APPENDIX B

Analysis of
Serious Incident Data
For
Natural Gas Distribution Pipeline Systems
1990 – 2002

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PART 1

BASES FOR ANALYSES OF INCIDENT DATA

Introduction

This appendix presents the details of the data analyses described in Section 4 of the report body. The figures and tables in the preceding table of contents are the serious incident data sets that were analyzed in this study. These consist of data on incidents where fatalities or injuries (F&I) occurred during the incident. They do not include data for non-serious incidents, such as incidents, where only property damage occurred, or where the incident was reported to DOT as being "significant in the judgment of the operator."

Because the guidelines for property damage reporting in the DOT incident report instructions are subject to interpretation, there is ample margin for variability in what is included in property damage estimates reported by operators, including for example variations in the cost of gas. Further, the effect of inflation also plays a role when incident counts are compared over long time frames are considered, and inflation is not taken into account in the property damage threshold. As a result, incidents involving increasingly smaller amounts of property damage are reported each year. For example, a $50,000 loss in 1989 dollars would be equivalent to a $61,543 loss in 1998.

Incidents reported as "significant in the judgment of the operator" include incidents that are reported because they draw significant media attention, even though they occurred on non-jurisdictional parts of the distribution systems, such as the customers' premises or property. A gas fire could have been the final outcome in a chain reaction type incident likewise a suicide or arson may have occurred involving gas.

Thus, the data that address fatalities and injuries were selected for analysis because they represent a more reliable measurement, even though they may also contain a margin of error for the same reasons as stated above. However, such error is thought to be small, although the DOT database does not provide enough information to allow a quantitative assessment of such error.

The data sets were selected from many possible ways that the incident database could be sorted. Representatives of the distribution pipeline operators and both state and federal regulatory agencies made the selection.

The basis of the analyses is discussed in this part of the appendix, followed by the figures and tables upon which the analyses were based, in Part 2 and Part 3 respectively.

The analyses address the fatality and injury incidents by part of system, material of construction, and cause from January 1, 1990 through December 31, 2002.

Study Period

Data are available from 1970 through the present. In 1985, reporting requirements, based on the value of property damage was changed from $5,000 to $50,000. Because of this, it was originally decided to analyze data only beginning in 1985. The cutoff year for the end point of the analysis was chosen as 2002 to ensure that all reports had been submitted and all adjustments had been made; in other words that the data was reasonably final for the end period. Subsequently, at the request of the Distribution Infrastructure Government-Industry Team (DIGIT), the period for analysis was restricted to 1990 through 2002. This is the study period used in this report. The rationale for this choice includes the desire to eliminate as many "non-reportable" reported data points as possible and also to consider a time frame that involves more recent events. The non-reportable reported incidents were prevalent for some years after the change in damage reporting criteria, with some operators continuing to report incidents under the $50,000 threshold.

Data Normalization

The serious incidents data can be evaluated in terms of the absolute number of incidents per year or the number of incidents per mile or part count based on the total mileage or number of items in each part of the distribution infrastructure. The number of incidents per year alone is not an appropriate unit of measure when the mileage changes over time. With no change in the number of incidents, say per 100,000 miles of system, if only the number of incidents per year was used as a performance indicator, the indicator would increase as the mileage increases, or decrease as the mileage decreased, even if there were no change in the fundamental incident rate or frequency over time. Therefore, to compensate for this effect, the data in this report have been normalized to the appropriate number of miles associated with data set being analyzed for each year in the 1990 – 2002 period; i.e. total miles of distribution system for all incidents regardless of part of system; miles of mains when addressing incidents associated with mains; miles of a particular material of construction when addressing that material; etc. The mileage used for normalization was obtained from the DOT/OPS Annual Reports Data. The mileage associated with each data set is tabulated in Part 3 of this appendix. The year-by-year incident counts and computed normalized values used in the time series graphs of incidents over the study period, for the various data sets, are also given in Part 3. Depending on the data set, data are normalized for each year in the study period using one of the following, appropriate mileage counts:

- Total distribution mileage for 1990 – 2002;
- Mains;
- Services;
- Steel mains;
- Polyethylene mains;
- Cast iron mains;
- Other materials mains;

- Steel services:
- Polyethylene services;
- Cast iron not applicable for services; and
- Other services.

Incident frequency values are expressed on a per 100,000 mile basis. One hundred thousand miles of pipe was selected for normalizing the data because it conveniently yields whole numbers as opposed to fractional numbers for many of the data analyses in the study and makes data interpretation and comparisons easier to communicate. This was also applied to meter set assemblies because there are no data in the OPS databases for meter counts, and those counts are fairly consistently proportional to the counts of services connections, to which services miles are also proportional. Therefore, it made sense to normalize the meter set assembly data on the same basis as services; that is services miles.

The remainder of this Appendix Part 1 provides an overview of some key previous studies and the results of the current effort. Topics discussed below cover the major points of the study with details relegated to Part 2.

Data Analysis

The serious incidents data analysis was divided into several parts: total incidents, incidents by part of system, by material of construction, and by cause. Table 1 provides a summary of the serious incident analysis matrix with the number of serious incidents shown for various cross-sections of the data.

Major parts of the system, based on definitions in the OPS database are:

- Mains;
- Service Lines;
- Meter Set Assemblies; and
- Other.

Table 1. Serious Incidents Analysis Matrix

Analysis Description	No. of Serious Incidents				
Total Incidents (1985 - 2002)	**2,467**				
Total Incidents (1985 - 1989)	**888**				
Total incidents (1990 - 2002)	**1,579**				
Total Incidents with no F&Is (1990 - 2002)	**978**				
Total Incidents with F&Is (1990 - 2002)	**601**				
Incidents on Mains	**276**				
Incidents on Service Lines	**161**				
Incidents on Meter Set Assembly	**43**				
Incidents on Other / No data Pipe	**121**				
Incidents caused by corrosion	**39**				
Incidents caused by outside force	**280**				
3rd Party		**208**			
Earth Movement		**46**			
Frost					
Landslide / Washout					
Subsidence					
Other / No Data					
Other / No Data		**26**			
Incidents caused by construction/ operating error	**59**				
Incidents caused by accidentally caused by operator	**59**				
Incidents caused by other / no data	**164**				
Incidents on Mains	**276**				
Steel Pipe		**95**			
Corrosion			**19**		
Outside force			**34**		
3rd Party				**27**	
Earth Movement				**4**	
Other / No Data				**3**	
Construction/ operating error			**10**		
Accidentally caused by operator			**15**		
Other / no data			**17**		
Cast Iron Pipe		**66**			
Corrosion			**3**		
Outside force			**36**		
3rd Party				**7**	
Earth Movement				**27**	
Frost					**13**
Landslide / Washout					**0**
Subsidence					**8**
Other / No Data					**6**
Other / No Data				**2**	
Construction/ operating error			**1**		
Accidentally caused by operator			**4**		
Other / no data			**22**		
Polyethylene Plastic Pipe		**103**			
Corrosion			**0**		
Outside force			**53**		
3rd Party				**47**	
Earth Movement				**2**	
Other / No Data				**4**	
Construction/ operating error			**26**		
Accidentally caused by operator			**14**		

Table 1. (continued)

Analysis Description	No. of Serious Incidents			
Other / no data			10	
Other Plastic Pipe		2		
Corrosion			0	
Outside force			1	
3rd Party				1
Earth Movement				0
Other / No Data				0
Construction/ operating error			0	
Accidentally caused by operator			0	
Other / no data			1	
Other / No Data Pipe		10		
Corrosion			1	
Outside force			2	
3rd Party				2
Earth Movement				0
Other / No Data				0
Construction/ operating error			2	
Accidentally caused by operator			3	
Other / no data			2	
Incidents on Service Lines	161			
Steel Pipe		68		
Corrosion			9	
Outside force			37	
3rd Party				31
Earth Movement				4
Other / No Data				2
Construction/ operating error			4	
Accidentally caused by operator			10	
Other / no data			8	
Cast Iron Pipe		0		
Corrosion			0	
Outside force			0	
3rd Party				0
Earth Movement				0
Other / No Data				0
Construction/ operating error			0	
Accidentally caused by operator			0	
Other / no data			0	
Polyethylene Plastic Pipe		71		
Corrosion			0	
Outside force			54	
3rd Party				47
Earth Movement				1
Other / No Data				6
Construction/ operating error			2	
Accidentally caused by operator			2	
Other / no data			13	

Table 1. (continued)

Analysis Description	No. of Serious Incidents			
Other Plastic Pipe		**5**		
Corrosion			**0**	
Outside force			**3**	
3rd Party				**1**
Earth Movement				**2**
Other / No Data				**0**
Construction/ operating error			**0**	
Accidentally caused by operator			**1**	
Other / no data			**1**	
Other / No Data Pipe		**17**		
Corrosion			**4**	
Outside force			**8**	
3rd Party				**6**
Earth Movement				**1**
Other / No Data				**1**
Construction/ operating error			**0**	
Accidentally caused by operator			**2**	
Other / no data			**3**	
Incidents on Meter Set Assemblies	**43**			
Steel Pipe		**28**		
Cast Iron Pipe		**0**		
Polyethylene Plastic Pipe		**1**		
Other Plastic Pipe		**1**		
Other / No Data Pipe		**13**		
Incidents on Other / No Data Pipe	**121**			
Steel Pipe		**22**		
Cast Iron Pipe		**4**		
Polyethylene Plastic Pipe		**5**		
Other Plastic Pipe		**2**		
Other / No Data Pipe		**88**		
Incidents Caused By Corrosion	**39**			
Main		**23**		
Steel Pipe			**19**	
Cast Iron Pipe			**3**	
Polyethylene Plastic Pipe			**0**	
Other Plastic Pipe			**0**	
Other / No Data Pipe			**1**	
Service Lines		**13**		
Steel Pipe			**9**	
Cast Iron Pipe			**0**	
Polyethylene Plastic Pipe			**0**	
Other Plastic Pipe			**0**	
Other / No Data Pipe			**4**	
Meter Set Assembly		**0**		
Steel Pipe			**0**	
Cast Iron Pipe			**0**	
Polyethylene Plastic Pipe			**0**	
Other Plastic Pipe			**0**	
Other / No Data Pipe			**0**	
Other / No Data		**3**		
Steel Pipe			**2**	

Table 1. (continued)

Analysis Description						No. of Serious Incidents				
					Cast Iron Pipe			0		
					Polyethylene Plastic Pipe			0		
					Other Plastic Pipe			0		
					Other / No Data Pipe			1		
		Incidents caused By Outside Force				280				
			3rd Party				208			
				Main				84		
					Steel Pipe					
					Cast Iron Pipe				7	
					Polyethylene Plastic Pipe				47	
					Other Plastic Pipe				1	
					Other / No Data Pipe				2	
				Service Lines				85		
					Steel Pipe				31	
					Cast Iron Pipe				0	
									47	
					Other Plastic Pipe				1	
					Other / No Data Pipe				6	
								22		
					Steel Pipe				17	
					Cast Iron Pipe				0	
					Polyethylene Plastic Pipe				1	
					Other Plastic Pipe				0	
					Other / No Data Pipe				4	
				Other / No Data				17		
					Steel Pipe				9	
					Cast Iron Pipe				1	
					Polyethylene Plastic Pipe				0	
					Other Plastic Pipe				0	
					Other / No Data Pipe				7	
			Earth Movement				46			
				Main				33		
					Steel Pipe				4	
					Cast Iron Pipe				27	
					Polyethylene Plastic Pipe				2	
					Other Plastic Pipe				0	
					Other / No Data Pipe				0	
				Service Lines				8		
					Steel Pipe				4	
					Cast Iron Pipe				0	
					Polyethylene Plastic Pipe				1	
					Other Plastic Pipe				2	
					Other / No Data Pipe				1	
				Meter Set Assembly				2		
					Steel Pipe				2	
					Cast Iron Pipe				0	
					Polyethylene Plastic Pipe				0	
					Other Plastic Pipe				0	
					Other / No Data Pipe				0	
								3		
					Steel Pipe				1	
					Cast Iron Pipe				1	
					Polyethylene Plastic Pipe				0	
					Other Plastic Pipe				0	

Table 1. (continued)

Analysis Description	No. of Serious Incidents			
Other / No Data Pipe				1
Other / No Data		26		
Main			9	
Steel Pipe				3
Cast Iron Pipe				2
Polyethylene Plastic Pipe				4
Other Plastic Pipe				0
Other / No Data Pipe				0
Service Lines			9	
Steel Pipe				2
Cast Iron Pipe				0
Polyethylene Plastic Pipe				6
Other Plastic Pipe				0
Other / No Data Pipe				1
Meter Set Assembly			6	
Steel Pipe				2
Cast Iron Pipe				0
Polyethylene Plastic Pipe				0
Other Plastic Pipe				0
Other / No Data Pipe				4
Other / No Data			2	
Steel Pipe				0
Cast Iron Pipe				0
Polyethylene Plastic Pipe				0
Other Plastic Pipe				0
Other / No Data Pipe				2
Incidents Caused By Construction / Operating Error	59			
Main		39		
Steel Pipe			10	
Cast Iron Pipe			1	
Polyethylene Plastic Pipe			26	
Other Plastic Pipe			0	
Other / No Data Pipe			2	
Service Lines		6		
Steel Pipe			4	
Cast Iron Pipe			0	
Polyethylene Plastic Pipe			2	
Other Plastic Pipe			0	
Other / No Data Pipe			0	
Meter Set Assembly		3		
Steel Pipe			1	
Cast Iron Pipe			0	
Polyethylene Plastic Pipe			0	
Other Plastic Pipe			0	
Other / No Data Pipe			2	
Other / No Data		11		
Steel Pipe			4	
Cast Iron Pipe			0	
Polyethylene Plastic Pipe			2	
Other Plastic Pipe			0	
Other / No Data Pipe			5	
Incidents Caused By Accidentally Caused By Operator	59			
Main		36		
Steel Pipe			15	

Table 1. (continued)

Analysis Description						No. of Serious Incidents				
					Cast Iron Pipe			4		
					Polyethylene Plastic Pipe			14		
					Other Plastic Pipe			0		
					Other / No Data Pipe			3		
				Service Lines			15			
					Steel Pipe			10		
					Cast Iron Pipe			0		
					Polyethylene Plastic Pipe			2		
					Other Plastic Pipe			1		
					Other / No Data Pipe			2		
				Meter Set Assembly			2			
					Steel Pipe			1		
					Cast Iron Pipe			0		
					Polyethylene Plastic Pipe			0		
					Other Plastic Pipe			0		
					Other / No Data Pipe			1		
				Other / No Data			6			
					Steel Pipe			1		
					Cast Iron Pipe			0		
					Polyethylene Plastic Pipe			1		
					Other Plastic Pipe			0		
					Other / No Data Pipe			4		
		Incidents Caused By Accidentally Other / No Data				164				
				Main			52			
					Steel Pipe			17		
					Cast Iron Pipe			22		
					Polyethylene Plastic Pipe			10		
					Other Plastic Pipe			1		
					Other / No Data Pipe			2		
				Service Lines			25			
					Steel Pipe			8		
					Cast Iron Pipe			0		
					Polyethylene Plastic Pipe			13		
					Other Plastic Pipe			1		
					Other / No Data Pipe			3		
				Meter Set Assembly			8			
					Steel Pipe			5		
					Cast Iron Pipe			0		
					Polyethylene Plastic Pipe			0		
					Other Plastic Pipe			0		
					Other / No Data Pipe			3		
				Other / No Data			79			
					Steel Pipe			5		
					Cast Iron Pipe			2		
					Polyethylene Plastic Pipe			2		
					Other Plastic Pipe			2		
					Other / No Data Pipe			68		

Major materials of construction, primarily associated with the pipe, valves, and pipe components are:

- Steel;
- Polyethylene Plastic; and
- Cast Iron.

The highest level of incident cause categories is:

- Corrosion;
- Outside forces;
- Construction operating error;
- Accidentally caused by operator; and
- Other and no data.

The analyses were taken to a given level of detail by the scope definition for this particular study agreed upon between representatives of industry, the National Association of Pipeline Safety Representatives (NAPSR) the National Association of Regulatory Utility Commissioners (NARUC) and OPS. More analyses are possible but are beyond the scope of the present study. The analyses were selected based on interest in specific issues and were intended to answer a first round of questions about performance of gas distribution systems examined from several perspectives. The OPS serious incidents data were examined by sorting the data based on the above parts of system, materials of construction and causes of incidents, in number of different combinations to reveal performance with regard to the specific parameters over the study period.

The data analyses graphs in Part 2 are presented as figures with accompanying tables in three types of displays:

- Bar charts;
- Line graphs; and
- Long term trend graphs.

The bar charts show a profile or distribution of incidents by various categories into which the data were sorted. In many cases, these data represent a subset of the total 601 serious incidents for distribution systems. Most figures express the incident counts as a percentage of the incidents within the subcategory or sorting group rather than as a percentage of all 601 serious incidents. Note that some figures will also report zero incidents for a given cause, part of system or material of construction category. This is a valid result and simply reflects the absence of incidents where F&Is occurred during the year in the relatively small number of incidents analyzed within some of the subcategory data sorts.
In addition, the category “other” is often shown on many of the figures for cause, part of system, or material of construction. This is a category specified as part of the DOT/OPS incident database and in the case of “other” causes, no additional information is available to discern the

particular cause of the incident. "No data" is another category often shown on the Part 2 analysis figures and simply reflects those incidents for which the DOT/OPS incident database has a null entry (i.e., nothing provided by operator) or the "no data" category was selected by the operator in their incident report.

The line graphs show the fluctuations in incident rates from year to year. Trend graphs show whether there is a generally upward or downward trend, when supported by a formal statistical test. If a trend could not be proven to a confidence level of at least 90%, then no trend graph was plotted. The 90% level is commonly accepted by the scientific and technical community as an acceptable confidence level for trends derived by statistical means. The variability from year to year makes it difficult to clearly discern whether or not there is an overall trend in incident rates. A visual suggestion of a trend from a graph is not always supported by a formal statistical test. This is important for two reasons. A clear determination of a real trend for the degree of variability in incident rates from year to year means that a few years of data are inadequate to tell anything definitive about whether performance is improving or getting worse. Additional discussion of statistical analysis techniques is found in Appendix D.

The types of graphs of data by year are referred to as time series. It is in the nature of time series that to determine a trend, one fits a mathematical function that smoothes the short-term variations. This is typically done with a regression analysis by one or more mathematical functions. The function chosen depends on the nature of the phenomenon being observed. A function is chosen and fit to the data such that a general trend direction can be observed. This is not the same as curve fitting the data to replicate the exact pattern of the data. All that accomplishes is to develop an empirical equation that cannot be extrapolated beyond the range represented by the data. Rather, a trending function provides some sense of direction and can be extended to a limited extend beyond the range of the data.

In the figures that follow in Part 2, data are plotted in line graphs that show the data points and fluctuations form year to year over the study period. Trending functions were fitted to every graph. However, a trending function is not shown for every graph. They are only shown for graphs that passed a specific statistical test. That test was the Mann-Kendall (MK) test for determining if an upward or downward trend was like to exist at two specified levels of confidence: 90% and 95%. Only if a trend line passed this test was it plotted in a companion figure to the line graph. If it did not meet the test criterion, no trend plot was made.
Table 2 summarizes the results of the MK test for all figures included in this analysis. Analyses showing a statistically significant trend at 90% and/or 95% confidence are highlighted.

A similar analysis was conducted for fatality and injury counts the details of which are presented in Appendix C.

Trends that were determined by the test are discussed along with each of the ensuing figures within Part 2. Data sets for which trending was indeterminate at a 90% to 95% confidence level, arranged by part of system, and also shown in the ensuing figures in Part 2 are:

<u>All parts of distribution infrastructure</u>

- "Other" cause category (other than: corrosion, outside force, construction / operating error, accidentally caused by operator);
- Third party damage on whole distribution system.

<u>Mains</u>

- Cast iron mains;
- Outside force, earth movement incidents on cast iron mains;
- Outside forces on steel mains;
- Outside forces on polyethylene mains;
- Outside forces on cast iron mains;
- Third party damage on all mains;
- Third party damage on steel mains;
- Third party damage on cast iron mains; and
- Third party damage on polyethylene mains;

<u>Services</u>

- Service lines, all parts of service line subsystem;
- Service lines, steel systems;
- Service lines, polyethylene systems;
- Outside forces on service lines;
- Outside forces on steel service lines;
- Outside forces on polyethylene service lines;
- Third party damage on service lines;
- Third party damage on steel service lines;
- Third party damage on polyethylene service lines; and
- Corrosion on service lines.

<u>Meter Set Assemblies</u>

- Meter set assemblies, all parts of meter set assembly subsystem;
- Outside forces on meter set assemblies.

When a trend is reported as indeterminate it simply means that an upward or downward trend could not be verified at either the 90% level of confidence.

Table 2. Summary of Results from Mann-Kendall Test

Report Figure No.	Type	Number of Samples	p-value for Mann-Kendall Test	Conclusion of Mann-Kendall Test (90% Confidence)	Conclusion of Mann-Kendall Test (95% Confidence)
B1	Total incidents	13	0.137		
B5	F & I Incidents	13	0.0164		Downward
B6	Serious Incidents-Main	13	0.0036		Downward
B6	Serious Incidents-Meter	13	0.214		
B6	Serious Incidents-Service Line	13	0.500		
B7	Mains Serious Incidents-Cast Iron	13	0.180		
B7	Mains Serious Incidents-Poly Plastic	13	0.016		Downward
B7	Mains Serious Incidents-Steel	13	0.044		Downward
B11	Service Serious Incidents-Poly Plastic	13	0.291		
B11	Service Serious Incidents-Steel	13	0.380		
B16	Serious Incidents Cause-Accident	13	0.078	Downward	
B16	Serious Incidents Cause-Construct	13	0.0085		Downward
B16	Serious Incidents Cause-Corrosion	13	0.077	Downward	
B16	Serious Incidents Cause-Other	13	0.476		
B16	Serious Incidents Cause-Outside Force	13	0.0087		Downward
B17	Corrosion Serious Incidents-Main	13	0.069	Downward	
B17	Corrosion Serious Incidents-Service	13	0.376		
B20	Outside Force Serious Incidents-Main	13	0.033		Downward
B20	Outside Force Serious Incidents-Meter	13	0.220		
B20	Outside Force Serious Incidents-Other	13	0.035		Downward
B20	Outside Force Serious Incidents-Service	13	0.401		
B21	Mains Outside Force Serious Incidents-Cast Iron	13	0.123		
B21	Mains Outside Force Serious Incidents-Poly Plastic	13	0.100		
B21	Mains Outside Force Serious Incidents-Steel	13	0.311		
B22	Mains 3rd Party Serious Incidents-Cast Iron	13	0.259		
B22	Mains 3rd Party Serious Incidents-Poly Plastic	13	0.232		
B22	Mains 3rd Party Serious Incidents-Steel	13	0.500		
B23	Mains Earth Movement Serious Incidents-Cast Iron	13	0.232		
B24	Service Lines Outside Force Serious Incidents-Steel	13	0.136		
B25	Service 3rd Party Serious Incidents-Poly Plastic	13	0.380		
B25	Service 3rd Party Serious Incidents-Steel	13	0.403		
B21A	Distribution Serious Incidents from Third Party	13	0.476		
B21B	3rd Party Serious Incidents-Main	13	0.064	Downward	
B21B	3rd Party Serious Incidents-Service Line	13	0.427		
B38B	Mains, Outside Force Serious Incidents-3rd Party	13	0.180		
B38C	Cast Iron mains, Outside Force-Earth	13	0.232		
B38D	Poly Mains-Outside Force Serious Incidents 3rd Party	13	0.380		
B38E	Steel Mains-Outside Force Serious Incidents 3rd Party	13	0.500		
B38F	Services-Outside Force Serious Incidents 3rd Party	13	0.476		
B38G	Steel Services-Outside Force Serious Incidents 3rd Party	13	0.427		
B38I	Service Lines Outside Force Serious Incidents-Poly Plastic	13	0.214		

The MK test does not address flat trends, yielding an "indeterminate" outcome, along with similar outcomes if the data do not meet other criteria even though they may appear the naked eye as rising or falling.

Also note that in the charts that follow in this Appendix, the tables shown below the trend curves give the actual data points (just as the table in the line graphs), and not the data values of the trend curve.

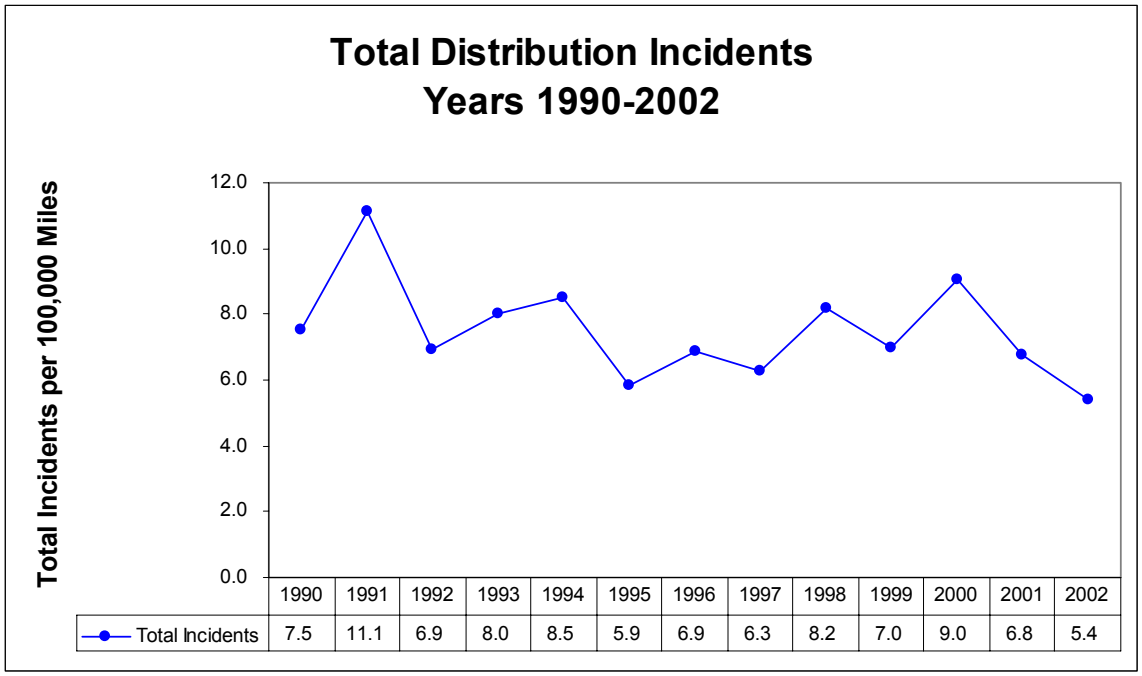
Finally, the period of 1990 through 2002 was selected at the request of the sponsor of this study. However, there is evidence that an analysis of data for an extended period, 1985 though 2002, might provide a higher level of confidence for more of the serious incidents data.

PART 2

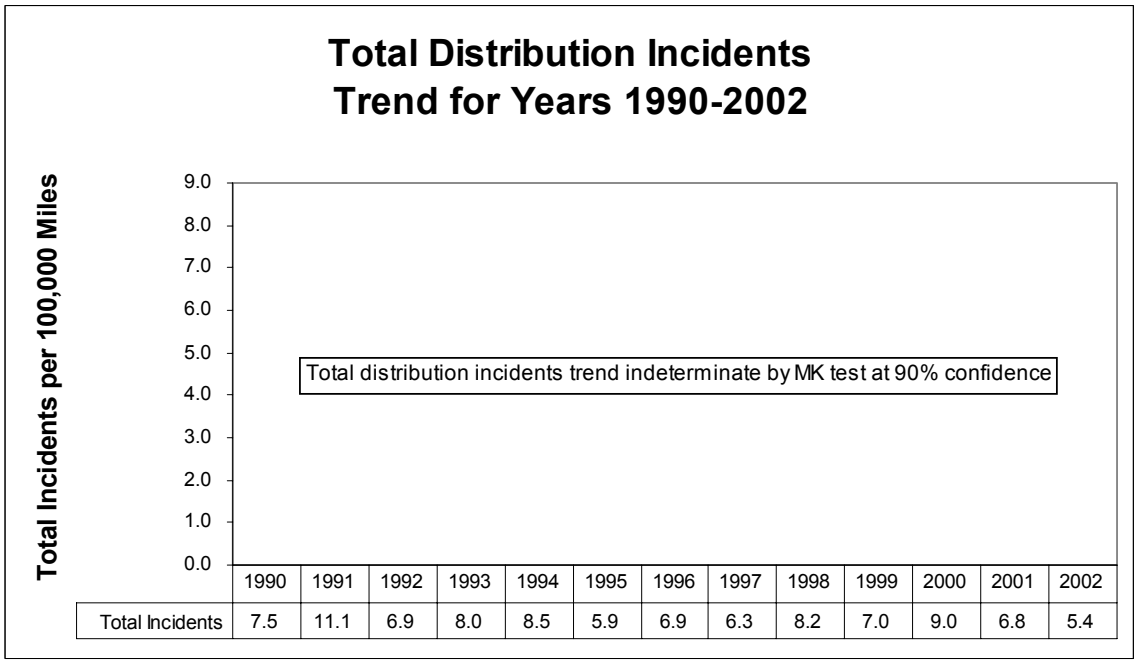
FIGURES AND ANALYSIS

Total Distribution Incidents

Figure B1(a) is a plot of total distribution incidents per 100,000 miles of total distribution piping mileage (mains and service lines) from 1990 through 2002. All distribution incidents, including property damage incidents, and those reported as "significant in the judgment of the operator" were included when calculating the incident rates shown. This figure is based on a total of 1579 incidents. This time series shows that the year-to-year variation in normalized incidents can be quite large, varying from a high in 1991 of 11.1 to a low of 5.4 in 2002. However, a trend analysis using the MK statistical test at 90% confidence yielded an indeterminate result as indicated in Figure B1(b). That means that no trend could be shown at those confidence levels.



