1.0 Introduction

1.1 Purpose of Study

Crude oil and biofuels are transported by rail within and through the state of Iowa. Several factors including the increased production of crude oil in the Bakken region of North Dakota, its transportation to markets in the Southern and Eastern U.S., and various accidents involving the rail transportation of crude oil and ethanol in the U.S. and Canada have led to additional scrutiny and study of the transportation of hazardous materials by rail and other transportation modes.

The Iowa Department of Transportation's (Iowa DOT) Office of Rail Transportation and the Iowa Homeland Security and Emergency Management Department (Iowa HSEMD) seek to define the characteristics and, risks of crude oil and biofuels transportation in Iowa, the current prevention methods used to reduce risk of incidents, and the capabilities of Iowa's emergency response and recovery system for crude oil and biofuels rail transportation incidents. Outcomes of this Iowa Crude Oil and Biofuels Rail Transportation Study (the Study) will identify gaps and assist in the development of policies, procedures, and actions to further reduce risks and improve emergency response throughout the state. Even though this Study focuses primarily on the rail transportation of crude oil and biofuels, any actions recommended through this Study, which translate readily to other hazardous materials transported by rail, should do so.

The purpose of the Study undertaken by the state of Iowa is identified below:

- Inform the state about the likely current and near-term future frequency, routes, volumes, and transportation characteristics of crude oil and biofuels by rail within and through Iowa
- Assess the potential risks to public health and safety, and the potential environmental impacts, created by rail transportation of crude oil and biofuels by rail
- Document current private- and public-sector programs and plans related to rail incident prevention and management, including access to emergency equipment and services
- Identify actions to address potential gaps in prevention, preparedness, response, and recovery methods and make public health and safety and environmental protection recommendations for appropriate federal, state, and local agencies, or the private sector
- Establish internal assignments and timelines to quantify successful implementation of findings and recommendations provided in the Study
- Formulate recommendations to close potential gaps in the following areas that would cause a shortfall in Iowa's capabilities for prevention, preparedness, response, and recovery: rail transportation infrastructure, rail transportation practices, rail transportation regulations and regulatory oversight, emergency response resources, organization, training, and response capabilities, communication systems and methods, and other concerns identified through the Study

The Study identified public and private stakeholders and engaged them for their insights and suggestions through a formal outreach process. Stakeholders included all Iowa railroads involved in the bulk transportation of crude oil and biofuels, selected rail producers/shippers of ethanol; selected local first responders in Iowa; principal state agencies involved in rail transportation, risk assessment, emergency planning, preparedness, response, and recovery including the Iowa DOT, Iowa HSEMD, the Iowa Department of Natural Resources (Iowa DNR), and other state agencies identified through the Study; relevant federal agencies including the Federal Railroad Administration (FRA), Pipeline and Hazardous Materials Safety Administration (PHMSA), the U.S. Department of Homeland Security (USDHS), and others identified through the Study.

Biofuels are liquid fuels used principally by motor vehicles, stationary power plants, and self-propelled machinery such as locomotives, earthmoving machinery, and farm machinery in lieu of refined products of crude oil such as diesel fuel, gasoline, and jet fuel. The principal biofuels produced in the U.S. are ethanol and biodiesel. Large quantities of ethanol are produced in Iowa and transported by rail, whereas very little biodiesel moves by rail within Iowa. Accordingly, throughout this Study, ethanol will be the principal focus for biofuels; however, findings, recommendations, and actions that concern ethanol would be in large part relevant to bulk transportation of biodiesel, should that occur in the future.

1.2 Significant Crude/Ethanol by Rail Transportation Accidents 2013-2015

National attention to crude oil transportation by rail risks occurred after an increase in railroad incidents involving trains carrying crude oil in the U.S. and Canada. This increase in incidents corresponds to an equivalent increase in the quantity of crude oil transported by rail in the U.S. and Canada. (Note: most crude oil and ethanol is moved in "unit" trains. A unit train is a train hauling a single commodity for a single customer or consortium of customers from one origin to one destination, under a single bill of lading. Unit trains are further defined in Section 3.0.) In 2014, 143 reported incidents involving crude oil in a total of 21 states By comparison, in 2010, there were nine incidents affecting only eight states.[2] The following are summaries of major crude by rail incidents from 2013 to present in Canada and the U.S.

