EVALUATION OF WATER QUALITY OF ELNASR-3 MAIN DRAIN IN EGYPT USING QUAL2K MODEL

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ABSTRACT

Drainage water reuse in Egypt represents a major potential water resource for expanding the cultivated area in the near future. At present time, about 5.30 BCM/y with low pollutants are reused officially and about 2.8 BCM/y are reused unofficially in Delta region [1]. El-Nobaria canal irrigates $1.12*10^6$ feddans (470,400 ha), in which five potable water intakes take their water from it which suffers from pollution by agriculture drainage water at seven locations. A 59% of such drainage water (DW) is coming from ElNasr-3 main drain which tends to cause a deterioration of El-Nobaria canal water quality downstream its outfall feeding all intakes (4 potable and several branches) locating downstream km (52,960) on El-Nobaria canal. A surface water quality model, QUAL2K, has been calibrated and validated to ElNasr-3 main drain according to the field data collected during summer and winter of the year 2005, respectively. The study concentrated on electric conductivity (EC), nitrate-nitrogen (NO_3-N), and pH. The quality of ElNasr-3 main drain water was investigated to estimate the impact of its discharged on quality of the canal water. A proposed drainage reuse scheme is presented in this study to improve the water quality in El-Nobaria canal and its branches downstream km (52,960), especially at the potable water intakes.

Keywords: water quality models, Drainage water reuse and ElNasr-3 main drain.

INTRODUCTION

Water supply augmentation has been practiced in Egypt for few decades through recycling the drainage water and shallow groundwater. In Nile valley and Delta main water resources are dependent on the Nile flows and consequently their reuse raises the water use efficiency of the Nile system in Egypt. Drainage water reuse started in 1928 and reached now a level of 5.3 BCM/y and it is planned to increase the reuse up to 9.4 BCM/y [2]. Although the resultant pollution of the mixed water may be tolerated by most of the agriculture crops, it can not be accepted for drinking for those canals serving the domestic uses. About 2.27 MCM/day of DW is added to El-Nobaria canal at different locations, which is about 8.67% of its maximum discharge. A 59% of such DW is coming from ElNasr-3 main drain. After completion of reclamation of the served area of ElNasr-3 main drain, its discharge is expected to be about 3.0

MCM/day, which raises the DW discharged to El-Nobaria canal to 4.0 MCM/day, 76% of this amount is coming from ElNasr-3 main drain. The average salinity (EC) of El-Nobaria canal water up to and downstream km (52.960) is 315 and 654 mg/l, respectively [3].

Several reports have been presented regarding water quality monitoring in the drains of the Nile Delta. The water quality model QUAL2E-UNCAS has been applied for the San Gerg and kabkab Drains in the Elemenya Governorate in Upper Egypt [4]. Average kinetic rates were assumed, and the model was calibrated. Different scenarios were conceived for several flow conditions with and without wastewater treatment plants. They recommended construction of secondary treatment plants to reduce the pollution in the two drains. The SIWARE Model Package has been applied to evaluate the short-term impacts of the use of the DW for agriculture land expansion in the western desert of Egypt through mixing the Umoum DW with fresh water (FW) in El-Nobaria canal [5]. The study showed that the average salinity of the receiving canal will increase, and this in turn will affect soil salinity and municipal water quality. The QUAL2E-UNCAS model has been applied for the Umoum drain in Lower Egypt [6]. A parametric study was presented, and the model was calibrated. A dynamic management strategy was presented for improving water quality before discharging into El-Nobaria canal. They recommended construction of primary treatment plants to reduce the pollution in the drain and identified the optimal amount of FW needed for the dilution of DW.

In the past decade, several mathematical models have been presented for evaluating and predicting water quality in streams. The most commonly models used are: multimedia fate models [Mackay and EUSES models], hydrodynamic models [Mike 11 and QUASAR models], steady state models [QUAL2E and QUAL2K models] and finally stochastic models [TOMCAT and GREAT-ER models] [7,8].

The QUAL series of computer programs has a long history in systems analysis in water quality management. The Texas Water Development Board (TWDB) laid the foundation upon which the series was built in the late 1960s, known as QUAL-I. In the early 1970s, the United States Environmental Protection Agency (USEPA) began a program to provide water quality models for major river basins and specified that QUAL-I is used as the basis for developing new, more advanced, basin-specific models, known as QUAL-II. One in particular included a special solution algorithm for the steady-state condition and improved in the mid-1970s for the Southeast Michigan Council of Governments (SEMCOG), the area wide wastewater planning agency for the Detroit metropolitan area, known as QUAL-II/SEMCOG. The National Council of the Paper Industry for Air and Stream Improvement (NCASI, 1982) undertook a thorough review, testing, and documentation project covering a variety of water quality models, including QUAL-II/SEMCOG. Changes resulting from this review were incorporated in the EPA distributed program and the model was renamed QUAL-II/NCASI. NCASI (1985) reviewed other versions of the QUAL-II model that included modifications for conditions found in the states of Vermont, Texas, and Wisconsin. A number of common modifications and extensions were discovered in the review and subsequently incorporated into an enhanced version of the model called QUAL2E. This model was improved extensively by the U.S. Environmental Protection Agency (USEPA) [9,20]. Modifications were made in the computer code to overcome such limitations and the modified version was named as QUAL2K, which stands for 2000-Year Version of USEPA's QUAL2E. The major enhancements of the QUAL2K model include the expansion of computational structure and the addition of new constituent interactions, such as algal BOD, denitrification, and DO change caused by fixed plant [10,11].

