PERFORMANCE ASSESSMENT OF EGYPTIAN CANALS

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ABSTRACT

Operation of the irrigation network with high efficiency is the main target for water management engineers to improve the water distribution due to the increase water demand. Evaluation of the performance of Egyptian canals is the main objective of this study to improve the canal's operation. Extensive and intensive field measurements have been carried out on five Egyptian canals, which are located in Upper Egypt, Middle Egypt, and Delta, to determine the actual geometrical parameters for the selected cross section. The physical properties for soil and water samples of selected canals were also determined. Various analysis were performed for the collected and measured data to evaluate the canals' performance. It can be concluded that the conveyance efficiency for all selected reaches recorded more than 90% except the canal end. Therefore, the maintenance methods have to be applied regularly to insure passing the required discharges. The operation and maintenance guidelines have to be prepared to asses operators to improve the canals' efficiency.

INTRODUCTION

The channels have to be designed to pass the adequate discharge and operate with low maintains cost. Most irrigation canals are designed based on the regime condition. Canal is defined in regime when the canal does not suffer from scour or deposition over a given time interval. However, after operation for some time, canals usually either silt or erode. Due to inadequate maintenance and improper design, the canals are operated with low efficiency (Ahmed 1992).

Flow of real fluids is always subject to resistance and energy dissipation. Hydraulic resistance coefficient is often the basic information needed for hydraulic computation and design. Values of resistance coefficient for channels have been presented by Chow (1959) and more recently by French (1985). For a fluid flowing through an alluvial channel, the hydraulic resistance to the flow is a function of the geometry of the cross section and reach, the physical characteristics of the sediment, and the fluid properties (Camacho and Yen, 1989). As pointed out by Rouse (1965) the hydraulic resistance may be divided into four categories: 1) surface resistance, which is due to the viscous action on the channel boundary; 2) Form resistance, which is due to obstacles attached to the channel boundary including the presence of bed forms which cause a form of drag, and hence additional resistance; 3) wave resistance, which is due to the free surface distortions, generating a net pressure difference between two cross-section; 4) Resistance due to flow unsteadiness.

Molesworth and Yenidunia (1922) introduced empirical formulae to design Egyptian canals (before construction of High Aswan Dam). These formulae depend on velocity, bed width, water depth, and water surface slope. Depending on analysis of some collected data from stable Egyptian canals, El-Difrawy derived another equation to design Egyptian canals which relates the mean velocity to the depth of flow (Framji, 1972).

After the construction of High Aswan Dam, the regime of Egyptian canals has to be changed and new empirical equations were deduced. Bakry (1985) and El-Samman (1991) deduced new regime equations for design large and small Egyptian canals. These equations were modified by El-Samman and Awad (1999) to be applicable for designing or reshaping the Egyptian canals.

Two distributaries irrigation canals in El-Minia Governorate, Egypt, have been analyzed and evaluated by El-Quosy et al. (2000). The first one is operating under continuous flow while the other is under rotational flow system. It has been concluded that the continuous flow system provides better adequacy than that in the rotational flow system.

Performance assessment of canals can be obtained by analyzing the available data regarding flow velocity and discharge capacity. These data can be measured in the field to situate the channel's section, longitudinal slope and bed material properties. The Purpose of this paper is to examine some selected Egyptian canals to judge about the performance assessment of these canals and deduced recommendation to improve canal performance.

METHODOLOGY

1. Selected Canals

Five Canals were selected in Upper Egypt, Middle Egypt and Delta. These canals are Nagh Hannadi EL–Sharkia, Nagh Hammadi EL–Garbaia, EL–Samana EL–Gidida, EL–Bohaia, and EL-Ibrahmia. Two canals, which are Nagh Hannadi EL–Sharkia and Nagh Hammadi EL–Garbaia canals, are located in Sohag and Asyot Governorates with total length 157.6 km and 170 km; respectively. These two canals receive with water from Nile River at km 359 upstream Nagh Hammadi Barrage and served 125 000 feddans and 440 000 feddans (feddan = 4200m^2); respectively.

El–Samana EL–Gidida and EL–Bohaia canals are located in Sharkia and Dakahalia Governrate with total length 34.5 km and 47.4 km; respectively. EL–Samana EL-Gidida canal is fed by fresh water from Bahr-Fakoos canal at km 23.200 to serve agricultural area of 71810 feddan. EL-Bohaia canal is supplied with water from EL-Rayaha EL-Tawfaky at km 69.700 to cover 125 482 feddan.

The fifth canal is EL-Ibrahmia canal which feed with water from Nile River at km 564 upstream Asyot Barrage to serve 146 7000 feddan. The reach from EL- Ibrahmia canal was selected from km 195.300 to km 276.900 which is located in Benswaf Governorate. The design parameters of the selected canals are shown in Table (1).

2. Field Measurements

Hydraulic investigations have been performed on twenty six selected reaches covering the five selected canals. Extensive hydraulic field measurements were carried out on the 48 cross sections to detect the actual hydraulic parameters. The selected reaches and number of measured cross sections are shown in Table (2). It has been assumed that each selected reach can be characterized by an average geometric section and the flow is steady and uniform.

The design information for the selected canals were collected from the irrigation authority that supervises the canals' status. The actual hydraulic parameters such as water depth (Y), water top width (W_t), water surface slope (S) were measured for each selected cross section. The velocity distributions were measured by using a calibrated Braystoke current flow meter and discharges were then determined.

From the actual field data, the geometrical parameters of the selected cross sections (e.g. cross section area, A, wetted perimeter, P, and hydraulic radius, R) were determined. Aquatic weeds survey along the twenty six reaches was done using an Echo-Sounder (Lawrence X-16B) for detecting the boundary of the cross sections and percentage of aquatic weeds infestation. Morphological changes were studied by surveying the selected cross sections to evaluate the amount of deposition and scouring.

Soil samples were collected from both bed and side slopes of the selected canals to determine the grain size distribution of boundary material to classify the soil type. Water samples were also collected from the selected canals to determine the physical and chemical properties of water. (PH, Electrical Conductivity, temperature, and light penetration).

