# FRIENDS OF THE HEADWATERS

**RESPONSE TO THE MINNESOTA DEPARTMENT OF COMMERCE**
**LINE 3 DRAFT EIS - Dockets CN-14-916, PPL-15-137**
**JULY 10, 2017**

## ***ATTACHMENTS "F"***

### F-1 LaSalle Creek-MinnCan Response Activities report bentonite frac-out

*MinnCan Pipeline Company letter to Minnesota Department of Natural Resources regarding a bentonite "frac-out" in the LaSalle Creek Valley in 2008*

### F-2 LaSalle Creek-Barr Response Activities Work Plan Bentonite clean-up plan

*Barr Engineering Technical Memorandum to MinnCan Pipeline Company regarding a clean-up work plan for the bentonite "frac-out" in the LaSalle Creek Valley*

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May 16, 2008

Ms. Cindy Buttleman
Regional Supervisor
Minnesota Department of Natural Resources
Division of Lands & Minerals
2115 Birchmont Beach Road NE
Bemidji, MN 56601

**Subject: La Salle Creek Response Activities Work Plan Implementation Report**

Dear Ms. Buttleman:

The purpose of this letter is to document bentonite recovery activities recently completed at the La Salle Creek frac-out location in Hubbard County, Minnesota. Recovery activities were conducted in accordance with the *Final LaSalle Creek Response Activities Work Plan* (Work Plan), which was submitted on February 1, 2008 and approved by the Minnesota Department of Natural Resources (DNR) on February 4, 2008. Background information regarding the site was provided in the Work Plan and is not re-iterated in this report. Recovery activities were conducted by Minnesota Limited Inc. under the direct supervision of Minnesota Pipe Line Company (MPL) staff.

## Results

The objective of the recovery activities was to remove bentonite material from the creek to the extent practical utilizing methods that do not create a high degree of disturbance to the creek or surrounding wetland. Recovery activities were based on the three criteria that were outlined in the Work Plan:

- Minimize the disturbance to the wetland area and La Salle Creek
- Minimize the risk to the active pipelines
- Protection of worker safety

Based on pilot scale test results, MPL utilized a vacuum-type recovery device operated with a 3-inch diameter trash pump to remove a bentonite/water slurry. The recovery flowrate was approximately 75 gallons per minute (gpm). The vacuum-type recovery device utilized low-suction pressure at the inlet to minimize the amount of natural streambed material removed, yet was effective at capturing the bentonite material. The intake device was fitted with a screen to prevent removal of rocks and natural material. MPL maintained an inspector on-site during active recovery periods to monitor progress and verify compliance with the three criteria described above. Site visits and inspections were also conducted by DNR staff and the Agency Monitor for the MinnCan project to verify that activities were conducted to minimize impacts, in accordance with the Work Plan

Once recovery activities commenced, the bentonite material had settled considerably, which enabled recovery with a high solids content. Minimal turbidity was observed in the river during recovery operations, which allowed for clear monitoring of progress as bentonite was removed and the river bottom was reached.

Initial recovery activities were commenced in the South Area (as defined in the Work Plan) on February 22, 2008 and consisted of pumping a bentonite/water slurry through 3-inch diameter hoses across La Salle Creek approximately 350 feet to a 500 gallon transfer tank staged on a tracked bombardier (i.e. low ground pressure vehicle) on the right of way (ROW). Bombardiers were utilized to transport the material to an upland area where it was transferred to a 1,500 gallon tank mounted on a dump truck. The dump truck hauled the material off-site to an upland area for re-use at a nearby farm field. Activities were completed in this manner for 4 days and 24,500 gallons of slurry was hauled off-site. However, progress was slow as the haul time of the bombardier prevented continuous operation of the recovery pump. In addition, progress was delayed by temperatures below 0 °F which prevented operation of the recovery pump.

As described in the Work Plan, MPL continually evaluated progress to determine if modification or enhancement was needed. Based on the initial results, MPL determined it was necessary to increase the recovery rate due to concerns of the upcoming spring thaw and run-off period. Since hauling of the recovered material in the bombardier was the rate-limiting step, MPL considered additional options. After consideration and discussions with DNR staff, MPL pursued pumping to an infiltration pit in a nearby upland area for dewatering within the ROW in a manner that would not impact the wetland area. The location, northwest of La Salle Creek within the ROW, was chosen based on the topography and utilized a recently backfilled excavation conducted as part of the MinnCan Project. A dike was formed around the excavation area with an approximate size of 20 feet by 300 feet. Clearwater County is the landowner, and permission to land apply was received from the Clearwater County Land Commissioner on February 25, 2008.

MPL proceeded with recovery activities on March 10 and utilized six pumps and approximately 2000 feet of 3-inch hose to move the material to the upland infiltration pit. The diked area around the infiltration pit was constantly monitored with radio communications between on-site workers to control pumping. The low point around the diked area was the east side, so an additional backup dike was added on this side. The first infiltration pit did become saturated after a few days of operation and one additional infiltration pit was added directly to the north on the ROW. MPL conducted frequent inspections of the infiltration pits to verify that material was not running off toward the wetland.

Recovery activities were concluded on March 14th with a total volume of slurry pumped of approximately 170,000 gallons. The majority of the bentonite remains on-site in the upland dewatering pit and will be hauled off-site once conditions allow. This material was not able to be removed in March due to wet conditions from thawing which prevented truck access.

The majority of the bentonite in the Creek was contained in the section referred to as the South Area (as described in the Work Plan). As a result, MPL focused recovery efforts on the South Area moving from south to north with removal down to the Creek bottom, along the bank, and completely across the Creek. The only exception is a small area between the second and third divider (from south) in which flowing water around the second divider created thin ice and limited access.

Upon completion of recovery activities in the South Area on March 14, MPL moved equipment to the North Area (as defined in the Work Plan). Upon inspection, reduced bentonite thicknesses were found in the North Area as the material had settled considerably. The frac-out near the North Area had occurred in the wetland area and traveled to the west side of the Creek. It was determined that bentonite was not completely across the Creek, as was the case in the South Area. In fact, it was only identified along the west side of an outside bend in the Creek. The initial bentonite volume estimate in the Work Plan was based on a maximum thickness of 18 inches and an average thickness of 9 inches across the Creek. Upon re-inspection, it was found that the maximum thickness was only 6 inches and this was for a limited area (approximately 4 square feet). The bentonite thickness in the majority of this area ranged from 0 to 1.5 inches. It is also believed that the bentonite settled in this area as the initial measurements were conducted shortly after the frac-out entered the Creek. To verify that bentonite had not migrated downstream, MPL inspected the river bottom downgradient of the North Area and did not find that any additional material. It is anticipated that any remaining material will be scoured from the river bed during spring thaws.

MPL also attempted to remove bentonite material from the wetland area that did not reach the stream. However, this material was frozen in place and could not be removed by hand shoveling or with a small excavator. To minimize impact to the wetland, MPL does not intend to mobilize equipment to remove this small amount of material. MPL will re-inspect the wetland areas after complete thawing to identify any potential spots that can be removed manually.

## Remaining Work

Upon conclusion of the recovery activities on March 14, MPL attempted to remove the in-stream sediment barriers. One barrier was successfully removed; however, the remaining were frozen into the stream bank and could not be readily removed. Cold evening temperatures continued beyond March 14, which allowed limited worker access utilizing plywood planking and removal of all barriers on March 28th and March 31st. The only exception is a small section of silt barrier fabric frozen underwater to one side of the Creek bank. Barrier material has been temporarily placed on the ROW on-site and will be removed off-site in the near future.

As previously mentioned, MPL will remove the accumulated bentonite from the infiltration pit and haul it off-site to the identified upland area for re-use in a farm field. Upon completion of recovery activities on March 14th, the access road had become too wet for a hauling truck to access. MPL intends to remove this material during drier ground conditions that allow for truck access.

Within the written approval dated February 4, 2008 of the La Salle Creek Recovery Plan, a special request was made by the DNR to take an additional step beyond effective bentonite removal from the Creek to remove the downstream beaver dam. MPL worked with the United States Department of Agriculture-Animal and Plant Health Inspection Services-Wildlife Services (USDA-APHIS-Wildlife Services) to have the beavers trapped and the dam removed. A total of four dams were removed from La Salle Creek, one upstream of the pipeline crossing and three downstream of the pipeline crossing, but prior to Big La Salle Lake. MPL did seek and receive approval from he DNR prior to all four being removed.

# Evaluation and Testing Results

During the course of this project, DNR staff requested a summary of the ideas and techniques that were evaluated and tested, the results of the testing, methods used, and the lessons learned during full-scale implementation. The remainder of this section provides a bullet-list summary of these items.

- MPL and DNR maintained close communication during horizontal direction drilling (HDD) and bentonite recovery activities. This teamwork with DNR allowed for quick discussion and review of *LaSalle Creek Frac-Out Monitoring and Response Plan* and *LaSalle Creek Response Activities Work Plan*. DNR input and on-site visits provided valuable assistance during this project.
- Ice removal to facilitate bentonite recovery was minimized by pushing ice out of the way versus lifting and removal from the Creek. The ice was cut with a chainsaw and could be pushed into previously vacuumed areas.
- Construction of a vacuum-type recovery device provided efficient bentonite removal in combination with a trash pump. Per a suggestion from DNR, a clear section of hose was installed which allowed the operator to gauge the amount of bentonite versus water being recovered. The vacuum-type recovery device was made out of steel exhaust pipe with a length of approximately 8 feet. The length allowed the operator to reach the Creek bank and bottom, which had pockets that were over 7 feet deep.
- The creek bottom was dark while the bentonite material was light grey. This allowed the operator to verify that the bentonite was removed down to bottom of Creek and the side of the bank.
- Bentonite/water removal with the vacuum-type recovery device worked well moving upstream or downstream. There was not a lot of turbidity and what little there was cleared quickly and did not flow over the downstream barrieres. The challenge was the bentonite did not easily separate and flow into the intake device. Thus it was required to apply pressure and constantly move the intake device to recover the bentonite.
- A series of 6 transfer pumps were utilized to move the slurry to the upland infiltration pit and were able to run continually without plugging or breakdown. Each transfer station had secondary containment, and all hose connections were wired or locked to provide additional protection. Pump refueling was performed within secondary containment. Bombardiers were initially used to haul the bentonite/water mix to an upland area. This was found to be

inefficient as the recovery pump could not operate continuously. This practice also created an additional risk of spillage at the transfer points.

- The upland area selected for infiltration was within the ROW with a natural berm on two sides. Two additional dikes were constructed on a low side to ensure containment. MPL utilized a recently backfilled trench from the MinnCan Project to act as an infiltration pit. The bentonite/water was pumped into the trench against straw bales with a slight slope to reduce erosion.
- Pilot scale filter testing showed that dewatering the bentonite slurry would be difficult as a sock type filter plugged immediately. During recovery activities, MPL also attempted to pump through a bag type filter in the infiltration pit at 75 gpm; however, the bag filter plugged after one hour of pumping and it was also found to allow some bentonite through the filter. The bentonite material proved to be too fine to efficiently separate from water with a filter material.
- Once the bentonite had dewatered in the infiltration pit, the accumulated bentonite was removed and hauled to an off-site location for re-use in a farm field. MPL staff inspected the off-site disposal site to verify containment within an upland area.
- MPL minimized the size of equipment to provide the least environmental disturbance to wetland and maintain safety near existing buried pipelines. Low ground pressure vehicles, such as a tracked bombardier, were utilized. MPL also utilized a hand-held pump intake device to eliminate the need for a backhoe to hold a larger intake device.
- Development and sharing of a site safety plan prior to work starting helped ensure safety. MPL performed a safety orientation with personnel prior to work starting, with topics including the following: identifying nearest medical facility with directions, wearing personal floatation devices, wearing proper rough service footwear on the ice, cold weather protection, chaps for chain saw use, and hearing protection.

If you have any questions regarding this implementation report, please feel free to call me.

Sincerely,

Mick Hemenway
Minnesota Pipe Line Company, MinnCan Project
Governmental Agency Coordinator
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# Technical Memorandum

**To:** Mick Hemenway, Minnesota Pipe Line Company
**From:** Brian Angerman and Brian Sillanpaa
**Subject:** FINAL - LaSalle Creek Response Activities Work Plan
MinnCan Project, Minnesota Pipe Line Company
**Date:** February 1, 2008
**Project:** 23/19-997 LSCR 002

# Introduction

This technical memorandum presents a work plan for recovering bentonite from the LaSalle Creek frac-out location which occurred during horizontal drilling activities completed as part of the MinnCan pipeline project. The site location is shown on Figure 1. Minnesota Pipe Line (MPL) intends to work closely with the Minnesota Department of Natural Resources (DNR) on an ongoing basis to determine the best method of recovery and disposal of the bentonite material. Therefore, MPL requests that the DNR approve this plan, and any subsequent plans/modifications as necessary, prior to proceeding with the work.

Based on a meeting with DNR staff held January 30, 2007, this memo has been revised to address DNR questions/concerns and represents a final work plan describing the proposed bentonite recovery effort. The following individuals were in attendance at the meeting:

- Cynthia Buttleman, MN DNR, Regional Operations Supervisor, Divison of Lands and Minerals
- Doug Kingsley, MN DNR, Area Fisheries Supervisor, Divionion of Fish and Wildlife
- Paul Stolen, MN DNR, Regional Environmental Assessment Ecologist, Ecological Resources
- Peter Buesseler, MN DNR, Regional Manager, Ecological Resources
- Walter Lundahl, MN DNR, Division of Lands and Minerals
- Mick Hemenway, Minnesota Pipe Line Company, Government Agency Coordinator
- Jim Mattson, Minnesota Pipe Line Company, Project Safety Director
- Brian Sillanpaa, Barr Engineering Company

# Objectives

Although not a contaminant, the bentonite material is considered potentially detrimental to the creek and, therefore, will be removed to the extent practical. However, the objective of the recovery effort is to remove the bentonite utilizing methods that do not create a high degree of disturbance to the creek and surrounding wetland. Recovery options were evaluated based on the following criteria:

- Disturbance to the wetland area and LaSalle Creek
- Risk to the active pipelines, as any damage potential caused by large-scale equipment could result in a release
- Worker safety, as the work will be completed during winter conditions with varying ice conditions/thickness due to flow in the creek

Multiple recovery options were evaluated, but not recommended in this plan, based on concerns with the above criteria. During the January 30$^{th}$ meeting, MPL discussed with DNR staff a potential endpoint/goal for the removal of the bentonite material. It was acknowledged that, removal of all the bentonite is likely not feasible and attempting to do so could result in removal of the natural stream bed, resulting in a higher degree of disturbance to the creek. Therefore, it was agreed that a target endpoint would be to remove the readily available bentonite down to the natural substrate/streambed. It was also acknowledged that, because of the unique circumstances associated with this project, it will be somewhat of a “discovery process”; therefore, it’s difficult to state at this point in time just how effective the overall recovery effort will be.

If additional options or enhancements are necessary, MPL will continue to work closely with DNR staff to address potential risks associated with the above criteria. Depending on the effectiveness of the recovery effort and the volume of bentonite material remaining, removal of a downstream beaver dam was discussed as a potential option for increasing the flow velocity in the creek to remove and disperse the material.

