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Canadian Crude Oil Transportation
Comparing the Safety of Pipelines and Railways

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MARSH & McLENNAN COMPANIES

Contents

I. Introduction

Canadian crude oil and related products are transported primarily by pipelines and railways. As rail has become a standard for transporting crude oil that exceeds pipeline capacity over the past half-dozen years, some industry analysts have raised questions about the "relative safety" of different modes of transport for crude oil. Some of these analyses have presented an incomplete picture, leading to unwarranted conclusions about the overall safety of one mode compared to another. This paper was originally published in October 2015 to provide a balanced perspective on this issue, by reviewing recent statistical data on pipeline and rail crude oil spills – both the number of incidents and the volume spilled. This updated version adds several years of new data concerning the safety record for crude oil movements by mode. The updated data confirms that with current regulation and investment both rail and pipeline have comparable safety records and are safe means of transporting crude oil.

This paper presents crude oil data for Canada's two largest "Class I" railways, Canadian National Railway Company (CN) and Canadian Pacific Railway Limited (CP). These two carriers together transport more than 99 percent of the Canadian crude oil that is transported by rail (Exhibit 1). It should be noted, however, that crude-by-rail movements only account for 1.84 percent of Canadian rail carloads.[1]

Exhibit 1: Canadian Crude Oil Transport by Railway Type, 2012-2018[2]

	Millions of Revenue Ton-Miles			Percent Share of Total	
	Class Is	Short Lines	Total	Class Is	Short Lines
2012	6,900	50	6,950	99.3%	0.7%
2013	15,829	65	15,895	99.6%	0.4%
2014	21,055	401	21,456	98.1%	1.9%
2015	17,965	526	18,491	97.2%	2.8%
2016	8,576	185	8,761	97.9%	2.1%
2017	10,903	106	11,009	99.0%	1.0%
2018	16,712	27	16,739	99.8%	0.2%

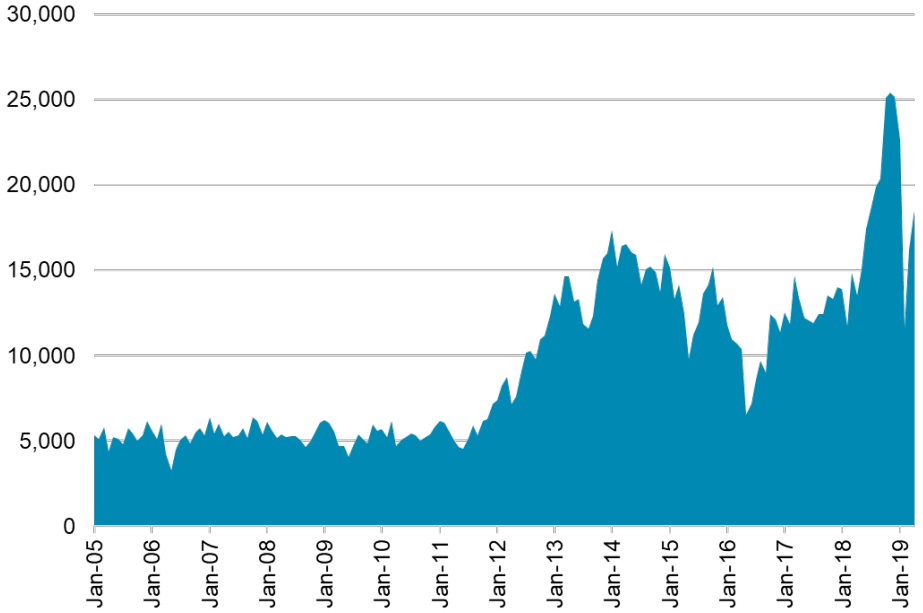
[1] Average for 2014-2018. Source: Railway Association of Canada.
[2] Note: Revenue ton-miles shown represent crude oil transported in Canada by CN, CP, and the Canadian short lines. Source: Canadian National, Canadian Pacific, the Railway Association of Canada.

II. Canadian Production and Transport of Crude Oil

Canada has the world's third largest proven oil reserves,[3] and development of these resources has accelerated since 2009, with year-over-year production growth of 4.1 percent on average, from 3.2 million barrels in 2009 to 4.6 million barrels in 2018.[4]

Historically, most of this oil moved by pipeline. Prior to 2012, rail moved less than 6,000 carloads (that is, filled tank cars) of fuel oil and crude oil per year (Exhibit 2).[5] Beginning in 2012, however, the amount of crude oil transported by rail began to grow (as did the amount transported by pipeline), as new sources of production in Canada became available. Early growth in the use of rail for transporting crude oil can primarily be attributed to the need to connect new oil fields with refineries in certain regions where pipelines either were not present or lacked sufficient capacity.

