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Squat and Bank effect as a consequence of unintentional grounding of vessels: Study of cases

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ABSTRACT

This paper is a compendium of theoretical and mathematical studies on the squat effect and the bank effect, analysing their influence on maritime casualties focused on unintentional groundings. Subsequently, the theoretical part is contrasted with the practical part by presenting real cases where these effects have been significantly involved and demonstrating the importance for the pilot to make a proper and rigorous management of the calculations and forecasts of these effects in order to carry out a safe navigation throughout his career. The guidelines for the identification of when they occur are brought together, so that measures can be taken to avoid their effects, or even to take advantage of them for one's own benefit.

1. Introduction.

Maritime transport continues to be, and increasingly so, despite the fact that in the last decade it has experienced a slight drop in data, the system by which global trade in goods and people is mainly sustained, with this being estimated at 90% of the total. (Allianz Global Corporate & Specialty SE, 2018) We must therefore consider that we live in a world in which maritime traffic is being taken over by ships with an increasingly larger displacement, as technology makes it possible to build larger ships.

This technological progress in terms of materials, resistance and propulsion engineering goes hand in hand with a considerable advance in terms of navigational safety, mainly contributed by an improvement in positioning and course planning systems. For example, the SIVCE, ARPA, GPS, AIS, INMARSAT, etc. systems have made a significant contribution to the increasing safety of maritime transport.

Although transport by road, rail and air is also experiencing a significant increase, when it comes to getting goods to their destination, a great effort is being made to promote maritime transport by making it reach more and more inland, incorporating waterways to these destination points, making it possible for larger and larger ships to enter river ports, without forgetting to mention the existence of different channels that considerably shorten trade routes by sea and the increases in size that have been experienced in the last few decades.

It is inevitable that with this considerable increase, so does the number of maritime accidents, which is the subject of this paper, especially those related to involuntary groundings caused by the squat effect and the bank effect.

As a consequence of a considerable increase in maritime traffic, in a river and coastal shipping environment, the possibility of a navigational failure resulting in an unintentional grounding must be taken into account.

These casualty eventualities must be considered from a casuistry perspective. This is why emphasis must be placed on continuous improvement, both in technical and human terms, in order to work towards a good prevention of groundings.

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2. Background.

It is common for a ship to have to sail very close to the coast, through narrow channels, estuaries and rivers due to the impossibility of having navigable waters in a more comfortable way to allow transport to the port of destination. A vessel entering one of these restricted water places sees dramatically increased and modified hydrodynamic forces to which it is subjected in normal navigation. These forces acting on the vessel must be foreseen and taken into account for a safe navigation that does not lead to an accident either by collision or grounding, which is the object of study of this work.

The Royal Spanish Academy defines beaching as; "To take a boat to the beach and put it dry, to protect it from the undertow or from the blows of the sea, or also to load it. To run aground on the coast or on the rocks, or on a sandbank". (Royal Spanish Academy, 2018)

This definition must be qualified in the context of this work, as we must first remove the part that refers to voluntariness. Then we will also clarify that there does not have to be grounding, as a vessel can hit the bottom and continue sailing, even to the extent that its occupants are unaware of the extent of the damage that could be caused, or even the grounding itself, as will be seen in a case that will be discussed later. (UK Marine Accident Investigation Branch, 2015).

The definition fits better: "Ships or vessels affected in their materiality as a consequence of the contact of the hull with the bottom, with the sand of the beaches or rocks of the coast, as well as with the remains of shipwrecks resting on the bottom" (González, 2013).

In order to better fit the term unintentional grounding in the context in question, we will therefore understand it as follows: when a ship sailing freely touches the bottom in an unforeseen manner. The grounding of a ship may have minor consequences, and the ship may even be freed by its own means in a short period of time, or cause quite serious damage given the large mass that is displaced, compared to the strength of the materials from which it is made, and may even result in the total loss of the ship and its cargo, as well as the loss of human lives.

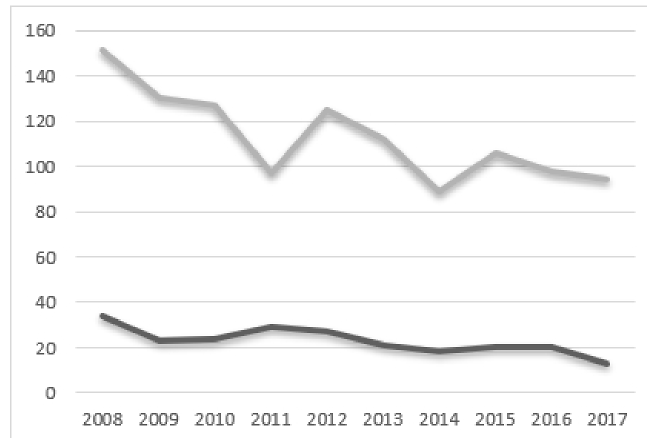
Table 1: Accidents by cause resulting in total loss 2008-2017.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Foundered (sunk, submerged)	73	61	64	45	55	70	50	66	48	61	593
Wrecked/stranded (Grounded)	34	23	24	29	27	21	18	20	20	13	229
Fire/explosión	16	14	12	9	13	15	6	9	12	6	112
Engine Damage/Failure	8	7	4	6	15	2	5	2	10	8	67
Collision (involving vessels)	13	13	10	3	5	2	2	7	1	1	57
Hull damage (holed, cracks, etc.)	4	8	4	3	7	1	5	2	4	5	43
Miscellaneous	1	2	6	1	1	1	2		1		15
Contact (e.g. harbor wall)	1	1			2		1				5
Missing/overdue	1		1						2		4
Piracy		1	2	1							4
Total casualties	151	130	127	97	125	112	89	106	98	94	1129

Source: Allianz Global Corporate & Specialty (2018).

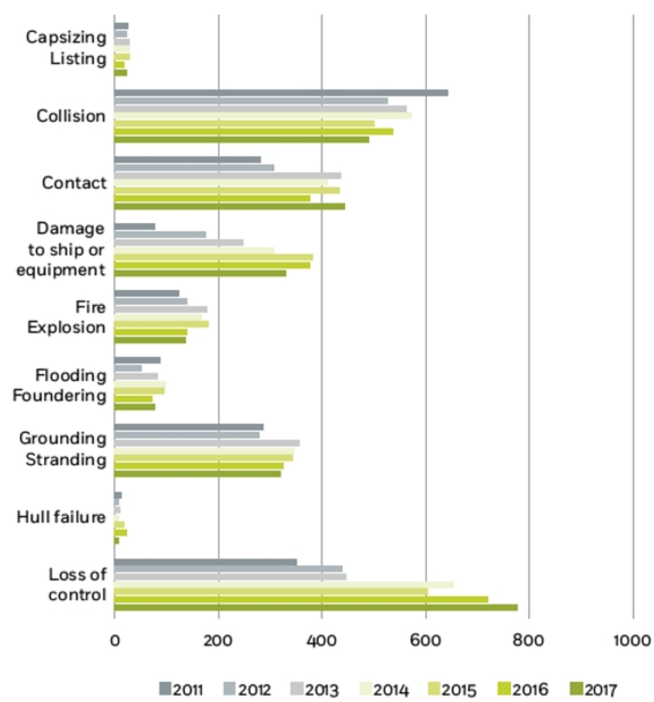
Although in the last decade, there has been a drop of around 38% compared to the previous decade in the overall accident rate in maritime transport resulting in total loss of the ship, with grounding being the main cause at 20%, (Allianz Global Corporate & Specialty SE, 2018) it is worth noting, for example, that from 2011 to 2017, 53.1% of total accidents in Europe, have as their origin a problem in the navigation of ships (European Maritime Safety Agency, 2018).

Figure 1: Total loss claims trend 2008-2017. Total (black), stranded (grey).



Source: Authors.

Figure 2: Accidents by cause in Europe.



Source: European Maritime Safety Agency (2018).

Mainly, we can divide the causes of involuntary groundings into two main groups according to the origin of the event that causes the incident; technical causes, in which a previous breakdown causes a loss of steering of the vessel and the grounding occurs, and human causes, in which the cause usually lies in human error when planning or executing the manoeuvre of the vessel in shallow waters. It should be noted, however, that there is usually no single cause, but rather a chain of events and factors that lead to the vessel hitting the bottom.

Among the technical factors, it is important to highlight anything that may cause a breakdown in the vessel that leads to a loss of steering capacity, or that the navigational aids on the bridge do not work correctly, causing the commanding officer to take the vessel where it was not planned to go in the planned course. A wide variety of failures can be listed with such negative endings as engine failure with loss of propulsion, rudder failure with the inevitable consequence of loss of the vessel's ability to manoeuvre effectively, false echoes in ARPA, error in GPS positioning or its entry in ECDIS, etc.

Among the most common causes of unintentional groundings are: the aforementioned steering failures, error in positioning the vessel, error in planning a safe course, error in executing the planned course, error in assessing the situation in which a vessel finds itself, failure to take into account or inadequate use of the squat effect or bank effect, or interaction with other vessels in restricted navigation zones, etc.

