

A COMPARATIVE STUDY OF CONVENTIONAL
REGIME EQUATIONS

Zidan, Abdel-Razik A*

ABSTRACT:

When any one of the alluvial canal parameters such as width, depth, slope or velocity is affected all other parameters are uniquely determined and independently adjusted, thus creating a new canal regime. Many formulae of canal regime have been presented, the best well known regime equations are those given by Lacey (1929, 1930, 1953), Blench (1957, 1966) and Simons-Albertson (1963).

Deviations of the observed canal dimensions of some cohesive canals located in El-Fayoum governorate, the eastern region of Delta in addition to Damietta branch, from those given by Lacey, Blench, and Simons, et al. are investigated.

INTRODUCTION:

The regime equations related to sediment transport is a purely empirical approach developed originally by British engineers working in India and Egypt. It is not a theory in the accurate sense, for it does not give a physical explanation for its findings. The regime theory has in its bases the concept of a channel that may scour or deposit at times but over the climatic cycle the net result is zero. Inglis Ref.(3) stated that channels which not alter appreciably from year to year although they may vary during the year are said to be in regime.

Some misconceptions about the meaning of the term regime exist. Frequently it has come to mean in equilibrium, but it must be stressed that the equilibrium of a transient nature. According to Blench to declare that a river in regime is comparable in the general sense to state that a country acquired a climate.

REGIME EQUATIONS:

It could be said that the regime method started with Kennedy in 1895. For twenty two canals in the upper Bori Doab of Punjab, Kennedy derived an expression in terms of velocity and depth.

* Lecturer, Irrigation and Hydraulics Dept., Fac. of Engrg., El-Mansoura University, Egypt.

$$V = 0.55 D^{0.64} \quad \text{m/sec.} \quad \dots(1)$$

where, V is the critical mean velocity at which for a given mean water depth D silting is just prevented.

Lacey's Equations:

The Lacey's equations are given as follows Ref.(10).

$$P = 4.8326 Q^{1/2} \quad \dots(2)$$

$$d_{mm} = f^2 / 2.52 \quad \dots(3)$$

$$A = 2.282 Q^{5/6} / f^{1/3} \quad \dots(4)$$

$$R = 0.4725 Q^{1/3} / f^{1/3} \quad \dots(5)$$

$$V = 0.4382 Q^{1/6} f^{1/3} \quad \dots(6)$$

in which;

V = critical mean velocity;

f = silt factor;

d = d₅₀ = median particle size in mm;

R = hydraulic radius;

S = bed slope;

Q = water discharge; and

P = channel wetted perimeter; after making the substitution.

V = Q/PR; it is possible to eliminate P and R from (2) through (5) with the result.

$$S = \frac{f^{5/3}}{3169.8 Q^{1/6}} \quad \dots(7)$$

The silt factor is poorly defined in equation (3) it must be determined by other factors beside the particle size, notably the sediment concentration which was made by Blench.

Blench's Equations:

The regime equations by Blench seem to have more generality than those given by Lacey Ref.(3). They are based on majority of field observations occurred in Pakistan, India, and some data from Egypt in addition to laboratory data. Inglis (1948) Ref.(3) gave a set of regime equations similar to those given by Blench.

Blench presented three equations based on two silt factors, a bed factor f_b and side factor f_s . The two factors are defined in the following way

$$f_b = \frac{V^2}{D} \quad \dots\dots(8)$$

$$f_s = \frac{V^3}{B} \quad \dots\dots(9)$$

in which;

V = mean velocity;
B = mean width; and
D = mean water depth.

The three independent regime equations are

$$B = (f_b Q/f_s)^{1/2} \quad \dots\dots(10)$$

$$D = (f_s \cdot Q/f_b^2)^{1/3} \quad \dots\dots(11)$$

$$S = \frac{f_b^{5/6} \cdot f_s^{1/2} \cdot \gamma^{1/4}}{3.63 \left(1 + \frac{c}{233}\right) \cdot g \cdot Q^{1/6}} \quad \dots\dots(12)$$

Where, γ is the kinematic viscosity of water and c is the sediment concentration in parts per million by weight (p.p.m.).

The value of side factor varies from 0.1 to 0.3 depending on the cohesiveness of the bank material Ref.(5).

The recommended value of bed factor is;

$$f_b = 0.579 \sqrt{d} (1 + 0.12 c) \quad \dots\dots(13)$$

The indian canals which supplied much of the data for Lacey and Blench equations have a sand bed of particle $0.1 \text{ mm} < d_{50} < 0.6 \text{ mm}$ and slightly cohesive to cohesive banks. A typical canals is trapezoidal with side slope of about two horizontal to one vertical. The breadth depth ratio $4 < B/D < 30$ and discharge $0.03 < Q < 300 \text{ m}^3/\text{sec}$. A further limitation of indian data is that they came from canals whose sediment is usually controlled. It is usually less than 500 p.p.m. Ref.(4).

Simons-Albertson's Equations:

Based on the lack of application of the regime equations in the United States, Simons and Albertson made a collection of field data from north american sources and using the indian data, Table (1). They gave the following equations:

$$P = K_1 Q^{1/2} \quad \dots\dots(14)$$

$$B = 0.9 P \quad \dots\dots(15)$$

$$B = 0.92 B_s - 0.61 \quad \dots\dots(16)$$

$$R = K_2 Q^{0.36} \quad \dots\dots(17)$$

$$Y = 1.21 R \text{ for } R < 2.1 \text{ m.} \quad \dots\dots(18)$$

$$Y = 0.61 + 0.93 R \text{ for } R > 2.1 \text{ m.} \quad \dots\dots(19)$$

$$V = K_3 (R^2.S)^n \quad \dots\dots(20)$$

$$\frac{C^2}{g} = \frac{V^2}{gYS} = K_4 \left(\frac{V.B}{Y} \right)^{0.37} \quad \dots\dots(21)$$

in which;

C = Chezy's roughness coefficient;

B = mean width;

B_s = surface width;

Y = depth of flow; and

y, P, R, and S have their usual meaning values of coefficients K₁, K₂, K₃, K₄ and n depend on the type of canal as in Table (2).

Limitations:

The regime methods were generally derived for bed load estimation with little account being given to the effect of suspended load or wash load. The equations are generally developed for steady state conditions, where the discharges are steady and the sediment loads are steady; and for canals which have adjusted their width, depth and slope to final values. The developments of the equations have largely for straight channels in alluvium, little account was made for the effect of meandering.

Table (3): Bahr Yusuf Distributaries (1980).

| Name | Max. Q m ³ /sec. | Average Q m ³ /sec. | Standard deviation m ³ /sec. | Coefficient of variation C _v | Frequency of max Q (36) |
|-------------------|--------------------------------|-----------------------------------|--|--|----------------------------|
| Sennoures | 5.630 | 3.890 | 1.260 | 0.324 | 2 |
| El-Zamya | 1.792 | 1.343 | 0.354 | 0.264 | 2 |
| Senrou | 2.350 | 1.404 | 0.523 | 0.373 | 5 |
| Talet | 2.980 | 2.190 | 0.785 | 0.359 | 4 |
| Wahby | 14.780 | 10.770 | 3.706 | 0.344 | 2 |
| Abou Seer | 0.630 | 0.344 | 0.118 | 0.344 | 3 |
| Agoose | 1.921 | 1.565 | 0.513 | 0.330 | 13 |
| El-Nahgara | 0.1302 | 0.078 | 0.026 | 0.330 | 1 |
| Kahafa | 0.1206 | 0.081 | 0.0314 | 0.387 | 6 |
| El-Aalam | 1.934 | 1.480 | 0.500 | 0.337 | 3 |
| Tanhala | 4.220 | 3.070 | 1.072 | 0.349 | 3 |
| Dar El Ramed | 0.1353 | 0.0968 | 0.0348 | 0.361 | 6 |
| Hawwara | 0.2851 | 0.212 | 0.073 | 0.312 | 19 |
| Baga | 0.1096 | 0.1096 | zero | zero | 36 |
| El-Agoose | 0.246 | 0.201 | 0.053 | 0.265 | 15 |
| Bahr Yusuf (1980) | 66.90 | 47.81 | 14.34 | 0.30 | 2 |
| Bahr Yusuf (1981) | 61.23 | 47.41 | 12.74 | 0.27 | 2 |
| Bahr Yusuf (1982) | 59.93 | 46.55 | 12.74 | 0.274 | 2 |

Table (4): Damietta Branch (1976).

| Frequency of max. discharge | Chainage K.M. | Max. Q m ³ /sec. | Average Q m ³ /sec. | Standard deviation m ³ /sec. | C _v | Name |
|-----------------------------|---------------|-----------------------------|--------------------------------|---|----------------|-------------------|
| 1/30 | 89.00 | 132.52 | 73.49 | 33.28 | 0.45 | Zefta barrage |
| 1/30 | 143.50 | 132.52 | 73.50 | 33.29 | 0.453 | Mansoura lock |
| 1/30 | 171.00 | 132.52 | 69.19 | 33.36 | 0.48 | Bozet strg |
| 1/30 | 201.00 | 128.93 | 58.18 | 30.78 | 0.53 | Kafr Saad strg |
| 1/30 | 212.80 | 123.72 | 56.02 | 30.08 | 0.54 | El-Passasy feeder |
| 1/30 | 221.5 | 105.2 | 48.60 | 29.87 | 0.615 | El-Enania lock |
| 1/20 | 89.00 | 109.20 | 63.81 | 32.09 | 0.50 | Ten days average |
| 1/20 | 143.50 | 109.20 | 64.67 | 30.76 | 0.48 | average |
| 1/20 | 171.00 | 98.78 | 59.10 | 29.15 | 0.491 | discharge |
| 1/20 | 201.00 | 79.43 | 46.04 | 22.91 | 0.50 | |
| 1/20 | 212.80 | 78.27 | 42.99 | 21.82 | 0.51 | |
| 1/20 | 221.50 | 77.12 | 33.28 | 26.96 | 0.81 | |

Table (1): Range of Data used by Simons & Albertson (After Raudikivi 1976).

| Number | Discharge m ³ /sec. | | Slope x 10 ³ | | Average sediment concentration p.p.m. | d mm |
|--------|--------------------------------|-------|-------------------------|-------|---------------------------------------|-----------------|
| | Min. | Max. | Min. | Max. | | |
| 15 | 0.48 | 42.5 | 0.79 | 9.70 | - | 20 - 80 |
| 42 | 0.14 | 254.9 | 0.12 | 0.34 | 238 | 0.43 |
| 28 | 8.81 | 256.5 | 0.059 | 0.100 | 156-3590 | 0.0346 - 0.1642 |
| 4 | - | - | - | - | 2500-8000 | - |
| 24 | 1.22 | 29.4 | 0.058 | 0.387 | - | 0.028-7.6 |

Table (2): Coefficients for Simon and Albertson's Eqns. in Metric System (After Henderson, 1970).

| Type of Material | K ₁ | K ₂ | K ₃ | K ₄ | n |
|---|----------------|----------------|----------------|----------------|------|
| Sand bed and banks | 6.34 | 0.572 | 9.28 | 0.33 | 0.33 |
| Sand bed and cohesive banks | 4.71 | 0.484 | 10.67 | 0.54 | 0.35 |
| Cohesive bed and banks | 3.98 | 0.407 | - | 0.87 | - |
| Coarse non cohesive material | 3.17 | 0.253 | 10.67 | - | 0.29 |
| Sand bed and cohesive banks with heavy sediment load. | 3.06 | 0.374 | 9.71 | - | 0.29 |