Exhibit 2: Canadian Fuel Oil and Crude Oil Moved by Rail, January 2005 to January 2019[6]
In carloads



Movements of crude-by-rail declined significantly in 2015 and 2016, due to softer demand and lower prices, but began to climb again in 2017, in part due to a number of pipeline projects stalling or being abandoned (e.g., the Trans Mountain pipeline) while global demand

[3] BP Statistical Review of World Energy, June 2018.
[4] BP Statistical Review of World Energy, June 2018; Estimated Production of Canadian Crude Oil and Equivalent, National Energy Board (https://www.neb-one.gc.ca/nrg/sttstc/crdlndptrlmprdct/stt/stmtdprdctn-eng.html).
[5] Transporting Crude Oil by Rail in Canada, Canadian Association of Petroleum Producers, March 2014.
[6] Table 23-10-0216-01, Railway Carloading Statistics, by Commodity, Monthly, Statistics Canada, op. cit.

strengthened. Crude-by-rail volumes began to surge starting in May 2018 and reaching a peak in November-December 2018. Year-over-year volumes for November and December 2018 were 91 and 80 percent higher than for the same month in 2017.[7]

Crude oil exports via rail grew even faster than overall totals. According to the National Energy Board, Canadian crude oil exports by rail more than doubled between December 2017 to December 2018 from 152,000 barrels per day to 354,000 barrels per day.[8] Daily crude oil export volumes by rail peaked in December 2018; while volumes are running below that peak for the first four months of 2019, they remain at or above 2018 volumes for the same month.

[7] Table 23-10-0216-01, Railway Carloading Statistics, by Commodity, Monthly, Statistics Canada (https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310021601).

[8] Canadian Crude Exports by Rail – Monthly Data, National Energy Board of Canada (https://www.neb-one.gc.ca/nrg/sttstc/crdlndptrlmprdct/stt/cndncrdlxprtsrl-eng.xls). The capacity of a rail tank car carrying crude oil varies according to the cubic and weight limits of the available railcars as well as the density of the crude oil. On average, Canadian crude has a higher density than lighter crude oil, thus reducing the carrying capacity of the railcars used to move it. Using an estimate of 600 bbl/car, Oliver Wyman estimates that Canada exported 7,850 and 18,279 carloads in December 2017 and 2018, respectively.

III. Evaluating Safety Metrics for Oil Transportation

Both railways and pipelines in Canada have made significant efforts to minimize spills and ensure the safe transport of crude oil. These efforts have included investments and improvements in transportation infrastructure and equipment, engineering processes, technology, training and safety culture. Between 2014 and 2018, Canadian pipelines and railways together transported 216,987 *billion* gallon-miles of crude oil within Canada; of this, 2.19 million gallons were spilled, highlighting that 99.999 percent of the volumes transported by rail and pipeline were done so without incident.

Some industry studies that have examined the number of oil spill incidents involving crude oil and related products have drawn the conclusion that pipelines provide a safer alternative for moving these products. These analyses have used as their basis of comparison what is known as the **"incident rate,"** which is based on how many separate release incidents each mode has experienced. This study uses a different metric, known as the **"spill rate,"** which more accurately characterizes safety performance, as it considers the total volume of oil released by each mode per year in comparison to each mode's workload. We conclude that both modes of transportation have similar – and extremely low – ratios of oil released to oil transported. This report reviewed incident and spill rate data together to assess safety performance and relative levels of risk for Class I railways and pipelines.

A. Incident Rate

The incident rate involves three data points:

- the total number of incidents for each mode (number of crude oil releases per year);
- the total volume of crude oil the mode transports (annual gallons); and
- the total distance the crude oil is moved (annual miles).

Gallons are then multiplied by miles, which gives the total volume moved over total distance, known as gallon-miles. This is important, as both the distance transported and volume shipped increase the potential for spills. The number of incidents is then divided by gallon-miles to derive the incident rate for the year:

Incident rate = Number of incidents / (total volume x total miles)

Exhibit 3 shows pipeline crude oil incident data for 2004-2018 and available Class I rail crude oil incident data for 2012-2018 (very small amounts of crude oil were moved by rail prior to 2012).

