DET NORSKE VERITAS™

REPORT

RISK ASSESSMENT STUDY FOR COAL BARGE OPERATION

FRASER SURREY DOCKS

REPORT NO./DNV REG NO.: PP050173 / 1-5EZEXO
REV 2A, 2012-09-26

MANAGING RISK

Risk Assessment Study for Coal Barge Operation

For:
Fraser Surrey Docks

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Account Ref.:

Date of Current Issue:		Project No.:	PP050173
Revision No.:	2A	Organisation Unit:	Vancouver Station
DNV Reg. No.:	1-5EZEXO	Report No.:	PP050173

Summary: Det Norske Veritas (Canada) Limited (DNV) was hired by Fraser Surrey Docks to perform a navigational risk assessment of proposed coal barge operations in the Fraser River to assess possible navigational risks associated with increased coal barge traffic. The risk assessment approach applied was an adaptation of the Fraser River Tanker Traffic Study work completed in June 2012 prepared for Port Metro Vancouver.

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- ☐ Unrestricted distribution (internal and external)
- ☒ Unrestricted distribution within DNV
- ☐ Limited distribution within DNV after 3 years
- ☐ No distribution (confidential)
- ☐ Secret

Keywords

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
0	2012-08-27	First issue signed and verified	D. Pertuz	T. Fowler	N. Roper
1	2012-09-14	Client comments addressed	D. Pertuz	S. Kale	N. Roper
2A	2012-09-26	Additional client comments addressed	D. Pertuz	S. Kale	N. Roper

Table of Contents *Page*

1 INTRODUCTION, OBJECTIVES AND SCOPE

Det Norske Veritas (Canada) Limited (DNV) was hired by Fraser Surrey Docks (FSD) to perform a navigational risk assessment of proposed coal barge operations in the Fraser River to assess possible navigational risks associated with the increased coal barge traffic. The risk assessment approach applied was an adaptation of the Fraser River Tanker Traffic Study completed in June 2012, prepared for Port Metro Vancouver (PMV) (Ref. /1/).

The objectives of the study are to:

1. To assess marine navigation risks of barging coal in the Fraser River, again specifically from kilometre marker -1.0 (mouth of the river) to FSD at kilometre marker +34.0.
2. To identify specific risk mitigation processes that could be implemented to reduce risk.

The stated Scope of Work is:

1. Determine Navigational Impacts of increased barge traffic in the River.
2. Conduct a risk review and mitigation analysis, including meeting with key stakeholders. The risk analysis should be related to the proposed coal barge movements on the Fraser River and should cover marine environmental, occupational health and safety and public safety risks.
3. Document the risk review, including the outcome of the stakeholder meetings, and provide a summary of the impact and risk mitigation processes that could be implemented.

2 PROPOSED OPERATIONS, STUDY AREA AND ROUTE

The proposed operations involve upgrades to FSD in way of additional rail, two dumper pits, and a conveyance system, that will allow the FSD to handle 8 Million Metric Tonnes (MT) of coal per annum at full capacity, with FSD seeking to handle 4 Million MT on an annual basis within the next 2-5 years.

Operations are expected to start in Q1 or Q2 of 2013 with the following annual coal volumes:

Annual Coal Volume	**2 million MT (Year 1)**	**4 million MT (Years 2-5)**	**8 million MT (Years 6+)**
Annual movements FSD to mouth of Fraser River	320 single formation fully-loaded barge tows. Two tows each second day, on average.	640 single formation fully-loaded barge tows. Two tows each day, on average.	1,280 single formation fully-loaded barge tows. Four tows each day, on average.
Annual movements mouth of Fraser River to FSD	320 single formation empty barge tows. Two tows each second day, on average.	640 single formation empty barge tows. Two tows each day, on average.	1,280 single formation empty barge tows. Four tows each day, on average.

Figure 1 shows the study area, from kilometre marker -1.0 (mouth of the river) to FSD facility at kilometre marker +34.0

Figure 1 Study Area and Route

Existing and proposed facilities as indicated in PMV's Fraser River Tanker Traffic Study were considered in the FSD Coal Barge Traffic Assessment.

3 ENVIRONMENT DATA AND OPERATIONAL CONTROLS

A modified version of the DNV Marine Accident Risk Calculation System (MARCS), a computer-based system for assessing the risks of marine accidents was used to assist with the FSD Coal Barge Traffic Assessment.

The following natural environment data is used by the MARCS risk model:

- Visibility. This affects the collision and powered grounding accident models.
- Wind speed and direction. This affects the drift grounding accident model if a water current is not applied
- Wave height (sea state). This affects the structural failure/ foundering accident model.
- Sea bottom and coastal or river bank characterization. This affects the drift and powered grounding accident model.
- Open water or river water. This affects the severity of the accident consequences for collision, powered and drift grounding and structural failure/ foundering accidents because such accidents are less likely to result in severe damage to the vessel in a sheltered river location compared to open water.
- Currents. Typical tidal currents are in the order of 1.5 knots. During freshet (approx. mid April to Mid - August), flows are predominantly seaward. Velocity however varies between reaches. The MARCS model was modified to simulate the effect of currents in the river as discussed later in this report.

As indicated, the environmental data and operational conditions used for PMV's Fraser River Tanker Traffic Study were also used in this FSD Coal Barge Traffic Assessment as input for the MARCS model. The data considerations used are reproduced below.

Visibility

On average visibility is reduced to 0.6 nautical miles for approximately 20 days/year in coastal areas (5.5%). At the Fraser River delta this figure can be as high as 60 days/year (16.4%)

Based on this data an annual average probability of poor visibility (less than 3.2 kilometres) of 10% was assumed.

Wind Speed and Direction

Figure 2 shows a wind rose summary of data of three years of data (Apr 2008 - Apr 2011) from the weather buoy at Gravesend Reach on Fraser River. It shows that southeast, south, and east winds predominate. The maximum wind speed observed is less than 20 knots.

