EFFECT OF WATER SURFACE FLUCTUATIONS ON WATER INTAKE PERFORMANCE

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ABSTRACT

The paper basically discusses the effect of water surface fluctuations due to vessel and wind motion on the performance of irrigation pumps along the River Nile. Therefore, the paper aims to emphasize the necessity of considering the water surface depression due to vessel and wind motion when designing the water plant intakes along the River Nile. The paper introduces a method for calculating the hydrostatic head (Minimum Submergence Depth "MSD") above the inlet of the intake pipe in case the free water surface is still. Also, methods of estimating wave heights and depressions due to wind and vessel motion are introduced. Two case studies at two locations (*Sebaeya*, in River Nile Reach "1" – *Khezendaria*, in Reach "3") suggested for water intake installations along the River Nile were selected for application to evaluate how significant the wave effect would be during minimum water levels. Field and technical data were collected at the two locations to estimate the appropriate hydrostatic heads. The results showed that the MSD could increase to be twofold or more when considering the wave effect. Finally, the paper concluded that the wave effect has to be considered upon the design of the submergence depth of an intake pipe, particularly in heavy touristic, navigational and stormy reaches of the River Nile to ensure complete avoidance of vortex occurrence.

Keywords: Water Fluctuation, Surface Water Waves, Water Intakes, Wind and Vessel Motion

1. INTRODUCTION

In practice, there are many different purposes such as irrigation, drinking, cleaning, and cooling that require water to be extracted through suction pipes from dynamic fresh water sources (DWS), such as rivers or streams. The inlets of these pipes are usually submerged under water surface to ensure continuous water supply. If such submergence is not deep enough or the water surface is fluctuating causing the pipe submergence depth to become smaller, problems of vortexing and cavitations are always expected. When the submergence is not sufficient, air enters the intake pipe by means of an air entraining free vortex. Vortexes and water surface fluctuations may produce adverse effects on the suction pump. The entrained air causes flow reductions, vibrations, structural damage and loss of efficiency in turbines or pumps and in water conveying structures.

Trials of having a rather still water surface to avoid vortexing have been made by immersing the pipe inlet in a water sump where the water surface theoretically undergoes no fluctuations.

The sump is a rectangular or cylindrical reinforced concrete caisson that may be constructed on the floodplain (offshore) or near shore to store water through side openings at different levels. If it is constructed on the floodplain, it is usually supplied with water through gravity pipes (intake lines) immersed in the DWS and connected with the openings. If it is near shore, water enters it through its side openings directly.

Overtime, as the water enters the pipe or the sump, the water suspended sediment grains accumulate inside the pipe, clog and block the graded screen (multiple screens with different filter opening sizes) fixed on the inlet causing the water hardly to enter the sump. Consequently, the sump water storage becomes insufficient frequently. The water plant may stop working because of water shortage. The pipe interior and screen needs to be cleaned continually, a matter which means high cost of operation and maintenance.

Therefore, in some other cases, the intake pipe inlet is preferred to be immersed directly under the free surface of the DWS. Of such cases is when water is needed in land irrigation. In such a case, the pump used is usually a movable one to save extension lines and head losses. It is not at all cost-effective to construct a sump. Accordingly, the pipe is preferred to be directly immersed in the DWS.

When the intake pipe inlet is to be immersed under the free water surface of the DWS, it should be submerged deeply enough to avoid vortexing. How deep?!! This depends on the magnitude of the anticipated fluctuation depth undergone by the free water surface. In the following sections, we will discuss the factors contributing to free water surface fluctuation and how far they affect the submergence depth of the intake pipe inlet. Two case studies will be presented to evaluate the effect and realize its influence.

2. OBJECTIVE

The paper basically aims to estimate the effect of water surface fluctuation due to vessel and wind motion on the submergence depth of an intake pipe inlet. It presents the methods used in computing such an effect. This helps to determine exactly how deep the pipe inlet should be submerged under the free water surface level of a DWS without vortex occurrence.

3. VORTEX DEFINITION

Intake (suction) pipe submergence under water surface is necessary to avoid the occurrence of a phenomenon called “vortexing” as shown in Figure 1. When the submergence of the intake pipe is not sufficient, air enters the intake by means of an air entraining free vortex, *Kocabas and Yildirim* (2000). *Isbasoiu* (2005) states that vortexes (vortices) may produce adverse effects on the suction pump. According to *Whitesides* (2008), the entrained air causes flow reductions, vibrations, structural damage and loss of efficiency in turbines or pumps and in water conveying structures. The value of the submergence for which the tip of the air-core just reaches the intake is called the ‘critical submergence. The critical submergence is one of the main characteristics of the air-entraining vortex. *Whitesides* (2008) elaborates that a vortex can be defined as a smooth, roughly conical, rotating liquid void that forms in a fluid body as a result of a low pressure area. Figure 2 shows the different positions of the intake pipe and the possible corresponding vortex shapes.

