basis that this motion does not affect the equilibrium of channel cross section (3, 8).

In Egypt, irrigation canals were usually designed according to empirical equations derived from measurements taken from stable canals (6). Changes in channel regimen were observed when comparing the rating curves of several irrigation canals before and after the construction of the Dam. This is due to clear water yield from the Dam i.e. changes in water properties, in addition to the modified operating conditions experienced after the partial closure of the Dam in 1964. Applications of conventional regime equations to Egyptian irrigation canals (Lacey, Blench and Simon-Albertson) revealed differences between observed field data and the calculated section properties (10).

CANALS UNDER STUDY

Eight irrigation canals were selected, east of Delta, for this study (7). All these canals are subjected to the system of irrigation turns, except the first ten kilometers of Zaghlola canal, which is used as a carrier canal. Fig. (1) gives the locations of these canals.

Representative soil samples were collected and analysed. Water discharges at selected cross sections for every canal were estimated based on the water duty and area served, water losses were considered in estimating the design discharges (9). Table (1) provides the maximum discharge and median particle size for every canal under study.

RESULTS AND ANALYSES

A set of equations for the relationships between different section properties and between these properties and water discharge are given in Table (2). The table also gives the correlation coefficient (r) for each equation Figs (2) through (7) provide the relationships between different section properties for canals under study as representative canal for the whole region (Dakahlia), silty soil. Also Figs (8) through (14) give the relationships between these properties and water discharges. Statistical analyses (1) for the mean value of discharge exponents are given in Table (3) using the analysis of variance (one way ANOVA), and the t-test in Table (4).

Exponential relationships between mean width and mean depth, for Shoha canal have shown good correlation in different years before and after the erection of the Dam. On the contrary linear relationship between the above mentioned two parameters is better in both Zaghlola and El Zahiara canals which may mean that the exponential relationship is more accurate in coarser materials.

Generally the relationships between discharge and section properties have values of exponents less than 0.5. No correlation was found between maximum water depth and water discharge in clayey soil (Zaghlola) or it may have a poor correlation.

It seems from the statistical analyses of Shoha canal properties in different years that the annual dredging has no effect on surface breadth, consequently water area. There is no difference between mean widths at 5% level of significance.

Calculations have shown changes in formulae of section properties from year to year, but there is no significant difference between such changes. The one way ANOVA, Table (3), shows that there is no significant difference between the mean values of discharge exponents of Shoha canal for years 1975/1976, 1977/1978, and 1978/1979 at 1% level. There is no significant difference at 5% level, between the mean values of discharge exponents of Shoha for years 1977/1978 and 1978/1979 using either the analysis of variance or the t-test, which could mean that one year after dredging is a sufficient period for a canal to reach a regimen behaviour.

Dischargae exponents before Aswan High Dam have smaller values than the corresponding values after the construction of the Dam, mainly due to the effect of colloidal particles in water.

Statistical analyses have shown that there is a significant difference between the mean value of discharge exponent of Shoha 1957/1958 and the mean values of discharge exponents of Shoha for years 1975/1976 and 1978/1979 which means that the canal regime changed after the Dam.

Discharge exponents of the section properties of Shoha canal are bigger than the corresponding exponents in El Zahiara canal. Also the exponents have higher values in El Zahiara canal than in Zaghlola canal. There is no significant difference between the mean values of discharge exponent of Shoha canal (coarse silt) and El Zahiara canal (medium to fine silt) at 5% level, but there is a significant difference between the mean value of discharge exponent of Shoha and the corresponding value of Zaghlola canal (clay) at the same level. Also there is a significant difference at 5% level between the mean values of discharge exponents of El Zahiara and Zaghlola canals. This means that the discharge exponent depends on the type of soil.

Bigger exponents of discharge are exhibited for a carrier canal, except the exponent of discharge for hydraulic radius, than canal subjectaed to irrigation turns, although the analysis of variance and t-test, Tables (3.4), have shown no significant difference between the mean values of discharge exponents of Zaghlola canal and Zaghlola (carrier) at 5% level.

There is a significant difference at 5% level between the mean value of discharge exponents for the representative canal of the area (Dakahlia) and the mean values of these exponents for Shoha ($F = 7.36$), El Zahiara ($F = 26.38$) and Zaghlola ($F = 79.08$) canals.