Table (6): Actual Measurements.
(Mean values of three successive cross sections)

Bahr Yusuf Distributaries. (1980)

| Name of canal | A m ² | Y m | B _s m ² | P m | B m | R m | D m | S x10 ⁵ |
|---------------|------------------|------|-------------------------------|-------|-------|-------|------|--------------------|
| Sennoures | 4.50 | 0.85 | 8.20 | 8.60 | 5.29 | 0.526 | 0.55 | - |
| El-Zawya | 9.25 | 1.33 | 9.07 | 10.13 | 6.93 | 0.913 | 1.02 | - |
| Seniro | 9.75 | 0.98 | 11.57 | 12.57 | 9.98 | 0.778 | 0.84 | - |
| Talat | 8.85 | 1.19 | 11.16 | 10.52 | 7.46 | 0.793 | 0.84 | - |
| Wahby | 28.5 | 1.90 | 21.40 | 20.45 | 15.00 | 1.330 | 1.39 | - |
| Aboueeer | 6.13 | 1.10 | 8.13 | 7.77 | 5.58 | 0.760 | 0.79 | - |
| Aroose | 13.1 | 1.63 | 12.57 | 11.83 | 7.98 | 1.042 | 1.11 | - |
| El-Mehgara | 1.75 | 0.60 | 4.27 | 3.77 | 2.99 | 0.406 | 0.46 | 35.71 |
| Kohafa | 0.68 | 0.38 | 2.73 | 2.47 | 1.94 | 0.250 | 0.28 | 31.15 |
| El-Aalam | 13.5 | 1.62 | 12.07 | 10.63 | 8.35 | 1.120 | 1.27 | 31.00 |
| Tanhala | 16.13 | 1.83 | 15.23 | 14.10 | 8.95 | 1.055 | 1.14 | 74.60 |
| Dar ElReaad | 1.25 | 0.30 | 0.40 | 4.30 | 4.17 | 0.326 | 0.29 | 16.60 |
| Hawwara | 4.42 | 0.73 | 4.10 | 3.80 | 3.33 | 0.573 | 0.64 | - |
| Baga | 1.60 | 0.60 | 4.16 | 3.63 | 2.67 | 0.384 | 0.44 | 41.06 |
| El-Agoose | 2.45 | 0.63 | 5.50 | 5.00 | 3.98 | 0.441 | 0.49 | - |

Table (5) Actual Measurements
(Mean values of three successive cross sections)

Zaghlola 1977/1978.

| c. No. | A m ² | Y m | B _s m ² | P m | B m | D m | R m | S x10 ⁵ |
|--------|------------------|-------|-------------------------------|-------|------|-------|-------|--------------------|
| 1 | 15.00 | 1.98 | 10.10 | 11.30 | 7.53 | 1.48 | 1.33 | - |
| 2 | 12.17 | 1.65 | 10.13 | 11.37 | 7.45 | 1.22 | 1.07 | 6.67 |
| 3 | 8.33 | 1.60 | 6.97 | 8.40 | 5.22 | 1.20 | 0.994 | - |
| 4 | 8.17 | 1.50 | 7.73 | 8.94 | 5.44 | 1.057 | 0.91 | 4.40 |
| 5 | 6.23 | 1.35 | 5.80 | 7.30 | 4.61 | 1.077 | 0.85 | 7.50 |
| 6 | 4.50 | 1.283 | 5.63 | 6.53 | 3.50 | 0.80 | 0.68 | 1.90 |
| 7 | 5.15 | 1.27 | 6.07 | 6.63 | 4.09 | 0.847 | 0.773 | 10.33 |

-Zahaira 1976/1977

| c. No. | A m ² | Y m | B _s m ² | P m | B m | D m | R m | S x10 ⁵ |
|--------|------------------|-------|-------------------------------|-------|-------|-------|-------|--------------------|
| 1 | 21.33 | 2.233 | 12.77 | 14.70 | 9.55 | 1.67 | 1.453 | 9.30 |
| 2 | 13.83 | 1.833 | 8.27 | 12.40 | 7.55 | 1.293 | 1.133 | 2.30 |
| 3 | 6.20 | 1.475 | 9.50 | 10.15 | 6.43 | 1.04 | 0.935 | - |
| 4 | 5.67 | 1.200 | 6.367 | 7.23 | 4.723 | 0.89 | 0.783 | 3.20 |
| 5 | 2.50 | 0.967 | 3.700 | 4.533 | 2.56 | 0.67 | 0.547 | - |

oha 1978/1979.

| c. No. | A m ² | Y m | B _s m ² | P m | B m | D m | R m | S x10 ⁵ |
|--------|------------------|------|-------------------------------|-------|------|-------|-------|--------------------|
| 1 | 10.83 | 1.85 | 8.90 | 10.13 | 5.77 | 1.20 | 1.05 | 9.75 |
| 2 | 3.25 | 0.87 | 4.67 | 5.27 | 3.70 | 0.69 | 0.607 | 11.70 |
| 3 | 2.50 | 0.70 | 4.70 | 5.033 | 3.58 | 0.533 | 0.497 | 5.40 |

oha 1957/1958.

| c. No. | A m ² | Y m | B _s m ² | P m | B m | D m | R m | S x10 ⁵ |
|--------|------------------|-------|-------------------------------|-------|-------|-------|-------|--------------------|
| 1 | 8.633 | 1.500 | 7.50 | 8.433 | 5.793 | 1.153 | 1.021 | 8.80 |
| 2 | 3.82 | 1.233 | 5.467 | 6.067 | 3.097 | 0.693 | 0.627 | 8.50 |
| 3 | 3.00 | 0.830 | 4.57 | 4.97 | 3.607 | 0.653 | 0.600 | 7.71 |

Table (7): Median Particle Sizes, Side Factors and Bed Factors For Canals Under Study.

| | Damietta Branch c=0.0 | K.M K.M | Zaghlola c=500p.p.m | El-Zahaira c=0.0 | Snoha c=500 p.p.m | Bahr Yusuf Distrib- uterias |
|--------------------|--------------------------|------------|------------------------|---------------------|-------------------------|--------------------------------------|
| d ₅₀ mm | 0.06 | 0.06 | 0.06 | 0.006 | 0.05 | 0.05 |
| f _s | 0.10 | 0.10 | 0.10 | 0.300 | 0.30 | 0.20 |
| f _b | 0.14 | 0.14 | 15.25 | 0.026 | 0.045 | 0.13 |

Available actual bed slopes were calculated from the actual bed levels, obtained from the longitudinal sections. This calculation was based on the method of least square. Table (5) gives the actual section properties for Zaghlola 1977/1978, El-Zahiara 1976/1977, Shoha 1978/1979, and Shoha 1957/1958. The observed section properties of Bahr Yusuf's distributaries, 1980, are given in Table (6).

Soil samples were collected and analysed mechanically. The median particle size for each sample was obtained. Zaghlola, El-Zahiara and Shoha were found to have cohesive bed and banks. Bahr Yusuf and its distributaries; at the selected sections, were considered to have a sand bed and cohesive banks. Table (7) gives the median particle size and the proposed coefficients for every type of soil under investigation. The sediment load before the erection of Aswan High Dam was considered to have the value of 500 p.p.m. in average, during the year Ref.(12).

Generally, for canals under investigations Lacey's equations provided higher values for the wetted perimeter, hydraulic radius, consequently water area, and also smaller values of bed slopes, than those given by Simons-Albertson's equations. The values of bed slope given by Simons-Albertson's equations are bigger than the corresponding values given by the two other approaches.

The values of velocity given by Simons Albertson's equations of Dakahlia region (Zaghlola, El-Zahiara and Shoha) were bigger than those given by both Lacey and Blench's equations. In El-Fayoum region Blench's equations provided higher values of velocity than the corresponding values given by the other two approaches.

Equation (2) of Lacey shows that the wetted perimeter of stable channel is constant for a given discharge and independent of the fineness of silt which is not true. However it is well known that the silt size influence the shape of cross sections. Coarse material will exhibit larger value of B_s ($B_s = P$ for wide rivers). Lacey advocated use of only wetted perimeter for rivers. Even this formula was shown to apply to rivers on the basis of limited data comprising only seven observations Ref.(2). Therefore it was considered to examine the fitness of Lacey's equations to more extensive data.

Blench's equations do allow for varying of bank cohesion although these equations show that B and D are very sensitive to errors in bed and side factors which could be estimated arbitrary; the engineer might be advised to select a test reach of the canals and investigate both the side factor f_s and bed factor f_b by himself.

RESULTS AND ANALYSES:

Parallel with the development of regime equations in India similar work was going in Egypt, Molesworth, et al. (1917), Buckley (1919), Kinder (1919) and Chaleb (1929 - 1930) Ref.(3). All of them have in common a Kennedy type relationship and breadth slope relationship. An account of these formulae is given in Leliavsky Ref.(6).

The regime equations under study were applied to two types of irrigation canals; canals subjected to the system of irrigation turns which are Zaghloa, El-Zahiara and Shoha, and those which are used as carriers such as Bahr Yusuf's distributaries. Also the different approaches were applied to some sections along Damietta branch of the river Nile and Bahr Yusuf downstream El-Lahoun regulator.

Water discharges at the selected cross sections for Zaghloa, El-Zahiara and Shoha were based on the water duty and area served. Water losses should be considered in estimating the actual discharge at every particular section; for main and secondary canals, losses vary between 10% during winter and 20% during summer. These losses are in the form of seepage losses, evaporation from water surface, transpiration of aquatic plants and intake leaks Ref.(11). However the actual water duty was considered to be 60 m³/fedd./day.

Discharges of Bahr Yusuf just downstream El-Lahoun regulator, its distributaries and Damietta branch were obtained from Ministry of Irrigation Refs.(7, 8). The average discharges during the year, standard deviations, and coefficients of variation for Bahr Yusuf and most of its distributaries are given in Table (3) and for Damietta branch are given in Table (4). A comparison between the coefficients of variation in the two tables demonstrates that the discharge of Damietta branch is more variable than the discharge of Bahr Yusuf or its distributaries, during the year.

The canal cross sections were chosen in straight reaches and being in their natural conditions, with the possible minimum influences of any hydraulic structures.

Section properties at each location were represented by the arithmetic mean of the properties of three successive cross sections each of about 200 m apart.

The water area of every natural cross section was planimeted, using a planimeter having an accuracy of 0.1 m².

These equations overestimated the water depth and underestimated the mean depth Tables (8, 12 and 13). This result implies a serious drawback in Blench's approach. Increasing the sediment concentration decreased the water depth and water area; increased the critical mean velocity, bed slope and mean width of the channel Table (12).

Due to the approximate nature of Simons-Albertson's equations, there are minor geometrical incompatibilities in the results given by these equations. One of them has already been shown in this research $R.P < B.Y$, Tables (9 & 10), although the two values should be equal giving the water area. Also $P < B_s$, although P should be greater than B_s . None of these errors are serious as they are no larger than 12% which could be accepted in this type of work.

For good results of Simons-Albertson's equations the bed load concentration should be less than 500 p.p.m. Ref. (3). No account was made, by Simons-Albertson's equations, for varying the sediment concentration. Also the equation did not allow for the variations of the median particle size inside any particular type of soil.

