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Study of Lowlands Drainage Problems, Case Study Kamal El-Den Hessen Reclaimed Area, North Sinai, Egypt

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Abstract

This paper deals mainly to study and solve field drainage problems in Kamal El-Den Hessen new reclaimed area (1650 hectares), North Sinai Egypt, where many farmers complain about the formation of water ponds in their lands, bad soil drainage, soil salinity, and low yields rate. Intensive field investigations were carried out regarding, topographic survey, digging 22 boreholes, instilling observation wells, measuring groundwater salinity and assessing the existing drainage network. The results showed that ground surface levels were ranging from 1.5 m to 4.28 m above mean sea level, predominated soil was sandy with a permeability coefficient ranged from 0.82 to 2.68 m/day, an impervious clay layer lies at 6.0 to 7.0 m below ground surface, and the groundwater salinity ranges from 4 to 12 dS/m high salinity for water ponds were observed at the observation wells that lay in the lift side of Kamal El-Den Hessen Canal. Lands surrounding Kamal El-Den Hessen Canal have high levels. The measured groundwater depths of the western observation wells were 0.50 m below ground surface and in the eastern wells ranging from 1.0 to 1.50 m. The analysis of results showed that field drainage problems that increased groundwater levels were: 1) infiltration water coming from the high-cultivated areas at the lift bank of Kamal El-Den Hessen Canal, 2) the impervious clay layers increasing the horizontal infiltration towards low lands and increase ponds areas. 3) Main Gelbana Drain cross-section needs dredging. It is recommended to dredge the Main Gelbana Drain and modified its cross-section to collect water from water ponds, filling the lowland areas utilizing sandy soil in the high lands, adopting types of crops grown to match with crop salt tolerant levels and soil and water salinity levels and constructing subsurface drainage network to decrease groundwater levels.

Keywords

Drainage Problems, Groundwater Levels, Soil Salinity, Soil Permeability

1. Introduction

The shortage of water resources forces many countries like Egypt to reuse agriculture drainage water of good quality in irrigation or to mix it with Nile fresh water to improve its quality to utilize in the cultivation of newly reclaimed areas [1]. In the long run, the low-quality irrigation water causes the rising of drainage problems and soil salinity [2] [3]. New land reclamation projects that lie in arid and semi-arid regions, usually the groundwater level is deep and the drainage network did not impalement coincidence with irrigation network to compact the project cost. After the operation of the project, the drainage problems such as increasing soil salinity, waterlogging, and rising groundwater table to the effective root zone was raised. Therefore, drainage should be practiced in parallel with irrigation to make sure maximum yields and for environmental safety in all irrigation projects [4] [5] [6]. Drainage problems dealt with impermeable soils, the high water table in depression areas, and side hill seepage [7]. To discuss drainage, separation has to be made between drainage of groundwater and drainage of surface water. Groundwater drainage helps to control soil salinity for irrigated lands [8]. The surface drainage may also be required to remove excess rainfall or increase irrigation water, especially for soil with low leakage rates [9] [10] [11]. Surface drainage is also needed if rice is grown. Shallow surface drains can also be used to filter salts. For example, with ditches, only 0.4 m deep, farmers in Egypt have managed to tame their new saline land. If rice is grown, alternately with dry foot crops, such as the old lands of the River Nile Delta, such as subsurface drainage required to control the groundwater of non-rice crops and to mitigate the risk of extreme percolation losses in periods that rice is grown [10] [12]. The solution worked out in Egypt is to grow rice in drainage units by backing up a device close to the drainage outlet for the water table control. The drainage of groundwater through horizontal water drainage can be adopted by pumping vertical wells in case of a permeable aquifer. The groundwater is often saline in arid lowlands, and often the salinity is increased with depth. Deep vertical drainage wells will produce highly saline water weak for re-use and difficult to dispose of [13] [14]. Impermeable soils, silty/clayey soil texture with flat topography and poor infiltration are classified as rates impermeable soils [15]. Depression areas can be defined as low wet areas where a significant amount of water ponds after rainfalls, there is no deep percolation obtainable for the surplus water. If the water ponds greater than 3 m in diameter or greater than 10 cm deep, then the problem should be treated as a depression area [16], installation of boreholes and observation wells are essentially for analyzing the soils and studying the water table depths over time. Side bank seepage can arise where a relatively permeable soil (sandy) overlies a relatively impermeable soil (silt/clay) on a slope. Excess water percolates into the sandy soil at high elevations. In clay soil, it cannot stay downwards and it is forced to move horizontally and to seep out where the sand layer ends. Sidehill seepage can also occur where clay soils have been reworked into banks or hills by machinery [17] [18] [19]. There will be large voids left in the disturbed clay since it is essentially impossible to re-compact it to its original state.

