

# MATHEMATICAL MODEL OF THE SPREAD OF MARINE PROPELLERS JETS IN THE PORT SOALARA MADAGASCAR A RADIUS OF 900M

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## Abstract

The current return results from the flow, and is located toward the stern. This current is opposed to the direction of the ship and increases the friction at the bottom. This friction exerts a drag force on the water in the direction of the boat. To compensate for this friction, the water level in front of the boat becomes higher than the rear level. With this lowering of the water, the boat's law affects the quay or jetty. The return current has very low erosive action on the seabed.

Impair the performance of the ship at a certain speed, it is not necessary to study this current situation in this report. In Soalara, for all the depths of the sea, the speed generated by the propeller of all jets (ship 2 tugs) exceeds: 0,3 node to a mean radius of 200m and 0.15 node to a mean radius of 300m.

*Keywords : Soalara, propeller jets, sea, marine environment, Panamax ship.*

## 1- INTRODUCTION

The passage of ships in the port changes the flow, especially during low tide. These changes are reflected in the bottom and works (breakwaters, groynes, ...) by increasing the erosive action of the sea. During the passage of a boat on a lake, one can simultaneously distinguish three forms of erosive actions: the return current, wave action, and the action of jet propellers on the sea bottom.

The return current causes the water to lower alongside the boat, followed by waves breaking if the ship speed is high. This has very little effect in the harbor. In our model, we do not take into account the effects of the wake as their erosive actions are negligible.

## 2. METHODS

It is about the hydraulic effects of jet propellers on ships.

### 21. The description of the phenomenon

The propeller jets have their maximum intensity after stopping the ship when it uses its power to start or maneuver. Erosions of the coarse material will meet in the port, or more precisely, along the dotes or jetty. The description of the effects of propeller jets involves parameters (water level, depressing, diameter and number of propeller rotational speeds, output power, etc ...) which are added the characteristics of erodible materials (sand and seabed). In this approach, there are three modeling steps:

- Modeling of the propulsion system to move its characteristics of operation (thrust propeller speed) at the speed of the water ejected from the outlet helix.
- Velocity field modeling which allows you to switch the speed behind the propeller speed near the bottom.
- Modeling the erosion phenomenon that allows moving from erosive to flow speed causes erosion.
- Our approach has been to follow these three steps based on theoretical studies to identify a methodology applicable to our study area and the mathematical model that we use to describe the cohesive particle transport process.

### 22. Modeling of the propulsion system

The simplest model assumes a uniform distribution of speed at a small distance from the propeller (Figure 1). Using the theorem of the amount of movement on a current tube subjected to action to calculate the total thrust on the

propulsion system. Then, the successive relationship between C and B and B' and A, is to calculate the part of the pressure differential across the propeller.

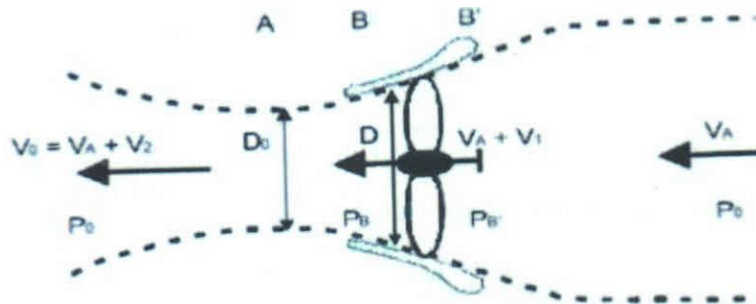


Figure 1 - Current in the axis of the helix

We deduce a speed  $V_2$  at the output of the propulsion system depending on the diameter  $D$  of the propeller, the number of revolutions  $n$  per second, the speed of advance of the boat  $V_A$ , the speed supplement level of  $V_1$  and the propeller thrust coefficients determined by the manufacturer and  $K_h$  and  $K_t$ :

$$V_2 = 1,6nD\sqrt{K_h} \left(1 + \frac{2V_A}{V_2}\right)^{-\frac{1}{2}} \quad (1)$$

$$\frac{D_0}{D} = \sqrt{\frac{V_A + V_1}{V_A + V_2}} \quad (2)$$

$$V_A + V_1 = \frac{4}{\pi} \frac{K_t n^2 D^2}{V_2} \quad (3)$$

- D: diameter of the impeller (m)
- $D_0$ : Diameter causing the jet (m)
- $K_h, K_t$ : thrust coefficients (unit less)
- $V_0$ : Speed causing the jet ( $m \cdot s^{-1}$ )
- $V_1$ : velocity supplement at the propeller ( $ms^{-1}$ )
- $V_2$ : Speed Supplement to the origin of the jet ( $ms^{-1}$ )
- $V_A$ : speed of advance of the boat ( $ms^{-1}$ )
- $n$ : the propeller speed ( $tours \cdot s^{-1}$ )

When thrust coefficients are not known, the following formula connects the output speed propeller to its diameter and its number of rotations per second:

$$V_0 = 0.95 n D \quad (4)$$

Is therefore used (4) for calculating the ship's propeller output speed selected in the modeling.

