Hudson River Oil Spill Risk Assessment

Volume 1:
Executive Summary

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Acknowledgments

This project was commissioned by Scenic Hudson, Inc., of Poughkeepsie, New York, under a Professional Services Contract with Environmental Research Consulting (ERC). RPS ASA, SEAConsult LLC, and Risknology, Inc., were all subcontractors to ERC under separate contracts.

The HROSRA research team acknowledges the invaluable inputs and discussions with Scenic Hudson over the course of the study period (September 2017 through May 2018), including the selection and development of the hypothetical spill scenarios. The contents of the report, data, analyses, findings, and conclusions are solely the responsibility of the research team and do not constitute any official position by Scenic Hudson. The Hudson River Oil Spill Risk Assessment was conducted as an independent, objective, technical analysis without any particular agenda or viewpoint except to provide quantitative and qualitative information that could be used to work to a common goal of spill prevention and preparedness. The study is intended to inform officials, decision-makers, stakeholders, and the general public about oil spill risk in the Hudson River.

The diligent efforts of the RPS SIMAP modeling team of Deborah Crowley, Jenna Ducharme, Matt Frediani, Emily Skeehan, and Matt Bernardo provided the necessary data, results, maps, and graphics that formed the foundation of much of the analysis in the HROSRA.

The research team also acknowledges the Launch 5 Foundation of Ossining who provided the team with transportation on a two-day river cruise between the Tappan Zee Bridge in Tarrytown and the Port of Albany, New York, on the *Patrolman Henry A. Walburger No. 5* ("Launch 5") on 15-16 September 2017. The Launch 5 was piloted by Greg Porteus and Steve Kardian. The 26-hour two-way trip allowed the research team to personally see, photograph, evaluate, and measure the features of both banks of the Hudson River, as well as observe vessel traffic and river conditions.

Cover Photograph Credits

The photographs on the report cover were taken by Dagmar Schmidt Etkin (Esopus Meadows Lighthouse and articulated tank barge) and Steve Kardian (bald eagle) on the Hudson River.

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Acronyms and Abbreviations

ACP: Area Contingency Plan

AMPD: average most-probable discharge

ANPRM: Advanced Notice of Proposed Rulemaking

ATB: articulated tank barge

bbl: barrels of oil (equivalent of 42 gallons)

BTEX: benzene, toluene, ethylbenzene, and xylene

CBR: crude-by-rail

CFR: *Code of Federal Register*

DPS: Distinct Population Segments

EIS: Environmental Impact Statement

EPA: Environmental Protection Agency

ERC: Environmental Research Consulting

ESA: Endangered Species Act

FOSC: Federal On-Scene Coordinator

FW: feet water

GIS: Geographic Information System

HROSRA: Hudson River Oil Spill Risk Assessment

HVPA: High-Volume Port Area

kts: knots

MHW: mean high water

MLW: mean low water

MMPD: maximum most-probable discharge

NEPA: National Environmental Policy Act

NMFS: National Marine Fisheries Service

NOAA: National Oceanic and Atmospheric Administration

NPRM: Notice of Proposed Rulemaking

NYSDEC: New York State Department of Environmental Conservation

PAH: polycyclic aromatic hydrocarbons (or polynuclear aromatic hydrocarbons)

PHAST: Process Hazard Analysis Software Tool

PHMSA: Pipeline and Hazardous Material Safety Administration

PTC: positive train control

QRG: Quick Response Guide

SIMAP: Spill Impact Model Application Package

SPM: suspended particulate matter

USCG: US Coast Guard

VTS: Vessel Traffic Service

WCD: worst-case discharge

Hudson River Oil Spill Risk Assessment Report Volumes

The Hudson River Oil Spill Risk Assessment (HROSRA) is composed of seven separate volumes that cover separate aspects of the study.

Executive Summary (HROSRA Volume 1)

The first volume provides an overall summary of results in relatively *non-technical* terms, including:

- Purpose of study;
- Brief explanation of risk as "probability times consequences" and the way in which the study addresses these different factors;
- Brief discussion of oil spill basics;
- Results – the "story" of each spill scenario, including the oil trajectory/fate/exposure, fire/explosion brief story (if applicable), and a verbal description of the consequence mitigation (response – spill and fire emergency); and
- Brief summary of spill mitigation measures with respect to response preparedness and prevention.

HROSRA Volume 2

The second volume provides an overview of the study approach and general introduction to unique features of the Hudson River.

HROSRA Volume 3

The third volume reviews the potential sources of oil spillage. It also presents the analyses of the probability of occurrences of spills of varying sizes from the potential sources under different conditions of traffic and oil transport.

HROSRA Volume 4

The fourth volume presents the analyses of the potential consequences or impacts of hypothetical spills, including the trajectory and fate of spills to the water, and the potential exposure of resources above thresholds of concern, based on oil modeling (including Appendices with detailed figures, etc.).

HROSRA Volume 5

The fifth volume presents the analyses of potential consequences or impacts of hypothetical fire and explosion events that may occur in addition to oil spills.

HROSRA Volume 6

The sixth volume presents the analyses of spill mitigation measures to reduce the risk of spills through prevention, preparedness, and response. The volume includes response and preparedness considerations for the specific modeled scenarios, as well as overall response issues for the Hudson River. It also includes more generic descriptions of prevention measures (vessels, trains, facilities, etc.).

HROSRA Volume 7

The seventh volume presents the summary tables with data – including probabilities, spill modeling, fire/explosion analysis, and response considerations for each of the 72 modeled spill scenarios. This volume pulls together everything from HROSRA Volumes 3, 4, 5, and 6.

Research Team

Dagmar Schmidt Etkin, PhD (Environmental Research Consulting)

Dr. Etkin has 42 years of experience in environmental analysis–14 years investigating issues in population biology and ecological systems, and 28 years specializing in the analysis of oil spills. Since 1999, she has been president of Environmental Research Consulting (ERC) specializing in environmental risk assessment, and spill response and cost analyses. She has been an oil spill consultant to the US Coast Guard, EPA, NOAA, Army Corps of Engineers, the Bureau of Ocean Energy Management, the Bureau of Safety and Environmental Enforcement, various state governments, the Canadian government, the oil and shipping industries, and non-governmental organizations. She is internationally recognized as a spill expert and has been a member of the UN/IMO/UNEP/UNESCO Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) since 1997. She has a BA in Biology from University of Rochester, and received MA and PhD degrees from Harvard University in Organismic/Evolutionary Biology, specializing in ecological modeling and statistics.

Deborah French McCay, PhD (RPS Ocean Science)

Dr. French McCay (formerly Dr. French) specializes in quantitative assessments and modeling of aquatic ecosystems and populations, oil and chemical transport and fates, and biological response to pollutants. She has developed water quality, food web and ecosystem models for freshwater, marine and wetland ecosystems. She is an expert in modeling of oil and chemical fates and effects, toxicity, exposure and the bioaccumulation of pollutants by biota, along with the effects of this contamination. Her population modeling work includes models for plankton, benthic invertebrates, fisheries, birds and mammals. These models have been used for impact, risk, and natural resource damage assessments, as well as for studies of the biological systems. She has provided expert testimony in hearings regarding environmental risk and impact assessments. She has over 30 years of experience in analyzing oil spills and is considered one of the leading international experts on the fate and effects of oil spills. She has a BA in Zoology from Rutgers College, and a PhD in Biological Oceanography from the Graduate School of Oceanography, University of Rhode Island.

Jill Rowe (RPS Ocean Science)

Jill Rowe specializes in biological and environmental data gathering, analysis and management; natural resource damage assessment (NRDA) modeling and analysis of pollutant fates and effects; ecological risk assessment; impact assessment of dredging and development projects, preparing sections of Environmental Impacts Statements; providing NEPA support, and GIS mapping and analysis. Ms. Rowe has applied her marine biological and GIS expertise to biological data set development, as well as mapping habitats and biological resource distributions that could ultimately be affected by oil/chemical spills and development projects. She performs quantitative assessments and modeling of aquatic ecosystems and populations, pollutant transport and fates, and biological response to pollutants. The populations to which she applies these models include plankton, benthic invertebrates, fisheries, birds and mammals. She has analyzed data and has applied water quality, food web and ecosystem models to case studies in freshwater, marine and wetland ecosystems. She has a BA in Biology from DePauw University, and an MS in Marine Biology from the College of Charleston.

Deborah Crowley (RPS Ocean Science)

Deborah Crowley is a senior consulting environmental scientist and project manager at RPS. She has experience working on issues and projects related to various aspects of environmental science such as environmental data analysis, hydrodynamic and water quality modeling and analysis, coastal processes, oil and gas fate and transport assessment in the environment, operational discharge modeling and assessment, renewable energy project development assessment support, environmental impact assessment in coastal and marine environments and permitting and regulatory compliance analysis and support. Ms. Crowley's experience with renewable energy projects includes cable burial studies, wind resource assessment, climatology assessment including extremal analysis, wind turbine siting, turbine power production and site capacity analysis, turbine impacts assessment, turbine visualizations, regulatory, permitting and zoning review, planning and management of terrestrial met tower deployment and associated data management and analysis. Areas of experience include numerical modeling, model development and application, field program design and support, data analysis and visualization in Matlab™ and geospatial analysis in ArcGIS™. She has a BS in Mechanical Engineering from Worcester Polytechnic Institute and an MS in Civil & Environmental Engineering from University of Rhode Island.

John W. Joeckel (SEAConsult LLC)

Mr. Joeckel is an executive management professional with a broad-based background in multi-modal transportation, oil, chemical and gas industry sectors, and manufacturing and production. He has extensive experience in legislative advocacy and regulatory compliance, crisis and consequence management, emergency preparedness and response, including hands-on response as an Incident Commander on multiple major emergency incidents and development of all hazard response/crisis management programs and plans including training and exercises. He has experience in ports, waterways and facility maritime security vulnerability analysis and security plan development including personnel training and exercise. Mr. Joeckel has a BS in Maritime Transportation from SUNY Maritime College, as well as many years of training in oil spill response. He has been involved in response research and development and supervising many spill response operations, including the BP Gulf of Mexico Deepwater Horizon incident, the Enbridge Pipeline Michigan oil tar sands crude oil spill in the Kalamazoo River, and the Exxon Valdez spill in Alaska.

Andrew J. Wolford, PhD (Risknology, Inc.)

Dr. Wolford is founder and President of Risknology, Inc., a company specializing in risk analysis of hazardous facilities. He is an expert risk engineer with 29 years of experience. He has directed risk assessments on a diverse range of engineered systems including; offshore and onshore oil and gas installations, mobile offshore drilling units, marine and land-based transportation systems, chemical and nuclear fuel processing plants, nuclear power and test reactors, and the Space Shuttle program. He has a BA in Physics from Wittenberg University, a BA in Nuclear Engineering from Georgia Institute of Technology, and a ScD from Massachusetts Institute of Technology.

Hudson River Oil Spill Risk Assessment Overview

The Hudson River Oil Spill Risk Assessment (HROSRA)[1] is a comprehensive study of the risks of oil spills into the Hudson River based on the various types of oils that are (or potentially would be) stored in facilities (e.g., terminals) and transported by tanker, tank barge (including articulated tank barges, or ATBs), rail, and pipeline at river-crossings (e.g., proposed Pilgrim Pipeline).[2]

The HROSRA was commissioned by Scenic Hudson[3] in August 2017. It was conducted over the period of August 2017 through May 2018 by a team of oil spill subject matter experts led by Dr. Dagmar Schmidt Etkin of Environmental Research Consulting based in Cortlandt Manor, New York.

Purpose of the HROSRA

The HROSRA is intended to provide both *quantitative* and *qualitative* information on oil spill risk that can be used for a variety of purposes, including, but not limited to:

- Assessing the efficacy of existing spill prevention measures;
- Developing or evaluating the potential for new spill prevention measures;
- Assessing the current state of spill response preparedness;
- Developing or evaluating the potential for new spill response preparedness measures;
- Assessing current spill contingency planning; and
- Developing new spill contingency planning measures.

The study is also intended to provide a measure of the degree to which the ecological and socioeconomic resources of the Hudson River might be affected by oil spills and the likelihood of that occurring. An understanding of the potential consequences of spills in the Hudson River supports the need to consider the mitigation of spills through prevention, preparedness, and response.

Defining Risk

As a risk assessment, the HROSRA addresses both the probability or likelihood of oil spills and the consequences or impacts of oil spills that could occur. Each factor can be analyzed independently, but the determination of "risk" includes both.

Oil spill risk is the probability of an oil spill occurring multiplied by the spill consequences. There can be high-probability (very likely) events with high or low impacts. Likewise, there can be low-probability (unlikely) events that have high or low impacts (Figure 1). Note that the term "likelihood" is also used to mean "probability."

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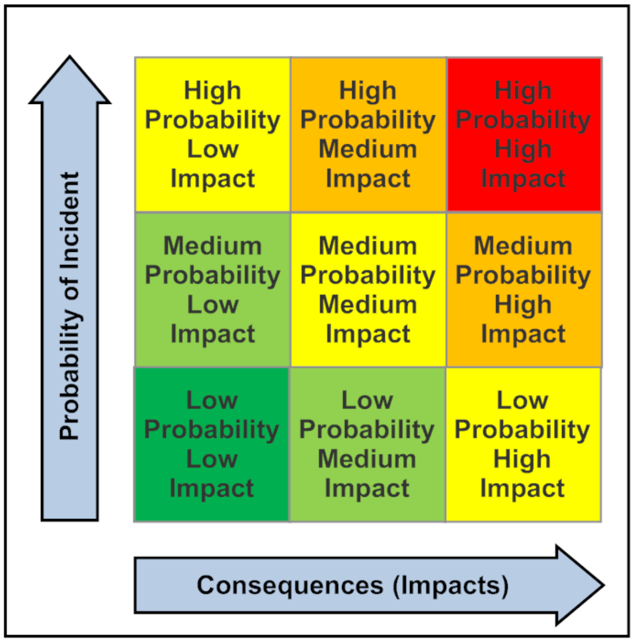
[1] A more extensive discussion of the HROSRA scope, technical approach, and scenarios is presented in Volume 2.

[2] Inland pipelines and sections of rail lines that do not intersect with the river were not evaluated in this study. In addition, chemical (e.g., ammonia, ethanol) and gas (e.g., propane, liquefied natural gas) spills were not included.

[3] https://www.scenichudson.org/



High Probability Low Impact	High Probability Medium Impact	High Probability High Impact
Medium Probability Low Impact	Medium Probability Medium Impact	Medium Probability High Impact
Low Probability Low Impact	Low Probability Medium Impact	Low Probability High Impact

Figure 1: Basis Risk Matrix

Approach to Calculating the Probability of Oil Spills

There are different ways to consider the probability of oil spills. One is based on the expected frequency of spills, for example, how often spills might occur in a year. Another way of expressing this is the "chance" of a spill occurring in a year. A "1 in 100" chance each year is the equivalent of an annual frequency of 0.01. This can also be expressed as a 1% chance each year.

Another way to view probability or frequency of spills is to consider the return period or recurrence interval. For spills that have a 0.01 frequency each year, the return period is 100 years, or the inverse of the frequency.

$$Frequency(event) = \frac{number(events)}{year}$$

$$Return = \frac{1}{Frequency(event)} = \frac{years}{event}$$

$$Frequency(event) = \frac{0.01}{year}$$

$$Return(event) = \frac{1}{0.01} = 100$$

The return period (e.g., 100 years) is used in an attempt to simplify the definition of a specific statistically-determined chance of an event occurring in any one year (1%). It does not however mean that it will necessarily take 100 years before this event occurs or that it will only occur once in a 100-year time frame. To avoid confusion, in the HROSRA, probabilities of oil spills are presented in two ways:

- Annual frequency expressed as the expected number of spills each year; and
- Annual probability expressed as a “1 in X” chance.

The probability of oil spills occurring in the Hudson River is explored in great detail in HROSRA Volume 3. Probabilities for each of the different types of spill sources (i.e., vessels, facilities, trains, and pipelines) were calculated based on historical data, past studies, and mathematical models. The probabilities were calculated based on current conditions (vessel traffic, presence of facilities, etc.) and based on potential future conditions (e.g., reintroduction of crude-by-rail transport, transport of crude by tank vessel, installation of pipelines, changes in traffic, and institution of certain prevention measures). Spill probabilities were also analyzed with respect to the potential volume or size of spills. In general, smaller spills are much more likely than very large spills.

Approach to Analyzing the Consequences of Oil Spills

The behavior and fate of oil spills and the potential for environmental and socioeconomic consequences are explored in detail in HROSRA Volume 4. Additionally, the potential for human health and safety impacts from fires and explosions that occur as a result of oil spill accidents is covered in detail in HROSRA Volume 5. Responses to the simulated scenarios are described in HROSRA Volume 6. Summaries of each of the 72 oil spill scenarios (plus the five fire/explosion scenarios) and related response options are provided in HROSRA Volume 7.

