North American Crude Oil Transportation

Implications for Emergency Preparedness and Response

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Introduction

Historically, the United States has imported more crude oil than it produces domestically. However, this trend was reversed in October, 2013, and the U.S. is now the leading crude oil producer in the world, due in part to increased domestic production of crude oil from the Bakken oil fields in North Dakota and the Eagle Ford oil fields in Texas. More domestic crude oil and natural gas is leading to increased chemical production, such as the production of ethane gas, which is leading to an increase in plans for constructing new chemical plants.

In response to these trends, there has been a significant increase in the transportation of crude oil across North American via maritime, pipeline, rail and motor carrier transportation systems. More specifically, the North American crude oil transportation profile has shifted, resulting in more crude by rail, more crude by barge and an increase in coastal crude oil transportation by coastal tankers and articulated barges.

Railroads became the most visible example of this shift in crude oil transportation when a train derailed and exploded in Lac-Mégantic, Quebec, on July 6, 2013, resulting in 47 fatalities and extensive property damage. Additional accidents occurred in the U.S. and Canada in 2103, including accidents in Alabama, North Dakota, Pennsylvania, Minnesota, Virginia, and New Brunswick.

Most average cities across the United States do not have adequate crude-oil response capabilities to handle moderate crude oil accidents.[1] This is in part because oil response plans are primarily developed at the facility level in the form of facility response plans. While Class I railroads all have some type of transportation response plan, such a plan is not required by the Federal Railroad Administration due to tank car capacity requirement in federal regulations.

With the increase of crude oil transportation in North America, there is an immediate need to improve state and local emergency preparedness and response programs. This paper examines North American crude oil transportation trends and flows to help those states and provinces through which the highest volumes are being transported. This will help states and provinces to improve emergency planning, to identify transportation infrastructure priorities, and to prioritize emergency response needs and capabilities.

[1] Rick Edinger (Edinger, 2014).

Domestic Crude Oil Production and Transportation

Crude oil extraction techniques continue to evolve with the advent of new techniques, including hydraulic fracking for extracting shale oil deposits. Hydraulic fracking, in particular, has enabled oil companies to extract more crude oil from shale deposits in the United States. Two examples are in the Bakken Oil Fields of North Dakota and the Eagle Ford oil fields in Texas.

There are currently 144 crude oil refineries in the United States, located primarily in the gulf coast, east coast, west coast, and Midwest. Refineries are located adjacent to coasts and rivers for maritime transportation and are connected by pipelines, railroads, and highways as displayed in Figure 1.