Due to the approximate nature of the derivation of these equation there are minor geometrical incompatabilities in the results given by these equations. The value of (P.R) should be equal to the value of (B.Y) giving the water area (A). For maximum discharges of canals under study, the difference between the two values is usually less than 15% which is not serious to this type of work.

Values of wetted perimeter (P) should have bigger values than surface width (B_s which are confirmed in this analysis on the contrary to Simon - Albertson equations which give $P < B_s$ (4).

CONCLUSIONS

It has been shown that the regime of irrigation canals has changed after the construction of Aswan High Dam. The value of discharge exponents have smaller values before the Dam than the corresponding values after the Dam. These values depend mainly on the particle size of soil and type of canal.

The analyses have declared that one year after the canal dredging could be a sufficient poeriod to reach a regime behaviour.

It is hoped that these relationships could be of use in the design of stable channel cross section. More accurate results will be obtained by using actual field measurements i.e. water discharges and section properties for stable canals.

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NOTATION

The following symbols are used in this paper:

A = water area;
B = mean width;
B_S = surface width;
D = mean depth;
d_{50} = median particle size;
F = statistical test;
P = wetted perimeter;
Q = water discharge;
R = hydraulic radius;
r = correlation coefficient;
S^2 = variance (within groups);
S_B^2 = variance (between groups)
t = statistical test;
X = mean value;
Y = maximum water depth; and
σ = standard deviation

Table (1) Maximum discharges and medium particle sizes for canals under study

Name of canal	Q m^3/sec	d_{50} mm	Type of soil
El Gammalia	2.70	0.100	Coarse silt
El Nazle	5.30	0.025	Coarse silt
Anbar	0.83	0.020	Coarse to medium silt
El Bardy	3.40	0.005	Clay
Meet roomy	1.44	0.012	Medium silt
Shoha	2.70	0.038	Coarse silt
El Zahiara	7.62	0.006	Medium to fine silt
Zaghlola	9.32	0.001	Clay

Table (2): Regime equations for canals under study

SHOHA CANAL 1957 - 1958

1.	$R = 0.869\,D + 0.024$	(r = 0.991)
2.	$B = 0.632\,P + 0.073$	(r = 0.912)
3.	$Y = 1.483\,R + 0.063$	(r = 0.908)
4.	$B = 0.705\,B_s + 0.060$	(r = 0.912)
5.	$B = 4.285\,D + 0.700$	(r = 0.822)
6.	$B = 4.967\,D^{0.864}$	(r = 0.845)
7.	$P = 5.917\,Q^{0.344}$	(r = 0.977)
8.	$Y = 1.034\,Q^{0.361}$	(r = 0.963)
9.	$B_s = 5.332\,Q^{0.338}$	(r = 0.965)
10.	$R = 0.679\,Q^{0.315}$	(r = 0.958)
11.	$B = 3.834\,Q^{0.308}$	(r = 0.911)
12.	$D = 0.740\,Q^{0.326}$	(r = 0.955)
13.	$A = 3.977\,Q^{0.668}$	(r = 0.987)

SHOHA CANAL 1975 - 1976

1.	$R = 0.740\,D + 0.095$	(r = 0.973)
2.	$B = 0.047\,P + 3.920$	(r = 0.925)
3.	$Y = 1.670\,R$	(r = 0.885)
4.	$B = 0.598\,B_s + 0.610$	(r = 0.928)
5.	$B = 3.095\,D + 1.720$	(r = 0.500)
6.	$B = 3.630\,Q^{0.410}$	(r = 0.833)
7.	$P = 5.930\,Q^{0.380}$	(r = 0.890)
8.	$Y = 1.030\,Q^{0.370}$	(r = 0.680)
9.	$B_s = 5.000\,Q^{0.500}$	(r = 0.770)
10.	$R = 0.630\,Q^{0.470}$	(r = 0.540)
11.	$B = 3.630\,Q^{0.410}$	(r = 0.833)
12.	$D = 0.700\,Q^{0.560}$	(r = 0.550)