QUAL2K or Q2K is a river and stream water quality model [10] intended to represent a modernized version of the QUAL2E model. The water quality of the Balatuin River, Philippines, has been investigated [12]. They used the water quality simulation model QUAL2E for predicting the impact caused by conventional pollutants, as well as the exposure concentration of consumer product ingredients. An intensive water quality study of the lower Whippany River, located in northeastern New Jersey has been performed to study DO dynamics using the USEPA Enhanced Stream Quality Model QUAL2E [13]. The water quality of the River Sava, Slovenia has been investigated using the QUAL2E [14]. They used the calibrated model to estimate the maximum BOD of discharged wastewater to maintain DO concentrations > 5 mg/l in all sections of the river. A water quality modeling study to the Nakdong River, Korea has been performed using both QUAL2K and QUAL2E in terms of DO, BOD, nitrogen and phosphorus series, and chlorophyll-a [11]. QUAL2K displayed better agreement with the field measurements than QUAL2E due to QUAL2K's ability to simulate the conversion of algal death to BOD, fixed plant DO, and the denitrification.

In this paper, a proposal for improving surface water quality is presented. The QUAL2K model was selected as a best available one for use in ElNasr-3 drain based on system nature. It has been the most widely used stream model that is numerically accurate and includes an updated kinetic structure for most conventional [15]. The QUAL2K is applied to estimate the impact of discharged DW of the drain on quality of El-Nobaria canal, which will be used for reuse. The study presents a plan to redistribute the DW of ElNasr-3 main drain by intermediate mixing of a considerable part of its water directly into El-Bostan canal at the most suitable locations according to the design values of discharges, levels, and measured quality indices. Such intermediate mixing will lead to the following advantages: improvement of the water quality in El-Nobaria canal and its branches downstream km (52,960) especially at the potable water intakes, using a considerable amount of DW instead of discharging it out into the sea, saving the cost required for improving the existing drainage structures along the drain, minimizing the maintenance cost of it, providing a good and a flexible management of mixing DW partially to El-Bostan canal and/or El-Nobaria canal according to agriculture requirements, minimizing the discharges passing in the drains downstream the mixing sites, which tend to lower the water surface elevation and consequently the groundwater table in the neighboring lands, and improvement the salinity of the land downstream km (52.960) on El-Nobaria canal.

METHODOLOGY

1. Study Site

The study area is divided into 6 drainage blocks, covers an area of 228,000 feddan (95,760 ha), Fig. (1). ElNasr-3 main drain is considered the main collective drain of the study area. Figure (2) shows a schematic sketch of ElNasr-3 main drain and its drainage network [16].

ElNasr-3 main collective drain has a length 12.200 km. It starts at the point of outfall of main drains No. (2) and (3). It discharges its flow into El-Nobaria canal at km (52.960). This discharge is used for domestic and irrigation purposes downstream ElNasr-3 main drain outflow (four treatment plants and areas of agricultural land downstream this location receives irrigation water with high drainage water content). It serves 95,760 ha of maximum design discharge = 31.67 m^3/sec. Design cross section of the drain is trapezoidal with side slopes 2:1 left and 3:1 to 2:1 right, bottom width ranges between 5.5m to 18 m and bed slope 10cm/km. It is located approximately between latitudes 30° 25' 41" and 30° 50' 30" North and longitudes 29° 56' 14" and 30° 29' 36" East. The field observations show that ElNasr-3 main drain suffers from the following problems:

1. Serious collapse of its side slopes.
2. Considerable sedimentation on its bed tends to decrease its waterway and its drainage capacity.
3. Existing crossing work at km (0.800) with Ganaklice airport road is a pipe culvert consisted of two pipes each of diameter 1.50m, which tends to a considerable water rising which affects the whole drainage system.

The climate of the study area can be classified as predominantly Desertic (long dry summer and short cool rainy winter). The average temperature Varies from 6°C in January to 33°C in the months of July and August. The study area is blessed with about 61.2 mm rainfall as an annual average with most rain falling between the months of November and February. The main water sources of the study area are El-Bostan canal and El-Nasr canal which are about 52 km and 82 km long and irrigate about 54% and 46% of the study area, respectively [17]. The soil in the study area in general is sandy soil with water-holding capacity of 6-8% by volume. The cropping pattern in the area involves the plantation of field crops, fodders, vegetables, and fruit trees.