Class I railroad data is presented as these railroads move more than 99 percent of crude oil in Canada. There is little data available on short line railroads. The most critical incident involving crude oil that has occurred on a short line was the 2013 Lac-Mégantic accident, which involved a railway that has since gone out of business. The line currently operates under new ownership and is no longer used to transport crude oil.

Exhibit 3 shows that the incident rate for both modes is very small – an average of 0.0076 incidents per billion gallon-miles for pipeline and 0.0054 for rail. Both modes also have seen significant declines in the number of incidents over the past few years. Incident rates remained low even as volumes increased in 2018, reflecting the safety measures and technology both modes have put in place and continue to refine.

Exhibit 3: Canadian Crude Oil Incident Rates for Pipelines and Class I Railways[9]

	Pipelines			Class I Railways		
Year	**Number of Incidents**	**Gallon-Miles Transported** (billions)	**Incident Rate**	**Number of Incidents**	**Gallon-Miles Transported** (billions)	**Incident Rate**
2004	301	19,533.1	0.0154			
2005	336	17,876.7	0.0188			
2006	299	20,054.2	0.0149			
2007	335	20,273.5	0.0165			
2008	293	20,694.0	0.0142			
2009	250	20,588.6	0.0121			
2010	262	20,950.3	0.0125			
2011	277	26,105.5	0.0106		235.6	
2012	291	28,627.3	0.0102	19	1,918.3	0.0099
2013[10]	*41*	*18,262.5*	*0.0022*	50	4,400.7	0.0114
2014	122	33,933.1	0.0036	32	5,853.5	0.0055
2015	80	35,333.9	0.0023	30	4,994.6	0.0060
2016	61	40,055.7	0.0015	5	2,384.1	0.0021
2017	85	41,906.7	0.0020	6	3,031.2	0.0020
2018	74	44,848.4	0.0017	6	4,646,2	0.0013
Total	**3,107**	**409,043.6**	**0.0076**	**148**	**27,464.2**	**0.0054**

Most important, the table demonstrates that both pipelines and railways have excellent safety records for crude oil transport overall. It is important to note also that the total number of rail incidents includes not only "accidental" releases, that is, caused by a derailment, collision, or

[9] Table 133-005, Operating Statistics of Canadian Pipelines Carriers for data up to 2014 and pipeline volumes 2015-2018 by request, Statistics Canada; Energy Resource Conservation Board and Alberta Energy Regulator Compliance Dashboard; Transportation Safety Board of Canada; Railway Association of Canada; Oliver Wyman analysis.
[10] Note table excludes pipeline volumes and incidents for February 1 to June 15, 2013, due to the lack of availability of Alberta incident data during the transition of incident monitoring responsibility from the Energy Resource Conservation Board to the Alberta Energy Regulator.

other rail-related accident, but “non-accidental” releases, which involve minor splashes and spills.

B. Spill Rate

The spill rate also involves three data points:

- the total volume of crude oil spilled by each mode (annual gallons);
- the total volume the mode transports (annual gallons); and
- the total distance the crude oil is moved (annual miles).

As above, gallons are then multiplied by miles, which gives the total volume moved over total distance, known as gallon-miles. This is important, as both the distance transported and volume shipped increase the potential for spills. The total volume of crude oil spilled in a given year is then divided by gallon-miles to derive the spill rate:

Spill rate = Volume spilled / (total volume x total miles)

Exhibit 4 shows pipeline crude oil spill data for 2004-2018 and available Class I rail crude oil spill data for 2012-2018. The table shows that, as in the case of the incident rate, the relative performance of railways and pipelines varies slightly by year, but overall both modes have excellent safety records. In addition, the safety of pipelines has improved significantly in recent years.

Exhibit 4: Canadian Crude Oil Spill Rates for Pipelines and Class I Railways[11]

Year	Pipelines			Railways		
	Gallons Spilled (000's)	Gallon-Miles Transported (billions)	Spill Rate	Gallons Spilled (000's)	Gallon-Miles Transported (billions)	Spill Rate
2004	932.4	19,533.8	47.7			
2005	612.0	17,876.7	34.2			
2006	660.5	20,054.2	32.9			
2007	500.8	20,273.5	24.7			
2008	234.7	20,694.0	11.3			
2009	830.2	20,588.6	40.3			
2010	189.4	20,950.3	9.0			
2011	1,465.7	26,105.5	56.1	0.12	235.6	0.5
2012	403.4	28,627.3	14.1	13.4	1,918.3	7.0
2013[12]	*51.0*	*19,262.5*	*2.6*	88.4	4,400.7	20.1
2014	126.5	33,933.1	3.7	61.9	5,853.5	10.6
2015	170.3	35,333.9	4.8	569.0	4,994.6	113.9
2016	246.4	40,055.7	6.2	0.02	2,384.1	0.01
2017	733.1	41,906.7	17.5	0.21	3,031.2	0.07
2018	281.7	44,848.4	6.3	1.2	4,646,2	0.26
Total	**7,438.0**	**410,044.2**	**18.1**	**734.3**	**27,464.2**	**26.7**

