CONCEPTUAL REMARKS ON THE SOLUTIONS OF PROSPECTIVE PROBLEMS FOR THE DEVELOPMENT OF EL-WADI EL-GIDEED WELLS FIELD

BY

Dr. Talaat M. Owais* (B.Sc., M.Sc., Ph.D.)

I. ABSTRACT

Egypt as an arid zone has utilized irrigation from the earliest times to grow various crops and continually establish the roots of civilization allover the country. Irrigated agricultural development and reclamation of new land have highest priority in the present world where production of foodstuffs must keep pace with a very rapidly increasing population rate.

Since great attention was directed toward El-Wadi El-Gideed area, extensive research and field works were carried out in the attempt to reclaim vast areas there and converted from plain yellow desert to productive green lands. This is for a sound ground water basin development leading to well developed agricultural zone with truly economic water development controled by systematic management, avoiding any striking discrepance between the major anticipated objectives of the project.

Most of the prospective problems and expected difficulties are fully identified and proposed solutions are domonstrated. Conceptual remarks were focused on: constructional precautions and selection of deep-well turbine pumps, hydrologic equilibrium, excessive well losses, safe yield and overdraft, excessive discharge(over-pumping) from an aquifer and specific capacity of a well, the drawdown and recovery curves, the rate of recovery in pressure wells, multilayers confined equifer and multiple interfering well systems, corrosivity of pumped water and precautions against pipes corrsion and finally the deterioration of ground water quality.

Several local examples accomodating with the environmental circumstances of the area under investigation were displayed and proposed analyses and procedures for satisfactory solutions were discussed and fully represented.

---

* Assoc. Prof. Civil Eng. Dept., El-Mansoura University El-Mansoura, Egypt.

Mansoura Bulletin-December 1977.

The research paper is concluded by itemizing few of the anticipated gains as well as the prospective side effects of the over-pumping activities under extensive rates. Few concluding remarks and recommendations are also provided; hoping to be, along with the context material presented, to be useful to all those engaged generally in irrigation and water development and those who are doing their extreme efforts to achieve anticipated progress in El-Wadi El-Gideed, Egypt.

II. INTRODUCTION

Throughout Egypt history, irrigation activities have been one of the earliest job and premier burden to grow food and to keep the wheel of life running safely. Due to the fact that close to 95 per cent of Egypt is considered an "arid zone." Thus, wells have been, for a long time, an integral part of Egyptians life among other activities, supplying clean pure water where ready surface supplies were not adequate, unreachable, at a distance very far from the field or subjected to severe seasonal variations.

Since the recorded ancient time in Egypt, there were always proofs that show the historical significance of wells allover the country including the area called now "El-Wadi El-Gideed" (an arabic expression means "The New Valley"). Continuously from the time system of deep artesian wells were drilled recently (within the last twenty years), several problems creating some difficulties in expanding new reclaimed green areas in addition to few technical, constructional, maintenance, development, social and management problems had arisen. Consequently, some urgent basic irrigation development problems require definite solutions. Meanwhile, it is worthy to mention here that there have been continual great effort and care done in this area and still anticipated projects are going on.

It is the main objective of this research paper to show some of these problems and trying to demonstate few conceptual remarks on proposed solutions of prospective problems for the sake of achieving an optimum oomprehensive development of El-Wadi El-Gideed wells field and similar ones.

III. THEORETICAL ANALYSIS

Considering radial horizontal flow in a confined water -bearing layer of thickness b toward a fully peneterating well. An expression for the rate of flow Q can be derived and finally expressed as:

$$Q = 2\pi.K.b(h_e - h_w)/2.3 \log_{10} (r_e/r_w), \ldots\ldots (1)$$

in which:

K = the coefficient of permeability,

h_e&r_e= the undisturbed piezometric head or that at which the radius of the influence circle = r_e(the intercept of draw-down curte with the unaffected water-table or influence circle of piazometric pressure),

h_w&r_w= the piezometric head at a well of radius = r_w,

(h_e-h_w)=the drawdown "D_w" which is subetantially directly proportional to the well discharge "Q", whereas Q varies only as the logarithm of the well radius r_w at the same time, and

b = the thickness of the confined aquifer.

On the other hand, for an unconfined well where the flow is not reetricted by any impervious layers above the flow and where the water table which is the plane of atmospheric presseure below which the pores of the aquifer are essentially saturated, a comparable equation for the well discharge can be simiraly expressed as follows

$$Q = \pi.K(h_e^2 - h_w^2)/2.3 \log_{10} (r_e/r_w) \qquad \ldots\ldots (2)$$

It has to be noticed that the above equations are based on the following conditions:

1- The flow motion toward the well is radial horizontal flow through uniform material perpendicular to vertical cylindrical surfaces,
2- The flow is steady,
3- The state of flow is assumed laminar,
4- Darcys'law is valid,
5- In case of confined flow, the thickness of the aquifer is constant and uniform all the way around the well,
6- No interference from adjacent wells.

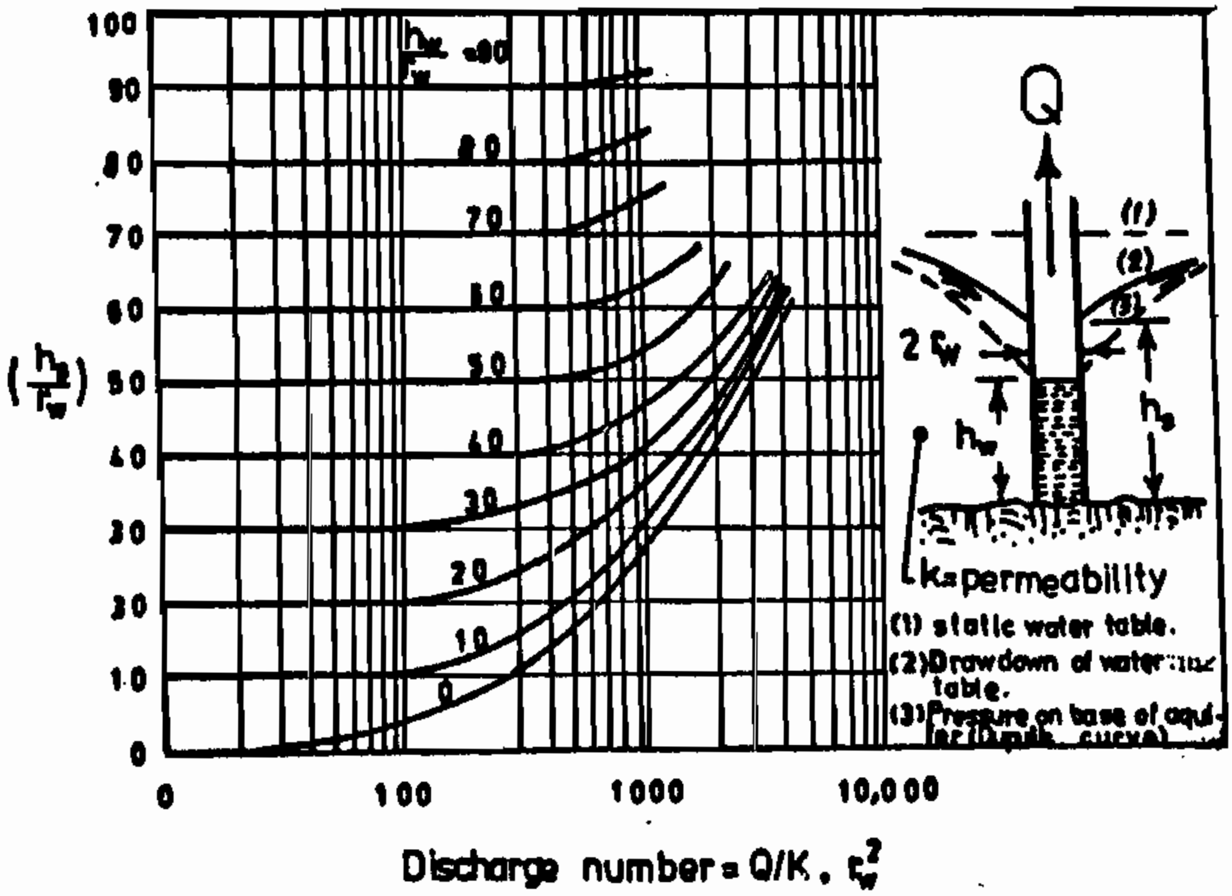
However, in actuality a seepage face "h_s" always oocurs above the water surface in an unconfined well (refer to Fig.(1)). This is due to the fact that, for instance, the unoonfined well flow near the well is not horizontal. Hence, the nearer the well the greater the error that can be expected. Consequently, the correct boundary Condition can be modified as follows:

$$Q = \pi K(h_e^2 - h_s^2)/2.3 \log_{10} (r_e/r_w) \qquad ......(3)$$

Nevertheless, equations (1), (2) and (3) can be, within a satisfactory range, practically applied to unsteady flow because the velocity of flow through the aquifer toward the well is relatively so small that kinetic energy is negligible.

So, two destinctive characteristics of artesion wells differentiating them from others, they are:
1- The direct relationship between the flew rate from the well, Q, and the drawdown, D_w, and
2- The quikcer recovery of the water level in artesian or pressure wells compared to gravitational wells, when pumping is stopped, which proved to be a useful evidence in this regard. This is because it is not necessary to add replaced water to the surrounding media as it is when a gravity well recovers.

To display any mathematical formulation and demonstrate the interrelationships between the variables involved, which



Fig(1)- Seepage face and depth of water in the well related to discharge number for an unconfined radial well.

make up the relevant parameters as controllers, it is worthy to list out some of these major variables, such as:

$$Q, r_w, r_e, h_w, h_e, h_s, K, b \;\&\; \gamma$$

The depth and so the length of drilling, housing (the part of the casing into which the deep well or submersible turbine pump is lowered), casing (the blind pipe extending below the housing), the screen length, type, dimensions, and other detail variables are all excluded for the time being because of the deficiency in field data and avoiding any early complications in the analyses. This is in addition to any introduced complexities, soil anisotropy and any hydrological, hydrogeological or human activities in both the recharge and the discharging areas.