- Lac-Mégantic, Quebec (2013, July 5): The engineer of a unit train with 72 tank cars carrying crude oil secured and left the train in Nantes, Quebec, following the completion of his tour of duty. The train was secured, using a combination of hand brakes and the train's air brakes on a main track with an approximate 1.2 percent descending grade. The train later began to move on its own after the air brake system ceased to be effective, and rolled down the descending grade toward the town of Lac-Mégantic. Near the center of town, 63 tank cars derailed, resulting in multiple explosions and a large fire. This resulted in 47 fatalities of residents, evacuation of 2,000 residents, and extensive destruction to the town. Investigations determined that the number of hand brakes applied to the train by its engineer was insufficient to prevent the train from rolling under the influence of gravity if the air brake system failed.[3]

[2] National Geographic, *This Map Shows How U.S. Oil Train Accidents Skyrocketed*, http://news.nationalgeographic.com

[3] Ibid

- Aliceville, Alabama (2013, November 8): A 90-car crude oil unit train from North Dakota to Mobile, Alabama, derailed on a section of track through a wetland near Aliceville, Alabama. Thirty tank cars derailed and approximately a dozen burned for more than 24 hours. No injuries or fatalities resulted.[4]
- Casselton, North Dakota (2013, December 30): An eastbound BNSF Railway (BNSF) crude oil unit train with 106 tank cars struck a westbound unit grain train that derailed onto the eastbound track. Twenty of the rail cars carrying crude oil derailed, resulting in a large explosion. Subsequently, a massive fire started and burned for more than 24 hours. Approximately 1,400 residents were evacuated but no injuries or fatalities were reported.[5]
- Plaster Rock, New Brunswick (2014, January 7): A train hauling crude oil from Manitoba and Alberta to Saint John, New Brunswick, derailed due to a wheel or axle failure. Five of the crude oil tank cars initially caught fire then exploded. Approximately 45 homes in the immediate area of the incident were evacuated. There were no reported injuries or fatalities.[6]
- Philadelphia, Pennsylvania (2014, January 20): Six tank cars carrying crude oil among a 101-car CSX train derailed on a bridge over the Schuylkill River. No injuries or leakage into the river were reported.[7]
- Vandergrift, Pennsylvania (2014, February 13): Twenty-one tank cars of a 120-car train derailed outside Pittsburgh. Nineteen of the derailed cars were carrying crude oil from western Canada, and four of them released crude oil. There was no fire or injuries.[8]
- Lynchburg, Virginia (2014, April 30): A train with 15 tank cars carrying crude oil derailed in the downtown area of Lynchburg. Three cars caught fire, and some cars derailed into a river along the tracks. The immediate area surrounding the derailment was evacuated. No injuries were reported, Approximately 30,000 gallons of oil spilled into the James River.[9]
- Dubuque, Iowa (2015, February 4): Fourteen railcars carrying ethanol in a Canadian Pacific Railway (CP) train derailed along the Mississippi River near Finley's Landing, 10 miles north of Dubuque. Eleven rail cars were involved, and ten were carrying ethanol.[10] At least three cars caught fire and at least three cars

[4] Ibid
[5] Ibid
[6] Ibid
[7] Ibid
[8] Ibid
[9] Ibid
[10] Des Moines Register, *Train cars derail near Dubuque, Plunge into Mississippi River*, http://www.desmoinesregister.com/story/news/2015/02/04/dubuque-train-derail/22873707/ (accessed January 28, 2016)

slipped into the river. An estimated 51,000 gallons of ethanol was released. No injuries or property damages were reported.[11]