For Damietta branch, the computed section properties, using the different approaches, deviate radically from the actual properties, both before and after the erection of Aswan High Dam Table (13). This could be due to a more variable discharge than the case of canals. Blench's equations underestimated the mean width and over estimated the mean water depth and bed slope. Also Lacey's approach underestimated the wetted perimeter, hydraulic radius and water area. All section properties were underestimated by using Simons-Albertson's method. However little contribution have been made for the regime equations in rivers as an accurate data are usually not available.

In case of Bahr Yusuf, Blench's equations underestimated the mean width and water area and over estimated the mean water depth. Lacey's equations may provide acceptable results for hydraulic radius, wetted perimeter and water area. Simons-Albertson's approach could also provide acceptable results for more section properties as given in Table (13). It may be said better results could be achieved in case of Bahr Yusuf as its discharge is less variable than the discharge of Damietta branch Tables (3 & 4).

C. 34 A.R. Zidan

Table (8): Bahr Yusuf Distributaries (1980).

| Name | Blench's Equations | | | | | Lacey's Equations | | | | |
|--------------|--------------------|------|-------------------------|--------|---------------|-------------------|----------------|-------|--------|---------------|
| | B | D | A _{av} | V | S | P | A | R | V | S |
| | m | m | $\frac{B \cdot D}{m^2}$ | m/sec. | $\times 10^5$ | m | m ² | m | m/sec. | $\times 10^5$ |
| Sennourea | 1.92 | 4.06 | 7.80 | 0.72 | 10.64 | 11.47 | 13.617 | 1.187 | 0.414 | 4.21 |
| El-Zawya | 1.08 | 2.77 | 2.99 | 0.60 | 12.88 | 6.47 | 5.173 | 0.800 | 0.342 | 5.55 |
| Senro | 1.24 | 3.03 | 3.76 | 0.63 | 12.32 | 7.41 | 6.574 | 0.887 | 0.358 | 4.87 |
| Talaat | 1.40 | 3.28 | 4.59 | 0.65 | 11.84 | 8.34 | 8.01 | 0.960 | 0.372 | 4.68 |
| Wahby | 3.11 | 5.60 | 17.42 | 0.85 | 9.06 | 18.58 | 30.43 | 1.638 | 0.466 | 3.57 |
| Abouseeer | 0.64 | 1.96 | 1.25 | 0.50 | 15.34 | 3.84 | 2.20 | 0.572 | 0.287 | 6.04 |
| Aroose | 1.12 | 2.83 | 3.17 | 0.61 | 12.74 | 1.921 | 1.59 | 0.830 | 0.346 | 5.04 |
| El-Mahgara | 0.29 | 1.16 | 0.34 | 0.38 | 19.95 | 1.74 | 0.59 | 0.338 | 0.221 | 7.89 |
| Kohafa | 0.28 | 1.13 | 0.32 | 0.38 | 20.20 | 1.68 | 0.55 | 0.330 | 0.218 | 7.99 |
| El-Aalam | 1.13 | 2.84 | 3.21 | 0.60 | 12.72 | 6.72 | 5.58 | 0.830 | 0.346 | 5.03 |
| Tenhala | 1.66 | 4.69 | 7.79 | 0.54 | 11.17 | 9.93 | 10.71 | 1.078 | 0.394 | 4.42 |
| Dar El-Ramad | 0.30 | 1.17 | 0.35 | 0.39 | 19.82 | 1.78 | 0.61 | 0.343 | 0.222 | 7.84 |
| Hawware | 0.43 | 1.50 | 0.65 | 0.44 | 17.50 | 2.58 | 1.13 | 0.439 | 0.252 | 6.92 |
| Baga | 0.27 | 1.09 | 0.29 | 0.38 | 20.53 | 1.60 | 0.51 | 0.319 | 0.215 | 8.11 |
| Aroose | 0.40 | 1.43 | 0.57 | 0.43 | 17.94 | 2.40 | 1.00 | 0.418 | 0.246 | 7.09 |

Table (9): Simons-Albertson Equations.
Bahr Yusuf Distributaries (1980).

| Name | P | B | B _g | R | Y | A ₁ _{av} | A ₂ _{av} | A _{av} | V | S ₁ | S ₂ | S _{av} |
|--------------|-------|-------|----------------|------|------|------------------------------|------------------------------|-----------------|--------|----------------|----------------|-----------------|
| | m | m | m | m | m | $\frac{P \cdot R}{m^2}$ | $\frac{B \cdot Y}{m^2}$ | m ² | m/sec. | $\times 10^4$ | $\times 10^4$ | $\times 10^4$ |
| Sennourea | 11.18 | 10.06 | 11.60 | 0.90 | 1.09 | 10.62 | 10.97 | 10.80 | 0.52 | 1.43 | 1.54 | 1.49 |
| El-Zawya | 6.31 | 5.68 | 6.84 | 0.60 | 0.73 | 3.79 | 4.15 | 3.97 | 0.45 | 2.08 | 2.22 | 2.15 |
| Senrou | 7.22 | 6.50 | 7.73 | 0.66 | 0.80 | 4.77 | 5.20 | 4.99 | 0.47 | 1.96 | 2.07 | 2.02 |
| Talet | 8.13 | 7.32 | 8.62 | 0.72 | 0.87 | 5.85 | 6.37 | 6.11 | 0.49 | 1.88 | 1.96 | 1.92 |
| Wahby | 18.11 | 16.30 | 18.38 | 1.28 | 1.55 | 23.18 | 25.27 | 24.23 | 0.61 | 1.14 | 1.17 | 1.16 |
| Abouseeer | 3.74 | 3.37 | 4.33 | 0.41 | 0.60 | 1.53 | 1.69 | 1.61 | 0.39 | 2.89 | 3.04 | 2.97 |
| Aroose | 6.53 | 5.88 | 7.05 | 0.61 | 0.74 | 3.98 | 4.35 | 4.17 | 0.46 | 2.15 | 2.26 | 2.21 |
| El-Mahgara | 1.70 | 1.53 | 2.33 | 0.23 | 0.28 | 0.39 | 0.43 | 0.41 | 0.32 | 5.13 | 5.43 | 5.28 |
| Kohafa | 1.64 | 1.48 | 2.27 | 0.23 | 0.28 | 0.38 | 0.41 | 0.40 | 0.30 | 4.19 | 4.94 | 4.57 |
| El-Aalam | 6.55 | 5.90 | 7.08 | 0.61 | 0.74 | 4.00 | 4.37 | 4.19 | 0.46 | 2.15 | 2.26 | 2.21 |
| Tenhala | 9.68 | 8.71 | 10.13 | 0.81 | 0.98 | 7.84 | 8.54 | 8.19 | 0.52 | 1.77 | 1.80 | 1.79 |
| Dar El-Ramad | 1.73 | 1.56 | 2.36 | 0.24 | 0.29 | 0.42 | 0.45 | 0.44 | 0.31 | 4.26 | 4.94 | 4.60 |
| Hawware | 2.52 | 2.27 | 3.13 | 0.31 | 0.38 | 0.78 | 0.86 | 0.82 | 0.35 | 3.69 | 4.00 | 3.85 |
| Baga | 1.56 | 1.40 | 2.19 | 0.22 | 0.27 | 0.34 | 0.38 | 0.36 | 0.30 | 4.63 | 5.22 | 4.93 |
| Al-Agoose | 2.34 | 2.11 | 2.96 | 0.29 | 0.35 | 0.68 | 0.74 | 0.71 | 0.35 | 4.21 | 4.46 | 4.34 |

Table (10): Simons-Albertson Equations

Zaghlola

| Sec. No. | P | B | B _g | R | Y | P.R | B.Y | A _{av} | V | S ₁ | S ₂ | S _{av} |
|----------|-------|-------|----------------|-------|------|----------------|----------------|-----------------|--------|----------------|----------------|-----------------|
| | m | m | m | m | m | m ² | m ² | m ² | m/sec. | $\times 10^4$ | $\times 10^4$ | $\times 10^4$ |
| 1 | 11.68 | 10.51 | 12.09 | 0.884 | 1.07 | 10.33 | 11.25 | 10.79 | 0.80 | 5.39 | 1.93 | 3.66 |
| 2 | 11.15 | 10.04 | 11.58 | 0.855 | 1.04 | 9.53 | 10.44 | 9.99 | 0.79 | 5.55 | 1.97 | 3.76 |
| 3 | 10.12 | 9.11 | 10.57 | 0.800 | 0.97 | 8.10 | 8.84 | 8.47 | 0.76 | 5.65 | 2.07 | 3.86 |
| 4 | 9.50 | 8.55 | 9.96 | 0.761 | 0.92 | 7.23 | 7.87 | 7.55 | 0.75 | 6.00 | 2.17 | 4.09 |
| 5 | 8.26 | 7.43 | 8.74 | 0.689 | 0.83 | 5.69 | 6.17 | 5.93 | 0.73 | 6.74 | 2.42 | 4.58 |
| 6 | 5.84 | 5.26 | 6.38 | 0.536 | 0.65 | 3.13 | 3.42 | 3.28 | 0.66 | 8.26 | 2.99 | 5.63 |
| 7 | 2.97 | 2.67 | 3.57 | 0.330 | 0.40 | 0.98 | 1.07 | 1.03 | 0.54 | 11.93 | 4.50 | 8.22 |

El-Zahara

| Sec. No. | P | B | B _g | R | Y | P.R | B.Y | A _{av} | V | S ₁ | S ₂ | S _{av} |
|----------|-------|------|----------------|-------|------|----------------|----------------|-----------------|--------|----------------|----------------|-----------------|
| | m | m | m | m | m | m ² | m ² | m ² | m/sec. | $\times 10^4$ | $\times 10^4$ | $\times 10^4$ |
| 1 | 10.98 | 9.88 | 11.40 | 0.845 | 1.02 | 9.28 | 10.08 | 9.68 | 0.79 | 5.68 | 2.01 | 3.85 |
| 2 | 9.50 | 8.55 | 9.96 | 0.761 | 0.92 | 7.23 | 7.87 | 7.55 | 0.75 | 6.00 | 2.17 | 4.09 |
| 3 | 5.65 | 5.09 | 6.20 | 0.524 | 0.63 | 2.96 | 3.21 | 3.09 | 0.65 | 8.23 | 3.04 | 5.64 |
| 4 | 4.33 | 3.90 | 4.90 | 0.432 | 0.52 | 1.87 | 2.03 | 1.95 | 0.61 | 10.00 | 3.69 | 6.85 |
| 5 | 2.78 | 2.50 | 3.38 | 0.314 | 0.38 | 0.87 | 0.95 | 0.91 | 0.53 | 12.39 | 4.71 | 8.55 |

Shoha

| Sec. No. | P | B | B _g | R | Y | P.R | B.Y | A _{av} | V | S ₁ | S ₂ | S _{av} |
|----------|------|------|----------------|-------|------|----------------|----------------|-----------------|--------|----------------|----------------|-----------------|
| | m | m | m | m | m | m ² | m ² | m ² | m/sec. | $\times 10^4$ | $\times 10^4$ | $\times 10^4$ |
| 1 | 6.29 | 5.66 | 6.82 | 0.566 | 0.69 | 3.56 | 3.91 | 3.74 | 0.67 | 7.74 | 2.80 | 5.27 |

Table (11): Lacey's Equations

Zaghlola

| Sec. No. | Q m ³ /sec. | F m | A m ² | R m | V m/sec. | S x10 ⁶ |
|----------|---------------------------|--------|---------------------|--------|-------------|-----------------------|
| 1 | 8.611 | 14.180 | 33.15 | 2.340 | 0.260 | 2.640 |
| 2 | 7.850 | 13.540 | 30.69 | 2.270 | 0.255 | 2.690 |
| 3 | 6.460 | 12.280 | 26.09 | 2.130 | 0.248 | 2.760 |
| 4 | 5.695 | 11.533 | 23.49 | 2.038 | 0.243 | 2.830 |
| 5 | 4.310 | 10.033 | 18.62 | 1.860 | 0.232 | 2.960 |
| 6 | 2.150 | 7.080 | 10.43 | 1.473 | 0.206 | 3.330 |
| 7 | 0.556 | 3.600 | 3.30 | 0.940 | 0.165 | 4.180 |

El-Zahara

| | | | | | | |
|---|-------|--------|-------|-------|-------|-------|
| 1 | 7.617 | 13.340 | 24.78 | 1.860 | 0.307 | 6.840 |
| 2 | 5.695 | 11.533 | 19.45 | 1.690 | 0.293 | 7.180 |
| 3 | 2.014 | 6.860 | 8.18 | 1.193 | 0.246 | 8.530 |
| 4 | 1.191 | 5.252 | 5.24 | 1.000 | 0.225 | 9.330 |
| 5 | 0.486 | 3.370 | 2.502 | 0.743 | 0.194 | 10.01 |

Shoha

| | | | | | | |
|---|------|-------|------|-------|-------|-------|
| 1 | 2.50 | 7.641 | 6.90 | 0.903 | 0.363 | 4.820 |
| 2 | 1.11 | 5.092 | 3.50 | 0.690 | 0.317 | 5.710 |
| 3 | 0.63 | 3.840 | 2.19 | 0.570 | 0.288 | 6.040 |

Table(12): Blench's Equations.

