Environmental Releases from E&P Operations in Oklahoma: Type, Volume, Causes and Prevention

J. Berton Fisher*
Center for Applied Biogeosciences
University of Tulsa
600 S. College Ave.
Tulsa, OK 74104
Phone: 918-631-3014
Fax: 918-631-2091
jbfisher@utulsa.edu

Kerry L. Sublette
Center for Applied Biogeosciences
University of Tulsa
600 South College Avenue
Tulsa, OK 74104
Phone: (918) 631-3085
Fax: (918) 631-3268
kerry-sublette@utulsa.edu

*corresponding author

ACKNOWLEDGEMENTS

The authors wish to thank the Oklahoma Corporation Commission (OCC) for access to the data reviewed in this paper. We also wish to thank Mike Schmidt, formerly of the OCC, for having the foresight to initiate the OCC Complaint Database in 1992.

ABSTRACT

A total of 16,906 recent fluid releases were reported to the Oklahoma Corporation Commission (OCC) during the ten-year period from 1993 to 2003. Of these, 12,863 were identified as exploration and production-related releases of oil or saltwater from identified geographic areas. The primary reported origins of oil and saltwater releases were leaks from lines, tanks, wellheads, surface equipment and pits. Important reported causes of fluid releases range from common overflows (tank, pit and dike), intentional dumping or other illegal activity, storms, fires or explosions, accidents (including the actions of livestock) and to occasional corrosion. Approximately 34% of all recent oil or saltwater releases resulted in reported injury to environmental receptors (surface water, crops or livestock, soil, fish or wildlife). For the ten year period of record, 41% of all E&P complaints to OCC involved the release of oil or

saltwater. On an annual basis, complaints involving the release of fluids decreased from 65.8% in 1993 to 46.1% in 2002. Releases specifically identified as involving oil or saltwater comprised 76.1% of all fluid releases. Quantified releases of oil had a median volume of 10 barrels (bbl), while quantified releases of saltwater had a median volume of 40 bbl. For those releases in which the volume of both oil and saltwater were quantified, the volume of saltwater spilled was approximately 76% of the total volume.

INTRODUCTION

Most oil and gas regulatory bodies prohibit pollution. For example, the Oklahoma Administrative Code provides at 165:10-7-5(a) that, **"**Pollution is prohibited. All operators, contractors, drillers, service companies, pit operators, transporters, pipeline companies, or other persons shall at all times conduct their operations in a manner that will not cause pollution." Even so, petroleum production, drilling operations, and improperly abandoned wells have caused contamination of surface and ground waters and soils in energy producing states (USEPA, 1987; Richter and Kreitler, 1993; Kharaka and others, 1995; Kharaka and Hanor, 2003). Surprisingly, even though pollution prevention, **r**ational management and decision making regarding environmental issues requires information, little is known about the specific origins, causes, and magnitudes of pollution incidents that result from exploration and production activities.

Although extensive statistical data are maintained by both governmental and private entities concerning releases of crude oil in marine environments, little information has been compiled concerning releases of crude oil or saltwater from onshore oil and gas exploration and production operations. The National Response System (NRS) operated by the National

Response Center (NRC) is the federal government's mechanism for emergency response to discharges of oil and the release of chemicals into the navigable waters or environment of the United States and its territories. Although this system initially focused on oil spills and selected hazardous polluting substances discharged into the environment, it has since been expanded by other legislation to include hazardous substances and wastes released to all types of media. (National Response Center, 2002a). Data regarding releases reported to the NRC are available online for the period 1982 through 2004 (National Response Center, 2002b). These data reflect a broad spectrum of released materials from a variety of sources. Spill reporting requirements vary by the governing statute. For oils, releases are to be reported to the NRC only if the releases violates applicable water quality standards, causes a film, sheen or discoloration of the water or adjoining shoreline, or causes a sludge or an emulsion to be deposited beneath the surface of the water or upon the adjoining shorelines (40 CFR Part 110.10, Part 300.300). Although there is no specific minimum reportable quantity for oils, reporting is required only for those oil spills that have some impact on inland or marine surface waters. There are no clear requirements to report oil spills that do not have a direct impact on surface waters, and as a consequence, the NRS data cannot be relied upon to evaluate onshore spills that do not impact surface waters. According to NRC data, in 2003 the NRC received 31,892 calls and recorded 29,702 incidents involving one or more identifiable materials released. Of these, just slightly fewer than 2,000 of these reported incidents involved the release of material that could be easily determined to reflect a release of crude oil or condensate, and of these, 407 specified soil or land as the affected medium and 1,482 indicated that water was the affected medium. In addition, the NRC data are inconsistent in their geographic specificity. Public land survey locations are not reported, and, although some reports provide specific addresses, most provide far less specific

location data. In short, data from NRC is focused on capturing release data as required by specific statutes, and, because of statutory reporting requirements, release data regarding releases of crude oil and condensate are biased toward releases that impact surface water. As a consequence, release data from the NRC are of limited value in examining releases from exploration and production activities.