Figure 1: Surface water Vortex due to insufficient pipe submergence depth

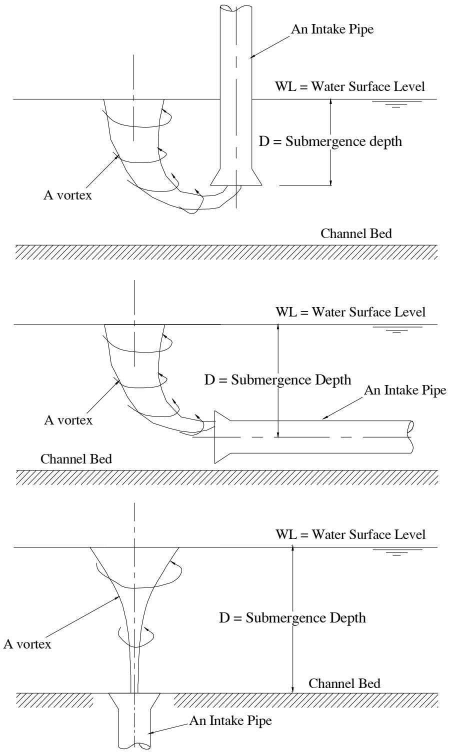

Figure 2: Vortex shapes and Submergence depths for 3 different positions of intake pipe

4. CALCULATION OF THE MINIMUM SUBMERGENCE DEPTH

Fluidic studies have demonstrated that vortices collapse, otherwise break-up, or fail to form before entering a suction conduit, as the low pressure source’s (inlet’s) distance is increased vertically from the free liquid surface level. It is therefore important that proven and established *Minimum Submergence Depths* (MSD) be maintained based upon the amount of liquid being handled and the inlet fluid velocity", *Whitesides* (2008).

Figure 3 shows the relationship between the inlet fluid velocity (V)- *suction velocity* - in (ft/s) and the recommended minimum submergence depth (D) in (feet) to avoid vortices.

According to *Whitesides* (2008), the following approximate mathematical relationship was developed:

$$D = 0.96\, e^{0.184V} \tag{1}$$

where: $(3 \leq V \leq 10)$ ft/s

It is worth mentioning that the inlet fluid velocity depends on the amount of flow rate required through the suction pipe (Q) and the pipe cross sectional area (A) to achieve the continuity principle which states that ($Q = V * A$).

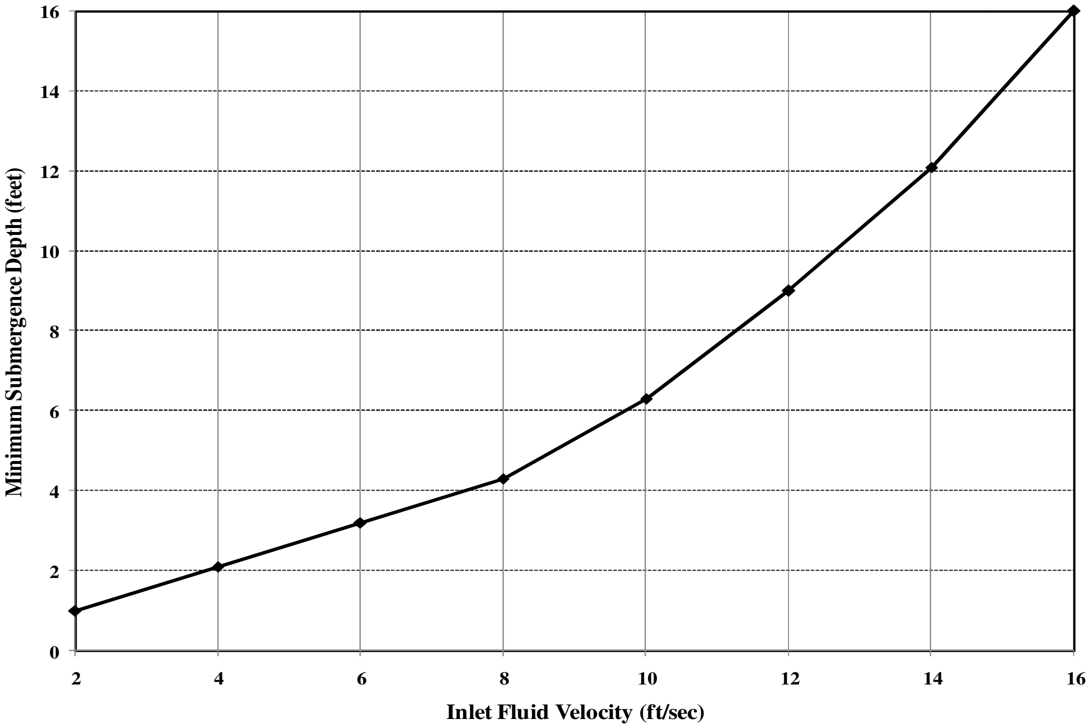

Figure 3: Relationship between the Minimum Submergence Depth of a suction pipe and the Inlet Fluid Velocity (After Whitesides, 2008)

The above relationship and graph are based on the determination of the MSD in a pump sump where the water surface is free from fluctuations. But when a suction pipe of a water intake is to be projected out and submerged into a DWS, there are other additional effects that must be considered on computing the MSD to ensure complete avoidance of vortices. The free water surface level of the DWS always experiences fluctuations and depressions resulting from the water waves generated by both the wind and the continuous vessel traffic motion. Such waves create depression areas around the pipe where the water surface drops down causing the submergence depth to reduce and the possibility of vortex occurrence to increase.

