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Bakken Crude Oil and Similar Shale Oil Spills: Responder Guidance

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Summary:

- Bakken crude oils (and similar shale oils) contain a higher percent of dissolved gases that pose a higher risk of ignition as well as the production of volatile organic compounds and benzene that pose risks to responders and the public shortly after a release, compared to other crude oils.
- The size and scale of an incident described in this guide may be such that significant logistical challenges will delay responses until adequate resources can be identified, dispatched, and deployed. Adequate planning must be done to ensure resources being deployed are adequate for the size of the event at the time resources will be ready at the scene. This may necessitate the need for a scaled, measured response.
- Air monitoring is needed to establish hot, warm, and cold zones (refer to ERG 128; see Table 1).
- Spills of Bakken crude will likely require continuous air monitoring for days at differing locations over time; therefore, the IC/UC will need to mobilize such resources and technical specialists quickly.
- First responders should have the proper air monitoring equipment. Without the ability to measure the Lower Explosive Limit (LEL), benzene, and volatile organic compounds (VOCs), a full hazard assessment will not be possible.
- First responders should have appropriate personal protective equipment (PPE), per the 2016 Emergency Response Guide (ERG 128) such as self-contained breathing apparatus (SCBA). Turnout gear offers limited protection and/or may need to be decontaminated.
- HAZWOPER regulations will apply. 29 CFR 1910.120 covers emergency response operations for releases of, or substantial threats of releases of, hazardous substances regardless of the location of the hazard.
- Many of these procedures are unique and must not be used without appropriate training.
- Obtain proper paperwork with details from shipper, i.e., consist, bill of lading, Safety Data Sheets (SDS), to determine the type of oil and its composition.
- Ensure all responders are provided safety and hazard information on the SDS and ERG 128 BEFORE being sent close to affected area.
- Efforts should be made to quickly obtain paperwork from shipper, i.e., consist, bill of lading.
- Determining the amount of product and area affected will assist in identifying appropriate response actions (see ERG 128).

First-responder guidance is provided for the following spill conditions:

1. Spill from a tank, rail car, tanker truck, pipeline on **LAND**
    a. with NO FIRE
    b. with FIRE
2. Spill from a barge or tanker to **WATER**
    a. with NO FIRE
    b. with FIRE

Table 1. Recommended air monitoring at spill sites for responder safety. LEL and H_2S pose acute risks of ignition and death, so they are highest in the order.

Parameter*	Measurement/Action
NO FIRE	
LEL	<10% – proceed to measure other parameters 10-25% – proceed to measure other parameters but with care >25% – stand back until measurement is <25% LEL (Note that USEPA and USCG responders do not enter an atmosphere that exceeds 10% LEL)
H_2S	<1 ppm – proceed to measure other parameters >1 ppm – select appropriate respiratory protection for responders
VOCs	<100 ppm – proceed to measure other parameters >100 ppm – select appropriate respiratory protection and PPE for responders
Benzene**	<0.5 ppm – proceed with operations >0.5 ppm – select appropriate respiratory protection and PPE for responders
FIRE (additional parameters to those above)	
Particulates	<150 µg of $PM_{2.5}$ per m^3, averaged over 1 hr – proceed with operations >150 µg of $PM_{2.5}$ per m^3, averaged over 1 hr – select appropriate respiratory protection and PPE for responders
SO_2	<75 ppb averaged over 1 hr; <0.5 ppm averaged over 3 hr – meets NAAQS**
NO_2	<100 ppb averaged over 1 hr – meets NAAQS
CO	<9 ppm averaged over 8 hr; <35 ppm averaged over 1 hr – meets NAAQS**

***** LEL = Lower Explosive Limit: the LEL for Bakken crude oil is estimated to be 0.4-0.8%

H_2S = Hydrogen sulfide

VOCs = Volatile organic compounds

SO_2 = Sulfur dioxide

NO_2 = Nitrogen dioxide

CO = Carbon monoxide

** Most first responders have limited or no ability to monitor benzene levels. Specialized resources will likely be needed to determine benzene levels

*** National Ambient Air Quality Standards

For a release of Bakken crude oil and similar shale oils on LAND with NO FIRE:

Secure the perimeter
• Establish and secure a safety zone. Refer to ERG 128. • Evacuate non-essential personnel or public based on area affected. • Eliminate ignition sources. • Conduct air monitoring to identify hazards and assist in establishing hot, warm, and cold zones and required PPE for responder safety (see Table 1).
Stop the source
• Close valves, plug holes if this can be done safely and using non-sparking tools. • However, only pipeline staff should attempt to open or close pipeline valves.
Determine the need for vapor suppression
• If LEL is >25%, apply Class B firefighting foam. Class B foam blankets prevent vapor production and ignition of flammable and combustible liquids. See Appendix B for additional information on firefighting foam.
Minimize spread of oil on land
• Construct berms, trenches, etc. but only at safe distances as determined by continuous air quality monitoring. • Monitor air quality at all areas where the oil is contained. • Be aware of vapor ignition hazards in areas where the oil has been contained, or in sewers and other confined space where the oil has spread.
Minimize spread of oil into a water body
• Construct dams, dikes, diversions, etc., but only at safe distances as determined by continuous air quality monitoring. • Be aware of vapor ignition hazards in areas where oil has been contained, or in sewers and other confined space where oil has spread. • Be aware that there can be renewed release of VOCs, benzene, etc. when oil that was thick on land reaches a water body and spreads into a thinner slick.
Determine if booms should be used to contain oil on water for recovery
• Monitor VOCs and benzene adjacent to floating oil on open water. • In addition, monitor for LEL for floating oil in smaller water bodies (such as streams and ponds), where vapors could concentrate in low areas and not be dispersed by air turbulence. • If levels are below thresholds, proceed with oil containment and recovery. • If LEL is >25%, do not attempt containment unless adequate Class B foam is available to suppress vapors, and continue monitoring; if oil has not been contained and vapor suppression applied, once levels are below 25% LEL, proceed with containment and recovery and continue monitoring. • If VOCs and benzene levels are above thresholds, provide appropriate PPE for responders.
Implement protection strategies at sensitive areas
• If oil is present, monitor for VOCs and benzene to determine responder PPE before implementing the protection strategy. Refer to OSHA's Respiratory Protection Standard 29 CFR 1910.134 for more information. • If no oil is present, proceed with implementing the protection strategy.

For a release of Bakken crude oil and similar shale oils on LAND with FIRE (tank, rail car, tanker truck, pipeline):

Secure the perimeter

- Establish and secure a safety zone. Refer to ERG 128.
- Evacuate non-essential personnel or public based on area affected. Refer to ERG 128.
- First responder vehicles should be parked away from manholes and storm sewers.
- Conduct air monitoring to identify hazards and assist in establishing hot, warm, and cold zones and required PPE for responder safety (see Table 1).

Stop the source

- Close valves, plug holes if this can be done safely and using non-sparking tools.
- However, only pipeline staff should attempt to open or close pipeline valves.

Determine fire-fighting approach (can change over time)

Intervention

- Apply Class B firefighting foam. Foam is most effective on static fires that are contained in some manner. Firefighting foam is not effective on hydrocarbon fuels in motion (i.e., three dimensional fires) that include product leaking or spraying from manways, valves, fractures in the tank shell (e.g., rips, tears, etc.) or spills on sloping terrain.
- Key Issue: Will need to have adequate foam supplies and equipment available for post-fire operations that may last for several hours or days.
- Apply cooling water to any adjacent tank cars, barges, trucks, etc. containing ignition or BLEVE (boiling liquid expanding vapor explosion) hazards. Consider using unmanned hose holders or monitor nozzles.
- Do not apply water directly inside a rail car or tank. Apply water from the sides and from a safe distance to keep fire-exposed containers cool. Use unmanned fire monitors for cooling rail cars when available. Withdraw immediately in case of rising sound from venting pressure relief devices or tank discoloration. If available, dry chemical extinguishing agents, such as potassium bicarbonate (i.e., Purple K) may also be used in conjunction with Class B foams.
- Improper application of fire streams may create a dangerous phenomenon known as a slopover, increasing risks to emergency responders. A slopover results when a water stream is applied to the hot surface of burning oil. The water is converted into steam causing agitation of the liquid and burning oil to slop over the sides of the tank or rail car. This can occur within 10 minutes of the product becoming involved in fire. Note: Slopover will not occur in a pool of crude oil on the ground. However, a water stream can spread the fire.
- Application of foam, even if done properly many cause frothover if fire cannot be immediately extinguished. Frothover can occur as foam breaks down on the surface of the water and drains into the burning oil prior to extinguishment causing conditions similar to slopover.
- Dry chemical extinguishing agents must be compatible with foam.

Non-intervention

- Let the currently burning oil burn.
- Move non-affected rail cars/containers from fire area if this can be done safely.
- Consider the need for additional fire breaks.
- Apply cooling water to adjacent rail cars, tanks, or other vehicles containing oil. Use unmanned hose holders or monitor nozzles to reduce fire fighter risk.
- Monitor the progress of the fire. Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.

