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Implications of Continuous Desiltation on Carrying Capacity and Canal Geometry: A Case Study: University of Gezira Farm, Gezira State, Sudan

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Abstract
Irrigation is a supplement natural supply of water for crop production within economic and efficient system. The Irrigation system includes planning, design, construction, operation and maintenance of irrigation structures. The main objective of this study is to evaluate the carrying capacity of the main canal of the University of Gezira farm. The experiment was conducted during the period 14th August to 10th September 2018 to assess the canal discharge (m^3 /sec), water level (m), bed width (m), bank width (m) and canal slope (m/km). Cross sections of the canal were performed at 500 m (10 cross section; X1, X2,…X10). The data was collected by using spirit level and GPS, then the collected data sets were processed and analyzed using the Excel spreadsheet. The existing canal geometry was compared with the canal design specifications obtained from the Ministry of Irrigation and Water Resources. Then the volume of cut and backfilling for the rehabilitation to original design was determined. The results showed that the existing cross-sections are wider than the design cross-sections, in all sections from X1 to X10, however the cross section X2 is somewhat similar to the design cross section. After 10 meters from the pump station the existing cross section was higher than the design cross section by 1.4 m, the rest of the cross-sections from X2 to X10 need backfilling, where the average backfill height is 0.5 m for the X2 to X5 Cross sections, and the average backfill height is 1.6 m for the Cross sections from X6 to X10. The average canal discharge was 1.9 m^3/sec, and it depends mainly on the pumping station at the beginning of the canal. There were different discharges from section to another, whereby the lowest discharge was 1.41 m^3/sec in cross section X8 and the highest was 2.81 m^3/sec. In cross section, the bed width was 1.4 meters higher than the design bed width, and at 400 m from pump station the bed width begins to decrease until it reaches 1.7 m in the downstream part. When comparing the existing cross sections and the original design section X1 needs to removal of (cut) 1.4 m from the canal bed, while the rest of the sections required 1.6 m backfill. For efficient irrigation practices and to avoid water shortage backfilling and annual cleaning of the canal are recommended.

Keywords: Implications, Desiltation, Carrying Capacity, Canal Geometry

Introduction
Irrigation is the artificial process of applying controlled amounts of water to land to assist in production of crop. Irrigation also has other uses in crop production, including frost protection, suppressing weed growth in grain fields and preventing soil consolidation. The Sudan is an integral part of the world with 728, 200 million square miles of land and good water quality. The Northern part which has rainfall less than 300 mm/year depends mainly on the Nile. Sudan can't

use the Nile water freely because of the bilateral agreement with Egypt in 1959 which determines its share as 20.5 billion cubic meters from the Nile at Sennar. Irrigation is an age-old art. Traditionally; development has followed the development of irrigation. Development have risen on irrigation lands; they have also decayed and disintegrated in irrigated regions. The conveyance of water requires extensive and costly engineering works, but, from the agricultural point of view, the means of conveyance are significant only in so far as they affect the availability, cost and quality of the water and extent to which their physical presence impedes farming operations (Elsheikh, 2005). Basic objective of irrigation is to supplement natural supply of water, for raising crops with economic and efficient system. Controlling and harnessing various natural resources. Irrigation system includes planning, design, construction, operation and maintenance of structures and efficient irrigation system is engineer's responsibility (Gadad, 2017). Methods of irrigation are: Surface Irrigation, Sub-surface Irrigation and Sprinkler Irrigation. Surface irrigation entails water flowing by gravity over soil. Water is usually supplied by gravity from the water source through canals, pipes or ditches to the field. In some locations, however, water may need to be pumped from the source to a field at a higher elevation. Types of surface irrigation systems include furrow, basin and border irrigation. Surface irrigation systems are typically used for field crops, pastures and orchards. Efficiency of surface irrigation systems vary tremendously because of variations in soil type, field uniformity, crop type and management. Surface irrigation is often considered less efficient than sprinkler irrigation because soil, not a pipe, conveys the water within surface of irrigated fields.

The main objective of this study was to determine the implications of continuous desiltation on the carrying capacity and geometry of the university of Gezira Farm canal.

The specific objectives were:

1)Determine the water level for any canal crodd section of ten longitudinal and transverse sections along the canal.

2)Calculate the actual canal discharge as determined by bed level, bank level, ground level,

3)Determine the required volume of cut and fill.

Materials and Methods

The study was conducted at the Experimental Farm of the Faculty of Agricultural Sciences, University of Gezira. University of Gezira has a main canal of about 4.75 km length, used to irrigated more than 1080 feddans (Fig.1). The Farm is located in the Gezira State and lies North of Wad Madeni town, and is located at 14.4º North and 33.5º East with an altitude of about 405 m above the mean sea level.

Climate: Gezira is located in the sahel zone and determined by the climatic and ecological transitions from the savannah in the South to the arid Sahara in the North. The marginal tropical, arid to semi-arid climate is affected by the location of Intertropical Convergence Zone (ITCZ) in summer (Ibrahim, 2017). Based on long-term averages, the Sahel of Sudan is marked by annual precipition close to 100 mm in the North and 600 mm in the South. Wad Medani town receives mean annual rainfall of about 254 mm (Elfaki *et al*, 2010). Temperature is high all the year around, the highest temperatures being in April which are above 40ºC and in October are around 36ºC. January is the coolest month with a maximum average temperature of 17ºC. The trend of annual temperature change is a drop in july and August as a result of high relative humidity and cloud cover. Then temperature begins to rise through September and October towards November with the retreating ITCZ and a declining cloud cover.It drops to a minimum with the advance of