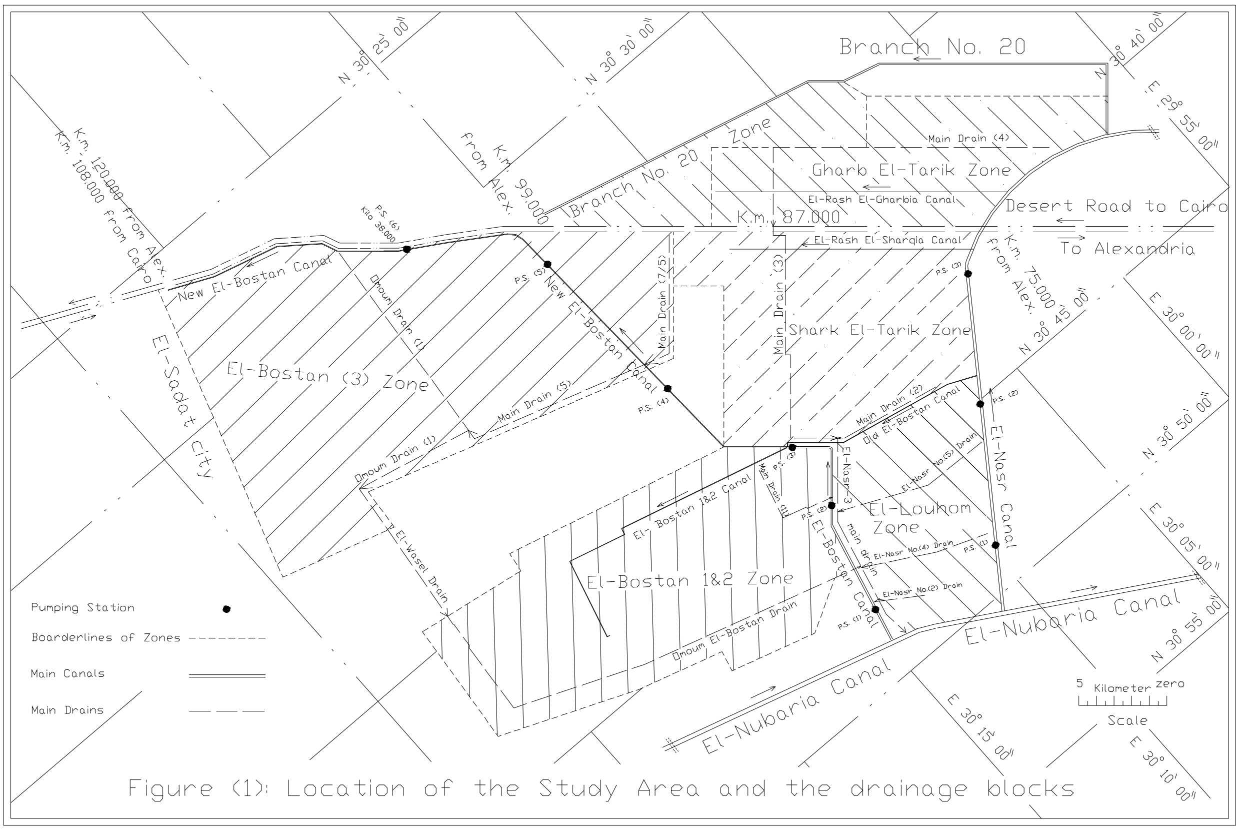

Figure (1): Location of the Study Area and the drainage blocks

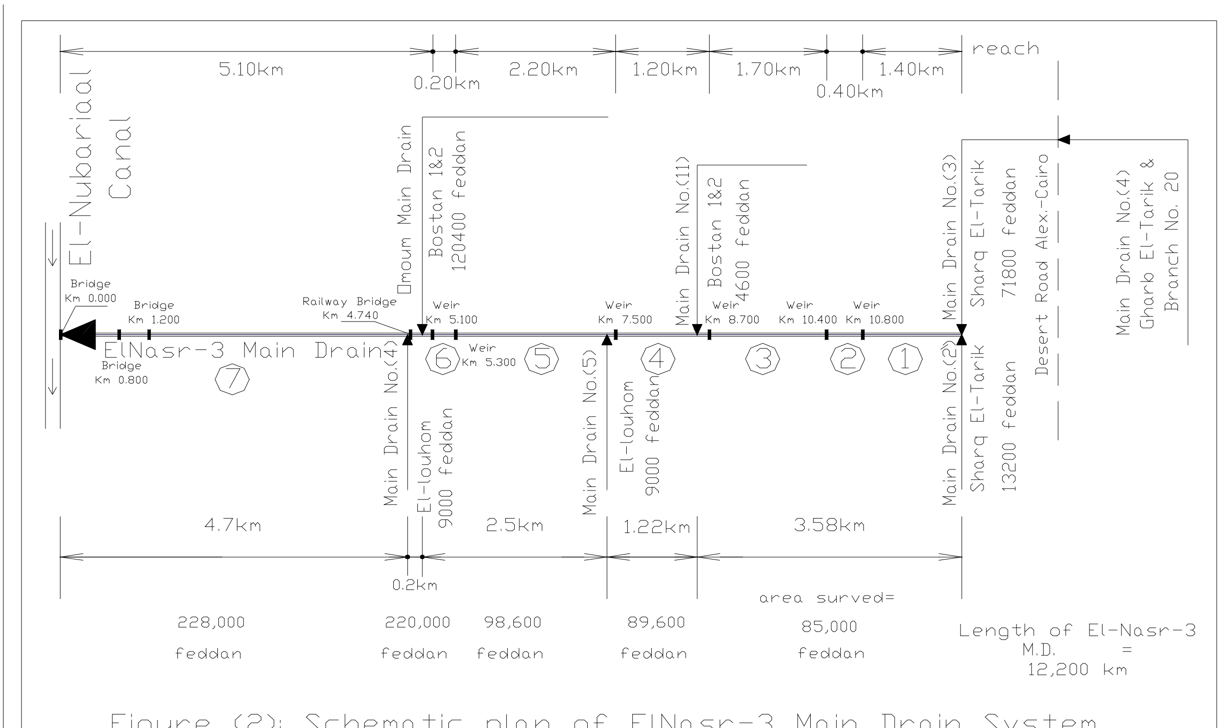

Figure (2): Schematic plan of ElNasr-3 Main Drain System

In order to examine the relationship between the pollution control strategies and the receiving water quality, the water quality modeling study was performed in the ElNasr-3 main drain and the results are presented in this paper. The modeling study includes development and application of a computer model, which is suitable for the large drain with a heavy algal growth.

2. Simulation of Water Quality in Drains

Simulation of water quality in the drains is complicated by the existence of many points and non-points sources adding several pollutants along the stream. It is difficult to identify biological and chemical processes occurring in drains without fully characterizing all inputs. Deriving the kinetic decay coefficients for the water quality modeling is the key step in water quality simulation. The kinetic coefficients can be obtained in four ways: direct measurements, field data, literature values, or model calibration.

3. Model Development

The water quality model QUAL2K was used to study the quality of ElNasr-3 main drain water. In this model the stream is conceptualized as a one-dimensional string of completely mixed segments that are linked sequentially via the mechanisms of advective transport and dispersion. The model uses a finite-difference solution for the advective-dispersion