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Some Expected Environmental Impacts according to New Ports Construction and Development

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Abstract The expected environmental impacts to occur due to new ports construction and development works are many and considered essential. This practical collective overview deals with some of them, which are related to dredging (as noise, visual hinder, smell, turbidity increasing, nutrient release and BOD change). The study also concentrated on some important measures to determine the suitable ones of the expected environmental impacts in the port vicinity. These measures are the accurate evaluation of the littoral drift and so the expected accumulated sediments in the port vicinity related to littoral drift movement direction. Besides, attention was given to the importance of the balance between cut and fill via a practical case study. The study gave a group of practical conclusion for the expected environmental impacts reduction/alleviation in the new constructed/developed port area.

Keywords: *port development, port construction, environmental impacts in ports, port morphological changes, balance between cut and fill in ports dredging, SWAN mathematical model*

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1. Introduction

Many previous researches and references made discussions about this research topic. These discussions came as rules or technical explanation about how to deal with expected environmental impacts due to new ports construction and development works. These studies discussed ports construction in both land and water front parts. One of the most important conclusions is that there is a remarkable expected impact on the environment. For the land activities, rock blasting, rock and sand damping, cause big effects due to the produced dust. Besides, other impacts as noise and visual hinder are also existed. For the water activities, sand dumping for construction purposes causes big effects due to turbidity (generated blooms). For the noise effect, noise due to dredging activities is particularly a nuisance when it occurs near residential areas and at night. The effect lies mainly in the psychological field and it seems that people are more affected than animals. However, residential areas are quite far from the direct vicinity of the site. The increased human activity, as a direct or indirect consequence of the dredging, can certainly disturb the wildlife life. The effect is strongly depending on the used excavation method and type of soil. For the fine soil, effect can be considered a bit remarkable under certain conditions. In general, the effect on the environment is not considered severe anymore BS [1] and Geense [3].

Many features and effects should be studied carefully to mitigate or at least alleviate their harm as possible. For the visual hinder effect, the appearance of the dredging equipment may create a visual nuisance. Such nuisance is of a psychological nature and refers mainly to human life. The digging process can disturb recreational areas or a landscape, Geense [3]. For the smell Effect, bad smells play no significant role during the sand and rock digging process. This effect appears clearly with the existence of contaminated soils dredging (especially soils with organic origins), (DMC [2] and Geense [4]). For the turbidity increasing effect, one of the most criticized environmental consequences of digging is the increased turbidity. In surface water, it is caused by dredging operations due to the fact that particles are stirred up and go into suspension. The fine particles may be transported over long distance as a result of their low fall velocity in comparison to the prevailing current velocities. The effect of an increased amount of suspended material on the environment can be in reduction of light penetration, coverage of certain areas with a layer of spoiled material, a negative influence on the food composition of so-called filter feeding animals and possible damage to the respiratory organs of fish and other animal species, Geense [3]. For the nutrients release effect, natural water sediments are sinks for aquatic nutrients and as a result, contain large concentrations of nitrogen and phosphorus compounds. In natural conditions, the primary factor controlling release of aquatic nutrients is the mixing of the sediments with the overlying water. For most sediment, the amount of mixing causes significant release of the aquatic nutrient content of sediments. Dredging operations, provide the opportunity for a potentially significant increase in the transfer rates for aquatic nutrients, which could cause localized algae at the dredging sites. On the other hand, turbidity increase could limit the growth of algae by reducing light penetration. Nutrient release as a result of dredging does not appear to be a major problem in the offshore zone and marine areas with strong currents and remarkable hydrodynamic conditions effects because of dispersal by currents and dilution. Thus, there is no expectation to have a serious problem in nutrients release, Geense [3]. For the biological oxygen demand (BOD) change effect, in the under layer of deep borrow pits, which form a sink for organic material, anaerobic conditions often develop, and are maintained by a situation of temperature stratification BS [1] and Geense [4].

