HAZARDOUS MATERIAL TRANSPORTATION STUDY
PHASE I

Prepared for
The State of Delaware Emergency Response Commission

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EXECUTIVE SUMMARY

Previous hazardous material flow studies were studied and a number of local and national incident databases were examined in this project to assist in identifying the appropriate focus of future efforts to address the movement of hazardous materials. Goals of the project were to summarize what is currently known about HazMat, examine risks, and identify areas of most concern. Information has been summarized and presented in this report.

Waterways

About a third of the vessels that arrive annually at ports along the Delaware are carrying crude petroleum, petroleum product or chemicals. Annually 47 million tons (325 million barrels), about 11% of total U.S. crude oil imports enter the area. Hazardous material traffic is restricted to the main waterways-the Delaware River, C&D Canal, and the Wilmington Harbor area. Between 1974 and 1998 there were 28 significant water accidents involving spills and fires. Larger and larger crude tankers with the ability to carry in some cases two million barrels of crude oil have begun arriving in the area. Spills, fires, and sinkings can cause catastrophic impacts to the local environment and economy and are the most likely type of major event among the various transportation modes.

Pipelines

Incidents involving movement of hazardous liquids and gases by pipeline can be expensive and often result in injuries or fatalities. The leading cause of pipeline incidents and the most dangerous and costly are when the pipe is damaged by some outside force, typically involving some type of excavation or construction. Massive quantities of HazMat are shipped by pipeline and there have been few problems and incidents. In the last decade, there has been one major incident in Delaware involving an estimated loss of 600,000 gallons of oil from a small leak in a pipeline over a 12 year period. One minor liquid transmission incident was reported over the last 15 years and no major gas transmission incidents have been reported in Delaware over the last decade. Nine gas distribution incidents were reported in Delaware between 1986 and 2000 with two injuries. While incidents are very infrequent, the large quantities of material moved and the risk to the waterways and ground water resources make pipeline transmission a big concern. Nationally, there is increasing concern about the aging of the pipeline systems and failures due to corrosion.

Highways

A little over 2% of the commercial vehicle truck fleet is involved in HazMat transport. Nationally, while only about 43% of all HazMat tonnage is transported by truck, approximately 94% of the individual shipments are carried by truck. Vehicular accidents are the leading causes of injury and death related to HazMat transportation on the highways. Accident data from 1997 to 2001 from the Delaware State Police was reviewed and 63 accidents occurred that involved HazMat. The National Response Center (NRC) data for Delaware between 1990 and 2000 listed 94 incidents with 13 injuries and 7 fatalities Most accidents occur in New Castle County and on major roads or interstates. Vehicular accidents involving HazMats were very infrequent with about one incident observed in 67,000 estimated shipments.

Rail

Nationally about 11% of total tonnage transported by rail is hazardous materials. Thirty four percent of the total HazMat tonnage by rail in Delaware is thru traffic. Rail incidents involving HazMat are few and mostly minor. The National Response Center lists 31 incidents involving HazMat in Delaware between 1990 and 2000. Nine of the NRC HazMat incidents for all modes in Delaware involving a death were persons hit on railroad tracks and two were the result of a shooting. The USDOT Hazardous Material Information System lists 19 rail incidents, mostly minor, and many involving packaging failures. Incidents mostly involve packaging problems or occur during material transfer/loading. Because of the large quantities of HazMat materials shipped by rail and the proximity of populations to rail lines, HazMat accidents have the potential to have large impacts.

Air

Large and varied shipments of HazMat are shipped by air at Dover Air Force Base as part of their mission. Dover Air Force Base has at least 821 listed hazardous materials, and in addition handles explosives and munitions, and large quantities of aviation fuels and lubricants. Explosives destined for DAFB come from the south and west, crossing the Bay Bridge in Maryland and are required to follow fixed specific routes. Recently, the State Emergency Response Commission (SERC) has re-examined HazMat cargo routes to the DAFB [1].

Other than military shipments, HazMat transportation by air is minimal. New Castle County Airport is the only non-military FAA certified aviation facility in Delaware, and this is the only civilian facility that can legally transport HazMat within the State. In communications with airport officials as part of the 1994 Delaware flow study it was noted that because of the special handling and cargo related size/shape and weight considerations, and the relative cost of air freight, there is nearly a "zero frequency" of HazMat air shipment into, through, and out of Delaware. The study said that sources indicated that package delivery companies, such as United Parcel Service and Federal Express, transport their HazMats by surface carriers to their main aviation hubs (Newark, New Jersey and Philadelphia, Pennsylvania), and ship by air from there. Again the high cost of air freight generally precludes large volumes of HazMats. There is relatively very low risk and vulnerability associated with non-military shipment of HazMat by air.

Findings associated with risk and vulnerability

There has generally been a low number of incidents over the past years and few serious incidents. Certainly the areas of greatest potential impacts are where large quantities are being moved as with water, rail, and pipeline transport. While these pipeline, rail, and water incidents are very infrequent in light of the huge quantities being shipped, when an incident does occur the danger to the environment and populations can be severe. About a quarter of pipeline incidents are caused by corrosion and it would be important to know the expected condition of pipeline facilities in Delaware. Of all HazMat incidents, waterway incidents, based on occurrence of past incidents and quantities involved, would seem to be the area of greatest vulnerability for danger to the environment.

Discussions with the Delaware Department of Natural Resources and Environmental Control (DNREC) Hazardous Material Response staff indicated that there are few if any cases where the types of incidents that are seen could be prevented by some type of new methods or regulations. Many of the incidents are associated with human or packaging failures that are inherent in the movement of any good. As the highways handle 94% of individual HazMat shipments there is a natural concern for what can be done to address highway transportation. Highway safety is addressed on a continual basis through DelDOT's Highway Safety Program and a review of HazMat highway incidents did not show a particular pattern or area that could be addressed from a prevention standpoint. The majority of the transport of HazMat is fuel, and fuel trucks must be permitted to service residential districts, and must have access to a number of commercial sites

across the State. No particular routing initiatives are foreseen at this time that would address the bulk of HazMat transport.

Perhaps the best focus of resources for the movement of HazMat are toward better and quicker response, rather than in prevention. Availability of improved response tools such as gas analyzers, or clean up materials could assist response efforts. Strategic positioning of response resources and personnel could aid in responding more quickly.

This review of previous studies and available HazMat incident information addressed flows of HazMat under normal circumstances. The risks and vulnerabilities associated with terrorist attack involving HazMat are of course very large and were not part of the scope of this study. In regards to terrorism, any vehicle filled with fuel or other HazMat is a potential weapon, and most concern would be where munitions or large quantities are involved as with pipeline and waterway transportation.

Introduction: Goals of Phase I

In this project, the Center for Applied Demography and Survey Research at the University of Delaware was asked by the Planning and Training Committee of the State Emergency Response Commission (SERC) to examine past studies and recommendations concerning the transportation of hazardous materials, and to assist in identifying the appropriate focus for future efforts to address the movement of hazardous materials. Goals of this phase include:

- Review past flow study information and develop a plan to build on efforts.
- Summarize what is known about hazardous materials being transported.
- Identify areas of most concern.
- Identify those incidents of most concern in Delaware toward setting priorities for future activities.
- Develop methods of determining the likelihood of various incidents and quantifying risk and impacts.

Data from previous hazardous material flow studies, national HazMat incident data, and information from State accident and incident databases was used.

SOURCES OF INFORMATION

This project reviewed information currently available concerning the transportation of hazardous materials (HazMat). This section briefly discusses the following information sources used in this report:

Figure 1
List Of Information Sources

Delaware Hazardous Material Transportation Flow Studies,
- Phase I - 1994
- Phase II - New Castle County, 1996
- Phase III – Kent County Highway Truck Survey, 1997
- Phase IV – Sussex County Highway Truck Survey, 1998

Delaware Waterborne Hazardous Material Transportation Flow Study, 1998
Delaware State Police Accident Database
DNREC Hazardous Material Response Database
National Response Center Data
USDOT/RSPA Hazardous Material Information System
1997 Commodity Flow Survey
Office of Pipeline Safety Incident and Accident Reports
Federal Railway Administration Railroad Accident/Incident Reporting System

Delaware Hazardous Material Transportation Flow Studies, 1994-1998

Four studies were commissioned by the State Emergency Response Commission (SERC) and published between June 1994 and January 1998. The purpose of the work was to identify specific hazardous materials being transported within and through the State of Delaware and provide a basis for planning efforts to address the transportation of materials. Objectives were to sample the present status and determine areas that might need additional study and to identify any major problems or possibilities of HazMat incidents. References to incidents were included in these reports.

The Phase I report investigated the movement of hazardous material by various modes (rail, water, highway, air) and incidents throughout Delaware and included a truck survey for each county. Phase II focused on New Castle County and reviewed HazMat transport by mode. Phase II also included a hospital survey to investigate the movement of medical or infectious wastes, and a highway truck survey. Phase III provided the results of a truck survey investigating the

movements of HazMats on selected roads in Kent County. Phase IV was a truck survey for movement of HazMats in Sussex County.

Delaware Waterborne Hazardous Material Transportation Flow Study, 1998

This study was commissioned by the Delaware Emergency Management Agency (DEMA) to study hazardous materials that enter the Delaware Bay and travel the Delaware River, Chesapeake and Delaware Canal and smaller waterways in Delaware. The study also included a survey of pipelines carrying hazardous materials that are adjacent to, or that cross these waterways. HazMat commodities and flows were identified and incident information was compiled.

Delaware State Police Accident Database 1996-2001

The Delaware State Police maintain an accident database that includes whether or not an incident involved hazardous materials. Incidents involving HazMat occurring in years 1996 thru 2001 were obtained and examined.

DNREC Hazardous Material Response Database

DNREC is the agency that is first contacted to respond to HazMat incidents. Incidents addressed are of all types, large and small, including a range of many scenarios, such as leaking underground storage tanks, accidents at commercial facilities, vehicular accidents on land and water, materials in transit, and residential accidents. For each incident a form is completed containing contact information, material type and quantities, incident descriptions and actions taken, and other information. This form is entered into computerized databases at DNREC.

