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A NUMERICAL SIMULATION FORTHE CIRCULATION ON A BEACH OF RESORT IN EL-AIN EL-SUKHNA

محاكاةعددية للسريان على شاطئ منتجع بالعين السخنة

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خلاصة

التلوث هو نتيجة الاضطراب الذى يحدثه التدخل البشرى فى الاتزان الطبيعى. وفي حالة العين السخنة، فإن جزيرة صناعية أعاقت السريان مما تسبب فى تجمع القمامة. ولقد استخدم نموذج رياضى لدراسة كل من تأثير الجزيرة الصناعية على السريان والتأثير الإيجابى للحل المقترح.

ABSTRACT:

Pollution is a result of disturbance produced by human intervention to the natural equilibrium. In the case of El-Ain El-Sukhna, an artificial island obstructed the flow causing trash accumulation. A numerical model was used to investigate both the effect of the artificial island on the circulation and the mitigation effect of the proposed alternative.

1. INTRODUCTION:

Usually nature is in dynamic equilibrium between excreta and degraders that result in a generally healthy environment for most ecosystems. Also, natural phenomena (hurricanes, eruptions...) allow for re-colonization up to higher organisms. Pollution is the disturbance of the natural equilibrium due to accumulation of excreta, garbage, trash, residual water, and so on caused by human intervention. To ensure healthy environment, it is necessary to mitigate; and ultimately prevent the impact of human intervention.

An example of human intervention is a development project in El-Ain El-Sukhna where the developer dumped construction waste into the sea to extend his territories. The dump took the shape of an island connected to the shore by a web. This new configuration disrupted the circulation causing many problems on the onshore side of the island. In this paper, a numerical model is used to investigate the effect of the artificial island and possible mitigation measures.

The investigated domain and difficulties created by human intervention will be discussed in Section Two. A brief description of the governing equations and their discretization will be given in Section Three. Issues on the calibration of the model will be discussed in Section Four. Section Five will be devoted to investigating the effect of the existing geometry as well as proposed geometry of the artificial island on circulation on the beach. Finally, the last section will provide conclusions of the research.

2. EL-AIN EL-SUKHNA RESORT:

The beach of El-Ain El-Sukhna is on the west coast of the Gulf of Suez, 80 km south to Suez (Fig. 1). The Egyptian government, in its efforts to develop the area, sold the beaches to businessmen who are supposed to construct recreational beaches in the form of so-called "tourist villages". The current research concentrates on one of these "tourist villages". The

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investigated "tourist village" has a shoreline approximately 710 m long (Fig. 2). North to the site, the shoreline is running almost in a straight line in north-south direction. 210 m from the north border of the site, a T-shaped artificial extension of the beach was constructed. This extension will be called hereafter "*artificial island*". 240 m further south, the shoreline goes deeper inland (towards east) forming a bay-like water body.

The artificial island created in its onshore side a stagnant water body. Floatig trash accumulate in the stagnant water on the onshore side of the artificial island disturbing the aesthetic scene and the sea users.

If the web connecting the artificial island to the shore is cut and replaced by a light bridge, circulation between north and south parts of the beach will be resumed. The circulation will prevent trash from accumulation and preserve a suitable biological habitat for the existing fauna.

2. NUMERICAL MODEL:

Governing Equations: The governing equations of shallow water flow are (Kashiyama et al, 1995):

$$\frac{\partial U_i}{\partial t}+U_j U_{i,j}+g\zeta_{,i}+\frac{\tau_i^b}{\rho(h+\zeta)}-A_l\left(U_{i,j}+U_{j,i}\right)_{,j}+f_i=0 \tag{1}$$

$$\frac{\partial \zeta}{\partial t}+\left[(h+\zeta)U_j\right]_{,j}=0 \tag{2}$$

where U is the mean horizontal velocity, ζ is the water elevation, h is the mean water depth, g is the gravitational acceleration, A_l is the eddy viscosity, and f is Coriolis force. The bottom friction, τ is determined as (Kashiyama et al, 1995):

$$\tau_i^b=\frac{n^2 g}{h^{1/3}}U_i\left(U_k U_k\right)^{1/2} \tag{3}$$

where n is the Manning Coefficient.

