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Performance of European cross-country oil pipelines

Statistical summary of reported spillages in 2015 and since 1971

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Statistical summary of reported spillages in 2015 and since 1971

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

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ABSTRACT

Concawe has collected 45 years of spillage data on European cross-country oil pipelines. At nearly 37,500 km the current inventory includes the majority of such pipelines in Europe, transporting some 751 million m^3 per year of crude oil and oil products. This report covers the performance of these pipelines in 2015 and a full historical perspective since 1971. The performance over the whole 45 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. The main feature of this 2015 survey is the continued rise of spillages related to product theft attempts, 87 of which were reported, confirming the trend already observed in 2014. Another 6 spillage incidents were reported in 2015, corresponding to 0.17 spillages per 1000 km of line, similar to the 5-year average and well below the long-term running average of 0.47, 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. 3 incidents were due to mechanical failure and 3 to corrosion. Over the long term, third party activities remain the main cause of spillage incidents and the rise of theft attempts will greatly increase this proportion.

KEYWORDS

Concawe, inspection pig, oil spill, performance, pipeline, safety, soil pollution, spillage, statistics, trends, water pollution

INTERNET

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

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SUMMARY

Concawe has collected 45 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 2015 and provides a full historical perspective since 1971. The performance over the whole 45 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.

77 companies and agencies operating a total of 37,403 km of oil pipelines in Europe are currently listed for the Concawe annual survey. For 2015 63 operators provided information representing over 141 pipeline systems and a combined length of 33,903 km. In addition Concawe could confirm from reliable industry sources that one other operator did not suffer any spillages in 2015. Although not accounted for in the throughput, traffic and in-line inspections data, this additional inventory has been taken into account in the spill statistics. The reported volume transported in 2015 was 760 Mm^3 of crude oil and refined products, higher than the 2014 figure. Total traffic volume in 2015 was about $121x10^9.m^3.km$.

87 spillages related to theft attempts (third party intentional) were reported, a large increase compared to the already high figure of 54 reported in 2014. Theft attempts caused a total of 28 spillage incidents between 1971 and 2012, and as many as 159 in the last 3 reporting years signalling the emergence of a whole new phenomenon.

Another 6 spillage incidents were reported, corresponding to 0.17 spillages per 1000 km of line, equal to the 5-year average and below the long-term running average of 0.47, 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.

3 spillages were related to mechanical causes (construction for one and design and materials for the other two) and 3 were caused by corrosion (2 external and 1 internal). Over the long term, third party activities remain the main cause of spillage incidents. Mechanical failure is the second largest cause of spillage. After great progress during the first 20 years, the frequency of mechanical failures appeared to be on a slightly upward trend over the last decade, although this trend has been reversed in the last five years.

When excluding theft events (for which the volume lost is impossible to determine in most cases), the gross spillage volume was 61 m^3 or 1.7 m^3 per 1000 km of pipeline compared to the long-term average of 67 m^3 per 1000 km of pipeline. 69% of that volume was recovered.

Pipelines carrying hot oils such as fuel oil have in the past suffered from external corrosion due to design and construction problems. Most have been shut down or switched to cold service, so that the great majority of pipelines now carry unheated petroleum products and crude oil. Only 45 km of hot oil pipelines are reported to be in service today. The last reported spill from a hot oil pipeline was in 2002.

In 2015 a total of 82 sections covering a total of 15,394 km were inspected by at least one type of inspection pig. Most inspection programmes involved the running of more than one type of pig in the same section, so that the total actual length inspected was less at 8487 km (24% of the inventory which is the highest figure recorded thus far).

Most 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 2015 less than 5% were 10 years old or less and 64% were over 40 years old. However, this has not led to an increase in spillages (excluding theft-related events).

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

1. INTRODUCTION

The Concawe Oil Pipelines Management Group (OPMG) has collected data on the safety and environmental performance of oil pipelines in Europe since 1971. Information on annual throughput and traffic, spillage incidents and 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 2014 data report 16/7. 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 next COPEX will be 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 2015 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.

The number of theft attempts has greatly increased over the last few years. Some of these result in a reportable spill and are then included in the standard spill reporting. Others, however, do not cause a spill and were therefore not covered thus far. In order to capture the full extent of this challenge, a new section was added to the annual survey to report all theft-related incidents. 2015 is the first reporting year and initial findings are discussed in **Section 8**.[1]

[1] It should be noted that the total number of theft incidents is higher than that reported in the 2015 Concawe survey. In their 2016 annual report, Unione Petrolifera show a higher number of incidents for Italy (http://www.unionepetrolifera.it/?wpdmpro=annual-report-2016&wpdmdl=6092), which suggests that Italian operators that did not report in the Concawe survey also experienced large numbers of theft incidents. 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)

2. PIPELINE INVENTORY, THROUGHPUT AND TRAFFIC

2.1. CRITERIA FOR INCLUSION IN THE SURVEY

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

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

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

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

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

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

It should be noted that all data recorded in this report and used for comparisons or statistical analysis relate to the reported inventory 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

77 companies and agencies operating a total of 37,403 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 2015 reporting year, 63 companies completed the survey. In addition Concawe received information from reliable industry sources confirming that 1 additional company suffered no spills in 2015. 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 13 companies, they have not been included in the statistics. The proportions 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 1971-2015

2.3.1. Pipeline service, length and diameter

The 63 companies that reported in 2015 operate 141 pipeline systems split into 647 active sections running along a total of 33,903 km as well as 26 sections covering 2068 km which are currently (but not permanently) out of service. These latter sections are included in the reporting statistics, so that the total reported length in 2015 was 35,971 km. The 14 companies from which we received no information for 2015 represent 1432 km split into 68 sections in 19 systems, giving a total Concawe inventory of 37,403 km (one 120 km section was permanently taken out of service in 2015).

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

Over the years a total of 265 sections have been permanently taken out of service, reducing the inventory by 10,348 km.

It is important to note that **Figure 1** represents the pipeline length reported to Concawe in each year and does not therefore give an account of when these pipelines were put into service. Most of the major pipelines were 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 265 sections that have been retired since 1971, 25 (1160 km) were in the “hot” category. The remaining “hot” inventory consists in 45 km distributed between

19 km in 3 sections transporting heavy fuel oil and 26 km in 3 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

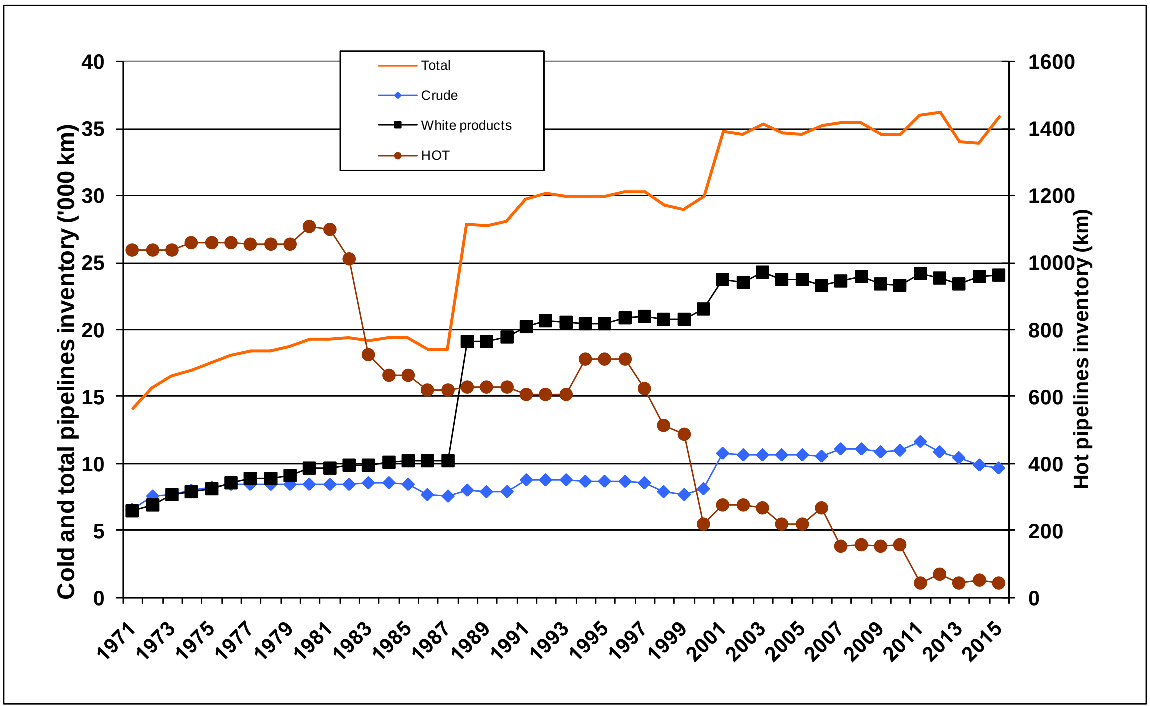
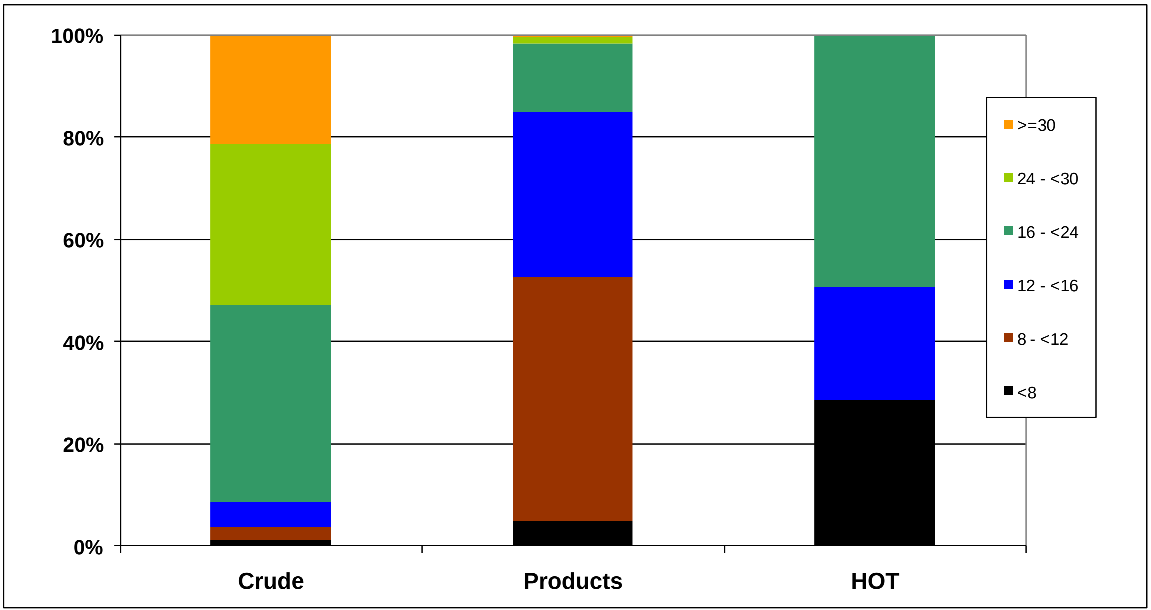


Figure 2 shows the diameter distribution in 2015 for each service category. In general, the crude pipelines are significantly larger than the other two categories. 91% of the crude pipelines are 16" (400 mm) or larger, up to a maximum of 44" (1100 mm), whereas 85% of the product lines are smaller than 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 2015

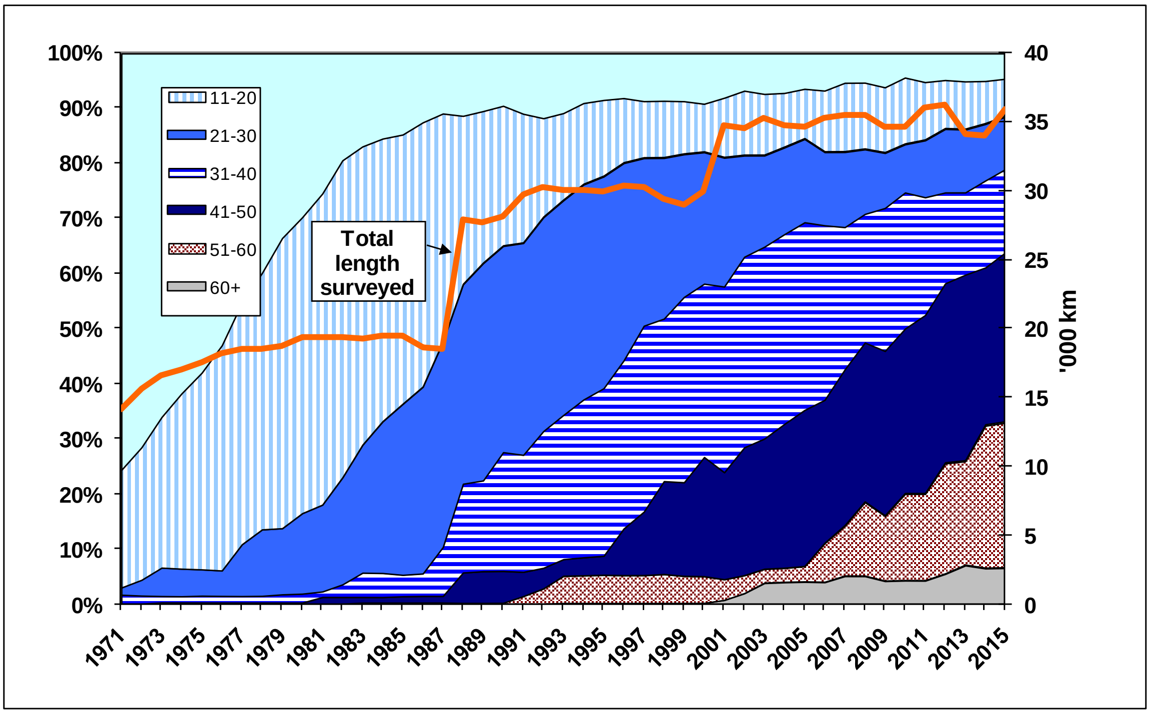


2.3.2. Age distribution

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.

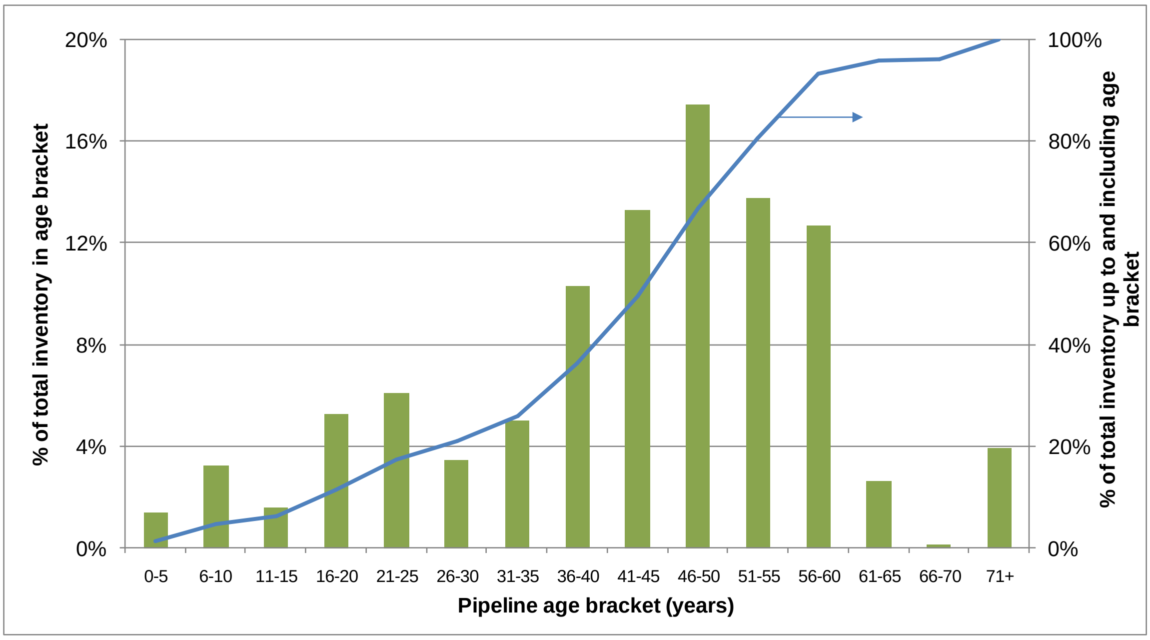
Over the years, a number of new pipelines have been commissioned, while older ones have been taken out of service. As mentioned above, existing lines were also added to the inventory at various stages, contributing their specific age profile. Although some short sections may have been renewed, there 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 2015 age distribution is shown on **Figure 3b** both for discreet age brackets and cumulatively: only 1653 km, i.e. 4.6% of the total, was 10 years old or less while 22,947 km (63.8%) 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 2015



2.4. THROUGHPUT AND TRAFFIC

Some 760 Mm^3 (418 Mm^3 of crude oil and 342 Mm^3 of refined products) were transported in the surveyed pipelines in 2015, a higher figure than recorded in the past few years. The crude oil transported represents about two thirds of the combined throughput of European refineries. It should be realised however, that this figure is only indicative. Large volumes of both crude and products pass through more than one pipeline, and whilst every effort is made to count the flow only once, the complexity of some pipeline systems is such that it is often difficult to estimate what went where. Indeed, there are a few pipelines where the flow can be in either direction.

