Performance of European cross-country oil pipelines

Statistical summary of reported spillages in 2010 and since 1971

Prepared by the CONCAWE Oil Pipelines Management Group's Special Task Force on oil pipeline spillages (OP/STF-1)

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ABSTRACT

CONCAWE has collected 40 years of spillage data on European cross-country oil pipelines. At about 35,000 km the inventory covered currently includes the vast majority of such pipelines in Europe, transporting around 800 million m^3 per year of crude oil and oil products. This report covers the performance of these pipelines in 2010 and a full historical perspective since 1971. The performance over the whole 40 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of inspections by in-line tools (intelligence pigs) is also reported. 4 spillage incidents were reported in 2010, corresponding to 0.12 spillages per 1000 km of line, well below the 5-year average of 0.25 and the long-term running average of 0.52, which has been steadily decreasing over the years from a value of 1.2 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. 2 incidents were due to mechanical failure, 1 to external corrosion, and 1 was connected to past third party activities. Over the long term, third party activities remain the main cause of spillage incidents although mechanical failures have increased in recent years, a trend that needs to be scrutinised in years to come.

KEYWORDS

CONCAWE, intelligence pig, oil spill, performance, pipeline, safety, soil pollution, spillage, statistics, trends, water pollution

INTERNET

This report is available as an Adobe pdf file on the CONCAWE website (www.concawe.org).

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SUMMARY

CONCAWE has collected 40 years of spillage data on European cross-country oil pipelines with particular regard to spillages volume, clean-up and recovery, environmental consequences and causes of the incidents. The results have been published in annual reports since 1971. This report covers the performance of these pipelines in 2010 and provides a full historical perspective since 1971. The performance over the whole 40 year period is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of inspections by in-line tools (intelligence pigs) is also reported.

77 companies and agencies operating oil pipelines in Europe currently provide data for the CONCAWE annual survey. For 2010 data was received from 69 operators representing over 160 pipeline systems and a combined length of 34,645 km, slightly less than the 2009 inventory. There were minor corrections to the reported data. 9 operators did not report but, to our knowledge, none of these suffered a spill in 2010. Nevertheless they are not included in the statistics. The reported volume transported in 2010 was just under 800 Mm^3 of crude oil and refined products, about 10% less than in 2009. Total traffic volume in 2010 was estimated at $125*10^9$ m^3*km.

4 spillage incidents were reported in 2010, corresponding to 0.12 spillages per 1000 km of line, well below both the 5-year average of 0.25 and the long-term running average of 0.52, which has been steadily decreasing over the years from a value of 1.2 in the mid ‘70s. There were no reported fires, fatalities or injuries connected with these spills. The gross spillage volume was low at 336 m^3. This is 10 m^3 per 1000 km of pipeline compared to the long-term average of 78 m^3 per 1000 km of pipeline. Essentially all the spilled volume was recovered or safely disposed of.

Two of the spills accounted for about 95% of the gross spill volume. Over the long term, less than 20% of the spillages are responsible for about 80% of the gross volume spilled. Pipelines carrying hot oils such as fuel oil have in the past suffered from external corrosion due to design and construction problems. Most have been shut down or switched to cold service, so that the great majority of pipelines now carry unheated petroleum products and crude oil. Only 159 km of hot oil pipelines are reported to be in service today. The last reported spill from a hot oil pipeline was in 2002.

Of the 4 reported incidents in 2010, 2 were related to mechanical failures, 1 was caused by external corrosion and 1 was the result of third party activities. Over the long term, third party activities remain the main cause of spillage incidents, although the number of events has progressively decreased over the years. Mechanical failure is the second largest cause of spillage. After great progress during the first 20 years, the frequency of mechanical failures has been on an upward trend over the last decade.

In-line inspections were at a record high in 2010. A total of 89 sections covering a total of 12,300 km, 45% more than in 2009, was inspected by at least one type of intelligence pig. Most inspection programmes involved the running of more than one type of pig in the same section, so that the total actual length inspected was less at 7178 km (21% of the inventory).

Most pipeline systems were built in the ‘60s and ‘70s. Whereas, in 1971, 70% of the inventory was 10 years old or less, by 2010 only 4.4% was 10 years old or less and 50% was over 40 years old. However, this has not led to an increase in spillages.

Overall there is no evidence that the ageing of the pipeline system implies a greater risk of spillage. The development and use of new techniques, such as internal inspection with intelligence pigs, hold out the prospect that pipelines can continue reliable operations for the foreseeable future. CONCAWE pipeline statistics, in particular those covering the mechanical and corrosion incidents, will continue to be used to monitor performance.

1. INTRODUCTION

The CONCAWE Oil Pipelines Management Group (OPMG) has collected data on the safety and environmental performance of oil pipelines in Europe since 1971. Information on annual throughput and traffic, spillage incidents and intelligence pig inspection activities are gathered yearly by CONCAWE via questionnaires sent out to oil pipeline operating companies early in the year following the reporting year.

The results have been analysed and published annually in a series of annual reports [1,2] and in a summary report [3] covering the years 1971 to 2000. From the 2005 reporting year, the format and content of the report was changed to include not only the yearly performance, but also a full historical analysis since 1971. This report uses the same format and therefore supersedes the 2009 data report 3/11. The map of the oil pipeline inventory covered by CONCAWE as at 2010 has been updated and is now available in digital and interactive form at www.concawe.org.

Aggregation and statistical analysis of the performance data provide objective evidence of the trends, focusing attention on existing or potential problem areas, which helps operators to set priorities for future efforts. In addition to this activity CONCAWE also holds a seminar, known as “COPEX” (CONCAWE Oil Pipeline Operators Experience Exchange), every four years to disseminate information throughout the oil pipeline industry on developments in techniques available to pipeline companies to help improve the safety, reliability and integrity of their operations. These seminars have included reviews of spillage and clean-up performance to cross-communicate experiences so that all can learn from each other’s incidents. The last COPEX was held in Brussels in March 2010.

Section 2 provides details of the pipeline inventory covered by the survey (length, diameter, type of product transported) and how this has developed over the years. Throughput and traffic data is also included.

Section 3 focuses on safety performance i.e. the number of fatalities and injuries associated with pipeline spillage incidents.

Section 4 gives a detailed analysis of the spillage incidents in 2010 and of all incidents over the last 5 years. **Section 5** analyses spillage incidents for the whole reporting period since 1971 while **Section 6** provides a more detailed analysis of the causes of spillage.

Finally **Section 7** gives an account of in-line inspections.

2. PIPELINE INVENTORY, THROUGHPUT AND TRAFFIC

2.1. CRITERIA FOR INCLUSION IN THE SURVEY

The definition of pipelines to be included in the CONCAWE inventory has remained unchanged since 1971. These are pipelines:

- Used for transporting crude oil or petroleum products,
- With a length of 2 km or more in the public domain,
- Running cross-country, including short estuary or river crossings but excluding under-sea pipeline systems. In particular, lines serving offshore crude oil production facilities and offshore tanker loading/discharge facilities are excluded.
- Pump stations, intermediate above-ground installations and intermediate storage facilities are included, but origin and destination terminal facilities and tank farms are excluded.

The minimum reportable spillage size has been set at 1 m^3 (unless exceptional safety or environmental consequences are reported for a < 1 m^3 spill).

All the above criteria are critical parameters to consider when comparing different spillage data sets, as different criteria can significantly affect the results.

The geographical region covered was originally consistent with CONCAWE's original terms of reference i.e. OECD Western Europe, which then included 19 member countries, although Turkey was never covered. From 1971 to 1987, only pipelines owned by oil industry companies were included, but from 1988, non-commercially owned pipeline systems (essentially NATO) were brought into the inventory. Following the reunification of Germany, the pipelines in former East Germany (DDR) were added to the database from 1991. This was followed by Czech and Hungarian crude and product lines in 2001, Slovakian crude and product lines in 2003 and Croatian crude lines in 2007.

Although CONCAWE cannot guarantee that every single pipeline meeting the above criteria is actually covered, it is believed that most such lines operated in the reporting countries are included. Notable exceptions are NATO lines in Italy, Greece, Norway and Portugal as well as all crude and product pipelines in Poland.

It should be noted that all data recorded in this report and used for comparisons or statistical analysis relate to the inventory reported on in each particular year, and not to the actual total inventory in operation at the time. Thus, year-on-year performance comparisons must be approached with caution and frequencies (i.e. figures normalised per 1000 km of line) are more meaningful than absolute ones.

2.2. REPORTING COMPANIES

For the 2010 reporting year, 69 companies completed the survey, out of the 78 operating companies with which CONCAWE maintains contact. This total includes affiliates and joint ventures of large oil companies. This number has remained essentially constant over the years, as the impact of new operators joining in was compensated by various mergers.

2.3. INVENTORY DEVELOPMENTS 1971-2010

2.3.1. Pipeline service, length and diameter

The 69 companies that reported in 2010 operate 153 pipeline systems split into 629 active sections and covering a total of 34,645 km. The 9 companies that did not report operate a total of 20 systems in 60 sections covering about 1000 km. There was no report either of new sections or of sections being permanently taken out of service in 2010.

Figure 1 shows the evolution of this "CONCAWE inventory" over the years since 1971. The two historical step increases occurred when systems previously not accounted for in the survey were added. In the late 80s the majority of the NATO pipelines were included and in the early part of this decade a number of former Eastern bloc systems joined the survey. The increase was mostly in the "products" category, the main addition in the crude oil category being the Friendship or "Druzba" system that feeds Russian crude into Eastern European refineries.

Over the years a total of 230 sections has been permanently taken out of service, reducing the inventory by about 9200 km.

It is important to note that **Figure 1** represents the pipeline length reported to CONCAWE in each year and does not therefore give an account of when these pipelines were put into service. Most of the major pipelines were indeed built in the '60s and '70s and a large number of them had already been in service for some time when they were first reported on in the CONCAWE survey. This aspect is covered in the discussion of pipeline age distribution in the next section.

The sections are further classified according to their service, i.e. the type of product transported, for which we distinguish crude oil, white products, heated black products (hot oil) and other products. A few pipelines transport both crude oil and products. Although these are categorised separately in the database they are considered to be in the crude oil category for aggregation purposes. A small number of lines may be reported as out of service in a certain year without being permanently retired. The three main populations are referred to as crude, product and "hot" in this report.

Figure 1 shows that the first two categories represent the bulk of the total inventory. Out of the 230 sections that have been retired since 1971, 24 (1147 km) were in the "hot" category. This represents two thirds of the original "hot" inventory of which only 159 km distributed amongst a dozen sections remain in operation. This reflects the decline in the heavy fuel oil business since the mid-1970s, but also specific action taken by operating companies because of the corrosion problems and generally poor reliability experienced with several of these pipelines (see **Section 5.1**).

Figure 2 shows the diameter distribution in 2010 for each service category. In general, the crude pipelines are significantly larger than the other two categories. Some 90% of the crude pipelines are 16" (400 mm) or larger, up to a maximum of 48" (1200 mm), whereas around 86% of the product and some 90% of the hot pipelines are less than 16". The smallest diameter product pipelines are typically 6" (150 mm) although a very small number are as small as 3" (75 mm).

Figure 1 CONCAWE oil pipeline inventory and main service categories

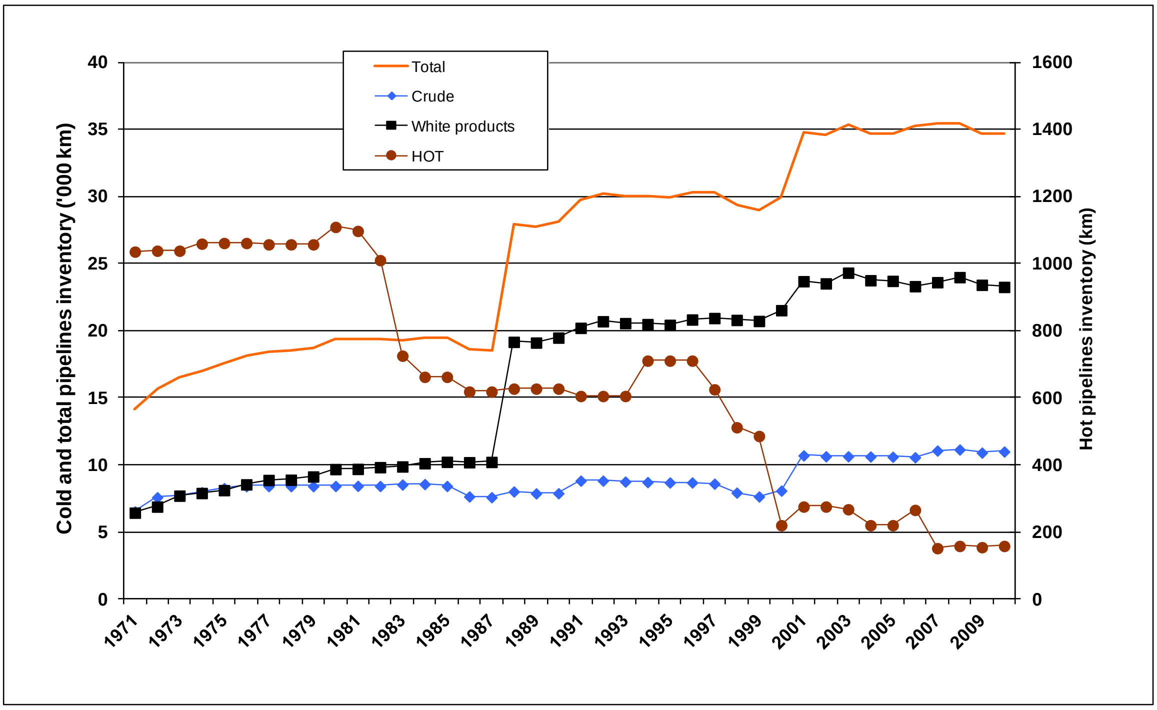
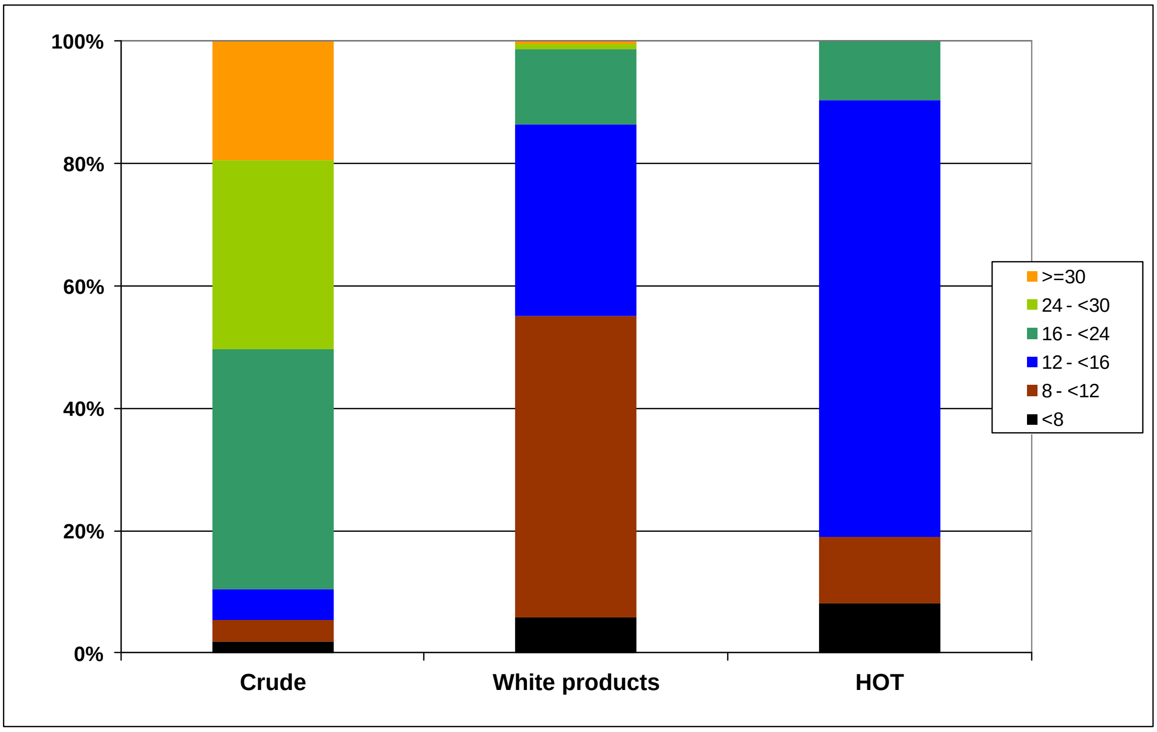


Figure 2 European oil pipeline diameter distribution and service in 2010



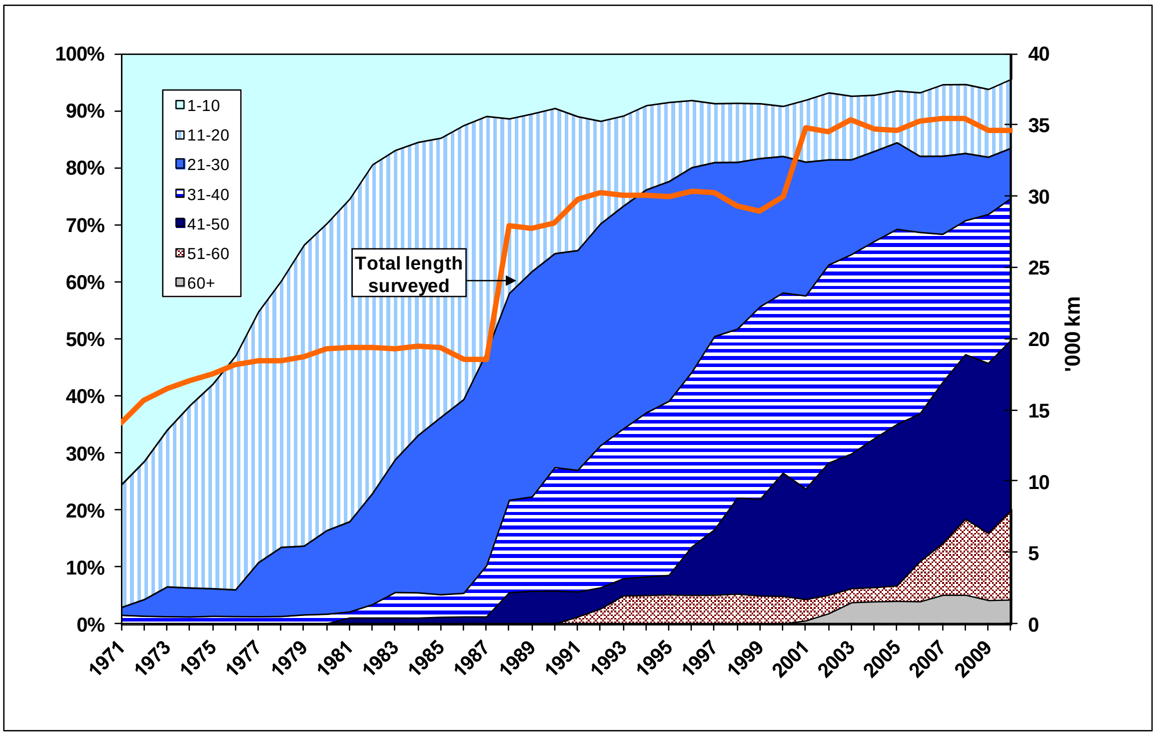
2.3.2. Age distribution

When the CONCAWE survey was first performed in 1971, the pipeline system was comparatively new, with some 70% being 10 years old or less. Although the age distribution was quite wide, the oldest pipelines were in the 26-30 year age bracket and represented only a tiny fraction of the inventory.

Over the years, a number of new pipelines have been commissioned, while older ones have been taken out of service. As mentioned above, existing lines were also added to the inventory at various stages, contributing their specific age profile. Although some short sections may have been renewed, there has been no large-scale replacement of existing lines. The development of the overall age profile is shown in **Figure 3**.

The system has clearly been progressively ageing. By 2010, only some 1520 km, i.e. 4.4% of the total, was 10 years old or less while 17,300 km (50%) was over 40 years old. The impact of age on spillage performance is discussed in **Section 6.3**.