(a)



(b)

Figure B1. Total Distribution Incidents

Figure B2 shows the total number of distribution system incidents by part of the distribution system for the years 1990 through 2002. All incidents, including property damage incidents, are included in this analysis. 649 total incidents were reported for mains, which accounted for the largest percentage of the total serious incidents at approximately 41%. Service lines showed the next highest percentage at approximately 24%. As discussed in Part 1, the "other" part of system category is a category defined in the DOT/OPS database. Additional breakdown is provided in the database to identify these parts further, however, a more detailed analysis of the "other" category was not conducted as part of this study.

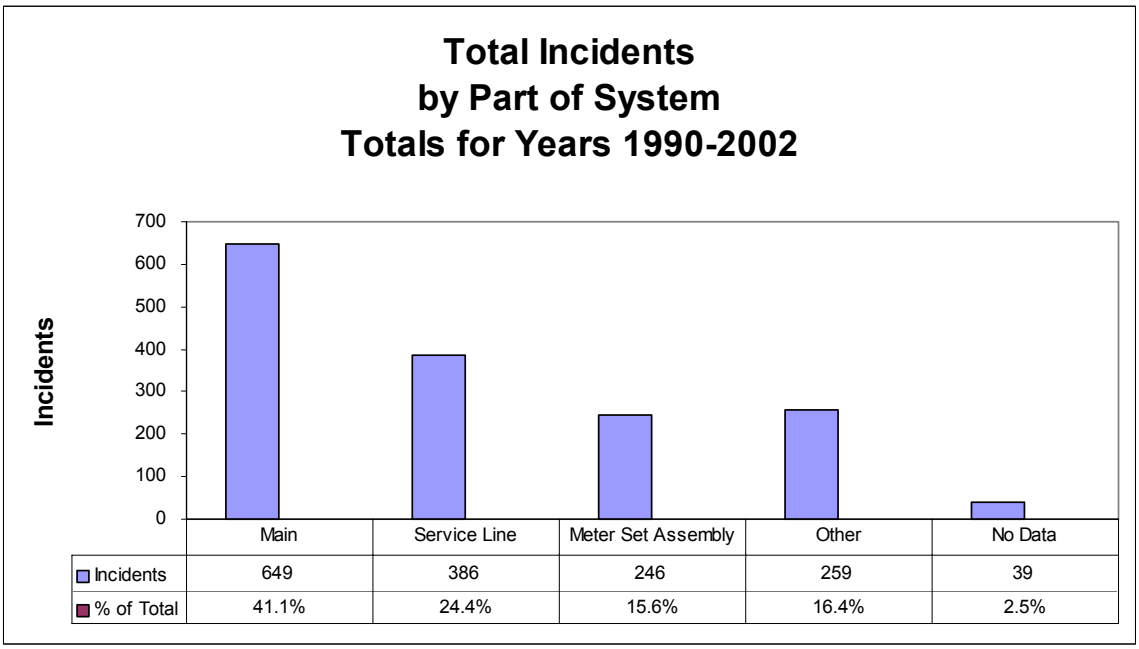


Figure B2. Total Incidents by Part of System

Total distribution system incidents by cause are shown in Figure B3 for the years 1990 through 2002. Here again, the total 1579 incidents are represented. Outside force incidents are the predominant cause of incidents, accounting for approximately 60% of the total. Incidents related to "other" causes show the next highest percentage at approximately 24%. The "other" cause category is one provided by DOT/OPS as part of their incident reporting form. Operators are free to choose this category if, in their judgment, the incident is not caused by corrosion, outside force, construction/operating error, or accidentally caused by operator. No additional cause details are provided in the DOT/OPS incident database for incidents reported as "other" so it is not possible to examine these types of incidents further, even though they represent a significant percentage of the total incidents.

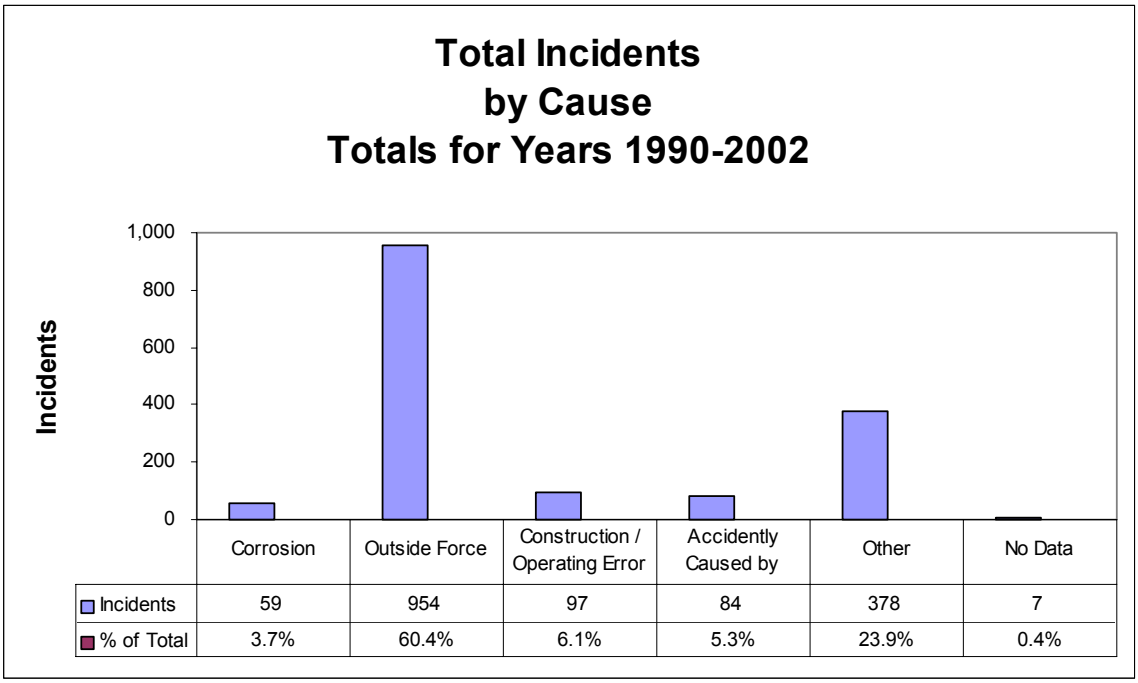
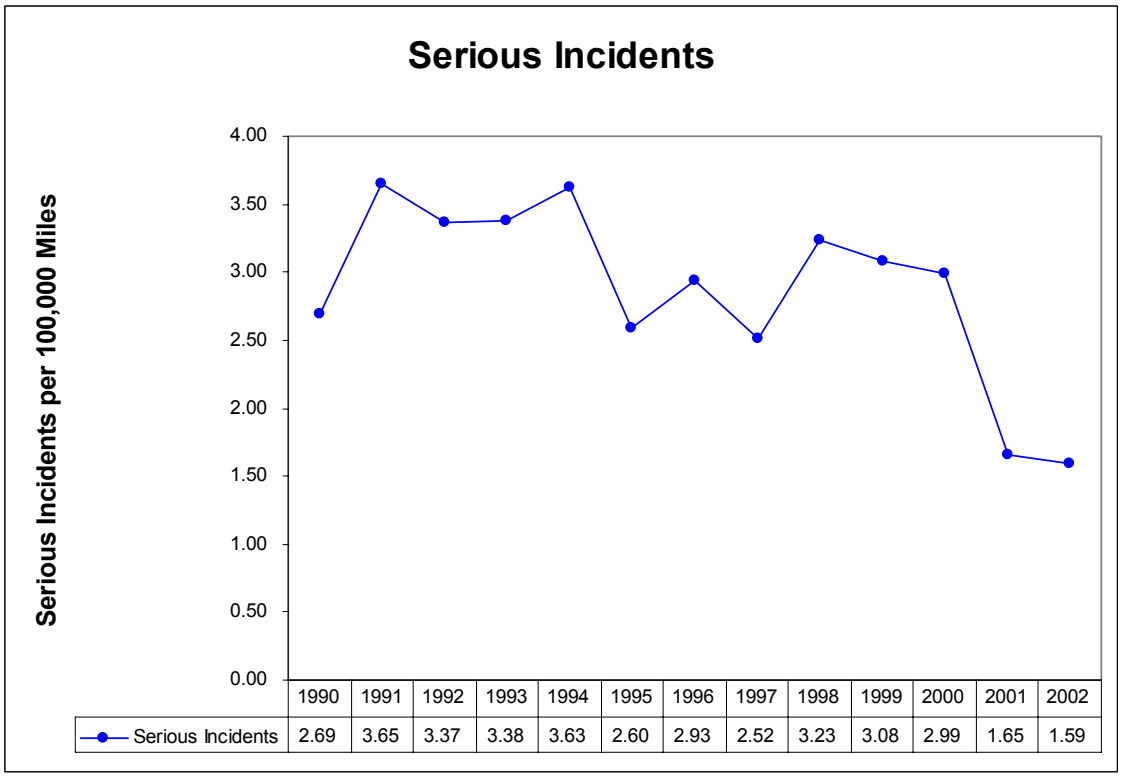


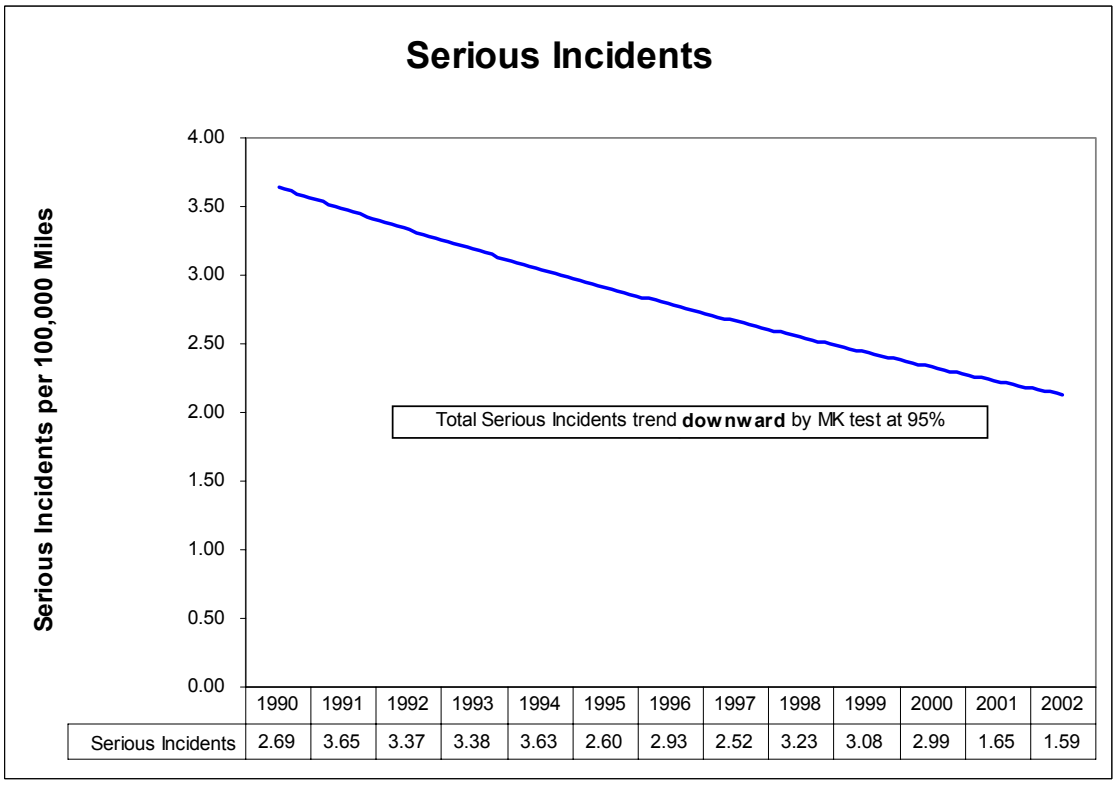
Figure B3. Total Incidents by Cause

Total Fatality and Injury Incidents

Figure B5 is a plot of total distribution incidents where F&Is occurred per 100,000 miles of total distribution piping mileage (mains and service lines) from 1990 through 2002. A total of 601 serious incidents was used as a basis in these analyses. Property damage incidents have been excluded. This time series shows that the year-to-year variation in normalized incidents falls in a more narrow range when compared to the results of Figure B1 where property damage and discretionary reporting incidents were included. For serious incidents, the normalized incident rates vary from a high in 1994 of 3.6 to a low of 1.6 in 2002. Unlike Figure B1, a trend analysis using the MK statistical test yielded a downward trend result at 95% confidence as indicated in Figure B5 when only serious incidents are used in the analysis.



(a)

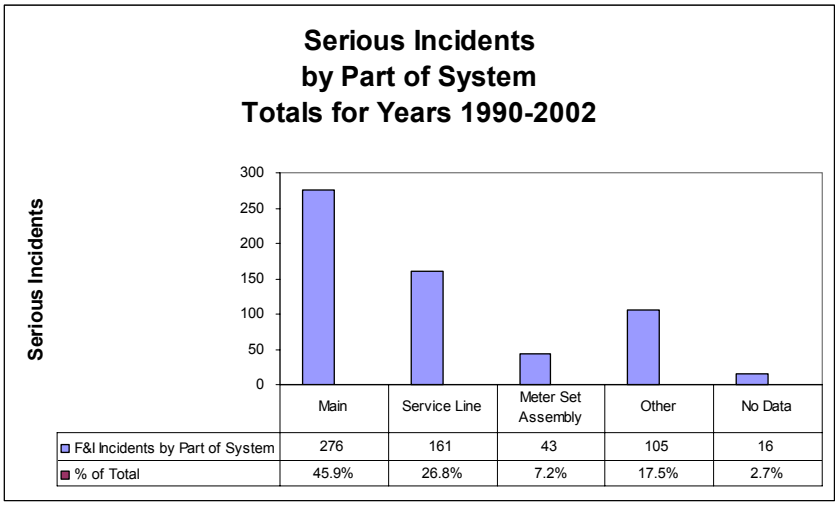


(b)

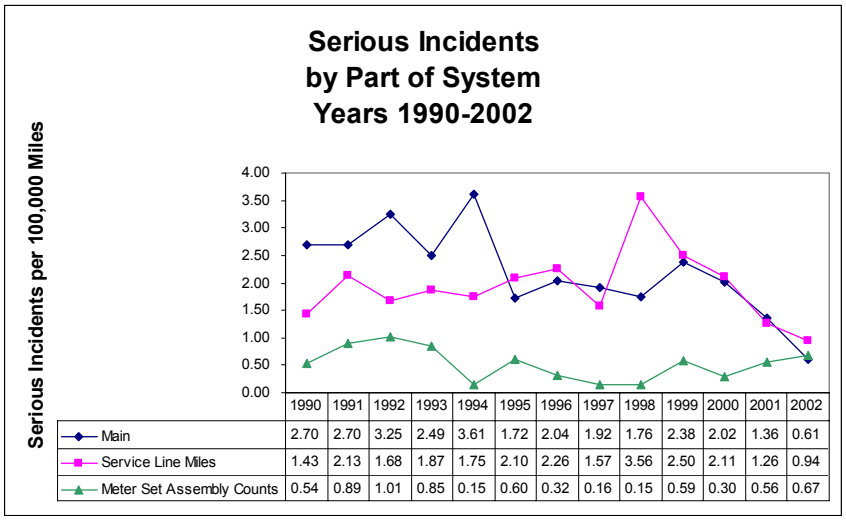
Figure B5. Serious Incidents

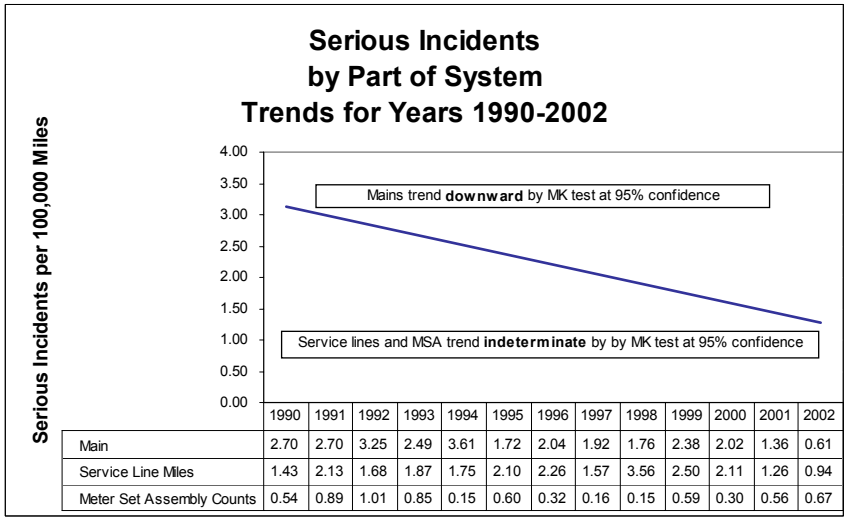
Figures B6(a), (b), and (c) show the serious incidents by part of system from 1990 through 2002. Mains and services account for most of the incidents with 45.9% and 26.6% respectively. The next largest category is "other", followed by meter set assemblies. The percentages shown are expressed as a percentage of the total 601 serious incidents.

A time series of these data for each part of the system based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure 6(b). A trend plot is shown in Figure B6(c). The MK test, at 90% confidence limits, yields an indeterminate result for all parts except mains. That means that no trend could be shown at those confidence levels. The MK test indicates a downward trend for mains at both the 95% confidence level with approximately a 59% decrease in serious incidents during the 1990 to 2002 time period based on beginning and end points of the trend line.



(a)





(c)

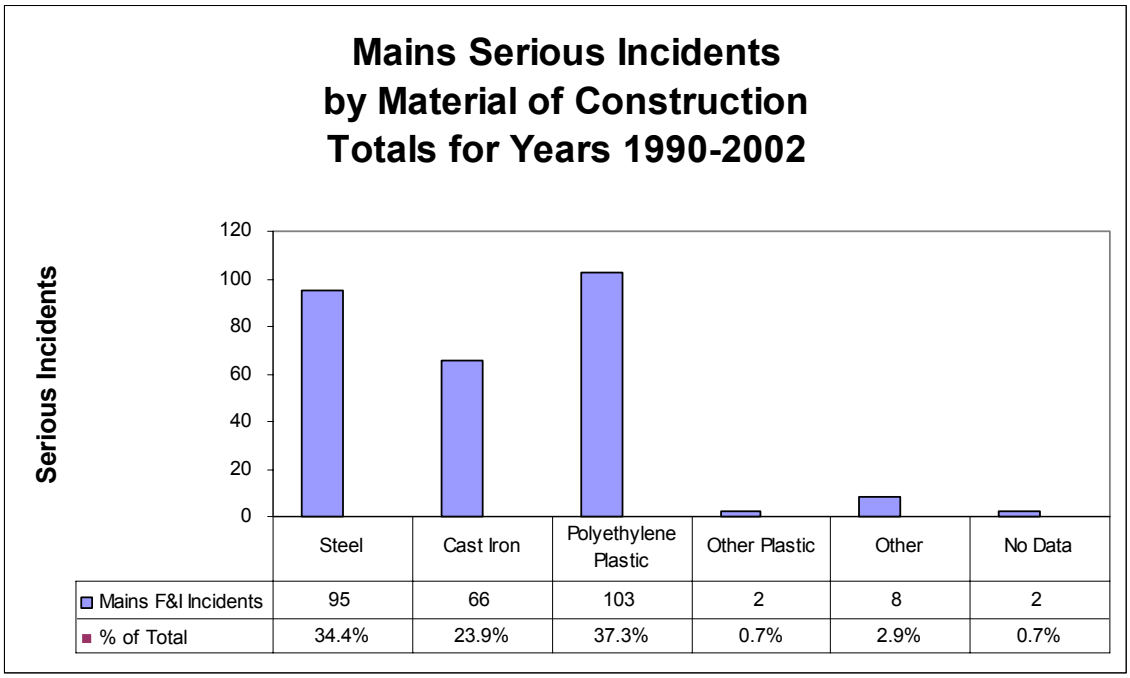
Figure B6. Serious Incidents by Part of System

Serious Incidents by Material of Construction

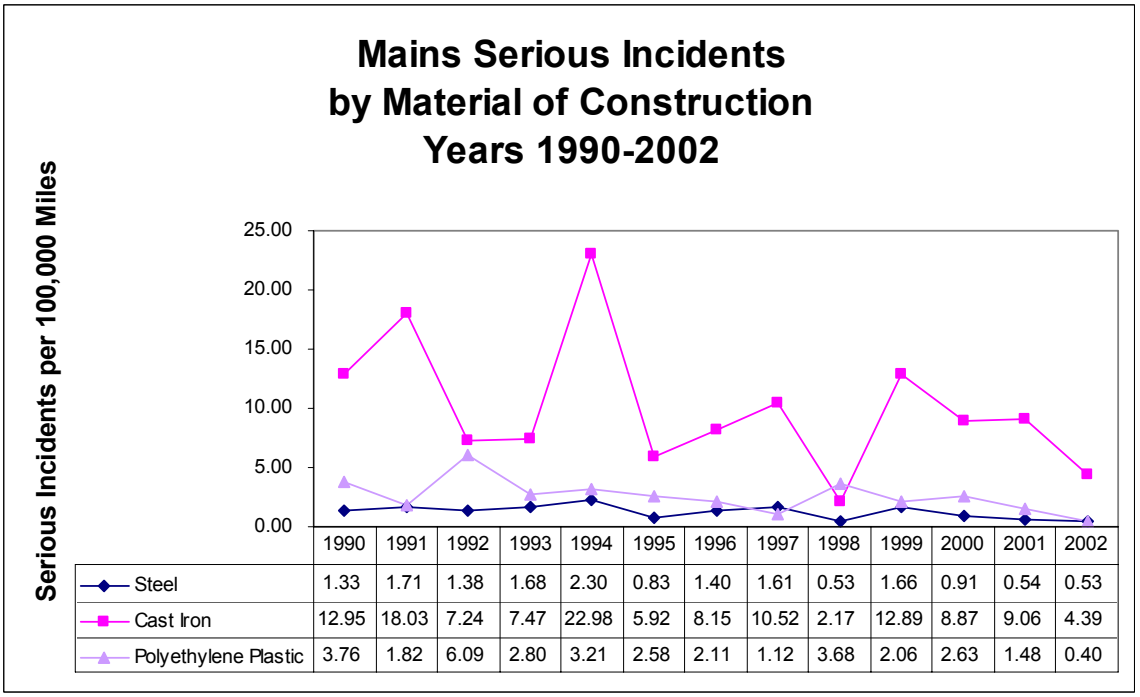
Figures B7(a), (b), (c), and (d) show the serious incidents for Mains by materials of construction from 1990 through 2002. Polyethylene plastic and steel materials account for most of the incidents with 37.3% and 34.4%, respectively. The next largest category is cast iron, followed by other and other plastic. The percentages shown are calculated as the percentage of total serious incidents for mains which is a subset of the total 601serious incidents. The 103 incidents shown for polyethylene plastic represents only about 17% of the all serious incidents (i.e., 103/601 x 100 = 17%). Note however, that to compare these incident counts, the data should be converted to incident rates, that is, be normalized by the actual mileage of each material of construction. Since this mileage varies annually, the incidents each year must be divided by the corresponding mileage.

A time series of these data for each material of construction based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure 7(b). The table under the line plot shows the normalized incident rates. The average incident rate for the 1990-2002 period for each material is the sum of the yearly rates divided by the number of years (13). This yields an average of 1.26 incidents per 100,000 miles for steel main, 2.59 for polyethylene main, and 10.0 for cast iron main.

Trend plots are shown in Figures B7(c) and B7(d); the latter is merely an expanded scale of the lower portion of Figure B7(c). For most years, incidents per 100,000 miles are generally higher for cast iron than steel or polyethylene plastic. The MK test, at 90% confidence limits, yields an indeterminate result for cast iron. That means that no trend could be shown at those confidence levels. However, the MK test indicates a downward trend for steel and polyethylene plastic lines at both the 95% confidence level. Incident frequency for steel shows approximately a 66% decrease in serious incidents during the 1990 to 2002 time period based on beginning and end points of the trend line. Polyethylene plastic shows a decrease of approximately 58% over the same time period.