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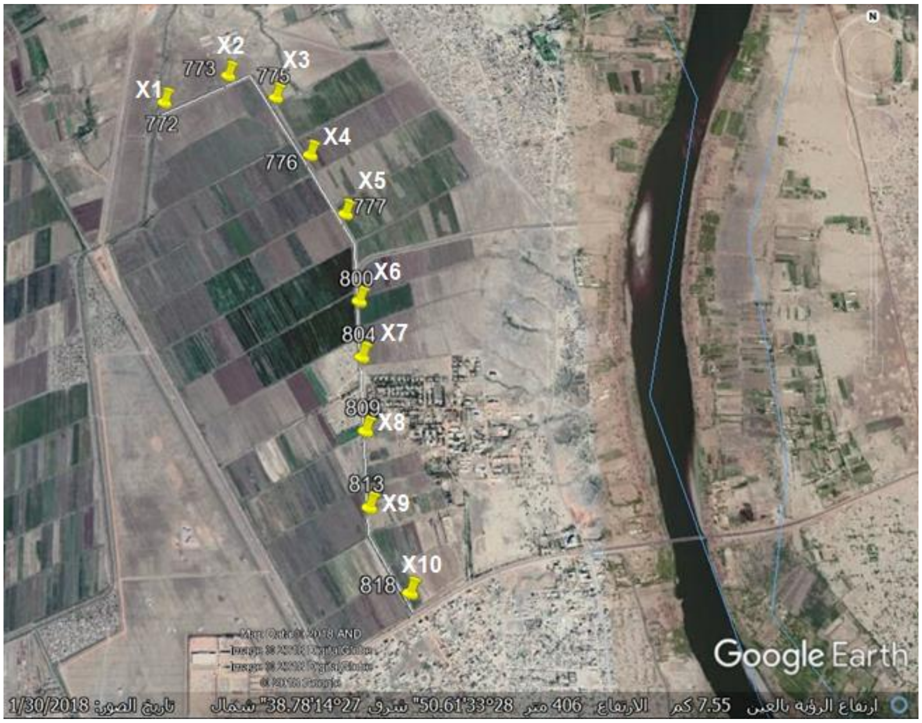
cool Northerly winds through December, January and February (Van der Kevie, 1976). Evapotranspiration (ET) is the major component of water balance. Hasegawa and Kasubchi (1993) rightly noted that ET has an effect on water balance almost throughout the year. ET is a central concept in the determination of the irrigation water requirement. It tends to decrease during the winter time (November to February) when temperature reaches its minimum values in these months,while in the summer season (March – June) ET increases rapidly when temperature reaches its maximum in April and May. In Wad Medani the mean annual Evapotranspiration ranges between 2500 – 3500 mm.



Pate. (1): Map of the main canal of University of Gezira Farm
Source: (Google earth)

Soil: The soil of the experimental farm of the Faculty of Agricultural Sciences belongs to the Central Clay Plains of the Sudan. Gezira clay plain falls between the latitudes of 13º30′ and 15º30′ North and the longitudes of 32º30′ and 33º30′ East. The soil is predominantly typical Vertisols that expand and contract markedly with changes in moisture content and develop deep vertical drying cracks. Such soils are developed from deposits carried by the Blue Nile from the Ethiopian Highlands (Ibrahim, 2017). Clay content may reach 60% or more throughout the soil profile. The dominant clay minerals are Smectites (Blokhuis *et al.*, 1964; Fadl, 1971; Adam *et al.*, 1983; Blokhuis, 1993). Soil pH is between 8 to 9.5 with little change below the soil surface (Robinson *et al.*, 1969). The soil content of organic carbon and nitrogen is very low.

Equipment and tools

a)A spirit level was used for testing to see if a surface is level. It consists of a plastic, frame containing a glass tube of liquid with an air bubble in it.

b)A level staff, also called leveling rod, with a graduated wooden rod was used with a leveling instrument to determine the difference in height between points or heights of points above a vertical datum.

c)The Global Positioning System (GPS) has been developed in order to allow accurate determination of geographical locations by military and civil users.

Data collection and Data analysis:

The data collected during the period 14th August to 10th September 2018 agricultural season included:

a)Determination of ten longitudinal and transverse sections along the canal.

b)Determination of bed width and bed slope and flow for each section.

c) Canal design dimensions are obtained from Ministry of Irrigation and Water Resources (MOIWR).

Canal water discharge:

By using the data collected the Manning equation was used to determine the water discharge in the canal as follows:

$$Q = A.V \quad (1)$$

$$Q = \frac{A}{n} R^{2/3} S^{1/2} \quad (2)$$

$$A = \varepsilon a_1 + a_2 + \cdots + a_n \quad (3)$$

$$P = p_1 + p_2 + \cdots + p_n \quad (4)$$

$$R = {}^{A}\!/_{p} \quad (5)$$

where:

Q = Canal discharge (m^3/s).

A = Canal area (m^2).

n = Manning's coefficient (0.020).

R = Hydraulic radius of the channel (m).

S = Canal slope (%).

P = Wetted diameter (m).

Cut and fill volume:

To determine the volume of the cut and fill to remove the sediment in the canal the following equation was used (Babapour and Naghdi, 2017):

$$V = {}^{D(A_1 + A_2)}\!/_{2} \quad (6)$$

where:

V = volume of the cut and fill (m^3).

D = the space between sections (m).

A_1 = Area of the first section (m).

A_2 = Area of the second section (m).

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Design Dimensions of Gezira University Farm:

The Design Dimensions of the Gezira canal were obtained from Ministry of Irrigation and Water Recourse (MOIWR) included:

1)Bed width = 3 m.
2)side slope = 2:1.
3)canal depth = 0.65 m.
4)Discharge =0.57m^3 /sec.
5)Gezira roughness coefficient n = 0.02.

Statistical analysis of data:

Microsoft Excel version 2010 under Windows was used for the data analysis.

RESULTS AND DISCUSSION

Cross sections of the U of G Main canal:

During period of 14th August to 10th September 2018, the cross-sections of the University of Gezira main canal was carried out. The canal was divided into 10 sections with distances of about 500 meters between sections on average (Table 1), where the elevations were obtained from Mean Sea Level (m.s.l) for the Ground Level (RL. Ex), Bed Level (B.L. Ex), and Bank Level (BK.L. Ex) in right side of the canal.