Figure 3 European Oil pipeline age distribution in 2010



2.4. THROUGHPUT AND TRAFFIC

A reported total of around 510 Mm^3 of crude oil and 280 Mm^3 of refined products were transported in the surveyed pipelines in 2010, a figure that is fairly stable from year to year (when considering the same pipeline inventory). The crude oil transported represents about 70% of the combined throughput of European refineries. It should be realised however, that this figure is only indicative. Large volumes of both crude and products pass through more than one pipeline, and whilst every effort is made to count the flow only once, the complexity of some pipeline systems is such that it is often difficult to estimate what went where. Indeed, there are a few pipelines where the flow can be in either direction.

A more meaningful figure is the traffic volume which is the flow-rate times the distance travelled. This is not affected by how many different pipelines each parcel of oil is pumped through. In 2010, the total reported traffic volume was about $125x10^9$ m^3.km, more or less the same as in 2009 and split between $77x10^9$ m^3.km for crude and $48x10^9$ m^3.km for products (with an insignificant number for hot lines).

Throughput and traffic are reported here to give a sense of the size of the oil pipeline industry in Europe. These are not, however, considered to be significant factors for pipeline spillage incidents. Although higher flow rates may lead to higher pressure, line deterioration through metal fatigue is more directly related to pressure cycles than to the absolute pressure level (as long as this remains within design limits). These figures are, however, useful as a divider to express spillage volumes in relative terms (e.g. as a fraction of throughput, see **Section 4**), providing figures that can be compared with the performance of other modes of oil transportation.

3. PIPELINE SAFETY

The CONCAWE pipeline database includes records of fatalities, injuries and fires related to spillages.

3.1. FATALITIES AND INJURIES

No spillage-related fatalities or injuries were reported in 2010.

Over the 40 reporting years there have been a total of 14 fatalities in five separate incidents in 1975, 79, 89, 96 and 99. All but one of these fatalities occurred when people were caught in a fire following a spillage.

In three of the four fire-related incidents the ignition was a delayed event that occurred hours or days after the spillage detection and demarcation of the spillage area had taken place. In one incident involving a spillage of chemical feedstock; naphtha, 3 bystanders were engulfed in fire, having themselves probably been the cause of ignition. In another incident, ignition of spilled crude oil occurred during attempts to repair the damaged pipeline. The repairers escaped but the spread of the fire caught 4 people who had entered inside the marked spillage boundary some distance away. The third incident also involved a maintenance crew (5 people) carrying out repair activities following a crude oil spill, none of whom escaped. These fatalities all occurred after the spillage flows had been stemmed, i.e. during the subsequent incident management and reinstatement period. It appears that the spillages themselves did not cause the fatalities. Stronger management of spillage area security and working procedures might well have prevented these fires and subsequent fatalities.

In just one case, fire ensued almost immediately when a bulldozer doing construction work hit and ruptured a gasoline pipeline. A truck driver engaged in the works received fatal injuries.

The single non-fire fatality was a person engaged in a theft attempt who was unable to escape from a pit which he had dug to expose and drill into the pipeline. This caused a leak that filled the pit with product in which the person drowned.

It is apparent that the casualties were not members of the general public going about their normal activities in locations where they should have been allowed to be at the time. Thus these occurrences should not be used out of context for any assessment of societal risk inherent to oil pipeline operations.

A total of 3 injuries have been reported over the years. Single non-fatal injuries were recorded in both 1988 and 1989, both resulting from inhalation / ingestion of oil spray/aerosol. There was one injury to a third party in 2006.

3.2. FIRES

There was no spillage-related fire reported in 2010.

Apart from those mentioned above, five other fires are on record:

- A large crude oil spill near a motorway probably ignited by the traffic.

- A gasoline theft attempt in an untypical section of pipeline located on a pipe bridge. The thieves may have deliberately ignited it.

- A slow leak in a crude production line in a remote country area found to be burning when discovered. It could have been ignited purposely to limit the pollution.

- A tractor and plough that had caused a gasoline spill caught fire, which also damaged a house and a railway line.

- A mechanical digger damaged a gasoline pipeline and also an electricity cable, which ignited the spill.

There were no casualties reported in any of these incidents.

4. SPILLAGE PERFORMANCE IN THE LAST 5 YEARS (2005-09)

4.1. 2010 SPILLAGE INCIDENTS

A total of 4 spillage incidents were recorded in 2010. **Table 1** gives a summary of the main causes and spilled volumes and environmental impact. For definition of categories of causes and gross/net spilled volume, see **Appendix 1**.

Table 1 Summary of causes and spilled volumes for 2010 incidents

Event (1)	Facility	Line size (")	Product spilled	Injury Fatality (2)	Fire	Spilled volume Gross (m^3)	Net loss	Contamination Ground area (m^2)	Water (3)
Mechanical									
Design & Materials									
475	Pump Station	2	Crude	-	-	125.0	13.0	200	
477	Pump Station	8.6	Gasoil	-	-	10.0	0.2	0	
Corrosion									
External									
476	Underground pipe	12.75	Gasoil	-	-	1.0	1.0	Insignificant	S
Third party activity									
Accidental									
478	Underground pipe	24	Crude	-	-	200.0	0.0	21000	S G

(1) Spillage events are numbered from the beginning of the survey in 1971
(2) I = Injury, F = Fatality
(3) S = Surface water, G = Groundwater, P = Potable water

The circumstances of each spill, including information on consequences, remediation and cost are described in the next section according to cause. Further details are available in **Appendix 2** which covers all spillage events recorded since 1971.

4.1.1. Mechanical Failure

There were 2 incidents resulting from mechanical failure in 2010. Both occurred in pump stations and were related to design or materials faults.

Event 475:
The local police station informed the control room of a strong hydrocarbon smell at the pumping station. The leak was located at a spectacle blind (between 2 flanges) and was due to a damaged gasket.

125 m^3 of product leaked via the damaged gasket. Most of it was contained in the retention pits located within the site but about 5 m^3 overflowed into the rainwater collecting system and ended up in the de-oiler for water treatment. The water in the de-oiler was frozen and so was the hydrocarbon detector, so that the oil escaped outside the pumping station into a small dry ditch about 300 m away.

Soil samples were taken at 17 locations both inside and outside the station, and analysed to estimate the level of contamination in the ground. The contamination remained on the clay surface so that all the polluted soil could be easily excavated. 745 tonnes of contaminated soil were taken away and sent to an approved centre.

Event 477:
During a routine inspection by field operators in a pump station, an oil contaminated area around a flange was discovered. The flange is located downstream of the pumps and is partially embedded in concrete up to the gasket.

The operators alerted the dispatching centre and pumping was stopped. The leakage was due to failure of the gasket.

Approximately 10 m^3 of product were spilled, nearly all of which was confined in the concreted area of the pipeline facility and was recovered in drainage pits from where it was routed to the contaminated water tank. The concreted area was cleaned up with water.

4.1.2. Operational

There were no spillages in this category in 2010.

4.1.3. Corrosion

There was one incident resulting from external corrosion in 2010.

Event 476:
The land owner detected a hydrocarbon smell and alerted the dispatching centre. Pumping was stopped immediately and the emergency response team was activated.

Excavation confirmed a small intermittent leak. The external coating of the pipe was damaged and direct contact between the pipeline metal and the soil caused galvanic corrosion resulting in a pinhole.

A containment barrier was deployed on the nearby stream, in order to stop the oil moving further downstream. Some product was skimmed off the water surface and removed by vacuum trucks. The contaminated soil was removed and disposed of.

Piezometers were installed to monitor the migration of hydrocarbons.

4.1.4. Natural causes

There were no spillages in this category in 2010.

4.1.5. Third party activity

There was one incident resulting from third party activity (“accidental”) in 2010.

Event 478:
During excavation work for drainage the pipeline was hit by the excavator causing failure of the pipeline. Pumping was stopped immediately and section valves were shut. The emergency team was activated to handle the situation, limit the impact and repair the pipeline.

Some 200 m^3 of crude oil leaked out. Oil was recovered from water-filled ditches with oil separators and vacuum trucks. The ditch walls were dug out and replaced and the polluted soil was removed in accordance with a remediation plan following local standards. Continuous monitoring of groundwater was maintained throughout the remediation process.

The pipeline was repaired and came back into operation within seven days. Remediation of contaminated soil and ditches was completed within nine months.

4.2. 2005-2010 SPILLAGE OVERVIEW

Table 2 shows the spillage performance for the 5-year period 2006-2010. Of the 42 spillages recorded for the period 35 caused some temporary environmental contamination. 6 spillages affected surface waters and 8 affected groundwater but none had any impact on potable water supplies.

At only 4, the number of reported spillages in 2010 was the lowest recorded, well below the average of 8.4 for the last five years, and of 12.0 per year since CONCAWE records began in 1971.

The total gross spillage volume 336 m^3 was the second lowest on record and, more remarkably, virtually all of it was recovered so that the net loss to the environment was only 1 m^3.

Table 2 Five-year comparison by cause, volume and impact: 2006 – 2010

		2006	2007	2008	2009	2010	2006-2010
Combined Length	km x 10^3	35.3	35.5	35.5	34.6	34.6	35.1
Combined Throughput	m^3 x 10^6	805	763	780	872	790	802
Combined traffic volume	m^3 x km x 10^9	130	129	130	125	125	128
Spillage incidents		**12**	**9**	**12**	**5**	**4**	**42**
MECHANICAL FAILURE							
Construction		2		2	1		5
Material		4		5	3	2	14
OPERATIONAL							
System							0
Human							0
CORROSION							
External			1	1		1	3
Internal		2	1				3
Stress corrosion cracking							0
NATURAL HAZARD							
Subsidence							0
Flooding							0
Other							0
THIRD PARTY ACTIVITY							
Accidental		2	4	4		1	11
Malicious		2	2				4
Incidental			1		1		2
Volume spilled	m^3						**Average**
Gross spillage		651	984	968	5476	336	1683
Net loss		9	466	167	833	1	295
Average gross loss / incident		54	109	81	1095	84	285
Average net loss / incident		1	52	14	167	0	47
Average gross loss/1000 km		18	28	27	158	10	29
Average net loss/1000 km		0	13	5	24	0	11
Gross spillage/ throughput	ppm	0.8	1.3	1.2	6.3	0.4	2
Gross spillage per cause							
Mechanical failure		132	0	562	5466	135	1259
Operational		0	0	0	0	0	0
Corrosion		12	195	1	10	1	44
Natural hazard		0	0	0	0	0	0
Third party activity		507	793	406	0	200	381
Net loss distribution							
(No of incidents)							
< 10		13	4	9	2	2	30
11 -100			3	2	2	1	8
101- 1000			2	1	1	1	5
> 1000 m^3							0
Environmental impact							
NONE		4		2		1	7
SOIL							
< 1000 m^2		12	6	7	1	3	29
> 1000 m^2			3	5	1	1	10
WATER BODIES							
Surface Water		1	2		1	2	6
Groundwater		4	1		2	1	8
POTABLE WATER							0

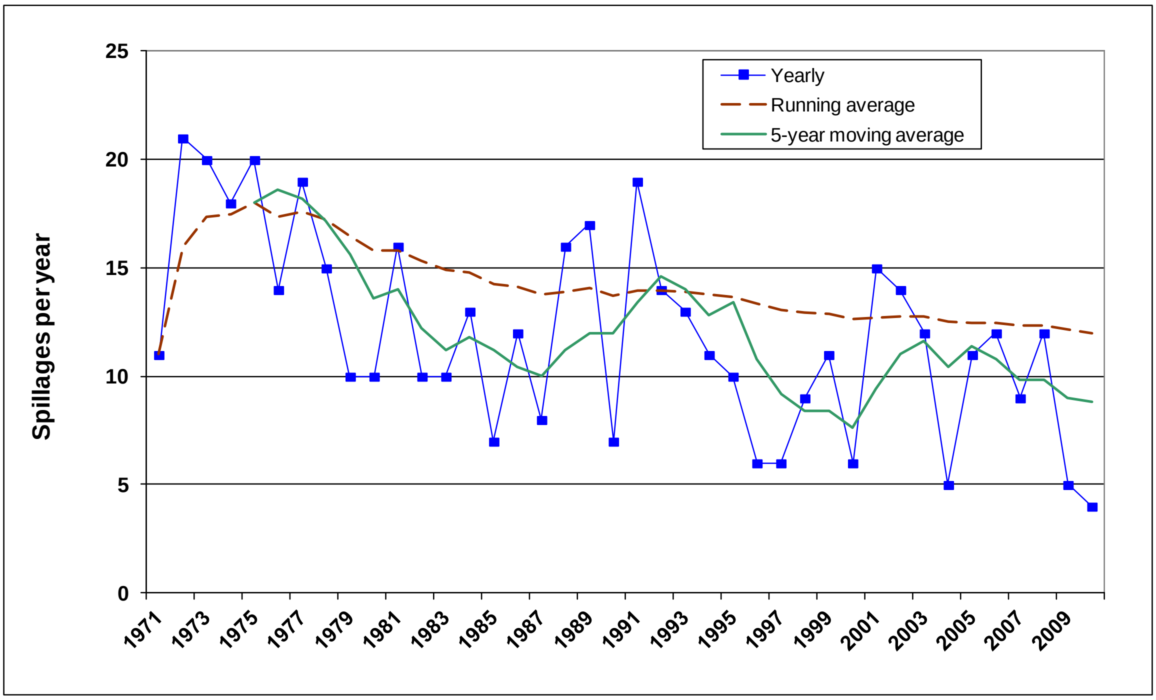
5. HISTORICAL ANALYSIS OF SPILLAGES 1971-2010

5.1. NUMBERS AND FREQUENCY

Over the 40-year survey period there have been 478 spillage incidents. 67 of these spillages occurred in "hot" pipelines, a disproportionately large proportion in relation to the share of such pipelines in the total inventory.

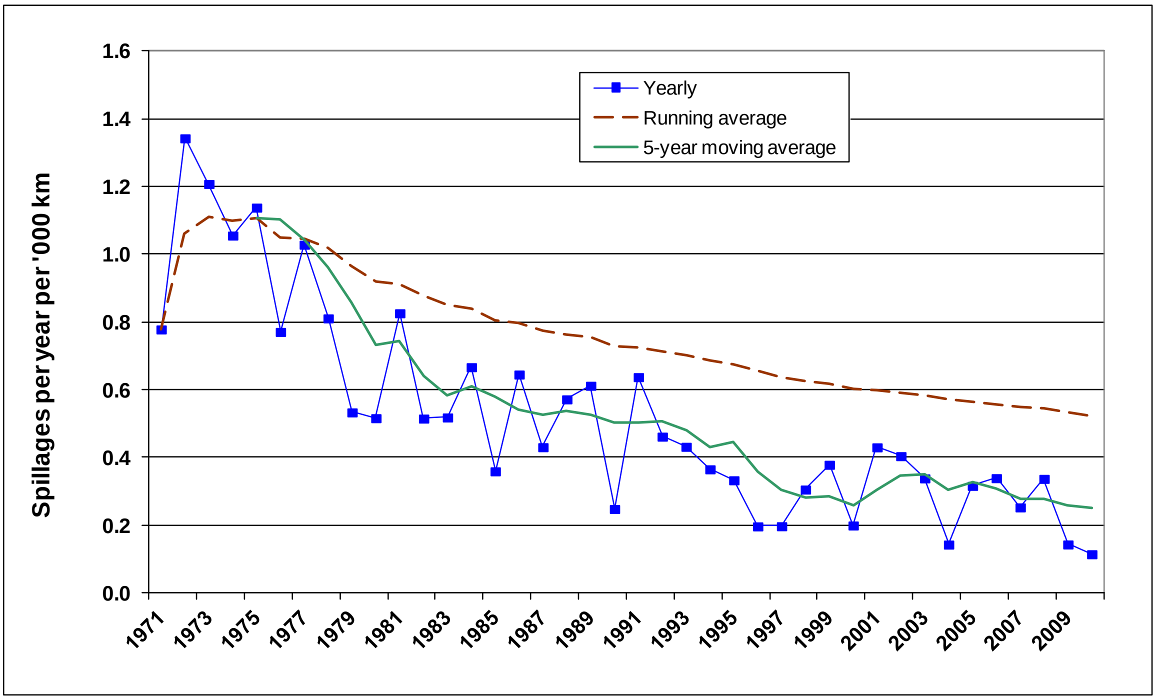
Figure 4 shows the number of spillages per year, moving average and 5-year average trends over the 40 years since 1971 for all pipelines. There is a clear long-term downward trend which bears witness to the industry's improved control of pipeline integrity. The overall 5-year moving average has reduced from about 18 spillages per year in the early 1970s to 8.4 by 2010. The moving average increases in the late '80s to early '90s and again in the early 2000 are partly linked to the additions to the pipeline inventory monitored by CONCAWE. The largest number of spillages recorded in any one year was 21 in 1972 and the smallest number was 4 in 2010.

Figure 4 40-year trend of the annual number of spillages (all pipelines)



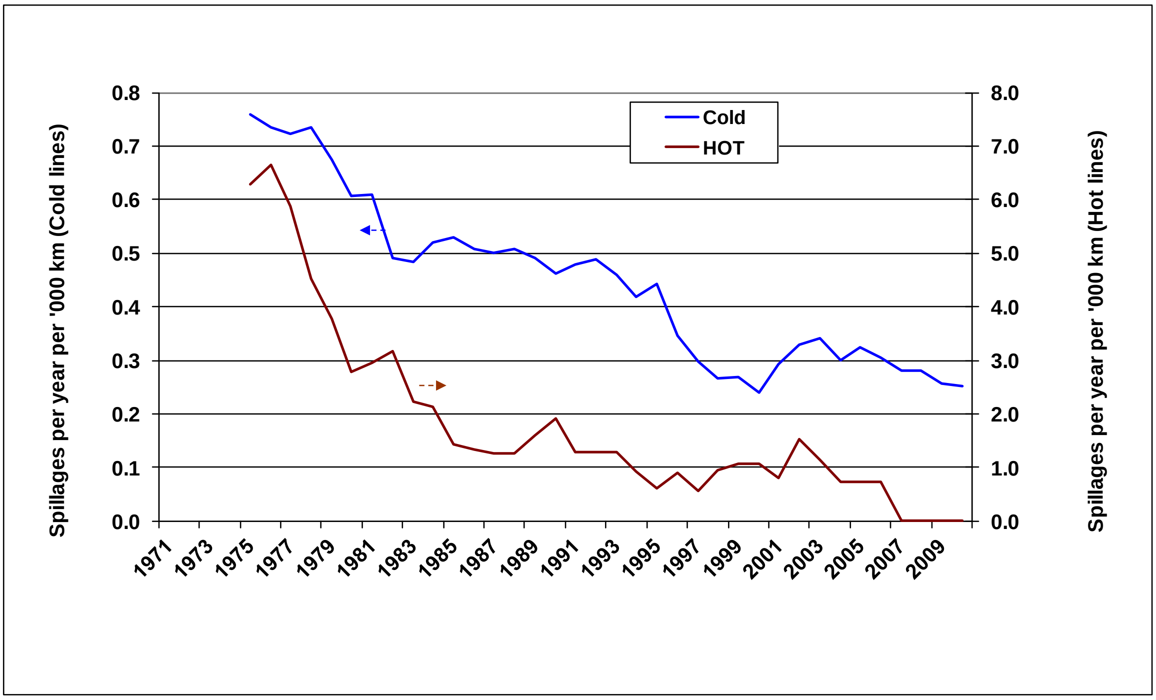
Several step changes in the inventory surveyed by CONCAWE over the years clearly make the absolute numbers difficult to interpret. The spillage frequency i.e. number of spills per unit length of pipeline is therefore a more meaningful metric. **Figure 5** shows the same data as **Figure 4**, now expressed in spillages per 1000 km of pipeline (as per the reporting inventory in each year) and the steady downward trend appears much more clearly. The 5-year frequency moving average has reduced from around 1.1 in the mid '70s to around 0.25 spills per year and per 1000 km of pipeline today.

Figure 5 40-year trend of the spillage frequency (all pipelines)



These overall figures mask the poorer performance of hot pipelines (related to corrosion issues, see **Section 5.1**), particularly in the early part of the period. This is illustrated in **Figure 6** which shows the spillage frequency for hot oil pipelines to be almost an order of magnitude higher than for cold pipelines. Hot oil pipelines have now been almost completely phased out, hence the low frequency in recent years.

Figure 6 5-year moving average of spillage frequency (hot and cold pipelines)



Clearly, the cold and the hot oil pipelines have demonstrated entirely different behaviour. **Figures 7 & 8** show the evolution over 5-year periods of the spillage frequency for hot and cold pipelines respectively, now broken down according to their main cause.

