BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF TRANSCANADA KEYSTONE PIPELINE, LP FOR ORDER ACCEPTING CERTIFICATION OF PERMIT ISSUED IN DOCKET HP-09-001 TO CONSTRUCT THE KEYSTONE XL PIPELINE	Cindy Myers' Witness and Exhibits List HP14-001

Cindy Myers, intervener in docket HP14-001, submits her Witness and Exhibits List, attached as separate file.

All exhibits are available per listed links, available on-line, or available electronically in the PUC docket for HP14-001.

Dated this 5th day of July, 2015

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Copies of Cindy Myers' cover letter to PUC, Exhibits List, and attached evidentiary files were sent electronically to the following:

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Witness/Exhibit List
Cindy Myers, Intervener for Hydrocarbon Pipeline HP14-001

Date	Exhibit Number	Document Description	Witness	Offer	Admit	Deny
04-20-15	Cindy 1	Cindy Myers Testimony, SD PUC HP14-001	Cindy Myers,RN			
04-20-15	Cindy 2	Paul Seamans Statement re. Missouri River Water Systems				
04-20-15	Cindy 3	Map: Missouri River Water Systems 				
04-20-15	Cindy 4	John Stansbury Study, "Analysis of Worst-Case Spills From the Proposed Keystone XL Pipeline". 4A-Summary, 4B-excerpts by Dr Stansbury				
04-20-15	Cindy 5	https://youtu.be/9Dw7a7YSnH0 Dr Stansbury Interview				
04-20-15	Cindy 6	Arden Davis Testimony SD PUC docket HP14-001				
04-20-15	Cindy 7	Madden Testimony, SD PUC docket HP09-001				
04-20-15	Cindy 8	FSEIS Keystone XL Pipeline, http://keystonepipeline-xl.state.gov/finalseis/index.htm Chapters 3 and 4 (3.13-4, 4.1, 4.3.2), Appendix P, Appendix Q				
04-20-15	Cindy 9	http://insideclimatenews.org/news/20022015/yellowstone-rupture-probe-stalled-pipeline-restart-plan-moving-forward Montana's Department of Environmental Quality				
04-20-15	Cindy11	TransCanada's discovery responses 11-A, 11-B, 11-C				
04-20-15	Cindy12	http://thinkprogress.org/climate/2014/10/21/3582480/north-dakota-spill-one-year-later/				
04-20-15	Cindy13	http://www.deq.mt.gov/statesuperfund/silvertipoilspill/default.mcpx				
04-20-15	Cindy14	http://www.mlive.com/news/grand-rapids/index.ssf/2014/11/2010_oil_spill_cost_enbridge_1.html				
04-20-15	Cindy15	http://www.yorknewstimes.com/editorial/the-keystone-xl-pipeline-is-dead/article_b8df8d1e-6e6c-11e4-8232-e32899788eb6.html#.VGvEjBln1QA.email				
04-20-15	Cindy16	http://www.denverpost.com/news/ci_26800380/dead-				

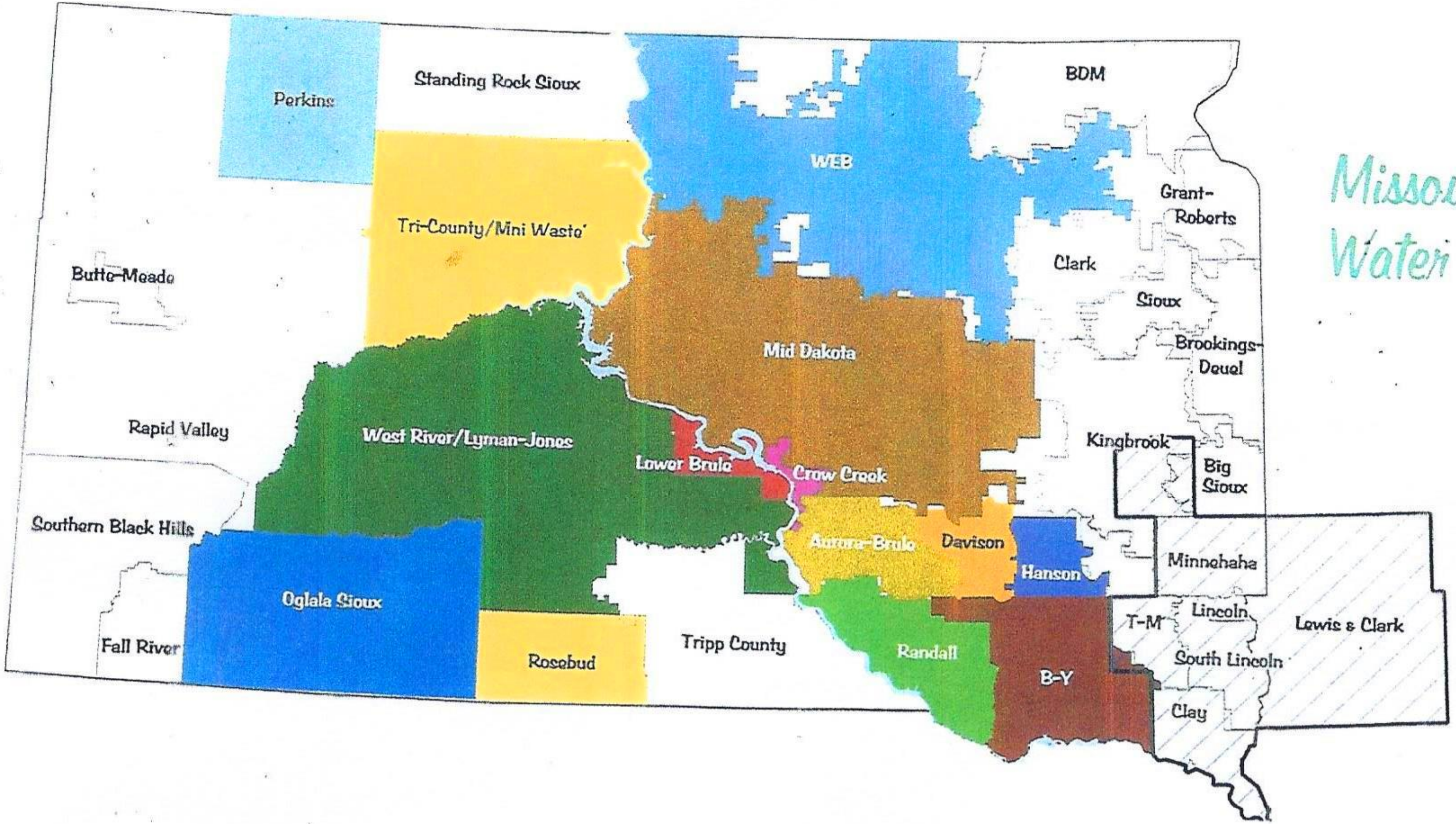
		babies-near-oil-drilling-sites-raise-questions				
04-20-15	Cindy17	http://blog.keloland.com/issues/blog/2009/11/02/madden-report-misses-distress-among-keystone-pipeline-neighbors/#.VPAIDQfZ5ms.email				
04-20-15	Cindy18	http://m.billingsgazette.com/news/state-and-regional/montana/article_c39e74b3-08ec-5fce-8d18-4085c5c03ed2.html?mobile_touch=true				
04-20-15	Cindy19	http://bigstory.ap.org/article/03d148c1029a4fe69ccfe60ad9e6f94e/yellowstone-oil-spills-fuel-arguments-over-keystone-line				
04-20-15	Cindy20	http://mediamatters.org/blog/2015/01/26/yellowstone-oil-spill-missing-from-keystone-xl/202266				
04-20-15	Cindy21	http://www.thewildlifenews.com/2015/01/26/pipeline-rupture-under-yellowstone-river/				
04-20-15	Cindy22	http://water.epa.gov/drink/contaminants/index.cfm#List				
04-20-15	Cindy23	http://mediamatters.org/blog/2015/01/26/yellowstone-oil-spill-missing-from-keystone-xl/202266				
04-20-15	Cindy24	http://m.missoulian.com/news/opinion/columnists/oil-and-water-don-t-mix/article_3c09934b-435e-5a43-a41b-e14646fc2d12.html?mobile_touch=true				
04-20-15	Cindy25	http://www.spokesman.com/stories/2015/jan/24/new-spill-into-yellowstone-river-prompts-pipeline/				
04-20-15	Cindy26	http://mobile.nytimes.com/aponline/2015/01/20/us/ap-us-pipeline-spill.html?referrer=&_r=0				
04-20-15	Cindy27	http://www.netzero-news.net/news/read/category/Top%20News/article/the_associated_press-montana_oil_spill_renews_worry_over_safety_of_old-ap#.VMGpUACr__U.facebook				
04-20-15	Cindy28	http://bigstory.ap.org/article/659021779c4f4cefb0393e5006c16af5/montana-oil-spill-renews-worry-over-safety-old-pipelines				
04-20-15	Cindy29	http://insideclimatenews.org/news/20150121/ice-hinders-cleanup-yellowstone-oil-pipeline-spill?utm_source=Inside+Climate+News&utm_campaign=3e1c34ad09-Weekly_Newsletter_1_25_20151_23_2015&utm_medium=email&utm_term=0_29c928ffb5-3e1c34ad09-327495949				
04-20-15	Cindy30	Brad Vann, Environmental Scientist, EPA, Region 7, email quotes				
04-20-15	Cindy31	Keystone "Oil Pipeline for Emergency Responders" Pamphlet 1533-1538				
04-20-15	Cindy32	SD PUC Amended Final Decision and Order; Notice of Entry HP09-001				
04-20-15	Cindy33	Missouri River and tributaries, trace upstream, USGS				

		http://nationalmap.gov/streamer/dataService/dataService.ashx/report?ID=20025251&traceDir=up&HUCs=&lat=44.50007083273387&lon=-94.5746712806176&elevFt=1030.469163&baseMap=terrainBaseMap&xmin=-10524714&ymin=5536454&xmax=-10510466&ymax=5539947&reportType=maponly&session_id=222255224634&caller=streamer				
04-20-15	Cindy34	http://www.vancouverobserver.com/news/first-nations-cancer-linked-oil-sands-toxins-wild-food-study				
04-20-15	Cindy35	http://www.vancouverobserver.com/news/alberta-doctor-tells-us-canada-lying-about-tar-sands-health-effects				
04-20-15	Cindy36	http://m.billingsgazette.com/news/state-and-regional/montana/cancer-causing-agent-detected-in-water-after-pipeline-spill/article_c39e74b3-08ec-5fce-8d18-4085c5c03ed2.html?utm_source=facebook&utm_medium=social&utm_campaign=curated&utm_content=BGKarenS&mobile_touch=true				
04-20-15	Cindy37	http://www.usnews.com/news/us/articles/2015/01/21/city-tries-to-repair-contaminated-water-system-after-spill				
04-20-15	Cindy38	http://m.missoulian.com/news/state-and-regional/yellowstone-river-sonar-shows-breached-pipeline-is-exposed-on-riverbed/article_aa9290f2-f997-52f1-9aa5-4f7d426b1f57.html?mobile_touch=true				
04-20-15	Cindy39	Acute Health Effects of the Enbridge Oil Spill https://snt150.mail.live.com/mail/ViewOfficePreview.aspx?messageid=mgv68drsZw5BGEemw75afaHg2&folderid=flzg-Wn7trtkiY3oFCUuZJ7Q2&attindex=4&cp=-1&attdepth=4&n=59596253				
04-20-15	Cindy40	MSDS Naphtha https://snt150.mail.live.com/mail/ViewOfficePreview.aspx?messageid=mgv68drsZw5BGEemw75afaHg2&folderid=flzg-Wn7trtkiY3oFCUuZJ7Q2&attindex=2&cp=-1&attdepth=2&n=56189677				
04-20-15	Cindy41	API, Diluted Bitumen Information				
04-20-15	Cindy42	SDCL, 49-41 B-22				
04-20-15	Cindy43	http://goo.gl/0GxqoM Video interview of TransCanada's Jeff Rauh and Andrew Craig				
04-20-15	Cindy44	PUC staff discovery responses 44-A, 44-B				
04-20-15	Cindy45	Map of KXL route in SD				
04-20-15	Cindy46	http://bismarcktribune.com/news/state-and-regional/unusual-alliance-on-oil-spill-cleanup-near-tioga/article_75164d8e-4b8f-11e4-bf7b-93e46e70604c.html				
04-20-15	Cindy47	Toxicology and Applied Pharmacology, Volume 276, Issue 2, April 15 (2014), pages 83-94 Current				

		understandings and perspectives on non-cancer health effects of benzene: A global concern.				
04-20-15	Cindy48	HHS Public Access, Advances in Understanding Benzene Health Effects and Susceptibility, Published in final edited form as: Annu Rev Public Health. 2010 ; 31: 133–148.doi:10.1146/annurev.publhealth.012809.103646.				
04-20-15	Cindy49	NIH Public Access, Systems biology of human benzene exposure, Published in final edited form as: Annu Rev Public Health. 2010 ; 31: 133–148. doi:10.1146/annurev.publhealth.012809.103646. Systems biology of human benzene exposure				
04-30-15	Cindy50	ATSDR, "Public Health Statement for Benzene"				
04-30-15	Cindy51	Wikipedia, IARC Group I Carcinogens				
07-05-15	Cindy52	Paul Seamans statement re. Condition #40, PVC pipe/BTEX				

Paul Seamans:

I have added up the counties populations of the rural water systems that rely on Missouri River water. It is hard to get an exact count because a lot of the water districts don't always follow county lines. I came up with an approximate 2010 census figure of 500,000 people that rely on Missouri River water. The 2010 census figures for South Dakota's population is 814,000. The percentage of South Dakota's population that gets their water from the Missouri would equal around 61%. The 2014 estimates have South Dakota's population at 853,000 and a large portion of that growth is in the Sioux Falls metro area so this figure would be closer to 64%. I think a person is real safe in saying that at least half of South Dakota relies on the Missouri River for their drinking water, in all actuality it is probably closer to two thirds.



Missouri River Water Systems

Analysis of Frequency, Magnitude and Consequence of Worst-Case spills from the Proposed Keystone XL Pipeline

John Stansbury, Ph.D., P.E.

Executive Summary

TransCanada is seeking U.S. regulatory approval to build the Keystone XL pipeline from Alberta, Canada to Texas. The pipeline will transport diluted bitumen (DilBit), a viscous, corrosive form of crude oil across Montana, South Dakota, Nebraska, Kansas, Oklahoma and Texas. As part of the regulatory process, the National Environmental Policy Act (NEPA) requires an assessment of the potential environmental impacts of a pipeline spill. The Clean Water Act (CWA) also requires TransCanada to estimate the potential worst-case discharge from a rupture of the pipeline and to pre-place adequate emergency equipment and personnel to respond to a worst-case discharge and any smaller spills. The Keystone XL environmental assessment documents (e.g., Draft Environmental Impact Assessment) as well as the environmental impacts documents for the previously built Keystone pipeline, can be found on the US State Department web site. It is widely recognized that the environmental assessment documents for the Keystone XL pipeline are inadequate, and that they do not properly evaluate the potential environmental impacts that may be caused by leaks from the pipeline (e.g., USEPA 2011a). The purpose of this paper is to present an independent assessment of the potential for leaks from the pipeline and the potential for environmental damage from those leaks.

The expected frequency of spills from the Keystone XL pipeline reported by TransCanada (DNV, 2006) was evaluated. According to TransCanada, significant spills (i.e., greater than 50 barrels (Bbls)) are expected to be very rare (0.00013 spills per year per mile, which would equate to 11 significant spills for the pipeline over a 50 year design life). However, TransCanada made several assumptions that are highly questionable in the calculation of these frequencies. The primary questionable assumptions are: (1) TransCanada ignored historical data that represents 23 percent of historical pipeline spills, and (2) TransCanada assumed that its pipeline would be constructed so well that it would have only half as many spills as the other pipelines in service (on top of the 23 percent missing data), even though they will operate the pipeline at higher temperatures and pressures and the crude oil that will be transported through the Keystone XL pipeline will be more corrosive than the conventional crude oil transported in existing pipelines. All of these factors tend to increase spill frequency; therefore, a more realistic assessment of expected frequency of significant spills is 0.00109 spills per year per mile (from the historical data (PHMSA, 2009)) resulting in 91 major spills over a 50-year design life of the pipeline.

The CWA requires that TransCanada estimate the "worst-case spill" from the proposed pipeline (ERP, 2009). TransCanada's calculation of the worst-case spill from the proposed Keystone XL pipeline was not available at the time of this assessment, so an assessment of the methods used by TransCanada for the existing Keystone pipeline and a comparison of the results of those methods with the methods recommended in this analysis were made. The worst-case spill volume at the Hardisty Pumping Station on the Keystone (the original pipeline will be referred to as simply the Keystone pipeline while the proposed pipeline is the Keystone Xl pipeline) pipeline predicted using methods recommended in this analysis was 87,964 barrels

(Bbl), while the worst-case spill predicted using TransCanada's methods was 41,504 Bbl (ERP, 2009). The difference is a factor of more than 2 times. The primary difference between the two methods was the expected time to shut down the pumps and valves on the pipeline. TransCanada used 19 minutes (TransCanada states that it expects the time to be 11.5 minutes for the Keystone XL pipeline). Since a very similar pipeline recently experienced a spill (the Enbridge spill), and the time to finally shut down the pipeline was approximately 12 hours, and during those 12 hours the pipeline pumps were operated for at least 2 hours, it is clear that the assumption of 19 minutes or 11.5 minutes is not appropriate for the shut-down time for the worst-case spill analysis. Therefore, worst-case spill volumes are likely to be significantly larger than those estimated by TransCanada. The worst-case spill volumes from the Keystone XL pipeline for the Missouri, Yellowstone, and Platte River crossings were estimated by this analysis to be 122,867 Bbl, 165,416 Bbl, and 140,950 Bbl, respectively. In addition, this analysis estimated the worst-case spill for a subsurface release to groundwater in the Sandhills region of Nebraska to be 189,000 Bbl (7.9 million gallons).

Among numerous toxic chemicals that would be released in a spill, the benzene (a human carcinogen) released from the worst-case spill into a major river (e.g., Missouri River) could contaminate enough water to form a plume that could extend more than 450 miles at concentrations exceeding the Safe Drinking Water Act Maximum Contaminant Level (MCL) (i.e., safe concentration for drinking water). Therefore, serious impacts to drinking water intakes along the river would occur. Contaminants from a release at the Missouri or Yellowstone River crossings would enter Lake Sakakawea in North Dakota where they would adversely affect drinking water intakes, aquatic wildlife, and recreation. Contaminants from a spill at the Platte River crossing would travel downstream unabated into the Missouri River for several hundred miles and affect drinking water intakes for hundreds of thousands of people in cities like Lincoln, NE; Omaha, NE; Nebraska City, NE; St. Joseph, MO; and Kansas City, MO, as well as aquatic habitats and recreational activities. In addition, other constituents from the spill would pose serious risks to aquatic species in the river. The Missouri, Yellowstone, and Platte Rivers all provide habitat for threatened and endangered species including the pallid sturgeon, the interior least tern, and the piping plover. A major spill in one of these rivers could pose a significant threat to these species.

The benzene released by the worst-case spill to groundwater in the Sandhills region of Nebraska would be sufficient to contaminate 4.9 billion gallons of water at concentrations exceeding the safe drinking water levels. This water could form a plume 40 feet thick by 500 feet wide by 15 miles long. This plume, and other contaminant plumes from the spill, would pose serious health risks to people using that groundwater for drinking water and irrigation.

Introduction

TransCanada is seeking U.S. regulatory approval to build the Keystone XL pipeline from Alberta, Canada to Texas. The pipeline will transport diluted bitumen (DilBit), a viscous, corrosive form of crude oil across Montana, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. As part of the regulatory process, TransCanada is required by the National Environmental Policy Act (NEPA) to evaluate the potential environmental impacts of a pipeline spill. The Clean Water Act (CWA) also requires TransCanada to estimate the potential worst-case discharge from a rupture of the pipeline and to pre-place adequate emergency equipment and personnel to respond to a worst-case discharge and any smaller spills. The Keystone XL environmental assessment documents (e.g., Draft Environmental Impact Assessment) as well as the environmental impacts documents for the previously built Keystone pipeline, can be found on the US State Department web site. It is widely recognized that the environmental assessment documents for the Keystone XL pipeline are inadequate, and that they do not properly evaluate the potential environmental impacts that may be caused by leaks from the pipeline (e.g., USEPA, 2011a). The purpose of this paper is to present an independent assessment of the potential for leaks from the pipeline and the potential for environmental damage from those leaks.

In addition to evaluating potential environmental damage from pipeline leaks, TransCanada is required by law to pre-position emergency equipment and personnel to respond to any potential spill. This paper does not address these requirements. However, an independent assessment of TransCanada's emergency response plans for the previously built Keystone pipeline was done by Plains Justice (Blackburn, 2010). This document clearly shows that the emergency response plan for the Keystone pipeline is woefully inadequate. Considering that the proposed Keystone XL pipeline will cross much more remote areas (e.g., central Montana, Sandhills region of Nebraska) than was crossed by the Keystone pipeline, there is little reason to believe that the emergency response plan for Keystone XL will be adequate.

Since spills from these pipelines will occur, and since they will be extremely difficult and expensive to clean up (likely tens to hundreds of millions of dollars), it is imperative that TransCanada be required to be bonded for these clean-up costs before any permits are granted. This proposed requirement is supported by the recent Enbridge spill, where a smaller crude-oil pipeline leak released crude oil into a tributary of the Kalamazoo River, and early clean-up costs, as reported in Enbridge's annual report, have exceeded $500 million (Enbridge, 2011).

Worst-Case Spill

One of the requirements of the CWA is to calculate the worst-case potential spill from the pipeline. An assessment of the potential worst-case spill from the Keystone pipeline was conducted by TransCanada; however, some of the methods and assumptions in that assessment are in question. The primary focus of this paper is to provide an independent assessment of the worst-case spill from the Keystone XL pipeline and to compare that to the assessment done by TransCanada.

Spill frequency

To support understanding of the potential impacts due to releases from the pipeline, an assessment of the likely frequency of spills from the pipeline is made. TransCanada calculated the likely frequency of a pipeline spill for the Keystone XL pipeline in the Draft Environmental Impact Statement (ENTRIX, 2010) using statistics from the Pipeline and Hazardous Materials Safety Administration (PHMSA). Nation-wide statistics from PHMSA for spills from crude oil pipelines show 0.00109 significant (i.e., greater than 50 Bbl) spills per mile of crude oil pipelines per year. When this rate is applied to the Keystone XL pipeline with a length of 1,673 miles, the expected frequency of spills is 1.82 spills per year (0.00109 spills/mi* 1,673 mi). Adjusting the nation-wide PHMSA data to only include data from the states through which the Keystone XL pipeline will pass results in a frequency of 3.86 spills per year for the pipeline length (ENTRIX, 2010).The state-specific data are more applicable to the Keystone location; however, the smaller state-specific data base might over-estimate spill frequency. Therefore, the frequency of 1.82 per year is adopted as the best available value for this assessment. Assuming a design life of 50 years for the pipeline, 1.82 spills per year results in 91expected significant spills (i.e., greater than 50 barrels) for the Keystone Pipeline project. According to the TransCanada Frequency-Volume Study of the Keystone Pipeline (DNV, 2006), 14 percent of the spills would likely result from a large hole (i.e., greater than 10 inches in diameter). Using the 14 percent value, the 91 expected spills during a 50-year lifetime for the pipeline would result in 13 major spills (i.e., from holes larger than 10 inches in the pipeline).

However, TransCanada diverged from historical data and modified the estimate of the expected frequency of spills from the pipeline (DNV, 2006). The company's primary rationale for reducing the frequency of spills from the pipeline was that modern pipelines are constructed with improved materials and methods. Therefore, TransCanada assumed that pipelines constructed with these new improved materials and methods are likely to experience fewer leaks. The revised expected frequency for spills was reported in the Frequency-Volume Study (DNV, 2006) to be 0.14 spills/year over the 1,070 miles from the Canadian border to Cushing, OK. This value was adjusted to 0.22 spills per year for the total 1,673 miles of pipeline, including the Gulf Coast Segment (ENTRIX, 2010). Using the 0.22 spills/year, TransCanada predicted 11 spills greater than 50 barrels would be expected over a 50-year project life.

This reduced frequency estimated by TransCanada is probably not appropriate for a couple of reasons. First, the study of the revised frequency ignored some of the historical spill data; i.e., the spill cause category of "other causes" in the historical spill data set (DNV, 2006). The "other causes" category was assigned for spills with no identified causes. Since this category represents 23 percent of the total spills, this is a significant and inappropriate reduction from the spill frequency data. In addition, the assumed reduction in spill frequency resulting from modern pipeline materials and methods is probably overstated for this pipeline. TransCanada used a reduction factor of 0.5 in comparison to historical data for this issue. That is, according to TransCanada, modern pipeline construction materials and methods would result in half as many spills as the historical data indicate. However, the PHSMA data used in the TransCanada report were from the most recent 10 years. Therefore, at least some of the pipelines in the analysis were modern pipelines. That is, the initial frequency estimate was calculated in part with data from modern pipelines; therefore, a 50 percent reduction of the frequency estimates is highly questionable based on the data set used. More importantly, DilBit, the type of crude oil to be transported through the Keystone XL pipeline will be significantly more corrosive and abrasive than the conventional crude oil transported in most of the pipelines used in the historical data set. The increased corrosion and abrasion are due to 15 – 20 times the acidity (Crandall, 2002), 5 – 10 times the sulfur content (Crandall, 2002), and much higher levels of abrasive sediments (NPRA, 2008) compared to conventional crude oil. In addition, the high viscosity of DilBit requires that the pipeline be operated at elevated temperatures (up to 158^{o}F for DilBit and ambient temperature for conventional oil) and pressures (up to 1440 psi for DilBit and 600 psi for conventional oil) compared to conventional crude oil pipelines (ENTRIX, 2010). Since corrosion and pressure are the two most common failure mechanisms resulting in crude oil releases from pipelines (DNV, 2006), increased corrosion and pressure will likely negate any reduced spill frequency due to improvement in materials and methods. Although pipeline technology has improved, new pipelines are subject to proportionally higher stress as companies use this improved technology to maximize pumping rates through increases in operational pressures and temperatures, rather than to use this improved technology to enhance safety margins.

Also, TransCanada relies heavily on “soft” technological improvements, such as computer control and monitoring technology, rather than only on “hard” improvements, such as improved pipe fabrication technology. Whereas “hard” technological improvements are built into pipelines, “soft” improvements require an ongoing commitment of monitoring and maintenance resources, which should not be assumed to be constant over the projected service life of the pipeline, and are also subject to an ongoing risk of error in judgment during operations. As demonstrated by the spill from Enbridge’s pipeline into the Kalamazoo River, as pipelines age maintenance costs increase, but pipeline company maintenance efforts may be insufficient to prevent major spills, especially if operators take increased risks to maintain return on investment. Moreover, TransCanada assumes that future economic conditions will allow it to commit the same level of maintenance resources from its first year to its last year of operation. Given future economic uncertainty, this is not a reasonable assumption. It is reasonable to assume that decades from now TransCanada or a future owner will likely fail to commit adequate maintenance resources, fail to comply with safety regulations, or take increased operational risks during periods of lower income. Overtime, PHMSA should assume that the risk of spill from the Keystone XL Pipeline will increase due to weakening of “soft” technological enhancements. Over the service life of the pipeline it is not reasonable to rely on TransCanada’s “soft” technological improvements to the same extent as built-in “hard” improvements.

The TransCanada spill frequency estimation consistently stated the frequency of spills in terms of spills per year per mile. This is a misleading way to state the risk or frequency of pipeline spills. Spill frequency estimates averaged per mile can be useful; e.g., for extrapolating frequency data across varying pipeline lengths. However, stating the spill frequency averaged per mile obfuscates the proper value to consider; i.e., the frequency of a spill somewhere along the length of the pipeline. Stating the spill frequency in terms of spills per mile is comparable to acknowledging that although some 33,000 deaths from automobile accidents occur annually in the U.S., the average annual fatality rate across 350 million people is only 0.000094; therefore, fatalities from automobile accidents are so rare as to be unimportant. In other words, it is of little importance to know the risk (frequency) of a release in any particular mile segment (frequency per mile); rather it is important to know the risk of a release from the pipeline. As shown above, the expected number of spills for the pipeline over the pipeline lifetime ranges between 11 and 91 spills, depending on the data and assumptions used.

In summary, there is no compelling evidence to reduce the frequency of spills because of modern materials and methods. The increased corrosiveness and erosiveness of the product being transported will likely cancel any gains due to materials and methods improvements and soft technological safeguards will likely become less effective over time. Moreover, the modified frequency stated by TransCanada should not have been reduced by omitting an important failure category. The frequency of spills should have been stated as frequency of spills across the pipeline length per year and per pipeline lifetime. Therefore, the best estimate for spill frequency is the value from the PHSMA historical data set resulting in 1.82 spills/yr or 91 significant spills over the pipeline lifetime. Table 1 compares the predicted number of spills over the lifetime of the pipeline computed from TransCanada's assumptions and from historical data.

Table 1: Predicted Number of Spills from Keystone XL Pipeline Over a 50-Year Lifetime.

	TransCanada Estimate	Estimates Using Historical Data
Spills per year per mile	0.00013[(a)]	0.00109[(a)]
Pipeline spills per year	0.22[(b)]	1.82[(b)]
Pipeline spills per 50-year lifetime	11[(c)]	91[(c)]
Pipeline spills from > 10 inch hole	1.54[(d)]	12.74[(d)]

(a) ENTRIX, 2010
(b) spills/year-mile *1673 miles
(c) spills/year* 50 years of pipeline lifetime
(d) spills/lifetime * 14percent spills from > 10 inch hole

<u>Most Likely Spill Locations</u>

Crude oil could be spilled from any part of the pipeline system that develops a weakness and fails. Likely failure points include welds, valve connections, and pumping stations. A vulnerable location of special interest along the pipeline system is near the side of a major stream where the pipeline is underground but at a relatively shallow depth. At these locations, the pipeline is susceptible to high rates of corrosion because it is below ground (DNV, 2006). Since the pipeline is below ground, small initial leaks due to corrosion-weakened pipe would potentially go undetected for extended periods of time (e.g., up to 90 days) (DNV, 2006) providing conditions for a catastrophic failure during a pressure spike. In these locations, pressures would be relatively high due to the low elevation near the river crossing. In addition, major leaks at these locations are likely to result in large volumes of crude oil reaching the river.

In addition to river crossings, areas with shallow groundwater overlain by pervious soils (such as the Sandhills region in Nebraska) where slow leaks could go undetected for long periods of time (e.g., up to 90 days) (DNV, 2006), pose risks of special concern.

<u>Worst Case Spill Volume</u>

The volume of a spill is calculated in two parts: the pumping rate volume and the drain-down volume. The pumping rate volume is the volume of crude oil that is pumped from the leaking pipe during the time between the pipe failure and stoppage of the pumps. The time to shut down the pumps after a leak can be divided into two phases: the time to detect the leak, and the time to complete the shut-down process. The pumping rate volume also depends on the size of the hole in the pipe and the pressure in the pipe. The drain-down volume is the volume of crude oil that is released after the pumps are stopped, as the crude oil in the pipe at elevations above the leak drains out. The following sections explain how the pumping rate volume, the drain-down volume, and the total spill volume are calculated.

<u>Pumping Rate Volume</u>

The pumping rate volume is calculated as:

$$PRV = PR * (DT + SDT)$$

Where:

PRV = pumping rate volume (Bbl)

PR = pumping rate (Bbl/min)

DT = detection time (time required to detect and confirm a leak and order pipeline shut-down (min))

SDT = shut-down time (time required to shut down pumps and to close valves (min))

TransCanada's Frequency-Volume Study (DNV, 2006) states that detection of a leak in an underground pipeline section can range from 90 days for a leak less than 1.5 percent of the pipeline flow rate to 9 minutes for a leak of 50 percent of the pipeline flow rate. The 90-day time to detection is for a very slow leak that would not be detected by the automatic leak detection system. The 9 minute time to detection is for a leak that is large enough to be readily detected by the leak detection system. However, this time estimate is questionable because, as has been shown by experience, it is difficult for the leak detection system to distinguish between leaks and other transient pressure fluctuations in a pipeline transporting high viscosity materials such as DilBit. For example, in the Enbridge pipeline spill, signals from the leak detection system were misinterpreted, and up to 12 hours elapsed between the time of the leak and final pipeline shut-down (Hersman, 2010). During the 12-hour period between the initial alarm and the final shut-down, the pipeline pumps were operated intermittently for at least two hours. It should be noted that the location of the Enbridge spill was a populated area where field verification of the leak should have been quick and easy. Indeed, local residents called 911 complaining about petroleum odors (likely from the leak) 10 hours before the pipeline was shut down. In the case of the Keystone XL pipeline, leaks could occur in remote areas (e.g., central Montana, or the Sandhills region of Nebraska) where direct observation would only occur by sending an observer to the suspected site; this could take many hours.

TransCanada states that the time to complete the pipeline shut-down sequence is 2.5 minutes (ERP, 2009). Therefore, using TransCanada's time estimates, for a 1.5 percent leak, the total time between leak initiation and shut-down could be up to 90 days, and for a large (>50 percent) leak, the total time between leak initiation and shut-down would be 11.5 minutes (ERP, 2009).

However, given the difficulty for operators to distinguish between an actual leak and other pressure fluctuations, the shut-down time for the worst case volume calculation should not be considered to be less than 30 minutes for a leak greater than 50 percent of the pumping rate. This would allow for 4 alarms (5 minutes apart) to be evaluated by operators and a 5th alarm to cause the decision to shut down. In addition, the time to shut down the systems (pumps and valves) would require another 5 minutes. The assumption that the decision to shut the pipeline down can be made after a single alarm , as is suggested by TransCanada(ERP, 2009) is unreasonable considering the difficulty in distinguishing between a leak and a pressure anomaly. The ability to make the decision to shut down the pipeline after 5 alarms is likely a reasonable "best-case" assumption. However, this "best-case" does not describe the "worst case" conditions that are being assessed here. Rather, the worst case should consider confusing and confounding circumstances where a shut-down decision is not clear and where the leak site is remote and not verifiable in a short time period. The total time is then considered to be between 30 minutes (a best-case scenario) and 12 hours (the time for the Enbridge final shut-down) from leak initiation to shut-down. Considering that the Keystone XL pipeline will cross extremely remote areas and that verification of a leak could take many hours, a shut-down time of 2 hours (i.e., the time the pumps were operated during the Enbridge shutdown process) is a reasonable time for the worst-case analysis.

Therefore, for the worst-case spill for a large leak, a shut-down time of 2 hours is assumed. With a maximum pumping rate of 900,000 Bbl/d, and a shut-down time of 2 hours, the pumping rate volume is 75,000 Bbl (900,000 Bbl/d * 1 d/24 hr* 2 hr). This pumping rate volume (75,000 Bbl) is used in the calculation of the total worst-case spill volume for all high-rate leaks (i.e., greater than 50 percent flow-rate).

The worst-case spill for a small leak could occur where the pipeline is buried and in a remote location (such as central Montana or the Sandhills region of Nebraska), and where direct observation would be infrequent. According to TransCanada documents (DNV, 2006), a slow leak of less than 1.5 percent of the pumping rate could go undetected for up to 90 days. However, since pipeline inspections are scheduled every few weeks, it is likely that the oil would reach the surface and be detected before the entire 90 days elapsed. Assuming that the pipeline is buried at a depth of 10 feet and that the 1.5 percent leak (75,802 ft^3/d) is on the bottom of the pipe, oil would fill the pore spaces in the soil mostly in a downward direction, but it would also be forced upward toward the surface. Assuming that the oil initially fills a somewhat conical volume that extends twice as far below the pipeline as above it, the oil would emerge at the surface within about one day (volume of a cone 30 feet deep with a base diameter of 30 feet is 7,068 ft^3). Therefore, the leak would likely be detected in 14 days during the next inspection (assuming bi-weekly inspections). A 1.5 percent spill at a pumping rate of 900,000 Bbl/d over 14 days would result in a release of 189,000 Bbl (7.9 million gallons).

Table 2: Pumping Rate Volume for Various Sized Leaks

Leak as percent of Pumping Rate[a]	Detection and Shut-Down Time	Pumping Rate Volume[d]
<1.5percent	14 days[b]	189,000 Bbl
100percent	2 hours	75,000 Bbl
100percent	11.5 minutes[c]	7,188 Bbl

(a) Design pumping rate for Keystone XL = 900,000 Bbl/d. Calculation of worst-case spill requires 100 percent of pumping rate.

(b) Time between pipeline inspections.(DNV, 2006)

(c) TransCanada's assumed shut-down time (ERP, 2009)

Drain-Down Volume

The drain-down volume is the volume in the pipe between the leak and the nearest valve or the nearest high point. Some oil in locally isolated low spots will tend to remain in the pipe. TransCanada arbitrarily assigned a drain-down factor of 0.6 for the Keystone XL pipeline, meaning that 40 percent of the oil in the draining pipeline at elevations above the leak will be captured in low spots. However, since siphon effects will tend to move much of the oil even in local low spots, the 40 percent retention factor is likely too high for a worst-case analysis. PHMSA regulations require valves to be placed on either side of a major water crossing. If these valves are working, they should limit the amount of crude oil that drains from the pipeline to the amount that is between the valves. However, to calculate a worst case spill, the volume should be calculated assuming that at least some of the valves fail (recall the failures of the safety devices in the recent Gulf oil spill). If the valves fail, the drain-down volume would be limited by the major high elevation points on either side of the leak, with a reasonable adjustment for residual crude oil remaining in the pipeline. For this worst-case analysis, a reasonable estimate for residual crude oil remaining in the pipeline is assumed at 20percent of the total volume of oil at elevations above the leak. All of these parameters are site-specific; therefore, for this assessment, the worst case drain-down volumes will be calculated for several of the river crossings of the Keystone XL pipeline, including the Missouri, Yellowstone, and Platte Rivers.

The drain-down volume is calculated using:

$$DDV = PLDV * DF$$

Where:

DDV = Drain Down volume (Bbl)

PLDV = Pipeline Drain Volume (Bbl) (volume of pipeline either side of the leak to next valve or high elevation point)

DF = Drainage Factor (80percent)

<u>Worst-Case Release Calculation for the Missouri River Crossing</u>

The Missouri River crossing is located at mile post (MP) 89 along the Keystone XL pipeline. The upstream valve is located at MP84, and the downstream valve is located at MP 91. The river is at an elevation of 2,035 feet. Figure 1 shows the elevation profile of the crossing at the Missouri River. Since there are no major high elevations between the river and the valve at MP 84, it is likely that nearly all of the oil in the pipeline between the valve and a hypothetical leak at the river will be siphoned or drained via gravity. If the valve at MP 84 fails, all of the oil in the pipeline between that point and the next valve (MP 81.5) could drain since the pipeline rises gradually in elevation between MP 84 and MP 81 (elevation of 2,225 feet). If the valve on the downstream side of the crossing (MP 91) fails, oil in the pipeline up to the major high point at MP 93 could drain to the hypothetical leak at the river crossing.

There are several scenarios that could affect the drain-down volume. In the worst-case scenario both valves could fail, and the drain-down volume would then be the cross-sectional area of the pipe, times the length of pipeline draining times 80 percent. For this scenario, the length of pipe is 11.5 miles (MP 81.5 to MP 93). The cross-sectional area of the 36 inch pipe is 7.07 ft^2. Thus the drain-down volume is $3.43x10^5$ ft^3 (61,164 Bbls, 2.57 million gallons). However it is highly unlikely that both valves will fail at the same time.

A second scenario would occur if both valves operated correctly but the siphon effect removed the oil from the high point downstream of the valve at MP 84. Under this scenario, the length of drained pipe is 7 miles, and the resulting drain-down volume is $2.09x10^5$ ft^3 (37,230 Bbls, 1.56 million gallons).

A third scenario would occur if both valves operated correctly, and the siphon effect did not remove the oil between the high point at MP 86.5 and the valve at MP 84. In this scenario, the length of drained pipe is 4.5 miles (valve at MP 91 to the high point at MP 86.5), and the drain-down volume is $1.34x10^5$ ft^3 (23,934Bbls, 1.01 million gallons).

A fourth scenario would occur if one of the valves fails. To be conservative, the valve closest to the river will be the assumed failed valve. In this scenario, the drain-down distance would be 9 miles (between the valve at MP 84 and the high point at MP 93). The resulting drain-down volume would be 2.69 x 10^5 ft^3 (9 mi * 5,280 ft/mi * 7.07 ft^2 * 0.8) (47,867 Bbl, 2.01 million gallons).

While the first scenario is very unlikely, valve failure is a reasonable consideration in the worst-case spill analysis. So for the purposes of this analysis the fourth scenario, where one of the valves fails, is used to calculate the worst-case spill drain-down volume for the Missouri River crossing site. Therefore, using the fourth drain-down scenario, the drain-down volume is 47,867Bbls. Adding the pumping rate volume of 75,000 Bbl, the worst-case release volume for the Missouri River crossing is 122,867 Bbl (5.16 million gallons).

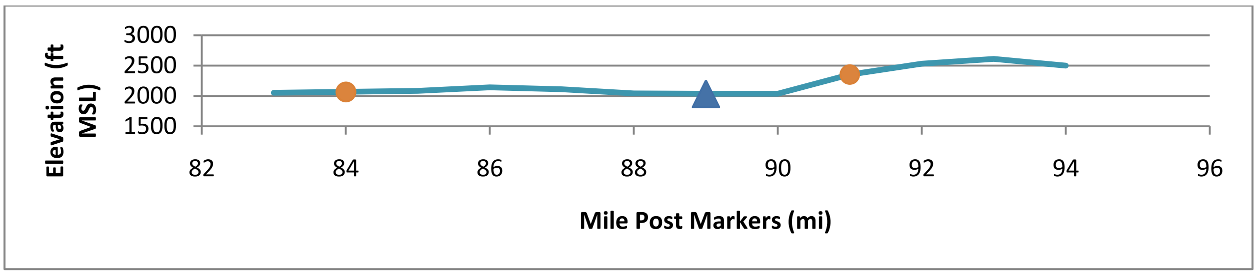


Figure 1: Horizontal profile of surface elevations at the Missouri River crossing. Note that the vertical axis is exaggerated compared to the horizontal axis. Solid circles show locations of pipeline valves. The solid triangle shows the location of the river crossing.

