Executive Summary: Health Impact Review of HB 1449

Concerning Oil Transportation Safety

Evidence indicates that decreasing risks from oil spills on land and water would likely decrease risks to water quality and public health, particularly for communities of color, low-income communities, and populations with lower levels of educational attainment.

BILL INFORMATION

Sponsors: Representatives Farrell, Carlyle, Fitzgibbon, Ortiz-Self, Peterson, Walkinshaw, Gregerson, Senn, McBride, Robinson, Tarleton, Pollet, Cody, Ormsby, Riccelli, Kagi, Blake, Fey, Hudgins, Lytton, Bergquist, Sells, Takko, Tharinger, Jinkins, Wylie, S. Hunt, Stanford, Reykdal, Sawyer, Appleton, Van De Wege, Clibborn, Ryu, Goodman, Kilduff

Bill by request: Governor Inslee

Companion Bill: SB 5087

Summary of Health Impact Review Request:

The intent of HB 1449 is to prevent oil spills and to improve the ability of the state to respond to spills if they do occur. Representative Farrell requested that we conduct a review of how HB 1449, assuming that the provisions of the bill meet this intent, would impact public health and health disparities in Washington state.

HEALTH IMPACT REVIEW

Summary of Findings:

This health impact review found the following evidence regarding the impacts of decreasing risks from oil spills on land and water:

- Strong evidence that decreasing risks from oil spills on land and water would decrease risks to public health.
  - Strong evidence that exposure to technical disasters such as train derailments and oil spills is associated with adverse mental health impacts.
  - Strong evidence that exposure to crude oil and its byproducts is associated with acute toxic symptoms such as headaches, eye irritation, nausea, and dizziness.
  - Strong evidence that exposure to crude oil and its byproducts is associated with acute respiratory symptoms and a fair amount of evidence that this exposure is associated with chronic respiratory symptoms.
  - A fair amount of evidence that spill response activities are associated with musculoskeletal disorders such as back injuries among response workers and volunteers.
- Very strong evidence that decreasing risks from oil spills on land and water would decrease risks to water quality.
- Very strong evidence that decreasing risks to water quality would decrease risks to public health (e.g. decreased risks of death, cancer, and damage to the liver, lungs, gastrointestinal track, endocrine system, and the central nervous system).
- Strong evidence that the decreased risks to public health would be particularly beneficial to communities of color, low-income communities, and populations with lower levels of educational attainment.

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Health Impact Review of HB 1449

Concerning Oil Transportation Safety

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Contents

Introduction and Methods

A health impact review is an analysis of how a proposed legislative or budgetary change will likely impact health and health disparities in Washington state (RCW 43.20.285). For the purpose of this review 'health disparities' have been defined as the differences in disease, death, and other adverse health conditions that exist between populations (RCW 43.20.270). This document provides summaries of the evidence analyzed by State Board of Health and State Department of Health staff during the health impact review of House Bill 1449 (HB 1449).

Staff analyzed the content of HB 1449 and created a logic model depicting possible pathways leading from the bill to decreased risks to health. We consulted with stakeholders and conducted objective reviews of the literature for each pathway using databases including PubMed and Google Scholar.

The following pages provide a detailed analysis of the bill including the logic model, summaries of evidence, and annotated references. The logic model is presented both in text and through a flowchart (Figure 1). The logic model includes information on the strength of the evidence for each relationship. The strength-of-evidence is defined using the following criteria:

- **Not well researched:** the literature review yielded few if any studies or only yielded studies that were poorly designed or executed or had high risk of bias.
- **A fair amount of evidence:** the literature review yielded several studies supporting the association, but a large body of evidence was not established; or the review yielded a large body of evidence but findings were inconsistent with only a slightly larger percent of the studies supporting the association; or the research did not incorporate the most robust study designs or execution or had a higher than average risk of bias.
- **Strong evidence:** the literature review yielded a large body of evidence on the relationship (a vast majority of which supported the association) but the body of evidence did contain some contradictory findings or studies that did not incorporate the most robust study designs or execution or had a higher than average risk of bias; or there were too few studies to reach the rigor of 'very strong evidence'; or some combination of these.
- **Very strong evidence:** the literature review yielded a very large body of robust evidence supporting the association with few if any contradictory findings. The evidence indicates that the scientific community largely accepts the existence of the association.

Staff made modifications to these criteria at the start of the 2015 legislative session beginning January 12, 2015. Therefore strength-of-evidence rankings may not be comparable between reviews completed before and those completed after this date.

This review was subject to time constraints, which influenced the scope of work for this review. The annotated references are only a representation of the evidence and provide examples of current research. In some cases only a few review articles or meta-analyses are referenced. One article may cite or provide analysis of dozens of other articles. Therefore the number of references included in the bibliography does not necessarily reflect the strength-of-evidence. In addition, some articles provide evidence for more than one research question so they are referenced multiple times.

Analysis of HB 1449 and the Scientific Evidence

Summary of Health Impact Review Request

The intent of HB 1449 is to prevent oil spills and to improve the ability of the state to respond to spills if they do occur. Representative Farrell requested that we conduct a review of how HB 1449, assuming that the provisions of the bill meet this intent, would impact health and health disparities in Washington state.

Health impact of HB 1449

Evidence indicates that decreasing risks from oil spills on land and water would likely decrease risks to water quality and public health, particularly for communities of color, low-income communities, and populations with lower levels of educational attainment.

Pathways to health impacts

The potential pathways leading from the provisions of HB 1449 to impacts on health and health disparities are depicted in Figure 1. There is strong evidence that decreasing risks from oil spills on land and water would decrease risks to public health such as adverse mental health, acute toxic, respiratory, and musculoskeletal symptoms.[1-11] There is very strong evidence that decreasing risks from oil spills would decrease risks to water quality,[8,12-22] and in turn decrease risks to public health.[2,8,14-16] There is strong evidence that the decreasing risks to public health from oil spills would be particularly beneficial to communities of color, low-income communities, and populations with lower levels of educational attainment.[13,23-34]

Magnitude of impact

Although we cannot predict with any certainty the number of oil spills that can be averted by increasing the safety of oil transportation in Washington, the evidence clearly indicates that the health impacts of spills are severe and can include Post-Traumatic Stress Disorder (PTSD), respiratory illness, cancer-risk, and even death.[1-11,14,15] These can include acute as well as long-term social and health impacts. The chronic impacts of a spill may be similar to the population effects of other major events that impact the culture and wellbeing of a community.

An estimated 776,768 Washingtonians (11%) live within a half mile of train tracks used to transport oil. These individuals are at increased risk of being exposed to an oil spill.[34] There is a large number of additional individuals who live, work, or spend time near rail lines, waterways, and shorelines or eat seafood and fish who are also at risk of being impacted by a spill. If groundwater is contaminated by a spill, individuals also risk acute and chronic exposure through tap water. In addition large numbers of response workers also come in contact with spill contaminants.