2.1. Human error as a decisive factor.

When technical failures occur, they are normally combated with an adequate maintenance programme, and even, in certain cases of failures in the ship's instruments dedicated to tracking the vessel's course and navigation, with an adequate evaluation of their proper functioning and, above all, a duplicity of instruments when taking the vessel's position at all times so that the commanding officer can assess their correct functioning at all times. This brings us to human failure, which is the major cause of maritime accidents.

Usually behind a grounding there is usually a large component of human error in the events that led to the vessel hitting the bottom. Even when there is an a priori technical failure, a grounding can often be prevented if the original failure is dealt with correctly by making the right decisions when acting and manoeuvring safely. In fact, between 2011 and 2017 out of a total of 1645 accidents in Europe, 57.8% are attributed to human error (European Maritime Safety Agency, 2018).

On the other hand, a study by Alliance Global Corporate & Specialty estimates that between 75% and 96% of accidents involve the human factor at some point in the accident, and in its study of insurance claims between 2011 and 2016, it concluded that in 75% of accidents human error was the main factor in causing the accident, with claimed losses valued at $1.6 billion. (Allianz Global Corporate & Specialty SE, 2018).

Human factors are of great importance in terms of the monetary figures they generate in the overall maritime trade casualty, but should not be considered trivial when judging the components and factors that influence human error to occur. This is beyond the scope of this paper, as it is very complex and requires detailed study and is beyond the scope of this paper.

However, it should be noted that commercial pressures from shipping companies on crews play an important role in making the wrong decisions at certain times (Allianz Global Corporate & Specialty SE, 2018). The fact of modifying the ship's course or speed to try to reach the destination port earlier has played a major factor in the cause of many accidents, including the following: (Schröder-Hinrichs, Hollnagel, & Baldauf, 2012).

3. Methodology.

3.1. Preliminary considerations.

For the purpose of this paper, a presentation of the effects to be studied will be made first, presenting their specific particularities and analysing them without going into mathematical depth beyond a practical question.

To emphasise the extent of the consequences of ignoring the effects to be studied, a series of particular cases are presented in which the squat effect and the bank effect came into play, first giving an account of the events, the conclusions reached in the two investigations, and then, in the conclusions, a brief personal analysis of the significance of these in the context that concerns us.

In the description of accidents, data that are not relevant to the purpose of this work will be omitted so as not to artificially extend it with data that are not relevant to the study.

After each effect, there will be a brief description of the actions to be taken to avoid its effects or to control them within safety margins.

3.2. Data collect.

For the realisation of this work, different bibliography was consulted, where all the theoretical information concerning the described effects was compiled, taking notes and then making a personal compendium of the relevant issues found on my part. Subsequently, for the conclusions I have made a contrast between my personal experience in my year of shipboard training and the compendium of data acquired in the bibliography. For the accidents, we have referred to the reports resulting from the investigation of the events that took place in each of them, carried out by the following:

- UK Marine Accident Investigation Branch.
- Maritime New Zealand Investigation Commission.
- Transportation Safety Board of Canada.
- Australian Transport Safety Bureau.

We consider these reports to be very useful, because they are made from an objective point of view, and as they are not intended to find fault or to prosecute anyone, they provide a good X-ray of the events and a study highlighting the events from a forensic perspective.

3.3. Research subject matter.

We have circumscribed the study to involuntary groundings, but within them, there are innumerable causes that lead to them, but for my personal interest of study, I have limited it to only the squat effect and the bank effect as I consider them sufficiently complicated, unpredictable and interesting to focus my study on them.

The effects are detailed from a preventive point of view in order to avoid groundings, and although I do go into some of the actions to be taken once a ship has grounded, my emphasis and main emphasis is on the part that concerns the previous events and the identification of effects and dangers.

The accidents studied have occurred in different parts of the world, not limited geographically by any criteria.

4. Results and discussion.

4.1. Squat effect.

The squat effect is the effect that occurs in any vessel navigating in shallow waters, which causes the vessel to increase its draught as it moves forward at a certain speed. This increase in draught is a function of the ship's speed and manifests itself in two ways: as an increase in draught in itself, and as a change in the ship's trim, which, although it does not change the ship's average draught, can increase the maximum draught due to drastic changes in the trim (Sagarra, 2006).

To understand this increase in draught, we first turn to the first law of thermodynamics, which states that energy is conserved at all times "In any process, the total energy neither increases nor decreases. Energy can be transformed from one form to another, and transferred from one object to another, but the total amount remains constant" (Giancoli, 2006).

Then we must resort to a basic principle of physics, "Bernoulli's principle states that where the velocity of a fluid is high, the pressure is low, and where the velocity is low, the pressure is high", (GIANCOLI, 2008) a fluid harbours energy within it in two ways; potential energy and kinetic energy, and tells us that by the principle of continuity the sum of energy at a given point in the system must be equal to the sum at any other point in the same system. Kinetic energy will be a function of weight and velocity, and potential energy a function of pressure.

- *Equation 1 Bernoulli's equation.*

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

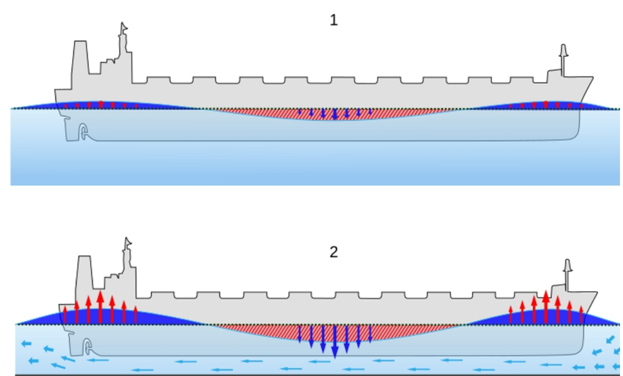
When a ship is moving at a certain speed, part of the water that is at the bow of the ship is pushed towards the front and sides of the ship and accumulates there, this water must return to the bottom and sides of the ship, this flow that is created increases the speed of the water moving under the keel of the ship to fill the gap that the ship creates in its displacement. According to Bernoulli's principle, if the velocity of the water moving under the boat increases, the pressure of the fluid must decrease, as this fulfils the sum of energies that the fluid system must have at all times. This decrease in the part of the potential

Figure 3: Water accumulation on the bow as a bulk carrier moves forward.

Source: Dawn Endico (2012).

energy results in a slight sinking of the ship as it passes through the water surrounding it at all times.

Figure 4: Open vs. shallow water squat effect.



Source: Walké & Sémhur (2008).

This effect occurs at all times when the ship is moving forward, regardless of whether it is in open water or in narrow channels where there is a shallow draught, but when it is in restricted waters, the less water under the keel, the higher the fluid velocity increases with a greater gradient to fill the void that the ship generates in its displacement. This higher velocity gradient results in a quite considerable drop in pressure, so the draught will increase considerably, something that is very important to take into account if the vessel is sailing in a channel where they have a fairly tight UKC.

A good way to calculate when the bottom starts to affect the hydrodynamic forces surrounding the vessel in a significant way is with the formula:

- *Equation 2 Initial depth.*

$$Hi = V \times 0.17 \times \sqrt[3]{\Delta}$$

Where:

Hi = Depth of probe where the effect becomes significant, in metres.

V = Vessel speed in knots.

Δ = Vessel displacement in tonnes.

This equation, which gives the starting depth of interaction of the bottom with the ship's hull, should be considered as significant when this depth is within 25-30% of the initial depth (UK Marine Accident Investigation Branch, 2015).

On the other hand, to obtain a more accurate or more realistic result, and when there is a restriction not only by sounding, but also by the width of the navigable channel, we can calculate in both dimensions when the bottom and the margins begin to interact with the ship's hull and cause a decrease in speed and squat. (Sagarra, 2006).

- *Equation 3 Influenceable channel width and probe.*

$$Influenceable\ channel\ width = 7.7 + 45(1 - C_f)^2$$

$$Influenceable\ channel\ probe = 4.96 + 52.68(1 - C_f)^2$$

Where C_f is the Buoyancy Coefficient of the vessel which if not known can be calculated:

- *Equation 4 Buoyancy coefficient of a vessel.*

$$C_f = \frac{2C_b + 1}{3}$$

The squat effect will affect all ships, but will do so in different ways depending mainly on certain factors:

- The shape of the ship's hull. The block coefficient of the ship will affect the squat effect to a different extent, both quantitatively and qualitatively. That is to say, depending on the hull tuning, the increase in draught will vary and will also affect the alteration of the vessel's trim in different ways, in some cases being able to move the vessel forward and out of the water in others.

- The shape and size of the channel through which the vessel sails. In short, the amount of water around the hull.

- The relative speed of the vessel with respect to the water through which it is sailing.