# Background Information

Background monitoring has been performed to characterize the existing conditions of the creek. Field observations of the two frac-out locations (designated as the South and North Areas) and approximate bentonite thickness are shown on Figure 2. Based on the preliminary field observations, the following baseline assumptions are made:

- The South Area encompasses approximately 300 feet of the creek. In this area, the thickness of bentonite varies from 12 to 32 inches.
- The volume of water in the South Area is approximately 51,000 gallons based on an average depth of 3.5 feet and an average width of 10 feet with 1:1 side slopes.
- The total in-place volume of bentonite in the South Area is 100 cubic yards.
- The North Area encompasses approximately 100 feet of creek. In this area, the thickness of bentonite varies from 1 to 18 inches.
- The volume of water in the North Area is approximately 28,000 gallons based on an average depth of 5 feet and an average width of 10 feet with 2:1 side slopes.
- The total in-place volume of bentonite in the North Area is 15 cubic yards.

# Bentonite Recovery

A pilot-scale study was completed to develop and test potential recovery equipment and possible treatment techniques. The pilot study was designed to simulate the conditions in the creek and was completed using bentonite material supplied by the driller.

Completion of the pilot study suggests a vacuum-type recovery device operated with a small trash pump could produce the desired results. A high-end flow rate for the equipment is estimated at 50 to 100 gpm. The vacuum-type recovery device utilizes low-suction pressure at the inlet to prevent large amounts of natural streambed material from being removed, yet will be effective at capturing the bentonite material. The intake device will be fitted with a screen to prevent removal of rocks and natural material. Photos of the pilot-study equipment and testing are provided as Attachment A. As suggested, a translucent intake device will be considered in order to assess the solids content of the slurry mixture during recovery.

In order to minimize the overall impact to the creek and surrounding wetland environment, MPL proposes to use small scale equipment that can be handled and maneuvered manually (limit the number of swamp mats required and also minimizes risk to the active pipelines in the area). Access and equipment transport to the site will be provided using a tracked bombardier and cargo box operated within the existing pipeline right-of-way.

Access holes in the creek will be cut using a new chainsaw that does not contain bar oil. A 'dark house' type structure will be placed over the access holes in order to enhance the visual capability of the operator. Operation of the recovery equipment will be performed in a manner that limits, to the degree possible, the amount of turbidity created during active recovery. Recovery activities will likely start on the downstream portion of each impacted area and progress upstream. Spacing of the access holes will be determined in the field based on the observed effectiveness and reach of the recovery equipment.

During active recovery, monitoring will be conducted at the furthest downstream weir of the work area. It was acknowledged during the January 30th meeting with DNR staff that some turbidity/bentonite solids may migrate over the top of the containment weir during the recovery effort and that coming up with a quantitative measure and/or standard governing this flow is not feasible. Rather, the effectiveness of the recovery effort will be based on a qualitative measure of the solids being recovered versus the turbidity of flow exiting the work area. Based on this evaluation it will be determined if the recovery methods being used are considered effective or should be stopped and further modified/enhanced prior to proceeding.

Once the recovery efforts have been completed to the extent practical and creek has been inspected and approved by DNR staff, the containment weirs will be removed and the natural flow of the creek returned to normal. As previously stated, if the natural stream flow is not sufficient at dispersing any remaining bentonite residual, removal of the downstream beaver dam will be considered and discussed with DNR.

## Materials Handling

As discussed, a pilot scale study was completed to develop and test potential recovery equipment and potential treatment techniques. Use of a bag filter was tested for treatment of the recovered bentonite water slurry. Results of the pilot scale study (see Attachment A for photos) showed that filtering the material will be difficult due mainly to the fact that the small size of the bentonite particles requires a small filter opening, thus causing frequent plugging. Also, due to the recovery method (i.e., pumping) the bentonite/water mixture will likely become highly emulsified, likely resulting in some percentage of solids passing through the filter media. Due to the unknown effectiveness of the filter process it was determined that onsite discharge of the filtrate could be problematic from an ecological standpoint. Also, an onsite discharge would require additional consultation and potential permitting by the Army Corp of Engineers, the County Soil and Water Conservation District, and the MPCA. In terms of schedule, this could significantly delay completion of the work which, if completed this winter, would minimize impact to the creek and disturbance to the surrounding wetland. Therefore, as discussed during the January 30th meeting with DNR staff, MPL will attempt to pump the bentonite slurry mixture to an upland area where it can be safely loaded into a vac-truck or tanker for application to agricultural land offsite in accordance with an existing contract with the landowner. This will involve utilizing a series of small tanks and pumps as "lift stations" in order to convey the material to an upland area for further transportation. To reduce the number of lift stations, MPL will likely incorporate the use of a small tank within the bombardier for some portion of the transfer. If dilution of the recovered material results in higher then anticipated volume, this disposal method may need to be revaluated and further discussed with DNR staff.

As discussed with DNR staff, the bentonite materials located outside of the creek in the surrounding wetland will be removed to the extent possible using hand tools and also disposed offsite. The silt fence material will be left in place for now and inspected in the spring, at which point some additional bentonite may be recovered if necessary prior to removing the silt fences.

## Regulatory Permitting and Approvals

In conjunction with the MinnCan Project, the following permits have been obtained by MPL:

- Major Modified NPDES/SDS Permit 56472
- Water Appropriation General Permit dated December 12, 2007, for activities relating to frac-out response in LaSalle Creek

It is assumed that the above permits for the MinnCan project cover the activities described in this work plan, and that DNR approval of this plan acknowledges that additional permitting is not necessary.

## Site Safety

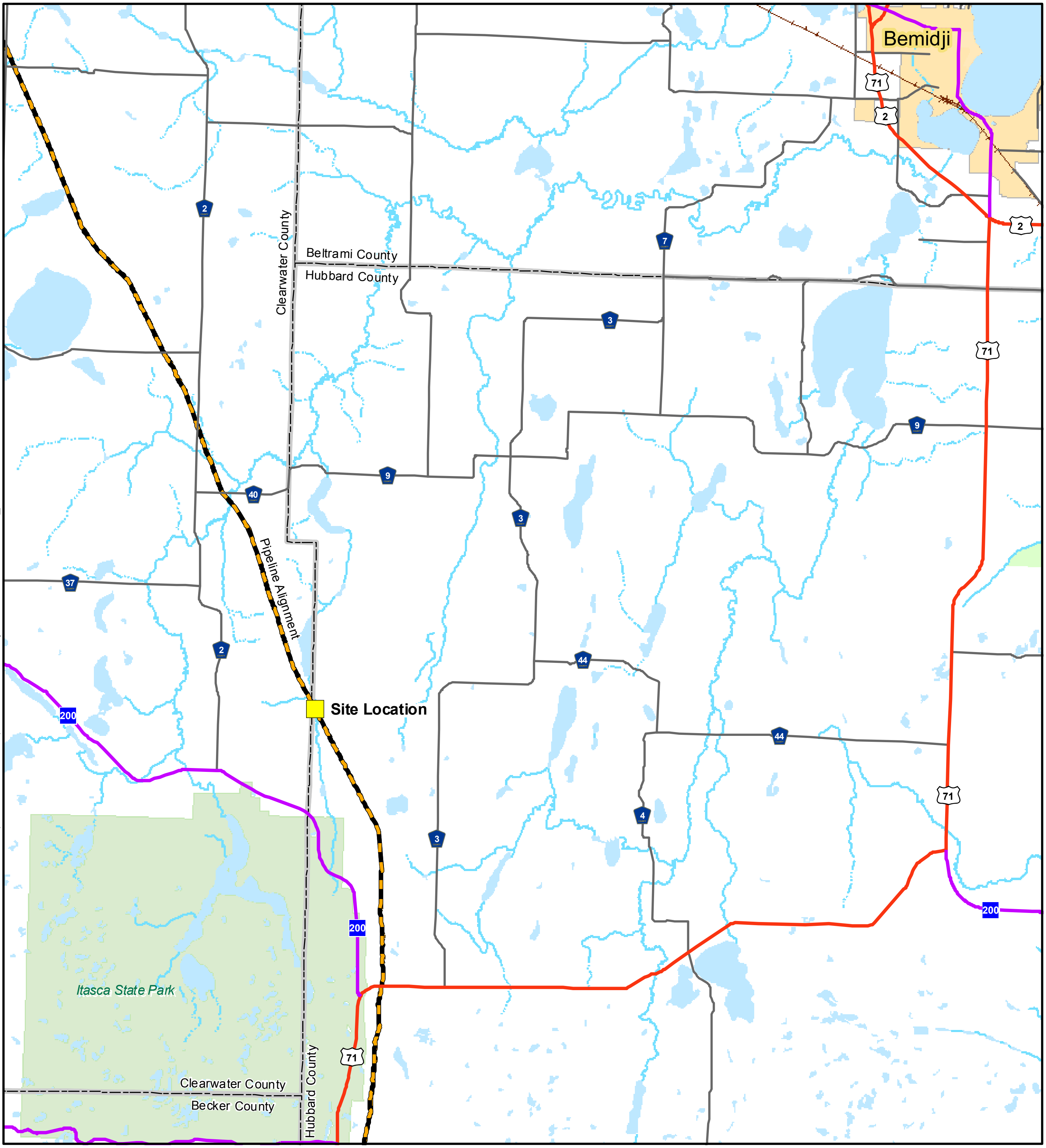
As previously discussed, a primary concern is the use of equipment over the existing pipelines, as any damage to the lines could result in a pipeline failure and have serious impacts to the environment and worker safety. MPL plans to minimize activity around the existing pipelines to the extent possible.

Work completed as part of this plan will be performed in accordance with the MinnCan Project health and safety program. All personnel will be required to attend training prior to working onsite. Personal protective equipment (PPE) shall be worn in accordance with the MinnCan health and safety program, with additional PPE for winter conditions and working in a wetland area. Due to the unstable nature of the snow and ice in the wetland area, the “buddy system” will be employed for all personnel within the wetland area. Full-scale recovery activities are currently planed for daylight hours only. If winter conditions require a more aggressive schedule, additional safety issues will be considered.

## Schedule and Reporting

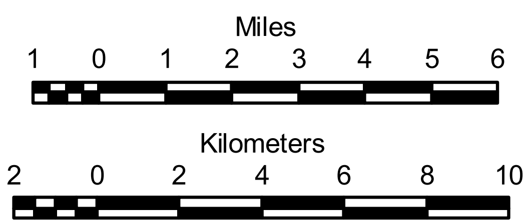
MPL is tentatively scheduled to begin recovery activities the week of February 4, 2008, pending DNR approval of this work plan. Written authorization to proceed is requested by February 4, 2008. It is anticipated that the project duration will be three to four weeks, including mobilization and demobilization. Within that timeframe, it is anticipated that there will be approximately three weeks of recovery operation.

MPL anticipates frequent communications with the Agency Monitor during this time, and will provide updates at a minimum of every 48 hours. If any significant changes in the process are considered, the changes will be discussed with the Agency Monitor and/or DNR prior to implementation. At the conclusion of this project, MPL intends to submit a report to DNR summarizing recovery activities and completion of the work in accordance with this work plan and any subsequent DNR communications.





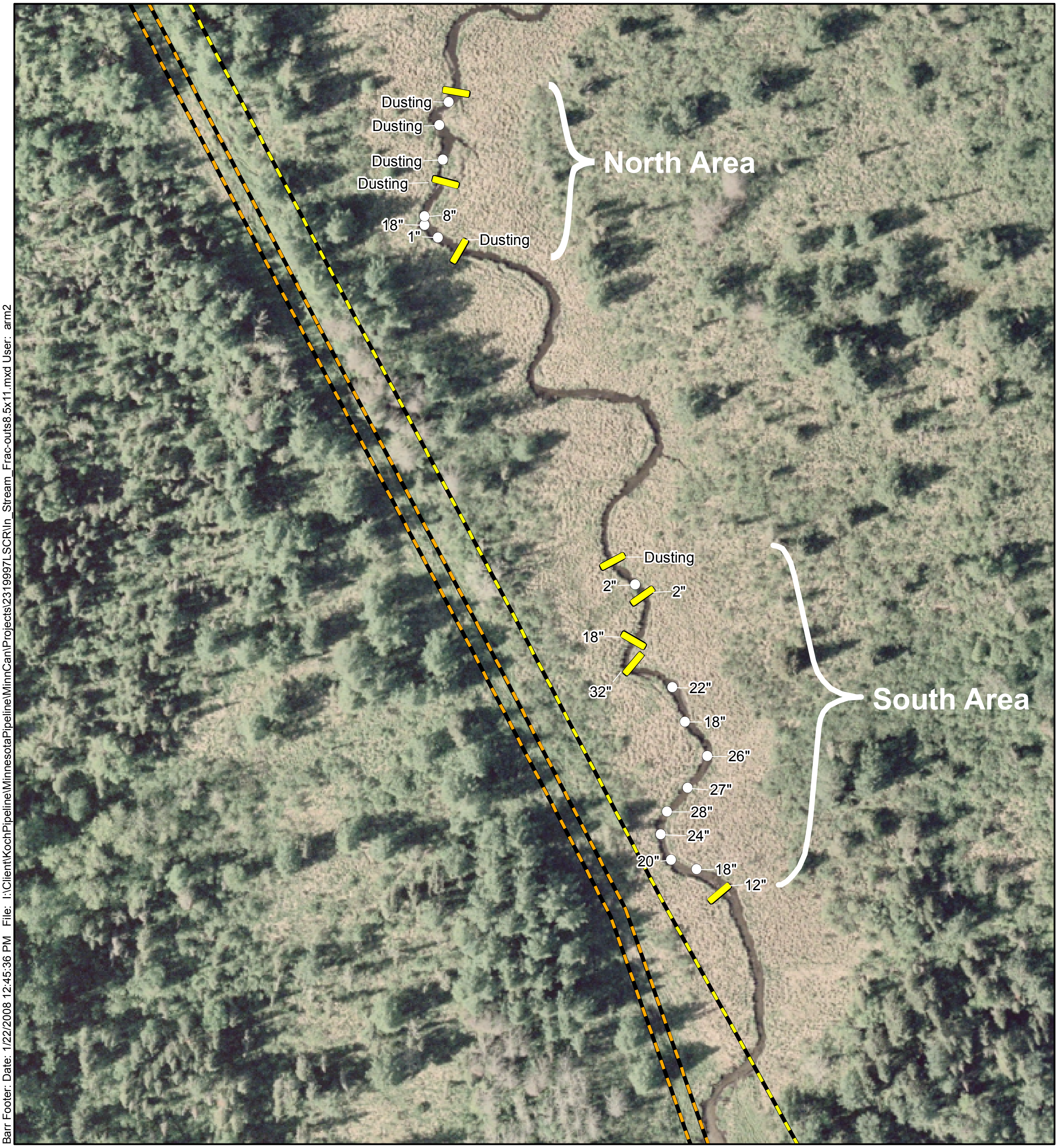





BARR

Figure 1

SITE LOCATION
LaSalle Creek
MinnCan Project




Observation Site
Silt Barrier
Existing Pipeline Alignment
MinnCan Pipeline Alignment

Feet
60 0 60 120 180 240

Meters
20 0 20 40 60

BARR

Figure 2

SITE MAP
LaSalle Creek
MinnCan Project

***Attachment A***


6060


FIRE
EXTINGUISHER
260574


WASTE
OIL
ONLY


EXTINGUISHER


EXIT
FIRE
EXTINGUISHER

# FRIENDS OF THE HEADWATERS
**RESPONSE TO THE MINNESOTA DEPARTMENT OF COMMERCE**
**LINE 3 DRAFT EIS - Dockets CN-14-916, PPL-15-137**
**JULY 10, 2017**

***ATTACHMENT "G"***

**G-1 RRVWNA Drake Letter**

*John Drake, PHD, National Center for Ecological Analysis and Synthesis, Santa Barbara, CA, letter to Paul Stolen regarding the proposed Surface Water Diversion Project between the Missouri River Basin and the Red River of the North in North Dakota*

National Center for Ecological Analysis and Synthesis
735 State Street, Suite 300
Santa Barbara, CA 93101
21 March 2006

Paul Stolen
Minnesota Department of Natural Resources
2115 Birchmont Beach Road NE
Bemidji, MN 56601

Dear Paul,

Thank you for bringing to my attention the recent report *Risk and Consequence Analysis Focused on Biota Transfers Potentially Associated with Surface Water Diversions Between the Missouri River and Red River Basins* by Greg Linder et al. (July 2005). This is an ambitious report, which is admirable. I believe such a comprehensive risk analysis for introductions of multiple species has not previously been attempted. Unfortunately, while the intended scope of this project is commendable, it overreaches and fails to deliver satisfactory answers to a number of important questions. In what follows, I try to address the questions you raised, followed by some additional concerns of my own.