Zaghlola

| Sec. No. | B m | D m | A=D.B m ² | V m/sec. | S x 10 ⁵ |
|----------|--------|--------|-------------------------|-------------|------------------------|
| 1 | 0.85 | 15.64 | 13.29 | 0.65 | 2.68 |
| 2 | 0.81 | 15.16 | 12.28 | 0.64 | 2.72 |
| 3 | 0.74 | 14.21 | 10.52 | 0.61 | 2.81 |
| 4 | 0.69 | 13.63 | 9.41 | 0.61 | 2.87 |
| 5 | 0.60 | 12.40 | 7.44 | 0.58 | 3.01 |
| 6 | 0.43 | 9.05 | 4.24 | 0.51 | 3.38 |
| 7 | 0.22 | 6.27 | 1.30 | 0.40 | 4.24 |

El-Zahira

| Sec. No. | B m | D m | A=D.C m ² | V m/sec. | S x 10 ⁵ |
|----------|--------|--------|-------------------------|-------------|------------------------|
| 1 | 1.08 | 10.41 | 11.24 | 0.60 | 4.32 |
| 2 | 0.93 | 9.45 | 8.79 | 0.55 | 4.54 |
| 3 | 0.55 | 6.68 | 3.67 | 0.55 | 5.30 |
| 4 | 0.42 | 5.50 | 2.35 | 0.50 | 5.89 |
| 5 | 0.27 | 4.16 | 1.12 | 0.43 | 6.83 |

Shoha

c = 0.00

| Sec. No. | B m | D m | A=B.D m ² | V m/sec. | S x 10 ⁴ |
|----------|--------|--------|-------------------------|-------------|------------------------|
| 1 | 1.04 | 3.54 | 3.66 | 0.60 | 1.26 |
| 2 | 0.70 | 2.70 | 1.85 | 0.59 | 1.45 |
| 3 | 0.52 | 2.24 | 1.17 | 0.54 | 1.59 |

Shoha

C = 500 P.P.m.

| | | | | | |
|---|------|-------|------|------|------|
| 1 | 8.13 | 0.290 | 2.36 | 1.00 | 1.23 |
| 2 | 5.42 | 0.174 | 0.94 | 1.16 | 1.41 |
| 3 | 4.08 | 0.144 | 0.59 | 1.07 | 1.59 |

Table (13): Comparison between Actual and Calculated Properties

Damietta Branch (1976), K.M. 221.5

Q_{max} = 105.2 m³/sec.

| | P m | B m | B _s m | R m | Y m | D m | A m ² | S x10 ⁵ | V m/sec. |
|---------------|--------|--------|---------------------|--------|--------|--------|---------------------|-----------------------|-------------|
| Actual | 286.7 | 194.1 | 294.0 | 6.170 | 9.33 | 5.88 | 172.70 | - | - |
| Lacey | 49.57 | - | - | 3.072 | - | - | 152.19 | 2.92 | 0.69 |
| Blench | - | 16.2 | - | - | - | 5.52 | 89.42 | 10.63 | 1.18 |
| Simons et al. | 65.03 | 58.53 | 64.28 | 3.060 | 3.46 | 3.12 | 200.75 | 2.99 | 0.52 |

Damietta Branch (1938), K.M. = 171.0

Q_{max} = 132.52 m³/sec.

| | P m | B m | B _s m | R m | Y m | D m | A m ² | S x10 ⁵ | V m/sec. |
|---------------|--------|--------|---------------------|--------|--------|--------|---------------------|-----------------------|-------------|
| Actual | 268.1 | 204.1 | 255.0 | 7.00 | 9.275 | 9.535 | 1876.0 | - | - |
| Lacey | 55.63 | - | - | 3.32 | - | - | 184.48 | 2.81 | 0.72 |
| Blench | - | 142.17 | - | - | - | 0.490 | 69.66 | 84.00 | 1.90 |
| Simons et al. | 72.98 | 65.68 | 72.05 | 3.32 | 3.700 | 3.370 | 242.66 | 2.95 | 0.55 |

Bahr Yusuf (1980), Downstream El-Lahoun Regr.

Max: Q = 66.9 m³/sec.

| | P m | B m | B _s m | R m | Y m | D m | A m ² | S x10 ⁵ | V m/sec. |
|---------------|--------|--------|---------------------|--------|--------|--------|---------------------|-----------------------|-------------|
| Actual | 42.57 | 29.07 | 39.47 | 2.910 | 4.25 | 3.130 | 123.90 | 36.33 | - |
| Lacey | 39.53 | - | - | 2.709 | - | - | 107.09 | 2.79 | 0.625 |
| Blench | - | 6.63 | - | - | - | 9.260 | 61.39 | 7.05 | 1.090 |
| Simons et al. | 38.52 | 34.67 | 38.35 | 2.200 | 2.66 | 2.307 | 88.48 | 7.50 | 0.760 |

C. 36 A.R. Zidan

Table (18): One Way ANOVA

$$F_{0.05,1,28} = 4.2$$

Dekahlia (Zghlola, El-Zehiara and Shoha)

| Source of variation | d.f. | Mean sum squares | P | B | B _g | R | Y | D | A | S | V |
|---------------------|------|------------------|--------|--------|----------------|-------|-------|--------|--------|--------|-----------------------|
| Between Groups | 1 | σ^2 | 0.042 | - | - | 4.214 | - | - | 575.30 | 10.170 | - |
| | | σ^2_{LB} | - | 344.60 | - | - | - | 902.10 | 37.260 | 17.450 | - |
| | | σ^2_{LS} | 36.974 | 13.09 | 0.508 | 1.405 | 7.754 | 3.135 | 158.43 | 150.93 | - |
| Within Groups | 28 | σ^2 | 10.800 | - | - | 0.218 | - | - | 70.400 | 163.15 | - |
| | | σ^2_{LB} | - | 1.782 | - | - | - | 10.305 | 22.470 | 24.580 | - |
| | | σ^2_{LS} | 8.990 | 5.700 | 7.606 | 0.056 | 0.114 | 0.070 | 19.390 | 38.057 | - |
| F-Calculated | | F _L | 0.004 | - | - | 19.33 | - | - | 8.100 | 0.062 | - |
| | | F _B | - | 193.40 | - | - | - | 87.540 | 3.260 | 0.710 | - |
| | | F _S | 4.110 | 2.30 | 0.070 | 25.31 | 68.01 | 45.110 | 8.180 | 0.004 | - |
| Between Groups | 1 | σ^2_{LB} | - | - | - | - | - | - | 1059.2 | 11.380 | 1.526 |
| | | σ^2_{LS} | 34.52 | - | - | 10.48 | - | - | 1337.6 | 144.86 | 2.700 |
| | | σ^2_{BS} | - | 492.0 | - | - | - | 1011.6 | 16.22 | 152.14 | 0.1654 |
| Within Groups | 28 | σ^2 | - | - | - | - | - | - | 66.24 | 314.37 | 4.7x10 ⁻³ |
| | | σ^2_{LB} | 11.55 | - | - | 0.203 | - | - | 63.10 | 432.04 | 5.6x10 ⁻³ |
| | | σ^2_{LS} | - | 3.982 | - | - | - | 10.28 | 15.19 | 361.47 | 7.75x10 ⁻³ |
| F-Calculated | | F _{LB} | - | - | - | - | - | - | 16.00 | 0.040 | 324.7 |
| | | F _{LS} | 2.99 | - | - | 51.63 | - | - | 21.20 | 0.003 | 482.1 |
| | | F _{BS} | - | 123.60 | - | - | - | 98.40 | 1.08 | 0.004 | 22.05 |

Table (19): One-Way ANOVA

$$F_{0.05,1,28} = 4.2$$

Bahr Yusuf Distributaries 1980.

| Source of variation | d.f. | Mean sum squares | P | B | B _g | R | Y | D | A | S | V |
|---------------------|------|------------------|--------|--------|----------------|--------|-------|--------|--------|--------|--------|
| Between Groups | 1 | σ^2 | 167.94 | - | - | 0.005 | - | - | 66.402 | 149.03 | - |
| | | σ^2_{LB} | - | 420.08 | - | - | - | 48.55 | 284.75 | 66.15 | - |
| | | σ^2_{LS} | 151.69 | 14.17 | 60.24 | 0.444 | 6.475 | 0.960 | 156.49 | 9.769 | - |
| Within Groups | 28 | σ^2 | 23.73 | - | - | 0.121 | - | - | 56.260 | 1.600 | - |
| | | σ^2_{LB} | - | 5.910 | - | - | - | 0.990 | 36.640 | 1.660 | - |
| | | σ^2_{LS} | 22.67 | 13.700 | 20.840 | 0.095 | 0.192 | 0.113 | 45.130 | 2.524 | - |
| F-Calculated | | F _L | 7.077 | - | - | 0.041 | - | - | 1.180 | 93.140 | - |
| | | F _B | - | 71.080 | - | - | - | 49.04 | 7.772 | 39.880 | - |
| | | F _S | 6.691 | 1.034 | 2.890 | 4.674 | 33.72 | 8.50 | 3.470 | 3.870 | - |
| Between Groups | 1 | σ^2_{LB} | - | - | - | - | - | - | 76.140 | 16.601 | 0.762 |
| | | σ^2_{LS} | 0.413 | - | - | 0.5415 | - | - | 19.020 | 82.490 | 0.170 |
| | | σ^2_{BS} | - | 279.94 | - | - | - | 63.610 | 19.050 | 25.080 | 0.216 |
| Within Groups | 28 | σ^2 | - | - | - | - | - | - | 39.240 | 0.0840 | 0.013 |
| | | σ^2_{LB} | 21.04 | - | - | 0.1143 | - | - | 47.730 | 0.950 | 0.0076 |
| | | σ^2_{LS} | - | 8.38 | - | - | - | 0.98 | 28.110 | 1.012 | 0.014 |
| F-Calculated | | F _{LB} | - | - | - | - | - | - | 1.940 | 197.63 | 58.62 |
| | | F _{LS} | 0.020 | - | - | 4.740 | - | - | 0.400 | 86.83 | 22.25 |
| | | F _{BS} | - | 33.41 | - | - | - | 64.45 | 0.680 | 24.78 | 15.43 |

STATISTICAL ANALYSES:(i) Analysis of Variance:

A one-way ANOVA table was used for the analysis of variance between every method used for the estimation of section properties and the actual measurements, and also between the different methods. The larger the number of observations on each treatment the smaller will be the standard error of the difference between two treatments means and hence the larger the power of the resulting significant test Ref.(1). However 5% level of significance was considered in all analyses.

$$F = \frac{\text{Treatment mean square}}{\text{Residual mean square}} \quad \text{.....(22)}$$

calculated

(ii) Least Significant Difference:

The next step after a construction of one way ANOVA table, is to decide if this table indicates that there is a significant difference between any two treatments. The least significant difference has to be calculated by the two tailed t-test; using the equation

$$s \cdot \sqrt{\frac{2}{n}} \cdot t \quad \text{.....(23)}$$

$$\frac{1}{2} \alpha, m(n-1)$$

in which;

- s = square root of the residual mean square;
- α = level of significance;
- $m(n-1)$ = degree of freedom;
- n = number of observation; and
- m = number of treatments = 2.