Two of these factors are "variables" that, as officers, we cannot change. The ship's hull is defined by its construction, and the channel through which we are going to sail is what it is, being only possible to act on the moment in which we transit, which can change the conditions of the channel due to natural factors, such as tides or weather conditions, which can affect the currents (and therefore the relative speed of the ship with respect to the water) and the amount of water that exists under the keel and along the sides up to the shore or navigable limit of the channel.

To calculate the safe depth to transit:

- *Equation 5 Safe transit depth.*

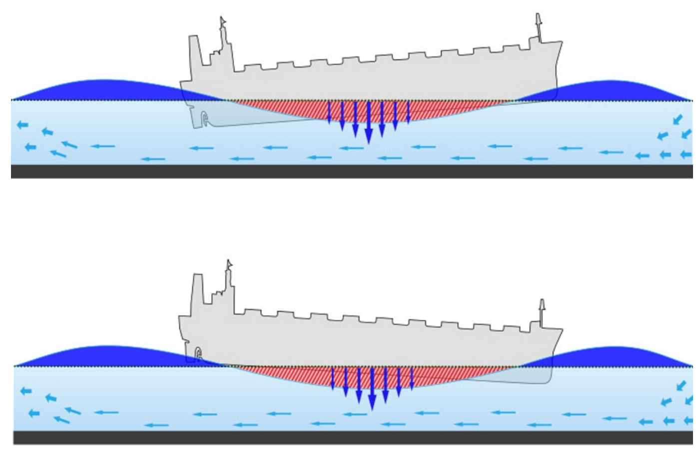
$$Safe\ depth = Draught + Squat + UKC\ min - Height\ of\ tide$$

The other variable that remains is the ship's engine speed, and here we can act directly, and it will also greatly affect the amount of squat that can be generated in transit through a narrow channel.

4.2. *Effect of Squat on trim.*

To predict how the squat will affect the ship's trim, one must start from the initial trim, since, if a ship has an apopant trim, then it will be the stern that starts to suffer the effect of the bottom first and it will be this head that will produce the increase in draft. If the ship's trim is forward, then it will be the bow that has the increase in draft before the rest of the ship.

Figure 5: Squat according to head closest to the bottom.



Source: Meisterkoch at German (2010).

When the vessel is in an equal water condition, then the squat will affect the vessel by increasing its draught, but this increase in draught usually affects one of the vessel's heads more depending on the C_b of the vessel. This effect does not occur at all speeds, but from a certain speed onwards, which is known as "critical speed". (Sagarra, 2006)

The critical speed can be calculated using a simple formula depending on the depth of the water.

- *Equation 6 Critical Speed Calculation.*

$$V_c = 3.13\sqrt{h}$$

Where h is the probe of the channel being navigated through.

In these circumstances the vessel will fall to bow if its $C_b > 0.7$ and will fall to stern when it is a more finely tuned vessel where $C_b < 0.7$ (Sagarra, 2006).

4.3. How to prevent the squat effect.

It is not a question of how to avoid the squat effect, as this is an effect that can be considered inherent to the forward motion of the ship, but rather how to prevent the squat effect from reaching a dimension that could be considered dangerous for the navigation of the ship in a certain place where we may have restricted the maximum draught that can be traversed.

Based on this premise, the most important thing when navigating in restricted waters is to plan the route to be followed and to control all the variables that may affect the squat effect.

The first, simple and fundamental one is that the higher the speed, the greater the squat effect generated, in fact we can consider that squat increases with the square of the speed approximately.

Although there are several fairly simple formulae for calculating the squat effect as a function of speed, it is something that is normally tabulated on the wheelhouse poster, usually located in the ship's logbook.

- Equation 7 Maximum squat in open water.

$$\delta_{max} = \frac{C_b \times V_k^2}{100}$$

- Equation 8 Maximum squat in restricted waters.

$$\delta_{max} = \frac{C_b \times V_k^2}{50}$$

Where:
δ_{max} is the maximum squat.
C_b the vessel block coefficient.
V_k the relative speed in Knots of the ship in relation to the water. (Derrett, 2006)

These formulas can be applied as long as there are no beam restrictions with respect to channel width, under these conditions other interactions related to channel blockage factor may occur (Derrett, 2006).

- Equation 9 Blocking factor.

$$Blocking\ Factor = S = \frac{A_s}{A_c} = \frac{b \times T}{B \times H}$$

Where:
A_s is the area of the master section of the live work.
b is the beam.
T is the static draught of the ship at equal water.
A_c is the effective channel section area.
B is the effective width of the fairway.
H is the depth of the channel.

When S gives values outside the range between 0.1 and 0.265, then it must be calculated by the squat formula from which the previous ones in Equation 7 and Equation 8 are based (Sagarra, 2006) (Derrett, 2006).

- Equation 10 Maximum Squat in all waters.

$$\delta_{max} = \frac{C_b \times S^{0.81} \times V_k^{2.08}}{20}$$

- Equation 11 Maximum squat under all conditions.

$$\delta_{max} = \frac{C_b}{30} \times S_2^{2/3} \times V_k^{2.08}$$

Where S_2 is obtained in the same way as S but taking into account only the wetted section of the channel, so that A_c must be subtracted from A_s.

Whether you consult the tables or have calculated it, for a planned speed you already have an initial draft measurement that must be added to the previous known draft.

Considering that the minimum water limit under the UKC keel must not be exceeded, all planning must be focused on maintaining that minimum margin at all times. To this end, an analysis of all natural variables is made prior to transit through the waters in question.

One of these natural variables, such as the tidal height, duly corrected for wind, atmospheric pressure, etc. The currents that exist, whether tidal or not, which must be taken into account in the previous step of calculating the speed, as this will affect the relative speed for the squat calculation. The density of the water, as if it is fresh water for example we must calculate the Fresh Water Allowance which will increase the draft of the vessel when entering from salt water into a river estuary.

Once the margin has been established it is then the job of the Officer in Charge of the watch to closely monitor both the plan and any deviations from the plan that may be observed that could be considered as a potential source of grounding hazards.

Paul R. Williamson, retired Senior Pilot, Port of London, in his work (Williamson, 2001) advises that this active observation will take into account four indications that the ship is generating an excessive squat effect and does not have sufficient UKC (Under Keel Clearance):

- The vessel begins to yaw erratically from the estimated course to be maintained.

- The vessel Increased vibrations coming from the propellers are perceived. These vibrations may also be caused by a resonance caused by water constricted between the hull and the bottom and the other vibrations of the ship..

- A change in the waves generated aft causing them to crest and break.

- A considerable drop in propeller revolutions and consequently in speed.

Apart from these four, we can list a few more such as:

- A considerable drop in speed does not necessarily have to be accompanied by a decrease in propeller revolutions, or at least to the same extent, and this decrease in speed can even be as much as 75% if it occurs in fairly restricted waters.

- In addition to yawing, certain movements of the boat may occur, such as rolling and unexpected pitching, which are symptoms of being too close to the bottom.

- An evolution curve that is too wide for the boat's normal turning capacity.

If any of these signals occur, the first thing to do would be to reduce the engine and observe the reaction of the boat, which, by reducing the squat effect, can even gain speed with respect to the ground, something to be taken into account as it can generate situations which, if not expected, can lead to a bad manoeuvre and even cause the boat to capsize in a bend if it is not foreseen in time to initiate an evolution curve appropriate to the turn to be made.

4.4. Cases of groundings involving squat effect.

4.4.1. Commodore Clipper.

Figure 6: Commodore Clipper.

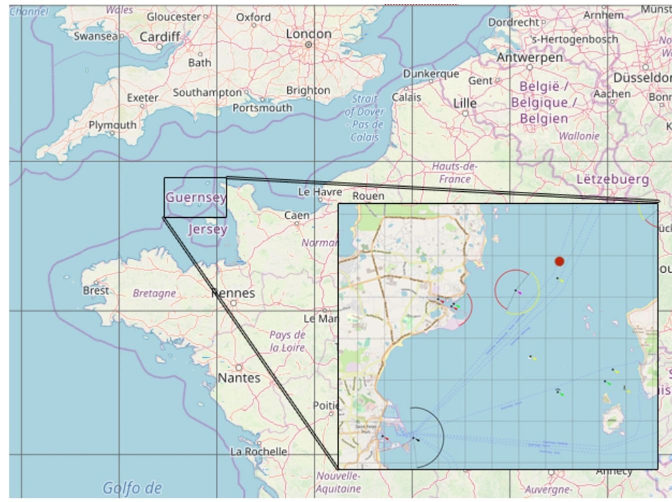
Source: Brian Burnell.

At 1515 on 14th july 2014 the passenger ferry Commodore Clipper, grounded while approaching its destination at St. Peters Port in Guernsey, where it hit bottom on a rock. After the grounding the ferry was able to continue sailing to its port of destination. Subsequently, once in port and after a visual underwater inspection, it was found that the hull had been significantly damaged with breaches and waterways.