Control firefighting water runoff

- Prevent runoff from entering storm or sewer systems and sensitive areas, as this may create a serious hazard and environmental problems.
- Notify proper authorities, downstream sewer and water treatment operations, and other downstream users of potentially contaminated water.

• Runoff may be flammable and/or toxic and should be contained, treated, and disposed of in accordance with applicable federal, state and local environmental regulations.
Minimize spread of unburned oil on land
• Construct berms, trenches, etc. but only at safe distances as determined by continuous air quality monitoring. • Be aware of vapor ignition hazards in areas where the oil has been contained, or in sewers and other confined space where oil has spread.
Minimize spread of unburned oil into a water body
• Construct dams, dikes, diversions, etc., but only at safe distances as determined by continuous air quality monitoring. • Be aware of vapor ignition hazards in areas where oil has been contained, or in sewers and other confined space where the oil has spread. • Be aware that there can be renewed release of VOCs, benzene, etc. when oil that was thick on land reaches a water body and spreads into a thinner slick.
Determine if booms should be used to contain oil on water for recovery
• Monitor VOCs and benzene adjacent to floating oil on open water. • In addition, monitor for LEL for floating oil in smaller water bodies (such as streams and ponds), where vapors could concentrate in low areas and not be dispersed by air turbulence. • If levels are below thresholds, proceed with oil containment and recovery • If LEL is >25%, do not attempt containment but continue monitoring. Once levels are below 25% LEL, proceed with containment and recovery and continue monitoring. • If VOCs and benzene levels are above thresholds, provide appropriate PPE for responders.
Implement protection strategies at sensitive areas
• If oil is present, monitor for VOCs and benzene to determine responder PPE before implementing the protection strategy. Refer to OSHA's Respiratory Protection Standard 29 CFR 1910.134 for more information. • If no oil is present, proceed with implementing the protection strategy.

For a release of Bakken crude and similar shale oils on WATER with NO FIRE:

Secure the perimeter
• Establish and secure a safety zone around the vessel. • Interface with vessel crew. Vessel Captain has responsibility. • Evacuate non-essential personnel or public based on area affected. • Eliminate ignition sources. • Notify downstream facilities and/or water intakes of impacts. • Conduct air monitoring to identify hazards and assist in establishing hot, warm, and cold zones and required PPE for responder safety (see Table 1). • Ensure that small boats working in the area do not operate in or around floating oil as this may impact engines and other equipment until hazard is adequately evaluated. This is especially important for initial first responders who are first dispatched to an incident that has not been adequately evaluated as to size, scope and impact.
Stop the source
• Close valves, plug holes if this can be done safely and using non-sparking tools.
Determine if booms should be used to contain oil on water for recovery
• Monitor for VOCs and benzene adjacent to floating oil concentrations on open water. • In addition, monitor for LEL for floating oil in smaller water bodies (such as streams and ponds), where vapors could concentrate in low areas and not be dispersed by air turbulence. • If levels are below thresholds, proceed with oil containment and recovery. • If LEL is >25%, evaluate ignition sources but do not attempt containment. • If oil will not be impacted by ignition sources, continue monitoring; once levels are below 25% LEL, proceed with containment and recovery and continue monitoring. • If ignition sources cannot be eliminated, evaluate ability to conduct diversion booming to keep oil away from ignition sources. Ensure all vessels operating in the area have air monitoring equipment to keep out of hazardous atmospheres. • If tug/barge is involved, with LEL <25% consideration for removing the tug should be made or for LEL >25% shutting down tug (as ignition source) and removing the crew must be evaluated. • If oil can be safely boomed and simultaneously covered with class B foam to reduce or eliminate vapors, consider booming oil to reduce fire risk and spread of oil. • If VOCs and benzene levels are above thresholds, provide appropriate PPE for responders.
Implement protection strategies at sensitive areas
• If oil is present, monitor for VOCs and benzene to determine responder PPE before implementing the protection strategy. • If no oil is present, proceed with implementing the protection strategy.
Determine if additional protective measures should be used to limit the impact of flammable vapors
• If flammable vapors are detected in areas of concern, consider the need for vapor dispersion utilizing fog streams from fixed or portable fire monitors. • If vapors cannot be suppressed utilizing Class B foams, consider using fire monitors to agitate oil on the water to more rapidly increase vaporization to facilitate mechanical oil removal from water.

