

# Minnesota House of Representatives



# Minnesota State Senate

July 10, 2017

To: Minnesota Department of Commerce

Re: PUC Docket Numbers CN-14-916 and PPL-15-137

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The following comments are submitted jointly by undersigned members of the Minnesota House of Representatives and Minnesota State Senate.

We respectfully request that the Department of Commerce make significant revisions to the Line 3 Draft Environmental Impact Statement (DEIS). We find the DEIS to be flawed in several areas.

The following deficiencies in the DEIS should be addressed prior to issuance of the final document. These include:

- Failure to appropriately quantify oil spill exposure to drinking water sources
- Tribal considerations and Line 3 abandonment
- Stronger emphasis on climate considerations and impacts
- A more comprehensive analysis of a no-build alternative

## **I: Failure to appropriately quantify oil spill exposure**

The DEIS does not analyze the potential harm of a spill to the million plus Minnesotans who drink Mississippi River water.

Be assured that the public interest of Minnesotans who live in St. Cloud, Minneapolis, St. Paul and the many metro communities that drink Mississippi River water is immense.

The existing corridor crosses the Mississippi River near Bemidji, again near Ball Club west of Deer River, then crosses the Prairie River just upstream of its confluence with the Mississippi east of Grand Rapids. The new proposed corridor has a crossing just north of Itasca State Park

(flowing north) at the very beginning of the river and a new crossing further downstream just south of Palisade, MN. Palisade is just NW of McGregor, near the intersection of 169 and 210.

John Stansbury of the University of Nebraska conducted a study of spill scenarios for the Keystone XL pipeline.<sup>1</sup> In public comments (Attachment A) submitted for Enbridge's Line 67 (Alberta Clipper) pipeline expansion project's certificate of need process, engineer Stan Sattinger adapted Stansbury's study to describe a scenario involving a tar sands pipeline spill in the Upper Mississippi River and concluded that there would be elevated levels of benzene (above the Safe Drinking Water Act Max Contaminant Level (MCL)) some 280 miles downstream.<sup>2</sup> Because the Mississippi has many bends and loops, the 280 miles from Grand Rapids reached the St. Cloud water intake but not the intakes for Minneapolis and St. Paul. Since the new corridor at Palisade is south of the old one, the EIS must analyze the potential for benzene to reach Minneapolis and St. Paul intakes.

However, a spill into the Mississippi creates additional problems for those who use the Mississippi as a drinking water source. Since petroleum spill data is outdated and new technology is available, the Minnesota legislature funded and the Governor signed into law an investigation that will reassess the toxicity of petroleum spills.<sup>3</sup> Specifically the investigation will look into "the chemical identity, quantity and toxicity of many chemicals present in petroleum-impacted groundwater and surface water, particularly the chemicals that result as the petroleum degrades over time...(because)...past toxicity assessments of petroleum-impacted surface and groundwater are: 1. Incomplete—because only a small subset of known chemicals have been assessed for toxicity, and 2. Inadequate for identification of many sublethal effects (including those on endocrine, immune and nervous systems)—which are important determinants of organism's survival and population health."<sup>4</sup>

The investigation is being conducted by faculty at the University of St. Thomas with the assistance of the United States Geological Survey "for use by regulatory agencies, such as the MPCA and MDH."<sup>5</sup>

The EIS must either incorporate the data from this investigation or complete its own investigation using the new technology that is available.

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<sup>1</sup> Stansbury, John. *Analysis of Frequency, Magnitude and Consequence of Worst-Case Spills From the Proposed Keystone XL Pipeline*. 2011. <http://engineering.unl.edu/downloads/civil/Worst-case-Keystone-spills-report-dis.pdf>.

<sup>2</sup> Sattinger, Stan. *Information on the risk to drinking water posed by the proposed Phase 2 of Enbridge Energy's Line 67 crude-oil pipeline*. Public Comment. Minnesota Department of Commerce. PUC Docket PI-9/CN-13-153/OAH Docket 8-2500-30952. 2014.

<sup>3</sup> SF 550, 90<sup>th</sup> Legislature, 8 (2017) (enacted).

<sup>4</sup> Martinovic-Weigelt, Dalma. *Reassessing Toxicity of Petroleum Spills with New Technologies*. University of St. Thomas. Legislative-Citizen Commission on Minnesota Resources. May 7, 2016: 2. <http://www.lccmr.leg.mn/proposals/2017/original/048-b.pdf>.

<sup>5</sup> *Ibid.*, 3.

