# HYDROGEOLOGICAL MAP OF IRAQ, SCALE 1: 1000 000, 2nd EDITION, 2013

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## INTRODUCTION

The updated hydrogeological information is used to compile the 2nd edition of the Hydrogeological Map of Iraq, at scale of 1: 1000 000. In view of present climatic conditions in Iraq and the region, and the shortage of surface water supply there is a need to search and find other sources of water supply from groundwater resource on regional scale, to assess their quantities and qualities and to determine their suitability for different purposes.

The water of the Tigris and Euphrates rivers and their tributaries is mainly utilized in a narrow belt along river valleys, in north Iraq and the Mesopotamia Plain of central and southern Iraq. Accordingly, it is important to assess the quantity and quality of the groundwater within the different Hydrogeological Zones in Iraq. The present hydrogeological data is concerned mainly with the first aquifer within these zones, in order to evaluate the groundwater characteristics hydraulically and chemically as well as its possible usages (Al-Jiburi and Al-Basrawi, 2013).

## METHODS AND MATERIALS

In order to update the previous hydrogeological map of Iraq (Araim, 1990), the hydrogeological information within the Hydrogeological Zones was updated, and recent data have been employed from the following sources:

- Hydrogeological and hydrochemical information from the updated Hydrogeological Data Base and other available hydrogeological references in Iraq.
- The available hydrogeological maps of different scales that have been previously complied.
- Geological and topographical maps of Iraq.
- Meteorological information.
- Application of GIS techniques.

The aim of updated map is to reveal the hydrogeological conditions of the upper main aquifers within the Hydrogeological Zones in Iraq, including nature of aquifer systems, their extents, the groundwater level, flow direction, recharge and discharge regions, type and salinity in order to supply the involved areas with sufficient amount of water of suitable quality

## THE HYDROGEOLOGICAL ZONES

From the Hydrogeological point of view, Iraq can be divided into seven Hydrogeological Zones (Regions) in accordance with the physiographical, structural, geological and Hydrogeological properties of these zones. Each zone has its Hydrogeological and hydrochemical characteristics of aquifer systems. These zones are described briefly in the following (Fig.1):

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- **Mesopotamia Zone**

The Mesopotamia Zone is totally covered by Quaternary sediments; the older formations below these sediments are Injana, Mukdadiyah, Bai Hassan, and Dibdibba formations. Injana and Dibdibba formations dip towards the plain from the Western and Southern Deserts in the west and south, while Bai Hassan, Mukdadiyah and Injana formations from the Low Folded Zone, in the east and northeast.

Quaternary sediments of the Mesopotamia Zone are considered regionally as a lithologically complex aquifer system. There is a hydraulic continuity within the entire Quaternary aquifer system in this zone. The presence of hydraulic continuity between surface water (rivers, lakes and irrigation channels) and the groundwater aquifers is assumed to a substantial extent. Another assumption is that, Quaternary Aquifer System in this zone and the underlying Bai Hassan, Mukdadiya and other aquifers are also in hydraulic continuity. Direction of the groundwater flow is towards this Zone, from all neighboring regions. The Mesopotamia Zone represents a regional discharge zone of the whole Mesopotamia Aquifer, the Mega System of Iraq. Salinity of the groundwater increases from the recharge areas mainly in the northern and northeastern areas, along the Low Folded Zone, and along western and southwestern areas bordering the Western and Southern Deserts, towards the discharge areas within the Zone. Chemical quality of the groundwater changes from sulphatic to chloridic type, from recharge to discharge areas in accordance with the groundwater movement (Al-Jiburi and Al-Basrawi, 2011 and 2013).

