HYDROGYEOLOGICAL CONDITIONS IN EGYPT
Introduction

The purpose of this report is to present a summary of hydrogeological condition in Egypt.

The main water-bearing formation in Egypt are the extensive Nubian sandstone underlying the Western and Eastern desert and Sinai. The alluvial aquifer underlying the cultivated Nile basin regions (The Delta and Nile valley). The post-Nubian deposits of carbonate rock also form an important source for groundwater within the country.

However due mainly to the great variation in the quality of water they contain such formations are not considered as important as the two previously mentioned aquifers. As regards safe yield exaction from the two main aquifers, The quality of water which could be with drawn from alluvial aquifer without depleting the resource is in of 4.4 milliard m$^3$ per annum.

Results of model prepared by the UNDP/FAO groundwater pilot scheme project in the new valley and desert irrigation development indicate that a volume of 2.5 milliard m$^3$ per annum can be exacted for the next 50 years, provided the pumping lift does not exceed 100 meters.
The Nile Delta

GEOLOGY

The Delta region can be broadly subdivided in three zones. The first zone is the southern province which constitutes as a portion of the upward zone. This zone is characterized by relatively thin sedimentary cover and by development of the grapen-like structure. The second one is the central province which coincides with the central portion of the down warp zone and which is more of a syncline orium feature.

The third zone is the thrusting zone which occupies the northern portion of the Delta and is characterised by the presence of a thrust fault oriented in the northeast direction.
The Pleistocene is recognized by the heavily rainy age in Egypt. A gradually rise in the land happened during this age. Consequently, many water channels were deformed.

The Pleistocene sediments have different facies, the marine facies in the form of terraces, and continental facies in the form of Deltaic alluvial, Torrential lacustrine "Lake" and spring facies.

The loose material transported by river Nile from the Ethiopian and Sudan rocks were deposited forming the Delta aquifer.

The groundwater bearing stratum consist of sands and gravels containing few isolated lenses of clay. Huge pebbles may be found in this stratum as an indication of torrential river flow. During Pliocene and Pliestocene ages the recent sediments began at the end of the rainy age. (Fig 1).

The aridness and dryness conditions were the features of the recent age.

During this age the following phenomena happened.
- The sea shore took its present location.
- The Nile Delta was raised over the sea level.
- Top cap soil of Delta was formed of Nile alluvium.
- Human civilization began appear.
Fig2.: Longitudinal stratigraphic section of the Nile Delta.
HYDROSTRATIGRAPHY

The sedimentary section in Delta area and its fringes according shata and El – Fayoumy and Amer et-al has a thickness of more than 10000 m of which about 5000 m belong to Neogene (Fig 2). Although no faults are evident from the study of the surface exposures they are likely to exist in the subsurface and are concealed underneath the Quaternary deposits. The strata of hydrological importance belong essentially to the Quaternary like the stratum of deltaic deposits 200 to 500 m thick (which belong to Pleistocene).

These strata are dominated by clay lenses, having an estimated porosity varying between 25 % - 40 %. The top boundary of the deltaic deposits is a formation belonging to the Holocene.

This formation, which acts as a cap of the aquifer, is a semi-pervious clay and silt aquitard. The thickness of the clay cap increases non-uniformly in the seaward direction. The basal portion of the deltaic deposits rests unconformably on a thick clay section, which belongs to the Neogene. This clay section acts as an aquiclude outside the central part of Delta, the gravelly deposits show a marked thinning both to east and to the west and outline a variety of formations which comprise the Pliocene clays and sandstones (Wadi El Natrun).

The Miocene sandstones and sandy limestone (Belbeis, El Khutatba) and the oligocene basalts (Abu Zaabal) within such localities, aquifers of secondary importance were developed and depend on their supply of water principally on the horizontal as well as the vertical upward leakage from the main Delta aquifer.
The aquifer system consists of alluvial sediments. These sedimentary deposits contain two layers within which groundwater can occur. The lower layer is formed of highly permeable graded sand and gravel, and the upper one is formed by the clay-silt layer of relatively low horizontal permeability and very low vertical permeability. The impermeable Pliocene clay constitutes the base of the system, sealing off any up or downward flow through this aquiclude.

The aquifer is bounded in the north by the Mediterranean sea, and in the east by the Suez Canal. At the south, the aquifer is diminished as shown later and seems to be isolated from the aquifer of Upper Egypt by thick layers of Pliocene and/or Miocene clay aquiclude approaching the clay cap near Cairo at El-Manawat. At the west, the aquifer is in direct contact with the desert.

