4. RISK MEASURES

4.1 Risk Measures and Exposure Measures

Current empirical evidence on the relative risks of transporting dangerous commodities by truck and rail has produced inconclusive results as to which mode is safer with respect to accident involvement and consequent damages. Glickman (1988) concluded that under most conditions trucks reflect lower risks than rail. Swoveland and Cawdery (1984) appear to conclude the opposite result. Most empirical evidence is consistent in attributing higher accident rates to trucks relative to rail for comparable shipment volumes (Saccomanno, Shortreed and Van Aerde, 1988). However, it is unclear whether these truck accidents are more likely to result in larger spills or more extensive damages to nearby population and the environment.

A comparison of the risks of transporting dangerous commodities by truck versus rail is complicated by differences in the volume of dangerous commodities that are shipped by each of these modes in total and on a per vehicle basis. In Canada, the proportion of total rail freight movement that is classified as "dangerous" by Transport Canada is 6.6%, while for trucks the value is 8.7%. Furthermore, rail bulk tankers carry twice the payload per vehicle than bulk tanker trucks for most types of dangerous commodities. Saccomanno, Shortreed and Van Aerde (1988) suggest average payload weights of 80 tonnes for some typical rail tankers carrying gasoline and LPG's, as compared to 25 to 30 tonnes for similar truck tankers. Differences in tanker carrying capacities and in the proportion of freight movement representing dangerous goods suggest that, all other factors assumed constant, rail tankers in an accident situation would tend to reflect more extensive damage areas than trucks. A fair analysis of the relative risks of transporting dangerous commodities must resolve variations in the nature of dangerous commodity traffic between the two modes.

A thorough comparison of the risks of transporting dangerous goods by truck and rail must:

1. present different risk measures for comparative analysis;
2. assess the sensitivity of various risk measures to changes in the transport environment; and
3. account for exposure to risks in terms of dangerous goods flows and vehicular movements for comparable distances and transportation environment.

Presentation of a number of risk measures in the form of summary tables for similar operating environments allows a comparison to be made between the different modes of dangerous goods transport. This section of the study presents a number of alternative risk measures for the transport of dangerous goods. These measures include: accident rates per vehicle kilometer and per tonne kilometer of material shipped, potential damage areas, and expected impacts to population and environment from a given spill situation.

Another important factor in the evaluation of risk is the determination of spill probabilities, which has been done previously by the use of fault trees (Saccomanno et al., 1986). This section of the study includes an in-depth analysis of actual dangerous goods spills data from the Dangerous Occurrence Report Forms filed with Transport Canada (Transport Canada, 1988). The analysis allows the validation of spill probability models, and the identification of any trends in the transportation of dangerous goods.

4.2 Accident Rates

Truck accident data were obtained for the Province of Ontario. The Ministry of Transportation of Ontario (MTO) compiles annually all motor vehicle accident statistics from provincial and municipal police records. The truck accident data base consists of 4,377 accidents in Ontario involving at least one large truck for the year 1983. Large trucks are defined as vehicles for which a Class A or D drivers' license is required. Where more than one truck is involved in a single accident, each truck is treated as a separate observation in the data file.

As in most jurisdictions, Ontario does not collect detailed information on the distribution of trucks at various times during the year on the provincial road network. Measures of exposure for truck accidents under different conditions were estimated using several indirect sources of truck flow data for Ontario. These sources include: the Commercial Vehicle Survey (Ontario Ministry of Transportation and Communications, 1984), the Provincial Highway Traffic Volumes from counting stations, and the Provincial Highway Inventory.

Rail accident data were obtained from Canadian Transport Commission (CTC) data bases. In Canada, all railway accidents with damages in excess of $750 (before November 1, 1987) must be reported to the CTC. The data file contains information on the causes of each accident, and whether a derailment, collision or both derailment and collision took place. The data file is further broken down into regions where the accident occurred (Ontario is part of the Central Region). The CTC rail data consist of 2344 derailment and collision accidents reported between 1980 and 1985 for the entire national network. In this time, approximately 690 derailment and collision accidents took place in the Central Region.

Exposure data were extrapolated from published reports from Canadian National and Canadian Pacific Railways (Institute for Risk Research, 1987). Information is available at the subdivision level based on train-kilometers and tonne-kilometers travelled annually.

Accident rate data for truck and rail were fitted with a series of GLIM loglinear expressions. Details of this analysis are given in Saccomanno, Shortreed, and Van Aerde (1988). Separate loglinear expressions were obtained from truck accidents located at road links and intersections (as summarized in Chapter 3). For ramp locations, loglinear models of truck accident rates were not found to be statistically significant. For rail, loglinear models of accident rates were calibrated for mainline derailments. Rail accidents taking place in railyards did not yield statistically significant expressions.

The results of the statistical analysis of truck and rail accident rates for relevant mitigating factors are summarized in Tables 4.1 (for truck) and 4.2 (rail derailments). The tables are a summary of expected accident rates for typical transportation conditions.

Table 4.1 non-link accidents are estimated from the accident rates for ramps given in Table 3.9, and for intersections in Table 3.8, which represent the majority of non-link accidents. These rates were converted to average annual accident rates by truck type and load status by considering overall truck accident experience for 1982-86 in Ontario, and expressing this as accidents per truck kilometer so these rates could be compared directly to the link accident rates. Overall, the non-link accidents represent an addition of 19.4% over the link accidents. These averages are presented for comparison purposes, but should be used with caution until a more in-depth analysis is possible.

The impact of "extra care" on accident rates for dangerous goods is still not known. It is expected that dangerous goods will have a lower accident rate than the "average" truck traffic. Dangerous goods represent only 6 to 9% of all traffic, and generally either the exposure information or the accident information does not indicate if there is a dangerous good involvement.

In an attempt to gain some indication of the impact of "extra care", the Tricil company was contacted. Tricil hauls hazardous wastes to a plant site near Sarnia, and most of their travel is in the Sarnia to Toronto corridor (Corridor Route A in Chapter 3 would be typical of their operations). About 60 to 70% of their vehicles are semi-trailer trucks, with the remainder being straight truck tankers with some B train doubles. They have operated about 9 million vehicle kilometers (loaded and empty) over the last 5 years, with 3 "accidents" within the definition used in this study. None of the 3 accidents led to a release. Using the semitractor trailer on Route A accident rate from Figure 3.1, the number of accidents expected is 8. Thus the observed accident rate is about 35% of that for the general or average truck traffic.

The "extra care" provided includes: extra training, regularly scheduled vehicle maintenance at a higher frequency level, inspection of vehicles (repeated every 100 miles), 90 km/hr maximum speed, no operation of any vehicles with defects, use of Tripmaster recording systems, etc. (Tricil, 1988).

