Water and drilling fluid chemistry from 'frac outs' during Enbridge Line 3 construction, 2021

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What is a frac out? In 2021, Enbridge used a process called Horizontal Directional Drilling, or HDD, to construct the Line 3 pipeline across 21 water bodies (rivers, streams and wetlands). This process involved drilling a tunnel underneath a river or wetland, at a depth of as much as ~60 ft, and then installing prefabricated sections of pipe into the tunnel. To drill these tunnels, Enbridge contractors lubricated a very large drill bit with something called drilling fluid or drilling mud. This fluid is a mix of bentonite clay and other unknown chemicals that Enbridge and state agencies refuse to disclose to the public; these drilling fluid formulations are listed in Line 3 permitting documents[1] as "proprietary", or trade secret. Because Enbridge is drilling through sensitive sediments beneath rivers and wetlands, the tunnels can easily lose structural integrity and develop leaks. These leaks are known as 'frac outs', and result in drilling fluid spills into the surrounding environment. Leaks happen initially in the subsurface, and can spread all the way to the land or water surface, or to other subsurface locations and aquifers.

On August 9, 2021 - and only after considerable pressure by water protectors, the public, tribal leaders and an official inquiry by state legislators -- the Minnesota Pollution Control Agency (MPCA) disclosed that there were 28 known 'frac outs' or drilling fluid spills during Line 3 HDD construction between June 25th and August 5th. Even after drilling fluid had been spilled to public waters, MPCA did not disclose the chemical makeup of the fluid.

Key information from water chemistry analysis:

- When drilling mud was spilled directly into river channels, **high levels of total suspended sediment (TSS) were measured in the river**. TSS can be damaging to aquatic life, and furthermore the very small particles that are typical of drilling mud can be more damaging than "natural" sediments[2]. This finding validates the observations of water protectors who have noted decreased visibility and cloudy waters at rivers where known drilling fluid spills occurred.
- **Drilling mud collected at one site had 401 mg/kg of sulfate**. Sulfate in water is damaging to wild rice. Furthermore, water samples downstream of the same drilling fluid spill had sulfate concentrations above the state standard for wild rice waters.
- On July 28 and 29, water samples collected from the Mississippi River headwaters immediately downstream of several known frac outs showed relatively high concentrations of **TSS, total phosphorus, oil and grease, total organic carbon,**

[1] https://www.pca.state.mn.us/sites/default/files/Attachment-L-Drilling-Mud-Additives-Information-2020.pdf
[2] Aslan, J.F., Weber, L.I., Iannacone, J., Lugon Junior, J., Saraiva, V.B. and Oliveira, M.M. 2919. Toxicity of drilling fluids in aquatic organisms: a review. Ecotoxicology and Environmental Contamination 14: 35-47.

calcium and barium, compared to upstream samples. It is possible that algal growth or some other biochemical event could have contributed to higher concentrations of TSS, total phosphorus, oil and grease and total organic carbon. (Note that the measure of oil and grease used here can detect the presence of contaminants like soap and some petroleum fuels, but also detects things like plant based oils). However, relatively high concentrations of barium are also consistent with a release or spill of drilling mud directly to the river channel. This finding is important because MPCA has never acknowledged contamination of the river channel itself at this location. Additional monitoring by state agencies is needed to determine the extent of drilling mud impacts on Mississippi River and all other sites where fluid was spilled.

- **Drilling fluid is now emplaced in the subsurface at all spill sites, and recent photos and videos indicate it's likely being mobilized.** Long-term monitoring should be initiated to determine if and when that drilling fluid is mobilized into the stream system (e.g. during stream meandering, floodplain inundation or stream incision). And, monitoring could determine whether soluble chemical compounds like sulfate may be leaching into the shallow subsurface flow and over a period of weeks or months begin impacting streams and downstream lakes.
- For more general information about drilling fluid, **see this fact sheet.**

Recommendations:

Based on the preliminary information provided by this volunteer-led sampling, rigorous and immediate sampling by state and/or federal agencies is needed to determine 1) whether sulfates or other contaminants are being released into sensitive waters, including wild rice waters, in locations where drilling mud spills have occurred; and 2) the magnitude and duration of elevated TSS in sensitive waters arising from drilling fluid spills, and 3) the spatial extent of subsurface contamination from drilling fluid. **All pipeline construction & operation activities should be put on hold until a complete independent investigation can be completed.** Based on the findings of such an investigation, agencies must release information to the public about plans for remediation and penalties for Enbridge appropriate to the level of degradation.