The hot pipeline spillage frequency starts from a much higher base than is the case for the cold pipelines, with a very large proportion of spillage incidents being due to corrosion. In the 1970s and early '80s several hot pipelines suffered repeated external corrosion failures due to design and construction deficiencies. They were gradually shut down or switched to clean (cold) product service, greatly contributing to the remarkable performance improvement. The recent spillage frequency from the remaining hot pipelines is still about on a par with that of the total product pipeline inventory back in 1971-75. There have been no hot corrosion spillages since 2002.

When the hot pipeline data are excluded, the cold pipelines show a somewhat slower improvement trend than for the total data set. Nevertheless, the incidence of spillages has been reduced by nearly three quarters over the last 40 years. This statistic best represents the performance improvement achieved by the operators of the bulk of the pipeline system.

Albeit with fluctuations, the analysis by cause shows that corrosion is a much less prevalent cause of failure for cold pipelines. There is a decrease in the frequency of all causes. Although third party activities have historically always been the most important cause of spillage, mechanical causes have for the first time taken the lead over the past 5 years. A more complete analysis of causes is given in **Section 6**.

Figure 7 Hot pipelines spillage frequencies by cause

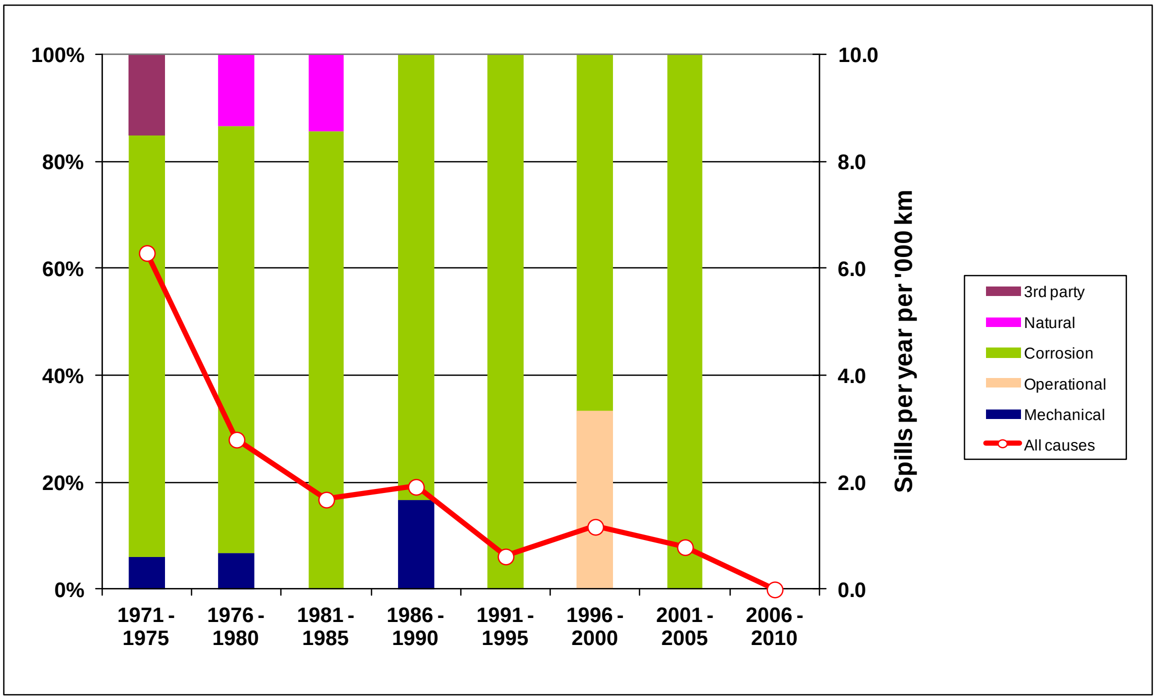
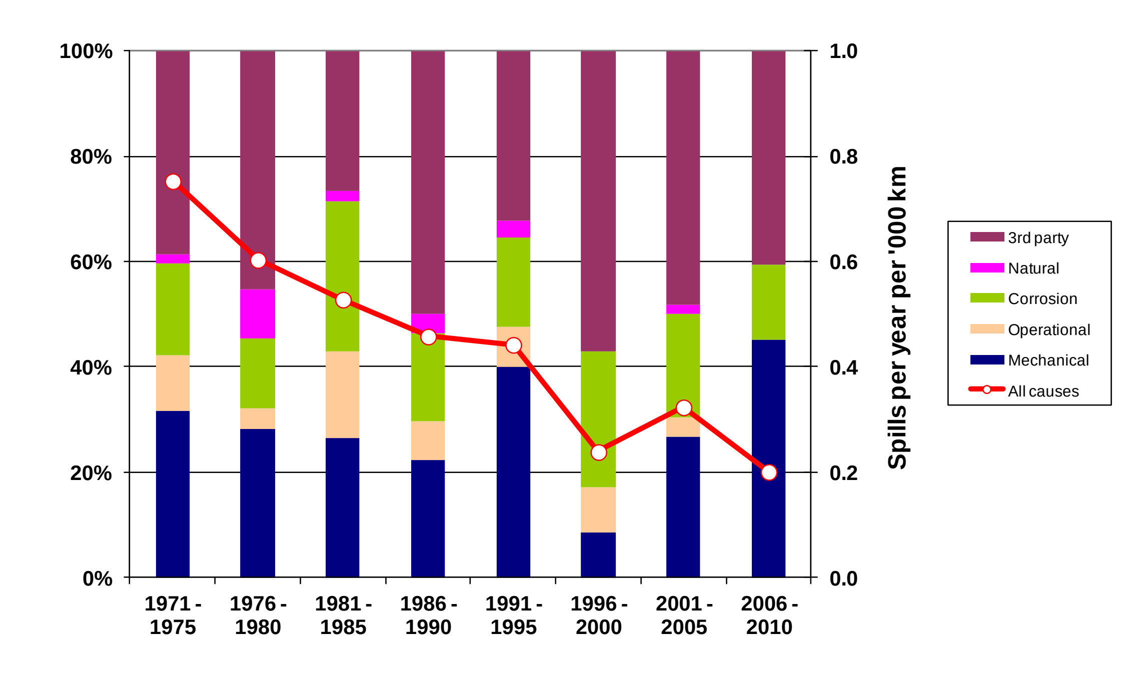


Figure 8 Cold pipelines spillage frequencies by cause



5.2. SPILLAGE VOLUMES

5.2.1. Aggregated annual spilled volumes

Figure 9 shows the total gross spillage volume over the complete period, year by year and in terms of running and 5-year moving average. The same data is shown per 1000 km of pipeline in **Figure 10** and as a proportion of throughput in **Figure 11**. Although there are fairly large year-to-year variations mostly due to a few very large spills that have occurred randomly over the years, the long-term trend is clearly downwards. Over the last 5 years, the gross pipeline spillage has averaged 1.9 parts per million (ppm), or 0.00019%, of the oil transported.

It might be expected that the trend in the differences between the annual gross volume spillage and the net volume spillage, i.e. the recovered spillage, would indicate the degree of success in improving clean-up performance. In practice this is not necessarily the case. Maximum removal by excavation of contaminated soil is not necessarily the correct response to minimise environmental damage and this is now better understood than it once was. Another compounding factor is that the growth in the pipeline inventory has been predominantly for refined product pipelines and it can be assumed that less invasive recovery techniques are justified for white oil products than for fuel oil or crude oil to achieve a given visual and environmental standard of clean-up. Nevertheless the development of annual recovery percentages (gross-minus-net / gross) shown in **Figure 12** indicates a continuous improvement of the recovery rate since the mid '90s. Over the whole period, the average recovery of the spilled oil is 55% leaving an average net loss of oil to the environment of 70 m^3 per spill.

Figure 9 Gross spillage volume

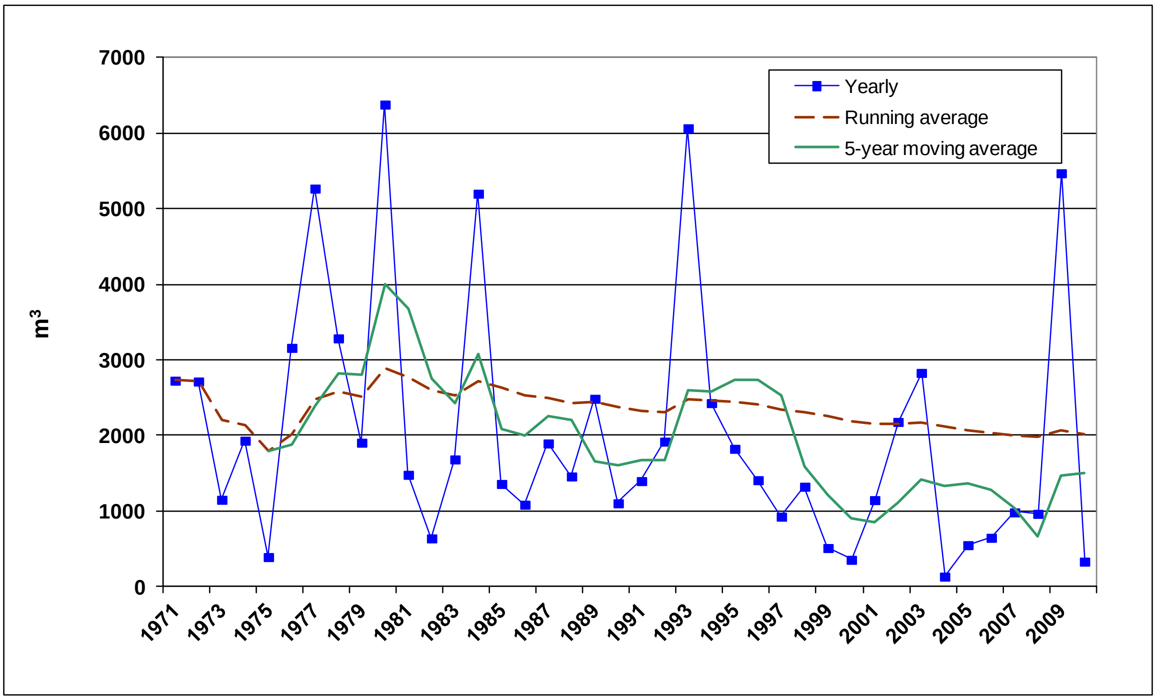


Figure 10 Gross spillage volume per 1000 km

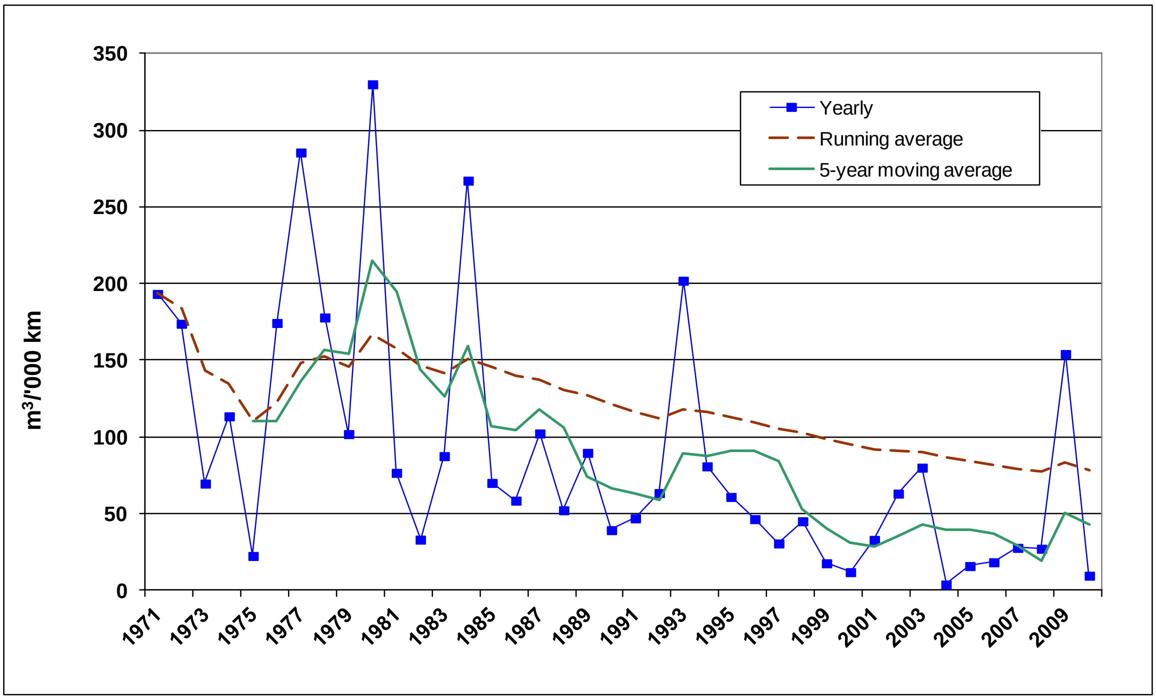


Figure 11 Gross yearly spillage volume as a proportion of throughput

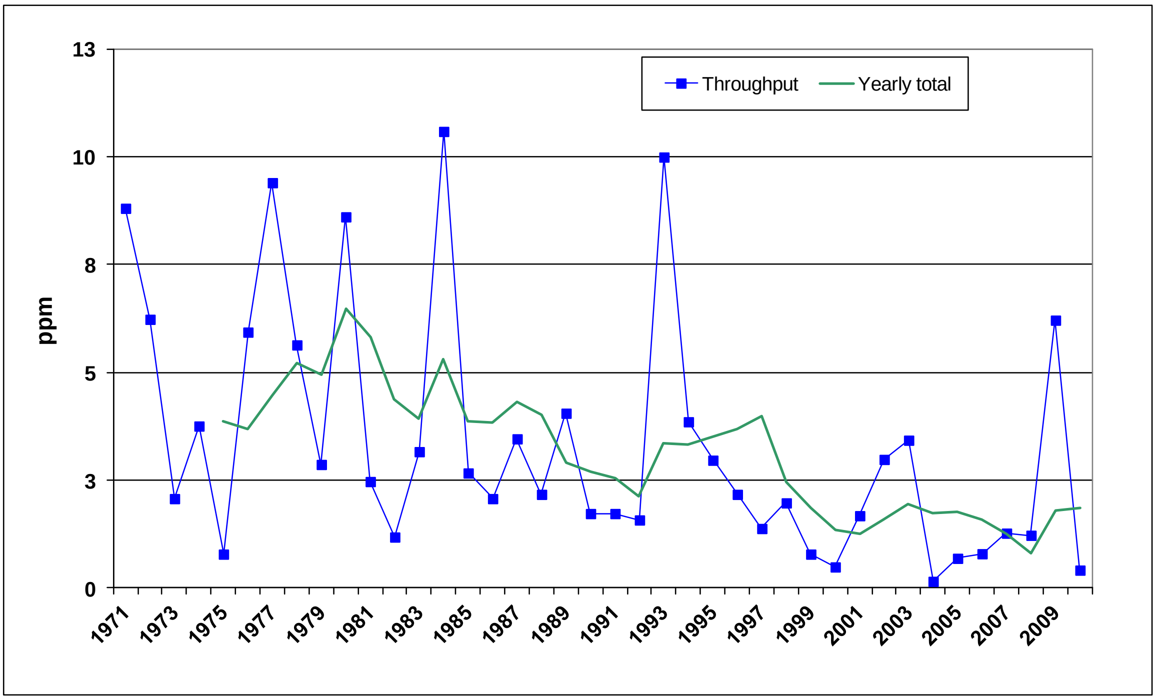
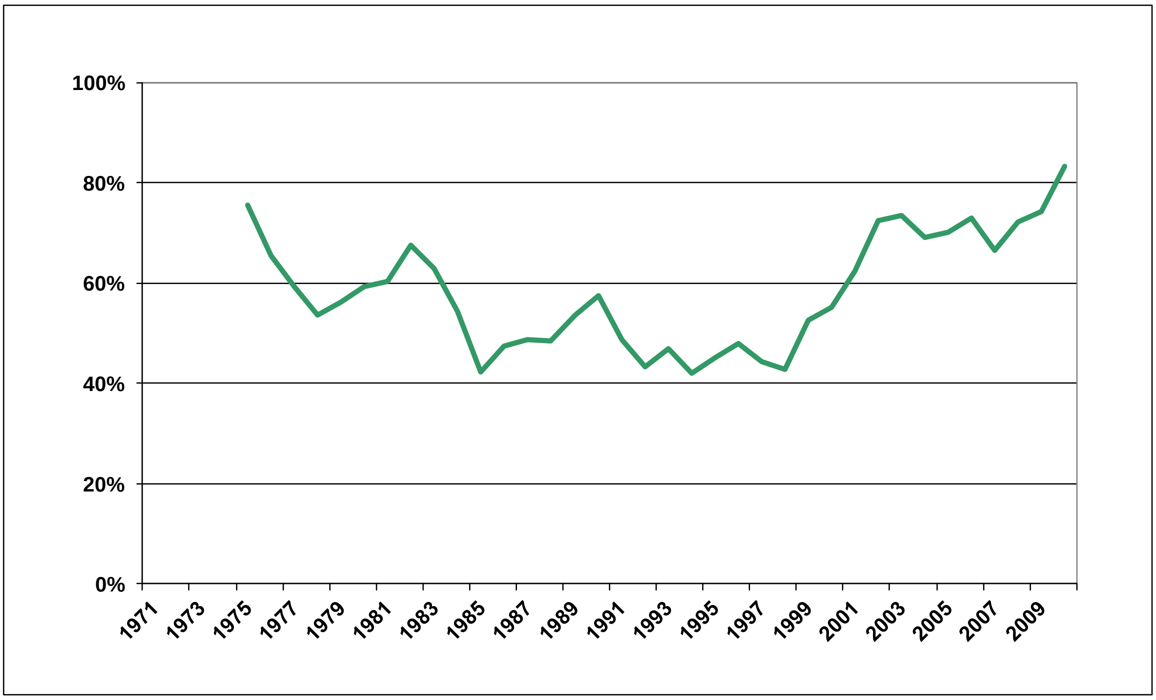


Figure 12 Spilled oil recovery (5-year moving average)



5.2.2. Spillage volume per event

The gross volume released is a measure of the severity of a spillage incident. **Figure 13** shows that, beyond the large year-by-year variations, there has been a slow reduction trend in the average spill size per incident since the early ‘80s. In other words, the gradual reduction of the annual total spilled volume appears to be related more to the reduction of the number of spillage incidents than to their severity. This is partly due to the mix of spillage causes changing over the years, e.g. the proportion of corrosion spillages, which on average are smaller ones, have decreased relative to third party spillages which are among the largest (see **Figure 14**).

At around 100 m^3 per spill, the 5-year gross volume moving average over the 9 years to 2008 had consistently been lower than the long-term average of 170 m^3 per spill. The large spill recorded in 2009 pushed back this figure to 179 m^3 per spill (169 m^3 in 2010). It can be expected that improved monitoring of pipelines and the generalised use of automated leak detection systems will lead to a reduction in spill sizes. There is insufficient data on record to establish any trend in the speed of detection or the response time to stem leakages.