Moreover, when a spill does occur a high proportion of exposed individuals are often impacted. For example, evidence indicates that rates of PTSD following technological disasters, such as train derailments, oil spills, and factory chemical explosions, ranges from 15% to 75% among exposed individuals.[6] Back pain has been reported among 20% to 37% of response workers and volunteers.[1,3-5,7]

Logic Model

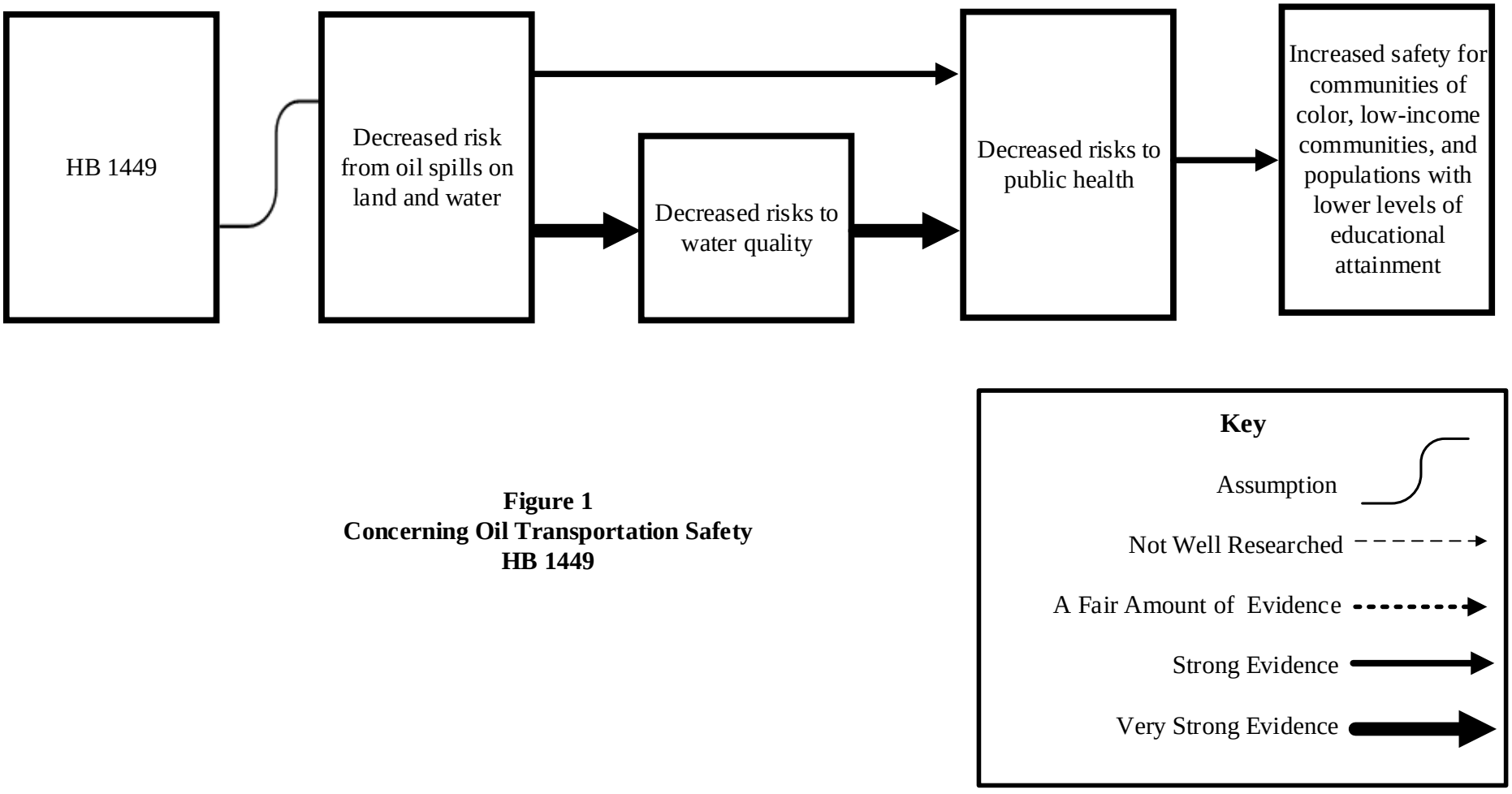

Figure 1
Concerning Oil Transportation Safety
HB 1449

Summaries of Findings

Assumption that HB 1449 will decrease risks from oil spills on land and water
Representative Farrell requested a health impact review of the following: "Assuming that the provisions of the bill would mitigate the risk of oil spills on land and water, what are the likely impacts of HB 1449 on health and health disparities?" She was interested in supplementing previous analyses of potential ways to increase the safety of oil transportation systems in Washington. For example, the Washington State Department of Ecology's *Draft 2014 Marine and Rail Oil Transportation Study*, funded by the 2014 budget, outlines the current state of oil transport in Washington and provides an analysis of potential ways to decrease the risks from oil spills on land and water. Therefore we have assumed that HB 1449 will decrease these risks and have evaluated the scientific evidence to determine how this decreased risk would likely impact health and health disparities. If this assumption is not met, than the health benefits outlined in this review may not be realized.

The intent of this review was to determine how the bill, if passed, would mitigate risks to public health. Due to increasing quantities of oil being transported across and around Washington, we may see an increase in oil spills even in the presence of effective spill prevention and mitigation legislation. The intent of this review, though, was to evaluate if HB 1449 (i.e., improving the safety of oil transport) would provide better protection for public health than the status quo (the absence of this bill).

The scope of this review includes only the health impacts of decreasing risks from oil spills and does not address health risks from normal daily transportation of oil without incident that include air pollution from diesel exhaust, noise pollution, vibrations, and community disruption including the disruption of emergency services. This review also does not explore the health impacts of mitigating risks from transport of toxic substances other than oil.

Will decreasing the risk of oil spills on land and water decrease risks to public health?
Oil spills occurring on land or at sea pose a public health threat and the absence of spills is a public health benefit. We assessed the public health impacts of oil spills to determine the potential reduction in health risks of averted spills. Most studies we reviewed had cross sectional designs and some were longitudinal. The highest quality studies were longitudinal studies and cross sectional studies with large sample sizes and appropriate control groups. Populations studied included community members, response workers, and first responders. Although many of the studies focused on occupational health, Goldstein et al. noted that workers were "integrated into their communities, and the ecologic, economic, and health effects of the spill are closely interconnected."[3] For this reason we did not differentiate between occupational health and community health studies in our review.

Mental health symptoms
There is strong evidence that community members, response workers, and volunteers exposed to technological disasters like train derailments and large scale marine oil spills suffer mental health impacts such as PTSD, depression, and anxiety.[1,3,6] We included studies on marine oil spills and

other technological disasters such as factory chemical explosions and excluded studies on natural disasters or human-made disasters such as mass shootings.

The most commonly evaluated disorder is PTSD followed by depression, general anxiety disorder, and other measures of psychological stress. Rates of PTSD after a technological disaster varied from 15% to 75%.[6] For most technological disasters there was a steep decline in PTSD rates over the first year post-disaster, however in at least one study the rate of PTSD ten years after the disaster was 73%.[1,3]

Acute toxic symptoms

There is strong evidence that exposure to crude oil and its byproducts causes acute toxic symptoms such as headaches, eye irritation, nausea, vomiting, fever, fatigue and dizziness.[1,3-5,7] Na et al. found that these symptoms persisted on average for seven to nine months.[5] Many studies also reported that the likelihood of having symptoms increased with the duration of exposure. Symptoms have been reported in community members, response workers, and volunteers exposed to oil.[1,3,4,7] There are many chemicals in oil products as defined in HB 1449 that are hazardous to human health including benzene, toluene, ethylbenzene, and xylene (BTEX).[2,8] Individuals may be exposed by inhalation, skin contact, or ingestion of oil or its byproducts in the environment.[2,8]

Additional health impacts from exposure to these chemicals referenced in the research but not evaluated as part of this review due to time limitations are carcinogenicity, damage to the liver and bloodstream, and biomarkers of exposure to individual constituents of crude oil.