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SHOHA CANAL 1977 - 1978

1.	$R = 0.822\ D + 0.037$	(r = 0.990)
2.	$B = 0.617\ P + 0.199$	(r = 0.963)
3.	$Y = 1.624\ R + 0.014$	(r = 0.967)
4.	$B = 0.684\ B_s + 0.292$	(r = 0.966)
5.	$B = 4.522\ D + 0.975$	(r = 0.883)
6.	$B = 5.395\ Q^{0.848}$	(r = 0.803)
7.	$P = 6.185\ Q^{0.179}$	(r = 0.402)
8.	$Y = 0.902\ Q^{0.351}$	(r = 0.830)
9.	$B_s = 5.078\ Q^{0.381}$	(r = 0.878)
10.	$R = 0.584\ Q^{0.296}$	(r = 0.763)
11.	$B = 3.660\ Q^{0.340}$	(r = 0.829)
12.	$D = 0.659\ Q^{0.316}$	(r = 0.746)

SHOHA CANAL 1978 - 1979

1.	$R = 0.890\ D + 0.012$	(r = 0.977)
2.	$B = 0.580\ P + 0.667$	(r = 0.926)
3.	$Y = 1.684\ R - 0.132$	(r = 0.913)
4.	$B = 0.689\ B_s + 0.336$	(r = 0.942)
5.	$B = 5.624\ D + 0.335$	(r = 0.769)
6.	$B = 5.902\ D^{0.985}$	(r = 0.808)
7.	$P = 5.861\ Q^{0.379}$	(r = 0.799)
8.	$Y = 0.894\ Q^{0.401}$	(r = 0.841)
9.	$B_s = 5.431\ Q^{0.379}$	(r = 0.762)
10.	$R = 0.490\ Q^{0.357}$	(r = 0.897)
11.	$B = 4.057\ Q^{0.342}$	(r = 0.812)
12.	$D = 0.670\ Q^{0.363}$	(r = 0.920)
13.	$A = 0.267\ Q^{1.050}$	(r = 0.838)

EL-ZAHIARA CANAL 1976 - 1977

1.	$R = 0.856\,D + 0.024$		$(r = 0.988)$
2.	$B = 0.677\,P + 0.027$		$(r = 0.997)$
3.	$Y = 1.430\,R + 0.112$		$(r = 0.959)$
4.	$B = 0.719\,B_s + 0.135$		$(r = 0.953)$
5.	$B = 6.134\,D + 0.647$		$(r = 0.841)$
6.	$B = 5.715\,D^{0.735}$		$(r = 0.708)$
7.	$P = 7.196\,Q^{0.269}$		$(r = 0.959)$
8.	$Y = 1.207\,Q^{0.256}$		$(r = 0.958)$
9.	$B_s = 6.306\,Q^{0.299}$		$(r = 0.944)$
10.	$R = 0.781\,Q^{0.268}$		$(r = 0.952)$
11.	$B = 4.679\,Q^{0.307}$		$(r = 0.923)$
12.	$D = 0.890\,Q^{0.267}$		$(r = 0.969)$
13.	$A = 5.615\,Q^{0.566}$		$(r = 0.966)$

ZAGHLOLA CANAL 1977 - 1978 (CARRIER)

1.	$R = 0.757\,D + 0.115$		$(r = 0.911)$
2.	$B = 0.710\,P + 0.711$		$(r = 0.890)$
3.	$Y = 0.957\,R + 0.589$		$(r = 0.764)$
4.	$B = 0.742\,B_s - 0.174$		$(r = 0.887)$
5.	$B = 4.017\,D + 0.992$		$(r = 0.730)$
6.	$B = 5.000\,D^{0.681}$		$(r = 0.626)$
7.	$P = 6.991\,Q^{0.145}$		$(r = 0.841)$
8.	$Y = 1.256\,Q^{0.118}$		$(r = 0.595)$
9.	$B_s = 6.009\,Q^{0.164}$		$(r = 0.896)$
10.	$R = 0.805\,Q^{0.085}$		$(r = 0.673)$
11.	$B = 3.908\,Q^{0.181}$		$(r = 0.714)$
12.	$D = 0.884\,Q^{0.123}$		$(r = 0.650)$
13.	$A = 5.217\,Q^{0.305}$		$(r = 0.799)$

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ZACHLOLA CANAL 1977 - 1978

1.	$R = 0.757\ D + 0.115$	(r = 0.911)
2.	$B = 0.710\ P + 0.711$	(r = 0.890)
3.	$Y = 0.957\ R + 0.589$	(r = 0.764)
4.	$B = 0.742\ B_s - 0.147$	(r = 0.887)
5.	$B = 4.017\ D + 0.992$	(r = 0.730)
6.	$B = 5.000\ D^{0.681}$	(r = 0.626)
7.	$P = 7.327\ Q^{0.138}$	(r = 0.810)
8.	$Y = 1.402\ Q^{0.051}$	(r = 0.380)
9.	$B_s = 6.349\ Q^{0.144}$	(r = 0.770)
10.	$R = 0.793\ Q^{0.123}$	(r = 0.655)
11.	$B = 4.442\ Q^{0.132}$	(r = 0.780)
12.	$D = 0.880\ Q^{0.117}$	(r = 0.690)
13.	$A = 5.753\ Q^{0.183}$	(r = 0.730)

