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Performance of European cross-country oil pipelines

Statistical summary of reported spillages in 2018 and since 1971

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Performance of European cross-country oil pipelines

Statistical summary of reported spillages in 2018 and since 1971

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ABSTRACT

Concawe has collected 48 years of spillage data on European cross-country oil pipelines. At nearly 36,000 km the current inventory includes the majority of such pipelines in Europe, transporting some 680 million m^3 per year of crude oil and oil products. This report covers the performance of these pipelines in 2018 and a full historical perspective since 1971. The performance over the whole 48 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. **Product theft attempts continued to be the main cause of spills in 2018 although the total number (10) confirmed the sharp decline observed in 2017 (11) from previous years (87 in 2015).** Another 2 spillage incidents were reported in 2018, corresponding to 0.06 spillages per 1000 km of line, about 40% of the 5-year average and an order of magnitude below the long-term running average of 0.45, which has been steadily decreasing over the years from a value of 1.1 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. One incident was related to a construction defect and the other caused by accidental third-party interference. **Although in recent years there have been relatively few incidents due to third party activities (excluding theft), this category remains the main source of spillage incidents.**

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

Data Collection and inventory statistics

Concawe has collected 48 years of spillage data on European cross-country oil pipelines with particular regard to spillage 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 2018 and provides a full historical perspective since 1971. The performance over the whole 48-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.

73 companies and agencies operating a total of 35,956 km of oil pipelines in Europe are currently listed for the Concawe annual survey. For 2018, 64 operators provided a full set of information representing over 131 pipeline systems and a combined active length of 32,886 km. The reported volume transported in 2018 was 703 Mm^3 of crude oil and refined products, somewhat lower than the 2017 figure. Total traffic volume in 2018 was about $117x10^9.m^3.km$.

In addition, Concawe could confirm from reliable industry sources that 3 other operators (representing 1213 km) did not suffer any spillages in 2018. Although not accounted for in the throughput, traffic and in-line inspections data, the additional inventory has been taken into account in the spills statistics. The 6 companies from which no data was obtained represent 444 km.

2018 spillage incidents

10 spillages related to theft attempts (third party intentional) were reported, close to the 2017 number (11) and in sharp decline from the record figures reported in 2015 (87) and 2016 (60). This is a good result although it is still relatively high compared to historical levels: 28 theft-related spillage incidents were reported between 1971 and 2012, and as many as 240 since then.

2 non theft-related spillage incidents were reported, corresponding to 0.06 spillages per 1000 km of line. This is about 40% of the 5-year average and nearly an order of magnitude below the long-term running average of 0.45, which has been steadily decreasing over the years from a value of 1.1 in the mid ‘70s. There were no reported fires, fatalities or injuries connected with these spills.

The 2 non-theft related spillages were in the Mechanical-Construction and Third party-accidental categories. Although in recent years there have been relatively few incidents due to third party activities (excluding theft), this category remains the main source of spillage incidents, after theft and mechanical failure. 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, but this trend has been reversed in the last 8 years.

When excluding theft events (for which the volume lost is unknown in most cases), the gross spillage volume was 49 m^3 or 1.4 m^3 per 1000 km of pipeline, which is lower than the 48-years average of 63 m^3 per 1000 km of pipeline. 97% of that volume was recovered.

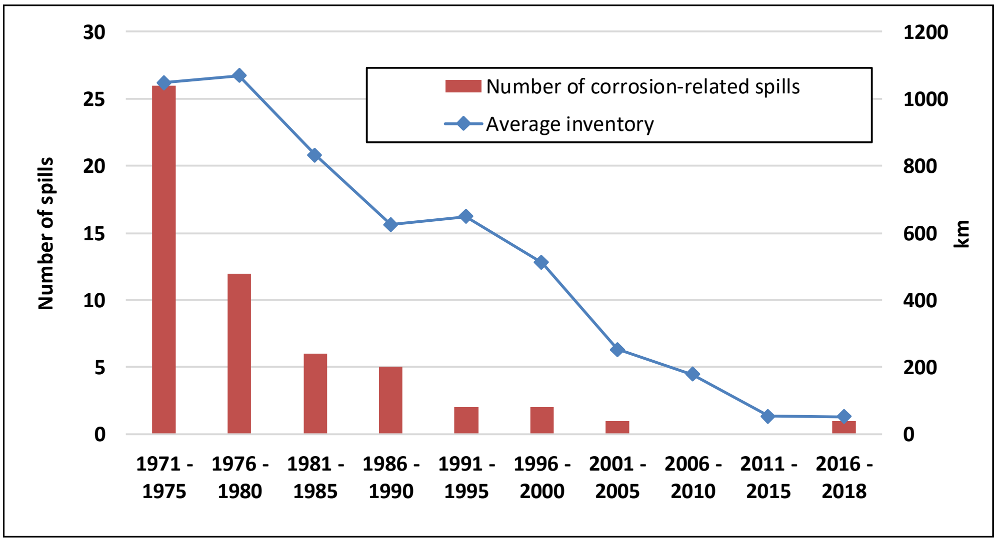
In-line inspections

In 2018 a total of 65 sections covering a total of 11,730 km were inspected by one or more type of in-line 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 5,182 km (16% of the inventory).

Overview of the main issues affecting pipeline integrity

Corrosion in hot pipelines: an historical problem now resolved

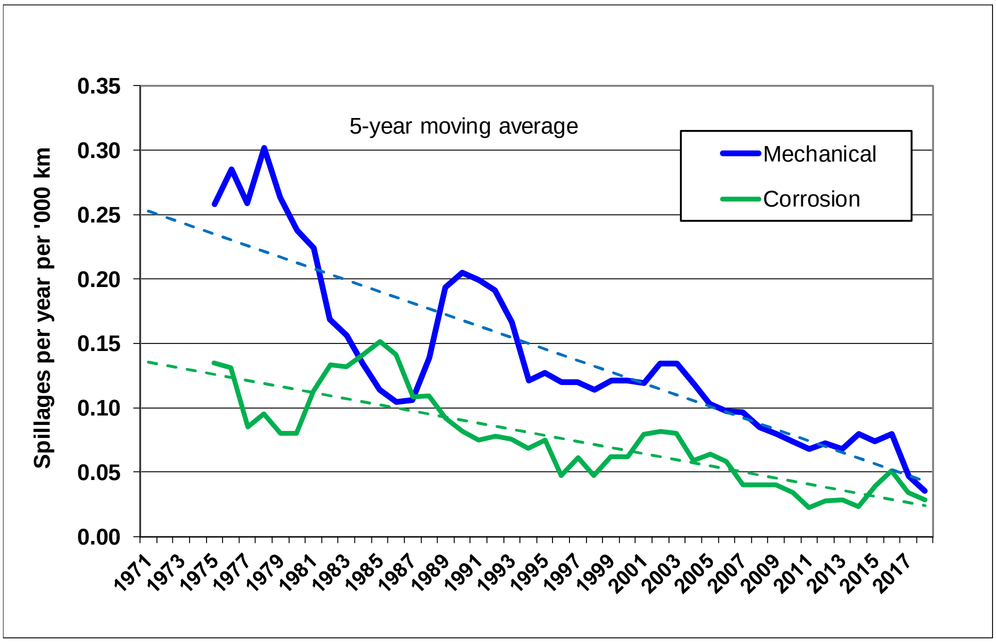
External corrosion in insulated pipelines transporting hot products has been a major issue in the past, particularly in the 70s and 80s with several failures reported in any one year. The problem was inherent to the design of these lines. Over time most such lines have been taken out of service (only 52 km remains today from a peak of over 1100 in the late 70s) and the issue disappeared with them, with only 4 cases recorded in the last 20 years.



Mechanical integrity and ageing: a relatively recent issue that requires continued attention

Most European pipeline systems were built in the '60s and '70s. Whereas, in 1971, 70% of the pipelines in the inventory were 10 years old or less, by 2018 less than 3% were 10 years old or less and 66% were over 40 years old. Over the last two decades, operators and regulators became concerned that ageing lines may be increasingly prone to mechanical (e.g. metal fatigue) or corrosion-related failures.

The Concawe database provides some reassurance in this respect, showing that the long-term decreasing trend of the failure frequency for both mechanical and corrosion causes has continued in recent years. A spike in mechanical failures observed towards the end of the last decade caused some concern. A detailed analysis showed, however, that there was no correlation between fatigue related failures and actual pipeline age. Over the last ten years the downward trend has resumed. There is therefore no evidence that the ageing of the pipeline inventory implies a greater risk of loss of integrity.

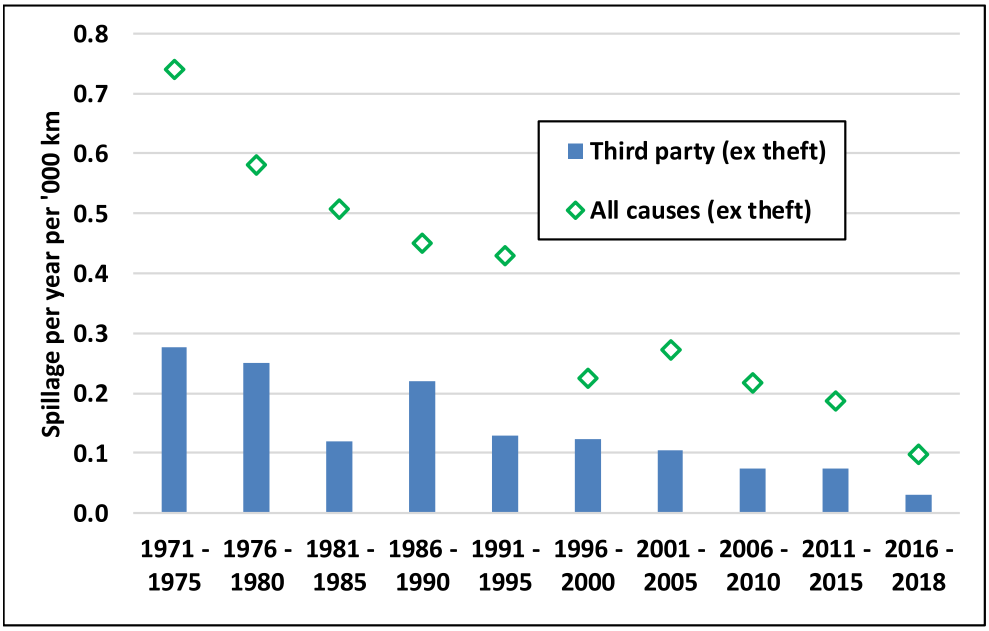


The development of sophisticated integrity management and maintenance systems including the use of new techniques, such as internal inspection with inspection pigs, has doubtlessly played a role and hold out the prospect that pipelines can continue reliable operations for the foreseeable future. Concawe pipeline statistics, in particular those covering the mechanical and corrosion incidents, will continue to be used to monitor performance.

Accidental third-party interference: an on-going problem not fully resolved

Pipelines run, mostly below ground, over long distances through diverse areas and are as such vulnerable to accidental damage caused by parties involved in digging, excavating and other earth moving activities.

This has been an issue ever since underground pipelines were first laid. Several measures have been put in place and actions taken over the years, including marking, enhanced surveillance, regular contacts with landowners, utility organisations and civil contractors and, in some countries, the development of so-called "one-call systems" designed to encourage potential "excavators" to declare their intentions in advance. These measures have had only limited success and, although the frequency of related incidents has decreased following the general trend, accidental third-party interference remains one of the major causes of failure in the European network.



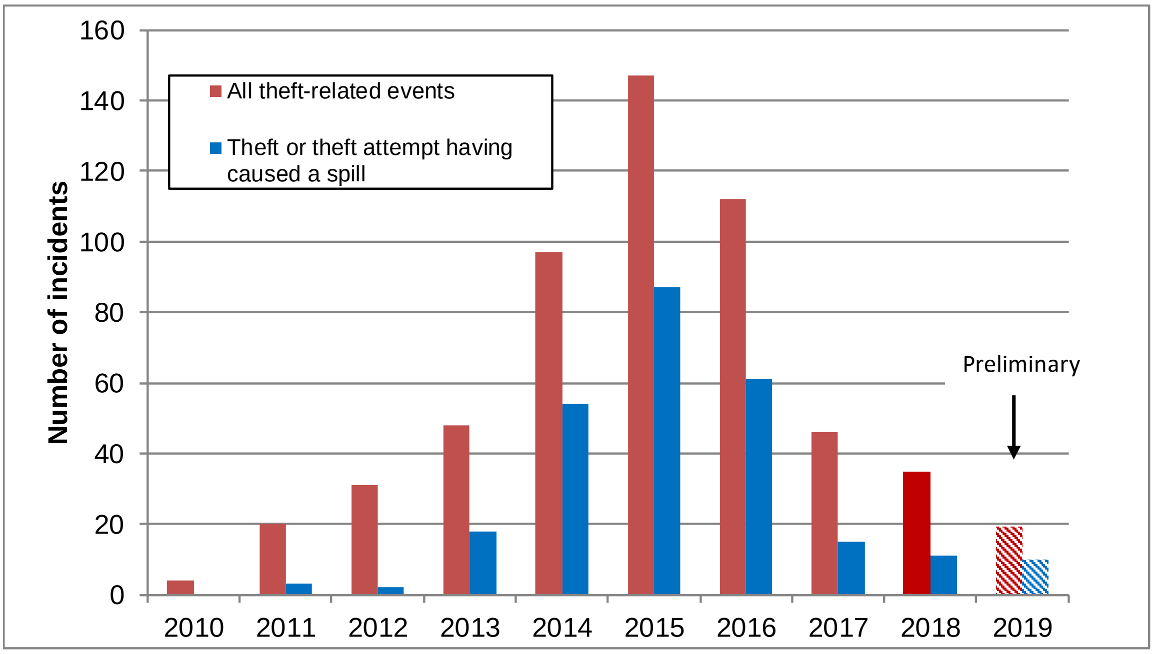
Product theft: a new threat being vigorously and successfully addressed

By the nature of their location and the fact that they transport valuable commodities, oil pipelines have always been a potential target for criminals, vandals or even terrorists. Up to the beginning on this decade, incidents involving any of the above were few and far between in Europe (less than one incident per year on average), mostly related to theft attempts and geographically concentrated in South-Eastern Europe.

From 2011, there was a sharp increase in the number of theft attempts culminating at 147 in 2015, 87 of which causing a spill. These occurred in several different countries across the continent, often with evidence of sophisticated criminal operations.

Beyond the potential loss of product and/or disturbance to operations, such interference with pipelines, which involve drilling through the pipeline to install a small-bore connection, can cause serious environmental damage and potentially injuries or even fatalities.

Faced with this serious new threat, operators reacted promptly, enhancing surveillance, improving leak detection system capabilities and increasing awareness of the problem with own staff, contractors and law enforcement authorities. Relevant information was shared within Concawe and good practices established and disseminated. These efforts have paid off and the trend was reversed with 112 events recorded in 2016, 46 in 2017 and 36 in 2018. Indications are that the downward trend continued in 2019 with a provisional total of 19 incidents. Nonetheless, the annual rate is still far above the 48-years average, requiring continued focus and vigilance.


Number of incidents
160
140
120
100
80
60
40
20
0
All theft-related events
Theft or theft attempt having caused a spill
Preliminary
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

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 in-line inspection activities are gathered yearly by Concawe via on-line questionnaires.

The results are 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 2017 data report 3/19. 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.eu

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 set priorities for future efforts. In addition to this activity Concawe also holds a seminar, known as “COPEX” (Concawe Oil Pipeline Operators Experience Exchange), every four years to disseminate information throughout the oil pipeline industry on developments in techniques available to pipeline companies to help improve the safety, reliability and integrity of their operations. These seminars have included reviews of spillage and clean-up performance to cross-communicate experiences so that all can learn from each other’s incidents. The last COPEX was held in 2018.

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 2018 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.

Section 7 gives an account of in-line inspections.

In 2015, to address the increasing number of theft-related spill incidents, the Concawe survey was updated to include an additional section on product theft. This new section captures data on all theft events, including those that did not result in a reportable spill. The findings from this new section of the survey are discussed in **Section 8**.

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 some of the Croatian crude lines in 2007. From 2013 additional Croatian crude lines were included.

Although Concawe cannot guarantee that every single pipeline that meets 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 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

73 companies and agencies operating a total of 35,956 km of oil pipelines in Europe are currently listed for the Concawe annual survey. 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.

For the 2018 reporting year, 64 companies completed the survey. In addition, Concawe received information from reliable industry sources confirming that 3 additional companies suffered no spills in 2018. Although not accounted for in the throughput, traffic and in-line inspections data, the additional inventory operated by this company has been taken into account in the spills statistics. Although there were no public reports of spillage incidents for the remaining 6 companies, they have not been included in the statistics. The proportion of responding companies, as well as the fraction of the inventory included in the statistics, have been reasonably stable over the years.

2.3. INVENTORY DEVELOPMENTS 1971-2018

2.3.1. Pipeline service, length and diameter

The 64 companies that reported in 2018 operate 131 pipeline systems split into 623 active sections running along a total of 32,886 km plus 25 sections covering 1413 km which are currently (but not permanently) out of service. These latter sections are included in the reported inventory which therefore stands at 34,264 km. The 9 companies from which we received no or partial information represent 1657 km split into 48 sections in 18 systems.

For the purpose of the spill statistics we considered the “active” inventory i.e. the 32,886 km mentioned above, to which we added that of the 3 companies that did not provide data but were confirmed to have suffered no spills in 2018 (1213 km), bringing the total active inventory to 34,099 km.

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, at the beginning of the last 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 oil into Eastern European refineries.

Over the years a total of 273 sections have been permanently taken out of service, reducing the inventory by 11,608 km.

Figure 1 represents the pipeline length reported to Concawe in each year and does not give an account of when these pipelines were put into service. Most of the major pipelines were 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. The last one refers to insulated lines transporting hot products such as heavy fuel oil or lubricant components.