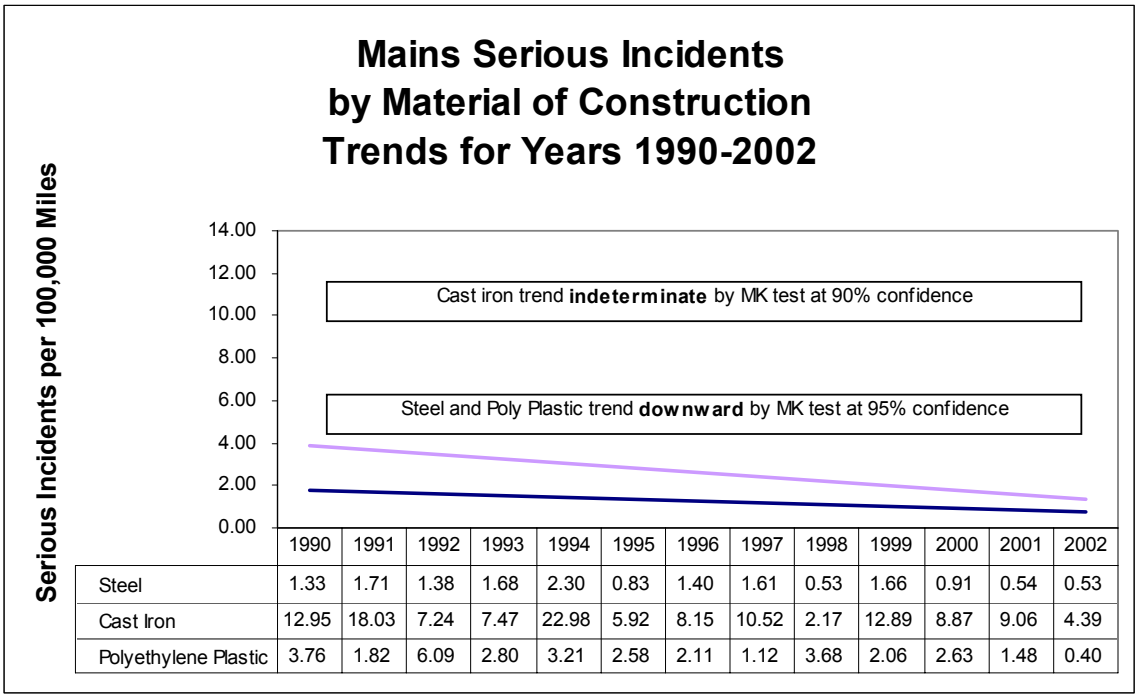


(a)



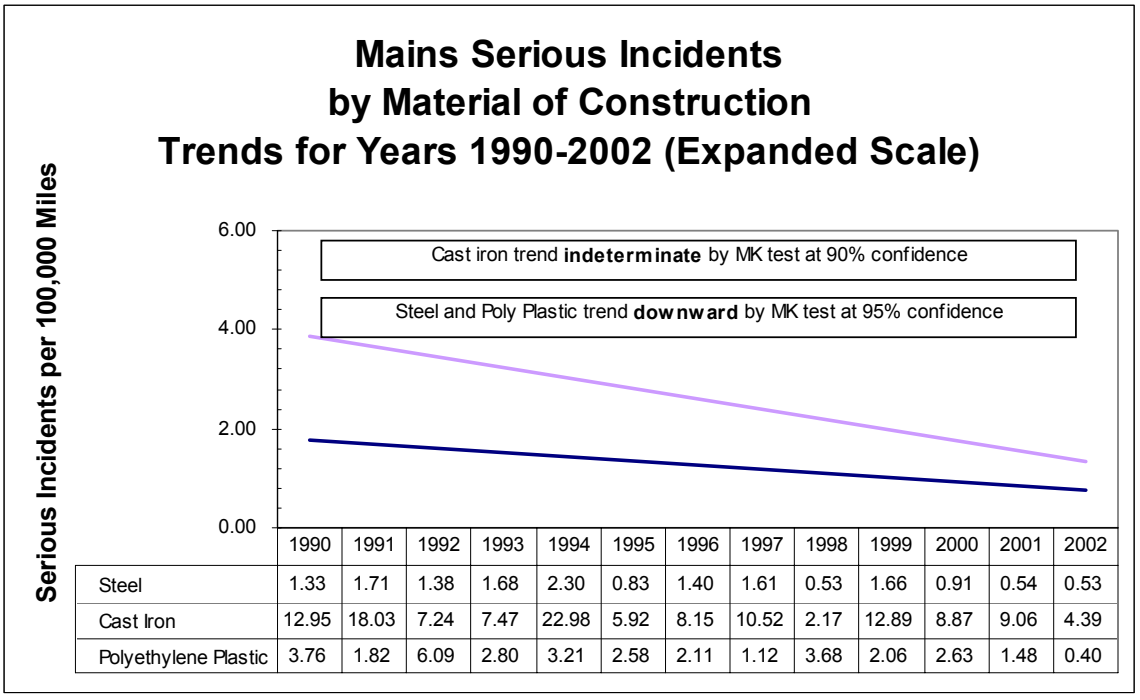
(b)

Figure B7(a) and B7(b). Mains Serious Incidents by Material of Construction



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Steel	1.33	1.71	1.38	1.68	2.30	0.83	1.40	1.61	0.53	1.66	0.91	0.54	0.53
Cast Iron	12.95	18.03	7.24	7.47	22.98	5.92	8.15	10.52	2.17	12.89	8.87	9.06	4.39
Polyethylene Plastic	3.76	1.82	6.09	2.80	3.21	2.58	2.11	1.12	3.68	2.06	2.63	1.48	0.40

(c)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Steel	1.33	1.71	1.38	1.68	2.30	0.83	1.40	1.61	0.53	1.66	0.91	0.54	0.53
Cast Iron	12.95	18.03	7.24	7.47	22.98	5.92	8.15	10.52	2.17	12.89	8.87	9.06	4.39
Polyethylene Plastic	3.76	1.82	6.09	2.80	3.21	2.58	2.11	1.12	3.68	2.06	2.63	1.48	0.40

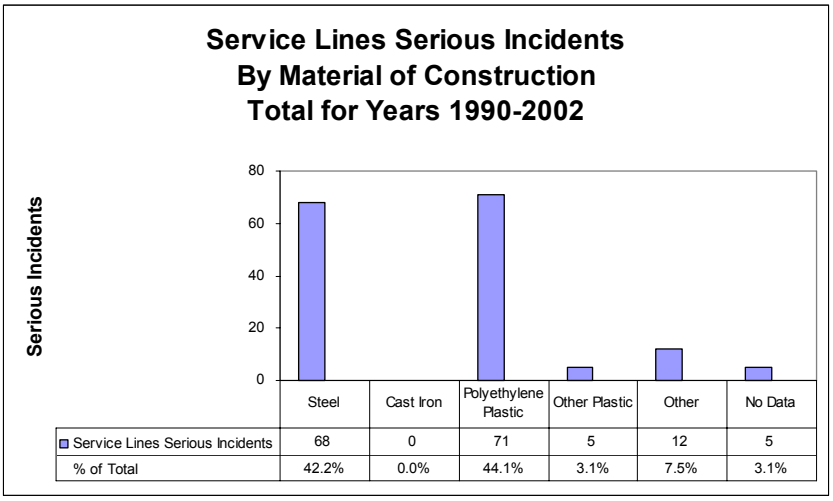
(d)

Figure B7(c) and B7(d). Mains Serious Incidents by Material of Construction

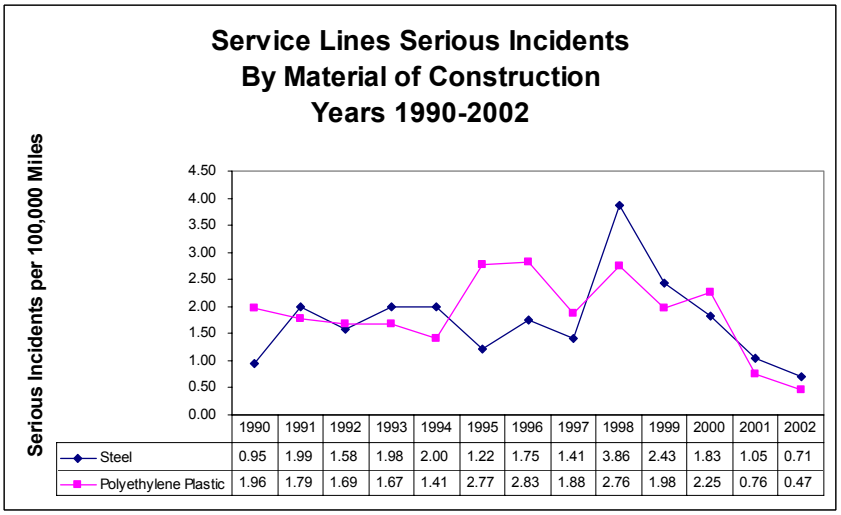
Figures B11(a), (b), and (c) show the serious incidents for service lines by materials of construction from 1990 through 2002. Like mains, polyethylene plastic and steel materials account for most of the incidents with 44.1% and 42.2%, respectively. The percentages shown are calculated as the percentage of total serious incidents for service lines which is a subset of the total 601 serious incidents. The 71 incidents shown for polyethylene plastic represents only about 12% of the all serious incidents (i.e., 71/601 x 100 = 12%).

A time series of these data for steel and polyethylene plastic based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure 11(b). Average normalized incident rates for the period 1990 – 2002 are 1.75 per 100,000 miles for steel services and 1.86 per 100,000 miles for polyethylene services.

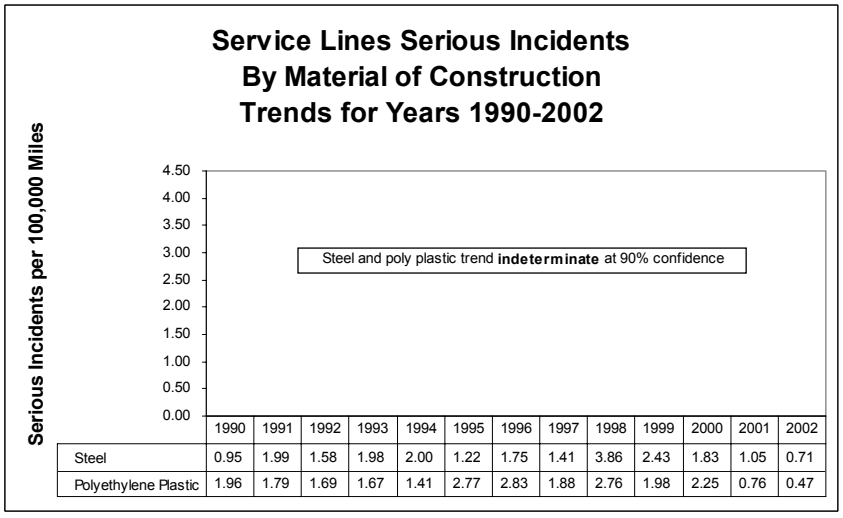
A trend plot is shown in Figures B11(c). Incidents per 100,000 miles are similar for both steel and polyethylene plastic. Unlike mains shown in the previous figure, the MK test yields an indeterminate result for both materials at 90% confidence limits. That means that no trend could be shown at those confidence levels for service lines.



(a)



(b)



(c)

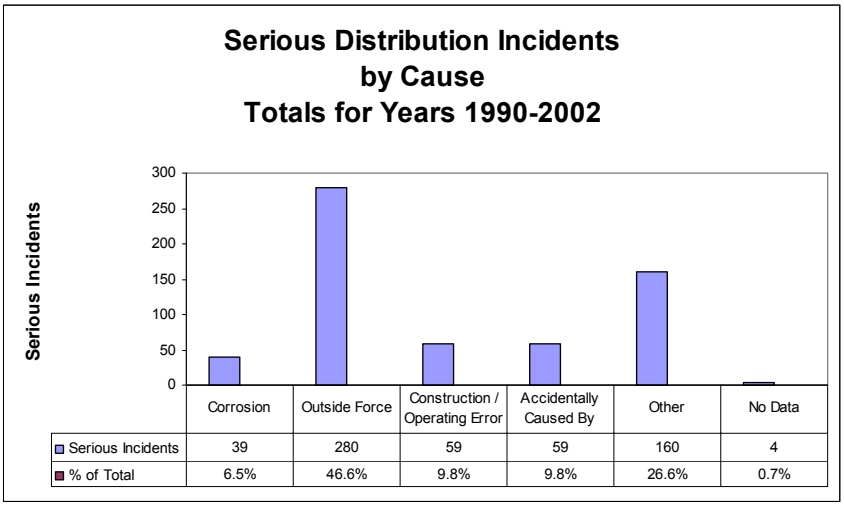
Figure B11. Service Line Serious Incidents by Material of Construction

Serious Incidents by Cause

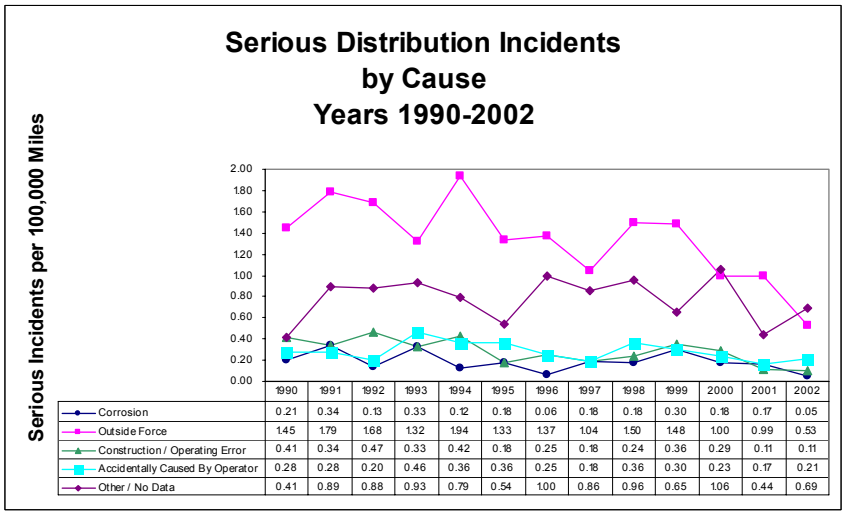
Figure B16(a), (b), and (c) show the serious incidents by cause category from 1990 through 2002. Outside force and other account for most of the incidents with 46.6% and 26.6% respectively. All other categories account for less than 10% of the total 601 serious incidents for distribution pipeline systems. The percentages shown are calculated as the percentage of the total 601 serious incidents.

A time series of these data for each cause category based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure 16(b). A trend plot is shown in Figures B16(c). The MK test, at 90% confidence limits, yields an indeterminate result for the other cause category. That means that no trend could be shown at those confidence levels. However, the MK test indicates a downward trend for outside force and construction/operating error causes at both the 95% confidence level. The MK test also shows a downward trend for corrosion and accidentally caused by operator cause categories at the 90% confidence level. The percent decrease in incident frequencies, calculated based on the beginning and end points of the trend line, for cause categories showing a downward trend are as follows:

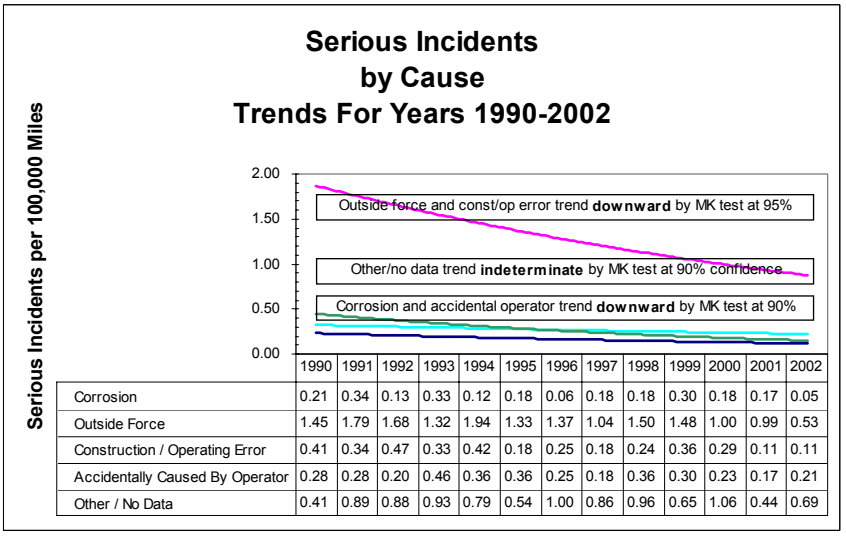
- Outside force, 58%
- Construction/operating error, 66%
- Corrosion, 48%
- Accidentally caused by operator, 31%



(a)



(b)



(c)

Figure B16. Serious Incidents by Cause

Figures B8, B9, and B10 are a set of similar plots showing serious incidents by cause category for steel mains, cast iron mains, and polyethylene mains, respectively. Each plot shows the total number of serious incidents attributed to each cause category for the period 1990 through 2002, as well as the percentage of the total attributed to each cause category. In all cases, outside force was the predominant cause of serious incidents for mains, regardless of material of construction, with outside force accounting for approximately 36% of total incidents for steel mains, 55% for cast iron mains, and 52% for polyethylene mains. As shown in Figures 8 and 9, the "corrosion" and "other" categories showed the second and third highest percentages for both steel mains, whereas "other" and "accidentally caused by operator" categories where the second and third ranking causes for cast iron mains. For polyethylene mains, Figure B10, the second and third highest percentages were attributed to "construction/operating error" and "accidentally caused by operator," respectively.

Again, note that the data sets represent subsets of the total 601 distribution system serious incidents and the percentages shown are calculated based on the number of incidents in each data subset. For example, Figure B8 shows 34 outside force incidents for steel mains (34.8% of the total for all steel mains); however, these 34 incidents only represent 5.6% of the total 601 serious incidents. Also note that it is not possible to determine an additional details for the "other" cause category due to limitations of the DOT/OPS incident database as discussed in Part 1.

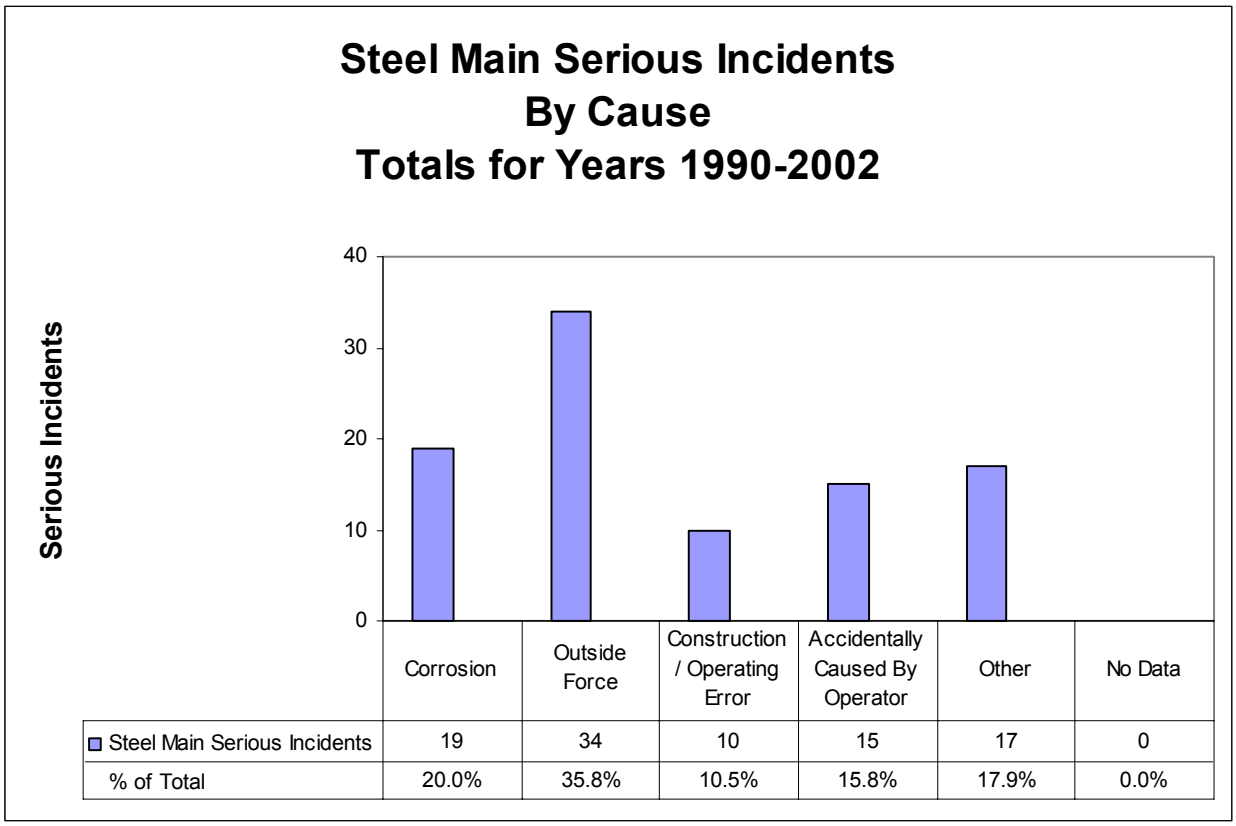


Figure B8. Steel Main Serious Incidents by Cause

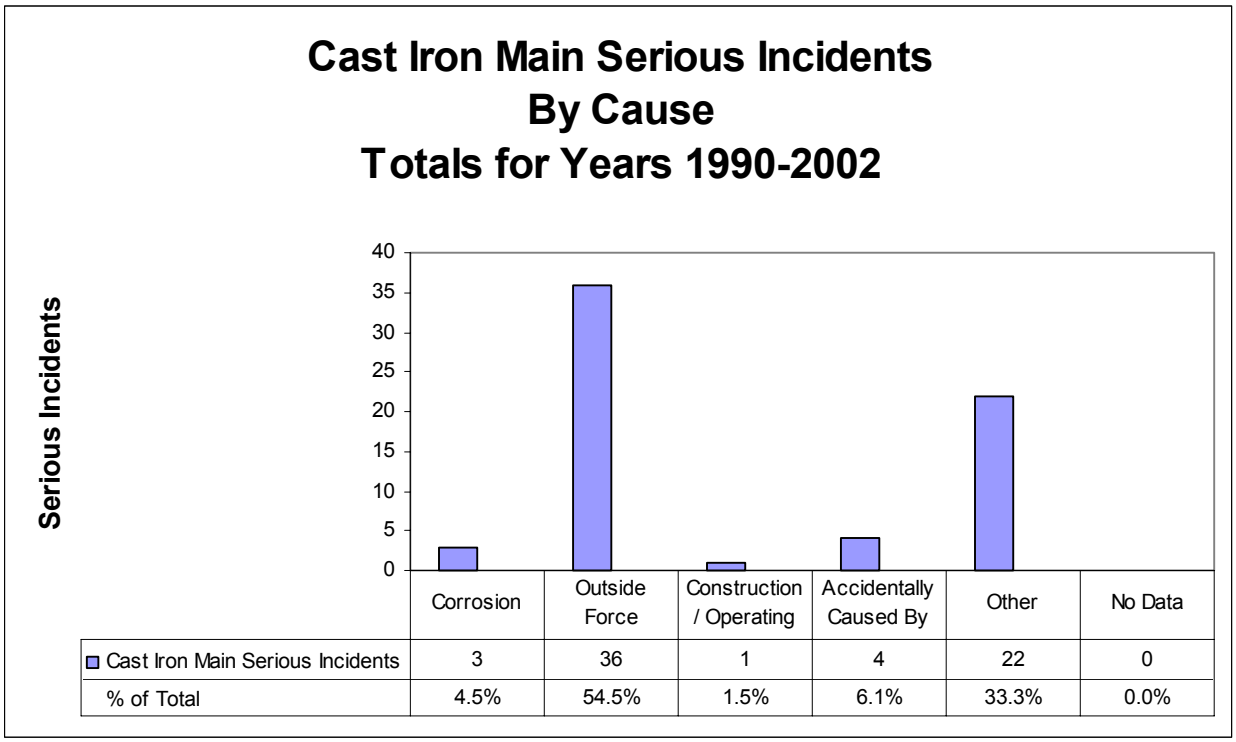


Figure B9. Cast Iron Main Serious Incidents by Cause

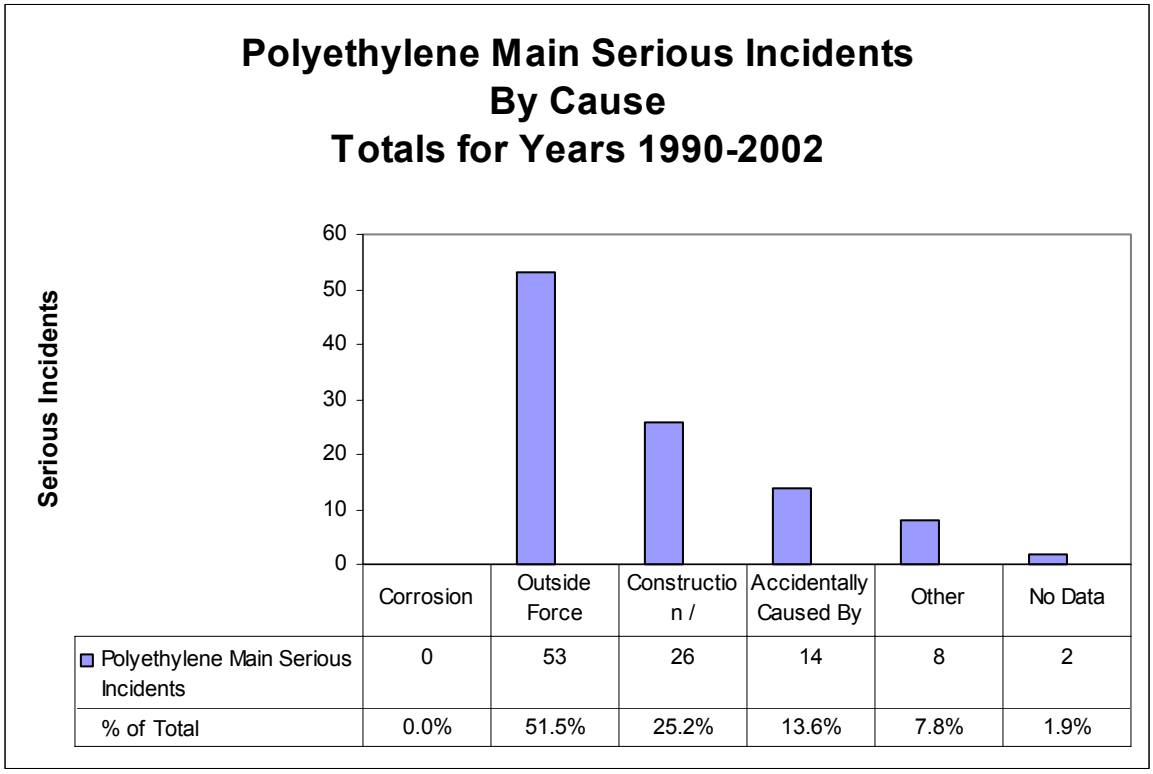


Figure B10. Polyethylene Main Serious Incidents by Cause

Figures B12 and B13 are a similar set of plots showing serious incidents by cause category for steel service lines and polyethylene service lines, respectively. Each plot shows the total number of serious incidents attributed to each cause category for the period 1990 through 2002, as well as the percentage of the total attributed to each cause category. Here again, "outside force" accounts for the highest percentage of incidents for both steel and polyethylene service lines. Approximately 54% of incidents for steel service lines are attributed to outside force and 76% are attributed to outside force for polyethylene service lines. As shown in Figure B12, "accidentally caused by operator" and "corrosion" were the second and third ranking causes for steel service lines. Data for polyethylene service lines, shown in Figure B13, show "other" and "accidentally caused by operator" as second and third ranking causes. As discussed previously for Figures B8 through B10, percentages shown in this set of plots are based on the total incidents within each data subset.