Figure 13 Yearly gross spillage volume per event (5-year moving average)

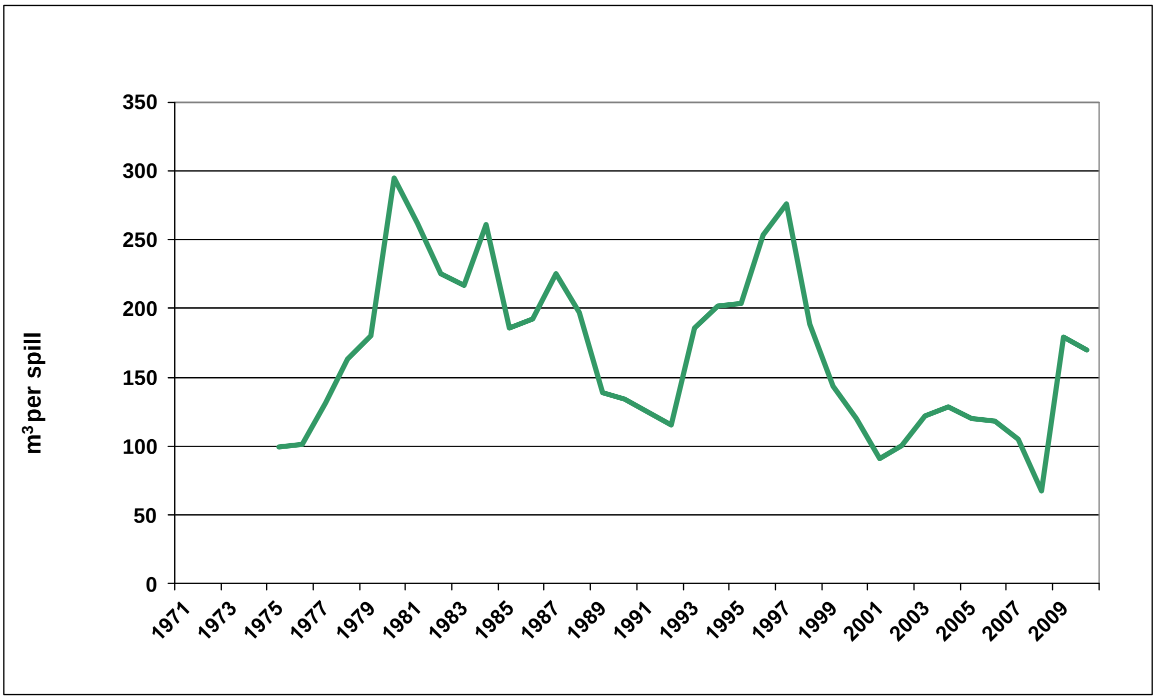


Figure 14 shows the average spill size for each cause category. The largest spillages on average have resulted from mechanical failure, third party activities and natural hazards, whereas operational problems and corrosion have caused smaller spills. As a rule of thumb, on average the three “largest spills” categories result in spillages that are twice the size of the two “smallest spills” categories.

Figure 14 40-year average gross spillage volume per event by cause

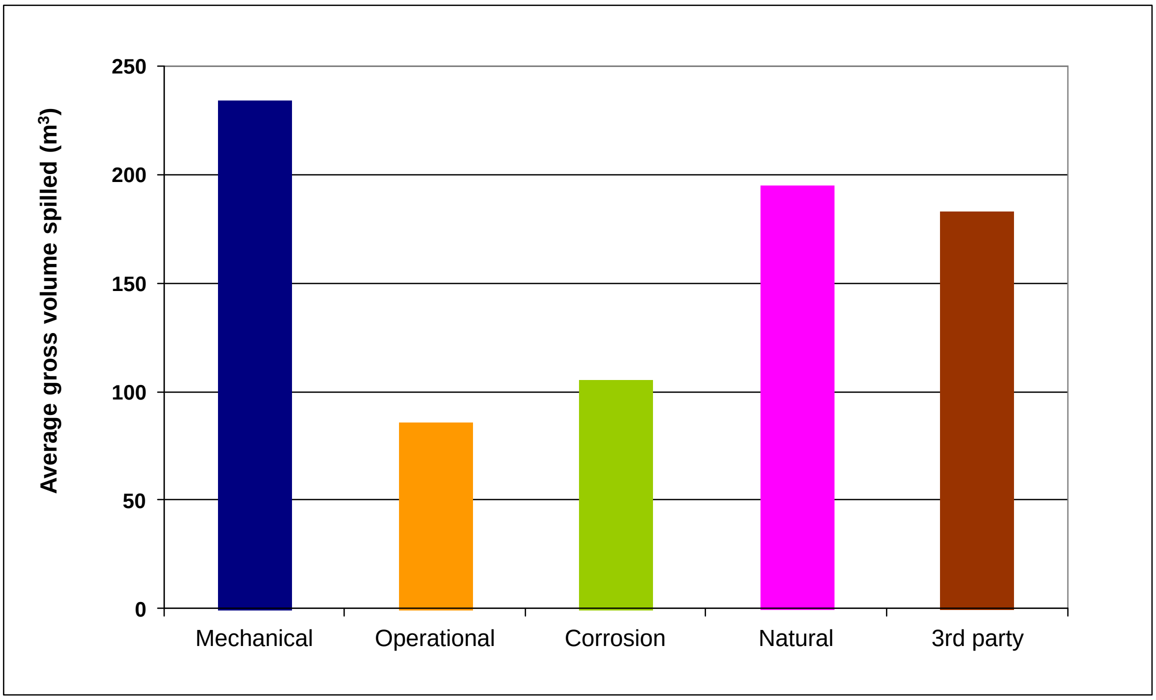
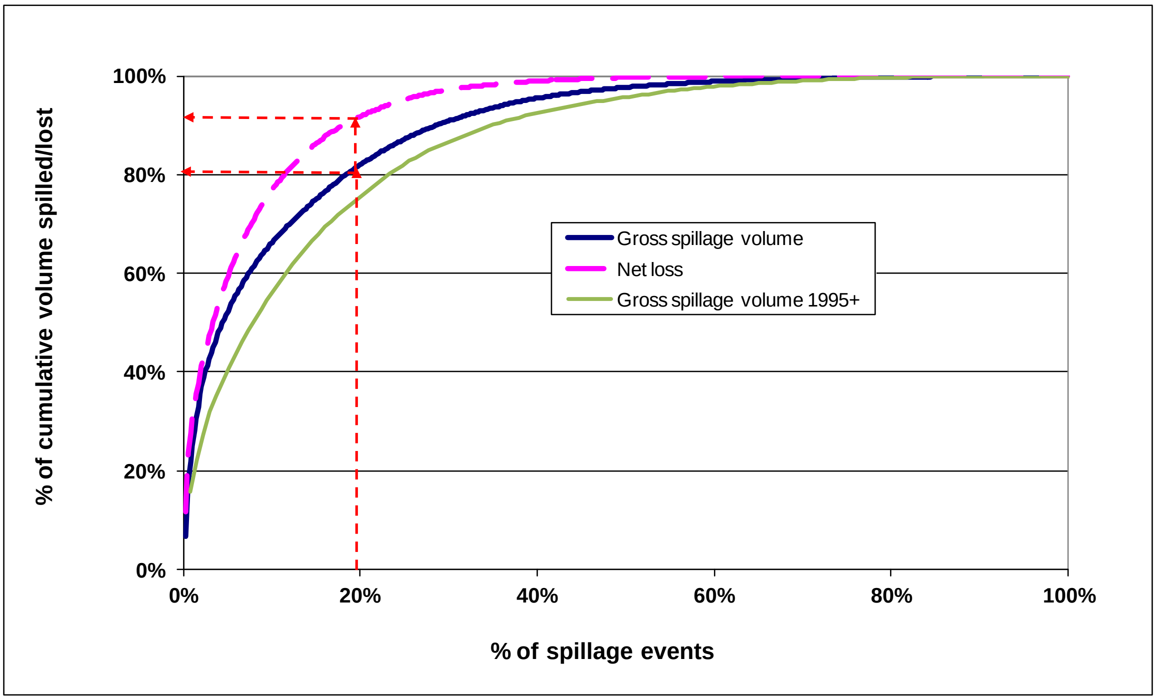


Figure 15 shows the distribution of spillage sizes, demonstrating that less than 20% of all spillages account for 80% of the cumulative gross volume spilled and over 90% of the net spillages, with little change over the years. Clearly a majority of the spillages recorded in the CONCAWE database were so small that they have only had a very limited and localised impact. This also highlights the importance of considering the cut-off spillage size before comparing data sets taken from different sources.

Figure 15 Distribution of Gross and net spillage sizes (over 40 years)



5.3. HOLE SIZE

The following definitions have been adopted within this report for classifying hole size:

- No hole = failure of a gasket or seal, or a mechanical breakage in a piece of equipment other than the pipeline itself,
- Pinhole = less than 2 mm x 2 mm,
- Fissure = 2 to 75 mm long x 10% max wide,
- Hole = 2 to 75 mm long x 10% min wide,
- Split = 75 to 1000 mm long x 10% max wide,
- Rupture = >75 mm long x 10% min wide.

Out of the 478 spillages, hole size data are only available for 268 (56%). The corresponding statistics are shown in **Table 3**.

Table 3 Distribution of spillages by hole size

Hole type		No hole	Pinhole	Fissure	Hole	Split	Rupture	Overall
Number of events		11	28	40	84	49	56	268
	%	4%	10%	15%	31%	18%	21%	100%
Gross average spillage per event	m^3	49	58	274	90	245	667	302
Hole caused by	%							
Mechanical		73%	11%	33%	15%	33%	13%	22%
Operational		0%	0%	3%	1%	6%	5%	3%
Corrosion		0%	71%	28%	27%	35%	9%	28%
Natural hazard		0%	4%	5%	0%	4%	4%	3%
Third party		27%	14%	33%	56%	22%	70%	44%
Size of hole	%							
Mechanical		13%	5%	22%	22%	27%	12%	
Operational		0%	0%	13%	13%	38%	38%	
Corrosion		0%	26%	14%	30%	22%	7%	
Natural hazard		0%	14%	29%	0%	29%	29%	
Third party		3%	3%	11%	40%	9%	33%	

The “no hole” category results in the smallest spillages. When the actual pipeline fails, pinholes result, as expected in the smallest spillages and ruptures in the largest. For the other three categories, other factors are clearly more important as determinants of the spillage outcome.

Pinholes are mostly caused by corrosion. Mechanical incidents often result in ruptures whilst operational and natural hazard incidents tend to cause more than their share of splits. Otherwise hole types follow similar patterns to the cause incidences.

A majority of mechanical, operational and natural hazard incidents cause the largest two types of hole whereas third party is equally divided and the corrosion preponderance is with the smaller hole types.

It would be expected that the larger the hole, the larger on average the spillage would be, under the assumption that material was actually being pumped through the pipeline at the time of the incident. The two rather obvious reasons for this are that higher leakage rates come out of larger holes and the hole sizes are to an extent related to the pipeline diameter which in turn tends to set the potential flow rate available for leakage. However, there are many other factors involved, including the pressure in the pipeline, the length of time between the start of leakage, the leak being detected, the pipeline shut in, and the volume of pipe available to leak after shut in. The table above shows that there is indeed a weak relationship between the average gross spillage size and the hole size.

Table 4 shows the frequencies by hole type. Note that early figures (say before 1980) are not very reliable as hole type was not commonly reported at the time.

Table 4 Spill frequency by hole size

Event/1000 km	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-05	2006-10
No hole	0	0	0	0	0	0	0.31
Pinhole	0.27	0.1	0.08	0.13	0.07	0.2	0.17
Fissure	0.32	0.21	0.29	0.2	0.24	0.17	0.08
Hole	0.16	0.41	0.54	0.37	0.54	0.63	0.28
Split	0.64	0.41	0.46	0.23	0.1	0.2	0.03
Rupture	0.27	0.31	0.33	0.43	0.17	0.26	0.28
All events	1.67	1.45	1.7	1.37	1.11	1.47	1.16
Not reported	1.99	1.45	0.79	0.87	0.17	0.17	0.03
Total including NR	3.65	2.89	2.48	2.23	1.28	1.64	1.19

5.4. PART OF FACILITY WHERE SPILLAGE OCCURRED

By far the greatest part of the material in place in a pipeline system is the underground pipe itself. It comes therefore as no surprise that most leaks occur in the main pipeline runs (**Table 5**). However, a sizeable proportion of incidents are related to valves, joints and small bore connection failures indicating that valves, flanges and other fittings are vulnerable items. Adding seemingly useful features such as more section block valves, instrument connections or sampling systems can therefore potentially have a negative impact on spillage frequency. Small bore lines are also a relatively common subject of leaks as they are mechanically vulnerable and often subject to corrosion. Wherever possible, these more vulnerable features should be designed out of the pipeline system.

Table 5 Part of facility where spillage occurred, by main cause

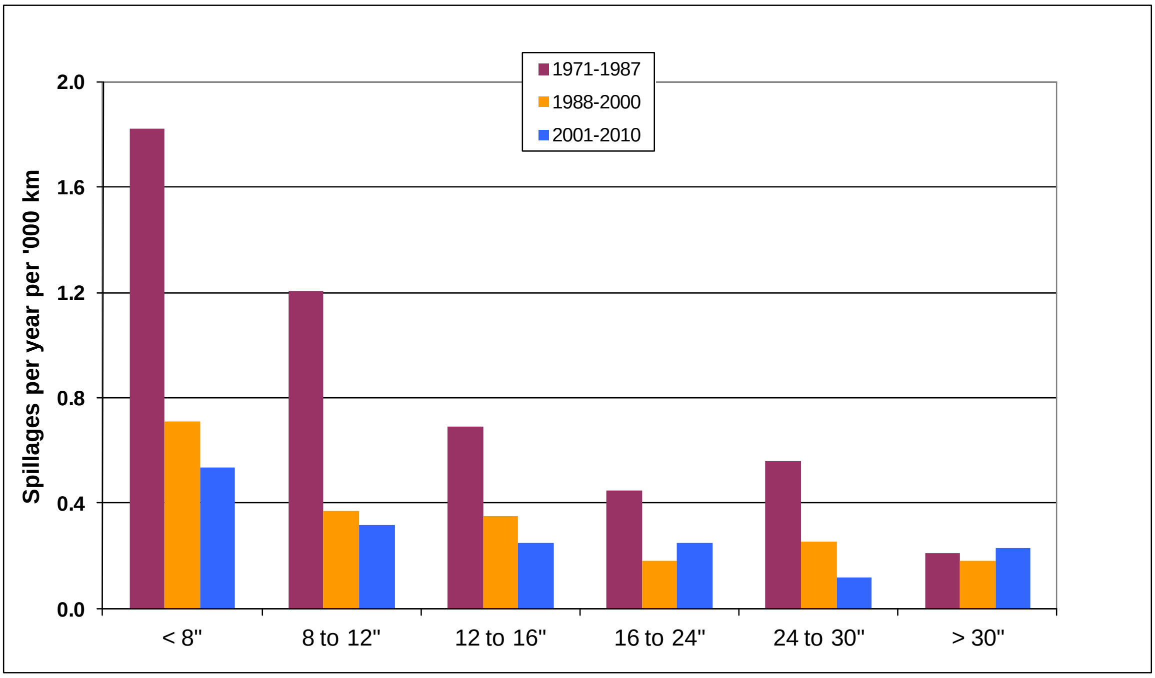
	Total	Bend	Joint	Pipe run	Valve	Pump	Pig trap	Small bore	Unknown
Mechanical	*125*	1.9%	8.6%	6.5%	4.2%	0.6%	0.4%	2.9%	1.0%
Operational	*31*	0.0%	0.4%	1.3%	2.1%	0.2%	0.6%	0.8%	1.0%
Corrosion	*131*	0.2%	1.9%	23.6%	0.0%	0.0%	0.2%	0.6%	0.8%
Natural	*15*	0.0%	0.2%	2.5%	0.0%	0.0%	0.0%	0.4%	0.0%
3rd party	*176*	0.2%	0.6%	32.8%	1.3%	0.0%	0.0%	0.8%	1.0%
All		2.3%	11.7%	66.7%	7.5%	0.8%	1.3%	5.6%	4.0%
	478	*11*	*56*	*319*	*36*	*4*	*6*	*27*	*19*

Percentages are related to the total of 478 reported events

5.5. SPILLAGES PER DIAMETER CLASS

In **Figure 16** the frequencies of spillages have been calculated for the average length of each group of diameters for the periods 1971 to 1987, 1988 to 2000 and 2001 to 2010. These periods have been chosen because of the major change in the reported pipeline inventory between 1987 and 1988 following the inclusion of the non-commercially owned pipelines and from the beginning of the current decade when a number of Eastern European pipelines operators joined the survey.

Figure 16 Spillage frequencies per diameter class



Clearly smaller pipelines are more liable to develop leaks than larger ones. A number of possible reasons for this could be postulated, but there is no way of determining from the available data what each risk-increasing factor might contribute. Neither is there sufficient data on depth below surface to indicate how much the risk is reduced by deeper coverage. It is not recorded if larger pipelines have greater coverage than small ones.

5.6. ENVIRONMENTAL IMPACT

5.6.1. Land use where spillage occurred

We differentiate between spillages occurring either in the pipeline itself or in pumping stations and also record the type of land use in the area. Not surprisingly, most incidents (77%) occur in the cross-country pipelines themselves. The type of location has been reported for a total of 407 spillages. The results of this analysis are provided in **Table 6**.

While we do not have statistics of the length of pipeline installed for each land use type, it is clear that the number of spillages in commercial and industrial areas is higher than would be expected from consideration of installed length alone. Evidently, the vulnerability of the pipelines is significantly increased in such areas by a factor of possibly as much as ten compared to other areas. The bulk of the spillages from pump stations occur in industrial areas simply because their location is mostly classified as such.

Table 6 Location of spillage incidents

	Underground pipe			Above ground pipe		Pump Station	
	Number	Crude/	%			Number	%
Residential high density	16	3/13	5%	2	6%	0	0%
Residential low density	194	55/139	62%	11	32%	8	14%
Agricultural	19	1/18	6%	3	9%	3	5%
Industrial or commercial	77	19/58	24%	17	50%	47	81%
Forest Hills	7	2/5	2%	0	0%	0	0%
Barren	2	1/1	1%	0	0%	0	0%
Water body	0	0/0	0%	1	3%	0	0%
Total	315			34		58	
Unspecified				62			

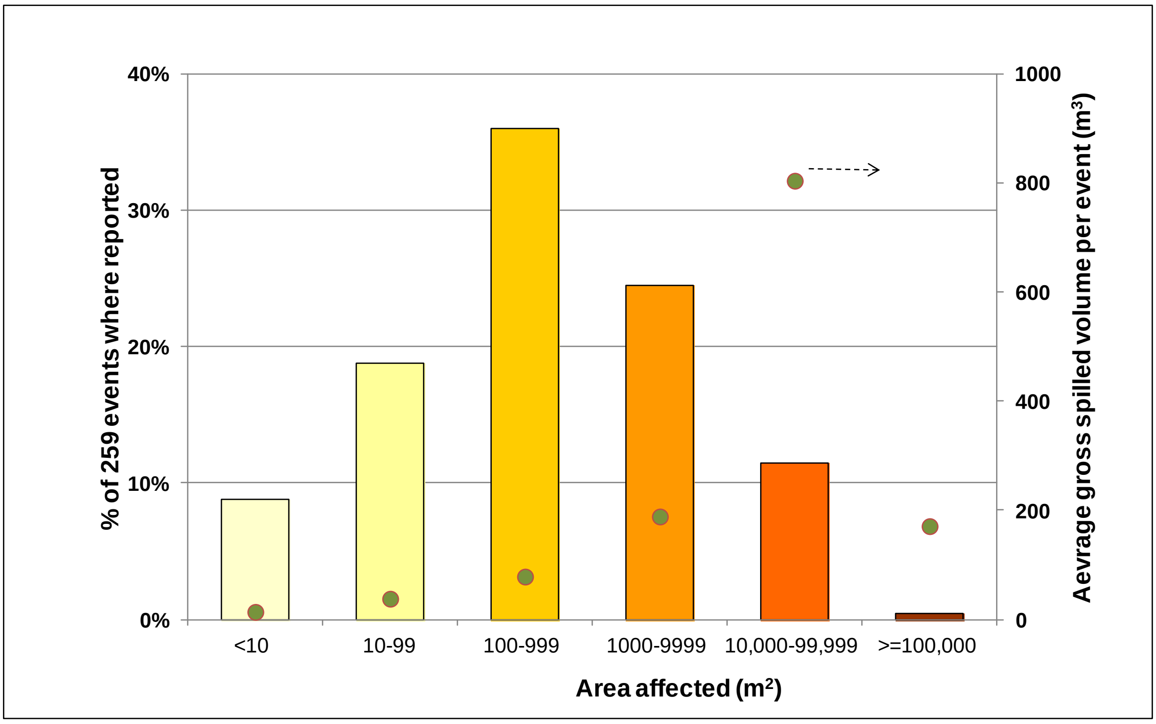
5.6.2. Ground area affected

The current CONCAWE performance questionnaire, in use with minor changes since 1983, requests reporting of the area of ground (m^2) affected by the spillage. Before that date, area data were reported infrequently. Out of the 478 recorded spillages, area data is available for 259 (54%). For these events, the percentages that fall within the area ranges are shown in **Figure 17** together with the average spill size for each category.