### 23. Modeling of the diffusive jet

It is estimated from this modeling velocities produced at any point by a propeller diameter and data speed. One distinguishes between a settlement area where the speed on the jet axis does not change and a set are (Figure 3), diffusive (Figure 2), where the speed decreases. In the established area, there are self-similarity speed profiles and a radial variation of the speed according to a Gaussian law.

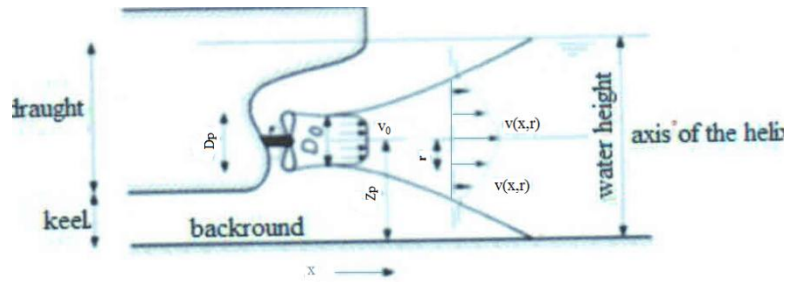
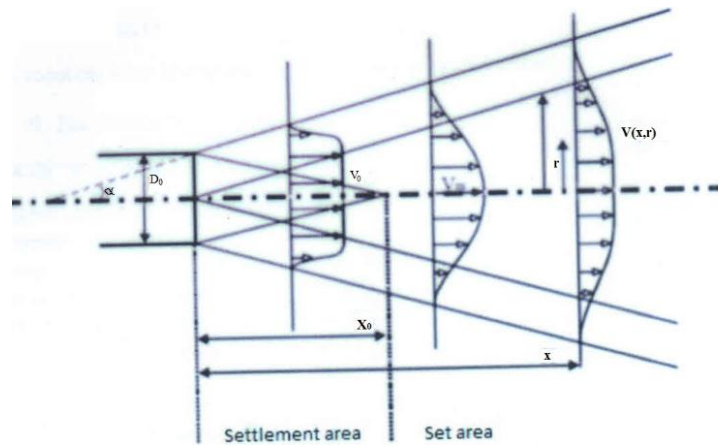


Figure 2 - Diffusive jet



(x belongs to the axis of the helix, and r is radial to the axis of the helix)

Figure 3- Settlement area - Set area

Thus, the speed is expressed in the following expressions, where the parameter c (coefficient of contraction) is the only unknown and must be determined experimentally:

$$\text{Settlement area, } X < X_0: \quad V(r,x) = V_0 \quad \text{if } r < \frac{D_0}{2} - cx$$

$$V(r,x) = V_0 e^{-\frac{(r + cx - \frac{D_0}{2})^2}{2c^2x^2}} \quad \text{if } r > \frac{D_0}{2} - cx \quad (5)$$

$$\text{Set area, } X > X_0: \quad \frac{V_m}{V_0} = \frac{1}{2c} \frac{D_0}{x} \quad \text{and} \quad v(r,x) = V_m e^{-\frac{r^2}{2c^2x^2}} \quad (6)$$

Along with:

$V_0$ : Speed propeller output

$D_0$ : Diameter causing the jet (m)

$c = 0.18$

$X_0 = 2.8 D_0 \quad (7)$

$\tan \alpha = 0.272 \quad (8)$

Thus, we can determine the speed at any point since the propeller jet reached the bottom of the sea.

### 3- RESULTS

It is about the effect of propagation speed in the marine environment.

#### 3.1. The characteristics of the ship and its tugs

The characteristics of the vessel used in the modeling are:

- Name: panamax boat with 2 tugs
- Tonnage: 100 000 tonnes
- Length: 220m
- Draught supported: 14m
- Propeller diameter: 7m

- Speed in Port: 500 tours/min = 8,3 tours/s
- Tugs: position of the axis of the helix: 3m  
propeller diameter: 2.5m  
Speed in Port: 2300 tours/min = 38,3 tours/s

### 32. Calculation of the settlement area and propeller output speeds (Table 1)

Table 1 - Helices characteristics

Type	establishment Zone $X_0$ (m)	Speed Release propeller (m/s) (4)
Ship	19,6	55,2
Tug	7	90,5

Regarding the two tugs, there is no phase between the speeds of the two tugs, Therefore, the two speeds are added in case of interference.

