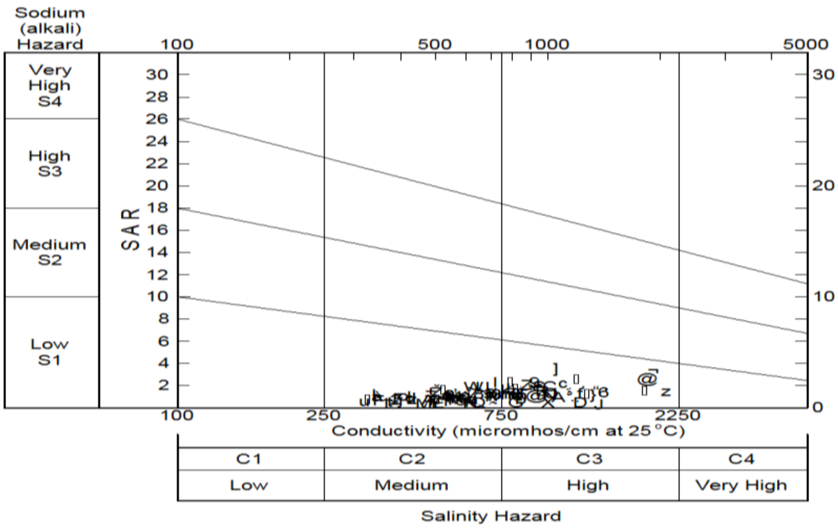


Figure 8-a: Classification of groundwater samples according to U.S. salinity staff classification (Richards 1954)

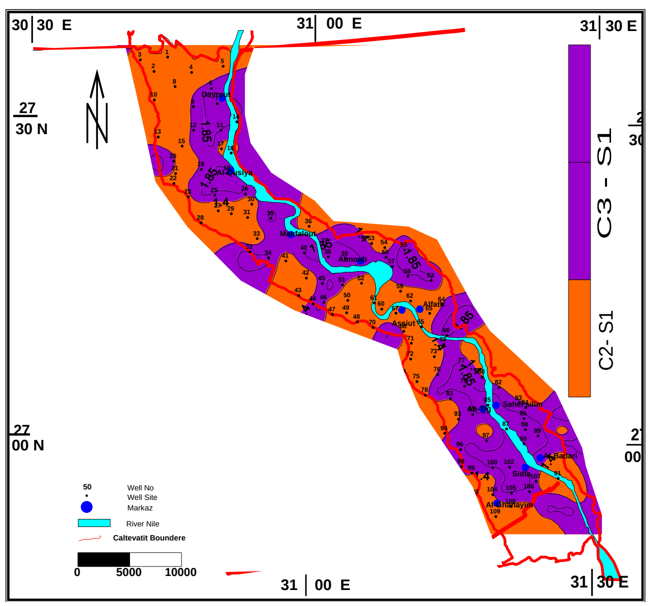


Figure 8-b: iso- contour map distribution of classes in groundwater samples according to U.S. salinity staff classification (Richards 1954)

## Residual Sodium Carbonates (Eaton's Classification, 1950)

When the sum of carbonate and bicarbonate is in excess of calcium and magnesium, there is an almost complete precipitation of the latter (Eaton's 1950). This can cause an increase in the proportionate amount of sodium, and so the effect on the soil is the high sodium content. The term residual sodium carbonates (RSC) is defined as follows:

$$RSC = (CO^{2+}_3 + HCO^{-}_3) - (Ca^{2+}+Mg^{2+}) \text{ all in mep/L}$$

The RSC is used to distinguish between the different water classes for irrigation purposes, because the high concentration of bicarbonate leads to an increase in the PH value, which causes the dissolution of the organic matter. Moreover, the high concentration of the bicarbonate ions in the

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irrigation water leads to its toxicity and affects the mineral nutrition of plants (see Eaton's classification, 1950).

The groundwater samples (Fig.9-a,b) have RSC values ranging from -26.15 to 2; about 95% can be positioned within the level of none restriction on use; they belong to the possibly safe water for irrigation; as they are free from residual sodium carbonate (RSC) hazard. Whereas, the remaining 5% is considered as belonging to the slight to moderate restriction on use (marginal) relatively to the RSC values.