The thickness of Pleistocene aquifer increases towards the Mediterranean Sea, while it decreases southward till it mostly diminishes near El-Manawat partly separating the two aquifers of Delta and Upper Egypt (Fig. 3). South of Tanta, in the transversal cross section the bottom boundary takes approximately a concaved shape. The thickness decreases in an eastward direction attaining its maximum value generally in the middle (Fig. 4). North of Tanta
Fig 3: Pleistocene lithological cross section in the Delta.
in the transversal section, the maximum thickness of the aquifer seems to be shifted to the east and the maximum thickness may occur at San El-Hagar and EI-Matariya.

The thickness of the aquifer ranges from 100 - 900 m. It shows in general a gradual thinning towards the fringes of the Delta.

The thickness of the fresh water (up to 1000 ppm) bearing zone ranges from zero - 300 metres (Fig.5). The fresh water body looks like a huge convexed lens of its maximum thickness at the southern part of the Delta near EI-Bagur while its thickness decreases mostly in all directions. To the south, the decrease is related to the outcropping of the base. In the north and east directions, the thickness decreases because of the sea water wedge intruding from the Mediterranean Sea and Suez Canal. The westward decrease is related to the decrease in the aquifer thickness in this direction.

The aquifer is recharged by the infiltration from irrigation system and irrigation water through the clay cap. It may also be recharged by any possible flow coming from Upper Egypt aquifer. The aquifer loses water through almost the entire length of Rosetta branch except Idfina barrage reach only, downstream Zifta barrage reach of Damietta branch, and to the western desert depressions especially Wadi EI-Natrun depression. The aquifer also loses some of its fresh water directly or indirectly to the Mediterranean Sea and Suez Canal. As any coastal aquifer, an extensive sea water wedge has been intruded in the coastal part forming the main obstacle for its exploitation.
Fig. 5: Contour map of fresh water thickness in the Delta.
In the last years the Delta aquifer has been subjected to several changes. These changes are mainly due to the construction of the Aswan High Dam, reclamation projects and building of new towns.

The clay cap aquitard forms a semi-pervious top boundary of the Nile Delta groundwater reservoir. It is a Nile alluvium deposits belonging to the Holocene. It is an heterogeneous and anisotropic formation. This cap is composed of clay, silt or fine sandy clay. It is distributed non-uniformly over the Delta area but its thickness increases, generally in the seaward direction (Fig. 6), while it fades away at the Delta fringes in the east and west. This clay cap defines the type and degree of the confinement of the Nile Delta aquifer and its fringes. It also affects the shape of the interface between the fresh water of the aquifer and the sea water at the seashore. The clay cap contains the subsoil water body in the Nile Delta. Its phreatic water is referred to as shallow or simply water table. This water comes from the infiltration water and the seepage from the irrigation network. There is an interconnection in the form of vertical motion between both the shallow water of the semi-pervious aquitard and the deeper water of the aquifer in the Nile Delta. This vertical motion is either downward or upward according to the difference between the levels of the water table in the clay cap and the piezometric head in the aquifer. The coefficient of permeability of the clay cap formation in the vertical direction and the saturated thickness are the main factors affecting the vertical flow. The average of the recommended value of the vertical permeability \( K_{cv} \) is equal to 25 mm/day and the average horizontal permeability, 250 mm/day. Other important factors are the total thickness of the clay cap, its lithology and the level of the water table.
The clay cap may contain or may be followed by silty soft P clay or clayey sand lenses or layers few meters thick of higher permeability. This profile is found in most of the Delta area.

The clay cap thickness can be divided into two layers. The first layer is the upper clay cap which acts as an aquitard, of thickness not more than 20 m and of low permeability. The second layer is a lower clayey sand layer a few meters thick and of higher permeability.

**Aquifer Characteristics:** Pump test data from 35 wells and associated piezometers at locations distributed within the Delta have been collected and analysed to get the hydraulic parameters of the Mile Delta. The estimated permeability values range from 23 to 179 in/day with an average of 100 m/day. Zaghloul estimated the permeability of the Nile Delta aquifer from analysis of pump test data and sieve analysis. The estimated values range from 200 - 1000 m/day. He also investigated the relationship between the aquifer's permeability and depth. The most permeable water bearing strata has been found at depths between 55 and 150 meters from land surface.

Analysis of various pump test data of the Research Institute for Groundwater indicate that the average permeability for the lower formation is 100 m/day. This value may be chosen to represent the regional value of hydraulic conductivity.

The storage coefficient of the Nile Delta aquifer varies with the degree of confinement. It has a value of 0.20 in the unconfined areas lying to the west and east of the Rosetta and Damietta branches respectively. Where the clay cap is predominating within the Delta and adjoining areas, the storage coefficient value of the aquifer decreases, ranging between the order of $10^{-4}$ - $10^{-3}$. 
Groundwater quality in the Nile Delta

Whilst the alluvial graded sandy aquifer underlying the Delta contains a huge amount of water, the amounts that can be safely withdrawn are governed by their present quality or potential quality deterioration by sea water intrusion, salt water upconing and/or general contamination.