The information in computerized databases was not readily accessible for use in this project. Incident information is not organized as to whether it is related to the transportation of HazMat and a study of those incidents could only be done by going through a laborious scan of hard copy reports. Instead, the experience and familiarity with incidents gained by DNREC staff was relied on for an understanding of the types of incidents that were occurring as it related to the transportation of hazardous materials.

National Response Center Data

Various types of incidents are reported to the National Response Center (NRC). As part of the Federal Water Pollution Control Act, the Outer Continental Shelf Lands Act, and the Deepwater Ports Act, responsible parties are to notify the NRC concerning an oil spill from a vessel or facility operating in U.S. navigable waters, outer continental shelf, or deep water ports. The Comprehensive Environmental Response, Compensation, and Liability Act requires that all hazardous substances exceeding reportable quantities be reported. (see Title 40 of the Code of Federal Regulations Part 302 for reportable quantities). Transportation accidents involving hazardous materials must be reported to the NRC immediately by the carrier when a person is killed, a person receives injuries requiring hospitalization, property damage exceeds $50,000 and or fire, and breakage or spillage of an etiologic agent occurs. Pipeline releases of a hazardous liquid are reported when they result in explosion or fire, a death or injury, property damage exceeding $50,000, or when the incident is deemed significant by the operator, or when an escape to the atmosphere of more than five barrels a day of highly volatile liquid or carbon dioxide occurs. Discharges from a hazardous waste treatment or storage facility must be reported by the emergency coordinator at the facility.

RSPA and USDOT Hazardous Material Information System

USDOT Research and Special Programs Administration (RSPA) collects information on hazardous material incidents involving death, injury, property damage, spills, evacuations, or transportation facility closures. RSPA maintains the Hazardous Material Information System that provides information on many incident factors (date, time, location, shipper, release consequences, quantities, cause, packaging, etc.)

The 1997 Commodity Flow Survey

The 1997 Commodity Flow Survey (CFS) was undertaken through a partnership between the Bureau of the Census, U.S. Department of Commerce, and the Bureau of Transportation Statistics, U.S. Department of Transportation. This survey produced data on the movement of goods in the United States and provides information on commodities shipped, their value, weight, and mode of transportation as well as the origin and destination of shipments of manufacturing, mining, wholesale, and selected retail establishments. The U. S. Department of Transportation

defines hazardous materials as belonging to one of nine hazard classes as shown in figure 2. This data was used in this project to view national data that was available on the quantities of hazardous material that was being shipped and by particular shipping modes.

Figure 2
U.S. Department of Transportation
Hazardous Material Classes

Class 1 - Explosives
Class 2 - Gases
Class 3 – Flammable Liquids
Class 4 – Flammable Solids
Class 5 – Oxidizers and Organic Peroxides
Class 6 – Toxic Materials and Infectious Substances
Class 7 – Radioactive Materials
Class 8 – Corrosive Materials
Class 9 – Miscellaneous Dangerous Goods

Office of Pipeline Safety Incident and Accident Reports

Data from the Office of Pipeline Safety includes leaks of natural gas or petroleum or petroleum by-products that meet reporting requirements as outlined in CFR 49, Parts 191, 192, and 195. Information includes quantities of material involved, conditions, equipment descriptions, injuries and losses of life and property,.

Federal Railway Administration, Railroad Accident/Incident Reporting System

Railroads are required by regulations to report highway railroad crossing crash data, fatality and injury data, and rail equipment and train accident information. A range of information about conditions, personnel, equipment, cause of incident, and related data were available from 1995 to 1999. The number of cars that were carrying hazardous material and whether there was a spill or not is included in this information.

WATER TRANSPORTATION

Flows of Hazardous Material by Water

The largest single shipments of HazMat are transported on the waterways of the Delaware River and Delaware and Chesapeake Canal. The volume of petroleum products through the Canal increased approximately 6.5% in 1992 to 4,429,000 tons. Approximately 15% of ships (average 2635 ships per year) using the Delaware River and Delaware Bay Shipping System are destined for either the Port of Wilmington or Delaware City. Approximately 20% of these 400 ships are bound for the Port of Wilmington and the remainder to Delaware City. 95% of the commodities due at the Port of Wilimington were non-hazardous, while 100% of the commodities destined for Delaware City were HazMats. Crude Oil made up 89% of the HazMats bound for Delaware City. The 1992 Chesepeake and Delaware Canal data indicate that over 13 million tons of commodities were transported, with petroleum products accounting for over 28%. [2]

The Delaware Waterborne Hazardous Material Transportation Flow Study (Waterborne Study) found that about 33% of the vessels that arrive annually at ports along the Delaware River were carrying crude petroleum, petroleum products, or chemicals. Crude petroleum accounts for the largest number of vessel arrivals and volume of product delivered to the region. Annually, 47 million tons (325 million barrels), about 11% of total U.S. crude oil imports, enter the area. These shipments go to the six major refineries along the Delaware River, so most hazardous material entering the region travels the length of the river. Hazardous material traffic is restricted to the main waterways – the Delaware River, C&D Canal, and the Wilmington Harbor area. Many of the smaller waterways report little or no hazardous material traffic. [3]

Waterborne commodity flow statistics for the area show imports out-numbering exports about ten to one, however the heavy importing of crude petroleum is the reason for the disparity. Crude petroleum alone accounts for almost 45% of the areas' total imports and is a routine import for the Delaware River's six major oil refineries. On average, each refinery utilizes some 200,000 barrels a day of crude petroleum; representing a delivery every 3-4 days [4].

Barges rank among the most frequent vessel traffic along the river. Barges in the range of 200,000-400,000 barrels capacity are used to lighter and transport crude oil up the river from the bay. Barges with 25,000 to 50,000 barrel capacity routinely carry refinery finished and semi-

refined products such as kerosene, home heating oil, various grades of gasoline, xylene, toluene, benzene, distillate fuel oil and residual fuel oil, chemicals such as alcohols, sodium hydroxide, and metallic salts, up and down the river to refineries, terminals, industrial users, government operations and general customers. Over 2000 barges move along the C&D Canal annually. Most barges make a return trip. Petroleum and chemical products carried by barge along the C&D Canal amount to about 4 million of the annual 14 million tons of canal traffic. [5]

Chemical vessels often carry one or multiple chemical cargos. While almost all crude tankers go down river empty, more than half of the incoming chemical vessels leave the area with chemical exports. Roughly 1.6 million tons of chemical and related products entered the region in 1996. Other than Methyl Tertiary Butyl Ether, which is utilized in the refining process and delivered to the various refineries, most chemical cargos travel to the Philadelphia harbor area. Alcohols, other hydrocarbons, organic compounds, sodium hydroxide and plastics make up the bulk of the Philadelphia bound cargoes. Nitrogen fertilizer, metallic salts and plastics account for the majority of the Wilmington cargoes. Acetone accounts for the majority of named chemical exports. [6]

Incidents

Figure 3 is taken from the Waterborne Study and lists the significant incidents in the Delaware River and Bay over the last 27 years. “Oil spills have occurred more often that other types of serious events along the river and the three largest spills occurred in the Marcus Hook area. The largest occurred in 1986, when the Tank Vessel (T/V) Grand Eagle ran aground in the Marcus Hook Range spilling approximately 462,000 gallons of crude oil in the Delaware River. The second largest spill occurred the following year at the BP facility when the T/V Intermar Alliance bound for Philadelphia lost steerage and collided with the BP dock facility. The collision caused a spill of approximately 387,000 gallons of crude oil, extensive damage to the BP dock and the vessel, and closed the BP dock and the river to traffic while the spill was cleaned up. The third largest incident, involving the T/V Presidente Rivera, occurred in the winter of 1989 when the vessel ran aground spilling approximately 307,000 gallons of bunker oil into the river. Besides closing the river to traffic and extensive cleanup efforts, the Presidente Rivera spill presented the most complex spill yet encountered on the river” because of a combination of air and water temperatures. Previous fire incidents, most notably the 1974 T/V Elias, and the 1975 T/V

Corinthos incidents resulted in extended interruption of river traffic and loss of both vessels, and huge resources to contain and extinguish the fires. The Corinthos incident caused an oil spill that stretched for almost 50 miles along the river and the bay. [7]

Figure 3
Significant Incidents, Delaware River – Bay
T/V = Tanker Vessel, M/V = Motor Vessel, T/B = Tug Boat

YEAR	Vessel	Location	Type	Spill/Result
1974	T/V Elias	ARCO Ft. Mifflin	Fire	13 Deaths
1975	T/V Corinthos	BP Marcus Hook, PA	Fire	29 Deaths
1976	M/V Olympic Games	Marcus Hook, PA	Spill	Power Line
1982	M/V Nord Thor	Wilmington, DE	Fire	2 Deaths
1982	T/V	Westville, NJ	Fire	Pump Room
1986	M/V Grand Eagle	Marcus Hook, Anch	Oil Spill	462,000 Gallons
1987	T/V	Westville, NJ	Fire	Pump Room
1987	T/V Intermar Alliance	Marcus Hook, PA	Collision/Spill	378,000 Gallons
1989	M/V Centaurus	Wilmington, DE	Fire	$6,500,000 Loss
1990	T/V Presidente Rivera	Marcus Hook, Anch	Oil Spill	372,000 Gallons
1990	M/V Faith/T/B Collision	Big Stone Anch, DE	Gasoline Spill	80,000 Gallons
1992	T/V Canadian Liberty	Westville, NJ	Oil Spill	1,000 Gallons
1992	T/V Elllen Knutsen	Philadelphia, PA	Cumene	10,000 Gallons
1993	T/V Kentucky	Paulsboro, NJ	Oil Spill	10,000 Gallons
1994	T/B Int 138	Ft. Mifflin, PA	Oil Spill	2,000 Gallons
1994	T/B	Philadelphia, PA	Fire	Engine Room
1994	T/B	Westville, NJ	Fire	Engine Room
1995	T/V Jahre Spray	Westville, NJ	Oil Spill	80,000 Gallons
1996	M/V B'Onal	Wilmington, DE	Fire	Cargo Loss
1996	T/B B155	Bombay Hook, Anch	Oil Spill	2,000 Gallons
1996	T/V Anitra	Bigstone Anch, DE	Oil Spill	40,000+ Gallons
1996	T/V Niki	Delaware City, DE	Oil Spill	1,500 Gallons
1996	USS Detroit	Chester, PA	Fire	Arson
1997	Tug Reedy Point	Delaware River, DE	Fire	Deck House
1997	Tug	Delaware River, PA	Fire	3 Mini NJ, Heater
1997	T/V Mystras	Bigstone Anch, DE	Oil Spill	10-40k Gallons
1998	USS America	Philadelphia, PA	Fire	Break Wtr. Tnk
1998	T/V New Ideal	Delaware City, DE	Oil Spill	1,500 Gallons

For Delaware vessel incidents referenced in the National Response Center data, about 25% were accidents (aground, fire, sinkings), about 20% spills (overflow, spills, transfer accidents), about 10% spills due to equipment failures, and about 40%+ were ruptures/leaks/releases of unknown cause. Of the top 30 releases in quantity, 6 were due to operator error with overfill or rupture.