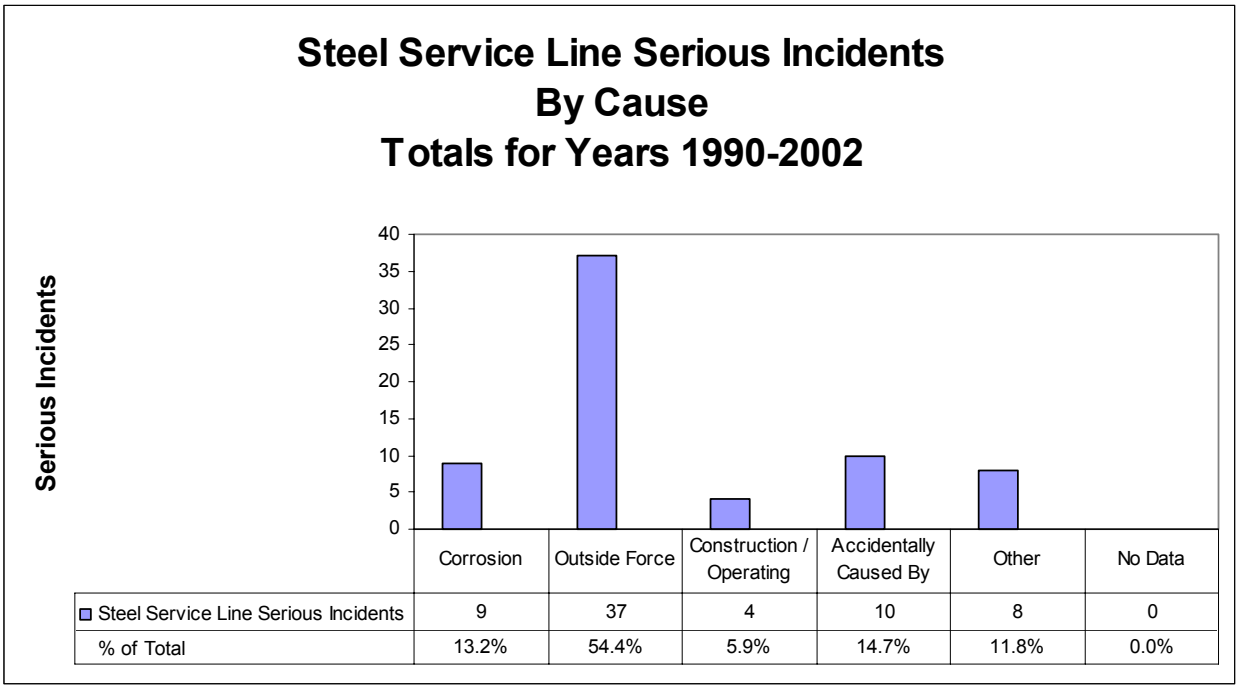


Figure B12. Steel Service Line Serious Incidents by Cause

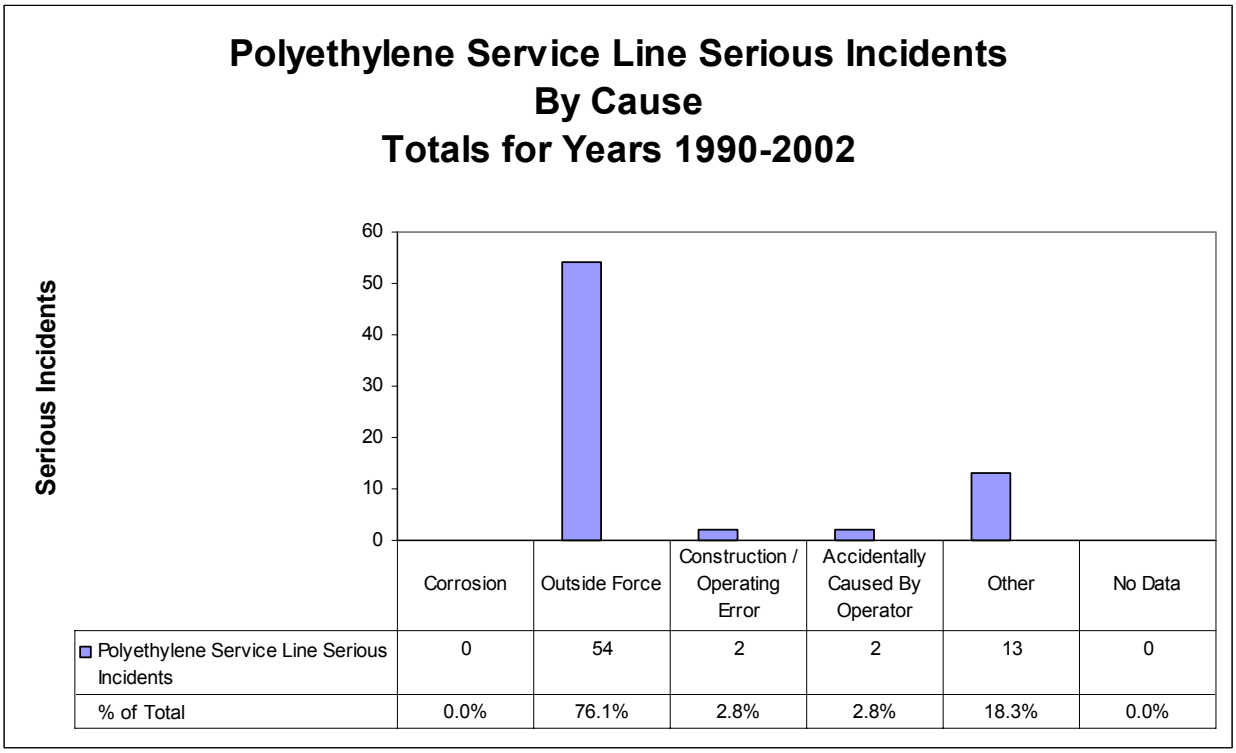
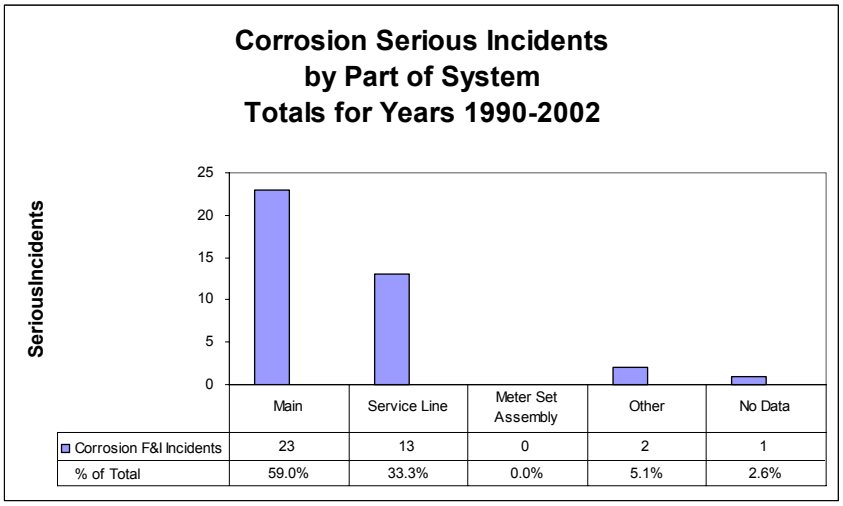


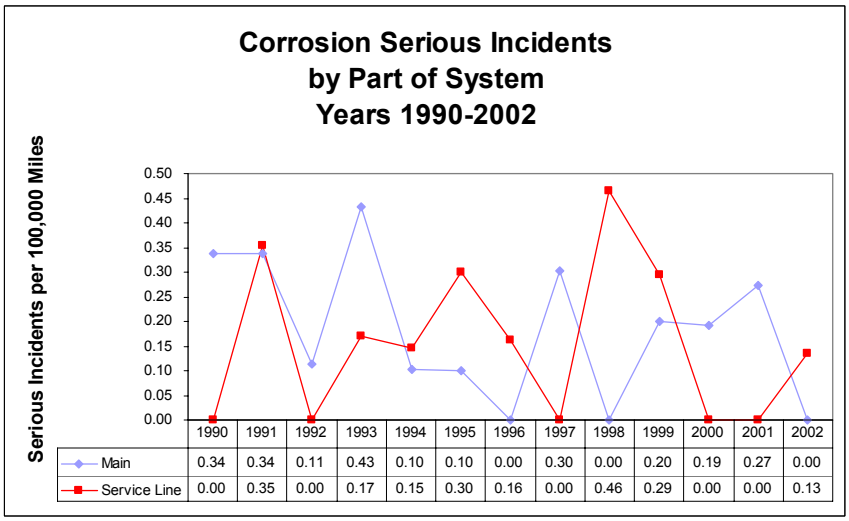
Figure B13. Polyethylene Service Line Serious Incidents by Cause

Figures B17(a), (b), and (c) show data for corrosion related serious incidents by part of the distribution system from 1990 through 2002. Mains and service lines account for most of the corrosion serious incidents with 59.0% and 33.3% respectively. The next largest percentage is for the "other" material of construction category. No corrosion related serious incidents were reported for meter set assemblies. The percentages shown are calculated based on the data subset. The 23 incidents for mains only account for 3.8% of the total 601 serious incidents.

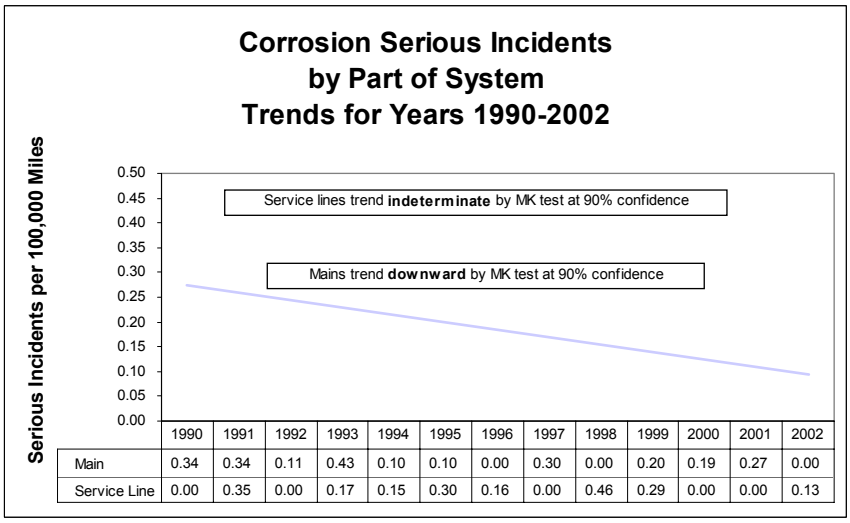
A time series of these data for each part of the system based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure 17(b). Trend plots are shown in Figure B17(c). The MK test, at 90% and 95% confidence limits, yields an indeterminate result for service lines. That means that no trend could be shown at those confidence levels. The MK test indicates a downward trend for mains at the 90% confidence level with approximately a 65% decrease in serious incidents caused by corrosion during the 1990 to 2002 time period based on beginning and end points of the trend line.



(a)



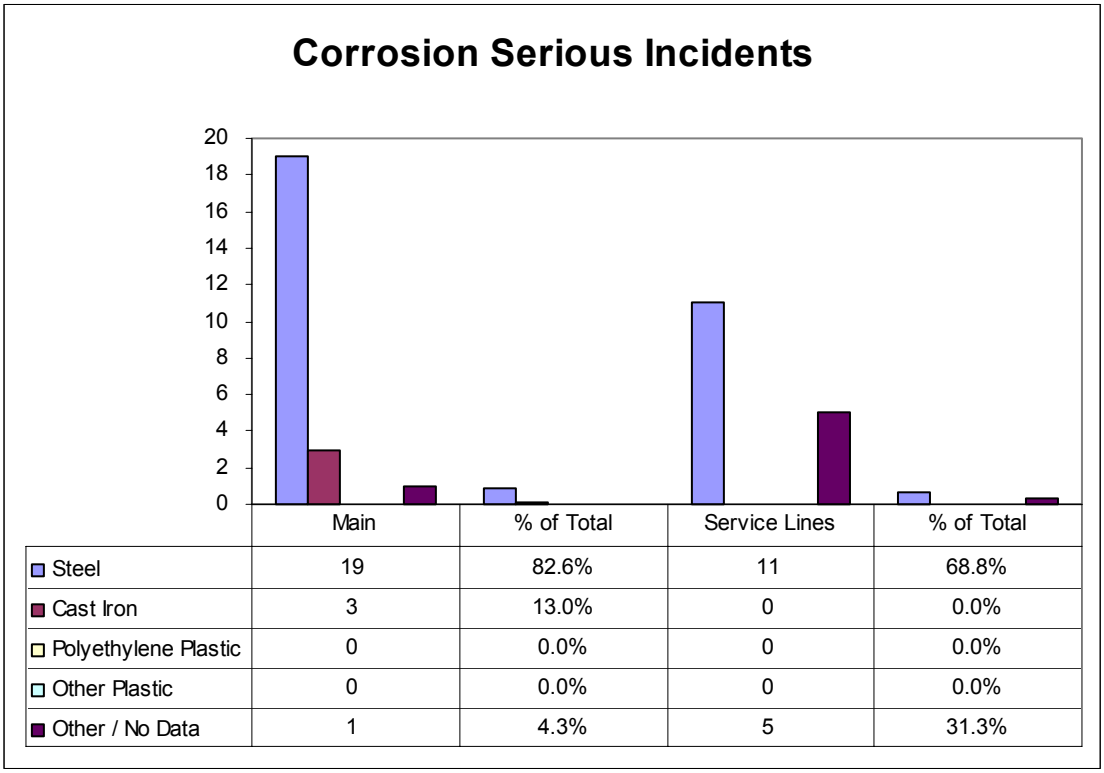
(b)



(c)

Figure B17. Corrosion Serious Incidents by Part of System

Figure B18/19 is a plot of corrosion related serious incidents for mains and service lines by material of construction for the 1990 through 2002 time period. The chart shows, for example, that 19 total corrosion related serious incidents are reported for mains which represents 82.9% of the total corrosion related incidents for mains. Data for mains and service lines shows that steel accounts for the largest percentage of incidents, 82.9% and 68.8%, respectively. For mains, cast iron showed the next highest percentage at 13%. For service lines, no corrosion related incidents were reported for cast iron, with the second highest percentage attributed to the "other/no data" material of construction category. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

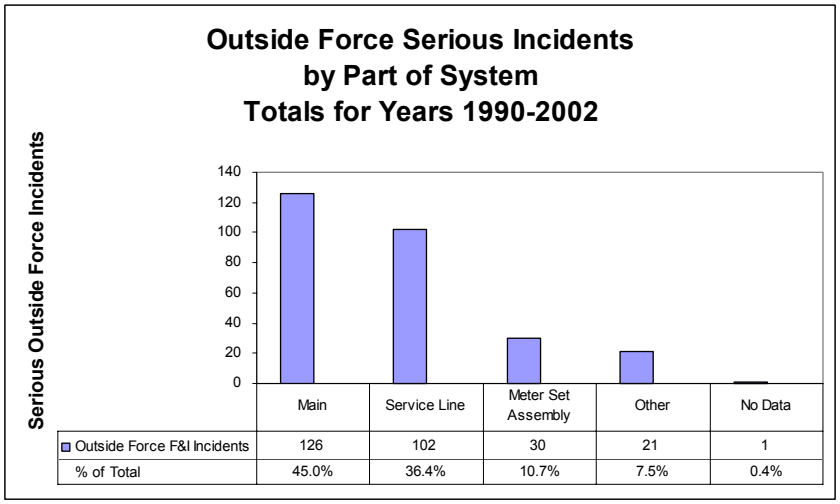


	Main	% of Total	Service Lines	% of Total
Steel	19	82.6%	11	68.8%
Cast Iron	3	13.0%	0	0.0%
Polyethylene Plastic	0	0.0%	0	0.0%
Other Plastic	0	0.0%	0	0.0%
Other / No Data	1	4.3%	5	31.3%

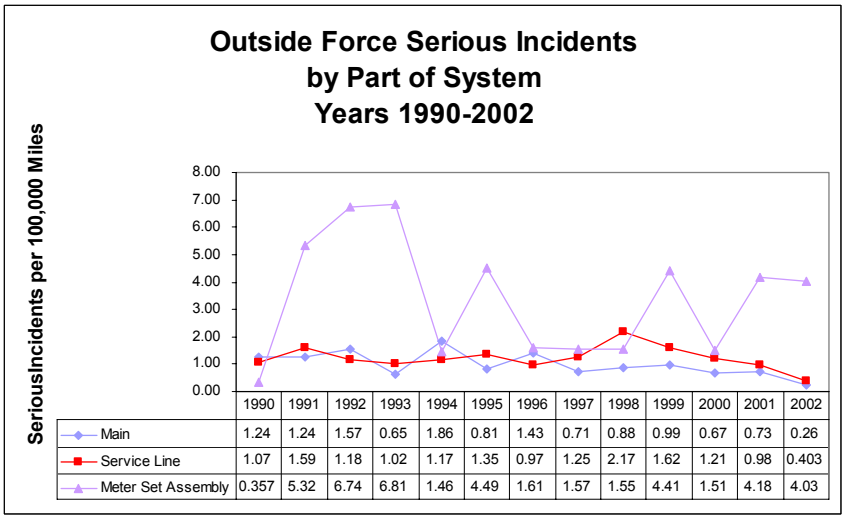
Figure B18/19. Corrosion Serious Incidents by Material of Construction

Figures B20(a), (b), and (c) show data for outside force serious incidents by part of the distribution system from 1990 through 2002. Mains and service lines account for most of the outside force incidents with 45.0% and 36.4%, respectively. The next largest percentage is shown for meter set assemblies. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

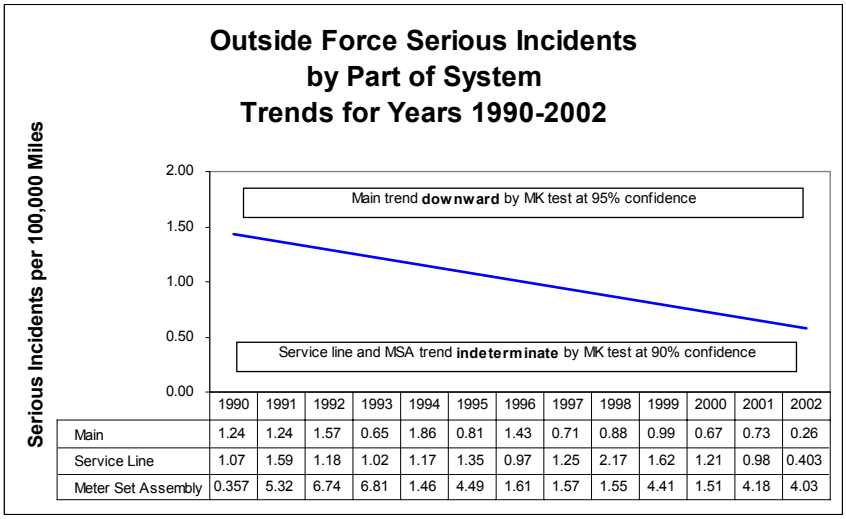
A time series of these data for each part of the system based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure 20(b). Trend plots are shown in Figure B20(c). The MK test, at 90% and 95% confidence limits, yields an indeterminate result for service lines and meter set assemblies. That means that no trend could be shown at those confidence levels. The MK test indicates a downward trend for mains at the 90% and 95% confidence levels with approximately a 60% decrease in main serious incidents caused by outside force during the 1990 to 2002 time period, based on beginning and end points of the trend line.



(a)



(b)



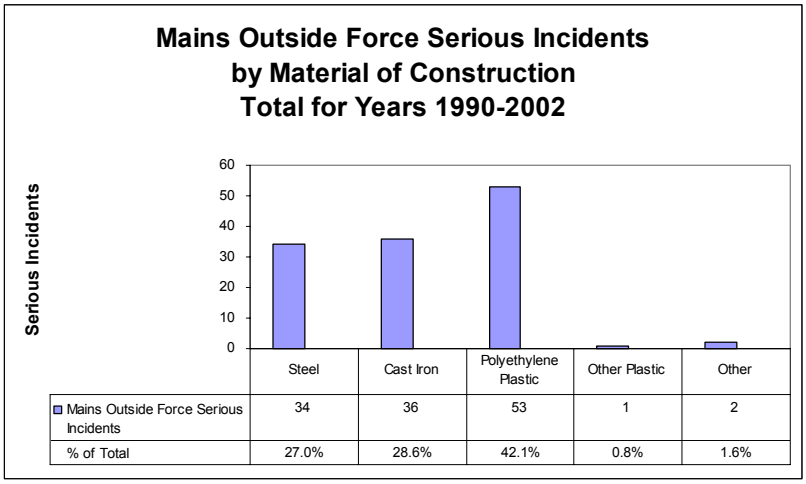
(c)

Figure B20. Outside Force Serious Incidents by Part of System

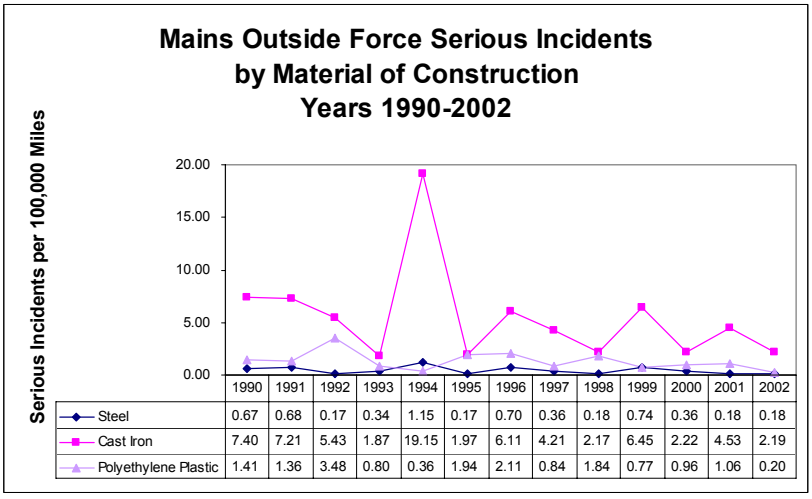
Figures B21(a), (b) and (c) show data for outside force serious incidents for mains by materials of construction from 1990 through 2002. Polyethylene plastic and cast iron account for most of the outside force incidents with 42.1% and 28.6%, respectively. The next largest percentage is shown for steel mains. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

A time series of these data for each material of construction based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure 20(b). Average normalized outside force serious incident rates for 1990 to 2002 are 0.45 incidents per 100,000 miles for steel, 1.32 incidents per 100,000 miles for polyethylene, and 5.45 for cast iron mains.

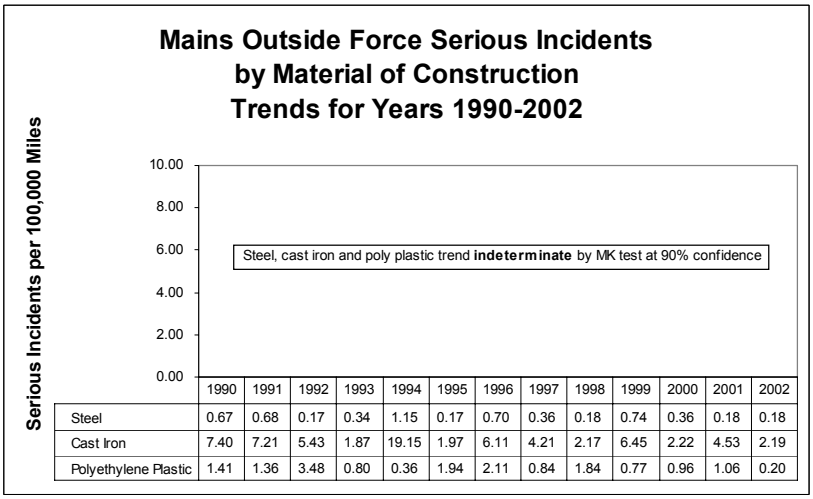
Trend plots are shown in Figure B20(c). The MK test, at 90% confidence limits, yields an indeterminate result for all material of construction. That means that no trend could be shown at those confidence levels.



(a)



(b)



(c)

Figure B21. Mains Outside Force Serious Incidents by Material of Construction

Figure B38H is a plot of all outside force serious incidents by type of outside force for the 1990 through 2002 period. Third party damage accounts for 74% of the total outside force serious incidents, followed by earth movement at 16%. All parts of the system are included in this analysis.

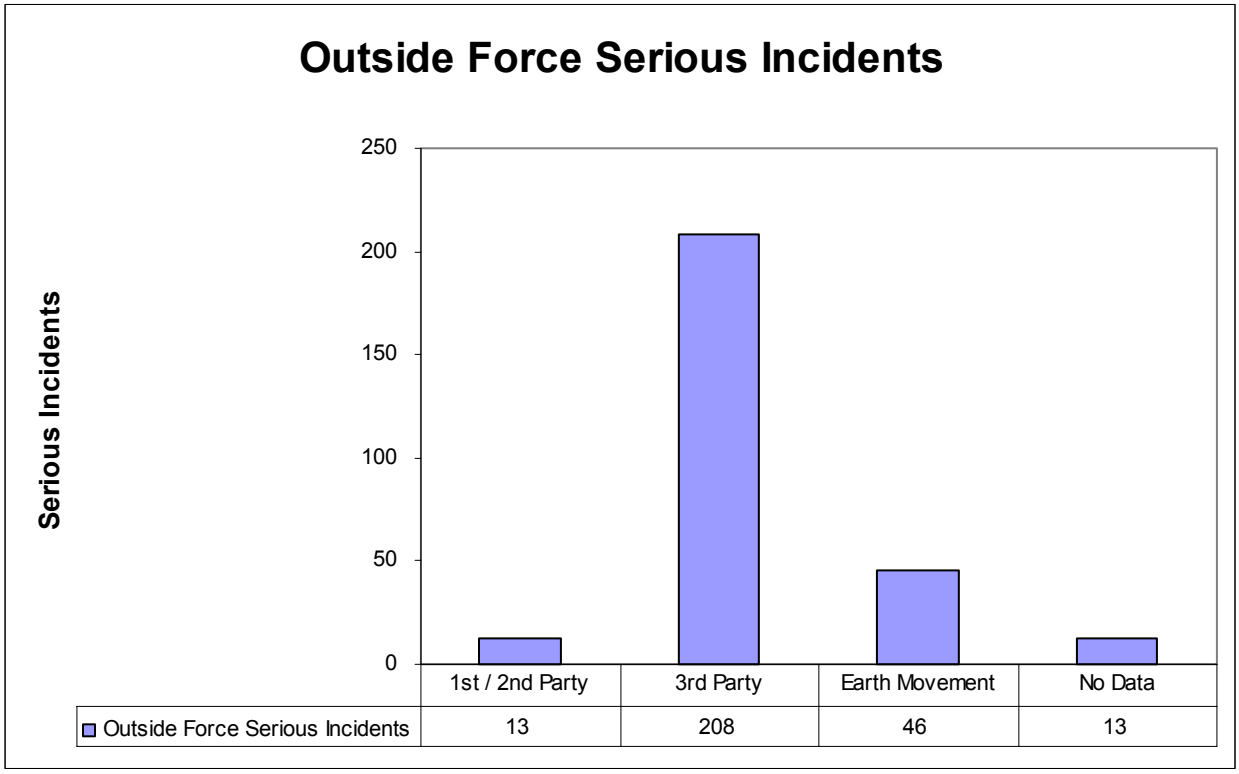
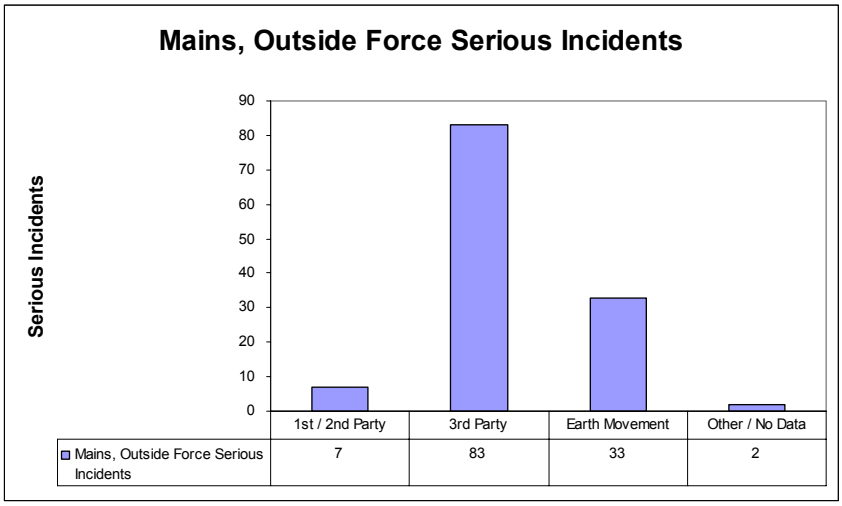


Figure B38H. Outside Force Serious Incidents

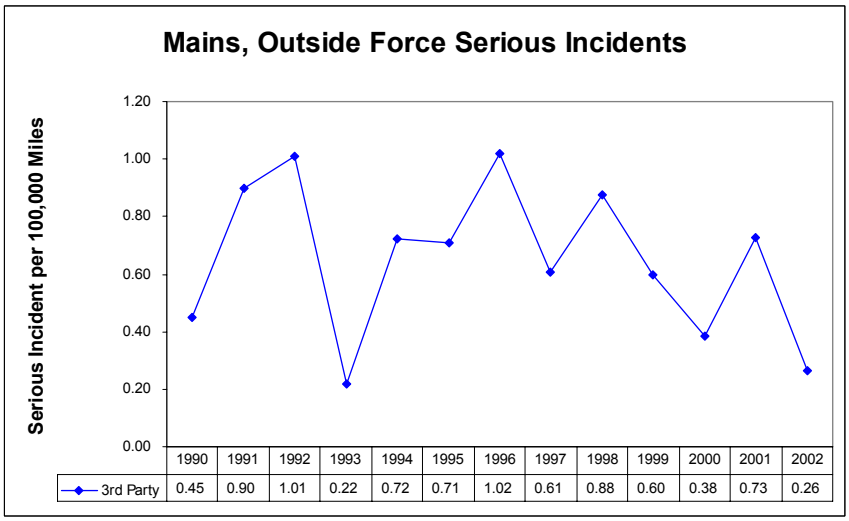
Outside Forces for Mains

Figures B38B(a), (b) and (c) show data for outside force serious incidents on mains by type of outside force from 1990 through 2002. Again, third party damage and earth movement account for most of the outside force incidents associated with mains.

A time series of the third party outside force incidents based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B38B(b). A trend plot is shown in Figure B38B(c). The MK test, at 90% confidence limits, yields an indeterminate result for all types of outside force incidents on mains. That means that no trend could be shown at those confidence levels.



