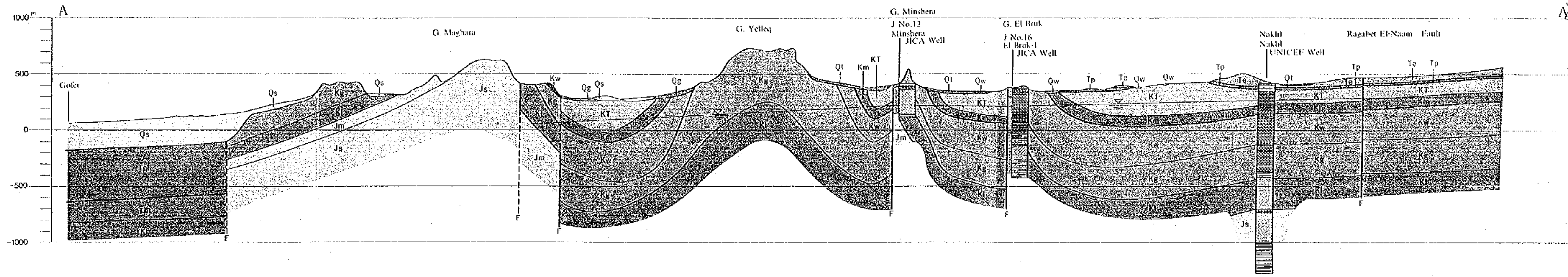
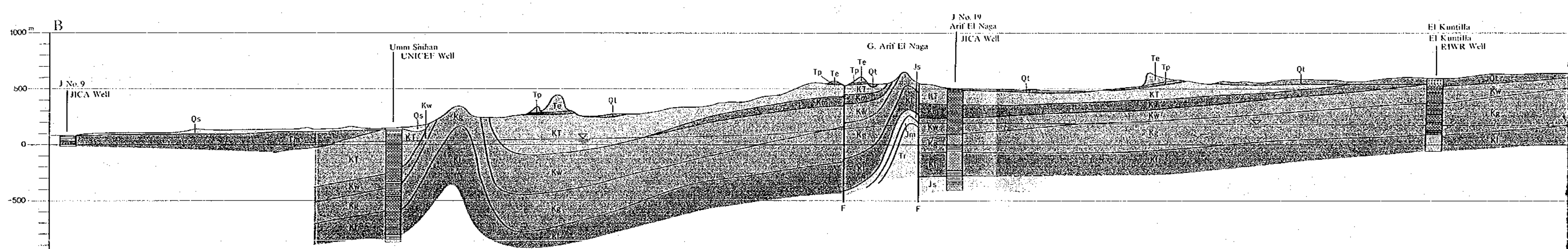

A
A'
1000
500
0
-500
-1000
Gofer
G. Maghara
G. Yelleq
G. Minshera
J No.12
Minshera
JICA Well
G. El Bruk
J No.16
El Bruk-1
JICA Well
Nakhl
Nakhl
UNICEF Well
Ragabet El-Naam Fault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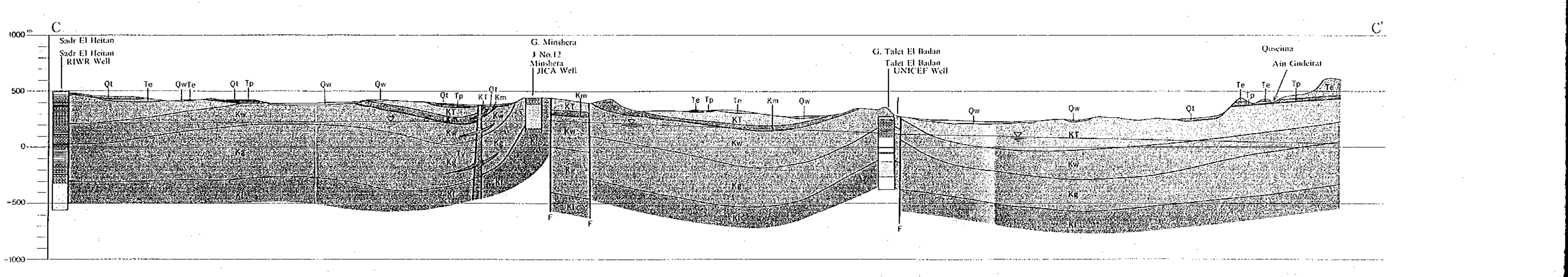
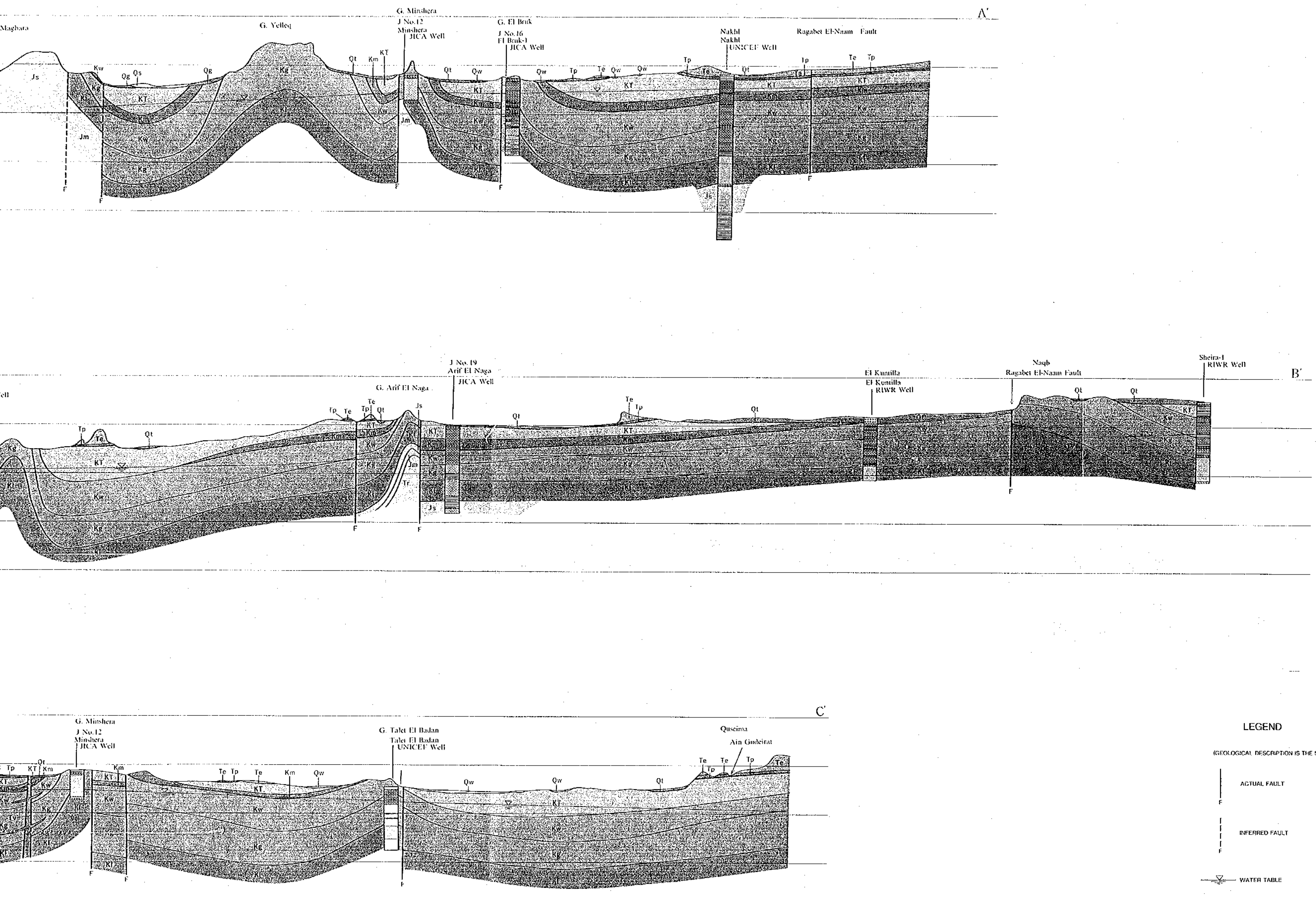
500
0
-500
-1000
J No. 9
JICA Well
Umm Shihan
UNICEF Well
G. Arif El Naga
J No. 19
Arif El Naga
JICA Well
El Kuntilla
El Kuntilla
RIWR Well


C
C'
1000
500
0
-500
-1000
Sadr El Heitan
Sadr El Heitan
RIWR Well
G. Minshera
J No.12
Minshera
JICA Well
G. Talet El Badan
Talet El Badan
UNICEF Well
Quseima
Ain Gudeirat