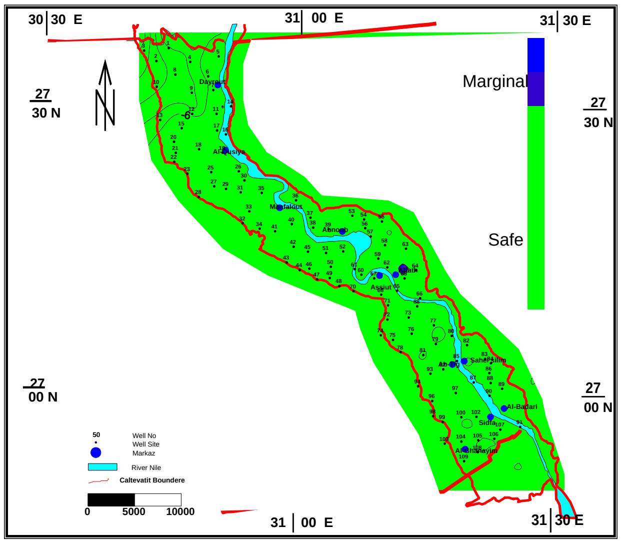


Figure 9-a: iso- contour map distribution of RSC values hazard in groundwater samples according to (Eaton 1950)

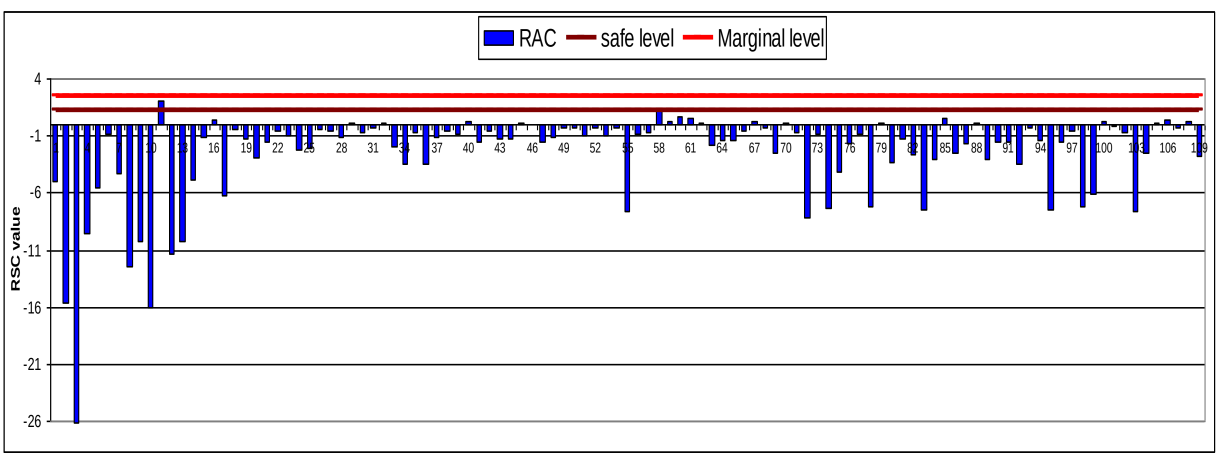


Figure 9-b: Histogram show classification of groundwater samples according RSC values hazard (Eaton 1950)

## Specific Ion Toxicity

The specific ion toxicity (like chloride and boron) occurs when the decline of crop growth is due to the excessive concentrations of that specific ion rather than to the osmotic effect alone (Yousry, et al., 2009).

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## Chloride

Chloride ions concentration (Fig.10-a, b), ranges between 15 mg/l (0.42 meq/l) and 477 mg/l (13.44 meq/l); Table 3. Comparing the data of chloride with FAO guidelines, it was found that about 83.5% of the values are lesser than 4 meq/l; meaning that there is no restriction on using it for some susceptible crops. On the other hand, about 15.5% of samples at sites no. 17, 19, 25, 34, 36, 37, 63, 64, 66, 80, 82, 84, 86, 89 and 92 are belonging to the slight to moderate restriction on use (marginal) relatively to the chloride ions values. While, 0.91% of samples at site no. 3 belongs to the severe restriction on use.

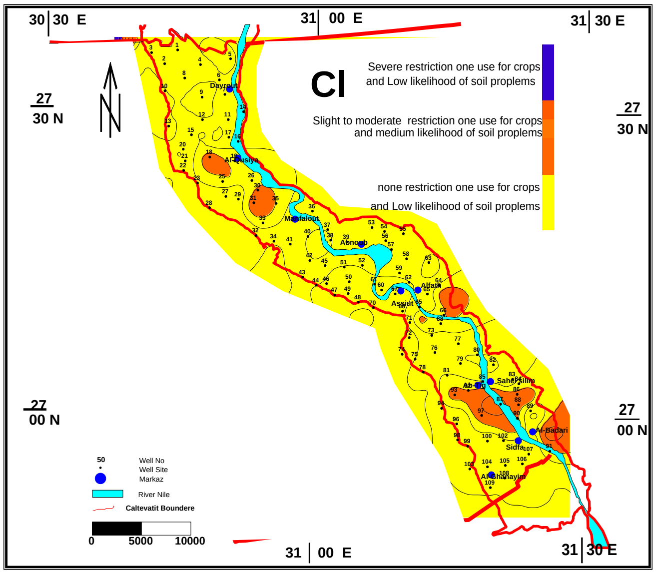


Figure 10-a: iso- contour map distribution of $Cl^-$ values hazard in groundwater samples according to (FAO, 1985, 2010)