A more meaningful figure is the traffic volume which is, 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 2015, the total reported traffic volume was about $121x10^9$ m^3.km, close to the 2014 figure and split between $79x10^9$ m^3.km for crude and $42x10^9$ 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 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 2015.

Over the 45 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 2015.

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 (2010-14)

4.1. 2015 SPILLAGE INCIDENTS

93 spillage incidents were recorded in 2015, **87 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 the 2015 figure confirms that this is an increasing challenge for operators. While theft tended in the past to be an issue in Southern and Eastern Europe, it is also notable that no areas of Europe are now immune to it.

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 2015 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									
585	Above ground	20	Crude oil	-	-	0.0	0.0	0	
Design and Materials									
674	Above ground	12	Diesel	-	-	30.0	0.0	0	
675	Above ground	0.5	Diesel	-	-	1.9	0.0	5	
Corrosion									
External									
672	Underground pipe	8	Jet Fuel	-	-	15.0	15.0	200	
673	Underground pipe	8	Jet Fuel	-	-	13.4	3.4	200	
Internal									
671	Above ground	6	Crude oil	-	-	0.3	0.3	20	
Third party activity									
Theft or theft attempt									
583	Underground pipe	12	Jet Fuel	-	-	59.3	38.3	500	
584	Underground pipe	10	Diesel	-	-	3.2	2.4	50	
586	Underground pipe	12	Jet Fuel	-	-	1.5	0.1	50	
665	Underground pipe	8	Diesel	-	-	39.0	34.0	275	
666	Underground pipe	14	Jet Fuel	-	-	25.0	25.0	0	
667	Underground pipe	10	Jet Fuel	-	-	8.5	8.5	10	
668	Underground pipe	10	Jet Fuel	-	-	22.0	20.0	100	
669	Underground pipe	10	Gasoline	-	-	15.0	13.5	0	
670	Underground pipe	10	Gasoline	-	-	2.8	2.8	0	
587-664	Underground pipe		White product	78 events, no details available					

(1) Spillage events are numbered from the beginning of the survey in 1971

(2) I = Injury, F = Fatality

4.1.1. Mechanical Failure

There was three spillage incidents related Mechanical failure in 2015, one in the Construction and two in the Design and Materials category.

Event 585:
A leak developed in an expansion box releasing crude oil. No further details were available.

Event 674 & 675:
One flange gasket and one small bore tapping flange gasket failed in short succession on above ground sections of the main line.

In the first instance a power cut caused a pressure surge (within the design limits of the line) that triggered the failure. This was detected by the leak detection system. In the second instance the failure occurred in an idle but pressurised line. The spillage was reported by a security guard on patrol.

In the first instance the entire volume spilled was collected in a pit and recovered. In the second instance minor soil pollution occurred and appropriate remediation carried out.

Upon investigation it appeared that the gaskets had been recently replaced and were defective. 18 such gaskets were subsequently replaced.

4.1.2. Operational activities

There were no spillages in this category in 2015.

4.1.3. Corrosion

There were 3 spillages related to corrosion in 2015, 2 in the external corrosion and 1 in the internal corrosion category.

Event 672:
A pinhole leak developed near an old cathodic protection (CP) lug in spite of a new (live) CP connection being present less than one metre away.

The coating condition was satisfactory. AC voltage was high and DC voltage acceptable. The failure was attributed to AC corrosion caused by nearby HV power lines.

The spillage was discovered by a third party.

Bunding and booms were installed in local drainage ditches to catch any runoff. Boreholes were drilled around the leak point to identify spread of contamination in soil. Following initial cleanup including surface water, monitoring of local groundwater and soil did not identify any migration.

The operator has increased the focus on the risk of AC corrosion in the entire network.

Event 673:
A pinhole leak developed about 2 m upstream of the point where the pipeline enters the bunded pig receipt area. The affected section was found to be isolated from the pipeline CP system. It was in "made ground", with distinctly different local soil characteristics than the rest of the pipeline.

The spillage was contained within the pipeline operator's property, adjacent to the bunded area. Clean-up involved monitoring existing boreholes to ascertain there were no off-site effects.

The majority of the lost product found its way into site drains and was collected through the site interceptor.

The operator has designed and implemented a programme to identify and address a design fault that causes short sections to be unprotected by the CP system.

Event 671:
A pinhole leak developed in an above ground section of an idle crude oil line ahead of a pig receiver. This was traced back to internal corrosion.

The leakage was discovered by an operator and could be kept to a minimum. It was contained onto concrete surfaces and collected into existing drainage systems.

4.1.4. Natural causes

There were no spillages in this category in 2015.

4.1.5. Third party activity

There were 87 spillage incidents in this category in 2015 all of which were the results of product thefts or theft attempts. Not all events have been described in detail.

Event 583:
In the early hours of the morning there was an attempted theft where a pipeline exits the ground to cross over a canal. A clamp was installed and the pipeline drilled, however, the clamp fitting failed to seal correctly and there was a leak. The criminals immediately left the area. Product was sprayed from the pipeline directly onto the canal and thus was reported to the pipeline operator by the fire service.

Booms and vacuum tankers were used to remove product from the canal. Follow on monitoring and clean-up work is still in progress.

Event 584:
The control room dispatcher observed a small pressure drop (about 120 mb) in an idle product pipeline.

Inspection of the line revealed a 1m x 1.5m pit that had been dug at the foot of a marker post. The pipeline had been drilled in a non-professional manner. The pit was partly filled with diesel fuel. An estimated 3.2 m^3 of diesel fuel was spilled, and some stolen.

Contaminated soil was removed and new soil brought in.

Event 586:
A third party observed a spray of kerosene onto a road near a terminal. The sprayed mist affected both the roadway and part of the terminal. The suspected pipeline was idle but under pressure at the time. The controller immediately released the pressure and ascertained this was the case.

The cause was a failed attempt to drill through the line and connect a fitting to steal fuel. The line was plugged as soon as access was in place and it was safe to do so. The relevant Authorities were informed.

Remediation started immediately. Repair took 10 days. A small amount of contaminated soil was removed from site and replaced. Dip tubes were put in place locally and absorbents dropped in to collect any surface oil on the water table over a six month period to a point when no more oil was recovered.

Event 587 to 664:
78 theft attempts in underground sections of pipelines, resulting in, mostly minor, spillages. No details available.

Event 665:
When the control centre detected a loss of pressure in a pipeline the emergency plan was immediately activated, pumping stopped and isolation valves closed. Local people were notified. The emergency response team tracked the route of the pipe line and found and illegal connection point threaded onto the pipe in a forested area.

The spilled product could be confined to a ditch, was pumped into tank trucks and sent to the operator's facilities. There were no water bodies in the vicinity. Some 1100 m^3 of contaminated soil were removed.

Event 666:
Agricultural machinery hit and cut an unknown hose producing a small spill of oil product on the ground. The landowner confined the spilled product spilled in a ditch He did not immediately report the event to either the pipeline operator or the local authorities until the next day when he found the hose has disappeared.

The emergency plan was activated. An illegal valved connection threaded to the pipe was soon discovered. This was undamaged which prevented a larger leak. A 2.2 km hose was subsequently found starting close to the connection and, after some street crossings and running across an industrial area through the sewage.

Contaminated soil was removed and treated.

Event 667:
Theft was attempted where a pipeline was exposed. A low pressure plastic clamp fitting was installed and the pipeline drilled. As the plastic clamp did not provide a tight seal there was an immediate leak from around the clamp into the ground. The criminals left leaving the pipeline exposed. Initial response could not identify or recover spilled fuel.

Long term monitoring is in place.

Event 668:
At a time unknown a fitting was installed on a pipeline for theft purposes. The pipeline was exposed and drilled, a hose connected and the pit backfilled. A third party reported product in the vicinity of the pipeline which was traced back to the fitting that was leaking. The underground spillage migrated into the ground.

Long term monitoring of the groundwater is in place.

Events 669 & 670:
Two attempts to install a tapping on a product pipeline failed and resulted into a spill. In the first instance a welded fitting was first installed but was not tight so a leak developed when drilling through the pipe was attempted. In the second instance a spike was used with no seal between spike and pipe. In both cases the thieves left the scene when the leak could not be controlled.

4.2. 2011-2015 SPILLAGE OVERVIEW

Table 2 shows 5 year trends in spill incident causes and also spill volumes, from 2011- 2015. 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 is apparent.

At 93 the total number of reported spillages in 2015 was the highest since Concawe records began in 1971. The statistics are, however, entirely skewed by the 87 theft-related incidents. Although such events have been recorded in the past, they were few and far between until an entirely new trend began to emerge at the beginning of the decade. The number in 2015 is unprecedented, representing nearly half of all such cases reported since 1971. When excluding these theft-related events, the 6 remaining 2015 spillages fall well within the long term decreasing trend. This is below the 6.3 spillages per year average for the last 5 years and well below the long term average of 10.9.

Excluding theft, the total reported gross spilled volume was 61 m^3 in 2015. Historically this is a very low number compared to the averages of 234 for the last 5 years and 1758 m^3 since records began in 1971. 69% of the spilled oil was recovered.

Some temporary environmental contamination was reported for 15 incidents, although no information was provided for the majority of the 2015 theft-related incidents.

Table 2 5-year comparison by cause, volume and impact: 2011– 2015

		2011	2012	2013	2014	2015	2011-2015
							Average
Combined Length	km x 10^3	36.0	36.3	34.1	36.0	36.0	35.7
Combined Throughput	m^3 x 10^6	714	701	680	760	760	723
Combined traffic volume	m^3 x km x 10^9	119	119	111	120	120	118
Spillage incidents							Total
		7	**13**	**26**	**58**	**93**	**197**
MECHANICAL FAILURE							
Construction				2		1	3
Design and Materials		1	1	1	1	2	6
OPERATIONAL							
System							
Human		2	1	1			4
CORROSION							
External			2			2	4
Internal			1	1		1	3
Stress corrosion cracking							
NATURAL HAZARD							
Ground movement							
Other							
THIRD PARTY ACTIVITY							
Accidental		1	4	2	2		9
Incidental			2	1	1		4
Intentional (theft)		*3*	*2*	*18*	*54*	*87*	*164*
Volume spilled (ex theft)	m^3						**Average**
Gross spillage		135	328	130	518	61	234
Net loss		101	191	107	4	19	84
Average gross loss / incident		34	30	16	130	10	36
Average net loss / incident		25	17	13	1	3	13
Average gross loss/1000 km		4	9	4	14	2	11
Average net loss/1000 km		3	5	3	0	1	6
Gross spillage/ throughput	ppm	0.2	0.5	0.2	0.7	0.1	0.3
Gross spillage per cause							
Mechanical failure		NA	1	6	5	32	11
Operational		36	1	19	0	0	11
Corrosion		0	5	5	0	29	8
Natural hazard		0	0	0	0	0	0
Third party activity (ex theft)		99	321	100	513	0	207
Net loss distribution							
(No of incidents)							
≤ 10		3	5	6	4	5	23
11 -100		1	3	2		1	7
101- 1000			1				1
> 1000 m^3							0
Environmental impact							
NONE or not reported		1	3	20	48	83	155
SOIL (affected surface area)							
< 1000 m^2		6	7	5	6	10	34
> 1000 m^2			2	1	4		7
WATER BODIES							
Surface Water		1	1		1		3
Groundwater		1	2				3
POTABLE WATER							

5. HISTORICAL ANALYSIS OF SPILLAGES 1971-2015

As mentioned in **section 4**, we are faced in 2015 with the unprecedented growth of theft-related spillage incidents, with 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 45 years survey period there have been a total of 674 spillage incidents, 489 when excluding theft. 67 of these spillages occurred in "hot" pipelines, a disproportionately large proportion in relation to the share of such pipelines in the total inventory (note that such hot pipelines have now virtually disappeared from the active inventory with only 45 km left in operation).

Figure 4a/b show the number of spillages per year, moving average and 5-year average trends over the 45 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, which bears witness to the industry's improved control of pipeline integrity, switching to an upward trend in 2012 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 6.3 in 2015 (33.5 with theft). 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 45-year trend of the total annual number of spillages (all pipelines)

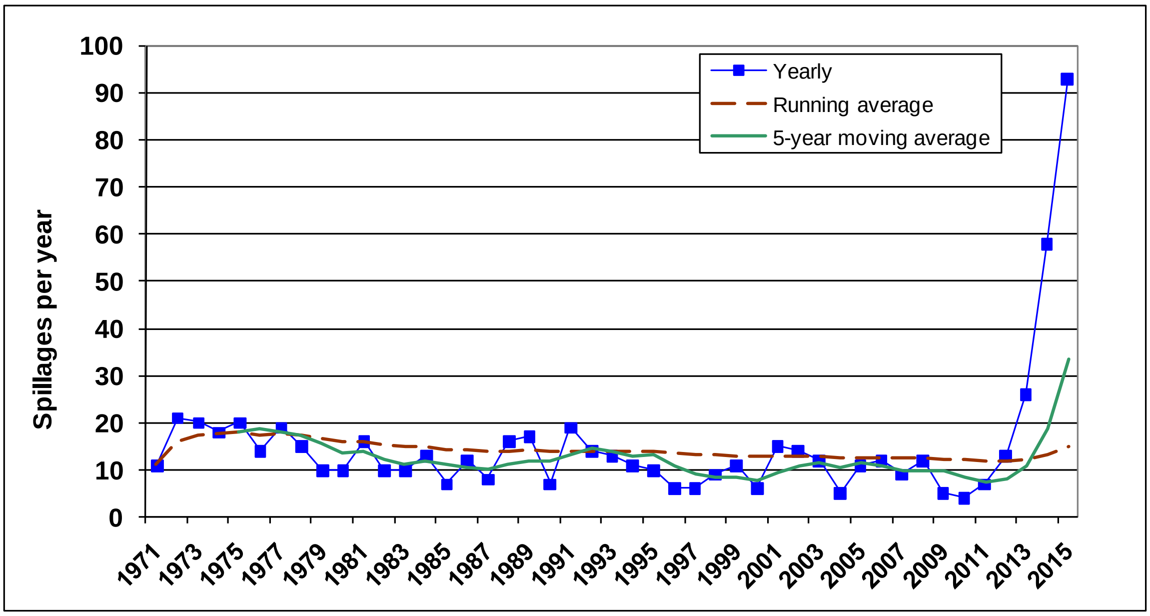
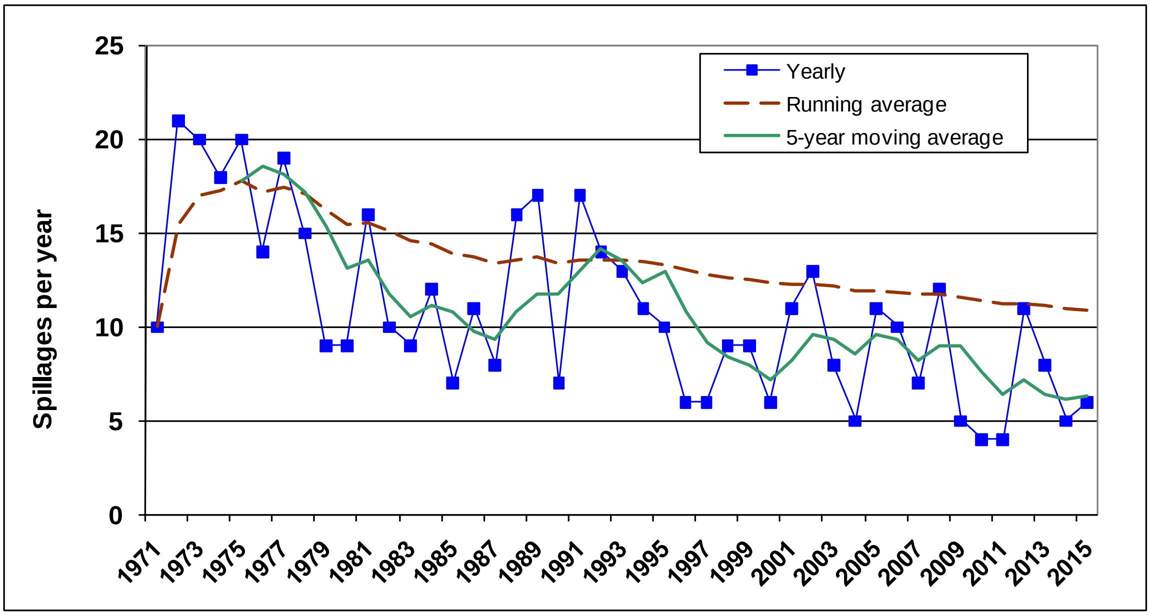


Figure 4b 45-year trend of the total annual number of spillages (all pipelines)
Excluding theft



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 0.17 spills per year and per 1000 km of pipeline in 2015. When theft is included (**Figure 5a**) the 2015 value increases to 0.95.