Each oil spill is a unique event. The behavior of the spilled oil is dependent on a number of inter-related factors, including:

- The type of oil and its chemical and physical properties;
- The volume of oil spilled; and
- The conditions of the environment into which the oil is spilled (e.g., water and air temperature, winds, currents, geography and bathymetry[4] of the waterbody, presence of ice).

There are an almost infinite variety of spill scenarios that might occur. The HROSRA study involved the modeling of 72 hypothetical spill scenarios representing twelve location-specific situations each with three seasons (spring under high flow conditions, summer under low flow conditions, and winter under medium flow conditions with ice) and two different tidal conditions (high tide and low tide). In addition, there were fire/explosion scenarios modeled for five of the location-specific situations, bringing the total to 77 scenarios:

12 location-oil situations x 3 seasons x 2 tides = 72 oil spill scenarios
72 oil spill scenarios + 5 fire/explosion scenarios = 77 total scenarios

Note that all of these scenarios are *hypothetical*, i.e., they have not actually occurred. There is no expectation that these particular spill scenarios are likely to occur, though it is *possible* that they might occur at some point in the future. Other similar or vastly different spill scenarios may occur.

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[4] Water depth.

The hypothetical spill scenarios are summarized in Table 1. (They are organized from north to south on the river.) For each of the twelve location-oil type-volume combinations, modeling was conducted for three different seasons – spring with high flow, summer with low flow, and winter with medium flow and ice. Within each of those seasons, the hypothetical spill was assumed to occur at high tide and low tide at the spill location. In addition, for five of the spills involving more volatile oils, a hypothetical fire/explosion was also modeled.

Table 1: HROSRA Modeled Hypothetical Spill Scenarios

Location	Spill Source	Volume[5]	Oil Type	Discharge Type	Fire/ Explosion
Port of Albany	Tanker accident	155,000 bbl	Bakken Crude	WCD	Yes
Coxsackie	Tanker collision	25,000 bbl	Home Heating Oil	MMPD-WCD	No
Kingston	ATB collision	150,000 bbl	Home Heating Oil	WCD	No
Kingston	ATB collision	150,000 bbl	Diluted Bitumen	WCD	No
Off Rondout Creek (ACP Scenario)	Tank barge collision	75,421 bbl	Bakken Crude	MMPD-WCD	Yes
	Cargo vessel collision	14,000 bbl	Heavy Fuel Oil	WCD	No
Newburgh	CBR train accident	11,000 bbl	Bakken Crude	Not defined	Yes
Bear Mountain	Tanker collision	2,500 bbl	Home Heating Oil	MMPD	No
Iona Island	CBR train accident	11,000 bbl	Bakken Crude	Not defined	Yes
Tappan Zee	Tanker allision	2,500 bbl	Home Heating Oil	MMPD	No
Tappan Zee	Tanker allision	50 bbl	Heavy Fuel Oil	AMPD	No
Yonkers	Collision with tanker	155,000 bbl	Gasoline	WCD	Yes

The scenarios were selected in discussions with the ERC study team and Scenic Hudson representatives. The selections were meant to represent a broad spectrum of potential and reasonably plausible spill cases varying the location within the study area, based on the type of oil transport that is currently occurring or may potentially occur in the future. In addition, the selected scenarios were meant to demonstrate the differences in oil behavior and effects based on oil type, season, and location. Two of the modeled scenarios are based on the scenario described in the Area Contingency Plan (ACP).

The volumes of spillage include several worst-case discharge (WCD) events that are very unlikely to occur, but represent the types of incidents that need to be considered as part of the region's spill response preparedness. The spills represent WCD, as well as volumes that are defined by the US Coast Guard as "maximum most-probable discharge" (MMPD) and "average most-probable discharge" (AMPD). Evaluating WCD scenarios along with more probable smaller spills is also essential for quantifying the spill risk for policy making. (Note that CBR spills do not currently have defined discharge volumes for contingency planning.)

It is important to keep in mind that these hypothetical scenarios were selected to illustrate the trajectory, fate, and effects of representative spills. If a spill were actually to occur, the specific circumstances of the scenario–location, timing, and environmental conditions would all affect the outcome. In addition, there

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[5] Oil or petroleum is usually measured in gallons, or more commonly in barrels (bbl). Each barrel contains 42 gallons. (Oil barrels are smaller than 55-gallon barrels or drums.) In this report, the unit of measure "barrels" (abbreviated as "bbl") is used.

would be cleanup response measures implemented that would mitigate the effects to varying degrees, depending on the timeliness and effectiveness of those operations.

The hypothetical spills were simulated using the SIMAP (Spill Impact Model Application Package) oil fate model (Figure 2).

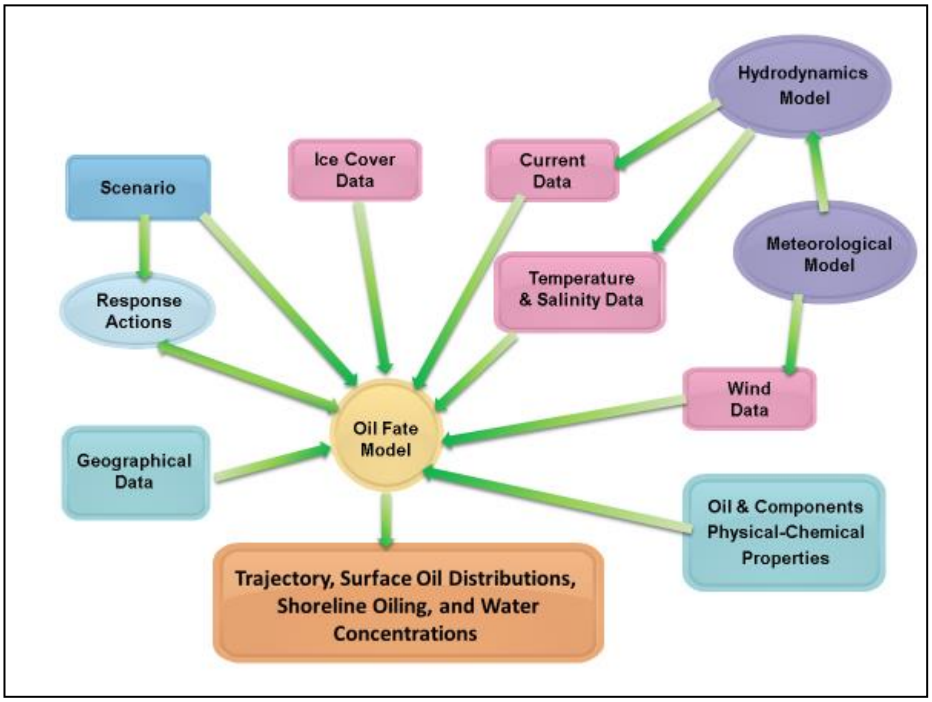

Figure 2: SIMAP 3-D Flow Diagram Oil Trajectory and Fate Model Components and Inputs

SIMAP quantifies oil trajectory (the path or paths of the oil in the water), concentrations of various oil hydrocarbon components in oil droplet and dissolved phases in the water column, areas swept by floating oil of varying mass concentrations and thicknesses, shorelines oiled to varying degrees, and amount of oil settling to sediments.

Processes simulated by SIMAP (Figure 3) include spreading, evaporation, transport on the surface and in the water column, dispersion (mixing), emulsification, entrainment of oil as droplets into the water, dissolution of soluble and semi-soluble hydrocarbon components, volatilization of dissolved hydrocarbons from the surface water, adherence of oil droplets to suspended particulate matter (SPM), adsorption of semi-soluble hydrocarbons to SPM, sedimentation, stranding on shorelines, and degradation.

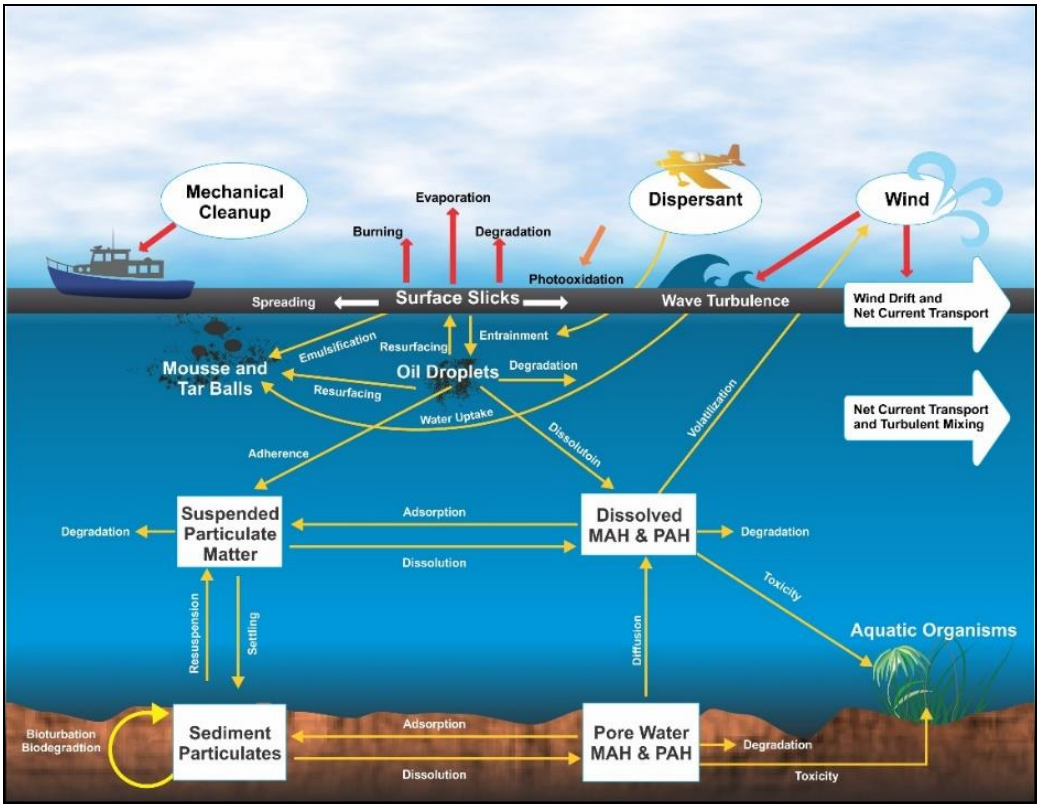

Figure 3: Open Water Oil Fate and Behavior Processed Simulated SIMAP

The SIMAP modeling results were presented as:

- Tables and graphs depicting the "mass balance" of the oil at the end of the hypothetical 30-day model run, i.e., a summation of where the spilled oil would end up (assuming none was removed in a response) – remaining on the water surface, evaporated into the atmosphere, in the water column, in sediment, on the shore, and biologically degraded;[6]
- Tables showing the miles of different types of shoreline oiled;[7]
- Summary tables showing the spatial extent of oiling above levels that might cause ecological or socioeconomic effects, as well as details of ecological shoreline exposure by shoreline type and wetland habitats;[8]
- Explanations of the behavior and fate of the oil in the various scenarios; [9] and
- A series of detailed time-sequence maps depicting oil on the water surface (floating oil), oil in the water column, and oil on the shoreline.[10]

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[6] Presented in HROSRA Volume 4.

[7] Presented in HROSRA Volume 4.

[8] Presented in HROSRA Volume 7.

[9] Presented in HROSRA Volume 4.

[10] Available in the separate HROSRA Volume 4 Appendix C files.

Approach to Analyzing the Consequences of Fire/Explosion from Oil Spills

One specific concern of the HROSRA is public safety, in particular, the potential for fire and/or explosion resulting from possible crude-oil and fuel releases. The public safety concern has been growing with the rise of unconventional extraction techniques leading to changing crude oil compositions, essentially increasing the content of light ends that flash off when exposed to the environment. The Department of Energy is currently conducting research to understand how the chemical composition of unconventional crude oils changes the risk they pose to the nation's transportation systems.

With the actual or potential transport of more volatile, flammable petroleum, such as gasoline and Bakken crude, on or along the Hudson River, there is the possibility of fires and explosions. In addition to spills, the following types of incidents, though very unlikely, could also occur and were considered in the HROSRA study for five of the spill scenarios:

- **Pool Fire:** This is a fire that burns from a pool of vaporizing fuel. The primary concern associated with pool fires is hazards associated with increased temperatures from thermal radiation (heat). For crude oil and fuel transported along the Hudson River in ships, barges and crude-by-rail trains, a pool fire could occur if there is an incident leading to a release of crude oil that forms a pool on the river surface and then catches fire.

- **Vapor Cloud Explosion:** A vapor cloud explosion is the result of a flammable material that is released into the atmosphere, at which point the resulting vapor cloud is ignited. The primary concern from a vapor cloud explosion is overpressure (pressure caused by a shockwave). For crude oil and fuel transported along the Hudson River in ships, barges and CBR trains, such an explosion could occur if oil was released during an incident and evaporated into the air, forming a vapor cloud. This requires that there be no immediate ignition source.

The five hypothetical oil spill scenarios that theoretically might present a higher likelihood of a fire and/or explosion were analyzed employing the Process Hazard Analysis Software Tool (PHAST) model. This model is routinely employed for analyzing the potential risks for facilities and activities involving the handling of a variety of hazardous substances, including flammable petroleum products. The PHAST model simulates the behavior of the spilled substance as it pools, spreads, disperses, and vaporizes in the environment. In addition, an analysis of the likelihood of ignition was conducted.

The scope of work for this project addressed consequence modeling for potential crude oil and fuel releases for flammable vapor dispersion, thermal hazard zones derived from pool fires, and explosion overpressures resulting from vapor cloud explosions for the five locations. The results included an assessment of the potential area that might be affected by a pool fire in the vicinity of the spill source, the flammable vapor, and the explosion overpressure hazard zone in tabulated areas as well as on maps.

Approach to Analyzing Spill Risk Mitigation

There are two basic ways to mitigate risk – by reducing the probability of a spill (or the circumstances that might lead up to a spill) by prevention measures, and by reducing the severity of the consequences of a spill through effective source control and spill response (Figure 4). The most effective way to mitigate oil spill risk is to prevent incidents from occurring or at least reduce the number of incidents to the extent possible.

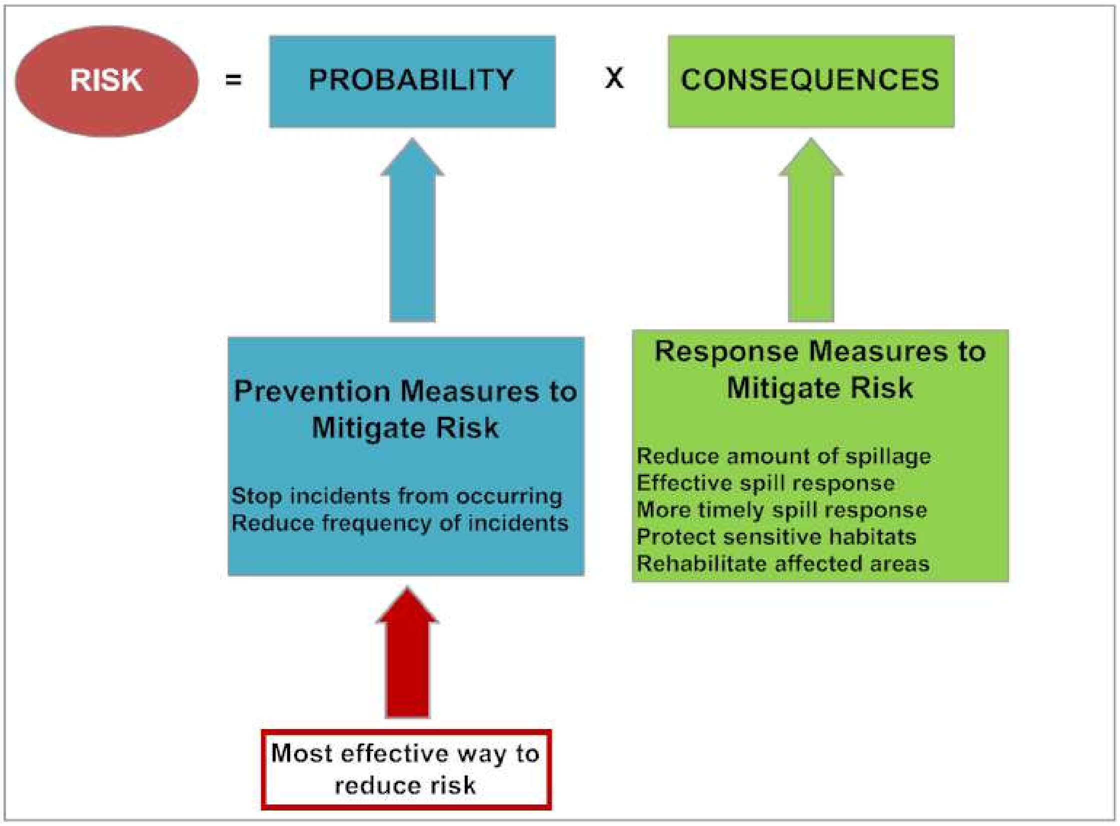

Figure 4: Mitigating Oil Spill Risk

On the other hand, some factors can increase or escalate oil spill risk (Figure 5) by increasing the likelihood of a spill or by decreasing the effectiveness of spill response. Mitigating risk also involves controlling the factors that might increase risk by increasing the probability of a spill or by reducing the effectiveness of consequence mitigation or spill response.