DAKAHLIA CANALS 1977 - 1978

1.	$R = 0.909\ D - 0.047$	(r = 0.920)
2.	$B = 0.633\ P - 0.072$	(r = 0.940)
3.	$Y = 1.447\ R + 0.129$	(r = 0.937)
4.	$B = 0.568\ B_s + 1.031$	(r = 0.780)
5.	$B = 4.662\ D + 0.769$	(r = 0.823)
6.	$B = 5.480\ D$	(r = 1.000)
7.	$P = 6.635\ Q^{0.246}$	(r = 0.831)
8.	$Y = 1.157\ Q^{0.190}$	(r = 0.686)
9.	$B_s = 5.584\ Q^{0.300}$	(r = 0.980)
10.	$R = 0.705\ Q^{0.227}$	(r = 0.746)
11.	$B = 4.120\ Q^{0.248}$	(r = 0.734)
12.	$D = 0.805\ Q^{0.221}$	(r = 0.716)
13.	$A = 4.370\ Q^{0.550}$	(r = 0.990)

Table (3): Comparison between mean discharge exponents using the t-test
$t_{0.005;\ 10} = 3.169$ $t_{0.025,\ 10} = 2.228$

Section props	Shoha 1957/58	Shoha 1975/76	Shoha 1977/78	Shoha 1978/79	El Zahiara 1976/77	Zaghlola 1977/78	Zaghlola Carrier
P	0.344	0.38	0.179	0.379	0.269	0.138	0.145
Y	0.361	0.37	0.351	0.401	0.256	0.051	0.118
B	0.338	0.50	0.381	0.379	0.299	0.144	0.164
R	0.315	0.47	0.296	0.357	0.268	0.123	0.085
B	0.308	0.41	0.340	0.342	0.307	0.132	0.181
D	0.326	0.56	0.316	0.363	0.267	0.117	0.123
X	0.332	0.446	0.3105	0.3702	0.278	0.1175	0.136
σ	0.0175	0.0682	0.0646	0.01882	0.0186	0.031	0.0316
Calculated (t)	4.034 (1957/58 vs 1975/76)		2.174 (1977/78 vs 1978/79)		10.86	1.023	
	3.586 (1957/58 vs 1978/79)						

Table (4) Comparison between mean discharge exponents using one way ANOVA
$F_{0.01,1,10} = 10.04$ $F_{0.025,1,10} = 6.94$ $F_{0.05,21,10} = 4.96$

	Shaha 1975/76 1977/78 1978/79	Shaha 1977/78	Shaha 1957/58	Shaha 1957/58	Shaha 1957/58	Shaha	Shaha	El Zahiara	Zaghlola
		Shaha 1978/79	Shaha 1975/76	Shaha 1977/78	Shaha 1978/79	El Zahiara	Zaghlola	Zaghlola	Zaghlola carrier
Between groups $(S_B^2) \times 10^3$	28.523	106.92	40.368	13.87	4.38	3.169	117.5	77.3	1.027
Within groups $(S^2) \times 10^4$	30.504	22.637	24.78	22.39	3.302	22.6	25.67	6.535	9.8
$F - \frac{S_B^2}{S^2}$	9.35	4.72	16.29	0.62	13.62	1.042	43.53	118.26	1.048

