Annual Journal of Hydraulic Engineering, JSCE, VOL.48, 2004, February

MODELING FOR FLOOD PREVENTION FOR THE COASTAL AREA OF NILE DELTA IN EGYPT

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Excess agricultural drainage water in Egypt is mainly disposed into the sea through a complex network of drains. Recently, the area around the Edko Drain in the west delta region faced problem of frequent flooding by storm water during the rainy season. A solution for the problem is presented in this paper through 1-D numerical simulation for flood routing in a drainage network, where the water surface level is affected by the released drainage flow, the lake water level, and the tide in the Mediterranean Sea. From the drainage model, it is concluded that the influence of tidal flow is restricted in the lake area and not extended to the drain reaches. As for flood mitigation, lowering of drain water levels is suggested through cutting the local mound in the drain.

Key Words: *Open channel flow, flood routing, 1-D numerical simulation, drainage management*

1. INTRODUCTION

Excess drainage water in the Nile Delta region is mainly disposed into the northern natural lakes, which in turn surge into the Mediterranean Sea as shown in **Fig.1**. The conveyance system is represented by drainage networks provided with drainage pump stations. The networks are designed to transport a targeted maximum load of agricultural drainage water. The Edko Drain is one of the largest drains in the north west of the Nile Delta. The Edko drainage system consists of a main drain fed by seven pump stations and the Edko Lake, which is a natural salt lake. The lake is connected with the Mediterranean Sea through a strait called the Maadia Bay, as shown in **Fig.2**. The Edko Lake is very important not only for drainage purpose but also for fishery wealth.

Recently, frequent flood occurs every winter season (the rainy season in Egypt) at the time of intensive irrigation in agricultural land due to the high intensity of rainfall. Consequently, the Edko Drain overflows the embankments, especially in the lower reach of the drain. In January 2002, one of the largest floods occurred and the drain overflow caused heavy damages on the roads, the agricultural lands and cities around the downstream reaches of the drain. Accumulative sedimentation in the drain and the lake are recorded through a regular survey of depth measurements and the maximum sedimentation depth reaches about 2.3 m in the Magror, which is the last reach of the drain located inside the lake. When the experts have gathered to take decisions regarding to the flood problem, the tidal effect on the flood and the cumulative sediment were discussed as the reason for the overflow. However, the cause of overflow was unrevealed and under extensive investigation after the flood.

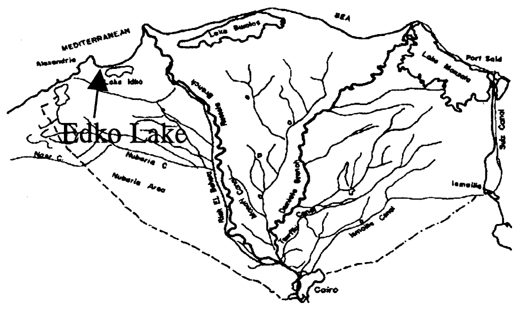

Fig.1 Delta of the Nile River

The canal hydraulic models are giving a discrete representation of a complex and continuous flow situation in channel networks to evaluate their performance and to improve the operation and management of such systems at low cost. In the last decade, a number of canal hydraulic models have been developed and tested. A survey of literatures shows that mathematical simulation of flow in channel networks, even in a single channel, has mostly been attempted through finite difference schemes[1]. A few models used finite element method[2]. Some of the presented canal hydraulic models are CANALMAN, DUFLOW and MIKE 11. All literatures are included in the reference of Kumar et al.[3]. Some models consider the entire network with full details of branches[4]. Other models use simpler analysis that considers the main canal system with the branches treated as bulk lateral outflows[5]. The Node-Branch model developed by Booij[6] can be applied for a large range of applications, such as flood waves in rivers, operation of irrigation and drainage systems. Node-Branch model implicitly solves an integrated form of the Saint-Venant equations of continuity and motion. Kantoush et al.[7] have successfully used the model to analyze the flow in one of the tree type channel networks in the delta of the Nile River.

This paper presents a dynamic one–dimensional unsteady flow simulation for the Edko Drain by using the Node-Branch model. The problem is presented through numerical simulation for flood routing in a drainage network affected by the released drainage flow, the lake water level, and the tide in the Mediterranean Sea.