<u>Worst Case Release Volume Calculation for the Yellowstone River</u>

The crossing on the Yellowstone River is at MP 196.5 which is at an elevation of 2,125 feet. The closest upstream valve is at MP 194.5 at an elevation of 2,230 feet. The nearest major high point on the upstream side is at MP 183 at an elevation of 2,910 feet. The closest valve on the downstream side is at MP 200 at an elevation of 2,506 which is also the high point on the downstream side of the crossing. Figure 2 shows the elevation profile for the crossing at the Yellowstone River.

The first scenario for drain-down volume is if all valves work properly. The drain-down volume is 80 percent of the volume between the valves (the cross-sectional area of the pipe (7.07 ft^2) times the pipe length between the valves (5.5. miles)) which equals 1.64x10^5 ft^3 (29,252 Bbl, 1.23 million gallons).

Another scenario considers the volume if the valve at MP 194.5 does not work. In this case, the drain-down volume is the volume of the pipe between the two high elevations which are at MP 183 and MP 200 (17 miles). In this scenario the drain-down volume is 5.07x10^5 ft^3 (90,416 Bbl, 3.80 million gallons).Assuming failure of the valve at mile-post 194.5 is a reasonable assumption for conditions of the worst-case spill volume. The total worst-case volume is then the drain-down volume of 90,416 Bbl plus the pumping rate volume of 75,000 Bbl totaling 165,416 Bbl (6.95 million gallons).

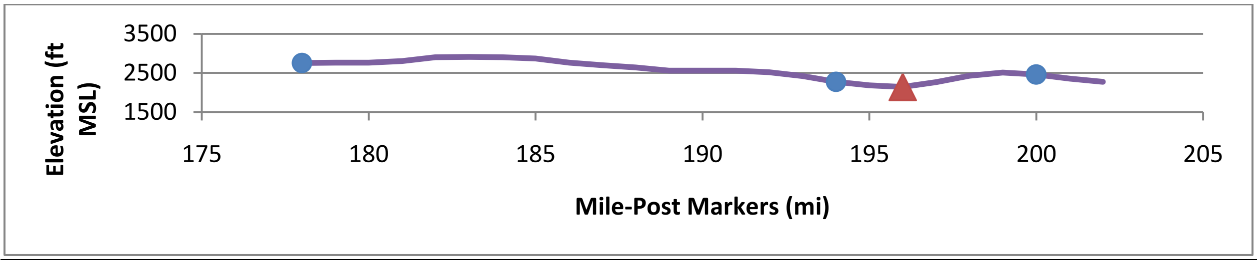


Figure 2: Horizontal profile of surface elevations at the Yellowstone River crossing. Note that the vertical axis is exaggerated compared to the horizontal axis. Solid circles show locations of pipeline valves. The solid triangle shows the location of the river crossing.

Worst-Case Release Volume Calculation for the Platte River, NE

The Keystone XL Pipeline is proposed to cross the Platte River in Nebraska at MP 756.5. There is an upstream valve at MP 747.6 and a downstream valve at MP 765. Figure 3 shows the elevation profile for the crossing at the Platte River. A reasonable worst-case spill scenario is to consider the valve at MP 765 (i.e., closest to the river) to fail. The drain-down volume would then be the pipeline volume between the high point at MP 760 and the valve at MP 747.6. The resulting drain-down volume would be 3.70×10^5 ft^3 (65,950 Bbl, 2.77 million gallons). Adding the pumping rate volume, the worst-case spill at the Platte River crossing would be 140,950 Bbl (5.92 million gallons).

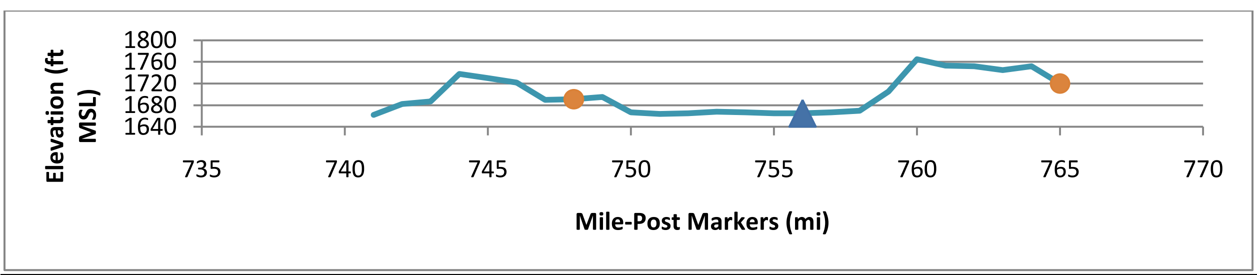


Figure 3: Horizontal profile of surface elevations at the Platte River crossing. Note that the vertical axis is exaggerated compared to the horizontal axis. Solid circles show locations of pipeline valves. The solid triangle shows the location of the river crossing.

Table 3: Worst-Case Spill Volume Estimates.

Location	Estimate from this analysis		
	Pumping Rate Volume (Bbl)	Drain Down Volume (Bbl)	Total Release (Bbl)
Groundwater	189,000[(a)]	NA	189,000
Missouri River	75,000[(b)]	47,867[(c)]	122,867
Yellowstone River	75,000[(b)]	90,416[(c)]	165,416
Platte River	75,000[(b)]	65,950[(c)]	140,950

(a) 900,000 Bbl/d (Keystone XL design pumping rate)* 1.5 percent leak * shut-down time of 14 days

(b) 900,000 Bbl/d (Keystone XL design pumping rate) * shut-down time of 2 hours

(c) Expected volume to drain from ruptured pipeline after pumps and valves closed

<u>Comparison to TransCanada methods</u>

TransCanada calculated the total Worst-Case Release Volume in a way that appears to be flawed. The worst-case volume was calculated from (ERP, 2009):

$$WCV = ALV + PRV$$

Where:

WCV = worst-case volume (Bbl)

ALV = adjusted line volume (Bbl)

PRV = pumping rate volume (Bbl) i.e., pumping rate (Bbl/min) * time to shut-down (min)

The adjusted line volume was calculated from:

$$ALV = (ILFV – PRV) * 0.60$$

Where:

ILFV = initial line fill volume (Bbl) i.e., the volume of the pipe between the leak and the nearest valve on both sides of the leak.

0.60 = drain-down factor where 60percent of the oil in the pipe will drain after shut-down.

For the Hardisty Pump Station/Regina Pump Station (Keystone pipeline) calculation, the ILFV was stated as 63,346 Bbl. The pumping rate was 662,400 Bbl/day, and the time to shut down was 19 minutes (10 minutes of evaluation of whether a leak had occurred and 9 minutes to shut down the system). This resulted in a PRV of 8,740 Bbl, and an ALV of 32,763 Bbl. The ALV plus the PRV resulted in a total release of 41,503 Bbl.

TransCanada does not explain how the initial line fill volume is calculated. They simply provide a value (ERP, 2009). For the Hardisty Pump Station/Regina Pump Station calculation, they state the value to be 63,346 Bbl. There is no way to verify this value. Whatever method was used, the value should be the pipeline volume between the leak and the high points of elevation on both sides of the leak. TransCanada then, in what appears to be a flawed process, subtracts the pumping rate volume from the initial line fill volume. It is not clear why this subtraction was done. Apparently, TransCanada considered that since the PRV would be pumped out of the pipeline during the leak discovery and shutdown time, that volume of oil would not be still in the pipeline during draining. However, even though the PRV would be removed from the pipeline during shutdown time, an equal amount would be pumped into the draining section. Therefore, the DDV should be calculated as simply the volume of the draining pipeline modified by the fraction of oil trapped in local low points. That is, the PRV should not have been subtracted from the ILFV. The result of subtracting the PRV from the ILFV was then multiplied by 0.60 to account for 40 percent of the oil in the pipe being caught in locally low spots in the pipeline and failing to drain out. Certainly some of the oil in the pipe will fail to drain, especially in locally low spots; however, considering siphon effects, it is very likely that nearly all of the oil will drain even through the locally low spots. Therefore, the 60 percent drain factor is likely to be a significant underestimate of the fraction of oil that will drain. For this worst case spill analysis, a drainage factor of 80 percent is a more reasonable assumption.

Table 4 shows the PRV, DDV, and total worst-case release estimates for the Hardisty Pumping Station on the original Keystone pipeline using methods recommended in this analysis and methods used by TransCanada (ERP, 2009). Note that the PRV values using the method of this paper are much larger than those using TransCanada's method because the assumed shut-down time is much shorter in TransCanada's method (19 minutes compared to 2 hours). The drain-down volumes used for both methods are the reported drain-down volumes from TransCanada's method because sufficient detail was not available in the TransCanada report (ERP, 2009) to allow a comparison of methods.

Table 4: Worst-Case spill volume estimate using the method recommended in this analysis and the method used by TransCanada for the Keystone Pipeline.

	Estimate from this Paper			TransCanada Estimate[(a)]		
	PRV (Bbl)	DDV (Bbl)	Total Release (Bbl)	PRV (Bbl)	DDV (Bbl)	Total Release (Bbl)
Hardisty Pumping Station	55,200[(b)]	32,764[(c)]	87,964	8,740[(d)]	32,764[(c)]	41,504

(a) ERP, 2009
(b) Pumping rate volume = 662,400 Bbl/d (Hardisty) * shut-down time of 2 hours
(c) Drain-down volume reported by TransCanada (ERP, 2009)
(d) Pumping rate = 662,400 Bbl/d * shut-down time of 19 min

Impacts from Worst-Case Spill

Impacts to the Air

The primary impacts to the air will be from benzene, hydrogen sulfide, and light molecular weight constituents of the DilBit. The DilBit will be pumped at high temperatures (up to 158^{o}F) and pressures (up to 1440 psi) causing these compounds to volatilize into the air at the site of the spill. The Occupational Health and Safety Agency (OSHA) acceptable concentration of benzene in the air for a workplace is 3.25 mg/m^3 (NIOSH, 1990) for short-term (8-hour) exposures. Since benzene is denser than air, it could accumulate in low-lying areas that are protected from the wind. Under these conditions, the benzene concentration could be above acceptable levels for inhalation. The basements of buildings located above groundwater plumes could also trap benzene gases that exceed safe levels. This could have serious consequences for the occupants of such a building, who may not be aware that a plume of benzene lies beneath the building.

Hydrogen sulfide is another toxic gas that could cause dangerous conditions at the site. The OSHA acceptable concentration for a workplace is 14 mg/m^3 for an 8-hour exposure and 21 mg/m^3 for even a momentary exposure (NIOSH, 1990). The concentrations of hydrogen sulfide in the air are expected to be above acceptable levels in areas near a spill site (Enbridge, 2010) and will likely be a serious health threat to emergency workers, remediation workers, and possibly to local residents.

In addition to toxicity effects, benzene, hydrogen sulfide, and the light molecular weight fractions of the oil could create explosive conditions as they volatilize from the spilled oil. Again, this risk will be greatest in areas that are protected from the wind and where concentrations could reach the explosive limits.

Impacts to Terrestrial Resources

The proposed pipeline will cross numerous types of terrestrial habitats (e.g., upland prairies, lowland prairies, woodlands, northern high plains, etc.) as it passes from Canada to Texas. Each of these habitats is unique in terms of its physical conditions (e.g., soils, climates), biological communities, and human communities. Because the physical, biological, and human conditions are so varied in these habitats, the potential impacts from a spill will be different for each type of habitat and location. Therefore, it is not possible to thoroughly assess the potential impacts to terrestrial habitats in this paper.

In general, a primary negative impact caused by a crude oil spill on land will be burial and smothering of plants and ground-dwelling animals. The spilled DilBit will form a very dense and thick layer over the ground that will kill essentially any organisms that are contacted. This effect will be localized to the immediate area of the spill, and most animals will be able to avoid contact with the oil. However, some animals may inadvertently contact the oil (e.g., birds landing in the oil) and be harmed or killed. In addition, the spill will release toxic constituents such as benzene, hydrogen sulfide, light molecular weight oil fractions, and polycyclic aromatic hydrocarbons (PAHs), all of which will have toxic effects on local wildlife. A significant concern arises when the pipeline crosses habitats of the numerous threatened or endangered species that are found along the pipeline route. Finally, the spill could affect human communities via exposures to the toxic constituents.

Impacts to Surface Water Resources

The primary constituents of concern in surface water are: benzene, PAHs, hydrogen sulfide, and bulk crude oil. The amounts of these constituents in the surface water are affected by several factors including: the concentration of the constituent in the crude oil, the solubility of the constituent, and the turbulence and velocity of the water. Constituents of special concern are benzene and certain PAHs because they are carcinogenic.

Benzene makes up 0.1 to 1.0 percent of DilBit crude oil (Shell Canada, 2008), and it is relatively soluble in water. The amount of benzene that will be dissolved in the water can be estimated from the octanol-water partition coefficient (a measure of how much of a contaminant will dissolve into the water) which is 131.8 for benzene (LaGrega et al., 2001). Using the octanol-water relationship, and assuming that the benzene concentration in the DilBit is 1 per cent(~$1x10^4$ mg/L), results in a benzene water concentration immediately at the oil/water interface of 75 mg/L ($1x10^4$ mg/L ÷ 131.8). This benzene concentration is 15,000 times the MCL for benzene of 0.005 mg/L. Since the temperature of the DilBit will be up to158^{o}F, the actual water concentration at the spill will likely be somewhat higher than this calculation, which is based on an octanol-water partition coefficient for ambient temperatures. The benzene concentration will decrease with distance from the oil/water interface. TransCanada's Risk Assessment calculated that the average (mixed) benzene concentration in surface water for a 10,000 Bbl spill in a 10,000 ft^3/sec stream would be 2.2 mg/L (ENTRIX, 2010); however, this calculated concentration assumes that all of the benzene would be released into the water within one hour (likely over-estimates resulting concentrations) and that the benzene is immediately mixed across the entire stream (under-estimates resulting concentrations). Note that 2.2 mg/L is 440 times the MCL for benzene. In most cases, the benzene will form a plume that travels downstream from the spill site. The concentration in the plume will gradually decrease as it moves farther from the spill site.

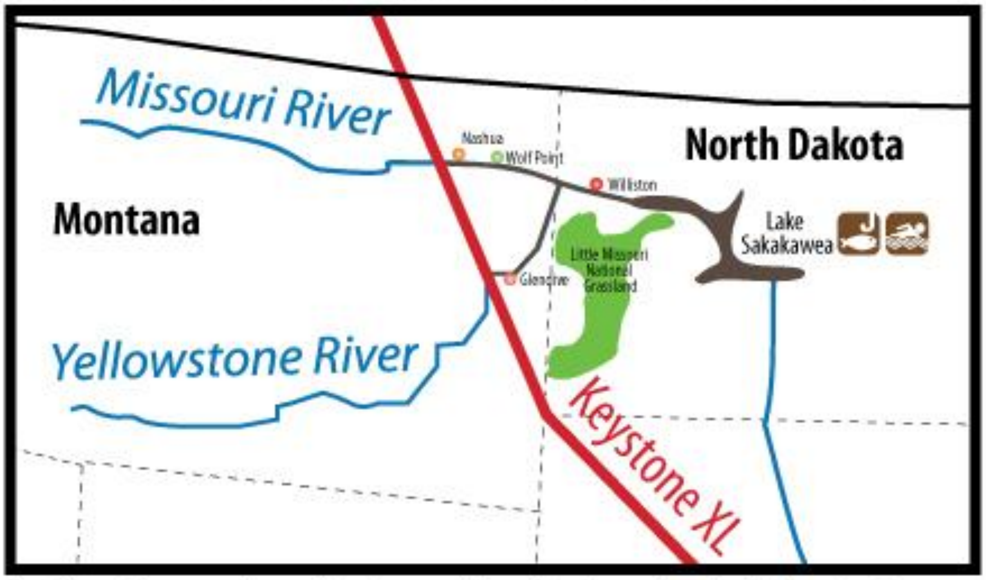
Besides human health risks from contaminated drinking water supplies, benzene also poses risks to aquatic species. The EPA Region III screening water concentration for benzene designed to be protective of aquatic biota is 0.370 mg/L (EPA, 2011b). The predicted benzene concentration at the oil/water interface is 75 mg/L which is 200 times higher than the screening concentration. Therefore, negative ecological impacts due to toxicity are expected, at least in localized areas where benzene is actively dissolving from the oil.

If a spill of 150,000 Bbl (i.e., in the range of predicted worst-case spill volumes) were to occur in a stream with a flow of 10,000 ft^3/sec and a velocity of 3 ft/sec (e.g., the Missouri River below Fort Peck dam has a flow of 9,225 cfs, and the Yellowstone River at Miles City, MT has a flow of 11,180 cfs (USGS, 2009)), the mass and resulting plume of the benzene in the water could be characterized as follows. Assuming that benzene makes up 1.0percent of the DilBit, 150,000 Bbl of DilBit would contain approximately $2.3x10^5$ Kg of benzene (150,000 Bbl * 42 gal/Bbl * 3.788 L/gal * 1 Kg/L * 0.01). If 80 percent of the benzene is lost via volatilization and product removal during and immediately after the spill, $4.77x10^4$ Kg of benzene would remain in the stream. This benzene would dissolve through time into the water from the DilBit mixture. To be released into the water, the benzene in the mass of crude would have to diffuse to the oil/water interface. Since the composition of DilBit is variable and since the thickness of the crude mass is case-specific (i.e., depends on turbulence, temperature, etc.), it is not possible to predict precisely the rate at which the benzene will diffuse to the oil/water interface; however, a reasonable assumption would be that 5percent of the benzene would reach the oil/water interface per day. If this assumption is too high, these calculations will over estimate the water concentrations but underestimate the duration of the negative impacts, and if it is too small, the opposite will be true. Assuming 5percent of the benzene is released into the water per day, over 2.3 million grams of benzene will be released to the water per day. This will result in a water concentration of 0.09 mg/L ($2.3x10^6$ g/d * sec/10,000 ft^3 * 1d/86,400 sec *1,000 mg/g * 35.3 ft^3/m^3 * 0.001 m^3/L) once the contaminant plume completely mixes across the entire width of the stream (several miles downstream of the spill). This concentration exceeds the MCL of 0.005 mg/L by 18.8 times. As the benzene plume migrates downstream, the concentration will decrease because of processes such as degradation and volatilization. Reported half-lifes of benzene in surface water range from 1 to 6 days (USEPA, 1986). Assuming a half-life of 3 days, a stream velocity of 3 ft/sec, and a tributary contribution of 20 cfs/mi (the measured value for the Missouri River downstream of the proposed crossing (USGS, 2009)), the plume would reach over 450 miles before its concentration would drop to the MCL and be safe for public water intakes. The plume length was modeled using a series of 10-mile long river reaches with first-order decay ($k=-0.231d^{-1}$) and increased flow of 200 cfs/10 mi reach.

Contaminants from a release at the Missouri or Yellowstone River crossing would enter Lake Sakakawea in North Dakota where they would adversely affect drinking water intakes, aquatic wildlife, and recreation. Contaminants from a spill at the Platte River crossing would travel downstream unabated into the Missouri River for several hundred miles affecting drinking water intakes for hundreds of thousands of people (e.g., Lincoln, NE; Omaha, NE; Nebraska City, NE; St. Joseph, MO; Kansas City, MO) as well as aquatic habitats and recreational activities. In addition, other constituents from the spill would pose serious risks to humans and to aquatic species in the river.

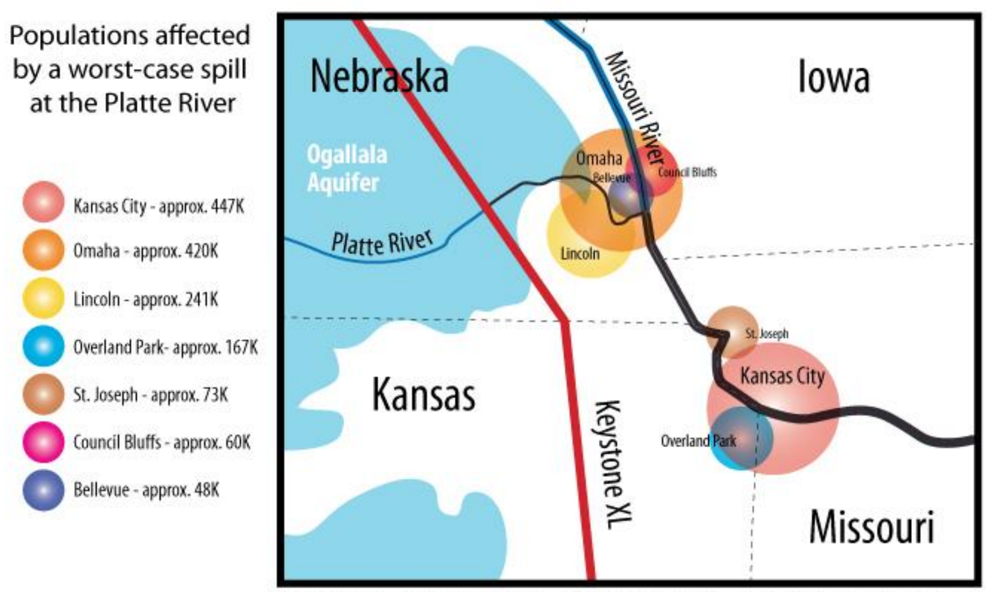
Map 1:

Worst-case spill at the Missouri River or Yellowstone River crossing.



A spill at either crossing could release millions of gallons of crude oil into the rivers and extending downstream as far as Lake Sakakawea, polluting drinking water, and threatening endangered species and recreation areas.

Map 2:



Population estimates based on available data from the U.S. Census Bureau, http://quickfacts.census.gov. Circles representing these cities are for illustrative purposes and are not to scale.

Of course other assumptions (e.g., shorter half-life) would give somewhat different results. For example, assuming that benzene makes up only 0.3 percent of DilBit and that 10 percent of the benzene is released per day, the calculated plume length would be reduced to around 200 miles. However, since the case-specific details are not known at this point, the precise impacts cannot be calculated; however, it has been clearly shown that if a worst-case spill occurs in a major stream, the impacts would be serious, far-reaching, and long-lasting, and claims to the contrary should be challenged.

The concentrations of PAHs (e.g., benz(a)pyrene) are not specified in the Material Safety Data Sheet(MSDS) for DilBit (Shell Canada, 2008). Also, the risk assessment done for the pipeline (ENSR, 2006) discusses the presence of PAHs, but doesn't detail specific concentrations. Therefore, this analysis will assume that PAHs make up 2 percent of DilBit, and that benz(a)pyrene (BaP) makes up one-tenth of the PAHs or 0.2 percent of the DilBit. This is likely an underestimate. PAHs are not as soluble or as mobile in surface water as is benzene. Much of the released PAH mass will sorb to sediments and remain closer to the location of the spill. However, they will be transported downstream with suspended solids and sediments, and the PAH fraction that does dissolve will form a plume and also be transported downstream. Since they are less soluble and mobile than benzene, PAHs pose less of a threat to municipal water intakes. Using the octanol-water coefficient for benz(a)pyrene (BaP) of 1.1×10^6 (LaGrega et al., 2001), the BaP concentration at the oil/water interface would be 0.0018 mg/L (1.8 µg/L). This concentration exceeds the MCL for BaP of 0.0002 mg/L by a factor of about ten; however, this concentration would be quickly reduced as the plume mixes in the stream. Therefore, based on the assumption that PAHs make up 2percent of the DilBit, drinking water is probably not significantly threatened from release of PAHs.

However, PAHs are toxic to aquatic organisms. The EPA Region III water quality criteria for benz(a)pyrene to protect aquatic species is 0.015 µg/L (EPA, 2011b). In addition, there are several other PAHs with water quality values to protect aquatic species (e.g., benzo(a)anthracene (0.018 µg/L), fluoranthene (0.04 µg/L), and naphthalene (1.1 µg/L)) that are likely to have concentrations that exceed water quality criteria in a major spill. Therefore, the estimated concentration of PAHs is approximately 100 times the allowable level for protection of aquatic life.

Hydrogen sulfide is very volatile, and much of it will likely volatilize to the air during a major spill. However, some of the hydrogen sulfide will dissolve into the surface water and cause toxic effects to the aquatic biota. The EPA Region III screening water concentration protective of aquatic species is 2.0 µg/L. Since the hydrogen sulfide will quickly volatilize, it is expected that these toxic effects will be limited to areas near the spill.

Bitumen, which makes up most of the DilBit, is more dense than water, so it will sink to the bottom and smother any aquatic plants or sediment-dwelling organisms. These effects will be limited to the immediate area of the spill and are expected to pose a significant risk primarily if the stream is the habitat to threatened or endangered species. Since the Missouri, Yellowstone, and Platte Rivers all provide habitat to threatened and endangered species, including the pallid sturgeon, interior least tern, and piping plover, these impacts should be considered potentially significant.

Table 5: Benzene Plume Development for Spill of 150,000 Bbl into a 10,000 cfs Stream.

	Estimate From This Analysis
Spill Volume	150,000 Bbl
Stream Discharge	10,000 cfs
Fully Mixed Concentration[a]	0.09 mg/L
Ratio of Concentration to MCL [b]	18.8
Length of Plume > MCL [c]	450 miles
Duration of Release to Water [d]	20 days

(a) mg/sec benzene release to stream ÷ L/sec of flow (10,000 cfs = 283,286 L/sec)
(b) fully mixed concentration ÷ 0.005 mg/L
(c) assumes half-life of 3 d; velocity of 3 ft/sec;
(d) assumes 5percent of benzene is released from DilBit mass per day

Impacts to Groundwater Resources

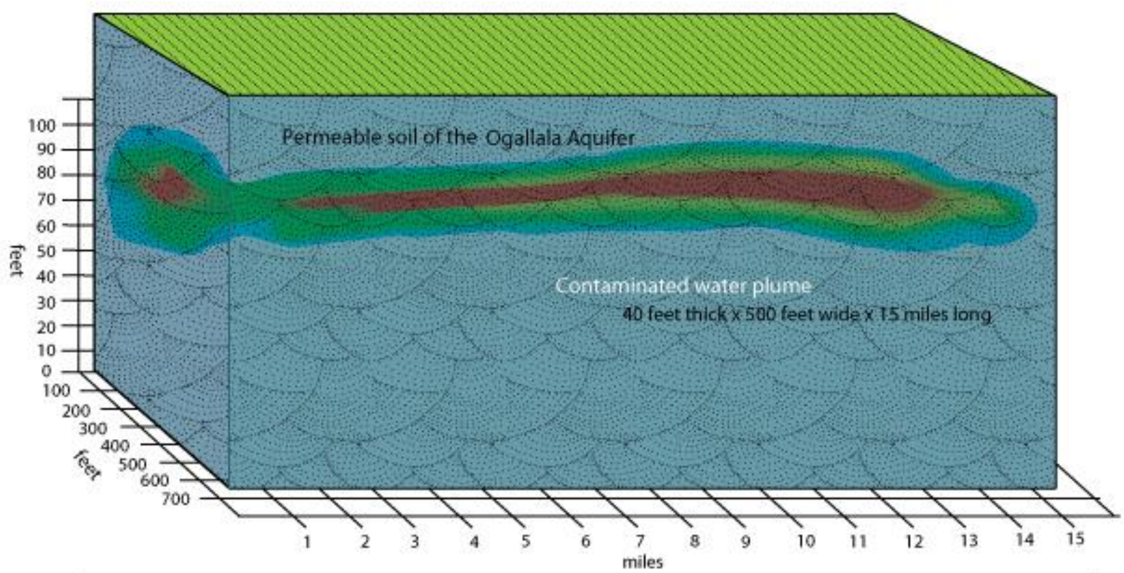
The primary constituent of concern for a spill into groundwater is benzene. Since DilBit is very viscous, the bulk crude oil will not likely migrate through the soil to groundwater in large quantities. However, if a small, underground leak remains undetected for an extended period of time, a large amount of benzene will be released with the DilBit. The released benzene could then be transported to groundwater via infiltrating rainwater. According to a TransCanada publication "Frequency-Volume Study of Keystone Pipeline" (DNV, 2006), a leak of 1.5 percent of total flow could remain undetected for 90 days. For this analysis, the discovery and shut-down time is assumed to be 14 days which corresponds to the time between pipeline inspections. At the design flow rate of 900,000 Bbl/d, a 1.5 percent leak would release 189,000 Bbl (7.9 million gallons) of DilBit in 14 days. Since DilBit is 0.1 to 1.0 percent benzene, this would result in a release of up to 79,380 gallons of benzene.

A spill of the magnitude of 189,000 Bbl of DilBit would occupy approximately 2.65×10^6 cubic feet of subsurface sands with a porosity of 0.4 (189,000 Bbl * 5.61 ft^3/Bbl ÷ 0.4). Assuming that theDilBit mass occupies a somewhat cylindrical volume and that the aquifer is 20 feet below the pipeline, the DilBit would spread to an area approximately 335 feet in diameter (335 feet diameter X 30 feet high). A reasonable worst-case 100-year, 24-hour storm would deposit 6 inches of rainwater on the site. In the Sandhills of Nebraska, nearly all of this water would infiltrate. Six inches of water infiltrating onto a contaminated area of 8.8×10^4 ft^2 (335 feet diameter) results in 4.4×10^4 cubic feet of water (8.8×10^4 ft^2 * 0.5 ft infiltrating water) contacting the DilBit. Using the octanol-water partition coefficient of 131.8 (LaGrega et al., 2001), the benzene concentration in the infiltrating water would be approximately 75 mg/L.

The 4.4x10^4 cubic feet of water at a concentration of 75 mg/L equates to 9.35x10^7 milligrams of benzene. Thus, this storm would transport 9.35x10^7 milligrams of benzene to the groundwater. Once in the groundwater, the benzene plume would migrate down-gradient, potentially to down-gradient water supplies or basements where it could pose a cancer risk to residents. The 9.35x10^7 milligrams of benzene in the groundwater, if evenly distributed (not likely) could pollute 1.9x10^{10} Liters (4.9x10^9 gallons) of groundwater at the MCL, enough water to form a plume 40 feet thick by 500 feet wide by more than 15 miles long (assuming porosity of 0.4) at the MCL. These plume dimensions are given for illustrative purposes only. The actual dimensions of a groundwater plume cannot be determined with the available information. Of course, the benzene would not be evenly distributed; however, the plume would still be many miles long. In addition, future storms would transport additional benzene to the groundwater increasing the size of the plume.

Figure 4:

Worst-case spill above the Nebraska Sandhills.



A spill over 14 days, releasing 7.9 million gallons of crude oil could contaminate 4.9 billion gallons of water and form a plume 40 feet thick by 500 feet wide by 15 miles long. By comparison:

The length of the plume is equal to 264 football fields.
Manhattan is 13.4 miles long.
The volume of the plume (1,584,000,000 feet^3) is equal to that of 19,631 Olympic sized pools.

The worst-case site for such a spill is in the Sandhills region of Nebraska. The Sandhills are ancient sand dunes that have been stabilized by grasses. Because of their very permeable geology, nearly 100 percent of the annual rainfall infiltrates to a very shallow aquifer, often less than 20 feet below the surface. This aquifer is the well-known Ogallala Aquifer that is one of the most productive and important aquifers in the world.

Table 6: Benzene Plume from a189,000 Bbl Spill to Groundwater.

Volume of released DilBit (Bbl)	189,000
Volume of benzene in spill (gal)	79,380
Mass of benzene dissolved in groundwater (mg)	9.35×10^{7}
Volume of contaminated water > MCL (gal)	4.9×10^{9}
Equivalent plume dimensions	40 feet X 500 feet X 15 miles

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Excerpts and thoughts by Dr. John Stansbury re. human health effects from KXL:

a. TransCanada's Risk Assessment calculated that the average (mixed) benzene concentration in surface water for a 10,000 Bbl spill in a 10,000 ft3/sec stream would be 2.2 mg/L (ENTRIX, 2010); however, this calculated concentration assumes that all of the benzene would be released into the water within one hour (likely over-estimates resulting concentrations) and that the benzene is immediately mixed across the entire stream (under-estimates resulting concentrations). Note that 2.2 mg/L is 440 times the MCL for benzene. Beyond admitting that the concentration will be unacceptable, and therefore, pose a human health risk, there is no further analysis. There should have been a human health risk assessment that would have estimated the increased risk of cancer, but there isn't any such assessment. They simply state that the concentration will be unacceptable and leave it at that.

b. Stansbury (not TransCanada) estimates benzo(a)pyrene (BaP) concentration at the oil/water interface of a major spill into a stream would be 1.8 μg/L. The EPA Region III water quality criteria for benz(a)pyrene to protect aquatic species is 0.015 μg/L (EPA, 2011b). In addition, there are several other PAHs with water quality values to protect aquatic species (e.g., benzo(a)anthracene (0.018 μg/L), fluoranthene (0.04 μg/L), and naphthalene (1.1 μg/L)) that are likely to have concentrations that exceed water quality criteria in a major spill. Therefore, the estimated concentration of PAHs is approximately 100 times the allowable level for protection of aquatic life. Note that the reason Stansbury's estimate is used here is that TransCanada failed to assess even the potential concentrations of PAHs let alone assess the potential health and environmental risks posed by the release of these chemicals.

c. According to a TransCanada publication "Frequency-Volume Study of Keystone Pipeline" (DNV, 2006), a leak of 1.5 percent of total flow could remain undetected for 90 days. For this analysis, the discovery and shut-down time is assumed to be 14 days which corresponds to the time between pipeline inspections. At the design flow rate of 900,000 Bbl/d, a 1.5 percent leak would release 189,000 Bbl (7.9 million gallons) of DilBit in 14 days. Since DilBit is 0.1 to 1.0 percent benzene, this would result in a release of up to 79,380 gallons of benzene into the groundwater. If the leak does go undetected for 90 days as the TransCanada document reports, a groundwater user could be exposed to unacceptable concentrations of benzene for a significant period of time. There should have been a human health risk assessment that would have estimated the increased risk of cancer, but there isn't any such assessment. They simply indicate that there could be a significant, undetected release of benzene which could be consumed by human receptors and leave it at that. Note, be careful using my "estimate" of a groundwater plume dimensions. As it states in my report, this is not a prediction of a plume size, it is only the dimensions that a plume could have for the predicted amount of released benzene – the actual plume size would depend on a lot of site-specific conditions.

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA

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IN THE MATTER OF THE APPLICATION BY TRANSCANADA KEYSTONE PIPELINE, LP FOR A PERMIT UNDER THE SOUTH DAKOTA ENERGY CONVERSION AND TRANSMISSION FACILITIES ACT TO CONSTRUCT THE KEYSTONE XL PROJECT	: : : : :	HP 14-001 TRANSCANADA KEYSTONE PIPELINE, LP'S OBJECTIONS TO CINDY MYERS' FIRST INTERROGATORIES AND REQUEST FOR PRODUCTION OF DOCUMENTS

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TransCanada Keystone Pipeline, LP ("Keystone") makes the following objections to interrogatories pursuant to SDCL § 15-6-33 and objections to request for production of documents pursuant to SDCL § 15-6-34(a). Keystone will further respond, as indicated throughout the objections, on or before February 6, 2015. These objections are made within the scope of SDCL § 15-6-26(e) and shall not be deemed continuing nor be supplemented except as required by that rule.

GENERAL OBJECTION

Keystone objects to the instructions and definitions contained in Cindy Myers' First Set of Interrogatories and Requests for Production of Documents to the extent that they are inconsistent with the provisions of SDCL Ch. 15-6. *See* ARSD 20:10:01:01.02.

{01808665.1}

Keystone's answers are based on the requirements of SDCL §§ 15-6-26, 15-6-33, 15-6-34, and 15-6-36.

INTERROGATORIES AND REQUEST FOR PRODUCTION OF DOCUMENTS

1. Please identify the person or persons providing each answer to an Interrogatory or portion thereof, giving the full name, address of present residence, date of birth, business address and occupation.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

2. Prior to answering these interrogatories, have you made due and diligent search of all books, records, and papers of the Applicant with the view of eliciting all information available in this action?

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

2(a). Describe how TransCanada will comply with these Acts as they apply to the project in relation to rivers, ground water and water system crossings in South Dakota.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

2(b). Provide research entailing migration of benzene in watersheds, rivers and ground water.

ANSWER: Any responsive, non-privileged documents will be provided on or before February 6, 2015.

8(a). Explain what changes have been made in the Emergency Response Plan and Integrity Management Plan since 2010.

OBJECTION: To the extent that this request seeks production of the Emergency Response Plan, the request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan and the integrity management plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

8(b). Provide the Emergency Response Plan.

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

8(c). Provide the Integrity Management Plan.

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the integrity management plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Integrity Management Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation.

18(a). Where will fuel storage facilities be located within 200 feet of private wells and 400 feet of municipal wells?

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

18(b). How will minimizing and exercising vigilance be enforced?

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

21(a). Define "frac-out."

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

21(b). What are concerns and safety issues related to a "frac-out."

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

21(c). Provide "frac-out plan."

ANSWER: Any responsive, non-privileged documents will be provided on or before February 6, 2015.

34(a). Describe what progress has been made in the evaluation and performance assessment activities regarding high consequence areas since 2010.

OBJECTION: To the extent that this request seeks a list of High Consequence Areas, the identity and location of High Consequence Areas is confidential by statute and Keystone is required by PHMSA to keep this information confidential. To the extent that this request seeks production of the Emergency Response Plan, the request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http:///keystonepipeline-xl.state.gov/documents/organization/221189.pdf. Without waiving the objection, Keystone will provide a response to the rest of the request on or before February 6, 2015.

34(b). Define "high consequence area."

OBJECTION: To the extent that this request seeks a list of High Consequence Areas, the identity and location of High Consequence Areas is confidential by statute and Keystone is required by PHMSA to keep this information confidential. Without waiving the objection, Keystone will provide a response to the rest of the request on or before February 6, 2015.

34(c). Provide a completed list of high consequence areas.

OBJECTION: The identity and location of High Consequence Areas is confidential by statute and Keystone is required by PHMSA to keep this information confidential.

34(d). Explain how project inhabitants and local communities will be informed and educated about high consequence areas.

OBJECTION: To the extent that this request seeks a list of High Consequence Areas, the identity and location of High Consequence Areas is confidential by statute and Keystone is required by PHMSA to keep this information confidential. Without waiving the objection, Keystone will provide a response to the rest of the request on or before February 6, 2015.

34(c). Provide a copy of the Emergency Response Plan. (Requested above with #8.)

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

34(f). Provide Integrity Management Plan. (Requested above with #8.)

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the integrity management plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Integrity Management Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation.

35(a). Provide the Integrity Management and Emergency Response Plans. (Requested above.)

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan and the integrity management plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit these documents to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

35(b). Define "Unusually Sensitive Areas."

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(c). Define "Hydrologically Sensitive Areas."

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(d). Explain how unusually sensitive areas and hydrologically sensitive areas are addressed differently compared to other areas.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(e). Confirm that you are not fully aware of all vulnerable and beneficially useful aquifers and your intent is to only become aware of them during construction and route evaluation not yet completed.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(f). Define "unconfined aquifers."

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(g). List known unconfined aquifers to be crossed by the project.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(h). Explain the concern of routing through unconfined aquifers.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(i). Describe how it could be possible to route through an unknown, unconfined aquifer during construction.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(j). Provide documentation of further route evaluation since 2010, including assessments for aquifers and hydrologically sensitive areas.

OBJECTION AND RESPONSE: This request is vague, overlybroad, and unduly burdensome. Without waiving the objection, any responsive, non-privileged documents showing changes in the route or addressing aquifers and hydrologically sensitive areas will be provided on or before February 6, 2015.

35(k). Explain how you will deem an aquifer vulnerable and beneficially useful?

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

35(l). This condition states: "…in some reaches of the Project in southern Tripp County, the High Plains Aquifer is present at or very near ground surface and is overlain by highly permeable sands permitting the uninhibited infiltration of contaminants." Sandy soil and ground water at or above the surface means a pipe with expected pinhole leaks will be immersed in ground water. This is the exact type of situation of soil/ground water which caused the route change in Nebraska. If this was reason to change the route in Nebraska, explain why it is still acceptable in South Dakota.

OBJECTION AND RESPONSE: This request is argumentative and assumes facts not in evidence. Without waiving the objection, Keystone will answer this interrogatory on or before February 6, 2015.

35(m). Explain TransCanada's follow-up with suggestion by DENR staff, given in testimony, to reroute the KXL pipeline around the city of Colome's source water area.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

36(a). Identify all emergency medical response planning contained within the emergency response plan.

OBJECTION: This request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the exclusive province of PHMSA. The PUC's jurisdiction over the emergency response plan is preempted by federal law, which has exclusive jurisdiction over issues of pipeline safety. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. See Amended Final Order, HP 09-001, Condition ¶ 36. Public disclosure of the emergency response plan would commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

36(b). What actions have been taken by TransCanada to ensure the medical communities in South Dakota are prepared and educated to treat people exposed to spills and water contamination from spills?

OBJECTION AND RESPONSE: To the extent that this request seeks production of the Emergency Response Plan, this request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the exclusive province of PHMSA. The PUC's jurisdiction over the emergency response plan is preempted by federal law, which has exclusive jurisdiction over issues of pipeline safety. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. See Amended Final Order, HP 09-001, Condition ¶ 36. Public disclosure of the emergency response plan would commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency

Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf. Without waiving the objection, Keystone will provide a response on or before February 6, 2015.

36(c). How will inhabitants and communities near the project area be notified of spills?

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

40(a). Provide documentation supporting your assertion that polyethylene water piping is permeable to BTEX.

ANSWER: Any responsive, non-privileged documents will be provided on or before February 6, 2015.

40(b). Explain health concerns related to BTEX.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

40(c). Provide an MSDS of all products to be transported in KXL, including the diluents.

ANSWER: Any responsive, non-privileged documents will be provided on or before February 6, 2015.

40(d). Provide list of ground water quality standards, specifically listing chemicals involved in tar sands oil product and diluents.

OBJECTION: Keystone does not determine ground water quality standards. They are established by the South Dakota Department of Environment and Natural Resources.

40(e). Describe how the decision was made to designate concern of BTEX only within 500 feet of the Project.

OBJECTION: This request seeks information that is not within Keystone's custody or control. This decision was made by the PUC as part of Amended Permit Condition 40.

40(f). Confirm this safety measure will only be implemented at the request of a landowner or public water supply system.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

40(g). Explain why this measure is optional instead of mandatory.

OBJECTION: This request seeks information that is not within Keystone's custody or control. This decision was made by the PUC as part of Amended Permit Condition 40.

40(h). TransCanada has agreed to do this: "At least forty-five days prior to commencing construction, Keystone shall publish a notice in each newspaper of general circulation in each county through which the Project will be constructed advising landowners and public water supply systems of this condition." What percent of inhabitants do you expect to reach by issuing a warning in this manner?