Figure 5a 45-year trend of the spillage frequency (all pipelines)

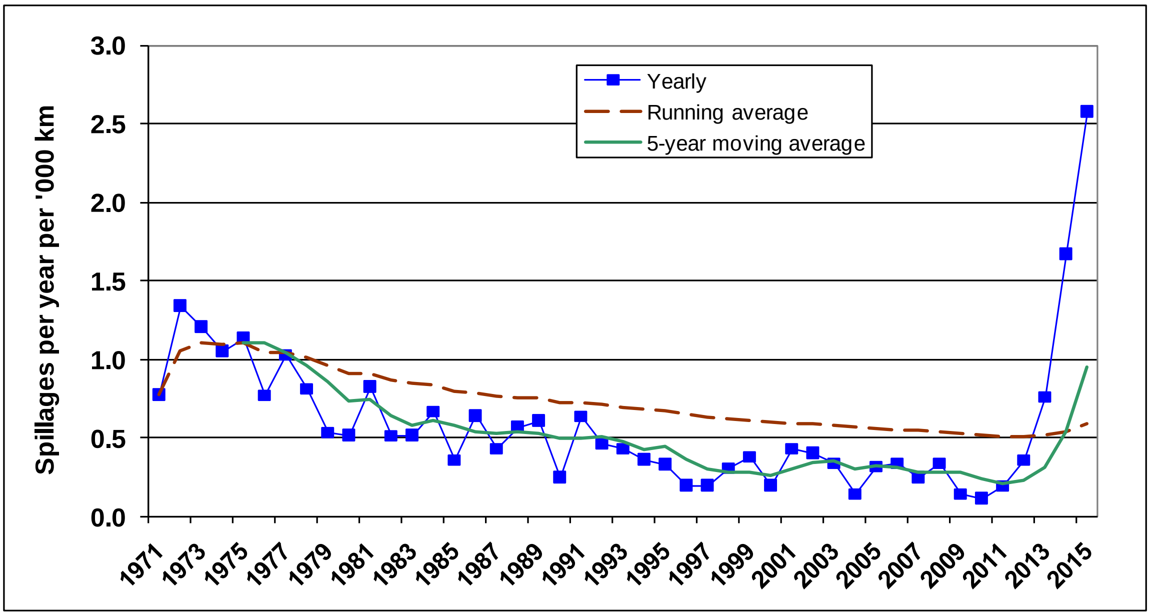
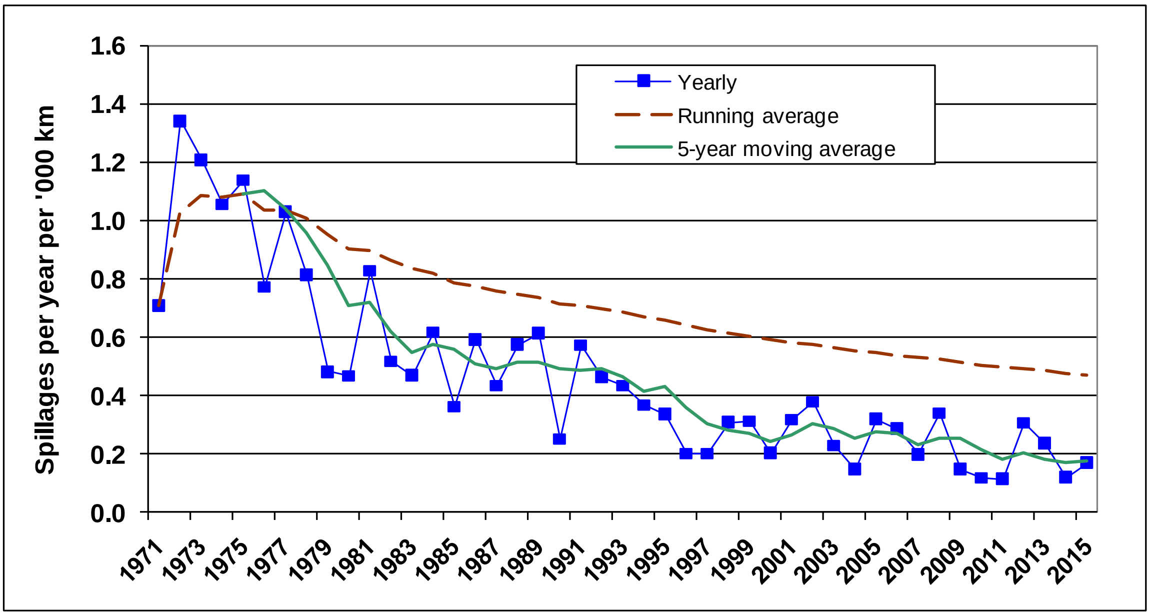
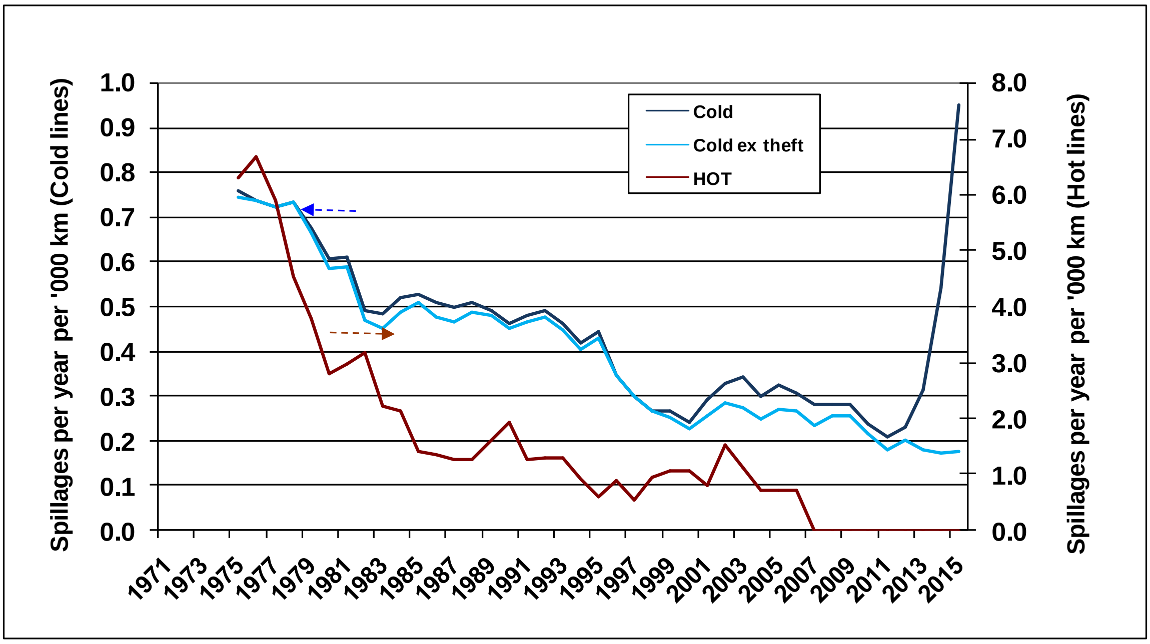


Figure 5b 45-year trend of the spillage frequency (all pipelines)
Excluding theft



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.

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



Clearly, the cold and the hot oil pipelines have demonstrated entirely different behaviour. **Figures 7&8** show the evolution over 5-year periods of the spillage frequency for hot and cold pipelines respectively, now broken down according to their main cause. 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 and the last recorded one was in 2002. As a result recent frequency figures are not meaningful.

When the hot pipeline data are excluded, the cold pipelines show a somewhat slower improvement trend than for the total data set. Nevertheless, the incidence of spillages has been reduced by nearly three quarters over the last 45 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. Albeit with fluctuations, the analysis by cause shows that corrosion is a much less prevalent cause of failure for cold pipelines. There is a gradual decrease in the frequency of all causes except theft. Although third party activities have historically by and large been the most prevalent cause of spillage, mechanical causes showed an increase during the last decade to be on a par with non-theft third party causes but this trend appear to have reversed over the last 5 years. A more complete analysis of causes is given in **Section 6**.

Figure 7 Hot pipelines spillage frequencies by cause

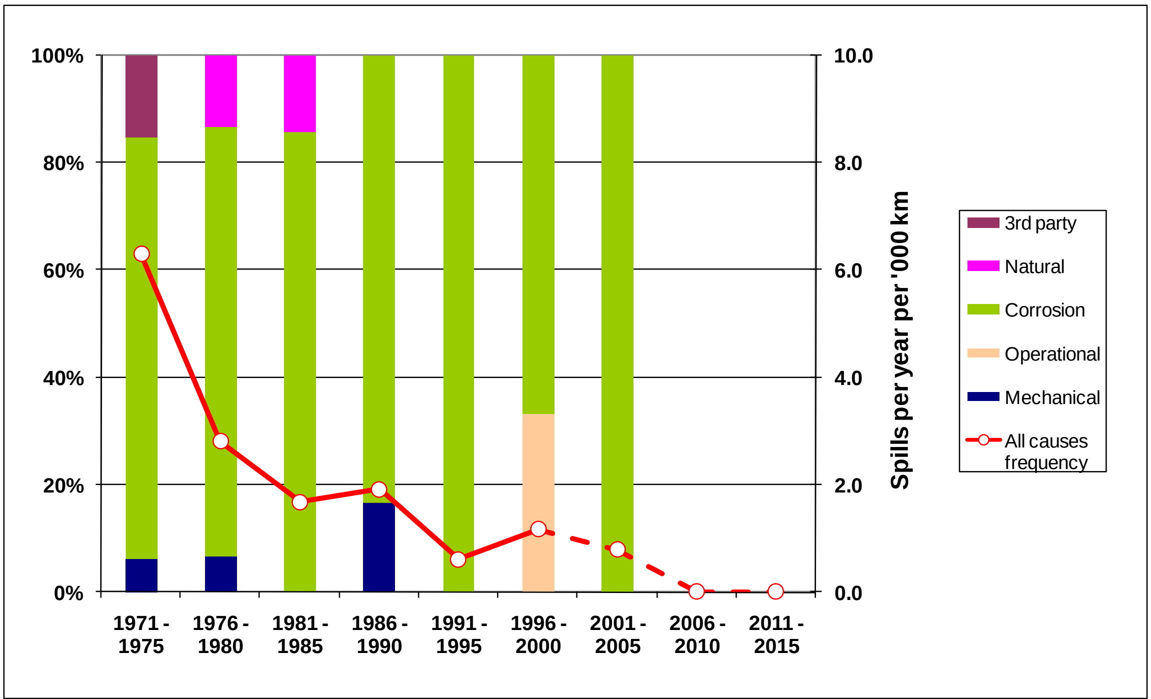


Figure 8a Cold pipelines spillage frequencies by cause

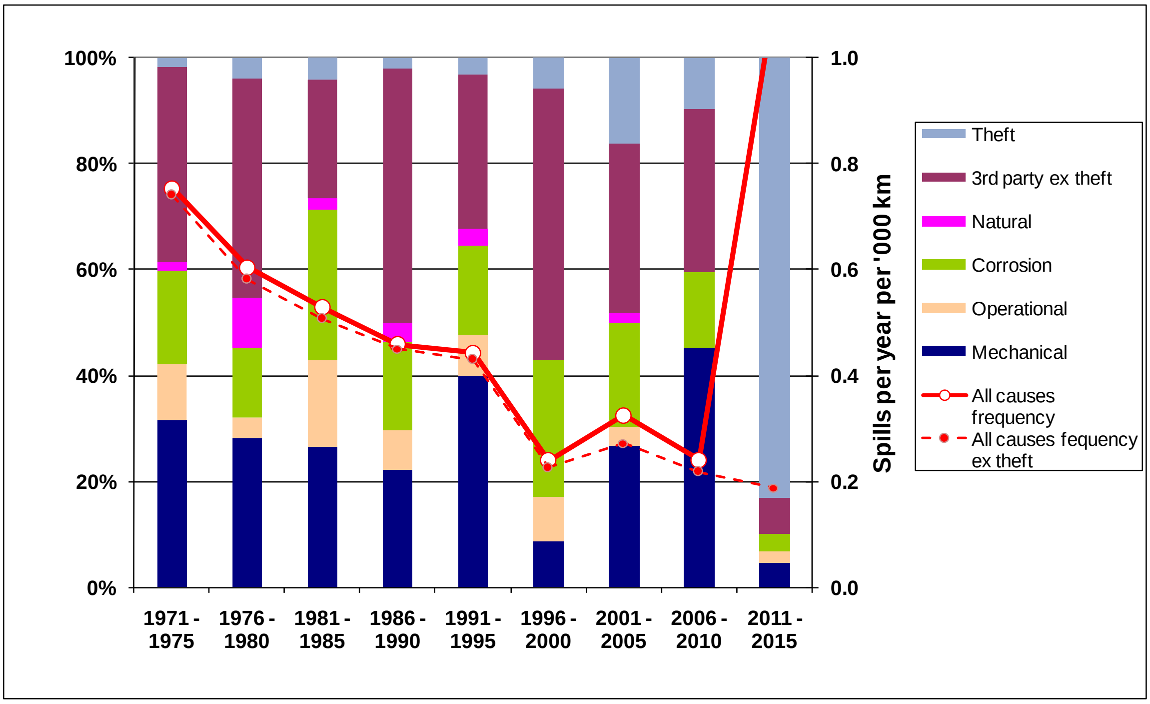
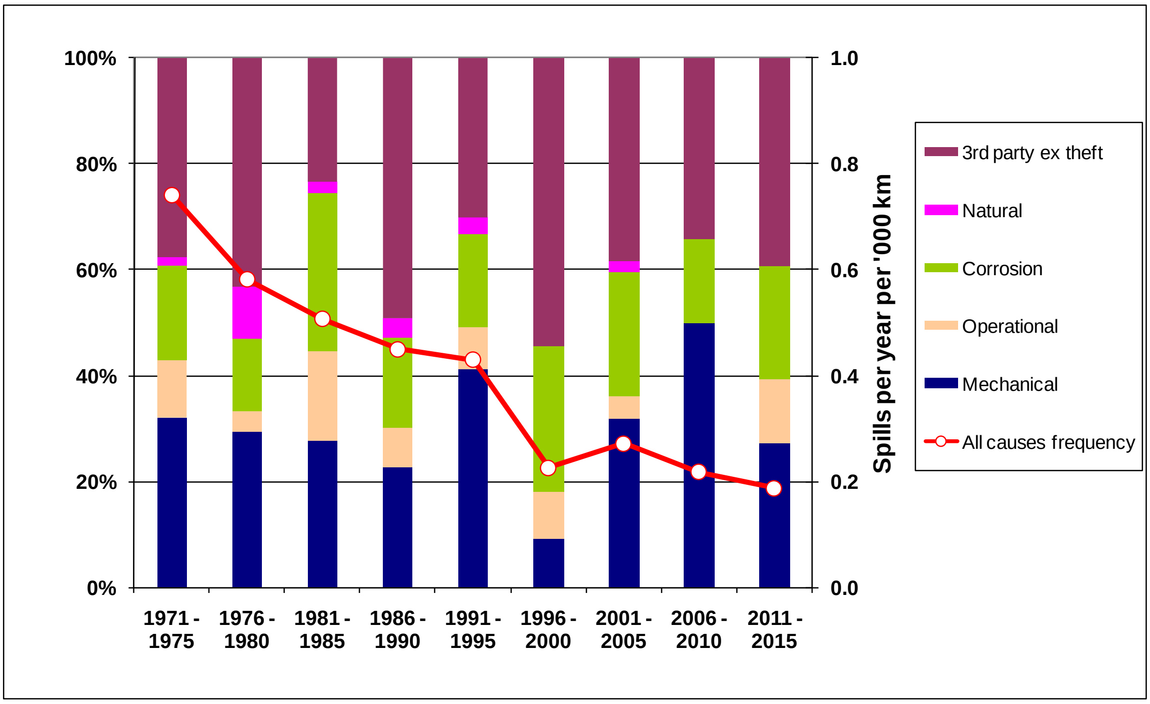