- **Low Folded Zone**

The Low Folded Zone extends in the central northern and northeastern parts of Iraq. From the regional tectonic point of view, the Low Folded Zone forms the central unit of the Unstable Shelf of the Outer Plate of the Nubio – Arabian Platform (Buday and Jassim, 1987 and Fouad, 2012). The broad synclinal valleys form the main groundwater basins, and are filled by sedimentary formations that range in age from Late Miocene to Recent (Sissakian, 2000). They are from the oldest: Fatha, Injana, Mukdadiyah and Bai Hassan, in addition to the Quaternary cover. These formations represent the main aquifers in this zone. There is a hydraulic continuity between the water bearing formations within the Low Folded Zone to some extent, depending on the piezometric relations of the water-bearing layers, throughout the area. The general trend of the groundwater movement at the western part of the zone (to the west of the Tigris River), is mainly from north and northwest towards south and southeast, except the area north of Sinjar Mountain, where the direction of flow is toward the north and west; towards the Iraqi – Syrian border. The direction of the groundwater flow at the eastern parts of the Low Folded Zone (to the east of Tigris River), is from north and northeast towards south and southwest, with local variations, due to topographic and structural characteristics of the area.

Generally, the salinity of the groundwater increases from north to south. It increases from the recharge sources at the high land areas (less than 1000 mg/l), towards the discharge areas along the Mesopotamia Zone and Al-Jazira Zone (more than 10000 mg/l). Groundwater quality is mainly bicarbonate at the recharge areas, and becomes sulphatic at the discharge areas (Al-Jiburi and Al-Basrawi, 2012 and 2013).