Table 4.2 for rail accidents is for mainline derailments only. The inclusion of mainline collision accidents and crossing accidents would increase the given values on average by 0.1 car accident involvements per million car kilometers, or about 20%. The fault tree analysis is based on the derailment accident rate since that is the source of almost all releases for the rail mode. It should be further noted that the estimates given in Table 4.2 were based on an average for the period 1980-1985. There was a continual decline in rail accident rates over this period, and since this has been sustained, the values in Table 4.2 should be considered as conservative or high. For example, the derailment rate for 1984 and 1985 were only 79% of the

Table 4.1 Truck Accident Rates.

		LINK ACCIDENTS		NON-LINK ACCIDENTS (Ramps, Intersections, etc.)
High Vol. Low Vol.		Location Freeway	Non-Freeway	
Truck Type	Load	(accident rates per million truck-km)		(average annual accidents per million truck-km)
A	Empty	2.46 1.06	1.89 1.11	0.39
	Loaded	1.19 0.52	0.86 0.51	0.19
B	Empty	0.21 0.09	0.47 0.27	0.08 +
	Loaded	0.17 0.08	0.36 0.21	0.08 +
C	Empty	1.53 0.67	2.34 1.44	0.43 +
	Loaded	0.76 0.34	1.09 0.68	0.21 +
D	Empty	1.04 0.53	1.57 0.88	0.13
	Loaded	0.62 0.32	0.88 0.50	0.15
E	Empty	0.13 0.08	0.39 0.22	0.14
	Loaded	0.72 0.44	2.05 1.22	0.16

+ Estimates based on limited data

Table 4.2. Rail Accident Rates (Derailments).

		Region							
		Atlantic		Central		Prairies		Mountain	
		High Speed	Low Speed	High Speed	Low Speed	High Speed	Low Speed	High Speed	Low Speed
Volume Class	Track Class	(Accident rates per million car-kilometers)							
1	Single	25.32	1.63	1.61	12.99	7.83	6.35	5.31	4.04
	Multiple	-	-	90.61 +	-	-	-	-	-
2	Single	0.62	4.67	1.37	1.46	7.31	1.55	0.68 +	0.84
	Multiple	-	-	-	16.95	-	1.22	1.16 +	-
3	Single	4.05	1.22	0.78	1.04	1.41	0.26	1.67	1.02
	Multiple	1.18	0.48	0.42	0.11 +	1.89	-	-	-
4	Single	0.56	-	0.26	-	0.06	0.03	0.70	0.35
	Multiple	-	0.18 +	0.47	0.20	0.06	0.29 +	0.43	0.43

Note: - Not included in the calibration (structurally empty cell)
+ Inaccurate due to low number of accidents or low exposure

Volume Class 1: < 100 million ton-miles/year
Volume Class 2: 100 - 1000 million ton-miles/year
Volume Class 3: 1000 - 10000 million ton-miles/year
Volume Class 4: > 10000 million ton-miles/year

Low Speed: < 35 mph
High Speed: > 35 mph

average rate for the whole perod 1980-1985. The variation in accident rates with variation in track type, region, volume class and speed are the main result of the analysis.

4.3 Empirical Analysis of Recent Canadian Dangerous Goods Spill Data

a. Introduction

Significantly improved data collection procedures by Transport Canada now make it possible to better analyze the characteristics of dangerous goods spills in Canada. Such analysis can be performed to identify any significant patterns or trends, or may alternatively be carried out to better calibrate or validate mathematical models of dangerous goods spills. Both uses of the data provide essential steps towards establishing more clearly the current level of safety in the transport of dangerous goods and assist in developing priorities for further research.

This section provides an analysis of recent Transport Canada dangerous goods spill data for truck and rail accidents on the transportation network and at terminals. The data were reported under the regulations specified by Transport Canada, and represent 586 observations between January 1986 and August 1987. The data base lists the class of dangerous good as well as its Product Identification Number (PIN). In addition, it also provides estimates of the type of spill and the quantity of material involved. Finally, the cause of the spill as well as any fatalities, injuries and/or evacuations are listed.

Following some additional background at the conclusion of this section, Section 4.3.2 provides an analysis of the frequency of spills by commodity type. Section 4.3.3 provides an analysis of spill causes for rail and truck, while Section 4.3.4 examines any statistics regarding the spill quantities involved for various types of accidents. The section concludes with a summary of the findings, and their relationship to current risk assessment and management procedures.

While the Transport Canada data base contains spill data on all modes and all dangerous commodities, this study considers only the road and rail modes, as these are of greatest interest within the urban or municipal context. Similarly, while aggregate statistics are obtained for all commodities, the analysis concentrates on data for chlorine, LPG sulphuric acid, and gasoline as these commodities have historically been treated as representative commodities of people's concerns.

b. Background on Dangerous Goods Research

Following the enforcement in 1985 of the Transport of Dangerous Goods Act of 1980, both the truck and rail transportation industries were required to report any dangerous goods spills of a specified minimum level that may represent a danger to health, life, property or the environment. This improved data collection effort has in itself resulted in an increase in safety as it raised the general awareness of dangerous goods and their potential risks. In addition, the resulting data base is also providing an empirical source of information for identifying further improvements through the application of risk assessment techniques.

The Transport Canada risk assessment approach consists of a methodology for evaluating spill frequencies and consequences in a systematic way. This procedure was initially developed for Transport Canada by the Institute for Risk Research (1987), but has since been continuously refined and updated (for example, see Van Aerde et al., 1988). Canadian rail (Turcke et al., 1988) and truck (Buyco and Saccomanno, 1988) accident rates have been calibrated, while improved fault tree models (Saccomanno et al., 1986) and spill damage models (Van Aerde et al., 1987a and b) have been derived. However, an empirical analysis of actual Canadian spill data was needed in order to complete the validation of the risk model's submodels.

c. General Rail and Truck Accident/Spill Rates

Extensive statistics on rail accident frequencies and dangerous goods involvements are provided by the Railway Transport Committee (RTC), and exposure data on general freight car movements are available from CN and CP Rail. The 1986 RTC annual report shows accident statistics for the years 1979 to 1986. On average, derailments number about 300 per year, collisions, about 90 and crossing accidents, about 690 for an average annual accident frequency of 1080 accidents. The majority of these accidents do not involve serious consequences; in fact, using the RTC (1986) classification of "serious" derailments and collisions, 20% of derailments from 1984 to 1986 were serious (about 60 per year), and 13% of collisions were serious (about 10 per year).

Dangerous goods were involved in approximately 175 of these train accidents per year (1980-1986 average), and the majority of releases occurred in derailments and collisions. Dangerous goods can also be involved in "incidents" which are not caused by transportation accidents; the RTC defines a dangerous commodity incident as:

> "a dangerous commodity leak that arises in the transportation of dangerous commodities other than due to train accidents."

The average number of dangerous goods incidents from 1980 to 1986 was 258 incidents per year.