1. **What is this study, since it appears not to be an ecological risk assessment? Page 1-7 explicitly states "USGS/CERC did not conduct an ecological risk assessment"**

In the EPA "Guidelines for Ecological Risk Assessment" a distinction is drawn between *risk assessment* and *risk analysis,* in which risk analysis is the scientific component of risk assessment. The other two components are prior problem formulation and (after analysis is complete) risk characterization. In section 1.3.2 the authors report that problem formulation was conducted, but do not report in detail how this step was conducted, which is not the purpose of this document. Accordingly, it is not possible to evaluate the appropriateness of the current problem formulation based on this report (*i.e.*, endpoints, conceptual models, etc.).

Before risk assessment will be complete, risk characterization must also occur, including risk estimation, risk description, development of alternative scenarios, and evaluation of evidence and uncertainty. In order to be viable, such a process should be well documented, transparent, and available for public comment as this is the stage where the relationship between the probabilities of hazards being realized and society's aversion to risk is determined.

2. **How can it be a risk analysis if it doesn't address the possible failure of the proposed biota treatment plant?**

Risk analysis must take into consideration any possible failures envisioned during the stage of problem formulation. This underscores the importance of integrating the different components of a risk assessment. Certainly it is acceptable to treat any possible component of failure as a "black box" or in some qualitative way. However, this judgment must be made transparent and is open to criticism. If the present risk analysis fails to consider the possible failure of technological components of the system (*e.g.*, failure of the treatment plant) or sets the probability of failure to zero, then problem formulation must be revisited. I find it inconceivable that a proposed technological solution (*e.g.*, treatment plant) should be assumed completely reliable (no engineered system is ever completely reliable). Indeed, I hope that before installing any technology there would be an independent comprehensive effectiveness analysis of proposed systems. My experience with technologies for reducing potentially invasive species in ships' ballast tanks inclines me to think that effective solutions will be extremely costly, possibly prohibitive. I believe these costs should be incorporated in any cost-effectiveness or cost-benefit analysis for the diversion project as a whole.

Given that research and development of technologies for treatment may yet not be completed, an alternative is to perform risk analysis along a range of possible failure rates for a hypothetical treatment technology. A cost-benefit analysis could be performed on this basis and a minimal cost-effectiveness tradeoff could be identified which would set a minimal standard for R&D to achieve, *i.e.*, on the basis of prospective analysis it could be determined that the ratio of economic cost to effectiveness (in terms of water quality standards, system down time, and other metrics) must be below some threshold to be acceptable. Such an approach would be defensible from the risk analysis standpoint while not relying on nonexistent data (*i.e.*, technology failure rates, which presumably are unknown).

3. **What other decision tools and analyses should be performed to improve this risk analysis?**

The assessment of uncertainty is insufficient throughout this study. Risk analysis must make very clear the potential sources of error in projected scenarios. Sometimes the focus of risk analysis on inherently unpredictable events (in the technical jargon, stochastic processes) obscures other sources of errors that must be assessed. These errors include estimation uncertainty of the ordinary statistical variety; uncertainty concerning the choice and structure of models used for making forecasts; uncertainty about extrapolation beyond observed values or from past experiences into the future; and uncertainty concerning the data used for model selection and estimation, particularly that they are representative. Additionally, supporting sensitivity analysis should be conducted for all analyses and reported in order to allow to decision makers to weigh the importance of different modeling assumptions.

The risk maps for invasion of New Zealand mud snail, zebra mussel, etc. are just one example of the failure to adequately estimate and represent uncertainty. These maps were produced using the genetic algorithm for rule-set production (GARP). Despite its faults (which are known and documented in the scientific literature) GARP is one of the most sophisticated tools for potential range mapping currently available and I recommend its use for risk analysis. It is important to realize, however, that the output gradient of the algorithm reflects only the uncertainty that the algorithm has identified the model that it intended to identify (*i.e.*, the model with the greatest ability to discriminate observations of species presence from places where species have not been collected). It does not represent any uncertainty associated with the correct selection of habitat variables, estimation from a finite data set, appropriateness of the set of models considered, etc. How sensitive these projections are to the choice of habitat variables is evident in an analysis I previously performed in which GARP was used to estimate zebra mussel distribution (Drake, J.M. and J.M. Bossenbroek. 2004. Bioscience 54:931-941). This analysis found that it was difficult to identify spurious predictors of habitat and that changing the set of habitat variables had a large effect on the outcome. I believe it is appropriate to continue using GARP for such analyses while we await development of technologies that overcome these limitations, but it is crucial that thorough sensitivity analysis be performed. It is too easy to misinterpret the stochastic output of the GARP algorithm as representing model uncertainty. Particularly, the percentage values associated with GARP-based risk maps should not be interpreted as probabilities of habitat presence.

As I mentioned earlier, the ambition of this analysis is proportionate to the magnitude of the decision under consideration to complete the diversion. In my view, the comprehensiveness of the analysis should be equally extensive. Other analyses that should be performed are:

(1) Better estimation of failure rates for different components of the treatment system (preferably based on experimentation);

(2) Bioeconomic analysis of system failure on markets for natural products or services derived from the Red River basin;

(3) Assessment of the risks of species transfer from Red River basin to the Missouri River basin (Note: Due to the direction of flow these would be extremely rare, but, because of connections between the Missouri River and Mississippi River basins, have the potential for extensive impacts; these kind of low-probability high-impact assessments are notoriously difficult);

(4) Non-market evaluation of the impact of system failure on environmental services, threatened and endangered species, and cultural activities within the basin;

(5) Legal and ethical analysis with respect to the relocation of species and causing new threats to native organisms;

(6) Forecasts of the effects of introduced species on physical properties of affected ecosystems (some species, such as carp, can affect whole ecological communities, not just individual species, by physically altering environments to which they are introduced);

(7) Cascading effects on lake food webs of potentially introduced pathogens and predators;

(8) Explicit analysis of the potential effects of zebra mussels on this system should be performed, particularly if there is any underwater infrastructure within the basin as this has been one of the most costly consequences of zebra mussels in the Midwest United States (Leung, B., et al. 2002. Proc. R. Soc. Lond. B 269:2407-2413) (Note: zebra mussels generally spread during a planktonic larval stage and the effectiveness of water treatment technologies would therefore be crucial to preventing their spread).

Obviously, such analyses represent numerous disciplines and a range of biologists, ecologists, engineers, statisticians, economists, and anthropologists would need to be consulted for an adequate assessment.

4. **Should this BRA receive an independent review, given its apparent breaking of "new ground"?**

It is my opinion that this risk assessment attempts to be the most comprehensive invasive species risk analysis to date. While invasive species risk analysis should be a part of any decision process and environmental impact assessment in which species translocations may result, this analysis would set a poor precedent for thoroughness and transparency. I strongly urge independent peer review.

5. **Is a 50 year time frame appropriate for a risk analysis of this scale? Are range expansions inevitable, such that even without the diversion project the Red River basin will soon be invaded by species of concern?**

Generally, environmental risk analyses presume much longer time frames than 50 years (*i.e.*, thousands to millions of years), particularly when hazards to human health are involved (*e.g.*, Committee on Technical Bases for Yucca Mountain Standards, National research Council. 1995. *Technical Bases for Yucca Mountain Standards*. National Academy Press: Washington D.C.). Arguments for and against these timeframes usually turn on a tension between bioeconomic arguments in which economic discounting devalues events in the moderate to distant future versus ethical arguments concerning rights of and duties to future generations and/or the natural environment that inflate the costs of such hazards. From the strictly economic standpoint, 50 years is probably sufficient as future value beyond this point will be small. However, it is important to underscore that invasive species are increasingly recognized to have effects on systems of natural and human production (*e.g.*, fisheries) and should therefore be viewed as investments with recurring and future (compounding) returns. Invasive species are also increasingly recognized as reservoirs, vectors, or indirect drivers of disease transmission in both wildlife and humans, including in aquatic ecosystems (*e.g.*, the probable link between zebra mussels and type E botulism).

In my view, range expansions of presently invading species are extremely likely but strictly speaking not inevitable. Given current levels of funding for invasive species management and control, reversing invasions of any but the most recent introductions is impossible. However, it is important to recognize that slowing a range expansion (*e.g.*, the slow-the-spread project for gypsy moths) can represent a substantial net economic benefit even if the program is quite costly. This is the other side of economic discounting. If invasion can be delayed, future economic damages can be considerable reduced from the standpoint of present value.

Further, it is important to note that introduction pathways are generally independent and therefore at least additive. Thus, the presence of a background introduction rate does not obviate the effects of a new pathway (in this case the diversion project), which will contribute to effects proportionally. In numerical terms, this means that if the rate of introduction is doubled by the addition of a new pathway, the expected time to invasion is decreased by half. Moreover, many species of interest will exhibit a nonlinear collective phenomenon referred to as the Allee effect which results in an acceleration of risk with the rate of introduction. In these cases, a doubling of the introduction rate results in a reduction in the expected time to invasion by more than half. Notably, this effect has already been documented for zebra mussels (Leung, B. et al. 2004. Ecology 85:1651-1660).

## Conclusion

In my view, this report is an ambitious attempt to perform risk analysis for invasive species. If successful it would represent an important precedent for future projects. While this report's attempt at comprehensiveness is admirable, it ultimately fails to address some important questions while the questions it does address have not been sufficiently thoroughly researched to draw definite conclusions. A fuller analysis would have considered a greater range of scenarios (particularly with respect to failure of the proposed treatment facility and to consequences of invasions) and would attempt to thoroughly identify sources of uncertainty and estimate its magnitude. Probably the assistance of a wider variety of experts will be required for an analysis complete enough to adequately characterize risk of biotic transfer.

As a compilation of current knowledge about the risk of biotic exchange due to water diversion between the Missouri and Red River basins, this report is undeniably comprehensive. The problem is that this knowledge is currently quite limited. Of course, whether this knowledge is required to make a decision depends on legal and political contingencies that go far beyond this risk analysis itself. The point is just that based on this report one cannot conclude that biotic transfer is either likely or unlikely and what the associated economic and environmental consequences would be. Undoubtedly this is because the study itself was under funded compared with its goals, a reflection on the devaluation of information necessary to make informed decisions of environmental consequence generally.

Sincerely yours,

John M. Drake, Ph.D.

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(Affiliation is for identification purposes and contact information only. The opinions expressed in this letter are my own and do not necessarily reflect the position of my organization.)

# FRIENDS OF THE HEADWATERS
**RESPONSE TO THE MINNESOTA DEPARTMENT OF COMMERCE**
**LINE 3 DRAFT EIS - Dockets CN-14-916, PPL-15-137**
**JULY 10, 2017**

***ATTACHMENTS “H”***

## H-1 Stolen - Risk & Consequences

*Paul Stolen Letter to:*
*Commissioner Mike Rothman, Minnesota Department of Commerce*
*Ken Westlake, Regional NEPA Contact, USEPA*
*Tamara Cameron, Chief, Regulatory Branch, USACE*

*Re: Proposed Enbridge Sandpiper and Line 3 Enlargement/Relocation/Abandonment projects in Minnesota: “Policy and technical reasons for independent, scientifically sound analysis of the risk and environmental, cultural, and human consequences of oil releases for the 50+ years of the project.”*

## H-2 DHS Solar Magnetic Storm Impact on Control Systems

*Department of Homeland Security Report “Solar Magnetic Storm Impact on Control Systems” Revised Jan 2014*

## H-3 AC Corrosion HV Power LIne Cathodic Protected Pipeline

*CEIT’14 Report “AC Corrosion Induced by High Voltage Power Line on Cathodically Protected Pipeline*

August 29, 2015
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218-435-1138

Michael Rothman, Commissioner
Minnesota Department of Commerce
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Tamara Cameron,
Chief, Regulatory Branch
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Regional NEPA Contact
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Chicago, IL 60604-3507

Re: Proposed Enbridge Sandpiper and Line 3 Enlargement/Relocation/Abandonment projects in Minnesota: *Policy and technical reasons for independent, scientifically sound analysis of the risk and environmental, cultural, and human consequences of oil releases for the 50 + years of the projects*

Dear Commissioner Rothman, Ms. Cameron, and Mr. Westlake:

I am writing this letter because two large industrial oil facilities are planned for a Minnesota landscape highly susceptible to oil releases. This landscape contains highly valuable natural and cultural resources, many of which are in inaccessible locations. . But even more concerning, they are being planned, to-date, *without adequate independent review by any government entity.* The topic of this letter is the portion of the independent review I refer to in the topic line of this memo: *independent, scientifically sound analysis of the risk and environmental, cultural, and human consequences of oil releases for the 50 + years of the projects.*

I am writing you at this time because crucial and as-yet unmade policy decisions are sorely needed on these two pipeline projects. Such decisions are past due. As I describe below, Minnesota agencies are currently not yet taking the proper approach to this subject. *I am thus urging that you collectively implement a coordinated state-federal policy that results in the proper science-based review of the two Enbridge pipelines with respect to the risks and impacts of oil releases.* And it is simply bad government to not coordinate federal and state reviews. The federal government, especially the Environmental Protection Agency, has more experience supervising the type of studies I am recommending. The model for such studies are contained in the three studies in Item 3 of Attachment 1 of this letter. I note that all of them were instigated by federal agencies.

I have the credentials for speaking about this topic. I worked for over 30 years on environmental policy and on the review of the potential impacts of many kinds of projects. This included numerous energy projects, and the review of about 12 pipeline projects—natural gas, carbon dioxide, crude oil, and water pipelines. (A short bio is included at the end of Attachment 1.) I am also familiar with risk assessment methods and with interstate and cross-border projects. I helped coordinate many reviews of projects with overlapping federal and state jurisdiction and permits. Such coordinated reviews simply reflect good government practice, but they are also written into regulations to some extent.

The three addressees of this letter are individuals who have the legal and policy authority to make decisions about the depth of technical analysis as well as locations of alternatives routes to be studied for the two proposed Enbridge pipelines. This is the level where policy, law, and regulations are interpreted and subsequent directives given to technical staff. Both the Clean Water Act and the National Environmental Policy Act provide this authority, and require that reasonable alternatives that have less potential impact be studied. And the US Fish and Wildlife Act *requires* federal consultation with the state fish and wildlife agency with respect to impacts of a project. This agency is the Minnesota Department of Natural Resources.

I am a copying key federal and state decision-makers with this letter. This includes the US Fish and Wildlife Service, and three State of Minnesota agencies—the Department of Natural Resources, Pollution Control Agency, and Department of Health. I have also included public participants who have been deeply involved and concerned about these projects. The other four agencies have the statutory ability to insist that the three addressees of this letter authorize the type of studies that are needed, and to insist that alternative routes through less sensitive landscapes be included in the analysis.