Besides, increasing of turbidity effects play a key role when the natural clarity of the water is good and when the covered areas have a rich flora and fauna. With respect to fauna, only those species that can survive with the natural sand transport are present. Normally, the major part of dredging operations takes place under water. For the sand dredging, Turbidity is not expected to affect the aquatic life. For the rock dredging, no problems are generally expected as well. Repopulation of the dredged area by benthic animals will depend on the magnitude, the disturbance, and water quality for borrow sites materials. The borrow site will be colonized by migration of organisms from adjacent areas. The stability and bottom sediments at the site after dredging are major factors in determining species re-colonization. Conceivably, mobile animals will be least affected by borrowing operations because of their ability to escape from any disturbed area.

One of the most important points to be checked is the impact of the project existence on the morphological system in the area. The corresponding problems as erosion/accretion are also required to be investigated and evaluated. At the beginning, a preliminary evaluation can be done via applying the suitable formulae for the studied area. This comes via considering some assumptions and approximations. The main points, which should be considered within that evaluation, are as follows (U.S. Army Corps of Engineers [14]). The first point is that what is the approximate expected rate of sediments to pass through the project area before the port construction? The second is that will the port existence cause severe problems in the port vicinity? This point should be discussed for all the proposed development phases of the selected alternative considering that they will be constructed in the scheduled time table. The third is that is there a possibility for sedimentation problems to occur within the access channel and the basin area? This point should be discussed in case of constructing the port in the scheduled time phases or stopping in a certain development phase, (Ligteringen [12] and U.S. Army Corps of Engineers [14]). The fourth point is that answering these questions needs a detailed morphological study to give the accurate answers. An important step is to evaluate the total longshre sediment transport (littoral drift) in the port area vicinity. This normally makes an important part of the total environmental impact assessment. Many formulae are internationally used for the required purpose of littoral drift evaluations. Good examples for the most common ones are CERC and Kamphuis formulae, U.S. Army Corps of Engineers [14].

In the following discussion, these two equations and their applicability boundaries will be disused in details, (U.S. Army Corps of Engineers [14]). The main purpose of this study is to be a direct effective step forward in both port development work and research for the improvement of previous research and engineering studies in that field.

2. Methodology

2.1. CERC Formula

It is the most widely used formula in coastal engineering practice all over the world. It was originally developed by the US-Corps of Engineers in 1984. It relates the immersed weight (I) of the longshore sediment transport rates to wave energy flux. It works based on the proportionality principle of both the volume of transported fine sediments ($Q_{t,vol}$) and the beach longshore wave power per unit length, as given in equations (1) through (6), (Khalifa *et al* [9]; Khalifa *et al* [10]; Khalifa *et al* [11] and U.S. Army Corps of Engineers [14]).

$$I = K_* E_* C_{g,br*} \mathrm{Sin}(\theta_{br})_* \mathrm{Cos}(\theta_{br}) \qquad (1)$$

$$E = 1/8_* \rho_{w*} g_* (H_{rms,br})^2 \qquad (2)$$

where,

I = longshore transport rate (immersed weight)

K = coefficient for the CERC (=0.39), the value that is derived from the carried out original field study by Komar and Inman (1970) by using tracers

E = wave energy at breaker line, $H_{rms,br}$ = root mean square wave height at breaker line.

$C_{g,br}$ = n_{br}*c_{br} = wave group celerity at breaker line (m/s)

θ_{br} = wave angle at breaker line (between wave crest line and coastline; or between wave propagation direction and shore normal direction (degree)

C_{br} = phase velocity of the waves at the breaker line (= $g*h_{br})^{0.5}$

h_{br} = water depth at the breaker line (m)

n_{br} = coefficient at breaker line

H_s = the significant wave height (equals 1.414*H_{rms})

ρ_w = 1030 kg/m^3 (salt water density)

$$Q_{t,vol} = 0.023*(H_{s,br})^2 * n_{br} * c_{br} * \mathrm{Sin}(2\theta_{br}) \qquad (3)$$

and

$$Q_{t,vol} = I / ((1-p)(\rho_s - \rho_w)*g) \qquad (4)$$

where,

$Q_{t,vol}$ = longshore sediment transport by volume, The sediment transport by dry mass, (m^3/s, including pores);

P = the porosity factor (= 0.40)

$H_{s,br}$ = significant wave height at the breaker line (m)

ρ_s = sediment density (kg/m^3)