5. WATER WAVES AND PARAMETER DEFINITIONS

According to *Crapper* (1984), *Mei* (1991), *Dean and Dalrymple* (1991), any basic physical description of a water wave involves both its surface form and the water motion beneath the surface. A wave that can be described in simple mathematical terms is called a simple wave. Waves comprised of several components and difficult to describe in form or motion are termed wave trains or complex waves. Sinusoidal or monochromatic waves are examples of simple waves, since their surface profile can be described by a single sine or cosine function. A wave is periodic if its motion and surface profile recur in equal intervals of time termed the wave period. A wave form that moves horizontally relative to a fixed point is called a progressive wave and the direction in which it moves is termed the direction of wave propagation. A progressive wave is called wave of permanent form if it propagates without experiencing any change in shape.

Figure 4 depicts parameters that define a simple, progressive wave as it passes a fixed point in the river. A simple, periodic wave of permanent form propagating over a horizontal bottom may be completely characterized by the wave height H wavelength L and water depth d. the highest point of the wave is the crest and the lowest point is the trough. For linear or small-amplitude waves, the height of the crest above the still-water level (SWL) and the distance of the trough below the SWL are each equal to the wave amplitude a. Therefore $a = H/2$, where H = the wave height. The time interval between the passage of two successive wave crests or troughs at a given point is the wave period T. The wavelength L is the horizontal distance between two identical points on two successive wave crests or two successive wave troughs.

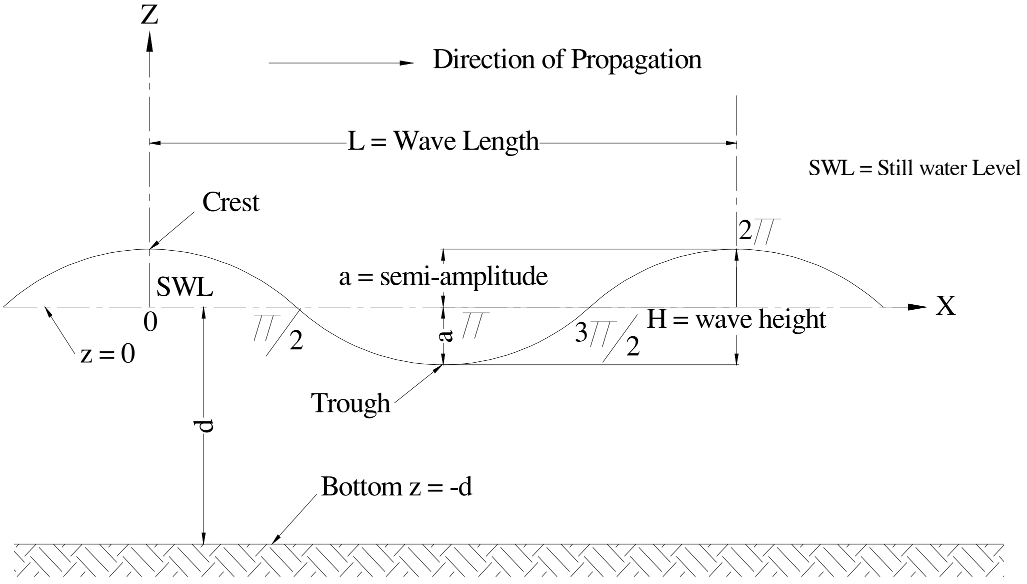

Figure 4: Water Wave Parameter Definitions

6. WAVE EFFECT ON THE MINIMUM SUBMERGENCE DEPT, MSD

As mentioned before, the water surface always undergoes depressions under the average still water level due to the waves generated by both the wind and vessel motion. The amount of depression which can be represented by the maximum wave trough depth (semi-amplitude $a = H/2$) should be added to the value of the MSD to obtain an overall MSD that can ensure complete avoidance of vortex formation. Therefore, the Overall Minimum Submergence Depth (MSD_o) that should be taken into consideration when submerging the suction pipe inlet can be calculated as follows:

$$MSD_o = MSD_i + \text{Wave Depression} \qquad (2)$$

where:

- MSD_i is the Minimum Submergence Depth computed in case of a still water surface as given in equation (1); and
- *Wave Depression = Wave depression $_{(due\ to\ vessel\ motion)}$ + Wave depression $_{(due\ to\ wind)}$*

6.1 Wave Depression Calculation

The wave depression meant here is the one that takes place during the worst probable conditions that may be ever encountered in practice at the study location. It is the summation of the half wave height (semi-amplitude) generated by the wind and that generated by the vessel motion. In the following sections, the methods used in the literature to calculate both heights are presented in some detail.