If the gap between any two means is less than the least significant difference then the treatments are not significantly different.

A one way ANOVA showed that the wetted perimeter given by Lacey's equations, could be accepted at 5% level of significance for all canals under investigation except for Bahr Yusuf distributaries in which this parameter could be accepted at 5% level by the least significant difference. For median particle size d_{50} varies between 0.006 mm and 0.05 mm, the hydraulic radius according to Lacey gave acceptable results at the same level Tables (16 & 17).

The water area was not given directly by Blench, it was calculated by the mean depth D multiplied by the mean width B. A one way ANOVA table provided water area, A, which could be accepted at 5% level of significance,

C: 38 A.R. Zidan

Table (14): One-Way ANOVA

$$F_{0.05,1,12} = 4.75$$

Zaghlola 1977/1978.

| Source of variation | d.f. | Mean sum squares | P | B | B _g | R | Y | D | A | S | V |
|---------------------|------|------------------|--------|--------|----------------|--------|--------|---------|---------|----------------------|----------------------|
| Between Groups | 1 | σ^2_{L} | 19.71 | - | - | 5.300 | - | - | 1052.15 | 120.80 | - |
| | | σ^2_{B} | - | 160.34 | - | - | - | 902.23 | 0.321 | 12.95 | - |
| | | σ^2_{S} | 0.137 | 35.340 | 15.541 | 0.630 | 3.230 | 1.19 | 24.220 | 1.35x10 ⁴ | - |
| Within Groups | 12 | σ^2_{1} | 7.951 | - | - | 0.127 | - | - | 56.690 | 0.0730 | - |
| | | σ^2_{2} | - | 1.073 | - | - | - | 4.807 | 14.590 | 0.2030 | - |
| | | σ^2_{3} | 5.960 | 4.437 | 5.608 | 0.037 | 0.134 | 0.043 | 12.001 | 115.74 | - |
| F-Calculated | | F _L | 2.480 | - | - | 41.732 | - | - | 18.560 | 1654.8 | - |
| | | F _B | - | 149.43 | - | - | - | 187.691 | 0.0220 | 63.790 | - |
| | | F _S | 0.023 | 7.965 | 2.771 | 17.027 | 24.104 | 27.674 | 2.0180 | 116.64 | - |
| Between Groups | 1 | σ^2_{LB} | - | - | - | - | - | - | 1089.2 | 54.650 | 0.810 |
| | | σ^2_{LS} | 23.14 | - | - | 9.582 | - | - | 1395.6 | 1.6x10 ⁴ | 1.681 |
| | | σ^2_{BS} | - | 346.24 | - | - | - | - | 968.91 | 18.970 | 1.43x10 ⁴ |
| Within Groups | 12 | σ^2_{1} | - | - | - | - | - | - | 58.100 | 0.1330 | 0.0038 |
| | | σ^2_{2} | 10.340 | - | - | 0.124 | - | - | 55.510 | 115.67 | 0.004 |
| | | σ^2_{3} | - | 3.410 | - | - | - | - | 4.803 | 13.410 | 115.80 |
| F-Calculated | | F _{LB} | - | - | - | - | - | - | 18.750 | 410.90 | 21.090 |
| | | F _{LS} | 2.240 | - | - | 77.270 | - | - | 25.140 | 138.41 | 419.20 |
| | | F _{BS} | - | 101.5 | - | - | - | - | 201.73 | 1.420 | 123.49 |

Table (15): One Way ANOVA

$$F_{0.05,1,8} = 5.32$$

El-Zahara 1976/1977.

| Source of variation | d.f. | Mean sum squares | P | B | B _g | R | Y | D | A | S | V | |
|---------------------|------|------------------|--------|--------|----------------|--------|-------|--------|--------|----------------------|----------------------|--------|
| Between Groups | 1 | σ^2_{L} | 15.00 | - | - | 0.545 | - | - | 22.58 | 22.180 | - | |
| | | σ^2_{B} | - | 151.97 | - | - | - | - | 188.81 | 100.00 | 29.620 | - |
| | | σ^2_{S} | 49.71 | 0.168 | 4.530 | 0.780 | 3.600 | 1.551 | 138.87 | 1.52x10 ⁴ | - | |
| Within Groups | 8 | σ^2_{1} | 13.65 | - | - | 0.137 | - | - | 60.21 | 0.06 | - | |
| | | σ^2_{2} | - | 2.90 | - | - | - | - | 2.804 | 30.90 | 0.47 | - |
| | | σ^2_{3} | 11.344 | 6.743 | 9.236 | 0.0674 | 0.130 | 0.136 | 29.023 | 154.93 | - | |
| F-Calculated | | F _L | 1.100 | - | - | 3.980 | - | - | 0.375 | 370.45 | - | |
| | | F _B | - | 52.403 | - | - | - | - | 67.340 | 3.240 | 63.02 | - |
| | | F _S | 4.382 | 0.025 | 0.491 | 11.57 | 27.69 | 11.404 | 4.785 | 98.11 | - | |
| Between Groups | 1 | σ^2_{LB} | - | - | - | - | - | - | 217.60 | 103.07 | 0.477 | |
| | | σ^2_{LS} | 10.10 | - | - | 2.63 | - | - | 273.43 | 3.27x10 ³ | 0.853 | |
| | | σ^2_{BS} | - | 124.05 | - | - | - | - | 224.58 | 3.184 | 1.38x10 ⁴ | 0.054 |
| Within Groups | 8 | σ^2_{1} | - | - | - | - | - | - | 44.55 | 0.430 | 0.0052 | |
| | | σ^2_{2} | 11.95 | - | - | 0.1082 | - | - | 42.68 | 154.90 | 0.0053 | |
| | | σ^2_{3} | - | 3.94 | - | - | - | - | 2.822 | 13.37 | 155.30 | 0.0087 |
| F-Calculated | | F _{LB} | - | - | - | - | - | - | 4.88 | 239.70 | 91.73 | |
| | | F _{LS} | 0.845 | - | - | 24.31 | - | - | 6.41 | 21.10 | 160.94 | |
| | | F _{BS} | - | 31.49 | - | - | - | - | 79.582 | 0.24 | 88.86 | 6.19 |

Table (16): One-Way ANOVA

$$F_{0.05,1,4} = 7.71$$

Shoha, 1978/1979.

| Source of variation | d.f. | Mean sum squares | P | B | B _g | R | Y | O | A | S | V |
|---------------------|------|------------------|--------|--------|----------------|---------|-------|--------|----------------------|--------|--------------------|
| Between Groupe | 1 | $\sigma^2_{L B}$ | 8.320 | - | - | 0.00003 | - | - | 5.230 | 0.608 | - |
| | | $\sigma^2_{S B}$ | - | 38.820 | - | - | - | 12.270 | 32.334 | 0.550 | - |
| | | σ^2_{BS} | 15.323 | 0.203 | 2.881 | 0.2240 | 1.080 | 0.466 | 32.413 | 96.02 | - |
| Within Groupe | 4 | $\sigma^2_{L B}$ | 23.712 | - | - | 0.168 | - | - | 68.840 | 1.587 | - |
| | | $\sigma^2_{S B}$ | - | 5.775 | - | - | - | 1.820 | 38.123 | 1.613 | - |
| | | σ^2_{BS} | 22.671 | 13.70 | 20.84 | 0.095 | 0.192 | 0.113 | 54.130 | 2.524 | - |
| F-Calculated | | F _L | 0.351 | - | - | 0.00002 | - | - | 0.076 | 0.383 | - |
| | | F _B | - | 6.722 | - | - | - | 6.742 | 0.848 | 0.341 | - |
| | | F _S | 0.676 | 0.015 | 0.138 | 2.360 | 5.625 | 4.124 | 0.600 | 38.04 | - |
| Between Groupe | 1 | σ^2_{LB} | - | - | - | - | - | - | 4.440 | 2.311 | 0.253 |
| | | σ^2_{LS} | 2.823 | - | - | 0.229 | - | - | 11.490 | 111.92 | 0.242 |
| | | σ^2_{BS} | - | 33.410 | - | - | - | 17.51 | 0.00005 | 82.06 | 5x10 ⁻⁵ |
| Within Groups | 4 | σ^2_{LB} | - | - | - | - | - | - | 2.530 | 0.0104 | 0.0022 |
| | | σ^2_{LS} | 2.100 | - | - | 0.014 | - | - | 2.572 | 0.590 | 0.0017 |
| | | σ^2_{BS} | - | 0.710 | - | - | - | 0.150 | 1.160 | 0.600 | 0.0029 |
| F-Calculated | | F _{LB} | - | - | - | - | - | - | 4.520 | 222.21 | 115.00 |
| | | F _{LS} | 1.344 | - | - | 16.36 | - | - | 4.470 | 189.70 | 142.40 |
| | | F _{BS} | - | 47.06 | - | - | - | 116.73 | 4.3x10 ⁻⁵ | 136.77 | 0.02 |

Table (17): One-Way ANOVA

$$F_{0.05,1,4} = 7.71$$

Shoha 1957/1958.