The major alluvial aquifer roughly south of Tanta is generally of very good quality, with salinity values of less than 1000 ppm. T.D.S. Salinity increases in a northerly direction with increasing influence of the sea, beyond an arc. line extending across the Delta from about 25 km. above Tanta eastward and westward. Thus, in the northern Delta, salinity ranges from 5000 ppm. T.D.S. just north of Kafr El-Sheikh (with similar values observed across the Delta, arc wise, to the east of Ismailia approaching the Suez Canal and Damanhour to the west) to 40000 ppm T.D.S. near the northern coastline (Fig. 7) South of Wadi El- Natrun, groundwater becomes mainly brackish, South of the Ismailia Canal to the Cairo-Ismailia desert road, the groundwater salinity ranges from about 1000 to 6000 ppm.

South of the arc line described earlier, water from the huge Delta aquifer is generally of very good quality. Local areas, however, do indicate high to medium salinity hazards. Thus, in a survey conducted by the Research Institute for Groundwater, of the Ministry of Irrigation, of wells across the central, southern and eastern parts of the Delta, two-thirds of the wells had water of medium salinity hazard while the remainder indicated high salinity hazards.
Fig. 7: Contour map of groundwater salinity in the Delta.
Another survey in south Beheira and Kafr El-Sheikh near the western and northern fringes of the Delta's fresh water zone also had similar results for the deep wells sampled. Shallow (hand pump) wells investigated in the same areas, that either tap the silty clay layer or the unconfined alluvial aquifer, indicated-waters of high to very high salinity hazards.

Within the Delta, chloride and sodium levels recorded were all within acceptable levels, although sodium concentrations apparently increase (between about 7 and 9 meq.) towards the southeast. Hardness also seems to increase towards the southeast near Abu Zaabal and Qalyub but is otherwise well suited for irrigation.

The Delta is one of the most densely populated regions in the world. It has been estimated that less than half the Egyptian population have reasonable access to nearby piped water supplies. A huge majority of the rural population therefore rely wholly, or at least in part, on local private mainly groundwater sources for domestic needs. Thus, such water's suitability for domestic purposes is of particular importance in this region.

Two main methods are presently used for abstraction within the Delta, namely deep wells of about 50-70 meters depth mostly used for public potable water supplies, and shallow handpumps of up to 15 meters depth which are the common private sources of domestic water in the Delta.
Chemically, the IDS levels in deep wells outside of the brackish and saline groundwater areas described above are generally within the maximum permissible levels (MPL) of the WHO (1971) for drinking water. Iron and manganese, however, are at undesirable levels locally, although there is no clear pattern as to the spatial distribution of water containing high concentrations. Concentrations in handpump well waters near canals were reportedly similar to levels in wells away from any surface water influence. It was therefore postulated that iron and manganese sources probably lie within the lower horizon of the clay cap and/or in the upper layers of the sandy aquifer.

Of the 19 handpump and 33 deep well samples collected by Taylor/Binnie in Beheira and Kafr El-Sheikh, the shallower water reportedly had high TDS, iron and manganese levels, the latter exceeding the maximum permissible levels in 58% of the shallow and 35% of the deep wells sampled. Results of deep well samples from central, southern and eastern areas indicate that the quality is generally within desirable levels recommended, by the WHO (1971) and no important constituent exceeds permissible levels.

However, due to the common rural combination in the populous Delta region of unlined septic tanks and adjacent groundwater abstraction, bacteriological contamination of such water sources frequently results in a cycle of human infection and reinfection. Generally, the presence of the silty clay cap is well suited to the reduction of such risks. In the southern and central Delta where the alluvial aquifer is confined,
movement of water downward from the silty clay is slow and residence time is long. However, the risk of contamination is increased where the silty clay cap is thin or absent, and/or where the pollution source is at least partially penetrating the silty clay, and/or where the head in the sandy aquifer is reduced by large abstractions in deep wells and downward movement is increased.

It is noteworthy, for example, that, of the wells surveyed in Kafr El-Sheikh and Beheira, 84 % of the shallow wells drawing from the unconfined as well as the confined aquifer were bacteriologically polluted, registering total coliform counts of over 5 MPN/100 ml. and reaching a maximum of 300 MPN/100 ml. 42 % were faecally contaminated. Though bacteriologically unsatisfactory, the deeper wells were of a better quality of the 33 deep wells sampled in Beheira, 12.5% contained unpermissible total coliform count levels but only one gave a faecal coliform count. In areas where risk of groundwater contamination is high, it is especially important that official regulation of groundwater abstraction for domestic use is instituted.