Applying $n_{br} \approx 1$, $c_{br} \approx (g\ h_{br})^{0.5}$, and ($\gamma_{br} = H_{br}/h_{br}$), it follows as given in equations (5) and (6):

$$Q_{t,vol} = 0.023 * g^{0.5} * (\gamma_{br})^{-0.5} * (H_{s,br})^{2.5} * \mathrm{Sin}(2\theta_{br}) \qquad (5)$$

$$Q_{t,mass} = (1-p)*\rho_s * Q_{t,vol} * 0.023 * (1-p)*\rho_s * g^{0.5} * (\gamma_{br})^{-0.5} * (H_{s,br})^{2.5} * \mathrm{Sin}(2\theta_{br}) \qquad (6)$$

where:

$Q_{t,mass}$ = longshore sand transport (kg/s; dry mass)
$H_{s,br}$ = significant wave height at breaker line (m)

2.2. KAMPHUIS Formula

Based on both the dimensional analysis and the carried out calibration by using both the laboratory work and field data (with median grain sizes in the range of d_{50} = 200 to 600 µm and surf zone slopes in range of tan (β) = 0.015 to 0.15), the longshore transport as immersed mass (kg/s) is given as presented in equation (7), (Khalifa *et al* [9]; Khalifa *et al* [10]; Khalifa *et al* [11] and U.S. Army Corps of Engineers [14]).

$$Q_{t,im} = 2.33 * \left(T_p\right)^{1.5} * m_b^{0.75} * \left(d_{50}\right)^{-0.25} * \left(Hs_{,br}\right)^2 * \left[\mathrm{Sin}\left(2\theta_{br}\right)\right]^{0.6} \quad (7)$$

where,

2.33 = coefficient, to be used with the units for other parameters in the formula as given under.

$Q_{t,im}$ = longshore sediment transport (immersed mass) (kg/s); the dry mass is related to the immersed mass by [$Q_{t,mass}$ = s/(s-w)$*$$Q_t$], immersed mass (kg/s) and the conversion factor is about 1.64

T_p = wave peak period (s)

m_b = the beach slope near the breaking, i.e., the slope over one or two wavelengths seaward of the breaker line

d_{50} = median particle size in surf zone (m)

tan (β) = beach slope defined as the ratio of the water depth at the breaker line and the distance from the still water beach line to the breaker one

tan (β) = beach slope defined as the ratio of the water depth at the breaker line and the distance from the still water beach line to the breaker one

Kamphuis, 1991 formula includes the wave period and beach slope. Each of them has an influence on the wave breaking, and the grain size. The last one (grain size) is an important factor for the mobilization and transport rates of sediments moving. In year 2002, Kamphuis gave some modifications on his formula for the purpose of making it more applicable efficiently on both field and laboratory data. The details and applicability of this modified formula is out of the scope covered in this study. For the longshore sediment transport evaluation, the wave nearshore transformation should be carried out. Thus, the significant wave height in the nearshoe area can be determined for the purpose of littoral drift evaluation.

2.3. Waves Nearshore Transformation by Swan Model

The primary purpose for the transformation of waves is using the transformed significant wave heights for the purpose of analysis. SWAN model gives a realistic estimates of waves in the coastal areas with a two dimensional wave action density spectrum, even when nonlinear phenomena dominate (*e.g.*, in the surf zone). The reason for using the spectrum in such highly nonlinear conditions is that even under such conditions, it seems possible to predict with reasonable accuracy the spectral distribution of the second order moment of waves. This spectrum is the action density one $N(\sigma,\theta)$ rather than energy density spectrum $E(\sigma,\theta)$. The evolution of the wave spectrum is described by the spectral action balance equation for Cartesian coordinates (Ris *et al.* [13]), as given in equation (8).

$$\frac{\partial}{\partial t}N + \frac{\partial}{\partial X}C_X N + \frac{\partial}{\partial Y}C_Y N + \frac{\partial}{\partial \sigma}C_\sigma N + \frac{\partial}{\partial \theta}C_\theta N = \frac{S}{\sigma} \quad (8)$$