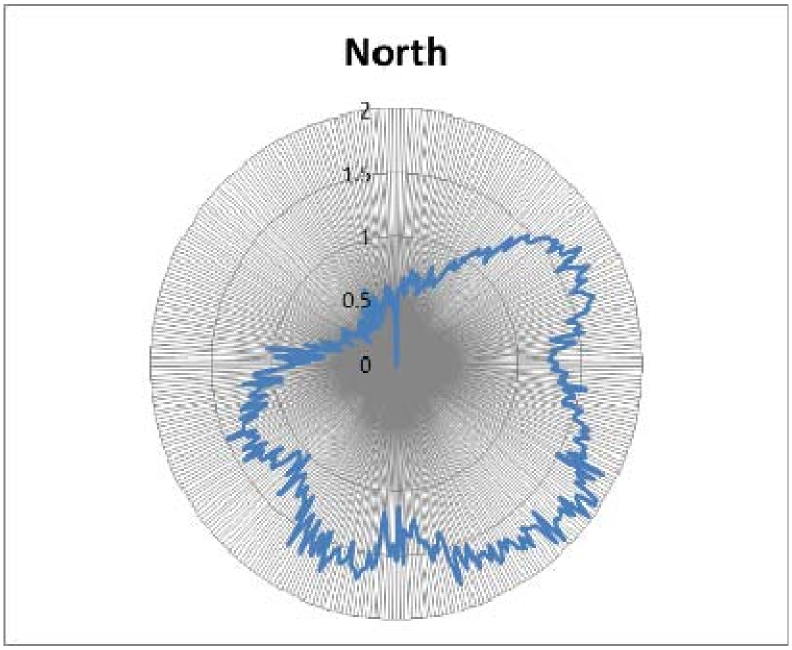

Figure 2- Wind Rose Recorded at Fraser River (Main Arm) at Gravesend Reach Buoy

The MARCS risk model tends to under-predict risks if infrequent high wind speeds are not represented. During the workshop conducted for the PMV tanker Traffic study it was agreed that winds in the study area can exceed 30 knots, but such conditions occur for less than 5% of the time. Strong northwest winds at the entrance of the river have been acknowledged. On this basis, the follow assumptions for wind speeds were made:

- Calm, up to Beaufort 4, 0 to 20 knots assumed for 90% of the time.
- Fresh, Beaufort 5 and 6, 20 to 30 knots assumed for 5% of the time
- Gale, Beaufort 7 to 9, 30 to 45 knots assumed for 4.8% of the time.
- Storm, Beaufort 10 to 12, greater than 45 knots assumed for 0.2% of the time.

These wind speed parameters were applied throughout the study area. However, the impact of the wind in the model is overridden by the impact of the currents as described below.

Wave Height (Sea State)

The entire study area is well-sheltered and no significant wave heights are included in the risk model.

Sea Bottom and Coastal Characteristics

The sea bottom is of importance to the risk assessment because it affects the probability of a hull plating puncture given a grounding. If a ship grounds on soft material such as mud, silt, or sand then the probability of a hull plating puncturing is very low. Conversely, if a ship grounds on hard material it might either be punctured directly by the grounding, or possibly indirectly if the ship becomes stuck and the tide then flows out.

Throughout the entire study area the river bottom and shoreline are predominantly sand, silt and mud with the exception of the areas where the George Massey tunnel and two groups of pipelines cross the channel. These exceptions were validated during the PMV Tanker Traffic HAZID workshop. All these crossings have layers of rocks on top to protect them from scour; however they are deeper than the current design grade of the deep-sea shipping channel. The other submerged pipelines and cables crossing the waterway have not been identified as relevant for this study.

In addition, although the river banks are primarily sand and mud, in many locations they are covered by a layer of rock to protect the banks from erosion. However, in most instances, there is shallow water that would have a vessel run aground before reaching the river bank.

An area of concern for potential grounding is Steveston Jetty at the entrance; a shorter jetty is on the South side of the main entrance. Steveston Jetty is marked by lights and day beacons however the top of the jetty is designed for ¾ tide so can often be submerged at high water.

As presented, the river banks are primarily sand and mud but many areas are covered by a layer of rock. It is difficult to assess the probability of a hull plate puncture given a grounding in this type of environment. Typically a probability of outer hull puncture of 5% to 10% when grounding on a soft shore-line is applied. For this study, the probability of puncturing the outer hull given a grounding was assumed to be 10%. This is taken into account through the spill models described below.

Open Water or River Water

In open water the consequence of collision, powered and drift grounding and structural failure/ foundering accidents are more likely to escalate to higher severities. This is because open water locations have higher wave energies which may further damage, or break open, or capsize, a damaged ship. In addition, for collision accidents in a river most collisions will not be high energy transfer side impacts which have the greatest potential to cause severe collision damage.

All routes are river water, except for the river entrance judged to be open water.

Currents

Strong currents can increase the navigation challenge in confined areas such as rivers and as such increase the potential of collision, powered and drift grounding. This is escalated if vessels are under the control of mariners not familiar with the waterway, or vessels are underpowered or suffer a propulsion or steering casualty. In addition strong currents can escalate the potential consequences of accidents by contributing to further damage or faster and wider spread of pollution if a spilling accident occurs.

Operational Controls

For the PMV Fraser River Tanker Traffic Study, DNV reviewed the operational controls in the Fraser River. It was found that the present-day river management and operational controls are adequate to manage the safe and efficient transit of vessels in the river. In this context, "adequate" means that waterways users could not identify any deficiencies in the navigational aids, requirements or procedures provided.

For the present study, operational controls considered included:

- All deep water vessels carry pilots throughout the study area.
- Tugs generally carry experienced operators familiar with the Fraser River and operations.
- There is no speed restrictions applied in the study area and the river is open for 2-way traffic at all times.
- Tug and barge traffic transits at average 6.3 knots speed over ground.
- No assist tugs engaged in river coal barge operations, however assist tugs could respond if needed in a short period of time.
- A surveillance-based Vessel Traffic Service (VTS), using AIS or primary radar applies throughout the study area.
- In general there is a lot of communication between vessel traffic in the river, tug masters, VTS and facilities, in addition all tugs in the river AIS equipped.

