TP 15417

Report of Simulation Manoeuvring Analysis – Vessel Low Speed Transits in Areas Identified as Whale Sensitive Habitat

Prepared for Innovation Centre of Transport Canada

By LANTEC Marine Inc.

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This report reflects the views of the authors and not necessarily those of the Innovation Centre of Transport Canada.

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Un sommaire français se trouve avant la table des matières.

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16. Abstract

TC commissioned this study to use vessel manoeuvring simulations as a mechanism to determine, in an empirical manner, the minimum safe transit speeds that can be adhered to by various vessel types with special consideration to the unique physical, weather, and prevailing navigational conditions in four known areas of concern for whale populations. Relevant environmental data related to prevailing wind conditions and tidal flow information (derived from both historical/recorded data sources, and predictions based on additional Acoustic Doppler Current Profiling surveys) was compiled in a format that could be used in the ship manoeuvring simulator. An extensive series of systematic tests were conducted using desktop simulation with 21 different vessel types. The results from this phase of the analysis were reviewed by Transport Canada and Marine Pilots from British Columbia and the St-Lawrence River, and then a series of focused manned simulation runs were conducted in order to have feedback/participation from the respective pilotage groups that are responsible for taking ships through the two of the four areas that require mandatory pilotage. Key findings included; a) water speed should be the metric used to manage vessel transit speeds, as opposed to using ground speed; b) in non-pilotage areas (Vessel Traffic Lanes) for most vessel types transits can be conducted safely with water transit speeds of 8 to 10 knots (15 to 18 km/h) provided that wind speeds do not exceed 25 knots (46 km/h), and c) in the two pilotage areas similar low transits speeds can be maintained on longer, straight course legs, but speed increases are required when encountering tidal eddies, and when making course changes.

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16. Résumé

Transports Canada a commandé la présente étude pour utiliser des simulations manœuvrières des bâtiments comme mécanisme pour déterminer de manière empirique les vitesses minimales de passage sécuritaire auxquelles peuvent se déplacer les divers types de bâtiments, en portant une attention particulière aux conditions physiques, météorologiques et de navigation prédominantes uniques dans quatre secteurs de préoccupation connus pour les populations de baleines. Des données environnementales pertinentes liées aux conditions du vent prédominantes et des renseignements sur les flux de marée (dérivés des sources de données historiques/consignées et des prévisions fondées sur des relevés supplémentaires réalisés au moyen d'un profileur de courant à effet Doppler) ont été rassemblées dans un format pouvant être utilisé dans le simulateur de manœuvre des navires. Une vaste série d'essais systématiques ont été réalisés dans le cadre d'une simulation théorique effectuée au moyen de 21 différents types de navires. Les résultats obtenus lors de cette phase d'analyse ont été examinés par Transports Canada et des pilotes de la Colombie Britannique et des pilotes qui naviguent sur le fleuve Saint-Laurent, et une série de simulations avec équipage ciblées ont été réalisées afin de recueillir les commentaires et d'assurer la participation des groupes respectifs chargés de piloter ces navires dans deux des quatre zones où le pilotage est obligatoire. Voici les principales constatations : a) la vitesse sur l'eau devrait être le critère de mesure utilisé pour gérer les vitesses de passage des bâtiments, par opposition à la vitesse au sol; b) dans les zones ne nécessitant pas de pilotage (voies de circulation des bâtiments) pour la plupart des types de bâtiments, les passages peuvent être sécuritaires si la vitesse sur l'eau est de 8 à 10 nœuds (de 15 à 18 km/h) dans la mesure où la vitesse du vent n'excède pas 25 nœuds (46 km/h); c) dans les deux zones de pilotage, des vitesses basses de passages similaires peuvent être maintenues pour les segments droits plus longs, mais des accélérations sont requises lorsqu'il y a des contre courants de marée et lorsque le cap est modifié.

17. Mots clés Navigation, vitesse sécuritaire, bruit sous-marin, manœuvre des bâtiments, mer des Salish, fleuve Saint-Laurent, épaulard résident du Sud.	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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Executive Summary

Overview of Study

In 2017 Transport Canada (TC), in conjunction with key stakeholders in the Canadian Maritime Industry, started to explore risk mitigation measures that would assist with protecting marine mammal populations, with specific focus on those identified in the Species at Risk Act (SARA), namely the Southern Resident Killer Whale (SRKW), the Saint-Lawrence Estuary Beluga (SLEB), and the North Atlantic Right Whale (NARW). For all species of whales, high vessel transit speeds in the coastal areas where they are concentrated potentially impacts on their well-being, either in the form of introducing higher than normal levels of ambient water noise which impedes their ability to find food, among other things, or by increasing the likelihood of serious injury or death if slower moving species are struck by a ship.

As part of the process of assessing viable options for implementing speed reductions on a more broad-based level TC commissioned this study to use vessel manoeuvring simulations as a mechanism to determine, in an empirical manner, the minimum safe transit speeds that can be adhered to by various vessel types with special consideration to the unique physical, weather, and prevailing navigational conditions in each of the known areas of concern for whale populations.

In simplistic terms, the lower a vessel's speed, the lower the level of noise that it creates, and the lower the threat of serious injury to a whale in the event of a strike. Determining a minimal safe speed for vessel transit is however a complex task, and it would be imprudent to assume that one given minimal speed could apply to all vessel types, apply in all locations, or in all environmental/ weather conditions. The over-riding objective of this project was to conduct relevant simulation tests which considered both the unique geographic/ physical and environmental characteristics of the various areas of concern as well as the manoeuvring characteristics of vessel types that frequent those waters, and from the results of these tests, identify key factors that need to be considered when implementing minimal transits speed policies for various ship types in the various locations of concern. The study thus focused on four test areas: the Salish Sea in British Columbia, home of the SRKW, was divided into the Traffic Separation Scheme (TSS) in Juan de Fuca Strait, and the mandatory pilotage area in Haro Strait/Boundary Pass, and the St-Lawrence River Estuary and the Gulf of St-Lawrence were split between the TSS on the south side of Anticosti Island, and the mandatory pilotage area at the confluence of the Saguenay and St-Lawrence Rivers.

The analytical process started by gathering relevant environmental data related to prevailing wind conditions (based on historical information from Environment Canada and the National Atmospheric and Oceanographic Administration), and tidal flow information derived from Canadian Hydrographic Society sources as well as predictions based on additional Acoustic Doppler Current Profiling surveys and tidal modelling performed by Canadian engineering companies WSP and Tetra Tech. Once data was gathered, it was compiled in a format that could be used in the ship manoeuvring simulator. Next, an extensive series of systematic tests were conducted using desktop simulation with 21 different vessel types. The results from this phase of the analysis were reviewed by Transport Canada and Marine Pilots from British Columbia and the St-Lawrence River, and a series of focused manned simulations were performed utilising "Full Mission

Simulators" in Vancouver and Quebec. This provided valuable feedback from the respective pilotage groups that are responsible for taking ships through these areas on a daily basis.

Information and findings gained on vessel manoeuvrability from these simulations can then be combined with other relevant operational/ implementation concerns and elements to develop, in collaboration with marine pilots and port authorities, a vessel transit speed policy that would be safe, logical, practical, and achievable.

General Considerations for Policy Implementation

Although the term "Minimum Safe Transit Speed" is used several places in this report, it should be first mentioned that the evaluation of what is "safe" can be somewhat subjective, and therefore, from a low speed transit policy implementation standpoint "safe" may not be the most useful metric. Certainly, in the case of the entry into the Saguenay River where the minimal channel width is only 650 metres, it is fairly easy to determine if a ship is transiting safely or not. However, in the case of the Anticosti TSS, and to a lesser degree Juan de Fuca TSS, a ship could lose all propulsion and it would not immediately be in danger, moreover, it could probably drift for hours in the wind and tide before it would be in a navigationally dangerous, or unsafe situation. With that said, it would clearly be operating under exceptional circumstances, and according to the Collision Avoidance Rules its manoeuvring status would be that of a vessel "Not Under Command". In terms of measuring or qualifying what is an acceptable minimum transit speed, it is perhaps best to consider the degree of manoeuvring control that is required by the officer directing the vessel such that it can follow its intended navigation plan and be able to manoeuvre as required to take avoiding action in accordance with the collision avoidance rules.

It should also be underlined that in the absence of wind, tidal stream, current or sea state, all of the vessels tested can navigate and be controlled at their Dead Slow Ahead telegraph setting; which for many ships is a water speed of less than 5 knots. While this may be safe, it is impractical and by no measure could be considered an efficient form of transportation.

Another consideration that while not within the scope of this analysis/assessment but that should be considered from an overall risk standpoint, is that low speed transits in the pilotage areas where vessels are exposed to strong currents/ tidal streams and transiting at distances of less than 1 nautical mile (1852 metres) from land for long periods may present an elevated level of risk compared to transiting at more typical operational speeds. This increased level of risk would stem from the increased duration in which the vessel is exposed to arduous environmental conditions, increased duration of vessel traffic interactions, and fatigue of ship's officers, helmsmen, and pilots.

Perhaps the most important overall consideration for any Low Speed Transit policy, and to remove inconsistencies that exist with the various speed reduction measures that are currently in place across Canada, is that "Water Speed" is the only reasonable metric to use to ascertain the noise that a vessel will transmit, and this is also the variable which would affect the severity of collision impact with a marine mammal. Of the four areas examined, the only one where it could be considered acceptable to use Ground Speed (Vessel Traffic Service RADAR Tracking or a ship's Automated Identification System broadcast speed) as a monitoring/ enforcement mechanism is in the Anticosti TSS, and this is simply because that for the majority of the time, the difference between ground speed and water speed in that body of water tend to be negligible.

Terminology

It was impossible to conduct this analysis and to report on its findings without making extensive use of specialised marine navigation terminology. For anyone that is not a professional marine navigator, it is highly recommended that Section 2.1 of the main body of the report is read prior to proceeding with the remainder of this Executive Summary.

Considerations for Low Speed Transits Juan de Fuca TSS

The results of the analysis identified several factors that should be considered in any decision to implement vessel transit speed restrictions in the Juan de Fuca TSS:

1) For nearly all vessel types, steering and positional control remained good at transit water speeds in the 8 to 10 knot range (loosely speaking Slow Ahead engine telegraph settings), provided that the wind speed did not exceed 30 knots;
2) When wind velocities were in the 30 to 35 knot range, most of the test vessels could maintain steering and positional control at transit speeds of 10 knots;
3) Given that the frequency of occurrence of winds above 30 knots in Juan de Fuca is quite low, and above 35 knots very rare, it would be practical to waive any speed restriction requirement should the sustained wind speed exceed 30 knots; and
4) If either the vessels' transmitted AIS speed, or calculated radar tracking speed by Vessel Traffic Services are to be used as a speed monitoring/ enforcement mechanism, then these ground speed values should be corrected to their water speed equivalent using either real time tidal stream (current) velocity data, or tidal stream prediction data that is actively updated using tidal hindcasting information. It is extremely important to consider that additional ground speed due to tidal effects does not increase the ambient sound level that a vessel is generating. Similarly, loss of ground speed due to tidal effects does not reduce the level of ambient noise that a vessel generates. Noise level predominately stems from water speed, and the amount of propeller RPM/Pitch/Propulsion power that is being applied.

Considerations for Low Speed Transits Anticosti TSS

The results of the analysis identified several factors that should be considered in any decision to implement vessel transit speed restrictions in the Anticosti TSS:

1) A large portion of the vessels that pass through the Anticosti TSS are full form vessels with top speeds in the 14 to 16 knot range, and generally have Slow Ahead Telegraph settings that equate to speeds of less than 8 knots;
2) While moderate wind speeds are common, the frequency of wind above 22 knots is less than 7% and although specific data was not available, it is likely that the frequency of winds in excess of 30 knots is less than 5%. With this consideration, it would be practical to waive any speed restriction requirement should the sustained wind speed exceed 30 knots;

3) The majority of the vessels that transit this area can maintain good steering and positional control with their telegraph RPMs set for 8 knots, but some vessels at this speed will experience a significant reduction in steering control if the wind speed exceeds 25 knots; and
4) With Telegraph RPMs set for 10 knots, or alternating Telegraph settings from Slow Ahead to Half Ahead to achieve an average speed of 10 knots, it would be very rare that vessels would be unable to maintain steering and position control at wind speeds up to 30 knots; and
5) In this area, since strong currents or tidal streams are rare, ground speed can be used as a speed monitoring metric.

Considerations for Low Speed Transits St-Lawrence/ Saguenay Pilotage Area

The results of the analysis identified several factors that should be considered in any decision to implement vessel transit speed restrictions in the confluence of the Saguenay and St-Lawrence:

1) For nearly all vessel types, steering (heading) control remained good at transit water speeds in the 8 to 10 knot range (loosely speaking Slow Ahead engine telegraph settings), provided that the wind speed did not exceed 25 knots;
2) When proceeding upriver and stemming the predominate outflow current, positional control, especially with strong winds on the quarter became degraded when the vessel's ground speed became less than approximately 1.5 times that of the current speed (i.e. current speed is 3.0 knots and ground speed is < 4.5 knots, or current speed is 4.0 knots and ground speed is < 6.0 knots);
3) Given that the frequency of occurrence of winds above 25 knots (based on data from Ile Rouge weather station) is less than 8% it would be practical to waive any speed restriction requirement should the sustained wind speed exceed 25 knots; and
4) Due to constriction in the channel width, changes in water depth, and a host of other physical and hydrodynamic factors, the velocity of the current can easily change by as much as 2.0 knots over a space of 500 metres or less. As such, it is virtually impossible for a vessel to maintain a narrow speed range (i.e. 8.0 to 8.5 knots) and any speed management policy should consider that a pilot will order vessel speeds so as to maintain a controlled average speed of a particular value (i.e. 9.0 knots, 10.0 knots, etc.) while transiting through the area of interest, however actual water/ ground speed values would then oscillate around this mean speed by as much as +/- 2.0 knots. If vessel speeds are to be monitored within a pilotage area, they should look at the average water speed that was maintained throughout an entire transit segment that is subject to slow down restrictions, and not monitor or be concerned with increases in speed over short time periods/distances.

Considerations for Low Speed Transits Haro Strait/ Boundary Pilotage Area

The results of the analysis identified several factors that should be considered in any decision to implement vessel transit speed restrictions in the area of Haro Strait and Boundary Pass:

1) In this area, the ability to maintain steering and positional control while following a long straight track (i.e.° 347 northbound in Haro Strait, or 245° southbound in Boundary Pass) is very different, and much more predictable, than when conducting the large 70° plus course alterations around Turn Point and East Point.
2) For nearly all vessel types, steering (heading) control remained good at transit water speeds in the 8 to 10 knot range (loosely speaking Slow Ahead engine telegraph settings), provided that the wind speed did not exceed 25 knots and when following a straight-line track;
3) When rounding Turn Point and East Point, given the highly dynamic and variable conditions of the tidal stream, and the fact that a shift in the ship's lateral position by distances as small as 200 metres can yield very different flow patterns, it can be stated with confidence that on a large portion of vessel transits, pilots will need to vary propeller RPM (Kicks ahead) in order to maintain steering control. Considering the complexities of these two turns, it would be practical to create a zone around Turn Point and East Point with a radius of 2 nautical miles where any speed restriction would not apply, and pilots would be at liberty to apply engine RPM as needed to control the vessel;
4) Given that the frequency of occurrence of winds above 22 knots (based on data from Saturna Island weather station) is less than 5% it would be practical to waive any speed restriction requirement should the sustained wind speed exceed 25 knots; and
5) Throughout the entire area of Haro Strait and Boundary Pass, due to variations in the channel width, changes in water depth, and a host of other physical and hydrodynamic factors, the velocity of the current can easily change by as much as 2.0 knots over a space of 500 metres or less. As such, it is virtually impossible for a vessel to maintain a narrow speed range (i.e. 8.0 to 8.5 knots) and any speed management policy should consider that a pilot will order vessel speeds so as to maintain a controlled average speed of a particular value (i.e. 9.0 knots, 10.0 knots, etc.) while transiting through the area of interest, however actual water/ground speed values would then oscillate around this mean speed by as much as +/- 2.0 knots. If vessel speeds are to be monitored within a pilotage area, they should look at the average water speed that was maintained throughout an entire transit segment that is subject to slow down restrictions, and not monitor or be concerned with increases in speed over short time periods/distances.

Sommaire

Aperçu de l'étude

En 2017, Transports Canada (TC), en collaboration avec des intervenants clés de l'industrie maritime canadienne, a commencé à explorer des mesures d'atténuation des risques qui pourraient contribuer à protéger les populations de mammifères marins, plus particulièrement celles énumérées dans la Loi sur les espèces en péril (LEP), à savoir les épaulards résident du Sud, les bélugas de l'estuaire du Saint-Laurent et les baleines noires de l'Atlantique Nord. Les vitesses de passage élevées des bâtiments dans les zones côtières où les baleines sont concentrées nuisent possiblement au bien-être de l'ensemble des espèces, soit en raison des niveaux de bruit sous-marin plus élevé que la normale qui limitent leur capacité de trouver de la nourriture, ou encore en augmentant la probabilité de blessure grave ou de mort si un navire entre en collision avec les espèces se déplaçant plus lentement.

Dans le cadre du processus d'évaluation des options viables pour mettre en œuvre des réductions de vitesse à plus grande échelle, TC a commandé la présente étude pour utiliser des simulations manœuvrières des bâtiments comme mécanisme pour déterminer de manière empirique les vitesses minimales de passage sécuritaire auxquelles peuvent se déplacer les divers types de bâtiments, en portant une attention particulière aux conditions physiques, météorologiques et de navigation prédominantes uniques dans chacune des zones préoccupantes connues pour les populations de baleines.

En termes simples, plus la vitesse d'un bâtiment est basse, moins le bâtiment fait de bruit et moins une baleine risque de subir une blessure grave en cas de collision. Toutefois, déterminer une vitesse minimale sécuritaire pour le passage des bâtiments est une tâche complexe, et il serait imprudent de supposer qu'une vitesse minimale pourrait s'appliquer à tous les types de bâtiments, à tous les endroits ou dans toutes les conditions environnementales ou météorologiques. L'objectif primordial de ce projet était de mener des essais de simulation pertinents qui tenaient compte à la fois des caractéristiques géographiques/physiques et environnementaux uniques des diverses zones préoccupantes et des caractéristiques manœuvrières des types de bâtiments qui sillonnent ces eaux, et, à partir des résultats de ces essais, de déterminer les facteurs clés qui doivent pris en compte lors de la mise en œuvre des politiques sur la vitesse de passage minimale pour les différents types de navires dans les diverses zones préoccupantes. Par conséquent, l'étude porte sur quatre zones d'essai. La mer des Salish en Colombie-Britannique, où vit l'épaulard résident du Sud, a été divisée selon le dispositif de séparation du trafic (DST) dans le détroit de Juan de Fuca, et la zone de pilotage obligatoire du détroit de Haro/le passage Boundary. L'estuaire du Saint-Laurent et le golfe Saint Laurent ont été séparés entre le DST du côté sud de l'île d'Anticosti et la zone de pilotage obligatoire au confluent de la rivière Saguenay et du fleuve Saint-Laurent.

Le processus d'analyse a commencé par la collecte de données environnementales pertinentes liées aux conditions du vent prédominantes (selon les renseignements historiques d'Environnement Canada et de la National Atmospheric and Oceanographic Administration), et des renseignements sur les flux de marée provenant des sources de l'Association canadienne d'hydrographie et des

prédictions fondées sur des relevés supplémentaires réalisés au moyen d'un profileur de courant à effet Doppler et de la modélisation des marées effectuée par les sociétés d'ingénierie canadiennes WSP et Tetra Tech. Une fois les données recueillies, elles ont été rassemblées dans un format pouvant être utilisé dans le simulateur de manœuvre des navires. Ensuite, une vaste série d'essais systématiques ont été réalisés dans le cadre d'une simulation théorique effectuée au moyen de 21 différents types de navires. Les résultats obtenus lors de cette phase d'analyse ont été examinés par Transports Canada et des pilotes de la Colombie Britannique et des pilotes qui naviguent sur le fleuve Saint-Laurent, et une série de simulations ciblées avec équipage ont été réalisées au moyen de « simulateurs de mission complète » à Vancouver et à Québec. Ces simulations ont permis de recueillir des commentaires utiles des groupes respectifs chargés de piloter ces navires dans ces zones chaque jour.

Les renseignements et les conclusions sur la manœuvrabilité des bâtiments provenant de ces simulations peuvent ensuite être combinés aux autres préoccupations opérationnelles et éléments pertinents relatifs à la mise en œuvre afin d'élaborer, en collaboration avec les pilotes et les autorités portuaires, une politique sur la vitesse de passage des navires qui serait sécuritaire, logique, pratique et réalisable.

Considérations générales relatives à la mise en œuvre de la politique

Bien que l'expression « vitesse de passage minimale sécuritaire » soit utilisée à plusieurs endroits dans le présent rapport, il faut d'abord dire que l'évaluation de ce qui « sécuritaire » est relativement subjective, et, par conséquent, du point de vue de la mise en œuvre d'une politique sur le passage à basse vitesse, le mot « sécuritaire » n'est peut-être pas le critère de mesure le plus utile. Bien sûr, dans le cas de l'entrée dans la rivière Saguenay, où la largeur minimale du canal est de seulement 650 mètres, il est relativement facile de déterminer si un navire se déplace de façon sécuritaire ou non, et la sécurité est une nécessité hautement prioritaire. Toutefois, dans le cas du DST d'Anticosti, et dans une moindre mesure le DST de Juan de Fuca, un navire pourrait perdre toute propulsion et il ne serait pas immédiatement menacé. De plus, il pourrait probablement dériver pendant des heures au gré du vent et des marées avant de se retrouver dans une situation de navigation dangereuse et non sécuritaire. Cela dit, le navire serait clairement piloté dans des circonstances exceptionnelles et, selon les Règles de prévention des abordages, son statut de manœuvre serait considéré comme un navire « non maître de sa manœuvre ». Pour ce qui est de mesurer ou de qualifier ce qui constitue une vitesse de passage minimale acceptable, il vaut peut-être mieux de tenir compte du degré de contrôle de la manœuvre requis par l'officier qui dirige le navire afin qu'il puisse suivre le plan de navigation prévu et qu'il soit en mesure de manœuvrer au besoin pour prendre des mesures d'évitement conformément aux Règles de prévention des abordages.

Il faut également noter qu'en absence de vent et de courant de marée et selon l'état du courant et de la mer, tous les navires mis à l'essai peuvent naviguer et être contrôlés lorsque les réglages télégraphiques sont en mode « en avant très lent », ce qui représente une vitesse de moins de cinq nœuds pour bon nombre de navires. Bien que cela puisse être sécuritaire, cela n'est pas pratique et ne peut d'aucune façon être considéré comme une forme efficace de transport.

Un autre aspect ne faisant pas partie de la portée de la présente analyse/évaluation, mais qui devrait être pris en compte du point de vue du risque global, est le fait que les passages à basse vitesse dans les zones de pilotage où des bâtiments sont exposés aux forts courants/aux courants de marée et se trouvent à moins d'un mille marin (1 852 mètres) de la terre ferme pendant de longues périodes peuvent représenter un risque accru comparativement aux vitesses opérationnelles plus typiques. Ce niveau de risque accru découle de la durée prolongée pendant laquelle le bâtiment est exposé à des conditions environnementales ardues, de la durée prolongée des interactions du trafic maritime et de la fatigue des officiers, des timoniers et des pilotes à bord du navire.

Le facteur global peut-être le plus important de la politique sur le passage à basse vitesse, qui vise à corriger les incohérences qui existent relativement aux diverses mesures de réduction de la vitesse prises à l'échelle du Canada, est le fait que la « vitesse sur l'eau » est le seul critère de mesure raisonnable à utiliser pour évaluer le bruit produit par un bâtiment et il s'agit également de la variable ayant une incidence sur la gravité des collisions avec un mammifère marin. Des quatre zones examinées, la seule où il serait acceptable d'utiliser la vitesse au sol (surveillance radar du Service du trafic maritime ou indication de la vitesse par le Système d'identification automatique du navire) comme mécanisme de surveillance/d'application des règles est le DST d'Anticosti, simplement parce que la majorité du temps, la différence entre la vitesse au sol et la vitesse sur l'eau à cet endroit a tendance à être négligeable.

Terminologie

Il était impossible de réaliser cette analyse et de faire rapport sur les conclusions sans utiliser largement la terminologie très spécialisée relative à la navigation maritime. Nous recommandons fortement aux personnes qui ne sont pas des navigateurs maritimes professionnels de lire la section 2.1 du rapport avant de poursuivre la lecture du sommaire.

Considérations relatives aux passages à basse vitesse dans le DST de Juan de Fuca

Les résultats de l'analyse ont mis en lumière plusieurs facteurs qui devraient être pris en compte dans toute décision visant à mettre en œuvre des restrictions relatives à la vitesse de passage des bâtiments dans le DST de Juan de Fuca :

1) Pour pratiquement tous les types de bâtiments, le cap et le contrôle de la position demeurent bons aux vitesses de passage de 8 à 10 nœuds (au sens

large, quand les réglages télégraphiques sont en mode « en avant très lent ») dans la mesure où la vitesse du vent n'excède pas 30 nœuds;

2) Lorsque le vent souffle à des vitesses de 30 à 35 nœuds, la plupart des bâtiments d'essai pouvaient maintenir le cap et le contrôle de la position à des vitesses de passage de 10 nœuds;
3) Vu que la fréquence des épisodes où le vent dépasse 30 nœuds dans le détroit de Juan de Fuca est relativement faible, et que les cas où le vent souffle à plus de 35 nœuds sont très rares, il serait pratique de lever l'exigence relative à la restriction de vitesse si la vitesse du vent excède 30 nœuds;
4) Si la vitesse transmise par le SIA du bâtiment ou la vitesse de surveillance radar calculée par le Service du trafic maritime doit être utilisée comme mécanisme de surveillance/d'application de la vitesse, alors ces valeurs de vitesse au sol doivent être corrigées afin qu'elles correspondent à la vitesse équivalente sur l'eau au moyen des données sur la vitesse du courant de marée en temps réel (courant), ou des données de prévision relatives au courant de marée qui sont activement mises à jour au moyen des prévisions de marée. Il est extrêmement important de tenir compte du fait que la vitesse au sol supplémentaire en raison des effets de marée n'augmente pas le niveau sonore que produit un bâtiment. De la même façon, la perte de vitesse au sol en raison des effets de marée ne réduit pas le niveau sonore que produit un bâtiment. Les niveaux de bruit découlent surtout de la vitesse sur l'eau et du régime de l'hélice, de son pas et de la puissance de propulsion appliquée.

Considérations relatives aux passages à basse vitesse dans le DST d'Anticosti

Les résultats de l'analyse ont mis en lumière plusieurs facteurs qui devraient être pris en compte dans toute décision visant à mettre en œuvre des restrictions relatives à la vitesse de passage des bâtiments dans le DST d'Anticosti :

1) Une grande partie des bâtiments qui passent par le DST d'Anticosti sont des bâtiments à forme pleine pouvant atteindre des vitesses maximales de 14 à 16 nœuds, et, habituellement, leurs réglages télégraphiques sont en mode « en avant très lent », ce qui correspond à des vitesses de moins de 8 nœuds;
2) Bien que des vitesses de vent modérées soient fréquentes, la fréquence des vents excédant 22 nœuds est de moins de 7 % et, même si des données précises n'étaient pas disponibles, il est probable que la fréquence des vents excédant 30 nœuds soit de moins de 5 %. Avec ce facteur à l'esprit, il serait pratique de lever l'exigence relative à la restriction de vitesse si la vitesse du vent excède 30 nœuds;
3) La majorité des bâtiments qui passent dans cette zone peuvent maintenir le cap et le contrôle de la position au moyen de leur régime télégraphique réglé à 8

nœuds, mais certains bâtiments qui voguent à cette vitesse verront leur contrôle de la direction réduite de façon importante si le vent excède 25 nœuds;

4) Quand le régime télégraphique est réglé à 10 nœuds ou si les réglages télégraphiques sont changés du mode « en avant très lent » au mode « en avant demie » pour atteindre une vitesse moyenne de 10 nœuds, il serait très rare que les bâtiments soient incapables de maintenir le cap et le contrôle de la position à des vitesses de vent d'au plus 30 nœuds;
5) Dans cette zone, puisque les courants forts ou les courants de marée sont rares, la vitesse au sol peut être utilisée comme critère de mesure pour surveiller la vitesse.

Considérations relatives aux passages à basse vitesse dans la zone de pilotage du fleuve Saint Laurent/de la rivière Saguenay

Les résultats de l'analyse ont mis en lumière plusieurs facteurs qui devraient être pris en compte dans toute décision visant à mettre en œuvre des restrictions relatives à la vitesse de passage des bâtiments au confluent de la rivière Saguenay et du fleuve Saint-Laurent :

1) Pour pratiquement tous les types de bâtiments, le contrôle de la direction (cap) demeure bon aux vitesses de passage sur l'eau de 8 à 10 nœuds (au sens large, quand les réglages télégraphiques sont en mode « en avant très lent ») dans la mesure où la vitesse du vent n'excède pas 25 nœuds;
2) Lorsque le bâtiment remonte le fleuve et qu'il navigue contre le courant prédominant, le contrôle de la position, surtout lorsque de forts vents par bâbord arrière se lèvent, devient difficile quand la vitesse au sol du bâtiment est réduite à moins d'environ 1,5 fois celle de la vitesse réelle (c.-à-d. une vitesse réelle de 3,0 nœuds et une vitesse au sol de moins de 4,5 nœuds, ou une vitesse réelle de 4,0 nœuds et une vitesse au sol de moins de 6,0 nœuds);
3) Vu que la fréquence des épisodes où le vent dépasse 25 nœuds (selon des données recueillies à la station météorologique de l'Île Rouge) est de moins de 8 %, il serait pratique de lever l'exigence relative à la restriction de vitesse si la vitesse du vent excède 25 nœuds;
4) En raison de la réduction de la largeur du canal, des changements de profondeur et d'une panoplie d'autres facteurs physiques et hydrodynamiques, la vitesse du courant peut facilement varier de 2,0 nœuds sur une distance aussi courte que 500 mètres ou moins. Par conséquent, il est pratiquement impossible pour un bâtiment de maintenir une vitesse dans une plage restreinte (p. ex. entre 8 et 8,5 nœuds), et toute politique de gestion de la vitesse devrait tenir compte du fait qu'un pilote ordonnera de régler la vitesse du bâtiment afin de maintenir une vitesse moyenne contrôlée d'une valeur particulière (p. ex. 9,0 nœuds, 10,0 nœuds) lorsque le bâtiment passe dans la zone d'intérêt. Toutefois, les valeurs réelles de vitesse sur l'eau/au sol varieraient jusqu'à 2 nœuds. Si les vitesses du bâtiment doivent être surveillées dans une zone de pilotage, il faudrait tenir compte de la vitesse sur l'eau moyenne qui a été maintenue tout au long de

l'ensemble d'un segment de passage visé par des restrictions de navigation à basse vitesse, et ne pas surveiller les augmentations de vitesse au cours de périodes ou de distances courtes ni se préoccuper de ces variations.

Considérations relatives aux passages à basse vitesse dans la zone de pilotage du détroit de Haro/du passage Boundary

Les résultats de l'analyse ont mis en lumière plusieurs facteurs qui devraient être pris en compte dans toute décision visant à mettre en œuvre des restrictions relatives à la vitesse de passage des bâtiments dans la zone du détroit de Haro et du passage Boundary :

1) Dans cette zone, la capacité de maintenir le cap et le contrôle de la position tout en suivant une longue voie droite (c.-à-d. 347° en direction nord dans le détroit de Haro ou 245° en direction sud dans le passage Boundary) est très différente et beaucoup plus prévisible que lorsqu'il y a de grandes modifications de cap de plus de 70° à la pointe Turn et à la pointe East.
2) Pour pratiquement tous les types de bâtiments, le contrôle de la direction (cap) demeure bon aux vitesses de passage sur l'eau de 8 à 10 nœuds (au sens large, quand les réglages télégraphiques sont en mode « en avant très lent ») dans la mesure où la vitesse du vent n'excède pas 25 nœuds et lorsque le bâtiment navigue en ligne droite;
3) Lorsque le bâtiment contourne la pointe Turn et la pointe East, vu les conditions très dynamiques et variables du courant de marée et le fait qu'un déplacement de la position latérale du bâtiment d'aussi peu que 200 mètres peut entraîner des courbes de débit très différentes, on peut affirmer avec confiance que, pour une bonne partie du passage du bâtiment, les pilotes devront modifier la vitesse de l'hélice (un petit coup en avant!) afin de maintenir le contrôle de la direction. Étant donné la complexité de ces deux virages, il serait pratique de créer une zone près de la pointe Turn et de la pointe East ayant un rayon de deux milles marins où la restriction de vitesse ne s'appliquerait pas et où les pilotes pourraient décider de régler le régime des machines au besoin pour contrôler le bâtiment;
4) Vu que la fréquence des épisodes où le vent dépasse 22 nœuds (selon des données recueillies à la station météorologique de l'île Saturna) est de moins de 5 %, il serait pratique de lever l'exigence relative à la restriction de vitesse si la vitesse du vent excède 25 nœuds;
5) Dans toute la zone du détroit de Haro et du passage Boundary, en raison de variations de la largeur du canal, des changements de profondeur et d'une panoplie d'autres facteurs physiques et hydrodynamiques, la vitesse du courant peut facilement varier de 2,0 nœuds sur une distance aussi courte que 500 mètres ou moins. Par conséquent, il est pratiquement impossible pour un bâtiment de maintenir une vitesse dans une plage restreinte (p. ex. entre 8 et 8,5 nœuds), et toute politique de gestion de la vitesse devrait tenir compte du fait qu'un pilote ordonnera de régler la vitesse du bâtiment afin de maintenir une

vitesse moyenne contrôlée d'une valeur particulière (p. ex. 9,0 nœuds, 10,0 nœuds) lorsque le bâtiment passe dans la zone d'intérêt. Toutefois, les valeurs réelles de vitesse sur l'eau/au sol varieraient jusqu'à 2 nœuds. Si les vitesses du bâtiment doivent être surveillées dans une zone de pilotage, il faudrait tenir compte de la vitesse sur l'eau moyenne qui a été maintenue tout au long de l'ensemble d'un segment de passage visé par des restrictions de navigation à basse vitesse, et ne pas surveiller les augmentations de vitesse au cours de périodes ou de distances courtes ni se préoccuper de ces variations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

In 2017 Transport Canada (TC), in conjunction with key stakeholders in the Canadian Maritime Industry, started to explore risk mitigation measures that would assist with protecting marine mammal populations, with specific focus on those identified in the Species at Risk Act (SARA), namely the Southern Resident Killer Whale (SRKW), the Saint-Lawrence Estuary Beluga (SLEB), and the North Atlantic Right Whale (NARW). For all species of whales, high vessel transit speeds in the coastal areas where they are concentrated potentially impacts on their well-being, either in the form of introducing higher than normal levels of ambient water noise which impedes their ability to find food, among other things, or by increasing the likelihood of serious injury or death if slower moving species are struck by a ship.

Cooperative voluntary initiatives in British Columbia involving the Vancouver Fraser Port Authority (VFPA) and the British Columbia Coast Pilots (BCCP) as part of the Enhancing Cetacean Habitat and Observation (ECHO) programme have demonstrated that reductions in vessel transit speed in coastal and pilotage areas have yielded ambient noise reductions in the range of 4.9 - 9.4 decibels (dB) depending on the vessel class. It has also shown that within pilotage areas vessel transit speed can to some extent be reduced without adversely affecting operational shipping schedules or vessel safety. Similarly, the Lower St-Lawrence River Pilots (Corporation des pilotes du Bas Saint-Laurent or CPBSL) for a number of years have been conducting a voluntary vessel slow-down in the vicinity of the confluence of the Saguenay and St-Lawrence Rivers.

As part of the process of assessing viable options for implementing speed reductions on a more broad-based level TC commissioned this study to use vessel manoeuvring simulations as a mechanism to determine, in an empirical manner, the minimum safe transit speeds that can be adhered to by various vessel types with special consideration to the unique physical, weather, and prevailing navigational conditions in each of the known areas of concern for whale populations.

Over the past ten years, vessel manoeuvring simulations have been used by many port authorities and pilotage groups in Canada as a mechanism to assess vessel manoeuvring risk, and to develop operational risk mitigation procedures. Additionally, TC for many years has mandated the use of manoeuvring simulations as part of the TERMPOL process. Many of these studies have been conducted/ facilitated by LANTEC Marine Inc. and hence TC contracted LANTEC Marine Inc. to perform this analysis.

Information and findings gained on vessel manoeuvrability from these simulations can then be combined with other relevant operational/ implementation concerns and elements to develop, in collaboration with marine pilots and port authorities, a vessel transit speed policy that would be safe, logical, practical, and achievable.

1.1 Simulation System

All portions of this analysis in the non-pilotage areas were conducted using LANTEC's desktop task simulator. The preliminary analysis for the pilotage areas was also performed on the desktop simulator, and the results then validated on Full Mission simulators using manned simulation with pilots from the BCCP and CPBSL performing the manoeuvres. This simulator software is produced by Kongsberg Digital and is identical to the core system software used on high fidelity, interactive simulation systems that are owned and operated by the PPA/BCCP and the CPBSL as well as a number of other provincially and federally operated training centres. This compatibility facilitates the involvement of the relevant pilotage groups at a later stage of the analysis to validate any key findings that may require additional local pilotage expertise. Key components of the simulation system include:

a. An extensive library of a wide range of vessel types (i.e. Container Ships, Crude Carriers, Gas Carriers, Bulk Carriers, Passenger Vessels, etc.);
b. Models of the relevant geographic areas and their bathymetry;
c. Models of typical wind and tidal conditions; and
d. Potential to develop additional dynamic, multi-layered tidal models as deemed appropriate.

By combining the relevant elements listed above, a range of test scenarios were created, and simulated manoeuvres conducted to determine vessel transit speed thresholds where either a loss or reduction in vessel steering and positional control occurred as a result of specific wind or tidal stream/ current conditions or a ship’s unique propulsion/ design characteristics.

2 PROJECT OBJECTIVE AND CONSIDERATIONS FOR ANALYSIS

In simplistic terms, the lower a vessel's speed, the lower the level of noise that it creates, and the lower the threat of serious injury to a whale in the event of a strike. Determining a minimal safe speed for vessel transit is however a complex task, and it would be imprudent to assume that a particular minimal speed could apply to all vessel types, apply in all locations, or in all environmental/ weather conditions. The over-riding objective of this project was to conduct relevant simulation tests which considered both the unique geographic/ physical and environmental characteristics of the various areas of concern as well as the vessel types that frequent those waters, and from the results of these tests, identify key factors that need to be considered when implementing minimal transits speed policies for various ship types in the various locations of concern. Key general factors that needed to be considered are found in the sub-sections of this part that follow.

2.1 Terminology and Definitions key to Understanding Test Procedures

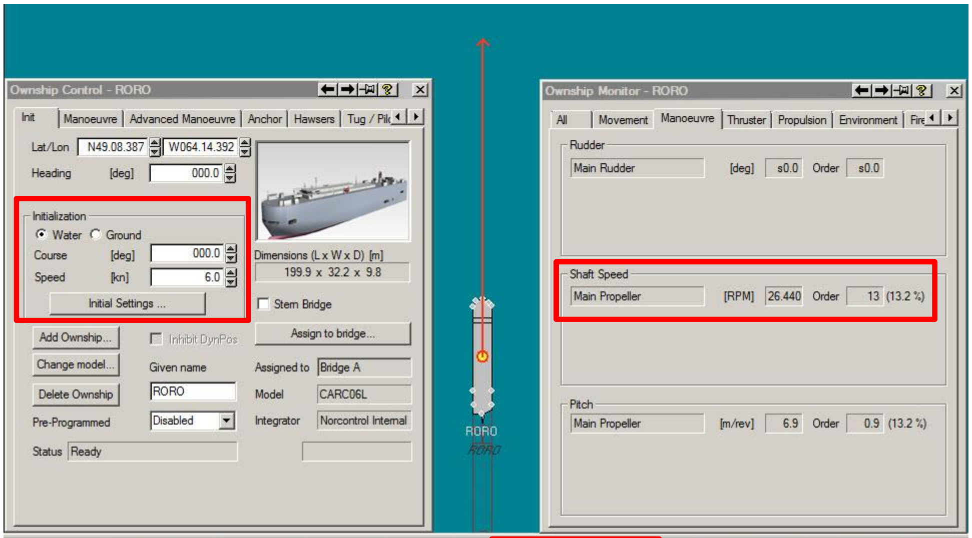
This report makes extensive use of maritime terminology. Even for seasoned mariners, it is important to note that depending upon place and language of training that certain terminology can be used in different ways dependent upon application. For this reason, the section below explains specifically how key maritime terminology is used and defined within the context of this report.

2.1.1 Water Speed (Speed through the water)

Unlike land-based vehicles, ships move in a medium (water) that is fluid and not static, in some instances, has its own velocity (i.e. water in a river flows at a particular rate). Water speed refers to a ship's speed relative to the body of water that it is floating in. If there is no wind, current, tidal stream or other external forces being applied to a ship, water speed is generated by the ship's propulsion system, and more specifically the ship's propeller(s) with a certain angle of pitch turning at a specific number of Revolutions Per Minute (RPM). For example, in Figure 1 below we can see instrument read-outs for a typical Roll-On-Roll-Off (RORO) vessel that its minimum speed of 6.0 knots (Dead Slow Ahead order on Telegraph) equates to a shaft or propeller RPM of 26. A vessel's water speed will vary dependent upon external factors/ phenomena that act on the vessel. As a point of comparison consider that in most automobiles that if you apply enough throttle (gas pedal) to proceed at 100 km/h on a flat highway with no incline, you will need to apply more throttle when going uphill due to resistance. If we take a similar approach with a ship, the RORO has a large surface area above the water which acts somewhat like a sail, and if the wind is from ahead of the ship, it generates resistance to motion. If the propeller RPM remains constant at 26, and we introduce a wind from ahead at 30 knots (55 km/h) the ship's speed through the water over a period of 15 minutes will slow from 6.0 knots to 2.7 knots (See Figure 2). If we wish to maintain a water speed of 6.0 knots when proceeding directly into the wind, we must increase the vessel's propeller rotation speed to 44 RPM (See Figure 3 below). In this report, Transit Speed is used to refer to RPMs set to produce a specific water speed with no external factors affecting the vessel (i.e. 26 RPM for 6.0

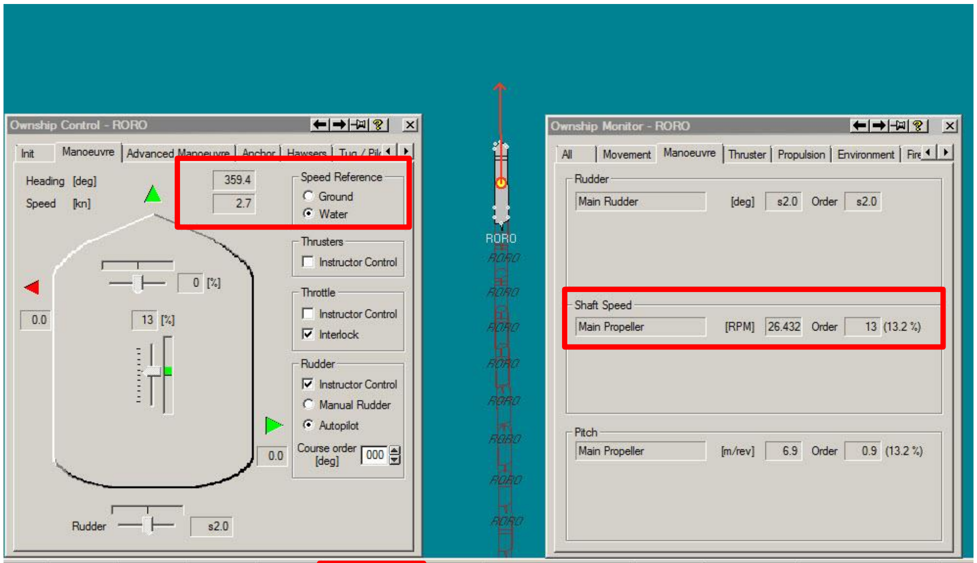
knots).

Figure 1: Vessel Water Speed Definition



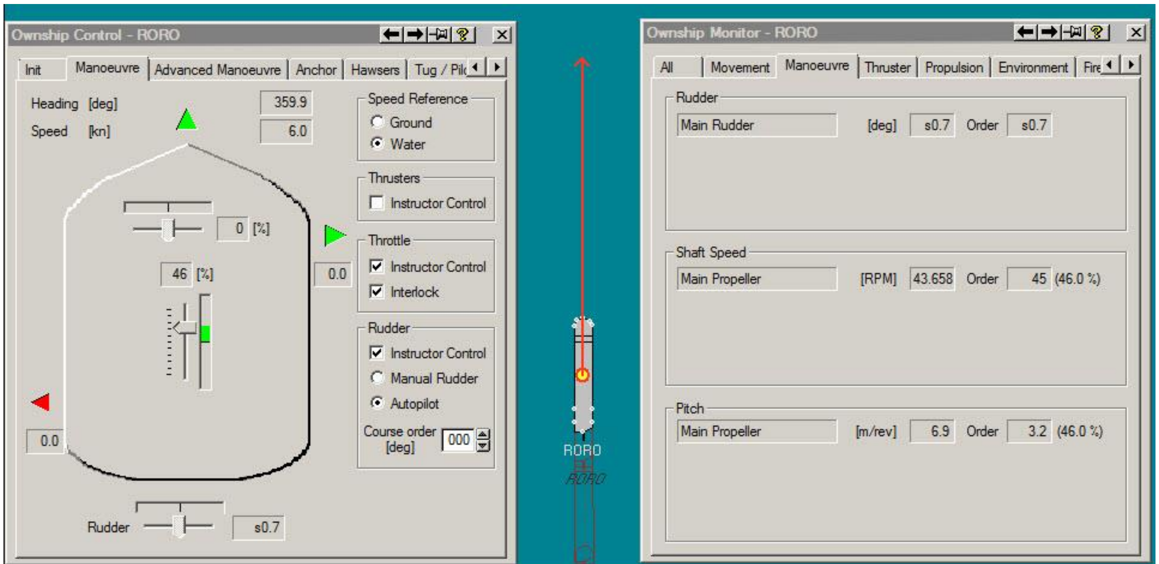
	Elapsed (hh:mm:ss)	RORO Heading	RORO Course	RORO Speed	RORO Water Speed	RORO Rudder (1	RORO Propeller revolution (1)	RORO Wind	RORO Wind direction	RORO Drift angle thru water
7	00:03:06	360	360	6.	6.0	s0.	26	0.0	000	-0
8	00:03:00	360	360	6.	6.0	s0.	26	0.0	000	-0
9	00:02:00	360	360	6.	6.0	s0.	26	0.0	000	-0
10	00:01:00	360	360	6.	6.1	s0.	26	0.0	000	-0
11	00:00:00	000	000	6.	6.1	s0.	27	0.0	000	0

Figure 2: Vessel Water Speed Definition Part 2



	Elapsed (hh:mm:ss)	RORO Heading	RORO Course	RORO Speed	RORO Water Speed	RORO Rudder (1)	RORO Propeller revolution (1)	RORO Wind	RORO Wind direction	RORO Drift angle thru water
7	00:17:17	359	359	2.	2.7	s1.9	26	30.0	000	0
8	00:17:01	360	360	2.	2.7	s1.8	26	30.0	000	-0
9	00:16:01	360	000	2.	2.7	s1.2	26	30.0	000	-0
10	00:15:01	000	000	2.	2.8	s1.0	26	30.0	000	0
11	00:14:01	000	360	2.	2.9	s1.0	26	30.0	000	0
12	00:13:01	360	359	3.	3.0	s1.3	26	30.0	000	1
13	00:12:01	359	358	3.	3.1	s1.6	26	30.0	000	1
14	00:11:01	359	358	3.	3.3	s1.7	26	30.0	000	0
15	00:10:01	359	359	3.	3.4	s1.2	26	30.0	000	0
16	00:09:01	360	360	3.	3.6	s0.7	26	30.0	000	-0
17	00:08:01	360	000	3.	3.8	s0.2	26	30.0	000	-0
18	00:07:01	000	000	4.	4.0	p0.0	26	30.0	000	0
19	00:06:01	360	360	4.	4.3	s0.0	26	30.0	000	0
20	00:05:01	360	360	4.	4.6	s0.1	26	30.0	000	0
21	00:04:01	360	360	5.	5.0	s0.1	26	30.0	000	-0
22	00:03:01	360	000	5.	5.4	p0.0	26	30.0	000	-0
23	00:02:01	000	000	5.	5.7	p0.0	26	20.0	000	-0
24	00:01:01	360	000	5.	5.8	p0.0	27	10.0	000	-0

Figure 3: Vessel Water Speed Definition Part 3



	Elapsed (hh:mm:ss)	RORO Heading	RORO Course	RORO Speed	RORO Water Speed	RORO Rudder (1)	RORO Propeller revolution (1)	RORO Wind	RORO Wind direction	RORO Drift angle thru water
7	00:10:11	360	360	6.	6.0	s0.7	44	30.0	000	0
8	00:10:01	360	360	6.	6.0	s0.8	44	30.0	000	0
9	00:09:01	360	360	5.	5.7	s0.8	43	30.0	000	0
10	00:08:01	360	360	5.	5.5	s0.7	41	30.0	000	0
11	00:07:01	360	359	5.	5.3	s0.8	39	30.0	000	0
12	00:06:01	359	359	5.	5.2	s0.8	37	30.0	000	0
13	00:05:01	360	360	5.	5.2	s0.6	36	30.0	000	-0
14	00:04:01	360	360	5.	5.2	s0.1	33	30.0	000	-0
15	00:03:01	360	000	5.	5.4	p0.0	31	28.7	000	-0
16	00:02:53	360	000	5.	5.5	p0.0	31	28.7	000	-0
17	00:02:01	360	000	5.	5.6	p0.0	29	18.7	000	-0
18	00:01:01	000	000	5.	5.7	p0.0	27	8.7	000	-0
19	00:00:00	000	000	5.	5.7	s0.0	26	0.0	000	0

2.1.2 Ground Speed (Speed over the ground)

Since the body of water that a ship is floating in can be moving, a vessel's speed in reference to a fixed point on the earth, or its ground speed (speed over the ground) is not always the same as its water speed. One of the easiest ways to picture this is with a ship in a river. The vessel could be stopped in the water, with no propulsion applied hence its water speed would be zero, yet the ship would still move in relation to the shoreline of the river bank as it would drift downstream with the river current. If the current is flowing at a velocity of 2 knots (3.7 km/h) the ship would have a ground speed of 2 knots and a water speed of 0 knots. Speed that is calculated by GPS positioning systems is derived from measuring changes in the position of the ship with reference to the earth (Latitude and Longitude) and hence is always ground speed and never water speed. Speed that is broadcasted on a ship's Automated Identification System (AIS) is also ground speed and not water speed. Going back to the example of the river, if a ship is anchored in a river with 2 knots of current, its ground speed is 0, but its water speed is 2 knots, and we can image that water could be easily observed flowing around the bow and off of the stern of the anchored ship. If this same ship were to transit the river with its speed set to 6 knots (as a comparative reference we will use the same RORO as in Figure 1) when proceeding up river it would have a ground speed of only 4 knots as it is proceeding against the current (water speed 6.0 – river current speed of 2.0 = ground speed of 4.0) see Figure 4 below. In a similar manner, if proceeding downstream it would have a ground speed of 8 knots (water speed 6.0 + river current speed of 2.0 = ground speed of 8.0), but in both cases the water speed is 6.0 knots.

Figure 4: Vessel Ground Speed Definition Part 1

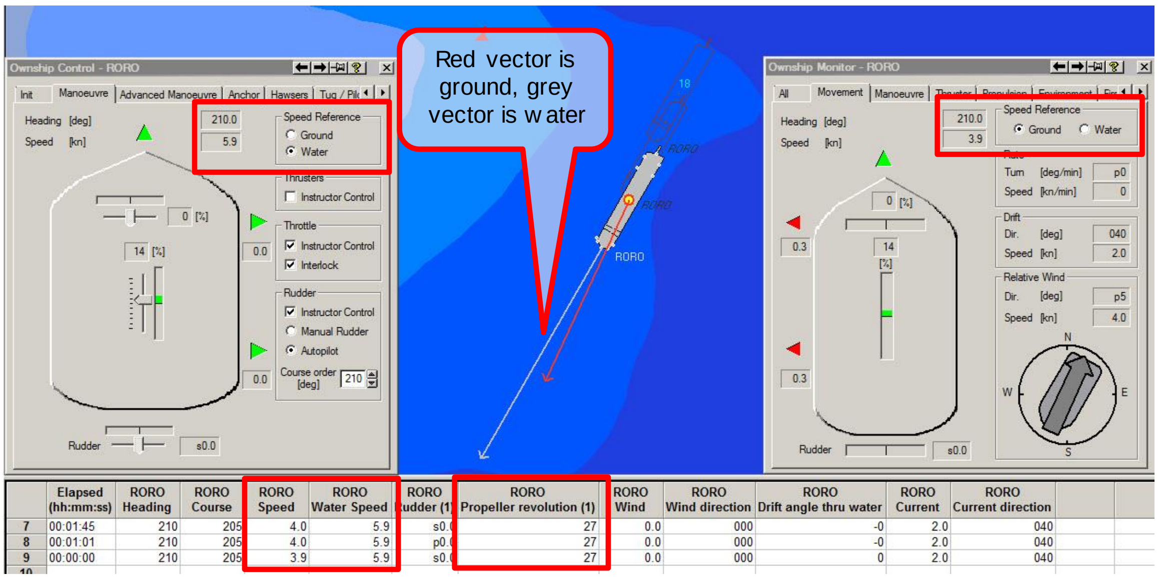
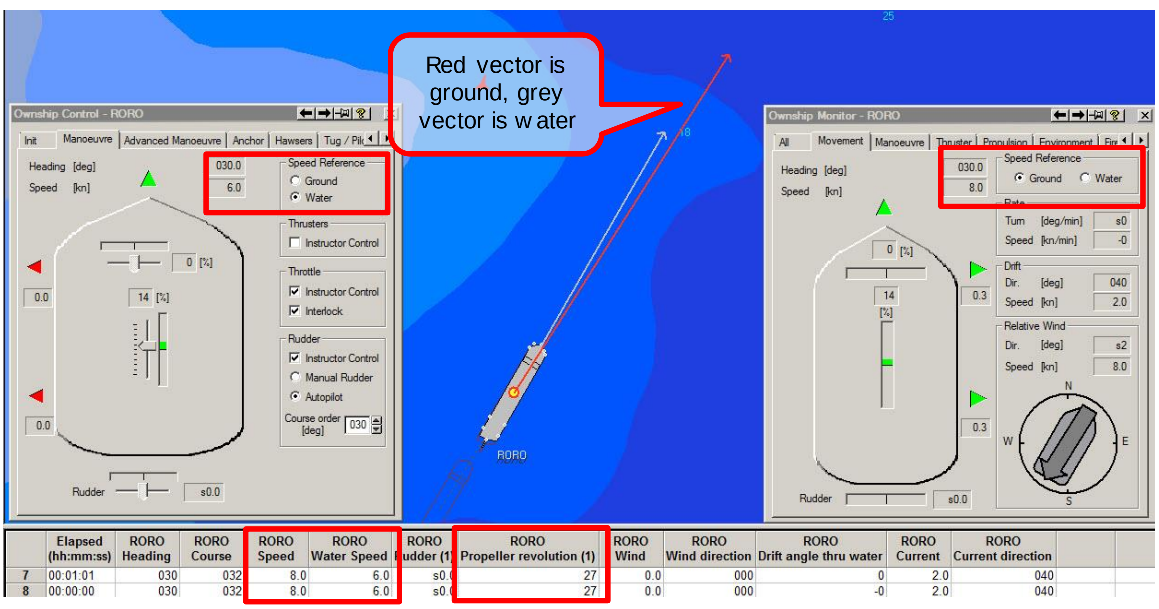


Figure 5: Vessel Ground Speed Definition Part 2



In the context of this report the differentiation between water speed and ground speed is crucial for two reasons:

a) Whales, like ships are immersed in and move through the water, hence in the event of a whale strike, the speed of impact with the whale and the magnitude of the impact speed is a function of water speed and not ground speed (i.e. ship and whale could both be drifting in the river current, each with their "propulsion systems stopped" and they would have 2 knots of ground speed, but relative to one another 0 knots of water or relative speed); and
b) The noise radiated by a vessel as it transits is predominately generated by its propulsion system (engine noise, vibrational noise generated by the propulsion system, propeller noise when it rotates and cavitates) and the motion of the vessel through the water (water moving around the vessel's hull form). As such the two identical vessels as per the examples depicted in Figures 4 and 5 should be generating approximately the same noise level, yet the one proceeding downriver has a ground speed of 8.0 knots and the one proceeding upriver a ground speed of 4.0 knots.

When points a) and b) are considered, we can see that it is water speed, and not ground speed that is an important metric in determining how a transiting vessels speed could potentially affect whales in its vicinity.

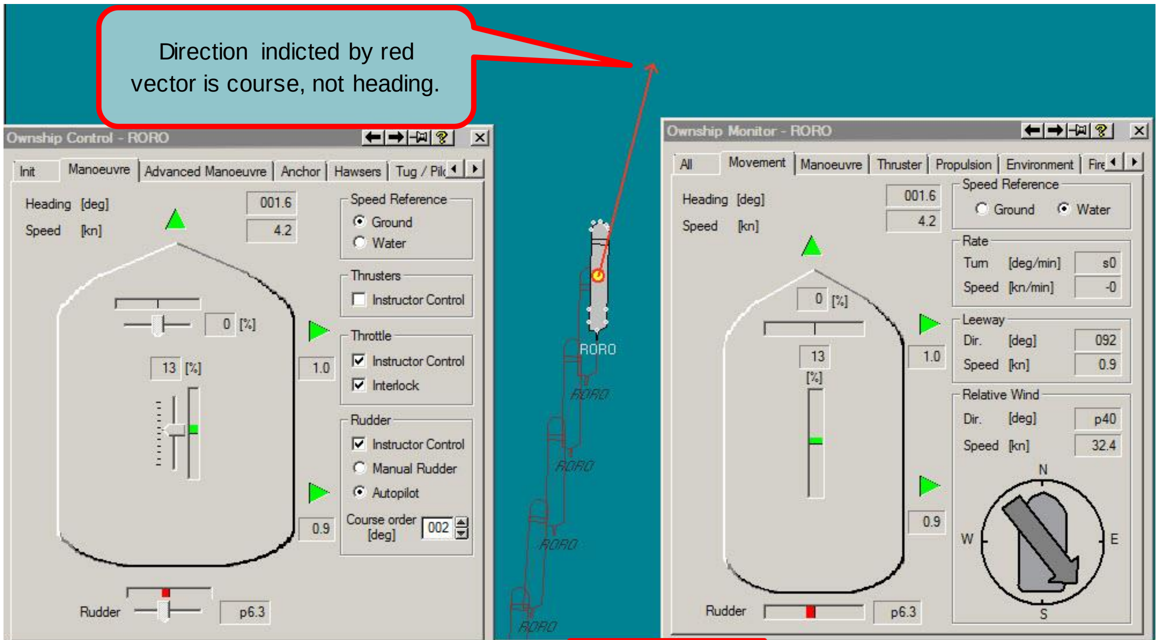
2.1.3 Heading

A vessel's heading refers to the direction in which a ship is pointed. In this report heading is always true heading or referenced to true north and not magnetic north. When there is no wind, current, tidal stream or other external forces acting on a vessel, when propulsion is applied the ship will proceed along its heading (i.e. it will go where it is pointed). In order to control a ship's direction, the helmsman will steer a course based on heading (i.e. steer 000° or north), or the autopilot will be set to steer a particular true heading.

2.1.4 Course

Course is the direction in which a vessel actually travels, and not necessarily where it is pointed. Perhaps the easiest way to imagine this is when a vessel moves astern (backs up) in which case its course generally speaking is in the opposite direction than its heading. Since a ship is rarely in a completely neutral environment, there are almost always external forces being applied to the ship, hence its course and heading are almost never identical. Two of the most important phenomena that affect the direction of a vessel's course when it is transiting are wind and current (tidal stream). Again, if we refer to a RORO vessel transiting at its Dead Slow speed of 6 knots and we introduce a wind of 30 knots blowing from an angle of 60° on its port bow (wind coming left side in relation to direction of travel/heading), the ship will not travel through the water (or over the ground) in the direction that it is pointed, but rather will develop drift to starboard (drift to the right of where it is pointed). See Figure 6 below:

Figure 6: Course – Wind Induced Drift



	Elapsed (hh:mm:ss)	RORO Heading	RORO Course	RORO Speed	RORO Water Speed	RORO Rudder (1)	RORO Propeller revolution (1)	RORO Wind	RORO Wind direction	RORO Drift angle thru water
7	00:07:33	002	014	4.3	4.3	p6.1	26	30.0	315	-12
8	00:07:01	001	014	4.4	4.4	p5.6	26	30.0	315	-12
9	00:06:51	001	013	4.5	4.5	p5.1	26	30.0	315	-12
10	00:06:01	001	012	4.6	4.6	p3.7	26	30.0	315	-11
11	00:05:01	001	012	4.9	4.9	p3.8	26	30.0	315	-12
12	00:04:49	001	013	4.9	4.9	p4.2	26	30.0	315	-11
13	00:04:29	002	014	5.0	5.0	p6.8	26	30.0	315	-11
14	00:04:19	003	014	5.1	5.1	p9.2	26	30.0	315	-11
15	00:04:15	003	014	5.1	5.1	p11.7	26	30.0	315	-11
16	00:04:09	004	014	5.1	5.1	p16.8	26	30.0	315	-10
17	00:04:05	004	014	5.2	5.2	p9.0	26	30.0	315	-10
18	00:04:01	004	014	5.2	5.2	p3.8	26	30.0	315	-10
19	00:03:39	004	013	5.3	5.3	p3.5	26	30.0	315	-9

Note that in Figure 6 above the ship was initially steering 000° with no wind and with a propeller speed of 26 RPM was making 6.0 knots in the direction of 000°, hence heading and course were initially identical. Over the first three minutes of simulation, the velocity of the wind is increased to 30 knots and the ship started to develop drift to starboard. After four minutes of exposure to a 30-knot wind, in addition to motion in its forward axis (heading of 000°) the ship has developed sideways or lateral motion, and since the resistance to motion is much greater when the ship moves sideways (larger cross-sectional area) the vessel also loses speed. As such its course is approximately 014°, its heading is approximately 002° and its water/ground speed is reduced to 4.2 knots with approximately 1.0 knots of lateral (sideways) speed. Also note that the difference between the heading and the course is referred to as drift angle, and this value is 12°.

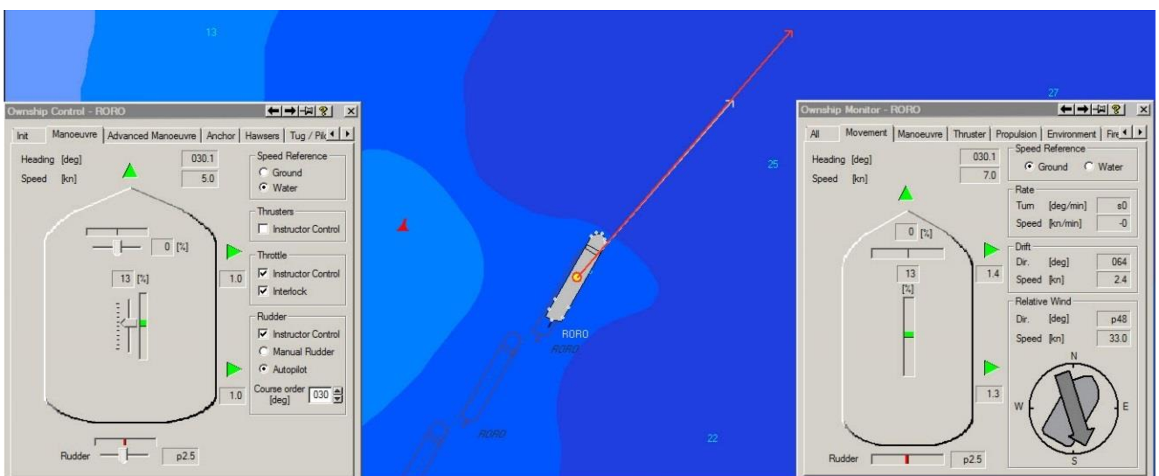
Similarly, drift can be induced by current or tidal (tidal stream) forces. In Figure 7 below we can see the same vessel proceeding downriver with a current flowing at an angle of 10° to the vessel's heading. In this example, the ship does not lose any appreciable water speed since the entire body of water (the river) is moving, but it does gain ground speed, and since its heading is not exactly parallel to the current, it develops current induced drift, and its course is 034° with a heading of 032°, and its ground speed is 7.9 knots

Figure 7: Course – Current Induced Drift

	Elapsed (hh:mm:ss)	RORO Heading	RORO Course	RORO Speed	RORO Water Speed	RORO Rudder (1)	RORO Propeller revolution (1)	RORO Wind	RORO Wind direction	RORO Drift angle thru water	RORO Current	RORO Current direction
7	00:03:53	032	034	7.9	5.9	s0.0	26	0.0	262	0	2.0	040
8	00:03:01	032	034	7.9	5.9	s0.0	26	0.0	262	0	2.0	040
9	00:02:01	032	034	7.9	5.9	s0.0	26	0.0	262	0	2.0	040
10	00:01:01	032	034	8.0	6.0	s0.0	26	0.0	262	0	2.0	040
11	00:00:00	032	034	8.0	6.0	s0.0	27	0.0	262	-0	2.0	040

Finally, course can be affected by a combination of external forces (wind, current, tidal stream, etc.). In figure 8 below we can see how the ship's course is affected by the effects of both wind (30 knots on the port bow) and current (2 knots downriver).

Figure 8: Course – Drift induced by Multiple Factors



	Elapsed (hh:mm:ss)	RORO Heading	RORO Course	RORO Speed	RORO Water Speed	RORO Rudder (1)	RORO Propeller revolution (1)	RORO Wind	RORO Wind direction	RORO Drift angle thru water	RORO Current	RORO Current direction
7	00:04:05	030	041	7.1	5.1	p2.8	26	30.0	330	-11	2.0	040
8	00:04:01	030	041	7.2	5.2	p2.2	26	30.0	330	-11	2.0	040

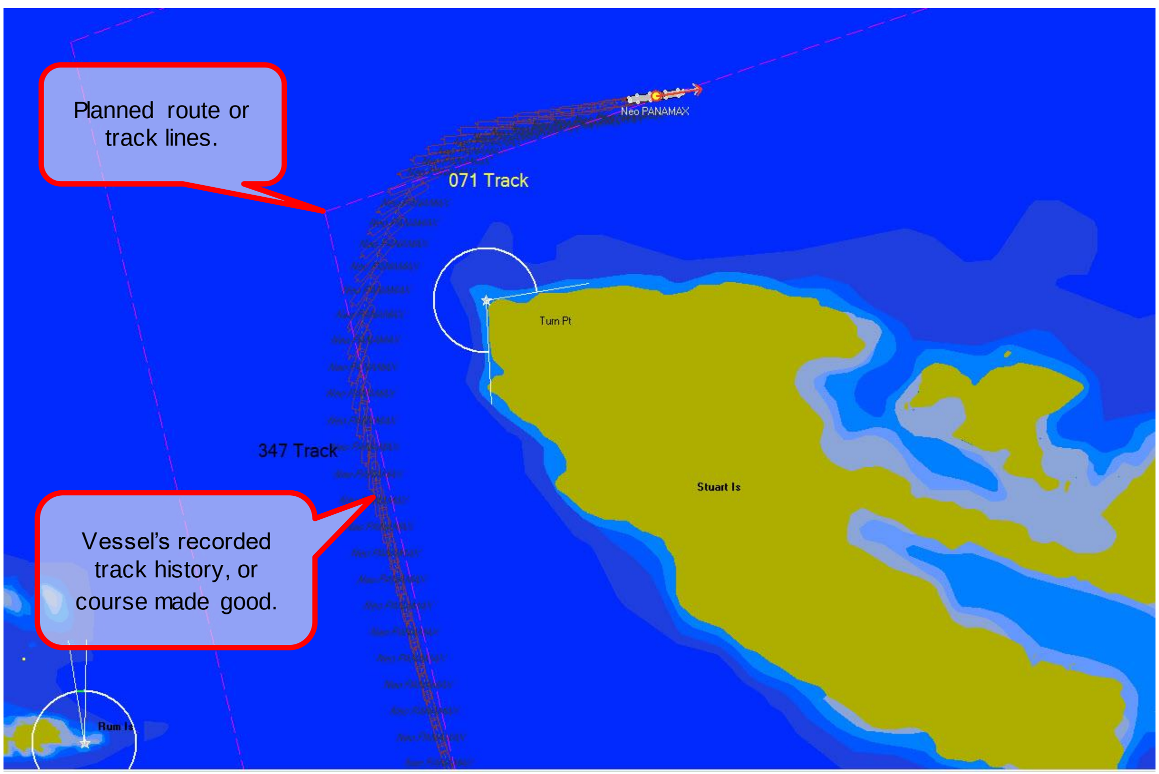
Note that in Figure 8 we can see that the ship has developed 1.4 knots of lateral drift due to the wind, and that the resultant ground speed is now 7.0 knots with a course of 041°.

For our purposes, throughout this report we will not breakdown course drift into its different components but will rather be concerned with total resultant drift (whether generated by wind, current, etc.) and reference to course will always be the true course over the ground as this provides us with the best reference as to where the ship actually travels or tracks in relation to the navigational channel.

2.1.5 Navigation Track – Course Line

A vessel's navigational track, or course line is the planned route that a vessel intends to follow. This route or track can be drawn on a chart and represents a specific line of position that connects two defined route waypoints. Although this route may be considered the ideal path for a vessel to follow, it often deviates from this route either intentionally (i.e. to avoid other vessels) or inadvertently because of wind or tidal induced drift. In Figure 9 below, we can see the planned route or track/course lines of 347° and 071° depicted in the image as broken purple coloured lines, which take the vessel from Haro Strait into Boundary Pass in British Columbia.

Figure 9: Navigation Track or Route Course Lines



2.1.6 Vessel Track – Course Made Good

A vessel's track is the actual path that a ship realises when it navigates along its planned track. In Figure 9 above, we can see the ship's track presented in the image as a series of ship-shape outlines that have been plotted at 30 second intervals. Note that due to tidal stream induced drift, the ship tracks approximately 100 metres to port of the 347° track prior to rounding Turn Point, and then drifts to the port side of the 071° prior to steadying on its course after completing the turn.

2.1.7 Current

This is a term that many professional mariners (especially those from the United States, or those that have sailed extensively in US waters) use in a general sense to refer to all lateral or horizontal movement of a body of water. In the purest sense however, and by proper nautical definition, current is the lateral movement of water that is generated either by a change in elevation of that body of water (i.e. river current), or by prolonged exposure to prevailing environmental phenomena such as prevailing winds, weather systems, differences in salinity, Coriolis Effect, etc. (i.e. Labrador Current, the Gulf Stream, etc.). In the context of this report, current is experienced in significant amounts only in the study area of the confluence of the Saguenay and St-Lawrence Rivers, and this current is river current, the velocity of which varies on a seasonal basis, and in most years achieves its highest velocity in the spring season as the snow and ice melt.

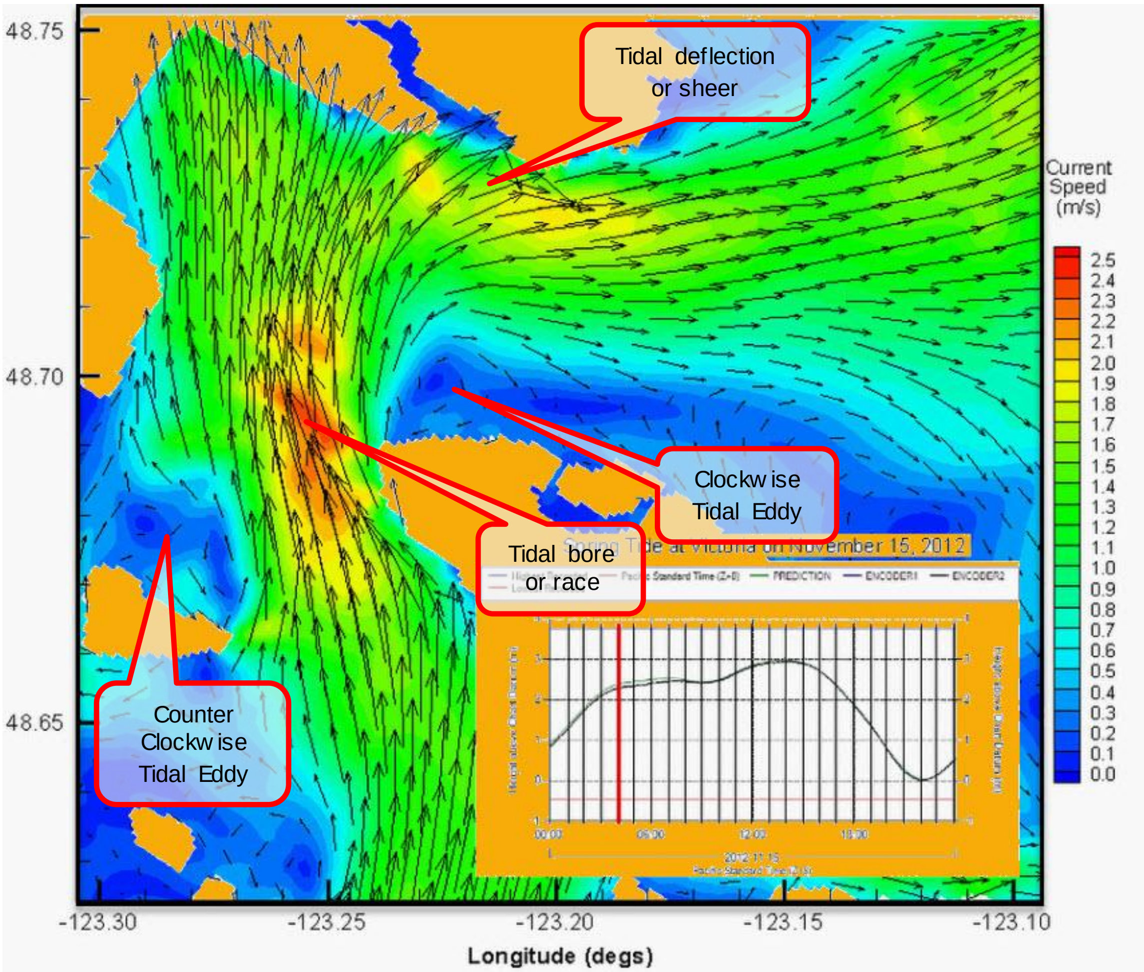
2.1.8 Tidal Stream

Tidal stream is the lateral or horizontal movement of a body of water which is generated by the daily variations in height of tide. As mentioned above, many mariners incorrectly (or simplistically) refer to this as current. Both of the mandatory pilotage areas in this study (Confluence of Saguenay/St-Lawrence, and Haro Strait/Boundary Pass) are subject to very strong tidal streams which stem from large vertical rises in the height of tide of approximately 5 to 6 metres coupled with physical constriction in the shape of the channels. The complexities of tidal stream are very pronounced in the Saguenay and St-Lawrence as they actually produce a reversal in the normal outflow of the river current for several hours each day.

2.1.9 Tidal Eddies, and Tidal Bores (Tidal Races)

Tidal eddies and tidal races are localised phenomena that are produced when physical shapes in the bottom depth, and or shape of the channel effect the horizontal or lateral flow of the water. Tidal bores or races form in areas when the channel narrows and a large volume of water is forced to flow through a channel with a smaller volumetric capacity, this results in an increase in velocity, and the resultant tidal bore or race can persist for as much as a kilometre or more after the water passes the area of constriction. Tidal eddies are caused either by physical deflection, or at the junction of a tidal race with a larger body of water, in which case circular flow patterns develop in areas of lower volumetric flow. In the context of this report, it is important to recognise that these effects can produce sudden and unpredicted changes in both the vessels heading, and its resultant course, and even for an experienced pilot, it can be difficult to predict (especially at night or in poor visibility) exactly where these effects will occur, and what their exact magnitude will be at any given time. Figure 10 below illustrates how some of the tidal flow patterns form during a flood (rising) tide at the junction of Haro Strait and Boundary Pass in British Columbia.