These large voids ratio will permit the water to move freely into the disturbed profile. This type of drainage problem can produce enough water to preserve a wide flat fairway, neighboring to the slope, very wet. This research deals mainly to identify and investigate the field drainage problems of Kamal El-Den Hessen Canal new reclaimed area (1650 hectares) at the North of Sinai, Egypt, where many farmers complain about the formation of water ponds in their lands, bad soil drainage, and low yields rate. As well as recommend the appropriate solutions.

2. Materials and Methods

2.1. Materials

Kamal El-Den Hessen Canal region, North Sinai Egypt was selected to be a study area. It lies in the North Sinai Peninsula, where the North Sinai Development project (NSDP) to reclaim and cultivate 168 thousand hectares (**Figure 1**). El-Sheikh Gaber Canal is the main feeder for the NSDP, the annual water resources for the project are 4.5 Millard m^3. The water resources in the study area are Nile freshwater mixed with agriculture drainage wastewater in a ratio 1:1 with salinity up to 1000 ppm [20]. Kamal El-Den Hessen Canal area served is 1650 hectares and it takes its water from the South East El-Qantara Canal (**Figure 2**). The Water Resources, Irrigation, and Infrastructures Sector, North Sinai, Ministry of Water Resources and Irrigation Egypt has operated the canal since 2000. The canal was lined with plain concrete since 2000 to prevent seepage losses where it is passed through sandy soil, the canal length is 10.500 km, water depth 1.5 m, bed width 1.5 m water slope 15 cm /km, and inside slopes 2:1. Surface drainage network consists of Main Gelbana Drain and Tall Elhair Drain

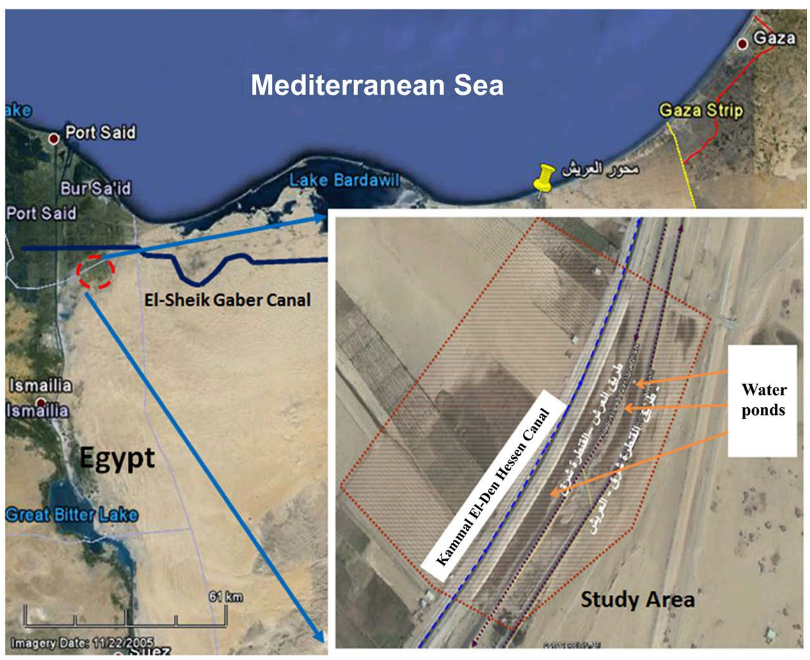

Figure 1. Location of study area.