Respiratory symptoms

There is strong evidence that exposure to crude oil and its byproducts is associated with acute respiratory symptoms and a fair amount of evidence that it is associated with chronic respiratory symptoms such as depressed lung function.[1,3-5,7,9-11] Studies evaluating respiratory symptoms used both survey and biometric measurements to assess symptoms. Studies using longitudinal study designs, biometric measurements, and consistent methodology were considered to be the most appropriate study designs. Seven studies were evaluated that assessed the association between exposure and acute respiratory symptoms only, and an additional six studies assessed chronic and acute respiratory effects on three different cohorts. All thirteen studies found positive associations with acute respiratory symptoms and five of six studies found positive associations with chronic symptoms. The one study finding a negative association with chronic effects (Meo et al.) used 20 exposed workers and 34 controls compared to the other five studies of two different cohorts each with over 400 exposed individuals. All studies controlled for smoking status, and most reported that smokers had a greater prevalence of symptoms after exposure than non-smokers. Two different strategies were used to assess lung function; subjective reports of symptoms on surveys (7 of 13 studies) and objective lung function tests (6 of 13 studies). Studies using either method found significant reductions in lung function associated with exposure to oil spills. [1,3-5,7,9-11]

Musculoskeletal symptoms

There is a fair amount of evidence that response workers and volunteers experience musculoskeletal disorders associated with participation in spill response activities. There were

six studies that evaluated musculoskeletal impacts. Most of these focused on back pain with prevalence of back pain ranging from 20-37%.[1,3-5,7] Suarez et al. reported an injury rate among bird cleaners of 19% that was associated with exposure that included days and hours worked.[1,3] Na et al. had the longest follow-up period of 12 months and found that back pain symptoms were reduced from 37% to 12% with an average duration of symptoms of 1.8 months.[5]

Will decreasing the risk of oil spills on land and water decrease risks to water quality?
There is very strong evidence that decreasing the risk of oil spills on land and water would decrease the risk to water quality in Washington state.[8,12-22] The negative impacts of marine oil spills on water quality are very well documented and can also be easily observed in layers of oil covering water, beaches, and marine animals following a spill.[13] In addition a large body of evidence documents the negative impacts of oil spills on seafood with documented increases in polycyclic aromatic hydrocarbons (PAH) and metals in seafood following marine spills.[14] Evidence also indicates that land-based spills such as those that can result from oil train derailments impact drinking water quality. This can occur through oil running directly into drinking water sources such as lakes or through the leaching of oil and its constituents into groundwater.[8,12,16-19,21,22]

Will decreasing risk to water quality decrease risks to public health?
There is very strong evidence that decreasing risks from oil spills on water quality would decrease risks to public health.[2,8,14-16] A number of the oil constituents that are commonly found in marine water, shellfish, and groundwater following oil spills on land and water have well-documented negative health impacts. BTEX and a number of PAHs have been classified as toxic substances and in some cases carcinogens by the Agency for Toxic Substances and Disease Registry (ATSDR) and the Environmental Protection Agency (EPA). In order to determine the human health risk of a substance the ATSDR conducts a peer-reviewed analysis of the available scientific evidence and summarizes this evidence in toxicological profiles. These profiles usually review hundreds of scientific publications which include animal studies and human studies when available. The toxicological profiles for benzene, toluene, ethylbenzene, and xylenes each show severe negative health effects associated with exposure and benzene has been classified as a known human carcinogen and ethylbenzene has been classified as a possible human carcinogen.[2,8] For example, ingestion, inhalation, or other contact with benzene is linked to a number of negative health impacts such as cancer-risk and damage to the liver, lungs, gastrointestinal track, endocrine system, and the central nervous system.[8] Several PAHs found in oil have also been classified as known animal carcinogens and probable human carcinogens. Humans can be exposed to these toxics through oil contaminated water through ingestion, seafood consumption, skin contact, or inhalation of contaminated steam while bathing or cooking.[2,8]

Will decreasing risks to public health associated with oil spills effect all populations equally?
There is strong evidence that that decreasing risks to public health associated with oil spills will have greater positive impacts on some populations.[1,13,23-33] Evidence indicates that individuals

with lower incomes or lower educational attainment are more likely than their counterparts to be exposed to oil and its constituents following a spill through participation on cleanup crews or other mechanisms.[27,28] In addition, even within the group of individuals who are exposed to these contaminants, individuals with lower incomes or lower educational attainment or those who are unemployed or uninsured are more likely to experience negative health outcomes as a result.[13,24-28]

After disasters individuals with pre-existing mental health conditions including alcoholism, were the most likely to experience symptoms. Immigrants, non-native English speakers, and individuals with a low degree of acculturation or a lack of social support are also at increased risk for negative mental health symptoms following a disaster. This was true of Vietnamese immigrants after Hurricane Katrina and the Deepwater Horizon oil spill and of American Indian/Alaska Natives (AI/AN) after the Exxon Valdez spill.[1,3,27,28] AI/AN members of the communities impacted by the Exxon Valdez oil spill were also more likely than their white neighbors to participate in oil cleanup activities—thereby increasing exposure.[27,28] Women, children, and young men appear to be particularly susceptible to mental health impacts of technological disasters for some measures as well.[1,3,10]

The populations who are disproportionately impacted by health problems following oil spills and other disasters are already facing disparities in Washington for a number of the health problems that can be caused or exacerbated by exposure to oil spills such as asthma and mental health issues.[23,29-33] The evidence also indicates that individuals who smoke cigarettes are more likely to be impacted by respiratory illness following an oil spill.[1,3,4,9] In Washington smoking rates are highest among communities with lower incomes and lower educational attainment as well as among many communities of color.[23]

In Washington the populations living within a half mile of train tracks used to transport crude oil have lower incomes, lower educational attainment, and consist of a higher proportion of people of color than Washington state as a whole. These individuals are at higher risk of acute exposure to a train derailment and oil spill.[34] Evidence also indicates that communities that eat higher quantities of seafood and fish, such as AI/AN and Asian and Pacific Islander populations,[35] or who depend more heavily on subsistence actives such as hunting and fishing are more likely to be negatively impacted by oil spills.[14,27,28]

For this component of the review, while we included some information on disparate impacts in disasters in general, we evaluated the strength-of-evidence based on the publications that specifically addressed disproportionate impacts following oil spills. The strength of evidence would likely have been stronger if we expanded the scope of research to include evidence relating to disasters other than oil spills.

Annotated References

1. Aguilera F, Méndez J, Pásaro E, Laffon B. Review on the effects of exposure to spilled oils on human health. *Journal of Applied Toxicology.* 2010;30(4):291-301.
Aguilera et al. reviewed twenty-eight studies of human health impacts from seven marine oil spills ranging from >6000 to 85,000 barrels and from the Exxon Valdez, Braer, Sea Empress, Nakhodka, Erika, Prestige, and Tasman Spirit tankers. The objective was to gather these studies to better understand health impacts from this complex exposure environment. They note that most studies of oil spills are cross sectional and do not always have control groups. The studies evaluated considered acute toxic effects including respiratory symptoms, skin, eye, and psychological effects. They were only able to evaluate genotoxicity and endocrine disruption in the aftermath of the Prestige spill. The researchers call for increased biomonitoring of people exposed to future oil spills to more accurately assess the short, medium, and long term effects of these types of disasters. They found that oil-contaminated food can cause genotoxic damage, and that muscles in particular carried oil in a form that was bioavailable to humans. Of the 21 studies evaluated for acute toxic symptoms 17 found positive associations, two were conflicting, and two were negative. Of the seven studies evaluated for genotoxic and endocrine toxicity six found a positive association and one did not.