Here, the standard index notation and the summation convention with repeated indices are employed. The governing equations mentioned above are based on the following assumptions:

1. Navier-Stokes equations are integrated over the depth assuming hydrostatic pressure distribution.
2. The Reynolds stresses together with the viscosity term are modeled by a constant eddy-viscosity term.

Finite Element Formulation: The finite element scheme developed by Kashiyama et al (1995, 1997) is applied in the present study. The scheme has the following characteristics:

1. The mesh consists of linear triangular elements.
2. The bottom friction term is linearized.
3. For discretization in time, the three-step explicit time integration scheme is used.
4. The so-called "*selective lumping scheme*" is applied to combine the advantages of both the consistent formulation and the lumped formulation.

Boundary Conditions: For the solid boundaries, the zero-normal-velocity condition was applied. For the open boundaries, the Sommerfeld Radiation Condition stated by Chapman (1985) as:

$$\frac{\partial \phi}{\partial t}+C\frac{\partial \phi}{\partial n}=0 \tag{4}$$

was applied, where φ is the variable to be defined at the open boundary (either U or ζ) and C is the phase speed (or advection velocity). The Someerfeld Open Boundary Condition (OBC) is suitable for problems dominated by advection and/or wave motion because it allows propagating waves, which are generated within the computational domain, to pass through with minimum reflection. Blumberg and Kanta (1985) applied Sommerfeld radiation OBC in finite difference method taking C equal to the local, flat-bottom, shallow-water, surface, gravity wave speed:

$$C = \sqrt{gh} \tag{5}$$

and adding an "*ad-hoc*" friction-like term $(\frac{-\phi}{T_f})$ on the right hand side of Equation 4, where T_f is a friction time scale. Elzeir and Hibino (1999) applied the Sommerfeld radiation OBC as formulated by Blumberg and Kanta (1985) in finite element method. Elzeir et al (2000) refined that application. In the current study, the final formulation of Elzeir et al (2000) was applied.

3. MODEL CALIBRATION:

The dominant force in the area under investigation is wind. Kinsman (1984) explained that wind generates waves due to its gustiness nature. He added that waves are driven by three sorts of wind force:

i. Direct push of the wind.
ii. Frictional drag of the air on the sea surface.
iii. Pressure difference in the air.

The numerical model used in the current study depends on the momentum equations rather than the energy equations. In the momentum equations, the wind force is represented by a constant surface stress allowing for no gustiness. Hence, the model could not reproduce waves induced by wind. Moreover, the domain under investigation is too small to provide enough fetch for the wind to produce waves. To overcome this difficulty, wind-waves generated in deep waters are analyzed to estimate a wave climate at the open boundaries of the numerical domain. The task of the numerical model is to investigate propagation of these waves into the domain.

In deep waters of the Gulf of Suez, where water depth to wavelength ratio is more than 0.5, the maximum wave height is 2 m (Center for Oceanographic Sciences, personal communication). Maximum wind speed on the gulf is 12.70 m/sec. This wind speed can produce a wind-wave of 6.5 seconds period and 65.00 m length (Kinsman, 1984). Waves propagate in the wind direction, which is north to northeast. As waves approach the beach, they experience shoaling causing refraction; and therefore waves attack the shore perpendicular to it. In the calculation domain, where maximum water depth is 4.00 m, wave direction is taken perpendicular to the shoreline.