| Source of variation | d.f. | Mean sum squares | P | B | B _g | R | Y | D | A | S | V |
|---------------------|------|------------------|--------|--------|----------------|--------|--------|--------|--------|--------|--------|
| Between Groupe | 1 | $\sigma^2_{L B}$ | 2.823 | - | - | 0.0024 | - | - | 2.730 | 0.656 | - |
| | | $\sigma^2_{S B}$ | - | 8.772 | - | - | - | 1.191 | 44.560 | 580.92 | - |
| | | σ^2_{BS} | 11.291 | 0.0192 | 1.600 | 0.277 | 0.875 | 0.527 | 25.420 | 129.71 | - |
| Within Groupe | 4 | $\sigma^2_{L B}$ | 2.300 | - | - | 0.028 | - | - | 6.053 | 0.0507 | - |
| | | $\sigma^2_{S B}$ | - | 2.098 | - | - | - | 0.028 | 3.375 | 85.850 | - |
| | | σ^2_{BS} | 1.892 | 1.370 | 1.571 | 0.023 | 0.0441 | 0.0309 | 3.684 | 0.636 | - |
| F-Calculated | | F _L | 1.227 | - | - | 0.086 | - | - | 0.540 | 12.940 | - |
| | | F _B | - | 4.181 | - | - | - | 42.540 | 13.203 | 6.77 | - |
| | | F _S | 5.968 | 0.014 | 1.019 | 12.04 | 19.84 | 17.060 | 5.900 | 203.95 | - |
| Between Groupe | 1 | σ^2_{LB} | - | - | - | - | - | - | 25.23 | 542.55 | 1.825 |
| | | σ^2_{LS} | 2.823 | - | - | 0.214 | - | - | 11.49 | 111.92 | 0.242 |
| | | σ^2_{BS} | - | 9.612 | - | - | - | 0.134 | 2.67 | 161.63 | 0.738 |
| Within Groups | 4 | σ^2_{LB} | - | - | - | - | - | - | 2.263 | 85.810 | 0.002 |
| | | σ^2_{LS} | 2.10 | - | - | 0.137 | - | - | 2.573 | 0.590 | 0.0017 |
| | | σ^2_{BS} | - | 2.100 | - | - | - | 0.071 | 0.984 | 86.392 | 0.0027 |
| F-Calculated | | F _{LB} | - | - | - | - | - | - | 11.15 | 6.323 | 912.50 |
| | | F _{LS} | 1.344 | - | - | 1.562 | - | - | 4.47 | 189.69 | 142.35 |
| | | F _{BS} | - | 4.577 | - | - | - | 18.873 | 2.99 | 1.871 | 273.33 |

Table (20): Least Significant Differences.

t = 2.179
0.025; 12

Zaghlola

| | P | B | B ₀ | R | Y | D | A | S | V |
|-------------------------|-------|-------|----------------|-------|-------|--------|-------|-------|--------|
| $\bar{x}_0 - \bar{x}_L$ | 1.678 | - | - | 0.87 | - | - | 12.26 | 4.154 | - |
| $\bar{x}_0 - \bar{x}_B$ | - | 4.786 | - | - | - | 11.353 | 0.214 | 1.360 | - |
| $\bar{x}_0 - \bar{x}_S$ | 0.14 | 2.247 | 1.49 | 0.30 | 0.679 | 0.412 | 1.860 | 43.84 | - |
| \bar{x}_1 | 2.82 | - | - | 0.36 | - | - | 7.53 | 0.270 | - |
| \bar{x}_2 | - | 1.036 | - | - | - | 2.190 | 3.82 | 0.451 | - |
| \bar{x}_3 | 2.44 | 2.110 | 2.37 | 0.192 | 0.366 | 0.207 | 3.464 | 10.76 | - |
| L.S.D. | 3.29 | - | - | 0.420 | - | - | 8.77 | 0.315 | - |
| | 1.21 | - | - | - | - | 2.550 | 4.45 | 0.525 | - |
| | 2.84 | 2.46 | 2.76 | 0.224 | 0.43 | 0.241 | 2.17 | 12.54 | - |
| $\bar{x}_L - \bar{x}_B$ | 1.817 | - | - | 1.17 | - | - | 12.47 | 2.790 | 0.31 |
| $\bar{x}_L - \bar{x}_S$ | - | - | - | - | - | - | 14.12 | 48.0 | 0.953 |
| $\bar{x}_S - \bar{x}_B$ | - | 7.033 | - | - | - | 11.77 | 1.650 | 45.2 | 0.002 |
| \bar{x}_1 | - | - | - | - | - | - | 7.622 | 0.365 | 0.062 |
| \bar{x}_2 | 3.22 | - | - | 0.352 | - | - | 7.450 | 10.76 | 0.0632 |
| \bar{x}_3 | - | 1.850 | - | - | - | 2.192 | 3.662 | 10.76 | 0.083 |
| L.S.D. | 3.75 | - | - | - | - | - | 8.88 | 0.430 | 0.072 |
| | 1.16 | - | - | 0.41 | - | - | 8.68 | 12.54 | 0.074 |
| | 2.16 | - | - | - | - | 2.550 | 4.27 | 12.54 | 0.007 |

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

| | P | B | B ₀ | R | Y | D | A | S | V |
|-------------|--------|--------|----------------|--------|--------|--------|--------|--------|-------|
| \bar{x}_0 | 6.643 | 5.406 | 7.490 | 0.994 | 1.519 | 1.097 | 8.58C | 4.460 | - |
| \bar{x}_L | 10.321 | - | - | 1.864 | - | - | 20.84 | 0.306 | 0.230 |
| \bar{x}_B | - | 0.620 | - | - | - | 12.45 | 9.366 | 3.100 | 0.570 |
| \bar{x}_S | 8.503 | 7.653 | 8.980 | 0.694 | 0.840 | 0.685 | 6.720 | 48.30 | 0.720 |
| \bar{x}_1 | 1.889 | 1.450 | 2.830 | 0.183 | 0.227 | 0.216 | 3.630 | 0.3785 | - |
| \bar{x}_L | 3.512 | - | - | 0.463 | - | - | 10.01 | 0.9506 | 0.031 |
| \bar{x}_B | - | 0.209 | - | - | - | 3.093 | 4.000 | 0.5130 | 0.082 |
| \bar{x}_S | 2.890 | 2.602 | 2.810 | 0.183 | 0.461 | 0.200 | 3.290 | 15.21 | 0.084 |
| \bar{x}_1 | 3.892 | - | - | 1.030 | - | - | 15.851 | 4.157 | - |
| \bar{x}_L | - | 4.791 | - | - | - | 11.766 | 4.006 | 1.461 | - |
| \bar{x}_B | 2.8934 | 3.438 | 3.1983 | 0.3514 | 0.7144 | 0.458 | 3.780 | 46.40 | - |
| \bar{x}_S | - | - | - | - | - | - | - | - | - |
| \bar{x}_1 | 0.4503 | - | - | 1.091 | - | - | 1.8474 | 0.932 | - |
| \bar{x}_L | - | 0.8862 | - | - | - | 10.726 | 0.4669 | 0.3274 | - |
| \bar{x}_B | 0.3348 | 0.636 | 0.427 | 0.3535 | 0.4493 | 0.4180 | 0.4405 | 10.404 | - |

Table (21): Least Significant Difference
El-Zehaira
t = 2.306
0.025; 9

| | P | B | B ₀ | R | Y | D | A | S | V |
|-------------------------|-------|-------|----------------|-------|-------|-------|-------|-------|-------|
| $\bar{x}_0 - \bar{x}_L$ | 1.732 | - | - | 0.330 | - | - | 2.125 | 2.106 | - |
| $\bar{x}_0 - \bar{x}_B$ | - | 5.513 | - | - | - | 6.145 | 4.472 | 2.434 | - |
| $\bar{x}_0 - \bar{x}_S$ | 3.153 | 0.183 | 0.951 | 0.395 | 0.848 | 0.557 | 5.270 | 55.04 | - |
| \bar{x}_1 | 3.700 | - | - | 0.370 | - | - | 7.760 | 0.245 | - |
| \bar{x}_2 | - | 1.703 | - | - | - | 1.680 | 5.560 | 0.690 | - |
| \bar{x}_3 | 3.370 | 2.600 | 3.040 | 0.260 | 0.361 | 0.370 | 5.390 | 12.45 | - |
| L.S.D. | 5.510 | - | - | 0.550 | - | - | 11.56 | 0.360 | - |
| | 2.540 | - | - | - | - | 2.500 | 8.280 | 1.030 | - |
| | 5.020 | 3.870 | 4.530 | 0.390 | 0.540 | 0.551 | 8.030 | 18.55 | - |
| $\bar{x}_L - \bar{x}_B$ | - | - | - | - | - | - | 6.600 | 4.540 | 0.312 |
| $\bar{x}_L - \bar{x}_S$ | 1.421 | - | - | 0.725 | - | - | 7.395 | 57.15 | 0.416 |
| $\bar{x}_S - \bar{x}_B$ | - | 5.330 | - | - | - | 6.702 | 0.800 | 52.61 | 0.104 |
| \bar{x}_1 | - | - | - | - | - | - | 6.680 | 0.660 | 0.072 |
| \bar{x}_2 | 3.460 | - | - | 0.330 | - | - | 6.530 | 12.45 | 0.073 |
| \bar{x}_3 | - | 1.990 | - | - | - | 1.680 | 3.660 | 12.46 | 0.094 |
| L.S.D. | 5.160 | - | - | 0.492 | - | - | 9.950 | 0.983 | 0.107 |
| | - | 2.970 | - | - | - | 2.503 | 5.450 | 18.56 | 0.140 |

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

| | P | B | B ₀ | R | Y | D | A | S | V |
|-------------|--------|--------|----------------|--------|--------|--------|--------|--------|-------|
| \bar{x}_0 | 9.803 | 6.163 | 6.1214 | 0.970 | 1.542 | 1.113 | 9.906 | 2.960 | - |
| \bar{x}_L | 8.071 | - | - | 1.300 | - | - | 12.031 | 0.8538 | 0.253 |
| \bar{x}_B | - | 0.650 | - | - | - | 7.256 | 5.434 | 5.394 | 0.562 |
| \bar{x}_S | 6.650 | 5.980 | 7.170 | 0.575 | 0.694 | 0.556 | 4.636 | 98.00 | 0.666 |
| \bar{x}_1 | 3.612 | 2.388 | 3.036 | 0.308 | 0.450 | 0.345 | 6.823 | 0.314 | - |
| \bar{x}_L | 3.775 | - | - | 0.420 | - | - | 8.594 | 0.145 | 0.042 |
| \bar{x}_B | - | 0.307 | - | - | - | 2.343 | 3.904 | 0.916 | 0.093 |
| \bar{x}_S | 3.105 | 2.790 | 3.040 | 0.200 | 0.241 | 0.392 | 3.390 | 17.60 | 0.094 |
| \bar{x}_1 | 4.1534 | - | - | 0.5341 | - | - | 8.853 | 2.100 | - |
| \bar{x}_L | - | 5.520 | - | - | - | 6.5772 | 5.9363 | 2.601 | - |
| \bar{x}_B | 4.4252 | 2.796 | 3.1654 | 0.4428 | 0.6816 | 0.681 | 6.2662 | 57.79 | - |
| \bar{x}_S | - | - | - | - | - | - | - | - | - |
| \bar{x}_1 | 0.4237 | - | - | 0.5507 | - | - | 0.8937 | 0.7095 | - |
| \bar{x}_L | - | 0.896 | - | - | - | 5.910 | 0.600 | 0.9790 | - |
| \bar{x}_B | 0.4514 | 0.4537 | 0.3922 | 0.4564 | 0.5717 | 0.612 | 0.6326 | 19.522 | - |

Table (23): Least Significant Difference.
t = 2.776
0.025,4

Shohe 1957/1958.