2. Centers for Disease Control and Prevention website. Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/. Accessed February 11, 2015.
A number of components of oil that have been found in marine systems and groundwater following oil spills have been classified as toxic substances by the Agency for Toxic Substances and Disease Registry (ATSDR) and the Environmental Protection Agency (EPA). In order to determine the human health risk of a substance the ATSDR conducts a peer-reviewed analysis of the available scientific evidence and summarizes this evidence in toxicological profiles. These profiles usually review hundreds of scientific publications which include animal studies and human studies when available. This evidence is then used to determine the highest level of exposure through inhalation and ingestion (acute and chronic) than humans can be exposed to without experiencing adverse health effects. The toxiclogical profiles for benzene, toluene, ethylbenzene, and xylenes (BTEX) each show severe negative health effects associated with these toxics and benzene has been classified as a known human carcinogen and ethylbenzene has been classified as a possible human carcinogen. Several polycyclic aro-matic hydrocarbons (PAH) found in oil (e.g. benz[a]anthracene and benzo[a]pyrene) have also been classified as known animal carcinogens and probable human carcinogens.

3. Goldstein BD, Osofsky HJ, Lichtveld MY. The Gulf oil spill. *New England Journal of Medicine.* 2011;364(14):1334-1348.
Goldstein et al. reviewed fourteen studies on health impacts of exposure to tanker oil from the tankers Sea Empress, Prestige, Tasman Spirit, Makhodka, MV Braer, and Erika. They found four categories of potential health consequences: (1) worker safety (2) toxicologic effects in workers, visitors, and community members (3) mental health effects of social and economic disruption and (4) ecosystem effects. For mental health effects Palinkas et al. 1993 reported the odds ratio of generalized anxiety disorder to be 3.73 (95% CI 1.99-6.97), while other studies simply noted that scores on anxiety and depression scales to be statistically significant. Carrasco et al. reported an odds ratio for the proportion of residents having poor scores on the SF-36 mental health

questionnaire of 1.28 (95% CI 1.02-1.58) while other studies simply noted differences in scores on various mental health questionnaires between exposed and unexposed individuals. For acute toxic symptoms there was variability in the symptoms assessed and how and when they were assessed, making comparisons across studies difficult. Odds ratios for headaches in cases versus controls ranged from 2.62 (95% CI 1.23-5.60) to 5.75 (95% CI 2.47-14.08); odds for eye irritation ranged from 2.89 (95% CI 1.21-6.90) to 6.72 (95% CI 2.53-19.45); odds for central nervous system toxicity (nausea, dizziness) was 2.25 (95% CI 1.17-4.23) to 2.50 (95% CI 1.09-5.74). Other studies reported prevalence of symptoms without reporting odds ratios, as a composite score, or as presence or absence of at least one toxic symptom. Despite the various assessment methods all studies reviewed found a positive association between exposure to an oil spill and acute toxic symptoms and many also reported that the likelihood of having symptoms increased with the duration of exposure. For respiratory effects three studies used spirometry to measure lung function on three different cohorts. The two larger cohorts showed reduced lung function and the smaller cohort did not. The remaining studies assessed lung function through surveys and reported odds ratios of 2.13 (95% CI 1.02-5.79) and 3.47 (95 % CI 1.89-7.40) and an incidence of respiratory symptoms of 6% for community members versus 1.2% and 0% for control groups. For musculoskeletal effects Suarez et al. reported an injury rate among bird cleaners of 19% that was associated with exposure that included days and hours worked and two studies that found workers complaining of low back pain. Apart from specific health impacts Goldstein et al. noted that "workers who responded to the Gulf oil spill were integrated into their communities and the ecologic, economic, and health effects of the spill are closely interconnected." They also noted that immigrant workers and vulnerable populations were at greater risk of mental and physical health impacts.

4. Gwack J, Lee JH, Kang YA, Chang KJ, Lee MS, Hong JY. Acute health effects among military personnel participating in the cleanup of the Hebei Spirit oil spill, 2007, in taean county, korea. *Osong public health and research perspectives.* 2012;3(4):206-212.
Gwack et al. evaluated the acute health effects on military personnel responding to the Hebei Spirit spill in Korea. They surveyed 2,624 military personnel for self-reported neurologic, respiratory, dermatologic, ophthalmic, and general symptoms. They also recorded gender, age, rank, education, smoking status, and personal protective equipment use. They found that duration of work days was positively associated with almost all symptoms assessed. They found that personnel under 25 were more succeptible to flushing and itchiness. They found back pain in 7.1% of personnel who worked on the spill for less than a week and 20.5% in persons working for more than three weeks. Similar dose response trends were found for respiratory symptoms including cough, sputum, runny nose, dry mouth, and sore throat. Neurological symptoms such as dizziness, headache, and nausea had high prevalence even in personnel who worked less than a week on the spill, but also increased over time. For headaches 26.1% had symptoms in the first week rising to 41.0% after three weeks.

5. Na JU, Sim MS, Jo IJ, Song HG. The duration of acute health problems in people involved with the cleanup operation of the Hebei Spirit oil spill. *Marine pollution bulletin.* Jun 2012;64(6):1246-1251.
Na et al. performed a prospective cohort study with people responding to the Hebei Spirit oil spill. The study was performed by a hospital group providing medical services to six sites where cleanup activities were being performed. They originally interviewed 846 people and one year

later they were able to follow up with 442. Of their survey respondents 86.1% were local residents and nearly 80% were over 50 years old. Among participants 39.1% had respiratory symptoms immediately after the spill and 11.6% of those affected were symptomatic a year later. For neurological symptoms the statistics were 34.8% and 38.3%, for back pain 36.9% and 7.4%, for headache 36.7% and 54.9%. Back pain and respiratory symptoms resolved relatively quickly after exposure with mean durations of 1.8 and 2.1 months respectively. Headache and eye irritation lasted longer with mean durations of 8.4 and 9.7 months respectively. Women were more susceptible to chronic headaches and people working more than 8 hours had greater eye symptoms. Age was not a significant predictor of symptoms.

6. Neria Y, Nandi A, Galea S. Post-Traumatic Stress Disorder following disasters: A systematic review. *Psychological medicine.* Apr 2008;38(4):467-480.

Neira et al performed a systematic review of studies assessing Post-Traumatic Stress Disorder (PTSD) following disaster. For the purposes of this health impact review we focused on the author's review of technological disasters and excluded natural disasters, human-made, and multiple disaster aggregate studies. The authors reviewed 65 studies from 40 technological disasters that took place between 1966 and 2002. They found that the prevalence of PTSD following a technological disaster was 15-75% in the first months following the disaster and in some cases prevalence was as high as 73% ten years after the event. Rates of PTSD following a technological disaster dropped off rapidly in many studies in the year following the event.