OBJECTION AND RESPONSE: This request is speculative and argumentative. A notice is not a "warning." Without waiving the objection, Keystone expects that notice in newspapers of general circulation would reach a substantial portion of the inhabitants.

46(a). Provide written plan as to how you will find and provide a permanent water supply for various locations along route if a well should become contaminated, including specific alternate sources.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

46(b). Define "quantity" as it is used in this condition.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

46(c). Provide cost estimates for providing water to the city of Colome, domestic wells or an entire ranching operation should water supplies become contaminated.

ANSWER: Any responsive, non-privileged documents will be provided on or before February 6, 2015.

46(d). Explain how providing a permanent water supply will be ensured into perpetuity.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

46(e). Explain how people and cattle using private wells and public wells can be assured their water is free of contamination from undetected leakage, particularly in Tripp County.

OBJECTION: This request seeks information that is not within Keystone's custody or control.

46(f). Describe what experience South Dakota has had cleaning up tar sands oil product spills into rivers and ground water.

OBJECTION: This request seeks information that is not within Keystone's custody or control.

46(g). Describe any experience the State of South Dakota or any other state has had in "sparging" ground water in order to cleanse tar sands oil product from aquifers.

OBJECTION: This request seeks information that is not within Keystone's custody or control.

46(h). Describe types of spills which may be difficult or impossible to remediate.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

46(i). Identify responsible parties who will conduct water analysis to assure toxins from undetected leaks have not migrated into water resources, including frequency of testing and who will assume cost of testing.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

46(j). Describe potential scenarios in which medical costs related to contamination will be reimbursed.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

46(k). Provide a detailed listing of potential toxins which could contaminate wells.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

46(l). Provide documentation detailing adverse health effects caused from exposure to these toxins, including the various routes of entry into the human body.

ANSWER: Any responsive, non-privileged documents will be provided on or before February 6, 2015.

18(a). Regarding an advisory warning issued in September, 2014 by the federal Pipeline and Hazardous Materials Safety Administration, what are TransCanada's plans to ensure pipeline safety due to the fact different types of product will be transported in KXL?

OBJECTION AND RESPONSE: This request seeks information related to pipeline safety, which is within the exclusive jurisdiction of PHMSA. Without waiving the objection, Keystone will answer this interrogatory on or before February 6, 2015.

18(b). PHMSA cautioned pipeline operators across the country about "the potential significant impact flow reversals, product changes and conversion to service may have on the integrity (safety) of a pipeline." The advisory adds: "Flow reversals, product changes, and conversions to service may impact various aspects of a pipeline's operation, maintenance, monitoring, integrity management, and emergency response. Pressure gradients, velocity, and the location, magnitude, and frequency of pressure surges and cycles may change. Operators may also consider increasing the throughput capacity of the pipeline. Increasing throughput may also impact the pressure profile and pressure transients. … Leak detection and monitoring systems may be affected."

OBJECTION: This request is not a question and cannot be answered. It also relates to an issue that is within the exclusive jurisdiction of PHMSA and is therefore not relevant or likely to lead to the discovery of admissible evidence.

18(c). Current regulations state: "Operators must review their integrity (safety) management program. … Operators must notify PHMSA if these changes will substantially affect their integrity management program, its implementation, or modifies the schedule for carrying out the program elements."

OBJECTION: This request is not a question and cannot be answered. It also relates to an issue that is within the exclusive jurisdiction of PHMSA and is therefore not relevant or likely to lead to the discovery of admissible evidence.

18(d). KXL is intended to transport two very different products, the much less dense and highly volatile Bakken oil product and the heavy diluted bitumen from Alberta. How will the two very different products affect KXL's operation, maintenance, monitoring, integrity management, and emergency response? How will the two very different products affect pressure gradients, velocity, and the location, magnitude, and frequency of pressure surges and cycles?

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

33(a). Provide updated maps.

OBJECTION: This request is vague, overlybroad, unduly burdensome, and seeks information that is not relevant or likely to lead to the discovery of admissible evidence. Without waiving the objection, Keystone will provide maps showing changes to the route on or before February 6, 2015.

41(a). Provide map detailing all water bodies to be crossed in S.D., to include locations KXL would cross the Missouri and Yellowstone Rivers upstream from S.D.

OBJECTION: Keystone has previously filed with the PUC maps showing the route through South Dakota, which also show where the pipeline crosses rivers and other water bodies. Waterbody crossing permitting is within the control of the United States Army Corps of Engineers, and is beyond Keystone's control.

41(b). Provide map clearly depicting all waterways crossed by route which are tributaries into the Missouri River.

OBJECTION: Keystone has previously filed with the PUC maps showing the route through South Dakota, which also show where the pipeline crosses rivers and other water bodies.

41(c). Identify distances from KXL waterway crossings to point of confluence with the Missouri River.

OBJECTION: This request seeks information that is beyond Keystone's custody and control and not maintained within the ordinary course of business.

41(d). Provide map(s) demonstrating all public water utility intakes on the Missouri River system.

OBJECTION AND RESPONSE: This request is overlybroad, unduly burdensome, and seeks information that is not within Keystone's custody or control.

Without waiving the objection, Keystone will provide information related to defined well head protection areas and source water intakes within the area of its risk assessment to the extent that they are not confidential.

41(e). By what date will permitting of water body crossings be completed?

OBJECTION: Permitting of water body crossings is within the control of the United States Army Corps of Engineers, and is beyond Keystone's control.

41(f). Provide a copy of the CMR Plan. Ex TC-1, 5.4.1, pp. 45-46.

OBJECTION: A current copy of the CMR Plan is attached to Keystone's certification petition and is on file with the PUC.

41(g). Provide research which describes migration of spillage in these waterways.

OBJECTION: This request is vague, overlybroad, and unduly burdensome.

41(h). Please explain and describe water protection areas located downstream of major river crossings on the proposed route.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

41(i). Explain risks of HDD, including possibility of contaminants being released into waterways during this process.

ANSWER: Keystone will answer this interrogatory on or before February 6, 2015.

50(a). Provide a map depicting the High Consequence Areas.

OBJECTION: This request seeks the identity and location of High Consequence Areas, which is confidential by statute, and Keystone is required by PHMSA to keep this information confidential.

50(b). Explain why the total length of pipe affecting HCA decreased from 34.3 miles to 19.9 miles.

OBJECTION: To the extent that this request seeks the identity and location of High Consequence Areas, that information is confidential by statute and Keystone is required by PHMSA to keep this information confidential. Keystone will provide a response to the rest of the request on or before February 6, 2015.

50(c). Explain how the statistic which states a spill could affect a HCA no more than once in 250 years.

OBJECTION: To the extent that this request seeks the identity and location of High Consequence Areas, that information is confidential by statute and Keystone is required by PHMSA to keep this information confidential. Keystone will provide a response to the rest of the request on or before February 6, 2015.

107(a). Provide the analysis by Dr. Michael Madden which professes the Project would not (ii) substantially impair the health, safety, or welfare of the inhabitants in the project area.

OBJECTION: Dr. Madden was PUC Staff's witness in Docket 09-001, and his direct testimony is a matter of public record.

107(b). Explain how the 2010 permit, which relies on the federal environmental impact statement prepared by the Department of State, addresses specific concerns of South Dakota, including the health, safety and welfare of South Dakota citizens.

OBJECTION: This request is vague, unclear, argumentative, and seeks information that is not relevant or likely to lead to the discovery of admissible evidence. The PUC addressed the health, safety, and welfare of South Dakota residents in the Amended Final Decision and Order in Docket 09-001. In addition, South Dakota residents had notice and opportunity to participate in the lengthy NEPA process conducted by the Department of State.

107(c). Explain your interpretation of "substantially" as it is used in state law SDCL 49-41 B-22 which states the applicant for a facility construction permit has the burden of proof to establish that:

(3) "The facility will not substantially impair the health, safety or welfare of the inhabitants."

OBJECTION: This request seeks a legal opinion or conclusion and is therefore beyond the scope of discovery and not likely to lead to the discovery of admissible evidence under SDCL § 15-6-26(b). It was an issue for the PUC to determine in Docket HP 09-001.

107(d). State with 100% certainty that this project will have no impact on the health, safety or welfare of the people of South Dakota.

OBJECTION: This request is argumentative and seeks information that is not relevant or likely to lead to the discovery of admissible evidence. The PUC addressed the health, safety, and welfare of South Dakota residents in the Amended Final Decision and Order in Docket 09-001. Keystone has not asserted that the project would have "no impact" on the health, safety, or welfare of the people of South Dakota.

107(e). Describe how areas of dense populations versus areas of sparse populations affect project decision.

OBJECTION AND RESPONSE: This request is vague and unclear. Without waiving the objection, to the extent feasible and consistent with other routing criteria, areas of dense population are avoided during project routing.

Dated this 23rd day of January, 2015.

WOODS, FULLER, SHULTZ & SMITH P.C.

By /s/ James E. Moore

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CERTIFICATE OF SERVICE

I hereby certify that on the 23rd day of January, 2015, I sent by e-mail transmission, a true and correct copy of Keystone's Objections to Cindy Myers' First Interrogatories and Request for Production of Documents, to the following:

Cindy Myers, R.N.
PO Box 104
Stuart, NE 68780
csmyers77@hotmail.com

/s/ James E. Moore
One of the attorneys for TransCanada

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA

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IN THE MATTER OF THE APPLICATION BY TRANSCANADA KEYSTONE PIPELINE, LP FOR A PERMIT UNDER THE SOUTH DAKOTA ENERGY CONVERSION AND TRANSMISSION FACILITIES ACT TO CONSTRUCT THE KEYSTONE XL PROJECT	: : : : :	HP 14-001 TRANSCANADA KEYSTONE PIPELINE, LP'S RESPONSES TO CINDY MYERS' FIRST INTERROGATORIES AND REQUEST FOR PRODUCTION OF DOCUMENTS

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Applicant TransCanada makes the following responses to interrogatories pursuant to SDCL § 15-6-33, and responses to requests for production of documents pursuant to SDCL § 15-6-34(a). These responses are made within the scope of SDCL 15-6-26(e) and shall not be deemed continuing nor be supplemented except as required by that rule. Applicant objects to definitions and directions in answering the discovery requests to the extent that such definitions and directions deviate from the South Dakota Rules of Civil Procedure.

GENERAL OBJECTION

Keystone objects to the instructions and definitions contained in Cindy Myers' First Set of Interrogatories and Requests for Production of Documents to the extent that they are inconsistent with the provisions of SDCL Ch. 15-6. *See* ARSD 20:10:01:01.02.

Keystone's answers are based on the requirements of SDCL §§ 15-6-26, 15-6-33, 15-6-34, and 15-6-36.

INTERROGATORIES AND REQUEST FOR PRODUCTION OF DOCUMENTS

1. Please identify the person or persons providing each answer to an Interrogatory or portion thereof, giving the full name, address of present residence, date of birth, business address and occupation.

ANSWER: Given the extremely broad scope volume of more than 800 discovery requests received by Keystone in this docket, a range of personnel were involved in answering the interrogatories. Keystone will designate the following witnesses with overall responsibility for the responsive information as related to the Conditions and proposed changes to the Findings of Fact, which are identified in Appendix C to Keystone's Certification Petition: Corey Goulet, President, Keystone Projects, 450 1st Street S.W., Calgary, AB Canada T2P 5H1; Steve Marr, Manager, Keystone Pipelines & KXL, TransCanada Corporation, Bank of America Center, 700 Louisiana, Suite 700, Houston, TX 77002; Meera Kothari, P. Eng., 450 1st Street, S.W., Calgary, AB Canada T2P 5H1; David Diakow, Vice President, Commercial, Liquids Pipeline, 450 1st Street S.W., Calgary, AB Canada T2P 5H1; Jon Schmidt, Vice President, Environmental & Regulatory, exp Energy Services, Inc., 1300 Metropolitan Boulevard, Suite 200, Tallahassee, FL 32308; Heidi Tillquist, Senior Associate, Stantec Consulting Ltd., 2950 E. Harmony Rd., Suite 290, Fort Collins, CO 80528.

2. Prior to answering these interrogatories, have you made due and diligent search of all books, records, and papers of the Applicant with the view of eliciting all information available in this action?

ANSWER: Yes, to the extent reasonably practicable in attempting to respond to over 800 discovery requests within the time allowed.

2(a). Describe how TransCanada will comply with these Acts as they apply to the project in relation to rivers, ground water and water system crossings in South Dakota.

ANSWER: Keystone will comply with Clean Water Act 404 by permitting the crossing of all jurisdictional waterbodies in South Dakota under the US Army Corps of Engineers Nationwide General Permit (NWP) 12. As part of the permitting process of the Project route in South Dakota, Keystone will submit a NOI to the US Army Corps of Engineers, South Dakota Regulatory Office and will consult as required with the South Dakota Regulatory Office.

No waterbody crossing in South Dakota requires permitting under the Section 10 Rivers and Harbor Act.

2(b). Provide research entailing migration of benzene in watersheds, rivers and ground water.

ANSWER: The fate and transport of benzene and other crude oil constituents is discussed in numerous studies and articles, including those in the Department of State SFEIS Appendix P, 2009 Keystone XL Risk Assessment, such as:

Freeze, R. A. and J. A. Cherry. 1979. Groundwater. Prentice Hall, Inc. Englewood Cliffs, New Jersey. 604 pp.

Minnesota Pollution Control Agency. 2005. Assessment of Natural Attenuation at Petroleum Release Sites. Guidance Document c-prp4-03, Petroleum Remediation Program, Minnesota Pollution Control Agency. April 2005. 11 pp.

Neff, J. M. 1979. Polycyclic aromatic hydrocarbons in the aquatic environment. Applied Science publ. Ltd., London. 262 pp.

Newell, C. J. and J. A. Connor. 1998. Characteristics of Dissolved Petroleum Hydrocarbon Plumes: Results from Four Studies. American Petroleum Institute Soil / Groundwater Technical Task Force. December 1998.

Spence, L. R., K. T. O'Reilly, R. I. Maagaw, and W. G. Rixey. 2001. Chapter 6 – Predicting the fate and transport of hydrocarbons in soil and groundwater. in: risk-based decision-making or assessing petroleum impacts at exploration and production sites. Edited by S. McMillen, R. Magaw, R. Carovillano, Petroleum Environmental Research Forum and US Department of Energy.

United States Geological Service (USGS). 1998. Groundwater Contamination by Crude Oil near Bemidji, Minnesota. US Geological Survey Fact Sheet 084-98, September 1998.

Additional references on this subject from the FSEIS include:

American Petroleum Institute (API). 1992. Review of Natural Resource Damage Assessments in Freshwater Environments: Effects of Oil Release into Freshwater Habitats. API Publ. No. 4514.

API. 1997. Petroleum in the Freshwater Environment: An annotated Bibliography 1946-1993. API Publ. No. 4640.

Grimaz, S., S. Allen, J. Steward, and G. Dolcetti. 2007. Predictive evaluation of the extent of the surface spreading for the case of accidental spillage of oil on ground. Selected Paper IcheaP8, AIDIC Conference series, Vol. 8, 2007, pp. 151-160.

Hult, M.F. 1984. Groundwater Contamination by Crude Oil at the Bemidji, Minnesota, Research Site: U.S. Geological Survey Toxic Waste—Ground-Water Contamination Study. Papers presented at the Toxic-Waste Technical Meeting, Tucson, Arizona, March 20-22. USGS Water Investigations Report 84-4188.

Weaver, J.W., R.J. Charbeneau, J.D. Tauxe, B.K. Lien, and J.B. Provost. 1994. The hydrocarbon spill screening model (HSSM) Volume 1: User's guide. USEPA/600/R-94/039a.U.S. Environmental Protection Agency, Office of Research and Development, Robert S. Kerr, Environmental Research Laboratory, Ada, OK.

8(a). Explain what changes have been made in the Emergency Response Plan and Integrity Management Plan since 2010.

OBJECTION: To the extent that this request seeks production of the Emergency Response Plan, the request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan and the integrity management plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

8(b). Provide the Emergency Response Plan.

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

8(c). Provide the Integrity Management Plan.

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the integrity management plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Integrity Management Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation.

18(a). Where will fuel storage facilities be located within 200 feet of private wells and 400 feet of municipal wells?

ANSWER: The locations of the fuel storage facilities have not been determined at this point in the planning process. The fuel storage facility locations will be determined at the time of construction. Refer to Section 2.1.5.3, Fuel Transfer Stations of the DOS FSEIS (2014). Wells will be identified prior to the fuel storage facility final locations and will adhere to HP 09-001, Condition 18.

18(b). How will minimizing and exercising vigilance be enforced?

ANSWER: Keystone will minimize and exercise vigilance by providing adequate training and supervision of its contractors with respect to this provision.

21(a). Define "frac-out."

ANSWER: "Frac-out" is addressed in the FSEIS in Section 4.3.3.2 at page 4.3-21, which provides:

> In some instances, pressurized fluids and drilling lubricants used in the HDD process have the potential to escape the active HDD bore, migrate through the sills, and come to the surface at or near the crossing construction site, an event commonly known as a frac-out. Measures identified in a required HDD contingency plan would be implemented, including monitoring of the directional drill bore, monitoring downstream for evidence of drilling fluids, and mitigation measures to address a frac-out should one occur.

21(b). What are concerns and safety issues related to a "frac-out."

ANSWER: This question is addressed at page 4.8-20 of the FSEIS:

> The HDD method avoids direct disturbance to the river, channel bed, or banks. While the HDD method poses a small risk of frac-out (i.e., release of bentonite-based drilling fluids), potential releases would be contained by best management practices that would be described within the HDD Contingency Plans required for drilled crossings. Most leaks of HDD fluids occur near the entry, exit locations for the drill, and are quickly contained and cleaned up. Frac-outs that may release drilling fluids into aquatic environments are difficult to contain primarily because bentonite readily disperses I flowing water and quickly settles in standing water. Should this type of release occur, bentonite is non-toxic but in sufficient concentration may physically inhibit respiration of adult fish and eggs.

It is also addressed at pages 4.7-11 to -12 of Section 4.7.3.2 of the FSEIS:

> The HDD method for crossing waterbodies would be used to minimize disturbance to aquatic habitat, stream banks, and recreational or commercial fisheries. Impacts could occur if there is an unintended release of drilling fluids (i.e., a frac out) during the HDD operation. A frac out could release bentonitic drilling mud into the aquatic environment. The released drilling mud would readily disperse in flowing water or eventually settle in standing

water. Although bentonite is non-toxic, suspended bentonite may produce short-term impacts to the respiration of fish and aquatic invertebrates due to fouled gills. Longer-term effects could result if larval fish are covered and suffocate due to fouled gills and/or lack of oxygen. If the frac out occurred during a spawning period, egg masses of fish could be covered, thus inhibiting the flow of dissolved oxygen to the egg masses. Benthic invertebrates and the larval stages of pelagic organisms could also be covered and suffocate.

To minimize the potential for these impacts to occur, a contingency plan would be implemented to address an HDD frac out. This plan would include preventive and response measures to control the inadvertent release of drilling fluids. The contingency plan would also include instructions for downstream monitoring for any signs of drilling fluid during drilling operations, and would describe the response plan and impact reduction measures in the event a release of drilling fluids occurred. Drill cuttings and drilling mud would be disposed of according to applicable regulations; disposal/management options may include spreading over the construction ROW in an upland location or hauling to an approved off-site, licensed landfill or other approved sites.

21(c). Provide "frac-out plan."

ANSWER: Keystone currently has no contractors retained to undertake construction. When Keystone employs a pipeline contractor, that contractor will develop the plan. *See* Section 7.4.5 and Appendix G.

34(a). Describe what progress has been made in the evaluation and performance assessment activities regarding high consequence areas since 2010.

OBJECTION: To the extent that this request seeks a list of High Consequence Areas, the identity and location of High Consequence Areas is confidential and Keystone is required by PHMSA to keep this information confidential. To the extent that this request seeks production of the Emergency Response Plan, the request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http:///keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

34(b). Define "high consequence area."

OBJECTION: To the extent that this request seeks a list of High Consequence Areas, the identity and location of High Consequence Areas is confidential and Keystone is required by PHMSA to keep this information confidential. Without waiving the objection, the definition of high consequence area can be found in Department of State SFEIS chapter 3 Section 3.13.4.1 and Code of Federal Regulation 49

CFR 195.450.

34(c). Provide a completed list of high consequence areas.

OBJECTION: The identity and location of High Consequence Areas is confidential and Keystone is required by PHMSA to keep this information confidential.

34(d). Explain how project inhabitants and local communities will be informed and educated about high consequence areas.

ANSWER: TransCanada Public Awareness Program is designed to increase awareness of pipeline safety to protect the public, environment and TransCanada facilities. The PA Program reaches out to affected public, excavators/contractors, emergency officials and local public to ensure they are engaged and education about living and working safely near TransCanada facilities. This includes awareness of areas that have been defined as high consequence areas.

34(c). Provide a copy of the Emergency Response Plan. (Requested above with #8.)

OBJECTION: To the extent that this request seeks production of the Emergency Response Plan, the request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of the U.S. Department of Transportation, Pipeline and Hazardous Materials

Safety Administration (PHMSA). The PUC's jurisdiction over the emergency response plan is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan could commercially disadvantage Keystone.

34(f). Provide Integrity Management Plan. (Requested above with #8.)

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the integrity management plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit its Integrity Management Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation.

19. Explain what has been discussed with the SD Geological Survey, the Dept. of Game Fish and Parks, local landowners and govt. officials.

ANSWER: Keystone referenced publicly available data/reports from the SD Geological Survey. Discussion between Keystone and the South Dakota Dept. of Game, Fish, and Parks focused on the identification of the potential biological resources that may be impacted by the Project route in South Dakota and the potential mitigation measures that could be implemented to minimize impacts.

The following is a summary of Keystone consultation history with SD Game, Fish, and Parks as documented in the USFWS issued May 2013 Biological Opinion (Appendix H of the of the Department of State FSEIS (2014))

- June 10, 2008: Keystone met with staff from USFWS and South Dakota Department of Game, Fish, and Parks (SDGFP), at the SDGFP office in Pierre, South Dakota, to discuss issues pertaining to wildlife, special status species, and sensitive habitat that could potentially occur in the Project area. The goal of the meeting was to gather input on agency recommendations based on the information sent to them in April 2008 for species occurrence, habitat assessments, and future field surveys. Keystone incorporated comments from the meeting into survey protocols and BMPs for future agency verification.

- January/February 2009: Keystone initiated section 7 consultation with the USFWS. Keystone continued discussions with BLM, and state wildlife agency offices for South Dakota that included state-specific special status species survey protocols and BMPs for the species identified as potentially occurring during the 2008 meetings. A summary of the findings from the 2008 biological field surveys was included in the discussions.

- January 27, 2009: Keystone met with staff from the USFWS and SDGFP at the SDGFP office in Pierre, South Dakota, to discuss issues pertaining to special status species surveys. The goals of the meeting were to verify Keystone's survey approach, BMPs, discuss required field surveys, and review the information that was sent to the USFWS in the January/February 2009, informal consultation package. The USFWS and SDGFP provided additional recommendations to Keystone's sensitive species mitigation approach to be updated prior to final agency concurrence.

- October 23, 2012: A meeting was held between the USFWS, Department, SDGFP, BLM, and Keystone regarding the greater sage–grouse and a compensatory mitigation plan for the species in South Dakota. Discussions included a management plan and avoidance, minimization, and mitigation strategies.

35(a). Provide the Integrity Management and Emergency Response Plans. (Requested above.)

OBJECTION: The request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the province of PHMSA. The PUC's jurisdiction over pipeline safety is preempted by federal law. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. Public disclosure of the emergency response plan and the integrity management plan could commercially disadvantage Keystone. In addition, Keystone is not required to submit these documents to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

35(b). Define "Unusually Sensitive Areas."

ANSWER: Unusually Sensitive Areas are defined by U.S. federal pipeline safety regulations (49 CFR 195.6) as:

> As used in this part, a USA means a drinking water or ecological resource area that is unusually sensitive to environmental damage from a hazardous liquid pipeline release.
>
> (a) An USA drinking water resource is:
>
> (1) The water intake for a Community Water System (CWS) or a Non-transient Non-community Water System (NTNCWS) that obtains its water supply primarily from a surface water source and does not have an adequate alternative drinking water source;
>
> (2) The Source Water Protection Area (SWPA) for a CWS or a NTNCWS that obtains its water supply from a Class I or Class IIA aquifer and does not have an adequate alternative drinking water

source. Where a state has not yet identified the SWPA, the Wellhead Protection Area (WHPA) will be used until the state has identified the SWPA; or

(3) The sole source aquifer recharge area where the sole source aquifer is a karst aquifer in nature.

(b) An USA ecological resource is:

(1) An area containing a critically imperiled species or ecological community;

(2) A multi-species assemblage area;

(3) A migratory waterbird concentration area;

(4) An area containing an imperiled species, threatened or endangered species, depleted marine mammal species, or an imperiled ecological community where the species or community is aquatic, aquatic dependent, or terrestrial with a limited range; or

(5) An area containing an imperiled species, threatened or endangered species, depleted marine mammal species, or imperiled ecological community where the species or community occurrence is considered to be one of the most viable, highest quality, or in the best condition, as identified by an element occurrence ranking (EORANK) of A (excellent quality) or B (good quality)."

35(c). Define "Hydrologically Sensitive Areas."

ANSWER: Hydrological sensitive areas were defined by the South Dakota Public Utilities Commission Amended Final Order as "the High Plains Aquifer area in southern Tripp County," as well as "other similarly vulnerable and beneficially useful surficial aquifers that Keystone is aware of."

35(d). Explain how unusually sensitive areas and hydrologically sensitive areas are addressed differently compared to other areas.

ANSWER: Unusually sensitive areas are High Consequence Areas (HCAs), as defined by 49 CFR 195.6. Keystone has elected to treat "hydrologically sensitive areas," as defined in the South Dakota Public Utilities Commission Order Condition 35, as operator-defined HCAs. By designating these segments as operator-defined HCAs, these locations are treated by Keystone as if they were PHMSA-identified HCAs . Portions of the pipeline that could potentially affect HCAs are subject to high levels of inspection and repair criteria, as mandated by 49 CFR 195.

35(e). Confirm that you are not fully aware of all vulnerable and beneficially useful aquifers and your intent is to only become aware of them during construction and route evaluation not yet completed.

ANSWER: Keystone does not confirm these statements. Keystone has consulted with groundwater staff with South Dakota's Department of Natural Resources (SD

DENR) and rural water districts regarding Keystone's route relative to aquifers in South Dakota. Keystone also used data available on the SDDENR website http://denr.sd.gov/data.aspx and published literature regarding the geology and hydrology of the along and near the pipeline ROW to assist in identifying vulnerable aquifers in South Dakota. Geological references and hydrogeological references are listed in Chapters 3 and 4 in the Department of State Supplemental FEIS. Some pertinent additional references are:

- Gutentag (1984): USGS Prof. Paper 1400-B
- Downey (1986): USGS Prof. Paper 1402-E
- Thamke et al (2014): USGS Scientific Inv. Report SIR 2014-5047.
- In addition, lithologic logs available from the SD DENR at

http://denr.sd.gov/des/wr/dblog.search.aspx and http://denr.sd.gov/data.aspx provide aquifer thickness data.

35(f). Define "unconfined aquifers."

ANSWER: From Applied Hydrogeology (1994) *"Unconfined Aquifer: Aquifer close to the surface with materials of high permeability extending from the land surface to the base of the aquifer. Water table aquifer."*

Source: Fetter, C.W. (1994.) Applied Hydrogeology. Prentice Hall. 680 pp.

35(g). List known unconfined aquifers to be crossed by the project.

ANSWER: Department of State Table 3.3-2 (SFEIS) presents a list of unconfined aquifers in South Dakota crossed by the Keystone XL Pipeline Project. Along the route in South Dakota, the High Plains Aquifer (Ogallala Formation) in Tripp County is often unconfined. Other areas with unconfined aquifers include alluvial aquifers associated with streams, and occasional unconfined stretches in the Hell Creek, Fox Hills, and Pierre Shale aquifers. However, along the majority of the route, aquifers crossed by the Keystone XL pipeline are confined.

35(h). Explain the concern of routing through unconfined aquifers.

ANSWER: In South Dakota, unconfined aquifers are found mainly associated with streams (alluvial aquifers) and in portions of the High Plains Aquifer (Ogallala Formation) in Tripp County (FSEIS). Table 3.3-2 (FSEIS) presents the unconfined aquifers in South Dakota. The Keystone XL pipeline in South Dakota was routed to reduce impacts to a number of valuable resources, including but not limited to, unconfined aquifers.

35(i). Describe how it could be possible to route through an unknown, unconfined aquifer during construction.

ANSWER: Keystone has attempted to identify vulnerable aquifers through consultation with State agencies and rural water districts, as well as data provided South Dakota Department of Environment and Natural Resources (SD DENR) (http://denr.sd.gov/data.aspx), and published literature. The location of unconfined aquifers is documented in the literature on the hydrogeology of South Dakota and the SD DENR website provides well logs for wells near the pipeline ROW, so that unconfined conditions can be identified.

It is possible that, during construction and through discussion with landowners crossed by the Project, Keystone may identify shallow wells located in unconfined aquifers. Many water-bearing units in South Dakota may be unmapped due to their small size and type of geological formation that has limited use due to low water productivity and generally lower water quality. If present, these wells are often associated with agricultural uses (e.g., livestock stock tanks).

35(j). Provide documentation of further route evaluation since 2010, including assessments for aquifers and hydrologically sensitive areas.

OBJECTION AND RESPONSE: This request is vague, overlybroad, and unduly burdensome. Without waiving the objection, since 2010, Keystone has continued to identify groundwater resources through agency consultation use of the South Dakota Department of Environment and Natural Resources (SD DENR) website (http://denr.sd.gov/data.aspx) and the following publications. Geological references and hydrogeological references are listed in chapters 3 and 4 in the FSEIS. Some pertinent additional references are:

- Gutentag (1984): USGS Prof. Paper 1400-B
- Downey (1986): USGS Prof. Paper 1402-E
- Thamke et al (2014): USGS Scientific Inv. Report SIR 2014-5047.

In addition, lithologic logs available from the SD DENR at http://denr.sd.gov/des/wr/dblog.search.aspx and http://denr.sd.gov/data.aspx provide aquifer thickness data. Since 2010, the Keystone XL pipeline route was evaluated using these data sources to identify hydrologically sensitive areas.

35(k). Explain how you will deem an aquifer vulnerable and beneficially useful?

ANSWER: Keystone relies on two primary sources to identify vulnerable and beneficially useful aquifers: Pipeline and Hazardous Materials Safety Administration (PHMSA)-identified unusually sensitive areas for drinking water, as defined in 49 CFR 195.6, and Source Water Protection Areas for groundwater as identified by the South Dakota Department of Environment and Natural Resources (SD DENR). Both PHMSA and the SD DENR have provided these data confidentially to Keystone.

35(l). This condition states: "…in some reaches of the Project in southern Tripp County, the High Plains Aquifer is present at or very near ground surface and is overlain by highly permeable sands permitting the uninhibited infiltration of contaminants." Sandy soil and ground water at or above the surface means a pipe with expected pinhole leaks will be immersed in ground water. This is the exact type of situation of soil/ground water which caused the route change in Nebraska. If this was reason to change the route in Nebraska, explain why it is still acceptable in South Dakota.

OBJECTION AND RESPONSE: This request is argumentative and assumes facts not in evidence. Without waiving the objection, "*Pipeline routing is optimized to reduce impacts and risks to the environment, population, and to reduce integrity concerns*." Routing decisions in each state were made in consultation with the various local state and federal agencies. Reroutes in Nebraska were determined based on public and agency input during the NEPA process. Routes approved in South Dakota were based on consultation with South Dakota local agencies. All routing decisions took into account the screening options outlined in the FSEIS Section 2.2.2.2 Major Pipeline Route Alternatives and Section 2.2.5.1 Screening of Major Route Alternatives. The first round of screening included the following criteria:

- "Meeting the proposed Project's purpose and need, including the extent to which additional infrastructure (pipeline) is necessary to access Bakken crude oil;
- Consistency with the proposed border crossing and therefore the approved routing in Canada;
- Availability;
- Reliability;

- Length within the United States;
- Total length of the pipeline, including both the United States and Canada;
- Estimated number of aboveground facilities;
- Length co-located within an existing corridor;
- Acres of land directly affected during construction; and
- Acres of land directly affected permanently." (FSEIS Section 2.2.2.2 pg 2-2-2).

The second round of screening included the following criteria:

- "Total length of the pipeline, including both the United States and Canada;
- Use of the Canadian-approved Keystone XL pipeline ROW outside of the United States;
- Approximate acres affected by construction of the proposed Project (based on a typical 110-foot construction ROW)
- Federal lands crossed (miles);
- Principal aquifers crossed (miles);
- American Indian lands crossed (miles);
- Total wetlands crossed (miles);
- USFWS critical habitat for threatened and endangered species crossed (miles);

- Known cultural resource sites (listed on National Register of Historic Places) within 500 feet of proposed pipeline;
- Number of waterbodies crossed; and
- Soils designated as highly erodible by wind crossed (miles)." FSEIS Section 2.2.5.1 pg 2.2-59)

Rerouting away from the environmentally sensitive Nebraska Department of Environmental Quality (NDEQ)-identified Sand Hills Region was based on input from the NDEQ and the public.

South Dakota Public Utilities Commission's (SD PUC) Amended Order identified the southern portion of Tripp County as having a "hydrologically sensitive area" for groundwater resources due to the sandy soils and presence of unconfined portions of the High Plains Aquifer. As discussed previously, Keystone will treat "hydrologically sensitive areas", as defined in the SD PUC Order Condition 35, as operator-defined high consequence areas (HCAs). By designating these segments as operator-defined HCAs, these locations are treated by Keystone as if they were Pipeline and Hazardous Materials Safety Administration (PHMSA)-identified HCAs. Portions of the Keystone XL pipeline that could potentially affect HCAs are subject to high levels of inspection and repair criteria, as mandated by 49 CFR 195.

Where soils are fragile (i.e., sandy soils that exhibit conditions similar to the Nebraska Department of Environmental Quality-identified Sand Hills Region that are highly susceptible to erosion by wind), special considerations and measures also would be undertaken in proposed Project areas to protect environmentally sensitive resources.

"Approximately 76 percent (11,664 acres) of the overall proposed Project would affect soils characterized as highly erodible by either wind or water (see Figure 4.2.1-1). Erosion control measures would be implemented wherever soil is exposed, steep slopes are present, or erosion potential is high. To enforce use of these methods, an environmental inspector (EI) would be assigned to each construction spread. In addition, specific procedures have been developed to address concerns related to potential erosion to the fragile soils in the southern South Dakota and northern Nebraska region; the proposed Project right-of-way (ROW) through these fragile soils would be monitored for several years to ensure that reclamation and revegetation efforts are successful (see Section 4.2.3.2, Operation Impacts)." (FSEIS Section 4.2 Soils, pg 4.2-2)

"**Fragile Soils in Southern South Dakota and Northern Nebraska**

In southern South Dakota and northern Nebraska, the proposed Project route would enter an area with fragile soils (i.e., landscapes where the soil exhibits conditions similar to the NDEQ-identified Sand Hills Region and the soils are very susceptible to wind erosion; see Soils Environmental Setting Sections 3.2.2.2, South Dakota, 3.2.2.3, Nebraska, and Figure 3.2.2-2, Highly Wind Erodible Soils). To address concerns related to potential erosion in the region, specific construction, reclamation, and post-construction procedures have been developed, as described in Section 4.15 of the CMRP, Fragile Soil Clean Up and Reclamation/Revegetation, (see Appendix G). This document provides site-specific reclamation plans that itemize construction, erosion control, and revegetation procedures for these fragile areas. Additionally, Keystone would implement micro-routing adjustments where practicable and appropriate to minimize steep topography with fragile soils.

To reduce potential impacts related to severe wind and water erosion, the following provides a summary of proposed Project best management practices (BMPs) that would be implemented during construction, reclamation, and post-construction. These BMPs are included in the CMRP for fragile soil areas. Additional procedures are also described in Sandy Prairie Construction/Reclamation Unit Plan (see Appendix R, Construction/Reclamation Plans):

- Keystone would educate construction personnel regarding the necessity to strictly adhere to the proposed Project BMPs designed to minimize impacts to fragile soil landscape areas.
- Minor route re-alignments would be incorporated through these fragile areas to avoid particularly erosion-prone locations, such as ridgetops and existing blowouts as much as practicable.
- Keystone would avoid highly saturated areas, such as wetlands, to the maximum extent possible.
- Construction soil handling procedures would strive to reduce the width of disturbance to the native prairie landscape by adopting Trench-line or Blade-width stripping procedures where practicable.
- Topsoil conservation would be conducted on all areas where excavation occurs.
- Topsoil piles would be protected from erosion through matting, mulching, watering, or tackifying as deemed practicable.
- Traffic management limitations would be employed on specific areas possessing high erosion potential or sensitive habitat.
- Native seed mixes would be developed with input from the local

NRCS offices and through collaboration with regional experts. All seed would be certified noxious weed-free and would be calculated on a pure live seed basis.

- Straw or native prairie hay may be used as mulch, applied to the ROW, and crimped into the soil to prevent wind erosion. All mulch would be documented as noxious weed-free.
- Land imprinting may be employed to create impressions in the soil, thereby reducing erosion, improving moisture retention, and creating micro-sites for seed germination. (Land imprinting adds a waffle-like texture to the soil, forming indentations that capture and absorb rainwater that otherwise runs off untreated land.)
- Sediment logs (barriers in the form of logs used to control soil erosion) or straw wattles would be used in place of slope breakers (short terraces) that are constructed of soil. Using sediment logs would result in less soil disturbance to the ROW.
- Photodegradable matting would be applied on steep slopes or areas prone to extreme wind exposure such as north- or west-facing slopes and ridge tops. Biodegradable pins would be used in place of metal staples to hold the matting in place.

- Keystone would work with landowners to evaluate fencing the ROW from livestock, or alternatively, provide compensation to rest a pasture until vegetation can become established.
- Management concerns such as livestock access to water or movement within a pasture would be addressed as necessary by Keystone working with the landowner.
- As part of post-construction monitoring and repair, Keystone would monitor reclamation on the ROW for several years and would repair erosion and reseed poorly revegetated areas as deemed necessary by Keystone. During monitoring, landowners would be informed of these efforts and intended actions going forward.
- A noxious weed management plan would be established based on consultation with state and county experts.

Fragile Soils in Southern South Dakota and in Northern Nebraska

To address concerns related to potential erosion in the fragile soil areas in southern South Dakota and northern Nebraska, specific construction, reclamation, and post-construction procedures have been developed as described in the Fragile Soils section within the CMRP (see Appendix G). This document provides a site-specific reclamation plan that itemizes construction, erosion control, and revegetation procedures for these fragile areas. Additional procedures are also described in Sandy Prairie Construction/Reclamation Unit Plan (see Appendix R, Construction/Reclamation Plans and Documentation). The proposed Project ROW through this region would be monitored for several years to ensure that reclamation and revegetation efforts are successful. Any proposed Project areas where reclamation and revegetation efforts are initially unsuccessful would be re-evaluated and restored.

Proposed Project areas that have been revegetated would be attractive as cattle forage. Due to potentially warmer soils in the immediate vicinity of the proposed pipeline, early forage may be concentrated along the ROW over time (Dave Wedin, personal communication, June 29, 2011). Additionally, animal trackways (i.e., a route of frequent travel by animals) can serve as incipient blowout areas. Keystone has agreed to inform landowners of this concern. Fencing of the ROW may be completed if required; however, fencing could be a serious impediment to landowner access. As described previously, Keystone would work with landowners to evaluate fencing the ROW from livestock, or alternatively, provide compensation to rest a pasture until vegetation can become established.

Also as previously indicated, Keystone would monitor reclamation on the ROW for several years and repair erosion and reseed poorly revegetated areas as necessary. Additionally, based on input received from the NRCS, Keystone would be required to employ a method of assessment of soil productivity such as yield comparison between ROW and non-ROW areas in areas where susceptible soils have been identified with the NRCS." (FSEIS, Section 4.2 Soils).

35(m). Explain TransCanada's follow-up with suggestion by DENR staff, given in testimony, to reroute the KXL pipeline around the city of Colome's source water area.

ANSWER: Routing is an iterative process where refinements to the route are continuously made as new, substantive data are obtained. In this case, Keystone had obtained HCA data from the Pipeline and Hazardous Materials Safety Administration (PHMSA) and consulted with the South Dakota Department of Environment and Natural Resources' (SD DENR) ground water Staff. During the consultation process, Keystone received Source Water Protection Area (SWPA) data. These data sets were integrated into the routing process and, upon identification of the route through the Colome SWPA, Keystone rerouted out of the area. Keystone consulted with the SD DENR's groundwater Staff and informed them of the issue with the initially proposed route and a proposed route refinement to avoid the SWPA. SD DENR staff confirmed that the reroute was acceptable.

36(a). Identify all emergency medical response planning contained within the emergency response plan.

OBJECTION: This request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the exclusive province of PHMSA. The PUC's jurisdiction over the emergency response plan is preempted by federal law, which has exclusive jurisdiction over issues of pipeline safety. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. See Amended Final Order, HP 09-001, Condition ¶ 36. Public disclosure of the emergency response plan would commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf.

36(b). What actions have been taken by TransCanada to ensure the medical communities in South Dakota are prepared and educated to treat people exposed to spills and water contamination from spills?

OBJECTION AND RESPONSE: To the extent that this request seeks production of the Emergency Response Plan, this request seeks information that is beyond the scope of the PUC's jurisdiction and Keystone's burden under SDCL § 49-41B-27. This request also seeks information addressing an issue that is governed by federal law and is within the exclusive province of PHMSA. The PUC's jurisdiction over the emergency response plan is preempted by federal law, which has exclusive jurisdiction over issues of pipeline safety. *See* 49 C.F.R. Part 194; 49 U.S.C. § 60104(c). This request further seeks information that is confidential and proprietary. See Amended Final Order, HP 09-001, Condition ¶ 36. Public disclosure of the emergency response plan would commercially disadvantage Keystone. In addition, Keystone is not required to submit its Emergency Response Plan to PHMSA until sometime close to when the Keystone Pipeline is placed into operation. Keystone's Emergency Response Plan is addressed in The Final Supplemental Environmental Impact Statement at http://keystonepipeline-xl.state.gov/documents/organization/221189.pdf. Without waiving the objection, TransCanada has provided educational information to possible affected public elected officials, excavators, and first responders. This educational material comes in the form of a pamphlet and is titled Oil Pipeline for Emergency Responders. It is marked as Keystone 1523-1538.