Figure 4
NRC Delaware Vessel Incident Causes, Year 1990 thru 2000

Mode / Cause	Incidents	Injuries	Deaths
Dumping	3	0	0
Equipment Failure	26	0	0
Natural Phenomena	4	0	0
Operator Error	27	0	0
Other	27	1	0
Transport Accident	2	0	0
Unknown	75	0	0
Total	**164**	**1**	**0**
Vessel as % all incidents	49	5	0

Risks and Vulnerabilities

The December 1998 Delaware Waterborne Hazardous Material Transportation Flow Study is the source of much of what is now known about transportation of HazMat by water. The study mentioned that while the number of chemical vessel arrivals is down slightly, the arrival of liquid petroleum gas (LPG) vessels into the area had more than doubled (13 to 32) between 1995 and 1998. In addition, larger crude tankers with the ability to carry some two million barrels of crude petroleum have begun arriving in the area increasing the risk and impact of potential accidents. The main concern associated with chemical vessels is their volatility and possible toxicity-noxious effects in the event of a fire, spill, or release.

"The worst case scenario cited in the study in regards to a hazardous material marine transportation incident is a vessel fire-explosion that results in the vessel sinking in the channel of the Delaware River or the C&D Canal. This type of incident would cause serious economic consequences and impact in the region. Maritime personnel and the U.S. Coast Guard estimate it could take a week to ten days for salvage efforts to open the river to some limited use. A general cargo vessel is susceptible to the same scenario, however the extent of the fire and explosion should be limited allowing the vessel time to seek safe ground or haven outside the channel, limiting impact. Another scenario would be a fire-explosion and spill to the river or canal from a stricken vessel. In this case the vessel impact may be limited but the resulting spill, according to the Coast Guard, could close down the river for 3-5 days and only provide limited access for a period of time until the spill is cleaned up." [8]

"The end results of a marine disaster could be substantial, especially to an area that produces over $70 billion in annual commercial revenues from waterway-port activities. A marine disaster

would have serious implications on the regional transportation infrastructure. Interruption of waterway traffic, and for that matter pipeline traffic, would press the area interstate system creating unexpected challenges that would further impact the area". [9]

Barges are not self propelled and require the support of a tugboat. In the transport of hazardous materials, barges pose a hazard for fire, explosion, spill and release, and the greater possibility of navigational problems without the ability to power or steer the vessel. Compared to the potential of a crude or chemical tanker however, barges carry less product, are much smaller, would be easier to handle and could reach a safe haven much more readily. [10]

AIR TRANSPORTATION

Flows

There were 13 public airports identified in the 1994 Delaware Flow Study, some of these were hard surfaced and some were turf. New Castle County Airport is the only FAA certified civilian aviation facility in Delaware, and this is the only civilian facility that can legally transport HazMat within the State. In communications with airport officials as part of the 1994 Delaware flow study it was noted that because of the special handling and cargo related size/shape and weight considerations, and the relative cost of air freight, there is nearly a "zero frequency" of HazMat air shipment into, through, and out of Delaware. The study said that sources indicated that package delivery companies, such as United Parcel Service and Federal Express, transport their HazMats by surface carriers to their main aviation hubs (Newark, New Jersey and Philadelphia, Pennsylvania), and then ship by air from there. Again the high cost of air freight generally precludes large volumes of HazMats. The National Response Center database showed 5 incidents in the last ten years.

Dover Air Force Base is under U. S. Department of Defense jurisdiction and transports whatever materials as required to support any operation consistent with their mission. Dover Air Force Base has at least 821 listed hazardous materials, and in addition handles explosives and munitions, and large quantities of aviation fuels and lubricants. Explosives destined for DAFB come from the south and west, crossing the Bay Bridge in Maryland and are required to follow fixed specific routes. Exports from DAFB greatly outnumber imports by more than three to one, indicating that the materials being shipped, probably arrived by truck for air shipment. Recently, the SERC has re-examined HazMat cargo routes to the DAFB [11].

Incidents

National Response Center data and USDOT Hazardous Material Information System information were examined for air incidents and are presented in the next figures. Over the last eight to ten years there have been few incidents, and none was serious.

Figure 5
NRC Air Incident Causes, Year 1990 thru 2000

Cause	Incidents	Injuries	Deaths	Damages
Equipment Failure	2	0	0	0
Unknown	2	0	0	0
Other	1	2	0	0
Total Air Incidents	5	2	0	0
Air as % all incidents	1%	9	0	0

The USDOT Hazardous Material Information System showed 6 air incidents between 1993 and 2001.

Figure 6
Delaware Air Incidents
USDOT Hazardous Material Information System
Summary Years 1993 thru June 2001

Cause	Incidents	Major Injuries	Minor Injuries	Deaths	Damages
Human Error	3	0	0	0	0
Package Failure	3	0	0	0	0
Vehicular Accidents	0	0	0	0	0
Other	0	0	0	0	0
Total	**6**	**0**	**0**	**0**	0

Risks and Vulnerabilities

As the number of shipments and quantities is very low, the risks and impacts of a non-military HazMat incident are low.

The scope of this study did not include an examination of the risks and practices associated with the Dover Air Force Base but there are certainly large quantities of munitions and HazMats leaving the area.

PIPELINE TRANSPORTATION

Flows

"Two primary gas companies operate in Delaware – Conectiv, formerly Delmarva Power operates gas pipelines north of the C&D Canal and Eastern States operates pipelines south of the Canal. Conectiv gas pipelines cross various waterways such as the Christina River near Newport, but do not cross the Delaware River or C&D Canal. Eastern States operates a variety of pipeline transmission lines crossing various waterways south of the C&D Canal and two crossings of the C&D Canal." [12]

Transcontinental Gas Pipe Line has one 16 inch gas transmission line and Columbia Gas has one 20 inch gas transmission crossing the Delaware River near, and just north of, New Castle, Delaware. Eight liquid petroleum pipelines cross the Delaware River at or just north of, the Delaware-Pennsylvania border near Marcus Hook. Colonial Pipe Line has two 30 inch lines (one inactive) carrying petroleum products across the Delaware River south of Marcus Hook toward Bridgeport, New Jersey. Sun Pipeline Company has six lines (3 inactive) in Delaware crossing the river. Equilon Pipeline operates a 16 inch petroleum product line that runs north from the Motiva Refinery toward the Delaware-Pennsylvania border. There are two Eastern Shore gas lines crossing the C&D Canal. One is a 12 inch overhead gas line near the Summit Bridge and the other is a 14" submerged gas transmission line near St. Georges, DE. The waterborne study lists all the pipelines crossing water bodies.

Three companies operate pipelines that cross, or run adjacent to, the Delaware River – Colonial Pipe Line Company, Sun Pipe Line Company and Equilon (formerly Getty, Texaco and Star Enterprise). The pipelines carry finished or semi-refined petroleum products, namely premium and regular unleaded gasoline, low sulfur diesel, and fuel oil. There are additional pipeline crossings further north along the river near Philadelphia. [13]

In 1999, as part of the DEMA Hazard and Vulnerability studies, gas pipelines and facilities were mapped. Natural gas facilities for Delmarva Power and Light, Chesepeake Utilities, and Texaco were included. This data was compiled as best as possible for the study but details are lacking for pipelines crossing the river, and for pipe sizes for Delmarva Power and Light, and it is suspected that petroleum product pipelines linking processing plants both in state and out of state, may not be mapped. Gas supply ties into the U.S. Transcontinental Pipeline System in two locations north

and west of Wilmington in Pennsylvania. Eastern Shore Natural Gas Company (a subsidiary of Chesapeake Utilities) and Delmarva maintain a 24" transmission pipe that crosses the Pennsylvania line near Claymont and runs about 6 miles to the Edgemoor power plant. There are other lines that are greater than 10" diameter but most of Delmarva's other lines are basically distribution lines operating at approximately 30 psig. [14]

Incidents

"Petroleum product pipeline leaks now tend to draw much more attention than they may have prior to the enactment of the Oil Pollution Act of 1990 and the consolidation of pipeline regulations in 1996, which require response plans and immediate reporting of incidents." [15] Overall, pipeline transportation in the region has operated free of major incidents. The natural gas industry reports the pipeline system to be safer than transportation by truck or train. U.S. statistics report 570 fatalities involving trucks and 656 associated with railroads in 1990, while there were only 5 involving pipelines. From the NRC data the biggest release in the 11 years (1990 thru 2000) was an estimated 600,000 gallons of oil from a small leak in a pipeline over a 12 year period. Nine incidents involved pipelines with some type of leak, rupture, or equipment failure. One death resulted from a pipeline explosion from a leak.