Figure 1 shows that the first two categories represent the bulk of the total inventory. Out of the 273 sections that have been retired since 1971, 25 (1160 km) were in the "hot" category. The remaining "hot" inventory consists of 52 km distributed between 20 km in 4 sections transporting heavy fuel oil and 32 km in 4 sections transporting lubricant components. 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

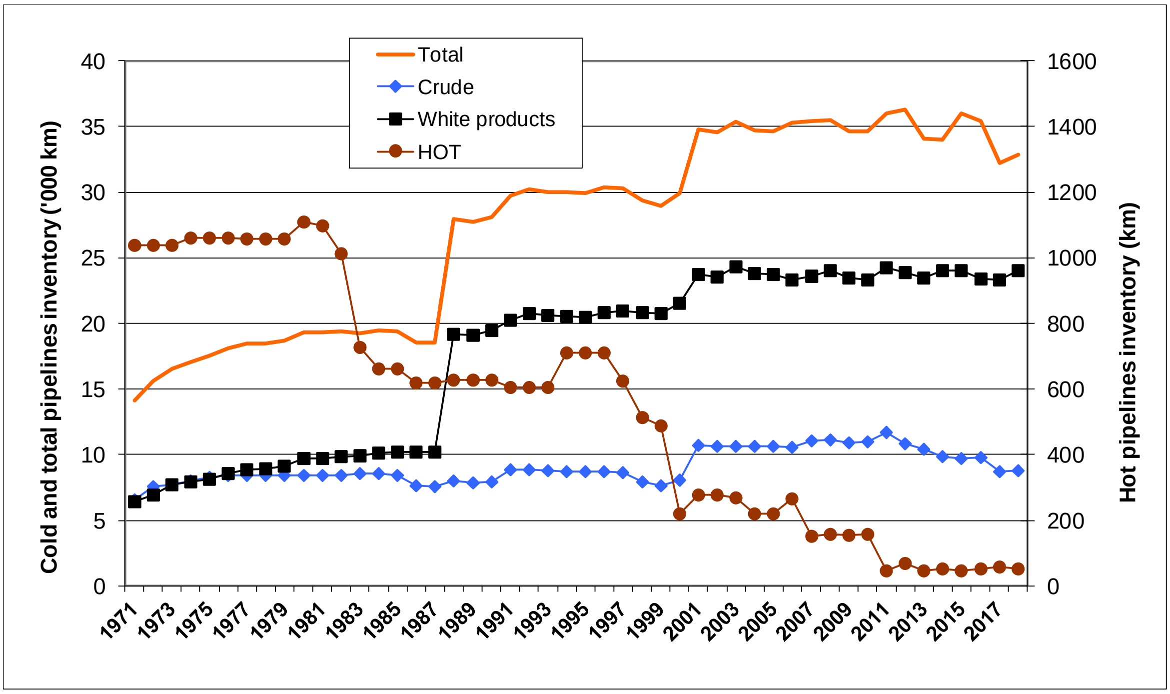
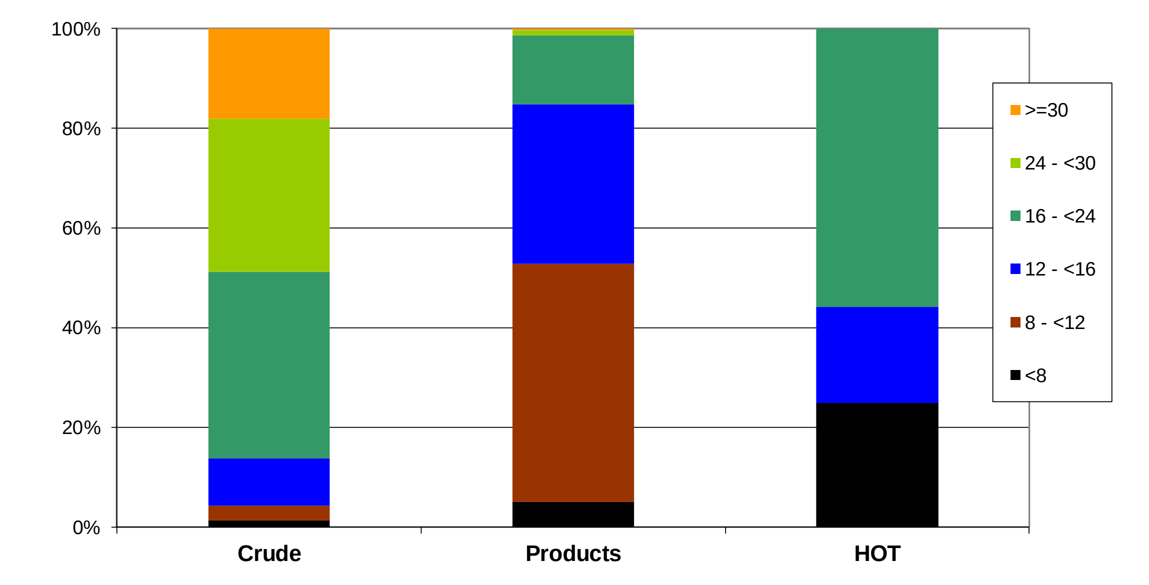


Figure 2 shows the diameter distribution in 2018 for each service category. In general, the crude pipelines are significantly larger than the other two categories. 86% of the crude pipelines are 16" (400 mm) or larger, up to a maximum of 44" (1100 mm), whereas 85% of the product lines are smaller than 16". The largest hot pipeline 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 (inches) distribution and service in 2018

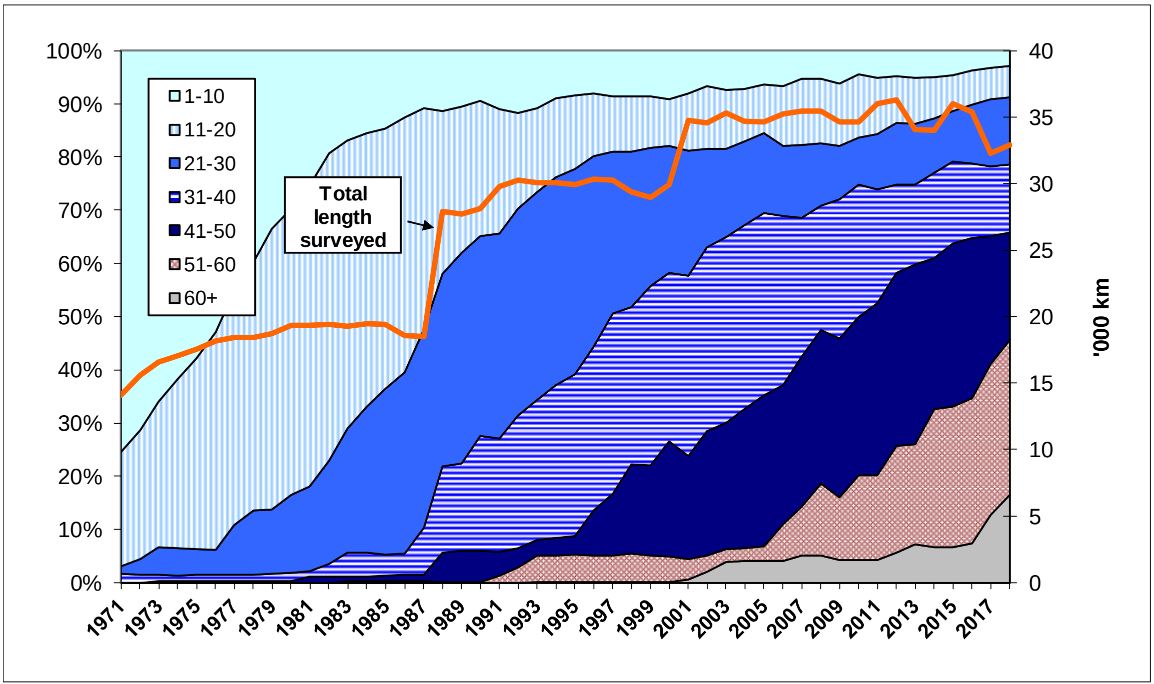


2.3.2. Age distribution

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.

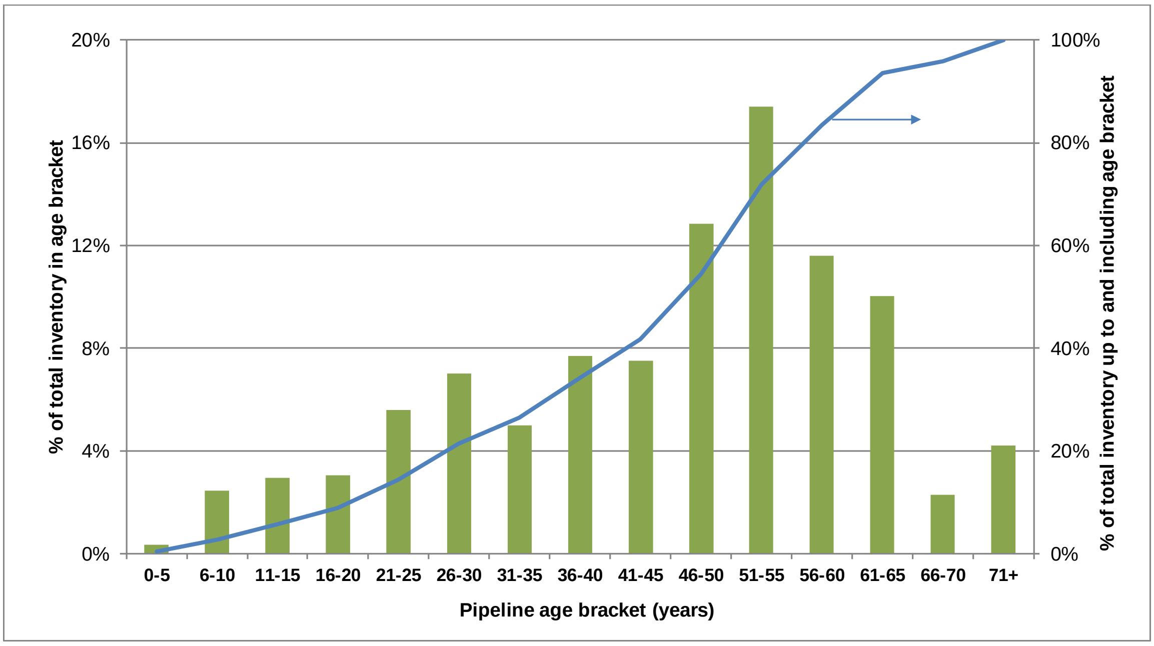
Over the years, a number of new pipelines have been commissioned, while older ones have been taken out of service. As mentioned above, existing lines were also added to the inventory at various stages, contributing their specific age profile. Although some short sections may have been renewed, there 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 (years)



The system has been progressively ageing. The 2018 age distribution is shown on **Figure 3b** both for discreet age brackets and cumulatively: only 929 km, i.e. 2.8% of the total, was 10 years old or less while 21,660 km (65.9%) 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 2018



2.4. THROUGHPUT AND TRAFFIC

Some 703 Mm^3 (324 Mm^3 of crude oil and 378 Mm^3 of refined products) were transported in the surveyed pipelines in 2018. The crude oil transported represents about 60% 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, for a given pipeline section, the total volume transported annually (m^3) times the length of the section (km). This is not affected by how many different pipelines each parcel of oil is pumped through. In 2018, the total reported traffic volume was about 117×10^9 m^3.km, slightly higher than the 2017 figure and split between 73×10^9 m^3.km for crude and 43×10^9 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 2018.

Over the 48 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 2018.

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 a 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 (2014-18)

4.1. 2018 SPILLAGE INCIDENTS

12 spillage incidents were recorded in 2018, **10 of which were related to theft attempts** (Third Party Intentional). **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**.

Theft attempt from pipelines has been a concern in recent years, causing a small number of spillages in 2011 and 2012. The number jumped to 18 in 2013, 54 in 2014, and 87 in 2015. The first sign of decline came in 2016 with 60 spillages followed by 11 in 2017. The 2018 figure strongly confirms that efforts by operators to reduce theft attempts have borne fruit. The problem still remains though, albeit at a low level, and continues to be a challenge for operators. While theft tended in the past to be an issue in Southern and Eastern Europe it is now more widespread, affecting also central and North/ West Europe.

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

Table 1 Summary of causes and spilled volumes for 2018 incidents

Event (1)	Facility	Line size (")	Product spilled	Injury Fatality (2)	Fire	Spilled volume Gross (m^3)	Spilled volume Net loss (m^3)	Contamination Ground area (m^2)	Contamination Water (3)
Mechanical									
Construction									
768	Underground pipe	12	White product	-	-	9.1	1.4	240	S, G
Third party activity									
Accidental									
767	Underground pipe	6	White product	-	-	40.0	0.0	0	
Theft or theft attempt									
757-765	No details available								
766	Underground pipe	12	White product	-	-	12.0	0.0	80	

(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

4.1.1. Mechanical Failure

There was one spillage in this category in 2018, in the "Construction" sub-category.

Event 768:
A temporary repair clamp, which had been installed on an attempted theft point, developed a leak. The leak was identified, and permanently repaired, in March 2018. The clamp had been installed in December 2016.

4.1.2. Operational activities

There were no spillages in this category in 2018.

4.1.3. Corrosion

There were no spillages in this category in 2018.

4.1.4. Natural causes

There were no spillages in this category in 2018.

4.1.5. Third party activity

There were 11 spillage incidents in this category in 2018 all but one theft-related. One incident was in the “Third Party Accidental” category.

Accidental

Event 767:
An excavator hit and punctures the pipeline in an agricultural area. It appeared that the pipeline operator was not made aware of this activity being undertaken while the machinery operator was also unaware of the presence of the pipeline. Some 40 m^3 of gasoline were spilled, the bulk of which was recovered through the emergency response actions and subsequent soil cleaning.

Theft-related

Events 757-766:
No details available.

Event 767:
The pipeline control centre was alerted of a leak by a member of the public (who is believed to be the perpetrator of the theft attempt). This was confirmed by pressure monitoring. Pumping was stopped immediately and the relevant section shutoff while staff were sent to the presumed location where the leak was quickly located and dealt with.

4.2. 2014-2018 SPILLAGE OVERVIEW

Table 2 shows 5-year trends in spill incident causes and also spill volumes, from 2014-2018. Spillage volume due to theft has been excluded from the spill volume statistics so that the baseline performance of the European pipeline network, excluding intentional damage (i.e. product theft) is apparent.

Only 2 non-theft related spillages were reported in 2018, well below the 5.2 spillages per year average for the last 5 years and well below the long- term average of 10.6.

Excluding product theft, the total reported gross spilled volume was low at 49 m^3 in 2018, compared to the averages of 283 m^3 for the last 5 years and 1665 m^3 since records began in 1971. 97% of the spilled oil was recovered.

Some temporary environmental contamination was reported for 2 of the 12 incidents, although no detailed information was provided for 10 out of the 11 theft-related incidents.

Table 2 5-year comparison by cause, volume and impact: 2014- 2018

		2014	2015	2016	2017	2018	2014-2018
							Average
Combined Length	km x 10^3	34.0	36.0	34.1	33.4	34.1	34.3
Combined Throughput	m^3 x 10^6	681	760	755	720	703	724
Combined traffic volume	m^3 x km x 10^9	120	121	119	128	117	121
Spillage incidents							Total
All incidents		**58**	**93**	**66**	**13**	**12**	**242**
Excluding theft		**4**	**6**	**6**	**2**	**2**	**20**
MECHANICAL FAILURE							
Construction			1	1			2
Design and Materials		1	2			1	4
OPERATIONAL							
System							
Human					2		2
CORROSION							
External			2	3			5
Internal			1				1
Stress corrosion cracking							
NATURAL HAZARD							
Ground movement							
Other							
THIRD PARTY ACTIVITY							
Accidental		2		2		1	5
Incidental		1					1
Intentional (theft)		*54*	*87*	*60*	*11*	*10*	*222*
Volume spilled (ex theft)	m^3						**Average**
Gross spillage		518	61	756	33	49	283
Net loss		4	19	235	0	1	52
Average gross loss / incident		130	10	126	17	25	71
Average net loss / incident		1	3	39	0	1	13
Average gross loss/1000 km		15	2	22	1	1	13
Average net loss/1000 km		0	1	7	0	0	4
Gross spillage/ throughput	ppm	0.8	0.1	1.0	0.0	0.1	0.4
Gross spillage per cause							
Mechanical failure		5	32	11	0	9	11
Operational		0	0	0	33	0	7
Corrosion		0	29	217	0	0	49
Natural hazard		0	0	0	0	0	0
Third party activity (ex theft)		513	0	528	0	40	216
Net loss distribution							
(No of incidents)							
≤ 10		4	5	3	2	4	18
11 -100			1	2			3
101- 1000				1			1
> 1000 m^3							0
Environmental impact							
NONE or not reported		48	83	66	13	10	220
SOIL (affected surface area)							
< 1000 m^2		6	10	7		2	25
> 1000 m^2		4			1		5
WATER BODIES							
Surface Water		1		2		1	4
Groundwater				1		1	2
POTABLE WATER							

5. HISTORICAL ANALYSIS OF SPILLAGES 1971-2018

As mentioned in **section 4**, the unprecedented growth in theft-related spillage incidents over the last few years has the potential to distort long term statistics. Where appropriate, we have presented the statistics with and without these incidents.

5.1. NUMBERS AND FREQUENCY

Over the 48 years survey period there have been a total of 766 spillage incidents, 498 when excluding theft. 68 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 52 km left in operation, from a peak of around 1100 km).

Figure 4a/b show the number of spillages per year, moving average and 5-year average trends over the 48 years since 1971 for all pipelines including and excluding theft-related incidents. **Figure 4a** shows a long-term downward trend in total spillages per year until the beginning of this decade followed by a major spike due to the sudden rise in product theft.

Figure 4b shows that the overall 5-year moving average, excluding theft, has decreased from about 18 spillages per year in the early 1970s to 4.0 in 2018 (48.4 when including theft-related spills), which bears witness to the industry's improved control of pipeline integrity. 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.