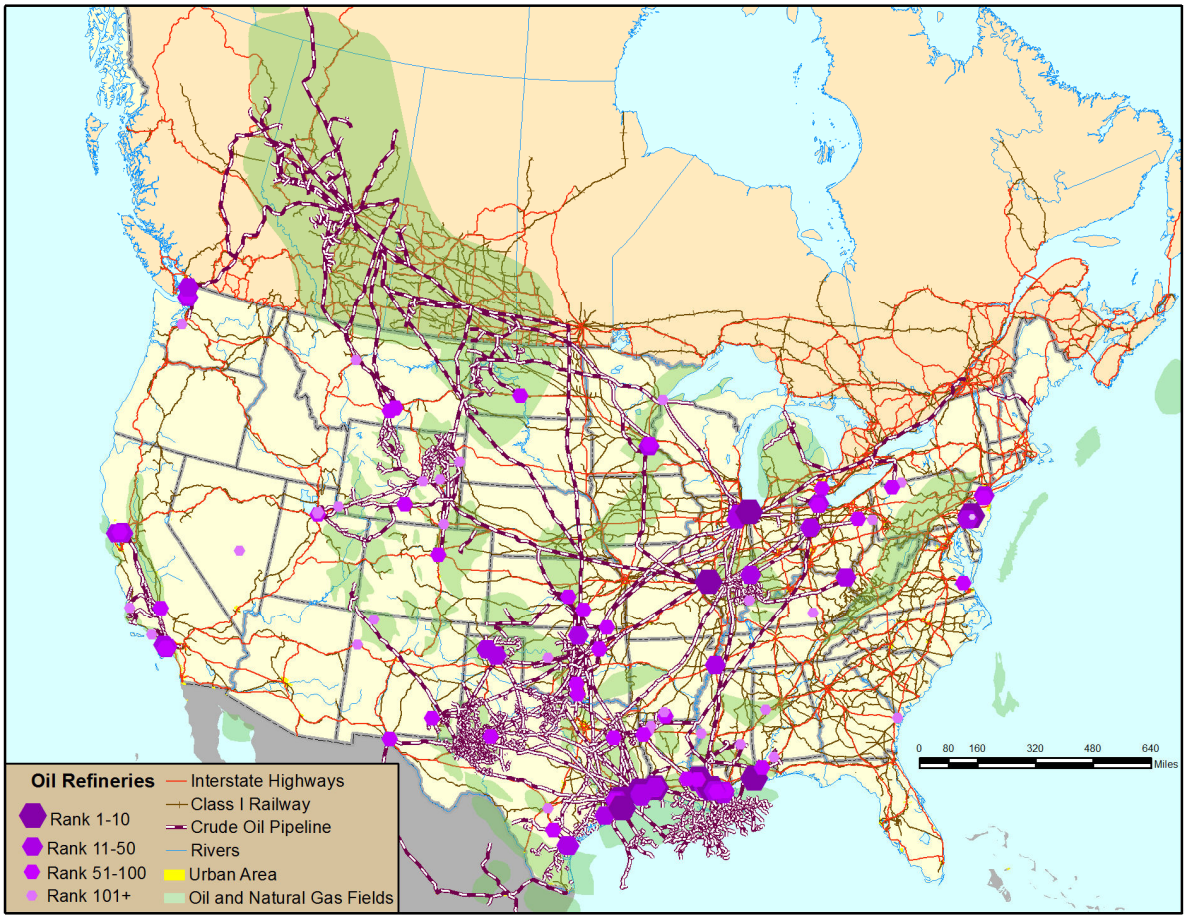

Figure 1: Crude Oil Refineries and Transportation Infrastructure

Oil refineries are supplied with crude oil from a variety of sources and transportation systems. Foreign crude oil shipments are transported by oil tankers and barges. Most of the domestic crude oil is supplied by pipeline and rail.
In the United States, petroleum areas are divided into five Petroleum Area Defense Districts (PADDs), which are shown below.

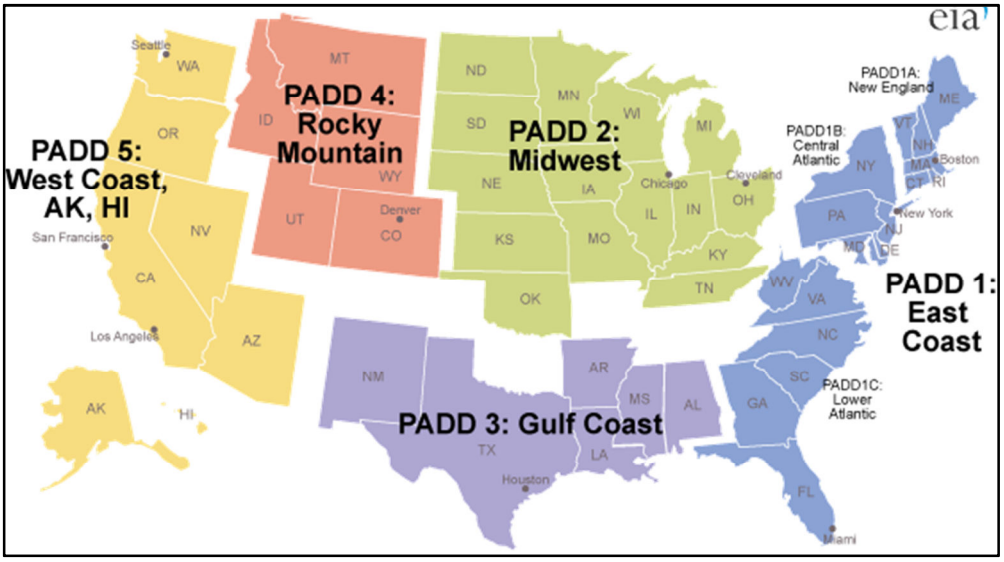

Figure 2: Petroleum Area Defense Districts

Figure 3 shows North American crude oil flows among the PADDs by pipeline, maritime, and rail. Each of these transportation flows and associated implications for emergency response are discussed in the following sections.

