Vol. 2, No. 3, pp. 190-201, (September2021)
DOI: 10.21608/aujes.2021.89249.1034
Aswan University Journal of Environmental Studies (AUJES)
Online ISSN: 2735-4237, Print ISSN: 2735-4229
Journal homepage: https://aujes.journals.ekb.eg/ E-mail: AUJES@aswu.edu.eg
Original research

Water-Saving from Rehabilitation of Irrigation Canals Case Study: El-Sont Canal, Assiut Governorate

Ashour M. A [(1)]; Tarek Sayed [(2)*]; AbdAllah A.A[(3)]

[(1)] *Prof. of Irrigation Engineering and Water Structures Civil Eng. Dept., Assiut University,*
[(2)] *Assis. Prof. of Irrigation Engineering and Water Structures Civil Eng. Dept., Assiut University*
[(3)] *Assis. Lecturer of Irrigation Engineering and Water Structures Civil Eng. Dept., Assiut University.*

Received: 1/8/2021 Accepted: 17/8/2021

Abstract:

In light of the national project for rehabilitation and the lining of the exposed irrigation canals which is currently under implementation all over Egypt, a field study is introduced to assess the technical, and environmental expected impacts that must be achieved in such a national project. In arid and semi-arid regions, with permeable soils like Egypt, water seeps significantly through the exposed canals cross-sections, in addition to the quantities lost by evaporation under high temperatures. Saving such tangible quantities of water became the most important goal that can be achieved to solve the problematic situation of irrigation water shortage that faces Egypt nowadays. This study is a field attempt to estimate the transmission losses in the El-Sont canal in Middle Egypt (Assuit Governorate) as a representative open channel for a specific type of soil, climate, topography, and beneficiary's lifestyle. The produced and developed equations introduced and recommended by the most popular authors in this field were studied, summarized, and presented in a tabulated form to be easily used, and for comparison purposes. Using the recommended equations developed by the most popular reviewed researchers, the conveyance and transmission losses for the understudy El-Sont canal, and its off-taking canals were calculated and evaluated to be about 248628 m^3/day, i.e., more than 39.54 Mm^3/year. That big quantity of saved or recovered water can be used for reclamation and irrigation of about five thousand new acres in the nearby area. The study and the field trips, visits, and the personal direct communication with the farmers and beneficiaries proved that the project had responded to their hopes for an improved living standard, health, in addition to the environmental situation for all the Egyptian countryside.

Keywords: Irrigation water saving - Canals rehabilitation - Canals transmission losses

Corresponding author*: E-mail address: tareksayed1986@aun.edu.eg

Abbreviations :

The following symbols are used in this paper:

a	Area of wetted perimeter	(M m^2);	L	Canal length	(m);
B	Bottom width	(m);	P	Wetted perimeter	(m);
C	Constant depends on soil type	-;	Q	Discharge	(m^3/s);
C_1	Seepage factor = (2e/v*H)	(m^{-1});	R	Hydraulic radius	(m);
C_2	Seepage factor =e*B	(m^2/s);	R_E	Evaporation losses	(m^3/day);
C_3	Seepage factor =2e*H((z^2+1)$^{0.5}$-z)	(m^2/s);	S	Seepage losses	(m^3/s/km);
E	Evaporation rate	(m/day);	T	Width of canal water surface	(m);
e	Permeability	(m/s);	v	Mean velocity	(m/s);
H	Water depth	(m);	z	Canal side slope	-; and
i	Bed slope	-;	ά	Seepage losses factors	-.

1- INTRODUCTION

In Egypt, open channels are the major conveyance system of irrigation water from its sources to where it may need through a total length exceeding 32000 km (El Gamal and Zaki, 2017). This network was excavated in the sedimentary permeable soils and running in hot weather conditions. A huge amount of water may be lost through more than one aspect, such as seepage, evaporation, evapotranspiration, and other bad behaviors in using the irrigation water for other purposes. As a compatible scientific-technical role of the university, this field study was conducted on one of the under-rehabilitation process canals in the Assuit countryside in the Middle Egypt region, to be a representative case study. About the rehabilitation and environment, many field trips were carried out through which the environmental condition of the understudy canal and its off-takings surrounding areas were recorded. The recorded observations included all the basic services and infrastructure related to the rehabilitation national project which were evaluated to assess the gained positive needed impacts.

2- LITERATURE REVIEW

The major types of losses in irrigation canals are the seepage losses through the canal sides and bed, the evaporation losses from the free surface of the canal top width, and the transpiration losses from grass and weeds that located at the side slope, bed of canals, or floating weeds. Other types such as leakage (water lost through channel banks and structures) and operational losses (outfalls, system fill, unmetered diversions, and inaccurate metering), (Allen et al., 1998; Kacimov, 1992; Swamee, 2000; Akkuzu, 2012; Ahuchaogu, 2015). Although the transpiration, leakage, and operational losses may be very high in some instances, these losses are out of the scope of this study. Two main types of water losses will be discussed in this paper, namely losses due to seepage and evaporation. The seepage losses in the irrigation canals account for about 98.37% of the water conveyance losses, while approximately 0.3 % of the total stream is lost due to evaporation (Jadhav, 2014).