Rail release volumes are generally much lower than for pipelines, as: 1) railways move less crude oil than pipelines overall, and 2) in any given rail incident, such as a derailment, generally few cars are involved. (Each car carries an average of 30,000 gallons of product.)

The year 2015 shows an unusually high spill rate for rail. This was due primarily to one incident, in which nearly 40 cars derailed on a train in Ontario carrying crude oil to a refinery that is not connected to a pipeline. The cause of the derailment was an improperly repaired piece of rail that failed. In response, the railway instituted changes to engineering standards for rail repairs and inspections, as well as training for employees.[13] Critically, 2018 saw a major reduction in the average rail spill rate for rail, despite a return to a volume level nearly equivalent to 2015.

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[11] Table 133-005, Operating Statistics of Canadian Pipelines Carriers for pipeline data to 2014 and pipeline volumes 2015-2018 by request, Statistics Canada; Resource Conservation Board and Alberta Energy Regulator Compliance Dashboard; Transportation Safety Board of Canada; Railway Association of Canada; Oliver Wyman analysis.
[12] Note table excludes pipeline volumes and incidents for February 1 to June 15, 2013, due to the lack of availability of Alberta incident data during the transition of incident monitoring responsibility from the Energy Resource Conservation Board to the Alberta Energy Regulator.
[13] "TSB blames botched rail repair for 2015 oil-train crash," Globe and Mail, 4 August 2017.

A review of the performance data confirms that the number of incidents and the volume of product spilled varies year to year, with railways achieving a slightly better record in some years and pipelines in others. Overall, however, the incident and spillage rates for both modes are low.

This analysis also provided an opportunity to take a closer look at railway releases. As shown in Exhibit 5, since 2012, the first year that Canadian Class I railways carried significant amounts of crude oil:

- 60.3 percent of derailments involving a release of product have involved only one car.
- 39 percent of spills involved quantities of less than five gallons of oil (and in some cases, as little as half a cup).
- 58.2 percent involved spills of less than 25 gallons.

Exhibit 5: Number of Railcars Releasing Crude Oil in Canadian Class I Derailments[14]

	Number of Cars Releasing Crude Oil					Number of Cars Segmented by Average Gallons Released				
	1	2	3	4+	Total	< 1	1-5	5-25	25-100	>100
2012	19	-	-	-	19	6	3	6	3	1
2013	47	2	-	1	50	16	15	13	2	4
2014	11	2	3	-	16	5	1	5	-	5
2015	3	-	-	37	40	3	-	-	-	37
2016	4	-	-	-	4	1	2	1	-	-
2017	-	2	3	-	5	-	-	2	3	-
2018	1	2	-	4	7	2	1	-	-	4
Total	85	8	6	41	141	33	22	27	8	51