6.1.1 Vessel-generated Waves

First of all, it should be mentioned that waves generated by vessel motion a long a DWS are usually classified into two systems; primary and secondary. *De Schipper* (2007) states that when an object (a vessel) moving through a straight canal with a constant velocity V_s, water is then displaced from the front of the object to its behind, as follows from continuity. The local increase in water velocity beside the hull (vessel body) causes a corresponding water level depression along the object. This return current and water level depression are called *the primary wave system* of a moving object.

The flow curving around the object causes velocity and pressure gradients in the flow. These gradients generate small waves that radiate into the fluid, much like a stone thrown in the water. Since this disturbance point (the vessel) moves, the radial waves will interfere with each other behind the vessel. The resulting interference pattern is the *secondary wave system* and can be seen behind a ship or any moving obstacle as a typical V-pattern as shown in Figure 5.

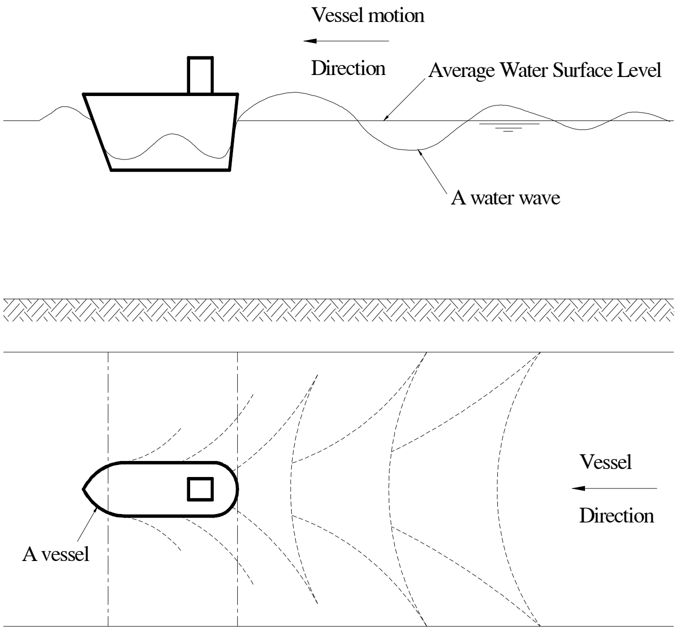

Figure 5: Primary and secondary wave systems for a moving vessel in top and side view

6.1.1.1 Calculation of Depression due to Primary Waves

De Schipper (2007) explains that the primary wave of a vessel in a canal is schematized by defining *a water level depression* alongside the ship z_a and the corresponding return current U_r. The magnitude of these variables can be calculated using mass and momentum conservation. For the calculation, it is convenient to change from reference frame. This means that instead of a vessel moving with V_s through a canal, a new reference frame is chosen on the vessel such that the vessel has no speed and the water flows by with V_s as shown in Figure 6. This transformation

(*Galilean* transformation) is valid as long as no energy loss (due to e.g. sidewalls or turbulence) is relevant in the calculation.

The balance equations in this reference frame lead to the following set of equations (assuming incompressibility of water).

Volume balance, given by:

$$A_c V_s = [A_c - A_s - z_a (B_c - B_s)]\,(V_s + U_r) \tag{3}$$

Momentum balance, given by:

$$\rho V_s^2 + \rho g h = \rho \alpha_u (V_s + U_r)^2 + \rho g\,(h - z_a) \tag{4}$$

with

V_s, velocity of the hull [m/s],
A_c, cross sectional area of the canal [m^2],
A_s, cross sectional area of the ship [m^2],
B_c, width of the canal [m],
B_s, width (beam) of the ship [m],
z_a, water level depression beside the hull [m],
U_r, depth averaged return current (water velocity) beside the hull [m/s],
h, water depth [m],
g, acceleration due to gravity [m/s^2]
ρ, density of the water [kg/m^3] and
α_u, velocity distribution coefficient ($\alpha_u = 1.4 - 0.4\,\frac{V_s}{\sqrt{gh}}$) [-].