However, group of several dimensionless parameters can be deduced like the following, just as samples:

(h_w/r_w) & (h_s/r_w): as geometrical indices adjacent to the well;

(h_w/r_e), (h_s/r_e) & (r_e/r_w): as relative geometrical indices for the well;

$(h_s-h_w)/r_w$ & $(h_s-h_w)/r_e$: as seepage face well ratio based on either well radius or influence circle radius;

$(Q/K.r_w^2)$ & $(Q/K.r_e^2)$: as the well discharge number $/\hat{Q}_w/$, and the limiting (boundary) discharge number $/\hat{Q}_e/$. $/\hat{Q}_w/$ is an indicative of the cone of influence; with large numbers indicating steep cones or greater drawdown, while small numbers indicate relatively shallow cones of depression or shallower piezometric pressure distributions;

$\left(\frac{Q}{K.b} \cdot \frac{r_e}{r_w}\right) = /\hat{Q}_w/ \cdot (r_e/b)$ $= \left(\frac{Q}{T} \cdot \frac{r_e}{r_w}\right)$: as a special confined well discharge number, which could be used as an indicative dimensionless parameter for the cone of influence of the piezometric pressure around an artesian confined well, (T: is the coeff. of transmissibilty and b: is the thickness of the confined aquifer);

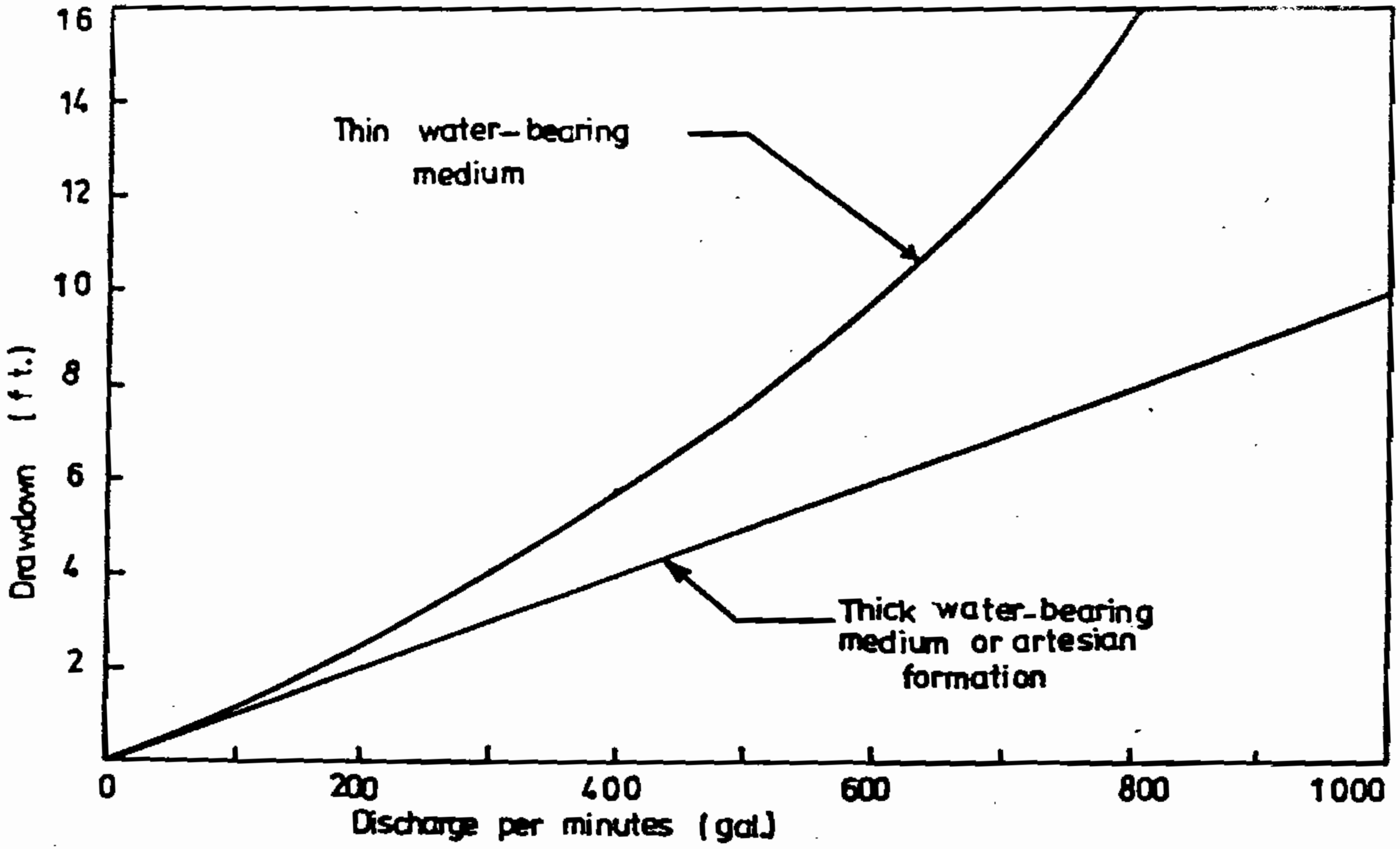
$(V_w . r_w / \nu) = IR_w$: as a well pseudo-Reynolds number, which can be considered as an indicative dimensionless parameter for the well discharging performance, ($V_w = Q/A_w$, $A_w = \pi . r_w^2$ & ν = Kinematic viscosity of pumped water).

Few of these relationships are displayed, for examples, like the one of Fig.(1) for unconfined wells while those of Figs. (6) and (7) for confined artesian wells selected over Karga Oasis of El-Wadi El-Gideed, Egypt.

Moreover, Fig.(2) is a useful demonstration for a typical discharge varsus a corresponding draw-down of a well draws its water from a thin water-bearing formation comparable to another one in a thick water-bearing formation or an artesian stratum.

IV. CONSTRUCIONAL PRECAUTIONS AND SELECTION OF DEEP-WELL TURBINE PUMPS

Generally speaking, according to the available design data, it is possible to decide on the likely deep-well turbin - pump: type, size, mechanical and hydraulic characteristics in addition to the approximate depth it is supposed to be lowered. Few details when constructing, operating and maintaining such wells must be taken into consideration. For instance, the housing pipe should be extended well below the anticipated pump setting and be two nominal pipe sizes larger than the bowl size of the pump. The former provision will allow for future pump setting changes, and the latter insures adequate clearance between pump



Fig(2) - Typical discharge draw-down relation of a well in thick water-bearing formation or an artesian stratum compared to that of a well in a thin water bearing formation.

and housing even if the latter is slightly out of plumb line. Furthermore, if some of the housing is screened above the pump setting, the annular space around it allows free water flow to the pump intake. Where the casing has to be extended to a considerable depth below the pump setting, its diameter may be reduced to certain extent providing the precaution of reducing frictional loss to a minimum value by keeping larger size pipes.

Moreover, the dimension of the outer and inner casing must be adequate to minimize the friction loss due to up-ward flow. The same discussion applies to the screen, which probably has a diameter smaller than that of the casing, in a way in order to allow for the velocity through the screen openings not to be more than 0.1 ft./sec. This providing proper well graded round aggregates with sufficient thickness all the way around the screen length properly placed and well packed as unconsolidated material. It is worth to notice that the total losses due to inlet and outlet pipes, through the screen and withing the casing, etc. These may appreciably influence both the pump head and the rate of discharge in addition to the "useful life expectancy" of the entire well. Appropriate selection for housing and casing sizes must be carefully done in relation to anticipated pump yield, taking into consideration of considerable excess artesian pressure exists. If "multiple-stage deep well centrifugal or turbine pump" is selected, proper components and operational process must be carefully followed.

In addition, it is not advised to design a permanent pump installations for maximum drawdown. As, this would be very risky and might lead to various future complications, especially if seasonal water table or piezometric head distribution fluctuation range is relatively appreciable. Working hours may reach 20 hours and Service protected reservoirs connected with collectors, distributers and other converyance system are fully utilized a desired for irrigation purposes. Facilities and equipment needed for modern irrigation methods should be provided as well.

However, discussing all constructional precautions needed in this regard is beyond the scope of this research paper. Other precautions will be mentioned under other subtitles and the rest are left for the engineer to deal with according to local circumstances.

Furthermore, regarding few of the basic information required in the selection of a deep-well turbine pump, considering both the pump operating conditions and the overall description of the well, are very briefly summarised in the following items: (according to J.A.W.W.A. standared Specifioations)

1) well type (gravity or artesian, say);
2) well capacity, gpm.;
3) maximum speed, rpm.;
4) elevation at site, m. or ft.;
5) pump level below ground level at rated capacity;
6) pump head above ground level; including discharge pipe friction, m. or ft.;
7) rate of total pump head;
8) operating range, maximum total head, m. or ft.;
9) pump setting, m. or ft.;
10) minimum inside diameter of well or casing;
11) total depth of well, m. or ft.;
12) well straight (when a cylinder 20 ft. long and equal to the bowl in diameter is lowered into the well without binding, as for as final screen setting);
13) static water level below ground surface;
14) drawdown, m. or ft., at various Q values;
15) electric power available, maximum HP., volts, cycles, etc.
16) other specifications, like engine type (gas, gasoline or diesel), etc.

For example, Fig. (3) illustrates a typical pump characteristics used in the selection of deep-well pump. Hence, the pump characteristics must be mainly suited to the drawdown in the

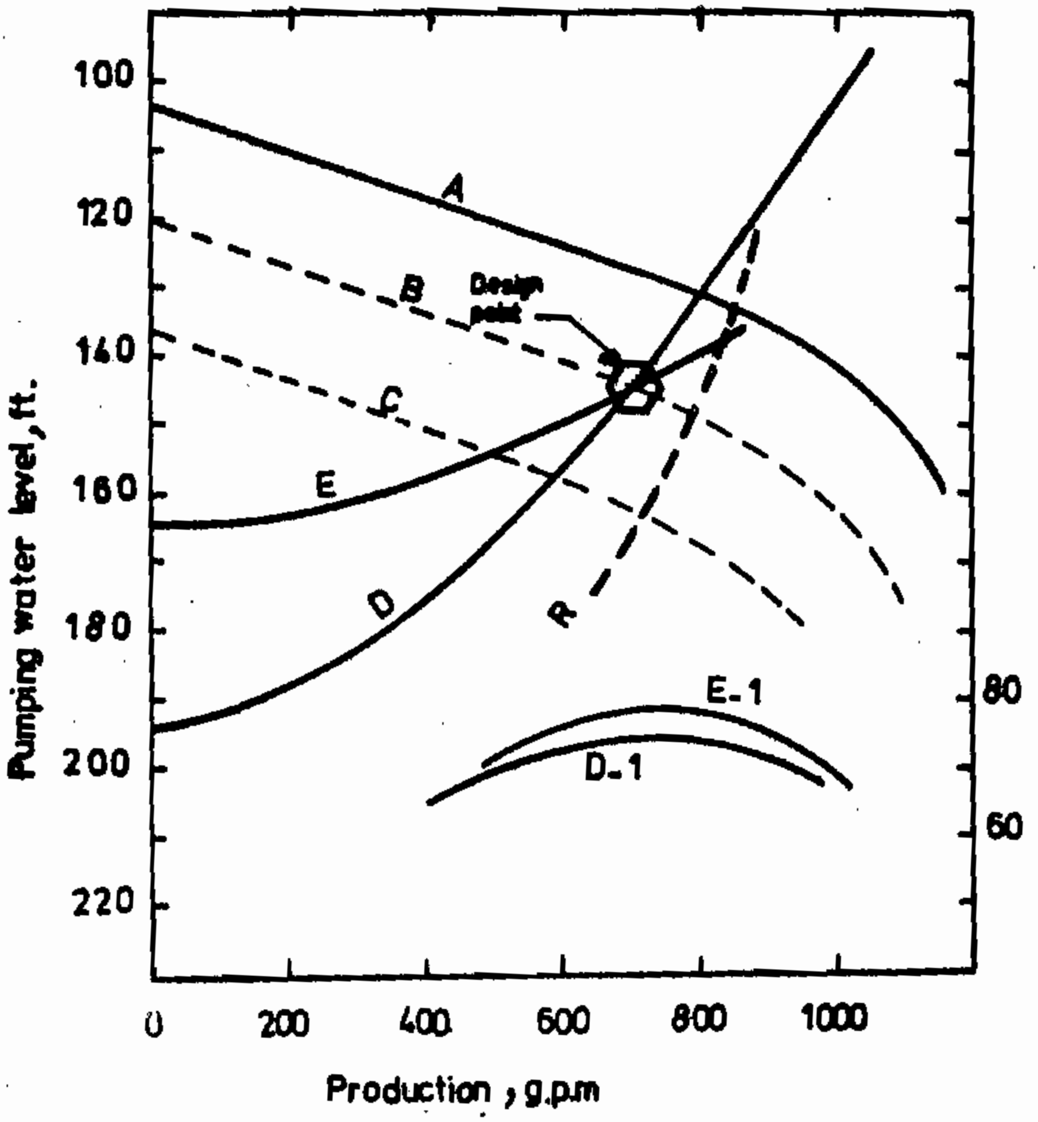


Fig (3)-Typical pump characteristics used in selection of deep well pump.