RESULTS AND DISCUSSIONS

1. Aquatic Weeds Monitoring

Aquatic weeds were monitored along the length of the selected canals using the observation and Echo Sounder to detect the percentage of weeds infestation. Analyzing the measurement data showed that the Nagha Hammadi EL–Sharkia and EL–Garbaia canals were infested by 3% and 15% (from the water surface area) from submerged weeds; respectively and they were infested by 10% from ditchbank weeds. The percentage of submerged weeds infested EL–Saman EL–Gidida canal can be neglected; however the reach from km 23.000 to km 25.000 was infested by 10%.

EL–Bohaia canal was infested by submerged weeds ranged from 4% to 8% but the reach from km 44.210 to km 46.310 was infested by percentage range from 25% to 45%. However the ditchbank infestation reached to 10%. The biological control method (Grass Carp) was applied to maintain the canal but the canal was injected with not sufficient amount of Grass Carp therefore the problems of submerged weeds appeared in some reaches. EL–Ibrahmia canal was infested by 5% and 11% (from water surface area) by submerged weeds and ditchbank; respectively, except, the reach from Km 251.600 to 276.900, was infested by 17% from submerged weeds.

The biological and mechanical control methods were used to control aquatic weeds for the selected canals. Therefore, it can be concluded that the infestation of aquatic weeds for the selected canals are under control but some reaches need a follow up for their maintenance methods.

2. Soil Classification and Water Properties

2.1. Soil Classification

The Soil samples were collected from bed and banks of selected canals from 35 locations (95 soil samples) and analyzed in laboratory to determine the soil classification along the selected canals. From the hydrometer and mechanical analysis for the soil samples, the soil of EL-Saman EL-Gidida canal was classified as loamy sand with seldom clay. The soil of El-Bohaia and EL-Ibrahmia canals were classified as silty clay and silty loam; respectively and the clay percentage in the soil samples did not exceed 22%. While the soil of Nagh Hammadi EL-Sharkia and Nagh Hammadi EL-Garbaia canals were classified as loam with clay percentage ranged between 63% and 84%.

2.2. Physical Chaaracteristics of Water Samples

Physical characteristics of the water samples from the selected canals (El-Samana El-Gidida, El-Bohaia, and Ibrahmia canals) as well as the productivity of water plants were measured. The physical characteristics of the investigation included water temperature, transparency, PH, dissolved oxygen (DO), electric conductivity (EC), and salinity.

Summary of water sample analysis is shown in table (3). From water sample analysis, it can be indicated that all measured parameters were below the Egyptian Standard of the law of environment (48/1982), except the value of water transparency in El-Bohaia canal (from km 32.850 to km 39.600) and along the El-Samana canal. The decrease of transparency is referred to the increase in phytoplankton and dissolved solids organic and inorganic substances (Abdalla et. al. 1991).

3. Assessment the Existing Section Factor

The Section Factor is used to assess the existing parameters of selected canals. Section Factor (SF), which depends only on the geometry of channel and is defined by the parameter $AR^{2/3}$ where A and R are water cross section area and hydraulic radius respectively.

The relation between Section Factor and existing and designing hydraulic parameters (discharge (Q), water depth (Y), water cross section area (A), and wetted perimeter (p)) were plotted from Fig. (1) to Fig. (4); respectively. The deduced equations (metric system) can be represented in the power formulae as follows:

Parameter	**Design**	R^2	**Existing**	R^2
Discharge	$Q = 0.375\ (SF)^{0.966}$	0.98	$Q = 0.24\ (SF)^{1.024}$	0.93
Water depth	$Y = 0.961\ (SF)^{0.232}$	0.94	$Y = 0.357\ (SF)^{0.406}$	0.97
Cross section area	$A = 1.299\ (SF)^{0.824}$	0.98	$A = 1.981(SF)^{0.747}$	0.99
Wetted perimeter	$P = 2.625\ (SF)^{0.505}$	0.97	$P = 5.522\ (SF)^{0.367}$	0.95

It can be shown from these relations that the existing discharge is less than the estimated discharge for the same value of Section Factor. Also, the existing water depths have smaller values than the estimated depths until the SF reach 300 and after that the opposite relation was observed. However, the existing and designed cross section areas were approximately the same value. While the existing wetted perimeters were higher than the designed until SF reach to 225 then this relation change to opposite relation.

It can be concluded that the existing discharges and water depths were decreased compared with designed. Also, it can be deduced that the existing cross section have wider section than the values designed one.

4. Assessment the Hydraulic Efficiency

The hydraulic efficiency (H.Eff.), which is represented by (Q_e/Q_d x 100) where Q_e and Q_d are existing and designed discharge; respectively, was assessed for selecting cross sections. The relation between hydraulic efficiency and water depth ratio (existing water depth/design water depth) was plotted as shown in Fig. (5) and the equation was deduced as follows:

$$H.EFF. = 7.026 e^{2.805\left(\frac{Y_{exist}}{Y_{design}}\right)} \quad \text{...(1)}$$

It can be shown that the hydraulic efficiency increases with increasing water depth ratio. Therefore the existing water depth should be increased to improve the canal efficiency. The effect of roughness factor, which represents existing Manning's roughness coefficient ($n_{existing}$) over the design one (n_{design}), on hydraulic efficiency of canal was also studied as shown in Fig (6) and the deduced equation can be represented as follows:

$$H.EFF. = 178.44e^{-0.773\left(\frac{n_{exist}}{n_{design}}\right)} \quad \text{..(2)}$$

It can be shown that decreasing the roughness factor improves the hydraulic efficiency. The roughness coefficient can be accepted when it is increased more than the designed one by 10%. These mean that accepting Manning's roughness coefficient when it is not more than 0.0275 (roughness factor = 1.1). From analyzing the available data, it can be shown that the 80% of roughness factor lies between 1.1 and 1.5 and 2% lies over 1.5. Therefore, these sections need more attention in the maintenance methods to decrease the existing roughness to increase the canal efficiency.

The relation between existing and designed Section Factor (SF_{exist}/SF_{design}) with hydraulic efficiency is studied as shown in Fig (7) and the following formula can be deduced:

$$H.EFF. = 13.606e^{1.837\left(\frac{SF_{exist}}{SF_{design}}\right)} \quad \text{..(3)}$$

It can be shown that the hydraulic efficiency will be also improved by increasing the section factor.