36(c). How will inhabitants and communities near the project area be notified of spills?

ANSWER: Keystone's response teams will use the National Incident Management System (NIMS) Incident Command System (ICS) to manage emergency response activities. First response to an incident will be provided by a Keystone local response team. Keystone's Regional Emergency Operations Center (EOC) will respond, to the degree necessary, to incidents exceeding local capability. Duties of the local responders are described in the TransCanada-Keystone Emergency Response Plan (see FSEIS, Appendix I) which will be adapted for use on Keystone XL.

Response teams will be led by an Incident Commander, and will include persons accountable for external notifications including a Public Information Officer (including media communications), and a Liaison Officer (including agency communications). External notifications are those made to entities outside of the Company including Federal, State and local regulatory agencies, as well as railroad and utility companies. These notifications include both verbal and written requirements. Landowners and appropriate public agencies will be notified in the case of potential groundwater contamination.

40(a). Provide documentation supporting your assertion that polyethylene water piping is permeable to BTEX.

ANSWER: Permeation of polyvinyl chlorine (PVC) and polyethylene (PE) pipes by any hydrocarbon is extremely rare (Gaunt et al. 2006). Permeation incidents were reported at a frequency of one per 14,000 miles of mains and one per 1,000,000 miles of PE/PVC service connections (Gaunt et al. 2006).

A number of studies have been conducted on the topic of hydrocarbon permeation through PVC and PE water piping, including:

Gaunt, James A. et. al. 2006. "Performance of Plastic Pipes and Pipe Gaskets In Hydrocarbon Contamination: Field Experience and Laboratory Studies". Department of Civil, Construction, and Environmental Engineering Iowa State University, Ames, IA. American Waterworks Association.

Berens, A.R. 1985. "Prediction of organic chemical permeation through PVC pipe". JAWWA 77 (11), 57-64 (1985).

40(b). Explain health concerns related to BTEX.

ANSWER: BTEX consists of benzene, toluene, ethylbenzene, and xylenes. Benzene can result in health impacts from short term (i.e., acute) exposure or long-term (i.e., chronic) exposure. Acute effects can include drowsiness, dizziness, rapid heart rate, headaches, and unconsciousness. At extremely high concentrations, acute toxicity can result in mortality. Benzene levels at these concentrations would not be anticipated from a release from the Keystone XL Pipeline Project. Potential chronic health effects of benzene exposure include anemia and excessive bleeding. Long-term exposure to high concentrations of benzene in the air can lead to cancer (ATSDR 2007a, EPA 2015). Due to emergency response cleanup, sampling, and monitoring, remedial actions, and the high volatility of benzene, benzene concentrations would largely dissipate within the first 24 hours, minimizing the potential for chronic effects in humans.

Toluene exposure may cause fatigue, confusion, and weakness (ATSDR 2001, EPA 2015). At extremely high levels, toluene may cause mortality. Toluene levels at this concentration would not be expected to occur due to a release along the Keystone XL Pipeline Project.

Ethylbenzene exposure may cause eye and throat irritation or dizziness (ATSDR 2010, EPA 2015). Chronic exposure to low levels of ethylbenzene (weeks to years) may cause damage to the inner ear or kidneys. Ethylbenzene has been identified as a possible human carcinogen.

High levels of xylene exposure, either acute or chronic, can cause headaches, lack of muscle coordination, confusion, and eye, skin, throat, and nose irritation. Extremely high levels can cause unconsciousness and mortality (ATSDR 2007b, EPA 2015). Xylene levels at this concentration would not be expected to occur due to a release along the Project. Studies by the International Agency for Research on Cancer and the EPA have not been able to rule xylene out as a carcinogen.

More detailed information is available through the Agency for Toxic Substances & Disease Registry (ATSDR; http://www.atsdr.cdc.gov/) and the US Environmental

Protection Agency (USEPA; http://water.epa.gov/drink/contaminants/).

Agency for Toxic Substances and Disease Registry. 2014. ATSDR Toxic Substances Portal. Available from: http://www.atsdr.cdc.gov/

Agency for Toxic Substances & Disease Registry (ATSDR). 2010. ToxFAQs for Ethylbenzene. Accessed January 20, 2015. http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=382&tid=66.

Agency for Toxic Substances & Disease Registry (ATSDR). 2001. ToxFAQs for Toluene. Accessed January 20, 2015. http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=160&tid=29.

Agency for Toxic Substances & Disease Registry (ATSDR). 2007a. ToxFAQs for Benzene. Accessed January 20, 2015. http://www.atsdr.cdc.gov/toxfaqs/TF.asp?id=38&tid=14.

Agency for Toxic Substances & Disease Registry (ATSDR). 2007b. ToxFAQs for Xylene. Accessed January 20, 2015. http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=295&tid=53.

US Environmental Protection Agency (EPA). 2015. Drinking Water Contaminants. Accessed January 20, 2015. http://water.epa.gov/drink/contaminants/.

Environmental Protection Agency. 2014. National Primary Drinking Water Regulations. Available from: http://water.epa.gov/drink/contaminants/

40(c). Provide an MSDS of all products to be transported in KXL, including the diluents.

ANSWER: Representative Material Safety Data Sheets are provided in Appendix Q of the FSEIS.

40(d). Provide list of ground water quality standards, specifically listing chemicals involved in tar sands oil product and diluents.

OBJECTION: Keystone does not determine ground water quality standards. They are established by the South Dakota Department of Environment and Natural Resources.

40(e). Describe how the decision was made to designate concern of BTEX only within 500 feet of the Project.

ANSWER: This decision was made by the PUC as part of Amended Permit Condition 40.

40(f). Confirm this safety measure will only be implemented at the request of a landowner or public water supply system.

ANSWER: Yes.

40(g). Explain why this measure is optional instead of mandatory.

ANSWER: This decision was made by the PUC as part of Amended Permit Condition 40.

40(h). TransCanada has agreed to do this: "At least forty-five days prior to commencing construction, Keystone shall publish a notice in each newspaper of general circulation in each county through which the Project will be constructed advising landowners and public water supply systems of this condition." What percent of inhabitants do you expect to reach by issuing a warning in this manner?

OBJECTION AND RESPONSE: This request is speculative and argumentative. A notice is not a "warning." Without waiving the objection, Keystone expects that notice in newspapers of general circulation would reach a substantial portion of the inhabitants.

46(a). Provide written plan as to how you will find and provide a permanent water supply for various locations along route if a well should become contaminated, including specific alternate sources.

ANSWER: In the unlikely event of a leak, petroleum hydrocarbons generally do not move more than 300 feet through the subsurface and substantive movement takes months to years offering ample time for emergency response and containment. Therefore, impacts to private and public wells are not anticipated. Further, Keystone will comply with the South Dakota Public Utilities Commission order (Condition of Permit #46): "In the event that a person's well is contaminated as a result of construction or pipeline operation, Keystone shall pay all costs associated with finding and providing a permanent water supply that is at least of similar quality and quantity; and any other related damages, including but not limited to any consequences, medical or otherwise, related to water contamination."

46(b). Define "quantity" as it is used in this condition.

ANSWER: Keystone interprets "quantity" to have its ordinary meaning.

46(c). Provide cost estimates for providing water to the city of Colome, domestic wells or an entire ranching operation should water supplies become contaminated.

ANSWER: Please refer to DOS SFEIS Appendiz Z Mitigation Measures page 108 item 7. Keystone has committed, in the event that a spill contaminates potable water supplies, be responsible for cleanup and restoration. Keystone would be responsible for providing an appropriate alternative potable water supply of comparable volume and quality to those impacted or provide compensation, if this option is agreed upon by the affected parties and Keystone. For groundwater used for industrial or irrigation purposes, Keystone may provide either an alternate supply of water or appropriate compensation for those facilities impacted, as may be agreed upon among the affected parties and Keystone. If the permit were approved, Keystone would memorialize that agreement through an appropriate written agreement with the Environmental Protection Agency.

46(d). Explain how providing a permanent water supply will be ensured into perpetuity.

ANSWER: *See* answer to interrogatory no. 46(a).

46(e). Explain how people and cattle using private wells and public wells can be assured their water is free of contamination from undetected leakage, particularly in Tripp County.

ANSWER: Given the leak detection methodologies that are part of the project, undetected well contamination is unlikely.

46(f). Describe what experience South Dakota has had cleaning up tar sands oil product spills into rivers and ground water.

OBJECTION: This request seeks information that is not within Keystone's custody or control.

46(g). Describe any experience the State of South Dakota or any other state has had in "sparging" ground water in order to cleanse tar sands oil product from aquifers.

OBJECTION: This request seeks information that is not within Keystone's custody or control.

46(h). Describe types of spills which may be difficult or impossible to remediate.

ANSWER: Crude oil spills can be remediated. Initial contaminant and cleanup is important to limit the area affected and to remove as much product as quickly as possible. Any residual oil can be remediated through a variety of remediation technologies as well as through natural attenuation.

As discussed in Section 2.1 of the FSEIS, Keystone has reviewed the National Transportation Safety Board 2012 Marshall, Michigan Accident Report, including the conditions that led to operational failures on the pipeline that resulted in the spill. Keystone has stated they would include lessons learned from this spill, including the following:

- "Get big quick: timeliness of a tactical response to an oil spill into water is imperative. While Keystone has stated that it already uses this philosophy, the Kalamazoo spill reinforced this need to respond with as many resources as possible as quickly as possible. To that end, Keystone would strategically store equipment and employ personnel and contractors along the length of the pipeline to ensure a maximum 6-hour response time.
- Pre-qualify a large contractor network: Contractors would be used to supplement any response Keystone would make to an oil spill. By ensuring a large pool of trained/skilled contractors along the length of the pipeline have been pre-qualified and contracted with Keystone, the response time would be minimized and resources (equipment and personnel) available are maximized.
- Emergency response planning details need to include source

containment: source containment plans including strategies and tactics would be included in the overarching ERP.

- Equipment resources required for sunken and submerged oil: Keystone would further identify equipment resources required to respond to sunken and submerged oil and ensure personnel are appropriately trained on the equipment. A primary strategy for oil spill response would still be to contain and recover as much oil as possible as quickly as possible to prevent oil from weathering and therefore potentially becoming submerged and sinking. In addition, Keystone already owns and practices the use of containment devices that would prevent downstream migration of submerged and sunken oil such as dams. This type of equipment would be further identified and procured for the proposed Project."

Section 2.1 of the FSEIS also covers remediation of potential crude oil spills and construction related spills.

"Corrective remedial actions would be dictated by federal, state, and local regulations and enforced by the PHMSA Office of Pipeline Safety as well as appropriate state and/or local agencies. Required remedial actions may be large or small, dependent upon a number of factors including state mandated remedial cleanup levels, potential effects to sensitive receptors, the volume and extent of the contamination, whether or not there is a violation of water quality standards, and the magnitude of adverse impacts caused by remedial activities. A large remediation action could include one or more of a number of approaches (such as excavation of soil, pumping and treating ground water, or natural attenuation). However, the selection of a remedial measure would be in coordination and agreement with the appropriate regulatory agency.

If, during construction, tanks or contamination are found, they would be managed according to federal, state, and/or local regulations. Further, Keystone would make individuals available who are trained in identifying and disposing of hazardous materials during construction.

If there is an accidental release from the proposed Project, Keystone would implement the remedial measures necessary to meet the federal, state, and local standards that are designed to help ensure protection of human health and environmental quality. Additional information on remediation is presented in Section 4.13 of the FSEIS, Potential Releases."

46(i). Identify responsible parties who will conduct water analysis to assure toxins from undetected leaks have not migrated into water resources, including frequency of testing and who will assume cost of testing.

ANSWER: If a release were to occur, Keystone would implement its Emergency Response Plan (ERP). This ERP is responsive to the size of spill and resources potentially affected. In the event surface waters were impacted, Keystone would implement its ERP and notify appropriate federal and state agencies. If the release is significant, an Incident Command Team will develop a sampling plan, determined in consultation with the appropriate state and federal agencies that identifies the appropriate sampling, frequency, and responsible payee.

46(j). Describe potential scenarios in which medical costs related to contamination will be reimbursed.

ANSWER: If it is determined that medical costs are incurred and result of contamination caused by Keystone, Keystone will reimburse such costs.

46(k). Provide a detailed listing of potential toxins which could contaminate wells.

ANSWER: The South Dakota Department of Environment and Natural Resources (SD DENR) identifies a number of compounds that can potentially contaminate wells (refer to the following list [SD DENR 2009]). Many of these chemicals are not constituents of petroleum hydrocarbons but are associated with farming, industrial activities, and urban runoff.

- 1,1,1-Trichlorethane
- 1,1,2-Trichlorethane
- 1,1-Dichloroethylene
- 1,2 Dibromo-3-chloropropane (DBCP)
- 1,2,4-Trichlorobenzene
- 1,2-Dichloroethane
- 1,2-Dichloropropane
- 2,4,5-TP (Silvex)
- 2,4-d, 3-Hydroxycarbofuran
- Alachlor (Lasso)
- Aldicarb
- Aldicarb sulfone
- Aldicarb sulfoxide
- Aldrin
- Antimony (total)
- Arsenic (total)
- Atrazine
- Barium (total)
- Benzene
- Benzo[a]pyrene
- Beryllium (total)
- Butachlor
- Cadmium (total)
- Carbaryl
- Carbofuran
- Carbon tetrachloride
- Chlordane
- Chromium (total)
- cis-1,2-Dichloroethylene
- Dalapon
- Di(2-Ethylhexyl) adipate
- Di(2-ethylhexyl) phthalate
- Dicamba
- Dichloromethane (methylene chloride)
- Dieldrin
- Dinoseb
- Diquat
- Endothall
- Endrin
- Ethylbenzene
- Ethylene dibromide (EDB)
- Glyphosate
- Heptachlor
- Heptachlor epoxide
- Hexachlorobenzene (HCB)
- Hexachlorocyclopenta-diene
- Lindane
- m-Xylene
- Mercury (total inorganic)
- Methomyl
- cis-1,2-Dichloroethylene
- Dalapon
- Di(2-Ethylhexyl) adipate
- Di(2-ethylhexyl) phthalate
- Dicamba
- Dichloromethane (methylene chloride)
- Methoxychlor
- Metolachlor
- Metribuzin
- Monochlorobenzene (Chlorobenzene)
- Nitrate
- Nitrite
- o-Dichlorobenzene
- o-Xylene
- Oxamyl (Vydate)
- p-Dichlorobenzene
- p-Xylene
- Pentachlorophenol
- Picloram
- Propachlor
- Selenium (total)
- Simazine
- Styrene
- Tetrachloroethylene
- Thallium (total)
- Toluene
- Total polychlorinated biphenyls (PCBs)
- Toxaphene
- trans-1,2-Dichloroethylene
- Trichloroethylene
- Vinyl chloride
-
-
-

South Dakota Department of Environment and Natural Resources (SD DENR). 2009.

Tripp County Water User District Drinking Water Quality Report. Available from:

http://www.ewg.org/tap-water/whatsinyourwater2/SD/tripp-county-water-user-district/4600520.

46(l). Provide documentation detailing adverse health effects caused from exposure to these toxins, including the various routes of entry into the human body.

ANSWER: As stated in the previous response (#54), many of these compounds identified in the previous response are not constituents of crude oil.

The U.S. Environmental Protection Agency has a detailed listing of potential drinking water contaminants. This includes the toxins addressed above and their potential health effects on humans due to ingestion of contaminated drinking water. This information is available at http://water.epa.gov/drink/contaminants/.

Additionally, the Agency for Toxic Substances and Disease Registry (ATSDR) website includes detailed reports on potential health effects of these toxins as well as potential routes of entry into the human body. This information is available at http://www.atsdr.cdc.gov/.

Agency for Toxic Substances and Disease Registry. 2014. ATSDR Toxic Substances Portal. Available from: http://www.atsdr.cdc.gov/

Environmental Protection Agency. 2014. National Primary Drinking Water Regulations. Available from: http://water.epa.gov/drink/contaminants/.

18(a). Regarding an advisory warning issued in September, 2014 by the federal Pipeline and Hazardous Materials Safety Administration, what are TransCanada's plans to ensure pipeline safety due to the fact different types of product will be transported in KXL?

OBJECTION AND RESPONSE: This request seeks information related to pipeline safety, which is within the exclusive jurisdiction of PHMSA. Without waiving the objection, PHMSA Advisory 2014-0040 is not applicable to Keystone. This advisory is related to flow reversal, product change (e.g., crude oil to refined product) and/or conversion to service (e.g., convert from natural gas to crude oil) and throughput capacity change.

18(b). PHMSA cautioned pipeline operators across the country about "the potential significant impact flow reversals, product changes and conversion to service may have on the integrity (safety) of a pipeline." The advisory adds: "Flow reversals, product changes, and conversions to service may impact various aspects of a pipeline's operation, maintenance, monitoring, integrity management, and emergency response. Pressure gradients, velocity, and the location, magnitude, and frequency of pressure surges and cycles may change. Operators may also consider increasing the throughput capacity of the pipeline. Increasing throughput may also impact the pressure profile and pressure transients. … Leak detection and monitoring systems may be affected."

OBJECTION AND ANSWER: This request is not a question and cannot be answered. It also relates to an issue that is within the exclusive jurisdiction of PHMSA and is therefore not relevant or likely to lead to the discovery of admissible evidence. Without waiving the objection, PHMSA Advisory 2014-0040 is not applicable to Keystone. This advisory is related to flow reversal, product change (e.g., crude oil to refined product) and/or conversion to service (e.g., convert from natural gas to crude oil) and throughput capacity change.

18(c). Current regulations state: "Operators must review their integrity (safety) management program. … Operators must notify PHMSA if these changes will substantially affect their integrity management program, its implementation, or modifies the schedule for carrying out the program elements."

OBJECTION: This request is not a question and cannot be answered. It also relates to an issue that is within the exclusive jurisdiction of PHMSA and is therefore not relevant or likely to lead to the discovery of admissible evidence.

18(d). KXL is intended to transport two very different products, the much less dense and highly volatile Bakken oil product and the heavy diluted bitumen from Alberta. How will the two very different products affect KXL's operation, maintenance, monitoring, integrity management, and emergency response? How will the two very different products affect pressure gradients, velocity, and the location, magnitude, and frequency of pressure surges and cycles?

ANSWER: Please refer to Department of State FSEIS Chapter 3 Section 3.13.3. The Keystone pipeline is designed to transport a range of crude oils. The hydraulic analysis considers various inputs such velocity, surge and cyclic loading. The operation, maintenance, monitoring, integrity management, and emergency response plans consider the range of products transported.

33(a). Provide updated maps.

OBJECTION AND ANSWER: This request is vague, overlybroad, unduly burdensome, and seeks information that is not relevant or likely to lead to the discovery of admissible evidence. Without waiving the objection, please refer to the attached route variation maps marked as Keystone 0470-0583.

41(a). Provide map detailing all water bodies to be crossed in S.D., to include locations KXL would cross the Missouri and Yellowstone Rivers upstream from S.D.

OBJECTION: Keystone has previously filed with the PUC maps showing the route through South Dakota, which also show where the pipeline crosses rivers and other water bodies. Waterbody crossing permitting is within the control of the United States Army Corps of Engineers, and is beyond Keystone's control.

41(b). Provide map clearly depicting all waterways crossed by route which are tributaries into the Missouri River.

OBJECTION: Keystone has previously filed with the PUC maps showing the route through South Dakota, which also show where the pipeline crosses rivers and other water bodies.

41(c). Identify distances from KXL waterway crossings to point of confluence with the Missouri River.

OBJECTION: Keystone withdraws its previous objection. For the perennial stream crossings where the downstream portions of the stream are located with the boundaries of South Dakota and have a point of confluence with the Missouri River, the distance from the KXL pipeline crossing of each waterway to the Missouri River are in Table 1 below.

Table 1. Downstream Distance to the Missouri River

Stream Name	Periodicity	Miles downstream to Missouri River
Cottonwood Creek	Perennial	87.2
Bad River	Perennial	93.4
South Fork Grand River	Perennial	290.4
Clarks Fork Creek	Perennial	285.7
South Fork Moreau River	Perennial	290.4
Pine Creek	Perennial	222.7
Dry Creek	Perennial	86.5

41(d). Provide map(s) demonstrating all public water utility intakes on the Missouri River system.

OBJECTION: This request is overlybroad, unduly burdensome, and seeks information that is not within Keystone's custody or control. In addition, the location of the information is related to HCA's and deemed confidential by PHMSA.

41(e). By what date will permitting of water body crossings be completed?

OBJECTION: Permitting of water body crossings is within the control of the United States Army Corps of Engineers, and is beyond Keystone's control.

41(f). Provide a copy of the CMR Plan. Ex TC-1, 5.4.1, pp. 45-46.

ANSWER: A current copy of the CMR Plan is attached to Keystone's certification petition and is on file with the PUC.

41(g). Provide research which describes migration of spillage in these waterways.

OBJECTION: This request is vague, overlybroad, and unduly burdensome.

41(h). Please explain and describe water protection areas located downstream of major river crossings on the proposed route.

OBJECTION: This request is overlybroad, unduly burdensome, and seeks information that is not within Keystone's custody or control. In addition, the location of the information is related to HCA's and deemed confidential by PHMSA.

41(i). Explain risks of HDD, including possibility of contaminants being released into waterways during this process.

ANSWER: This issue is addressed in the FSEIS at pages 4.3-21, 4.8-20, and 4.7-11, 12.

50(a). Provide a map depicting the High Consequence Areas.

OBJECTION: This request seeks the identity and location of High Consequence Areas, which is confidential by statute, and Keystone is required by PHMSA to keep this information confidential.

50(b). Explain why the total length of pipe affecting HCA decreased from 34.3 miles to 19.9 miles.

OBJECTION AND ANSWER: To the extent that this request seeks the identity and location of High Consequence Areas, that information is confidential by statute and Keystone is required by PHMSA to keep this information confidential. Without waiving the objection, during the detailed engineering design phase of the Project, the route was adjusted. In doing so, the route deviated away from DOT designated HCA areas there by reducing total HCA miles crossed by the Project. Please refer to the attached route variation list and maps.

50(c). Explain how the statistic which states a spill could affect a HCA no more than once in 250 years.

OBJECTION AND ANSWER: To the extent that this request seeks the identity and location of High Consequence Areas, that information is confidential by statute and

Keystone is required by PHMSA to keep this information confidential. Without waiving the objection, page 4-21 of the 2009 KXL Risk Assessment shows that a spill affecting HCA in any state crossed by the Project has an occurrence interval of 53 years. This is calculated based on historical incident data from Pipeline and Hazardous Materials Safety Administration, as discussed in Section 3.0. This is calculated by taking the inverse of the incident frequency (measured as incidents per mile per year) multiplied by the miles of high consequence areas crossed (141.2 miles). The result is an estimate, in years, of the time between spills. This is similar to the concept of flood recurrence intervals (e.g., 100-year floods).

107(a). Provide the analysis by Dr. Michael Madden which professes the Project would not (ii) substantially impair the health, safety, or welfare of the inhabitants in the project area.

OBJECTION: Dr. Madden was PUC Staff's witness in Docket 09-001, and his direct testimony is a matter of public record.

107(b). Explain how the 2010 permit, which relies on the federal environmental impact statement prepared by the Department of State, addresses specific concerns of South Dakota, including the health, safety and welfare of South Dakota citizens.

OBJECTION: This request is vague, unclear, argumentative, and seeks information that is not relevant or likely to lead to the discovery of admissible evidence.

The PUC addressed the health, safety, and welfare of South Dakota residents in the Amended Final Decision and Order in Docket 09-001. In addition, South Dakota residents had notice and opportunity to participate in the lengthy NEPA process conducted by the Department of State.

107(c). Explain your interpretation of "substantially" as it is used in state law SDCL 49-41 B-22 which states the applicant for a facility construction permit has the burden of proof to establish that:

(3) "The facility will not substantially impair the health, safety or welfare of the inhabitants."

OBJECTION: This request seeks a legal opinion or conclusion and is therefore beyond the scope of discovery and not likely to lead to the discovery of admissible evidence under SDCL § 15-6-26(b). It was an issue for the PUC to determine in Docket HP 09-001.

107(d). State with 100% certainty that this project will have no impact on the health, safety or welfare of the people of South Dakota.

OBJECTION: This request is argumentative and seeks information that is not relevant or likely to lead to the discovery of admissible evidence. The PUC addressed the health, safety, and welfare of South Dakota residents in the Amended Final Decision and Order in Docket 09-001. Keystone has not asserted that the project would have "no impact" on the health, safety, or welfare of the people of South Dakota.

107(e). Describe how areas of dense populations versus areas of sparse populations affect project decision.

OBJECTION AND RESPONSE: This request is vague and unclear. Without waiving the objection, to the extent feasible and consistent with other routing criteria, areas of dense population are avoided during project routing.

Dated this 5th day of February, 2015.

TRANSCANADA KEYSTONE PIPELINE, LP
by its agent, TC Oil Pipeline Operations, Inc.

By ____________________

Its Director, Authorized Signatory

Subscribed and sworn to before me

this 5th day of February, 2015.

____
John W. Love, Lawyer
Notary Public - Canada

OBJECTIONS

The objections stated to Cindy Myers' Interrogatories and Request for Production of Documents were made by James E. Moore, one of the attorneys for Applicant TransCanada herein, for the reasons and upon the grounds stated therein.

Dated this 6th day of February, 2015.

WOODS, FULLER, SHULTZ & SMITH P.C.

By____________________________
William Taylor
James E. Moore
Post Office Box 5027
300 South Phillips Avenue, Suite 300
Sioux Falls, SD 57117-5027
Phone: (605) 336-3890
Fax: (605) 339-3357
Email: Bill.Taylor@woodsfuller.com
James.Moore@woodsfuller.com
Attorneys for Applicant TransCanada

CERTIFICATE OF SERVICE

I hereby certify that on the 6th day of February, 2015, I sent by e-mail transmission, a true and correct copy of Keystone's Responses to Cindy Myers' First Interrogatories and Request for Production of Documents, to the following:

Cindy Myers, R.N.
PO Box 104
Stuart, NE 68780
csmyers77@hotmail.com

One of the attorneys for TransCanada

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA

o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o

IN THE MATTER OF THE APPLICATION BY TRANSCANADA KEYSTONE PIPELINE, LP FOR A PERMIT UNDER THE SOUTH DAKOTA ENERGY CONVERSION AND TRANSMISSION FACILITIES ACT TO CONSTRUCT THE KEYSTONE XL PROJECT	: : : : :	HP 14-001 TRANSCANADA KEYSTONE PIPELINE, LP'S SUPPLEMENTAL RESPONSES TO CINDY MYERS' FIRST INTERROGATORIES AND REQUEST FOR PRODUCTION OF DOCUMENTS

o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o-o

Applicant TransCanada makes the following supplemental responses to interrogatories pursuant to SDCL § 15-6-33, and responses to requests for production of documents pursuant to SDCL § 15-6-34(a). These supplemental responses are made within the scope of SDCL 15-6-26(e) and shall not be deemed continuing nor be supplemented except as required by that rule. Applicant objects to definitions and directions in answering the discovery requests to the extent that such definitions and directions deviate from the South Dakota Rules of Civil Procedure.

GENERAL OBJECTION

Keystone objects to the instructions and definitions contained in Cindy Myers' First Set of Interrogatories and Requests for Production of Documents to the extent that they are inconsistent with the provisions of SDCL Ch. 15-6. *See* ARSD 20:10:01:01.02.

Keystone's answers are based on the requirements of SDCL §§ 15-6-26, 15-6-33, 15-6-34, and 15-6-36.

INTERROGATORIES AND REQUEST FOR PRODUCTION OF DOCUMENTS

1. Please identify the person or persons providing each answer to an Interrogatory or portion thereof, giving the full name, address of present residence, date of birth, business address and occupation.

ANSWER: Given the extremely broad scope volume of more than 800 discovery requests received by Keystone in this docket, a range of personnel were involved in answering the interrogatories. Keystone will designate the following witnesses with overall responsibility for the responsive information as related to the Conditions and proposed changes to the Findings of Fact, which are identified in Appendix C to Keystone's Certification Petition: Corey Goulet, President, Keystone Projects, 450 1st Street S.W., Calgary, AB Canada T2P 5H1; Steve Marr, Manager, Keystone Pipelines & KXL, TransCanada Corporation, Bank of America Center, 700 Louisiana, Suite 700, Houston, TX 77002; Meera Kothari, P. Eng., 450 1st Street, S.W., Calgary, AB Canada T2P 5H1; David Diakow, Vice President, Commercial, Liquids Pipeline, 450 1st Street S.W., Calgary, AB Canada T2P 5H1; Jon Schmidt, Vice President, Environmental & Regulatory, exp Energy Services, Inc., 1300 Metropolitan Boulevard, Suite 200, Tallahassee, FL 32308; Heidi Tillquist, Senior Associate, Stantec Consulting Ltd., 2950 E. Harmony Rd., Suite 290, Fort Collins, CO 80528.

In addition to the witnesses previously identified, Keystone may offer rebuttal testimony from Danielle Dracy regarding emergency response; Lou Thompson regarding tribal engagement; Steve Klekar regarding tax issues; and Doug Robertson regarding SCADA and leak detection. Resumes for these possible rebuttal witnesses are marked as Keystone 1930-1934.

Dated this 10 day of March, 2015.

TRANSCANADA KEYSTONE PIPELINE, LP
by its agent, TC Oil Pipeline Operations, Inc.

By ______________________
Joseph Brown
Director, Authorized Signatory

Subscribed and sworn to before me

this 10 day of March, 2015.

____
John W. Love, Lawyer
Notary Public - Canada

{01855195.1}

008980

CERTIFICATE OF SERVICE

I hereby certify that on the 10th day of March, 2015, I sent by e-mail transmission, a true and correct copy of Keystone's Supplemental Responses to Cindy Myers' First Interrogatories and Request for Production of Documents, to the following:

Cindy Myers, R.N.
PO Box 104
Stuart, NE 68780
csmyers77@hotmail.com

One of the attorneys for TransCanada

Subject: Re: Review quotes for accuracy please
> To: csmyers77@hotmail.com
> From: Vann.Bradley@epamail.epa.gov
> Date: Fri, 10 Jun 2011 15:51:45 -0500
>
> •Brad Vann, Environmental Scientist, EPA, Region 7
> "Its a lot easier to put chemicals in the ground than to take them out
> of the ground or groundwater"
> •"I would also be concerned if I had a drinking water well down-gradient
> from any petroleum or chemical source, and would want to know
> specifically what safety protocols are being employed to ensure that a
> release has not occurred, or if it did, it would not impact my water
> supply (i.e., leak preventers, inspection frequency, routine testing,
> installation of sentinel wells, leak response protocols, etc.)."
> "Petroleum is a mixture of many of organic compounds"
> •Benzene:
> Is a known human carcinogenic.
> •Benzene is a degradation chemical from crude oil. In pure form it is
> not soluble with water but solubility can occur with mixtures of other
> chemicals and at dilute concentrations. These dilute concentrations do
> mix with the water sufficiently to exceed safe drinking water limits.
> •"The safe drinking water limit (Maximum Contaminant Level or MCL) for
> Benzene in drinking water is 5 parts per billion"
> •Because this is such a minute amount, "you can't smell, taste or see it
> (below odor and taste threshold). It requires laboratory analysis to
> detect at these concentrations. Therefore, it would be possible to
> drink dilute Benzene above the MCL and not know.
>
> Bradley Vann - RPM
> US EPA Region VII (SUPR/IANE)
> 901 N. 5th Street
> Kansas City, KS 66101
> phone: (913) 551-7611
> fax: (913) 551- 9611
> vann.bradley@epa.gov
>
>
>
>
> From: Cindy Myers <csmyers77@hotmail.com>
>
> To: Bradley Vann/R7/USEPA/US@EPA
>
> Date: 06/10/2011 02:56 PM
>
> Subject: Review quotes for accuracy please
>
>
>
>
>

>
> •Brian Vann, EPA, Region 7
> “Lot easier to put in the ground than to take out of the ground”
> •“I would be concerned also if I had a well down-gradient from a
> chemical source”
> •Benzene:
> Known carcinogenic
> •A degree of benzene from crude oil is soluble in water, mix with the
> water.
> •“Allowable limit in drinking water is 5 parts per billion”
> •Because this is such a minute amount, “you can’t smell, taste or see
> it.” Analysis required to detect. Would be possible that you would
> drink and not know.

Safety in the Community

Safety is a core value at TransCanada. We make safety — for ourselves, each other, our contractors and for members of our communities — an integral part of the way we work.

TransCanada's operations extend across North America with established offices in various communities. Each region is fully staffed with qualified employees trained in pipeline safety and emergency response to ensure the safe and efficient operation of the facilities in the area.

We view the communities we operate in as emergency response partners. We will work collaboratively with emergency responders, extending invitations to participate in exercises and training.

In the event of an emergency, we work with emergency response officials in a Unified Command to ensure everyone is familiar with local operations and is ready to respond in the event of an incident. TransCanada does not expect volunteer or dedicated local emergency services to have the equipment or specific experience needed to respond to a leak or rupture with the exception of protecting the public by conducting evacuations if necessary and keeping them out of the impacted area.

KEYSTONE 1533

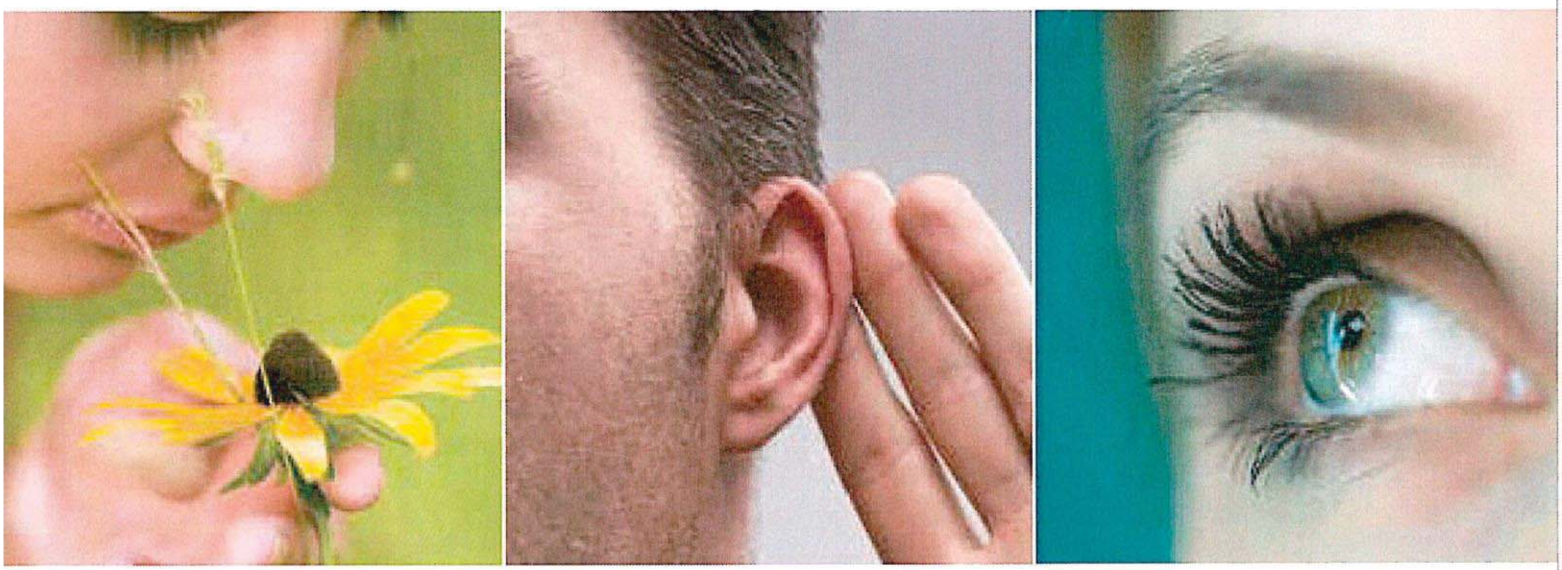
Actions for Emergency Services

Do

- Protect yourselves and the public.
- Contain and extinguish any secondary fires if safe to do so.
- Refer to 128 in the 2012 ERG for guidance on initial response including potential evacuation distances.
- Provide traffic and crowd control.
- Secure the site and establish a safe zone to ensure public safety. Keep a safe distance away.
- Evacuate unnecessary personnel.
- Monitor for I-EL, H S and benzene if possible.
- Eliminate all ignition sources if safe to do so.
- Provide first aid as needed.
- Allow TransCanada employees clear and quick access to the emergency site.

Do Not

- Attempt to operate any valves.
- Go near the spill until a hazard assessment has been conducted by TransCanada.
- Attempt to contain the oil or try to identify the oil.



Leak Detection

Although a pipeline leak is rare, it is important to know how to recognize the signs. Use your senses of smelling, seeing and hearing to detect a potential pipeline leak.

What you may smell

- Many petroleum products have a distinct smell. Crude oil can possess a rotten egg, gasoline, tar or "skunk-like" odor.

What you may hear

- A hissing or roaring sound.

What you may see

- Amber to black liquid.
- Rainbow sheen or black liquid on top of water.
- Discolored vegetation on or near a pipeline in an area that is usually green.
- Stained or melted snow/ice over pipeline areas.

KEYSTONE 1534

If You Suspect a Leak

If you witness any of the typical signs listed, or any other unusual sights, sounds or smells near a pipeline location, it is important that you follow these steps:

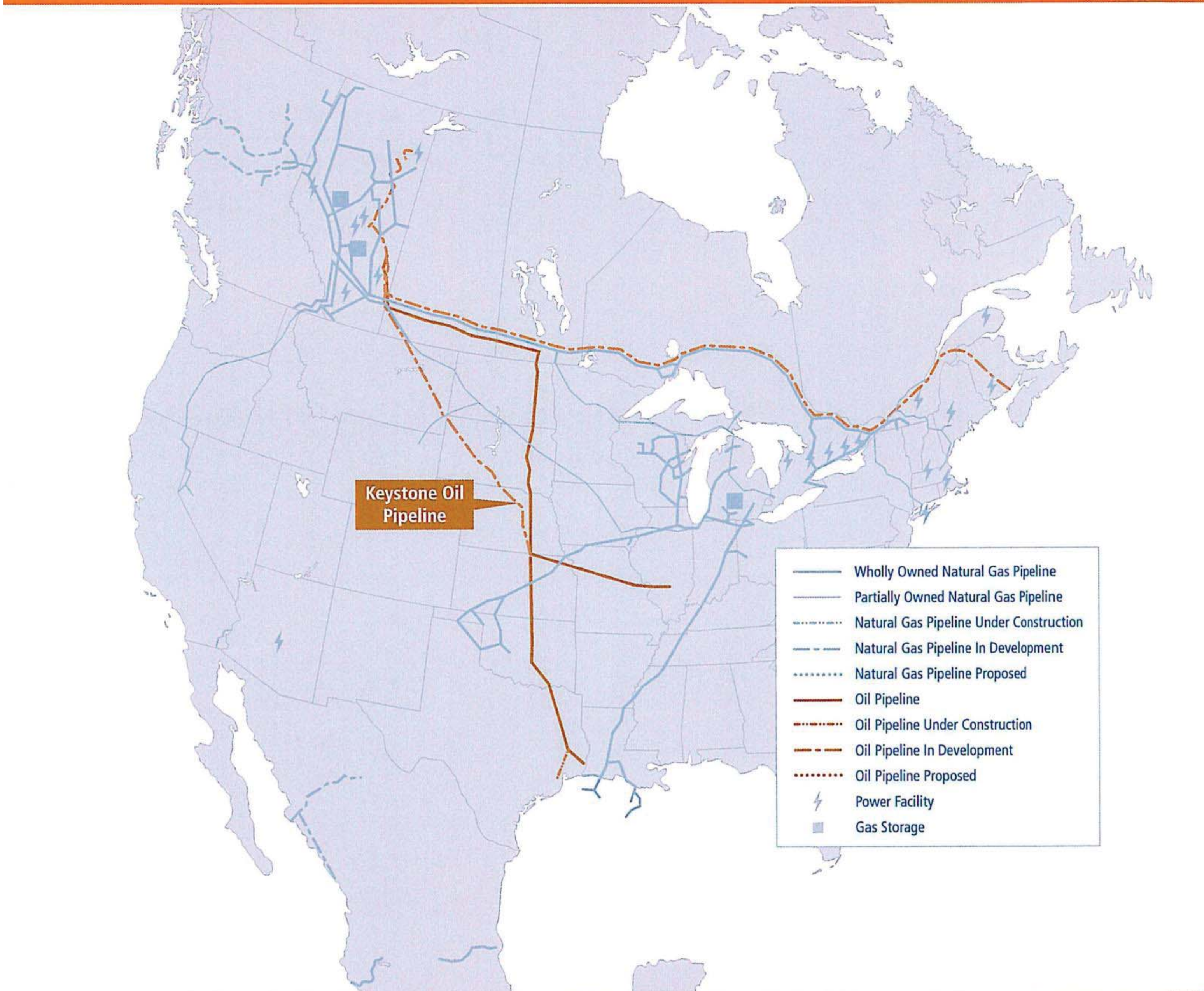
1. Leave the area immediately.

2. Move to a safe location, call '911'.

3. Call TransCanada's emergency number: 1.800.447.8066. This number can be found on all pipeline marker signs and facility gates.

4. Warn others to stay away.

North American Assets



KEYSTONE 1536

Important Contact Information

Call Before You Dig - It's Free

United States 811

-50

008990

Emergencies 1.800.447.8066

General Inquiries..1 .866.717.7473

For Crossing or Encroachment Agreements.. us_crossings@transcanada.com

Actions for Emergency Services

Do

- Protect yourselves and the public.
- Contain and extinguish any secondary fires if safe to do so.
- Refer to 128 in the 2012 ERG for guidance on initial response including potential evacuation distances.
- Provide traffic and crowd control.
- Secure the site and establish a safe zone to ensure public safety. Keep a safe distance away.
- Evacuate unnecessary personnel.
- Monitor for I-EL, H2S and benzene if possible.
- Eliminate all ignition sources if safe to do so.
- Provide first aid as needed.
- Allow TransCanada employees clear and quick access to the emergency site.

Do Not

- Attempt to operate any valves.
- Go near the spill until a hazard assessment has been conducted by TransCanada.
- Attempt to contain the oil or try to identify the oil.