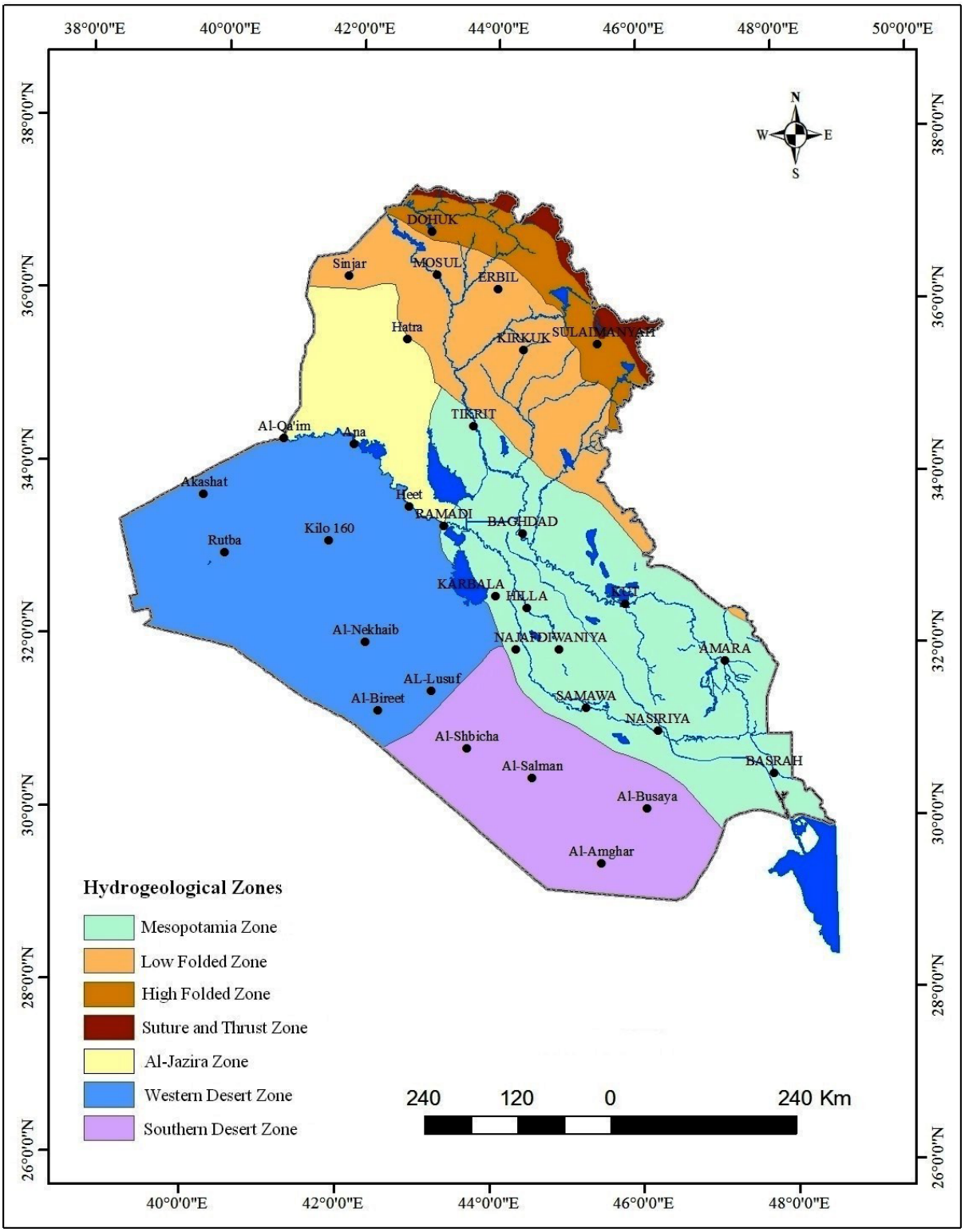


Fig.1: Hydrogeological Zones of Iraq

- **High Folded Zone**

The High Folded Zone is characterized by rugged topography, and presence of deep canyons and narrow valleys with well defined mountainous structures. The groundwater is stored within the limits of these valleys and form groundwater basins of limited extents. In this zone, the groundwater drainage boundaries are assumed to coincide with the surface drainage boundaries. The main groundwater recharge is from direct precipitation and snow melt during summer at the highest elevated areas of the zone, while the discharge takes place in the form of springs and partially evapotranspiration where the water table is shallow. This zone is characterized by low salinity water, typically with a salinity < 500 mg/l and only exceptionally reaching 1000 mg/l (Krasny *et al*., 2006; Al-Jiburi, 2008a and b). The prevailing type of karst water is bicarbonate. Two main groups of carbonate aquifers were described by Stevanovic and Iurkiewicz (2004), based on geological and hydrogeological characteristics: Bekhme Karst Aquifer, which includes carbonates of Qamchuqa, Dokan and Kometan formations, and Pila Spi Fractured Karst Aquifer, which includes carbonates of Sinjar, Khurmala and Avanah formations. The aquifers within the High Folded Zone are of two groups: carbonate and clastic. A hydraulic continuity is assumed between the aquifers within the aquifer systems in the carbonate and clastic rocks. The regional trend of groundwater movement is generally towards southwest and south, with the presence of different directions due to the presence of water divides and the complexity of structure and topography of this zone. The Low Folded Zone represents the main discharge area of the High Folded Zone (Al-Jiburi and Al-Basrawi, 2013).

- **Suture and Thrust Zone**

The Suture and Thrust Zone includes the oldest Paleozoic hard rocks, clastic and carbonate rock units and igneous and metamorphic rocks. Little hydrogeological information is available in this zone. The largest known Zulam spring in the zone has a minimum yield of 0.38 $m^3/s$ and a normal yield of over 2.0 $m^3/s$ (Stevanovic and Iurkiewicz, 2004). The shallow or near surface permeable hard rocks, which represent shallow aquifers, may reach depths of several tens of meters and generally conforms to the land surface. They consist of an upper weathered zone of basement rocks with apposed non-indurated Quaternary sediments and lower fractured layers. The shallow or "close to surface" aquifer is underlain by the so called massive layers, where only few permeable fractures occur. Local deep seated fracture layers occur in fault areas in igneous rocks creating hot springs (Stevanovic and Iurkiewicz, 2004). This zone includes three Hydrogeological basins: Kani Mase Basin, which is located in the extreme northern part of Iraq, along the Iraqi – Turkey border, Sidakan Basin which is located in the central part of the zone, along the extreme northern part of the Iraqi – Iranian border, and Penjween Basin which is located in the southeastern part of the zone, along the Iraqi – Iranian border. This zone is characterized by low salinity water (Al-Jiburi and Al-Basrawi, 2013).