| | P | B | B _g | R | Y | D | A | S | V |
|-------------------------|-------|-------|----------------|-------|-------|-------|-------|-------|-------|
| $\bar{x}_A - \bar{x}_L$ | 0.970 | - | - | 0.028 | - | - | 0.954 | 0.468 | - |
| $\bar{x}_B - \bar{x}_B$ | - | 1.710 | - | - | - | 0.630 | 3.854 | 13.92 | - |
| $\bar{x}_B - \bar{x}_S$ | 1.940 | 0.080 | 0.730 | 0.304 | 0.540 | 0.419 | 2.911 | 6.580 | - |
| θ_1 | 1.520 | - | - | 0.167 | - | - | 2.250 | 0.225 | - |
| θ_2 | - | 1.450 | - | - | - | 0.167 | 1.840 | 9.270 | - |
| θ_3 | 1.576 | 1.171 | 1.253 | 0.152 | 0.210 | 0.176 | 1.920 | 0.800 | - |
| L.S.D. | 3.450 | - | - | 0.379 | - | - | 5.100 | 0.510 | - |
| | 3.120 | 2.660 | 2.840 | 0.345 | 0.476 | 0.400 | 4.350 | 1.810 | - |
| $\bar{x}_L - \bar{x}_B$ | - | - | - | - | - | - | 2.900 | 13.45 | 0.780 |
| $\bar{x}_L - \bar{x}_S$ | 0.970 | - | - | 0.276 | - | - | 1.937 | 6.110 | 0.284 |
| $\bar{x}_S - \bar{x}_B$ | - | 1.810 | - | - | - | 0.211 | 0.943 | 7.340 | 0.496 |
| θ_1 | - | - | - | - | - | - | 1.504 | 9.260 | 0.045 |
| θ_2 | 1.450 | - | - | 0.370 | - | - | 1.604 | 0.768 | 0.041 |
| θ_3 | - | 1.450 | - | - | - | 0.084 | 0.950 | 9.300 | 0.052 |
| L.S.D. | 3.290 | - | - | 0.840 | - | - | 3.640 | 1.740 | 0.093 |
| | - | 3.290 | - | - | - | 0.190 | 2.150 | 21.10 | 0.118 |

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

| | F | B | B _g | R | Y | D | A | S | V |
|---------------|--------|--------|----------------|--------|--------|--------|--------|--------|--------|
| \bar{x}_A | 6.490 | 4.170 | 5.840 | 0.749 | 1.188 | 0.633 | 5.154 | 0.0845 | - |
| \bar{x}_L | 5.520 | - | - | 0.721 | - | - | 4.200 | 0.952 | 0.323 |
| \bar{x}_B | - | 5.680 | - | - | - | 0.203 | 1.300 | 14.00 | 1.103 |
| \bar{x}_S | 4.590 | 4.090 | 5.110 | 0.445 | 0.648 | 0.414 | 2.243 | 6.660 | 0.607 |
| θ_A | 1.445 | 1.170 | 1.226 | 0.192 | 0.275 | 0.227 | 2.483 | 0.314 | - |
| θ_L | 1.582 | - | - | 0.138 | - | - | 1.985 | 0.0515 | 0.031 |
| θ_B | - | 1.681 | - | - | - | 0.063 | 0.765 | 13.10 | 0.0544 |
| θ_S | 1.302 | 1.170 | 1.280 | 0.0915 | 0.112 | 0.101 | 1.097 | 1.083 | 0.049 |
| θ_{SL} | 1.856 | - | - | 0.1408 | - | - | 2.221 | 0.2782 | - |
| θ_{SB} | - | 2.400 | - | - | - | 0.633 | 3.930 | 21.730 | - |
| θ_{SS} | 2.3364 | 1.1727 | 1.4735 | 0.3175 | 0.650 | 0.431 | 3.111 | 5.760 | - |
| θ_{VL} | 0.286 | - | - | 0.188 | - | - | 0.4308 | 0.330 | - |
| θ_{VB} | - | 0.5750 | - | - | - | 0.7601 | 0.7624 | 25.73 | - |
| θ_{VS} | 0.360 | 0.2812 | 0.2523 | 0.4239 | 0.6576 | 0.517 | 0.6036 | 5.750 | - |

Table (22): Least Significant Difference.
t = 2.776
0.025,4

Shohe 1978/1979.

| | P | B | B _g | R | Y | D | A | S | V |
|-------------------------|-------|-------|----------------|-------|-------|-------|-------|-------|-------|
| \bar{x}_A | 1.290 | - | - | 0.003 | - | - | 1.330 | 0.450 | - |
| \bar{x}_B | - | 3.597 | - | - | - | 2.022 | 3.283 | 0.430 | - |
| $\bar{x}_B - \bar{x}_S$ | 2.260 | 0.260 | 0.980 | 0.273 | 0.600 | 0.394 | 3.287 | 5.660 | - |
| θ_1 | 4.870 | - | - | 0.410 | - | - | 8.300 | 1.260 | - |
| θ_2 | - | 2.400 | - | - | - | 1.350 | 6.174 | 1.270 | - |
| θ_3 | 4.760 | 3.700 | 4.570 | 0.310 | 0.440 | 0.336 | 7.360 | 1.590 | - |
| L.S.D. | 11.04 | - | - | 0.930 | - | - | 18.92 | 2.860 | - |
| | 10.79 | 8.390 | 10.36 | 0.703 | 1.00 | 0.762 | 24.20 | 3.610 | - |
| $\bar{x}_L - \bar{x}_B$ | - | - | - | - | - | - | 1.953 | 0.880 | 0.280 |
| $\bar{x}_L - \bar{x}_S$ | 0.970 | - | - | 0.276 | - | - | 1.937 | 6.110 | 0.284 |
| $\bar{x}_S - \bar{x}_B$ | - | 3.337 | - | - | - | 2.416 | 0.004 | 5.230 | 0.004 |
| θ_1 | - | - | - | - | - | - | 1.590 | 0.102 | 0.047 |
| θ_2 | 1.450 | - | - | 0.118 | - | - | 1.604 | 0.768 | 0.041 |
| θ_3 | - | 0.843 | - | - | - | 0.387 | 1.080 | 0.775 | 0.054 |
| L.S.D. | 3.290 | - | - | 0.268 | - | - | 4.420 | 0.231 | 0.107 |
| | - | 1.910 | - | - | - | 0.880 | 2.450 | 1.760 | 0.122 |

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

| | F | B | B _g | R | Y | D | A | S | V |
|---------------|--------|--------|----------------|--------|--------|---------|--------|--------|-------|
| \bar{x}_A | 6.810 | 4.350 | 6.090 | 0.718 | 1.140 | 0.808 | 5.530 | 1.0025 | - |
| \bar{x}_L | 5.520 | - | - | 0.721 | - | - | 4.200 | 0.5523 | 0.323 |
| \bar{x}_B | - | 0.753 | - | - | - | 2.830 | 2.247 | 1.430 | 0.603 |
| \bar{x}_S | 4.590 | 4.090 | 5.110 | 0.445 | 0.540 | 0.414 | 2.243 | 6.660 | 0.607 |
| θ_A | 2.349 | 1.005 | 1.990 | 0.239 | 0.507 | 0.285 | 1.763 | 0.626 | - |
| θ_L | 1.982 | - | - | 0.138 | - | - | 1.985 | 0.0515 | 0.031 |
| θ_B | - | 0.216 | - | - | - | 0.538 | 1.056 | 0.135 | 0.058 |
| θ_S | 1.302 | 1.170 | 1.280 | 0.0915 | 0.112 | 0.101 | 1.097 | 1.083 | 0.049 |
| θ_{SL} | 2.0413 | - | - | 0.138 | - | - | 2.389 | 0.4531 | - |
| θ_{SB} | - | 3.6035 | - | - | - | 2.09235 | 1.448 | 0.4483 | - |
| θ_{SS} | 2.6082 | 1.1985 | 1.6121 | 0.2879 | 0.6104 | 0.407 | 3.4652 | 5.9170 | - |
| θ_{VL} | 0.2998 | - | - | 0.192 | - | - | 0.4321 | 0.452 | - |
| θ_{VB} | - | 0.8284 | - | - | - | 2.590 | 0.624 | 0.4472 | - |
| θ_{VS} | 0.383 | 0.2755 | 0.2647 | 0.4010 | 0.5354 | 0.503 | 0.6266 | 7.024 | - |

Table (25): Least Significant Difference

$t_{0.025,28} = 2.048$

Bahr Yusuf Distributaries Q_{max} .

| | P | B | B _g | R | Y | D | A | S | V |
|-------------------------|-------|-------|----------------|-------|-------|-------|-------|-------|--------|
| $\bar{x}_g - \bar{x}_L$ | 3.346 | - | - | 0.018 | - | - | 2.104 | 3.152 | - |
| $\bar{x}_g - \bar{x}_B$ | - | 5.292 | - | - | - | 1.799 | 4.357 | 2.100 | - |
| $\bar{x}_g - \bar{x}_S$ | 3.180 | 0.972 | 2.004 | 0.172 | 0.527 | 0.253 | 3.230 | 0.807 | - |
| θ_1 | 4.870 | - | - | 0.348 | - | - | 7.500 | 1.270 | - |
| θ_2 | - | 2.431 | - | - | - | 1.000 | 6.053 | 1.290 | - |
| θ_3 | 4.760 | 3.700 | 4.570 | 0.308 | 0.436 | 0.336 | 6.720 | 1.590 | - |
| L.S.D. | 3.653 | - | - | 0.261 | - | - | 5.630 | 0.953 | - |
| $\bar{x}_L - \bar{x}_B$ | - | 1.820 | - | - | - | 0.750 | 4.540 | 0.970 | - |
| $\bar{x}_L - \bar{x}_S$ | 0.166 | - | - | 0.190 | - | - | 1.126 | 2.345 | 0.1054 |
| $\bar{x}_B - \bar{x}_S$ | - | 4.320 | - | - | - | 1.037 | 1.127 | 1.293 | 0.120 |
| θ_1 | - | - | - | - | - | - | 6.264 | 0.290 | 0.114 |
| θ_2 | 4.590 | - | - | 0.338 | - | - | 6.910 | 0.980 | 0.0874 |
| θ_3 | - | 2.900 | - | - | - | 0.990 | 5.300 | 1.060 | 0.1183 |
| L.S.D. | 3.440 | - | - | 0.254 | - | - | 4.700 | 0.220 | 0.086 |
| | - | 2.180 | - | - | - | 0.743 | 3.960 | 0.800 | 0.089 |

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

| | P | B | B _g | R | Y | D | A | S | V |
|-------------|---------|--------|----------------|--------|--------|-------|--------|--------|--------|
| \bar{x}_g | 9.110 | 6.310 | 8.474 | 0.713 | 1.044 | 0.770 | 7.990 | 3.840 | - |
| \bar{x}_L | 5.764 | - | - | 0.731 | - | - | 5.886 | 0.688 | 0.3146 |
| \bar{x}_B | - | 1.018 | - | - | - | 2.569 | 3.633 | 1.740 | 0.540 |
| \bar{x}_S | 5.930 | 5.338 | 6.470 | 0.541 | 0.517 | 0.517 | 4.760 | 3.033 | 0.420 |
| θ_1 | 5.036 | 3.350 | 4.752 | 0.318 | 0.505 | 0.346 | 7.325 | 1.7805 | - |
| θ_2 | 4.700 | - | - | 0.374 | - | - | 7.672 | 0.1416 | 0.0814 |
| θ_3 | - | 0.766 | - | - | - | 1.362 | 4.429 | 0.384 | 0.138 |
| θ_4 | 4.470 | 4.022 | 4.370 | 0.298 | 0.368 | 0.325 | 6.050 | 1.370 | 0.093 |
| S_L | 5.770 | - | - | 0.3744 | - | - | 7.960 | 3.156 | - |
| S_B | - | 5.347 | - | - | - | 2.045 | 6.213 | 0.2136 | - |
| S_S | 5.486 | 4.138 | 4.809 | 0.3340 | 0.5283 | 0.412 | 6.8582 | 1.368 | - |
| CV_L | 0.6333 | - | - | 0.5252 | - | - | 0.996 | 0.822 | - |
| CV_B | - | 0.8475 | - | - | - | 1.959 | 0.778 | 0.556 | - |
| CV_S | 0.60221 | 0.6558 | 0.5675 | 0.4825 | 0.5065 | 0.535 | 0.8584 | 0.3563 | - |