I have looked at the draft proposed contents of the Department of Commerce Comparative Environmental Assessment for the Sandpiper project (and cumulative impacts of Line 3.) "Worst-case" risk is mentioned only in passing. This is completely inadequate and, if pursued as proposed, will neither result in a proper risk assessment nor consequence analysis. It will not result in proper comparison of routes because alternative routes through landscapes less susceptible to damage from oil spills and that are more accessible are not being included in the analysis.

Up to now, it appears that Minnesota agencies contemplating permits for proposed new oil pipelines have never previously considered potential impacts of oil spills. Nor have they considered the cumulative impacts of adding new and ever larger pipelines alongside old and small pipelines permitted long before modern environmental laws were created—*even though Minnesota environmental law and regulations require that this be done.* Given this woeful lack of study, It is not surprising that existing pipeline corridors are given automatic preference.

The two Enbridge projects apparently are still being treated by Minnesota agencies as if they are relatively routine pipeline projects. As if there are no better landscapes than where old pipelines were originally routed. As if the chances of pipeline rupture and serious leaks are only theoretical events that happen in other states or countries. *As if selecting pipeline routes that all cross environmentally sensitive, difficult landscapes does not bias the outcome of a comparison of routes with respect to human, environmental, and cultural impacts.* I believe that this is not because of ill intent by state employees—rather it is because of lack of policy analysis and coordination, and lack of understanding of risk and consequence analysis methods for large industrial oil facilities. This is why I believe that federal assistance on the complex topic is needed.

*Attachment 1* provides the technical reasons why the studies I am recommending must be accomplished for these two projects. For example, In recent weeks, the new Nexen pipeline in Canada recently ruptured and apparently leaked for weeks in spite of sophisticated new automated control systems. The Keystone 1 pipeline in Missouri, built in 2009, *suffered extreme and unexpected corrosion only three years after installation.* An internal report commissioned by the pipeline company found that this was caused by stray voltages. The result was deep corrosion pits that nearly ate through the pipeline wall. And time and time again, pipeline management failures have caused serious spills or explosions that caused loss of life.

Furthermore, there are even some indications that new technologies, new engineering complexities, and sophisticated control systems may even introduce new risks and causes of pipeline failures. These two Enbridge projects, costing billions of dollars, are technically complex industrial facilities, and will be remotely monitored and controlled from a high-tech, satellite-connected control center 1,000 miles away in Canada. Such control centers are the subject of a 2014 Department of Homeland Security warning that they can fail or result in false pipeline pressure readings from the effects of solar storms.

*Attachment 2* contains descriptions of two specific areas extremely vulnerable to very damaging oil releases. These are: 1. The LaSalle Creek Valley, with its lakes north of Itasca Park, and the short distance to the Mississippi river; and 2. Upper and Lower Rice Lakes in southern Clearwater County. Both areas have very extensive and important wetlands, as well as highly valued public and cultural natural resources. *Should a significant release occur at the pipeline river crossings at these sites under certain normal conditions, oil recovery would likely be very difficult or impossible, recovery efforts would add to the damages, and human and natural resource impacts could occur for generations into the future.*

I am not claiming the Enbridge pipelines will certainly rupture and severely damage Minnesota's human and natural environment. But they will be in place for 50 or more years. I am *merely* saying an independent, appropriate, and thorough analysis be done of the risk and consequences of such events. *This is an eminently reasonable request, based in law, regulations, and common sense.* And I expect that route alternatives be included in the study that cross landscapes inherently less prone to damage from oil releases and more prone to easier clean-up. In fact, in my 30 year career doing environmental review—sometimes of complex projects—I have never encountered a situation where such large projects are not thoroughly and independently reviewed in this manner. *Ever.*

Of course, I am not a lawyer, but I have lots of policy experience, including interpreting the policy implications of court opinions and providing direction to other staff. I am reminded of a project I was deeply involved in where a federal judge made a statement quite appropriate to the current Enbridge situation. It was a proposal from the state of North Dakota to move Missouri River water into the Hudson Bay drainage, and was one of two such projects under consideration. Such proposals have lots of potential problems, including policy problems. The Bureau of Reclamation had only done an Environmental Assessment on one of the projects, known as "NAWS." They had dismissed adverse effects from introducing damaging biota across the Continental Divide into the Hudson Bay basin during the transfer. They were hoping to do the same with the other project. Manitoba sued, asking for an Environmental Impact Statement.

In an opinion admonishing the error of the Bureau of Reclamation, one could almost replace Judge Collyer's reference to "biota" with "risk and consequences of oil releases":

*"Federal Defendants argue that the risks of leakage are low and, therefore, that no further study is necessary.. . . "What may seem minor in terms of percentages may be substantial in net effect. . . . Therefore, even a low risk of leakage may be offset by the possibility of catastrophic consequences should any leakage occur. Without some reasonable attempt to measure these consequences instead of bypassing the issue out of indifference, fatigue, or through administrative legerdemain, the Court cannot conclude that BOR took a hard look at the problem."* (My emphasis added.) (United States District Court for the District of Columbia, Government of the Province of Manitoba, Plaintiff, v. Gail A. Norton, Secretary, United Stated Department of the Interior, et al., Defendants. Civil Action No. 02-cv-02057 (RMC) February 3, 2005.

I have in the past served as a technical consultant to Friends of the Headwaters, a citizens group advocating a more suitable route for these projects. Technical testimony I prepared was submitted by this group during the early rounds of hearings on the Sandpiper project. This current letter is my own, and has not been reviewed by that organization. For those who seek motives behind this letter, mine is simple and uncomplicated: I am profoundly concerned that these very large projects could greatly damage Minnesota's environment during the more than 50 year project life. My career experience with pipelines and other very large projects also drives this concern.

Thank you for your consideration, and please give me a call if you have any questions.

Sincerely,

Paul Stolen

Paul Stolen

C: John Linc Stine, PCA Commissioner
Tom Landwehr, DNR Commissioner
Will Seuffert, Minnesota EQB
Joe Plumer, Counsel, White Earth
Richard Smith, Friends of the Headwaters
Steve Schulstrom, Carlton County Land Stewards
Craig Sterle, CCLS
Bill Grant, Department of Commerce
Willis Mattison
Bill Sierks, MPCA
Tom Melius, US Fish and Wildlife Service
Dr. Edward Ehlinger, Commissioner for Health
Kathryn Hoffman, Counsel, MCEA
Jerry Von Korff, Counsel for Carlton County Land Stewards
Molly Pederson, Governor Dayton's Office
Randall Doneen, MDNR
Winona LaDuke, Honor the Earth
Paul Blackburn
Todd Moilanen, Mille Lacs Ojibway Band

**ATTACHMENT 1**

**Enbridge Sandpiper and Line 3 Enlargement/Relocation/Abandonment projects**
**Policy and technical reasons for independent, scientifically sound analysis of the risk and environmental, cultural, and human consequences of oil releases for the 50 + years of the projects**

1. Lack of study to-date. No study of the Enbridge Sandpiper and Line 3 proposals has yet been done by any government agency of Minnesota--or any federal agency--of the risk of oil releases and consequences to natural resources and to people from such releases. There may be an assumption that the decision to do such a study is connected with the decision to do an EIS. The need for a state EIS is under litigation, and the need for a federal EIS has been recommended, but not yet decided. A proper risk and consequence analysis of oil releases is needed to determine where to locate the pipelines, is also needed for proper environmental permitting and any other public interest decision. It is not dependent on the decision to do an EIS.

2. Recent (since about 2009) very large and damaging pipeline accidents and ruptures have changed how risk assessments are conducted and demonstrated why they are needed. These events, and subsequent studies, all have occurred after the last two large Enbridge projects were permitted in Minnesota (Alberta Clipper (now Line 67) and Southern Lights.) These events caused extreme damage to natural resources, loss of life, and have demonstrated lack of adequate federal oversight of pipeline regulations. They have demonstrated appalling failures of those managing the pipelines, and ensuring their integrity. Some of the events include the Enbridge oil pipeline rupture in Michigan, the San Bernadino gas pipeline explosion in California, the two recent river pipeline ruptures in the Yellowstone River riverbed. In addition, there are two 2015 incidents with new pipelines specifically described below in Items #5 and 6. These events have led to recent studies of pipeline oil release risk and consequence analysis that are much more rigorous than studies done prior to 2009. Some are described in Item #3 below. *(See Sandpiper hearing record before the Minnesota PUC.)*

3. Keystone XL Environmental Impact Statement studies, as well as other recent studies provide sound guidance for conducting the proper risk and consequence studies. Excellent studies of the risk and consequences of oil releases from pipeline ruptures and leaks were recently completed for the Keystone pipeline. Another excellent study was done recently by the Oak ridge National Laboratory. It contained highly useful methods of determining potential costs of pipeline ruptures and damage to natural resources. These studies were accomplished even though natural resources—a surface and groundwater resources—along the Keystone route are of less magnitude and extant than those found along the Enbridge proposed route. The three main studies that can be used as a rough model are:

--"Third-Party Consultant Environmental Review of the TransCanada Keystone XL Pipeline Risk Assessment" Exponent, 1800 Diagonal Road, Suite 500 Alexandria, VA 22314 April 26, 2013

--"Keystone XL Pipeline: Independent Engineering Assessment – Final Report" December 2013. Energy Systems, Battelle Memorial Institute, 505 King Avenue, Columbus, OH 43201

"Studies for the Requirements of Automatic and Remotely Controlled Shutoff Valves on Hazardous Liquids and Natural Gas Pipelines with Respect to Public and Environmental Safety." October 2012. Prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6283, managed by UT-Battelle, LLC for the U.S. Department of Energy.

4. Forecasts of new pipeline failures over a 25 year period contained in the Bristol Bay EIS on Pebble Mine. There are three pipelines in support of this proposed Alaska mining project. The final EIS indicated the probability of large rupture under several scenarios over the 25 year life of the project. It found that the chance of rupture ". . . .would exceed 25%, 30%, and 67% . . . .. . (and) In each of the three scenarios, there would be a greater than a 99.9% chance that at least one of the three pipelines carrying liquid would fail during the project." (*See January 2014 Final EIS release, Chapter 11, pipeline failures.*)

5. July 2015 rupture of the new Nexen Pipeline in Alberta. This double-walled pipe was carrying a mixture of hot tar sand oil and water. Over 31,000 barrels leaked out into wetlands, and, in spite of a new automatic monitoring system, the rupture might have gone undetected for as long as two weeks (*See Toronto Globe and Mail article on Nexen Pipeline, July 23, 2015.*)

6. Deep corrosion in only three years of the new Keystone 1 pipeline in Missouri. This pipeline, built in 2009, was found in 2012 to have developed deep corrosion pits at sites in Missouri. According to an internal report prepared for the company, and inadvertently made public, these pits had corroded almost through the pipeline wall in only three years, and were caused by stray electrical voltage. This was in spite of modern, high-tech and cathodic protection coatings similar to those used by Enbridge, which are touted as sufficient to protect against such corrosion. A possible cause of such rapid erosion is discussed in Item #7 below. (*Note: See available on the web: TransCanadaKeystone Root Cause Report_ Feb 15 ver1docx _2_.pdf; a confidential report prepared for TransCanada Pipeline Company that was inadvertently put into the public record of the South Dakota Public Utility Commission.*)

7. Pipelines are subject to rapid corrosion in certain conditions of exposure to electric fields that induce an electric current. Long steel structures develop measurable electrical currents because of the earth's electromagnetic field, proximity to high voltage power lines, stray ground currents, large solar storms, and so forth. This has long been known to increase corrosion. Pipeline owners have responded with "cathodic protection" measures to prevent the corrosion. (Note the previous Item #6 regarding the Keystone 1 rapid erosion caused by stray voltage.) However, such protection itself isolates the pipeline further, which in turn can increase the induced current, and result in more difficult design issues, including site specific variations, and even more rapid corrosion. Enbridge proposes to follow some existing high voltage transmission lines, as well as places where such lines cross the proposed routes. (*See for example, **a.** " AC Corrosion Induced by High Voltage Power Line on Cathodically Protected Pipeline, " 2014. International Conference on Control, Engineering & Information Technology (CEIT'14) Proceedings IPCO-2014 ISSN 2356-5608; **b.** "The effects of geomagnetic disturbance on electrical systems at the earth's surface", Adv. Space Res. Vol 22, No. 1, pp. 17-27; **c.** "Geomagnetic disturbances and their impact on power systems, Status report," Olof Samuelsson, Industrial Electrical Engineering and Automation, Lund University; **d.** "Solar Storm Impacts on Wireless Networks, 2012. Nigel McKelvey, International Journal of Engineering and Technology Volume 2 No. 4, April, 2012. ISSN: 2049-3444 © 2012 Letterkenny Institute of Technology, Port Rd., Letterkenny, Co Donegal, Ireland; and **e.** Calculation and Analysis of the Coupling Effects of High Voltage Transmission Lines in Joint-use Corridors Shared by Multi-systems. 2011. PIERS Proceedings, Suzhou, China, September 12{16, 2011 School of Electrical Engineering, Southwest Jiaotong University.* )

8. Department of Homeland Security 2014 warnings about pipeline control system damage from solar storm events. This federal agency issued an advisory warning about the effects on satellite based pipeline control systems, as well as effects on other types of industrial control systems from solar storms. The advisory pertains to systems such as Enbridge's modern control center in Alberta, and

indicated that GPS as well as satellites could be affected. This advisory has partly resulted because of the very rapid adoption of such control systems in a short period of time, accompanied by the realization that large and unusual solar storms have not occurred during this recent short time period. With respect to other pipeline effects besides control systems, the advisory also states: "Solar storms can affect pipe-to-soil voltages, leading to currents that disturb flow meter signals, which can result in false pipeline flow rate data. The induced currents can also increase pipeline corrosion rates. Insulating flanges meant to interrupt current flow create an additional point where electric potential can result in current flow to ground, increasing the risk for corrosion." *(See Department of Homeland Security Advisory (ICSA-11-084-01) "Solar Magnetic Storm Impact on Control Systems Original," release date: March 26, 2011 | Last revised: January 02, 2014. See also Risk Management Issue Brief, May 2011. "Geomagnetic Storms: An Evaluation of Risks and Risk Assessments," By the U.S. Federal Office of Risk Management and Analysis*)

<u>9. Rupture of pipelines of this size can result in large oil releases even if ideal rupture detection and shutdown actions occur</u>. Enbridge relies on what they say is a state of the art pressure and automatic block valve control system based in Alberta. It relies on GPS and satellite systems. They say this will allow rapid shutdown of any pipeline that is ruptured by third party actions (such as non-pipeline company excavators) or any other cause of rupture. But on pipelines of the size of Line 3 (36 inches), even ideal shutdown response times can result in a worst-case release of over 20,000 barrels of oil from the rupture. The Sandpiper/Line 3 route has landscapes particularly susceptible to long-term damage from such a release. (*For "worst case" risk assessment results, and discussions of the kinds of damage that can occur, as well as discussions of the kind of landscape susceptibility along the proposed Enbridge routes, see "Third-Party Consultant Environmental Review of the TransCanada Keystone XL Pipeline Risk Assessment" Exponent, 1800 Diagonal Road, Suite 500 Alexandria, VA 22314 April 26, 2013; "Keystone XL Pipeline: Independent Engineering Assessment – Final Report" December 2013. Energy Systems, Battelle Memorial Institute, 505 King Avenue, Columbus, OH 43201; and "Studies for the Requirements of Automatic and Remotely Controlled Shutoff Valves on Hazardous Liquids and Natural Gas Pipelines with Respect to Public and Environmental Safety." Prepared by Oak Ridge National laboratory, Oak Ridge, Tennessee 37831-6283, managed by UT-Battelle, LLC for the U.S. Department of Energy.)*

<u>10. Modern remote controlled block valves can accidentally close and result in oil releases.</u> A report to Congress that was recently done after a number of pipeline accidents found that automatic block valves can shut down accidentally, resulting in oil releases. (*See "PIPELINE SAFETY, Better Data and Guidance Needed to Improve Pipeline Operator Incident Response," Report to Congressional Committees January 2013. GAO-13-168. United States Government Accountability Office (GAO)*).