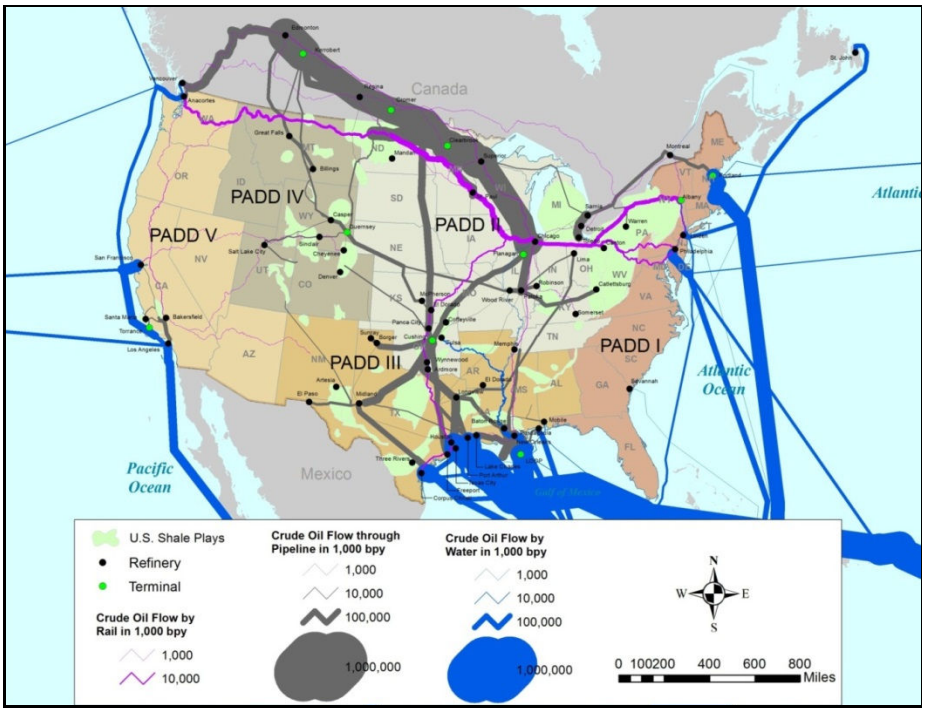

Figure 3: Crude Oil Transportation by Pipeline, Maritime, and Rail

Crude Oil by Pipeline

Crude oil pipelines collect oil from inland production areas including Canada and North Dakota for transportation to refineries in the Midwest and Gulf Coast PADDs. The largest volume is from Canada to Chicago. Cushing, Oklahoma serves as the primary hub for all Midwest pipelines between North Dakota and Texas, and is where prices for West Texas Intermediate (WTI) crude oil are determined. Vancouver is served by pipeline from Canada where oil is transported by tanker and barge.

Although the assumption in the oil business is that pipelines are the least expensive mode of transport, they only provide transport from any one producing region to a very limited number of market destinations. This is effective when pipelines have available capacity to reach markets where crude is needed. However, because there is limited pipeline capacity in North America and increasing demand for crude, pipelines are becoming congested. This has led to the crude by rail boom that expanded in 2012 starting in the North Dakota Bakken and spreading to producing regions in Texas, Wyoming, the Midcontinent and Canada.

The North American pipeline network is extensive, as shown in Figure 4, below. However, crude oil pipelines do not reach east and west coast oil refineries.