Figure 8b Cold pipelines spillage frequencies by cause
Excluding theft



5.2. SPILLAGE VOLUMES

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 volumes

Figure 9 shows the total gross spillage volume over the complete period, year by year and in terms of running and 5-year moving average. The same data is shown per 1000 km of pipeline in **Figure 10** and as a proportion of throughput in **Figure 11**. Although there are fairly large year-to-year variations mostly due to a few very large spills that have occurred randomly over the years, the long-term trend is clearly downwards. Over the last 5 years, the gross pipeline spillage has averaged 0.5 parts per million (ppm), or 0.00006%, 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 58% leaving an average net loss of oil to the environment of 51m^3 per spill.

Figure 9 Gross spillage volume (excluding theft)

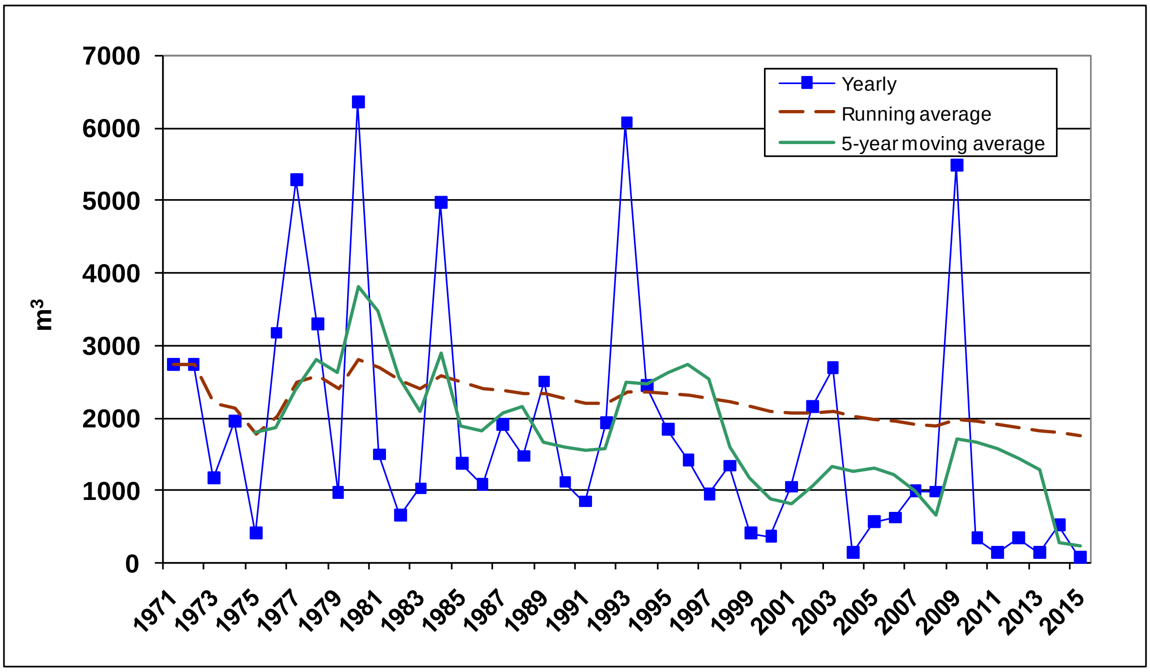


Figure 10 Gross spillage volume per 1000 km (excluding theft)

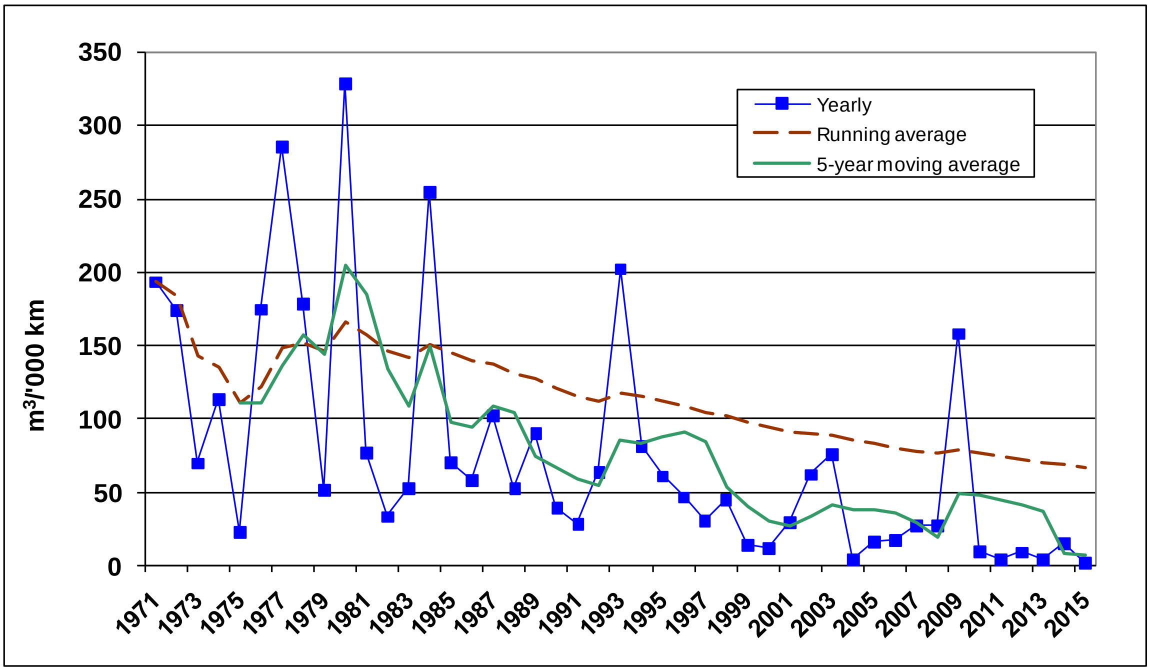


Figure 11 Gross yearly spillage volume as a proportion of throughput (excluding theft)

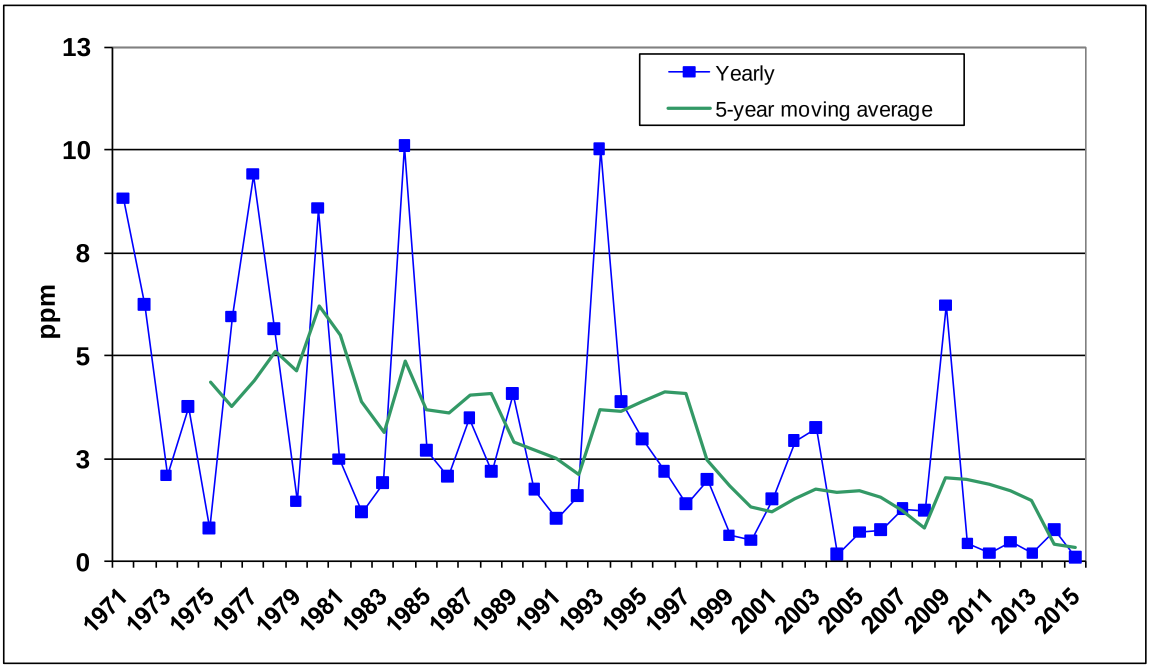
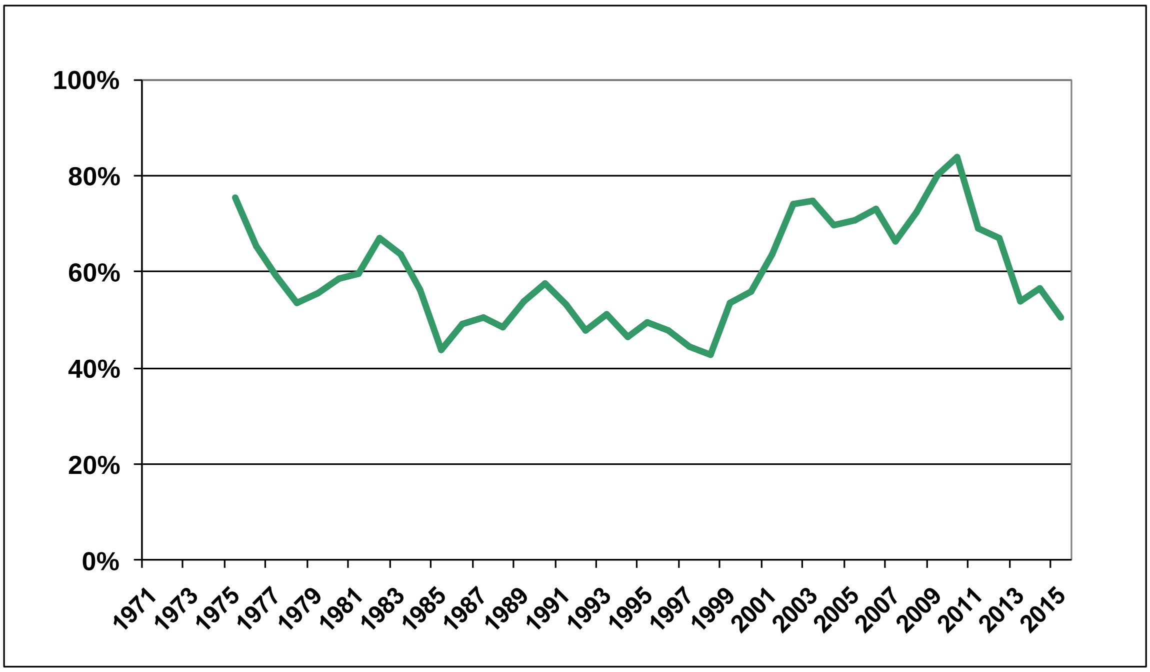


Figure 12 Spilled oil recovery (5-year moving average) (excluding theft)



5.2.2. Spillage volume per event

The gross volume released is a measure of the severity of a spillage incident. One or a few events involving large volumes can, however, 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 5-year gross volume moving average over the 9 years to 2008 had consistently been lower than the long-term average of 170 m^3 per spill. A single very large spill recorded in 2009 pushed up this figure to 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 2104 figure is again low at 34 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 that, beyond the large year-by-year variations, the reduction trend in the average spill size per incident since the early '80s has been at best very slow. In other words, the gradual reduction of the annual total spilled volume appears to be related more to the reduction of the number of spillage incidents than to their severity. This may be partly due to the mix of spillage causes changing over the years, e.g. the proportion of corrosion spillages, which on average are smaller ones, have decreased relative to third party spillages (excluding theft) which tend to be larger (see **Figure 14**).