The DEIS addresses the risk to Tulibee Lakes, Lakes of High and Outstanding Biological Significance, Wild Rice Lakes, and Trout Streams.<sup>6</sup> However, the Summary does not address risk to warmwater streams in the state across alternatives. Warmwater streams are also not addressed in the analysis of exposure to High Consequence Areas (HCAs) in Chapter 10 of the DEIS. Many of these stream systems are in very good biological condition, and are of high quality. Furthermore, the MPCA is in the process of implementing a strategy to prioritize high quality and ‘exceptional’ streams and rivers for preservation in their current form, as part of its Tiered Aquatic Life Use Strategy.

The Minnesota Pollution Control Agency has collected abundant datasets documenting the biological quality of warmwater streams and rivers (i.e., not just trout streams) in the region of interest. Warmwater streams and rivers constitute the vast majority of total running waters in the northern part of the state that are crossed by the proposed project alternatives. Thus, the impact of the proposed Line 3 project to these warmwater systems, including to streams and rivers of exceptional quality, must be included in the EIS for Line 3 and all alternatives.

The threat to drinking water and the urgent need to address surface water protection is particularly important given the DEIS's contention that pipeline spill quantity is greater than with rail and truck alternatives. The DEIS states, “the average release of crude oil from a truck incident is 16 barrels (687 gallons) from a train incident, 40 barrels (1688 gallons) and from a pipeline incident, 462 barrels (19,412 gallons).”<sup>7</sup>

The significantly higher risk of a major spill from a pipeline compared to other alternatives is compounded by the proposer's poor response to a tar sands pipeline spill in Kalamazoo, Michigan in 2010, and the pipeline industry's strong position in opposition to 2014 Minnesota state legislation mandating faster spill response.<sup>8</sup> As a result of heavy pipeline industry lobbying, pipeline companies are exempted from requirements that apply to the railroad industry mandating that company officials advise first responders on clean-up protocols within an hour of first responders' confirmation major spill and to provide on-site expertise within three hours of a spill.

## **II: Tribal considerations and Line 3 abandonment**

The DEIS states, "American Indian communities and individuals have unique health issues associated with historical trauma and structural racism. Data from the Minnesota Department of Health indicates that American Indians in Minnesota have greater health disparities and poorer health outcomes compared to other racial or ethnic groups in Minnesota. Tribal impacts are magnified because (1) impacts would be associated with abandonment or removal of the existing

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<sup>6</sup> Minnesota Department of Commerce. Energy Environmental Review and Analysis. *Line 3 Replacement Project Draft Environmental Impact Statement*. Executive Summary. May 15, 2017: ES-14. [https://mn.gov/commerce/energyfacilities/documents/34079/1.DEIS\\_Line\\_3\\_Executive%20Summary.pdf](https://mn.gov/commerce/energyfacilities/documents/34079/1.DEIS_Line_3_Executive%20Summary.pdf). (Hereafter, “*Line 3 Replacement Project Draft Environmental Impact Statement*.”)

<sup>7</sup> Ibid., ES-12.

<sup>8</sup> HF 3134/SF 2796, 88<sup>th</sup> Legislature (2014).

Line 3; and (2) additional impacts would be associated with replacement of Line 3 in a new location."<sup>9</sup>

The concerns regarding abandonment of the existing Line 3 are particularly important to Indigenous Communities. There are no state rules addressing abandonment, and the absence of such regulations demands a very comprehensive accounting of the clean-up costs for the cumulative environmental hazards resulting from the pipeline.

Given the number of spills associated with Line 3, particularly the quantity of oil spilled and leaked since the Line started operation, the EIS must address issues of abandonment and site clean-up. The EIS must also quantify the costs and environmental liability for damages caused by the line, and identify the source of funds for hazardous materials clean-up.

In addition to abandonment, Indigenous communities have identified impacts to wild rice, waterways, and cultural sites. The proposer's preferred route also raises issues related to treaty rights and tribal sovereignty. While the DEIS correctly refers to disparities and historical trauma suffered by indigenous communities, **the document fails to adequately address these issues.** Ignoring or avoiding the key concerns of Indigenous communities will serve to exacerbate the disparities and environmental justice issues that are raised, but not addressed in the DEIS.

### **III: Stronger consideration of climate impacts**

In denying the permit for the Keystone XL pipeline in 2015, President Barack Obama stated, "America is now a global leader when it comes to taking serious action to fight climate change. And frankly approving this project would have undercut that global leadership. And that is the biggest risk we face—not acting."