- **Al-Jazira Zone**

Al-Jazira Zone is located in the central northwestern part of Iraq. The main water bearing formations in the Jazira Zone are represented by Fatha and Injana Formations in addition to Quaternary sediments. The recharge sources of the groundwater in the Jazira Zone are mainly direct infiltration and/ or run off from the intermittent wadis in the form of percolation in shallow aquifers. The presence of hydraulic continuity between aquifers is assumed to some extent, depending on the piezometric relations of the water-bearing layers, throughout the region. The groundwater discharge areas occur along the Tharthar Valley and Tharthar Lake and the low land of salt marshes in the region, in addition to the Euphrates River and Haditha

Lake. The regional trend of the groundwater movement in all aquifers is generally from north towards south, southeast and southwest. But, locally, the flow of the groundwater may take different directions depending on the geological setting and topographic and structural features. Salinity of the groundwater increases generally from fresh water in the recharge areas in the northern parts, towards the discharge areas to become highly saline water. The quality of the groundwater is mainly sulphatic, with chloridic and bicarbonatic water types in some areas (Al-Jiburi and Al-Basrawi, 2009b and 2013).

- **Western Desert Zone**

The Iraqi Western Desert lies to the west of the Euphrates River, extending west and southwest into Syria, Jordan and Saudi Arabia, and its southeastern boundary with the Iraqi Southern Desert is represented by Wadi Al-Khir.

The main water bearing formations underlying the Iraqi Western Desert from the oldest are represented by: Suffi, Ga'ara, Mulussa, Ubaid, Muhaiwir, Rutba, Ms'sad, Hartha, Tayarat, Umm Er-Radhuma, Akashat, Dammam, Euphrates and Injana formations. While other formations are not considered as yield aquifers either due to their locations above regional groundwater level, or lithologic and structural properties or due to local extension. The recharge sources of groundwater in Iraqi Western Desert are mainly direct infiltration and/ or run-off the intermittent wadis in the form of percolation into the shallow aquifers. The recharge areas extend outside Iraqi border into Saudi Arabia. The groundwater discharge zone occurs in the area along the right bank of the Euphrates River. The discharge is either in the form of underground inflow in the Euphrates River and/ or Habbaniya, Razzaza and Haditha Lakes, or in the form of springs. Within some places, in this zone, a phenomenon of self-flowing wells exists that forms an artificial discharge of groundwater. The regional trend of groundwater movement is generally towards east and northeast, i.e., following the discharge zone along the right bank of the Euphrates River. But, locally, the flow of groundwater takes different directions throughout the region depending on geological setting and topographic and structural features. Salinity of water increases generally from the recharge areas, in the western parts towards the discharge zone in the eastern parts along the Euphrates River. The quality of water varies from bicarbonate (or mixed) to sulphatic and chloridic in some direction (Al-Jiburi and Al-Basrawi, 2007 and 2013).

- **Southern Desert Zone**

The Southern Desert Zone represents the southwestern and southern parts of Iraq. It lies to the west of Euphrates River and Shatt Al-Arab and extends to west and south into Saudi Arabia and Kuwait. The main investigated water bearing formations underlying the Southern Desert Zone from the oldest are represented by: Hartha, Tayarat, Umm Er Radhuma, Dammam, Ghar/ Euphrates and Dibdibba formations in addition to Quaternary sediments. A hydraulic continuity is assumed between the aquifers of Hartha, Tayarat, Umm Er Radhuma and to some extent Dammam. There is leakage either downwards or upwards from one aquifer to another, depending on the piezometric relations of the water-bearing layers throughout the region. Dammam Formation is considered the most important regional aquifer in the Southern Desert Zone due to its wide extent and content of large amount of water. The regional trend of groundwater movement is generally towards east and northeast, i.e. following the discharge zone along the western bank of the Euphrates River, Hor Al-Hammar and Shatt Al-Arab. But, locally, the flow of groundwater takes different directions throughout the region depending on geological setting, topographic and structural features. Groundwater is considered of low salinity in the recharge areas at the western parts of the Southern Desert

Zone. Salinity of the groundwater is mainly in the range between (less than 1000 – 2000) mg/l, with chemical water type Ca – bicarbonate – sulphate type. In the discharge area, salinity of groundwater is higher, where long term contact of water with the host rocks and low circulation of groundwater, may attain more than 10000 mg/l, with predominate Ca – Na – sulphate – chloride water type (Al-Jiburi and Al-Basrawi, 2009a and 2013).