- Timmins, Ontario (2015, February 14): Twenty-nine cars of a 100-car Canadian National (CN) Railway unit train carrying diluted bitumen crude oil derailed in a remote area 50 miles south of Timmins, Ontario, spilling oil and catching fire. The train was headed from Alberta to Eastern Canada. No injuries were reported.[12]
- Mount Carbon, West Virginia (2015, February 16): A CSX train derailed during which 19 tank cars caught fire and leaked crude oil into a nearby Kanawha River tributary. The fire lasted for almost a week, and it spread to a nearby house, which was destroyed. Approximately 1,100 residents were evacuated and two injuries were reported.[13]
- Galena, Illinois (2015, March 5): Twenty-one cars of a 105-car unit crude oil BNSF train, derailed three miles south of Galena. Ten of the cars released oil and ignited. No injuries or fatalities were reported. Local officials requested a voluntary evacuation of a one-mile radius around the incident site because of the train's proximity to a propane tank.[14]
- Hornepayne, Ontario (2015, March 5): A CN freight train derailed in a remote area of northern Ontario; the company reported no injuries or fire. The derailed cars were empty tank cars that contained residual quantities of crude oil or gasoline. No leaks or spillages of product were reported.[15]
- Gogama, Ontario (2015, March 7): A CN train carrying crude oil derailed approximately three miles from the Ontario community of Gogama. Multiple tank cars ignited and caught on fire, which resulted in a destroyed bridge and oil leak into the nearby waterway. Five of the tank cars landed into the waterway. CN reported that the tank cars were the newer American Association of Railroads (AAR) CPC-1232-compliant design; these tank cars have been regarded to be better protected against damage than older types.[16]
- Heimdal, North Dakota (2015, May 6): A BNSF train derailed east of the unincorporated community of Heimdal in Wells County. Six CPC-1232 tank cars derailed, of which four caught fire but did not explode. Approximately 25 people were evacuated for several hours. An estimated 60,000 gallons of oil leaked into a

[11] Telegraph Herald, *FRA Report includes details about Dubuque train derailment*, http://www.thonline.com/news/dubuque/article_c80e4ca0-f5c4-11e4-a397-736047563561.html (accessed October 27, 2015)
[12] Global News, *No Injuries After CN Train Derails in Northern Ontario*, March 5, 2015, Print
[13] U.S. Department of Transportation, Federal Railroad Administration Office of Safety Analysis, Accident Detail Report, http://safetydata.fra.dot.gov/officeofsafety/publicsite/Query/incrpt.aspx (accessed June 22, 2015)
[14] Ibid
[15] Huffington Post, Crude Oil Train Derailment in Ontario, Canada Is Third in Less Than a Month, March 7, 2015, Print
[16] U.S. Department of Transportation, Pipeline Hazardous Materials Safety Administration, Hazardous Materials: Rail Petitions and Recommendations to Improve the Safety of Railroad Tank Car Transportation, Federal Register 80, No. 89, May 8, 2015, 26644, http://www.regulations.gov/#!docketDetail;D=Pipeline Hazardous Materials Safety Administration-2012-0082 (accessed June 22, 2015)

nearby waterway that drains into the James River; containment booms were put in place to contain the spilled oil. Additional containment dykes also were built around the derailment site. The derailment did not cause any injuries, fatalities, or structural losses.[17]

- Culbertson, Montana (2015, July 16): A BNSF train derailed east of Culbertson near the North Dakota border, of which at least three CPC-1232 tank cars spilled an estimated 35,000 gallons of crude oil. The incident did not result in any fire, explosion, property damage, injuries, or fatalities. Multiple homes in the area were evacuated and Highway 2, a major roadway in the region was forced to shut down for several hours during incident response.[18]
- Scotland, South Dakota (2015, September 19): Seven cars of a 98-car BNSF unit ethanol train derailed in rural South Dakota. Three cars lost their contents in the derailment and at least one car caught fire. No injuries or property damages were reported.[19]

In the last ten years, there has been only one domestic crude oil or ethanol incident that has resulted in a fatality directly caused by the commodity. This occurred in Cherry Valley, Illinois (near Rockford) on June 19, 2009.[20] A CN unit ethanol train derailed at a highway grade crossing; a total of 19 tank cars derailed. Of these, 13 cars were breached, punctured, and/or lost product and caught fire.[21] Several motorists were parked near the at-grade crossing, but the resulting fire fatally injured one motorist and injured several others.[22] The National Transportation Surface Board (NTSB) concluded that the probable cause of the train derailment was a precipitation-caused washout of the track structure.[23] In addition, the NTSB concluded that CN's emergency management procedures inadequately communicated knowledge of the washout to the train crew in a timely fashion.[24] The NTSB also stated that the inadequate design of the DOT-111 tank cars contributed to the severity of the accident.[25]