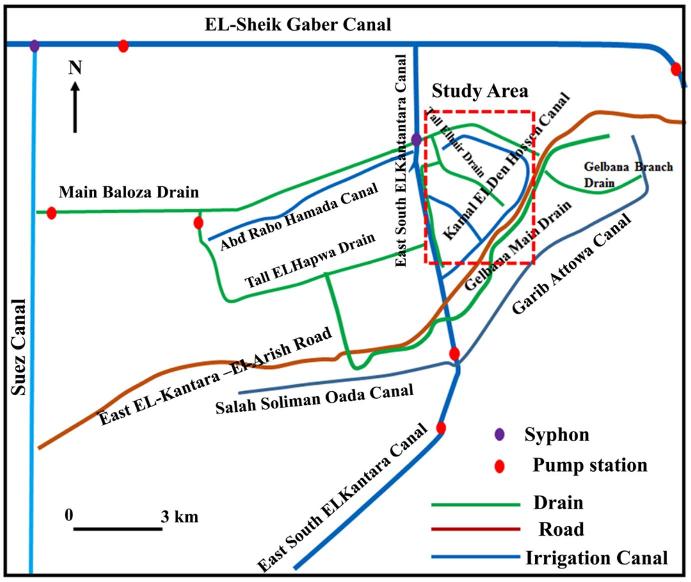

Figure 2. Irrigation and drainage canal networks in the study area.

(Figure 2). Many farmers complain about the formation of water ponds in their lands, bad soil drainage, and low yields rate. The studied area experiences a semi-arid climate type. The topography is sand terrain with large differences in elevations and steep slopes. The applied irrigation systems are sprinkler irrigation and drip irrigation. The surface drainage network was implemented together with irrigation facilities. Subsurface drainage networks did not implement till now. Wheat, sugar beet and corn are the major crops grown in the study area, besides vegetables, and fruits.

2.2. Methods

Eight infiltration paths were selected based on land topography, existing water ponds and irrigation canal (Kamal El-Den Hessen Canal). Twenty-two boreholes were carried out to describe land topography, soil permeability, groundwater levels and directions. Figure 3 shows the suggested infiltration paths, location of boreholes and the ground water observation wells distribution. Coordinates of the selected boreholes and groundwater observation wells for the infiltration paths coordinates were shown in Table 1. Topographic survey for the study area was carried out using double difference GPS Device by the Drainage Research Institute (DRI) team, National Water Research Center (NRC), Ministry of Water Resources and Irrigation (MWRI), Egypt. The existing drainage system was investigated where a group of 11 cross-section along the Main Gelbana Drain were measured at distances 0.00 km, 1.00 km, 1.300 km, 2.500 km, 4.200 km, 8.00 km, 9.00 km, 10.50 km, 13.00 km, 15.00 km, and 16.00 km from its outlet using total station survey instrument. The measured cross-sections were compared with designed cross-sections. The results showed that the main Gelbana Drain cross-section is suffering from deposition and needs dredging. Figure 4 shows the contour map, the ground surface levels were ranging from 1.5 m to 4.28 m

Table 1. Coordinates of the selected boreholes and groundwater observation wells for the infiltration paths coordinates.

Symbols of boreholes and groundwater observation wells	Infiltration Path Number	Vertical coordinate	Horizontal coordinate	Ground level (m)
A1		453548.2	3426591	2.55
A2	Path No. 1	453609.1	3426543	2.68
A3		453665.4	3426498	2.81
A4		453761.2	3426462	2.17
A5	Path No. 2	453796.4	3426438	2.08
A6		453838.3	3426418	3.11
B7		453553.2	3426483	2.38
B8	Path No. 3	453534.7	3426397	2.17
B9		453585.2	3426361	2.30
B11	Path No. 4	453743.2	3426234	2.29
B12		453767.1	3426212	2.3
C13		453386.5	3426400	2.79
C14	Path No. 5	453448.8	3426325	1.50
C15		453510.4	3426243	1.74
C16		453629.4	3426160	2.05
C17	Path No. 6	453649.7	3426131	1.98
C18		453689.8	3426097	3.43
D19		453838.3	3426168	1.77
D20	Path No. 7	453548.2	3426238	1.53
D21		453609.1	3426153	2.01
D23	Path No. 8	453575.4	3426035	2.11
D24		453601.7	3425969	4.28