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

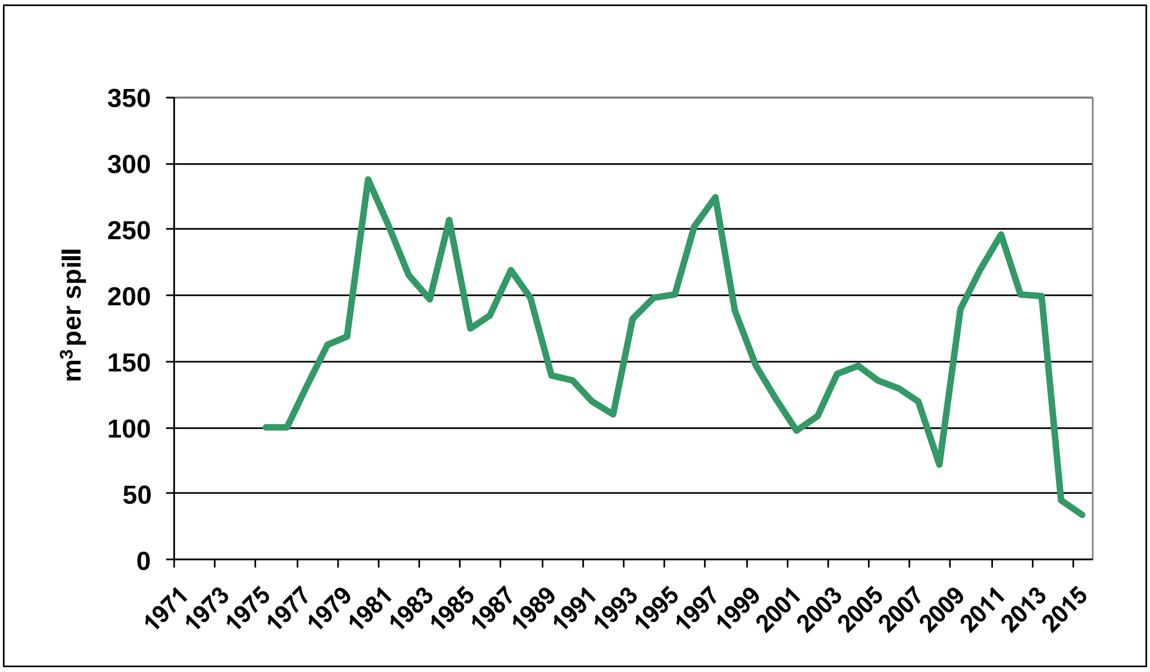


Figure 14 shows the average spill size for each cause category. The largest spillages on average have resulted from mechanical failure, third party activities and natural hazards, whereas operational problems and corrosion have caused smaller spills. As a rule of thumb, on average the three "largest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

Figure 14 45-year average gross spillage volume per event by cause (excluding theft)

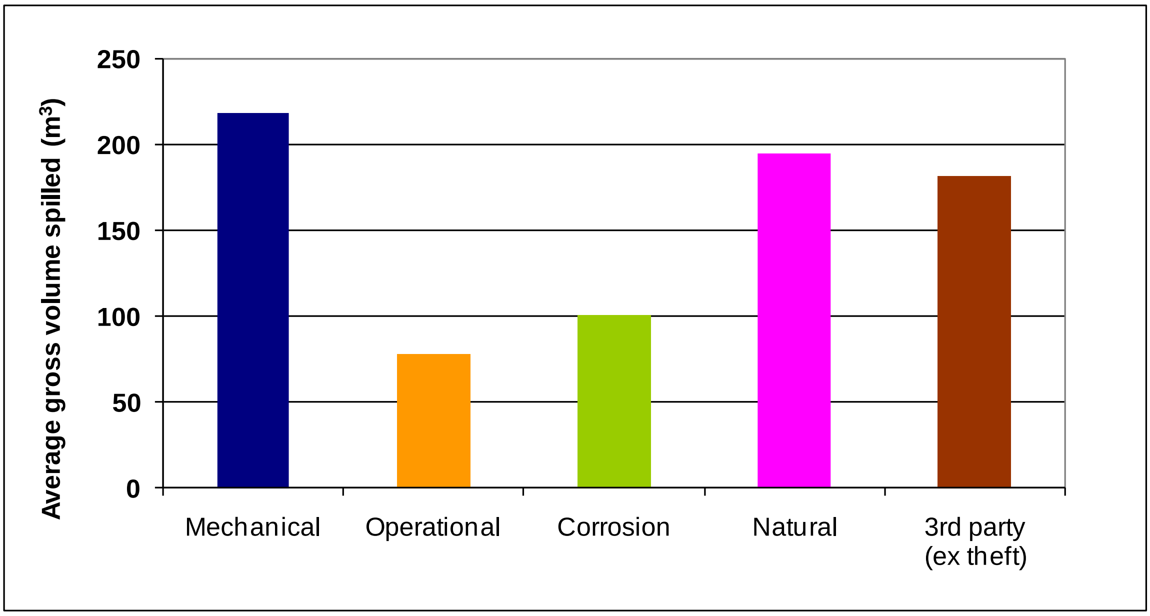
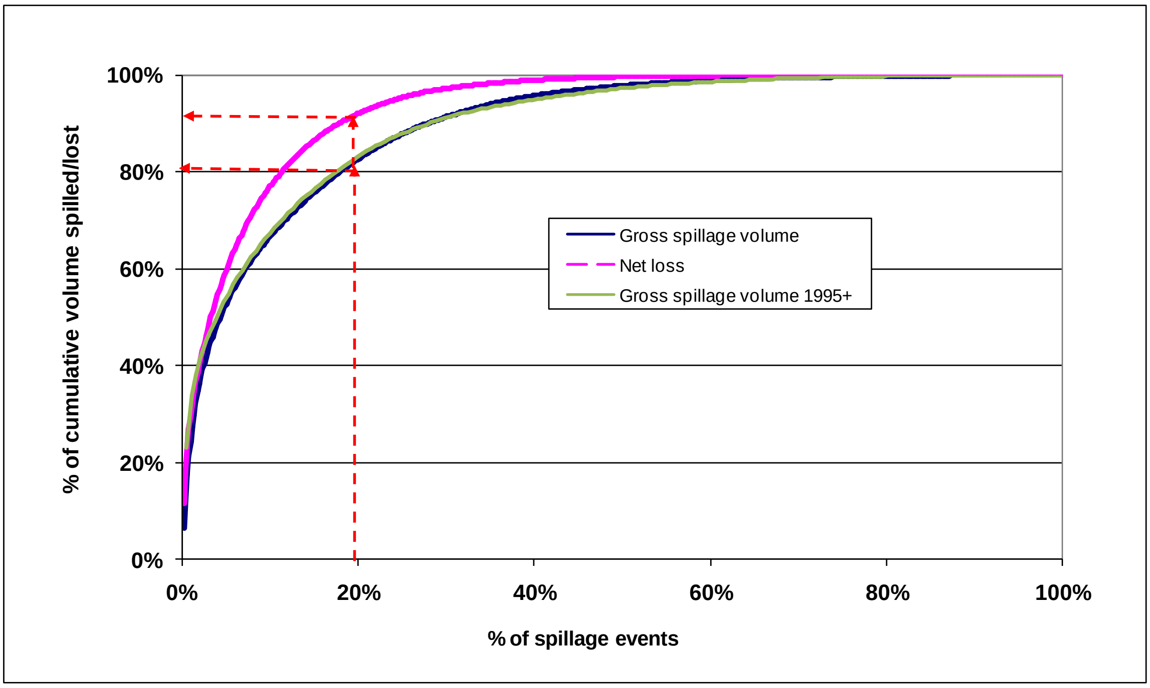


Figure 15 shows the distribution of spillage sizes, demonstrating that less than 20% of all spillages **account** for 80% of the cumulative gross volume spilled and over 90% of the net spillages, with little change over the years. Clearly a majority of the spillages recorded in the Concawe database were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

Figure 15 Distribution of Gross and net spillage sizes (over 45 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.

Out of the 675 spillages, hole size data are only available for 335 (50%). The corresponding statistics are shown in **Table 3**.

Table 3 Distribution of spillages by hole size

Hole type		No hole	Pinhole	Fissure	Hole	Split	Rupture	Overall
Number of events		15	37	54	117	52	60	335
	%	4%	11%	16%	35%	16%	18%	100%
Hole caused by								
Mechanical		10	4	14	13	17	7	65
Operational		2	0	1	2	3	4	12
Corrosion		0	26	11	24	17	5	83
Natural hazard		0	1	2	0	2	2	7
Third party		3	6	26	78	13	42	168
Gross average spillage per event	m^3	36	45	206	70	238	354	247

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

The majority of third party incidents result in larger holes.

It would be expected that the larger the hole, the larger on average the spillage would be, under the assumption that material was actually being pumped through the pipeline at the time of the incident. The two rather obvious reasons for this are that higher leakage rates come out of larger holes and the hole sizes are to an extent related to the pipeline diameter which in turn tends to set the potential flow rate available for leakage. However, there are many other factors involved, including the pressure in the pipeline, the length of time between the start of leakage, the leak being detected, the pipeline shut in, and the volume of pipe available to leak after shut in. **Table 3** shows that there is indeed a weak relationship between the average gross spillage size and the hole size.

Table 4 shows the evolution of the number of events per 1000 km of pipeline inventory (frequency) by hole type and 5-year period. Note that early figures (say before 1985) are not very representative as hole type was not commonly reported at the time. There is no discernible trend.

Table 4 Spill frequency by hole size

Event/1000 km	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-05	2006-10	2011-15
No hole	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.11
Pinhole	0.27	0.10	0.08	0.13	0.07	0.20	0.17	0.26
Fissure	0.32	0.21	0.29	0.20	0.24	0.17	0.09	0.40
Hole	0.16	0.41	0.54	0.37	0.54	0.63	0.28	0.95
Split	0.64	0.41	0.46	0.23	0.10	0.20	0.03	0.09
Rupture	0.27	0.31	0.33	0.43	0.17	0.26	0.28	0.11
All reported events	1.67	1.45	1.70	1.37	1.11	1.47	1.17	1.92
Not reported	1.99	1.45	0.79	0.87	0.17	0.17	0.03	0.17

5.4. PART OF FACILITY WHERE SPILLAGE OCCURRED

By far the greatest part of the material in place in a pipeline system is the underground pipe itself (and particularly so as far as theft-related events are concerned). It comes therefore as no surprise that most leaks occur in the main underground pipeline runs (**Table 5**). However, a sizeable proportion of incidents are related to valves, flanges, joints and small bore connection failures indicating that these and other fittings are

vulnerable items. Adding seemingly useful features such as more section block valves, instrument connections or sampling systems can therefore potentially have a negative impact on spillage frequency. Small bore lines are also a relatively common subject of leaks as they are mechanically vulnerable and often subject to corrosion. Wherever possible, these more vulnerable features should be designed out of the pipeline system.

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

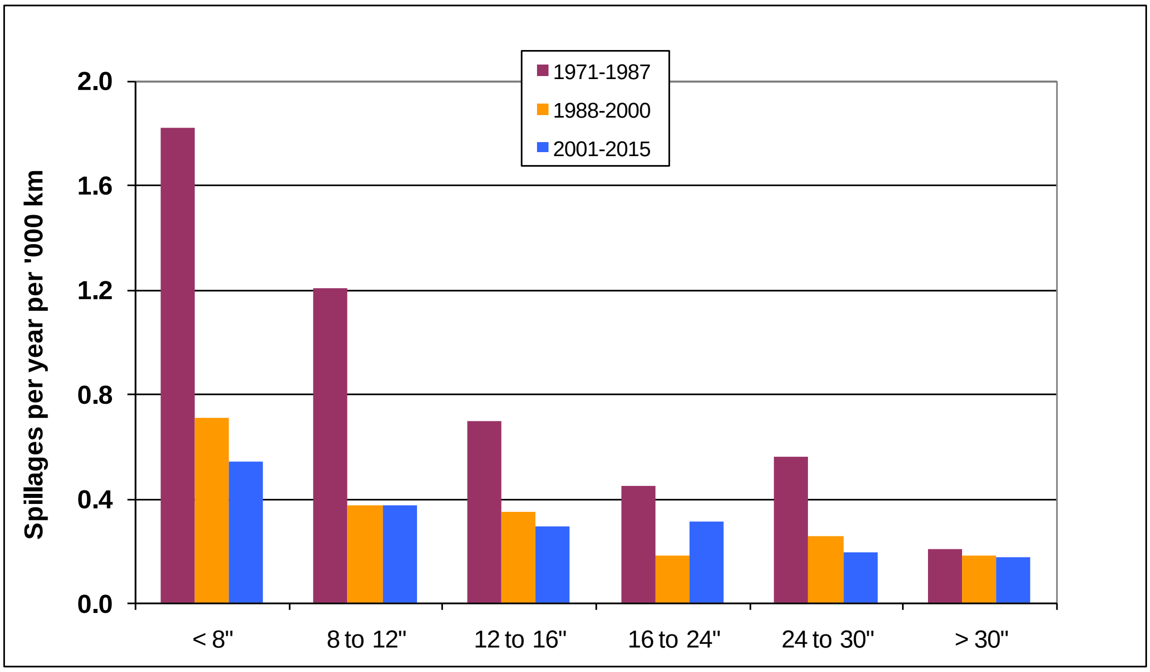
	Total	Bend	Joint	Pipe run	Valve	Pump	Pig trap	Small bore	Unknown
Mechanical	*134*	1.5%	7.4%	5.5%	3.5%	0.5%	0.3%	2.5%	1.2%
Operational	*35*	0.0%	0.3%	1.0%	2.0%	0.2%	0.5%	1.0%	0.8%
Corrosion	*138*	0.2%	1.5%	20.1%	0.0%	0.0%	0.2%	0.5%	0.7%
Natural	*15*	0.0%	0.2%	2.0%	0.0%	0.0%	0.0%	0.3%	0.0%
3rd party (ex theft)	*166*	0.2%	0.3%	26.0%	0.2%	0.0%	0.0%	0.5%	0.7%
3rd party (theft)	*109*	2.8%	0.2%	9.4%	5.4%	0.0%	0.0%	0.2%	0.3%
All		4.7%	9.9%	64.0%	11.1%	0.7%	1.0%	5.0%	3.7%
	597	*28*	*59*	*382*	*66*	*4*	*6*	*30*	*22*

Percentages are related to the total of 597 reported events out of a total of 675

5.5. SPILLAGES PER DIAMETER CLASS

In **Figure 16** the frequencies of spillages have been calculated for the average length of each group of diameters for the periods 1971 to 1987, 1988 to 2000 and 2001 to 2015. These periods have been chosen because of the major change in the reported pipeline inventory between 1987 and 1988 following the inclusion of the non-commercially owned pipelines and from the beginning of the current decade when a number of Eastern European pipelines operators joined the survey.

Figure 16 Spillage frequencies per diameter class



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

5.6. ENVIRONMENTAL IMPACT

5.6.1. Land use where spillage occurred

We differentiate between spillages occurring either in the pipeline itself or in pumping stations and also record the type of land use in the area. Not surprisingly, most incidents (79%) occurred in the cross-country pipelines themselves. The type of location has been reported for a total of 476 spillages (out of 675). The results of this analysis are provided in **Table 6**.

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

Table 6 Location of spillage incidents

	Underground pipe			Above ground pipe		Pump Station	
	Number	Crude/ Product	%	Number	%	Number	%
Residential high density	17	3/14	4%	2	6%	0	0%
Residential low density	197	55/142	52%	11	31%	8	13%
Agricultural	62	5/57	16%	3	8%	3	5%
Industrial or commercial	82	22/60	22%	18	50%	51	82%
Forest Hills	14	2/12	4%	0	0%	0	0%
Barren	4	2/2	1%	0	0%	0	0%
Water body	2	0/2	1%	2	6%	0	0%
Total	378			36		62	
Unspecified	198						

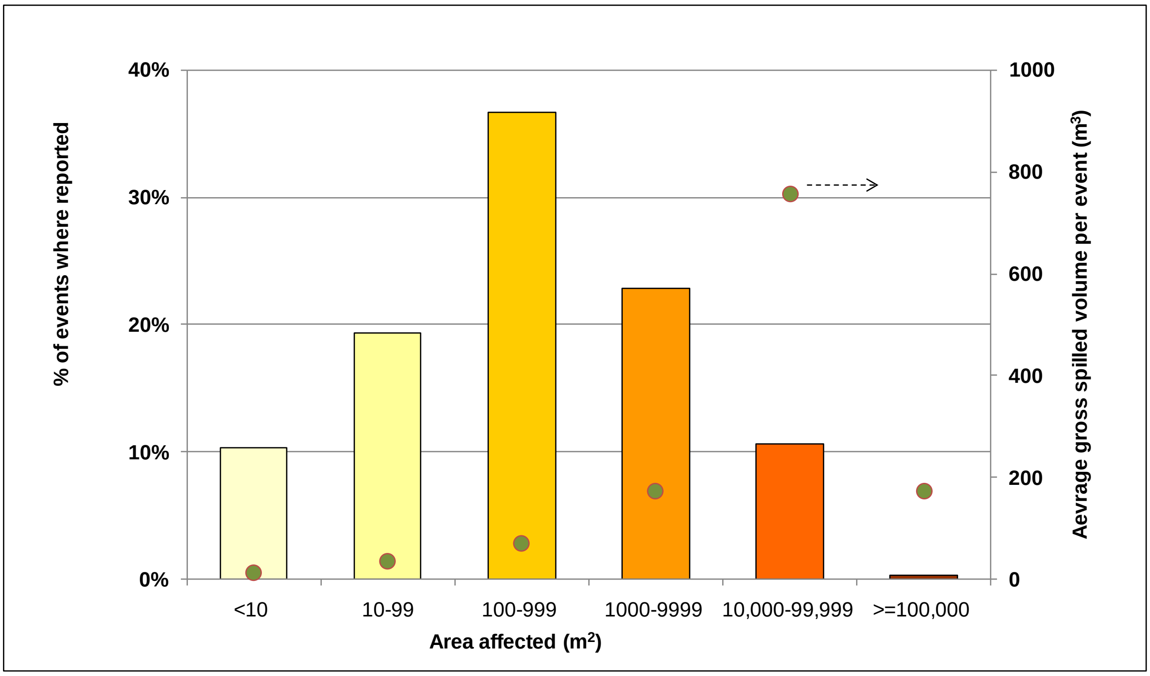
5.6.2. Ground area affected

The current Concawe performance questionnaire, in use with minor changes since 1983, requests reporting of the area of ground (m^2) affected by the spillage. Before that date, area data were reported infrequently. Area data is available for 311 events (46% 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. Bigger spillage volumes affect larger areas.