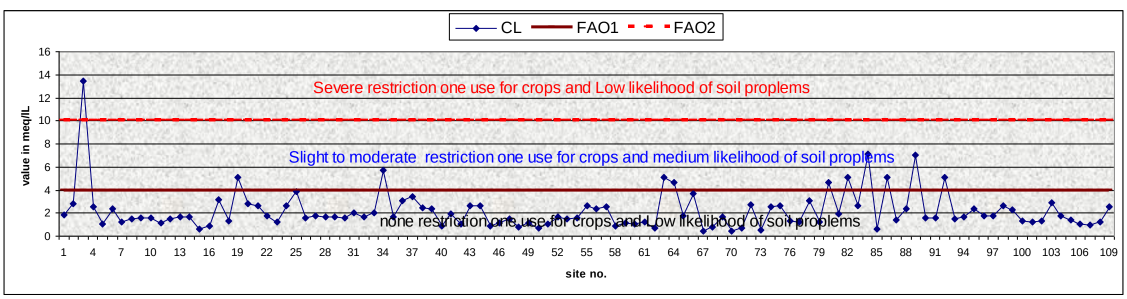


Figure 10-b: Histogram show classification of groundwater samples according $Cl^-$ values hazard (FAO, 1985, 2010

## Boron

The boron is another element that is essential in low amount for plant growth, but it is toxic at higher concentrations. In fact, toxicity can occur on sensitive crops at concentrations lesser than 1 mg/l. surface water rarely contain enough boron to be toxic but groundwater occasionally contain toxic amounts. Boron toxicity symptoms normally sow first an older leaves as a yellowing, spotting, or drying of leaf tissue at the tips and edges (Yousry, et al., 2009).

According to (Leeden et al. 1990), the surface and groundwater in the study area can be classified depending on the boron content and the crops tolerant to it in the following manner:

For groundwater samples, about (78.9%) (range between 0.008 and 0.31 mg/) have $B^{2+}$ values less than 0.33 mg/l are suitable for irrigation of all crops (excellent), while about (8.26%) of groundwater samples have $B^{2+}$values between 0.35 mg/l and 0.63 mg/l are good for irrigation of Sensitive Crop group and excellent for irrigation of semi- tolerant and tolerant crops. about (11%) of groundwater samples have $B^{2+}$values between 0.67 mg/l and 0.95 mg/l are permissible for irrigation of Sensitive Crop group, good for irrigation of semi- tolerant while excellent for irrigation of Tolerant Crop group , and about (1.84%) of groundwater samples have $B^{2+}$values between 1.1 mg/l and 1.2 mg/l are doubtful for irrigation Sensitive Crop group , while permissible for irrigation of semi- tolerant Crop group and good for irrigation of tolerant Crop group (Fig. 11-a,b).

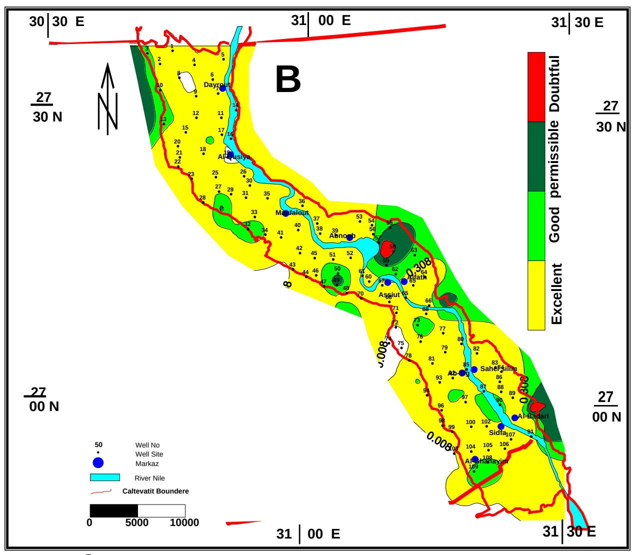


Figure 11-a: Distribution of $B^{2+}$concentration contour map of groundwater samples in study area on basis of Crop groups of boron tolerance (Leaden, et al., 1990)

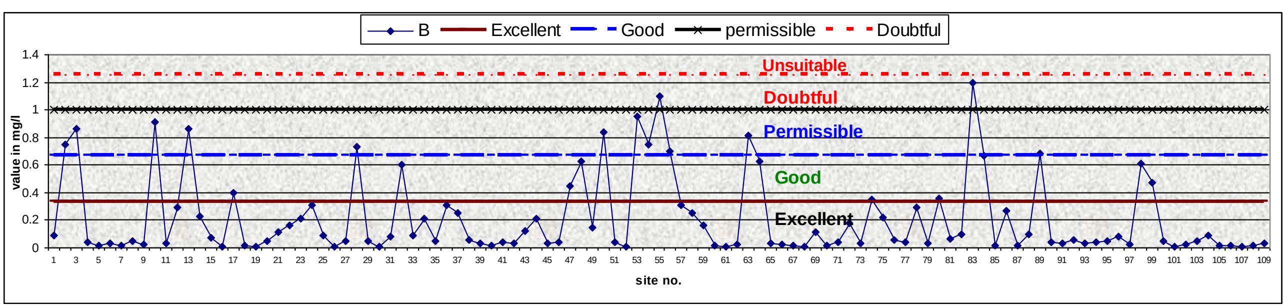


Figure 11-b: Histogram show classification of groundwater samples according $B^{2+}$concentration on basis of Crop groups of boron tolerance (Leaden, et al., 1990)