After a regular trip of the ferry, as it was about to enter the approach to the harbour, on the bridge were the Captain in command, the First and Second Officer and a helmsman at his post. At that moment, in the vicinity of the Roustel beacon passage, at 1510, the captain ordered the helmsman to fall a little to port to make the ship go to the planned course, as there was a cable to starboard, but when he gave the order to return to the original course of 220°, the ship's steering was not stable and he continued to give consecutive orders for new courses, each time more to Er to correct, eventually giving the helm order to set a course of 226°. At 1515 and on a course of 226° and at a speed of 18.2 knots over the bottom, a shudder and a noise was felt throughout the ship that lasted 9 seconds.

Following this vibration, the order was given to slow down and check if there was anything wrong with the ship, but when nothing was found, except the perceived vibration and shuddering, which the Chief Engineer described as something he had never experienced before, the ship returned to the route to the port of destination at full speed, the Captain alluding that it must be nothing serious, no more than a line caught in the propeller, as it had previously passed even closer to the Roustel beacon and he assured that there was enough water.

Figure 7: Commodore Clipper accident location.



Source: Authors.

All appeared normal after that, so much so that once in port, and once unloaded, they began to load again to leave again, while routine (pre-programmed) underwater visual inspection work was carried out, where it was found that considerable damage had been sustained to the hull as a result of the grounding, with several spaces in the double hull being found full of water due to the breaches that were found.

Table 2: Commodore Clipper Accident Information.

SHIP PARTICULARS	
Vessel Name	*Commodore Clipper*
IMO number	9201750
Port of Registry	Nassau
Date of Build	1999
Vessel Category	Ro-ro passenger ferry
Overall Length (m)	129.5
Maximum Breadth (m)	26
Draught (m)	5
Gross Tonnage	14000
Flag	Bahamas
VOYAGE PARTICULARS	
Port of departure	Portsmouth, UK
Port of arrival	St Peter Port, Guernsey
Cargo information	Road freight trailers, cars and passengers
Manning	39
MARINE CASUALTY INFORMATION	
Date and time	14 July 2014, 1515 UTC + 1
Casualty Type	Grounding
Location of incident	Little Russel, Guernsey 49°29.36'N, 002°28.73'W
Damage/environmental impact	Hull damage, void space flooding
Ship operation	On passage
External & internal environment	Wind: south-westerly, force 5 / Sea state: slight / Visibility: good
Persons on board	39 crew and 31 passengers

Source: Authors.

Subsequently, the investigation found the following conclusions (UK Marine Accident Investigation Branch, 2015):

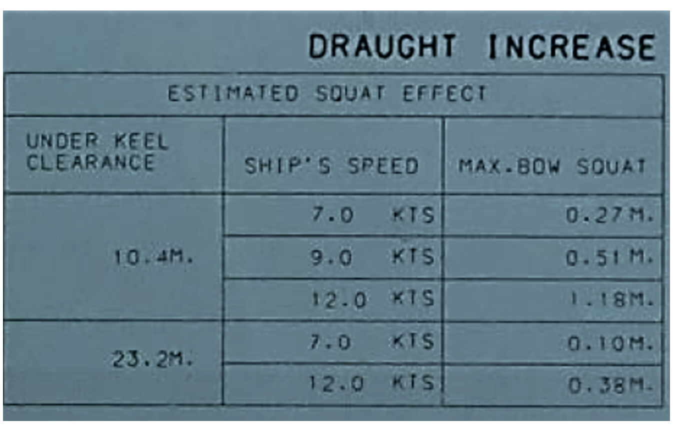
- The ship had collided with two granite spires in an area mapped with a 5.2 m sounding.

- The low tide for that day was at 1509 with a height of 0.8 m, and at 1515, the time of the accident, the tidal height was calculated at 0.9 m and there was an abnormal tidal current of 2-3 kts in the area which deflected the ship to portside from its course to follow.

- With a displacement of 7975 T, and a speed of 18 kts, as soon as it sailed at less than 18 metres it would already encounter a significant effect from the bottom on the hull.

- The ship's deck officer did not take sufficient measures to position himself accurately and did not properly assess the squat effect, which was calculated at the time of impact at 1.46 m. Even taking the squat tabulated on the wheelhouse poster and estimating it at 1.2 m (see Figure 9), as the draught was 5 m, the minimum UKC established by the company of 1 m, a minimum safe depth of 6.3 m was established. An error of +/- 1.2m was disregarded as the charts of the 1960 area.

Figure 8: Report on the investigation of the grounding and flooding of the ro-ro ferry Commodore Clipper in the approaches to St Peter Port, Guernsey on 14 July 2014.



DRAUGHT INCREASE

ESTIMATED SQUAT EFFECT

UNDER KEEL CLEARANCE	SHIP'S SPEED	MAX.BOW SQUAT
10.4M.	7.0 KTS	0.27M.
	9.0 KTS	0.51M.
	12.0 KTS	1.18M.
23.2M.	7.0 KTS	0.10M.
	12.0 KTS	0.38M.

Source: Crown, (2015).

4.4.2. Capella Voyager.

On 16th april 2003, the tanker Capella Voyager arrived at the port of Whangarei in New Zealand to unload the crude oil she was bringing from the United Arab Emirates. At 0530 she proceeded to the Pilot Station for loading.

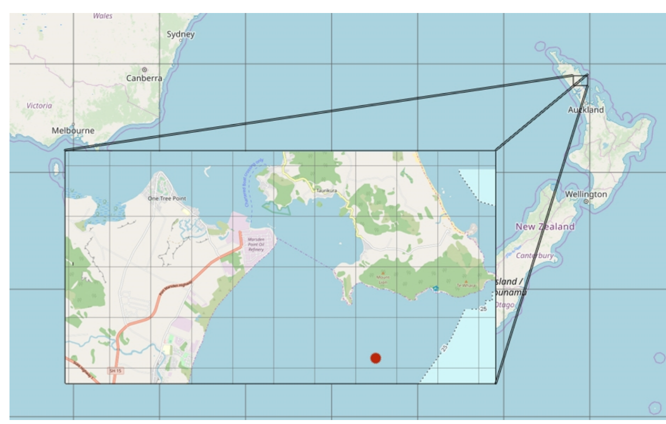
The weather forecast predicted an easterly swell of 4m for that morning and when they were 5 miles from the entrance bar, which has a heading of 320°, the Captain observed a roll of 5° and estimated a pitching of 2.5m. This movement of the vessel caused by the heavy seas increased as they reached 2.3 nm from the bar, which prompted the Master to abort the entry into port. He alerted the pilot officer of the fact, as he had not yet arrived to embark, and they agreed to try again on the next tide and to assess the situation with the pilot officer on board.

At 1600 hours the Capella Voyager again began an approach to the harbour entrance bar to assess the conditions to see if this time it was feasible to enter, this time at 5 nm from the bar and being aligned with the entrance, the ship only experienced a roll of 2°, At 1728 the Pilot boarded 2 miles from the bar and after discussing the situation, they agreed to begin the manoeuvre to enter the harbour, observing that the conditions were much better than in the previous attempt.

Figure 9: Capella Voyager.

Source: Capt. Lawrence Dalli, (2004).

Figure 10: Capella Voyager accident location.



Source: Authors.

At 1 nautical mile from the bar, the distance previously agreed as the point of no return, an order was given to make a 360° turn to starboard to assess the ship's behaviour in the swell. After completing the turn, it was agreed to continue with the manoeuvre.

At 1813, the Capella Voyager had the buoy marking the entrance to the channel through and was developing a speed of between 5 and 6 knots. Just after entering, the ship began to yaw 6° to starboard and 9° to port while the bow began to pitch 1.5m in what they estimated to be a 3m swell, occasionally 4m, and a 5° roll was generated.

At 1816 the ship bottomed out as it pitched and rolled, and could even be seen to sag from the bridge. At the bottom there was a drop in speed to 3 kts.

In total the ship hit bottom twice in her movement, but was able to continue sailing until berthing, during which time it was observed that the bow peak was damaged and water was entering. The ship was moored at her berth at 2036 hours.

Table 3: Capella Voyager Accident Information.

Vessel Details	
Vessel Name	Capella Voyager
IMO number	9012616
Port of Registry	Crude Oil Tanker
Date of Build	1993
Vessel Category	Crude Oil Tanker
Overall Length (m)	258.9
Maximum Breadth (m)	48.3
Draught (m)	14,42
Gross Tonnage	80 914
Flag	Bahamas
VOYAGE PARTICULARS	
Port of departure	Fujairah, United Arab Emirates
Port of arrival	Whangarei, New Zealand
Cargo information	107800 tonnes of light crude oil
Manning	27
Casualty Details	
Date of Casualty	16 April 2003
Time of Casualty	1816 LT
Casualty Type	Grounding
Casualty Location	Approaches to Port of Whangarei, New Zealand
Weather	south west by west wind 14 Kts, easterly Swell 3 m

Source: Authors.

Subsequent investigations found (Maritime New Zealand, 2003):

- In the proximity of where the Capella Voyager beached, a difference in channel depth was found in just 2 cables from 18.5m to 14.6m, which is considered to be a significant variation affecting the squat effect differently than if it were over a constant bottom.