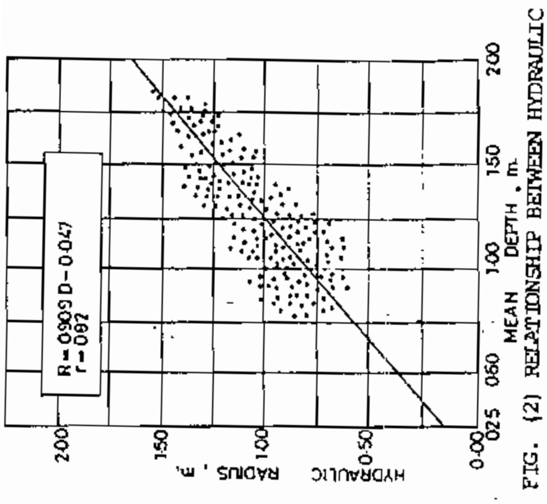

FIG. (2) RELATIONSHIP BETWEEN HYDRAULIC RADIUS AND MEAN DEPTH

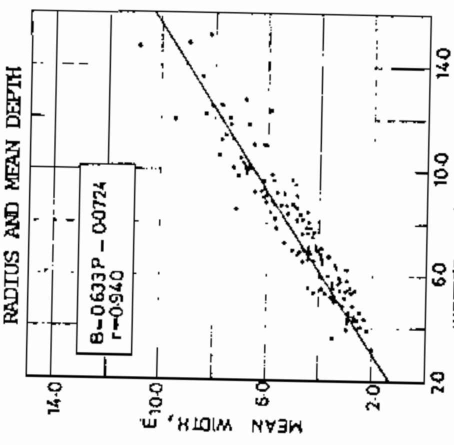

FIG. (3) RELATIONSHIP BETWEEN MEAN WIDTH AND WETTED PERIMETER

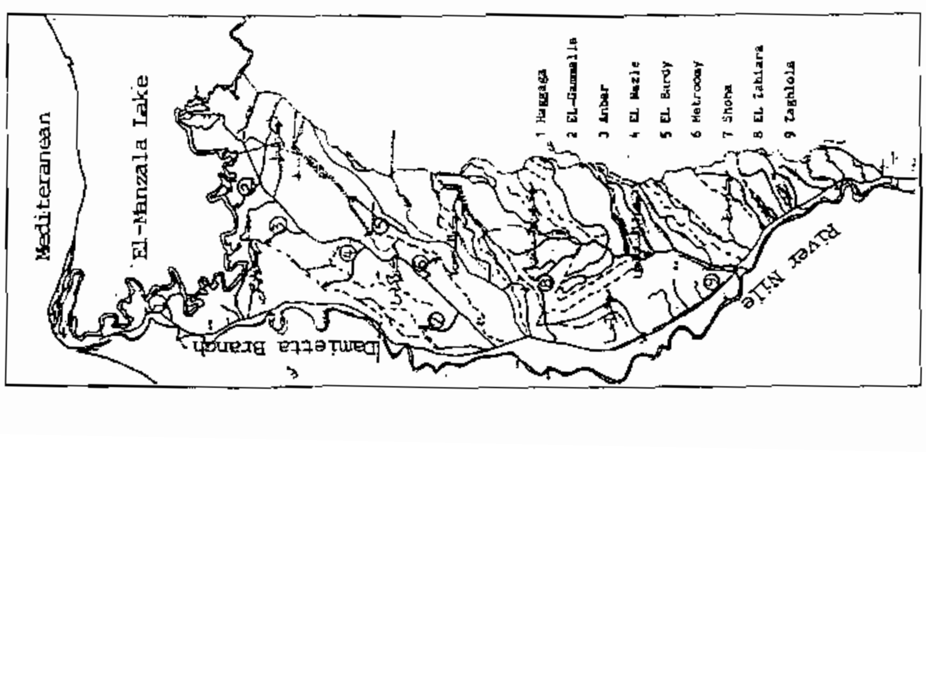

FIG. (1) CANALS UNDER STUDY

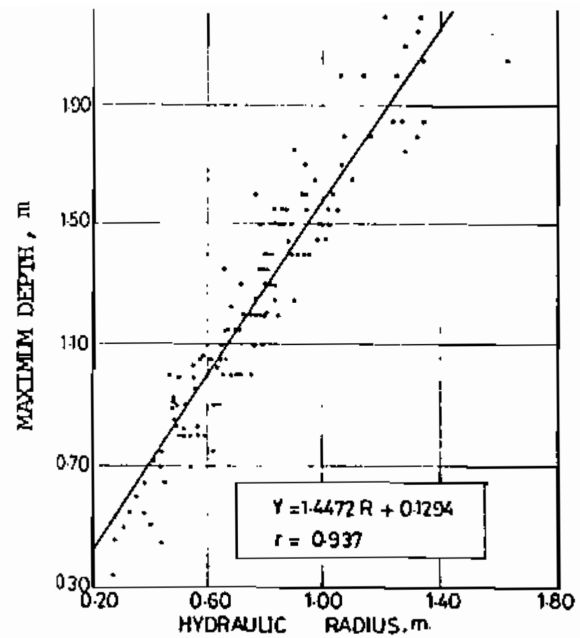

FIG. (4) RELATIONSHIP BETWEEN MAXIMUM DEPTH & HYDRAULIC REDIUS.