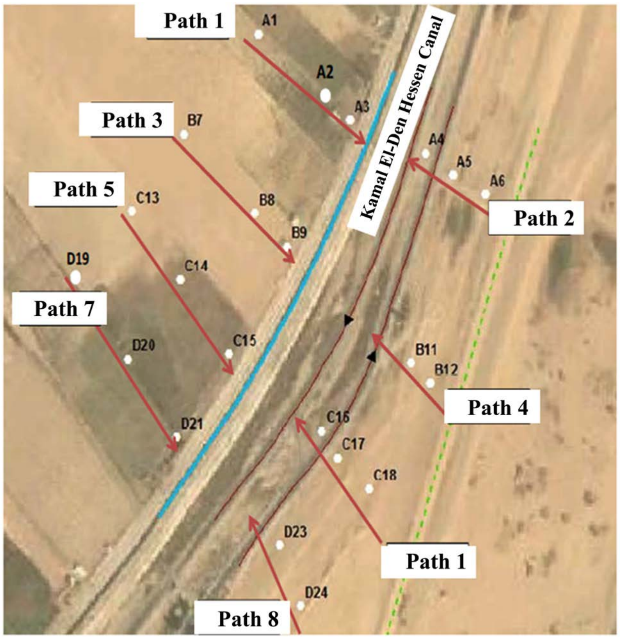

Figure 3. Suggested infiltration paths, 22 boreholes and observation wells distributions.

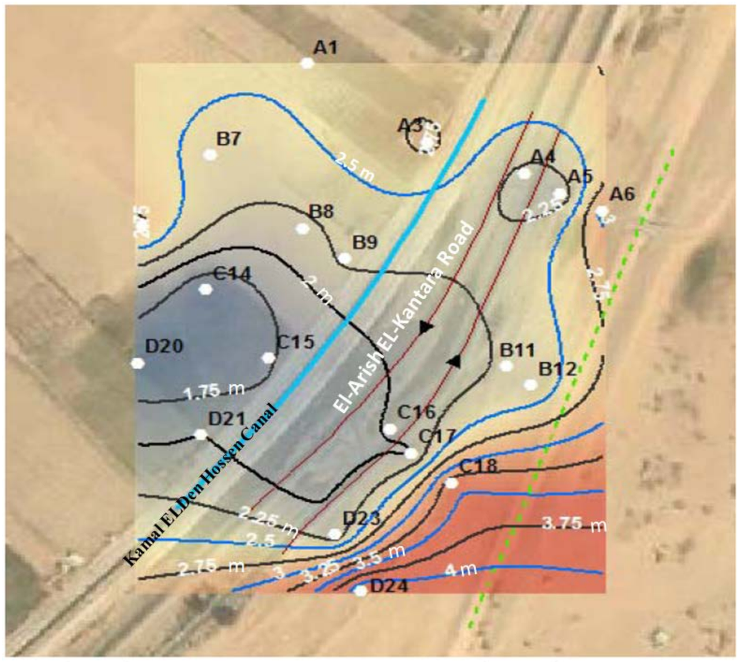

Figure 4. Contour map for the study area.

above mean sea level. A 22 soil classification and permeability tests were carried out [21], the results showed that, the predominate soil is sand (Table 2), measured coefficients of permeability was ranging from 0.82 m/day to 2.68 m/day as shown in Table 3. Average surface groundwater levels during the period from May 2013 to December 2013 were presented in Table 4, the groundwater depth was ranging from 0.1 m to 2.42 m, and Figure 5 shows the average groundwater levels. A four deep groundwater monitoring wells (D1, D2, D3, and D4) of a depth of 9.0 m were implemented to monitor the depth and direction of the deep groundwater, the location of wells were selected near the surface groundwater well numbers A1, B9, C16, and D23, respectively, Table 5 shows deep and surface groundwater levels during the period (October 2013 to December 2013). The water quality of the infiltration water in terms of salinity was measured based on [22]; Table 6 shows measured average groundwater electric conductivity (EC) in dS/m for the observation wells during the period from March 2013 to January 2014).