Table (24): Least Significant Difference Dakahlia Inspectorate.

| | P | B | B _g | R | Y | D | A | S | V |
|-------------------------|-------|-------|----------------|-------|-------|--------|--------|-------|-------|
| $\bar{x}_g - \bar{x}_L$ | 0.053 | - | - | 0.530 | - | - | 6.193 | 0.330 | - |
| $\bar{x}_g - \bar{x}_B$ | - | 4.793 | - | - | - | 10.305 | 22.470 | 0.123 | - |
| $\bar{x}_g - \bar{x}_S$ | 1.570 | 0.934 | 0.184 | 0.306 | 0.719 | 0.457 | 3.250 | 5.037 | - |
| θ_1 | 3.290 | - | - | 0.470 | - | - | 8.390 | 0.319 | - |
| θ_2 | - | 1.340 | - | - | - | 3.210 | 4.740 | 0.418 | - |
| θ_3 | 3.000 | 2.390 | 2.760 | 0.240 | 0.340 | 0.270 | 4.400 | 1.227 | - |
| L.S.D. | 2.460 | - | - | 0.530 | - | - | 6.270 | 0.240 | - |
| $\bar{x}_L - \bar{x}_B$ | - | 1.000 | - | - | - | 2.400 | 3.540 | 0.310 | - |
| $\bar{x}_L - \bar{x}_S$ | 1.517 | - | - | 0.836 | - | 8.212 | 1.041 | 4.910 | 0.105 |
| $\bar{x}_B - \bar{x}_S$ | - | 5.727 | - | - | - | - | 8.403 | 0.460 | 0.319 |
| θ_1 | - | - | - | - | - | - | 9.443 | 5.370 | 0.424 |
| θ_2 | 3.900 | - | - | 0.451 | 0.451 | - | 7.940 | 1.200 | 0.075 |
| θ_3 | - | 2.000 | - | - | - | 3.210 | 3.900 | 1.230 | 0.088 |
| L.S.D. | 2.542 | - | - | 0.337 | - | - | 6.090 | 0.290 | 0.051 |
| | - | 1.492 | - | - | - | 2.400 | 2.920 | 0.920 | 0.065 |

L.S.D. = Least Significant Difference.

Mean Value Standard Deviation & Coefficient of Variation.

| | P | B | B _g | R | Y | D | A | S | V |
|-------------|-------|-------|----------------|-------|-------|-------|--------|--------|-------|
| \bar{x}_g | 8.663 | 5.450 | 7.420 | 0.910 | 1.450 | 1.045 | 8.380 | 0.0483 | - |
| \bar{x}_L | 8.610 | - | - | 1.440 | - | - | 14.573 | 0.1532 | 0.256 |
| \bar{x}_B | - | 0.657 | - | - | - | 8.800 | 6.170 | 0.611 | 0.575 |
| \bar{x}_S | 7.093 | 6.384 | 7.604 | 0.604 | 0.731 | 0.588 | 5.130 | 5.520 | 0.680 |
| θ_1 | 2.870 | 1.870 | 2.430 | 0.266 | 0.411 | 0.303 | 5.160 | 0.403 | 0.680 |
| θ_2 | 3.790 | - | - | 0.604 | - | - | 10.684 | 0.203 | 0.050 |
| θ_3 | - | 0.252 | - | - | - | 4.530 | 4.280 | 0.432 | 0.083 |
| θ_4 | 3.120 | 2.810 | 3.055 | 0.200 | 0.241 | 0.218 | 3.4700 | 1.690 | 0.093 |
| S_L | 3.790 | - | - | 0.604 | - | - | 12.350 | 0.387 | - |
| S_B | - | 4.800 | - | - | - | 8.980 | 4.817 | 0.451 | - |
| S_S | 3.490 | 2.962 | 3.060 | 0.370 | 0.798 | 0.506 | 4.7550 | 5.310 | - |
| CV_L | 0.438 | - | - | 0.880 | - | - | 1.474 | 0.601 | - |
| CV_B | - | 0.680 | - | - | - | 8.590 | 0.574 | 0.934 | - |
| CV_S | 0.403 | 0.543 | 0.412 | 0.401 | 0.523 | 0.484 | 0.570 | 11.00 | - |

although B and D could be rejected at the same level. This is for Zahlola, El-Zahiara and Shoha. But for Shoha 1957/1958 the water area could be accepted at the same level using the least significant difference. A comparison between Shoha 1978/1979 and Shoha 1957/1958 may indicate that clear water could provide more acceptable section properties than silty water.

The bed slope introduces many uncertainties even if equations like (7), (12), (20) and (21) give a correct value of minimum bed slope to which the channel will automatically adjust itself it may be possible to use greater slopes with wider channel Ref.(4). A further point is that if as it seems likely equation (2) of wetted perimeter by Lacey is strongly dependent on equation (7) of bed slope, the designer should be aware of using equation (2) in natural river, where the bed slope may not have reached its stable value. This is particularly true in coarse alluvium Ref.(4).

Also the ANOVA and Least significant Difference tables demonstrate the degree of accuracy between every pair of approaches in calculating the section properties for canals under study; i.e. between Lacey's method and Blench's method; Lacey's method and Simons-Albertson's method and between Blench's method and Simons-Albertson's method.

(iii) Coefficient of Variation:

The coefficient of variation is defined as S/\bar{x}_a , where S is the standard deviation from the actual mean and \bar{x}_a is the arithmetic mean of the measured section property.

The coefficient of variation could be used for the comparison between the accuracy of the different methods. The section properties which could be accepted by Simons-Albertson's equations are more accurate than those given by Lacey's formulae, for Bahr Yusuf's distributaries, Zahlola, El-Zahiara, but for Shoha which has a bigger median particle size $d_{50} = 0.05$ mm; Lacey's approach provided more accurate results than the corresponding values given by Simons-Albertson's method. The section properties which could be accepted at 5% level of significance may exhibit relative larger values of some coefficients of variation, Table (25). This is mainly due to certain error in the actual measurements Ref.(9).

Table (26) demonstrates the section properties of canals under investigation which could be accepted at 5% level of significance. Also the common properties between every two approaches which could be accepted at the same

Table (26): Section Properties Which Could be Accepted at 5% Level of Significance.

| | | | | | | |
|---------------------------|-------------------------------------|-------------------------|---------------------------------|---------------------------------------|---|---|
| Equation | Zaghlola 1977/1978 | El-Zahiera 1976/1977 | Shoha 1978/1979 | Shoha 1957/1958 | Dakahlia | Bahr Yusuf Distribut- aries |
| Lacey | P | P,R,A | P,R,A,S | P,R,A,S | P,S | P [*] ,R,A |
| Blench | A | A | B,D,A,S | B,A [*] ,S | A,S | A |
| Simons,et al. | P,B _s ,B [*] ,A | P,B _s ,B,A | P,B _s ,B,R,Y, D,A | P,B _s ,B,R [*] ,A | P,B _s ,B, A [*] ,S | P [*] ,B _s ,B,A, R [*] ,S |
| Lacey-Blench | V [*] | A | A | S | S | A |
| Lacey - Simons,et al. | P,V [*] | P,A [*] | P,A | P,R,A | P,S | P,A |
| Blench - Simons,et al. | A,V [*] | A,V [*] | A,V | B,A,S | A,S | A |

* Accepted only by least significant difference.

level when calculated by any one of the two approaches, for example there is no significant difference between the calculated wetted perimeter by using either Lacey's equation or Simons-Albertson equations at 5% level of significance.

It should be emphasized that the analyses in this study were based on the maximum discharges which could have a little frequency during the year Tables (3 & 4). All canals under this investigation like all natural rivers are subjected to flow which is not steady not only does the flow vary with season of the year but it could also vary from year to year. It would be necessary to relate these calculation to some sort of dominant discharge. This could be true for calculations related to depth and breadth, but bed slope does not respond to a pronounced extent to the discharge variation.

CONCLUSIONS:

- 1) This study has confirmed that neither coefficients nor exponents of the equations are true constants, but they depend on the locality of the channel and the value of sediment discharge. This is must be expected as the regime equations are not based on rational deduction but they are equation of an empirical nature.
- 2) Discrepancies were observed between calculated properties and field data as well as between the results from various formulae under different conditions.
- 3) Simons-Albertson's method gives values of some section properties closest to the natural conditions Lacey's equations too, give reasonable results, but Blench's equations overestimate the depth and underestimate the mean width, but they could provide water area accepted at 5% level of significance.
- 4) Lacey's equations could possibly represent an alternative solution for some section properties especially for the wetted perimeter and hydraulic radius, as indicated in Table (26), but the designer would probably be safer with Simons-Albertson's equations, which have shown to fit a comprehensive range of data.
- 5) The study revealed that the more deviation of discharge from steady condition, the more discrepancies between the observed and calculated section properties (Damietta branch). This could be true as most of the regime equations were usually derived for steady state conditions. Clear water could provide more accurate results than silty water.

6) It was found in all canals under investigation that most of their natural cross sections exhibit wider surface breadths, and shallower depths than the designed typical sections (Ornakes) given by Ministry of Irrigation. However it would be recommended to collect more extensive data in order to establish more accurate regime equations being more relevant to the Egyptian canals especially after the erection of Aswan High Dam.

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APPENDIX (II) NOTATION:

The following symbols are used in this paper.

| | |
|----------------------|---|
| A | = water area; |
| ANOVA | = analysis of variance; |
| B | = water mean width; |
| C | = chezy's roughness coefficient; |
| C_v | = coefficient of variation; |
| c | = sediment concentration in p.p.m.; |
| D | = mean water depth A/Bs; |
| d.f. | = degree of freedom; |
| d50 | = median particle size in mm; |
| F | = F-test; |
| f | = silt factor; |
| f_b | = bed factor; |
| f_s | = side factor; |
| g | = acceleration due to gravity; |
| K_1, K_2, K_3, K_4 | = coefficient used for Simons-Albertson's eqns.; |
| L.S.D. | = least significant difference; |
| m | = number of treatments; |
| n | = coefficient; |
| | = number of observations or calculated properties; |
| Q | = water discharge; |
| R | = hydraulic radius; |
| S | = critical bed slope; |
| | = standard deviation from the actual mean; |
| S_{av} | = average bed slope; |
| s | = square root of the treatments mean square; |
| s_1 | = square root of the residual mean square using Lacey's equations; |
| s_2 | = square root of the residual mean square using Blench's equations; |
| s_3 | = square root of the residual mean square using Simons-Albertson's equations. |
| $\cdot s_1$ | = square root of the residual mean square within Lacey and Blench's equations; |
| $\cdot s_2$ | = square root of the residual mean square within Lacey and Simons-Albertson equations; |
| $\cdot s_3$ | = square root of the residual mean square within Blench and Simons-Albertson equations; |
| \bar{x}_a | = mean of the actual measurements; |
| \bar{x} | = mean of the calculated values; |
| α | = level of significance; |
| ν | = kinematic viscosity of water; and |
| \sim | = standard deviation. |

Subscripts

| | |
|----|---------------------------------|
| a | = actual measurements; |
| B | = Blench's equations; |
| L | = Lacey's equations; |
| S | = Simons-Albertson's equations; |
| LB | = Lacey-Blench; |
| LS | = Lacey-Simons-Albertson; and |
| BS | = Blench-Simons-Albertson. |