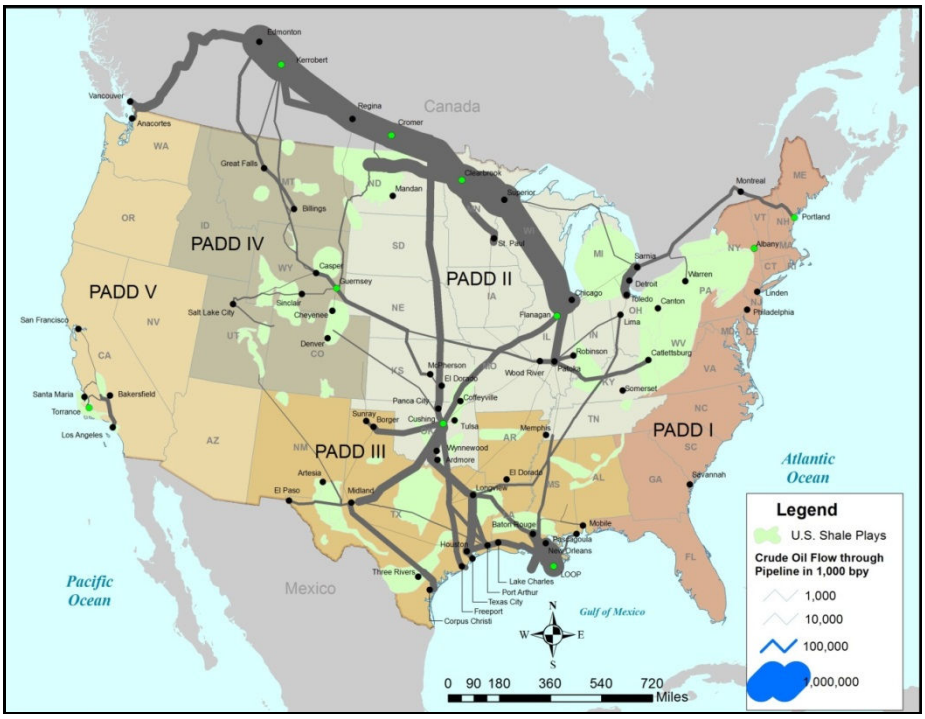

Figure 4: Crude Oil Volumes by Pipeline 2013

Implications for Emergency Preparedness and Response

All pipeline companies develop emergency response procedures and are required under federal law to develop an emergency procedures manual for each pipeline. The emergency response plans are designed to protect the public from health effects and serious injury as well as to limit any damage to pipeline facilities and reduce impacts to the environment and to endangered species and their habitats. Emergency response plans are designed to address worst-case emergency scenarios. They identify potential hazards to the public and the environment and set out a chain of command and other systems to ensure an adequate response in case of emergency. Federal Response Plans (FRP) require facilities to retain a clean-up company with the capacity to respond to an event involving their specific needs.

Crude Oil by Rail

While there are about 57,000 miles of crude oil pipelines in the United States, there are nearly 140,000 miles of railroad.[2] Due to the limitations of pipeline capacity and geography, additional crude oil has been transported by rail in the past two years in response to increasing demand.

According to the American Association of Railroads (AAR), in 2008, U.S. Class I railroads transported 9,500 carloads of crude oil. This amount has jumped to nearly 234,000 carloads in 2012 and nearly 400,000 carloads in 2013.[3] According to the Pipeline and Hazardous Materials Safety Administration (PHMSA), the overall volume of crude oil moving by rail has quadrupled in less than a decade.