Similarly, among states, Minnesota has developed strong protocols in state law to address climate change. Transportation fuels account for nearly 30% of total greenhouse gas emissions,<sup>10</sup> and tar sands oil that is proposed for transfer in Line 3 emits 17% more greenhouse gas emissions than other forms of crude.<sup>11</sup> The EIS makes important points regarding tar sands oil and climate change, stating, "the project creates 760,000 barrels per day of new production and consumption of Western Canadian Sedimentary Basin heavy crude, causing GHG emissions from extraction, upgrading, transporting, refining, and consuming 760,000 barrels of WCSB crude oil each day."<sup>12</sup>

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<sup>9</sup> *Line 3 Replacement Project Draft Environmental Impact Statement*, ES-24.

<sup>10</sup> United States Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015*. Executive Summary. April 13, 2017: ES-24. [https://www.epa.gov/sites/production/files/2017-02/documents/2017\\_executive\\_summary.pdf](https://www.epa.gov/sites/production/files/2017-02/documents/2017_executive_summary.pdf).

<sup>11</sup> United States Department of State. Bureau of Oceans and International Environmental and Scientific Affairs. *Final Supplemental Environmental Impact Statement for the Keystone XL Project*. Executive Summary. January 2014: ES-15. <https://2012-keystonepipeline-xl.state.gov/documents/organization/221135.pdf>.

<sup>12</sup> *Line 3 Replacement Project Draft Environmental Impact Statement*, ES-18.

President Obama's actions on Keystone set an important precedent that links denial of a pipeline permit to action curbing climate change. The rationale for such a policy was laid out in the December 2015 Minnesota Environmental Quality Board (EQB) Interagency Report on Pipelines.

As a member agency of the EQB, the Department of Commerce was involved in producing the report and accepting the report's content. With regard to the relationship between climate change and development of new pipelines, the EQB concluded, "Development of infrastructure to support extraction, transportation, refinement, and combustion of oil has the potential to release additional carbon into the atmosphere and may perpetuate a carbon based economic structure that contributes to climate change. Minnesota has a state goal to reduce greenhouse gas emissions 80% below 2005 levels by 2050, building infrastructure for fossil fuels and making capital investments in this infrastructure should take this goal into account."<sup>13</sup>

The writing and production of the DEIS took place prior to President Trump's announcement that the United States will be pulling out of the Paris climate accords, and Governor Dayton's subsequent statement announcing Minnesota's participation in the United States Climate Alliance, a new effort by state and local governments to uphold the Paris agreement and the carbon emission reductions contained in the accord. Governor Dayton stated, "We will show the world what we can achieve by working together to conserve energy, use cleaner and renewable energy, and to leave a livable planet to our children and grandchildren."

The significant increase in global carbon emissions that accrue from the extraction, refining and combustion of tar sands oil transported via Line 3 runs counter to the U.S. Climate Alliance's intention to adhere to the Paris climate accord's greenhouse gas emissions goals.

Minnesota's record of legislation and policy directives on climate and energy are consistent with the Minnesota Environmental Policy Act which states: "In order to carry out the policy set forth in Laws 1973, chapter 412, it is the continuing responsibility of the state government to use all practicable means, consistent with other essential considerations of state policy, to improve and coordinate state plans, functions, programs and resources to the end that the state may: ... (9) practice thrift in the use of energy and maximize the use of energy efficient systems for the utilization of energy, and minimize the environmental impact from energy production and use; ... (12) minimize wasteful and unnecessary depletion of nonrenewable resources."<sup>14</sup>

A revised Line 3 EIS must directly address and refer to state goals and policies regarding climate change and mitigation.

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<sup>13</sup> Minnesota Environmental Quality Board. Interagency Pipeline Coordination Team. *Interagency Report on Oil Pipelines*. December 15, 2015: 49.  
[https://www.eqb.state.mn.us/sites/default/files/documents/Interagency%20Report%20on%20Oil%20Pipelines4\\_0.pdf](https://www.eqb.state.mn.us/sites/default/files/documents/Interagency%20Report%20on%20Oil%20Pipelines4_0.pdf).

<sup>14</sup> Minnesota Statutes 2016, section 116D.02, subdivision 2.

