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Performance of European cross-country oil pipelines

Statistical summary of reported spillages in 2012 and since 1971

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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 42 years of spillage data on European cross-country oil pipelines. At over 36,000 km the inventory covered currently includes the vast majority of such pipelines in Europe, transporting close to 700 million m^3 per year of crude oil and oil products. This report covers the performance of these pipelines in 2012 and a full historical perspective since 1971. The performance over the whole 42 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 (inspection pigs) is also reported. 12 spillage incidents were reported in 2012, corresponding to 0.33 spillages per 1000 km of line, above the 5-year average of 0.22 and below the long-term running average of 0.51, 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. 1 incident was due to mechanical failure, 3 to corrosion, and 8 were connected to third party activities, 2 of which malicious. 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, inspection 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 42 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 2012 and provides a full historical perspective since 1971. The performance over the whole 42 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 (inspection pigs) is also reported.

79 companies and agencies operating oil pipelines in Europe currently provide data for the CONCAWE annual survey. For 2012 information was received from 71 operators representing over 156 pipeline systems and a combined length of 36,251 km, a little more than the 2011 inventory. 8 operators did not report and, although there have been no public reports of spillage incidents, they have not been included in the statistics. The reported volume transported in 2012 was 701 Mm^3 of crude oil and refined products, about 4% less than in 2011. Total traffic volume in 2012 was estimated at $115x10^9$ m^3.km.

12 spillage incidents were reported in 2012, corresponding to 0.33 spillages per 1000 km of line, above the 5-year average of 0.22 and below the long-term running average of 0.51, 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.

Of the 12 reported incidents in 2012, 8 were directly caused by third party activities (2 of which related to theft or vandalism), three to corrosion (one internal and two external) and one Mechanical (design and materials). Over the long term, third party activities remain the main cause of spillage incidents. Theft attempts have caused a total of 20 spillage incidents between 1971 and 2012, 4 of which (20%) were in the past two reporting years. Mechanical failure is the second largest cause of spillage. After great progress during the first 20 years, the frequency of mechanical failures appeared to be on a slightly upward trend over the last decade, although figures from recent years are again low.

The gross spillage volume was 371 m^3 or 10 m^3 per 1000 km of pipeline compared to the long-term average of 73 m^3 per 1000 km of pipeline. About 45% of that volume was recovered.

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 60 km of hot oil pipelines are reported to be in service today. The last reported spill from a hot oil pipeline was in 2002.

In-line inspections were at a sustained level in 2012. A record total of 119 sections covering a total of 13,050 km were inspected by at least one type of inspection 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 7119 km (20% 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 2012 only 4.8% was 10 years old or less and 58% was over 40 years old. However, this has not led to an increase in spillages.

Overall, based on the CONCAWE Incident database and reports, 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 inspection 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 inspection 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. Summary reports were compiled after 20 and 30 years. 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, effectively creating an evergreen document updated every year. This report uses this same format and therefore supersedes the 2011 data report 3/13. All previous reports have also been superseded and are now obsolete.

In this single annual integrated report, it was, however, not considered practical to include the full narrative description of the circumstances and consequences of each past spillage. We have therefore created a series of separate appendices to this report where this information can be accessed via the following links:

1971-1983 / 1984-1993 / 1994-2004 / 2005+

CONCAWE also maintains a map of the oil pipeline inventory covered by the annual survey. The recently updated map is 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 next COPEX will be held in Brussels in April 2014.

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 2012 and of all incidents over the last 5 reporting 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 figures.

2.2. REPORTING COMPANIES

For the 2012 reporting year, 65 companies completed the survey, out of the 79 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. In addition we had direct contact with an additional 6 companies that confirmed they had no spills in 2012 and their inventory have therefore been included in the spillage statistics. Although there were no public reports of spillage incidents in the remaining 8 companies they have not been included in the statistics.

2.3. INVENTORY DEVELOPMENTS 1971-2012

2.3.1. Pipeline service, length and diameter

The 65 companies that reported in 2012 operate 145 pipeline systems split into 664 active sections running along a total of 35,336 km. The 6 companies that did not report but were confirmed to have suffered no spills operate a total of 11 systems in 16 sections covering 915 km, bringing the total length used for the statistical analysis to 36,251 km. The 8 companies from which we received no information represent 1084 km split into 53 sections in 18 systems. There was no report of sections being either started up or permanently taken out of service in 2012.

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 have 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 in which case they are still considered to be part of the inventory. 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 the bulk of the original "hot" inventory of which only 60 km distributed amongst 7 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 1 CONCAWE oil pipeline inventory and main service categories

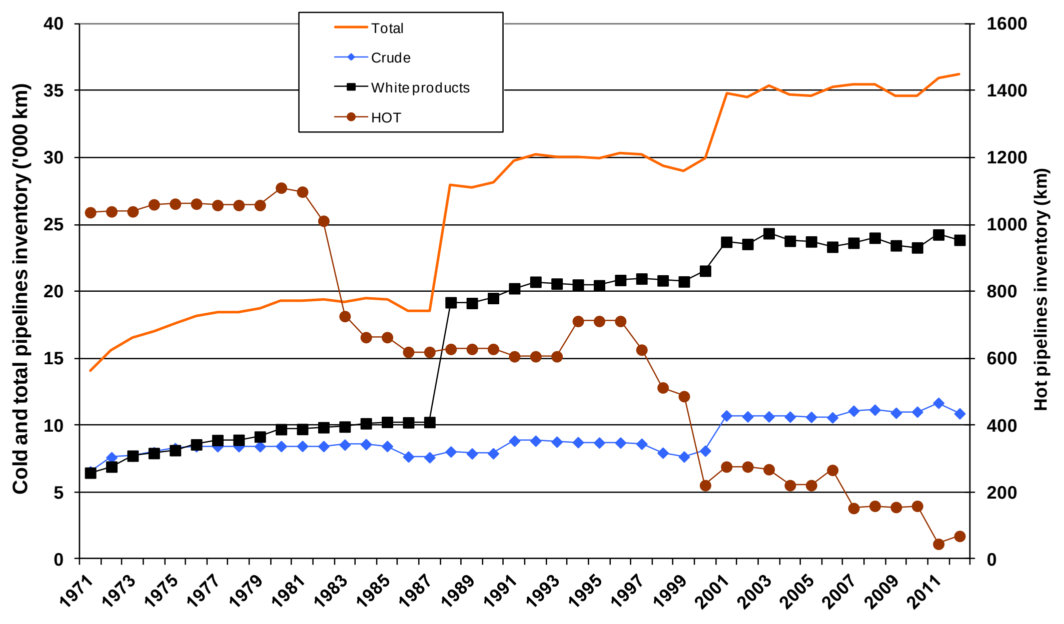
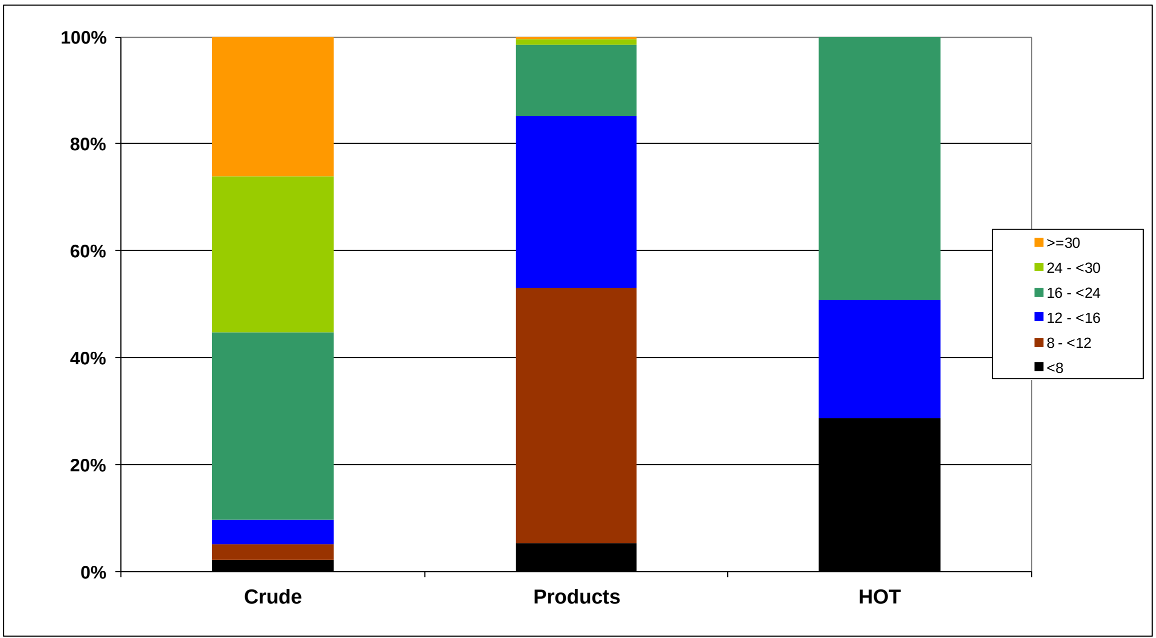


Figure 2 shows the diameter distribution in 2012 for each service category. In general, the crude pipelines are significantly larger than the other two categories. 90% of the crude pipelines are 16” (400 mm) or larger, up to a maximum of 48” (1200 mm), whereas 85% of the product lines are smaller than 16”. The largest hot pipelines is 20”. The smallest diameter product pipelines are typically 6” (150 mm) although a very small number are as small as 3” (75 mm).

Figure 2 European oil pipeline diameter distribution and service in 2012

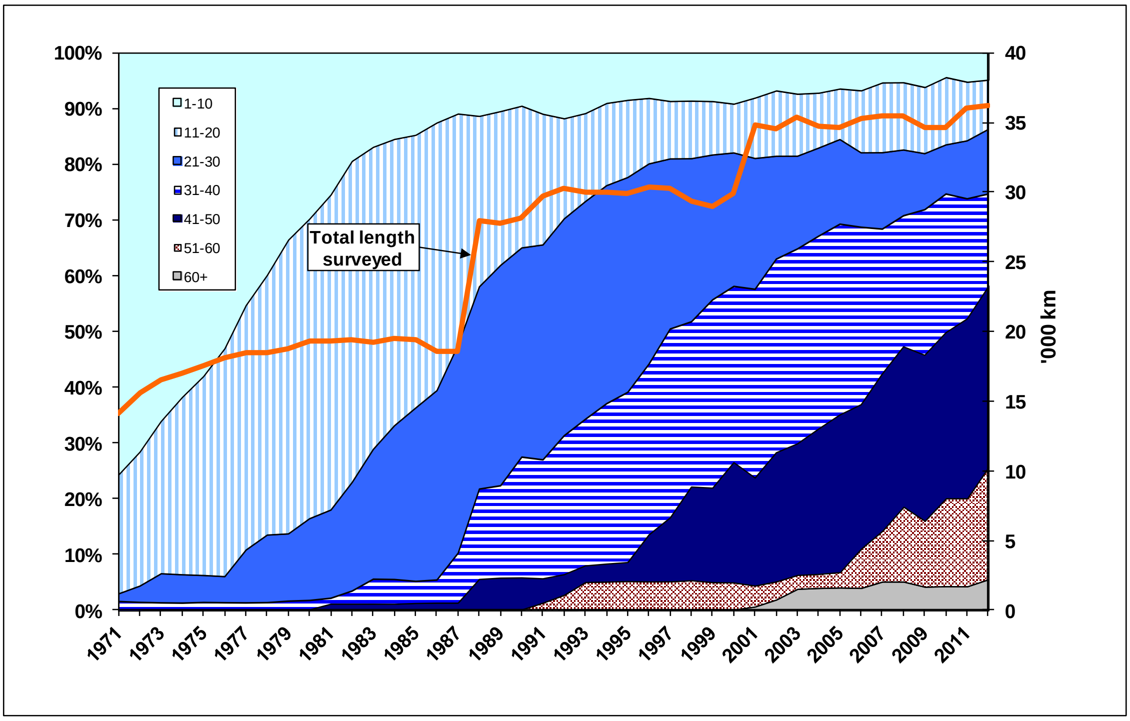


2.3.2. Age distribution

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.