The values of  $v(x,r)$  in nodes, due to the vessel : general case (Table 2)

Applying the formulas (5) and (6) with respect to the vessel's characteristics and tugs. (0;0) is the center of the helix.

x r	2	4	6	8	10	12	14	16	20	40	60	80	100	200	300	400	500	700	900
2	107,3	107,3	107,3	107,3	105,6	102,4	98,84	95,67	89,41	50,19	34,18	25,83	20,74	10,42	6,950	5,214	4,172	2,980	2,318
4	6,186	25,54	36,80	43,30	47,43	50,27	52,33	53,89	56,28	44,70	32,47	25,09	20,36	10,37	6,936	5,206	4,169	2,979	2,138
6	0	0,005	0,441	2,541	6,186	10,46	14,75	18,74	26,01	36,86	29,80	23,91	19,74	10,29	6,912	5,198	4,163	2,977	2,316
8	0	0	0	0,022	0,235	0,925	2,216	4,025	8,832	28,14	26,43	22,35	18,90	10,18	6,879	5,184	4,156	2,974	2,315
10	0	0	0	0	0,003	0,035	0,177	0,533	2,202	19,8/8	22,65	20,49	17,88	10,04	4,937	5,166	4,147	2,971	2,314
12	0	0	0	0	0	0	0,008	0,044	0,403	13,01	18,76	18,43	16,71	9,869	6,785	5,144	4,136	2,967	2,312
14	0	0	0	0	0	0	0	0,002	0,054	7,877	15,01	16,26	15,42	6,673	6,725	5,119	4,122	2,962	2,309
16	0	0	0	0	0	0	0	0	0,005	4,416	11,60	14,07	14,06	9,451	6,656	5,089	4,108	2,957	2,307
20	0	0	0	0	0	0	0	0	0	1,010	6,260	9,941	11,25	8,940	6,494	5,019	4,071	2,943	2,301
40	0	0	0	0	0	0	0	0	0	0	0,036	0,55	1,766	5,627	5,286	4,470	3,780	2,834	2,248
60	0	0	0	0	0	0	0	0	0	0	0	0,004	0,080	2,601	3,751	3,686	3,341	2,661	2,165
80	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,883	2,321	2,813	2,811	2,436	2,052
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0,220	1,252	1,998	2,251	2,175	1,916
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,007	0,110	0,352	0,845	1,081
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,016	0,175	0,416
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,019	0,109
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,019
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The values of  $v(x,r)$  in nodes, due to the tug (Table 3)

(0;0) is the center of the helix.

x r	1	3	5	7	9	12	14	16	20	40	60	80	100	200	300	400	500	700	900
1	163,4	152,6	135,8	127,9	112,4	91,60	80,83	72,05	54,90	36,34	20,32	15,26	12,22	6,119	4,060	3,060	2,448	1,749	1,360
3	0	0,021	2,310	10,16	24,49	38,94	43,06	44,48	43,26	28,09	19,63	14,97	12,07	6,101	4,047	3,058	2,447	1,749	1,360
5	0	0	0	0,065	1,361	7,001	12,21	16,95	23,33	24,05	18,33	14,44	11,78	6,063	4,064	3,053	2,445	1,747	1,360
7	0	0	0	0	0,012	0,534	1,846	3,990	9,245	19,03	16,54	13,60	11,35	6,007	4,047	3,046	2,441	1,746	1,359
9	0	0	0	0	0	0,017	0,148	0,579	2,689	10,01	14,42	12,59	10,80	5,933	4,025	3,037	2,436	1,744	1,358
12	0	0	0	0	0	0	0,001	0,013	0,237	7,633	11,08	10,81	9,804	5,791	3,981	3,019	2,427	1,741	1,357
14	0	0	0	0	0	0	0	0	0,032	4,622	8,808	9,541	9,048	5,676	3,946	3,003	2,419	1,738	1,355
16	0	0	0	0	0	0	0	0	0,003	2,591	6,810	8,256	8,248	5,546	3,906	2,986	2,410	1,735	1,353
20	0	0	0	0	0	0	0	0	0	0,646	3,673	5,834	6,604	5,246	3,810	2,945	2,389	1,727	1,350

40	0	0	0	0	0	0	0	0	0	0	0,21	0,323	1,036	3,302	3,102	2,623	2,218	1,663	1,319
60	0	0	0	0	0	0	0	0	0	0	0	0,002	0,047	1,526	2,201	2,163	1,960	1,561	1,270
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0,518	1,362	1,651	1,649	1,430	1,204
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0,129	0,734	1,167	1,321	1,276	1,124
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,004	0,064	0,207	0,496	0,634
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,009	0,103	0,245
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011	0,064
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

### 33. Representative of the map of the propagation speed on a radius of 900m at different levels

Regarding the speed  $v(x, r)$ , (0,0) is the center of the propeller. In the sea, each item is identified by its cartesian coordinates (x,y,z), the origin (0,0,0) is the center of the helix. Here are the relations between the two coordinate systems (Table 4):

$$x=x \quad \text{and} \quad r = \sqrt{y^2 + z^2}$$

Note: When the value of y is large enough (100m) compared to the depths z: the value  $r = y$ . Therefore, the velocities are roughly the same for all these depths.