While According to (FAO, 1985 & 2010) guidelines for irrigation water, depended on boron content and likelihood of soil problems can be classified surface and groundwater in study area as the following manner:

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For groundwater, 89% fo samples have $B^{2+}$ values less than 0.7 mg/l.(ranged from 0.008 to 0.68 mg/l) They belong to low likelihood of soil problems (none degree of restriction on use) for irrigation (the possibly safe water). While the rest samples (11%) have $B^{2+}$ values ranged from 0.7 to 1.2 mg/l, They belong to likelihood of soil problems (Slight to moderate degree of restriction on use) for irrigation (Fig. 12-a,b).

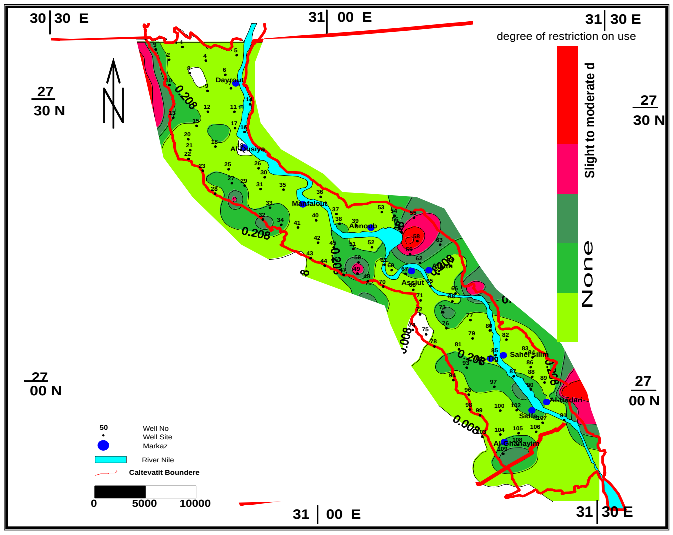


Figure 12-a: Distribution of $B^{2+}$concentration contour map of groundwater samples in study area on basis of likelihood of soil problems (FAO, 1985 & 2010)

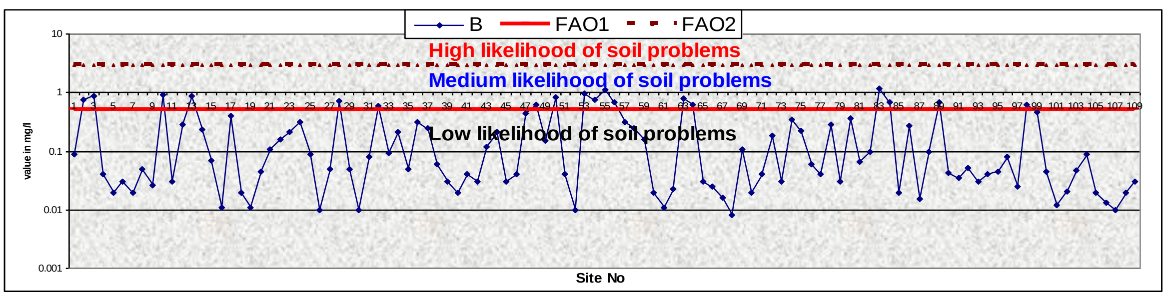


Figure 12-b; Histogram show classification of surface water samples according $B^{2+}$ concentration on basis of likelihood of soil problems (FAO, 1985 & 2010)

## Bicarbonates

The presence of bicarbonate leads to the precipitation of calcium carbonate (scale) at water pH greater than 7.5. Acidification of the water is the best way to manage bicarbonate, where water levels lesser than 1.5 mg/l will not cause problems. Severe problems can be noticed at levels above 2.5 mg/l.

For groundwater samples (Fig.13-a,b), the bicarbonate ions concentration ranges from 90 mg/l to 730 mg/l (1.5 to 11.94 meq/l) all the groundwater samples are belonging to the level of slightly to moderate restriction on use (medium likelihood of soil problem), except at sites no. 17, 38, 64, 84, and 89, which show bigger problem.

**Heavy Metals**

Not all trace elements are toxic and many of them are essential for plant growth, but in small quantities (e.g. Fe, Mn, Zn). However, excessive quantities will cause undesirable accumulations in the plant tissues and reduces the growth rate.