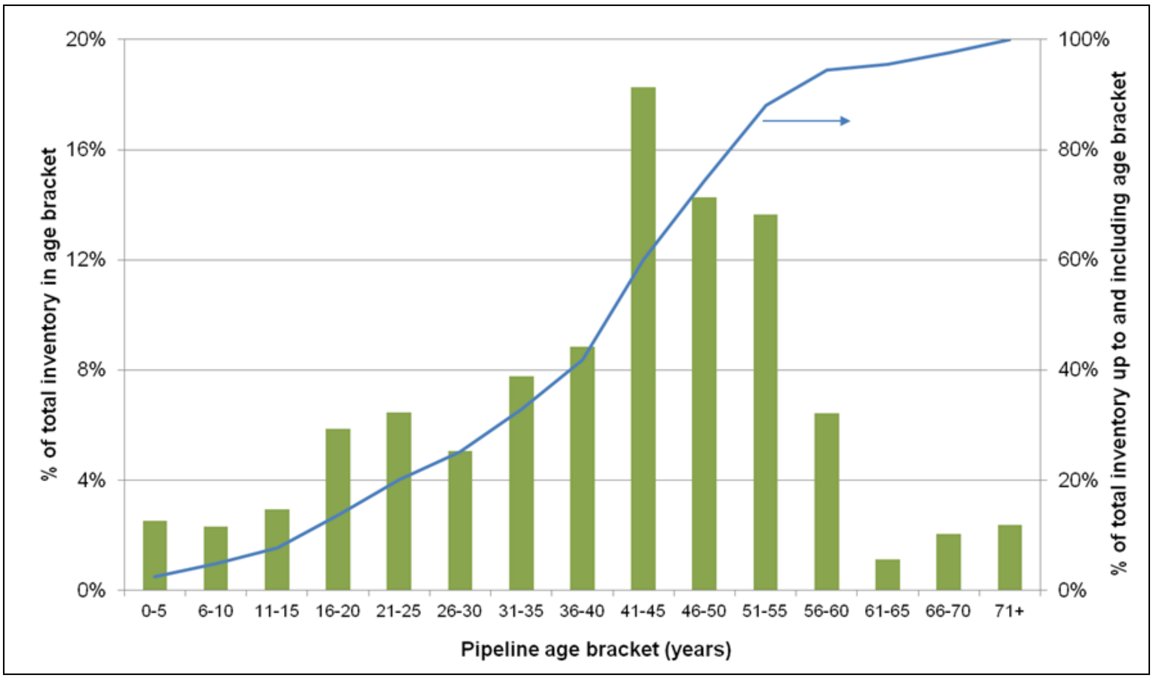
Over the years, a number of new pipelines have been commissioned, while older ones have been taken out of service. As mentioned above, existing lines were also added to the inventory at various stages, contributing their specific age profile. Although some short sections may have been renewed, there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

Figure 3a European oil pipeline historical age distribution



The system has been progressively ageing. The 2012 age distribution is shown on **Figure 3b** both for discreet age brackets and cumulatively: only 913 km, i.e. 4.8% of the total, was 10 years old or less while 21,085 km (58%) was over 40 years old. The relevance of age on spillage performance is discussed in **Section 6.3**.

Figure 3b European Oil pipeline age distribution in 2012



2.4. THROUGHPUT AND TRAFFIC

A reported total of around 461 Mm^3 of crude oil and 240 Mm^3 of refined products were transported in the surveyed pipelines in 2012, a figure that is fairly stable has been dropping slowly from year to year (when considering the same pipeline inventory). The crude oil transported represents about two thirds 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 2012, the total reported traffic volume was about $115x10^9$ m^3.km, slightly less than in 2011 and split between $77x10^9$ m^3.km for crude and $38x10^9$ 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 known to be related to pressure cycles rather 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 2012.

Over the 42 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 people were engulfed in fire, having themselves possibly 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. In all three cases the fatalities were not directly caused by the spillages but by fires occurring during the remediation process. 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.

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 2012.

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 perpetrators 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, and the fire 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 (2008-12)

4.1. 2012 SPILLAGE INCIDENTS

A total of 12 spillage incidents were recorded in 2012. **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 2012 incidents

Event	Facility	Line size	Product	Injury	Fire	Spilled volume		Contamination	
Design and Materials									
495	Underground joint (flange)	16	Diesel	-	-	1.0	0.0	Insignificant	
Corrosion									
External									
493	Underground pipe	10	White product	-	-	1.0	0.0	Insignificant	
494	Underground pipe	10	White product	-	-	1.0	0.0	Insignificant	
Internal									
492	Underground pipe	10	Crude oil	-	-	2.5	0.0	150	
Third party activity									
Accidental									
488	Underground pipe	8.6	Jet fuel	-	-	1.0	1.0	200	
489	Underground pipe	24	Diesel	-	-	5.0	0.0	20	
497	Underground pipe	10	Diesel	-	-	20.0	0.0	Not reported	
Intentional/Malicious									
486	Underground pipe	10	Diesel	-	-	7.0	7.0	300	S
491	Underground pipe	20	Crude oil	-	-	37.0	12.0	10000	G
Incidental									
487*	Underground pipe	6	Diesel	-	-	15.0	15.0	10	G
490	Underground pipe	10	Gasoline	-	-	240.0	175.0	15000	
496	Underground pipe	10	Diesel	-	-	40.0	0.0	Not reported	

(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

** Tentative classification pending on-going investigation*

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 one spillage incident related to Design and Materials in 2012.

Event 495:
A small leak at a flanged joint in an underground section of a product line was discovered during routine monitoring. The leak was detected by the operator during routine surveillance and quickly brought under control. Although some soil was removed as a precaution, there was no significant environmental impact.

4.1.2. Operational activities

There were no spillages in this category in 2012.

4.1.3. Corrosion

There were 3 spillage incidents related to corrosion in 2012.

4.1.3.1. External corrosion

Event 493:
A small leak in a product line was discovered during routine monitoring. This was traced to external corrosion caused by an old wood spacer not removed after construction and which damaged the protective coating. Although some soil was removed as a precaution, there was no significant environmental impact.

Event 494:
A small leak in a product line was discovered during routine monitoring. This was traced to external corrosion caused by contact with an old piece of metal left in the ground probably during the construction. Although some soil was removed as a precaution, there was no significant environmental impact.

4.1.3.2. Internal corrosion

Event 492:
An oil leakage was reported on a private property. The source of the leak was determined to be the nearby buried crude pipeline. The incident was reported to the Authorities.

Initial activities focused on isolating the pipeline, minimizing the volume of leaked oil (diesel) and cleaning up this oil. The total volume of leaked oil was estimated at 2.5 m^3.

Upon investigation, a very small single penetrated defect (leak path) was identified. This defect had a very unusual morphology and destructive testing was unable to confirm the corrosion type with any degree of certainty. Additional, non-penetrating, defects from close to the penetrated defect site were also destructively tested. The morphology of these additional defects clearly showed oxygen corrosion. This conclusion was confirmed in reviews held with corrosion experts.

The size of the pinhole defects was below that of the detection specification of In Line Inspection pigs (both MFL and UT types). Tests are ongoing to determine whether UT pigs could detect this size of defect.

4.1.4. Natural causes

There were no spillages in this category in 2012.

4.1.5. Third party activity

There was 7 confirmed incidents in this category in 2012 plus one incident tentatively classified as “third party incidental”.

4.1.5.1. Accidental

Event 488:
A product pipeline was hit by a plough in a field. The machinery was operated by the landowner who was aware of the existence of the pipeline on his property. The impact caused a fissure in the pipe and some product leaked into the ground and appeared on the surface.

The landowner contacted the local authorities who alerted the Operator's Dispatching Centre. The emergency plan was activated immediately (the pumps were stopped in that moment). The pipeline was uncovered and the leak brought under control. The next day the damaged pipe was replaced and the contaminated soil was removed.

The depth of cover was found to be less than expected. This is a 55 year old line and a programme is underway to restore the depth of cover to about 800 mm in areas where it has decreased. This particular section was not considered high priority as the land had not been under cultivation for many years.

Event 489:
In a section with two adjacent lines owned by different operators, one of the owners drilled into the wrong line. A crude oil leak ensued. Operation was immediately stopped and the leak brought under control.

The pipeline was repaired. Polluted soil was excavated and cleaned.

Event 497:
A third party excavator hit and ruptured the pipeline while cleaning an irrigation channel.

4.1.5.2. Intentional / Malicious

Event 486:
A leak from an underground section of a product pipeline was reported by a third party. It appeared that thieves had uncovered the pipeline and installed a small bore connection with a valve connected to a rubber pipe leading to a parking area in a small wood about 400 m away. Following a pressure surge during start-up, the rubber pipe ruptured causing pollution to the surroundings.

It is believed that the thieves were able to divert some product from the pipeline at low flow rate below the detection limit of the system.

A small stream and water meadow were contaminated and skimmers were installed to protect a larger stream nearby. Approximately 400 t of soil were removed.

Event 491:
The Environmental authorities were informed by a citizen of a strong smell coming from the retention pit for a manifold on a crude line. The pipeline control centre was alerted and pumping immediately stopped. A leak was discovered near a valve, caused by a drill hole. This was identified as vandalism rather than theft attempt.

The retention pit was emptied with a suction trunk and the soil around was removed and sent to waste treatment.

4.1.5.3. Incidental

Event 487:
An outside party reported a hydrocarbon leak in the vicinity of a product pipeline. A failure was detected in the line. Some groundwater was affected.

The failure mode is under investigation. Indications are that the root cause may have been some earlier damage to the line although this still has to be confirmed. Tentatively, we have classified this event as “Third party Incidental” although this may be reviewed when investigations are complete.

Environmental investigation and remediation are in progress.

Event 490:
A product pipeline failed as a result of a pressure surge following an emergency shutdown. The leak was detected by the automatic detection system.

Upon investigation, it appeared that the failure had occurred in an area that had been dented and scratched by third party activities at some point after the last in line Inspection pig (carried out in 2011). The defect created a zone of concentrated stress under higher than usual pressure (under normal circumstances the elasticity limit of the steel would be well above the maximum recorded pressure).

About 4 m^3 of hydrocarbons reached the groundwater. This was pumped out and monitoring put in place. The most polluted excavated soil (about 300 m^3) was biologically treated. The balance of polluted soil (1700 m^3) is being treated on site by sieving and land farming as required.

Event 496:
A double dent caused by a third party excavator at some point in the past caused a crack in the pipeline, releasing some diesel. An anomaly had indeed been detected by in-line inspection but classified as “ovality”, hence not further investigated.

4.2. 2008-2012 SPILLAGE OVERVIEW

Table 2 shows the spillage performance for the 5-year period 2008-2012. Of the 40 spillages recorded for the period, 33 caused some temporary environmental contamination. 5 spillages affected surface waters and 7 affected groundwater but none had any impact on potable water supplies.

At 12, the number of reported spillages in 2012 was the highest for the last 5 years and close to the running average of 11.8 per year since CONCAWE records began in 1971.

The total reported gross lost volume was 371 m^3 (this does not include the unknown volume extracted by the thieves in relation to event 487). Historically it is a low number compared to the averages of 1499 for the last 5 years and 1943 m^3 since records began in 1971. All spilled oil was recovered in 7 events. Overall about 45% of the spilled oil was recovered.