Figure 4a 48-year trend of the total annual number of spillages (all pipelines) **Including theft**

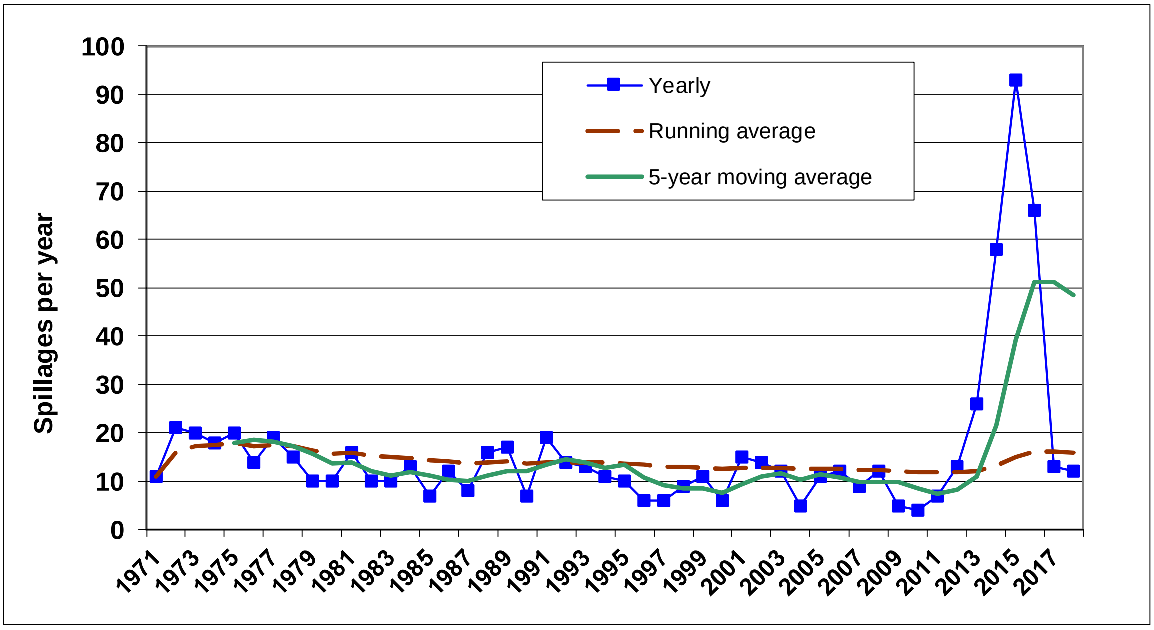
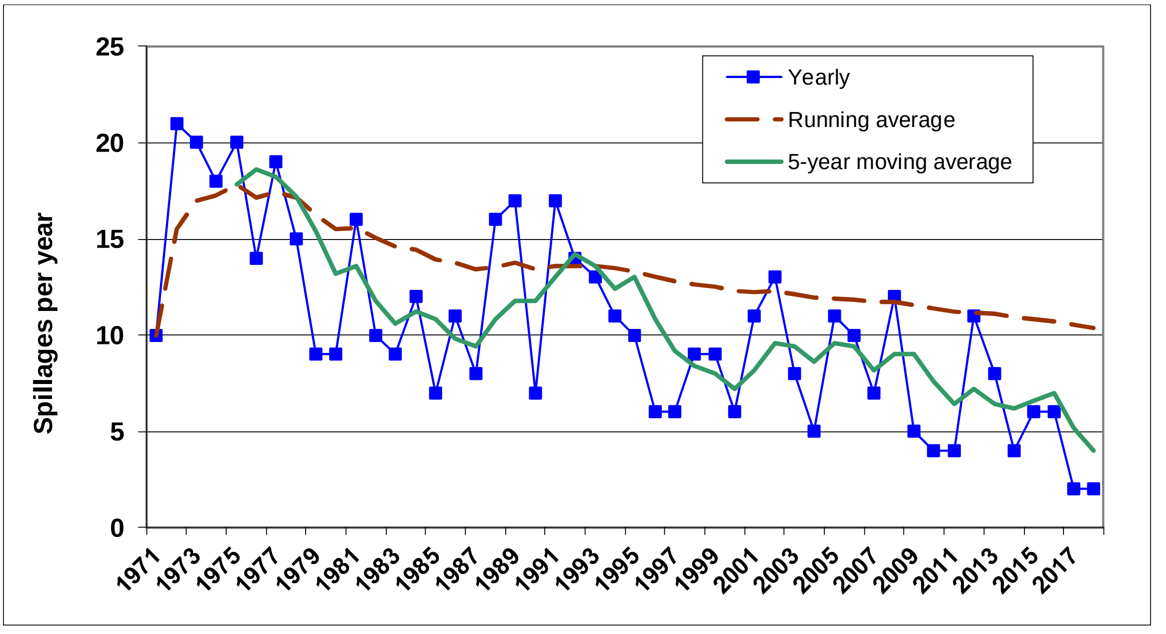


Figure 4b 48-year trend of the total annual number of spillages (all pipelines)
Excluding theft



Several step changes in the inventory surveyed by Concawe over the years 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 5a/b** shows the same data as **Figure 4a/b**, now expressed in spillages per 1000 km of pipeline (as per the reporting inventory in each year). **Figure 5b** shows that the 5-year moving average spillage frequency has reduced from around 1.1 in the mid '70s to 0.12 spills per year and per 1000 km of pipeline in 2018. When theft is included (**Figure 5a**) the 2018 value increases to 1.39.

Figure 5a 48-year trend of the spillage frequency (all pipelines)
Including theft

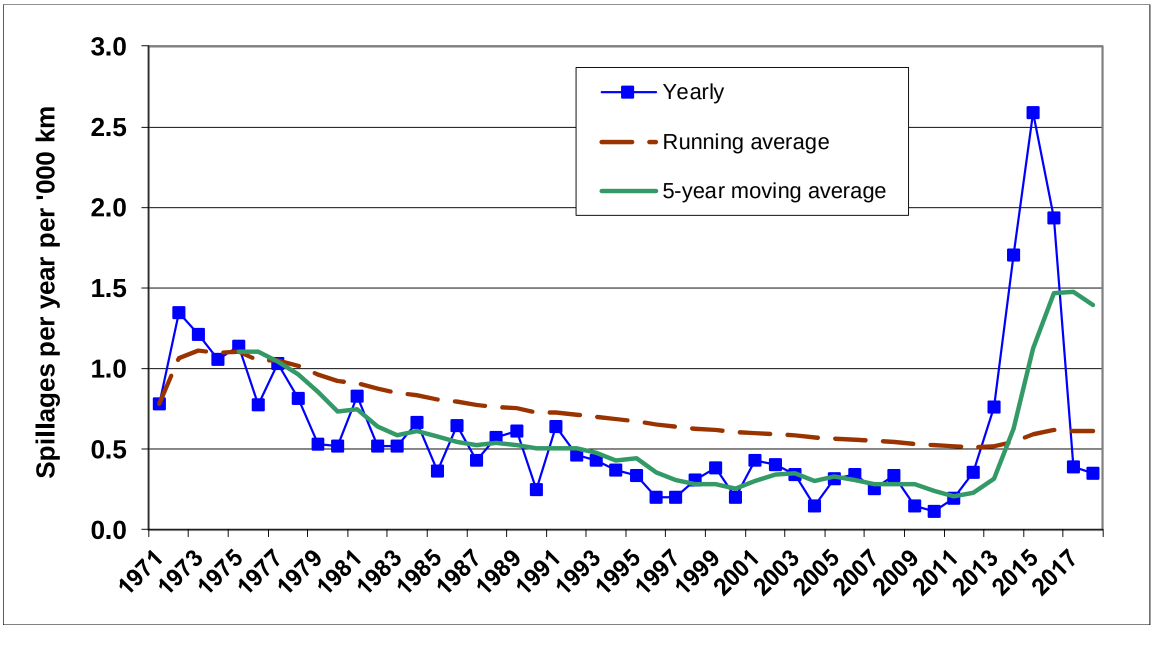
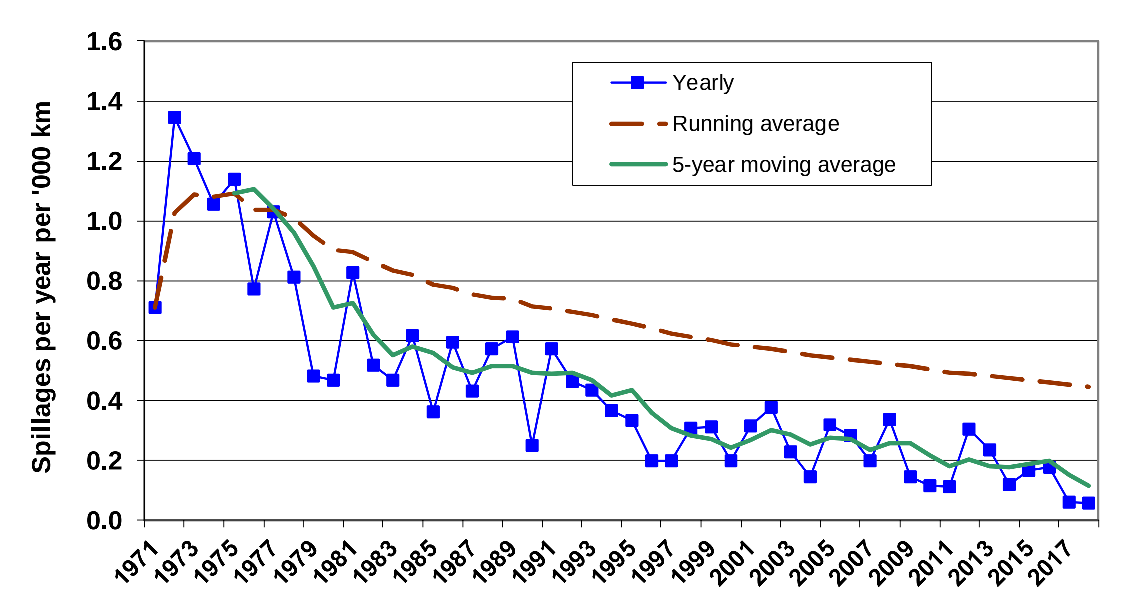
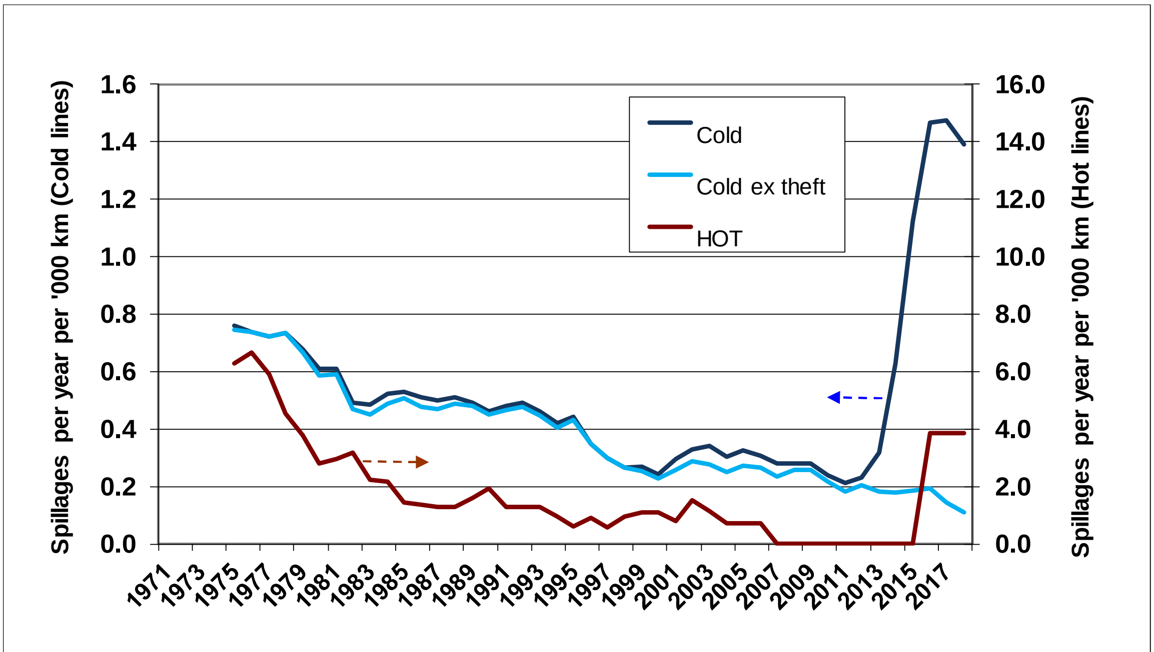


Figure 5b 48-year trend of the spillage frequency (all pipelines)
Excluding theft



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, although one such pipeline developed a leak in 2018.

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



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. For cold pipelines we have presented the figures with (**Figure 8a**) and without theft-related events (**Figure 8b**).

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 shutdown or switched to clean (cold) product service, greatly contributing to the remarkable performance improvement. There were 3 spillages between 1996 and 2000, one in 2002 and one in 2016. Recent frequency figures are strongly skewed by the 2016 event and not statistically 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 frequency of spillages has been reduced by nearly three quarters over the last 48 years (when excluding theft). This statistic best represents the performance improvement achieved by the operators of the bulk of the pipeline system.

For cold pipelines we have shown theft-related events separately. There is a gradual decrease in the frequency of all causes except theft. Corrosion is a much less prevalent cause of failure for cold than hot pipelines. Although third party activities (excluding theft) have historically by and large been the most prevalent cause of spillage, there have been relatively few cases in recent years so that the cause structure has become more balanced. Mechanical causes increased during the last decade to be on a par with non-theft third party causes but this trend appears to have reversed since the beginning of this decade. A more complete analysis of causes is given in **Section 6**.

Figure 7 Hot pipelines spillage frequencies by cause

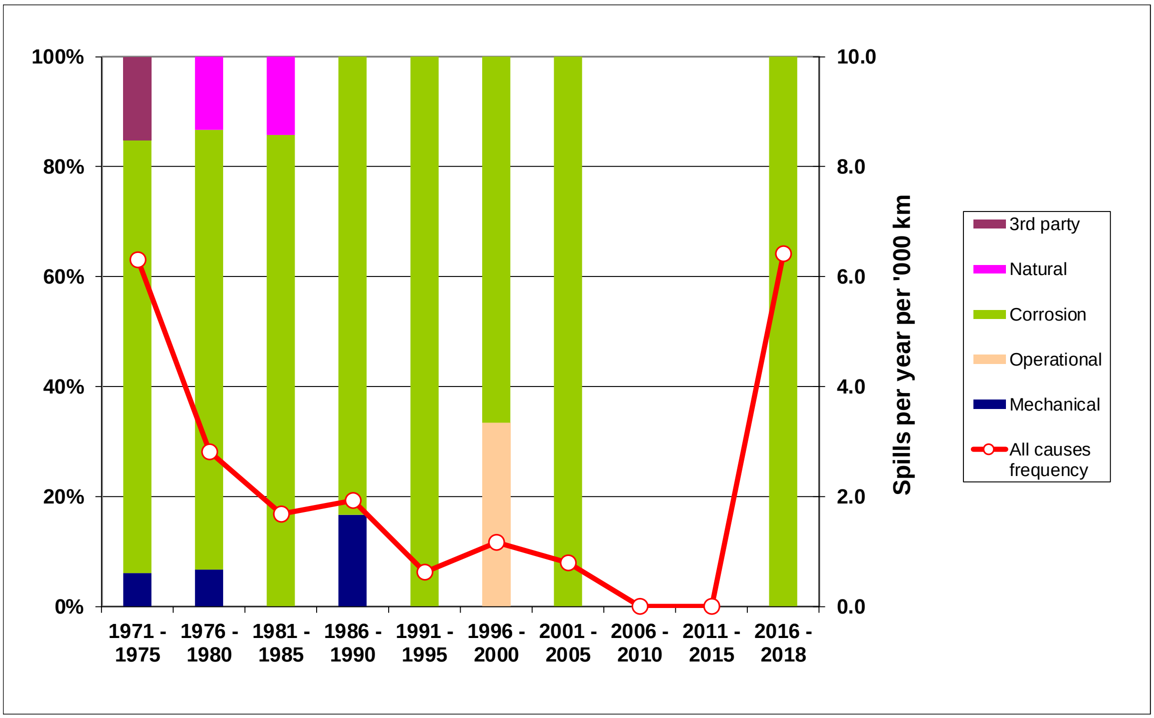


Figure 8a Cold pipelines spillage frequencies by cause
Including theft

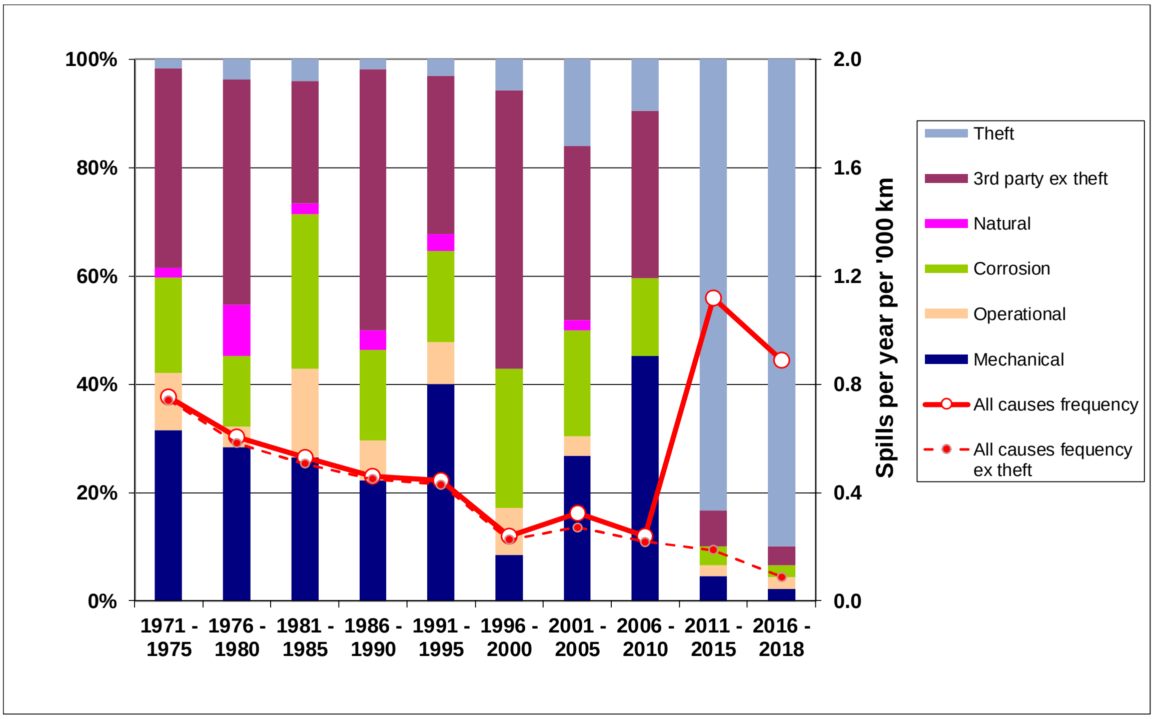
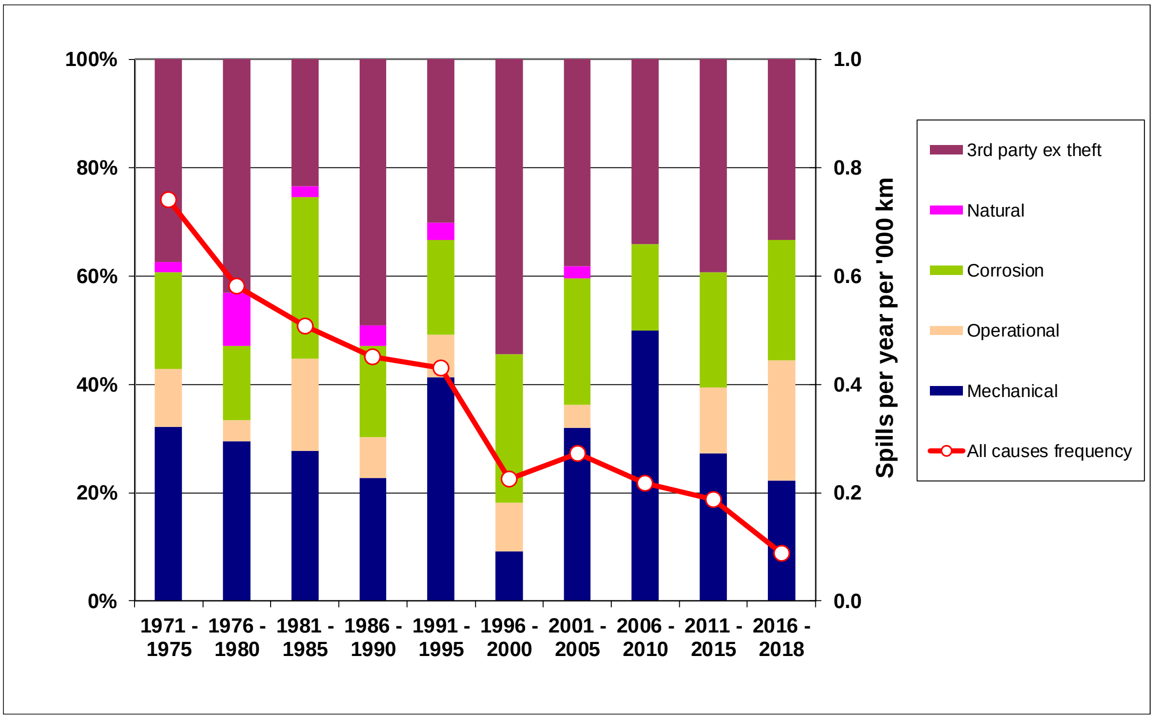