008991

TransCanada Emergency Number:

1-8001447-8066

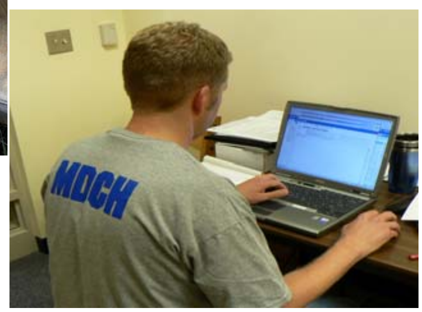
10towwhat'sbelow.
Call beforeyoudig.

TransCanada
In business to deliver

KEYSTONE 1538

Acute Health Effects of the Enbridge Oil Spill

November 2010
(Minor revisions 12/20/2010)



Michigan Department of Community Health

MDCH

CALHOUN COUNTY MICHIGAN ORGANIZED 1833

008994

Acute Health Effects of the Enbridge Oil Spill

November 2010
(Minor revisions December 20, 2010)

Martha Stanbury,[1] MSPH, Kim Hekman, MPH,[1] Eden Wells, MD, MPH,[1] Corinne Miller, DDS, PhD,[1] Susan Smolinske, PharmD,[2] James Rutherford, RS, MPA [3]

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PO Box 30195, Lansing, MI 48909
stanburym@michigan.gov
517-335-8364.

1. Michigan Department of Community Health, Lansing, MI
2. Poison Control Center, Children's Hospital of Michigan, Detroit, MI
3. Calhoun County Public Health Department, Battle Creek, MI

Acute health effects of the Enbridge Oil Spill

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Executive Summary

On Monday July 26, 2010, Enbridge Energy Partners, L.P., reported the burst of a 30-inch pipeline near Marshall, Michigan, in Calhoun County. In response to concerns about acute health effects from exposure to spilled oil in this major disaster, state and local public health in Michigan quickly set up a multi-faceted public health surveillance system that included health care provider reporting, community surveys, calls from the public to the Poison Control Center, and analysis of data submitted to the state's syndromic surveillance system. The surveillance system received 147 health care provider reports on 145 patients, identified 320 (58%) of 550 individuals with adverse health effects from four community surveys along the impacted waterways, identified one small worksite symptomatic employees, and tracked 41 calls that were placed to the poison center by the public. Headache, nausea, and respiratory symptoms were the predominant symptoms reported by exposed individuals in all reporting systems. These symptoms are consistent with the published literature regarding potential health effects associated with acute exposure to crude oil.

I. Background

On Monday July 26, 2010, Enbridge Energy Partners, L.P., reported the burst of a 30-inch pipeline near Marshall, Michigan, in Calhoun County. The spill started at least a day earlier based on 911 calls and other reports of strong odors starting July 25. Approximately 800,000 gallons of crude oil spilled into the Talmadge Creek, a waterway that feeds the Kalamazoo River. The contamination ultimately affected 25 miles of the creek and river. While the greatest impact was in Calhoun County, the spill also affected an area of Kalamazoo County encompassing five miles of the river downstream from the border of Calhoun County to a dam just upstream from the city of Kalamazoo (See map in the appendix). The U.S. Environmental Protection Agency (EPA), Calhoun County Public Health Department (CCPHD), Calhoun County Emergency Management, the Michigan Department of Community Health (MDCH) and many other agencies and organizations quickly became involved with public health and environmental response to this massive spill.

Beginning July 26, when the spill was reported to authorities, individuals near Talmadge Creek and the Kalamazoo River began complaining of strong, noxious odors and associated health symptoms in calls to CCPHD and the Michigan PCC. Subsequently, once it had been established, citizen concerns and complaints were routed to a phone hotline developed by Enbridge. Callers reported respiratory, gastrointestinal, and neurological symptoms, predominantly headache and nausea.

To adequately characterize the impact of the oil spill on the public's health, CCPHD, MDCH, and the Kalamazoo County Health and Community Services Department (KCHCS) developed and implemented a public health surveillance system to collect data on individuals with adverse health outcomes secondary to exposure to spilled oil and its vapors. The goal of this surveillance was to describe the magnitude and distribution of human health impacts due to exposure to the spilled oil, so that decision-makers could make informed decisions about actions needed to protect the public.

The surveillance system included four components: (1) active solicitation of health care provider reports, under legal authority of the Public Health Code, and (2) door-to-door health surveys in selected communities self-identified as particularly impacted by the spill, (3) monitoring daily counts of self-reported illnesses based on calls to the PCC, and (4) utilization of MDCH's syndromic surveillance system.

In order to protect personal confidential medical information, MDCH obtained a "Medical Research Designation".[1] This designation legally protected individual identifying information from disclosure by the participating public health authorities to other parties, including those situations in which the information could be requested under the Michigan Freedom of Information Act or by subpoena.

This report describes the methods and results of the public health surveillance system established to measure and monitor health impacts from the Enbridge oil spill. Information about environmental sampling, clean-up efforts and other aspects of the spill response are available elsewhere.[2]

II. Methods and Results

A. Health care provider reporting

Methods

Initially, contacts were made at the two hospitals in the area, and they were asked to provide a daily count of the number of patients seen in the Emergency Department (ED) or admitted with oil exposure-related complaints. Then, on August 5, the CCPHD and the KCHHS sent out “blast faxes” to all health care providers in their respective counties requesting that clinicians and healthcare facilities formally report any patients seen due to illness or symptoms associated with oil spill exposure. Providers were advised that this reporting is required under the Michigan Public Health Code (R 325.71-75), and they were provided reporting information and forms.[3] To gather data on patients who were seen at the local ED prior to establishment of this healthcare reporting system, medical records of patients identified as exposed to the oil or its vapors were abstracted by the MDCH medical epidemiologist.

The Michigan PCC was authorized as a legal agent of the state to receive the reports from health care providers for the purposes of this investigation. This allowed for 24/7 reporting, and allowed for PCC medical toxicologists to provide consultation to health care providers regarding oil spill-related patient diagnosis or treatment. Patient information collected included name, contact information and demographics, medical encounter date, clinical effects, laboratory test results, diagnosis, treatment, and contact information for the reporting provider.

Reported information was entered into Toxicall®, the electronic case management system used by the Michigan PCC. Each case was given a “medical outcome” classification based on information about reported clinical effects as follows: no effect (no symptoms due to exposure); minor effect (some minimally troublesome symptoms); moderate effect (more pronounced, prolonged symptoms); major effect (symptoms that are life-threatening or cause significant disability or disfigurement); death; not followed, judged as nontoxic exposure (clinical effects not expected); not followed, minimal clinical effects possible (no more than minor effect possible); unable to follow, judged as a potentially toxic exposure; unrelated effect, the exposure was probably not responsible for the effect(s); or, confirmed non-exposure.

Daily summary reports were provided by the PCC to MDCH, CCPHD, and KCHHS on numbers of reports and severity of illness (i.e. “medical outcome”). A spreadsheet of all case information was provided to MDCH for data analysis. Analysis was performed using SAS® version 9.2 (SAS Institute, Cary, NC).[4]

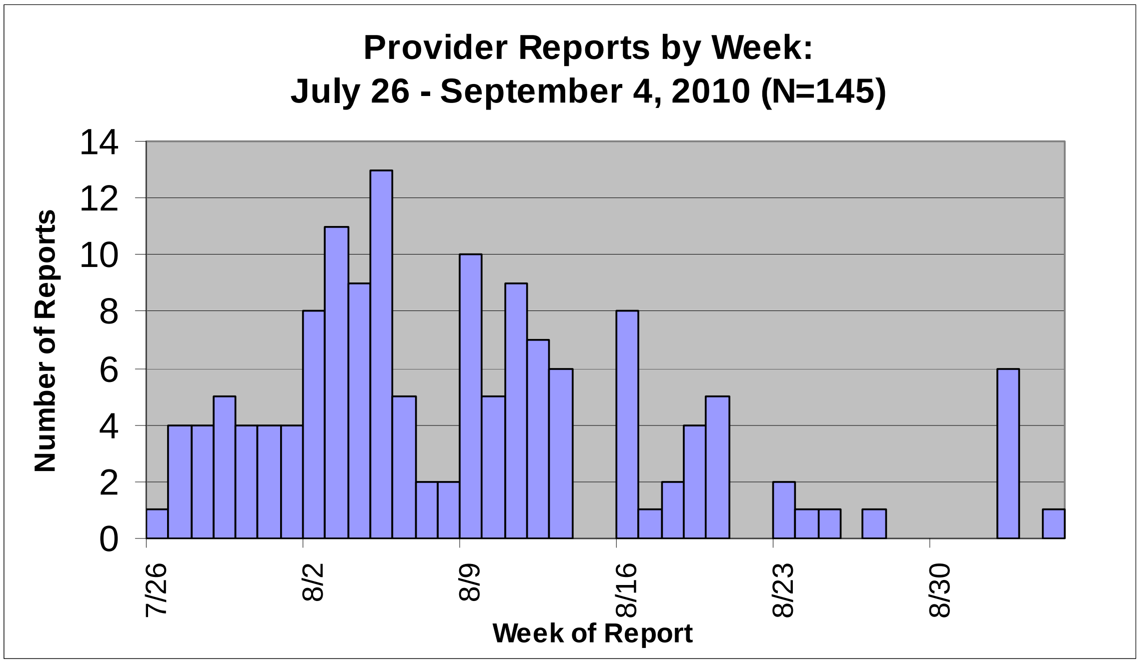
Results

Between July 26 and September 4, 2010, one hundred forty-seven health care visits for 145 individuals were reported by health care providers. (Two individuals were reported twice, by different providers, for separate visits.) One hundred seventeen (80.7%) of the 145 individuals lived and/or worked in areas near the affected waterways, 24 (16.5%) were oil-spill response workers, and four (2.7%) were transients/visitors.

The average age of these 145 individuals was 38. There were slightly more females (77/53.1%) than males (68/46.9%) reported. Adults age 18 to 64 predominated (100/69%), with the remainder being children under age 18 (36/24.8%), and a small number of adults over age 65 (9/6.2%).

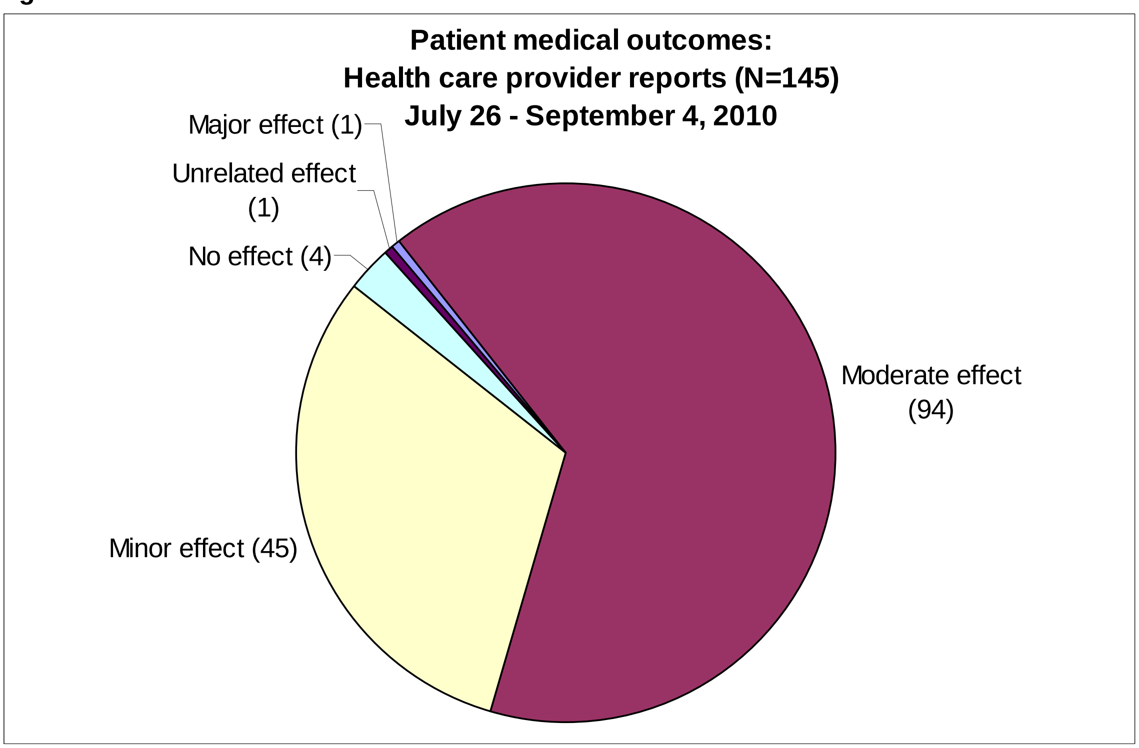
The date of the reported visit to the health care provider is shown in **Figure 1**. (The two individuals reported twice are counted for date of their first visit.) The frequency of reported health care provider visits peaked in the second week after the spill, coinciding with the week providers were notified of the new reporting requirements. These visits included outpatient (N=77; 53%), hospital emergency department (N=64; 44%), hospital inpatient (N=1; 0.6%), and 3 (2%) where type of facility was unknown.

Figure 1



Approximately one-third (31%) of the medical outcomes of these individuals were classified as minor and two-thirds (64.8%) as moderate. There were no deaths. **(Figure 2**) The one individual with medical outcome classified as “major” had significant exposure and had 8 reported clinical effects. Those with a medical outcome of “moderate” had on average 3.7 clinical effects whereas those classified as “minor” had 2.4 clinical effects.

Figure 2



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Four (2.8%) of the reported individuals had no clinical effects. The remainder had from one to more than six clinical effects each (**Table 1**).

Table 1

Number of Clinical Effects in Health Care Provider Visits	Total	
	N	%
Number of Clinical Effects		
0 symptoms	4	2.8%
1 symptom	21	14.5%
2 symptoms	38	26.2%
3 symptoms	26	17.9%
4-5 symptoms	37	25.5%
6+ symptoms	19	13.1%

Neurological effects were reported most frequently (94/ 64.8%), with headache being the predominant of all neurological effects reported 83 (57.2%). Eighty-six individuals (59.3%) had at least one gastrointestinal clinical effect, with nausea predominating, and 68 (46.9%) had with at least one respiratory clinical effect with cough and choke predominating (**Table 2**).

Table 2

Frequency of Clinical Effect Categories in Health Care Provider Visits	Total	
	N	%
Clinical Effect Category		
Cardiovascular	11	7.6
Dermal	9	6.2
Gastrointestinal	86	59.3
Nausea	*57*	*39.3*
Neurological	94	64.8
Headache	*83*	*57.2*
Ocular	23	15.9
Renal	1	0.7
Respiratory	68	46.9
Cough/Choke	*47*	*32.4*
Other	41	28.3

B. Community and Workplace Surveys

Methods: Four communities along the Talmadge Creek and Kalamazoo River and one small workplace were identified (from calls to the toll-free number and the CCPHD) as having multiple reports of adverse health effects and concerns about oil spill impacts.

A door-to-door health survey was conducted by MDCH and the CCPHD in each community. The community survey obtained information on whether the household had, or were planning to, relocate because of the spill; observations about the intensity and duration of the odor since July 25; and, for all members of the household, information about chronic/pre-existing health conditions that made them sensitive to fumes or odors. They were also asked about new or exacerbated health symptoms after the spill event. After the first survey, a question was added to assess whether those who had symptoms had seen a physician for their symptoms. For the most part, answers were provided by the person answering the door for all household members. Answers were provided in an open-ended format. Where no one was home, information was left at the door; in the second, third, and fourth communities, including a fact sheet from EPA on the oil spill and a cover letter that invited someone in the household to call a toll-free number at MDCH to answer the survey questions by telephone. In order to have an approximate measure of socio-economic status for each of these communities, a local realtor was asked to provide his estimate of the range of home prices that could be expected in each community.

The first health survey was conducted on August 6, 11 days after the spill was reported, in a neighborhood approximately 14 miles downstream from the spill origin and immediately adjacent to an area of wetland fed by the Kalamazoo River. Previously, on August 2, the CCPHD had visited the neighborhood to assess the need for temporary relocation of individuals concerned about the odors and their health, and to give information about how Enbridge would cover the costs of that relocation. However, information about health symptoms was not requested at that initial visit. Home prices in the neighborhood, which is referred to as “Neighborhood” in the tables, are estimated to range from $500 to $15,000.

The second community survey was conducted 16 days after the spill in a subdivision approximately two miles downstream. Home prices in the “Subdivision” are estimated to range from $120,000 to $325,000.

The third community, referred to as “Spill Site” in the tables, was surveyed in two parts, 22 and 24 days after the spill. This community included the homes surrounding the immediate area on the Creek where the pipeline burst. It was the only community where a voluntary evacuation notice had been issued, due to air sampling indicating elevated levels of benzene– a potential concern for long-term health. Each of these two surveys took place within 24 hours after the evacuation notice was lifted for that area. A environmental contractor accompanied the survey team and offered air monitoring outside and inside homes to each of the interviewees, using a real-time monitoring instrument. Home values in this community are estimated to range from $75,000 to $350,000.

The fourth survey occurred 23 days after the spill in a small village of approximately 80 homes, situated directly on the river about five miles downstream from the spill's origin. Home values in the "Village" are estimated to range from $10,000 to $125,000.

For comparison purposes, a door-to-door survey was conducted 25 days after the spill in a community approximately fifteen miles stream upstream of the spill, in order to obtain information on the occurrence of health symptoms in the previous four weeks. The six neighborhoods surveyed in this community were on the Kalamazoo River; they were similar to the exposed communities in demographics and the range of home prices, encompassed homes valued from $5,000 to $225,000.

All 12 workers at the small workplace located a little less than one mile northeast of the confluence of Talmadge Creek and the Kalamazoo River were interviewed using the same open-ended format as the community surveys.

Results

Community Surveys

Table 3 shows the survey completion rates by community and in the Comparison community. Overall, 201 (59.6%) of the 337 homes visited provided information for a total of 550 household members in the exposed communities, and 51 (27.9%) of the 183 homes surveyed in the Comparison community provided information on 137 individuals. The average number of household members ranged from 2.5 to 3.1 in the exposed communities and was 2.7 in the Comparison community.

Table 3

Survey Completion by Community						
	Neighborhood	**Subdivision**	**Spill Site**	**Village**	**Total**	**Comparison**
Total Number of Homes Visited	78	121	55	83	337	183
Number of Homes that Completed Survey	45	75	37	44	201	51
Number of Homes that Refused Survey	0	0	0	1	1	18
Number of Homes with No One Home	33	46	18	38	135	114
Percentage of Homes Surveyed	57.7%	62.0%	67.3%	53.0%	59.6%	27.9%
Number of Individuals with Survey Information	117	233	92	108	550	137
Average Number of Individuals per Household	2.6	3.1	2.5	2.5	2.7	2.7

In terms of race/ethnicity, all communities were almost entirely white. There were some differences between communities in other demographics. The community at the spill site was on average older, had fewer children, and was over 50% male, in contrast to the other three exposed communities and the Comparison group. Smoking prevalence, which was asked in all surveys except at the Neighborhood, was notably different, with the two communities with more expensive homes reporting much lower smoking rates in adults (Spill site: 5.1%; Subdivision: 6.0%) than the other one (Village) at 20.7%. Smoking prevalence in the Comparison community was 19.8% (**Table 4**).

Table 4

Demographics and Smoking Profile by Community						
	Neighborhood	**Subdivision**	**Spill Site**	**Village**	**Total**	**Comparison**
Gender (%)						
Male	47.8%	44.2%	53.3%	46.3%	46.9%	45.3%
Female	52.2%	55.8%	46.7%	53.7%	53.1%	54.7%
Average Age (yrs)	32.1	35.8	48.9	41.9	38.4	39.1
Age Distribution (%)						
0-7 yrs	13.9%	12.2%	2.2%	5.7%	9.6%	9.0%
8-17 yrs	15.6%	21.8%	13.0%	16.2%	17.9%	14.3%
18-30 yrs	20.0%	6.5%	6.5%	9.5%	9.95%	10.5%
31-50 yrs	28.7%	31.3%	16.3%	29.5%	27.85%	34.6%
51-65 yrs	18.3%	17.8%	43.5%	26.7%	24.0%	19.6%
66+ yrs	3.5%	10.4%	18.5%	12.4%	10.7%	12.0%
Missing (n)	2	3	0	3	8	4
Smoker (age 18 and older)	not asked	6.0%	5.1%	20.7%		19.8%

The percent of residents that reported symptoms according to smoking status is shown in **Table 5**. A higher proportion of non-smokers reported no symptoms (39.6%) compared to smokers (25.0%). Similarly, a higher proportion of smoker reported 1 symptom and 4+ symptoms (39.3%, 10.7%), compared to non-smokers (26.8%, 5.4%). The proportion of residents that report 2-3 symptoms was very similar between smokers and non-smokers.

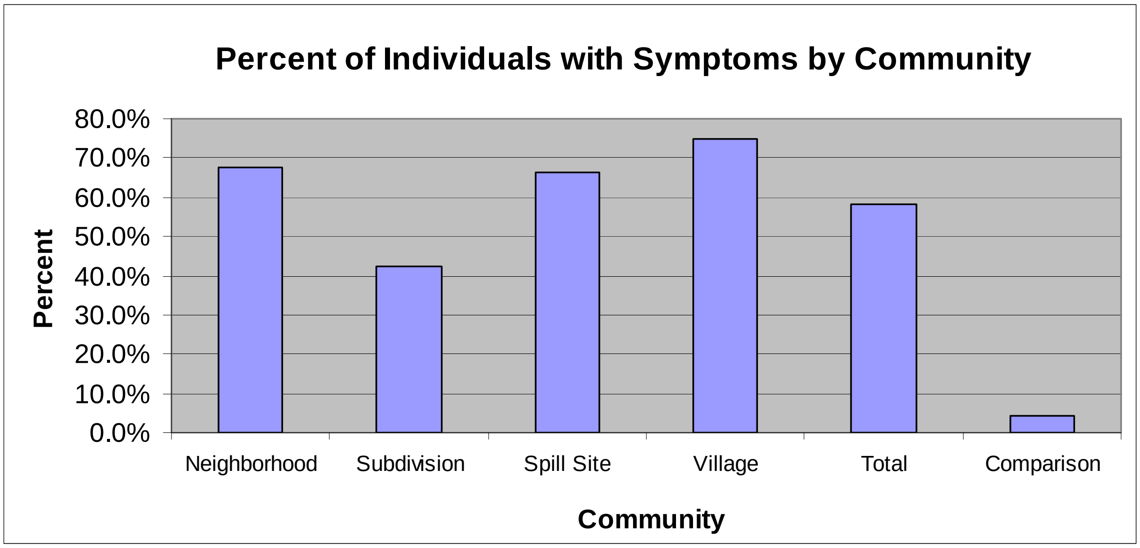
Table 5

Symptoms by Smoking Status among Adults		
	Smoker	
	Yes	No
Percent with Symptom		
0 symptoms	25.0%	39.6%
1 symptom	39.3%	26.8%
2-3 symptoms	25.0%	28.2%
4+ symptoms	10.7%	5.4%

Nearly all of the households in each of the four exposed communities reported noticing an odor since July 25, 2010 (Neighborhood: 100%, Subdivision: 97.3%, Spill Site: 97.2%, Village: 100%). In comparison, only a small minority of households in the Comparison community reported smelling an odor at any time after July 25 (15.7%).

Overall, 320 (58.2%) of the 550 individuals reported at least one new or exacerbated symptom after July 25 in contrast to 4.4% in the Comparison community. The frequency of symptoms varied by community. The Subdivision, which has homes more widely spread out from the river than any of the others, reported the lowest frequency (42.5%), and the Village had the highest (75.7%). By contrast, only 6 (4.4%) of the 131 individuals in the Comparison community reported any new or worsened symptoms in the timeframe following the spill (**Figure 3**).

Figure 3



Of the 320 individuals in the exposed communities who reported symptoms, 42.8% reported only one symptom, 44.7% reported 2-3 symptoms, and 12.5% reported 4 or more symptoms (**Table 6).** The proportion of exposed residents reporting symptoms was significantly greater than the proportion in the comparison community ($p < .0001$).

Table 6

Frequency of Symptoms by Community												
	Neighborhood		**Subdivision**		**Spill Site**		**Village**		**Total**		**Comparison**	
	N	%	N	%	N	%	N	%	N	%	N	%
Number/percent without any Symptoms	38	32.5%	134	57.5%	31	33.7%	27	25.0%	230	41.8%	131	95.6%
Number/percent with any Symptom	79	67.5%	99	42.5%	61	66.3%	81	75.0%	320	58.2%	6	4.4%
1 symptom	27	34.2%	49	49.5%	27	44.3%	34	42.0%	137	42.8%	5	83.3%
2-3 symptoms	37	46.8%	44	44.4%	28	45.9%	34	42.0%	143	44.7%	1	16.7%
4+ symptoms	15	19.0%	6	6.1%	6	9.8%	13	16.0%	40	12.5%	0	0.0%

Headache was the most frequently reported symptom (34.5%) in all exposed communities, ranging from 25.3% in the Subdivision to 42.6% in the Village. This was followed by respiratory symptoms (e.g., breathing difficulty, cough) at 29.6% and gastrointestinal complaints (e.g., nausea and vomiting), 21.6% (**Table 7**). In the Comparison community, only 1 resident reported headache symptoms and respiratory symptoms, respectively. None of the comparison residents reported gastrointestinal or skin/eyes symptoms. New onset or worsened anxiety was reported by 4.9% of all exposed residents. The Subdivision reported the least amount of anxiety (1.3%) and the Neighborhood reported the most (11.1%). There were no reports of anxiety among any of the residents in the Comparison community. Data on other symptoms were also included and compiled into an 'other' category, with 24.7% of residents in the exposed communities reporting other new or worsened symptoms and only 3.6% in the Comparison community.

Overall, 12.2% of exposed residents visited a doctor for new or worsened symptoms, and doctor visits ranged from 9.8% in the Spill Site to 14.8% in the Village. While only 6 individuals in the Comparison community reported new or worsened symptoms, 4 (66.7%) saw a health care provider for these symptoms.

Table 7

Frequency of Types of Symptoms and Doctor Visits by Community

	Neighborhood		Subdivision		Spill Site		Village		Total		Comparison	
	N	%	N	%	N	%	N	%	N	%	N	%
Symptoms												
Headache	48	41.0%	59	25.3%	37	40.2%	46	42.6%	190	34.5%	1	0.7%
Respiratory (breathing diff., cough, sore throat/nose)	34	29.1%	53	22.7%	23	25.0%	53	49.1%	163	29.6%	1	0.7%
Gastrointestinal (nausea, vomiting, stomach ache)	41	35.0%	31	13.3%	15	16.3%	32	29.6%	119	21.6%	0	0.0%
Skin/Eyes	10	8.5%	11	4.7%	11	12.0%	23	21.3%	55	10.0%	0	0.0%
Anxiety	13	11.1%	3	1.3%	7	7.6%	4	3.7%	27	4.9%	0	0.0%
Other (dizziness, fatigue, chest pain, & other)	51	43.6%	20	8.6%	25	27.2%	40	37.0%	136	24.7%	5	3.6%
Individuals with One or more Symptoms	79	67.5%	99	42.5%	61	66.3%	81	75.0%	320	58.2%	6	4.4%
Individuals who Visited a Doctor for these Symptoms	11	13.9%	10	10.1%	6	9.8%	12	14.8%	39	12.2%	4	66.7%

The prevalence of reported chronic conditions/pregnancy potentially causing increased sensitivity to odors ranged from 23.6% in the Subdivision, to 26.1% (Spill site), 40.7% (Village), and 61% (Neighborhood), including four pregnancies. The prevalence of chronic conditions in the Comparison community was 40.7%. (It should be noted that some individuals reported chronic conditions that were not likely to increase sensitivity to odor, e.g., musculoskeletal disorders.) Individuals with chronic conditions reported proportionally more symptoms than individuals without chronic conditions (**Table 8**).

Table 8

Frequency of Symptoms by Chronic Condition

	Chronic Condition	
	Yes	No
Number of Symptoms (%)		
0 symptoms	30.9%	47.1%
1 symptom	27.0%	23.9%
2-3 symptoms	29.8%	24.2%
4+ symptoms	12.3%	4.8%

Information was available on 501 of the 550 individuals in the four communities on relocation after the spill and 169 (33.7%) of the 501 relocated. These included 50 households where everyone left and 10 households where only some members left. Thus, relocation impacted 60 (29.9%) of the 201 households surveyed. Symptoms were more prevalent overall in the 169 individuals who relocated (71.6%) than the 332 individuals who did not (50.9%). A greater percent of those with symptoms who relocated saw a physician (11.8%) than those who did not relocate (5.1%) (**Table 9**).

Table 9

Symptoms by Relocation Status				
	Relocated (n=169)		**Didn't Relocate (n=332)**	
Number/percent without Symptoms	48	28.4%	163	49.1%
Number/percent with any Symptom	121	71.6%	169	50.9%
1 symptom	44	26.0%	77	23.2%
2-3 symptoms	58	34.3%	72	21.7%
4+ symptoms	19	11.2%	20	6.0%
Number/percent that Visited Doctor/ED	20	11.8%	17	5.1%

Workplace survey

At the small worksite where the symptom survey was conducted, 100%* of the workers noted the odor. Eighty-three percent noted that the worst days for odor were early in the first week following the oil release (the week of July 26). The others did not identify the worst days.

- 92% said they still smelled the odor when they were interviewed, which was three weeks after the spill.
- 33% noted that they had pre-existing chronic health conditions that made them sensitive to fumes or odors.
- 92% noted a variety of new onset or worsened symptoms after the release, including: headache (92%), respiratory symptoms (33%); dizziness (50%); gastrointestinal symptoms (33%); fatigue (33%); eye, nose, throat irritation (75%); and anxiety (42%).
- 17% noted that they were planning to see a physician for these symptoms.

C. Calls to the PCC from the public

Methods

As noted above, within a few days of the spill, individuals began making calls to the PCC with concerns about the oil spill, using the nationwide poison control toll-free number. Although the PCC toll-free number and its services were not publicized to the public in Calhoun and Kalamazoo Counties during the spill event, these calls were consistent with the understanding among the general public that poison centers are available to answer questions about chemicals, poisonings, and toxic exposures. All calls were logged according to PCC standard operating procedures. They were coded so that they could be identified

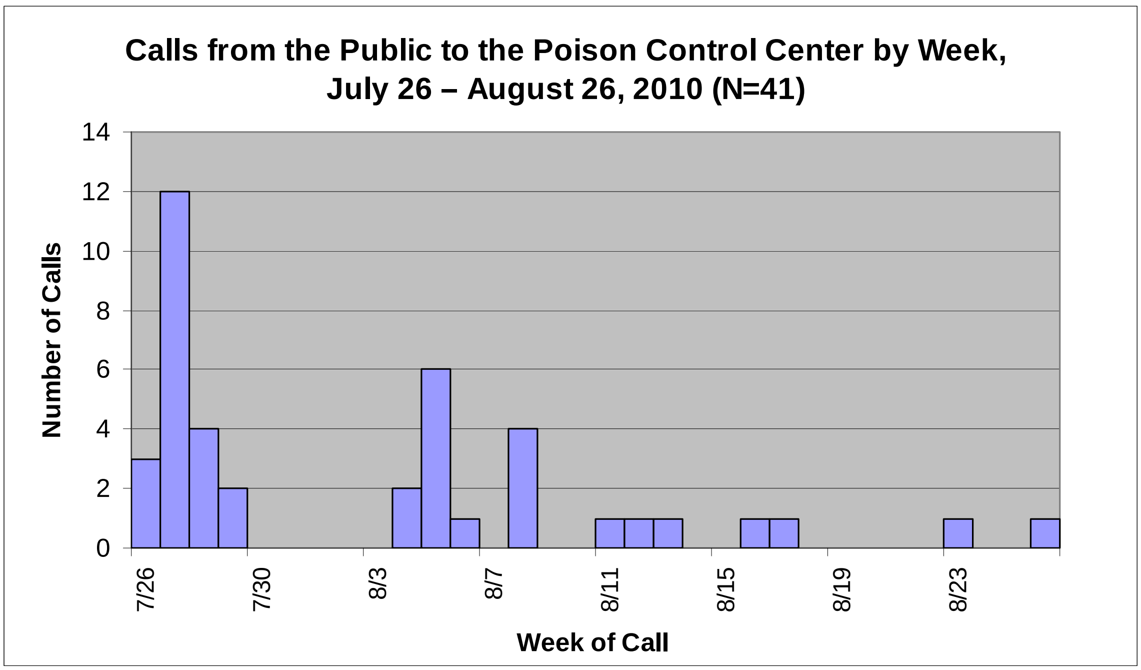
* Because of the small number of employees, numbers are not presented.

as related to the Enbridge spill event. Daily summaries of citizen calls were provided by the Michigan PCC to MDCH, in conjunction with the daily summaries of health care provider reports.

Results

Between July 26 and August 26, 41 calls were received by the PCC from individuals reporting health effects from exposure to the oil spill. No calls were received after August 26. **Figure 4** shows the number of calls by day of call. Over half (51%) of the calls (21 of 41) were received in the first week of the spill; July 27 was the day with the greatest number of calls (N= 12; 29%).

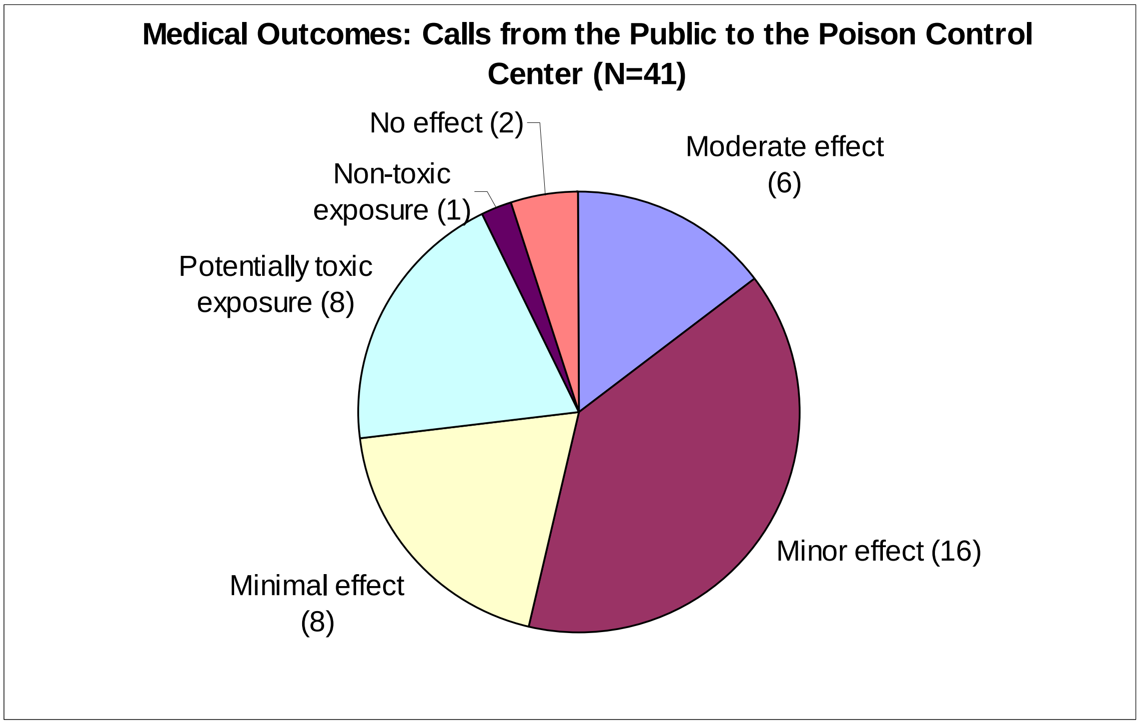
Figure 4



The ages of the individuals for whom a call was made ranged from 1 month to 60 years, with a mean of 26 years. Twenty-three (57.5%) of the 40 reports that documented gender were female.

The medical outcome classification assigned by the PCC for these calls included 39% with minor outcomes; 19.5% had possible minimal effects and 14.6% were classified with moderate effects (**Figure 5**). Nine (22%) individuals noted that they had seen a health care provider for their clinical effects, but no health care provider reports were received about these individuals.

Figure 5



D. Syndromic surveillance

Methods

The MDCH maintains a syndromic surveillance system designed to facilitate early and rapid detection and response to outbreaks that may be the result of bioterrorism, natural and/or emerging infectious disease, or other public health threats and emergencies. Real-time detection of significant increases in patients presenting with similar symptoms at designated Michigan hospital EDs is done through the use of statistical algorithms; these are applied to data obtained from hourly electronic searches through patient "chief complaints" in the electronic medical records. An "alert" is triggered when the proportion of visits for defined syndromes or geographic areas exceeds three standard deviations above predicted values, which are based on historical data. MDCH identified those potentially associated with oil exposure, which included rash, neurological, respiratory, and gastrointestinal syndromes. In addition, MDCH added an ad hoc query in order to detect chief complaints in the ED that contained "oil" and/or "spill". A limitation of this method, however, is that not all hospitals in the impacted communities participate in the MDCH ED syndromic surveillance system.

MDCH also monitors over-the counter pharmaceutical sales from several hundred retail pharmacies throughout the state, using computer algorithms to detect statistically significant increases in daily sales of: anti-diarrheal and anti-fever medications, cough syrup and other respiratory medications; child electrolytes; and thermometers; and related products. This system was continually monitored with attention to the communities within the area of the Enbridge oil spill.

Results

One "alert" was recorded in Kalamazoo County for rash several days after the spill. Otherwise there were no notable changes in the frequencies of syndromes of interest in the area compared to overall daily rolling averages and yearly comparisons.

There were no notable increases in sales of over-the-counter pharmaceutical products; numbers of sales remained within typical levels for the season.

III. Discussion

MDCH and the impacted local health departments quickly established a multi-component public health surveillance system to assess and measure the health impacts associated with exposure to crude oil, its vapors, and/or its odors resulting from the Enbridge pipeline spill in July 2010. The surveillance system received 147 health care provider reports on 145 patients; identified 320 (58%) of 550 individuals with adverse health effects from four community surveys along the impacted waterways, and tracked forty-one calls that were placed to the poison center by the public.

Headache, nausea, and respiratory symptoms were the predominant symptoms reported by exposed individuals in all reporting systems. These symptoms are consistent with the published literature and the Enbridge Material Safety Data Sheet regarding potential health effects associated with acute exposure to crude oil.[5,6] A number of epidemiologic studies performed in the weeks or months following major oil spills have reported similar types of symptoms to those identified in our community surveys. Studies of acute health effects from an oil spill in Shetland, Scotland and Wales documented significant differences in similar sets of self-reported symptoms between exposed residents and control groups.[7,8] The post-spill prevalence of headache in the exposed for these two studies was similar to our that in our community surveys (Shetland: 32%; Wales: 38%; Enbridge communities: 34.5%) but higher in their control groups than our Comparison group (Shetland: 8%; Wales: 14.1%; Enbridge: 0.7%). This pattern was similar for other symptoms. In a study of a spill near Karachi Pakistan, the frequency of one or more symptoms was markedly higher in both the exposed and the control groups (96% in exposed and 70% in controls) than in our populations.[9] In a comprehensive review of all studies regarding the impact of oil exposure on human health, Aguilera et al. concluded that most studies "…provide evidence on the relationship between exposure and the appearance of acute physical, psychological, genotoxic and endocrine effects in the exposed individuals."[10]

Symptom prevalence as determined by our community surveys was significantly greater overall in the exposed communities than in the comparison community upstream from the spill. At the same time, there were some differences between the four communities regarding symptom prevalence. These differences may be associated with differences in geographical proximity to the river or health risk factors, including prevalence of chronic health conditions and smoking, both of which are inversely associated with socio-economic status. Symptom prevalence was lowest in the community (the Subdivision) with the lowest smoking and chronic disease prevalence, and the highest home values; and it was highest in the "Neighborhood", which had the highest chronic disease prevalence as well as the lowest home values.

There are a number of potential biases and limitations to the data obtained using this surveillance system. Regarding health care provider reporting, it is very likely that there was a significant amount of under-reporting by clinicians, a common problem with public health surveillance systems based on health care provider reporting. Reasons for under-reporting may include: not making a diagnosis that associates the oil exposure (either to the oil itself or to odors from the spill) to the symptoms, lack of understanding of reporting requirements, or lack of compliance because of barriers (e.g., time, office staffing, or concerns about patient confidentiality).

In the community surveys, there may have been response biases in the exposed communities associated with exaggerated reporting of symptoms, due to the considerable publicity surrounding the event and attendant legal issues. At the same time, there could have been underreporting of symptoms given the possibility that most affected individuals and households had relocated and were not at home when the door-to-door surveys were completed. Additionally, underreporting could have occurred because the respondents at the households were not completely familiar with the range of symptoms experienced by other household members about whom they provided information during the survey.

The lower completion rates in the Village and Comparison communities may have been because the survey teams started earlier in the evening than at the other sites, and thus missed people not yet home from work. It is unknown how this might have affected results. However, the very low refusal rate in the exposed communities suggested that these individuals understood why they were being interviewed and that it may have been in their best interest to participate. There was a much higher refusal rate in the Comparison community than the exposed communities (15% vs. 0.5%). We did not determine the reasons for refusing and therefore we do not know how this would have biased results from the comparison community survey. It could have reflected that there was no self-motivation for individuals in the Comparison community to participate other than general concern and good will, and thus some people were not willing to take the time to talk with the interviewers, but there could have been a variety of reasons.

The survey of the workers in the one small worksite should be interpreted with caution. Results are subject to the instability of small numbers and there are no comparison data by which to judge the significance of the findings. Additionally, like the community surveys, there are a number of factors that could have contributed to recall bias, resulting in over- or under-reporting of symptoms. Because these individuals worked closely together, individual responses could have been influenced by prior discussions and concerns about the release. Further, overstated reporting of symptoms could have resulted from the considerable publicity surrounding the event and attendant legal issues. On the other hand, the open-ended format of the questions, rather than a structured list of possible responses, could have resulted in individuals being less likely to remember and report on specific types of symptoms.

A number of studies of the health effects of previous oil spills have focused on acute and chronic health effects to responders.[11,12,13] Current surveillance of response workers in the Deepwater Horizon spill in the Gulf of Mexico is tracking all injuries and illnesses of response workers, not just illnesses associated with oil exposure.[14] Our surveillance system, which was established to provide rapid detection of and response to acute health effects of oil exposure, was not designed to evaluate all injuries and illnesses, short or long term, in response workers. Other systems were in place within the Unified Command structure of the response to track all illnesses, injuries and "near-misses" among the response workers. Nevertheless, approximately 18% of the health care provider reports were of response workers experiencing health effects apparently associated with exposure to the oil.