Table 2 Five-year comparison by cause, volume and impact: 2008 – 2012

		2008	2009	2010	2011	2012	2008-2012
Combined Length	km x 10^3	35.5	34.6	34.6	36.0	36.3	35.4
Combined Throughput	m^3 x 10^6	780	872	790	714	701	771
Combined traffic volume	m^3 x km x 10^9	130	125	125	119	119	124
Spillage incidents		**12**	**5**	**4**	**7**	**12**	**40**
MECHANICAL FAILURE							
Construction		2	1				3
Design and Materials		5	3	2	1	1	12
OPERATIONAL							
System							
Human					2		2
CORROSION							
External		1		1		2	4
Internal						1	1
Stress corrosion cracking							
NATURAL HAZARD							
Subsidence							
Flooding							
Other							
THIRD PARTY ACTIVITY							
Accidental		4		1	1	4	10
Intentional/Malicious					3	2	5
Incidental			1			2	3
Volume spilled	m^3						**Average**
Gross spillage		968	5476	336	343	371	1499
Net loss		167	833	1	308	210	304
Average gross loss / incident		81	1095	84	49	31	268
Average net loss / incident		14	167	0	44	18	48
Average gross loss/1000 km		27	158	10	10	10	42
Average net loss/1000 km		5	24	0	9	6	9
Gross spillage/ throughput	ppm	1.2	6.3	0.4	0.5	0.5	1.8
Gross spillage per cause							
Mechanical failure		562	5466	135	NA	1	1541
Operational		0	0	0	36	0	7
Corrosion		1	10	1	0	5	3
Natural hazard		0	0	0	0	0	0
Third party activity		406	0	200	307	365	256
Net loss distribution							
(No of incidents)							
< 10		9	2	4	2	9	26
11 -100		2	2		3	2	9
101- 1000		1	1		1	1	4
> 1000 m^3							0
Environmental impact							
NONE		2		1	1	3	7
SOIL (affected surface area)							
< 1000 m^2		4	1	1	6	7	19
> 1000 m^2		5	1	1		2	9
WATER BODIES							
Surface Water			1	2	1	1	5
Groundwater		1	2	1	1	2	7
POTABLE WATER							

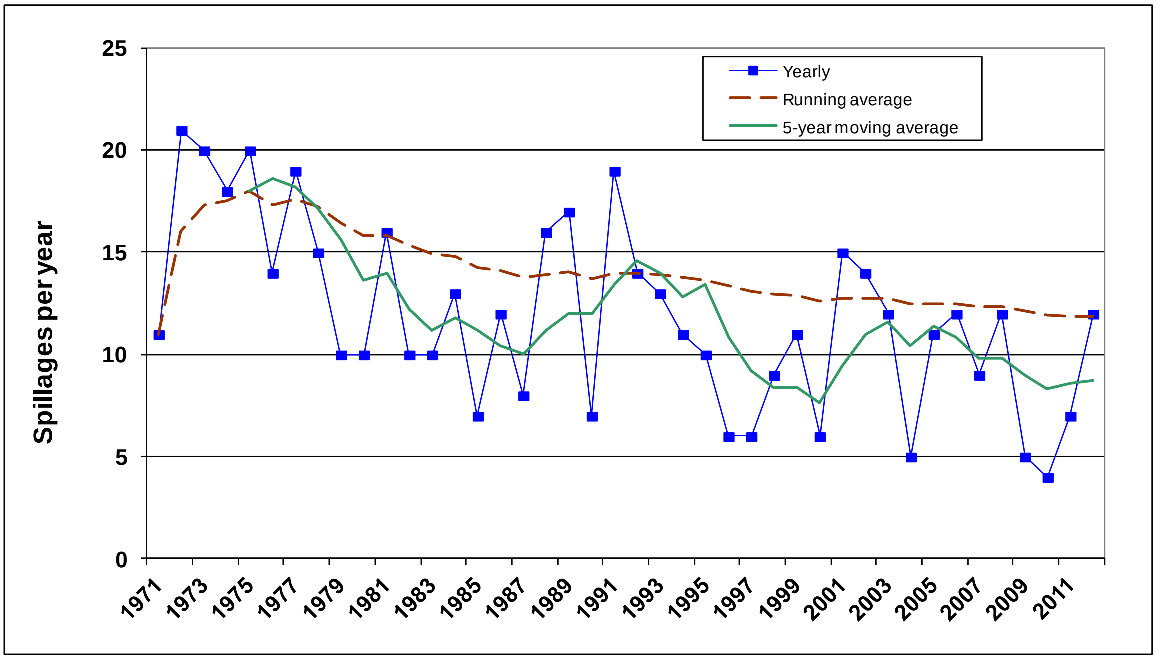
5. HISTORICAL ANALYSIS OF SPILLAGES 1971-2012

5.1. NUMBERS AND FREQUENCY

Over the 42-year survey period there have been 497 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 (note that such hot pipelines have now virtually disappeared from the active inventory with only 60 km left in operation).

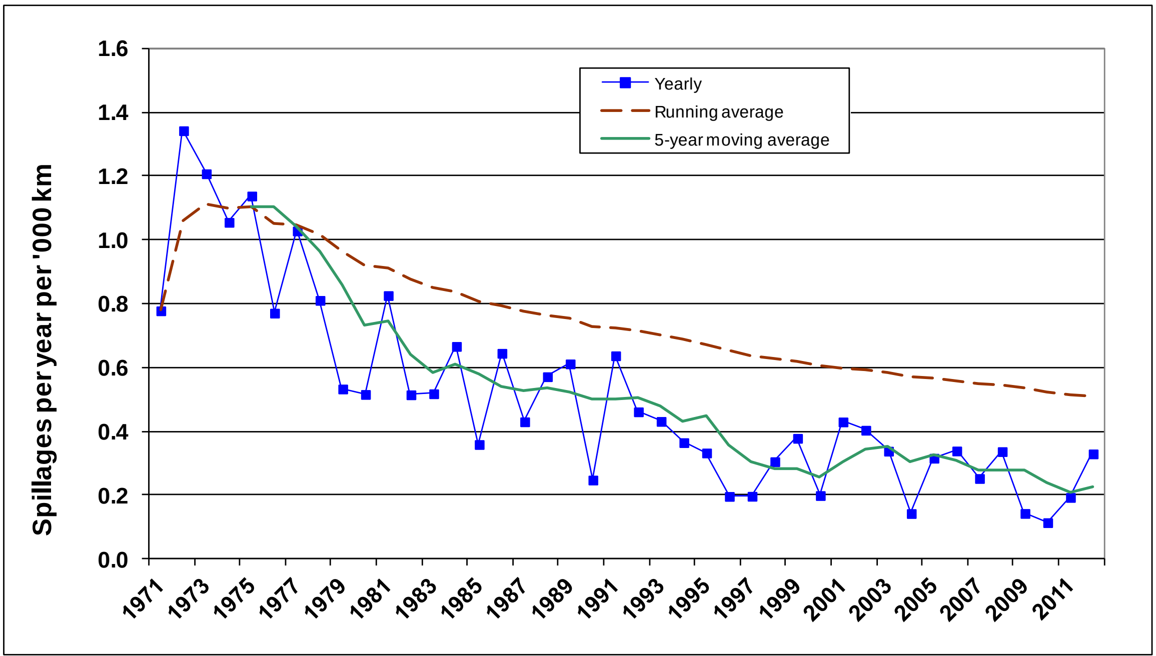
Figure 4 shows the number of spillages per year, moving average and 5-year average trends over the 42 years since 1971 for all pipelines. There is a clear long-term downward trend which bears witness to the industry's improved control of pipeline integrity. The overall 5-year moving average has reduced from about 18 spillages per year in the early 1970s to 8.7 by 2012. The moving average increases in the late '80s to early '90s and again in the early 2000s 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 42-year trend of the annual number of spillages (all pipelines)



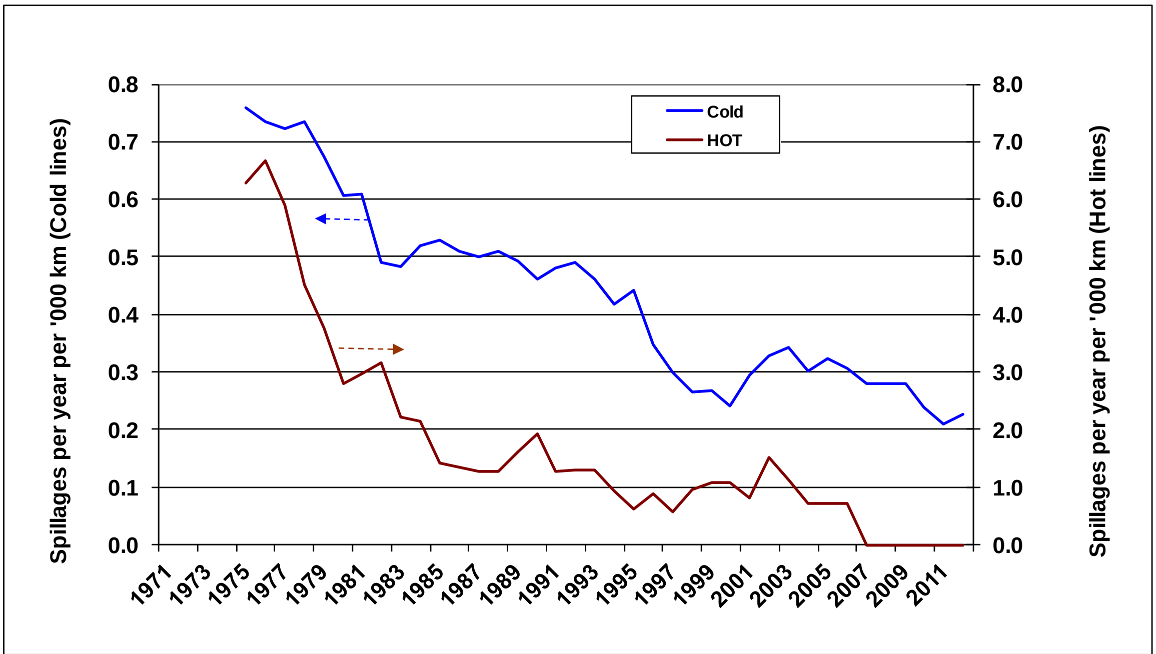
Several step changes in the inventory surveyed by CONCAWE over the years clearly make the absolute numbers difficult to interpret. The spillage frequency i.e. number of spills per unit length of pipeline is therefore a more meaningful metric. **Figure 5** shows the same data as **Figure 4**, now expressed 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 0.2 spills per year and per 1000 km of pipeline today.

Figure 5 42-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. There were 3 spillages between 1996 and 2000 and the last recorded one was in 2002. As a result recent frequency figures are not meaningful.

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 41 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 prevalent cause of spillage, mechanical causes have increased in the last 15 years to be now on a par with third party causes. A more complete analysis of causes is given in **Section 6**.

Figure 7 Hot pipelines spillage frequencies by cause

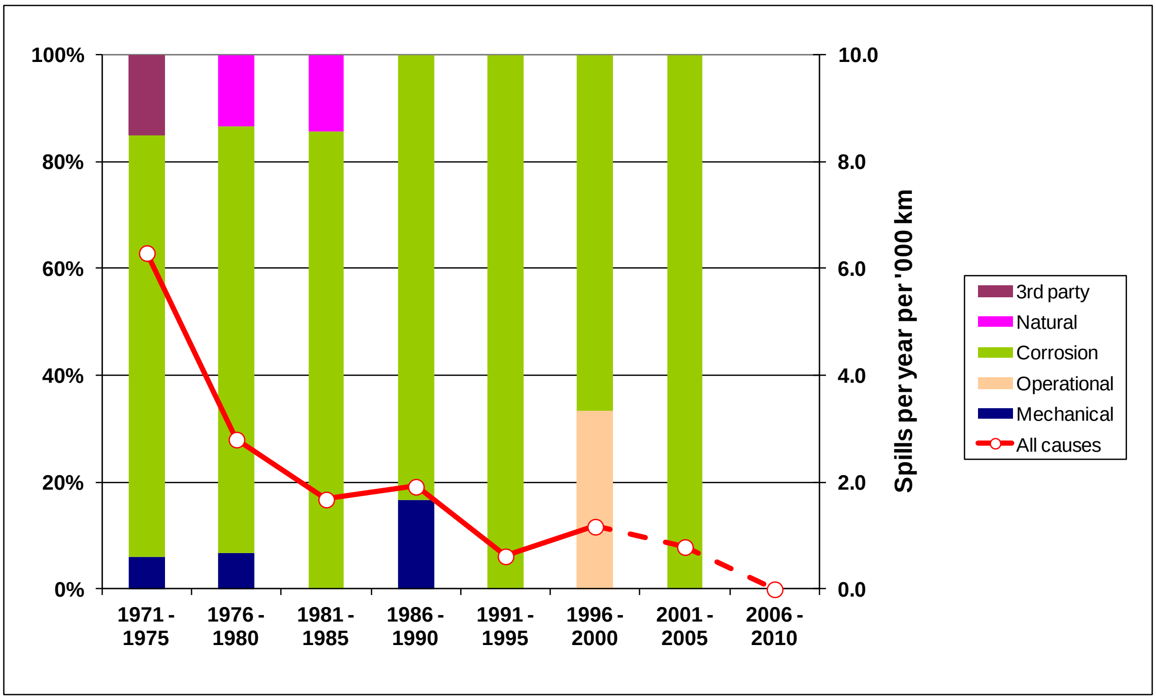
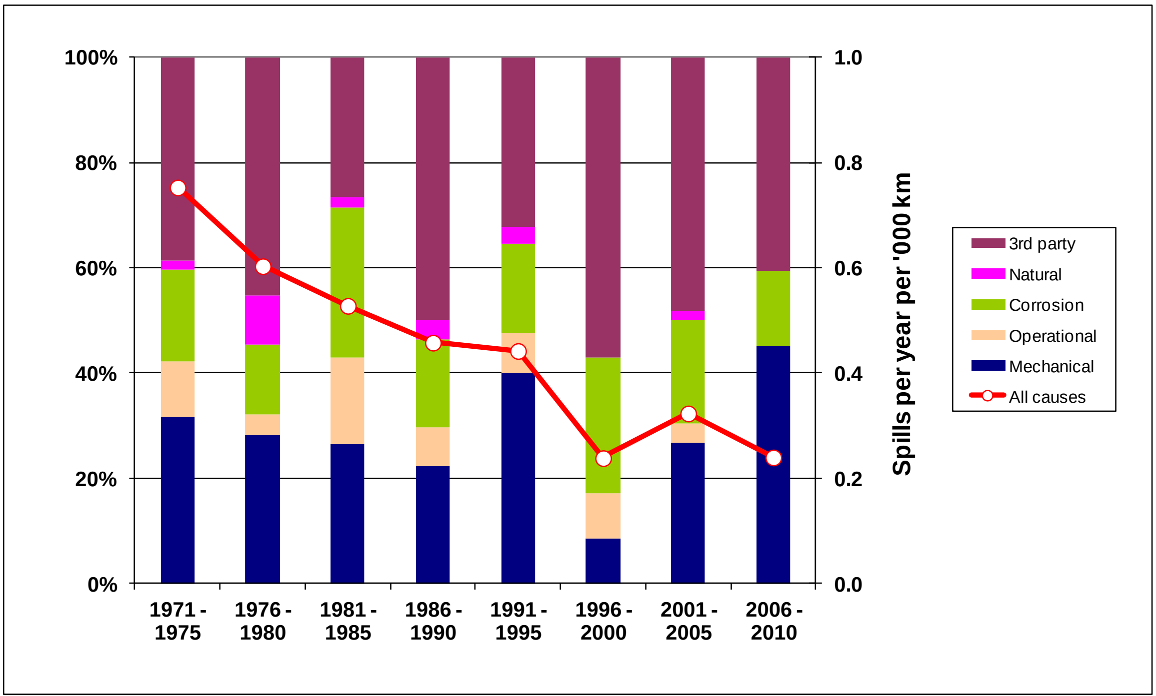