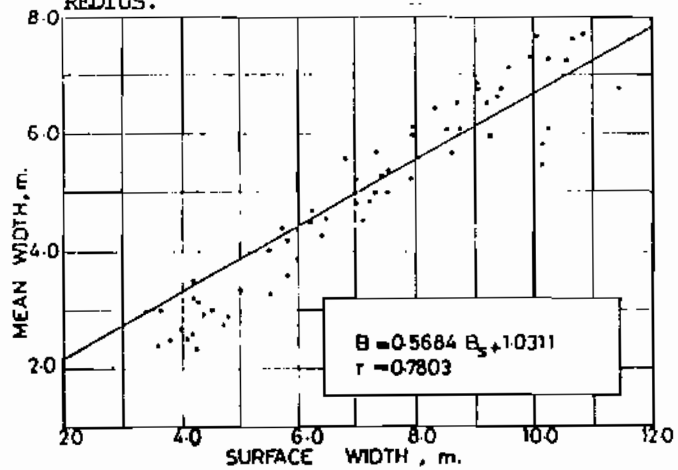

FIG. (5) RELATIONSHIP BETWEEN MEAN WIDTH AND SURFACE WIDTH

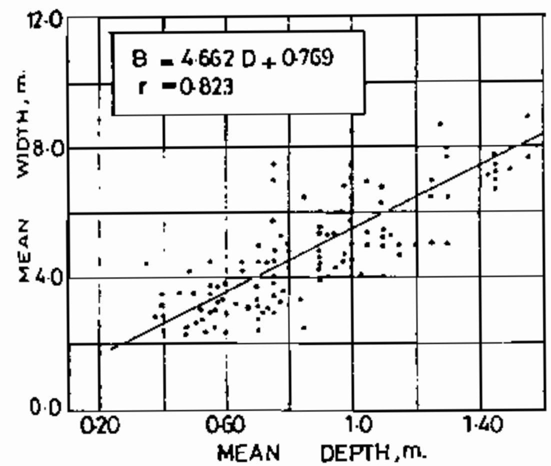

FIG. (6) RELATIONSHIP BETWEEN MEAN WIDTH AND MEAN DEPTH

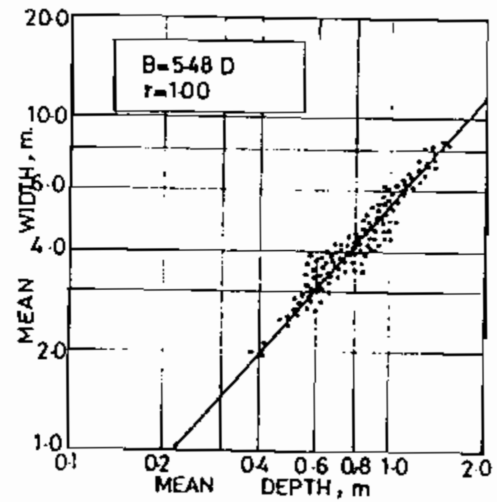

FIG. (7) RELATIONSHIP BETWEEN MEAN WIDTH AND MEAN DEPTH

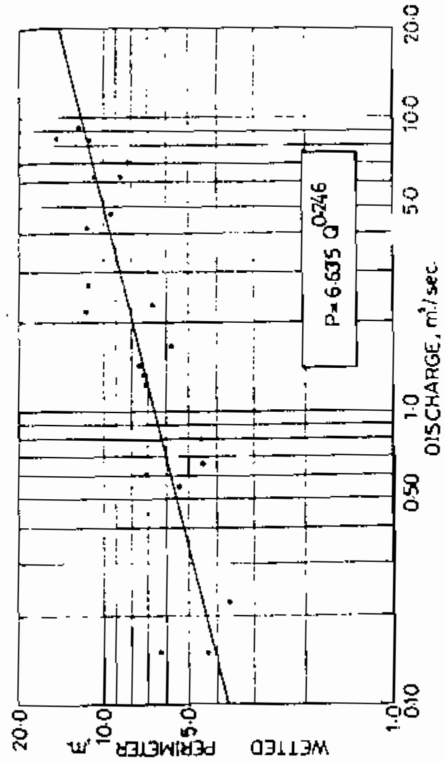