Figure 8b Cold pipelines spillage frequencies by cause
Excluding theft



5.2. SPILLAGE VOLUME

Spilled volume is generally difficult or impossible to determine in the case of theft-related events as spillage may have occurred over a period of time and one cannot determine how much was spilled or indeed how much was stolen. **This section therefore excludes theft-related incidents.**

5.2.1. Aggregated annual spilled volume

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, probably a consequence of the lower number of spills per year. Over the last 5 years, the gross pipeline spillage has averaged 0.5 parts per million (ppm) 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-net) / gross) is shown in **Figure 12**, fluctuating around the 60% mark. Over the whole period, the average recovery of spilled oil is 60% (100% in 2018) leaving an average net loss of oil to the environment of 65 m^3 per spill.

Figure 9 Gross spillage volume (excluding theft)

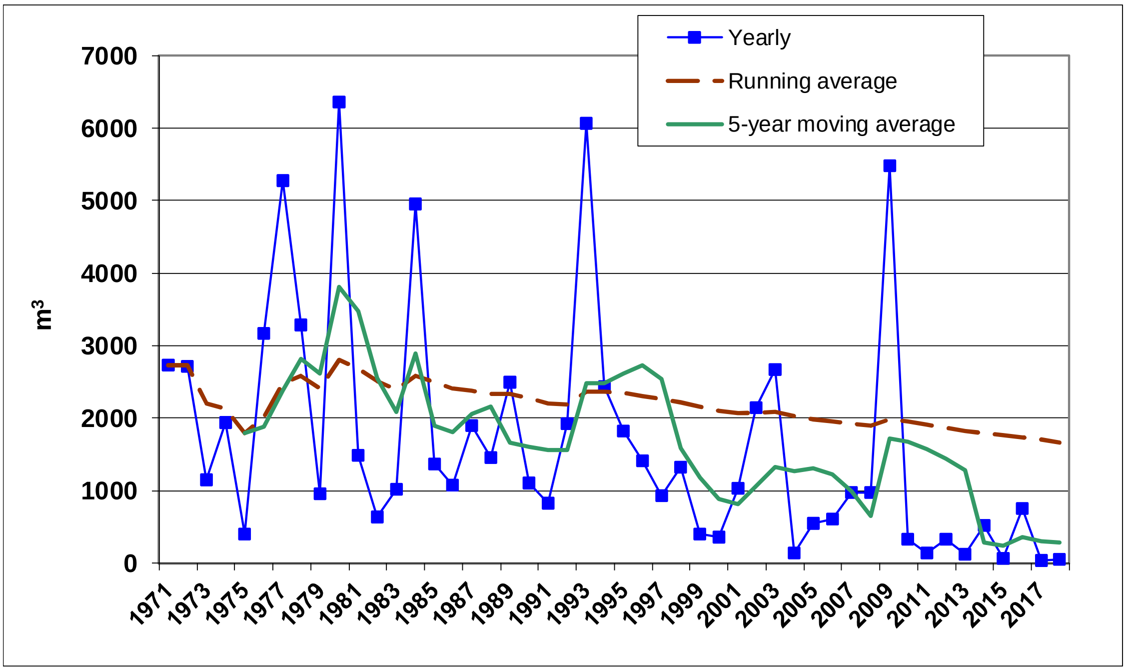


Figure 10 Gross spillage volume per 1000 km (excluding theft)

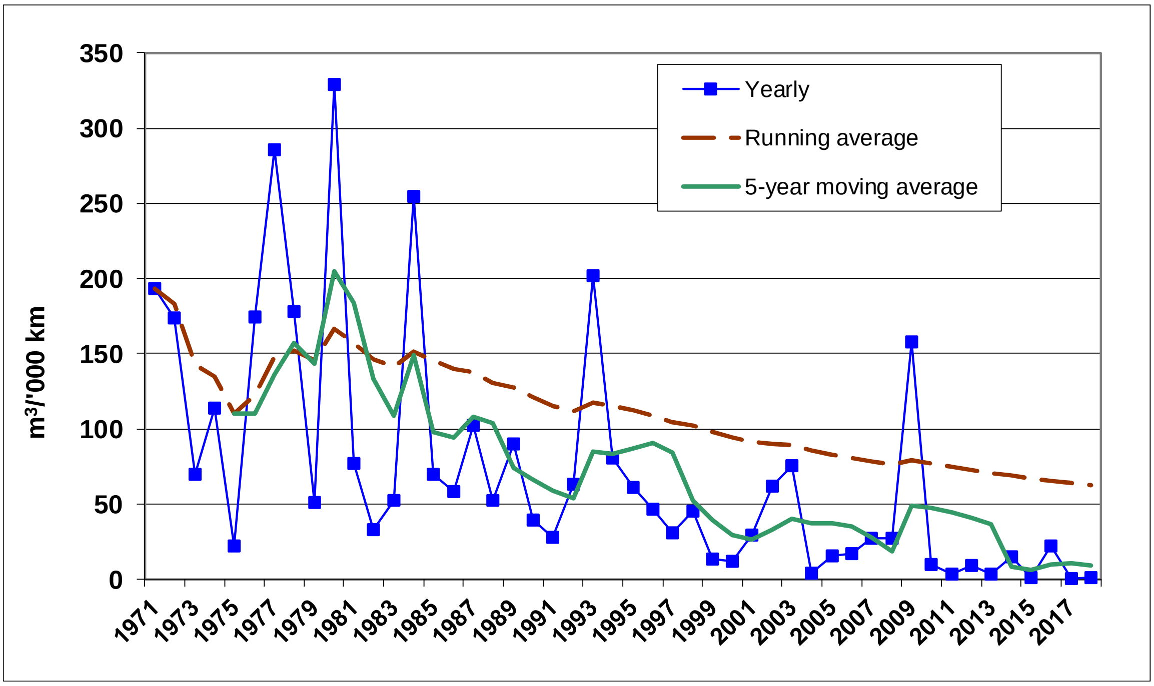


Figure 11 Gross yearly spillage volume as a proportion of throughput (excluding theft)

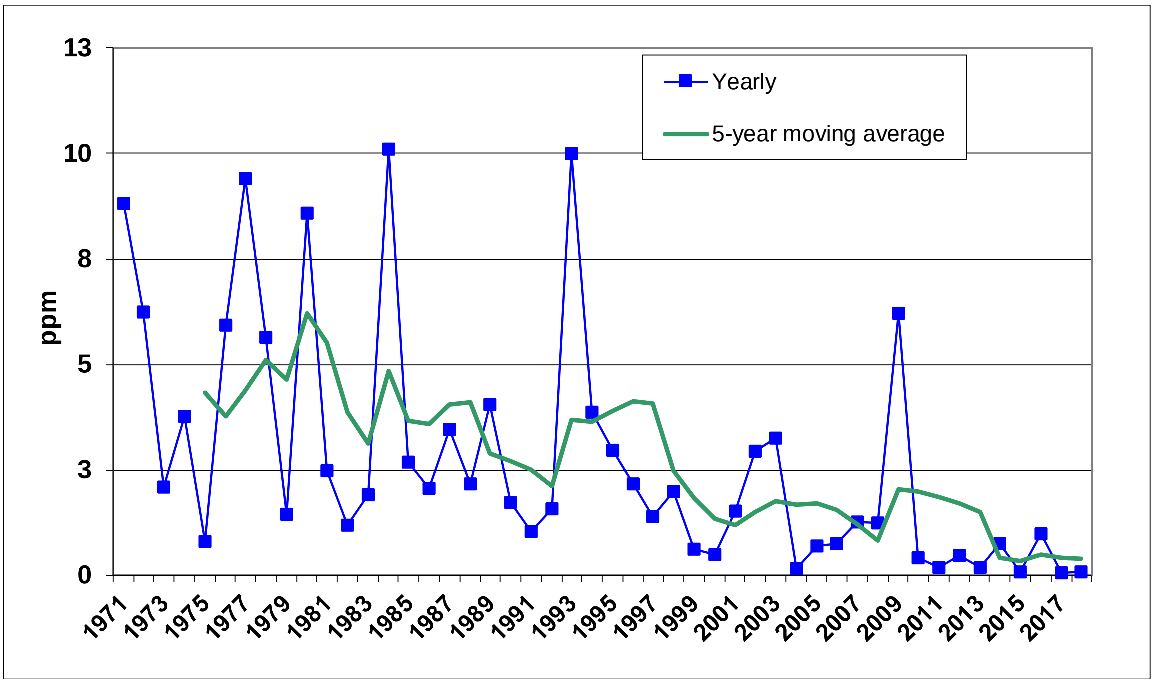
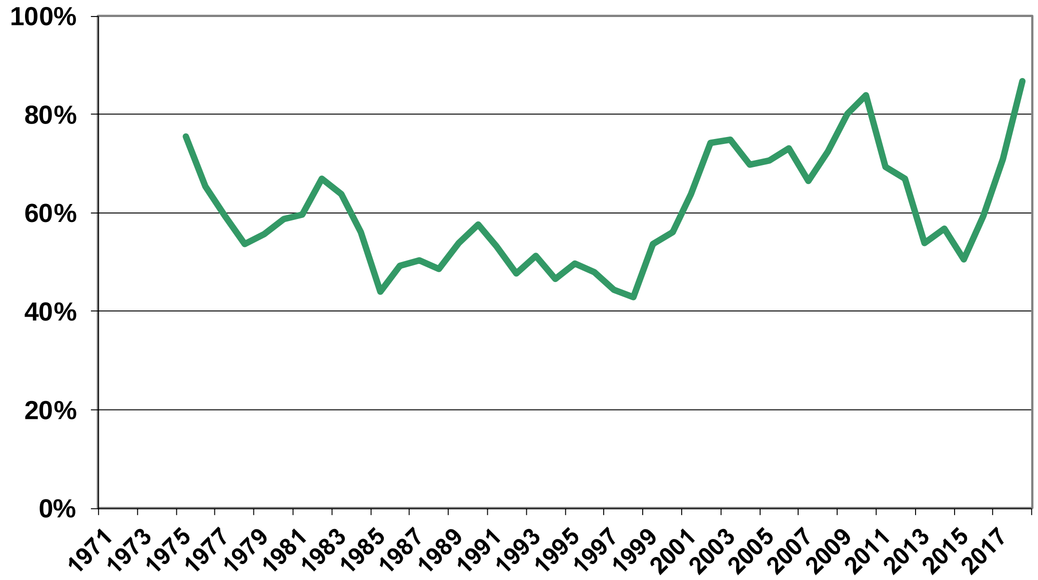


Figure 12 Spilled oil recovery (5-year moving average) (excluding theft)



5.2.2. Spillage volume per event

The gross volume released is a measure of the severity of a spillage incident. While a large proportion of spills involve low volumes, one or a few events involving large volumes can have a very large impact on the annual as well as long term averages so that trends can be difficult to discern.

At around 120 m^3 per spill, the gross spill volume 5-year 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 191 m^3 per spill for that year and even higher for the 4 subsequent years. With no such large incidents in the last 5 years the 2018 figure is again low at 77 m^3 per spill. 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 shows a small reduction in the gross spill volume 5-year moving average since 1975, with superimposed large year-by-year variation. This indicates that the long-term reduction in total spilled volume (c.f. **Figure 9**) is mainly due to a reduction in the number of incidents, rather than the spill volume per incident. Changes in the mix of spillage causes may also account for this: for example, the proportion of corrosion spillages, which on average are smaller ones, has decreased relative to third party spillages (excluding theft) which tend to be larger (see **Figure 14**).

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

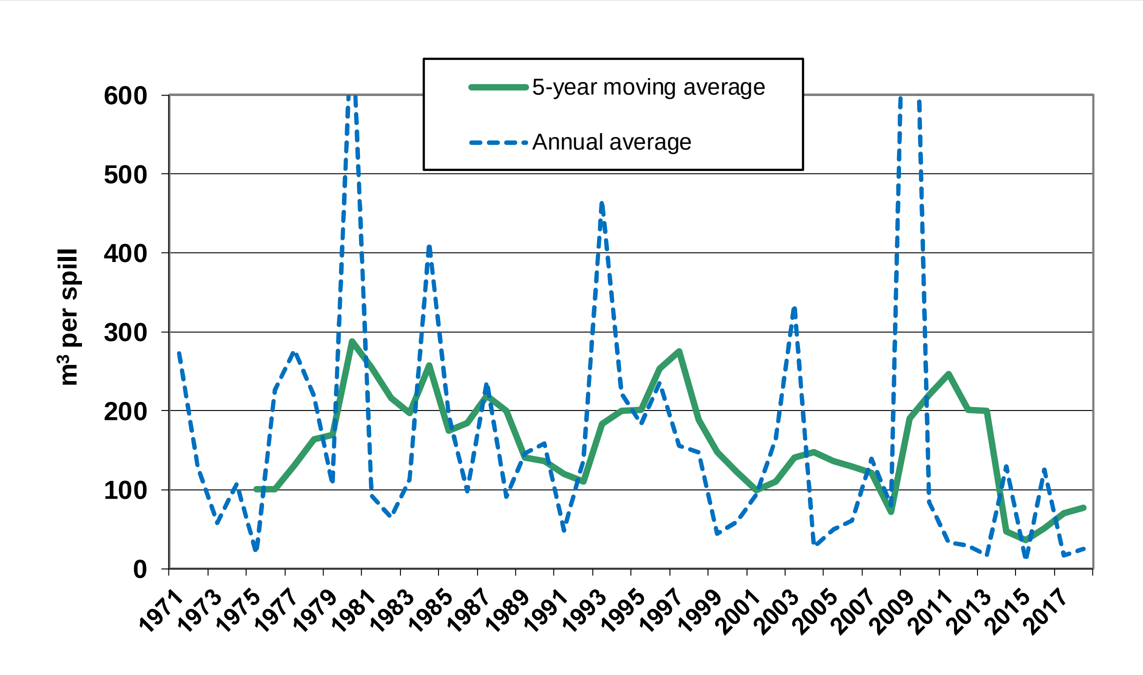


Figure 14 shows the average spill size for each cause category. The largest spillages on average have resulted from mechanical failure, third party activities and natural hazards, whereas operational problems and corrosion have caused smaller spills. As a rule of thumb, on average the three "largest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

Figure 14 48-year average gross spillage volume per event by cause (excluding theft)