For a release of Bakken crude and similar shale oils on WATER with FIRE:

Secure the perimeter

- Determine jurisdictional boundaries (important to determine local Incident Commander).
- Interface with vessel crew. Vessel Captain has responsibility.
- Establish and secure a safety zone around the vessel.
- Evacuate non-essential personnel or public based on area affected.
- Determine if vessel can be anchored or transit to safe haven (Places of Refuge).
- Utilize Thermal Imaging Cameras or FLIR to determine extent of fire impact on adjoining tanks or structures.
- Conduct air monitoring to identify hazards and assist in establishing hot, warm and cold zones and offsite impacts and required PPE for responder safety (see Table 1).

Stop the source

- Close valves, plug holes if this can be done safely and using non-sparking tools.

Determine fire-fighting approach (can change over time)

Intervention

- Have vessel owner activate their Vessel Marine Firefighting and Salvage Annex of their Vessel Response Plan.
- Apply cooling water externally to any structures including adjacent docks, piers, tanks, vessel hull and deck. Avoid putting water into interior of vessel to prevent destabilization. Water streams may be needed to cool fire before application of firefighting foam.
- Fire systems on board tank vessels may be used to provide boundary and exposure protection, but this system should be augmented using the International Shore Connection (ISC) from an off vessel source (fireboat, facility system, fire engine).
- Fire systems on facilities may be used to protect facility exposures and if practical assist in protecting exposures on vessels as well.
- Do not apply water directly inside vessel tanks or other spaces. Apply water from the facility, fireboats, sides, deck, and superstructure from a safe distance to keep fire exposed vessel structures cool. Use unmanned fire monitors and hose lines for cooling where available.
- Apply Class B firefighting foam. Foam is most effective on static fires that are contained in some manner. Foam is ineffective on free-floating fuel fires.
- Vessel may be ringed in fire boom or oil boom (if foam is applied on the inside of the boom as it encircles). This requires close coordination of application of foam and booming vessels. Steel cable will be required by booming vessels to protect tow lines from fire. Foam must be available and ready for application prior to booming vessel.
- Booming vessel may increase fire impact on vessel initially until foam is effective at reducing fire.
- Fire in tanks that have been compromised may require foam hand lines to reach fire areas.
- If available, dry chemical extinguishing agents, such as potassium bicarbonate (i.e., Purple K) may also be used in conjunction with Class B foams. Dry chemical may be required to extinguish fires in tanks or piping.
- Key Issue: Will need to have adequate foam supplies and equipment available for post-fire operations that may last for several hours or days.

Non-intervention

- Let the currently burning oil burn.
- Apply cooling water to any structures including adjacent docks, piers, tanks, vessel hull and deck. Avoid putting water into interior of vessel to prevent destabilization.
- Fire systems on board tank vessels may be used to provide boundary and exposure protection, but this system should be augmented using the International Shore Connection (ISC) from an off vessel source (fireboat, facility system, fire engine).
- Monitor the progress of the fire. Withdraw immediately in case of rising sound from venting safety devices on non-burning tanks indicating excessive heating of tanks. Apply cooling water to sides and tops of tanks if possible.

• Monitor heating spread using thermal imaging devices. **Caution**: As oil burns or leaks from impacted tanks, a hogging or sagging condition may occur causing the vessel's hull to fracture. This could greatly increase the fire and or stability of the vessel significantly increasing risk or impacts. Additionally, fire impinging on the hull or tank structure may weaken the structure causing it to catastrophically fail.
Minimize spread and impact of burning oil away from vessel
• Booming may be used to reduce the impact and spread of floating fuel fires. Fire boom can be used if available, but normal boom may be used if it is protected by Class B foam to keep fire from affecting the boom. • Fire streams may be set up on areas (waterfronts/piers/facilities) that could be impacted by floating fuel fires to deflect fuel and/or protect exposures.
Minimize impact of floating fuel fires on vessel
• Utilize shipboard firefighting systems to protect vessel exposures (superstructure, deck, hull) until fire can be extinguished. • If fire involves a barge or dead-ship tanker, then fireboats may be required to provide adequate water supply for cooling or exposure protection.
Determine if additional protective measures should be used to limit the impact of flammable vapors
• If flammable vapors are detected in areas of concern, consider the need for vapor dispersion utilizing fog streams from fixed or portable fire monitors. • If vapors cannot be suppressed utilizing Class B foams, consider using fire monitors to agitate oil on the water to more rapidly increase vaporization to facilitate mechanical oil removal from water.