Figure 7
NRC Data For Pipeline Incidents, Years 1990 thru 2000

Mode / Cause	Incidents	Injuries	Deaths	Damages ($)
Dumping	1	0	0	0
Equipment Failure	20	0	0	0
Operator Error	8	3	0	50,000
Other	2	0	0	0
Unknown	13	0	1	200,000
Total	**44**	**3**	**1**	**250,000**
Pipeline as %all incidents	13%	14	5	33

The Office of Pipeline Safety collects and manages pipeline incident data as part of industry regulations for both liquid and gas pipelines. Between 1986 and 2000 only one accident in Delaware was reported for liquid petroleum products that was an equipment failure (failed valve gasket) that resulted in $5000 property damage and a spill of 360 barrels of diesel fuel all of which was recovered.

Figures 8 thru 10 outline the cause and losses involved with pipeline accidents in the United States. Some of the quantities released are quite high. Most notably, while 26% of the incidents are caused by outside force damage, 93% of all the injuries, about a third of all fatalities, a third of the material released, and close to 40% of the monetary losses are due to pipes being struck during some type of construction or excavation. A similar situation is seen in regards to gas transmission and gas distribution incidents. Outside force damage is by far the leading cause of gas pipeline incidents and fatalities. The Office of Pipeline Safety listed no Delaware accidents for the gas pipeline transmission systems in the years 1986 thru 2000. Nine gas distribution incidents in Delaware were listed with $2.1 million in property damage, 2 injuries, and no fatalities.

Figure 8
National Liquid Pipeline Incidents, 1986 thru year 2000
Hazardous Liquid Accidents Datafile
Office of Pipeline Safety

Cause of pipeline accident	# (%)	Loss	Recov	$M	Injury	Fatality
Corrosion	721(25)	476k	261k	96.7	4	1
Failed Pipe	156(6)	259k	105k	54.3	2	0
Failed Weld	139(5)	134k	79k	31.3	4	2
Incorrect operation by operator personnel	181(6)	123k	65k	11.6	25	1
Malfunction of control or relief equipment	139(5)	81k	60k	6.1	2	0
Other	763(27)	704k	262k	110.6	117	19
Outside Force Damage	735(26)	903k	237k	192.9	1933	12
TOTALS	**2834**	**2681k**	**1069**	**503.5**	**2087**	**35**

Figure 9
National Gas Pipeline Transmission Incidents, 1986 thru year 2000
Office of Pipeline Safety

Cause	Number	Property($M)	Injury	Fatality	Hours lost
Construction/Material Defect	164	39.1	19	1	444
Corrosion	267	34.7	9	0	1244
Damage by Outside Force	465	122.0	72	31	1072
Other	263	54.3	104	10	479

Figure 10
National Gas Pipeline Distribution Incidents, 1986 Thru Year 2000
Office of Pipeline Safety

Cause	Num	Property ($M)	Injury	Fatality	Hours lost
Blank	1	5	42	33	- (1996 in Peurto Rico)
Operator	87	2.4	88	3	70
Construction/Operating	120	6.3	100	7	-
Corrosion	78	7.9	66	12	186
Damage by Outside Force	1133	119.4	551	132	1730
No Data	7	350k	2	4	6
Other	529	83.2	355	83	737
Location					
Blank	1	5	42	33	0
Above Ground	385	35.7	89	32	0
No data	38	2.3	39	5	47
Other	163	38.1	130	11	170
Under Ground/water	622	52.9	351	66	1026
Under Pavement	338	47.2	287	47	925
Within/Under Bldg	408	43.3	266	80	510

Risks and Vulnerabilities

"Massive quantities of petroleum products are transported by pipeline. Pipelines transport over half of all crude oil and refined petroleum products in the United States. They move much of the nation's energy supply. Therefore it is essential to national security and economic prosperity that the system be operated and maintained in a safe and reliable manner. The same is true in this region where pipelines serve as a vital transportation link. Disruption to the pipeline system in Delaware could cause serious energy supply problems, potential adverse impact to area waterways and produce a pressing economic dilemma." [16]

"Two major concerns regarding pipelines are the effects of age on pipeline integrity and the continuing encroachment of population and industrial areas on pipeline right-of-ways. Most pipeline failures, whether the pipeline is natural gas or petroleum product, are a result of human error, generally result from damage to the pipe by excavations or work around excavations. Most pipeline incidents occur from construction equipment that accidentally strikes the line during excavations. The release of natural gas under pressure and the availability of an ignition source can spell disaster to those in the immediate area. Damage from outside forces, such as nicks or gouges to the pipe that go unreported and eventually cause a failure, is the number one cause for

pipeline incidents and dollar losses. Pipelines have rarely been perceived as a menace across the nation. As a result, apartment complexes, schools, and other kinds of land development have occurred along the pipeline right-of-way. The U.S. Office of Pipeline Safety allows building within one foot of a pipeline. Detailed maps of pipelines have not been easily available and communities have often been unaware of them and not included them in their planning process.

In natural gas pipelines other causes for incidents are corrosion accidentally caused by operations. External-internal corrosion ranks as the secondary cause of incidents in hazardous liquid pipelines. [17] Federal reports blame corrosion for nearly one out of every five pipeline breaks. In the U. S. between 1992 and 1998, there were 1976 pipeline accidents with corrosion related failures accounting for approximately 360 such accidents. Some experts contend that the U.S. Pipeline system is getting old and that the industry is not doing enough to take care of it. Facing the greatest risk of corrosion failures are at least 85,000 miles of transmission and distribution lines in the U.S. that are more than 50 years old. Older pipelines and those in metropolitan areas have the highest corrosion rates. Age and the added activity around pipes in urban areas, and the proximity of other underground utility lines have been shown to have an impact on corrosion of pipelines.

Pipeline leaks can severely impact ground and surface waters. "Leaks of a hazardous liquid on or near water spread for many miles from the release site presenting significant environmental concerns. Oil, depending on type, will tend to travel with the current and tides, but will present a lesser risk of fire or explosion though they disburse and evaporate quicker."[18] Shutoff valves are a true mitigation tool in pipeline emergencies and can greatly minimize the effects of a pipeline waterway incident. It is a requirement that hazardous liquid pipelines have shutoff valves on each side of water crossing (100 feet or more across) but studies reviewed did not verify the existence of shutoff valves. [19]

Knowing how incidents occur is the first step toward prevention. In this regard, many larger pipeline companies are starting to develop and utilize risk management programs. These programs focus on pipeline inspection, preventive maintenance, rehabilitation, and repair strategies. In recent years the Office of Pipeline Safety has changed its pipeline inspection process to a more risk-based approach and redirected their historical compliance "checklist" inspections to a system-oriented program. This program is designed to better understand pipeline operations and pipeline integrity management systems. [20]

In Delaware, in line with federal requirements, the Public Service Commission oversees the Pipeline Safety Program to regulate natural gas pipelines. This program addresses construction, inspection, and maintenance of the entire natural gas pipeline system. The inspections do not find every leak, but the more serious leaks can be detected. The gas companies, Conectiv in New Castle County, and Chesapeake Utilities in Kent County and Sussex County are required to follow comprehensive safety procedures and fix any problems immediately. Like systems throughout the country, Delaware has, in place, many pipes that have been in the ground for decades. Corrosion Control is part of the process of inspection that would address problems due to age. As problems are found with cast iron pipes and other metal pipes, the process of fixing leaks includes replacement with plastic. Compared to systems in other parts of the country, Delaware's system is in good shape and we fortunately have had few incidents. Gas companies are required by regulations to have emergency and response plans in place, and current response capabilities so far have been adequate.

In summary, while pipeline incidents have been infrequent and relatively minor in Delaware, the quantities involved and the potential impact to populations and the environment are of great concern. The principal causes of pipeline failure are damage from outside sources and corrosion.

HIGHWAY TRANSPORTATION

Flows

While freight railroads remain a vital part of the nation's transport sector and economy, the dominant U.S. freight mode is truck. Although accounting for only about 25% of ton-miles and 45% of total tons moved annually, the trucking sector accounts for over 75% of freight revenues. Truck share for hazardous material shipment is close to 94% for all HazMat shipments. In 1992, estimates were that about 2.3% (about 365,000 trucks) of the nation's commercial truck fleet is involved in HazMat transportation. Of the 800,000 daily HazMat shipments in the U.S., approximately 770,000 are transported by truck. [21]

Results of the 1995 Delaware Highway Truck Survey showed that the top three placards for all three counties, accounted for 50% of all placards observed. These three are UN1203 (gasoline), UN1993 (fuel oil), and UN1075(propane), all petroleum products. New Castle County had the bulk of the highway transport activity in the state accounting for over 80% of all placarded vehicles observed during the survey. About 7.3% of the trucks surveyed at the ten sites were observed with hazard class markings with over 145 different placards identified.[22] Addition of truck survey sites designed to observe truck traffic in and around the aquifers indicated that very few full-sized tank trucks were observed at these sites.

Trucks handle most of the medical and biohazard wastes as well. Results of the Hospital HazMat/biohazard survey indicate that the New Castle County hospitals generate infectious/pathological/chemotherapeutic wastes in proportion to the number of beds at the facility. Chemotherapeutic wastes account for less than five percent of the total wastes transported. The number of BioHazard waste loads averaged one to two loads per week, and were transported by just two contractors (Incendre and BFI) to incinerators and landfill destinations out of state.

Incidents

The Delaware State Police provided references to 63 accidents involving hazardous materials between the years 1997 and 2001. Most were relatively minor and involved no injuries. These accidents were mapped as in figure 14 on the next page that shows the area where 35% of the New Castle accidents occurred. Perhaps the most noticeable thing that can be said from a review of Delaware accident data is that accidents tend to be at highway ramps and intersections.