In the HROSRA, the factors that cause spills were evaluated along with potential prevention measures for each type of spill. In addition, the potential for risk mitigation through spill response and emergency response was analyzed for the specific modeled spill scenarios as well as in general. The spill response and emergency response issues are described in greater detail in HROSRA Volume 6, and summarized for each spill scenario in summary tables in HROSRA Volume 7.

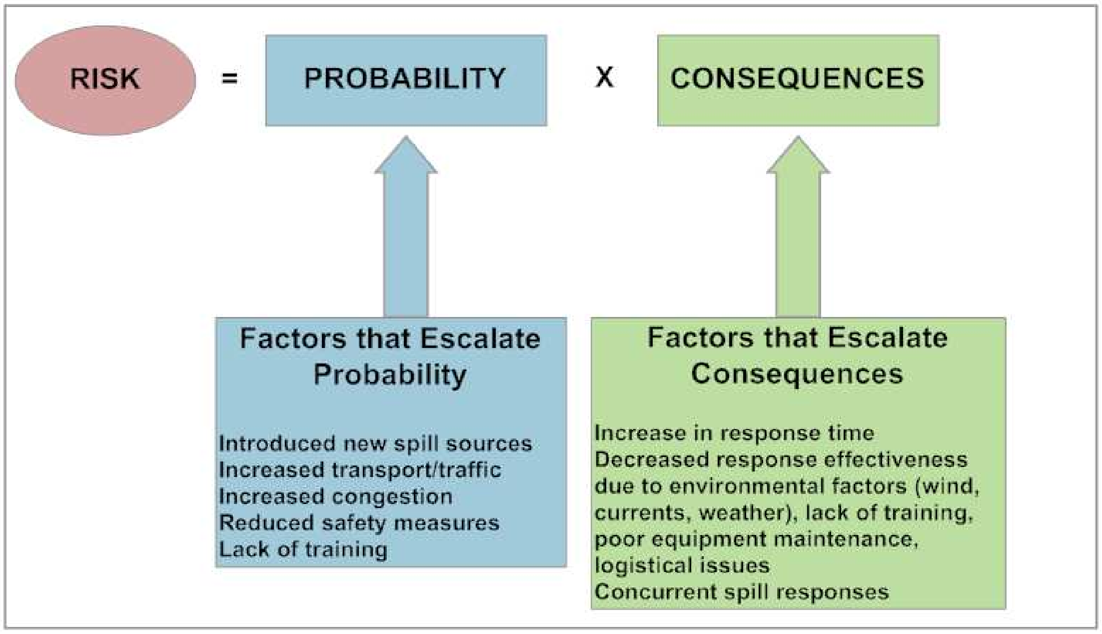

Figure 5: Escalating Oil Spill Risk

Oil Spill Basics

The incidence of oil spills in the US and throughout the world has decreased significantly over the last several decades. Spill prevention measures brought about by regulation and voluntary improvements to industry practices, as well as a greater awareness of the environmental, socioeconomic, and cultural consequences of spills, have reduced the frequency and severity of spills. However, oil spills do still occur, including such significant events as the 2010 Macondo MC252/Deepwater Horizon spill in the Gulf of Mexico. The large variety of spills that have occurred from small ones to catastrophic incidents have offered scientists and field practitioners to learn a great deal about the behavior, fate, and effects of oil when spilled into the environment.

General Behavior of Spilled Oil

When oil spills into water, several things begin to happen (Figure 6):

- The oil, which is generally lighter than water, floats on the water surface and moves with winds and currents to form oil slicks;
- Parts of the oil begin to evaporate into the atmosphere;
- As waves and turbulence break up the oil, parts of the oil slicks become entrained in the water column in the form of droplets as dissolved compounds;
- Dissolved oil is biologically degraded as it is metabolized by microbes in the water column;
- Some of the oil droplets may come in contact with particles of sediment that form aggregates that may be heavier than water and settle in sediment; and
- The remaining floating oil will become stranded on shorelines and adhere to surfaces or penetrate into substrates, such as sand.

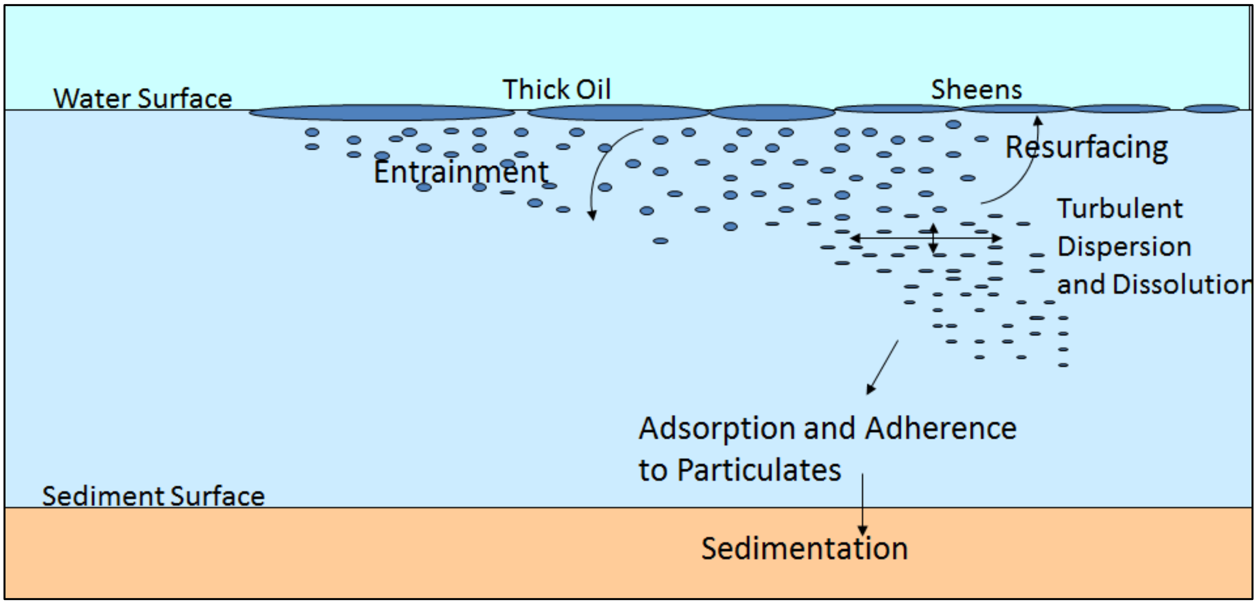

Figure 6: Oil Behavior in Water

Different Oil Types

Petroleum or oil is made up of a large number of different types of components that have different properties. When crude oil is refined (Figure 7), the various components are used to make a variety of refined products, such as gasoline, diesel fuel, jet fuel, intermediate and heavy fuel oil, and asphalt. Crude oil and all refined products contain different proportions of lighter, more volatile or soluble components, and heavier, more persistent components (Figure 8). Different oils have diverse chemical and physical properties that affect their behavior when spilled.

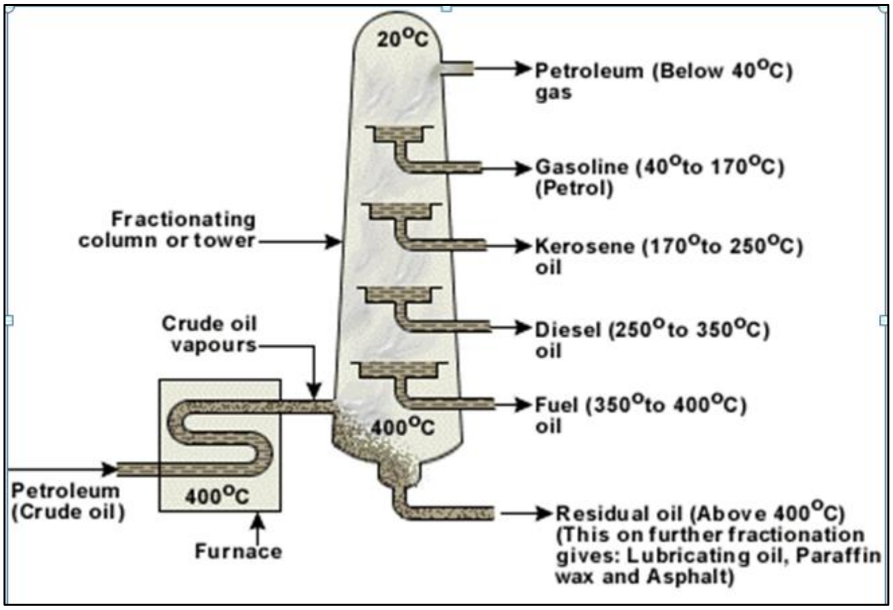

Figure 7: Fractional Distillation or Refining of Crude Oil

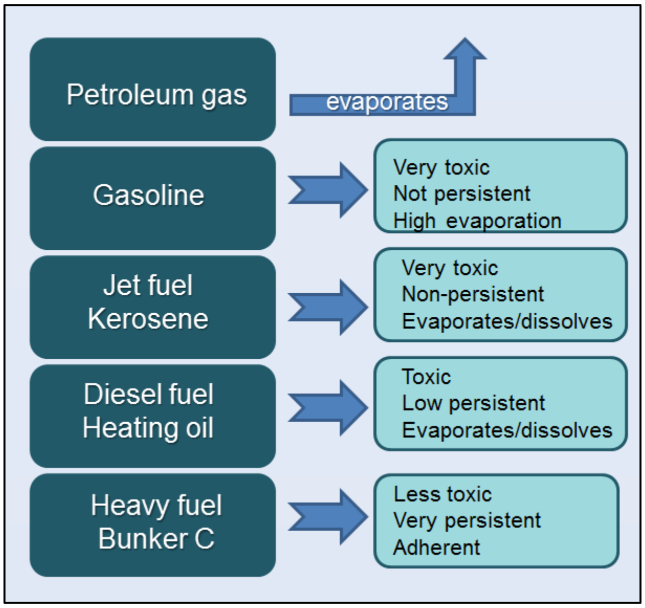

Figure 8: General Properties of Refined Petroleum Products

A summary of the physical and chemical properties of different general oil types and their adverse effects on the environment is shown in Table 2.

Table 2: Summary of Oil Properties and Adverse Environmental Effects[11]

Oil Type	Examples	Physical/Chemical Properties	Adverse Effects on Environment
Light to Volatile Oils	Gasoline Home Heating Oil Diesel	• Spread rapidly • High evaporation and solubility • May penetrate substrate	• Toxicity related to type and concentration of aromatic fractions • Toxicity depends on biological half-life in different species • Toxic to biota when fresh • Marsh plants may be chronically affected due to penetration and persistence of aromatic compounds in sediments
Moderate to Heavy Oils	Crude Oil Diluted Bitumen	• Weathered residue may sink and become absorbed by sediment • Penetration into substrate depends on particle size • Weathers to tarballs • Diluted bitumen may become neutrally buoyant to sink, depending on weathering, type, and water properties	• Adverse effects to organisms result from chemical toxicity and smothering • Toxicity depends on proportion of lighter fraction • Low toxicity residue tends to smother plants or animals • Light fractions may contaminate water column • Diluted bitumen toxicity typically lower due to rapid evaporation of more toxic light ends
Very Heavy Oils	Asphalt Heavy Fuel Oil Bunker C	• Forms tarballs at ambient temperatures • Resists spreading and may sink • May soften and flow when exposed to sunlight	• Immediate and delayed adverse effects due to toxicity from small aromatic fractions and smothering • Most toxic effects due to incorporation in sediment • Lower toxicity on plants than mobile animals

In the HROSRA, five different oil types were modeled based on the spectrum of oil types that are or could potentially be transported along the Hudson River:

- Bakken crude;
- Diluted bitumen (also called “dilbit”);
- Heavy fuel oil;
- Home heating oil (similar to diesel fuel); and
- Gasoline.

Bakken crude is a very light crude oil that readily volatilizes and evaporates, which increases its flammability. When it spills, much of the oil evaporates readily and the rest disperses into the water column. Some of the residual hydrocarbons that do not evaporate of dissolve may become stranded on shorelines or interact with sediment particles to settle.

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[11] Based on: Polaris 2014.

Diluted bitumen (dilbit) is a mixture of a highly weathered (light ends evaporated) heavy oil diluted with a hydrocarbon solvent (diluent) to make it flow and behave more like a liquid crude oil. The blend ratio may consist of 25 to 55% diluent by volume, depending on characteristics of the bitumen and diluent, pipeline specifications, operating conditions, and refinery requirements. In the HROSRA, the assumed dilbit compositions contained 40% volatile (light) hydrocarbons. When dilbit spills the light volatile components readily evaporate or dissolve, much like with Bakken crude. The remaining non-volatile bitumen portions remain floating on the water surface or settle to the bottom after combining with suspended particulate matter. Dissolved components biodegrade readily, but the floating and stranded bitumen is very slow to degrade.

Heavy fuel oil (also called Bunker C or intermediate fuel oil) is primarily used as a vessel fuel. It is composed mainly of heavier hydrocarbons that do not readily evaporate or dissolve. When spilled, the small portion of volatile components evaporates, dissolves, and degrades in the water column. The high viscosity (resistance to flow) of the remaining portion is not readily broken down by wave action. Most of the oil remains floating until it strands on shorelines where it degrades very slowly. Spills of heavy fuel oil tend to form bands of adherent black residue and tarballs on shorelines.

Home heating oil, which is similar to diesel fuel, is composed primarily of volatile hydrocarbons, which readily evaporate or dissolve when spilled. The dissolved hydrocarbons readily biodegrade in the environment.

Gasoline is composed almost entirely of highly volatile (and thus flammable) hydrocarbons that evaporate or dissolve very rapidly after a spill. There are some toxic components that may dissolve into the water column.

Environmental Effects of Spilled Oil

A wide variety of natural resources and biota (e.g., water, shorelines, sediments, habitats such as wetlands, fish, shellfish and other invertebrates, reptiles, mammals, and birds) may be exposed to oil through various pathways, including direct exposure with oil and contact with contaminated water, air, vegetation, and sediments. Oil affects organisms and habitats in the environment in three basic ways: by toxicity, by adherence and coating, by toxicity upon uptake via skin, inhalation or food ingestion, and by behavioral changes affecting exposure persistence. Floating oil can move through habitats and intercept surface-dwelling organisms such as birds, mammals, reptiles and vegetation, whereupon adverse effects may result from adherence and coating. Oil and chemical components may be mixed into or dissolve in the water column, exposing fish, invertebrates, and aquatic plants to hydrocarbons. The air above floating oil may experience elevated concentrations of volatile compounds that evaporate from the surface oil. Small droplets (aerosols) containing these chemicals and reaction products may also form in the air. Air-breathing animals are exposed to both evaporated compounds and aerosols. Animals may be exposed to oil hydrocarbons by drinking or ingesting contaminated water, food, and sediments; and this may be a pathway of exposure to their predators.

Oil is comprised of thousands of different chemicals, many of which are known to be toxic to exposed biota. Some of the more toxic compounds in oil are the aromatic chemicals—a subset of organic compounds that share a common chemical structure, namely at least one benzene ring. These include mono-aromatic (i.e., containing one benzene ring) compounds such as benzene, toluene, ethylbenzene, and xylenes (BTEX). These volatile and soluble aromatic hydrocarbons readily evaporate and are often responsible for the odors from petroleum. Another group of aromatic compounds is less volatile, but still soluble to varying degrees. These compounds are called polycyclic aromatic hydrocarbons (PAHs) because they contain two or more benzene rings. PAHs from oil often remain long enough in the environment to cause effects on aquatic biota and their consumers. Because of the known toxic effects of PAHs, scientists often present oil concentrations in water and animal tissues in terms of the concentrations of PAHs.

Aquatic biota (fish, invertebrates and aquatic plants) may suffer acute effects and direct impacts (lethal and sublethal) in the short-term; sublethal effects of chronic contamination; behavioral changes resulting in reduced growth, survival or reproductive success; indirect effects via reduction in food supply, habitat, or other changes in the ecosystem; impacts of spill response activities; and population level impacts caused by mortality and sublethal effects. When birds, mammals and reptiles are directly exposed to or ingest food contaminated with oil, they may suffer from a variety of adverse health effects, including hemolytic anemia, liver dysfunction, kidney damage, hypothermia, weight loss, lethargy, abnormal feces, moribundity (near death), and death. External oiling of birds causes feather damage and reduced flight performance. Oiled birds have demonstrated more erratic and less-efficient flying, shorter flight times, and higher energetic costs. Overall, disruption of organ physiology and function can have negative consequences for an animal’s fitness and survival.