By comparing the result with the recommended maximum concentrations of some trace elements in irrigation water (FAO, 1985) and (Rowe et al., 1995) were 5, 5, 2, 0.2, 0.2, 0.2, 0.1, 0.1, 0.05 and 0.01 the maximum limit (for lead, iron, zinc, copper, nickel, manganese, arsenic, chromium, cobalt and cadmium, respectively can be obtained the following:

For groundwater samples, comparing the above recommended values with the data obtained from the analysis of heavy metals revealed that lead, iron, zinc, copper, arsenic, and chromium values are within the limits recommended by FAO (1985), and Rowe et al. (1995), indicating none restriction on use. Manganese concentration is high at all sites except sites no. 29, 80, 83 and 84, and lies within the level of none restriction on use. The cadmium concentration is higher at 52% of the sites. The copper concentration is higher at 12% of the sites, and the iron concentration is higher at all sites, except sites no. 63, 80, 83, 84 and 92, and lies within the slightly – medium to severe restriction on use (fig.14).

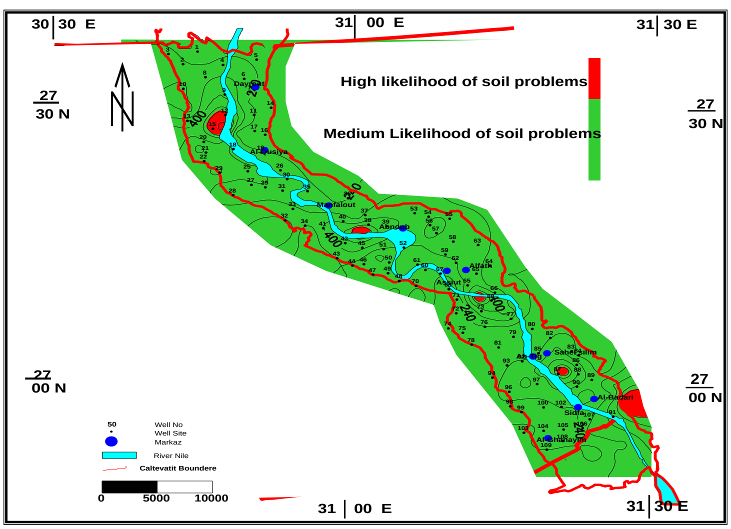


Figure 13-a: Distribution of $HCO_3$ concentration contour map of groundwater samples in study area on basis of likelihood of soil problems (FAO, 1985 & 2010)

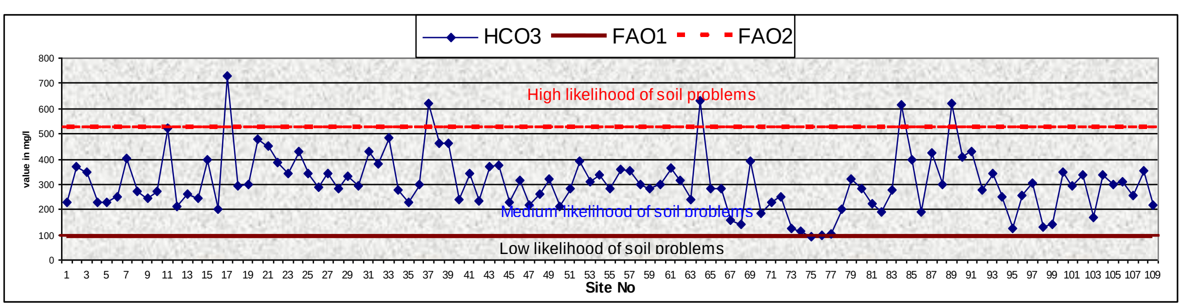


Figure 13-b: Histogram show classification of surface water samples according $HCO_3$ concentration on basis of likelihood of soil problems (FAO, 1985 & 2010)