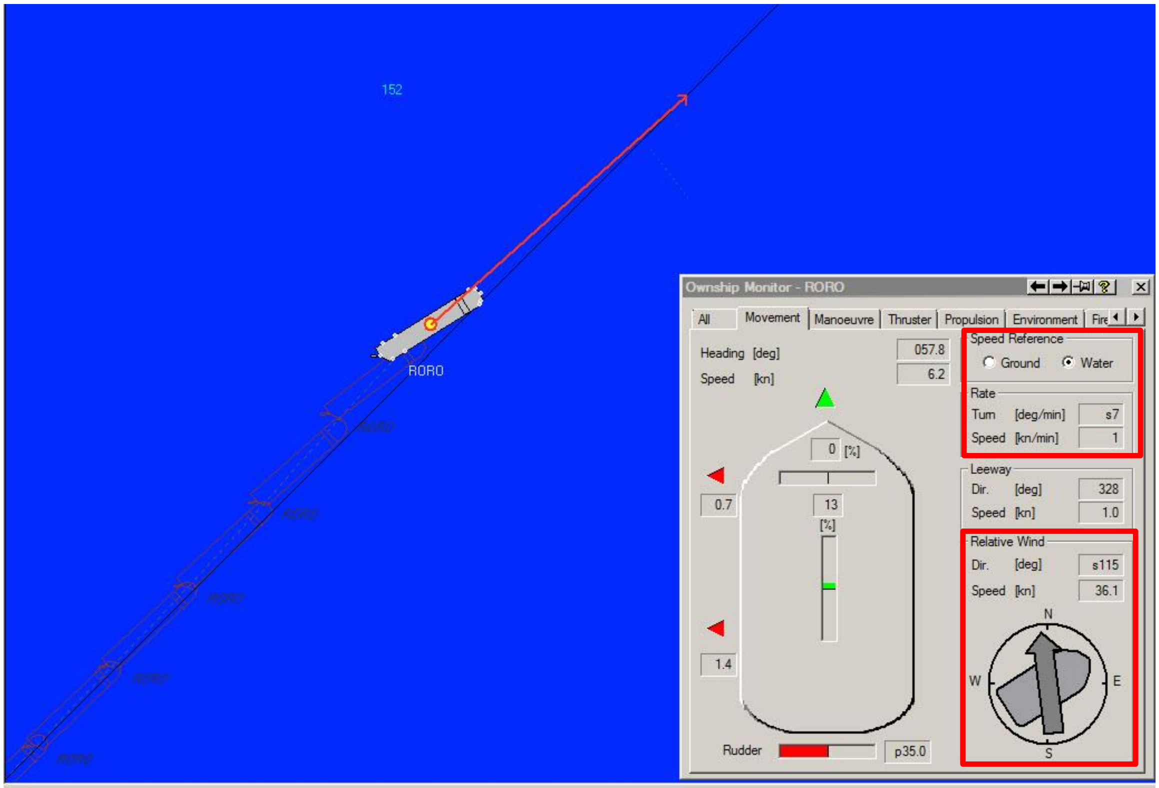
Figure 10: Tidal Eddies and Tidal Race at Turn Point



2.1.10 Steering Control

In the context of this report, steering control refers to the vessel's ability to maintain the ordered heading or direction in which it is pointed. Strong winds from the astern hemisphere (abaft the ship's beam or from behind the ship) particularly those on the quarter can results in wind induced rotation which will required increased amounts of rudder angle just for the ship to maintain heading. At low transit speeds, wind velocities above 30 knots can produce sufficient rotational forces that even the application of full rudder (especially on high sided vessels) may not be sufficient for a ship to maintain its heading. This is illustrated in Figure 11 below where a RORO vessel at its Dead Slow Ahead Speed of 6.0 knots (26 propeller RPM) with 40 knots of wind on the starboard quarter is unable to maintain its heading even with full port rudder applied. In a situation like this, steering control can only be regained by ordering a significant increase in propeller RPM. The increase in propeller RPM will increase the volume and velocity of the water (wash) passing over the rudder surface and will increase the turning power or "lift" of the rudder; over time increased RPM will also increase the vessel's water speed. Loss of heading control can also be tidal induced, and this occurs when a ship passes through a tidal eddy, tidal sheer, or other area where there is a rapid change in the direction and/or velocity of the tidal stream or current over a very short distance.

Figure 11: Loss of Steering Control – Wind Induced

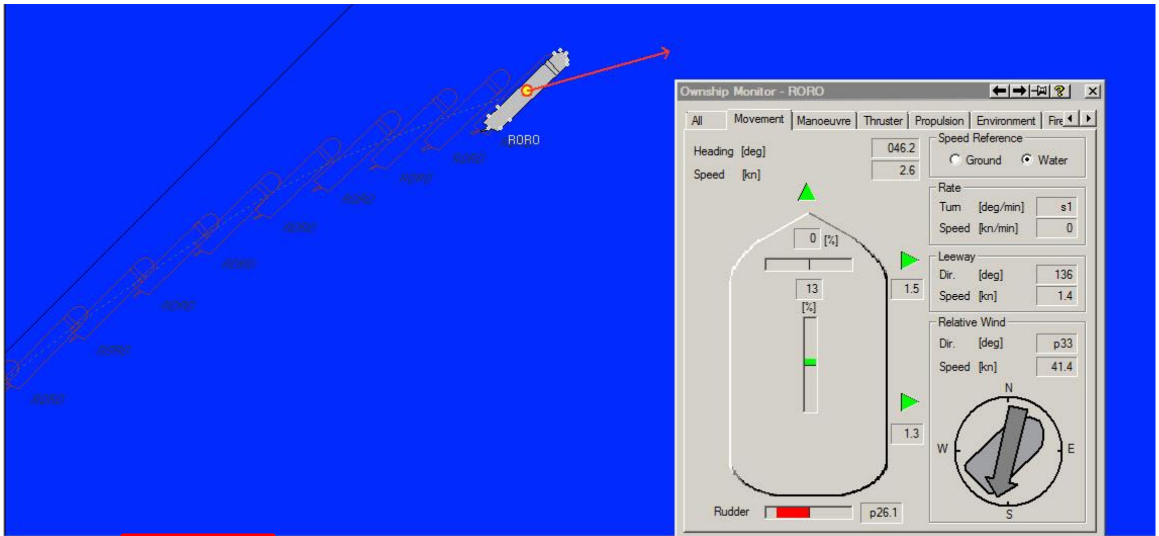


	Elapsed (hh:mm:ss)	RORO Heading	RORO Course	RORO Speed	RORO Water Speed	RORO Rudder (1)	RORO Propeller revolution (1)	RORO Wind	RORO Wind direction	RORO Drift angle thru water	RORO Current
7	00:05:35	057	047	6.4	6.4	p35.0	26	40.0	180	11	0.0
8	00:05:29	057	048	6.2	6.2	p35.0	26	40.0	180	9	0.0
9	00:05:15	054	045	6.2	6.2	p35.0	26	40.0	180	9	0.0
10	00:05:01	053	044	6.2	6.2	p35.0	26	40.0	180	9	0.0
11	00:04:59	053	044	6.2	6.2	p35.0	26	40.0	180	9	0.0
12	00:04:45	051	042	6.2	6.2	p35.0	26	40.0	180	8	0.0
13	00:04:29	050	041	6.2	6.2	p35.0	26	40.0	180	8	0.0
14	00:04:01	048	042	6.2	6.2	p35.0	26	39.4	180	6	0.0

2.1.11 Positional Control

In this report the term Positional Control refers to the ability to maintain the intended route track line or general intended direction of travel (route corridor). Positional control can be considered to have two components - one is the lateral displacement, or distance that a ship is to port or starboard (left or right) of its intended track, and the other is the course that the ship is realising versus the course that is desired, and the size of the angular difference between the desired course and the one that is being achieved. As with heading control, wind induced rotation/drift and current/tidal stream induced rotation/drift are the most common phenomena that contribute to loss of positional control. In Figure 12 below, we can see how a RORO vessel at its Dead Slow Ahead speed of 6 knots with 40 knots of wind on the port bow can maintain heading (046°) but due to wind induced drift and a greater than 50% loss of water speed cannot maintain positional control and drifts off its track line. In this case, although heading control is maintained, positional control is lost and the course made good is 074°.

Figure 12: Loss of Positional Control – Wind Induced



	Elapsed (hh:mm:ss)	RORO Heading	RORO Course	RORO Speed	RORO Water Speed	RORO Rudder (1)	RORO Propeller revolution (1)	RORO Wind	RORO Wind direction	RORO Drift angle thru water	RORO Current	RORO Current direction
7	00:11:10	046	074	3.1	3.1	p27.6	26	40.0	010	-27	0.0	040
8	00:11:00	046	074	3.1	3.1	p27.3	26	40.0	010	-27	0.0	040
9	00:10:58	046	074	3.0	3.0	p28.2	26	40.0	010	-28	0.0	040
10	00:10:54	046	074	3.0	3.0	p24.4	26	40.0	010	-27	0.0	040
11	00:10:52	046	073	3.1	3.1	p27.2	26	40.0	010	-27	0.0	040
12	00:10:48	046	075	2.9	2.9	p25.7	26	40.0	010	-29	0.0	040
13	00:10:46	046	072	3.1	3.1	p23.3	26	40.0	010	-26	0.0	040
14	00:10:42	046	074	3.1	3.1	p25.8	26	40.0	010	-28	0.0	040

2.2 Physical Characteristics of the Areas of Concern

The four areas of concern identified by TC for investigation represent a combination of narrow navigation channels, wide open straits, and pilotage and non-pilotage areas. In the pilotage areas, vessels benefit from the expertise of a local pilot. These areas tend to be navigationally more challenging with the ship in close proximity to navigational hazards in a constrained channel where there is less distance to respond to a degradation in steering or positional control. Pilotage areas also tend to have a higher vessel traffic density as they are close to major ports and terminal facilities.

In the case of the Southern Resident Killer Whale (SRKW), the overall area is nearly equally divided between pilotage and non-pilotage area. The area within Juan de Fuca Strait is non-pilotage, the vessel's route/course legs are long, straight and more than 4 nautical miles (7.5 kilometers) from the nearest shoreline for much of the transit. Although tidal streams in this area can be moderate in strength, they tend to parallel the channel/ shoreline therefore having little effect on the vessel's steering or positional control. Tidal streams must be considered when evaluating a vessel's speed, or setting transit speed limits. The use of ground speed as a metric for establishing speed limits is discussed extensively in latter sections of this report. In Juan de Fuca Strait the most important factor with respect to maintaining vessel steering and positional control at lower speeds is the wind. It is likely that the same minimum speed threshold can be used for any given vessel type for the entire transit. In sharp contrast, in the pilotage area from the southern end of Haro Strait through Boundary Pass to the South end of Georgia Strait, ships routinely transit within 0.75 nautical miles (1.4 kilometres) of the shoreline, and the route/course legs can be less than 1 nautical mile in length. Additionally, the tidal streams in this area are strong and, at periods of maximum flood and ebb, significantly effect a vessel's ground speed. Large rotational tidal eddies which form as a regular part of the daily tidal cycle can make course maintenance difficult. To establish minimal safe transit speeds in Boundary Pass and Haro Strait, the combination of localised wind and tidal stream effects needed to be evaluated and consideration given to the possibility that different minimal speed thresholds may apply to certain segments of the transit. See Figures 13 and 14 below:

Figure 13: Juan de Fuca Strait and Haro Strait Boundary Pass Areas

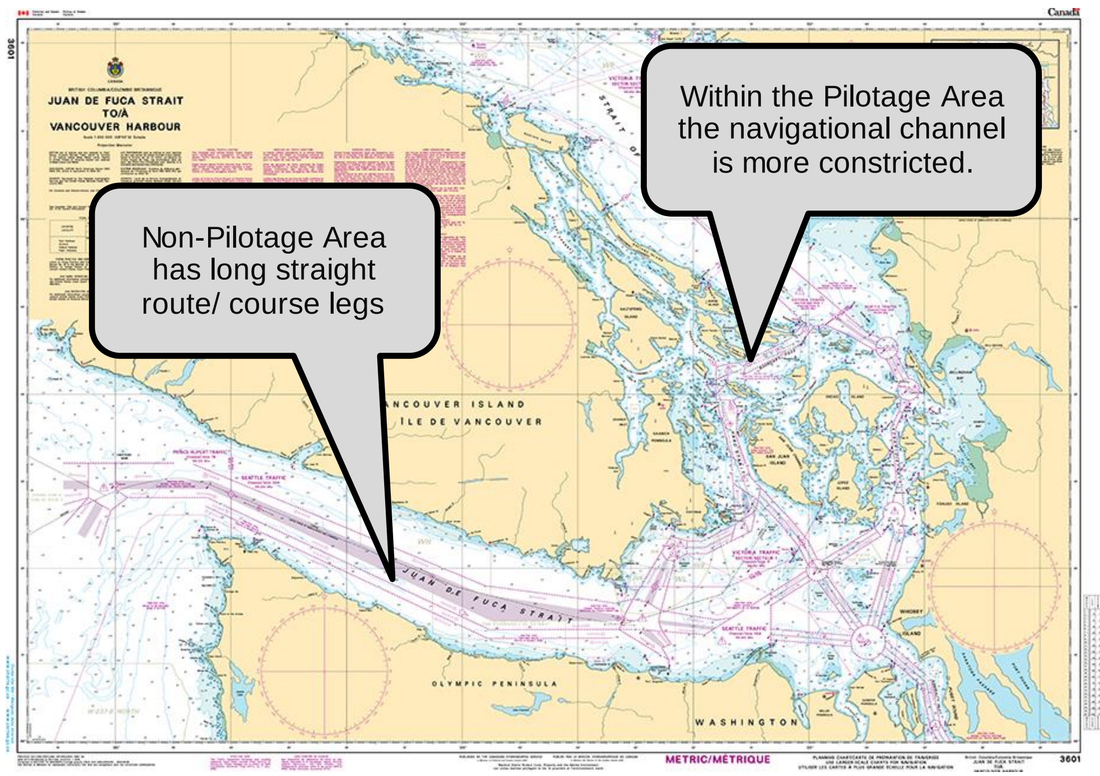
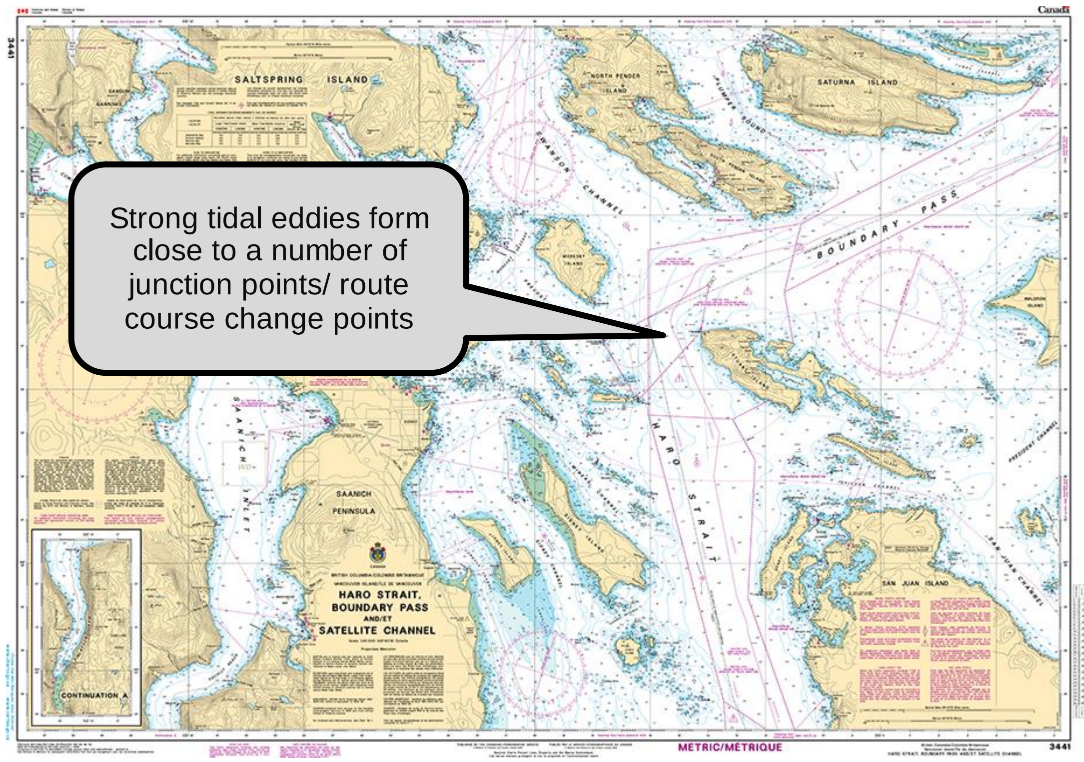
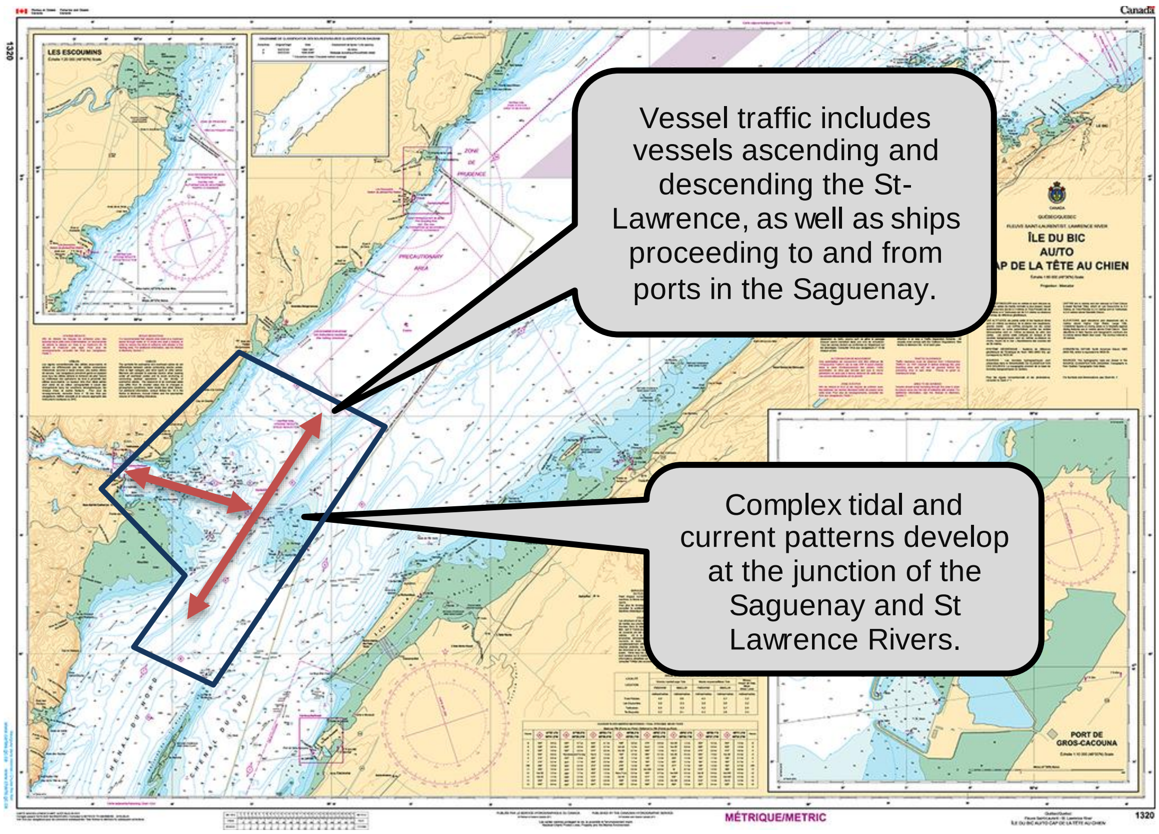


Figure 14: Haro Strait Boundary Pass Areas



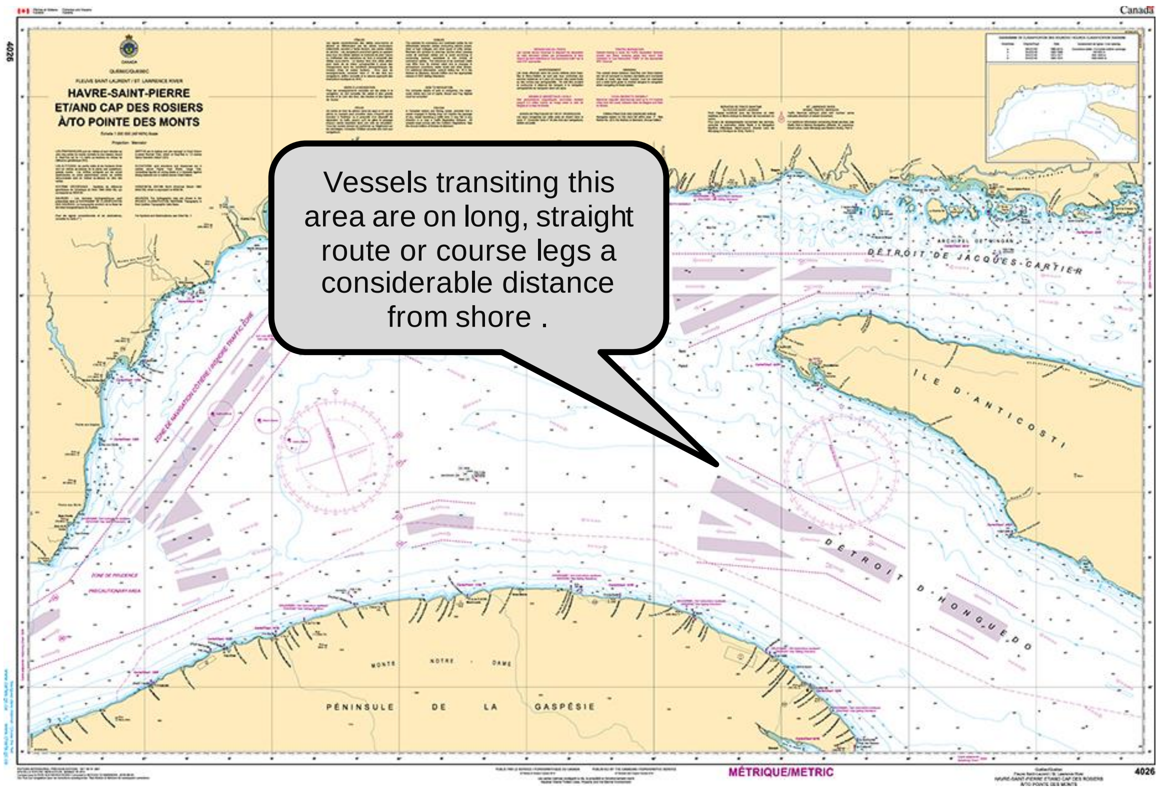
The area of concern for the Saint-Lawrence Estuary Beluga (SLEB) is in the vicinity of where the Saguenay tributary meets the St-Lawrence River. This region is subject to compulsory pilotage, and the environmental parameters in this area are quite extreme. The tidal range exceeds 5 metres and when coupled with the confluence of the Saguenay and St-Lawrence Rivers, particularly during freshet river conditions (high level during spring run-off), can produce very complicated tidal and current flow patterns. Additionally, there are a number of shoals and banks that present navigational hazards in close proximity to vessel transit routes. In this area, consideration was given to the possibility that speed thresholds for degradation of steering and positional control may vary on a seasonal basis. The analysis also examined the possibility that different thresholds may apply for vessel transits to and from the Saguenay versus transits within the St-Lawrence. See Figure 15 below:

Figure 15: Saguenay and St-Lawrence Estuary Area



The final area of interest is in the vessel traffic lanes to the South of Anticosti Island. This is a non-pilotage coastal area where the Strait is wide and unobstructed. Vessels are typically transiting at distances of more than 9 nautical miles (16.6 kilometres) from the shoreline. The vertical tidal range in this area is less than 1.5 metres, and the associated tidal stream/current flows in this area are very light and not considered to be a factor in this evaluation. Wind speed was the predominate environmental factor that was evaluated to determine the speed thresholds for lost of steering or positional control. See Figure 16 below:

Figure 16: Traffic Separation Scheme South of Anticosti Island



2.3 Considerations for Vessel Manoeuvring Characteristics

A second factor in establishing minimal safe vessel transit speed is the manoeuvring characteristics of the vessels that frequent the area. The scope of vessel manoeuvrability and propulsion systems is as broad as the diversity of the area's physical characteristics. For example, all four areas are frequented by passenger vessels, which in general are highly manoeuvrable and range in size from 20 metres length overall (LOA) to more than 350 metres LOA. They are also highly prone to wind induced drift and rotation at low speeds. Similarly, all four areas would be transit zones for Bulk Carriers, which when in ballast can be prone to wind and current induced rotation/ course deviation. Finally, Container vessels which are common in all four regions often have a minimal cruising (Dead Slow Ahead) speed of 7.5 knots or more. Without over-complicating the intricacies of vessel manoeuvring characteristics, it is important to recognise that the analysis considered the following factors:

a. With the exception of passenger vessels, and small vessels engaged in coastal trade, most commercial ships use low speed diesel engines, and the majority of these use a propeller with fixed blades, with speed adjusted by changing engine/shaft revolutions (RPM). These engines also use heavy fuel when in "At Sea" or cruising mode, and switch to lighter fuel when entering port or congested waterways when the engine is switched to "manoeuvring mode". Many vessels have some restriction on their ability to change speed, or to stop the engine when in sea or cruising mode. Also for most vessels, there is a range of propeller RPMs that cannot be ordered (critical RPM) without risk of stalling the engine. See Figure 17 for example of Engine Telegraph and RPM – Speed Table:

Figure 17: Sample Engine Telegraph and RPM Speed Table

For the purpose of this analysis, it will be assumed that vessels within pilotage areas will be in Manoeuvre Mode. Therefore vessels may use brief increases in engine RPM (i.e. from Slow Ahead to Half) to correct heading deviations (increase waterflow over the rudder surface) and maintain steering without appreciably changing speed. In non-pilotage areas, tests will be conducted with the engine remaining at a given RPM setting (i.e. Slow Ahead). If steering control is lost, the engine RPM will be changed to the next setting (i.e. Half Ahead) and will remain at this setting, allowing the ship to accelerate to its next speed setting level.

b. For vessels that are routinely navigated in both loaded and empty conditions (i.e. Tankers and Bulk Carriers) tests were conducted with both loaded and ballasted versions. Generally, loaded tankers and bulkers are not highly prone to wind induced course deviation. The ballasted ships are more prone to wind induced drift and rotation and also tend to be directionally unstable.

c. The categories of test vessels also varied somewhat form one area to the other as a function of the types of vessels that call on that region. For example, due to draught and beam width restrictions in the Port of Montreal (the only large container port in the St-Lawrence Region), the largest type of Container Vessel is typically PANAMAX size, whereas Delta Port in Vancouver will receive Neo-PANAMAX size and larger Container Vessels.

The points mentioned above also played a key role in the development of the Testing Plan and sequence that is described in Section 3 of this report.

2.4 Wind Effects on Manoeuvrability

The environmental factor which most commonly effects a vessel's low speed steering and positional control is wind. In order to ensure that tests with wind were geographically relevant, and that they looked at worst case situations (typically wind from a direction on the vessel's quarter), tests were conducted using winds from the quadrant with the greatest frequency of probability for the area and from a direction that was at an angle of 135° from the vessel's intended route or track-line. See Figures 18 and 19 below. Additionally, although the frequency with which wind speeds exceed a particular threshold may be quite relevant with respect to implementing a minimum transit speed policy (i.e. if a specific vessel type has difficulty maintaining steering control at a speed of 7 knots, in winds of 25 knots, and the frequency of winds at this speed is 40%, then obviously it would be difficult to implement a 7 knot speed restriction), the objective of these test is to identify the wind speed threshold at which steering/positional control become difficult to maintain for a given transit speed.

Figure 18: Historic annual wind direction probability for Pointe de l'Islet (Source Environment Canada)

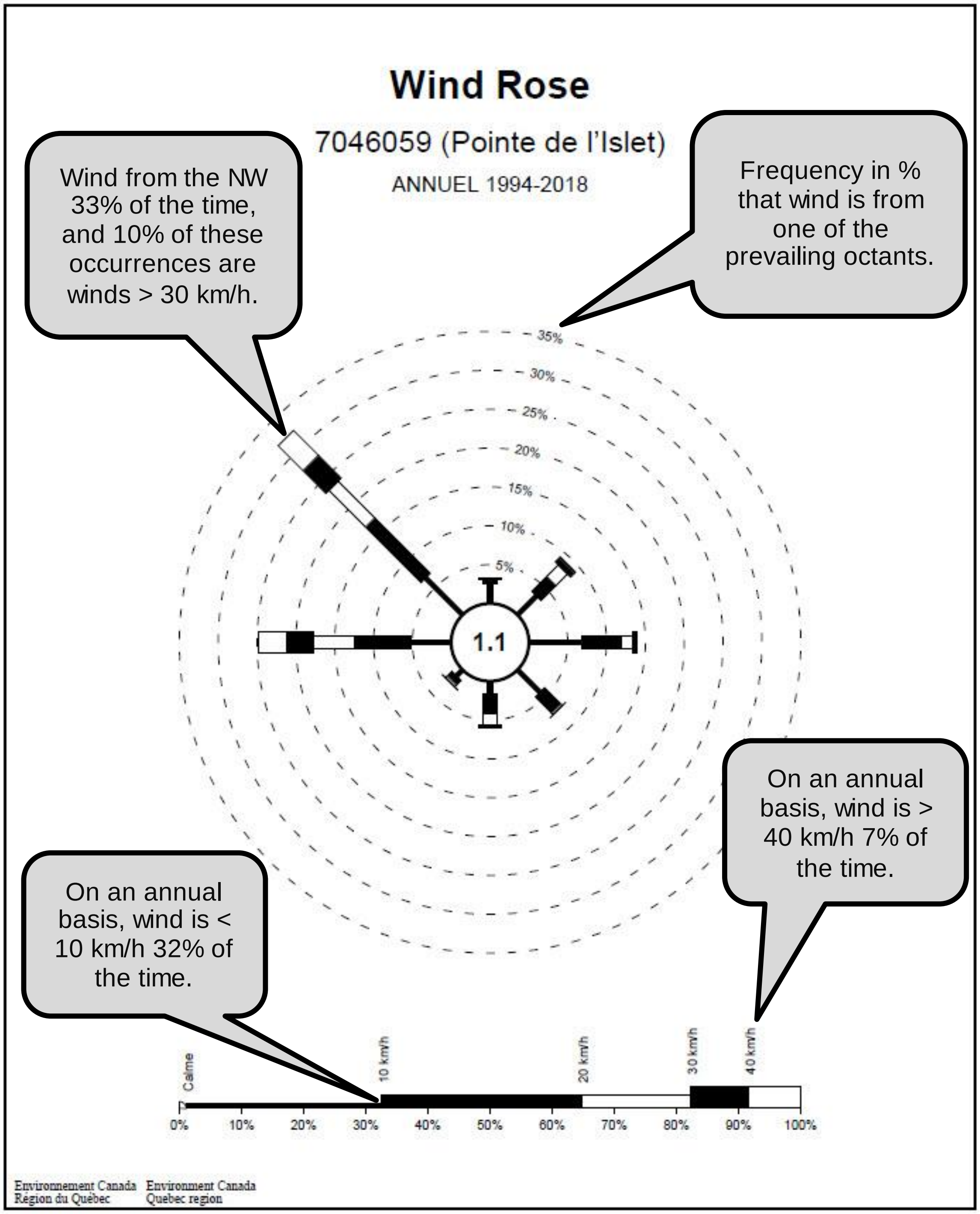
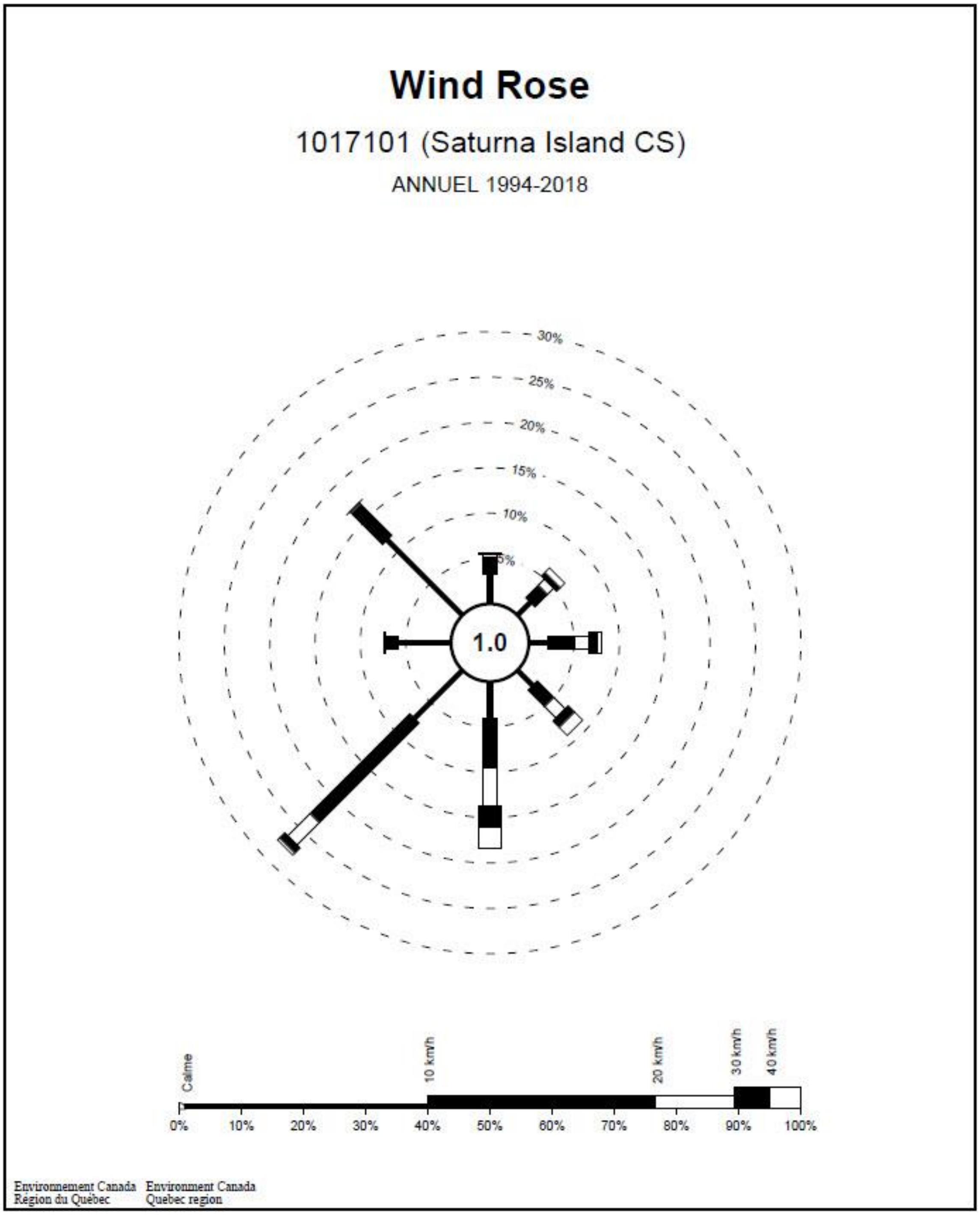


Figure 19: Historic annual wind direction probability for Race Rocks/ Juan de Fuca Strait (Source Environment Canada)

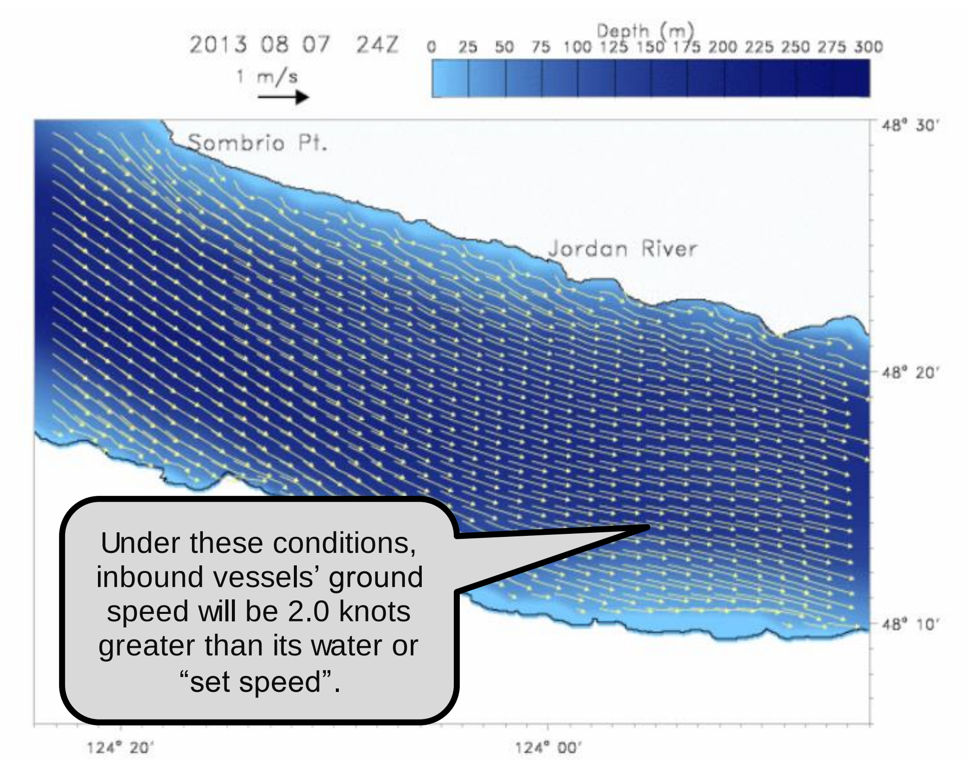


2.5 Tidal Stream and Current Effects on Manoeuvrability

For the purposes of this project, and as discussed previously in Items 2.1.7 and 2.1.8, a differentiation is made between tidal stream and current. In the waters of Juan de Fuca Strait and Haro Strait/Boundary Pass, our analysis focused purely on tidal stream, and it is safe to say that any significant variations are limited to the normal monthly tidal cycle. At the junction of the Saguenay and St-Lawrence Rivers the resultant water flow is a combination of river outflow current, which can vary significantly on a seasonal basis (i.e. typically much stronger in the spring runoff season) and tidal stream stemming from the 5-metre vertical tidal range. Finally, in the vicinity of Anticosti Island, the vertical tidal range is less than 1.5 metres, tidal stream is not significant, and there was no database of tidal or current information readily available therefore it was not factored into the analysis.

In general terms, relatively homogenous horizontal waterflow, such as that experienced in large straits and gulfs (Juan de Fuca and Anticosti), do not cause appreciable current induced course rotation and have little effect on vessel heading deviation. However, with velocities in the surface layers approaching 2.0 knots or more, they are an important consideration for the actual speed that a vessel makes over the ground, which is the speed that would be measured and calculated by radar systems such as those used by the Vessel Traffic Management Systems (VTMS). See Figure 7 below:

Figure 20: Tidal Stream Predictions for Juan de Fuca Strait at Maximum Flood (Source http://www.pac.dfo-mpo.gc.ca/sci/juandefuca/jdf_west_animation.htm)



Within the area of Haro Strait/Boundary Pass geographical constriction, physical obstructions, change in water depths and density all contribute to complex and highly dynamic tidal stream patterns. In certain locations strong tidal eddies and tidal races can form. These tidal eddies and races can cause sudden and severe deviations in a vessel's course and can be very difficult to correct at low speed/low propeller RPM. Given that these phenomena are present on a daily basis, at a range of intensity, they were factored into the analysis of safe minimum transit speed within the confines of very specific regions (i.e. within 2 nautical miles of Turn Point in Haro strait, Gowlland Point in Boundary Pass and East Point at the junction of Boundary Pass with the Strait of Georgia). See Figures 21 to 23 below:

Figure 21: Tidal Stream Flow at Turn Point during Spring Flood Tide

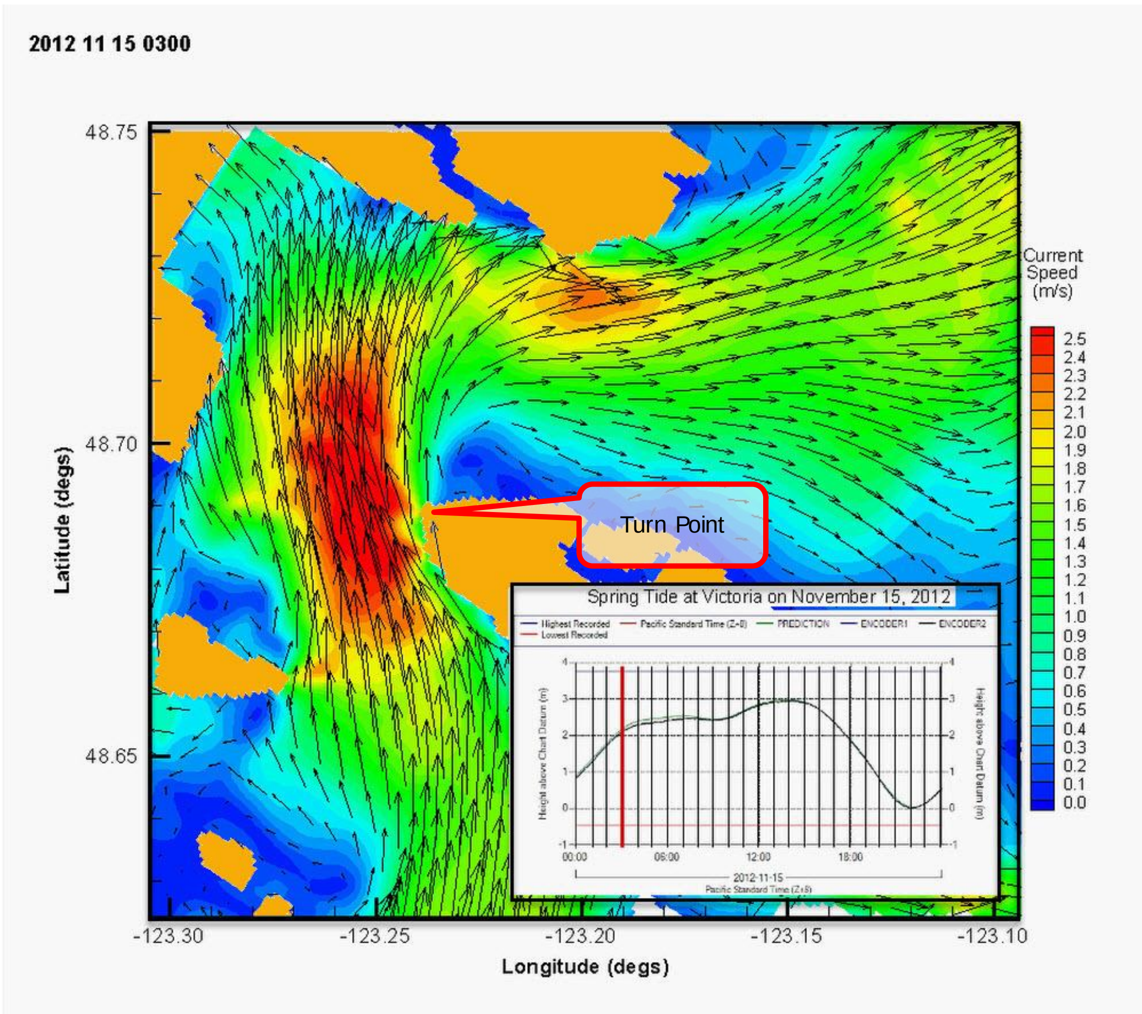


Figure 22: Tidal Stream Flow at Gowlland Point during Neap Ebb Tide

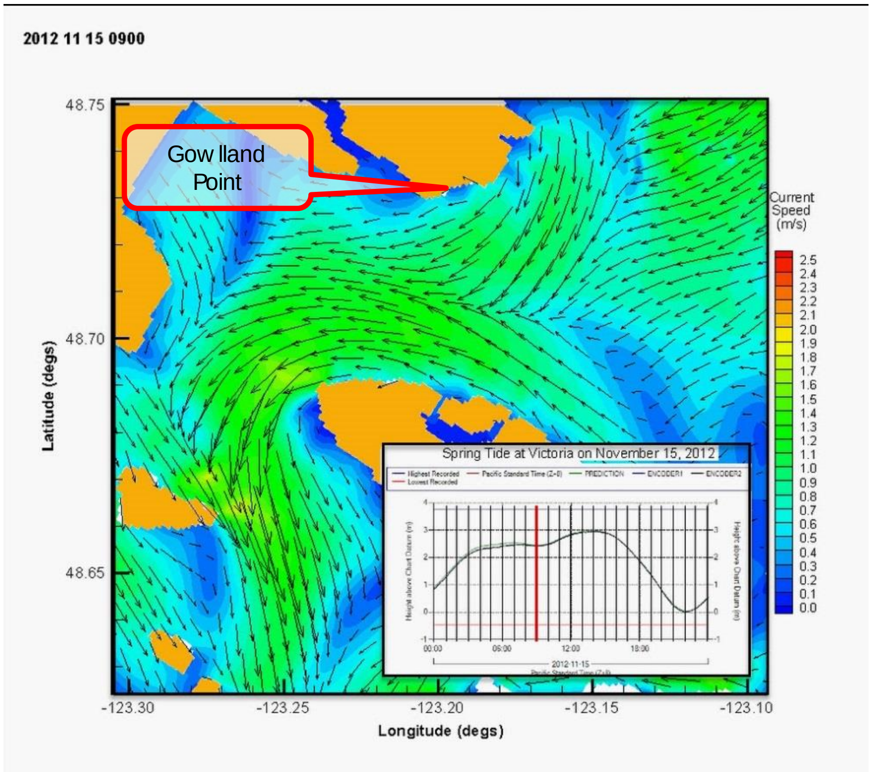
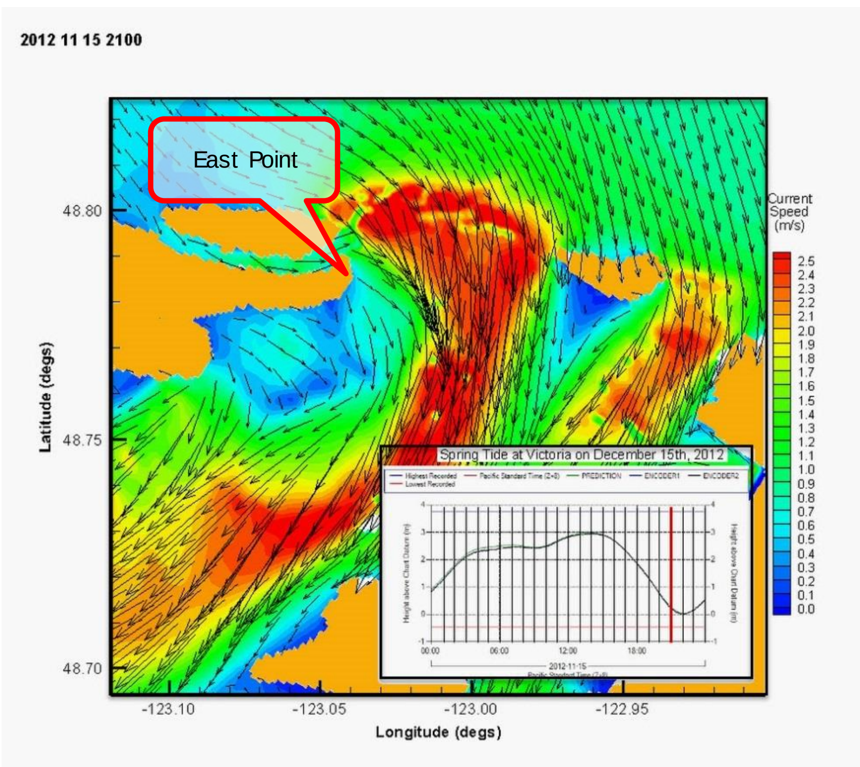
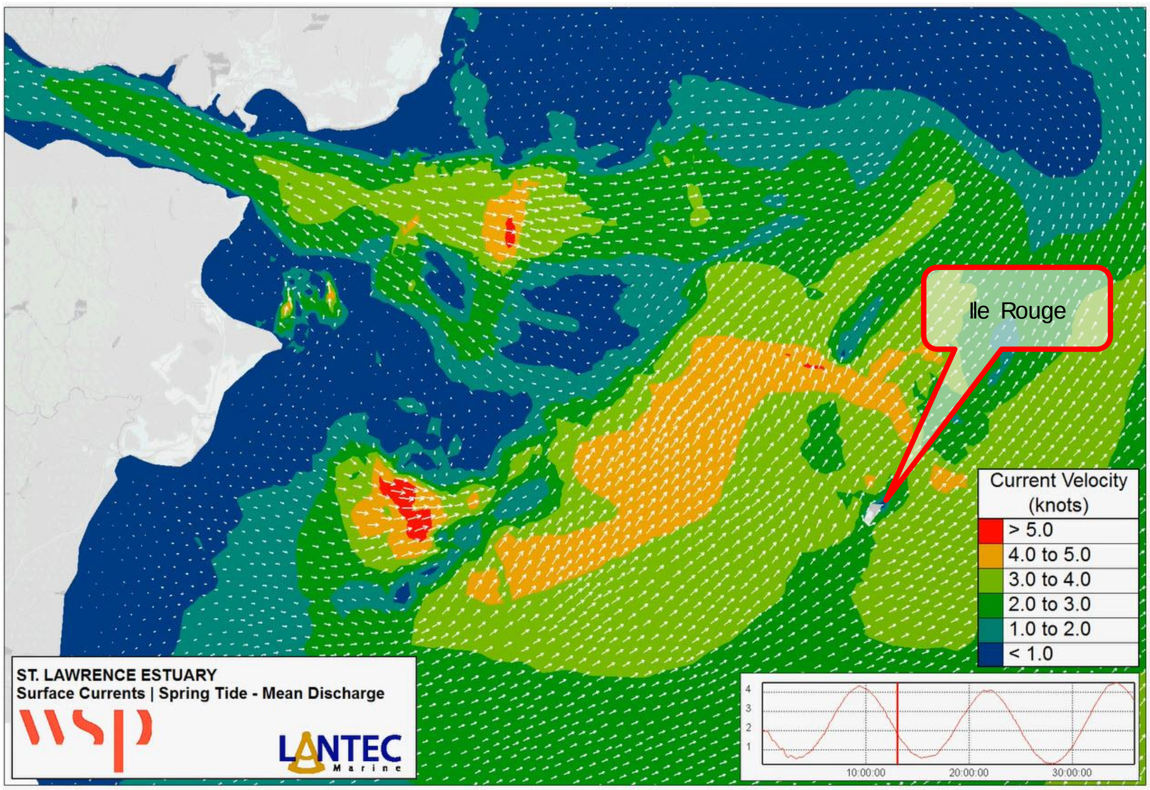


Figure 23: Tidal Stream Flow at East Point during Spring Ebb Tide



Similarly, at the mouth of the Saguenay River, the combination of river outflow currents with tidal stream effects, shallow banks, and other forms of geographical constriction result in extremely complex tide and current flow patterns, which can cause vessel course deviation. To provide the type of tidal and current flow data needed for this analysis, tidal flow models that combined river out flow currents with tidal stream were created for conditions of high and mean volume river flow coupled with both spring and neap tidal conditions to cover the entire area from approximately 5 nautical miles (9.3 kilometres) up and down river from Ile Rouge and the confluence of the Saguenay River. See Figure 24 below:

Figure 24: Tidal Flow Model Area at the Confluence of the Saguenay and St-Lawrence



To ensure that these extreme tidal effects were accurately incorporated into the simulation analysis, 3-D tidal flow prediction models were developed which covered the period of an entire tidal cycle. Each tidal model was multi-layered comprised of tidal flow data at various depth levels from the surface down to depths of 15 metres and contained more than 20,000 unique data nodes which had values for tidal velocity, direction and depth. These models of the tidal flow allowed transit scenarios to be conducted under a full range of typical daily tidal conditions.

2.6 Evaluation Metrics

As with any empirical analysis, it is important to be clear about the evaluation and assessment criteria. For this project the following metrics were used:

2.6.1 General Metrics Applicable to All Tests

a. Since vessels were transiting, they had no tug assistance and transverse thrusters were not considered to be available/used.
b. It was assessed that a vessel experienced difficulty with maintaining steering control at a given speed if it continuously utilised more than 57% of its available rudder angle to maintain heading (i.e. on a ship with a 35° degree rudder working angle port/starboard, if it needed to continuously carry 20° of rudder to maintain course). In this situation, it was deemed that the amount of reserve rudder power remaining was marginal. On most ships at sea speeds, maximum rudder force or lift is generated at an angle between 25° and 30°. Hence, if the ship is continuously using 20° to maintain a steady course, there is very little rudder power left to initiate a turn away from the direction of the wind, or to arrest a turn if the ship turns into the direction of the wind.
c. It was considered that a ship was unable to maintain steering or positional control at a given speed if, with application of full rudder angle, it was unable to prevent the vessel from falling off her heading/course within the traffic lane.
d. All references to minimum speed are to a given set speed on the ship's telegraph, or a specific number of propeller RPMs (or pitch angle on vessels with controllable pitch propellers), which corresponds to water speed (i.e. Slow Ahead = 8.5 knots). Corresponding ground speed, which will be affected by environmental factors such as tidal stream, will also be recorded and monitored.

2.6.2 Metrics Specific to Non-Pilotage Areas (TSS)

a. All tests were performed with the ship's telegraph at standard settings (i.e. Slow Ahead, Half Ahead, etc.) to reflect a typical "At Sea" bridge and engine-room watch states, and that the ship's propulsion system in a "At Sea" manoeuvring and control mode. For initial baseline heading and course holding tests, no effort was made on each ship type to assess speeds that fell in between telegraph pre-sets. For some validation tests, propeller RPMs/Pitch were set for a specific water speed (i.e. 8 knots) to ensure that all vessel types were transiting at as close to the same speed as possible.
b. Wind velocity was augmented starting with an initial speed of 15 knots at a progressive rate of 0.5 knots per minute until a maximum value of 40 knots was achieved. Tests were limited to a maximum wind speed of 40 knots, as historical climatic data indicated that in all test areas, the frequency of winds in excess of 40 knots occurs less than 0.5% of the time.
c. In the Juan de Fuca TSS, separate runs were conducted with Tidal Stream set to the maximum ebb and flood values experienced in the region, based on data from CHS sources and a 2-dimensional surface flow model developed by LANTEC using this data. The vessel's speed was logged both as water and ground referenced speed.

** Note that in this area a vessel's ground speed can differ from that of its water speed (set speed based on propeller RPM) by as much as +/- 2 knots depending on if the vessel is stemming or running with the tidal stream.*

2.6.3 Metrics Specific to Pilotage Areas

a. All baseline tests were initiated with the ship's telegraph at standard settings (i.e. Dead-Slow Ahead, Slow Ahead, etc.) closest to a transit speed of 8 knots, and to reflect a typical "Manoeuvring" bridge and engine-room watch states where the ship's propulsion system is in a "Manoeuvring" control mode. RPM/propeller pitch was adjusted (increased) if the ship started to experience either steering or positional control issues. Also, "Kicks Ahead" (brief increases in propeller RPM) on the engine were used to assist with steering control, particularly in the case where localised tide/current induced course variations occur.
b. 3-Dimensional current prediction models were created for both High and Mean River water levels, and for Spring and Neap Tides. Since it would have been time prohibitive to test all possible current conditions and combinations, based on experience from the pilots transiting the region, for the St-Lawrence/Saguenay area the most difficult conditions of High River coupled with Spring Tides and maximum Ebb or outflow tidal condition will be used, as well as Mean River Level with a Spring Tide and Maximum Flood or inflow conditions. For Haro Strait/Boundary Pass, both Spring and Neap Tidal conditions were tested within selected areas, to ensure a range of tidal eddy/ tidal race patterns were evaluated.
c. For all initial current velocity assessment runs, based on results from testing conducted in the TSSs, and wind statistics for the region, wind velocity was set at 15 knots from the prevailing wind direction.
d. Once it is determined where or if current velocity thresholds existed in order to conduct transits at speeds of 12 knots or less, then validation tests were conducted with the worse-case current scenarios, and winds from the stern quadrant at 30 knots (again choice of wind speed based on results from TSS testing, and historical data of wind speed > 30 knots < 3% occurrence).

   ** Note that in these areas a vessel's ground speed can differ from that of its water speed (set speed based on propeller RPM) by as much as +/- 7 knots depending on if the vessel is stemming or running with the combined tidal stream/ river current.*

e. In pilotage areas where course legs are short and in close proximity to dangers, the ability to conduct course alterations safely and to steady on the next course track effectively was also evaluated (for example: rounding Turn Point in Haro Strait or altering from the St-Lawrence into the Saguenay River). In these situations, it was critical that course overshoot was manageable, the evaluation criteria varied somewhat dependent upon location, but as a guideline it was considered that an overshoot of more than 10° represented a reduction in steering and positional control and that more than 20° represented a loss of steering and positional control.
f. In pilotage waters, the level of steering and positional control must be sufficient to ensure that the vessel remains within the navigational channel and does not come within an unacceptable distance of shoals or opposing vessel traffic. Given the

potentially subjective nature of this assessment, findings related to this item were validated by the appropriate pilotage group using manned, full mission simulations.

3 TEST PROCEDURES, METHODOLOGY AND SEQUENCE

As described in Sections 2 to 2.5 above, each area of interest has somewhat unique environmental characteristics. However, wind effects were deemed to be significant in all four areas, and with the exception of the Anticosti TSS, tidal stream effects were also a key element affecting vessels' low speed steering and positional control. It was thus assessed that the best location to perform initial baseline tests was the area of Juan de Fuca Strait TSS. Given that both the wind and tidal stream in this region tend to be quite homogenous over a relatively large area, the location was perhaps the most "clinical" or generic. It was also the test area that had the largest variety of vessel types. Hence observations from this area, both with respect to general wind effects and linear tidal stream/current effects, would also be applicable to all other test areas. Findings made from the Juan de Fuca analysis could then be used to focus testing in the other three areas and to reduce redundancy in general baseline testing, allowing more time to be spent on area specific tests. For the desktop analysis the sequence of the test procedures was as follows:

a. Juan de Fuca TSS, a full range of baseline wind and tidal stream heading, course holding, and course alteration tests;
b. Anticosti TSS focused (based on control limits identified in Juan de Fuca) wind heading and course holding and course alteration tests;
c. St-Lawrence upriver/downriver transits to assess heading and course holding in strong combined river current and tidal stream conditions (velocities up to 5 knots) on two relatively long (4 nautical mile) track-lines with an approximately 20° alteration of course between the two tracks;
d. As per item c) but with 30 knot winds (note maximum wind limited to 30 knots based on results from TSS testing);
e. Saguenay River course holding and course alteration tests on shorter track lines (legs of approximately 2 nautical miles) with two alterations of course each of approximately 25° with resultant tidal stream/current of up to 3 knots whilst altering course and nearly 6 knots on one straight line segment; and
f. Haro Strait/ Boundary Pass course holding and course alteration tests on shorter track lines (legs of approximately 2 nautical miles) with course alteration of 80° occurring in a tidal race with a velocity of up to 5 knots.

Furthermore, the results of the tests conducted as per items c) through f) above were subsequently examined/validated using manned simulation with the participation of the local pilots from the BCCP and CPBSL conducted at their respective Full Mission Simulator sites in Vancouver and Quebec City.

The summary of key findings highlights the factors that affected the vessel's steering and manoeuvring control, and from strictly a navigational and manoeuvring perspective, identifies the minimal transit speeds that specific vessel types can safely maintain within the identified geographic areas/ zones. It should be noted that the objective of this project was not to make specific recommendations for a minimum safe speed implementation policy, as other components and factors such as commercial impact, pilot shift times/schedules, and enforcement mechanisms are beyond the knowledge, expertise and mandate of LANTEC Marine Inc. The results of this analysis rather provide empirical evidence related to vessels' abilities to maintain navigation and manoeuvring control, which TC can then combine with other factors and considerations to develop a minimum transit speed policy which is viable, practical and achievable.

3.1 General Categories of Test Vessel

TC had stipulated that the scope of general test vessels would encompass the general categories listed in Table 1 below. Based on specific vessel types that frequent the waters of British Columbia, St-Lawrence Estuary, and the Gulf of St-Lawrence, and the availability of vessel models in the Kongsberg ship model library, specific vessel types were selected for testing within each of the four test areas. This also included vessels that do not currently call within the regions but are expected to within the next five years (for example, LNG ships).

Table 1: Proposed Categories of Test Vessels

Proposed Simulation Test Vessels					
General Category		Sub-Category 1	Sub-Category 2	Sub-Category 3	Sub-Category 4
1	Container Vessels	PANAMAX	Post-PANAMAX		
2	Fine Hull Form Cargo (Break Bulk and General Cargo)	Handy Size	SUPRAMAX		
3	Full Hull Form Cargo (Bulk Carriers and Tankers)	Handy Size	PANAMAX	AFRAMAX	Cape Size
4	High Windage	Ferry > 100 metres LOA	Ro-Ro/ Auto Carrier	PANAMAX Cruise	Ultra Large Cruise
5	Gas Carriers	Moss Spherical	Membrane < 150,000 CBM	QFLEX	

3.1.1 Test Vessels used in Juan de Fuca TSS Analysis

In Juan de Fuca, the outbound lane of the TSS (inbound is in US waters) is used not only by vessels originating from British Columbia ports, but also from ports in Washington State. The variety of vessel types is very extensive, ranging from coastal trade tugs and small vessels to transoceanic Neo-PANAMAX design container ships, Ultra Large Cruise vessels, Cape Size Bulk Carriers, and SUEZMAX tankers (from Cherry Point). Table 2 below lists the vessels used in the Juan de Fuca analysis.

Table 2: Test Vessels Used in Juan de Fuca TSS

Juan de Fuca TSS Test Vessels							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
1	ULCC CNTNR39	1	249,931	399	59	16	16
2	Neo-PANAMAX Design Container CNTNR35	1	176,500	366.5	48.2	15	15
3	Post-PANAMAX Container CNTNR33	1	134, 900	336	45.8	14.0	14.1
4	PANAMAX Container CNTNR31	1	64,244	294.1	32.2	12.0	12.0
5	Break Bulk Bulkc07	2	56,927	200	31.0	12.0	12.0
6	Cargo	2	45,843	205	32.0	10.0	10.0
7	Product/ Chemical Tanker	3	22,848	141.5	23.0	9.0	9.0
8	PANAMAX Bulk Ballasted	3	39,024	215.4	31.8	6.8	8.5
9	PANAMAX Bulk Loaded	3	59,434	215.4	31.8	11.5	11.5
10	AFRAMAX Tanker Ballasted	3	59,824	250	43.8	5.96	8.57
11	AFRAMAX Tanker Loaded	3	116,488	250	43.8	13.5	13.6
12	SUEZMAX Tanker Ballasted	3	83,902	274.5	50.0	8.0	10.2
13	SUEZMAX Tanker Loaded	3	176,585	274.5	50.0	17.1	17.3
14	Cape Size Bulker Ballasted	3	88,780	289	45	8.1	9.7
15	Cape Size Bulker Loaded	3	193,951	289	45	17.5	18.3

Juan de Fuca TSS Test Vessels							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
16	Ferry (Small Cruise)	4	8,140	151.8	23	5.0	5.0
17	Car Carrier	4	31,688	200	32.2	9.4	9.9
18	PANAMAX Cruise	4	44,195	294	32.2	8.0	8.0
19	Ultra Large Cruise	4	71,000	338.7	38.6	8.5	8.5
20	135,000 CFM LNG	5	99,317	293	45.8	11.0	11.0
21	QFLEX LNG	5	139,220	315	50.0	12.0	12.0

3.1.2 Test Vessels used in Anticosti TSS Analysis

In the Anticosti TSS, vessels are proceeding to and from Sept Isles, Port Cartier, ports in the Saguenay region, and ports in the St-Lawrence River. With the exception of the St-Lawrence ports, the majority of the vessels proceeding to and from ports in eastern Quebec are Bulk Carriers, as large as Cape Size. There are however serious plans for LNG terminal development within the region. Ports in the St-Lawrence proper receive a broader mix of vessel types, however air draught restrictions on Pont de Quebec and a beam width restriction of 44 metres generally limit container vessels to PANAMAX size and tankers to AFRAMAX size with loaded draughts not generally exceeding 11.5 metres. Based on results from the Juan de Fuca analysis, tests were conducted in the Anticosti TSS using the vessel types that frequent the area, and that experienced some measure of reduced steering control due to wind. This served as a further validation of the findings of the Juan de Fuca analysis. Table 3 below lists the vessels used in the Anticosti TSS analysis.

Table 3: Test Vessels Used in Anticosti TSS

Anticosti TSS Test Vessels							
	Vessel Type	Vessel Category	Displacement (tonnes)	Length LOA (m)	Beam (m)	Forward Draught (m)	Stern Draught (m)
1	PANAMAX Bulk Ballasted	3	39,024	215.4	31.8	6.8	8.5
2	PANAMAX Container	1	64,244	294.1	32.2	12.0	12.0
3	Handymax Bulk Ballasted	2	19,000	200	23.8	3.5	6.5

Anticosti TSS Test Vessels							
	Vessel Type	Vessel Category	Displacement (tonnes)	Length LOA (m)	Beam (m)	Forward Draught (m)	Stern Draught (m)
4	AFRAMAX Tanker Ballasted	3	59,824	250	43.8	5.96	8.57
5	Ferry (Small Cruise)	4	8,140	151.8	23	5.0	5.0
6	Ultra Large Cruise	4	71,000	338.7	38.6	8.5	8.5
7	Cape Size Bulker Ballasted	3	88,780	289	45	8.1	9.7
8	QFLEX LNG	5	139,220	315	50.0	12.0	12.0

3.1.3 Test Vessels used in St-Lawrence River Analysis

When selecting test vessels for the St-Lawrence River transits, consideration was given to the types of vessel (both present and future) that frequent the St-Lawrence, recommendations received from the Lower St-Lawrence River Pilots (CPBSL) of most common vessel types, and observations on vessel control that have been experienced over the past few years of the voluntary slowdown of 10 knots water speed. The availability of ship models at the CPBSL simulator site (MSRC) was also considered as it was used to conduct full mission validation of the desktop findings. The Port of Quebec receives Bulk Carriers as large as Cape Size and Tankers of AFRAMAX size loaded up to 15 metres draught. Upriver from Quebec in the St-Lawrence, air draught restrictions on Pont de Quebec and a beam width restriction of 44 metres generally limit container vessels to PANAMAX size and tankers to AFRAMAX size with loaded draughts not generally exceeding 11.5 metres. Based on these facts, Table 4 below provides details on the vessels that were used for tests in the St-Lawrence.

Table 4: Test Vessels used in the St-Lawrence Analysis

St-Lawrence Test Vessels (Group 1)							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
1	PANAMAX Container	1	64,244	294.1	32.2	12.0	12.0
2	Cargo	2	45,843	205	32.0	10.0	10.0
3	Handymax Bulk Ballasted	2	19,000	200	23.8	3.5	6.5

St-Lawrence Test Vessels (Group 1)							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
4	Handymax Bulk Loaded	2	31,680	200	23.8	8.1	8.1
5	Product/ Chemical Tanker	3	22,848	141.5	23.0	9.0	9.0
6	Ferry (Small Cruise)	4	8,140	151.8	23	5.0	5.0
7	PANAMAX Cruise	4	44,195	294	32.2	8.0	8.0
8	Ultra Large Cruise	4	71,000	338.7	38.6	8.5	8.5
St-Lawrence Test Vessels (Group 2)							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
9	PANAMAX Bulk Ballasted	3	39,024	215.4	31.8	6.8	8.5
10	PANAMAX Bulk Loaded	3	59,434	215.4	31.8	11.5	11.5
11	AFRAMAX Tanker Ballasted	3	59,824	250	43.8	5.96	8.57
12	AFRAMAX Tanker Loaded	3	116,488	250	43.8	13.5	13.6
13	Cape Size Bulker Ballasted	3	83,140	300	53	7.0	10.0
14	Cape Size Bulker Loaded	3	200,000	300	53	15.0	15.0

3.1.4 Test Vessels used in Saguenay River Analysis

With the exception of cruise vessels, the largest ships that regularly call on ports in the Saguenay region are less than 220 metres in length, and predominately bulk carriers. However, there are plans for a future LNG terminal that would be able to accommodate QFLEX size vessels. It is also important to note that all terminals in the Saguenay are export terminals, hence inbound runs were conducted with ballasted ships, and outbound runs with loaded ships. A list of test vessels is contained in Table 5 below.

Table 5: Test Vessels used in the Saguenay Analysis

Saguenay Test Vessels (Inbound)							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
1	PANAMAX Bulk Ballasted	3	39,024	215.4	31.8	6.8	8.5
2	Handymax Bulk Ballasted	2	19,000	200	23.8	3.5	6.5
3	PANAMAX Cruise	4	44,195	294	32.2	8.0	8.0
4	Ultra Large Cruise	4	71,000	338.7	38.6	8.5	8.5
5	177 CBM LNG Ballasted	5	91,500	298	46	9.7	9.4
Saguenay Test Vessels (Outbound)							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
6	PANAMAX Bulk Loaded	3	59,434	215.4	31.8	11.5	11.5
7	Handymax Bulk Loaded	2	31,680	200	23.8	8.1	8.1
8	PANAMAX Cruise	4	44,195	294	32.2	8.0	8.0
9	Ultra Large Cruise	4	71,000	338.7	38.6	8.5	8.5
10	177 CBM LNG Loaded	5	120,000	298	46	11.9	11.9

3.1.5 Test Vessels used in Haro Strait Boundary Pass Analysis

When selecting test vessels for the Haro Strait and Boundary Pass transit tests, consideration was given to the types of vessel (both present and future) that frequent the ports of Vancouver and Nanaimo, and recommendations received from the BCCP of most common vessel types and observations on vessel control issues experienced during the voluntary ECHO programme transit slowdown. Finally, the availability of ship models at the PPA simulator site was also considered as it was used to conduct manned, full mission validation of the desktop findings. A list of test vessels used is provided in Table 6 below:

Table 6: Test Vessels used in the Boundary Pass Analysis

Boundary Pass Test Vessels Group 1							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
1	Neo-PANAMAX Design Container CNTNR35	1	176,500	366.5	48.2	15	15
2	PANAMAX Container CNTNR31	1	64,244	294.1	32.2	12.0	12.0
3	Car Carrier	4	31,688	200	32.2	9.4	9.9
4	PANAMAX Cruise	4	44,195	294	32.2	8.0	8.0
5	Ultra Large Cruise	4	71,000	338.7	38.6	8.5	8.5
6	QFLEX LNG	5	139,220	315	50.0	12.0	12.0
Boundary Pass Test Vessels Group 2							
	Vessel Type	**Vessel Category**	**Displacement (tonnes)**	**Length LOA (m)**	**Beam (m)**	**Forward Draught (m)**	**Stern Draught (m)**
7	PANAMAX Bulk Ballasted	3	39,024	215.4	31.8	6.8	8.5
8	PANAMAX Bulk Loaded	3	59,434	215.4	31.8	11.5	11.5
9	AFRAMAX Tanker Ballasted	3	59,824	250	43.8	5.96	8.57
10	AFRAMAX Tanker Loaded	3	116,488	250	43.8	13.5	13.6
11	Cape Size Bulker Ballasted	3	88,780	289	45	8.1	9.7
12	Cape Size Bulker Loaded	3	193,951	289	45	17.5	18.3

3.2 Analysis of Juan de Fuca Traffic Separation Scheme (TSS)

As discussed at the beginning of Section 3, Juan de Fuca was selected as the starting point for this analysis as it is frequented by the broadest range of vessels of any of the four areas. Also, the prevailing wind and tidal stream conditions provided the opportunity to conduct very good benchmark testing that could then serve to focus the remainder of the analysis in the other three areas. Factors that affected the specific testing process and testing sequence in Juan de Fuca are described in the Sections that immediately follow.

3.2.1 Environmental and Physical Factors/ Considerations

The non-pilotage area of the Salish Sea which is home to Southern Resident Killer Whale (SRKW), consists of the outbound lanes of the Traffic Separation Scheme in Juan de Fuca Strait on the Canadian Side of the Canada/US border. There are two primary track legs - one of approximately 278° for 16 nautical miles, the other of approximately 293° for 35 nautical miles. On the 278° track, ships are generally more than 2 nautical miles from the nearest shoreline, and on the 293° track, the transit is more than 4 nautical miles from the nearest shoreline. See Figure 25 below. Although tidal streams in this area can be moderate in strength, they tend to parallel the channel/shoreline and as such have little effect on the vessel's steering or positional control but do have to be considered when evaluating a vessel's speed/setting speed limits if ground speed is used as the metric for establishing speed limits. See Figures 26 and 27 below. In Juan de Fuca Strait the most important factor with respect to maintaining vessel steering and positional control at lower speeds is the wind.

Figure 25: Juan de Fuca Strait TSS

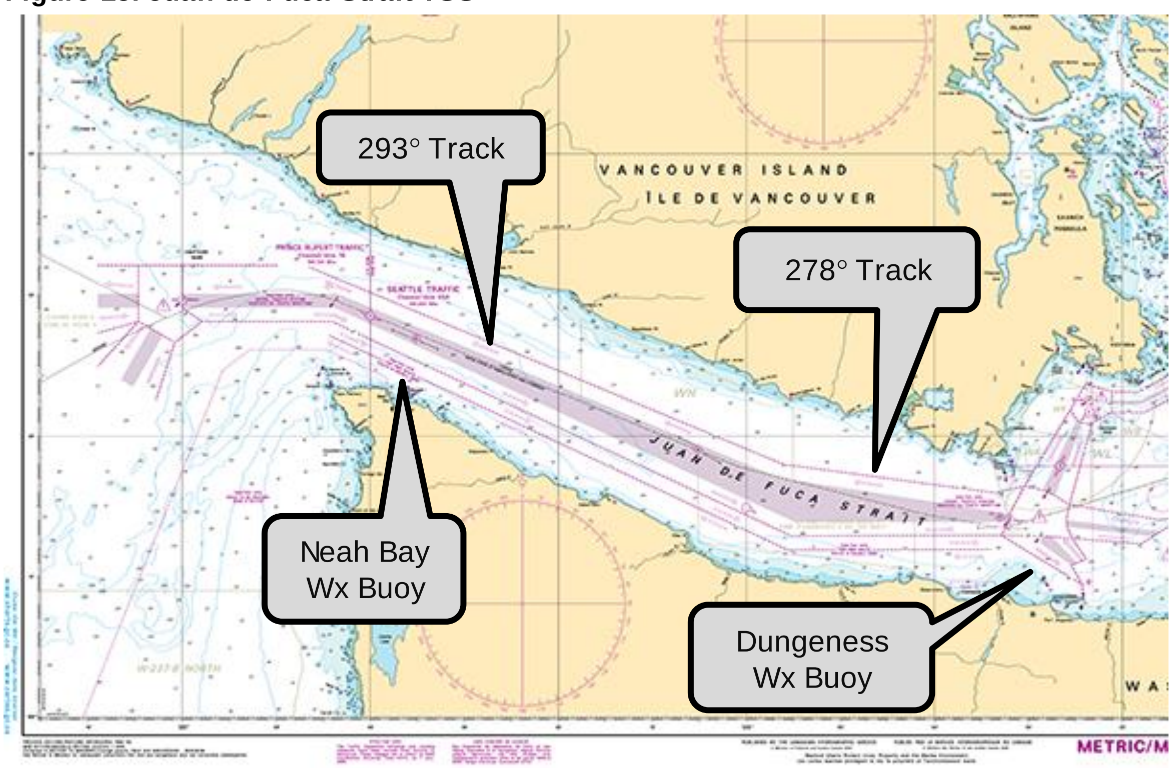


Figure 26: Juan De Fuca Strait Maximum Ebb Tidal Stream

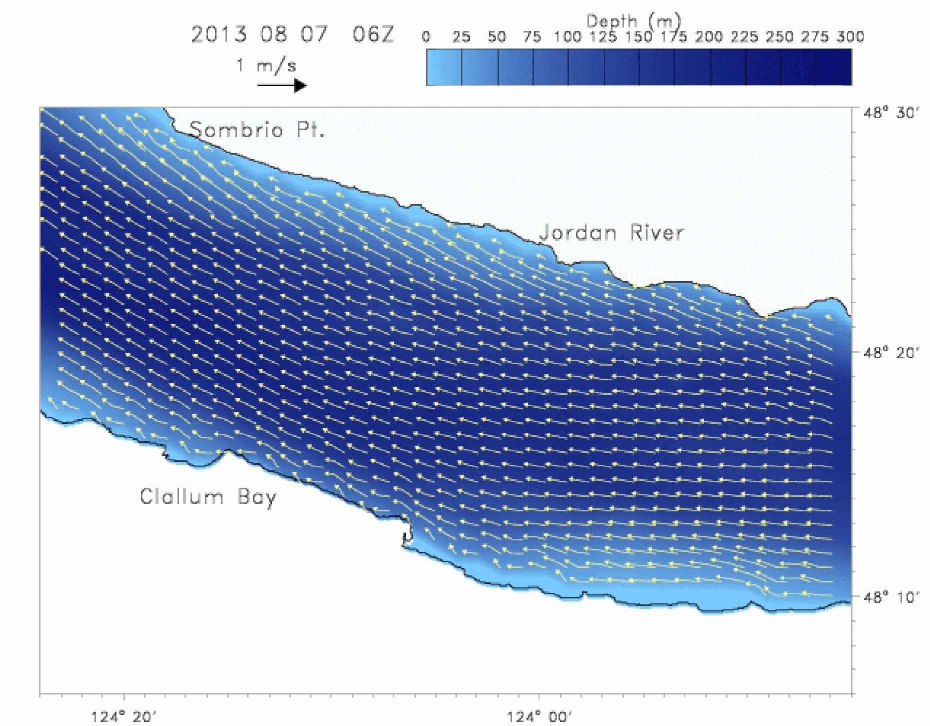
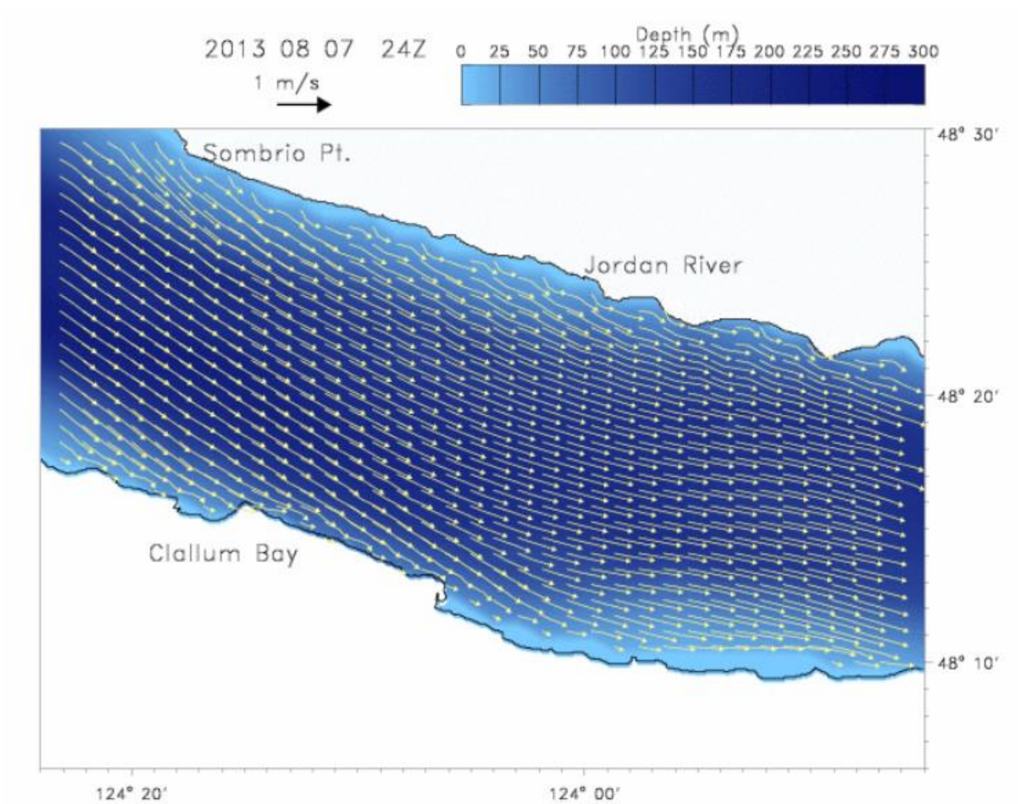


Figure 27: Juan De Fuca Strait Maximum Flood Tidal Stream



With respect to wind direction and speed in Juan de Fuca the following patterns and tendencies are noteworthy:

a. The wind tends to blow nearly parallel to the strait (funnelling effect) on most occasions;
b. During the summer season, in the eastern portion of the strait the dominant wind octant is from 225° to 270°;
c. During the summer season, in the western portion of the strait the dominant wind octant is from 255° to 300°;
d. Items b and c above imply that for outbound vessels in the summer the wind on average is between 15° and 30° on the port bow and from this direction would have a marginal effect of vessel manoeuvrability;
e. During the winter season, in the eastern portion of the strait the dominant wind octant is from 110° to 155° (Port quarter relative R168° to R123° when on 278° Course);
f. During the winter season, in the western portion of the strait the dominant wind octant is from 080° to 125° (Starboard quarter relative G147° to Port quarter relative R168°);
g. Items e and f above imply that for outbound vessels in the winter the wind on average is from astern, ranging from relative R123° to relative G147°, and would have a noticeable effect of vessel manoeuvrability;
h. Occurrences of sustained winds above 16 m/s or 31 knots are extremely rare at any time of the year (Based on 5-Year Historic Observations 0.3% for Western Portion and 0.2% for Eastern Portion).