Although not exactly a risk control, another factor considered is that the river bottom in the study area is predominantly soft sand and thus would probably not damage to barge hulls if contact with the river bottom were to occur.

FSD Coal Barge Operations

The coal barge operations have been described as follows:

- Barges are 8,000 DWT in capacity, with the dimensions of 284' long x 72' wide x 16' draft and a 20' load height on average. Deck to top of side walls will be 10'.
- They are coastal barges, single hull, with approximately 9 compartments, transversely framed.
- Barges will be loaded at maximum 85% capacity for transit to the mouth of the river.
- Tugs with engine power from 1,200 to 1,600 hp.
- Transit inbound or outbound expected to be approximately 3 hours (study area).
- Transit speeds about 6.3 knots over ground.
- Coal barges are at the berth for between 5 and 24 hours (average 15 hours).
- Cargo: Sub-bituminous coal (at least during start of operations).
- Cargo loading operations to be conducted at FSD berth No. 2 & 3.

Figure 3 shows a proposed typical barge type that will be used for the operations

Figure 3 - Barge type intended for proposed operations

Figure 4 shows a cross-section schematic of the barge type intended to be used for the operations

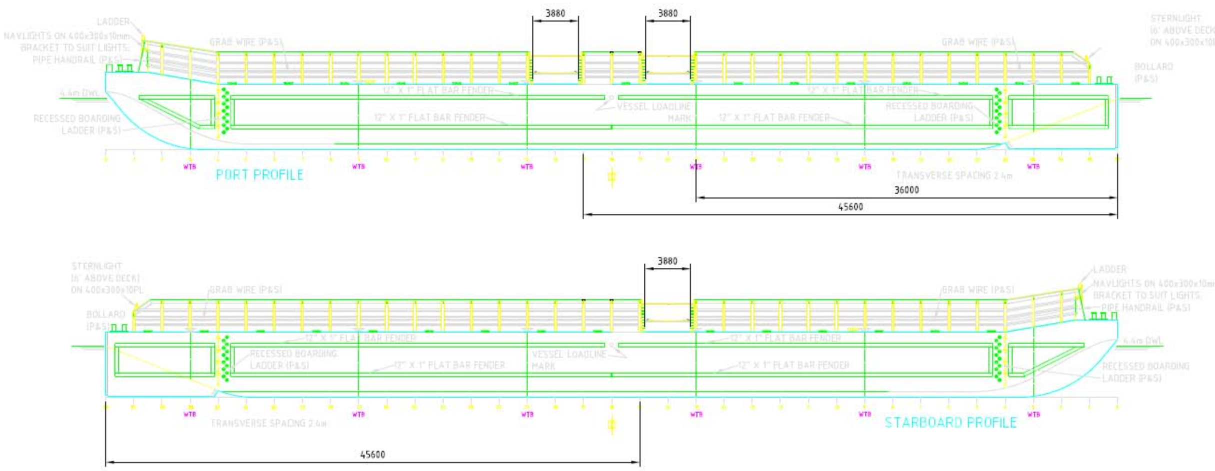

Figure 4 - Cross-section schematic of the barge type intended for proposed operations

Figure - 5 shows the location of FSD berth (highlighted) where the proposed loading operations will take place.

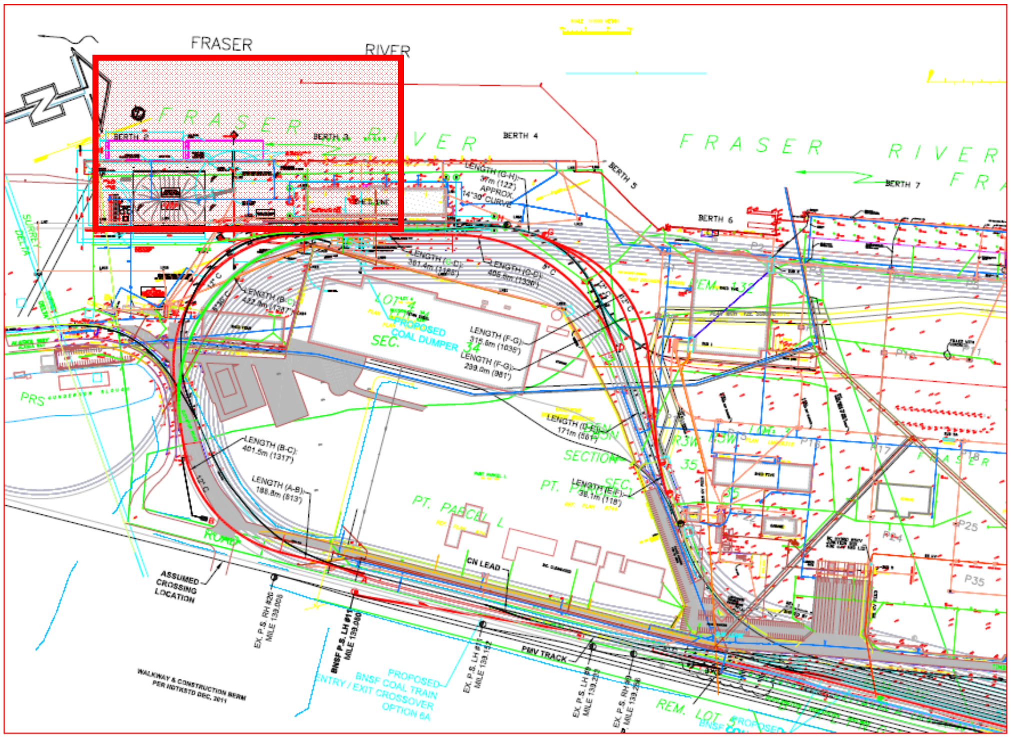

Figure - 5 Layout of FSD Berth 2 and Proposed Shore side Operations

Figure 6 is a close up of the berthing area. The breakwater fence extends to the end of Berth 3, which provides notional protection for the barges at berth 2, given it is downriver from berth 3.