7. Sim MS, Jo IJ, Song HG. Acute health problems related to the operation mounted to clean the Hebei Spirit oil spill in taean, korea. *Marine pollution bulletin.* 2010;60(1):51-57.

Sim et al. performed a cohort study on people responding to the Hebei Spirit oil spill. The study was performed by a hospital group providing medical services to six sites where cleanup activities were being performed. They surveyed 846 people at eight cleanup sites where they were providing medical support during the cleanup. The survey included questions on symptoms related to cleanup activities. The incidences of symptoms were: back pain 36.4%, skin lesion 5.0%, headache 29.3%, eye irritation 17.7%, neurological symptoms 27.9%, and respiratory symptoms 41%. The authors performed logistic regression analysis to identify risk factors for the presence of exposure. They found that women and people working more than one or two days at the sites were at greater risk of back pain; that not wearing a protective suit was associated with skin lesions, eye symptoms, and neurological symptoms; that hours per day and lack of protective mask were associated with headaches; and that hours per day was associated with respiratory symptoms.

8. Wilbur S, Wohlers D, Paikoff S, Keith LS, Faroon O. ATSDR evaluation of health effects of benzene and relevance to public health. *Toxicology and industrial health.* 2008;24(5-6).

Wilbure et al. provide a review of the literature on the health effects of benzene. The authors indicate that low levels of benzene have been found in tap water, but that these levels do not generally constitute a risk to human health. However they cite four studies which have found that release from underground gasoline storage tanks, landfills, and hazardous waste sites have resulted in significant benzene well water contamination. They note that tap water contamination can lead to benzene exposure through ingestion as well as skin contact and inhalation during

bathing or cooking. The National Exposure Registry was tracking 1,143 people with benzene in their drinking water in 1995 and had not identified any health conditions caused by this exposure. Reports have shown cases of death and other serious health effects from benzene ingestion, but the amount ingested was not documented. Animal studies have found that mice exposed to benzene in drinking water for one to six months experienced negative impacts on their red and white blood cells. Oral administration of benzene in animal studies has also been associated with a number of other negative health impacts such as harms to the liver, lungs, gastrointestinal track, the endocrine system, and the central nervous system. Central nervous system toxicity has also been observed in humans after a one-time ingestion of 125 mg/kg of benzene. Benzene used in chemotherapy treatments also was associated with hemorrhages with advanced anemia, though it is unclear if this was a result of the treatment or the leukemia. Benzene has also been shown in animal studies to be a multiple site carcinogen when ingested. This evidence is used to calculate the minimum risk levels (MRL) for humans which are estimates of the exposure levels posing minimal risk to human health. The MRL of chronic-duration oral exposure (365 days for more) to benzene is 0.0005mg/kg/day. Benzene is classified as a known human carcinogen.

9. Zock JP, Rodriguez-Trigo G, Rodriguez-Rodriguez E, et al. Persistent respiratory symptoms in clean-up workers 5 years after the Prestige oil spill. *Occupational and environmental medicine.* Jul 2012;69(7):508-513.

Zock et al. performed a longitudinal study on fisherman who responded to the Prestige oil spill and a control group that was not exposed. Of 501 fisherman 466 participated in the study and of 177 controls 146 participated in the study. The authors found that in both exposed and control groups there was a slight decrease in respiratory symptoms five years after the Prestige oil spill. Symptoms remained higher among the exposed individuals with a relative risk of 1.4 (95% CI 1.1-1.9). This association increased with increased exposure to the spill with relative risks of 1.7 (95% CI 0.9-3.1) for moderately exposed and 3.3 (95% CI 1.8-6.2) for highly exposed participants. A weakness of this study was that it did not use the same spirometry measures from the original 2007 publication.

10. Zock JP, Rodriguez-Trigo G, Rodriguez-Rodriguez E, et al. Evaluation of the persistence of functional and biological respiratory health effects in clean-up workers 6 years after the Prestige oil spill. *Environ Int.* Jan 2014;62:72-77.

Zock et al. performed a longitudinal study on fisherman who responded to the Prestige oil spill and a control group that was not exposed. Of the 501 fisherman who participated in the original study 158 non-smokers and 57 non-smoking unexposed fisherman were included in the study. The methods and individuals performing the spirometry testing were the same as in the original study. The researchers found that functional and biological respiratory health in cleanup workers did not improve over the four year period and there was no evidence that degree of exposure was associated with long term effects. The control group experienced significant declines in respiratory health, greater than those of the exposed group. The authors hypothesized that this could partially be explained by the exposed group recovering relative to controls but the differences made comparisons between the two groups difficult to make.

11. Rodriguez-Trigo G, Zock JP, Bouso L, et al. Health changes in fishermen 2 years after clean-up of the Prestige oil spill. *Ann. Intern. Med. Annals of Internal Medicine.* 2010;153(8):489-498.

Rodriguez-Trigo performed a cross-sectional study on fisherman exposed to the Prestige oil spill. The study included 501 exposed fisherman and 177 unexposed fishermen. The authors used objective spirometry tests and markers of oxidative stress and airway inflammation and other biological markers of exposure. They found that exposed individuals were eight times more likely to have lower respiratory tract symptoms (RR 8.0; 95% CI 1.1-14.8), however they did not find that lung function tests were significantly different between exposed and unexposed fishermen. Exposed fishermen also had elevated markers of airway injury and chromosomal damage.

12. Doherty VF, Otitoloju AA. Monitoring of soil and groundwater contamination following a pipeline explosion and petroleum product spillage in Ijegun, Lagos Nigeria. *Environ Monit Assess.* May 2013;185(5):4159-4170.

In May of 2008 a petroleum pipeline exploded in Lagos in Nigeria. Doherty and Otitoloju indicate that the spill resulted in BTEX contamination of groundwater and wells. The explosion also led to a fire which resulted in loss of lives and property. The authors collected 20 groundwater and 19 soil samples around the explosion site and at a control site over a two year period (2009-2010) using random sampling. The authors found the total hydrocarbon content (THC) levels at the contaminated site sampling stations were far above the World Health Organization (WHO) admissible value of 0.1mg/l for drinking water and significantly higher than the levels at the control station. All of the wells sampled also had significant levels of hydrocarbons in the groundwater 500 meters beyond the explosion site—indicating the extent of the spilled petroleum. Nearly two years after the event the groundwater was still contaminated with petroleum hydrocarbon above the WHO limit for drinking water. The highest concentration measured in the two years was 780.54 mg/l. The groundwater samples collected within 150 meters of the explosion also had very high levels of BTEX. These concentrations were higher in the groundwater than in the soil samples indicating that BTEX easily enters the groundwater system.

13. Gill D, Picou J, Ritchie L. The exxon valdez and bp oil spills: A comparison of initial social and psychological impacts. *American Behavioral Scientist.* 2012;56(1):3-23.

Gill et al. provide a background on the Deep Horizon and Exxon Valdez oil spills. They cite evidence indicating that the smaller of the two spills, the Exxon Valdez spill from an oil tanker, resulted in an oil slick contaminating 44,000 square kilometers, 1,900 kilometers of coastline, and fatally damaged thousands of seabirds, otters, whales, and fish. The authors indicate that research documented long-term impacts to the ecosystem including persistence of volatile levels of oil in intertidal regions, on beaches, and in streams. The authors conducted a telephone survey of residents in Mobile County Alabama in September of 2010 following the Deep Horizon spill (n=412 with a response rate of 46%). They found that non-white respondents, those with lower income, and those with lower educational attainment reported significantly higher stress levels than their counterparts. They also found that respondents who reported exposure to the spill (through cleanup activities, ownership of damaged property, or other contact) and those that had a commercial connection to the coastal areas reported higher levels of stress than their counterparts.