The wind data described above is based on data from the Neah Bay and Dungeness weather buoys and derived for annual periods 2004 to 2017. Excerpts of data from selected years during this period are shown in Figures 28 to 33 to provide illustrations of the seasonal wind tendencies.

Tests were not conducted in the inbound traffic lanes as they experience the same prevailing wind conditions, and course holding results would generally be similar to that of the outbound lanes in that the prevailing summer wind would be on the vessel's starboard quarter while inbound, and the prevailing winter winds would be on the vessel's starboard bow.

Figure 28: Juan De Fuca Strait Eastern End Summer Prevailing Winds

Historical Meteorological Data Search - Station 46088

(search by thresholds you can set)

Station 46088 Change Station ID
NEW DUNGENESS - 17 NM NE of Port Angeles, WA

Select Year: 2014 ▾ View all meteorological observations for station 46088 in 2014

Search Criteria

	Select Observations	First Range Limit		Second Range Limit
Search1:	Wind Direction (degT)	> 225	AND	< 270
Search2:			AND	
Search3:			AND	

Submit

An event is defined as more than three hours of consecutive data records that match the criteria.
Total Events: 185 Summary
Duration (hrs) **Min:** 4 **Max:** 52 **Avg:** 10

Observations:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Total Records	1485	1333	1241	497	437	1428	1468	1468	1420	1470	1423	1473	15143
Records Matching Search Criteria	243	195	275	176	239	874	1020	957	387	222	158	150	4896
Percent of Records Matching Search Criteria	16%	15%	22%	35%	55%	61%	69%	65%	27%	15%	11%	10%	32%

Figure 29: Juan De Fuca Strait Eastern End Winter Prevailing Winds

Historical Meteorological Data Search - Station 46088

(search by thresholds you can set)

Station 46088 Change Station ID
NEW DUNGENESS - 17 NM NE of Port Angeles, WA

Select Year: 2014 ▾ View all meteorological observations for station 46088 in 2014

Search Criteria

	Select Observations	First Range Limit		Second Range Limit
Search1:	Wind Direction (degT)	> 110	AND	< 155
Search2:			AND	
Search3:			AND	

Submit

An event is defined as more than three hours of consecutive data records that match the criteria.
Total Events: 70 Summary
Duration (hrs) **Min:** 4 **Max:** 20 **Avg:** 8

Observations:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Total Records	1485	1333	1241	497	437	1428	1468	1468	1420	1470	1423	1473	15143
Records Matching Search Criteria	170	228	208	124	6	77	42	21	115	352	233	373	1949
Percent of Records Matching Search Criteria	11%	17%	17%	25%	1%	5%	3%	1%	8%	24%	16%	25%	13%

Figure 30: Juan De Fuca Strait Western End Summer Prevailing Winds

Historical Meteorological Data Search - Station 46087

(search by thresholds you can set)

Station 46087 Change Station ID
Neah Bay - 6NM North of Cape Flattery, WA (Traffic Separation Lighted Buoy)

Select Year: 2014 View all meteorological observations for station 46087 in 2014

Search Criteria

	Select Observations	First Range Limit		Second Range Limit
Search1:	Wind Direction (degT)	> 255	AND	< 300
Search2:			AND	
Search3:			AND	

Submit

An event is defined as more than three hours of consecutive data records that match the criteria.
Total Events: 141 Summary
Duration (hrs) **Min:** 4 **Max:** 23 **Avg:** 7

Observations:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Total Records	1482	1336	1478	1432	1484	1432	1484	1460	1431	1478	1431	1477	17405
Records Matching Search Criteria	182	175	209	317	412	498	441	347	168	161	194	117	3221
Percent of Records Matching Search Criteria	12%	13%	14%	22%	28%	35%	30%	24%	12%	11%	14%	8%	19%

Figure 31: Juan De Fuca Strait Western End Winter Prevailing Winds

Historical Meteorological Data Search - Station 46087

(search by thresholds you can set)

Station 46087 Change Station ID
Neah Bay - 6NM North of Cape Flattery, WA (Traffic Separation Lighted Buoy)

Select Year: 2014 View all meteorological observations for station 46087 in 2014

Search Criteria

	Select Observations	First Range Limit		Second Range Limit
Search1:	Wind Direction (degT)	> 80	AND	< 125
Search2:			AND	
Search3:			AND	

Submit

An event is defined as more than three hours of consecutive data records that match the criteria.
Total Events: 209 Summary
Duration (hrs) **Min:** 4 **Max:** 80 **Avg:** 10

Observations:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Total Records	1482	1336	1478	1432	1484	1432	1484	1460	1431	1478	1431	1477	17405
Records Matching Search Criteria	863	442	531	388	333	159	137	99	518	628	591	830	5519
Percent of Records Matching Search Criteria	58%	33%	36%	27%	22%	11%	9%	7%	36%	42%	41%	56%	32%

Figure 32: Juan De Fuca Strait Eastern End Frequency of Winds > 31 Knots

Historical Meteorological Data Search - Station 46088

(search by thresholds you can set)

Station 46088 Change Station ID
NEW DUNGENESS - 17 NM NE of Port Angeles, WA

Select Year: 2014 View all meteorological observations for station 46088 in 2014

Search Criteria

	Select Observations	First Range Limit		Second Range Limit
Search1:	Wind Speed (m/s)	> 16	AND	
Search2:			AND	
Search3:			AND	

Submit

An event is defined as more than three hours of consecutive data records that match the criteria.
Total Events: 1 Summary
Duration (hrs) **Min:** 4 **Max:** 4 **Avg:** 4

Observations:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Total Records	1485	1333	1241	497	437	1428	1468	1468	1420	1470	1423	1473	15143
Records Matching Search Criteria	11	9	0	0	0	0	0	0	0	8	0	3	31
Percent of Records Matching Search Criteria	1%	1%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%

Figure 33: Juan De Fuca Strait Western Frequency of Winds > 31 knots

Historical Meteorological Data Search - Station 46087

(search by thresholds you can set)

Station 46087 Change Station ID
Neah Bay - 6NM North of Cape Flattery, WA (Traffic Separation Lighted Buoy)

Select Year: 2014 View all meteorological observations for station 46087 in 2014

Search Criteria

	Select Observations	First Range Limit		Second Range Limit
Search1:	Wind Speed (m/s)	> 16	AND	
Search2:			AND	
Search3:			AND	

Submit

An event is defined as more than three hours of consecutive data records that match the criteria.
Total Events: 2 Summary
Duration (hrs) **Min:** 6 **Max:** 9 **Avg:** 8

Observations:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Total Records	1482	1336	1478	1432	1484	1432	1484	1460	1431	1478	1431	1477	17405
Records Matching Search Criteria	6	6	0	0	0	0	0	0	0	3	22	18	55
Percent of Records Matching Search Criteria	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	1%	0%

3.2.2 Low Speed Heading and Course Holding Tests

These baseline or standard tests were conducted in groupings of up to eight different ship models within the same test exercise. From the test vessels identified in Table 2, The first test group was comprised of Test Vessels 1 to 6, the second grouping Test Vessels 8 to 15, and the third grouping Test Vessels 16 to 21 and 7.

Since the relative angle of the course lines in the TSS (both in the eastern and western portions of Juan de Fuca) to the prevailing wind directions are similar, simulated ship models were placed in the TSS at the eastern end of the 278° course as this portion of the traffic lane passes closest to the shore. For baseline tests, all vessels had the same corresponding engine telegraph setting, and the corresponding speed for that particular vessel type (i.e. Dead Slow Ahead – Speed 6.2). There were a couple of exceptions to this which are noted in the test details for one vessel that had a controllable pitch propeller, and another vessel which had a very high (8.2 knot Dead Slow) minimum speed.

Environmental test conditions included wind from the prevailing mean summer direction 247° and the prevailing mean winter direction of 143° coupled with both flood and ebb tidal conditions. Each series of baseline tests commenced with an initial wind velocity of 15 knots, which was progressively augmented to 40 knots (extremely rare in JDF) over a period of 50 minutes (i.e. 0.5 knot increase in wind velocity every minute). Tidal stream were also tested at slack, maximum ebb, and maximum flood values in order to illustrate ground versus water speed considerations. The vessel's speed was logged both as water and ground referenced speed. Table 4 below outlines the various test conditions.

Once the baseline course holding tests were completed, a series of validation tests were conducted as follows:

a. when a vessel started to lose steering, propeller RPM was increased, and actual minimum speed to hold course was determined; and
b. based on the results of baseline testing, and observed wind effects, tests were conducted with the vessels making the turn at Race Rocks as would be required when sailing from the Victoria Pilot Station and entering into the central portion of Juan de Fuca Strait. This involved altering from an initial course of approximately 210° to the final course of 278°. These tests were only conducted with the vessels that had experienced some difficulty maintaining course with either a Slow Ahead engine telegraph setting, or at speeds less than 10 knots.

Table 7: Juan de Fuca Strait Test Conditions

Juan de Fuca Strait Test Conditions			
Test No	Wind Direction/ Speed	Tidal Stream	Vessel Initial State: Course and Engine Telegraph
1	247° (15 building to 40 knots)	Slack	Steady 278° /Dead-Slow*
2	247° (15 building to 40 knots)	Flood ≅1.6 kts	Steady 278° /Dead-Slow*
3	247° (15 building to 40 knots)	Ebb ≅ 2.0 kts	Steady 278° /Dead-Slow*
4	143°(15 building to 40 knots)	Slack	Steady 278° /Dead-Slow*
5	143°(15 building to 40 knots)	Flood ≅ 1.6 kts	Steady 278° /Dead-Slow*
6	143°(15 building to 40 knots)	Ebb ≅ 2.0 kts	Steady 278° /Dead-Slow*
7	247° (15 building to 40 knots)	Slack	Steady 278° /Slow
8	247° (15 building to 40 knots)	Flood ≅1.6 kts	Steady 278° /Slow
9	247° (15 building to 40 knots)	Ebb ≅ 2.0 kts	Steady 278° /Slow
10	143°(15 building to 40 knots)	Slack	Steady 278° /Slow
11	143°(15 building to 40 knots)	Flood ≅ 1.6 kts	Steady 278° /Slow
12	143°(15 building to 40 knots)	Ebb ≅ 2.0 kts	Steady 278° /Slow
13	247° (15 building to 40 knots)	Slack	Steady 278° /Half
14	247° (15 building to 40 knots)	Flood ≅1.6 kts	Steady 278° / Half
15	247° (15 building to 40 knots)	Ebb ≅ 2.0 kts	Steady 278° / Half
16	143°(15 building to 40 knots)	Slack	Steady 278° / Half
17	143°(15 building to 40 knots)	Flood ≅ 1.6 kts	Steady 278° / Half
18	143°(15 building to 40 knots)	Ebb ≅ 2.0 kts	Steady 278° / Half
19	132° speed set to 5 knots < threshold in tests 4 to 6 where vessels started to lose steering control.	Flood ≅ 2.0 kts	Turn at race Rocks from 210° to 278°/TBD
20	132° speed set to 5 knots < threshold in tests 4 to 6 where vessels started to lose steering control.	Ebb ≅ 2.5 kts	Turn at race Rocks from 210° to 278°/TBD

*Note: For some vessels Tests 1 to 6 at Dead-Slow (Tankers and Bulk Carriers) were not applicable, as the associated water speed in nearly all cases tended to be below 5 knots. For vessels of this type, the first level of testing will begin at a slow ahead setting where water speeds would be in the 6-knot plus range. Similarly, Tests 13 to 15 were not conducted with all vessels, as most vessels were able to maintain heading/course going into the wind with telegraph settings that were less than Half Ahead, or at speeds of less than 10 knots.

3.3 Analysis of Anticosti Traffic Separation Scheme (TSS)

Of the four test areas, the Anticosti TSS is the one that generally speaking presents the lowest level of navigation risk as it is in a wide-open strait with a comparatively low density of vessel traffic. The nearest coastline is more than 9 nautical miles (16.7 kilometres) away, and the only environmental parameter that was assessed as necessary for analysis was wind. Given that detailed wind heading and course holding tests were conducted in the Juan de Fuca TSS, only an abbreviated or validation assessment of the Juan de Fuca TSS findings was required.

3.3.1 Environmental and Physical Factors/ Considerations

The Anticosti TSS is comprised of a number of different routes/ track-lines intended to direct traffic either towards/from ports in the Gulf of St-Lawrence or to and from the St-Lawrence River. Given that the prevailing winds are westerly, transit assessments were conducted on the 297° track with westerly winds on the port bow to assess heading and course holding abilities with winds from the forward hemisphere. Tests were also conducted starting on the 095° with the requirement to alter to the 117° track with a westerly wind; this provided validation of course holding and course alteration abilities with wind from the stern hemisphere. See Figures 34 to 36 below:

Figure 34: Track-lines Tested in Anticosti TSS

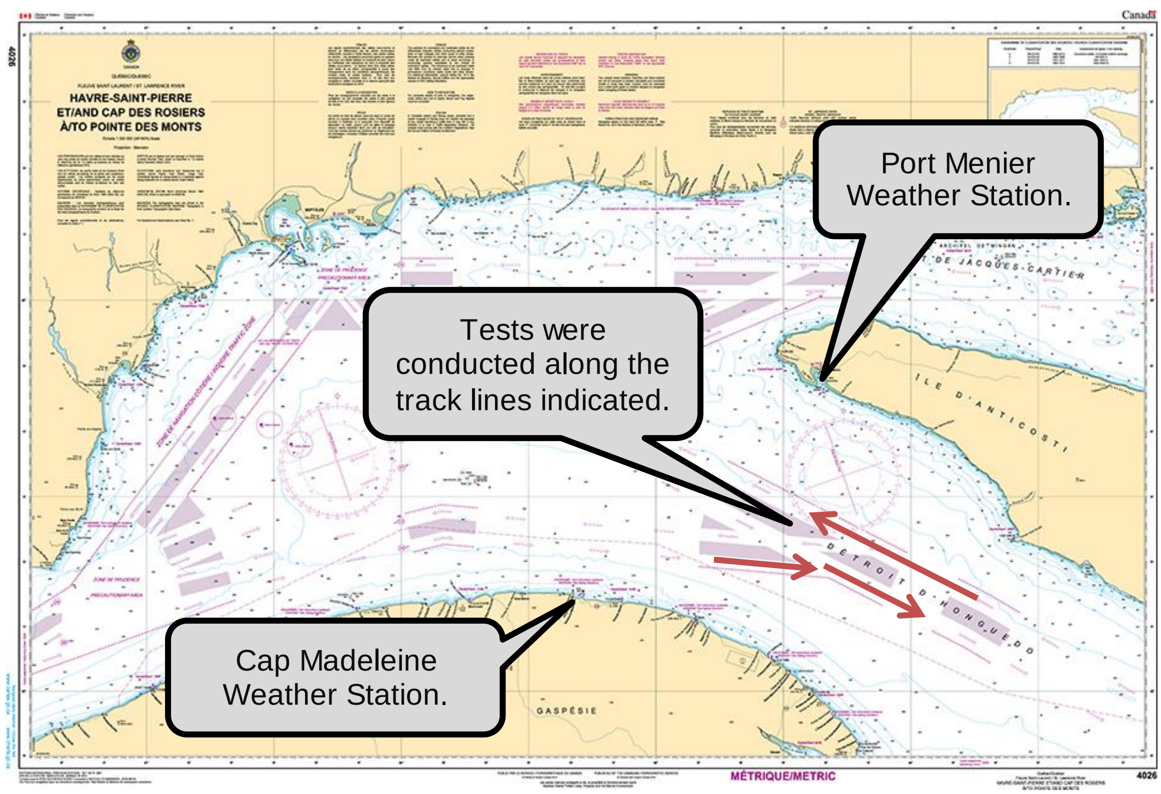


Figure 35: Annual Historic Wind Values Cap Madeleine

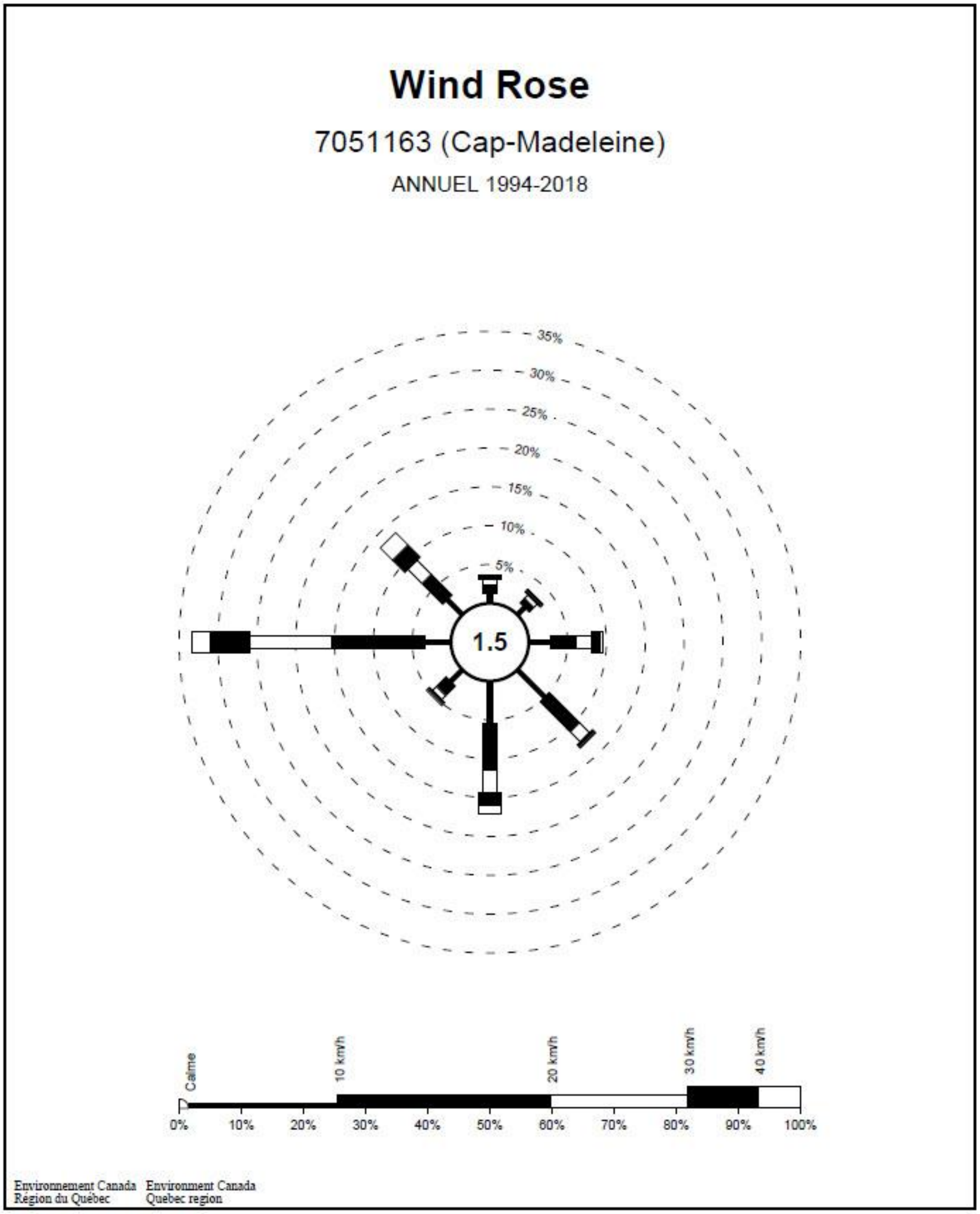
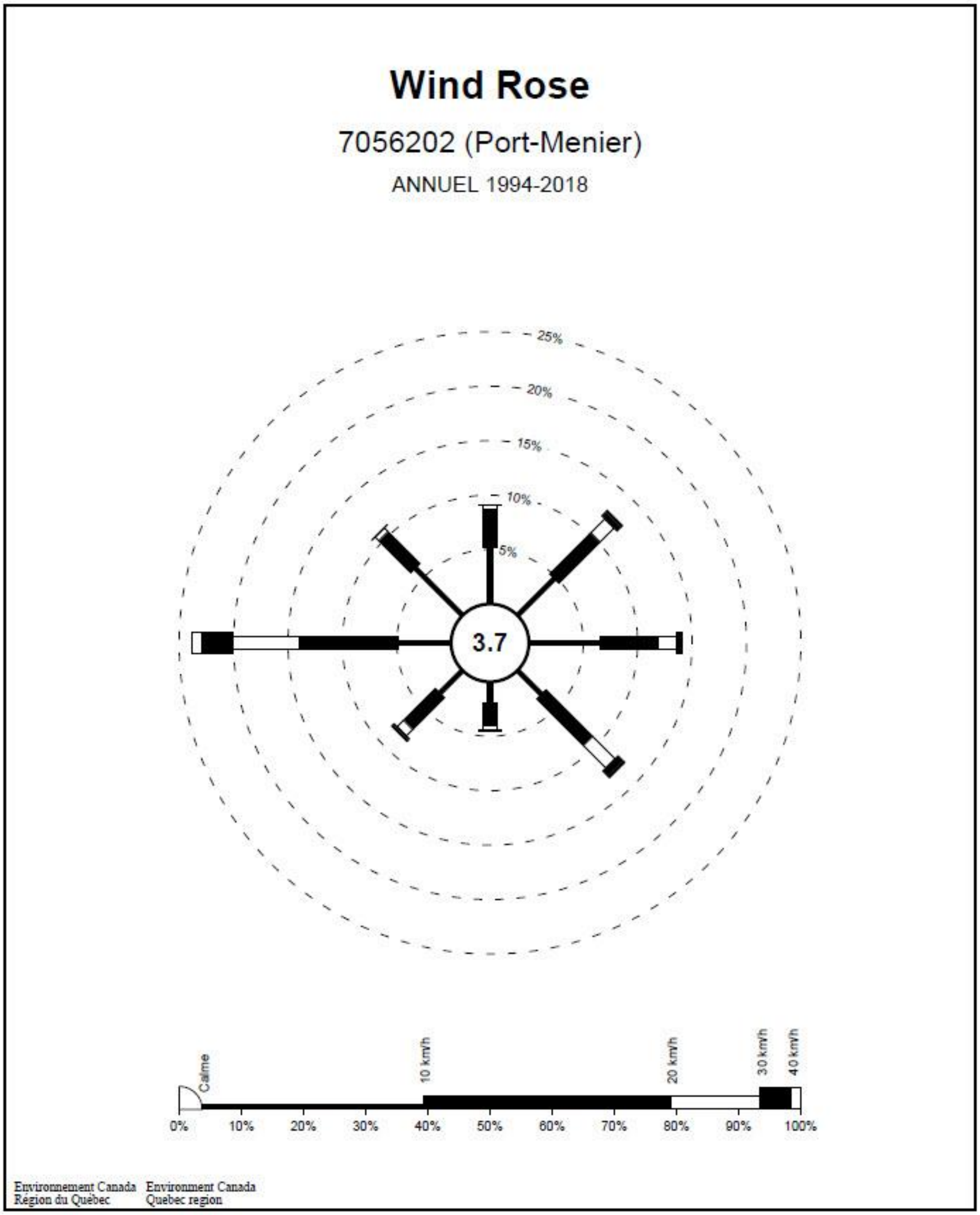


Figure 36: Annual Historic Wind Values Port Menier



3.3.2 Low Speed Course Holding and Course Alteration Tests

Based on results derived from testing in the Juan de Fuca TSS, it was known that a number of vessels would experience an appreciable reduction in water speed with a wind on the bow at velocities greater than 25 knots. As such, two validation tests were conducted on the 297° track with the westerly wind. In the first test, the cargo ships were set at their respective Slow Ahead speeds, and the passenger vessels at RPM/Pitch for 8 knots. Propeller RPMs/pitch were not varied for the remainder of the test, and heading was adjusted in order to maintain the planned course of 297°. This test examined if indeed course could be maintained, and also determined the amount of speed loss for each vessel type. In the next test the procedure was the same with the exception that when vessels started to experience speed loss, the propeller RPMs were increased to maintain a water speed of 8 knots. This test provided for a determination of whether course holding ability improved, and also demonstrated the degree to which propeller RPM (and associated noise level) would have to be increased in strong head winds in order to maintain the vessel's minimal transit speed.

Similarly, it was illustrated in the Juan de Fuca tests that with winds on the quarter at velocities of 30 knots that some vessels would experience difficulty maintaining course, and particularly steadying on course after a course alteration. For the course alteration test from 095° to 117° (Wind from 270°) the first test was conducted with the vessels' telegraphs set to the order that provided a speed closest to 8 knots. On the second comparative test, propeller RPMs/Pitch were set for a water speed of 10 knots. These two tests provided an indication of the vessel's abilities to steady on course at the two different speed settings.

Table 8: Anticosti TSS Test Conditions

Anticosti TSS Test Conditions			
Test No	Wind Direction/ Speed	Planned Route	Vessel Initial State: Course and Engine Telegraph
1	270° (15 building to 40 knots)	297° track	Steady 297° /Slow*
2	270° (15 building to 40 knots)	297° track	Steady 297° /Slow*
3	270° (15 building to 30 knots)	095° to 117°	Steady 095° /Slow*
4	270° (15 building to 30 knots)	095° to 117°	Steady 095° /RPM for 10 knots

*Note: Cargo ships' engine telegraphs were at Slow Ahead except for the PANAMAX Bulk Carrier whose Dead-Slow Ahead speed corresponded to 7.8 knots, hence it was set to Dead-Slow Ahead. The two passenger vessels set their propulsion speed for 8.0 knots of water speed.

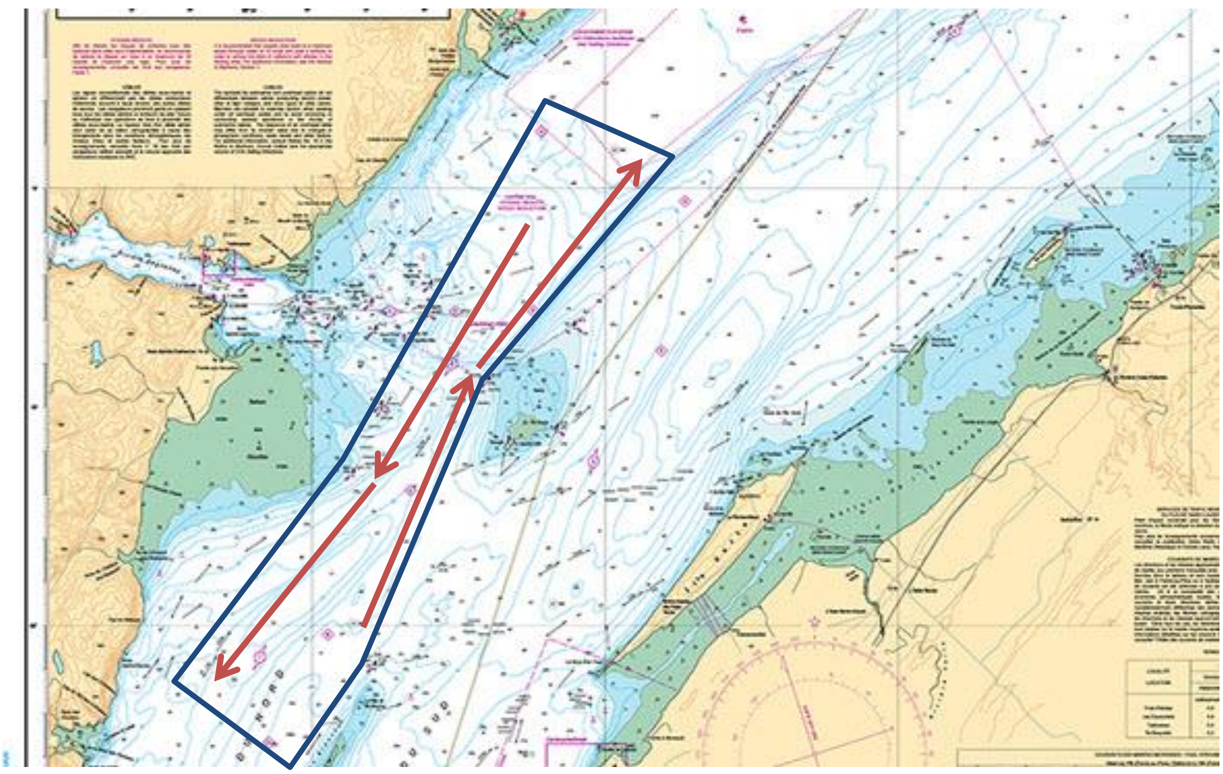
3.4 Analysis of Saguenay/ St-Lawrence Pilotage Area

The analysis of the Saguenay/St-Lawrence pilotage area introduced the requirement for an evaluation of how complex tidal stream and current patterns and the associated tidal eddies and tidal races would affect steering and positional control during low speed transits. Factors that affected the specific testing process and testing sequence at the confluence of the St-Lawrence and Saguenay Rivers are described in the following Sections..

3.4.1 Environmental and Physical Factors/ Considerations

Initial tests were conducted with transits of vessels both upbound and down-bound in the main St-Lawrence navigation channel to the west of Ile Rouge. See Figure 37 below:

Figure 37: St Lawrence Test Routes

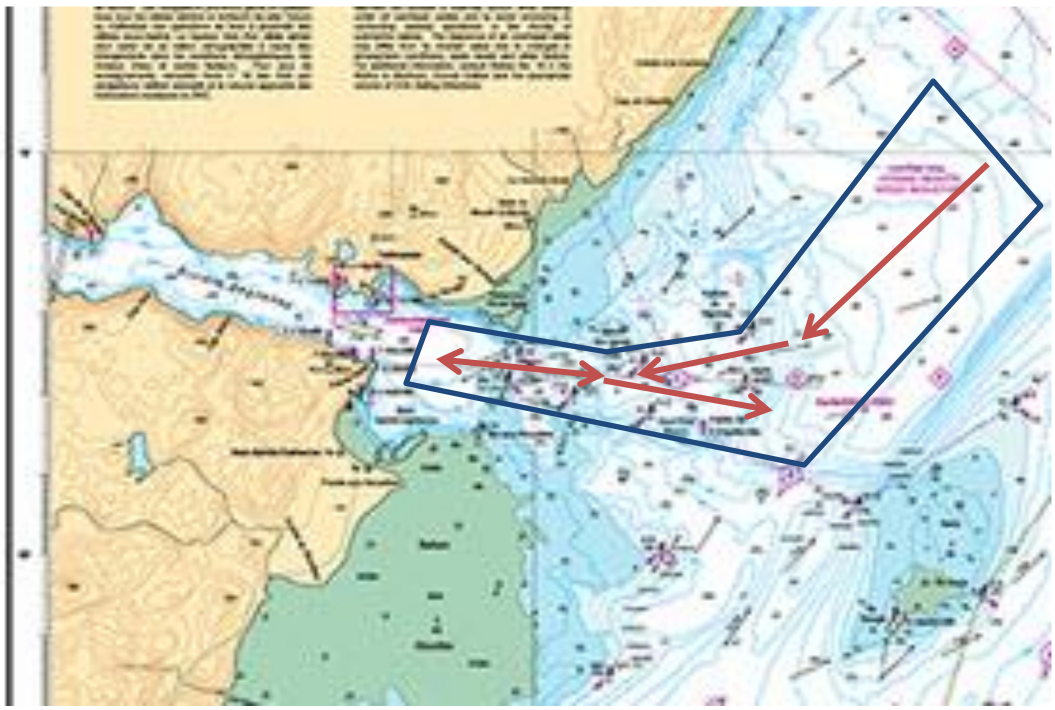


This area was tested first as the tracks through the area of interest are quite straight, one of approximately 8 nautical miles (14.8 kilometres) when proceeding upriver and two each of approximately four miles (7.4 kilometres) in length with a course alteration of approximately 20°. Over the length of these transits the tidal flow is very dynamic and changes direction and speed fairly quickly over quite short distances of a few hundred metres.

Once the analysis of transits in the St-Lawrence were complete, building on observations from these tests, runs were conducted at the junction of the Saguenay with the St-

Lawrence River. Since all ports in the Saguenay are export terminals, inbound ballasted vessels approached the Saguenay from the northeast, and outbound loaded vessels passed to the south of the fairway buoy such that they could then join the main St-Lawrence Channel to proceed outbound. See Figure 38 below:

Figure 38: Saguenay Test Routes



Transits were conducted with a combination of high and low river conditions and spring tidal conditions. See overall tidal patterns for maximum possible inflow and outflow tidal/current conditions in Figures 39 and 40 below:

Figure 39: High River Level – Spring Tide Maximum Outflow (Ebb) Current

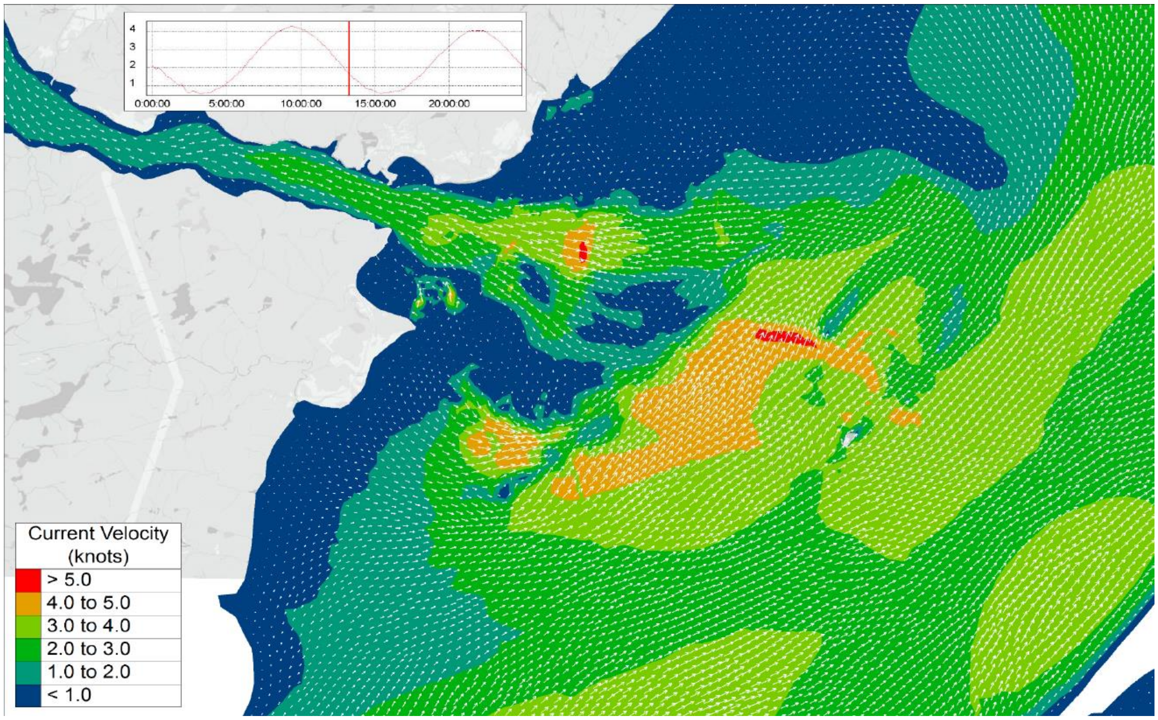
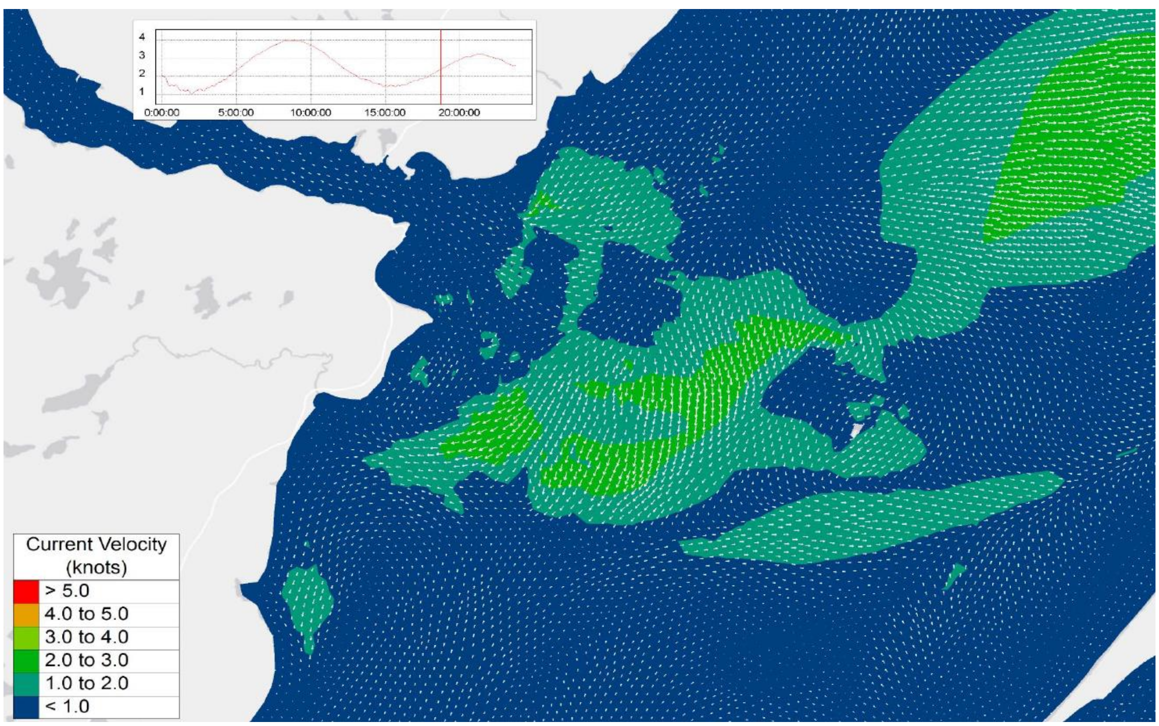


Figure 40: Low River Level – Spring Tide Maximum Inflow (Flood) Current



Wind direction in the Saguenay River is dictated to a large degree by topography (it is a fjord) and the prevailing weather systems. With respect to wind direction and speed at the confluence of the Saguenay and St-Lawrence the following patterns and tendencies are noteworthy:

a. At the eastern end of the Saguenay River the prevailing wind, and particularly strong winds above 20 knots in velocity are predominately from the west-northwest;
b. During the summer season, there is a tendency for the prevailing winds in the Saguenay to be more frequent from the west, and of lower velocity than in the winter;
c. Even in February when the winds are strongest, the frequency of winds in the Saguenay that exceed 16 knots (40 Km/h) is less than 15%;
d. Once clear of the mountainous terrain of the Saguenay Fjord, the wind patterns in the Lower St-Lawrence are governed much less by topography and more by weather systems, although winds are still from the western quadrant more than 41% of the time;
e. Ile-Rouge, located in the middle of the St-Lawrence is unsheltered by shoreline in any direction and the strongest winds tend to be when the wind funnels up or down the St-Lawrence (southwest or northeast quadrants, or when a very strong westerly outflow from the Saguenay reaches across the St-Lawrence; and
f. Although Ile-Rouge is completely unsheltered from wind, more than 97% of the time the wind speed is less than 30 knots;

The wind data described above is based on historic data from 1994 to 2018 recorded at Pointe de l'Islet and Ile-Rouge weather stations. See Figures 40 to 44 below:

Figure 41: Annual Historic Wind Distribution – Direction and Speed at Mouth of Saguenay

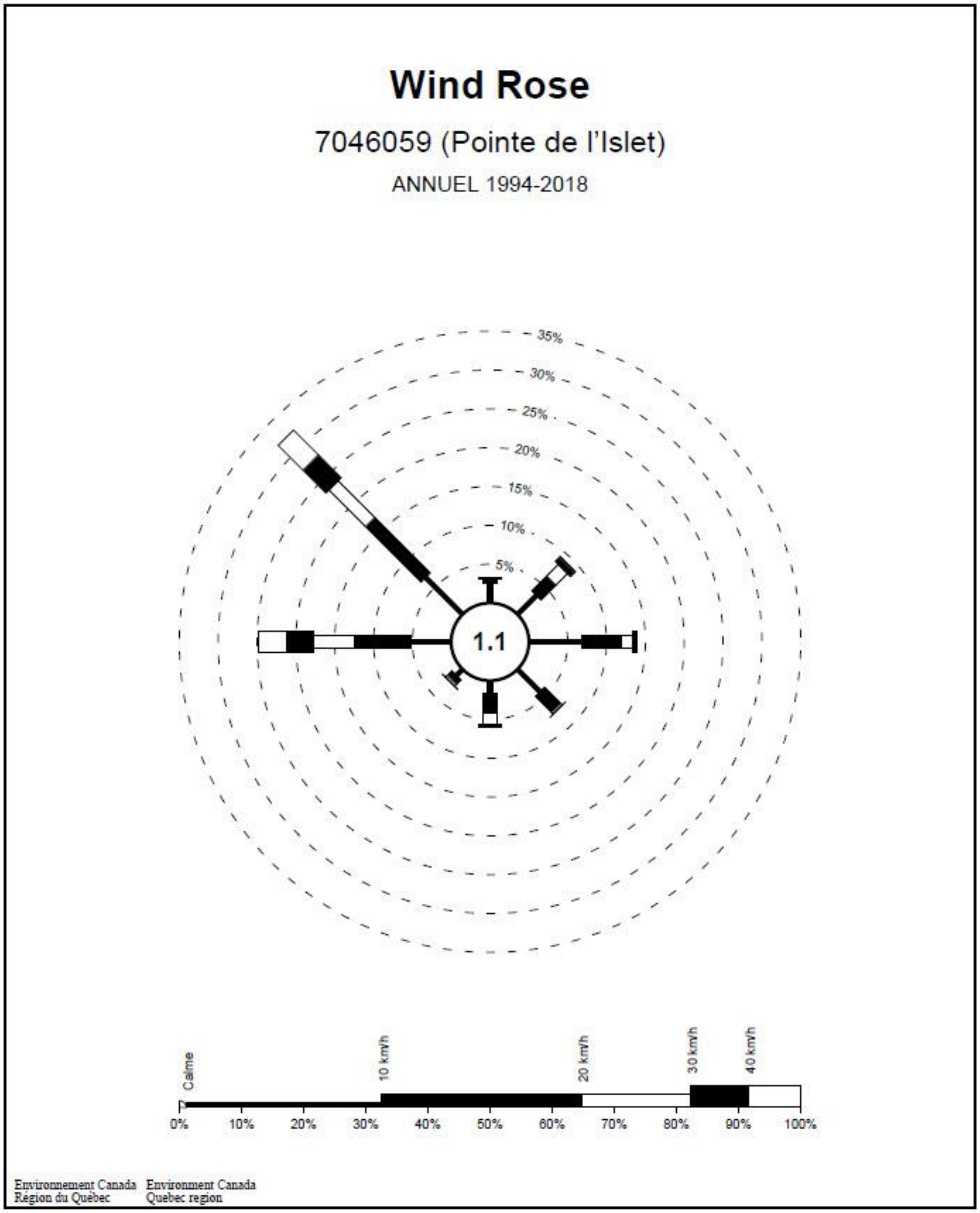


Figure 42: February Historic Wind Distribution – Direction and Speed at Mouth of Saguenay

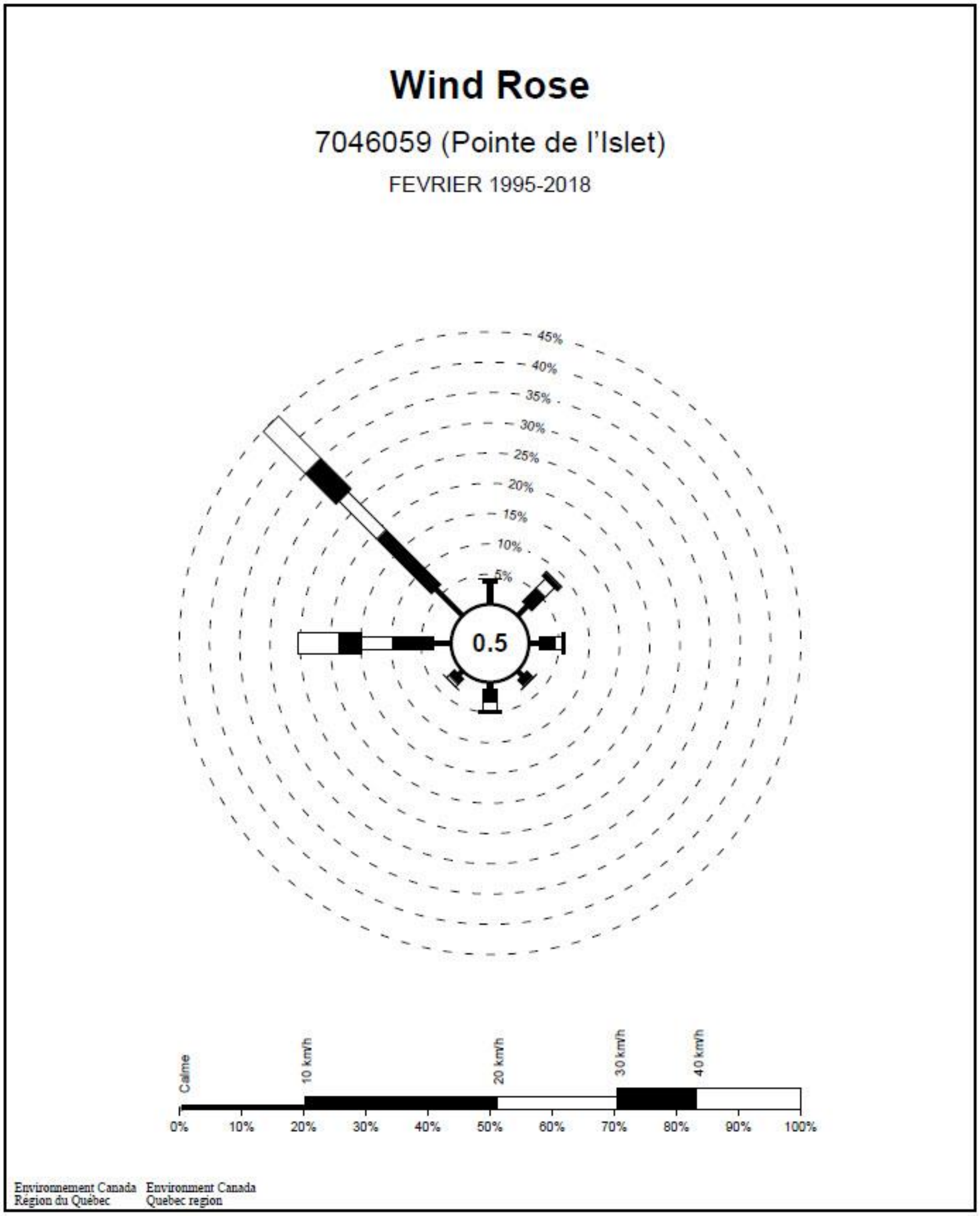


Figure 43: Summer Historic Wind Distribution – Direction and Speed at Mouth of Saguenay

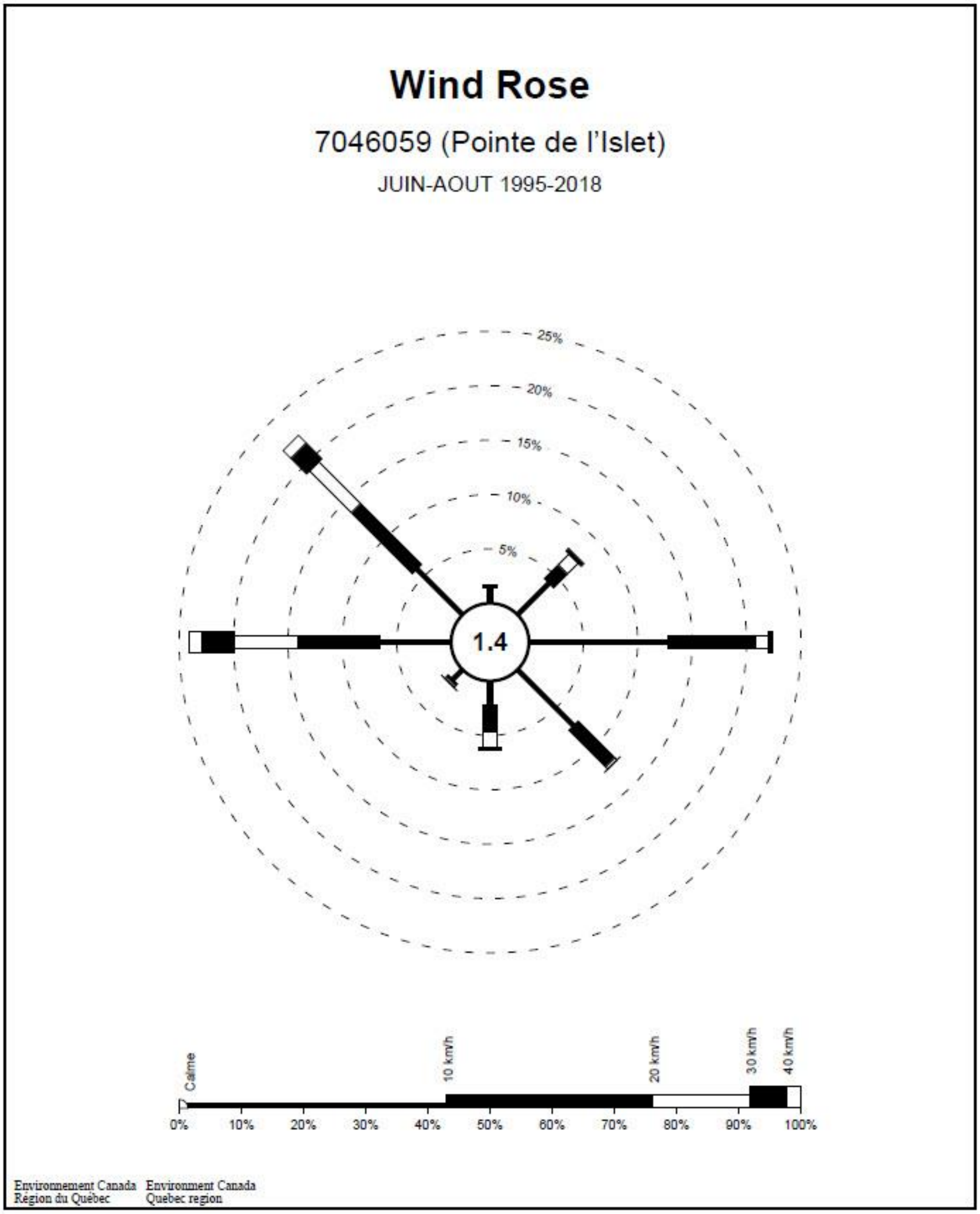


Figure 44: Historic Wind Statistics – Direction and Speed at Ile-Rouge

Fréquences d'occurrence des vents (nombre d'heures) par vitesses et directions pour la station de l'Île-Rouge.

Vent		Direction																			
(noeuds)	Calme	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	%	% Cumul	% Dépass
Calme	1592																	1592	0.9	0.9	100.0
0.0 - 2.7		687	398	398	345	514	320	293	270	427	358	328	358	573	382	435	397	6483	3.6	4.5	99.1
2.7 - 5.4		2083	1800	1882	1703	1655	739	698	812	1604	1525	1585	1333	1771	1197	1298	1395	23080	12.8	17.3	95.5
5.4 - 8.1		1188	1608	2279	1724	1175	398	386	493	1414	1924	1637	1004	1227	1057	1136	741	19391	10.8	28.0	82.7
8.1 - 10.8		1246	2684	3927	1879	1187	375	357	548	2177	3865	2487	1078	1816	1911	2039	980	28556	15.8	43.9	72.0
10.8 - 13.5		1021	2623	3070	907	642	178	195	257	2026	4065	1907	564	1668	2860	2712	935	25630	14.2	58.1	56.1
13.5 - 16.2		485	1767	1590	365	198	54	57	104	1323	2958	924	264	1191	2616	2048	536	16480	9.1	67.2	41.9
16.2 - 18.9		536	2022	1493	285	79	24	36	92	1307	3722	984	215	1429	3957	2652	579	19412	10.8	78.0	32.8
18.9 - 21.6		354	1437	976	140	13	1	7	24	590	3059	690	129	1194	3451	2125	325	14515	8.0	86.0	22.0
21.6 - 24.3		193	916	699	51	4	1	1	5	246	2445	502	64	926	2806	1741	134	10734	6.0	92.0	14.0
24.3 - 27.0		62	305	311	19	0	1	0	1	80	1153	264	18	477	1456	814	48	5009	2.8	94.8	8.0
27.0 - 29.7		37	206	252	14	0	0	0	2	48	926	203	4	361	1478	860	25	4416	2.4	97.2	5.2
29.7 - 32.4		12	61	137	3	0	0	0	2	26	428	86	4	188	940	557	7	2451	1.4	98.6	2.8
32.4 - 35.1		5	23	57	0	0	0	0	0	8	149	25	0	47	468	206	2	990	0.5	99.1	1.4
35.1 - 37.8		3	10	26	0	0	0	0	0	2	106	16	1	34	385	236	2	821	0.5	99.6	0.9
37.8 - 40.5		0	4	13	1	0	0	0	0	1	33	6	0	17	218	112	0	405	0.2	99.8	0.4
40.5 - 43.2		0	1	7	0	0	0	0	0	2	8	3	0	7	89	39	0	156	0.1	99.9	0.2
43.2 - 45.9		0	0	2	0	0	0	0	0	0	6	0	0	4	77	29	0	118	0.1	99.9	0.1
45.9 - 48.6		1	0	0	0	0	0	0	1	0	1	0	0	7	53	15	0	78	0.0	100.0	0.1
48.6 - 51.3		0	0	0	0	0	0	0	0	0	0	0	0	2	8	1	0	11	0.0	100.0	0.0
51.3 - 54.0		0	0	0	0	0	0	0	0	0	0	0	2	2	1	2	0	7	0.0	100.0	0.0
54.0 - 56.7		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0.0	100.0	0.0
56.7 - 59.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.0	100.0	0.0
59.4 - 62.1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0	0.0
62.1 - 64.8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0	0.0
64.8 - 67.5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0	0.0
67.5 - 70.2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0	0.0
70.2 - 72.9		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0	0.0
72.9 - 75.6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0	0.0
75.6 - 78.3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0	0.0
78.3 - 81.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0	0.0
Total	1592	7913	15865	17119	7436	5467	2091	2030	2611	11281	26731	11647	5038	12943	25410	19058	6106	180338			
%	0.9	4.4	8.8	9.5	4.1	3.0	1.2	1.1	1.5	6.3	14.8	6.5	2.8	7.2	14.1	10.6	3.4	100.0			

3.4.2 Course Holding and Current Limits Tests St-Lawrence

These tests were conducted in groupings using up to eight different ship models within the same test exercise. From the test vessels identified in Table 4, the first test group was comprised of Test Vessels 1 to 8, the second grouping Test Vessels 9 to 14.

Tests were conducted with each vessel grouping first proceeding downstream, then proceeding upstream with outflow tidal conditions followed by downstream/upstream transits with inflow tidal conditions. Note that due to the river outflow, combined outflow river current and tidal streams (ebb tide) always produce a higher velocity combined tidal flow than the tidal inflow, hence the outflow was tested first. The test area was the most commonly utilised upriver/downriver routes to the west of Ile Rouge starting from positions approximately 4 nautical miles upriver/downriver from Ile Rouge (See Figure 8 next page). This round of tests was conducted with winds from the south-southwest (202°), as 15 knots winds from this point have the most common frequency of occurrence (14.8%).

Once it was determined that all vessels could transit both upriver and downriver with maximum ebb and flood tidal conditions (albeit the loaded AFRAMAX and Cape Vessels when proceeding upriver with full ebb tide had marked reduction in steering control), validation runs were conducted. Down river validation was conducted with winds from 202° at 30 knots, and upriver validation with the wind from 315°, which represented the third most common wind point, but the worse relative direction (starboard quarter) for course holding when passing the Saguenay/ St-Lawrence junction. Table 9 below lists all planned potential test conditions, and those that were not conducted/required are crossed out.

Table 9: St-Lawrence Test Conditions

St-Lawrence Test Conditions – Conducted with Each Vessel Group			
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed
1	High River/Spring/Max Ebb	202°@15 knots	Steady 020° @ 8 knots
2	High River/Spring/Max Ebb	202°@15 knots	Steady 200° @ 8 knots
3	Mean River/Spring/Max Flood	202°@15 knots	Steady 020° @ 8 knots
4	Mean River/Spring/Max Flood	202°@15 knots	Steady 200° @ 8 knots
~~5~~	~~Pending Results of Test 1 may conduct tests with lower velocity Ebb/Outflow~~	~~202°@15 knots~~	~~Steady 020° @ 8 knots or higher speed pending Test 1 results~~
~~6~~	~~Pending Results of Test 2 may conduct tests with lower velocity Ebb/Outflow~~	~~202°@15 knots~~	~~Steady 200° @ 8 knots or higher speed pending Test 2 results~~
~~7~~	~~Pending Results of Test 3 may conduct tests with lower velocity Flood/Inflow~~	~~202°@15 knots~~	~~Steady 020° @ 8 knots or higher speed pending Test 3 results~~
~~8~~	~~Pending Results of Test 4 may conduct tests with lower velocity Flood/Inflow~~	~~202°@15 knots~~	~~Steady 200° @ 8 knots or higher speed pending Test 4 results~~
9	Worse case ebb tide/ ebb tide threshold	202°@30 knots	Steady 020° @ 8 knots or higher speed pending Test 1/5 results
10	Worse case flood tide/ flood tide threshold	315 @ 30 knots	Steady 200° @ 8 knots or higher speed pending Test 3/7 results

3.4.3 Course Holding and Current Limits Tests Saguenay

Terminals in the Saguenay are predominately export terminals, so for this group of tests (with the exception of the two cruise vessels) ballasted (empty) versions of the ship models were used on all inbound runs, and loaded vessel models were used on all outbound runs. The centreline of the narrowest portion of the channel is marked by a set of ranges oriented 273°/ 093° true. In general terms the CPBSL pilots consider that under most environmental conditions it is more difficult to position the ship and to maintain the plan track-lines when proceeding inbound; hence for each tidal condition, inbound tests were conducted first. Inbound runs commenced approximately 1.5 nautical miles to the northeast of the seaward starboard buoy and continued until within 0.5 nautical miles of the last pair of channel buoys (See Figures 45 and 46 below). Outbound test runs commenced approximately 1 nautical mile to the west of the channel marker buoys and continued until south of the mid-channel fairway buoy. Note that due to the river outflow, combined outflow river current and tidal streams (ebb tide) always produce a higher velocity combined tidal flow than the tidal inflow, hence the outflow was tested first. Initial current assessment runs were conducted with winds from the prevailing direction of 295° at 15 knots. Once current thresholds were identified, validation runs were conducted with the wind from the worse direction for inducing rotation; for inbound test runs 045°@ 30 knots, and for outbound runs, 295° @ 30 knots. Table 10 below outlines the various test conditions.

Figure 45: Saguenay Transit Test Area – Overall Inbound Route

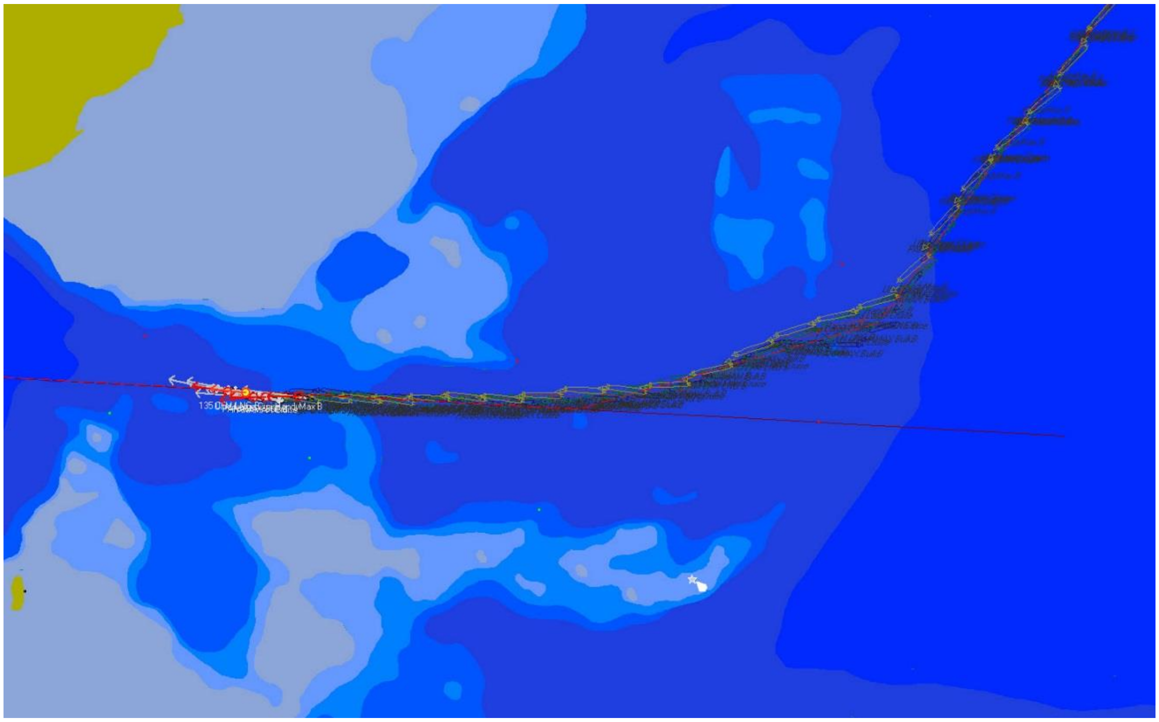


Figure 46: Saguenay Transit Test Area – Zoom Inbound Route Track-plot

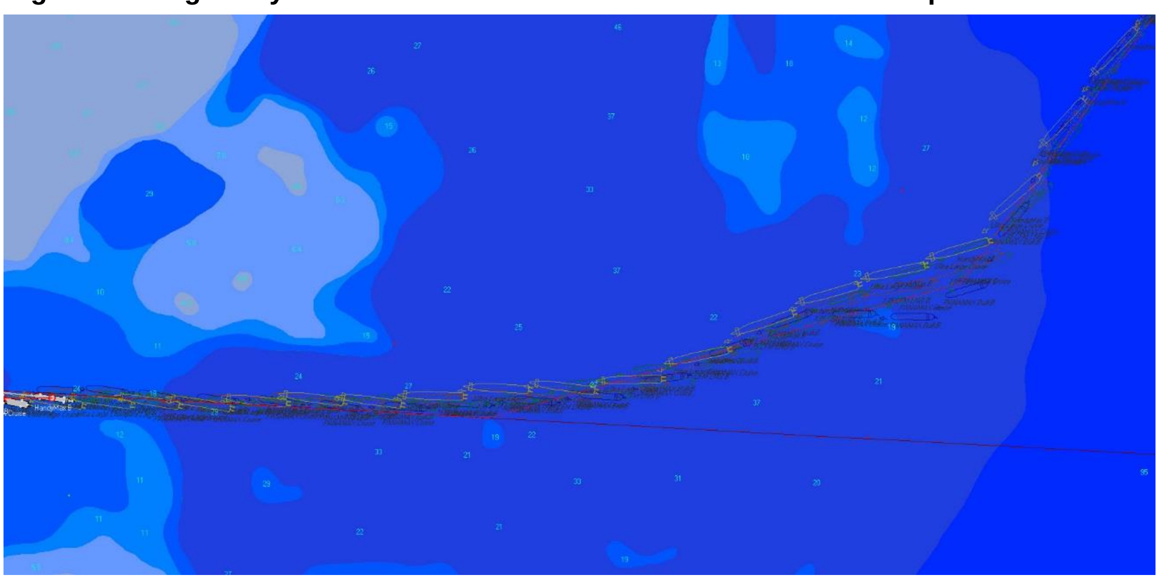


Table 10: Saguenay River Test Conditions

Saguenay Test Conditions – Conducted Inbound Vessel Group			
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed
1	High River/Spring/Max Ebb	295°@15 knots	Steady 222° @ 8 knots
2	Mean River/Spring/Max Flood	295°@15 knots	Steady 222° @ 8 knots
3	Pending Results of Test 1 may conduct tests with lower velocity Ebb/Outflow	295°@15 knots	Steady 222° @ 8 knots or higher speed pending Test 1 results
4	Pending Results of Test 2 may conduct tests with lower velocity Flood/Inflow	295°@15 knots	Steady 222° @ 8 knots or higher speed pending Test 2 results
5	Worse case ebb tide/ ebb tide threshold	045°@30 knots	Steady 222° @ 8 knots or higher speed pending Test 1/3 results
6	Worse case flood tide/ flood tide threshold	045°@30 knots	Steady 222° @ 8 knots or higher speed pending Test 2/4 results
Note determinations and findings from Inbound runs may affect test plan for Outbound runs			
Saguenay Test Conditions – Conducted Outbound Vessel Group			
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed
7	High River/Spring/Max Ebb	295°@15 knots	Steady 105° @ 8 knots
8	Mean River/Spring/Max Flood	295°@15 knots	Steady 105° @ 8 knots
9	Pending Results of Test 7 may conduct tests with lower velocity Ebb/Outflow	295°@15 knots	Steady 105° @ 8 knots or higher speed pending Test 7 results
10	Pending Results of Test 8 may conduct tests with lower velocity Flood/Inflow	295°@15 knots	Steady 105° @ 8 knots or higher speed pending Test 8 results
11	Worse case ebb tide/ ebb tide threshold	045°@30 knots	Steady 105° @ 8 knots or higher speed pending Test 7/9 results
12	Worse case flood tide/ flood tide threshold	045°@30 knots	Steady 105° @ 8 knots or higher speed pending Test 8/10 results

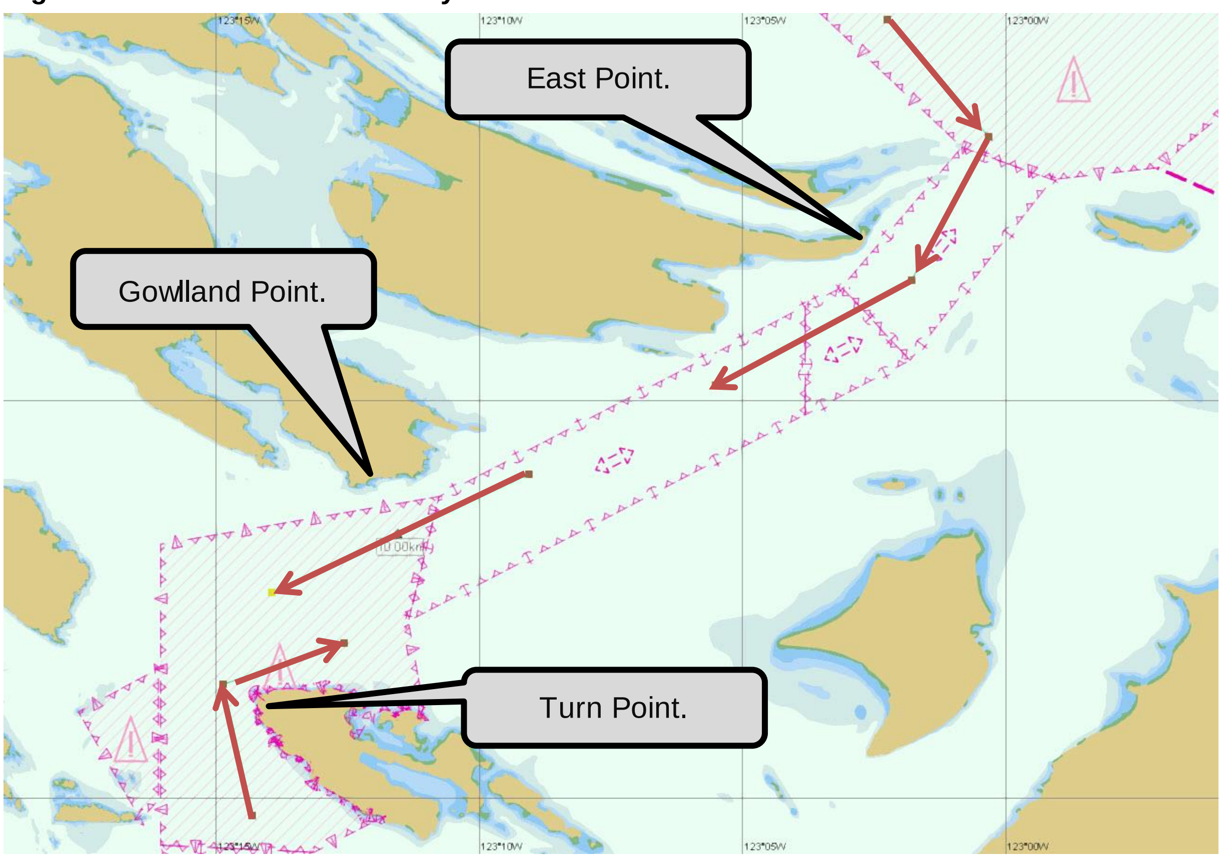
3.5 Analysis of Haro Strait/ Boundary Pass Pilotage Area

The analysis of the Haro Strait and Boundary Pass Pilotage areas built on the findings of the St-Lawrence and Saguenay analysis (evaluation of how complex tidal stream patterns and the associated tidal eddies and tidal races would affect steering and positional control during low speed transits on relatively straight tracks). The analysis was expanded to include conducting very large turns (60° to 80°) while manoeuvring within a tidal race, and transiting through an area where the tidal flow sheers nearly 90°. Factors that affected the specific testing process and testing sequence in Haro Strait – Boundary Pass are described in the Sections that immediately follow.

3.5.1 Environmental and Physical Factors/ Considerations

Throughout the transit of Haro Strait and Boundary Pass, ships are rarely at a distance of more than 1 nautical mile (1.85 kilometres) from the shoreline, and when passing Turn Point northbound, and Gowlland and East Point southbound, may pass within 0.5 nautical miles (926 metres) from the shore. Hence the transit testing focused on these areas. See Figure 47 below:

Figure 47: Haro Strait – Boundary Pass Test Routes



In terms of testing sequence, it was elected to start with the transit segment approaching Turn Point northbound as the track (approximately 347°) from Haro Strait to the junction of Boundary Pass is quite long and exposed the ship to tidal flow/vessel control conditions quite similar to those tested in the St-Lawrence.