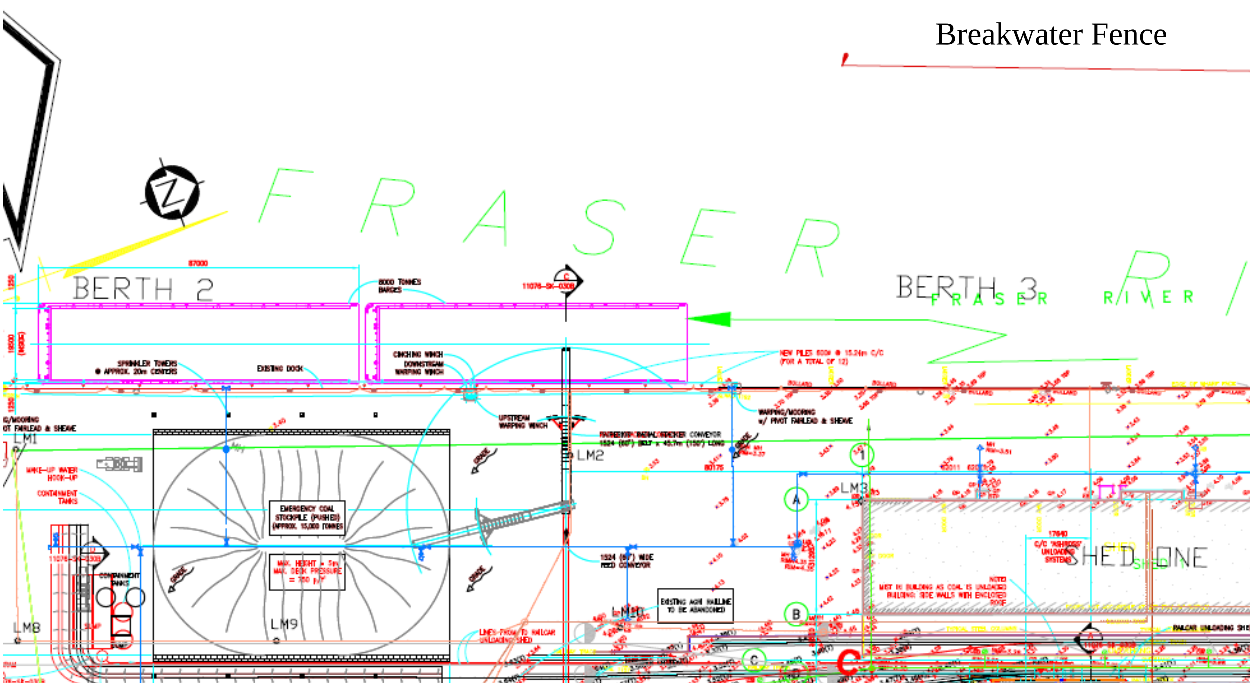

Figure 6 - Close-up Berthing Area and Breakwater Fence

4 FRASER RIVER VESSEL TRAFFIC AND TRAFFIC PATTERNS

As indicated for the FSD Coal Barge Traffic Assessment, the current and forecasted traffic for cases 1 and 2 of the PMV Fraser River Tanker Traffic study and its escalation were used, with the addition of the forecasted FSD coal barge traffic. Likewise, the same route segments were used to conduct the FSD barge traffic assessment.

Figure 7 shows the study area and the routes used. Each route is composed of one or more straight segments and consists of a start point, an end point, and a direction (traffic flows from start to end only). These routes were established from the analysis of the Automatic Information System (AIS) data conducted for the PMV Tanker Traffic Study the same facility destinations of current and forecasted vessel traffic that were applied.

Figure 7 Routes and Facilities

Table 1 presents the routes between the open sea and the facilities considered for this study.

Table 1 Summary of Routes and Facilities

Up-River Segments	Down-River Segments	Facility	Facility	Facility	Facility	Facility
2.2	12.2					
1.1	11.1					
1.2	11.2	A	B (VAFFC)			
1.3	11.3					
1.4	11.4			C		
1.5	11.5					
1.6	11.6					
1.7	11.7				D	E (FSD)
1.8	11.8					

- The routes to and from The FSD facility are composed of segments 2.2, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6 and 1.7 up-river and 11.7, 11.6, 11.5, 11.4, 11.3, 11.2, 11.1 and 12.2 for down-river.

Current Vessel Traffic

For the PMV Tanker Traffic Study, Automatic Information System (AIS) data (from July 2010 to June 2011) were analysed to determine the traffic patterns of ships in the study area, adjustments were made to assist with data accuracy and reduce double counting.

Table 2 presents the best estimated current traffic for each route segment.

Table 2 - Ship Movements from July 2010 to June 2011 by Type and Route

AIS Base Data - Upriver									
Route	**2.2**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**
Deep Water Vessel	538	538	538	538	431	431	431	431	0
Cargo Ferry	2288	2288	2288	2288	0	0	0	0	0
Dredger	358	349	334	550	220	57	27	31	1
Fishing	67	67	25	14	14	10	9	25	1
Military Ops	3	0	0	0	0	0	0	0	0
Passenger	38	24	24	10	11	10	10	10	4
Pilot Vessel	2	2	1	1	1	0	0	0	0
Pleasure	26	17	51	15	28	9	26	61	20
Sailing Vessel	2	1	2	0	1	0	0	0	0
SAR	67	74	65	38	36	23	27	25	12
Tug	2604	2638	3023	3712	3443	3040	2988	3205	2370
Unspecified	4	2	2	2	2	2	2	65	1
Traffic Total	5997	6000	6353	7168	4187	3582	3520	3853	2409