The conveyance efficiency (CE) for the selected reaches was studied by measuring the inlet discharge (Q_{in}) and outlet discharge (Q_{out}) from the reach and applying the formula CE = (Q_{out}/Q_{in}) x100. Conveyance efficiency for the selected reaches for the five canals can be shown in Fig (8). It can be shown that the conveyance efficiency for all selected reaches recorded more than 90% except the end reach of EL–Saman EL–Gidida and Nagha Hammad EL–Sharkia canals. Therefore, the water requirement for the end reach should have been taken into consideration in water distribution. Also, the maintenance methods have to be applied regularly to insure passing the required discharges.

5. Canal Conveyance

The canal conveyance ($CC= Q/S^{1/2}$), which is a measure of the carrying capacity of the channel section, was evaluated for the selected canals. The relation between canal conveyance ratio (CC_{exist}/CC_{design}) and ratio of water depth (Y_{exist}/Y_{design}), water cross section area (A_{exist}/A_{design}), velocity (V_{exist}/V_{design}) and Manning's roughness coefficient (n_{exist}/n_{design}), were deduced as shown from Fig. (9) to Fig. (12). The deduced equations can be expressed as follows:

$$\frac{CC._{exist}}{CC._{design}} = 1.025\left(\frac{Y_{exist}}{Y_{design}}\right)^{1.882} \quad \text{..(4)}$$

$$\frac{CC._{exist}}{CC._{design}} = 0.842\left(\frac{A_{exist}}{A_{design}}\right)^{1.887} \quad \text{....(5)}$$

$$\frac{CC._{exist}}{CC._{design}} = 0.839\left(\frac{V_{exist}}{V_{design}}\right)^{0.993} \quad \text{....(6)}$$

$$\frac{CC._{exist}}{CC._{design}} = 0.835\left(\frac{n_{exist}}{n_{design}}\right)^{-1.233} \quad \text{....(7)}$$

From analyzing these relations, it can be found that there are direct relation between canal conveyance ratio and ratio of water depth, ratio of cross section area, and velocity ratio. While the relation between canal conveyance ratio and Manning's roughness coefficient ratio is indirect. Therefore increasing the existing water depth, cross section area, and velocity will improve the canal conveyance ratio. However, the roughnesses have to be decreased to increase the canal conveyance.

The charts from Fig. (9) to Fig. (12) can be also used to estimate the existing parameters by knowing the existing water depth as follows:

1- Existing water depth can be measured by using vertical staff gauges.
2- The ratio $Y_{existing}/Y_{design}$ can be calculated.
3- From Fig. (9) the conveyance ratio can be obtained.
4- The existing cross section area can be determined by knowing design area and conveyance ratio from Fig (10).
5- Using the same methodology, existing velocity and existing Mainning's roughness coefficient can be obtained from Fig. (11) and Fig. (12); respectively.

By applying this method, the roughness coefficient can be estimated without field measurements. Therefore, the canal can be operated and maintained easily to improve the canal efficiency.

6. Canal Stability Assessment

Assessment of the canal stability is very essential to determine if the canal is working under the regime condition or not. Therefore, the developed equations, which were deduced by EL-Samman and Awad (1999), were applied in this paper to evaluate the canals conditions. These developed equations can be used in designing, reshaping or examining of small and large Egyptian stable canals (small canals Q < 2 m^3/sec and large canals 250 m^3/sec >Q>2 m^3/sec). These equations are deduced depending on the relation between geometrical parameters (Y and A) with the parameter (n $Q/S^{0.5}$) and type of soil.

The developed equations for large canal in cohesive soil are applied to examine the existing condition for the selected canals. The curve representing the regime condition was plotted in Figures (2) and (3) to compare the existing condition with the regime condition. From these figures, it can be shown that the existing water cross section areas were less than the regime condition by 9% in average. Therefore, it can be deduced that the existing cross sections are approximately under regime condition. However, the existing water depths are approximately the same as regime condition for discharge less than 50 m^3/sec. While, the existing water depths are increased compared with regime condition by 18% in average for discharge above 50 m^3/sec. It can be concluded that the cross sections of the selected canals are working under the regime condition but the water depths need to be adapted.

7. Water Level Assessment

The available data about water levels along the selected canals were collected from water districts to cover difference available years. The analysis of data showed that the water level of EL–Saman EL–Gidida was decreased by 45 cm compared with the designed water level. Therefore, the canal feeding EL–Saman canal should be evaluated to improve the water level of EL–Saman canal.

The water levels of Bahaia canal were also decreased by 46 cm in the reach from the canal intake to km. 26.450, while in the remaining reach; the water levels were decreased by 69 cm in average. The data analysis showed also that the existing discharges are approximately equal to the designed discharges in these reaches. For EL–Ibrahimia canal, the water levels are approximately as the designed one except for two reaches. These reaches were from km 251.600 to 261.400 the water level decreased by 77cm while the second reach from km 264.500 to 276.900 the water levels decreased by 130 cm.

The decrease in water level may be due to the increase in the water cross section area due to the application of the unsuitable mechanical methods to maintain the canals. It can be concluded that the decrease in the water level in the selected canals will affect the water distribution for branches canal. The water distribution system depends on the water level in main canal. Therefore, it can be suggested to distribute water according to discharge and not according water level to ensure adequate water distribution.

CONCLUSIONS

Assessment of the Egyptian canals performance is considered to be the main objective of this study based mainly on experimental measurements. From analysis of the data, the the following conclusions can be reached:

- The existing discharges and water depths were decreased comparing with design and the existing cross sections have wider section than the existing
- The cross sections of the selected canals are working under the regime condition however the water depths need to be adapted.
- The water level in most selected reaches were decreased which consequently affected water distribution for branch canals.

- The cross sections having roughness factor more than 1.1 should be maintained to improve the canal efficiency.
- Conveyance efficiency for all selected reaches recorded more than 90% except the end reach of two selected canals.
- Increasing existing water depth, cross section area, and water velocity will improve the canal conveyance.

Finally, it can be concluded that the guidelines to operate and maintain the canals have to be prepared to improve the canal efficiency.

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Table (1): Design Parameters for the Selected Canals.

Canal Name	Q (m^3/s)	Y (m)	b (m)	A (m^2)	V (m/s)	S (cm/km)	Side Slope
El-Samana El-Gidida	39.08	2.85	16	57.78	0.68	7	3:2
El-Bohaia	51.65	3.13	22	83.56	0.62	7	3:2
Nagha Hammadi El-Sharkia	49.70	3.22	24	92.83	0.54	5	3:2
Nagh Hammadi El-Garbaia	136.5	4.35	42	211.08	0.65	5	3:2
El-Abrahmia	71.15	3.00	30	108.00	0.66	8.5	2:1

Table (2): Locations of the Selected Cross Sections.