Transits rounding Turn Point were conducted with both full flood and ebb tidal conditions at Spring Tides, as both presented unique manoeuvring challenges and represented the worst case conditions. The transit segment at Gowlland Point was conducted with full flood on a Neap tide as this period creates a specific tidal flow pattern where the tidal flow deflects off South Pender Island and changes direction nearly 90° over a short distance. Finally, tests at East Point were conducted with a full ebb and Spring Tide conditions, as this is the situation where the tidal bore/race is most developed. In the final stage of turning into Boundary Pass, ships must exit from the intense tidal race into relatively slow-moving water, which tends to produce strong tidal induced rotation. See Figures 48 to 51 below:

Figure 48: Maximum Ebb – Spring Tide at Turn Point

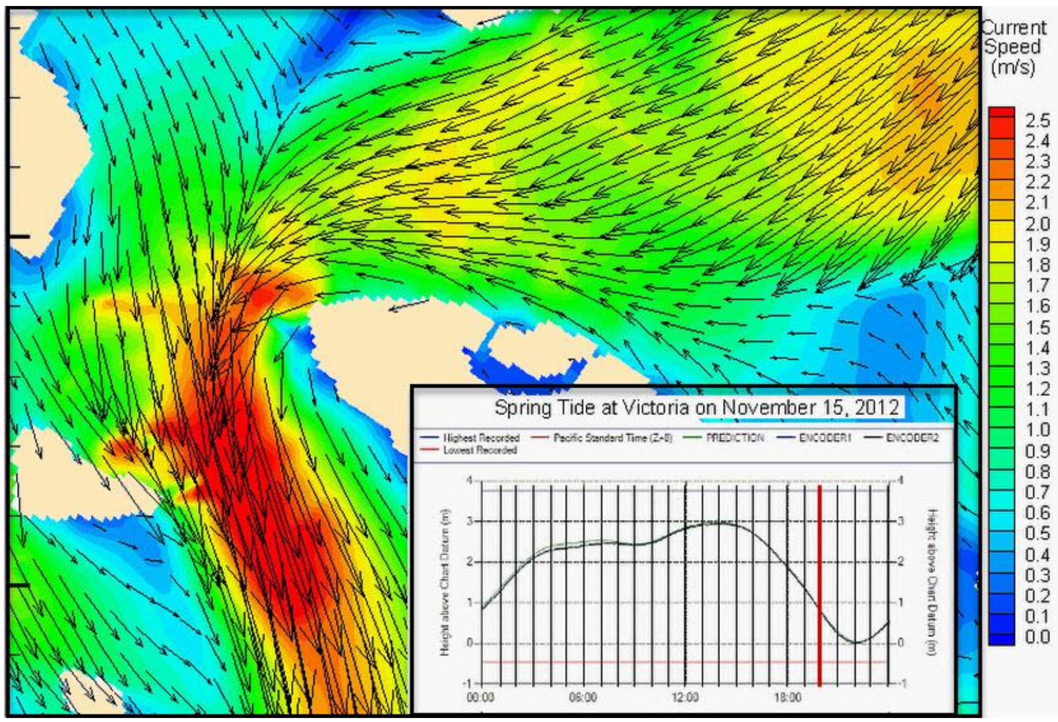


Figure 49: Maximum Flood – Spring Tide at Turn Point

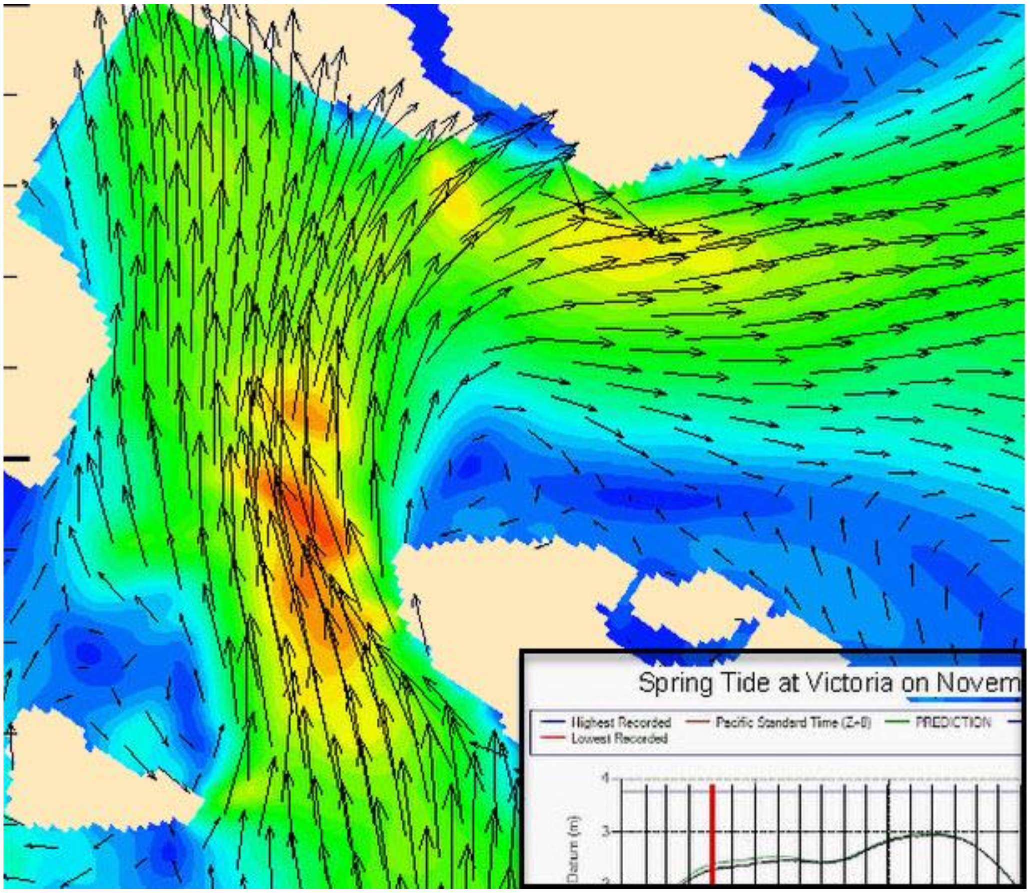


Figure 50: Maximum Flood – Neap Tide at Gowlland Point

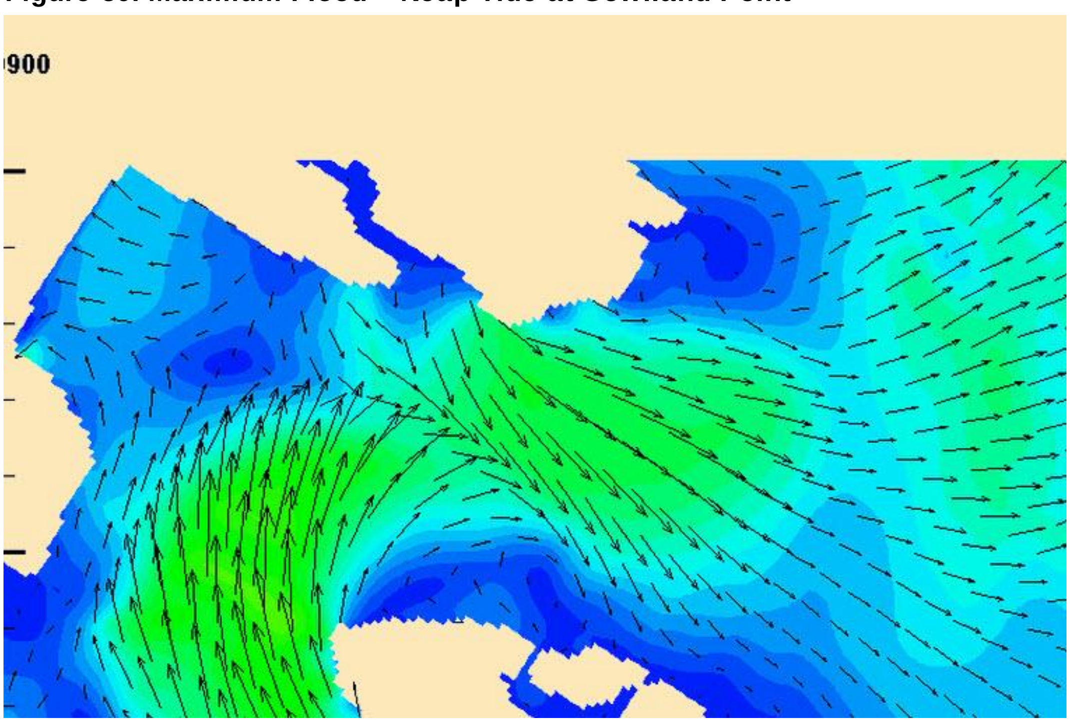
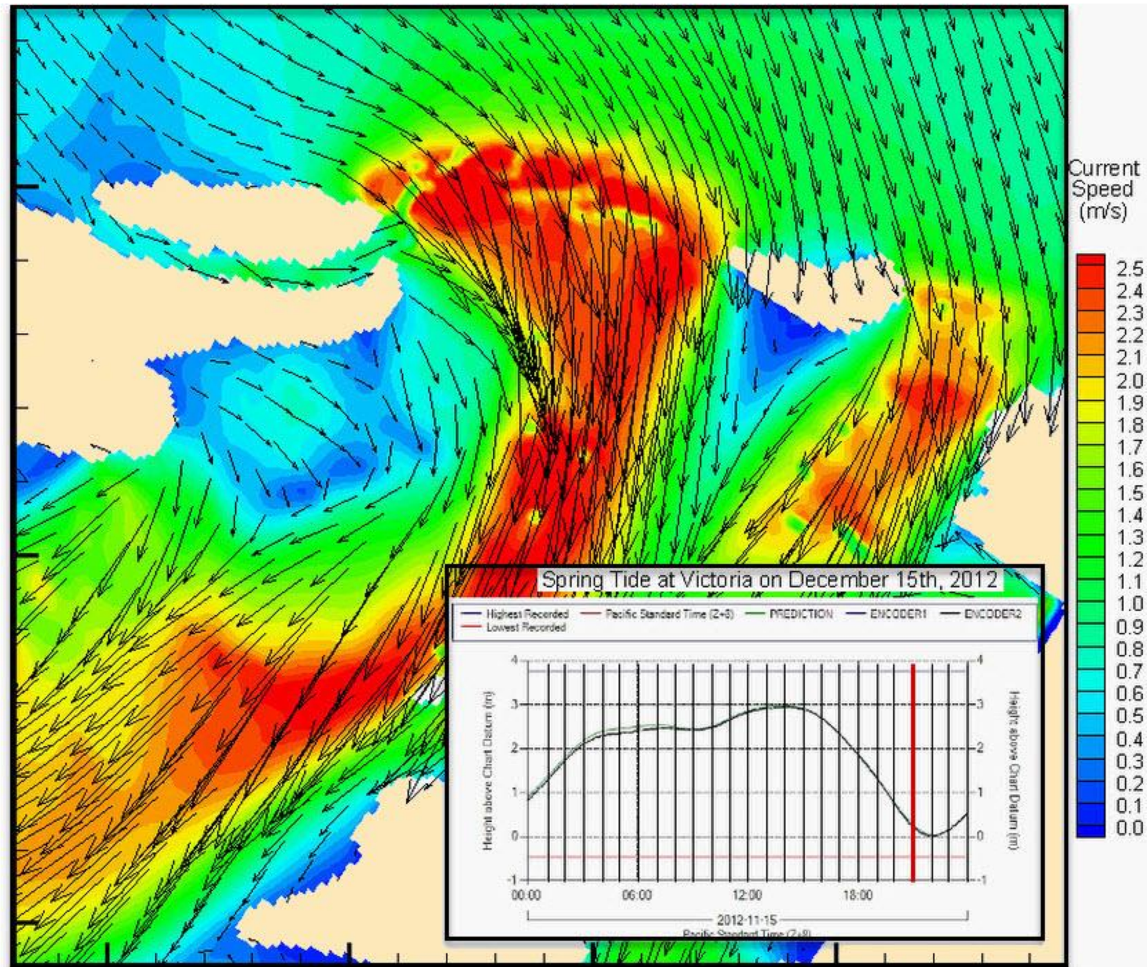


Figure 51: Maximum Ebb – Spring Tide at East Point



Wind direction in Haro Strait and Boundary pass is dictated mostly by weather systems rather than topography, with slow moving warm fronts being much more common than cold frontal passes. As a result the following patterns and tendencies are noteworthy:

a. The frequency of high velocity winds greater than 22 knots (41 km/h) on an annual basis occurs only 5% of the time and these winds are most frequently from the south;
b. During the summer season, the frequency of winds in excess of 22 knots occurs only 0.3% of the time;
c. The winter months have the highest frequency of strong winds, with winds greater than 22 knots occurring 11% of the time; and
d. The prevailing wind direction is from the southwest, and generally have a velocity of 11 knots (20 km/h) or less;

The wind data described above is based on historic data from 1994 to 2018 recorded at Saturna Island weather station. See Figures 52 and 53 below:

Figure 52: Annual Historic Wind Distribution – Direction and Speed at Saturna Island

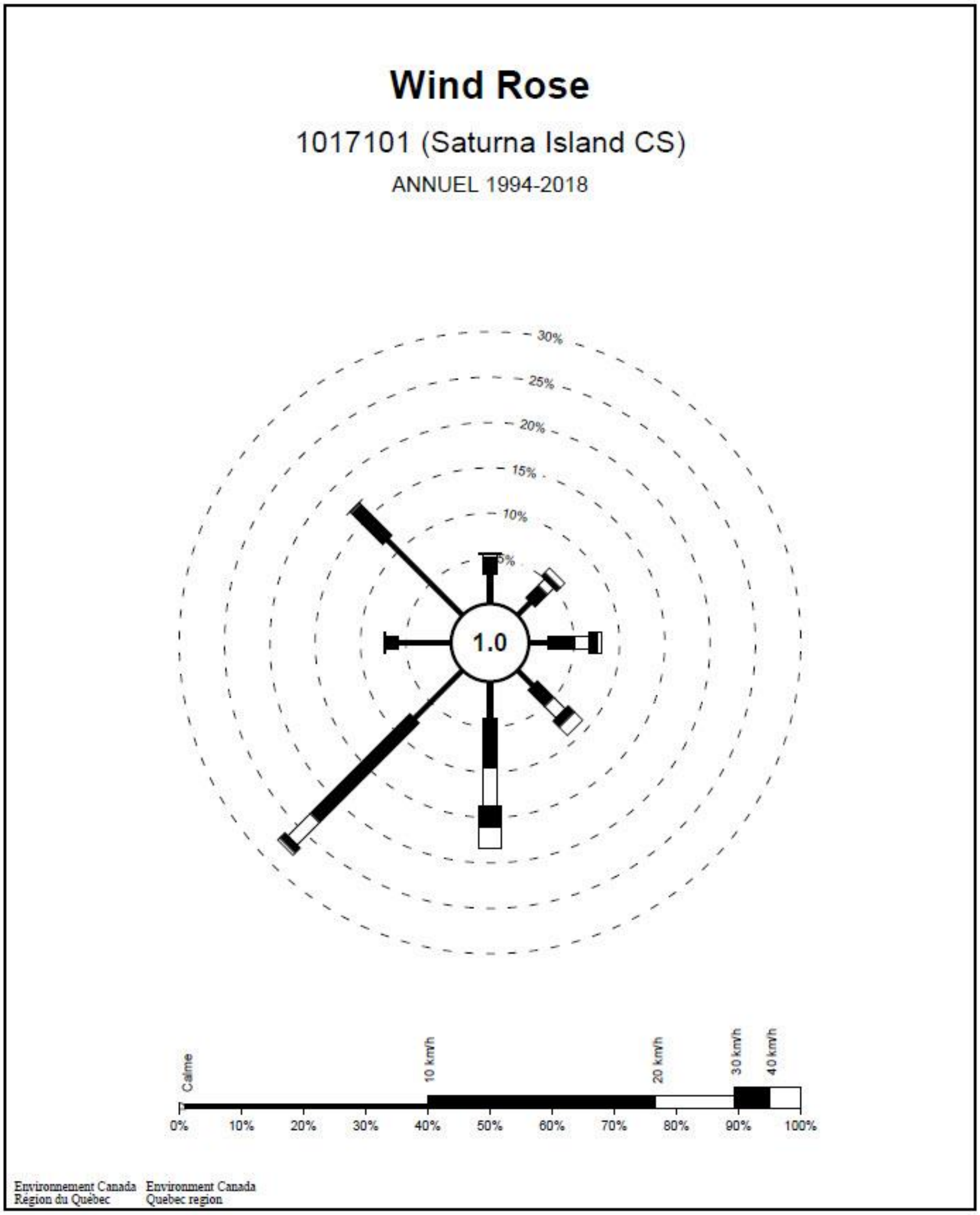


Figure 53: Historic Annual, Summer and Winter Wind Frequency Data

Wind Rose 1017101 (Saturna Island CS) ANNUEL 1994-2018

FREQUENCE DES VENTS PAR DIRECTION A 8 POINTS DE COMPAS
(Vitesses en km/h; frequences en pourcentage)

	NE	E	SE	S	SW	W	NW	N	
CALME									1.0
1- 10	2.0	2.1	2.4	4.1	7.5	5.8	11.7	3.2	38.9
11- 20	2.0	2.9	2.6	5.4	15.6	1.4	4.9	2.0	36.7
21- 30	1.0	1.7	1.7	4.2	3.5	0.1	0.2	0.3	12.6
31- 40	0.6	0.8	1.0	2.4	0.8	0.0	0.0	0.1	5.7
41+	0.7	0.4	1.2	2.4	0.3	0.0	0.0	0.0	5.0
Toutes	6.2	7.9	9.0	18.4	27.7	7.3	16.9	5.6	
Vit moy.	19.4	18.9	22.4	23.0	15.1	7.5	8.6	10.6	15.7

Nombre d'observations: 207450
Nombre d'invalides: 0

Wind Rose 1017101 (Saturna Island CS) JUIN-AOUT 1994-2018

FREQUENCE DES VENTS PAR DIRECTION A 8 POINTS DE COMPAS
(Vitesses en km/h; frequences en pourcentage)

	NE	E	SE	S	SW	W	NW	N	
CALME									1.2
1- 10	1.4	1.8	3.1	6.3	10.6	5.9	10.4	2.7	42.2
11- 20	0.2	0.7	1.7	5.8	30.0	1.9	3.2	0.7	44.3
21- 30	0.0	0.1	0.6	3.7	5.3	0.2	0.1	0.0	10.1
31- 40	0.0	0.0	0.1	1.3	0.4	0.0	0.0	0.0	1.9
41+	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.3
Toutes	1.7	2.6	5.6	17.4	46.4	8.1	13.6	3.4	
Vit moy.	7.0	8.9	11.7	16.1	14.8	8.4	8.0	7.5	12.7

Nombre d'observations: 52426
Nombre d'invalides: 0

Wind Rose 1017101 (Saturna Island CS) DECEMBRE-FEVRIER 1994-2018

FREQUENCE DES VENTS PAR DIRECTION A 8 POINTS DE COMPAS
(Vitesses en km/h; frequences en pourcentage)

	NE	E	SE	S	SW	W	NW	N	
CALME									0.7
1- 10	2.3	2.0	1.5	1.7	3.2	4.0	10.5	3.1	28.3
11- 20	4.4	5.5	3.1	4.3	4.8	0.9	6.0	3.6	32.6
21- 30	2.4	3.7	2.6	4.6	2.4	0.1	0.3	0.7	16.9
31- 40	1.6	2.0	1.7	3.6	1.4	0.0	0.0	0.1	10.5
41+	2.2	1.2	2.4	4.5	0.7	0.0	0.0	0.1	11.0
Toutes	12.9	14.4	11.4	18.7	12.4	5.0	16.8	7.6	
Vit moy.	24.0	22.4	27.8	30.0	18.9	7.3	9.3	12.8	20.4

Nombre d'observations: 49706
Nombre d'invalides: 0

3.5.2 Course Alterations/Holding and Current Limits Tests Haro Strait and Boundary Pass

These tests were conducted in two groupings using six different ship models within the same test exercise. From the test vessels identified in Table 6, the first test group was comprised of Test Vessels 1 to 6 which were fine hull form ships, the second grouping Test Vessels 7 to 12 which were full hull form ship.

Tests at Turn Point were conducted with both ebb and flood tidal stream, Gowlland Point with Flood tidal stream, and East Point with ebb tidal stream. Initial runs at all three locations were performed with the prevailing wind direction of 225° and winds set to an upper mean value of 15 knots. Based on observations during the Saguenay analysis, and also the fact that winds in this area exceed 22 knots only 5% of the time, once tests were completed with all tidal conditions and the wind from 225° at 15 knots, additional runs were conducted with the wind on the quarter (relative angle of 135° to the vessel's track) at a velocity of 25 knots. A detailed list of all assessment tests is contained in Table 11 below.

Table 11: Haro Strait Boundary Pass Test Conditions

Note all tests performed with both vessel groups			
Boundary Pass Test Conditions – Turn Point Northbound			
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed
1	Maximum Ebb Spring Tide	225°@15 knots	Steady 341° @ 8 knots
2	Maximum Flood Spring Tide	225°@15 knots	Steady 345° @ 8 knots
3	Maximum Ebb Spring Tide	225°@25 knots	Steady 341° @ 8 knots
4	Maximum Flood Spring Tide	225°@25 knots	Steady 345° @ 8 knots
Boundary Pass Test Conditions – Gowlland Point Southbound			
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed
5	Maximum Flood Neap tide	225°@15 knots	Steady 252° @ 8 knots
7	Maximum Flood Neap tide	125°@15 knots	Steady 252° @ 8 knots
Boundary Pass Test Conditions – East Point Southbound			
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed
6	Maximum Ebb Spring Tide	225°@15 knots	Steady 133° @ 8 knots
8	Maximum Ebb Spring Tide	030°@15 knots	Steady 133° @ 8 knots

3.6 Full Mission Analysis of Pilotage Areas

The Full Mission Analysis or manned simulation was conducted as a final step in the overall testing process to provide an opportunity for pilots from the CPBSL and BCCP to participate in the evaluation process. Prior to commencing the manned simulation analysis, a summary report of findings from the St-Lawrence/Saguenay and Haro Strait Boundary Pass desktop analysis was forwarded to both groups for review and discussion. At the start of each manned simulation session, the results of the desktop study were again reviewed, and the pilots indicated that the preliminary findings were generally consistent with their real-life experiences and expectations. A discussion was also held to determine, based on real life experiences, which vessels tended to be prone to a degradation in steering and positional control at low transit speeds, and under which type of environmental conditions. It was then decided which of the desktop simulations runs would be conducted by the pilots using manned, real-time full mission simulation, and with which vessel types. It is important to underline that the goal of this phase of the study was not to repeat the entire desktop analysis, but rather to validate key findings using select vessels and test conditions, and also to perform any testing that the pilots may consider to be important, but that had perhaps not been included in the desktop analysis.

3.6.1 Full Mission Analysis of St-Lawrence -Saguenay

Stemming from the process described in Item 3.6 above, it was decided in the validation of the St-Lawrence test runs to commence testing with heavily laden vessels followed by high sided vessels that are prone to wind induced rotation. As such, in the main St-Lawrence channel, one manned simulation run was conducted with each of the following vessels: Cape Size Bulk Carrier Loaded to 15 metres, AFRAMAX Tanker loaded to 15 metres, SUEZMAX Tanker loaded to 15 metres, and a St-Lawrence-Max Container loaded to 10.5 metres. Additionally, five runs were conducted with an Ultra Large Cruise Ship with a conventional propulsion system. In the Approaches to the Saguenay, one run was conducted with a ballasted PANAMAX size Bulk Carrier and one with a PANAMAX size, Azi-POD propeller cruise ship. Three runs each were conducted with a 177,000 CFM LNG carried in both loaded and ballasted condition, and five runs with an Ultra Large Cruise Ship with a conventional propulsion system.

The results of these runs are detailed in Section 4 which follows.

3.6.2 Full Mission Analysis of Haro-Strait and Boundary Pass

Stemming from the process described in Item 3.6 above, and the results of the manned simulation in the St-Lawrence (which was conducted the week prior) it was decided in the validation of the Haro Strait and Boundary Pass test runs to commence testing to focus on high sided vessels that are prone to wind induced rotation. As such, one manned simulation run was conducted with a PANAMAX size Container Vessel and one with a QFLEX size LNG Carrier. Four runs were conducted with an Ultra Large Cruise Ship with a conventional propulsion system, and six runs were conducted with a Neo-PANAMAX size container ship.

The results of these runs are detailed in Section 4 which follows.

4 SUMMARY OF TEST RESULTS AND KEY FINDINGS

This section of the report contains the overall details of the outcomes of all simulation testing. General assessments of outcomes have been compiled in a results tables, the format of which varies slightly dependent upon test location, conditions, and relevant assessment metrics. A legend to each table is provided adjacent to the table to facilitate understanding. There is also a written summary of key observations from each test group in this section. Detailed explanations of observations on specific transit tests and/or environment effects on vessel control will be provided in the parts of Section 5 of this report.

4.1 Juan de Fuca Strait TSS Desktop Results and Findings

The most significant general observations, in order of importance are as follows:

i. Wind velocity is by far the most important variable that affects the amount of rudder that a vessel needs to carry to maintain a course heading. When the wind velocity is less than 20 knots, all vessel types can maintain a straight course without difficulty even at a dead-slow ahead (minimal) engine telegraph setting. When the wind velocity is less than 30 knots, all vessel types can maintain a straight course (one or two with marginal control) at a slow ahead (25%) engine telegraph setting. When the wind velocity reaches 30 knots, all vessels require a noticeable increase in the amount of rudder angle that they are carrying to maintain their course heading. In certain vessel types, steering control becomes marginal at a wind velocity of 30 knots. When the wind velocity reached 35 knots, all vessel types require a significant increase in rudder angle to hold course. Seven test vessels could not maintain their course heading at a Dead Slow Ahead engine telegraph setting and five could not maintain course at a Slow Ahead Telegraph setting. With a wind speed of 40 knots, most vessel types experienced marginal steering control even at Slow Ahead engine settings, and several vessel types fell off their course unless an engine telegraph setting of Half Ahead or more was used. Complete details of this effect are provided in the Detailed Observations on Test Vessel Groups 1, 2 and 3 in the sections that follow.

ii. Closely related to wind velocity, is the importance of wind angle relative to the direction of travel of the vessel. Winds from the stern hemisphere (abaft the beam), particularly relative angles of 110° to 155° in relation to the ship's heading (quartering winds) generate wind induced rotation. To counter this rotation, the amount of rudder used to hold a course heading must be increased. Winds from these quadrants, particularly when above 30 knots in velocity, cause high-sided vessels that are prone to wind induced rotation to fall off course (i.e. maximum rudder angle at low propeller RPM/Pitch settings does not generate sufficient steering force to counter the wind induced rotation).

    To explain this phenomenon in terms that a non-mariner can relate to, quartering winds tend to cause a ship to "weather vane". In comparative terms, if we imagine a classic weather vane of a rooster on a barn roof, if the wind starts to blow on the *rear section of the rooster, it will rotate such that the head of the rooster and the tip of the indicator arrow point into the wind. In order to counter wind induced rotation, the ship's rudder is applied in the opposite direction of the rotation (i.e. in our test cases wind on the port quarter caused the ship to rotate to port and starboard rudder was applied by the autopilot to counter this rotation and to maintain the ordered heading).*

iii. It was also observed in Tests 1-3, 7-9 and 13-15 that winds from the forward hemisphere, in contrast, induced very little heading rotation and with most vessel types had a marginal effect on course holding abilities. The exception to this was vessels with high windage areas, particularly the Ultra Large Cruise Vessel (ULCV) and the 151-metre-long Ferry; these ships were highly prone to wind induced lateral drift. At lower transit speeds (Dead Slow Ahead Telegraph orders) when the wind velocity exceeded 30 knots, these vessels developed considerable course drift (The angular difference between their heading and course over the ground started to increase). Additionally, winds above 30 knots acting on the large forward cross-sectional area of the vessels' superstructure resulted in considerable loss of forward speed, and if propeller RPM or Pitch Angle were not increased, the vessels would lose almost all forward motion and develop a very large drift angle.

To explain this phenomenon in more detail, passenger vessels and automobile carriers in particular tend to have a very large portion of their hull above the water line, and correspondingly have a relatively shallow draught (5 to 9 metres). As a consequence, the large portion of the vessel's hull that is above the water (windage area) acts like a sail. These vessels, much like a sailboat, in strong winds are never going where they are pointed (heading) but rather develop lateral drift, and the difference between their heading (where they are pointed) and their course over the ground (where they are actually going or tracking) is known as the drift angle. When a vessel's drift angle becomes large (specifically when it exceeds 45°), a vessel will actually be moving faster in the lateral axis (or sideways) than it is in the forward axis.

iv. Overall test results demonstrated that at lower transit speeds, container vessels were the ship type that experienced the most difficulty holding course, and that loaded tankers (closely followed by loaded Bulk Carriers) had the least amount of difficulty maintaining course at low speeds.

v. Test results from runs that included tidal stream (current) in both ebb and flood directions demonstrated that it had little effect on a vessel's ability to maintain steering control. In the Juan de Fuca TSS, the tidal flows tend to be quite linear and homogeneous in direction and their predominate effect is to either increase or decrease vessel ground speed dependent upon whether the ship is stemming the tide (travelling in the opposite direction to the tidal flow) or running with the tide (travelling in the same direction as the tidal flow). The only real exception to this was in the case of the high windage vessels proceeding at low speed into the wind (as described in item iii) above) where the large wind induced drift angle could be further augmented when stemming the tidal stream.

vi. As previously mentioned, vessel speed through the water is the relevant parameter when considering both noise emissions and vessel-whale strike scenarios. Further to the observations from item v) above, the use of AIS or VTS radar tracking (without further interrogation) is not suitable for assessing a vessel's speed in the Juan de Fuca TSS since these are both measuring the vessel's ground speed. For example, the same vessel with a Slow Ahead Engine Telegraph setting (same propeller RPM throughout) in a slack tide was making a ground speed identical to its water speed of 8.0 knots. When stemming the flood tide the ground speed decreased to 6.4 knots (water speed was still 8.0). When running with an ebb tide, the ground speed increased to 10.0 knots (water speed was still 8.0).

4.1.1 Summary Assessment of Baseline Heading Holding Tests

A summary of the baseline test results for both when a ship is sailing into the wind (wind from forward hemisphere) and sailing downwind (wind from stern hemisphere) are provided in Tables 12 and 13 below. Note that for each test vessel, any threshold where steering control became marginal due to wind speed effects is highlighted in yellow. If steering control was lost, this is highlighted in red colour.

Note in order to fit information into the table in a compact manner, short forms have been used as follows:

- GC means Good Control;
- MC means Marginal Control;
- LC means Loss of Control; and
- S and P denote either Starboard or Port rudder directions.

Also note that when loss of steering control occurred at a particular speed setting (for example Slow Ahead) generally the test was then repeated at the next highest engine telegraph setting (i.e. Half Ahead). There are some exceptions to this rule; for example with the ballasted SuezMax Tanker, steering control at Slow Ahead with 35 knots of wind was Marginal with a drift angle of 12° and a water speed reduced by wind drag to 3.3 knots. At a wind speed of 40 knots, the water speed was reduced to only 1.8 knots and the drift angle became 36°, not because heading control was lost, but simply due to loss of forward speed. Since the Half Ahead setting would increase the vessel's set speed from 5.6 knots to 9.0 knots, this would clearly resolve this issue, hence there was no requirement to run a test.

Table 12: Juan de Fuca Strait TSS Results Summary – Wind from Forward Hemisphere

Vessel Test Group One – Wind from Forward Hemisphere					
PANAMAX Container 294 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (6.3 Kts/ 28 RPM)	GC/S3.9°	GC/S5.7°	GC/S9.3°	GC/S14.0° Drift 7° Speed 4.3	MC/S6.0° Drift 11° Speed 3.8
Slow (8.9 Kts/ 38 RPM)	GC/S1.8°	GC/S4.0°	GC/S5.3°	GC/S6.4°	GC/S9.2° Drift 4° Speed 6.7
Half (13.3 Kts/ 54 RPM)	GC/S3.5°	GC/S3.4°	GC/S7.4°	GC/S7.4°	GC/S13.9° Drift 1° Speed 13.5
Post-PANAMAX Container 336 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (6.0 Kts/ 20 RPM)	GC/S5.4°	GC/S9.5°	MC/S14.0° Drift 7° Speed 3.5	MC/S10.5 Drift 13° Speed 2.6	LC/P9.6 Drift 27° Speed 1.7
Slow (7.7Kts/ 27 RPM)	GC/S3.1°	GC/S5.4°	GC/S8.4°	GC/S13.8° Drift 5° Speed 5.4	MC/S17.5° Drift 10° Speed 4.0
Half (10.3 Kts/ 33 RPM)	GC/S3.9°	GC/S9.8°	GC/S15.5°	GC/S23.6° Drift 1° Speed 10.6	MC/S31.5° Drift 2° Speed 11.0
Vessel Test Group One – Wind from Forward Hemisphere					
Neo-PANAMAX Container 366 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (7.0 Kts/ 31 RPM)	GC/S3.4°	GC/S5.3°	GC/S5.9°	GC/S7.2° Drift 7° Speed 5.1	MC/S5.8 Drift 12° Speed 4.3
Slow (8.5 Kts/ 41 RPM)	GC/S2.1°	GC/S2.9°	GC/S4.1°	GC/S6.0°	MC/S6.2 Drift 6° Speed 6.8
Half (12.6 Kts/ 51 RPM)	GC/S1.6°	GC/S3.7°	GC/S7.1°	GC/S11.4°	GC/S13.6° Drift 2° Speed 12.9
Ultra Large Container Vessel 399 metres (Twin Screw)					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (5.8 Kts/ 18 RPM)	GC/S1.8°	GC/S2.2°	GC/S1.8° Drift 8° Speed 4.1	MC/P1.2 Drift 13° Speed 3.5	LC/P9.1 Drift 26° Speed 2.6
Slow (7.4 Kts/ 24 RPM)	GC/S1.1°	GC/S1.6°	GC/S2.1°	GC/S1.5°	GC/P0.0° Drift 10° Speed 4.9
Half (11.8 Kts/ 36)	GC/P0.2°	GC/S2.3°	GC/S4.4°	GC/S5.4°	GC/S8.0° Drift 2° Speed 12.2

Vessel Test Group One – Wind from Forward Hemisphere					
Break Bulk Carrier 199 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (6.6 Kts/ 36 RPM)	GC/S2.8°	GC/S3.5°	GC/S3.1°	GC/P12.3°	GC/P6.9° Drift 10° Speed 4.7
Slow (8.0 Kts/ 48 RPM)	GC/S1.4°	GC/S1.7°	GC/S1.3°	GC/P1.6°	GC/S7.9° Drift 5° Speed 6.9
Half (10.7 Kts/ 65 RPM)	GC/S3.4°	GC/S5.4°	GC/S5.2°	GC/S8.8 °	GC/S18° Drift 1° Speed 11.2
General Cargo Vessel 225 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (6.1 Kts/ 26 RPM)	GC/ P0.2°	GC/ P0.9°	GC/ P1.5° Drift 3° Speed 3.8	MC/ P3.3° Drift 6° Speed 2.8	LC/P17.8 Drift 13° Speed 1.7
Slow (7.3 Kts/ 33 RPM)	GC/ S0.1°	GC/ P0.1°	GC/ P0.8°	GC/P1.1° Drift 2° Speed 5.8	GC/ P7.2° Drift 6° Speed 3.2
Half (9.8 Kts/ 45 RPM)	GC/S5.4°	GC/S4.1 °	GC/S8.0 °	GC/S13.0 °	GC/S17.9° Drift 0° Speed 10.1
Vessel Test Group Two – Wind from Forward Hemisphere					
PANAMAX Bulk Carrier Ballasted 215 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (7.8 Kts/ 46 RPM)	GC/S2.0°	GC/S3.4°	GC/S5.6°	GC/S8.6°	GC/S16.5°
Slow (12.3 Kts/ 76 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Half (14.6 Kts/ 96 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
PANAMAX Bulk Carrier Loaded 215 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (6.3 Kts/ 47 RPM)	GC/S0.9°	GC/S1.2°	GC/S2.0°	GC/S3.9°	GC/S13.1°
Slow (11.4 Kts/ 75 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Half (13.3 Kts/ 96 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Cape Size Bulk Carrier Ballasted 289 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (4.8 Kts/ 30 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (6.2 Kts/ 38 RPM)	GC/P2.0°	GC/P3.2°	GC/P4.3°	GC/P6.0°	MC/P10.0° Drift 14.0° Speed 3.4
Half (9.9 Kts/ 54 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Cape Size Bulk Carrier Loaded 274 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (5.5 Kts/ 33 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (7.0 Kts/ 41 RPM)	GC/S1.9°	GC/S2.2°	GC/S4.0°	GC/S5.0°	GC/S6.5°
Half (10.9 Kts/ 59 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested

Vessel Test Group Two – Wind from Forward Hemisphere					
AFRAMAX Tanker Ballasted 250 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (4.5 Kts/ 34 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (7.7/ 53 RPM Kts)	GC/S0.4°	GC/S0.9°	GC/S1.2°	GC/S1.3°	GC/S3.7°
Half (11.7/ 70 RPM Kts)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
AFRAMAX Tanker Loaded 250 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (4.2 Kts/ 34 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (7.6 Kts/ 53 RPM)	GC/S1.3°	GC/S2.1°	GC/S4.2°	GC/S5.4°	GC/S10.2°
Half (10.5 Kts/ 70 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
SUEZMAX Tanker Ballasted 274 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (4.2 Kts/ 28 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (5.6 Kts/ 35 RPM)	GC/S1.6°	GC/S2.2°	GC/S0.9° Drift 6° Speed 4.1	MC/S0.9° Drift 12° Speed 3.3	LC/P9.9° Drift 36° Speed 1.8
Half (9.0 Kts/ 46 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
SUEZMAX Tanker Loaded 274 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (4.0 Kts/ 27 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (5.4 Kts/ 35 RPM)	GC/S1.6°	GC/S2.6°	GC/S3.4°	GC/S4.5°	GC/S6.8°
Half (7.9 Kts/ 46 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Vessel Test Group Three – Wind from Forward Hemisphere					
Chemical Tanker 141 metres - Controllable Pitch Propeller/ Constant RPM					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
DeadSlow (3.8 Kts/105 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (7.0 Kts/107 RPM)	GC/S1.5°	GC/S1.9°	GC/S2.8°	GC/S5.7°	GC/S5.7°
Half (10.2 Kts/ 118 RPM)	GC/S1.0°	GC/S1.6°	GC/S2.1°	GC/S2.6°	GC/S5.7°
Ferry 151 metres – Twin Screw Controllable Pitch Propeller/ Constant RPM					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
DeadSlow (3.8Kts/ 105 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (9.9 Kts/ 110 RPM) *Tested 8.0 or 21% Pitch*	GC/P4.1°	GC/P6.4°	GC/P10.9° Drift 13° Speed 6.6	MC/P19.2° Drift 19° Speed 5.8	LC/P32.4° Drift 30° Speed 4.2
Half (13.4 Kts/ 125 RPM)	GC/P1.4°	GC/P2.3°	GC/P3.5°	GC/P6.5°	GC/P9.0° Drift 9° Speed 11.2
Automobile Carrier (RoRo) 200 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (6.0 Kts/ 26 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (8.1Kts/ 36 RPM)	GC/S0.5°	GC/P0.5°	GC/P7.0° Drift 15° Speed 3.3°	MC/P19.7° Drift 18° Speed 2.6	LC/P35° Wind 38.1 Drift 31° Speed 3.2
Half (10.3 Kts/ 45 RPM)	GC/S0.1°	GC/S0.8°	GC/S0.9°	GC/S1.3° Drift 6° Speed 7.4°	GC/P0.3° Drift 9° Speed 6.5°

Vessel Test Group Three – Wind from Forward Hemisphere					
PANAMAX Cruise Vessel 294 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (4.3 Kts/ 26 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (8.4 Kts/ 49 RPM)	GC/S1.0°	GC/S1.1°	GC/P0.3° Drift 1° Speed 7.1	MC/P3.4° Drift 16° Speed 6.6	LC/P10.3° Drift 24° Speed 5.7
Half (12.5 Kts/ 75 RPM)	GC/S0.6°	GC/S0.8°	GC/S1.0°	GC/S1.0°	GC/S0.5° Drift 9° Speed 10.8
Ultra Large Cruise Vessel 338 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (3.5 Kts/ 23 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (6.5 Kts/ 40 RPM)	GC/S0.6°	GC/P1.6° Drift 14° Speed 6.2	MC/P6.2° Drift 20° Speed 5.9	MC/P15.2° Drift 29° Speed 5.6	LC/P29.7° Drift 42° Speed 5.1
Half (12.3 Kts/ 75 RPM)	GC/S0.8°	GC/S1.0°	GC/S1.8°	GC/S1.1°	GC/P0.7° Drift 11° Speed 11.9
135 CFM LNG Carrier 293 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (5.4 Kts/ 30 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (9.5 Kts/ 50 RPM)	GC/S1.9°	GC/S2.7°	GC/S5.2°	GC/S4.5°	GC/S5.6°
Half (11.8 Kts/ 60 RPM)	GC/S1.5°	GC/S2.1°	GC/S3.0°	GC/S3.8°	GC/S5.1°
QFLEX LNG Carrier 315 metres – Twin Screw					
Engine Telegraph Setting	Wind Speed Knots/ Direction 247° True				
	20	25	30	35	40
Dead Slow (4.8 Kts/ 27 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (6.7 Kts/ 36 RPM)	GC/P1.1°	GC/P1.7°	GC/P2.6°	GC/P4.0°	GC/P7.6°
Half (9.7 Kts/ 50 RPM)	GC/P0.8°	GC/P1.1°	GC/P1.5°	GC/P2.4°	GC/P4.3°

Table 13: Juan de Fuca Strait TSS Results Summary – Wind from Stern Hemisphere

Vessel Test Group One – Wind from Stern Hemisphere					
PANAMAX Container 294 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (6.3 Kts/ 28 RPM)	GC/ S11.4°	LC/S35° Wind 23.7	LC/S35° Wind 23.7	LC/S35° Wind 23.7	LC/S35° Wind 23.7
Slow (8.9 Kts/ 38 RPM)	GC/ S6.8°	GC/ S10.6°	GC/ S16.5°	LC/S35° Wind 33.0	LC/S35° Wind 33.0
Half (13.3 Kts/ 54 RPM)	GC/ S3.8°	GC/ S4.0°	GC/ S6.7°	GC/ S8.7°	GC/ S15.8°
Post-PANAMAX Container 336 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (6.0 Kts/ 20 RPM)	MC/S19.1°	MC/S33°	LC/ S35° Wind 25.3	LC/ S35° Wind 25.3	LC/ S35° Wind 25.3
Slow (7.7Kts/ 27 RPM)	GC/ S7.7°	GC/ S18.5°	MC/S23.5°	LC/ S35° Wind 33.8	LC/ S35° Wind 33.8
Half (10.3 Kts/ 33 RPM)	GC/ S3.9°	GC/ S9.8°	GC/ S16.1°	MC/S23.6°	MC/S31.6°

Vessel Test Group One – Wind from Stern Hemisphere					
Neo-PANAMAX Container 366 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (7.0 Kts/ 31 RPM)	GC/S7.0°	GC/S11.3°	GC/S17.2°	MC/S25.1°	LC/S35 Wind 35.4
Slow (8.5 Kts/ 41 RPM)	GC/S4.1°	GC/S6.4°	GC/S10.9°	GC/S14.5°	GC/S19.2°
Half (12.6 Kts/ 51 RPM)	GC/S1.8°	GC/S4.2°	GC/S6.9°	GC/S11.4°	GC/S14.2°
Ultra Large Container Vessel 399 metres (Twin Screw)					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (5.8 Kts/ 18 RPM)	GC/S5.6°	GC/S9.1°	GC/S14.2°	LC/S35° Wind 34.1	LC/S35° Wind 34.1
Slow (7.4 Kts/ 24 RPM)	GC/S3.2°	GC/S4.8°	GC/S7.8°	GC/S11.7°	GC/S18.3°
Half (11.8 Kts/ 36)	GC/ S0.4°	GC/ S2.3°	GC/ S4.2°	GC/ S5.3°	GC/ S8.0°
Break Bulk Carrier 199 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (6.6 Kts/ 36 RPM)	GC/S8.6°	MC/S19.4°	LC/S35° Wind 26.3	LC/S35° Wind 26.3	LC/S35° Wind 26.3
Slow (8.0 Kts/ 48 RPM)	GC/S3.4°	GC/S8.9°	GC/S10.2°	MC/S23.3°	LC/S35°0
Half (10.7 Kts/ 65 RPM)	GC/S3.3°	GC/S5.4°	GC/S6.0°	GC/S8.4°	MC/S21.7°
General Cargo Vessel 225 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (6.1 Kts/ 26 RPM)	GC/S11.2°	MC/S23.5°	LC/S35° Wind 26.6	LC/S35° Wind 26.6	LC/S35° Wind 26.6
Slow (7.3 Kts/ 33 RPM)	GC/S8.6°	GC/S10.7°	MC/S20.7°	LC/S35° Wind 33.1	LC/S35° Wind 33.1
Half (9.8 Kts/ 45 RPM)	GC/S3.5°	GC/S5.4°	GC/S7.9°	GC/S13.6°	MC/S22.2°
Vessel Test Group Two – Wind from Stern Hemisphere					
PANAMAX Bulk Carrier Ballasted 215 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (7.8 Kts/ 46 RPM)	GC/S7.0°	GC/S13.6°	MC/S20.4°	MC/S24.6°	LC/S35 Wind 39.9
Slow (12.3 Kts/ 76 RPM)	GC/S1.4°	GC/S3.2°	GC/S5.1°	GC/S9.3°	GC/S13.8°
Half (14.6 Kts/ 96 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
PANAMAX Bulk Carrier Loaded 215 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (6.3 Kts/ 47 RPM)	GC/S3.3°	GC/S4.9°	GC/S8.9°	GC/S12.4°	GC/S19.2°
Slow (11.4 Kts/ 75 RPM)	GC/S0.3°	GC/S2.1°	GC/S2.0°	GC/S3.3°	GC/S7.7°
Half (13.3 Kts/ 96 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Cape Size Bulk Carrier Ballasted 289 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (4.8 Kts/ 30 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (6.2 Kts/ 38 RPM)	GC/S3.7°	GC/S6.5°	GC/S10.4°	GC/S13.2°	LC/S35 Wind 39.0
Half (9.9 Kts/ 54 RPM)	GC/S0.8°	GC/S3.3°	GC/S4.7°	GC/S6.4°	GC/S14.6°
Cape Size Bulk Carrier Loaded 274 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (5.5 Kts/ 33 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (7.0 Kts/ 41 RPM)	GC/S2.4°	GC/S5.4°	GC/S7.7°	GC/S8.9°	GC/S13.4°
Half (10.9 Kts/ 59 RPM)	GC/P0.1°	GC/S2.8°	GC/P1.4°	GC/S3.8°	GC/S7.3°

Vessel Test Group Two – Wind from Stern Hemisphere					
AFRAMAX Tanker Ballasted 250 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (4.5 Kts/ 34 RPM)					
Slow (7.7/ 53 RPM Kts)	GC/S2.5°	GC/S7.1°	GC/S9.8°	GC/S13.7°	LC/S35 Wind 39
Half (11.7/ 70 RPM Kts)	GC/S1.8°	GC/S2.2°	GC/S5.4°	GC/S5.5°	GC/S14.7°
AFRAMAX Tanker Loaded 250 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (4.2 Kts/ 34 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (7.6 Kts/ 53 RPM)	GC/S2.4°	GC/S1.9°	GC/S3.4°	GC/S5.2°	GC/S8.9°
Half (10.5 Kts/ 70 RPM)	GC/S3.8°	GC/S1.4°	GC/S1.8°	GC/S3.4°	GC/S4.8°
SUEZMAX Tanker Ballasted 274 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (4.2 Kts/ 28 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (5.6 Kts/ 35 RPM)	GC/S4.3°	GC/S7.1°	GC/S6.2°	GC/S16.7°	GC/S18.9°
Half (9.0 Kts/ 46 RPM)	GC/P0.0°	GC/S3.6°	GC/S5.7°	GC/S8.6°	GC/S12.9°
SUEZMAX Tanker Loaded 274 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (4.0 Kts/ 27 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (5.4 Kts/ 35 RPM)	GC/S3.0°	GC/S5.1°	GC/S12.0°	GC/S7.5°	GC/S10.0°
Half (7.9 Kts/ 46 RPM)	GC/S1.7°	GC/S1.9°	GC/S3.4°	GC/S5.3°	GC/S5.9°
Vessel Test Group Three – Wind from Stern Hemisphere					
Chemical Tanker 141 metres - Controllable Pitch Propeller/ Constant RPM					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
DeadSlow (3.8 Kts/105 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (7.0 Kts/107 RPM)	GC/S1.4°	GC/S3.4°	GC/S5.5°	GC/S4.5°	GC/S11.1°
Half (10.2 Kts/ 118 RPM)	GC/S0.7°	GC/S1.4°	GC/S3.7°	GC/S5.8°	GC/S10.6°
Ferry 151 metres – Twin Screw Controllable Pitch Propeller/ Constant RPM					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
DeadSlow (3.8Kts/ 105 RPM)					
Slow (9.9 Kts/ 110 RPM) *Tested 8.0 or 21% Pitch*	GC/S1.3°	GC/S2.0°	GC/S2.8°	GC/S6.3°	GC/S10.3°
Half (13.4 Kts/ 125 RPM)	GC/S0.7°	GC/P0.1°	GC/S2.7°	GC/S3.7°	GC/S3.1°
Automobile Carrier (RoRo) 200 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (6.0 Kts/ 26 RPM)	GC/S7.1°	GC/S10.7°	GC/S16.9°	MC/S25.2°	LC/ S35° Wind 38.1
Slow (8.1Kts/ 36 RPM)	GC/S1.5°	GC/S2.9°	GC/S5.5°	GC/S8.4°	GC/S10.7°
Half (10.3 Kts/ 45 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
PANAMAX Cruise Vessel 294 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (4.3 Kts/ 26 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (8.4 Kts/ 49 RPM)	GC/S3.5°	GC/S6.6°	GC/S10.9°	GC/S16.5° Drift 9° Speed 7.3	MC/S24.3° Drift 15° Speed 6.6
Half (12.5 Kts/ 75 RPM)	GC/S1.2°	GC/S2.3°	GC/S4.0°	GC/S6.2°	GC/S9.3°

Vessel Test Group Three – Wind from Stern Hemisphere					
Ultra Large Cruise Vessel 338 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (3.5 Kts/ 23 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (6.5 Kts/ 40 RPM)	GC/S7.1°	GC/S11.0°	MC/S15.4° Drift 15° Speed 5.4	LC/S21.3° Drift 25° Speed 4.9	LC/S35° Drift 54° Speed 4.7
Half (12.3 Kts/ 75 RPM)	GC/S1.5°	GC/S3.9°	GC/S4.3°	GC/S6.7°	GC/S11.6°
135 CFM LNG Carrier 293 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (5.4 Kts/ 30 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (9.5 Kts/ 50 RPM)	GC/S4.2°	GC/S5.3°	GC/S8.9°	GC/S16.5°	MC/S22.3°
Half (11.8 Kts/ 60 RPM)	GC/S3.3°	GC/S4.9°	GC/S5.5°	GC/S9.1°	GC/S17.3°
QFLEX LNG Carrier 315 metres – Twin Screw					
Engine Telegraph Setting	Wind Speed Knots/ Direction 143° True				
	20	25	30	35	40
Dead Slow (4.8 Kts/ 27 RPM)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Slow (6.7 Kts/ 36 RPM)	GC/S5.8°	GC/S10.5°	MC/S21.9°	LC/ S35° Wind 31.4	LC/ S35° Wind 31.4
Half (9.7 Kts/ 50 RPM)	GC/S3.0°	GC/S4.7°	GC/S7.1°	GC/S11.8°	MC/S23.0°

4.2 Anticosti TSS Desktop Results and Findings

The most significant general observations, in order of importance are as follows:

i. In all of the Anticosti test runs, the differential between water speed and ground speed was minimal. Of the four test areas, this is the only one where ground speed, calculated by the GPS system and transmitted on the vessels' AIS, is suitable for use as a speed monitoring tool. It should be noted that the actual water speed realised (versus default RPM set water speed) varied considerably when the wind was from astern, and even more so when it was from ahead. Hence ship's actual water and ground speed in this area can be accelerated by the wind.

ii. Consistent with the observations in the Juan de Fuca TSS tests, alterations of course with the wind on the quarter causes a deterioration in vessel steering and course holding control for certain high sided vessels when the wind velocity reaches 30 knots, and if the vessels' speeds are below 10 knots.

iii. As was observed during the Juan de Fuca TSS tests, winds from the forward hemisphere, specifically within 20° to 40° on the bow produce a pronounced level of both drift and speed loss. At Slow Ahead Telegraph settings with test vessel initial water speeds ranging from 6.2 to 8.5 knots, all of the vessels started to develop appreciable speed loss when the winds reached speeds of 30 knots or greater. At 40 knots, half of the vessels had drift angles greater than 10° and the ballasted Cape Size Bulk Carrier lost more than half of its forward speed. In all cases however, ships were able to maintain their intended course.

iv. If the main concern in this area is reduction in whale strikes, versus noise generation, the situation described in Item iii) above can be resolved by setting the engine telegraph to the next highest speed setting (i.e. from Slow Ahead to Half

Ahead) when water speed loss starts to develop. If necessary, the ship's telegraph can be alternated on occasion between Slow and Half ahead settings to maintain a water speed in the range of 8 to 10 knots.

4.2.1 Summary Assessment of Course Holding/Alteration Tests

The desktop tests in the Anticosti TSS served as a follow-on to findings of the Juan de Fuca analysis as they applied to the geographic and environmental specifics of this area. The results of these analysis are found in Tables 14 and 15 below. In the case of tests listed in Table 14 (Course holding with wind from the forward hemisphere), the primary factor examined was the amount of speed loss and any adverse effect on positional control. The tests listed in Table 15 (Course holding with wind from the stern hemisphere), examined wind speed thresholds where wind induced rotation required application of large rudder angles, and/or resulted in a reduction in steering control.

Note that for each test vessel, any threshold where steering control or positional control became marginal due to wind speed effects is highlighted in yellow. If steering control was lost, this is highlighted in red colour.

Note in order to fit information into the table in a compact manner, short forms have been used as follows:

- S and P denote either Starboard or Port rudder directions.

Table 14: Anticosti TSS Results Summary – Course Holding Wind from Forward Hemisphere

Wind from Forward Hemisphere: Constant RPM Heading Adjusted to Achieve Course					
HandyMax					
Engine Telegraph Setting	Wind Speed Knots/ Direction 270° True				
	20	25	30	35	40
Slow (6.3 Kts/ 53 RPM)	Drift Angle 1° Speed 6.0	Drift Angle 2° Speed 5.7	Drift Angle 3° Speed 5.4	Drift Angle 5° Speed 4.9	Drift Angle 8° Speed 4.1
PANAMAX Container 294 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 270° True				
	20	25	30	35	40
Slow (8.5 Kts/ 38 RPM)	Drift Angle 0° Speed 8.3	Drift Angle 1° Speed 8.0	Drift Angle 1° Speed 8.0	Drift Angle 2° Speed 7.2	Drift Angle 4° Speed 6.6
PANAMAX Bulk Carrier Ballasted 215 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 270° True				
	20	25	30	35	40
Dead Slow (7.8 Kts/ 46 RPM)	Drift Angle 1° Speed 7.3	Drift Angle 2° Speed 7.0	Drift Angle 3° Speed 6.7	Drift Angle 5° Speed 6.3	Drift Angle 8° Speed 5.2
Cape Size Bulk Carrier Ballasted 289 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 270° True				
	20	25	30	35	40
Slow (6.2 Kts/ 38 RPM)	Drift Angle 1° Speed 6.0	Drift Angle 2° Speed 5.5	Drift Angle 4° Speed 5.0	Drift Angle 6° Speed 4.3	Drift Angle 11° Speed 2.8
AFRAMAX Tanker Ballasted 250 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 270° True				
	20	25	30	35	40
Slow (7.7/ 53 RPM Kts)	Drift Angle 1° Speed 7.7	Drift Angle 2° Speed 7.3	Drift Angle 2° Speed 6.6	Drift Angle 3° Speed 5.9	Drift Angle 7° Speed 4.4

Wind from Forward Hemisphere: Constant RPM Heading Adjusted to Achieve Course					
Ferry 151 metres – Twin Screw Controllable Pitch Propeller/ Constant RPM					
Engine Telegraph Setting	Wind Speed Knots/ Direction 270° True				
	20	25	30	35	40
Tested 8.0 or 21% Pitch	Drift Angle 3° Speed 7.8	Drift Angle 6° Speed 7.5	Drift Angle 6° Speed 7.2	Drift Angle 9° Speed 6.7	Drift Angle 11° Speed 6.2
Ultra Large Cruise Vessel 338 metres					
Engine Telegraph Setting	Wind Speed Knots/ Direction 270° True				
	20	25	30	35	40
Speed set for 8 knots: Half (42 RPM)	Drift Angle 4° Speed 7.8	Drift Angle 6° Speed 7.5	Drift Angle 6° Speed 7.2	Drift Angle 9° Speed 6.8	Drift Angle 11° Speed 6.2
QFLEX LNG Carrier 315 metres – Twin Screw					
Engine Telegraph Setting	Wind Speed Knots/ Direction 270° True				
	20	25	30	35	40
Slow (6.7 Kts/ 36 RPM)	Drift Angle 4° Speed 6.5	Drift Angle 5° Speed 6.2	Drift Angle 7° Speed 5.7	Drift Angle 9° Speed 5.1	Drift Angle 14° Speed 3.9

Table 15: Anticosti Course Alteration 095° to 117 ° Wind from Stern Hemisphere

Test 3: Telegraph set to position with resultant water speed closest to 8 knots				
Test No		Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
ANT T3		262°@30 knots	Steady Heading 095	
Vessel	Ability to Hold Course 117°	Water Speed Range	RPM/ Pitch	Rudder
1 PanC	Good: Drift angle 1° carry 13° port rudder.	8.4 to 9.4	38	S4.8 to P29.0
2 Pan B B	Good: Drift angle 1° carry 13° port rudder.	7.2 to 8.0	45	S6.0 to P35
3 Handy B	Good: Drift angle 1° carry 5° port rudder.	6.2 to 7.2	53	S11.0 to P7.6
4 Cape B	Good: Drift angle 1° carry 8° port rudder.	7.0 to 7.8	38	S7.5 to P21.3
5 Ferry	Good: Drift angle 5° carry 6° port rudder.	8.0 to 8.5	109	S7.6 to P8.6
6 Afra B	Good: Drift angle 1° carry 12° port rudder.	7.7 to 9.0	53	S6.0 to P35
7 Ultra Cr	Moderate: Drift angle 5° carry 25° port rudder.	7.4 to 10.2	47 to 68	S3.6 to P35
8 QFlex	Moderate: Drift angle 5° carry 32° port rudder.	6.5 to 8.6	33 to 50	S7.6 to P35
Notes: Ultra Large Cruise required a kick ahead to steady on 117° course. QFLEX required a kick ahead to steady, and two subsequent kicks to maintain heading/course.				

Test 4: Telegraph set for RPMs to achieve 10 knots water speed				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
ANT T3		262°@30 knots	Steady Heading 095	
Vessel	Ability to Hold Course 117°	Transit Speed Range	RPM/ Pitch	Rudder
1 PanC	Good: Drift angle 0° carry 10° port rudder.	10 to 10.3	42	S3.2 to P16.2
2 Pan B B	Good: Drift angle 1° carry 7° port rudder.	9.7 to 10.2	57	S8.1 to P13.6
3 Handy B	Good: Drift angle 0° carry 2° port rudder.	9.9 to 10.1	76	S5 to P16.6
Vessel	Ability to Hold Course 117°	Transit Speed Range	RPM/ Pitch	Rudder
4 Cape B	Good: Drift angle 0° carry 8° port rudder.	10 to 10.3	54	S12.9 to P9.1
5 Ferry	Good: Drift angle 4° carry 4° port rudder.	9.5 to 10.3	109	S7.2 to P12.5
6 Afra B	Good: Drift angle 1° carry 7° port rudder.	9.6 to 10.1	60	S14.4 to P15.2
7 Ultra Cr	Good: Drift angle 3° carry 13° port rudder.	9.8 to 10.2	60	S6.0 to P20.8
8 QFlex	Good: Drift angle 2° carry 10° port rudder.	9.7 to 10.0	48	S5.0 to P15.0
Notes: All vessels experienced an enhanced degree of steering control at speed 10. Ultra Large Cruise and QFLEX did not need kicks to steady, and QFLEX carried just 10 ° of rudder to maintain heading versus 25 °.				

4.3 St-Lawrence/ Saguenay Desktop Results and Findings

The most significant general observations, in order of importance are as follows:

i. Differences in the level of steering control (ability to maintain heading) at low transit speeds for all vessel types whether running with the current (current from astern) or stemming the current (current from ahead) were not dramatically different. In areas of stronger current conditions (greater than 3 knots), particularly for deep draught vessels, and vessels with an overall length (LOA) greater than 250 metres, there was a notable reduction in course holding and positional control (ability to maintain a specific ground track) at lower transit speeds when stemming the current. When stemming the current, particularly when the velocity of the current and the velocity of the vessels' ground speed became similar (i.e. river outflow current of 4.0 knots and vessel's upriver ground speed of 4.0 knots), if the angle of the vessel's heading relative to that of the current flow became more than 10 °, the ship would start to develop pronounced lateral drift. In areas where the current changed direction quickly (over the space of a few hundred metres), it was often difficult to control lateral drift and current induced sheer when proceeding against the current at low speed.
ii. Given that there is a predominate outflow current in the St-Lawrence and the Saguenay, and that the velocity of the combined flood tidal stream and current is weaker than the combined ebb tidal stream and current, it was observed that it is generally more difficult to maintain overall positional and steering control when proceeding upriver than when proceeding downriver. In fact, it was observed that in certain areas, when proceeding upriver against maximum ebb tide, the vessel's

ground speed would only be about 50% of the velocity of the outflow current (i.e. ground speed of 2.5 knots, current speed of 5.0 knots).

iii. Consistent with observations during the TSS transit testing, wind speed also becomes an important factor when the wind velocity exceeds 25 knots, particularly for container ships and passenger vessels. Strong winds from a relative direction on the vessel's quarter created the worse conditions for steering and positional control, particularly when proceeding against the current flow. In this situation, the ships were often carrying 15° to 20° of rudder to counter wind induced rotation and to maintain heading, this left very little reserve rudder angle (steering force) to counter current effects that caused the vessel to either rotate or drift.

iv. When passing through areas where strong tidal sheers occurred such as where the Saguenay outflow meets the St-Lawrence outflow current, particularly when sailing downriver with a following tide, ships experience almost instantaneous, uncontrollable water speed acceleration. This phenomenon occurs because the ship has momentum (kinetic energy) which is generated by the following current, when the following current suddenly is deflected 60° to 90° by the Saguenay outflow, the ship still carries its momentum along its original path of travel and accelerates instantly in relation to the new body of water that it is travelling in. There is nothing that the pilot can do to prevent these accelerations and note in the tables that follow that the range of water speed values frequently vary by more than 3.0 knots. In terms of trying to accomplish a specific transit speed in this area, the only practical way to accomplish this is to set propeller RPM for a value which in neutral environmental conditions would give the desired speed (for example RPM set for 8 knots, 9 knots, etc. based on the vessel's speed table) with the goal of sailing at an average speed as per the RPM setting but with an actual water speed (and ground speed) that will continually oscillate in value.

4.3.1 Summary Assessment of St-Lawrence Course Holding Tests

A summary of the downriver and upriver course holding test results for both when a ship is sailing into the current and sailing with the current are provided in Table 16 below. Note that for each test vessel, any threshold where steering, course holding, or positional control became marginal due to current or wind speed effects is highlighted in yellow. If steering/positional control was lost, this is highlighted in red colour. Vessels names listed in column 1 use short form identifiers, in sequence they are: PANAMAX Container, General Cargo, Handymax Ballasted, Handymax Loaded, Chemical Tanker, Ferry, PANAMAX Cruise-ship, Ultra Large Cruise-ship, PANAMAX Bulker Ballasted, PANAMAX Bulker Loaded, AFRAMAX Tanker Ballasted, AFRAMAX Tanker Loaded, Cape Size Bulker Ballasted, and Cape Size Bulker Loaded. Note that Group 2 (full form vessels) are shaded in blue to facilitate identification of the two vessel types. Also note that the table illustrates the variation in heading that was needed to achieve the desired course(s), the variation in water speed, and the range of the working rudder angle. It should also be emphasised that in areas of tidal eddies, the full range of the rudder is often used to counter tidal rotation, and it was assessed that steering control was reduced only if near full rudder was used continuously for a period of several minutes, or if a significant increase in propeller RPM was required to arrest a sudden heading sheer (i.e. full rudder alone would not stop the heading from rotating).

Table 16: St-Lawrence Main Navigation Channel Test Assessment Matrix

St-Lawrence Test Assessment Matrix				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
1	High River/Spring/Max Ebb	202°@15 knots	Steady 020° @ 8 knots	
Vessel	Ability to Hold Ground Course/ Heading Variation	Water Speed Range	RPM/ Pitch	Rudder
1 PC	Good: 15° to 25°	6.4 to 8.6	32 to 34	S18.4 to p35.0
2 GC	Good: 15° to 28°	6.7 to 9.1	33 to 34	S19.0 to p35.0
3 HB	Good: 14° to 23°	7.1 to 9.2	62 to 62	S15.0 to S8.7
4 HL	Good: 14° to 24°	6.9 to 9.3	62 to 62	S14.2 to P12.9
5 CT	Good: 17° to 24°	6.9 to 8.9	31%	S21.7 to P23.4
6 F	Good: 16° to 24°	6.8 to 9.0	21%	S9.5 to P8.6
7 PCr	Good: 15° to 23°	8.1 to 8.9	48 to 48	S15.6 to P9.1
8 UCr	Good: 14° to 23°	7.4 to 9.1	49 to 51	S14.0 to P14.0
9 PB	Good: 9° to 23°	6.8 to 9.1	47 to 47	S25.6 to P24.9
10 PL	Good: 13° to 24°	6.5 to 8.9	44 to 54	S25.6 to P23.2
11 AB	Good: 11° to 24°	6.3 to 9.0	46 to 47	S20.4 to P21.9
12 AL	Good: 14° to 29°	5.8 to 8.7	50 to 57	S25.9 to P25.6
13 CB	Good: 11° to 24°	6.8 to 9.1	42 to 48	S14.4 to P13.3
14 CL	Good: 15° to 26°	6.4 to 9.1	42 to 54	S18.6 to P14.2
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
2	High River/Spring/Max Ebb	202°@15 knots	Steady 200° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PC	Good: 191° to 218°	7.0 to 8.5	34 to 35	S31.8 to p35.0
2 GC	Good: 186° to 212°	7.2 to 8.6	34 to 37	S35.0 to p35.0
3 HB	Good: 193° to 210°	7.2 to 8.6	61 to 64	S14.6 to P30.7
4 HL	Good: 191° to 213°	7.2 to 8.6	60 to 63	S30.7 to P32.2
5 CT	Good: 194° to 208°	6.9 to 8.3	32%	S16.8 to P23.7
6 F	Good: 197° to 210°	7.4 to 8.1	21%	S11.6 to P15.2
7 PCr	Good: 186° to 211°	7.1 to 8.4	49 to 49	S35.0 to P32.2
8 UCr	Good: 194° to 210°	7.2 to 8.4	48 to 50	S21.1 to P25.6
9 PB	Good: 191° to 207°	7.7 to 8.51	44 to 54	S25.6 to P18.4
10 PL	Good: 190° to 218°	7.3 to 8.2	44 to 60	S31.2 to P27.3
11 AB	Good: 193° to 208°	7.7 to 8.4	47 to 54	S16.7 to P14.4
12 AL	Marginal: 182° to 215°	7.1 to 8.3	50 to 57	S28.0 to P29.7
13 CB	Good: 190° to 209°	7.6 to 8.6	45 to 49	S19.0 to P18.9
14 CL	Marginal: 181° to 219°	5.8 to 8.5	49 to 53	S35.0 to P35.0

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
3	Mean River/Spring/Max Flood	202°@15 knots	Steady 020° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PC	Good: 10° to 31°	6.7 to 8.2	31 to 33	S19.7 to p20.0
2 GC	Good: 9° to 31°	6.3 to 8.6	30 to 34	S21.5 to p35.0
3 HB	Good: 12° to 34°	6.7 to 8.3	57 to 62	S14.6 to S34.8
4 HL	Good: 12° to 34°	6.6 to 8.3	57 to 61	S15.2 to P32.6
5 CT	Good: 11° to 31°	6.7 to 8.4	31%	S21.7 to P23.4
6 F	Good: 12° to 31°	7.0 to 8.3	20%	S9.9 to P14.2
7 PCr	Good: 10° to 33°	6.9 to 8.5	40 to 48	S15.2 to P32.6
8 UCr	Good: 13° to 31°	6.8 to 8.3	46 to 48	S14.2 to P30.8
9 PB	Good: 13° to 26°	6.8 to 8.6	45 to 49	S13.6 to P27.1
10 PL	Good: 9° to 33°	6.5 to 8.1	45 to 63	S33.4 to P33.6
11 AB	Good: 12° to 27°	6.3 to 8.4	42 to 53	S18.2 to P27.2
12 AL	Marginal: 10° to 31°	5.8 to 8.5	45 to 54	S18.9 to P35.0
13 CB	Good: 13° to 28°	6.3 to 8.6	45 to 47	S14.2 to P28.5
14 CL	Marginal: 7° to 34°	5.9 to 8.2	46 to 54	S29.9 to P35.0
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
4	Mean River/Spring/Max Flood	202°@15 knots	Steady 200° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PC	Good: 195° to 205°	6.3 to 8.6	34 to 36	S20.0 to p20.0
2 GC	Good: 196° to 204°	6.1 to 9.0	35 to 38	S35.0 to p29.1
3 HB	Good: 196° to 206°	6.1 to 8.5	60 to 66	S29.2 to S26.1
4 HL	Good: 196° to 205°	6.3 to 8.8	60 to 65	S28.8 to P27.7
5 CT	Good: 197° to 205°	6.6 to 8.6	32%	S21.7 to P23.4
6 F	Good: 196° to 206°	7.0 to 8.3	21%	S13.0 to P11.1
7 PCr	Good: 198° to 204°	6.3 to 8.6	46 to 50	S24.6 to P23.8
8 UCr	Good: 196° to 206°	6.8 to 8.3	48 to 51	S21.8 to P25.5
9	Good: 196° to 206°	6.0 to 8.4	46 to 50	S25.4 to P25.6
10	Good: 197° to 206°	6.2 to 8.3	51 to 64	S23.5 to P18.9
11	Good: 196° to 208°	6.3 to 8.7	53 to 55	S12.1 to P25.1
12	Good: 197° to 206°	5.7 to 8.0	53 to 56	S27.3 to P24.2
13	Good: 196° to 208°	6.6 to 8.6	49 to 50	S12.2 to P22.4
14	Good: 197° to 206°	5.7 to 8.3	49 to 51	S25.3 to P21.1

**Note: Results from these tests with mean average winds of 202 ° at a velocity of 15 knots showed that all vessels maintained an acceptable level of steering and positional control at transit (water speeds) between 8 and 10 knots, hence proceeded to tests 9 and 10 with 30 knot winds from various directions.*

Test No	Tidal Condition	Wind Direct/ Speed	Vessel Initial State: Course and Water Speed	
9	High River/Spring/Max Ebb	245°@30 knots	Steady 020° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PC	Good: 359° to 29°	7.8 to 11.2	33 to 54	S35.0 to p20.8
2 GC	Good: 9° to 33°	7.1 to 9.4	35 to 35	S35.0 to p24.4
3 HB	Good: 18° to 26°	7.3 to 9.5	64 to 65	22.9 to S20.5
4 HL	Good: 17° to 26°	7.3 to 9.6	65 to 66	S25.0 to P29.2
5 CT	Good: 16° to 23°	7.2 to 9.3	31%	S18.3 to P11.1
6 F	Good: 14° to 27°	7.5 to 9.1	20%	S13.3 to P12.3
7 PCr	Good: 16° to 24°	6.9 to 9.1	48 to 52	S35.0 to P35.0
8 UCr	Good: 12° to 34°	7.9 to 9.9	46 to 48	S35.0 to P18.0
Test9_1	High River/Spring/Max Ebb	245°@30 knots	Steady 020° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
9 PB	Good: 14° to 23°	7.0 to 9.3	45 to 47	S2.3 to P22.0
10 PL	Good: 16° to 24°	7.0 to 9.3	44 to 54	S2.1 to P19.9
11 AB	Good: 16° to 24°	6.4 to 8.7	38 to 47	S3.4 to P19.8
12 AL	Marginal: 16° to 29°	6.2 to 8.8	51 to 57	S19.9 to P35.0
13 CB	Good: 15° to 24°	7.0 to 9.2	42 to 48	S16.1 to P13.9
14 CL	Good: 15° to 23°	6.2 to 8.3	45 to 53	S14.3 to P17.4
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
10	Mean River/Spring/Max Ebb	315°@30 knots	Steady 200° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PC	Marginal: 186° to 228°	7.8 to 11.1	34 to 35	S29.8 to p35.0
2 GC	Marginal: 195° to 231°	7.8 to 9.8	34 to 37	S22.1 to p35.0
3 HB	Good: 193° to 209°	7.6 to 8.5	61 to 64	S23.4 to P15.8
4 HL	Good: 196° to 206°	7.8 to 8.7	60 to 63	S15.2 to P30.7
5 CT	Good: 195° to 207°	7.4 to 8.3	32%	S10.0 to P16.1
6 F	Good: 188° to 212°	7.5 to 9.3	21%	S14.5 to P15.4
7 PCr	Good: 191° to 214°	6.6 to 8.3	49 to 49	S18.5 to P35.0
8 UCr	LC: 183° to 238°	7.6 to 12.0	48 to 50	S4.0 to P35.0
Test10a	Mean River/Spring/Max Flood	315°@30 knots	Steady 200° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
9 PB	Good: 195° to 207°	7.5 to 8.7	48 to 48	S2.0 to P35.0
10 PL	Good: 196° to 208°	7.6 to 8.6	55 to 55	S19.7 to P32.2
11 AB	Marginal: 195° to 204°	6.9 to 8.3	56 to 60	S0.8 to P35.0
12 AL	Good: 195° to 206°	6.7 to 7.9	53 to 60	S14.5 to P35.0
13 CB	Good: 197° to 207°	6.4 to 8.3	47 to 47	S5.5 to P33.1
14 CL	Good: 196° to 208°	6.0 to 8.6	55 to 55	S27.2 to P20.7

**Note: Results from these tests with the wind from 315 °at a velocity of 30 knots showed that* three of the vessels in Group 1 (1 to 8) experienced steering and positional control issues with transit speeds (water) in the 7 to 9 knot range. Repeated tests for this group with transit speed increased to 10 knots (9 to 11 range) and then with wind spe ed reduced to 25 knots.

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
10_2	Mean River/Spring/Max Ebb	315°@30 knots	Steady 200° @ 10 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PC	Marginal: 189° to 215°	9.8 to 11.5	42 to 54	S29.8 to p35.0
2 GC	Good: 185° to 219°	9.3 to 10.6	45 to 45	S31.7 to p35.0
3 HB	Good: 185° to 222°	9.8 to 10.5	75 to 75	S34.7 to P20.6
4 HL	Good: 196° to 206°	9.8 to 10.6	76 to 76	S35.0 to P35.0
5 CT	Good: 187° to 225°	9.1 to 11.3	53%	S22.7 to P35.0
6 F	Good: 189° to 209°	9.4 to 10.2	24.6%	S11.8 to P10.6
7 PCr	Good: 190° to 214°	8.4 to 10	59 to 59	S18.6 to P29.9
8 UCr	Marginal: 185° to 224°	8.7 to 12.1	61 to 80	S10.8 to P45.0

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
10_3	Mean River/Spring/Max Ebb	315°@25 knots	Steady 200° @ 10 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PC	Good: 191° to 207°	9.4 to 10.7	41 to 41	S14.7 to p35.0
2 GC	Good: 190° to 211°	9.4 to 10.9	45 to 47	S21.8 to p34.5
3 HB	Good: 191° to 209°	9.3 to 10.8	75 to 76	S30.4 to P23.3
4 HL	Good: 192° to 210°	9.2 to 11.0	76 to 78	S32.7 to P26.2
5 CT	Good: 194° to 212°	8.7 to 10.5	43.4%	S19.8 to P33.8
6 F	Good: 192° to 208°	9.5 to 10.3	24.7%	S11.2 to P10.8
7 PCr	Good: 196° to 207°	9.0 to 10.0	60 to 60	S26.8 to P24.4
8 UCr	Good: 193° to 210°	8.9 to 10.6	59 to 80	S22.0 to P35.0

For entry and departures from the Saguenay River the testing encompassed evaluating course and position holding on three different track legs. It should be noted that unlike the tests in Table 16, when in the Saguenay approach channel, the tidal currents often run near perpendicular to the vessels' tracks, hence the size of the drift angle was an important parameter in evaluating the vessel's level of positional control.

Table 17: Saguenay Approach Channel Test Assessment Matrix

Inbound Ballasted Commercial Vessels				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
1	High River/Spring/Max Ebb	295°@15 knots	Steady 222° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PB	Good: 215°/256°/ and 273° Maximum Drift Angle 12°	6.6 to 8.8	45 to 82	S30.8 to p30.5
3 HB	Good: 215°/256°/ and 273° Maximum Drift Angle 9°	6.0 to 8.2	39 to 62	S25.1 to P7.9
5 PCr	Good: 215°/256°/ and 273° Maximum Drift Angle 4°	7.1 to 8.3	44 to 50	S20.4 to P13.8
6 UCr	Good: 215°/256°/ and 273° Maximum Drift Angle 6°	7.1 to 8.3	45 to 50	S10.0 to P14.6
7 LNG B	Good: 215°/256°/ and 273° Maximum Drift Angle 6°	7.1 to 8.6	34 to 42	S20.0 to P16.0
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
2	Mean River/Spring/Max Flood	295°@15 knots	Steady 222° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PB	Good: 215°/256°/ and 273° Maximum Drift Angle 11°	5.9 to 7.9	45 to 73	S18.0 to p22.8
3 HB	Good: 215°/256°/ and 273° Maximum Drift Angle 10°	6.4 to 7.8	64 to 64	S20.1 to P9.9
5 PCr	Good: 215°/256°/ and 273° Maximum Drift Angle 10°	6.3 to 7.7	49 to 49	S15.8 to P12.9

Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
6 UCr	Good: 215°/256°/ and 273° Maximum Drift Angle 11°	6.6 to 7.8	50 to 50	S8.0 to P13.1
7 LNG B	Good: 215°/256°/ and 273° Maximum Drift Angle 9°	6.1 to 7.6	40 to 40	S10.8 to P20.1

*Note: Since no steering or control issues were experienced with maximum tidal conditions in Tests 1 and 2, moved to planned Tests 5 and 6 with 25 knot winds on the quarter.