2.1. Seepage Losses

A review of the literature confirmed that seepage rates from canals are greatly affected by the permeability of canal soil, canal wetted perimeter length and shape, canal water depth, uniformity of the soil or canal lining, flow rate, sediment load, and size distribution, canal age, groundwater table location, and constraints on groundwater flow, presence of wells, rivers, drains and impermeable boundaries, etc. Other relatively less significant factors like viscosity, the salinity of water, aquatic plants, operational time, water chemistry, and temperature (Swamee, 2000; Alam, 2004). According to Zhang (2017) seepage has many impacts on canals' water quantity and quality. Seepage losses can account for 20-30% of the total flow volume in unlined earthen canals (Martin, 2015). Seepage rate can be evaluated by three methods: direct measurement methods (field measurements), analytical equations, and empirical formulas (Robinson and Rohwer 1957). Field tests for measuring seepage such as inflow–outflow measurement method, ponding tests, point measurement method, double-ring infiltration test, and parameter measurement method (Alam, 2004). There are different empirical and analytical equations used to evaluate the seepage losses. Mowafy (2001) evaluated several empirical and analytical formulas with seepage tests performed on different sections of the Ismailia canal in Egypt. The results showed that the Molesworth-Yennidumia empirical formula (Shaikh, 2016) as follows in Eq. 1, had good agreement with the field results.

$$S = CLP\sqrt{R} \quad \ldots\ldots (1)$$

Where: S is seepage (m^3/s/km); L is the canal length (m), P is wetted perimeter (m); R is hydraulic radius, C is constant whose value depends on the type of soil and was taken to be equal to 0.003, 0.0015, 0.0018, 0.0022, and 0.0026 for sandy loam, clay, silty clay, clay loam, and silty loam, respectively (Shaikh, 2016; Awan, 2017).

International commission on irrigation and drainage developed another equation called the Indian formula which used for estimating the earthen canals seepage as follows (Khan, 2015):

$$S = CaH \quad \ldots\ldots (2)$$

Where S is the total seepage losses (ft^3/s); a is the area of wetted perimeter (million ft^2); H is the depth (ft); and C is a factor which depends on soil types and varies from 1.1 to 1.8.

Moritz formula was proposed by the United States Bureau of Reclamation (USBR) for estimating seepage losses per mile of the unlined canal as follows (Kraatz, 1977; Leigh, 2014):

$$S = 0.2 \times C \times \sqrt{Q/V} \quad \ldots\ldots (3)$$

Where S is the seepage losses in (ft^3/sec /mile), Q is the discharge (ft^3/sec), V is the mean velocity (ft/sec), and C is a constant value depending on soil type. (cemented gravel and hard pan with sandy loam 0.34, clay and clayey loam 0.41, sandy loam 0.66, sandy soil with rock 1.68, sandy and gravelly soil 2.20)

Mowafy (2001) reviewed that Molesworth and Yennidunia derived analytical formula to estimate seepage losses as follows:

$$S = \frac{\propto * 10^{-4}}{R^{1.166} * i^{0.5}} \quad \ldots\ldots (4)$$

Where S is the seepage losses in m^3/s/km; R is the hydraulic radius. i is the bed slope, $\propto$ is seepage losses factors equal to 0.375 m^{-1} for clay soil, and 0.75 m^{-1} for sandy soil.

Farouk (1979) developed an analytical equation to estimate seepage losses in the earthen canal as given below:

$$S = Q\left[\frac{e^{C_1 L} - 1}{e^{c_1 L}}\right] - L(C_2 - C_3)/e^{c_1 L/2} \quad \ldots\ldots (5)$$

Where S is the seepage losses from canal in m^3/sec; Q is the flow discharge in m^3/sec; e_2 is the permeability in m/sec; L is length of canal in m; Vis average velocity in m/sec; D is the water depth in m; B is the bottom width m; and z is the side slope, $C_1 = (2e_2/v.d)$: the seepage factor in m^{-1}; $C_2 = e_2 b$: the seepage factor m^2/sec; $C3 = 2e_2 d((z^2+1)^{0.5} - z)$: the seepage factor m^2/sec.

Davis-Wilson formula (Eq. 6) relates seepage losses directly to the cube root of the water height in the canal and considers infiltration to be equal around the wetted perimeter. Davis-Wilson equation was cited for estimating seepage losses for lined canals, but also provided constant values for an array of soil types (Kraatz, 1977; Leigh, 2014):

$$S = C\frac{P \times L \times H^{1/3}}{4 \times 10^6 + 2000\sqrt{v}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where: S is seepage losses (ft^3 per second per length of canal); L is the length of canal (ft); P is the wetted perimeter (ft); H is the mean water depth in the canal (ft); v is the velocity of flow in the canal (ft/sec); and C are the constant values depending on lining (values of C=1 concrete (3 to 4 inches thick), 4 clay puddle or mass clay (6 inches thick), 5 thick new coat of crude oil or light asphalt, 6 cement plaster (1 inch thick), 8 clay puddle (3 inches thick), 10 cement grout or asphalt, 12 clay soil, 15 clay loam soil, 20 Medium loam, 25 Sandy loam, 40 Fine sand, (Leigh, 2014).

Mowafy (2001) advised of using all analytical equations and the empirical formula of Molesworth and Yennidunia for computing seepage losses in all canals of Egypt. So, in this paper, the empirical formula of Molesworth and Yennidunia will be used for computing seepage losses in El-Sont canal and its network. Also, for increasing the accuracy of the results, the Indian equation and Mortez's equation will be used.