Quantification of biological impacts of oil exposure should consider the degree and duration of exposure of biota to oil and component hydrocarbons, accounting for the movements and amounts of both oil and biota. Thus, summing the areas of water and shoreline surfaces or volumes of water contaminated above threshold concentrations, and multiplying by numbers of animals present at any instant in time, would not quantify numbers of animals expected to be killed or otherwise impacted. Animal behavior and movements in and out of the contaminated area would need to be considered, as would the ephemeral nature of the oil exposure and the sensitivity of the organisms exposed (e.g., life stage, physical health). However, the approach of summing areas/volumes exposed above a threshold of concern at any instant in time after a spill does provide quantitative measures of areas/volumes where there is the potential for adverse effects. Such a conservative analysis as this is appropriate to an ecological risk assessment, whereby the objective is to be protective of the resources of concern.

Due to their divergent chemical and physical properties, the oil types in the HROSRA study tend to affect the environment in different ways. The oils with more of the lighter components (particularly PAHs) tend to have more toxic effects, depending on the degree of exposure of the organisms. Oils that have more of the heavier, persistent components cause more impacts by adherence and coating or smothering. All types of organisms are susceptible to toxic effects of oil, with different species having varying sensitivities. Birds and marine mammals are also susceptible to injuries from coating and inhalation of volatile hydrocarbons.

Thus, the HROSRA does not quantify the environmental impacts of the modeled spill scenarios, but presents data on the levels of exposure on the water surface, in the water column, and on the various types of shorelines and quantifies areas and volumes where exposures could potentially cause ecological effects. The levels of contamination that would cause ecological effects for most shoreline organisms and habitats are 100 times greater than those that would tend to cause socioeconomic effects. This is because humans will be much more affected by the presence of small amounts of hydrocarbons due to odor, aesthetic concerns, and perceptions than would actually cause any lethal or sub-lethal effects to organisms.

Socioeconomic and Cultural Effects of Oil Spills

The types of socioeconomic and cultural impacts that might occur in the event of an oil spill include, but are not limited to:

- Effects on water intakes for drinking water, industrial use, agricultural use, and recreational use;
- Blockage or restrictions to vessel traffic and port activity due to spill response operations, which can have rippling economic impacts;
- Oiling of waterfront beaches, facilities, parks, and real estate, which could have economic effects, including on tourism;
- Oiling of marina structures and recreational boats;
- Effects on recreational and commercial fishing;
- Disruption of waterfront activities due to spill response operations;
- Restrictions on recreational boating and other on-water activities;
- Health and safety effects for responders and riverside communities exposed to volatilized oil components and/or fire and explosion hazards; and
- Psychological effects on riverfront communities and populations.

The effects of oil spills are realized at much lower thresholds than those that may cause ecological effects. This is because humans are much more sensitive to the aesthetic concerns about the presence of oil on shorelines or the water surface based on visual appearance and/or odor even when there are no actual health effects. In addition, the perception that there has been or could be oiling or oil tainting may have effects on property values and tourism.

Hudson River Overview (HROSRA Volume 2)[12]

In this HROSRA, the term "Hudson River" is generally used to denote the 115-nautical mile stretch of the Hudson River north of the confluence of the Spuyten Duyvil/Harlem River Creek, excluding the part of the Hudson River that runs alongside Manhattan Island south through the New York Harbor and out to the New York Bight. The northern extent of this definition is the Troy Lock, excluding the sections of the Hudson River that flow from the river's source at Lake Tear of the Clouds to the Troy Locks (Figure 9).

Figure 9: Hudson River Section for Report

Hudson River Conditions Affecting Spill Likelihood

The Hudson River is an active waterway with commercial vessel traffic, recreational boating, and rail traffic on both sides of the river. In addition, there are facilities storing oil (terminals and fuel depots) along the riverbanks.

The Hudson River north of New York City up to the Port of Albany (as in the HROSRA study area) acts as an important port area. Vessel traffic on the Hudson River has been transporting an average of nearly 17 million tons of commodities up and down the river for decades. Currently, there are an estimated 16,000 vessel trips up and down the river, 91% of which are shallow-draft vessels (14 feet or less). Vessels on New York waterways transport $264 million of domestic freight daily.

The commercial vessel traffic on the Hudson River is the most likely source of oil spillage on the Hudson River. This includes both tank vessels (those carrying oil as cargo, as well as for fuel) and non-tank vessels (those that carry oil only as bunker fuel). These commercial vessels could cause very large spills. However, spills from recreational boats may also occur, though these spills would tend to be smaller.

Spills from oil facilities along the river present another potential risk. Spills from rail traffic (locomotives and oil tank cars) are also a potential concern for the Hudson River corridor.

Environmental Conditions in the Hudson River Affecting Oil Spill Risk

Given that there is vessel traffic, along with other potential sources of spillage in the Hudson River, there are factors inherent in the river that may affect the probability of spills and/or the consequences of spills that do occur. There are a number of environmental conditions in the Hudson River that could affect oil spill risk with respect to:

- The likelihood that there will be an accident that could cause an oil spill;
- The behavior and movement of oil in the event of a spill;
- The types of ecological and socioeconomic effects an oil spill would cause; and

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[12] HROSRA Volume 2 consists of two major parts – one describing the study approach, the second providing an overview of the unique features of the Hudson River as they may affect oil spill risk.

- The degree to which oil spill response operations would be affective in mitigating the effects of an oil spill.

These factors are summarized in Table 3.

Table 3: Environmental Conditions in Hudson River Affecting Oil Spill Risk

Condition	Affecting Spill Probability	Affecting Spill Consequences		Affecting Mitigation by Response
		Oil Behavior	Oil Effects	
Tides and Currents	-	Will determine oil trajectory	Will determine types and areas of shorelines affected	Will impede boom effectiveness and complicate strategies
Bathymetry and River Bottom	Will affect vessel groundings	May affect oil submergence if bottom has much sediment	-	May complicate response if oil submerges
Salinity	-	Increases likelihood of submergence in less saline or freshwater	-	-
Fog	Reduced visibility causes significant navigational hazard increasing accident likelihood	-	-	May complicate response if visibility is issue for tracking oil
Ice	Increased accident likelihood by covering navigation aids, hindering transits	Affects movement of oil in water	-	Significantly impedes response
Shoreline Types and Habitats	-	-	Significant sensitive wetlands and mudflats	Response in wetlands and mudflats may cause more harm than oiling; access may be restricted in some shore areas
Presence of PCBs	-	-	Some habitats already contaminated by PCBs; oiling could exacerbate effects	Dredged substrates need to be tested for PCBs before disposal

Resources at Risk in Event of Hudson River Oil Spill

The Hudson River is highly cherished by residents and visitors with respect to its natural beauty, historic significance, and recreational utility. The river also provides important resources with respect to municipal water, commercial vessel transportation, commerce, and industry. All of these resources are potentially at risk in the event of a major oil spill. Individual resources may be at risk even in the event of a relatively small spill, depending on the location and circumstances.

The Hudson River natural, socioeconomic, and cultural resources that are potentially at risk in the event of an oil spill include:

- **Ecological habitats:** The Hudson River and its shoreline areas provide vital habitats for a wide variety of flora and fauna, including threatened sturgeon, as well as wildlife (birds and mammals) that are important resources for nature study and viewing, and waterfowl for hunting.
- **Municipal and industrial water intakes:** A number of communities and industrial facilities along the Hudson River depend on the river for water.
- **Waterfront properties and public facilities**: There has been a significant effort over the last 25 years to revitalize the Hudson River waterfront from industrial use towards more usage for residential, recreational, and land preservation purposes.
- **Recreational boating**: There are over 59,000 registered recreational vessels in the counties along the Hudson River many of which are regularly used in the river, especially during the summer season. Kayaking, canoeing, and paddleboard sports are also prevalent on the river.
- **Recreational and subsistence fishing**: While PCB contamination and over-fishing has affected commercial fisheries, and PCB levels have affected the consumption safety of fish, there is still a lot of recreational fishing and some degree of subsistence fishing conducted in the Hudson River year-round.
- **Swimming beaches**: There are several private and public swimming beaches and waterfront recreational facilities along the Hudson River.
- **Port activities:** The Hudson River is a major port with commercial traffic bringing fuel and other materials to facilities, terminals, and communities along the river, all of which may be significantly affected during a major spill and the ensuing response operations.

Oil Spill Probability Analysis Summary (HROSRA Volume 3)

There are a variety of potential oil spill sources on the Hudson River, including:

- Tank vessels (tankers and tank barges, including articulated tank barges or ATBs) carrying oil or petroleum, which can spill oil cargo and/or bunker fuel;
- Non-tank vessels (all other commercial vessels that carry oil only as fuel or bunkers);
- Recreational vessels;
- Locomotives on passenger and commuter trains;
- Locomotives on freight trains;
- Tank cars and locomotives on crude-by-rail (CBR) trains;
- Facilities that store oil (oil terminals, fuel depots, etc.); and
- Oil pipelines that cross or run near the river.

Hudson River Vessel Spills

The probability of oil spills from tank vessels, including tankers and tank barges (including ATBs), and non-tank vessels involved:

- Analyses of vessel casualties or accidents (i.e., groundings, collisions, allisions, equipment failures, fire, structural failures, and minor spill incidents) the factors that would affect the rate of casualties by vessel type;
- Analyses of the likelihood of the spillage of oil in the event of a casualty;
- Analyses of the likelihood of a spill during transfer operations (fueling or cargo transfer);
- The potential volume released in the event of a spill;
- Potential changes in vessel casualties and spills with different levels of traffic.

The vessel casualty rates applied in the analysis to determine spills were based on a combination of historical data on the Hudson River, data from other studies around the world, and on modeling of potential collisions. The historical data on vessel casualties for the Hudson are shown in Table 4.

Table 4: Annual Casualty Rates for Hudson River Study Area (2002-2015)

Vessel Type	Annual Casualty Rate (Number of Incidents per Year)							
	Allision	Collision	Grounding	Equip Failure	Fire	Structural Failure	Any Casualty	Minor Spill
Tank Barge	0.37	0.00	0.74	0.00	0.00	0.59	**1.7**	0.22
Tanker	0.074	0.00	0.15	0.00	0.00	0.00	**0.22**	0.074
Cargo Ship	0.074	0.00	0.30	0.074	0.00	0.52	**0.96**	0.074
Freight Barge	0.59	0.15	0.67	0.00	0.00	0.074	**2.1**	0.37
Towing Vessel	0.52	0.00	0.15	0.15	0.22	2.5	**3.6**	0.44
Any Vessel	**1.6**	**0.15**	**2.0**	**0.22**	**0.22**	**4.4**	**8.6**	**1.2**

The casualty rates that are “0.00” indicate only that this type of casualty did not occur during the time period of 2002 through 2015. This does not indicate that it would be impossible for such an event to occur (e.g., for there to be a tank barge collision). Collision rates are based on the density of vessels (congestion) and the frequency of vessel encounters on the waterway. Vessel collisions are relatively rare events. For this reason, a modeling technique was used to determine the potential rate of collisions based on vessel density under different hypothetical traffic situations.

The per-transit casualty rates calculated from the Hudson River historical data are shown in Table 5. There are a number of factors that affect the casualty rate per transit in the Hudson River including: ice, fog, close passing quarters, lack of a Vessel Traffic Service (VTS), grounding hazards, and blind curves. The grounding rate in the Hudson River (averaging 0.00059 per transit for all vessels, 0.0023 per transit for tankers, and 0.0003 per transit for tank barges) is higher than for most other waterways that have been studied. Those rates range from about 0.0001 to 0.0002 per transit. The other casualty rates (other than collisions) are similar to those measured in other waterways.

Table 5: Per-Transit Casualty Rates for Hudson River Study Area (2002-2015)

Vessel Type	Per-Transit Casualty Rate							
	Allision	**Collision**	**Grounding**	**Equip Failure**	**Fire**	**Structural Failure**	**Any Casualty**	**Minor Spill**
Tank Barge	0.00015	0.00	0.00030	0.00	0.00	0.00024	**0.00069**	0.000090
Tanker	0.0012	0.00	0.0023	0.00	0.00	0.00	**0.0035**	0.0012
Cargo Ship	0.0000093	0.00	0.000037	0.0000093	0.00	0.000065	**0.00012**	0.0000093
Freight Barge	0.00021	0.000051	0.00023	0.00	0.00	0.00026	**0.00075**	0.00013
Towing Vessel	0.00022	0.00	0.000062	0.000062	0.000093	0.0010	**0.0015**	0.00019
Average	**0.00036**	**0.000010**	**0.00059**	**0.000014**	**0.000019**	**0.00031**	**0.0013**	**0.00032**

The calculated frequencies of oil spills from vessel by volume based on different assumptions of vessel traffic are summarized in Table 6. The likelihood of a spill of 100,000 bbl or more, like some of the scenarios modeled in the HROSRA, is about 1 in 670,000 with current vessel traffic. With increased overall traffic, and, in particular with increases in tank vessels, this probability increases to as much as 1 in 170,000. With decreased traffic, the probability likewise decreases. With a 200% increase (i.e., doubling) of the tank vessels on the river, the probability of a 100,000-bbl or larger spill is 1 in 170,000 each year.

The annual probabilities of spills during transfer operations (fueling or cargo transfers to/from vessels at terminals or between vessels) are summarized in Table 7.

Table 6: Predicted Annual Spill Frequencies based on Vessel Traffic Changes

Vessel Traffic Assumption	Estimated Annual Number of Spills by Volume Category (bbl)							
	<1	**1**	**10**	**100**	**1,000**	**10,000**	**100,000**	**Total**
Current Traffic	3.66	0.47	0.27	0.22	0.14	0.044	0.0000015	**4.81**
50% Overall Decrease	1.83	0.24	0.13	0.11	0.07	0.022	0.0000007	**2.40**
10% Overall Decrease	3.29	0.43	0.24	0.20	0.13	0.039	0.0000013	**4.32**
50% Decrease Tank Vessels	3.16	0.40	0.20	0.19	0.12	0.035	0.0000007	**4.11**
20% Decrease Tank Vessels	3.46	0.44	0.24	0.21	0.13	0.040	0.0000012	**4.53**
10% Decrease Tank Vessels	3.56	0.46	0.25	0.22	0.14	0.042	0.0000013	**4.67**
10% Increase Tank Vessels	3.75	0.49	0.28	0.23	0.15	0.045	0.0000016	**4.94**
20% Increase Tank Vessels	3.85	0.50	0.29	0.24	0.15	0.047	0.0000018	**5.08**
50% Increase Tank Vessels	4.15	0.55	0.33	0.26	0.17	0.053	0.0000022	**5.50**
10% Overall Increase	4.02	0.52	0.29	0.25	0.16	0.048	0.0000016	**5.29**
100% Increase Tank Vessels	4.64	0.62	0.39	0.29	0.19	0.061	0.0000030	**6.19**
20% Overall Increase	4.39	0.57	0.32	0.27	0.17	0.052	0.0000018	**5.77**
200% Increase Tank Vessels	6.62	0.91	0.63	0.44	0.28	0.097	0.0000059	**8.97**
50% Overall Increase	5.49	0.71	0.40	0.34	0.22	0.066	0.0000022	**7.22**
100% Overall Increase	7.27	0.89	0.51	0.42	0.26	0.085	0.0000080	**9.44**

Table 7: Estimated Annual Transfer Spills in Hudson River

Spill Volume (bbl)	Annual Spill Rate (Annual Probability)					
	Oil Cargo Transfer		Bunkering		Total	
	Annual Spills	Annual Probability	Annual Spills	Annual Probability	Annual Spills	Annual Probability
<1 bbl	0.365	1 in 3	0.514	1 in 2	0.86	1 in 1
1-9 bbl	0.09	1 in 11	0.126	1 in 8	0.216	1 in 5
10-99bbl	0.045	1 in 22	0.063	1 in 16	0.108	1 in 9
100-999 bbl	0.0045	1 in 222	0.0063	1 in 159	0.011	1 in 91
1,000-9,999 bbl	0.00045	1 in 2,222	0.00063	1 in 1,587	0.0011	1 in 909
10,000 bbl +	0.00005	1 in 20,000	0.00007	1 in 14,286	0.00012	1 in 8,333
Total	**0.505**	**1 in 2**	**0.71**	**1 in 1**	**1.19622**	**1 in 1**

Hudson River Recreational Boating Spills

Most recreational vessels have fuel tanks of 0.5 to 3 bbl. The largest yachts can hold as much as 250 bbl. The estimated total annual volume of oil spillage from recreational vessels in the Hudson River is about 20 bbl. With an estimated 16 annual accidents, this comes to about 1.3 bbl per accident. There would be smaller volumes of spillage for smaller vessels, and more for larger ones.