FIG. (8) RELATIONSHIP BETWEEN WETTED PERIMETER AND DISCHARGE

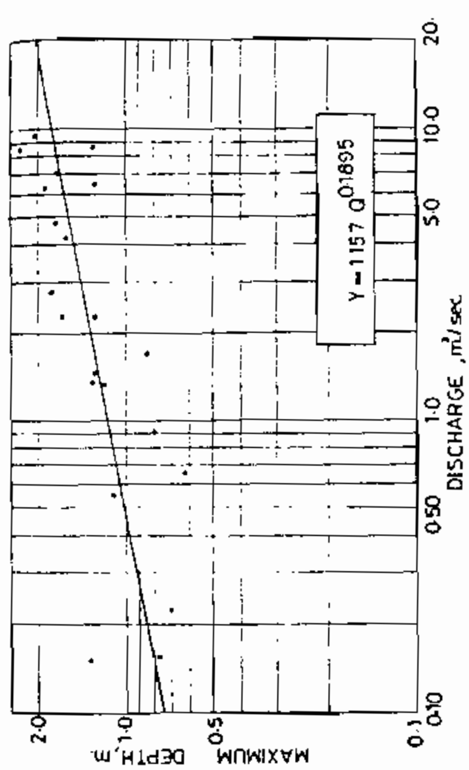

FIG.(9) RELATIONSHIP BETWEEN MAXIMUM DEPTH AND DISCHARGE

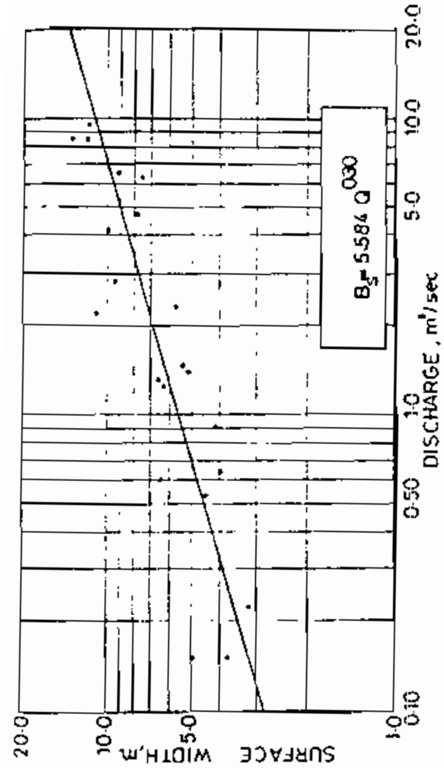

FIG. (10) RELATIONSHIP BETWEEN SURFACE WIDTH AND DISCHARGE

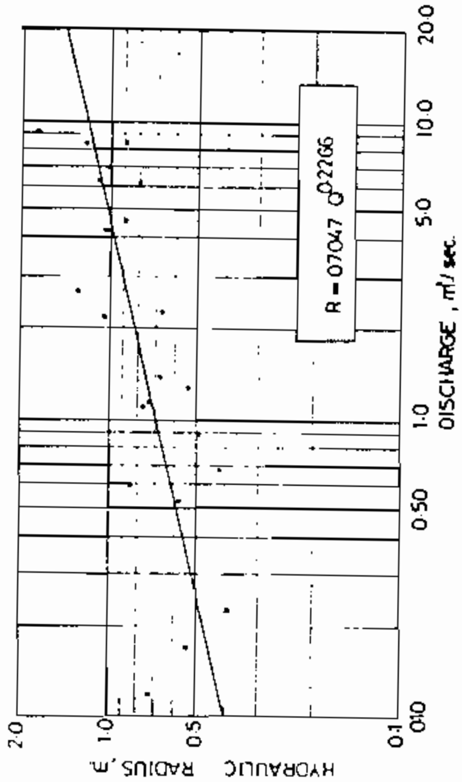