Table (1): The existing Cross-sections elevations from Mean Sea Level (m.s.l)

Cross section	Distance from the pump station (m)	RL. Ex (m)	B.L. Ex (m)	BK.L. Ex (m)
X1	10	406.849	406.980	408.564
X2	452	405.580	405.350	407.580
X3	951	405.354	405.100	407.372
X4	1449	405.650	404.960	407.022
X5	1945	405.609	404.610	407.127
X6	2583	405.470	404.040	406.398
X7	3074	405.515	404.350	406.174
X8	3466	404.752	403.560	405.873
X9	3963	404.966	403.220	405.527
X10	4569	404.872	403.600	405.835

NOTE:
R. L. Ex = Existing Reduced level (m).
B. L. Ex = Existing Bed level (m).
B. K. L. Ex = Existing Bank level (m).

The Reduced Levels of the cross sections from collected data were calculated, then the calculated RL were compared with the design cross sections obtained from MOIWR. In general, the results show that the existing cross-sections were wider than the design cross-sections, as shown in Figures (1) to (10), expect the cross section X2 is somewhat similar to the design cross section and this is due to the continuous desiltation and weed removing of the canal despite the residues in canal bank.

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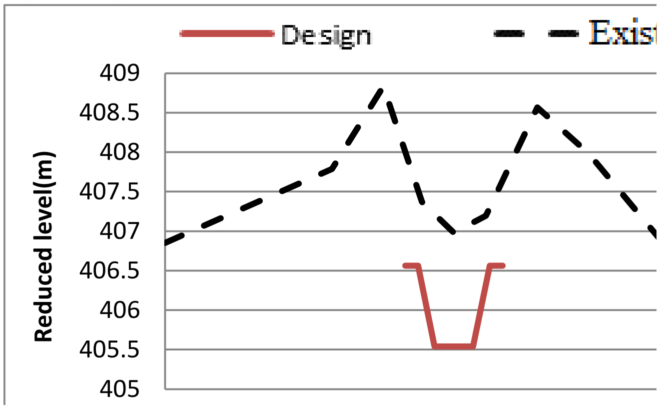