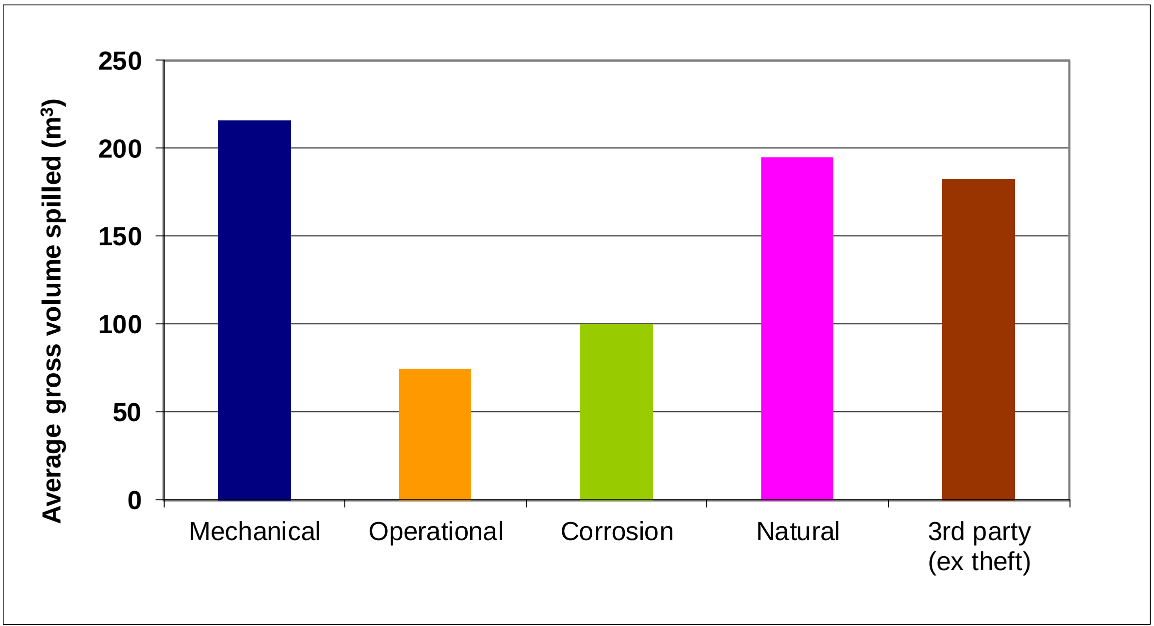
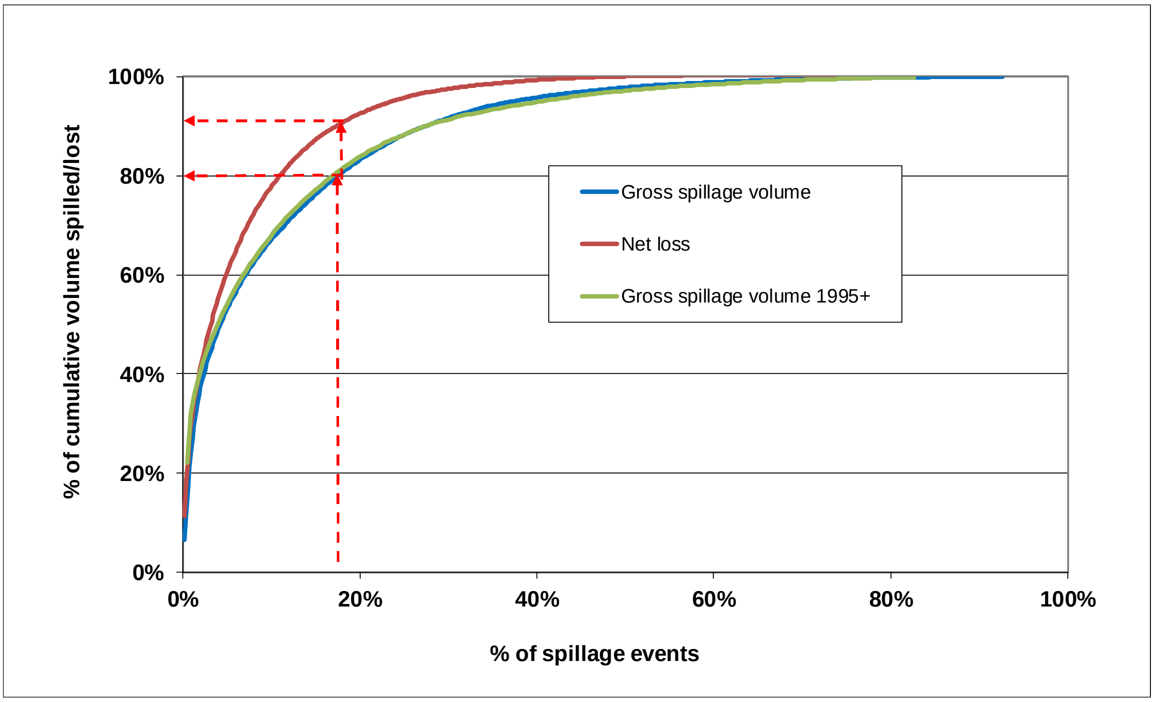


Figure 15 shows the distribution of spillage sizes, demonstrating that less than 20% of all spillages account for 80% of the cumulative gross volume spilled and over 90% of the net spillages, with little change over the years. Clearly a majority of the spillages recorded in the Concawe database were so small that they 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 48 years and since 1995) (excluding theft)



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.

Hole size data are only available for 352 (46%) out of the 766 spillages recorded (286 out of 498 or 57% ex theft). The corresponding statistics are shown in **Table 3** for all spillages (excluding theft).

Table 3 Distribution of spillages by hole size (excluding theft)

Hole type	No hole	Pinhole	Fissure	Hole	Split	Rupture	Overall
Number of events	13	37	48	75	52	61	286
%	5%	13%	17%	26%	18%	21%	100%
Hole caused by							
Mechanical	10	5	14	14	17	7	67
Operational	2	0	1	2	3	5	13
Corrosion	0	27	11	25	17	5	85
Natural hazard	0	1	2	0	2	2	7
Third party (ex theft)	1	4	20	34	13	42	114
Gross average spillage per event m^3	41	29	230	83	238	355	0

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.

A relationship may be expected between hole size and spill volume for an operational pipeline on the basis that higher leakage rates arise from larger holes, and because hole sizes are to an extent related to the pipeline diameter, which in turn sets the potential flow rate available for leakage. However, there are many other factors involved, including the pressure in the pipeline, the volume of pipe available to leak after shut in and the length of time between the start of leakage, the leak being detected and pipeline shut- in. **Table 3** suggests 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	2011-15	2016-18
No hole	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.11	0.00
Pinhole	0.27	0.10	0.08	0.13	0.07	0.20	0.17	0.26	0.09
Fissure	0.32	0.21	0.29	0.20	0.24	0.17	0.09	0.40	0.00
Hole	0.16	0.41	0.54	0.37	0.54	0.63	0.28	0.94	0.33
Split	0.64	0.41	0.46	0.23	0.10	0.20	0.03	0.09	0.03
Rupture	0.27	0.31	0.33	0.43	0.17	0.26	0.28	0.11	0.06
All reported events	1.67	1.45	1.70	1.37	1.11	1.47	1.17	1.90	0.50
Not reported	1.99	1.45	0.79	0.87	0.17	0.17	0.03	0.23	0.06

Note: total figures exclude multiple theft events for which no details are available

5.4. PART OF FACILITY WHERE SPILLAGE OCCURRED

Table 5 shows this data expressed in both percentage of all spills within each category and percentage of all reported events (non-theft related). 67% of all non-theft related leaks and 86% of theft-related incidents occur in underground pipeline sections, which form the major part of the overall pipeline system.

However, particularly for Mechanical and Operational causes, 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 associated with a higher spillage frequency because 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

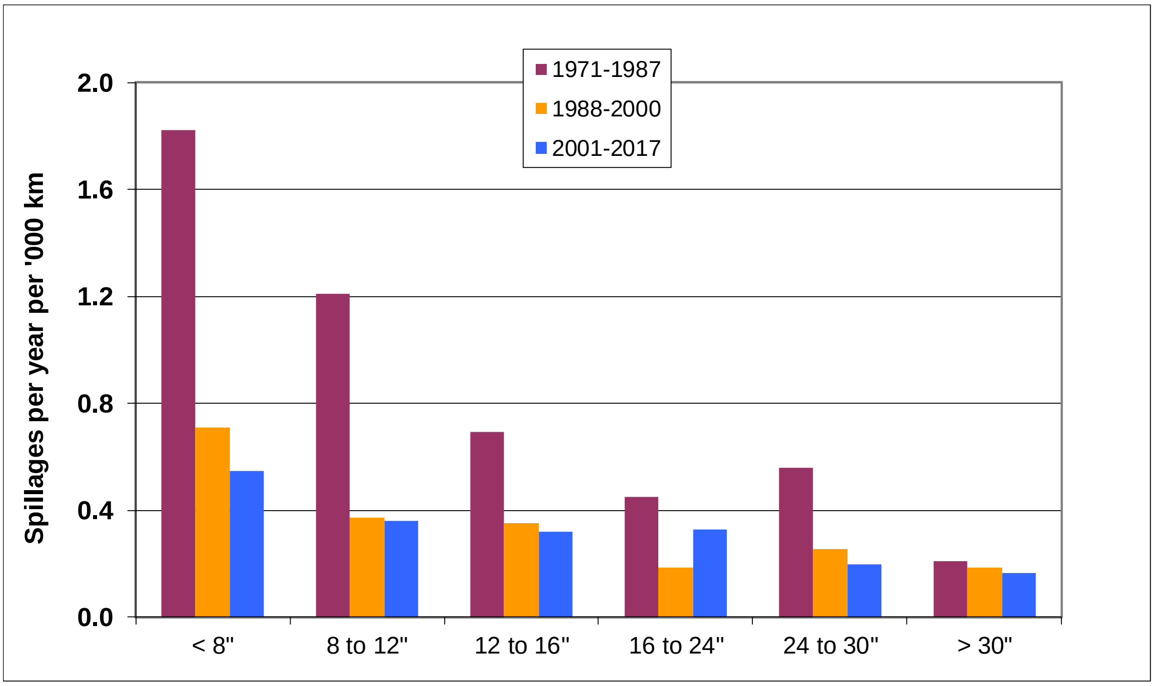
	Total	Bend	Joint	Pipe run	Valve	Pump	Pig trap	Small bore	Not reported
Mechanical	*136*	7.4% *2.0%*	32.4% *8.9%*	25.0% *6.8%*	15.4% *4.2%*	2.2% *0.6%*	1.5% *0.4%*	11.0% *3.0%*	5.1% *1.4%*
Operational	*37*	0.0% *0.0%*	5.4% *0.4%*	16.2% *1.2%*	32.4% *2.4%*	2.7% *0.2%*	10.8% *0.8%*	16.2% *1.2%*	16.2% *1.2%*
Corrosion	*141*	0.7% *0.2%*	6.4% *1.8%*	87.2% *24.7%*	0.0% *0.0%*	0.0% *0.0%*	0.7% *0.2%*	2.1% *0.6%*	2.8% *0.8%*
Natural	*15*	0.0% *0.0%*	6.7% *0.2%*	80.0% *2.4%*	0.0% *0.0%*	0.0% *0.0%*	0.0% *0.0%*	13.3% *0.4%*	0.0% *0.0%*
3rd party (ex theft)	*168*	0.6% *0.2%*	1.2% *0.4%*	93.5% *31.6%*	0.6% *0.2%*	0.0% *0.0%*	0.0% *0.0%*	1.8% *0.6%*	2.4% *0.8%*
All (ex theft)	*497*	*2.4%*	*11.7%*	*66.8%*	*6.8%*	*0.8%*	*1.4%*	*5.8%*	*4.2%*
3rd party (theft)	*265*	0.0%	0.4%	86.4%	12.1%	0.0%	0.0%	0.4%	0.8%

Percentages in italic are related to the total of all non-theft -related events

5.5. SPILLAGES PER DIAMETER CLASS

In **Figure 16** the frequencies of spillages have been calculated for the average length of each diameter class for the periods 1971 to 1987, 1988 to 2000 and 2001 to 2018. 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 large diameter pipelines have greater coverage than smaller 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 (80%) occurred in the cross-country pipelines themselves. The type of location has been reported for a total of 496 spillages (out of 766). The results of this analysis are provided in **Table 6**.

While we do not have statistics for 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 majority of the spillages from pump stations occur in industrial/commercial areas simply because this is where most of them are located.

Table 6 Location of spillage incidents

	Underground pipe			Above ground pipe		Pump Station	
	Number	Crude/ Product	%	Number	%	Number	%
Residential high density	17	3/14	4%	2	5%	0	0%
Residential low density	200	55/145	51%	11	30%	9	14%
Agricultural	73	5/68	18%	3	8%	3	5%
Industrial or commercial	83	22/61	21%	19	51%	51	81%
Forest Hills	17	2/15	4%	0	0%	0	0%
Barren	4	2/2	1%	0	0%	0	0%
Water body	2	0/2	1%	2	5%	0	0%
Total	396			37		63	
Unspecified	270						

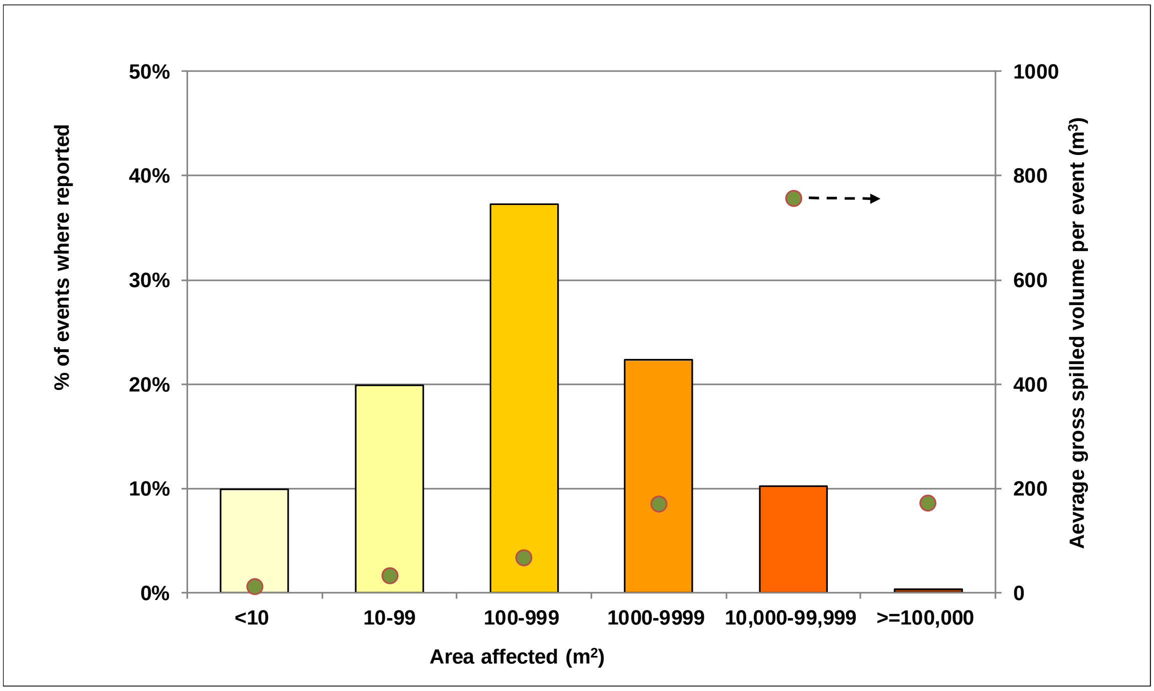
5.6.2. Ground area affected

The current Concawe pipeline 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 322 events (42% 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.

In the history of the survey 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, with the area affected increasing slowly at first and then more rapidly where the average spill volume exceeds 100 m^3. This suggests that very large spills behave differently to smaller releases, which could happen, for example, if product escaping at a high flow rate was to migrate across the surface, rather than in the subsurface.

It should be noted that small spillage volumes can affect larger areas at the surface if fine sprays are directed upwards and spread around by winds, or if material is spread over larger areas by flowing water. Conversely, comparatively large spills, particularly those that occur over extended periods of time and in the lower quadrants of the pipeline circumference, can have their main effect underground with relatively little impact on the surface. Porous ground and hot, arid conditions can also lead to the surface consequences being limited.

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



5.6.3. Impact on water bodies

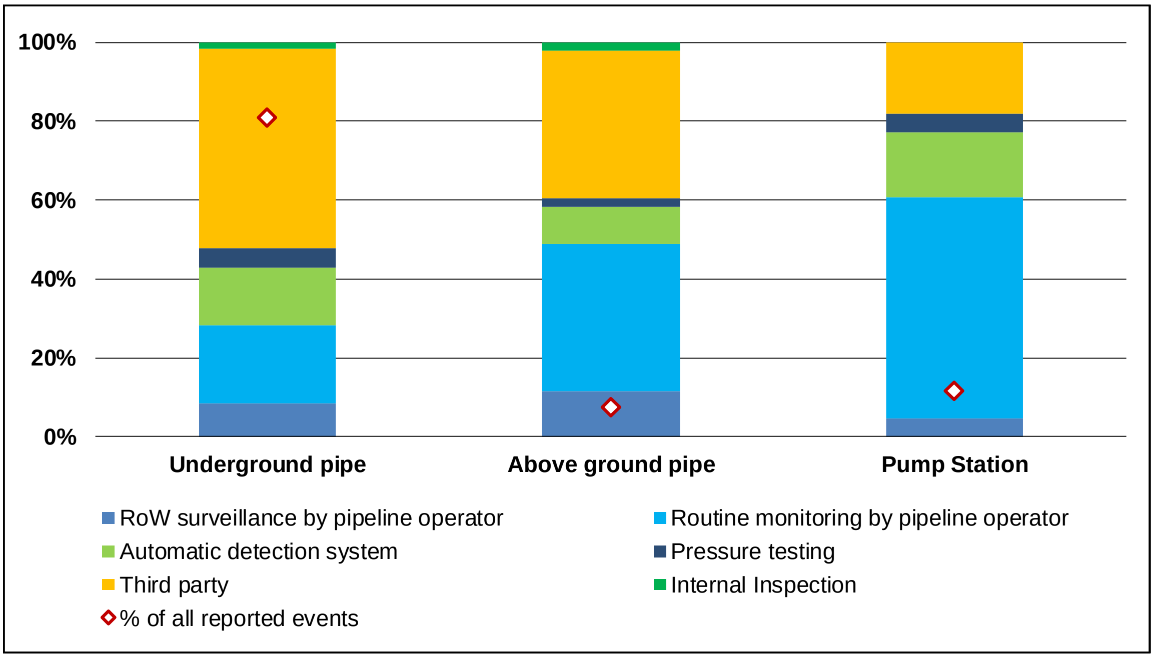
The Concawe survey records whether spillages had consequences for the abstraction of potable water. 14 spillages, representing 1.9% of the total, have had some effect. It is understood that all of these effects have been temporary.

Since 2001 impacts on other types of water have been included. Of the 375 reported spillages since then, 19 have affected surface water, 18 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 6 categories (**Figure 18**) and for three types of facility. The pattern for spillages from pump stations differs from that from pipelines.