mass transport equations and also has the capability of performing an uncertainty analysis. The model permits the simulation of 36 water quality constituents. The stream can be divided into 100 reaches and each reach has 1000 computational elements. Each computational element has constant hydrogeological characteristics and reaction constants, Fig. (3). The single constituent mass balance model equation numerically integrated by QUAL2K, with respect to time [10], is written as:

$$\frac{dC_i}{dt} = \frac{Q_{i-1}}{V_i} c_{i-1} - \frac{Q_i}{V_i} c_i - \frac{Q_{ab,i}}{V_i} c_i + \frac{E'_{i-1}}{V_i}(c_{i-1} - c_i) + \frac{E'_i}{V_i}(c_{i+1} - c_i) + \frac{W_i}{V_i} + S_i \qquad (1)$$

Where C = concentration [mg/l]; V_i = incremental volume of i^{th} reach [m^3]; t = time [day]; S_i = internal sources or sinks of constituent due to reactions and mass transfer mechanisms for water constituents [$g/m^3/d$ or $mg/m^3/d$]; E'_i = bulk longitudinal dispersion coefficient between reaches i and i+1 [m^3/d]; W_i = external loading of constituent to reach i [g/d or mg/d]; Q_i = outflow from reach i into reach i+1 [m^3/d]; Q_{i-1} = inflow from reach i-1 [m^3/d]; and $Q_{ab,i}$ = outflow from the reach i due to point and non-point abstraction [m^3/d]. On the left-hand side of the equation the term $d\,C_i / d\,t$ refers only to the constituent change with respect to growth and decay and should not be confused with the term $\delta C/\delta t$ which is the local concentration time gradient.

