POTENTIALITY OF REUSE OF THE IRRIGATION CANALS PARAMETERS USING AN OPTIMAL VERIFICATION TECHNIQUE FOR OPEN CANALS DESIGN WITHIN THE RECLAMATION PROJECTS IN THE MIDDLE OF IRAQ +

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Abstract :

An optimal with analytical formula of flow to open canal is evaluated to calculate the roughness coefficient and the canal slope. Utilizing a simulation program with the steepest descent technique for searching of minimum starts from an initial estimation is considered, by this analysis. The analysis proceeds along the direction of the gradient to a new point, such that gives minimum mean deviation between observed to set of the sample data obtained from irrigation canals flow tests for any selected open canal.
Relevant field data obtained from the irrigation canals of flow tests conducted in experiment plots for(Eskendriya – Mahaweel, Hilla – Diwaniyah, and Diwaniyah – Shafiyah) projects in the middle of Iraq, are gathered and analyzed for the evaluation process.
Irrigation canals parameters for open canals flow of roughness coefficient and canal slope can be found from the initial estimated values of these parameters ,by using the irrigation canals tests(bed width ,water depth ,side slope ,and canal discharge) of the trapezoidal cross section canal.
The calculated values of the roughness coefficient and canal slope by the optimal verification technique, are in agreement with the limits of those obtained from the experiment plots in Iraq. However, the calculated roughness coefficient and canal slope by this simulation, are found to be (0.0225) and(0.0001) respectively.
Several relations can be obtained from the results of the simulation model, from the calculated parameters (roughness coefficient and canal slope) and they are reused with the irrigation canals data (bed width, water depth, side slope, and canal discharge) of the trapezoidal cross section canal . These relations can be used to find the normal water depth directly for each specified canal bed width (0.5-50m) and the utilized side slope (1:1).The normal water depth varies with the range of (0.1-5.5m) against the term of the roughness coefficient multiply by the discharge divided by the square root of the canal slope, which varies with the range of (0.01-105).
Therefore; these relations can be useful for canals design within the reclamation projects in the middle of Iraq to calculate the normal depth.
Key words: - Open Canals Design , Optimal Verification Technique, Reclamation Projects.

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امكانية اعادة استخدام معاملات قنوات الرى بأستخدام تقنية التحقيق الامثل فى تصميم القنوات المفتوحة لمشاريع الاستصلاح فى وسط العراق

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المستخلص:

تم تقويم امثل تحليل وبالصيغة التحليلية لحركة مياه القناة المفتوحة لحساب معامل الخشونة وانحدار القناة هذا التحليل يؤخذ بنظر الاعتبار استعمال نموذج حاسوب وتقنية الهبوط المنحدر في البحث عن اصغر بدايات اولية مخمنة يستمر التحليل باتجاه الانحدار الى النقطة الجديدة بحيث يعطي اقل معدل انحراف بين التصريف المحسوب والمرصود. نموذج المحاكاة يمكن تطبيقه على مجاميع بيانات مستحصله من اختبارات مياه قنوات الرى لأي قناة مفتوحة منتخبة

لقد تم تجميع وتحليل معلومات حقلية من فحوصات مياه قنوات الرى التى اجريت في حقول تجريبية (اسكندرية- محاويل, حلة- ديوانية,وديوانية – شافعية) في وسط العراق لغرض التقويم .

يمكن الحصول على معاملات قنوات الرى لتدفق القناة المفتوحة من معامل الخشونة وانحدار القناة ومن خلال القيم الاولية المخمنة لهذه المعاملات بأستخدام فحوصات مياه قنوات الرى (عرض القناة,ارتفاع الماء,انحدار الجوانب,والتصريف) لمقطع قناة شبه منحرف. تتوافق قيم معامل الخشونة وانحدار القناة المحسوبة بألطريقة المثلى بواسطة هذا النموذج مع تلك المعاملات المستحصلة للحقول التجريبية بالعراق . حيث ان قيم معامل الخشونة وانحدار القناة المحسوبة بواسطة هذا النموذج وجدت تساوى(0.0225)و(0.0001)على الترتيب .

كذلك عدة علاقات تم الحصول عليها من نتائج محاكاة النموذج , من المعاملات المحسوبة بألطريقة المثلى (معامل الخشونة وانحدار القناة) وبأعادة استخدامها مع بيانات قنوات الرى (عرض القناة, ارتفاع الماء, انحدار الجوانب, والتصريف) لمقطع قناة شبه منحرف. هذه العلاقات يمكن استخدامها لأيجاد عمق الماء العمودي لكل عرض قناة محدد(0.5–50m)وانحدار الجوانب المستخدم (1 : 1).عمق الماء العمودي يتغير بحدود(0.1-5m) مع المقدار لقيم معامل الخشونة مضروبا بالتصريف ومقسوما على الجذر التربيعي لأنحدار القناة والذي يتغير بحدود (0.01-105) . لذلك تكون ,هذه العلاقات مفيدة لتصميم القنوات لمشاريع الاستصلاح في وسط العراق لايجاد عمق الماء العمودى.

مفتاح الكلمات : نصميم القنوات المفتوحة, تقنية التحقيق الامثل, مشاريع الاستصلاح.

Introduction :

Many problems in water resources are nonlinear. In some instances, the problem may be linearized and linear programming is employed in an iterative scheme, where the solution is refined with each iteration.

Nonlinear optimization algorithms can be classified broadly as search methods as reported by [1]. Free-surface flow can be estimated when flow parameters should be evaluated with numerical solutions. Free- surface flow can be estimated when flow parameters are considered for any selected open canal.