Fig. (1): Cross Section X1

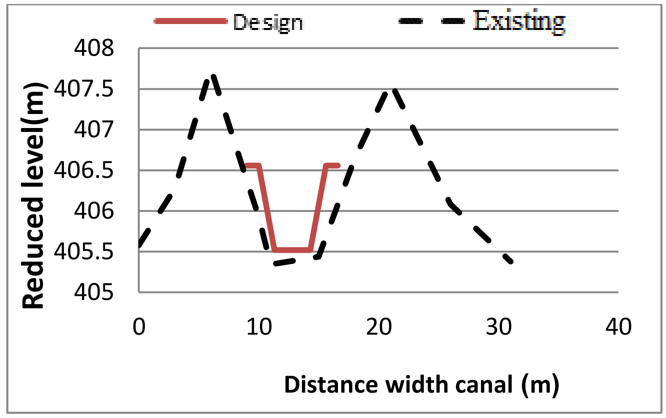

Fig. (2): Cross Section X2

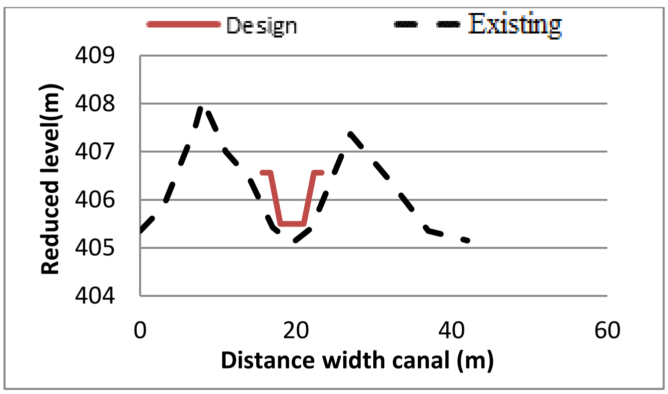

Fig. (3): Cross Section X3

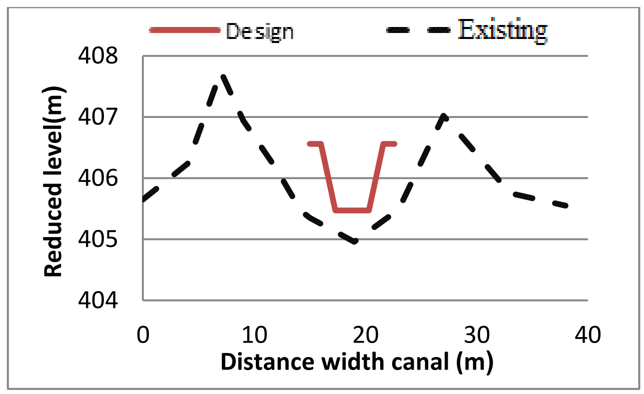

Fig. (4): Cross Section X4

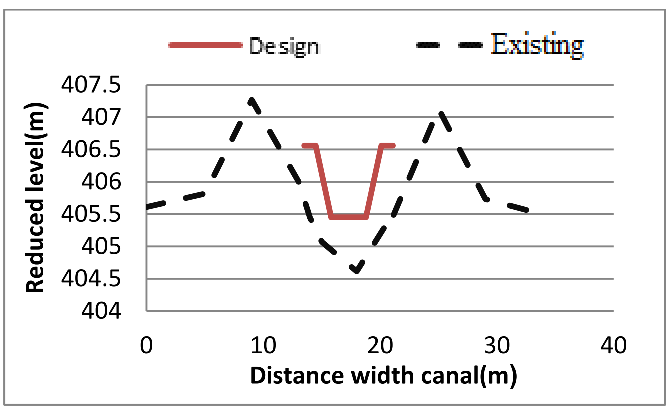

Fig. (5): Cross Section X5

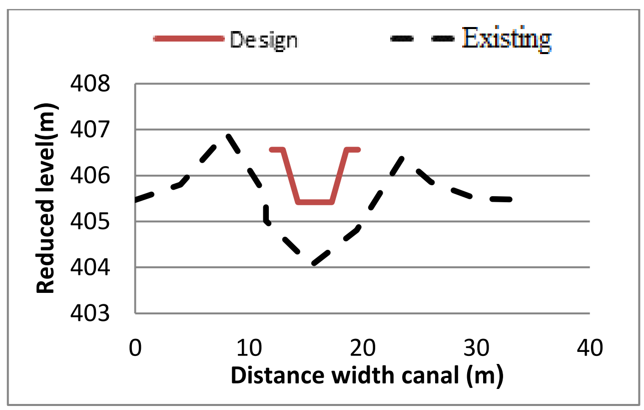

Fig. (6): Cross Section X6

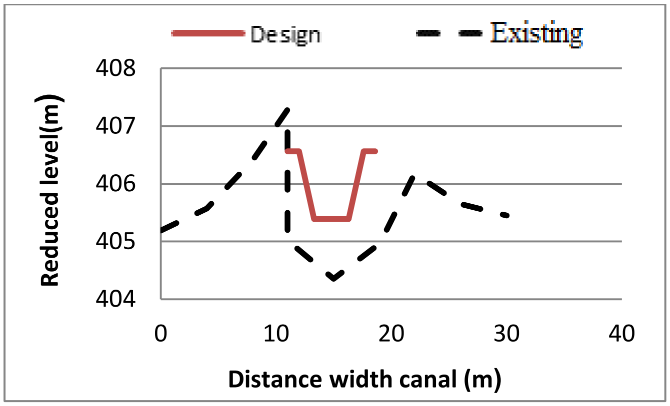

Fig. (7): Cross Section X7

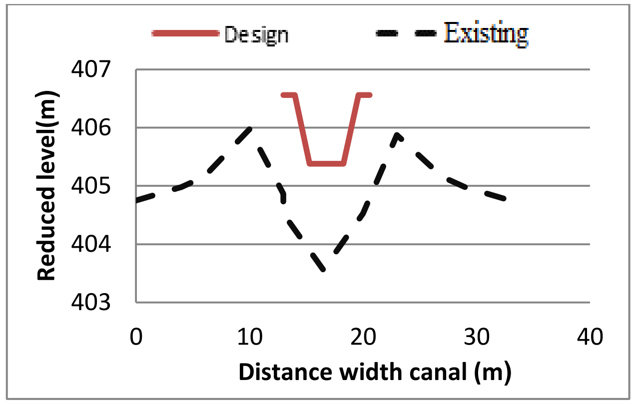

Fig. (8): Cross Section X8

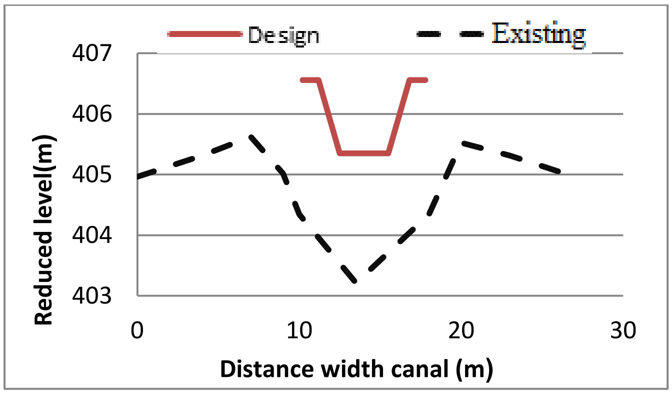

Fig. (9): Cross Section X9

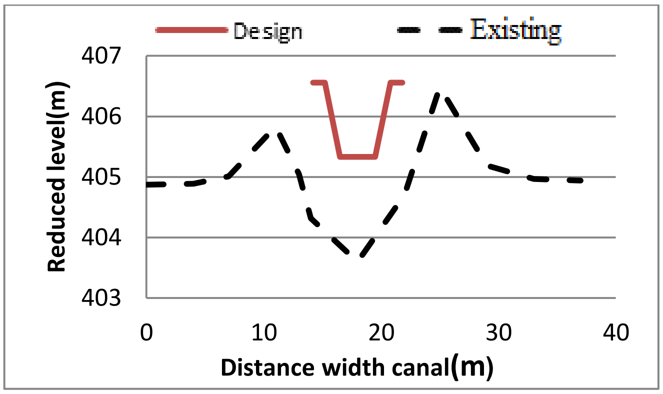

Fig. (10): Cross Section X10

Comparison between the design and existing structure of U of G canal
Longitudinal cross section of the canal

Figure (11) shows the design cross section data of the canal. Figure (12) illustrate the design longitudinal section of the canal where the Bank level (BKL) is at a height of 406.56 (m. s. l) fully horizontal from the start point to end of the canal, and the Bed level (BL) starts with elevation point 405.54 (m. s. l) to 405.31 (m. s. l) and ends (4800 m distance) with slope 5 cm/km While the full supply level (FSL) point starts at elevation 406.21 (m. s. l) with slope 5 cm/km to the end with the same bed level slope, and this means the canal operates as a reservoir. The obtained RL of cross sections were used to draw the existing longitudinal sections of Bl and BK of the canal (Fig12). From comparison between design and existing slope it is noticed that the bed level slope from the upstream direction (pumping station) to the downstream is equal to 0.0007 (70 cm/km), while the longitudinal section for the bed level in design section had a slope equal to 50 cm/km, therefore the difference in slope was significant (Fig. 13).