If we exclude the one spillage that affected more than 100,000 m^2, and for which the gross spillage was relatively modest, there appears to be a direct relationship between spill size and area affected. Bigger spillage volumes affect larger areas.

This relationship is, however, to some extent fortuitous. There are two ways in which small spillage volumes can affect larger areas of ground. Fine sprays directed upwards can be spread around by winds. This factor tends to be more prevalent in the smaller area ranges. Other smaller spillages can be spread over larger areas by the influence of groundwater or surface water flows. This is the main mechanism by which relatively small spillages can affect very large areas. Conversely, comparatively large spills, particularly those that occur over extended periods of time and in the lower quadrants of the pipeline circumference, can have their main effect underground with relatively little impact on the surface. Porous ground and hot, arid conditions can also lead to the surface consequences being limited.

Figure 17 Ground area (m^2) affected by spillages (% of number reporting)



5.6.3. Impact on water bodies

The spillage reports record those incidents where oil pollution of the water table and underground aquifers and surface watercourses has had consequences for the abstraction of potable water. Some 14 spillages, representing 3% of the total, have had some effect. It is believed that all of these effects have been temporary. Since 2001 impacts on other types of water have been reported. Of the 99 reported spillages since then, 13 have affected surface water, 13 have affected ground water but only 2 have impacted potable water supplies.

5.7. SPILLAGE DISCOVERY

The way in which the occurrence of a spillage was detected is reported in 7 categories (**Table 7**) and for three types of facility. The pattern for spillages from pump stations differs from that from pipelines.

The most common means of detection of underground pipeline spillages was by a third party (52%), while automatic detection systems were involved in detecting only 11% of those spillages. Although this may seem a rather small proportion, one has to realise that third parties are often on the scene when the leak occurs and detection systems are relatively new additions. Indeed, over the last 5 years 35% of underground spills were discovered via leak detection systems.

Pipeline company resources detected some 83% of the pump station spillages. When third party have detected spillages, 17% of the total, the spills have tended on average to be the smaller ones; presumably those that are below the warning capabilities of the instrumentation.

Table 7 Discovery of spillages

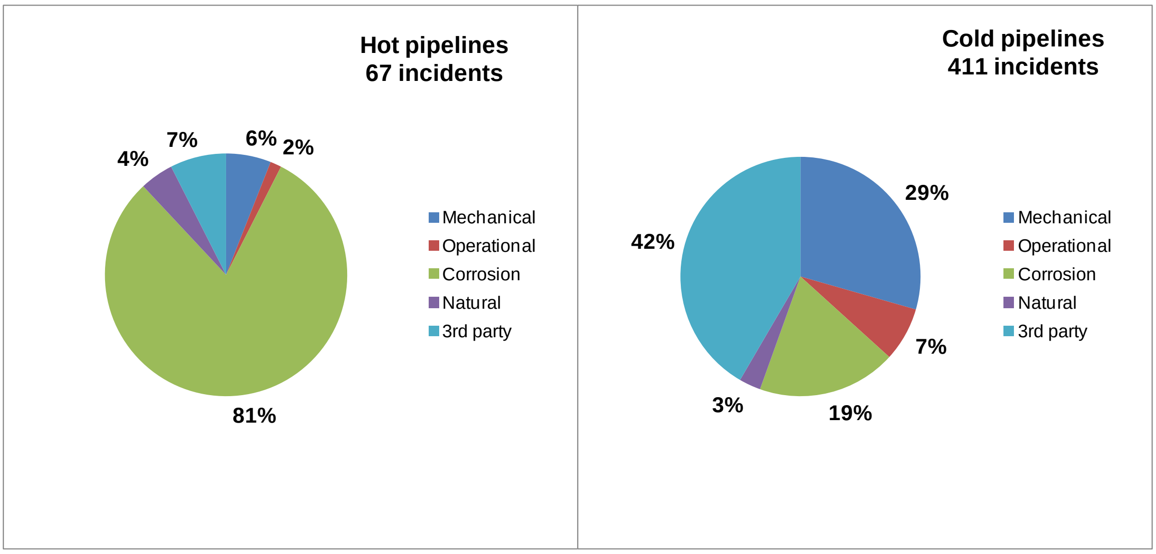
	Underground pipe			Above ground pipe			Pump Station		
	Number	%	Average gross spillage m^3	Number	%	Average gross spillage m^3	Number	%	Average gross spillage m^3
Right-of-Way surveillance by pipeline	31	8%	234	4	11%	43	1	2%	10
Routine monitoring by pipeline operator	83	22%	373	15	39%	92	35	58%	85
Automatic detection system	43	11%	159	3	8%	37	11	18%	48
Pressure testing	20	5%	145	1	3%	30	3	5%	18
Outside party	198	52%	130	15	39%	92	10	17%	37
Internal Inspection	4	1%	6	0	0%	0	0	0%	0
Total	379		195	38		81	60		51

6. DETAILED ANALYSIS OF SPILLAGE CAUSES

CONCAWE classifies spill causes into five major categories: mechanical failure, operational, corrosion, natural hazard and third party, themselves divided into sub-categories. Definitions are given in **Appendix 1**. The survey returns provide more detailed information on the actual cause and circumstances of spillage incidents and these are analysed in this section.

As already discussed in **Section 5**, the main causes of incidents are very different for hot and cold pipelines and this is further illustrated in **Figure 18**. Whereas 81% of hot oil pipeline spillages are related to corrosion, the figure is only 19% for cold pipelines, for which mechanical failure and third party-related incidents are the most prevalent.

Figure 18 Distribution of major spillage causes



Figures 19 and **20** further show the distribution of primary and secondary causes, for all pipelines and for cold pipelines respectively, illustrating again the prominent impact of corrosion for hot pipelines. Secondary causes are unremarkably distributed except perhaps for the large proportion of accidental causes within third party-related incidents.

There is a general debate regarding the increasing age of the pipeline inventory and the potential integrity issues that could be related to such ageing infrastructure. Out of the 5 incident categories, Mechanical and Corrosion would be the most likely to be related to such phenomena. Specific attention is being paid to this, as will be seen in the detailed discussion below.

Figure 19 Distribution of major and secondary spillage causes – All pipelines

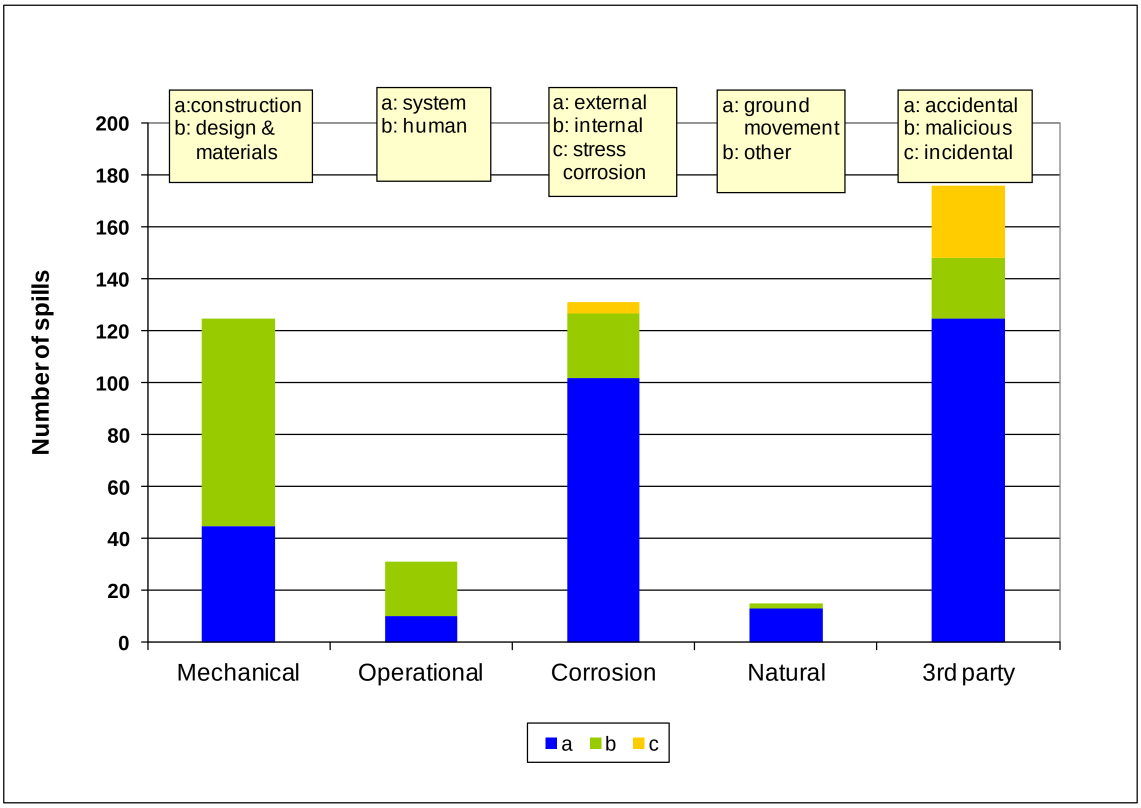
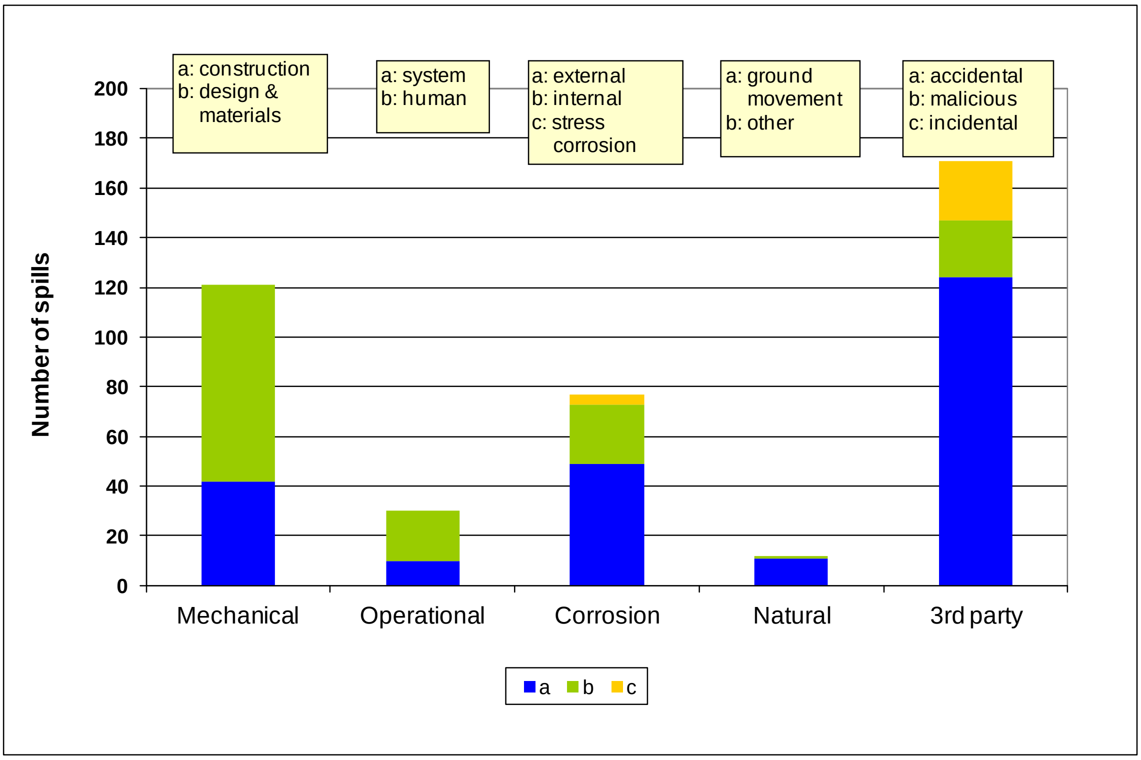


Figure 20 Distribution of major and secondary spillage causes – Cold pipelines



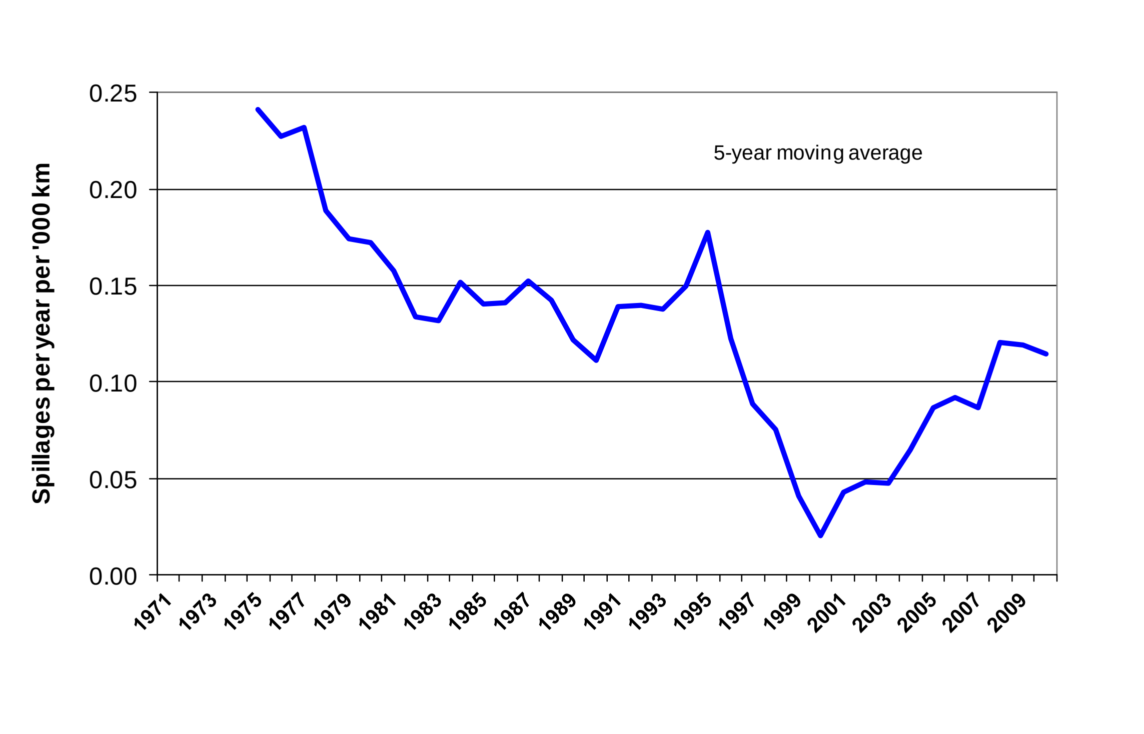
6.1. MECHANICAL

There have been 125 cases of mechanical failure, 26% of the total of 478 spillage events. This is an average of 3.1 spillages per year. 46 failures were due to construction faults and 79 to design or materials faults.

Note: It is not always straightforward to classify certain types of failures. For instance a number of leaks can be traced back to some damage to a pipeline such as a dent. Whenever it is clear that such damage was caused after the pipeline was installed it is classified as “third party / incidental” (this was the case for one of the 2010 spillages). If no such evidence is available it is classified as “mechanical / construction”.

The 5-year moving average frequency of mechanical failures is shown in **Figure 21**.

Figure 21 Frequency of mechanical failures for cold pipelines



Although the historical trend is downward it appears to have reversed since the beginning of the decade.

Within each of the sub-categories, the most common reasons for mechanical failures are illustrated in **Table 8**.

Table 8 Reasons for mechanical failures

Number of spills due to					
Construction	Faulty weld	Construction damage	Incorrect installation		Not reported
	11	6	12		16
Design & Materials	Incorrect design	Faulty material	Incorrect material specification	Age or fatigue	Not reported
	8	30	3	9	30

The total number of reported age- or fatigue-related failures remains low. However, 6 of the 9 registered events occurred in the last 10 years.

The seemingly increasing occurrence of mechanical failures combined with the appearance of an increase in fatigue-related failures may be an indication of the ageing process, defined as the deterioration of the metal structure of pipelines resulting from fatigue caused by normal operation (pressure cycles etc). In order to gain more insight into this point all 34 mechanical failures of the last 10 years were further investigated in cooperation with the relevant operators. It was found that only 4 events could be linked with certainty to ageing according to the above definition, a further 7 being undecided because of lack of appropriate information.

The above finding suggests that the recent increase in reported mechanical failures cannot be directly linked to ageing of the metal structure. This remains, however, an area of focus for the pipeline operators and for CONCAWE.

6.2. OPERATIONAL

There have been 31 spillage incidents related to operation, 6% of the total of 478 spillage events. This is an average of 0.8 spillages per year. 21 incidents were due to human errors and 10 to system faults. The most common reasons for operational incidents are illustrated in **Table 9**.

Table 9 Reasons for operational incidents

Number of spills due to					
System	Equipment	Instrument & control systems			Not reported
	2	3			5
Human	Not depressurised or drained	Incorrect operation	Incorrect maintenance or construction	Incorrect procedure	Not reported
	3	13	4	0	1

6.3. CORROSION AND IMPACT OF AGEING

There have been 131 failures related to corrosion, 27% of the total of 478 spillage events. This is an average of 3.3 spillages per year. As noted earlier though, 54 of these occurred in the more vulnerable hot pipelines and in the early years. For cold pipelines the number of failures is 77, 16% of the total and an average of 1.9 spillages per year.

The events have been subdivided into external and internal corrosion and, 10 years ago, stress corrosion cracking (SCC) was introduced as an extra category. The number of spillages in each sub-category is shown in **Table 10**.

Table 10 Corrosion-related spillages

Number of spills due to			
	Hot	Cold	All
External corrosion	53	49	102
Internal corrosion	1	24	25
Stress corrosion	0	4	4

Internal corrosion is much less prevalent than external corrosion. 18 out of the 24 cold pipeline internal corrosion incidents occurred in crude oil service although crude pipelines only account for less than a third of the cold pipeline inventory. Thus crude pipelines appear to be more vulnerable to internal corrosion than product pipelines. This was to be expected, as crude oil is potentially more corrosive than refined products. Only one of the pipelines suffering a spill reported that inhibitor was used, one did not report and the others did not use inhibitors.

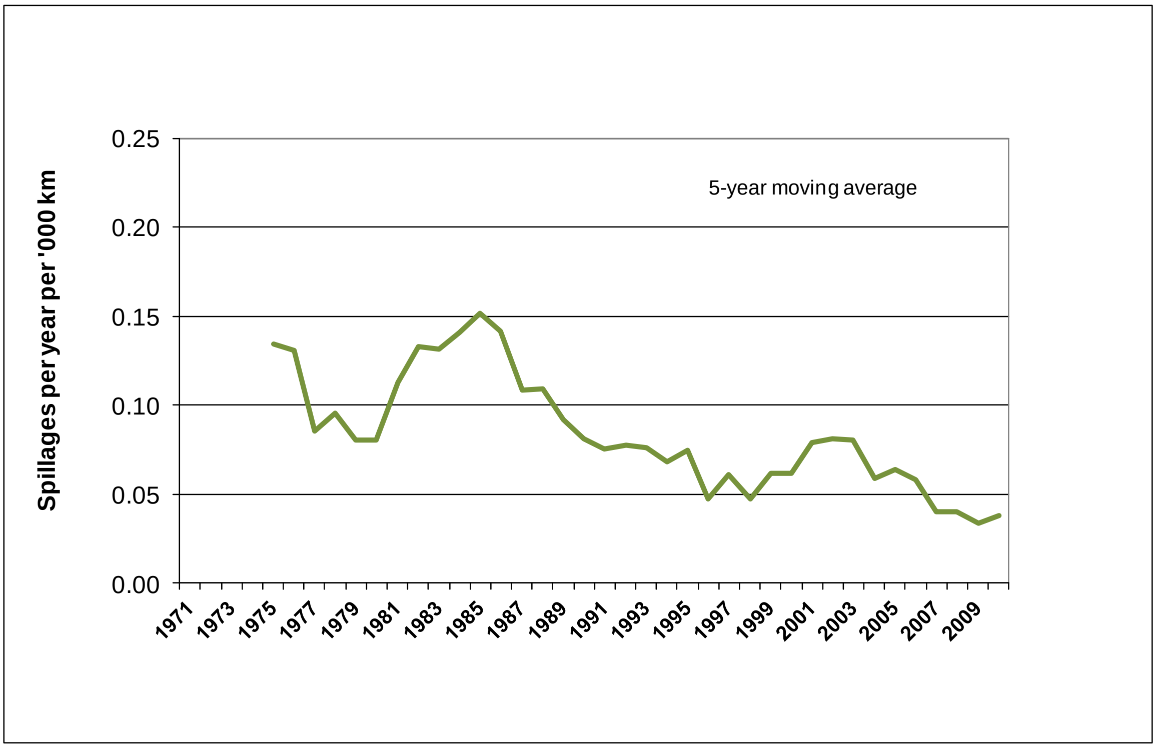
Although there have only been four Stress Corrosion Cracking (SCC) related spillages to date (including one re-categorised from external corrosion), these have been relatively large spillages, possibly as a result of the more severe failure mechanisms.