#### **IV: A more comprehensive analysis of a no-build alternative**

The DEIS spends considerable time discussing oil transportation alternatives to pipelines— primarily truck and rail transportation. The DEIS affirms there are considerable risks associated with all forms of tar sands oil transportation. Pipelines can leak larger amounts of oil than rail or truck options and as the Enbridge tar sands spill of 2010 and other tar sands incidents depict, clean-up of tar sands oil, particularly when spilled into surface waters, is highly problematic.

A no-build alternative section should be far more expansive than simply comparing transportation modes. There are significant socio-economic changes taking place in the oil and tar sands oil industry that must be taken into account in the DEIS. The document pays scant attention to emerging trends that indicate that there is a glut in world oil supplies and additional oil production and distribution may not be needed. CNN Money reported as recently as June 17, 2017, that "the big fear gripping the energy markets is that the world continues to have too much oil, despite the deal between OPEC and Russia to pump less."<sup>15</sup>

The DEIS assumes that if a new Line 3 is not built, oil by rail facilities would be constructed at the Canadian-US border, or the oil would be transported by truck across Minnesota. There is no evidence to suggest that pipeline capacity along the Line 3 route will be replaced with rail or trucking options.

This scenario is not realistic, as no such facilities appeared when Keystone XL was denied, for example. Instead, many oil sands projects were cancelled due to the plunging price of oil worldwide, and the high cost of extraction and transportation of the Canadian tar sands fields. The DEIS does not address or enumerate the cancelled projects, the bankruptcies, the sell-off of assets by foreign nationals, or potentially stranded assets if the price of oil does not increase.

The DEIS does not compare the historical movement of oil-by-rail from the Bakken fields versus the Canadian fields to verify the hypothesis that vast quantities of crude oil by rail would be shipped from Canada, nor does it discuss the relative flammability of the oils.

There is also growing evidence of a long-term slowdown in tar sands oil production. Data related to that trend should be part of the final EIS.

#### **V: Conclusion**

The DEIS as it now stands is deficient and needs considerable revision. We have outlined our serious concerns regarding the document's treatment of spill prevention and mitigation, particularly in surface and drinking water sources, concerns related to Indigenous communities, climate change, and the overall need for additional tar sands oil infrastructure. We believe all of the issues we raised can be appropriately incorporated in a vastly revised EIS consistent with state law and policy.

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<sup>15</sup> Egan, Matt. "Oil prices enter bear market as supply glut fears return." CNN Money. June 17, 2017. <http://money.cnn.com/2017/06/20/investing/oil-prices-bear-market/index.html>.

Thank you for your consideration,



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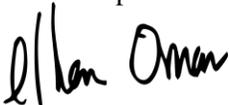
Paul Rosenthal  
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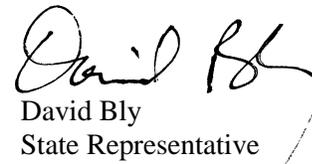
Erin Maye Quade  
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Jim Davnie  
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Ilhan Omar  
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David Bly  
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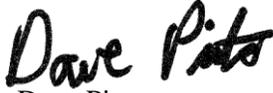
Tina Liebling  
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Raymond Dehn  
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Erin Murphy  
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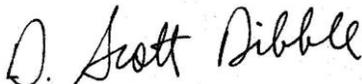
Dave Pinto  
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Connie Bernardy  
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D. Scott Dibble  
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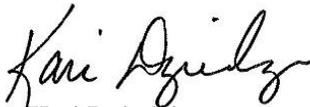
Jeff Hayden  
State Senator



John Marty  
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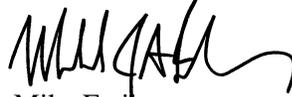
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Kari Dzedzic  
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Paul Thissen  
State Representative



Mike Freiberg  
State Representative



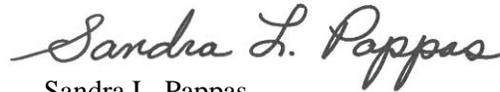
Fue Lee  
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Carolyn Laine  
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PUC Docket PI-9/CN-13-153  
OAH Docket Number (8-2500-30952)

Dear Judge Lipman,

I'm a registered mechanical engineer and resident of Minneapolis who wishes to provide information on the risk to drinking water posed by the proposed Phase 2 upgrade of Enbridge Energy's Line 67 crude-oil pipeline.