Figure 8 Cold pipelines spillage frequencies by cause



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. The 5-year running average of the annual recovery percentages (gross-minus-net / gross) shown in **Figure 12** increased around the turn of the century and now appears to have settled around 60-70%. Over the whole period, the average recovery of the spilled oil is 58% leaving an average net loss of oil to the environment of 68 m^3 per spill.

Figure 9 Gross spillage volume

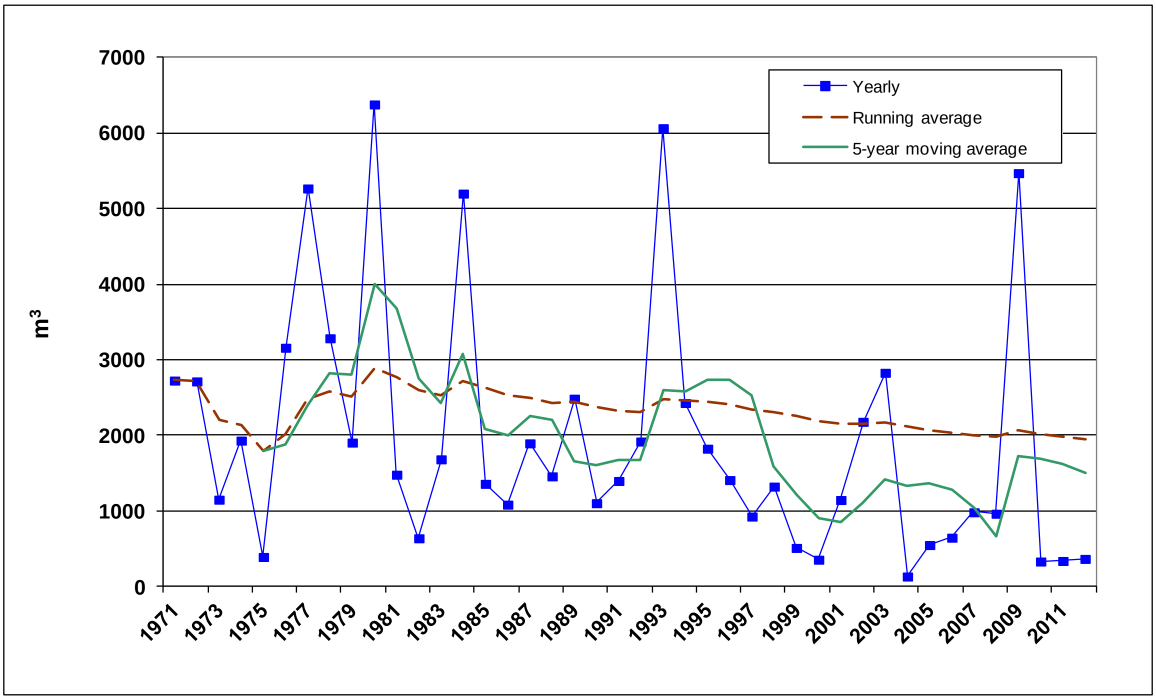


Figure 10 Gross spillage volume per 1000 km

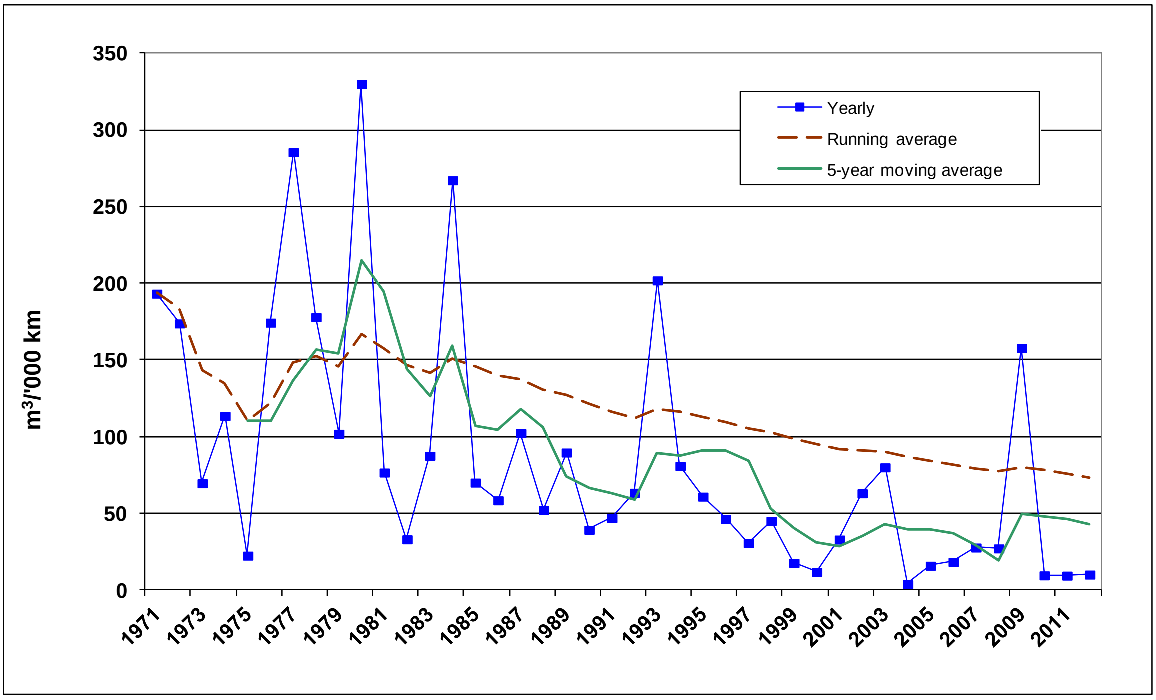


Figure 11 Gross yearly spillage volume as a proportion of throughput

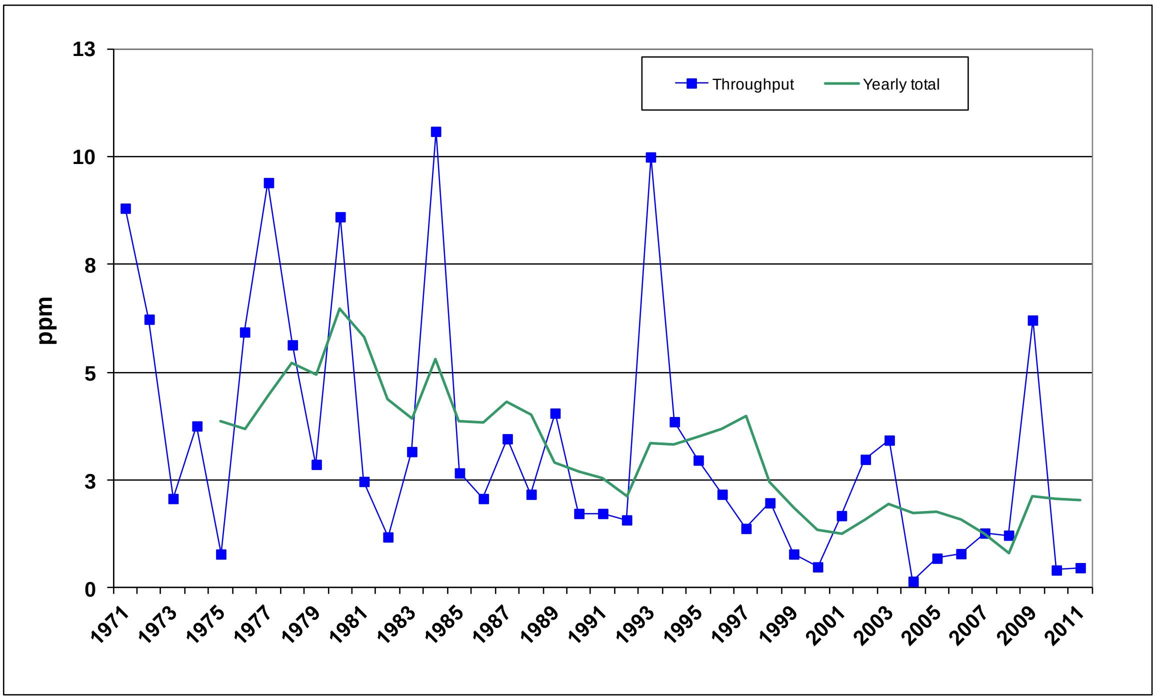
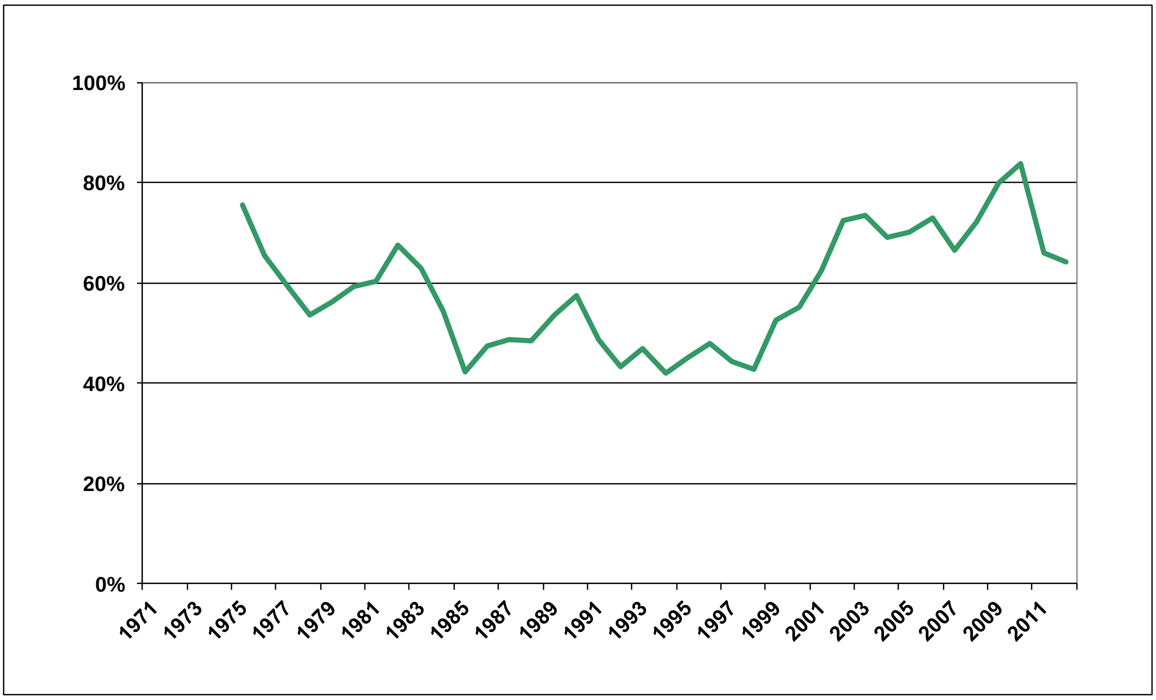