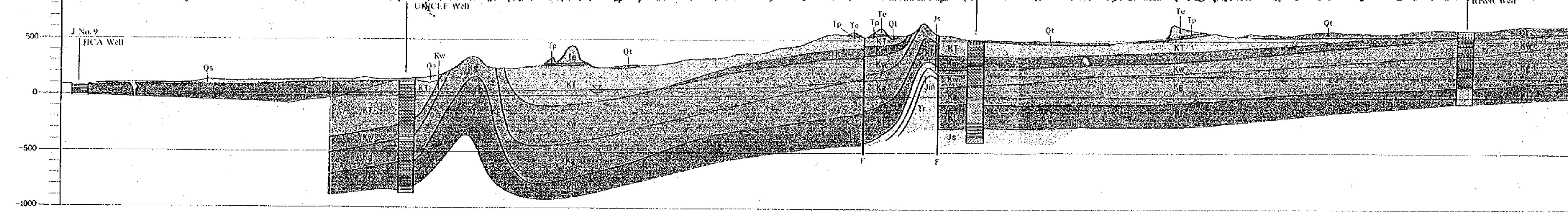
LEGEND

(GEOLOGICAL DESCRIPTION IS THE SAME AS HYDROGEOLOGICAL MAP)

ACTUAL FAULT

INFERRED FAULT

WATER TABLE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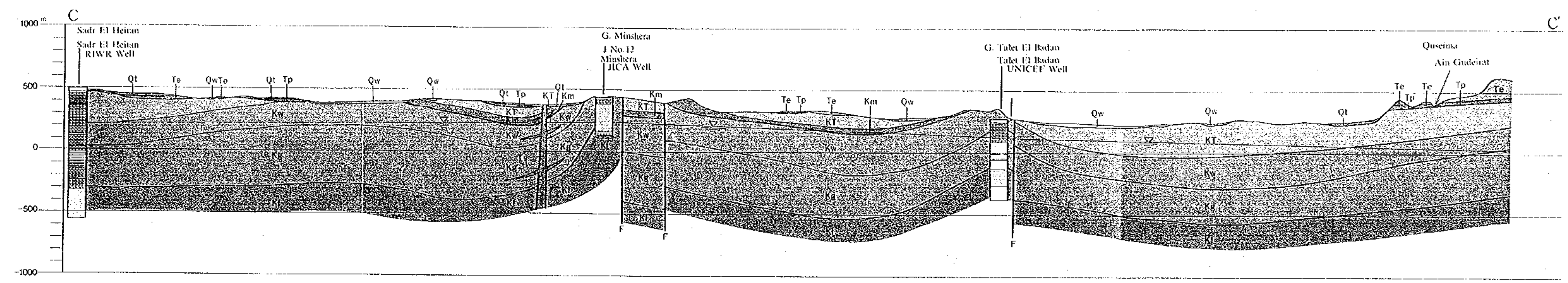
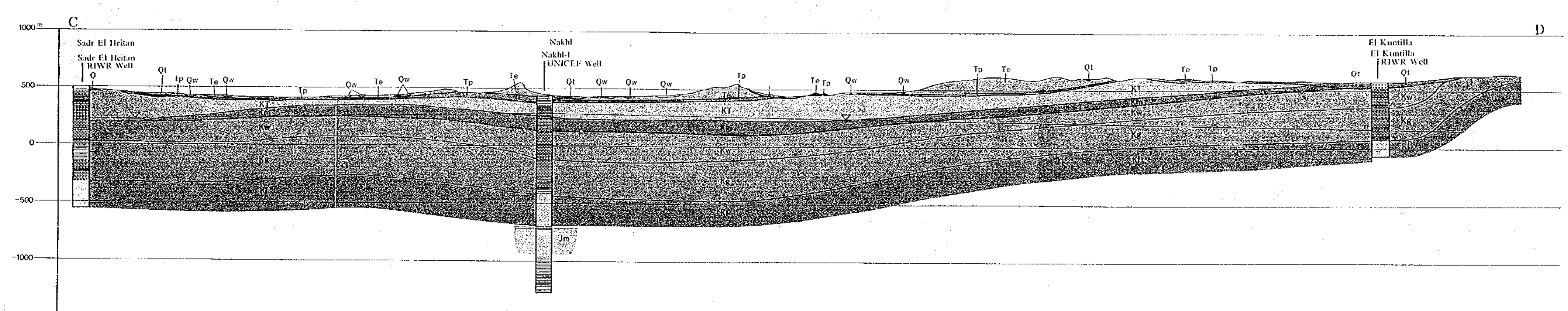
J No.9
JICA Well
RIWR Well
500
0
-500
-1000


C
C'
1000 m
500
0
-500
-1000
Sadr El Heitan
Sadr El Heitan
RIWR Well
G. Minshera
J No.12
Minshera
JICA Well
G. Talet El Badan
Talet El Badan
UNICEF Well
Quseima
Ain Gudeirat


C
D
1000 m
500
0
-500
-1000
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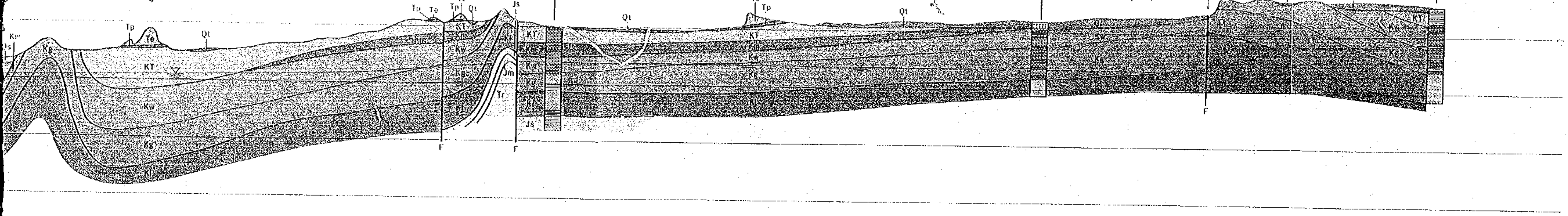
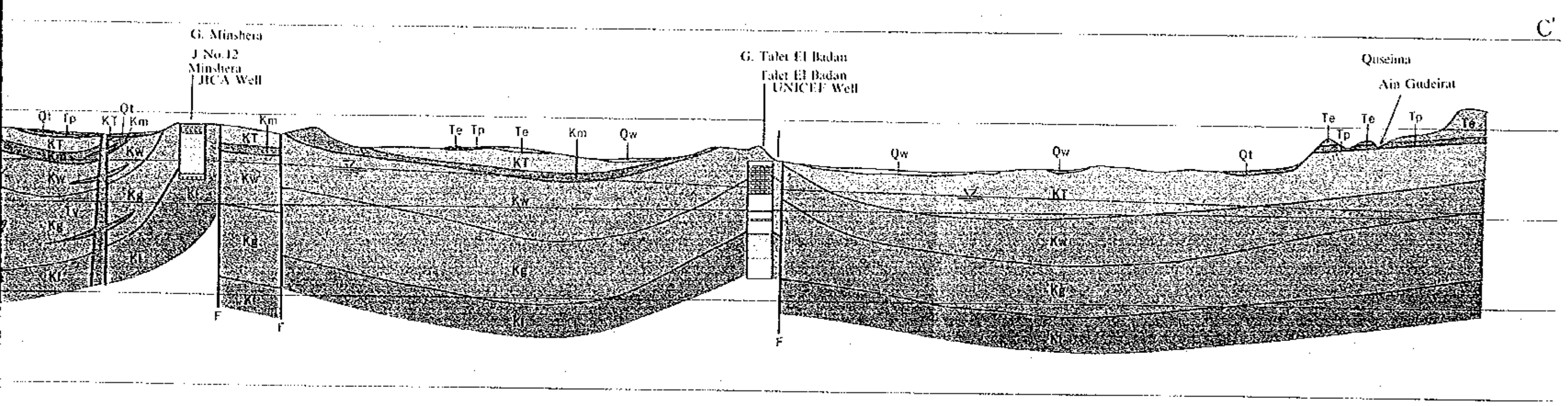
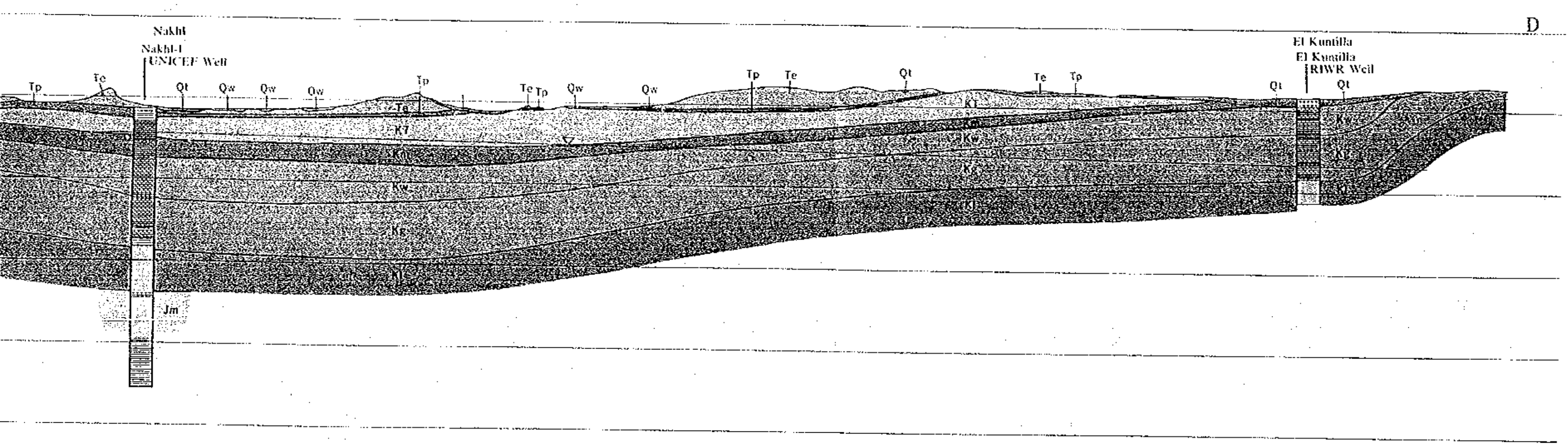
Sadr El Heitan
RIWR Well
Nakhl
Nakhl-1
UNICEF Well
El Kuntilla
El Kuntilla
RIWR Well