2. EDKO DRAINAGE SYSTEM

The drain discharges its water into a natural salt lake called the Edko Lake, which is connected with the Mediterranean Sea through the Maadia Bay as shown in **Figs. 2** and **3**. The Edko Lake is situated about 30 km east of Alexandria. It is a shallow brackish water lake with a complex basin, islands and peninsulas. The water depth in the main area of the lake is from 0.8 m to 1.2 m. The area of the lake is about 80 km^2. A strait between the lake and the sea is called the Maadia Bay with about 500 m in length and about 200 m in width.

The Edko Drainage System was constructed about 50 years ago. The designed drains are channels having trapezoidal cross sections by bed width from 10.0 m to 50.0 m, and the bed levels shown as the designed bed level in **Fig. 4**. The reach from km 14.0 to km 48.8 is the main drain called the Edko Drain. The downstream reach of the drain from km 8.0 to km 14.0 is called the Magror Edko, which also has been constructed inside the lake as a channel with two side banks. However, the channel

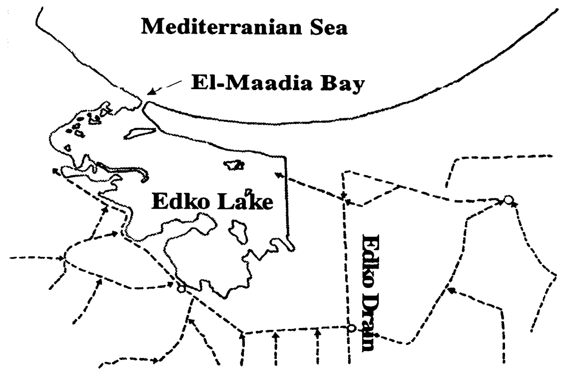

Fig. 2 Map for the northern lake (Edko Lake)

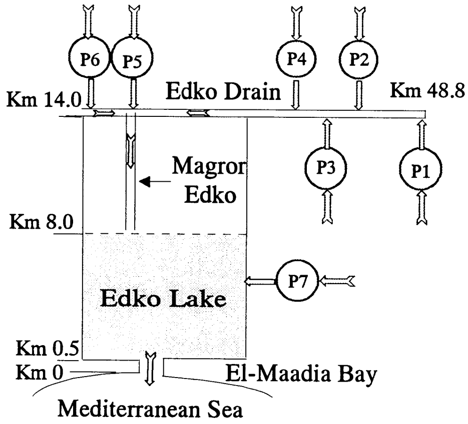

Fig.3 Outline sketch for the drainage system

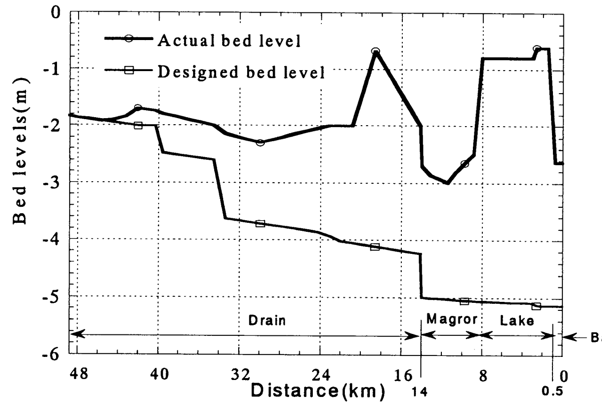

Fig.4 Longitudinal bed levels

inside the lake from km 0.5 to km 8.0 has not been constructed.

Floods for 50 years have caused an accumulation of sediment in the drain due to: (a) the sediment from the irrigable land, (b) side slopes failures because of embankments without lining. The present cross sections have been deformed from the designed one and also the bed levels have been changed by sedimentation as shown in **Fig.4**. Actual geometrical properties of the drain reaches were obtained from the field measurements taken by Deputy of Drainage, Ministry of Water Resources and Irrigation, Egypt[8].