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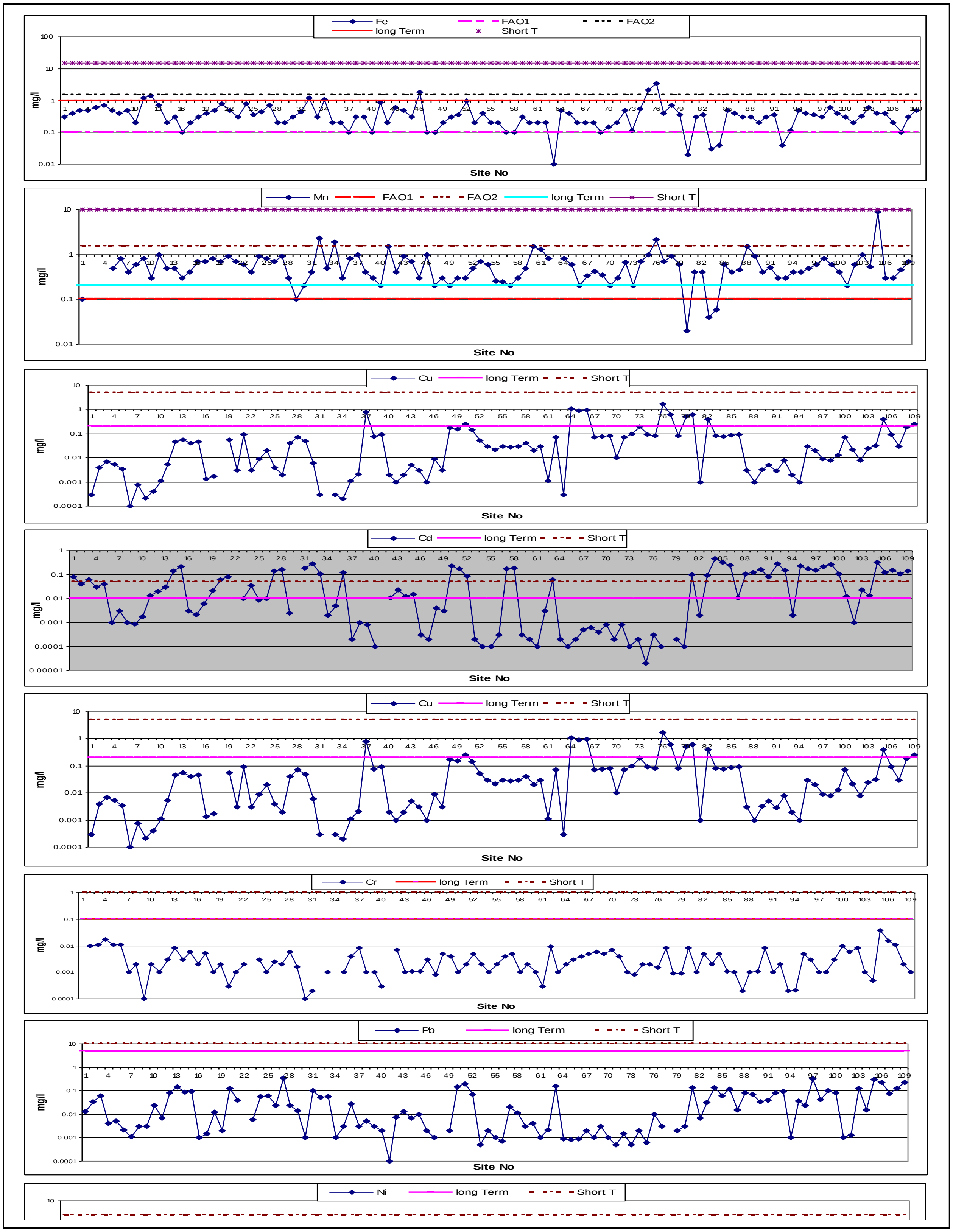


Figure 14: Variation in trace and heavy metals concentration of groundwater samples according to recommended limits of (FAO, 1985) guideline for irrigation water and ( Rowe,. el at 1995)

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## Miscellaneous Elements

The miscellaneous elements include the pH values, the total alkalinity, and the nutrients (ammonia and nitrates)

## PH values

For surface water samples, the pH values range between 6.6 and 8.9

The increase of pH values at sites no. 6, 7, 9, 11, 12, 13 and 16 could be related to photosynthesis and growth of aquatic plants (Allem, et al., 1969; El-Wakeel et Al., 1970). Photosynthesis consumes carbon dioxide leading to the rise of pH value.

However, chemical reactions in water that are controlled by the pH values and the biological activity is usually restricted to a fairly pH range of 5 to 8 (Tebbutt, 1998).

The greatest direct hazard of an abnormal pH value is its impact on the irrigation equipments.

For groundwater samples, the pH values range from 7.4 to 9.7, and lies within the slight to moderate restriction on use level. At sites no. 16, 18, 34, 51, 72 and 83; the values lie within the severe restriction on use level; indicating high pollution around these sites (fig.15).

## Total Alkalinity

Alkalinity serves as a pH reservoir for inorganic carbon. It is usually taken as an index of productive potential of water (Ravindra et al., 2003).

For groundwater samples, the total alkalinity ranges between 102 to 695 mg/l (about 1.7 to 11.37 meq/l), The bicarbonate concentrations of groundwater ranges between 1.5 and 11.49 meq/l indicating that there is a slight to moderate restriction of use; while sites no. 17, 38, 64, 84 and 89 are considered as belonging to the level of high severe restriction on use (fig.13-a, b).