The first term on the left-hand side represents the local rate of change action density with time. The second and third terms represent the propagation of action in geographical space (with propagation velocities of C_X and C_Y in both X and Y spaces, respectively). The fourth term represents shifting of the relative frequency due to variations in depth and currents (with a propagation velocity of C in space). The fifth term represents depth-induced and current-induced refraction (with propagation velocity *"C"* in space). The expressions for these propagation speeds are taken from linear wave theory (*e.g.*, Ris *et al.*, 1998 and others). The term [$S(\sigma,\theta)$] on the right-hand side of the action balance equation is the source term with respect to energy density, representing the effects of generation, dissipation and nonlinear wave–wave interactions. The action balance equation gives a statistical description of the time evolution of interacting weakly nonlinear sea waves. The time evolution depends on the statistical description in which the probability of finding a particular sea state is considered the probability distribution. The external conditions such as tide and wind should be specified. In this equation, the density function specifies the distribution of energy (Ris *et al. [13]*).

The action balance equation describes the variation of wave spectrum on the slow space and time scale, which is conveniently expressed in terms of wave action density (wave spectrum–intrinsic frequency). This equation also enables us to use the general laws of physics to compute the sea state at a later time. Therefore, the action balance equation is as applicable in this study. Based on the assumption that the free surface boundary conditions are liberalized and the wave amplitude is small in comparison with the wavelength, studies proved that it is not always possible to obtain an analytical solution if the geometry of the bottom boundary is complicated. Based on this theory, the wavelength in deep water is defined as follows (Goda [5], Horikawa [6], IAPH [7] and Khalifa [8]), as presented in equation (9).

$$L_o = g * T^2 / 2n = 1.56 * T^2 \quad (9)$$

where,

L_o = deep water wavelength (m)

g = acceleration of gravity = 9.81 (m/s^2)

T = wave period (s)

According to the swell amplitude wave theory, wave celerity (C) is a function of the wavelength and water depth, as given in Equation (10).

$$C = \sqrt{\frac{g}{K}\tanh kh} \quad (10)$$

where,

C = wave celerity (m/s), (C_o in case of deep water)

K = (2/L), the wave number, (L = wave length, (m))

The wave celerity group can be directly determined, as in Equation (11).

$$C_g = 0.5C_o \quad (11)$$

For waves that are incident normal to the shore line with straight and parallel contours, changes in wave profile are caused by water depth changing slowly. This is caused by shoaling effect and can be treated as a two-dimensional problem; theoretically. The definition of the shoaling coefficient (K_s) is as given in Equation (12), (Horikawa [6]).

$$K_s = \frac{H}{H_o} = \sqrt{\frac{1}{2n} * \frac{C_o}{C}} = \sqrt{\frac{1}{2n} * \frac{1}{Tanh(kh)}} \qquad (12)$$

Where:

K_s = the shoaling coefficient

H = shallow water wave height

H_o = deep water wave height

n = Parameter, (in order of 0.50).

For the handled case study domain, the calculations were carried out by using the admiralty bathymetry charts in the studied bay area in the Indian ocean. The dimensions of the study area were 3.00 km in length toward offshore and 2.50 km in width along the bay area. Two cases were seriously studied. The first case was for swell waves existence effect and the second one for wind sea waves effect. The design time conditions of once per one year occurrence was considered. The different considered boundary conditions are as follows:

H_s (1/1 year)$_{Swell}$ = (3.40 m, T_p = 13 s and propagation direction equals 180° from north).

H_s (1/1 year)$_{Wind\ Sea}$ = (4.50 m, T_p = 7.60 s and propagation direction equals 245° from north)

where,

H_s (1/1 year)$_{Swell}$ = Maximum significant wave height to annually occur for swell waves (m)

H_s (1/1 year)$_{Wind\ Sea}$ = Maximum significant wave height to annually occur for wind sea waves, (m)

T_p = Wave mean period, (s)

Quite averaged grid spacing was considered (100 m spacing apart in both horizontal and vertical directions) to cover the whole domain. In addition, simplifications, approximations, and adjustments for water depths were carried out for the studied domain, especially for the outer boundaries, nearshore areas, *etc.* The purpose of these adjustments is to ensure the carried out accuracy and stability of the numerical calculations.