Thus, the open canal parameters should be evaluated with numerical solutions. Free –surface flow for open canal has been studied by [2,3,4,5 and 6] . The numerical studies are used to optimize the parameters of the equation of a straight line such that it minimized the errors between the equation and the observed data. The formulation of the problem within different methods for these studies will be illustrated laterally.
An optimal analysis of flow in the open canal is evaluated in the present study; the optimization of the model is the method of steepest descent as studied by [5]. This method represents the search for minimum starts from an initial estimation and proceeds along the direction of the gradient to a new point, utilizing rating-curve data.
This optimization is used to find the aquifer parameters as reported by the study of [8].
The analysis takes into account the following factors: discharge, side slope, canal bed width, and canal water depth, furthermore, roughness coefficient, and canal slope are treated as unknown boundaries for the current simulation and obtained in an iterative process.

Objectives of the study:

Computational results are presented for the minimum mean deviation between observed and predicted discharge. The effect of different initial values with the unknown parameters on the convergence method of the simulation model is stated during the application. Moreover, the calculated roughness coefficient and canal slope by this model are verified with limits of those obtained from the experimental plots in Iraq. The calculated roughness coefficient and canal slope by the optimal verification technique are reused with the irrigation canals flow data for obtaining several relations. These relations may be used to find the normal water depth for canals design.

Case study:

For steady flow in a trapezoidal open canal, manning's equation (based on the shear friction at the water – canal interface) can be used to determine the velocity as a function of canal characteristics, as reported by the work of [4]:

$$V = 1/n\,(R^{2/3}\,S^{1/2}) \quad \ldots\ldots\ldots (1)$$

Where V: Mean water velocity (m/sec), n :Canal Manning roughness coefficient, R: Canal hydraulic radius (m) = A/P , A:Canal cross sectional area (m^2), P: Canal wetted parameter (m) ,and S:Canal slope.

Note that A and P are related to the more fundamental parameters b and D by:

$$A = (b + KD)^* D \quad \ldots\ldots\ldots\ldots (2)$$

$$P = b + 2\sqrt{(KD)^2 + D^2} \quad \ldots\ldots(3)$$

Where, b: Canal bed width (m), D: Mean water depth (m), and K:Canal side slope.
In addition, the continuity equation (which is based on the system mass balance) can be used to determine follow:

$$Q = V\,A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where Q: Flow rate (m^3/sec).
This can be illustrated by eliminating V from substituting Eq. (1) into Eq. (4)

$$Q = (S^{1/2}/n)\, R^{2/3}\, A \ \ldots\ldots\ldots\ldots\ldots (5)$$

By reformulating equations, the depth (D) can be determine numerically with different methods, as a root problem as follows:

$$N\, Q/S^{1/2} = A\, R^{2/3} \ \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Operational and optimization procedure of the model :

The simplest method of estimating irrigation canals parameters from observed discharge by means of a model is the rating – curve data.

The model can be considered by an analytical formula and unknown irrigation canals parameters of roughness coefficient, n , and canal slope, S.

The unknown values n, S are chosen, such that the over all deviation between measured and calculated values of discharge is defined by the following objective function:

$$f(n , S) = \text{Min.}\ \sum(Qi^{\text{ observed}} - Q^{\text{ calculated}})^2 = \text{Min.}\ [Qi - Q\,(bi,Ki,Di,n,S)]^2 \ \ldots\ldots (7)$$

Where $f(n , S)$ is the objective function and Q(bi,Ki,Di,n,S) is calculated from equation (5), and (Qi) is the observed value.

In the iterative Gauss – Newton method as studied by [9], the function Q(n , S) is linearized around initially estimated values, n° , S° , and performed multiple linear regression the resulting n, S are used in place of n° , S° and iterate the process until convergence is reached, after linearization of ,o, the function, f , was give by :

$$F(n,s) = \sum_{(i=1)}^{N} [[Qi - Q(bi,ki,n^{o},s^{o}) - Z_1(n,i)\,(n - n^{o}) - Z_1(s,i)\,(s - s^{o})]]^{2} \ \ldots\ldots\ldots (8)$$

With

$$Z_{n,i} = \left.\frac{\partial Q(bi,ki,Di,\ n,s)}{\partial n}\right|_{n=n^{\circ}\ s=s^{\circ}},\quad Zsi = \left.\frac{\partial Q(bi,ki,Di,n,s)}{\partial s}\right|_{n=n^{\circ}\ ,\ s=s^{\circ}}$$

The requirement for a minimum of , f, is:

$$\frac{\partial f}{\partial n} = 0\ ,\ \frac{\partial f}{\partial s} = 0 \quad \ldots\ldots\ldots (9)$$

Thus, the normal equations for the unknown (n) and (s) are :

$$(n-n^{\circ})\sum_{i=1}^{N} Z_{n,i}^{2} + (s-s^{\circ})\sum_{i=1}^{N} Z_{n,i}Z_{s,i} = \sum_{(i=1)}^{N} [[Qi - Q(bi,ki,Di,n^{o},s^{o})]] \ \ldots\ldots\ldots (10)$$

$$(n-n^{\circ})\sum_{i=1}^{N} Z_{n,i}\, Z_{s,i} + (s-s^{\circ})\sum_{i=1}^{N} Z_{s,i} = \sum_{(i=1)}^{N} [[Qi - Q(bi,ki,Di,n^{o},s^{o}]\, Z_1(s,i)\,]] \ \ldots\ldots\ldots (11)$$