Background

Who collected water samples and why?

Water quality sampling and analysis was coordinated by water protectors at Firelight Encampment, Red Lake Treaty Camp, and Welcome Water Protectors Camp, together with members of the grassroots collectives Science for the People-Twin Cities and Watch the Line. Water samples were collected because 1) it wasn't (and still isn't) apparent whether the Minnesota Pollution Control Agency (MPCA) has conducted any on-site monitoring of frac outs or subsequent environmental degradation that could arise from drilling fluid spills; 2) MPCA had not released complete or accurate information to the public about impacts from frac outs even while water protectors were witnessing these events on the ground first-hand; 3) water protectors were concerned that Enbridge or the "Independent

Environmental Monitors" (IEMs) contracted and paid for by Enbridge would not report the full extent of frac outs to state regulators; 4) water protectors were concerned about impacts from drilling fluid to Manoomin (wild rice), other plant and animal life and to human health; and 5) water protectors and other concerned members of the public had no way to assess the potential hazards of drilling fluid, because the chemical make up of the fluid was unknown and never disclosed by Enbridge nor by state agencies.

Timeline of spill events

On July 6, 2021, water protectors observed a frac out on Willow River. This was the first frac out observed by water protectors during construction of Line 3 in 2021, although MPCA subsequently revealed that additional frac outs had occurred earlier in the season at other locations.

On August 9, 2021, MPCA released information indicating that, as of that time, there had been 28 known spills of drilling fluid into the environment as the result of Line 3 HDD construction between June 8 and August 5, 2021 (Figure 1). The MPCA confirmed that 12 of the 15 river crossings where Enbridge used HDD methods were contaminated by spills of drilling fluid (Table 1). Thirteen of the 28 spills were directly to wetlands at crossing locations. The grassroots, volunteer led organization Watch the Line has compiled some additional context and information about these spills here. Additional information for the 28 known spills - including spill volumes - was also compiled from the MPCA by MN Reformer journalist Rilyn Eischens here. It should be noted that some water protectors believe there are additional unreported spills based on observed frac-outs at locations such as Mississippi River Crossing #1.

HDD methods were permitted by MPCA for certain stream, river and wetland crossings because of the high sensitivity of these particular ecosystems to degradation. Ostensibly, HDD methods result in less degradation to the environment than open trenching, i.e, digging an open trench directly across the land surface or stream bottom. Open trenching is the primary method Enbridge used to construct most of the pipeline, including across most of the ~200 streams and hundreds of acres of wetlands crossed by the project. However, when drilling fluid spills occur during HDD, the ostensibly more protective aspects of HDD construction are diminished.