Canal Name	El-Samana El-Gidida (km)	El-Bohaia (km)	Nagha Hammadi El-Sharkia (km)	Nagh Hammadi El-Garbaia (km)	El-Ibrahmia (km)
Selected Reaches	0.130-1.70 10.15-14.8 21.15-23.68 32.68-25.30 29.80-31.35	1.50-9.60 11.18-15.50 19.30-22.00 23.15-26.45 29.69-32.85 37.00-39.60 44.21-46.31	0.30-20.00 20.00-40.00 40.00-65.00 69.00-88.00 108.00-125.00 126.00-142.00 142.00-157.00	0.300-21.00 65.00-81.00 107.00-123.50	195.3-208.65 217.9-239.9 251.6-261.4 264.5-276.9
No. of Selected Reaches	5	7	7	3	4
No. of Measured Cross Sections	9	14	11	6	8

Table (3): Physical Characteristics of Water Samples of Selected Canals.

Canal name	No	Location	Temperature	Transparency	PH	DO	EC	Salinity
El-Samana	1	Intake	26	35	7.8	10.80	325	208
	2	1.695	27	30	7.7	10.60	365	234
	3	10.150	29	38	7.6	10.90	360	230
	4	14.175	29	40	7.7	10.55	410	266
	5	21.150	27	28	7.7	10.75	430	275
	6	25.300	27	36	7.9	10.90	400	256
El-Bohaia	1	1.500	32	100	7.1	11.21	352	225
	2	9.600	32	95	7.7	11.63	345	221
	3	11.180	31	95	8.1	11.54	351	225
	4	15.500	31	85	8.5	11.86	350	224
	5	19.300	30	85	7.5	11.43	340	218
	6	22.000	31	85	8.2	11.86	351	225
	7	23.150	31	75	7.9	11.55	345	221
	8	26.450	31	50	8.4	11.23	350	224
	9	29.685	29	50	7.4	11.74	340	218
	10	32.850	31	40	7.5	11.68	345	221
	11	37.000	31	40	7.8	11.78	350	224
	12	39.600	31	40	8.4	11.50	353	226
El-Ibrahmia	1	195.300	32	90	7.47	11.87	280	179
	2	208.650	32	71	7.67	12.12	290	186
	3	217.90 0	31	74	7.97	12.56	270	173
	4	239.900	31	72	7.85	12.36	230	147
	5	251.600	30	71	7.89	12.61	250	160
	6	261.400	31	75	7.96	12.48	300	192
	7	264.500	31	65	7.99	12.45	340	218
	8	276.900	31	57	7.79	12.26	360	230
The law (48/1982)			Normal temp. + 10 ºc	50	7-8.5	5	-	500

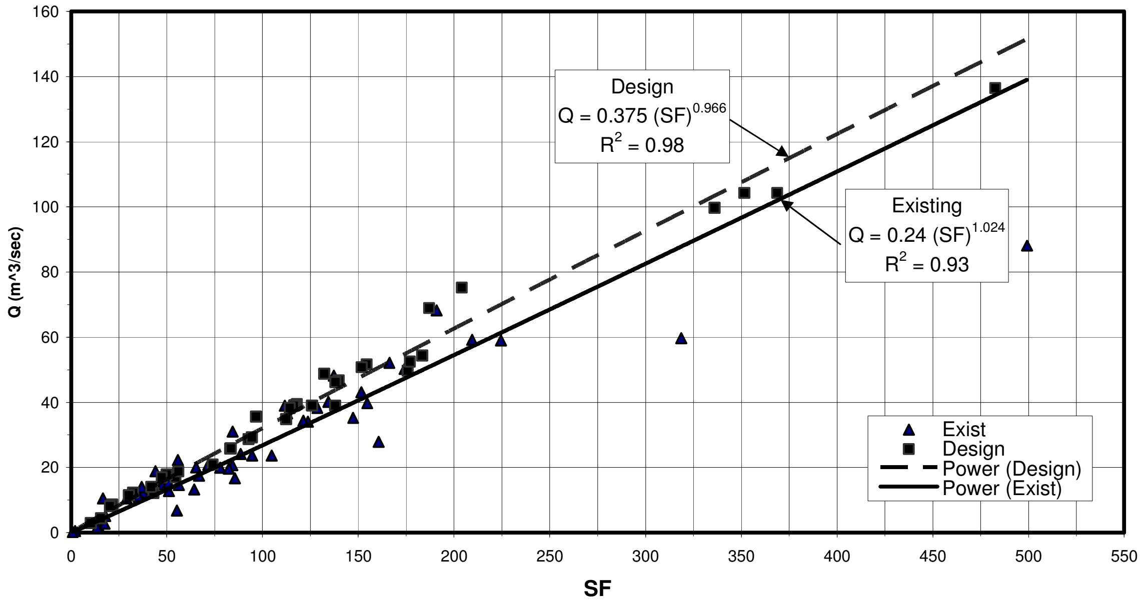

Figure (1): Relation between Section Factor and Existing and Designing Discharge.