LEGEND

(GEOLOGICAL DESCRIPTION IS THE SAME AS HYDROGEOLOGICAL MAP)

ACTUAL FAULT

INFERRED FAULT

WATER TABLE

SAND AND GRAVEL

CHALK

MARL

LIMESTONE

DOLOMITE

SANDSTONE

SHALE

GRANITIC ROCKS

NO DATA

RESEARCH INSTITUTE FOR WATER RESOURCES
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MINISTRY OF PUBLIC WORKS AND
WATER RESOURCES DEVELOPMENT

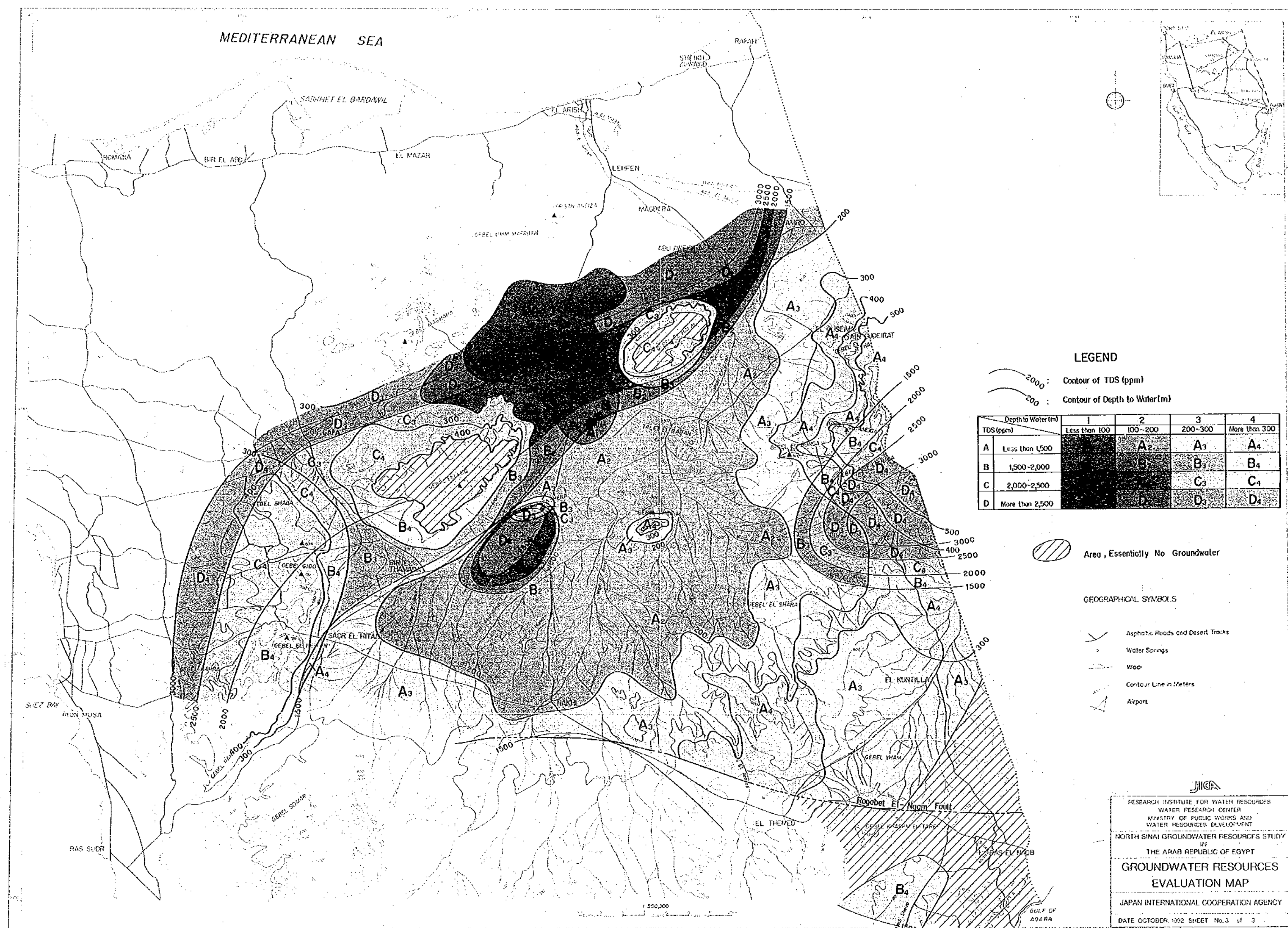
NORTH SINAI GROUNDWATER RESOURCES STUDY
IN
THE ARAB REPUBLIC OF EGYPT

HYDROGEOLOGICAL CROSS SECTION

H=1/250,000 V=1/2,500

JAPAN INTERNATIONAL COOPERATION AGENCY

DATE OCTOBER, 1992 SHEET No.2 of 3


MEDITERRANEAN SEA
SABKHET EL BARDAWIL
EL ARISH
RAFAH
SHEIKH ZUWAYID
ROMANA
BIR EL ABD
EL MAZAR
LEHFEN
MAGDEBA
EL KUNTILLA
SUDR EL HITAN
RAS MUSA
SUEZ BAY
RAS SUDR
EL THEMED
Ragabet El Naam Fault
GULF OF AQABA
LEGEND
Contour of TDS (ppm)
Contour of Depth to Water (m)
Depth to Water (m) / TDS (ppm)
1 Less than 100
2 100~200
3 200~300
4 More than 300
A Less than 1,500
B 1,500~2,000
C 2,000~2,500
D More than 2,500
A2 A3 A4
B3 B4
C3 C4
D3 D4
Area, Essentially No Groundwater
GEOGRAPHICAL SYMBOLS
Asphaltic Roads and Desert Tracks
Water Springs
Wadi
Contour Line in Meters
Airport
JICA
RESEARCH INSTITUTE FOR WATER RESOURCES
WATER RESEARCH CENTER
MINISTRY OF PUBLIC WORKS AND
WATER RESOURCES DEVELOPMENT
NORTH SINAI GROUNDWATER RESOURCES STUDY
IN
THE ARAB REPUBLIC OF EGYPT
GROUNDWATER RESOURCES
EVALUATION MAP
JAPAN INTERNATIONAL COOPERATION AGENCY
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WATER RESEARCH CENTER