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

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



5.6.3. Impact on water bodies

We keep a record of whether oil pollution of the water table and underground aquifers and surface water courses has had consequences for the abstraction of potable water. Some 14 spillages, representing 2% 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 295 reported spillages since then, 16 have affected surface water, 16 have affected ground water but only 2 have impacted potable water supplies.

5.7. SPILLAGE DISCOVERY

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

Underground pipeline spillages are most commonly first detected by a third party (51%), often by those who caused the incident in the first place. Automatic detection systems were involved in detecting only 14% of those spillages. Although this may seem a rather small proportion, one has to realise that third parties are often on the scene when the leak occurs and detection systems are relatively new additions. Indeed, over the last 5 years 30% of underground spills were discovered via leak detection systems.

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

Table 7 Discovery of spillages

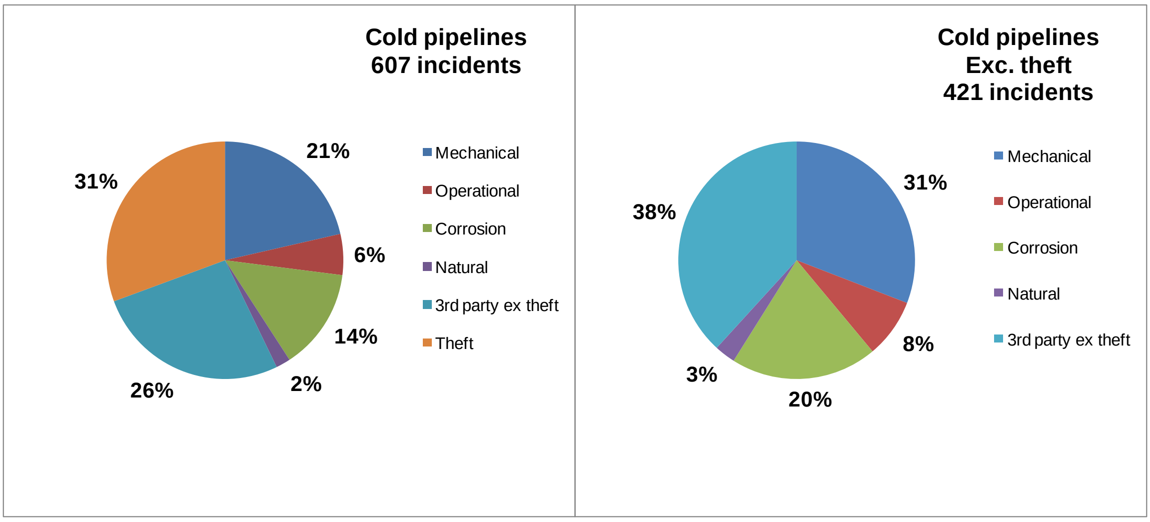
	Underground pipe			Above ground pipe			Pump Station		
	Number	%	Average gross spillage m^3	Number	%	Average gross spillage m^3	Number	%	Average gross spillage m^3
Right-of-Way surveillance by pipeline staff	39	9%	188	5	12%	35	3	5%	6
Routine monitoring by pipeline operator	89	20%	349	16	37%	86	37	57%	81
Automatic detection system	62	14%	126	4	9%	35	11	17%	48
Pressure testing	23	5%	135	1	2%	30	3	5%	18
Third party	225	51%	117	16	37%	86	11	17%	45
Internal Inspection	5	1%	6	1	2%	0	0	0%	0
Total	443		171	43		73	65		48

6. DETAILED ANALYSIS OF SPILLAGE CAUSES

Concawe traditionally classifies spill causes into five major categories: mechanical failure, operational, corrosion, natural hazard and third party, themselves divided into sub-categories. Definitions are given in **Appendix 1**. As discussed in 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 main causes of incidents are very different for hot and cold pipelines. For hot oil pipeline spillages this was dominated by corrosion issues (81%). For cold pipelines the main causes are mechanical and third-party related. Corrosion accounts for 14% of the total (20% when excluding theft). This is illustrated in **Figure 18**.

Figure 18 Distribution of major spillage causes for cold pipelines



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

There is a wider debate regarding the increasing age of the pipeline inventory and the potential integrity issues that could be related to such ageing infrastructure. Out of the 5 incident categories, Mechanical and Corrosion would be the most likely to be affected by ageing. Specific attention is being paid to this, as will be seen in the detailed discussion in **section 6.1 and 6.3** below.

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

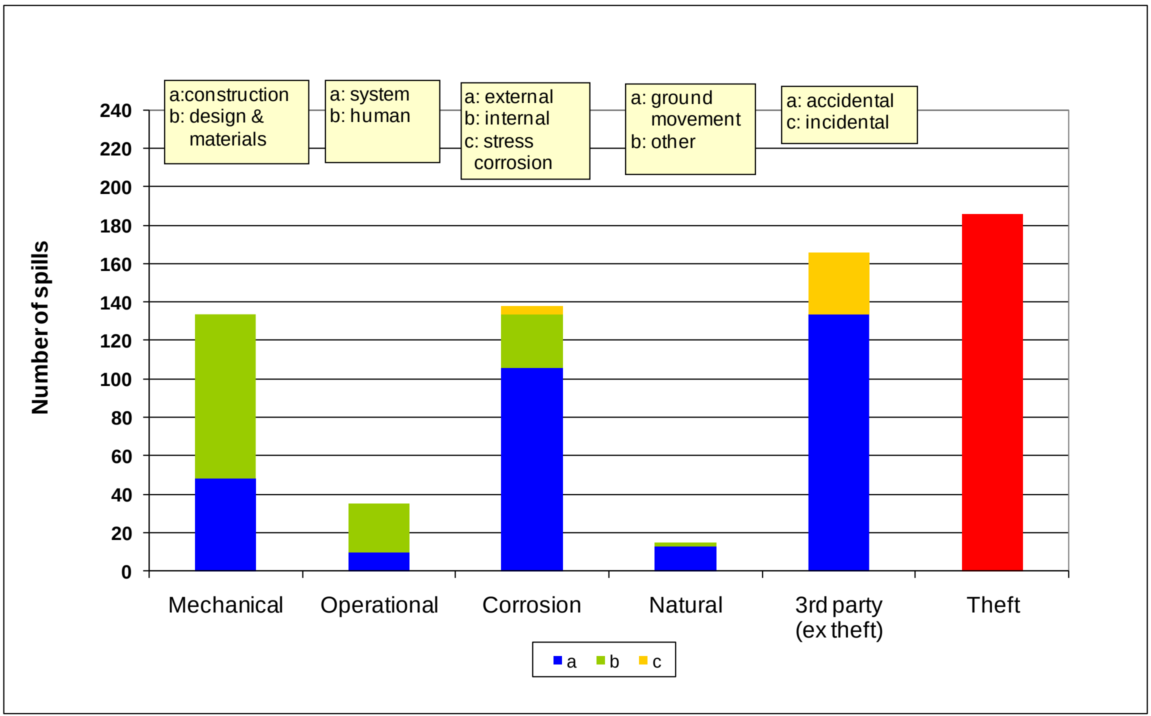
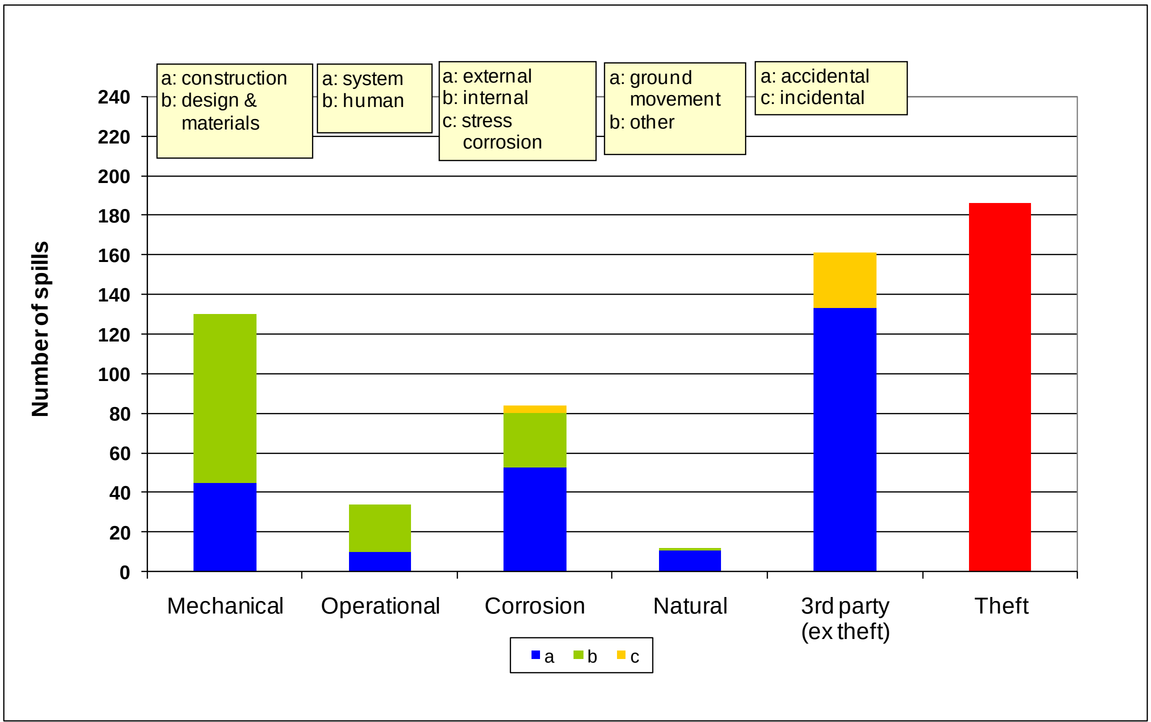


Figure 20 Distribution of major and secondary spillage causes – Cold pipelines



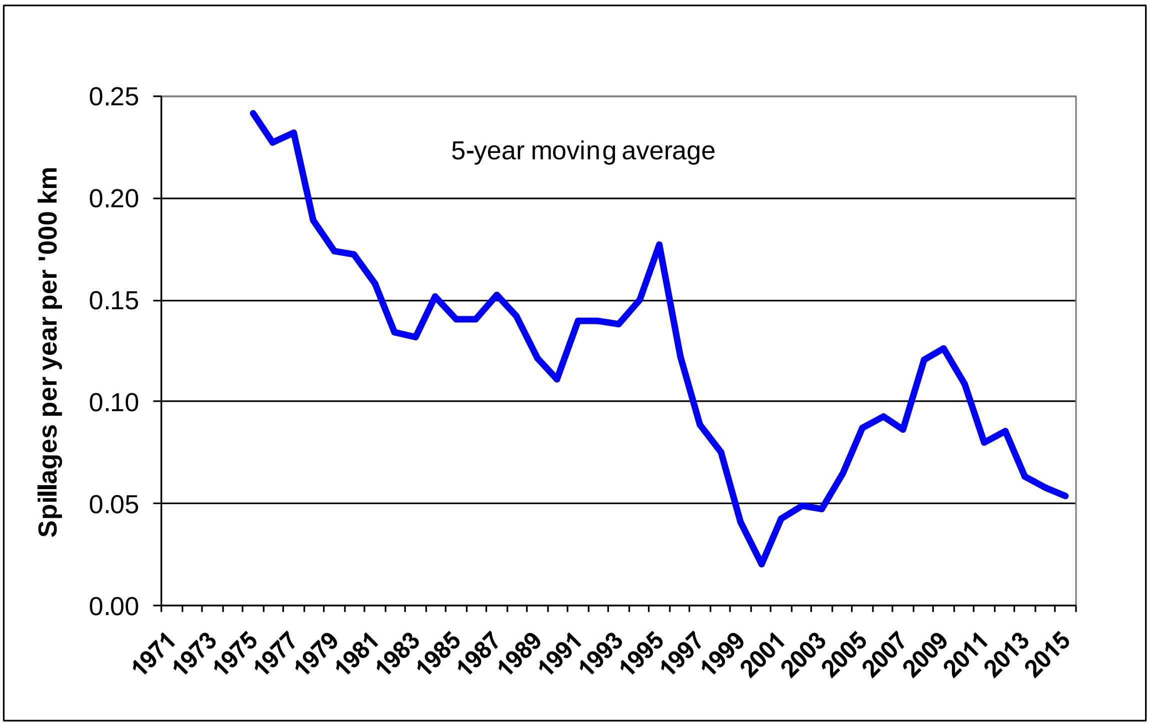
6.1. MECHANICAL

There have been 134 cases of mechanical failure, 20% of all spillage events (27% excluding theft). This is an average of 3.0 spillages per year. 48 failures were due to construction faults and 86 to design or materials faults.

Note: It is not always straightforward to classify certain types of failures. For instance a number of leaks can be traced back to some damage to a pipeline such as a dent. Whenever it is clear that such damage was caused after the pipeline was installed it is classified as "third party / incidental" (this was the case for one of the 2011 spillages). If no such evidence is available it is classified as "mechanical / construction".

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

Figure 21 Frequency of mechanical failures for cold pipelines



The downward historical trend is downward which appeared to have reversed from the beginning of the last decade seems to have resumed in the last 5 years.

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

Table 8 Reasons for mechanical failures

Number of spills due to					
Construction	Faulty weld	Construction damage	Incorrect installation		Not reported
	11	6	13		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. However, 4 of the 10 registered events occurred in the last 10 years.

The seemingly increasing occurrence of mechanical failures combined with the appearance of an increase in fatigue-related failures may be an indication of the ageing process, defined as the deterioration of the metal structure of pipelines resulting from fatigue caused by normal operation (pressure cycles etc). In order to gain more insight into this point all 34 mechanical failures reported between 2001 and 2010 were further investigated in cooperation with the relevant operators. It was found that only 4 events could be linked with certainty to ageing according to the above definition, a further 7 being undecided because of lack of appropriate information.

The increase in reported mechanical failures observed between 2000 and 2010 caused some concern in this respect but the trend has been reversed since the beginning of this decade. This 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 35 spillage incidents related to operation, 5% of all spillage events (7% excluding theft). This is an average of 0.8 spillages per year. 25 incidents were due to human errors and 10 to system faults. The most common reasons for operational incidents are illustrated in **Table 9**.

Table 9 Reasons for operational incidents

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

6.3. CORROSION AND IMPACT OF AGEING

There have been 138 failures related to corrosion, 20% of all spillage events (28% excluding theft). This is an average of 3.1 spillages per year. As noted earlier though, a large proportion of these events (54) occurred in the more vulnerable hot pipelines and in the early years. For cold pipelines the number of failures is 84, 12% of the total (20% excluding theft) and an average of 1.9 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 10**.

Table 10 Corrosion-related spillages

Number of spills due to			
	Hot	Cold	All
External corrosion	53	53	106
Internal corrosion	1	27	28
Stress corrosion	0	4	4

Internal corrosion is much less prevalent than external corrosion. 20 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.