1.3 Hazard Profiles: Crude Oil and Ethanol

Both crude oil and ethanol spills, caused by train derailments, are the hazard presented to the Iowa public and environment. First, an understanding of each commodity's hazards is necessary for identifying risk and is needed in order to provide the appropriate level of emergency preparedness and response. Volatility, or the tendency for a material to vaporize, is an important concept. Typically, the more volatile a material is, the more readily it can evaporate and create vapor (gas). Vapor can be easily ignited when an energy source is introduced near the vapor.

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[17] Wilz, Greg (North Dakota DES Director), Roehrich, Tammy (Wells County, North Dakota, Emergency Management). Interview. May 13, 2015

[18] CBS News, Rail cars leaking crude after oil train derails in Montana, http://www.cbsnews.com/news/rail-cars-leaking-crude-after-oil-train-derails-in-montana/ (accessed October 26, 2015)

[19] NBC News, Ethanol Tankers Derail in South Dakota, One Catches Fire, http://www.nbcnews.com/news/us-news/ethanol-tankers-derail-south-dakota-one-catches-fire-n430426 (accessed October 27, 2015)

[20] National Transportation Surface Board, *Railroad Accident Report RAR-12-01, http://www.ntsb.gov/investigations/AccidentReports/Pages/RAR1201.aspx*

[21] Ibid.

[22] Ibid.

[23] Ibid

[24] Ibid.

[25] Ibid.

Therefore, a highly volatile substance, with a low flash point, is more prone to igniting than a less volatile substance. Ethanol and crude oil are both volatile compounds, but have other defining characteristics and properties that can dictate their impact to the public and environment.

1.3.1 Industry Descriptions of Crude Oil

The term "crude oil" generally refers to "a mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities."[26] Crude oil composition can vary from thin, lightweight, and volatile, to thick, semi-solid, and heavy. Crude oil also varies in flammability, volatility, toxicity, and American Petroleum Institute (API) gravity.

There are two major variables in crude material characteristics: gravity and sulfur content.

- Gravity ranges from light to heavy, expressed in degrees based on the API scale. The API gravity describes the weight of a petroleum product relative to water (greater than 10° API floats on water and less than 10° API sinks in water).[27]
- The sulfur content of a crude product determines whether the product is considered low, intermediate, or high sulfur crude. It is commonly referred to as "sweet" or "sour" crude oil. Sour crude oil is high in sulfur content, whereas sweet crude is low in sulfur. Sweet crude carries a sulfur content of less than 0.5 percent by weight, while sour crude has sulfur content greater than 1 percent by weight. Intermediate crude oil (neither sweet nor sour) has sulfur content from 0.5 percent to 1 percent.

Crude oils that are light (higher API gravity) and sweet (low sulfur content) are typically more desirable for refiners because they have fewer impurities and are easier (and therefore less expensive) to process. Heavier crudes (those with lower API gravity) and sour crudes (high sulfur content) require more complicated refining processes to make them into retail products such as gasoline.

Figure 1: DOT Hazard Classification Identification Placard for Petroleum Crude Oil Products

Light, sweet crude oil tends to be more volatile than heavier crudes and possesses natural gases that release from the oil when it is heated. These flammable natural gases, such as propane and ethane, can cause additional atmospheric risks for fire spread and inhalation hazards because propane gas is heavier than air and collects near the ground. Light crude oil also floats on water, which will spread quickly in moving waters.[28]

[26] U.S. Energy Information Administration, *Crude Oils Have Different Quality Characteristics*, Today in Energy, http://www.eia.gov/todayinenergy/detail.cfm?id=7110 (accessed June 22, 2015).
[27] National Fire Protection Agency, *704 Frequently Asked Questions on NFPA 704*, http://www.nfpa.org/Assets/files/AboutTheCodes/704/704_FAQs.pdf (accessed June 22, 2015).
[28] U.S. Department of Transportation, Emergency Response Guidebook, Guide 115, Propane. 2012, Print.