Hudson River Railroad-Related Spills

The probability of spills from railroads included:

- Spills from tank cars carrying crude oil in CBR trains;
- Spills from locomotives pulling freight trains, including crude-by-rail (CBR) trains;

- Spills from locomotives pulling/pushing commuter trains; and
- Spills from locomotives pulling long-distance passenger trains (Amtrak).

There currently are no regular CBR trains transiting the Hudson River corridor. If there are no CBR trains there is no probability of spillage from these sources. However, during 2017, there were eight (8) trains that were diverted through the Hudson River rails due to extenuating circumstances with the hurricane damage in Houston.

The analyses for potential CBR spills were conducted with various traffic assumptions – ranging from diversion transport (as with the 8 trains in 2017), and occasional and frequent diversion transport (up to 96 trains per year). In addition, two different levels of historical transport (moderate and peak), as well as a hypothetical maximum transport level that would cover the entire capacity of refineries in the Northeast, were analyzed.

The calculated annual frequencies of CBR spills of oil cargo (e.g., Bakken crude) along the Hudson River based on the different traffic scenarios are shown in Table 8. *Note that these are only spills that might potentially affect the Hudson River because of the proximity of the tracks to the river. This is not an estimate of the numbers of spills along the inland lengths of track.*

Table 8: Projected Numbers of CBR Spills along Hudson River

Hypothetical CBR Transport Scenario	Annual CBR Trains	Low Spill Estimate		High Spill Estimate	
		Annual Frequency	Annual Probability	Annual Frequency	Annual Probability
Current (No Diversion Transport)	0	0	n/a	0	n/a
Current (Diversion Transport)	8	0.0000020	1in 510,000	0.000046	1in 22,000
Occasional Diversion Transport	32	0.0000078	1in 128,000	0.00019	1in 5,400
Frequent Diversion Transport	96	0.000024	1in 43,000	0.00056	1in 1,800
Moderate Historical Transport	780	0.00019	1in 5,200	0.0045	1in 220
Peak Historical Transport	1,560	0.00038	1in 2,600	0.0090	1in 110
Maximum Hypothetical Transport	4,015	0.00098	1in 1,000	0.023	1in 43

Note that these are spills of *any volume into the Hudson River,* not necessarily a spill the size of the modeled scenarios (11,000 bbl). The expected frequencies of CBR spills into the Hudson River based on "pessimistic" assumptions about the implementation of rail accident and spill prevention measures is shown in Table 9.

The probability of a diesel locomotive spill into the Hudson River is summarized in Table 10.

Table 9: Projected Annual Frequency of CBR Spills into Hudson River (High Estimate)

Spill Volume	Annual Probability of Spills (Based on Trains per Year)					
	8 trains Current Diversion	**32 trains Occasional Diversion**	**96 trains Frequent Diversion**	**780 trains Moderate Historical**	**1,560 trains Peak Historical**	**4,015 trains Maximum Hypothetical**
<238 bbl	1 in 1 million	1 in 210,00	1 in 71,000	1 in 9,000	1 in 4,400	1 in 1,700
2,500 bbl	1 in 1.1 million	1 in 230,000	1 in 77,000	1 in 10,000	1 in 4,800	1 in 1,900
4,000 bbl	1 in 1.2 million	1 in 250,000	1 in 83,000	1 in 11,000	1 in 5,300	1 in 2,100
5,000 bbl	1 in 1.7 million	1 in 360,000	1 in 120,000	1 in 16,000	1 in 7,700	1 in 2,900
8,000 bbl	1 in 1.9 million	1 in 390,000	1 in 230,000	1 in 17,000	1 in 8,300	1 in 3,200
10,000 bbl	1 in 2.9 million	1 in 590,000	1 in 200,000	1 in 26,000	1 in 12,000	1 in 4,800
15,000 bbl	1 in 3.7 million	1 in 770,000	1 in 260,000	1 in 33,000	1 in 16,000	1 in 6,300
20,000 bbl	1 in 10 million	1 in 2.1 million	1 in 710,000	1 in 91,000	1 in 44,000	1 in 17,000
40,000 bbl	1 in 100 million	1 in 21 million	1 in7.1 million	1 in 910,000	1 in 430,000	1 in 170,000
50,000 bbl	1 in 1 billion	1 in 210 million	1 in 71 million	1 in 9.1 million	1 in 4.3 million	1 in 1.7 million

Table 10: Estimated Annual Hudson River Spills from Diesel Locomotives by Volume

Volume	Annual Spills	Annual Probability
5 bbl	0.078	1 in 13
25 bbl	0.069	1 in 15
40 bbl	0.065	1 in 16
50 bbl	0.043	1 in 23
60 bbl	0.041	1 in 25
70 bbl	0.027	1 in 37
100 bbl	0.020	1 in 49
250 bbl	0.0078	1 in 130
300 bbl or more	0.00078	1 in 1,300
Total	**0.35**	**1 in 3**

Hudson River Facility Spills

There are currently 16 major petroleum storage facilities dotting the Hudson River shorelines storing approximately 144 million gallons (3.5 million barrels, bbl). Individual storage tanks may contain as much as 250,000 to 300,000 bbl of oil. There are 16 facilities that are noted by the US Energy Information Administration as holding *at least* 50,000 bbl. The projected annual spillage from *existing* facilities is summarized in Table 11.

Table 11: Projected Annual Oil Facility Spills into Hudson River

Spill Volume	Spills/Year	Annual Probability
Any Volume	0.011	1 in 88
≥10 bbl	0.0041	1 in 240
≥238 bbl (Major)	0.00090	1 in 1,100
1–9 bbl	0.0069	1 in 150
10–99 bbl	0.0026	1 in 380
100–999 bbl	0.0012	1 in 830
1,000–9,999 bbl	0.00027	1 in 3,700
10,000–99,999 bbl	0.000028	1 in 36,000
≥100,000 bbl	0.00000080	1 in 1.2 million

Hudson River Pipeline Spills

Currently, pipelines are not a very likely source of spillage into the Hudson River study area. There is no crude oil or refined product pipeline crossing the Hudson River study area at this time. Another factor that could potentially change the nature of crude oil transport in the Northeast and in and along the Hudson River is the construction of the Pilgrim Pipeline. The proposed pipeline would have two river crossings and run alongside parts of the river.

The potential for pipeline spills with the Pilgrim Pipeline was calculated as shown in Table 12. Note that these probabilities only apply if the proposed pipeline is constructed and put into service.

Table 12: Projected Annual Pipeline Spills into Hudson River with Pilgrim Pipeline

Pipeline Volume	Crude Pipeline		Refined Product Pipeline		Total	
	Spills/Year	Annual Probability	Spills/Year	Annual Probability	Spills/Year	Annual Probability
≥10 bbl	0.0023	1 in 440	0.0011	1 in 930	0.0031	1 in 320
≥238 bbl (Major)	0.00060	1 in 1,700	0.00030	1 in 3,300	0.00044	1 in 2,300
<1 bbl	0.0025	1 in 400	0.0012	1 in 840	0.0034	1 in 300
1–9 bbl	0.0025	1 in 400	0.0012	1 in 840	0.0034	1 in 300
10–99 bbl	0.0014	1 in 740	0.00067	1 in 1,500	0.0019	1 in 530
100–999 bbl	0.00074	1 in 1,400	0.00035	1 in 2,800	0.0010	1 in 1,000
1,000–9,999 bbl	0.00019	1 in 5,300	0.000091	1 in 11,000	0.00026	1 in 3,900
≥10,000 bbl	0.000017	1 in 56,000	0.0000081	1 in 120,000	0.000023	1 in 44,000

Other Oil Inputs to the Hudson River

In addition to occasional spills, there are other chronic inputs of oil into the Hudson River, including oil from non-point sources through runoff and dumping of oil. These chronic inputs cannot be effectively removed. The only risk mitigation measures involve the prevention or reduction of these discharges. The estimated annual oil input to the Hudson River from non-point sources and runoff is 60,000 bbl per year.

Another source of chronic oil input is two-stroke engines (personal watercraft and outboard motors), which discharge an estimated 194 bbl into the river each year. Another 1,400 bbl of annual inputs are attributable to operational spillage of lubricating oils from large commercial vessels.

Summary of Current Probability of Oil Spills in the Hudson

The probabilities of oil spills based on *current conditions* are summarized in Table 13 and Figure 10 by volume and source type. The annual probability of a spill of each volume category is shown in Table 14. Currently, about six spills can be expected annually of which most will be very small and cause only localized effects. There is a 1 in 500,000 chance of a spill the magnitude of the WCD scenarios modeled in the HROSRA.

Table 13: Annual Frequency of Oil Spills in Hudson River based on Current Conditions

Spill Volume (bbl)	Vessels			Rail		Facilities	Total
	Tank Vessel	Bunkers	Transfers	CBR	Diesel Fuel		
<1	0.48	3.18	0.86	0	0	0	**4.5**
1 – 9	0.081	0.39	0.22	0	0.078	0.0069	**0.77**
10 – 99	0.093	0.17	0.108	0	0.25	0.0026	**0.62**
100 – 999	0.041	0.18	0.011	0.000001	0.029	0.0012	**0.26**
1,000 – 9,999	0.024	0.12	0.0011	0.0000029	0	0.00027	**0.14**
10,000– 99,999	0.012	0.031	0.00012	0.00000073	0	0.000028	**0.043**
100,000+	0.0000015	0	0	0	0	0.00000080	**0.000002**
Total	**0.73**	**4.1**	**1.2**	**0.0000046**	**0.35**	**0.011**	**6.36**

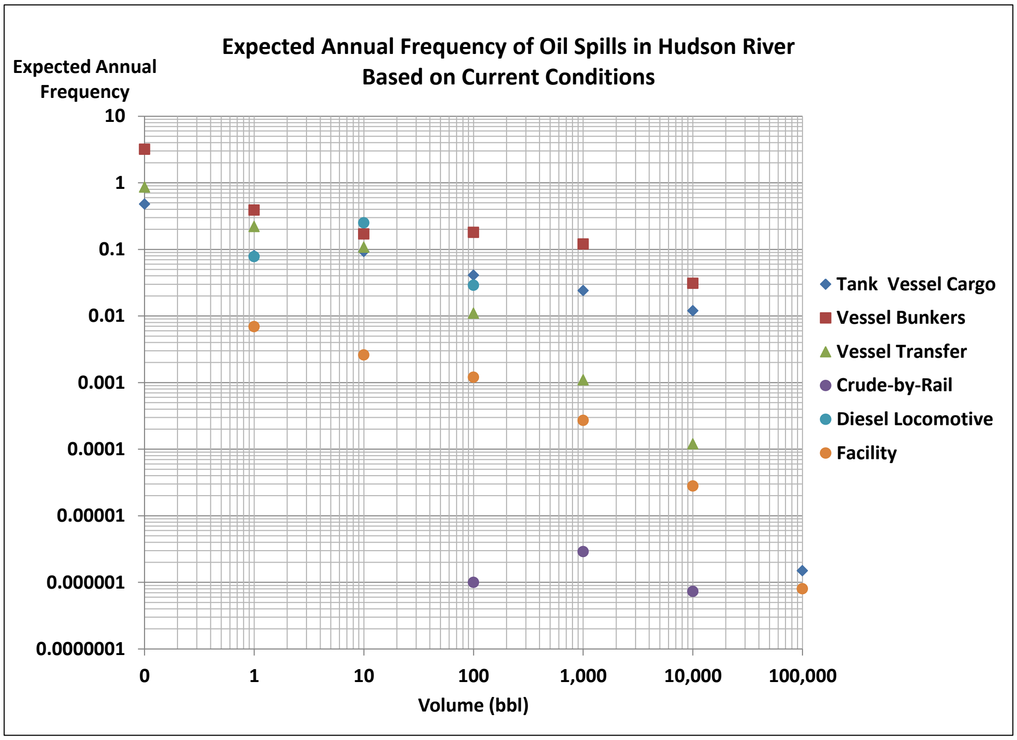

Figure 10: Expected Annual Oil Spill Frequency in Hudson River (Current Conditions)[13]

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[13] Note logarithmic scales.

Table 14: Annual Probability of Oil Spills in Hudson River based on Current Conditions

Spill Volume (bbl)	Expected Annual Number of Spills	Annual Probability
<1	4.5	4 – 5 spills per year
1 – 9	0.77	1 in 1.3
10 – 99	0.62	1 in 1.6
100 – 999	0.26	1 in 4
1,000 – 9,999	0.14	1 in 7
10,000– 99,999	0.043	1 in 23
100,000+	0.000002	1 in 500,000
Total	**6.36**	**6 spills per year**

Summary of Oil Spill Scenario Modeling Results (HROSRA Volume 4)

Each oil spill incident is a unique event with respect to the way the oil behaves and its effects on the environment. The type of oil affects both its behavior and its effects on the environment. The location of the spill along with the weather, wind direction and speed, current speed, tide conditions, and other factors can affect the way in which the oil will move. The effects of a spill will also be influenced by the season and timing of the spill –for example, whether birds are migrating or nesting, if fish are spawning, or it is the height of the summer boating season. The location of a spill, the type of oil involved, and the volume of spillage will depend on the source and circumstances of the accident.

Port of Albany 155,000-bbl Bakken Crude Tanker Loading Accident

The scenario at the Port of Albany would involve a fully-loaded tanker accidentally pulling away from the dock during transfer operations and spilling 155,000 bbl of Bakken crude. This would constitute a worst-case discharge (WCD) from a vessel in the Hudson River.

In this hypothetical modeled scenario, nearly half of the spilled Bakken crude evaporated, and the rest dissolved and degraded in the water column. In winter with ice cover, less oil evaporated or entrained into the water than in spring or summer. The amount of oil going ashore is highest in winter because of its being retained on the surface longer and carried well down-stream.

Floating oil from the spring spills were transported down river, reaching the Tappan Zee area by 28 days. In contrast, in the summer, the river flow is much weaker than the tidal flow, and the oil was not carried downstream appreciably. In winter, oil was transported downstream as far as Newburgh. Over 200 miles of shoreline would be oiled at levels above the potential ecological effects threshold. In summer, the floating oil moves the least distance from the spill site and less than 20 miles would be oiled above the ecological threshold.

High river currents would be expected to reduce the effectiveness of containment and protection booms. Flammability is a great concern for responders and for public safety. In the event of an ignition, a fire might affect 21 acres at the site. In the event of an explosion, the effects would be felt across 476 acres. There is a significant possibility of human injuries and fatalities at the port and during response operations. Evacuation of about one-half mile around the spill site would be recommended.

Coxsackie 25,000-bbl Home Heating Oil Spill

The scenario would involve a grounding or collision of a tanker or tank barge causing the release of 25,000 bbl of home heating oil off Coxsackie near the Vosburgh Swamp Wildlife Management Area. While this is not a WCD in terms of volume, it is nevertheless a very large spill that could potentially impact sensitive wetlands and wildlife areas.

In the modeling, much of the spilled home heating oil evaporated, and most of the remaining oil was entrained into the water column. In all seasons, less than 1% of the oil remained on the surface by 30 days after the release. Higher wind speeds in spring caused more oil to become entrained and subsequently dissolve and degrade in the water column. In summer, there was less wind and thus less entrainment into the water column, and more of the oil evaporated owing to warmer temperatures. In winter, the 50% ice cover reduced entrainment into the water as well as evaporation, and so more oil came ashore.

Floating oil from the spring spills at both high and low tide were transported down river, reaching New York Harbor by 28 days after the spill. In contrast, in the summer, the river flow is much weaker than the tidal flow, and the floating home heating oil was blown upstream past Albany and downstream to Stockport Creek (just north of Lorenz Park). In winter, oil spilled was transported downstream as far as Kingston when spilled at low tide and Staatsburg when spilled at high tide.

Because strong river flows carried floating oil a long distance downstream in spring and winter, the shore oiling is extensive in those seasons for spills at any stage of the tide. In summer, floating oil and shoreline exposures occur closer to the spill site, but still over a considerable distance both up and downstream. Up to 100 miles of shoreline would be oiled above the ecological threshold in winter, but only about 70 miles in the summer. High river currents would be expected to reduce the effectiveness of containment and protection booms.

Proposed Kingston Anchorage[14] 150,000-bbl Home Heating Oil Spill

A hypothetical worst-case discharge of 150,000 bbl of home heating oil due to a collision or allision of a tank barge at the proposed Kingston Anchorage was modeled.