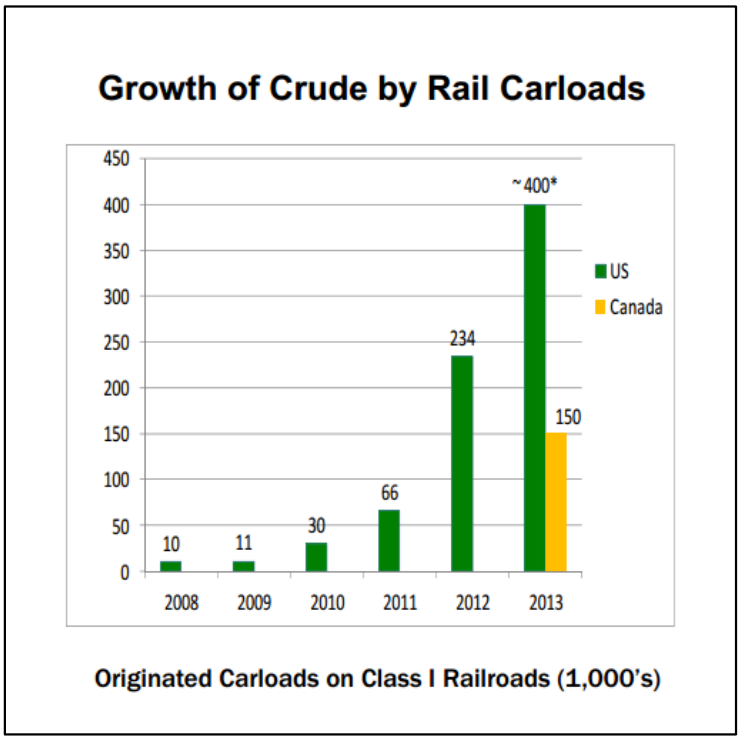

Figure 5: Crude by Rail Growth 2008-2013

Multiple crude oil unit trains/day are traversing North America through numerous major metropolitan areas. Over one hundred-car trains are rolling out from the Bakken Region in all directions: west to Washington state and Los Angeles, south to Gulf Coast refiners, north to Canada, and east to refineries in Philadelphia and New Jersey. Figure 6 below depicts crude oil flows by rail in 2013.

[2] USDOT Pipeline and Hazardous Materials Safety Administration (PHMSA)

[3] American Association of Railroads (AAR)

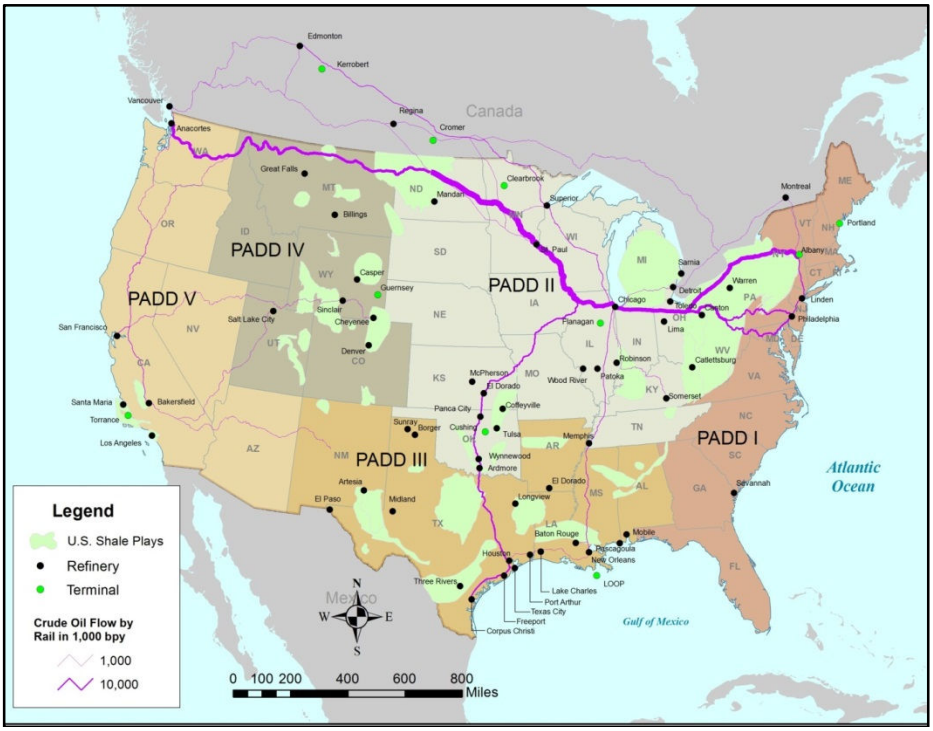

Figure 6: Crude by Rail Volume 2013

Implications for Emergency Preparedness and Response

The recent surge in crude oil transportation incidents in North America has raised concerns about transporting crude oil, particularly by rail. These concerns include transportation carrier responsibilities, crude oil classification, tank car safety, track conditions, and emergency response capabilities. Even a derailment and spill of a single tank car of 34,000 gallons, without combusting, will overwhelm most cities and towns' resources. Moreover, there is a major gap between the planning required for railroads, pipelines, and terminals, and the planning conducted at the local level. However, local first responders will be the first line of defense when an event occurs. This will require access to pipeline, railroad, and terminal data.

In California, for example, lawmakers are concerned the state is not prepared for crude oil rail accidents. To support emergency preparedness and response capabilities, California will apply a 6.5 cent fee beginning in 2015 on oil companies per barrel of crude oil arriving in California or oil piped from inside state's refineries.[4] In 2014, railroads responded to this emerging need for increased emergency preparedness by providing funding for oil emergency response training and for states through which large volumes of crude oil are transported.