1.3.2 Crude Oil Composition Variability Poses Challenges in Transport

The variability in types of crude raises challenges for the transport of crude oil products. Understanding the variability in crude oil composition and related terms helps policymakers, planners, and responders determine likely consequences, should a transportation incident occur, and prepare for an appropriate response. There are multiple classifications of crude oil products and national standards for labeling and identifying each. Proper container labeling can provide insight into the type of product in transit, but labels may not provide enough information for responders to determine the best operational response. Shipping papers, such as manifests, bills of lading, and material safety data sheets, are held by the train operator based on regulatory requirements and industry practices; these can also provide further insight and details about the products in transit, including:

- Proper shipping name of the material
- Hazard class and four-digit identification number
- Total quantity of materials
- Number and type of packages
- Packing group
- Emergency response telephone number
- Shipper (origination)
- Consignee/buyer (destination)

Emergency responders use hazard identifiers to develop and maintain situational awareness of preparedness and response measures to hazardous materials incidents, which include crude oil transportation accidents. Use of the hazard classification and labeling systems, as noted below, improves response tactical considerations that are designed to reduce loss of life and property, and environmental impacts.

1.3.3 USDOT Placards (Crude Oil)

Transportation containers carrying certain types of hazardous materials are required to display a USDOT Hazard Classification Identification Placard. USDOT placards identify all petroleum crude oil products as UN1267, regardless of gravity or sulfur content. They are designated as Class 3 flammable liquids under 49 CFR 173.120. The placard proves useful to first responders, who use it as an initial indicator of what type of hazardous material they are facing.

1.3.4 PHMSA Classifications for Crude Oil

PHMSA regulations further classify hazardous materials in transport according to risk characteristics. The three classifications are:

- Packing Group III (minor danger)
- Packing Group II (medium danger)
- Packing Group I (great danger)

Light sweet crude oil may be classified within Packing Group I, II, or III depending on the specific properties of the batch of oil being transported. Specific properties include vapor pressure, initial boiling points, flashpoints, and dissolved gas content, all of which vary based on the grade of the crude oil (light versus heavy), source of extraction (different well sites), and time of year it is produced (crude may contain a higher concentration of dissolved gases during cold weather).

1.3.5 USEPA Classifications for Crude Oil

The U.S. Environmental Protection Agency (USEPA) has also developed its own classification specifically for crude oil. USEPA classifications describe general toxicity, physical state, and changes that occur with time and weathering. The four classifications are:

- Class A: Light, Volatile Oils: Class A oils are highly fluid, often clear, spread rapidly on solid or water surfaces, have a strong odor, high evaporation rate, and are usually flammable. They penetrate porous surfaces such as dirt and sand, and may be persistent in such a matrix. They do not tend to adhere to surfaces. Flushing with water generally removes them. Class A oils may be highly toxic to humans, fish, and other organisms.[29] Most refined products and many of the highest-quality light crudes are included in this class. Light sweet crude oil fits within this category.
- Class B: Non-Sticky Oils: Class B oils have a waxy or oily feel. Class B oils are less toxic and adhere more firmly to surfaces than Class A oils, although they can be removed from surfaces by vigorous flushing. As temperatures rise, their tendency to penetrate porous substrates increases and they can be persistent. Evaporation of volatiles may lead to a Class C or D residue. Medium to heavy paraffin-based oils fall into this class.
- Class C: Heavy, Sticky Oils: Class C oils are characteristically viscous, sticky or tarry, and brown or black. Flushing with water will not readily remove this material from surfaces, but neither does it readily penetrate porous surfaces. The density of Class C oils may be near that of water, and they often sink. Weathering or evaporation of volatiles may produce solid or tarry Class D oil. Toxicity is low, but wildlife can be smothered or drowned when contaminated. This class includes residual fuel oils and medium to heavy crudes.
- Class D: Non-Fluid Oils: Class D oils are relatively non-toxic, do not penetrate porous substrates, and are usually black or dark brown in color. When heated, Class D oils may melt and coat surfaces, making cleanup very difficult. Residual oils, heavy crude oils, some high paraffin oils, and some weathered oils fall into this class.