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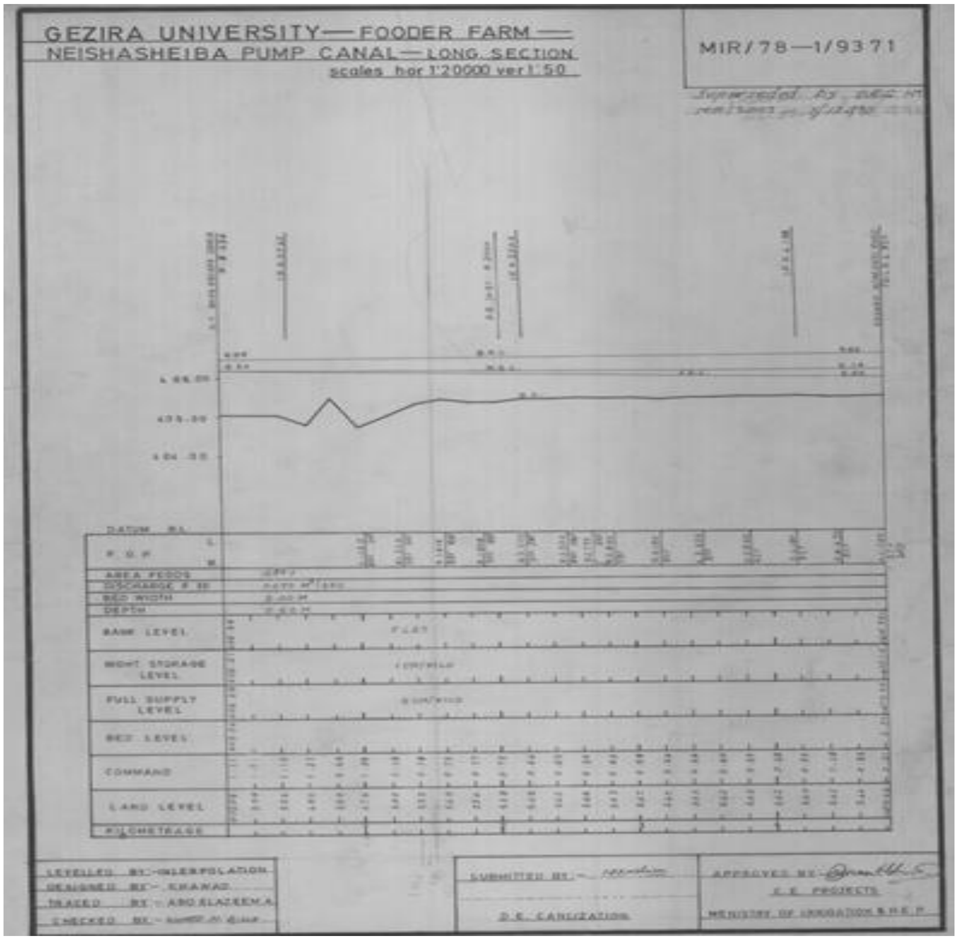

Fig11: design cross section data
Source: Ministry of Irrigation and Water Resources

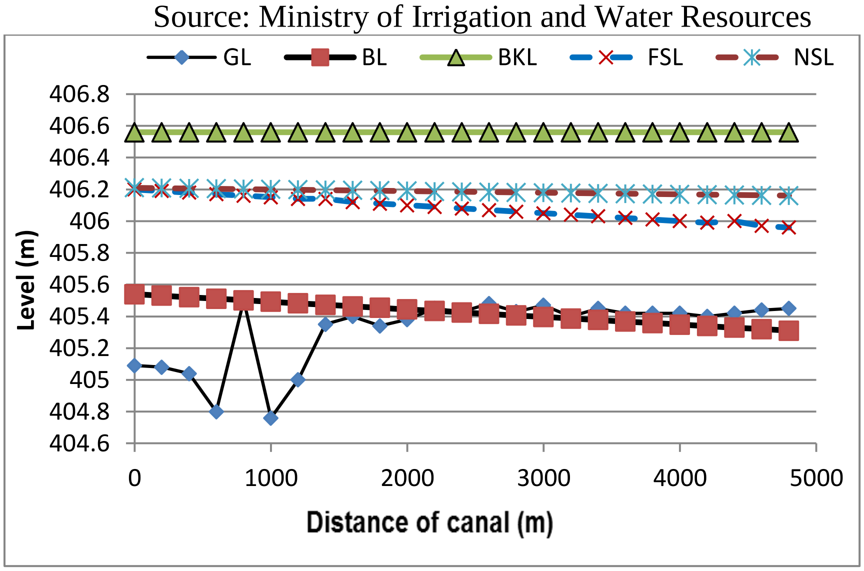

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Fig. (12): The design longitudinal sections

* GL = Ground level; BL = Bed level of canal; BKL= Bank level of canal
FSL = Full supply level; NSL = Night storage level

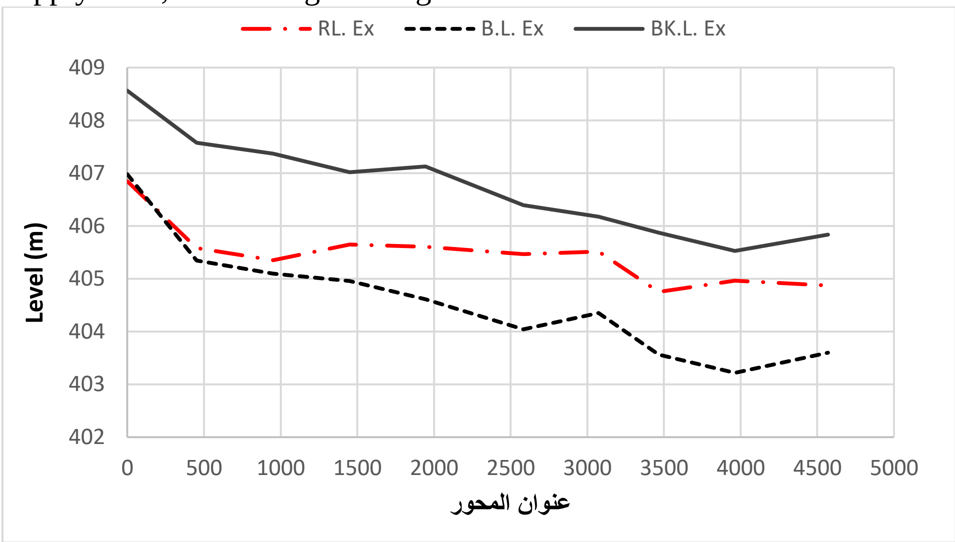

Fig. (13): The existing longitudinal sections

Bed level comparison:

By comparing the bed level between the existing and longitudinal section design, the existing section begins 1.4 meters higher than the design, and at 400 m distance the existing section begins to decrease from the design until it reaches 1.7 m at the end downstream (Fig. 14).