[4] Bizjack, 2014.

In September, 2014, FEMA was tasked by the White House to design a series of emergency response exercises for Bakken crude oil. This exercise series will be comprehensive and interdisciplinary with whole community engagement and including some aspects of mutual aid for response.

Crude Oil by Motor Carrier

Motor carriers have been a critical link in moving crude oil from domestic drilling sites to rail terminals and to oil refineries. Tanker capacities range from 200 to 250 barrels of crude oil. Trucks readily serve the need for moving crude oil across shorter distances where flexibility is required. A large volume of crude oil is being transported by truck between production areas and refineries in Texas due to the distances involved. Therefore, most motor carrier movements are within North Dakota and Texas, with some trips extending west from North Dakota to Washington and south to California. Figure 7 below depicts crude oil shipments by pipeline, maritime, and rail to show areas where motor carrier transport is needed the most.

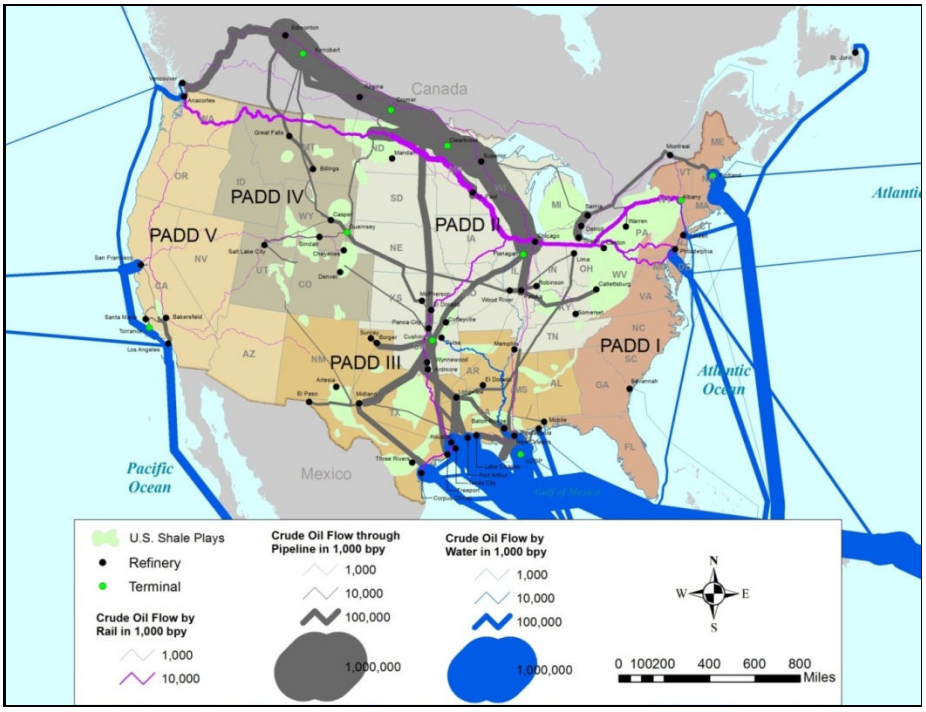

Figure 7: Crude Oil by Pipeline, Maritime, and Rail

Implications for Emergency Preparedness and Response

Increases in motor carrier crude oil transport will have ramifications on emergency response plans, particularly in states with significant crude oil motor carrier movements. The trend toward longer distance motor carrier trips is the result of

crude oil production in states with limited pipeline and storage capacity. For example, there are increasing motor carrier trips from the Midwest to the west coast to supplement increased crude oil demand. In North Dakota, motor carriers play an important role transporting product to rail terminals. In Texas, motor carriers transport crude oil from production sites directly to refineries. Emergency response plans need to be modified in affected states in response to these trends.

Crude Oil by Maritime

Most of the U.S. oil refineries are located near the coastline with access to port facilities. The largest crude oil volumes in North America are in the Gulf of Mexico accessing ports along the Gulf Coast. East coast ports include Portland ME, Philadelphia, PA and New York, NY. West coast ports include Long Beach, CA, San Francisco, CA, and Vancouver, WA.

