Impact of the Hydrographic Changing in the Open Drains Cross Sections on the Hydraulic Efficiency of Open Drains

Esam El-Deen .Y. El-Azab[1], Hosam Ibrahim[2], Mohamed.M.F.Sobeih[3], Mahmoud Zayed[4]
[1,3](Department of Irrigation and Hydraulic, Civil Engineering/ Minoufia University, Egypt)
[2,4] (Channel Maintenance Research Institute, National Water Research Center, Egypt)

ABSTRACT : *Drained water is collected through 16000 km of open drains spread all over Egypt. Therefore, drains hydraulic problems lead to reduce their efficiency and ability to the free drainage of cultivated land. The work of the present investigation is based mainly on field data measurements along a group of selected drains. The derived relations were developed taking into consideration the degree of the drains. The main objective of this study is to carry out a research program include a group of Egyptian open drains. The developed new relations help in giving a set of rules that control the cross – section and gradient of regime alluvial drains in Egypt to improve its efficiency, achieve the highest operating efficiency of open drains, increase the ability of open drains cross sections for conveyance and identify scientifically study about the maintenance program of open drains.*

Keywords: *Hydraulic Efficiency, Open Drains, Hydraulic Parameters, Hydrographic Changing, Field Measurements.*

I. INTRODUCTION

Drainage of agricultural land is one of the pillars of the sustainability of agricultural production and protection of land degradation as a result of the high ground water level and the accumulation of salts. Therefore, the hydraulic problems of open drains affect the efficiency of drains, which leads to the existence of economic, environmental and social consequences. Molesworth and Yenidunia (1922) recommended an empirical formula for Egyptian trapezoidal drains. Preliminary investigations revealed that the previous empirical equations may not be valid for the present condition, where the suspended material of the river Nile decreased to value of less than 100 part per million after construction of High Dam. Therefore, improving the hydraulic efficiency of the drainage network in Nile Delta region is the most important concern for Ministry of Water Resources and Irrigation to raise efficient use and conservation of water loss.

II. INDENTATIONS AND EQUATIONS

Dimensional analysis is used in the derivation of general equation to compute the hydrographic changing in the open drains cross sections on the hydraulic efficiency of open drains were studied, This equation may be written in the following form:

$$\frac{K_d}{K_a} = f\left(\frac{y_d}{y_a}, \frac{T_d}{T_a}, \frac{R_d}{R_a}, \frac{A_d}{A_a}, \frac{P_d}{P_a}, \frac{d_{50}}{y_a}\right) \quad (1)$$

$$\frac{R_d}{R_a} = f\left(\frac{y_d}{y_a}, \frac{T_d}{T_a}, \frac{A_d}{A_a}, \frac{K_d}{K_a}, \frac{P_d}{P_a}, \frac{d_{50}}{y_a}\right) \quad (2)$$

Where: (y_d) is the design water depth of the channel, (y_a) is the actual water depth of the channel,(T_d) is the design top width of the channel,(T_a) is the actual top width of the channel,($K_d= (A_dR_d)^{2/3}$) is the design factor of hydraulic efficiency, ($K_a= (A_aR_a)^{2/3}$) is the actual factor of hydraulic efficiency, (R_d) is the design hydraulic radius of the channel, (R_a) is the actual hydraulic radius of the channel, (A_d) is the design channel area, (A_a) is the actual channel area,(P_d) is the design wetted perimeter of the channel ,(P_a) is the actual wetted perimeter of the channel and (d_{50}) is the median size of bed material.
A definition sketch for these hydraulic parameters is shown in Fig (1, 2).

III. FIELD MEASUREMENT AND DATA COLLECTION

To achieve the main goal of this study seven drains have been chosen to represent the operating conditions at west Delta in Egypt. They are chosen to cover the main drains and branches drains. These drains are El-Umum main drain and its branches Hares, Deshody, Troga, Ganabia El Umum El Bahrea, Shereshra and Abo Homes branch drains as shown in Fig (3) and Table (I) illustrate the characteristic design parameters of the selected drains at out let . The work program that implemented was divided into two parts, field and laboratory measurements.

For field measurements, the velocity measurements were accomplished by means of a calibrated electro-megnatic current meter at 0.2 and 0.8 of at least 15 vertical local water depth. Afterward, the discharge value was calculated using the simultaneous velocity and the water depth measurements. The boat equipped with echo-sounding apparatus to trace the shape of the drain cross-section at the selecting stations simultaneously with the velocity measurements. GPS was used to conduct the hydrographic measurements and it connected with the satellite and give high survey efficiency. From these data, the geometrical elements of the drain section such as water depth, cross sectional area, side slope, top width of water, hydraulic mean depth, and hydraulic radius are measured and calculated. The surface Water slope was calculated along a sufficient length of straight reach. Also full survey was carried out for the selected reaches of drains to identify degree of infestation and types of aquatic weed. Results and information obtained showed that, about 35 % of reaches are infested by emergent weeds In general, it can be concluded that state of weeds was acceptable and of negligible effect of flow.

For soil samples analysis, a series of laboratory tests were carried out for samples collected from bed and sides of the open drains to determine the grain size distribution particles. Sieve analysis tests were done for soil fraction retained by sieve 200 while for soil passed sieve No. 200, the hydrometer analysis was used. The total solid suspension in water samples was also determined. Table (II) illustrate the soil analysis for the selected drains.

IV. ANALYAIS OF THE RESULTS

For achieving the main objective of the present study, the field measurements and laboratory tests were analyzed to correlate the variable such as cross section area, water depth, top width, hydraulic radius, wetted parameter and Median size of bed material). The relationships represented for the studied main drain and branch drains between the hydraulic efficiency that represented by the section factor (K_a/K_d)= ($(A_aR_a)^{2/3}$/ $(A_dR_d)^{2/3}$), and the expression of the hydraulic efficiency represented by the hydraulic radius (R) versus the different hydraulic parameters.