MINISTRY OF PUBLIC WORKS AND WATER RESOURCES DEVELOPMENT

NORTH SINAI GROUNDWATER RESOURCES STUDY

IN

ARAB REPUBLIC OF EGYPT

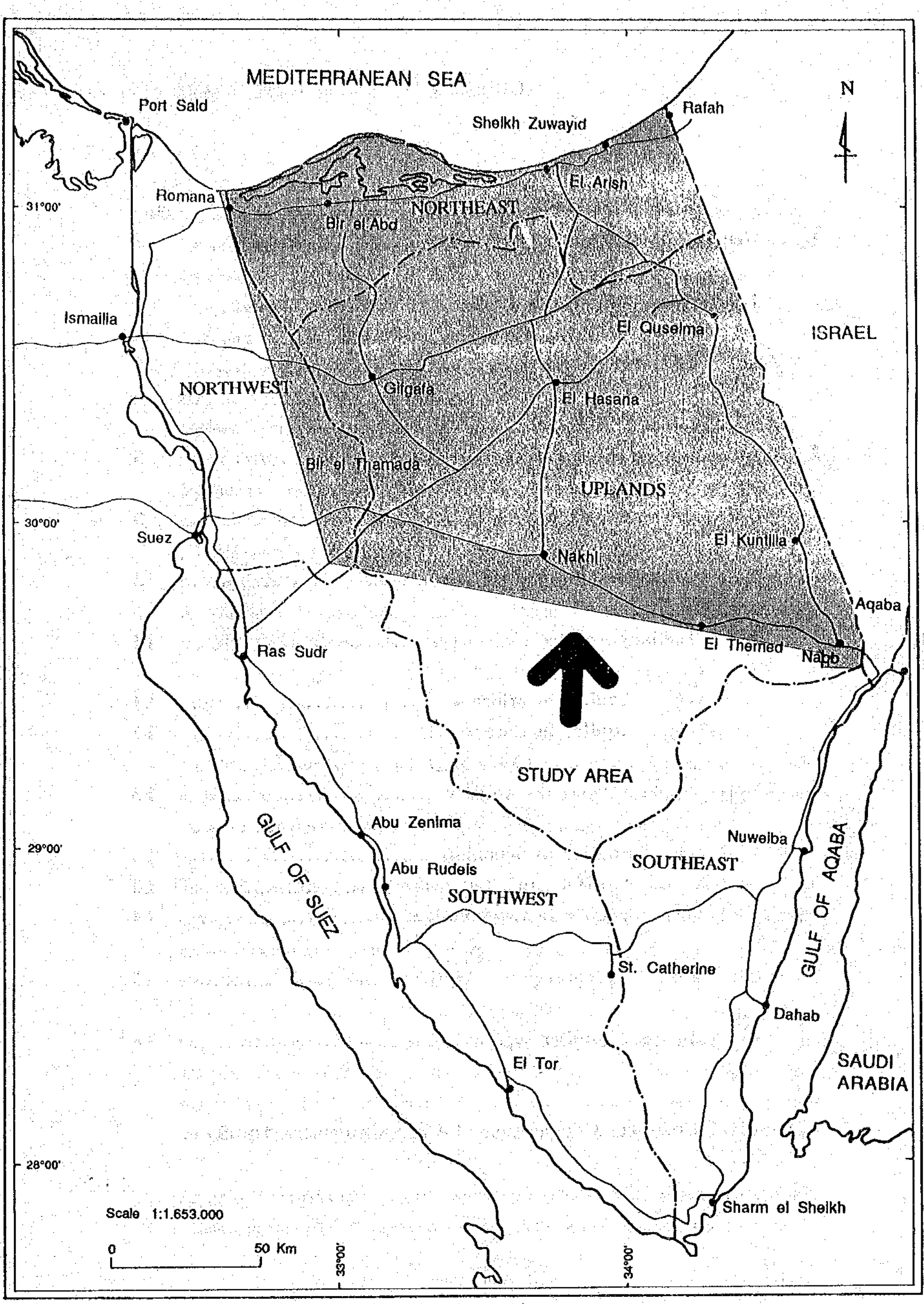
SUMMARY OF HYDROGEOLOGY AND EVALUATION

OF

GROUNDWATER RESOURCES

OCTOBER 1992

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)



STUDY AREA

1142055 (1)

CONTENTS

1 GENERAL DESCRIPTION OF STUDY AREA

1-1 Geography

The Sinai Peninsula lies between the two arms of the Red sea and the Aqaba. The western side of the Red Sea represents part of the highlands which form the African base known for its extremely old age. It ends eastwardly and westward with two ditch-like regions, namely the Aqaba Gulf and the Gulf. This rocky plateau that slopes down towards the Mediterranean Sea in the northern section represents the sedimentary formation.

Sinai takes on the form of a rectangle with its base extending along the shore of the Mediterranean Sea starting from Port Fouad in the west to Rafah in the east for a distance of 200 km. The apex of the rectangle lies in the extreme south at Ras Mohamed which is 390 km from the coast of the Mediterranean Sea. The western edge extends for about 510 km whereas the eastern edge does not extend more than 240 km. The imaginary line for the political border between Sinai and Palestine, from Rafah in the north to Taba on the Aqaba Gulf, extends for 215 km. Sinai's total area is 61,000 km^2. This is three times larger than the Nile Delta. The study area is the northern half of the peninsula covering 26,000 km^2 of the total 27,574 km^2 area of the North Sinai Governorate.

1-2 Climate

The air temperature in the northern coast of Sinai is generally higher than that in the inland area of the Peninsula. The mean temperature decreases during winter reaching its minimum value in January and increasing to its maximum in August during the summer.

The study area is characterized by cold winters. The average temperature is about 13 degrees centigrade at El-Arish, with a mean minimum value of 7 degrees centigrade in the early morning and rising normally to 11 degrees centigrade by noon with a mean maximum of about 18 degrees centigrade.

In summer, the temperature increases to 26 degrees centigrade as the mean value at El-Arish. The mean maximum temperature varies between 29.9 and 31.1 degrees centigrade. During summer nights, the air temperature drops to its mean minimum temperature of 22 degrees centigrade, while the average maximum temperature exceeds 30 degrees centigrade.

Spring is characterized by moderate temperatures of about 20 degrees centigrade with hot Khamsin periods when the air temperature sometimes rises above 40 degrees centigrade. The mean minimum temperature during this season is about 13 degrees centigrade while the mean maximum temperature is 26 degrees centigrade.

Autumn is characterized by moderate temperatures similar to Spring but slightly lower than in the summer. Temperatures during September normally range between 15 degrees centigrade at midnight and 28 degrees centigrade at midday.

Rainfall has been a serious problem in the study area. The highest annual rainfall of 300 mm is observed in the Rafah area, the northeastern corner of the study area. However, this amount of rain is observed only in a limited area. More than 80% of the study area receives an annual rainfall of less than 60 mm. Most of the study area is under an arid condition. Furthermore, the problem of the arid area is that the rainfall is capricious. For this reason, the area is always subject to either heavy drought or flooding. In general, the climate is extremely dry and the extent of groundwater recharge is limited.

2 EVALUATION OF GROUNDWATER RESOURCES

2-1 Introduction

The most promising aquifers are found in the Quaternary and the Lower Cretaceous. The major concern in the aquifer in the Quaternary is to prevent seawater intrusion in the well field extensively utilized at present and further data collection will be urgently required in the coastal plain from El-Arish to Sheik Zuwayid for development of an additional well field.

Distribution of favourable aquifer of the sandstone of the Lower Cretaceous is identified and the total volume of the groundwater storage in favourable conditions is estimated at 30×10^9 m^3.

The aquifers in the Tertiary, the Upper Cretaceous and Jurassic formations are considered to be the second priority aquifers compared to those in the Quaternary and the Lower Cretaceous.

2-2 Quaternary Aquifer

The Quaternary formation, with prospecting aquifers, extends for 30 km in the coastal plain from El-Arish to Rafah with widths ranging between 10 and 15 km along the coast. Its thickness is estimated to be 80 to 100 m. The thickest part is 120 m. However, the base level of the Quaternary in the area is estimated by the interpretation of resistivity survey so that further conformation is required before the final conclusion (Fig. 1).

According to the test well results on the western side of El-Arish, it is assumed that this formation extends beyond El-Arish town.

A schematic cross section of the Quaternary in a NS direction is shown in Fig. 2. Kurkar is underlain by the Pre-Quaternary consisting mainly of shale. However, sandstone or limestone are encountered at some places. Although the kurkar is assumed to occupy most of the bottom of the Quaternary in this area, it is absent in some areas. The sand dune is underlain by old beach sand overlying kurkar. Clay and gravel beds are interbedded in these sandy formations in various thickness and varying scales.

The gravel is assumed to be old wadi deposits, incising the sandy formations in the N-S. Distribution is assumed to be limited. In general, the water levels of the wells having gravel beds in their profiles stay below the gravel bed. Therefore, it is thought that the gravel beds in this Quaternary formation are of no importance from a hydrogeological point of view.