#### *The propagation speed within a radius of 900m to a depth of 5m below the resting level Ship: speeds $v(x, y, z)$ in nodes for a depth of 5m*

The depth of the propeller axis is 12 m deep. So  $z = 12\text{m} - 5\text{m} = 7\text{m}$ .

(0; 0; 0) is the center of the helix. In our benchmark, a depth of 5m corresponds to  $z = 7\text{m}$ .

x r	1	2	4	8	10	12	14	16	20	40	60	80	100	200	300	400	500	700	900
1	0	0	0	0,252	1,251	1,176	5,781	6,732	15,16	32,21	28,07	23,12	19,32	10,23	6,895	5,191	4,160	2,976	2,316
2	0	0	0	0,150	0,878	2,445	4,714	7,402	13,50	31,29	27,71	22,96	19,22	10,22	6,892	5,189	4,159	2,975	2,316
4	0	0	0	0,065	1,361	1,846	2,067	3,807	8,497	27,86	26,31	22,29	18,87	10,17	4,878	5,183	4,156	2,974	2,315
8	0	0	0	0	0	0,010	0,070	0,255	1,333	17,54	21,42	19,86	17,53	9,987	6,821	5,159	4,144	2,970	2,313
10	0	0	0	0	0	0	0,005	0,032	0,332	12,39	18,36	18,21	16,58	9,850	6,779	5,142	4,134	2,966	2,311
12	0	0	0	0	0	0	0	0,002	0,060	8,108	15,20	16,38	15,49	9,684	6,728	5,120	4,123	2,962	2,309
14	0	0	0	0	0	0	0	0	0,008	4,910	12,17	14,45	14,29	9,491	6,669	5,094	4,110	2,957	2,307
16	0	0	0	0	0	0	0	0	0,001	2,752	9,407	12,50	13,03	9,274	6,601	5,065	4,095	2,952	2,304
20	0	0	0	0	0	0	0	0	0	0,686	5,074	8,834	10,43	8,773	6,439	4,995	4,058	2,938	2,286
40	0	0	0	0	0	0	0	0	0	0	0,029	0,489	1,637	5,522	5,242	4,449	3,769	2,829	2,246
60	0	0	0	0	0	0	0	0	0	0	0	0,003	0,074	2,552	3,720	3,668	3,331	2,657	2,162
80	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,866	2,301	2,800	2,802	2,432	2,050
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0,216	1,241	1,978	2,244	1,272	1,914
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,007	0,109	0,352	0,844	1,080
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,016	0,174	0,416
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,019	0,109
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,019
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

A tug: soeeds  $v(x, y, z)$  in nodes for a depth of 5m: (Table 5)

(0;0) is the center of the helix. In our benchmark, a depth of 5m corresponds to  $z = -2$  m.

x	1	2	4	8	10	12	14	16	20	40	60	80	100	200	300	400	500	700	900	
r																				
1	0	0,162	10,64	15,84	56,60	59,71	58,99	56,61	50,46	29,17	19,97	15,12	12,15	6,110	4,078	3,059	2,448	1,749	1,360	
2	0	0	1,080	22,24	35,64	43,29	46,58	47,25	44,96	28,34	19,72	15,01	12,09	6,103	4,075	3,058	2,447	1,748	1,360	
4	0	0	0	1,231	5,591	11,96	18,11	22,92	28,30	25,24	18,,37	14,58	11,87	6,075	4,067	3,055	2,445	1,748	1,360	
8	0	0	0	0	0,003	0,009	0,413	1,209	4,441	15,89	15,25	12,99	11,02	5,963	4,034	3,041	2,438	1,745	1,358	
10	0	0	0	0	0	0,001	0,024	0,145	1,107	11,23	13,07	11,91	10,43	5,881	4,009	3,030	2,433	1,743	1,357	
12	0	0	0	0	0	0	0	0,010	0,202	7,344	10,82	10,71	9,744	5,782	3,979	3,017	2,426	1,742	1,356	
14	0	0	0	0	0	0	0	0	0,027	4,447	8,658	9,449	8,992	5,667	3,943	3,002	2,418	1,738	1,355	
16	0	0	0	0	0	0	0	0	0,002	2,493	6,695	8,197	5,537	3,903	2,985	3,003	2,409	1,734	1,353	
20	0	0	0	0	0	0	0	0	0	0,621	3,611	5,778	6,564	5,238	3,808	2,944	2,388	1,727	1,350	
40	0	0	0	0	0	0	0	0	0	0	0,021	0,320	1,030	3,297	3,100	2,622	2,218	1,663	1,319	
60	0	0	0	0	0	0	0	0	0	0	0	0,002	0,047	1,524	2,200	2,162	1,960	1,561	1,270	
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0,517	1,361	1,650	1,649	1,429	1,204	
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0,129	0,734	1,166	1,320	1,276	1,124	
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,004	0,064	0,207	0,496	0,634	
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,009	0,102	0,245	
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011	0,064	
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011	
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