Figure 11
Accidents Involving Commercial Vehicles
Delaware State Police Accident Database

Year	# of accidents
1997	1208
1998	1205
1999	1161
2000	1145
2001 (thru Nov)	995

Figure12
Accidents Involving Hazardous Materials
Delaware State Police Accident Database

Year	# of accidents
1997	9
1998	14
1999	21
2000	12
2001 (thru Nov)	7

Figure 13
Accidents Involving Hazardous Materials
Delaware State Police Accident Database
County Breakdown

County	# of accidents
Kent	11
New Castle	47
Sussex	5

Figure 14
New Castle County Vehicular Accidents
Involving Hazardous Materials
Delaware State Police Accident Database 1997 to 2001

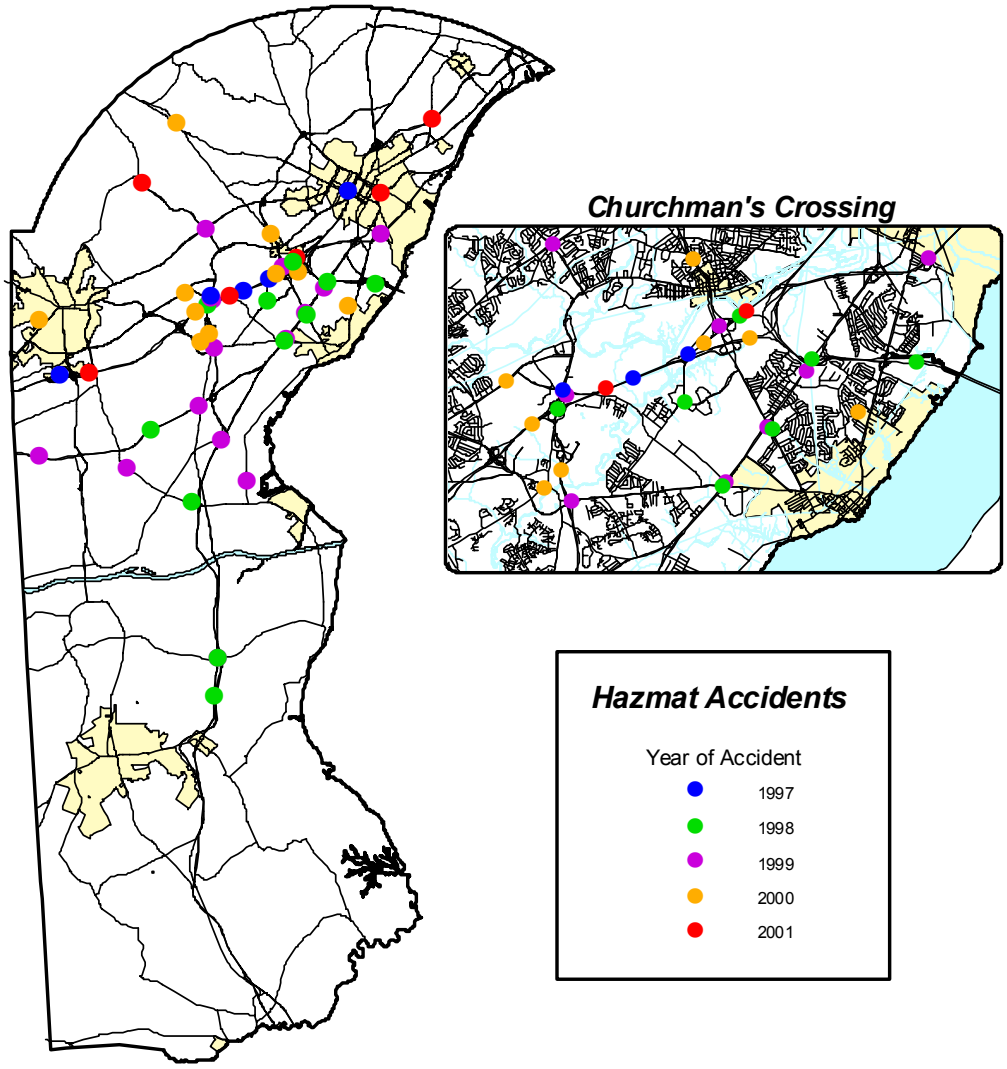
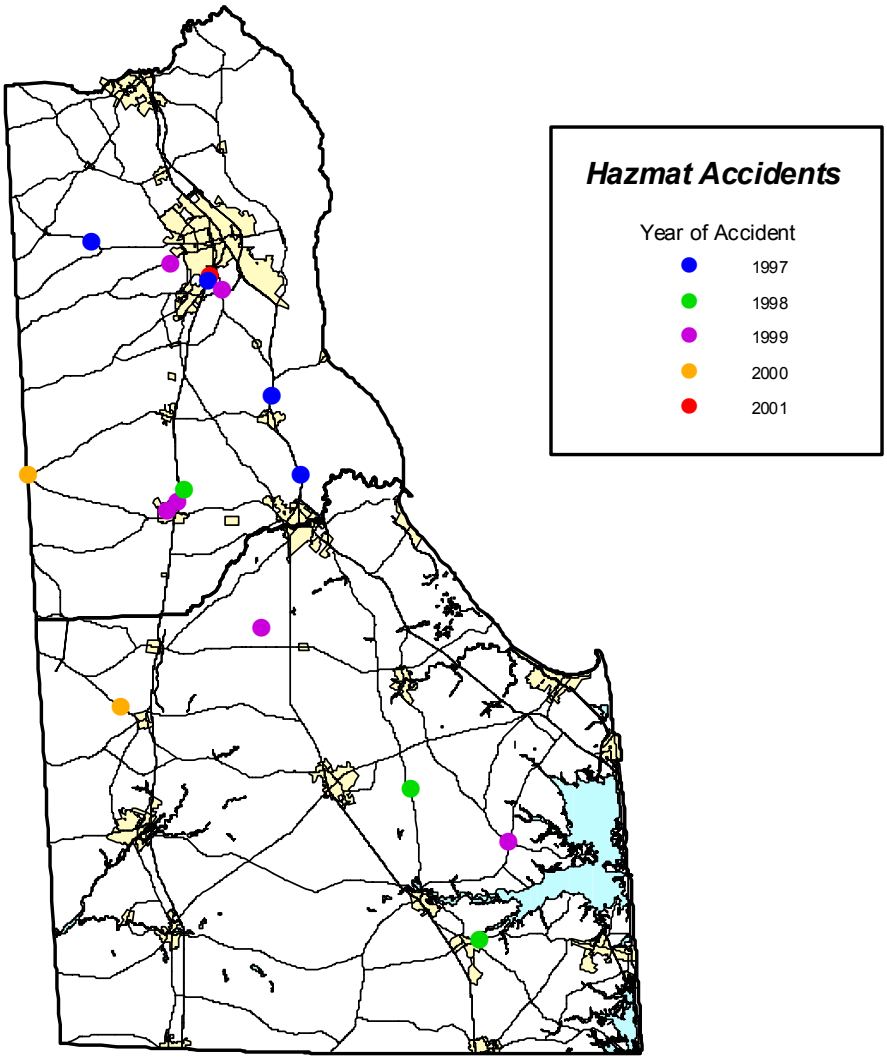


Figure 15
Kent and Sussex County Vehicular Accidents
Involving Hazardous Materials
Delaware State Police Accident Database 1997 to 2001



A 1994 review of the accident data from the Delaware State Police indicated that there are few incidents involving hazardous material vehicles, averaging just over 4 accidents per year. More than half of these accidents involved vehicle or cargo fuels. DNREC databases indicated that on average there were 42 spills reported per year, with 75% involving petroleum products, and over half of these spills involving vehicle, not cargo fuel. The average release of material was 414 gallons. [23]

Not considering deaths that occur as a result of persons getting hit on railway tracks, highway accidents by National Response Center data are the chief cause for deaths related to hazardous material transport.

Figure 16
NRC Highway Incident Data for Delaware
Years 1990 thru 2000

Cause	Incidents	Injuries	Deaths
Criminal Intent	1	0	0
Dumping	2	0	0
Equipment Failure	25	0	1
Operator Error	27	6	0
Other	12	0	0
Transport Accident	12	7	6
Unknown	15	0	0
Total Highway incidents	**94**	**13**	**7**
Highway as % of all incidents	28%	59	37

Risks and Vulnerabilities

While 94% of the HazMat shipments are by truck, the quantities involved in most shipments are relatively small. Generally incidents do not cause major impact to populations or the environment and do not involve deaths or injuries. Many incidents, as with railway incidents, involve packaging problems or accidents while loading or unloading materials. Some incidents are a result from the puncture of the gas saddlebags on trucks for whatever reason, usually from striking something in the roadway. HazMat vehicular accidents do not seem to occur with any special frequency or circumstances. Accidents seem to follow the same type of distribution as one would expect for traffic of other types, and there is generally no strategy available for prevention beyond general road safety measures.

DNREC's focus of improvement is primarily in response. Methods of responding quicker to incidents by placement of crews or availability of equipment, such as air analyzers, are being considered and additional funding for equipment and clean up materials would be helpful. For chemical spills, DNREC is fostering a program that uses personnel from private industry who are very familiar with various substances and appropriate response.

RAIL TRANSPORTATION

Flows

Most of the information contained in the flow studies concerning rail transport is from a May 1991 U.S. Department of Commerce report entitled "Flows of Selected Hazardous Materials by Rail". This report contains some interesting figures for Delaware for the year 1986:

- 11% of total tonnage transported by rail is hazardous materials (1986). In 1986 about 15.3 million tons of product were transported by rail in Delaware, and about 1.6 million tons were HazMat. Pennsylvania is indicated in the top ten States for receipt of HazMats and New Jersey is one of the top ten States for destination of chemicals or allied products.
- 34% of the total HazMat tonnage by rail is passing thru Delaware (not originating or destined for a Delaware location)
- 40% of the total chemical product tonnage by rail is hazardous.
- 35% of petroleum and coal products shipped by rail are hazardous.