## **SUMMARY**

- The discharge pressures for the pumping stations under Phase 2 operation with dilbit would be up to 48% larger than those under present-day operation, and the summertime pipeline temperature is likely to rise to 120°F or higher.
- The increases in pressure and temperature that would be brought on by the Phase 2 upgrade would significantly increase the risk of pipeline ruptures.
- Ruptures releasing dilbit into surface water would present risks to the safety of drinking water supplies, because one of the typical diluent ingredients is benzene, a toxic and carcinogenic, water-soluble compound.
- The benzene concentrations for a worst-case spill from the upgraded Line 67 at its crossing of the Mississippi River near Grand Rapids, MN have been calculated using methods developed by Prof. John Stansbury of the Department of Civil Engineering of the University of Nebraska.
- At the spill location the concentration would reach 32 times the Safe Drinking Water Act Maximum Contaminant Level (MCL) for benzene, and it would remain above the MCL over a distance of 280 miles as the plume travelled downstream.
- This kind of analysis is not mandated by any section of Minnesota Rules, but I believe that it should be. This increased risk to Minnesota's drinking water supplies is a risk that should not be taken. In my opinion, based on the above findings alone, the consequences to society of granting the certificate of need for Phase 2 are not more favorable than the consequences of denying the certificate.

## **DISCUSSION AND RECOMMENDATIONS**

Below is outlined a calculation of the pumping station discharge pressures for dilbit transport. At the Phase 2 design-capacity flow rate of 880,000 barrels per day, the discharge pressure would be

approximately 48% higher than at the present annual-capacity flow of 450,000 barrels per day. Also, results shown in the Final Supplemental Environmental Impact Statement for the similar Keystone XL pipeline [2] indicate that we could expect a rise in pipeline temperature under the higher flow conditions to 120°F or higher in summertime. The increases in both pressure and temperature levels that would be brought on by the upgrade would increase the risk of pipeline ruptures due to corrosion or manufacturing flaws, major earth movement in landslides or floods, improper pipeline operation, or mechanical damage from excavation work.

A rupture releasing dilbit into the surface water at or near many of the 19 major rivers or tributaries crossed by Line 67 (see Table 1) would present a risk to the safety of drinking water supplies, because one of the typical diluent ingredients is benzene, a toxic and carcinogenic compound [3]. The benzene is water-soluble and would be swept downstream in a plume. The important questions are: what benzene concentrations would be reached, and how far downstream would the plume extend, in a worst-case spill?

<b>Alberta Clipper &amp; Waterways Rivers, Steams, Brooks &amp; Creeks Crossed</b>
Mississippi
Red River of the North
Red Lake River
Tamarac River
Middle River
Snake River
Branch Swale River
Clearwater River
Lost River
Swan River
Kelley Brook
Mirbat Creek
East Savana River
Stoney Brook
Cear Creek
Moose Horn River
Otter Creek
West Branch Floodwood River
Prairie River

Table 1  
Rivers and tributaries crossed by Line 67

No answers to either question are included in either the Application for Certificate of Need [4] or the Final Environmental Impact Statement [5] for the initial construction of Line 67, nor are such estimates given in the application for the Phase 2 upgrade [6]. A study by Professor John Stansbury of the Department of Civil Engineering of the University of Nebraska [7] addressed worst-case spills from the proposed Keystone XL pipeline's crossings of the Missouri and Yellowstone Rivers. He predicted that benzene concentrations at either event would rise to 19 times the Safe Drinking Water Act Maximum Contaminant Level (MCL) for benzene at the spill location, and that concentrations in the plume would remain above the MCL for a distance of 450 miles downstream.

The benzene concentrations for a worst-case spill from the upgraded Line 67 at the town of Ball Club, Minnesota, crossing of the Mississippi River have been calculated using Prof. Stansbury's methods. At the spill location, the concentration would reach 32 times the MCL, and it would remain above the MCL over a distance of 280 miles as the plume travelled downstream. The drinking water intakes for the communities of Grand Rapids, Libby, Aitkin, Brainerd, Royalton, and St. Cloud would be affected. Serious health risks would be created for tens of thousands of Minnesota residents, and aquatic habitats and recreational activities would be compromised. Other constituents from the spill would pose additional risks to humans and to aquatic species in the river.

This kind of analysis is not mandated by Section 7853.0620 Subpart 1, Point discharges to water, or any other section of Minnesota Rules, but I believe that it should be. This increased risk to drinking water supplies in Minnesota is a risk that should not be taken. In my opinion, based on the above findings alone, the consequences to society of granting the certificate of need are not more favorable than the consequences of denying the certificate. The additional bitumen should remain in the ground and be supplanted by renewable energy sources.