4.1 Relationship between the Hydraulic Efficiency of Sections and Cross Section Area

By plotting the values of the hydraulic efficiency of sections versus the cross section area ratio (A_a/A_d) as shown in Fig (4) and (5), where these curves were obtained, with the following equations:

Hydraulic Efficiency % = 100.51(A_a / A_d) -15.057…………………..…..(3)

For open main drain with correlation coefficient R^2 = 0.98

(R_a / R_d) = 0.9586 (A_a / A_d) + 0.0753 ……………….…………………..…(4)

For open main drain with correlation coefficient R^2 = 0.89

Hydraulic Efficiency % = 93.749(A_a / A_d) -9.5612…….………………..…..(5)

For open branch drains with correlation coefficient R^2 = 0.93

(R_a / R_d) = 0.6556 (A_a / A_d) + 0.1369 ………..………...…………..……..(6)

For open branch drains with correlation coefficient R^2 = 0.80

4.2 Relationship between the Hydraulic Efficiency of Sections and Water Depth

By plotting the values of the hydraulic efficiency of sections versus the water depth ratio (y_a/y_d) as shown in Fig (6) and (7), where these curves were obtained with the following equations:

Hydraulic Efficiency % = 121.72(y_a / y_d) -24.268……..……..………….(7)

For open main drain with correlation coefficient R^2 = 0.929

(Ra / Rd) = 0.7816 (y_a / y_d) + 0.0547 ………....…………………………(8)

For open main drain with correlation coefficient R^2 = 0.977

Hydraulic Efficiency % = 146.87(y_a / y_d) -10.536……………......……..(9)

For open branch drains with correlation coefficient R^2 = 0.68

(Ra / Rd) = 1.246 (y_a / y_d) - 0.0187 …………………...……….……..…(10)

For open branch drains with correlation coefficient R^2 = 0.914

4.3 Relationship between the Hydraulic Efficiency of Sections and Hydraulic Radius

The relation between the hydraulic efficiency of sections versus the hydraulic radius ratio (R_a/R_d) was plotted in Fig (8) and (9), where these curves were obtained with the following equations:

Hydraulic Efficiency % = 96.692(R_a / R_d) -18.473……….……..…….(11)

For open main drain with correlation coefficient R^2 = 0.938

Hydraulic Efficiency % = 126.94(R_a / R_d) -15.421……….…………….(12)

For open branch drains with correlation coefficient R^2 = 0.777

4.4 Relationship between the Hydraulic Efficiency of Sections and the Wetted Perimeter

By plotting the values of the hydraulic efficiency of sections versus the wetted perimeter ratio (P_a/P_d) as shown in Fig (10) and (11), where these curves were obtained with the following equations:

Hydraulic Efficiency % = 138.53(P_a / P_d) -85.092……….…………...(13)

For open main drain with correlation coefficient R^2 = 0.63

(R_a / R_d) = 1.5898 (P_a / P_d) - 0.849 …………….………......………(14)

For open main drain with correlation coefficient R^2 = 0.63

Hydraulic Efficiency % = 94.194(P_a / P_d) -39.951…...……....……...(15)

For open branch drains with correlation coefficient R^2 = 0.624

(R_a / R_d) = 0.5743 (P_a / P_d) + 0.0153……………..……................…(16)

For open branch drains with correlation coefficient R^2 = 0.618

4.5 Relationship between the Hydraulic Efficiency of Sections and Top Width

By plotting the values of the hydraulic efficiency of sections versus the top width ratio (T_a/T_d) as shown in Fig (12) and (13), where these curves were obtained with the following equations:

Hydraulic Efficiency % = 127.08(T_a / T_d) -77.52…………..…..….(17)

For open main drain with correlation coefficient R^2 = 0.63

$(R_a / R_d) = 1.0415 (T_a / T_d) - 0.396$ …………………….......………(18)
For open main drain with correlation coefficient $R^2 = 0.55$
Hydraulic Efficiency % = $236.3(T_a / T_d) -182.88$..…..…………….….(19)
For open branch drains with correlation coefficient $R^2 = 0.63$
$(R_a / R_d) = 0.4897 (T_a / T_d) + 0.0638$……………..………….......…(20)
For open branch drains with correlation coefficient $R^2 = 0.51$

4.6 Relationship between the Hydraulic Efficiency of Sections and the Median Size of Material to Water Depth

The relation between the hydraulic efficiency of sections versus the median size of bed material (d_{50}/y_a) was plotted in Fig (14) and (15), where these curves were obtained with the following equations:
Hydraulic Efficiency % = $- 100333(d_{50}/y_a) +52.311$……..……......(21)
For open main drain with correlation coefficient $R^2 = 0.70$
$(R_a / R_d) = - 919.73 (d_{50}/y_a) + 0.71$……… …….………………......…(22)
For open main drain with correlation coefficient $R^2 = 0.66$
Hydraulic Efficiency % = $- 56678 (d_{50}/y_a) + 71.747$….……………..(23)
For open branch drains with correlation coefficient $R^2 = 0.70$
$(R_a / R_d) = - 608.82 (d_{50}/y_a) +0.8195$…….……………….…......…(24)
For open branch drains with correlation coefficient $R^2 = 0.73$

V. FIGURES AND TABLES

Table I: The Characteristic Design Parameters of the Selected Drains at Out Let

Section No.	Drains Name	Area Served (Fed)	Discharge (m3\s)	Area (m2)	Water Depth (m)	Bed Width (m)	Water slope (cm/km)	Side Slope
1	El-Umum	400000	78.75	169.65	4.25	40	3	2:1
2	Hares	69000	19.44	42.24	2.01	18	10	3:2
3	Deshody	17500	5.64	15.46	1.79	6	9	2:1
4	Troga	15500	2.62	10.82	1.5	5	6	3:2
5	Ganabia El-Umum	31500	8.32	18.89	2.1	8	8	3:2
6	Shereshra	136000	34.89	74.34	3.3	18	6	2:1
7	Abo Homos	13000	4.05	12.35	1.05	5	9	3:2

Table II: Soil Analysis

Section No.	Drains Name	Type of Soil	
		Bed	Bank
1	El- Umum	Sand to Sandy Loam	Cohesive
2	Hares	Sand to Sandy Loam	Cohesive
3	Deshody	Sand to Sandy Loam	Cohesive
4	Troga	Sand to Sandy Loam	Cohesive
5	Ganabia El-Umum	Sand to Sandy Loam	Cohesive
6	Shereshra	Sand to Sandy Loam	Cohesive
7	Abo Homos	Sand to Sandy Loam	Cohesive