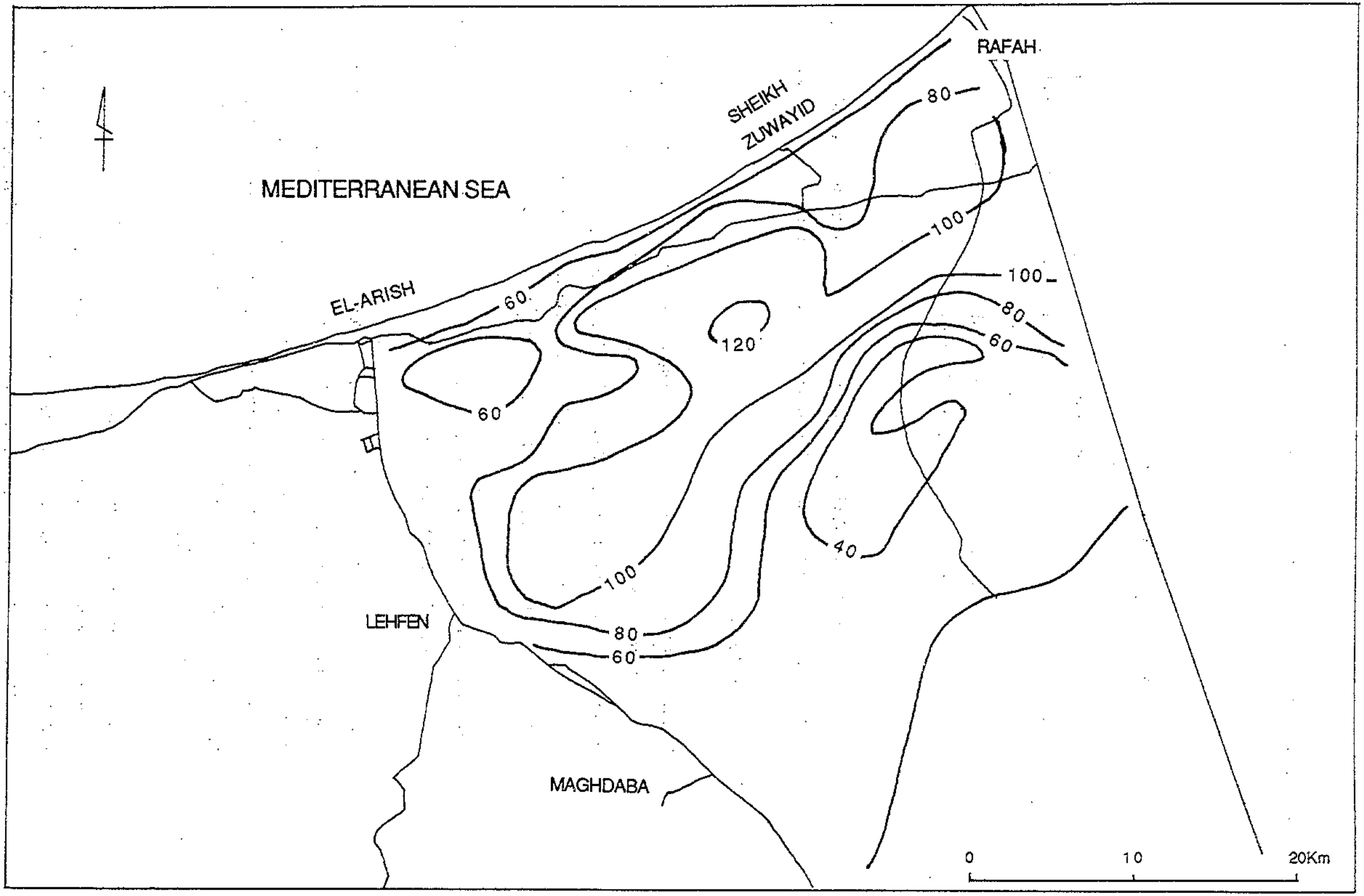


Fig. 1 Isopach of Quaternary

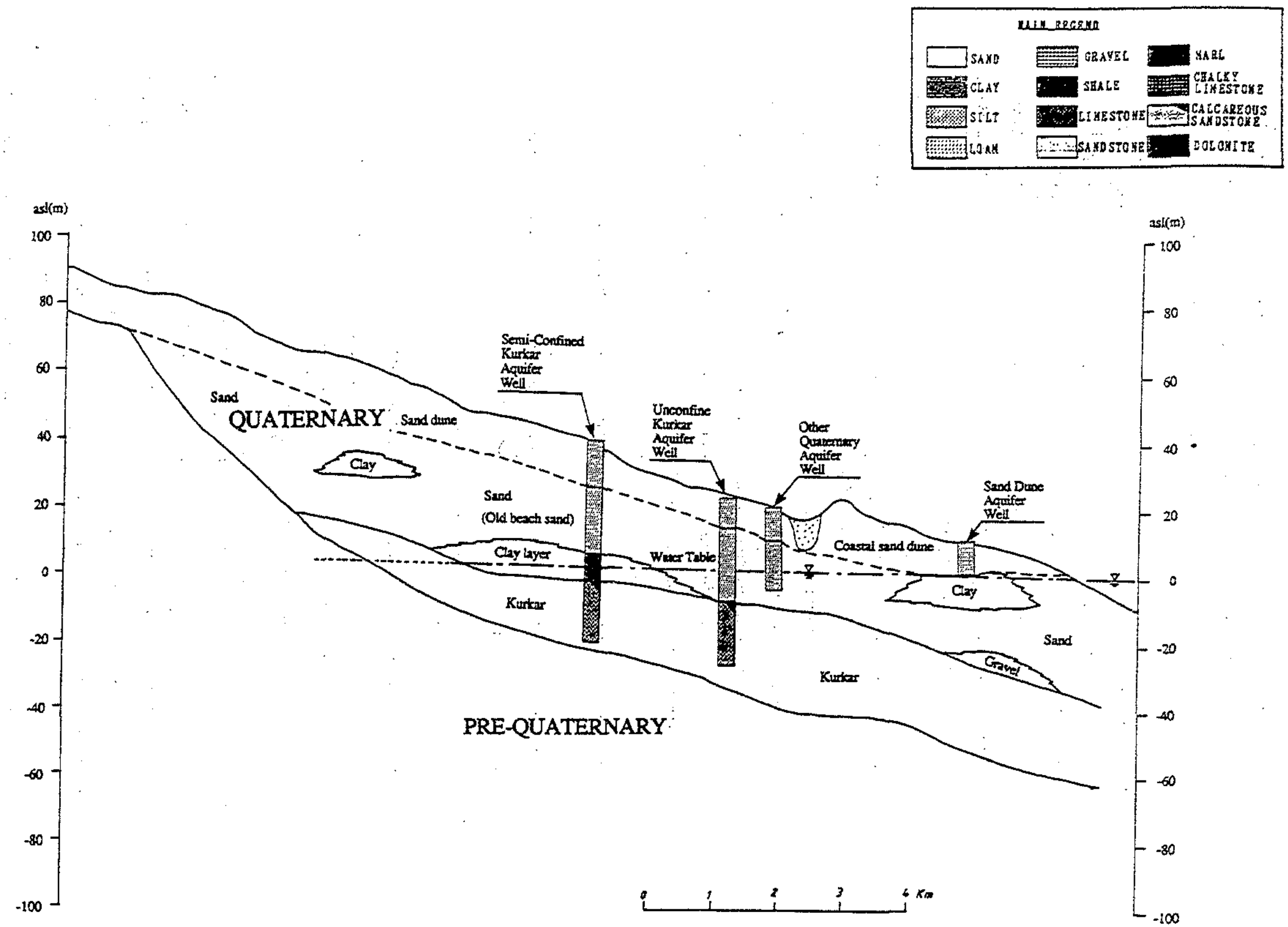


Fig. 2 Schematic Geological Section of Quaternary in the Coastal Plain

The elevation of the gravel bed in the Wadi El-Arish deposits is low so that the lower half of the gravel is within the piezometric potential surface of the underlying kurkar aquifer. For this reason there are some wells having screens installed at the gravel bed (Fig. 3).

Where kurkar is overlain by thick clay, a confined aquifer occurs in kurkar. However, where the extension of the clay bed is limited, the hydraulic continuity is maintained between kurkar and the aquifer of the overlying Quaternary and the water level is determined by the piezometric potential of the kurkar aquifers. In general, the piezometric potential level is assumed to be determined by the hydraulic head of the kurkar aquifer as far as the aquifer is not isolated from kurkar by a certain aquiclude..

The aquifer in the coastal sand dune is thought to be the one isolated from the kurkar by clay.

Total extraction of the groundwater from the well field of El-Arish and of the coastal plain between Sheikh Zuwayid and Rafah is estimated to be 51,000 m^3/day and 39,000 m^3/day, respectively. Due to the heavy pumpage in these well fields there is an assumed decrease in the water levels. The recession of the water level at some part of the well field in the western side of El-Arish has exceeded 4 m since 1962.

The heavy extraction also resulted in deterioration of the water quality at many wells.

A significant recession of groundwater level took place at the western side of El-Arish Town (more than 4 m). The lowered water level in the well field of the Wadi El-Arish alluvial plain exceed 3 m.

This recession of the groundwater level is most probably caused by the heavy pumpage especially during the 1980's. The highest extraction of groundwater in the well field at El-Arish was observed (6,150 m^3/day/km^2). This heavy groundwater extraction was observed in areas southwest and southeast of El-Arish town.

Although available data are limited in 15 km^2 of the well field in the the Wadi El-Arish, this area is the central part of this well field. The estimated annual recharge is in a range between 94 mm/year and 876 mm/year which exceeds the total depth of an average annual rainfall. The estimated recharge exceeds 800 mm/year at grids No. 82 and 9-3, although the estimated annual recharge at grids 7-7, 9-2 and 10-4 is less than 200 mm/year. In the remaining grids, it is in a range between 200 mm/year and 80 mm/year. Considering the magnitude of this recharge it should be ascribed to the inflow of groundwater from other aquifers into these Quaternary aquifers.