2.2. Evaporation Losses

In hot weather conditions, when the canal water is exposed to the atmosphere, the surface water transfer from the liquid stage to the vapor stage. The evaporation losses are very small compared to the seepage losses. It may range from 0.25 to 1 % of the total canal discharge (Sahasrabudhe, 2011). Commonly, there are many methods used for estimating evaporation loss from canals like the evaporation pan, the water balance method, the heat balance method (the energy balance method), and the aerodynamic method which given by Liu (2016) and Wang (2019). The rate of evaporation from a running water surface depended not only on the surface wind speed but also on the flow speed. In the evaporation pan test, the evaporation rate from pans filled with water is easily obtained. In the absence of rain, the amount of water evaporated during a period (mm/day) corresponds to the decrease in water depth in that period. Pans provide a measurement of the integrated effect of radiation, wind, temperature, and humidity on the evaporation from an open water surface. According to Liu (2016) the evaporation losses of water in irrigation canals (R_E) from the intake to the fields through total canal length is estimated by the following equation:

$$R_E = (K_p \times E) \times T \times L \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

In which K_p is the pan coefficient; E is the evaporation rate (m/day); T is the width of canal water surface (m); L is the total canal length (m).

3- MATERIALS AND METHODS

3.1- Description of the study area

The present study was conducted on the El-Sont canal as one of the under-rehabilitation canals in Assuit countryside in the Middle Egypt region, as a case study. The length of the canal is about 40 km. It takes its water at km 157 from Eastern Nag-Hamadi main canal. It serves an area of about 34040 acres, distributed between Abnoub (23550 acres), and Sahel-Seleem (10490 acres). Both belong to the irrigation engineering administration in Assiut City. Twenty-four off-taking canals are branched directly from the El-Sont canal, with a network of 58 off-taking canals as shown in Fig. 1. Canals network is divided into three watering shifts (five days' work and 10 days off). The total length of the off-taking canals is about 149.16 km (MWRI, 2020). The area is characterized by an arid climate. The geometrical dimensions for the designed water sections of the El-Sont canal and its network are presented in Table 1.

3.2- Soil type

For knowing, the soil along the path of the canal, it was necessary to take some samples to determine the type of soil, its nature, and degree of permeability. Soil samples were taken every five km along the canal at different depths under the bed of the canal and from the side slopes. Also, the different parameters and coefficients which are used in the empirical equations concerning the study were determined.

3.3- Seepage losses computations

The estimated quantities of water lost by seepage for both the designed, and the existing sections of the El-Sont canal and its network, were estimated using the Egyptian formula (Eq. 1) as recommended by Mowafy (2001). At the same time, for the accuracy purposes, such quantities were calculated also using the Indian formula (Eq. 2) and Mortiz formula (Eq. 3). The work was carried out for reaches of 300 m. long, for the under-study canals. The results of such calculations are summarized in Table 2.

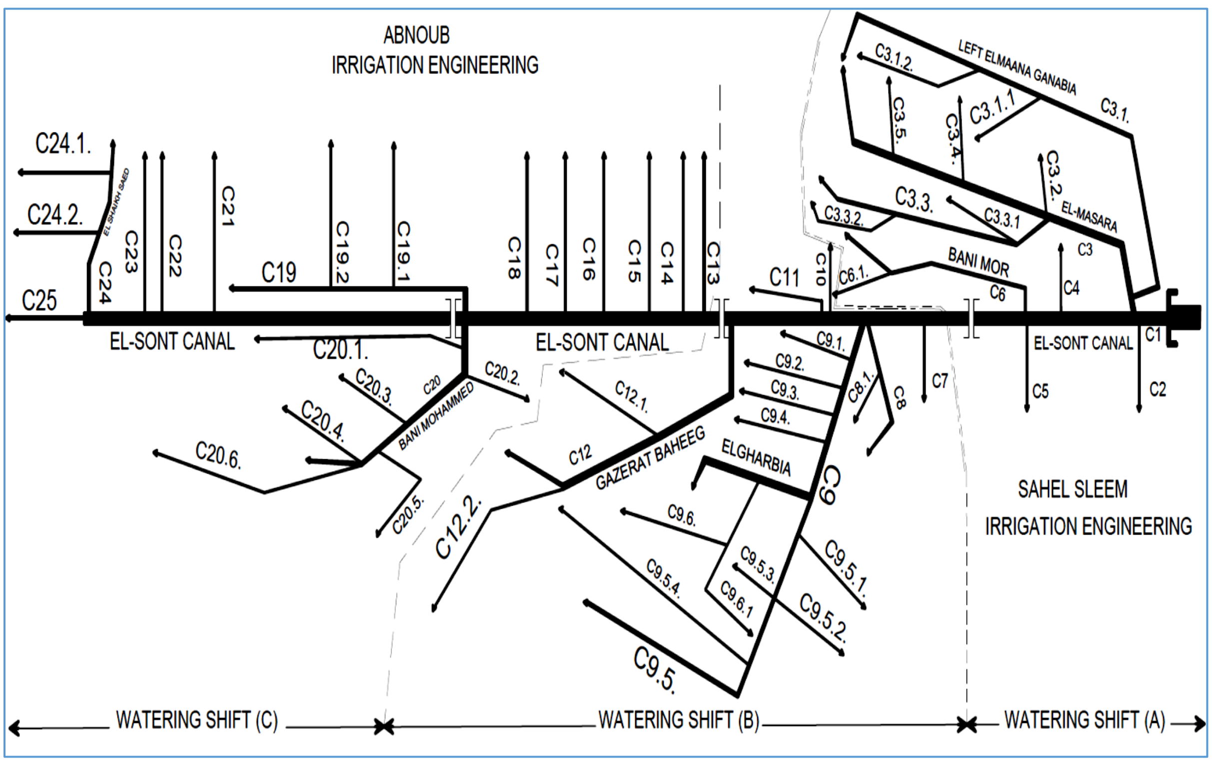

Fig. 1. El-Sont canal and its network.