AIS Base Data – Downriver									
Route	**12.2**	**11.1**	**11.2**	**11.3**	**11.4**	**11.5**	**11.6**	**11.7**	**11.8**
Deep Water Vessel	538	538	538	538	431	431	431	431	0
Cargo Ferry	2288	2288	2288	2288	0	0	0	0	0
Dredger	358	349	334	550	220	57	27	31	1
Fishing	67	67	25	14	14	10	9	25	1
Military Ops	3	0	0	0	0	0	0	0	0
Passenger	38	24	24	10	11	10	10	10	4
Pilot Vessel	2	2	1	1	1	0	0	0	0
Pleasure	26	17	51	15	28	9	26	61	20
Sailing Vessel	2	1	2	0	1	0	0	0	0
SAR	67	74	65	38	36	23	27	25	12
Tug	2604	2638	3023	3712	3443	3040	2988	3205	2370
Unspecified	4	2	2	2	2	2	2	65	1
Traffic Total	5997	6000	6353	7168	4187	3582	3520	3853	2409

The traffic in the river for future years was estimated based on the following same assumptions used in the PMV Tanker Traffic Study. These assumptions are:

- Deep Water Vessel traffic increases as forecasted by the Port
- Cargo Ferry traffic is unchanged as verified with ferry operators
- Dredger traffic is unchanged.
- Fishing traffic is unchanged.
- Military Ops traffic is unchanged.
- Passenger traffic is unchanged.
- Pilot vessel traffic increases are unchanged.
- Pleasure traffic increases is unchanged.
- Search and Rescue traffic is unchanged.
- Tug traffic increases at 3% per year from the base year.
- Unspecified traffic is unchanged.

As listed, only tug vessel traffic is expected to escalate in the future.

The above data and assumptions were used as the basis for the FSD coal barge traffic assessment adding the additional proposed traffic to the forecasted “tug” traffic.

DNV is aware there is other traffic in the river that is not accounted, however these other vessels are small and, for the purpose of this study, do not represent a significant additional risk to the coal barges.

5 METHODOLOGY AND APPROACH

Three specific operations (cases) were selected for assessment by FSD:

- **Case 1 Year 2014**. 320 barge tows per year inbound (empty) and 320 tows per year outbound (loaded) in 2014. Other traffic taken from 2016 case from PMV's Fraser River Tanker Traffic Study case 1 (Ref. /1/), including new liquid bulk due to Vancouver Airport Fuel Facilities Corporation (VAFFC) (12 tankers and 48 barge deliveries per year). This is a conservative case, as 320 coal barges per year are expected in 2014 but this is combined with other traffic data estimated for 2016.
- **Case 2 Year 2016**. 640 barge tows per year inbound (empty) and 640 tows per year outbound (loaded) in 2016. Other traffic taken from 2016 case from PMV's Fraser River Tanker Traffic Study case 1 (Ref. /1/), including new liquid bulk due to VAFFC (12 tankers and 48 barge deliveries per year). This is consistent, as 640 coal barges per year are expected in 2015/16 and this is combined with other traffic estimated for 2016.
- **Case 3 Year 2018**. 1280 barge tows per year inbound (empty) and 1280 tows per year outbound (loaded) in 2018. Other traffic taken from 2021 case from PMV's Fraser River Tanker Traffic Study case 2 (Ref. /1/), including new liquid bulk due to VAFFC (18 tankers and 72 barge deliveries per year). This is a conservative case, as 1280 coal barges per year are expected in 2018 onwards, but this is combined with other traffic estimated for 2021.

The risk assessment performed for this study followed a traditional process consisting of the following elements:

- **System Description**: In this study, the system description consisted of detailed information about current and future marine traffic, the environment and the operations in the study area.
- **Hazard Identification**: What may go wrong with an operation?
- **Frequency Assessment**: How often might hazards occur?
- **Consequence Assessment**: What might be harmed (people, the environment, property and business) as a result of a hazard occurring and how severe is the harm likely to be?
- **Risk Analysis**: What is the total risk to the operation from all hazards?
- **Risk Management:** What can be done to reduce the risk? The identification of options that could reduce the frequency and/or consequence of hazards, and the coarse evaluation of their implementation

The system description and hazard identification elements were mostly extracted from the Fraser River Tanker Traffic Study prepared for PMV (Ref. /1/), as the study area, navigation routes current and future marine traffic, environmental on operational conditions were the same parameters of the work requested.

The frequency assessment, consequence assessment and risk analysis, were performed by modelling from a modified version of the DNV Marine Accident Risk Calculation System (MARCS), a computer-based system for assessing the risks of marine accidents.

The risk management element was conducted via a workshop facilitated by DNV and attended by Fraser River stakeholder organisations.

6 RISK ASSESSMENT MODEL AND RESULTS FOR THE PROPOSED OPERATIONS

The risk models developed for PMV Tanker Traffic Study (Ref. /1/), were applied without modification except that:

- New coal barge traffic as described above was added to two selected cases developed for PMV Tanker Traffic Study (PMV Case 1 and PMV Case 2). PMV Case 1 was used for the new FSD Cases 1 and 2 reported below and PMV Case 2 for used for the new FSD Case 3 reported below.
- It was assumed that coal barges are at the berth for between 5 and 24 hours (average 15 hours).
- It was assumed that the barges complete their transit up and down the river in an average of 3 hours (6.3 knots between the -1km to +34km mark).
- The liquid bulk accident consequence models were not applied to the proposed coal barge trade as they are not appropriate.

As in the previous study for PMV Tanker Traffic Study it is assumed that the new coal barge facility to be developed at FSD will be notionally separated from the main channel of the Fraser River by a breakwater fence that extends over berths 3 and 4 at FSD. This significantly reduces the frequency of striking.

In all other respects the models previously developed were unchanged.

It must be noted that in view of not available data sets for tug and barge operations, small cargo ship data were used to represent tug and barges. DNV considers that the assumption of small ships to represent a tug-barge combination is justified because:

- In the Fraser River the amount of sea room available to a mechanically disabled vessel is so small that almost all disabled vessels will ground irrespective of if steerage is maintained for a few minutes after loss of propulsion for a small ship.

- Fire or explosion is not a significant risk contributor. Modelling the tug-barge as a small ship will tend to over-estimate fire/explosion risks.

- The length of the towline will be reasonably short in the river given the amount of sea room above.