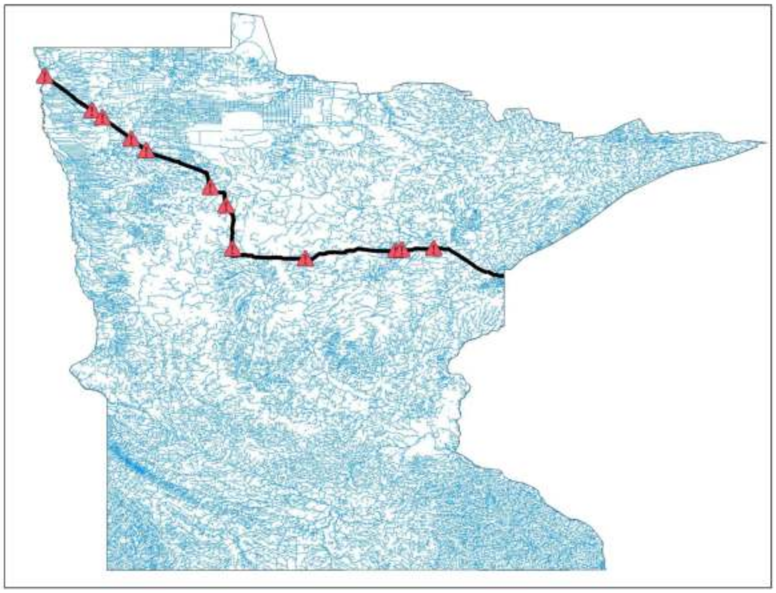

Figure 1. Locations (red triangles) of drilling fluid spills along the Line 3 route (black line) in between June 8-August 5, 2021. Blue lines show streams and rivers across Minnesota.

Location	Date	# Releases	Volume Fluid Released (gallons)
Snake River	6/8/21	1	20
Straight River	6/16/21	1	Not known
Mississippi River Crossing # 2	6/25/21	1	6,000-9,000
Red River	6/25/21, 6/28/21	2	450
Willow River	7/6/21, 7/17/21, 7/21/21	3	170
East Savanna River	7/15/21, 7/17/21, 7/26/21, 7/31/21, 8/5/21	6	1465-1480
Middle River	7/16/21, 7/20/21	4	315
Red Lake River	7/16/21, 7/19/21	2	1280
Clearwater River Crossing # 1	7/18/21	2	40-50
Pine River	7/19/21	1	60-100
Mississippi River Crossing #1	7/20/21, 7/30/21	3	160
Clearwater River Crossing # 2	7/28/21	2	35

Table 1. River crossings where HDD drilling mud spills occurred.

Where and when were water samples collected?

Concerned about the impacts of drilling fluid spills on water and wetlands, water protectors collected a number of samples at crossings where frac outs were observed. These samples included water from 3 rivers, and a direct sample of drilling mud from one active spill site (at Mississippi River Crossing # 1/aka Firelight Encampment):

- River water samples were collected from **Willow River** on July 6, 2021, after water protectors observed an active plume of what appeared to be drilling fluid in the river. This crossing is listed in MPCA documents as Willow River HDD (MP 1066.5)

- River water samples were collected from **Mississippi River** headwaters on July 20, July 23 and July 29 of 2021. These samples were collected after water protectors observed a frac out in a wetland located in the floodplain of Mississippi River on July 20, 2021 (Figure 2). Several additional frac outs were subsequently observed and documented at various locations at this same pipeline river crossing by Ron Turney of the Indigenous Environmental Network. In addition to collecting river water, water protectors obtained one direct sample of drilling mud where it was actively leaking from a wetland at this crossing. This crossing is listed in MPCA documents as Mississippi River HDD (MP 941.0).

- River water samples were collected by water protectors from **Clearwater River** crossing on July 24, 2021. This crossing is listed in MPCA documents as Clearwater River HDD (MP 875.4)

These were very limited sampling events due to: (i) the public being restricted from accessing these sites and being intimidated by security and law enforcement when collecting samples, and (ii) limited private funding available.

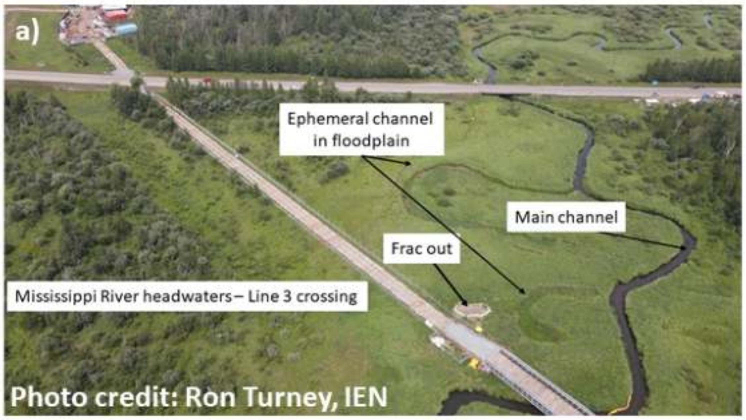

Figure 2. a) Top photo shows location of first known frac out at Mississippi River Crossing #1, observed by water protectors in a wetland on July 20, 2021. b) Right photo shows Enbridge workers attempting to clean up drilling fluid spill in the same wetland.