Legend:

A: High static water level.
B: Average static water level.
C: Low static water level.
D &E: Pump cores.
R: Range of most economical production.

well for the required rate of discharge and the lift desired. Referring back to Fig.(3) where the characteristics and the drawdown may be coordinated by constructing productivity curves and characteristic curves of the deep well and the pumps under consideration. These curves show, for instance, that pumps "D" and "E" are best suited to draw 700 to 750 gpm. from the well with a total lift of about 144 ft. at an overall efficiency close to 67 to 70 per cent respectively. However, pump "D" is better suited for all conditions since it follows the range of most economical production more nearly. That in addition to the fact that pump "D" has a higher capacity under low-water conditions during the summer season when more water is badly needed.

In addition, other control parameters like the specific speed speed "N_s" (= $\underline{N\sqrt{Q/H^{3/4}}}$) and the dimensionless factor "K_s" (= $\underline{QN^2/V^3}$), etc. and many others contribute significant role in the selection of pumps and the types of their vertical rotating shafts. This is in addition to several handy emperical formulas and available design charts made especially for that regard. For instance, one of these emperical formulas, based on the recommendations stated by several experts in this regard, can simply expressed as follows:

$$D = 236 \quad Q^{0.154} . \; H^{0.256} / N_s^{0.678} \qquad \ldots\ldots(5)$$

in which

D = outside diameter of pump casing, inches;
H = total head for one stage of wheel, ft. of water;
N_s= specific speed of wheel, rpm.; and
Q = rate of discharge, gpm.

The above equation is just an emperical example showing an interelationship between some controlling conditions in pump selection. Nevertheless, back experience proved that the application of the above formula is limited to pumps of the highest efficiency and with specific speeds between 4100 and 1500. Keeping in mind that tendency to use larger size pump diameter will probably give better life-operational processing and efficiency than using relatively smaller size.

Finally, characteristics of importance to be consdiered in well pumps selection must include also the following items covering other inner components;

1) bowls: best-grade iron;
2) pump shaft: stainless steel;
3) line shaft: polished, cold-rolled steel;
4) pump characteristics: must be primary and beforehand known from the shutoff to cavitation and possible hammering;
5) Motor: of such size that rated horsepower is never exceeded;
6) Impellers: bronze: say 85 to 88 per cent copper, 5 to 10 percent tin, 2 to 5 per cent zinc, and 5 per cent lead if the same bronze is used for both the impellers and the line-shaft bearings.

Other detailed specifications are left to local circumstances especially those relevant to: Connections at top of well, submersible motors on well pumps; air-lift pumps, air-lift boosters, etc. That includes the variation of "pumping duty", several "pupm combinations", its installation, fittings, housing and their overall characteristics and equipment classifications desirable for an optimum irrigation service and that fit the need and circumstances exist in El-Wadi El-Gideed and similar areas.

V. HYDROLOGIC EQUILIBRIUM

Before establishing any hydrological equilibrium for a particular ground water basin, the elements of the "Hydrologic Cycle" involved must be individually defined and evaluated. Hydrological equilibrium demonstrates, controle and correlate a BALANCE exist between the quantity of water supplied to the basin and the amount stored within or leaving the basin. A mathematical model representing such equilibrium expressed in terms of equations (deterministic or stochastic) provides a quantitative statement of such a balance.

of the most general forms expressing this phenomenon is as follows:

> (Surface inflow) + Subsurface inflow) + (precipitation) + (Imported Water) + (Decrease in surface storage) + (Decrease in ground water storage) = (Surface outflow) + (Subsurface outflow) + (Consumptive use) + (Exported water) + (Increase in surface storage) + (Increase in ground water storage).
>
> ...... (5)

The above form (in discharge units) includes all waters - both surface and subsurface - entering and leaving a ground water basin, where the left hand side of the equation represents the possible supply items as an input and the right hand side stands for the disposal elements as an output with a certain differential storage balanced out.

For the present situation considered concerning El-Wadi El-Gideed ground water basin, it is possible to eliminate certain items from the hydrologic equilibrium equation because they are negligible or because they do not effect the solution significantly. For example, the hydrologic equilibrium in this case is independent of and local overlying surface waters; therefore, items of surface inflow, precipitation (which is actually nill), surface outflow and changes in surface stroage can be omitted from the equation. On the other hand, evaporation, absorption and seepage losses as surface and subaruface outflows contribute a significant role in the hydrologic balancing equation. It has to be noted that the amount of net unbalance, if there is any due to some permissible accuracies, should not exceed the limits of accuracy of the basic data to be accepted, otherwise further investigation becomes necessary.

Adequate hydrologic data and careful analysis of the geological formation are vitally important to carry out the hydrologic investigation completely. Verification of the proposed mathematical balancing modeling utilizing computer facilities is considered incomplete without implementing the solution with actual field results under existing conditions selected for this purpose.

VI. EXESSIVE WELL LOSSES

The drawdown at a well is affected by both the logarithmic drawdown curve and the well screen loss in addition to the pump intake losses and any other added minor losses. Several hypothetical assumptions were covered in the literature (refere to indicated Refs.) trying to evaluate such losses.

Thus, the total drawdown D_w at the well for the confined case may be expressed as follows:

$$D_w = h_o - h_w = Q.B + C.Q^n, \qquad \text{........(6)}$$

in which:

$Q.B$ = aquifer loss,

$C.Q^n$ = well loss,

Q = steady pumping discharge of the well, = 2 .T. $(h_o - h_w)/\ln(r_o/r_w)$

B = $\ln(r_o/r_w)/\ 2\pi.Kb$,

r_o = the radius of influence at which the piezometric head equals to h_o, = r_e the radius of influence circle,

h_o = the undisturbed initial uniform head, = h_e = the piezometric head at whidh $r = r_e$;

r_w = the radius of the well,

h_w = the piezometric head at the well,

$K.b$ = T = the coefficient of transmissibility,

K = the coefficient of permeability,

b = the aquifer thickness,

c = a constant governed by the radius, construction and the condition of the well (=2.10, experimentally) and

n = an exponent computed from step-drawdown pumping tests (= 2.0 as suggested by Jacob, but = 1.77 experimentally),

Obviously, the well losses can be minimized by developing properly well screens, constructional elements and installation procedures in addition to any of the well completion processing that provide any improvement for ready entrance of ground water into the well with minimum resistance in and around the casing. On the other hand well losses can also be reduced to certain extent by keeping velocities into and within wells to a minimum. In this regard, the well discharge equation for both confined and unconfined aquifers show that the discharge is inversely proportional to $\ln(r_o/r_w)$, when all other variables are held constant. In the meantime, it has to be noticed that the discharge varies slightly with the well size. For instance, doupling the well radius increases the discharge only TEN per cent. Meanwhile, doupling the well radius doubles the intake area, reduces entrance velocities to almost HALF, and (if $n \cong 2$) cuts the frictional loss to less than a THIRD. Moreover, for axial flow within the well, the cross sectional area increases FOUR times, reducing this loss an even greater extent. These differences become appreceable for relatively high pumping rates and consequently contribute significant fraction of the total drawdown.

It has to be noticed also that the above expression for the total drawdown can also be used for the detection of clogged screens for these wells too.

VII. SAFE YIELD AND OVERDRAFT

One of the important aspect for the improvement of any basin-wide ground water development, like the one allocated in El-Wadi El-Gideed, is to keep track with a continual record for the safe yield of each individual well and for the mutiples too. Such analysis is essential to provide optimum development of this ground water resource and ensure continual beneficial use of its natural underground reservoir . Keeping into consideration that certain hydrologic equilibrium must exist between all input waters entering and leaving the basin as output in balancing fashion.

The "Safe Yield" of a ground water-bearing formation, in this regard, is defined as the maximum rate at which water may be withdrawn technically and economically without impairing the quantity or quality of the supply and without any undesirable results to the basin landowners or to those within the nearby vicinity. Consequently, pumpage in excess of safe yield is "overdraft". Other technical terms relevant to the same subject like: "Maximum Sustained Yield", and "Permissive Mining Yield", etc. may also be introduced to put more clarification and distinction to the "Safe Yield" of a ground water basin.

In an artesian system such as the "Nobian sandstones" and other local formations involved, in El-Wadi El-Gideed area, the safe yield is limited by the transmissibility of the sandstones, the intake capacity of the sandstones, the amount of water that can be taken from storage, and the danger of chemical contamination by water from formation below in addition to higher temperature effect. Accurate determination of these limiting conditions requires an extensive study of the entire aquifer which, in this case, covers most of the Western Desert (The Great Sahara).

Moreover, reconsidering the basic definition of the safe yield, it reveals that there can be more than one "undesired from pumping a ground water basin, that the safe yield may be limited to an amount less than the net amount of water supplied to the basin, and that the safe yield can vary as the conditions governing it vary. If the groundwater reservoir that serves

El-Wadi El-Gideed Zone and the nearly area is regarded as a renewable resource, then only certain quantity of water may be withdrawn annually as an optimum exraction from the underground reservoir, yet still maintain that supply unimpaired. So, the determination of the safe yield becomes very essential to safe guard the ground water basin from any deterioration or any overdraft. spots. Until over drafts are reduced to safe yields within the basin, permanent damage or "depletion" of the ground water supplies must be anticipated.

The importance of determining the safe yield (either in mass quantity or rate concept) reflects the essential features of all factors governing its numerical values and its ranges of acceptance. Generally speaking, the main factors which contribute significant effect are;

1) The water supply available to the basin and the recharge area (s),
2) The economics of pumpage from the basin,
3) The quality features of ground water, and
4) The water rights in and near the basin.

Although the parmeters relevant to the water supply factor plays the major part in determining the safe yield quantitatively, the other factors contribute important role in ground water management and administrative control for the whole system. This is in addition to proper operation and economical evaluation which must be achieved quantitatively as well as qualitiavity. Any sort of restrictions or limitations must be allocated and a solution be estabilished along with the pre-evaluation of probable conjunctive use of other water resources (like surface water through Toshka, say) before the right value for the safe yield could be determined. Several methods may be suggested to compute numerical values for the safe yield, like: Hills', Hardings', Simpsons', Darcys', fluctuations', pumpings' and water table and specific yields' methods, etc. (refer to references).

VIII. EXCESSIVE DISCHARGE AND THE SPECIFIC CAPACITY OF A WELL

Continual excessive discharge for beyond the safe yield of the existing wells system or with a rate exceeding the ground water replenishment rate represents one of the very series water resource managment problem, in addition to several side effects involved. As a result, well flow never reach its steadiness within a reasonabls period of time besides draining out the confined reservoir within a short time and suddonly release its piezometric pressures to a great extend.

Steady-state wells are rarely accomplished as most of the newly developed wells are initially transient. Technically speaking, the wells must continue in the transient state indefinitely unless they intercept a source of replenishment. Even transient wells appear to approach a relatively steady state condition within a certain tested time because the water table perturbations rapidly decrease in magnitude with both time and distance from the well. However, a well may be treated as though it is in steady state, if within a reasonable radial influenced distance, there exists no appreciable perturbations of the water table or piezometric surface as the result of pumping.