14. Gohlke JM, Doke D, Tipre M, Leader M, Fitzgerald T. A review of seafood safety after the Deepwater Horizon blowout. *Environ Health Perspect.* Aug 2011;119(8):1062-1069.

Gohlke et al. conducted a review of the literature on seafood contamination following marine oil spills. They found that seafood contamination is impacted by numerous factors including the type of oil spilled, temperatures, and potential for bioaccumulation at different levels of the food chain. The authors cite at least seven studies which found that following oil spills polycyclic aromatic hydrocarbons (PAH) accumulated in fish and shellfish at unsafe levels and that these levels remained elevated from several weeks to several years following the spills. These studies have shown higher PAH concentration among study samples within the spill zones compared to reference samples outside of spill zones. The authors also found evidence (at least seven studies) that indicate that metal constituents of crude oil have been found to accumulate in sediments and marine organisms following a spill. Gohlke et al. indicate that National Oceanic and Atmospheric Administration and the Food and Drug Administration assess the risk to human health when determining when to reopen fishing in areas that have been closed following an oil spill. These agencies determine the level of concern (LOC) which is the concentration of specific chemicals in seafood samples that would be considered unsafe for human consumption. LOCs are determined using a cancer risk calculation for carcinogens such as some PAHs and are based on toxic potential derived from previous research and other factors such as consumption estimates.

15. Gong Y, Zhao X, Cai Z, O'Reilly SE, Hao X, Zhao D. A review of oil, dispersed oil and sediment interactions in the aquatic environment: Influence on the fate, transport and remediation of oil spills. *Marine pollution bulletin.* Feb 15 2014;79(1-2):16-33.

Gong et al. provide a review of the literature on oil dispersion and sediment interaction in the water. The authors highlight multiple instances of spills that resulted in the discharge of large quantities of oil into marine waters. For example the Exxon Valdez oil spill in 1989 discharged 11 million gallons of crude oil following a ruptured hull of an oil tanker. The M/V Blue Master spill south of Texas in 1999 discharged 100 barrels of Intermediate Fuel Oil 180 following a collision with a fishing vessel. The authors cite evidence that the water soluble fraction of oil and their derivative products are one of the major concerns for environmental safety and public health and they can persist for a long time in the environment. The authors indicate that polycyclic aromatic hydyrocarbons (PAH)—one water soluble component of oil and oil derivatives—are "toxic, mutagenic, carcinogenic and persistent." They also cite two publications indicating that several PAHs (e.g. naphthalene, phenanthrene, and pyrene) were found in the water column during and after the 2010 Deepwater Horizon oil spill.

16. Lopez E, Schuhmacher M, Domingo JL. Human health risks of petroleum-contaminated groundwater. *Environ Sci Pollut Res Int.* May 2008;15(3):278-288.

Lopez et al. cite evidence that benzene, toluene, ethylbenzene, and xylene (BTEX) are frequently found in petroleum products. They also cite one animal laboratory study that found that BTEX gastrointestinal and respiratory exposure has been linked to liver cancer and leukemia in mice and rats. They indicate that drinking water contamination can lead to exposure to toxics through ingestion, indoor air quality, and absorption of pollutants through the skin. The authors estimated the indoor exposure from contaminated tap water for a location in Spain using modeling. This

was the site of an industrial oil spill (12% BTEX) resulting from an accident in a storage tank. Lopez et al. used a multiphase and multicompartment modeling program to predict if the spilled oil would reach a nearby drinking well and lead to health risks for the individuals using the well water. The well was 70 meters from the spill and 6 meters deep. These models were based on a number of assumptions, previously conducted models, and other evidence. The authors conclude that the BTEX that would reach the wells was not sufficient to pose human health risk. This modeling did not include risk from outdoor exposure and did not use actual water contamination levels to calculate health risk.

17. Schirmer M, Butler BJ. Transport behaviour and natural attenuation of organic contaminants at spill sites. *Toxicology.* Dec 15 2004;205(3):173-179.

Schirmer and Butler summarize findings from two field experiments at Canadian Forces Base Borden in Ontario, Canada. These studies were conducted in order to evaluate the movement of different contaminants though aquifers under natural conditions. The authors indicate that the mixture of the contaminant and other conditions impact this movement, but that plumes of 100% gasoline, coal tar creosote organics, and other petroleum mixtures when added to the groundwater can move quickly and extensively through the groundwater. For example one experiment found that a naphthalene plume emanating from a complex creosote source continued to grow for over three years following the time of contamination.

18. Spalding RF, Toso MA, Exner ME, et al. Long-term groundwater monitoring results at large, sudden denatured ethanol releases. *GWMR Groundwater Monitoring & Remediation.* 2011;31(3):69-81.

Spalding et al. cite two studies (one controlled experiment and one field investigation) that found that ethanol is transported horizontally with groundwater from the point of contamination at the rate of groundwater flow. This study aimed to measure the long-term impacts of large (more than 20,000 gallon) ethanol releases on groundwater and soil quality. The authors indicate that their interest in the effect of ethanol on groundwater is largely due to the increase in use of ethanol blended gasoline. The authors monitored ethanol and BTEX indicators in groundwater at three train derailment sites for six years. At the spill site in Balaton, Minnesota ethanol concentrations up to 2.9% were measured in shallow groundwater two months after the spill. In 2005 two tank cars derailed in South Hutchinson, Kansas and released 28,488 gallons of E95 natural gasoline. The spill reached a nearby lake killing approximately 150 catfish and carp. Strong fumes necessitated the evacuation of nearby homes, a middle school, and mental health facility. Two months after the spill samples detected low ethanol concentrations indicating that the leading edge of the contamination had reached the water table within two months of release. The third spill site was in Cambria, Minnesota where a train derailment released 24,977 gallons of E95. The authors indicate that measures of ethanol concentrations at the Balaton and Cambria sites suggest rapid vertical transport of ethanol to the groundwater. They detected high groundwater ethanol at these sites. The concentrations decreased to less than 100mg/L in about 14 months—however at the Cambria and South Hutchinson site they found ethanol in low percent concentrations four and five years after the spills. They note that the ethanol had been confined to the specific wells in the source zone as of the time of the study. For all study sites the ethanol denaturant was gasoline-based and contained BTEX. Benzene is considered a carcinogen, and was measured at levels far above the maximum contamination level at all three spill sites. They did not find evidence for deep or extensive groundwater contamination downgradient of the

spills. Many of the source-zone wells also contained significant concentrations of acetate (produced during fermentation of ethanol) and methane (produced during anaerobic degradation of acetate). Methane concentrations were high enough at all three sites to pose a risk of ignition. The measurements also indicate that methane concentrations were not limited to the spill zone but were also found in wells not directly impacted by ethanol. This study was funded by the American Petroleum Institute, the Nebraska Ethanol Board, and ICM Inc. (a company which produces equipment to make ethanol production more efficient), which could introduce a conflict of interest.