3. Results and Discussion

The results obtained from 22 boreholes soil samples (Table 1) showed that the soil surface layer was sandy soil with thin salt crest and changing to silt soil, the groundwater table was observed at 0.15 m above the ground surface to 1.25 m below ground surface (Table 2). An impervious clay layer lies at 6.0 to 7.0 m below ground surface, this layer increases horizontal percolation towards low-level lands. The results of soil permeability for the 22 location distributed in the study area showed the coefficient of permeability ranging from 0.82 to 2.68 m/day (Table 3). The depths of groundwater in the western observation wells were 0.50 m below ground surface and in the eastern wells, ranging from 1.0 to 1.50 m, at

Table 2. Soil Description and groundwater levels.

Symbol	Depth (m)	Soil description	Groundwater depth (m)	Ground level (m)
A1	0.00 - 2.00	sand	1.19	2.55
A2	0.00 - 1.60	sand	1.85	2.68
A3	0.00 - 2.00	sand	1.73	2.81
A4	0.00 - 1.50	sand	1.82	2.17
A5	0.00 - 1.60	sand	1.92	2.08
A6	0.00 - 2.00	sand	1.80	3.11
B7	0.00 - 2.00	sand	1.51	2.38
B8	0.00 - 2.00	sand	1.64	2.17
B9	0.00 - 2.00	sand	1.70	2.30
B11	0.00 - 1.40	sand	2.18	2.29
B12	0.00 - 1.10	sand	1.89	2.30
C13	0.00 - 2.00	sand	1.23	2.79
C14	0.00 - 2.00	sand	1.33	1.50
C15	0.00 - 2.00	sand	1.37	1.74
C16	0.00 - 2.00	sand	1.98	2.05
C17	0.00 - 1.40	sand	1.86	1.98
C18	0.00 - 1.10	sand	2.42	3.43
D19	0.00 - 0.80	sand	Dry	1.77
D20	0.80 - 2.00	Sandy clay	0.1	1.53
D21	0.00 - 2.00	sand	1.64	2.01
D23	0.00 - 2.00	sand	1.77	2.11
D24	0.00 - 2.00	sand	Dry	4.27

Table 3. Measured coefficient of permeability.

Well Number	Vertical coordinate	Horizontal coordinate	Hydraulic conductivity (m/day)
A1	453548.2	3426591	1.89
A2	453609.1	3426543	2.68
A3	453665.4	3426498	1.93
A4	453761.2	3426462	0.93
A6	453838.3	3426418	2.08
B7	453553.2	3426483	1.19
B8	453534.7	3426397	2.10
B9	453585.2	3426361	0.89
B11	453743.2	3426234	0.82
B12	453767.1	3426212	2.10
C14	453448.8	3426325	1.26
C15	453510.4	3426243	1.36
C16	453629.4	3426160	1.12

Continued

C18	453689.8	3426097	0.68
D 19	453535.7	3426316	0.66
D 20	453381.6	3426238	1.19
D 21	453443.6	3426153	2.10
D23	453575.4	3426035	0.89
D24	453601.7	3425969	0.82

Table 4. Average surface groundwater levels during the period (May 2013 to December 2013).

Symbol	Depth (m)	Average groundwater depth (m)	Average ground water levels (m)	Ground level (m)
A1		1.309	1.19	2.55
A2	Path No. 1	0.888	1.85	2.68
A3		1.08	1.73	2.81
A4		0.353	1.82	2.17
A5	Path No. 2	0.169	1.92	2.08
A6		1.32	1.80	3.11
B7		0.809	1.51	2.38
B8	Path No. 3	0.52	1.64	2.17
B9		0.591	1.70	2.30
B11	Path No. 4	0.11	2.18	2.29
B12		0.464	1.89	2.30
C13		1.60	1.23	2.79
C14	Path No. 5	0.152	1.33	1.50
C15		0.399	1.37	1.74
C16		0.086	1.98	2.05
C17	Path No. 6	0.133	1.86	1.98
C18		1.144	2.42	3.43
D 19		Dry	Dry	1.53
D 20	Path No. 7	0.1	1.43	1.53
D 21		0.432	1.64	2.01
D23	Path No. 8	0.332	1.77	2.11
D24		Dry	Dry	4.27

Table 5. Deep and surface groundwater levels during the period (October 2013 to December 2013).