Comparable aggregate truck accident rates are not available from a similar central government agency. However, based on police accident records, and the Ontario Ministry of Transportation and Communications (MTC) records of Average Annual Daily Traffic (AADT) and percentage trucks for exposure data, a composite picture for trucks can be assembled. Saccomanno et al. (1988) also used the 1983 MTC Commercial Vehicle Survey to estimate exposure by truck characteristics.

d. Data Collection Procedure

The conditions for which a spill occurrence report should be filed are outlined by Transport Canada (1985) in their Guide for Completion of Dangerous Occurrence Report. A summary of these requirements from the guide is provided in Figure 4.1, while a reduced version of the actual report is provided in Figure 4.2.

4.3.1 Spill Frequencies According to Commodity Type and Class

A data base of 586 entries was analysed to determine the frequency of spills by dangerous goods class and specific commodity for each mode of transport. Four categories of mode of transport were considered: road en route, road terminal, rail en route, and rail yard.

a. Spills by Commodity Class

A total of 551 entries could be classified by dangerous goods class and are summarized in Table 4.3a. Four classes comprise almost 80% of the incidents: Class 8 corrosives (32%), Class 3.1 flammable liquids (20%), Class 3.2 flammable liquids (18%), and Class 9.2 environmental hazards (10%).

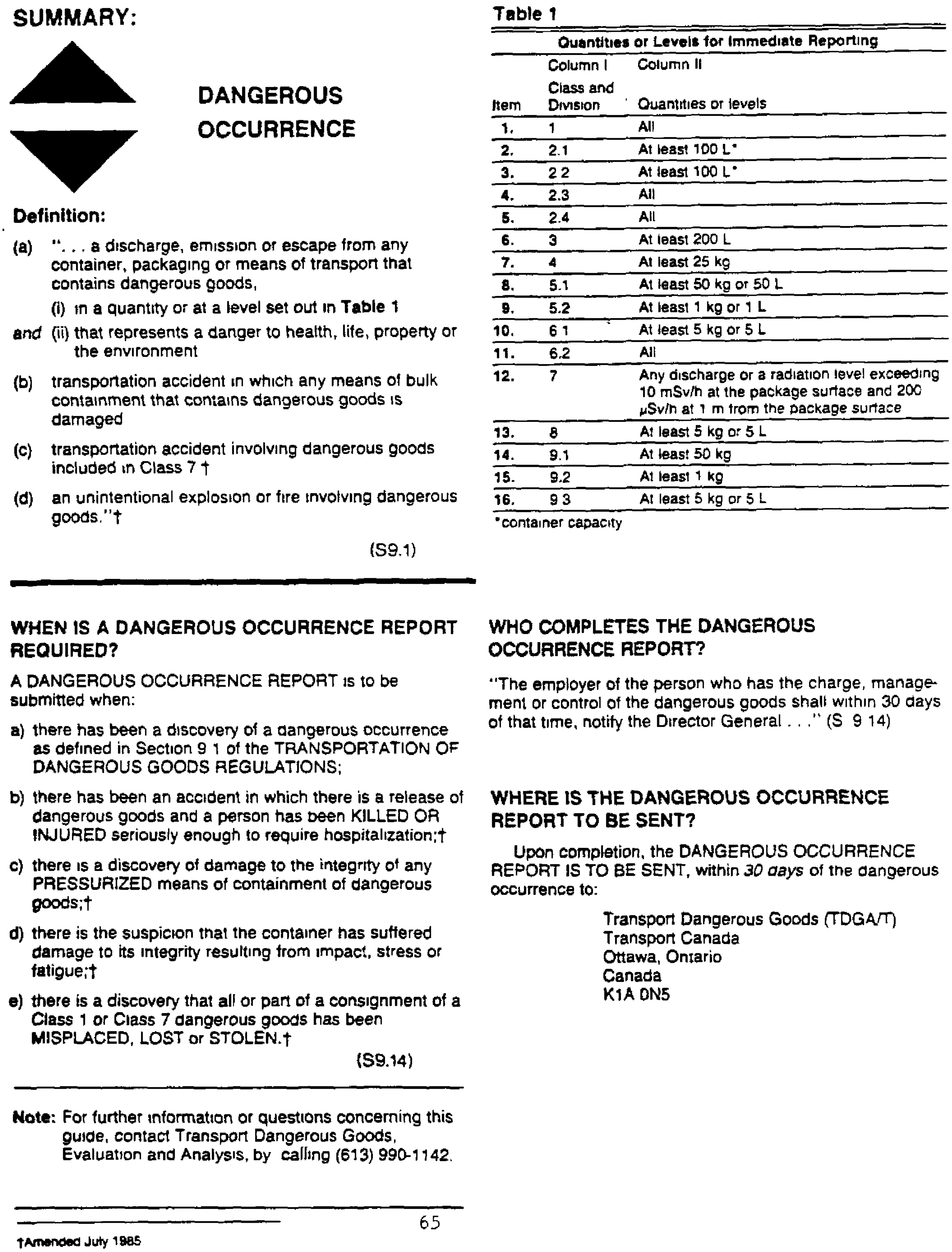
Of the Class 8 spills, PIN 1760, corrosive liquids, not otherwise specified, is the most commonly spilled commodity (46 incidents). Class 3.1 includes gasoline, PIN 1203, the most frequently spilled commodity recorded in the data base (66 incidents). Of the Class 3.2 spills, the most frequently spilled commodity is paint, PIN 1263 (26 incidents). Class 9.2, environmental hazards, includes numerous commodities, of which 1,1,1 - trichloroethane, PIN 2831, is the most common (11 incidents).

For every class shown in the table, truck incidents en route and in terminals outnumber rail incidents en route and in yards, respectively. In fact, approximately 42% of the incidents occurred during truck transportation en route and another 41% occurred at truck terminals. This ratio of truck to rail incidents of 4:1 may reflect the larger number of individual truck shipments compared to the fewer number of trains which haul the goods.

Table 4.3b shows the frequency of consequences resulting from the 551 recorded spills in the data base. Consequences include fatalities, injuries, and evacuations. It is not indicated whether the consequences are due to the accident itself or the hazards associated with the dangerous goods.

Classes 3.1 and 3.2 have the most fatality/injury accidents; approximately 12 and 13% of the total incidents in these classes result in such consequences. Other classes have higher percentages of fatality or injury accidents, in particular, 36% of Class 2.4 corrosive gases incidents, 19% of Class 5.1 oxidizers incidents, and 15% of Class 2.1 flammable gases incidents result in fatality/injury accidents. Class 4.2 spontaneous combustibles has the highest percentage of fatality/injury accidents, but only 2 incidents for this class were included in the data base. These fatality and injury consequences are likely reflecting the accident environment,

Figure 4.1. Guide for Completion of Dangerous Occurrence Report (TC,1985).