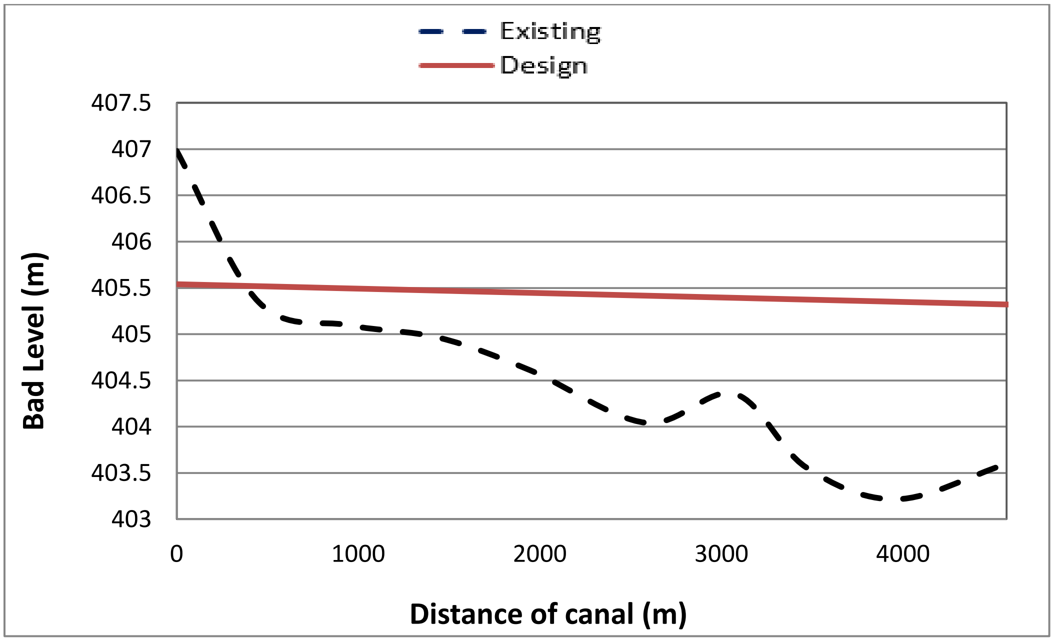

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Fig. (14): Comparing of the design and existing bed level

Bank level comparison:

From Fig. (15) it can be seen that the existing bank level has an irregular shape compared with the design BKL (which is a straight line from upstream to downstream of the canal), this means that the existing section is sloping in the direction of the downstream, and the design section is completely horizontal.

Ground level comparison:

The level of the design ground level was level (Fig.16) at the beginning of the straight line and then the difference began from 500 m to 1000 m and then increased and fluctuated until the end of the design level, and the level of the ground standard began from a high area and then decreased and also fluctuated with the increase of distance.