The method of steepest descent as reported by [7], is used for searching about minimum starts from an initial estimation (n° , S°) and proceeds along the direction of the gradient to a new point (n , S). The new point serves as starting point for the next iteration step. The general step is given by:

$$\begin{vmatrix} n \\ s \end{vmatrix} = \begin{vmatrix} n^{\circ} \\ s^{\circ} \end{vmatrix} + \frac{\eta}{\sqrt{\left(\frac{\partial f}{\partial n}|_{\circ}\right)^2 + \left(\frac{\partial f}{\partial s}|_{\circ}\right)}} \begin{vmatrix} \frac{\partial f}{\partial n}|_{\circ} \\ \frac{\partial f}{\partial s}|_{\circ} \end{vmatrix} \ldots\ldots\ldots(12)$$

The step width, η, can be optimized by choosing its size such that:
$f[n(\eta),S(\eta)]\rightarrow$minimum …… (13)

with n(η) , S(η) from Eq. (12). The determination of the best step size is only a one - dimensional optimization problem. The procedure is stopped as soon as, n , and, S , do not change by more than some given small increment.

The method of steepest descent may be improved by choosing weights, S, for the components of the gradient vector. This leads to the New-Raphson method as reported by [10], and the function, f, is expanded up to second order as follows:

$$(n+\square n,s + \square s)=f(n,s) + (\square n + \square s)\begin{vmatrix} \frac{\partial f}{\partial n} \\ \frac{\partial f}{\partial s} \end{vmatrix} + \frac{1}{2}(\square n, \square s)He\begin{vmatrix} \delta n \\ \delta s \end{vmatrix}\ldots\ldots\ldots(14)$$

With

$$He=\begin{vmatrix} \frac{\partial^2 f}{\partial n^2} & \frac{\partial^2 f}{\partial n \partial s} \\ \frac{\partial^2 f}{\partial n \partial s} & \frac{\partial^2 f}{\partial s^2} \end{vmatrix}$$

Using the extreme condition that the first derivatives of, f, with respect to δn and δs are zero, by differentiating equation (14), the following expression is reached at:

$$0=\begin{vmatrix} \frac{\partial f}{\partial n} \\ \frac{\partial f}{\square s} \end{vmatrix} + He\begin{vmatrix} \delta n \\ \delta s \end{vmatrix}\ldots\ldots\ldots(15)$$

After multiplication with the inverse of the hesse – matrix the iteration rule is arrived at:

$$\begin{vmatrix} n \\ s \end{vmatrix} = \begin{vmatrix} n^{\circ} \\ s^{\circ} \end{vmatrix} - He^{-1}\begin{vmatrix} \frac{\partial f}{\partial n} \\ \frac{\partial f}{\partial s} \end{vmatrix}\ldots\ldots\ldots(16)$$

It states in the Newton – Raphson method, the components of the gradient vector are weighted with the inverse of the hesse – matrix.

Input data of the program:

- Number of data sets, NM.
- Maximum number of iterations, IM, NM data sets consisting of:
- Flow rate, Q, in m^3/sec.
- Canal side slope, K, (1 : 1).

Canal bed width ,b ,in m. -
- Water depth, D, in m.

Starting values of free-surface flow parameters of roughness coefficient, n, and canal slope, S.

Out put data of the program:

The main aim of this research is to find the roughness coefficient and canal slope parameters for the irrigation canals by the optimal verification technique. Then, several relations can be reformulated to find the normal water depth for each specified canal bed width (0.5 – 50m). The steepest descent technique is the verification procedure for estimation the parameters, and this procedure is used for other researches to obtain specified parameters for several fields. The calculated roughness coefficient and canal slope parameters are verified by this optimal technique with the same parameters which are used in the experiment plots in the middle of Iraq. And, this verification is revealed that the values of these parameters are in agreement which are reused for computational relations to find the normal depth for irrigation canals design. While any value for the roughness coefficient and the canal slope according to the canals design, can be used for this simulation to reformulate in the computational relations.

The program is prepared for any type of canal cross sections. The case study for this research which is used for calculations is the trapezoidal section, due to the effect of the side slope is significant for calculations. And, any desired value of the canal side slope can be used, where, the applied side slope for this program is (1:1).

In every iteration step, IT, the values of the two parameters n, and S, as well as the mean deviation, DE, are shown in table (2), and final values of n, and S are given.

The results of the reuse of these calculated parameters for manning equation in open canals relations are revealed by tables (3-10) and figures (2-9). The operational and optimization of the simulation program are show schematically by the flow chart in figure (1).