19. Szabo J, Minamyer S. Decontamination of chemical agents from drinking water infrastructure: A literature review and summary. *Environ Int.* Nov 2014;72:119-123.
Szabo and Minamyer conducted a review of the literature on the persistence of chemical contamination in drinking water infrastructure such as pipes. They focused on a number of contaminants including petroleum products. They cite one study which found that diesel fuel was persistent in the cement-mortar pipes and that flushing removed only 36-38% of the contamination. They also cite evidence from a case-study of an accidental diesel fuel contamination of drinking water that indicated that flushing and continue use of water for household sanitation brought the amount of fuel below the "taste and odor threshold" over two days.

20. Tao Z, Bullard S, Arias C. High numbers of *Vibrio vulnificus* in tar balls collected from oiled areas of the north-central Gulf of Mexico following the 2010 BP Deepwater Horizon oil spill. *EcoHealth.* Dec 2011;8(4):507-511.
Tao et al. cite one study which found that following the 2010 BP Deepwater Horizon oil spill there was a marked increase in heterotrophic microbes in the water column. They also cite evidence that the human pathogen Vibrio vulnificus is the leading cause of seafood-borne fatalities in the United States. Negative health effects can be observed following ingestion and exposure to seawater, fish, shellfish, or fishing gear contaminated with the bacterium which can also cause severe wound infections with a fatality rate of 20-30%. Following the spill, tar balls washed up on the coast of Alabama and Mississippi. Exposure to tar balls was associated with allergic reactions to hydrocarbons. The authors collected sand, tar balls, and seawater in July through October 2010. The authors found significantly higher counts of total aerobic bacteria and V. vulnificus in tar ball samples than in seawater and sand. The tar ball counts of V. vulnificus were ten times higher than that in the sand and 100 times higher than in the seawater. The counts that the authors found for seawater and sand were comparable to those reported in the Gulf of Mexico in the 1990s. Tao et al. then attempted to culture several strains of V. Vulnificus on tar ball-enriched seawater agar plates but found no visible growth after seven days. The authors express that this could indicate that this bacterium may not actively consume organic compounds in the tar balls but may benefit from byproducts of microbes that do degrade oil.

21. Thornton SF, Tobin K, Smith JWN. Comparison of constant and transient-source zones on simulated contaminant plume evolution in groundwater: Implications for hydrogeological risk assessment. *GWMR Groundwater Monitoring & Remediation.* 2013;33(3):78-91.
Thornton et al. cite four studies which indicate that petroleum releases have historically been a significant source of groundwater contamination. The authors developed two models to predict

the changing light nonaqueous phase liquid composition and aqueous solubility of six common constituents of unleaded petroleum. They tested this model against groundwater measurements from a contaminated site on the Cretaceous Chalk aquifer in southern England. They cite previous research which found that the groundwater beneath the spill cite was impacted by a plume of petroleum, primarily BTEX, methyl tertiary-butyl ether, and tert-Amyl methyl ether. The authors also found elevated rates of these constituents in groundwater samples taken over a six year period.

22. Wise WR, Chang C-C, Klopp RA, Bedient PB. Impact of recharge through residual oil upon sampling of underlying ground water. *GWMR Groundwater Monitoring & Remediation.* 1991;11(2):93-100.Wise et al. investigated the effect on ground water quality following percolation of water (to simulate rainfall) over an aviation gasoline spill site in Traverse City, Michigan over 20 years after the spill. The authors sampled the soil and groundwater and found that benzene, toluene, ethylbenzene, and ortho-zylene reached the groundwater elevating the concentrations of these oil constituents in the water.

23. Boysun M, Wasserman C. *Health of Washington State Report: Tobacco.* Washington State Department of Health; 2012.
Washington state Behavioral Risk Factor Survaillance System (BRFSS) data from 2008-2010 indicate that adults with lower incomes or lower educational attainment are significantly more likely to report smoking cigarettes than their counterparts. AI/AN and black populations also have significantly higher smoking rates than white, Hispanic, and Asian populations.

24. Cope MR, Slack T, Blanchard TC, Lee MR. Does time heal all wounds? Community attachment, natural resource employment, and health impacts in the wake of the BP Deepwater Horizon disaster. *Social Science Research.* 2013;42(3):872-881.
Cope et al. cite five studies supporting that social vulnerability to disasters is often associated with gender, education, race/ethnicity, religion, occupation, age, and extend of social networks. They also cite evidence from four studies on the Exxon Valdez Oil Spill which indicate that communities and individuals which maintain a high level of economic, social, and cultural attachment to threated resources can also be particularly vulnerable following a disaster. They analyzed data from the Louisiana Community Spill Survey following the Deepwater Horizon oil spill. This is a randomly sampled telephone survey. The authors used baseline data from June 2010 (when the oil was still flowing) and follow-up data from October 2010 and April 2011. The response rates for each of these waves was between 20 and 25%. The data indicate that fishing households, individuals without employment, those with lower educational attainment, Cajuns, and women exhibited significantly higher levels of negative mental health impacts compared to their counterparts. They also found that fishing households, individuals without employment, those with less education, women, and older adults reported significantly greater negative physical health impacts than their counterparts.

25. Drescher CF, Schulenberg SE, Smith CV. The Deepwater Horizon oil spill and the Mississippi Gulf Coast: Mental health in the context of a technological disaster. *The American journal of orthopsychiatry.* 2014;84(2):142-151.
Drescher et al. cite four studies (unique from those cited by Cope et al.) supporting that individuals with lower socioeconomic position, people of color, and women are more likely to

experience greater post-disaster distress. The authors analyzed questionnaire data collected between March 2011 and June 2012 from clients in various mental health agencies in the Gulf Coast of Mississippi (n=1,119) following the Deepwater Horizon oil spill. They did not report the response rate. The authors found oil-spill related declines in finances, social relationships, physical health , and self-reported mental health symptoms. The data indicate that low-income individuals experienced significantly higher rates of depression, anxiety, stress, and posttraumatic stress symptoms than their higher-income peers. Individuals living below the poverty line who reported being impacted by the oil spill (financially, socially, or physically) experienced a significant negative impact on mental health outcomes for all of these measures while those living above the poverty line only experienced a significant negative impact for one measure (posttraumatic stress symptoms). The authors note several limitations of this study including a post-only design, a common limitation for disaster studies.

26. Fan AZ, Prescott MR, Zhao G, Gotway CA, Galea S. Individual and community-level determinants of mental and physical health after the Deepwater Horizon oil spill: Findings from the Gulf States Population Survey. ***J Behav Health Serv Res The Journal of Behavioral Health Services & Research : Official Publication of the National Council for Community Behavioral Healthcare.*** **2015;42(1):23-41.**

Fan et al. analyzed data from the Gulf States Population Survey, a 12-month random-digit dial adult telephone survey (response rate 44.2%). There were 27,947 participants who resided in one of 25 coastal counties/parishes within a 32-mile region where fishing was closed due to the Deepwater Horizon oil spill and 10,414 participants living outside of these zones but within the four Gulf States (Alabama, Florida, Louisiana, and Mississippi). The data indicate that women reported significantly higher prevalence of frequent mental distress and current depression than men. Unemployed populations also reported significantly higher rates of frequent physical and mental distress and current depression than employed or retired populations as did those who reported loss of a job or decreased income as a result of the oil spill. Individuals with chronic health conditions (e.g. asthma, diabetes, heart disease, etc.) reported significantly higher rates of frequent physical and mental distress and current depression than those without chronic conditions reporting nearly four times higher prevalence (Prevalence Ratio 3.93 95% CI 2.81-5.50) of frequent physical distress than those without chronic conditions. Low income individuals also had significantly higher prevalence of all three of the negative health outcomes than their higher income counterparts. Individuals without a current health plan also had significantly higher prevalence of frequent physical and mental distress than their insured peers. Hispanic populations also had higher prevalence of all three of these negative outcomes than white populations, but this did not reach statistical significance. The race/ethnicity questions on the survey only included non-Hispanic white, non-Hispanic black, Hispanic, and other. Direct contact with the oil spill was also significantly associated with negative health outcomes. The authors highlight several limitations of this study including the potential for self-report bias and an inability to determine the extent of the relevance of the survey responses to the oil spill.