## THE HYDROGEOLOGICAL MAP OF IRAQ, 2nd EDITION

The updated Hydrogeological Map of Iraq, at scale 1: 1000 000, 2nd edition has significant differences from the 1st edition which are mentioned hereinafter.

### ▪ Hydrogeological Characteristics

– Updated hydrogeological information is available within the new map covering all the hydrogeological zones, in comparison with limited and old information of the previous map.
– The new map covers all parts of Iraq, while in the previous map, the northern parts of Iraq are excluded due unavailable hydrogeological information.
– More field work was carried out to check the hydrogeological information and collection of water samples for more chemical analysis.
– Application of GIS techniques for evaluation of the hydrogeological information in order to get more precise results.

### ▪ The Legend

The legend of the updated hydrogeological map is modified with respect to salinity of water where six classes instead of five are identified according to data applied on the hydrogeological maps at scale 1: 250 000, in order to give more detail information for groundwater uses.

### ▪ Auxiliary Maps

Three auxiliary maps are added to the hydrogeological map, they are all at scale of about 1: 6000 000. They are described below:

**– Map of Mean Annual Meteorological Parameters in Iraq:** General characteristics on the climate of Iraq have been drawn from the data recorded at different meteorological stations (Iraqi Organization for Meteorological Information, 2000). It is shown from this data (Fig.2) that the mean annual rainfall in Iraq ranges between less than 100 to 1000 mm/yr, the mean annual temperature ranges between 18 and 24 °C; the mean annual relative humidity ranges between 36 and 48%; the mean annual evaporation ranges between 1700 and 3500 mm/yr; the mean annual wind speed ranges between 2 and 4 m/s; and the mean annual dryness coefficient ranges between 5 and 45. This data reflects the arid and semi arid conditions of Iraq, which is characterized mainly by hot and dry summer and relatively mild to cold winter with low rainfall.

**– Map of the Groundwater Depth:** The depth of the groundwater below ground surface is an important factor in using groundwater and choosing the suitable mechanism for drilling purposes. The depth of groundwater in different Hydrogeological Zones is represented as auxiliary map (Fig.3) which reflects the variation in depth of groundwater from greater than 300 m within the Western Desert Zone to less than 10 m within the Mesopotamia Zone.

**– Map of the Suitability of the Groundwater for Agricultural Purposes:** The suitability of the groundwater for agricultural purposes, in the Hydrogeological Zones of Iraq, is evaluated according to Richards's classification (1954) and represented on a map (Fig.4). This

map reflects the variation in water and soil salinity (Buringh, 1960) within the different Hydrogeological Zones and possible uses of groundwater for irrigation purposes according to the applied classification.