- The UKC calculation by Capella Voyager's First Officer includes the squat effect, but does so for calm water and does not include the effect of the sea lying.

- The Pilot's calculation of UKC was to add 10% to the draft. He did not include in his calculations either the squat effect or the effect of the sea.

- With the UKC noted on the pilot card of 2.1m the investigator considered the grounding to be almost inevitable with the sea conditions combined with the squat effect that was generated.

- A ship of this type, with the forward and backward motion created by the swell of the ground waves combined with a second transverse heeling effect, would create an additional draft increase of about 0.83m.

Just 3 months after the Capella Voyager accident, the Easter Honor, an oil tanker of very similar characteristics, dimensions and cargo to the Capella Voyager, proceeding to enter Whangarei harbour through the same channel, with similar swell conditions, struck bottom on its bow in the vicinity of the entrance to the main channel (Transport Accident Investigation Commission New Zealand, 2003).

4.4.3. Canadian Transfer.

On 14th may 2001 at 1300, the Canadian Transfer, a bulk carrier carrying salt for road de-icing, departed the port of Goderich in Canada. The weather was fine, with good visibility, a light W breeze and between medium and one knot of current N. The tide was 0.08m below the chart sounder.

Once out of the harbour, on the bridge there remained; the Captain who was training to take command of the boat and a helmsman. Given the relative ease with which the departure manoeuvre was made through the outer exit channel to the dock, there was no pre-departure voyage plan, the Captain gave a course order of 272° which the helmsman executed, normally the existing aids to navigation would indicate a departure course of 266.5°, but no change of course was given. Normally given the characteristics of the location and the good weather, few corrections had to be made to the helm to maintain the course.

Figure 11: Canadian Transfer.

Source: Jim Hoffman, (2010).

As the ship gained speed, the Second Officer, who was the officer on watch for navigation, arrived on the bridge, and received the Captain's orders for navigation and calculations to arrive at the agreed ETA. This exchange was carried out by the two of them on the bridge's quarterdeck, at the back of the bridge, while they took a quick look at the ECPINS to check that everything was OK. The vessel at the time was sailing 1.6 cables north of the port departure track at a speed of 11.4 knots when a loud booming sound was heard. According to the crew it sounded as if an anchor had been let go in to give anchorage, so they even went to check that both anchors were stowed in place, which they found they had hit bottom.

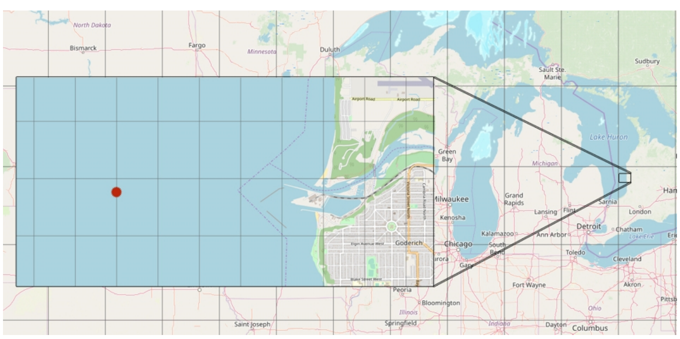
Because of the damage caused to the hull of the vessel, a heel of 6 to 8 degrees to portside was generated and the incumbent Captain, after taking command, took the decision to anchor.

Table 4: Canadian Transfer Accident Information.

Vessel Details	
Vessel Name	Canadian Transfer
IMO number	6514869
Port of Registry	Toronto, Ontario
Date of Build	1965, converted in 1998
Vessel Category	Self-Unloading Bulk Carrier
Overall Length (m)	198
Maximum Breadth (m)	20
Draught (m)	F: 7,34 A:7,625
Gross Tonnage	11120
Flag	Canada
VOYAGE PARTICULARS	
Port of departure	Goderich, Ontario
Cargo information	14 846 metric tonnes of road salt
Manning	24
Casualty Details	
Date of Casualty	14 may 2001
Time of Casualty	1318 LT
Casualty Type	Grounding
Casualty Location	43° 44.8' N, 081° 46' W
Weather Forecast Area	clear and calm

Source: Authors.

Figure 12: Canadian Transfer accident location.



Source: Authors.

Subsequent investigations revealed the following (Transportation Safety Board, 2003):

- There was no officer exclusively dedicated to the navigation of the ship once it had passed the harbour breakwater. There was no active monitoring of the vessel's course and the electronic chart safety parameter settings were not entered, so no navigational safety alarm was triggered.

- The vessel was on a wrong course outbound which was not corrected at any time, entering an area where the chart showed a depth of 8.23m which at that time was 8.15m at the tide. The ship's static draught on leaving port was 7.34m forward and 7.63m aft.

- With the Canadian Transfer's C_b of 0.8 at the speed of 11.4 Kts the ship produced a squat of 1.10m being more pronounced fore than aft, so with the UKC of only 0.67m it was insufficient for the ship's transit through that area.

- The routine speed used to leave Goderich Harbour is 6-7 kts, which, had this been the case that day on the Canadian Transfer, would have caused a squat of 0.29 to 0.39m, making it pass smoothly without ever touching the bottom.

4.4.4. Additional cases in which the Squat effect was involved.

Queen Elizabeth 2

On 7th august 1992, the Queen Elizabeth 2 grounded against inadequately charted rocks while sailing in Vineyard Sound, off the coast of Massachusetts, coming from Martha's Vineyard, the weather was fine and visibility was good. The cause of the grounding was found to be a combination of several factors; the chart soundings were significantly smaller than charted, the state of the tide was not properly assessed, and the squat effect was substantially greater than allowed in the area due to the high speed of the ship as it was running late. This squat, which the Captain estimated was somewhat minor and would be apopant due to the ship's tuning on the hull, was in fact apopant, as it came out of the initial static condition. (Marine Accident Investigation Branch).

Herald Of Free Enterprise

On 6th march 1987, late and with a tight schedule to keep, the Ro-Ro Pax Herald of Free Enterprise manoeuvred out of Zeebrugge harbour. This is perhaps one of the most famous accidents involving the squat effect due to the high cost in lives that the incident claimed, resulting in 188 fatalities and the speed at which the wreck occurred. The combination of fatalities that contributed to the disaster were: the bow helmet was not left in its stowage due to the carelessness of an officer who did not check it because he was in a hurry to leave. The ship was also carrying more cargo than estimated due to a difference between the real weight of the vehicles transported and the declared weight, which meant that it was carrying more draft than calculated, and also with a larger bow seat. Due to the same haste and the design of the vessel, the Herald reached a high speed of 18 kts in a short period of time before it left the harbour exit channel, which caused a squat, sinking the bow and increasing the height of the wave generated at the bow enough to allow water to enter the hold of the ro-ro cargo, which caused the vessel to capsize. (UK Department of Transport, 1987).

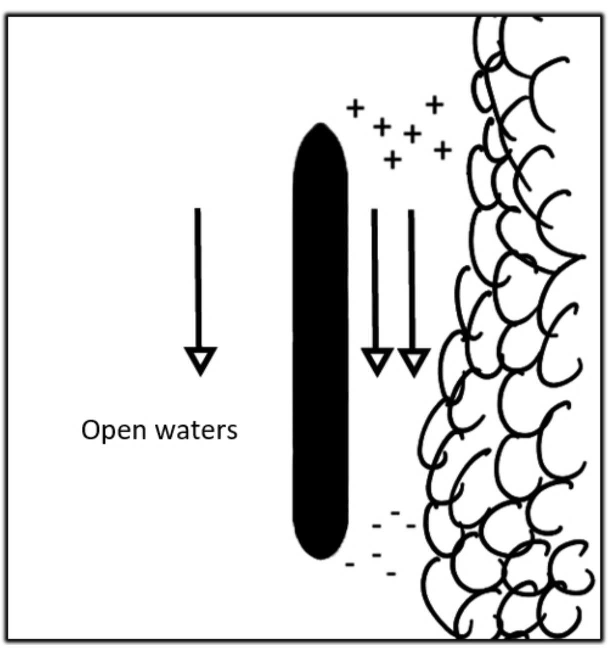
Desh Rakshak

On 4th january 2006, the tanker Desh Rakshak with 80,000 tonnes of crude oil on board, on approach to the port of Port Phillip, Australia, with Pilot on board, deviated from the entrance channel more than the Pilot estimated, but no one noticed anything until, once at anchor, they found that the bow peak was punctured and water was entering. In the investigation, among other factors, it was found that the Pilot did not estimate the squat effect generated by the ship's forward motion at 8 kts as problematic, but what he did not take into account was that squat should be calculated by the speed relative to the water and not the bottom, and not the bottom, so given the tidal current which was estimated to be between 5 and 6 kts against the ship's forward motion, the speed to be taken into account for the squat calculations was over 13 kts and not 8, which generated a squat of 1.35m and not 0.5m. (Australian Transport Safety Bureau, 2007)

4.5. Bank effect.

A ship navigating in a fluid, displaces a certain amount of water towards the sides of the fluid, which then gain speed towards the rear of these sides to fill the void generated in its movement. If navigation takes place in open water or in the middle of a channel, the pressure differences produced on the sides will be equal and counteract each other, so there is no lateral effect on the ship that would affect its attitude towards navigation. On the other hand, when leaving the centre of the channel and sailing through an area where the navigable limit of the channel or the shore is considerably closer to one side, there is an asymmetry in the forces acting on the vessel due to the difference in fluid velocities on the sides of the vessel, and consequently, a pressure difference is produced by the same principles mentioned above, causing a suction tendency on the boundary of the channel closest to the vessel, which can cause a yawing effect, even making the steering inoperative as the rudder loses all its effect on the manoeuvrability of the vessel. This effect is known as the bank effect.