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
5	High River/Spring/Max Ebb	045°@25 knots	Steady 222° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PB	Good: 215° and 256°. Marginal 273° Maximum Drift Angle 10°	6.4 to 8.4	45 to 57	S35.0 to p30.5
3 HB	Good: 215°/256°/ and 273° Maximum Drift Angle 10°	7.5 to 9.0	61 to 63	S35.0 to P12.1
5 PCr	Good: 215°/256°/ and 273° Maximum Drift Angle 14°	6.8 to 8.3	48 to 48	S25.3 to P19.0
6 UCr	Good: 215° and 256°. Marginal 273° Maximum Drift Angle 9°	7.6 to 11.3	48 to 80	S21.1 to P35.0
7 LNG B	Good: 215°/256°/ and 273° Maximum Drift Angle 9°	6.4 to 8.3	39 to 39	S33.5 to P31.1

**Note: Since two vessels experienced marginal control on the 273° track, repeated test 5 to determine if results would be consistent.*

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
5_1	Mean River/Spring/Max Ebb	045°@25 knots	Steady 222° @ 10 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PB	Good: 215°/256° and 273° Maximum Drift Angle 10°	6.5 to 8.6	50 to 53	S35.0 to p35.0
3 HB	Good: 215°/256°/ and 273° Maximum Drift Angle 7°	7.2 to 11.2	66 to 69	S35.0 to P35.0
5 PCr	Good: 215°/256°/ and 273° Maximum Drift Angle 11°	6.4 to 7.8	45 to 55	S20.2 to P14.9
6 UCr	Good: 215°/ 256°/ and 273° Maximum Drift Angle 11°	7.5 to 11.5	52 to 80	S30.3 to P35.0 for long periods
7 LNG B	Good: 215°/256°/ and 273° Maximum Drift Angle 8°	6.4 to 8.2	42 to 42	S35.0 to p35.0
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
6	Mean River/Spring/Max Flood	045°@25 knots	Steady 222° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PB	Good: 215°/256°/ and 273° Maximum Drift Angle 16°	5.9 to 7.9	45 to 73	S18.0 to p22.8
3 HB	Good: 215°/256°/ and 273° Maximum Drift Angle 10°	6.4 to 7.8	64 to 64	S20.1 to P9.9
5 PCr	Good: 215°/256°/ and 273° Maximum Drift Angle 13°	6.3 to 7.7	49 to 49	S15.8 to P12.9
6 UCr	Good: 215°/256°/ Good. 273° Marginal Maximum Drift Angle 13°	6.6 to 7.8	50 to 50	S8.0 to P13.1
7 LNG B	Good: 215°/256°/ and 273° Maximum Drift Angle 12°	6.1 to 7.6	40 to 40	S10.8 to P20.1

Outbound Loaded Commercial Vessels				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
7	High River/Spring/Max Ebb	295°@15 knots	Steady 105° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PL	Good: Maximum Drift Angle 7°	5.3 to 7.8	50 to 50	S35 to P35.0
3 HL	Good: Maximum Drift Angle 8°	6.0 to 8.4	59 to 59	S35 to P35.0
5 PCr	Good: Maximum Drift Angle 9°	6.3 to 7.9	46 to 46	S35 to P35.0
6 UCr	Good: Maximum Drift Angle 8°	6.3 to 8.3	46 to 46	S35 to P35.0
7 LNG L	Good: Maximum Drift Angle 6°	5.8 to 7.9	40 to 40	S35 to P35.0
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
8	Mean River/Spring/Max Flood	295°@15 knots	Steady 105° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PL	Good: Maximum Drift Angle 7°	5.3 to 7.8	50 to 50	S35 to P35.0
3 HL	Good: Maximum Drift Angle 9°	6.0 to 8.4	59 to 59	S35 to P35.0
5 PCr	Good: Maximum Drift Angle 8°	6.3 to 7.9	46 to 46	S35 to P35.0
6 UCr	Good: Maximum Drift Angle 6°	6.3 to 8.3	46 to 46	S35 to P35.0
7 LNG L	Good: Maximum Drift Angle 6°	5.8 to 7.9	40 to 40	S35 to P35.0

*Note: Since no steering or position control issues were experienced with maximum ebb and flood tide, proceeded to planned tests 11 and 12 with winds at 30 knots.

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
11	High River/Spring/Max Ebb	315°@30 knots	Steady 105° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PL	Good: Maximum Drift Angle 10°	5.9 to 8.9	46 to 63	S35 to P26.7
3 HL	Good: Maximum Drift Angle 9°	6.1 to 8.7	58 to 61	S35 to P31.8
5 PCr	Good: Maximum Drift Angle 13°	6.7 to 8.9	45 to 55	S35 to P24.6
6 UCr	Marginal Maximum Drift Angle 11°	7.3 to 10.2	44 to 68	S35 to P26.2 Full S for extended periods
7 LNG L	Marginal Maximum Drift Angle 11°	5.4 to 9.2	38 to 60	S35 to P23.1 Full S for extended periods
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
12	Mean River/Spring/Max Flood	315°@30 knots	Steady 105° @ 8 knots	
Vessel	Ability to Hold Course	Transit Speed Range	RPM/ Pitch	Rudder
1 PL	Good: Maximum Drift Angle 9°	6.4 to 9.7	48 to 49	S35 to P35
3 HL	Good: Maximum Drift Angle 9°	6.6 to 9.8	57 to 57	S34.4 to P35
5 PCr	Good: Maximum Drift Angle 12°	6.4 to 8.9	44 to 50	S29.9 to P35
6 UCr	Marginal Maximum Drift Angle 10°	5.7 to 8.4	45 to 80	S35 to P27.9
7 LNG L	Loss of Control Maximum Drift Angle 10°	5.8 to 9.8	38 to 38	S35 to P35

4.4 Haro Strait/ Boundary Pass Desktop Results and Findings

The most significant general observations, in order of importance are as follows:

i. Differences in the level of steering control (ability to maintain heading) at low transit speeds for all vessel types whether running with the tidal stream (tidal stream from astern) or stemming the tidal stream (tidal stream from ahead) were not dramatically different while holding course on a longer, relatively straight track. In areas of stronger tidal conditions (greater than 3 knots), particularly for deep draught vessels, and vessels with an overall length (LOA) greater than 250 metres, there was a notable reduction in course holding and positional control (ability to maintain a specific ground track) at lower transit speeds when stemming the tidal flow. When stemming the tidal stream, particularly when the velocity of the tidal stream, and the velocity of the vessels' ground speed became similar (i.e. tidal stream of 4.0 knots and vessel's ground speed of 4.0 knots) if the angle of the vessel's heading relative to that of the tidal flow became more than 10°, the ship would start to develop pronounced lateral drift. In areas where the tidal stream changed direction quickly (over the space of a few hundred metres), it was often difficult to control lateral drift and tidal induced sheer when proceeding against the tidal stream at low speed. This was consistent with observation made during the St-Lawrence analysis.

ii. When making large turns such as northbound around Turn Point, heading control when stemming the tide can initially be difficult, especially if the angle of the tidal stream on the starboard bow becomes large. However, once control of the heading is regained, the ship can be repositioned in the channel without extreme difficulty or too much track displacement. This is because the vessel's ground speed is low, so it does not cover a lot of distance during the period of the sheer. In comparison, when sailing with a strong following tide, the ship's ground speed is quite high, and when making turns of greater than 60°, much of the ships' momentum is transferred into lateral speed at the stern of the vessel. This makes arresting the turn, especially with a wind from the stern quadrant, quite difficult. If these turns are not precisely executed, there is a tendency for the ship to track wide in the turn and to develop large course overshoot angles.

iii. Whether proceeding against or with the tidal stream flow, in order to execute large turns in a tidal race which also follows the shape of the channel, the heading, or more correctly the longitudinal axis of the ship, must be kept as close as possible to the angle of the tidal flow. Otherwise the vessel is set across the channel. In the absence of other vessel traffic, and in daylight and good visibility where visual cues can provide an indication of the tidal flow, this can be achieved. Although the scope of this testing did not include traffic management or vessel avoidance, there is no doubt that at low speeds, it would be difficult take vessel avoidance manoeuvres while rounding Turn or East Point at low speed with strong tidal streams. Although the pilots could in all cases keep the ships a safe distance from the shoreline, precise positional control through the turns was not very good due to current induced drift, and this could for example make it difficult to pass between multiple small vessels where the lateral spacing between these vessels might be only a few hundred metres.

iv. Similar to what was experienced in the St-Lawrence tests, when exiting the tidal race into still water, or when passing through a tidal eddy, ships experience almost instantaneous uncontrollable water speed acceleration. This phenomenon occurs because the ship has momentum (kinetic energy) which is generated by the tidal race; when the ship exits the race into slow moving water, or a back eddy, it still carries its momentum along its original path of travel and accelerates instantly in relation to the new body of water that it is travelling in. There is nothing that the pilot can do to prevent these accelerations and note in the tables that follow that the range of water speed values frequently vary by more than 3.0 knots. In terms of trying to accomplish a specific transit speed in this area, it cannot be over emphasised, that the only practical way to accomplish this is to set propeller RPM for a value which in neutral environmental conditions would give the desired speed (for example RPM set for 8 knots, 9 knots, etc. based on the vessel's speed table) with the goal of sailing at an average speed as per the RPM setting but with an actual water speed (and ground speed) that will continually oscillate in value.

4.4.1 Summary Assessment of Haro Strait/ Boundary Pass Course Alteration Tests

A summary of the results achieved when conducting large turns, both when sailing into the current and sailing with the current, as well as course holding when passing an area of strong tidal deflections/sheer are provided in Tables 18 and 19 below. Note that for each test vessel, any threshold where steering, course holding, or positional control became marginal due to current or wind speed effects is highlighted in yellow. If steering/ positional control was lost, this is highlighted in red colour. Note that for these tests, the ships generally did not experience difficulty maintaining course and positional control on the longer straight legs, but on occasion did while turning. Issues experienced while turning are described in the Notes in the bottom section of the Tables.

Table 18: Haro Strait/ Boundary Pass - Turn Point Northbound Test Assessment Matrix

Turn Point Northbound - Group 1				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G1 T1	Maximum Ebb	225°@15 knots	Steady Heading 341° @ 8 knots	
Vessel	Ability to Hold Course 347°	Transit Speed Range	RPM/ Pitch	Rudder
1 NPan Container	Good: Drift angle 6° to 9°	5.9 to 9.6	37 to 51	S30.8 to P30.0
2 Pan Container	Good: Drift angle 6° to 9°	7.6 to 10.2	34 to 54	S35 to P18.8
3 CAR Carrier	Good: Drift angle 6° to 9°	7.5 to 9.1	38 to 39	S35 to P35
4 PAN Cruise	Good: Drift angle 6° to 9°	7.7 to 8.6	48 to 52	S35 to P6.8
5 Ultra Cruise	Good: Drift angle 6° to 9°	7.1 to 9.2	49 to 53	S35 to P34.4
6 QFlex LNG	Good: Drift angle 6° to 9°	6.7 to 8.3	39 to 42	S35 to p20.8
Notes: Both Neo-PANAMAX container and PANAMAX container required RPM "kicks" to generate initial turn-rate and to arrest turn-rate when altering from 347° to 072°. Speed remained < 10.0 knots. Also note failed to set PANAMAX Container throttle back to Slow Ahead after one kick hence artificially high water speed near end of run.				

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G1 T2	Maximum Flood	225°@15 knots	Steady 345° @ 8 knots	
Vessel	**Ability to Hold Course 347°**	**Transit Speed Range**	**RPM/ Pitch**	**Rudder**
1 NPan Container	Good: Drift angle 3° to 5°	5.9 to 8.3	36 to 67	S32.2 to P35
2 Pan Container	Good: Drift angle 3° to 5°	6.4 to 12.0	34 to 54	S35 to P18.8
3 CAR Carrier	Good: Drift angle 3° to 5°	6.8 to 8.4	37 to 37	S18.2 to P28.8
4 PAN Cruise	Good: Drift angle 3° to 5°	6.2 to 8.4	49 to 49	S35 to P35
5 Ultra Cruise	Good: Drift angle 3° to 5°	7.5 to 8.3	49 to 53	S35 to P34
6 QFlex LNG	Good: Drift angle 3° to 5°	7.2 to 9.3	50 to 68	S27.3 to P35
Notes: All ships except for the PANAMAX Cruise and the Car Carrier required RPM "kicks" to generate initial turn-rate and to arrest turn-rate when altering from 347° to 072°. Speed remained < 10.0 knots				
Test No	**Tidal Condition**	**Wind Direction/ Speed**	**Vessel Initial State: Course and Water Speed**	
G1 T3	Maximum Ebb	180°@25 knots	Steady Heading 341° @ 8 knots	
Vessel	**Ability to Hold Course 347°**	**Transit Speed Range**	**RPM/ Pitch**	**Rudder**
1 NPan Container	Good: Drift angle 6° to 9°	6.8 to 9.0	36	S25 to P20.3
2 Pan Container	Good: Drift angle 6° to 9°	7.1 to 9.0	33	S30 to P35
3 CAR Carrier	Good: Drift angle 6° to 9°	6.8 to 8.9	36	S35 to P28.0
4 PAN Cruise	Good: Drift angle 6° to 9°	6.4 to 7.8	46	S35 to P21.5
5 Ultra Cruise	Good: Drift angle 6° to 9°	7.0 to 9.0	49	S30 to P33.5
6 QFlex LNG	Good: Drift angle 6° to 9°	6.5 to 8.0	38	S25.0 to P20.3
Notes: Started turn early and once heading was 000° wind augmented turn rate. Used just enough starboard rudder to keep turn rate in 10°/min to 15°/min range until heading 045° then < 10° to finish turn and ensure starboard turn-rate could be arrested. Did not need RPM kicks.				

Turn Point Northbound - Group 1				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G1 T4	Maximum Flood	180°@25 knots	Steady 345° @ 8 knots	
Vessel	Ability to Hold Course 347°	Transit Speed Range	RPM/ Pitch	Rudder
1 NPan Container	Good: Drift angle 3° to 5°	6.0 to 9.5	37 to 67	S25 to P32.2
2 Pan Container	Good: Drift angle 3° to 5°	6.7 to 11.3	50 to 60	S20.0 to P35.0
3 CAR Carrier	Good: Drift angle 3° to 5°	6.6 to 8.2	37 to 37	S17.0 to P25.8
4 PAN Cruise	Good: Drift angle 3° to 5°	5.7 to 8.2	50 to 60	S30.4 to P18.2
5 Ultra Cruise	Good: Drift angle 3° to 5°	6.7 to 10.5	50 to 80	S15.0 to P35.0
6 QFlex LNG	Good: Drift angle 3° to 5°	5.5 to 8.2	41 to 63	S33.4 to P30.0
Notes: All ships except for the Car Carrier required RPM "kicks" to generate initial turn-rate and to arrest turn-rate when altering from 347° to 072°. Speed remained < 10.0 knots except for PANAMAX Container and Ultra Large Cruise. Once ships had turned approximately 30° care had to be taken to keep turn rate 15° to starboard or less to ensure that they could steady on the 072°. Neo-PANAMAX and PANAMAX Containers, and Ultra Large Cruise applied port rudder approximately half way through turn to control turn rate and to avoid rounding up into wind.				

Turn Point Northbound - Group 2				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G2 T1	Maximum Ebb	225°@15 knots	Steady Heading 341° @ 8 knots	
Vessel	Ability to Hold Course 347°	Transit Speed Range	RPM/ Pitch	Rudder
7 PAN Bulk Ball.	Good: Drift angle 5° to 7°	6.6 to 8.5	52	S35 to P8.0
8 PAN Bulk Load	Good: Drift angle 5° to 7°	6.1 to 8.3	45	S35 to P13.6
9 AFRA Ball.	Good: Drift angle 5° to 7°	6.5 to 8.3	47	S35 to P5.1
10 AFRA Load	Good: Drift angle 5° to 7°	5.2 to 8.3	52	S35 to P21.3
11 CAPE Ball.	Good: Drift angle 5° to 7°	6.6 to 8.2	41	S35 to P2.2
12 CAPE Load	Good: Drift angle 5° to 7°	6.8 to 8.5	50	S35 to P7.4
Note: Adjusted rudder as needed to keep turn rate Starboard 7°/min to 12°/min while rounding turn point. Did not need RPM kicks or excessive rudder to steady on 072° track.				

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G2 T2	Maximum Flood	225°@15 knots	Steady 345° @ 8 knots	
Vessel	**Ability to Hold Course 347°**	**Transit Speed Range**	**RPM/ Pitch**	**Rudder**
7 PAN Bulk Ball.	Good: Drift angle 2° to 4°	5.2 to 7.9	44 to 84	S25.0 to P35.0
8 PAN Bulk Load	Good: Drift angle 2° to 4°	5.2 to 8.5	48 to 83	S30.0 to P35.0
9 AFRA Ball.	Good: Drift angle 2° to 4°	4.4 to 8.6	48 to 70	S25.0 to P30.0
10 AFRA Load	Good: Drift angle 2° to 4°	3.3 to 7.9	54 to 70	S25.0 to P30.0
11 CAPE Ball.	Good: Drift angle 2° to 4°	5.9 to 8.2	42 to 54	S20.0 to P30.0
12 CAPE Load	Good: Drift angle 2° to 4°	5.5 to 7.8	49 to 63	S35.0 to P33.3
Notes: Easy to initiate the turn but needed full rudder and propeller RPM kicks to arrest starboard turn-rate, and to regain water speed lost while sliding sideways with 4 to 5 knot current.				
Test No	**Tidal Condition**	**Wind Direction/ Speed**	**Vessel Initial State: Course and Water Speed**	
3	Maximum Ebb	180°@25 knots	Steady Heading 341° @ 8 knots	
Vessel	**Ability to Hold Course 347°**	**Transit Speed Range**	**RPM/ Pitch**	**Rudder**
7 PAN Bulk Ball.	Good: Drift angle 5° to 7°	7.6 to 9.5	61	S35 to P12.1
8 PAN Bulk Load	Good: Drift angle 5° to 7°	7.1 to 9.2	54	S35 to P24.0
9 AFRA Ball.	Good: Drift angle 5° to 7°	7.6 to 9.1	54	S35 to P10.0
10 AFRA Load	Good: Drift angle 5° to 7°	6.9 to 8.0	54	S20.0 to P20.0
11 CAPE Ball.	Good: Drift angle 5° to 7°	7.7 to 9.4	46	S35.0 to P20.0
12 CAPE Load	Good: Drift angle 5° to 7°	7.7 to 9.7	55	S33 to P5.0
Note: Adjusted rudder as needed to keep turn rate Starboard 7 °/min to 12 °/min while rounding turn point. Did not need RPM kicks or excessive rudder to steady on 072 ° track. Wind augmented turn, especially on ballasted ships. Needed more starboard rudder in early stage of turn than in Test 1, and less starboard rudder to complete last half of turn. Wind from astern augmented water speed with same RPM settings as Test 1.				

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
4	Maximum Flood	180°@25 knots	Steady 345° @ 8 knots	
Vessel	Ability to Hold Course 347°	Transit Speed Range	RPM/ Pitch	Rudder
7 PAN Bulk Ball.	Good: Drift angle 2° to 4°	5.4 to 7.9	44 to 84	S25.0 to P35.0
8 PAN Bulk Load	Good: Drift angle 2° to 4°	5.6 to 9.3	48 to 83	S30.0 to P34.6
9 AFRA Ball.	Good: Drift angle 2° to 4°	5.7 to 7.9	48 to 70	S30.0 to P35.0
10 AFRA Load	Good: Drift angle 2° to 4°	3.4 to 7.9	54 to 70	S30.0 to P30.0
11 CAPE Ball.	Good: Drift angle 2° to 4°	6.0 to 8.2	42 to 54	S30.0 to P30.0
12 CAPE Load	Good: Drift angle 2° to 4°	5.8 to 7.9	49 to 63	S34.7 to P35.0
Notes: Easy to initiate the turn but needed full rudder and propeller RPM kicks to arrest starboard turn-rate, and to regain water speed lost while sliding sideways with 4 to 5 knot current. Applied propeller RPM kicks earlier than in Test 2.				

Table 19: Boundary Pass - Gowlland/East Point Southbound Test Assessment Matrix

Gowlland Point/East Point Southbound - Group 1				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G1 T5	Neap Maximum Flood (0930)	225°@15 knots	Steady 252° @ 8 knots	
Vessel	Ability to Hold Course 250°	Transit Speed Range	RPM/ Pitch	Rudder
1 NPan Container	Good: Drift angle 3° to 5°	7.3 to 8.3	36	S25.0 to P31.3
2 Pan Container	Good: Drift angle 3° to 5°	7.4 to 8.3	35	S21.1 to P22.6
3 CAR Carrier	Good: Drift angle 3° to 5°	7.7 to 8.5	40	S15.0 to P20.0
4 PAN Cruise	Good: Drift angle 3° to 5°	7.1 to 8.2	49	S23.9 to P21.1
5 Ultra Cruise	Good: Drift angle 3° to 5°	7.6 to 8.2	50	S24.2 to P18.6
6 QFlex LNG	Good: Drift angle 3° to 5°	7.3 to 8.7	40	S23.7 to P24.3
Drift easily controlled. Current sheer required up to full rudder to correct on some vessels, but only for brief periods.				

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G1 T6	Spring Max Ebb 2100	225°@15 knots	Steady 133° @ 8 knots	
Vessel	**Ability to Hold Course°**	**Transit Speed Range**	**RPM/ Pitch**	**Rudder**
1 NPan Container	On 196° track drift angle is 24°+	3.5 to 8.3	38 to 52	S35 to P35
2 Pan Container	On 196° track drift angle is 24°+	4.6 to 8.3	35	S35 to P35
3 CAR Carrier	On 196° track drift angle is 24°+	4.2 to 8.1	38	S35.0 to P21.0
4 PAN Cruise	On 196° track drift angle is 24°+	4.6 to 8.2	48	S35 to P21.9
5 Ultra Cruise	On 196° track drift angle is 24°+	5.3 to 8.6	49	S33.6 to P29.3
6 QFlex LNG	On 196° track drift angle is 24°+	3.5 to 8.1	39	S35 to P28.3
Required a kick ahead on Neo-PANAMAX when exiting tidal bore to prevent sheer to starboard. All other vessels controlled with up to full rudder and constant RPM.				
Test No	**Tidal Condition**	**Wind Direction/ Speed**	**Vessel Initial State: Course and Water Speed**	
G1 T7	Neap Maximum Flood (0930)	125°@25 knots	Steady 252° @ 8 knots	
Vessel	**Ability to Hold Course 250°**	**Transit Speed Range**	**RPM/ Pitch**	**Rudder**
1 NPan Container	Good: Drift angle 3° to 5°	7.3 to 8.3	36	S25.0 to P31.3
2 Pan Container	Good: Drift angle 3° to 5°	7.4 to 8.3	35	S21.1 to P22.6
3 CAR Carrier	Good: Drift angle 3° to 5°	7.7 to 8.5	40	S15.0 to P20.0
4 PAN Cruise	Good: Drift angle 3° to 5°	7.1 to 8.2	49	S23.9 to P21.1
5 Ultra Cruise	Good: Drift angle 3° to 5°	7.6 to 8.2	50	S24.2 to P18.6
6 QFlex LNG	Good: Drift angle 3° to 5°	7.3 to 8.7	40	S23.7 to P24.3
Drift easily controlled. Current sheer required up to full rudder to correct on some vessels, but only for brief periods.				

Gowlland Point/East Point Southbound - Group 1				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G1 T8	Spring Max Ebb 2100	030°@25 knots	Steady 133° @ 8 knots	
Vessel	Ability to Hold Course°	Transit Speed Range	RPM/ Pitch	Rudder
1 NPan Container	On 196° track drift angle is 24°+	4.3 to 11.9	38 to 96	S35 to P30.5
2 Pan Container	On 196° track drift angle is 24°+	6.5 to 10.2	34 to 54	S35 to P35
3 CAR Carrier	On 196° track drift angle is 24°+	5.5 to 10.2	41	S35.0 to P21.6
4 PAN Cruise	On 196° track drift angle is 24°+	5.3 to 9.5	51	S35 to P35
5 Ultra Cruise	On 196° track drift angle is 24°+	5.8 to 9.4	49 to 68	S35 to P35
6 QFlex LNG	On 196° track drift angle is 24°+	4.5 to 10.3	43 to 47	S35 to P20.7
With the exception of the Car Carrier and PANAMAX Cruise required a kick ahead either to initiate/ augment starboard turn rate and/or to steady when exiting tidal bore to prevent sheer to starboard. Neo-PANAMAX briefly required a kick of full ahead when exiting tidal bore with 25 knot wind on starboard quarter. Wind from astern also augmented water speed.				
Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G2 T7	Neap Maximum Flood (0930)	125°@25 knots	Steady 252° @ 8 knots	
Vessel	Ability to Hold Course 250°	Transit Speed Range	RPM/ Pitch	Rudder
7 PAN Bulk Ball.	Good: Drift angle max 14°	7.4 to 8.2	46	S16.9 to P7.6
8 PAN Bulk Load	Good: Drift angle max 14°	7.8 to 8.6	54	S23.7 to P3.8
9 AFRA Ball.	Good: Drift angle max 14°	7.2 to 8.3	49	S19.7 to P2.9
10 AFRA Load	Good: Drift angle max 14°	7.2 to 8.4	53	S15.0 to P14.5
11 CAPE Ball.	Good: Drift angle max 14°	7.7 to 8.7	42	S16.8 to P7.9
12 CAPE Load	Good: Drift angle max 14°	7.9 to 8.7	50	S9.0 to P8.5
Drift easily controlled. Current sheer was corrected with 20 ° of rudder or less. Maximum heading variation was 6 °.				

Test No	Tidal Condition	Wind Direction/ Speed	Vessel Initial State: Course and Water Speed	
G2 T8	Spring Max Ebb 2100	030°@25 knots	Steady 133° @ 8 knots	
Vessel	**Ability to Hold Course°**	**Transit Speed Range**	**RPM/ Pitch**	**Rudder**
7 PAN Bulk Ball.	On 196° track drift angle is 20°+	4.2 to 9.0	46 to 83	S35 to P32.5
8 PAN Bulk Load	On 196° track drift angle is 20°+	4.6 to 8.6	46 to 83	S35 to P35
9 AFRA Ball.	On 196° track drift angle is 20°+	4.7 to 10.1	47 to 70	S35 to P35
10 AFRA Load	On 196° track drift angle is 20°+	4.6 to 8.6	53 to 70	S35 to P35
11 CAPE Ball.	On 196° track drift angle is 20°+	5.3 to 9.2	38 to 48	S35 to P34.8
12 CAPE Load	On 196° track drift angle is 20°+	4.7 to 8.8	49 to 63	S35 to P35
With the exception of the Car Carrier and PANAMAX Cruise required a kick ahead either to initiate/ augment starboard turn rate and/or to steady when exiting tidal bore to prevent sheer to starboard. Neo-PANAMAX briefly required a kick of full ahead when exiting tidal bore with 25 knot wind on starboard quarter.				

5 DETAILED OBSERVATION ON SIMULATION TEST RESULTS

Expanding on the Summary of Findings and Test Results from Section 4 above, this portion of the report will describe in further detail specific observations from the analysis of the four different geographic areas that are deemed to be of importance to low speed vessel control. This information will assist in substantiating the recommendations and considerations for policy implementation that are provided in Section 6.

5.1 Observations Derived from Tests of Juan de Fuca TSS

This first portion of the analysis provided a broad range of information and insight into the low speed manoeuvring characteristics of 21 different vessel types when manoeuvring in relatively open water, with winds and tidal streams of a uniform nature. Findings from this portion of the analysis, in terms of general vessel manoeuvring characteristics and minimal safe (or practical) transit speeds, is applicable to the other three test areas and played an important role in focusing the follow-on portions of the study.

5.1.1 Detailed Observations on Test Vessel Group 1 (Fine Hull Form Ships)

Although fine hull form vessels tend to handle well, and accelerate/decelerate faster than full form vessels, from a design perspective, this category of ship is generally designed to operate at higher speeds. This is particularly true of container vessels, many of which have top speeds of 24 knots or more, and often Dead Slow Ahead speeds of more than 7 knots. As a result, the steering forces generated by their rudders and propellers at Dead Slow and even at Slow Ahead settings are not that great relative to the ship size. The latest generation of Large and Ultra Large Container Vessels (ULCV) have been designed to operate at lower speeds (cruising speeds of 18 to 21 knots) and comparatively steer better at lower engine telegraph settings than older vessels.

5.1.1.1 Sailing/Proceeding into the Wind

When proceeding into the wind (wind from forward hemisphere), this group of ships did not experience any difficulty maintaining heading, and only experienced appreciable course drift when the winds exceed 35 knots. It should also be noted that the baseline tests did not include heading adjustments in order to maintain course, but rather were intended to measure the drift angle that the vessels developed and the amount of speed that they lost. Course holding tests were conducted in the latter stage of the testing and will be commented on separately.

It can be seen in Figures 54 to 56 below that at a Dead-Slow Telegraph setting, only the ULCV and the Post-PANAMAX Container vessels developed a significant drift angle and suffered from a loss of forward speed when the wind speed exceeded 35 knots. It should be noted that the ULCV with a 58-metre beam, and Bridge (Wheelhouse) forward design has a very large forward cross section, and hence very high wind drag. The Post-PANAMAX vessel was modelled in what is referred to as a Hi-Lo condition, which means that it had a full load of containers, but a large portion were empty, resulting in maximum wind area with relatively low displacement. As such, these two vessels represent the worse-case condition for wind induced speed loss and drift.

Figure 54: JDF TSS Heading Holding Test 1-Group 1 Wind 247° Dead-Slow Track-plot

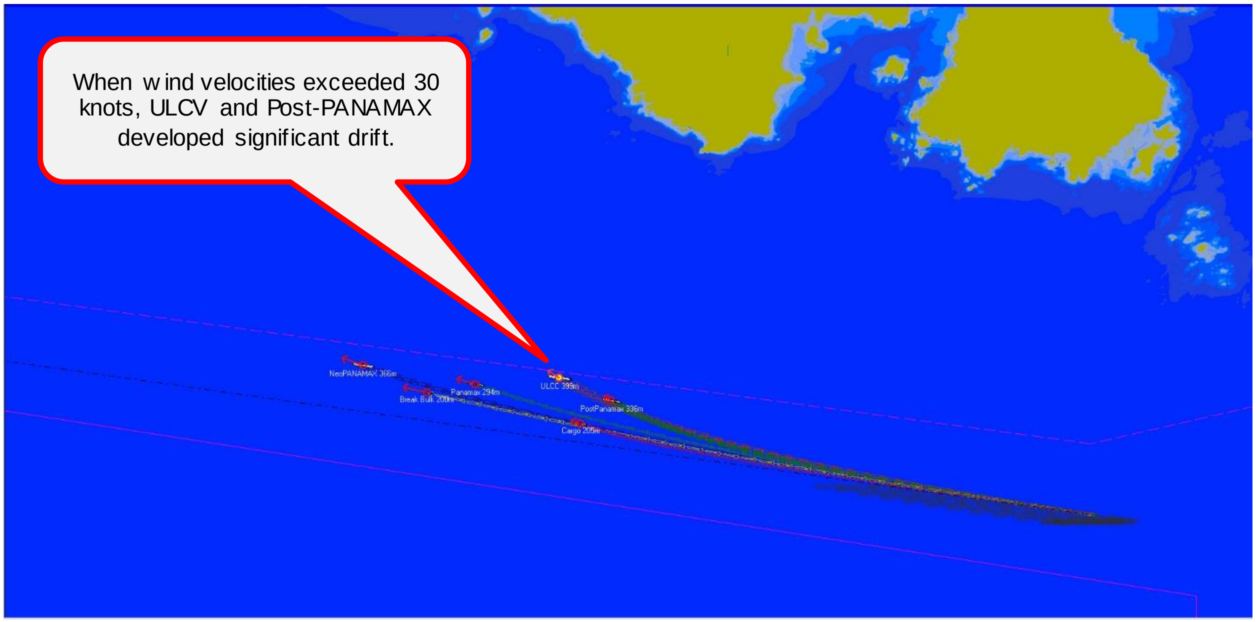


Figure 55: JDF TSS Heading Holding Test 1-Group 1 Wind 247° Dead-Slow Zoom Track-plot

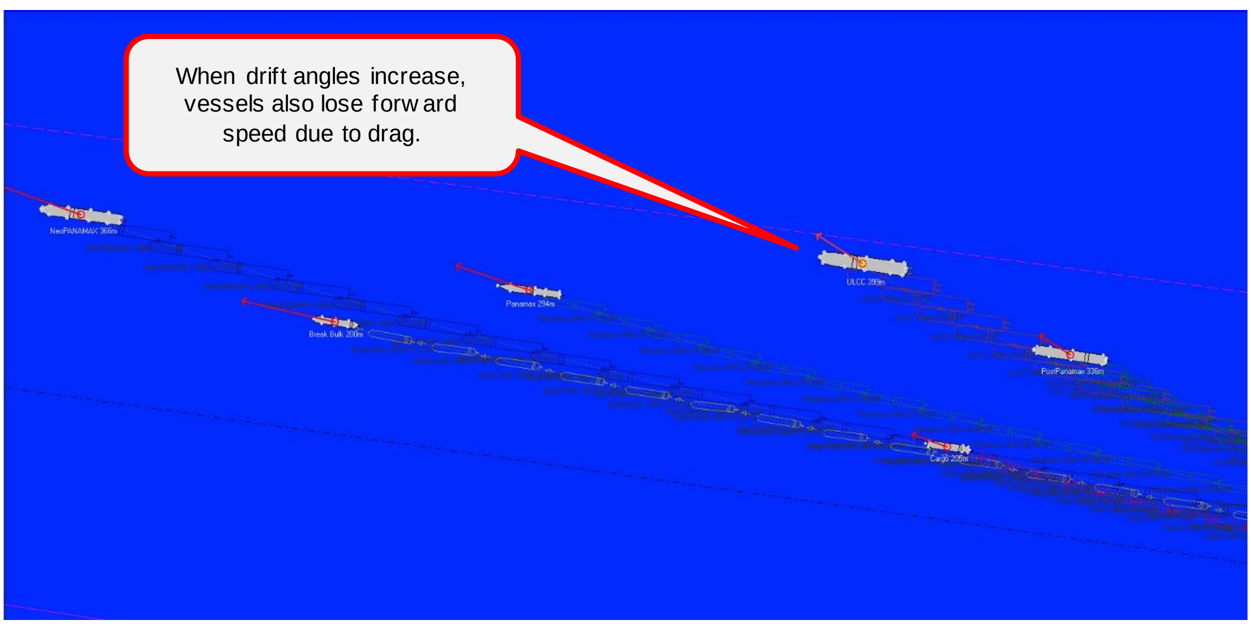


Figure 56: JDF TSS Heading Holding Test 1-Group 1 Wind 247° Heading and Course Graph

In tests sailing into the wind where the engine telegraph setting was Slow-Ahead, the ULCV and Post-PANAMAX still experienced appreciable drift, but this was quite manageable. In addition to the baseline test, a course holding/track maintenance test was also conducted to confirm that with a Slow-Ahead telegraph setting, if heading was adjusted to compensate for drift, that the ships could follow the planned track/course over the ground in the TSS. It should be noted that the ULCV, Post-PANAMAX and Cargo vessels required marginal increases to propeller RPMs in order to maintain transit speed. See Figures 57 to 62 below:

Figure 57: JDF TSS Heading Holding Test 9-Group 1 Wind 247° Slow Ahead Track-plot

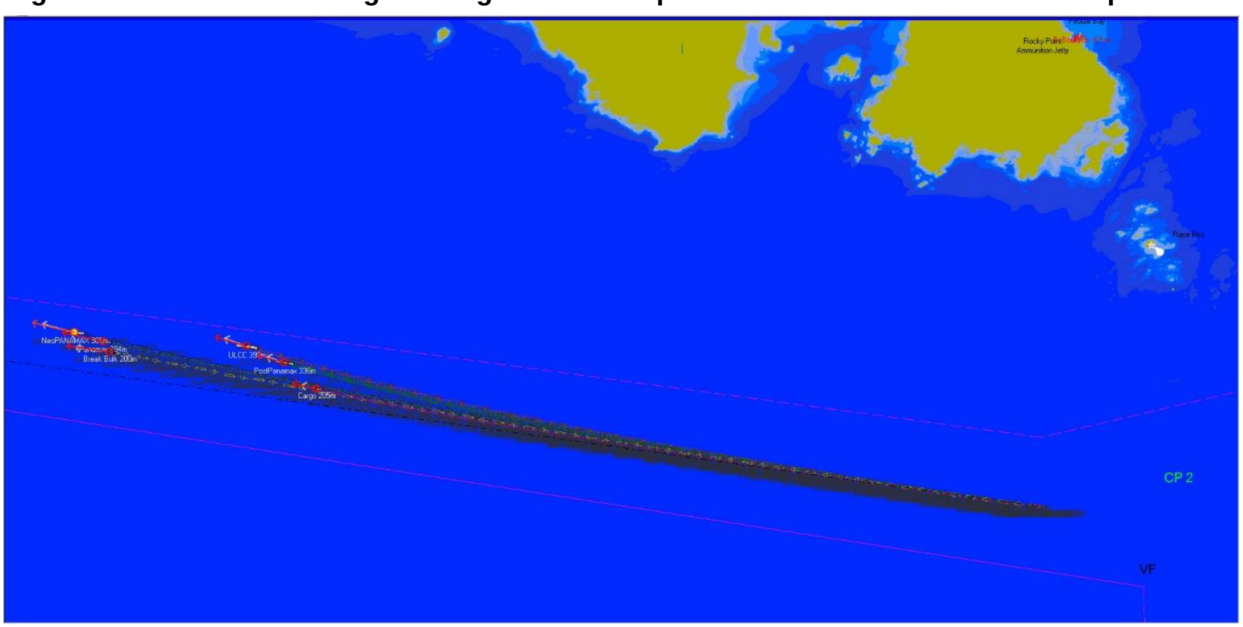


Figure 58: JDF TSS Heading Holding Test 9-Group 1 Wind 247° Heading and Course Graph

Figure 59: JDF TSS Course Holding Test 9-1-Group 1 Wind 247° Slow Ahead Track-plot

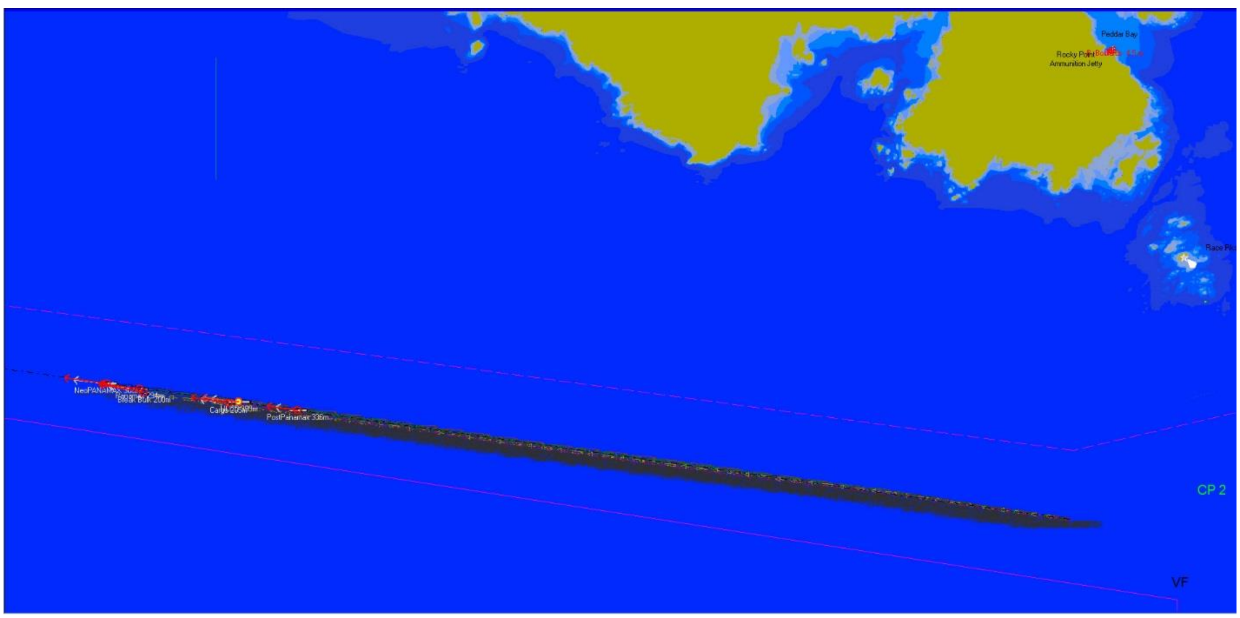
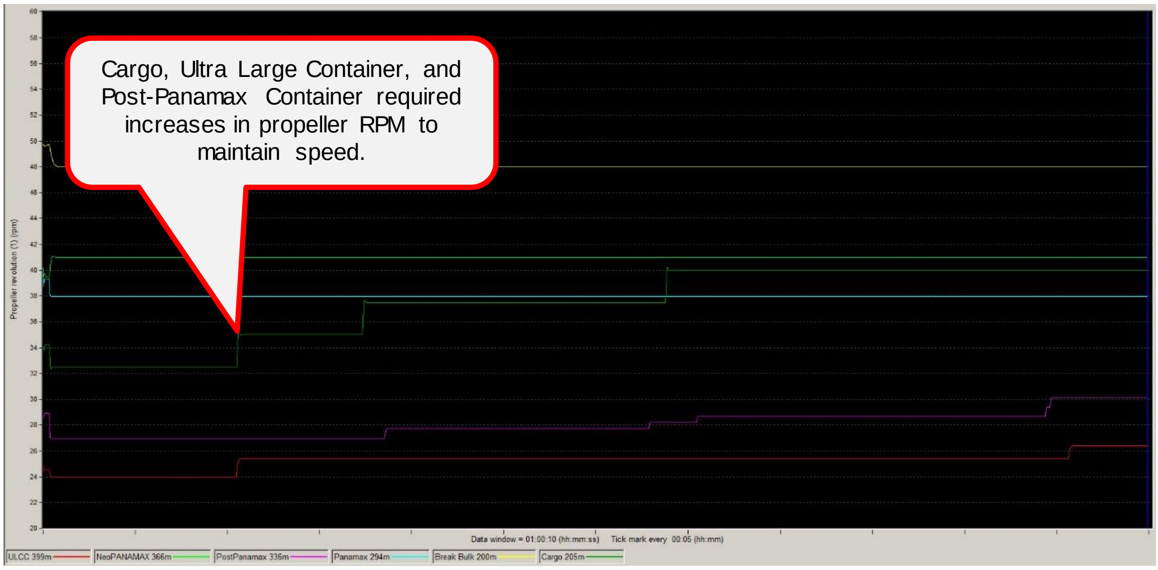


Figure 60: JDF TSS Course Holding Test 9-1-Group 1 Wind 247° Slow Ahead Zoom Track-plot

Figure 61: JDF TSS Heading Holding Test 9-1-Group 1 Wind 247° Heading and Course Graph

Figure 62: JDF TSS Heading Holding Test 9-1-Group 1 Wind 247° RPM Increase



5.1.1.2 Sailing/Proceeding with Wind from Astern (Downwind)

When proceeding with the wind (wind from stern hemisphere), this group of ships experienced the most difficulty maintaining heading as by design they are prone to wind induced rotation, and at relatively low speeds, their rudders and propellers often do not produce enough steering forces to counter the effects of the wind. At a Dead Slow Ahead telegraph setting, four of the six vessels in this group experienced complete loss of steering control with wind speed of 27 knots or less. The other two vessels experienced complete loss of steering control at 34.1 and 35.4 knots. At slow ahead engine settings three of the vessels experience complete loss of steering control at wind speeds of approximately 33 knots and one at 40 knots. At Half Ahead telegraph setting, three of the vessels experienced marginal steering control when the wind exceeded 30 knots (see Figures 63 to 67 below). It should also be emphasized, that these reductions/losses of steering control are occurring in the absence of other external forces such as complex tidal streams or current patterns and are occurring when the vessel is simply trying to maintain a straight-line course/heading. Whenever a vessel needs to alter course (planned route alteration, to avoid other vessels, fishing equipment or floating debris, these effects will be even more pronounced.

Figure 63: JDF TSS Heading Holding Test 4 Group 1 Wind 143° Dead Slow Ahead Track-plot

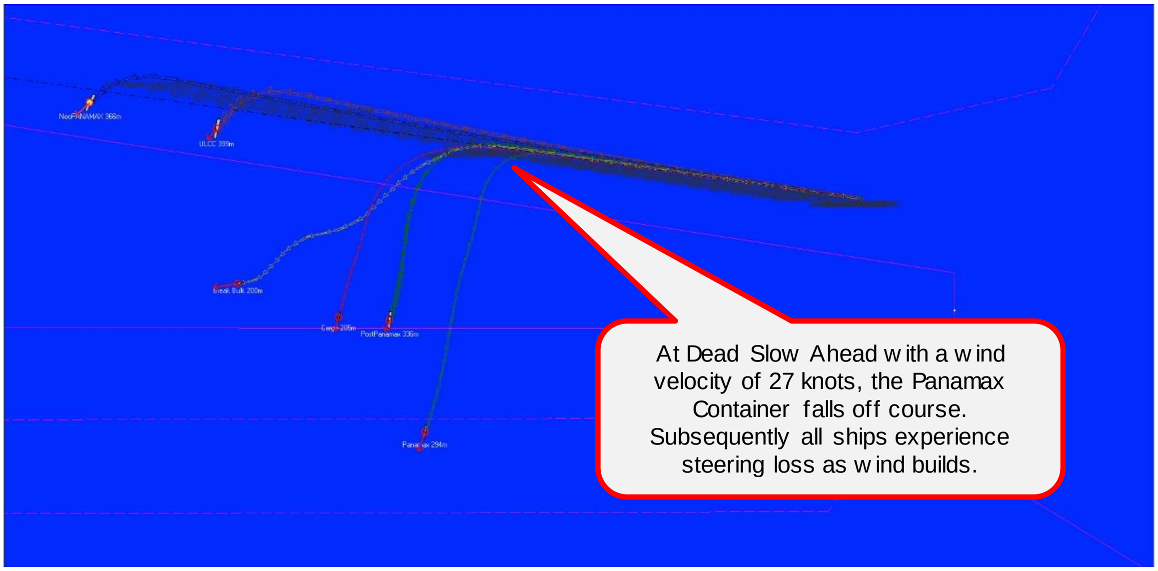


Figure 64: JDF TSS Heading Holding Test 4 Group 1 Wind 143° Heading and Course Graph

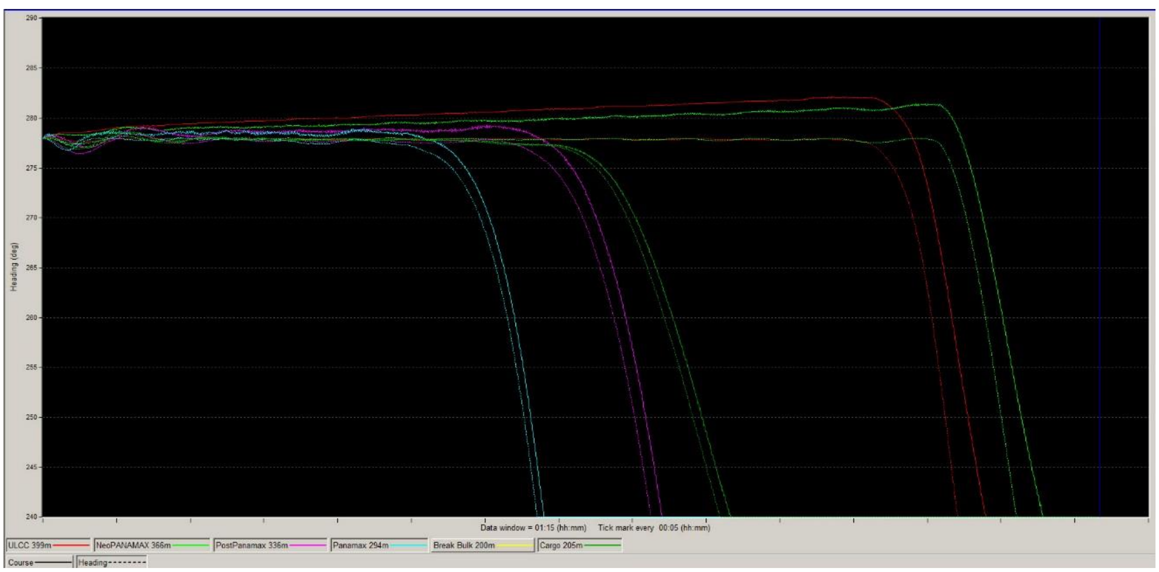


Figure 65: JDF TSS Heading Holding Test 10 Group 1 Wind 143° Slow Ahead Track-plot

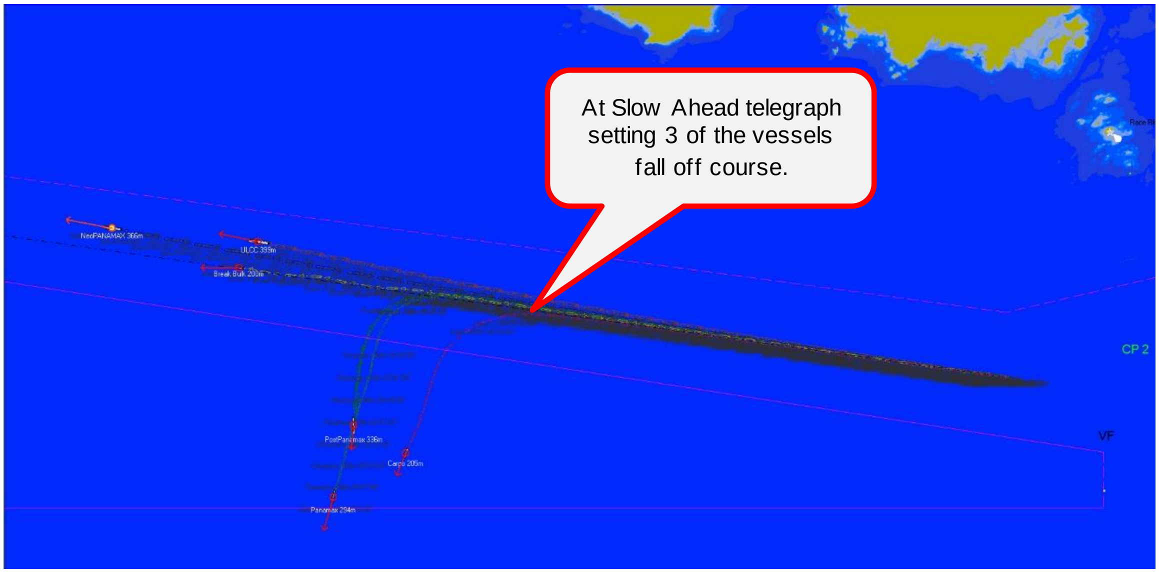


Figure 66: JDF TSS Heading Holding Test 16 Group 1 Wind 143° Half Ahead Zoom Track-plot

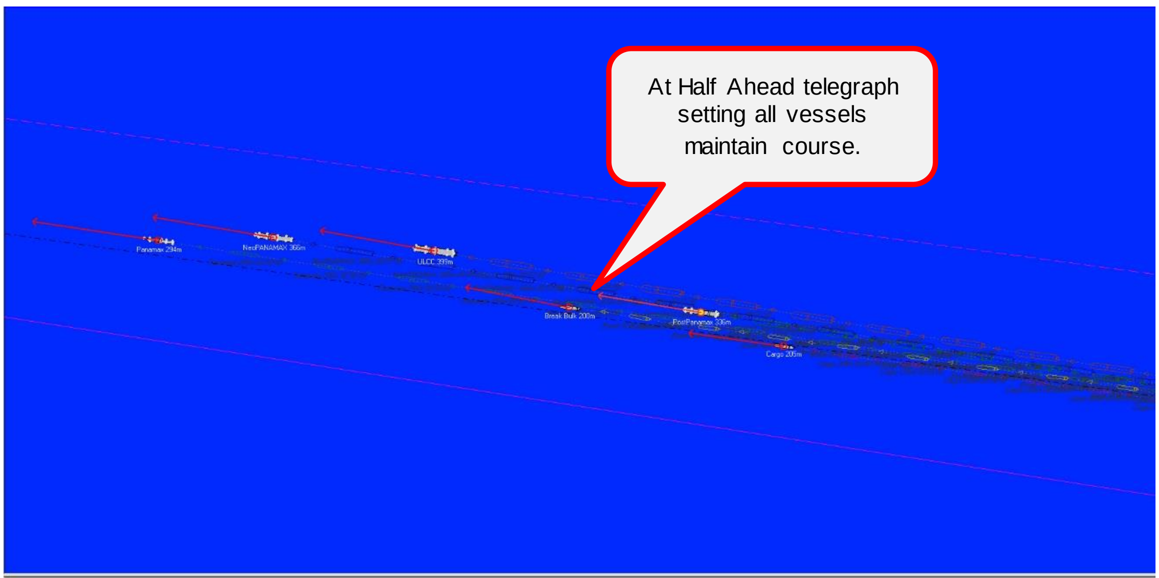
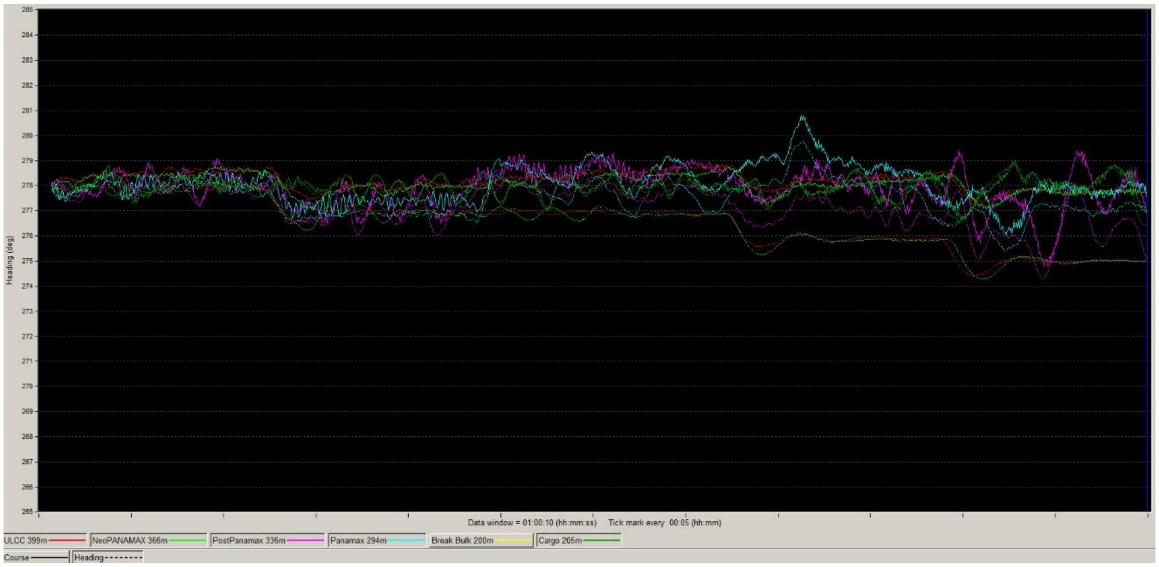


Figure 67: JDF TSS Heading Holding Test 16 Group 1 Wind 143° Heading and Course Graph



It was also determined that with this group of ships that wind speeds in excess of 35 knots proved to create steering control problems for any transit speed below 10 knots of water speed. To validate this observation, two additional tests were conducted with telegraph settings (propeller RPM) for a speed of 10 knots. It was observed that for the PANAMAX and Post-PANAMAX vessels that in order to maintain steering control, additional RPM had to be ordered in order to prevent the ships from falling off course. See Figures 68 to 71 below:

Figure 68: JDF TSS Heading Holding Test 16_1 Group 1 Wind 143° Speed 10 Track-plot

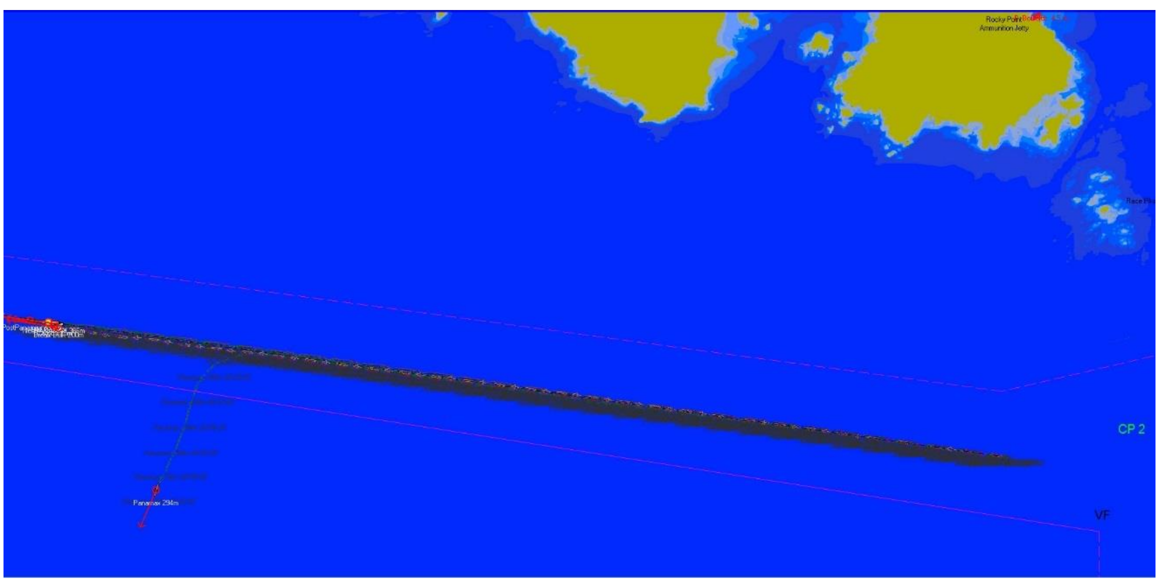


Figure 69: JDF TSS Heading Holding Test 16_1 Group 1 Wind 143° Rudder and Wind Speed Comparison

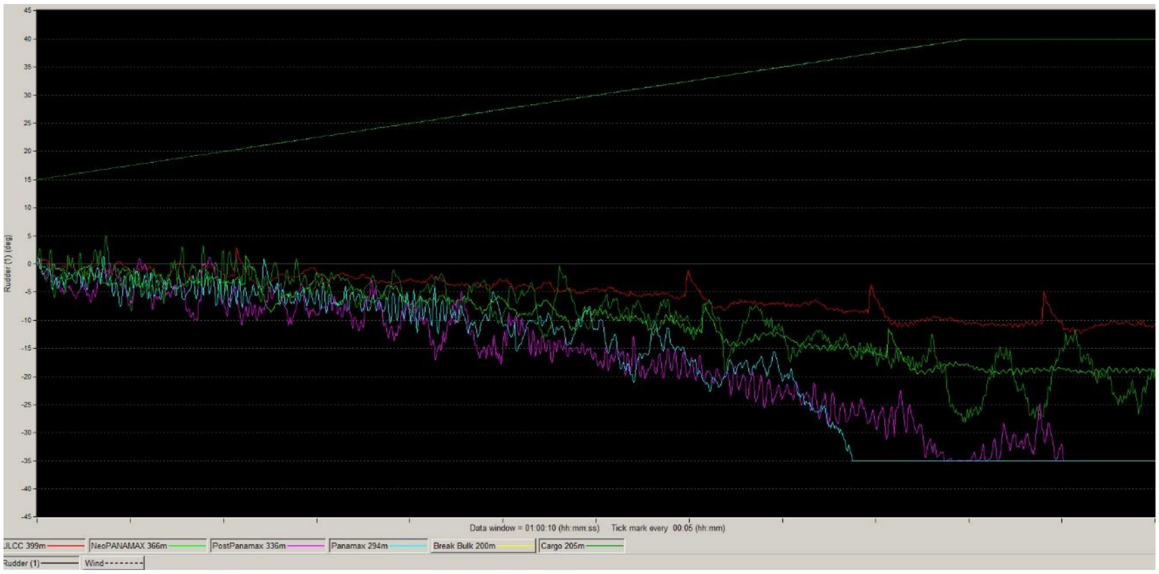


Figure 70: JDF TSS Heading Holding Test 16_1_2 Group 1 Wind 143° Speed 10 Track-plot Zoom

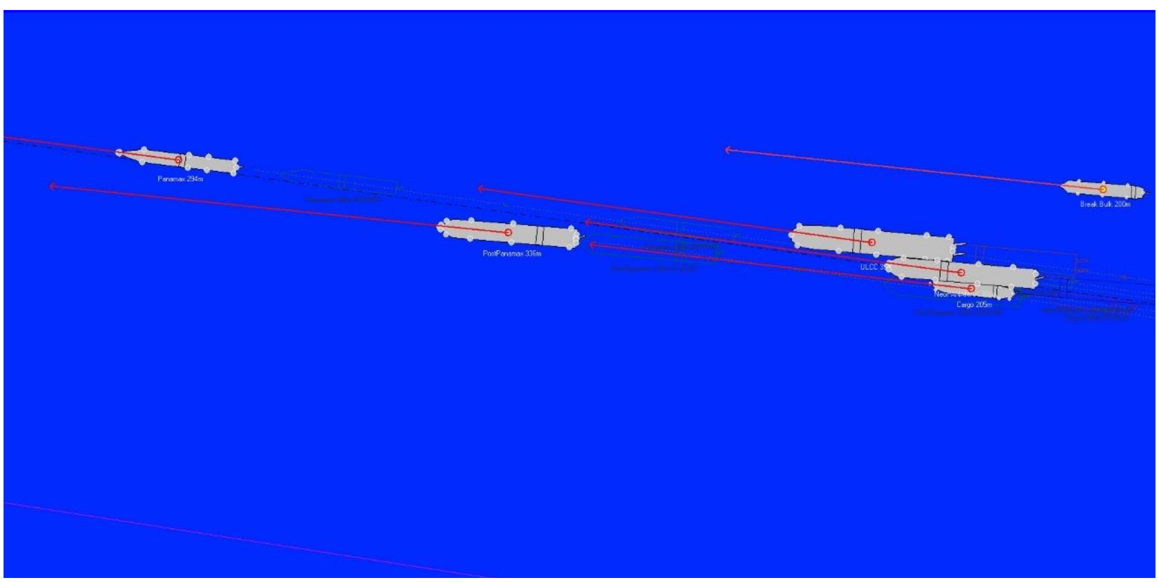
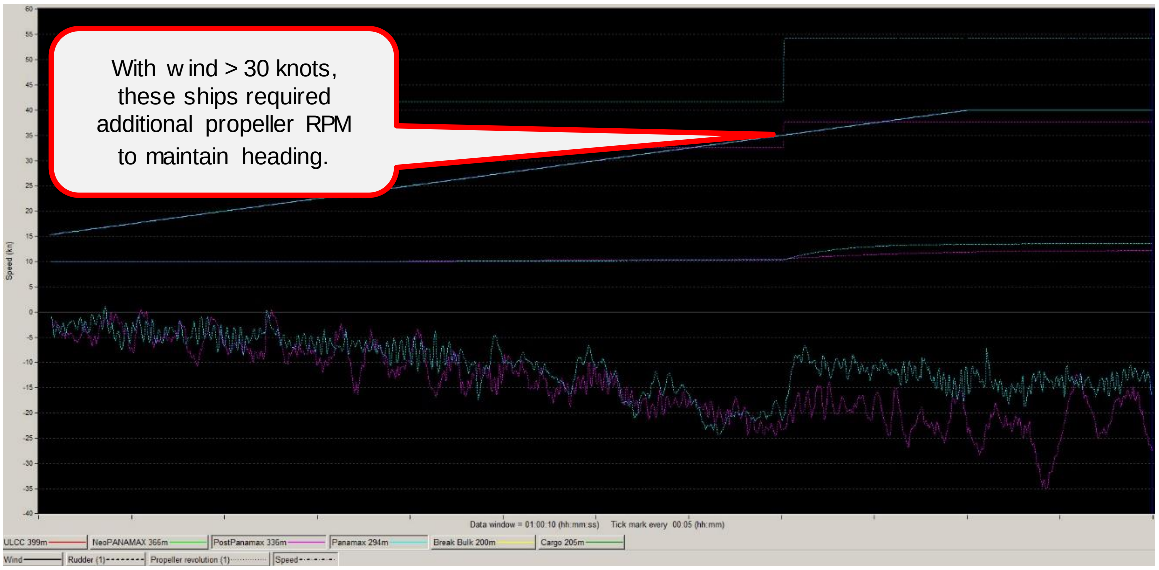


Figure 71: JDF TSS Heading Holding Test 16_2 Group 1 Wind 143° Rudder/RPM/ Vessel Speed/Wind Speed Comparison PANAMAX and Post-PANAMAX



5.1.2 Detailed Observations on Test Vessel Group 2 (Full Hull Form Ships)

Full form vessels tend to accelerate and decelerate slower than other vessel types, and often require more rudder to initiate a turning moment, hence are generally categorised as having poor to moderate manoeuvring capabilities. However, due to the fact that in loaded conditions they tend to have a relatively small portion of their hull forms above the water, they are much less prone to wind induced rotation and drift unless they are nearly completely empty (lightly ballasted). In terms of overall ability to maintain heading and course, this group of vessels, led by tankers faired the best.

5.1.2.1 Sailing/Proceeding into the Wind

When proceeding into the wind (wind from forward hemisphere), this group of ships did not experience any difficulty maintaining heading. Only the ballasted (completely empty) Cape Size Bulk Carrier and ballasted SUEZMAX Tanker experienced appreciable course drift when the winds exceed 35 knots. Also, since the Dead Slow Ahead speed for six of these vessels was less than 5 knots, tests commenced with the engine telegraph set to Slow Ahead which produced transit speeds of 6 to 8 knots. The exception to this was the PANAMAX Bulker which had its telegraph set for Dead Slow which corresponded to a transit speed of 6.3 knots in the loaded vessel, and 7.8 in the ballasted ship. It should also be noted that the baseline tests did not include heading adjustments in order to maintain course, but rather were intended to measure the drift angle that the vessels developed, and the amount of speed that they lost.

The ballasted Cape Size Bulk Carrier and ballasted SUEZMAX Tanker had a relatively large portion of their hulls above the water, which created a large windage area resulting in both appreciably forward speed loss and lateral drift particularly when the winds exceeded 35 knots. Given that the initial transit speed for the Cape Size was 6.2 knots and for the SUEZMAX only 5.6 knots (see Figures 72 and 73 below). It was assessed that a small to moderate increase in RPM to maintain these speeds would eliminate the problem with the lateral drift. The other six vessels would simply require heading changes to maintain course. As such, there was no need to test this group at a Half Ahead engine telegraph setting, as they were holding course at Slow Ahead.

Figure 72: JDF TSS Heading Holding Test 7 Group 2 Wind 247° Speed 10 Track-plot Zoom

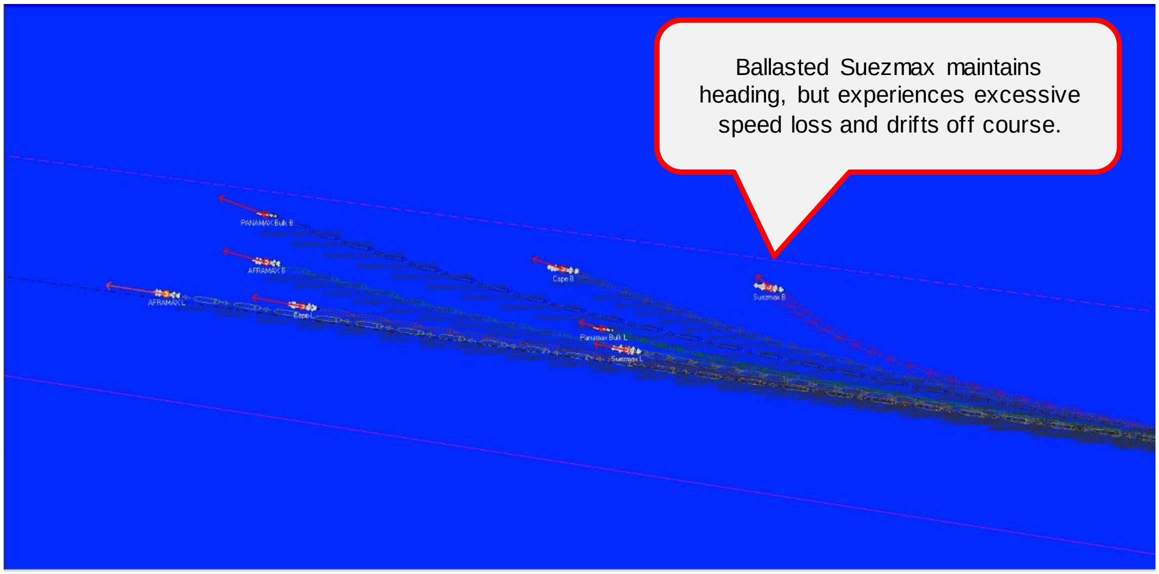
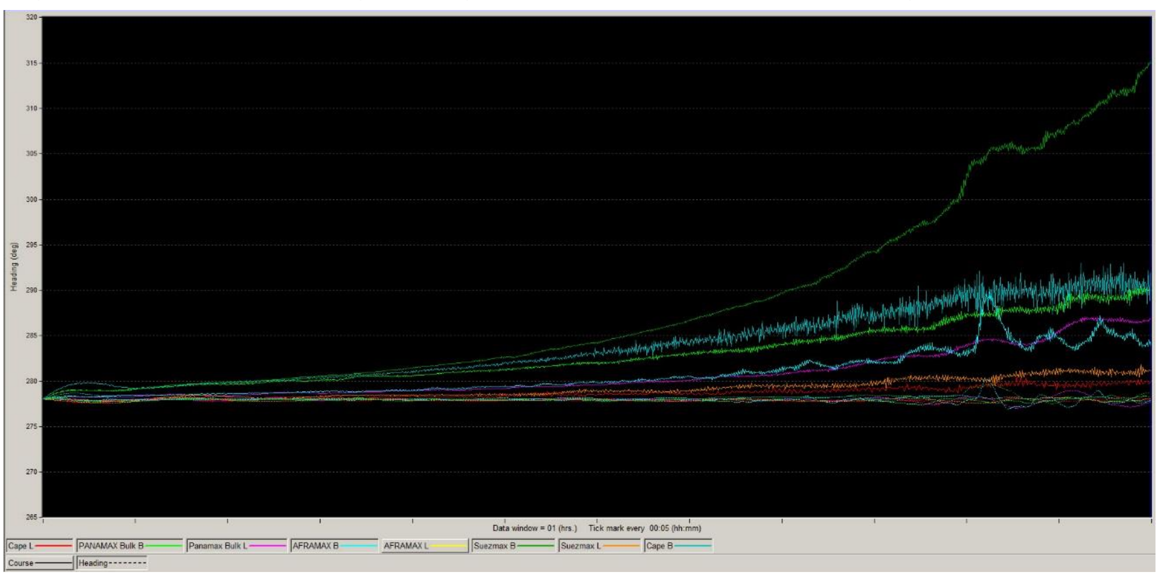


Figure 73: JDF TSS Heading Holding Test 7 Group 2 Wind 247° Heading and Course Graph



5.1.2.2 Sailing/Proceeding with Wind from Astern (Downwind)

When proceeding with the wind (wind from stern hemisphere), at a Dead Slow Ahead telegraph setting for the PANAMAX and Slow Ahead for the remaining six vessels, none of the loaded vessels experience a significant degradation in steering control. The PANAMAX Ballasted experienced marginal steering control at 30 knots, and a loss of steering control at 39.9 knots. The ballasted Cape Size bulker and the ballasted AFRAMAX tanker both experienced loss of steering control at a wind speed of 39 knots. This equated to transit speeds ranging from 5.4 to 7.8 knots. At a Slow Ahead telegraph setting for the PANAMAX and Half Ahead for the remaining six vessels, none of the vessels experienced any significant degradation in steering control. This equated to transit speeds ranging from 7.9 to 12.3 knots. See Figures 74 and 75 below:

Figure 74: JDF TSS Heading Holding Test 10 Group 2 Wind 143° Slow Ahead Track-plot

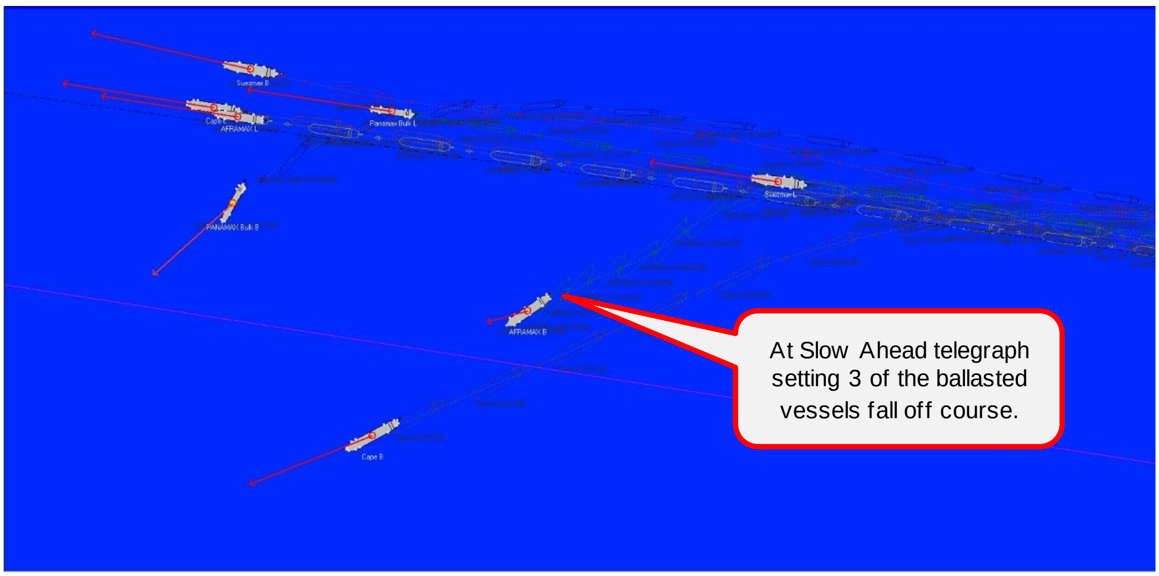
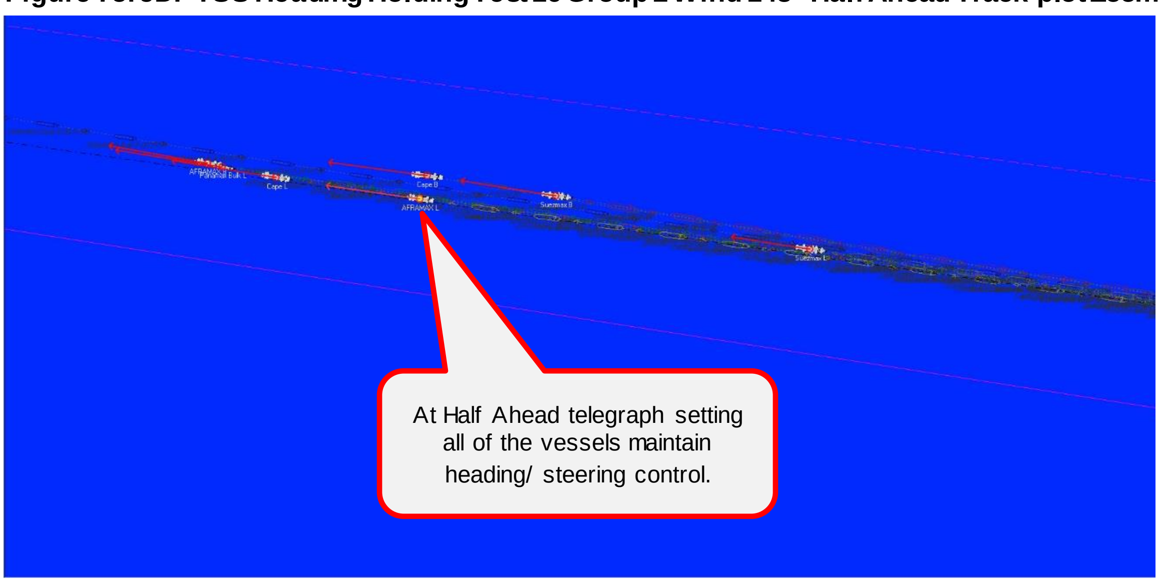


Figure 75: JDF TSS Heading Holding Test 16 Group 2 Wind 143° Half Ahead Track-plot Zoom



Based on the results of the baseline tests, a validation test was conducted with all vessels at an engine telegraph setting that equated to 8 knots. As the wind built in velocity, propeller RPM was increased when it was noted that the ships were beginning to experience marginal steering control. In this test case, all vessels maintained their headings. At a sustained wind speed of 40 knots, once the ships' propeller RPM/ rudder orders and headings were in a state of equilibrium the corresponding water transit speeds ranged from 7.6 to 10.3 knots. See Figures 76 and 77 below:

Figure 76: JDF TSS Heading Holding Test 10_1 Group 2 Wind 143° Speed 8 Track-plot Zoom

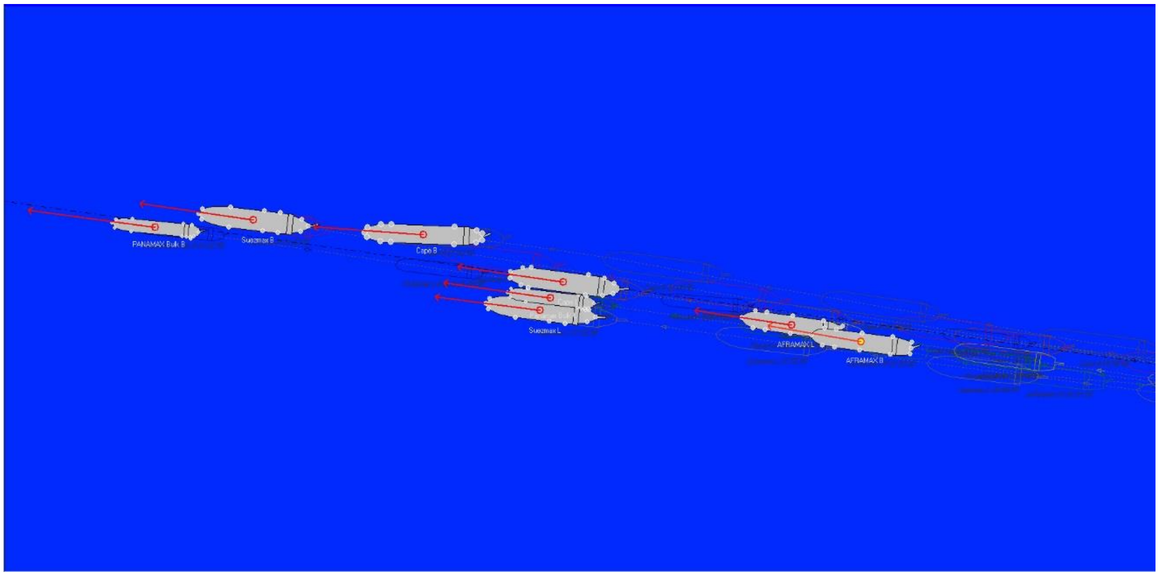


Figure 77: JDF TSS Heading Holding Test 10_1 Group 2 Wind 143° Speed 8 /RPM/Wind Speed/ Transit Speed and Rudder Comparison

5.1.3 Detailed Observations on Test Vessel Group 3 (High Sided Vessels)

This test group was comprised of high sided vessels, with the exception of the chemical tanker, which with a controllable pitch propeller and high level of manoeuvrability, had some similarities in propulsion system with the 151-metre ferry. It should also be underlined that all of the passenger vessels are highly manoeuvrable, but that their manoeuvrability in high winds hinges on the use of the power of the ship's engines, which in turn increases the propeller pitch/ angle or RPM, and increases propulsion generated noise and propeller cavitation. Hence observations or findings with the passenger vessels losing steering control are directly related to the deliberate act of limiting applied engine power.