Figure 17
Top Ten Hazardous Material Tonnage by Rail in Delaware

	Originating				
	Total	**Orig-Term**	**Terminating**	**Passing thru**	**Total**
Chlorine	69,220	7,200	75,240	36,200	180,660
Ferric Chloride	157,200	0	0	0	157,200
Adipic Acid	0	0	130,960	22,640	153,600
Liq CO2	6,680	0	3,360	104,560	114,600
Vinyl Chloride	0	0	113,760	0	113,760
Sulphuric Acid	15,760	0	0	89,880	105,640
Hexamethylene Diamene	0	0	104,960	0	104,960
Caustic Soda	73,560	0	3,960	9,280	86,800
Hydrochloric Acid	34,560	0	0	21,040	55,600
Methanol	45,840	0	0	0	45,840
Total	**402,820**	**7,200**	**432,240**	**283,600**	**1,118,660**

Source: 1996 data from1991 NTIS report "'Flows of Selected Hazardous Materials by Rail"

In 1996, there were six operating railroads in Delaware. Conrail and CSX Corporation are the primary rail transporters of HazMats in Delaware. Conrail is the major interstate railroad that supplies all commodities, including HazMat, to other lines throughout Delaware and into adjacent areas in Maryland. Reports used in the flow studies indicate chlorine and ferric chloride were the highest tonnage of HazMat traversing Delaware, and that sulfuric acid and LPG were among the

highest volume HazMats transported. The 1992 Delaware Hazardous Material Flow Study lists origins and destinations, companies, line numbers, and substances transported in Conrail shipments.

Figure 18
General Commodities in Rail Transit
Delaware Rail Administration (In Tons)

Commodity	Originating In Delaware	Terminating In Delaware	1992 Total	1992 Percentage
Autos incl. Parts	13,562	22,342	35,904	36.9
Coal	427	22,496	22,923	23.5
Chemicals	9,190	7,399	16,589	17.0
Farm/Food products	1,793	8,384	10,177	10.5
Forest Products	159	3,911	4,070	4.2
Petroleum Products	1,231	3,358	4,589	4.7
Metallic Ore	36	1,458	1,494	1.5
Other	583	1,068	1,651	1.7

Figure 19
Rail Shipments Originating in Delaware
USDOT 1994

Commodity	Tonnage
Chemicals	668,020
Transportation equip	313,480
Nonmetallic minerals	122,560
Farm Products	91,612
Petroleum or coal	76,160

Figure 20
Rail Shipments Terminating in Delaware
USDOT 1994

Commodity	Tonnage
Coal	2,078,949
Chemicals	1,019,152
Farm Products	635,356
Transportation Equipment	455,600
Food products	325,020

Incidents

The 1996 flow study includes data from CSX Corporation for the years 1993 thru 1999. Figures show that non-accident related railroad HazMat incidents range from a high of 365 incidents in 1988 to a low of 188 incidents in 1993 after some programs were put in place by CSX. The decline in the number of incidents identified in the 1996 study is attributed to increased HazMat awareness and handling procedures on the part of rail transport companies. Incidents were mostly controlled safety incidents as where safety vent disc and the safety relief valve failed as they are meant to, to prevent catastrophic failures. Other non-accident releases for CSX were related to valves where corrosion and wear would be expected.

Figure 21
CSX Corporation Railroad HazMat Releases
Number of Incidents in Year 1993

Combustible Liquid	89
Corrosive	89
Flammable Liquid	50
NonFlammable Gas	21
Flammable Gas	15
Oxidizer	12
Poison Gas	3
Poison	3
Miscellaneous	2
Explosive	1

Nine of the National Response Center HazMat incidents for all modes in Delaware involving a death from the 1990 thru 2000 data were persons (trespassers) hit on the railroad tracks. Three deaths were train accidents, one was a propane gas explosion, two were results of a shooting, and one resulted from a gas pipeline explosion from a leak. The nine deaths of pedestrians on the tracks and the two shootings for the railroad type, though they may be coincident with shipments of hazardous waste, are related to general safety rather than hazardous material transport issues.

Figure 22
HazMat Railway Incidents
National Response Center Data
Years 1990 thru 2000

Cause	Incidents	Injuries	Deaths	Damages ($)
Equipment Failure	7	0	0	0
Operator Error	5	0	0	0
Other	3	0	2	0
Suicide	1	0	0	0
Transport Accident	1	0	0	0
Unknown	14	3	9	50,000
Total	**31**	**3**	**11**	**50,000**
Railway as %all incidents	9%	14	58	67

Figure 23
Delaware HazMat Railway Incidents List In
USDOT Hazardous Material Information System
Summary Data For Years 1993 thru June 2001

Cause	Incidents by cause	Maj injuries	Min injuries	Deaths	Damages($)
Human Error	5	0	0	0	1110
Package Failure	11	0	3	0	3510
Vehicular Accid.	1	0	0	0	0
Other	2	0	0	0	4300
All railway inc.	19	0	3	0	8920

Data from the Federal Railway Administration, Railroad Accident/Incident Reporting System was reviewed for years 1995 thru 1999. In that period there were 23 accidents listed. There was one accident where two cars were carrying HazMat but there were no releases.

Risks and Vulnerabilities

Rail transport has shown few incidents over the past decade. Most incidents have been minor and have involved packaging or loading failures. Most deaths are attributed to trespassers being hit by trains incidental with cars carrying HazMat. Recent safety initiatives have proven to be effective in decreasing incidents. The most serious incidents would be those involving derailments and other train crashes that, like shipment by truck, are the subject of general safety rather than anything particular to HazMat. Large quantities of HazMats are transferred and railways are often in close proximity to populations, and accidents can produce tragic consequences in the vicinity of the site. The condition of the rail infrastructure must be maintained to maximize safety.

COMPARISON OF MODES OF HAZMAT TRANSPORTATION AND EXAMINING RISK

In addition to reviewing past efforts, other goals of this project were to identify areas of most concern and to develop estimates of the relative risks associated with the various modes of transportation. This section presents some comparisons between the transportation modes and demonstrates a method to estimate the probability of incidents.

Comparison Of Modes

Each transportation mode for HazMat is best viewed in terms of :

- The quantity per shipment
- The number of individual shipments.
- The expected impacts of incidents
- The types of prevention and response that are possible.

From Office of Hazardous Safety data, about 94% of all HazMat shipments are by truck, and trucking accounts for 75% of freight revenues. Air shipments account for about 5% of total HazMat shipments. Pipeline, rail, and water modes account for only 1% of the total shipments. There is a vast difference though if transportation of HazMat is looked at in terms of quantities (tons). From national data, the truck mode then has about 43% of total HazMat tonnage, pipeline at about 38%, water at 15%, rail at a little over 4% , and air transport at only a half a percent. Figure 24 on the next page summarizes this information from the Office of Hazardous Materials Safety.

Impacts vary widely as well. Many HazMat incidents that are reported for the truck and rail modes are packaging failure where minimal quantities are released. Other truck incidents are mostly vehicular accidents that in general also release low quantities, though at times materials can be released requiring cleanup of the site and disruption of traffic. Injuries and deaths are typically the result similar to other vehicular accidents and not related to HazMat itself. Looking at the data for truck incidents does not reveal any particular actions that can be taken for prevention, and the best approach is to have sufficient equipment, materials, and logistics to

quickly identify the nature of the incident and perform the cleanup. Since the air mode involves small quantities, and incidents typically result from packaging or loading problems, impacts are generally minor. In contrast, the pipeline and water modes transport very large quantities of HazMat and impacts from incidents can cause great damage and effects that extend well beyond the site of the incident. For these large quantity modes it is vital that comprehensive monitoring, maintenance, and safety measures be in place.

Figure 24
HazMat Shipments, Movements, And Tons By Transportation Mode
National Data Prepared By The Office of Hazardous Materials Safety [24]

	Shipments	%	Movements	%	Tons Shipped	%	Tons Moved	%
			CHEMICALS & ALLIED PRODUCTS					
Truck	445,218	90.3%	830,761	89.36%	808,662	55.52%	894,452	37.30%
Rail	3,723	0.8%	11,169	1.20%	335,070	23.00%	1,005,210	41.92%
Pipeline	34	0.0%	34	0.00%	127,500	8.75%	127,500	5.32%
Water	82	0.0%	164	0.02%	181,279	12.45%	362,558	15.12%
Air	43,750	8.9%	87,500	9.41%	4,049	0.28%	8,098	0.34%
SUBTOTAL -- a	492,807	100%	929,628	100%	1,456,560	100%	2,397,818	100%
			PETROLEUM PRODUCTS					
Truck	313,689	99.5%	313,689	99.15%	2,857,470	40.04%	2,857,470	34.39%
Rail	448	0.1%	1,344	0.42%	40,320	0.57%	120,960	1.46%
Pipeline	839	0.3%	839	0.27%	3,146,250	44.09%	3,146,250	37.87%
Water	253	0.1%	506	0.16%	1,091,646	15.30%	2,183,292	26.28%
Air	-	0.0%	-	0.00%	-	0.00%	-	0.00%
SUBTOTAL -- b	315,229	100%	316,378	100%	7,135,686	100%	8,307,972	100%
			OTHER HAZMAT					
Truck -- c	10,000	98.6%	10,000	95.9%	43,048	92.43%	43,048	80.27%
Rail	144	1.4%	432	4.1%	3,526	7.57%	10,578	19.73%
Pipeline	-	0.0%	-	0.0%	-	0.00%	-	0.00%
Water	-	0.0%	-	0.0%	-	0.00%	-	0.00%
Air	-	0.0%	-	0.0%	-	0.00%	-	0.00%
SUBTOTAL	10,144	100%	10,432	100%	46,574	100%	53,626	100%
			TOTAL HAZMAT					
Truck	768,907	93.98%	1,154,450	91.88%	3,709,180	42.94%	3,794,970	35.27%
Rail	4,315	0.53%	12,945	1.03%	378,916	4.39%	1,136,748	10.57%
Pipeline	873	0.11%	873	0.07%	3,273,750	37.90%	3,273,750	30.43%
Water	335	0.04%	670	0.05%	1,272,925	14.73%	2,545,850	23.66%
Air	43,750	5.35%	87,500	6.96%	4,049	0.05%	8,098	0.08%
DAILY TOTALS -- d,e	818,180	100%	1,256,438	100%	8,638,820	100%	10,759,416	100%
ANNUAL TOTALS -- f	298,635,700		458,599,870		3,153,169,300		3,927,186,840	

Data from the NRC for the years 1990 to 2000 was downloaded from the NRC web site and examined for incidents in Delaware as well. Over half of the 41 incidents occurring in Delaware over the past 10 years, involving injuries or fatalities, involved some type of vehicular accident. About 2/3 of the Delaware incidents involve some type of oil product. The largest releases of HazMats are thru pipeline, and vessel mode, followed by railroad incidents. The vast majority of shipments (around 90%) are through mobile (truck) carriers but the largest releases are associated

with pipeline, rail, and vessel transportation as these modes always involve much larger quantities per shipment. Of the top 30 Delaware releases in quantity, almost all were oil leaks, a few dichlorobenzene, a couple acid, seven were rail resulting from overfill or other operator error, seven were highway, five of which were vehicle accidents. Half of the top ten largest releases were pipeline incidents.