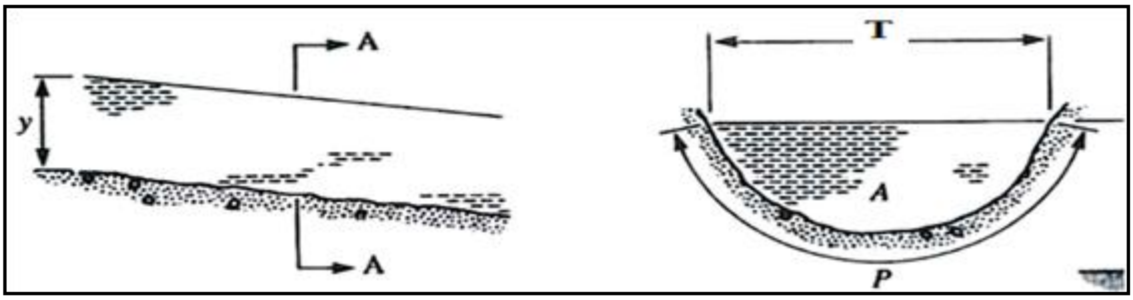


Figure 1: Definition sketch of actual geometric channel properties

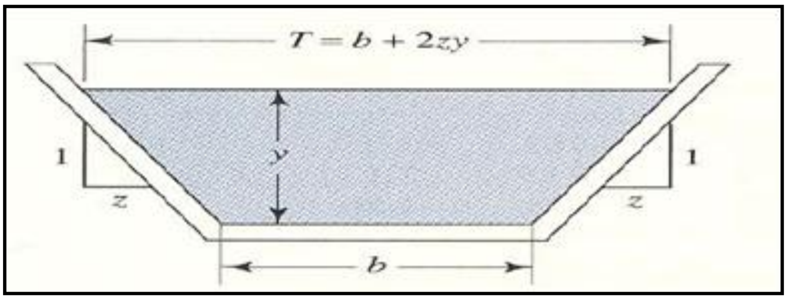


Figure 2: Definition sketch of design geometric channel properties

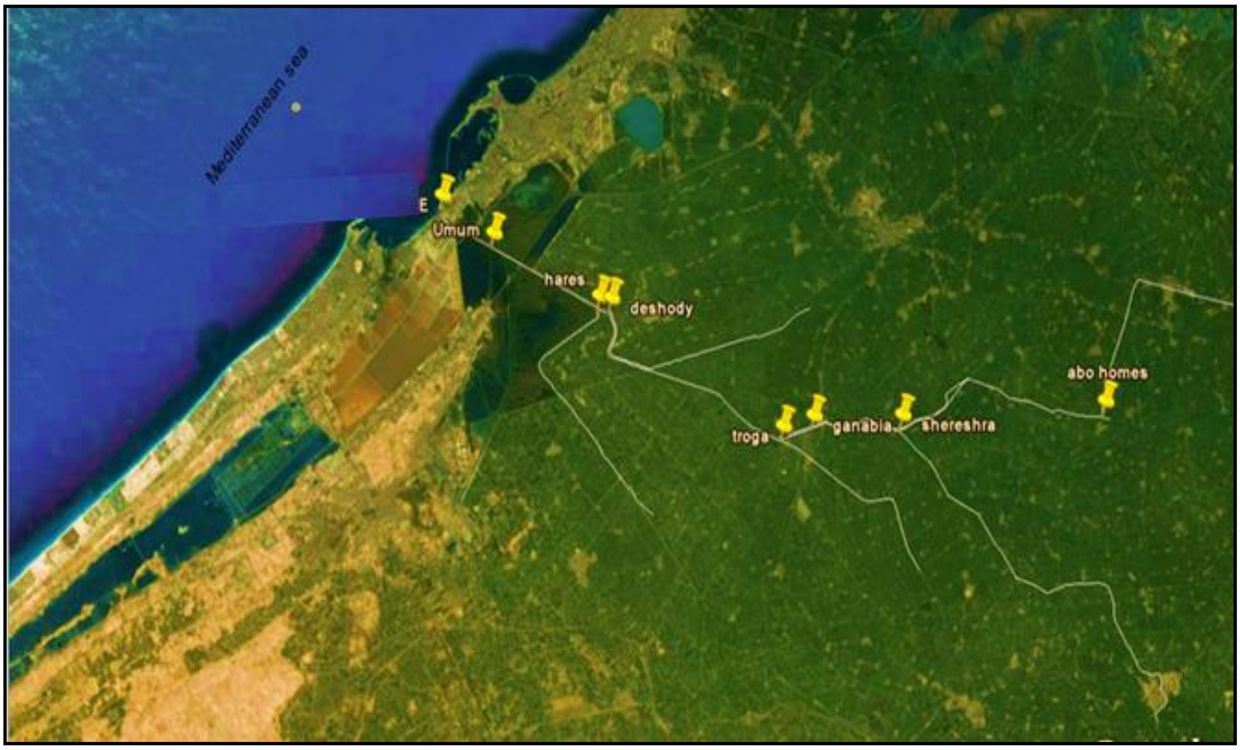


Figure 3: Google earth map of the selected drains under investigation