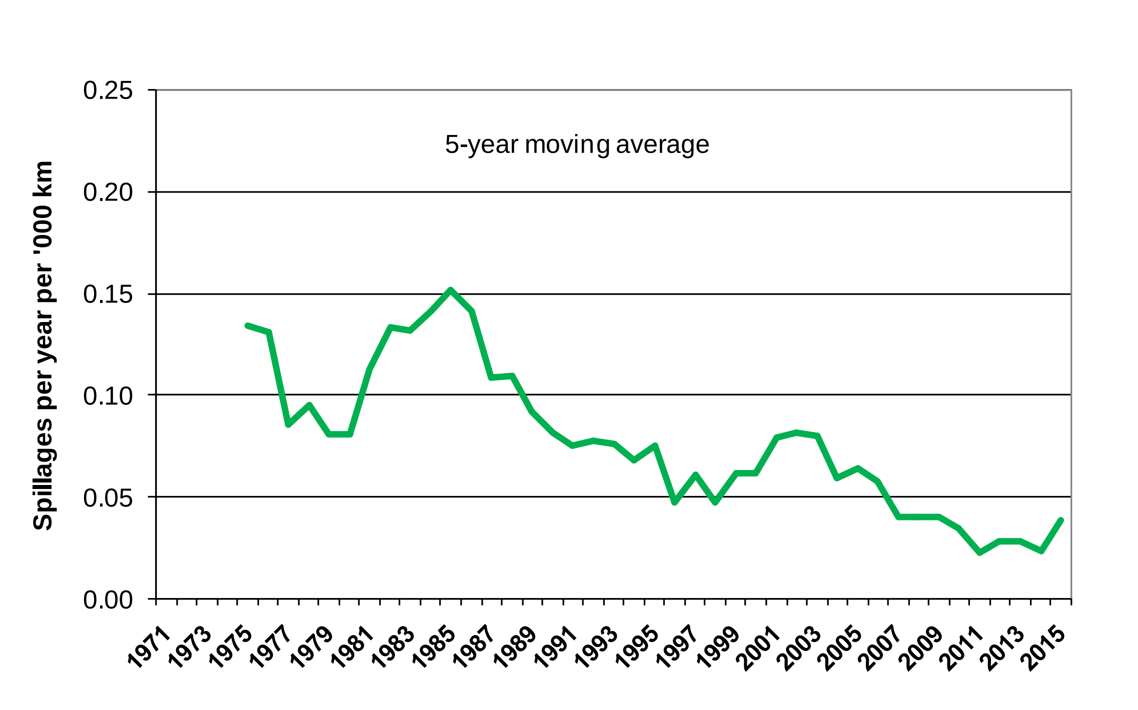
Although there have only been four Stress Corrosion Cracking (SCC) related spillages to date (including one re-categorised from external corrosion), these have been relatively large spillages, possibly as a result of the more severe failure mechanisms.

Out of the 84 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.

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

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

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



6.4. NATURAL HAZARDS

There have been 15 spillage incidents related to natural hazards, 2% all spillage events (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 11 Details of natural causes due to ground movement

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

6.5. THIRD PARTY

Third parties have caused the largest number of spillages with 352 events, an average of 7.8 per year and 52% of all spillage events. 134 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 186 were intentional (almost exclusively theft attempts). 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. When excluding theft, accidental and incidental third party events caused 34% of all spills.

6.5.1. Accidental damage

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

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

Figure 23 Causes of accidental third party spills

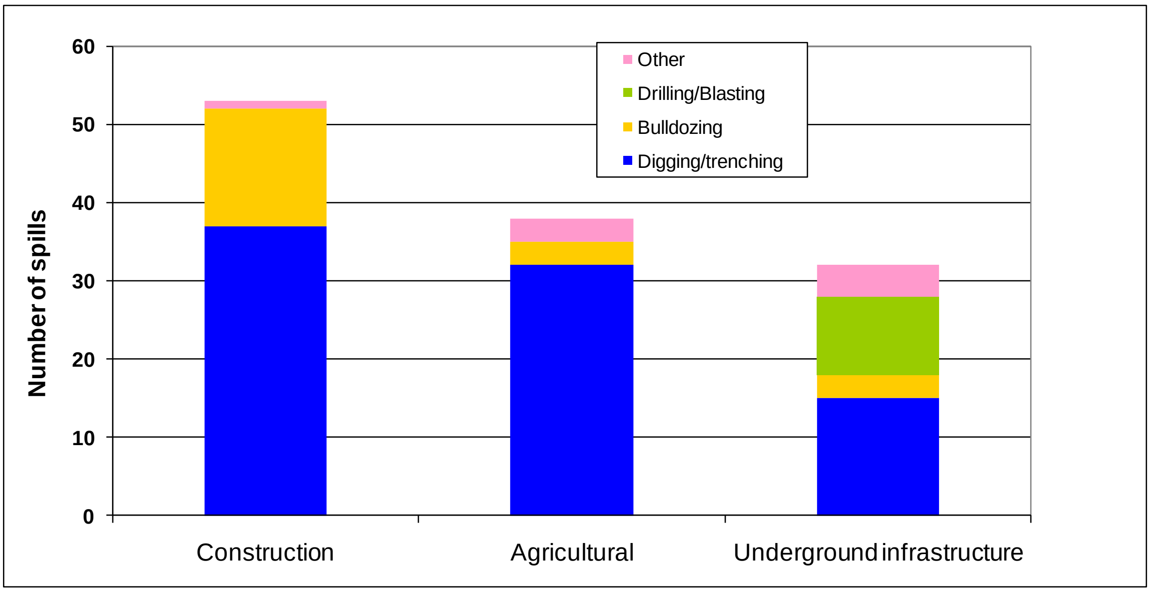
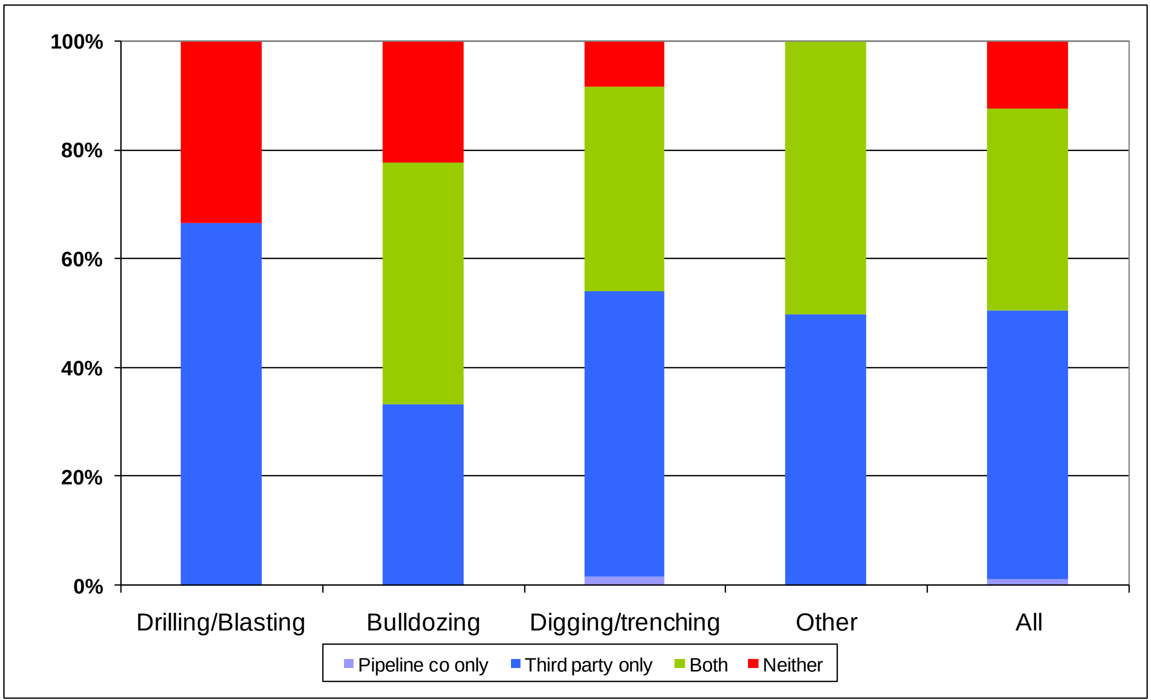


Figure 24 shows the awareness data (reported for about 68% of the third party-related spillages) as the percentage of cases where each party was aware of either the impending activity (pipeline operator) or the presence of a pipeline (machinery operator).

In 48% of cases, third parties undertook some form of excavation activities in the full knowledge that a pipeline was present in the vicinity but without the pipeline operating company being aware of these activities. In contrast, only 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.

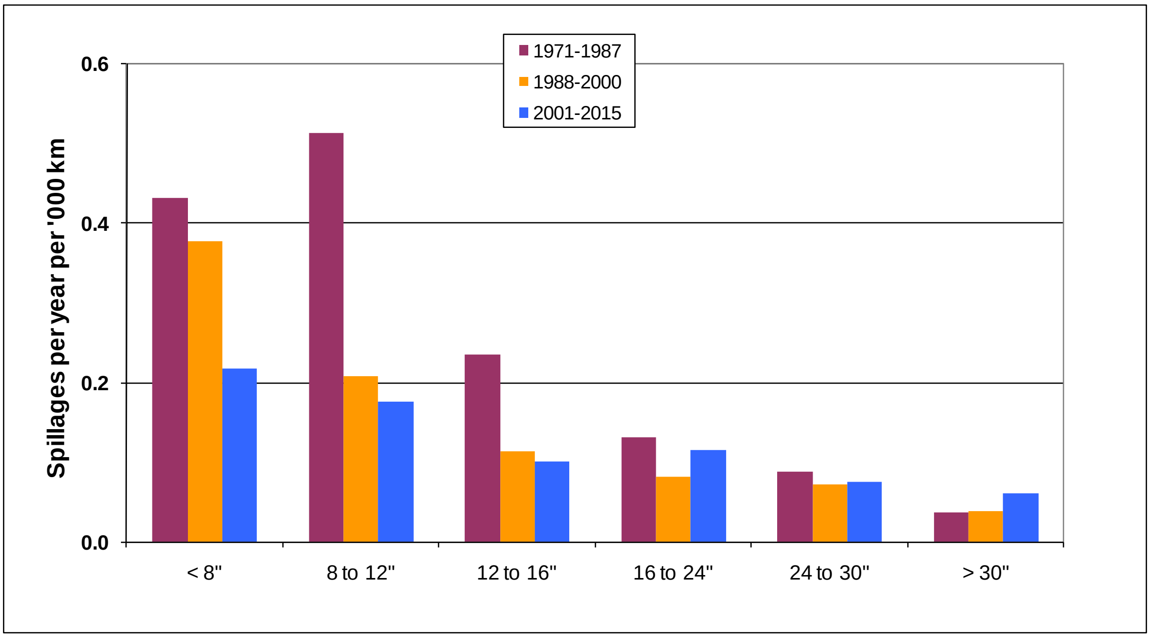
Figure 24 Awareness of impending works and of pipeline location



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

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

Figure 25 Third party accidental spillage frequencies per diameter class



6.5.2. Incidental damage

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

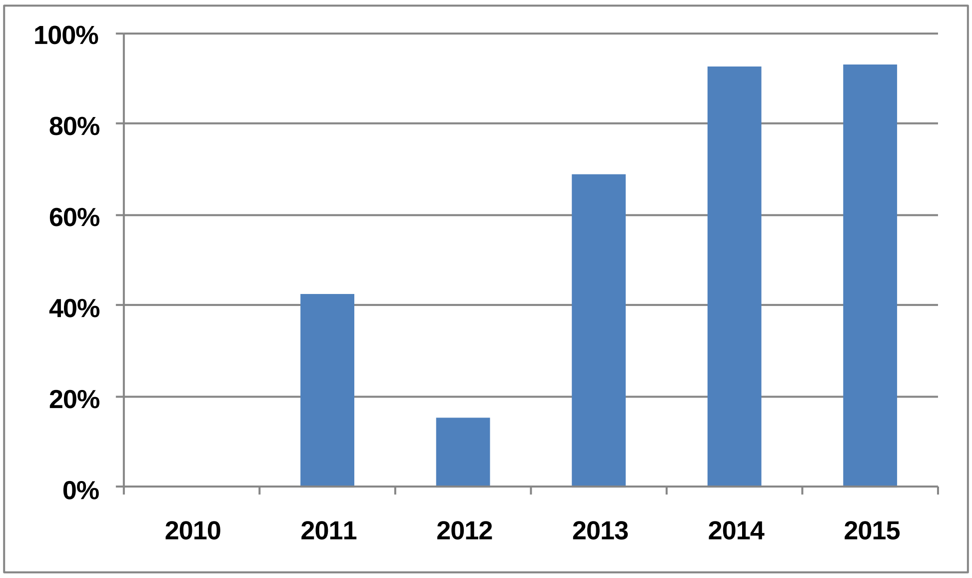
There have been 32 incidental damage incidents. These all started off from dents, scrapes and such like. Thus they share the characteristic that they might be detectable by in-line inspections.

6.5.3. Intentional damage

186 spillages were caused by intentional damage by third parties. 2 resulted from terrorist activities and 6 from vandalism. 178 were caused by attempted or successful product theft, 158 of which occurred in the last three reporting years.

Only one of the terrorist or vandalism incidents was in underground piping; one was from an above-ground section of pipeline, all the rest were at valves or other fittings at pump stations or road / river crossings, etc. 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 is unprecedented and presents a significant challenge for pipeline operators. We understand that the figure for 2016 will also be high, with incidents reported in several countries across Europe. This trend is further illustrated in **Figure 26** which shows that theft activities now accounts for a very large proportion of all spillage events.

Figure 26 Percentage of all spills due to theft activities



7. IN-LINE INSPECTIONS

Concawe has been collecting data on in-line inspection activities (inspection pig) for over 35 years, including a one-off exercise to collect back data from the time inspection pigs were first used around 1977. Separate records are kept for metal loss, crack detection and for geometry (calliper) inspections. Each inspection may entail one or more passes of a pig along a "piggable" pipe section. Leak detection pigs are also sometimes used but their function is quite different. They can reduce the consequences of a leak that has already started, by detecting it earlier. They cannot, however, help prevent the leak occurring in the first place.

In 2015 the 63 companies who reported inspected a total of 93 sections with at least one type of inspection pig, covering a total combined length of 15394 km, split as follows amongst the individual types of pig:

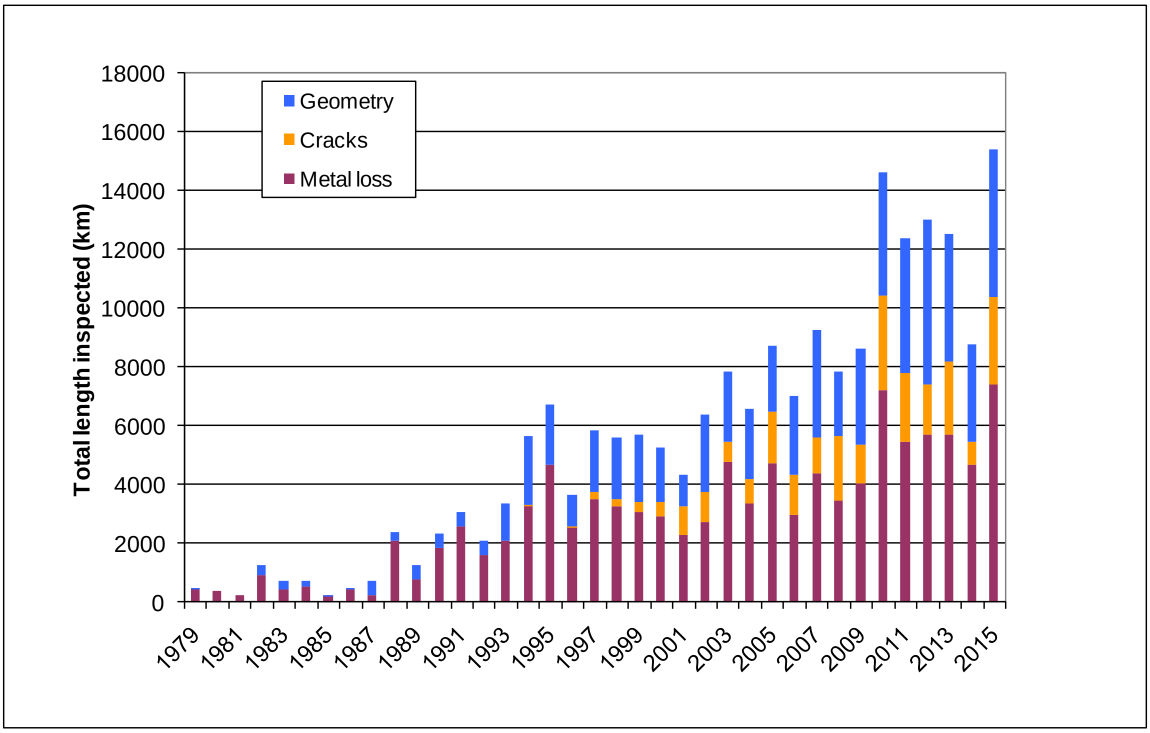
- Metal loss pig 7406 km, 83 sections
- Crack detection pig 3005km, 13 sections
- Geometry pig 4983 km, 55 sections

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 8487 km (24% of the inventory).