How were samples collected?

Where available, samples were collected in lab-grade plastic bottles provided by a private certified lab. Water protectors were trained in and followed a standardized sampling protocol which included collecting samples both upstream and downstream of observed potential spill sites, enacting methods to reduce possibilities for contamination, and securing a chain of custody from time of sampling to time of analysis. In some cases when standard collection bottles were not available, samples were collected in clean plastic bottles or glass jars. Where samples were collected in non-standard bottles, it was not possible to analyze samples for the full range of water chemistry, because certain water chemistry tests need very specific conditions (i.e., need to be collected in bottles pre-treated with acid, etc).

Where was water and drilling fluid chemistry tested?

A certified private lab conducted all chemical analyses on water and drilling fluid samples.

What were samples tested for?

Water and drilling mud samples were tested for a range of chemical constituents that were deemed likely to occur based on a literature review of drilling fluid chemistry, and that might be of concern to human or environmental health.

- For water samples, we tested for concentrations of: total suspended solids (TSS), sulfate, calcium, magnesium, sodium, chromium, total phosphorus, chloride, oil and grease, barium.
- For the one drilling fluid sample collected, we tested for a wider set of chemistry including: calcium, phosphorus, magnesium, sodium, barium, chromium, lead, silver, sulfate, chloride, oil & grease, mercury, arsenic, cadmium and selenium.
- **See the Appendix for a full list of all water chemistry results.**

Note that because of grassroots citizen science challenges such as use of non-standard sample bottles at some collection sites and time delays in sample transportation to the lab, there were some additional parameters of interest we were not able to test for, including PAHs and surfactants.

What did water & drilling fluid chemistry results show?

Elevated Total Suspended Solids (TSS)

TSS is a measure of how much sediment, algae and other particles are in the water. High TSS levels over a period of time can inhibit aquatic plant and animal growth and survival. High sediment loads can lead to sediment settling out or "silting in" habitats like mussel beds and fish spawning locations. Importantly, the TSS from drilling mud is "finer" (smaller particles) and chemically different than natural sediment. Scientific evidence indicates that these characteristics make it particularly damaging to the gills of mussels and aquatic insects[3], which Enbridge and regulatory agencies did not take into account. The water quality standard for TSS that is considered protective of aquatic life in Minnesota rivers is 10 mg/L, which cannot be exceeded for more than 10% of the time over a multi-year period without requiring the water body to be classified as "impaired". In other words, this means that it is often legal under MPCA state regulations to discharge heavy sediment loads that lead to a stream exceeding 10 mg/L TSS *so long as* those high TSS levels do not last for more than 10% of the time. *However*, it's still illegal to discharge TSS into a stream unless the activity is permitted. Here, we believe the MPCA 401 permit allows TSS "discharges" (spills) as long as they don't cause impairment according to Minnesota pollution standards.

At river sites where drilling fluid plumed up from the subsurface directly into the river, the river showed elevated levels of TSS. At the Willow River, TSS concentrations upstream of the spill ranged from 0-24 mg/L, while at the spill site TSS concentrations averaged 148 mg/L.

At the Mississippi River, TSS measurements up and downstream of the known frac out varied depending on the day of collection (River water samples were collected on three different dates in July following the identification of frac outs at this site). On July 23, TSS levels were relatively low, ranging from 8 - 10 mg/L, however on July 28 and 29, TSS levels ranged as high as 340 mg/L for a sample collected upstream of the known frac out and 1550 mg/L for a sample

[3] Aslan, J.F., Weber, L.I., Iannacone, J., Lugon Junior, J., Saraiva, V.B. and Oliveira, M.M. 2919. Toxicity of drilling fluids in aquatic organisms: a review. Ecotoxicology and Environmental Contamination 14: 35-47.

collected downstream of the frac out. (Note that the 'frac outs' were reported by MPCA as occurring 'in a wetland', and not in the river itself).