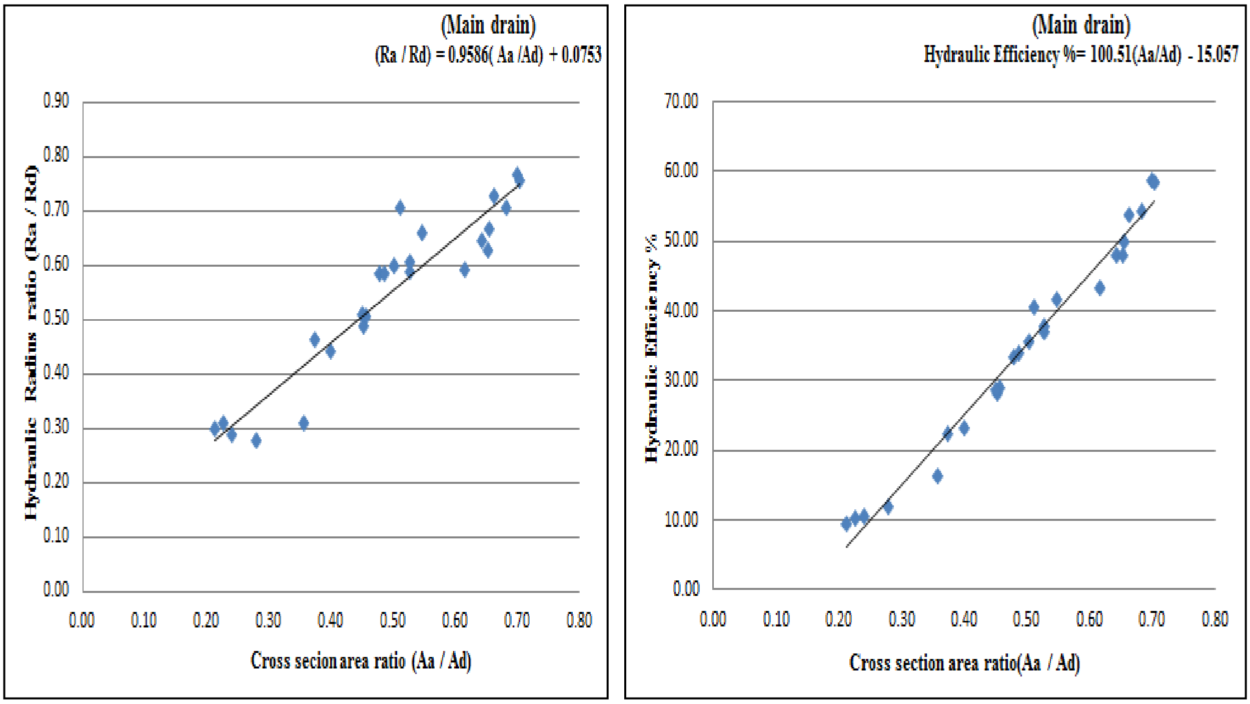


Figure 4: Relationship between hydraulic efficiency and hydraulic radius versus cross section area of main drain

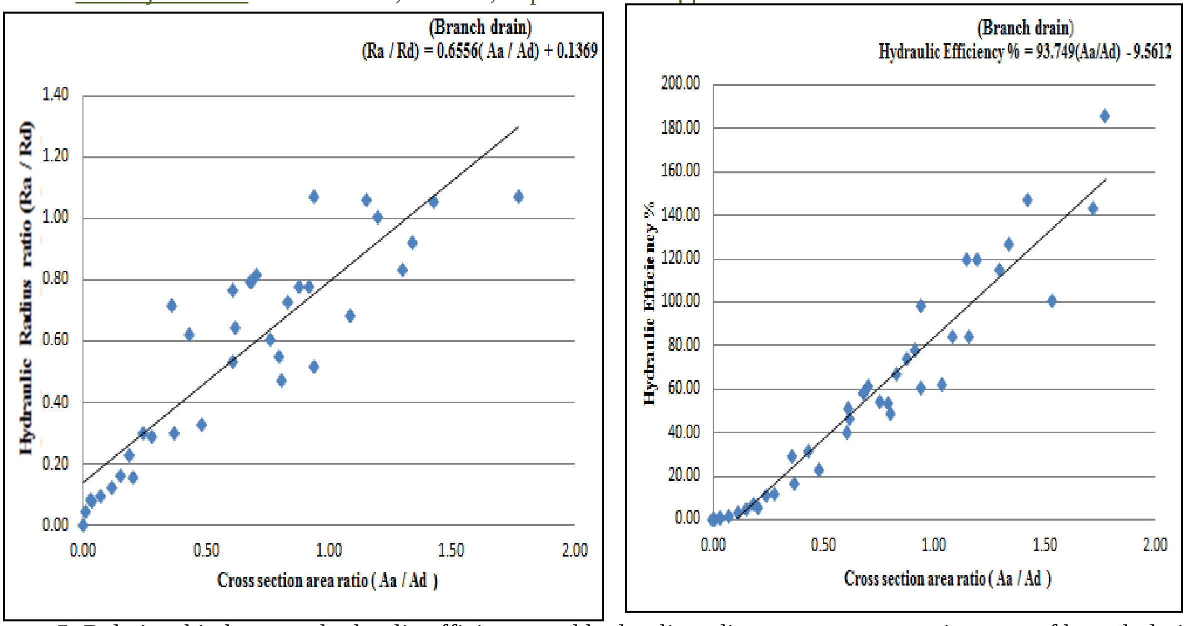


Figure 5: Relationship between hydraulic efficiency and hydraulic radius versus cross section area of branch drains