<u>11. Highly significant leaks of many barrels per day can remain undetected for weeks.</u> Automatic monitoring systems respond to drops in pipeline pressure. Even the most sophisticated leak and pressure detection systems cannot detect some leaks. This can occur because small leaks don't result in a pressure drop that is detectable by monitoring systems. According to the Exponent report cited it #3 above, such leaks can go undetected for months. They estimated that for a 36-inch pipeline the leak was about 28 barrels/day. If this is correct, this means a potential underground leak of 840 barrels, or 20 35,280 gallons, per month. Such leaks are only found when they reach the surface. Clearly, given the project's 50-year life, deep pipeline burial under rivers due to Horizontal Directional Drills, and the prevalence of both surface and groundwater, along the proposed route, this issue must be thoroughly addressed in a risk and consequences study, and when comparing alternative routes. (*See "Third-Party Consultant Environmental Review of the TransCanada Keystone XL Pipeline Risk Assessment, " Exponent 1800 Diagonal Road, Suite 500 Alexandria, VA 22314 April 26, 2013.)*

12. Federal pipeline safety regulations require "worst-case" risk assessments yet these studies allow companies to keep them from the public. Enbridge has done these for the Sandpiper project and their other pipelines. Therefore, since they are secret, there is no ability to determine findings or adequacy of the reports. The Keystone XL review indicated substantial underestimation of risk when the company's forecasts were made available. (*See several locations in the PUC hearing record, Sandpiper project; also note the discussion above about the rapid corrosion of the Keystone 1 pipeline discussed in #6 above.*)

13. Standard risk assessment methods require assessing rare events when they have high consequences. Many miles of pipelines in the United State haven't ruptured. But a fundamental principle of risk assessments as practiced in the USA and elsewhere is that if the consequences of a pipeline rupture are very high, then rare and unlikely scenarios must be addressed in the risk assessment. The large size of the Sandpiper and Line 3 pipelines and their location in highly sensitive areas certainly mean potentially large releases and large consequences over a 50 or more year project life. Furthermore, there are obviously differences in landscapes such that consequences are lower in some locations, and containment of spills is easier in some locations. Therefore, it is a certainty that risk and consequence analysis results should be considered in deciding the proper location of pipelines. (*See hearing record, Sandpiper before the Minnesota PUC. See also Risk Management Issue Brief, May 2011. "Geomagnetic Storms: An Evaluation of Risks and Risk Assessments," By the U.S. Federal Office of Risk Management and Analysis*)

14. Standard "worst case" risk assessments should also consider the consequences of liquid pipeline ruptures being accompanied by fire that damages adjacent pipelines. Since Enbridge proposes to locate its pipelines as close as 25 feet from its other pipeline, a rupture and fire scenario may cascade to adjacent pipelines. Some products carried by these large pipelines (30-36 inches in diameter) are considered to be as explosive as gasoline. Risk and consequence studies need to consider whether cascading damages to adjacent lines could occur, and, if so, examine consequences. (*For a risk assessment study of liquid pipeline rupture accompanied by fire see "Studies for the Requirements of Automatic and Remotely Controlled Shutoff Valves on Hazardous Liquids and Natural Gas Pipelines with Respect to Public and Environmental Safety." October 2012. Prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee.)*

Summary biography of Paul Stolen

My scientific training is in fisheries and wildlife management, and I have published papers on waterfowl behavior in refereed journals. I also attended graduate school in the University of Minnesota School of Journalism and Humphrey Institute of Public Affairs. I am retired, after working for the University of Minnesota, Minnesota Department of Natural Resources, Minnesota Legislature, Montana Department of Natural Resources and Conservation (Energy Division), University of Minnesota, and a short time for a private consulting firm.

My professional experience and personal interest involves a focus on the use of scientific information in public policy and decision making. A main focus while employed and as an involved citizen during this 40 year career has been on applying impact assessment laws and regulations, and on policy analysis. I have written and reviewed many environmental impacts studies, and written environmental regulations for energy facilities, including pipelines. I've worked with other states and the federal government on water, energy, and other projects. I have worked as a reviewer/regulator on about 12 different pipeline projects, was Assistant Director of the Montana Interagency Pipeline Task Force, and have been an environmental inspector on a number of pipeline projects. I first began my involvement with pipelines as a union laborer on the bending crew of 34-inch pipeline in Minnesota, which is now known as Enbridge Line #3.

I have also worked with Canada—both the federal Foreign Affairs Office, Manitoba, and Canadian Consulate in Minneapolis—and U.S. federal agencies and other states on water issues, including boundary issues with Canada. I am a veteran of the US Army, and spent a year at the Walter Reed Institute of Research in Washington, D.C. and a year in Vietnam doing diagnostic work and research on tropical diseases affecting people and animals.

**ATTACHMENT 2**

**Two examples of locations along the Enbridge proposed route needing careful analysis of the risk and consequences of "worst-case" oil releases.**

I have selected the following two examples because I am familiar with both locations. This knowledge comes from my professional and educational career, as well as personal knowledge. During the initial period of review of the Sandpiper project, several alternative routes were proposed to take Bakken oil directly to its destination in the Chicago instead of continuing to expand pipeline corridors—or create new ones—through landscapes sensitive to damage from oil spills. My education and career in the Minnesota DNR, Minnesota Legislature, and Minnesota EQB, and with a private consulting company, has given me broad knowledge of the landscapes of Minnesota. I can say with some confidence that those southern and western routes are unlikely to cross areas of such high cultural, ecological, and natural resource significance as the following two examples. In addition, those southern and western routes are *much* more accessible when compared to these two examples, should a serious oil release occur.

**Example 1: Proposed Enbridge Sandpiper/Line 3 projects crossings of LaSalle Creek Valley and potential impacts to LaSalle Creek, Big LaSalle Lake, associated wetlands, LaSalle Lake State Recreation Area, Scientific and Natural Area, cultural and historic sites, Mississippi River, etc.**

<u>Example 1: Site description and Enbridge proposals</u>. This site straddles the Clearwater and Hubbard County line and is about five miles north of Itasca Park, Minnesota. This area is very hilly glacial till, with many isolated depressions that result in precipitation entering groundwater rather than running off. The till is very mixed, with gravel or sand layers mixed in with more impervious material. Groundwater flows can be very rapid laterally, and are complex. LaSalle Creek runs through a glacial tunnel valley with steep ridges on each side that are on the order of 100 feet above the valley. The valley bottom is covered in wetlands with deep organic material—likely 40 or more feet deep--except where the lakes are present. Many emergent springs from the hillsides result in wetlands actually are being found on the lower slopes of the hills. The creek itself is a trout stream at the pipeline crossing location, and it meanders through the wetlands until reaching Big LaSalle Lake about one-half mile from the pipeline crossing.

The proposed Enbridge route follows a pipeline corridor established 60 or so years ago, prior to any significant environmental laws. My familiarity with the site dates to 2007-2008 when I was employed by the MDNR. The 24-inch MinnCan pipeline was constructed within a few feet of the old pipelines in that time period. I also am familiar with groundwater issues in this terrain. While employed at the DNR, I was the representative dealing with a nearby difficult highway project. Test drilling for bridge foundations resulted in severe eruption of groundwater from the test hole when groundwater under high pressure from nearby higher terrain was intercepted.

I recommended, after an internal coordinated review of the MinnCan proposal, that the LaSalle Creek Valley area was the most problematic in my work area. At that time, this was about a 100 mile length of the proposed pipeline. After the project was approved by the Department of Commerce, the creek crossing was done with an HDD bore of about 3,000 feet in length in the winter. There was a large "frac-out" of drilling mud that resulted in a major clean-up operation and difficulty. The cause of this was almost certainly the uprising groundwater, and very saturated muck in the valley. The issues that came up during this clean-up operation are somewhat indicative of the problems that could occur if there was a pipeline rupture in this location, as discussed in the next section regarding oil release consequences in this area.

Now, Enbridge proposes—with Sandpiper—to cross the valley with a trenched crossing closer to Big LaSalle Lake. I assume they will propose the same with the Line 3 project. In my experience, this type of site will need sheet pile, at best, in order to dig a trench. At worst, this could well be a construction engineering experiment with very bad environmental consequences during construction, such as a very wide disturbed area, and siltation into Big LaSalle lake. Concrete weights will be needed to suspend the pipes below the surface within the water-saturated wetland muck soils.

There are two lakes downstream of Big LaSalle Lake in the same tunnel valley, Middle LaSalle Lake (a small lake about two miles from the pipeline crossing,) and LaSalle Lake, about 3.5 miles from the crossing. The Mississippi River is immediately downstream of LaSalle Lake, about 5.5 miles from the pipeline crossing. LaSalle Lake is an extremely high value Minnesota resource, based on the following information from the DNR about the LaSalle Lake State Recreation Area (SRA):

*"At 221 acres and 213 feet deep, with over 18,600 feet of shoreline, LaSalle Lake is one of Minnesota's most pristine and deepest lakes. The lake supports walleye, northern pike, largemouth bass, black crappie, and bluegill sunfish populations. . . .In the early 1990s, an early Native American Elk Lake Culture prehistoric site was discovered adjacent to LaSalle Creek near the outlet of LaSalle Lake. The site was identified during planning for an upgrade of the county highway and was partially excavated in 1995 before the road was rebuilt.*

*The Institute for Minnesota Archaeology states: "...artifacts recovered from the LaSalle Creek site have provided archaeologists with a clearer picture of how the producers of Brainerd Ware ceramics lived, what they ate, and what tools they made. In addition, the date of 3,180 years ago obtained from charred residue on the inside of a ceramic shard at the LaSalle Creek Site is one of the earliest known dates for an Elk Lake Culture occupation in Minnesota."*

*The northern headwaters of the Mississippi River is an extremely important area for these early archaeological sites, and additional cultural resource areas may be discovered on the property. Because the side slopes of the LaSalle Creek glacial tunnel valley and LaSalle Lake's bottom are so steep, the lake's littoral zone is relatively narrow and represents a very small portion of the lake's surface area.. . . .The landscape was identified by the Minnesota County Biological Survey (MCBS) as an area of "High and Outstanding Biodiversity Significance." Over 90 species of trees and shrubs and more than 140 species of herbaceous plants, including 12 species of orchids, have been surveyed and recorded growing in the area.*

*MCBS has also identified numerous rare, threatened, endangered, and special concern species of plants and animals, including ram's head lady slipper, hair-like sedge, northern oak fern, two species of caddisfly, and trumpeter swan.*

*LaSalle Lake's west facing slopes host red pine and jack pine forests and woodlands. East facing slopes are covered with hardwood forests that include occasional large white pines, balsam fir, and white spruce. To the north, close to where the LaSalle Creek empties into the Mississippi River, a small but high quality old-growth northern white cedar forest exists where springs emerge from terraced slopes. A portion of La Salle Lake SRA has been designated as a scientific and natural area (SNA), recognizing the high quality native communities and rare plant and animal species found there." (MDNR web site description of SRA.)*

Example 1: Consequence analysis of an "worst-case" pipeline rupture and oil release at the crossing of the LaSalle Creek tunnel valley. The following is a preliminary list of issues that need to be addressed in a proper analysis:

1. A "worst-case" pipeline rupture for a 36 inch pipeline is calculated to be about 20,000 barrels of oil, according to the studies cited in Item #3 above, even with a rapid response time. Also, the Enbridge 36-inch pipeline rupture in 2010 in Michigan was about 20,000 barrels, even though it wasn't a "worst-case" rupture with respect to the type of rupture that occurred (a "fish-mouth" break occurred whereas normal "worst-case" considers a "decapitation" break where the entire pipe is opened. The issue at the Michigan spill was that Enbridge didn't shut down the pipeline for 17 hours after the rupture.) That rupture polluted at least 35 miles of the Kalamazoo River, and clean-up costs have reached $1.3 billion.

2. As noted, the two Enbridge pipelines are proposed to be constructed alongside three other older pipelines now present at the LaSalle Creek crossing. As discussed in Item #14 in Attachment 1, "worst-case" risk assessments consider the scenario of a pipeline rupture accompanied by fire. Therefore, study is needed to assess whether if this occurs, adjacent pipelines will be damage and also rupture before they could be shut down.

3. Critical resources are very close to the pipeline route. Big LaSalle Lake is one-half mile downstream of the pipeline crossing of the tunnel valley and creek, and would be closer than that with the proposed Enbridge crossings. The LaSalle Lake State Recreation Area is 3.5 miles downstream, and the Mississippi River is 5.5 miles downstream from the crossing. In other words, *these stream reaches are much closer and could have a similar result as occurred in the 35 mile stretch of the Kalamazoo River in Michigan polluted by another Enbridge project.* In addition, the Exponent Report cited in Item #3 in attachment 1 indicated that impacts associated with small streams should be assessed out to 10 miles from the pipeline in landscapes such as this.

4. All of the tunnel valley, creeks, lakes, and Mississippi River have poor access for clean-up equipment.

5. Steep terrain means pipeline ruptures at various locations can reach these critical waters.

6. The break-out of drilling mud during construction of the MinnCan pipeline occurred in the winter. Springs were so abundant that the ground and wetland surfaces were unfrozen even in a cold midwinter. Even relatively light motorized equipment for clean-up could not be used, and clean-up was done largely by hand, and with small pumps. This characteristic of the lower parts of the slopes of the LaSalle Creek tunnel valley is present all the way to the outlet of LaSalle Lake. *Therefore, heavy equipment either will not be able to be used for clean-up, or, if used, will cause all sorts of long-term environmental damage.*

7. A proper assessment must take into account whether an oil spill at this location could ever be cleaned up, and would need to address potential impacts to all of the values inherent in these downstream locations.

8. A proper assessment of alternatives must compare potential impacts at this site with potential impacts along other routes, such as the southern and western alternative to take Bakken oil directly to the Chicago area rather than through Superior, Wisconsin. The federal Clean Water Act, and National Environmental Policy Act requires that alternatives that have fewer impacts be carefully considered.

**Example 2: Proposed Enbridge Sandpiper/Line 3 projects effects on Upper and Lower Rice lakes, the Wild Rice River and potential impacts to wetlands, cultural resources, wild rice, and environmental justice issues. Southern Clearwater County Minnesota.**

Site description and Enbridge proposals. The proposed route crosses the upper watershed of the Wild Rice River, and crosses the edge of Mud Lake, a small shallow lake containing wild rice. This lake has an outlet that reaches the Wild Rice River via a ditch about three miles long. The river itself originates as an outlet of Upper Rice Lake. The existing pipeline route also crosses wetlands that are about one-half mile from Upper Rice Lake.

Upper Rice Lake is a well-known wild rice lake, and is considered a highly important waterfowl lake. Even though shallow, at times it has a significant northern pike population and fishery. The Upper Rice Lake Wildlife Management Area is adjacent to this lake, and is described as follows: "*This WMA is mixed grassland, wetland and forest which adjoins Upper Rice Lake, a 1860-acre major migratory waterfowl and wild rice lake. About 40% of this unit is upland and lowland forest, 35%wet meadow, shrub wetland and marsh. Deer, bear, ruffed grouse, goose and duck hunting and wildlife observation opportunities exist on this unit.*" (DNR web site.)