Deep Well Number	Surface Well Number	Deep groundwater depth (cm)					
		October		November		December	
		Deep Well	Surface Well	Deep Well	Surface Well	Deep Well	Surface Well
D1	A1	145	115	148	123	150	125
D2	B9	60	58	62	62	65	62
D3	C16	70	10	72	14	73	13
D4	D23	30	29	45	31	48	30

Table 6. Measured average groundwater electric conductivity (EC) in dS/m for the observation wells during the period from March 2013 to January 2014).

Well Number	March	July	August	September	October	November	December	January
A1	2.45	ND[1]	ND	4.5	2.25	2.5	2.25	2.65
A2		2.55	2.77	9.28	3.1	9.50	2.80	2.85
A3	3.69	2.40	2.56	3.16	7.45	8.20	9.1	8.31
A4	7.2	1.53	1.55	1.05	1.76	1.97	9.15	8.27
A5	7.2	0.96	0.96	2.18	0.50	0.45	0.54	0.76
A6	ND	1.51	1.52	1.36	1.64	1.50	5.10	5.98
B7	5.08	ND	ND	7.1	5.4	6.00	6.02	6.52
B8	8.21	4.1	4.50	6.51	7.3	8.00	6.25	7.50
B9	21.1	3.11	3.51	13.50	8.20	15.20	15.10	15.30
B11	6.82	1.42	1.41	1.47	1.51	1.27	6.00	5.90
B12	5.2	1.06	1.06	1.76	1.54	1.52	6.50	6.39
C13	28.09	7.20	ND	ND	ND	ND	29.40	29.90
C14	18.50	12.0	12.45	55.8	57.5	55.00	52.1	52.4
C15	53.4	17	17.85	89.20	80.00	88.15	95.70	90.7
C16	21.8	3.50	2.51	2.47	2.45	2.15	8.25	7.67
C17	8.6	0.15	0.16	1.47	1.50	0.15	6.15	6.25
C18	9.2	0.36	0.36	ND	ND	ND	ND	ND
D 20	19.5	10.14	10.14	ND	ND	ND	ND	ND
D 21	19.5	3.50	3.20	15.32	ND	ND	19.7	20.70
D23	ND	3.10	2.64	1.85	60.00	16.17	ND	ND
D24	25.1	ND	ND	ND	30.00	0.15	16.50	15.72

N.D. (not detected).

locations D20 and C16 water ponds have existed, (**Table 4** and **Figure 5**) showed average surface groundwater levels. Studying of groundwater levels results of infiltration paths were shown in **Figure 6** as following: 1) for infiltration path 1, at location A1 the mean groundwater depth was 1.36 m, then decrease at A2 to 0.83 m, then increased to 1.08 m at A3. 2) For infiltration path 2, at location A4 the mean groundwater depth was 0.35 m, then decrease at A5 to 0.16 m, and then increased to 1.31 m at A6. 3) For infiltration path 3, at location B7the mean groundwater depth was 0.8 m, then decrease at B8 to 0.53 m and then increased to 0.6 m at B9. 4) For infiltration path 4, at location B11 the mean groundwater depth was 0.11 m, then decrease at B12 to 0.41 m. 5) for infiltration path 5, at location C13 the mean groundwater depth was 1.56 m, then decrease at C14 to 0.17 m, then increased to 0.4 m at C15. 6) For infiltration path 6, at location C16 the mean groundwater depth was 0.07 m, then increased at C17 to 0.12 m, and then increased to 1.01 m at C18. 7) For infiltration path 7, at location D19 no