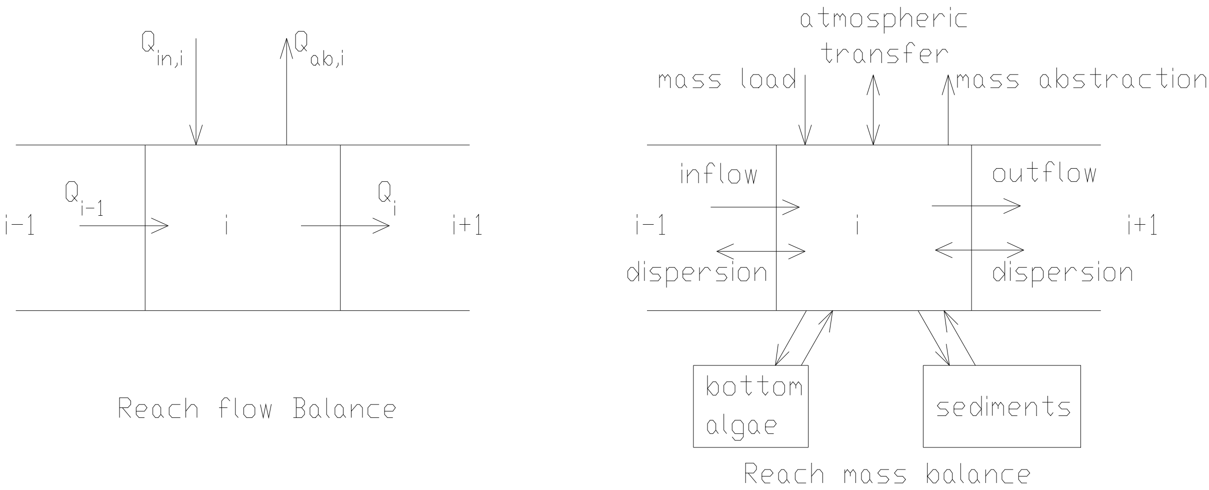

Fig. (3): Conceptual representation of a stream

The differential equation is solved numerically using an implicit backward differencing method. A number of simultaneous equations are generated and solved using matrix algebra. The reactions of constituents and their interrelationships are represented in the model. A full description of the model formulation for QUAL2K is provided in the manual [10]. The differential equation used in QUAL2K to describe the rate of NO_3 change is down below. Each term represents a major source or sink of NO_3. Nitrate nitrogen increases due to nitrification of ammonia and is lost via denitrification and plant photosynthesis [10,13].

$$\frac{dNO_3}{dt} = F_{na} K_{na} NH_4 - (1 - F_{dn}) K_{dn} NO_3 - r_{na}(1 - P_p)\mu_p P - r_{nd}(1 - P_b)\mu_a A \qquad (2)$$

Where F_{na} = attenuation due to low oxygen [dimensionless]; K_{na} = Nitrification rate for ammonia nitrogen [/d]; F_{dn} = effect of low oxygen on denitrification [dimensionless]; K_{dn} = Denitrification rate [/d]; r_{na} = ratio of oxygen consumed in nitrification [gO_2/gN]; P_p = preference for ammonium as a nitrogen source for phytoplankton [dimensionless]. μ_p = phytoplankton photosynthesis rate, temperature dependent [/d]; P = phytoplankton [mgC/l]; r_{nd} = ratio of oxygen consumed in denitrification [gO_2/gN]; P_a = preference for ammonium as a nitrogen source for bottomalage [dimensionless]; μ_a = algal growth rate, temperature dependent [/d]; and A = algal biomass concentration [mgA/l].

Parameter coefficients were corrected for temperature using the Arrhenius equation [13,18]. The general form of this equation is:

$$K_T = K_{20}\phi^{T-20} \qquad (3)$$

Where K_T = temperature-corrected coefficient; K_{20}=coefficient at 20°C; Φ = temperature correction constant; and T = temperature in °C.

Each reach is idealized as a trapezoidal channel [10,19]. Under conditions of steady flow, the Manning equation can be used to express the relationship between flow and depth as:

$$Q = \frac{S_o^{1/2}}{n} \frac{A_c^{5/3}}{P^{2/3}} \tag{4}$$

Where Q = flow [m^3/sec]; S_0 = bottom slope [m/m]; n = Manning roughness coefficient; A_c = cross sectional area [m^2]; and P = wetted perimeter [m].

4. Geometrical and hydraulic properties

The main drain was divided into 7 reaches, Fig. (2). Each reach was then subdivided into uniform computational elements, which form the basis for model's finite difference numerical solution. The size of these elements that are assigned to one of seven different types, including headwater elements, standard elements, elements just upstream from a junction, junction elements, last element in system, input elements, and withdraw elements was chosen to be 0.2 km [15]. The drain is considered a conveyor drain with incremental lateral flow. In the simulation, the four feeding drains are considered as four source points and two incremental lateral flow reaches are considered as two non-points sources. The geometrical properties of the drain reaches were obtained from the longitudinal section of the drain developed by El-Nasr Drainage Directorate, Ministry of Water Resources and Irrigation (MWRI). The velocity, cross-sectional area, and water depth are computed from the drain flow by trial and error solution of Manning's equation and the method is fully described [20,21]. The average value for Manning's coefficient is 0.03.

5. Calibration and Validation

The reliability of model calibration and validation depends on accuracy of input data. The values of model parameters in surface water quality models can be found in the literature. Model parameters vary widely according to the site of investigation so the parameter values are often stated in wide intervals. That is the reason why the literature values can serve us only as a guide [13]. After field and laboratory measurements, average summer (June to August) and winter (November to December) data during 2005 have been obtained for calibration and validation of the model, respectively. All parameters were modeled in a steady-state mode. The model was calibrated in the summer period when the situation is the most critical due to high temperatures. Measurements have always been taken early in the morning so the influence of production of oxygen due to photosynthesis was excluded. Using the input summer conditions, the model was run and the results compared to the field measurements. System coefficients were appropriately adjusted until reasonable agreement between model results and field measurements was achieved as shown in

Fig. (4). The values of system coefficients were based on the typical values cited in the model documentation [20] and the calibrated values of selected coefficients were summarized in Table 1. Temperature dependent coefficients were corrected using default values for QUAL2K, which are listed in Table 2.