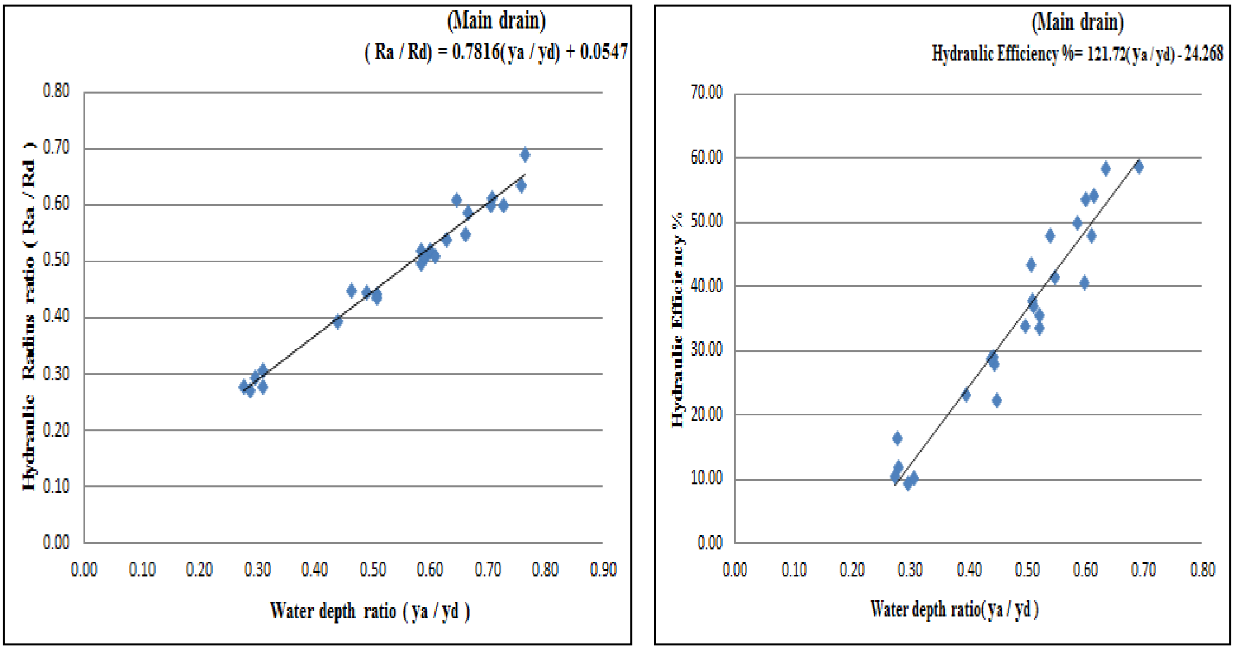


Figure 6: Relationship between hydraulic efficiency and hydraulic radius versus water depth of main drain

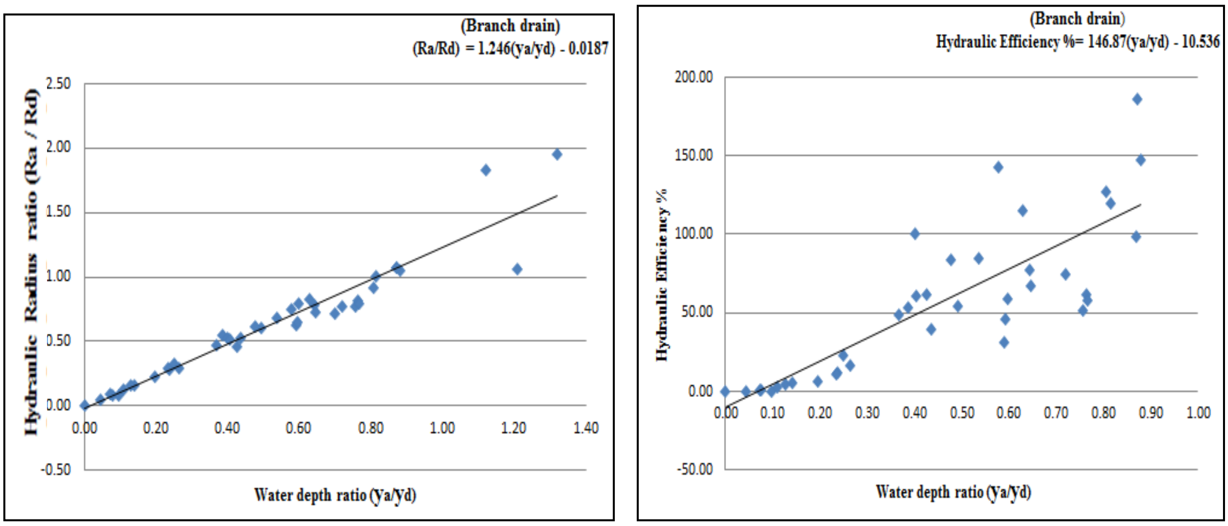


Figure 7: Relationship between hydraulic efficiency and hydraulic radius versus water depth of branch drains

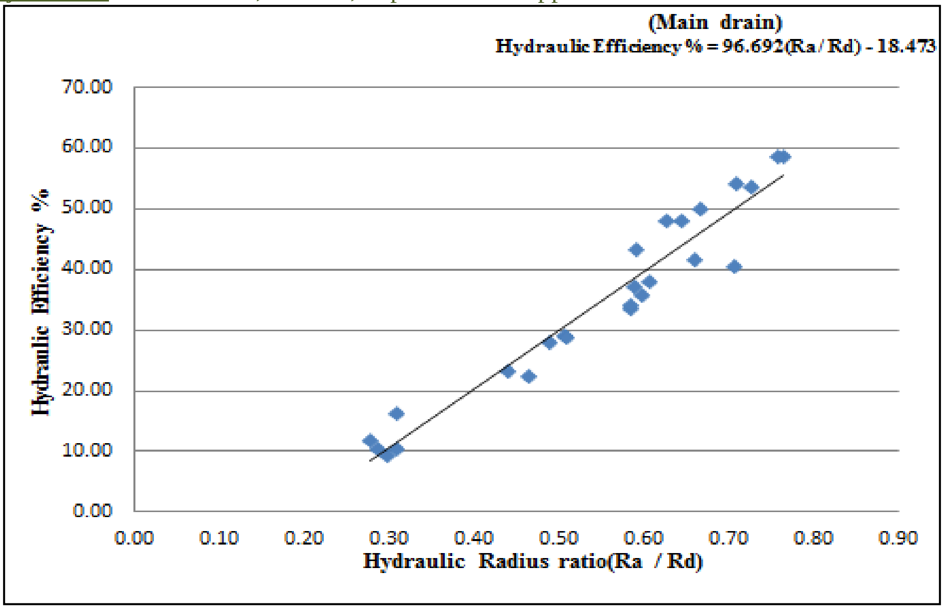


Figure 8: Relationship between hydraulic efficiency versus hydraulic radius of main drain