SUMMARY:

DANGEROUS OCCURRENCE

Definition:

(a) ". . . a discharge, emission or escape from any container, packaging or means of transport that contains dangerous goods,

(i) in a quantity or at a level set out in **Table 1**

and (ii) that represents a danger to health, life, property or the environment

(b) transportation accident in which any means of bulk containment that contains dangerous goods is damaged

(c) transportation accident involving dangerous goods included in Class 7 †

(d) an unintentional explosion or fire involving dangerous goods."†

(S9.1)

Table 1

	Quantities or Levels for Immediate Reporting	
	Column I	Column II
Item	Class and Division	Quantities or levels
1.	1	All
2.	2.1	At least 100 L*
3.	2.2	At least 100 L*
4.	2.3	All
5.	2.4	All
6.	3	At least 200 L
7.	4	At least 25 kg
8.	5.1	At least 50 kg or 50 L
9.	5.2	At least 1 kg or 1 L
10.	6.1	At least 5 kg or 5 L
11.	6.2	All
12.	7	Any discharge or a radiation level exceeding 10 mSv/h at the package surface and 200 μSv/h at 1 m from the package surface
13.	8	At least 5 kg or 5 L
14.	9.1	At least 50 kg
15.	9.2	At least 1 kg
16.	9.3	At least 5 kg or 5 L

*container capacity

WHEN IS A DANGEROUS OCCURRENCE REPORT REQUIRED?

A DANGEROUS OCCURRENCE REPORT is to be submitted when:

a) there has been a discovery of a dangerous occurrence as defined in Section 9.1 of the TRANSPORTATION OF DANGEROUS GOODS REGULATIONS;

b) there has been an accident in which there is a release of dangerous goods and a person has been KILLED OR INJURED seriously enough to require hospitalization;†

c) there is a discovery of damage to the integrity of any PRESSURIZED means of containment of dangerous goods;†

d) there is the suspicion that the container has suffered damage to its integrity resulting from impact, stress or fatigue;†

e) there is a discovery that all or part of a consignment of a Class 1 or Class 7 dangerous goods has been MISPLACED, LOST or STOLEN.†

(S9.14)

WHO COMPLETES THE DANGEROUS OCCURRENCE REPORT?

"The employer of the person who has the charge, management or control of the dangerous goods shall within 30 days of that time, notify the Director General . . ." (S 9.14)

WHERE IS THE DANGEROUS OCCURRENCE REPORT TO BE SENT?

Upon completion, the DANGEROUS OCCURRENCE REPORT IS TO BE SENT, within *30 days* of the dangerous occurrence to:

Transport Dangerous Goods (TDGA/T)
Transport Canada
Ottawa, Ontario
Canada
K1A 0N5

Note: For further information or questions concerning this guide, contact Transport Dangerous Goods, Evaluation and Analysis, by calling (613) 990-1142.

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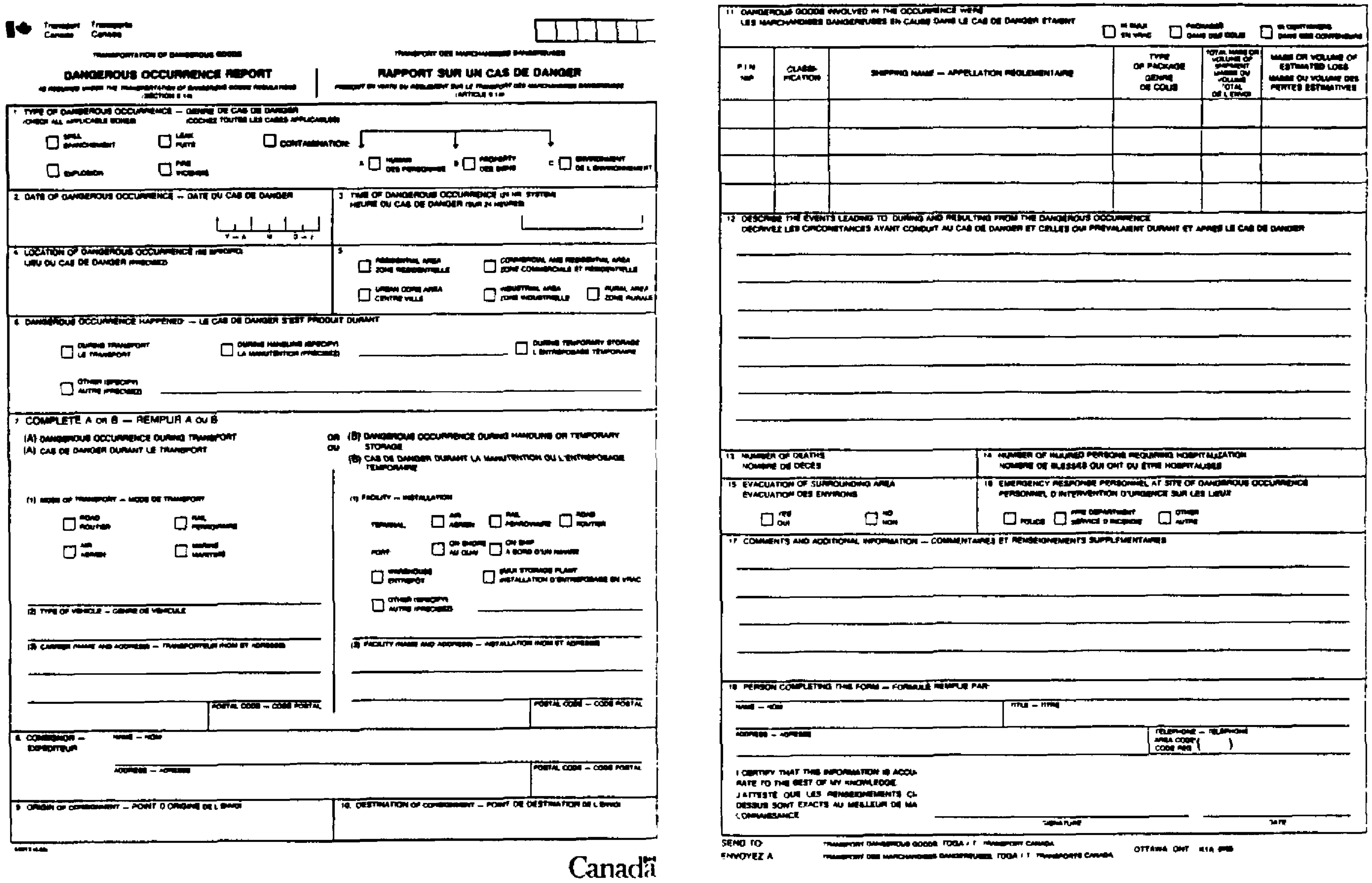
†Amended July 1985

Figure 4.2. Dangerous Occurrence Report Form (TC,1985).