## **DETAILS OF THE MISSISSIPPI RIVER CALCULATION**

### **Worst-Case Spill:**

Prof. Stansbury's report describes a calculation of spill magnitude comprised of two parts: the pumping rate volume and the drain-down volume. Because I had no access to the topographic data needed to estimate the drain-down volume, I generated only a pumping rate volume. I applied a combined detection time and shut-down time of 1.5 hours to a leak of 100 percent of the 800,000 barrel-per-day annual average flow rate, giving a spill volume of 50,000 barrels. In view of the 12-hour pump-shutoff time for the Line 6B Kalamazoo River tributary spill [8], this is a reasonable time value.

As to why the 50,000-barrel spill volume is so much larger than the estimated 20,000-barrel volume in the Kalamazoo event, I note that Line 6B was designed for the much smaller maximum flow rate of 240,000 barrels per day [9]. For the Keystone XL pipeline analysis, Prof. Stansbury had used a shut-down time of 2 hours as a reasonable time for the worst-case analysis. I assumed that there would be no cleanup of the spill during the time of peak concentration of benzene in the water.

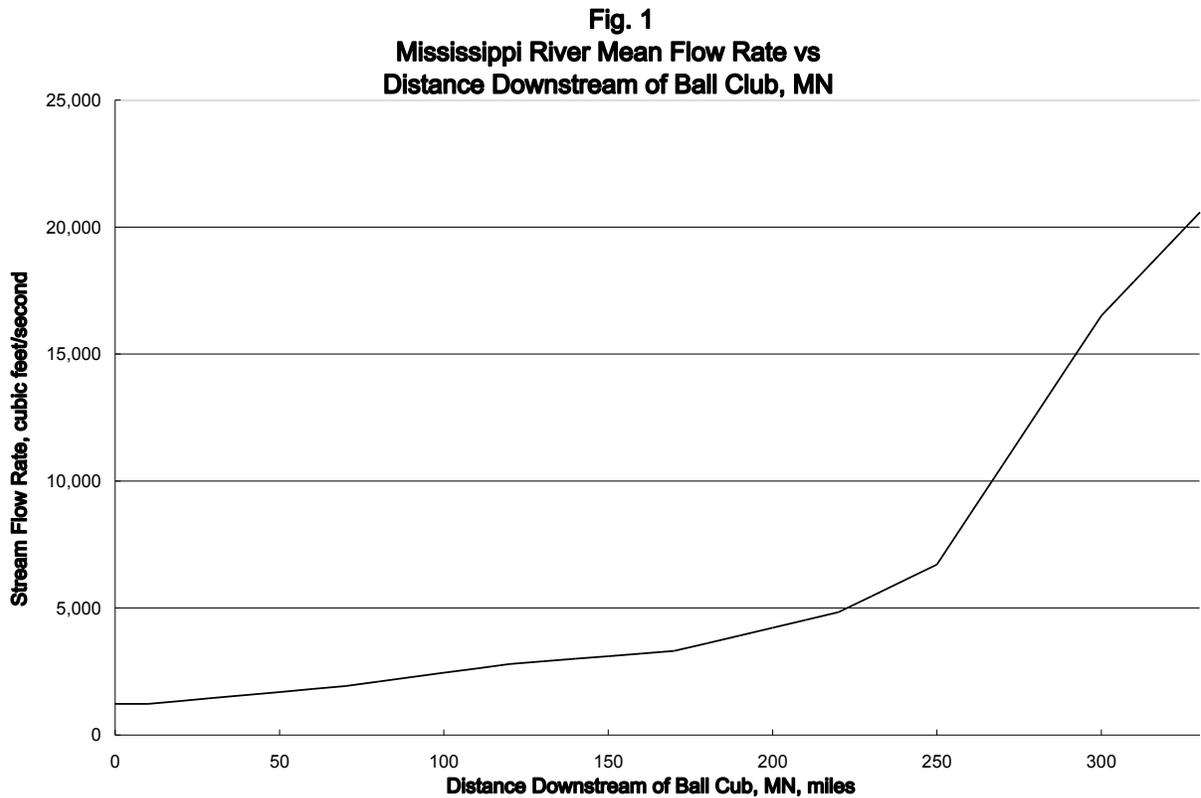
### **Impacts to Surface Water:**

Benzene makes up 0.1 to 1.0 percent of dilbit crude oil and is relatively soluble in water [10]. Prof. Stansbury estimates for the 1 percent case that the benzene/water concentration immediately at the oil/water interface is 75 milligram/liter, with the concentration decreasing with distance from the interface. He considers it reasonable that 5 percent of the benzene in the spill volume would reach the oil/water interface per day. Dividing this release rate by the stream flow rate produces an estimate for the benzene/water concentration after the benzene plume completely mixes across the width of the stream.