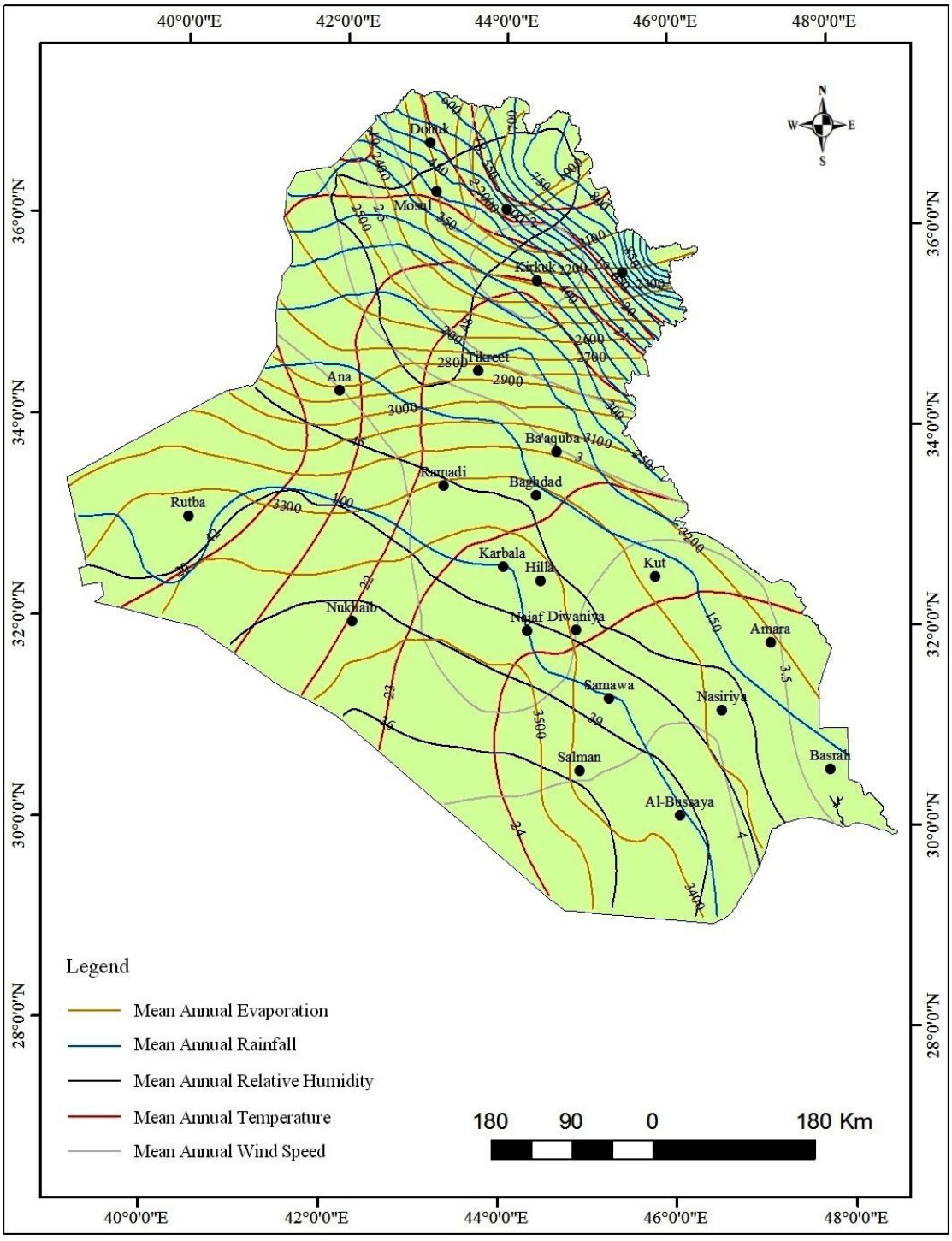


Fig.2: Mean annual values of meteorological parameters in Iraq, modified after IOM (2000)