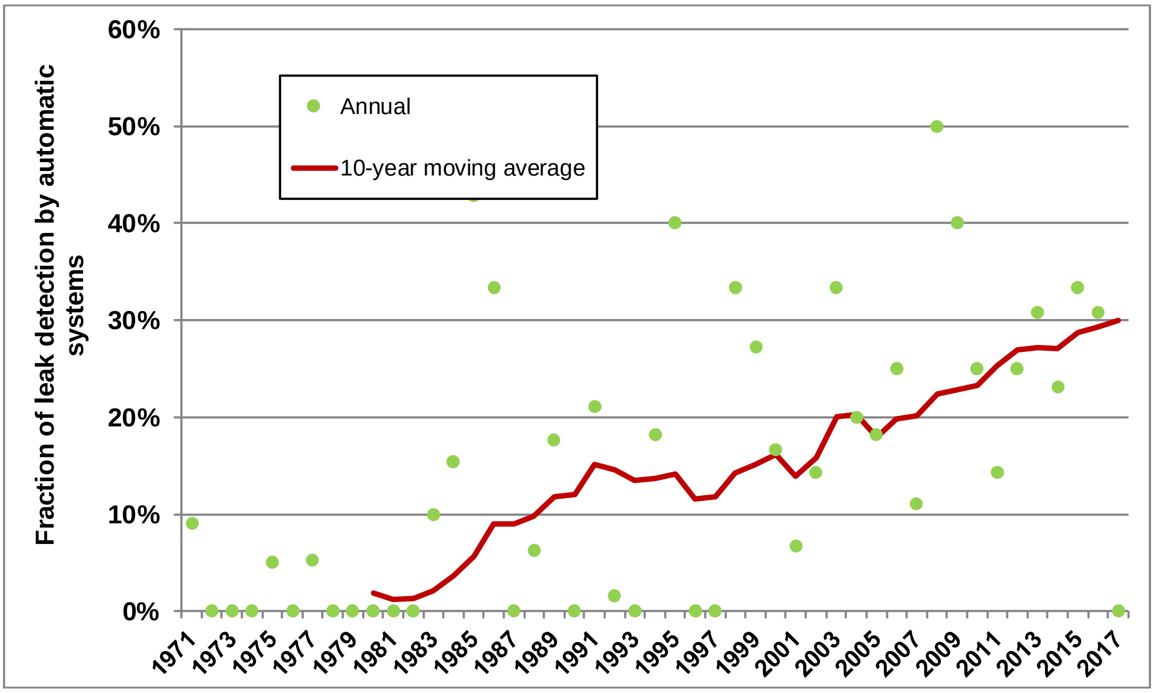
Figure 18 Discovery of spillages



Underground pipeline spillages are most commonly first detected by a third party (51%), often by those who caused the incident in the first place. Automatic detection systems were involved in detecting only 15% 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. As the technology improved and more such systems were installed, their effectiveness and contribution increased. Indeed, over the last 5 years 30% of underground spills were discovered via leak detection systems. This is further illustrated in **Figure 19**. Although the annual percentage shows considerable variation, the 10-year moving average clearly demonstrate the upward trend in the proportion of all spills discovered via LDSs.

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

Figure 19 Proportion of all annual spillage discovered via leak detection systems

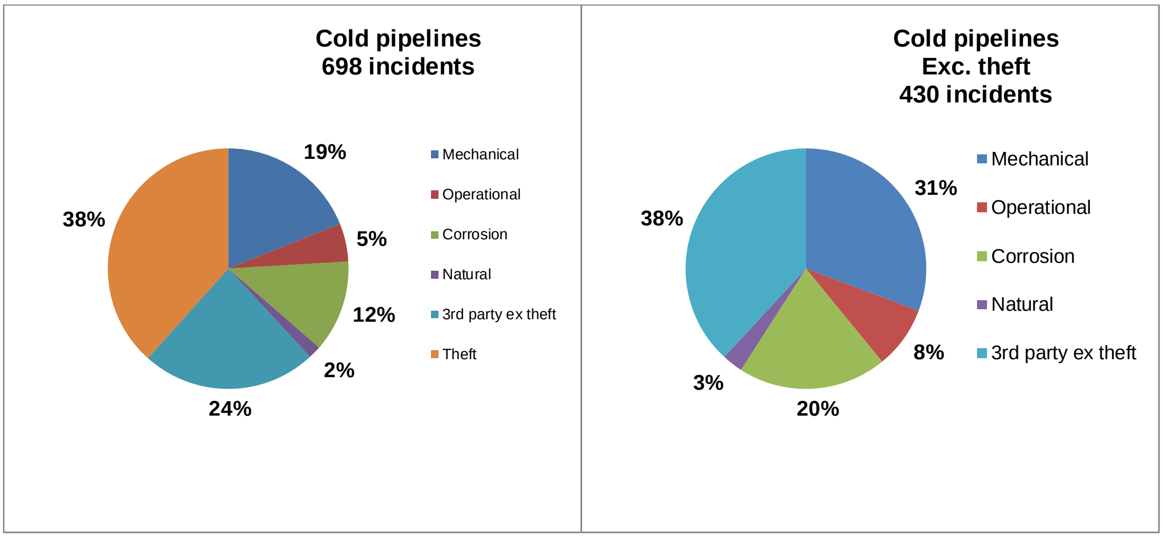


6. DETAILED ANALYSIS OF SPILLAGE CAUSES

Concawe traditionally classifies spill causes into five major categories: mechanical failure, operational, corrosion, natural hazard and third party. These are then further divided into sub-categories (see definitions in **Appendix 1**). As discussed in the previous chapter we now show theft-related incidents separately, as a sixth main category. 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 causes of spillage incidents are different for hot and cold pipelines. For hot oil pipelines spillages are mainly corrosion related (81%), whereas for cold pipelines mechanical problems and third-party activities dominate, with corrosion accounting for only 12% of the total (20% when excluding theft). This is illustrated in **Figure 20**.

Figure 20 Distribution of major spillage causes for cold pipelines



Figures 21 and **22** 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 EU pipeline inventory and potential integrity issues related to ageing infrastructure. Of the 5 main causes of spillage mentioned above, age- related defects are anticipated to play a role in the Mechanical and Corrosion categories and so these are further analysed in **section 6.1 and 6.3** below.

Figure 21 Distribution of major and secondary spillage causes – All pipelines

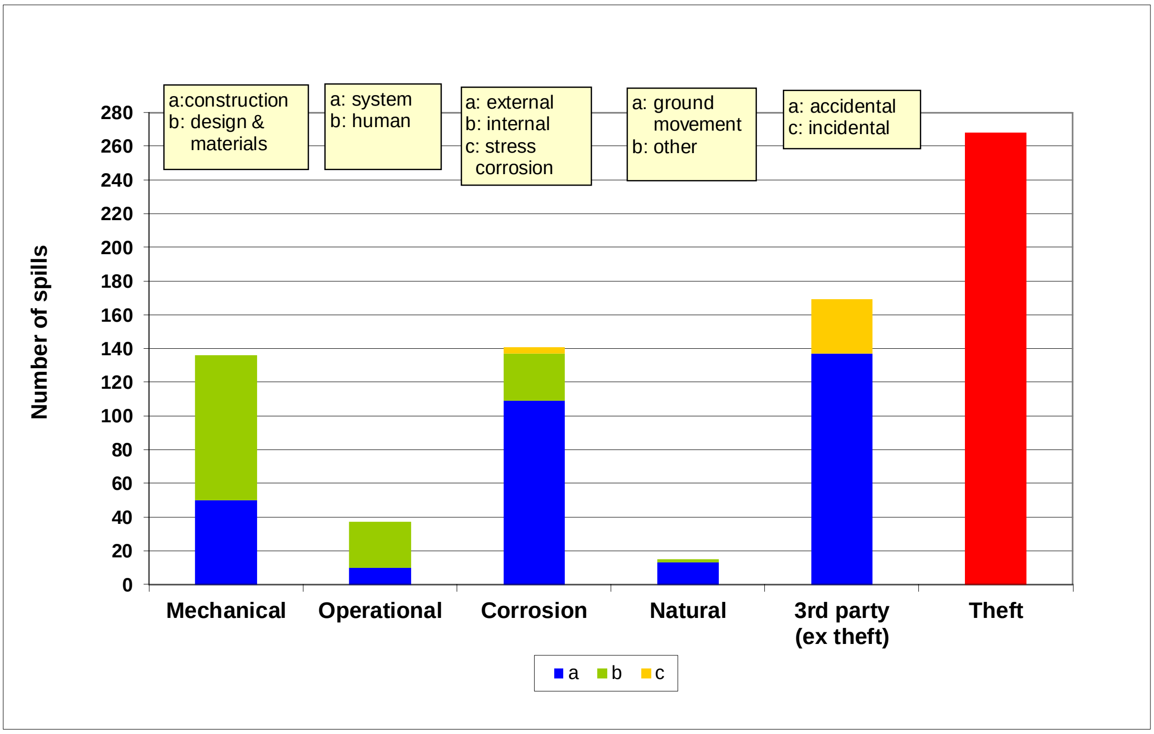
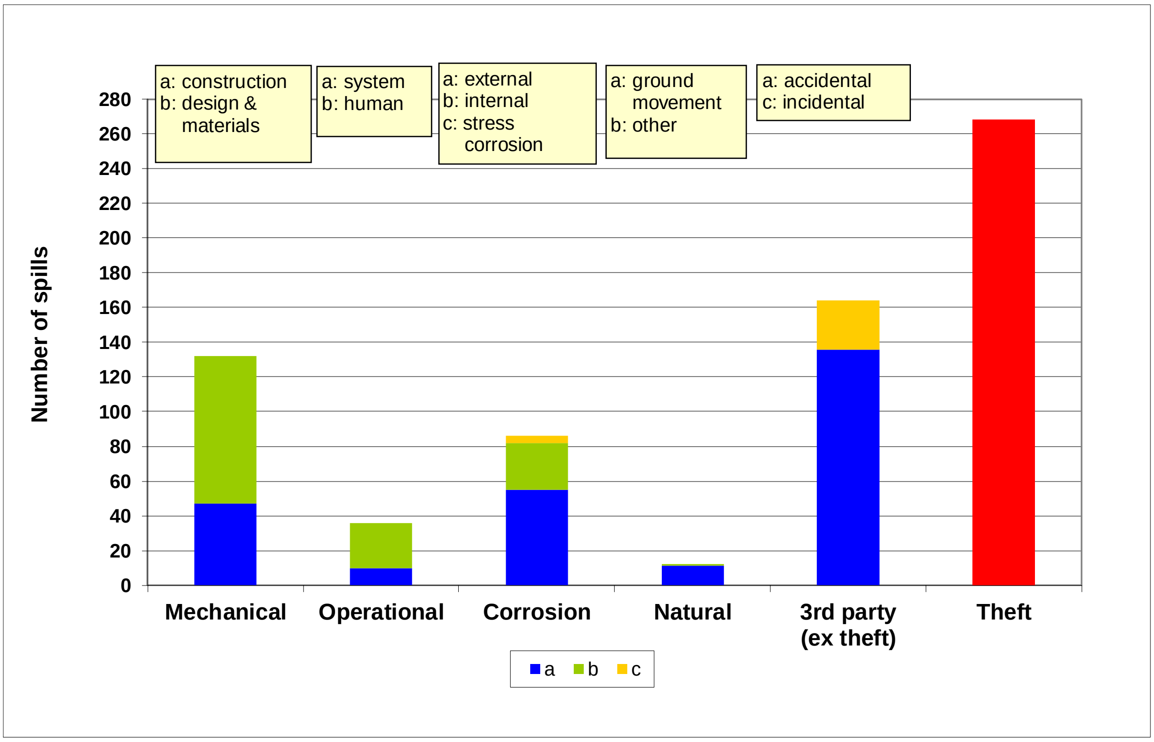


Figure 22 Distribution of major and secondary spillage causes – Cold pipelines



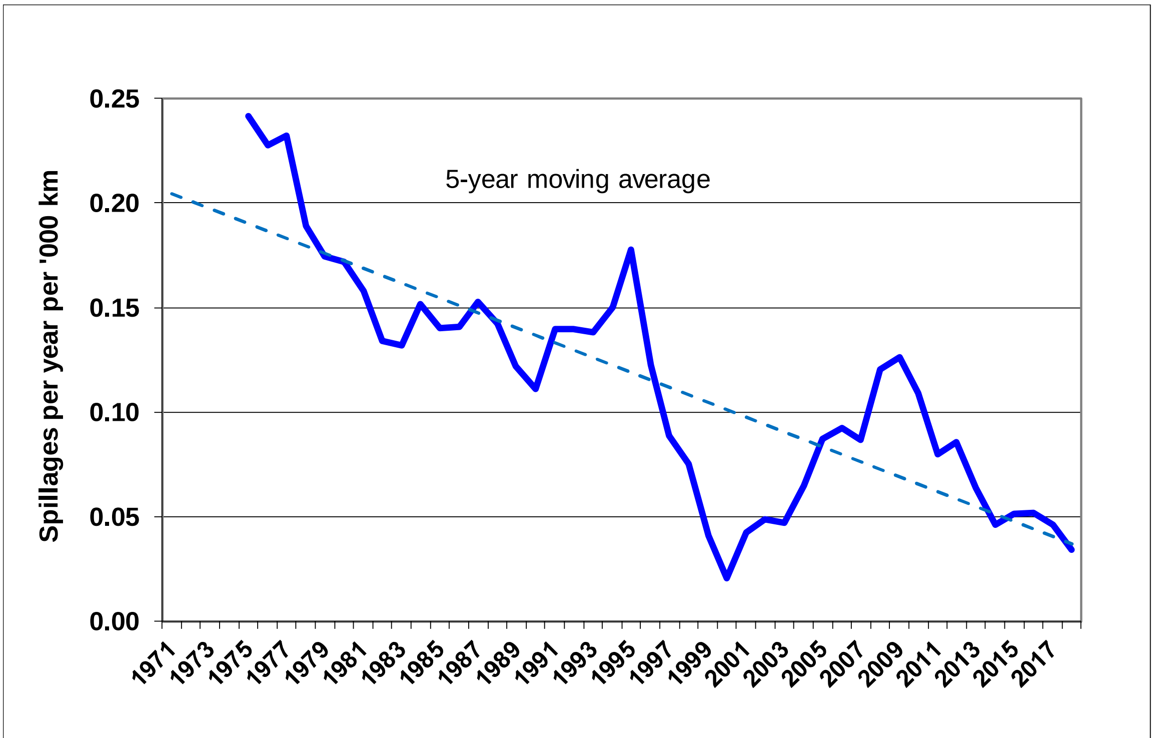
6.1. MECHANICAL

There have been 136 cases of mechanical failure (18% of all spillage events, or 27% excluding theft). This is an average of 2.8 spillages per year. 50 failures were due to construction faults and 86 to design or materials faults.

Note: It is not always straightforward to classify the cause of a spillage. For instance, a number of leaks can be attributed to pipeline damage (e.g. a dent). If 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 23**.

Figure 23 Frequency of mechanical failures for cold pipelines



The downward historical trend which appeared to have reversed from the beginning of the last decade seems to have resumed in the last 8 years.

Within each of the sub-categories, the most common reasons for mechanical failures are illustrated in **Table 7**.

Table 7 Reasons for mechanical failures

Number of spills due to					
Construction	Faulty weld	Construction damage	Incorrect installation		Not reported
	12	6	14		18
Design & Materials	Incorrect design	Faulty material	Incorrect material specification	Age or fatigue	Not reported
	9	34	3	10	30

The total number of reported age- or fatigue-related failures remains low. 2 of the 10 registered events occurred in the last 10 years.

The increasing occurrence of mechanical failures observed between 2000 and 2010, combined with the appearance of an increase in fatigue-related failures caused some concern as it may have been 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 be linked with certainty to ageing according to the above definition, a further 7 being undecided because of lack of appropriate information.

The trend has been reversed since the beginning of this decade which reinforces the view that the frequency of mechanical failures is not 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 37 spillage incidents related to operation (5% of all spillage events, or 7% excluding theft). This is an average of 0.8 spillages per year. 27 incidents were due to human errors and 10 to system faults. The most common reasons for operational incidents are illustrated in **Table 8**.

Table 8 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	Incorrect procedure	Not reported
	3	13	5	5	1

6.3. CORROSION AND IMPACT OF AGEING

There have been 141 failures related to corrosion (18% of all spillage events, or 29% excluding theft). This is an average of 2.9 spillages per year. As noted earlier though, a large proportion of these events (56) occurred in the more vulnerable hot pipelines and in the early years (with the exception of 1 event in 2016). For cold pipelines the number of failures is 86 (11% of the total, 20% excluding theft) and the average is 1.8 spillages per year.

The events have been subdivided into external and internal corrosion and stress corrosion cracking (SCC) that was introduced as an extra category in the late 80s. The number of spillages in each sub-category is shown in **Table 9**.

Table 9 Corrosion-related spillages

Number of spills due to			
	Hot	Cold	All
External corrosion	54	55	109
Internal corrosion	1	27	28
Stress corrosion	0	4	4

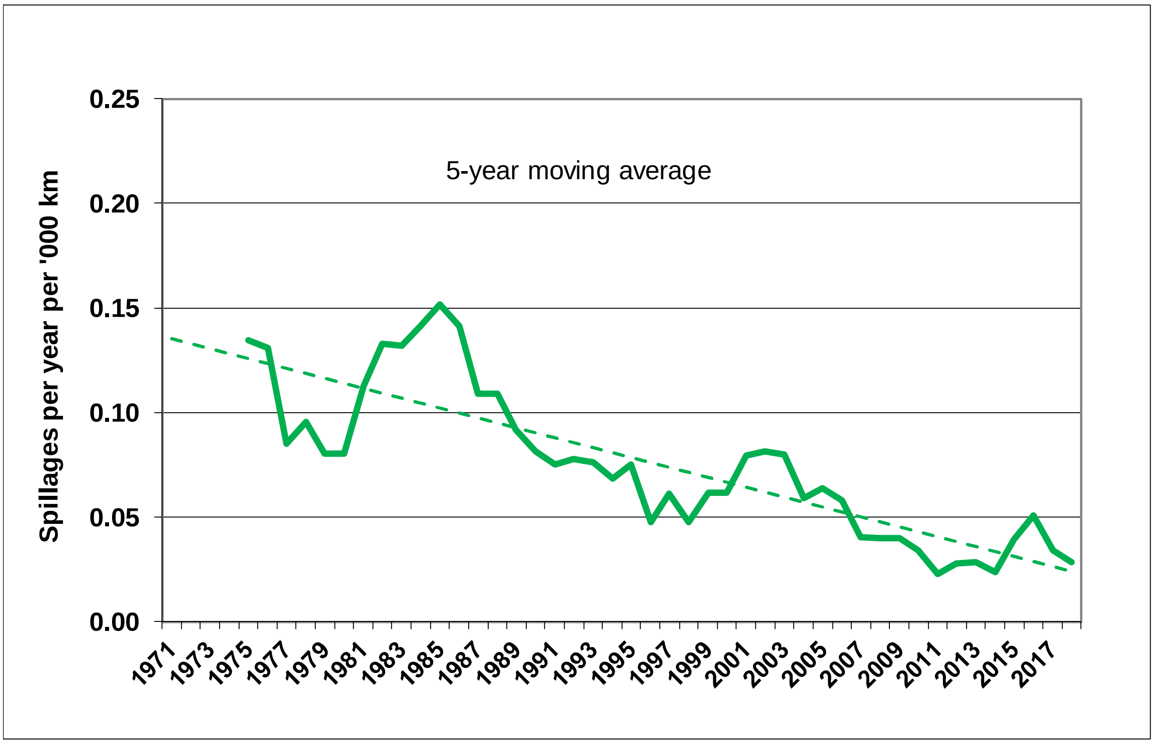
Internal corrosion is much less prevalent than external corrosion. 21 out of the 27 cold pipeline internal corrosion incidents occurred in crude oil service, although crude pipelines only account for less than a third of the cold pipeline inventory. Thus crude pipelines appear to be more vulnerable to internal corrosion than product pipelines. This is 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.