Mental health effects of disasters, including anxiety, post-traumatic stress disorder, and depression have been an area of particular concern. Studies following the *Exxon-Valdes* oil spill in Alaska[15] and the *Sea Empress* in Wales[6] found that post-spill prevalence of a number of psychiatric disorders was significantly higher in exposed populations than unexposed individuals. Likewise, there was a greater proportion of individuals with self-reported psychiatric symptoms in our exposed communities than our Comparison community (4.7% vs. 0%), but overall prevalence was much lower than other studies. Unlike some other studies, which used validated mental health survey methodologies, our survey included only an open-ended question about symptoms, thus psychological symptoms were captured only if volunteered. Therefore, our assessment may have not fully captured the mental health effects of the spill.

Use of the PCC as the surveillance data center was an effective and responsive approach to the need for a rapidly functioning data collection and analysis system. Daily reports of numbers and types of reports were thus able to be provided by the PCC to the Command Center from where the spill response was coordinated. The ED syndromic surveillance system was not notably sensitive, but this was not surprising because the hospital ED closest to the spill site does not participate in the system.

Beyond the significance of the health data itself for documenting the health impacts of the spill, the value of the face-to-face encounters between public health officials and the families coping with feelings of ill health, plummeting home values, and anxieties about their safety should be noted. These personal encounters provided some assurance to families that their needs and concerns were being heard and provided public health with an in-depth understanding of the situation. Combining a rapid community needs assessment and a health assessment is an approach that is being used more and more frequently during disasters.[16] Currently, the Centers for Disease Control and Prevention and the Council of State and Territorial Epidemiologists are organizing a series of trainings and workshops in "disaster epidemiology."[17] Results of these efforts will help inform future responses in Michigan to disasters.

IV. Conclusion

In response to concerns about acute health effects from exposure to spilled oil in this major disaster, state and local public health in Michigan quickly set up a multi-faceted public health surveillance system that included health care provider reporting, community surveys, calls from the public to the poison control center, and analysis of data submitted to the state's syndromic surveillance system. In spite of the limitations noted above, these data appear to provide a reasonable picture of the oil spill's acute health impacts, and these findings are consistent with other studies of oil spills.

A number of aspects to the public health surveillance response are noteworthy for consideration by public health agencies that are refining their non-infectious disease surveillance emergency response plans.

- A multi-component surveillance system was necessary to support the response.
- Chemical poisoning reporting regulations, which Michigan had put in place in 2007, were essential to support mandated health care provider reporting of oil-spill related illnesses.
- Use of the poison center as the data repository for reports by health care providers was an innovation that was effective and efficient. Daily summaries from the poison center provided the responders and public health agencies with sufficient information to understand the magnitude of the actual on-going health impacts of the spill, rather than relying on rumors or anecdotes.
- Epidemiologic competencies necessary for a quick response included survey design, data management, and analytic skills in descriptive epidemiology.
- Having the surveillance response take place in the oil-spill's Command Center, rather than public health offices at the state or county level, was

critical for ensuring that surveillance activities supported the daily needs of the Unified Command.

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Michigan State University: Joanna Kica
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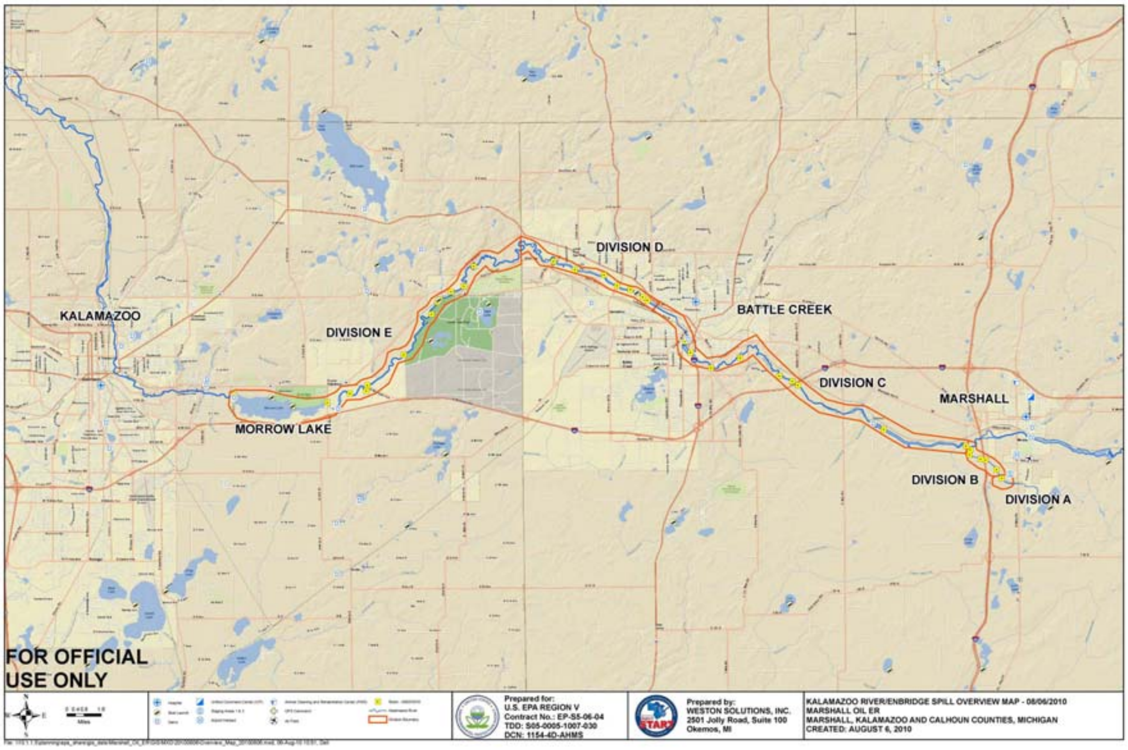
Appendix: Map of the oil spill in Michigan (source: EPA[18])



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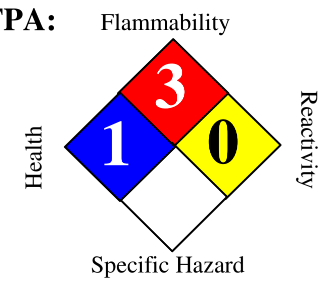
Material Safety Data Sheet
Naphtha

NFPA:



TESORO

HMIS III:

HEALTH	1
FLAMMABILITY	3
PHYSICAL	0

0 = Insignificant, 1 = Slight, 2 = Moderate, 3 = High, 4 = Extreme

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product name : Naphtha

Synonyms : Light Naphtha, Japan Open Spec Bonded Naphtha, SNG Naphtha, Light Cat Naphtha, Sweet Virgin Naphtha (SVN), Debutanized Naphtha, Atmospheric Naphtha (DAN), HCU Light Naphtha, Light CR Gasoline, Full Range Cracked Naphtha, Full Range Hydrocracked Naphtha, Full Range Reformed Naphtha, Light Chemical Treated Naphtha, Light Cracked Naphtha, Light Hydrocracked Naphtha, Light Hydrotreated Naphtha, Aviation Alkylate Naphtha, 888100004450

MSDS Number : 888100004450 **Version** : 2.12

Product Use Description : Fuel Component, Refinery Intermediate Stream

Company : For: Tesoro Refining & Marketing Co.
19100 Ridgewood Parkway, San Antonio, TX 78259

Tesoro Call Center : (877) 783-7676 **Chemtrec (Emergency Contact)** : (800) 424-9300

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Regulatory status : This material is considered hazardous by the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (29 CFR 1910.1200).

Signal Word : DANGER

Hazard Summary : Extremely flammable. Irritating to eyes and respiratory system. Affects central nervous system. Harmful or fatal if swallowed. Aspiration Hazard.

Potential Health Effects

Eyes : High vapor concentration or contact may cause irritation and discomfort.

Skin : Brief contact may cause slight irritation. Skin irritation leading to dermatitis may occur upon prolonged or repeated contact. Can be absorbed through skin.

Ingestion : Aspiration hazard if liquid is inhaled into lungs, particularly from vomiting after ingestion. Aspiration may result in chemical pneumonia, severe lung damage, respiratory failure and even death.

Inhalation : Vapors or mists from this material can irritate the nose, throat, and lungs, and can cause signs and symptoms of central nervous system depression, depending on the concentration and duration of exposure. Inhalation of high concentrations may cause central nervous system depression such as dizziness, drowsiness, headache, and similar narcotic symptoms, but no long-term effects.

Chronic Exposure : Long-term exposure may cause effects to specific organs, such as to the liver, kidneys, blood, nervous system, and skin. Contains benzene, which can cause blood disease, including anemia and leukemia.

Target Organs : Skin, Central nervous system, Liver, Kidney, Blood

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS-No.	Weight %
Naphtha; Low boiling point naphtha	8030-30-6	100%
N-hexane	110-54-3	25 - 35%
Xylene	1330-20-7	25 - 35%
Toluene	108-88-3	15 - 20%
Cyclohexane	110-82-7	15 - 20%
Pentane	109-66-0	15 - 20%
Heptane [and isomers]	142-82-5	12.5 - 15%
Ethylbenzene	100-41-4	5 - 7%
Benzene	71-43-2	3 - 5%
1,2,4-Trimethylbenzene	95-63-6	2 - 3%
Sulfur	7704-34-9	0 - 1.5%

SECTION 4. FIRST AID MEASURES

General advice : Remove from exposure, lie down. In the case of accident or if you feel unwell, seek medical advice immediately (show the label where possible). When symptoms persist or in all cases of doubt, seek medical advice. Never give anything by mouth to an unconscious person. Take off all contaminated clothing immediately and thoroughly wash material from skin.

Inhalation : If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Seek medical attention immediately.

Skin contact : In case of contact, immediately flush skin with plenty of water. Take off contaminated clothing and shoes immediately. Wash contaminated clothing before re-use. Contaminated leather, particularly footwear, must be discarded. Note that contaminated clothing may be a fire hazard. Seek medical advice if symptoms persist or develop.

Eye contact : Remove contact lenses. In the case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

Ingestion : If swallowed Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Seek medical attention immediately.

Notes to physician	:	Symptoms: Dizziness, Discomfort, Headache, Nausea, Kidney disorders, Liver disorders.

SECTION 5. FIRE-FIGHTING MEASURES

Form	:	Liquid
Flash point -typical	:	-21.7 °C (-7.1 °F)
Auto Ignition temperature	:	225 °C (437 °F)
Lower explosive limit	:	1.2 %(V)
Upper explosive limit	:	6.9 % (V)
Suitable extinguishing media	:	Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide. Do not use a solid water stream as it may scatter and spread fire.
Specific hazards during fire fighting	:	SMALL FIRES: Any extinguisher suitable for Class B fires, dry chemical, CO2, water spray, fire fighting foam, or Halon. LARGE FIRES: Water spray, fog or fire fighting foam. Water may be ineffective for fighting the fire, but may be used to cool fire-exposed containers.
Special protective equipment for fire-fighters	:	Fire fighters should wear positive pressure self-contained breathing apparatus (SCBA) and full turnout gear. Firefighters' protective clothing will provide limited protection.
Further information	:	Isolate area around container involved in fire. Cool tanks, shells, and containers exposed to fire and excessive heat with water. For massive fires the use of unmanned hose holders or monitor nozzles may be advantageous to further minimize personnel exposure. Major fires may require withdrawal, allowing the tank to burn. Large storage tank fires typically require specially trained personnel and equipment to extinguish the fire, often including the need for properly applied fire fighting foam. Exposure to decomposition products may be a hazard to health. Use extinguishing measures that are appropriate to local circumstances and the surrounding environment. Use water spray to cool unopened containers. Fire residues and contaminated fire extinguishing water must be disposed of in accordance with local regulations.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions	:	Evacuate personnel to safe areas. Ventilate the area. Remove all sources of ignition. Response and clean-up crews must be properly trained and must utilize proper protective equipment (see Section 8).
Environmental precautions	:	Should not be released into the environment. Avoid subsoil penetration. If the product contaminates rivers and lakes or drains, inform respective authorities.
Methods for cleaning up	:	Contain and collect spillage with non-combustible absorbent material, (e.g. sand, earth, diatomaceous earth, vermiculite) and place in container for disposal according to local / national regulations.

SECTION 7. HANDLING AND STORAGE

Handling	:	Keep away from fire, sparks and heated surfaces. No smoking near areas where material is stored or handled. The product should only be stored and handled in

areas with intrinsically safe electrical classification.

Advice on protection against fire and explosion : Hydrocarbon liquids including this product can act as a non-conductive flammable liquid (or static accumulators), and may form ignitable vapor-air mixtures in storage tanks or other containers. Precautions to prevent static-initated fire or explosion during transfer, storage or handling, include but are not limited to these examples:
(1) Ground and bond containers during product transfers. Grounding and bonding may not be adequate protection to prevent ignition or explosion of hydrocarbon liquids and vapors that are static accumulators.
(2) Special slow load procedures for "switch loading" must be followed to avoid the static ignition hazard that can exist when higher flash point material (such as fuel oil or diesel) is loaded into tanks previously containing low flash point products (such gasoline or naphtha).
(3) Storage tank level floats must be effectively bonded.
For more information on precautions to prevent static-initated fire or explosion, see NFPA 77, Recommended Practice on Static Electricity (2007), and API Recommended Practice 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents (2008).

Dust explosion class : Not applicable

Requirements for storage areas and containers : Keep away from flame, sparks, excessive temperatures and open flame. Use approved containers. Keep containers closed and clearly labeled. Empty or partially full product containers or vessels may contain explosive vapors. Do not pressurize, cut, heat, weld or expose containers to sources of ignition. Store in a well-ventilated area. The storage area should comply with NFPA 30 "Flammable and Combustible Liquid Code". The cleaning of tanks previously containing this product should follow API Recommended Practice (RP) 2013 "Cleaning Mobile Tanks In Flammable and Combustible Liquid Service" and API RP 2015 "Cleaning Petroleum Storage Tanks".

Advice on common storage : Keep away from food, drink and animal feed. Incompatible with oxidizing agents. Incompatible with acids.

Other data : No decomposition if stored and applied as directed.

SECTION 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Guidelines

List	Components	CAS-No.	Type:	Value
OSHA	Benzene - 29 CFR 1910.1028	71-43-2	TWA	1 ppm
		71-43-2	STEL	5 ppm
		71-43-2	OSHA_AL	0.5 ppm
OSHA Z1	Naphtha; Low boiling point naphtha	8030-30-6	PEL	100 ppm 400 mg/m3
	Xylene	1330-20-7	PEL	100 ppm 435 mg/m3
	N-hexane	110-54-3	PEL	500 ppm 1,800 mg/m3
	Cyclohexane	110-82-7	PEL	300 ppm 1,050 mg/m3
	Heptane [and isomers]	142-82-5	PEL	500 ppm 2,000 mg/m3
	Ethylbenzene	100-41-4	PEL	100 ppm 435 mg/m3
ACGIH	Naphtha; Low boiling point naphtha	8030-30-6	TWA	400 ppm

	Xylene	1330-20-7	TWA	100 ppm
		1330-20-7	STEL	150 ppm
	N-hexane	110-54-3	TWA	50 ppm
	Toluene	108-88-3	TWA	50 ppm
	Cyclohexane	110-82-7	TWA	100 ppm
	Pentane	109-66-0	TWA	600 ppm
	Heptane [and isomers]	142-82-5	TWA	400 ppm
		142-82-5	STEL	500 ppm
	Ethylbenzene	100-41-4	TWA	100 ppm
		100-41-4	STEL	125 ppm
	Benzene	71-43-2	TWA	0.5 ppm
		71-43-2	STEL	2.5 ppm

Engineering measures : Use adequate ventilation to keep gas and vapor concentrations of this product below occupational exposure and flammability limits, particularly in confined spaces. Use only intrinsically safe electrical equipment approved for use in classified areas.

Eye protection : Safety glasses or goggles are recommended where there is a possibility of splashing or spraying. Ensure that eyewash stations and safety showers are close to the workstation location.

Hand protection : Gloves constructed of nitrile or neoprene are recommended. Consult manufacturer specifications for further information.

Skin and body protection : If needed to prevent skin contact, chemical protective clothing such as of DuPont TyChem®, Saranex or equivalent recommended based on degree of exposure. The resistance of specific material may vary from product to product as well as with degree of exposure.

Respiratory protection : A NIOSH/ MSHA-approved air-purifying respirator with organic vapor cartridges or canister may be permissible under certain circumstances where airborne concentrations are or may be expected to exceed exposure limits or for odor or irritation. Protection provided by air-purifying respirators is limited. Refer to OSHA 29 CFR 1910.134, ANSI Z88.2-1992, NIOSH Respirator Decision Logic, and the manufacturer for additional guidance on respiratory protection selection. Use a NIOSH/ MSHA-approved positive-pressure supplied-air respirator if there is a potential for uncontrolled release, exposure levels are not known, in oxygen-deficient atmospheres, or any other circumstance where an air-purifying respirator may not provide adequate protection.

Work / Hygiene practices : Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure. Use good personal hygiene practices. Avoid repeated and/or prolonged skin exposure. Wash hands before eating, drinking, smoking, or using toilet facilities. Do not use as a cleaning solvent on the skin. Do not use solvents or harsh abrasive skin cleaners for washing this product from exposed skin areas. Waterless hand cleaners are effective. Promptly remove contaminated clothing and launder before reuse. Use care when laundering to prevent the formation of flammable vapors which could ignite via washer or dryer. Consider the need to discard contaminated leather shoes and gloves.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Form	:	Liquid
Appearance	:	Colorless to light yellow
Odor	:	Characteristic hydrocarbon-like
Flash point - typical	:	-21.7 °C (-7.1 °F)
Auto Ignition temperature	:	225 °C (437 °F)
Thermal decomposition	:	Heating can release hazardous gases, No decomposition if stored and applied as directed.
Lower explosive limit	:	1.2 % (V)
Upper explosive limit	:	6.9 % (V)
pH	:	Not applicable
Specific gravity	:	0.77 (H20=1)
Boiling point	:	26.7 - 148.9 °C(80.1 - 300.0 °F)
Vapor Pressure	:	758 - 896 hPa at 20 °C (68 °F)
Vapor Density (Air = 1)	:	3.5
Water solubility	:	Negligible
Viscosity, kinematic	:	Not determined
Percent Volatiles	:	100 %
Work / Hygiene practices		Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure. Use good personal hygiene practices. Avoid repeated and/or prolonged skin exposure. Wash hands before eating, drinking, smoking, or using toilet facilities. Do not use as a cleaning solvent on the skin. Do not use solvents or harsh abrasive skin cleaners for washing this product from exposed skin areas. Waterless hand cleaners are effective. Promptly remove contaminated clothing and launder before reuse. Use care when laundering to prevent the formation of flammable vapors which could ignite via washer or dryer. Consider the need to discard contaminated leather shoes and gloves.

SECTION 10. STABILITY AND REACTIVITY

Conditions to avoid	:	Avoid high temperatures, open flames, sparks, welding, smoking and other ignition sources.
Materials to avoid	:	Strong acids and strong bases. Oxidizing agents.
Hazardous decomposition products	:	Carbon monoxide, carbon dioxide and noncombusted hydrocarbons (smoke).
Thermal decomposition	:	Heating can release hazardous gases. No decomposition if stored and applied as directed.
Hazardous reactions	:	Vapors may form explosive mixture with air. Hazardous polymerization does not occur. Note: Stable under recommended storage conditions.

SECTION 11. TOXICOLOGICAL INFORMATION

Carcinogenicity

NTP	:	Benzene (CAS-No.: 71-43-2)
IARC	:	Ethylbenzene (CAS-No.: 100-41-4) Benzene (CAS-No.: 71-43-2)
OSHA	:	Benzene (CAS-No.: 71-43-2)
CA Prop 65	:	WARNING! This product contains a chemical known to the State of California to cause cancer. Ethylbenzene (CAS-No.: 100-41-4) Benzene (CAS-No.: 71-43-2)
	:	WARNING! This product contains a chemical known to the State of California to cause birth defects or other reproductive harm. Toluene (CAS-No.: 108-88-3) Benzene (CAS-No.: 71-43-2)
Skin irritation	:	Repeated or prolonged contact with the preparation may cause removal of natural fat from the skin resulting in desiccation of the skin. The product may be absorbed through the skin.
Eye irritation	:	The liquid splashed in the eyes may cause irritation and reversible damage. Strong lachrymation can make it difficult to escape
Further information	:	This product contains benzene. Human health studies indicate that prolonged and/or repeated overexposure to benzene may cause damage to the blood-forming system (particularly bone marrow), and serious blood disorders such as aplastic anemia and leukemia. Benzene is listed as a human carcinogen by the NTP, IARC, OSHA and ACGIH. Acute toxicity of benzene results primarily from depression of the central nervous system (CNS). Inhalation of concentrations over 50 ppm can produce headache, lassitude, weariness, dizziness, drowsiness, or excitation. Exposure to very high levels can result in unconsciousness and death. Symptoms of overexposure may be headache, dizziness, tiredness, nausea and vomiting. Ingestion may cause gastrointestinal disturbances, including irritation, nausea, vomiting and diarrhea, and central nervous (brain) effects similar to alcohol intoxication. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory arrest and death may occur.

Component:

009024

N-hexane	110-54-3	Acute oral toxicity: LD50 rat Dose: 25,000 mg/kg Acute dermal toxicity: LD50 rabbit Dose: 2,001 mg/kg Acute inhalation toxicity: LC50 rat Dose: 171.6 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Skin irritation Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation Teratogenicity: N11.00418960
Xylene	1330-20-7	Acute oral toxicity: LD50 rat Dose: 2,840 mg/kg Acute dermal toxicity: LD50 rabbit Dose: ca. 4,500 mg/kg Acute inhalation toxicity: LC50 rat Dose: 6,350 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Repeated or prolonged exposure may cause skin irritation and dermatitis, due to degreasing properties of the product. Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation
Toluene	108-88-3	Acute oral toxicity: LD50 rat Dose: 636 mg/kg Acute dermal toxicity: LD50 rabbit Dose: 12,124 mg/kg Acute inhalation toxicity: LC50 rat Dose: 49 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Prolonged skin contact may defat the skin and produce dermatitis. Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation
Cyclohexane	110-82-7	Acute dermal toxicity: LD50 rabbit Dose: 2,001 mg/kg Acute inhalation toxicity: LC50 rat Dose: 14 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Skin irritation Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation
Pentane	109-66-0	Acute oral toxicity: LD50 rat Dose: 2,001 mg/kg Acute inhalation toxicity: LC50 rat

		Dose: 364 mg/l Exposure time: 4 h Skin irritation: Repeated or prolonged exposure may cause skin irritation and dermatitis, due to degreasing properties of the product. Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation
Heptane [and isomers]	142-82-5	Acute oral toxicity: LD50 rat Dose: 15,001 mg/kg Acute inhalation toxicity: LC50 rat Dose: 103 g/m3 Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Skin irritation Repeated or prolonged exposure may cause skin irritation and dermatitis, due to degreasing properties of the product. Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation
Ethylbenzene	100-41-4	Acute oral toxicity: LD50 rat Dose: 3,500 mg/kg Acute dermal toxicity: LD50 rabbit Dose: 15,500 mg/kg Acute inhalation toxicity: LC50 rat Dose: 18 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Eye irritation: Classification: Irritating to eyes. Result: Risk of serious damage to eyes.
Benzene	71-43-2	Acute oral toxicity: LD50 rat Dose: 930 mg/kg Acute inhalation toxicity: LC50 rat Dose: 44 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Mild skin irritation Repeated or prolonged exposure may cause skin irritation and dermatitis, due to degreasing properties of the product. Eye irritation: Classification: Irritating to eyes. Result: Risk of serious damage to eyes.
1,2,4-Trimethylbenzene	95-63-6	Acute inhalation toxicity: LC50 rat Dose: 18 mg/l Exposure time: 4 h Skin irritation: Classification: Irritating to skin. Result: Skin irritation Eye irritation: Classification: Irritating to eyes. Result: Eye irritation

Sulfur	7704-34-9	Acute oral toxicity: LD50 rat Dose: 5,001 mg/kg Acute dermal toxicity: LD50 rabbit Dose: 2,001 mg/kg Acute inhalation toxicity: LC50 rat Dose: 9.24 mg/l Exposure time: 4 h Eye irritation: Classification: Irritating to eyes. Result: Mild eye irritation

SECTION 12. ECOLOGICAL INFORMATION

Additional ecological information : Keep out of sewers, drainage areas, and waterways. Report spills and releases, as applicable, under Federal and State regulations.

Component:

N-hexane	110-54-3	Toxicity to fish: LC50 Species: Pimephales promelas (fathead minnow) Dose: 2.5 mg/l Exposure time: 96 h Acute and prolonged toxicity for aquatic invertebrates: EC50 Species: Daphnia magna (Water flea) Dose: 2.1 mg/l Exposure time: 48 h
Toluene	108-88-3	Toxicity to fish: LC50 Species: Carassius auratus (goldfish) Dose: 13 mg/l Exposure time: 96 h Acute and prolonged toxicity for aquatic invertebrates: EC50 Species: Daphnia magna (Water flea) Dose: 11.5 mg/l Exposure time: 48 h Toxicity to algae: IC50 Species: Selenastrum capricornutum (green algae) Dose: 12 mg/l Exposure time: 72 h
Cyclohexane	110-82-7	Acute and prolonged toxicity for aquatic invertebrates: EC50 Species: Daphnia magna (Water flea) Dose: 3.78 mg/l Exposure time: 48 h
Pentane	109-66-0	Acute and prolonged toxicity for aquatic invertebrates: EC50 Species: Daphnia magna (Water flea) Dose: 9.74 mg/l Exposure time: 48 h
Heptane [and isomers]	142-82-5	Toxicity to fish: LC50 Species: Carassius auratus (goldfish) Dose: 4 mg/l Exposure time: 24 h

		Acute and prolonged toxicity for aquatic invertebrates: EC50 Species: Daphnia magna (Water flea) Dose: 1.5 mg/l Exposure time: 48 h
1,2,4-Trimethylbenzene	95-63-6	Toxicity to fish: LC50 Species: Pimephales promelas (fathead minnow) Dose: 7.72 mg/l Exposure time: 96 h Acute and prolonged toxicity for aquatic invertebrates: EC50 Species: Daphnia Dose: 3.6 mg/l Exposure time: 48 h
Sulfur	7704-34-9	Acute and prolonged toxicity for aquatic invertebrates: EC0 Species: Daphnia magna (Water flea) Dose: > 10,000 mg/l Exposure time: 24 h

SECTION 13. DISPOSAL CONSIDERATIONS

Disposal : Dispose of container and unused contents in accordance with federal, state and local requirements.

SECTION 14. TRANSPORT INFORMATION

CFR

Proper shipping name	:	PETROLEUM DISTILLATES, N.O.S.
UN-No.	:	1268
Class	:	3
Packing group	:	II
Hazard inducer	:	(Naphtha; Low boiling point naphtha)

TDG

Proper shipping name	:	PETROLEUM DISTILLATES, N.O.S.
UN-No.	:	UN1268
Class	:	3
Packing group	:	II
Hazard inducer	:	(Naphtha; Low boiling point naphtha)

IATA Cargo Transport

UN UN-No.	:	UN1268
Description of the goods	:	PETROLEUM DISTILLATES, N.O.S. (Naphtha; Low boiling point naphtha)
Class	:	3
Packaging group	:	II
ICAO-Labels	:	3
Packing instruction (cargo aircraft)	:	364
Packing instruction (cargo aircraft)	:	Y341

IATA Passenger Transport

UN UN-No.	:	UN1268
Description of the goods	:	PETROLEUM DISTILLATES, N.O.S. (Naphtha; Low boiling point naphtha)
Class	:	3
Packaging group	:	II
ICAO-Labels	:	3
Packing instruction (passenger aircraft)	:	353
Packing instruction (passenger aircraft)	:	Y341

IMDG-Code

UN-No.	:	UN 1268
Description of the goods	:	PETROLEUM DISTILLATES, N.O.S. (Naphtha; Low boiling point naphtha)
Class	:	3
Packaging group	:	II
IMDG-Labels	:	3
EmS Number	:	F-E S-E
Marine pollutant	:	No

SECTION 15. REGULATORY INFORMATION

OSHA Hazards : Flammable liquid
Moderate skin irritant
Severe eye irritant
Carcinogen
Teratogen

TSCA Status : On TSCA Inventory

DSL Status : All components of this product are on the Canadian DSL list.

SARA 311/312 Hazards : Fire Hazard
Acute Health Hazard
Chronic Health Hazard

SARA III US. EPA Emergency Planning and Community Right-To-Know Act (EPCRA) SARA Title III Section 313 Toxic Chemicals (40 CFR 372.65) - Supplier Notification Required

Components	CAS-No.
1,2,4-Trimethylbenzene	95-63-6
Benzene	71-43-2
Ethylbenzene	100-41-4
Cyclohexane	110-82-7
Toluene	108-88-3
N-hexane	110-54-3
Xylene	1330-20-7

PENN RTK US. Pennsylvania Worker and Community Right-to-Know Law (34 Pa. Code Chap. 301-323)

Components	CAS-No.
Heptane [and isomers]	142-82-5
Ethylbenzene	100-41-4
Benzene	71-43-2
1,2,4-Trimethylbenzene	95-63-6
Sulfur	7704-34-9
Pentane	109-66-0
Naphtha; Low boiling point naphtha	8030-30-6
Xylene	1330-20-7
N-hexane	110-54-3
Toluene	108-88-3
Cyclohexane	110-82-7

MASS RTK US. Massachusetts Commonwealth's Right-to-Know Law (Appendix A to 105 Code of Massachusetts Regulations Section 670.000)

Components	CAS-No.
Heptane [and isomers]	142-82-5
Ethylbenzene	100-41-4
Benzene	71-43-2
1,2,4-Trimethylbenzene	95-63-6
Sulfur	7704-34-9
Naphtha; Low boiling point naphtha	8030-30-6
Xylene	1330-20-7
N-hexane	110-54-3
Toluene	108-88-3
Cyclohexane	110-82-7

NJ RTK US. New Jersey Worker and Community Right-to-Know Act (New Jersey Statute Annotated Section 34:5A-5)

Components	CAS-No.
Heptane [and isomers]	142-82-5
Ethylbenzene	100-41-4
Benzene	71-43-2
1,2,4-Trimethylbenzene	95-63-6
Sulfur	7704-34-9
Naphtha; Low boiling point naphtha	8030-30-6
Xylene	1330-20-7
N-hexane	110-54-3

Toluene	108-88-3
Cyclohexane	110-82-7

CERCLA SECTION 103 and SARA SECTION 304 (RELEASE TO THE ENVIROMENT)
The CERCLA definition of hazardous substances contains a "petroleum exclusion" clause which exempts crude oil. Fractions of crude oil, and products (both finished and intermediate) from the crude oil refining process and any indigenous components of such from the CERCLA Section 103 reporting requirements. However, other federal reporting requirements, including SARA Section 304, as well as the Clean Water Act may still apply.

California Prop. 65 : WARNING! This product contains a chemical known to the State of California to cause cancer.

Ethylbenzene	100-41-4
Benzene	71-43-2

WARNING! This product contains a chemical known to the State of California to cause birth defects or other reproductive harm.

Toluene	108-88-3
Benzene	71-43-2

SECTION 16. OTHER INFORMATION

Further information

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

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79, 80, 81, 83, 165, 264, 318, 1017, 1018, 1019, 1020, 1021, 1027, 1032, 1055, 1136, 1716

DILUTED BITUMEN

BACKGROUND ON DILUTED BITUMEN

One of the types of crude oil derived from the Canadian oil sands is bitumen, a heavy, sour oil. Bitumen would not flow through a pipeline efficiently, so it is mixed with diluents to be readied for pipeline transportation as diluted bitumen, or 'dilbit.' Diluents are usually natural gas condensate, naphtha or a mix of other light hydrocarbons.

Bitumen is a mixture of heavy oil, sand, clay and water. It is separated from the sand and water in a centrifuge prior to dilution for transportation.

CORROSIVITY OF DILUTED BITUMEN COMPARED TO OTHER CRUDE OILS

Diluted bitumen is no more corrosive in pipelines than other heavy crude oils. Diluted bitumen has characteristics similar to other heavy crude oils, such as those produced in Venezuela, Mexico, and California, which have been transported and refined in U.S. pipelines for decades.

The corrosivity of a crude oil type can be measured against other crude oils by the presence of sand and other sediments, sulfur, and salt. The Battelle Memorial Institute (Battelle) developed a pipeline oil comparison index (POCI) assessing seven types of diluted bitumen from Canada against heavy sour crudes from Canada, Mexico, and Colombia.

Corrosivity statistics of several types of diluted bitumen derived from the Canadian oil sands were compared against those of many other crude oils by Battelle, at the request of API. Six of the seven Canadian diluted bitumen crudes had a lower corrosivity than a blend of Western Canadian Blend, a conventional crude. All seven of the Canadian diluted bitumen crudes had a lower corrosivity than Mexican Maya crude and Colombian crude from the Rubiales Oil Field, which have been transported by U.S. pipelines for more than 40 years.

Corrosion experts support these facts and do not believe that diluted bitumen poses a unique threat to pipelines. In a recent statement, Oliver Moghissi, President of NACE International, said:

> *"Corrosivity of diluted bitumen is largely similar to crude oil, which is considered to be low. In addition, the threat of corrosion from diluted bitumen can be managed by conventional engineering practice in the same way as crude oil."*

Testing and studies conducted by Alberta Innovates, ASTM International (an internationally recognized testing and materials organization), and, most recently, Penspen (an English pipeline integrity engineering firm) all support the conclusion that diluted bitumen is not more corrosive than other crude oils.

PRODUCT SPECIFICATIONS FOR CRUDE OILS TRANSPORTED IN PIPELINES

Sediments, such as sand, can contribute to corrosion in a pipeline, as can water. Like other crude oils, diluted bitumen must meet standard product quality specifications for sediment and water content in Federal Energy Regulatory Commission (FERC) tariffs. Generally, these FERC tariffs prohibit crude oil from containing more than 0.5% of sediments and water. Tariffs are agreements between pipeline operators and pipeline customers, referred to as "shippers", and are enforceable by FERC. Product specifications in FERC tariffs and other agreements protect shippers, including refinery customers that might receive the crude oil, and pipeline operators.

To verify product quality, pipeline operators take samples of incoming batches before accepting products for shipment. Operators also take samples during transit. Pipeline operators are responsible to deliver agreed-upon batch quality to the destination refinery.

March 20, 2013

PHMSA regulations require that pipeline operators have a corrosion management program in place for their pipelines. This includes consideration of the use of corrosion inhibitors and cleaning pigs to reduce the likelihood of internal corrosion in pipelines. These measures are especially important in pipelines where there is not turbulent flow, which keeps water and sediment which are common in crude oils from settling and promoting corrosion.

THE SAFETY RECORD OF TRANSPORTING DILUTED BITUMEN BY PIPELINE

Diluted bitumen has been transported safety in the U.S. for more than 40 years. PHMSA accident reports since 2002 show zero internal corrosion-related releases from pipelines carrying diluted bitumen.[1] Also, there are no known examples before 2002 of corrosion-caused failures on U.S. pipelines carrying diluted bitumen.

Statistics in Alberta also show no signs of additional corrosivity. The Alberta Energy Resources Conservation Board (ERCB) reported:

> *"Analysis of pipeline failure statistics in Alberta has not identified any significant differences in failure frequency between pipelines handling conventional crude versus pipelines carrying crude bitumen, crude oil or synthetic crude oil."*

The ERCB further noted that it is inappropriate to compare releases in Alberta's data, where there is no reporting threshold, to PHMSA's U.S. data, with a 5 barrel threshold.

PIPELINE PRESSURE AND DILUTED BITUMEN

Diluted bitumen is transported at comparable pipeline pressures as other heavy crude oils. All U.S. pipelines must operate under Maximum Operating Pressure requirements administered by PHMSA. Any pipeline operator seeking to transport crude oil at a higher pressure than other operators is choosing to do so for commercial reasons, and must comply with Maximum Operating Pressure determinations made by assessing the strength of the pipe.

TEMPERATURE OF DILUTED BITUMEN DURING PIPELINE TRANSPORTATION

Diluted bitumen is not heated for transportation in pipelines above the temperature of other crude oils. Any heating of the bitumen during the time it is processed into diluted bitumen terminates after the processing is complete. Diluted bitumen cools long before it is inserted into a pipeline for transportation. The range of temperatures for all crude oils from Canada is 40-135 degrees Fahrenheit. The temperature of crude can increase as it moves down a pipeline, especially just downstream of pumping stations, due to the extra energy imparted by pumps. The American Society of Mechanical Engineers (ASME) Code for *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids* (ASME B31.4) does not consider pipeline temperatures to be elevated unless they exceed 150 degrees Fahrenheit. Much has been made about how increased temperatures in pipelines might increase the corrosivity of acids in crude, however, "[t]otal acid concentrations are a parameter that is important under refinery conditions where the product is exposed to temperatures in excess of 240C [464F]. It cannot be used to assess the likelihood of corrosion occurring in a transmission pipeline."[2]

PIPELINE ECONOMICS SUPPORT MANAGING CORROSIVITY OF CRUDE OIL

Pipelines are very expensive to build, and are intended to have long useful lives. It would not be logical to place any commodity in the pipeline that would put that investment at risk.

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[1] The review of PHMSA accident reports covers a period between 2002, when PHMSA accident reports became more comprehensive, and mid-2012.

[2] Penspen Integrity. *Dilbit Corrosivity*, February 2013, p. 35.

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF THE PETITION OF TRANSCANADA KEYSTONE PIPELINE, LP FOR ORDER ACCEPTING CERTIFICATION OF PERMIT ISSUED IN DOCKET HP09-001 TO CONSTRUCT THE KEYSTONE XL PIPELINE	* * * * * * * * *	**STAFF'S RESPONSE TO INTERROGATORIES AND REQUESTS FOR PRODUCTION OF DOCUMENTS FROM CINDY MYERS, R.N.** **HP14-001**

COMES NOW, Commission Staff by and through its attorney of record, Kristen N. Edwards, and hereby provides the following response to Cindy Myers, R.N.'s Interrogatories and Requests for Production of Documents.

Dated this 10th day of March, 2015.

Kristen N. Edwards
Staff Attorney
South Dakota Public Utilities Commission
500 East Capitol Avenue
Pierre, SD 57501

1-1) As a health professional, I'm concerned about the health community being educated and prepared to treat people adversely affected from tar sands spills. I've requested a copy of TransCanada's Emergency Response Plan to identify specific components of medical emergency response planning. This information was not divulged. How may I obtain a copy of the emergency health plan? If this hasn't been completed for KXL, would it be possible to obtain a copy of the ERP for Keystone I?

Who is responsible for emergency medical response planning in the situation of spillage from TransCanada's KXL project?

Response: OBJECTION. Staff objects to this question on the grounds that it attempts to shift the burden from the company to staff, as well as on the grounds that it attempts to shift the regulatory burden from the federal government to commission staff for the purpose of inspecting Emergency Response Plans of an interstate pipeline.

Subject to and without waiving its objection, staff provides the following answer. It is staff's understanding that the Emergency Response Plan is not completed until close to the time a pipeline is ready to begin operations. All information submitted to the PUC regarding Keystone I's ERP is available in 7.0 of the company's Quarterly Report. For the last Quarterly Report filed by TransCanada for Keystone I, view the report at http://www.puc.sd.gov/commission/dockets/HydrocarbonPipeline/2007/HP07-001/4thquarterly2010.pdf.

Additionally, the final version of the Keystone Pipeline Emergency Response Plan will be amended to include Keystone XL. A redacted version of the ERP is available in Appendix I of the Finial Supplemental Environmental Impact Study, which is publicly available. The company may choose to redact information for public viewing due to the sensitive nature of the information contained in the ERP.

1-2) Re. Amended Permit Condition #40: According to TransCanada, the SD PUC made the decision to designate the concern of BTEX being hazardous if polyethylene and PVC water pipe is being used near this compound of chemicals. Is this correct? How was it decided that residents could request for their water piping to be changed if they lived within 500 feet of the project? How come this idea was not mandatory, and instead only at the request of the landowner?

Response: OBJECTION. This question calls for a legal opinion from the commission, which Staff is unable to provide. Staff is unable to answer for the commission, as Staff is separate from the commissioners, who are the decision-makers in the process.

1-3) I understand that that TransCanada must obtain permits from the US Army Corps of Engineers before crossing water bodies with their project. Does the US Army Corps of Engineers document studies of benzene migration in water before granting these permits? Does the Army Corps of Engineers rely on the FSEIS for this information? Who will be enforcing the Clean Water Act regulations re. this project?

Response: OBJECTION. This question attempts to shift the regulatory burden from the US Army Corps of Engineers to PUC staff. Furthermore, this information is more appropriately sought from the company or from the US Army Corps of Engineers. Subject to and without waiving its objection, staff provides the following answer.

It is staff's understanding that TransCanada has not submitted any permit applications to the US Army Corps of Engineers. As such, staff does not have any information as to what information would be analyzed should the company apply for a permit.

Enforcement of the Clean Water Act does not fall under the PUC's purview, and therefore, will not be responsible for enforcing the Clean Water Act. It is Staff's understanding that enforcement of the Clean Water Act would be done by the SD DENR and the EPA.

1-4) How did the PUC determine "the facility will not substantially impair the health, safety or welfare of the inhabitants."?

Response: The Commission made that determination after carefully reviewing all of the evidence in HP09-001. See Amended Final Decision and Order and transcript of formal hearing available online in Docket No. HP09-001. However, in HP09-001, as in this and any proceeding before the Commission, staff is a party to the docket and dos not take part in in Commission decisions. Therefore, staff has no more information than any other party or member of the public.

1-5) Has the PUC considered that toxins from KXL spillage could migrate via flowing water into public water intakes along the Missouri River? Where can I discover information as to locations of public water intakes along the Missouri River?

Response: Staff would rely on DENR's expert testimony on this matter. Staff has not received this information from DENR as of the due date of these responses. However, Staff will supplement this answer if and when this information is received from Staff's DENR witness.

1-6) Who is responsible for testing water for those expected/undetected leaks? Particularly in Tripp County where the pipeline will be immersed in groundwater?

Response: Staff would rely on DENR's expert testimony on this matter. Staff has not received this information from DENR as of the due date of these responses. However, Staff will supplement this answer if and when this information is received from Staff's DENR witness.

1-7) If high consequence areas are kept confidential by TransCanada, how can residents be assured of their safety? I feel residents are entitled to know this information.