27. Palinkas LA, Petterson JS, Russell JC, Downs MA. Ethnic differences in symptoms of Post-Traumatic Stress after the Exxon Valdez oil spill. ***Prehospital Disaster Med. Prehospital and Disaster Medicine.*** **2004;19(1):102-112.**

Palinkas et al. collected interview data in 1990 from 714 randomly sampled households in 11 Alaskan communities directly exposed to the Exxon Valdez oil spill in 1989 and from two

control communities (n=599). They achieved a response rate of 84%. The authors found that the prevalence of posttraumatic stress disorder (PTSD) was significantly associated with declines in subsistence activities and increased social disruption for all participants. They found that AI/AN participants who reported a decline in subsistence activities or a high level of social disruption were seven times more likely to experience PTSD than AI/AN respondents who saw an increase or no impact on subsistence activities or low social disruption. White participants who experienced these same negative impacts were twice as likely as their white peers who had not to experience PTSD. This indicates that even among the population that was negatively affected by the oil spill, AI/AN were more likely than their white counterparts to experience PTSD as a result. In addition PTSD was significantly associated with increased exposure to the oil spill among AI/AN participants but not among white respondents. Individuals who identified as Asian, Hispanic, black, or other were excluded from analysis due to the small sample size.

28. Palinkas LA, Russell J, Downs MA, Petterson JS. Ethnic differences in stress, coping, and depressive symptoms after the Exxon Valdez oil spill. *The Journal of nervous and mental disease.* 1992;180(5):287-295.

Palinkas et al. collected interview data in 1990 from 596 randomly sampled households in 11 Alaskan communities directly exposed to the Exxon Valdez oil spill in 1989 and from two control communities (n=589). They achieved a response rate of 84%. The authors found that increasing level of exposure to the spill was significantly associated with depression and declines in traditional relations. AI/AN respondents were more likely than white respondents to report working on cleanup activities, damage to commercial fisheries, and effects of the spill on subsistence activities such as hunting, fishing, and gathering. AI/AN participants also had significantly higher depressive symptom scores than white participants. In addition, white respondents reported significantly higher incomes and educational attainment than AI/AN respondents. For AI/AN respondents, participation in oil cleanup and other contact with oil was associated with depression. For white respondents, damage to commercial fisheries, use of affected areas, and geographic proximity to the spill were associated with depressive symptoms. Individuals who identified as Asian, Hispanic, black, or other were excluded from analysis due to the small sample size.

29. Centers for Disease Control and Prevention. Behavioral Risk Factor Surveillance System Prevalence and Trends data: Washington. 2013; http://apps.nccd.cdc.gov/brfss/page.asp?cat=XX&yr=2012&state=WA#XX. Accessed February 11, 2015.

Behavioral Risk Factor Surveillance System (BRFSS) 2013 data from Washington state indicate that as educational attainment increases income level also increases. This relationship is significant. These data also find significant correlations between lower income and lower educational attainment and a number of health indicators including: worse overall self-reported health, depression, asthma (significantly different for income only), and limited activity as a result of a disability. BRFSS data from 2011 show that black, AI/AN, and Hispanic respondents are significantly more likely to report fair or poor general health than white or Asian respondents. Participants who identified as multiracial also reported significantly higher rates of asthma than white and Hispanic respondents.

30. Reed P KD, Cheng E, Kinne S. Washington State Department of Health. *Health of Washington State Report: Mortality and Life Expectancy.* 2013.
The authors present Washington state data on mortality and life expectancy. The data show that age-adjusted death rates were higher in Washington census tracks with lower college graduation rates and also in census tracks with higher poverty. The state data also show that self-reported health status decreases both as income and as educational attainment decrease. Age-adjusted death rates from 2009-2011 Washington state death certificate data indicate that AI/AN, black, and Native Hawaiian and Other Pacific Islander populations have significantly higher death rates than white, Hispanic and Asian populations. This report indicates that death certificates often misclassify race/ethnicity and highlights that death data may underreport for American Indians and Alaska Natives.

31. Tran N, Wittenberg R, Zang K. *Health of Washington State Report: Asthma.* Washington State Department of Health; 2012.
Combined BRFSS data from 2008-2010 indicates that adult age-adjusted asthma rates for AI/AN populations are significantly higher than those for all other racial/ethnic groups. Rates for multiracial respondents are not broken out for this report.

32. VanEenwyk J BG, Bezruchka S, Pobutky, A. Washington State Department of Health. 2013. *Health of Washington State Report: Social and Economic Determinants of Health.* 2013.
VanEenwyk et al. conducted a review of the literature on the complex relationships between the social factors that impact health. The authors found that the literature provides extensive evidence of the association between lower educational attainment and poor health outcomes, and of the association between lower income and poor health outcomes.

33. Washington State Department of Health. *Health of Washington State Report: Mental Health.* 2008.
Combined BRFSS data from 2004-2006 indicates that AI/AN respondents were significantly more likely to report frequent poor mental health days than any other racial/ethnic group. Individuals with lower educational attainment and lower income were also significantly more likely than their counterparts to report frequent poor mental health days.

34. Washington State Department of Health. Demographics of Washington State Residents within a Half-Mile of the Train Tracks, unpublished data. 2015.
The Washington State Department of Health's Environmental Epidemiology unit created a geographic information system (GIS) model to estimate the demographics of Washington state residents living within a half mile of train tracks used to transport crude oil. The model calculated the percentage of each block group that was within a half mile of railroads that transport oil and multiplied that percentage by demographic characteristics from the American Community Survey 2009-2013 5-year estimates. The analysis found that 11% of Washington state residents lived within a half mile of a railroad that transported oil. This population had lower incomes, lower educational attainment, and consisted of a higher proportion of people of color than Washington state as a whole. These difference were found to be statistically significant at the $p<0.001$ level for all differences reported using a chi-square test of significance. The median household income of block groups that were at least 25% within the buffer was

$53,852 compared to $65,307 for the state ($p<0.001$, Welch two sample t-test). The authors believe this is likely an underestimate of the income disparity because the model is more likely to exclude rural block groups than urban ones. Communities of color overrepresented near railroads were Hispanics and people identifying as Multi-Racial. There were also differences in educational attainment with fewer college graduates and more people who did not complete high school.

35. Washington State Department of Ecology. Fish consumption rates: Technical support document. Version 2.0. Final. 2013. https://fortress.wa.gov/ecy/publications/publications/1209058.pdf.
This report indicates that in Washington populations that consume high quantities of fish include AI/AN and Asian and Pacific Islander populations as well as subsistence and recreational fishers. Traditional fishing areas for Washington tribes "cover essentially all of Washington" indicating that an oil spill in almost any area in the state has potential to impact traditional tribal fishing areas.