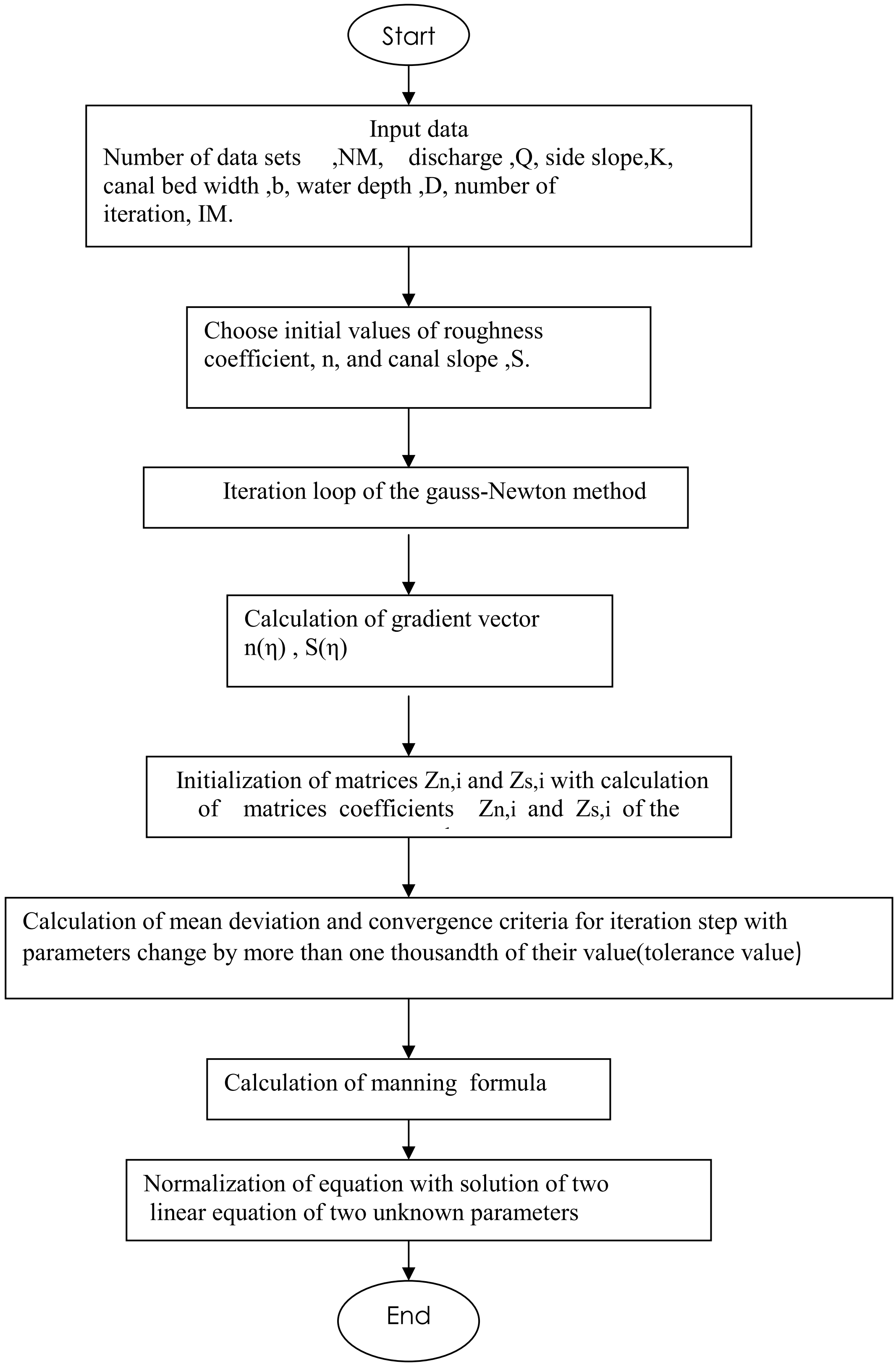

Fig. (1): Flow chart of the Program.

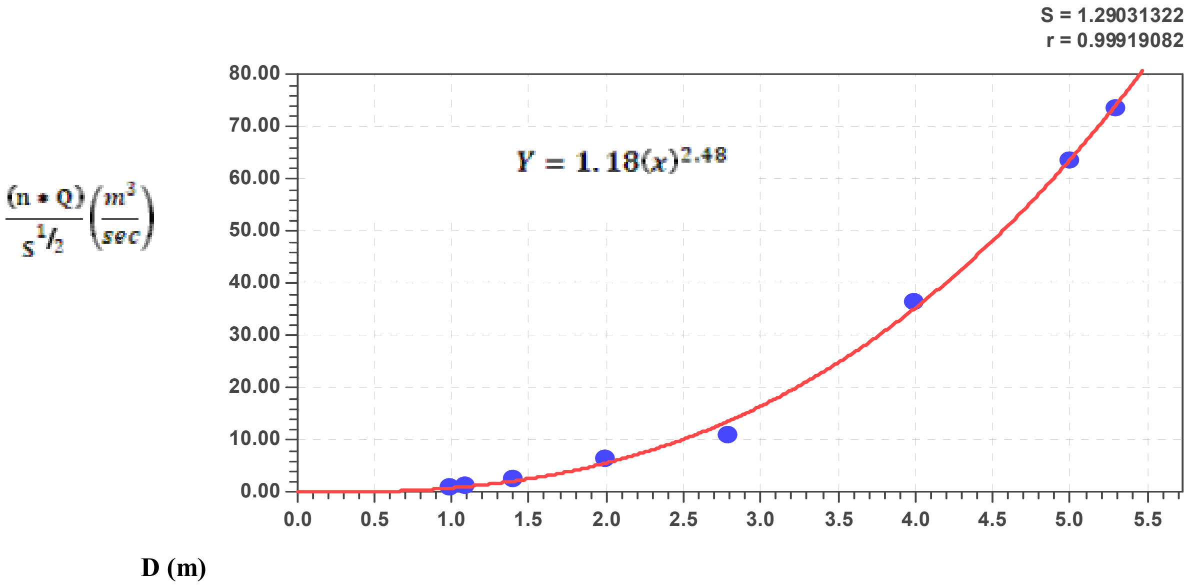

Figure (2):- Variations of the normal depth (D) values for canals bed width (b=0.5 m).