Transport Canada Transports Canada

DANGEROUS OCCURRENCE REPORT | **RAPPORT SUR UN CAS DE DANGER**

1 TYPE OF DANGEROUS OCCURRENCE — GENRE DE CAS DE DANGER

☐ SPILL / DÉVERSEMENT ☐ LEAK / FUITE ☐ CONTAMINATION: A ☐ HUMAN / DES PERSONNES B ☐ PROPERTY / DES BIENS C ☐ ENVIRONMENT / DE L'ENVIRONNEMENT

☐ EXPLOSION ☐ FIRE / INCENDIE

2 DATE OF DANGEROUS OCCURRENCE — DATE DU CAS DE DANGER

3 TIME OF DANGEROUS OCCURRENCE — HEURE DU CAS DE DANGER

4 LOCATION OF DANGEROUS OCCURRENCE — LIEU DU CAS DE DANGER

5 ☐ RESIDENTIAL AREA / ZONE RÉSIDENTIELLE ☐ COMMERCIAL AND RESIDENTIAL AREA / ZONE COMMERCIALE ET RÉSIDENTIELLE ☐ URBAN CORE AREA / CENTRE VILLE ☐ INDUSTRIAL AREA / ZONE INDUSTRIELLE ☐ RURAL AREA / ZONE RURALE

6 DANGEROUS OCCURRENCE HAPPENED — LE CAS DE DANGER S'EST PRODUIT DURANT

☐ DURING TRANSPORT / LE TRANSPORT ☐ DURING HANDLING / LA MANUTENTION ☐ DURING TEMPORARY STORAGE / L'ENTREPOSAGE TEMPORAIRE ☐ OTHER / AUTRE

7 COMPLETE A OR B — REMPLIR A OU B

(A) DANGEROUS OCCURRENCE DURING TRANSPORT
(A) CAS DE DANGER DURANT LE TRANSPORT

OR / OU

(B) DANGEROUS OCCURRENCE DURING HANDLING OR TEMPORARY STORAGE
(B) CAS DE DANGER DURANT LA MANUTENTION OU L'ENTREPOSAGE TEMPORAIRE

(1) MODE OF TRANSPORT — MODE DE TRANSPORT: ☐ ROAD / ROUTIER ☐ RAIL / FERROVIAIRE ☐ AIR / AÉRIEN ☐ MARINE / MARITIME

(2) TYPE OF VEHICLE — GENRE DE VÉHICULE

(3) CARRIER NAME AND ADDRESS — TRANSPORTEUR (NOM ET ADRESSE)

POSTAL CODE — CODE POSTAL

(1) FACILITY — INSTALLATION: TERMINAL ☐ AIR / AÉRIEN ☐ RAIL / FERROVIAIRE ☐ ROAD / ROUTIER; PORT ☐ ON SHORE / AU QUAI ☐ ON SHIP / À BORD D'UN NAVIRE; ☐ WAREHOUSE / ENTREPÔT ☐ BULK STORAGE PLANT / INSTALLATION D'ENTREPOSAGE EN VRAC ☐ OTHER / AUTRE

(2) FACILITY NAME AND ADDRESS — INSTALLATION (NOM ET ADRESSE)

POSTAL CODE — CODE POSTAL

8 CONSIGNOR — EXPÉDITEUR NAME — NOM ADDRESS — ADRESSE POSTAL CODE — CODE POSTAL

9 ORIGIN OF CONSIGNMENT — POINT D'ORIGINE DE L'ENVOI

10 DESTINATION OF CONSIGNMENT — POINT DE DESTINATION DE L'ENVOI

Canada

11 DANGEROUS GOODS INVOLVED IN THE OCCURRENCE WERE
LES MARCHANDISES DANGEREUSES EN CAUSE DANS LE CAS DE DANGER ÉTAIENT ☐ IN BULK / EN VRAC ☐ PACKAGED / DANS DES COLIS ☐ IN CONTAINERS / DANS DES CONTENEURS

P I N NIP	CLASSIFICATION	SHIPPING NAME — APPELLATION RÉGLEMENTAIRE	TYPE OF PACKAGE GENRE DE COLIS	TOTAL MASS OR VOLUME OF SHIPMENT MASSE OU VOLUME TOTAL DE L'ENVOI	MASS OR VOLUME OF ESTIMATED LOSS MASSE OU VOLUME DES PERTES ESTIMATIVES

12 DESCRIBE THE EVENTS LEADING TO, DURING AND RESULTING FROM THE DANGEROUS OCCURRENCE
DÉCRIVEZ LES CIRCONSTANCES AYANT CONDUIT AU CAS DE DANGER ET CELLES QUI PRÉVALAIENT DURANT ET APRÈS LE CAS DE DANGER

13 NUMBER OF DEATHS
NOMBRE DE DÉCÈS

14 NUMBER OF INJURED PERSONS REQUIRING HOSPITALIZATION
NOMBRE DE BLESSÉS QUI ONT DU ÊTRE HOSPITALISÉS

15 EVACUATION OF SURROUNDING AREA
ÉVACUATION DES ENVIRONS
☐ YES / OUI ☐ NO / NON

16 EMERGENCY RESPONSE PERSONNEL AT SITE OF DANGEROUS OCCURRENCE
PERSONNEL D'INTERVENTION D'URGENCE SUR LES LIEUX
☐ POLICE ☐ FIRE DEPARTMENT / SERVICE D'INCENDIE ☐ OTHER / AUTRE

17 COMMENTS AND ADDITIONAL INFORMATION — COMMENTAIRES ET RENSEIGNEMENTS SUPPLÉMENTAIRES

18 PERSON COMPLETING THIS FORM — FORMULE REMPLIE PAR

NAME — NOM TITLE — TITRE
ADDRESS — ADRESSE TELEPHONE — TÉLÉPHONE AREA CODE / CODE RÉG. ( )

I CERTIFY THAT THIS INFORMATION IS ACCURATE TO THE BEST OF MY KNOWLEDGE.
J'ATTESTE QUE LES RENSEIGNEMENTS CI-DESSUS SONT EXACTS AU MEILLEUR DE MA CONNAISSANCE

SIGNATURE DATE

SEND TO: TRANSPORT DANGEROUS GOODS TDGA / TRANSPORT CANADA OTTAWA ONT
ENVOYEZ À: TRANSPORT DES MARCHANDISES DANGEREUSES TDGA / TRANSPORTS CANADA

Table 4.3a. Frequency of Incidents by Dangerous Goods Class.

CLASS	NAME	FREQUENCY TOTAL	FREQUENCY BY MODE			
			TRUCK		RAIL	
			En route	Terminal	En route	Yard
1.1	Explosives (mass)	2	1	-	-	1
1.5	Explosives	2	1	-	-	1
2.1	Flammable gases	20	13	6	-	1
2.2	Non flammable gases	7	3	3	-	1
2.4	Corrosive gases	11	3	4	-	4
3.1	Flammable liquids	108	61	36	4	7
3.2	"	99	48	42	4	5
3.3	" (notes a,b,c)	22	9	9	1	3
4.2	Spontaneous combustible	2	-	2	-	-
4.3	" in water (note d)	1	-	1	-	-
5.1	Oxidizer	16	10	3	1	2
5.2	" (note e)	4	-	3	-	1
6.0	Poisonous substance	1	1	-	-	-
6.1	" thru inhalation (f)	20	5	10	2	3
8.0	Corrosives	174	61	71	3	39
9.0	Miscellaneous	1	1	-	-	-
9.1	Dangerous to health	6	4	1	-	1
9.2	Environmental hazard	54	15	33	-	6
9.9	Miscellaneous	1	-	1	-	-
TOTALS		551	236	225	15	75

Notes:

a Class 3.1: Closed-cup flash point < -18°C.

b Class 3.2: Closed-cup flash point > -18°C.

c Class 3.3: Closed-cup flash point > 23°C, but < 37.8°C; < 60.5°C for air;
< 60.5°C for marin

d or emits flammable gasses on contact with water or water vapour.

e strong oxidizer in decomposition (contains bivalent -O-O-) or is sensitive to heat, shock, or friction.

f Solid or liquid that is poisonous through inhalation, or by skin contact, or by ingestion.