5.1.3.1 Sailing/Proceeding into the Wind

When proceeding into the wind (wind from forward hemisphere), this group of ships, with the exception of the chemical tanker, have high windage areas. In particular the Ultra Large Cruise Vessel (ULCV), the 151-metre-long Ferry, and the automobile carrier were highly prone to wind induced lateral drift. At lower transit speeds (Dead Slow Ahead Telegraph orders), when the wind velocity exceeded 30 knots, these vessels developed considerable course drift (The angular difference between their heading and course over the ground started to increase). Additionally, winds above 30 knots acting on the large forward cross-sectional area of the vessels' superstructure resulted in considerable loss of forward speed, and if propeller RPM or Pitch Angle were not increased, the vessels would lose almost all forward motion and develop a very large drift angle.

At a Slow Ahead telegraph setting (transit speeds of 6.5 to 9.5 knots) the 151-metre ferry, automobile carrier, PANAMAX cruise ship, and ULCV all developed drift angles of more than 20° and speed losses ranging from 20% to 60%. At Half Ahead Telegraph settings, (transit speeds of 9.7 to 13.4 knots) none of the vessels experienced degraded steering or course holding ability. See Figures 78 to 79 below:

Figure 78: JDF TSS Heading Holding Test 7 Group 3 Wind 247° Slow Ahead Track-plot

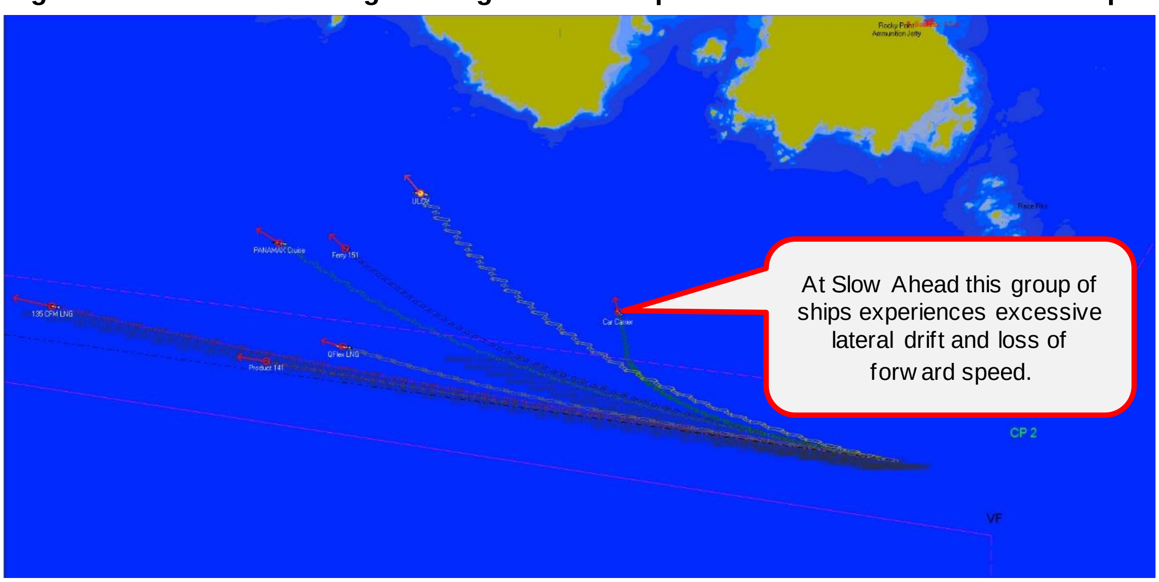


Figure 79: JDF TSS Heading Holding Test 7 Group 3 Wind 247° Heading and Course Graph

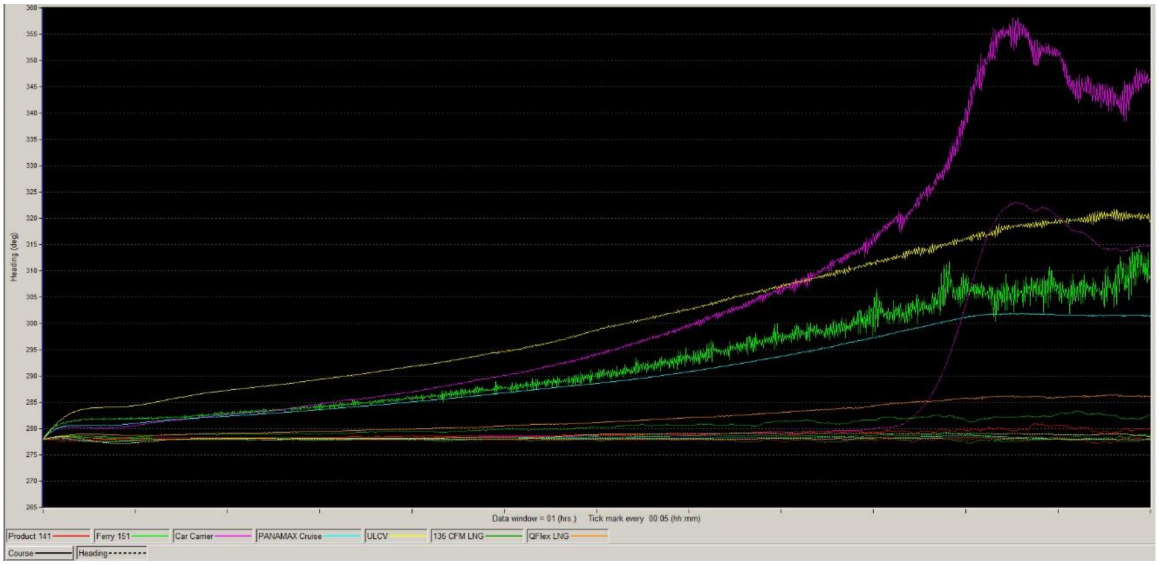


Figure 80: JDF TSS Heading Holding Test 13 Group 3 Wind 247° Half Ahead Track-plot

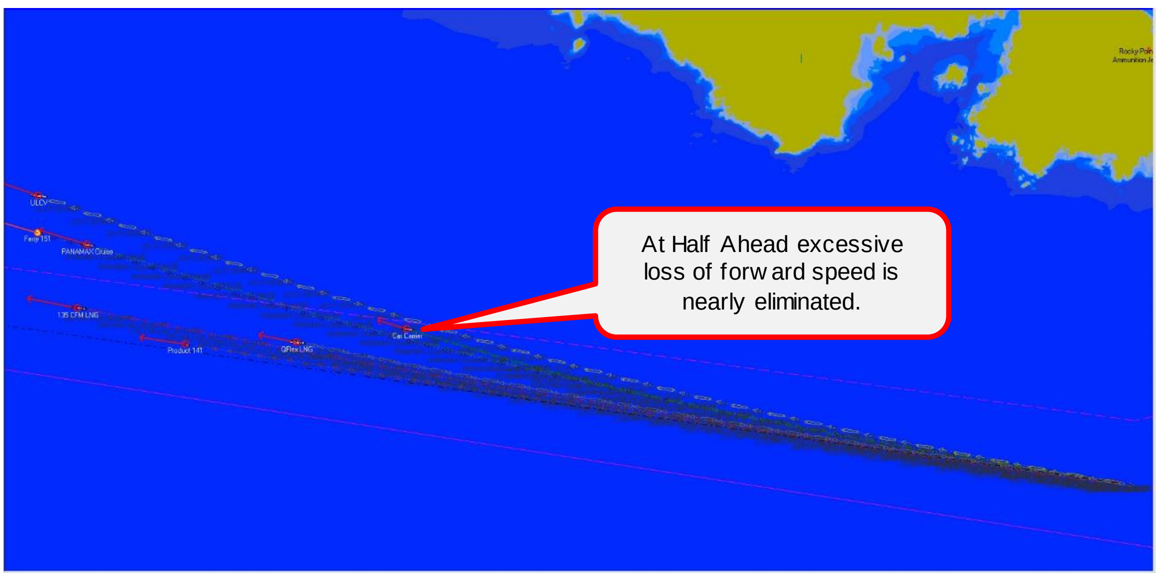
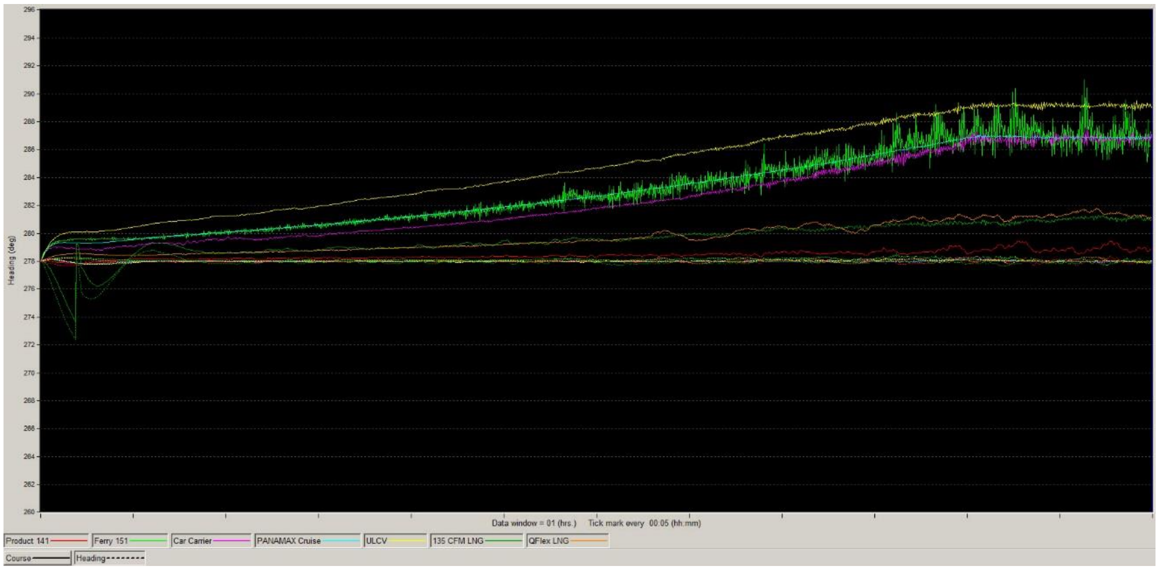


Figure 81: JDF TSS Heading Holding Test 13 Group 3 Wind 247° Heading and Course Graph



After completing the baseline tests, a validation test was performed with a Slow Ahead engine telegraph setting. Headings were adjusted as needed to maintain course, and propeller RPM/Pitch angles were adjusted as needed to maintain transit speeds between 4.5 and 8.5 knots. This test showed that all of the test vessels could maintain course under these conditions. See Figures 82 and 83:

Figure 82: JDF TSS Course Holding Test 7_1 Group 3 Wind 247° Track-plot Zoom

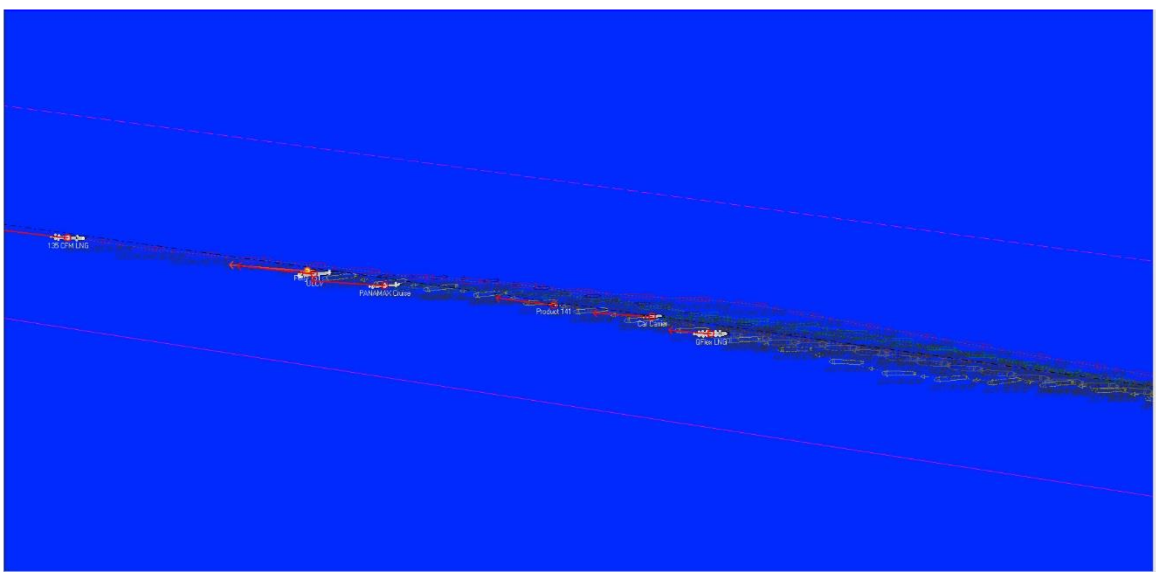


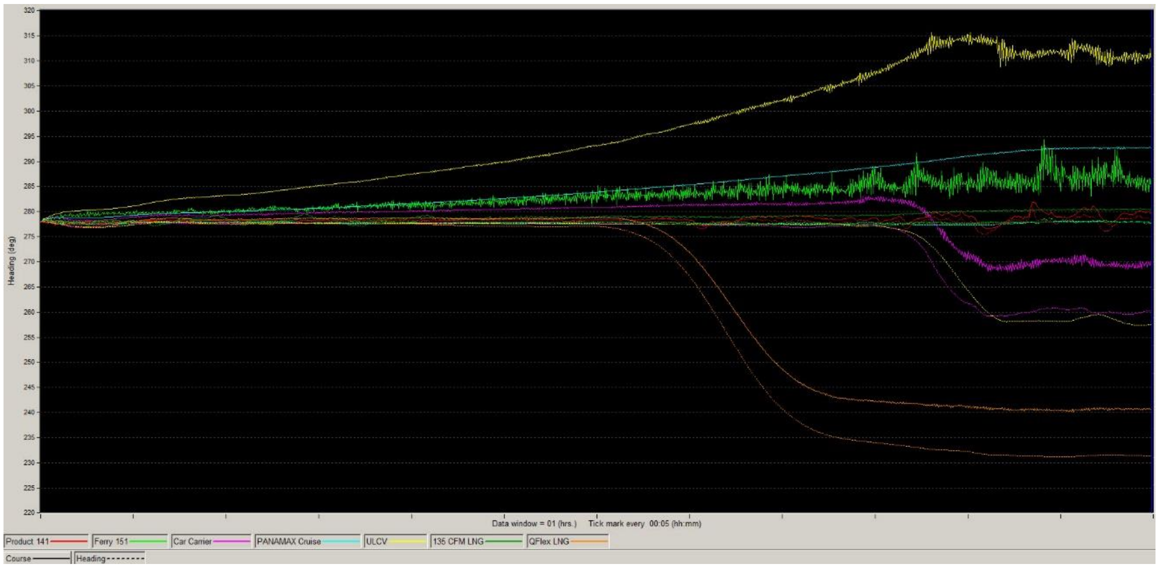
Figure 83: JDF TSS Course Holding Test 7_1 Group 3 Wind 247° RPM Graph

5.1.3.2 Sailing/Proceeding with Wind from Astern (Downwind)

When proceeding with the wind (wind from stern hemisphere), at a Dead Slow Ahead telegraph setting, the automobile carrier and the QFLEX LNG experienced wind induced rotation and lost steering control when the wind velocity exceeded 30 knots. The PANAMAX Cruise Ship and the 151-metre Ferry experienced moderate later drift at wind speeds above 30 knots, and the Ultra Large Cruise Ship experienced excessive lateral drift. See Figures 84 and 85 below:

Figure 84: JDF TSS Heading Holding Test 10 Group 3 Wind 143° Dead Slow Ahead Track-plot

Figure 85: JDF TSS Heading Holding Test 10 Group 3 Wind 143° Heading and Course Graph



At a Half Ahead telegraph setting all vessels in this group maintained heading control, and only the Ultra Large Cruise Vessel experienced moderate lateral drift. For these tests the associated transit speeds ranged from 9.5 to 12.7 knots. See Figures 86 and 87 below:

Figure 86: JDF TSS Heading Holding Test 16 Group 3 Wind 143° Half Ahead Track-plot Zoom

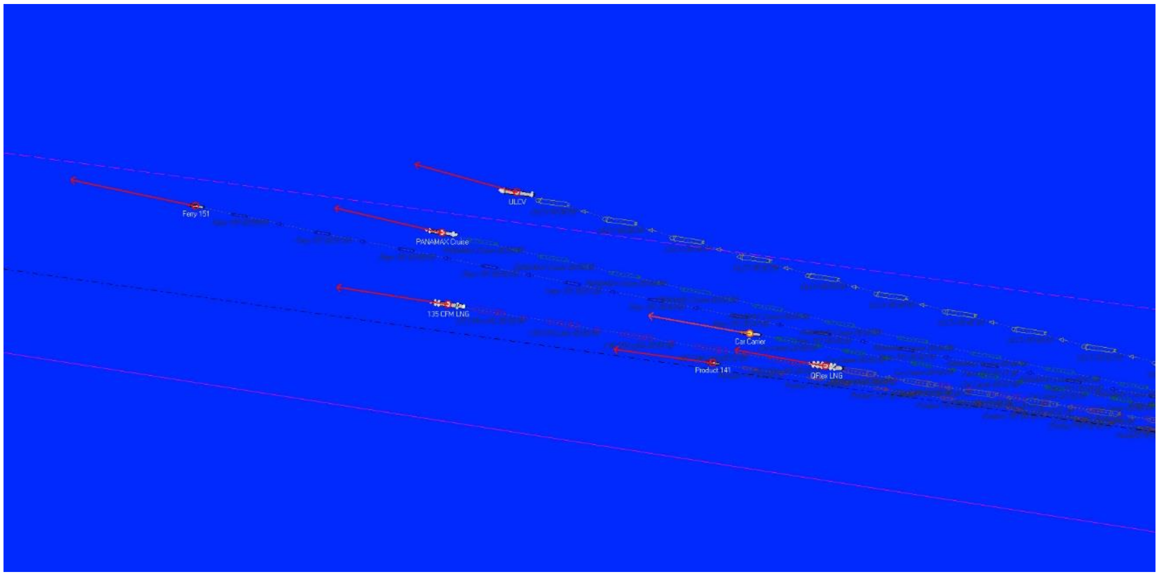
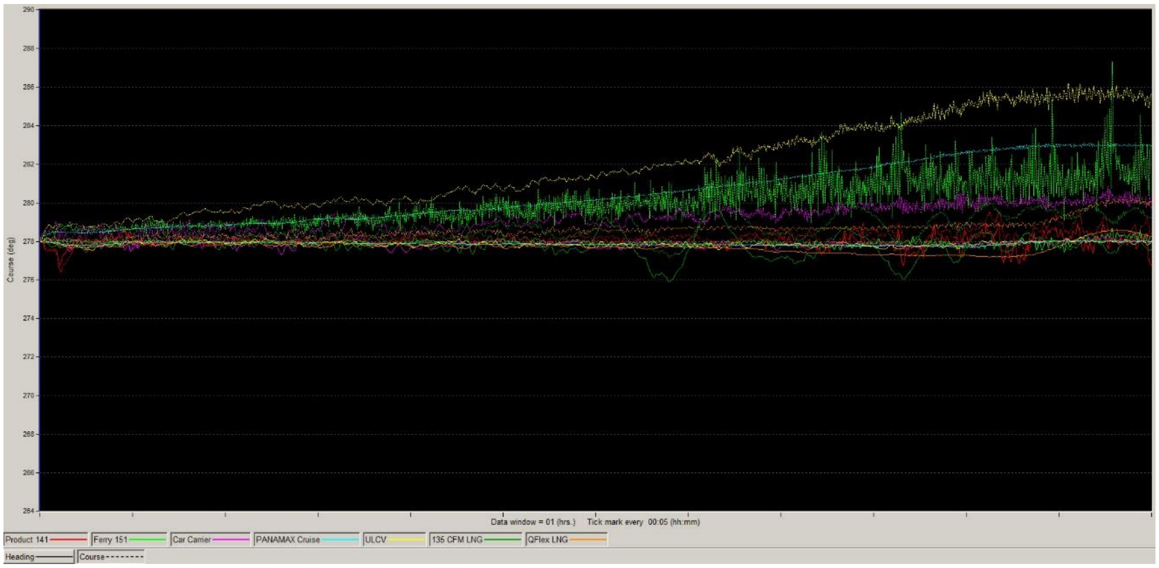


Figure 87: JDF TSS Heading Holding Test 16 Group 3 Wind 143° Heading and Course Graph



Based on the results of the baseline tests, a validation test was conducted with the engine telegraph setting for all vessels set to 8 knots, and the ships adjusted their heading as needed to achieve the 278° course/track-line. At these speed settings, all vessels maintained their course at wind speeds up to 40 knots. See Figures 88 to 90 below:

Figure 88: JDF TSS Course Holding Test 16_1 Group 3 Wind 143° Speed 8 Track-plot Zoom

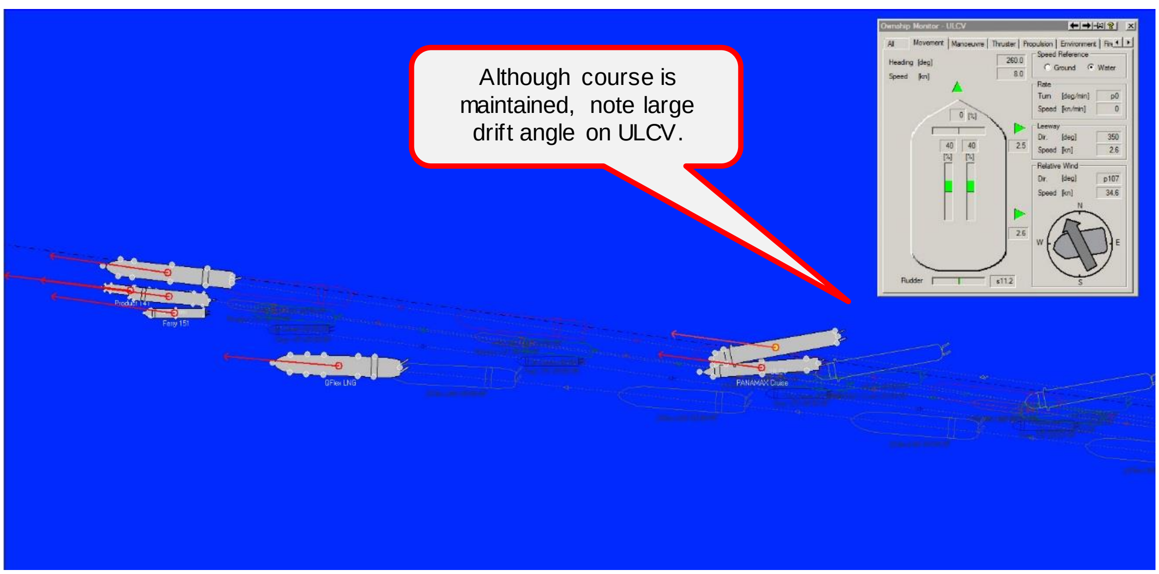


Figure 89: JDF TSS Course Holding Test 16_1 Group 3 Wind 143° Speed 8 Heading and Course Graph

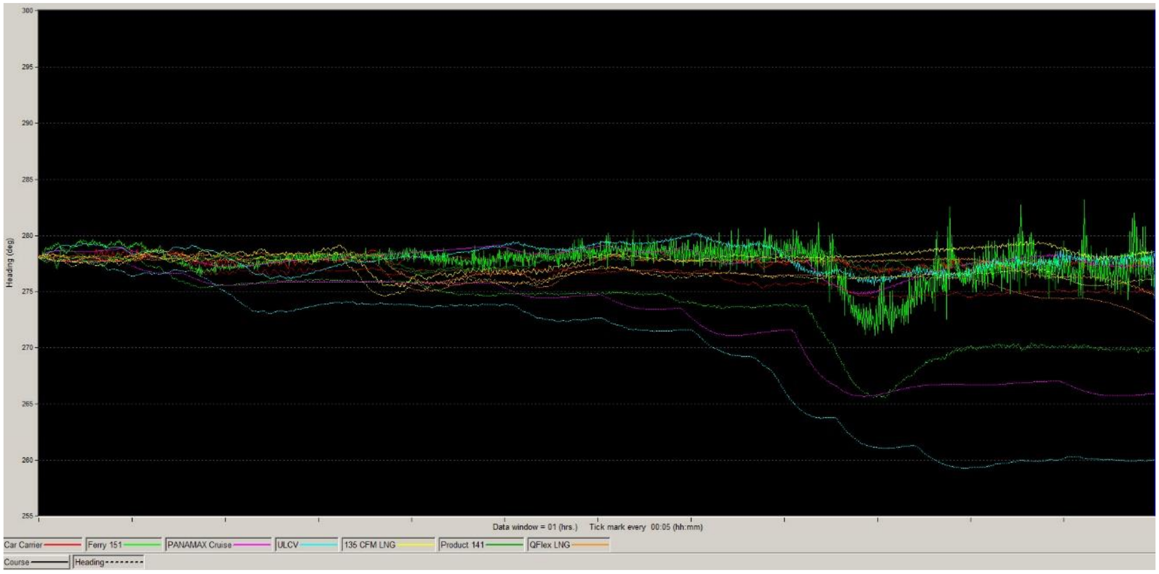
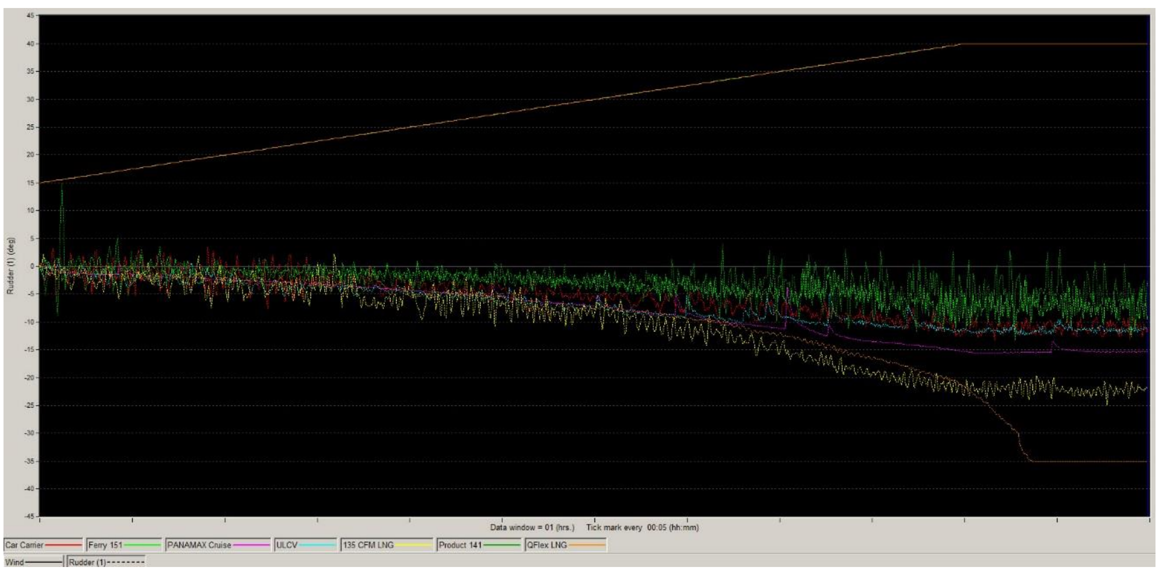


Figure 90: JDF TSS Course Holding Test 16_1 Group 3 Wind 143° Speed 8 Wind and Rudder Comparison



5.1.4 Detailed Observations on Alterations of Course

As a final step in verifying the ability to maintain steering and positional control, two tests were conducted using the eight vessels that had proven to be most prone to wind induced rotation and drift. For these tests, the wind speed was set to a constant 30 knots from a direction of 132° (prevailing winter direction) and the vessels had to conduct the course alterations in the TSS from the 210° track around Rack Rocks to the 278° track. One manoeuvre was conducted at maximum ebb tide, the other at maximum flood. In all cases the initial engine telegraph setting was set for 8 knots, and vessels used temporary increases in propulsion power (RPM or Pitch) as needed to maintain steering control. All of the vessels were able to maintain the intended route, and average water speeds ranged from 7.3 (QFLEX) to 9.6 knots (PANAMAX Container). See Figures 91 to 94 below:

Figure 91: JDF TSS Course Alteration Test 19 Flood Tide Wind 132° Speed 8 Track-plot

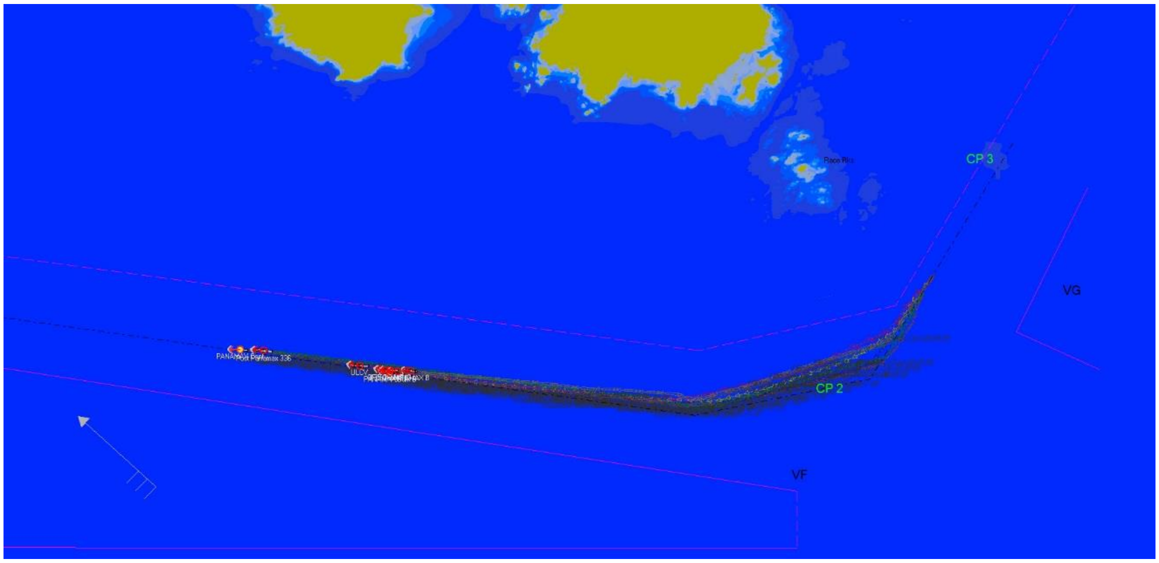


Figure 92: JDF TSS Course Alteration Test 19 Flood Tide Wind 132° PANAMAX Container Speed and Rudder Graph

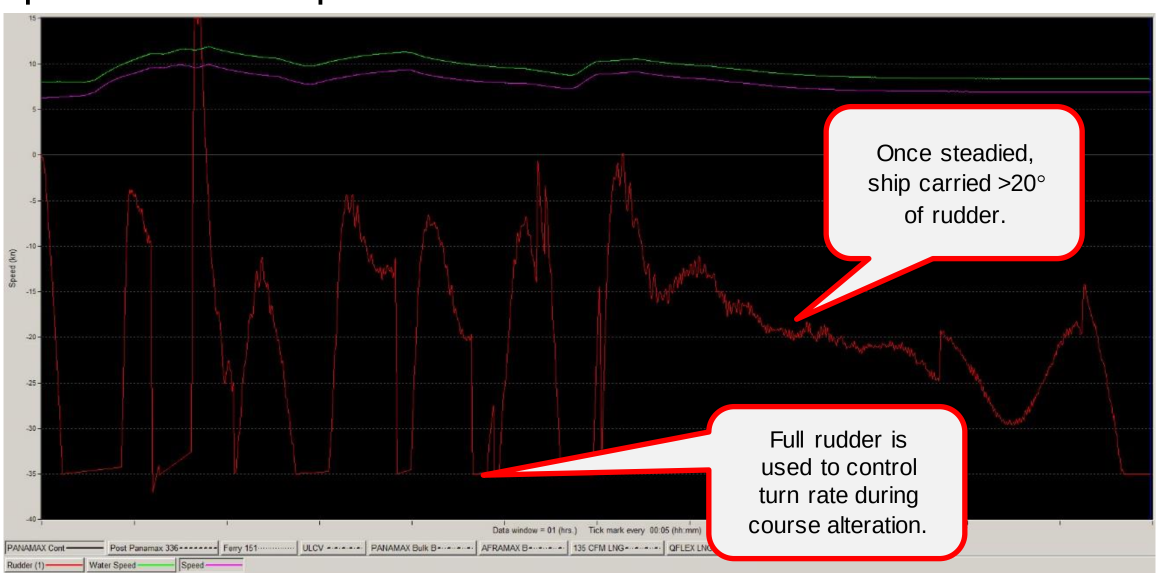


Figure 93: JDF TSS Course Alteration Test 20 Ebb Tide Wind 132° Speed 8 Track-plot

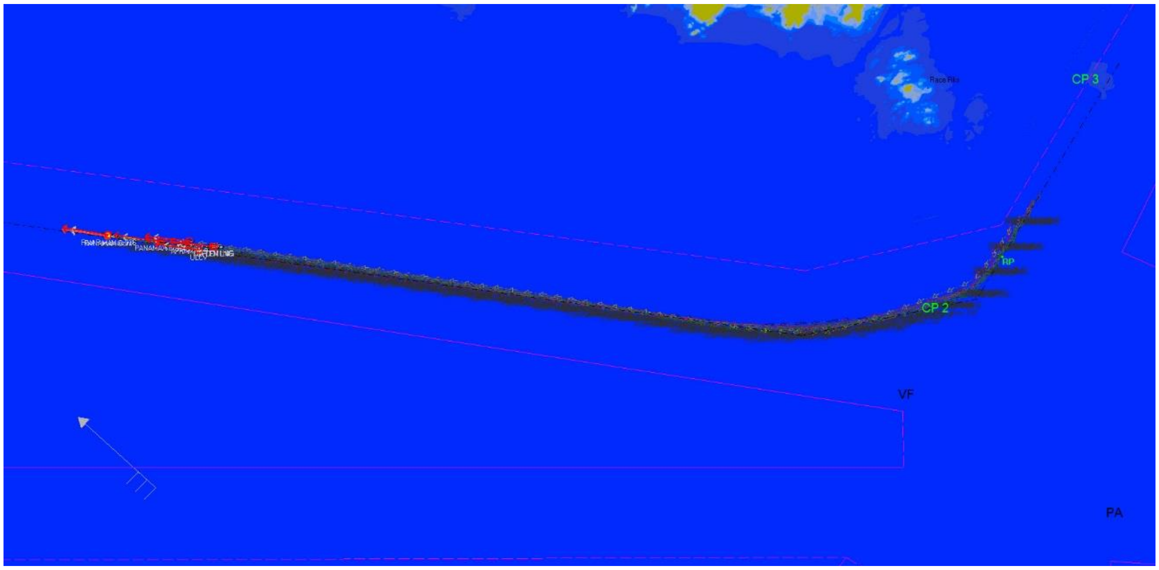
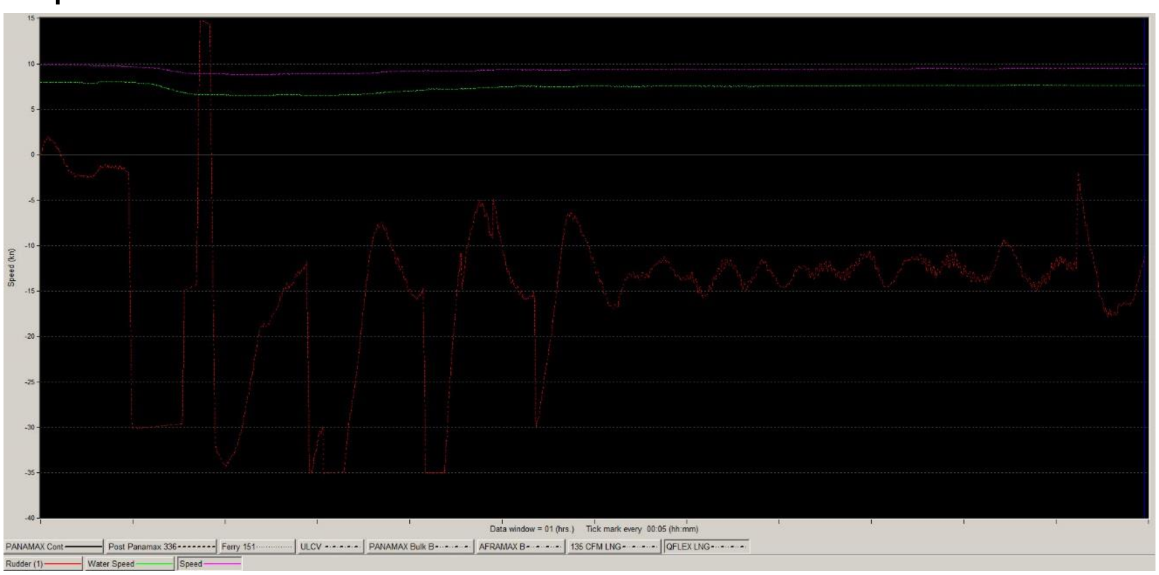


Figure 94: JDF TSS Course Alteration Test 19 Ebb Tide Wind 132° QFLEX Speed and Rudder Graph



5.1.5 Detailed Observations on Effects of Linear Tidal Streams

Test results from runs that included tidal stream (current) in both ebb and flood directions demonstrated that it had little effect on a vessel's ability to maintain steering control. In the Juan de Fuca TSS, the tidal flows tend to be quite linear and homogeneous in direction and the predominate effect is to either increase or decrease vessel ground speed dependent upon whether the ship is stemming the tide (travelling in the opposite direction to the tidal flow) or running with the tide (travelling in the same direction as the tidal flow). The only real exception to this was in the case of the high windage vessels proceeding at low speed into the wind where the large wind induced drift angle could be further augmented when stemming the tidal stream. See comparison track-plots in Figures 95 to 98 below of track history with slack tide versus maximum ebb and maximum flood.

Figure 95: JDF TSS Heading Holding Test 7 Group 2 – Slack Tide Track-plot Zoom

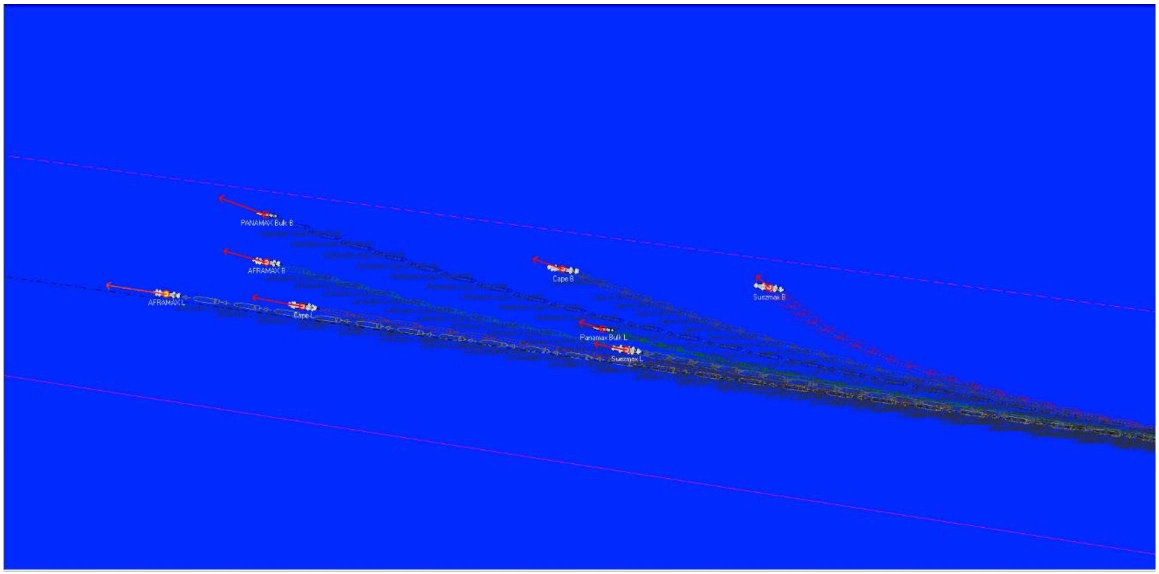


Figure 96: JDF TSS Heading Holding Test 8 Group 2 – Flood Tide Track-plot Zoom

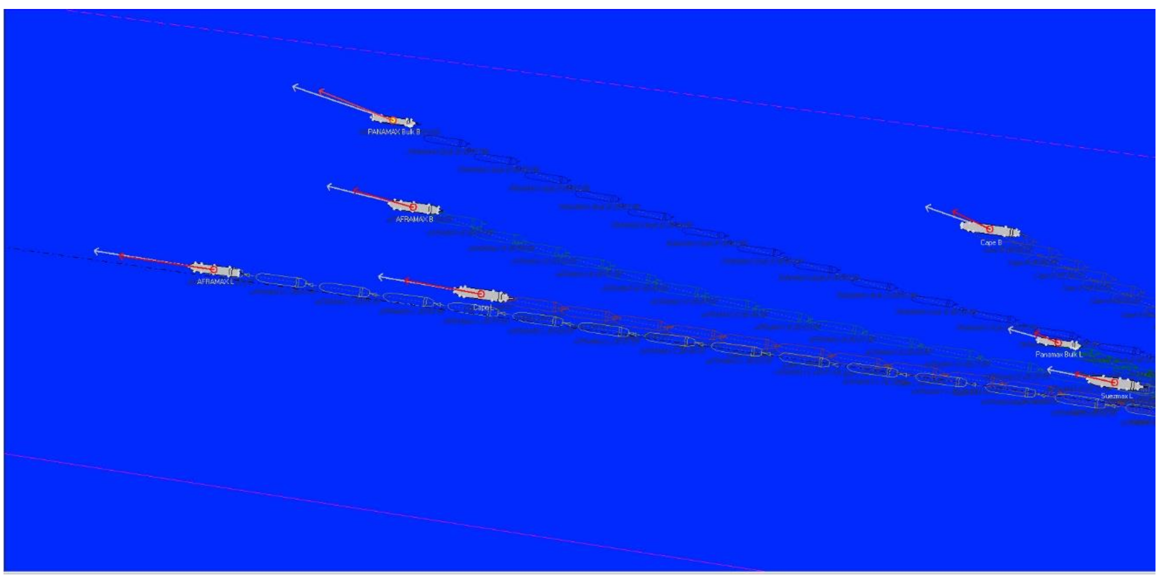


Figure 97: JDF TSS Heading Holding Test 8 Group 2 – Flood Tide Track-plot Zoom_2

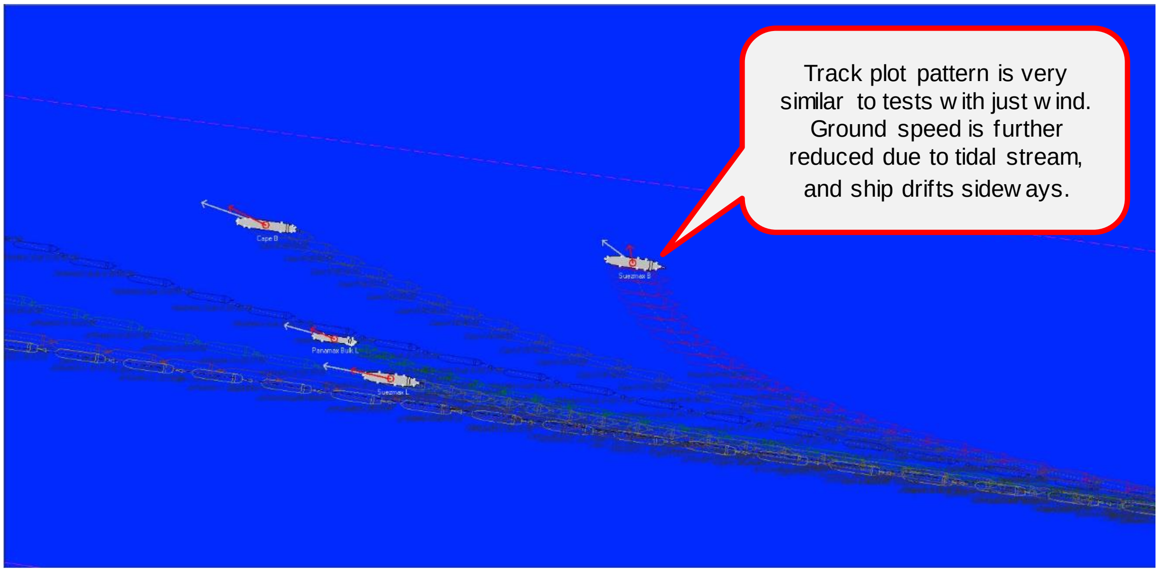
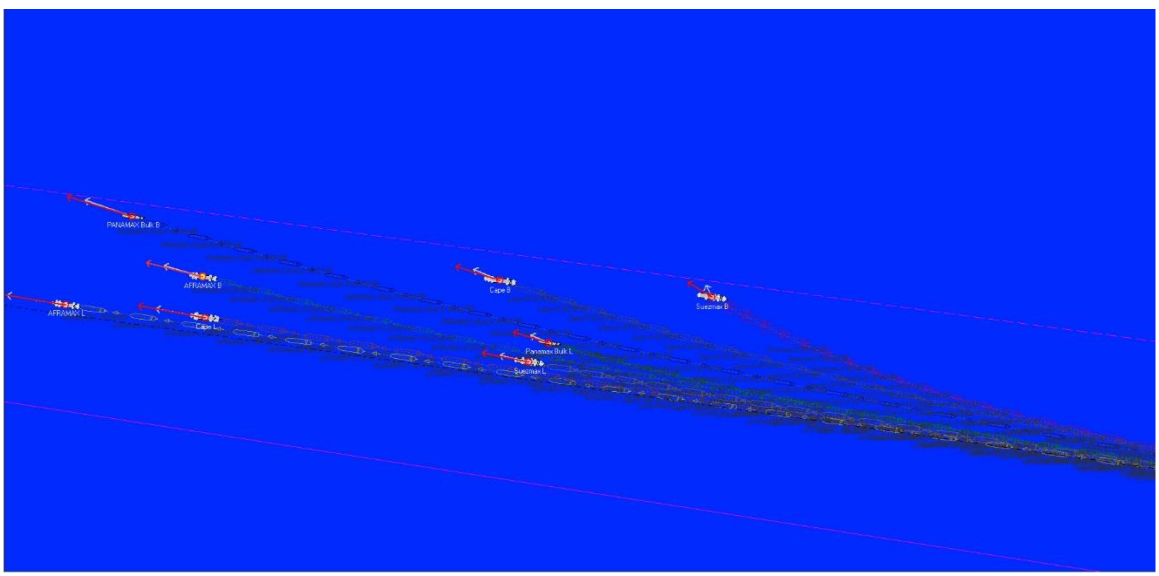


Figure 98: JDF TSS Heading Holding Test 9 Group 2 – Ebb Tide Track-plot Zoom



5.2 Observations Derived from Tests of Anticosti TSS

Given that the Anticosti TSS is located in a strait that is even more open than Juan de Fuca, with wider traffic lanes that are further from the shoreline, the range of vessel types and the traffic volume is lower. This area did not require/warrant a large amount of additional testing with the exception of the area specific effects of the prevailing winds, and the validation of vessel course holding/course alteration thresholds.

5.2.1 Observations on Prevailing Winds and Course Holding – Inbound Vessels

The prevailing winds in this area are westerly, and winds with the velocities above 20 knots also tend to originate most frequently from the west. Given that the two main traffic lanes are oriented approximately 297° and 117° this means that high sided vessels proceeding inbound will have the prevailing winds at approximately 30° on the port bow. Tests in Juan de Fuca illustrated that at speeds below 8 knots, with strong winds 30° on the bow, many high sided vessels suffered loss of water speed unless propeller RPM were increased.

Tests in the Anticosti TSS showed that if the ships set their engine Telegraph to the position that gave propeller RPM as close as possible for 8 knots (generally Slow Ahead), when wind speeds exceeded 30 knots, all vessels experienced a noticeable reduction in water speed. In the case of the ballasted QFLEX LNG, and the ballasted Cape Size Bulk Carrier, the water speed fell below 4 knots. All vessels were however able to maintain course. See Figures 99 and 100 below:

Figure 99: Anticosti Test 1 Trackplot – Wind on Bow, Constant Propeller RPM at Slow Ahead

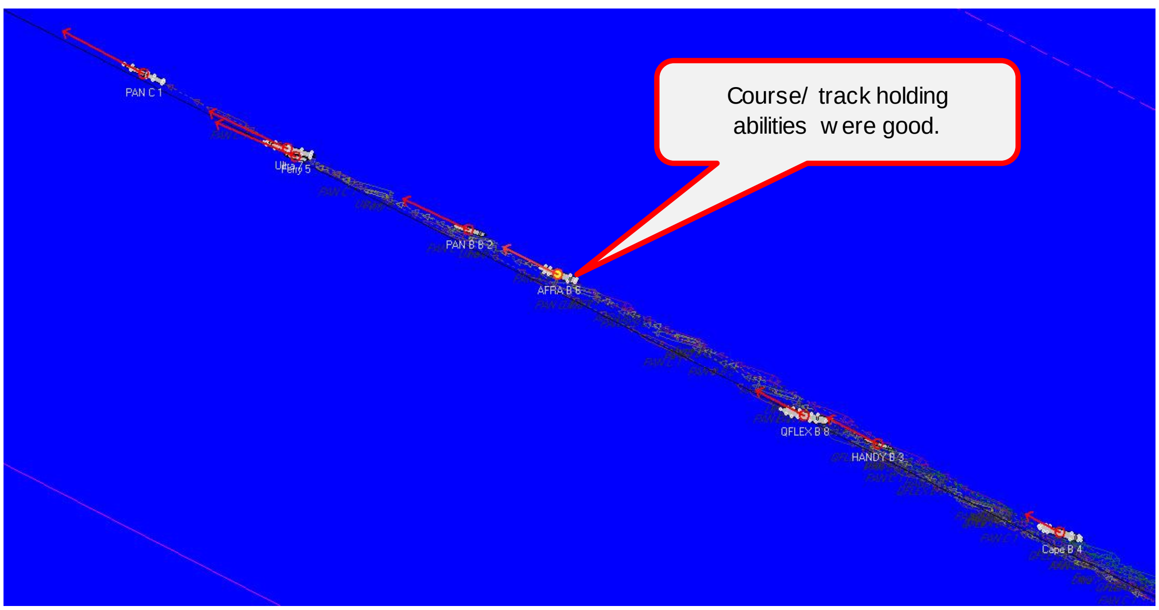
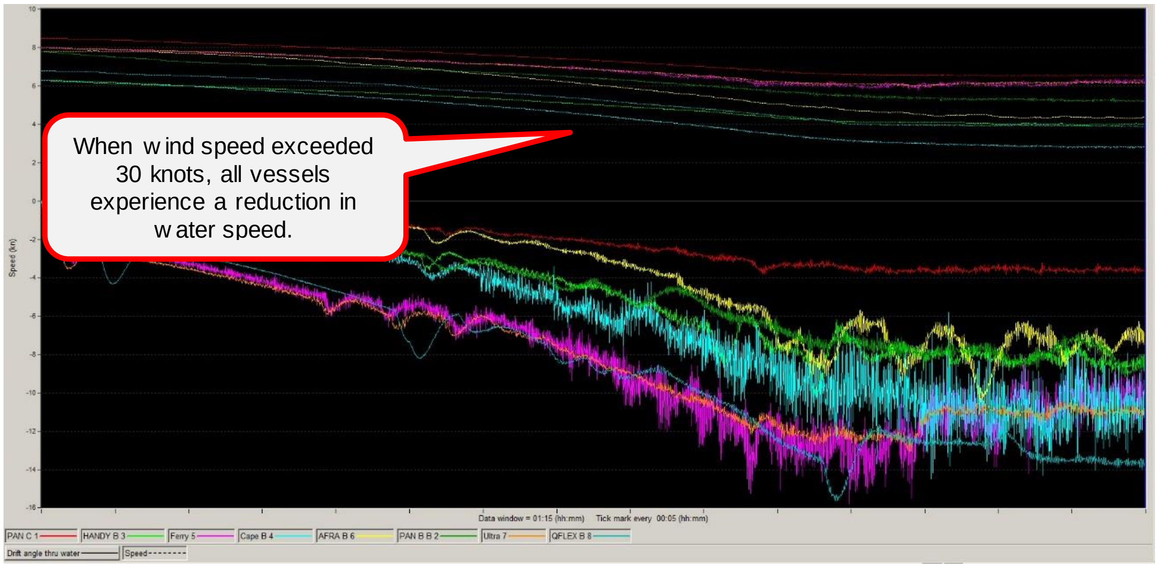


Figure 100: Anticosti Test 1 Speed and Drift Angle – Wind on Bow, Constant Propeller RPM



In a follow-on test, when the vessels started to experience wind induced speed loss, engine RPMs were progressively increased to determine how much of a RPM increase would be needed to maintain a transit speed in the range of 8 knots. It can be seen in the graph in Figure 101 that the ballasted Panamax Bulker, the ballasted Cape Size bulker, and the ballasted QFLEX, all required kicks of Half Ahead to sustain transit speed once the wind speed exceeded 25 knots. With wind speeds above 35 knots, the Cape Size and Panamax Bulkers were operated primarily at a Half Ahead telegraph setting. The ballasted AFRAMax and the QFLEX alternated between Slow and Half Ahead settings. It can be seen in Figure 102 that even with increases in propeller speed, the vessels' transit speeds remain below 8 knots. Figure 103 shows that the speed range, and distance covered by all vessels was much closer in this test than in the previous one.

Figure 101: Anticosti Test 2 – Propeller RPM Settings

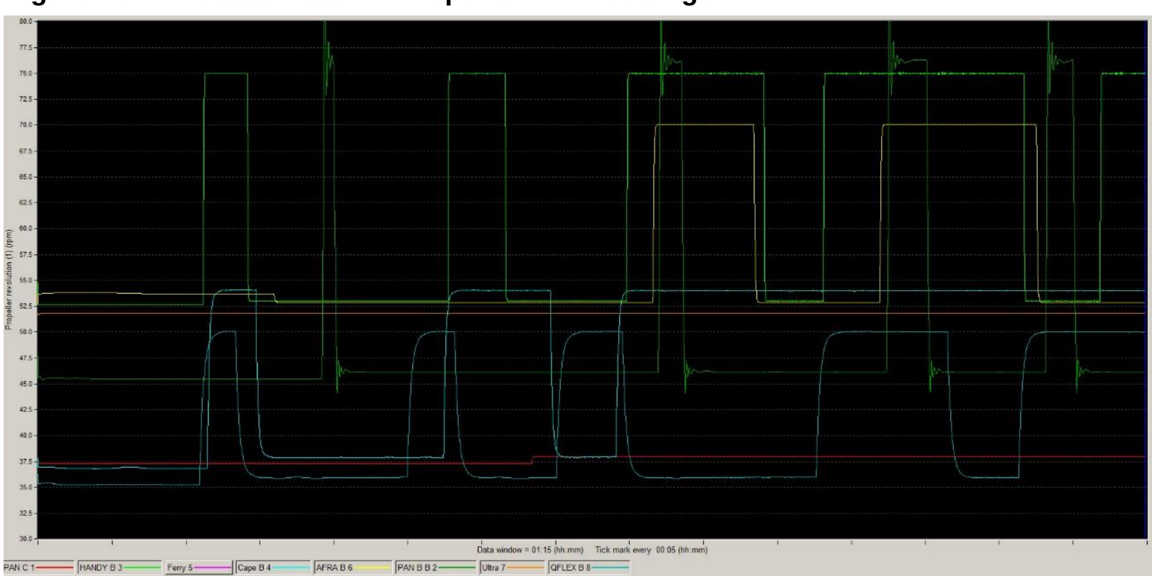
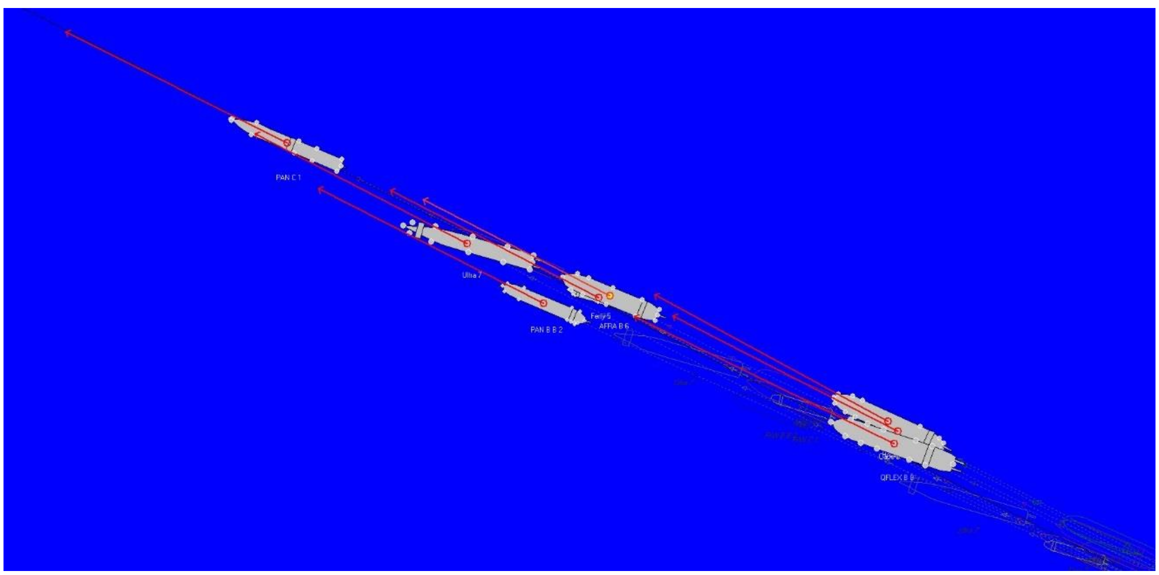


Figure 102: Anticosti Test 2 – Vessel Transit Speeds

Figure 103: Anticosti Test 2 – Vessel Trackplot Zoom



The second transit element that was examined during the Anticosti analysis was the ability to conduct a low speed course alteration with a wind from astern on the initial course, followed by the wind being on the inside quarter of the ship when coming out of the turn. The portion of the TSS lanes that is designed to route ships into the St-Lawrence River runs approximately 275°/ 095°; this means that ships outbound from the St-Lawrence will have the wind from nearly directly astern. They will then have the wind on the starboard quarter as they come out of the turn into the main portion of the TSS which runs at an angle of 117°. Two tests were conducted in this position, both with winds from 270° at 30 knots. It was noted that most of the ships with the following wind of 30 knots were accelerated by the wind with resultant water/ground speeds that were more than 0.5 knots above the default propeller RPM set speed. With the following wind, steering and positional control, they were very good with minimum drift angle. Also, with the following wind, it was easy to initiate the turn to starboard with only a small application of rudder. For the first test, the engine Telgraphs were set for a speed close to 8 knots (generally

Slow Ahead) with the plan to maintain constant RPM unless heading control was lost. When steadying onto the 117° track however, the ballasted QFLEX and the Ultra Large Cruise with full port rudder applied overshot the desired 117° heading and in order to arrest the turn rate both required kicks of Half Ahead on the engine telegraph. See Figures 104 and 105 below:

Figure 104: Anticosti Test 3 – Vessel Trackplot Zoom

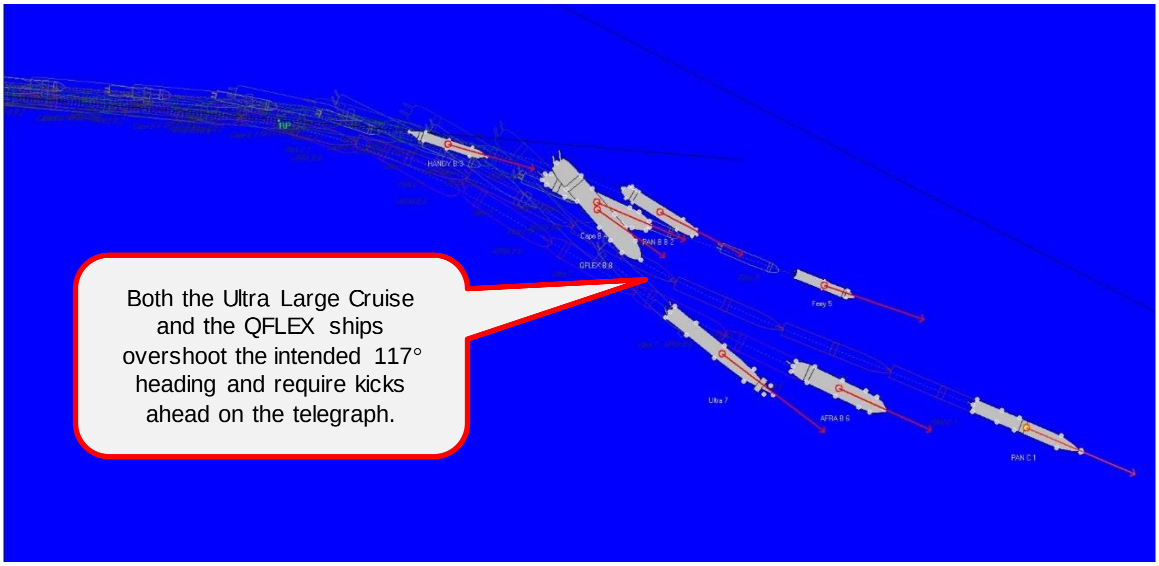


Figure 105: Anticosti Test 3 – RPM and rudder Graph QFLEX and Ultra Large Cruise

A final test was conducted where all ships set propeller RPM/ Pitch for a water speed of 10 knots to determine if this would facilitate steadying onto the 117° track with the 30-knot wind on the quarter. In this case, all vessels steadied onto the 117° track without difficultly, and even the QFLEX and Ultra Large Cruise only required 20° of port rudder to arrest their starboard turn rate, and they did not over shoot their course. See Figures 106 to 108 below:

Figure 106: Anticosti Test 4 – Applied Rudder Angle

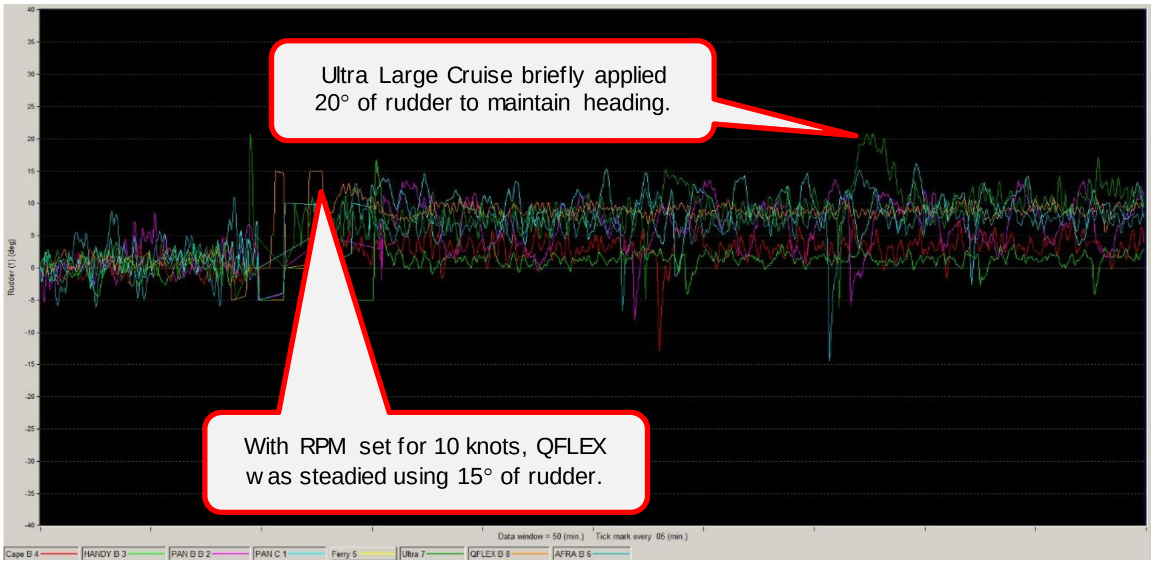


Figure 107: Anticosti Test 4 – Resultant Vessel Speed

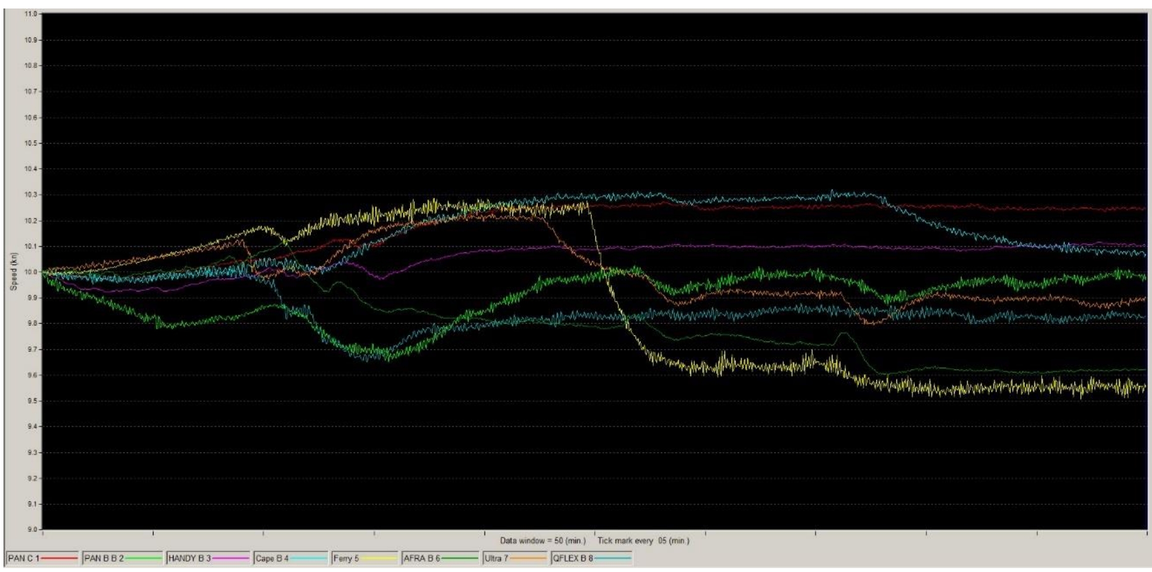
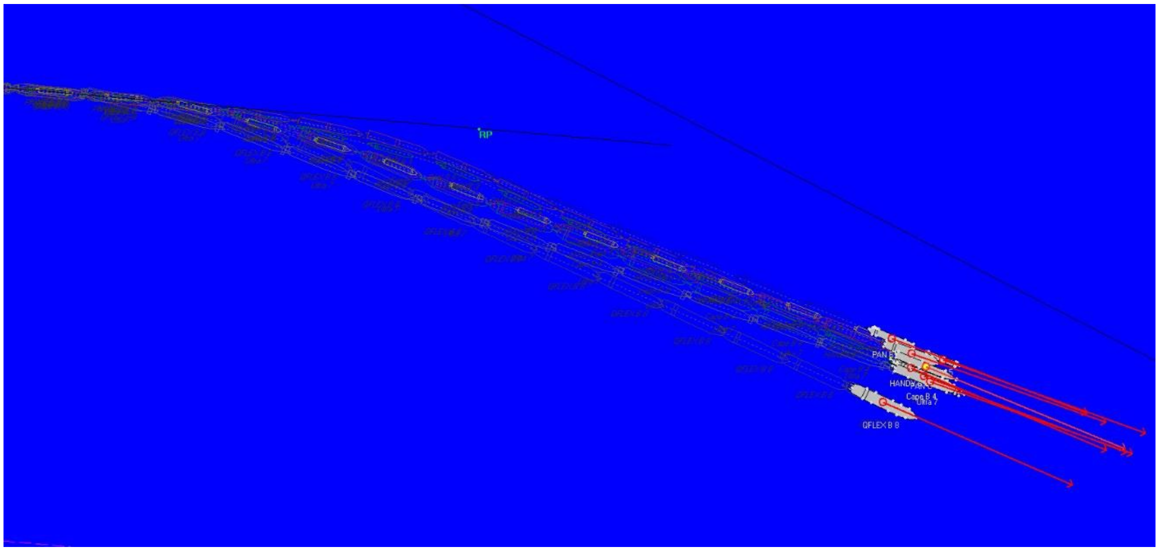


Figure 108: Anticosti Test 4 – Trackplot Zoom



5.3 Observations Derived from St-Lawrence/ Saguenay Pilotage Area

Important findings from this phase of the analysis, above and beyond those of the Juan de Fuca and Anticosti TSS analysis, related to the behaviour of a broad range of ships (both with fine and full hull form, high windage areas, etc.) in an area with very complex tidal stream and river current patterns. Once the effect of tidal flow on vessel control during low speed transits were established, wind tests were combined with worse case tidal flow conditions, building on findings from the previous phases. As will be explained in the Sections that immediately follow, wind effects remain a very significant factor in the ability to maintain low speed steering and positional control.

5.3.1 Detailed Observations on Test Vessel Group 1 (Fine Hull Form Ships)

In general, this group of vessels steered well in the current and tidal stream as they have good directional stability and are somewhat less prone to tidal sheer than full form vessels. From a design perspective however, this category of ship is generally intended to operate at higher speeds. This is particularly true of container vessels, many of which have top speeds of 24 knots or more, and often Dead Slow Ahead speeds of more than 7 knots. As a result, the steering forces generated by their rudders and propellers at Dead Slow and even at Slow Ahead settings in some vessels are not that great relative to the ship size.