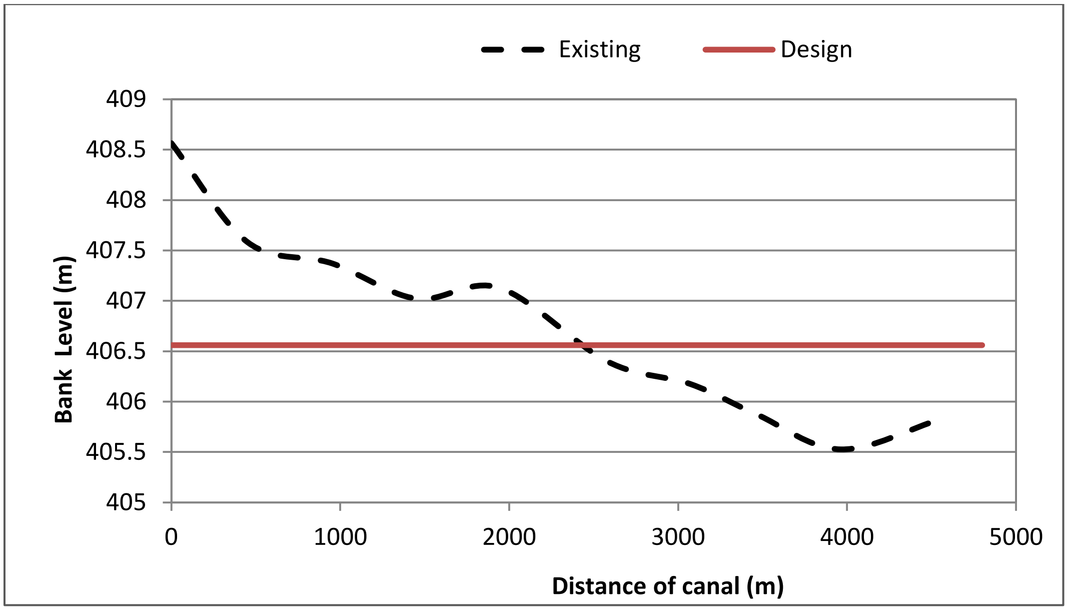

Fig. (15): Comparing of the design and existing bank level

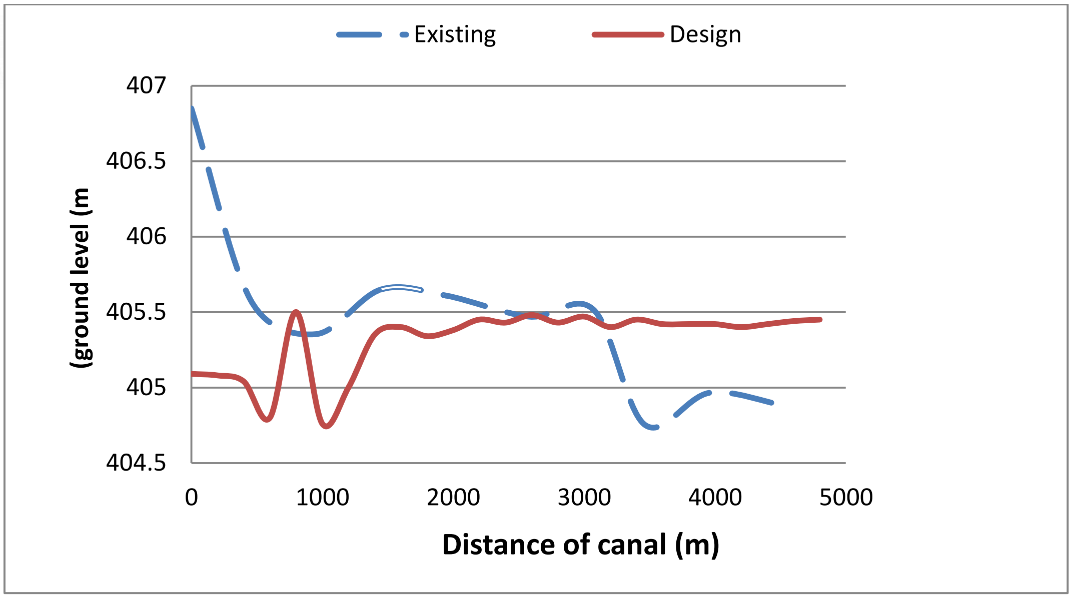

Fig. (16): Comparing of the design and existing ground level

Water Discharge and Water level of the U of G main Canal

Canal discharge:

From the data analysis and equation (1) the discharge for each section was calculated (Table 2). The average canal discharge was 1.9 m^3/sec, and it depends mainly on the pumping station at the beginning of the canal. At the beginning of the discharge of cross section test the reading for X1 were not studied because the pump was out of service, and therefore there was no values for wetted parameter, hydraulic reduce and discharge. There is no significant difference between the discharge in different sections ($P \leq 0.05$), but sections X2 and X5 had higher discharge, while sections X8, X9 and X10 had lower discharge and this was due to the limiting factor of the wetted parameter. This means that the upper Abu XX is not facing any water shortage.

Table (2): Discharge of cross sections.

X cross section	Area (m^2)	Wetted parameter(m)	Hydraulic radius(m)	Discharge (m^3/sec)
X1	**2.54**	**0**	**0**	**0**
X2	4.775	7.927	0.6023	0.347
X3	2.815	9.073	0.3102	0.045
X4	3.383	10.152	0.3332	0.058
X5	4.700	7.129	0.6593	0.125
X6	2.395	7.975	0.3003	0.038
X7	2.900	7.087	0.4092	0.056
X8	1.800	7.241	0.2486	0.025
X9	1.700	7.218	0.2355	0.023
X10	1.810	7.286	0.2484	0.0252

Water level:

In the beginning water level was low because it depends on the discharge of the pumping station, storage in the canal, and the withdrawal of water by Abu XX. Figure (17) shows the comparison between the design and existing water level, and it indicates that the existing water level is lower than the design level, where the highest difference was 1.3 m at the measured time in section X4.

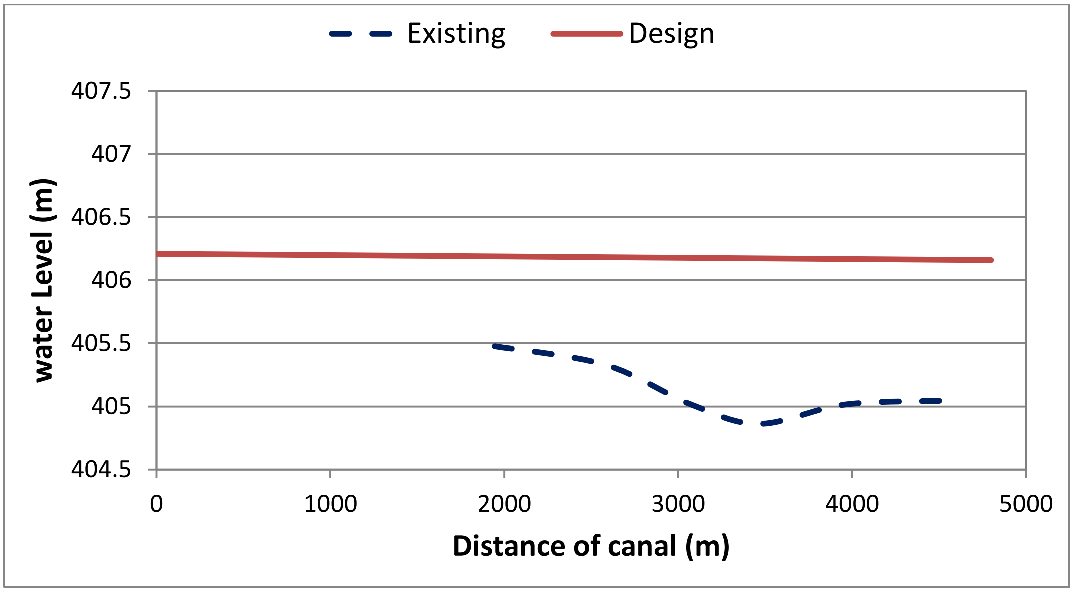

Fig. (17): Comparison between the design and existing water level

Rehabilitation of the U of G main canal:

To return the original design cross-sections with the same area and shape, the bed level can be re-leveled by the process of backfilling and digging. For recovering the canal to its original design, cut and fill processes need to be carried out to avoid water shortage and flooding in the University farm and crop failure. By using equation (6) the volume of cut and fill was calculated. For the first section (X1) as in Table 3, the distance was taken from the beginning of the pump with zero distance, and then it was taken every 500 meters concurrently. When comparing the existing cross sections and design ones it is noted that in section X1 there is a need to cut (digging) about 1.4 meter, while the rest of the cross-sections (from X2 to X10) needs backfilling, where the average backfill height is 0.5 m in the X2 to X5 cross sections, and the average backfill height is 1.6 m in the cross sections from X6 to X10 as shown in Fig. (18) and Fig. (19).