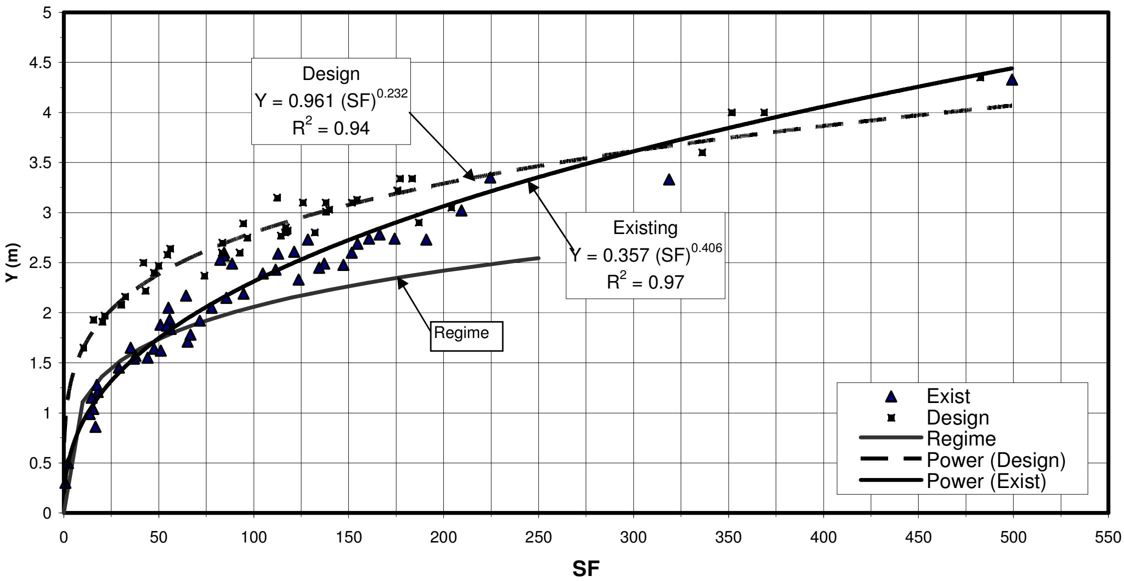

Figure (2): Relation between Section Factor and Existing and Designing Water Depth.

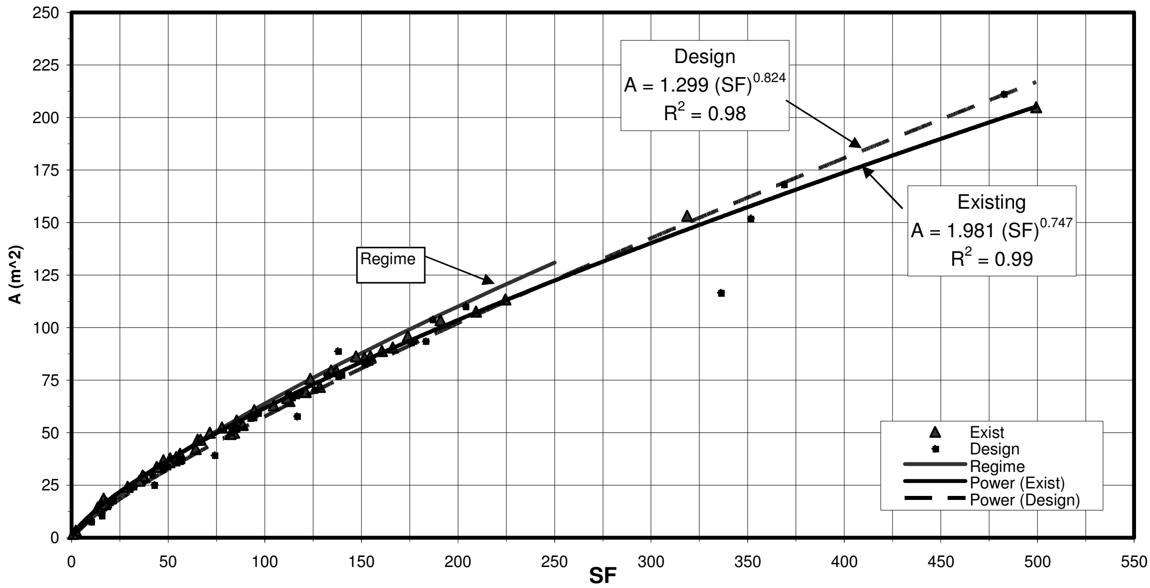

Figure (3): Relation between Section Factor and Existing and Designing Water Cross Section.

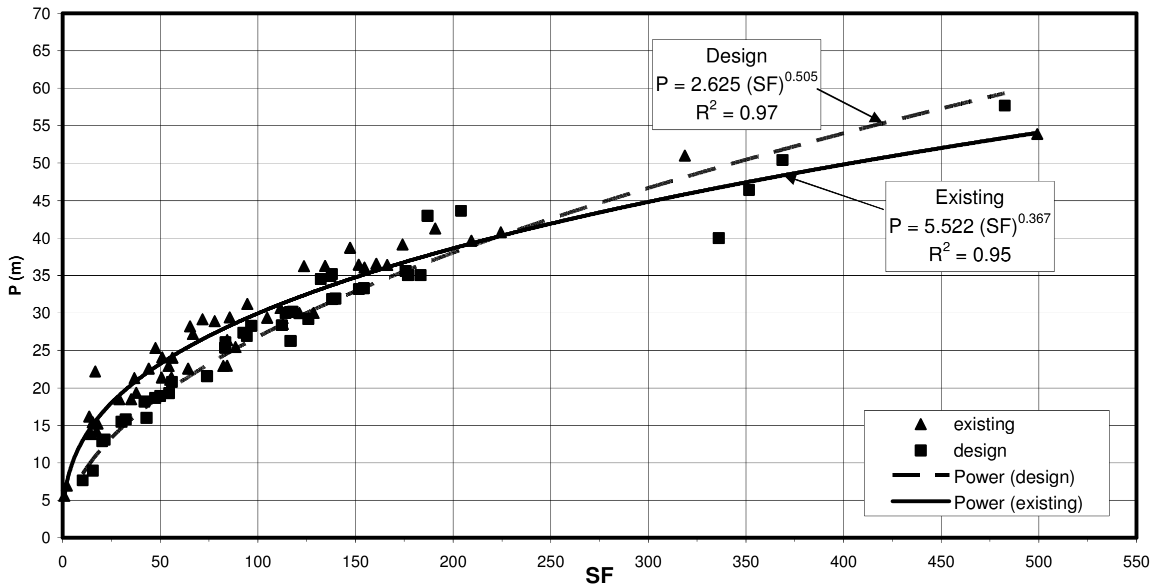

Figure (4): Relation between Section Factor and Existing and Designing Wetted Perimeter.