3. Result

3.1. Wave Nearshore Transportation

In this case study, the used data for constant wind fields (speed and directions) for different seasons were obtained from earlier literature, which leads to another source of approximation. That is why the values and distributions reported in this study should be used for estimates only and not for precise maritime and engineering purposes. Figure 1 presents wave near shore transformation for both swell and wind sea waves in the study bay area for the case of 1/1 year wave conditions. In more details, Figure 1 (a) presents wave near shore transformation for swell waves 1/1 year design condition for the condition of propagation direction from southland and (b) presents wave near shore transformation for wind sea waves 1/1 year design condition and the propagation direction from 245° from north, respectively.

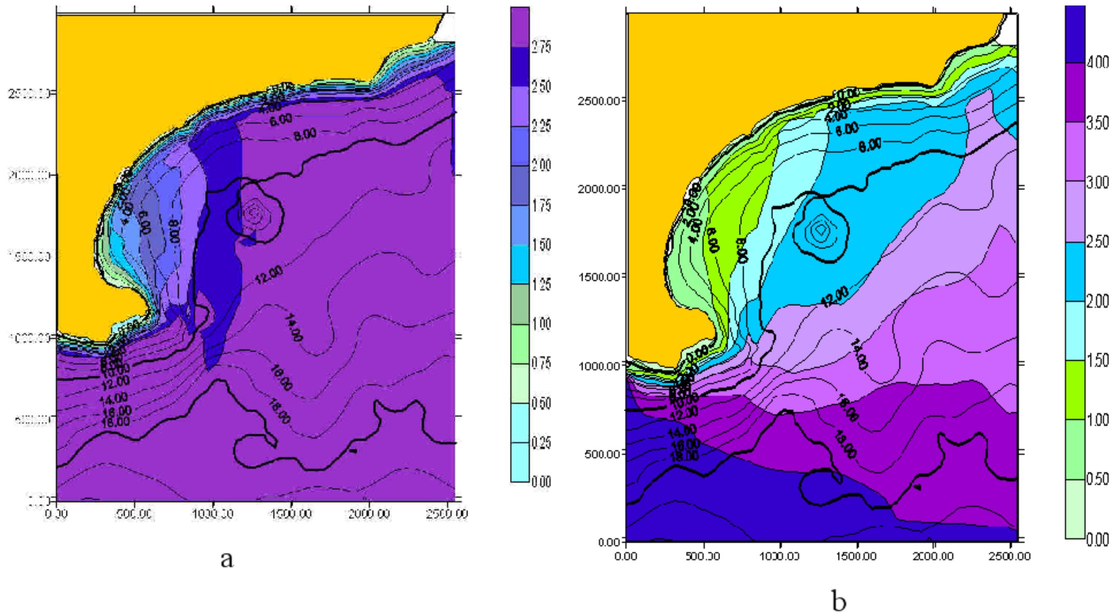

Figure 1. (a) Waves nearshore transpormation for swell (Hs (1/1 year)$_{Swell}$ = 3.40 m, Tp = 13 Sec. and propagation direction from 180° to north) and (b) wind sea waves (Hs (1/1 year)$_{Wind\ Sea}$ = 4.50 m, Tp = 7.60 Sec. and propagation direction from 245° to north), respectively

3.2. Preliminary Evaluation of the Littoral Drift in the Coastal Area

To explain and study the morphological impacts in the port project vicinity, a case study was handled for the presented port layout with an open basin system constructed in a bay, as presented in Figure 14. In this virtual example, the tide in the area is considered insignificant as the tidal range is in order of 0.40 m approximately. For the first development phase, three berths will be extended from south. For the constructed berths distribution along phases, they are distributed on phase (I): Berths Number (1, 2 and 3), phase (II): Berths Number (4 and 5), phase (III): Berths Number (6) and

Phase (IV): Berths Number (7 through 11), as presented in Figure 2.

The preliminary evaluation for the total amount of the sediments accumulation was roughly estimated. For that estimation, CERC formula [14] was used. The sediment accumulation in front of the port sided southern boundary was also evaluated. The estimation of the accumulated quantities and the time required for the sediments to reach the tip depend on the length of the sea wall, a dedicated routine of sediments accretion in face of the sea wall. The cross shore sediment transport is not expected to play a significant role in the transport mechanism in this area. For sediment accumulation, evaluation in face of the southern boundary sea wall was carried out. Table 1 presents the water depth variation and sea wall lengths facing sediments accretion for the four suggested different development phases (I through IV) CERC formula [14].