Table 4.3b. Frequency of Consequences by Dangerous Goods Class.

Column number:		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CLASS	NAME	INCIDENT TOTAL	INJ/ FATAL ACC	% of CLASS WITH F./I.	FATAL ACC.	F./ F.A.	INJ. ACC.	I./ I.A.	#of Ev	% of CLASS WITH EVAC
1.1	Explosives (mass)	2	0	0	0	0	0	0	0	0
1.5	Explosives	2	0	0	0	0	0	0	0	0
2.1	Flammable gases	20	3	15	0	0	3	1.3	5	25
2.2	Non flammable gases	7	0	0	0	0	0	0	1	14
2.4	Corrosive gases	11	4	36	0	0	4	3.8	2	18
3.1	Flammable liquids	108	13	12	6	1	10	5.6	5	5
3.2	"	99	13	13	4	2	10	1.3	5	5
3.3	"	22	1	4	0	0	1	1.0	0	0
4.2	Spontaneous combustible	2	1	50	0	0	1	1.0	0	0
4.3	" in water	1	0	0	0	0	0	0	0	0
5.1	Oxidizer	16	3	19	1	1	2	1	1	6
5.2	"	4	0	0	0	0	0	0	0	0
6.0	Poisonous substance	1	0	0	0	0	0	0	0	0
6.1	" thru inhalation	20	1	5	0	0	1	4	1	5
8.0	Corrosives	174	9	5	0	0	9	1.1	5	3
9.0	Miscellaneous	1	0	0	0	0	0	0	0	0
9.1	Dangerous to health	6	0	0	0	0	0	0	1	17
9.2	Environmental hazard	54	3	6	0	0	3	4	2	4
9.9	Miscellaneous	1	0	0	0	0	0	0	0	0
TOTALS		551	51		11	(a)	44	(b)	28	

Notes:

Column (1) shows the number of incidents per class recorded in the TC data

Column (2) records the number of accidents with either fatalities or injuries ie, a consequence to human life and health.

Column (3) = 100 * Column (2) / Column (1)

Column (4) records fatality accidents (incidents with one or more fatalities)

Column (5) shows the average number of fatalities per fatality accident

Column (6) records injury accidents

Column (7) shows the average number of injuries per injury accident

Column (8) shows the number of evacuations per class

Column (9) = 100 * Column (8) / Column (1)

(a) A total of fifteen fatalities were recorded.

(b) A total of 121 injuries were recorded.

i.e., high speed highway accident versus low speed terminal accidents.

Another measure of the severity of the accident/spill is the number of fatalities or the number of injuries per fatality or injury accident. Only three classes have fatalities recorded: Classes 3.1, 3.2, and 5.1; Class 3.2 has two fatalities per fatality accident on average; the others have one. For injuries, the highest number of injuries per injury accident occurred with Class 3.1 -- on average 5.6 injuries (this class includes one railroad incident with 42 injuries). Class 6.1, poisonous through inhalation substances, and Class 2.4, corrosive gases, are next with approximately 4 injuries per injury accident. Although Class 8, corrosives, had approximately the same number of injury accidents as Class 3.1, the injury per injury accident average was much lower at 1 injury. This variation in injury per injury accident may reflect the hazards of the goods to a certain degree.

Evacuations are spread more evenly among the classes, and tend to reflect consequences due to dangerous goods, since it is likely that a decision to evacuate results when the goods have been or are in jeopardy of being released. This potential for release could explain why approximately 2/3 of the incidents with evacuations had neither an injury nor a fatality recorded. Table 4.3b shows that Class 2.1, flammable gases, has the highest percentage of incidents that prompted evacuation, followed by Class 2.4, corrosive gases, then Class 9.1, dangerous to health, and Class 2.2, non flammable gases.

Table 4.3c shows the frequency of consequences by transportation mode and en route and terminal classifications. The frequency of fatality/injury accidents and the number of fatalities is highest for the truck mode, en route accidents. Using the total number of incidents recorded in the data base per mode and location, the percent of incidents with consequences are:

	Fatalities or Injuries	Evacuations
truck en route	13%	5%
truck terminal	8%	7%
rail en route	7%	0%
rail yard	0%	3%

It is interesting to note that the most injuries were recorded for rail en route (42 injuries), and all of these occurred in one incident. Accidents having such large consequences are often considered the "typical rail accident", yet the large number of zeros in Table 4.3c indicates that few rail accidents have any consequences at all. Rail accidents are much fewer than truck accidents in this 20 month period, which suggests that a much longer length of time is required to develop "typical" rail accident consequences.

Table 4.3c. Frequency of Consequences by Dangerous Goods by Class and by Mode.

	FREQUENCY BY MODE															
	TRUCK								RAIL							
	En route				Terminal				En route				Yard			
CLASS NAME	F/I ACC	F	I	EV	F/I ACC	F	I	EV	F/I ACC	F	I	EV	F/I ACC	F	I	EV
1.1 Explosives (mass)	0	0	0	0*	-	-	-	-	-	-	-	-	0	0	0	0
1.5 Explosives	0	0	0	0	-	-	-	-	-	-	-	-	0	0	0	0
2.1 Flammable gases	2	0	2	3	1	0	2	2	-	-	-	-	0	0	0	0
2.2 Non flammable gases	0	0	0	0	0	0	0	1	-	-	-	-	0	0	0	0
2.4 Corrosive gases	1	0	6	1	3	0	9	1	-	-	-	-	0	0	0	1
3.1 Flammable liquids	12	6	17	4	0	0	0	1	1	0	42	0	0	0	0	0
3.2 "	9	7	7	1	4	1	6	4	0	0	0	0	0	0	0	0
3.3 "	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2 Spontan. combustible	-	-	-	-	1	0	1	0	-	-	-	-	-	-	-	-
4.3 " in water	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-	-
5.1 Oxidizer	3	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0
5.2 "	-	-	-	-	0	0	0	0	-	-	-	-	0	0	0	0
6.0 Poisonous substance	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
6.1 Poison (inhalation)	1	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0
8.0 Corrosives	2	0	2	0	6	0	7	4	0	0	0	0	0	0	0	1
9.0 Miscellaneous	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
9.1 Dangerous to health	0	0	0	0	0	0	0	1	-	-	-	-	0	0	0	0
9.2 Environmental hazard	0	0	0	0	3	0	12	2	-	-	-	-	0	0	0	0
9.9 Miscellaneous	-	-	-	-	0	0	0	0	-	-	-	-	-	-	-	-
TOTALS:	31	14	41	11	18	1	37	16	1	0	42	0	1	0	1	2
	F/I ACC	F	I	EV	F/I ACC	F	I	EV	F/I ACC	F	I	EV	F/I ACC	F	I	EV
TOTAL INCIDENTS:	236				225				15				75			
	En route				Terminal				En route				Yard			
	TRUCK								RAIL							