4. EFFECT OF THE ARTIFICIAL ISLAND ON CIRCULATION:

Numerical Domain: An area of the beach, 300 m wide and 700 m long with bathymetery as shown in Figure 3 is used for simulation. The following parameters are used in the simulation: $A_l = 0.0$ m^2/s, e: lumping parameter = 0.9 for both continuity and momentum equations, n = 0.002, and $T_f = 5.0$ at north and south open boundaries and = 5.2 at the east open boundary. Flow in the domain was investigated under two configurations. The first configuration is the existing one, where the domain was discretized into 8373 nodes and 16266 elements. The second configuration is the proposed one with the artificial island detached from the shore. In this case, the domain was discretized into 8385 nodes and 16295 elements.

Patterns of Circulation: The existing configuration of the beach causes severe obstruction to the flow. From figure 4, it is clear that velocity is strongly reduced at the point of trash accumulation. As the flow slows down, the trash settles disturbing the aesthetic scene. The (hydrodynamically) ideal solution is to demolish the artificial island allowing for completely free circulation. This solution is economically unfeasible. Therefore, alternatives that mitigate the impact of the artificial island were to be proposed. The proposed solution was to detach the artificial island from the shore by cutting a 25-m wide channel between the island and the shore. The gap introduced by cutting the channel is bridged by a lightweight (steel or wooden) bridge, which poses almost no obstruction to the flow. Circulation after cutting the channel is shown in Figure 5. It is clear that although the island reflects part of the wave energy, wave diffraction helps producing current on the onshore side of the island. The current crosses through the channel back and forth between the north and south parts of the beach. This circulation prevents trash from settling in the domain under investigation. From Figure 6, it is clear that the strong damping caused by the earthen passage is drastically reduced when the channel is cut.

5. CONCLUSIONS:

A finite element model using Navier-Stokes primitive-variable equations was used to investigate the effect of an artificial island on circulation on the beach of resort in El-Ain El-Sukhna. During model calibration the following findings were concluded. First, the current model, with the surface stress in the momentum equation the only term representing wind effect, is not capable of predicting wind-induced waves. Moreover, the domain under investigation is too small to provide enough fetch for wind-waves generation. Hence, the model was used to investigate propagation of waves imposed at the open boundaries into the domain.

Although demolishing the artificial island is the best alternative to avoid trash accumulation, this alternative is economically unfeasible. The next alternative is to cut a 25-m wide channel between the island and the shore. The numerical model revealed that the channel allowed for free circulation between north and south parts of the domain while the existing configuration produced a stagnant water body on the onshore side of the island where trash settles.

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NOTATION

The following symbols are used in this paper:

A_t:	eddy viscosity
C:	phase speed (advection velocity)
e.	lumping parameter
f:	Coriolis force
g:	gravitational acceleration
h:	mean water depth
n:	Manning coefficient
OB:	Open Boundary
OBC:	Open Boundary Condition
T_f.	friction time scale
U:	mean horizontal velocity
φ:	variable to be defined at the open boundary
τ.	bottom friction
ζ:	water level variation around mean water level.

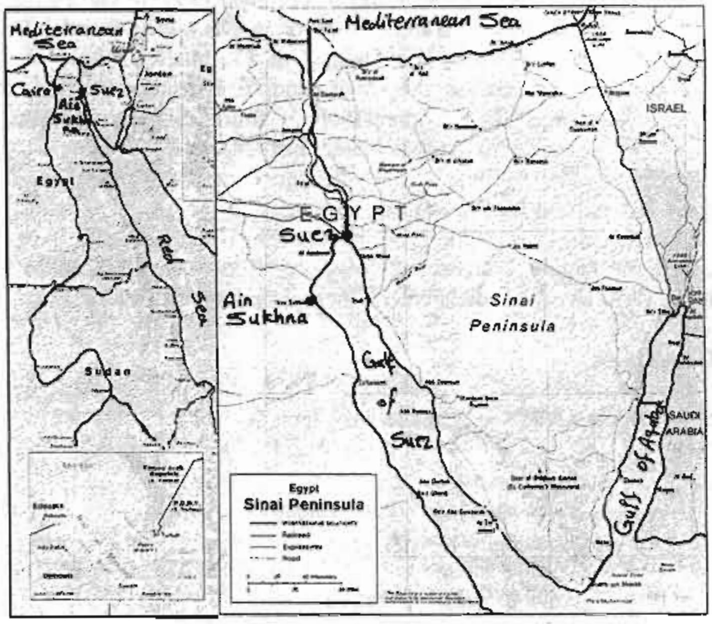

Figure 1. Location of El-Ain El-Sukhna on the Gulf of Suez (an arm of the Red Sea).