Identified differences between a tug-barge and a small cargo ship are:

- A loss of power to a cargo ship would not result in an immediate loss of vessel steerage as it would be the case for tugs.
- Draughts are different
- In case of loss of power, the turning swing for a tug and barge would be different and would follow a different path than that of a small cargo ship.
- Cargo ships trim can be adjusted, loaded barges trim cannot and there are no pumping possibilities in barges. Therefore movement of cargo during transit or loading errors, etc. cannot be compensated for once in transit.
- Fire and explosion will be different because the engine room is not in the same hull.
- Similarly collision may be different because of the swing / length of the tow etc.
- If a tug grounds, an almost certain consequence is for the barge to run over the tug specially if the barge is empty (when a barge is loaded its draught will be usually more than that of the tug)

RISK MODEL RESULTS

Accident Frequencies

The following numerical risk model results are provided:

- The total accident frequency (accidents per year).
- The "spilling" accident frequency (accidents per year). This result characterizes those accidents that are sufficiently severe that results on cargo spilled from the cargo holds
- The total loss frequency (accidents per year). This is an estimate of those accidents that are sufficiently severe that may lead to the total loss of the barge. (beyond economic repair)).

The "spilling" accident frequency and the total loss frequency were calculated using probabilities derived from an analysis of spills from tanker accidents worldwide. DNV considers that this approximation is justified given the level of risk estimated.

These accident frequency results for Cases 1, 2 and 3 are shown in Table 3

Table 3 Numerical Risk Results for FSD Coal Barge assessment Case 1, Case 2 and Case 3

	Case 1			Case 2			Case 3		
Accident Type	Total Frequency	“Spilling” Frequency	Total Loss Frequency	Total Frequency	“Spilling” Frequency	Total Loss Frequency	Total Frequency	“Spilling” Frequency	Total Loss Frequency
Collision	0.127	0.017	0.010	0.270	0.036	0.022	0.650	0.087	0.052
Structural Failure/ Foundering	0.0004	0.0001	0.0001	0.0007	0.0002	0.0001	0.0015	0.0005	0.0003
Fire/ Explosion	0.0006	0.0002	0.0001	0.0012	0.0005	0.0002	0.0024	0.0010	0.0005
Powered Grounding	0.636	0.011	0.006	1.272	0.022	0.013	2.545	0.044	0.025
Drift Grounding	0.299	0.006	0.003	0.599	0.013	0.006	1.197	0.025	0.012
Impact at Fraser Surrey Docks	0.118	0.004	0.0	0.237	0.008	0.0	0.474	0.017	0.0
Striking at Fraser Surrey Docks	0.00605	0.00003	0.0	0.01651	0.00009	0.0	0.05192	0.00030	0.0
Total Frequency (per year)	1.19	0.039	0.020	2.40	0.080	0.042	4.92	0.175	0.094
Accident Return Period (years)	0.8	25.8	49.5	0.4	12.5	23.8	0.2	5.7	10.6

Risk is a function of both accident frequency and accident consequence. Consequence can be assessed using a number of different metrics.

The scope of this study is confined to an assessment of consequence to the environment.

The coal expected to be transported during this operations, at least during the early years, is sub-bituminous coal.

Sub-bituminous coal accounts for about 38% of Canada's coal production. It is softer than bituminous coal and contains a higher moisture content. It is abundant in Alberta and is mainly used for electricity generation. Sub-bituminous coal may be dull, dark brown to black, soft and crumbly at the lower end of the range, to bright jet-black, hard, and relatively strong at the upper end. Sub-bituminous coal is non-coking and has less sulfur but more moisture (approximately 10 to 45 percent) and volatile matter (up to 45 percent) than bituminous coals. Carbon content is 35-45 percent and ash ranges up to 10 percent. Sulfur content is generally under 2 percent by weight.. Besides the major elements, sub-bituminous coal always contains a large number of other elements in minor and trace amounts. Some of these are considered toxic, for instance, mercury (Hg), arsenic (As), cadmium (Cd), lead (Pb), selenium (Se), and uranium (U). Further, sub-bituminous coal might contain large concentrations of Polycyclic Aromatic Hydrocarbon (PAHs) - (Ref. /3/). Still the environmental toxicity and impact from unburned coal has not been addressed in impact assessments of coal. It is mainly the mining impacts, coal slurry impacts and impacts from burning coal that are of interest while assessing environmental impact from coal. The environmental effects of Sub-bituminous coal spills into the river are unknown. It is believed that if sub-bituminous coal is spilled in the river, it would sink almost immediately. The reason for the lack of focus on environmental impact from sunken coal might be that the trace elements and PAH in sunken coal in the sediment are little bio-available. Thus it will most likely not pose any major risk for impact on the environment. The impacts that can occur might be from PAH contamination of sediment dwelling organisms in immediate vicinity of the coal. However, it is no available literature on PAH leakage from coal. Based on the little knowledge about harmful effects from accidental spilled coal in the environment DNV ranks the potential impact as Medium (D) according to the consequence definition in the risk matrix.

The next step in the risk process is to categorise the risk frequencies and consequences estimated previously into classes (frequency from Improbable (5) to Highly Probable (1), consequence from Extreme (A) to Low (E)). Using frequency and consequence, each risk is then mapped against a risk acceptance criteria matrix to define its level. The level of risks corresponds to the level of attention the risks shall receive.

The risk acceptance criteria used for this study are based on the Transport Canada Pilotage Risk Management Methodology (PRMM) (Ref. /2/), with some modifications to cover economic and operational considerations.

The actual criteria used in this study are presented Table 4. Again, it should be noted that the scope of this study is confined to an assessment of consequence to the environment as such; other consequence parameters are not included in the table.

The colour of each frequency-consequence pair on the matrix indicates the level of risk:

- **Green**: Risk is tolerable, though low cost risk reduction measures should still be considered for implementation.
- **Yellow**: Risk is As Low as Reasonably Possible (ALARP) if all justified risk reduction measures have been implemented.
- **Red:** Risk is unacceptable and the proposed operation should be re-considered, or additional risk mitigating measures introduced to lower the risk consequence or frequency and to bring the risk down to an acceptable level.

The risk results are shown in Table 5.