Eventhough, practically speaking for establishing a safe field and drawdown curve of a well, a large test pump exceeding the well capacity should be used to draw the water down to its maximum continuous yield and drawdown. This test should be run for several days to ascertain that the yield has become constant. In order to establish the "yield-drawdown Curve", the maximum pumping rate should be successively reduced from maximum by ONE-FIFTH of the maximum capacity. For this purpose, the flow rate and water depth must be recorded accurately each time.

It is advised not to design the permanent pump for maximum drawdown, avoiding any future complications, especially with seasonal and yearly water level fluctuations. The well exploitation should be limited between an operated range representing 60 to 70 per cent of the maximum drawdown, Accordingly, the actual reduction in the yield would be only about 10 per cent of maximum as opposed to the considerable reduction required for pumping head and relatively safe continuous exploitation potential.

Moreover, the pumping plant should generally be designed on the basis of a 20 to 22 hours per day pumping duration and the yield to be preferably discharged into a service reservoir from where it can be conveyed to the fields or utilized as desired. This water management system proved to be more economical and convenient than a centeral plant designed for a flow rate required for immediate irrigation, especially where surface irrigation methods are employed. That is excluding relatively small sprinkling and dripirrigable fields, where it might be preferable to design the pumping plant for direct application to use up available conveyed pressures evenly in aclosed circuit allover the farm.

In the meantime, exploitation of an artesian aquifer should be limited to its replenishment potential, which can be established only by long-term piezometric pressures establishment and geo-hydrological study. Meanwhile, before embarking on a large-scale, deep - well development project (like the one in El-Wadi El-Gideed), it is important to investigate by ISOTOPES the age of the water confined in the bearing aquifer. Such a study is invaluable in helping to establish the following:

1) The recharge rate of the aquifer versus its rate of replenishment,
2) The advancement rate and the velocity of water movement in the aquifer, and thereby,
3) The safe extraction rate without having to draw on the water capital.

On the other hand, excessive discharge from a well or their multiples from a completely saturated aquifer can be regulated scientifically by varies control parameters, like "Specific yield", "specific retention" and the "specific capacity". The specific yield can be calculated by dividing the total quantity of water drained out from the aquifer, after a relatively long time (within steady state range validity), by the original volume. It is the ratio of the volume of water it will yield, under the pull of gravity or net balanced piezometric pressures, to its own volume. The specific yield represents numerically a maximum value for the coefficient of storage of an aquifer "storativity" which can be approximated by the "specific yield" of the material which it is composed. While the "specific retention" of an aquifer which has been saturated is the ratio of the volume of water it will retain under any specified hydraulic conditions to its own volume. It is numerically represents the difference between the "prrosity" minus the "specific yield".

If both the coefficient of storage "S" and the coefficient of transmissibility "T" are available for a well field, the drawdown resulting from any rate of pumping in the field can be determined, where:

$$T = 264.\ Q / \Delta s \qquad \ldots\ldots\ldots(7)$$

and

$$S = T.\ t_o \ /\ 4790.\ r^2 \qquad \ldots\ldots\ldots(8)$$

in which:

Q = rate of pumping, g.p.m.,

r = distance from center of pumping, well to center of observation well, ft,

s = drawdown of water level, ft.,

S = rate of drawdown for each log cycle of straight - line portion of graphic plot, i.e. slope of drawdown curve,

and t_o = time, min., when straight-line portion of curve, extended, intersects value of zero drawdown.

Then applying "Theis nonequilibrium formula" with a well function W (U), the "safe yield" rating of the tested well can be obtained in addition to the information needed to determine the economic interference allowable between wells in the field. The "Capacity" of a field can thus be determined also by applying observations of drawdowns and corresponding rates of flow according to Dupuit formulas, say.

However, if the discharge is divided by the drawdown of the "specific capacity" of the well field can be obtained. This is a measure of the "effectiveness of the well". Solving equation (6) of the total drawdown D_w for the specific capacity, then:

$$Q/D_w = 1/(B + C.Q^{n-1}) \qquad ....(9)$$

It can be noticed that the above equation indicates that the "specific capacity of an artesian well" is NOT CONSTANT, as is sometimes assumed; rather it decreases with increasing Q.

(N.B.: An analogous situdation can be demonstrated for the unconfined case.)

Moreover, the approximate solution of the nonequilibrium equation demonstrated that the specific capacity of a well varies not only with "Q" but also with time "t", where:

$$D_w = (2.30\ Q/4\pi.T)\ \log\ (2.25\ T.t/r_w^2.S) + C.Q^n \quad ..(10)$$

and

$$Q/D_w = 1/((2.30/4\pi.T).\ \log\ (2.25\ T.t/r_w^2.S) + C.Q^{n-1}) \quad ..(11)$$

The above equation for the specific capacity ensures the fact that it decrease with "Q" and "t" too. Hence the practice of assuming that the discharge is directly proportional to the corresponding drawdown, implying a constant specific capacity, may introduce sizable errors.

On the other hand, if it is assumed, for the purpose of convenience in computations, that the radius of the circle of influence, r_e (= r_o), varies directly as "Q" for equilbirium conditions, then,:

$$r_e = C.Q, \qquad ....(12)$$

and then the steady pump discharge equation becomes:

$$Q = 2\pi.T.\ (h_o - h_w) / \ln (CQ/r_w) \qquad ....(13)$$

The above equation leads to another definition for the specific capacity of a well as the rate of flow per unit of drawdown, usually expressed in gallons per minute (g.p.m.) per foot of drawdown. Since such relationship vaires all the way along the drawdowns, the specific capacity must be determined for one special foot, often the first foot of drawdown.

It is to be noted also that "K" and so "T" in different aquifers is not the same, thus the specific capacities of wells in different aquifers are not always comparable. When treating the multilayers aquifer, superposition technique is considered one way for an overall evaluation; that represents most of the cases one may face in El-Wadi El-Gideed area.

IX. THE DRAWDOWN AND RECOVERY CURVES

A "drawdown curve" of a well is a graph whose coordinates are the drawdown (or relief in piezometric pressures) in a well and the time after pumping started. While the coordinates in a "recovery curve" are those after pumping stopped, after some time of operation, leaving residual drawdown beyond the original static water level (for gravity wells) or original piezometric pressure distribution (in case of pressure or artesian confined wells).

Few trials in the literature covered definite expressions as an aid to construct such curves (refer to Refs.) For instance, one of these expressions is:

$$\Delta t = (h_o - \sqrt{h_o^2 - 1.7\ (Q/K)}.\ \ (0.184\ r_o^2.\ f/Q); \ldots\ldots(14)$$

in which:

Δt = the time (in seconds) of pumping to develop a radius of influence r_o (in ft.);
h_o = the undisturbed initial uniform head, (ft.);
Q = net rate of flow from well, (cfs.);
K = the coefficient of permeability, (ft./day); and
f = the specific yield of material ratio (defined in Sec. (VII.)).

And the drawdown (in ft.) in a well can be expressed as follows:

$$D_w = (1/2.3)(h_o - \sqrt{h_o^2 - 1.7(Q/K)}.\ \ \log_{10}\ (r_o/r_w),\ \ldots(15)$$

in which "r_w" is replaced by "r_r": the distance from the well center to the point in question.

It has to be noticed here that Theis method for the non-equilibrium condition can also be used too, where:

$$D_w = (114.6\ Q/T)\ \int_U^{\infty} (e^{-U}/U).\ dU = (114.6/T).\ \ (W(U)). \quad \ldots\ldots(16)$$

in which:

D_w = drawdown in the observation well, (ft);
Q = constant rate of pumping, (g.p.m.);
T = coefficient of transmissibility, (g.p.d. per ft.) under unit hydraulic gradient;
e = base of natural logarithms, (2.718),

and $U = 1.87\ r_x^2.\ S/T.t,$ ....(17)

where r_x = distance from observation well (or the point in question) to the center of pumped well, (ft.);
S = the coefficient of storage, as fraction, indicating yield of water from storage in water-bearing material under unit decline in head;

and t = time since pumping began, (days).

The well known "Well Function W (U)" of U, can be expressed as:

$$W(U) = (-0.5772 - \log_e U + U - \frac{U^2}{2.2!} + \frac{U^3}{3.3!} - \frac{U^4}{4.4!} + \dots) \qquad \dots\dots\dots(18)$$

To facilitate the computations, if Thesis method is applied, a graphical representation for U and W (U) relationship, which is handy, can be used.

X. THE RATE OF RECOVERY IN PRESSURE WELLS

It is very recognizable to see that the rate of recovery in a pressure well after pumping has stopped is more rapid than in a similar gravity well, and that gives a credit for artesian wells. This is because in a pressure well there is no "cone of depression" to be refilled with water, instead the piezometric pressure distribution regain itself much faster.

An approximate estimation for the rate of recovery in a pressure well devised by Slichter was stated as follows:

$$t_r = \bar{K} \cdot \log_{10} (y_o/y_1) \qquad \dots\dots\dots(19)$$

in which:

t_r = time for water level to rise from y_o to y_1;
$\bar{K}$ = constant for well and units used, say:
($= 7.5 \pi K p / 2.3 \times 1440$, while K: ft./ day, and p is the proportion of cross-sectional area of aquifer "A" normal to flow direction through which water flows. (A.p) represents the net cross sectional area of flowing stream through the media.);
y_o = drawdown in well at any instant; and
y_1 = drawdown in well at any time "t_r" after observing value of y_o, well having recovered by gravity.

It worth to be noticed that the above equation is based on the assumption that the radius of the circle of influence remains constant during the period of recovery. Also, in pressure wells possessing only relatively small drawdowns comparable with the depth of the well, the solutions obtained by the use of the above formula are considered practicably applicable. On the other hand, it is undersirable to use the same previous formula, for estimating the rate of recovery in a pressure well, where the drawdown is contributing a major proportion of the total depth of water column in the well.

XI. MULTI-LAYERS CONFINED AQUIFER AND MULTIPLE INTERFERING WELL SYSTEMS

For most of the deep wells, we sometimes face the situation where the confined aquifer consists of several multi-layers of different geological formations and so with various permeabilities, transmissibilities storage and water holding capacities, etc. Thus the corresponding "safe yield" of the multiple-water - bearing formation can be evaluated by following a superposition technique while the "gross specific capacity of a well" can be summed up as a whole while special treatment for the equations has to be achieved if needed for each individual aquifer independently. And so for the other aquifer and well parameters.

For instance, the discharge may be expressed as follows: (for "n" multiples)

$$Q = 2\pi \cdot \sum_{i=1}^{n} (K_i \cdot b_i) . \frac{[h_o - h_w]}{l_n(r_o/r_w)} \quad ....(20)$$

Similar expressions can also be inserted into the other equations concerning the other parameters like the "specific capacity, "specific retention," etc.

Similar situations are displayed for El-Wadi El-Gideed equifer formation indicated by the geological sections through selected wells located within Kharga Oasis vicinity shown in

Figures (4) and (5); Spotaneous potential and resistivity logs of the Kharga wells are demonstrated for examples through these figures too (4 & 5) as indication for such formations, while the piezometric map for this area is shown in plate (I). Meanwhile, water depth in well to well radius (h_w/r_w) related to the "discharge number" ($Q/K. r_w^2$) for the confined indicated discharging wells in Kharga are shown in figures (6) and (7).