Table 1: The rate coefficients used in QUAL2K [10,20]

Parameter	Units	Symbol	Range	Calibrated
Michaelis-Menten half-saturation constant for light	Ly/d	K_{Lp}	20-100	57.6
Michaclis-Menten half-saturation constant for nitrogen	µg/l	K_{sNp}	10-300	15
Michaclis-Menten half-saturation constant for phosphorus	µg/l	K_{sPp}	1-50	2
Max. bottom alage photosynthesis rate	$gD/m^2/d$	C_{gb}	10-100	60
Max. phytoplankton photosynthesis rate	/d	K_{gp}	1.0-3.00	2.5
Nitrification rate for ammonia nitrogen	/d	K_{na}	0.3-3.00	0.80
Denitrification rate	/d	K_{dn}	0.1-1.00	0.20
Partial pressure of carbon dioxide	ppm	Pco_2	-	373

The model was validated in the winter period when the situation is less critical due to low temperatures. Comparison between field measurement and modeling results is shown in Fig. (5). Figures (4 and 5) show that a good calibration and validation of the model to the 2005 data were achieved.

Table 2: Temperature coefficients used in QUAL2K [10]

Parameter	Temperature coefficient θ	Parameter	Temperature coefficient θ
K_{Lp}	1.071	K_{na}	1.083
C_{gb}	1.068	K_{gp}	1.068
K_{sNp}	1.064	K_{dn}	1.047
K_{sPp}	1.066		

RESULTS AND DISCUSSIONS

1. Water Quality of the Drain

From Figures (4 and 5), it is clear that salinity, nitrate and pH decrease as the drain travels toward El-Nobaria canal. Compared to the standard criteria for assessing suitability of saline DW given in table (3), it looks that the drain has suitable water quality. This means that the DW of ElNasr-3 drain can be used directly in irrigation moderately tolerant and salt tolerant crops without mixing. Mixing it with FW (needed for the dilution of DW) makes its suitable for irrigation of sensitive and moderately sensitive crops but not suitable for potable water use.