(a)



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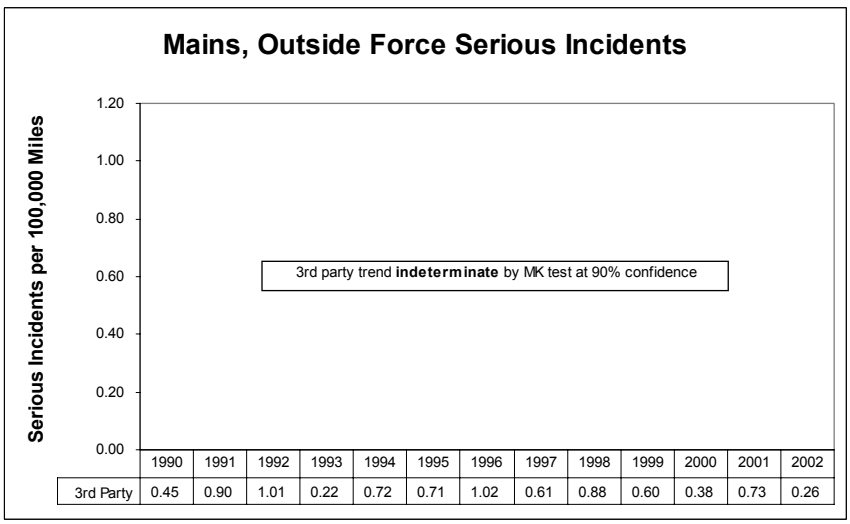


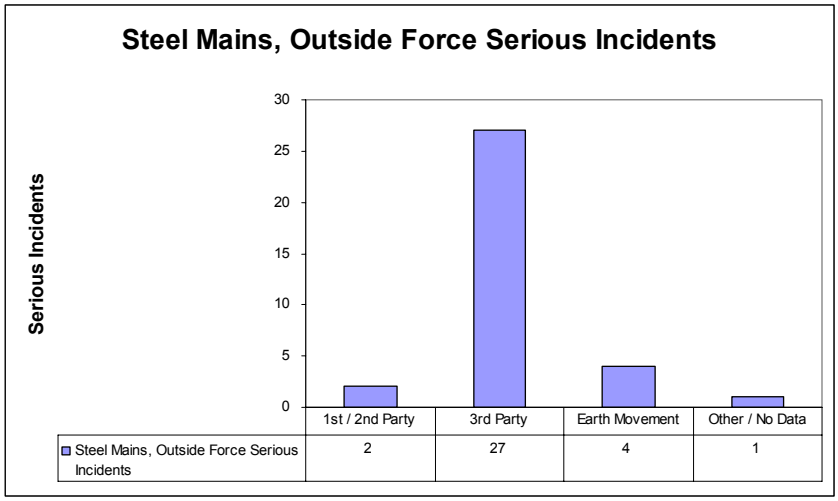
(c)

Figure B38B. Mains, Outside Force Serious Incidents

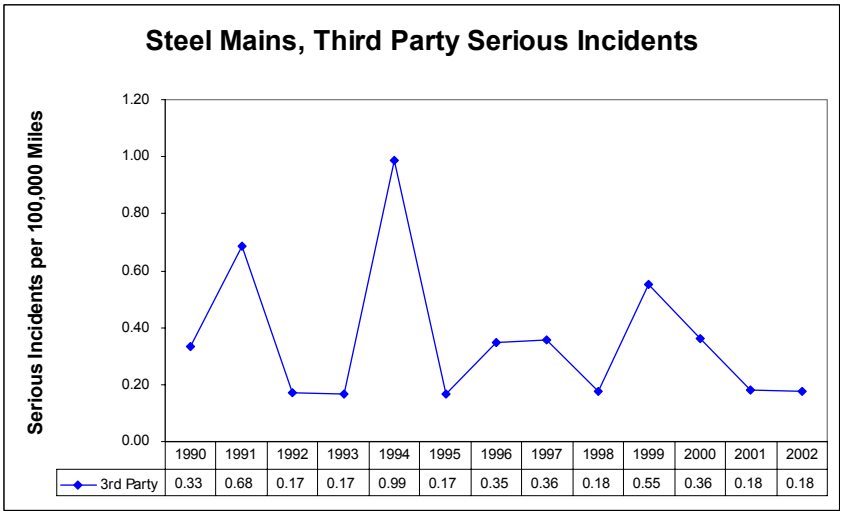
Figures B38E(a), (b) and (c) show data for outside force serious incidents on steel mains by type of outside force from 1990 through 2002. Again, third party damage and earth movement account for most of the outside force incidents associated with steel mains.

A time series of the third party outside force incidents based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B38E(b). For the 1990-2002 time period, the average normalized rate is 0.36 incidents per 100,000 miles of steel main.

A trend plot is shown in Figure B38E(c). The MK test, at 90% confidence limits, yields an indeterminate result for all types of outside force incidents on steel mains. That means that no trend could be shown at those confidence levels.



(a)



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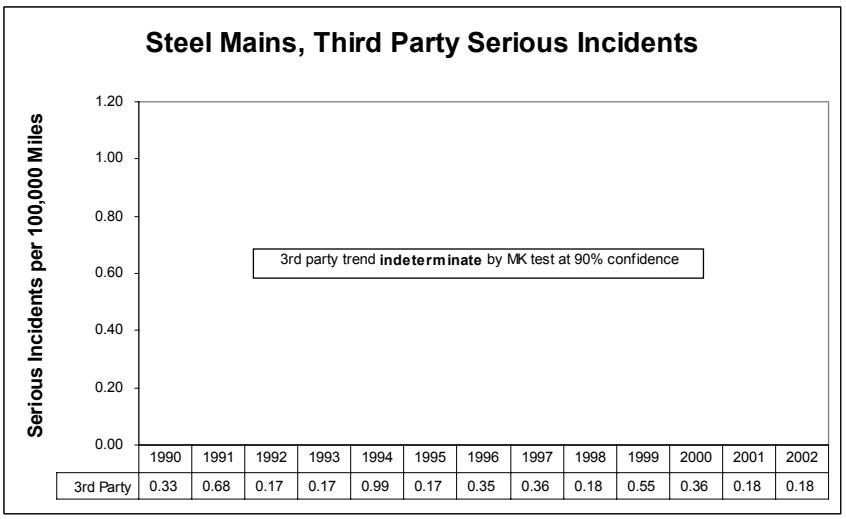


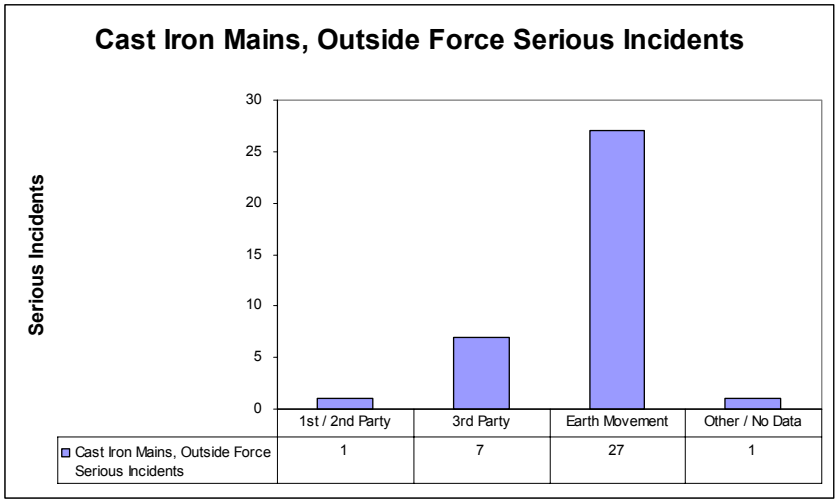
(c)

Figure B38E. Steel Mains, Outside Force Serious Incidents

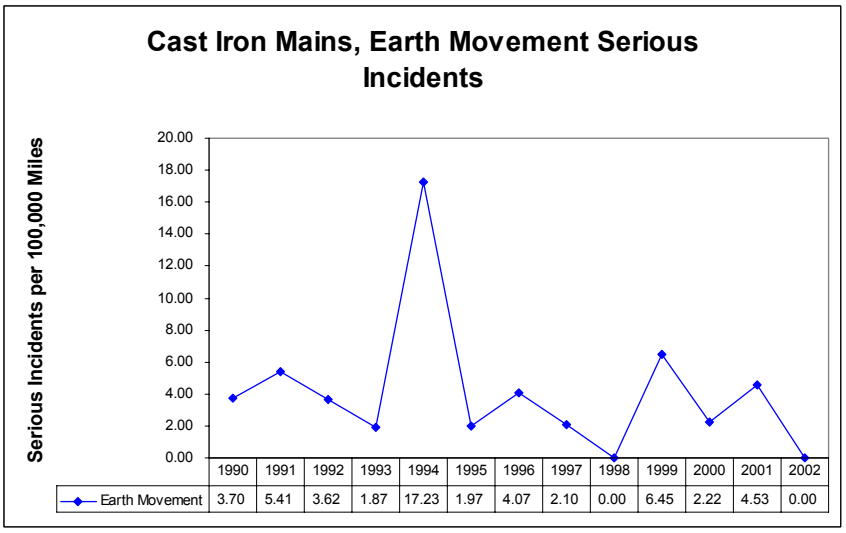
Figures B38C(a), (b) and (c) show data for outside force serious incidents on cast iron mains by type of outside force from 1990 through 2002. Unlike steel mains, data for cast iron mains show earth movement accounts for 75% the outside force incidents, followed by third party damage at 20%, which is a significantly lower percentage of incidents.

A time series of the earth movement data based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B38C(b). For the 1990-2002 time period, the average normalized rate is 4.08 incidents per 100,000 miles due to earth movement for cast iron main.

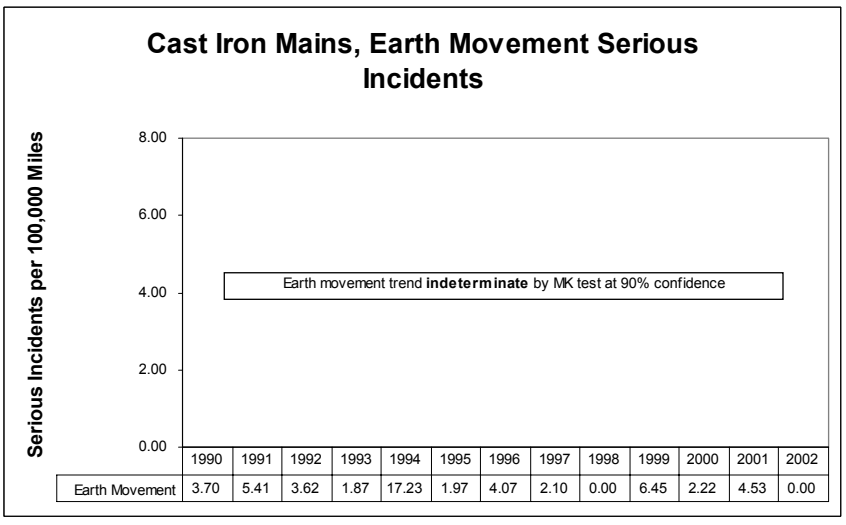
A trend plot is shown in Figure B38C(c). The MK test, at 90% confidence limits, yields an indeterminate result for all types of outside force incidents on cast iron mains. That means that no trend could be shown at those confidence levels.



(a)



(b)



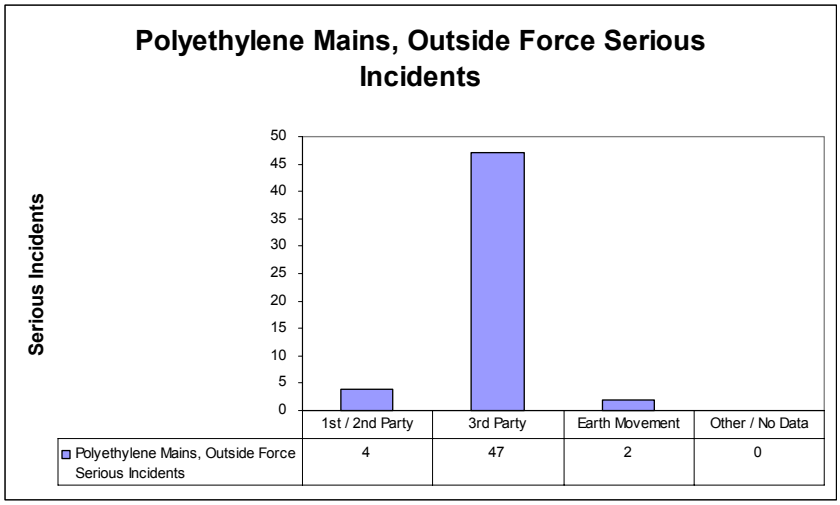
(c)

Figure B38C. Cast Iron Mains, Outside Force Serious Incidents

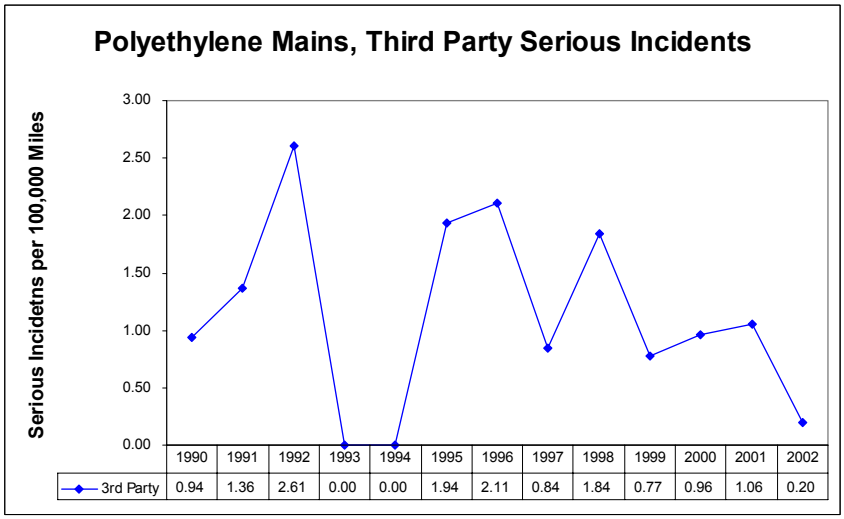
Figures B38D(a), (b) and (c) show data for outside force serious incidents on polyethylene mains by type of outside force from 1990 through 2002. Like steel mains, data for polyethylene mains show third party damage accounts for most of the outside force incidents, followed by first/second party damage at a significantly lower number of incidents.

A time series of these data for each type of outside force based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B38D(b). For the 1990-2002 time period, the average normalized rate is 1.13 incidents per 100,000 miles for polyethylene.

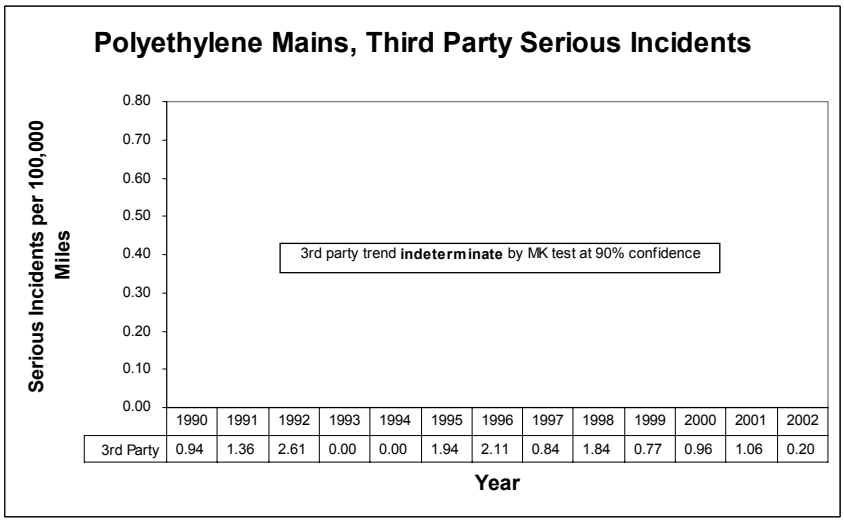
A trend plot is shown in Figure B38D(c). The MK test, at 90% confidence limits, yields an indeterminate result for all types of outside force incidents on polyethylene mains. That means that no trend could be shown at those confidence levels.



(a)



(b)



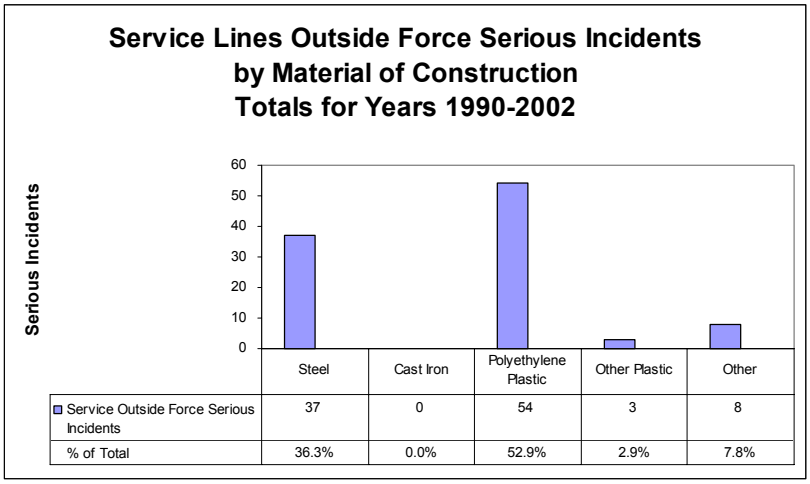
(c)

Figure B38D. Polyethylene Mains, Outside Force Serious Incidents

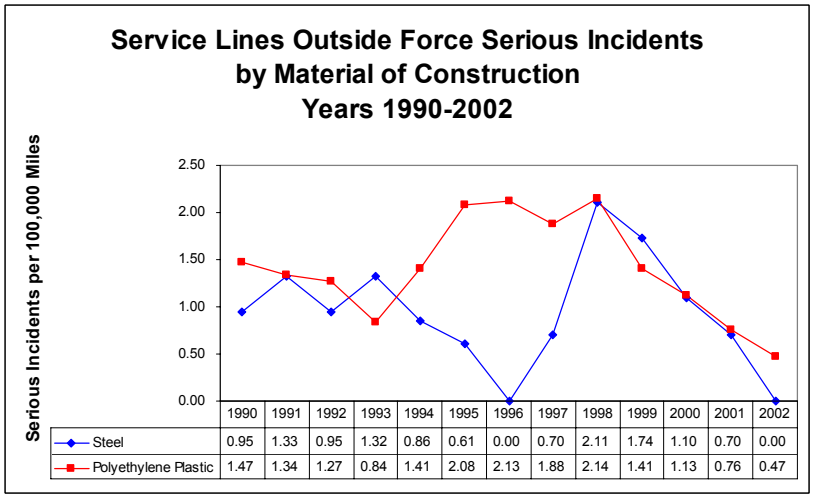
Figures B24(a), (b) and (c) show data for outside force serious incidents on service lines by material of construction from 1990 through 2002. Polyethylene plastic and steel account for most of the outside force incidents, at 52.9% and 36.3%, respectively. No outside force serious incidents were reported for cast iron service lines. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

A time series of these data for each material of construction based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B24(b).

A trend plot is shown in Figure B24(c). The MK test, at 90% confidence limits, yields an indeterminate result for both steel and polyethylene plastic service lines. That means that no trend could be shown at those confidence levels.



(a)



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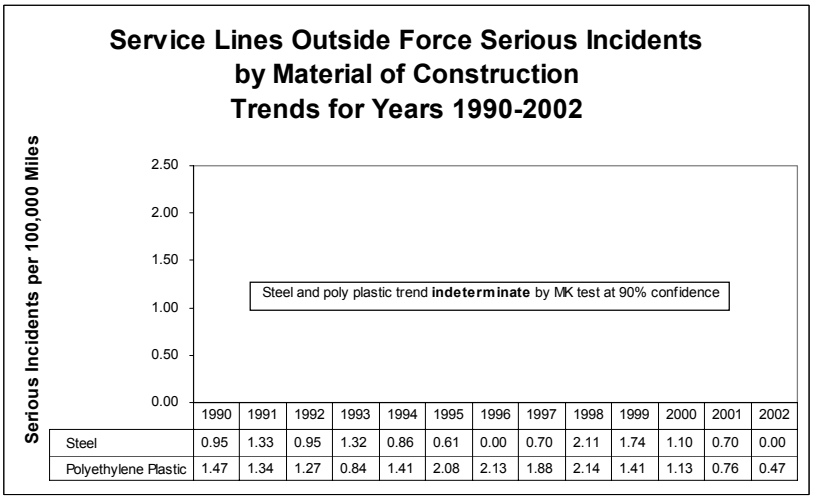
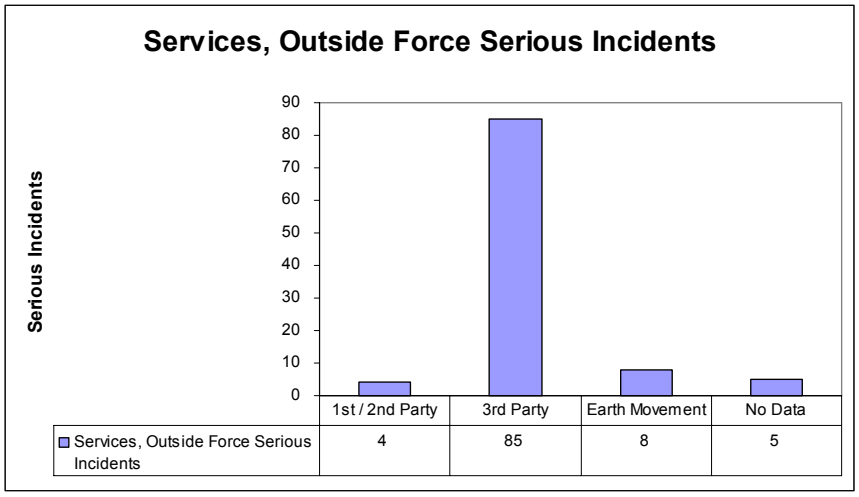


(c)

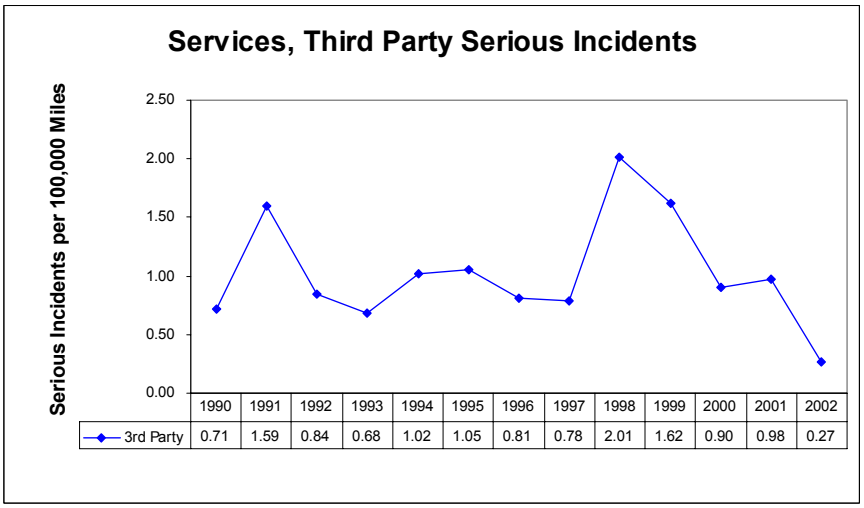
Figure B24. Service Lines Outside Force Serious Incidents by Material of Construction

Figures B38F(a), (b) and (c) show data for outside force serious incidents on service lines by type of outside force from 1990 through 2002. Like mains, third party damage and earth movement account for most of the outside force incidents associated with service lines.

A time series of the third party outside force incidents based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B38F(b). A trend plot is shown in Figure B38F(c). The MK test, at 90% confidence limits, yields an indeterminate result for third party outside force incidents on service lines. That means that no trend could be shown at those confidence levels.



(a)



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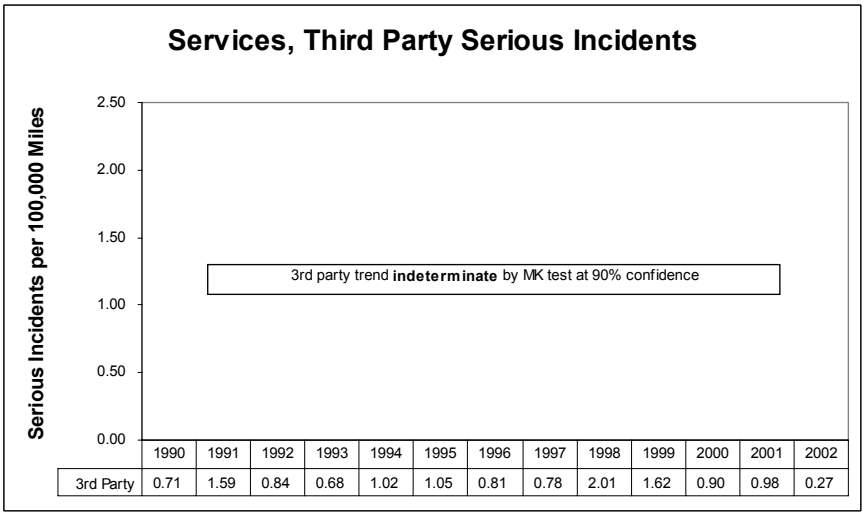


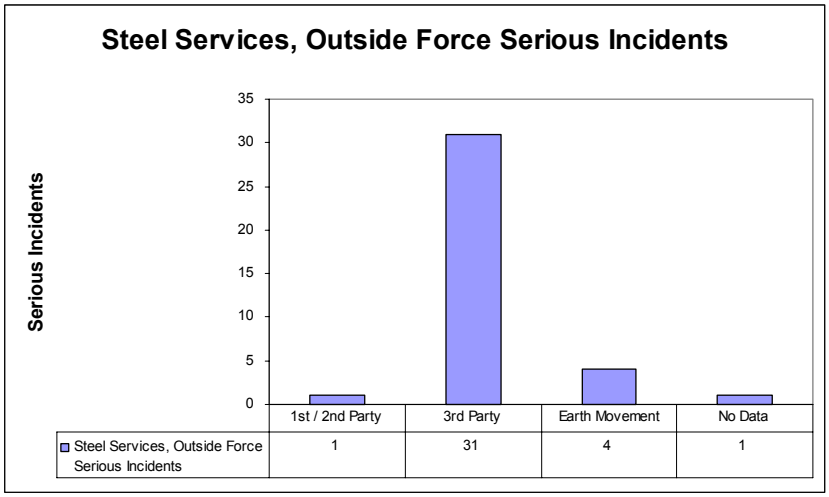
(c)

Figure B38F. Services, Outside Force Serious Incidents

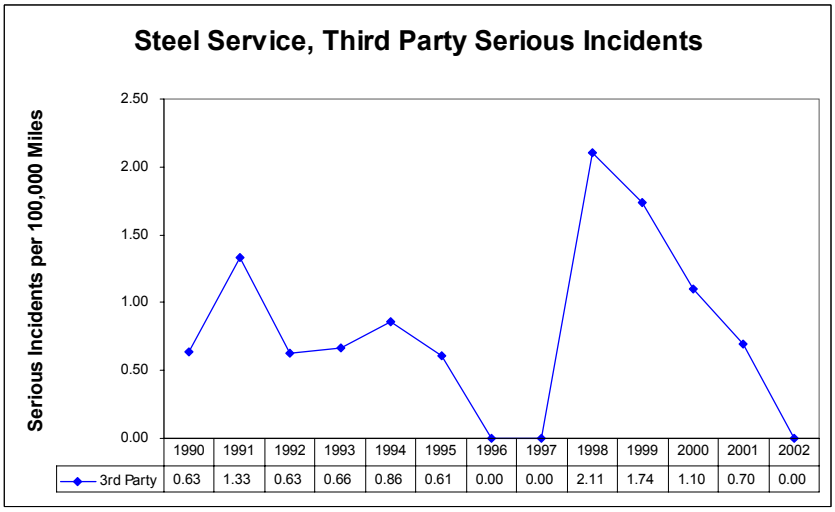
Figures B38G(a), (b) and (c) show data for outside force serious incidents on steel service lines by type of outside force from 1990 through 2002. Like steel mains, third party damage and earth movement account for most of the outside force incidents associated with steel service lines.

A time series of the third party outside force incidents based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B38G(b). For the 1990-2002 time period, the average normalized rate is 0.80 incidents per 100,000 miles for steel services.

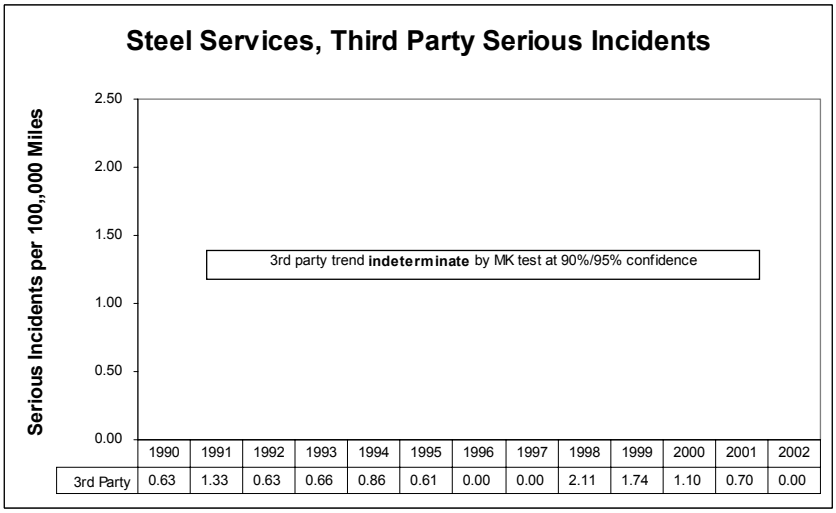
A trend plot is shown in Figure B38G(c). The MK test, at 90% confidence limits, yields an indeterminate result for third party outside force incidents on steel service lines. That means that no trend could be shown at those confidence levels.