Out of the 76 corrosion-related failures in cold pipelines, 25 were related to special features such as road crossings, anchor points, sleeves, etc. which therefore appear particularly vulnerable.

In a gradually ageing pipeline inventory, increased occurrence of corrosion is a concern which is addressed by pipeline operators through the use of increasingly sophisticated inspection techniques. As already mentioned in **Section 5.1** the frequency of incidents associated with hot pipelines, mostly related to corrosion, has fallen dramatically over the years. **Figure 22** shows no sign of any increasing trend in corrosion failures of cold pipelines. If anything, the rate has decreased.

There is therefore no evidence as yet to suggest that generalised corrosion is becoming a problem. There is, of course no guarantee that this will not start to happen at some point and thus there is a need for continued monitoring of performance on this basis. Inspection methods involving intelligence pigs are now available to monitor pipeline condition and to enable early identification of the onset of corrosion. These techniques, together with the general adoption of integrity management systems by all EU pipeline companies, should ensure that any upturn in age-related spillages is prevented or delayed for many years.

Figure 22 Corrosion-related spillage frequency (all types) for cold pipelines



6.4. NATURAL HAZARDS

There have been 15 spillage incidents related to natural hazards, 3% of the total of 478 spillage events. This is an average of 0.4 spillages per year. 10 spillages were due to some form of ground movement and 4 to other hazards.

No less than 10 of the natural hazards spills have occurred in the same country. This appears to be a direct consequence of the difficult terrain and hydrological conditions that apply to a significant part of that country's pipeline network.

Table 11 Details of natural causes due to ground movement

Number of spills due to					
Ground movement	Landslide	Subsidence	Earthquake	Flooding	Not reported
	5	3	1	3	1

6.5. THIRD PARTY

Third parties have caused the largest number of spillages with 176 events, an average of 4.4 per year and 37% of the total. 124 events were accidental, 23 were intentional (mostly theft attempts) and 29 were incidental i.e. resulting from damage inflicted to the pipeline by a third party at some point in the past. As discussed in **Section 5,** third party activities also result in relatively large spills and account for the largest total volume spilled of all causes.

6.5.1. Accidental damage

The most common causes of accidental third party spills are shown in **Figure 23**.

In one case an electrical earthing fault had arisen on a pipeline with no previous problem, as a consequence of the electrification of an adjacent electric railway line. In the other, an electricity pylon fell over and one of the arms punctured a pipeline.

The vast majority of events, however, were caused by direct damage from some form of digging or earth moving machinery. Damage by machinery occurs due to a combination of lack of communication and awareness, and lack of care or skill. Pipeline operators are not always made aware of impending ground working jobs so cannot therefore supply appropriate advice on exact pipeline location and working procedures, and exercise adequate supervision of the work. Even when good communication has been established between the pipeline operator and the third party company, the actual machinery operator may be left partially or completely unaware of a pipeline's existence or fail to apply the requisite care or skill.

Figure 23 Causes of accidental third party spills

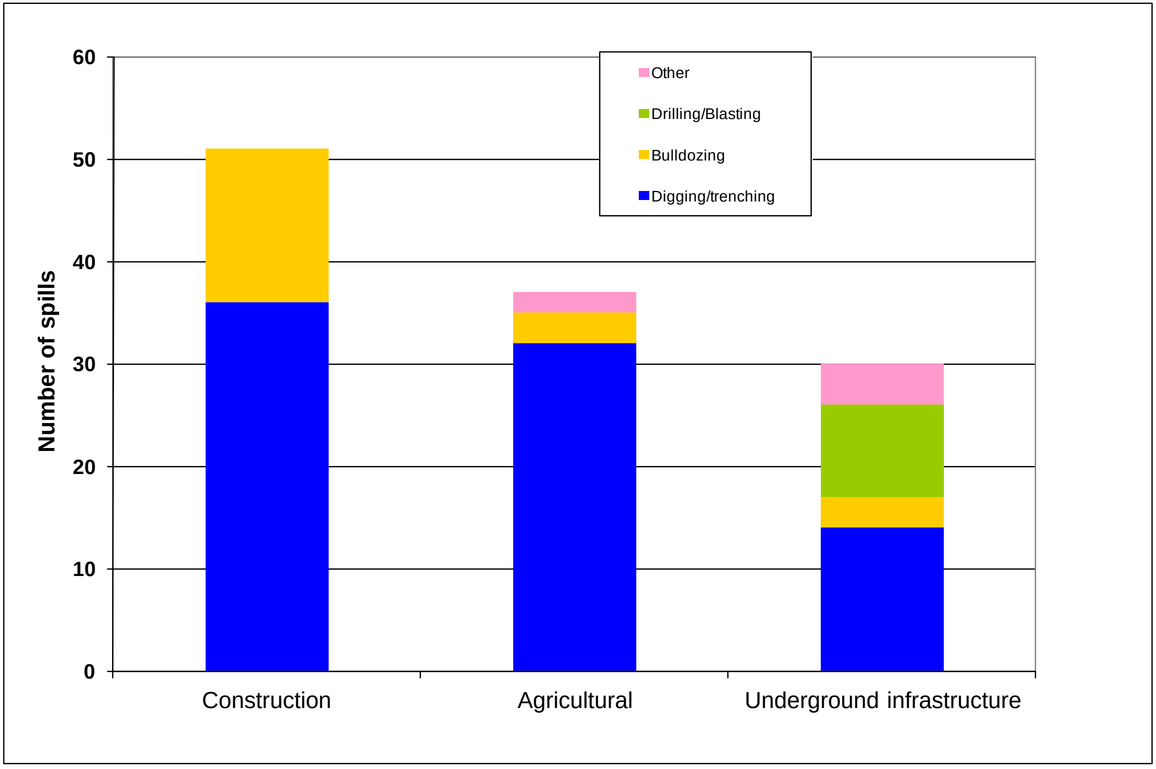
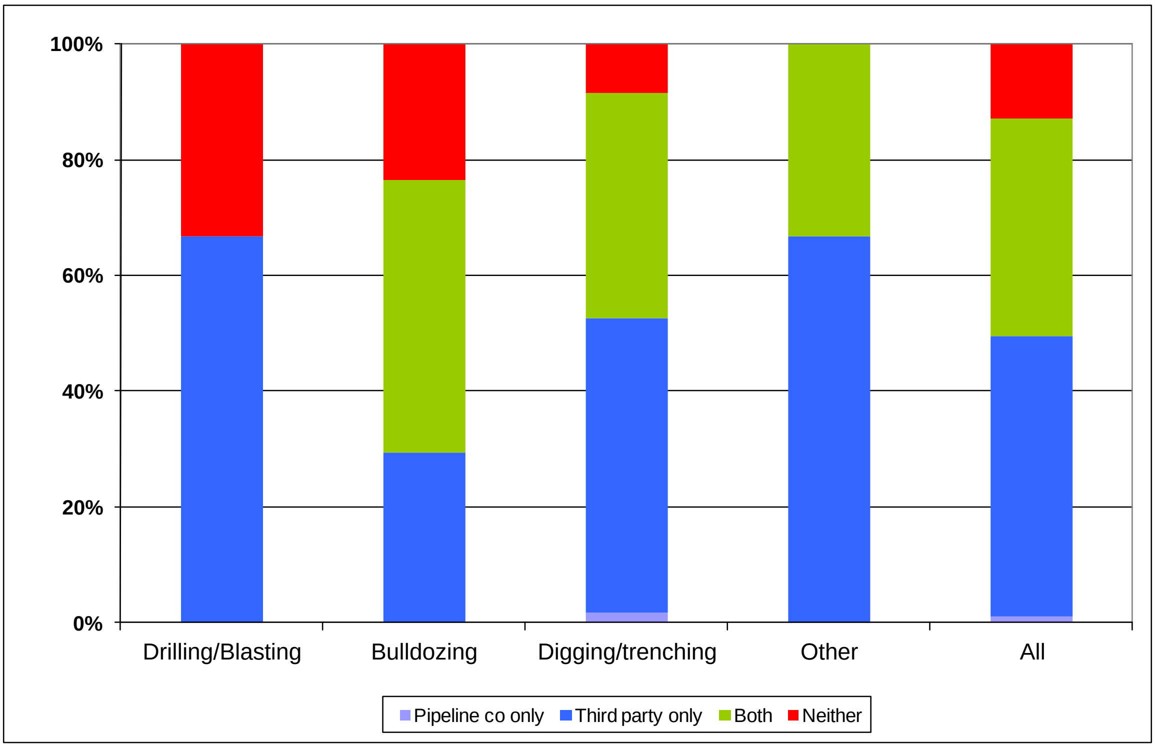


Figure 24 shows the awareness data (reported for about 80% of the third party-related spillages) as the percentage of cases where each party was aware of either the impending activity (pipeline operator) or the presence of a pipeline (machinery operator).

In some 50% of the cases, third party undertook some form of excavation activities in the full knowledge that a pipeline was present in the vicinity but without the pipeline operating company being aware of these activities. In contrast, only one case was reported where the pipeline company was aware of the impending work but the third party was not informed of the presence of the pipeline. In about 14% of the cases neither party was aware of “each other”. In the remaining 34% of the cases the pipeline was hit in spite of the fact that the pipeline operator know about the work and the third party was aware of the presence of the pipeline. These cases often denote a lack of communication at the working level or a lack of proper care or skill by the third party.

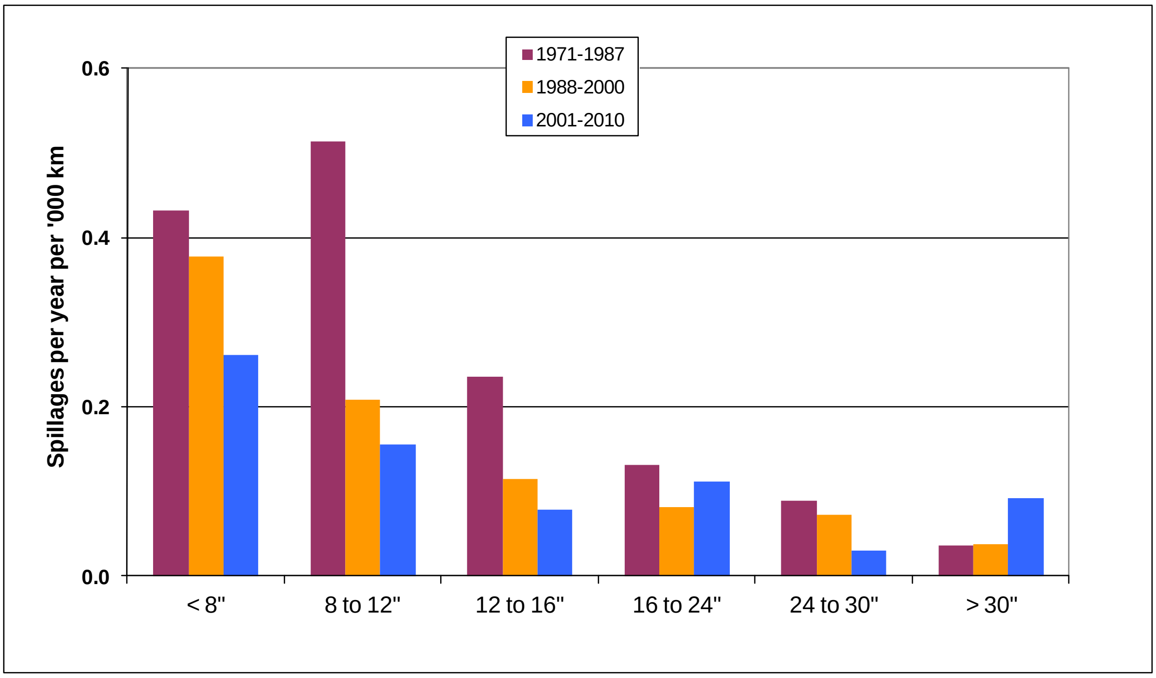
Figure 24 Awareness of impending works and of pipeline location



The strong relationship between spillage frequency and diameter noted in **Section 5.5** is also apparent for accidental damage (**Figure 25)**.

The prevention of third party accidental spillages is of the highest priority due to its place in the spillage cause league. It is also the most amenable to improvement by sharing experiences, improving communication and awareness and comparing operating and work control practices between pipeline operators from different companies and countries.

Figure 25 Third party accidental spillage frequencies per diameter class



6.5.2. Intentional damage

There have been 23 spillages caused by intentional damage by third parties: 2 as a result of terrorist activities, 5 from vandalism but the majority (16) from attempted or successful product theft.

None of the terrorist or vandalism incidents was in underground piping; one was from an above-ground section of pipeline, all the rest were at valves or other fittings at pump stations or road / river crossings, etc. Since 1999, theft attempts by drilling into pipes have become a regular feature of the spillage statistics, including 2 such incidents in both 2006 and 2008. In addition, a number of theft attempts have been discovered which fortunately did not lead to spillages.

6.5.3. Incidental damage

This category captures those incidents where damage was done at some unknown point in a pipeline's lifetime, which subsequently suffers deterioration over time resulting eventually in a spill. In general they result from unreported damage done after the original construction when a pipeline has been knowingly or unknowingly hit during some or other third party groundwork activities.

There have been 29 incidental damage incidents. These all started off from dents, scrapes and suchlike. Thus they share the characteristic that they might be detectable by intelligence pig inspections.

7. IN-LINE INSPECTIONS

CONCAWE has been collecting data on intelligence pig inspection activities for the past 20 years, including a one-off exercise to collect back data from the time intelligence pigs were first used around 1977. Separate records are kept for metal loss pig, crack detection pig and for geometry (calliper) pig inspections. Each inspection may entail one or more passes of a pig along a piggable pipe section. Leak detection pigs are also sometimes used but their function is quite different. They can reduce the consequences of a leak that has already started, by detecting it earlier. They do nothing to help prevent the leak occurring in the first place.

In 2010 a total of 89 sections were inspected by at least one type of intelligence pig, covering a total combined length of 12,300 km, split as follows amongst the individual types of pig:

- Metal loss pig 6687 km, 78 sections
- Crack detection pig 2326 km, 24 sections
- Geometry pig 3287 km, 40 sections

Most inspection programmes involved the running of more than one type of pig in the same section so that the total actual length inspected was less at 7178 km (21% of the inventory).

As shown in **Figures 25 and 26**, the use of intelligence pigs for internal inspection of pipelines grew steadily up to 1994. After a stabilisation and slight decrease of activity around the turn of the millennium, the upward trend resumed, with an average annual total of about 9000 km covered by any pig run and 5500 km actually inspected each year over the last 5 years. 2010 shows the highest rate of inspection on record.

Over the last ten years, a period considered as a reasonable cycle for this type of intensive activity, 453 (72%) of the total of 629 active sections included in the 2010 survey were inspected at least once by at least one type of pig, representing 83% of the total length of the network. This suggests that the inspected sections are longer than average. There are certainly some pipeline sections (mainly older ones) which were not designed to be pigged and which, because of small size or tight bends or lack of suitable pig launchers or receivers, cannot be intelligence-pigged. Also, a number of pipeline companies in Eastern Europe have joined the survey in recent years, but have provided few previous pigging records. The length of un-inspected pipelines is therefore certainly less than the above figure and should continue to decrease in future years.

Figure 25 Annual inspections by type of intelligence pigs

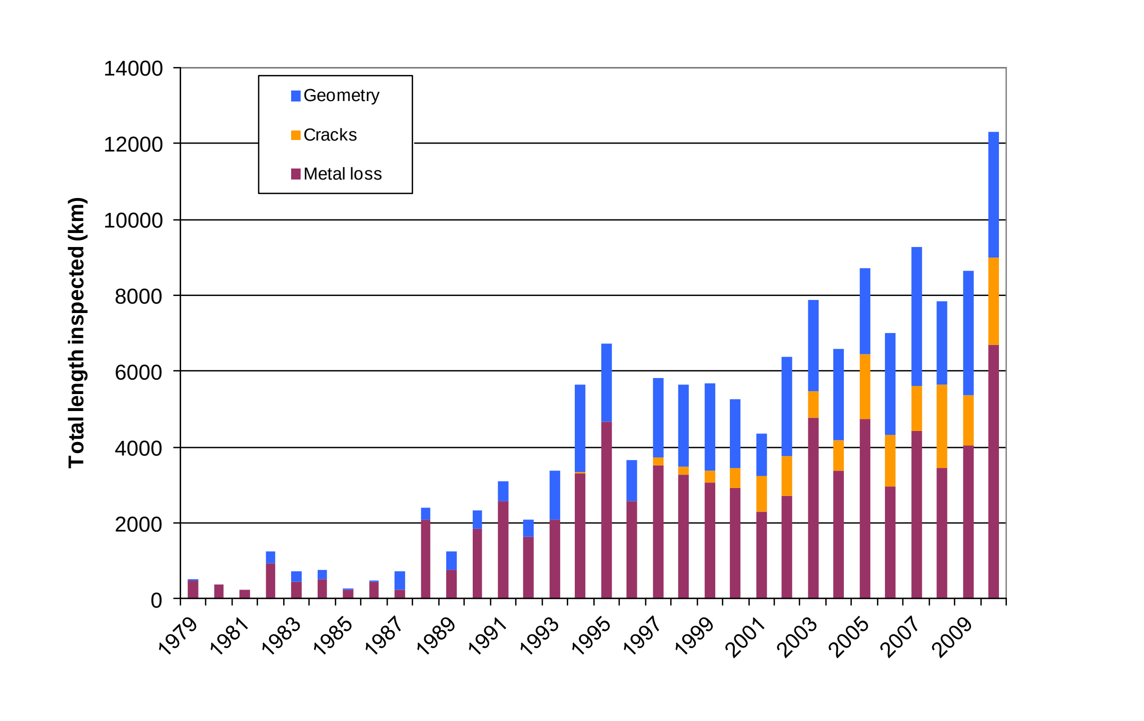
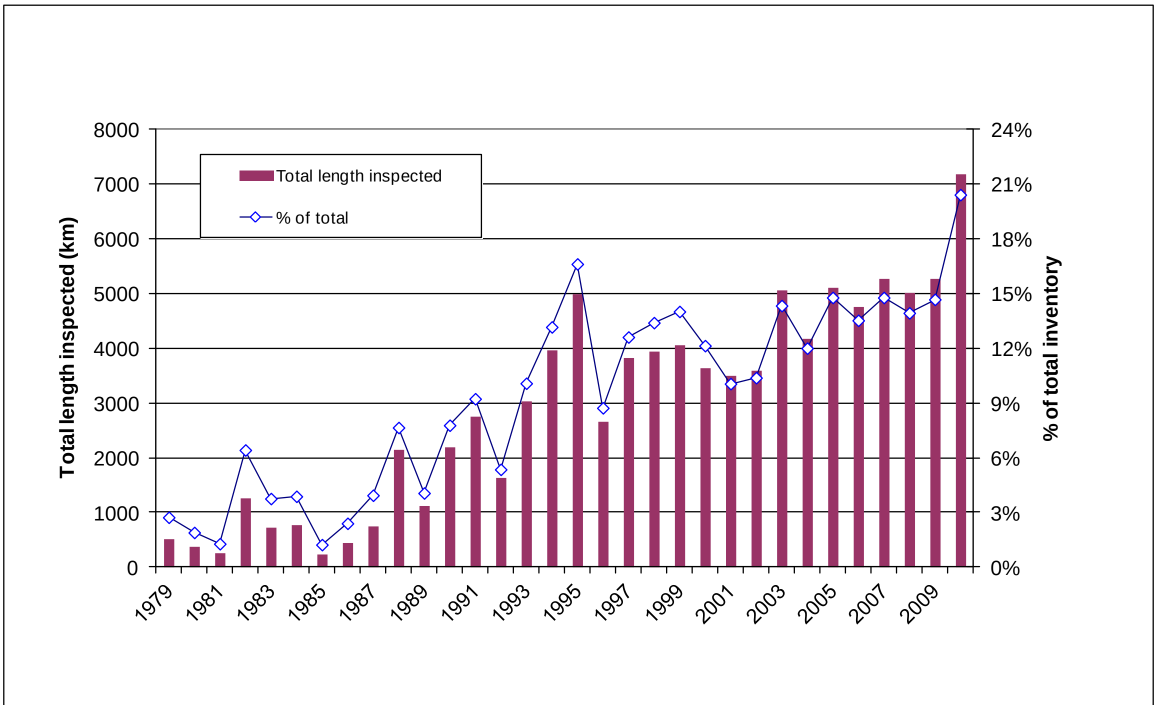
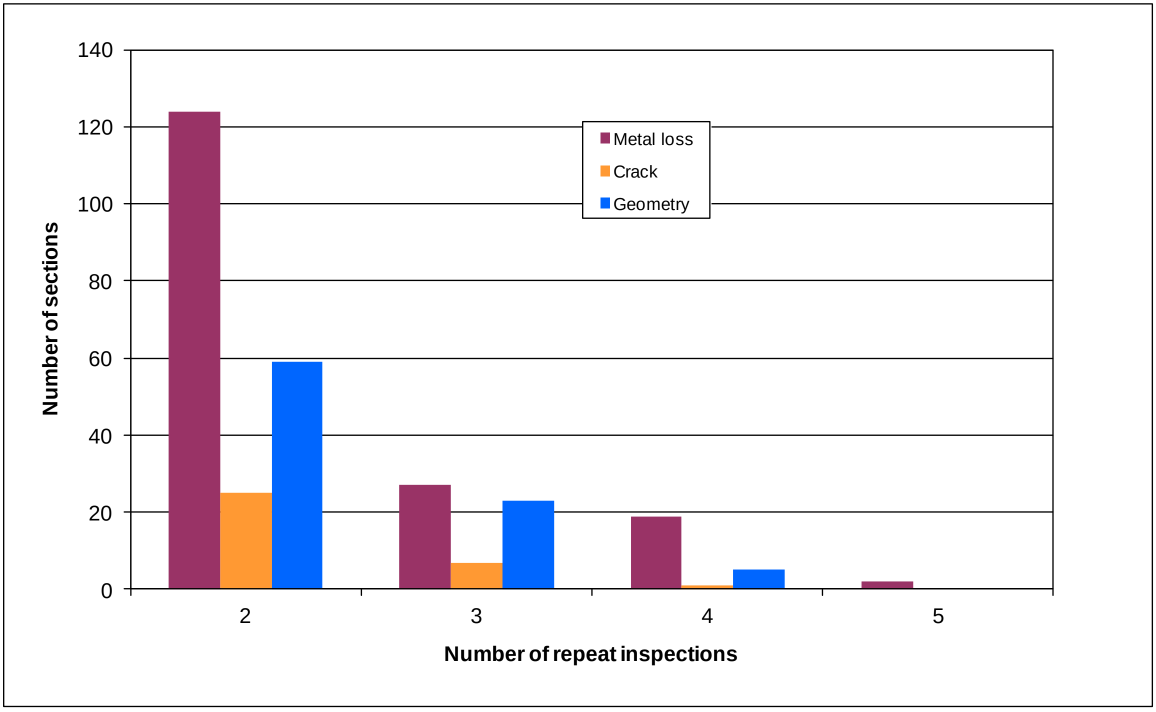