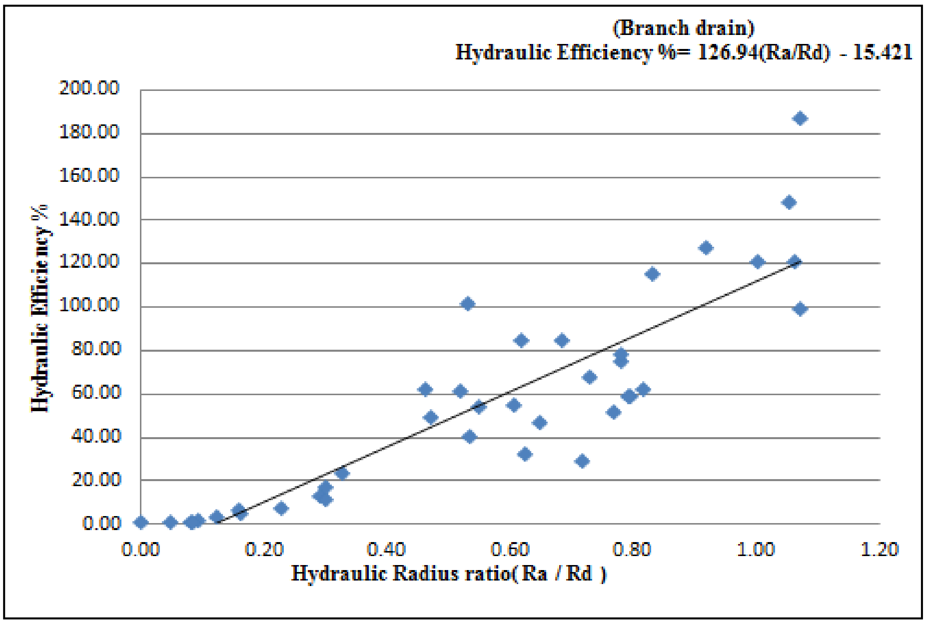
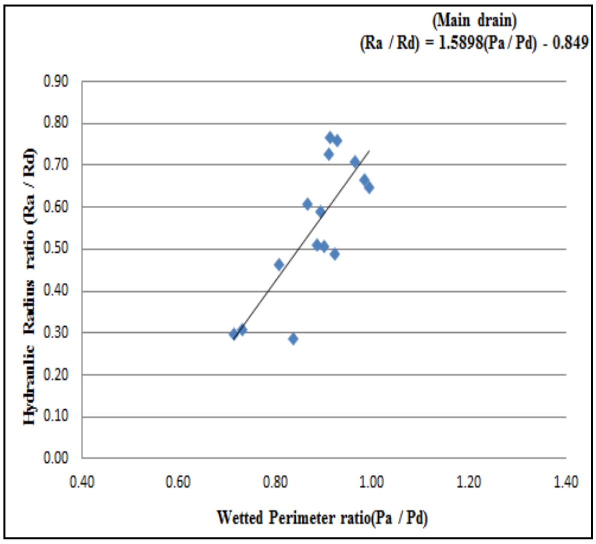


Figure 9: Relationship between hydraulic efficiency versus hydraulic radius of branch drains



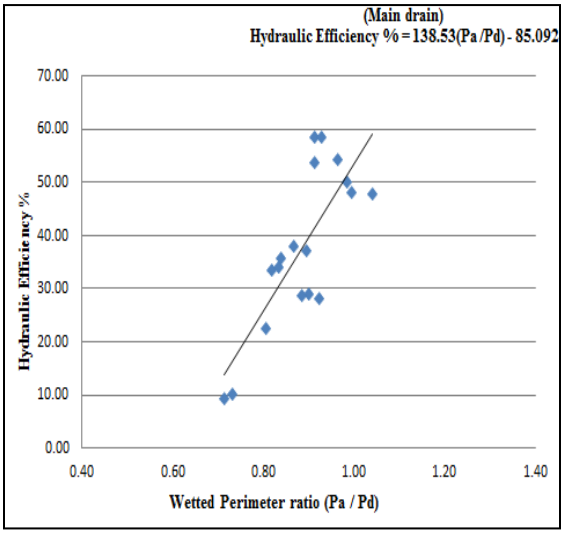


Figure 10: Relationship between hydraulic efficiency and hydraulic radius versus wetted perimeter of main drain

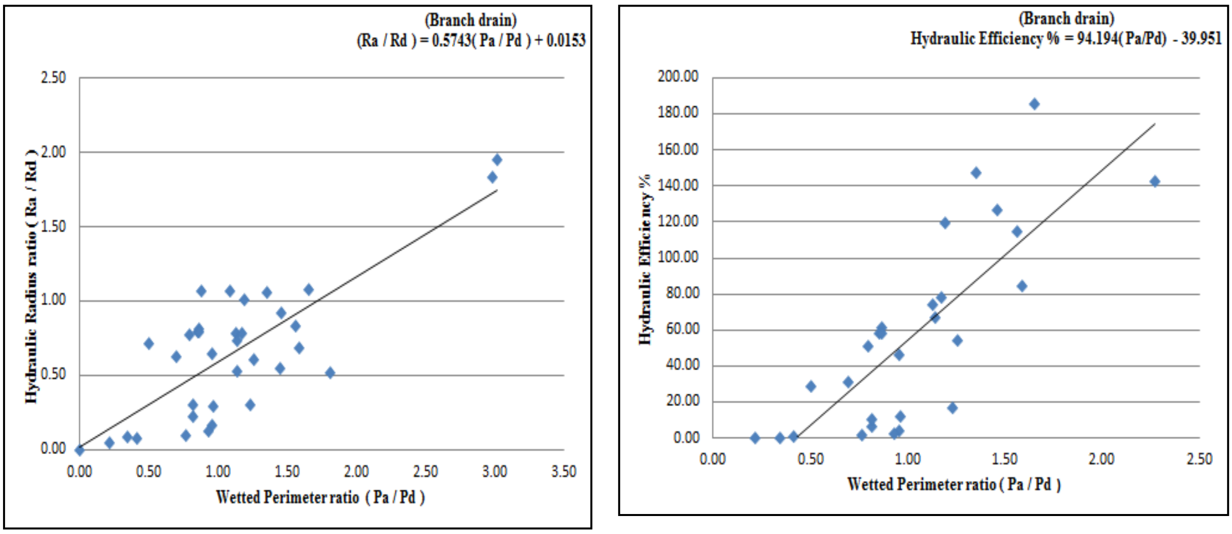


Figure 11: Relationship between hydraulic efficiency and hydraulic radius versus wetted perimeter of branch drains