Figure 12 Spilled oil recovery (5-year moving average)



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. A single very large spill recorded in 2009 pushed up this figure to 176 m^3 per spill (187 m^3 in 2012). For the last 4 years the average is 46 m^3. 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)

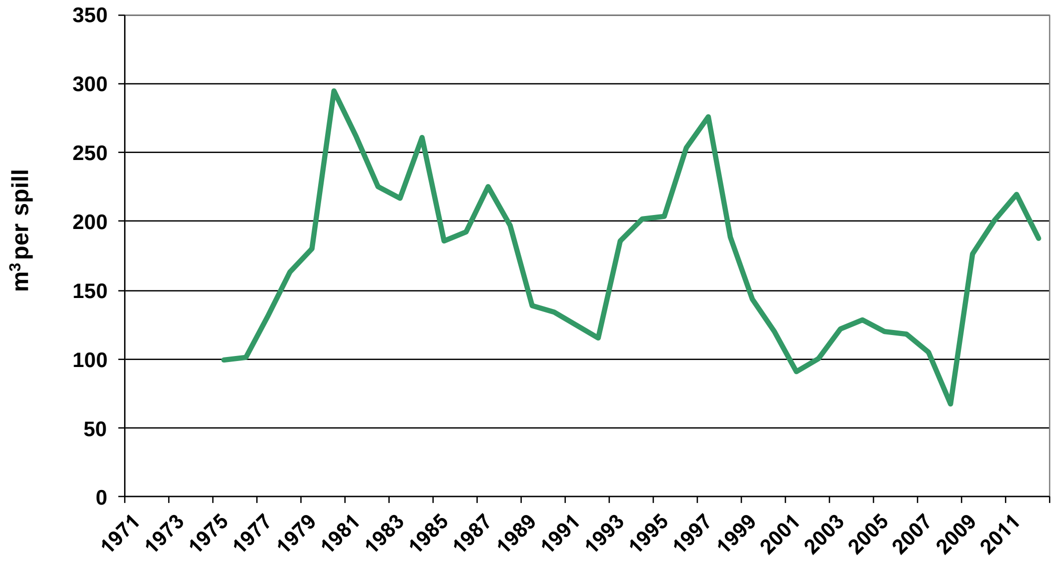


Figure 14 shows the average spill size for each cause category. The largest spillages on average have resulted from mechanical failure, third party activities and natural hazards, whereas operational problems and corrosion have caused smaller spills. As a rule of thumb, on average the three “largest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

Figure 14 42-year average gross spillage volume per event by cause

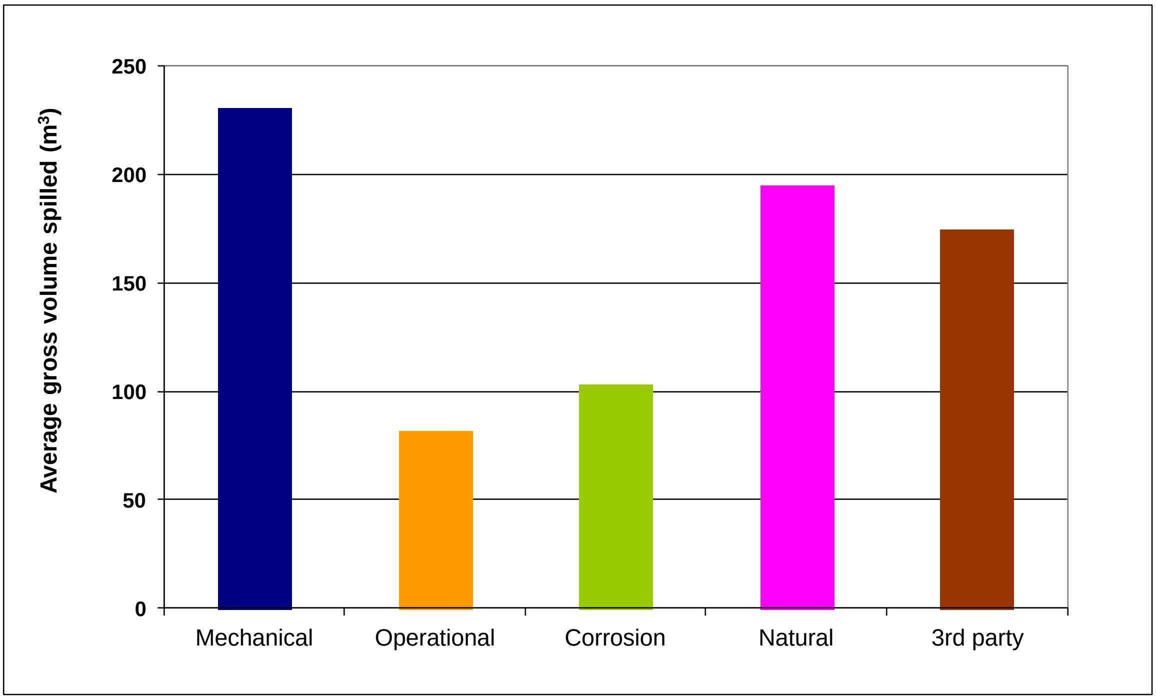
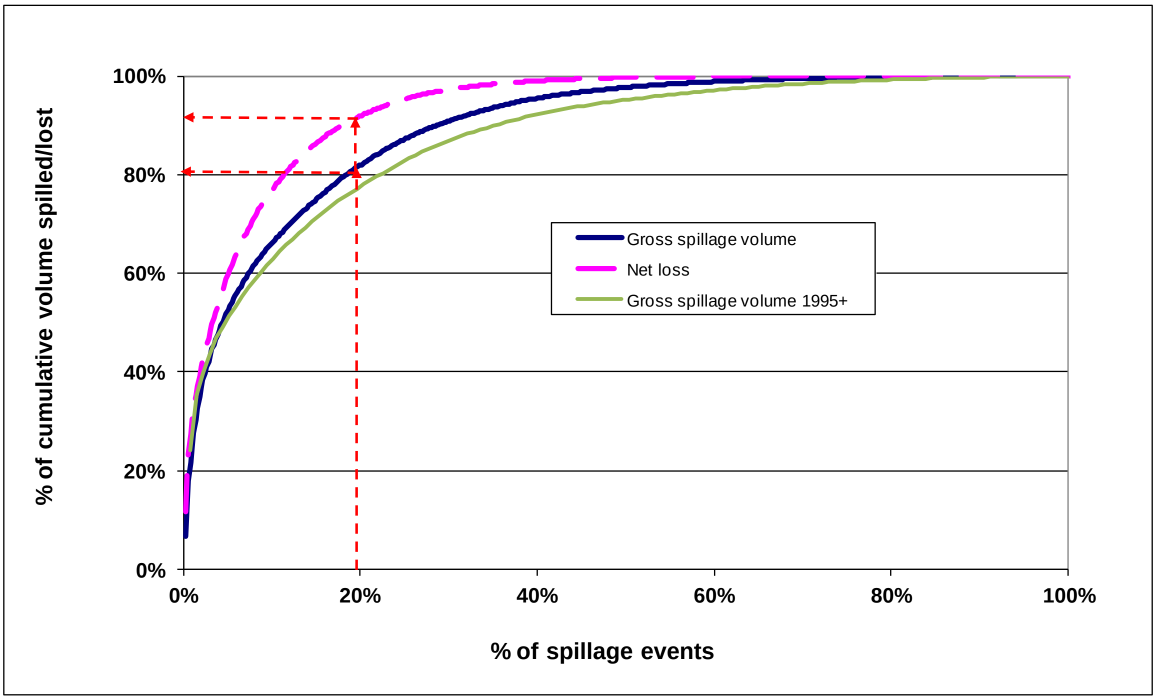


Figure 15 shows the distribution of spillage sizes, demonstrating that less than 20% of all spillages account for 80% of the cumulative gross volume spilled and over 90% of the net spillages, with little change over the years. Clearly a majority of the spillages recorded in the CONCAWE database were 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 42 years and since 1995)



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.

Note that the “no hole” category was only introduced in the mid 00s. Before that time the hole size for such events was reported as “unknown” or left blank.

Out of the 497 spillages, hole size data are only available for 286 (58%). 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		12	33	45	88	51	57	286
	%	4%	12%	16%	31%	18%	20%	100%
Hole caused by								
Mechanical		8	4	14	13	16	7	62
Operational		1	0	1	1	3	4	10
Corrosion		0	23	11	23	17	5	79
Natural hazard		0	1	2	0	2	2	7
Third party		3	5	17	51	13	39	128
Gross average spillage per event	m^3	45	49	245	89	242	362	285

Spillages not involving a hole in the lines normally relate to failures of fittings and other ancillary equipment (gaskets, pump seals, etc), hence the strong link to mechanical failures. Pinholes are mostly caused by corrosion. Larger holes are often the result of third party activities, although corrosion and mechanical failures also take their share.

The majority of third party incidents result in larger holes.

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 evolution of the number of events per 1000 km of pipeline inventory (frequency) by hole type and 5-year period. Note that early figures (say before 1985) are not very representative as hole type was not commonly reported at the time. There is no discernible trend.

Table 4 Spill frequency by hole size

Event/1000 km	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-05	2006-10	2011-12
No hole	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.03
Pinhole	0.27	0.10	0.08	0.13	0.07	0.20	0.17	0.14
Fissure	0.32	0.21	0.29	0.20	0.24	0.17	0.09	0.14
Hole	0.16	0.41	0.54	0.37	0.54	0.63	0.28	0.11
Split	0.64	0.41	0.46	0.23	0.10	0.20	0.03	0.06
Rupture	0.27	0.31	0.33	0.43	0.17	0.26	0.28	0.03
All reported events	1.67	1.45	1.70	1.37	1.11	1.47	1.17	0.50
Not reported	1.99	1.45	0.79	0.87	0.17	0.17	0.03	0.03

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 underground pipeline runs (**Table 5**). However, a sizeable proportion of incidents are related to valves, flanges, joints and small bore connection failures indicating that these 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

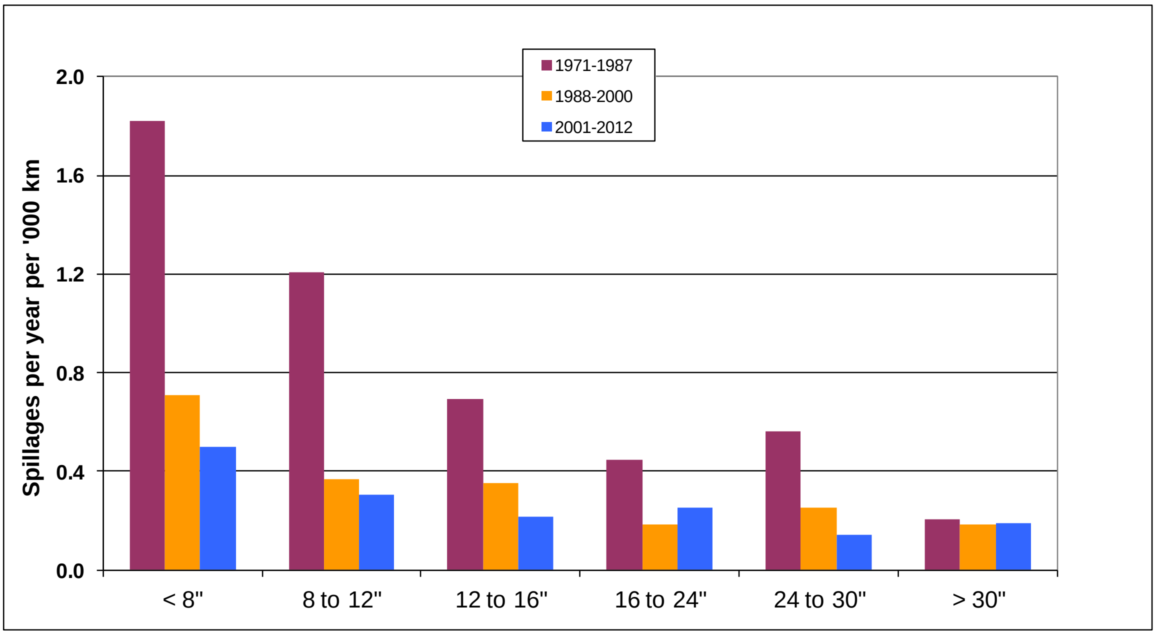
	Total	Bend	Joint	Pipe run	Valve	Pump	Pig trap	Small bore	Unknown
Mechanical	*127*	1.8%	8.5%	6.4%	4.0%	0.6%	0.4%	2.8%	1.0%
Operational	*33*	0.0%	0.4%	1.2%	2.2%	0.2%	0.6%	1.0%	1.0%
Corrosion	*134*	0.2%	1.8%	23.3%	0.0%	0.0%	0.2%	0.6%	0.8%
Natural	*15*	0.0%	0.2%	2.4%	0.0%	0.0%	0.0%	0.4%	0.0%
3rd party	*188*	0.2%	0.6%	34.0%	1.2%	0.0%	0.0%	0.8%	1.0%
All		2.2%	11.5%	67.4%	7.4%	0.8%	1.2%	5.6%	3.8%
	497	*11*	*57*	*335*	*37*	*4*	*6*	*28*	*19*