On the other hand, another common problem, we face in the analysis and management of basin ground-water development, is to determine the interference level produced by a group of pumping wells of which their cones of depression intersect and so their areas of influence in this case are overlapping. The amount of interference in any well being represented by the ratio of the diminution of flow from the well without interference. There are special formulas proposed for computing such interference effects based on logical analysis (Refs. 20 and 9). Others are deduced from field tests comparable to Laboratory experimental results (Ref. (6)). These formulas, whether for gravity wells or pressure wells, were found to be in close agreement with laboratory observations, and could be adaptable to El-Wadi El-Gideed wells field with necessary, modifications for the pressure wells to fit individual situations.

For instance, interference between TWO pressure wells a distance "W" apart can be formulated as follows:

$$Q_1 = Q_2 = 2K\,(h_o - h_w)/\log_{10}\,(r_o^2\,(W + r_o^2)) - \log_{10}\,(2W \cdot r_o^3 + W^2 \cdot r_w^2) \qquad \ldots\ldots.(21)$$

Which can also be expressed for TWO wells as follows

$$Q_1 = Q_2 = 2\pi \cdot T\,(h_o - h_w)/\ln\,(R^2/r_w \cdot W), \qquad \ldots\ldots.(22)$$

in which:

h_o = the average piezometric head at the external boundary,
h_w = that at the wells,

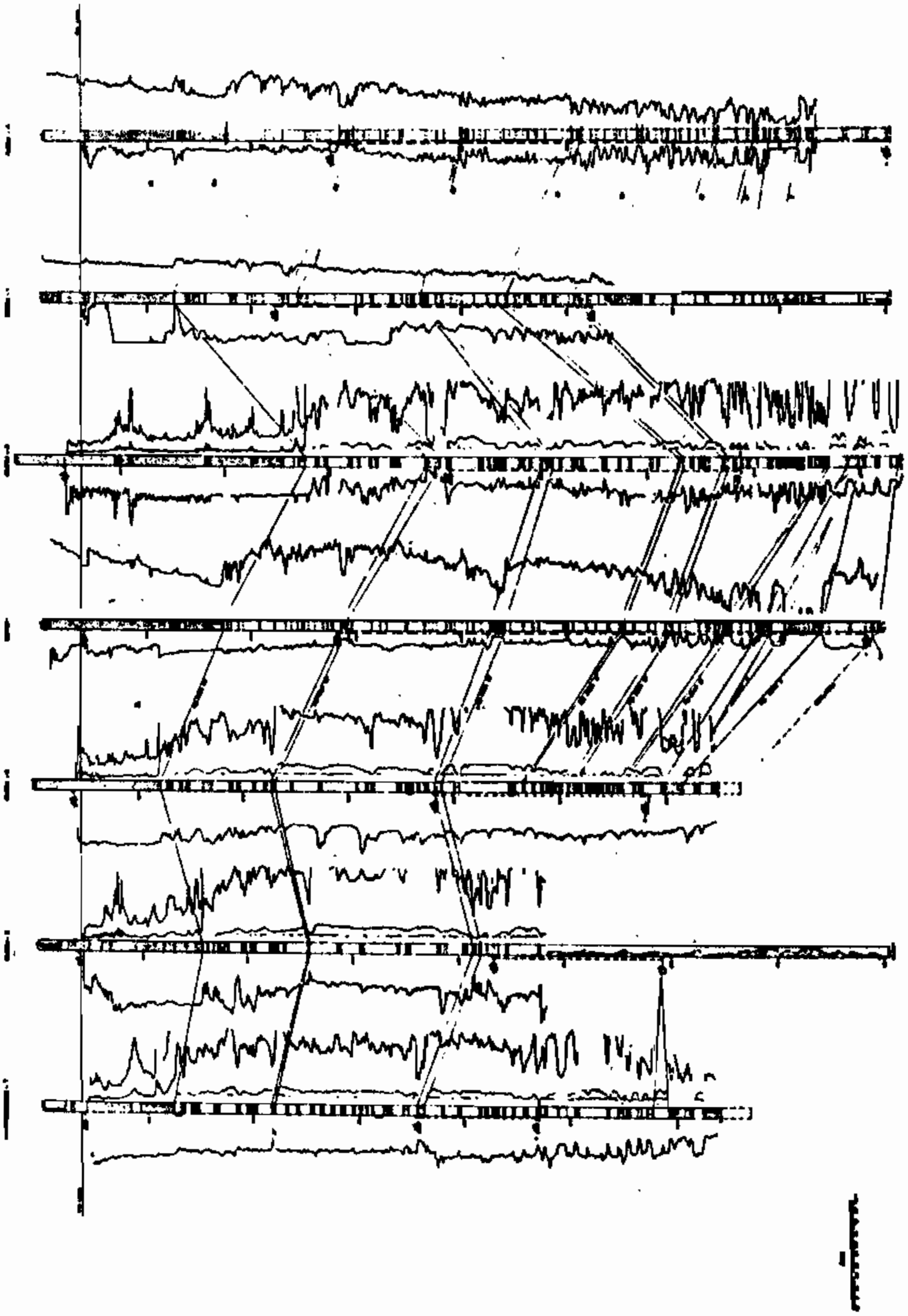


Figure 4.--North-south geologic section through 7 wells in the [illegible] District.

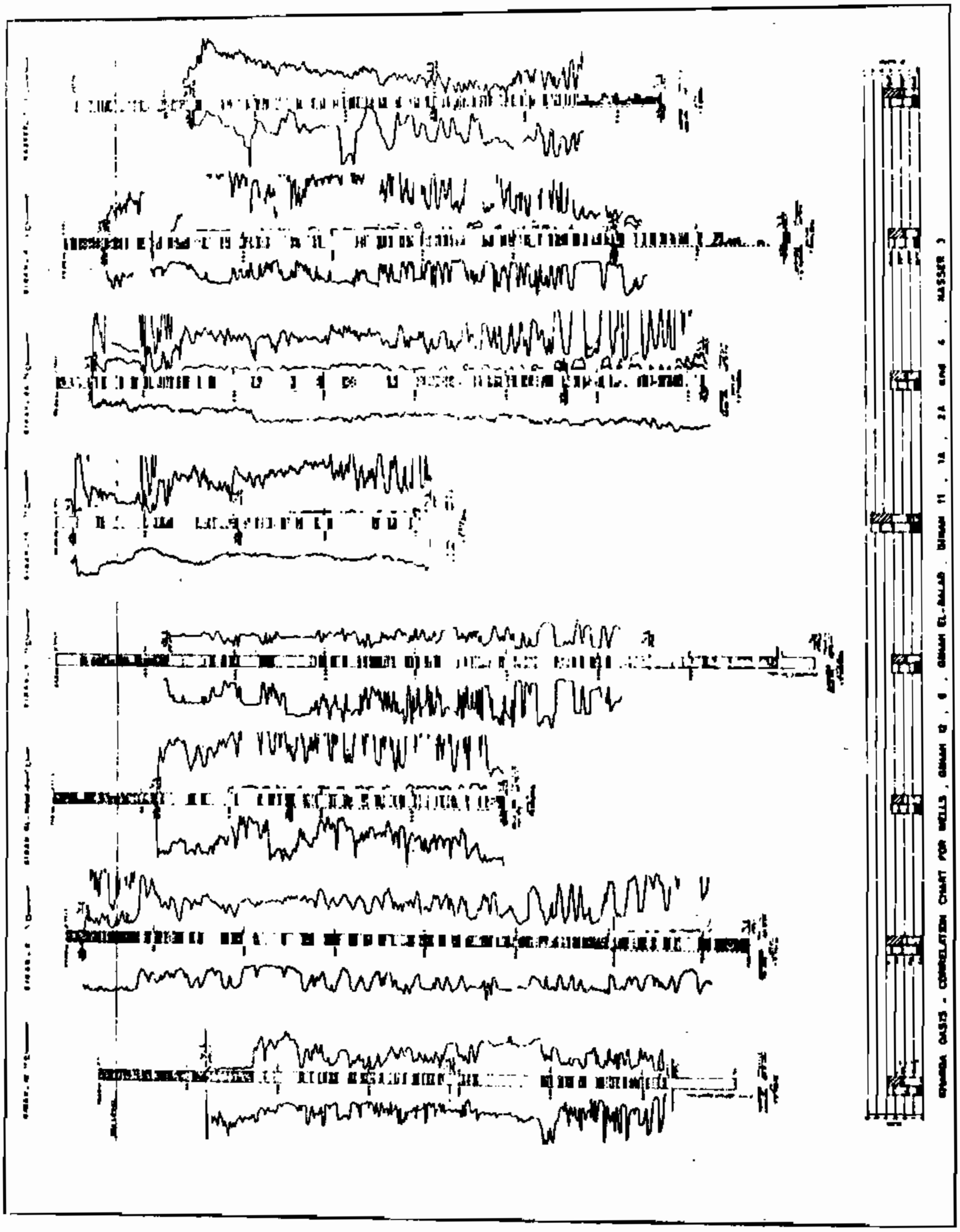


Fig.(5) Geological Sections Through Selected Wells Located Within Kharga Oasis Vicinity.

R = the radius of the area of influence, up to the external boundary, $(R \gg W)$,

and r_w = the well radius.

(N.B.: $T = K.b$)

Also the flow from the middle well in a group of THREE wells in a line, a distance "W" apart, all pumped with the some drawdown under steady state pumping condition, can be expressed as follows:

$$Q_3 = K\ (h_o - h_w)/\ \log_{10}\ \left[((r_o^2 + W^2)\ r_o\right] - \log_{10}(W^2\ .\ r_w), \qquad \ldots\ldots(23)$$

which can also be expressed for THREE wells on a line and equally spaced at a distance W apart, where the outer wells will then be discharging at a rate of:

$$Q_1 = Q_3 = 2\pi.T.(h_o - h_w).\ \ln(W/r_w)/(2\ \ln(R/W).\ \ln(W/r_w) + \ln(W/2r_w).\ (\ln(R/r_w), \qquad \ldots\ldots(24)$$

whereas for the middle well, it discharges at:

$$Q_2 = 2\pi.T.(h_o - h_w).\ \ln(W/2r_w)/(2\ \ln(R/W).\ \ln(W/r_w) + \ln(W/2r_w).\ \ln(R/r_w) \qquad \ldots\ldots(25)$$

Meanwhile, similar to the situation of equation (22), but for THREE wells forming, in this case, and equilateral triangle a distance "W" on a side, the discharge is:

$$Q_1 = Q_2 = Q_3 = 2\pi.T.(h_o - h_w)/\ln\ (R^3/r_w.W^2) \qquad \ldots\ldots(26)$$

Similarly, the discharge of each of FOUR wells forming a square of side W is:

$$Q_1 = Q_2 = Q_3 = Q_4 = 2\pi.T.(h_o - h_w)/\ln\ (R^4/\sqrt{2}.r_w.W^3) \qquad \ldots\ldots(27)$$

Finally, if a FIFTH well is pumped in the center of the previous square, any of the corner wells yields:

$$Q_1 = Q_2 = Q_3 = Q_4 = 2\pi . T . (h_o - h_w) . \ln(W/\sqrt{2}.r_w)/(4 \ln(\sqrt{2}.R/W) . \ln(W/\sqrt{2}.r_w) + \ln(R/r_w) . \ln(W/4\sqrt{2}.r_w)), \quad ......(28)$$

While the center well discharges only

$$Q_5 = 2\pi . T . (h_o - h_w) . \ln(W/4\sqrt{2}.r_w)/(4 \ln(\sqrt{2}R/W) . \ln(W/\sqrt{2}\, r_w) + \ln(R/r_w) . \ln(W/4\sqrt{2}.r_w)) \quad ......(29)$$

And so on, etc. for any other combinations.