As already mentioned in **Section 5.1,** the number of corrosion- related spillage incidents on hot pipelines has fallen significantly over the years as these have been taken out of service. On cold pipelines there is no sign of an increase in the frequency of corrosion- related spillage and if anything, the frequency has decreased, as shown on **Figure 24**. Out of the 86 corrosion-related failures in cold pipelines, 27 were related to special features such as road crossings, anchor points, sleeves, etc. which therefore appear particularly vulnerable.

While there is no evidence to suggest that corrosion is becoming a problem, pipeline operators undertake regular monitoring to identify and rectify any weaknesses before they develop to the point of failure. Inspection methods involving in-line pigs are used 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 prevent any increase in the frequency of age-related spillages.

Figure 24 Corrosion-related spillage frequency (all types) for cold pipelines



6.4. NATURAL HAZARDS

There have been 15 spillage incidents related to natural hazards (2% all spillage events, or 3% excluding theft). This is an average of 0.3 spillages per year. 13 spillages were due to some form of ground movement and 2 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 10 Details of natural causes due to ground movement

Number of spills due to					
Ground movement	Landslide	Subsidence	Earthquake	Flooding	Others or not reported
	5	3	1	3	3

6.5. THIRD PARTY

Third parties have caused the largest number of spillages with 437 events, an average of 9.1 per year and 57% of all spillage events. 137 events were accidental, 32 were incidental i.e. resulting from damage inflicted to the pipeline by a third party at some point in the past, and 268 were intentional (almost exclusively theft attempts). When excluding theft, accidental and incidental third party events caused 34% of all spills. 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 25**.

The vast majority of events were caused by direct damage from some form of digging or earth moving machinery. Damage by machinery may occur 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 work and so cannot supply appropriate advice on exact pipeline location and working procedures or 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 25 Causes of accidental third party spills

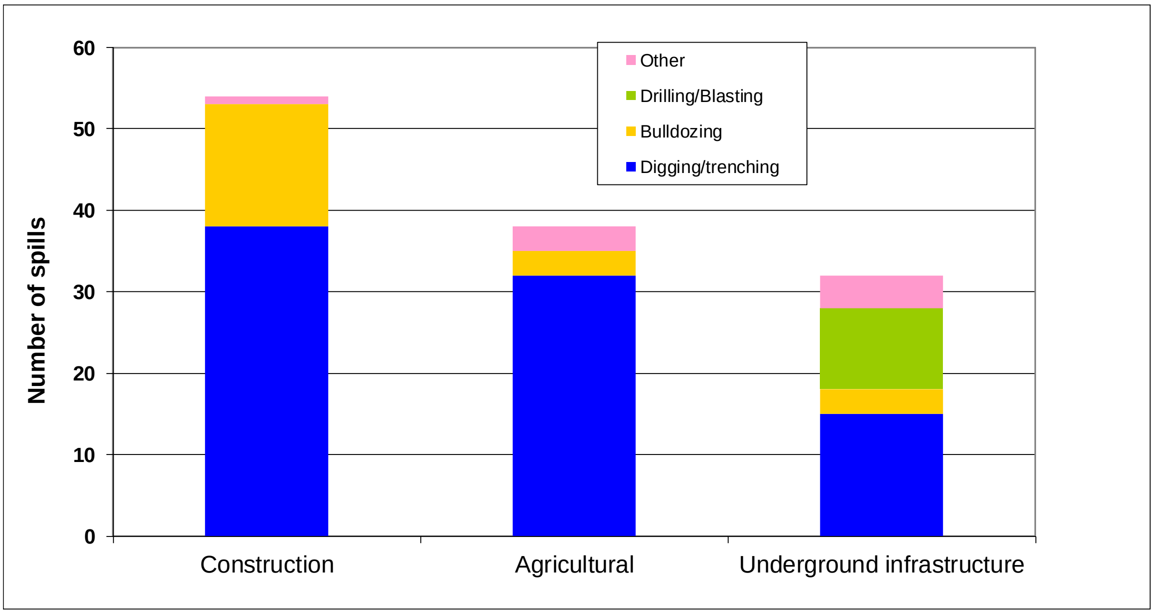
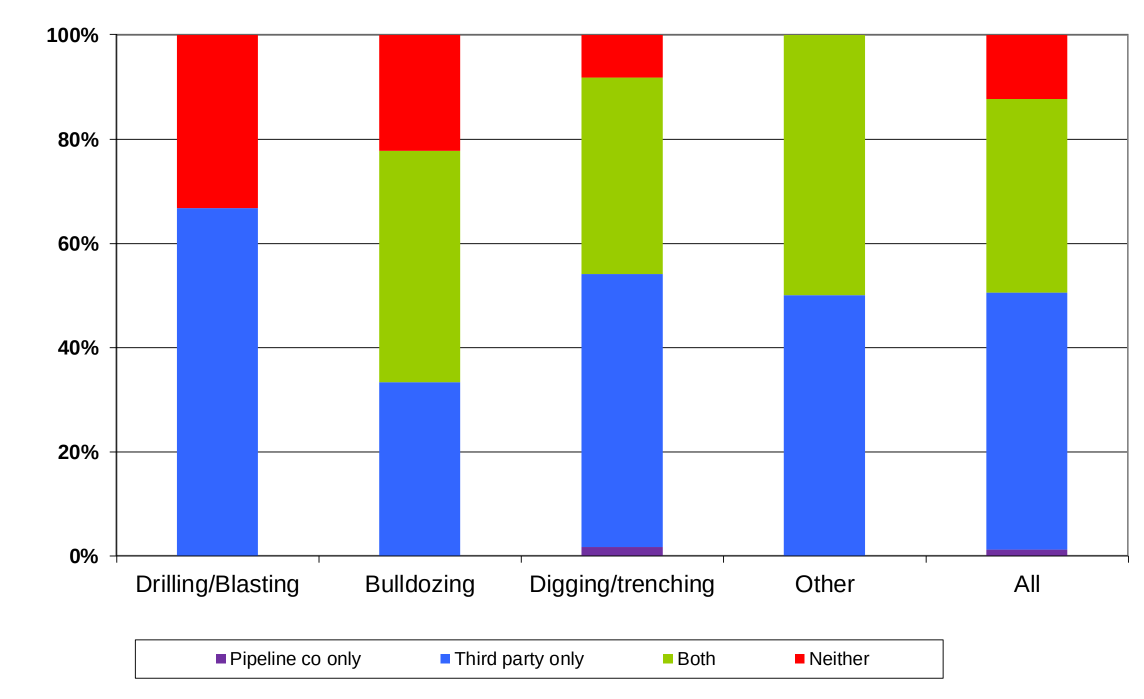


Figure 26 shows the percentage of third party-related spillages where pipeline companies were aware of the impending activity, or third parties were aware of the pipeline location (this data was reported for about 68% of the third party-related accidental spillages).

In 48% of cases, third parties undertook some form of excavation activity in the knowledge that a pipeline was present in the vicinity, but without notifying the pipeline operating company. In contrast, only 1 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 12% of the cases neither party was aware of the other. In 36% 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.

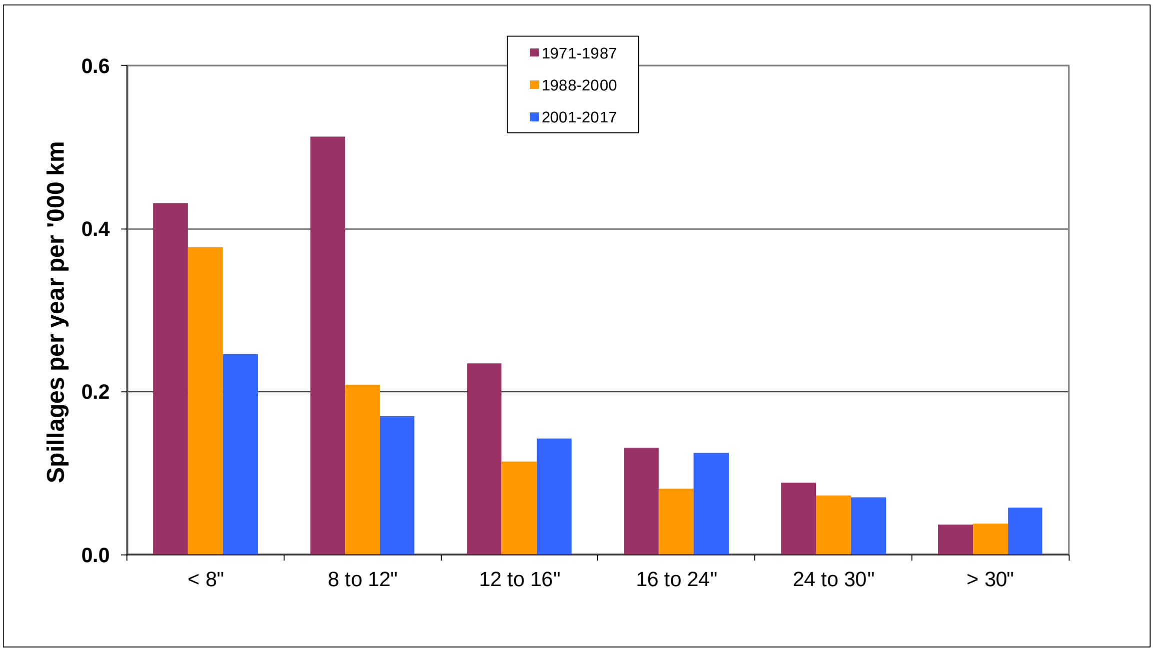
Figure 26 Awareness of impending works and of pipeline location



The strong relationship between spillage frequency and diameter noted in **Section 5.5** is also apparent for accidental damage (**Figure 27**), possibly suggesting a lower level of awareness around the location of smaller pipelines.

While third party accidental damage is a leading cause of spillage, the risk can be effectively mitigated through improved communication and mutual awareness, and the sharing of good practice between pipeline operators from different companies and countries.

Figure 27 Third party accidental spillage frequencies per diameter class



6.5.2. 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 third party groundwork activities.

There have been 32 incidental damage spillage incidents which all originated from dents, scrapes or other physical damage to the pipeline. Thus they share the characteristic that they might be detectable by in-line inspections.

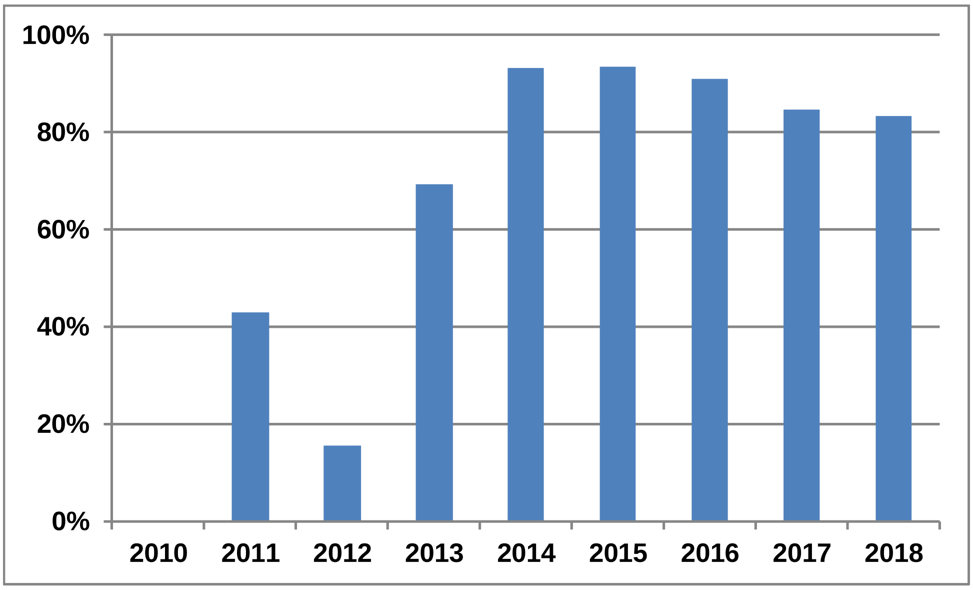
6.5.3. Intentional damage

268 spillages were caused by intentional damage by third parties. 2 resulted from terrorist activities and 6 from vandalism. 260 were caused by attempted or successful product theft, 222 of which occurred in the last 5 reporting years.

Only one of the terrorist or vandalism incidents was on an underground pipeline; 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.

From the middle of the last decade, a few theft attempts by drilling into pipelines were recorded (2 such incidents in each of 2006 and 2007, 3 in 2011 and 1 in 2012). The sudden increase to 18 recorded in 2013, 54 in 2014 and 87 in 2015 was extremely concerning. The 2016 figure was somewhat lower although still very high in the historical context but the downward trend was amplified in 2017 with only 11 events. The 2018 figure of 10 confirms the trend and strongly suggests that measures taken by operators and law enforcement authorities are bearing fruit. Nevertheless, theft activities still occur at a significantly higher level that used to be the case before the recent spike. They also account for a very large proportion of all spillage incidents (**Figure 28**).

Figure 28 Percentage of all spills due to theft activities



It is important to note that product theft is more widespread than is apparent from the spills data alone, since a large number of tampering events do not result in a spill (even when they are successful in terms of extracting product). An analysis of additional data on product theft events, which has been collected by the Concawe survey since 2015, is presented in **Section 8**.

7. IN-LINE INSPECTIONS

Concawe has been collecting data on in-line inspection activities (inspection pig) for 40 years, including a one-off exercise to collate data from paper records generated when 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 2018 the 64 companies that reported inspected a total of 65 sections with at least one type of inspection pig, covering a total combined length of 11,730 km, split as follows amongst the individual types of pig:

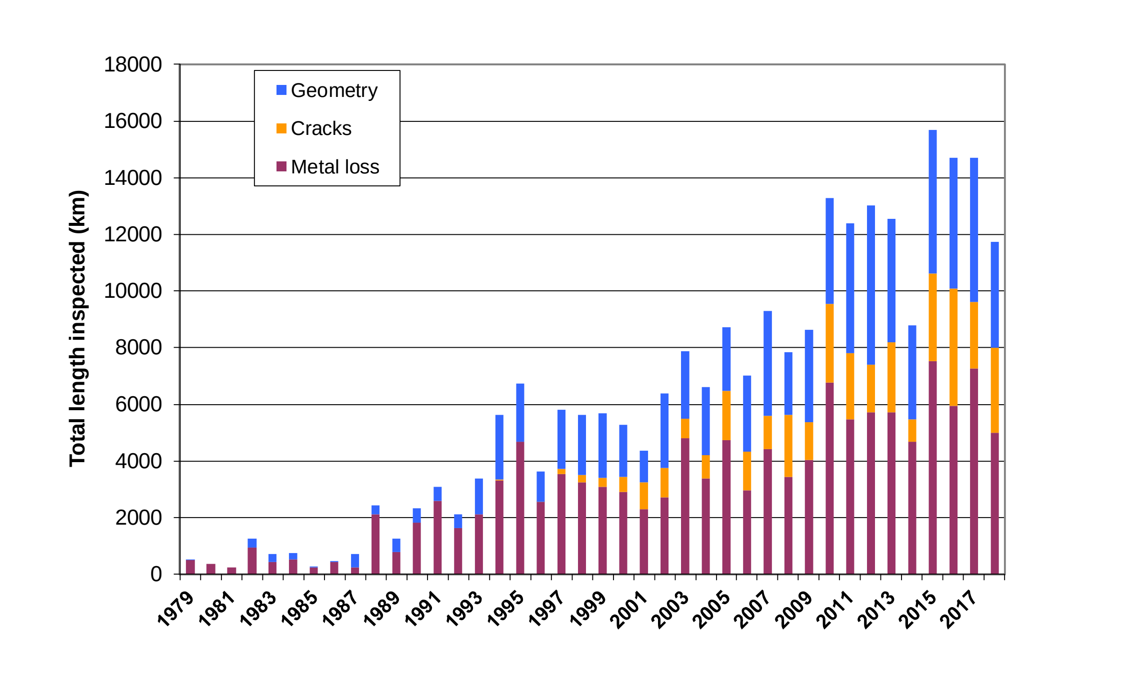
- Metal loss pig 5,003 km, 63 sections
- Crack detection pig 2,994 km, 26 sections
- Geometry pig 3,734 km, 43 sections

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 5,182 km (16% of the inventory).

As shown in **Figures 29 and 30**, the use of inspection pigs for internal inspection of pipelines grew steadily up to the mid 90s, stabilising around 12% of the inventory every year. This further increased to around 15% in the first decade of the new millennium and reached 20% in the early years of the current decade. After a relatively low point in 2014 and a record high figure in 2015, the 2018 figure is relatively low, slightly lower than the 10-year average.