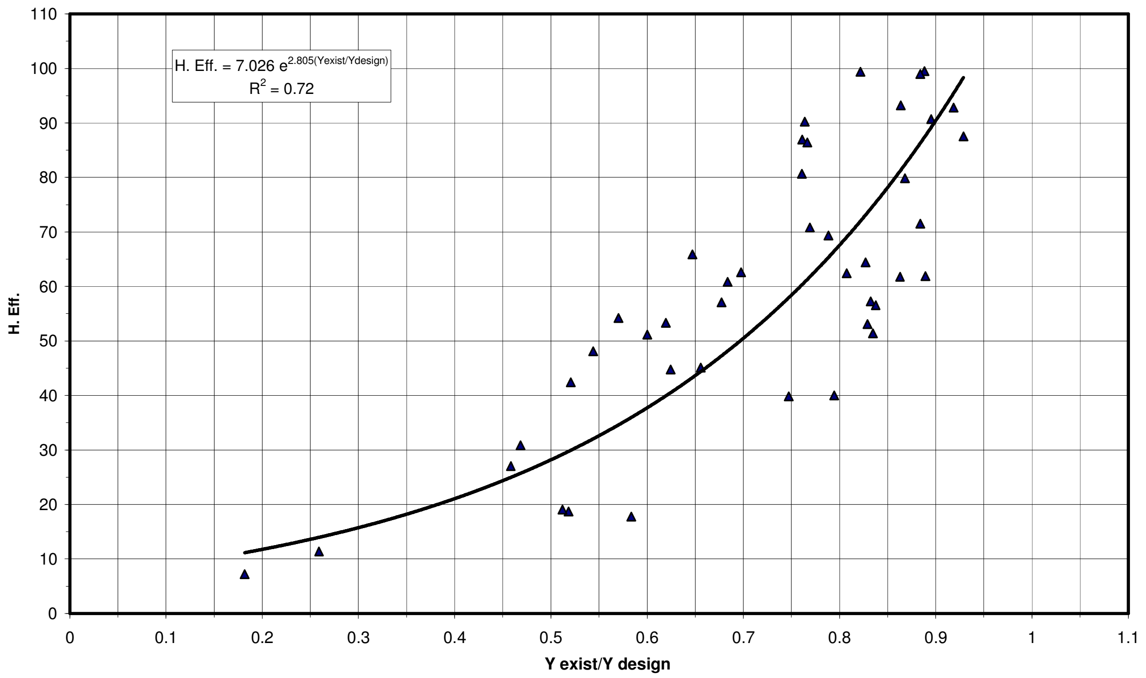

Figure (5): Relation between Hydraulic Efficiency and Water Depth Ratio

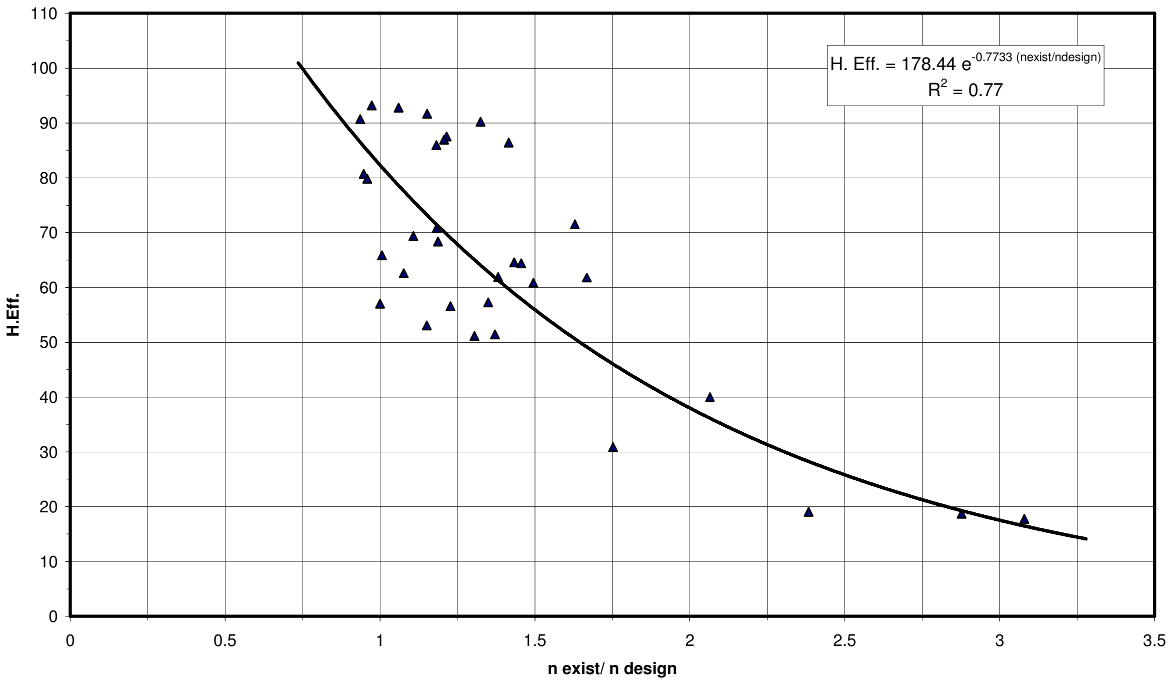

Figure (6): Relation between Hydraulic Efficiency and Roughness Factor.

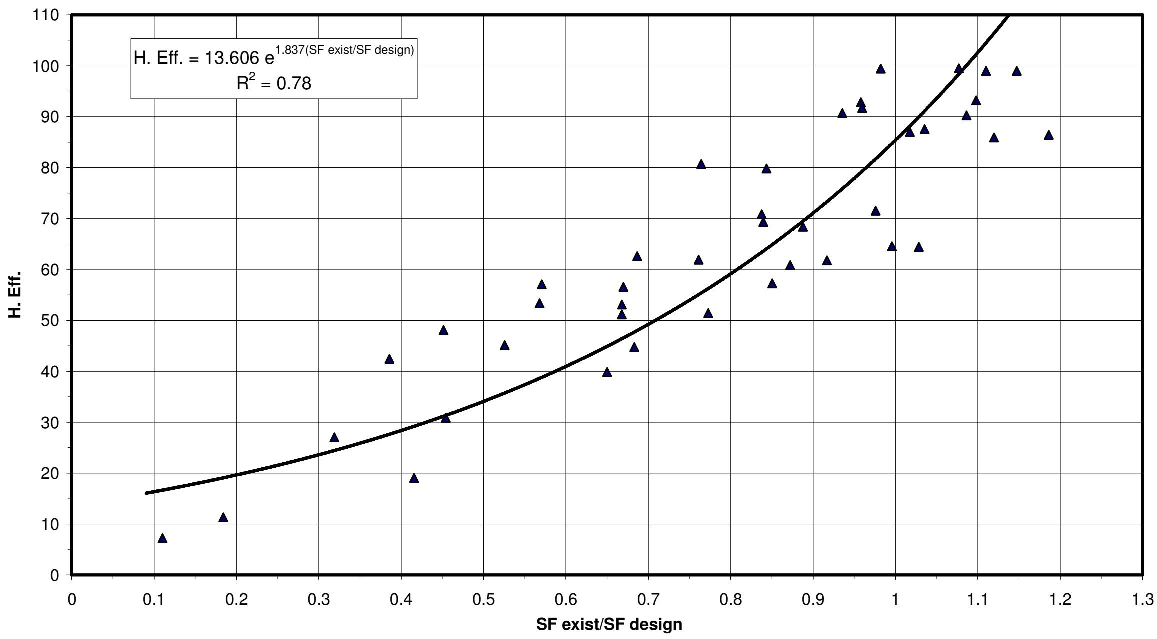

Figure (7): Relation between Hydraulic Efficiency and Section Factor Ratio.