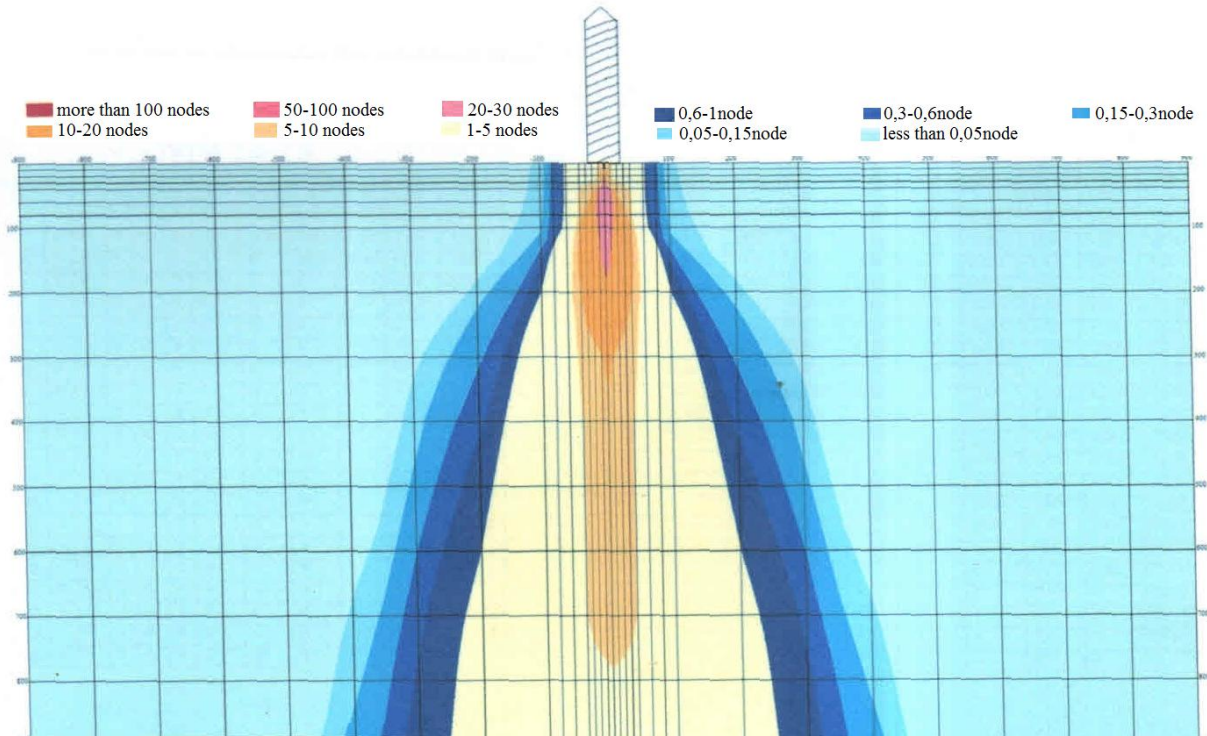


Figure 4 - Speed in nodes to a depth of 5 meters

**The propagation speed within a radius of 900m to a depth of 10m below the resting level Ship: speeds  $v(x, y, z)$  in nodes for a depth of 10m (Table 6)**

(0; 0) is the center of the helix. In our benchmark, a depth of 10m corresponds to  $z = 2m$ .

x r	1	2	4	8	10	12	14	16	20	40	60	80	100	200	300	400	500	700	900
1	107,3	107,3	107,3	106,5	102,5	98,46	94,77	91,67	86,12	49,71	34,03	25,71	20,70	10,41	6,949	5,213	4,171	2,980	2,318
2	107,3	107,3	107,1	96,06	88,16	84,63	81,99	79,97	76,62	48,29	33,60	25,58	20,61	10,40	6,945	5,212	4,171	2,980	2,318
4	0	0,114	6,780	26,38	32,78	37,50	41,08	43,81	48,22	43,01	31,92	24,85	20,23	10,35	4,931	5,206	4,167	2,978	2,317
8	0	0	0	0,010	0,144	0,646	3,221	7,569	27,07	25,98	22,14	18,79	10,16	6,874	6,874	5,182	4,155	2,974	2,315
10	0	0	0	0	0,001	0,023	0,425	1,887	19,13	22,27	20,30	17,77	10,02	6,832	6,832	5,164	4,146	2,971	2,313
12	0	0	0	0	0	0	0,034	0,345	12,51	18,44	18,25	16,61	9,853	6,780	6,780	5,142	4,135	2,967	2,311
14	0	0	0	0	0	0	0,001	0,046	7,579	14,75	16,10	15,32	9,658	6,721	6,721	5,116	4,122	2,962	2,309
16	0	0	0	0	0	0	0	0,004	4,248	11,41	13,93	13,97	9,437	6,652	6,652	5,087	4,106	2,956	2,307
20	0	0	0	0	0	0	0	0	0	1,059	6,154	9,846	11,19	8,927	6,489	5,017	4,070	2,943	2,300
40	0	0	0	0	0	0	0	0	0	0	0,036	0,545	1,755	5,619	5,282	4,469	3,779	2,834	2,248
60	0	0	0	0	0	0	0	0	0	0	0	0,004	0,080	2,597	3,749	3,684	3,340	2,661	2,164
80	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,881	2,319	2,812	2,810	2,436	2,052
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0,219	1,251	1,987	2,250	2,175	1,916
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,007	0,110	0,353	0,846	1,081
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,016	0,175	0,417
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,019	0,110
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,019
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