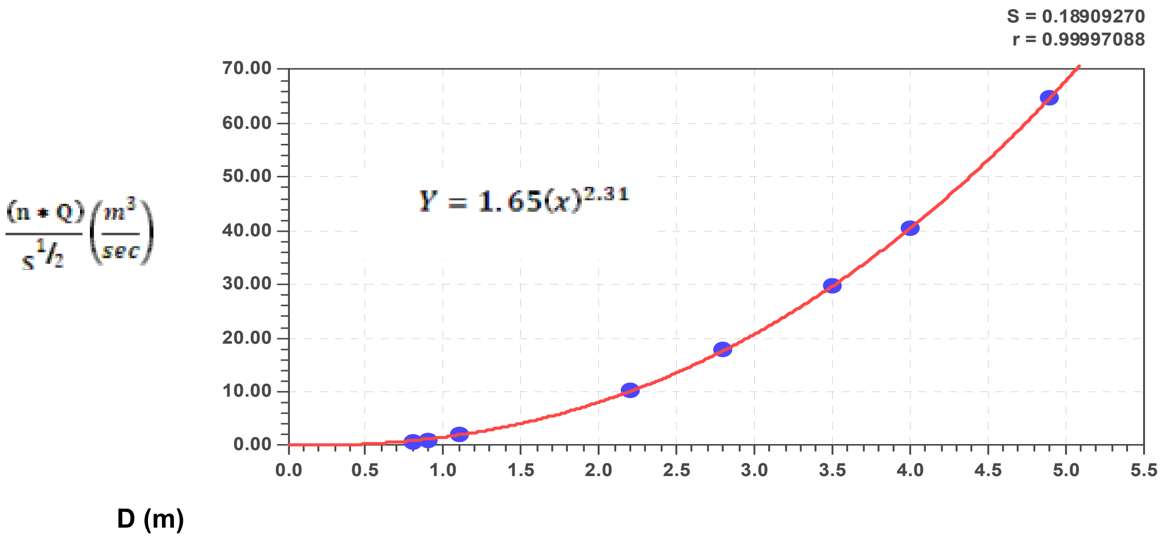

Figure (3):- Variations of the normal depth (D) values for canals bed width (b=1.0 m).

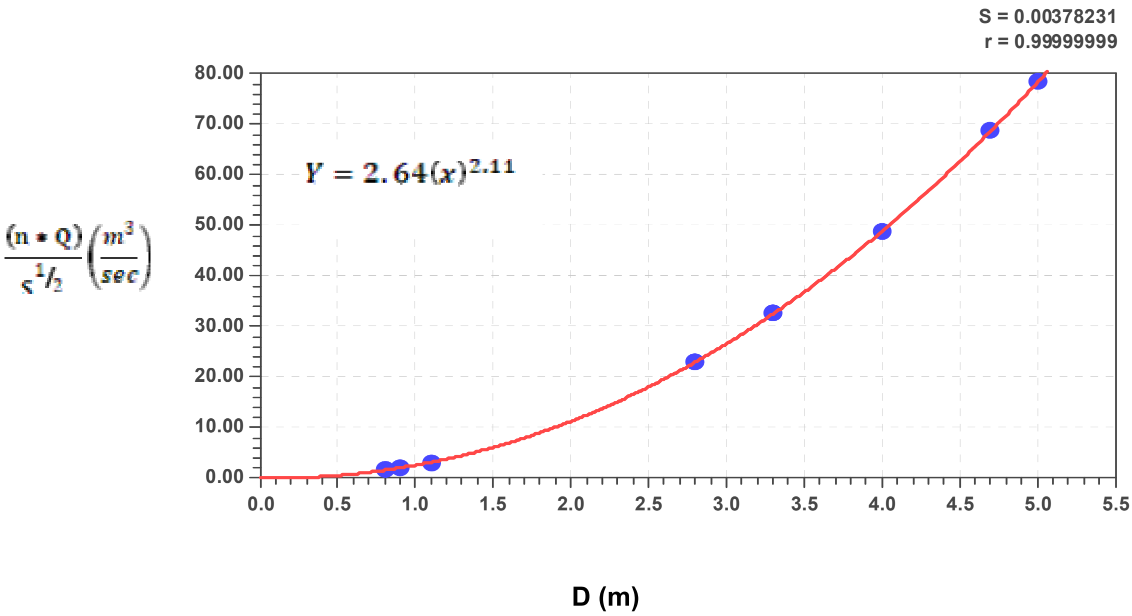

Figure (4):- Variations of the normal depth (D) values for canals bed width (b=2.0 m).

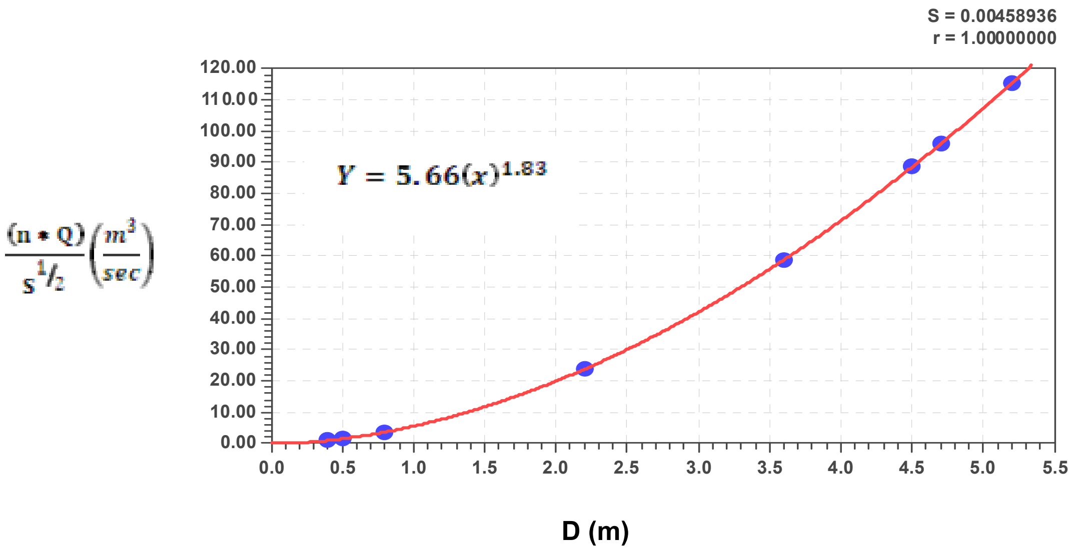

Figure (5):- Variations of the normal depth (D) values for canals bed width (b=5.0 m).