It has to be noticed that in the above equations it was assumed that all wells penetrate a confined aquifer, have the same diameter and drawdown, and that the estimated discharges are over the same period of time, holding other variables unchangeable.

The above equations for the discharges of TWO, THREE, FOUR and FIVE wells penetrated through confined aquifer can be modified for application to unconfined aquifers as follows:

$$Q_1 = Q_2 = \pi . K(h_o^2 - h_w^2)/ \ln(R^2/r_w . W) \quad ....(30)$$

(for the TWO wells case),

$$Q_1 = Q_2 = Q_3 = \pi . K(h_o^2 - h_w^2)/ \ln(R^3/r_w . W^2) \quad ....(31)$$

(for the THREE wells forming an equilateral triangle),

$$Q_1 = Q_3 = \pi . K(h_o^2 - h_w^2) . \ln(W/r_w)/(2 \ln(R/W) . \ln(W/r_w) + \ln(W/2r_w) . \ln(R/r_w)) \quad ....(32)$$

(for the outer wells of a multiple of THREE wells on a line), where for the middle one:

$$Q_2 = \pi . K(h_o^2 - h_w^2) . \ln(W/2r_w)/(2 \ln(R/W) . \ln(W/r_w) + \ln(W/2r_w) . \ln(R/r_w)), \quad ....(33)$$

$$Q_1 = Q_2 = Q_3 = Q_4 = \pi . K(h_o^2 - h_w^2)/\ln(R^4/\sqrt{2}.r_w . W^3) \quad ....(34)$$

(for each of the FOUR wells lying at the corners of a square),

$$Q_1 = Q_2 = Q_3 = Q_4 = \pi . K(h_o^2 - h_w^2) . \ln(W/\sqrt{2}.r_w)/(4 \ln(\sqrt{2}R/W) . \ln(W/\sqrt{2}.r_w) + \ln(R/r_w) . \ln(W/4\sqrt{2}.r_w)), \quad ....(35)$$

and the unconfined gravitational well at the center of the square yields:

$$Q_5 = \pi . K(h_o^2 - h_w^2) . \ln(W/4\sqrt{2}.r_w)/(4 \ln(\sqrt{2}.R/W) . \ln(W/\sqrt{2}.r_w) + \ln(R/r_w) . \ln(W/4\sqrt{2}.r_w) \quad ....(36)$$

And so on, etc. for any other combinations of the multiple well systems.

In the meantime it is worth to mention here that special treatment for all the expressions and procedure of analysis for the cases concerning "partially penetrating wells" whether for "a single isolated confined well" or for "the multiple well systems." The same remark may go also for most of the special cases of "leaky aquifers."

In the meantime, there are graphical methods for determining the "permissible Interferences Among Wells" in a tested field in which the coefficients of transmissibility and of storage can be determined. Similar analysis can also be extended to cover any number of wells "N" in this regard.

Further analysis concerning "Multiple Well Systems" spread over a given well field, where the drawdown can be determined at any point if the well discharges are known, or vice versa. The procedure of analysis can be concisely follow a superposition technique considering equilibrium condition. For instance, the drawdown at any point in the area of influence caused by the discharge of several wells is equal to the sum of the drawdowns caused by each well indvidually, i.e.;

$$D_T = D_1 + D_2 + D_3 + ... + D_N = \sum_{i=1}^{N} D_i \quad ....(37)$$

in which:

D_T = the total drawdown at a given location,
D_i = the drawdown at any well "i" where $i = 1,2,3,\ldots N$.

A graphical procedure can also be followed starting with the individual cone of depression of each well and ending up with summed composite drawdown curves for the whole multiple well system, knowing in advance and precisely the number of wells, their locations, piezometric map, the geological formation, their spontaneous potential and resistivity logs in addition to the geometrical properties of the well field.

Consequently, for "N" pumping wells spread over a well field pumping from a confined a quifer, a composite drawdown at an arbitrary point (x,y) at which the piezometric head "$h_{(x,y)}$ can be expressed as $D_{(x,y)} = (h_o - h_{(x,y)})$

$$= \sum_{i}^{N} \frac{Q_i}{2\pi T} \ln(R_i/r_i), \qquad \ldots\ldots\ldots(38)$$

in which:

$(h_o - h_{(x,y)})$ = the drawdown at a given point within the area of influence,
T = the coefficient of transmissibility of an aquifer of thickness b
= K.b,
R_i = the distance from the ith well to a point at which the drawdown becomes negligible, and
r_i = the distance from the ith well to the given indicated point.

The above equation is valid for pressure or artesian wells draw their water from confined aquifer of any homogeneous thickness "b", the case adaptable closely to El-Wadi El-Gideed case. While, on the contrary, the corresponding equation for an unconfined aquifer, valid only for relatively small drawdowns which can be expressed as follows:

$$D_{(x,y)} = h_o^2 - h^2_{(x,y)} = \sum_{i}^{N} \frac{Q_i}{\pi K} \cdot \ln(R_i/r_i) \quad \ldots\ldots(39)$$

Finally, it might be advantageous to mention here that in places where water-bearing materials have low permeability, it is sometimes advisable as a solution to draw water with ONE pump from multiple wells system or what is so called "BATTERIES OF WELLS", where the most economical spacing between wells should be given through scientific study for minimum interference.

XII. CORROSIVITY OF PUMPED WATER AND PRECAUTIONS AGAINST PIPES CORROSION

The importance of corrosion and its considerable effect on the development of any well field of a ground water basin, like the one in El-Wadi El-Gideed area, must occupy great attention. The corrosivity of water must be identified and predetermined in order to select properly the type of casing material and especially the screen material which may be crucial for the life expectancy of the whole well.

Corrosive water may be indicated by one or more of the following symbolic indications:

1) low pH (< 7.0),
2) dissolved oxygen $(> 2.$ p.p.m),
3) presence of hydrogen sulfide (H_2S),
4) high electric conductivity $(EC > 600$ micromohs at 25°C),
5) high carbon dioxide content $(CO_2 > 50$ p.p.m.) and
6) high chloride content $(Cl > 500$ p.p.m.).

Generally speaking, corrosion resistant agents should be adequate for casing especially when water analysis indicates a corrosive tendency through well pipes especially the lower ones and the screen which should be lightly coated with suitable tar or asphalt, plastics, enamels, resins, lacquers, paints, zinc coating, cement lining, any antireacted chemicals, metallizing, or using any treated metallic or nonmetallic materials resistive to corrosive water. Glass mat and asbestos fell, which is mixed with synthetic fibers, are proved to be effective wrapping materials for coal-tar enamels. Moreover, one of the best possibilities also in this regard as coating linings for steel pipes are: phenolic, vinyl, thiokol, vinyl thiokol in addition to neoprene materials, which proved to be resistible against corrosion. If any of these solutions proved to be irremediable and irresistible against corrosivity, the lower part of the well pipes and the screen may be properly galvanized or made out of a special kind of treated material or even made out of stainless steel. Coatings and linings are used primarily to minimize or retard the corrosion and in the meantime to prevent water contamination and increasing smoothness of pipe walls.

It may be noted here, just by the way of examples, that overall desirable features of any of the carefully selected coating include the following items and specifications:

1) the ease of application,
2) good adhesion to well pipe material,
3) resistance to impact and abrasion,
4) flexibility and durability,
5) resistance to flowing under heat condition in accordance with the "geothermal gradient of the earths' crust".
6) immunity to sunlight for exposed pipes and anticorrosion for the embedded parts,
7) nonabsorbency,
8) low electrical conductance,
9) resistance to age to last for a reasonal life time in optimal shape and working condition, and
10) resistance self ability against bacterial or any sort of biological actions.

Basically, the decision concerning the selection for any of the above alternatives should be selected according to sound technical and economical studies free from any defect or uncertainty, valid and fit the actual situation. Keeping in mind that hasty decision in this regard proved to be very costly especially if application covered in large scale or influenced by sort of generalities. Eventually, back experience showed that losses due to corrosion, and any snnsible and reasonalbe steps to avoid completely or at least diminishing these losses to minimum and optimizing wells efficiency to their utmost favourable working condition. This is considered a sizable item of the over-all costs in most wells fields and connected waterworks and corresponding convering system.

When artesian water holds higher temperature above normal in addition to activating the ability of corrosivity of pumped water, like the case in majority of well fields in El-Wadi El-Gideed area, where the problem becomes more complex and need further extensitive studies taking into consideration the above discussion.

XIII. DETERIORATION OF GROUND WATER QUALITY

Although the ground water basin under investigation is confined artesian and at considerable great depths from the local earth surface, there must be great care keeping this water clean and check its quality versus its suitability for its uses.

Generally speaking, the main causes of deterioration of ground water quality are due to one or more of the following listed pollution sources.

A. Contamination and Pollution Sources:

1. industrial wastes, in general;
2. organic wastes, in general;
3. food processing;
4. lumber processing (natural or artficial);
5. paper, spinning and clothier factories, etc.;
6. mineral wastes, in general;
7. metal processing industries;
8. steel and iron factories;
9. mining and ore extraction industries;

10. oil and soap industries;
11. chemical industries;
12. fertilizers factories;
13. chemical formulas, extractions and solvents against insects and plant diseases, and their application in the fields;
14. natural and artificial skin treating and processing.
15. wastes from power plants;
16. cooling water (physiochemical, biological and temperature pollution);
17. any recharging and feed-back activities;
18. any refuse or wastes from the various transportation means;
19. solid and semisolid refuse, in general;
20. any human activities; etc.

B. <u>Degradation</u>:

1. effect of development, use and reuse of water, in general;
2. irrigation return water;
3. surface and subsurface drainage;
4. percolation, infiltration leakage and seepage activities.
5. interchange between aquifers due to improperly constructed, defective or abondoned wells;
6. interchange between aquifers due to differentials in pressure levels resulting from excessive withdrawal;
7. overdraft conditions;
8. sea water intrusion;
9. any brackish or brine water nearby;
10. salt-ionic exchange and salt-balance;
11. upward or lateral diffusion of connate brines and/or juvenile water due to overpumping;
12. contamination from the surface due to improperly constructed wells;
13. any other natural causes; including all components of the hydrologic-equilibrium equation;

14. inflow and/or percolation of juvenile water from highly mineralized nearby springs and streams (or carrying canals or drains);
15. other causes like accelerated erosion, mineralization resulting from plant excessive transpiration and/or evaporation, etc.