Table 4 Risk Acceptance Criteria Matrix

		Consequence				
		A-Extreme	**B-Very High**	**C-High**	**D-Medium**	**E-Low**
Consequence Metric	**Environment**	Sustained long term harm (i.e. damage lasts longer than a month)	Sustained medium term harm (i.e. damage lasts up to one month)	Medium term harm (i.e. damage lasts up to two weeks)	Short term harm (i.e. damage lasts no longer than a week)	Minimal harm (i.e. damage lasts no longer than a day)
	Human Safety	Multiple deaths and multiple people with serious long-term injuries. Intensive Care	Single death and multiple people with serious long-term injuries. Intensive Care	Some people with serious long-term injuries and multiple minor injuries.	One person with serious long-term injuries. Some minor injuries.	Single or multiple minor injuries requiring on site First Aid and\or off-site treatment.
	Port Business (Operational)	Sustained long-term disruption (longer than a month)	Sustained medium-term disruption (up to a month)	Medium-term disruption (up to two weeks)	Short-term disruption (no longer than a week)	Minimal disruption (no longer that a day)
	Property (Economic)	Damage to property is such that it ceases operations for a period of time exceeding one month or financial loss exceeds $10 million.	Damage to facilities is such that operations cease for up to one month or financial loss of $5 - $10 million	Damage to facilities is such that the operations cease for up to two weeks or financial loss of $1 - $5 million.	Damage to facilities cause operations to cease for up to one week or financial impact of $500,000 - $1 million.	Damage to facilities cause operations to cease for up to 72 hours or a financial impact up to $500,000.
		Risk Ranking				
Frequency Metric	**1 - Highly Probable**	**1A**	**1B**	**1C**	**1D**	**1E**
	2 - Probable	**2A**	**2B**	**2C**	**2D**	**2E**
	3 - Possible	**3A**	**3B**	**3C**	**3D**	**3E**
	4 - Unlikely	**4A**	**4B**	**4C**	**4D**	**4E**
	5 - Improbable	**5A**	**5B**	**5C**	**5D**	**5E**

Frequency Definitions	**Definition**	**Accident Return Period (interpretation)**
Highly Probable	Almost certain the event will occur OR at least once over a period of one year.	Less than or equal to 1 year
Probable	Expected that the event will occur OR at least once over a period of three years	Between 1 and 3 years
Possible	The event could occur over a period of 10 years	Between 3 and 10 years
Unlikely	It is not expected that the event will could occur during a period of 10 years	Between 10 and 25 years
Improbable	It is not expected that the event will occur during any defined period.	Assume greater than 25 years (once per career)

Table 5 Risk Results

Accident Type	Case 1			Case 2			Case 3		
	Total Frequency	"Spilling" Frequency	Total Loss Frequency	Total Frequency	"Spilling" Frequency	Total Loss Frequency	Total Frequency	"Spilling" Frequency	Total Loss Frequency
Collision	3D	5D	5D	3D	5D	5D	2D	4D	4D
Structural Failure/ Foundering	5D	5D	5D	5D	5D	5D	5D	5D	5D
Fire/ Explosion	5D	5D	5D	5D	5D	5D	5D	5D	5D
Powered Grounding	2D	5D	5D	1D	5D	5D	1D	4D	5D
Drift Grounding	3D	5D	5D	2D	5D	5D	1D	5D	5D
Impact at Fraser Surrey Docks	3D	5D	5D	3D	5D	5D	2D	5D	5D
Striking at Fraser Surrey Docks	5D	5D	5D	5D	5D	5D	4D	5D	5D
Total Frequency (per year)	5D	5D	5D	5D	5D	5D	5D	5D	5D

Table 5 shows that the majority of the risks assessed are green (risk is tolerable, though low cost risk reduction measures should still be considered for implementation). A small number however are yellow (risk is ALARP if all justified risk reduction measures have been implemented). This risk assessment therefore concludes that from a technical risk point of view, provided that all justified risk reduction options are implemented, the proposed coal barge operations are acceptable.

It should be noted, however, that the proposed barge operations may increase to 1280 coal movements per year by 2018, subject to further project permit and environmental review. This represents just over 15% of the total traffic predicted to be on the Fraser River in 2021. In addition, the total traffic forecast (including the 1280 coal barges) predicts an average of just under 30 movements a day upriver *plus* just under 30 movements a day downriver (predicted annual traffic divided by 365). Deep sea traffic already uses tidal assist to maintain under keel clearance, so "traffic bunching" may lead to river capacity constraints if this potential problem is not managed effectively.

7 RISK ASSESSMENT PROCESS

The DNV risk assessment, including risk identification, expected frequency and consequences, was presented to a workshop of key Fraser River stakeholders ("FR Stakeholders") who collectively and individually make a direct contribution to safe operations on the Fraser River

The FR Stakeholders include:

- Fraser River Pilots
- Council of Marine Carriers
- FSD's barge operator partner ("Barge Partner");
- Fraser Surrey Docks
- Transport Canada (represented by Compliance, Navigable Waters)
- BC Chamber of Shipping
- Port Metro Vancouver, and
- DNV (Facilitation Team).

FSD presented to the FR Stakeholders and DNV, the proposed movement of coal on barges from FSD to Texada Island, BC.

The frequency assessment, consequence assessment and risk analysis, were performed by modelling from a modified version of the DNV Marine Accident Risk Calculation System (MARCS), a computer-based system for assessing the risks of marine accidents. This was used to simulate the proposed coal barge scenarios in Section 2 in order to assess the potential risks associated with the coal barge traffic on the Fraser River. Reference is made to Section 6.

DNV's analysis considered the risk and consequences in relation to seven potential accident types, which are outlined in Table 3 in relation to the barging operations.

The expected frequency and consequences of these accident types were modeled and the results shown in Table 5.