Notes:

F = number of fatalities
I = number of injuries
F/I = number of accidents that involved either a fatality or an injury
ACC = accident
EV = number of evacuations

* Whenever zeros are shown in the table, incidents have been recorded for that mode in the data base, but no consequences are recorded.

b. Spills by Specific Commodity Type

The spills were further analysed by PIN number, and data for four commodities of interest were extracted: liquefied petroleum gas (LPG), chlorine, sulphuric acid, and gasoline. Their spill frequencies and the average percent spilled per mode are given in Tables 4.4a, b, c, and d. In a previous study, volumes of the first three commodities transported in Ontario were estimated and accident rates were predicted (Saccomanno et al., 1988). The spill frequencies shown in Table 4.4 could be matched with the accident rate predictions of the previous study to produce an estimate of spill likelihood in Ontario for each commodity.

Note that in Table 4.4a, a number of products are considered to be LPG and these are noted in the bottom of the table. The product name LPG can be used, or the product may be labelled with its individual PIN (see Stewart et al., 1987b); therefore, the designation LPG PIN 1075 may include any of the products noted in the table. When referring to LPG in this paper all of the products in Table 4.4a are included.

It appears that incidents involving LPG and gasoline are much more frequent in the truck mode of transport. Sulphuric acid incidents are also more frequent for truck transport than rail transport. For chlorine, with only one incident, which occurred in a truck terminal, it is not possible to say which is more frequent. To make a valid comparison of the relative safety of these modes, more spill data will be required along with data concerning volume of each of these commodities that is transported by truck and rail.

Table 4.4a. LPG (PIN 1075, 1011, 1969, 1055, 1978, 1077).

Class: 2.1 LPG % of Class 2.1: 75%

	TRUCK		RAIL		TOTAL
	En route	Terminal	En route	Terminal	
Frequency:	9	5	0	1	15
Percent :	60%	33%	0	7%	100%

PIN	Product Name	% of LPG incidents
1075	liquefied petroleum gas	73%
1011	butane	7%
1969	isobutane	0%
1055	isobutylene	0%
1978	propane	20%
1077	propylene	0%

Table 4.4b. Chlorine (PIN 1017).

Class: 2.4   Cl % of Class: 9%

	TRUCK		RAIL		TOTAL
	En route	Terminal	En route	Terminal	
Frequency:	0	1	0	0	1
Percent :	0%	100%	0%	0%	100%

Table 4.4c. Sulphuric Acid (PIN 1830, 1831, 1982).

Class: 8   SA % of Class 8: 11%

	TRUCK		RAIL		TOTAL
	En route	Terminal	En route	Terminal	
Frequency:	7	7	1	5	20
Percent :	35%	35%	5%	25%	100%

PIN	Product Name	% of SA incidents
1830	sulphuric acid	95%
1831	sulphuric acid, fuming or oleum	0
1932	sulphuric acid, spent	5%

Table 4.4d. Gasoline (PIN 1203*).

Class: 3.1   Gasoline % of Class 3.1: 68%

	TRUCK		RAIL		TOTAL
	En route	Terminal	En route	Terminal	
Frequency:	42	22	4	4	72
Percent :	58%	30%	6%	6%	100%

* Six entries for gasoline PIN 1203 were found in Class 3.2. These data were assumed to be gasoline data entered in the wrong class, therefore they are included with the Class 3.1 entries in this table.

c. Spills by Region

Table 4.5 shows geographic regions in which these accidents occurred and Table 4.6 shows the injuries, deaths and evacuations caused by the release of these goods. These tables should reflect large production or consumption centres of these commodities, i.e., more transport activity should involve more accidents.

From Table 4.5, LPG incidents are fairly evenly distributed among 6 provinces: British Columbia, Alberta, Saskatchewan, Ontario, Quebec and Nova Scotia. Chlorine has only one incident recorded, which perhaps reflects superior safety measures in chlorine transport, or very little transport activity. The one incident involved a truck in the Yukon, and no consequences were recorded.

Table 4.5 shows that sulphuric acid incidents were most frequent in Ontario, followed by Alberta, British Columbia, Manitoba, Quebec, and New Brunswick. Gasoline incidents were recorded in all provinces, but were most frequent in Ontario, closely followed by Alberta, British Columbia and Quebec.

Table 4.5. LPG, Chlorine, Sulphuric Acid and Gasoline Releases by Region.

	COMMODITY			
PROVINCE	LPG	CHLORINE	SULPHURIC ACID	GASOLINE
British Columbia	2	-	1	12
Alberta	2	-	4	13
Saskatchewan	2	-	-	5
Manitoba	-	-	1	4
Ontario	3	-	11	15
Quebec	4	-	1	8
New Brunswick	-	-	2	3
Nova Scotia	2	-	-	3
Pr. Edward Island	-	-	-	2
Newfoundland	-	-	-	2
Yukon	-	1	-	2
TOTALS:	15	1	20	69

In Table 4.6, each line for each commodity shows consequences recorded for the incidents shown in Table 4.5, if consequences occurred. If incidents were recorded, but no consequences resulted, a zero is shown in Table 4.6. The consequence rate (i.e., fatalities, injuries, evacuations per number of incidents) are shown for each commodity at the bottom of the table.

LPG has the highest consequence rate; 40% of these incidents had some kind of consequence. Next is gasoline with 25% of incidents with consequences, then sulphuric acid with 15%. Chlorine, as previously mentioned, only has one incident and no consequences recorded.

The injury accident rate is highest for LPG, with sulphuric acid next in frequency, followed by gasoline. Fatalities were only recorded with the transport of gasoline. These rates do not necessarily reflect the hazards of the dangerous goods, but rather the hazards of the transportation accident.

It is interesting to note that the consequences are not necessarily more frequent in higher populated areas, for example, Ontario's gasoline consequence rate was 20%, whereas the average consequence rate for gasoline across the country was 25%. However, the largest evacuations occurred in this province: two evacuations were recorded with 300 people evacuated per incident.

Table 4.6. Consequences by Region.