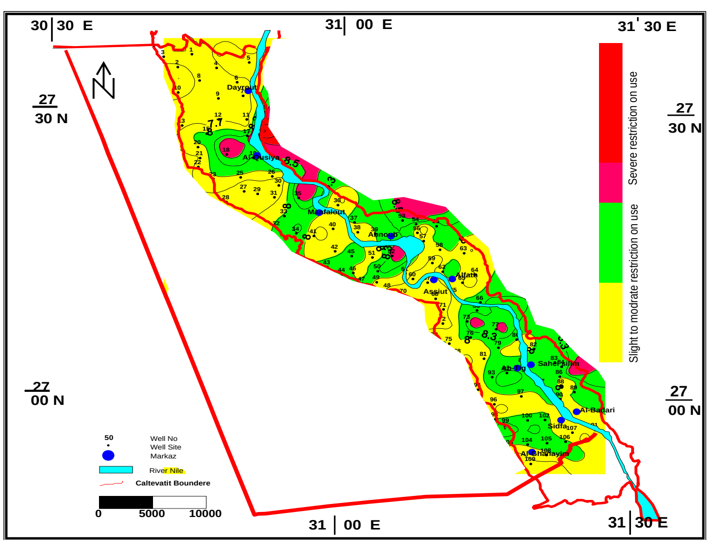


Figure 15: Distribution of PH values contour map of groundwater samples according to recommended limits of (FAO, 1985) guideline for irrigation water

**Nutrients (Ammonia and Nitrates)**

For groundwater samples, the concentration of ammonia ranges from zero to 1.8 mg/l (Fig.16) within the permissible low level of likelihood of soil problems (none restriction of use at all sites for all crops).

The nitrate concentration along groundwater samples ranges from zero to 28 mg/l. About 54% of these samples (Fig.17) lies within the permissible low level of likelihood of soil problems (none restriction of use at all sites for all crops), and about 43% of samples is belonging to the level of the slight to moderate restriction on use.

The high concentration of ammonia in wastewater discharging from drain or sewage waste led to the high contamination of the water by ammonia. The ammonia concentration in unpolluted water is lesser than 0.2 mg/l as nitrogen (chapman, 1992).

By comparing the ammonia and nitrate values with the FAO guidelines (5 mg/l N) it is found that there is no restriction on using the studied water samples for sensitive crops except above mentioned sites.

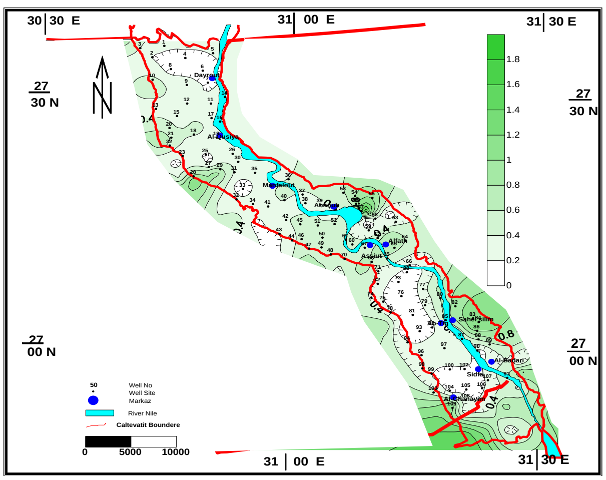


Figure 16: Distribution of NH4 concentration contour map of groundwater samples according to recommended limits of (FAO, 1985) guideline for irrigation water

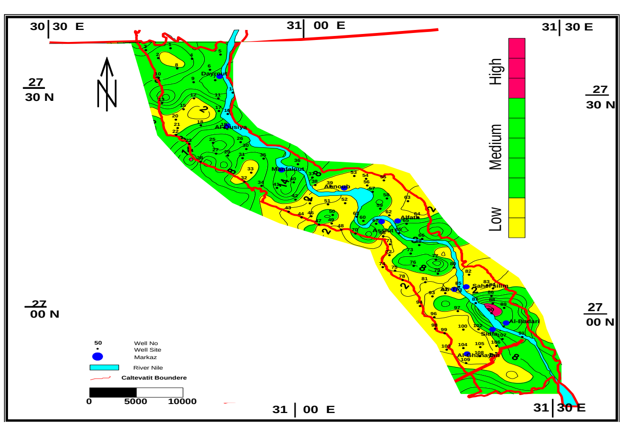


Figure17: Distribution of NO3 concentration contour map of groundwater samples according to recommended limits of (FAO, 1985) guideline for irrigation water

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## 4. Conclusions and Recommendations

Our analyses detected the variation in the properties of the groundwaters. All the PH values of groundwater samples are within the recommended limits of FAO (1985), except at sites no. 16, 18, 34, 51, 72 and 84 of groundwater samples, which exhibit more than the recommended limits. All the TDS concentrations in groundwater samples are within the recommended limits of FAO (1985) indicating none restoration on use, except 47%of groundwater samples; these are considered as belonging to the slight to moderate restoration on use. All the Na concentrations at groundwater samples are within the recommended limits of FAO (1985) (e.g. none restoration on use), except 21.1 % of groundwater samples which are belonging to the slight to moderate restoration on use. All the Boron concentrations at groundwater samples belong to the safe limits of irrigation water for the sensitive crops (excellent), except 14.6 % of groundwater samples which are good for irrigation of Sensitive crop group and excellent for irrigation of semi- tolerant and tolerant crops. There are about 1.8% of groundwater samples have $B^{2+}$values more than 1 ppm (excellent to good for irrigation of tolerant crop group), and good for irrigation of semi-tolerant crop group, while permissible for irrigation of sensitive crop group. Chloride concentrations at surface and groundwater samples (within the recommended limits), except 15.5 % of groundwater samples which are considered as belonging to the slight to moderate restoration on use, and 0.91% at site no. 3 (severe restriction on use).