Beginning in about 1992 and continuing through at least 2002, the Oklahoma Corporation Commission (OCC) established and maintained an Access database containing information derived from complaints made to the OCC. These data were largely specific to oil and gas exploration and production, were typically highly specific geographically (i.e. provided a location specific to a single section), often provided quantitative estimates of volumes of released fluids, and provided narrative information that could be abstracted to deduce the specific origins, causes, and environmental consequences of the release of oil and/or saltwater.

In this paper, we review the data compiled by OCC concerning the sources, causes, consequences, and locations of oil and saltwater releases from exploration and production activities in Oklahoma. We believe that this review is instructive concerning the most profitable foci for actions that can be taken by operators and regulatory entities to reduce or eliminate such releases. These data are equally instructive to technology developers and funders (whether public or private), and provide the opportunity to focus resources and initiatives on the most significant sources and causes of such releases.

METHODS

OCC Database

The source of the information reviewed for this study was an electronic compilation of complaints collected by the OCC in an Access database for the period 1993 through 2002 (Oklahoma Corporation Commission, 2002). The data reported in this paper were collected by reviewing narrative data for each complaint and abstracting information pertaining to the types and volumes of fluids released, the origins and causes of these releases, and environmental damage resulting from these releases

Determination of Release Timing

The narrative data were used to determine whether a spill was current or historic. Spills were considered 'recent' (i.e. occurring within the last 12 months of the report) if a release volume was estimated or if, the narrative provided evidence of a release from ongoing operations. For example, the narratives, "Oil spilling over top of tanks," and, "Flow line leak. Loss 25 BBL." were considered as representing evidence of current releases. In contrast, a narrative stating, "Oil and saltwater has killed vegetation. Old tank battery not in use. Fence around tanks is down. Lease road not maintained." was considered evidence of an historic release. In some instances, it was impossible to determine from the narrative whether or not a spill was recent or historic. For example, a narrative stating, "Oil contaminated soil", is silent as to the time of the fluid release. In these instances, the fluid release was considered to be historic.

Determination of Fluid Release Volumes

All numeric reports of release volumes were converted to units of 42 U.S. gallon barrels (bbl). Qualitative reports of oil release volume were assigned fractional bbl values. For oil

releases, the term “sheen” was assigned a value of 0.001 bbl, and the term “trace” was assigned a value of 0.01 bbl. For saltwater spills, qualitative terms describing release volume were not assigned numeric values. In some instances, a specific volume for released fluid was reported, but no information was provided as to the type of fluid released. In these cases it was assumed that the released fluid was a mixture of oil and saltwater, and the reported release volume was apportioned into separate volumes based on knowledge of those fluid releases involving both oil and saltwater for which the volumes of oil and saltwater were known. Estimates of the volume of oil and saltwater released in events for which no quantitative or qualitative volumetric data were available were assigned the mean volume of oil or saltwater for the year in which the release took place.

Sources and Causes of Fluid Releases and Damages

The sources of fluid release were categorized by location with respect to production and other operations. In general, the sources of fluid release were classified as “well” (occurring at a wellhead), “flowline” (occurring as the consequence of a breach in the piping connecting wells to tank batteries or a breach in a saltwater disposal line), “surface equipment” (occurring at a piece of fluid processing equipment such as a heater treater or pump), tank (occurring as the consequence of an operational failure related to a tank such as an overflow, leak, or load line failure) and “pit” (occurring as the consequence of a breach, overflow or other failure related to a pit). The record of a release was sometimes related to multiple sources of fluid release.

The causes of fluid release were categorized as due to overflows (tank, dike, pit), storms (flood, rainfall, lightening, etc.), fires and explosions, corrosion, illegal activity (theft, dumping and vandalism) and accidents (accidental damage to equipment and accidental valve openings by livestock).

Injury resulting from fluid release was categorized by affected receptor. If oil or saltwater reached a stream, lake or pond, an injury to “surface water” was recorded. Any release of oil or salt water that resulted in death or injury to livestock or damage to a crop or to pasture was recorded as an injury to “crop/stock”. Contamination of soil outside of containment structures was classified as an injury to “soil”. If oil or saltwater contamination resulted in soil erosion, the injury was categorized as “erosion”. For instances in which oil or saltwater was stated as having harmed groundwater or any instance in which groundwater contamination was reported in conjunction with oilfield operations the injury was categorized as “groundwater”. If a release of oil or saltwater was reported to have injured or killed fish or wildlife, the injury was categorized as “wildlife”. A single release of oil or saltwater could cause injury to multiple environmental receptors.

RESULTS AND DISCUSSION

Crude Oil Releases 1993-2002

Summary data for recent releases of crude oil at exploration and production sites in Oklahoma, as well as the average oil spot price, and total Oklahoma liquids (oil + condensate) production data are given in Table 1. Based on these data, on average, about 850 fluid releases containing oil occurred each year, and those releases averaged ~62,000 bbl annually. The data indicate that spills were typically small (50% of all quantified spills are 10 bbl or less and 75% of all quantified oil spills were 35 bbl or less), but large (>500 bbl) spills did occur each year.

There appears to have been a change in oil spill reporting during the course of development of the database. The percentage of unquantified spills was about 46% in 1993 and showed a progressive increase to about 70% by 2002. This may reflect greater reporting of oil

spills in later years. The average size of quantified oil spills remained relatively constant (34-46 bbl) during the period of record.