The FR Stakeholders were asked to consider the initial DNV findings and comment on other potential risks associated with the coal barge traffic as well as risk prevention and mitigation strategies. Key comments from the FR Stakeholders were:

1. Similar barge and tug operations are already occurring on the Fraser River, including many by the proposed Barge Partner. These existing operations are conducted safely and without incident, so the FR Stakeholders did not see that the proposed FSD barge operations carried materially increased risk

2. The FR Stakeholders viewed the increase in Fraser River traffic as the largest risk exposure, but they thought that this could be managed. There was a thought that consideration should be given to widening and deepening the channel, marking secondary lanes for smaller vessel traffic (including tug and barges), in order to better accommodate increased potential traffic. It is important to communicate scheduled barge transits to pilots.

3. The use of an adequately sized and powered tug boat, length and condition of the tow line and bridles is critical to a safe barge operation. The FR Stakeholders commented that the significant experience of Barge Partner is important in this context and should help in reducing the risk of accidents by taking into consideration the key variables above

4. During freshets, a tug assist should be considered for increased safety of the barge operations

5. Regular maintenance and safety checks of tugs, their equipment and barges is very important. It is expected that the standard operating procedures of the Barge Partner shall provide guidelines to address these issues.

As noted in Table 5, the majority of risks associated with the coal barge movements, identified in green, are considered tolerable with the suggestion that some low cost risk reduction measures be considered. A small number of risks, identified in yellow, are considered ALARP, or As Low As Reasonably Possible, if justified risk reduction measures are taken. None of the risks are considered unacceptable or considered to require a material change to the proposed operations.

This model result, which states that proposed operations are not expected to lead to significant risk exposure, is consistent with the general views expressed by the FR stakeholders at the marine risk workshop.

8 CONCLUSIONS RECOMMENDATIONS

The proposed coal barge operations do not present any new operations or issues of concern that are not already being conducted or considered in the river. From the technical risk point of view, based on a semi-quantitative risk assessment conducted, risks identified are acceptable provided that all justified risk reduction options are implemented.

The assessment conducted, however, identifies probable risks of powered grounding with medium consequences for year 2014 operations, and highly probable risk of powered grounding with medium consequence for years 2016 and 2018. It is important to note, that the risk model results are conservative in nature and take in consideration contact of the vessel with the bottom and may not result in a reportable event. The majority of these groundings, should they occur, are unlikely to result in damage to the tug or barge as the river bottom is mostly soft (not rock) and so is unlikely to puncture a hull.

FSD and its Barge Partner have also proposed the below risk mitigation strategies (listed in Table 6 below), among others, in addition to established good practice in an effort to minimize potential exposure related to the seven risks identified in Table 5.

FSD and its Barge Partner inform DNV that the majority of these strategies have been incorporated in their barging standard operating procedures or project design and that the partners intend to periodically review and update these strategies and related procedures should significant changes take place which would affect existing measures and experience or as new information as a result of lessons learned during the course of operations.

Several of these management strategies were concluded in discussion with the FR Stakeholders while some based on are existing measures already in place.

Table 6 Risk Mitigation Strategies

Category	Risk Management Strategies / Mitigating Factors
Equipment Selection and Inspection	• All tugs will be inspected at regular intervals to ensure they meet the required Transport Canada regulations. Barges will be inspected at regular intervals by the barge partner in the absence of regulations or requirements for periodic inspections mandated by Transport Canada for dumb barges. • Tugs will be selected in accordance with the then-current weather conditions and barge load characteristics, in order to ensure a proper match between tugs and barges. Equipment selection criteria will be based on Barge Partners' significant experience in operating in the Fraser River. • The proposed 8,000 DWT barges are compartmentalized, typically with nine compartments, such that if one compartment is punctured and begins taking on water, the damage will be contained in that compartment and the barge may be

	transported to a safe location for unloading and repair • All tugs will have monthly fire drills / training and have fire suppression equipment including fire house and pumping equipment
Operational Structure	• Barge operations will not be conducted in high wind conditions, in order to lessen the chances of an accident. The criteria will be defined in broad terms leaving room for taking into account operator experience. • All night time operations will follow mandatory lighting and manning requirements • The FSD berth face to be used for the proposed barge operations is not directly open to the main shipping channel, reducing the potential for a vessel impact • The Fraser River bed and bank consists largely of mud and sand, which is expected to lessen the risk of potential vessel damage in the event of a grounding • The FSD berth face to be used is designed to bear regular loads of barge and tug rubbing that occurs with tidal action, lessening the potential impact of striking incidents
Communication with Relevant Stakeholders	• FSD will use two methods to notify vessel pilots of barge operations: (i) FSD will include barges in its vessel schedule and post this vessel schedule online, such that it is available to the public and (ii) whenever a shipping line places an order for berth space at FSD, FSD will notify the pilots and agents of the presence of any coal barges • Fraser River pilots will be aware of the coal barge presence and may order additional tug assist for vessel entry and exit at the FSD berth face
Accident Response	FSD / Barge operator will: • Contact emergency services, including the coast guard and other relevant agencies, immediately following any accident • Communicate with the Barge Partner dispatch • Verify the safety of all vessel occupants and assess the need for first aid or water rescue • Check coal cargo to ensure it is secure. It is noted that The coal will not be contained in the barge hull, but rather on the barge

	deck. Therefore a puncture of the hull would not directly lead to a coal spill • As needed, contain any spills in accordance with the FSD / Barge Partner Spill Containment Plan and the FSD Environmental Management Plan. • If applicable and to extent possible, ensure that tug and barge are out of the shipping lane • If needed, solicit assistance from other tug traffic on the Fraser River. Assistance may be available from one of the many Barge Partner tugs on the Fraser River or from a third party operator • If tug still has power, decision will be made to re-commence journey and control barge movements through two-line management in order to prevent a barge-related accident

9 REFERENCES

1	DNV Fraser River Tanker Traffic Study, prepared for Port Metro Vancouver, Rev. 1 06 June, 2012
2	Transport Canada Pilotage Risk Management Methodology (PRMM) Publication No.TP 13741E (05/2010)
3	Achtena C. and Hofmanna T. 2009, Native polycyclic aromatic hydrocarbons (PAH) in coals – A hardly recognized source of environmental contamination. Science of the Total Environment page 2461-2473.

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