These high TSS values are well above the water quality standard considered protective of aquatic life (10mg/L). However, as previously stated, MPCA allows a stream to exceed the standard for short periods during a year without necessitating an impairment listing. With only 1-3 days of citizen science water monitoring, we do not have sufficient data to understand the long-term risks of drilling fluid spills for TSS impairment. **A key consideration for MPCA to monitor for and report to the public would be how long TSS concentrations have been elevated at spill locations in rivers, and whether prolonged periods of high TSS can be attributed to drilling mud.**

Sulfate

Chemical analysis of the drilling mud collected at the Mississippi River headwaters pipeline crossing (Firelight Encampment) showed a concentration of 401 mg/kg of sulfate. In addition, water chemistry for a sample collected in Mississippi River downstream of the known frac out showed a sulfate concentration of **12.6 mg/L, which is above the state sulfate standard of 10 mg/L for Manoomin (wild rice) waters.**

Barium sulfate, also known as barite, is a likely constituent of drilling fluid. Barium sulfate is a mineral that is often considered insoluble. However, at least one study of barium sulfate in floodplain sediments of the Mississippi River has shown that this compound can become soluble under acidic and anaerobic conditions that are found in wetland environments. More importantly, **the concentration of sulfates in the drilling fluid appears to exceed that expected from barium sulfate alone**, based on the barium concentration and the fact that barium sulfate ($BaSO_4$) occurs in a 1:1 stoichiometric ratio. Thus, the sulfates in the drilling fluid appear to exceed that contributed by barite alone. **It is possible that these sulfates are more readily soluble and thus more likely to contaminate surface or groundwaters. Only additional monitoring could determine the form of these sulfates and their potential risk to wild rice and other sensitive ecosystems.**

Additional Chemistry Findings

We tested the water for a number of other constituents that we identified as possible indicators of the presence of drilling mud, based on the scientific literature, or that might be of concern if they were spilled into the environment. For example, we tested water samples for levels of sodium, chloride, barium, chromium, phosphorus, and oil and grease. Additional notable findings from these results include the following:

- On July 28 and 29, water samples collected **downstream of the frac out** location on Mississippi River had **relatively high concentrations of TSS, total phosphorus, oil and grease, calcium, total organic carbon, and barium**, compared to upstream samples. (Note that the measure of oil and grease used here can detect the presence of contaminants like soap and some petroleum fuels, but also detects things like plant based oils). These findings could indicate that drilling mud had reached the Mississippi River channel itself on these days. While higher concentrations of phosphorus and organic carbon could also indicate algal growth or some other biological event, the higher concentration of barium suggests drilling fluid may have been present. More monitoring would be needed to ascertain why water quality was altered downstream of the frac outs at the time of sampling. MPCA has never acknowledged whether drilling fluid has contaminated the river channel at this crossing location.

- The drilling mud sample, in addition to containing environmentally relevant concentrations of sulfates, also contained sodium, chloride and magnesium.

Finally, it is important to note that our sampling regime was very limited relative to the extent of the potential problem, and without a more comprehensive monitoring plan we will not be able to fully understand the pollution risks of the frac-outs, or their break down products.

What are the long term concerns?

Plumes of drilling mud contaminants in the subsurface and floodplain can take days, weeks or months to become evident at the surface, and/or to affect the main river channel. River conditions this summer were very low flow due to the historic drought, and spills in the floodplain are likely to be mobilized under higher flow/storm conditions. Evaluating the longer term impacts of frac outs would thus require longer term monitoring by state agencies responsible for protecting the health of Minnesota waters. **Based on the available water chemistry data provided here and documented observations of water protectors, all pipeline construction & operation activities should be put on hold until a complete independent investigation of the extent of environmental degradation from frac outs can be completed.**