In the simulation, nearly half of the spilled home heating oil evaporated, and most of the remaining oil was entrained into the water column. In the winter, when it is cold and there is ice cover, there is less evaporation and entrainment into the water column so that about 11% of the non-volatile fraction remained floating by the end of the 30-day simulation. In spring and summer less than 1% of the oil remained on the surface. Higher wind speeds in spring caused more oil to become entrained and subsequently dissolve and degrade in the water column. In summer, there was less wind and thus less entrainment into the water column, and more of the oil evaporated owing to warmer temperatures.

Floating oil from the spring spills at both high and low tide were transported down river, reaching New York Harbor by 21 days after the spill. In contrast, in the summer, the river flow is much weaker than the tidal flow, and the floating home heating oil was blown upstream past Lorenz Park and downstream to Poughkeepsie when spilled at high tide. Likewise, in the summer, the floating home heating oil was blown upstream past Coxsackie and downstream to Staatsburg when spilled at low tide. In winter, oil spilled was transported downstream past Bear Mountain Bridge. In spring and winter, up to 120 miles of shoreline would be oiled above the ecological threshold, while in the summer about 90 miles would be oiled at this level.

Because strong river flows carried floating oil a long distance downstream in spring and winter, the shore oiling is extensive in those seasons for spills at any stage of the tide. In summer, floating oil and shoreline exposures occur closer to the spill site, but still over a considerable distance both up and downstream. Higher current velocities may reduce the effectiveness of booms during a spill response.

Proposed Kingston Anchorage 150,000-bbl Diluted Bitumen Oil Spill

The same scenario at the proposed Kingston anchorage was repeated with 150,000 bbl of diluted bitumen. In this case, nearly 30% of the spilled diluted bitumen (dilbit) evaporated, and the remaining light

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[14] Note: The location of this hypothetical spill scenario was based on the proposed location for an anchorage near Kingston. This anchorage has not been approved or officially implemented.

hydrocarbons from the diluent dissolved and degraded in the water column. Most of the non-volatile bitumen fraction remained floating over the 30-day simulation, with some of going ashore or settling to the sediments. After the spring spills, 7-9% of the floating oil exited the model domain into New York Harbor.

Floating oil from the spring spills (at both high and low tide) was transported down river, reaching New York Harbor by 21 days after the spill. Little oil was carried upstream in the spring. In contrast, in the summer, the river flow is much weaker than the tidal flow, and the oil was carried both up and down river, and only carried downstream as far south as Poughkeepsie. The floating oil was carried north by flood tides and blown upstream by the prevailing southerly winds as far north as Coxsackie. In winter, oil spilled at either high or low tide was transported downstream as far as Haverstraw Bay, and upstream towards Catskill. In the spring and winter about 190 miles would be oiled above the ecological threshold; in summer about 135 miles would be oiled at this level.

Because strong river flows carried floating oil a long distance downstream in spring and winter, the shore oiling is extensive, particularly in spring, for spills at any stage of the tide. In summer, floating oil and shoreline exposures are also extensive, both up and downstream of the spill site. The sediment contamination from these dilbit spills was relatively low because the highly viscous bitumen remained floating and went ashore, as opposed to being mixed into the water where it could bind with suspended particulate matter and settle.

The potential for submerged oil in high-sediment areas would complicate response efforts. Higher current velocities may reduce the effectiveness of booms during a spill response.

Rondout Creek 75,421-bbl Bakken Crude Spill (ACP Scenario)

This scenario is based on the worst-case-discharge scenario described in the 2016 New York-New Jersey Area Contingency Plan (ACP). It involves the collision of a tank barge loaded with Bakken crude and a cargo vessel resulting in the spillage of 75,421 bbl of Bakken crude and 14,000 bbl of heavy fuel oil near Rondout Creek. The scenario was divided into two separate spills for modeling. However, in the ACP, the two incidents would be concurrent.

Nearly half of the spilled Bakken crude evaporated, and most of the remaining oil was entrained into the water column, where some of it dissolved and degraded by 30 days after the release. In the winter, when there is less evaporation because of ice cover and cold temperatures, about 22% of the non-volatile fraction remained floating over the 30-day simulation whereas in spring and summer no floating oil is predicted to remain on the surface. About 22-23% of the oil spilled in spring reached New York Harbor after being entrained into the water column. The percentage of oil going ashore varies from 3 to 14% based on the season.

Floating oil from the spring spills at both high and low tide were transported down river, reaching New York Harbor by 21 days after the spill. In contrast, in the summer, Bakken oil was blown upstream past Lorenz Park after 14 days (at both high and low tide) but after 21+ days the floating oil was pushed back downstream closer to the Catskills. In winter, spilled oil was initially (in the first few days) transported upstream and downstream but after 14 days, the floating oil was past Bear Mountain Bridge (at both high tide and low tide) in the 30-day simulations. In the spring and summer about 90 miles above the ecological threshold; in winter 124 miles would be oiled at this level.

Because strong river flows carried floating oil a long distance downstream in spring and winter, the shore oiling is extensive in those seasons for spills at any stage of the tide. In summer, floating oil and shoreline exposures also occur over a considerable distance both up and downstream.

Higher current velocities may reduce the effectiveness of booms during a spill response. Flammability is also a concern. If there were to be an ignition, the fire would be limited to about 1.4 acres. In the event of an explosion, about 418 acres would be impacted. There is a significant possibility of human injuries and fatalities to individuals in the area, including responders. Evacuation of about one-half mile around the spill site would be recommended.

Rondout Creek 14,000-bbl Heavy Fuel Oil Spill (ACP Scenario)

In the second part of the ACP scenario, 14,000 bbl of heavy fuel oil were spilled. This heavier oil behaves very differently from the lighter more volatile Bakken crude. As only a small percentage of heavy fuel oil is comprised of volatile or soluble hydrocarbons, most of the oil remains floating until it goes ashore. A small percentage of the heavy fuel oil evaporates, and some of the stranded oil degrades by 30 days after the spill.

Floating oil from the spring spills were transported down river, reaching the farthest (New York Harbor) when spilled at high tide and just north of the George Washington Bridge after 28 days when spilled at low tide. In contrast, in the summer, heavy fuel oil was blown upstream past Saugerties after 28 days when spilled at high tide, but transported even farther upstream (closer to the Catskills) when spilled at low tide. In winter, oil spilled was initially (in the first few days) transported upstream and downstream but after 28 days, the floating oil was past Newburgh when spilled at high tide and even further downstream (closer to West Point) when spilled at low tide in the 30-day simulations. In spring about 115 miles of shoreline would be oiled above the ecological threshold. In summer and winter oiling at this level would occur on up to 75 miles of shoreline. Higher current velocities may reduce the effectiveness of booms during a spill response.

Newburgh Waterfront Crude-by-Rail 11,000-bbl Bakken Crude Spill

A hypothetical scenario of a train accident in Newburgh provided the opportunity to simulate not only the impact of oil into the Hudson River, but also the effect of a potential fire/explosion situation in a populated area.[15] In the scenario, a crude-by-rail train derails and spills 11,000 bbl of oil (about 16 or 17 tank cars worth) at the Newburgh waterfront. In one case the spilled oil ignites, in another case it does not.

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[15] Since the stated purpose of the HROSRA is to determine risk of spills to the river and not necessarily the risk to communities from crude-by-rail (CBR) transport, two CBR scenarios (Newburgh and Iona Island) were selected based on the likelihood of oil spillage into the river. To address additional concerns about effects on communities through which CBR traffic would go, the Newburgh scenario was included. A more comprehensive study of CBR accidents is required to determine the risk of CBR overall.

When it does not ignite, about 40-50% of the spilled Bakken crude evaporated, and most of the remaining oil was entrained into the water column. For spring spills, much of the oil was transported within the water column into New York Harbor because of the high flow of the river and, because of this and especially when spilled at low tide, a smaller percentage evaporated or came ashore compared to the other seasons. The percentage going ashore ranged from 4 to 40%, partially the result of variable wind conditions. Shoreline oiling above the ecological threshold would cover about 60 miles in winter, and less in spring and summer, covering about 35 to 40 miles.

Flammability is a significant concern because of the proximity to populated areas and during response operations. If there is ignition, about 5.3 acres would be affected by the burn. If an explosion were to occur, 34 acres would be affected. There is a significant possibility of human injuries and fatalities. Evacuation of about one-half mile around the spill site would be recommended.

Note that if the oil does burn, it would be expected that much less (if any) oil would enter the river.

Bear Mountain Bridge 2,500-bbl Home Heating Oil Spill

This scenario would involve a hypothetical collision between two vessels just above the Bear Mountain Bridge, which is a difficult area to navigate especially if there is limited visibility with fog. This scenario would involve a fully-loaded tanker (the largest of which holds 310,000 bbl) releasing 155,000 bbl (which would be the largest outflow likely with a double hull) of home heating oil.

The majority (>56%) of the spilled home heating oil evaporated, and most of the remaining oil was entrained into the water column, where some of it dissolved and degraded by 30 days after the release. In spring, more oil mass entered the water column than in other seasons, but much of this entrained oil was swept downstream into New York Harbor. What remained in the water column in the river readily degraded (between 4 to 11% of the spilled oil). With the exception of the spring scenario at low tide, where little shoreline oiling occurred because the oil was rapidly swept downstream, 16-20% of the home heating oil washed ashore. In spring and summer, about 5 to 15 miles of shoreline might be oiled above the ecological threshold. In winter, nearly 30 miles would be oiled at this level. Higher currents could reduce the effectiveness of booming.

Iona Island Crude-by-Rail 11,000-bbl Bakken Crude Spill

This scenario involves a derailment of a fully-loaded unit train at Iona Island, just south of the Bear Mountain Bridge at the over-water trestle crossing of the rails. The likely worst-case discharge volume here would be 11,000 bbl of Bakken crude. The scenario also includes a fire and/or explosion.

About half of the spilled Bakken crude evaporated, and much of the remaining oil was entrained into the water column. For the high tide spill in the spring, some of the oil that entered the water column was swept downstream into New York Harbor. Much of the oil spilled at low tide in the spring entered Iona marsh and settled to the sediments. The percentage of oil going ashore varies from 1 to 17% based on the season, reflecting the amount of oil that had remained floating in the river. In the spring and summer, up to about 30 miles of shoreline might be oiled above the ecological threshold. In winter, 50 miles might be oiled.

Flammability is a significant concern during response operations and for individuals in the vicinity. This is not a residential area, though there may be large populations at the Bear Mountain State Park and the Bear Mountain Bridge nearby. If there is ignition, about 5.3 acres would be affected by the burn. If an explosion were to occur, 34 acres would be affected. There is a significant possibility of human injuries and fatalities. Evacuation of about one-half mile around the spill site would be recommended.

Note that if the oil does burn, it would be expected that much less (if any) oil would enter the river.

Tappan Zee 2,500-bbl Home Heating Oil Spill

In this hypothetical scenario, an allision of a tanker or tank barge at one of the bridge structures at Tappan Zee[16] would cause a release of 2,500 bbl of home heating oil. This represents a maximum most-probable discharge (MMPD) scenario.

The majority (>66%) of the spilled home heating oil evaporated, and most of the remaining oil was entrained into the water column, where some of it dissolved and degraded by 30 days after the release. In spring and winter, entrained and dissolved oil was transported into New York Harbor. In summer, evaporation is faster with higher temperature therefore the percentage evaporated and dissolved was higher than the other seasons. Also, river flow is lowest in summer and little of the oil reaches New York Harbor. In spring, only up to one mile of shoreline would be oiled above the ecological threshold. In summer and winter, three to five miles would be oiled at this level.

Tappan Zee 50-bbl Heavy Fuel Oil Spill

Another hypothetical scenario at the same Tappan Zee location involved an average most probable discharge (AMPD) of 50 bbl of heavy fuel oil. As only a small percentage of heavy fuel oil is comprised of volatile or soluble hydrocarbons, most of the oil remained floating until it went ashore. A small percentage of the heavy fuel oil evaporated.

Floating oil from the spring spills at both high and low tide were transported down river, reaching New York Harbor before 7 days. In summer, within the first three days, floating oil moved both upstream and downstream but after 14 days all traces of floating oil had disappeared at both high and low tide. The down-river extents of the winter spill trajectories reached just south of the Tappan Zee after 3 days when spilled at high tide and 60 hours when spilled at low tide but disappeared after 14 days for high tide spills and 3 days for low tide spills. Shoreline oiling above the ecological threshold would occur over less than three miles for all seasons.

Yonkers Anchorage 155,000-bbl Gasoline Spill

A collision or allision of a tanker at the proposed Yonkers Anchorage Extension could cause a worst-case discharge release of 155,000 bbl of gasoline. This scenario was modeled along with a fire and explosion. Despite the proximity to the New York Harbor in this scenario, less than 4% was transported downstream to the harbor. The majority (>92%) of the spilled gasoline evaporated, and a very small percentage of the remaining oil dissolved and degraded in the water column.

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[16] "Tappan Zee" includes the existing Tappan Zee Bridge and the new Mario Cuomo Bridge under construction.

Floating oil from the spring spills was transported down river, reaching New York Harbor after 54 hours when spilled at high tide and 3 days when spilled at low tide. In contrast, in the summer, the river flow carried the floating gasoline downstream to Manhattan (only when spilled at high tide), as well as upstream north of the Tappan Zee when spilled at both high and low tide. In winter, oil spilled was transported downstream to New York Harbor as soon as 7 days (at both high tide and low tide) in the 30-day simulations.

Shoreline oiling is least in summer and extends furthest in winter where the ice cover and low temperatures slow evaporation and moderate flow carries the residual hydrocarbons downstream. In all seasons less than three miles of shoreline would be oiled above the ecological threshold.

Response operations would need to take into account the high risk of flammability and exposure to benzene, toluene, ethylbenzene, and xylene (BTEX) vapors. The containment of gasoline by booming and skimming operations would likely present a danger. Unified Command might consider forgoing booming and skimming operations for safety purposes. Most of the gasoline would evaporate naturally.

In the event of an ignition, a fire might affect just over three acres at the site. In the event of an explosion, the effects would be felt across 166 acres. There is a significant possibility of human injuries and fatalities in the vicinity of the spill and during response operations. Evacuation of about one-half mile around the spill site would be recommended.

Summary of Fire/Explosion Scenario Modeling (HROSRA Volume 5)

Five of the oil spill scenarios were selected for additional modeling of fire/explosion events that occur in the aftermath of the hypothetical spills. There are two major hazards that may occur if there is ignition in the aftermath of a spill of oil:

- **Pool Fire:** a fire that burns from a pool of vaporizing fuel. The primary concern associated with pool fires is hazards associated with increased temperatures from thermal radiation (heat).
- **Vapor Cloud Fire (Flash Fire): a** rapidly moving flame front characterized by combustion. Flash fires occur in an environment where fuel and air become mixed in adequate concentrations to combust.

Pool Fire and Explosion Hazards

The worst-case hazard distances for pool fires and explosions that are representative for each location are shown in Table 15. These compile the distances to hazard limits and the land use areas impacted. The table shows that the predicted land areas impacted by thermal radiation hazards from pool fires range from less than an acre to three acres, the major contributor being the Port of Albany, and explosion overpressure hazard distances range from 34 to 476 acres, the major contributor also being the Port of Albany, due to land development density. The entries marked with an asterisk (*), indicate no impacts from this scenario impact land use areas of the indicated type (the hazard does not reach the target).

Table 15: Worst-Case Hazard Impacts

Location and Hazard Type		Downwind Distance	Impact (Acres)				
			Total	Residential	Commercial	Industrial	Public Use
Port of Albany	**Pool Fire**	581 ft	0.3	0.1	0.1	0	0.1
	Explosion	1.66 miles	476	305	47	124	0
Rondout	**Pool Fire**	581 ft	0.8	0	0	0.4	0.4
	Explosion	2.19 miles	418	155	134	50	79
Newburgh Waterfront	**Pool Fire**	581 ft	0.2	0	0.1	0	0.1
	Explosion	0.33 mile	34	22	8	0	13
Iona Island	**Pool Fire**	581 ft	0.2	0	0	0	0.2
	Explosion	0.84 mile	68	0	0	0	68
Yonkers Anchorage	**Pool Fire**	1,473 ft	3.1	0	1.6	1.6	0
	Explosion	0.033 mile	166	103	27	8	27

An example of the worst-case hazard distances from a Bakken crude tanker spill is shown for the Port of Albany scenario in Figure 11. The blue circle indicates the extent of the pool fire, the yellow circle indicates the dispersion of flammable vapor, and the red circle indicates the explosion overpressure hazard zone. The actual spill location is at the dockside within the blue circle.

The probability of a fire or explosion in the event of a release is dependent on an incident and a release first occurring. The probabilities of oil release for the different scenarios depend on the source type (tank vessel, cargo vessel bunkers, and rail) and oil volume (larger-volume spills are less likely within each source type category). Past research has demonstrated that there is an 8% probability of an ignition leading to a fire in the event of a release. Of these ignited events, there is a 30% probability that that fire would result in a vapor cloud explosion, hence a 2.4% probability (i.e. 8% x 30% = 2.4%). Table 16 outlines the expected frequencies and return periods of a fire or explosion based on the release frequencies calculated in the probability analysis.