Locations where railroads transfer crude oil to barges include St. Louis and Hayti, MO; Osceola, AR; Hennepin, IL; Albany, NY; Yorktown, VA; and Anacortes and Vancouver, WA. Crude oil produced at Eagle Ford, TX, is transported along the coast by either barge or ship.

The Mississippi River and its tributaries are playing an increasing role in moving crude by barge. Unlike pipelines or railroads, barges can deliver to any refinery that has waterborne access without having to develop new infrastructure such as rail unloading terminals or pipeline connections. Crude is transported from producing regions to barge terminals on the river either by railroad or pipeline.

Tank barges are being used to move rail-shipped crude oil from North Dakota and Canada to ports along the Mississippi River. After shale oil and natural gas have been refined, inland barges are used to transport these refined products, including gasoline and jet fuel, back up the river to manufacturing hubs in the Northeast.

A river barge can hold 30,000 barrels of oil and when combined can reach capacities of 90,000 barrels, about the same load as a unit train. Trains from the Bakken region can unload in St. Louis, MO, where crude oil is loaded on to barges for the trip to the Gulf Coast. Refined products make the reverse trip north, ensuring consistent barge capacity north and south.

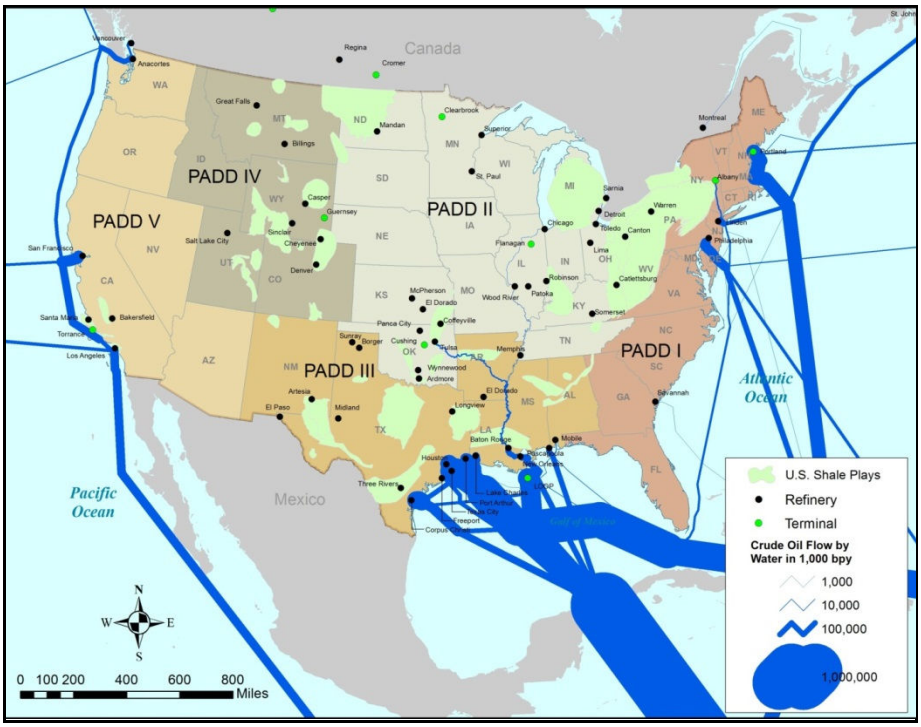

Figure 8: Crude Oil by Maritime – Tanker and Barge

Implications for Emergency Preparedness and Response

The National Contingency Plan (NCP) is the framework for all maritime spill response plans. The NCP designates the Coast Guard as the lead federal agency or Federal On-Scene Coordinator (FOSC) for directing the removal and mitigation of oil spills from waters and adjoining shorelines of the coastal zone. At the local level, ports develop Area Maritime Security Plans that will need to be modified to reflect the shift of crude by maritime to crude by rail. Examples of locations that should consider modifying plans include Albany, Philadelphia, Delaware City, Vancouver, St. Louis, and the San Francisco Bay Region.

Conclusion

The recent surge in domestic crude oil production has significantly changed how crude oil is transported in North America. Pipeline flows have been modified to account for additional crude oil refining requirements in Texas and the Gulf Coast. More crude oil is being transported by rail across northern states. There has also been an increase in coastal and river barge traffic. Motor carriers are transporting crude oil over larger distances in addition to providing important connections between production areas and refineries.