Response: Similar to the ERP, the Integrity Management Plan could also contain sensitive information that the company may choose to keep confidential. The HCAs per se are not confidential, but TransCanada could be choosing to keep confidential the locations of the sections of pipe that have the ability to impact an HCA due to the sensitive nature of the information. Per code, an HCA is defined as:

(1) A commercially navigable waterway, which means a waterway where a substantial likelihood of commercial navigation exists;

(2) A high population area, which means an urbanized area, as defined and delineated by the Census Bureau, that contains 50,000 or more people and has a population density of at least 1,000 people per square mile;

(3) An other populated area, which means a place, as defined and delineated by the Census Bureau, that contains a concentrated population, such as an incorporated or unincorporated city, town, village, or other designated residential or commercial area;

(4) An unusually sensitive area, as defined in §195.6.

This information is readily available on census bureau websites and other sources.

1-8) What actions has the PUC taken to assure the South Dakota Health Care Community has been educated and trained to treat patients adversely affected from KXL spillage? Has there been communication with IHS and other health centers in SD?

Response: OBJECTION. This question attempts to shift the regulatory burden from DENR and the federal government, specifically the EPA or PHMSA, to Staff. This information is covered by the Emergency Response Plan, which is under the jurisdiction of the aforementioned agencies.

1-9) What education and training has been completed for SD public water treatment utilities to prepare them for tar sands spillage into SD waterways?

Response: OBJECTION. This question attempts to shift the burden from the company to Staff. It is the burden of the company to produce this information. Subject to and without waiving its objection, should Staff acquire any information from our experts to answer this question, we may supplement this answer at that time.

1-10) Please explain the reroute in Tripp County. How did the reroute improve safety?

Response: OBJECTION. This question attempts to shift the burden from the company to staff. Subject to and without waiving its objection, staff provides the following answer.

It is staff's understanding that the each route revision in Tripp County was made for the follow reason or reasons:

1. To minimize landowner impacts and reduce crossing of varying terrain features;
2. To minimize constructability and safety concerns with current Interstate 90, Hwy 16, and State Railroad crossings;
3. Per landowner requests to avoid a row of trees and minimize landowner impacts;
4. To minimize multiple creek crossings;
5. To avoid a well and impacts to a fence;
6. To avoid road crossing within a wetland area;
7. To minimize side slope construction;
8. To avoid a well and construction footprint impacts to a fence surrounding a historical site;
9. To avoid a drainage crossing and accommodate a road crossing;
10. To avoid side slop construction and sudden terrain changes;
11. To accommodate pump station design;
12. To accommodate pump station design;
13. To avoid any well impacts;
14. To avoid any well impacts; and
15. To avoid swampy low lying area near a pond.

1-11) What information have you shared with water treatment plants which access the Missouri River about oil spills into the Missouri River or tributaries of the Missouri River?

Response: OBJECTION. This question is outside of the scope of discovery as established by the commission's order, dated, December 17, 2014. Furthermore, water system operators had the opportunity to intervene in this proceeding, as well as HP09-001 if they had concern that their potable water intakes could be adversely impacted by the pipeline. Subject to and without waiving its objection, Staff will provide more information from its DENR witness when such information is received.

1-12) What information about tar sands spills into waterways has TransCanada provided the Department of Environment and Natural Resources?

Response: OBJECTION. This question is outside of the scope of discovery as established by the commission's order, dated, December 17, 2014. This question does not draw from a condition change, as required by the commission Order. Subject to and without waiving its objection, Staff will provide more information from its DENR witness when such information is received.

1-13) What plan do you have in place to respond to tar sands oil spills into the Missouri River or tributaries of the Missouri River?

Response: OBJECTION. This question attempts to shift the regulatory burden from DENR, PHMSA, and the EPA to Staff. The PUC does not have jurisdiction over interstate pipelines and would, therefore, not be involved with spill cleanup. Subject to and without waiving its objection, Staff will provide more information from its DENR witness when such information is received.

1-14) What education and training has been provided to water treatment facilities accessing Missouri River water regarding how to adequately respond to tar sands oil spills into the Missouri River or tributaries of the Missouri River?

Response: OBJECTION. This question attempts to shift the burden from the company to Staff. It is the burden of the company to produce this information. Subject to and without waiving its objection, Staff has asked this question of its DENR witness and will supplement its response if and when that information is received.

1-15) How do you plan to clean up a tar sands spill into the High Plains Aquifer in Tripp County?

Response: The PUC is not involved in cleanup. This would be the responsibility of the company, with the oversight of DENR and the EPA. The company must have a plan, subject to the approval or agreement of DENR and the EPA.

1-16) Describe the experience the State of South Dakota has had using "sparging" to clean up an aquifer. Has "sparging" ever been used to clean tar sands oil product from an aquifer?

Response: This is outside the technical expertise of Staff. Staff does not have knowledge of sparging. Should we acquire such information from one of our experts, Staff may supplement this answer at that time.

Questions from Cindy Myers to PUC Staff

5) Has the PUC considered that toxins from KXL spillage could migrate via flowing water into public water intakes along the Missouri River? Where can I discover information as to locations of public water intakes along the Missouri River?

Information about public water intakes in South Dakota is available on DENR's website at http://denr.sd.gov/des/dw/sysinfomap.aspx.

6) Who is responsible for testing water for those expected/undetected leaks? Particularly in Tripp County where the pipeline will be immersed in groundwater?

TransCanada, with regulatory oversight by the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), will be responsible for the monitoring and operation of the proposed Keystone XL pipeline throughout South Dakota. PHMSA's construction, operation and monitoring requirements are outlined in the Code of Federal Regulations Title 49, Part 195 – Transportation of Hazardous Liquids by Pipeline.

If the pipeline leaked, South Dakota Codified Law (SDCL) 34A-18 requires crude oil pipeline operators to implement their response plan regardless of who caused the release. DENR has regulatory authority over the assessment and cleanup of pipeline spills and will ensure cleanup continues until all state requirements and standards are met. This would include sampling water supplies to ensure no water supply sources are impacted. If a water supply is impacted, TransCanada would be responsible for mitigating those impacts.

In addition, the federal Safe Drinking Water Act requires public water systems to periodically sample for volatile organic chemicals. Samples are collected by water systems operation specialists and analyzed in a laboratory certified to analyze drinking water samples for volatile organic chemicals. Samples are collected from the entry point to the distribution system at a frequency based on prior detections with all data reported to DENR's Drinking Water Program. If contamination is detected in a water supply above regulatory limits, operators work with DENR to correct the problem and identify the contaminant source.

9) What education and training has been completed for SD public water treatment utilities to prepare them for tar sands spillage into SD waterways?

DENR contracts for water system operation specialist certification training through the South Dakota Association of Rural Water Systems. The certification training includes information and education on emergency response activities resulting from a variety of scenarios including petroleum releases and other contamination events.

In addition, a research project was conducted through South Dakota's Regional Water System Research Consortium titled *Improving Safety of Crude Oil and Regional Water System Pipeline Crossings*. The report findings were presented at several conferences attended by water system

personnel. The study dealt specifically with crude oil pipelines and makes design recommendation for pipeline designs when crossing regional water systems distribution lines. The report is available on the internet at:
http://www.sdarws.com/PDF/SDRWRC/PipelineCrossingSafetyFinalReport.pdf

11) What information have you shared with water treatment plants which access the Missouri River about oil spills into the Missouri River or tributaries of the Missouri River?

DENR along with representatives from Iowa, Nebraska, local emergency managers, wildlife experts, EPA Region VII, and industry representatives including TransCanada are all participants in the Siouxland Sub-area Spill Contingency Committee who worked to develop a Siouxland Sub-area Spill Contingency Plan. As part of the implementation of this plan the group holds exercises, training sessions and meetings to discuss response and recovery efforts needed to respond to large oil or chemical releases. The plan addresses potential impacts to water supply intakes and notification procedures in the event of a release.

In addition, if there is a release into the Missouri River DENR's spill program works with the Drinking Water Program to ensure potentially impacted downstream facilities are notified and assisted as needed.

12) What information about tar sands spills into waterways has TransCanada provided the Department of Environment and Natural Resources?

TransCanada has not provided DENR with any specific information about tar sands spills into waterways from the proposed Keystone XL pipeline. However, SDCL 34A-18 requires crude oil pipeline operators to submit an oil spill response plan to DENR prior to operating the pipeline. The plan will address crude oil spills into waterways. DENR expects TransCanada to comply with SDCL 34A-18 prior to placing the Keystone XL pipeline into operation.

In compliance with SDCL 34A-18, TransCanada has provided DENR with an oil spill response plan for the existing Keystone pipeline and has conducted two full-scale spill response exercises in Yankton, SD where the pipeline crosses the Missouri River.

13) What plan do you have in place to respond to tar sands oil spills into the Missouri River or tributaries of the Missouri River?

SDCL 34A-18 requires crude oil pipeline operators to submit their oil spill response plan to DENR for approval and requires crude oil pipeline operators to implement their response plan in the event of a spill regardless of where the spill is or who caused the release.

In the event of a pipeline leak, DENR has regulatory authority over the assessment and cleanup of the spill and will ensure the cleanup continues until all state requirements and standards are met.

If the pipeline company did not responds to a spill, DENR has the authority to take legal action against the company to force their response, and while legal action is pending, has access to state and federal safety net clean up funds that could be used to initiate a response to protect against immediate threats to human health and the environment.

In addition DENR has been involved in the development of the following response plans and procedures which may be implemented in the event of a major crude oil spill: EPA Region VIII Emergency Response Plan, South Dakota Emergency Response Plan, South Dakota Disaster Recovery Plan, DENR Emergency Operations Plan, and DENR's Handbook for Reporting, Investigating, and Remediating Petroleum Releases in South Dakota.

14) What education and training has been provided to water treatment facilities accessing Missouri River water regarding how to adequately respond to tar sands oil spills into the Missouri River or tributaries of the Missouri River?

Education and training associated with spill response and other source water contamination events is included in DENR's contracted system operations specialist training as noted in question #9 above.

15) How do you plan to clean up a tar sands spill into the High Plains Aquifer in Tripp County?

SDCL 34A-18 requires crude oil pipeline operators to submit their oil spill response plan to DENR for approval and requires crude oil pipeline operators to implement their response plan in the event of a spill regardless of where the spill is or who caused the release. If the proposed Keystone XL pipeline leaked into the High Plains aquifer, TransCanada would be responsible for the cleanup.

However, DENR has regulatory authority over the assessment and cleanup of the spill and will ensure the cleanup continues until all state requirements and standards are met. In general, required cleanup actions would include: stopping the release, removal of free product, sampling of soil, surface water and groundwater to define the nature and extent of the contamination, design and implementation of cleanup actions to remediate remaining contamination to levels below state standards.

If the pipeline company did not responds to a spill, DENR has the authority to take legal action against the company to force their response, and while legal action is pending, has access to state and federal safety net clean up funds that could be used to initiate a response to protect against immediate threats to human health and the environment.

16) Describe the experience the State of South Dakota has had using "sparging" to clean up an aquifer. Has "sparging" ever been used to clean tar sands oil product from an aquifer?

DENR has not used sparging to cleanup a tar sands oil spill in an aquifer because there has not been a tar sands oil spill that has impacted an aquifer in South Dakota. However, DENR staff do have experience with the installation and operation of soil vapor extraction and sparging systems used to remediate aquifers contaminated with refined petroleum products such as gasoline and diesel fuel.

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Advances in Understanding Benzene Health Effects and Susceptibility

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Abstract

Benzene is a ubiquitous chemical in our environment that causes acute leukemia and probably other hematological cancers. Evidence for an association with childhood leukemia is growing. Exposure to benzene can lead to multiple alterations that contribute to the leukemogenic process, indicating a multimodal mechanism of action. Research is needed to elucidate the different roles of multiple metabolites in benzene toxicity and the pathways that lead to their formation. Studies to date have identified a number of polymorphisms in candidate genes that confer susceptibility to benzene hematotoxicity. However, a genome-wide study is needed to truly assess the role of genetic variation in susceptibility. Benzene affects the blood-forming system at low levels of occupational exposure, and there is no evidence of a threshold. There is probably no safe level of exposure to benzene, and all exposures constitute some risk in a linear, if not supralinear, and additive fashion.

Keywords

leukemia; hematology; molecular epidemiology; genetic polymorphism; risk assessment

INTRODUCTION

Benzene is widely used in the United States and ranks in the top 20 chemicals for production volume (see ATSDR Toxicological Profile of Benzene, http://www.atsdr.cdc.gov/toxprofiles/tp3.pdf). It is the primary starting material for chemicals used to make plastics, resins, synthetic fibers, dyes, detergents, drugs, and pesticides. Natural sources of benzene include emissions from fires. Benzene is also a component of crude oil, gasoline, and cigarette smoke. Occupational exposures in the developing world are sometimes very high because of the continuing presence of benzene in industrial solvents and glues. In the United States, workers continue to be exposed to potentially high levels of benzene in the chemical industry, in petroleum refineries, in oil pipelines, on ships and tankers, in auto repair shops,

DISCLOSURE STATEMENT
The author has received consulting and expert testimony fees from lawyers representing both plaintiffs and defendants in cases involving claims related to exposure to benzene. The author has also received consulting fees from the governments of Australia, Norway, and the United States.

and in bus garages. Shipping may be particularly hazardous because there is little awareness or regulation, and exposures can be considerable. For example, on marine vessels benzene air concentrations typically range from 0.2–2.0 ppm during closed loading and 2–10 ppm during open-loading operations (121). The general public is exposed mainly from mobile sources, such as automobiles. The benzene content of gasoline is, therefore, strictly regulated in the United States and Europe, with limits typically around 1%. The U.S. Environmental Protection Agency (EPA) recently set new regulations that will lower the benzene content in gasoline to 0.62% in 2011 (20).

HISTORICAL OVERVIEW OF THE HEMATOTOXIC EFFECTS OF BENZENE

Benzene is the simplest aromatic chemical and an excellent solvent. Its toxicity to the blood-forming organs was realized soon after its industrial use began. In 1897, Santesson described nine cases of chronic benzene hematotoxicity (88). The hematotoxic effects of benzene were further documented in studies by Selling (90) and Weiskotten (114, 115). This research led Alice Hamilton (35) and others to warn about the occupational dangers of benzene (98).

The first case of benzene-associated leukemia was described by Delore & Borgomano in 1928 (16). Many leukemia cases associated with benzene exposure were reported between 1930 and the 1960s (3, 4, 30, 109), and by 1961 benzene had been identified as one of two industrial leukemogens, the other being ionizing radiation (15). Reports of multiple cases of leukemia and other hematological disorders among shoe workers using benzene as a solvent and in glues were generated by Vigliani and colleagues in Italy (23) and by Aksoy and coworkers in Turkey in the 1960s and 1970s (1, 2), confirming the association with leukemia.

TRADITIONAL EPIDEMIOLOGICAL STUDIES OF THE CARCINOGENIC EFFECTS OF BENZENE EXPOSURE

It was not until 1977 that the first positive finding of increased leukemia risk in an epidemiological cohort study of workers in the U.S. rubber industry was published, by Infante et al. (43). They reported that workers occupationally exposed to benzene between 1940 and 1949 had at least a fivefold excess risk of all leukemias and a tenfold excess of deaths from myeloid and monocytic leukemias combined compared with controls. The environment of the workers in the study population was not contaminated with solvents other than benzene, showing that benzene must be the cause. This study became known as the Pliofilm study because it investigated workers exposed to benzene in rubber hydrochloride (the Goodyear trade name for which was Pliofilm) manufacturing plants in Ohio. Subsequent follow-ups of this cohort were published by Rinsky and coworkers, with the most recent being in 2002, which reaffirmed the leukemogenic effects of benzene exposure in this cohort (83, 84). Because of its importance as the first epidemiological study to provide quantitative estimates of leukemia risk from benzene exposure, as well as its role in the lowering of the Occupational Safety and Health Administration (OSHA) permissible exposure level to 1 ppm, the Pliofilm study has been the subject of much reanalysis by consultants to the oil and chemical industry (e.g., 73, 74) with the intention of influencing regulatory or legal proceedings as described in detail by Michaels (68). However, subsequent studies in China and Australia have confirmed and expanded on its findings, as described below.

After President Nixon's visit to China in 1972, China became much more open to trade with the west and became much more industrialized. The manufacturing of shoes and leather goods increased dramatically, along with exposure to benzene through its use as a solvent and as a contaminant in glues. Reports of significant health problems associated with benzene in workplaces in China soon began to appear. These reports led to pioneering studies of benzene-exposed workers in China by Songnian Yin and colleagues of the Chinese Academy of Preventive Medicine (CAPM), who identified more than 500,000 workers exposed to benzene (124). A follow-up survey of 28,460 benzene-exposed and 28,257 unexposed workers from 1972 through 1981 found an increased risk of mortality due to leukemia [standardized mortality ratio (SMR) = 5.7] (123). In 1987, the U.S. National Cancer Institute (NCI) began collaborating with the CAPM team to identify all incident cases of hematologic neoplasms and related disorders in an expanded study cohort of 74,828 benzene-exposed and 35,805 unexposed workers employed from 1972 through 1987 in 12 cities in China (37, 122). The study confirmed increased risks of acute myeloid leukemia (AML) and other malignant and non-malignant hematopoietic disorders associated with benzene exposure and found evidence for hematopoietic cancer risks at levels substantially lower than had previously been established. In contrast to the findings among rubber hydrochloride workers, the NCI-CAPM study showed excess risk at relatively low levels of exposure (<10 ppm average and <40 ppm-years cumulative) but found a relatively modest dose-response effect, with proportionally smaller increases in risk at increasing levels of exposure. The study also reported that workers with 10 or more years of benzene exposure had a relative risk (RR) of developing non-Hodgkin lymphoma (NHL) of 4.2 [95% confidence interval (CI) 1.1–15.9] and an excess risk of myelodysplastic syndromes (MDS) (36, 37, 104). This study considerably expanded the health effects associated with benzene beyond AML and suggested benzene produced effects at levels lower than previously thought. It has again been the subject of much criticism by industry consultants to which the NCI-CAPM investigators have responded (36). They will soon report on an additional 10 years of follow-up through 1997.

Glass and coworkers performed a nested case-control study of lympho-hematopoietic cancer nested within the existing Healthwatch cohort study to examine the role of benzene exposure (26, 28, 36). Cases identified between 1981 and 1999 (n = 79) were age-matched to five control subjects from the cohort. Each subject's benzene exposure was estimated using occupational histories, local site-specific information, and an algorithm using Australian petroleum industry–monitoring data. This exposure assessment is probably the best of any epidemiological study of benzene to date (25, 27). Matched analyses showed that the risk of leukemia was increased at cumulative exposures above 2 ppm-years and with intensity of exposure of highest exposed job more than 0.8 ppm. Risk increased with higher exposures; for the 13 case-sets with greater than 8 ppm-years cumulative exposure, the odds ratio (OR) was 11.3 (95% CI 2.85–45.1). The risks for acute nonlymphocytic leukemia (ANLL) and chronic lymphocytic leukemia (CLL) were raised for the highest exposed workers. A cumulative exposure of >8 ppm-years was associated with a sevenfold significantly increased risk specifically of ANLL. No association was found between NHL or multiple myeloma and benzene exposure, but this finding may have been due to limited follow-up. The Glass et al. study is important because it found an excess risk of leukemia associated with cumulative benzene exposures and benzene exposure intensities that were considerably lower than reported in previous studies. Furthermore, no evidence was found of a threshold cumulative exposure below which there was no risk. However, it has been suggested that the high incidence of CLL may be due to a surveillance bias (29).

Apart from these three important studies, there have been many other epidemiological studies of the carcinogenicity of benzene, which are too numerous to review here. For reviews, see recent articles in References 10, 48, and 120. The consensus clearly shows that benzene causes AML/ANLL and MDS, even at relatively low doses, and that AML often arises secondary to MDS. However, a series of questions important to the risk assessment of benzene remain (Table 1).

IS IT ONLY ACUTE MYELOID LEUKEMIA THAT IS PRODUCED BY BENZENE?

The evidence for other forms of leukemia apart from AML being caused by benzene exposure as well as different forms of NHL has grown steadily over the years. Lymphomas were reported long ago in experimental animals given long-term exposure to benzene. Because all leukemias arise in the stem and progenitor cells of the bone marrow, which are clearly damaged by benzene, there is a biologically plausible basis for suggesting benzene as a causal factor for acute lymphoblastic leukemia (ALL) and chronic myeloid leukemia (CML). Some studies of benzene-exposed workers have reported such an increased risk, but the assessment of the association of benzene with these malignancies is hampered mainly by their rarity and is certainly stronger for ALL than CML. Several epidemiological studies, including the above study by Glass et al. (26), have reported an association between benzene exposure and CLL. The main problems in assessing the risk of CLL are the different disease classifications used by investigators over time, the fact that the disease is present with only very low incidence in Asians, and the lack of specific information on CLL in most studies. CLL is now classified as a form of NHL along with multiple myeloma because they are now considered subclassifications of mature B-cell neoplasms (107). Mechanistic and molecular epidemiology studies may contribute to our understanding of the association of benzene with these neoplasms. For example, both CLL and multiple myeloma have precursor forms: Almost all CLL patients are preceded by a monoclonal B-cell lymphocytosis precursor state (54), and monoclonal gammopathy of undetermined significance (MGUS) is a common precursor to myeloma (116). Demonstration that these precursors were elevated in benzene-exposed populations would add support to the hypothesis that benzene was causatively linked to CLL and myelomagenesis, as has recently been shown for certain pesticides (55).

Epidemiological studies on the association between benzene and NHL have produced mixed results. For example, in the NCI-CAPM cohort study discussed above, a relative risk of 4.7 (95% CI 1.2 to 18.1) for NHL was reported (37). In contrast, Sorahan et al. reported a relative risk of 1.00 for NHL in a cohort study of benzene-exposed workers in England and Wales (100). The reasons for these discrepancies are not entirely clear but could be related to differences in study populations, exposure levels, lack of statistical power, and study designs leading to biases such as the healthy worker effect. We systematically reviewed the evidence relating to benzene and NHL and noted problems of bias due to the healthy worker effect (95). We performed formal meta-analysis of studies of NHL and occupational exposure to benzene in work settings other than refineries and formal meta-analysis of NHL and refinery work, a setting that has historically been associated with benzene exposure (101). These were done separately because refinery work can be associated with many chemical exposures other than benzene. In 22 studies of benzene exposure, the summary relative risk for NHL was 1.22 (95% CI 1.02 to 1.47; $p = 0.01$). When studies that likely included unexposed subjects in the exposed group were excluded, the summary relative risk increased to 1.49 (95% CI 1.12 to 1.97, $n = 13$), and when studies based solely on self-reported work history were excluded, the relative risk rose to 2.12 (95% CI 1.11 to 4.02, $n = 6$). In refinery workers, the summary relative risk for NHL in all 21 studies was 1.21 (95% CI 1.00 to 1.46; $p = 0.02$). When adjusted for the healthy worker effect, this relative risk estimate increased to 1.42 (95% CI 1.19 to 1.69) (101). The finding of elevated relative risks in studies of both benzene exposure and refinery work provides further evidence that benzene exposure is associated with an increased risk of NHL. There are many similarities between cancer chemotherapy drugs and benzene in their abilities to produce both AML and NHL. Both appear to be highly efficient at producing AML with high relative risks and both also produce NHL, but with lower relative risks and a longer latency period than for AML (49). The lower relative risks observed may be due to the fact that NHL is a diverse set of tumors and that benzene and chemotherapy drugs produce only certain subtypes of NHL.

German researchers have concluded that benzene could cause any malignant hemato-logic disease because these diseases all arise from damaged omnipotent stem cells (9). More recently, Beelte et al. convened a committee of experts to evaluate the international literature (10). They concluded that “all kinds of myeloid and lymphoid malignancies including their prestages can be caused by occupational benzene exposure” (p. 197).

EVIDENCE FOR AN ASSOCIATION WITH CHILDHOOD LEUKEMIA

Multiple studies have shown an increase in childhood leukemia risk in relation to air pollution sources emitting benzene, such as gas stations and traffic. For example, a recent nationwide study in France of 765 acute leukemia cases and 1681 controls found that acute leukemia was significantly associated with residence next to gasoline stations or automotive repair garages (OR 1.6, 95% CI 1.2 to 2.2) (12). Furthermore, in a study of the area around Houston, Texas, census tracts with the highest benzene levels, estimated by EPA models, had elevated rates of all leukemias (RR = 1.37; 95% CI 1.05, 1.78), with the association being stronger for AML (117). More studies of pediatric cancers are needed that include estimates of environmental benzene exposure, rather than surrogate exposures such as proximity to gasoline stations or traffic.

Recent mechanistic work adds support to the potential association between benzene exposure and childhood leukemia. Because the genotoxic action of benzene metabolites on pluripotent bone marrow precursor cells appears promiscuous, producing multiple genetic abnormalities, it seems probable that benzene exposure can initiate both AML and ALL by causing the chromosomal rearrangements and mutations that are on the causal pathway to these malignancies. For childhood ALL and AML, studies have shown that the disease is usually initiated in utero because the leukemic translocations and other genetic changes are present in blood spots collected at birth (32, 66, 118, 119). Thus, exposure of the mother, and perhaps the father, to benzene could be just as important as childhood exposures in producing childhood AML and ALL, as has been suggested by epidemiological studies (67, 89, 92, 106). Supporting this hypothesis are animal studies demonstrating that in utero exposure to benzene increases the frequency of micronuclei and DNA recombination events in hematopoietic tissue of fetal and postnatal mice (6, 57). Studies also show that oxygen radicals play a key role in the development of in utero–initiated benzene toxicity through disruption of hematopoietic cell signaling pathways (6). These studies support the idea that genotoxic and nongenotoxic events following benzene exposure may be initiators of childhood leukemia in utero.

MECHANISMS OF BENZENE CARCINOGENICITY: MECHANISMS OF MYELOID LEUKEMIA DEVELOPMENT

AML and MDS are closely related diseases of the bone marrow that arise de novo in the general population or following therapy with alkylating agents, topoisomerase II inhibitors, or ionizing radiation [therapy-related AML and MDS (t-AML and t-MDS)] (75, 76). Occupational exposure to benzene is widely thought to cause leukemias that are similar to t-AML and t-MDS (44, 56, 128). AML and MDS both arise from genetically altered CD34+ stem or progenitor cells in the bone marrow (70) and are characterized by many different types of recurrent chromosome aberrations (71, 76). These aberrations often result in the genetic mutations that produce leukemia. Cytogenetic analysis of chromosome number and structure has therefore become important in diagnosing and treating MDS and AML (71, 76). The chromosome aberrations and gene mutations detected in therapy-related and de novo MDS and AML are very similar, although the frequencies with which they are observed in different subtypes may differ (75). Hence, therapy-related and de novo MDS and AML are considered very similar diseases (75).

At least three cytogenetic subtypes of AML and MDS are commonly observed.

1. Unbalanced aberrations. Cases with unbalanced chromosome aberrations, primarily 5q–/–5 or 7q–/–7 and +8, represent the first subtype (75, 76). They often present with a complex karyotype and point mutations of p53 or AML1 and are common after therapy with alkylating agents.

2. Balanced rearrangements. Cases with the recurrent balanced translocations [e.g., t(11q23), t(8;21) and t(15;17)] or inversions [e.g., inv(16)] represent the second subtype and arise, at least in the therapy-related subset, as illegitimate gene recombinations related to the inhibition of topoisomerase II (75).

3. Normal karyotype. Cases with a normal karyotype comprise the third subtype and often harbor mutations of *NPM1*, internal tandem duplications of *FLT3*, and/or point mutations or altered methylation status of *C/EBP*α(75).

Within these three cytogenetic categories there are at least eight different genetic pathways to MDS and AML, as defined by the specific chromosome aberrations present in each (Pathways I–VIII in Figure 1). As more information is revealed about the molecular cytogenetics of leukemia, it seems likely that numerous other pathways to AML and MDS will be discovered. For example, recent unbiased high-resolution genomic screens have identified many genes that were not previously implicated in AML and which may be relevant for pathogenesis, along with many known oncogenes and tumor suppressor genes (58, 64, 111).

An important role for epigenetic changes is also emerging in the development of leukemia. Functional loss of the *CCAAT/enhancer binding protein*α(*C/EBP*α), a master regulatory transcription factor in the hematopoietic system, can result in a differentiation block in granulopoiesis and thus contribute to leukemic transformation (24). Recent work has shown that epigenetic alterations of C/EBPα are a frequent event in AML (34). *C/EBP*α can also steer *miRNA-223* expression, which is vital in granulocytic differentiation (22).

Referring to Figure 1, extensive evidence indicates that benzene can induce AML via Pathways I, II, and IV and demonstrates considerable support for Pathway V. There is some evidence for Pathway III but little information regarding Pathways VI–VIII. Benzene exposure has been associated with higher levels of chromosomal changes commonly observed in AML, including 5q–/–5 or 7q–/–7, +8, and t(8;21) in the blood cells of highly exposed workers (97, 127, 129). Its metabolites also produce these same changes in human cell cultures, including cultures of CD34+ progenitor cells (96, 102). This research provides strong evidence for benzene's role in the production of AML by Pathways I, II, and IV (Figure 1).

Pathways III, IV, and V are related to the inhibition of the DNA-related enzyme topoisomerase II (topo II), which is essential for the maintenance of proper chromosome structure and segregation. There are different types of topo II inhibitors. Epidophyllotoxins, such as etoposide, cause chromosome damage and kill cells by increasing physiological levels of topoisomerase II-DNA cleavage complexes (17). These drugs are referred to as topoisomerase II poisons to distinguish them from catalytic inhibitors of the enzyme because they convert this essential enzyme to a potent cellular toxin. Other drugs, such as merbarone, act as inhibitors of topo II activity; however, in contrast to etoposide, they do not stabilize topo II-DNA cleavable complexes but are still potent clastogens both in vitro and in vivo (112).

Several studies have shown that benzene in vivo and its reactive benzene metabolites hydroquinone (HQ) and 1,4-benzoquinone (BQ) in vitro inhibit the functionality of topo II and enhance DNA cleavage (13, 60). Bioactivation of HQ by peroxidase to BQ enhances topo II inhibition (19). Indeed, BQ is a more potent topo II inhibitor than is HQ in a cell-free assay system (7, 42). These findings demonstrate that benzene, through its reactive quinone metabolites, can inhibit topo II and probably cause leukemias with chromosome translocations and inversions known to be caused by topo II inhibitors, including AMLs harboring t(21q22), t(15;17), and inv(16) in a manner consistent with Pathways IV and V (69, 75). The evidence for rearrangements of the *MLL* gene through t(11q23) via Pathway

III in benzene-induced leukemia is less convincing but may occur through an apoptotic pathway (108).

AML can arise de novo via Pathways VII and VIII without apparent chromosome abnormalities, but molecular analysis has revealed many genetic changes in these apparently "normal" leukemias, including mutations of *NPM1*, *AML1*, *FLT3*, *RAS*, and *C/EBPα*(Figure 1) (21, 64). Research is needed to clarify the ability of benzene and its metabolites to produce mutations of the types found in these leukemias.

The ability of benzene and/or its metabolites to induce epigenetic changes related to the development of leukemia, such as altered methylation status of *C/EBPα*, is unclear at this time. A recent study reported that hypermethylation in *p15* (+0.35%; $p = 0.018$) and hypomethylation in *MAGE-1* (-0.49%; $p = 0.049$) were associated with very low benzene exposures (~22 ppb) in healthy subjects, including gas station attendants and traffic police officers, although the corresponding effects on methylation were very low (11). Further study of the role epigenetics plays in the hematotoxicity and carcinogenicity of benzene is warranted, including studies of aberrant DNA methylation and altered microRNA expression.

Although benzene and its metabolites are clearly capable of producing multiple forms of chromosomal mutation, including various translocations, deletions, and aneuploidies, these are usually insufficient as a single event to induce leukemia. Other secondary events, such as specific gene mutations and/or other chromosome changes, are usually required (33, 61). Thus, benzene-induced leukemia probably begins as a mutagenic event in the stem or progenitor cell, and subsequent genomic instability allows for sufficient mutations to be acquired in a relatively short time period. Studies have shown that the benzene metabolite HQ is similar to ionizing radiation because it induces genomic instability in the bone marrow of susceptible mice (31). Recent findings showing the importance of DNA repair and maintenance genes, such as *WRN*, in genetic susceptibility to benzene toxicity also support this mechanism (52, 82).

Thus, benzene exposure can lead to multiple alterations that contribute to the leukemogenic process. Benzene may act by causing chromosomal damage (aneuploidy, deletions, and translocations) through the inhibition of topo II; disrupting microtubules; generating oxygen radicals that lead to point mutations, strand breaks, and oxidative stress; causing immune system dysfunction that leads to decreased immunosurveillance (14, 59); altering stem cell pool sizes through hematotoxicity (45); inhibiting gap-junction intercellular communication (85); and altering DNA methylation and perhaps specific microRNAs. This multimodal mechanism of action suggests that the effects of benzene on the leukemogenic process are not singular and can occur throughout the process. This finding implies that both background and added exposures from occupation and hobbies will have similar impacts on the process and that the effects will be additive. Thus, given the high background exposure to benzene as a combustion by-product in our environment, it seems unlikely that any practical threshold exists, and the effects of each molecule of benzene will be additive in a linear fashion.

METABOLISM OF BENZENE AND ITS RELEVANCE TO BENZENE CARCINOGENICITY

Benzene must be metabolized to become carcinogenic (86, 99). Its metabolism is summarized in Figure 2. The initial step involves cytochrome P450 (CYP)-dependent oxidation of benzene to benzene oxide, which exists in equilibrium with its tautomer oxepin. Most benzene oxide spontaneously rearranges to phenol (PH), which is either excreted or further metabolized to HQ and 1,4-BQ. The remaining benzene oxide is either hydrolyzed to produce catechol (CA) and 1,2-BQ or reacts with glutathione to produce *S*-phenylmercapturic acid (SPMA). Metabolism of oxepin is thought to open the aromatic ring, yielding the reactive muconaldehydes and *E,E*-muconic acid (MA). Human exposures to benzene at air concentrations between 0.1 and 10 ppm result in urinary metabolite profiles with 70%–85% PH, 5%–10% each of HQ, MA, and CA, and less than 1% of SPMA (47). Benzene oxide, the BQs, muconaldehydes, and benzene diol epoxides (formed from CYP oxidation of benzene dihydrodiol) are electrophiles that readily react with peptides and proteins (8, 39, 65, 110) and can thereby interfere with cellular function (94). It remains unclear what role these different metabolites play in benzene carcinogenicity, but BQ formation from HQ via myeloperoxidase in the bone marrow may be key (94). Considerable evidence indicates that this pathway plays an important role in BQ formation because the BQ-detoxifying enzyme NQO1 protects mice against benzene-induced myelodysplasia (46, 62) and protects humans against benzene hematotoxicity (87). However, this protection does not rule out adverse effects from other metabolites.

Benzene is most likely metabolized initially to PH and MA via two enzymes rather than just one CYP enzyme, and the putative high-affinity enzyme is active primarily below 1 ppm (79). Because CYP2E1 is the primary enzyme responsible for mammalian metabolism of benzene (72, 105), it is reasonable to assume that the low-affinity enzyme is responsible for benzene metabolism mainly at higher levels of exposure. CYP2F1 and CYP2A13 are reasonable candidates for the high-affinity metabolic enzymes, which are active at environmental levels of exposure below 1 ppm (77, 79, 91). Interestingly, these CYPs are highly expressed in the human lung. Despite much research, more work is needed to elucidate the different roles of multiple metabolites in benzene toxicity and the pathways that lead to their formation.

EMERGING ROLE OF THE ARYL HYDROCARBON RECEPTOR

The aryl hydrocarbon receptor (AhR) is known mainly as the mediator for the toxicity of certain xenobiotics. However, this transcription factor has many important biological functions, and emerging evidence indicates that it has a significant role in the regulation of hematopoietic stem cells (HSCs) (40, 93). AhR expression may be necessary for the proper maintenance of quiescence in HSCs, and AhR downregulation is essential for the stem cells to "escape" from quiescence and undergo subsequent proliferation (93). This hypothesis implicates the AhR as a negative regulator of hematopoiesis to curb excessive proliferation. This, in turn, prevents the premature exhaustion of HSCs and sensitivity to genetic alterations, thus preserving HSC function over the organism's life span. However, AhR dysregulation may result in the altered ability of HSCs to sense appropriate signals in the bone marrow microenvironment, leading to hematopoietic disease.

Inoue and colleagues have shown that AhR-knockout (KO) mice do not show any hematotoxicity after benzene exposure (125). Follow-up studies showed that mice that had been lethally irradiated and repopulated with marrow cells from AhR-KO mice essentially did not have signs of benzene-induced hematotoxicity (41). The most likely explanation for these findings is that the absence of AhR removes HSCs from their quiescent state and makes them susceptible to DNA damage from benzene exposure and subsequent cell death through apoptosis. Further research is needed to examine the effects of benzene and its metabolites on cycling and quiescent HSCs.

SUSCEPTIBLE SUBPOPULATIONS

Aksoy (1) reported striking variation in benzene toxicity among workers with comparable levels of occupational exposure. The reasons underlying this variation are unknown. Part of the variation may be caused by biological factors such as gender, age, genetics, and amount of adipose tissue, with the remainder being due to environmental influences such as routes of exposure, physical activity, coexposures, smoking, alcohol consumption, and dietary habits.

Studies to date have identified a number of single-nucleotide polymorphisms (SNPs) in candidate genes that appear to confer susceptibility to benzene hematotoxicity. The first ones identified were related to metabolism, including polymorphisms in cytochrome P450 2E1 (CYP2E1), NAD(P)H:quinone oxidoreductase 1 (NQO1), myeloperoxidase (MPO), glutathione-*S*-transferases (GSTs), and microsomal epoxide hydrolase (mEH) in Figure 2. The role of metabolizing enzyme polymorphisms was reviewed by Dougherty et al. (18) in 2008. They concluded that the polymorphisms produced a modest effect on the biomarkers of benzene exposure and effect analyzed in 22 studies; GSTM1 and GSTT1 showed some consistent associations.

In a study of 1395 SNPs in 411 cancer-related genes on lowered white blood cell (WBC) counts in benzene-exposed workers, highly significant findings were clustered in genes (BLM, TP53, RAD51, WDR79, and WRN) that play a critical role in DNA repair and genomic maintenance (52). In vitro functional studies revealed that deletion of SGS1 in yeast, equivalent to lacking BLM and WRN function in humans, caused reduced cellular growth in the presence of the toxic benzene metabolite HQ, and knockdown of WRN increased susceptibility of human lymphoid TK6 and myeloid HL60 cells to HQ toxicity (52, 82). Thus, SNPs in genes involved in DNA repair and genomic maintenance play an important role in susceptibility to benzene-induced hematotoxicity. Other possible associations with DNA repair and genome maintenance include the recent findings that polymorphisms in the p53-dependent genes p21 and p14(ARF) may play a role in susceptibility to chronic benzene poisoning (103).

The other class of genetic polymorphisms associated with benzene toxicity is in cytokine and chemokine genes. Associations have been reported with SNPs in VEGF, IL-1A, IL-4, IL-10, IL-12A, VCAM1, and lowered WBC counts (53) and with an SNP in TNF-alpha and chronic benzene poisoning (63). Additional studies are needed to confirm these associations.

Thus, genetic polymorphisms that confer susceptibility to benzene toxicity should be taken into account when assessing the risks of benzene exposure. Select combinations of genetic polymorphisms may increase susceptibility of individuals and/or population subgroups. However, gene-gene interactions are not yet analyzed in well-designed studies that incorporate multiple biological end points and multiple genes, and a genome-wide study is needed to truly assess the role of genetic variation in conferring susceptibility.

WHAT IS THE DOSE-RESPONSE CURVE? IS IT LINEAR AND IS THERE A FUNCTIONAL THRESHOLD IN THE LOW-DOSE REGION?

Although there is undoubtedly a causal link between benzene exposure and leukemia, the shape of the exposure-response relationship is controversial, particularly at low doses at or below 1 ppm in air. Indeed, when considering regulatory actions, litigation, and potential clean-up costs in the billions of dollars, this uncertainty represents a major challenge for environmental toxicology and epidemiology. Recent action by the U.S. EPA to reduce cancer risks from mobile sources underscores this point (see 20). In justifying its decision to lower the benzene content of gasoline, the EPA cited studies pointing to supralinear (greater-than-proportional) production of benzene-related protein adducts at air concentrations below 1 ppm (80, 81). Such behavior would likely result from saturation of the metabolism of benzene to benzene oxide-oxepin. Because the EPA had previously assumed that human benzene metabolism proceeded according to nonsaturating (first-order) kinetics at exposure concentrations well above 10 ppm, saturation of metabolism below 1 ppm “could lead to substantial underestimation of leukemia risks” in the general population (20).

Traditional epidemiology is unlikely to determine the shape of the dose-response curve for benzene-induced leukemia in the low-dose region, although the Glass et al. study shows effects at 1–2 ppm in air and no sign of a threshold. Chronic animal toxicity studies are also unlikely to be informative for two reasons: (*a*) no accepted animal model of benzene-induced leukemia exists at the present time, and (*b*) low-dose studies would require a prohibitively large number of animals. In situations like this, where traditional epidemiology and toxicology are of limited value, investigators have proposed that nontumor data such as biological markers (biomarkers) be employed in the risk-assessment process (5).

The most appropriate biomarker of leukemia risk appears to be lowered WBC counts because this factor has been associated with an increased risk of hematological malignancies. Ward et al. (113) found no evidence of a threshold for hematotoxic effects of benzene and suggested that exposure to <5 ppm benzene could result in hematologic suppression. Occupational exposure decreased WBC count in petrochemical workers exposed to <10 ppm benzene (126), and Qu et al. reported that depressions in blood cell counts in benzene-exposed Chinese workers were not only exposure dependent, but also significantly different in the lowest exposed group (at or below 0.25 ppm) compared with unexposed subjects (78). In a large study of more than 400 workers, hematotoxicity occurred in workers exposed to <1 ppm benzene (51). Further analysis of this data showed a linear monotonicity of the association between lowered blood cell counts and benzene exposure by spline regression analyses (50). Thus, the literature shows that benzene affects the blood-forming system at low levels of occupational exposure, at or below 1 ppm, and that there is no evidence of a threshold. As a result, the threshold limit value has recently been lowered by the ACGIH to 0.5 ppm, and various government agencies and scientific bodies have recommended the 8-hour time-weighted average standard be lowered to 0.1 ppm. The latest research indicates that there is likely no safe level of exposure to benzene and that all exposures constitute some risk in a linear, if not supralinear, and additive fashion. Public health agencies should act accordingly.