Saltwater Releases 1993-2002

Summary data for releases of saltwater at exploration and production sites in Oklahoma are given in Table 2. Based on these data, on average, 790 fluid releases containing saltwater occurred each year, and those releases averaged ~146,000 bbl annually. The data indicate that spills were typically small (overall 50% of all quantified spills were 40 bbl or less and 75% of all quantified oil spills were 100 bbl or less), but large (>500 bbl) spills did occur each year. As with oil spills there appears to have been a change in saltwater spill reporting. The percentage of unquantified spills was about 50% in 1993 and showed a progressive increase to about 70% by 2002. Aside from 2001, the average size of saltwater spills remained relatively constant (89-158 bbl) during the period of record.

Crude Oil and Saltwater Release Drivers 1993-2002

During the ten-year period reviewed, exploration and production operations in Oklahoma are estimated to have released 620,025 bbl of crude oil and 1,460,154 bbl of saltwater. There does not appear to be any correlation between oil price and the number or size of spills of either oil or saltwater during the period of record. The average size of oil spills for the period 1993 through 2002 remained relatively constant (34 bbl to 46 bbl) during the period of record. Further, given that oil production in Oklahoma has declined by about 32% from 1993 to 2002 (Oklahoma Corporation Commission, 2003.), it could be argued that releases of both oil and saltwater have actually increased with respect to the total volume of oil produced. To put the volume of oil released from exploration and production operations in Oklahoma in perspective, for the ten-year period between 1992- 2001, the U.S. Coast Guard (2003) reported

that the average crude oil spill to water ranged between 2.6 and 13.1 bbl, and the cumulative crude oil released to marine coastal waters during this period was 93,366 bbl. Consequently, the estimated volume of crude oil released in Oklahoma from exploration and production operations for the 10-year period of record reflected by the OCC database was about six times greater than all crude oil spills to coastal marine waters recorded by the U. S. Coast Guard form all sources between 1992 and 2001. In total, the amount of oil released in Oklahoma from exploration and production activities was about 2.2 times the oil lost from the Exxon Valdez in March 1989 (National Oceanic and Atmospheric Agency, 1992).

Sources of Crude Oil and Saltwater Release

Crude Oil Releases 1993-2002

Summary data concerning the source of released oil are given in Table 3. The majority of oil releases classifiable by source were from lines, followed closely by tanks and wells. Surface equipment served as the source for substantially fewer releases, and pits accounted for approximately half the number of releases as surface equipment. A substantial number of oil releases were from other identified sources or from an unclassified source. With respect to those spills from identified sources for which the volume of released oil was quantified, pits had the highest median release volume (34 bbl) followed by tanks (30 bbl), surface equipment (15 bbl), lines (10 bbl) and wells (3 bbl). Oil releases from both tanks and pits exceeded 80 bbl in 25% of all reported quantified occurrences, but exceeded only 35 bbl when the source of release was surface equipment and only 30 bbl when the source of release was a line. When wells were the source of oil release, 25% of all reported quantified occurrences exceeded 10 bbl. The largest releases of oil were from tanks with a maximum value of 89,000 bbl; followed by lines (3,000 bbl), surface equipment (2,000 bbl), wells (250 bbl) and pits (170 bbl).

Saltwater Releases 1993-2002

Summary data concerning the source of released saltwater are given in Table 4. The majority of classifiable saltwater releases were from lines, followed by tanks and wells. Surface equipment served as the source for substantially fewer releases, and pits accounted for less than half the number of releases as surface equipment. A substantial number of saltwater releases were from another identified source or from an unclassified source. With respect to those spills from identified sources for which the volume of released saltwater was quantified, pits had the highest median release volume (81 bbl) followed by tanks (48 bbl), lines (40 bbl), surface equipment (30 bbl), and wells (10 bbl). Saltwater releases from both surface equipment and pits exceeded 120 bbl and 125 bbl, respectively, in 25% of all reported quantified occurrences. Tanks and lines exceeded 106 bbl and 100 bbl, respectively, in 25% of all reported quantified saltwater release occurrences. Although it is generally believed that purging wells and casing leaks are significant sources of saltwater release, this belief is not supported by these data which, in fact, suggest that wells were unlikely sources of large saltwater releases. When the source of a saltwater release was a well, saltwater release volume exceeded 30 bbl in only 25% of all reported quantified occurrences. The largest releases of saltwater were associated with lines (5,000 bbl maximum) followed by tanks (2,700 bbl), surface equipment (1,800 bbl), pits (600 bbl) and wells (400 bbl).

Overview of Release Sources

For both oil and saltwater, tanks and lines were the source of about 80% of the total estimated volume of both fluids when a source of release was identified. Tanks were the more important source for oil release (46.7% of total estimated volume released), while lines were the more substantial origin of saltwater release (~48 % of total estimated volume released).