I became acquainted with this area when the MinnCan pipeline was proposed and constructed through the Mud Lake wetland. While working at the Minnesota DNR, I documented that long-term impacts have resulted from installation of the pipelines at this location.

Lower Rice Lake is about seven miles "as the crow flies" from Upper Rice Lake, and likely about 10 river miles downstream on the Wild Rice River. This lake is about 2,000 acres in size, and, according to a report on the lake, it is "*the major wild rice producing lake on (the White Earth Reservation and) produces more than 200,000 pounds of rice each year. Many individuals gather here in the fall to harvest wild rice.*" ("Lower Rice Lake, the major wild rice-producing lake on the White Earth Reservation: Historic to Present Water Levels," Lainey Fineday, White Earth Tribal and Community College, 2011 NASA- Kiksapa Summer REU.)

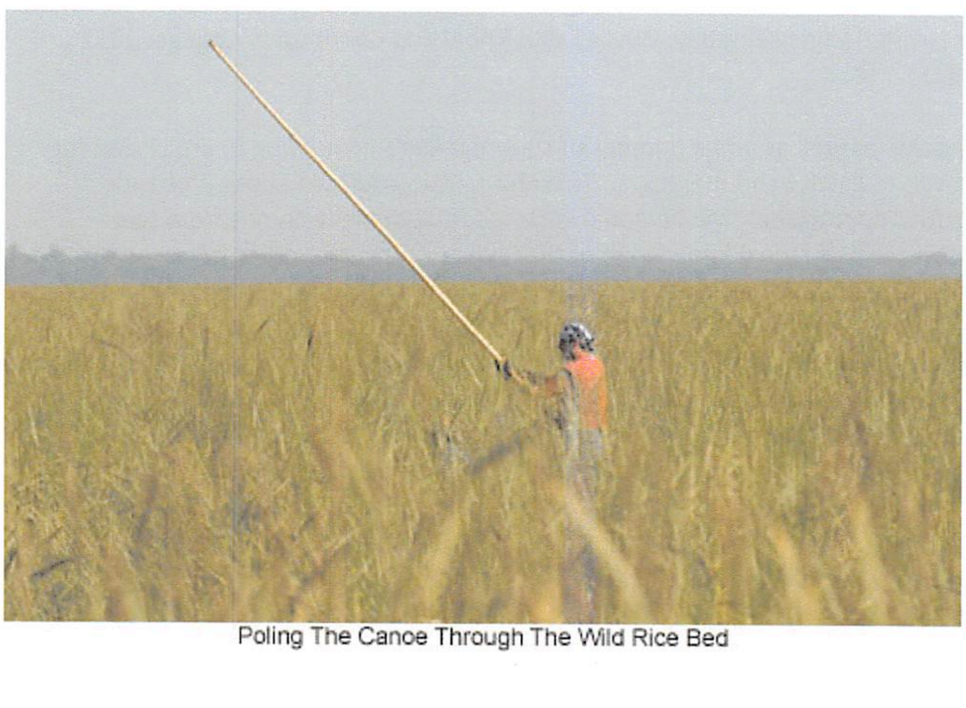
The surface of Lower Rice Lake, as well as and a number of square miles surrounding it, are closed for ricing and hunting by non-White Earth band members. Therefore, little is known about it outside of Ojibway people and waterfowl specialists. My personal knowledge of the lake comes from two technical sources, and a long-term personal knowledge of the lake and its surrounding area. I did a waterfowl study of the lake for an undergraduate class while attending the University of Minnesota field station at Itasca State Park. But importantly, while employed at the DNR, I was involved in the restoration of the river and wetlands south of Minnesota Highway 200. They are immediately upstream of the lake, and are important to its water quality and growth of rice. The Wild Rice River crosses Highway 200 twice, first flowing south, and then back north and on into the lake. A bypass ditch was built in the 1930s to divert flow along the north side of the highway in order to reduce the need for bigger bridges for the two crossings. I worked with the Minnesota Department of Highways, and the White Earth Biology Office to accomplish the restoration while employed at the Minnesota DNR.

The restoration of the river and wetlands resulted in less fluctuations of water levels in Lower Rice Lake and potential long-term improvement in water quality—because flood flows spread out over the wetlands instead of immediately dumping into the lake. The White Earth Biology Office concluded that this benefited the wild rice growth, and reduced the potential for contamination from large, old poultry operations a short distance upstream on the Wild Rice River.

Since I have had a professional and personal interest in this lake for many years, I have seen first-hand the abundance of waterfowl that use the lake when the wild rice is ripe. I have seen waterfowl concentrations as large or larger than those I have seen elsewhere, including in other states. Data on this use will be available in DNR files, since they fly the lake doing waterfowl counts. One autumn about seven years ago, while I watched from Bonga Landing, the ricing access near the outlet, enormous numbers of waterfowl flights were in the air and in the rice. Many species were represented. Later, I learned the DNR had coincidentally flown the lake about the time I was there in order to count waterfowl. They estimated conservatively that 20,000 waterfowl were on the lake. When pressed, the individual who did the count said it could have been 40,000 birds present. There were so many birds in the air they could only safely make one pass over the lake, he said.

Lower Rice Lake is of high cultural and heritage significance to not only the White Earth Band, but likely to the Ojibway of Minnesota in general. George Bonga, for which the name "Bonga Landing" comes from, was an early fur trader and historic figure in this area. Also, according to an individual in the White Earth Biology Office, this was the pre-settlement site of peaceful gatherings between the Ojibway and the Santee from the Dakotas—while trading for rice and perhaps buffalo hides. (These tribes were normally enemies, at least at times.) In addition, the original land survey of Minnesota identified a trail already in existence at the time of the 1850s survey from the Lower Rice Lake area to the outlet of the Red Lake River at Upper Red Lake Northwest of Bemidji.

Lastly, I need not describe the cultural and religious significance of wild rice to the Ojibway. I only wish to emphasize as strongly as possible that wild rice on Lower Rice Lake could be considered almost the epitome of growth of this plant, and of its significance to the Ojibway. At times, it looks as if the entire 2,000 acres is all in one stand of rice. Below is a picture taken of ricing at the lake. (Source: Canku Ota (Many Paths), An Online Newsletter Celebrating Native America, October 1, 2009 - Volume 7 Number 10.)



Poling The Canoe Through The Wild Rice Bed

Example 2: Consequence analysis of an "worst-case" pipeline rupture and oil release affecting Upper and Lower Rice Lakes, adjacent wetlands, cultural and religious significance of wild rice, and waterfowl and other natural resources values.

The following is a preliminary list of issues that need to be addressed in a proper analysis. There are some similarities to Example 1 for the LaSalle Creek area:

1. A "worst-case" pipeline rupture for a 36 inch pipeline is calculated to be about 20,000 barrels of oil, according to the studies cited in Item #3 above, even with a rapid response time. Also, the Enbridge 36-inch pipeline rupture in 2010 in Michigan was about 20,000 barrels—even though it wasn't a "worst-case" rupture with respect to the type of rupture that occurred (a "fish-mouth" break occurred whereas normal "worst-case" considers a "decapitation" break where the entire pipe is opened. The issue at the Michigan spill was that Enbridge didn't shut down the pipeline for 17 hours after the rupture.) That rupture polluted at least 35 miles of the Kalamazoo River, and clean-up costs have reached $1.3 billion.

2. The two Enbridge pipelines are proposed to be constructed alongside 3-4 other older pipelines now present on this route. As discussed in Item #14 in Attachment 1, "worst-case" risk assessments consider the scenario of a pipeline rupture accompanied by fire. Therefore, study is needed to assess whether there is any chance adjacent pipelines will be damaged and also rupture before they could be shut down. If so, the analysis must address this additional "worst-case."

3. Both Upper and Lower Rice Lake and associated wetlands are within about 10 miles of the Enbridge proposed crossings of their watershed and of waterways capable of carrying oil downstream. The Exponent Report cited in Item #3 in attachment 1 indicated that impacts associated with small streams should be assessed out to 10 miles from the pipeline in landscapes such as this. Furthermore, as noted above, the Enbridge pipeline rupture in Michigan in 2010 polluted a 35 mile stretch of the Kalamazoo River in Michigan.

4. Wild rice is sensitive to oil pollution, and is likely sensitive to dredging operations to clean up oil spills. Wetlands adjacent to wild rice waters are important for maintaining water quality in these lakes.

5. This area has extremely poor access for clean-up equipment, especially heavier equipment. Clean-up operations themselves can damage wetlands for the long-term.

6. Steep terrain is less of an issue in this area as compared to the LaSalle Creek area. However, the large drainage area can mean rapid downstream transport of oil if leaks and ruptures that reach the Wild Rice River during high flow periods.

7. A proper assessment must take into account whether an oil spill at this location could ever be cleaned up. It would need to address potential impacts to all of the values inherent in these downstream locations, including environmental, cultural, historic, and religious issues.

8. A proper assessment of alternatives must compare potential impacts at this site with potential impacts along other routes, such as the southern and western alternative to take Bakken oil and Line 3 oil directly to the Chicago area rather than through Superior, Wisconsin, given the requirements of the federal Clean Water Act, and National Environmental Policy Act to address alternatives that have fewer impacts.

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**Solar Magnetic Storm Impact on Control Systems**
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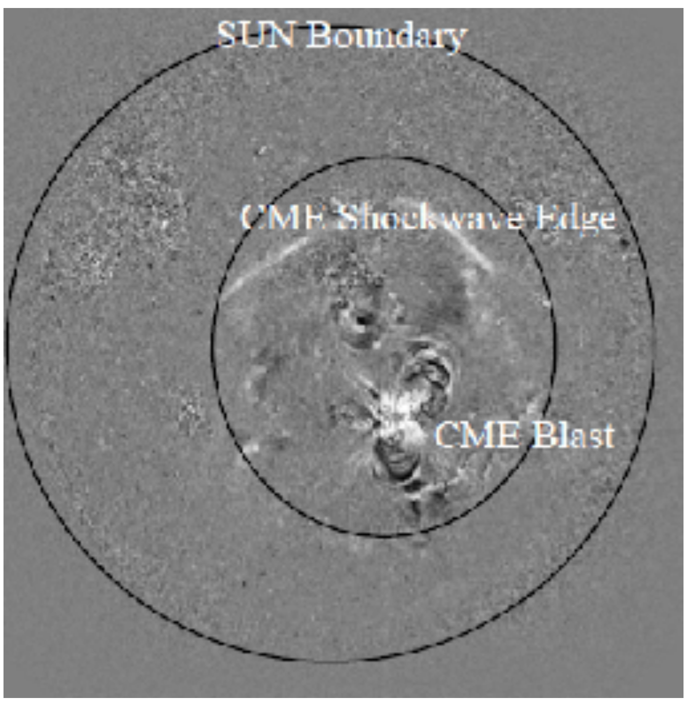
Overview

The sun generates solar flare and coronal mass ejection (CME) events in an approximate 11year cycle. The plasma clouds generated from these events have the potential to cause geomagnetic storms that can interfere with terrestrial communications and other electronic systems, posing a risk to critical infrastructure.

In a recent case, Earthorbiting satellites detected the strongest magnetic storm in more than 4 years resulting from a solar flare and CME event.(a) Figure 1 illustrates the size of the CME shockwave edge in relation to the size of the sun at the point of the eruption.



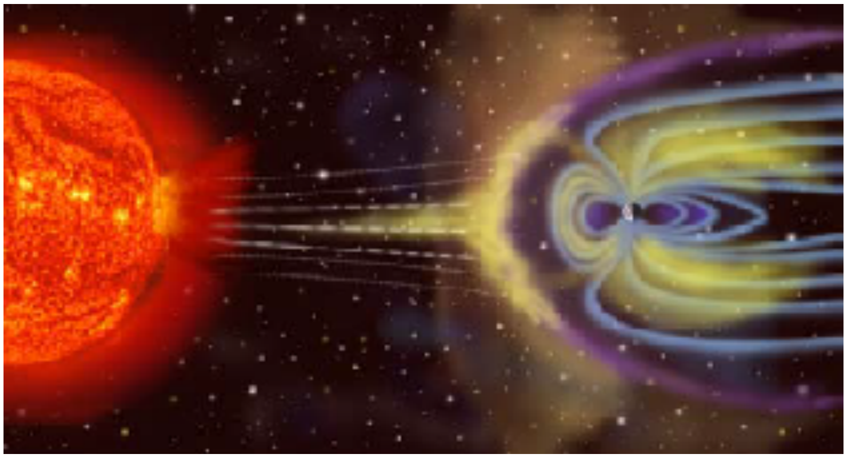


Figure 1. X2solar flare and coronal mass ejection at the time of the eruption.

At 0156 UT on February 15, 2011, Active Region 11158 unleashed an X2class eruption. X-flares are the largest type of Xray flares, and this is the first such eruption of new Solar Cycle 24. The explosion that produced this flare also sent a solar tsunami rippling through the sun's atmosphere and hurled a CME toward Earth. By the time the CME reached the Earth, the shockwave leading edge had expanded to approximately 40 million miles across. CME activity will continue to occur as this solar cycle progresses.

The purpose of this Advisory is to inform the industrial control systems (ICS) community of the possible impacts of solar magnetic storms on critical infrastructure control systems. This Advisory provides a highlevel overview of the potential problems and offers some general mitigation strategies for consideration by the ICS community.

Forecasts

The National Oceanic and Atmospheric Administration (NOAA) provides daily weather forecasts regarding solar activity as well as space weather alerts and advisories for solar flare and CME events that could impact navigation, radio, electric power, and satellite operations.

Solar Storm Background

Solar events associated with sunspot activity fall into three categories:

1. Solar flares involve a powerful burst of radiation (Xrays, extreme UV rays, gamma rays and radio frequency waves) that heats and increases the ionization of the upper atmosphere. Solar flares cause interference with satellite communications, radar, and shortwave radio. The radiation burst travels at the speed of light, reaching the Earth about 8 minutes after the eruption. Solar flares are categorized by relative size: Bclass flares are roughly 10% the size of Cclass flares; Cclass flares are roughly 10% the size of Xclass flares. Within the Xclass, flares are categorized on a linear scale (e.g., X1, X2). The largest measured solar flare occurred on November 4, 2003, and was rated as X45. (b)

2. Solar proton events (SPE) follow the flares. They travel at sublight speeds, reaching the Earth about 1 hour after the eruption. A SPE involves highenergy cosmic rays (protons and ions) that can disorient satellites, damage spacecraft electronics, interfere with shortwave radio in the Earth's polar regions, and deplete the atmosphere's ozone layer.

3. CMEs involve large clouds of charged plasma with an embedded magnetic field whose leading edge can expand to nearly 40 million miles across by the time it reaches the Earth. CME shockwaves travel at various speeds, some at nearly 5 million miles per hour, reaching Earth in about 18 hours or more.

The ionosphere (the upper layer of the atmosphere, 85 to 600 kilometers above the Earth) is critical to radio signal propagation. Solar radiation creates the ionosphere by ionizing the upper layer of the atmosphere. Broadcast radio transmissions reflect off the ionosphere to reach the intended receiver.

When the magnetic field associated with a CME impacts the Earth's magnetic field, the resulting geomagnetic storm can last several days, with storm effects continuing 1 to 2 days more. The CME's electromagnetic energy disrupts the ionosphere's reflectivity, adversely impacting broadcast radio signal transmissions. This can also affect global positioning system (GPS) satellite signals, interfering with the GPS timing reference used by navigation systems and many control systems.