5.3.1.1 Steering and Positional Control in Current

In general, this group of vessels had good directional stability, and their steering behaviour in current, (without strong winds) was predictable even at water transit speeds in the 8 to 10 knot range. The rudders on these vessels also provided sufficient steering forces to counter current sheer (rotation) effects. Although full rudder was used on occasion, this was generally to check current sheer (rotation) effects and was for a brief period of time. See Figure 109 to 1116 below:

Figure 109: Test Group 1 Track-plot: Downriver with Maximum Ebb

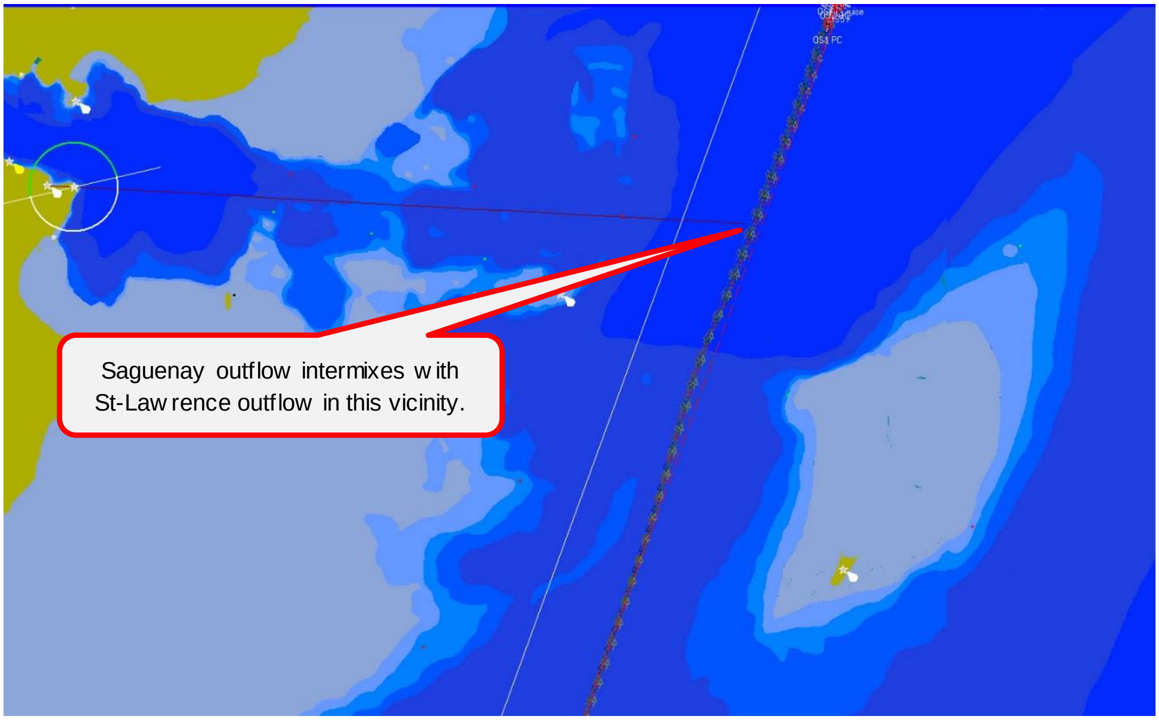


Figure 110: Test Group 1 Applied Rudder Graph: Downriver with Maximum Ebb

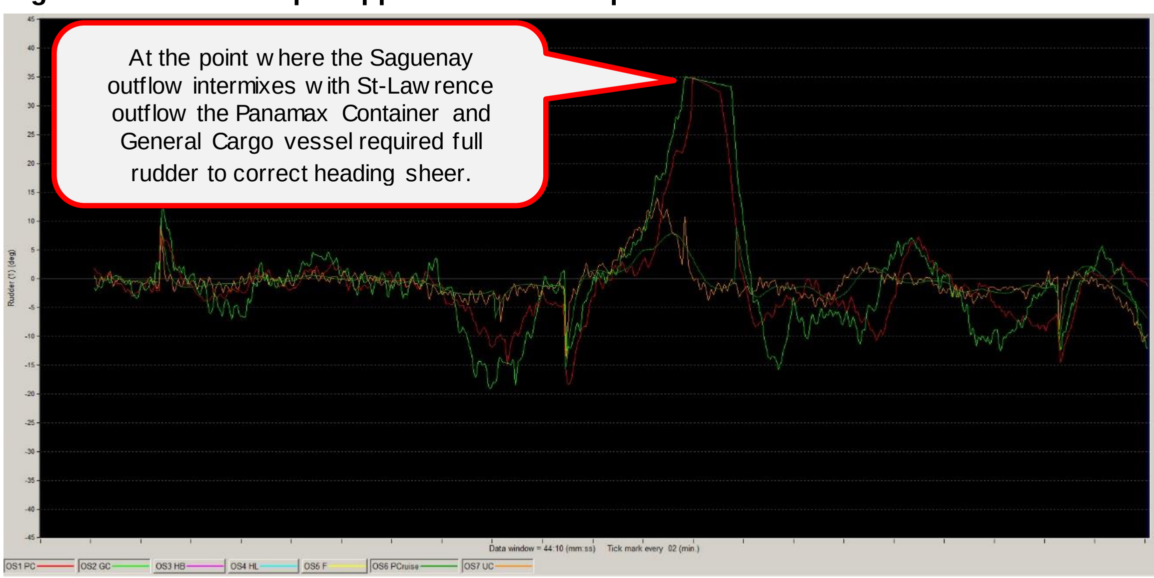


Figure 111: Test Group 1 Track-plot: Upriver with Maximum Ebb

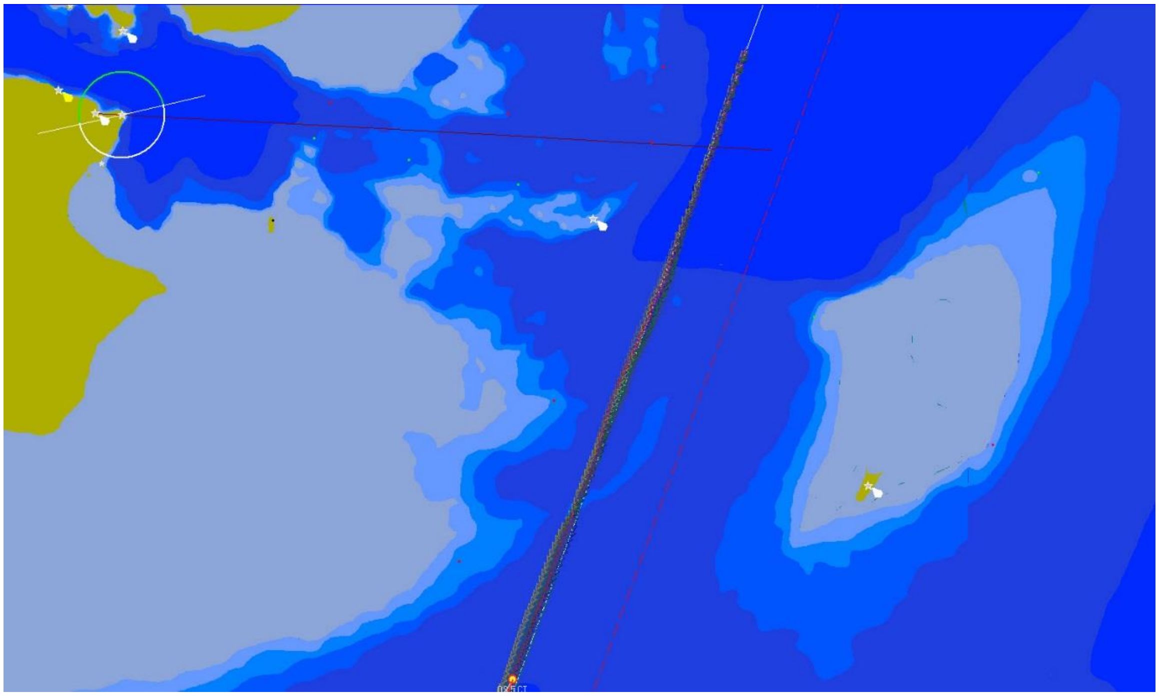


Figure 112: Test Group 1 Applied Rudder Graph: Upriver with Maximum Ebb

Figure 113: Test Group 1 Track-plot: Downriver with Maximum Flood

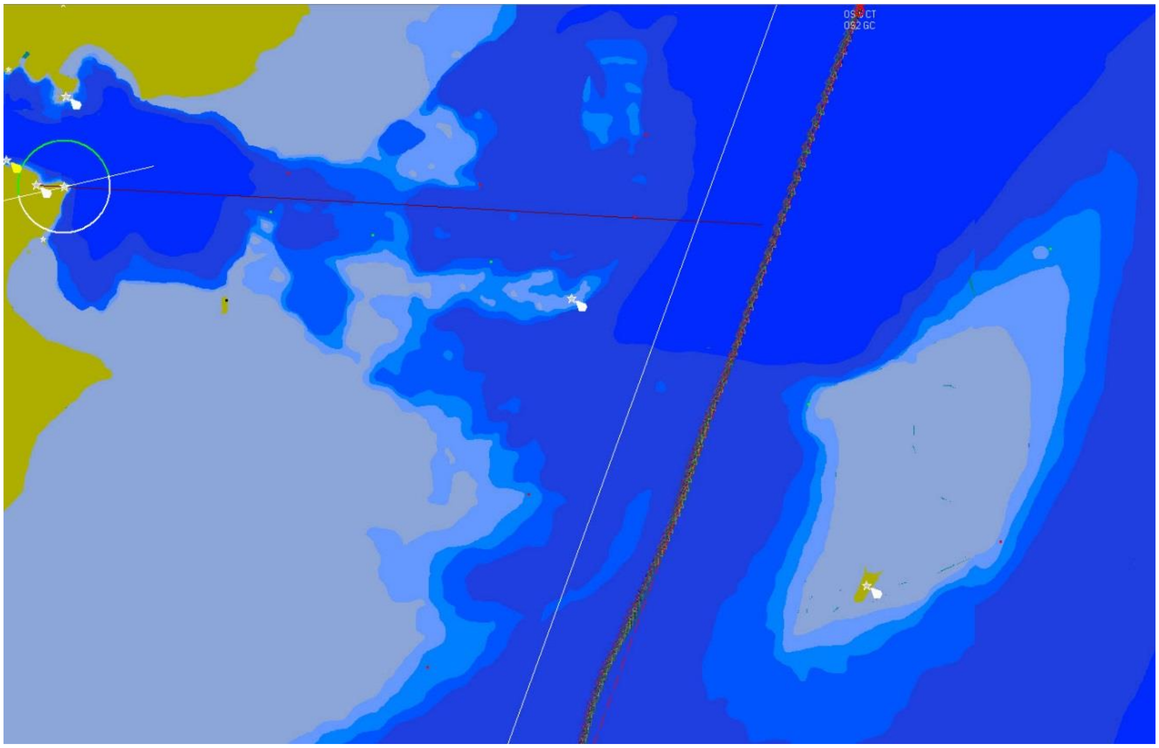


Figure 114: Test Group 1 Applied Rudder Graph: Downriver with Maximum Flood

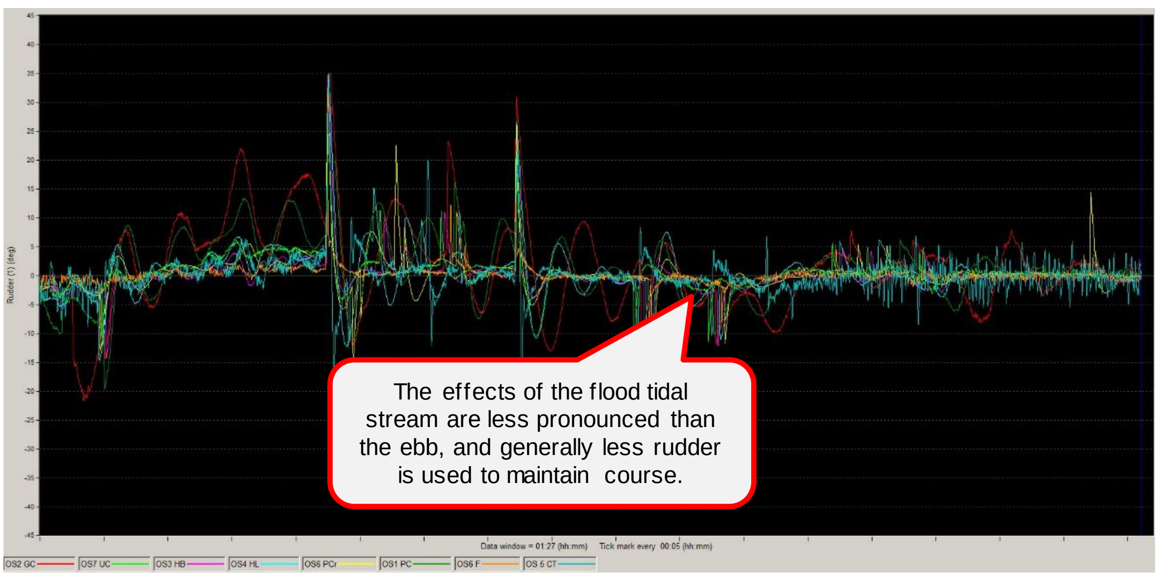


Figure 115: Test Group 1 Track-plot: Upriver with Maximum Flood

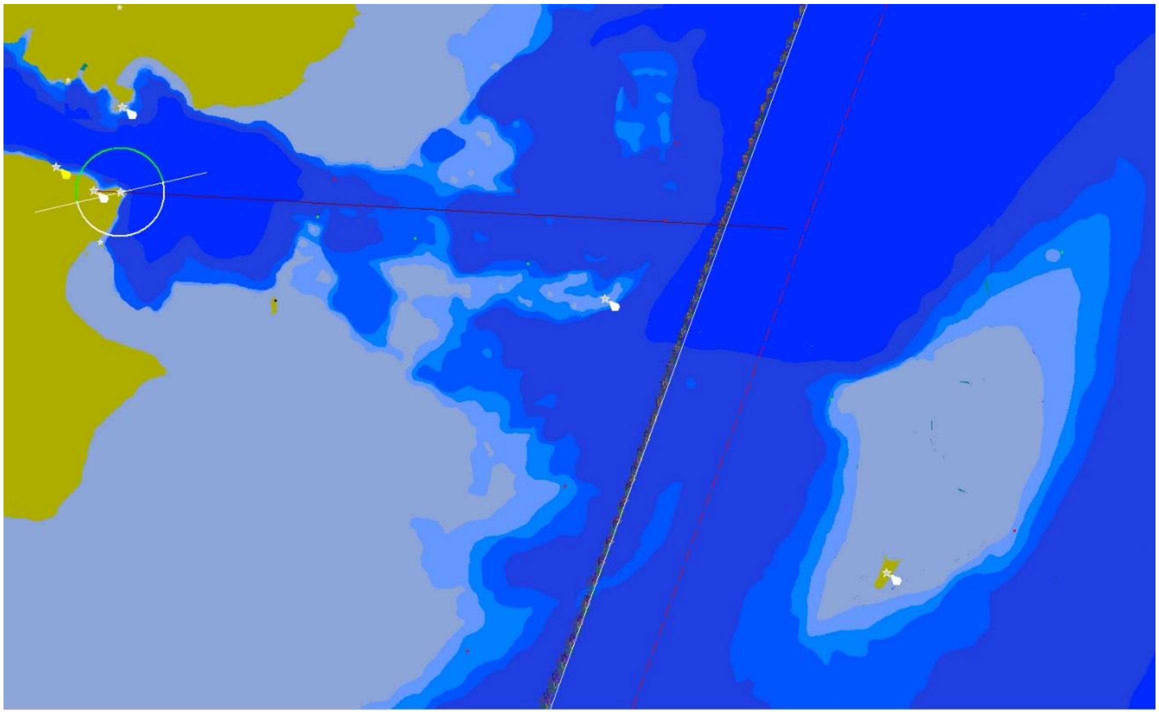
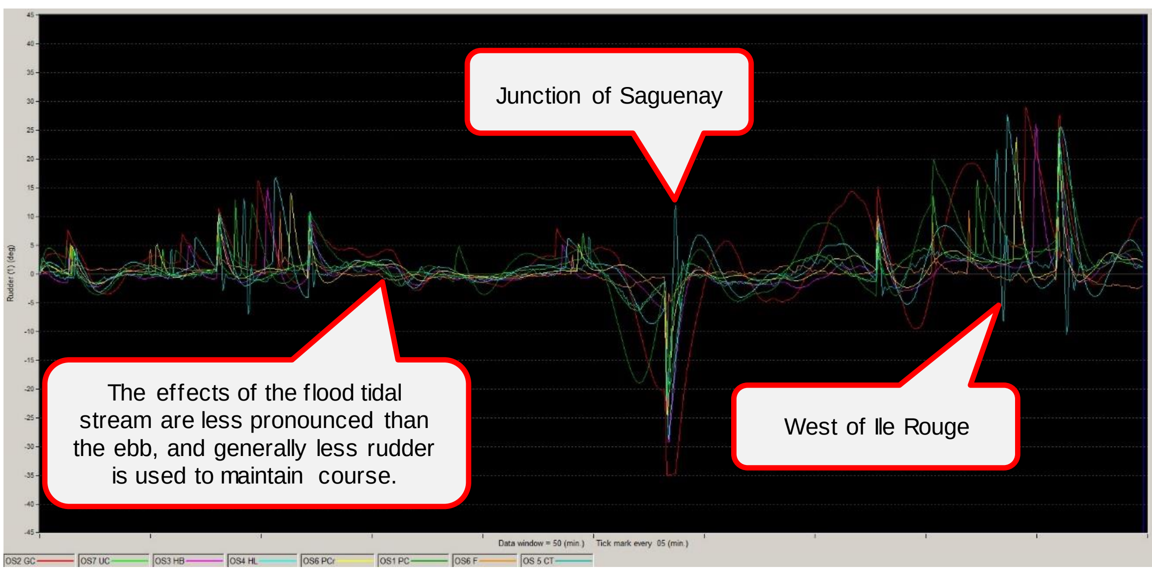


Figure 116: Test Group 1 Applied Rudder Graph: Upriver with Maximum Flood



5.3.1.2 Steering and Positional Control in Strong Winds

Observations in these tests were quite consistent with that of the TSS in that the high sided vessels in this group are prone to wind induced rotation and drift. With winds on the quarter all vessels carried more rudder to maintain the ordered heading. When proceeding downriver with maximum ebb tide, and winds of 30 knots on the quarter (245° True) all ships were able to maintain an acceptable level of steering and positional control albeit the Ultra Large Cruise Ship and PANAMAX Container were often carrying 35° of rudder and the General Cargo vessel was frequently carrying more than 20° of rudder. See Figures 117 and 118 below:

Figure 117: Test Group 1 Track-plot: Downriver with Maximum Ebb – Wind 245°@30 knots

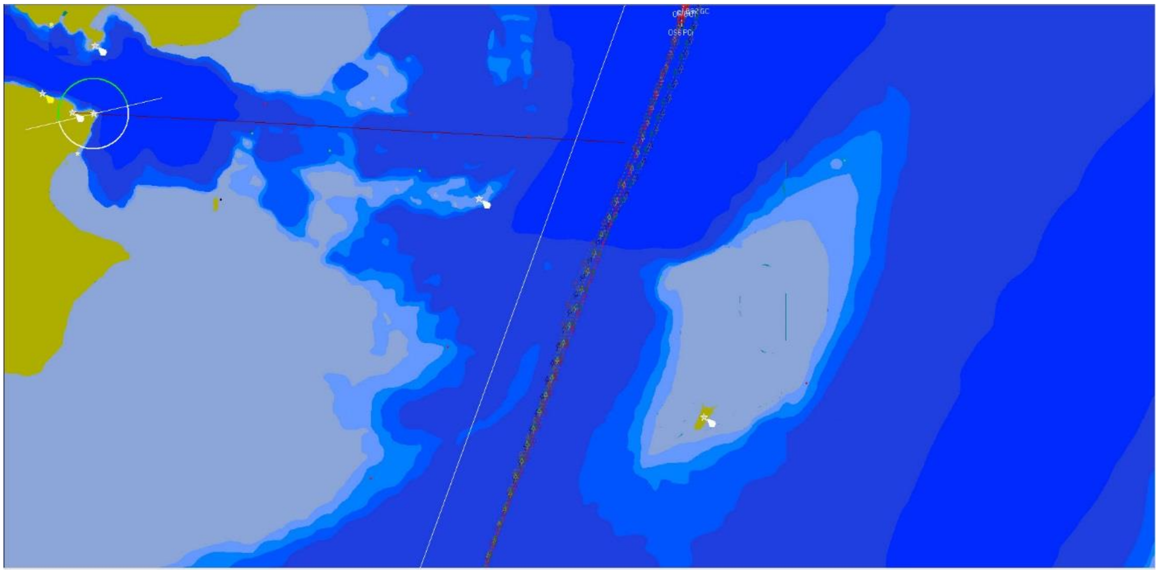
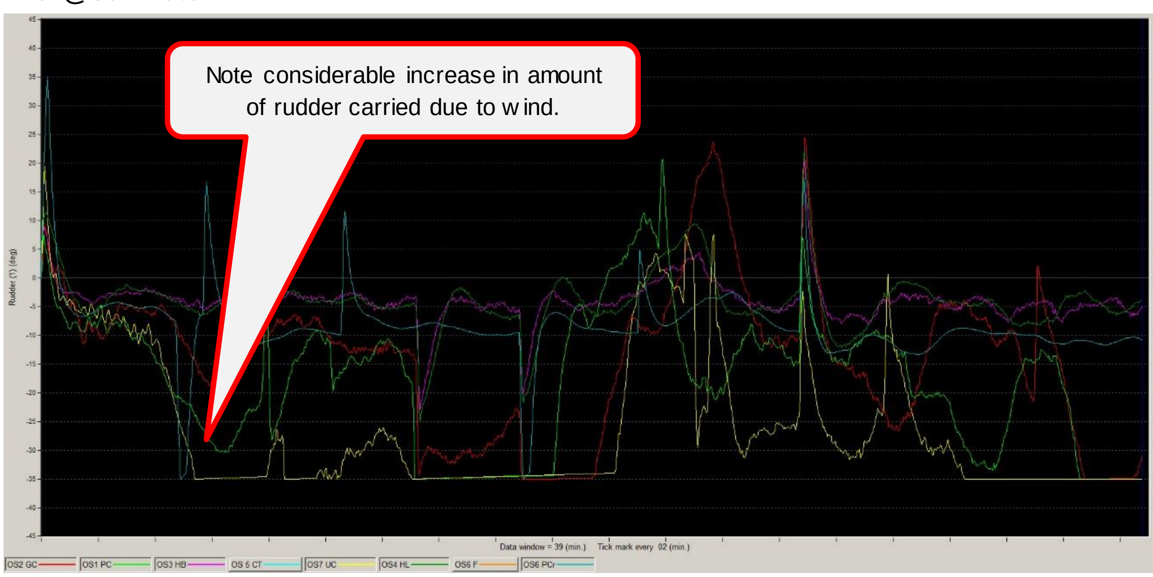


Figure 118: Test Group 1 Applied Rudder Graph: Downriver with Maximum Ebb - Wind 245°@30 knots



When proceeding upriver against maximum ebb tide with the wind from 315° at 30 knots, the Ultra Large Cruise Ship, PANAMAX Container, and General Cargo vessel experienced loss of steering control at a transit speed of 8 knots when east of Haut Fond Prince Lighthouse and required kicks ahead of Full and Half Ahead respectively in order to arrest a combined wind and current induced sheer to starboard. Even at transit speed of 10 knots these two ships still needed to increase propeller RPMs in order to arrest combined wind and current induced drift. It was not until the wind speed was reduced to 25 knots that these vessels were able to maintain acceptable steering and course control at a water transit speed of 10 knots. See Figures 119 to 121 below:

Figure 119: Test Group 1 Rudder Order: Upriver/Maximum Ebb/Wind 315°@30 knots Speed 8

Figure 120: Test Group 1 Track-plot_1: Upriver/Maximum Ebb/Wind 315°@30 knots/Speed 8

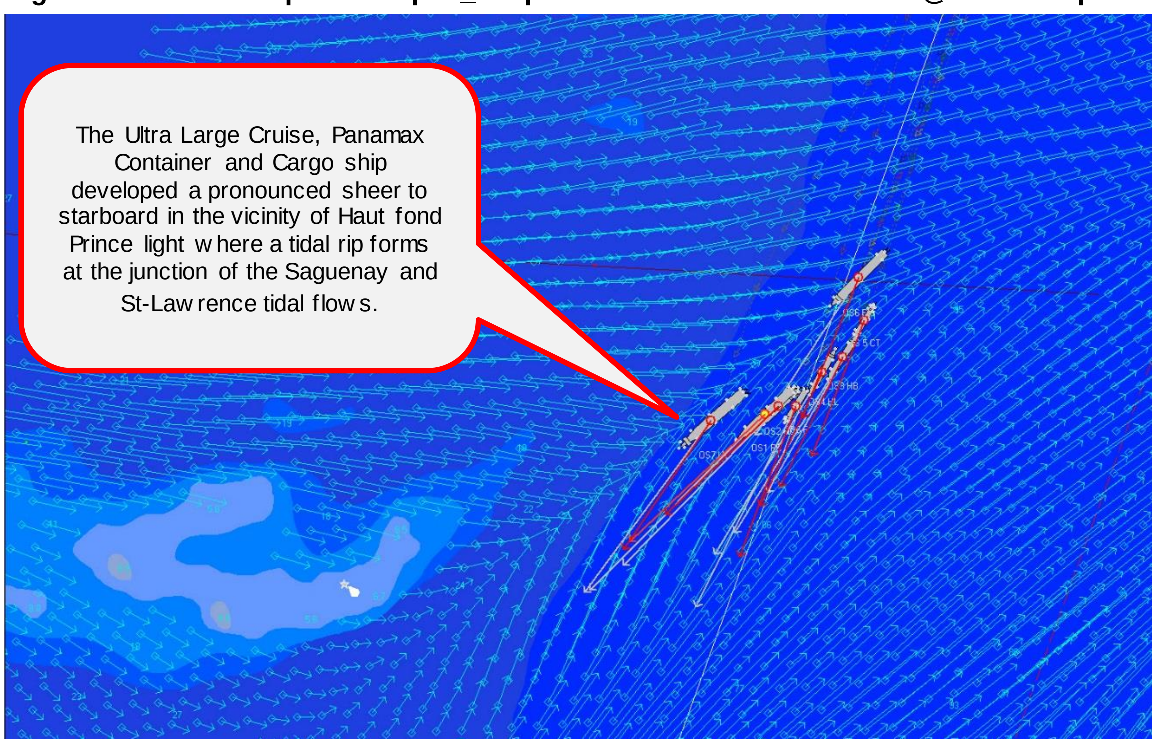
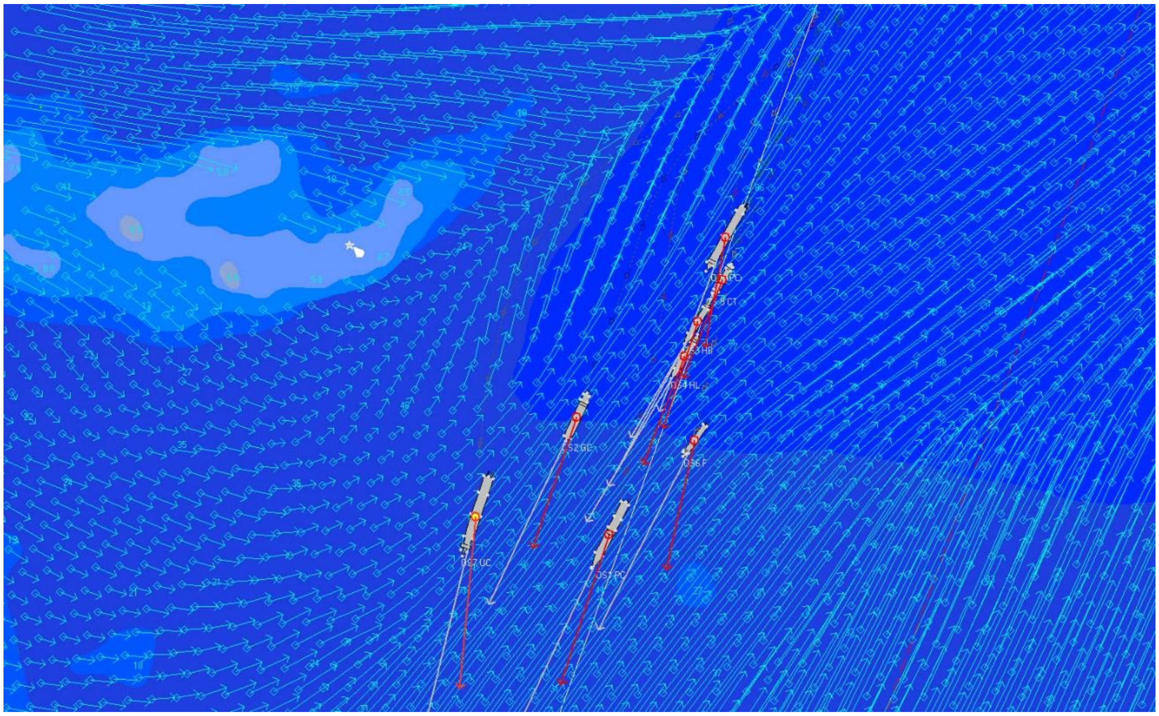


Figure 121: Test Group 1 Track-plot_2: Upriver/Maximum Ebb/Wind 315°@30 knots/Speed 8



This test was repeated with the vessels initial transit speed set to 10 knots and with the wind still at 315° at 30 knots, and the Ultra Large Cruise Vessel still required full rudder and Full Ahead for a period of nearly three minutes in order to counter current induced sheer when it was east of Haut Fond Prince. Likewise, the PANAMAX ship required a shot of Half Ahead with full rudder for two minutes in order to counter the current sheer. It was not until the wind speed was reduced to 25 knots with a water transit speed of 10 knots that an acceptable level of steering control was achieved with all Group 1 vessels. See Figures 122 and 123 below:

Figure 122: Test Group 1 Track-plot: Upriver/Maximum Ebb/Wind 315°@25 knots/Speed 10

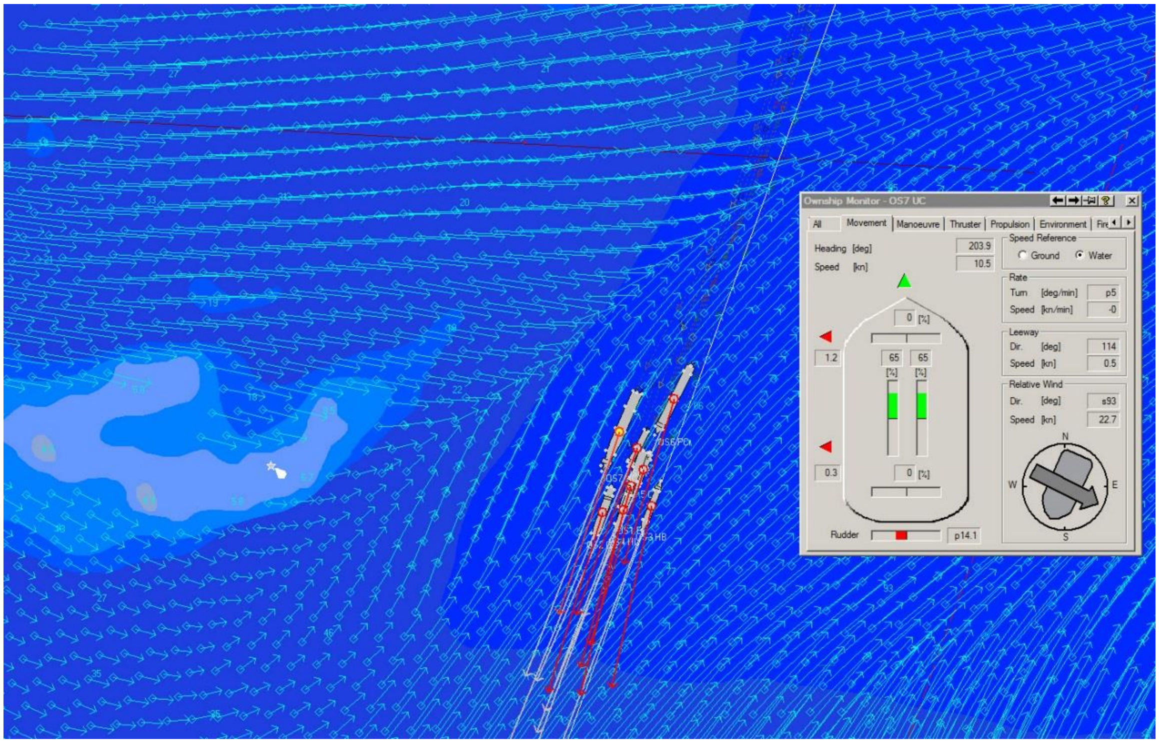
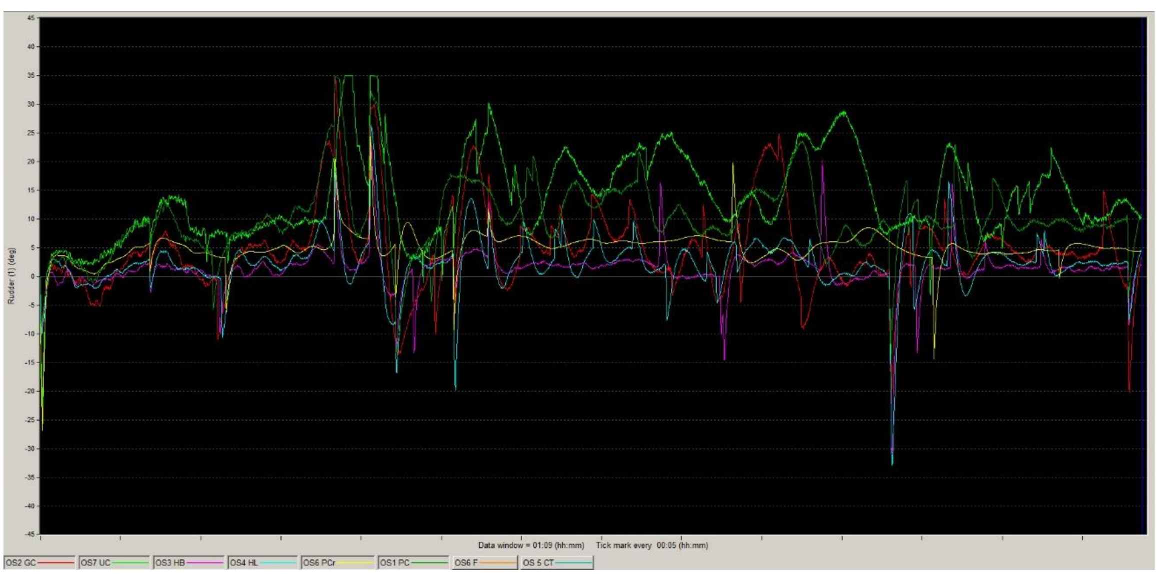


Figure 123: Test Group 1 Rudder Order: Upriver/Maximum Ebb/Wind 315°@25 knots/Speed 10



5.3.2 Detailed Observations on Test Vessel Group 2 (Full Hull Form Ships)

Full form vessels tend to accelerate and decelerate slower than other vessel types, and often require more rudder to initiate a turning moment and hence are generally categorised as having poor to moderate manoeuvring capabilities. In areas where current and tidal flow can vary at different depth levels, it can also be difficult to predict exactly how deep draught vessels will be affected. The tidal eddies and current sheer that can be observed on the river surface, or on buoys can be very different than what is affecting most of the hull at depths of 5 to 15 metres. However, due to the fact that in loaded conditions they tend to have a relatively small portion of their hull forms above the water, they are much less prone to wind induced rotation and drift unless they are nearly completely empty (lightly ballasted). In terms of overall ability to maintain heading and course, this group of vessels, led by tankers faired the best.

5.3.2.1 Steering and Positional Control in Current

Since this vessel group tends to be slower to respond to rudder orders/develop turn rate they took longer than the Group 1 vessels to effect heading changes. As a result, although steering control was still good, and large amounts of rudder did not have to be carried to maintain heading, the deviations in course over the ground were significantly greater than with Group 1 vessels. This was noticeable on all loaded vessels, but particularly on the two largest, the AFRAMAX and Cape Size. The magnitude of course variation was also more pronounced when stemming the current (Down bound on a flood and upbound on an ebb). In the case of the higher velocity ebb outflow current, when proceeding both upbound against more than 4.0 knots of current the course variation and the degree of positional control that was experienced by the loaded Cape and AFRAMAX ships was considered to be marginal. See Figures 124 to 127 below:

Figure 124: Test Group 2 Rudder Order: Upriver/Transit Speed 8

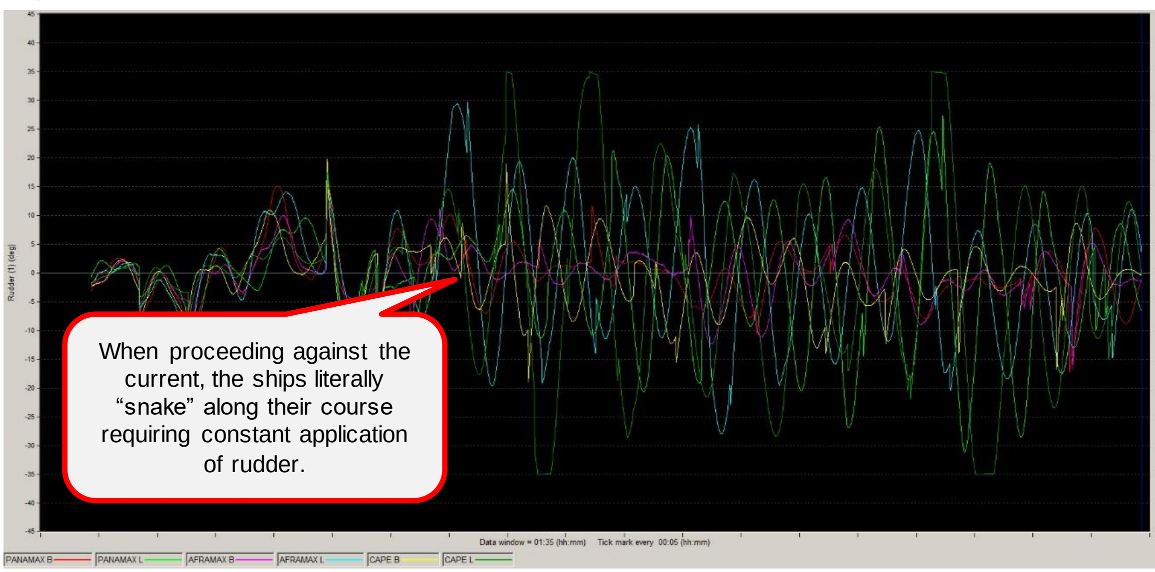


Figure 125: Test Group 2 Courses Made Good: Upriver/ Transit Speed 8

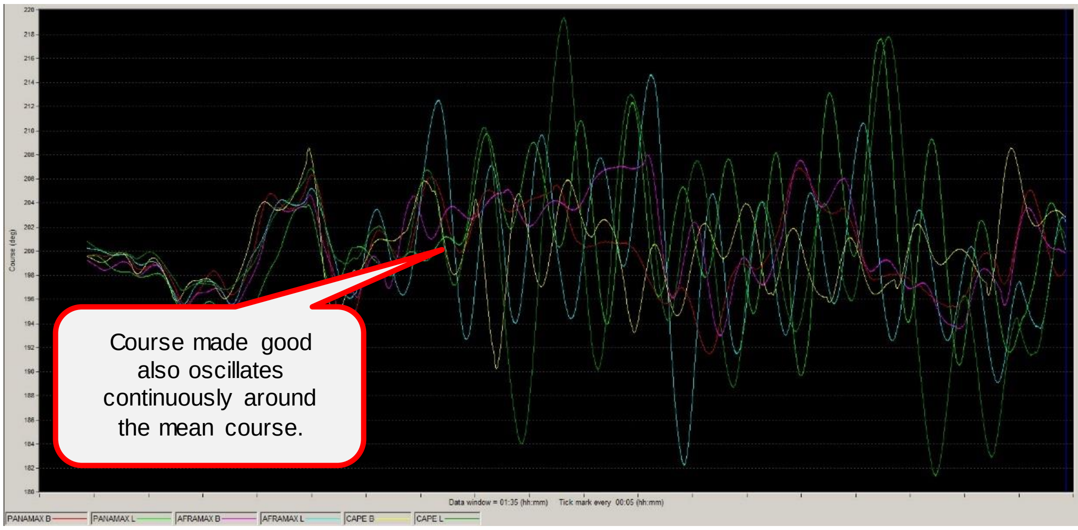


Figure 126: Test Group 2 Rudder Order: Downriver/ Transit Speed 8

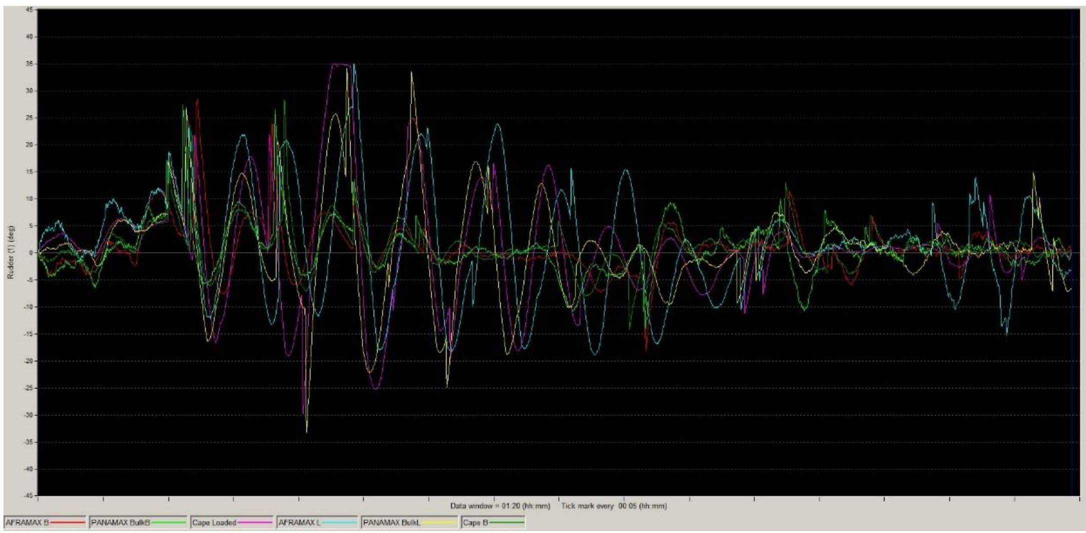
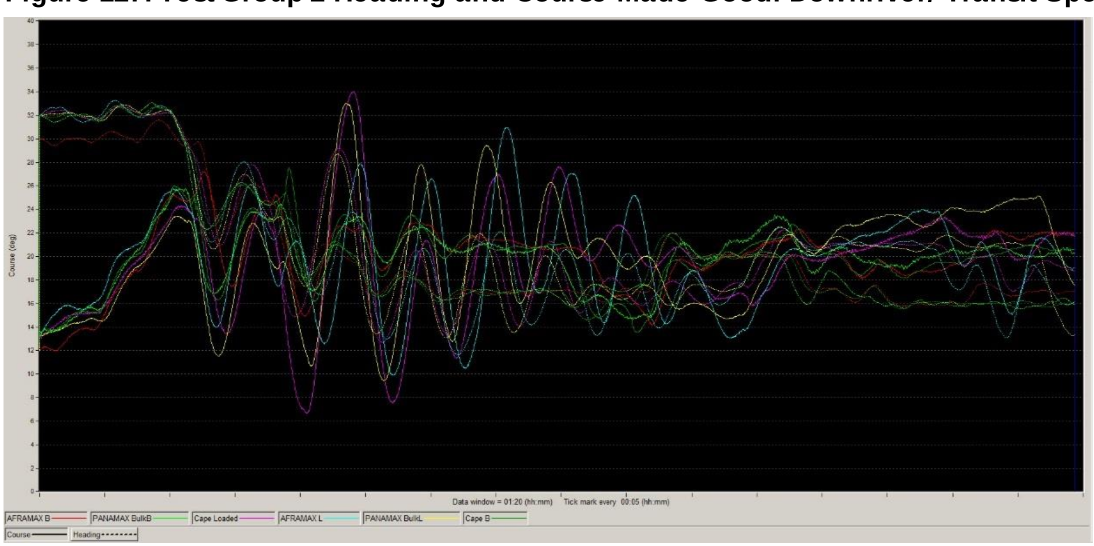


Figure 127: Test Group 2 Heading and Course Made Good: Downriver/ Transit Speed 8

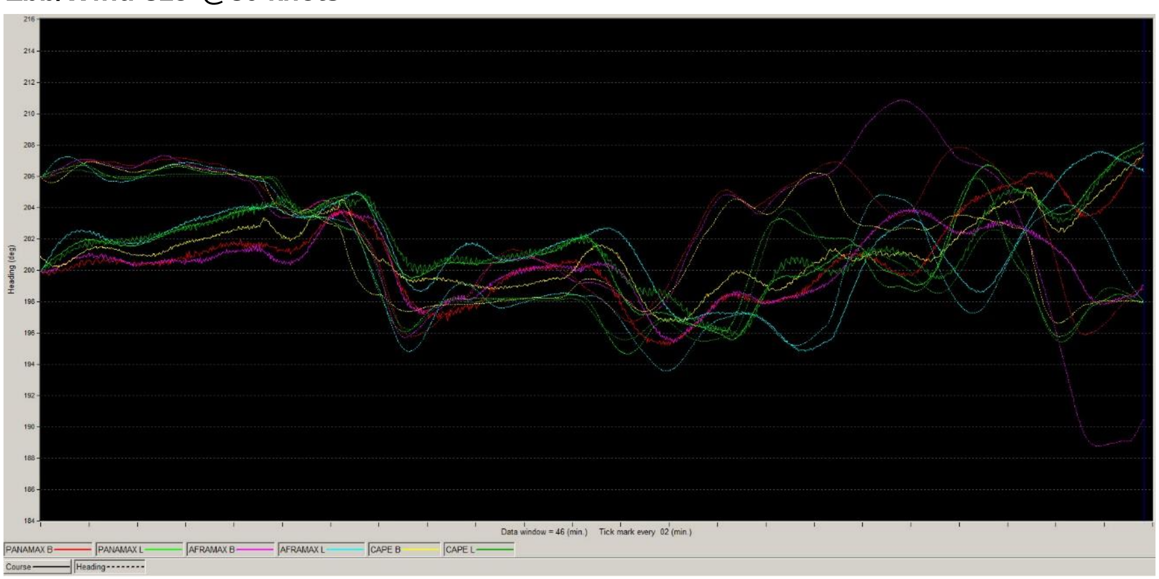


5.3.2.2 Steering and Positional Control in Strong Winds

Observations in these tests were quite consistent with that of the TSS in that only the ballasted vessels were appreciably affected by wind induced rotation or drift. When proceeding upriver against the maximum ebb current, the ballasted AFRAMAX experienced marginal steering control with the wind on the starboard quarter from 315° at 30 knots and carried full rudder for an extended period. See Figures 128 and 129 below:

Figure 128: Test Group 2 Rudder Order: Upriver/Transit Speed 8 – Max Ebb/Wind 315°@30 knots

Figure 129: Test Group 2 Heading and Course Made Good: Upriver/Transit Speed 8 – Max Ebb/Wind 315°@30 knots



5.3.2.3 Observations on Course Alterations

The entry into the Saguenay consists of three tracks and two course alterations. Even with maximum flood and ebb conditions, when the wind speed was 15 knots from the prevailing direction of 295° steering and positional control could be maintained with an average water speed of 7.5 knots. When the wind direction was changed to 045° at 25 knots such that it was on the starboard quarter when altering from the 254° track to the 273° track, the drift angle for all ships increased to more than 10° and the Ballasted Panamax, and the Ultra Large Cruise ships could not arrest the turn rate with RPMs for 8 knots and had to use kicks ahead to generate additional steering forces. See Figures 130 to below:

Figure 130: Saguenay Test 5 Trackplot Zoom

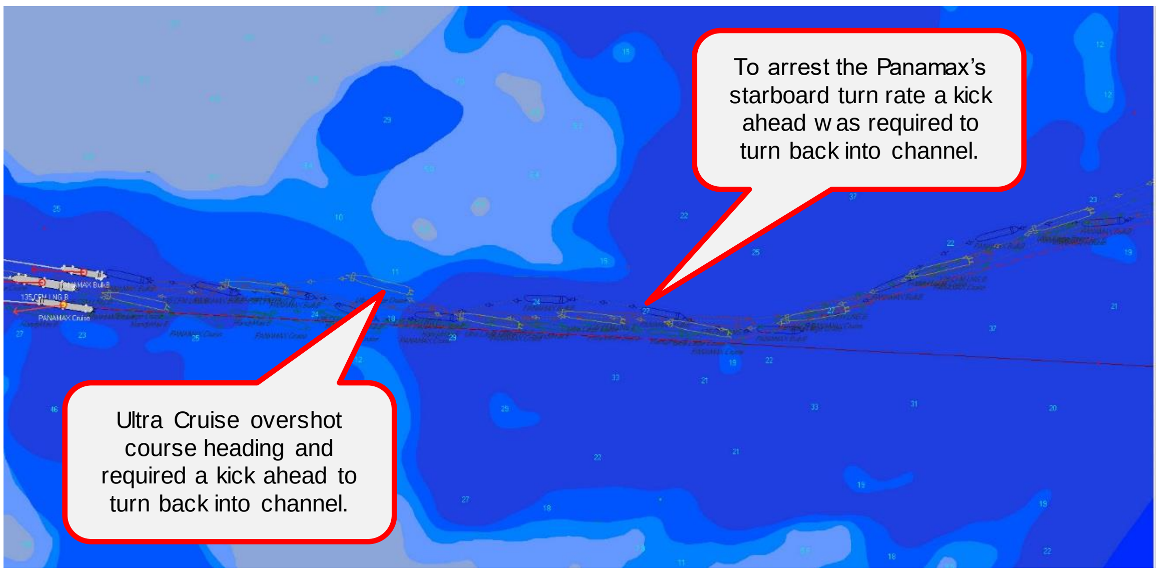


Figure 131: Saguenay Test 5 Applied Rudder Angle

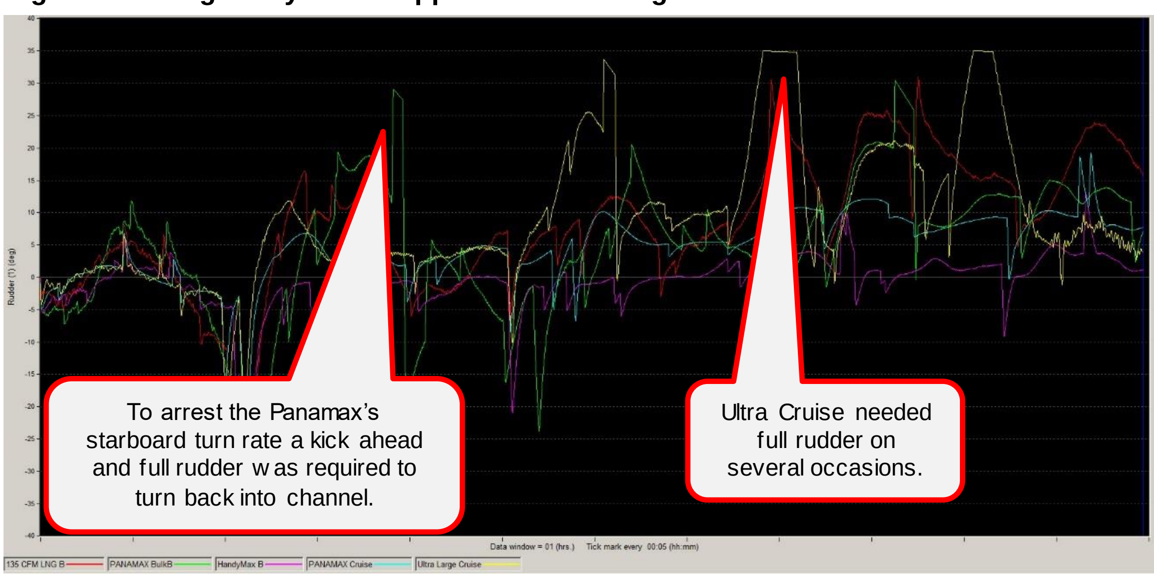


Figure 132: Saguenay Test 5 Propeller RPM

5.3.2.4 Observations on Wind Speeds above 25 knots

Since the outbound route from the Saguenay is straighter than the inbound one, and generally considered easier for ship control, it was decided to conduct some tests with the wind from 315° at a speed of 30 knots to examine how a wind of this velocity would affect steering control in an area of high tidal velocity. These tests showed that while at 25 knots, tidal induced sheer could be corrected with RPM kicks and full rudder. Furthermore, at 30 knots, several ships developed combined wind and current induced sheers that should be considered uncontrollable. See Figures 133 to 135 below:

Figure 133: Saguenay Test 12 Trackplot Zoom – Wind 315@30 Knots with 3.5 Knot Current

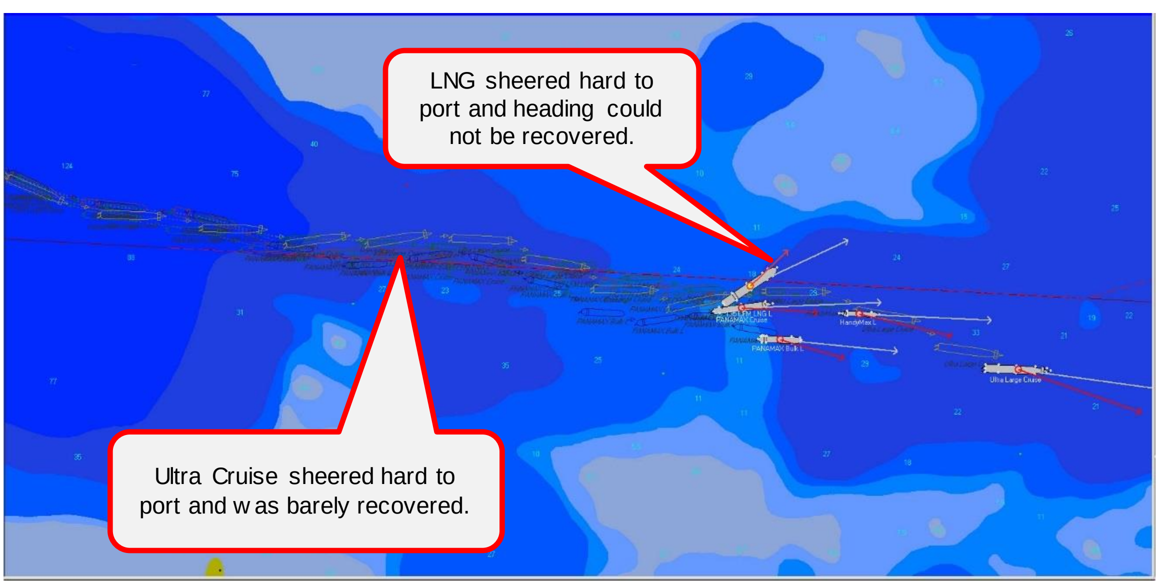


Figure 134: Saguenay Test 12 – Applied Rudder Angle

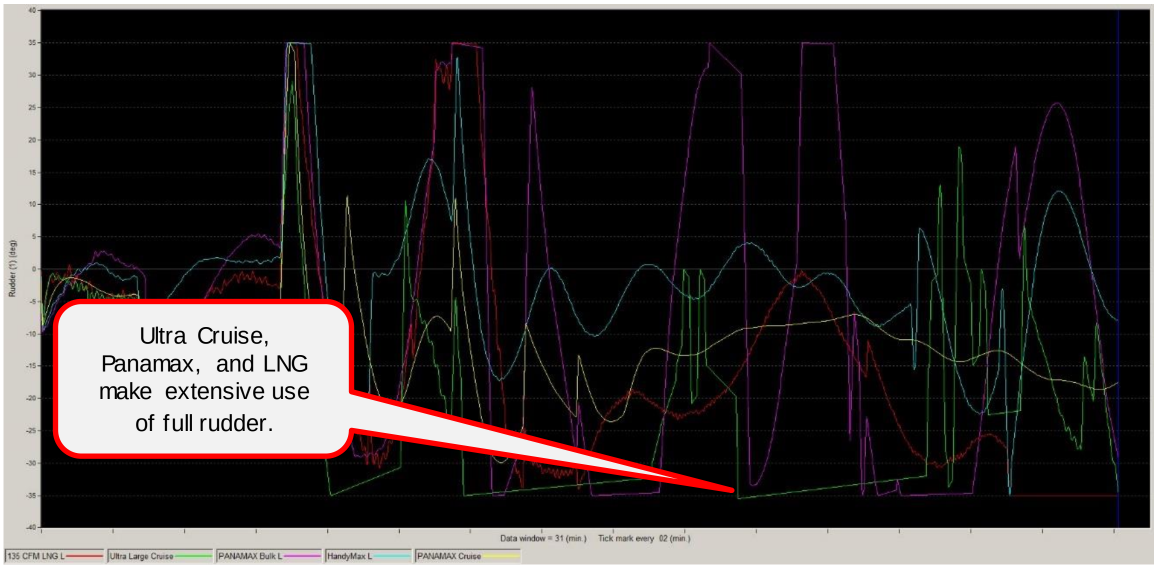
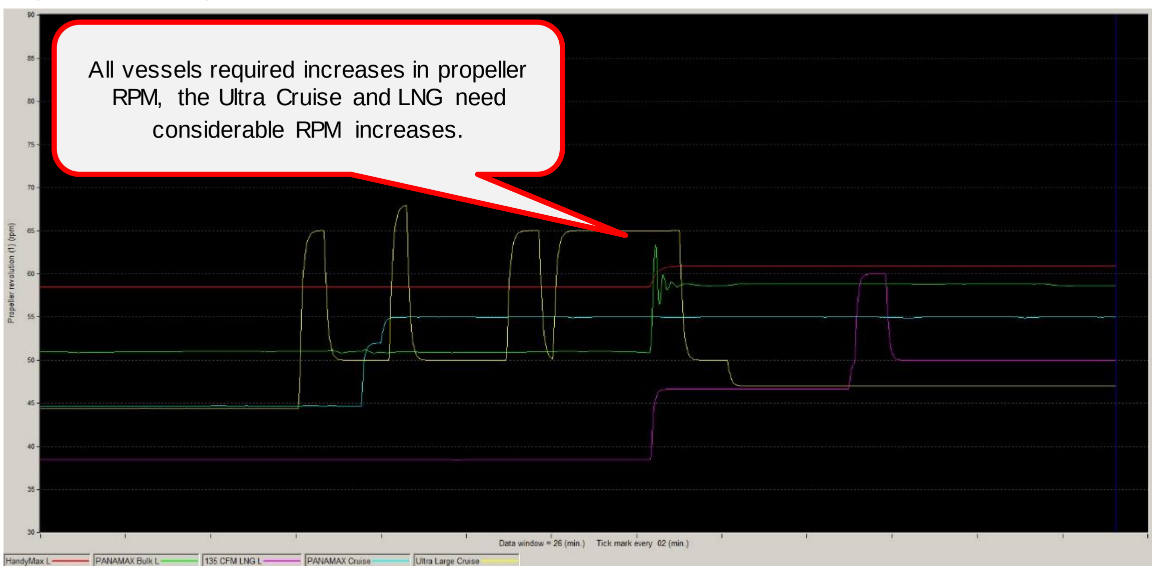


Figure 135: Saguenay Test 12 – Propeller RPM



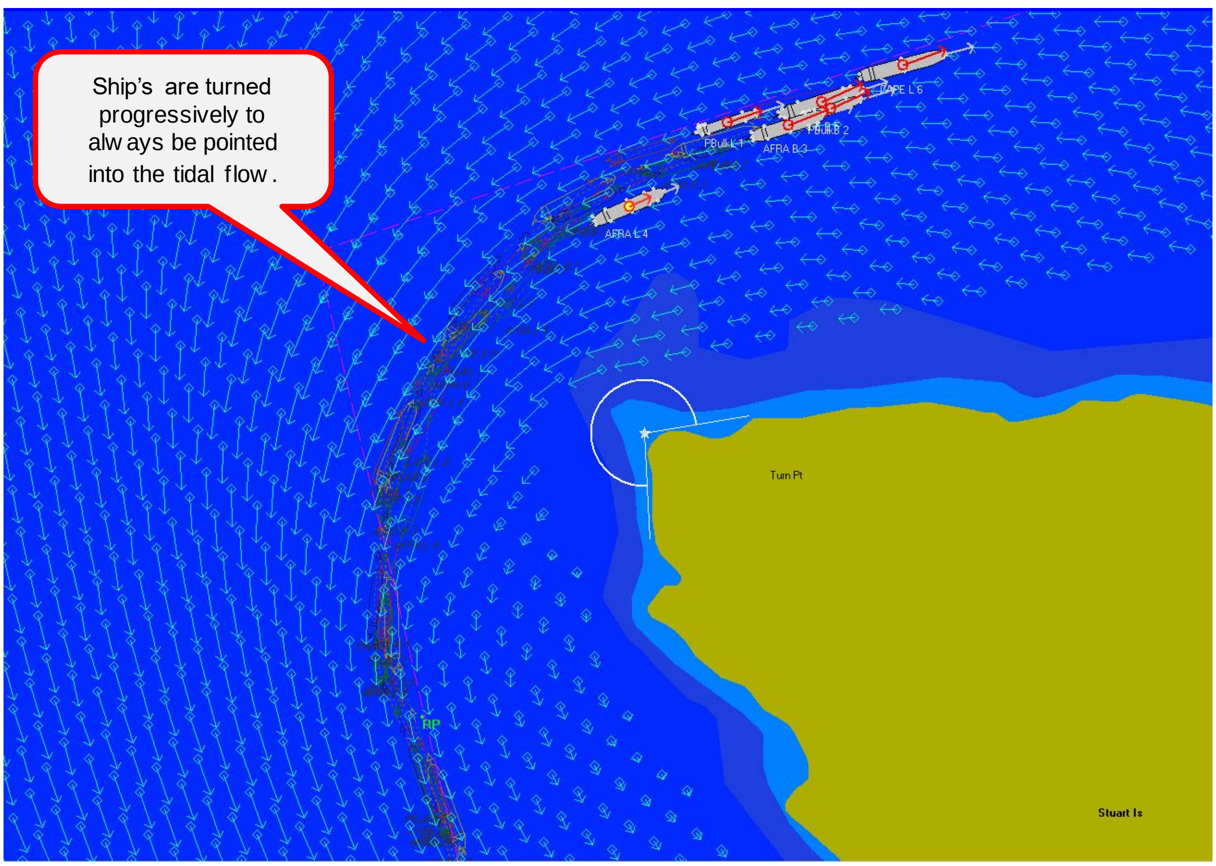
5.4 Observations Derived from Haro Strait/ Boundary Pass Pilotage Area

Building on the previous three series of tests, the important findings from this final phase of the desktop analysis relate to vessel control when conducting very large turns where the ship enters and exits a tidal race in the process of conducting the turn (Rounding East Point southbound requires a total change in direction of approximately 115°. Rounding Turn Point northbound a total direction change of approximately 85°). This phase also examined vessel control in a situation where the tidal stream due to geographic particulars sheers or is deflected in direction by more than 90° over a very short distance. Once findings were made related to these conditions with moderate winds of 15 knots, then each transit segment was run with winds on the quarter at 25 knots to ascertain the effect of combined tidal stream and wind. Note that wind speed was limited to 25 knots, as the St-Lawrence/Saguenay study showed that with even smaller turns, steering and positional control was serious degraded if the wind speeds exceeded 25 knots.

5.4.1 Observations on Angle of Tidal Flow in Relation to the Turn

This phase of testing clearly indicated the importance of the relationship between the angle of tidal flow in relation to the intended track, and the ability to maintain steering and positional control at low transit speeds. Somewhat in contrast to the situation that exists in the St-Lawrence, at the entry points into Boundary Pass the tidal stream flow does not always run near parallel to the navigation channel, hence the ship cannot always directly stem or run directly down the tidal flow. For example, when approaching Turn Point northbound on an ebb tide, the tidal race tends to run quite close to Turn Point and curves in a reasonably uniform manner from Boundary Pass into Haro Strait. In this situation, Turn Point is in essence the apex point of the tidal flow, and the ship's heading can be kept at a small angle to the tidal flow as it rounds Turn Point. Provided that the tidal stream is kept at a small angle on the ship's starboard bow, steering and positional control can be quite good. Care must still be taken not to get the relative angle of the tidal stream on the port bow as this can cause the ship to sheer towards Turn Point. See Figure 136 below:

Figure 136: Rounding Turn Point with Ebb Tidal Stream Test G2 T1



In contrast, on the flood tide, the tidal race continues to the north towards Swanson Channel and it is not until it gets close to South Pender Island that it curves into Boundary Pass. In this situation, when proceeding northbound, the ship will start the turn in the tidal race and as it turns, will develop a relative angle of nearly 70° to the tidal flow. As a result, the ship achieves a lateral speed of upwards of 5 knots, and this makes arresting the turn and precisely positioning the ship on the desired track quite difficult. In essence, under these conditions the ship "drifts" around the turn. See Figures 137 and 138 below:

Figure 137: Flood Tidal Stream Directional Flow Pass Turn Point

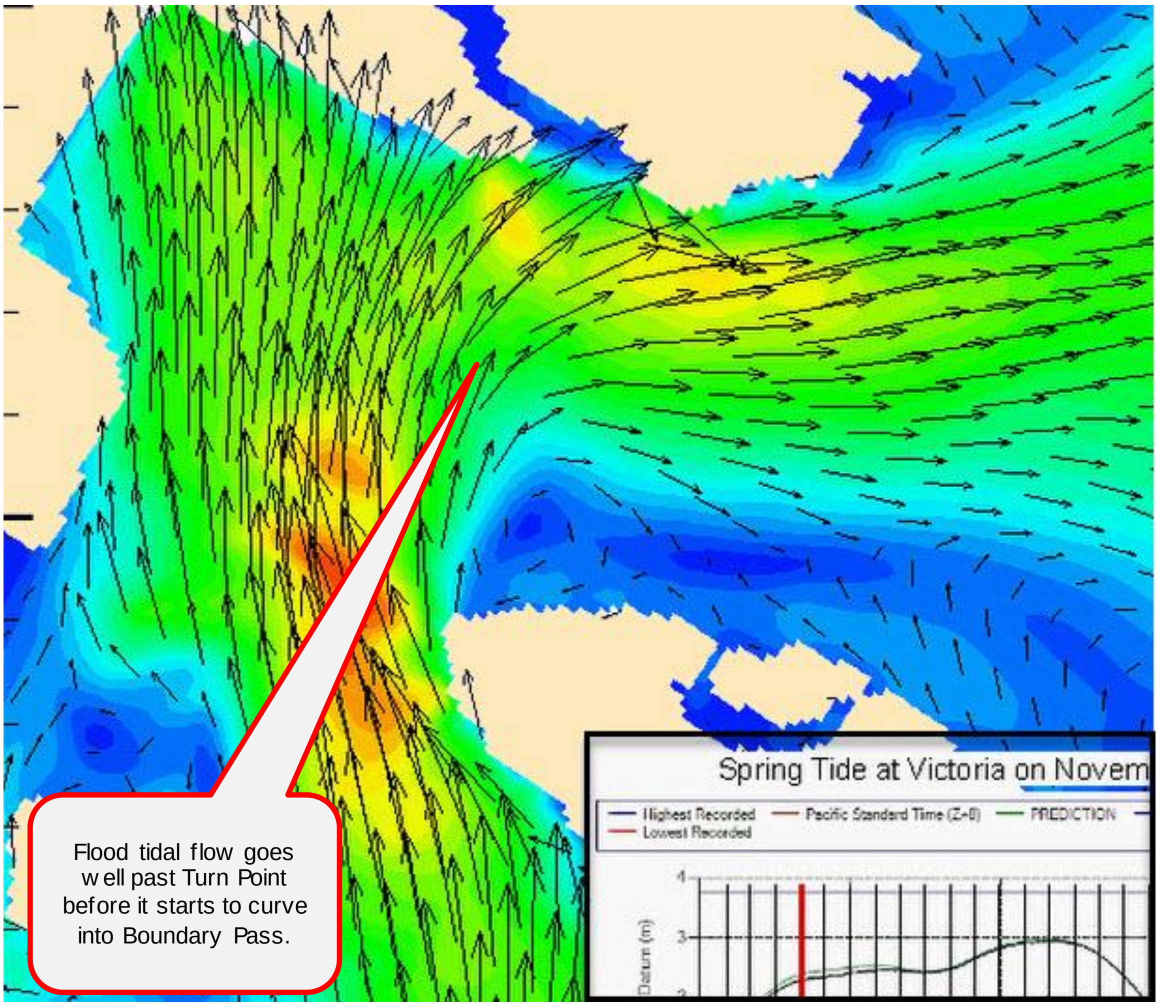
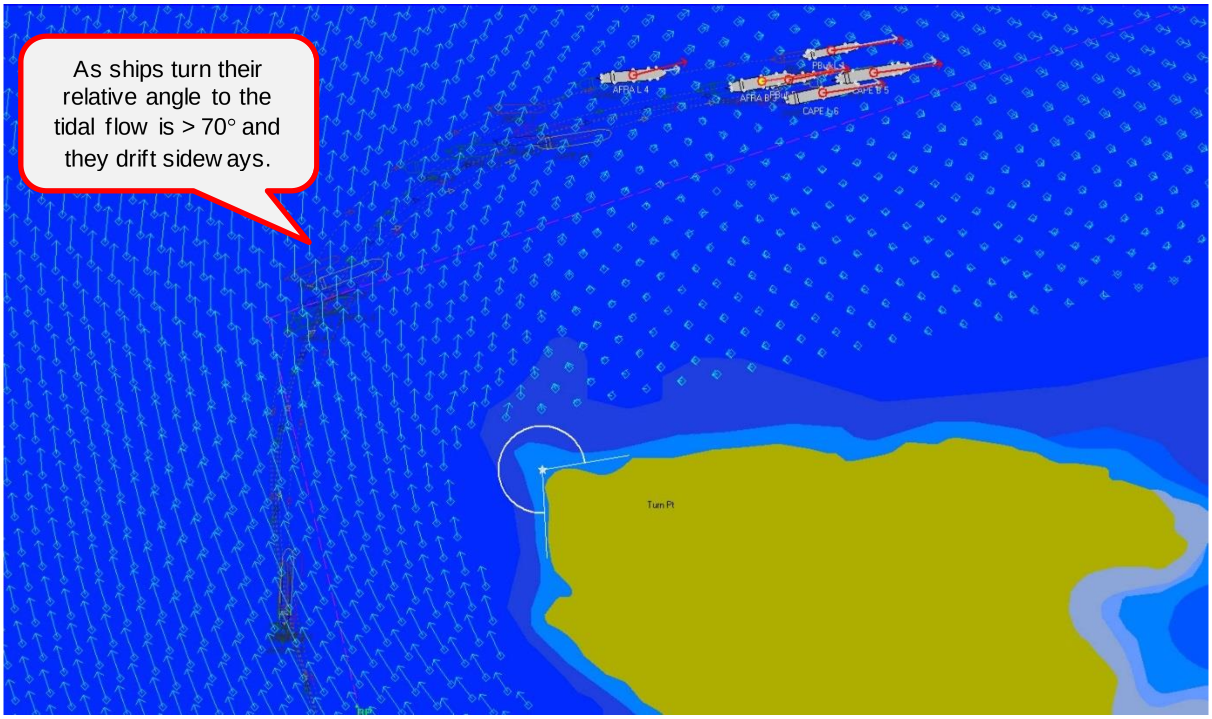


Figure 138: Rounding Turn Point Northbound with Flood Tidal Stream Test G1 T4



When the fully developed flood tide was coupled with 25 knots of wind from 180° there was a tremendous amount of rotational force applied to the ships and for most vessels, with RPM set for a speed of 8 knots, full port rudder was applied when they were halfway through the starboard turn in order to control the turn rate and to be able to steady close to the desired 070° heading. Also, with the fine hull form vessels, with the exception of the Car Carrier, all ships required RPM kicks in order to steady on course. See Figures 139 to 140 below:

Figure 139: Rounding Turn Point - Flood Tidal Stream Applied Rudder Test G1 T4

Figure 140: Rounding Turn Point - Flood Tidal Stream propeller RPM Test G1 T4

It should also be noted that when the ships exit the tidal bore into the relatively slow-moving water, they still carry their momentum that was generated by the tidal stream. Hence they experience an instantaneous acceleration in water speed, and there is no way that this can be controlled by the pilot. See Figure 141 below:

Figure 141: Exiting Tidal Race Instantaneous Acceleration: Test G1 T4 Speed Graph

5.4.2 Speed Loss During Long Periods of "Drifting" Through a Turn

Another observation that is very significant with respect to maintaining low speed transit control is the magnitude of speed loss that is experienced when making large turns. Both fine and full form vessels experience this effect, and ships with a greater length overall tend to be affected more than shorter vessels. This effect when passing East Point Southbound with an ebb tidal stream, and a northerly wind, most ships developed a drift angle of more than 30° and carry this angle for a considerable distance. As a result, the ship's water speed is greatly reduced, and as it enters the most intense portion of the tidal race, the rudder has little positive water flow. See Figure 142 and 143 below:

Figure 142: Speed Loss Due to Drift – East Point Southbound Test G2 T8 Zoom Trackplot

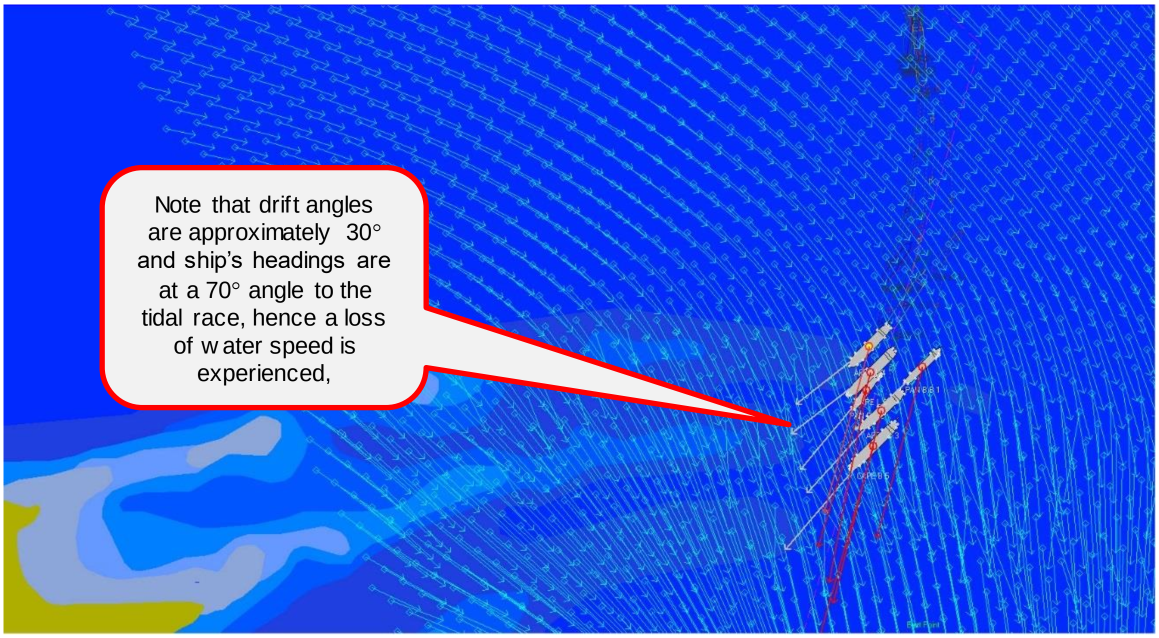


Figure 143: Speed Loss Due to Drift – East Point Southbound Test G2 T8 Speed Graph

5.5 Observations from Full Mission Simulation Validation Tests

As discussed previously, one of the primary purposes of the Full Mission simulations was to provide an opportunity for pilots from each of the two areas to review the findings of the desktop analysis. They could then compare its findings with their own real-life experiences over the past few years conducting low speed transits as part of their respective voluntary low speed transit programmes (where vessel transit speed for some vessels, such as container ships, has been reduced by nearly 50%). They then selected particular ship types and test conditions from those used in the desktop analysis and conducted the same runs with the vessel under their control in order to both validate the findings of the desktop analysis, and to illustrate to the test director certain steering and positional control issues/situations that they feel must be considered when developing or refining any low speed transit policy.

In general terms, the manned simulations proved to be very consistent with the results of the desktop findings. Although certain manoeuvring techniques used by the pilots may have been more effective/refined than those used in the desktop analysis (i.e. Manual steering versus autopilot, etc.), the key issues of vessel control yielded very similar results. Although results were similar, there are certain key findings that are worthy of specific mention to reinforce points raised from the desktop analysis.

5.5.1 Observations in the Main St-Lawrence Channel

Under moderate wind (10 to 20 knots) and moderate tidal current (< 3 knots) conditions, steering and positional control of all vessel types, with propeller RPMs set for a water speed of 8 knots, whether proceeding upstream or downstream, was generally good and always at a level that would be considered safe. In areas of tidal constriction, and tidal sheer (i.e. west of Ile Rouge, at the junction of the Saguenay outflow) where tidal velocities increased above 3 knots, or where the ship had to transit through areas of tidal transition, it was observed that there was a reduction in the level of steering and positional control. However, in most cases the level of control would be considered to be safe under normal operating circumstances. It should be underlined that this analysis made no attempt to assess contingency manoeuvring such as taking emergency manoeuvring action to avoid other vessels, or to respond to mechanical failures.

It is also important to emphasis a finding highlighted earlier in the report that any time when the vessel's ground speed became less than 150% of the current speed (i.e. 6 knots of ground speed with 4 knots of current speed) there was a tendency for the ship to move or be displaced laterally very quickly if the ship had any angle to the tidal flow. In normal transit conditions this is manageable, however if for some reason the ship needs to turn quickly to avoid another vessel or floating object, it can produce a lateral sheer that is difficult to control. Also, if we consider a transit speed of 8 knots, when we are proceeding against 3 knots of current, the vessel's ground speed will be 5 knots hence a ratio of vessel ground speed to current speed of 5/3 or 166% which places use close to the threshold mentioned above where lateral control becomes an issue.