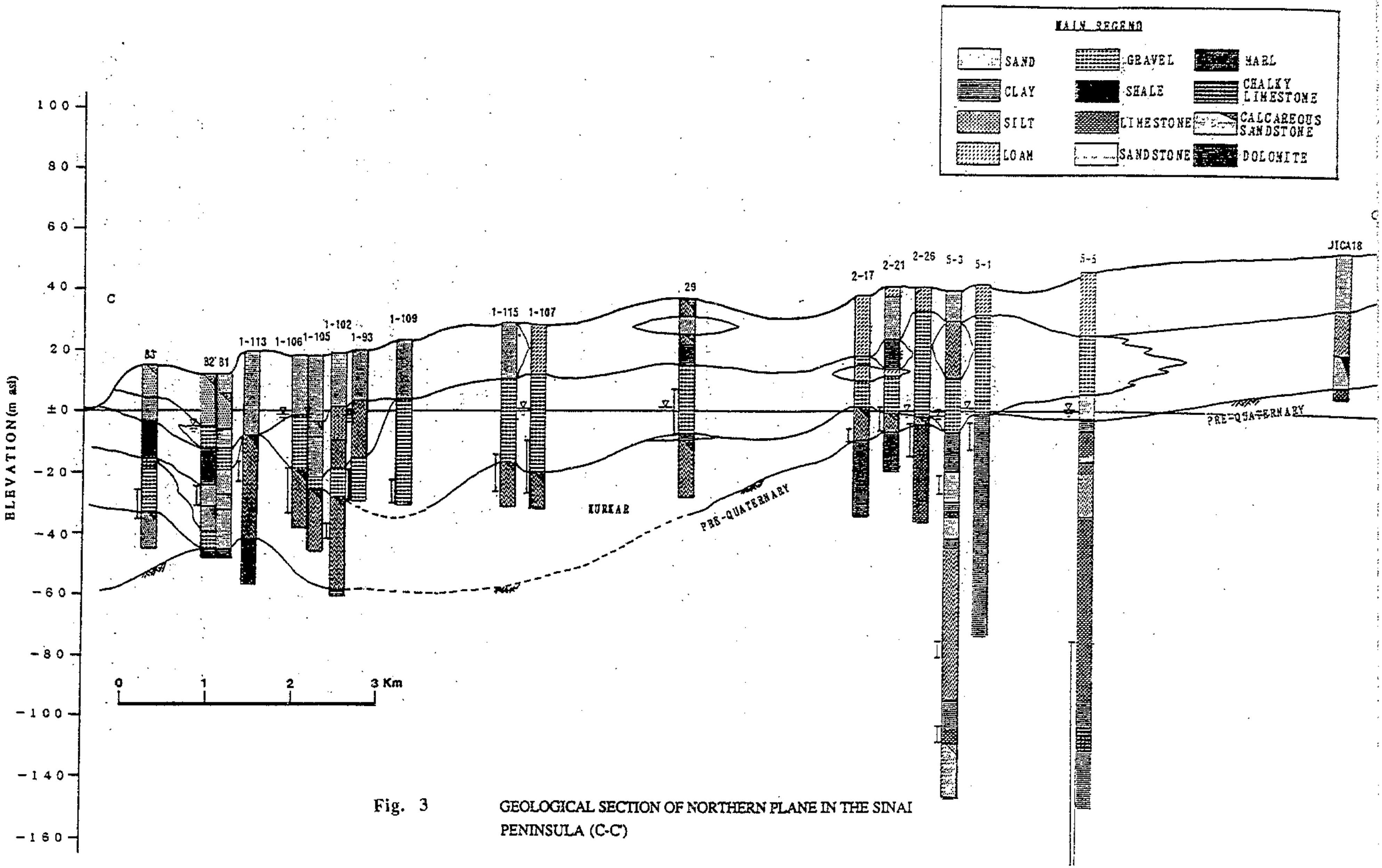


Fig. 3 GEOLOGICAL SECTION OF NORTHERN PLANE IN THE SINAI PENINSULA (C-C')

Hydrogeological conditions of these wells have been characterized as being of high salinity which may caused by a high yield of the wells and high inflow of groundwater from outside.

The most broadly extending Quaternary aquifer is developed in kurkar. And the TDS of groundwater in the kurkar aquifer is in a range between 2,500 ppm and 3,800 ppm in the well field in the Wadi El-Arish alluvial plain and between 3,500 ppm and 5,600 pm in the well field in the coastal plain from El-Arish to Rafah.

The difference in these two ranges of TDS may be caused by the influence of flash floods which occur once every 10 to 15 years. Although its occurrence is very rare, the highly saline groundwater of the aquifer in the Quaternary deposits may be diluted to a certain extent in the well field in the lower stretch of the Wadi El-Arish, while there is little opportunity to recieve recharge at coastal plain from El-Arish to Rafah due to clayey beds overlying kurkar.

According to the C-14 dating, the age of groundwater at wells No. 1123 and 1-119 are estimated to be 8,620 ±420 and 6,770 ±290Y.BP, respectively. These wells are located on the eastern end of the alluvial plain. While the age of groundwater at wells No. 1-75 and 164, located on the eastern bank of the Wadi El-Arish are estimated to be 1,730 ±140 and 4,390 ±240Y.BP, respectively which may suggest influence of recharge in the current climate.

On the other hand, kurkar in the coastal plain, where these test wells with high salinity were drilled, is overlain broadly by clay, so that the TDS of groundwater in this aquifer may maintain its original level.

However, the extent to which groundwater in the aquifer of kurkar in the alluvial plain of the Wadi El-Arish could be diluted, is thought to be limited as shown in the age of the groundwater. This means that the recharge by fresh water, under the current hydrometorological conditions, to the aquifers in the coastal plain, is limited only to a certain extent. Accordingly, when over extraction of groundwater takes place, groundwater with the original low TDS that is stored in the aquifer in the Quaternary deposits other than kurkar as fresh water lense may easily be exhausted and replenished by the groundwater which had been stored in the kurkar aquifer.

Therefore, to prevent an increase in TDS of groundwater, the allowable extraction must be within the amount of the recharge of the current climate. However, it would be limited to a very small amount considering the amount of rainfall. For this reason it is unable to prevent the increase in the TDS, and the ultimate level of the TDS would be the level of the original TDS of kurkar or that of the mother aquifer providing the groundwater to the kurkar aquifer..

However, over extraction may easily cause the recession of the groundwater level. Although there is no proof of seawater intrusion, it may occur immediately when the recession of the water level exceeds a certain level. To prevent further deterioration, the safe yield for preventing seawater intrusion must be determined.

Comparing the pumpage rate and the recession of the water level, an annual recharge rate is estimated. In the same manner, the safe yield for preventing the groundwater level recession is estimated in the rest of the grids where necessary data is available (Table 1):

Table 1 Safe Yield for Preventing Water Level Recession

Grid number	Safe yield (m^3/day)	Present extraction (m^3/day)
7-3	1,650	1,870
7-4	1,090	1,330
7-5	920	1,070
7-6	810	1,000
7-7	30	460
8-2	2,400	2,580
8-3	1,180	1,250
8-4	1,980	3,210
8-5	1,350	1,520
9-2	740	800
9-3	510	510
9-4	2,390	2,490
9-5	760	890
9-6	1,610	1,619
10-4	500	570

Major groundwater sources in the Quaternary in the coastal plain from El-Arish to Rafah is in kurkar. Assuming the distribution of kurkar to be 10 km wide and 30 km long with an average thickness of 10 m, the total volume of kurkar is estimated to be 3,000 million m^3. Taking an effective porosity of 0.25, the amount of total storage in the kurkar aquifer is approximately of 750 million m^3.

The total extraction of groundwater in these well fields (El-Arish and the coastal plain) is estimated to be 90,000 m^3/day. When this amount of extraction continued for 8 years from 1981 to 1988, the total extraction was 262.8 million m^3 which is an enormous amount, considering the total volume of the storage in the kurkar aquifer (750 x 10^6 m^3). This may suggest that there would be groundwater inflow into the Quaternary aquifer from some other older formations since limestone and sandstone of the Pre-Quaternary are in contact with kurkar. It should be clarified how these aquifers of the Pre-Quaternary are implicated with the Quaternary aquifer in the vicinity of the coastal plain.