Appendix

Water chemistry results for all samples collected June-July 2021. “Upstream” and “Downstream” refer to where water samples were collected from the river relative to the longitudinal position of known frac outs. “Upstream” indicates samples were collected upstream of the frac out locations, “downstream” indicates samples were collected downstream of the frac out location. All units are mg/L except where noted. “NA” = chemical analysis was not run for that sample. **Highlighted results indicate chemistry that could be of potential/possible concern to the environment and that should be the focus on continued monitoring, assessment and remediation.**

Table A1. Willow River 7/6/21

	Time	Upstream	Downstream
TSS	10:30AM 16:00PM	0 24	135 160
Sodium	10:30AM 16:00PM	NA	9.23 10.10
Magnesium	10:30AM 16:00PM	NA	14.82 16.19
Calcium	10:30AM 16:00PM	NA	58.15 65.27
Chromium	10:30AM 16:00PM	NA	0.001 0.001
Iron	10:30AM 16:00PM	NA	0.002 0.002
Copper	10:30AM 16:00PM	NA	0.008 0.008
Zinc	10:30AM 16:00PM	NA	0.011 0.011
Arsenic	10:30AM 16:00PM	NA	0.001 0.001
Lead	10:30AM 16:00PM	NA	0.002 0.002
Barium	10:30AM 16:00PM	NA	0.079 0.094

Table A2. Mississippi River Crossing # 1 (Firelight) 7/20/21

	Upstream	Downstream
TSS	36	72
Sulfate	<5	<5
Calcium	33.8	51.8
Magnesium	8.55	13.1
Sodium	2.41	3.65
Chromium	<0.01	<0.01

Table A3. Water chemistry results from Mississippi River Crossing # 1 (Firelight) 7/23/21

	Upstream	Downstream
TSS	10	8
Sulfate	<5	<5
Calcium	69.5	70.2
Magnesium	24.4	24.5
Sodium	7.29	7.18
Chromium	<0.01	<0.01
Ortho Phosphorus	0.035	0.035
Chloride	<3	<3
Total Phosphorus	0.07	0.065
Oil and grease	<5	<5

Table A4. Drilling fluid chemistry results from Mississippi River frac-out 7/23/21 - this sample of drilling fluid was obtained from an active frac out in a wetland in the floodplains of the Mississippi River

Units are mg/kg	Drilling fluid in clay
Calcium	6400
Total Phosphorus	78.21
Magnesium	1677
Sodium	917.6
Barium	16.19
Chromium	2.24
Lead	3.12
Silver	<0.4876
Sulfates	401
Chloride	263
Oil and grease	NA
Mercury	<0.037
Arsenic	1.281
Cadmium	<0.049
Selenium	0.562
All measured PAHs	NA

Table A5. Water chemistry results from Mississippi River Crossing # 1 (Firelight) 7/28/21

	Upstream	Downstream
TSS	340	1550
Sulfate	<5	12.6
Calcium	75.30	136.0
Magnesium	26.10	32.10
Sodium	7.96	8.970
Chromium	<0.01	<0.01
Ortho P	NA	NA
Chloride	<3	<3
Total Phosphorus	0.101	4.28
Oil and grease	NA	NA
Total Organic Carbon	5.20	12.30
Barium	0.195	0.938

Table A6. Water chemistry results from Mississippi River Crossing # 1 (Firelight) 7/29/21

	Upstream	Downstream
TSS	317	1500
Sulfate	<5	<5
Calcium	67.60	79.10
Magnesium	25.60	27.20
Sodium	7.86	8.14
Chromium	<0.01	<0.01
Ortho P	NA	NA
Chloride	<3	<3
Total Phosphorus	0.065	4.33
Oil and grease	<5	12.5
Total Organic Carbon	5.10	10.10
Barium	0.123	0.231

Table A7. Water chemistry results from Clearwater River 7/24/21

	Upstream	Downstream
TSS	408	402
Sulfate	NA	NA
Calcium	67.60	71.00
Magnesium	29.00	30.30
Sodium	8.67	8.91
Chromium	<0.01	<0.01
Ortho P	NA	NA
Chloride	13.8	13.9
Total Phosphorus	0.1489	0.157
Oil and grease	<5	<5
Total Organic Carbon	NA	NA
Barium	0.09	0.09