**A tug: soeeds  $v(x, y, z)$  in nodes for a depth of 10m: (Table 7)**

(0;0) is the center of the helix. In our benchmark, a depth of 10m corresponds to  $z = -7 m$ .

x r	1	2	4	8	10	12	14	16	20	40	60	80	100	200	300	400	500	700	900
1	0	0	0	0	0,054	0,480	1,706	3,756	8,895	18,89	16,47	13,56	11,33	6,005	4,046	3,046	2,441	1,746	1,359
2	0	0	0	0	0,034	0,348	1,347	3,135	7,923	18,36	16,26	13,47	11,28	5,998	4,044	3,045	2,441	1,746	1,359
4	0	0	0	0	0	0,096	0,523	1,520	4,986	16,35	15,44	13,08	11,07	5,970	4,036	3,042	2,439	1,745	1,358
8	0	0	0	0	0	0	0,011	0,084	0,762	10,29	12,57	11,65	10,28	5,861	4,003	3,027	2,431	1,743	1,357
10	0	0	0	0	0	0	0	0,009	0,195	7,273	10,77	10,69	9,729	5,780	3,978	3,017	2,426	1,741	1,356
12	0	0	0	0	0	0	0	0	0,035	4,758	8,922	9,610	9,090	5,682	3,948	3,004	2,419	1,738	1,355
14	0	0	0	0	0	0	0	0	0,004	2,881	7,139	8,477	8,389	5,570	3,913	2,989	2,412	1,735	1,354
16	0	0	0	0	0	0	0	0	0	1,615	5,520	7,335	7,647	3,442	3,873	2,972	2,403	1,732	1,352
20	0	0	0	0	0	0	0	0	0	0,402	2,977	5,163	6,123	5,148	3,779	2,931	2,331	1,724	1,348
40	0	0	0	0	0	0	0	0	0	0	0,017	0,287	0,961	3,240	3,076	2,611	2,211	1,660	1,318
60	0	0	0	0	0	0	0	0	0	0	0	0,002	0,043	1,498	2,183	2,152	1,955	1,559	1,269
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0,508	1,350	1,643	1,644	1,427	1,203
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0,126	0,728	1,161	1,316	1,274	1,123
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,004	0,064	0,206	0,495	0,632
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,009	0,102	0,244
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011	0,064
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