For the 50,000-barrel spill into the Mississippi River, which has a mean flow rate of 1,226 cubic feet/second at the Ball Club crossing, the peak, fully mixed concentration was calculated to be 0.16 milligram/liter, which is a factor of 32 larger than the Safe Drinking Water Act Maximum Contaminant Level (MCL) [11].

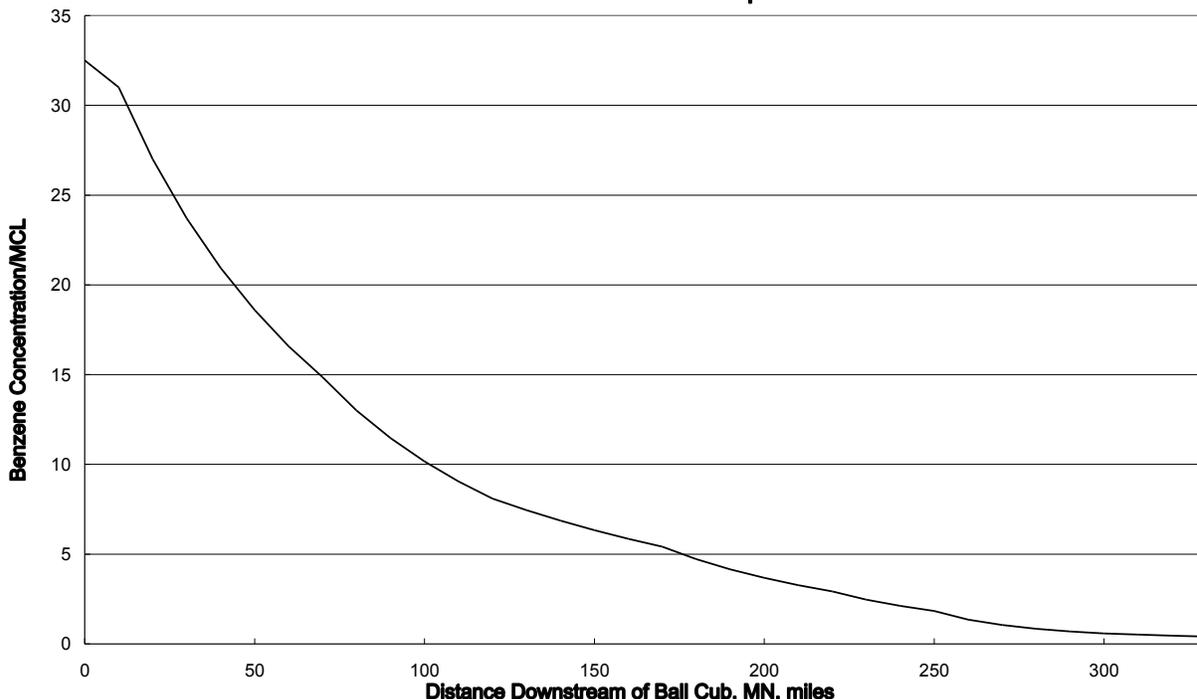
**Migration of the Benzene Plume:**

As the benzene plume migrates downstream, the concentration decreases due to volatilization and dilution by the increasing stream flow. A half-life of 3 days for benzene in surface water and a stream velocity of 2 feet/second are assumed. Data on the variation in Mississippi River stream flow rate with distance downstream, shown in Fig. 1, was provided by the USGS and was used in the calculations to predict concentration decrease with distance downstream of the spill. The plume length was modeled using a series of 10-mile long river reaches with first-order decay of concentration in each.



As seen in the Fig. 2 plot of concentration results, normalized to the benzene MCL, the plume would reach over 280 miles before its concentration would drop to the MCL and be safe for public water intakes.