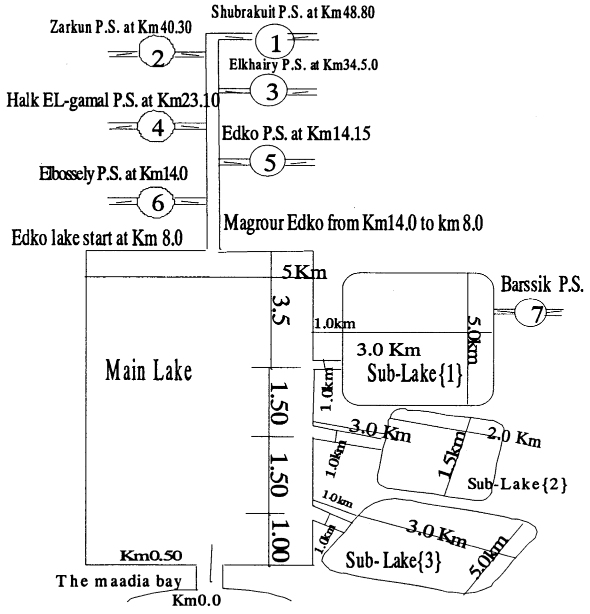

Fig. 5 Schematization of the practical situation

There are seven pump stations in this drainage system. They discharge the water from the irrigable land of 120.54 thousand ha in the delta area to the Edko Drain and the Edko Lake. The pump stations data were obtained from the Department of Mechanical and Electric in DAMANHOUR[8], which controls these stations on the working hours and the discharge amount.

3. METHODOLOGY

(1)Formulation

In the present study, the Node-Branch modeling system has been applied for simulating the drain flow in unsteady state. The Node-branch model governing equations are the two Saint-Venant equations for one-dimensional unsteady flow. One of these is the continuity equation, as Eq. (1):

$$\frac{\partial B}{\partial t} + \frac{\partial Q}{\partial x} = 0 \tag{1}$$

where B is the total wet cross-sectional area, Q is the flow rate, x is the distance and t is the time. The second is the momentum equation, as Eq. (2):

$$\frac{\partial Q}{\partial t} + \frac{\partial (QV)}{\partial x} + gA\frac{\partial h}{\partial x} + J(Q,h) = 0 \tag{2}$$

where V is the flow velocity, h is the water level from a specific datum, A is the flow cross-sectional area and J is the rate of force due to friction. Equations (1) and (2) are discretized in space and time using the four-point implicit Preissmann scheme.

(2)Model Setup

a) Modeling for the Edko Lake

The Edko Lake stretches some 8.0 km southern, behind and parallel to the coast and has a width of 8.0 km. The southern shore shape is complicated and there are several islands and peninsula inside the lake. Because of the complexity of the basin, the lake is divided into a main lake and other three closed basins as illustrated in **Fig.5**. The main lake is simulated as a rectangular channel with width of 5.0 km and length of 7.5 km. The three sub lakes are also simulated as rectangular channels. The dimensions of these basins are shown in **Fig.5**.

b) Schematized channel network

The schematized channel network is analyzed through the computational procedures of the Node-branch model. The schematization used in the Edko networks contains 92 nodes with 91 branches. The schematization has seven lines for the seven pump stations and another three lines for the three sub-Lakes. These 10 lines are connected with one long line till the sea, which represents the Edko drain, the main lake and the bay. The input variables for the model are channel characteristics, boundary conditions for the downstream water level and the inflows for the source nodes in the network.

c) Boundary conditions

The model run was carried out under the effect of tidal flow of the Mediterranean Sea shown in **Fig.6** as a downstream boundary condition. The tidal range is 0.4 m, and the tidal period is 12.5 hours. The data was obtained from the Coastal Research Institute, Egypt[9].

The boundary conditions at the upstream ends are specified by the maximum discharges from each

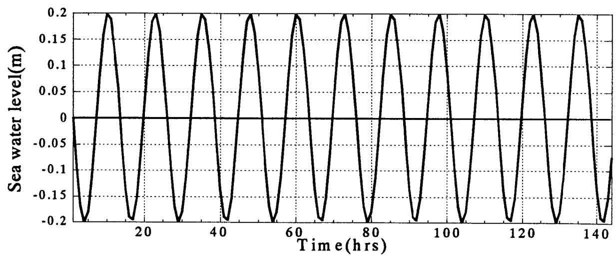

Fig.6 Boundary condition at the downstream end

Table 1 Discharge boundary conditions at source nodes

Source Node No.	Pump station name	Maximum discharge (m^3/sec)
1	SHUBRAKUIT	11.50
12	ZARKUN	11.00
20	ELKHIRY	11.25
33	HALK EL-GAMAL	11.46
44	EDKO	10.00
47	ELBOSSELIY	11.46
61	BARSSIK	11.43
	Total	78.10