3.4- Evaporation losses computation

Using the meteorological data of the study area according to the recorded sheets of Arab-Alawamer official meteorological station which is shown in Table 3, the evaporation losses were calculated using (Eq. 7). The values of maximum evaporation losses for both the designed and existing water sections of El-Sont canal and its network were calculated for reaches 300 m. long and summarized in Table 4.

Table 1: Geometric dimensions for the designed water sections of El-Sont canal and its network, (MWRI, 2020).

No	Canal Name	Section From Km	Section To Km	Bed Width (m)	Side Slope	Water Depth (m)	Discharge (m^3/s)
1	El-Sont (sahel sleem)	0	7.6	12	3: 2	2.6	21.8
	El-Sont (abnoub)	7.6	15.94	11	3: 2	2.6	17.62
		15.94	23.2	9	3: 2	2.6	17.62
		23.2	26.4	8	3: 2	2.35	15.33
		26.4	34.12	7	3: 2	1.9	6.64
		34.12	39.9	5	3: 2	1.4	5.76
2	Sothern Elnabary	0	3.2	1	1: 1	1	0.35
3	Elmaasara	0	3.6	4	1: 1	2.4	6.76
		3.6	6.98	3	1: 1	1.75	3.98
		6.98	8.8	2	1: 1	1.5	1.64
3.1	Left Elmaana Ganabia	0	5	3	1: 1	1.85	2.7
		5	8.8	2	1: 1	1.6	2.35
		8.8	10.45	1	1: 1	1.15	0.82
3.1.1	Serage Banch	0	2	1	1: 1	0.8	0.35
3.1.2	Elfaiama Branch	0	4	1	1: 1	1	0.71
3.2	Amro Branch	0	2.4	1	1: 1	0.9	0.27
3.3	Salebat Elmaasara Ganabia	0	1.3	4	1: 1	1.4	1.52
		1.3	4.34	3	1: 1	1.18	1.25
		4.34	5.4	2.5	1: 1	1.1	0.85
		5.4	6.7	2	1: 1	1	0.5
3.3.1	Elmanshia Branch	0	1.4	1	1: 1	0.8	0.27
3.31	Elgamasea Branch	0	2.1	1	1: 1	0.9	0.39
3.4	Elqasr Branch	0	1.14	1	1: 1	0.9	0.27
3.5	Elquata Branch	0	1.36	1	1: 1	0.75	0.26
4	Elghwaish Branch	0	1.3	1	1: 1	0.75	0.21
5	Elnabari Alwasta	0	2.45	1	2: 1	1	0.35
6	Bani Mor	4.5	5.2	3	1: 1	1.5	2.04
		5.2	6.3	2	1: 1	1	1
6.1	Quernaw Branch	0	1.42	2	1: 1	0.75	0.27
7	Gazerat Bani Mor	0	1.6	1.5	3: 2	1	0.4
8	Sahel Bani Mor	0	2.65	1.5	2: 1	1	0.73
8.1	Elbaharwa	0	1.3	1	1: 1	0.75	0.15
9	Elgharbia	0	2	4	3: 2	1.75	4.62
		2	5.99	2.5	1: 1	1	2.47
9.1	**Hoshet Kom Aboshil**	0	1.65	1	1: 1	0.75	0.1
9.2	Ali Bek	0	2.1	1	1: 1	0.9	0.35
9.3	Western Elnasara	0	3.75	2	1: 1	1.65	0.85
9.4	Eastern Elnasara	0	3	2	1: 1	1.7	0.85
9.5	Hablass	0	5	2	1: 1	1.4	1