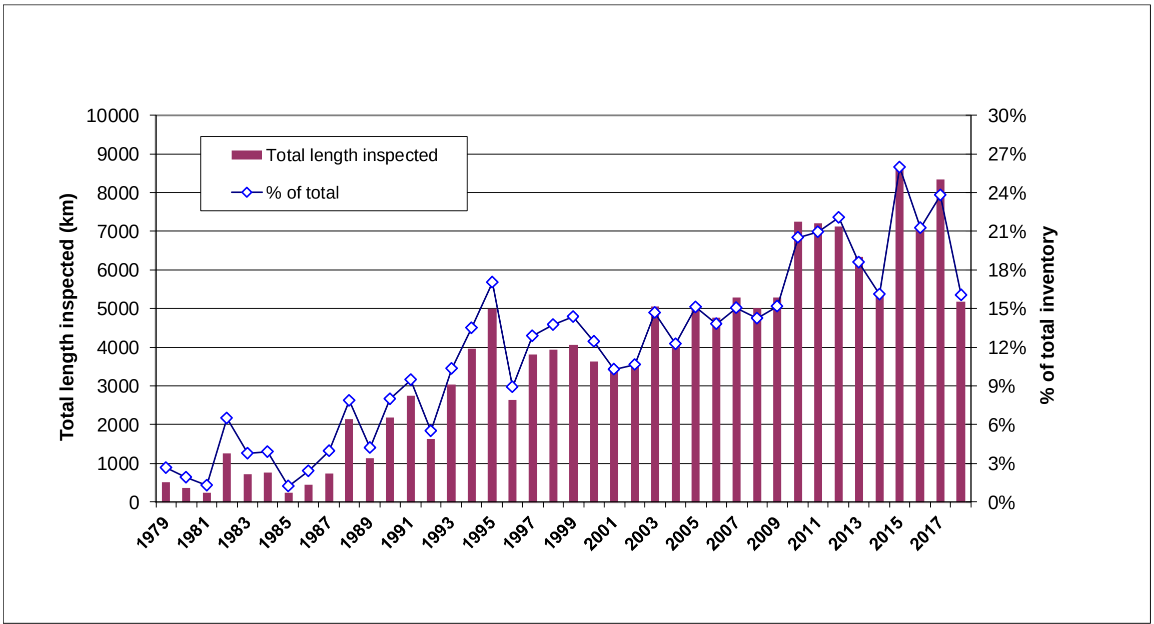
Over the last ten years, a period considered as a reasonable cycle for this type of intensive activity, 421 (68%) of the total of 621 active sections included in the 2018 survey were inspected at least once by at least one type of pig, representing 87% of the total length of the surveyed network. This 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 29 Annual length inspected by each type of pig



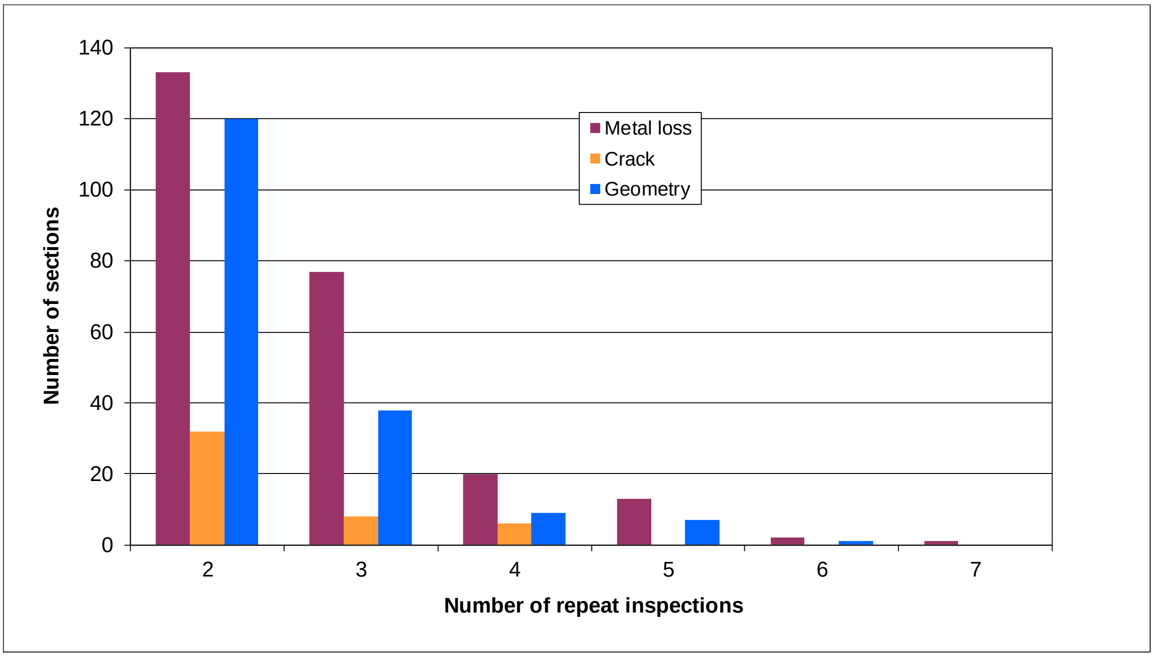
Note: the total length shown above may be higher than shown in Figure 29 as some sections may have been inspected by more than on pig type

Figure 30 Total annual portion of the inventory inspected by inspection pigs



As shown in **Figure 31**, 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 31 Repeat inspections in the last 10 years



In-line inspection technology can detect flaws, corrosion and other sorts of damage in or on the pipe inner or outer walls. Over the past 48 years, 22 spills were caused by faulty welds or construction defects and 32 were caused by some kind of damage inflicted by third parties at some undetermined time. All these could, in principle, have been detected by inspection pigs. There were 6 such spills in the last 10 years. There are also 109 spillages related to external corrosion and 28 to internal corrosion, at least some of which could in principle have been detected. Note that nearly two thirds of the 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 8 and 3 events related to external and internal corrosion respectively.

8. PRODUCT THEFT FROM PIPELINES

The recent emergence of theft or attempted theft as a new threat to pipelines in Europe has been discussed in **section 6**, which addresses theft events that resulted in a reportable spill. However, there are many theft-related events that do not cause a spill either because thieves do not succeed in drilling through the pipe wall or because they install a product withdrawal system with sufficient integrity to ensure containment. Also, operators are increasingly able to detect tampering early enough to avoid causing a spill.

From the 2015 reporting year a new section was added to the annual survey requesting respondents to report the characteristics of all theft attempts, whether or not they were successful or resulted in a spill. The results for 2018 are summarised in **Table 11** while **Figure 32** shows the evolution of the number of incidents since 2010.

In 2018, a total of 36 theft-related incidents were reported in 6 different countries (10 of which resulted in a reportable spill). All were on refined products pipelines.

A variety of connection techniques were used by the thieves, displaying a range of technical knowledge and skills. Hole size was only reported in about a quarter of all cases. The most typical hole size was in the >3 mm bracket.

The automatic leak detection systems only played a very modest part in the discovery of illegal connections. One reason for this could be that operators are now very much aware of the possibility of illegal connections and actively search for them even if they are not active. Another factor may be that criminals are “learning” and adapting their operations (e.g. flow rate) to avoid detection.

Most connections were located in open countryside. The distance to the abstraction point varied a great deal. In a small number of cases, sophisticated storage facilities were found, mostly inside industrial or farm building. This was not the rule though and in most cases there was no fixed storage on site.

Faced with this serious new threat, operators reacted promptly, enhancing surveillance, improving leak detection system capabilities and increasing awareness of the problem with own staff and contractors. Relevant information was shared within Concawe and best practices established and disseminated. **Figure 32** shows the development of the product theft issue since 2010, in terms of the annual number of theft-related events and theft-related spills, and also the cumulative number of theft events. These efforts have clearly paid off and the trend was reversed with 112 events recorded in 2016 to 46 in 2017 and 36 in 2018. Indications are that the downward trend continued in 2019 with a provisional total of 19 incidents. Nonetheless, the annual rate is still far above the long-term average, requiring continued focus and vigilance. The figures also indicate a gradual reduction of the proportion of theft events causing a spill since 2015. Although it may not be statistically significant at this point, this may be the result of increased “professionalism” of thieves and/or early detection by operators.

It should be noted that the total number of theft events is higher than that reported in this Concawe survey. In their 2019 annual report, Unione Petrolifera show a higher number of theft events for Italy (see annual report at https://www.unionepetrolifera.it/pubblicazioni/), which suggests that some Italian operators that did not report in the Concawe survey also experienced theft events. The number of events reported by Unione Petrolifera for 2018 is almost identical to the 2017 figure, which is consistent with the trend suggested by the Concawe figures.

In addition not all pipelines are included in the Concawe inventory (for example NATO lines in Italy, Greece, Norway and Portugal as well as all crude and product pipelines in Poland).

Figure 32 Evolution of the number of theft-related events since 2010 (with provisional figures for 2019)

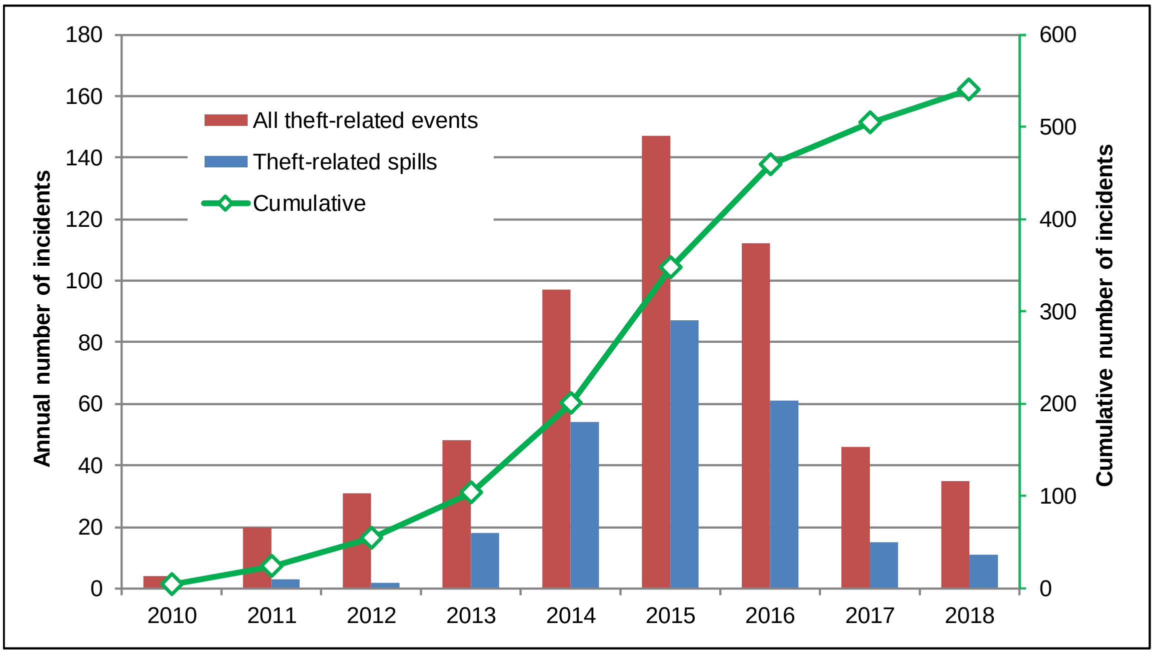


Table 11 Summary of 2018 attempted theft events attributes
(note that not all attributes were reported for all events)

								Number reported
Number of events	**36**							
Successful thefts	**18**							
Spills caused	**10**							
Code	1	2	3	4	5	6	7	
Service (type of product transported)	0%	60%	3%	14%	23%	0%		31
Facility part	56%	3%	39%	3%				21
Connection type	2%	16%	40%	42%				29
Hole size	0%	73%	27%	0%	0%			15
Detection (how was tampering detected)	6%	14%	3%	6%	6%	28%	39%	31
Flow rate (estimated abstraction rate)	64%	36%	0%					4
Location (type of environment)	58%	17%	17%	8%				7
Distance (between pipeline and abstraction point)	38%	38%	19%	6%				20
Storage (facility installed by thieves)	76%	0%	24%					30

Key

Service (type of product transported)
1 Crude oil
2 Multi product
3 Gasoline
4 Diesel
5 Jet
6 Other

Facility part
1 Underground pipe
2 Overground pipe
3 Valve station
4 Other

Connection type
1 Clamped
2 Welded
3 Screwed
4 Other

Hole size
1 No hole
2 < 3 mm
3 3-6 mm
4 6-10 mm
5 > 10 mm

Detection (how was tampering detected)
1 Automatic detection system
2 Operational monitoring
3 Routine surveillance
4 Ultrasonic LD pig
5 Line internal inspection
6 Third party
7 Other

Flow rate (estimated abstraction rate)
1 < 1 m^3/h
2 1-5 m^3/h
3 > 5 m^3/h

Location (type of environment)
1 Open land
2 Car park / Lay-by
3 Shrub / wooded area
4 Building

Distance (between pipeline and abstraction point)
1 < 10 m
2 10-100 m
3 100-1000 m
4 > 1000 m

Storage (facility installed by thieves)
1 None
2 <1 m^3
3 >1 m^3

APPENDIX 1 DEFINITIONS AND CODES

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 into secondary causes and “Reasons” as shown in **Table 1.1**.

Table 1.1 Cause categorisation tree

Primary		*Secondary*		*Reason*	
A	Mechanical	Ab	Design and Materials	1	Incorrect design
				2	Faulty material
				3	Incorrect material specification
				4	Age or fatigue
		Aa	Construction	5	Faulty weld
				6	Construction damage
				7	Incorrect installation
B	Operational	Ba	System	8	Equipment
				9	Instrument & control systems
		Bb	Human	10	Not depressurised or drained
				11	Incorrect operation
				12	Incorrect maintenance or construction
				13	Incorrect procedure
C	Corrosion	Ca	External	14	Coating failure
				15	Cathodic protection failure
		Cb	Internal	16	Inhibitor failure
		Cc	Stress corrosion cracking		
D	Natural	Da	Ground movement	20	Landslide
				21	Subsidence
				22	Earthquake
				23	Flooding
		Db	Other		
E	3rd Party	Ea	Accidental	17	Construction
				18	Agricultural
				19	Underground infrastructure
		Ec	Incidental		
		Eb	Intentional	24	Terrorist activity
				25	Vandalism
				26	Theft (incl. attempted)

APPENDIX 2 SPILLAGE SUMMARY

Key to table

Cause categories: see **Appendix 1**

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

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

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (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 (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)
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 (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)
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	36	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	2012	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		
498		20	1			1	0	2	3	4	0	4	Bb	13		0
499	2013	28	1			2	0	2	1	3	47	4	Aa	7		100
500		28	1			19	0	1	1	7	34	6	Bb	12		0
501		8	2			88	88	3	1	3	0	3	Ea	17		50
502		8	2			12	12	3	1	3	0	0	Ea	17		
503		10	2			10	9	1	1	3	39	3	Eb	26		40
504		12	2			6	6	3	1	3	37	3	Eb	26		30
505		12	1			5	5	1	1	3	33	4	Cb	0		50
506		40	1			2	0	1	2	7	46	0	Aa	0		1,000
507		12	2			7	4	5	1	3	13	3	Eb	26		150
508		10	2			50	38	2	1	3	25	3	Eb	26		200
509		8	2			10	2	5	1	3	56	3	Eb	26		
510		16	2			0	0	5	1	3	39	3	Eb	26		
511		16	2			0	0	3	1	3	39	3	Eb	26		
512		16	2			0	0	3	1	3	39	3	Eb	26		
513		16	2			0	0	3	1	3	39	3	Eb	26		
514		12	2			0	0	3	1	3	40	3	Eb	26		
515		12	2			0	0	5	1	3	40	0	Eb	26		
516		12	2			0	0	5	1	3	40	3	Eb	26		
517		22	2			0	0	5	1	3	42	3	Eb	26		
518		22	2			0	0	5	1	3	42	3	Eb	26		
519		22	2			0	0	3	1	3	42	3	Eb	26		
520		8	2			0	0	5	1	3	43	3	Eb	26		
521		8	2			0	0	5	1	3	43	3	Eb	26		
522		12	2			2	2	2	1	4	0	5	Ab	4		3
523		10	2			30	30	2	1	3	0	3	Eb	26		3,000
524		10	2			0	0	5	1	3	0	3	Ec	18		50

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)
525	2014	24	1			3	3	1	3	3	57	4	Ea	19		200
526		6	2			10	0	3	1	3	50	3	Ea	18		100
527		14	2					5	1	3	47	3	Eb	26	S	1,400
528		24	1			5	5	6	1	3	43	3	Eb	26		1,500
529		20	2			1	0		1	3	48	5	Eb	26		
530		8	2					5	1	3	24	5	Eb	26		414
531		12	2					1	1	3	58	3	Eb	26		1,500
532		11	2			5	1	1	3	8	58	4	Ab	2		0
533		10	2					5	1	3	27	3	Eb	26		184
534		16	2			15	9	5	1	3	41	2	Eb	26		250
535		10	2			2	0	4	1	3	50	5	Eb	26		100
536		10	2			2	0	3	1	3	50	3	Eb	26		
537		20	1			500	0	3	1	3	50	3	Ec			64,000
538		14	2			150	150	5	1	3	29	3	Eb	26		
539 to 555			2						1	3			Eb	26		
556 to 582			2						2	4			Eb	26		
583	2015	12	2			59	38	5	1	8	47	7	Eb	26		500
584		10	2			3	2	3	1	3	41	3	Eb	26		50
585		20	1				0	6	2	8	48	7	Aa			
586		12	2			2	0	5	1	3	42	2	Eb	26		50
587 to 664			2							3			Eb	26		
665		8	2			39	34	3	1	3	24	5	Eb	26		275
666		14	2			25	25	5	1	3	5	3	Eb	26		
667		10	2			9	9	3	1	3	33	3	Eb	26		10
668		10	2			22	20	5	1	3	33	3	Eb	26		100
669		10	2			15	14	5	1	3	34	3	Eb	26		
670		10	2			3	3	3	1	3	34	3	Eb	26		
671		6	1			0	0	2	2	3	26	4	Cb			20
672		8	2			15	15	5	1	3	38	3	Ca	14		200
673		8	2			13	3	2	1	3	39	4	Ca	15		200
674		12	2			30	0	3	2	2	49		Ab	2		
675		1	2			2	0	5	2	2	61		Ab	2		5
676	2016	24	2			11	1	5	1	1	58	3	Aa	5	S G	200
677		16	2			128	13	3	1	3			Ea			
678		10	2				0		1	3		3	Eb	26		
682		12	2			7	0	2	1	3		2	Eb	26		75
683		12	2					5	1	3	26	3	Eb	26		100
684		14	2			3	0	3	1	3	7	3	Eb	26		20
685		6	2			13	10	3	1	3	51	3	Eb	26		50
686		12	2			16	16	5	1	3		3	Eb	26	S	
687		12	2			9	9	3	1	3	50	3	Eb	26		
688		12	2			400	20	5	1	3	52	2	Ea	17		
689		18	3			1	1	5	1	3	44		Ca			
690		16	2			16	0	5	1	3	48	4	Ca	15		100
691		11	2			200	200	6	1	3	64	2	Ca	14		
692		16	2			97	70	5	1	3	20	5	Eb	26		850
693 to 742			2							3			Eb	26		
743	2017	10	2			8	5	5	1	3	26	3	Eb	26		300
744 to 753			2						1			3	Eb	26		
754		13	2			1	0	5	3	8		2	Bb	13		
755		16	2			32	0		2	6	49	4	Bb	13		2,000
756		8	2			3	0	6	1	3	65	3	Eb	26		
757 to 765	2018												Eb	26		
766		12	2			12		5	1		60	3	Eb	26		80
767		6	2			40		3	1		35	5	Ea	18		
768		12	2			9	1	2	1	3		5	Aa	7	S G	240

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