Figure 26 Total annual portion of the inventory inspected by intelligence pigs



As shown in **Figure 27**, a number of sections have been inspected more than once during the last 10 years. Indeed, for some pipelines, regular intelligence pig inspections are required by the authorities.

Figure 27 Repeat Inspections in the last 10 years



The intelligence pig inspection technique only finds flaws, corrosion and other sorts of damage in or on the pipe inner or outer walls. Over the past 40 years, 51 spills have been caused by mechanical damage (including incidental damage by third parties) or faulty welds that could, in principle, have been detected by intelligence pigs. There were 11 such spills in the last 10 years. There are also 102 spillages related to external corrosion and 25 to internal corrosion, at least some of which could have been detected. Note that nearly two thirds of the 102 spillages related to external corrosion occurred in hot pipelines, most of which have now been retired. For the last 10 years these numbers are reduced to 10 and 6 events related to external and internal corrosion respectively.

8. REFERENCES

1. CONCAWE (1972) Spillages from oil industry cross-country pipelines in Western Europe. Statistical summary of reported incidents 1966 - 1970. Report No. 2/72. Brussels: CONCAWE

2. CONCAWE Performance of oil industry cross-country pipelines in Western Europe. Statistical summary of reported spillages. Reports No. 2/73, 1/74, 5/74, 7/75, 7/76, 9/77, 3/78, 6/79, 10/80, 2/82, 11/82, 9/83, 12/84, 9/85, 7/86, 8/87, 8/88, 9/89, 6/90, 4/91, 4/92, 2/93, 5/94, 4/95, 4/96, 7/97, 6/98, 3/99, 3/00, 4/01, 1/03, 7/04, 3/05, 3/06. Brussels: CONCAWE

3. CONCAWE (2002) Western European cross-country oil pipelines – 30-year performance statistics. Report No. 1/02. Brussels: CONCAWE

APPENDIX 1 DEFINITIONS

Spillage volume

Gross spilled volume: the estimated total quantity, expressed in m^3, of hydrocarbons released from the pipeline system as a result of the incident.

Recovered oil: the estimated quantity, expressed in m^3, recovered during the clean-up operation, either as oil or as part of the contaminated soil removed.

Net loss: the difference between gross spilled volume and recovered oil.

Categories of spillage causes

CONCAWE classifies spill causes into five major categories: mechanical failure, operational, corrosion, natural hazard and third party.

Mechanical: a failure resulting from either a design or material fault (e.g. metallurgical defect, inappropriate material specification) or a construction fault (e.g. defective weld, inadequate support etc). This also includes failure of sealing devices (gasket, pump seal etc).

Operational: a failure resulting from operational upsets, malfunction or inadequacy of safeguarding systems (e.g. instrumentation, mechanical pressure relief system) or from operator errors.

Corrosion: a failure resulting from corrosion either internal or external of either a pipeline or a fitting. A separate category is foreseen for stress corrosion cracking.

Natural hazard: a failure resulting from a natural occurrence such as land movement, flooding, lightning strike, etc.

Third party: a failure resulting from an action by a third party, either accidental or intentional. This also includes "incidental" third party damage, undetected when it originally occurred but which resulted in a failure at some later point in time.

These main categories are subdivided to give a total of 12 subsets shown in **Table 1.1**.

Table 1.1 Categories of spillage causes

Main		Secondary		
		a	b	c
A	Mechanical Failure	Design & Materials	Construction	
B	Operational	System	Human	
C	Corrosion	External	Internal	Stress Corrosion
D	Natural Hazard	Ground movement	Other	
E	Third Party Activity	Accidental	Intentional	Incidental

Detailed reporting in **Appendix 2** further identifies, within each category, a primary cause.

APPENDIX 2 SPILLAGE SUMMARY

Key to table

Service

1	Crude oil
2	White product
3	Fuel oil (hot)
4	Crude oil or product
5	Lubes (hot)

Leak first detected by

1	R/W surveillance by pipeline staff
2	Routine monitoring P/L operator
3	Automatic detection system
4	Pressure testing
5	Outside party
6	Internal Inspection

Land use

1	Residential high density
2	Residential low density
3	Agricultural
4	Industrial or commercial
5	Forest Hills
6	Barren
7	Water body

Facility

1	Underground pipe
2	Above ground pipe
3	Pump station

Facility part

1	Bend
2	Joint
3	Pipe run
4	Valve
5	Pump
6	Pig trap
7	Small bore
8	unknown

Reason

1	Incorrect design
2	Faulty material
3	Incorrect material specification
4	Age or fatigue
5	Faulty weld
6	Construction damage
7	Incorrect installation
8	Equipment
9	Instrument & control systems
10	Not depressurised or drained
11	Incorrect operation
12	Incorrect maintenance or construction
13	Incorrect procedure
14	Coating failure
15	Cathodic protection failure
16	Inhibitor failure
17	Construction
18	Agricultural
19	Underground infrastructure
20	Landslide
21	Subsidence
22	Earthquake
23	Flooding
24	Terrorist activity
25	Vandalism
26	Theft (incl. attempted)

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (m3)		Leak first detected by	Facility	Facility part	Age	Land use	Cause		Impact	
						Gross	Net loss				Years		Category	Reason	Water bodies	Contaminated land area (m²)
1	1971	11	2			1	1	2	1	2	3	2	Aa	7		
2			1			4		2	3	2			Aa			
3		11	2			0		5	1	3	6		Aa	5		
4		20	1			40	5	3	3	2	5		Ab			60,000
5			1			350		2	3	8	9	4	Ba	9		
6			1			25		2	3	7			Bb	11		
7		5	3			3		5	1	3	8		Ca			
8		8	2			6	6	2	1	3	20		Ca			
9		20	1			300	50	5	1	3	5		Ea	19		1,000
10		34	1			2000		5	1	3	9		Ea	19		
11		8	2			2	2	5	1	3	20		Eb	25		
12	1972	16	2			5		2	1	4	4		Ab	12		
13		28	1			800	150	2	3	1	12	4	Ab	5		
14		12	2			70	39	5	1	2	5	2	Ab			
15		9	1			10	5	5	1	3	29		Ca			
16		9	1			40	35	5	1	3	29		Ca			
17		10	1			1	1	2	2	3	39	4	Ca			
18		10	1			1	1	2	2	3	39	4	Ca			
19		12	3			500		5	1	3	12	4	Ca			
20		12	3			5	1	5	1	3	12	4	Ca			
21		10	2			150	50	2	1	3	7		Ca			
22		4	3			0		5	1	3	15	4	Ca			
23		6	3			1	0	5	1	3	15		Ca			
24		20	1			200	60	2	1	3	8	4	Ea	17		
25		20	1			250	100	2	1	3	8		Ea	17		
26		28	1			60	12	5	1	3	16		Ea	17		
27		10	1			90		5	1	3	6		Ea			
28		8	1			7		5	1	3	8	2	Ea	17		
29		10	2			30		5	1	3	9		Ea	17		
30		8	2			400	350	2	1	3	2	2	Ea	18		
31		10	2			99	96	5	1	3	6	2	Ea			
32		12	3			0		5	1	3	5		Ec			
33	1973	5	3			4		1	1	3	8		Aa	4		
34		20	1			25	3	5	3	2	1	4	Aa			
35		16	1			0		2	3	4	3	4	Ab			
36			1			4		2	3	7	11	4	Ab	4		
37		24	2			25		2	3	2	2	4	Ab			
38		18	1			11	1	2	3	5	13	4	Ab	4		
39		6	2			12	6	5	1	2	1	4	Ab			
40		9	1			12	12	1	1	3	32		Ca			
41		5	3			15		1	1	3	8		Ca			
42		5	3			15		1	1	3	8		Ca			
43		12	3			200	2	5	1	3	13		Ca			
44		12	3			12	2	2	2	3	13		Ca			
45		12	3			250	5	5	2	3	13		Ca			
46		12	3			150	2	1	2	3	13		Ca	14		
47		12	3			310	10	5	1	3	13	4	Ca			30,000
48		28	1			100	40	5	1	3	16		Da			
49		10	3			8		5	1	3	9	2	Ea	18		
50		12	3			0		5	1	3	6		Ec			
51		12	3			1		5	1	3	6		Ec			
52		12	3			0		1	1	3	6		Ec			
53	1974		1			1	0	2	3	7	4	4	Aa	7		
54			1			3	2	2	3	7	5	4	Aa	4		1,000
55		6	1			20		5	1	1	15		Aa	4		
56		9	1			10		1	1	3	33		Ca			
57			2			2	2	2	2	7	6		Ca			
58		10	3			1		2	1	3	9	4	Ca	14		
59		12	3			5		5	1	3	8		Ca	14		
60		13	3			5		5	1	3	8		Ca	14		
61		4	3			1		5	1	3	17	4	Ca	14		
62		6	3			0		5	1	3	16		Ca	14		
63		16	3			1		5	1	3	9	2	Cb		P	
64		7	1			1		5	1	3	8	2	Cb			
65		16	1			500		5	1	3	10		Ea	17		
66		5	2			1	0	5	1	3	21		Ea	19		
67		8	2			30	4	2	1	3	22		Ea	19		
68		8	2			200	2	5	1	3	22		Ea	17		
69		10	2			668	668	2	1	3	18		Ea	18		
70		10	2			489	405	2	1	3	18	2	Ea	17		

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (m3)		Leak first detected by	Facility	Facility part	Age	Land use	Cause		Impact	
						Gross	Net loss				Years		Category	Reason	Water bodies	Contaminated land area (m^2)
71	1975	20	2			30	10	4	2	7	11	2	Ab	5		
72		34	1	4		30	2	5	1	2	12		Ab	5		
73		10	3			3		2	2	2	5	1	Ab			
74			1			10	2	2	3	8		4	Ba	11		
75			2			4		3	3	7		4	Ba	9		
76		8	2			20	10	2	3	7	4	4	Bb	11		
77			1			5		2	3	7		4	Bb	11		
78		10	3			50		2	1	3	11		Ca	15		
79		12	3			3		5	1	3	9		Ca	14		
80		6	3			25		1	1	3	9		Ca	14		
81		10	3			1	0	2	3	6	6	4	Ca			
82		4	3			1		5	1	3	18		Ca			
83		8	3			0		6	1	3	6		Ca			
84		8	3			0		1	1	3	6	2	Ca			
85		12	3			0		2	3	3	6	4	Ca			
86		6	1			15	0	5	1	3	23	2	Ea	18		
87		18	1			5	0	2	1	3	12		Ea	19		
88		8	1			120	3	2	1	3	9		Ea	17		
89		8	2			60	60	2	1	3	23		Ea	19		
90		6	1			15	6	5	1	3		2	Ea	18		
91	1976	8	2					5	1	7	9		Aa	5		
92		8	3					5	1	4	13	2	Aa	2		
93			1			9		2	1	4	13	4	Ab	2		
94		24	2			17	1	5	2	2	17	4	Ab	1		
95		16	1			1322	433	2	1	2	13		Ab	1		
96		10	3			80		2	1	3	11		Ca	14		
97		4	2			90	90	5	1	3	16		Ca	15		
98		24	1			200		2	1	3	10		Da	21		
99		10	3			50	25	2	1	3			Da	21		
100		10	1			40	2	5	1	3	13	2	Ea	18		
101		8	2			44	14	2	1	3	24	2	Ea	18		
102		18	1			802	606	5	1	3	7	2	Ea	18		
103		8	2			153	153	2	1	3		2	Ea	18		
104		14	2			358	358	5	1	3	23	2	Ec			
105	1977		2			32		2	3	4	9	4	Ab			150
106			2			28		2	3	2	9	4	Ab			140
107		20	2			2		5	1	2	8	2	Ab	2		
108		36	1					2	1	4	3	4	Ab	1		
109			1			50		2	3	4	19	4	Bb	11		
110			1			1		2	3	4	7	4	Bb	11		
111		12	2			350	220	4	1	3	10	2	Ca	15		
112		10	3			315	90	2	1	3	8	1	Ca			
113			1			6		2	3	7	9	4	Cb			
114		12	2			103		5	1	3	19		Da	20		
115		20	1			550	500	1	1	3	13	2	Da	23		
116		24	1			600	25	3	1	3	11	2	Db			
117		10	1			160		2	1	3	12	2	Ea	17		1,500
118		18	1			80		2	1	3	5	2	Ea	18		400
119		8	2			3	3	2	1	3	25	2	Ea	18		
120		8	2			3	1	2	1	3	13	2	Ea	17		
121		12	2			191		2	1	3	19	2	Ea	17		
122		8	2			269		5	1	3	19	2	Ea	17		
123		20	2			2530	2500	2	1	2	9	2	Ec			
124	1978	34	1			2000	300	5	1	2	16	2	Ab	2		
125		8	2			235	205	2	1	4	16	2	Ab	2		
126		22	1			19		5	1	3	7	2	Ab	2		1,800
127		6	2			12	6	5	1	3	18	4	Ca	15		
128		10	2			100	10	2	1	3	14	2	Ca	15		
129		12	3			2		5	1	3	14	2	Ca	15		
130		8	3			120	60	4	1	2	7	2	Ca	15		
131		8	3			80	40	4	1	3	7	2	Ca	15		
132		12	3			2		1	1	3	12	4	Ca			
133		18	3			4	1	5	1	3	6	4	Ca	15		
134		16	4			400	250	2	1	3	14	2	Da	23		
135		11	2			3	0	5	1	3	10	2	Ea	17		
136		12	2			58	40	4	1	8	10	2	Ea	19		
137		24	1			1		5	1	7	4		Ea	19		
138		16	1			255	245	2	1	3	15	2	Ea	18		5,865
139	1979	22	1			100	40	4	1	3	8	2	Aa	6		16,000
140		24	1			100	1	5	1	3	5		Aa	6		2,700
141		9	2			50		5	1	3	17	2	Ca	14		350
142		12	2			300	200	1	1	3	23	2	Ca	15		
143		18	3			20		1	1	3	12	4	Ca	15		500
144		18	3			5		1	1	3	12	4	Ca	15		100
145		18	1	5		50	1	5	1	3	16	2	Ea	17		2,500
146		12	2			90	50	5	1	3	23	2	Ea	18		
147		8	1			245	150	5	1	3	23	2	Ea	18		
148		11	2			950	380	2	2	3	15	4	Eb	26	P	6,400

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (m³)		Leak first detected by	Facility	Facility part	Age	Land use	Cause		Impact	
						Gross	Net loss				Years		Category	Reason	Water bodies	Contaminated land area (m²)
149	1980	13	2			8	1	2	3	2	12	4	Ab	7		
150		40	1			4800	400	5	1	3	9	2	Ab	2		10,000
151		10	3			80		5	1	3	10	2	Ca	14		
152		10	3			10		1	1	3	10	2	Ca	14		
153		7	3			1		1	1	3	15	2	Ca	15		10
154		12	3			111	12	5	1	3	15	2	Da	21	P	10,000
155		10	4			762	135	2	1	3	15	2	Ea	18		10,000
156		12	2			270		5	1	3			Ea	19		
157		8	2			313		2	1	3			Ea	17		
158			1			30		5	3	4		4	Eb	25		
159	1981	34	4			10	2	5	1	4	6		Ab			
160		40	1			10		5	2	2	5	4	Ab			80
161		10	2			600	150	2	1	3			Ab	2		
162		20	1			19	1	5	1	3	17	2	Ca	14		
163		8	3			5		4	3	2	12	2	Ca	14		
164		8	3			19		4	3	2	12	2	Ca	14		
165		12	3			5	2	5	1	3	15	4	Ca	14		50
166		10	2			92	58	2	1	3	25	2	Ca	15		
167		20	1			5	3	5	1	7	15	4	Ca	14		
168		10	2			10		5	1	3			Ca	14		
169		26	2			125	45	5	1	2	18	2	Da	20		
170		24	3			30	10	4	3	7	14	4	Db			
171		7	1			132	132	2	1	3	15	2	Ea	18		
172		8	2			322	317	2	1	3	24	2	Ea	17		
173		5	1			96		5	1	3			Ea	19		
174		28	1			5	0	1	1	3	16	4	Ec			
175	1982	8	2			12	12	5	2	3	20	2	Aa	6	P	
176		24	1			9		5	1	3	18	2	Ab	2		1,000
177		8	1			2		1	1	3	20	2	Ca			
178		12	3			8		5	1	3	16	4	Ca	15		30
179		10	3			400	16	5	1	3	19	2	Ca	15		
180		5	1			20		5	3	3	10	4	Cb			
181		7	1			140	140	5	1	3	16	2	Cb			3,000
182		22	1			15	5	5	1	3	18	1	Cb			
183		6	1			31		5	1	3	20	2	Ea	18		
184		8	2			7	1	2	1	3	30	4	Ec			
185	1983	4	5			10		2	1	2	22	2	Aa	1		100
186		4	5			1		3	1	2	22	2	Aa	1		9
187		4	5			4		5	1	2	22	2	Ab	1		80
188		16	4			442	111	4	1	3	18	2	Bb	11		
189		6	2			12		4	1	3	15	4	Ca	15		3,600
190		7	1			182	120	2	1	3	17	2	Cb			20,000
191		7	1			148	110	5	1	3	17	2	Ea	17		18,000
192		10	2			213	171	5	1	3	29	2	Ea	17		
193		14	2			675	470	5	1	4	3	2	Eb	24		
194		12	1			1	0	5	1	3	20	4	Ec			15
195	1984	28	1			4363	3928	1	1	3	10	2	Aa	6		6,500
196		24	1			141		5	1	1	18	2	Aa	6		4,500
197		28	1			3		3	2	4	11	2	Ab	2		120
198		8	2			16	3	5	2	2	17	2	Ab	2		720
199		34	1			5	2	2	3	4	13	4	Ba	8		1,000
200		16	1			10		2	3	6	18	2	Ba	8		50
201			1			10	10	2	1	3	21	2	Bb	10		50
202		12	3			2		1	1	3	17	4	Ca			
203		6	1			20	16	5	1	3	24	4	Ca	15		250
204		16	2			5	1	5	3	3	11	4	Ca	14		10
205		9	2			236	236	5	1	3	11	2	Cb			200
206		10	1			150	1	5	1	3	23	5	Ea	17		100
207		11	2			244	240	3	1	4	21		Eb	24		
208	1985	24	1			1	1	1	1	8	14	2	Aa	7		18
209		20	1			25	4	5	3	5	9	4	Ba			
210		10	2			16		3	3	4	17	4	Ba			
211		10	2			7		3	3	2	17	4	Ba			
212		6	2			4		3	3	4	17	4	Ba			
213		16	1			1100	756	2	1	3	9	2	Cc			13,000
214		8	2			211	195	2	1	3	33	2	Ec	18		1,000
215	1986	16	2			160	6	3	3	2	17	2	Ab			200
216		20	1			53	6	2	1	3	12	2	Ab	2		3,000
217		24	2			292	4	2	1	2	26	2	Ab	7		3,000
218		16	3			20	5	5	1	3	38	1	Ca	14		
219		20	2			2	2	5	1	3	22	1	Ca	15		
220		8	3			10		4	1	3	25	2	Ca			20
221		9	1			10	10	5	1	3	45	2	Cb			180
222		34	1			7	7	1	1	2	14	4	Cb			84
223		8	2			192	95	5	1	3	15	2	Ea	19		1,500
224		14	2			280	56	3	1	3	18	2	Ea	17		100
225		6	2			52	41	3	1	3	13	2	Ea	17		10
226		8	2			11	6	3	1	2	19	2	Eb	25		3