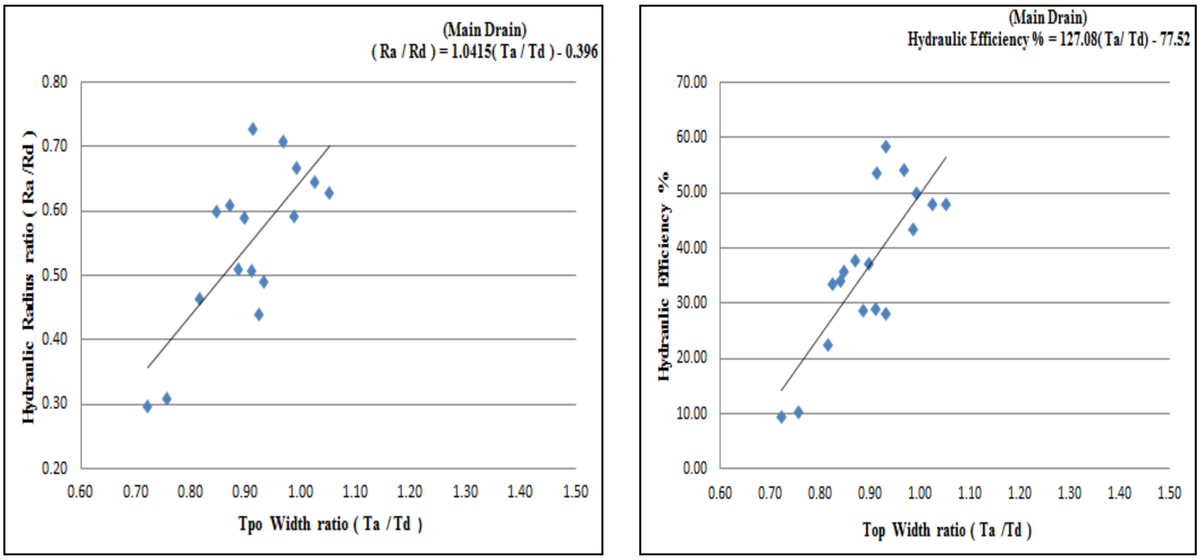


Figure 12: Relationship between hydraulic efficiency and hydraulic radius versus Top width of main drain

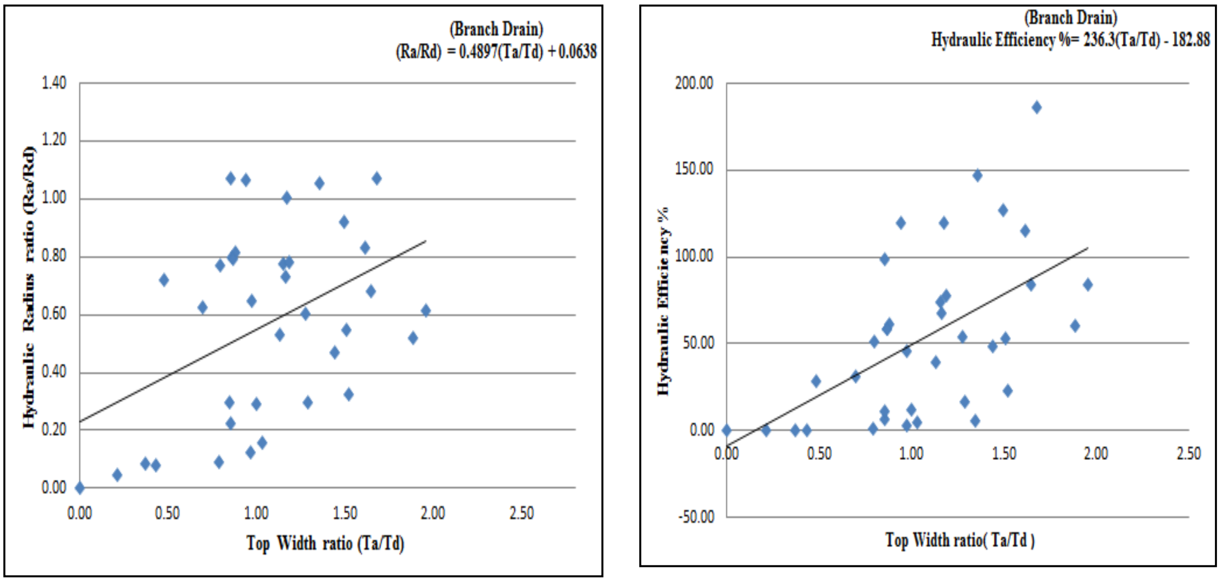


Figure 13: Relationship between hydraulic efficiency and hydraulic radius versus top width of branch drains

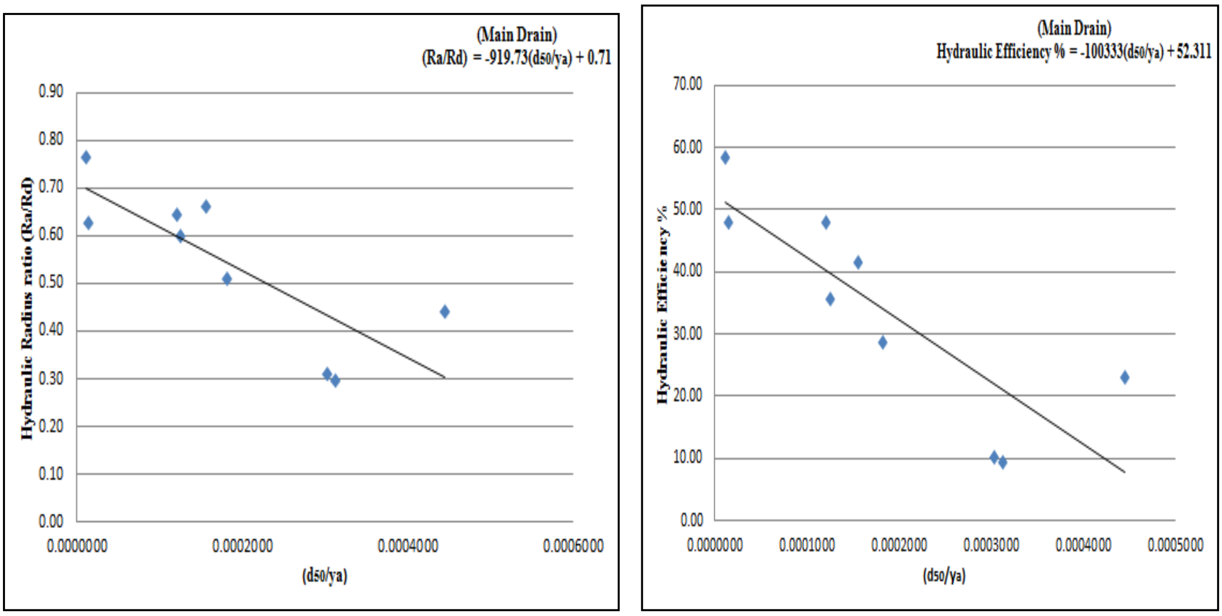


Figure 14: Relationship between hydraulic efficiency and hydraulic radius versus median size of material to water depth of main drain