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Glossary

EPA	Environmental Protection Agency
CAPM	Chinese Academy of Preventive Medicine
NCI	National Cancer Institute
AML	acute myeloid leukemia
NHL	non-Hodgkin lymphoma
MDS	myelodysplastic syndromes
OR	odds ratio
HQ	hydroquinone
SNP	single nucleotide polymorphism

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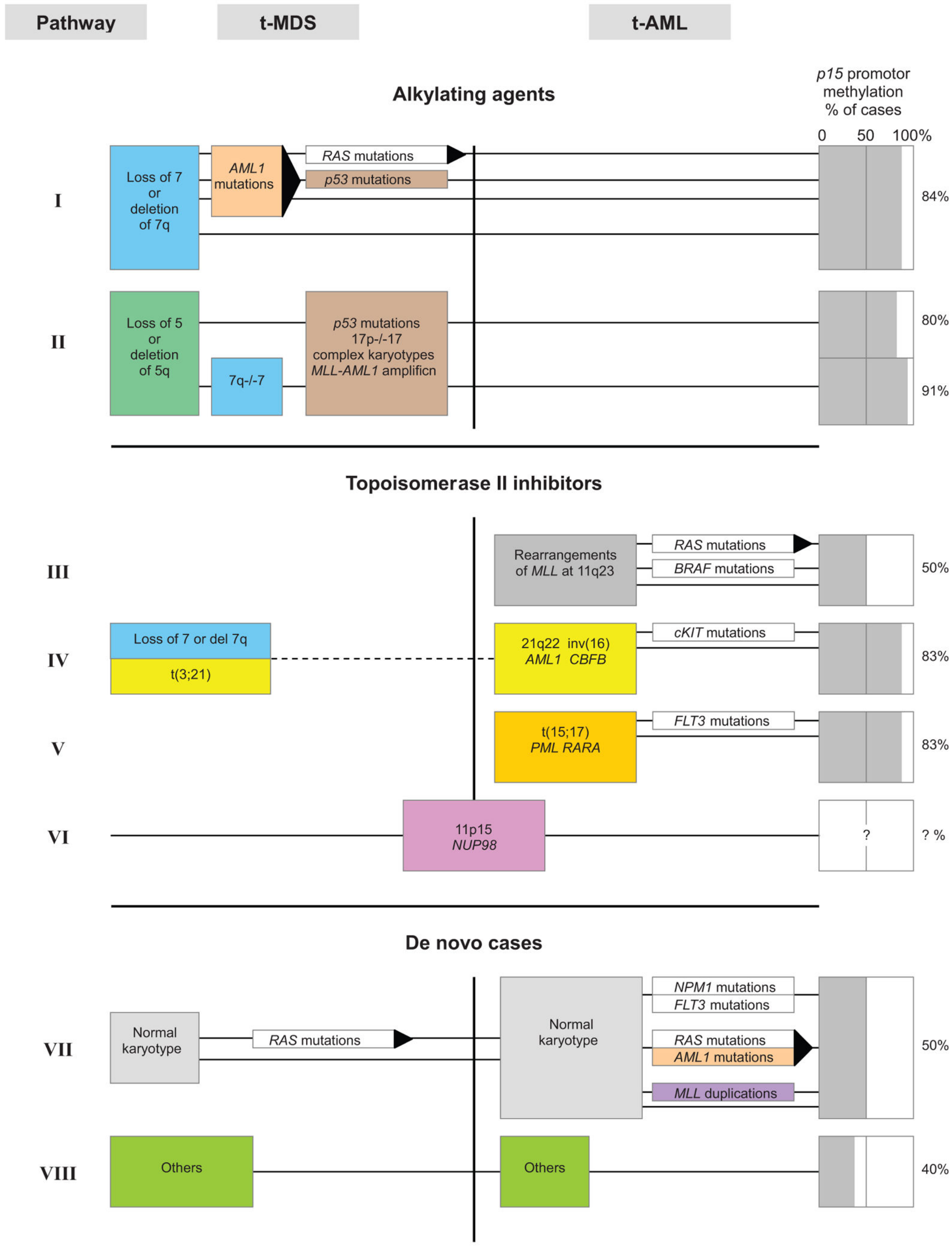

Figure 1.

Genetic pathways to myeloid leukemia (adapted from Reference 76).

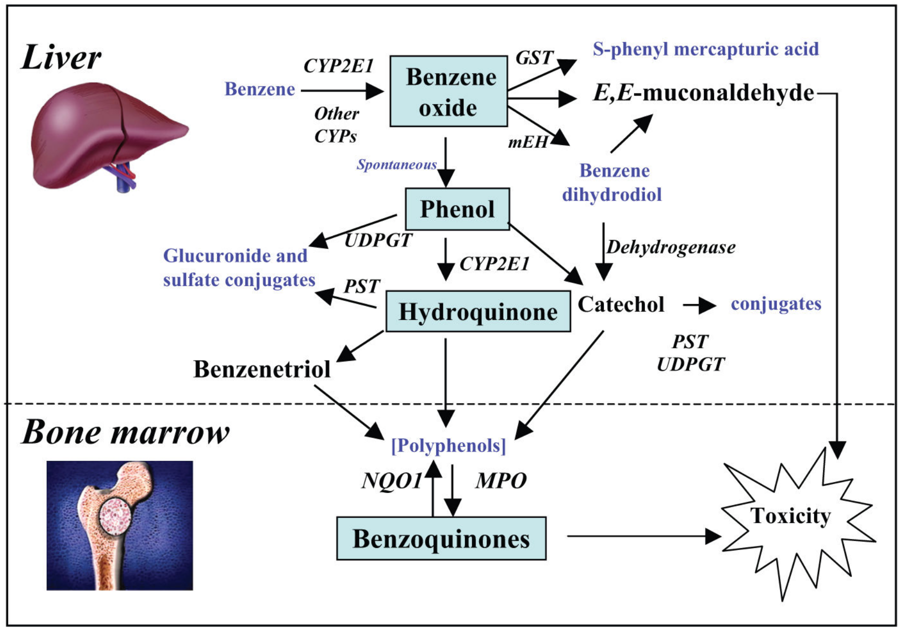

Figure 2.

Simplified metabolic scheme for benzene showing major pathways and metabolizing enzymes leading to toxicity. CYP2E1, cytochrome P450 2E1; GST, glutathione-*S*-transferase; NQO1, NAD(P)H:quinone oxidoreductase 1; MPO, myeloperoxidase; UDPGT, uridine diphosphate glucuronyl transferase; PST, phenol sulfotransferase; mEH, microsomal epoxide hydrolase.

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Table 1

Current issues in the risk assessment of benzene

Is it only acute myeloid leukemia that is produced by benzene?
What is the mechanism(s) of benzene carcinogenicity?
Are there susceptible subpopulations?
What is the dose-response curve? Is it linear, and is there a functional threshold?

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Systems biology of human benzene exposure

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Abstract

Toxicogenomic studies, including genome-wide analyses of susceptibility genes (genomics), gene expression (transcriptomics), protein expression (proteomics), and epigenetic modifications (epigenomics), of human populations exposed to benzene are crucial to understanding gene-environment interactions, providing the ability to develop biomarkers of exposure, early effect and susceptibility. Comprehensive analysis of these toxicogenomic and epigenomic profiles by bioinformatics in the context of phenotypic endpoints, comprises systems biology, which has the potential to comprehensively define the mechanisms by which benzene causes leukemia. We have applied this approach to a molecular epidemiology study of workers exposed to benzene. Hematotoxicity, a significant decrease in almost all blood cell counts, was identified as a phenotypic effect of benzene that occurred even below 1ppm benzene exposure. We found a significant decrease in the formation of progenitor colonies arising from bone marrow stem cells with increasing benzene exposure, showing that progenitor cells are more sensitive to the effects of benzene than mature blood cells, likely leading to the observed hematotoxicity. Analysis of transcriptomics by microarray in the peripheral blood mononuclear cells of exposed workers, identified genes and pathways (apoptosis, immune response, and inflammatory response) altered at high (>10ppm) and low (<1ppm) benzene levels. Serum proteomics by SELDI-TOF-MS revealed proteins consistently down-regulated in exposed workers. Preliminary epigenomics data showed effects of benzene on the DNA methylation of specific genes. Genomic screens for candidate genes involved in susceptibility to benzene toxicity are being undertaken in yeast, with subsequent confirmation by RNAi in human cells, to expand upon the findings from candidate gene analyses. Data on these and future biomarkers will be used to populate a large toxicogenomics database, to which we will apply bioinformatic approaches to understand the interactions among benzene toxicity, susceptibility genes, mRNA, and DNA methylation through a systems biology approach.

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Keywords

benzene; toxicogenomics; epigenetics; systems biology; hematotoxicity; human

Introduction to Systems Biology

Systems biology is a recent and evolving interdisciplinary field that focuses on the systematic study of complex interactions in biological systems [1,2]. Systems biology employs a holistic approach to study all components and interactions in the network of DNA (genes), RNA, proteins and biochemical reactions within a cell or organism. This new field utilizes powerful tools that include toxicogenomics, epigenomics, bioinformatics, and phenomics, classical toxicological or phenotypic endpoints (Figure 1).

Toxicogenomics combines toxicology with molecular profiling technologies, including genomics (DNA), transcriptomics (mRNA), proteomics (proteins) and metabolomics (chemical metabolites) to elucidate molecular mechanisms involved in chemically-induced toxicity. Chemically-induced alterations in the transcriptome, proteome, and metabolome are analyzed in the context of the stable, inherited genome, which is assessed by genomics. Toxicogenomic studies of human populations are crucial to understanding gene-environment interactions, and can provide the ability to develop novel biomarkers of exposure (exposome), early effect (responsome), and susceptibility (genome) [3–5]. Epigenomics is the study of epigenetic elements, including DNA methylation (methylomics), non-coding microRNA (miRNAomics) along with small interfering RNA (siRNA) and short hairpin RNA (shRNA) for RNA interference (RNAi), and histone modification. Epigenetic modifications play an essential role in regulating gene expression and biological and molecular functions in living cells, without altering the genome.

Another tool central to systems biology is bioinformatics, the application of computational information technology to the field of molecular biology to understand how cells and cell systems work [6,7]. Bioinformatics facilitates the analysis of complex biological data (toxicogenomic and epigenomic endpoints) and applies knowledge from annotated functions, pathways and networks to describe normal and perturbed biological states, also known as phenomics, the study of outcomes (phenotypic endpoints). Together, these omic technologies can each provide a “molecular signature” or “fingerprint” of chemical exposure, early effect or genetic susceptibility, which may enhance our understanding of gene-environment interactions. Thus, this holistic approach known as systems biology has the potential to comprehensively define the mechanisms contributing to disease. The purpose of this review paper is to describe how and why it is important to apply the “Systems Biology” approach to benzene mechanistic studies and future directions.

Application of Systems Biology in Studies of Benzene Toxicity

Benzene, a ubiquitous chemical, is an established cause of acute myeloid leukemia (AML), myelodysplastic syndromes (MDS), and probably lymphocytic leukemias and non-Hodgkin lymphoma (NHL) in humans [8–11]. Benzene-induced toxicity in blood-forming systems has been known for more than a century [12]. In 1982, the International Agency for Research on Cancer (IARC) stated, “*There is sufficient evidence that benzene is carcinogenic to man*” [13], and when a new IARC classification system was established in 1987, benzene was immediately placed in the Group 1 human carcinogen category [14].

Potential mechanisms of benzene toxicity have been investigated primarily in the following areas [15]: 1) benzene metabolism in the liver (CYP2E1, etc.) and transportation to the bone marrow for secondary metabolism (MPO, NQO1) [16,17]; 2) oxidative stress from reactive oxygen species generated by redox cycling [18,19]; 3) chromosome alterations including translocations, deletions, and aneuploidy [12]; 4) protein damage to tubulin, histone proteins, topoisomerase II, etc. [15]; and 5) immune system dysfunction (TNF-α, INF-γ, AhR, etc.) [20–22]. Benzene induces chromosomal alterations similar to those found in therapy-related MDS and AML (t-MDS/AML), and in *de novo* leukemia [23]. Distinct chromosome effects arise following exposure to alkylating agents (5q-/-5 or 7q-/-7 and associated genetic abnormalities) and topoisomerase II inhibitors (recurrent balanced translocations or inversions) used in chemotherapy treatment. Exposure to benzene or its metabolites has been associated with loss and long (q) arm deletion of chromosomes 5 and 7 [24] and translocations involving t(21q) [25,26], further suggesting that benzene induces leukemia through multiple different mechanisms.

Studies to date have provided evidence for multiple potential mechanisms using approaches that rely on limited research tools that analyze only one or a few, *a priori* selected genes, pathways or metabolites at a time. A systems biology approach is necessary to interrogate all potential mechanisms by which benzene exposure contributes to disease, through the application of unbiased omic-based technologies in an integrated manner. Since the last international benzene conference at Munich in 2004, we have adopted such an approach to understand the mechanisms underlying human benzene toxicity. This review summarizes our findings published over the last 5 years and preliminary data from recent pilot studies (Table 1). It also provides an overview of our current understanding of benzene-induced hematotoxicity and suggestions for further research.

We describe the studies in the context of systems biology as defined in Figure 1. First, we discuss hematotoxicity as a phenotypic outcome of benzene exposure, with implications for adverse future health effects. We then discuss findings from two toxicogenomic studies, transcriptomics and proteomics, followed by preliminary epigenomics data. As these toxicogemomic and epigenomic responses to exposure are likely influenced by susceptibility, next we describe how we investigated human susceptibility genes using a yeast genomic screening approach with validation of homologous human genes in human cells. We also describe genotyping studies of candidate genes in human exposed populations. Finally, we discuss how the current and future omic datasets could be integrated, using sophisticated bioinformatics approaches in progress, into one consolidated model of the perturbations effected by benzene. This could identify robust biomarkers and help to clarify the molecular and cellular networks impacted by benzene, yielding a more comprehensive understanding of the mechanistic effects of benzene.

Hematotoxicity as a Phenotypic Outcome of Benzene Exposure

Although benzene was known to have toxic effects on the hematopoietic system (hematotoxicity) at high, occupational doses for over a century [12], the degree of hematotoxicity at low levels of exposure was largely unknown. Recently, a study of 250 workers exposed to varying levels of benzene and 140 unexposed controls in Tianjin, China, during which benzene and other chemical exposure levels were monitored repeatedly for up to 12 months, was conducted. Air, urine and blood samples were collected and complete blood counts (CBC) analyzed [27]. In comparison with the non-exposed controls (n=140), a significant decrease was observed in almost all blood cell counts, such as white blood cells (WBC), granulocytes, lymphocytes, platelets etc, in workers exposed to benzene (n=250), even at exposures below 1 ppm (n=109), the current occupational standard in the U.S. Additionally, lymphocyte subset analysis showed significant, dose-dependent, decreases in $CD4^+$-T cells, $CD4^+/CD8^+$ ratio, and B cells at < 1 ppm benzene exposures. These findings, based on the differentiated blood cell counts, provide evidence of bone marrow toxicity in workers exposed to benzene at or below 1 ppm [27].

Because all types of WBC counts were suppressed, it was suspected that the number or functionality of hematopoietic stem and/or progenitor cells generated in the bone marrow had been reduced by benzene. To test this hypothesis, we cultured the progenitor cells circulating in peripheral blood and examined the effects of benzene on different types of progenitor cell colony formation (CFU-GM, BFU-E, CFU-GEMM). The results showed highly significant dose-dependent decreases in colony formation from all three types of progenitor cells, especially when compared to the corresponding decreased levels of differentiated WBC and granulocytes [27]. This suggests that early myeloid progenitor cells are more sensitive than mature cells to the effects of benzene, and clarifies the role of benzene in reduced blood cell counts.

Overall, these hematologic effects could reflect events in the bone marrow that may be associated with adverse health effects in the future [28]. Having established that hematotoxicity, specifically effects myeloid progenitor cells, as a phenotypic anchor of benzene toxicity, we began to examine the molecular mechanisms underlying these effects, through the comprehensive systems biology approach proposed above.

Gene Expression Profiling by Transcriptomics

Transcriptomic studies are useful in determining the impact of environmental or occupational exposure to chemicals on the transcriptome, the set of all mRNA transcripts expressed within a cell. To better understand the risks of benzene in humans, the peripheral blood mononuclear cell (PBMC) transcriptomes from occupationally exposed workers in China were examined by microarray (Affymetrix). Analysis of six exposed-control pairs revealed differential expression in 29 genes in the exposed individuals, compared to the controls. Four genes, *CXCL16*, *ZNF331*, *JUN*, and *PF4*, were shown to be potential biomarkers of early response to benzene exposure as they were confirmed by quantitative-polymerase chain reaction (*q*-PCR) [29].

A later study of 8 exposed-control pairs confirmed these results, using 2 different microarray platforms (Affymetrix & Illumina) to identify global gene expression changes. The differential expression of 2692 genes and 1828 genes was found by Affymetrix and Illumina, respectively, and the 4 genes, *CXCL16*, *ZNF331*, *JUN*, and *PF4*, were among the most significantly altered, validating the findings from the earlier Forrest *et al.* study. This study additionally identified biological pathways that were associated with high benzene exposure, including genes involved in apoptosis and lipid metabolism. This study used a two-platform approach that identified robust changes in the PBMC transcriptome of benzene-exposed individuals [30].

The effects of exposure to high levels of benzene are well documented compared to low-level exposure, the latter being more challenging due to confounders. More recently, we have shown, in an expanded study of 125 factory workers, that low-dose benzene exposure (<1 ppm, n=59) can also cause widespread subtle, yet highly significant, perturbation of gene expression in PBMC. This study was designed with sufficient power to detect robust expression changes, accounting for technical variability as well as age, gender and other confounders. Our microarray analysis revealed significant dysregulation of more than 2500 genes by low dose benzene exposure, over 70 of which had differential expression ratios exceeding 1.5. Several of the detected genes exhibited significantly altered expression only at low levels of benzene exposure, and are thus potential biomarkers of low-dose exposure. The findings show that even low levels of occupational benzene exposure cause a significant perturbation of expression of genes involved in immune and inflammatory responses [31].

Proteomic Biomarkers of Benzene

Another important toxicogenomic tool, proteomics, can be used to measure alterations in the proteome (e.g. protein levels, posttranslational modifications) associated with exogenous chemical exposure. Effects on the blood proteome may reflect effects at distal body sites. As with transcriptomics, proteomics can be used to discover biomarkers of exposure and early effect, as well as increase our understanding of the mechanisms underlying disease.

We examined the impact of benzene on the human serum proteome in exposed factory workers and controls to obtain insight into the mechanism of action of benzene [32]. Serum samples were fractionated and proteins were bound to surface-enhanced laser desorption/ionization time-of-flight mass spectrometry (SELDI-TOF-MS) chips. Three proteins (4.1, 7.7, and 9.3 kDa) were consistently down-regulated in the exposed (n=10) compared to the control (n=10) individuals in two separate sets of study subjects (40 subjects total). All proteins were highly inversely correlated with individual estimates of benzene exposure. The 7.7- and 9.3-kDa proteins were identified as platelet factor 4 (PF4), also down-regulated at the gene expression level described above, and connective tissue activating peptide CTAP-III, respectively, both platelet-derived CXC chemokines. Thus, reduced protein levels of PF4 or CTAP-III are potential biomarkers of the early biologic effects of benzene. Future proteomic studies could identify further biomarkers of benzene exposure, and elucidate the mechanisms underlying benzene toxicity and associated disease.

Epigenomics in Pilot Benzene Studies

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Gene expression and ultimately protein expression is regulated at the epigenetic level by processes including DNA methylation, histone modification and miRNA (microRNA) expression. The epigenome, while stable through cell division and even in some cases reproduction, can be reprogrammed by nutritional, chemical, and physical factors [33]. Thus, the study of toxic effects on the epigenome is crucial to understanding mechanisms of action. Further, epigenetic modifications represent more stable biomarkers and fingerprints of exposure than altered gene or protein expression [34]. While epigenetics refers to the study of individual or specific gene activity, epigenomics focuses on global analyses of epigenetic changes across the entire genome. A recent study reported that hyper-methylation in *p15* and genome-wide hypo-methylation assessed by LINE-1 (Long Interspersed Nuclear Element-1) were associated with very low benzene exposures (~22 ppb), in healthy subjects including gas station attendants and traffic police officers, although the corresponding effects on methylation were very low [35]. To determine whether epigenetics plays a role in the hematotoxicity of benzene, we have recently performed several pilot epigenomic studies including DNA methylation and miRNA expression arrays in the blood of workers occupationally exposed to benzene. The results described below are very preliminary, and serve mainly as a proof of principle of this epigenomic approach.

DNA Methylation Array

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A DNA methylation array (GoldenGate Methylation Cancer Panel I, Illumina) was applied to determine the methylation status of the CpG islands of >800 genes in DNA isolated from the buffy coats of 6 benzene-exposed workers (2 male, 4 female) and 4 unexposed controls (2 male, 2 female). As expected gender-specific methylation patterns were seen for numerous genes including *ELK1*, *EFNB1*, *MYCL2*, *VBP1*, *DNASE1L1*, *DKC1* and *CDM*. This pilot study also found altered methylation induced by benzene at many CpG sites. Decreased methylation of *RUNX3 (AML2*), a gene whose altered expression has been associated with myeloproliferative disorders [36] occurred at three different CpG sites (Figure 2A). Increased methylation of *MSH3*, a critical gene in the maintenance of genome integrity, and *Sema3C*, a secreted guidance protein implicated in tumorigenesis [37], was also observed (Figure 2A).

There appeared to be a gender-specific effect of benzene on the methylation of several genes, although the sample number was small.

We examined the methylation status of the same panel of genes in DNA from TK6 cells treated *in vitro* with hydroquinone (HQ) at 10, 15, and 20 μM, for 48 h. The most significantly hyper-methylated gene was *IL12* (Figure 2B), whose expression has previously been shown to be down-regulated by HQ in mouse macrophages [38]. *RUNX1T1* (runt-related transcription factor 1, also known as *ETO*), was hypo-methylated by HQ *in vitro* (Figure 2B). The protein encoded by this gene is commonly fused to *RUNX1* (*AML1*) in the t(8;21)(q22;q22) translocation, which is one of the most frequent karyotypic abnormalities in AML [39]. *MAGEA1* (melanoma antigen family A, 1), also known as *MAGE-1*, was also hypo-methylated by HQ in the present study (data not shown). Interestingly, this gene was reported recently to be hypo-methylated weakly in subjects exposed to increasing airborne benzene levels [35].

miRNA Microarrays

Human miRNA microarrays (Agilent), containing probes for 470 human and 64 human viral miRNAs, were used to analyze the differential expression of miRNAs in the total PBMC RNA from 7 exposed-control matched pairs, in a pilot study. Preliminary analysis showed upregulation of 4 miRNAs (miR-154*; miR-487a; miR-493-3p; and, miR-668) by benzene exposure. Upregulation of miR-154* expression, possibly through a change in the methylation and acetylation status of the 14q32 region, has been reported in patients with acute promyelocytic leukemia bearing the t(15;17) translocation [40].

While both of these studies are relatively small, and the data are very preliminary, the findings suggest that further studies to examine the epigenetic effects of benzene on gene-specific promoter methylation and miRNA expression, in a larger study of exposed workers, are warranted.

Identification of Susceptibility Genes by Genomics

Genome-wide association studies (GWAS) are a well-established means to examine the association of genetic susceptibility, i.e. single-nucleotide polymorphisms (SNPs), with disease. Such studies have been performed for two diseases related to benzene toxicity, NHL [41] and t-AML [42]. A very small number of pharmacogenomic GWAS have been reported [43], while to our knowledge, no GWAS on occupational or environmental exposure and associated toxic outcomes have been performed. Given the relatively small effects observed in disease GWAS, such studies are very expensive to undertake for less well-defined, pre-disease, toxicological outcomes. We adopted an alternative genomic approach to discover human susceptibility genes, the aims of which are: 1) to discover/screen susceptible genes in yeast by genomics; 2) to select human homolog genes using bioinformatics; 3) to test identified gene (e.g. *WRN* etc) functions by RNAi in human cells; 4) to identify human susceptible genes by SNP genotyping in population studies.

Genomic screening in yeast

In order to reduce the complexity and expense of analyzing the human genome, while retaining the ability to systematically screen a genome highly relevant to human biology, we chose a screening system in yeast (*Saccharomyces cerevisiae*). As we reported recently, this genomics approach has been employed to discover novel biomarkers of benzene toxicity in yeast cells exposed to the major active metabolites of benzene, hydroquinone (HQ), catechol (CAT), and 1,2,4-benzenetriol (BT) [44]. Using a collection of yeast strains representing a complete set of non-essential gene deletions, genetically tagged so that individual strains can be identified in competitive growth experiments, fitness assays were performed to identify mutant strains whose fitness is significantly altered following treatment with benzene metabolites. A comparison of the global deletome profiles of the metabolites revealed that deletion of certain genes rendered yeast cells sensitive to all three compounds. Several of the genes identified in the yeast studies have human orthologs with conserved biological function, supporting the notion that the mechanisms of toxicity identified in yeast are relevant to human disease.

Selection of homologous human genes by bioinformatics

To select and prioritize likely human candidate genes from complex yeast genomic data, we applied bioinformatic analyses using specific computational programs including “clustering” by HOPACH (Hierarchical Ordered Partitioning And Collapsing Hybrid) algorithm methods [45], pathway analysis using Cytoscape with the BiNGO Gene Ontology identification plugin [46,47] and a comparative genomics approach. It is suggested that toxicants of similar mechanisms of action most likely have similar profiles of genes required for tolerance. We thus employed a variety of computational “clustering” methods to analyze the sensitivity and resistance data and to identify yeast strains most sensitive to each of the benzene metabolites tested as well as the genes specifically involved in sensitivity to each toxicant. We also set out to identify biologically significant patterns and features involved in toxicant response between metabolites. Similarly, a comparative genomics approach has been applied to identify functional orthologs and pathways between evolutionarily distant organisms. This approach assists in the identification of yeast and subsequently human candidate genes and pathways for further evaluation in the mammalian cell culture system.

Functional testing of candidate genes by RNAi in human cells

The roles of the human homologs of selected genes in benzene toxicity have been examined through mechanistic studies in human cell lines. SNPs in WRN, an important protein that plays a role in the maintenance of genomic stability, have been associated with an increased risk for some cancers and benzene hematotoxicity. We knocked down WRN protein using siRNA in HeLa cells and examined sensitivity to toxicity following exposure to the benzene metabolite, HQ [48]. Depletion of WRN led to decreased cell proliferation and increased HQ cytotoxicity, evident by increased necrosis. Additionally, these cells displayed increased DNA double-strand breaks (DSB), a potential biomarker of benzene hematotoxicity. Together, the results showed that WRN plays an important role in resistance to benzene toxicity in HeLa, and perhaps other cells.

More recently, we used shRNA to silence WRN in the human HL60 acute promyelocytic cell line [49]. Upon exposure to HQ, HL60 cell growth rates were accelerated, and DNA breaks and sensitivity to HQ-induced cytotoxicity and genotoxicity were increased, similar to the findings in HeLa cells. Loss of WRN also resulted in higher levels of early apoptosis. An accumulation of such genetic lesions can lead to the development of AML. The data from this study provides mechanistic support for the link between WRN and benzene-induced hematotoxicity, and possibly even benzene-induced leukemia. Studies are underway to confirm the role of other susceptibility genes in benzene toxicity.

Genotyping results in human population studies

In addition to the yeast genomic studies, large-scale human population genotyping studies have also been conducted. In collaboration between the National Cancer Institute and China CDC, such a study analyzed 1,395 SNPs in 411 potential carcinogenesis-related genes using an Illumina GoldenGate assay in 250 benzene-exposed workers and 140 unexposed controls in China [50]. One or more SNPs in five genes (*WRN*, *BLM*, *TP53*, *RAD51*, and *WDR79*) which play critical roles in DNA repair and genomic maintenance, were associated with highly significant 10–20% reductions (p values ranged from 0.0011 to 0.0002) in the WBC count among benzene-exposed workers but not controls, with evidence for gene-environment interactions for SNPs in *BLM*, *WRN* and *RAD51*. Earlier candidate gene studies identified a small number of SNPs in genes involved in benzene metabolism, cytokine and cellular adhesion molecules [51], and DNA DBS repair [52], which appear to confer susceptibility to benzene hematotoxicity. These studies were the first to provide evidence that genetic polymorphisms in certain genomic stability maintenance genes, like *WRN* [53], impact benzene-induced phenotypic outcomes such as hematotoxicity.

The human population studies confirm a critical role for DNA repair and genomic maintenance in susceptibility, and further support these effects as benzene-induced phenotypic outcomes. In addition, genetic variants in metabolizing enzymes responsible for activating and detoxifying benzene, in particular *MPO* and *NQO1*, have also been linked to increased susceptibility to benzene hematotoxicity [27]. Together, these genomic and genotyping studies provide important information regarding benzene toxicity and disease pathways.

Systems Biology Approach in Current and Future Studies

From our omic studies to date, benzene appears to cause hematotoxicity through multiple mechanisms that may involve alterations in the expression of multiple genes and proteins, DNA methylation patterns and miRNA profiles even at low-doses. Transcriptomics has identified many genes, functions and pathways altered by benzene, offering insight into mechanisms and providing potential signatures of benzene exposure, and/or early effect. These data could be integrated with information on susceptibility genes to further understand gene-environment interactions and perhaps to identify the most susceptible individuals. We will expand our proteomic studies by conducting further analyses on different protein fractions and affinity chips to identify more altered proteins. As discussed earlier, expanded DNA methylation and miRNA profiling studies are necessary in larger populations of exposed individuals. All studies will be performed at a range of benzene exposures to examine dose-response effects. Several of these individual omic datasets are large, measuring e.g. the expression level of ~24,000 genes or the methylation status of >14,000 genes at multiple CpG islands and bioinformatic methods to analyze them continue to be refined.

Each individual omic dataset is anticipated to provide information on the effects of benzene, and potentially identify biomarkers of exposure and early effect. Through our systems biology approach, we will use sophisticated bioinformatics to integrate individual datasets into one consolidated model of the perturbations effected by benzene. From this model we will make inferences, specifically, we will aim to understand the interactions between benzene toxicity, SNPs, mRNA, miRNA, protein, and DNA methylation. This could identify robust biomarkers and help to clarify the molecular and cellular networks impacted by benzene, yielding a more comprehensive understanding of the mechanistic effects of benzene. While all the toxicogenomic endpoints have the potential to yield biomarkers, some endpoints such as DNA methylation and gene expression may reflect more upstream mechanistic effects while others such as proteomics may reflect more downstream, phenotypic effects, and might be more informative of actual molecular and cellular processes affected. Multiple regulatory mechanisms probably determine the phenotypic outcome (e.g. a gene could be up-regulated by DNA methylation and down-regulated by miRNA). The systems biology approach will require a high level of computing power and will capitalize on the ever-expanding knowledge of biological pathways and networks. In order to realize this approach, future studies need to be designed with sufficient power to robustly detect effects of benzene and to allow for analysis of the interrelationship among the different endpoints. With respect to sample processing, the ideal scenario is to analyze DNA, RNA and protein from the same cell population but this remains challenging with existing protocols and sample availability.

The findings from the systems biology study of benzene could also contribute more generally to the field of risk assessment. Comparison of the toxicogenomic, epigenomic and genomic profiles associated with different exposures, e.g. suspected leukemogens or carcinogens, and diseases (NHL, AML), may help to clarify the connection between chemicals, genes/proteins, pathways/networks, and disease. Initiatives such as the Comparative Toxicogenomics Database [54] and Chemical Effects in Biological Systems [55] have been developed towards this goal. It has been also discussed how omic data/measurements obtained through a systems biology approach can be applied to identify all potential mechanisms of action and serve as an information base for subsequent evaluation of these mechanisms when conducting risk assessment [56].

In conclusion, the systems biology approach described here should help inform the mechanisms underlying benzene hematoxicity and associated disease, and identify robust biomarkers of exposure, early effect, susceptibility and disease development.

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Abbreviations

AML	Acute Myeloid Leukemia
BFU-E	Burst Forming Unit – Erythroid
BiNGO	Biological Network Gene Ontology
BT	1,2,4-Benzenetriol
CAT	Catechol
CBC	Complete Blood Counts
CFU-GEMM	Colony Forming Unit – Granulocyte, Erythrocyte, Monocyte, Megakaryocyte
CFU-GM	Colony Forming Unit – Granulocyte, Monocyte
CYP2E1	Cytochrome P450 2E1
GWAS	Genome-Wide Association Studies
HQ	Hydroquinone
IARC	International Agency for Research on Cancer
MDS	Myelodysplastic Syndromes
miRNA	microRNA
MPO	Myeloperoxidase
NHL	Non-Hodgkin Lymphoma
NQO1	NAD(P): HQuinone Oxidoreductase 1
PBMC	Peripheral Blood Mononuclear Cells

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PF4	Platelet Factor 4
q-PCR	Quantitative-Polymerase Chain Reaction
RNAi	RNA Interference
SELDI-TOF-MS	Surface-Enhanced Laser Desorption/Ionization Time-Of-Flight Mass Spectrometry
shRNA	short hairpin RNA
siRNA	small interfering RNA
SNPs	Single-Nucleotide Polymorphism
t-MDS/AML	therapy-related MDS and AML
WBC	White Blood Cells

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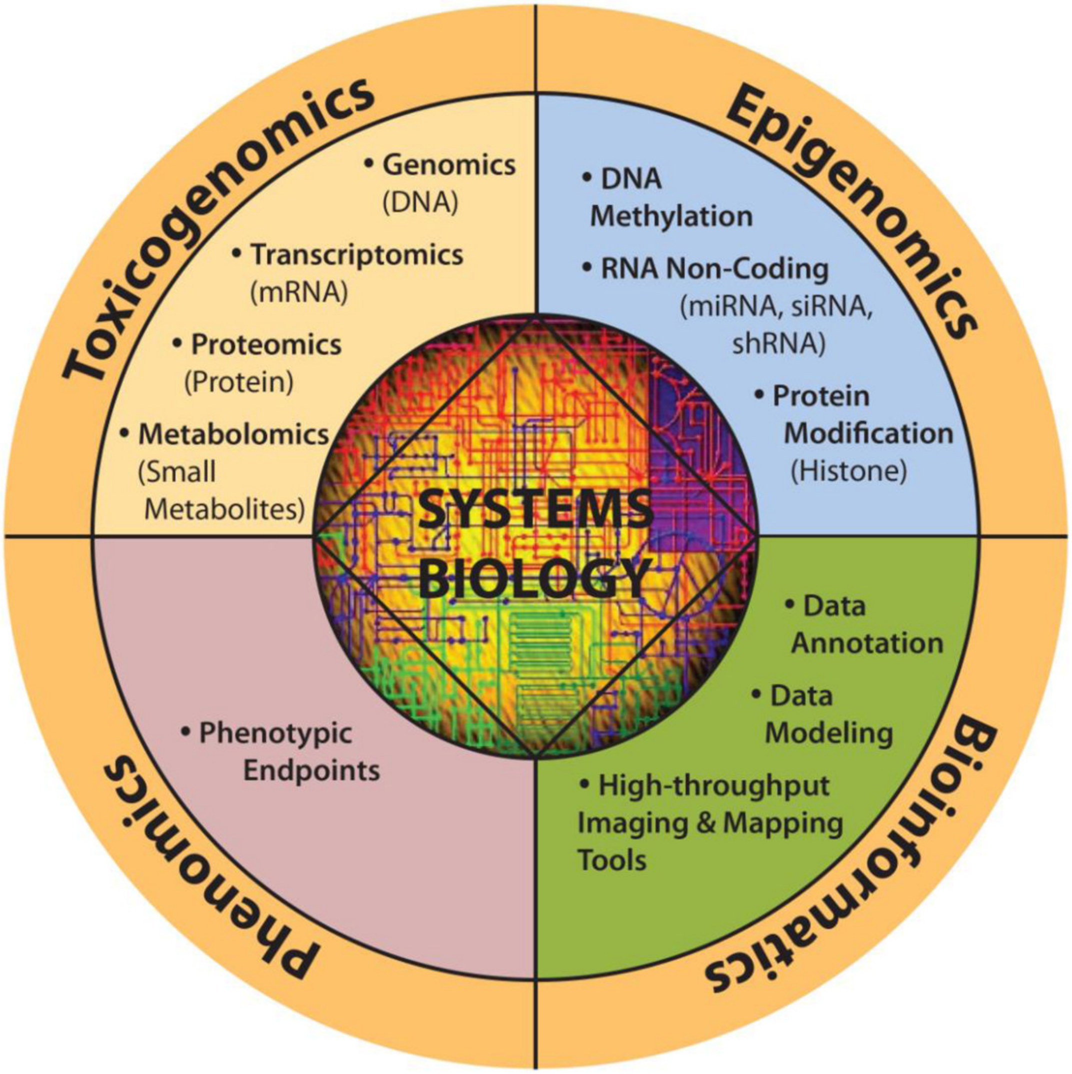

Figure 1. Overview of systems biology and its components

(Center of image, Wired Systems Biology, adapted from *Chemical & Engineering News*, 81 (20), 2003)

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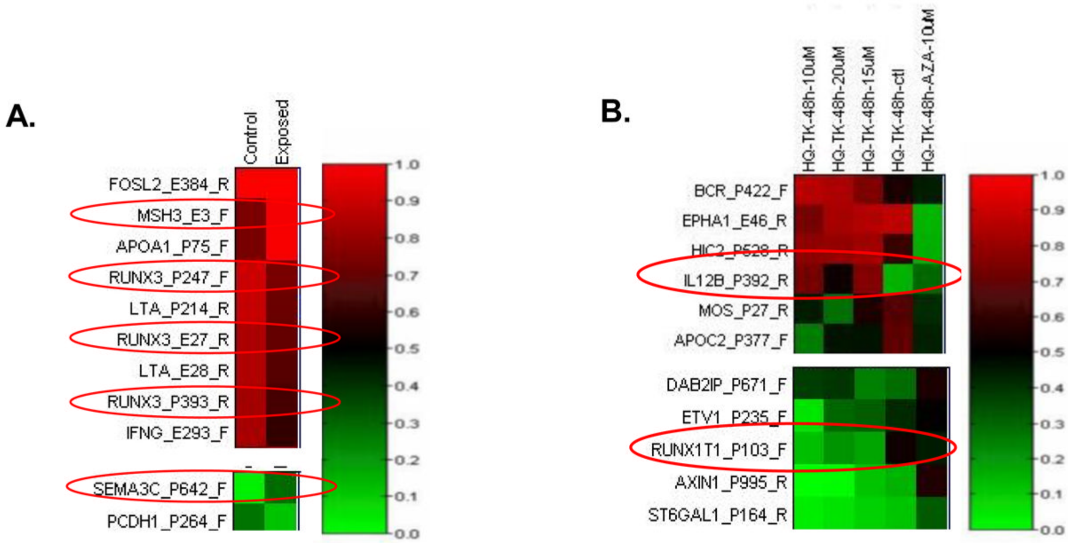

Figure 2. Heatmap of methylation profiles of (A) workers exposed to benzene and controls, and (B) TK6 cells exposed to hydroquinone (HQ)

A. A total of 6 benzene exposed subjects and 4 controls were analyzed. **B:** Human TK 6 cells were treated with HQ at 0, 10, 15 and 20 μM for 48 hrs. 5-azacytidine, a demethylating agent, was included as a positive control. Examples of genes with methylation levels significantly altered by benzene or HQ are shown. Values range from 1.0 fully methylated (Red) to 0 fully unmethylated (Green)

Table 1

Summary of benzene studies applying systems biology approach

Systems Biology	Study Method	Study Size: Exposed	Study Size: Controls	Benzene Exposure (ppm)	Major Findings	Reference
Phenomics						
Hematotoxicity	CBC	250	140	<1, <10, >10	Decrease in all blood cell counts	Lan et al. 2004 [27]
	Colony	24	29	<10, >10	Decrease in colony formation	Lan et al. 2004 [27]
Toxicogenomics						
Transcriptomics	Affymetrix	6	6	≥10	29 genes differentially expressed	Forrest et al. 2005 [29]
	& *q*-PCR	13	15	≥10	Validated 6 of 29 genes	
	Affymetrix & Illumina	8	8		Confirms Forrest findings	McHale et al. 2009 [30]
	Illumina	83	42	<1, <10, >10	Different gene pathways identified at low and high exposures	McHale et al. 2008 [31]
Proteomics	SELDI-TOF	20	20	31.3 & 37.9 (mean)	Identified two down-regulated proteins as PF4 and CTAP-III	Vermelen et al. 2005 [32]
		(2 sets of 10)				
Epigenomics						
DNA Methylation	Illumina (GoldenGate)	6	4	8.9±9.1 (mean±sd)	Results preliminary (MSH3, RUNX3)	Pilot Study
		Human TK6 Cells		HQ (0, 10, 15, 20 μM)	Results preliminary (RUNX1, IL12)	
miRNA	Agilent	7	7	<1 ppm	Results preliminary (4 miRNAs)	Pilot Study
Genomics						
	PDA in Yeast	~4600 homozygous deletion strains		HQ, CAT, BT	Oxidative stress response	North 2009 [44]
	RNAi	WRN		HQ	DNA repair HR pathway	Galvan 2008, Ren 2009 [48,49]
Genotyping						
	Illumina (GoldenGate)	250	140	0, < 1, < 10, > 10	Identified *MPO*, *NQO1*, and a group of DNA repair & cytokine genes	Lan 2004, 2005, 2009, Shen 2006 [50–52]

On Jul 3, 2015, at 12:03 PM, Paul Seamans <jacknife@goldenwest.net> wrote:

> We have talked some about PUC permit Condition #40 that addresses replacing PVC piping with pipe that is resistant to BTEX chemicals. Condition #40 says that it will be replaced for a distance within 500 feet of the water line.
> A couple of years ago my rural water system provider, West River/Lyman Jones, a subsidiary of the Mni Wiconi, contracted with a company to come in and install sleeves that run under the Keystone XL. These sleeves are a plastic pipe of a diameter of 6-10 inches. The idea is to run the water lines through these sleeves and with the sleeve you can run water lines through these sleeves without having to dig around the KXL pipeline. I have one of these sleeves just adjacent to my pasture that the KXL crosses. The area that the contractor dug up to install these sleeves is only 40 feet wide. They evidently have not replaced the water line with BTEX resistant pipe or the disturbed area would have been 1000 feet (500 feet on each side of the KXL pipeline), not only 40 feet.
> Maybe this is immaterial at this point but TransCanada so far has not lived up to Condition #40. Maybe TC needs to explain to the PUC why this has not been done.

> Paul Seamans