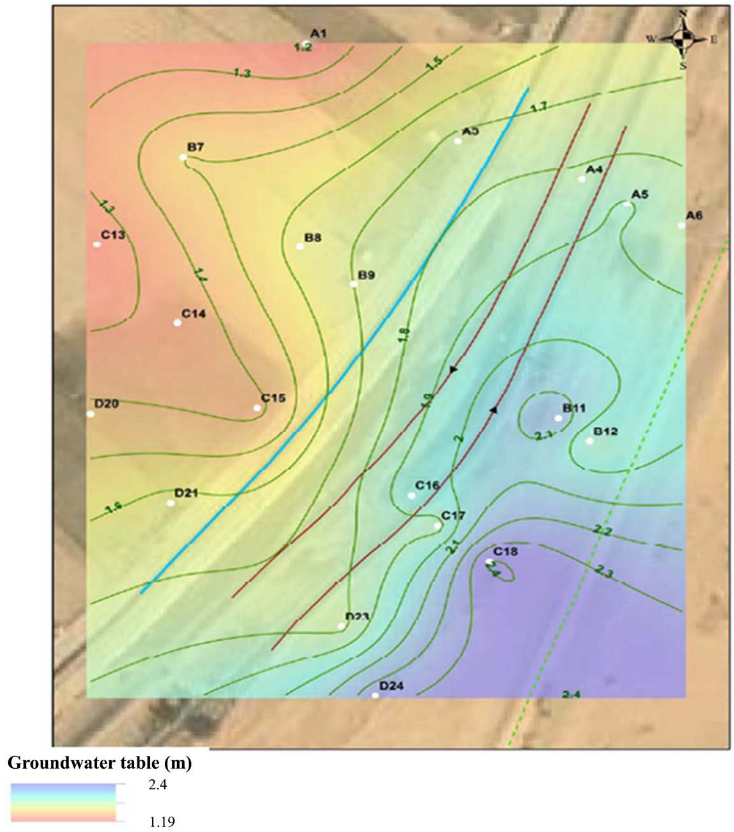

Figure 5. Average groundwater levels.

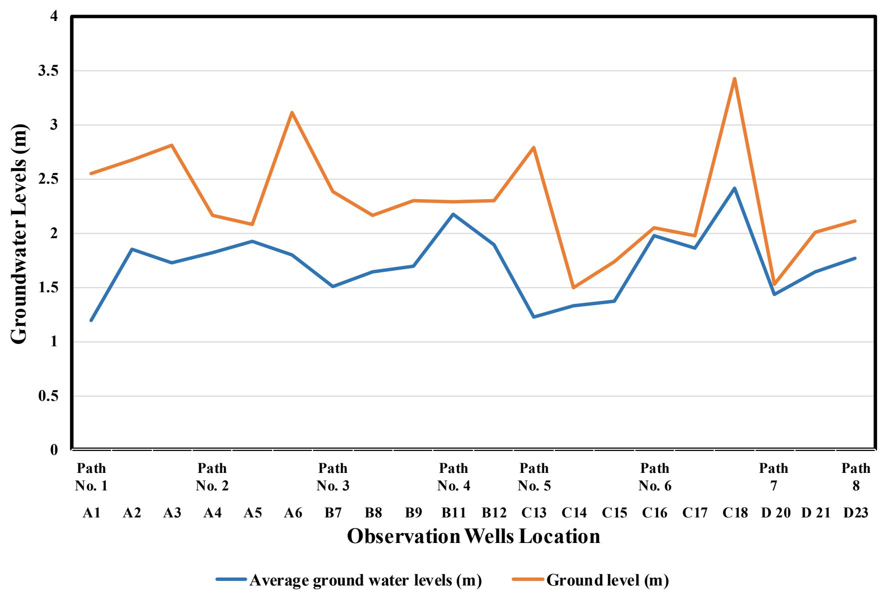

Figure 6. Average groundwater levels through infiltration paths 1, 2, 3, 4, 5, 6, 7, and 8.