Percentages are related to the total of 497 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 2012. 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 (78%) occurred in the cross-country pipelines themselves. The type of location has been reported for a total of 425 spillages (out of 497). 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	17	3/14	5%	2	6%	0	0%
Residential low density	195	55/140	59%	11	32%	8	14%
Agricultural	28	2/26	8%	3	9%	3	5%
Industrial or commercial	79	19/60	24%	17	50%	48	81%
Forest Hills	9	2/7	3%	0	0%	0	0%
Barren	3	1/2	1%	0	0%	0	0%
Water body	1	0/1	0%	1	3%	0	0%
Total	332			34		59	
Unspecified				72			

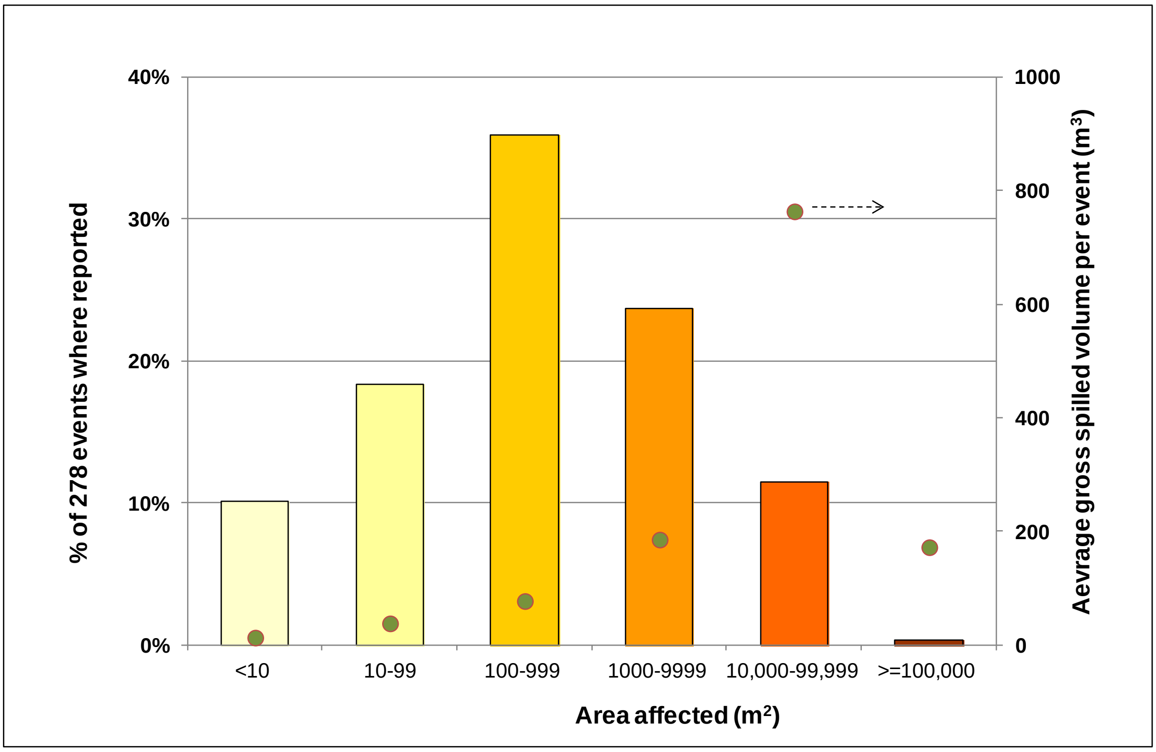
5.6.2. Ground area affected

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. Area data is available for 278 (56% of all recorded spillages). 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.

Only one spillage affected more than 100,000 m^2, although the gross volume spilt was relatively modest. For all other spillages, 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

We keep a record of whether 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 included. Of the 118 reported spillages since then, 14 have affected surface water, 16 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.

Underground pipeline spillages are most commonly first detected by a third party (52%), often those causing the incident in the first place. Automatic detection systems were involved in detecting only 12% 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 30% of underground spills were discovered via leak detection systems.

Failures in above ground lines are more readily detected by pipeline company resources presumably because they tend to be located in areas where personnel is more routinely present. This is even more the case for pumping stations.

Table 7 Discovery of spillages

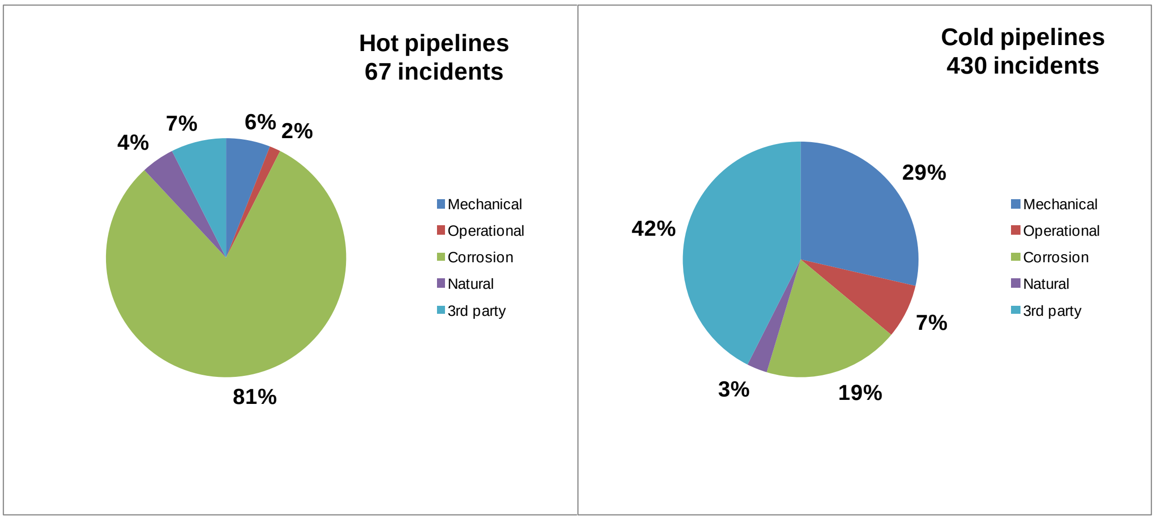
	Underground pipe			Above ground pipe			Pump Station		
	Number	%	Average gross spillage m^3	Number	%	Average gross spillage m^3	Number	%	Average gross spillage m^3
Right-of-Way surveillance by pipeline	35	9%	208	4	11%	43	1	2%	10
Routine monitoring by pipeline operator	84	21%	369	15	39%	92	36	58%	83
Automatic detection system	47	12%	152	3	8%	37	11	18%	48
Pressure testing	22	6%	141	1	3%	30	3	5%	18
Outside party	204	52%	127	15	39%	92	11	18%	45
Internal Inspection	4	1%	6	0	0%	0	0	0%	0
Total	396		188	38		81	62		50

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 third party-related incidents and mechanical failure 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 (largely related to excavations).

There is a wider 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 affected by ageing. Specific attention is being paid to this, as will be seen in the detailed discussion in **section 6.1 and 6.3** below.

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

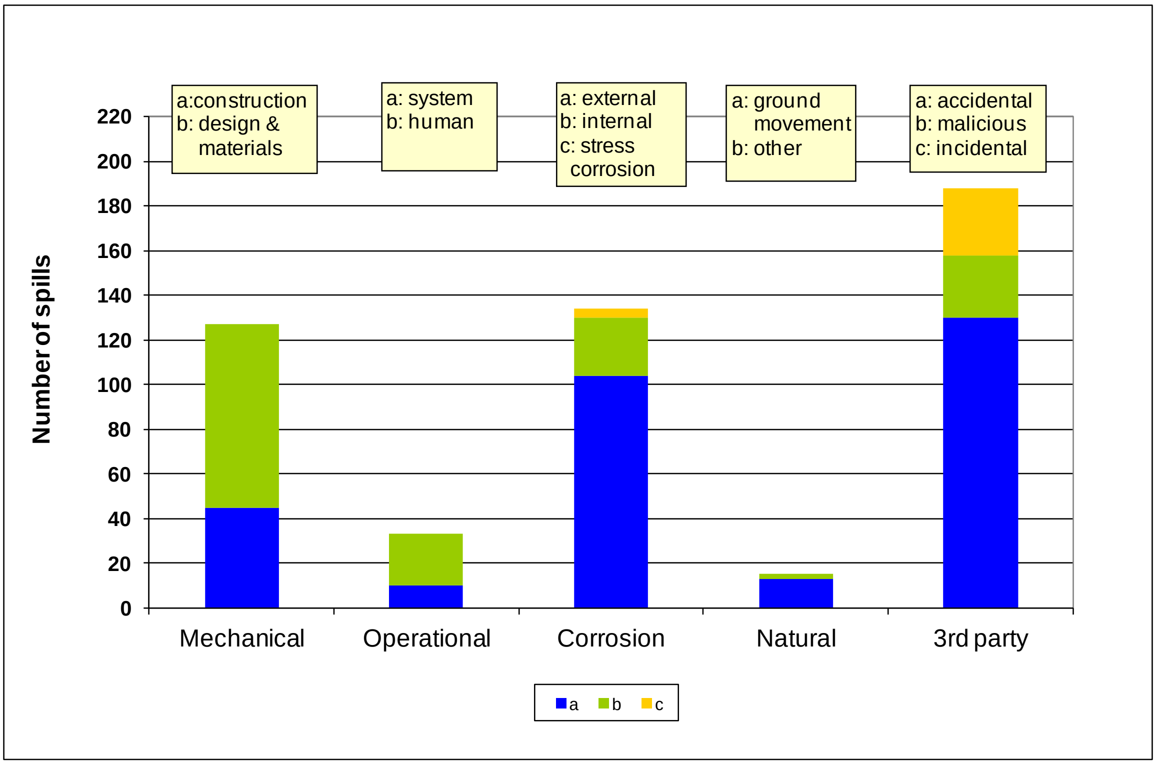
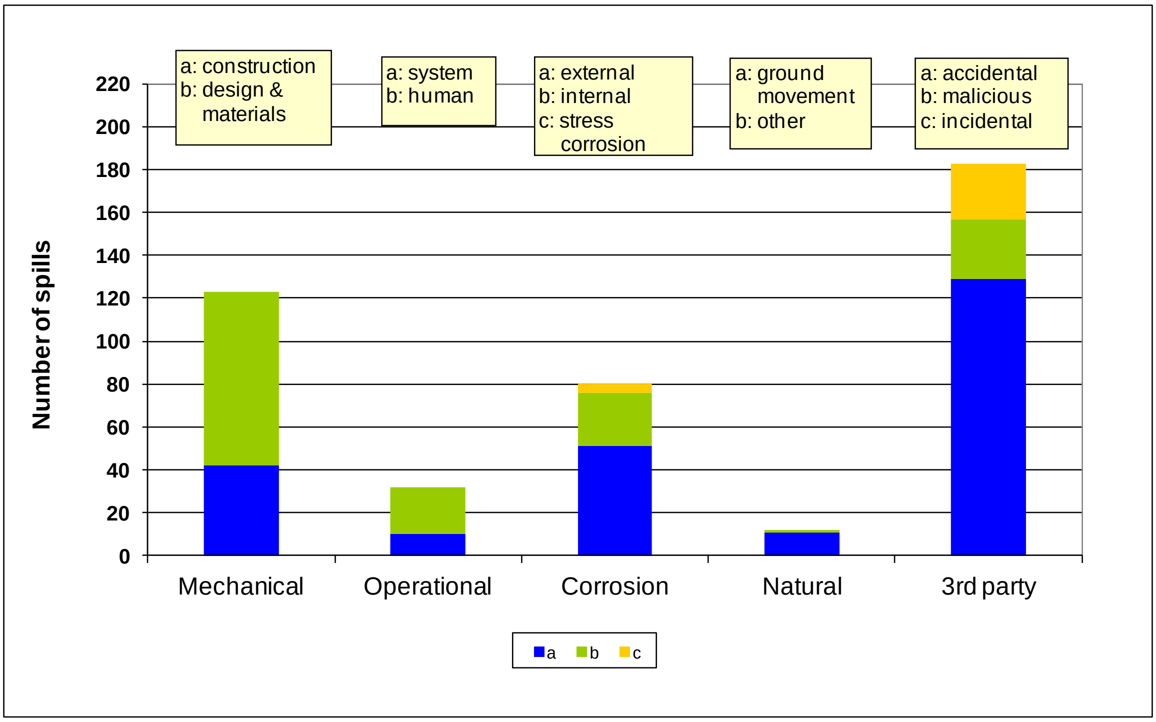