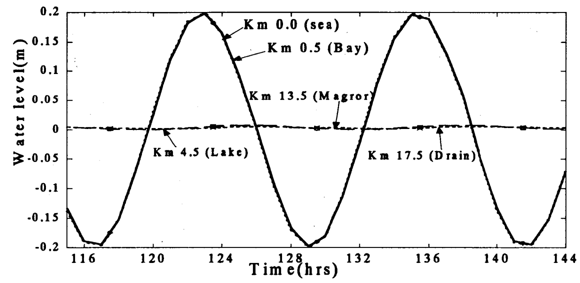

Fig.7 Water level oscillations

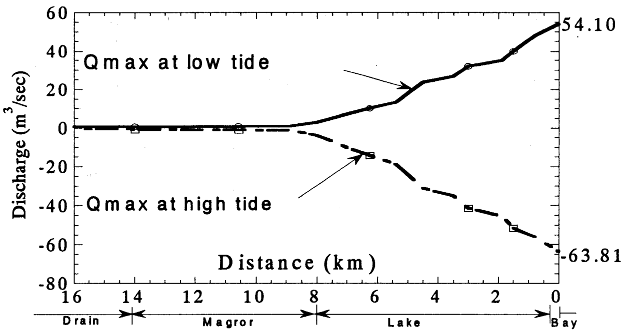

Fig.8 Peak discharges by tides

pump stations at the source nodes. The maximum discharge capacities from the pump stations in the rainy season are shown in **Table 1**. The sum of input discharges to the network is 78.1 m^3/sec.

4. CHARACTERISTICS OF TIDAL FLOW

The main purpose of this section is to know the lake effects on the drainage system. The condition of the simulation is that the pump stations are shutdown. It means that there is no downward discharge from the pump stations and the inflow discharge to the drainage system is due to only the tidal flow from the sea.

(1)Characteristics of the water level oscillations

To evaluate the drainage performance when the pump stations are shutdown, characteristics of the water level oscillations due to the tide will be discussed. **Figure 7** shows the variations of the water levels at different locations, km 0.0 (Sea), km 0.50 (Bay), km 4.5 (Lake), km 13.5 (Magror), and km 17.5 (Drain) along the drain. The water level oscillations in the bay are caused mainly by the meteorological forcing and are the same at the sea. The tidal ranges in the lake, Magror and drain are very small comparing with that in the bay. These oscillations vanish in the upstream of the drain. It is clear that the oscillation of the water level is decreased inside the lake and the water surface upward of the lake retains almost a constant level around the mean sea level.

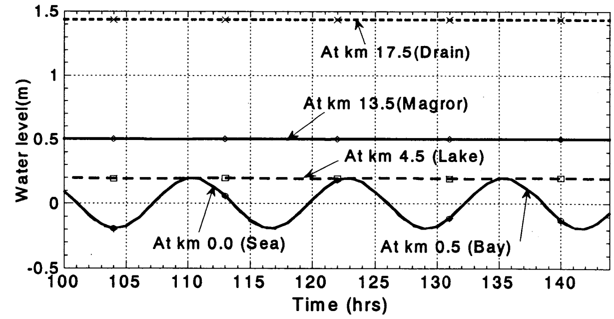

Fig. 9 Tidal water levels at different locations

(2) Discharge caused by tide

Figure 8 shows a comparison between the peak discharges at the high and low tides when the pump stations are shut down. It is found that the maximum offshore discharge from the sea towards the Edko Lake is 63.8 m^3/sec and the maximum out flow discharge to the sea is 54.1 m^3/sec. These discharges gradually decrease during the lake and almost disappear at km 8.0 (the end of the lake). Since the energy of wave motion decreases owing to the frictional resistance in the lake, tidal range rapidly decreases and disappears.

5. DYNAMIC FLOOD ROUTING

In this section the pump stations are in duty with the maximum discharges in the rainy season. One of the objectives of the dynamic flood routing is to clear the main reasons for overflow and introduce a suitable solution to reduce the damage due to the flood. For flood prediction, the drain is simulated with the full capacity of pump stations discharges shown in **Table 1**.