Table 1. Water depths and sea wall length which face sediments accretion

Phase No.	No. of Constructed Berths	Water Depth at Sea wall southern Tip (m)	Sea wall Length Facing Accretion Process (m)
(I)	1, 2 & 3	20.00	2585
(II)	5 & 4	20.00	2585
(III)	6	21.50	3000
(IV)	7 through 11	22.50	3860

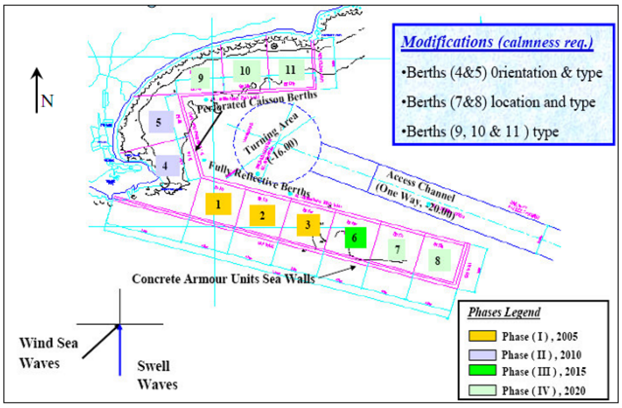

Figure 2. Development phases for the open basin and port in a bay facing accretion accumulated on its southern boundary. Phase (I): Berths Number (1, 2 and 3), Phase (II): Berths Number (4 and 5), Phase (III): Berths Number (6) and Phase (IV): Berths Number (7 through 11), respectively

3.3. Evaluation of the Accumulated Sediments on the Port Southern Boundary

For investigating the possibility of the sedimentation problem at the port entrance and how long it will take to start, the variation of the sediments passing rate at the tip of the sea wall ($S_{tip,}$ m^3/year) was evaluated for the different expected periods. For the expected percentage of time that the wave occurs, it is assumed that for the maximum significant wave height of 1.60 m to occur in a percentage of at least 20% of time. $(H_{so})_{mean}$ equals 1.60 m (T_p equals 5.3s), (Θ_{br} equals 50°), (γ equals 0.60). The occurrence percentage of 30% is also checked. (d_{50}) equals 200 micron, (ρ_s) equals 2650 (kg/m^3), (ρ_w) equals 1025 (kg/m^3) and the beach slope equals (1:100) approximately. The porosity of sediments equals 40%. Sea wall length facing accretion process for the first development phase equals 2585 m and increase in the 3rd. and 4th development phases to be 3000 m and 3860 m, respectively.

The annual sediment transport in the port area was evaluated by using both CERC and Kamphuis formulae, U.S. Army Corps of Engineers [14]. The evaluated average annual sediment transport equals 430261 m^3/ year. The evaluated accumulated sediment at the sea wall face ($S_{tip)}$ equals 124425 m^3/year. This represents approximately a percentage of 30% of the total transported sediments via CERC and Kamphuis formulae calculations, U.S. Army Corps of Engineers [14].

3.4. Accurate Evaluation for the Cut Volumes to be Balanced with Fill

Balance between cut and fill is considered very important to reduce/alleviate some of the expected environmental impacts. When the quality of sediments is suitable for reclamation works (soil free of heavy salts and materials with organic origins), it can be used in reclamation works instead of sand borrow. To make this balance, two important quantities should be known, as follows (IAPH [7], Khalifa [8] and Ligteringen [12]). Soil volume required for dredging works and soil dredging for the port basin, for the turning circle and the approach channel. Soil volume required for reclamation works: Initial reclamation (pancake), sea wall construction, light protection and quay walls construction. By knowing these two volumes, the required balance can be achieved.

3.5. Dredged Soil Volume Evaluation

For the dredging soil volumes evaluation inside the port basin and access channel area, the following procedure to be followed by using a suitable surveying software. The inner borders for the basin within the berthing lines, the turning and the access channel should be all considered, (BS-6349 [1] and IAPH [7] and Khalifa [8]). The bottom levels variation and boundaries in the selected port area are as shown in Figure 3. Normally, a complete hydrographic survey is carried out for the port project area. In case of lack of survey data, the public domain admiralty charts and digital contour files can be used with a careful adjusting. In the selected port site, the shallow soil levels start from level (-13.00 m). Towards south, the levels become deeper than ones of north till the recommended southern location for berths of the first phase. In this area, the soil levels are considered deep as they vary among (-17.00 and -19.00). The design dredging levels are (-16.00) for both the basin and the turning area and (-20.00) for the access channel respectively.