Additional Resources:

NOAA ADIOS (Automated Data Inquiry for Oil Spills) oil weathering model. Available at: http://response.restoration.noaa.gov/adios

Emergency Response Guidebook. USDOT. 2016. Available at: http://www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/Hazmat/ERG2016.pdf

Region III LEPC Fact Sheet: Bakken Crude Oil: Available at: https://crrc.unh.edu/sites/crrc.unh.edu/files/lepc_update_2015_february_regioniii_rev3_0.pdf

Sandia Report on Literature Survey of Crude Oil Properties Relevant to Handling and Fire Safety in Transport. DOE/DOT Tight Crude Oil Flammability and Transportation Spill Safety Project. March 2015. Available at: http://prod.sandia.gov/techlib/access-control.cgi/2015/151823.pdf

TRANSCAER API AAR Crude Oil by Rail Safety Course. March 2015. Available at: http://www.api.org/~/media/files/oil-and-natural-gas/rail-transportation/transcaer-api-aar-crude-oil-by-rail-safety-course.pdf

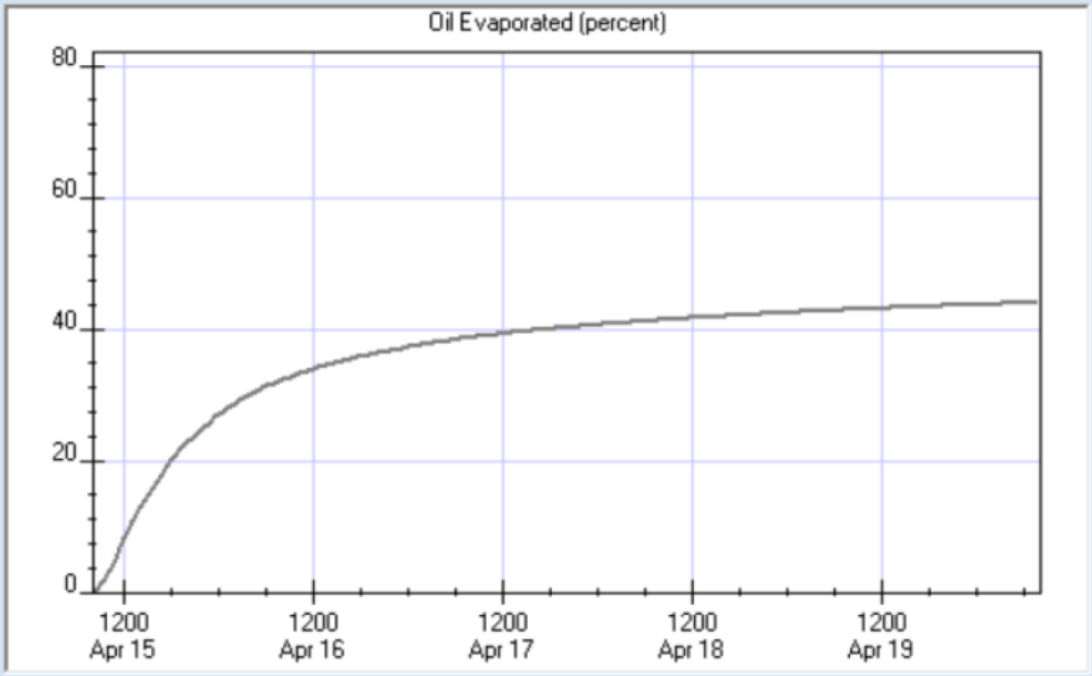
Consensus Ecological Risk Assessment of Potential Transportation-related Bakken and Dilbit Crude Oil Spills in the Delaware Bay Area: Comparative Evaluation of Response Actions. 2015. Available at: https://www.uscg.mil/d5/sectDelawareBay/Planning/Final_ERA_report_093015%20REV.pdf

National Response Team Webinar. Available at: http://www.nrt.org/production/NRT/NRTWeb.nsf/AllPagesByTitle/SP-EmergingRisksResponderAwarenessTrainingBakkenCrudeOil(2015)?Opendocument

Transportation Rail Incident Preparedness & Response: Flammable Liquid Unit Trains Resource Fact Sheet. Available at: https://www.iafc.org/files/1HAZ/TRIPRFlammableLiquidUnitTrainsFactSheet.pdf

Though each spill will be different, the graph below shows the results of the NOAA oil weathering model (ADIOS 2) for a release of 50,000 barrels of Bakken crude oil from a barge in the Delaware River with winds of 3 knots and 60°F. Benzene levels were modeled to be very high for the first several hours, and above 0.5 ppm for ~16 hours.

Evaporation



Benzene