(1)Water level

To evaluate the drainage system performance, oscillations for the water levels at different sections (the Sea, the bay, the lake, the Magror, and the drain) are shown in **Fig.9**. The water level oscillations in the bay are the same as in the sea. It can be observed that the amplitudes of oscillations are decreased during the lake after the bay and approximately disappear at km 4.5. The water level in the lake is about 0.2 m at km 4.5 and increases to 0.5 m at km 13.5 in the Magror and reaches 1.43 m at km 17.5 in the drain. A comparison between **Figs.7** and **9** at the different locations will be held to clarify the effect of the discharges from the pump stations. The oscillations in the bay are the same in both figures, however the small oscillations in the lake and the drain are disappeared. It means that there is no effect of the pump stations flow on the water levels at the bay.

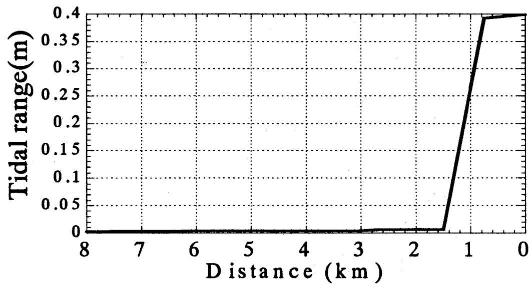

Fig.10 Tidal range for the actual model

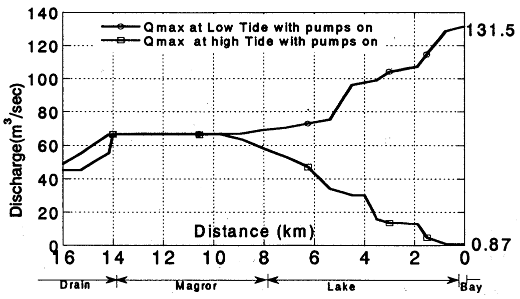

Fig. 12 Maximum discharges at low and the high tides

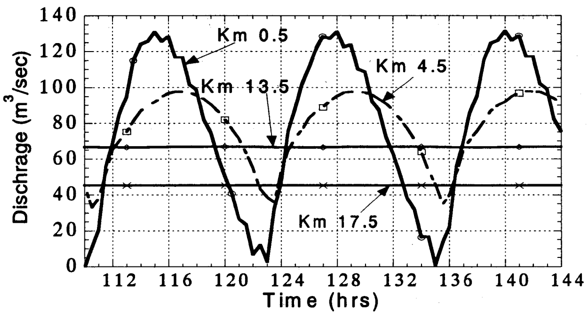

Fig.11 Discharge oscillations for the actual model

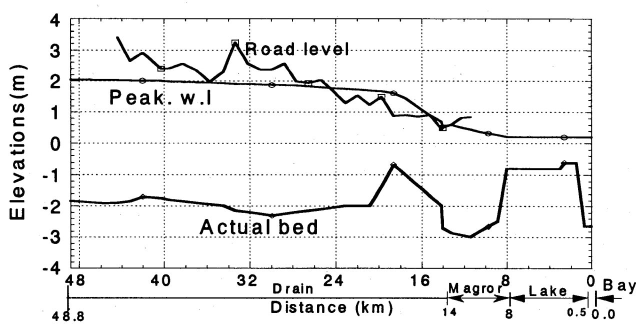

Fig. 13 Flood simulation

The pump stations flow reduced the variations of the water level in the lake. Moreover, the water levels gradually increase in the upstream direction due to the discharges from the pump stations that interrupted the incoming wave from the sea. **Figure 10** shows the difference between high and low water levels (tidal range). It is observed that the tidal effect rapidly decreases near the bay and disappears inside the lake.

(2)Discharges

Figure 11 represents the variations of the discharge at km 0.5, km 4.5, km 13.5, and km 17.5. It is noticed that there is no negative discharge (offshore discharge) but onshore discharge is 131.5m^3/sec in the bay due to the downward discharges from the pump stations. Then, salt water does not intrude the lake when pump stations are in duty with maximum capacity of 78.1 m^3/sec. The discharge variations in the bay are higher than that in the lake, the Magror and the drain, and the discharges are gradually decreased from the bay to the drain. The discharges fluctuate inside the lake by small amplitude comparing with in the bay, but it almost disappears in the Magror and the drain.