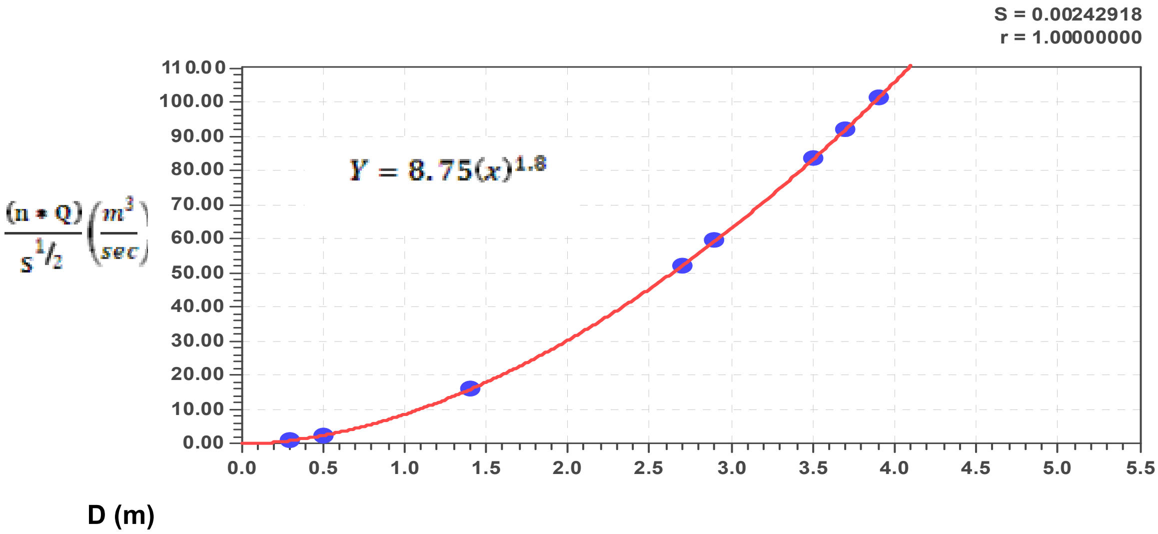

Figure (6):- Variations of the normal depth (D) values for canals bed width (b=8.0 m).

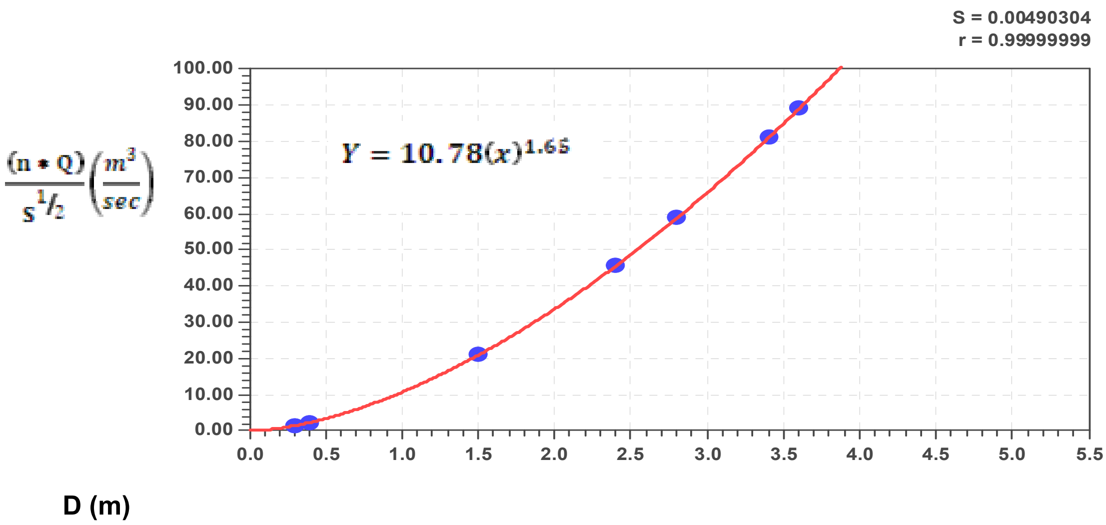

Figure (7):- Variations of the normal depth (D) values for canals bed width (b=10.0 m).