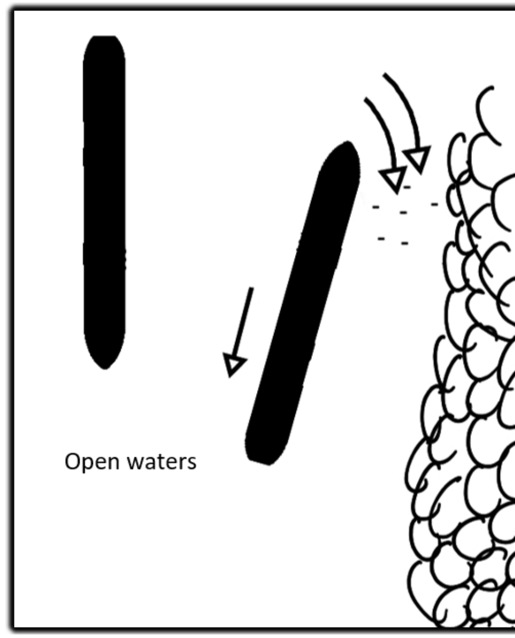
Figure 13: Bank effect.



Source: Authors.

When the ship moves forward, if it is parallel to the shore, following the waves generated at the bow, the water elevation between the ship and the shore is less than that between the ship and the centre of the channel through which it sails or the open water, and this causes a suction to be generated towards the shore by the stern, since the resultant of the forces generated is towards the stern of the centre of gravity. On the other hand, if the vessel is sailing at an angle towards the shore because, for example, it is trying to avoid another vessel that is coming from the opposite side and falls to the side, it will be the bow that will produce the suction as it is closer to the bank and it will be the bow that falls towards the shore (Hooyer, 1983).

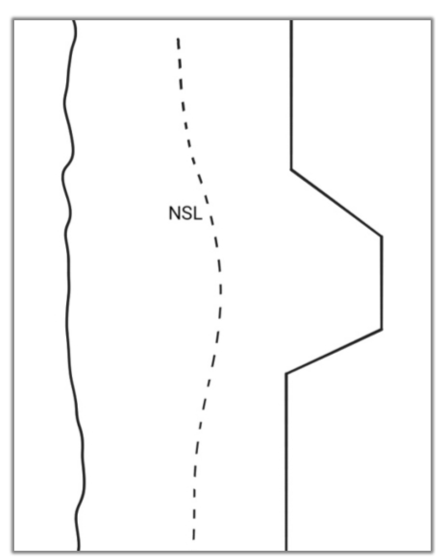
Figure 14: Bank effect over one head.



Source: Authors.

Due to this lateral effect that occurs in the channels, it should be noted that in all of them there is a theoretical line known as the Neutral Steering Line (NSL) (Gates, 1989), which is the line along which the vessel retains a neutral attitude without having any rudder angle in the tiller. The position of the NSL can be estimated as the point where both water flows generated at the sides of the ship are equalised in their advance, it should be noted that given the natural asymmetry of most of the channels or rivers navigated, this line does not necessarily have to be located in the navigable centre of that section of the channel.

Figure 15: Neutral Steering Line.



Source: Authors.

The variables that affect the suction produced by the channel margin are as follows:

- The length, beam and draft of the vessel.
- The depth and width of the channel being navigated.
- The distance of the vessel from the NSL of the channel through which it is navigating.
- The density of the fluid being navigated and the relative speed of the vessel.

In this case, these interactions give rise to an effect on the yaw or yaw moment caused by the bank effect which will be a function of:

- Bank effect itself.
- The length and draught of the vessel, and the depth of the channel.

As with the squat effect, all of the above variables, some will be variables that we cannot control because they are defined by the construction of the vessel or at most by choosing the moment that the channel is traversed according to variables affected by natural events, such as wind, tides, etc. On the other hand, we can act directly on the relative speed of the vessel by applying changes to the engine, just as we have control over the distance of the vessel to the NSL of the channel we are navigating, provided we have taken care to actively find that line.

4.6. How to prevent the Bank effect.

As occurs for the squat effect already analysed, good planning is the key to a successful and safe transit, taking into account the variables that affect an eventual interaction effect with a bank or shore.

Within this planning, it is necessary to identify the possible deviations that can be found within the planned course of the NSL with the centre of the fairway, which is important when judging whether or not the ship is distant from the NSL at any time during navigation, since it is indisputable that it is much easier to intuit which is the centre of the channel, than a certain position away from it (Gates, 1989).

The NSL can be affected by many irregularities; asymmetries, currents inherent in the shape of the channel, tidal currents, bends, a submerged object, etc. This data is normally provided by the pilot as it is something that is calculated in a complicated way and requires large operations that are normally done at different site conditions and that in his experience, the pilot also refines. For its calculation, what must first be established is an ”effective width” of the ship, which is the width at which the ship offers influence on its surrounding waters, which can be calculated with the following equation (Gates, 1989):

- Equation 12 Effective breadth of a vessel.

$$B = b \times \sqrt{101 - (L/b)^2}$$

Where b is the breadth of the vessel and L its length between perpendiculars. It should be noted that on each side of the ship the water affected will be up to a distance B/2.

The NSL will be found where the hydraulic radii on both sides of the vessel equal the hydraulic radius of the entire channel, where the hydraulic radius will be the quotient between the area of the section to be considered and the ”wetted” perimeter of the section.

- Equation 13 Hydraulic radius calculation.

$$Hydraulic\ radius = R = \frac{A}{P}$$

A is the area of the channel section and P is the perimeter of the ”wetted” part of that section.

Once the position of the NSL is clear, it is necessary to plan in advance when it may be necessary to deviate from the reference line, usually at points where it is necessary to deviate from the course either because there is another boat on the way back, you want to overtake another boat that is catching up, or on the contrary, you have to give way to someone who is catching up. It is good practice to know, both from the pilot and the AIS, the position and speed of the existing traffic in order to foresee in good time where the crossings and encounters with these ships will occur and thus choose a good place where the moment of greatest proximity to them will occur.

Although it is not the purpose of this study, it should be mentioned that, when passing close to another vessel of considerable displacement in relation to its own vessel, there will be interactions between both of a similar nature to the squat and bank effect, where it should be considered that if the relative speeds of both vessels are added together, so that the interactions between them can become considerable.

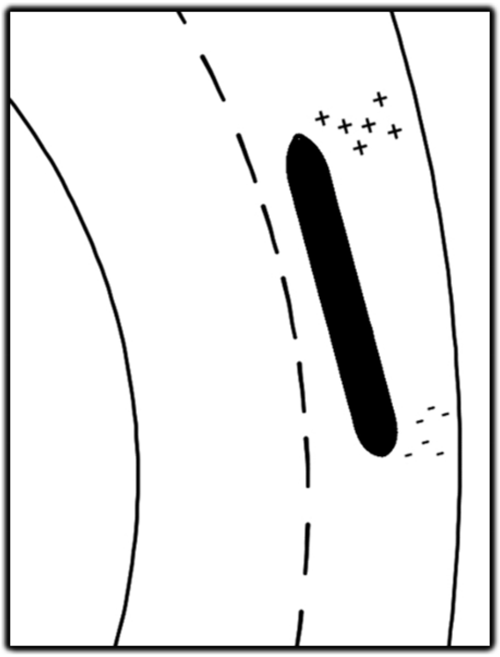
To avoid these interactions between vessels, the ship normally changes course, moving away from the NSL towards the side of the channel, where the suction effect due to the bank effect comes into play. To correct this effect, the pilot must act on the attitude of the vessel by setting the rudder angle to stop the rotation of the vessel and by changing the drift angle to avoid the translational movement towards the shore generated by this effect.

The ship's attitude works with the ship's lateral forces and the ship's yaw moment to counteract the lateral suction force from the shore, and the yaw moment created by this suction. As the lateral suction force of the bank effect and the lateral force produced by the ship's attitude increase as the ship's speed increases, we can disregard this variable when dealing with the appropriate manoeuvre to avoid suction.