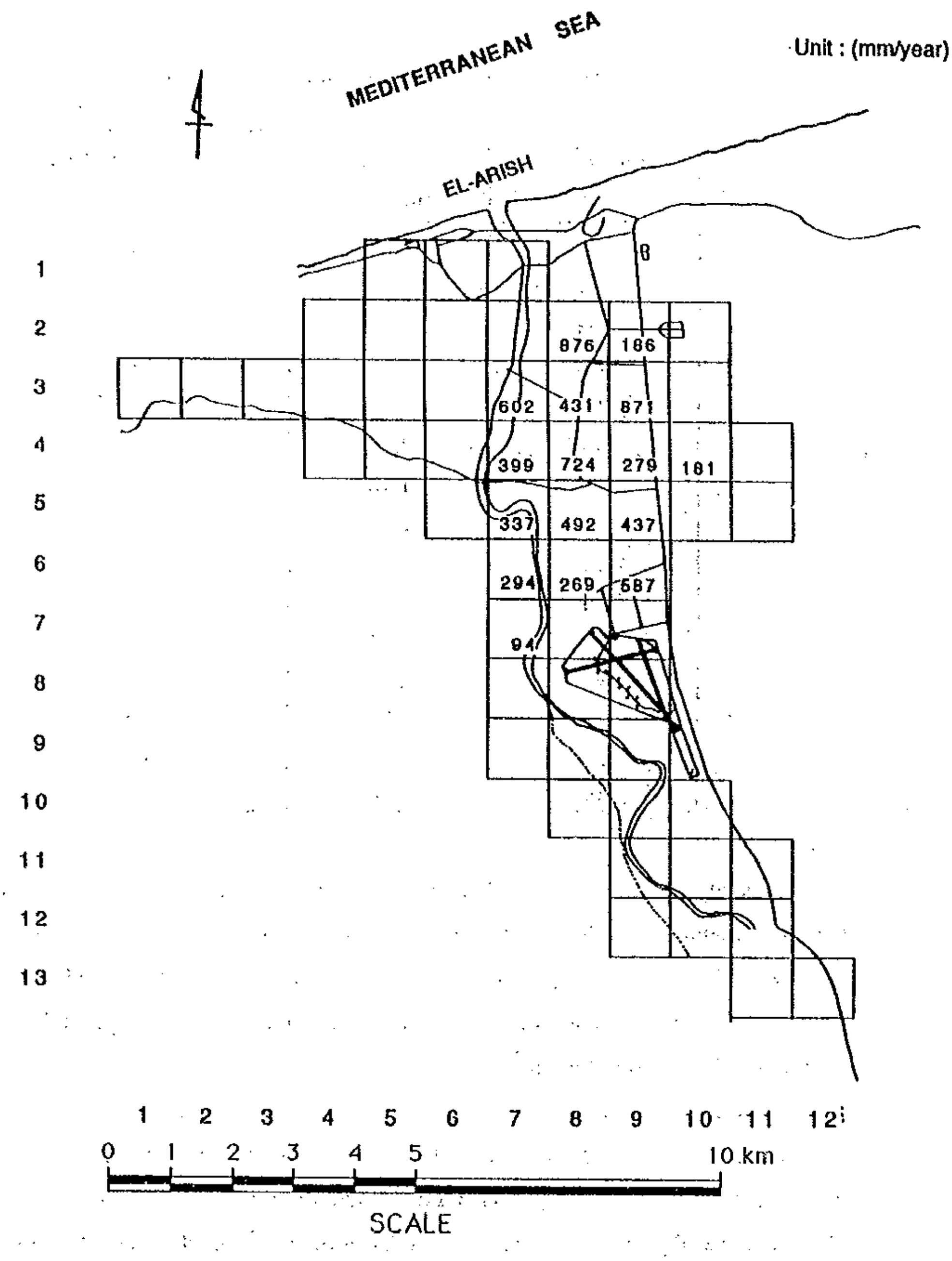


Fig. 4 Estimated Recharge At El-Arish Area

2-3 Tertiary Aquifer

2-3-1 Aquifer in Miocene

The formations assigned to this age are distributed in the coastal foreshore area. The lithology is represented by shale and clay with interbedded sandstone and limestone. Aquifers are contained in these sandstone and limestone in the coastal foreshore. The aquifer developed in the sandstone is represented by well J No. 9 El-Massora and the one in the limestone by well Misri-1. These two are the only wells of this type of aquifer at present (Section 8-3-2, Main Text).

Table 2 Wells of Miocene aquifer

Well Number	Depth to Water (m BGL)	Depth to Aquifer (m BGL)	TDS (ppm)
J No. 9 Massora	68	76	3,470
Misri-1	27	141	10,450

It is important to collect further information about this aquifer, since this formation is overlain by the Quaternary and the TDS of the groundwater in the aquifer is in a high range. There is an indication which may suggest the up-coning of the groundwater of the aquifer in the Miocene into the aquifer in the Quaternary.

The hydrogeological properties of the groundwater in the Miocene aquifer are unknown at present. Although the groundwater is available at a shallow level from the ground surface, development of this aquifer would be of insignificant importance since its TDS is assumed to be high. However, additional data collection of this aquifer is required to clarify the influence of this aquifer on the Quaternary aquifer, especially in the coastal plain.

2-3-2 Aquifer in Eocene

The Eocene is represented by limestone and marl distributed in the area south of the line combining Risan Aneiza and Gebel Maghara. A large scale outcrop is found in the areas listed below:

Quseima area
Hasana
The northwest of Gebel Giddi
The area south of the line between Gebel Minshera
Gebel Kherim

These formations are distributed independently in each area and aquifer develops in the limestone.

There are three wells sunk into the aquifer of the Eocene;

Table 3 Wells in the Eocene Aquifer

Well Number	Depth to Water (m BGL)	Depth to Aquifer (m BGL)	TDS (ppm)
El-Mewaleh No.1	47	23	-
El-Arish well No. 10	95	22	5,200

Hydrogeological data of this type of aquifer remain scarce. However, the depth to the water level and the aquifer is rather shallow in the above cases, and the groundwater is outcropping at Ain Gudeirat. The yield is estimated at 1,500 m^3/day and the TDS is 1,440 ppm.

Two wells are dug in the area 10 km south of Ain Gudeirat. These wells are extracting water at the boundary between the Esna shale and the overlaying Eocene limestone. Priority for the future study on this aquifer should be given to the area on the northern side of the line combining Nakhl and Themed, since the geological setup is similar to that in Ain Gudeirat.

2-4 Upper Cretaceous Aquifer

2-4-1 Aquifer in Senonian

The Senonian is distributed over a broad area in the study area. However, due to heavy erosion, it is absent around Gebel Maghara and Yelleq and the upper part is eroded in some other areas.

The upper part of the Senonian is represented by chalk with limestone, and the lower part is characterized by marl with limestone and shale.

The aquifers develop in the limestone of both of the upper and the lower Senonian. These limestones are partly porous, although it is lithologically compact. So, the groundwater is stored in the joints or fissures.

There are three wells sunk into this type of aquifer;

Table 4 Wells of the Senonian Aquifer

Well Number	Depth to Water (m BGL)	Depth to Aquifer (m BGL)	TDS (ppm)
Wadi El-Maleiz 1	157	97	8,480
El-Arish well No. 14	?	140	2,200
Gebel Libni No. 1	205	132	4,500

Based on the above data there is a possibility of developing this aquifer along the Wadi El-Arish where the water with low TDS is available. Otherwise the TDS would be too high.

2-4-2 Aquifer in Turonian

The Turonian is represented by the foraminifera rich limestone with shale at the base. This bed is distributed in the area around Kuntilla and in the area to the west from Arif El-Naga.

The aquifers develop in the limestone. There are three wells which are assumed to be sunk into the Turonian aquifer at Hasana No. 50. Naqb No.3 and Sheira-2. However, the well drilled at Naqb and Hasana require further confirmation of their details. The TDS of these wells are more than 7,000 ppm.

The water level at well Sheira-2 is at 81 m below the ground surface and the depth to the aquifer is 149 m. The TDS of this well is 1,100 ppm. According to the pump test, the physical parameter of this aquifer is;

$T = 0.94\ m^2/day$
$Sc = 2.01\ m^3/day/m$

Although the salinity of the groundwater is high in the aquifer of the Turonian in the North Sinai, further confirmation will be necessary for the final decision. The aquifer of the Turonian in the southern side of Ragabet El-Naam Fault is assumed to be productive with a low TDS value. However, further data collection will be required since the physical parameters of the aquifer are favorable and the TDS value of the groundwater at well Sheira-2 is the lowest among all groundwaters of the Pre-Quaternary aquifers in the study area.

2-4-3 Aquifer in Cenomanian

This formation is distributed over the study area except at domes. The lithology of the base of the Cenomanian overlying the Lower Cretaceous is calcareous sandstone. In the upper part of the Cenomanian, the lithology is represented by limestone, dolomite and dolomitic limestone.

The aquifer develops in the limestone. There are five wells sunk into the aquifer of the Cenomanian limestone. The depth to the aquifer is in a range between 150 m and 516 m, and the top of the aquifer is shallow in the area near the dome. The depth to the water level is in a range between 35 m and 219 m, and the water level is shallow in the area around El-Amro.

The TDS is distributed in a range between 1;800 ppm and 5,600 ppm. A relatively low TDS value was observed in the area of Hasana and Gifgafa.

The transmissivity of this type of aquifer is in a wide range between 75 m^2/day and 4,500 m^2/day. A large value of transmissivity was observed at Hasana and El-Bruk. The lowest value was at Gifgafa. It seems that the aquifer in the Cenomanian produces groundwater with relatively low TDS. The largest transmissivity was observed at

Hasana. Further testing will be necessary to confirm the property of the aquifer in the area of Hasana.

2-5 Lower Cretaceous Aquifer

This formation is distributed throughout most of the study area. This formation consists of porous quartzose sandstone with occasional shale. The content of shale is higher in the north and almost absent in the south. However, the facies changes to limestone in the northern part.

The thickness of the formation varies from place to place; however, in general, it is in a range between 200 m and 300 m. It is very thick at Halal, where it reaches 600 m. Excluding the thickness of the interbedded shale, the thickness of the aquifer of the Lower Cretaceous is estimated to be 200 m.