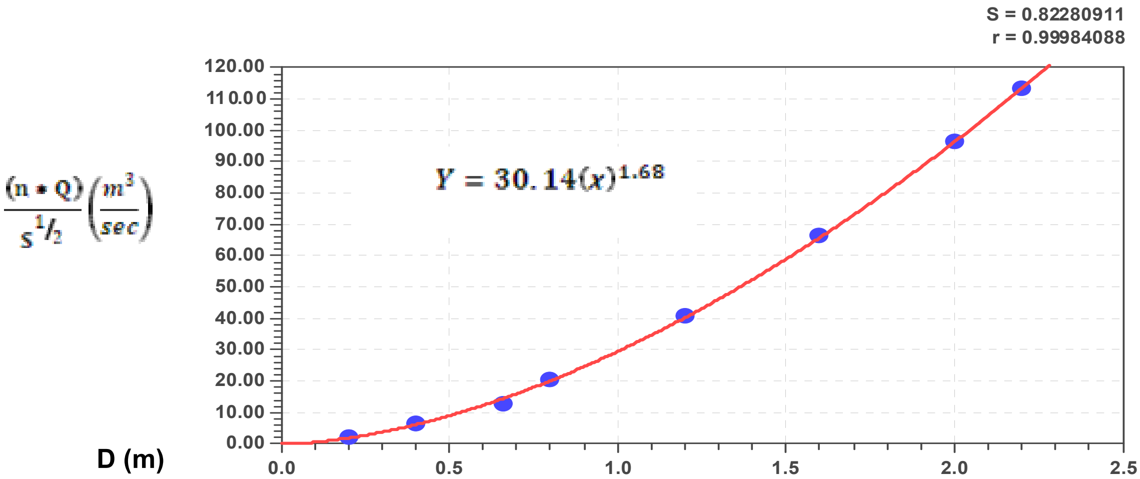

Figure (8):- Variations of the normal depth (D) values for canals bed width (b=30.0 m).

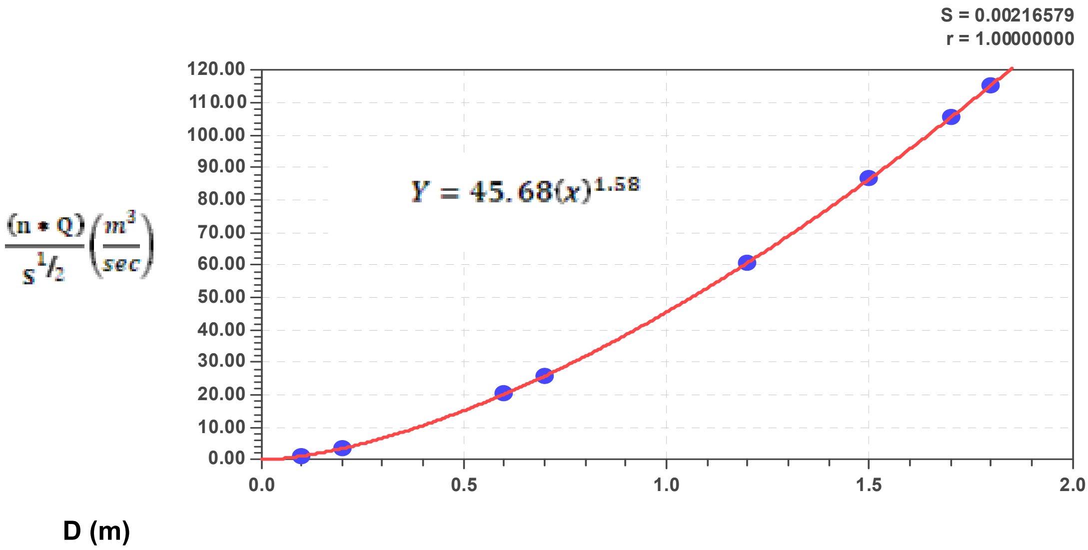

Figure (9):- Variations of the normal depth (D) values for canals bed width (b=50.0 m).

Results and discusion :

The simulation is applied with sets of irrigation canals flow data collected from many selected experimental plots in Iraq. Sample of data is presented for the sake of private, as shown in table (1).

These data are collected according to Al- furat center [11,12,and 13], with different discharge ,Q, canal bed width ,b, water depth ,D, and side slope ,K. These data are gathered from(Eskendriya- Mahaweel canals , Hilla- Diwaniyah canals , and Diwaniyah –Shafiyah canals) with each other. Moreover, these data are reformulated by limits values as shown in table (1), to support our study for calculations. The limits of roughness coefficient and canal slope are pointed for these canals.

The data of these plots can be found in the mentioned references. The initial estimated values of roughness coefficient, n; and canal slope ,S, can be fed as input to the model. These values may be used to calculate the applied roughness coefficient ,n, and canal slope ,S, for the selected open canals. Furthermore, the effect of increasing or decreasing of these initial values on the simulation is investigated.

This simulation which is using the method of steepest descent, evaluates the calculated values of ,n, S, after each initial estimated values ,n°, and ,S°, until a pre- specified iteration number ,IT, and average deviation ,DE, are obtained. A sample of such information is given in table (2).

The calculated parameters for calculated values of ,n, and ,S, by the optimal technique as shown in agreement with limited of those obtained by Al- furat [11,12,and 13], however these experimental parameters are between 0.02 to 0.03 for roughness coefficient and between 0.00001 to 0.001 for canal slope.

Table (1): Limits values of data for selected irrigation canals.
(After,Al- furat center ,1993,1995, and 1996)

Q m^3 **/sec**	**b** **m**	**D** **m**	**K**
0.028- 350	0.5	1- 5	1 : 1
0.028- 350	1	0.8- 5	1 : 1
0.028- 350	2	0.7- 5	1 : 1
0.028- 350	5	0.4- 5	1 : 1
0.028- 350	8	0.3- 3.8	1 : 1
0.028- 350	10	0.3- 3.6	1 : 1
0.028- 350	30	0.2- 2	1 : 1
0.028- 350	50	0.1- 1.7	1 : 1

Table (2): Sample output of n, and ,S,values and different values of ,n°, and ,S°, for various values of ,b,D,K, and,Q.

n°	**S°**	**n**	**S**	**DE**	**IT**
0.05	0.01	0.0225	0.0001	0.004	15
0.01	0.001	0.0225	0.0001	0.004	14
0.002	0.0002	0.0225	0.0001	0.004	14
0.02	0.001	0.0225	0.0001	0.004	4
0.023	0.0001	0.0225	0.0001	0.004	3
0.1	0.00002	0.0225	0.0001	0.004	17

The initial values of n° and S° are varied with each other during the application where, these values are taken close to and far- off the calculated values of n and S to verify the effect of IT- values on the convergence process. From table (2) can be seen that the calculated n, S and DE- value are reached the same values with each iteration, due to utilizing specified irrigation canals data (b,K,D, and Q) as shown in table (1). Moreover, the IT -values are varied with each iteration due to utilizing different values of n° and S°.