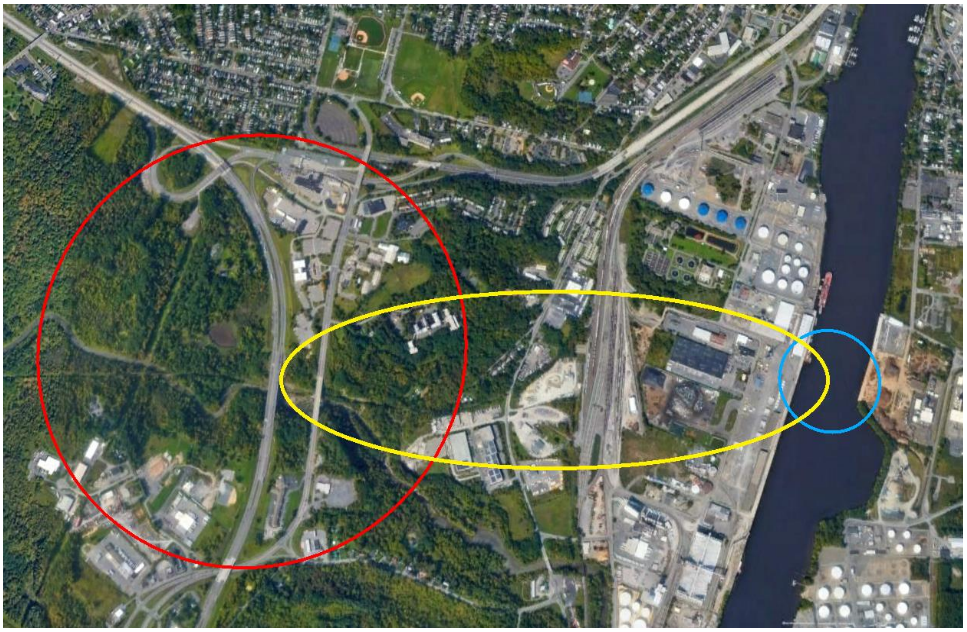

Figure 11: Port of Albany Worst-Case Hazard Distances

The blue circle indicates the extent of the pool fire, the yellow ellipse indicates the dispersion of flammable vapor, and the red circle indicates the explosion overpressure hazard zone.

Table 16: Frequency and Annual Probability of Fire or Explosion in Event of Release

Incident Type	Albany and Yonkers Tank Vessel Spills (150,000-155,000 bbl)		Rondout Tank Vessel Spills (75,421 bbl)		Newburgh and Iona CBR Spills (11,000 bbl)	
	Frequency (Event/Year)	Annual Probability	Frequency (Event/Year)	Annual Probability	Frequency (Event/Year)	Annual Probability
Oil Release	0.0000015	1 in 670,000	0.012	1 in 83	0.00000035	1 in 2,900,000
Pool Fire	0.00000012	1 in 8,300,000	0.00096	1 in 1,000	0.00000003	1 in 33,000,000
Vapor Cloud Explosion	0.00000004	1 in 25,000,000	0.00029	1 in 3,500	0.0000000084	1 in 120,000,000

The frequency and return period of these potential events were calculated. The calculated frequency of a pool fire ranged between 0.00096 and 0.00000003 pool fires per year, which is equivalent to between one in every 1,000 years to one in every 33 million years. The calculated frequency of a vapor cloud explosion ranged between 0.00029 and 0.0000000084 vapor cloud explosions per year or, between one in every 3,500 years to 120 million years.

Summary of Spill Risk Mitigation Measures (HROSRA Volume 6)

Mitigating Spill Risk through Prevention

Preventing spills is more cost-effective than response, cleanup, and restoration. It is far less expensive to prevent an oil spill than it is to clean one up. No spill is acceptable — once oil is released into the environment, harmful consequences have already occurred. All oil spills are toxic and pose a significant risk to the environment, economy, public health, and historical and cultural resources. The aim should be for a zero spills strategy to prevent any oil or hazardous substances from entering waters of the United States. The waters of the United States are a treasured environmental and economic resource that should not be put at undue risk from an oil spill. Understanding the causes of spills is important for preventing them. Most oil spill incidents are caused by human and organizational factors, some say human factors may account for up to 80% of spill incidents.

Strategies for preventing and reducing the incidence of spills on the Hudson River include, but are not limited to:

1. Establishing and actively supporting the Hudson River Harbor Safety Committee;
2. Considering and following up on the recommendations arising from the Hudson River PAWSA;
3. Extending the Vessel Traffic Service (VTS) to the Hudson River (north of the New York Harbor area);
4. Educating recreational boat operators on ways to prevent spills during fueling and other boating activities;
5. Establishing vessel oil transfer regulations or best practices that have been shown to reduce the likelihood of spills during cargo transfers and fueling;
6. Continuing and enforcing state and federal regulations to prevent spills from facilities; and
7. Preventing railroad accidents through the use of positive train control (PTC) and supporting the other federally-regulated prevention measures for trains, including crude-by-rail trains.

In addition, consideration of activities and situations that may enhance or increase oil spill risk should be included in planning and risk management strategies for the Hudson River. These potentially risk-enhancing conditions would include the introduction to new or additional oil transport or other vessel traffic or rail traffic, as well as new pipelines and facilities.

Mitigating Spill Risk through Response

Once oil spills into water, responders are confronted with a race against time and the forces of physics, chemistry, and biology in their quest to remedy the situation and minimize damages. Oil spreads quickly into a thin sheen (less than the width of a hair) on the water and starts to evaporate, disperse, dissolve, and move with the winds and currents.

Despite decades of research and development, there are no fool-proof solutions. Each response strategy presents potential benefits and drawbacks. The strategic decision-making process is often a matter of evaluating tradeoffs – e.g., birds in the marsh may be spared, but fish are impacted; the oil can be kept out of this wetland, but a sandy beach will be oiled instead. The response itself may have adverse impacts (e.g., toxicity, marsh trampling, or air pollution). Ultimately, the *net benefit to the environment* needs to be paramount.

After spill prevention, for most oil spill situations in rivers, the priorities for response in order of precedence are:

- **Source Control**: Keeping as much additional oil as possible from being released into the environment;
- **Site Containment:** Corralling oil in the near vicinity of the spill site by secondary containment berms (storage tank spills) and/or booming (on water);
- **Monitoring and Tracking:** Following and predicting the most likely path (trajectory) of floating and entraining oil with weather and current/tidal information, modeling, and remote sensing;
- **Protection:** Proactively shielding previously-identified sensitive sites in local geographic response plans or strategies from oil incursion with deflection or exclusionary booming;
- **Deflection:** Altering the trajectory or path of floating oil away from sensitive and difficult-to-clean areas towards locations that are less sensitive to oil and more amenable to effective oil removal;
- **On-Water Containment:** Corralling and amassing floating oil with booms to assure greater efficiency and effectiveness of mechanical removal operations;
- **On-Water Recovery:** Skimming and vacuuming of contained floating oil;
- **Shoreline Removal:** Cleanup of stranded oil on shorelines and coastal structures with manual and mechanical methods; and
- **Disposal:** Gathering and transport of collected oily debris and recovered oil-water mixtures to hazardous waste disposal sites.

Oil spill response can help to mitigate the effects of an oil spill, but it has limitations. All response options – or the "tools in the toolbox" – available have benefits, drawbacks, and challenges. The effectiveness in removing oil varies depending on the oil behavior, environmental conditions and the manner in which the strategies are applied. A summary of oil response options for on-water recovery is shown in Table 17. The options for cleanup once the oil nears or strands on shorelines are summarized in Table 18.

The most effective on-water response options (chemical dispersants and in situ burning) are not options for spills in rivers. In addition to that, for spills in the Hudson River, there are certain factors that will preclude high levels of effectiveness in removing oil on the water, including:

- Currents (>0.7kts) often exceeding the capability of boom to hold back oil;
- Geography of river and tides spreading oil across a large area;
- Ice conditions that may impede mechanical removal equipment, booms, and boat access; and
- High degree of sediment in some locations that may lead to oil submergence.

In addition, the extensive wetland areas along the river will require particularly careful cleaning operations. High levels of foot traffic and incursion with equipment can often cause more harm than oil.

Table 17: On-Water Spill Response Strategies

Strategy	How it Works	When Appropriate	Effectiveness	Benefits	Challenges	Drawbacks
Mechanical Containment and Recovery (Booms and Skimmers)	Oil on the water surface is herded or contained by booms that float on the water surface. Oil is vacuumed up or removed from the water surface with skimming devices or vessels.	This strategy works best when there is a relatively thick layer of oil on the water surface and the oil is not too frothy (mousse-like) and not too viscous (thick and resistant to flow). The boom containment will only be effective if the currents do not exceed 0.7 – 1 knot. This approach is appropriate for Hudson River, though there will be significant challenges with currents in many locations.	Offshore, rarely more than 5 to 10% of oil is recovered. It may be more effective in more sheltered areas with calmer water. It is possible to remove more oil (25% or more) in situations in which the spill site (e.g., offloading tanker) is already boomed off and the removal equipment is nearby.	There is very little, if any, additional environmental impact. The only conceivable effects would be adverse impacts caused by the boats that are involved in the operations.	In a large spill, it may be difficult to track oil movement to locate areas with high oil concentrations that would lend themselves to effective removal. It takes time to get equipment in place during which time oil may have spread or moved due to wind and current action. High current velocities and waves can preclude effective containment booming. Availability of storage barges or tanks for oil/water mixtures is often a limiting factor and may cause delays. This technique can be difficult to carry out under stormy conditions.	This is a very labor- and equipment-intensive strategy that is generally not very effective. Large volumes of oily water mixture are recovered, often with very small percentages of oil content. The mixture needs to be collected and stored and then needs to be processed to remove the small percentage of oil and often the remaining oil-tainted water cannot be disposed of without hazardous material disposal permits.
Sorbents	Mats and pads that act like sponges are applied to the oil on the water surface to remove the oil.	On-water sorbent placement can be effective in small areas with low concentrations of oil, especially if there is a need to have a minimally-	Sorbents vary in effectiveness based on the materials involved and for the oil types and conditions of the spill.	Sorbent application is relatively non-invasive and does not require large machinery.	Placing the sorbents on the water surface in an effective manner can be difficult especially in inaccessible areas.	Once sorbent pads and mats absorb oil they need to be replaced. Oil-soaked sorbents become hazardous waste that needs to be disposed. Some

Table 17: On-Water Spill Response Strategies

Strategy	How it Works	When Appropriate	Effectiveness	Benefits	Challenges	Drawbacks
		invasive response.				sorbents are reusable. Sorbents cannot be effectively applied on a large scale or in situations in which there are high concentrations of oil.
On-Water Augmented Bioremediation	Genetically-engineered oil-eating bacteria are applied to the water to break down the oil.	This technique may be appropriate for small-scale spills particularly on land.	Few tests that have been conducted for on-water applications of oil-eating bacteria have given disappointing results.	There are no documented benefits to this strategy.	Applying bacteria solution or dry mixture to make contact with surface oil can be difficult. There are relatively small supplies of bacteria available.	Addition of non-indigenous bacteria species may be of concern.
Natural Removal	The oil is not removed offshore but rather left to break up on its own with wave action and natural weathering.	Natural removal may be the best alternative (i.e., with the best longer-term environmental benefit) when there is a very exposed rocky shoreline with high wave energy or exposed marsh area with a good deal of water flushing through tidal flow. In very remote areas, this may be the only practical and safe alternative.	This can be highly effective when the wave energy and natural flushing action is high. It works best for less persistent oils, though it can also break down more persistent oils given enough time.	There is no environmental impact from the response itself unlike some other more aggressive methods that can cause more harm than good. It is always possible to implement a response at a time that is safer or more logistically feasible (e.g., in summer rather than in winter).	It is often difficult to convince the public and government officials that nothing should be done for the time being. The ultimate effectiveness of this strategy might not be demonstrated for months to years.	Natural removal may not be completely effective, especially with more persistent (heavier) oils or if the wave or flushing action of the water is not sufficient. The opportunity for an effective on-water response may be lost.

Table 18: Shoreline/Nearshore Oil Spill Response Strategies

Strategy	How it Works	When Appropriate	Effectiveness	Benefits	Challenges	Drawbacks
Protective/ Deflective Booming	Booms are placed to prevent oil from entering particularly sensitive shoreline or near-shore areas. The oil is deflected to other areas where it is easier to remove the oil mechanically or remove it from the shoreline or where the damage will be less than in the sensitive area under protection.	This strategy is appropriate when there is particular concern about a shoreline area, such as a wetland or bird nesting habitat.	Protective booming can be highly effective if coastal currents and tidal currents do not exceed 0.7 to 1.0 knots or booms are placed angles to partially compensate for the currents since booms can withstand higher currents if placed at angle to current direction.	Keeping oil out of sensitive areas can significantly reduce damages to these areas.	Booms often need to be moved with the incoming and outgoing tides. The condition and placement of the boom (proper anchoring, etc.) will determine effectiveness. Booms that have been stored for long periods without inspection and repair or replacement are often	Placing boom in one location means that the oil has to go somewhere else. There will need to be a tradeoff decision-making process.
Sorbent Booms and Pads	Sausage-like booms filled with sorbent materials are placed in the water to soak up oil on the water surface that may come in proximity of the boom. (Sorbent mats can also be used for this purpose.)	This relatively low-invasive strategy is appropriate in very low wave, calm water areas when there are low concentrations of oil in marshes or other near-shore areas.	Sorbent booming can be fairly effective if the water is very calm and oil concentrations are low.	The sorbent booms may keep minimal amounts of oil out of sensitive areas.	Sorbent placement can be difficult in relatively inaccessible areas. The continuous replacement of the sorbents can be labor intensive.	This strategy does not work in locations with high concentrations of oil or if the water is rough. As with sorbent pads, the booms need to be replaced and disposed when they are soaked with oil. The large numbers of people involved can cause more harm to the marsh through trampling.

Table 18: Shoreline/Nearshore Oil Spill Response Strategies

Strategy	How it Works	When Appropriate	Effectiveness	Benefits	Challenges	Drawbacks
Marsh Flushing	Seawater is pumped through the marsh to flush out and dilute the oil that is sticking to marsh grass.	Marsh flushing is an appropriate strategy when there are moderate to higher concentrations of oil.	The flushing can be very effective in removing and diluting the oil.	The flushing procedure simulates and enhances natural tidal movements to promote the natural recovery of an oiled marsh.	Logistical access with pumps and hoses can be difficult. Access to the marsh may be difficult from the land side requiring boat access.	The flushing action may take considerable time and the results of the operations may not be immediately apparent.
Marsh Grass Cutting	Heavily oiled areas of marsh grasses are cut and removed.	This relatively high-impact strategy is appropriate if oiling is very heavy and other alternatives have been exhausted and there are other more sensitive locations (e.g., bird nesting areas) proximate to the marsh that will be oiled or re-oiled if the oil is not aggressively removed from that marsh.	The grass cutting can be relatively effective in removing gross contamination in some marsh areas.	The removal of the heavily-oiled marsh grass may protect other more sensitive areas.	Bringing people and equipment into a marsh often causes more harm to the marsh than the oil itself. Decision-making on tradeoffs (i.e., this marsh area is protected at the expense of another area) needs to be addressed. Disposal of the oiled grasses and debris needs to be addressed.	The marsh areas in which grasses were cut often take much longer to recover than oiled areas that were not cut.
Mechanical Removal	Heavy machinery (e.g., bulldozer) is brought in to remove oiled sediments, grasses, and debris.	The very high impact strategy is appropriate in marshes only if all other methods have failed and it is essential to remove gross contamination to prevent the oiling or re-oiling of even more sensitive areas.	Mechanical removal can be relatively effective in removing gross contamination in some marsh areas and on sandy beaches.	The removal of the heavily-oiled sediments, grasses, and debris may protect other more sensitive areas. Heavily-oiled sandy beach areas can be cleaned	Bringing people and equipment into a marsh often causes more harm to the marsh than the oil itself. Decision-making on tradeoffs (i.e., this marsh area is protected at the expense of another area) needs to be	The marsh areas in which the equipment and personnel worked often take much longer to recover than oiled areas that were not cut.