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (m³)		Leak first detected by	Facility	Facility part	Age	Land use	Cause		Impact	
						Gross	Net loss				Years		Category	Reason	Water bodies	Contaminated land area (m²)
227	1987	20	2			1000	120	4	1	2	20	4	Aa	5		
228		26	4			2	1	5	1	3	25	2	Aa	7		1,000
229		9	1			25	2	5	1	1	46	2	Ab	2		200
230		16	3			550	150	2	1	3	39	2	Ca	15		200
231		9	1			8	1	5	1	3	46	1	Cb			280
232		12	2			12	10	5	1	3	21	2	Da	20	P	2,000
233		22	2			3	1	5	1	7	20	4	Ea	19		10
234		16	2			300	115	5	1	8	18	4	Ec		P	
235	1988	34	1			10	1	5	1	2	26	4	Ab			200
236		12	2			90	42	5	1	1	30	1	Ab	2	P	1,500
237		8	2			97	21	2	3	2	28	2	Ab	4		500
238		34	1			81	1	5	1	3	17	4	Ca	15		5,000
239		11	2			80	80	2	1	3	35	1	Ca	15		
240		28	1			5	1	5	2	2	31	1	Ca	15		400
241		10	2			305	5	2	1	3	23	2	Da	20		5,000
242		20	2			40	10	5	1	3	24	4	Ea	17		30
243		3	1			2	1	5	1	3	28	2	Ea	17		100
244		10	1			14	1	5	1	3	23	2	Ea	18		100
245		8	2			3	1	5	1	3	35	1	Ea	17		20
246		16	2			3	1	5	1	3	16	2	Ea	19		150
247		16	1		1	650	650	3	1	3	23	1	Ea	17		550
248		4	2			2	1	5	1	3	26	2	Ea	19		9
249		6	2			63	56	5	1	3	33	2	Ea	17		1,200
250		6	2			18	1	5	1	3	33	2	Ea	18		1,800
251	1989	26	1			3	2	5	1	2	26	2	Aa	5		100
252		12	3			1		5	1	2		4	Aa	5		6
253		1	2			25	7	5	2	7	1	2	Aa	7		10,000
254		26	1			155	5	5	1	3	26	2	Ab	5	P	2,000
255		10	2		1	66	16	2	1	2	27	2	Bb	11		
256		9	1			25	5	4	1	3	48	2	Ca	14		50
257		12	3			240	150	2	1	3	17	4	Ca	15		
258		10	2			400	90	3	1	3	24	2	Cb			2,000
259		16	2	3		253	253	5	1	3	22	2	Ea	19		500
260		16	2			660	472	3	1	3	20	2	Ea	18	P	
261		10	2			82	4	3	2	3	24	2	Ea	17		200
262		12	2			298	298	2	1	3	32	2	Ea	18		6,000
263		6	2			52	27	5	1	3	33	2	Ea	18		2,000
264		8	2			3		5	1	3	32	2	Ea	19		66
265		8	2			186	126	5	1	3	29	2	Ea	18		
266		40	1			40	5	5	1	3	17	2	Ec			4,000
267		11	1			2		5	1	3	26	2	Ec	18		
268	1990	13	2			105	105	5	1	4		2	Bb	12		30
269		10	2			252	221	5	3	6	33	2	Bb	11		1,500
270		8	2			9		2	2	4	48	2	Bb	12		10
271		11	3			325	11	2	1	3	22	4	Ca	15		
272		11	2			225	194	5	1	3	11	2	Ea	17		3
273		6	2			3	1	5	1	3	34	2	Ea	18		324
274		10	2			189	34	5	1	3	24	2	Ea	18		
275	1991	20	2			275	118	3	1	3	24	2	Aa	1		14,000
276			2			50	38	5	1	7	10	2	Aa	1		1,200
277		20	1			20	13	5	1	3	24	2	Aa	7		4,500
278		12	2			25	7	2	3	7	20	4	Aa	6		150
279		12	2			5	2	5	1	7	21	2	Aa	7		320
280		12	2			29	29	5	1	3	38	2	Ab	2		600
281			2			4	1	3	3	7	31	4	Ab	4		250
282			2			172	68	3	3	4	11	4	Ab	2		100,000
283			2			2		5	2	2		2	Ab			
284		10	2			80	4	5	1	3	26	2	Ca	15		1,500
285		7	1			20		5	1	2	30	2	Cb			300
286		8	2			100	60	4	1	3	17	2	Cb			10,000
287		8	2			15	10	4	1	3	17	4	Cb			25
288		8	2			4		5	1	3	49	2	Ea	19		6
289		6	2			21	13	5	1	3	34	2	Ea	18		500
290		6	2			1		5	1	3	37	2	Ea	19		2
291			2			84	75	3	3	4	1	2	Eb	25		
292		13	2			485	485	2	3	3	24	2	Eb	25		7,000
293		8	2			10	1	5	1	3	24	2	Ec			30
294	1992	8	2			1000	400	2	1	3	34	4	Aa	2		
295			2			128	98	2	1	2		2	Ab			5,400
296			2			113	8	2	3	4	12	4	Ab	2		
297		8	2			30	15	2	2	2	33	4	Ab	5		
298		8	2			5	5	6	1	3	13	5	Ab	2		10
299			2			275	248	2	3	4		4	Bb	11		1,100
300			2			5	1	2	2	8	22	4	Bb	10		1,350
301		10	2			2		2	1	4	30		Bb			
302		8	3			200		5	1	3	25	2	Ca			300
303		24	2			13	1	5	1	2	27	4	Ca			250
304		6	2			3	3	4	1	3	49	2	Ca	15		2
305		12	2			75	75	5	1	3	28	2	Da	23		
306		8	2			50	50	4	1	3	25	2	Ec			20
307		8	2			25	25	4	1	3	25	2	Ec			60

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (m3)		Leak first detected by	Facility	Facility part	Age	Land use	Cause		Impact	
						Gross	Net loss				Years		Category	Reason	Water bodies	Contaminated land area (m²)
308	1993	34	1			248	18	4	1	3	31	2	Aa	2		45,000
309			2			3		5	3	2	2	4	Ab			80
310		12	2			2	1	1	1	4	23	4	Ab			400
311		18	2			14	13	6	1	3	27	4	Ca			400
312		13	2			580	500	2	1	8	26	2	Cb			800
313		20	1			2000	500	2	1	3	19	2	Cb			25,000
314		26	2			10	7	5	1	3	31	5	Da	20	P	
315		9	2			8	6	5	1	3	30	2	Ea			50
316		24	2			49	39	5	1	3	33	2	Ea	18		40,000
317		8	2			3	1	5	1	3	37	2	Ea	19		100
318		12	2			101	19	5	1	3	31	2	Ea	19		
319		20	2			3050	1450	2	1	3	29	4	Ec			
320		7	2			3	3	5	1	3	13	1	Ec			6
321	1994	16	1			200	160	3	1	3	31	2	Ab	2		6,000
322		16	1			1350	1295	2	1	3	31	2	Ab	2		25,000
323		6	2			250	14	2	3	2	16	4	Ab			50
324		6	2			1	1	1	1	3	16	4	Ab	2		25
325		11	2			5	5	5	2	2	9	2	Ab			100
326			1			2	2	5	3	8		4	Ba	9		100
327		12	3			90	60	5	1	3	24	2	Ca	14		
328		32	1			10	5	2	2	3	21	4	Cb			500
329		10	2			285	285	5	1	3	26	2	Ea	17		
330		9	2			195	170	3	1	3	37	2	Ea	18	P	8,000
331		8	2			46		5	1	3	36	2	Ea	17		1,150
332	1995		2			280	80	2	2	6	22	4	Aa	7		10,000
333		10	2			30	30	5	1	2	35	2	Aa	5		750
334			2			53	41	5	1	7	5	2	Ab	2		
335		6	2			115		1	1	3	36	2	Ab	2		500
336		16	1			132	82	3	1	3	30	2	Bb	11		6,500
337		10	2			1000	270	1	1	3	31	4	Ca	15		55,000
338		9	2			48	18	3	1	3	28	2	Ea	17		1,500
339		9	2			20	20	3	1	3	39	4	Ea	17		100
340		13	2			139	113	5	1	3	5	2	Ea	17		300
341		6	2			12		3	1	3	37	2	Ea	17		30
342	1996	9	2			165	99	2	3	2	5	4	Ab			40
343		14	2			292	209	5	1	3	40	1	Bb	10		300
344		12	3			1		5	1	3	30	4	Ca			16
345		9	2	1		437	343	2	1	3	40	4	Ea	19		20
346		7	2			19	19	5	1	3	40	2	Ea	17		350
347		10	2			500	62	5	1	3	64	4	Ec			23,000
348	1997	12	2			19	3	1	1	3	27	2	Ca	14		2,800
349		10	1			2	0	1	1	2	7	4	Cb			20
350		12	2			422	341	2	1	3	30	2	Cc			
351		12	2			435	267	2	1	3	30	1	Cc		P	
352		8	2			13	2	2	1	4	33	2	Ea	19		150
353		12	2			40	1	5	1	3	24	4	Ec	17		
354	1998		1			30	4	2	3	5	30	4	Ab	1		400
355		6	3			0	0	5	1	3	34	2	Bb	11		
356		13	2			486	247	2	1	3	42	2	Bb	11		100
357		16	2			250	20	5	1	3	30	4	Ca	14		
358		10	2			340	313	3	1	3	6	1	Ea	17		500
359		10	2			15	14	1	1	3	4	2	Ea	19		600
360		9	2			176	67	3	1	3	42	2	Ea	18		160
361			2			30	2	3	1	7		2	Ea	19		650
362		8	2			0		5	1	3	25	2	Ea	19		4
363	1999		1			7		2	3	6		4	Bb	11		200
364		1	3			30		2	1	3	32	4	Ca	14		300
365		11	2			167	64	2	1	3	32	2	Ca	14		60
366		6	2			1	1	3	1	3	25	2	Ca	14		5
367		4	1			1	1	5	3	8	35	4	Ca	14		
368		8	2			80	20	5	1	3	48	2	Ea	17		500
369		13	2			84	13	3	1	3	10	4	Ea	17		
370		6	2			29	14	5	1	3	40	2	Ea	18		
371		8	2	1		80	30	5	1	3	35	2	Eb	26		1,000
372		11	2			36	28	3	1	7	5	2	Eb	26		100
373		12	2			1		2	1	3	36	4	Ec			
374	2000		2			175	3	5	2	4	24	4	Ab			60
375		12	1			10	7	5	1	3	30	4	Cb			150
376		12	2			8	8	5	1	3	31	2	Ea	17		
377		11	2			159	64	3	1	3	8	2	Ea	17		5,000
378		12	2			7	1	5	1	3	26	1	Ea	19		
379		24	2			1	1	5	1	3	41	2	Ec	19		150

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (m3)		Leak first detected by	Facility	Facility part	Age	Land use	Cause		Impact	
						Gross	Net loss				Years		Category	Reason	Water bodies	Contaminated land area (m²)
380	2001	20	1			800	8	5	2	8	35	2	Aa	5		10,000
381		10	2			1	1	5	1	2	39	2	Aa	5		10
382		10	2			5	5	5	1	3	38	2	Ab	2		500
383		6	2			37	7	4	1	1	27	2	Ab	2		900
384		12	2			10	2	5	1	1	15	4	Ab	2		120
385		34	1			6	1	3	1	3	29	4	Ca	14		500
386		12	2			4	4	5	1	3	26	2	Ca	14		1,000
387		13	1			103	50	2	3	8	23	4	Cb			225
388		11	2			55	51	5	1	3	9	2	Ea	17		
389		10	2			10	1	5	1	3	11	2	Ea	17		
390		6	2			5	5	5	1	3	47	1	Ea	18		400
391		12	1			10	7	5	1	3	30	2	Eb	26		250
392		12	1			17	12	5	1	3	30	2	Eb	26		400
393		16	2			2	2	5	1	3	18	2	Eb	26		350
394		8	2			85	24	2	1	3	47	2	Eb	26	P	404
395	2002	8	2			10	10	5	1	3	47	2	Ab			325
396		20	1			100		2	1	3	36	4	Ca	15		500
397		10	2			80	20	5	1	3	38	4	Ca	14		10,000
398		10	3			1		5	1	3	28	2	Ca	15		14,000
399		6	2			17		2	2	3	33	4	Ca			400
400		8	2			70		2	1	2	?	4	Ca			
401		13	2			225	58	3	1	3	46	2	Cc			400
402		24	2			250	20	5	1	7	39	4	Da	22		5,000
403		30	1			2		5	2	2	40	4	Ea	19		40
404		8	2			170	120	4	1	3	57	2	Ea	18		
405		16	1			750	45	1	1	3	39	2	Ea	17		20,000
406		20	1			280	30	5	1	3	40	2	Ea	17		12,000
407		12	1			40	15	5	1	3	33	2	Eb	26		6,000
408		8	2			190		3	1	3		4	Ec	19		
409	2003	14	2			30	30	3	1	8			Aa			
410		20	4			2		2	1	3	52	4	Ca		S	2
411		12	2			2		5	1	3	32	4	Ea		S	5
412		11	2			83	74	3	1	3	46	3	Ea	18		1,800
413		11	2			45	31	5	1	3	46	4	Ea	17		600
414		6	2			2		3	1	8			Ea			
415		11	2			74	49	3	1	8	46	3	Eb	26		500
416		16	1			5	5	1	1	3	41	5	Eb	26		120
417		16	2			28	10	5	1	3	29	2	Eb	26		400
418		16	2			52	3	4	1	3	29	2	Eb	26		400
419		12	2			11	7	4	1	3	45	4	Ec			800
420		20	2			2500	1100	5	1	3	31	6	Ec	19	P	80,000
421	2004	16	2			2	0	1	1	3	32	3	Aa			4,000
422		10	2			26	18	2	2	7	40	2	Aa			6,000
423		22	1			20	6	2	3	8	5	4	Ab			200
424		8	2			90	50	5	1	1	5	3	Ea	18		1,500
425		10	2					3	1	8	29	1	Ea			2,000
426	2005	12	2			19	19	2	3	4		3	Aa	7		
427		12	2					5	1	2		4	Aa	5	G	
428		20	1			350	10	3	1	8	45	2	Ab	1	G	15,000
429		6	2			20		2	1	1	28	3	Ab	4	S	58
430		6	2			38		5	1	1	28	3	Ab	4	S	42
431		9	1			30	4	3	1	8	14	2	Bb	12	G	1,000
432		10	1			15		5	2	4	22	3	Bb	12		1,000
433		10	2			3	1	5	1	3	25	4	Ca	14	S	50
434		24	1			64	1	2	1	8	40	4	Cb		G	150
435		8	2			15	8	5	1	3	41	2	Ea	17	G	1,000
436		24	2			0		5	1	3	46		Ec	19	S G	3,000
437	2006	12	2			75		5	1	4	58	4	Ab			50
438		8	2			6	6	2	1	4	19	4	Ab	2		60
439		9	2			5		1	2	2	1	3	Aa	7		
440		14	2			5		2	2	4		4	Ab	2		
441		11	2			245		2	1	3	13	3	Ea	18		
442		11	2		1	37		5	2	3		3	Aa	5		
443		11	2			223		5	1	3		5	Ea	17		
444		13	2			4		1	2	7		4	Ab	1		
445		20	2			2		3	1	3		4	Cb		S G	
446		12	1			10	3	5	1	1	8	4	Cb			50
447		6	2			23		3	1	3	41	5	Eb	26	G	100
448		6	2			16		3	1	3	41	5	Eb	26	G	80
449	2007	8	2			150	70	3	1	3		4	Ec	4		400
450		8	2			30	1	5	1	3		2	Ea	17		2,000
451		11	2			12	10	2	1	4	28	3	Eb	26		1,600
452		13	2			301	38	5	1	3	17	3	Ea	19		452
453		9	2			117	54	2	1	3	50	3	Ea	19		120
454		9	2			2	2	5	1	3	16	3	Eb	26		100
455		11	2			182	133	5	1	3	50	3	Ea	19	S	500
456		13	2			185	159	2	1	3	50	3	Ca	14		1,200
457		16	1			7		5	3	3	40	3	Cb		S G	700

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (m3)		Leak first detected by	Facility	Facility part	Age	Land use	Cause		Impact	
						Gross	Net loss				Years		Category	Reason	Water bodies	Contaminated land area (m^2)
458	2008	16	2			4	4	6	1	3	40	4	Aa	5		25
459		40	1			6	0	5	2	7	36	7	Ab	2		0
460		11	2			30	0	3	3	5	29	4	Ab	2		40
461		11	2			52	37	3	1	4	29	3	Ab	4		50
462		11	2			12	0	1	2	4	20	4	Aa	7		0
463		11	2			129	108	3	1	3	29	3	Ab	2		90,000
464		9	2			44	17	3	1	3	16	3	Ea	17		3,600
465		6	2			40	0	2	1	3	52	4	Ea	0		5,000
466		4	2			28	0	5	1	3	0	3	Ea	18		250
467		16	1			294	0	3	1	3	46	4	Ea	17		11,000
468		16	1			328	0	3	1	3	46	4	Ab	4		3,600
469		18	1			1	1	5	1	3	1972	2	Ca	14	S	0
470	2009	20	1			30	0	2	2	4	25	4	Ab	1		0
471		34	1			10	10	5	1	3	45	4	Ec	0	S	0
472		40	1			5401	811	2	1	3	37	6	Ab	4	G	50,000
473		24	1			10	0	3	3	6	48	4	Ab	3	G	50
474		10	2			25	12	3	2	2	0	4	Aa	7		0
475	2010	2	1			125	0	0	3	2	0	3	Ab	3		0
476		13	2			1	1	5	1	3	34	3	Ca	14	S	0
477		9	2			10	0	1	3	2	18	4	Ab	3		0
478		24	1			200	0	3	1	3	38	3	Ea	18	S G	21,000

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