**Fig. 2**  
**Benzene Concentration in Plume vs**  
**Distance Downstream of Spill**

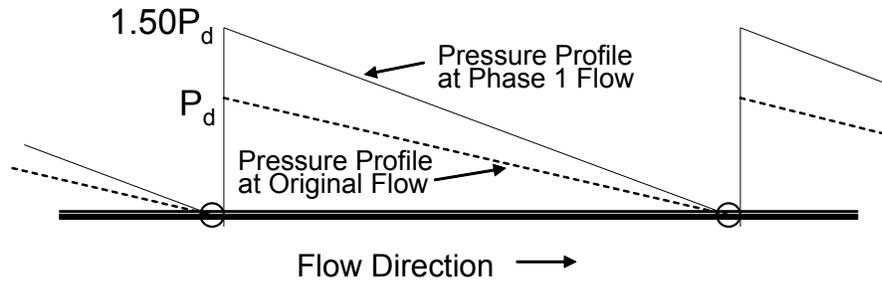


Other sets of assumptions (e.g., shorter half-life) would give somewhat different results. For example, assuming that benzene makes up only 0.3 percent of the dilbit and that 10 percent of the benzene is released per day, the calculated plume length would be reduced by about one-half. While the impacts thus cannot be calculated with precision, these results demonstrate that if a worst-case spill occurs in a major stream, the impacts would be both far-reaching and long-lasting.

### **DETAILS OF PUMPING STATION DISCHARGE PRESSURE INCREASES DUE TO LINE 67 UPGRADES**

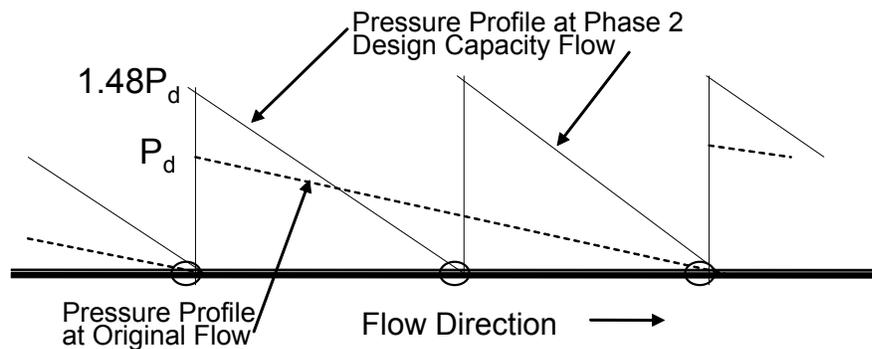
Crude oil flows in a pipeline segment because the upstream pumping station produces a lengthwise gradient of pressure (psi per foot of length) that overcomes flow resistance. That gradient can be calculated for a given flow rate (barrels per day), and, when multiplied by the segment length, it can give an estimate of the required discharge pressure at the upstream pumping station. This idealized estimate represents pumping-induced pressure without account of components of pressure due to variations in elevation (grade).

For the Phase 1 upgrade, instead of the gradient itself, I calculated the ratio of the gradients at the upgraded (570 kbpd) and the original (450 kbpd) annual capacities, which turned out to be 1.50. Based on that result, the peak pressure load in a given pipeline segment, which occurs at the discharge of the upstream pumping station, would have to increase by 50% to produce the higher annual-capacity flow rate of Phase 1.



For the Phase 2 upgrade I again calculated the ratio of the pressure gradients at the upgraded and the original flow rates. But now the pipeline segment length would be half of the original length, because a new pumping station is to be inserted between each pair of the original stations. So the ratio of pumping-station discharge pressures would now be one-half the ratio of the gradients. The results are tabulated below. All calculations were performed using the well-established plot of friction factor versus Reynolds number, often identified as the Moody Diagram [1].

Case	Flow, kbpd	Ratio of Gradients, Upgrade/Original	Ratio of Pumping Station Discharge Pressures, Upgrade/Original	Increase in Discharge Pressure
Original Line 67 at Annual Capacity	450	--	--	--
Phase 1 Upgrade at Annual Capacity	570	1.50	1.50	50%
Phase 2 Upgrade at Annual Capacity	800	2.59	1.30	30%
Phase 2 Upgrade at Design Capacity	880	2.95	1.48	48%



Respectfully submitted,  
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**REFERENCES**

[1] Victor L. Streeter, Fluid Mechanics, 2<sup>nd</sup> Edition, McGraw-Hiill Book Company, Inc., p.183

[2] Final Supplemental Environmental Impact Statement for the Keystone XL Pipeline, Appendix S, Pipeline Temperature Effects Study, Figure 1, <http://keystonepipeline-xl.state.gov/documents/organization/221245.pdf>

[3] "Tar Sands Crude Oil: Health Effects of a Dirty and Destructive Fuel," NDRC Issue Brief, February, 2014. IB:14-02-B, p.2, <http://www.nrdc.org/energy/files/tar-sands-health-effects-IB.pdf>

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