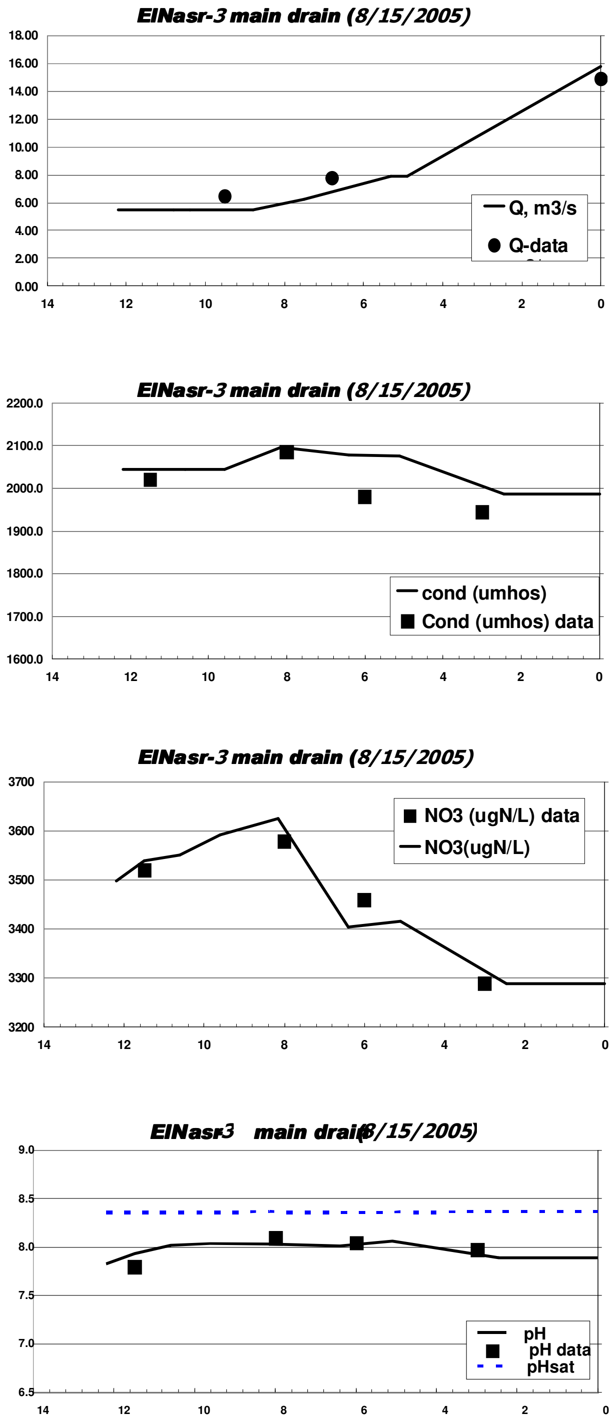

Fig. 4. Model calibration results

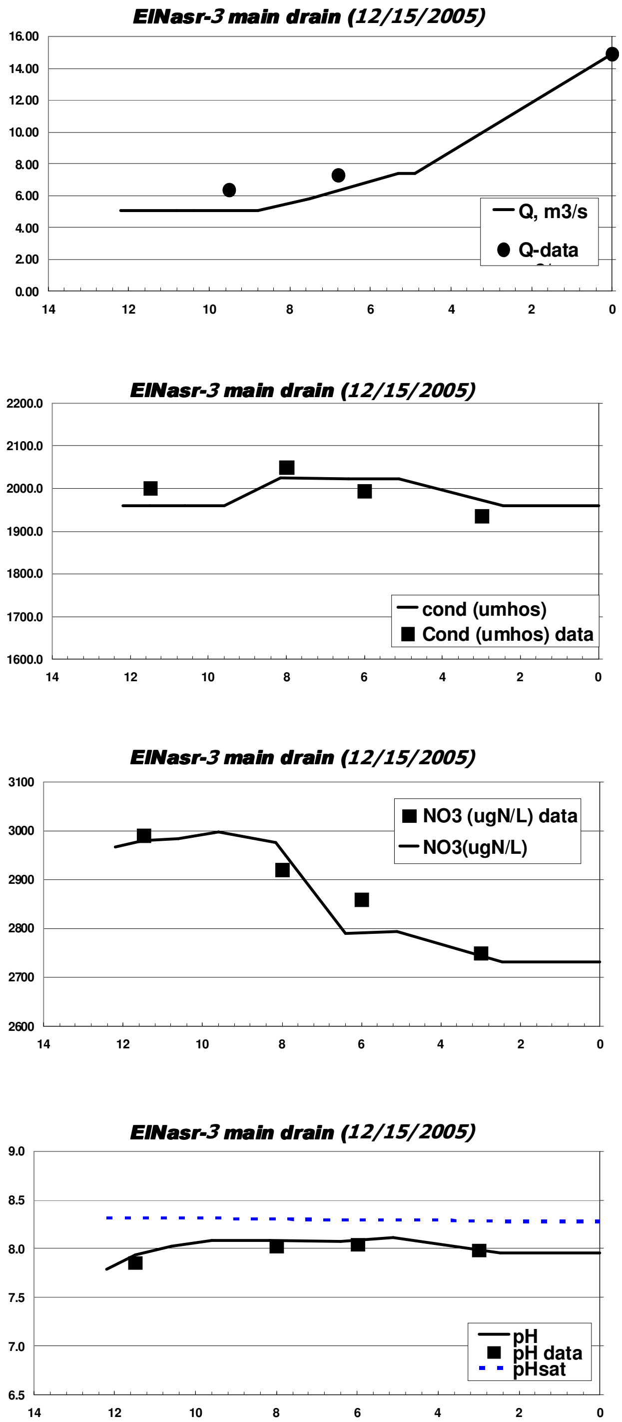

Fig. 5. Model validation results

Calibrated and validated average EC of ElNasr-3 main drain at km (2.500-0.000) are 1987 and 1959 mg/l, with an average NO_3 concentration of 3.29 and 2.73 mg/l and an average pH of 7.90 and 7.95, respectively. Both expected salinity values are higher than the standard for discharging into irrigation canals, i.e. 500 mg/l of EC, 10 mg/l of NO_3, and 7.0-8.0 of pH after mixing with fresh water [1,6,22]. DRI has studied the suitability of El-Nobaria canal mixing water by taking water samples downstream km (52.960) at different locations. After water quality analyses in NWRC, it shows that the mixing canal water is not suitable for potable water use because its high EC and MPN. To solve this problem, a proposed solution is intermediate mixing of a considerable part of DW directly into El-Bostan canal at the most suitable locations according to the design values of discharges, levels, and measured quality indices.

Table (3): Standard criteria for assessing suitability of saline DW for irrigation [22]

PARAMETERS	DEGREE OF RESTRICTION ON USE		
	NONE	SLIGHT TO MODERATE	SEVERE
EC (DS/M)	< 0.7	0.7-3.0	> 3.0
NO_3 (MG/L)	< 5.0	5.0 – 30	> 30
DO (MG/L)	NORMAL VALUE > 5.0		
PH	NORMAL RANGE = 6.5-8.4		

2. Water Quality of the Receiving Canal

El-Nobaria canal is considered the major canal in the West-Delta area. The intake of it is located on El-Raiah El-Behary at km (81.650) left upstream Kafr Buleen Barrage. This intake feeds El-Nobaria canal with discharge up to 12.90 MCM/day. Additional feeding of El-Nobaria canal at km (7.000) is from El-Raiah El-Nasery with discharges up to 9.50 MCM/day. El-Nobaria canal's discharge varies from a minimum value of 14.95 MCM/day during the least requirements period to a maximum value of 22.40 MCM/day during the maximum requirements period. The average EC, NO_3-N concentration and pH in the canal upstream ElNasr-3 main drain outfall are lower than the standard but its water quality (i.e. EC > 654 mg/l) downstream the drain outfall is higher than the potable water standard.