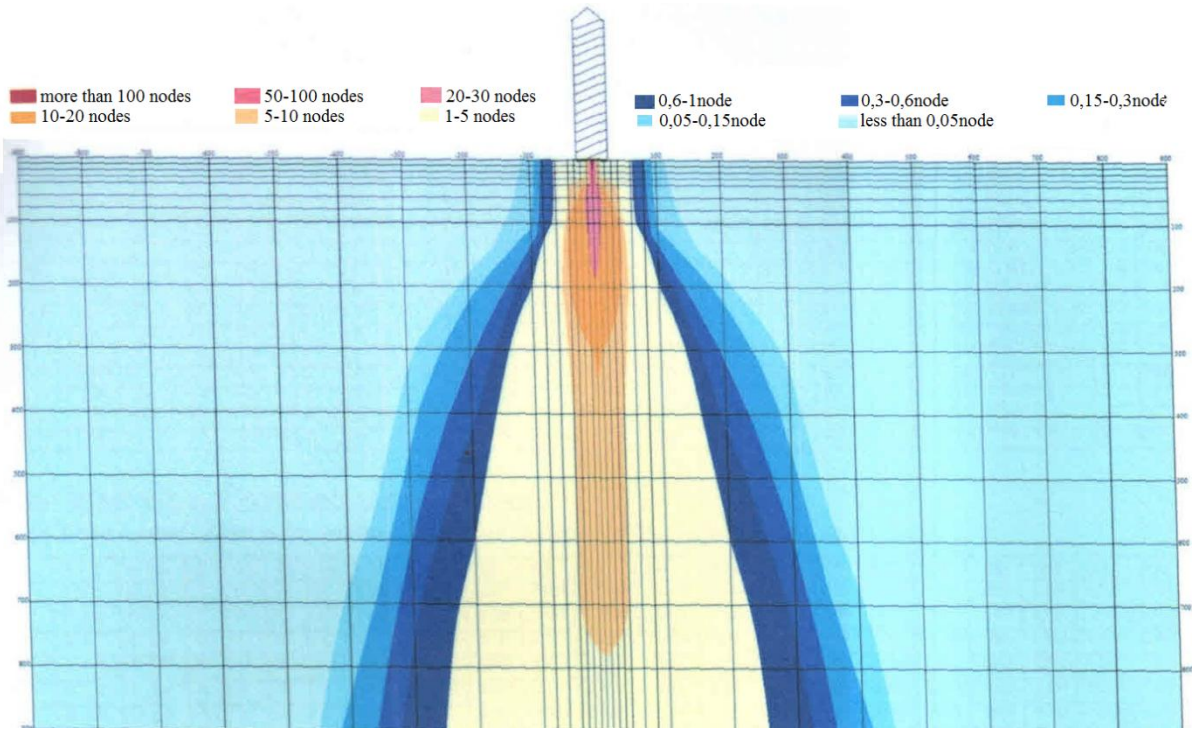


Figure 5 - Speed in nodes to a depth of 10 meters

*The propagation speed within a radius of 900m to a depth of 15m below the resting level Ship: speeds  $v(x, y, z)$  in nodes for a depth of 15m (Table 8)*

(0; 0) is the center of the helix. In our benchmark, a depth of 15m corresponds to  $z = -3m$ .

x r	1	2	4	8	10	12	14	16	20	40	60	80	100	200	300	400	500	700	900
1	107,3	107,3	93,20	80,06	77,14	75,17	73,29	72,68	70,93	47,37	33,32	25,46	20,55	10,39	6,943	5,211	4,170	2,979	2,318
2	30,49	46,50	55,61	60,32	64,27	61,91	62,36	62,70	63,18	46,91	32,89	25,28	20,45	10,38	6,934	5,207	4,168	2,979	2,318
4	0	0	0,925	13,35	19,98	25,54	30,06	33,80	39,76	40,98	31,24	24,56	20,07	10,33	6,925	5,204	4,166	2,978	2,317
8	0	0	0,004	0,077	0,412	0,412	1,186	2,436	6,241	25,80	25,43	21,87	18,64	10,14	6,868	5,179	4,154	2,973	2,315
10	0	0	0	0	0,015	0,015	0,093	0,320	1,556	18,23	21,79	20,05	17,63	10,01	6,826	5,161	4,145	2,970	2,313
12	0	0	0	0	0	0	0,003	0,026	0,285	11,92	18,05	18,03	16,47	9,834	6,775	5,140	4,133	2,966	2,311
14	0	0	0	0	0	0	0	0	0,038	7,222	14,44	15,91	15,21	9,639	6,715	5,114	4,120	2,961	2,309
16	0	0	0	0	0	0	0	0	0,003	4,048	11,16	13,77	13,86	9,419	6,646	5,085	4,105	2,956	2,306
20	0	0	0	0	0	0	0	0	0	1,009	6,023	9,728	11,09	8,909	6,484	5,014	4,069	2,942	2,300
40	0	0	0	0	0	0	0	0	0	0	0,035	0,538	1,742	5,608	5,278	4,466	3,778	2,833	2,248
60	0	0	0	0	0	0	0	0	0	0	0	0,004	0,079	2,592	3,745	3,682	3,339	2,660	2,164
80	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,880	2,317	2,811	2,809	2,435	2,052
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0,219	1,250	1,986	2,249	2,175	1,916
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,007	0,110	0,353	0,845	1,082
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,016	0,175	0,417
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,019	0,109
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,001	0,019
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



A tug: soeeds  $v(x, y, z)$  in nodes for a depth of 15m: (Table 9)

(0;0) is the center of the helix. In our benchmark, a depth of 15m corresponds to  $z = -12m$ .