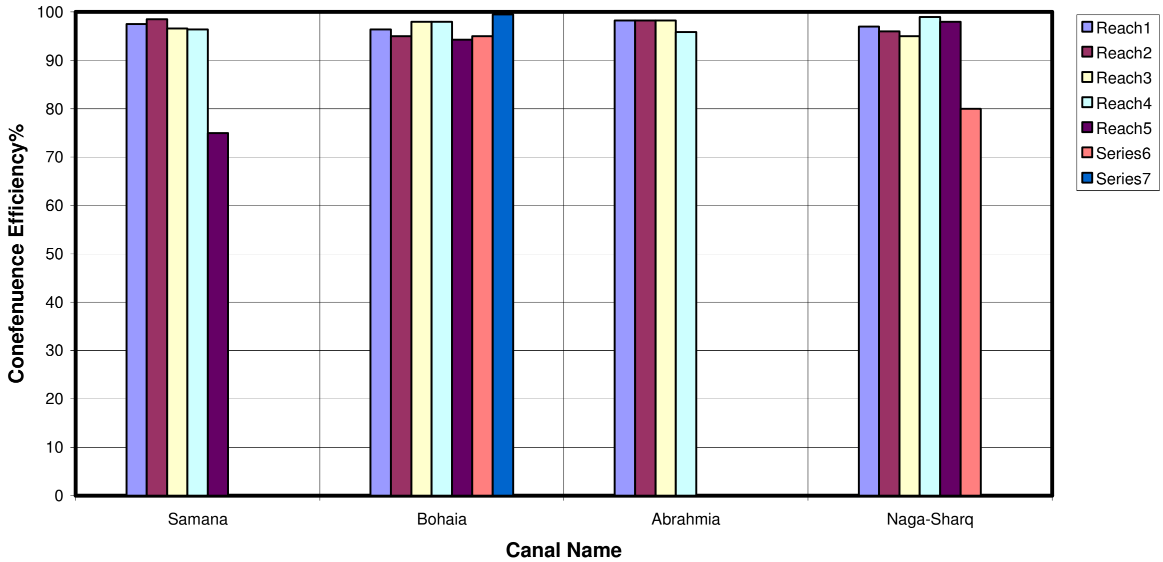

Figure (8): Conveyance Efficiency for Selected Reaches for the Five Canals.

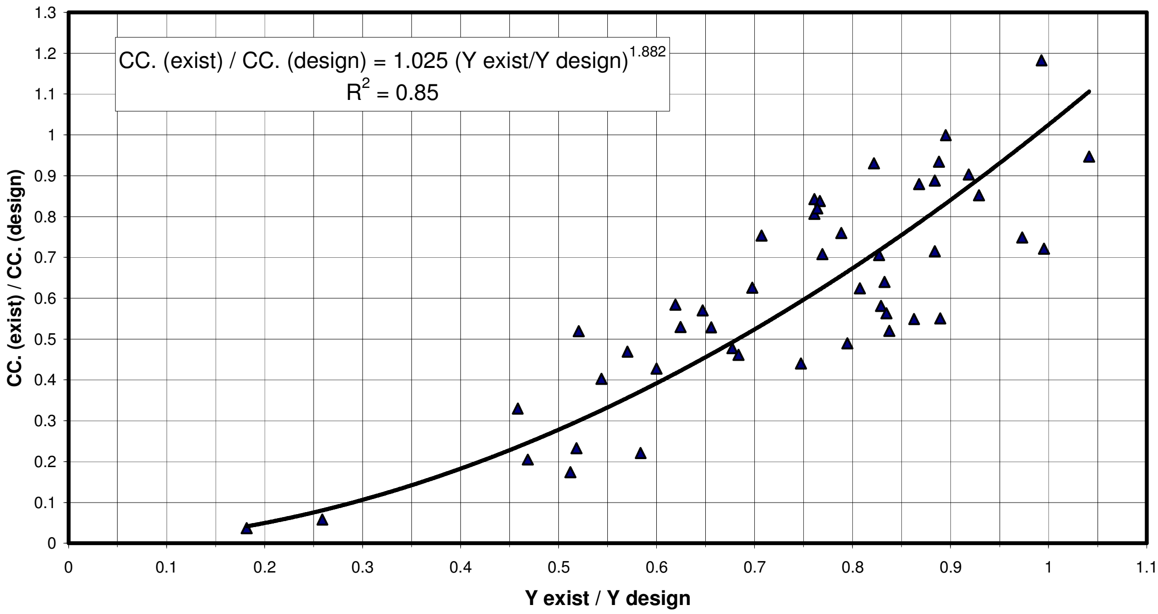

Figure (9): Relation between Canal Conveyance Ratio and Water Depth Ratio.