3.6. Earth Reclamation Volume Evaluation

Figure 4 (a), (b) and (c), respectively present soil levels within the port basin area for both conditions before and after dredging cases to the previously mentioned design levels. The dredged soil will be used in constructing both the sea wall core and the reclamation activities behind berths and protection constructions, as presented in Figure

5 (a) and (b), respectively. From calculations, the dredged volume from the port basin and the access channel equals 15*10^6 m^3, approximately. The surface areas which require reclamation of the different development phases are evaluated, (BS-6349 [1]; IAPH [7], Khalifa [8] and Ligteringen [12]).

Average depths for the filling (reclaimed) areas behind berths are evaluated. For being close to depths accuracy, the evaluation will be done for each berth in the different proposed development phases separately. Table 2 presents a rough estimate for the required reclamation volumes in m^3 for the different development phases. These volumes equal 10325165 m^3, 1295801 m^3, 3681563 m^3 and 12060499 m^3 with percentages of 38%, 5%, 13% and 44% for the development phases (I through IV) respectively. The total soil reclamation volume in m^3 for the four development phases equals 28.25*10^{6}m^3.

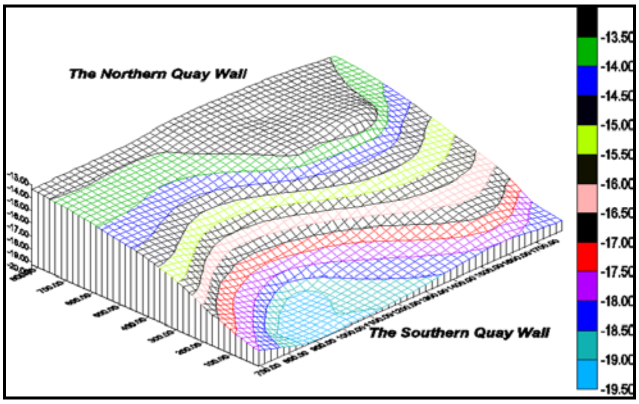

Figure 3. Bottom levels variation and boundaries in the selected port area

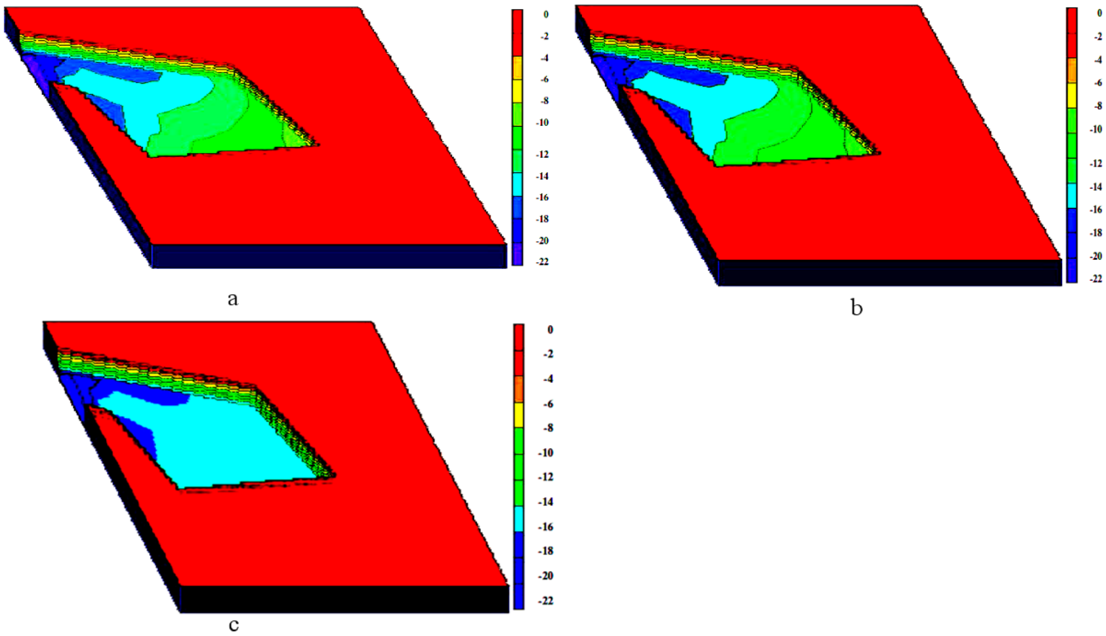

Figure 4. (a), (b) and (c) are soil levels within the port basin area for both conditions Before and after dredging to the design levels

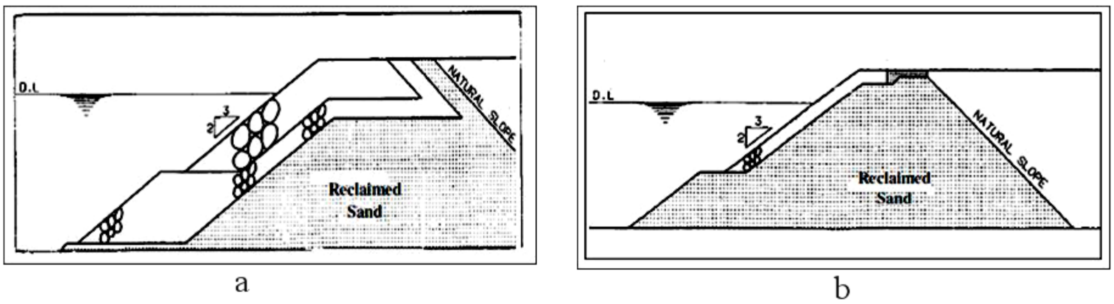

Figure 5. (a) and (b) are typical sea wall and light protection sections for dredged materials usage

Table 2. Required reclamation works for the different development phases

Dev. Phase	Berth No.	Surface Area (m^2)	AverageSoil Depth (m)	**Filling** Volume (m^3)	Dev. Phase	Berth No.	Surface Area (m^2)	Average Depth (m)	**Filling** Volume (m^3)
(I)	1	372,704	10	3,727,040	(IV)	7	191,250	21	4,016,250
	2	191,250	15	2,868,750		8	192,277	6	1,153,662
	3	191,250	19,5	3,729,375		9	189,125	7,5	1,418,438
(II)	4	122,275	7,25	8,864,938		10	202,806	6	1,216,836