No	Canal Name	Section From Km	Section To Km	Bed Width (m)	Side Slope	Water Depth (m)	Discharge (m^3/s)
9.5.1	Elakrad Branch	0	1.8	1	1: 1	1	0.17
9.5.2	Bani Zeid Branch	0	2	1.5	1: 1	0.85	0.22
9.5.3	Diab Branch	0	0.9	1	1: 1	0.9	0.1
9.5.4	Hablas Elgadida	0	4.8	2	1: 1	1.58	1.02
9.6	Hoshet Eltwabia	0	1.1	2	1: 1	1.1	0.47
9.6.1	Eltwabia Southern Branch	0	2.25	2	1: 1	1	0.27
10	Kom Abo Shail Branch	0	1	1	1: 1	0.9	0.4
11	Right Southern Elsont Ganabiat	0	3	2	1: 1	0.85	0.6
12	Baheege	0	2.4	4	3: 2	1.5	2.71
		2.4	4.5	3	3: 2	0.9	2.1
		4.5	6.3	2	3: 2	0.75	0.4
12.1	Abo Amera	0	1.9	2	1: 1	1.4	0.55
12.2	Elkhalifaa	0	1	1.5	1: 1	1.2	0.35
13	Bani Rezah	0	2.6	2	1: 1	1.1	0.42
14	Abnoub Branh	0	2	1	1: 1	0.75	0.47
15	Elkadadeh Western Branch	0	2.2	1.5	1: 1	1	0.93
16	Bani Ibrahem Western Branch	0	2.3	1	1: 1	1.1	0.47
17	Elsawalem Southern Branch	0	2	1	1: 1	0.95	0.6
18	Elrawateb Branch	0	1.25	1	1: 1	0.85	0.38
19	Right Northern Elsont Ganabiat	0	3.3	4	3: 2	1.5	3.25
		3.3	5.7	2	3: 2	1.15	1.7
19.1	Elsihabia Branch	0	2.05	1	3: 2	1.3	1
19.2	Asham Allah	0	1.6	1	3: 2	1	0.5
20	Bani Mohamed	0	0.38	5	3: 2	1.45	4.47
		0.38	3.7	4	3: 2	1.3	3.34
		3.7	6.4	3	3: 2	1.2	2.09
20.1	Left Northern Elsont Ganabiat	0	2.55	2	1: 1	1	0.79
20.2	Elmarwna	0	1.1	1.5	1: 1	1	0.23
20.3	Sahel Elaqab	0	1.3	1	3: 2	1	0.31
20.4	Abo Diab Branch	0	1.7	1	1: 1	1	0.63
20.5	Elmansora Western Branh	0	1	1	1: 1	0.85	0.4
20.6	Sahel Bani Mohammed	0	4.5	2.5	3: 2	0.9	1.04
21	Shaqequel	0	2	2.5	1: 1	1.1	0.88
22	Elmaabda Sothern Branch	0	1.25	1	1: 1	1	0.5
23	Elmaabda Northern Branch	0	2.8	2	1: 1	1.25	1.5
24	Elshikh Saed Branh	0	1.2	3	1: 1	1.2	1.88
24.1	Abo Meshel	0	1.1	1	1: 1	0.75	0.28
24.2	Sahel Elmaabda	0	2.3	2	1: 1	0.75	0.76
25	Emtedad Elsont	0	2	2	3: 2	1.3	0.85

Aswan University Journal of Environmental Studies (AUJES) 2 (3), pp. 190-201, (2021).
Online ISSN: 2735-4237, Print: ISSN 2735-4229. https://aujes.journals.ekb.eg/

Table 2: Seepage losses for designed and existing water sections of El-Sont canal and its network (m^3/day)

No	Canal Name	Designed section			Existing section		
		Egyptian	Indian	Mortiz	Egyptian	Indian	Mortiz
1	El-Sont (sahel sleem)	29279	40141	19986	29398	49146	18481
	El-Sont (abnoub)	30366	41989	21231	21670	24543	16225
		23358	32963	17197	30110	48338	20741
		8760	11773	6811	9233	13684	6961
		16108	19308	13660	12729	16160	11738
		7486	7727	7453	9064	11964	8839
2	Sothern Elnabary	1148	1164	1851	2196	2911	2698
3	Elmaasara	6006	8859	5771	5053	5968	4993
		3556	4462	3980	4737	5595	4681
		1354	1624	1710	2562	3025	2531
		359	364	578	1404	1658	1387
3.1	Left Elmaana Ganabia	5569	7237	6126	4969	27942	5411
		3019	3771	3730	3639	19719	3962
		693	767	1061	752	1941	924
3.1.1	Serage Banch	562	496	982	1053	1255	1356
3.1.2	Elfaiama Branch	1435	1455	2314	1100	821	1829
3.2	Amro Branch	766	728	1284	1022	876	1472
3.3	Salebat Elmaasara Ganabia	1307	1377	1462	959	1067	1128
		2203	2161	2761	2243	2496	2638
		648	622	863	782	870	920
		641	597	921	959	1067	1128
3.3.1	Elmanshia Branch	393	347	687	492	307	757
3.31	Elgamasea Branch	670	637	1123	1106	1317	1424
3.4	Elqasr Branch	364	346	610	701	780	903
3.5	Elquata Branch	357	303	637	511	434	736
4	Elghwaish Branch	341	289	609	206	148	376
5	Elnabari Alwasta	1287	1274	1736	2196	2911	2698
6	Bani Mor	634	723	744	638	1018	671
		543	505	779	843	1025	1006
6.1	Quernaw Branch	537	417	834	390	292	649
7	Gazerat Bani Mor	812	776	1133	851	708	1151
8	Sahel Bani Mor	1570	1504	2028	950	592	1356
8.1	Elbaharwa	341	289	609	175	82	327
9	Elgharbia	2834	3429	2785	3151	3519	2914
		2233	2021	3053	4126	4875	4171
9.1	Hoshet Kom Aboshil	433	367	773	196	135	327
9.2	Ali Bek	670	637	1123	747	618	1173
9.3	Western Elnasara	3080	3921	3764	1170	782	1727
9.4	Eastern Elnasara	2544	3300	3077	1472	1208	1968