(a)



(b)



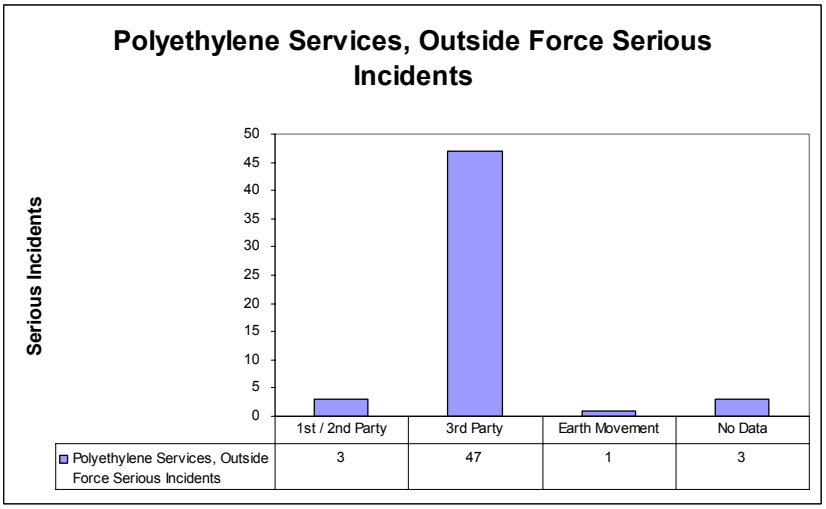
(c)

Figure B38G. Steel Services, Outside Force Serious Incidents

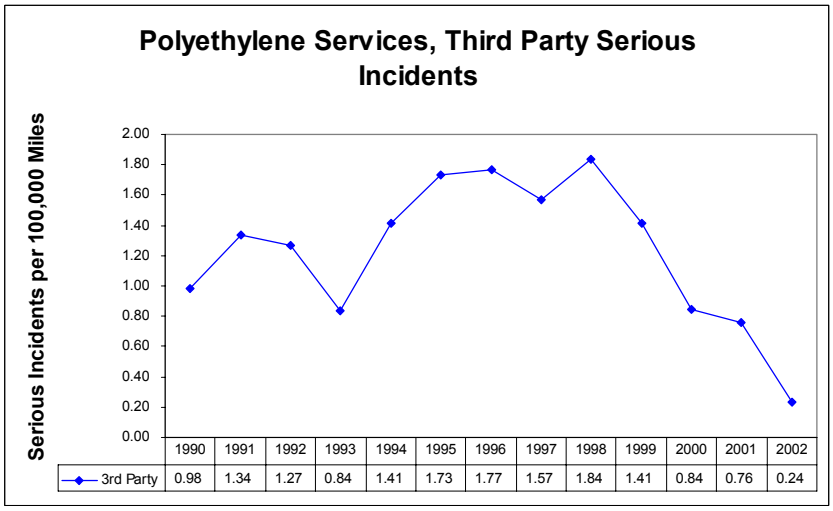
Figures B38I(a), (b) and (c) show data for outside force serious incidents on polyethylene plastic service lines by type of outside force from 1990 through 2002. Like steel service lines, third party damage accounts for most of the outside force incidents associated with polyethylene plastic service lines. First/Second party damage is the next largest cause, but only accounts for 3 incidents compared to 47 for third party damage.

A time series of the third party outside force incidents based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B38I(b). For the 1990-2002 time period, the average normalized rate is 1.23 incidents per 100,000 miles for polyethylene services.

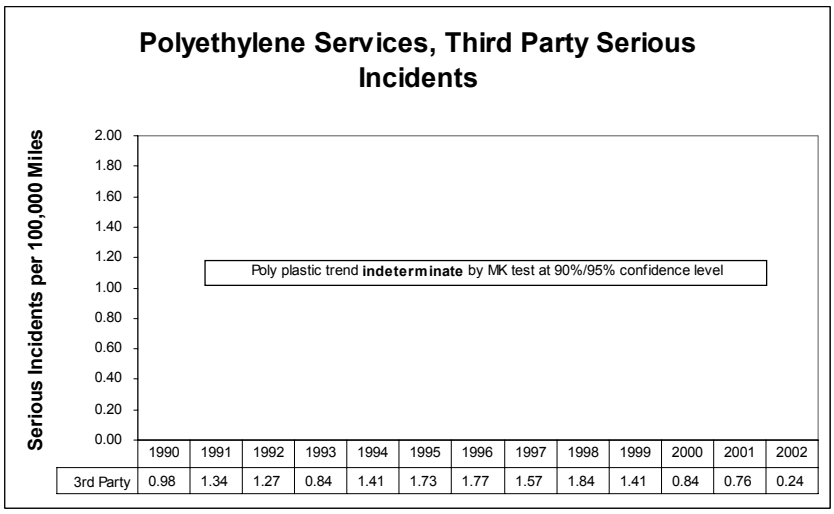
A trend plot is shown in Figure B38I(c). The MK test, at 90% confidence limits, yields an indeterminate result for third party outside force incidents on polyethylene plastic service lines. That means that no trend could be shown at those confidence levels.



(a)



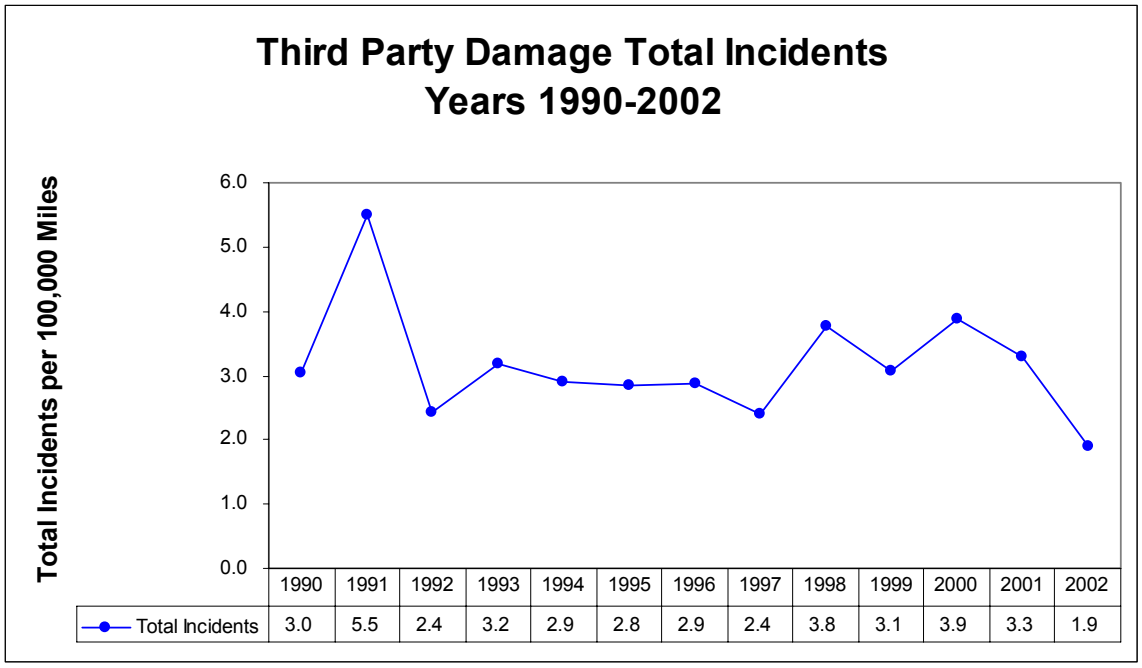
(b)



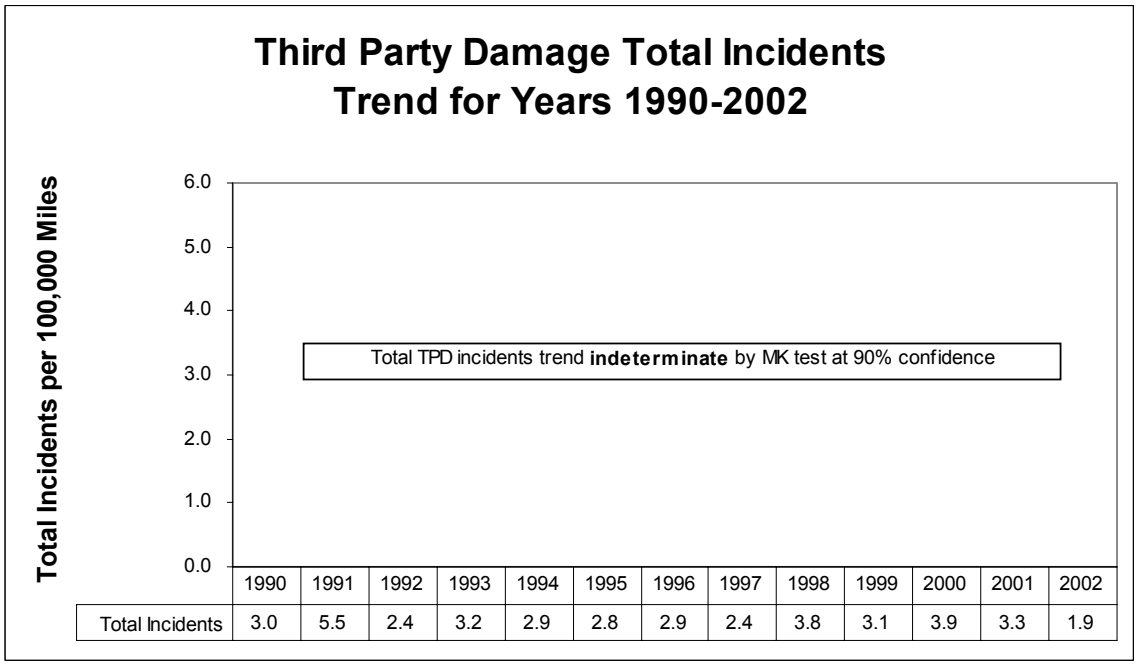
(c)

Figure B38l. Outside Force Serious Incidents by Cause for Polyethylene Services

Figures B21A(a) and (b) show data for total third party damage serious incidents from 1990 through 2002. A time series of the third party damage outside force incidents based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B21A(a). A trend plot is shown in Figure B21A(b). The MK test, at 90% confidence limits, yields an indeterminate result for third party outside force incidents. That means that no trend could be shown at those confidence levels.



(a)

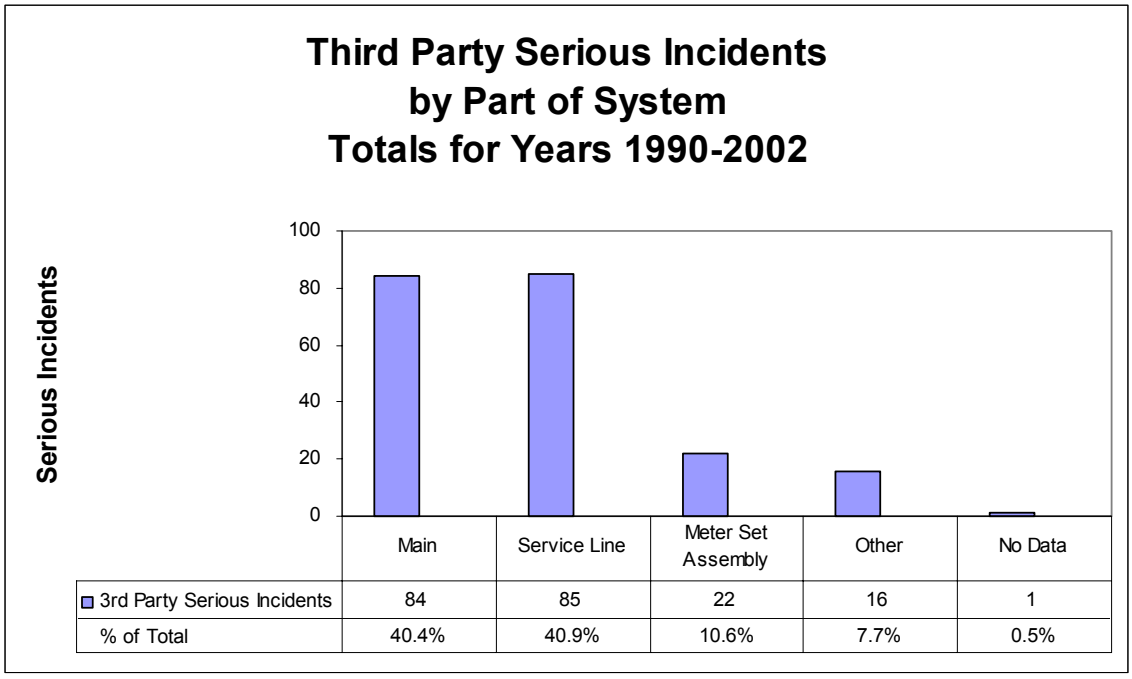


(b)

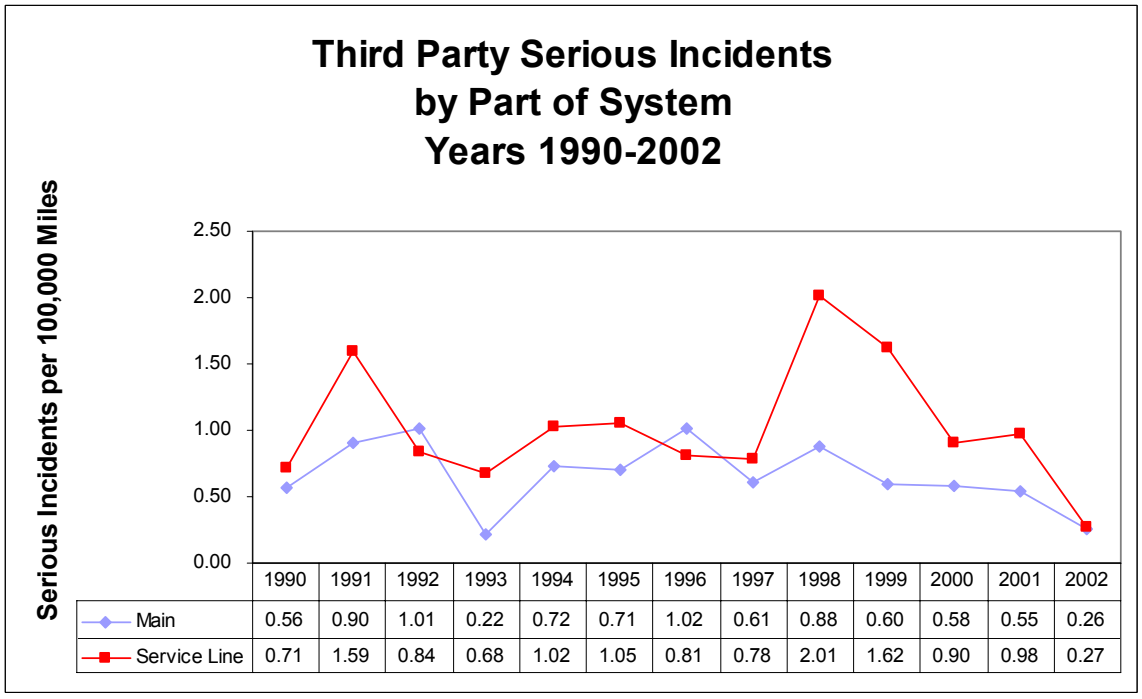
Figure B21A. Third Party Damage Distribution Incidents

Figures B21B(a), (b), (c), and (d) show data for third party damage serious incidents by part of system from 1990 through 2002. Service lines and mains account for most of the third party damage incidents, at 40.9% and 40.4%, respectively. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

A time series of these data for each material of construction based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B21B(b). A trend plot is shown in Figure B21B(c); Figure 21B(d) is merely a plot of the lower portion of Figure 21B(c) on using an expanded scale. The MK test, at 90% confidence limits, yields an indeterminate result for mains. That means that no trend could be shown at those confidence levels. The MK test for service lines showed a downward trend at the 90% confidence level.

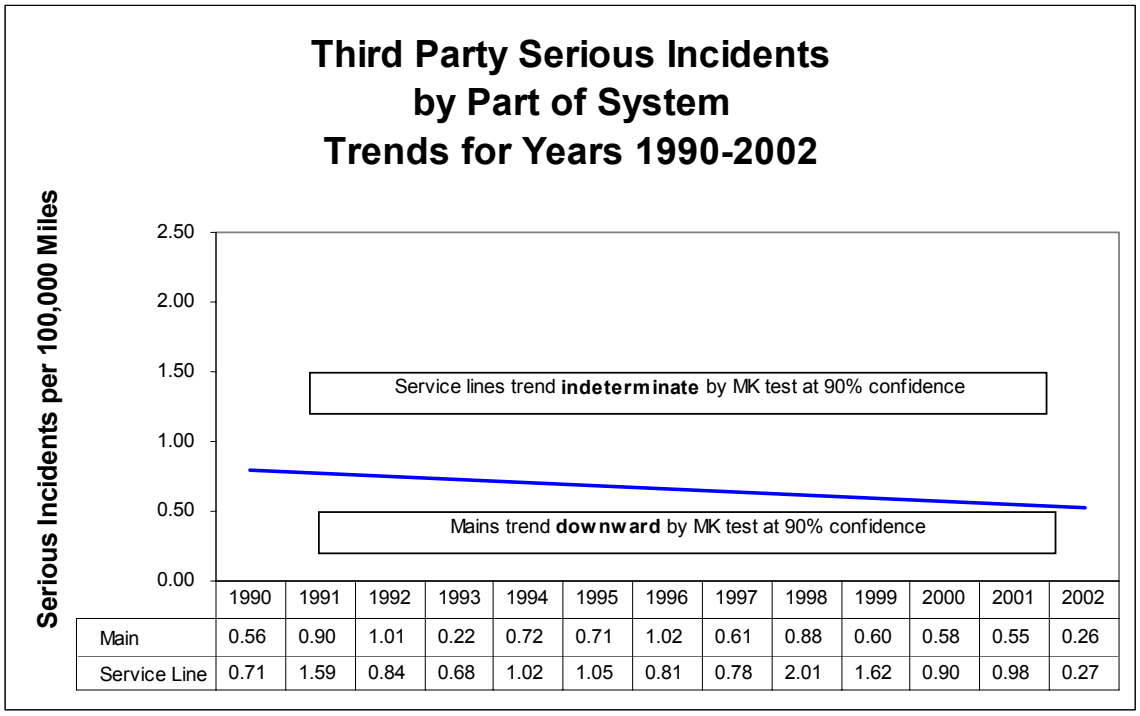


(a)



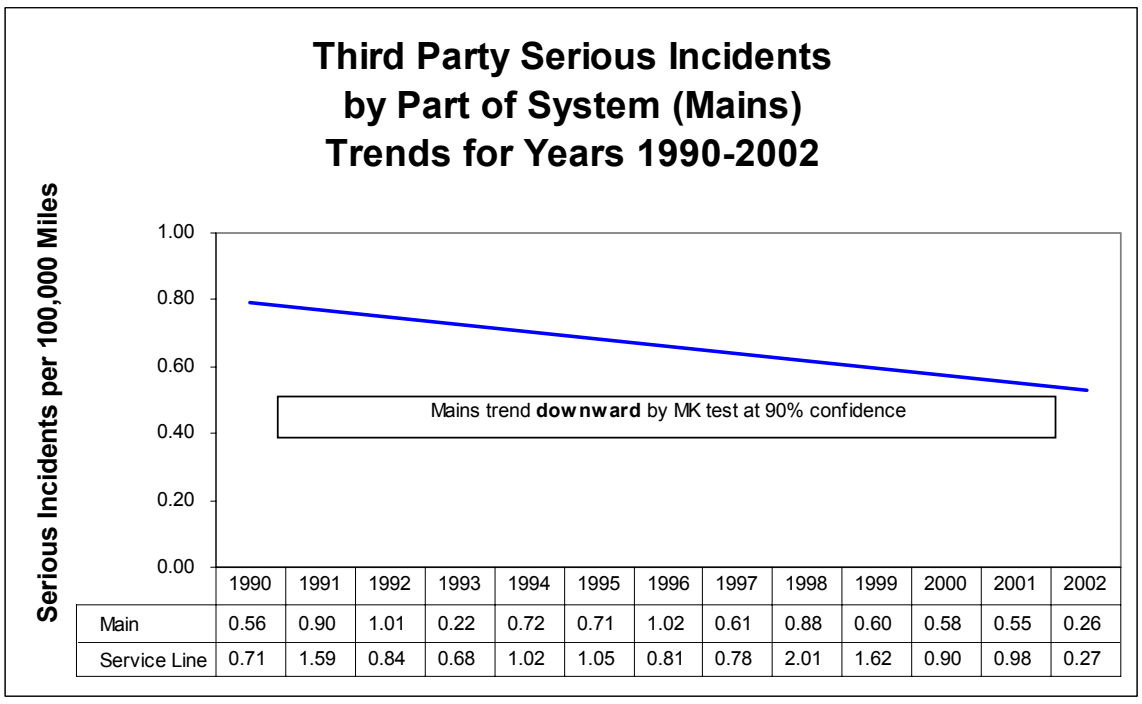
(b)

Figure B21B(a) and B21B(b). Third Party Serious Incidents by Part of System



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Main	0.56	0.90	1.01	0.22	0.72	0.71	1.02	0.61	0.88	0.60	0.58	0.55	0.26
Service Line	0.71	1.59	0.84	0.68	1.02	1.05	0.81	0.78	2.01	1.62	0.90	0.98	0.27

(c)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Main	0.56	0.90	1.01	0.22	0.72	0.71	1.02	0.61	0.88	0.60	0.58	0.55	0.26
Service Line	0.71	1.59	0.84	0.68	1.02	1.05	0.81	0.78	2.01	1.62	0.90	0.98	0.27

(d)

Figure B21B(c) and B21B(d). Third Party Serious Incidents by Part of System

Figures B22(a), (b) and (c) show data for third party damage serious incidents on mains by material of construction from 1990 through 2002. Polyethylene plastic and steel account for most of the third party damage incidents, at 56.0% and 31.2%, respectively. 8.3% of third party serious incidents were associated with cast iron mains. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

A time series of these data for steel, cast iron, and polyethylene plastic based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B22(b). For the 1990-2002 time period, a comparison of the effects of third party damage on steel and polyethylene main incident rates per 100,000 miles of each material yields an average incident rate of 0.36 for steel, 1.12 for polyethylene and 1.08 for cast iron.

A trend plot is shown in Figure B22(c). The MK test, at 90% confidence limits, yields an indeterminate result for all three materials of construction. That means that no trend could be shown at those confidence levels.

Table B-1.1 below, compares the average serious incident rates for mains, normalized per 100,000 miles, for all causes, outside force (all), outside force (third party damage), and outside force (earth movement) by material of construction.

Table B-1.1. Comparison of Average Annual Incidence Rates on Mains Over The Period 1990 - 2002

Material	All Causes	Outside Force, All	Outside Force, TPD	Outside Force, EM	Outside Force Excluding TPD	Outside Force Excluding TPD and EM	All Causes Excluding Outside Force
Steel	1.26	0.45	0.35	NC	0.12	NC	0.81
Polyethylene	2.59	1.31	1.12	NC	0.23	NC	1.28
Cast Iron	10.0	5.45	1.08	4.09	4.53	0.44	4.61

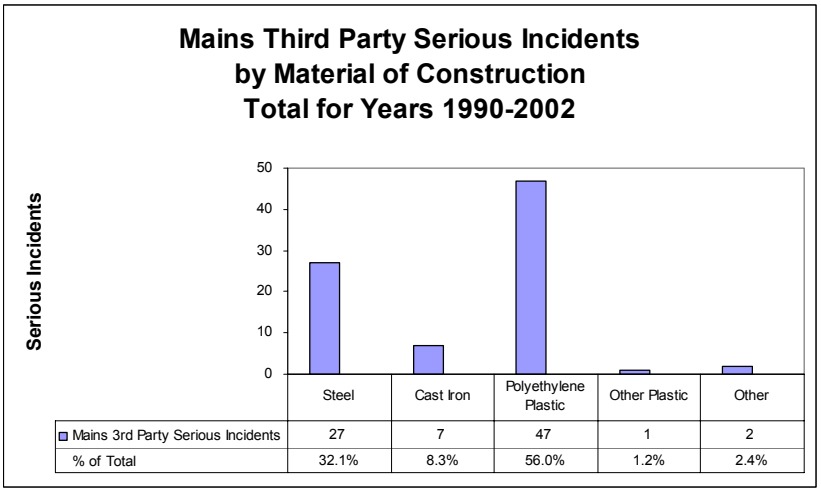
TPD = Third Party Damage

EM = Earth Movement

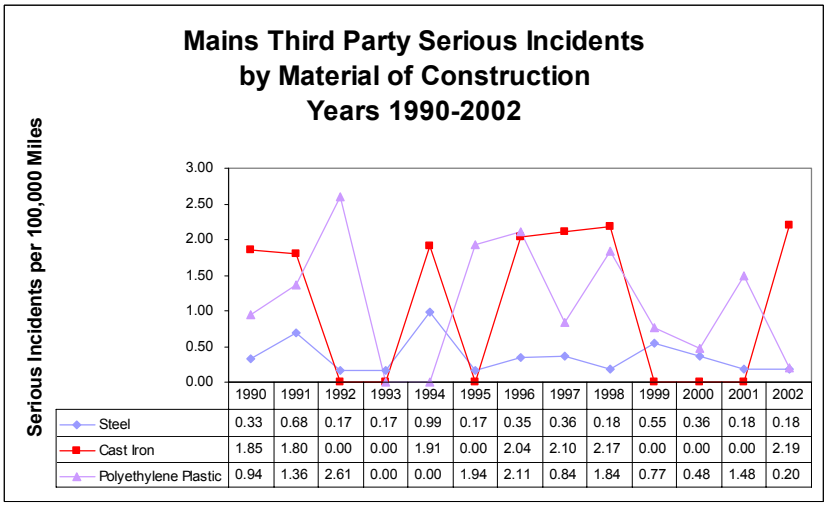
NC = Not Calculated

This table shows that on a normalized or incidence rate basis, over the period from 1990 to 2002:

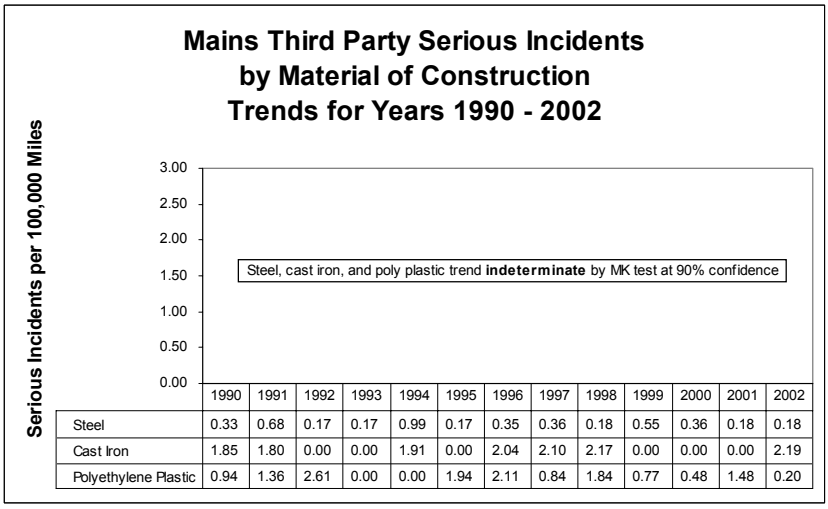
1. The third party damage incident rate was 43% of the incident rate due to all causes for polyethylene main (1.12 / 2.59 * 100 = 43%);
2. The third party damage incident rate was 28% of the incident rate due to all causes on steel main (0.35 / 1.26 * 100 = 28%);
3. Among the three materials of main construction, polyethylene showed the highest incident rate due to third party damage, followed by cast iron and steel;
4. Third party damage represents only about 20% of the outside force incidence rate for cast iron main (1.08 / 5.45 * 100 = 20%);
5. The third party damage incidence rate accounts for the majority of the outside force incident rate (78%) for steel main (0.35 / 0.45 * 100 = 78%) ;
6. The third party damage incidence rate accounts for the majority of the outside force incident rate (85%) for polyethylene main (1.12 / 1.31 * 100 = 85%) ;
7. The outside force incident rate is 51% of incident rate due to all causes on polyethylene main (1.31 / 2.59 * 100 = 51%);
8. The incident rate for causes other than outside force are 64% of incident rate due to all causes on steel main (0.81 / 1.26 * 100 = 64%);
9. The incident rate for earth movement is 75% of the outside force incident rate on cast iron main (4.09 / 5.45 * 100 = 75%); and
10. The incident rate for outside force is 54% of incident rate for all causes on cast iron main (5.45 / 10.0 * 100 = 54%).



(a)



(b)



(c)

Figure B22(a) and (b). Third Party Serious Incidents for Mains by Materials of Construction

Figures B25(a), (b) and (c) show data for third party damage serious incidents on service lines by material of construction from 1990 through 2002. Like mains, polyethylene plastic and steel account for most of the third party damage incidents, at 55.3% and 36.5%, respectively. No third party damage serious incidents were reported for cast iron mains. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

A time series of these data for steel and polyethylene plastic based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B25(b). For the 1990-2002 time period, a comparison of the effects of third party damage on steel and polyethylene service line incident rates per 100,000 miles of each material yields an average incident rate of 0.80 for steel and 1.23 for polyethylene.