Table 18: Shoreline/Nearshore Oil Spill Response Strategies

Strategy	How it Works	When Appropriate	Effectiveness	Benefits	Challenges	Drawbacks
		Mechanical removal may be appropriate on heavily-oiled sandy beaches (e.g., swimming beaches) that need to be cleaned relatively quickly.		effectively in this manner.	addressed. Disposal of the oiled grasses, sediments, and debris needs to be addressed. In sandy beach areas, the sand needs to be replaced with clean sand.	
Natural Recovery	The shoreline or marsh area is left alone to allow natural tidal flushing and wave action to break the oil down to enhance biodegradation.	Exposed shoreline areas that are subject to high wave action and/or storms are ideal locations for natural recovery. Marshes and other areas in which aggressive cleaning may cause more harm than the oil itself are also ideal candidates for this approach.	This can be highly effective when the wave energy and natural flushing action is high. It works best for less persistent oils, though it can also break down more persistent oils given enough time.	There is no impact to the environment from the response itself unlike some other more aggressive methods that can cause more harm than good in the long-term. It is always possible to implement a response (e.g., a shoreline cleanup) if the action of storms and tides are not sufficiently effective or at a time that is safer or more logistically feasible (e.g., in summer rather than during a stormy, dark winter).	It is often difficult to convince the public and government officials that nothing should be done for the time being. The ultimate effectiveness of this strategy might not be demonstrated for months to years.	Natural removal may not be completely effective, especially with more persistent (heavier) oils or if the wave or flushing action of the water is not sufficient. The opportunity for an effective on-water response may be lost.

Table 18: Shoreline/Nearshore Oil Spill Response Strategies

Strategy	How it Works	When Appropriate	Effectiveness	Benefits	Challenges	Drawbacks
Manual Shoreline Cleanup	Tar balls, oily patches, and oiled debris are picked up manually with shovels, gloved hands, and rakes.	Lightly- or moderately-oiled sandy or pebbly shorelines lend themselves to manual cleanup operations.	The cleanup process can be very effective.	No heavy equipment is needed and unskilled workers can easily be trained to participate in the operations.	Workers need to be trained to recognize oil and reduce personal exposure. The collected oily debris needs to be disposed.	The process is labor-intensive and time-consuming.
High-Pressure Water Washing	High-pressure hoses are used to spray the oil off of affected substrates. The oil is collected from the water with skimmers, vacuum pumps, and/or sorbents.	Seawalls, piers, boats, and other hard surfaces that do not otherwise support biological species and can withstand high-pressure water can be treated.	This technique is very effective especially on lighter oils.	The structures can be effectively cleaned.	Logistical issues with access and equipment availability may be present.	This approach should not be used on shorelines that support marine life. Damage from high-pressure washing is far greater than the oil itself.
Fertilizer-Enhanced Bioremediation	Natural biodegradation of oil through action of naturally-occurring microbes is enhanced through addition of fertilizers that contain limiting nutrients. Addition of certain mineral nutrients enhances growth of microbes that can then better break down oil. This has been used successfully for land-based spills.	This technique may be appropriate on some rocky shorelines.	Enhanced-bioremediation can be reasonably effective in helping to breakdown oil though it may not give any benefits beyond what might be accomplished naturally.	Natural biodegradation may be enhanced.	Proper application of the fertilizer usually needs to be done manually and is labor-intensive. Workers need to be protected from exposure to the fertilizers.	The application may cause health impacts in the workers applying the fertilizers. Application of additional fertilizers may not be necessary and may cause problems with eutrophication.

Oil spill response operations can be made as effective as possible by:

1. Increasing preparedness through contingency planning at the regional and local levels, and proper maintenance of equipment;
2. Periodic evaluation of geographic response plans and strategies to protect sensitive resources;
3. Regular training and exercising of spill responders; and
4. Reducing the amount of time needed for equipment and personnel to arrive on-scene at a spill through better positioning of equipment caches.

One of the ways in which spill response for the Hudson River could be enhanced is for the US Coast Guard to designate the river as a High-Volume Port Area (HVPA), which would require enhanced spill preparedness and reduced response time. This is already in place in the New York Harbor.

Nevertheless, spill response will always be less effective at reducing oil spill risk than prevention of spills in the first place.

Risk Mitigation Measures Identified in the Hudson River PAWSA[17]

In November 2017, two Ports and Waterways Safety Assessment (PAWSA) workshops were conducted by the US Coast Guard for the Hudson River.[18] The purpose of the Hudson River PAWSA workshops was to bring together waterway uses, stakeholders, and member of the Hudson River community for collaborative discussions regarding:

- The quality of vessels and crews that operate on the waterway;
- The volume of commercial, non-commercial, and recreational small craft vessel traffic using the waterway; and
- The ability of the waterway to handle current and future increases in traffic volume levels.[19]

The PAWSA discussions addressed a very specific set of issues related to vessel traffic and the waterway, some, but not all of which are potentially connected with oil spill risk (Figure 12). Most of the observations of existing trends, identification of existing risk mitigation measures, and recommendations for additional risk mitigation strategies were directly related to vessel safety, including for small craft, personal watercraft (e.g., jet skis), and paddlecraft (canoes, paddleboards, and kayaks). Recommendations related to improving the safety and reducing or preventing accidents with vessels carrying oil were indirectly related to oil spills. There was also one section on petroleum discharges as a consequence of vessel traffic on the river.

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[17] More information on the Hudson River PAWSA, including mitigation measures, is presented in HROSRA Volume 6.

[18] Dagmar Schmidt Etkin of ERC was a participant in the Albany Hudson River PAWSA workshop on 15-16 November 2017.

[19] US Coast Guard 2018.

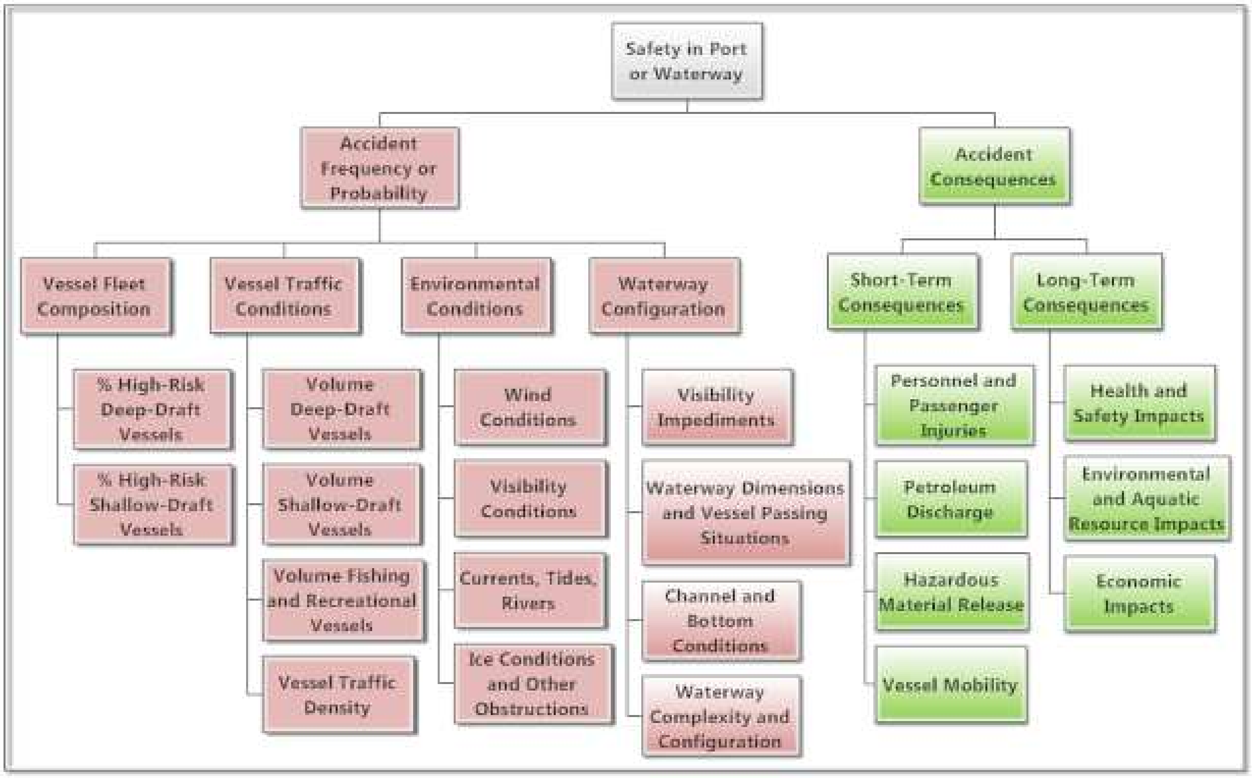

Figure 12: Basic PAWSA Waterway Risk Model

The most significant new recommendations for reducing the risk of oil spills that may be derived from the PAWSA workshops include:[20]

- Establish a Hudson River Harbor Safety Committee.
- Expand AIS coverage.
- Expand the VTS in New York to cover the Hudson River to Albany.
- Establish a Regulated Navigation Area for the entire river.
- Increased information sharing on traffic congestion.
- Make Hudson River bridge crossing cameras accessible to the maritime community.
- Dredge west of Hudson, so there are channels on both sides of the island.
- Increase frequency of Safety Broadcast Notice to Mariners (BNM).
- Install additional ATON.
- Limit vessel sizes so that vessels are not tide restricted due to vessel draft during their transits
- Improve clearing of debris from the river.
- Improve ice breaking capacity.
- Increase types and quantities of emergency response equipment to increase response capability.
- Provide funding for equipment for local emergency responders.

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[20] Note that the observations and recommendations are based solely on the opinions of the PAWSA participants. There was not universal agreement on all of the statements made. The statements have not been fact-checked or vetted.

- Display contact information to report spills on signs at small boat marinas and boat ramps.
- Improve long-range and/or contingency planning and better coordinate activities.
- Conduct an inter-agency emergency response drill for the upper Hudson River.
- Train local responders on contents and use of the Federal Area Contingency Plan (ACP).

The topic of designated anchorages was brought up in part of the meetings. There were varying opinions about definitions related to anchorages (e.g., “long term” and “emergency”), as well as the degree to which anchorages would either mitigate or escalate spill risk in the Hudson River. The recommendations related to anchorages included:

- Implement federal anchorages as proposed in the ANPRM.
- Federally designate historically-used anchorages.
- Establish federally designated anchorages. Define “emergency” in the anchorage regulations. Establish anchorage areas that are for “emergency” only. The definition of emergency should not include parking or staging. In the anchorage regulations, replace the word “emergency” with “for purposes of safe navigation.” The anchorages should be available, clearly marked, and used for short-term emergency purposes. Eliminate “long-term” from the anchorage regulations.[21]
- Specify time limits for anchorages.
- Relax conditions allowing vessels to anchor for something less than a “great emergency” such as adverse weather or a mechanical condition.
- Designate anchorages in appropriate and strategic locations, and define time limits and the definition of emergency or circumstantial anchoring.
- Prohibit oil-laden barges to remain at anchorage in order to avoid and prevent the economic impact of spills.
- Do not categorically exclude anchorages from National Environmental Policy Act (NEPA) requirements.
- Avoid placing anchorages in aquatic habitat areas.

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[21] The designation of anchorages as “long term” in USCG regulations is not meant to determine the amount of time that vessels may anchor but rather to distinguish them from “temporary” anchorages. The existing Hudson River anchorages and those that were proposed in the ANPRM are all designated as “long-term,” which differentiates them from “temporary” anchorages, such as those that are set up during special circumstances, such as boat races, construction activities, fireworks launching, etc. Typical long-term anchorages are limited to 96 hours (four days).

Summary of Major Recommendations

The findings of the HROSRA suggest a number of recommendations for better understanding and mitigating the oil spill risk for the Hudson River.

Spill Probability: Measures to Prevent or Reduce the Incidence of Oil Spills

The best approach to mitigating oil spill risk is to prevent or reduce the frequency of the conditions that cause oil spills. The major recommendations in this regard for the Hudson River include:

1. Establish and actively support the Hudson River Harbor Safety Committee.
2. Consider and follow up on the recommendations arising from the Hudson River PAWSA, including:
    a. Expand AIS coverage;
    b. Established a Regulated Navigation Area for the entire river; and
    c. Improve ice-breaking capacity.
3. Extend the Vessel Traffic Service (VTS) to the Hudson River (north of New York Harbor area).
4. Educate recreational boat operators on ways to prevent spills during fueling and other boating activities.
5. Establish vessel oil transfer regulations or best practices that have been shown to reduce the likelihood of spills during cargo transfers and fueling.
6. Enhance enforcement of state and federal regulations to prevent spills from facilities.
7. Prevent railroad accidents through the use of positive train control (PTC) and support the other federally-regulated prevention measures for trains, including crude-by-rail trains.
8. Evaluate new spill risks with increases or significant changes in traffic, or addition of new pipelines or facilities, so that appropriate accident and spill prevention measures may be developed.

Spill Probability: Measures to Improve Understanding of Anchorage Risk

The results of the PAWSA, as well as comments submitted in response to the ANPRM on anchorages, make clear that there are varying opinions about whether the implementation of newly-designated anchorages in the Hudson River would increase or decrease oil spill risk.[22] Until the proposals for anchorage locations and specifications (length of stay and appropriate use) are clearly defined by USCG in a future ANPRM or NPRM, any attempts to quantify the effects on risk will be speculation.

Despite the uncertainties of any future anchorage proposals, it would be instructive in the evaluation and decision-making process to be able to assess the potential changes to vessel accident and oil spill risk. This assessment may be based on hypothetical locations and conditions for anchorages, such as the proposed sites from the 2016 ANPRM[23] or alternate hypothetical sites.

A custom-designed simulation study could test the hypotheses that anchorages at specific hypothetical locations and with varying degrees of usage and vessel traffic on the river would increase, decrease, or

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[22] There were many concerns about the potential effects of the proposed anchorages. The HROSRA focuses only on the vessel accident and oil spill risk aspects of the anchorages.

[23] For details, refer to HROSRA Volume 3.

otherwise affect the probability and/or consequences (spill volume and effects) of accidents. Such a study would involve computer simulations of vessel movements at various hypothetical anchorage locations and adjacent vessel transit channels and incorporate fault tree analyses of vessel encounter rates, evasive maneuvering, steering failure rates, human error rates, and navigational issues (e.g., fog, visibility, ice).

Risk Mitigation: Measures to Improve Oil Spill Response Effectiveness

When spills due occur, despite prevention measures, the next approach for mitigating the consequences of oil spills is effective spill response. Increasing the effectiveness of spill response can be accomplished by improving the timeliness of the response, increasing the skill of responders, enhancing the availability of equipment, and better understanding the local conditions that may hinder response effectiveness. The major recommendations to improve the effectiveness of oil spill response for the Hudson River include:

1. Extend the New York High-Volume Port Area (HVPA) to Albany, which would decrease the minimum time for response mobilization in the event of a spill.
2. Increase the availability of spill response equipment at caches along the Hudson River.
3. Conduct more frequent spill exercises, including for Salvage and Marine Firefighting.
4. Develop Quick Response Guides as practical aids for spill management teams.
5. Conduct pro-active GRP and GRS boom deployment exercises and training programs with local responders and volunteers, including training on boom angling and changes needed with tidal cycles.
6. Evaluate the potential effectiveness of GRP and GRS-designated booms at protecting sensitive resources, particularly for the most sensitive resources that will not easily be cleaned (i.e., wetlands and mudflats), by using model simulations to test boom angles relative to current vectors (velocity and direction) during different tidal cycles and seasons.
7. Evaluate existing GRPs and GRSs with respect to prioritizing sensitive resources for protection.
8. Educate recreational boaters on spill response reporting requirements and the most effective immediate response measures.
9. Include emergency response training for fires and explosions in spill exercise programs.

Spill Consequences: Measures to Better Understand Ecological Risk

The spill consequence modeling conducted as part of the HROSRA provided a means to quantify the exposure of various ecological habitats to concentrations of oil that could potentially cause effects. In order to more completely evaluate and quantify the potential for oil spills to cause biological impacts on specific types of organisms (birds, fish, invertebrates, mammals), a more comprehensive study could be conducted. Such a study would expand on the existing modeling simulations conducted for the HROSRA with possible additions or modifications to the existing scenarios, if necessary (e.g., different spill volumes, locations, and/or oil types).

By incorporating biological data on known species or types of organisms at different life stages (including species of concern, such as sturgeon), the dose exposure (the duration and concentration of exposure to toxic oil components) and encounter rates (e.g., diving or dabbling waterfowl being coated by oil depends on the fraction of time spent on the water surface) can be used to estimate potential biological impacts in hypothetical scenarios. The methodology would be similar to that employed during Natural Resource Damage Assessments in the aftermath of oil spills.

This type of analysis could provide a means to specifically quantify the risks associated with certain types of spills (e.g., by oil type, location, season) for specific types of organisms (e.g., fish, birds) or specific species (e.g., Atlantic sturgeon) that accounts for their variable distributions in space and time, as well as their differing sensitivities to oil exposure. This risk quantification may be used for contingency planning or risk mitigation purposes, such as enhancing protection for certain areas based on season, oil type, spill location, or location of anchorage sites.

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