No	Canal Name	Designed section			Existing section		
		Egyptian	Indian	Mortiz	Egyptian	Indian	Mortiz
9.5	Hablass	1504	2028	1570	3517	3833	4230
9.5.1	Elakrad Branch	646	655	1041	522	377	875
9.5.2	Bani Zeid Branch	724	631	1156	684	362	942
9.5.3	Diab Branch	287	273	481	117	58	238
9.5.4	Hablas Elgadida	3763	4663	4669	3517	3833	4230
9.6	Hoshet Eltwabia	1183	1116	1683	1503	1093	1898
9.6.1	Eltwabia Southern Branch	1110	1033	1594	324	211	525
10	Kom Abo Shail Branch	319	303	535	724	662	1028
11	Right Southern Elsont Ganabiat*	1270	1067	1910	0	0	0
12	Baheege	2921	3219	3006	2295	2443	2622
		1346	1122	1699	1515	1441	1711
		775	604	1127	1093	774	1318
12.1	Abo Amera	1312	1507	1695	811	673	1163
12.2	Elkhalifaa	516	558	736	486	416	691
13	Bani Rezah	1407	1389	1964	1048	690	1398
14	Abnoub Branh	525	445	937	1343	1224	1714
15	Elkadadeh Western Branch	938	905	1423	837	594	1138
16	Bani Ibrahem Western Branch	919	989	1430	720	468	1099
17	Elsawalem Southern Branch	677	666	1113	602	452	968
18	Elrawateb Branch	375	344	641	358	260	583
19	Right Northern Elsont Ganabiat	4017	4426	4133	2761	2144	3134
		1596	1612	2032	1602	916	2004
19.1	Elsihabia Branch	1241	1441	1642	1066	946	1481
19.2	Asham Allah*	287	273	481	0	0	0
20	Bani Mohamed	508	536	501	368	331	385
		3527	3563	3777	3204	2658	3559
		2273	2256	2650	2517	2254	2927
20.1	Left Northern Elsont Ganabiat	1258	1170	1806	876	749	1313
20.2	elmarawna	469	453	711	347	246	549
20.3	Sahel Elaqab	572	569	841	521	309	789
20.4	Abo Diab Branch	610	619	983	491	364	804
20.5	Elmansora Western Branh	300	275	513	369	282	559
20.6	Sahel Bani Mohammed	2602	2211	3426	2408	1962	2977
21	Shaqequel	1222	1173	1628	807	609	1179
22	Elmaabda Sothern Branch	448	455	723	211	108	404
23	Elmaabda Northern Branch	1721	1841	2308	1444	509	1888
24	Elshikh Saed Branh	1524	1472	2023	1991	1343	2351
24.1	Abo Meshel	289	245	515	313	214	502
24.2	Sahel Elmaabda	869	676	1351	931	618	1333
25	Emtedad Elsont	1519	1652	1854	433	362	627

Table 3: Meteorological data of El-Sont canal and its distributaries region, (Abu-Zeid, 2021)

Month	Max. Temp. oC	Min. Temp. oC	Avg. Temp. oC	% RH max	Pan Evaporation mm/day	wind speed (km/h)	No. of sunny hours / day
Jan	18	6.50	22.40	60.30	2.80	16.00	8.90
Feb.	22.5	11.20	26.10	52.60	3.20	17.30	9.70
Mar.	25	14.20	30.50	42.90	4.40	19.80	9.90
Apr.	29	17.10	35.10	36.50	6.40	21.30	10.30
May	32	22.00	38.10	35.10	6.60	20.30	11.40
Jun.	36	24.90	40.70	37.40	6.90	21.00	12.30
Jul.	37	25.30	39.10	41.50	7.40	19.50	12.20
Aug.	34.5	24.80	40.30	40.70	8.00	19.80	11.90
Sep.	29	23.80	38.50	46.20	7.00	21.70	10.80
Oct.	29	20.90	33.00	51.30	5.70	19.20	10.00
Nov.	27	13.20	27.00	54.70	5.00	15.20	9.40
Dec.	22.5	9.00	23.20	63.20	3.10	16.80	9.00

Table 4: Evaporation losses for designed and existing water sections of El-Sont canal and its network

No	Canal Name	Max. Evaporation losses (m^3/day)		No	Canal Name	Max. Evaporation losses (m^3/day)	
		Designed	Existing			Designed	Existing
1	El-Sont (sahel sleem)	963	3044	9.6	Hoshet Eltwabia	65	106
	El-Sont (abnoub)	3060	1021	9.6.1	Eltwabia Southern Branch	58	27
2	Sothern Elnabary	61	102	10	Kom Abo Shail Branch	18	44
3	Elmaasara	421	533	11	Right Southern Elsont Ganabiat*	0	0
3.1	Left Elmaana Ganabia	376	475	12	Baheege	256	285
3.1.1	Serage Banch	33	51	12.1	Abo Amera	58	50
3.1.2	Elfaiama Branch	77	90	12.2	Elkhalifaa	25	29
3.2	Amro Branch	43	65	13	Bani Rezah	70	90
3.3	Salebat Elmaasara Ganabia	226	268	14	Abnoub Branh	32	70
3.3.1	Elmanshia Branch	23	27	15	Elkadadeh Western Branch	49	66
3.31	Elgamasea Branch	38	54	16	Bani Ibrahem Western Branch	47	57
3.4	Elqasr Branch	20	33	17	Elsawalem Southern Branch	37	45
3.5	Elquata Branch	22	30	18	Elrawateb Branch	22	39
4	Elghwaish Branch	21	21	19	Right Northern Elsont Ganabiat	263	236
5	Elnabari Alwasta	78	102	19.1	Elsihabia Branch	64	20
6	Bani Mor	55	73	19.2	Asham Allah*	0	0
6.1	Quernaw Branch	32	32	20	Bani Mohamed	305	331
7	Gazerat Bani Mor	46	51	20.1	Left Northern Elsont Ganabiat	65	64
8	Sahel Bani Mor	93	78	20.2	Elmarawna	25	25
8.1	Elbaharwa	21	23	20.3	Sahel Elaqab	33	50
9	Elgharbia	233	316	20.4	Abo Diab Branch	33	37
9.1	Hoshet Kom Aboshil	26	17	20.5	Elmansora Western Branh	17	25
9.2	Ali Bek	38	52	20.6	Sahel Bani Mohammed	150	157
9.3	Western Elnasara	127	99	21	Shaqequel	60	58
9.4	Eastern Elnasara	104	93	22	Elmaabda Sothern Branch	24	66
9.5	Hablass	116	132	23	Elmaabda Northern Branch	81	98