1.3.6 Industry Descriptions of Ethanol

Ethanol is a colorless, clear liquid that has a weak, vinous odor. It is also a volatile substance whose flammability is dependent on water content. Most ethanol is created through fermentation

[29] U.S. Department of Transportation, Pipeline Hazardous Materials Safety Administration, https://primis.phmsa.dot.gov/comm/MarkersBrief.htm (accessed June 22, 2015).

of sugar, starches, or feedstocks, with the most common feedstock being corn.[30] Ethanol is an ingredient found in alcoholic beverages and other industrial products, such as solvents, pharmaceuticals, cleaning products, etc. However, the most common use for ethanol is that of fuel for internal combustion engines. In the U.S., ethanol is blended with gasoline to create gasohol. Gasohol blends typically have a 10 percent ethanol (E10) composition, with gasoline blends having ethanol content as high 85 percent (E85). Typically, pure ethanol is transported to tank farms, where the fuel is stored until mixing and customer delivery.

1.3.7 Ethanol Challenges in Transport

Transporting ethanol has been reduced to truck, rail, and barge, since transporting by pipelines is problematic. Pipelines have been an area of concern due to the corrosive nature of ethanol and the fact that ethanol reacts with other products and substances within the pipeline. Corrosion is a major concern as it can affect the structural integrity of the piping material making it possible to release the product. The solvent and miscible properties of ethanol also allows it to mix with other soluble materials, e.g. water, dirt, etc., which in turn creates a product that can no longer meet specification.

Ethanol can be transported in different mixed concentrations and as an additive to different media (e.g. gasohol) and in its pure state. Similar to bulk crude oil, shipping papers, and hazard identifiers are needed to assist emergency responders reacting to hazardous materials incidents involving ethanol.

1.3.8 USDOT Placards (Ethanol)

Transportation containers carrying certain types of hazardous materials are required to display a USDOT Hazard Classification Identification Placard. USDOT placards identify:

- Gasoline, E1 thru E10 as UN 1203
- Ethanol and Gasoline Mixtures, E11 thru E99 as UN 3475
- Alcohol, not otherwise specified (n.o.s.), E95 thru E99 as UN 1987
- Ethanol or Ethyl alcohol, E100 only as UN 1170

All of the above placards categorized ethanol as a Class 3 flammable liquid under 49 CFR 173.120. The placards prove useful to first responders, who use them as an initial indicator of what type of hazardous material they are facing.

1.4 2012 Emergency Response Guidebook (ERG)

1.4.1 Crude Oil and Ethanol

The U.S. Department of Transportation's (USDOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) publishes a guidebook for first responders for use during the initial

[30] USEPA – Section II Ethanol Industry and Process Descriptions: https://www.osha.gov/dts/osta/otm/otm_iv/descriptions.pdf

phase of dangerous good/hazardous material transportation incident. [31] The most recent ERG was published in 2012, and is updated on a four-year cycle. The 2016 edition will be available in early 2016. The ERG allows first responders to look up commodities by either proper shipping name or 4-Digit Number (UN or NA) to determine the appropriate course of action for response, with respect to the commodity and nature of incident. Several other resources are also included in the ERG.

Per the ERG, potential hazards for both ethanol and crude oil are similar since they both are classified as Class 3 flammable liquids. It is important to note that initial evacuation distances are recommended to be 0.5-mile in all directions, in the event of a fire. This fact will be used in the development of the Study's "Risk and Vulnerability Analysis." Also worth noting is the fact that firefighting strategies vary between the two commodities. Ethanol and other alcohol-based solvents require alcohol-resistant foam, whereas regular firefighting foam can be used to extinguish crude oil fires. [32]

[31] USDOT- PHMSA, *2012 Emergency Response Guidebook*, http://phmsa.dot.gov/pv_obj_cache/pv_obj_id_7410989F4294AE44A2EBF6A80ADB640BCA8E4200/filename/ERG2012.pdf

[32] Ibid.