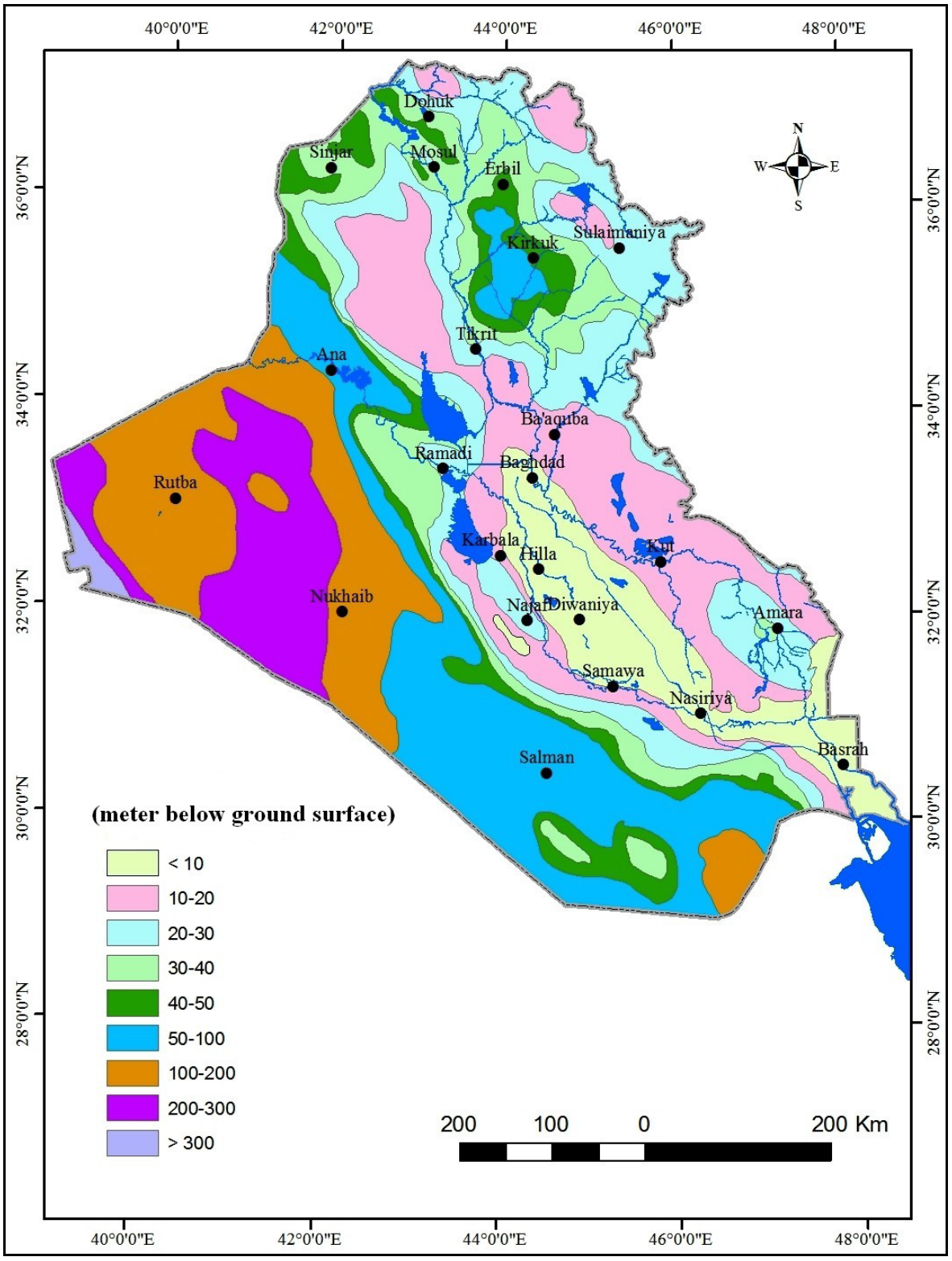


Fig.3: Depth of the groundwater in the Hydrogeological Zones

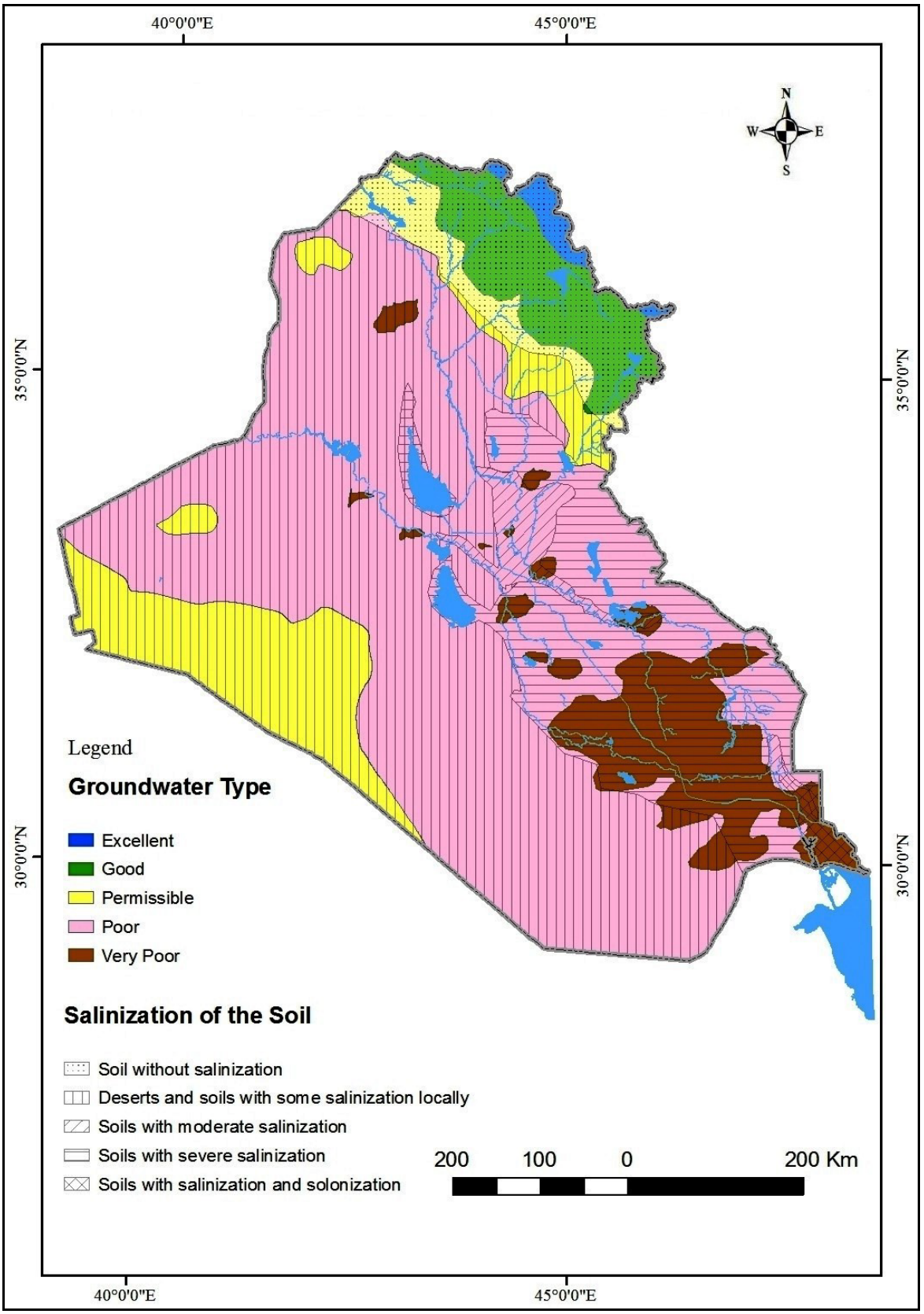


Fig.4: Suitability of the groundwater for agricultural purposes

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REPUBLIC OF IRAQ
MINISTRY OF INDUSTRY AND MINERALS
IRAQ GEOLOGICAL SURVEY


# HYDROGEOLOGICAL MAP OF IRAQ

35 17.5 0 35 70 105 140 175 Km


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### REGIONAL WATER-BEARING SEDIMENTS

- Flood Plain
- Alluvial
- Clastics (Injana, Mukdadiya, Bai Hassan and Dibdibba formations)
- Evaporites (Fat'ha Formation)
- Valley or Plain Promising for Production Drilling
- Carbonate formations
- Clastics Ga'ara Formation
- Igenious and Metamorphic Rocks

### SALINITY OF THE GROUNDWATER (mg/l)

- Fresh Water (< 1000)
- Slightly Brackish Water (1000 - 3000)
- Moderately Brackish Water (3000 – 5000)
- Highly Brackish Water (5000 – 10000)
- Salty Water (10000 - 50000)
- Brine Water (> 50000)

### GROUNDWATER TYPE

- Bicarbonate
- Chloride
- Sulphate

### TYPE OF WATER IN WELLS

- Bicarbonate
- Chloride
- Sulphate
- Unknown

### DISCHARGE SPRING ( l/sec)

- <10
- 10 - 50
- 50 -100
- 100 - 500
- >500

### HYDROGEOLOGICAL SYMBOLS

- Groundwater Level ( meter above sea level)
- Direction of Groundwater Flow
- Area of Flowing Artesian Wells
- Groundwater Divide

### TOPOGRAPHICAL SYMBOLS

- International Boundary
- Express way No. 1
- Main road
- Secondary road
- Railway
- Lake
- River
- Valley
- Governorate center


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