As a geomagnetic storm impacts the Earth's magnetic field, it generates potential differences across the surface because of variations in the Earth's resistivity (see Appendix A). The electromagnetic field from a CME changes the potential difference in power distribution and transmission system groundtoline voltages, producing geomagneticinduced currents (GIC) that can damage the large wyeconnected transformers used at power plants and substations. GICs of 1000 A are theoretically possible, though most large transformers are not tested for GICs in that range. Those transformers are typically critical power grid devices; they are expensive and have extended replacement lead times (often 1 to 2 years).

Effects on Critical Infrasctucture Control Systems

Radio Interference

Geomagnetic storms can interfere directly with GPS and radio communication because of the ionosphere disturbances. The interference can range from induced noise to complete signal loss. Geomagnetic storms can indirectly affect many other systems, including control systems that rely on GPS or radio technologies.

Control systems that employ the following technologies may experience partial or complete service outages of varying durations, depending on the intensity of the storm (and other factors).

Directly Affected Systems

Distributed control systems relying on GPS Position Navigation and Timing (PNT) signals to sequence and control processes

Used in oil and gas, electrical, marine, aviation, water and wastewater, trains

Shortwave frequency band wireless communications

Emergency services handheld wireless communications.

Indirectly Affected Systems

Control systems components supporting wireless technologies (e.g., WiFi, cellular) that rely on GPS timing signals

Remote terminal units (RTUs), programmable logic controllers (PLCs), intelligent electronic devices (IEDs), and other controllers

Portable instrumentation and test equipment.

Electrical Grid Interference

The continuing trend toward transmitting more electrical power over longer transmission lines, closer to maximum power limits, creates a directly proportional relationship between the intensity of a geomagnetic storm and electric grid impact. A geomagnetic storm can cause severe problems for electrical power systems during their peak hours of operation. This is especially true in certain regions of the northern United States and in coastal regions where igneous rock geology reduces the Earth's conductivity in those areas (see Appendix B).

During a solar storm, the CME plasma cloud and its magnetic field collides with the Earth's magnetic field, causing large transient magnetic disturbances. These disturbances, or geomagnetic storms, can affect the Earth's magnetic field for as much as 2 days. The geomagnetic storms can induce voltage variations along the Earth's surface, creating potential differences in voltage between grounding points that cause GICs to flow through transformers, power transmission lines, and grounding points. GICs can severely affect grounded wyeconnected transformers and autotransformers because of cumulative overheating effects on winding insulation and induced harmonics (see Appendix C).

Regions of low conductivity, such as the regions of igneous rock geology that are common over large portions of North America, are more susceptible to geomagnetic storm affects. Power transmission systems built in those areas experience significantly larger GICs from geomagnetic disturbances. The Earth's conductivity varies by as much as five orders of magnitude across North America (see Appendix A). The magnitude of GICs is also inversely proportional to the resistivity of the transmission system. The transmission lines become an effective short circuit between distribution system transformers for GICs flowing through the transformer ground connections.

A solar storm can affect the power grid simultaneously at many points, resulting in multi-point failures. Large transformers that support transmission lines are costly and can also have long lead times for delivery and commissioning, sometimes as long as 2 years (see Appendix B).

The NOAA Space Weather Prediction Center provides several scales for geomagnetic and solar radiation storms, and radio blackouts. The following two links to the NOAA Space Weather Prediction Center should be a part of all electric utility weather situational awareness programs.

Electric Power—Electrical Utilities Information Site (Alerts and Advisories):

http://www.swpc.noaa.gov/ElecPower/

NOAA Space Weather Scales (NOAA Space Weather for Geomagnetic Storms Table): http://www.swpc.noaa.gov/NOAAscales/index.html#RadioBlackouts.

While the NOAA scales reflect the 3hour average for changes in the magnetic field, GICs are a result of the rate of change in the magnetic field. That is analogous to a storm that causes damage not from the low atmospheric pressure, but from the wind created by the changing pressure. Magnetic field rate of change information is not currently readily available, though NASA is working on a new index that will include the rate of change.

Oil, Gas, and Other Pipeline Interference

Solar storms can affect pipetosoil voltages, leading to currents that disturb flow meter signals, which can result in false pipeline flow rate data. The induced currents can also increase pipeline corrosion rates. Insulating flanges meant to interrupt current flow create an additional point where electric potential can result in current flow to ground, increasing the risk for corrosion.

Mitigation

Electrical Grid

For electrical power systems, mitigations should start long before an actual solar storm occurs. Mitigation involves significant engineering and simulations regarding the fault protection design employed for protection of the stepup feeder transformers supplying transmission lines. Without a proper engineering review, making changes to the distribution system to potentially protect against the effects of solar storms can defeat or reduce the effectiveness of the original power systemprotection design. Adequate protection against these risks requires a holistic approach to the system design to avoid such undesired interactions. Reverse current and voltage effects must be analyzed and understood to ensure optimal overall fault protection in system design. In addition, asset owners and control system vendors must also consider methods for shielding the fault protection instrumentation and its communication media. If an asset owner determines, based on engineering fault calculations, that the expected induced energy from a CME event may exceed system protection capabilities, the best mitigation option may be a controlled outage for the duration of the storm.

Other proposed mitigation methods (some patents exist) involve switching either a capacitor or resistor bank (or combination) into the ground leg of distribution transformers to reduce the maximum GIC. Such a system would also require a GIC sensor to trigger the switching and reset the ground leg circuit after the storm passes. The expense to develop and deploy such systems makes their actual deployment unlikely in the near term. In addition, the switching circuit impedes the intended ground leg safety function while it is active. NERC currently has a geomagnetic disturbance task force that is expected to recommend more active research in this area.

Other Control Systems

During solar storm events, operations personnel should monitor control system communications data to detect offnormal ranges or outages, because data communication may be affected. Communication systems may experience temporary or extended outages. Communications using shielded physical layer media may not experience outages. The owner should continue to monitor surge protection and uninterruptible power supply (UPS) systems during this period. PLC, RTU, IED, and other controllers, if installed with effective voltage and current protection, will not be affected by cellular or wireless service interruptions.

Electronics installed in metal building facilities are likely to be adequately shielded from direct electromagnetic interaction. However, utilities should still audit line power protection devices to confirm proper operation. Owners can consider adding protection to electronic devices not shielded by metal packaging. If not essential to operation, owners can consider powering off equipment and disconnecting from the power sources during a stormwarning period.

Control system communication systems are not directly affected by GICs, but they rely on the electric grid for power. Many also rely on GPS timing signals. For those control systems, the engineering staff should use engineering judgment regarding the system's resilience in the event of electric grid or GPS outages.

Based on engineering fault calculations, if the engineering staff determines that the potentialinduced energy may exceed system design protection capabilities, a possible mitigation is a controlled outage.

Solar storm interference may impact rail supervisory control and data acquisition (SCADA) system dispatch operations and communication networks that employ wireless technologies, especially those dependent on GPS timing signals. Engineers and field maintenance personnel will need to coordinate efforts during the CME event, especially if the decision is made to run systems in manual mode.

As a longterm approach, owners and operators of industrial control systems that are reliant on GPS timing signals (i.e., cellular RTUs, IEDs) should consider including integrated backup timing systems to accommodate the temporary loss of GPS because of interference or actual failure. Interference with GPS navigation and position information may also impact critical infrastructure in the oil and gas industries' marine fleets, where exploration activities often require precise station keeping operations. Vessels may be equipped with bottom fix capability as a redundant functionality. However, when the shipcontrol system does not include bottom fix capability, mitigation may require suspending operations until the solar storm subsides.

APPENDIX A: Earth Ground Resistivity

Figure 2. Earth ground resistivity based on underlying rock strata. Conductivity measurements from the Geomagnetic Laboratory of the Geological Survey of Canada in Ottawa with Extension to the United States Completed by Electric Power Research Institute-Sunburst Project. Units: siemens per meter (regions in red are essentially nonconductive).

APPENDIX B: Historical Impacts of Solar Storm Activity

August 2, 1972—GICs resulting from a solar storm caused a 230 kV transformer explosion at a hydro and power plant.

December 19, 1980—A 735 kV transformer failed 8 days after the Great Red Aurora. A replacement 735 kV transformer also failed the next year after another geomagnetic storm.

March 13, 1989—GICs resulting from a solar storm overloaded transformers on a North American power system, causing the deactivation of reactive power compensators at various substations. Within 1½ minutes, the power system was in complete blackout due to the linked malfunction of more than 15 discrete protective system operations. In addition, GICs resulting from the solar storm destroyed a $12 million generator stepup transformer in another power system. The transformer was a criticalcomponent for electrical power distribution from the generating plant in that system. The 288.8/24 kV singlephase shellform transformers were connected in a groundedwye configuration. The damage to the transformers included damage to the low-voltage windings, thermal degradation of the insulation of all three phases, and conductor melting. When the utility ordered a replacement, the supplier indicated the order would receive top priority but would still require nearly 2 years to fill. The utility obtained an interim spare unit that still required 6 weeks for installation before going online.

October 30, 2003—A power grid in Sweden experienced a 20 to 50minute blackout due to a strong solar storm. The same storm damaged 15 transformers in South Africa, some beyond repair.

APPENDIX C: Technical Analysis of Solar Storm Effects on Transformers

US Navy physicist, James A. Marusek, in his paper titled, “Solar Storm Threat Analysis,” reported the following analysis:

“Geomagnetic Induced Currents (GIC) can cause transformers to be driven into halfcycle saturation where the core of the transformer is magnetically saturated on alternate half cycles. A few amperes are needed to disrupt transformer operation. A GIC levelinduced voltage of 1 to 2 volts per kilometer and 5 amperes in neutral of the highvoltage windings is sufficient to drive grounded wyeconnected distribution transformers into saturation in a second or less.

[i] During geomagnetic storms, GIC currents as high as 184 amperes have been measured in the United States in the neutral leg of transformers. [f] The largest GIC measured thus far was 270amperes during a geomagnetic storm in Southern Sweden on April 6, 2000. “If transformer halfcycle saturation is allowed to continue, stray flux can enter the transformer structural tank member and current windings. Localized hot spots can develop quickly inside the transformer’s tank as temperatures rise hundreds of degrees within a few minutes.

[k] Temperature spikes as high as 750°F have been measured. As transformers switch 60 times per second between saturated and unsaturated, the normal hum of a transformer becomes a raucous, cracking whine. Regions of opposed magnetism as big as a fist in the core steel plates crash about and vibrate 100ton transformers, which are nearly the size of a small house. This punishment can go on for hours for the duration of the geomagnetic storm. GIC-induced saturation can also cause excessive gas evolution within transformers.

Besides outright failure, the evidence of distress is increased gas content in transformer oil, especially those gases generated by decomposition of cellulose, vibration of the transformer tank and core, and increased noise levels of the transformers (noise level increases of 80 dB have been observed).

i GIC transformer damage is progressive in nature. Accumulated overheating damage results in shortening transformer winding insulation lifespan eventually leading to premature failure.

“In addition to problems in the transformer, halfcycle saturation causes the transformer to draw a large exciting current which has a fundamental frequency component that lags the supply voltage by 90 degrees and leads to the transformer becoming an unexpected inductive load on the system. This results in harmonic distortions and added loads due to reactive power or VoltAmpere Reactive (VAR) demands. This results in both a reduction in the electrical system voltage and the overloading of long transmission tielines. In addition, harmonics can cause protective relays to operate improperly and shunt capacitor banks to overload. The conditions can lead to major power failures."

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# AC Corrosion Induced by High Voltage Power Line on Cathodically Protected Pipeline

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***Abstract — The implications of the influence of alternating currents on buried pipelines are of great concern to all pipeline owners in world. The relevance of the interference is always increasing for operational personnel and for the protection of buried metallic structures from corrosion. The paper studies the electromagnetic interference problem between an existing high voltage power line and a newly designed underground pipeline cathodically protected. Induced voltages and currents are evaluated for steady state operating conditions of the power line. It is found that on pipelines suffering from A.C. interference traditional pipe-to-soil potential measurements do not guarantee efficient cathodic protection against corrosion. A specific approach to assess the effectiveness of cathodic protection should be adopted.***

***Keywords— AC Interference, Induced Voltages, Electric Power Transmission Lines, pipeline, AC Corrosion, cathodic protection, soil resistivity.***

## I. INTRODUCTION

A new corrosion phenomenon has been added to the list of corrosion phenomena, and it is related to A.C. currents. These usually result from A.C. voltages induced into the pipeline where the pipeline route is in parallel with, or crosses, high voltage power lines [1].

AC Corrosion is caused by current exchange between soil and metal. This exchange of current depends on the voltage induced on pipelines. The amplitude of induced voltage is due to various parameters such as: the distance between phase cables, the distance between the high voltage electricity lines and the pipeline and the overhead line operating current. Corrosion is mainly influenced, or associated with the A.C. current density, size of coating defect and the local soil resistivity [2], [3] and [4].

The interference between a power system network and neighboring gas pipeline has been traditionally divided into three main categories: capacitive, conductive and inductive coupling [5], [6], [7], and [8].

Capacitive Coupling: Affects only aerial pipelines situated in the proximity of HVPL. It occurs due to the capacitance between the line and the pipeline. For underground pipelines the effect of capacitive coupling may not to be considered, because of the screening effect of earth against electric fields.

Inductive Coupling: Voltages are induced in nearby metallic conductors by magnetic coupling with high voltage lines, which results in currents flowing in a conducting pipeline and existence of voltages between it and the surrounding soil. Time varying magnetic field produced by the transmission line induces voltage on the pipeline.

Conductive Coupling: When a ground fault occurs in HVPL the current flowing through the grounding grid produce a potential rise on both the grounding grid and the neighboring soil with regard to remote earth. If the pipeline goes through the "zone of influence" of this potential rise, then a high difference in the electrical potential can appear across the coating of the pipeline metal.

There has been a considerable amount of research into interference effects between AC power line and pipeline including computer modeling and simulation. [9], [10]. A general guide on the subject was issued later by CIGRE [11], while CEOCOR [12] published a report focusing on the AC corrosion of pipelines due to the influence of power lines.

This piper evaluates and analyzes the electromagnetic interference effects on buried pipelines cathodically protected created by the nearby high voltage transmission lines. We calculate the various parameters of the sacrificial anode cathodic protection system, then we analyze the problem of interference between the power line and pipeline by the calculation of the magnetic field, induced voltage and current density during both normal conditions on the power line and finally we evaluate the AC corrosion likelihoods of pipelines. It is found that on pipelines suffering from A.C. interference traditional pipe-to-soil potential measurements do not guarantee efficient cathodic protection against corrosion. A specific approach to assess the effectiveness of cathodic protection should be adopted.

## II. CATHODIC PROTECTION

To protect buried pipelines against corrosion, a noncorrosive coating is used and additional protection is applied by means of cathodic protection (CP) in order to control galvanic current in such a way as to avoid anodic current flow from the pipe to the soil. Though large voltage differences are an efficient protection, this is limited by the thickness of the coating. The usual rule is to maintain the pipeline at a constant potential between 0.850 V to 1.3 V (with respect to a copper/saturated copper sulfate electrode $Cu/CuSo_4$) [13], [14].

There are two main CP system types:

A first method consist of connecting a galvanically more active metal to the pipeline, in this case the metal will behave as the anode (typically Zn, Al or Mg); thus the galvanically more active metal (anode) sacrifices itself to protect the pipeline (cathode). A galvanically more active metal is a metal that is able to lose its peripheral electrons faster other than other metals. The first method is described in figure1.