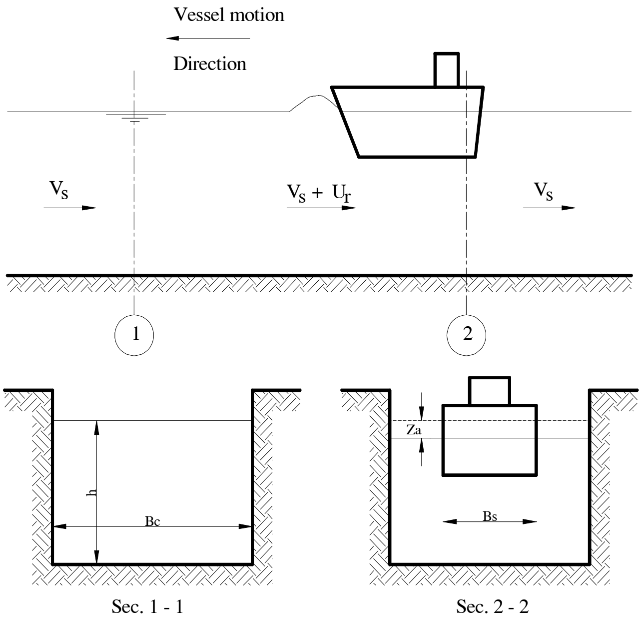

Figure 6: Primary wave schematization (After *De Schipper,* 2007)

The schematization is valid when the width and depth of the canal are the same order of magnitude as the width and depth of the hull. Accordingly, the assumption of a constant water level depression z_a is valid. As an approximation, the value z_a will be accepted whatever the width and depth of the concerned waterway with respect to those of the moving vessel.

It is clear from equation (4) that the water level depression beside the hull z_a can be calculated if the depth averaged return current (water velocity) beside the hull U_r is known.

Lap (1954) derived a single fundamental equation of a ship moving through a canal that can calculate U_r as shown below:

Assuming a uniform velocity distribution, he used ($\alpha_u = 1$).

$$\frac{V_s}{\sqrt{gh}} = \frac{V_s + U_r}{\sqrt{gh}} \left\{ 1 - K - \frac{\alpha_u \beta}{2} \left[\left(\frac{V_s + U_r}{\sqrt{gh}} \right)^2 - \left(\frac{V_s}{\sqrt{gh}} \right)^2 \right] \right\} \tag{5}$$

Where:

The geometries of the canal and ship required for the calculation can made dimensionless by defining a factor K, representing the blockage:

$$K = \frac{A_s}{A_c}$$

Identically, the width of the free surface $B_{f.s}$ can be made to a dimensionless factor β:

$$\beta = \frac{B_{f.s}}{B_c}$$

Knowing the other parameters of equation (5) and by trial and error, you can get the value of U_r that can be used in equation (4) to get the depression value z_a as follows:

$$\text{Wave Depression}_{\text{(Primary Waves)}} = WD_p = Z_a = \frac{\alpha_u}{2g}(V_s + U_r)^2 - \frac{V_s^2}{2g} \tag{6}$$

6.1.1.2 Calculation of Depression due to Secondary Waves

The secondary waves are the interference pattern created behind the vessel, forming a typical V-pattern in deep water as shown in Figure 7. The wave pattern is stationary with respect to the hull, which implies that the longitudinal velocity component of all waves must equal the hull velocity. The hull velocity (v) is the velocity of the hull with respect to the water.

Figure 7: Deep water ship wave pattern. (Photograph by Adrian Pingstone)

The exact description of secondary wave pattern in deep water has been derived first by Lord Kelvin and is the subject of many publications (Stoker (1957)). In deep water (*roughly when "the Froude depth number* (*ship speed relative to the bank*)" $F_{r,d} = \frac{v_s}{\sqrt{gh}} \leq 0.6$), it has the same shape regardless of the speed or shape of the vessel. The V-pattern consists of diverging and transverse waves. These waves interfere on a line about 19° (θ) with the sailing line. The resulting interference cusps (called feather let waves) lie on this interference line. The feather let waves have an angle φ of about 55° with the sailing line. The full pattern with angles is shown in Figure 8 below.

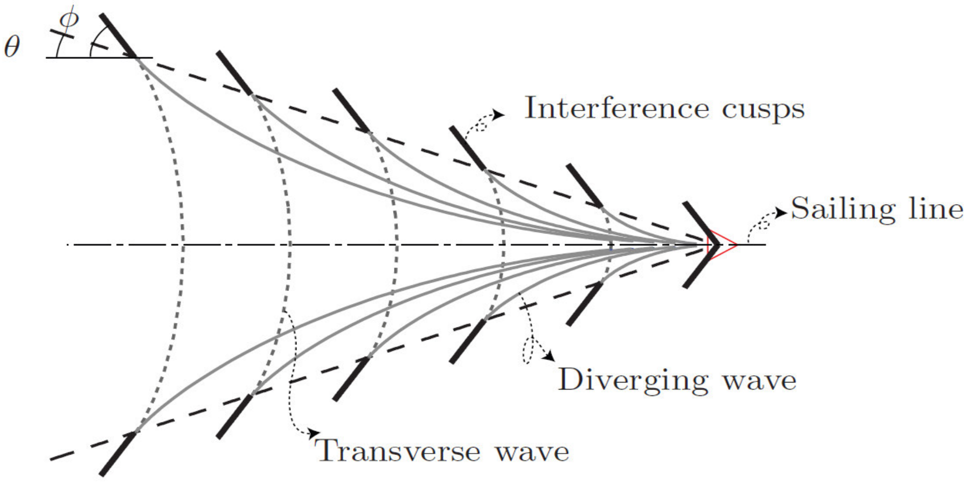

Figure 8: Deep water secondary wave pattern. The angle of the feather let waves φ is 55° (After by *De Schipper,* 2007)

In shallow water the interference angle and feather let wave angle are larger, and increases up to 90°.