	5	199,354	6,5	1,295,801		11	191,250	22,25	4,255,313
(III)	6	191,250	19,25	3,681,563	Total (m^3)		Total Reclamation volume = 28.25*10^6 (m^3)		

From the preliminary estimation, the dredged soil volumes represent 55% approximately of the required reclamation volumes behind berths. This percentage is considered moderate efficiency for the required balance between cut and fill.

4. Conclusions

The study came up with a group of practical conclusions. A summary for these conclusions are as follows:

- Expected impacts in the dredging phase of a new port construction (Noise, visual hinder, smell, turbidity increasing, and nutrient release with BOD changes) are considered variable in effect based on the dredged soil materials.
- Minimum dredging works are required in case of correct usage of the natural deep water conditions. Reducing the dredging materials quantities will cause a significant positive impact on the marine environment. The impact severity depends also on the dredged soil type.
- Long time is normally required for the sediments to reach the port entrance passing whole the breakwater or sea wall length, and so start to cause a sediment accumulation problem there. This time should be evaluated accurately for all the proposed development phases (I through IV) and their associated variable lengths in the southern boundary of the port. This boundary faces the sediments movement progress under the hydrodynamic conditions effects.
- From the carried out transport rates evaluation for the treated case study, the expected time for the starting of sedimentation problems close to the port entry require tens of years for the sediments to reach the wall tip and enter the port basin. Regular maintenance dredging will be required within the southern boundary of the port in the first phase of the port construction.
- Making the balance between cut (dredging works) and fill reclamation works in ports construction is vital to reduce/alleviate the impact on the site environment. Cut volumes (the volumes of dredged materials) to be used for fill purposes behind berths.

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