Causes of Crude Oil and Saltwater Release

Crude Oil Releases 1993-2002

Summary data concerning the cause of oil release are given in Table 5. Overflows (dominantly of tanks) were the most frequently reported cause of oil release. Releases of oil due to illegal activity (theft, vandalism, dumping, etc) and storms were reported with approximately equal frequency, followed by releases due to fire and equal numbers of releases due to corrosion and accidents. With respect to those releases with identified causes for which the volume of released oil was quantified, fires had the highest median release volume (35 bbl) followed by illegal activity (30 bbl), storms (23 bbl), overflows (20 bbl), and wells (20 bbl). Although overflows resulted in the largest reported oil release (89,000 bbl), releases due to overflows exceeded 50 bbl in only 25% of the reported quantified occurrences. Illegal activity resulted in quantified oil releases that exceeded 130 bbl in 25% of reported quantified occurrences, and releases due to fires and accidents exceeded 100 bbl in 25% of reported quantified occurrences. Oil releases due to storms exceeded 80 bbl in 25% of reported quantified occurrences, and exceeded 45 bbl in 25% of reported occurrences when caused by noted corrosion. The largest oil releases were caused by overflows (89,000 bbl maximum), followed by corrosion (1,200 bbl), fire (1,000 bbl), illegal activity (500 bbl), and storms (300 bbl).

Saltwater Releases 1993-2002

Summary data concerning the cause of saltwater release are given in Table 6. Overflows (dominantly of tanks) were overwhelmingly (~50% of all releases for which a cause was reported) the most frequently reported cause of saltwater release followed by illegal activity, storms, fire, accidents and corrosion. Storms resulted in the greatest median release volume (60 bbl) followed by overflows (50 bbl), fires (48 bbl), illegal activity (theft, vandalism, dumping,

etc.) (47 bbl), accidents (25 bbl) and corrosion (20 bbl). The largest releases were due to illegal activity (25% of saltwater releases due to illegal activity were greater than 100 bbl with a maximum quantified release of 2,800 bbl) and overflows (25% of saltwater releases due to overflows were greater than 160 bbl with a maximum quantified release of 1,450 bbl).

Overview of Release Causes

Overflows accounted for nearly 50% of all incidents involving saltwater and nearly 35% of all incidents involving oil. When the volume of fluid release is considered, overflows completely dominated the causes of oil release (~83% of the total estimated volume released), and substantially dominated saltwater release (~54% of the estimated volume of saltwater released). Although line leaks result in the release of more saltwater, line leaks were infrequently assigned a cause. Based on the field experience of the authors, the dominant cause of line leaks was likely corrosion. Illegal activity (theft, vandalism, dumping, etc.) was a frequent cause of both oil and saltwater release (~15% of reported incidents). When estimated release volume was considered, however, illegal activity was a substantially more important cause for saltwater release (~24 % of total estimated volume released) than for oil release (~5% of the total estimated volume released). Storm events accounted for ~10% of the total estimated volume of saltwater released but was a minor cause of oil released (<5% of the total estimated volume released).

Geography of Oil and Saltwater Releases

Because much more saltwater is produced with oil than with gas, releases of crude oil and saltwater were more closely allied to oil production than to gas production. Based on data obtained from Oklahoma Corporation Commission (2003), Oklahoma counties were classified as dominantly oil producing if the ratio of oil wells to gas wells was > 0.5, while those with an

oil well to gas well ratio < 0.5 were considered gas producing. Oil producing counties accounted for 81.6 of all complaints involving oil releases and 82.4% of all complaints involving saltwater releases. In contrast, gas producing counties accounted for only 18.4% of all complaints involving oil releases and 17.6% of all complaints involving saltwater releases. Not surprisingly, there is a strong relationship between the total hydrocarbon fluids produced in a county and the number of complaints concerning releases of oil or saltwater. If, for example, the number of complaints concerning oil release within each Oklahoma county is plotted against total liquid hydrocarbon production (1993-2002), the relationship is remarkably linear (see Figure 1). One way to analyze these data is to examine the residuals about the regression line. The counties with the greatest positive residuals (i.e the actual number of complaints concerning oil release is higher than expected based on reported production) were Pittsburg, Tulsa, Okmulgee, Creek, Seminole, Pontotoc, and Pottawatomie. The same analysis applied to saltwater releases reached the same conclusion.

Impacts of Release

Crude Oil Releases 1993-2002

Summary data concerning the impact of oil releases are given in Table 7. The most frequently reported impact of oil release was injury to surface water, followed by crop or stock injury, soil injury, soil erosion, groundwater injury, and wildlife injury. This is the same frequency order as that observed for saltwater releases (see below). Releases of oil resulting in injury to groundwater or in soil erosion had the largest median release volumes (20 bbl). Releases resulting in surface water or soil injury, or injury to crops or stock all had median release volumes of 10 bbl. Most releases of oil that resulted in reported environmental injury were small. For all of the injuries reported, spills exceeded 30 to 35 bbl in only 25% of all

quantified occurrences, and exceeded 50 bbl in 25% of quantified occurrences reporting soil damage.