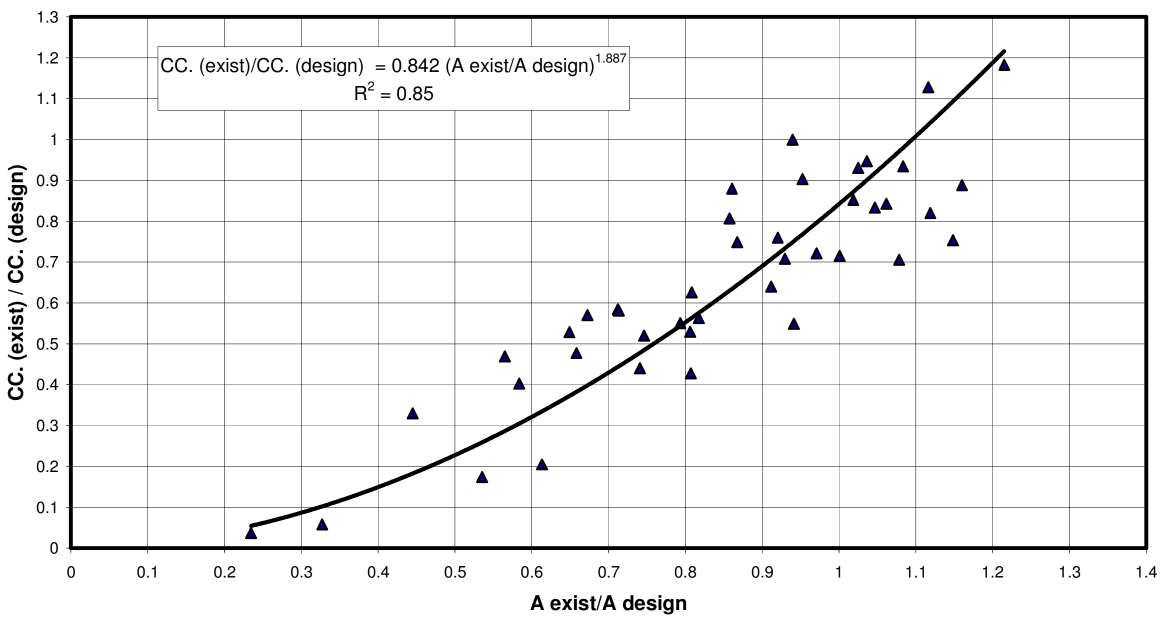

Figure (10): Relation between Canal Conveyance Ratio and Water Cross Section Area Ratio.

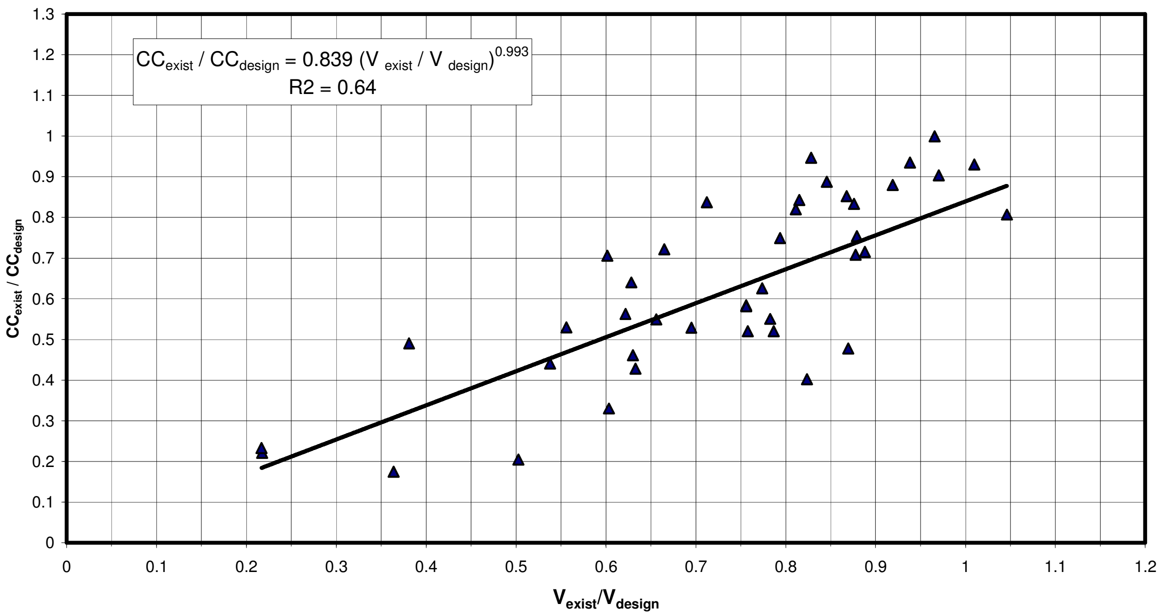

Figure (11): Relation between Canal Conveyance Ratio and Water Velocity Ratio.

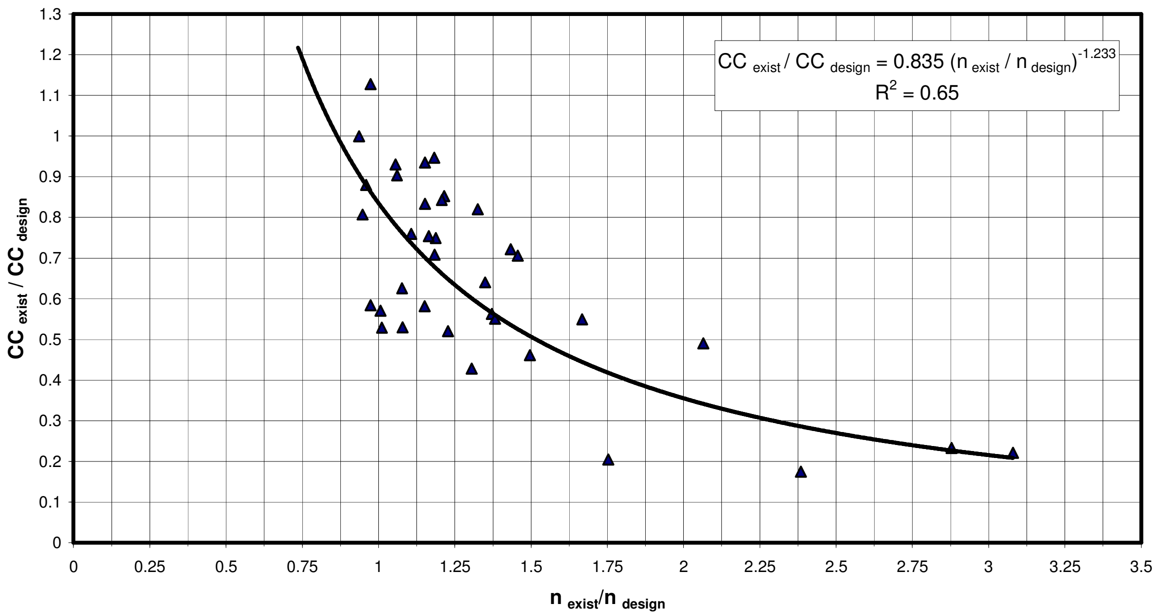

Figure (12): Relation between Canal Conveyance Ratio and Manning's Roughness Ratio.