The bicarbonate concentrations in groundwater samples are within the moderate –medium level of likelihood of soil problem, except at site no. (7, 38, 64, 84 and 89 of groundwater samples, which fit in the higher severe restriction on use. The NH3 concentrations in all groundwater samples are within the recommended limits (none restoration on use) for all sensitive crops, while the NO3 concentrations in all groundwater samples are within the recommended limits (none restoration on use) for all sensitive crops, except 43% of groundwater samples, which are within the moderate – medium level of likelihood of soil problem, and about 3% of groundwater samples, which are considered as belonging to the high Severe restriction on use (high soil problem).

Consequently, we recommend a strong control is needed concerning the use of fertilizers and pesticides in the agriculture purposes, as well as selecting the suitable kind of crops for each area as in (fig. 18) and (fig.8) which show classified the groundwater in study area based on the hazard of TDS, Na, EC and SAR values and their effected on planet growth and its products in related to soil problems, also as show in details in (fig. 19) and (fig. 11,12) and (table 9) which obtained more details based on Boron hazard in related to the sensitivity and tolerant of deferent crops to it. preventing the direct disposal of sewage, domestic waste water, and industrial waste water before treatment to the darning ground well, irrigation canals and the River Nile. We also stress on preventing the construction of open septic tanks, especially near the pumping well.

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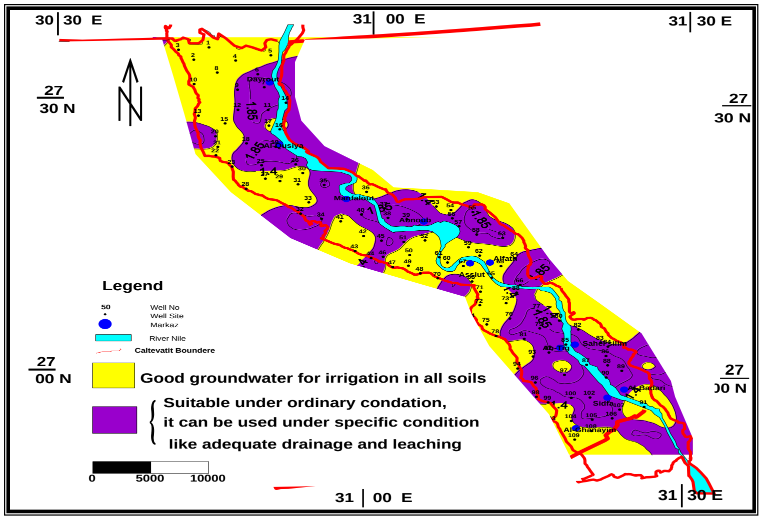


Figure 18: contour map showing Distribution of suitability of groundwater for irrigation purpose in related to likelihood soil problems according to recommended limits of (FAO, 1985, 2010) guideline for irrigation water

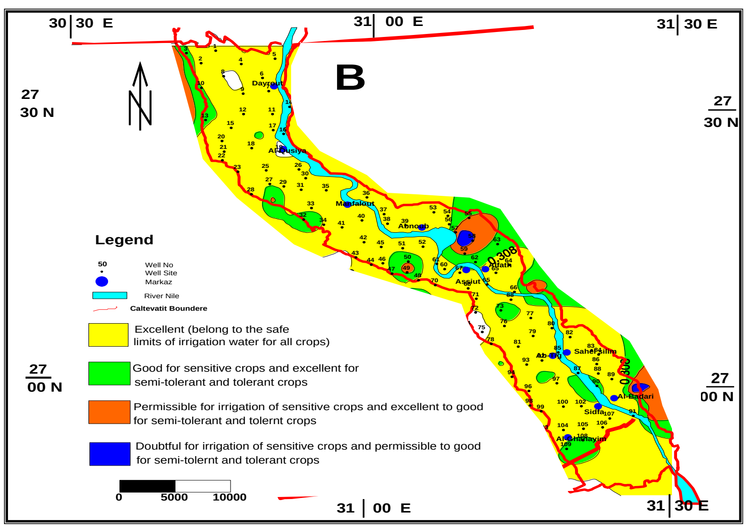


Figure 19: contour map showing Distribution of suitability of groundwater for irrigation purpose in related to Boron hazard and crop groups' tolerance according to recommended limits of (FAO, 1985, 2010) and (Leeden et. Al., 1990) guideline for irrigation water

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