Saltwater Releases 1993-2002

Summary data concerning the impact of saltwater release are given in Table 8. The most frequently reported impact of saltwater release was injury to surface water, followed by crop or stock injury, soil injury and erosion, groundwater injury and wildlife injury. This is the same frequency order as that observed for oil releases. Releases of saltwater resulting in injury to surface water had a median value of 80 bbl followed by those resulting in damage to crops or stock (45 bbl) and soil (40 bbl). The number of quantified saltwater releases reported that involved soil erosion (3 quantified occurrences), groundwater injury (2 quantified occurrences) or (wildlife injury (1 quantified occurrence) were small, and consequently, discussion of saltwater release volumes not statistically meaningful. Saltwater releases that resulted in reported environmental injury to surface water exceeded 250 bbl in only 25% of all reported quantified occurrences. Saltwater releases that resulted in injury to soil exceeded 140 bbl in 25% of all reported quantified occurrences. Saltwater releases that resulted in injury to crops or stock exceeded 100 bbl in 25% of all reported quantified occurrences. Saltwater releases that resulted in soil erosion exceeded 80 bbl in 25% of all reported quantified occurrences.

Overview of Impacts

For oil, 29.4 % of all quantified oil releases produced environmental injury, and for saltwater, 21.6% of all quantified saltwater releases produced environmental injury. On average, then, about 170 incidents of environmental injury due to saltwater release, and about 250 such incidents due to oil release would be expected each year as the consequence of exploration and production operations in Oklahoma. For oil, the median reported volume for releases resulting

in environmental injury (10 bbl) was equal to the median for all oil releases with reported volume estimates. Moreover, the maximum oil release volume with reported environmental damage was only 2,000 bbls and only 25% of oil releases with reported injury to environmental receptors exceeded 30 bbls. For saltwater, the median reported volume for releases resulting in environmental damage was 60 bbl (the 60th percentile value for all quantified saltwater releases). The maximum saltwater volume released that produced environmental damage was 10,000 bbl, and only 25% of saltwater releases with reported environmental damage exceeded 166.5 bbl (~ the 83.5th percentile value for all quantified saltwater releases).

CONCLUSIONS

A substantial volume of oil and saltwater is released to the environment every year from exploration and production operations in Oklahoma. Tanks and lines were by far the most significant sources of oil and saltwater releases when a source of release was given. Overflows, principally of tanks, were the most significant cause of both oil and saltwater release when a cause of release was reported. The greatest potential reduction in the release of oil and saltwater from exploration and production activities in Oklahoma would be achieved if fluid releases from tanks and lines were eliminated. Consequently, the OCC, oil and gas producers, and technology developers and funding agencies should focus resources on the maintenance of tanks and line systems. Such a focus would produce an immediate decrease in environmental releases of oil and saltwater from exploration and production operations in Oklahoma. Of particular interest would be corrective action focused on the elimination of tank overflows. In addition, resources should be focused on monitoring, replacing and repairing flowlines. Pittsburg, Tulsa, Okmulgee, Creek, Seminole, Pontotoc, and Pottawatomie counties exhibited a higher frequency of complaints concerning oil and saltwater release than would be expected based on the total

monthly production of liquid hydrocarbons in these counties. A potentially effective strategy for focusing and leveraging enforcement and financial resources to reduce the frequency and severity of oil and saltwater releases from exploration and production activities could be to focus these efforts on area with higher than expected spill frequency or severity. Injury to environmental receptors is a frequent consequence of oil or saltwater release of from exploration and production operations, and injury to environmental receptors is reported from relatively small releases of oil and from releases of saltwater that were only slightly larger than the overall median saltwater release for all quantified saltwater releases.

REFERENCES

Kharaka, Y.K., J.J. Thordsen, and G. Ambats, 1995. *Environmental degradation associated with exploration for and production of energy sources in USA, in* Kharaka, Y.K., and Chudaev, O.V., eds., Water-Rock Interaction (WRI-8): Rotterdam, A.A. Balkema, p. 25-30.

Kharaka, Y.K. and J.S. Hanor, 2003, *Deep fluids in the continents: I. Sedimentary basins*: In Drever, J.I., ed., Treatise on Geochemistry, v.16, p. 294-336.

National Response Center, 2002a. National Response System. <http://www.nrc.uscg.mil/nrsinfo.html>, January 15, 2004.

National Response Center, 2002b. Download NRC Data. <http://www.nrc.uscg.mil/download.html>, January 15, 2004.

National Oceanic and Atmospheric Agency, 1992. Oil Spill Case Histories 1967-1991, Summaries of Significant U.S. and International Spills. Report No. HMRAD 92-11.

Oklahoma Corporation Commission, 2002. Environmental Complaints Data (November 25, 2002).

Oklahoma Corporation Commission, 2003, 2002 Report on Crude Oil and Natural Gas Activity Within the State of Oklahoma, <http://www.occ.state.ok.us/>, March 17, 2004.

Richter, B.C. and C.W. Kreitler, 1993, Geochemical techniques for identifying sources of ground-water salinization: Boca Raton, C. K. Smoley, CRC Press, 258 p.

Tukey, J. W. (1977). Exploratory data analysis: Reading, MA, Addison-Wesley Publishing Company.