Figure 12 illustrates the difference between the peak discharges at the low and high tides. The peak value of offshore discharge is 0.87 m^3/sec and there is no negative discharge at all for the drainage system networks. On the other hand, the peak value of onshore discharge reaches to 131.5 m^3/sec and gradually decreases to the outflow from the pump stations.

(3)The simulated results for flooding

Figure 13 demonstrates the simulation for flood routing in the drainage network. In the same figure the bed levels are plotted with the road levels along the drain. The overflow zone of the Edko Drain can be found from this figure. It can be seen that the peak water level significantly increases near the downstream end of the drain and is higher than the road level from km 25.0 to the downstream end of km14.0 by the overflow distance of 11.0 km. According to the visual observations, the water overflowing was found near km 38 and between km 14 and km 20. It can be said that the simulated result shows a fairly good agreement with the actual situation.

6. FLOOD MITIGATION

Generally, the flood can be controlled in two ways: the peak flow rate must be reduced, or the capacity of the stream must be enlarged enough to prevent overtopping its banks. A scenario has been proposed herein to solve the problem by degrading the excess sedimentation.

One of the solutions for the Edko Drain flood prevention is suggested by cutting a local mound from km 14.0 to km 20.8 to the bed level of -2.0 m, as illustrated in **Fig. 14.** It can be seen that the water level is reduced by 0.6 m at the high peak point after cutting the local mound and the overflows occur at two locations between km 15.0 and km 19.0.

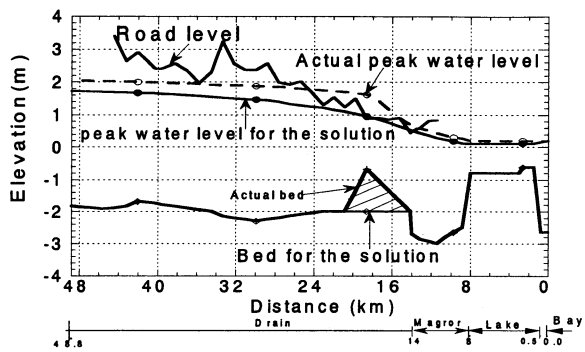

Fig. 14 Solution by cutting the local mound

As a result, the peak water level in the flooded area is dropped by 0.6 m, and the overflow zone is reduced from 11.0 km to only 4.0 km in total. Since the water level during the left four kilometers is still higher than the bank level (the road level), another solution should be taken into consideration. Raising banks of these local parts of the drain may be one of the optimal solutions to prevent the overflow of the drain.

7. CONCLUSIONS

This research is to clarify the main reasons for flooding from the Edko Drain in the Nile Delta of Egypt and it has the originality of dealing with problems of this coastal drainage area.

The Node-Branch model has been applied for flood routing in the drainage system network. From the model calibration, it is concluded that:

1-The maximum net offshore and onshore discharges from and to the sea are 63.8 m^3/sec and 54.1 m^3/sec, respectively. When the pump stations are in duty, there is no reflux from the sea to the upstream of the drain and the maximum discharges at the high and the low tides are 0.87 m^3/sec and 131.5 m^3/sec, respectively.

2-It was found that the lake works as a buffer between the Edko drain and the sea. Tidal flow is restricted in the lake and the reflux by tide does not occur in the drain. It can be concluded that there is no tidal effect on the flood in the Edko Drain.

3-Water levels exceed the road levels in some locations in the down stream reach. It can be found that sediments accumulation causes overflowing its banks.

4-For flood mitigation, reduction in water levels in the drain results by removing the excess sediments from the drain at km 20.8 to km 14.0 to a bed level of -2.0 m and the overflow zone is reduced from 11.0 km to 4.0 km in total length. Raising banks is urgently needed in some parts of the drain to prevent the overflows. Moreover, the cross-sections and slopes of the drain should be modified to prevent sedimentation.

ACKNOWLEDGMENT: The authors are grateful to the personal working at the Coastal Research Institute and Deputy of Drainage, Ministry of Water resources and Irrigation, Arab Republic of Egypt, for their help and allowing us to use field data.

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(Received September 30, 2003)