XIV. ANTICIPATED GAINS AND PROSPECTIVE SIDE EFFECTS OF PUMPING ACTIVITIES UNDER EXTENSIVE RATES

Comprehensive invesitagations have indicated great potential concerning vast areas in El-Wadi El-Gideed for reclamation where soil suitability for cultivation, availability of artesian ground water, under reasonable pressures stored and renewable within thick confined aquifer, is attainable for use. This is in addition to other potentials concerning variety of natural and human resources available. Supplying this area with the right amount of suitable water would cover the main deficiency for this particular area. Such new activity will assess, in the meantime, redistributing the population which is heavily concentrated along the narrow band within the Nile valley and where the utmost is bounded within the Delta region. It is expected to face many difficulties which may retard the progressive extension of such project to cover bigger served green areas, due to lack of: water (quantity or quality), soil management, equipment, qualified technicians, etc., or due to irrigation development, or any land consolidation, implications generated from the social problems in the resettlement process. However, regardless of these difficulties and many more constrictions, this will undoubtly accomodate better life and alternative employment for many farmers and workers squeezing themselves within several overpopulated areas. It is a good chance for Capable new srttlers to adapt themselves and their life in this newly developed resources practicing their shared duties and overcoming obstacles and any avoidable problems. Meanwhile, it should be unmissing opportunity to establish a brand new society adaptable in harmony with that in existence, applying all updated scientific knowledge and refreshing selected valuable sound traditions and life practicing mixed up with acceptable customary performance to be freely exercised covering the various activities of this newly established community and the newborn society made up with the newcomers (settlers).

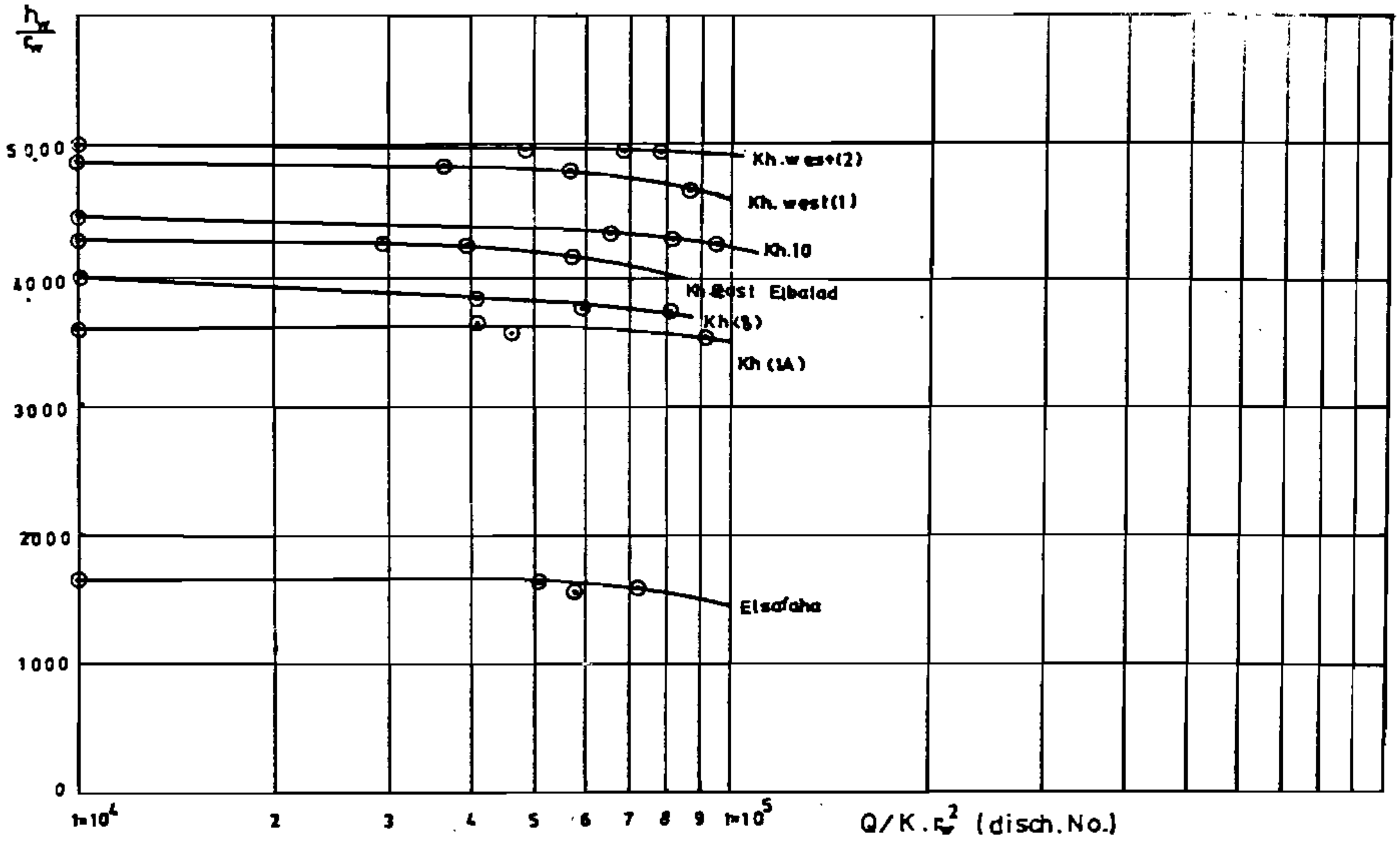
It is always beneficial, in a situation like this, to practice our utmost capability and utilize our own experience and get at the some time the benefit of others observations in similar situations for the sake of achieving enhanced comprehensive management. Back experience showed that, in settling a new irrigation area, the people who are to inhabit it have to be chosen carefully to assure a stable community. Only capable people and those able to accept the new society, have the ability to emerge into the established community and those who are willing to serve the new province according to their individual profession whether farmers, labors, technicians, engineers, administrants, etc. The authority must provide in the meantime all kind of motives to attract new settlers to take place, taking into consideration their background and culture when carefully selected in selfcontained massive groups.

Stating now few of the side effects due to pumping activities under extensive rates, it worth to exceclude the "Feedback Effects" which was previously discussed, in the hydrological equilibrium and the multiple interfering well systems. Nevertheless, side effects in that manner of speaking are of a different nature. They range from the "subsidence of Land Surface", "Squeezing of Confined Water", to the "Recovery of a Water Table" due to curtailment of pymping (to reduce seawater intrusion, say) to the "Soil Thawing, Swelling and Shrinkage" Locally in the indicated area (El-Wadi El-Gideed), etc. All these side effects and others with its consequent threat to undisturbed buildings, stable roads and placid operations going on in the community above, through or nearby.

"Land Subsidence", which may be considered the most important side effect that accompanies the large-scale removal of water from an artesian aquifer, has many causes. Some of these causes can be summarized as follows:

1) Loading or superimosed loading at land surface;
2) Vibration at or near land surface;
3) Compaction due to irrigation, drainage and other farming activities,
4) Solution and liquefy of soil due to irrigation;
5) Drying out and shrinking of deposits;
6) Oxidation of organic materials;
7) Lowering of water table;
8) Decline of pressure head in confined aquifers; due to any reason, whether lowall or within the recharging zone, or due to extensive pumping rate i.e. - relatively higher values of discharge number $(Q/K.r_w^2)$ refer to figures (6) and (7) applied to Kharga Oasis selected well fields;
9) Decline of pressure in the nearby oil zones due to removal of oil or gas or both. In other wards, it could be due to the removal of hydrocarbons and connate water from oil zones;
10) Decline of pressure head could also be due to the removal of any substances or minerals, etc., from beneath the land surface; and
11) Shaking or trembling of any of the layers of the local geological formation or due to an overall earthquake activity or any kind of tectonic movement; and
12) Any drastic hydrological or hydrogeological changes within either the discharging or the recharging areas and including any of the "hydrologic equilibrium equation" or "water-budget balance." The kind of ground water utilization and the sort of human activities and the rate and frequency of recharging within the considered area must be counted too.

Again, it is worthwhile to restress the fact that any side effects appears in El-Wadi El-Gideed area is due to both local activities and due to any changes within the confined water through the stretched nubian formation. Geologically speaking,



Fig(6) - Water depth in well to well radius related to the discharge number for confined indicated wells.

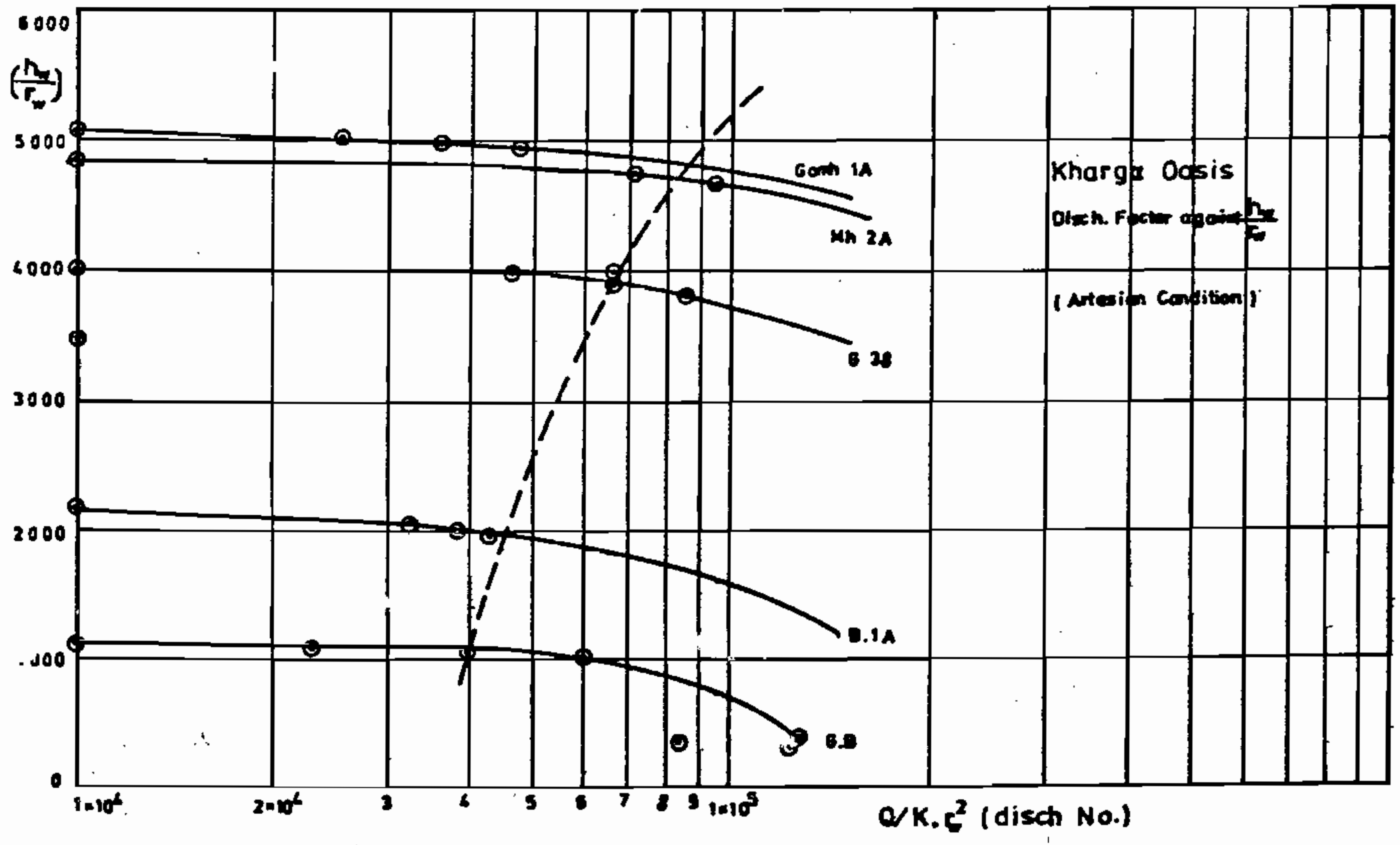


Fig (7) - Water depth in well to well radius related to the discharge number for confined indicated wells.

this confined waterbearing aquifer is extended all the may in a fashion for great distances till it hits the catchment or the recharging zone, which might be relatively far from the discharging well field where the elements of the hydrologic equilibrium and thus the water budget balance is influenced by direct input and output parameters in addition to several unforeseen circumstances with all relevant hidden uncontrable variables. It is the hydrologist job to collect all kind of data needed to clarify such situation and continually checking the replinishment of the confined water and the fast recovery of piezometric pressure distributed satisfactory.