United States Coast Guard, 2003, U. S. Coast Guard Polluting Incident Compendium, Cumulative Data and Graphics for Oil Spills 1973-2001, < http://www.uscg.mil/hq/g-m/nmc/response/stats/summary.htm>, March 17, 2004.

United States Department of Energy, Energy Information Administration. U. S. Crude Oil, <http://www.eia.doe.gov/oil_gas/petroleum/info_glance/crudeoil.html>, March 16, 2004.

United States Environmental Protection Agency, 1987, Management of wastes from the exploration, development and production of crude oil, natural gas and geothermal energy: EPA/530-SW-88-003.

Dr. J. Berton Fisher is Assistant Professor of Geosciences at the University of Tulsa and President of Lithochimeia, Inc. Dr. Fisher is a geochemist with extensive experience in the applied biogeochemistry of organic and inorganic materials. His principal research interests are the application of biogeochemical knowledge to environmental issues and hydrocarbon exploration and production problems.

Dr. Kerry Sublette is Professor of Chemical Engineering and Geosciences and Sarkeys Chair of Environmental Engineering at the University of Tulsa. He also serves as the Director of the Integrated Petroleum Environmental Consortium (IPEC), an EPA Research Center. His research interests include the remediation of oil and brine contaminated sites and ecological indicators of the restoration of damaged soil ecosystems.

Table 1. Reported and Estimated Release of Oil from Oil and Gas Production Activities in Oklahoma 1993 through 2002.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Average Spot Oil Price at Cushing, OK ($/bbl)[1]	$18.43	$17.20	$18.43	$22.12	$20.61	$14.42	$19.35	$30.38	$25.98	$26.19	--
Oklahoma Liquids Production (bbl x 10^6)[2]	96.8	91.0	87.65	85.62	83.4	77.8	71.0	69.0	68.8	66.0	**797.07**
Maximum (bbl)	1,200	3,000	89,000	1,400	2,310	1,500	1,000	350	3,000	600	--
Q3 (bbl)	25	25	30	35	37.5	35	30	52.25	50	34	--
Median (bbl)	9.5	10	10	10	10	10	15	15	15	10	--
Mean (bbl)	45.3	42.3	295	45.9	58	42.1	36.5	39.8	58.5	34	--
Q1 (bbl)	3	3	3	3	4	4	3	4.75	4.25	3.25	--
Minimum (bbl)	0.07	0.01	0.01	0.005	0.01	0.01	0.001	0.1	0.01	0.001	--
Number of Quantitative Reports	204	452	344	319	280	231	224	180	214	191	**2,639**
Total Spills Involving Oil (number)	423	1012	935	907	815	880	935	909	973	740	**8,529**
Total Quantified Oil Spills (number)	204	452	344	319	280	231	224	180	214	191	**2,639**
Total Unquantified Oil Spills (number)	195	484	531	535	485	613	665	684	697	509	**5,398**
Total Quantified Oil+Saltwater Spills	24	76	60	53	50	36	46	45	62	40	**492**
Oil from Quantified Spills (bbl)	9,247	19,175	101,476	14,642	16,235	9,724	8,205	7,167	12,529	6,485	**204,885**
Estimated Oil from Unquantified Spills (bbl)	8,834	20,473	156,645	24,557	28,130	25,807	24,273	27,223	40,775	17,306	**374,023**
Estimated Oil from Oil+Saltwater Spills (bbl)	231	732	578	510	482	347	443	434	597	385	**4,739**
Estimate of Total Oil Released (bbl)	19,307	43,163	275,660	42,056	48,346	37,548	34,432	36,531	57,417	25,565	**620,025**

[1] United States Department of Energy, Energy Information Administration (2004). U. S. Crude Oil, downloaded from http://www.eia.doe.gov/oil_gas/petroleum/info_glance/crudeoil.html on March 16, 2004.
[2] Oklahoma Corporation Commission (2003).

Table 2. Reported and Estimated Release of Saltwater (SW) from Oil and Gas Production Activities in Oklahoma 1993 through 2002.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Maximum (bbl)	1,100	2,000	1,500	10,000	2,800	2,500	2,800	5,000	80,000	3,000	**80,000**
Q3 (bbl)	100	100	100	100	125	100	100	120	155	78	**100**
Median (bbl)	36.3	37.1	35.0	50.0	45.0	49.5	50.0	50.0	51.0	40.0	**40.0**
Mean (bbl)	94.0	130.4	88.7	155.2	141.5	115.6	157.6	132.9	745.9	131.7	**165.6**
Q1 (bbl)	10	10	10	15	15	19	20	20	20	15	**15**
Minimum (bbl)	0.01	0.01	0.00	0.10	0.01	0.05	0.25	0.10	0.50	0.02	**0.001**
Number of Quantitative Reports	161	333	333	333	270	236	218	155	144	182	**2365**
Total Spills Involving SW (number)	373	844	913	880	806	825	886	853	826	710	**7,916**
Total Quantified SW Spills (number)	161	333	333	333	270	236	218	155	144	182	**2,365**
Total Unquantified SW Spills (number)	188	435	520	494	486	553	622	653	620	488	**5,059**
Total Quantified Oil+SW Spills	24	76	60	53	50	36	46	45	62	40	**492**
SW from Quantified Spills (bbl)	15,138	43,430	29,528	51,691	38,211	27,273	34,350	20,603	107,407	23,971	**391,602**
Estimated SW from Unquantified Spills (bbl)	17,676	56,733	46,109	76,683	68,779	63,906	98,008	86,799	462,447	64,273	**1,041,413**
Estimated Oil from Oil+SW Spills (bbl)	1,324	4,192	3,310	2,923	2,758	1,986	2,537	2,482	3,420	2,206	**27,138**
Estimate of Total SW Released (bbl)	34,138	104,356	78,946	131,298	109,748	93,165	134,895	109,884	573,274	90,451	**1,460,155**