FIG. (11) RELATIONSHIP BETWEEN HYDRAULIC RADIUS AND DISCHARGE

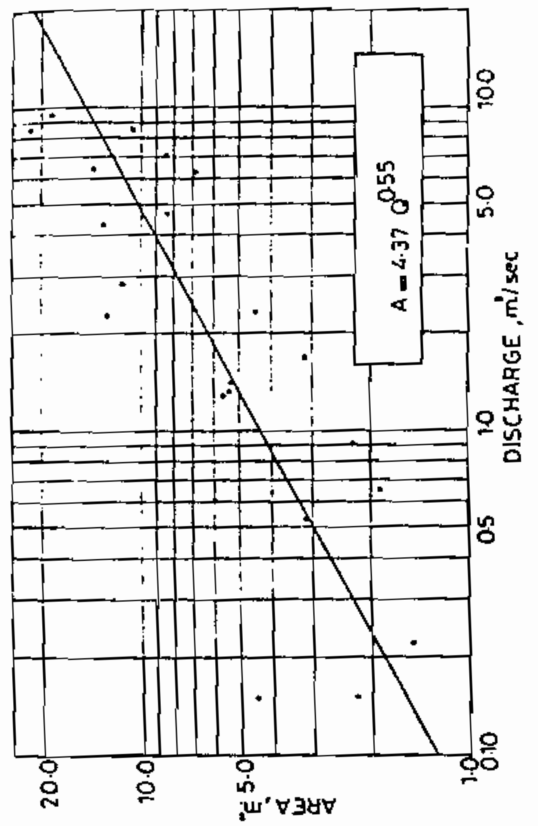

FIG. (14) RELATIONSHIP BETWEEN WATER AREA AND DISCHARGE

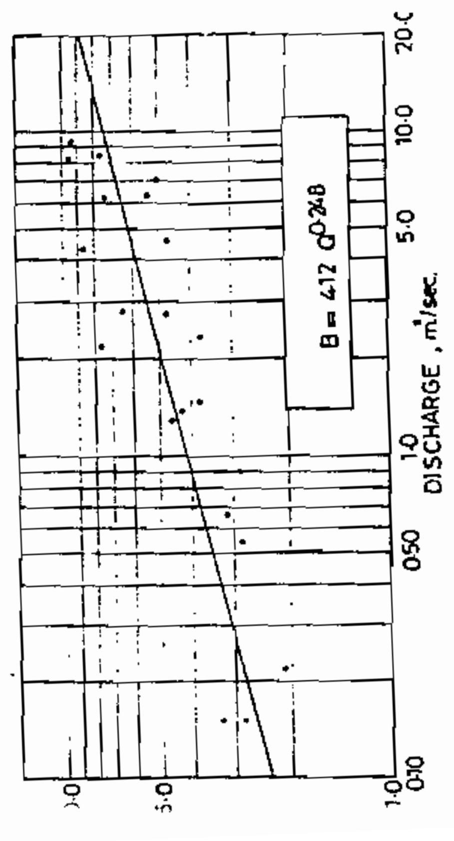

FIG. (12) RELATIONSHIP BETWEEN MEAN WIDTH AND DISCHARGE

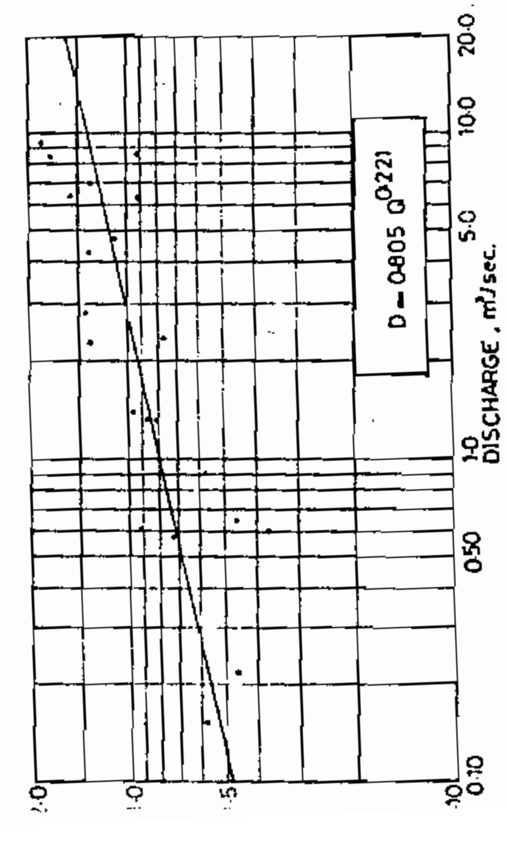

FIG. (13) RELATIONSHIP BETWEEN MEAN DEPTH AND DISCHARGE