x	1	2	4	8	10	12	14	16	20	40	60	80	100	200	300	400	500	700	900	
r																				
1	0	0	0	0	0	0	0	0,012	0,227	7,559	10,96	10,79	9,789	5,789	3,981	3,018	2,427	1,741	1,356	
2	0	0	0	0	0	0	0	0,010	0,202	7,344	10,82	10,71	9,744	5,782	3,979	3,017	2,426	1,741	1,356	
4	0	0	0	0	0	0	0	0	0,127	6,541	10,28	10,41	9,565	5,755	3,971	3,014	2,424	1,740	1,356	
8	0	0	0	0	0	0	0	0	1,020	4,117	8,366	9,269	8,882	5,650	3,938	3,000	2,417	1,737	1,355	
10	0	0	0	0	0	0	0	0	0,004	2,909	7,170	8,498	8,402	5,572	3,914	2,989	2,412	1,735	1,354	
12	0	0	0	0	0	0	0	0	0	1,903	5,937	7,642	7,850	5,478	3,884	2,977	2,405	1,733	1,353	
14	0	0	0	0	0	0	0	0	0	1,152	4,751	6,742	7,245	5,369	3,850	2,962	2,398	1,730	1,351	
16	0	0	0	0	0	0	0	0	0	0,646	3,673	5,834	6,604	5,246	3,811	2,945	2,389	1,727	1,350	
20	0	0	0	0	0	0	0	0	0	0,161	1,981	4,122	5,288	4,963	3,718	2,904	2,368	1,719	1,346	
40	0	0	0	0	0	0	0	0	0	0	0,011	0,228	0,830	3,123	3,026	2,587	2,198	1,655	1,316	
60	0	0	0	0	0	0	0	0	0	0	0	0,001	0,037	1,444	2,147	2,133	1,943	1,554	1,266	
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0,490	1,328	1,628	1,635	1,423	1,201	
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0,122	0,716	1,150	1,309	1,270	1,121	
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,004	0,063	0,205	0,494	0,633	
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,042	0,009	0,102	0,244	
400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011	0,064	
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011	
700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

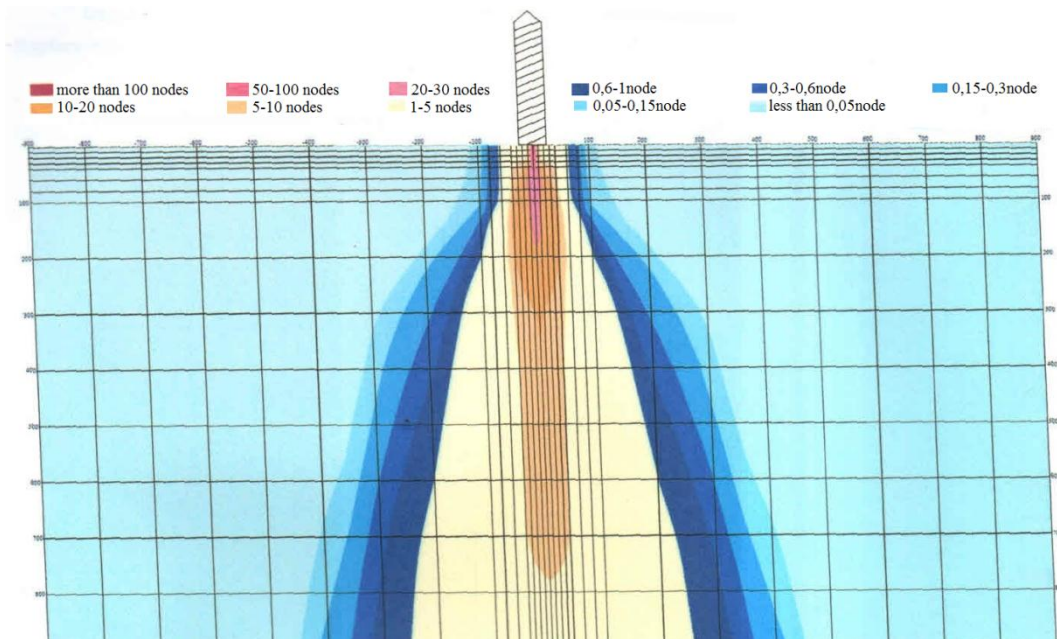


Figure 6 - Speed in nodes to a depth of 15 meters

#### 4- DISCUSSIONS

The limit of modeling is cyclones that obstruct spontaneously the lanes and cannot be considered in this modeling.

Data collection: to be as accurate as possible, this study requires manual counts of displacement and socio-economic surveys, which are relatively expensive.

This study constitutes an introduction to research. It can and must be deepened in order to approach, as much as possible, reality and to become a very effective tool in decision making.

## 5- CONCLUSION

In this study, we investigated the effects of hydraulic propeller jets on the "Panamax Ship with two tugs" on a radius of 900m. For all the depths of the sea, the speed generated by the propeller of all jets (ship 2 tugs) exceeds:

- 0.3 node to a mean radius of 200m
- 0.15 node to a mean radius of 300m

The surface current near the Soalara port is of the order of 0.3 node. The passage of this ship is not detrimental to the ecosystem when its speed is less than 0.15 node (half of the current surface). Thus, according to this study, the passage of the "Panamax Ship with two tugs" is possible in the port of Soalara. Its pass frequency must not be more than 3 times per week to avoid nuisance to the ecosystem place.

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