Now, having an idea about the nature of the secondary waves generated behind a moving vessel, it is important to compute the wave height close to the vessel so that the required depression could be obtained. It is known that the wave depression (trough depth) is half the wave height as presented earlier in this paper.

6.1.1.2.1 Wave Height Calculation

De Schipper (2007) states that the height of the interference cusps has been the subject of various research projects. None of these however resulted in a sound theoretical relation between the hull shape and velocity versus the wave height. Several formulas are nevertheless derived for a small range of conditions based on experimental data. The work of several of these research projects is reviewed and summarized in *Verheij and Bogaerts* (1986). Generally speaking, the observed wave height H at location y from the ship is a function of the ship geometry, water depth h, velocity v and this distance to the ship y.

$$H = f\,(L_s, B_s, D_s, h, v, y) \tag{7}$$

The interference cusps can be described as a superposition of point disturbances. The strength of these point disturbances and consequently the interference cusps is related to the pressure gradients close to the hull. A sharp bow generates large pressure changes over a short length, and consequently large waves. The overall length of the vessel L_s is remarkably only of minor importance. The decay of the feather let wave height in deep water is proportional to $y^{-1/3}$, which is mathematically derived in *Havelock* (1908). For speeds up to $F_{r,d}$ = 1, this decay rate is confirmed by *MCA* (2001).

Equation (8) gives an indication for the cusp heights to be expected for deep water ship waves (θ = 19.47°).

$$\frac{H}{h} = \alpha_1 \left(\frac{y}{h}\right)^{-1/3} \left(F_{r,d}\right)^{\alpha_2} \tag{8}$$

where:

H, the wave height [m],
h, the water depth [m],
y, the distance to the bow perpendicular to the sailing line ($y > 0$) [m]. "y" will be taken in calculations as half of the ship width at the middle,
$F_{r,d}$, the Froude depth number $\frac{v_s}{\sqrt{gh}}$ [-] (should be < 1 to keep the flow subcritical),
α_1, shape coefficient [-] and

α_2, dimensionless wave height versus Froude depth number coefficient (speed dependency coefficient [-].

The coefficient α_1 is associated with the geometry of the vessel. Uniform parts amidships therefore barely contribute to the pattern and the overall length of the hull, L_s, has a small influence. The changes in the cross section can be characterized by D_s/L_e (with L_e, the entry length, the length from the bow to the parallel cross section). It can be computed for a specific hull shape but generally speaking the coefficient varies from 0.35 for (unloaded) slender ships to 1.0 for blunter hull shapes. The relation between the wave height and Froude depth number is given by the exponent α_2, and an $\alpha_2 = 4$ showed the best agreement with experimental data.

According to equation (8), the wave depression at any distance "*y*" from the ship can be calculated as follows:

$$\text{Wave Depression}_{\text{(secondary waves)}} = WD_s = \frac{H}{2} = \frac{h}{2}\ \alpha_1 \left(\frac{y}{h}\right)^{-1/3} \left(F_{r,d}\right)^{\alpha_2} \tag{9}$$

Now, in order to obtain the final wave depression required to calculate the safe MSD that can avoid vortexing, the bigger of the two wave depressions calculated above (Eqs. 6 and 9) due to the primary and secondary waves of a moving vessel should be considered as they occur near the suction pipe at consecutive times.

6.1.2 Calculation of Depression due to Wind

There are a number of developed formulae for calculating the significant wind wave height. The Wave Hind casting Model of the US Army Corps of Engineers (1984) is used as it is the most widely applied in rivers and bounded DWS. It uses different parameters such as the wind speed (*U*), the fetch length (*F*), and the DWS average depth (*d*). The wave depression due to wind can be determined as follows:

$$\text{Wave Depression}_{\text{(Wind)}} = WD_w = \frac{SignificantWindWaveHeight}{2} = \frac{H_s}{2}$$

$$= \frac{1}{2} \times \left[\frac{0.283 * U^2}{g}\right] \times \tanh\left[0.53\left(\frac{gd}{U^2}\right)^{\frac{3}{4}}\right] \times \tanh\left\{\frac{0.00565(gF/U^2)^{1/2}}{\tanh\left[0.53\left(\frac{gd}{U^2}\right)^{3/4}\right]}\right\} \tag{10}$$

where:

U = Average wind speed in (ft/s) over the study area (obtained from the Weather Forecast Authority);

g = gravitational acceleration in (ft/s^2);

d = average depth of the DWS under study in (ft); and

F = fetch length in (ft) (obtained from the Weather Forecast Authority).