As shown in **Figures 28 and 29**, 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, 2015 shows the highest figure ever recorded, resuming the long term upwards trend.

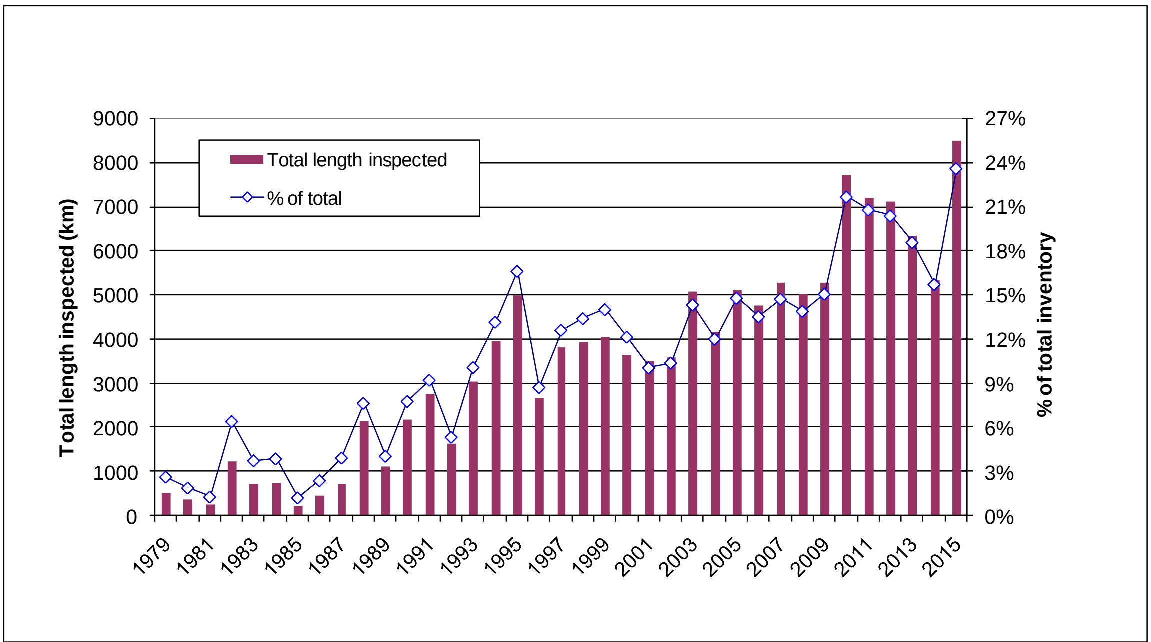
Over the last ten years, a period considered as a reasonable cycle for this type of intensive activity, 426 (66%) of the total of 647 active sections included in the 2015 survey were inspected at least once by at least one type of pig, representing 80% of the total length of the surveyed network. This 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 28 Annual length inspected by each type of pig



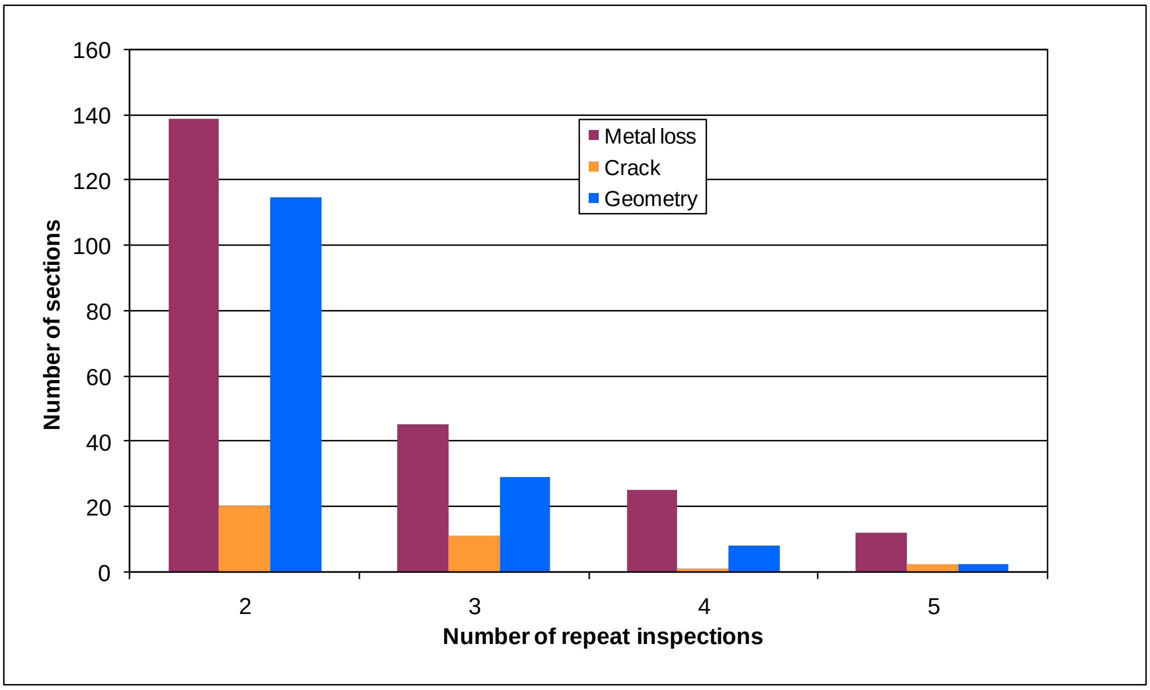
Note: the total length shown above may be higher than shown in Figure 29 as some sections may have been inspected by more than on pig type

Figure 29 Total annual portion of the inventory inspected by inspection pigs



As shown in **Figure 30**, 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 30 Repeat inspections in the last 10 years



The inspection technology can detect flaws, corrosion and other sorts of damage in or on the pipe inner or outer walls. Over the past 45 years, 17 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 106 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 106 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 7 and 6 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. The current statistics, however, only cover those events that resulted in a spill. Many more theft-related events do not cause a spill either because thieves do not succeed in drilling through the pipe wall or install a product withdrawal system with sufficient integrity to ensure containment.

From the 2015 reporting year a new section was added to the annual survey requesting respondents to report all theft attempts, whether successful or not and whether resulting in a spill or not.

The results are summarised in **Table 12**.

A total of 147 theft-related incidents were reported in 7 different countries (87 of which resulting 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. In 10% of the cases the pipeline was not successfully holed. Where the pipeline was breached the holes were mostly less than 3 mm in diameter.

Automatic leak detection systems were able to detect 35% of the attempts even though the abstraction flow rates were consistently under 1 m^3/h (suggesting that the thieves have an understanding of the operator's detection capabilities).

Most connections were located in open countryside. The abstraction point was mostly close to the pipeline although, in a small number of cases, the distance was in excess of 1 km. 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.

Figure 31 shows the rapid increase in spillage incidents related to product theft from 2010 to 2015. Since 1971, 186 spillages have been caused by intentional damage by third parties, with 2 resulting from terrorist activities and 6 from vandalism. The remaining 178 were caused by attempted or successful product theft, and 158 of these were reported in the last three reporting years.

It should be noted that the total number of theft incidents is higher than that reported in this Concawe survey. In their 2016 annual report, Unione Petrolifera show a higher number of incidents for Italy (http://www.unionepetrolifera.it/?wpdmpro=annual-report-2016&wpdmdl=6092), which suggests that Italian operators that did not report in the Concawe survey also experienced large numbers of theft incidents. 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).

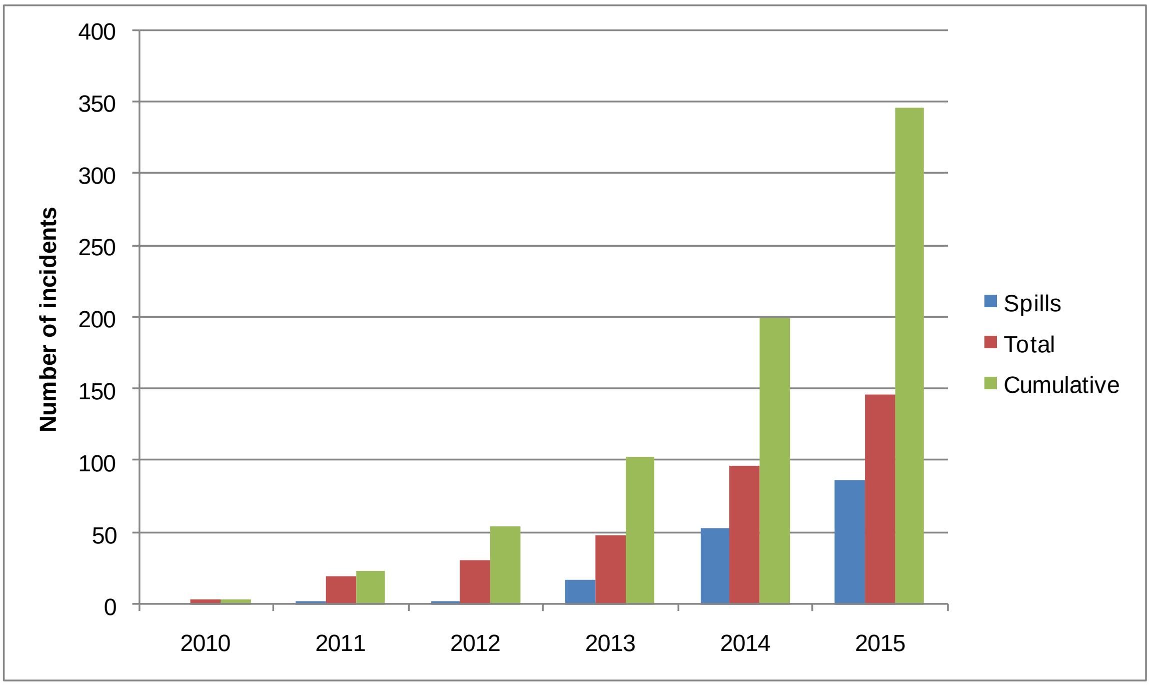
Table 12 Summary of 2015 attempted theft events attributes
(note that not all attributes were reported for all events)

Number of events	**147**							Number reported
Successful thefts	**48**							
Spills caused	**87**							
Code	1	2	3	4	5	6	7	
Service (type of product transported)	0%	91%	1%	4%	4%	0%		139
Facility part	97%	3%	0%	0%				65
Connection type	31%	44%	22%	4%				55
Hole size	10%	64%	15%	8%	3%			39
Detection (how was tampering detected)	35%	15%	19%	1%	15%	13%	3%	75
Flow rate (estimated abstraction rate)	100%	0%	0%					17
Location (type of environment)	72%	6%	15%	7%				54
Distance (between pipeline and abstraction point)	58%	23%	15%	4%				52
Storage (facility installed by thieves)	80%	8%	12%					50

Key

Service (type of product transported)		**Detection (how was tampering detected)**	
1	Crude oil	1	Automatic detection system
2	Multi product	2	Operational monitoring
3	Gasoline	3	Routine surveillance
4	Diesel	4	Ultrasonic LD pig
5	Jet	5	Line internal inspection
6	Other	6	Third party
Facility part		7	Other
1	Underground pipe	**Flow rate (estimated abstraction rate)**	
2	Overground pipe	1	< 1 m^3/h
3	Valve station	2	1-5 m^3/h
4	Other	3	> 5 m^3/h
Connection type		**Location (type of environment)**	
1	Clamped	1	Open land
2	Welded	2	Car park / Lay-by
3	Screwed	3	Shrub / wooded area
4	Other	4	Building
Hole size		**Distance (between pipeline and abstraction point)**	
1	No hole	1	< 10 m
2	< 3 mm	2	10-100 m
3	3-6 mm	3	100-1000 m
4	6-10 mm	4	> 1000 m
5	> 10 mm	**Storage (facility installed by thieves)**	
		1	None
		2	<1 m^3
		3	>1 m^3

Figure 31 Evolution of the number of theft-related incidents since 2010



APPENDIX 1 DEFINITIONS AND CODES

Pipeline Inventory

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,
- Pipelines with a length of 2 km or more in the public domain,
- Pipelines 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.

Spillage volume

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).

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		Aa	4		
34		20	1			25	3	5	3	2	1	4	Aa			
35		16	1			0		2	3	4	3	4	Ab			
36			1			4		2	3	7	11	4	Ab	4		
37		24	2			25		2	3	2	2	4	Ab			
38		18	1			11	1	2	3	5	13	4	Ab	4		
39		6	2			12	6	5	1	2	1	4	Ab			
40		9	1			12	12	1	1	3	32		Ca			
41		5	3			15		1	1	3	8		Ca			
42		5	3			15		1	1	3	8		Ca			
43		12	3			200	2	5	1	3	13		Ca			
44		12	3			12	2	2	2	3	13		Ca			
45		12	3			250	5	5	2	3	13		Ca			
46		12	3			150	2	1	2	3	13		Ca	14		
47		12	3			310	10	5	1	3	13	4	Ca			30,000
48		28	1			100	40	5	1	3	16		Da			
49		10	3			8		5	1	3	9	2	Ea	18		
50		12	3			0		5	1	3	6		Ec			
51		12	3			1		5	1	3	6		Ec			
52		12	3			0		1	1	3	6		Ec			
53	1974		1			1	0	2	3	7	4	4	Aa	7		
54			1			3	2	2	3	7	5	4	Aa	4		1,000
55		6	1			20		5	1	1	15		Aa	4		
56		9	1			10		1	1	3	33		Ca			
57			2			2	2	2	2	7	6		Ca			
58		10	3			1		2	1	3	9	4	Ca	14		
59		12	3			5		5	1	3	8		Ca	14		
60		13	3			5		5	1	3	8		Ca	14		
61		4	3			1		5	1	3	17	4	Ca	14		
62		6	3			0		5	1	3	16		Ca	14		
63		16	3			1		5	1	3	9	2	Cb		P	
64		7	1			1		5	1	3	8	2	Cb			
65		16	1			500		5	1	3	10		Ea	17		
66		5	2			1	0	5	1	3	21		Ea	19		
67		8	2			30	4	2	1	3	22		Ea	19		
68		8	2			200	2	5	1	3	22		Ea	17		
69		10	2			668	668	2	1	3	18		Ea	18		
70		10	2			489	405	2	1	3	18	2	Ea	17		

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

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

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

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

Spillage ID	Year	Pipe dia (")	Service	Fatalities	Injuries	Spillage volume (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	1968	7	Eb	26		500
584		10	2			3	2	3	1	3	41	3	Eb	26		50
585		20	1				0	6	2	8		7	Aa			
586		12	2			2	0	5	1	3	42	2	Eb	26		50
587 to 664			2										Eb	26		
665		8	2			39	34	3	1	3	1991	5	Eb	26		275
666		14	2			25	25	5	1	3	2010	3	Eb	26		
667		10	2			9	9	3	1	3	1982	3	Eb	26		10
668		10	2			22	20	5	1	3	1982	3	Eb	26		100
669		10	2			15	14	5	1	3	1981	3	Eb	26		
670		10	2			3	3	3	1	1	1981	3	Eb	26		
671		6	1			0	0	2	2	3	1989	4	Cb			20
672		8	2			15	15	5	1	3	1977	3	Ca	14		200
673		8	2			13	3	2	1	3	1976	4	Ca	15		200
674		12	2			30	0	3	2	2			Ab	2		
675		1	2			2	0	5	2	2			Ab	2		5

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