No	Canal Name	Max. Evaporation losses (m^3/day)		No	Canal Name	Max. Evaporation losses (m^3/day)	
		Designed	Existing			Designed	Existing
9.5.1	Elakrad Branch	35	37	24	Elshikh Saed Branh	75	105
9.5.2	Bani Zeid Branch	41	69	24.1	Abo Meshel	18	25
9.5.3	Diab Branch	16	12	24.2	Sahel Elmaabda	52	67
9.5.4	Hablas Elgadida	158	180	25	Emtedad Elsont	76	28

*In the time of field trips, the canal was in off turn and not works.

4- RESULTS AND DISCUSSIONS

4.1- Seepage losses

Table 2 shows the values of the total seepage losses in the El-Sont canal and its network. From which, it is clear that:

- There are tangible differences in the values of seepage losses calculated by using the above most popular three equations. The Indian equation gives the biggest value, while Moritz's equation gives the lowest values, for El-Sont canal, and its network.
- There is a clear difference in the values of irrigation water losses through seepage that calculated from the existing real cross-sections on the ground and those calculated according to the dimensions obtained from the executive design sheets for those canals.
- The total values of seepage losses according to the dimensions obtained from the executive design sheets for El-Sont canal, and its off-taking canals, were about 213635, 261105, and 212144 m^3/day by using the Egyptian, Indian, and Moritz equations, respectively, with an average value of about 228962 m^3/day. While, using the dimensions of the existing on the ground sections, those values were about 210231, 298582, and 201515 m^3/day, with an average of about 236776 m^3/day. That is to say that, about 7814 m^3/day is lost only due to less care of maintaining the waterway dimensions on the ground exactly as it is in the executive design engineering sheets.
- The total amount of seepage losses from the designed sections of the El-Sont canal and its network, estimated by using the Egyptian, Indian, and Moritz's equations represents about 11.34%, 13.86%, and 11.26 %, respectively, with an average of about12.15% of the total discharge given at the head of the El-Sont canal.
- The total amount of seepage losses from the existing sections of the El-Sont canal and its network, estimated by using the Egyptian, Indian, and Moritz's equations represents about 11.16%, 15.85%, and 10.70 %, with an average of about12.66% from the total discharge that given at the head of the El-Sont canal, which is somewhat bigger than that percentage expected according to the dimensions taken from the official design sheets.
- The total lost water by seepage of the El-Sont canal and its network was estimated to be about 38.9 million cubic meters annually for the designed sections. While it was estimated to be about 39.54 million cubic meters for the dimensions of the existing sections. This difference is due to distortions and collapses in the water section, and internal side slopes of the canals. This significant amount of lost water will be saved when the rehabilitation national project is implemented and finished for the El-Sont canal and its network.

4.2- Evaporation losses

Table (4) shows the maximum calculated values of the total evaporation losses from the El-Sont canal and its network. From this table, it can be seen that:

- The total values of evaporation losses from the designed sections of the El-Sont canal and its network are about 8681 m^3/day. While it was estimated for the existing sections with about 9480 m^3/day, with a difference reaches 800 m^3/day.
- The total amount of evaporation losses from the designed sections and the existing sections of the El-Sont canal and its network represent about 0.46%, and 0.50% of the total discharge given at the head. This agrees with the study presented by Sahasrabudhe (2001) and Jadhav (2014).
- The values of evaporation losses for the existing sections are more than those calculated using the designed sections of the El-Sont canal network. This is due to the distortions of the water sections in some locations along the canal and its off-takings.

Based on the foregoing, the total average expected losses due to seepage and evaporation for the designed, and existing sections of the El-Sont canal and its network are estimated to be about 239,812 m^3/day, 248,628 m^3/day respectively, with an absolute average of about 244,220 m^3/day, at the season of maximum water needs. Most of these quantities of water will be saved by lining the canals with plain concrete, through the implementation of the national project of rehabilitation.

The amount of saved water in the case of lining with plain concrete was estimated using Davis Willson's equation (Leigh, 2014) to be about 36.31 million cubic meters annually, which is a significant value considering the water shortage faces Egypt at the present time.
The quantity of saved water, by the completion of the nowadays under implementation of the national rehabilitation project, can be sufficient to irrigate more than new 5000 acres using the modern irrigation systems, which equals about 15 % of the total existing area irrigated now through EL-Sont canal and its off-takings.