7. PRACTICAL APPLICATION (CASE STUDY)

In order to examine and estimate the depression depth that water waves generated by both vessel and wind motions may produce and consequently see how significant it is, with respect to the initial minimum submergence depth (in case of a still water surface), two case studies at two different locations (Sebaeya and Khezendaria) along the River Nile (see Figure 9) were considered. The locations were selected at two different reaches of the river with different conditions regarding the vessel motion and wind speed to stress the importance of the wave effects.

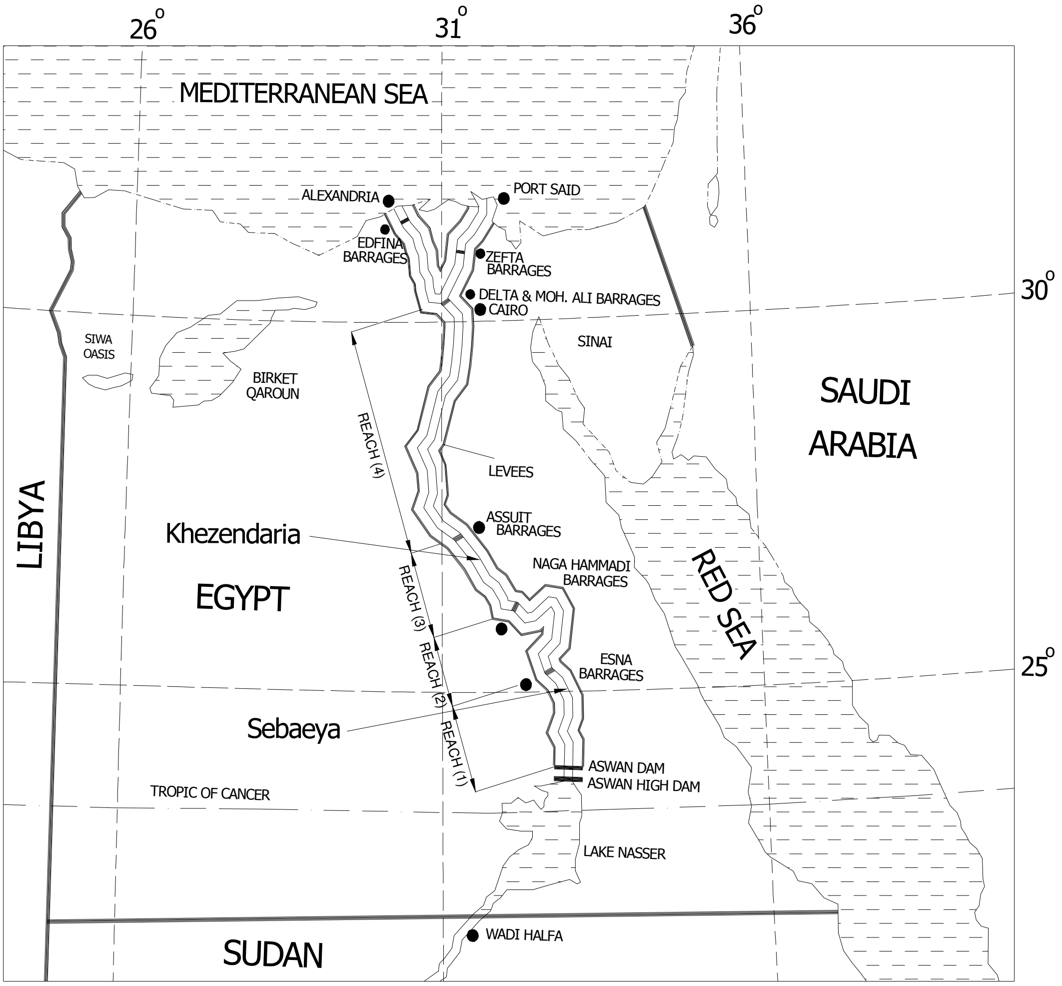

Figure 9: Selected Sites (Khezendaria and Sebaeya) along the River Nile

Sebaeya is in Reach (1) where navigation movement is frequent, the river is deep and the wind speed is higher. As for Khezendaria, it is located in Reach (3). The navigation movement is less, the river is shallower, and the wind speed is less. However, the most prevailing and worst conditions ever expected at the two sites regarding the navigational motion (where the vessel hull is assumed to be very close to the intake pipe), wind blowing, hydrology (*during minimum water levels*), and riverbed morphology (average water depth) were modeled using the abovementioned equations based on the field data collected.

It is worth mentioning that the vessel (sailing) speed selected at the two sites is subject to the condition that the water flow should be subcritical. This means that the Froude number should be less than one ($F_{r,d} = \frac{v_s}{\sqrt{gh}} < 1$). Also, the Froude number depends on the water depth. Therefore, the vessel speed differs according to the change in water depth to keep the Froude number less than unity. However, according to Verheij and Bogaerts (1986), wave heights in the region where $F_{r,d}$ is more than 0.8, are overestimated. Therefore, Froude number is kept under 0.8 during computations of wave depressions.