Incidents that occurred in Delaware were studied and data for the years 1993 through 2001 from the US DOT Hazardous Material Information System were also examined. Tables from this analysis are shown below to compare the modes. The appendix of this report includes other tables for Delaware incident data from the NRC and USDOT. Figure 29 shows a 10 year nationwide summary of incidents reported to the NRC.

Figure 25
Percentage Of Total Incidents By Various Modes For Delaware
National Response Center data, year 1990 to 2000

	Incidents	Injuries	Deaths	Damages($)
Total Number	338	22	19	$750,500
% Highway	27.8	59.1	36.8	0
% Vessel	48.5	4.5	0	0
% Pipeline	13.0	13.6	5.3	33.3
% Railway	9.2	13.6	57.9	66.7
% Air	1.5	9.1	0	0

Figure 26
Cause of HazMat Incidents in Delaware
USDOT Hazardous Material Information System
Summary data for years 1993 to June 2001

Cause	Incidents	Maj Injuries	Minor Injuries	Deaths	Damages
All incidents	185	0	6	0	$273,940
% Human Error	72.4	0	16.7	0	44.1
% Package Failure	24.3	0	83.3	0	13
% Vehicular Accident	1.1	0	0	0	40.9
% Other	2.2	0	0	0	0

Figure 27
Delaware HazMat Incidents, County Breakdown
USDOT Hazardous Material Information System
Summary data for years 1993 to June 2001

	Num.incidents	Highway	Rail	Air
New Castle	114	96	14	4
Kent	25	21	2	2
Sussex	39	36	3	0

Figure 28
Commodity Class for Delaware incidents
USDOT Hazardous Material Information System
Summary Data For Years 1993 to June 2001

	Number of incidents
Corrosive material	81
Flammable combustible liquid	57
Poisonous materials	22
Misc HazMat	5
Non Flammable compressed gas	5
Combustible Liquid	4
Organic peroxide	4
Poisonous gas	2
Oxidizer	2
Flammable compressed gas	1
Flammable solid	1
Spontaneously combustible	1

Figure 29
National Response Center Incidents Nationwide 1991-2000
Source: National Response Center

Incident by Type Per Year
(by Fiscal Year (OCT 1 - SEP 30))

Incident Type	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Fixed	11,404	12,536	13,556	14,656	15,080	12,067	10,388	10,961	11,230	11,813
Unknown Sheen	3,794	3,784	4,416	5,087	5,147	4,433	4,228	4,809	4,802	4,016
Vessel	2,914	2,690	2,886	3,598	3,967	4,091	3,778	3,886	3,877	3,945
Mobile	1,832	1,850	2,782	3,456	3,133	2,511	2,490	2,718	2,835	3,597
Pipeline	1,794	2,030	1,918	1,945	1,530	1,737	1,740	1,657	1,404	1,618
Platform	2,331	2,166	1,617	1,671	1,770	2,106	1,943	1,570	1,465	1,428
Storage Tank	**Prior to 2000, Storage Tank Incidents were taken as FIXED Reports**									1,379
Railroad Non-Release	248	441	502	493	455	446	586	823	1,049	1,335
Railroad	966	1,162	1,425	1,530	1,578	1,645	1,883	2,266	2,252	1,332
Continuous	333	323	476	215	183	177	170	304	376	938
Aircraft	138	203	264	265	225	173	207	181	241	248
Drill/Exercise	0	0	88	188	228	349	349	503	532	669
Unknown	0	0	6	21	8	46	14	3	52	84
Terrorist Non-Release	**Prior to 1998, the NRC did not take Terrorist Reports**							18	51	33
TOTAL	**25,754**	**27,185**	**29,936**	**33,125**	**33,304**	**29,781**	**27,776**	**29,699**	**30,166**	**32,435**

Examining Risk, Incidents and Shipments

A simple estimate of the risk involved in various transportation modes for HazMat could be derived by taking the total number of incidents divided by the total number of movements by each mode for the year. This would provide some estimate of the frequency of incidents with respect to a level of activity.

Types of Incidents

Before viewing incidents with respect to the number of shipments, it is necessary to classify incidents. There are major incidents and minor incidents with varying impacts.

Highway Incident – Vehicular Accident
About 12 accidents involving HazMat per year in Delaware (DE State Police 1995-2001)

Water Shipping Incident – Major spill, fire, injury, large loss of life and/or property
About 1 major incident per year (Significant incidents referenced in the Waterborne Study 1974 to 1998)

Railway Incidents – Minor Incidents
17 incidents in 1995, no injuries or deaths – $6,390 in damages
(USDOT, RSPA, Hazardous Materials)

Major NRC Pipeline Incidents (1990 to 2000)
One large release of 600,000 gallons of oil from a small leak in a pipeline over a 12 year period.
4 incidents involving injuries or fatalities over an 11 year period. (about 68 injuries per 1000, about 23 fatalities per 1000)

Minor NRC Reported Pipeline Incidents (1990 to 2000)
In Delaware about 4 incidents per year, an average of about $6000 damage reported per incident.

Liquid Pipeline Transmission Incident -
One minor incident in Delaware in years 1986 to 2000
Nationally about 167 per year with average material loss at 950 gallons; average material recovered 40%; $178,000 per incident; 736 injuries and 12 fatalities per 1000 incidents.

Gas Distribution Incidents
9 incidents in Delaware in 15 years (1986-2000) with $2.1M in property damage (about $234,000 per incident), 2 injuries, no fatalities.
Nationally, about 130 a year with an average $115,000 damages, 616 injured per 1000 incidents, about 140 fatalities per 1000 incidents

Gas Transmission Incidents
No incidents reported in Delaware between 1986 and 2000.
Nationally, about 77 per year, with on average $216,000 per incident, 176 injuries per 1000 incidents, and 36 fatalities per 1000 incidents

Shipments

The Office of Hazardous Materials Safety provides data on shipments of HazMat by mode at the national level circa 1995. The National Response Center data references the number of incidents per year by mode.

Figure 30
HazMat Daily Shipments And Quantity Information
National Level Data

Mode	Daily Movements 1995	Daily Tons moved 1995	Tons per movement
Truck	1,154,450	3,794,970	3
Rail	12,945	1,136,748	88
Pipeline	873	3,273,750	3,750
Water	670	2,545,850	3,800
Air	87,500	8,098	0.1 (185 pounds)

Source: Office of Hazardous Materials Safety

The DelDOT Travel Demand Forecasting Model estimates there are 133,000 daily truck trips in Delaware. With an estimate of 2.3% of the national truck fleet being involved in HazMat transport, an estimate of the daily HazMat trips in Delaware would be 3060 per day, about 800,000 per year.

The number of shipments of hazardous material on waterways in Delaware was not available but there is some information that would provide a minimum estimate of about 7,500 waterway HazMat shipments per year, about 20 per day. Details of how this estimate was derived are provided in the Appendix.

Information was available for this study in terms of what major pipelines were present in Delaware but not for the amounts of material moved. No estimates of quantities by pipeline in Delaware were available from Census surveys, previous flow studies, or other sources reviewed. One estimate for comparison of risk by mode by shipment could be derived from using an estimate of 1% of the national flows, which would be 32,737 tons per day. Using national level data for tons per shipment, yields an estimate of about 3200 shipments per year. An estimate of shipments is difficult when discussing pipeline transmissions. Most figures are in terms of tonnage.

About 1.6 million tons of HazMat were transported by rail in Delaware in 1986. Using national estimates for tons per movement (90 tons) would provide an estimate of the yearly rail movements of hazardous materials at close to 18,000 shipments per year, about 50 per day in Delaware.

Comparative Risk

Using estimates for shipments/movements and incidents by mode, it is then possible to develop a rough comparison of the relative risks by mode. Figure 31 below shows one comparison using national data from the National Response Center. The highway (truck) and air modes are seen as the safest and the water mode is the least safe in terms of incidents per movement. When viewed in terms of incidents per tonnage the pipeline mode and the other large quantity modes of water and rail can be considered the safest. NRC data includes very minor as well as major incidents and there is probably some bias as to the types of incidents that are reported. Identifying incidents of more serious impact would form a better comparison.

Figure 31
Probability Of An Incident By Mode With Respect To Incidents Tabulated By The National Response Center National Level Data

Mode	Annual Incidents, 1995 NRC	1995 Incidents per 100,000 movements	(1995) Incidents per 10 million ton moved
Truck	3,113	0.7	22.0
Rail	1,578	33	3.8
Pipeline	1,530	481	1.3
Water	3,967	1,622	4.2
Air	225	0.7	75.0

Note: Table above is an example of a rough estimate of the risk associated with each HazMat transport mode using NRC data. A large portion of the pipeline incidents involve pipes being struck by construction equipment and not associated with a particular shipment. Many rail incidents include safety type incidents as where safety vent disk and safety relief valves failed as they are meant to, to prevent catastrophic failures.

Figure 32 on the next page shows an attempt to compare risk by transport mode from Delaware incidents and estimates of shipments. Again in terms of incidents per number of shipments the highway mode would appear as the safest, but when viewed in terms of incidents per tons moved the bulk modes are safer, particularly the pipeline mode. The water mode showing an estimate of one major incident in 7,500 shipments would appear to be of most concern.