C. Rail Transport of Dangerous Goods

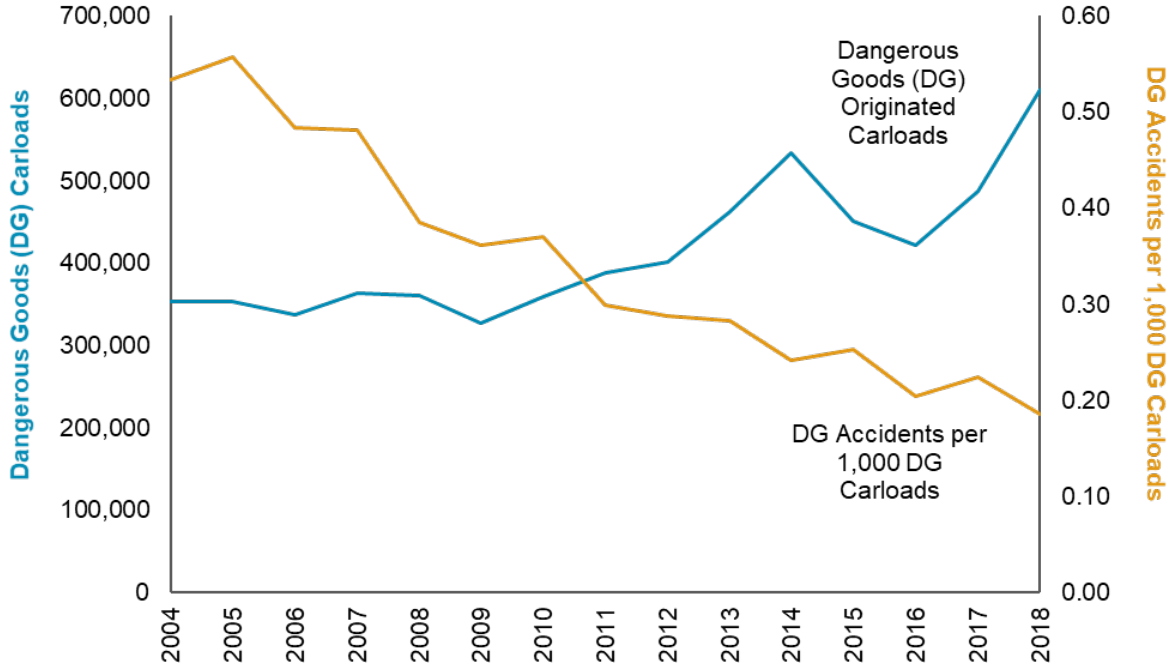
While railway data for crude oil transport only goes back seven years, the results are consistent with the railways' safety record for transporting similar commodities, known as "dangerous goods."[15] As Exhibit 6 demonstrates, Canadian railways have safely transported a wide variety of dangerous goods for many years and continue to improve safety year over year.

[14] Canadian National, Canadian Pacific, Oliver Wyman analysis.

[15] Dangerous goods are defined in the Schedule to the Transportation of Dangerous Goods Act, 1992 (S.C. 1992, c. 34). In general, these are products, substances, or organisms that could be dangerous to life, health, property, or the environment when handled, offered for transport, or transported. Examples include explosives, flammable and combustible liquids, poisonous and infectious substances, nuclear substances, and corrosives. Transport of dangerous goods requires special safety provisions. Some 12 percent of Canadian rail traffic consists of dangerous goods (see: http://www.railcan.ca/operations/dangerous_goods).

The accident rate for dangerous goods moved by freight rail has fallen steadily since 2004. From 2017 to 2018, the accident rate decreased from 0.22 to 0.18 accidents per 1,000 originated DG carloads – a record low – even as dangerous goods volumes grew by more than 25 percent over the same time period.[16]

Exhibit 6: Canadian Railway Accidents Involving Dangerous Goods, 2004-2018[17]



[16] Railway Association of Canada.
[17] Ibid.

IV. Recent Regulatory and Safety Improvements

Railways and pipelines continue to work to improve crude oil transportation safety. On the rail side, 99.999 percent of chemical and petroleum shipments in Canada arrive at destination without a release of product caused by an accident.[18] And total federally regulated railway accidents on Class I railways in Canada (including minor incidents) declined from 1,670 in 2004 to 1,454 in 2018, a drop of 13 percent.[19]

Railways have taken a number of steps to reduce incidents like derailments. Recent updates include, but are not limited to:

- *Automated emergency brakes*, which engage if cars start to separate
- *Dragging-equipment detectors* – trackside detectors to determine if any piece of equipment is dragging – these are a priority in areas where a spill would be an environmental issue, such as on bridges over water
- *Electromagnetic wayside detectors* that can flag surface and subsurface cracks in railcar wheels – as wheel fractures can cause derailment[20]
- *"Cold wheel"* technology to help identify the braking effectiveness of railcars on trains (cold weather makes equipment more prone to failure) [21]
- *Foam trailers* positioned at key points on crude oil routes to fight fires, together with *dangerous goods transfer trailers* to shift an intact load if involved in an accident onto a truck.
- *Predictive analytics* and *machine learning* to ensure rail equipment and track is maintained more proactively
- *Leading-edge inspection and detection technologies* to mitigate risk, such as machine vision, tie rating, ground penetrating radar and drone inspection of tracks

The federal government has actively taken steps to improve overall crude oil rail safety. The use of older DOT-111 tank cars (the least crash-resistant tank cars) for the movement of crude-by-rail was phased out in November 2016 and the use of CPC-123 (TP14877) unjacketed tank cars for crude-by-rail in November 2018.[22] New and retrofitted car designs have been introduced to