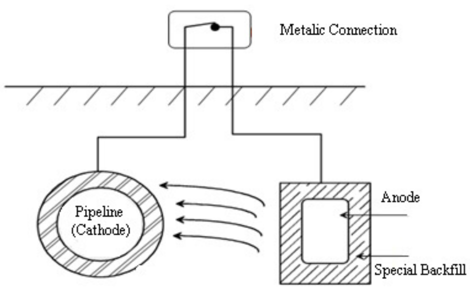


Fig.1. sacrificial anode cathodic protection System

As shown in figure.2, in the second method a DC current source is connected which will force the current to flow from an installed anode to the pipeline causing the entire pipeline to be a cathode. This method is called impressed current cathodic protection where the DC power supply may be a rectifier, solar cell or generator.

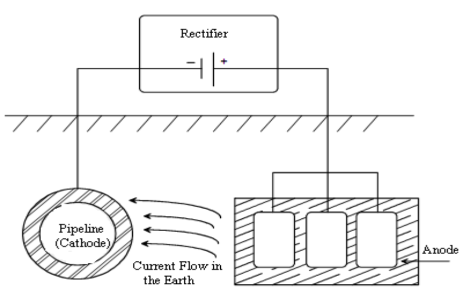


Fig.2. Impressed current cathodic protection System

## III. INDUCTIVE INTERFERENCE

### A. *Electric field*

To calculate the electric field under the power line, phase conductors are considered as infinite line charges. The horizontals and verticals components of the electric field due to the three phase conductors at the desired locations are calculated separately using equation (1) given below. Figure 3 shows the components of the electric field at the observation point M(x,y) due to one phase conductor and its image.

$$\begin{cases} E_{hi} = \dfrac{Q_i}{2\pi\varepsilon_0}(x-x_i)\left[\dfrac{1}{(D_i)^2} - \dfrac{1}{(D_i^{'})^2}\right] \\ E_{vi} = \dfrac{Q_i}{2\pi\varepsilon_0}\left[\dfrac{(y-y_i)}{(D_i)^2} - \dfrac{(y+y_i)}{(D_i^{'})^2}\right] \end{cases} \quad (1)$$

Where:

Q is the charge of the conductor, $\varepsilon_0$ is the relative permittivity.

Resultant of horizontal and vertical components of the field gives the total electric field at the desired locations as shown in equation given below.

$$E=\sqrt{(E_{hi})^2+(E_{vi})^2}$$

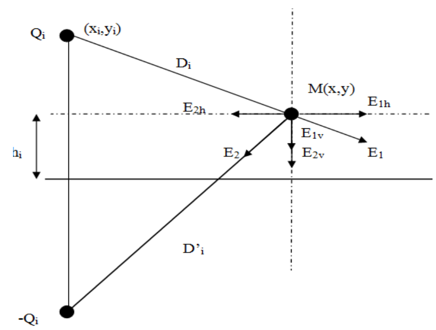


Fig.3: Components of electric field due to HVPL

### B. *Magnetic field*

A magnetic field will be created by the current going though the conductors. As in the electric field, each point charge will produce a magnetic field having a horizontal and a vertical component.

$$B=\sqrt{(B_{hi})^2+(B_{vi})^2}$$

Where B is the magnetic field, $B_{hi}$ and $B_{vi}$ are the horizontal and vertical components respectively.

$$\begin{cases} B_{hi} = \dfrac{\mu I}{2\pi}(x-x_i)\left[\dfrac{1}{(D_i)^2} - \dfrac{1}{(D_i^{'})^2}\right] \\ B_{vi} = \dfrac{\mu I}{2\pi}\left[\dfrac{(y-y_i)}{(D_i)^2} - \dfrac{(y+y_i)}{(D_i^{'})^2}\right] \end{cases} \quad (2)$$

Where:

$\mu$ is the air relative permeability, I is the current through the conductor.

*C. Induced Voltage*

The induced voltage on the pipeline is generated by the electromagnetic field in the soil. The level of induced voltage from a high voltage power transmission line on an adjacent pipeline is a function of geometry, soil resistivity and the transmission line operating parameters. The image method was used to calculate the induced voltage in a pipeline, in a single soil resistivity layer.

$$V=\frac{\rho I}{4\pi}\left(\frac{1}{\sqrt{x^2+y^2+(z-h)^2}}+\frac{1}{\sqrt{x^2+y^2+(z+h)^2}}\right) \quad (4)$$

Where, ρ is the soil resistivity, I is the current in the line, h is the depth of the pipeline in the soil and x, y, z represent the point where the voltage potential should be found.

## IV. RESULTS

*A. Design details for the sacrificial anode CP system*

The pipeline under study is buried. Table.1 lists the characteristics for the buried pipeline such as radius, wall thickness, length, coating thickness. The anode material should not be located at three meter from the pipeline and must be surrounded by a backfill. Table .2 lists the characteristics for the Mg sacrificial anode. The following eight steps are required when designing galvanic cathodic protection systems.

**Tab.1.** Pipeline characteristic

| | |
|---|---|
| Material | X42 |
| Length | 10 (Km) |
| Pipe diameter | 219.1 (mm) |
| Coating thickness | 6.4 (mm) |

**Tab. 2.** Anode characteristic

| | |
|---|---|
| Constituents | 90% Mg,6%Al 3%Zinc |
| Consumption Rate | 7 (Kg/A an) |
| Dimension | 3 inch x3 inch x14 inch |
| Potential | -1.7 (V) |
| Current efficiency | 1100 (Ah/Kg) |
| Weight | 20 (kg) |
| backfill material | 75% hydrated gypsum, 20%bentonite and 5% sodium sulfate. |
| Backfill resistivity | 3 (Ω.m) |
| Efficiency (%) | 50 |

*1. Review soil resistivity*

If resistivity variations are not significant, the average resistivity will be used for design calculations. The soil resistivity measurements are given in table3.

$$\rho_{soil}=\frac{1}{N}\sum_{1}^{N}\rho_i=72.5\ \Omega.m$$

**Tab. 3.** Soil resistivity measurements

| PK(km) | Resistivity (Ω.m) | PK(km) | Resistivity (Ω.m) | PK(km) | Resistivity (Ω.m) |
|---|---|---|---|---|---|
| 00.000 | 65 | 04.980 | 45 | 06.900 | 90 |
| 01.000 | 70 | 05.000 | 55 | 07.250 | 90 |
| 01.500 | 80 | 05.750 | 70 | 07.560 | 85 |
| 02.000 | 65 | 05.950 | 70 | 07.850 | 85 |
| 02.500 | 65 | 06.100 | 70 | 08.100 | 90 |
| 03.000 | 60 | 06.350 | 90 | 08.500 | 90 |
| 03.500 | 45 | 04.500 | 50 | 09.150 | 90 |
| 04.000 | 50 | 06.450 | 90 | 09.255 | 80 |

*2. Area to be protected*

The area to be protected by is calculated by:

$$A=\pi(d+2tc)L=0.7281*10^4\ m^2$$

Where:
d is the pipe diameter (m), tc is the coating thickness (mm) and L is the length of pipe (m).

*3. Current to protect the steel structure*

Using a design current density of J=0.15 mA/m2, the current demand required to protect the steel structure from corrosion is determined by the following formula:

$$I=A*J_{dc}=1.09\ A$$

*4. Calculate net driving potential for anodes*

The average potential of the pipeline system is -0.67 V. Hence the net initial driving potential (E) is given by:

$$E=-1.70-(-0.67)=-1.03\ V$$

*5. Anode-to-electrolyte resistance*

The anode to electrolyte resistance is an important parameter in order to predict the current output of an anode. To determine the resistance of a single vertical anode, the following relationship is applied (Dwight's equation): [15]

$$R_{anode}=R_{anode/backfill}+R_{backfill/soil}$$

$$R_{anode/backfill}=\frac{0.00521\rho_{backfill}}{L_{anode}}\left(\ln\frac{8L_{anode}}{d_{anode}}-1\right)$$

$$R_{backfill/soil}=\frac{0.00521\rho_{soil}}{L_{backfill}}\left(\ln\frac{8L_{backfill}}{d_{backfill}}-1\right)$$

Where:

$\rho_{backfill}$ : Resistivity of backfill in ohm-m;
$\rho_{soil}$ : Soil resistivity in ohm-m;
$L_{anode}$ : Length of anode in meters;

$L_{anode}$ : Length of backfill in meters;
$d_{anode}$ : Diameter of anode in meters;
$d_{backfill}$ : Diameter of backfill in meters.

$$R_{anode} = 1.58\ \Omega$$

*6. Current per anode*

To predict the current output of protective current from a sacrificial anode the voltage between anode and cathode (driving voltage) is divided by the resistance of the anode to the electrolyte. The maximum output current from each anode is given by:

$$I_{max} = E/R = 0.65\ A$$

*7. Number of anodes needed*

The number of galvanic anodes required to protect the pipeline is given by

$$N = I_{total}/I_{max} \simeq 2 \text{ anode}$$

*8. Net driving force of the anodes*

This implies that the anodes should be spaced at 3.3 km intervals. Because the pipeline will be polarised to at least a potential of (-0.850 V/Cu-cuSo4), the net driving force of the anodes is given by;

$$E = -1.70V - (-0.85V) = -0.85V$$

Current (I) per anode 0.54A

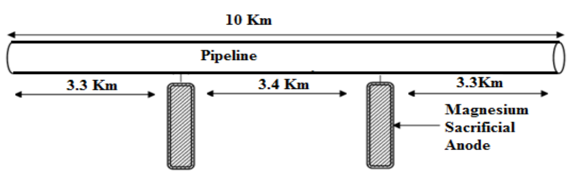

Fig.4. Schematic of the distribution of galvanic anodes along the pipeline

*B. Interference Problem*

We carried out within the context of this work the calculations carried out on a high voltage power line (HVPL) having the following characteristics. P = 750 MW under a cos (θ) =0.85 and U = 400 KV. Metallic pipeline (MP) Crossings with power lines at the points PK00.970 Km and PK01.170 Km (Figure5)

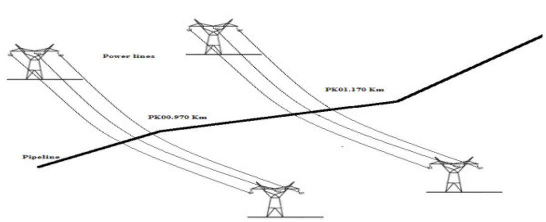

Fig.5. Plan view of the HVPL-MP common distribution corridor.

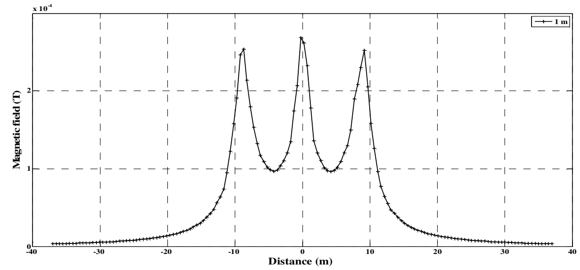

Fig.6. Magnetic field

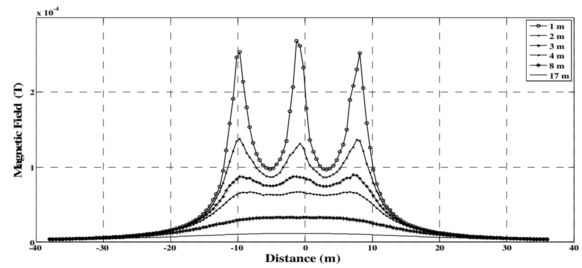

Fig.7. Magnetic field with varying height

Figure 6 shows the magnetic field profile for the horizontal configuration less than one meter of the high voltage power line. Three peaks corresponding to the location of the three phase conductors. The peak at the center of the right of way has a slightly larger magnitude than the two peripheral peaks.
Figure7 shows the magnetic field for horizontal configuration of the power line with varying height. As the height increases, the distance between the charges and the pipe line increases causing a decrease in the magnitude of the magnetic field.

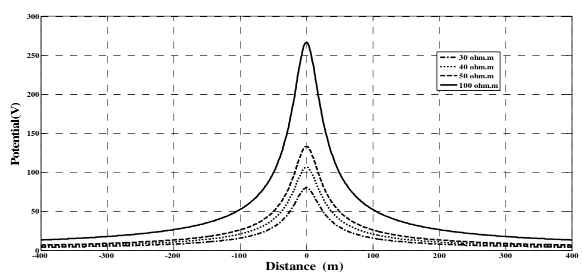

Fig.8. Induced voltage

The resultant pipeline induced voltages are calculated with the variation of the soil resistivity (soil resistivity varied from 30 to 100 Ω.m). In Fig.8, it is clear that the soil resistivity has an influence on the induced voltage. The pipeline induce-voltage reduces by reducing the soil resistivity (i.e. high soil resistivity gives high induced voltage).

## V. AC CORROSION

The risk of AC corrosion of the metallic structures is closely linked with the pipeline isolation defects, which might occur, for instance during construction work. From an electrical point of view, coating holidays can be seen as a small, low impedance AC earthing system connected to the pipeline. If the coating holiday size for example exceeds a certain dimension, corrosion risk likelihood neutralizes according to the relevant current density.

We consider a situation where a pipeline is buried near a high voltage power lines, and let us assume that the pipeline coating has a single defect. At the defect point, the pipeline has a resistance to earth whose approximate value is:

$$R = \frac{\rho_{soil}}{2.D} \cdot \left(1 + \frac{8t_c}{D}\right) \quad (4)$$

Thus the current density $J_{ac}$ ($A/m^2$) through the coating defect is:

$$J_{ac} = \frac{8.U_{ac}}{\rho_{soil}.\pi(8t_c + D)} \quad (5)$$

$U_{ac}$ is the induced voltage, $t_c$ is the thickness of the coating, $\rho_{soil}$ is the soil resistively, D is the diameter of the coating defect.

Based on actual investigation in the field of AC corrosion, as well as to the actual European technical specifications [16] the AC corrosion risk can already be expected from current densities at coating holidays among 30 $A/m^2$ . For current densities between 30 $A/m^2$ and 100 $A/m^2$ there exists medium AC corrosion likelihood. For current densities upper 100 $A/m^2$ there is a very high $A/m^2$ corrosion likelihood [17].

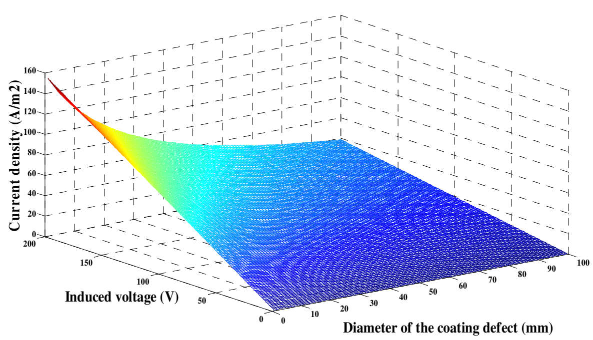


Fig.9. Current density

In Fig.9, the current density varies linearly with induced voltage and depends on soil characteristics by its resistivity, i.e. current density is greater in soil with low electrical resistivity. Moreover, current density increases by decreasing the dimension of the coating defect. The structures with a coating defect of small size may have a higher risk of AC corrosion.

## VI. CONCLUSION

The interference problems that affect pipelines near high voltage AC power (HVAC) transmission lines have been well defined .The magnetic field on the pipeline in the vicinity of a high voltage power line have been calculated for horizontal configuration. The voltage profiles for normal operation conditions have been simulated. It is found that on pipelines suffering from A.C. interference traditional pipe-to-soil potential measurements do not guarantee efficient cathodic protection against corrosion.

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