Figure 32
Estimated Probability Of Incidents In Delaware By Mode

	Estimates Shipments Per year in DE	Reported	Estimated Probability Incidents per so many shipments	Estimated Probability per ton shipped
Truck	800,000	about 12 vehicular accidents per year	1 highway accident in 67,000 shipments	1 in 201,000 tons
		About 20 death/inj in 11 years (NRC)	1 in about 440,000 shipments	1 in 1.3M tons
		About 84 minor in 11 years (NRC)	1 in about 105,000 shipments	1 in 315,000 tons
Rail	18,000	about 10 major in 11 yrs (NRC)	1 in 20,000 shipments	1 in 1.76M tons
		About 3 major in 8 years (HMS)	1 in 48,000 shipments	1 in 4.2M tons
		About 27 minor in 11 yrs (NRC)	1 in 7,400 shipments	1 in 650,000 tons
		About 16 minor in 8 years (HMS)	1 in 9,000 shipments	1 in 792,000 tons
		About 23 minor in 5 years (rail rep)	1 in 3,900	1 in 343,000 tons
Water	7,500	about 1 major incident per year	1 in 7,500 shipments (spills, fire, injury, death)	1 in 28.5M tons
Pipline	3,200	1 major incident (1 in 11 yrs, NRC)	1 in 35,200 shipments	1 in 132M tons
	3,200	4 minor incidents per year` (NRC)	1 in 800 shipments	1 in 3M tons
Liquid transmission		no DE incidents reported		
Gas transmission		no DE incidents reported		
Gas distribution		9 DE incidents in 15 yrs	No estimate on number of shipments	

OBSERVATIONS

Having examined and compared incidents and risks for the various HazMat transportation modes, a few observations can be made.

- The occurrence of major HazMat transportation incidents in Delaware is low over the last decade.
- Discussions with the Delaware Department of Natural Resources and Environmental Control (DNREC) Hazardous Material Response staff indicated that there are few, if any, cases where the types of incidents that are seen could be prevented by some type of new methods or regulations. Perhaps the best focus of resources for the movement of HazMat are toward better and quicker response, rather than in prevention.
- While pipeline, rail, and water incidents are very infrequent in light of the huge quantities being shipped, when an incident does occur, the danger to the environment and populations can be severe.
- In regards to water transportation, spills, fires, and sinkings can cause catastrophic impacts to the local environment and economy and are the most likely type of major event among the various transportation modes. Estimates of the relative risks between the various modes of HazMat transport show waterway incidents as the most frequent and severe.
- The large quantities of material moved and the risk to the waterways and ground water resources make pipeline transmission a big concern. The leading cause of pipeline incidents and the most dangerous and costly are when the pipe is damaged by some outside force, typically involving some type of excavation or construction. Most notably, while 26% of the incidents are caused by outside force damage, 93% of all the injuries, about a third of all fatalities, a third of the material released, and close to 40% of the monetary losses are due to pipes being struck during some type of construction or excavation. Nationally, there is increasing concern about the aging of the pipeline systems and failures due to corrosion.
- Vehicular accidents are the leading causes of injury and death related to HazMat transportation on the highways. Vehicular accidents involving HazMats were very infrequent with about one incident observed in 67,000 estimated shipments. There are however few measures that can be taken to prevent accidents beyond the highway safety programs now in place. While 94% of the HazMat shipments are by truck, the quantities

involved in most shipments are relatively small. Generally, incidents do not cause major impact to populations or the environment and do not involve deaths or injuries.

REFERENCES

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2. Delaware Hazardous Material Transportation Flow Study, Phase II – New Castle County, commissioned by the State Emergency Response, Pennoni Associates Inc., Wilmington, DE, January 1996, pgs 4-6
3. Delaware Waterborne Hazardous Material Transportation Study, commissioned by Delaware Emergency Management Agency, The Doyle Group, Newport DE , December 1998, page 1
4. Delaware Waterborne Hazardous Material Transportation Flow Study, pgs 1-5
5. Delaware Waterborne Hazardous Material Transportation Flow Study, page 16
6. Delaware Waterborne Hazardous Material Transportation Flow Study, pgs 15-16
7. Delaware Waterborne Hazardous Material Transportation Flow Study, page 32
8. Delaware Waterborne Hazardous Material Transportation Flow Study, page 36
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12. Delaware Waterborne Hazardous Material Transportation Flow Study, page 24
13. Delaware Waterborne Hazardous Material Transportation Flow Study, page 24
14. Delaware Hazardous Material Transportation Flow Study June 1994, pgs 24-27
15. Delaware Waterborne Hazardous Material Transportation Flow Study, page28
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18. Delaware Waterborne Hazardous Material Transportation Flow Study, page 28
19. Delaware Waterborne Hazardous Material Transportation Flow Study, page 28
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21. Hazardous Materials Shipments, Office of Hazardous Materials Safety, Research and Special Programs Administration, U.S. Dept. of Transportation, Washington DC October 1998, Pgs. 8-9.
22. Delaware Hazardous Material Transportation Flow Study, Phase II, pgs 4-6, (this paragraph and the one preceding it.)
23. Delaware Hazardous Material Transportation Flow Study June 1994, page 6
24. “Hazardous Materials Shipments”, Office of Hazardous Materials Safety, U.S. DOT, Washington, D.C., October 1998, Based on 1993 Bureau of Census Commodity Flow Survey shipment distribution data for standard transportation commodity classification; 1995 CMA tonnage figures; 1995 EPA hazardous waste shipment and manifest data; 1996 DOE Energy Information Administration data; 1996 Waterborne Commerce Statistics; and 1997 BTS Air Carrier Traffic Statistics

APPENDIX

Waterway Shipment Estimate

In 1998 about 2635 ships were using the Delaware River annually. About 33%, or about 870 ships of this traffic carried crude petroleum. About 35 HazMat ships, that are not crude petroleum, enter Delaware City and about 4 ships go to Wilmington. Over 2000 barges use the C&D Canal annually carrying various HazMats. Barges are among the most frequent vessel traffic along the river. Barges in the range of 200,000 to 400,000 barrels capacity are used to lighter and transport crude oil up the river. Barges with 25,000 to 50,000 barrel capacity routinely carry refinery finished and semi-refined products. On return trips many of these ships and barges carry other HazMat products. If there are about 5000 HazMat barge trips in the area and about 1000 ships carrying HazMat up the Delaware River per year, and if about a quarter of those return with finished products, there would be about on the order of 7500 HazMat trips a year on the waterway, or about 20 a day. Nationally it is estimated that 670 HazMat movements occur on average each day by waterway.

Additional Figures Not Included In The Main Body Of The Report

Figure 33

DNREC Environmental Response Branch
Incident Response Statistics
Calendar Year 2000

Total number of responses	462
Total number of residential oil spill responses	35
Total number of UST responses	18
Total number of fish kill responses	13
Total number of DNREC responses	255
Total number of Partial responses	176
Total number of telephone responses	11
Total number of SERT Level 1 responses	18
Total number of SERT Level 2 responses	1
Total number of SERT Level 3 responses	0
Total number of New Castle County responses	275
Total number of Kent County responses	102
Total number of Sussex County responses	81
Total number of other responses (Pennsylvania)	4
Total number of petroleum responses	252
Total number of non-petroleum responses	207

Figure 34

Hazardous Material Shipment Characteristics by Mode of Transportation U.S. 1997

	Tons (thousands)	%
All Modes	1,565,196	100.0
Truck	869,796	55.6
Rail	96,626	6.2
Water	143,152	9.1
Air	66	-
Pipeline	432,075	27.6

Figure 35
Hazardous Material Shipment Characteristics by Hazard Class, U.S. 1997

	Tons (x 1000)	Percent
All HazMat	1,565, 196	100
Class 1 - Explosives	1,517	0.1
Class 2 – Gases	115,021	7.3
Class 3 – Flammable liquids	1,264,281	80.8
Class 4 – Flammable solids	11,804	0.8
Class 5 – Oxidizers and Organic Peroxides	9,239	0.6
Class 6 – Toxic Materials (infectious, poisons)	6,366	0.4
Class 7 – Radioactive Materials	87	-
Class 8 – Corrosive Materials	91,564	5.9
Class 9 – Miscellaneous Dangerous Goods	65,317	4.2

Figure 36
Hazardous Materials Shipments Movements and Tons

Product Group	Daily Shipments	Daily Movement	Tons shipped	Tons moved
Chemicals & Allied	500,000	900,000	0.53 billion	0.85 billion
Petroleum Products	300,000	300,000	2.60 billion	3.03 billion
Other	10,000	10,000	0.01 billion	0.02 billion
Totals	**>800,00**	**>1,200,000**	**>3.1 billion**	**>3.9 billion**

Figure 37
NRC Data for Delaware, County Breakdown

Kent

	Fixed	Mobil	Rail	Air	Vessel	Pipeline	Total	Total wo fixed
Incidents	42	8	3	1	18	4	76	34
Injured	0	0	0	0	0	1	1	1
Dead	0	1	0	0	0	0	1	1
Damage ($)	0	0	0	0	0	0	0	0

New Castle

	Fixed	Mobil	Rail	Air	Vessel	Pipeline	Total	Total wo fixed
Incidents	553	70	31	3	68	35	760	207
Injured	33	10	3	2	0	2	50	17
Dead	0	3	9	0	0	1	13	13
Damage ($)	0	0	500k	0	0	250k	750k	750k

Sussex

	Fixed	Mobil	Rail	Air	Vessel	Pipeline	Total	Total wo fixed
Incidents	95	15	2	0	70	5	187	92
Injured 6	3	0	0	1	0	10	6	
Dead	0	3	2	0	0	0	5	5
Damage ($)	500	0	0	0	0	0	500	500

Figure 38
Incident Origins and Destinations
USDOT Hazardous Material Information System
Summary data for years 1993 to June 2001

Incidents (%)	
58 (31.4%)	incidents passing thru Delaware
11 (5.9%)	incidents to and from Delaware (9 of 11 Flammable combustible liquid)
34 (18.4%)	beginning in Delaware and going somewhere else
82 (44.3)	beginning somewhere else and going to Delaware
75.7%	originating in another state
24.3%	originating in Delaware