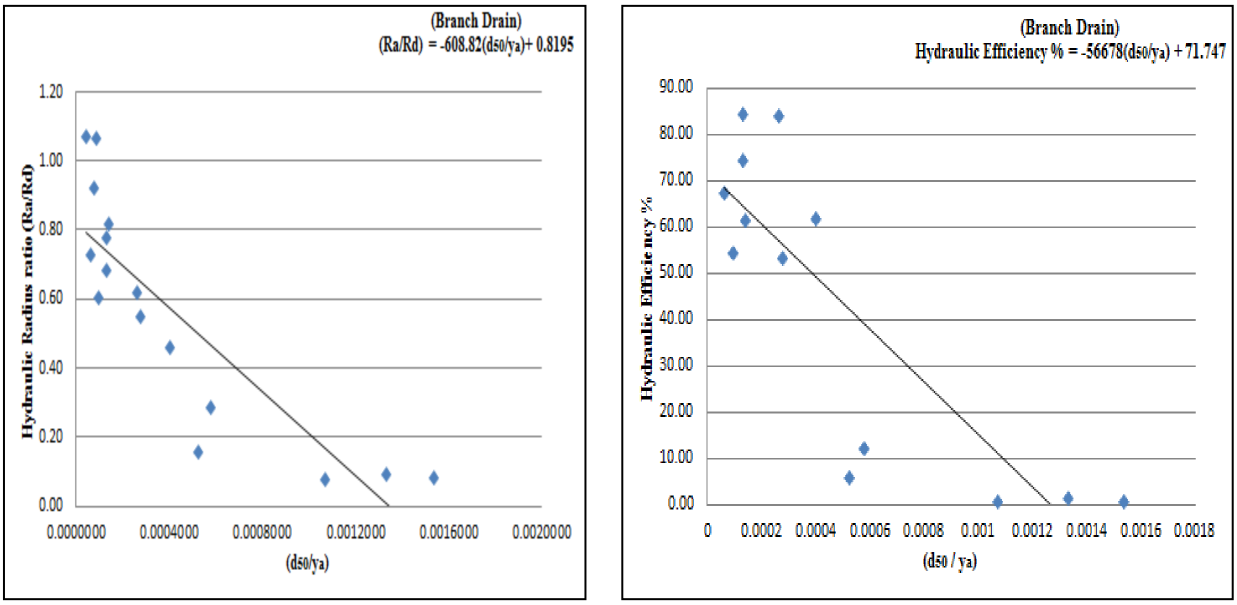


Figure 15: Relationship between hydraulic efficiency and hydraulic radius versus median size of material to water depth of branch drains

VI. CONCLUSION

Field work study was conducted to investigate the possibility of minimizing the drains hydraulic problems that lead to reduce their efficiency and ability to the free drainage of cultivated land, by identifying the most effective parameters that affect the hydraulic efficiency in order to achieve the highest operating efficiency of open drains, increase the ability of open drains cross sections for conveyance and give scientifically study about maintenance program of open drains. The developed equations are only valid for the limited range of conditions upon which they are based as follows:

- The designs of flow discharge along these selected drains are ranging among 2.62 m^3/s – 78.75 m^3/s and the side slope of the selected drains are 2/1 and 3/2.
- The boundary condition between the design and actual cross sections are the design water level. For applying the deduced relations all actual and design parameters are calculated till the design water level, to reserve the levels of earth banks and collectors out fall without any flooding for banks and submerging of collectors out fall.
- The main drains in Egypt having sandy loam beds and silty clay bank represents about 10% of the total length for Egyptian open drains. While the Branch open drains having cohesive beds and banks. Represent about 30% of Egyptian open drains. The boundary is considered as a sandy type when the medium diameter d_{50} range from 0.06 to 0.40 mm with 0.5 – 1% clay and 5-6% silt. A sandy loam type is considered when the percentage of the silt and clay

in the hydrometer analysis are ranging from 20% to 30%. Also a cohesive bed and bank types are considered when the percentage of the silt and clay in the hydrometer analysis are ranging from 50% to 65%.

ACKNOWLEDGEMENTS

This research and included work would never have been completed without the financial and technical support of the staff of Channel Maintenance Research Institute, National Water Research Center, Cairo, Egypt.

REFERENCES

Journal Papers:

[1] Bakry, M.F , The hydraulic roughness of stable alluvial canals in Egypt, *Water Science, National Water Research Center, 11th ISSUS,* April 1992*, pp. 41-46*.

Books:

[2] Chow, V.T, *Open channel hydraulics*(McGraw-hill, new York, N.Y,1959).

Theses:

[3] El-Syaed . A.H, *Design of Open Drains In Egypt*, M.Sc. Thesis, Ain Shams Univ., Cairo, Egypt,1998.

Proceedings Papers:

[4] Hosny, M.M, Regime design concept of Egyptian earthen channels: *Militray technical college, Third International Conference on Civil and Architecture Engineering*, Egypt, March 1999.

Proceedings Papers:

[5] Khattab,A.F, M.M.Abu sieda, Z. El- Gharably ,M.M.Bakry, New design for the egyptian canals system the construction of High Aswan Dam: *5^{th} Afro-Asian Regional Conference,* Townsville, (Australia),1985.

Books:

[6] MPWWR, *Drainage policy in Egypt*(Ministry of Irrigation, Cairo, Egypt, 1981 in Arabic).