3. Proposed Scheme

An intermediate mixing of DW directly into El-Bostan canal at the most suitable locations is a proposed solution for improving El-Nobaria canal water downstream km (52,960). Criteria for selection of DW reuse locations are: canal does not serve drinking purposes downstream the proposed reuse location, water deficit is always recorded along the canal, crops cultivated in the study area are not sensitive to mixed water, drain has continues drainage water, drain is free of domestic and industrial pollution, extension connection between drain and canal is closer, drainage water reuse can assist to operate the IIP canal under continuous flow conditions, and water levels in both drain and canal to allow flow by gravity to the canal. Based on these criteria, location at km (2.400) on ElNasr-3 main drain is chosen to mix its water with FW of El-Bostan canal at km (2.400) – suction of PS. No.(1) that discharges its water to El-Bostan (1, 2 and 3) zones. So, regulator is proposed to be constructed at this location (the water levels in the drain are higher than the water levels in the canal). To control the water levels in ElNasr-3 main drain system, an escape regulator is required to be constructed at a suitable location in the reach extended from km (0.000) to km (2.400) i.e. downstream the last proposed reuse location. The proposed reuse project can feed El-Bostan canal with about (0.50 – 1.0) BCM/y of DW for irrigation purposes (available FW to El-Nobaria canal is about 0.50 – 1.0 BCM/y). To study the feasibility of the project, a benefit–cost analysis has been carried out by calculating the present values of cost (PVC) and benefit (PVB) using the following considerations: benefit rate as recommended by the World Bank, life time of project, and capital costs are assumed to be paid totally in the year of construction (year 0) just one year before operation [23]. Using the above procedures, an economic evaluation for the proposed reuse project has been carried out approving the proposed project is acceptable if the quantity of available fresh water to El-Nobaria canal greater than 23.141 MCM/y. Environmental impact assessments showed that this scheme impacts is mostly positive. This scheme is tending to lower water table level, stop soil deterioration under the unofficial drainage water reuse practices, increase the flow velocity in the drain, which reduces the opportunity for water-born diseases to develop, positive effect on the erosion and sediment process of the drains, the income and amenity for farmers at the tail of the canal, the public health, the disease control and resettlement of farmers. It has negative impact on the solute dispersion and the ecological system of the canal.

CONCLUSIONS

The obtained conclusions of the present study can be summarized as follows:

1) At present, about 2.27 MCM/day of DW is added to El-Nobaria canal at different locations, which is about 8.67% of its maximum discharge. A 59% of such DW is coming from ElNasr-3 main drain. This tends to a deterioration of El-Nobaria canal water quality downstream the drain outfall feeding all (irrigation and potable) intakes locating downstream km (52,960) on El-Nobaria canal.
2) The methodology used in this study is highly recommended to be applied to other streams, especially to where a long-term in situ observation is physically or economically limited.
3) Mathematical model QUAL2K is used worldwide for the evaluation of surface water quality. This model is used to evaluate the water quality in ElNasr-3 main drain which will be used for reuse. Calibration and validation procedure of QUAL2K model for the drain was made using field measurements and results that were obtained for summer and winter period, respectively. So the model is reliable

to state concentrations in the drains at similar conditions and when extremely different conditions occur.

4) The water quality concentrations included in the model were EC, NO_3-N, and pH.
5) The model can be used as a tool to state concentrations at more flows from two point sources (Shark El-Tarik (3) and Umoum El-Bostan drains) after completion of reclamation of the drain served area.
6) Analyses of DW quality showed that ElNasr-3 drain system have suitable water quality for irrigation but not suitable for drinking even after mixing with FW of El-Nobaria canal. This means that DW of the drain can be used directly in irrigation of moderately tolerant and salt tolerant crops without mixing. Mixing DW of it with El-Bostan canal water makes its suitable for irrigation of sensitive crops.
7) The proposed intermediate drainage reuse is through mixing a considerable part of DW of the drain and its branches directly into El-Bostan canal. It will give the decision-maker a flexible tool to manage both water quality and quantity in El-Nobaria canal and its branches system and to decrease the maintenance and improvement cost of the drainage system.
8) The case study proved that the intermediate reuse scheme could feed El-Bostan canal with about 0.5-1.0 BCM/y for irrigation purposes. This amount can compensate the shortage in water recourses in El-Bostan 1, 2 and 3 areas. Daily monitoring program should be done for the whole network. An integrated dynamic management for both water quality and quantity in both ElNasr-3 drain and El-Bostan canal is highly recommended.

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