This last statement is not entirely correct because at low speeds, both for the bank effect and for the squat, the opposite effect or ”cushion” can be produced, in which instead of suction being pruduced, an opposite thrust is produced caused by the accumulation of a ”cushion” of water that repels the vessel from the surface it is approaching. This makes it more difficult to foresee at all times all the effects that could be generated, so this is where the skill and instinct of the commanding officer, and the pilot if any, comes into play, as these effects can be generated in different ways under the same conditions due to the different constructions of each ship.

On the other hand, the bank effect can be used in favour of the intention to follow the course of a river by simply taking the boat beyond the NSL towards the opposite bank to the side to which the boat wants to fall, because of the effect of the suction at the stern, the boat will tack on its own without having to apply rudder, except to correct the fall at the desired rate. (Hooyer, 1983).

Figure 16: Use of the Bank Effect for tacking.



Source: Authors.

4.7. Cases of groundings where Bank effect was involved.

4.7.1. Algontario.

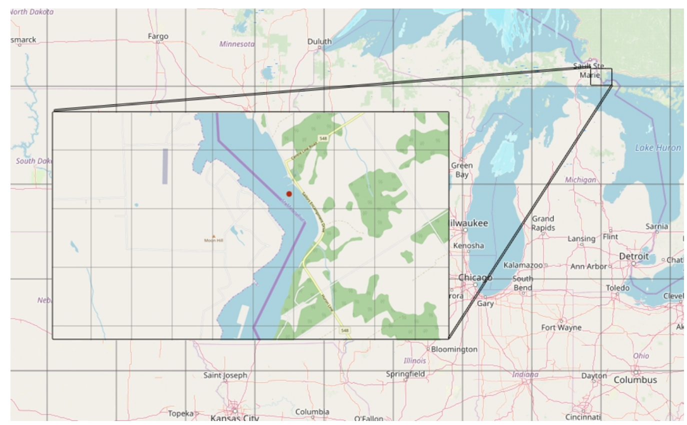
Figure 17: Bulk Carrier Algontario moored in Toronto.

Source: Geo Swan.

On 5th april 1999 at 0345 hours, while navigating the St. Marys River, the Algontario was approaching a bend with the Captain in command of the watch, an officer and a coxswain. The night was clear and there was a light breeze from the E. For navigation on the river, reference was being made to the lights on the banks as well as the ECDIS for support.

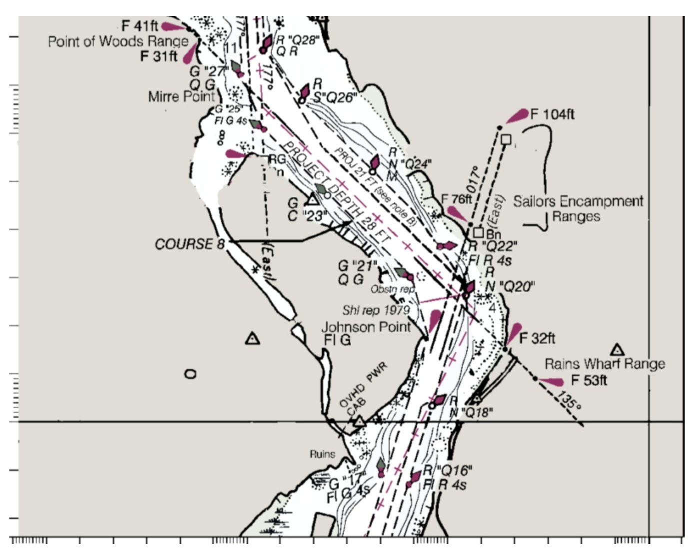
The Algontario was approaching from the left hand side of the sidelights and the skipper moderated the engine to obtain a speed of 7.1 kts off buoy Q18 (see Figure 19). At 0439 when about 60 m from Johnson Point through Br and already more than half a length past that point, the Captain ordered all Br to make the turn around the bend and increased the engine to 6 points to gain rudder steerability.

Figure 18: Algontario accident location.



Source: Authors.

Figure 19: Johnson Point where the Algontario beached.



Source: Transportation Safety Board of Canada.

The bend was a left turn of about 63° change of course and as the rudder came all the way to portside, the ship began to fall back to the same side. The Master and the officer on the bridge followed the evolution of the ship's fall and noticed that the turn was slower than normal so he increased the engine to 7 points. The vessel continued to fall to portside as it drifted to starboard as well and it was then that a vibration was felt as it hit the bottom.

The grounding occurred on the starboard side up to the stern, several ballast tanks were damaged and the ship heeled over and rested on the edge of the fairway.

Table 5: Algontario accident data.

Vessel Details	
Vessel Name	Algontario
IMO number	5301980
Port of Registry	Toronto, Ontario
Date of Build	1977
Vessel Category	Gearless bulk carrier
Overall Length (m)	222,5
Maximum Breadth (m)	23,1
Draught (m)	F: 6,6 A:7,8
Gross Tonnage	18883
Flag	Canada
VOYAGE PARTICULARS	
Port of departure	Clarkson, Ontario
Port of arrival	Duluth, Minnesota
Cargo information	18,910 tonnes of bulk cement
Manning	23
Casualty Details	
Date of Casualty	5 april 1999
Time of Casualty	0443 LT
Casualty Type	Grounding
Casualty Location	46º 15.6' N, 084º 06.1' W
Weather Forecast Area	clear and good; winds light from the east at 10 knots

Source: Authors.

Subsequent investigations revealed that (Transportation Safety Board, 2001):

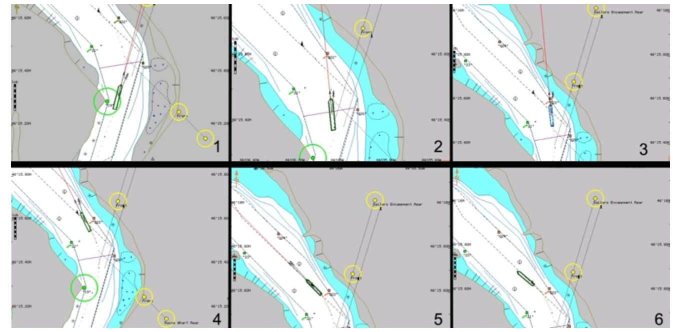
- In the Great Lakes, there is a specific flow of water that causes the mean water level to change and generate specific currents; on that day at 0443 the lowest level was one inch above the chart sounder.
- At Johnson Point a current against the vessel's course of 2 kts was estimated at the time of grounding.
- The vessel described a much larger than normal turning arc evolution due to a combination of:

1. When the all to portside command was given, the ship's stern was considerably closer to the shore at her portside, while the bow was in much more open water, so that because of the speed she was carrying, there was a suction from the shore on her stern, causing her to slow the bow's fall to that side.

2. At the speed the Algontario was going, a squat of 0.7 m was estimated, which reduced the UKC of the stern to about 0.33 m, causing the resistance of the wave generated at the bow to increase, slowing the manoeuvrability of the vessel.

3. The action of the 2 kts of current against, influenced portside's tack, pushing the bow against the intended direction of the ship's turn.

Figure 20: Evolution sequence of the Algontario at Johnson Point.



Source: Transportation Safety Board of Canada.

To rescue the ship from the grounding, a plan to lighten the ship's fuel had to be carried out, as well as to release all the ballast from the undamaged tanks, and it was refloated at 1830 hours on 7th april.

4.7.2. Attilio Ievoli.

Figure 21: Attilio Ievoli in Rotterdam.

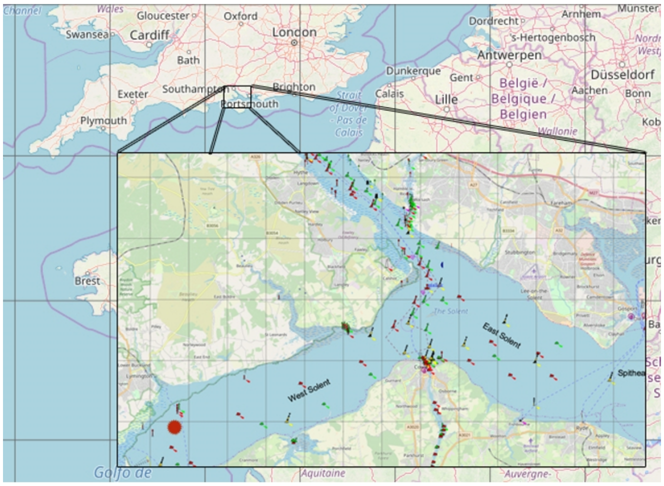
Source: Alf van Beem (2006).

On 3rd june 2004 at 1515 hours, the chemical tanker Attilio Ievoli left the port of Southampton for the English Channel bound for Barcelona using the Solent's West route as it was the shortest way to its destination, something that a priori already contravenes the company's guidelines, which stipulate using the East route.

On the mentioned west route, there is no pilotage service from a point called East Lepe, so the pilot disembarked at that point. They were on autopilot, there was no significant traffic and the weather was fine. It was not clear to either the Second Officer or the Trainee who was in charge of the navigational position watch, but both were taking some positions relative to the passing of the buoys. The Captain was distracted talking on the ship's mobile phone.