A trend plot is shown in Figure B25(c). The MK test, at 90% confidence limits, yields an indeterminate result for both steel and polyethylene plastic mains. That means that no trend could be shown at those confidence levels.

Table B-1.2 below, compares the average serious incident rates for service lines, normalized per 100,000 miles, for all causes, outside force (all), and outside force (third party damage) by material of construction.

Table B-1.2. Comparison of Average Incident Rates on Service Lines Over the Period 1990-2002

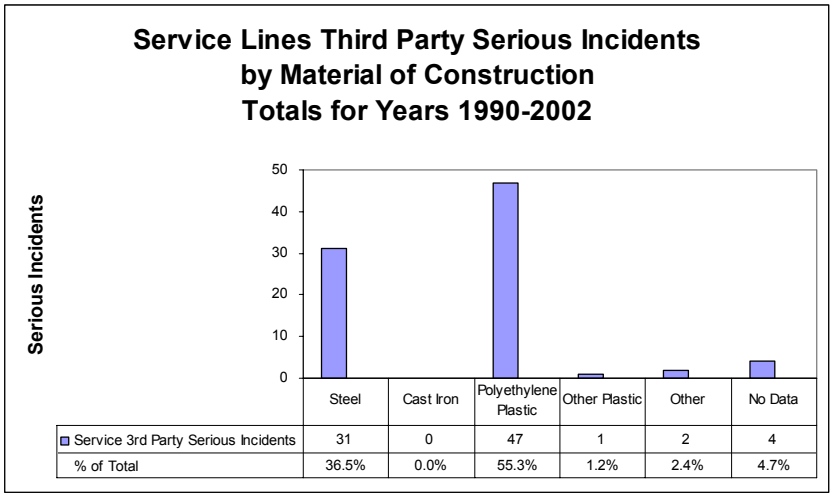
Material	All Causes	Outside Force, All	Outside Force, TPD	Outside Force Excluding TPD	All Causes Excluding Outside Force
Steel	1.75	0.95	0.80	0.15	0.80
Polyethylene	1.86	1.41	1.23	0.18	0.45

TPD = Third Party Damage

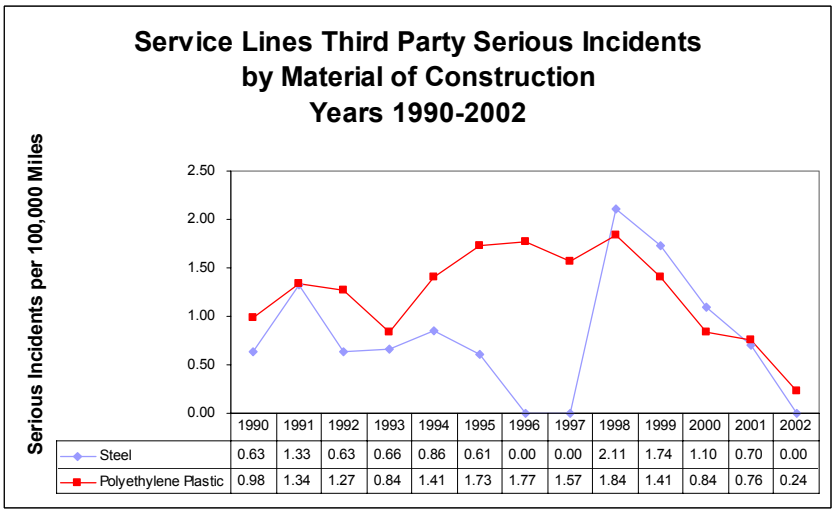
This table shows that on a normalized or incidence rate basis, over the period from 1990 to 2002:

1. The third party damage incident rate was 66% of the incident rate due to all causes for polyethylene service lines (1.23 / 1.86 *100 = 66%);
2. The third party damage incident rate was 46% of the incident rate due to all causes on steel service lines (0.80 / 1.75 * 100 = 46%);
3. Among the two materials of service lines construction, polyethylene showed the highest incident rate due to third party damage, followed by steel;
4. The third party damage incidence rate accounts for the majority of the outside force incident rate (84%) for steel service lines (0.80 / 0.95 * 100 = 84%);

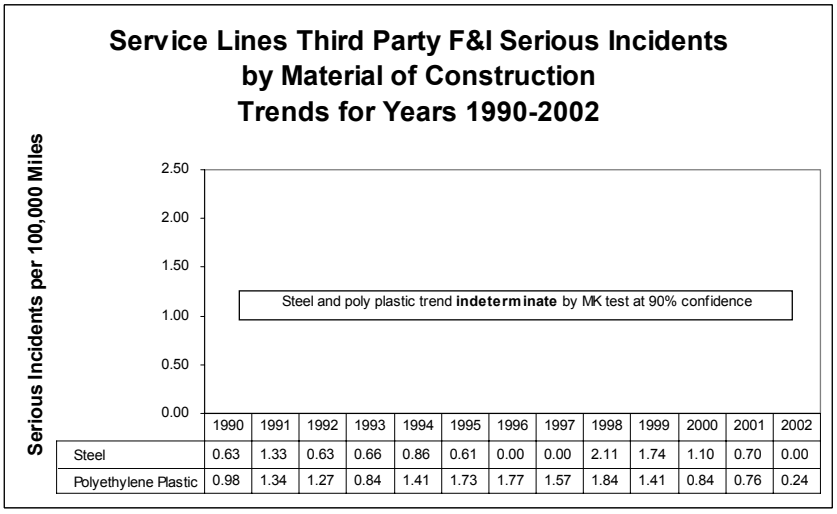
5. The third party damage incidence rate accounts for the majority of the outside force incident rate (87%) for polyethylene service lines (1.23 / 1.41 * 100 = 87%);
6. The outside force incident rate is76% of incident rate due to all causes on polyethylene service lines (1.41 / 1.86 * 100 = 76%); and
7. The incident rate for causes other than outside force are 46% of incident rate due to all causes on steel service lines (0.80 / 1.75 * 100 = 46%).



(a)



(b)

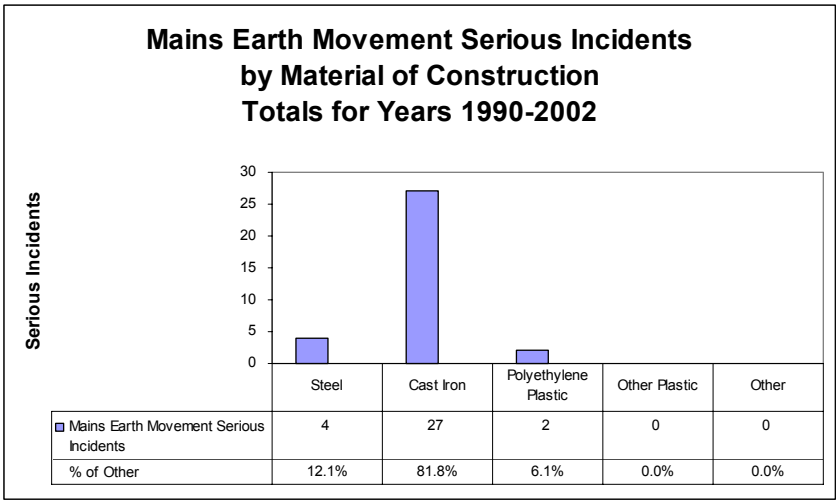


(c)

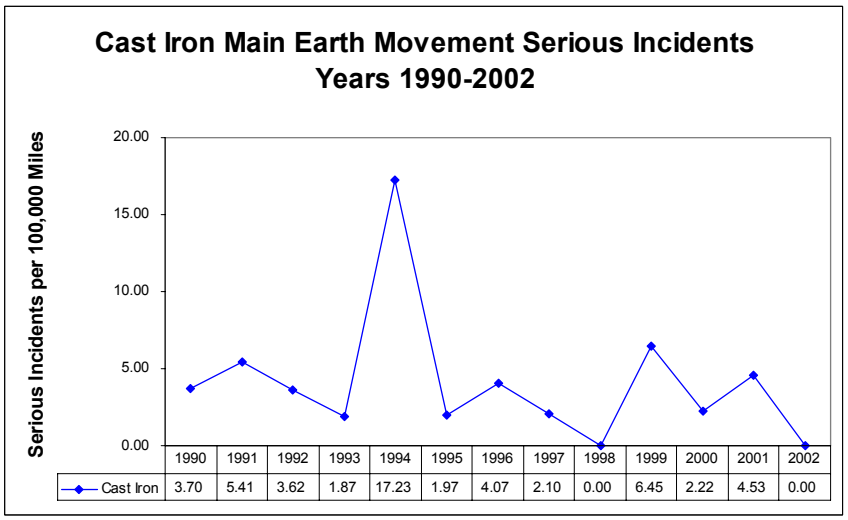
Figure B25. Service Lines Third Party Serious Incidents by Material of Construction

Figures B23(a), (b) and (c) show data for earth movement serious incidents on mains by material of construction from 1990 through 2002. Cast iron accounts for 81.8% of the earth movement incidents. No earth movement serious incidents were reported for polyethylene plastic mains. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

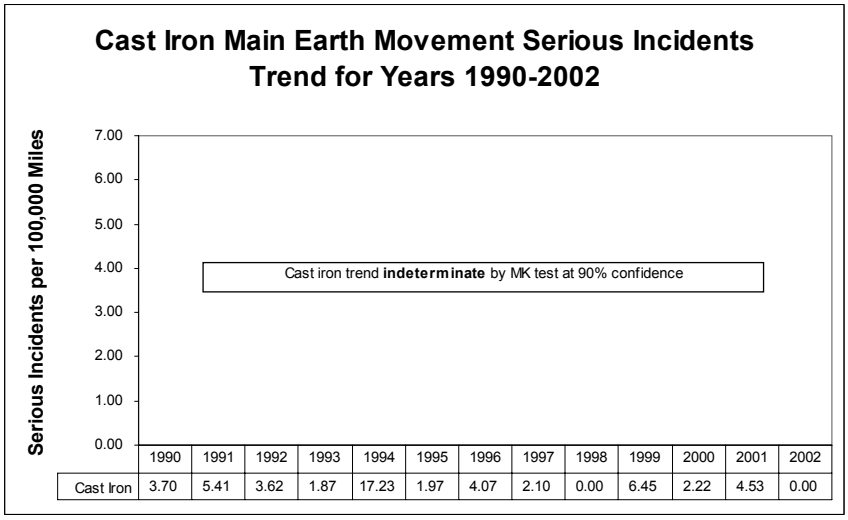
A time series of these data for cast iron mains based on 100,000 miles of the appropriate mileage, as discussed in Part 1 of this appendix, is shown in Figure B23(b). A trend plot is shown in Figure B23(c). The MK test, at 90% confidence limits, yields an indeterminate result for cast iron mains. That means that no trend could be shown at those confidence levels.



(a)



(b)



(c)

Figure B23. Mains Earth Movement Serious Incidents Material of Construction

Figure B26 shows data for earth movement serious incidents on service lines by material of construction from 1990 through 2002. The number of incidents is relatively small for any given type of material. Within the limitations posed by the size of the data set, steel and other plastic account for most of the third party damage incidents, at 50.0% and 25.0%, respectively. No earth movement serious incidents were reported for cast iron service lines. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

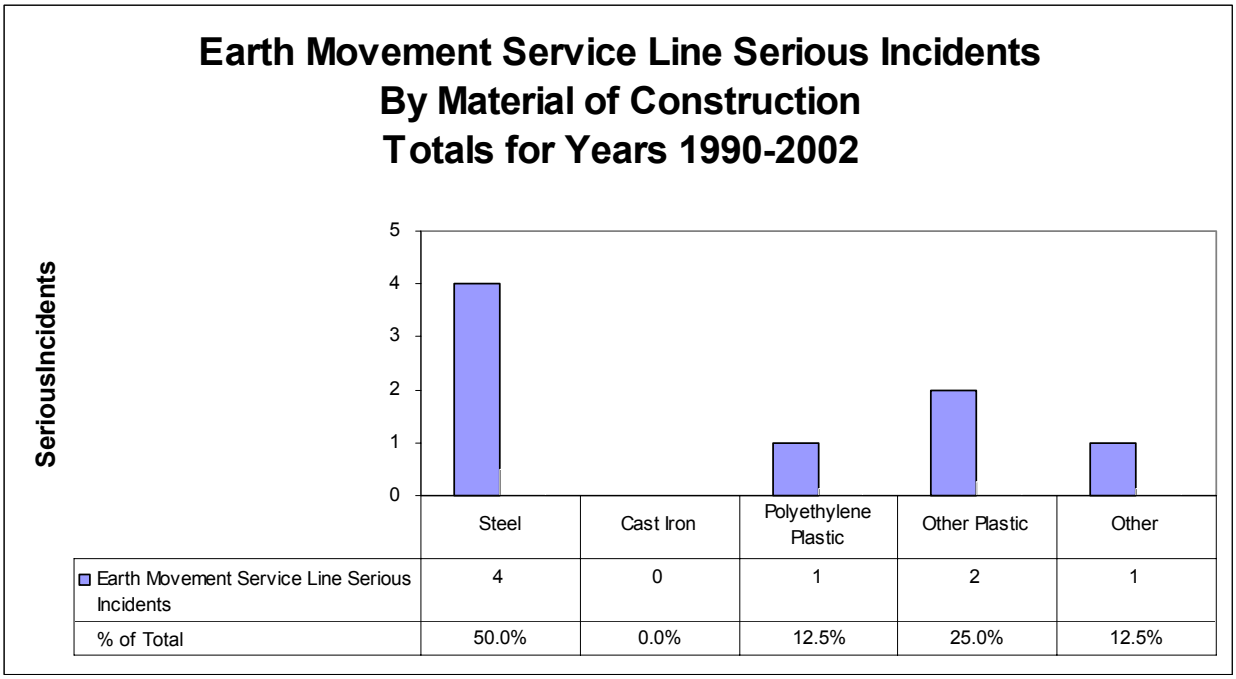


Figure B26. Earth Movement Service Line Serious Incidents by Material of Construction

Figure B27 shows data for construction/operating error serious incidents by part of the system from 1990 through 2002. Mains and "other" parts of the system account for most of the construction/operating error incidents, at 66.1% and 16.9%, respectively. Service lines accounted for approximately 10% of the total construction/operating error serious incidents. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

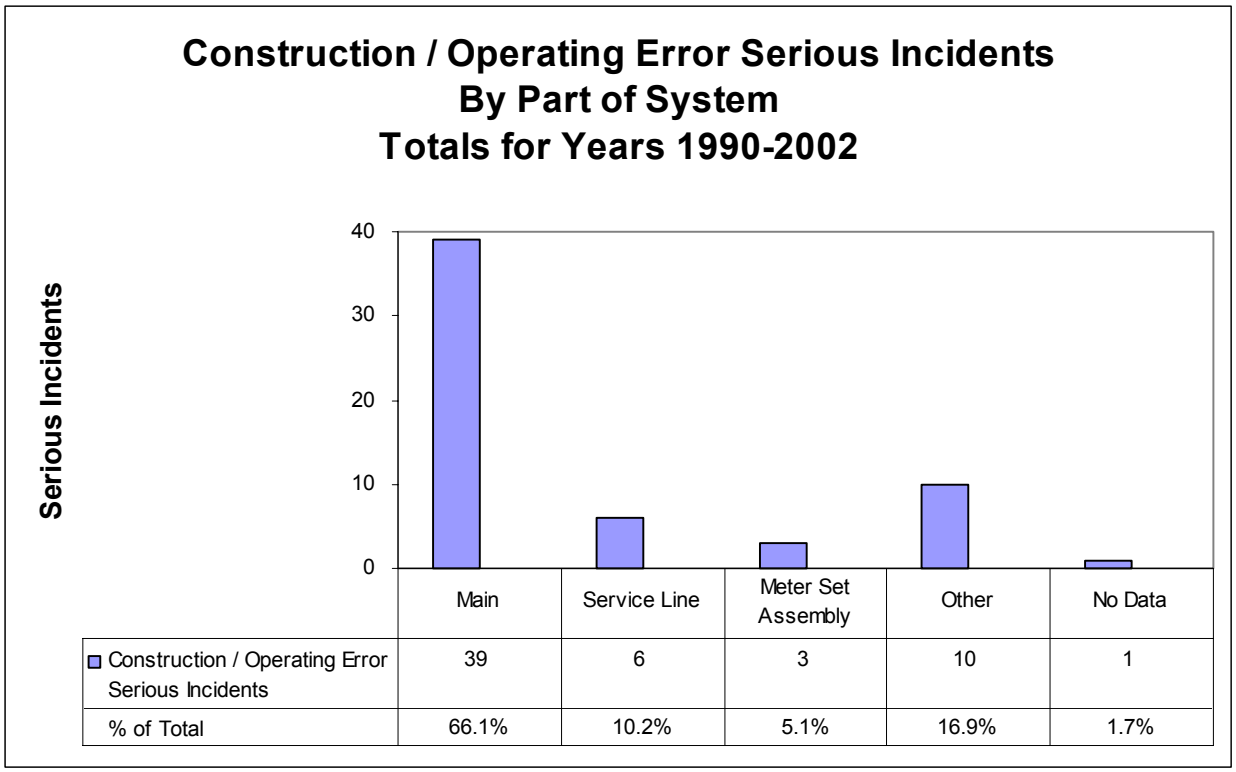


Figure B27. Construction/Operating Error Serious Incidents by Part of System

Figure B28 shows data for accidentally caused by operator serious incidents by part of the system from 1990 through 2002. Mains and service lines account for most of the accidentally caused by operator incidents, at 61.0% and 25.4%, respectively. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

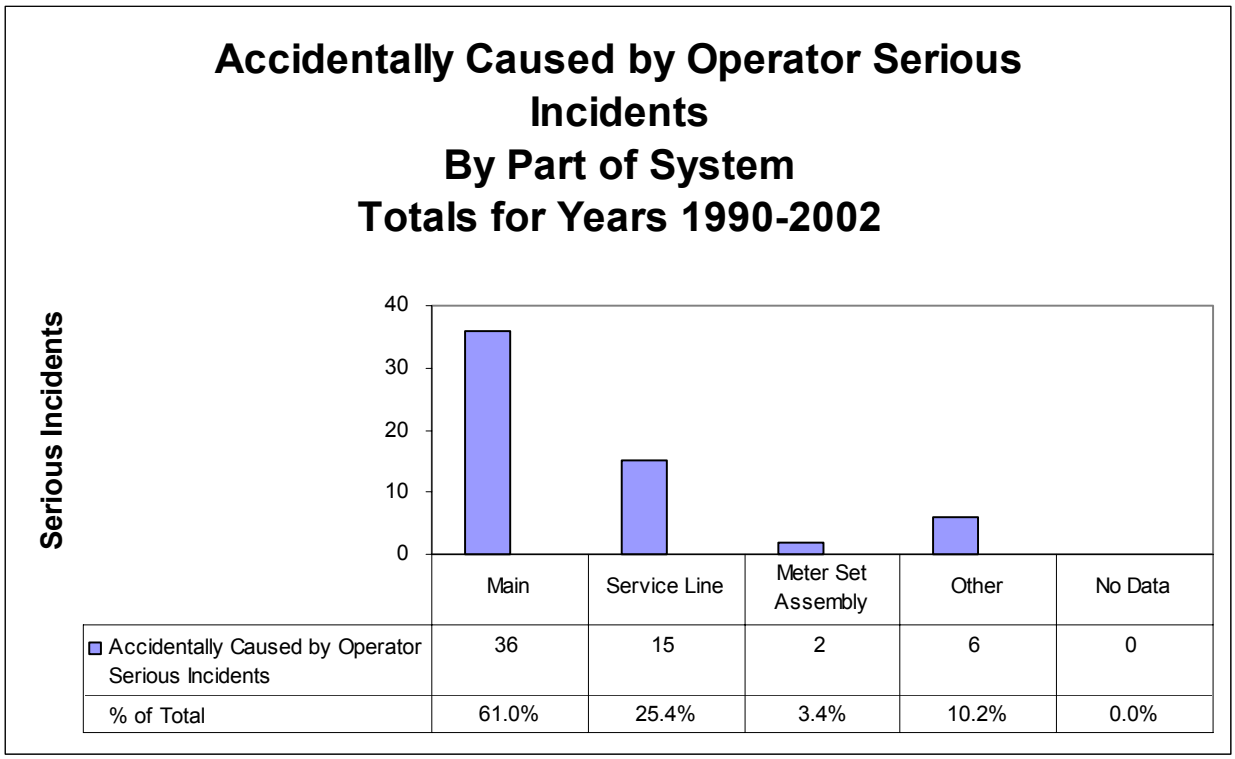


Figure B28. Accidentally Caused by Operator Serious Incidents by Part of System

Figure B29 shows data for "other/no data" serious incidents by part of the system from 1990 through 2002. These are incidents where the cause was indicated as "other" or the cause information was not reported by the operator in the DOT/OPS incident database. Insufficient information are available in the OPS database to further define this "other" cause category, so they have been grouped with the no data category in this analysis. The "other" part of system category accounts for 40.2% of the total, followed by mains at 31.7% and service lines at 15.2%. As discussed previously for Figure B17, these percentages are based on a subset of the total serious incidents.

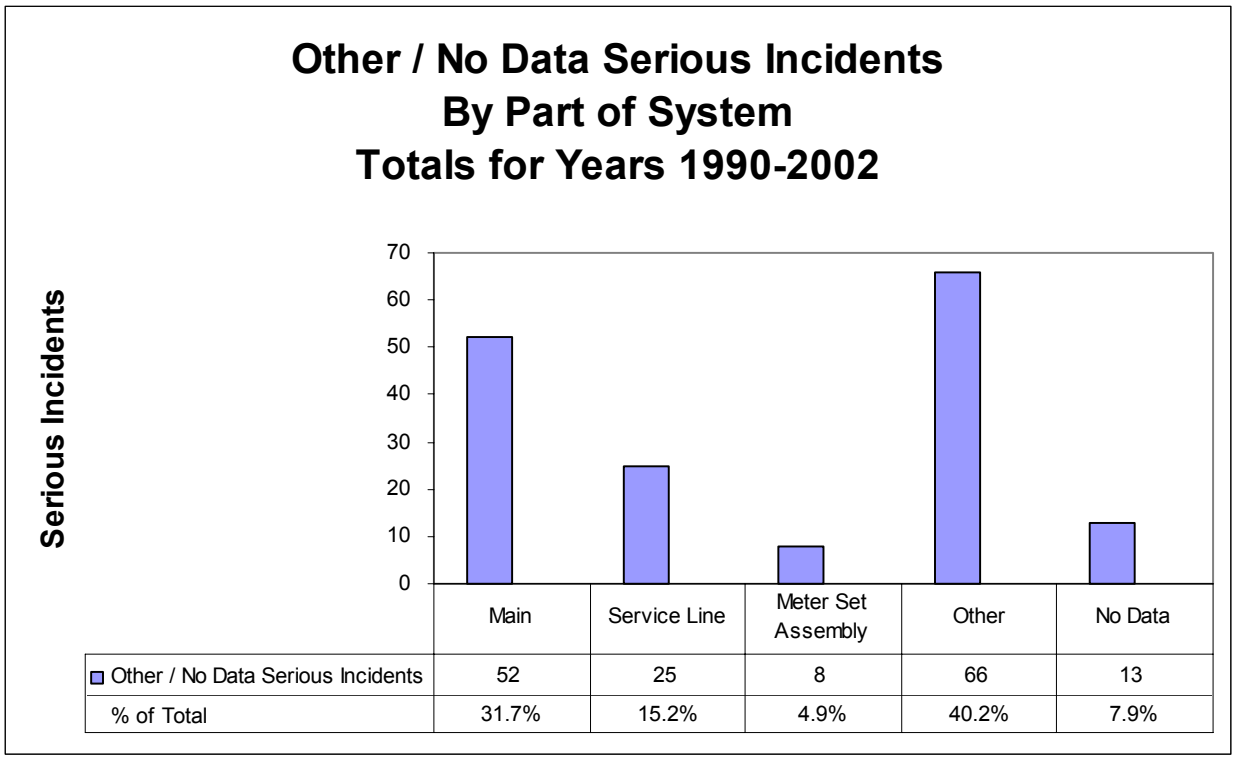


Figure B29. Other/No Data Serious Incidents by Part of System

PART 3

DATA TABLES

Total Distribution Incidents

Table B1. Total Distribution Incidents

	Total Incidents				
1990	109				
1991	162				
1992	103				
1993	121				
1994	141				
1995	97				
1996	110				
1997	102				
1998	137				
1999	118				
2000	154				
2001	123				
2002	102				
	1,579				
			Main Mileage	**Estimated Service Mileage**	**Total Mileage**
1990	1,449,399		889,566	559,833	1,449,399
1991	1,452,922		888,558	564,364	1,452,922
1992	1,484,975		891,171	593,804	1,484,975
1993	1,510,696		923,670	587,026	1,510,696
1994	1,652,703		968,193	684,510	1,652,703
1995	1,656,857		988,818	668,039	1,656,857
1996	1,601,556		980,900	620,657	1,601,556
1997	1,628,880		991,390	637,490	1,628,880
1998	1,671,461		1,025,492	645,969	1,671,461
1999	1,687,403		1,006,580	680,823	1,687,403
2000	1,704,334		1,041,159	663,175	1,704,334
2001	1,816,409		1,099,500	716,909	1,816,409
2002	1,888,882		1,143,949	744,933	1,888,882
	Total Incidents				
1990	7.5				
1991	11.1				
1992	6.9				
1993	8.0				
1994	8.5				
1995	5.9				
1996	6.9				
1997	6.3				
1998	8.2				
1999	7.0				
2000	9.0				
2001	6.8				
2002	5.4				

Table B2. Total Distribution Incidents by Part of System

	Incidents	% of Total
Main	649	41.1%
Service Line	386	24.4%
Meter Set Assembly	246	15.6%
Other	259	16.4%
No Data	39	2.5%
Total	1,579	

Table B3. Total Distribution Incidents by Cause

	Incidents	% of Total
Corrosion	59	3.7%
Outside Force	954	60.4%
Construction/ Operating Error	97	6.1%
Accidentally Caused by Operator	84	5.3%
Other	378	23.9%
No Data	7	0.4%
Total	1,579	

Total Serious Incidents

Table B5. Serious Incidents

	Serious Incidents				
1990	39				
1991	53				
1992	50				
1993	51				
1994	60				
1995	43				
1996	47				
1997	41				
1998	54				
1999	52				
2000	51				
2001	30				
2002	30				
	601				
	Total Miles		**Main Mileage**	**Estimated Service Mileage**	**Total Mileage**
1990	1,449,399		889,566	559,833	1,449,399
1991	1,452,922		888,558	564,364	1,452,922
1992	1,484,975		891,171	593,804	1,484,975
1993	1,510,696		923,670	587,026	1,510,696
1994	1,652,703		968,193	684,510	1,652,703
1995	1,656,857		988,818	668,039	1,656,857
1996	1,601,556		980,900	620,657	1,601,556
1997	1,628,880		991,390	637,490	1,628,880
1998	1,671,461		1,025,492	645,969	1,671,461
1999	1,687,403		1,006,580	680,823	1,687,403
2000	1,704,334		1,041,159	663,175	1,704,334
2001	1,816,409		1,099,500	716,909	1,816,409
2002	1,888,882		1,143,949	744,933	1,888,882
	Normalized Serious Incidents				
1990	2.69				
1991	3.65				
1992	3.37				
1993	3.38				
1994	3.63				
1995	2.60				
1996	2.93				
1997	2.52				
1998	3.23				
1999	3.08				
2000	2.99				
2001	1.65				
2002	1.59				

Table B6. Serious Incidents by Part of System

	Main	Service Line	Meter Set Assembly	Other	No Data	Total
1990	24	8	3	4	0	35
1991	24	12	5	12	0	41
1992	29	10	6	5	0	45
1993	23	11	5	12	0	39
1994	35	12	1	12	0	48
1995	17	14	4	7	1	35
1996	20	14	2	10	1	36
1997	19	10	1	9	2	30
1998	18	23	1	9	3	42
1999	24	17	4	5	2	45
2000	21	14	2	10	3	37
2001	15	9	4	1	2	28
2002	7	7	5	9	2	19
	276	161	43	105	16	601
	Main Mileage	Service Line Mileage	Service Line Mileage			
1990	889,566	559,833	559,833			
1991	888,558	564,364	564,364			
1992	891,171	593,804	593,804			
1993	923,670	587,026	587,026			
1994	968,193	684,510	684,510			
1995	988,818	668,039	668,039			
1996	980,900	620,657	620,657			
1997	991,390	637,490	637,490			
1998	1,025,492	645,969	645,969			
1999	1,006,580	680,823	680,823			
2000	1,041,159	663,175	663,175			
2001	1,099,500	716,909	716,909			
2002	1,143,949	744,933	744,933			
	Main	Service Line	Meter Set Assembly	Other	No Data	Total
1990	2.70	1.43	0.54			
1991	2.70	2.13	0.89			
1992	3.25	1.68	1.01			
1993	2.49	1.87	0.85			
1994	3.61	1.75	0.15			
1995	1.72	2.10	0.60			
1996	2.04	2.26	0.32			
1997	1.92	1.57	0.16			
1998	1.76	3.56	0.15			
1999	2.38	2.50	0.59			
2000	2.02	2.11	0.30			
2001	1.36	1.26	0.56			
2002	0.61	0.94	0.67			