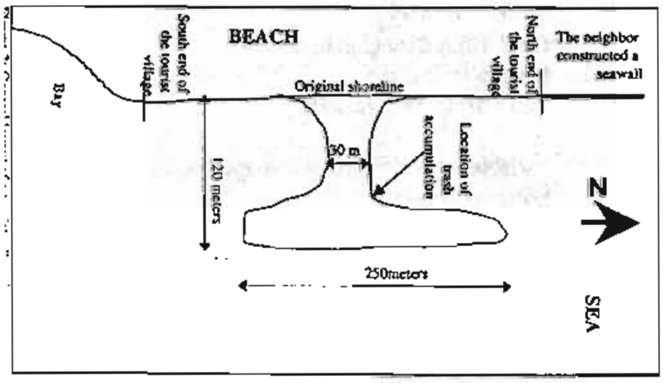

Figure 2. General layout of a tourist village at El-Ain El-Sukhna.

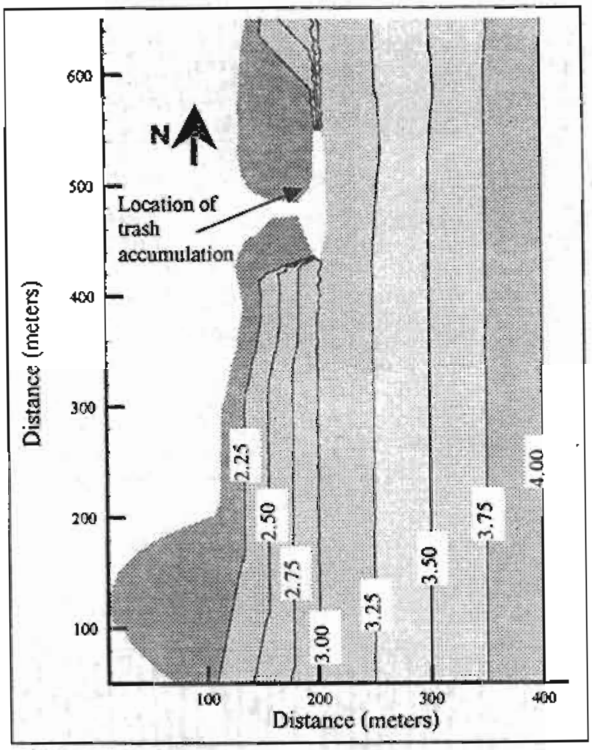

Figure 3: Bathymetry of the area under investigation.

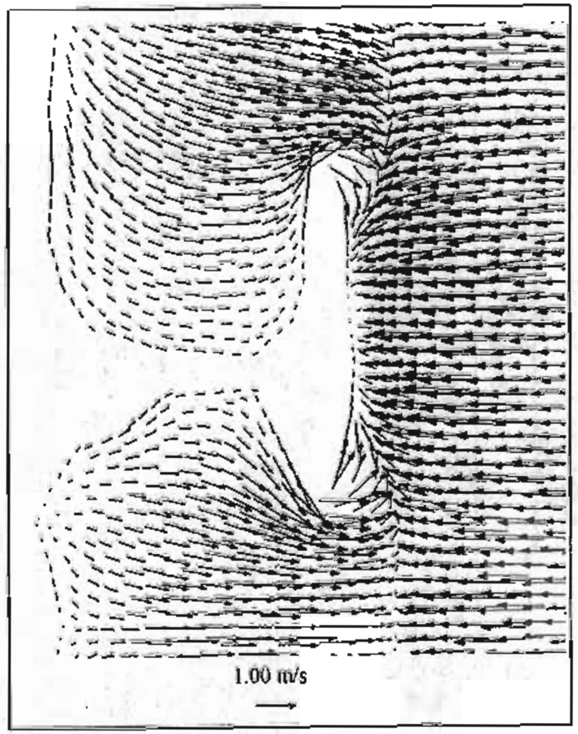

Figure 4: Circulation behind the artificial island under the current configuration.