Figure 20 Distribution of major and secondary spillage causes – Cold pipelines



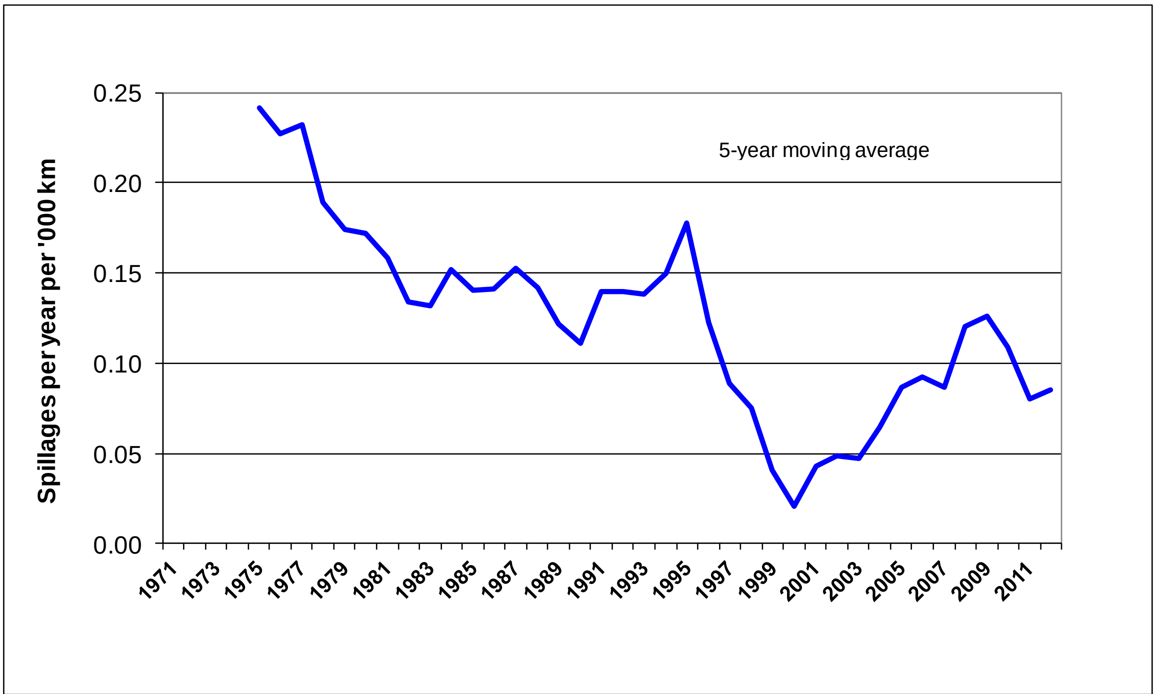
6.1. MECHANICAL

There have been 127 cases of mechanical failure, 26% of the total of 497 spillage events. This is an average of 3.0 spillages per year. 45 failures were due to construction faults and 82 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 2011 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 appeared to have reversed from the beginning of the last decade. The figure was, however, low in the last 4 years.

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
	9	31	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 reported between 2001 and 2010 were further investigated in cooperation with the relevant operators. It was found that only 4 events could probably 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 33 spillage incidents related to operation, 7% of the total of 497 spillage events. This is an average of 0.8 spillages per year. 23 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	2	1

6.3. CORROSION AND IMPACT OF AGEING

There have been 134 failures related to corrosion, 27% of the total of 497 spillage events. This is an average of 3.2 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 80, 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	51	104
Internal corrosion	1	25	26
Stress corrosion	0	4	4

Internal corrosion is much less prevalent than external corrosion. 19 out of the 25 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 80 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 inspection 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 497 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 188 events, an average of 4.5 per year and 38% of the total. 130 events were accidental, 28 were intentional (mostly theft attempts) and 30 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**.

The vast majority of events 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

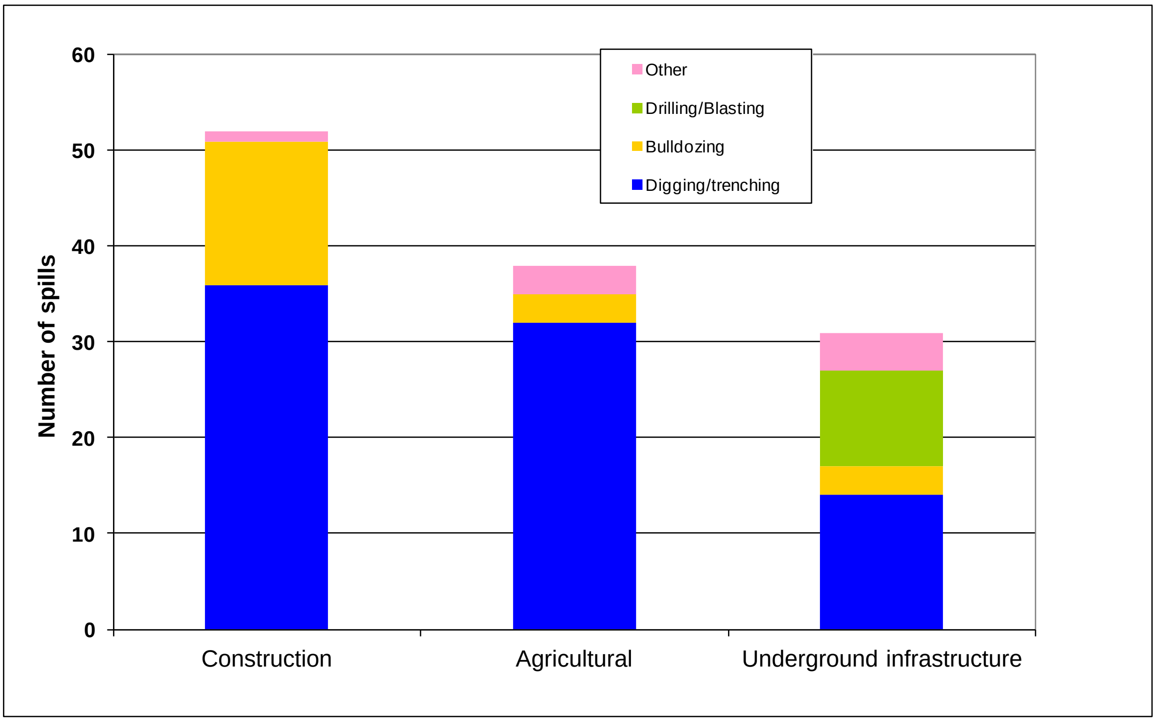
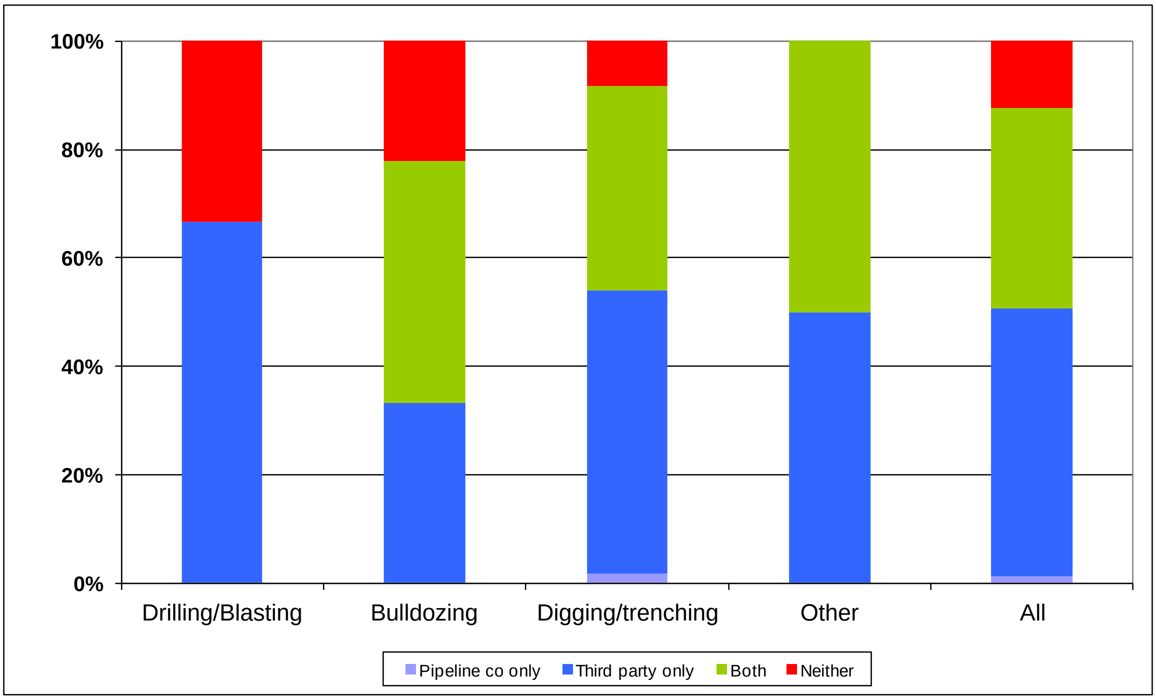


Figure 24 shows the awareness data (reported for about 80% of the third party-related spillages) as the percentage of cases where each party was aware of either the impending activity (pipeline operator) or the presence of a pipeline (machinery operator).

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 34% of the cases the pipeline was hit in spite of the fact that the pipeline operator knew 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.

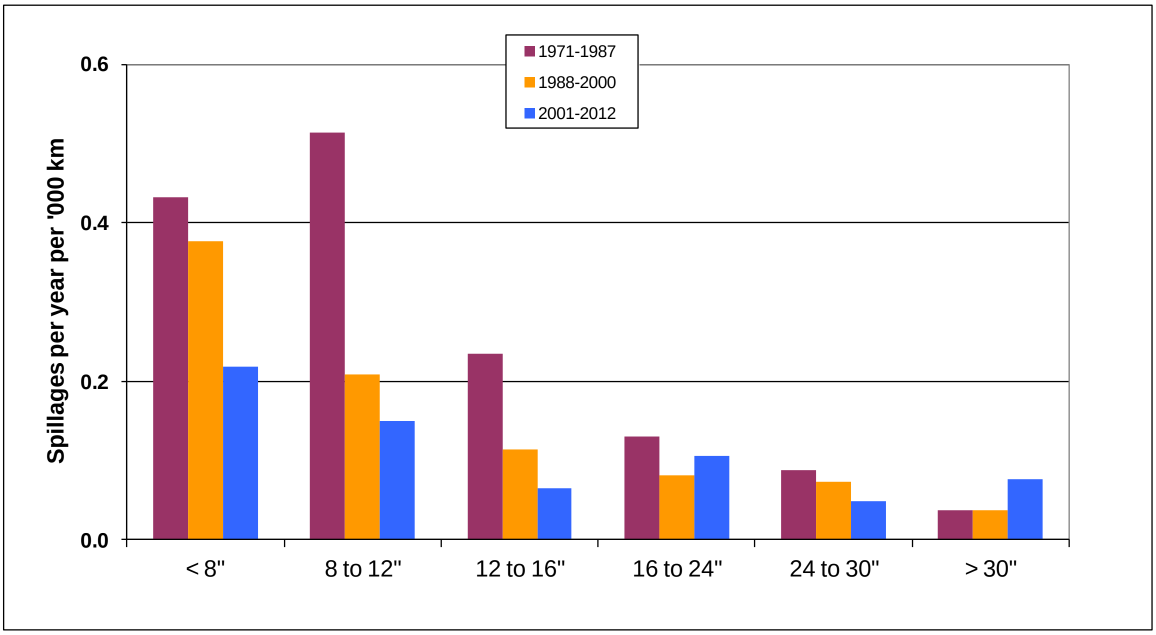
Figure 24 Awareness of impending works and of pipeline location



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 28 spillages caused by intentional damage by third parties: 2 as a result of terrorist activities, 6 from vandalism but the majority (20) from attempted or successful product theft.