The portside radar was not available as the station was being used by the Chief Engineer to monitor the engine, and to use the Es radar it was necessary to do so by occupying the space of the Master's station.

Figure 22: Attilio Ievoli accident location.



Source: Authors.

At 1610 at West Lepe Buoy by the traverse, the Second Officer took position and saw that he was at a distance of 2.1 cables from the buoy, so he communicated to the Captain that they were further North than projected, but the Master did not hear him. The Second left the bridge and when he returned a few minutes later he saw that his previous position at 1610 had been erased by the Pupil who had corrected it as if the ship was on the planned course, which the Second did not agree with. At 1618 hours another position was taken within the course but neither recalled who had taken it.

At 1632 hours at a speed of 11 kts the Attilio Ievoli ran aground about half a mile north of the course it was to follow. The Attilio Ievoli did not report that it was stranded, but it was from a passing yacht that alerted VTS Southampton and they alerted the Solent Coastguard. The Coastguard tried repeatedly to communicate with them on VHF, but were unsuccessful until 1720.

At 1805 the Attilio Ievoli was clear of the grounding and after underwater inspection was found to have no major damage. Subsequently, the investigations revealed that (Marine Accident Investigation Branch, 2005):

- From 1600 to 1642 various calls were made on the ship's mobile phone from the bridge. During the grounding, a call from the Master was in progress.

- According to the data recorded on the VDR it was found that from 1614 to 1624 the course set on the autopilot was 249° when the planned course was 246°, so the ship was gradually drifting away from the plotted course.

- At 1924 there began to be a slow drop from course 249° to 240°, but as noted on the rudder log, the rudder was attempting to regain course by setting rudder 10° to Er, from which it is inferred at that time the ship was experiencing suction on her stern from the navigable limit of the channel, causing the bow to drop to Br and the autopilot was attempting to correct by setting rudder to starboardside.

Table 6: Attilio Ievoli accident data.

Vessel Details	
Vessel Name	Attilio Ievoli
IMO number	9104873
Port of Registry	Naples
Date of Build	1995
Vessel Category	Chemical tanker, IMO Type II
Overall Length (m)	115,5
Maximum Breadth (m)	16
Draught (m)	A:6,5
Gross Tonnage	4450
Flag	Italy
VOYAGE PARTICULARS	
Port of departure	Fawley, Southampton
Port of arrival	Barcelona
Cargo information	completed of toluene and styrene monomer
Manning	16
Casualty Details	
Date of Casualty	3 june 2004
Time of Casualty	1632 LT
Casualty Type	Grounding
Casualty Location	50°43.'5N 001°30.'7W
Weather Forecast Area	south-westerly force 3 to 4 with a slight sea

Source: Authors.

- At no time did any of the crew realise this and the vessel eventually ran aground.

4.7.3. Other cases where the Bank effect was involved.

Regal Princess

On 16 March 2001 at 0200, the passenger ship Regal Princess, proceeded to sail from the Queensland port of Cairns after having delayed the originally scheduled departure time of 1700 the previous day due to wind and tide slackening. During the course of the departure through the harbour channel at a speed of 15 kts the vessel suddenly began to experience uncontrollable heavy yawing, eventually running aground on the starboard side. Subsequently, it was soon able to free itself by its own means and the damage was minor.

On further investigation it was determined that the vessel was blown to starboard by the wind, bringing it closer to the channel margin, where it experienced the Bank effect combined with the blocking factor of the channel due to the ratio of the vessel's beam to the effective width of the channel, as well as the vessel's low manoeuvrability as it was a twin propeller vessel with only one rudder. (Australian Transport Safety Bureau, 2002).

Kakariki

On the 23rd september 1999, the tanker Kakariki was leaving the port of Dunedin through the Victoria Channel and at Port Otago at a speed of between 6 and 7 kts the ship yawed abruptly towards Br, something that could hardly be counteracted, resulting in the tanker coming very close to grounding.

No accident occurred in this case, but it is noteworthy because of the circumstances surrounding the event, so much so that an investigation was initiated which in this case recommended a new dredging of the channel to reduce the blockage factor that used to occur and the continuous interactions that were generated in the transit of the channel by different ships.

The investigation found that the cause of the sudden yaw was due to a combination of the following:

- As the ship was approaching the starboard bank the Pilot (who was on training) suggested putting the rudder to portside to return to the centre of the channel just as the helmsman was at starboard rudder to counteract the bank effect of the starboard bank.

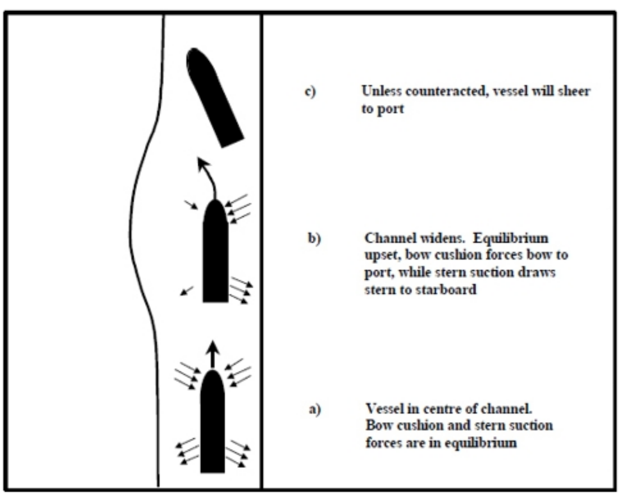
- Just at that moment the boat was moving from a narrower part of the channel to a more open part of the channel to portside, causing the NSL to be on the port side of the boat.

- Just such a change coincided with a moderation in the engine which led to less effective rudder.

- The boat was also experiencing squat at the bow causing the turning point of the boat to move to the bow of the boat, resulting in oversteer.

- The team on the bridge did not notice the yaw until it occurred and reacted with some delay.

Figure 23: Schematic diagram of the effects of the canal on the Kakariki.



Source: Transport Accident Investigation Comission New Zealand.

Conclusions.

Immediately after a ship has grounded, action should always be taken in accordance with a pre-established plan documented in the shipboard safety manual, which will also contain the necessary records to be filled in, taking note of all events, actions taken and results obtained. Even so, several considerations should be noted, as although no two groundings are ever the same, several common aspects can be taken into account.

After detecting a grounding, the first thing to do is to stop the engine and close all watertight doors and make an initial assessment of the damage, survey all tanks and spaces on the ship and survey the depth around the perimeter with the depth sounder to determine, by comparing the depth with the draft, how much surface area is in contact with the bottom.

Determine on the chart the position of the grounding, taking note of the nature of the bottom, state of the current, tide, weather, etc.

Make an assessment with all the data gathered to see if it is possible to get out of the grounding by your own means or if you will have to use external means such as tugboats, Coast Guards that can deploy barriers to contain pollutants if there is a risk of pollution, etc.

In this case, it is recommended to immediately reverse the engine, as this will allow the propeller to drive a cushion of water in the forward half of the vessel, providing an extra buoyancy thrust and a backward momentum that can save the situation gracefully and allow the vessel to get out of the grounding by its own means (Williamson, 2001). This order to pull back should not be given with delay if the tide is running, as every minute that passes, the amount of water under the ship will be less and will considerably affect the buoyancy available and there will be few options to pull out under one's own power, without having to move weights or wait for the next tide. The order to immediately pull back should be avoided whenever there is any suspicion that the bottom that has been struck may have a stone spike or material that may have damaged the hull at any point, as pulling back may worsen the damage or cause it to impact again with such a protrusion.

Immediately after a ship has grounded, action should always be taken in accordance with a pre-established plan documented in the shipboard safety manual, which will also contain the necessary records to be filled in, taking note of all events, actions taken and results obtained. Even so, several considerations should be noted, as although no two groundings are ever the same, several common aspects can be taken into account.

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Determine on the chart the position of the grounding, taking note of the nature of the bottom, state of the current, tide, weather, etc.

Unintentional groundings are nowadays a major source of losses, not only in economic terms but also in terms of human lives. This must be taken into account when planning and executing an effective and efficient course in order to reach port.

The squat effect can affect the draft of a ship, modifying its trim, and greatly affecting the shelter that a ship must keep under the keel at all times when passing through waters where the bottom is very present, just a few centimetres away. Within the complexity of its behaviour, we can always make a composition of the place and with few tools, we can make an accurate forecast of how the bottom is going to throw us, and how we can act. As I have seen in several reports, many times when it has intervened in the involuntary grounding of a ship, it has either not been taken into account, or its power has been underestimated.

The bank effect, to our understanding, is attitude, it is the attitude of the ship in front of the channel to be navigated, and it is personal attitude, a proactive attitude of alertness and astute supervision of the ship's behaviour. We have the tools; on any bridge worth its salt there is the necessary data to know where we are, how we are, and what risks we run in that place, and what is more important, where we are going to be next.

In shallow water, the speed of the machine and the attitude with respect to the channel are the most significant factors to consider, in order to control the effects that may be generated.

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