Fatalities (F#) Injuries (I#) and Evacuations (E#)
(R) = ROAD ENROUTE (T) = ROAD TERMINAL
(RR)= RAILROAD ENROUTE (Y) = RAIL YARD

	COMMODITY			
PROVINCE	LPG	CHLORINE	SULPHURIC ACID	GASOLINE
British Columbia	E5(T)	-	0	E(T) I1(R) E50(R)
Alberta	E+I1(R); I1(R)	-	I1(Y)	I2(R) F1(R) F1(R) E50(T)
Saskatchewan	E+I2(T)	-	-	I1(R)
Manitoba	-	-	0	0
Ontario	0		I1(T) I2(T)	I2+F1+E300(R) E300(R) I3(R)
Quebec	E20(R)	-	0	I42(RR) E3(R)
New Brunswick	-	-	0	E20(T)
Nova Scotia	E(R)	-	-	I2+F1(R)
Pr. Edward Island	-	-	-	I1+F1(R)
Newfoundland	-	-	-	I4(R)
Yukon	-	0	-	-
Conseq. rate:	6/15 (40%)	0/1	3/20 (15%)	17/69 (25%)
I.Acc. rate:	3/15 (20%)	0	3/20 (15%)	8/69 (12%)
F.Acc. rate:	0	0	0	5/69 (7%)
Evac. rate:	5/15 (33%)	0	0	7/69 (10%)
	LPG	CHLORINE	SULPHURIC ACID	GASOLINE

4.3.2 Analysis of Spill Causes by Mode

Using the cause description given in the Transport Canada data base, the spills were divided into transport accident and non transport accident spills. The latter group was further divided into fixed plant, equipment, operational, and other categories. Similar causal information was not available for the transportation accident related incidents. Some interpretation of the cause descriptions was required since these descriptions are not defined explicitly on the Transport Canada reporting form, and they varied considerably.

The spill or leak classification under "spill type" was not used in this analysis since these categories both showed loss percentages from 1 to 98%. This is expected since even a small leak could empty a container given adequate time; however, without this time estimate, there is no way of knowing if the leak was small or massive. In addition there seems to be some confusion regarding the definition of "spill" and "leak" since some causes (for example, overfill) were classified at times as spills and at other times as leaks.

4.3.2.1 Railway Spills

Only 92 of the 586 releases occurred on the railways during the 20 month period. The 92 incidents include both those releases caused by transportation accidents and those having other causes. Seventy-seven of the incidents occurred in railway yards, and 15 on mainline track.

a. Mainline

Of the 15 mainline incidents, 6 were classified as accident related spills, and 9 were classified as non-accident related spills. A further breakdown of causes for the latter case revealed 5 operational related incidents, 3 equipment related incidents, and 1 in the other causes category. The descriptive causes were coded as shown in Table 4.7. These 15 incidents involved 42 injuries which all occurred in one incident, and no fatalities or evacuations.

b. Yard Spills

Of the 77 railway yard spills, 3 were classified as transportation accident-caused spills and 74 were classified as non-accident incidents. Two unknown causes were again assumed to be in this non-accident category since railway transportation accidents are well documented. Further classification of the non-accident releases produced 36 operational related incidents, 32 equipment related incidents and 6 incidents in the other category. The descriptive cause codes and corresponding frequencies are shown in Table 4.8.

The statistics shown in Table 4.8 indicate that approximately 96% of yard spills or leaks are the result of a non-transportation accident spill. On the other hand, from Table 4.7, 60% of mainline spills are classified as non-accident spills. From these data base records, the ratio of yard to mainline dangerous goods spills is 5 yard spills to 1 mainline spill. For non-transportation accident spills only, the ratio of yard leaks to mainline leaks is approximately 8 to 1.

These yard incidents resulted in 1 injury, no fatalities and 2 evacuations. No evacuation counts were listed in the data base, however. One evacuation occurred following a derailment (transport accident) and the other one occurred after a valve failed (non-transport accident). The injury was recorded when the dome of a tank car failed (non-transport accident).

Table 4.7. Railway Mainline Cause Codes (15 incidents).

Transportation Accident Code 1			Non-Transportation Accident Release Code 2		
Subcode	Description	Freq	Subcode	Description	Freq
			OPERATIONAL		
1	Collision	2	1	Improper bracing	2
2	Derailment	4	2	Improper blocking	1
			3	Loadshift	1
	SUBTOTAL:	6	4	Puncture*	1
			EQUIPMENT		
			5	Fitting Failure	2
			6	Package Failure	1
			OTHER		
			7	Unknown	1
	TOTAL:	15		SUBTOTAL:	9

*Not clear how the puncture occurred, but assumed not to be a result of a collision or derailment which are well reported for rail accidents.

Table 4.8. Railway Yard Cause Codes (77 incidents).

Transportation Accident
Code 1

Subcode	Description	Freq
1	Collision	1
2	Derailment	1
3	Brakes	1
	SUBTOTAL:	3

Non-Transportation Accident Release
Code 2

Subcode	Description	Freq
	OPERATIONAL	
1	Loadshift	4
2	Improper Bracing	7
3	Valve loose	2
4	Overfill/overflow	3
5	Improper loading	4
6	Package damaged[+]	6
7	Puncture[*]	10
	EQUIPMENT	
8	Package failed[+]	11
9	Valve/vent failure	12
10	Dome failure	3
11	Tank fail/rupture/seam sep	5
12	TRSR failure[#]	1
	OTHER	
13	Sabotage	1
14	Stolen	1
15	Reaction	1
16	Water Damage	1
17	Unknown	2
	SUBTOTAL:	74
	TOTAL:	77

[+] Package damaged assumed to imply human error in handling;
Package failed assumed to imply a fault in the container.

[*] As in Table 4.7, collision and derailments are assumed to be recorded as such. It is assumed these punctures occurred due to improper loading or bracing. The punctures occurred in rail cars, box cars, containers on flat cars and tank cars.

[#] Assumed to be transfer equipment failure.

4.3.2.2 Road Spills

The remaining 494 spills occurred on roads en route and in road terminals. Slightly more occurred en route; 260 as opposed to 234 in road terminals. For each situation, transportation related accidents were separated from non-transportation accidents spills. The latter spills were separated into cause of spill. Consequences of all the spills are discussed.

a. Road En Route Spills

Of the 260 road en route incidents, 128 resulted from transportation accidents. The remaining 132, approximately 51%, were classified as non transportation accident spills that were further classified into 65 operational related spills, 60 equipment related spills, and 7 in the other category. The descriptive cause codes are shown in Table 4.9.

The road spills resulted in 43 injuries, 15 fatalities and 11 evacuations. Six hundred and eighty-three people were evacuated in 6 of these evacuations -- on average 114 persons/evacuation. The vast majority of injuries, fatalities and evacuations occurred in the transportation accident related releases.

Only 2 of the 11 evacuations were recorded for the non-transport accident releases, with 1 of these affecting 3 people. Both of these incidents involved damage to a containment system. Also recorded for non-transport accident releases were one injury and one fatality, occurring in separate accidents, both of which resulted from damage to the containment system.