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[18] Safely Transporting Dangerous Goods, Railway Association of Canada (https://www.railcan.ca/101/safely-transporting-dangerous-goods/).
[19] Railway Occurrence Data from January 2004, Transportation Safety Board of Canada (http://www.tsb.gc.ca/eng/stats/rail/data-1.html).
[20] "Railroad targets problems with new safety systems amid string of derailments," Calgary Herald, 14 March 2019.
[21] Ibid.
[22] Protective Direction 38, issued 31 October 2016 and Protective Direction 39, issued 19 September 2018, Transport Canada.

replace these cars, such as the TC-117, which has a number of additional safety features, including thicker steel, a head shield, thermal protection, and top fitting protection.[23]

In addition, since March 2016, Transport Canada has required federally regulated railways that carry dangerous goods to have a mandatory minimum level of insurance (based on the type and volume of dangerous goods carried), ranging from $25 million to $1 billion.[24] Furthermore, Transport Canada can issue fines for non-compliance with rail safety regulations and rules.[25]

In the near term (2019-2021), Transport Canada plans to introduce a regulatory framework for the security of dangerous goods transport in Canada to mitigate potential security risks (such as from terrorism). These regulations will align with US hazardous materials requirements and international standards and practices.[26]

Railway-led innovation is also driving safety improvements. A recent invention led by a Canadian Class I could potentially improve safety in the future by turning heavy oils produced in Canada, like bitumen, into solid tablets that look like hockey pucks.[27] These polymer-infused "CanaPux" are expected to be less flammable and thus safer to transport than the current method for crude-by-rail (which requires mixing bitumen with a more flammable petroleum additive). In the event of a spill, the tablets can be picked up by machinery on land or, since they float, vacuumed from the water.

Pipelines too have made improvements in the safe handling of oil and related products. The *Pipeline Safety Act* of 2016 strengthened regulatory oversight of the industry, as well as prevention, preparedness and response, and liability and compensation related to pipeline incidents. Of the 1.3 billion barrels of oil moved per year by federally regulated pipelines, 99.999 percent reaches its destination without incident.[28] In addition, 100 percent of liquids released in recent years has been recovered.[29]

As well as meeting regulatory requirements for construction and inspection, the pipeline industry continually invests in new technology to improve safety. Leak detection and prevention are being addressed in a number of ways:

- Upgraded pipeline welding and metallurgy for new or replacement pipelines are improving the ability of pipelines to withstand corrosion and reducing the potential for leaks.

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[23] Protective Direction 38, issued 31 October 2016, Transport Canada.
[24] Measures to enhance railway safety and the safe transportation of dangerous goods, Transport Canada (https://www.tc.gc.ca/eng/mediaroom/infosheets-menu-7564.html).
[25] *See* SOR/2014-2333, "Railway Safety Administrative Monetary Penalties Regulations," Railway Safety Act.
[26] Rail and surface initiatives planned for April 2019-April 2021, Transport Canada (https://www.tc.gc.ca/eng/acts-regulations/rail-surface-initiatives-planned.html).
[27] "CN develops technology that could make bitumen transportation safer," Globe and Mail, 14 April 2017.
[28] Canada's Pipeline Safety System, National Resources Canada (https://www.nrcan.gc.ca/energy/infrastructure/18858).
[29] Key Facts on Canada's Pipelines, National Resources Canada, 2016.

- The latest generation of "smart pigs" – devices that travel with the flow of material and clean pipeline walls – can detect corrosion as well, to prevent leaks or catch leaks while they are small.
- Fiber optic cables laid alongside pipelines are used to detect temperature changes that might indicate a leak and sounds associated with unauthorized excavation near pipelines.
- Drones (UAVs) equipped with high-resolution visual, infrared and thermal cameras are being used to inspect and document possible leaks.

In summary, analysis of the available data shows that differences between the modes are inconsequential. The data shows that though differences between the modes vary by metric and from year to year, those differences are small. Both modes have excellent safety records and are continuing to work to improve safety. Most critically, both pipelines and railways are needed to handle Canada's production of crude oil and related products – especially as Canadian crude oil production continues to grow in the future.

REPORT QUALIFICATIONS, ASSUMPTIONS, AND LIMITING CONDITIONS

Oliver Wyman was commissioned by the Railway Association of Canada to develop a report that presents a balanced analysis of the comparative safety of railways and pipelines in transporting crude oil and associated products. It is intended for an audience of persons interested in this issue.

Oliver Wyman shall not have any liability to any third party in respect of this report or any actions taken or decisions made as a consequence of the results, advice or recommendations set forth herein.

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