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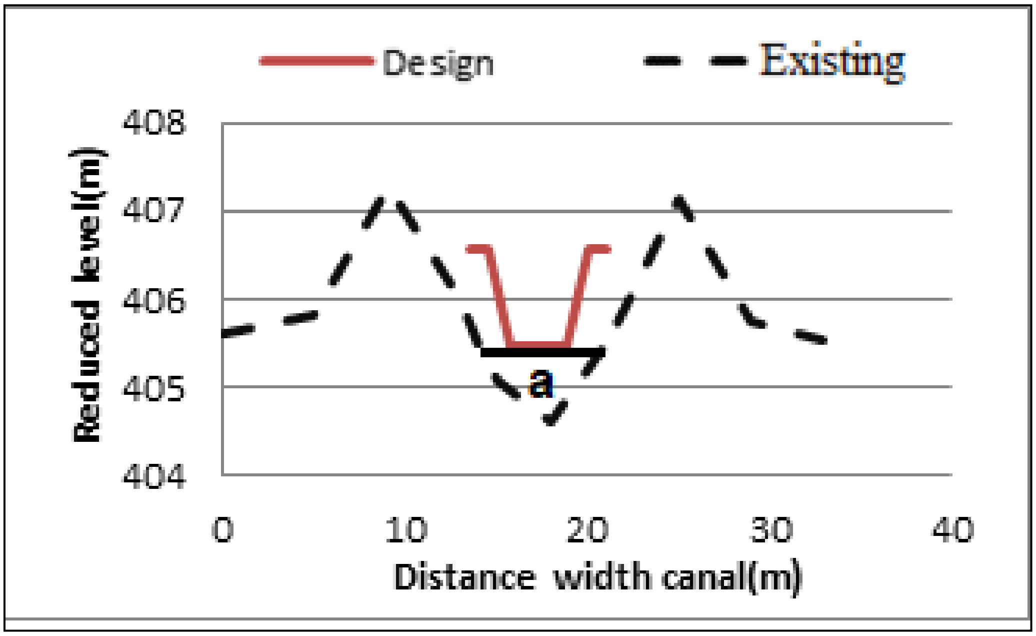

Fig. (18): Backfill area under the design cross section

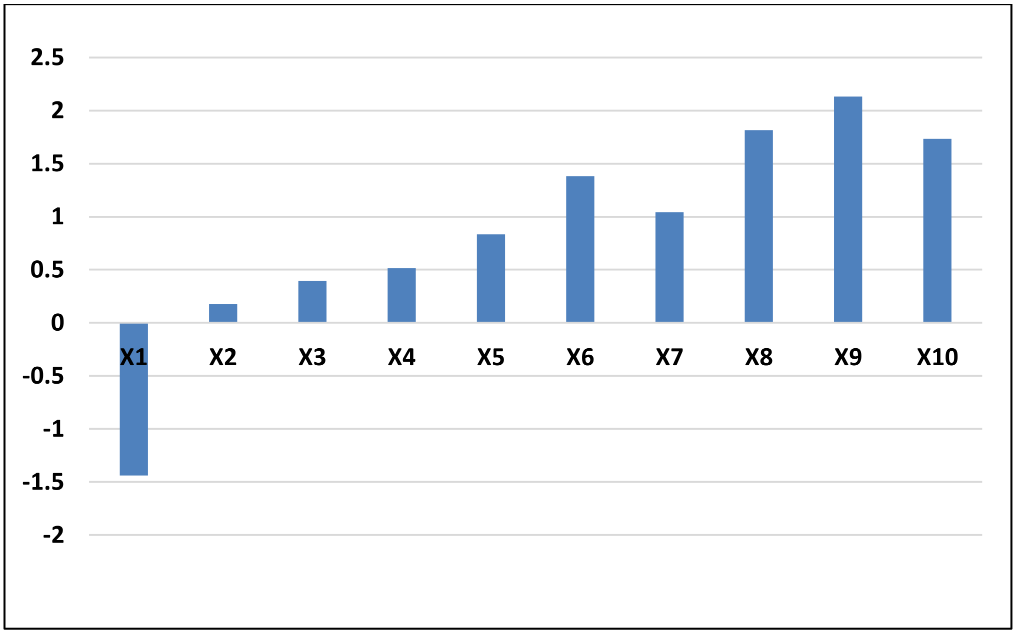

Fig. (19): The Digging and backfilling Depth (m).

Table (3): Calculation of cut and fill

Section	Design RL	Existing RL	C	B	Area(a)	Distance	Volume (m^3)
X_1	405.5	407	-1.5	5	-3.75	**0**	0
X_2	405.5	405.3	0.2	5	0.5	500	-812.5
X_3	405.5	405	0.5	2	0.5	500	250
X_4	405.5	404.5	1	9	4.5	500	1250
X_5	405.5	404	1.5	7	5.25	500	2437.5
X_6	405.5	404.5	1	8	4	500	2312.5
X_7	405.3	403.5	1.8	10	9	500	3250
X_8	405.4	403.3	2.1	9	9.45	500	4612.5
X_9	405.5	403.2	2.3	11	12.65	500	5525
X_{10}	405.5	403.3	2.2	10	11	500	5912.5

Conclusions:

From the results of this study the following conclusions could be drawn:

1)The cross sections in current situation of the canal showed that they are wider than the design cross section.

2)The current slope of the canal is higher than the design slope with a relatively steep slope.

3)Nine out of ten cross sections of the canal need backfilling, especially towards the downstream of the canal near the southern Gate of the University Farm.

Recommendations

From the results and conclusion of this study the following recommendation can be drawn:

1)The canal must be returned to its original design by backfilling for efficient irrigation practices and to avoid water shortage.

2)The annual cleaning of the canal must be done.

3)Survey studies must be carried out inside the farm to determine the topography (contour lines) to improve irrigation operations.

4)A reference Bench Mark point must be fixed in the University Farm, which is equal to 406.982 m.

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