Serious Incidents by Material of Construction

Table B7. Mains, Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	No Data	Total
1990	8	7	8				23
1991	10	10	4				24
1992	8	4	14				26
1993	10	4	7				21
1994	14	12	9				35
1995	5	3	8				16
1996	8	4	7				19
1997	9	5	4				18
1998	3	1	14				18
1999	9	6	8				23
2000	5	4	11				20
2001	3	4	7				14
2002	3	2	2				7
	95	66	103	2	8	2	276

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	No Data	
1990	600,000	54,053	212,800				
1991	585,000	55,450	220,000				
1992	580,000	55,242	230,000				
1993	593,940	53,543	250,000				
1994	607,880	52,223	280,000				
1995	603,396	50,660	310,000				
1996	573,136	49,106	332,000				
1997	558,550	47,551	356,000				
1998	569,908	46,023	380,000				
1999	542,289	46,541	388,686				
2000	551,865	45,105	417,660				
2001	554,855	44,169	472,082				
2002	569,000	45,577	505,000				

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	No Data	
1990	1.33	12.95	3.76				
1991	1.71	18.03	1.82				
1992	1.38	7.24	6.09				
1993	1.68	7.47	2.80				
1994	2.30	22.98	3.21				
1995	0.83	5.92	2.58				
1996	1.40	8.15	2.11				
1997	1.61	10.52	1.12				
1998	0.53	2.17	3.68				
1999	1.66	12.89	2.06				
2000	0.91	8.87	2.63				
2001	0.54	9.06	1.48				
2002	0.53	4.39	0.40				

Table B11. Service Lines, Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	No Data	Total
1990	3		4				
1991	6		4				
1992	5		4				
1993	6		4				
1994	7		4				
1995	4		8				
1996	5		8				
1997	4		6				
1998	11		9				
1999	7		7				
2000	5		8				
2001	3		3				
2002	2		2				
	68	0	71	5	12	5	161
	Steel	**Cast Iron**	**Polyethylene Plastic**	**Other Plastic**	**Other**	**No Data**	
1990	315,247		204,063				
1991	301,203		223,807				
1992	316,760		237,149				
1993	302,419		238,862				
1994	349,680		283,500				
1995	328,093		288,494				
1996	285,584		282,322				
1997	284,407		318,910				
1998	284,784		326,566				
1999	288,180		354,209				
2000	273,335		355,201				
2001	286,651		394,091				
2002	282,614		423,655				
	Steel	**Cast Iron**	**Polyethylene Plastic**	**Other Plastic**	**Other**		
1990	0.95		1.96				
1991	1.99		1.79				
1992	1.58		1.69				
1993	1.98		1.67				
1994	2.00		1.41				
1995	1.22		2.77				
1996	1.75		2.83				
1997	1.41		1.88				
1998	3.86		2.76				
1999	2.43		1.98				
2000	1.83		2.25				
2001	1.05		0.76				
2002	0.71		0.47				

Serious Incidents by Cause

Table B16. Serious Incidents by Cause

	Corrosion	Outside Force	Construction / Operating Error	Accidentally Caused By Operator	Other	No Data	Total
1990	3	21	6	4	6	0	40
1991	5	26	5	4	13	0	53
1992	2	25	7	3	13	0	50
1993	5	20	5	7	14	0	51
1994	2	32	7	6	13	0	60
1995	3	22	3	6	9	0	43
1996	1	22	4	4	15	1	47
1997	3	17	3	3	14	0	40
1998	3	25	4	6	16	0	54
1999	5	25	6	5	11	0	52
2000	3	17	5	4	15	3	47
2001	3	18	2	3	8	0	34
2002	1	10	2	4	13	0	30
	39	280	59	59	160	4	601

	Corrosion	Outside Force	Construction / Operating Error	Accidentally Caused By Operator	Other	No Data	Total
1990	1,449,399	1,449,399	1,449,399	1,449,399	1,449,399		
1991	1,452,922	1,452,922	1,452,922	1,452,922	1,452,922		
1992	1,484,975	1,484,975	1,484,975	1,484,975	1,484,975		
1993	1,510,696	1,510,696	1,510,696	1,510,696	1,510,696		
1994	1,652,703	1,652,703	1,652,703	1,652,703	1,652,703		
1995	1,656,857	1,656,857	1,656,857	1,656,857	1,656,857		
1996	1,601,556	1,601,556	1,601,556	1,601,556	1,601,556		
1997	1,628,880	1,628,880	1,628,880	1,628,880	1,628,880		
1998	1,671,461	1,671,461	1,671,461	1,671,461	1,671,461		
1999	1,687,403	1,687,403	1,687,403	1,687,403	1,687,403		
2000	1,704,334	1,704,334	1,704,334	1,704,334	1,704,334		
2001	1,816,409	1,816,409	1,816,409	1,816,409	1,816,409		
2002	1,888,882	1,888,882	1,888,882	1,888,882	1,888,882		

	Corrosion	Outside Force	Construction / Operating Error	Accidentally Caused By Operator	Other	No Data	Total
1990	0.21	1.45	0.41	0.28	0.41		
1991	0.34	1.79	0.34	0.28	0.89		
1992	0.13	1.68	0.47	0.20	0.88		
1993	0.33	1.32	0.33	0.46	0.93		
1994	0.12	1.94	0.42	0.36	0.79		
1995	0.18	1.33	0.18	0.36	0.54		
1996	0.06	1.37	0.25	0.25	1.00		
1997	0.18	1.04	0.18	0.18	0.86		
1998	0.18	1.50	0.24	0.36	0.96		
1999	0.30	1.48	0.36	0.30	0.65		
2000	0.18	1.00	0.29	0.23	1.06		
2001	0.17	0.99	0.11	0.17	0.44		
2002	0.05	0.53	0.11	0.21	0.69		

Table B8. Steel Mains, Serious Incidents by Cause

	Corrosion	Outside Force	Construction / Operating Error	Accidentally Caused By Operator	Other	No Data	Total
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							
2001							
2002							
	19	34	10	15	17	0	95

Table B9. Cast Iron Mains, Serious Incidents by Cause

	Corrosion	Outside Force	Construction / Operating Error	Accidentally Caused By Operator	Other	No Data	Total
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							
2001							
2002							
	3	36	1	4	22	0	66

Table B10. Polyethylene Mains, Serious Incidents by Cause

	Corrosion	Outside Force	Construction/ Operating Error	Accidentally Caused By Operator	Other	No Data	Total
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							
2001							
2002							
	0	53	26	14	8	2	103

Table B12. Steel Service Lines, Serious Incidents by Cause

	Corrosion	Outside Force	Construction/Operating Error	Accidentally Caused By Operator	Other	No Data	Total
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							
2001							
2002							
	9	37	4	10	8	0	68

Table B13. Polyethylene Service Lines, Serious Incidents by Cause

	Corrosion	Outside Force	Construction/Operating Error	Accidentally Caused By Operator	Other	No Data	Total
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							
2001							
2002							
	0	54	2	2	13	0	71

Table B17. Corrosion, Serious Incidents by Part of System

	Main	Service Line	Meter Set Assembly	Other	No Data	Total
1990	3	0				
1991	3	2				
1992	1	0				
1993	4	1				
1994	1	1				
1995	1	2				
1996	0	1				
1997	3	0				
1998	0	3				
1999	2	2				
2000	2	0				
2001	3	0				
2002	0	1				
	23	13	0	2	1	39
	Main	**Service Line**	**Meter Set Assembly**	**Other/ No Data**		
1990	889,566	559,833				
1991	888,558	564,364				
1992	891,171	593,804				
1993	923,670	587,026				
1994	968,193	684,510				
1995	988,818	668,039				
1996	980,900	620,657				
1997	991,390	637,490				
1998	1,025,492	645,969				
1999	1,006,580	680,823				
2000	1,041,159	663,175				
2001	1,099,500	716,909				
2002	1,143,949	744,933				
	Main	**Service Line**	**Meter Set Assembly**	**Other/ No Data**		
1990	0.34	0.00				
1991	0.34	0.35				
1992	0.11	0.00				
1993	0.43	0.17				
1994	0.10	0.15				
1995	0.10	0.30				
1996	0.00	0.16				
1997	0.30	0.00				
1998	0.00	0.46				
1999	0.20	0.29				
2000	0.19	0.00				
2001	0.27	0.00				
2002	0.00	0.13				

Table B18/19. Corrosion, Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other/ No Data	Total
Main	19	3	0	0	1	23
% of Total	82.6%	13.0%	0.0%	0.0%	4.3%	
Service Lines	11	0	0	0	5	16
% of Total	68.8%	0.0%	0.0%	0.0%	31.3%	39

Table B20. Outside Force Damage, Serious Incidents by Part of System

	Main	Service Line	Meter Set Assembly	Other	No Data	Total
1990	11	6	2	2	0	21
1991	11	9	3	3	0	26
1992	14	7	4	0	0	25
1993	6	6	4	4	0	20
1994	18	8	1	5	0	32
1995	8	9	3	2	0	22
1996	14	6	1	1	0	22
1997	7	8	1	1	0	17
1998	9	14	1	1	0	25
1999	10	11	3	0	1	25
2000	7	8	1	1	0	17
2001	8	7	3	0	0	18
2002	3	3	3	1	0	10
	126	102	30	21	1	280
	Main	Service Line	Meter Set Assembly	Other	No Data	
1990	889,566	559,833	559,833			
1991	888,558	564,364	564,364			
1992	891,171	593,804	593,804			
1993	923,670	587,026	587,026			
1994	968,193	684,510	684,510			
1995	988,818	668,039	668,039			
1996	980,900	620,657	620,657			
1997	991,390	637,490	637,490			
1998	1,025,492	645,969	645,969			
1999	1,006,580	680,823	680,823			
2000	1,041,159	663,175	663,175			
2001	1,099,500	716,909	716,909			
2002	1,143,949	744,933	744,933			
	Main	Service Line	Meter Set Assembly	Other	No Data	
1990	1.24	1.07	0.357			
1991	1.24	1.59	5.32			
1992	1.57	1.18	6.74			
1993	0.65	1.02	6.81			
1994	1.86	1.17	1.46			
1995	0.81	1.35	4.49			
1996	1.43	0.97	1.61			
1997	0.71	1.25	1.57			
1998	0.88	2.17	1.55			
1999	0.99	1.62	4.41			
2000	0.67	1.21	1.51			
2001	0.73	0.98	4.18			
2002	0.26	0.403	4.03			

Table B21. Mains, Outside Force Damage Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	Total
1990	4	4	3			11
1991	4	4	3			11
1992	1	3	8			12
1993	2	1	2			5
1994	7	10	1			18
1995	1	1	6			8
1996	4	3	7			14
1997	2	2	3			7
1998	1	1	7			9
1999	4	3	3			10
2000	2	1	4			7
2001	1	2	5			8
2002	1	1	1			3
	34	36	53	1	2	126
	Steel	**Cast Iron**	**Polyethylene Plastic**	**Other Plastic**	**Other**	
1990	600,000	54,053	212,800			
1991	585,000	55,450	220,000			
1992	580,000	55,242	230,000			
1993	593,940	53,543	250,000			
1994	607,880	52,223	280,000			
1995	603,396	50,660	310,000			
1996	573,136	49,106	332,000			
1997	558,550	47,551	356,000			
1998	569,908	46,023	380,000			
1999	542,289	46,541	388,686			
2000	551,865	45,105	417,660			
2001	554,855	44,169	472,082			
2002	569,000	45,577	505,000			
	Steel	**Cast Iron**	**Polyethylene Plastic**	**Other Plastic**	**Other**	
1990	0.67	7.40	1.41			
1991	0.68	7.21	1.36			
1992	0.17	5.43	3.48			
1993	0.34	1.87	0.80			
1994	1.15	19.15	0.36			
1995	0.17	1.97	1.94			
1996	0.70	6.11	2.11			
1997	0.36	4.21	0.84			
1998	0.18	2.17	1.84			
1999	0.74	6.45	0.77			
2000	0.36	2.22	0.96			
2001	0.18	4.53	1.06			
2002	0.18	2.19	0.20			

Table B38H. Outside Force Damage, Serious Incidents by Category

	1st / 2nd Party	3rd Party	Earth Movement	Landslide / Washout	No Data	Total
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						
2002						
	13	208	46	9	4	280

Table B38B. Mains, Outside Force Damage Serious Incidents by Category

	1st / 2nd Party	3rd Party	Earth Movement	No Data	Total
1990		4			
1991		8			
1992		9			
1993		2			
1994		7			
1995		7			
1996		10			
1997		6			
1998		9			
1999		6			
2000		4			
2001		8			
2002		3			
	7	83	33	2	125
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Other / No Data**	
1990		889,566			
1991		888,558			
1992		891,171			
1993		923,670			
1994		968,193			
1995		988,818			
1996		980,900			
1997		991,390			
1998		1,025,492			
1999		1,006,580			
2000		1,041,159			
2001		1,099,500			
2002		1,143,949			
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Other / No Data**	
1990		0.45			
1991		0.90			
1992		1.01			
1993		0.22			
1994		0.72			
1995		0.71			
1996		1.02			
1997		0.61			
1998		0.88			
1999		0.60			
2000		0.38			
2001		0.73			
2002		0.26			

Table B38E. Steel Mains, Outside Force Damage Serious Incidents by Category

	1st / 2nd Party	3rd Party	Earth Movement	No Data	Total
1990		2			
1991		4			
1992		1			
1993		1			
1994		6			
1995		1			
1996		2			
1997		2			
1998		1			
1999		3			
2000		2			
2001		1			
2002		1			
	2	27	4	1	34
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Other / No Data**	
1990		600,000			
1991		585,000			
1992		580,000			
1993		593,940			
1994		607,880			
1995		603,396			
1996		573,136			
1997		558,550			
1998		569,908			
1999		542,289			
2000		551,865			
2001		554,855			
2002		569,000			
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Other / No Data**	
1990		0.33			
1991		0.68			
1992		0.17			
1993		0.17			
1994		0.99			
1995		0.17			
1996		0.35			
1997		0.36			
1998		0.18			
1999		0.55			
2000		0.36			
2001		0.18			
2002		0.18			

Table B38C. Cast Iron Mains, Outside Force Damage Serious Incidents by Category

	1st / 2nd Party	3rd Party	Earth Movement	No Data	Total
1990			2		
1991			3		
1992			2		
1993			1		
1994			9		
1995			1		
1996			2		
1997			1		
1998			0		
1999			3		
2000			1		
2001			2		
2002			0		
	1	7	27	1	36
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Other / No Data**	
1990	54,053	54,053	54,053	54,053	
1991	55,450	55,450	55,450	55,450	
1992	55,242	55,242	55,242	55,242	
1993	53,543	53,543	53,543	53,543	
1994	52,223	52,223	52,223	52,223	
1995	50,660	50,660	50,660	50,660	
1996	49,106	49,106	49,106	49,106	
1997	47,551	47,551	47,551	47,551	
1998	46,023	46,023	46,023	46,023	
1999	46,541	46,541	46,541	46,541	
2000	45,105	45,105	45,105	45,105	
2001	44,169	44,169	44,169	44,169	
2002	45,577	45,577	45,577	45,577	
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Other / No Data**	
1990			3.70		
1991			5.41		
1992			3.62		
1993			1.87		
1994			17.23		
1995			1.97		
1996			4.07		
1997			2.10		
1998			0.00		
1999			6.45		
2000			2.22		
2001			4.53		
2002			0.00		

Table B38D. Polyethylene Mains, Outside Force Damage Serious Incidents by Category

	1st / 2nd Party	3rd Party	Earth Movement	No Data	Total
1990		2			
1991		3			
1992		6			
1993		0			
1994		0			
1995		6			
1996		7			
1997		3			
1998		7			
1999		3			
2000		4			
2001		5			
2002		1			
	4	47	2	0	53
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Other / No Data**	
1990		212,800			
1991		220,000			
1992		230,000			
1993		250,000			
1994		280,000			
1995		310,000			
1996		332,000			
1997		356,000			
1998		380,000			
1999		388,686			
2000		417,660			
2001		472,082			
2002		505,000			
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Other / No Data**	
1990		0.94			
1991		1.36			
1992		2.61			
1993		0.00			
1994		0.00			
1995		1.94			
1996		2.11			
1997		0.84			
1998		1.84			
1999		0.77			
2000		0.96			
2001		1.06			
2002		0.20			

Table B24. Service Lines, Outside Force Damage Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	Total
1990	3		3			
1991	4		3			
1992	3		3			
1993	4		2			
1994	3		4			
1995	2		6			
1996	0		6			
1997	2		6			
1998	6		7			
1999	5		5			
2000	3		4			
2001	2		3			
2002	0		2			
	37	0	54	3	8	102
	Steel	**Cast Iron**	**Polyethylene Plastic**	**Other Plastic**	**Other**	
1990	315,247		204,063			
1991	301,203		223,807			
1992	316,760		237,149			
1993	302,419		238,862			
1994	349,680		283,500			
1995	328,093		288,494			
1996	285,584		282,322			
1997	284,407		318,910			
1998	284,784		326,566			
1999	288,180		354,209			
2000	273,335		355,201			
2001	286,651		394,091			
2002	282,614		423,655			
	Steel	**Cast Iron**	**Polyethylene Plastic**	**Other Plastic**	**Other**	
1990	0.95		1.47			
1991	1.33		1.34			
1992	0.95		1.27			
1993	1.32		0.84			
1994	0.86		1.41			
1995	0.61		2.08			
1996	0.00		2.13			
1997	0.70		1.88			
1998	2.11		2.14			
1999	1.74		1.41			
2000	1.10		1.13			
2001	0.70		0.76			
2002	0.00		0.47			

Table B38F. Services, Outside Force Damage Serious Incidents by Category

	1st / 2nd Party	3rd Party	Earth Movement	Lightning / Fire	No Data	Total
1990		4				
1991		9				
1992		5				
1993		4				
1994		7				
1995		7				
1996		5				
1997		5				
1998		13				
1999		11				
2000		6				
2001		7				
2002		2				
	4	85	8	4	1	102
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Lightning / Fire**	**No Data**	**Total**
1990		559,833				
1991		564,364				
1992		593,804				
1993		587,026				
1994		684,510				
1995		668,039				
1996		620,657				
1997		637,490				
1998		645,969				
1999		680,823				
2000		663,175				
2001		716,909				
2002		744,933				
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Lightning / Fire**	**No Data**	**Total**
1990		0.71				
1991		1.59				
1992		0.84				
1993		0.68				
1994		1.02				
1995		1.05				
1996		0.81				
1997		0.78				
1998		2.01				
1999		1.62				
2000		0.90				
2001		0.98				
2002		0.27				

Table B38G. Steel Services, Outside Force Damage Serious Incidents by Category

	1st / 2nd Party	3rd Party	Earth Movement	Lightning / Fire	No Data	Total
1990		2				
1991		4				
1992		2				
1993		2				
1994		3				
1995		2				
1996		0				
1997		0				
1998		6				
1999		5				
2000		3				
2001		2				
2002		0				
	1	31	4	1	0	37
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Lightning / Fire**	**No Data**	**Total**
1990		315,247				
1991		301,203				
1992		316,760				
1993		302,419				
1994		349,680				
1995		328,093				
1996		285,584				
1997		284,407				
1998		284,784				
1999		288,180				
2000		273,335				
2001		286,651				
2002		282,614				
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Lightning / Fire**	**No Data**	**Total**
1990		0.63				
1991		1.33				
1992		0.63				
1993		0.66				
1994		0.86				
1995		0.61				
1996		0.00				
1997		0.00				
1998		2.11				
1999		1.74				
2000		1.10				
2001		0.70				
2002		0.00				

Table B38l. Polyethylene Services, Outside Force Damage Serious Incidents by Category

	1st / 2nd Party	3rd Party	Earth Movement	Lightning / Fire	No Data	Total
1990		2				
1991		3				
1992		3				
1993		2				
1994		4				
1995		5				
1996		5				
1997		5				
1998		6				
1999		5				
2000		3				
2001		3				
2002		1				
	3	47	1	2	1	54
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Lightning / Fire**	**No Data**	**Total**
1990		204,063				
1991		223,807				
1992		237,149				
1993		238,862				
1994		283,500				
1995		288,494				
1996		282,322				
1997		318,910				
1998		326,566				
1999		354,209				
2000		355,201				
2001		394,091				
2002		423,655				
	1st / 2nd Party	**3rd Party**	**Earth Movement**	**Lightning / Fire**	**No Data**	**Total**
1990		0.98				
1991		1.34				
1992		1.27				
1993		0.84				
1994		1.41				
1995		1.73				
1996		1.77				
1997		1.57				
1998		1.84				
1999		1.41				
2000		0.84				
2001		0.76				
2002		0.24				

Table B21A. Third Party Damage, Distribution Incidents

	Total Incidents				
1990	44				
1991	80				
1992	36				
1993	48				
1994	48				
1995	47				
1996	46				
1997	39				
1998	63				
1999	52				
2000	66				
2001	60				
2002	36				
	665				
	Total Mileage		**Main Mileage**	**Estimated Service Mileage**	**Total Mileage**
1990	1,449,399		889,566	559,833	1,449,399
1991	1,452,922		888,558	564,364	1,452,922
1992	1,484,975		891,171	593,804	1,484,975
1993	1,510,696		923,670	587,026	1,510,696
1994	1,652,703		968,193	684,510	1,652,703
1995	1,656,857		988,818	668,039	1,656,857
1996	1,601,556		980,900	620,657	1,601,556
1997	1,628,880		991,390	637,490	1,628,880
1998	1,671,461		1,025,492	645,969	1,671,461
1999	1,687,403		1,006,580	680,823	1,687,403
2000	1,704,334		1,041,159	663,175	1,704,334
2001	1,816,409		1,099,500	716,909	1,816,409
2002	1,888,882		1,143,949	744,933	1,888,882
	Total Incidents				
1990	3.0				
1991	5.5				
1992	2.4				
1993	3.2				
1994	2.9				
1995	2.8				
1996	2.9				
1997	2.4				
1998	3.8				
1999	3.1				
2000	3.9				
2001	3.3				
2002	1.9				

Table B21B. Third Party Damage, Serious Incidents by Part of System

	Main	Service Line	Meter Set Assembly	Other	No Data	Total
1990	5	4	2	1	0	12
1991	8	9	1	1	0	19
1992	9	5	3	0	0	17
1993	2	4	2	3	0	11
1994	7	7	1	5	0	20
1995	7	7	3	1	0	18
1996	10	5	1	1	0	17
1997	6	5	1	1	0	13
1998	9	13	1	1	0	24
1999	6	11	3	0	1	21
2000	6	6	0	1	0	13
2001	6	7	1	0	0	14
2002	3	2	3	1	0	9
	84	85	22	16	1	208
	Main	Service Line	Meter Set Assembly	Other	No Data	
1990	889,566	559,833				
1991	888,558	564,364				
1992	891,171	593,804				
1993	923,670	587,026				
1994	968,193	684,510				
1995	988,818	668,039				
1996	980,900	620,657				
1997	991,390	637,490				
1998	1,025,492	645,969				
1999	1,006,580	680,823				
2000	1,041,159	663,175				
2001	1,099,500	716,909				
2002	1,143,949	744,933				
	Main	Service Line	Meter Set Assembly	Other	No Data	
1990	0.56	0.71				
1991	0.90	1.59				
1992	1.01	0.84				
1993	0.22	0.68				
1994	0.72	1.02				
1995	0.71	1.05				
1996	1.02	0.81				
1997	0.61	0.78				
1998	0.88	2.01				
1999	0.60	1.62				
2000	0.58	0.90				
2001	0.55	0.98				
2002	0.26	0.27				

Table B22. Mains, Third Party Damage Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	Total
1990	2	1	2			5
1991	4	1	3			8
1992	1	0	6			7
1993	1	0	0			1
1994	6	1	0			7
1995	1	0	6			7
1996	2	1	7			10
1997	2	1	3			6
1998	1	1	7			9
1999	3	0	3			6
2000	2	0	2			4
2001	1	0	7			8
2002	1	1	1	1	2	6
	27	7	47	1	2	84
	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	
1990	600,000	54,053	212,800			
1991	585,000	55,450	220,000			
1992	580,000	55,242	230,000			
1993	593,940	53,543	250,000			
1994	607,880	52,223	280,000			
1995	603,396	50,660	310,000			
1996	573,136	49,106	332,000			
1997	558,550	47,551	356,000			
1998	569,908	46,023	380,000			
1999	542,289	46,541	388,686			
2000	551,865	45,105	417,660			
2001	554,855	44,169	472,082			
2002	569,000	45,577	505,000			
	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	
1990	0.33	1.85	0.94			
1991	0.68	1.80	1.36			
1992	0.17	0.00	2.61			
1993	0.17	0.00	0.00			
1994	0.99	1.91	0.00			
1995	0.17	0.00	1.94			
1996	0.35	2.04	2.11			
1997	0.36	2.10	0.84			
1998	0.18	2.17	1.84			
1999	0.55	0.00	0.77			
2000	0.36	0.00	0.48			
2001	0.18	0.00	1.48			
2002	0.18	2.19	0.20			

Table B25. Service Lines, Third Party Damage Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	No Data	Total
1990	2		2				
1991	4		3				
1992	2		3				
1993	2		2				
1994	3		4				
1995	2		5				
1996	0		5				
1997	0		5				
1998	6		6				
1999	5		5				
2000	3		3				
2001	2		3				
2002	0		1				
	31	0	47	1	2	4	85
	Steel	**Cast Iron**	**Polyethylene Plastic**	**Other Plastic**	**Other**	**No Data**	
1990	315,247		204,063				
1991	301,203		223,807				
1992	316,760		237,149				
1993	302,419		238,862				
1994	349,680		283,500				
1995	328,093		288,494				
1996	285,584		282,322				
1997	284,407		318,910				
1998	284,784		326,566				
1999	288,180		354,209				
2000	273,335		355,201				
2001	286,651		394,091				
2002	282,614		423,655				
	Steel	**Cast Iron**	**Polyethylene Plastic**	**Other Plastic**	**Other**	**No Data**	
1990	0.63		0.98				
1991	1.33		1.34				
1992	0.63		1.27				
1993	0.66		0.84				
1994	0.86		1.41				
1995	0.61		1.73				
1996	0.00		1.77				
1997	0.00		1.57				
1998	2.11		1.84				
1999	1.74		1.41				
2000	1.10		0.84				
2001	0.70		0.76				
2002	0.00		0.24				

Table B23. Mains, Earth Movement Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	Total
1990		2				
1991		3				
1992		2				
1993		1				
1994		9				
1995		1				
1996		2				
1997		1				
1998		0				
1999		3				
2000		1				
2001		2				
2002		0				
	4	27	2	0	0	33
	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	
1990		54,053				
1991		55,450				
1992		55,242				
1993		53,543				
1994		52,223				
1995		50,660				
1996		49,106				
1997		47,551				
1998		46,023				
1999		46,541				
2000		45,105				
2001		44,169				
2002		45,577				
	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	
1990		3.70				
1991		5.41				
1992		3.62				
1993		1.87				
1994		17.23				
1995		1.97				
1996		4.07				
1997		2.10				
1998		0.00				
1999		6.45				
2000		2.22				
2001		4.53				
2002		0.00				

Table B26. Service Lines, Earth Movement Serious Incidents by Material of Construction

	Steel	Cast Iron	Polyethylene Plastic	Other Plastic	Other	Total
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						
2002						
	4	0	1	2	1	8

Table B27. Construction/Operating Error, Serious Incidents by Part of System

	Main	Service Line	Meter Set Assembly	Other	No Data	Total
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						
2002						
	39	6	3	10	1	59

Table B28. Accidentally Caused by Operator, Serious Incidents by Part of System

	Main	Service Line	Meter Set Assembly	Other	No Data	Total
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						
2002						
	36	15	2	6	0	59

Table B29. Other/No Data, Serious Incidents by Part of System

	Main	Service Line	Meter Set Assembly	Other	No Data	Total
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						
2002						
	52	25	8	66	13	164