groundwater (dry well), at location D20 the mean groundwater depth was 1.43 m, then decrease at D21 to 0.37 m. 8) For infiltration path 8, at location D23 the mean groundwater depth was 0.34 m, and at location D24 no groundwater (dry well). Table 5, shows the results for surface and deep groundwater levels measurements during the period (October 2013 to December 2013) that, maximum deep groundwater depth in well D1 was 150 cm, minimum 145 cm, and the average 147.67 cm, compared to surface well A1 maximum surface groundwater depth was 125 cm, and minimum 121 cm and the average value was 121 cm, so there is no percolation from bottom to topsoil. Maximum deep groundwater depth in well D2 was 65 cm and the minimum 60 cm and the average 62.33 cm compared to surface well B9 maximum surface groundwater depth was 65 cm, and the minimum 62 cm and the average value was 60.76 cm. Maximum deep groundwater depth in well D3 was 73 cm, the minimum 70 cm, and the average 62.33 cm compared to surface well C16 maximum surface groundwater depth was 14 cm, the minimum was 10 cm and the average value was 12.33 cm. Maximum deep groundwater depth in well D4 was 48 cm, the minimum was 30 cm and the average 41 cm compared to surface well D23 maximum surface groundwater depth was 31 cm, the minimum was 29 cm and the average value was 30 cm so there is no percolation from bottom to topsoil. Table 6, shows the measured average groundwater electric conductivity (EC) in dS/m for the observation wells during the period from March 2013 to January 2014. The groundwater salinity range from 4 to 12 dS/m, the groundwater quality is classified as medium saline water according to [23], high salinity for water ponds were observed at C13, C14, C15, D20, and D21 that lay in the lift side of Kamal El-Den Hessen Canal, where water percolation from high level cultivated areas towards low-level lands. Also the high evaporation rates lead to increase the salinity degree for the water ponds.

4. Conclusion and Recommendations

Many farmers complain about the formation of water ponds in their lands, bad soil drainage, and low yields rate in the Kamal El-Den Hessen new reclaimed area (1650 hectares) lies at the North Sinai Egypt. The study concluded that constant monitoring of soil permeability, salinity, irrigation water, groundwater levels, and groundwater salinity levels in the newly reclaimed lands is a good indicator to check irrigation drainage network efficiency, and changing types of crops grown to match with crop salt tolerant levels and soil and water salinity levels. Intensive field investigations were carried out during the period from March 2013 to January 2014 regarding, topographic survey using double difference GPS Device, assessing the existing drainage network, digging 22 boreholes to classify soils and testing soil permeability, instilling observation wells to monitor groundwater levels fluctuations, and measuring groundwater salinity. The analysis of results for field investigation of Kamal El-Den Hessen region showed that the ground surface levels were ranging from 1.5 m to 4.28 m above mean sea level, the soil classification analysis showed that the predominant soil is sandy soil, and the soil permeability was ranged from 0.82 to 2.68 m/day. The depths of groundwater in the western observation wells were 0.50 m below ground surface and in the eastern wells, ranging from 1.0 to 1.50 m. The groundwater salinity ranges from 4 to 12 dS/m, high salinity for water ponds were observed at the observation wells that lay in the lift side of Kamal El-Den Hessen Canal, where water percolation from high level cultivated areas towards low-level lands. Also the high evaporation rates lead to increase the salinity degree for the water ponds. Field drainage problems that increased groundwater levels are: An impervious clay layer lies at 6.0 to 7.0 m below ground surface increases the horizontal infiltration towards low lands and increase ponds areas. The lands surrounding Kamal El-Den Hessen Canal have a high level; the ground surface sloped from to Kamal El-Den Hessen Canal to Main Gelbana Drain. Main Gelbana Drain cross-section needs dredging. The Infiltration water comes from the high-cultivated areas at the lift bank of Kamal El-Den Hessen Canal. It is recommended to dredging Main Gelbana Drain and modified its cross-section to collect water from water ponds, filling the lowland areas utilizing sandy soil in the high lands, and constructing subsurface drainage network to decrease groundwater levels.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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