Table 3. Total and Quantified Reported Releases of Oil from Oil and Gas Production Activities in Oklahoma 1993 through 2002 Classified by Reported Origin of Release.

Origin	Total	Quantified	Minimum (bbls)	Q1 (bbl)	Median (bbl)	Mean (bbl)	Q3 (bbl)	Maximum (bbl)	Estimated Total Volume (bbl)
Lines	2,063	928	0.001	4	10	47	30	3,000	96,000
Tanks	1,881	540	0.01	10	30	232	80	89,000	127,000
Wells	1,414	81	0.010	2	3	9	10	250	12,700
Surface Equipment	539	150	0.010	6	15	43	35	2,000	22,900
Pits	284	14	0.500	10	34	48	80	170	13,600
Other/ Unclassified	3,203	1,155	0.001	3	9	36	25	1,400	113,600

Table 4. Total and Quantified Reported Releases of Saltwater from Oil and Gas Production Activities in Oklahoma 1993 through 2002 Classified by Reported Origin of Release.

Origin	Total	Quantified	Minimum (bbl)	Q1 (bbl)	Median (bbl)	Mean (bbl)	Q3 (bbl)	Maximum (bbl)	Estimated Total Volume (bbl)
Lines	2,390	1,015	0.010	15	40	138	100	5,000	328,600
Wells	1,345	65	0.050	10	15	34	30	400	45,600
Tanks	1,817	467	0.100	20	48	113	106	2,700	205,800
Surface Equipment	589	131	0.100	10	30	114	120	1,800	67,200
Pits	217	12	1.000	19	81	126	125	600	27,500
Other/ Unclassified	2,516	928	0.003	15	40	222	100	80,000	559,000

Table 5. Total and Quantified Reported Releases of Oil from Oil and Gas Production Activities in Oklahoma 1993 through 2002 Classified by Reported Cause.

Cause	Total	Quantified	Minimum (bbl)	Q1 (bbl)	Median (bbl)	Mean (bbl)	Q3 (bbl)	Maximum (bbl)	Estimated Total Volume (bbl)
Overflows	383	136	0.010	5	20	690	50	89,000	264,000
Illegal Activity	188	55	0.001	10	30	80	130	500	14,600
Storm	184	64	0.250	5	23	50	80	300	9,300
Fire	156	60	0.010	15	35	100	100	1,000	16,000
Corrosion	104	87	0.050	4	15	55	45	1,250	5,800
Accidents	104	57	0.120	10	20	70	100	350	7,600

Table 6. Total and Quantified Reported Releases of Saltwater from Oil and Gas Production Activities in Oklahoma 1993 through 2002 Classified by Reported Cause.

Cause	Total	Quantified	Minimum (bbl)	Q1 (bbl)	Median (bbl)	Mean (bbl)	Q3 (bbl)	Maximum (bbl)	Estimated Total Volume (bbl)
Overflows	484	103	0.360	15	50	120	160	1,450	60,000
Illegal Activity	174	39	2.000	30	47	150	100	2,800	26,200
Storms	122	55	2.000	37	60	91	127	600	11,100
Fire	81	28	1.000	20	48	79	120	500	6,400
Accidents	78	38	2.000	12	25	39	40	200	3,000
Corrosion	42	25	0.010	6	20	78	30	750	3,300

Table 7. Total and Quantified Reported Releases of Oil from Oil and Gas Production Activities in Oklahoma 1993 through 2002 Classified by Reported Damage Caused.