The calculated roughness coefficient and canal slope by the optimal verification technique for this simulation, are reformulated with the irrigation canals data as shown in tables (3-1 0) and figures (2-9). These tables with figures, can be utilized to find the normal water depth from the term (n*Q/S^1/2) for each b- value, and the utilized K- value (1 : 1).

The relations of these tables and figures, can be applied for open canals in the Mesopotamian plain. Also, it can be seen from these tables and figures, that the normal depth increases with increasing the (n*Q/S^1/2) values according to formula for each b- value. This formula is specified for each canal bed width as shown in the tables. Moreover, it can be seen from these tables that for b-values of (0.5-5 m), the corresponding D-values are with range of (0.5-5.5 m), while the b-values of (8-50 m), the corresponding D-values are with range of (0.2-3.8 m). It means that the values of the canals normal depths decrease with increasing the values of canals bed widths, and vice versa, which agrees with irrigation canals designs in many researches.

Conclusions :

The simulation can be applied to sets of sample data obtained from the irrigation canals flow data for any selected open canal.

Irrigation canals parameters for open canal of roughness coefficient and canal slope may be found from the initial estimated values of these parameters. The calculated roughness coefficient and canal slope by the optimal technique for this simulation, are in agreement with the limits of those obtained from the experimental plots in Iraq.

However, the calculated roughness coefficients and canal slope by this program, are found to be(0.0225) and(0.0001) respectively.

Several relations can be obtained from the program, within the calculated parameters (n,s) and the irrigation canals flow data (b,K,D,and Q). These relations can be used to find the normal water depth for each specified canals bed width (0.5- 50m) and the utilized side slope (1 : 1). Therefore; these relations can be used for canals design within the reclamation projects in the middle of Iraq.

Table (3): Variations of the normal depth (D) values for canals bed width (b=0.5m)

R^2	Formula	D (X) m	$(n*Q)/S^{1/2}$ (y) m^3/sec
0.98	Y=1.18(x)^2.48	1	1.18
		1.1	1.49
		1.4	2.71
		2	6.58
		2.8	11.22
		4	36.72
		5	63.87
		5.3	73.8

Table (4): Variations of the normal depth (D) values for canals bed width (b=1.0m)

R^2	Formula	D (X) m	$(n*Q)/S^{1/2}$ (y) m^3/sec
0.99	y=1.65(x)^2.31	0.8	0.7
		0.9	0.92
		1.1	2.05
		2.2	10.19
		2.8	17.8
		3.5	29.8
		4	40.57
		4.9	64.83

Table (5): Variations of the normal depth (D) values for canals bed width (b=2.0m)

R^2	Formula	D (X) m	$(n*Q)/S^{1/2}$ (y) m^3/sec
0.99	y=2.64(x)^2.11	0.8	1.64
		0,9	2.1
		1.1	3.21
		2.8	23.09
		3.3	32.66
		4	49.01
		4.7	68.87
		5	78.48

Table (6): Variations of the normal depth (D) values for canals bed width (b=5.0m)

R^2	Formula	D (X) m	$(n*Q)/S^{1/2}$ (y) m^3/sec
0.99	y=5.66(x)^1.83	0.4	1.05
		0.5	1.59
		0.8	3.76
		2.2	23.95
		3.6	59
		4.5	88.75
		4.7	96.1
		5.2	115.63

Table (7): Variations of the normal depth (D) values for canals bed width (b=8.0m)

R^2	Formula	D (X) m	$(n*Q)/S^{1/2}$ (y) m^3/sec
0.99	Y=8.75(x)^1.8	0.3	1.0
		0.5	2.51
		1.4	16.03
		2.7	52.29
		2.9	59.47
		3.5	83.43
		3.7	92.20
		3.9	101.37

Table (8): Variations of the normal depth (D) values for canals bed width (b=10m)

R^2	Formula	D (X) m	$(n*Q)/S^{1/2}$ (y) m^3/sec
0.98	Y=10.78(x)^1.65	0.3	1.47
		0.3	1.47
		0.4	2.37
		1.5	21.04
		2.4	45.70
		2.8	58.94
		3.4	81.20
		3.6	89.23

Table (9): Variations of the normal depth (D) values for canals bed width (b=30m)

R^2	Formula	D (X) m	$(n*Q)/S^{1/2}$ (y) m^3/sec
0.99	Y=30.14(x)^1.68	0.2	2.01
		0.4	6.46
		0.66	12.77
		0.8	20.71
		1.2	40.94
		1.6	66.38
		2.0	96.57
		2.2	113.34

Table (10): Variations of the normal depth (D) values for canals bed width (b=50m)

R^2	Formula	D (X) m	$(n*Q)/S^{1/2}$ (y) m^3/sec
0.98	Y=45.68(x)^1.58	0.1	1.2
		0.2	3.59
		0.6	20.38
		0.7	26.00
		1.2	60.93
		1.5	86.68
		1.7	105.64
		1.8	115.62

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