Only one 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 more common feature of the spillage statistics, including 2 such incidents in both 2006 and 2007, 3 in 2011 and 1 in 2012. In addition, a number of theft attempts have been discovered which fortunately did not lead to spillages, and hence outside the scope of this report.

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 30 incidental damage incidents. These all started off from dents, scrapes and suchlike. Thus they share the characteristic that they might be detectable by in-line inspections.

7. IN-LINE INSPECTIONS

CONCAWE has been collecting data on in-line inspection activities (inspection pig) for over 20 years, including a one-off exercise to collect back data from the time inspection pigs were first used around 1977. Separate records are kept for metal loss, crack detection and for geometry (calliper) 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 cannot, however, help prevent the leak occurring in the first place.

In 2012 the 65 companies who reported inspected a record total of 119 sections with at least one type of inspection pig, covering a total combined length of 13,050 km, split as follows amongst the individual types of pig:

- Metal loss pig 5699 km, 99 sections
- Crack detection pig 1720 km, 20 sections
- Geometry pig 5631 km, 90 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 7119 km (20% of the inventory).

As shown in **Figures 26 and 27**, the use of inspection 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. 2012 shows the highest rate of inspection on record in terms of number of sections, although 2010 was the record year for length.

Over the last ten years, a period considered as a reasonable cycle for this type of intensive activity, 442 (65%) of the total of 675 active sections included in the 2012 survey were inspected at least once by at least one type of pig, representing 78% 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 inspected with a pig. 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 26 Annual inspections by type of inspection pigs

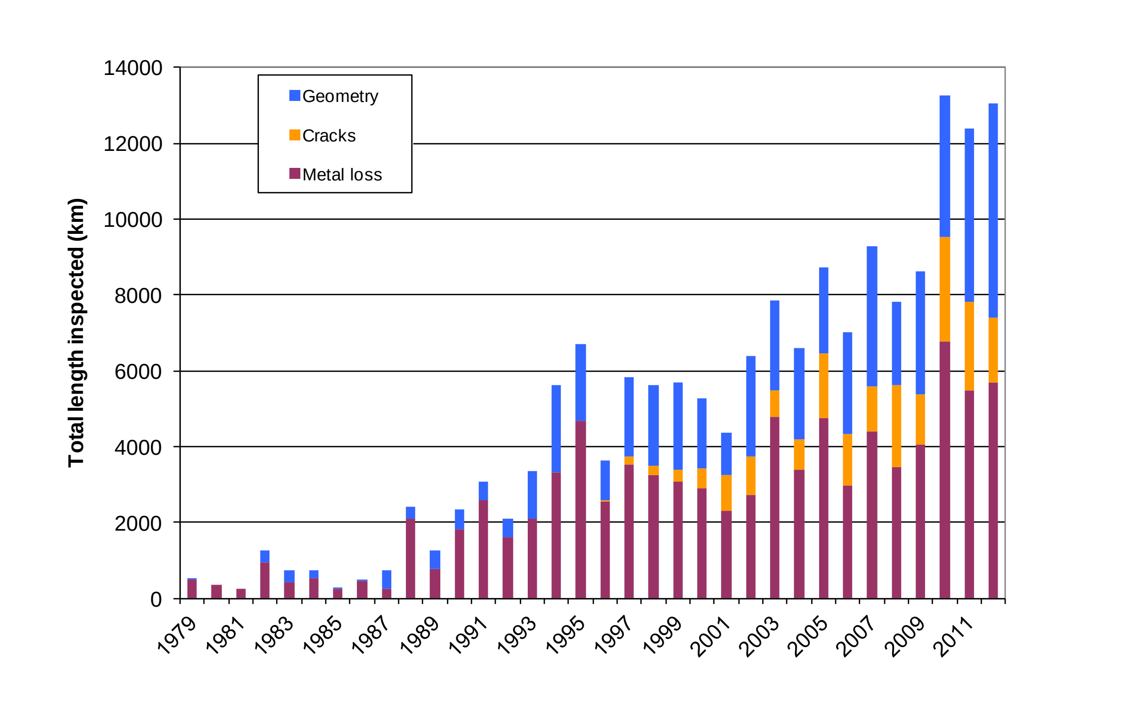
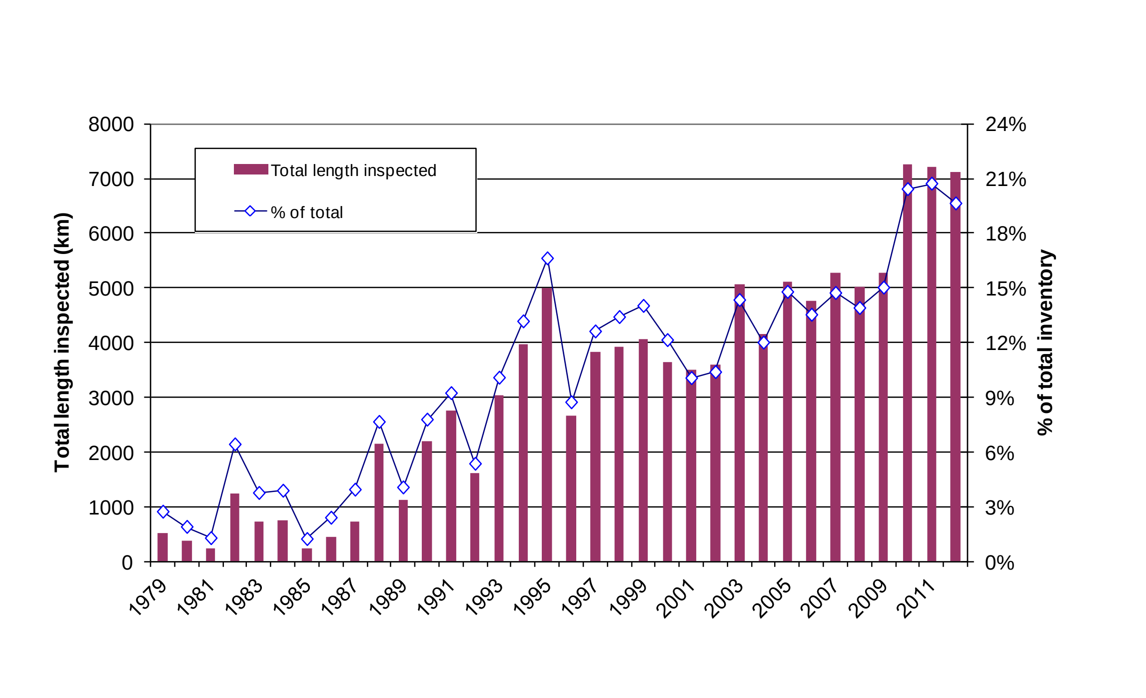
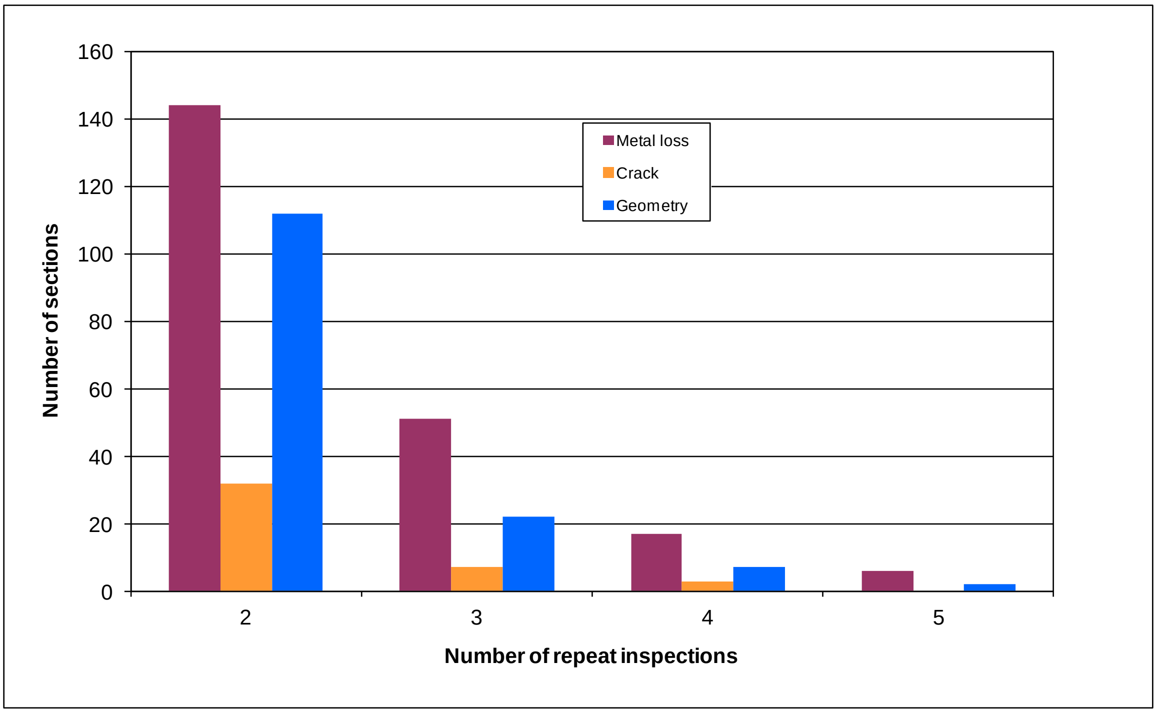


Figure 27 Total annual portion of the inventory inspected by inspection pigs



As shown in **Figure 28**, a number of sections have been inspected more than once during the last 10 years. Indeed, for some pipelines, regular inspection pig inspections are required by the authorities.

Figure 28 Repeat Inspections in the last 10 years



The inspection pig inspection technique only finds flaws, corrosion and other sorts of damage in or on the pipe inner or outer walls. Over the past 42 years, 52 spills have been caused by mechanical damage (including incidental damage by third parties) or faulty welds that could, in principle, have been detected by inspection pigs. There were 9 such spills in the last 10 years. There are also 104 spillages related to external corrosion and 26 to internal corrosion, at least some of which could in principle have been detected. Note that nearly two thirds of the 104 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 7 events related to external and internal corrosion respectively.

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 (m^3) Gross	Spillage volume (m^3) Net loss	Leak first detected by	Facility	Facility part	Age Years	Land use	Cause Category	Cause Reason	Impact Water bodies	Impact Contaminated land area (m^2)
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 (m^3)		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 (m^2)
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 (m^3)		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)
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 (m^3)		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)
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 (m^3) Gross	Spillage volume (m^3) Net loss	Leak first detected by	Facility	Facility part	Age Years	Land use	Cause Category	Cause Reason	Impact Water bodies	Impact Contaminated land area (m^2)
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 (m²)
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		
471		34	1			10	10	5	1	3	45	4	Ec		S	
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		
475	2010	2	1			125	0	5	3	2	0	3	Ab	3		200
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
479	2011	20	1			1	0	2	3	4	44	4	Bb	13		0
480		8	2			0.3	0.3	1	1	3	47	3	Ab	2	S	1,000
481		16	2			30	30	4	1	3	37	3	Eb	26		600
482		16	2			166	166	4	1	3	37	4	Eb	26		250
483		13	2			35	1	1	1	7	35	6	Bb	13		150
484		28	2			99	99	5	1	3	6	1	Ea	19	G	1,500
485		8	2			12	12	3	1	3	27	3	Eb	26		5
486		10	2			7	7	5	1	3	45	7	Eb	26	S	300
487		6	2			15	15	5	1	3	51	3	Ec	0	G	10
488		9	2			1	1	5	1	3	55	3	Ea	18		200
489		24	1			5	0	5	1	3	43	4	Ea	17		20
490		10	2			240	175	3	1	3	59	3	Ec	0		15,000
491		20	1			37	12	5	1	3	12	3	Eb	25	G	10,000
492		10	1			3	0	0	1	3	26	3	Cb	0		150
493		10	2			1	0	1	1	3	52	5	Ca	14		0
494		10	2			1	0	1	1	3	52	5	Ca	0		0
495		16	2			1	0	2	1	2	57	0	Ab	1		0
496		10	2			40	0	3	1	3	50	2	Ea	19		
497		10	2			20	0	3	1	3	50	3	Ea	18		

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