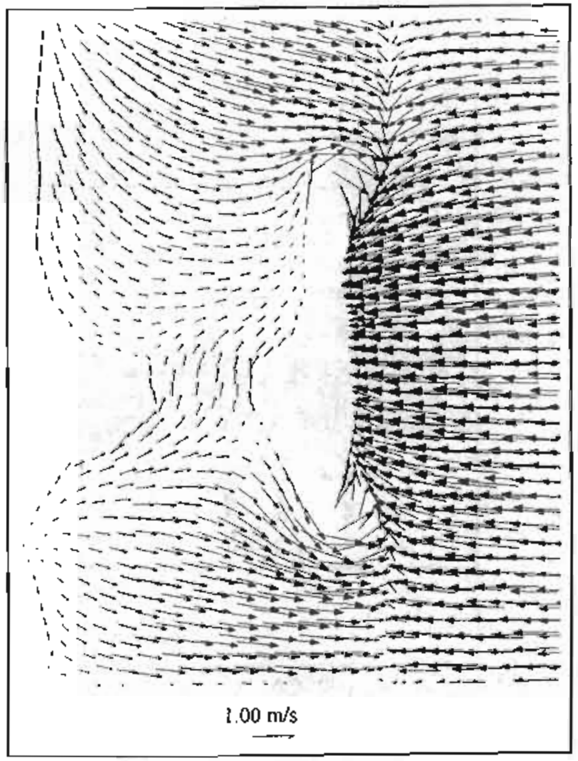

Figure 5: Circulation behind the artificial island under the proposed configuration.

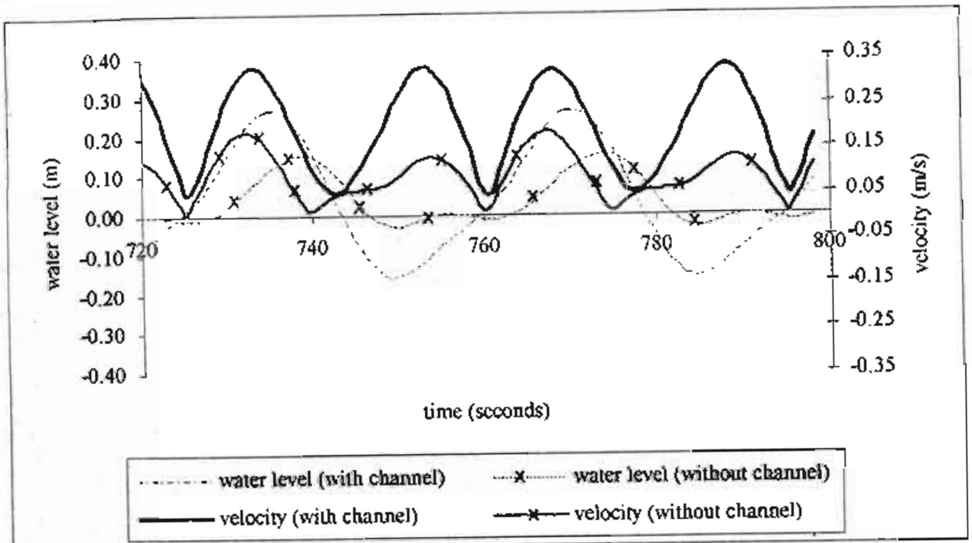

Figure 6: Water level and current speed behind the artificial island in the cases of present (without channel) and proposed (with channel) configurations.