8. RESULTS AND ANALYSES

Table 1 shows the computation results of the depressions due to vessel motion and winds at the two locations selected. Comparing the depression values due to primary and secondary waves, it has been found that the values due to the secondary ones are always bigger. They actually represent a relatively significant percentage comparable to the initial minimum submergence depth (MSD_i). This means that they are effective and not to be ignored. Also, the depression due to wind should be considered whatever it is as it increases the overall minimum submergence depth (MSD_o).

By Adding up the values of (MSD_i), (WD_s), and (WD_w), we obtain the MSD_o that should be considered on submerging the intake pipe inlet under the free water surface of the River Nile at these locations.

Also, it is clear from the table that the height of the secondary waves is sensitive and directly proportional to the average river depth. Therefore, in deep waters, the overall minimum submergence depth is expected to be bigger as the wave depressions are always deeper. As for the height of the primary wave, it is not so significant and hardly gets affected by the change in the average river depth. Regarding the wind effect, it depends on the wind speed and fetch length reported at the study area. The more the speed and fetch length, the bigger the wave height. Therefore, it is advisable to construct the intake pipe in areas of low speed wind and short fetches if possible, otherwise their effect should be considered.

Table 1: Calculation of the Overall Minimum Submergence Depth at the two selected sites during minimum water levels

	Site Name			***Sebaeya***	***Khezendaria***
	Location along the Nile			***Reach (1)***	***Reach (3)***
Parameter Definition		**Notation**	**Unit**	**Value**	**Value**
Inlet Fluid Velocity through suction pipe	**Data**	V_i , $(3 \le V_i \le 10)$	(ft/s)	6	6
Min Submergence Depth (still water surface)	**Result**	**MSD_i**	(m)	**0.88**	**0.88**
Ship Speed	**Data**	V_s	(m/s)	7	4.30
Average River Depth		d	(m)	8	3
Ship Draft		D	(m)	1.8	1.8
Ship x-sectional area in the middle		A_s	(m^2)	32.4	32.4
River x-sectional area at the site		A_c	(m^2)	2960	1800
Geometry Factor		$K = (A_s/A_c)$		0.01	0.02
Ship Width in the middle		$B_{f,s}$	(m)	18	18
River top width during minimum flow		B_c	(m)	370	600
Geometry Factor		$\beta = (B_{f,s}/B_c)$		0.05	0.03
Acceleration of Gravity		g	(m/s^2)	9.81	9.81
Froude Depth Number (less than 0.8)		$F_{r,d}=V_s/\sqrt{gd}$		0.79	0.79
Velocity Distribution Coefficient		$\alpha_u = 1$		1.00	1.00
Depth averaged return current beside the hull		U_r	(m/s)	0.08	0.08
Wave Depression due to Primary Waves	**Result**	**WD_p**	(m)	**0.06**	**0.04**
Distance to the ship sailing line	**Data**	y	(m)	9	9
Hull shape coefficient		$\alpha_1 = (0.35 \text{ to } 1)$		0.5	0.5
Hull speed dependency coefficient		$\alpha_2 = 4$		4.00	4.00
Wave Depression due to Secondary Waves	**Result**	**WD_s**	(m)	**0.75**	**0.21**
Average wind speed at study area	**Data**	U	(m/s)	4.8*	4.2*
Fetch length		F	(m)	8000	5000
Wave Depression due to Wind	**Result**	**WD_w**	(m)	**0.09**	**0.07**
Overall Minimum Submergence Depth $= MSD_i + WD_s + WD_w$	**Final Result**	***MSD_o*** **	(m)	***1.72***	***1.16***

* ***Average wind speed according to Wind Atlas for Egypt, 2006. Research Department, Egyptian Meteorological Authority, Cairo, Egypt.***

** ***Since (WD_s > WD_p) , WD_p should be neglected as the effect of the two waves never occurs at the same time and we have to consider the bigger one.***

9. CONCLUSIONS

1. The Minimum Submergence Depth (MSD) computation of an intake pipe has to consider the water surface fluctuation effect due to the waves generated by both wind and vessel motions. It's been explained in figures that the water surface depression value due to fluctuation is sometimes close to the MSD value when computed in case of still water surface as shown in the case of Sebaeya. Also, this value might be estimated bigger at other locations. Therefore, it should always be considered in the MSD computations to ensure complete avoidance of vortexing and cavitations.
2. The secondary wave effect is always bigger than that of the primary one (which can be neglected) and therefore, it is significant in calculating the overall submergence depth.
3. The overall minimum submergence depth determines where the intake pipe inlet should be projected out and immersed in the DWS. Sometimes, it requires a water depth bigger than that available during low flows. Accordingly, it affects the selection process of an intake location.
4. Also, in case of shallow water and where there is no possibility of changing the location, the MSD may decide whether the DWS at the site will need bed regulation works such as dredging or not.
5. As a rule of thumb, in river reaches abounding with/in navigational traffic movement and where the wind blows frequently and strongly, the effect of the consequent water surface wave fluctuation on the submergence of an intake pipe inlet can never be ignored.

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