5- Conclusions

The main conclusions of the current study can be summarized as follows:

(1) The study proved the high feasibility and the great economic, developmental, and environmental returns expected upon the completion of such a national project. In addition to the moral impact on the beneficiaries and farmers, which will raise the ceiling of their civilization and human aspirations.

(2) The estimated average seepage losses from the designed sections of the El-Sont canal and its network reaches about 228,962 m^3/day. This value represents 12.15 % of the total discharge of the El-Sont canal, while it reaches about 248,628 m^3/day, which represents 12.66 % if it is calculated for the existing on the ground cross-sections.

(3) The annual lost water by seepage only from the El-Sont canal and its network was estimated to be about 38.9, and 39.54 million cubic meters for the designed and existing sections, respectively.

(4) The total maximum evaporation losses from the existing and the designed sections of the El-Sont canal network were calculated to be about 9480 and 8681 m^3/day, respectively.

(5) The great quantities of saved or recovered water can be used for the reclamation and the irrigation of about 5000 new acres in the nearby area, representing about 15 % of the existent served area.

(6) The study, the field trips, the visits, and the personal direct communication with farmers and beneficiaries proved that the project had a great response to their hopes. Also, it

improved their living standards, health, in addition to the environmental situation for all the Egyptian countryside.

References

Abu-zeid, T.S. (2021). Conveyance Losses Estimation for Open Channels in Middle Egypt, Case Study: Almanna Main Canal, and Its Branches., (JES) Journal of Engineering Sciences, 49(1), 64-84.

Ahuchaogu, I. E. (2015). Evaluation of Seepage Losses in an Earth Lined Canal: A Case Study of University of Uyo Farm. International Journal of Engineering Sciences and Management Research, 2(2), 2349-6193.

Akkuzu, E. (2012). Usefulness of Empirical Equations in Assessing Canal Losses through Seepage in Concrete-Lined Canal. Journal of Irrigation and Drainage Engineering, 138(5), 455-460.

Alam, M. M. (2004). Comparative Evaluation of Canal Seepage Investigation Techniques. Agricultural Water Management, 66(1), 65-76.

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Fao Irrigation and Drainage Paper No. 56. Rome,. Food and Agriculture Organization of the United Nations, 56 (97), E156.

Awan, A. A. (2017). Optimum Length of Lining to Reduce Losses in Watercourses by Using Advanced Non Linear Modelling. Doctoral Dissertation.

El Gamal, T. and. N. Zaki (2017). Egyptian Irrigation after the Aswan High Dam. Irrigated Agriculture in Egypt. (Pp. 47-79). Springer, Cham.

Farouk, M. (1979). Conveyance Losses in Canals. Conference on Water Resources Planning in Egypt, Cairo.

Jadhav, P. B. (2014). Conveyance Efficiency Improvement through Canal Lining and Yield Increment by Adopting Drip Irrigation in Command Area. International Journal of Innovative Research in Science, Engineering and Technology, 3 (4), 120-129.

Kacimov, A. R. (1992). Seepage Optimization for Trapezoidal Channel. Journal of Irrigation and Drainage Engineering, 118(4), 520-526.

Khan, A. K. (2015). Relationship between Seepage and Discharge for Kabul River in District Nowshera. Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences, 31(2), 249-259.

Kraatz, D.B. (1977). Irrigation Canal Lining. Fao Land and Water Development Series No. 1, 18–50.

Leigh, E. (2014). Evaluation of Methods for Predicting Seepage Loss Rates for the Hard Lined Irrigation Canals of the Lower Rio Grande Valley of Texas. Doctoral Dissertation.

Liu, S. W. (2016). Estimating The Evaporation from Irrigation Canals in Northwestern China Using the Double-Deck Surface Air Layer Model. Advances in Meteorology. Volume 2016 |Article ID 3670257 | https://doi.org/10.1155/2016/3670257

Martin, C. A. (2015). Uncertainty in Measuring Seepage from Earthen Irrigation Canals Using the Inflow-Outflow Method and in Evaluating the Effectiveness of Polyacrylamide Applications for Seepage Reduction. Doctoral Dissertation, Colorado State Universit.

Mowafy (2001). Seepage Losses in Ismailia Canal.. Sixth International Water Technology Conference, Iwtc, March, (Pp. 195-211). Alexandria, Egypt.

MWRI (2020). Minsiatry of Water Resources and Irrigation,. Assiut Departement.

Robinson, A. R., and Rohwer, C. (1957). Measurement of Canal Seepage. Transactions of the American Society of Civil Engineers Paper No. 2865.

Sahasrabudhe, S. K. (2011). Irrigation Engineering and Hydraulic Structures. Publisher of Engineering & Compute Books, 3rd Edition.

Shaikh, I. A. (2016). Estimating Earthen Tertiary Water Channel Seepage Losses as A Function of Soil Texture. Journal of Hydrologic Engineering, 21(2), 06015012.

Swamee, P. K. (2000). Design of Minimum Seepage Loss Canal Sections. Journal of Irrigation and Drainage Engineering, 126(1), 28-32.

Wang, W. X. (2019).Estimating Evaporation from Irrigation Canals in The Midstream Areas of the Heihe River Basin by A Double-Deck Surface Air Layer (Dsal) Model. Water, 11(9), 1788.

Zhang, Q. C. (2017). Investigation of Irrigation Canal Seepage Losses through Use of Four Different Methods in Hetao Irrigation District, China. Journal of Hydrologic Engineering, 22(3), 05016035.