The TDS of the groundwater of this aquifer is in a range between 1,200 ppm and 3,000 ppm. The high TDS value was observed at the limestone facies (Umm Shihan), and in the area near the dome structure where the geological structure is significantly disturbed. It is assumed that the movement of the groundwater is restricted where the geological structure is significantly disturbed. At Talet El-Badan, an extremely high TDS (5,360 ppm) was observed. It is assumed that the aquifer of the Lower Cretaceous is influenced by the highly saline water in the aquifer of the Upper Cretaceous due to the reverse fault in the area. The same situation may occur in Minshera and Arif El-Naga where the reverse fault was observed.

The TDS of the groundwater in the Lower Cretaceous sandstone aquifer is in a range between 1,200 ppm and 1,500 ppm, where there is no significant disturbance of the geological structure. Such groundwater is found in the area surrounded by Hasana, Nakhl and Kuntilla.

The depth to the aquifer is in a range between 300 m and 1,000 m. It is the deepest in the central part of the study area and most shallow in the area around the dome.

The depth to the water level is in a range between 161 m and 340 m. The shallower water level was observed at the central part of the study area and the deeper water level was observed at Quseima, Kuntilla and Sadr El-Heitan. The water level is also deep at Sheira on the southern side of the Ragabet El-Naam Fault.

The transmissivity of the sandstone of the Lower Cretaceous is in a range between 12 m^2/day and 400 m^2/day. The smaller value of transmissivity was observed in the area near domes where there is significant structural disturbance. The higher value of transmissivity was observed in the area where no significant structural disturbance was observed. Such an area occupies a broad area in the central part of North Sinai.

The Specific capacity at Sheira-1, is 118 m^3/day/m and the draw-down is only 4.5 m.

The thickness of the aquifer is an important parameter for the evaluation of the aquifer. The aquifer of the sandstone of the Lower Cretaceous has high transmissivity in the broad area where there is no significant disturbance of the geological structure. In this respect, the thickness of the aquifer is of no significant importance since the transmissivity includes the concept of the thickness of the aquifer.

From the viewpoint of water usage, important parameters for evaluating the aquifer of the sandstone in the Lower Cretaceous are the TDS and the depth to the water. The TDS determines the restriction of the water use and the depth to the water determines the operation cost of the water source.

For this reason, the TDS and the depth to the water are taken as parameters for evaluating the groundwater of the Lower Cretaceous aquifer. The contour map of the TDS is meshed over the contour map of the depth to water level, as shown in the groundwater evaluation map. It should be noted that this evaluation is based on the assumption that the base map of TDS and depth to water level indicate the general feature of these aspects of the groundwater in the sandstone aquifer of the Lower Cretaceous.

Table 5 Evaluation of Aquifer in the Lower Cretaceous

Depth to Water (m) / TDS (ppm)		1	2	3	4
		Less than 100	100 ~ 200	200 ~ 300	More than 400
A	Less than 1,500	A1	A2	A3	A4
B	1,500 ~ 2,000	B1	B2	B3	B4
C	2,000 ~ 2,500	C1	C2	C3	C4
D	More than 2,500	D1	D2	D3	D4

The area indicated as A1 shows that there is a high possibility of obtaining groundwater having a TDS less than 1,500 ppm within 100 m from the ground surface. However, exact conditions are subject to further confirmation. The areas indicated by B1, B2, B3, C4 and D3 are also in the same situation since these are narrow areas circumscribed by two kinds of contour lines.

It is found that a broad area surrounded by Hasana, Sadr El-Heitan, Nakhl and Arif El-Naga is classified as A2. A2 is categorized as the area where the groundwater of the sandstone aquifer of the Lower Cretaceous is obtainable at the water level between 100 m and 200 m from the ground surface, with TDS less than 1,500 ppm, except the area around domes where there is significant disturbance of the structure. The first priority for groundwater development shall be given to this area; its boundary shall be verified by actual well data..

Area A3 is A2's surrounding area. The TDS of the groundwater is expected to be the same magnitude as A1's. However, the depth to the water is expected to be deeper, in a range between 200 m and 300 m. The area under this category is found around Sadr El-Heitan, Nakhl and Quseima.

In area A4, the depth to water is more than 300 m although the TDS of the water is expected to be less than 1,500 ppm.

The rest of the area may produce water with a high TDS. It is assumed that the high TDS is caused by structural disturbance which restricts water movement. This is also subject to further confirmation by sufficient information.

With all this information, it is proposed to place a high priority on the areas classified as A1 and A2. Immediate investigations shall be made of the area listed below:

Hasana
Surrounding areas of Gebel Kherim
Quseima
Kuntilla
El-Themed.

In addition, the sandstone of the Lower Cretaceous is distributed broadly in the study area. It extends beyond Regabet El-Naam Fault which is assumed to be a barrier of the groundwater movement in the sandstone of the Lower Cretaceous. The importance of the aquifer in the southern side of the fault is that it is part of the sandstone aquifer assumed to be the source of the groundwater to the north. For this reason, it is necessary to determine the function of the aquifer in the southern side of the fault within the entire aquifer system of the sandstone of the Lower Cretaceous.

2-6 Jurassic Aquifer

The Jurassic formations found in North Sinai are the Upper and Middle to Lower formations. The Middle to Lower Jurassic formation is represented by sandstone and shale interbedded by thin coal beds. Rocksalt is found in the coal mine in Maghara. The Upper Jurassic formation is represented by limestone. These formations are found in the dome structures in the study area. The wells sunk into the aquifer in these formations are found only in the Gebel Maghara area.

The aquifer develops in the limestone of the Upper Jurassic formation, and the depth to the aquifer is in a range between 111 m and 265 m from the ground surface. The depth to the water is in a range between 28 m and 123 m from the ground surface. Although the TDS is in a wide range between 1,650 ppm and 3,800 ppm, the yield is relatively high in a range between 120 m^3/day and 840 m^3/day.

At present, these wells are found only in the area at Gebel Maghara. The TDS of the groundwater in this type of aquifer is at a high level, so there is a high possibility of contamination of the low TDS water in the sandstone aquifer by the high salinity water in the underlying limestone aquifer since hydraulic continuity between the two aquifers is assumed.

The aquifer of the Middle to Lower Jurassic develops in the sandstone distributed in the dome at Gebel Maghara. Depth to the aquifer is in a range between 153 m and 275 m. However, depth data is very scarce and are available only at the coal mine at Gebel Maghara (29m from the ground surface).

The TDS is rather high, ranging between 4,140 ppm and 7,455 ppm. This is assumed to be one of the characteristics of this groundwater, since rocksalt is occasionally interbedded in this formation.

Chemical Composition of Groundwater by Aquifer

Age		Aquifer	Well No./Name	Cation (ppm)				Anion (ppm)					Total
				Mg^{2+}	Ca^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	CO_3^{2-}	NO_3^{-}	(ppm)
Quaternary		Kurkar	J No.7	105	148	1,485	15	791	819	2,165	-	32	5,560
			J NO. 10	92	289	810	16	191	802	1,384	-	15	3,622
		Sand Dune (Eastern Area)	16-3	14	30	27	2	110	40	50	36	-	309
			16-15	20	40	37	2	159	36	71	-	365	710
		Sand Dune (Western Area)	JR6	27	35	111	8	168	74	115	-	14	552
			JR282	316	625	1,770	22	795	788	4,010	-	100	8,426
Tertiary	Miocene	Sandstone	Misri-1	300	444	-	-	103	1,163	-	0	-	2,010
		Gravel	J No. 9	71	108	900	10	121	40	1,047	-	35	2,332
	Eocene	Limestone	Ain Gudeirat	53	86	31	5	223	222	568	0	-	1,188
Upper Cretaceous	Senonian	Limestone	No. 63A Libni-1	47	481	943	26	55	755	1,901	0	-	4,208
	Turonian	Limestone	No. 50 El-Arish-15	253	368	175	10	175	1,585	2,805	0	-	5,371
			Sheira-2	1,265	2,605	43,815	0	17,391	2,690	101,132	0	-	168,898
	Cenomanian	Limestone	P1 Gifgafa	268	330	1,066	34	432	494	2,609	0	-	5,233
			P4 Hasana	148	249	771	9	188	629	1,419	0	-	3,413
			J No. 17 El-Bruk-2	104	130	1,994	0	285	56	2,852	0	-	5,421
Lower Cretaceous		Sandstone	J NO. 12 Minshera	185	232	534	0	0	849	1,012	0	-	2,812
			J NO. 16 El-Bruk-1	52	31	790	0	285	39	1,156	0	-	2,353
			J NO. 19 Arif El-Naga	156	220	559		396	740	937	-	-	3,008
			Sheira-1	96	140	228		366	340	405	-	-	1,575
			Sudr El-Heitan	57	39	285	21	57	423	361	0	-	1,243
Upper Jurassic		Sandstone	No. 8 Coal Mine	520	590	1,256	0	170	1,627	3,261	0	-	7,424
Middle to Lower Jurassic		Limestone	No. WX2 Coal Mine	56	220	600	6	200	853	743	0	-	2,678

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