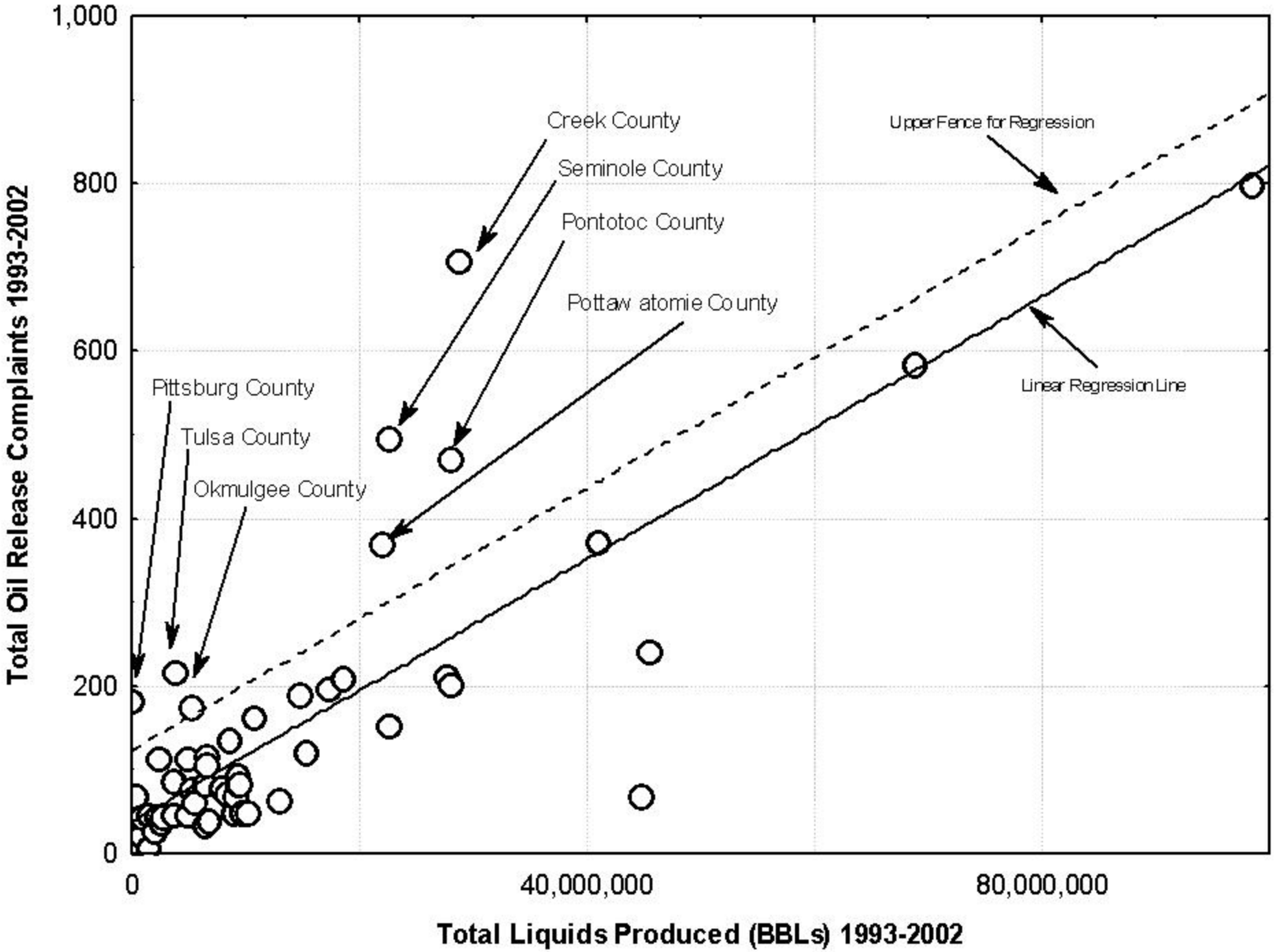
Damage	Total Reports (number)	Quantified Reports (number)	Minimum (bbl)	Q1 (bbl)	Median (bbl)	Mean (bbl)	Q3 (bbl)	Maximum (bbl)	Estimated Total Volume (bbl)
Surface water	1579	609	0.003	3	10	47	30	2,000	74,900
Crop/Stock	658	176	0.001	3	10	49	33	2,000	32,600
Soil	454	22	0.1	3	10	58	50	600	26,300
Erosion	101	5	0.71	10	20	26	35	60	2,600
Groundwater	119	1	20	20	20	20	20	20	2,400
Wildlife	21	2	10	10	10	10	10	10	210

Table 8. Total and Quantified Reported Releases of Saltwater from Oil and Gas Production Activities in Oklahoma 1993 through 2002 Classified by Reported Damage Caused.

Damage	Total	Quantified	Minimum (bbl)	Q1 (bbl)	Median (bbl)	Mean (bbl)	Q3 (bbl)	Maximum (bbl)	Estimated Total Volume (bbl)
Surface water	931	346	0.010	20	80	260	250	10,000	243,600
Crop/Stock	761	185	0.100	20	45	140	100	2,500	104,600
Soil	498	16	2.0	10	40	90	140	300	44,400
Erosion	236	3	25	25	25	44	80	81	10,300
Groundwater	164	2	150	150	1,075	1,075	2,000	2,000	176,300
Wildlife	19	1	1500	1,500	1,500	1,500	1,500	1,500	28,500

Figure Captions

Figure 1. Total Oil Release Complaints as Related to Total Liquids Production (Oklahoma Corporation Commission, 2003) by County in Oklahoma from 1993 through 2003. The “upper fence” for the regression is the value predicted by the regression plus 1.5 times the inter-quartile range for the regression residuals; values exceeding this are not reasonably expected based on the distribution of residuals (see Tukey, 1977).


1,000
800
600
400
200
0
Total Oil Release Complaints 1993-2002
0
40,000,000
80,000,000
Total Liquids Produced (BBLs) 1993-2002
Creek County
Seminole County
Pontotoc County
Pottawatomie County
Pittsburg County
Tulsa County
Okmulgee County
Upper Fence for Regression
Linear Regression Line