More domestic crude oil and natural gas is also leading to more chemical production such as ethane gas and other chemicals. More chemical companies are making plans to construct new chemical plants, which will lead to more chemical transportation in the United States. The increase is chemical transportation will have implications for how commodity flows of hazards materials change within the United States and from region to region.

This recent increase in domestic crude oil transportation has resulted in increases in crude oil incidents and accidents, mostly by rail. The USDOT has responded by proposing additional laws to regulate the operational controls such as braking and routing for High Hazard Flammable Trains (HHFT). The most recent Notice to Proposed Rulemaking (NPRM) addresses emergency response notification, train routing, classification, HHFT requirements, tank car designs, and phasing out DOT 111 and 112 tank cars. These proposed changes are still under discussion.

State and local officials have already recognized the need to improve state and local emergency preparedness and response programs. In addition, port officials are taking into account the shift from maritime crude oil shipments to inland crude oil rail shipments. This is impacting Area Maritime Plans and Area Maritime Security Plan in U.S. ports. States should also consider developing or updating statewide commodity flow studies of hazardous materials to ensure local officials are prepared for what is being transported "through their back yard." Such studies help to identify high risk areas associated with chemical facility and transportation sources, better understand affected populations, and improve emergency response capabilities.

About the Author

David Willauer, IEM Manager of Transportation and Geospatial Technology, is also serving as the Chairman of the TRB Subcommittee on Crude Oil Transportation. This subcommittee was formed in June 2013 in response to significant national increases in crude by rail, and the need for additional research on crude oil transportation by motor carrier, rail, pipeline, and barge. The composition of the committee includes federal and state government, industry, academia, consultants, and transportation agencies.

Willauer has over 20 years of experience with transportation and emergency planning, including evacuation studies, commodity flow studies of hazardous materials, transportation corridor plans, port security plans, and hazmat risk assessments. He is a seasoned mariner and licensed captain for up to 100 ton vessels and previously served as Planning Director for the Council of Governments in Portland, Maine.

Appendix A: Methodology

Information for this paper was collected from sources within the U.S. Energy Information Association (EIA). Using a multimodal approach, IEM assigned flows based on crude oil movements to and from oil refineries by pipeline, rail, ship and barge. Motor carrier movements were derived from assumptions of short distance crude oil transportation by state. The five Petroleum Area Defense Districts (PADDs) formed the basis for most of the data organized by the EIA. The following data sets were used to develop the maps displayed in this report:

- Crude oil supply and disposition by PAD district[5]
- Crude oil movements by pipeline between PAD districts[6]
- Crude oil movements by rail or barge between PAD districts[7]
- Crude oil production by state[8]
- Crude oil maritime imports by port[9]
- Crude oil transportation by water between states[10]
- Refinery receipts of crude oil by method of transportation by PAD district[11]
- Refinery capacities[12]
- Individual refinery crude oil source information

The crude oil flow volumes were estimated from one PAD district to another and the movements were captured in both directions. Refineries were grouped by cities for the purpose of oil flow estimation. IEM determined the volumes and routes using the known quantity of crude oil disposition (refinery capacity/input), the projected supply (production, import, and transport from other PADDs), and the mode split between pipeline, maritime, rail, and motor carrier.

[5] EIA, http://www.eia.gov/dnav/pet/PET_SUM_SND_A_EPC0_MBBL_A_CUR.htm
[6] EIA, http://www.eia.gov/dnav/pet/pet_move_pipe_a_EPC0_LMV_mbbl_a.htm
[7] EIA, http://www.eia.gov/dnav/pet/pet_move_tb_a_EPC0_BMV_mbbl_a.htm
[8] EIA, http://www.eia.gov/dnav/pet/PET_CRD_CRPDN_ADC_MBBL_A.htm
[9] US Army Corps of Engineers, http://www.navigationdatacenter.us/data/dataimex.htm
[10] US Army Corps of Engineers, http://www.navigationdatacenter.us/data/datapdom.htm
[11] EIA, http://www.eia.gov/petroleum/refinerycapacity/table9.pdf
[12] EIA, http://www.eia.gov/maps/map_data/EIA_Petroleum_Refineries_US_2013.zip