When tests were conducted with wind speeds in the range of 25 to 30 knots, with winds from the stern hemisphere, there was an appreciable reduction in both steering and positional control. In areas of tidal constriction and sheer steering, positional control became marginal, especially when proceeding upriver against the stronger outflow tidal currents. With high sided vessels it was found that 25 knots of wind was the limit where steering and positional control could be considered acceptable, and that with wind speeds of 30 knots the ships did not have sufficient reserve steering forces to be considered safe. See illustrations that follow in Figures 144 to 150 below:

Figure 144: Vessel Trackplot Test G1 T10 – Upbound Maximum Ebb Wind 315 @ 30 Knots

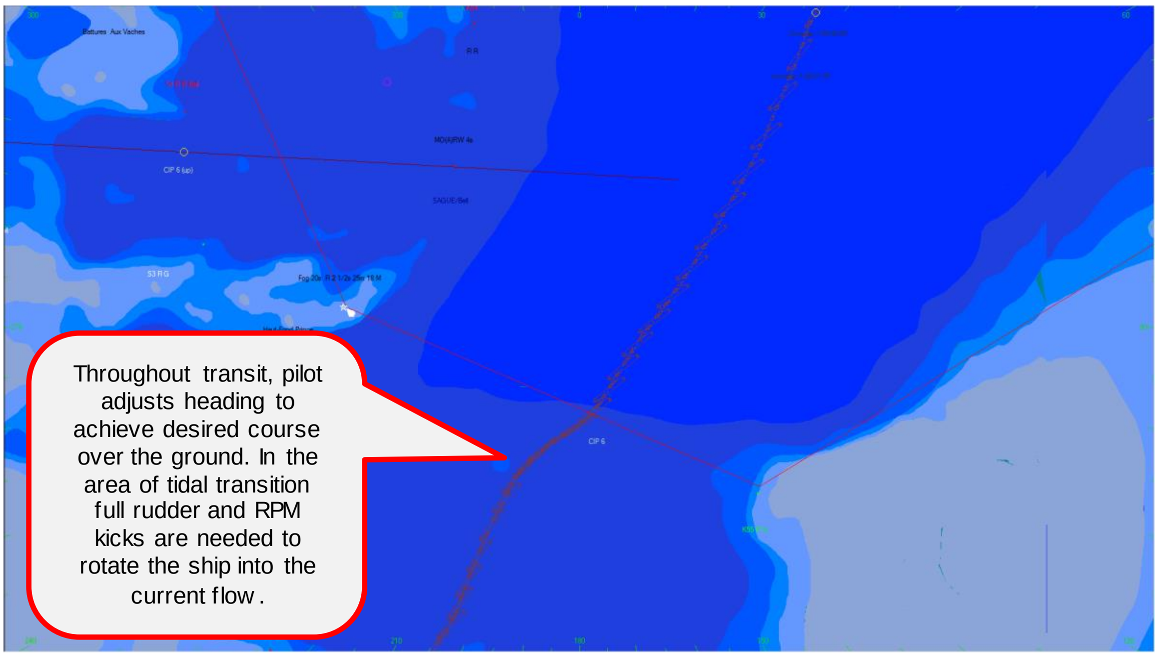


Figure 145: Vessel Rudder Test G1 T10 – Upbound Maximum Ebb Wind 315 @ 30 Knots

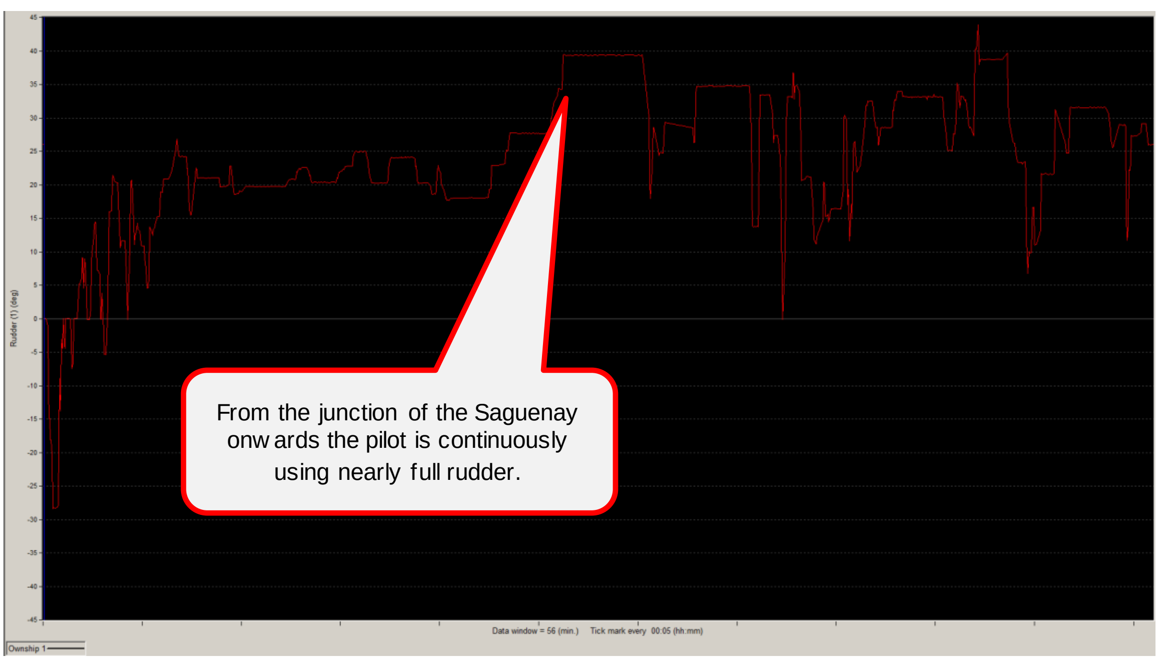


Figure 146: Propeller RPM Test G1 T10 – Upbound Maximum Ebb Wind 315 @ 30 Knots

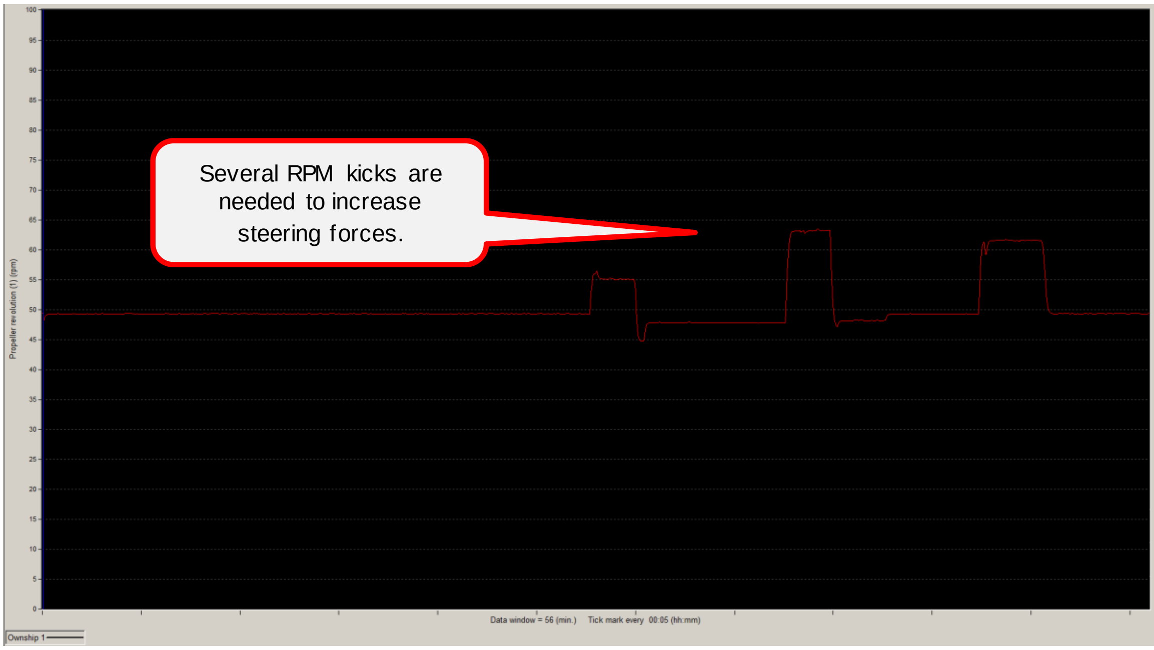


Figure 147: Vessel/Current Speed Comparison Test G1 T10 – Upbound Maximum Ebb Wind 315 @ 30 Knots

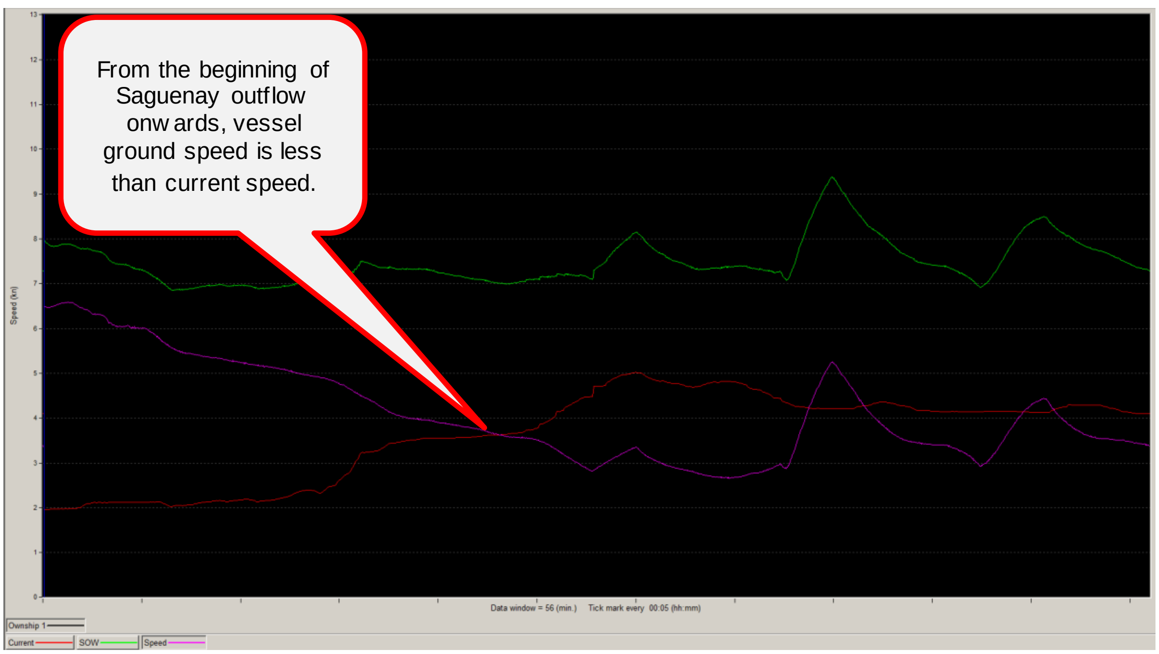


Figure 148: Trackplot Test G1 T10_2 – Upbound Maximum Ebb Wind 315 @ 25 Knots

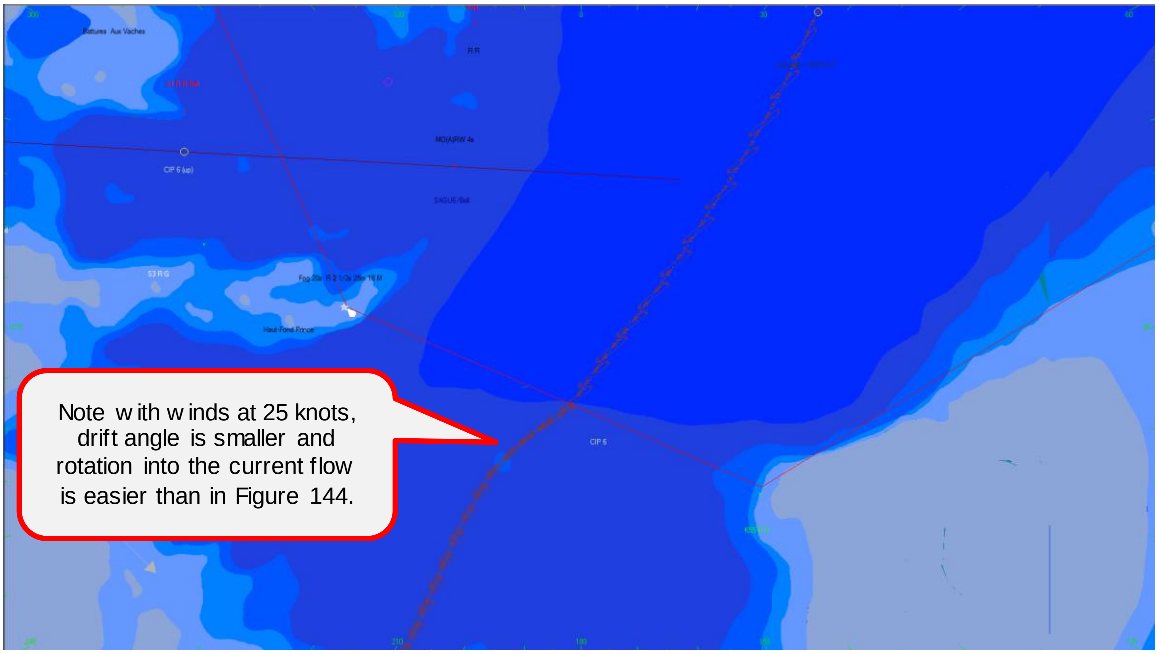


Figure 149: Vessel Rudder Test G1 T10_2 – Upbound Maximum Ebb Wind 315 @ 25 Knots

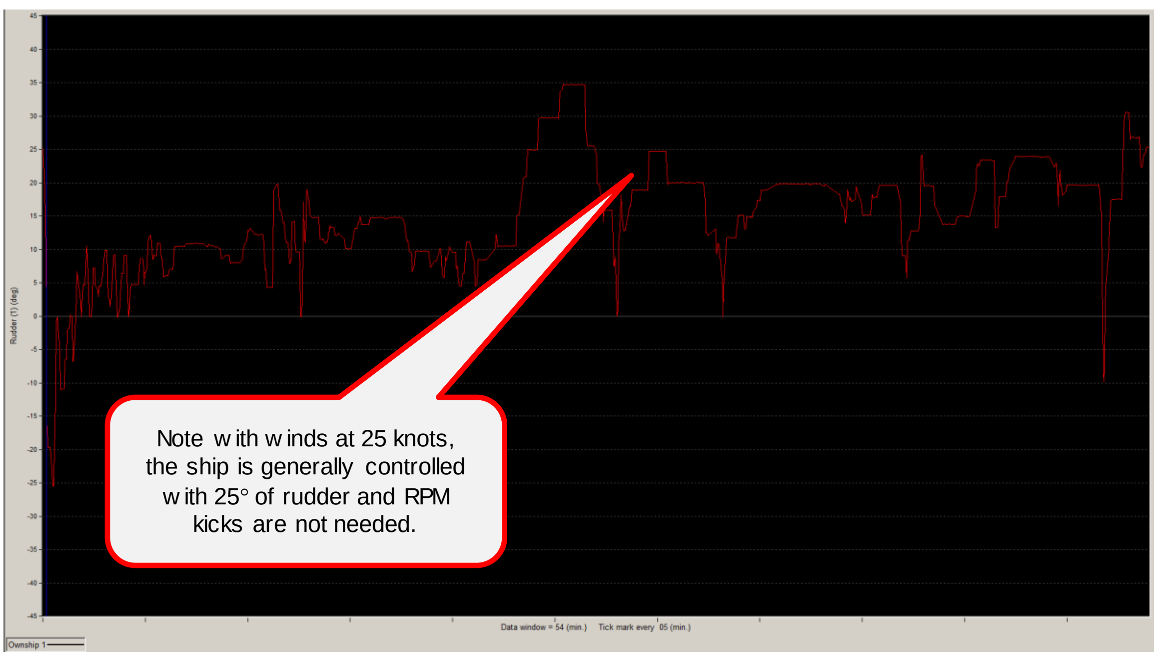
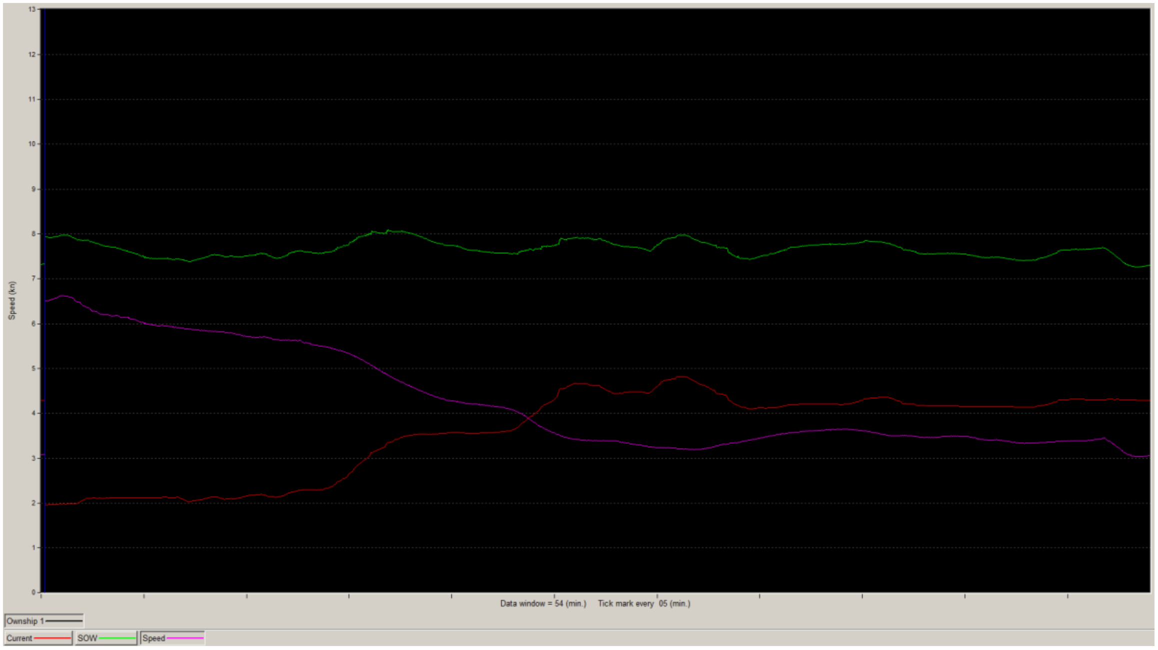


Figure 150: Vessel/Current Speed Comparison Test G1 T10_2 – Upbound Maximum Ebb Wind 315 @ 25 Knots



5.5.2 Observations at the Entrance to the Saguenay

As per the test transits in the St-Lawrence, it was observed both entering and departing the Saguenay that 25 knots of wind was the limit where steering and positional control could be considered acceptable. With wind speeds of 30 knots the LNG and passenger vessels did not have sufficient reserve steering forces to be considered safe. Furthermore, it was determined that overall control improved significantly with RPM set for 9.5 knots versus 8 knots. This was most apparent at the western end of the channel in the vicinity of Buoys S7 and S8 where a tidal eddy forms to the immediate west of these buoys. It is also interesting to note in the speed graphs that follow a very good illustration of instantaneous water speed acceleration that is caused by the tidal eddy. See illustrations in Figures 151 to which follow:

Figure 151: Trackplot - Test T12_2 Buoy S7/8 Maximum Flood – Wind 315@30

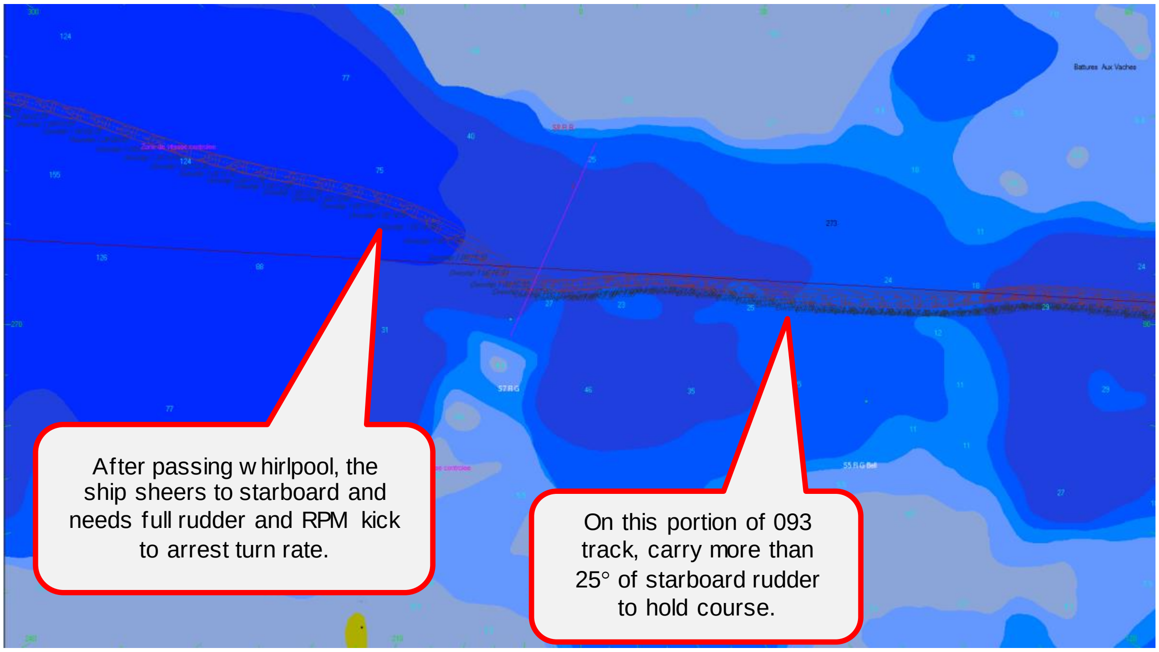


Figure 152: Applied Rudder - Test T12_2 Buoy S7/8 Maximum Flood – Wind 315@30

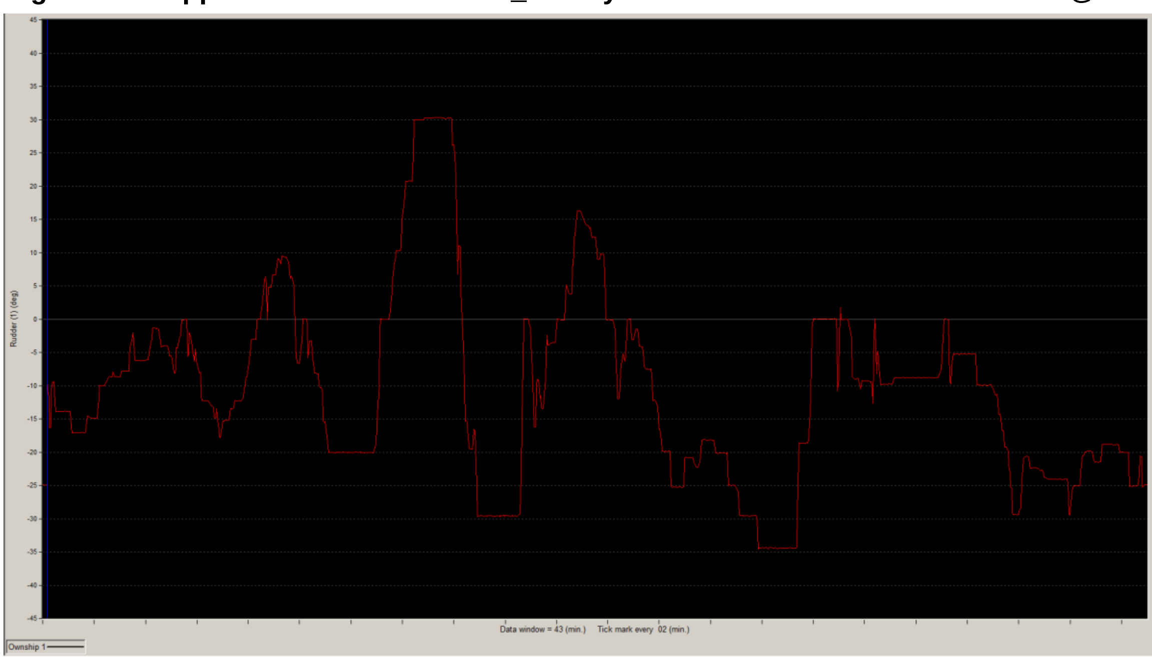


Figure 153: Propeller RPM - Test T12_2 Buoy S7/8 Maximum Flood – Wind 315@30

Figure 154: Vessel/Current Speed - Test T12_2 Buoy S7/8 Maximum Flood – Wind 315@30

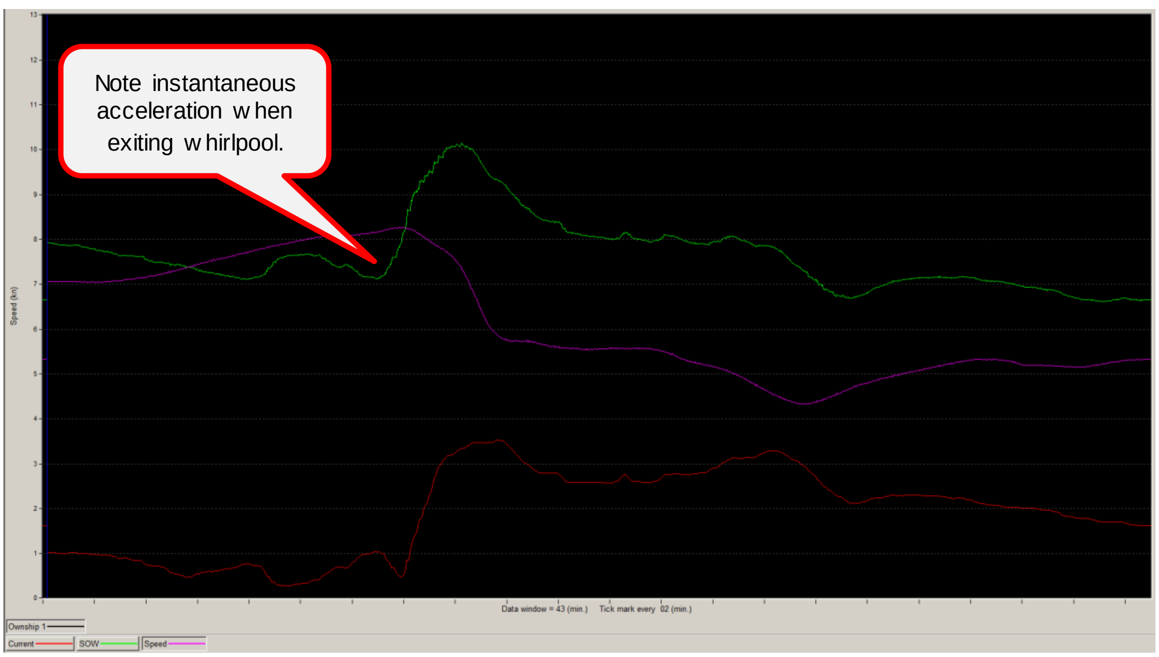


Figure 155: Trackplot - Test T12_3 Buoy S7/8 Maximum Flood – Wind 315@25

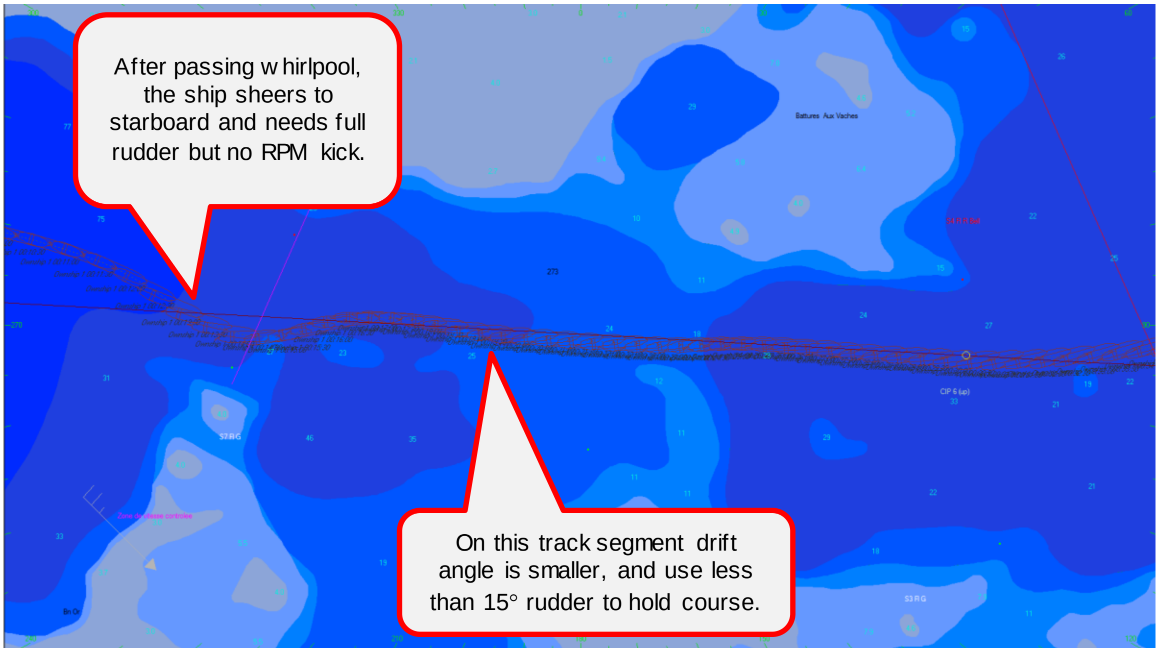


Figure 156: Applied Rudder - Test T12_3 Buoy S7/8 Maximum Flood – Wind 315@25

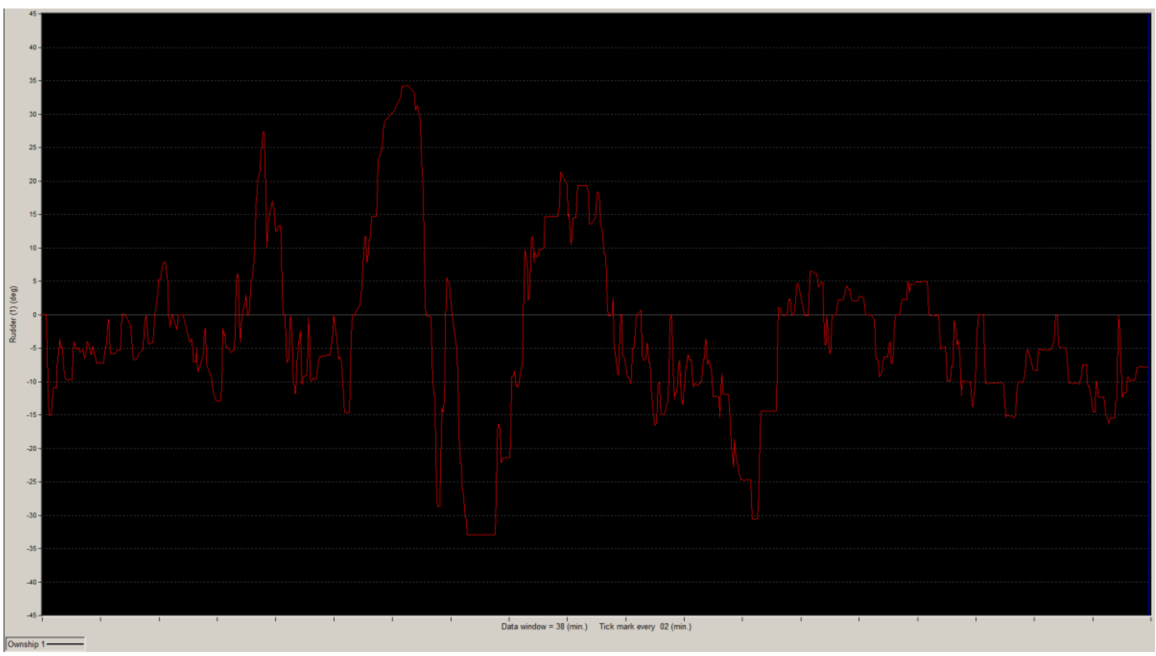


Figure 157: Propeller RPM - Test T12_3 Buoy S7/8 Maximum Flood – Wind 315@25

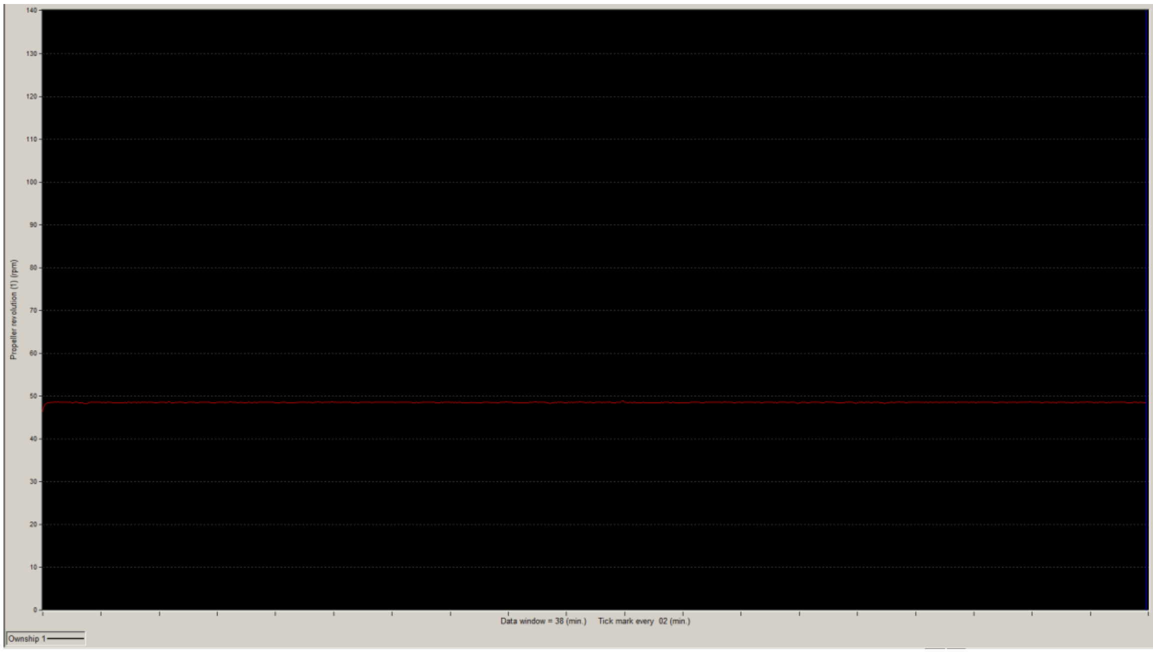
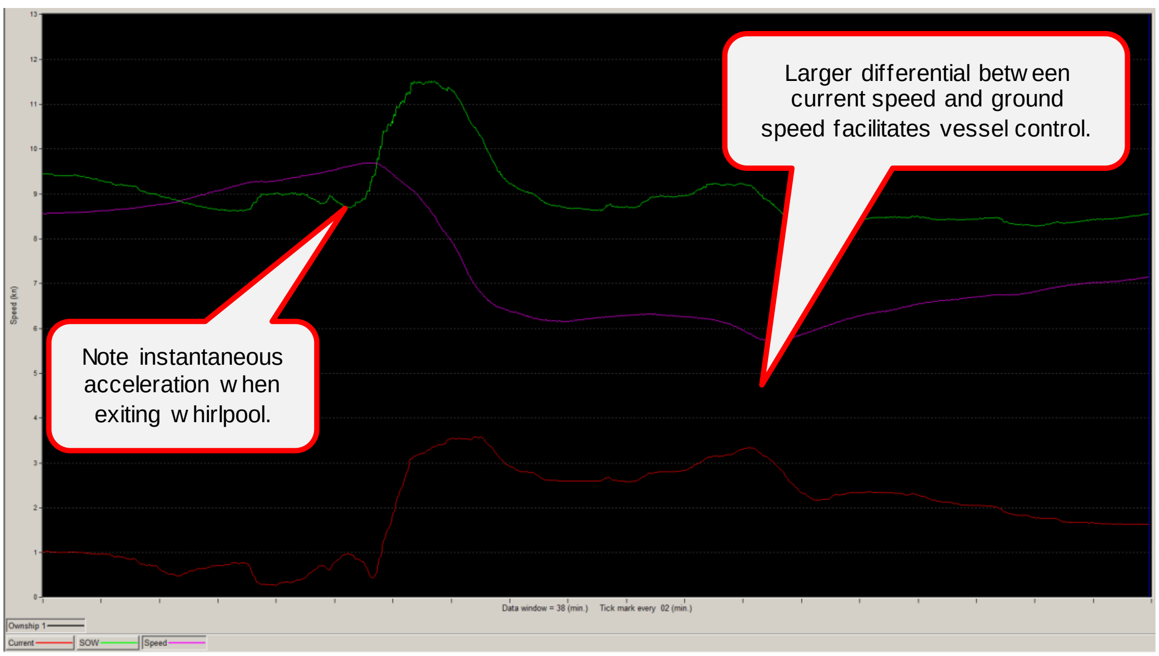


Figure 158: Vessel/Current Speed - Test T12_3 Buoy S7/8 Maximum Flood – Wind 315@25



5.5.3 Observations in Haro Strait/ Boundary Pass

Consistent with the manned simulation runs in the St-Lawrence, under moderate wind (10 to 20 knots) and moderate tidal current (< 3 knots) conditions steering and positional control of all vessel types, with propeller RPMs set for a water speed of 8 knots, whether stemming or running with the tidal stream was generally good, and always at a level that would be considered safe. In areas of tidal constriction, and tidal sheer (i.e. Turn Point Northbound and East Point southbound) where tidal velocities increased above 3 knots, or where the ship had to transit through areas of tidal transition and eddies, it was observed that with propeller RPM set for 8 knots, and moderate winds, there was a reduction in the level of steering and positional control. However, in all cases the level of control would be considered to be safe under normal operating circumstances. It should be underlined that this analysis made no attempt to assess contingency manoeuvring, such as taking emergency manoeuvring action to avoid other vessels, or to respond to mechanical failures.

The BCCP have observed that during their participation in the voluntary ECHO programme slow-down that they have on occasion experienced control issues with larger, high windage area vessels during windy conditions. As such, based on observations from the St-Lawrence Full Mission Analysis, the Haro Strait/Boundary Pass desktop findings, and their own personal experience, it was decided that all runs would be conducted with Container Vessels, LNG Carriers, Passenger ships, predominately the Neo-PANAMAX size Container ship, and the Ultra Large, conventionally-propelled Cruise Ship. All runs were conducted with winds at 25 knots, and the direction varied such that it was always on the quarter when trying to steady the vessel coming out of the large turns.

Following on to the results of the desktop analysis, the manned testing underlined that with strong tidal streams and quartering winds, it is possible to execute the large turns at low speed in a controlled manner. However, there is very little room for deviation from the few manoeuvring techniques that will actually work, and specifically that the relative angle of the ship to the prevailing tidal flow must be kept as small as possible. This was clearly illustrated on one run northbound at Turn Point with full ebb tide where the pilot purposely delayed the turn by just a couple of hundred metres beyond what would be considered the ideal point to initiate the turn under those conditions. This slight delay in turning resulted in the tidal stream being at about a 30° angle on the bow, at the point when the pilot attempted to initiate the turn. The bow of the ship started to pay off to port, and full starboard rudder was ordered, but it was not until the telegraph was set to half ahead that the ship started to turn into the tidal stream. Once the heading was correctly aligned with the tidal stream flow, then control was regained at a normal level and the telegraph set back to Slow Ahead. See Figures 159 to 161 below:

Figure 159: Rounding Turn Point, Test G1 T3_1 Turning Late Max Ebb Wind 180@25

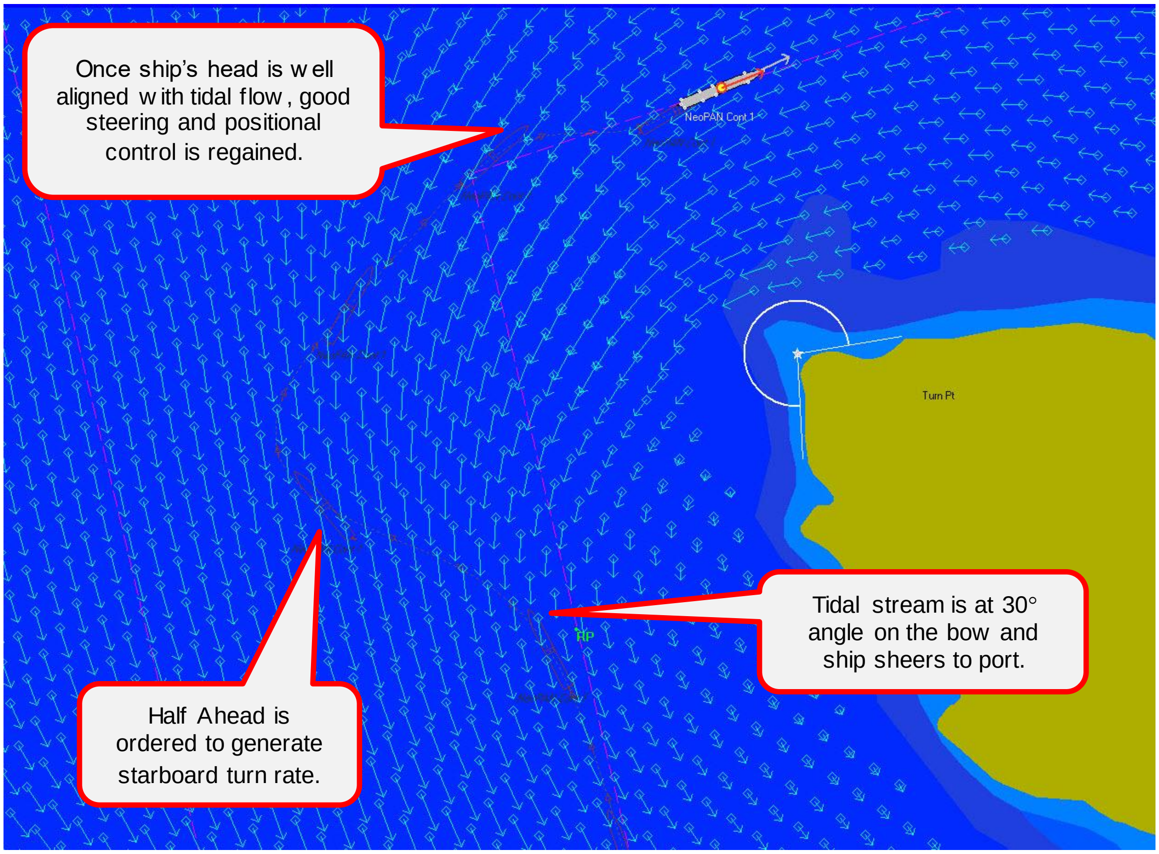
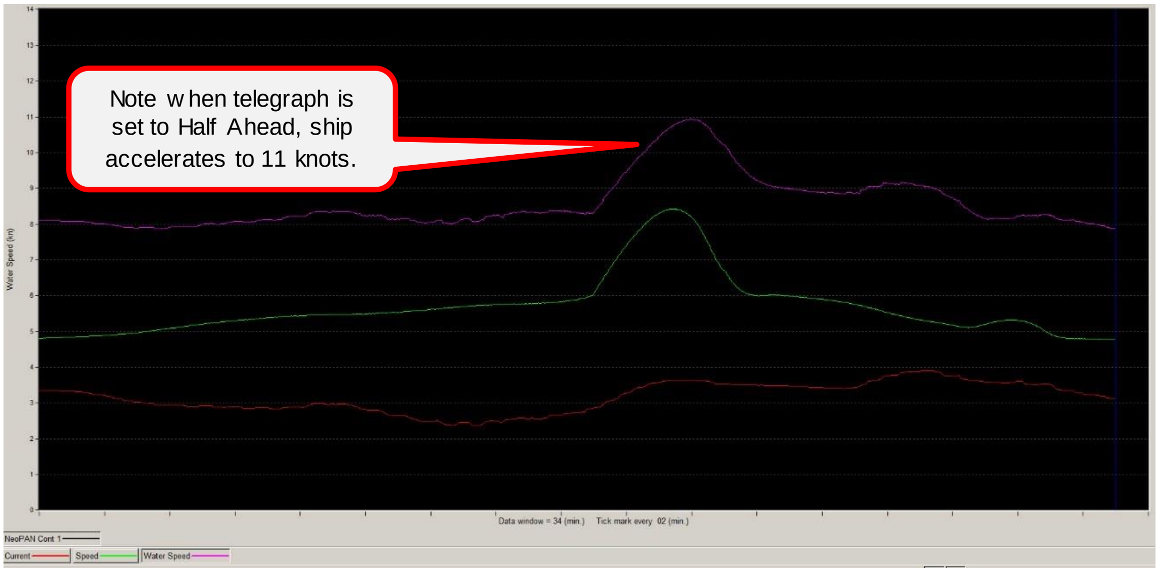


Figure 160: Rounding Turn Point, Test G1 T3_1 Rudder and RPM - Max Ebb Wind 180@25

Figure 161: Rounding Turn Point, Test G1 T3_1 Rudder and RPM - Max Ebb Wind 180@25



The manoeuvre that was illustrated in Figures 159 to 161 above was performed with a PANAMAX size vessel. As a comparison, we can see below in Figure 162 that if the turn and the tidal flow are monitored very carefully, the manoeuvre can be conducted with precision in a much larger Neo-PANAMAX vessel. It also illustrates how small the manoeuvring margin is with these conditions, and how rapidly a ship can transition from a state of complete control to one of marginal control.

Figure 162: Rounding Turn Point, Test G1 T3_2 Neo-PANAMAX - Max Ebb Wind 180@25

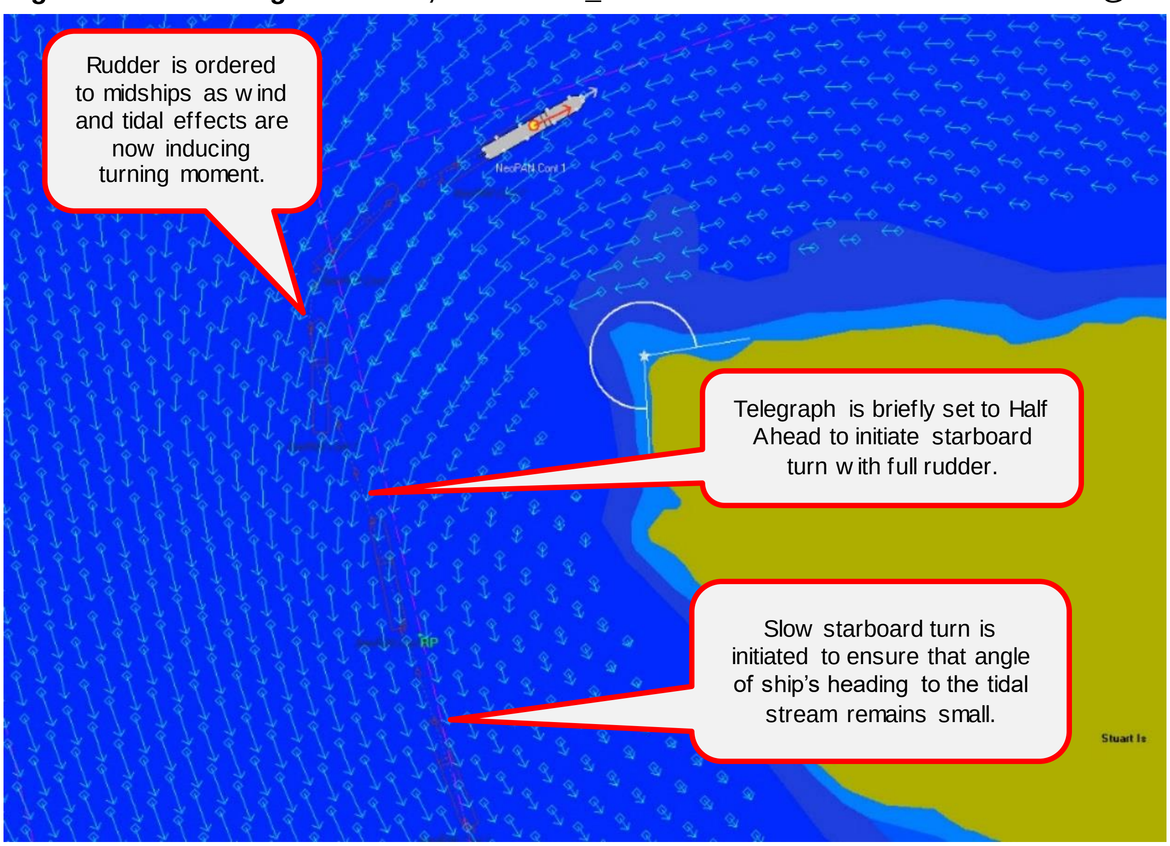
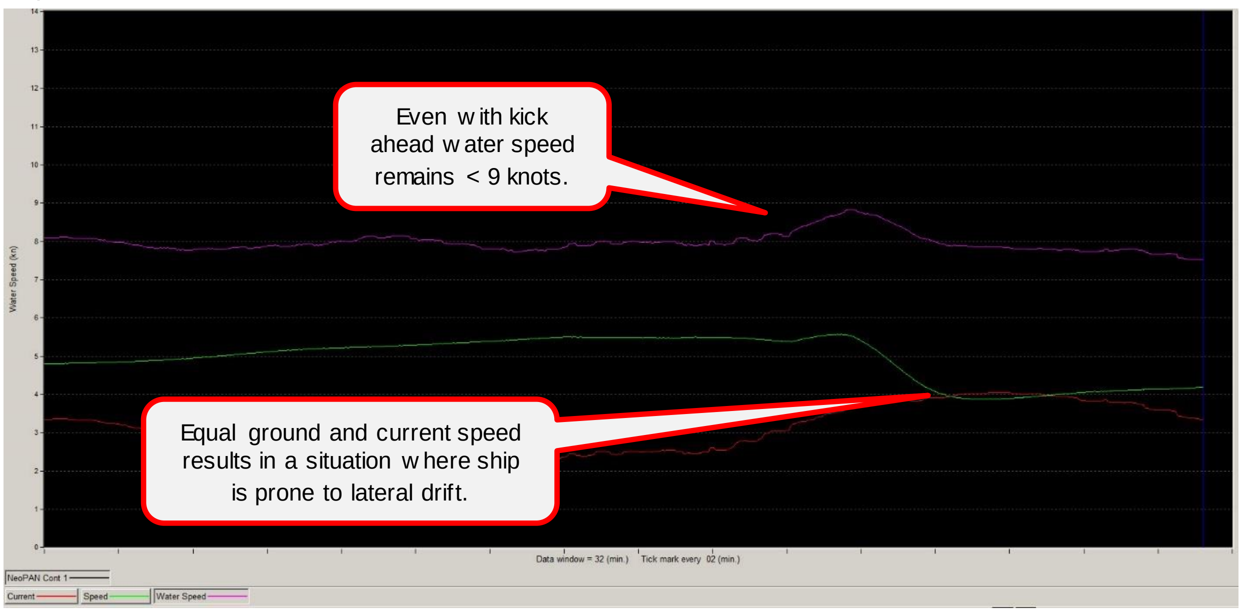


Figure 163: Rudder and RPM Test G1 T3_2 Neo-PANAMAX - Max Ebb Wind 180@25

Figure 164: Vessel and Current Speed Test G1 T3_2 Neo-PANAMAX - Max Ebb Wind 180@25



When comparing test transits at RPMs settings for 8 and 10 knots, it was noted that steering control was better with RPMs set for 10 knots. However, the angle of the ship to the tidal flow remained the most important factor in determining the level of difficulty that the pilot experienced in positioning the ship. It was noted that due to the dynamic nature of the tidal flow, that even a change in lateral position of as little as 100 metres could have a significant effect on the tidal conditions that the ship experienced. In the illustrations that follow, we can see a comparison of the Neo-PANAMAX ship rounding Turn Point with initial RPM set at 8 knots and initial RPM set at 10 knots. In the case of the later, the ship responds better to the initial rudder application and ends up turning closer to the point. As a result, when exiting the turn, the bow and stern of the ship are in very different tidal flows and the ship develops a strong sheer to starboard. This ultimately requires a RPM kick of Full Ahead in order to arrest the starboard turn rate and to regain heading control. In the vast majority of test runs with strong following tidal streams, and winds on the quarter, the ships needed RPM kicks of Half or Full Ahead to steady on course. See Figures 165 to 168 below:

Figure 165: Rounding Turn Point, Test G1 T4_1 Neo-PANAMAX - Max Flood Wind 180@25

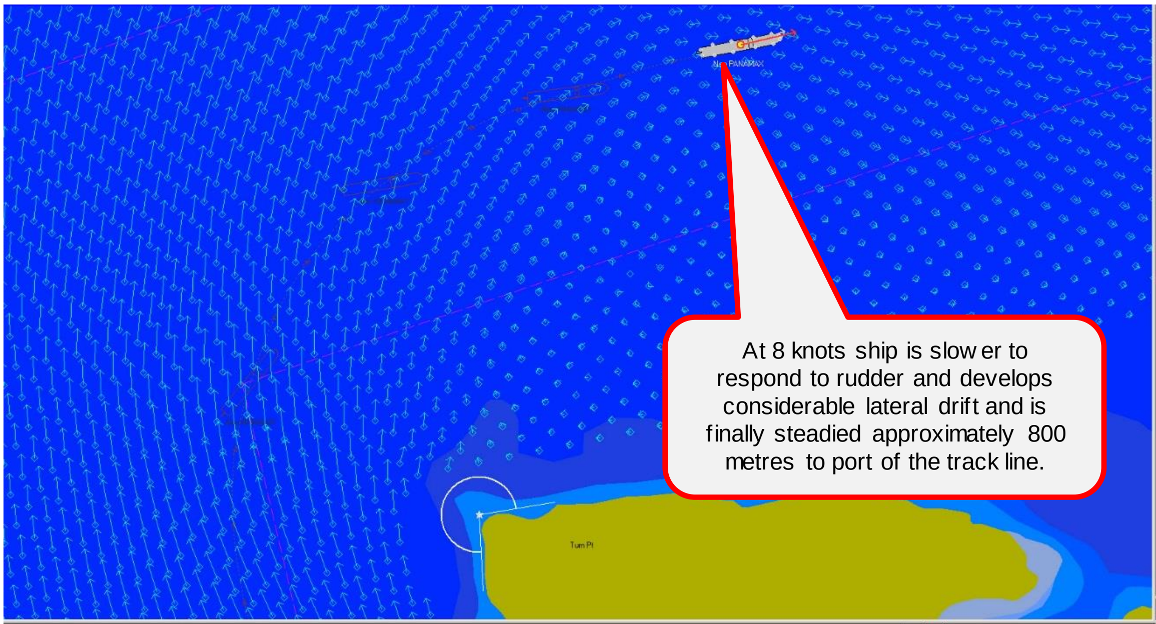


Figure 166: Rounding Turn Point, Test G1 T4_4 Neo-PANAMAX - Max Flood Wind 180@25

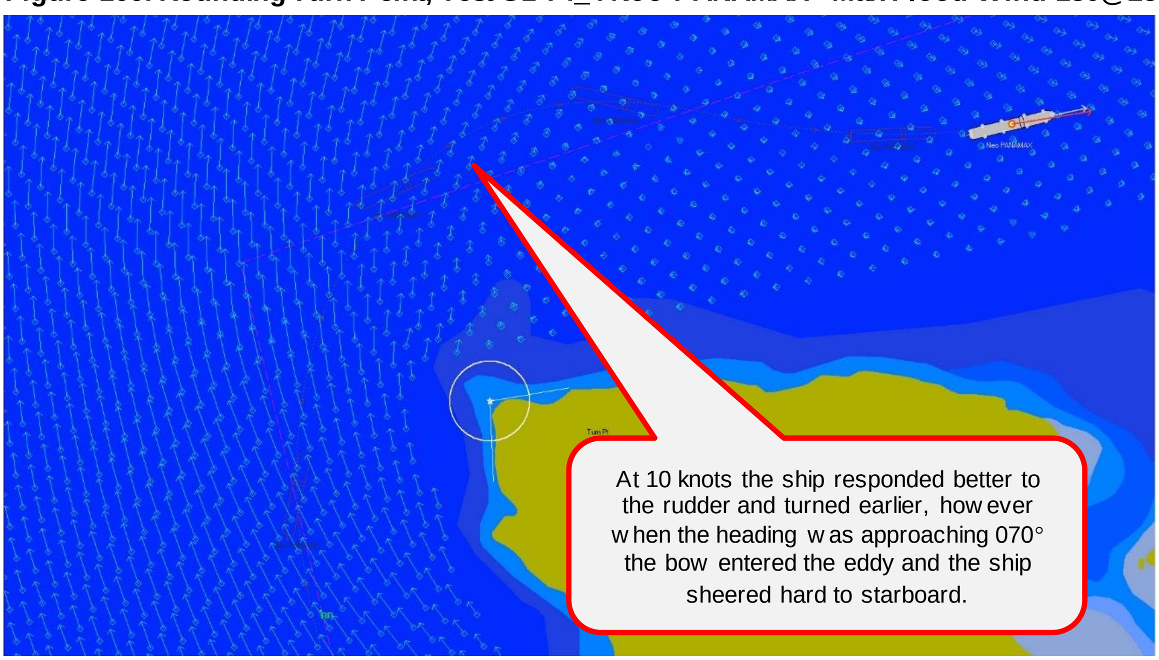


Figure 167: Propeller RPM Test G1 T4_1 Neo-PANAMAX - Max Flood Wind 180@25

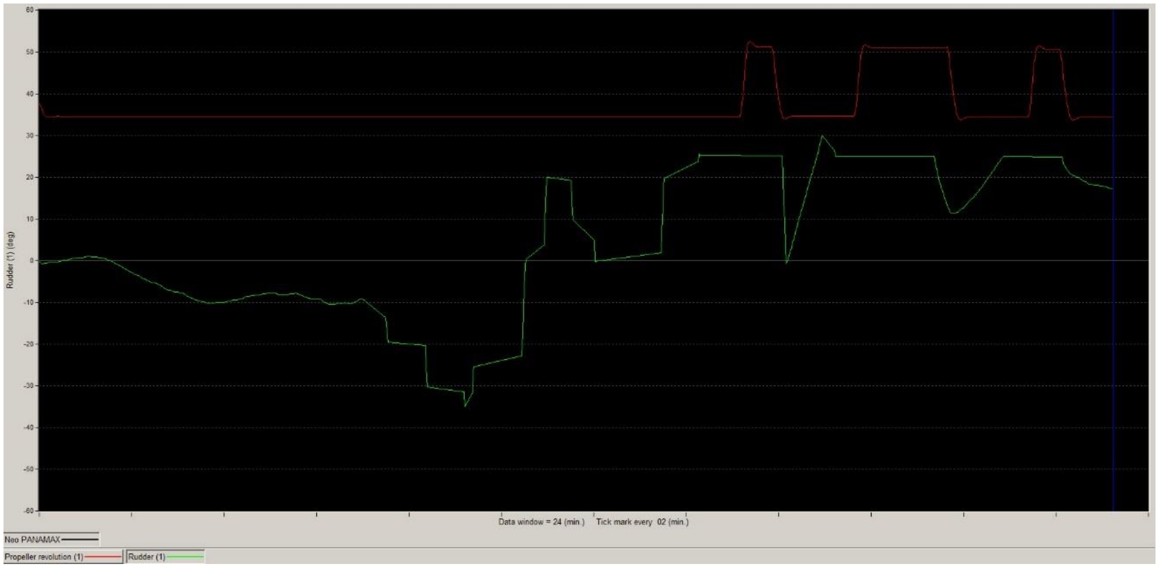
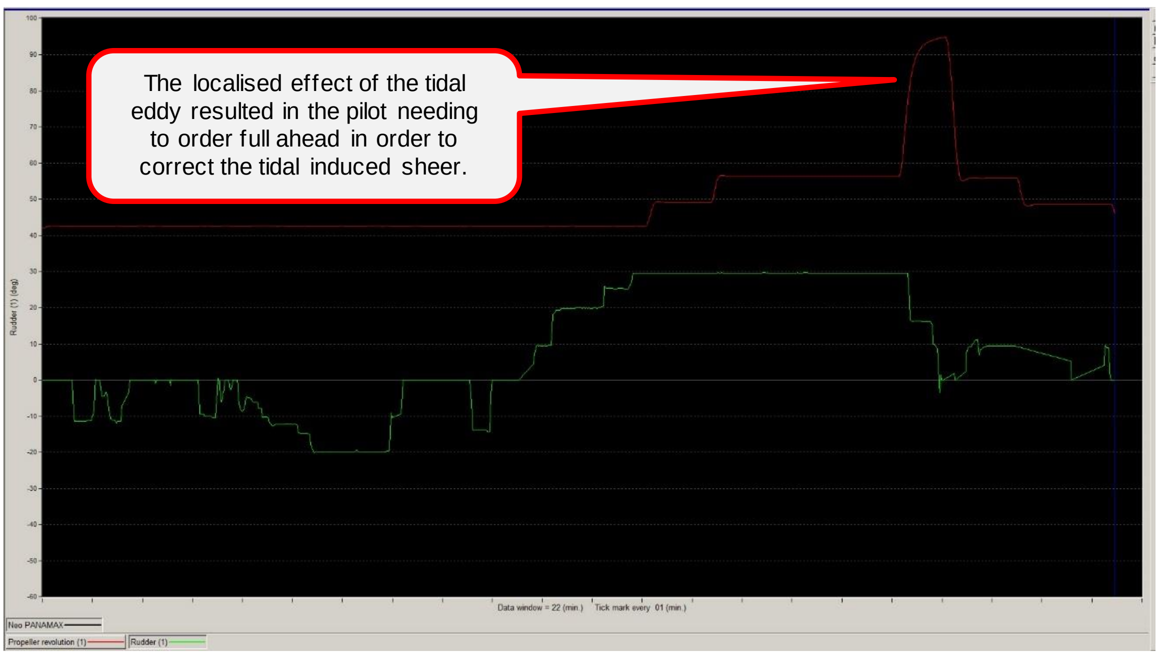


Figure 168: Propeller RPM, Test G1 T4_4 Neo-PANAMAX - Max Flood Wind 180@25



It cannot be over emphasized that when operating in these types of environmental conditions, if the ship for any reason loses the state of equilibrium, low transit speeds cannot be maintained. Also, as much as Full engine power maybe required to correct tidal and wind induced sheer and to maintain the vessels' alignment within the channel.

When proceeding southbound at East Point with the following ebb tidal stream it was noted that in the longer, wider radius turn that a propeller RPM setting of 10 knots provided an appreciable increase in control over a propeller RPM setting of 8 knots. In this specific case, at 10 knots the drift angle on the track of approximately 195° was less, resulting in less speed loss due to drift, better positioning control, and better heading control when steadying onto the track of approximately 245°. Also, at 10 knots, only a small kick ahead was required to steady the ship, and less rudder was carried throughout the transit. This is illustrated in Figures 169 to 173 which follow:

Figure 169: Rounding East Point, Test G1 T8_1 Neo-PANAMAX - Max Ebb Wind 030@25

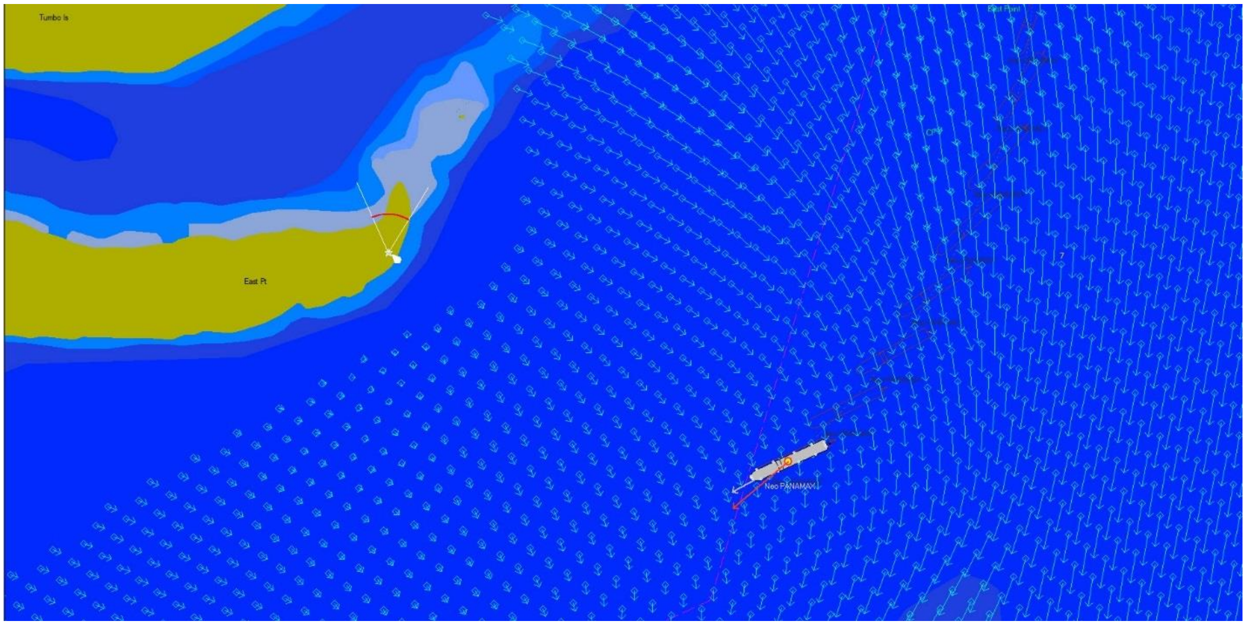


Figure 170: Rounding East Point, Test G1 T8_4 Neo-PANAMAX - Max Ebb Wind 030@25

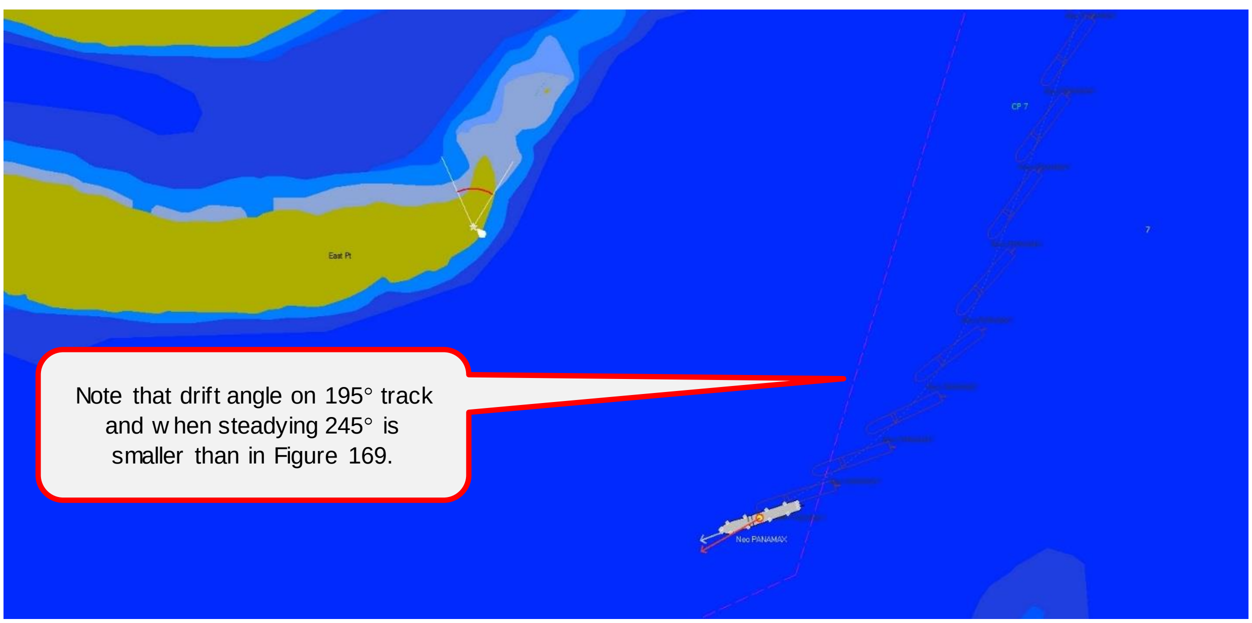


Figure 171: Rudder and RPM, Test G1 T8_1 Neo-PANAMAX - Max Ebb Wind 030@25

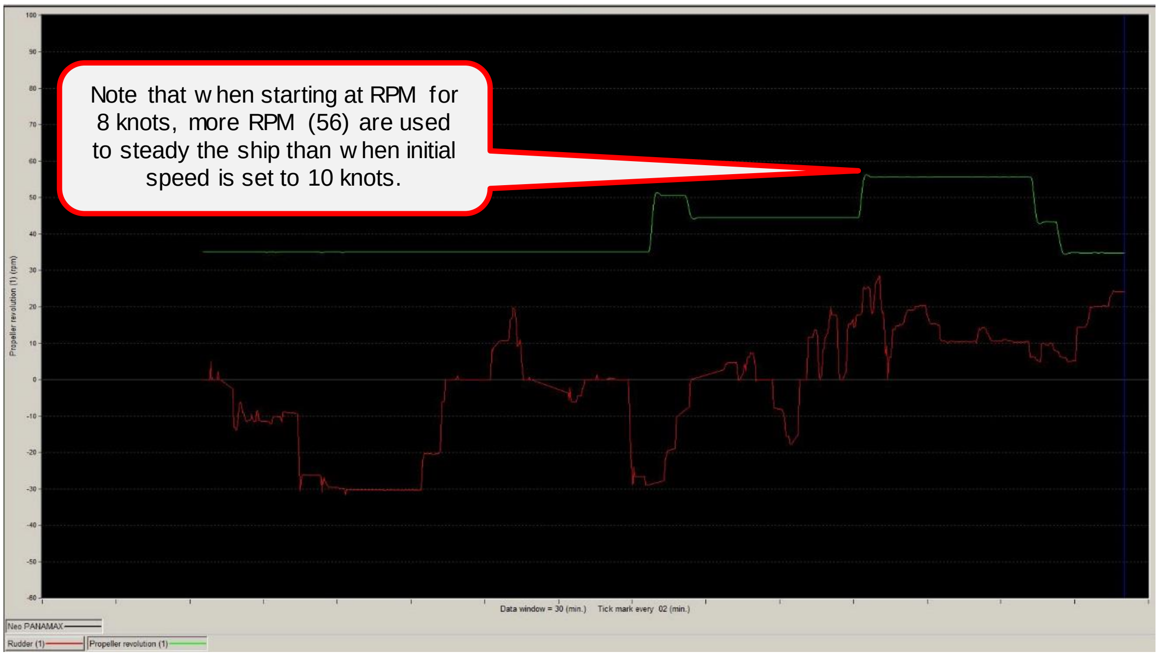


Figure 172: Rudder and RPM, Test G1 T8_4 Neo-PANAMAX - Max Ebb Wind 030@25

6 CONCLUSIONS/ CONSIDERATIONS - POLICY IMPLEMENTATION

Although the term “Minimum Safe Transit Speed” is used several places in this report, it should be first mentioned that the evaluation of what is “Safe” can be somewhat subjective. Therefore, from a low speed transit policy implementation standpoint, “safe” may not be the most useful metric. Certainly, in the case of the entry into the Saguenay River where the minimal channel width is only 650 metres, it is fairly easy to determine if a ship is transiting safely or not, and safety is a high priority necessity. However, in the case of the Anticosti TSS, and to a lesser degree Juan de Fuca TSS, a ship could lose all propulsion and it would not immediately be in danger, moreover, it could probably drift for hours in the wind and tide before it would be in a navigationally dangerous, or unsafe situation. With that said, it would clearly be operating under exceptional circumstances, and according to the Collision Avoidance Rules its manoeuvring status would be that of a vessel “Not Under Command”. In terms of measuring or qualifying what is an acceptable minimum transit speed, it is perhaps best to consider the degree of manoeuvring control that is required by the officer directing the vessel such that it can follow its intended navigation plan and be able to manoeuvre as required to take avoiding action in accordance with the collision avoidance rules.

It should also be underlined that in the absence of wind, tidal stream, current or sea state, all of the vessels tested can navigate and be controlled at their Dead Slow Ahead telegraph setting; which for many ships is a water speed of less than 5 knots. While this may be safe, it is impractical and by no measure could be considered an efficient form of transportation.

Another consideration that, while not within the scope of this analysis/assessment, should be considered from an overall risk standpoint, is that low speed transits in the pilotage areas where vessels are exposed to strong currents/ tidal streams and transiting at distances of less than 1 nautical mile (1852 metres) from land for long periods may present an elevated level of risk compared to transiting at more typical operational speeds. This increased level of risk would stem from the increased duration in which the vessel is exposed to arduous environmental conditions, increased duration of vessel traffic interactions, and fatigue of ship’s officers, helmsmen, and pilots.

Perhaps the most important overall consideration for any Low Speed Transit policy, and to remove inconsistencies that exist with the various speed reduction measures that are currently in place across Canada, is that Water Speed is the only reasonable metric to use to ascertain the noise that a vessel will transmit, and this is also the variable which would affect the severity of collision impact with a marine mammal. Of the four areas examined, the only one where it could be considered acceptable to use Ground Speed (VTS Tracking or AIS broadcast speed) as a monitoring/ enforcement mechanism is in the Anticosti TSS, and this is simply because that for the majority of the time, the difference between ground speed and water speed in that body of water tend to be negligible.

6.1 Considerations for Low Speed Transits Juan de Fuca TSS

The results outlined in Sections 4 and 5 above clearly indicate several facts that should be considered in any decision to implement vessel transit speed restrictions in the Juan de Fuca TSS:

1) For nearly all vessel types, steering and positional control remained good at transit water speeds in the 8 to 10 knot range (loosely speaking Slow Ahead engine telegraph settings), provided that the wind speed did not exceed 30 knots;
2) When wind velocities were in the 30 to 35 knot range, most of the test vessels could maintain steering and positional control at transit speeds of 10 knots;
3) Given that the frequency of occurrence of winds above 30 knots in Juan de Fuca is quite low, and above 35 knots very rare, it would be practical to waive any speed restriction requirement should the sustained wind speed exceed 30 knots; and
4) If either the vessels' transmitted AIS speed, or calculated radar tracking speed by Vessel Traffic Services are to be used as a speed monitoring/enforcement mechanism, then these ground speed values should be corrected to their water speed equivalent using either real time tidal stream (current) velocity data, or tidal stream prediction data that is actively updated using tidal hindcasting information. It is extremely important to consider that additional ground speed due to tidal effects does not increase the ambient sound level that a vessel is generating. Similarly, loss of ground speed due to tidal effects does not reduce the level of ambient noise that a vessel generates. Noise level predominately stems from water speed, and the amount of propeller RPM/ Pitch/ Propulsion power that is being applied.

6.2 Considerations for Low Speed Transits Anticosti TSS

The results outlined in Sections 4 and 5 above clearly indicate several facts that should be considered in any decision to implement vessel transit speed restrictions in the Anticosti TSS:

1) A large portion of the vessels that pass through the Anticosti TSS are full form vessels with top speeds in the 14 to 16 knot range, and generally have Slow Ahead Telegraph settings that equate to speeds of less than 8 knots;
2) While moderate wind speeds are common, the frequency of wind above 22 knots is less than 7% and although specific data was not available, it is likely that the frequency of winds in excess of 30 knots is less than 5%. With this consideration, it would be practical to waive any speed restriction requirement should the sustained wind speed exceed 30 knots;
3) The majority of the vessels that transit this area can maintain good steering and positional control with their telegraph RPMs set for 8 knots, but some vessels at this speed will experience a marginal degree of steering control if the wind speed exceeds 25 knots;
4) With Telegraph RPMs set for 10 knots, or alternating Telegraph settings from Slow Ahead to Half Ahead to achieve an average speed of 10 knots, it would be very

rare that the vessels that frequent this area would not be able to maintain steering and position control at wind speeds up to 30 knots; and

5) In this area, since strong currents or tidal streams are rare, ground speed can be used as a speed monitoring metric.

6.3 Considerations for Low Speed Transits St-Lawrence/ Saguenay Pilotage Area

The results outlined in Sections 4 and 5 above clearly indicate several facts that should be considered in any decision to implement vessel transit speed restrictions in the area of the confluence of the Saguenay and St-Lawrence:

1) For nearly all vessel types, steering (heading) control remained good at transit water speeds in the 8 to 10 knot range (loosely speaking Slow Ahead engine telegraph settings), provided that the wind speed did not exceed 25 knots;
2) When proceeding upriver and stemming the predominate outflow current, positional control, especially with strong winds on the quarter became degraded when the vessel's ground speed became less than approximately 1.5 times that of the current speed (i.e. current speed is 3.0 knots and ground speed is < 4.5 knots, or current speed is 4.0 knots and ground speed is < 6.0 knots);
3) Given that the frequency of occurrence of winds above 25 knots (based on data from Ile Rouge weather station) is less than 8% it would be practical to waive any speed restriction requirement should the sustained wind speed exceed 25 knots; and
4) In all portions of the St-Lawrence and Saguenay, due to variations in the channel width, changes in water depth, and a host of other physical and hydrodynamic factors, the velocity of the current can easily change by as much as 2.0 knots over a space of 500 metres or less. As such, it is virtually impossible for a vessel to maintain a narrow speed range (i.e. 8.0 to 8.5 knots). Any speed management policy should consider that a pilot will order vessel speeds so as to maintain a controlled average speed of a particular value (i.e. 9.0 knots, 10.0 knots, etc.) while transiting through the area of interest. However actual water/ground speed values would then oscillate around this mean speed by as much as +/- 2.0 knots. If vessel speeds are to be monitored within a pilotage area, they should look at the average water speed that was maintained throughout an entire transit segment that is subject to slow down restrictions, and not monitor or be concerned with any increases in speed over short periods/distances.

6.4 Considerations for Low Speed Transits Haro Strait/ Boundary Pilotage Area

The results outlined in Sections 4 and 5 above clearly indicate several facts that should be considered in any decision to implement vessel transit speed restrictions in the area of Haro Strait and Boundary Pass:

1) In this area, the ability to maintain steering and positional control while following a long straight track (i.e.° 347 northbound in Haro Strait, or 245° southbound in Boundary Pass) is very different, and much more predictable, than when conducting the large 70° plus course alterations around Turn Point and East Point.
2) For nearly all vessel types, steering (heading) control remained good at transit water speeds in the 8 to 10 knot range (loosely speaking Slow Ahead engine telegraph settings), provided that the wind speed did not exceed 25 knots and when following a straight-line track;
3) When rounding Turn Point and East Point, given the highly dynamic and variable conditions of the tidal stream, and the fact that a shift in the ship's later position by distances as small as 200 metres can yield very different flow patterns, it can be stated with confidence that on a large portion of vessel transits, pilots will need to vary propeller RPM (Kicks ahead) in order to maintain steering control. Considering the complexities of these two turns, it would be practical to create a zone around Turn Point and East Point with a radius of 2 nautical miles where any speed restriction would not apply, and pilots would be at liberty to apply engine RPM as needed to control the vessel;
4) Given that the frequency of occurrence of winds above 22 knots (based on data from Saturna Island weather station) is less than 5% it would be highly practical to waive any speed restriction requirement should the sustained wind speed exceed 25 knots; and
5) Throughout the entire area of Haro Strait and Boundary Pass, due to variations in the channel width, changes in water depth, and a host of other physical and hydrodynamic factors, the velocity of the current can easily change by as much as 2.0 knots over a space of 500 metres or less. As such, it is virtually impossible for a vessel to maintain a narrow speed range (i.e. 8.0 to 8.5 knots). Any speed management policy should consider that a pilot will order vessel speeds so as to maintain a controlled average speed of a particular value (i.e. 9.0 knots, 10.0 knots, etc.) while transiting through the area of interest. However actual water/ground speed values would then oscillate around this mean speed by as much as +/- 2.0 knots. If vessel speeds are to be monitored within a pilotage area, they should look at the average water speed that was maintained throughout an entire transit segment that is subject to slow down restrictions, and not monitor or be concerned with increases in speed over short time periods/distances.