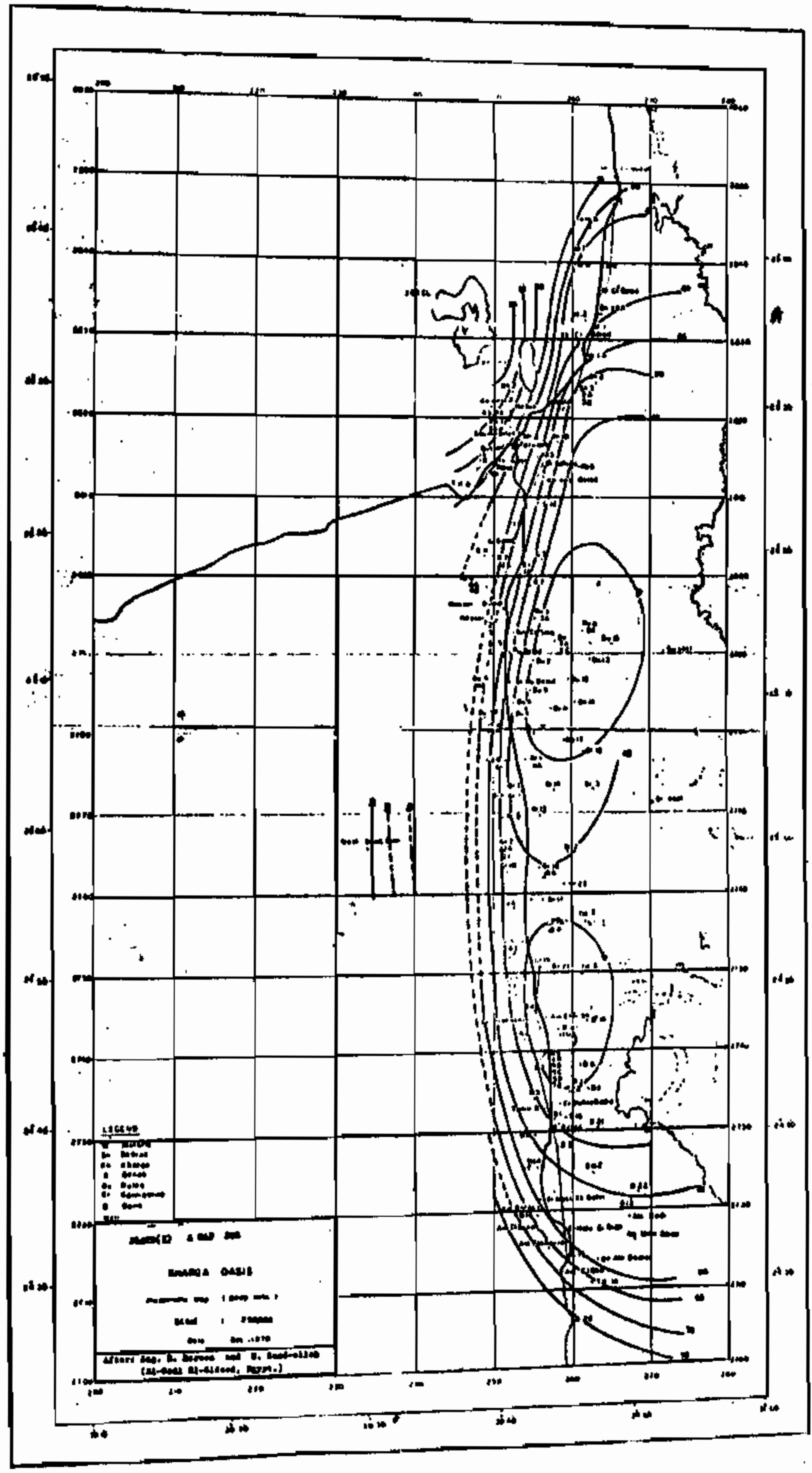
Finally, the main intellectual difficulty about not discussing all of the side effects, is that this is a rather lengthy subject by itself and beyond the scope of this research paper, for the time being.

XV. CONCLUSIONS AND RECOMMENDATIONS

From all the above discussions, it can be very briefly and precisely concluded that the area under quesion (El-Wadi El-Gideed) is a great potential for the extension of more clean green area and an excellent chance to encourage new capable Egyption settlers to inhabit such areas.

Nevertheless, there are very specific requirements to achieve full success of the whole project. These requirements were idividually discussed in detail provided with all possible proposed solutions for all the problems counted in this research paper. Keeping in mind that developing an irrigation well field is almost as important as drilling it, avoiding any deterioration in ground water quality. This in addition to the precautions listed concerning all the aspects in this regard for full establishment of a stable community serving a modern irrigation network system.

Urgent solutions for all the prospective problems listed in the body of this research paper are greatly encouraged. A complete data bank for all the variables and parameters involved is needed in the first place.


LEGEND
KHARGA OASIS

It is recommended to carry out similar studies covering complete survey for soil classification and individual potentiality for the most fit: crops, water duties, modern irrigation and drainage methods, etc. to optimize its utmost benefits enlighted by both technical and economical principles for the achievement of high "irrigation effeciency".

In conclusion, it is worthy to state that: to provide optimum development of ground water resources, like the one under investigation, for the best beneficial use, this requires thinking in terms of the entire ground water basin, taking individualized local environmental and all dynamic components into consideration. At the sametime giving considerable attention to the "human factor" who takes over the burden, fulilling reasons of achievment, justify his life and make the success.

XVI. BIBLIOGRAPHY

1. American Water Works Assoc., A.W.W.A. 1958: "Standard for deep wells", N.Y., U.S.A.

2. Anderson, K.E., 1951: "Water well Handbook" Missouri Water well Drillers Assoc., Rolla, U.S.A.

3. Anderson, K.E., 1955: "The corrosion and incrustation of well screens", Bull. 834, Edward E., Johnson, St. Paul, Minn, U.S.A.

4. A.W.W.A., 1955: "American standard specifications for deep well vertical turbine pumps", Jour. A.W.W.A., Vol. 47, N.Y., U.S.A.

5. Babbitt, H.E., J.J. Donald and J.L. Cleasby, 1959: "Water supply Engineering", McGraw-Hill Book Co., Inc., N.Y., U.S.A.

6. Caldwell, D.H., 1943: "The Hydraulics of Gravity Flow Water Wells", Thesis, University of Illinois, Urbana, U.S.A.

7. DeWiest, R.J.M., 1966: "Hydrogeology," John Wiley & Sons, Inc., N.Y., U.S.A.

8. Eagleson, P.S., 1970: "Dynamic Hydrology" McGraw-Hill Book Co., Inc., N.Y., U.S.A.

9. Hansen, Vaughn E., 1953: "Unconfined Ground Water Flow to Multiple Wells," Am. Soc. Civil Eng., Vol. 118, P. 1098, 1953, U.S.A.

10. Hantush, M.S. and C.E. Jacob, 1955: "Steady threedimensional flow to a well in a two-layered Aquifer", Trans. Amer. Geophysical Union, Vol. 36, pp. 286-292, 1955, U.S.A.

11. Israelsen, O.W. and V.E.Hansen, 1962: "Irrigation principles and Practices", John Wiley and sons, Inc., N.Y., U.S.A.

12. Jacob, C.D., 1947: "Draw-down Test to Determine Effective Radius of Artesian Well", Trans. A.S.C.E., Vol. 112, 1947, N.Y., U.S.A.

13. Johnson, Edward. E. Inc., 1947: "The Yield of water wells", Bull. 1238, N.Y., U.S.A.

14. Johnson National Drillers Journal, 1955: "Judging proper Gravel-Pack Thickness", Vol. 27, No. 2, Mar.-Apr. 1955, N.Y., U.S.A.

15. Johnston, C.N., 1945: "Irrigation wells and well Drilling Methods in California", Calif. Agr. Exp. Sta. Circ. No. 361, 1945, Calif., U.S.A.

16. Kazmann, R.G., 1965: "Modern Hydrology", Harper & Row, Publishers, N.Y., U.S.A.

17. Luthin, J.N., 1957: "Drainage of Agricultural Lands", Amer. Soc. of Agronomy, Madison, Wisconsin, U.S.A.

18. Luthin, J.N., 1966: "Drainage Engineering", John Wiley & sons, Inc., N.Y. U.S.A.

19. Milaeger, R.E., 1942: "Development of deep wells by dynamiting", Jour. A.W.W.A., Vol. 34, N.Y., U.S.A.

20. Muskat, M., 1946: "The Flow of Homogeneous Fluids Through Porous Media", J.W. Edwards, Inc., Ann Arbor, Michigen, U.S.A.

21. Nebolsine, R., 1942: "New Trends in Ground-Water Derelopment", Jour. New England Water Works Assoc., Vol. 57, U.S.A.

22. Rohwer, C., 1940: "Putting down and developing wells for irrigation", U.S. Dept. Agric. Circ. 546, Washington, D.C., U.S.A.

23. Rohwer, Carl, 1941: "Putting Down and Developing Wells for Irrigation, " U.S.D.A. Circ. 546, rev. March, 1941, U.S.A.

24. Rorabaugh, M.I., 1953: "Graphical and Theoretical Analysis of Step-Draw-Down Test of Artesian Well", Proc. A.S.C.E., Vol. 79, Dec. 1953, N.Y., U.S.A.

25. Poland, J.F., B.E.Lofgren and G.H. Davis, 1958: "Progress Reports on land Subsidence Investigations in the San Joaquin Valley, California, through 1957", Sacramento, Calif., Interagency Committee on Land Subsidence in the San Joaquin Valley, U.S.A.

26. Poland, J.F., and J.H. Green, 1962: "Subsidence in the Santa Clara Valley, California", U.S.G.S. Water supply paper No. 1619-C, Virginia, U.S.A.

27. Poland., J.F. and G.H.Davis, 1956: "Subsidence of the land surface in the Tulare-Wasco (Delano) and Los Benos-Kettheman city area, San Joaquin Valley, California, Trans. A.G.U., Vol. 37, No. 3, 1956, Virginia, U.S.A.

28. Petersen, J.S., C. Rohwer and M.L. Albertson, Jr., 1953: "Effect of well screens on flow into wells", proc. A.S.C.E., Vol. 79, Sep. 1953, N.Y., U.S.A.

29. Polubarinova - Kochina, P.Y., 1952: "Theory of Ground-Water Movement" Gostekhizdat, Moscow (Russian edition) and U.S. Dept. of Int., Virginia, U.S.A. (Trans. into English Ed.).

30. Smith, L.A., 1941: "Deep wells in sandstone rock", water works Eng., Vol. 94, N.Y., U.S.A.

31. Theis, C.V., 1938: "Ground water flow", Trans. Am. Geophys. Union, Econ. Geol., Vol. 23 P. 889, Wash., U.S.A.

32. Todd, D.K., 1968: "Ground water Hydrology", John Wiley & Sons, Inc., N.Y., U.S.A.